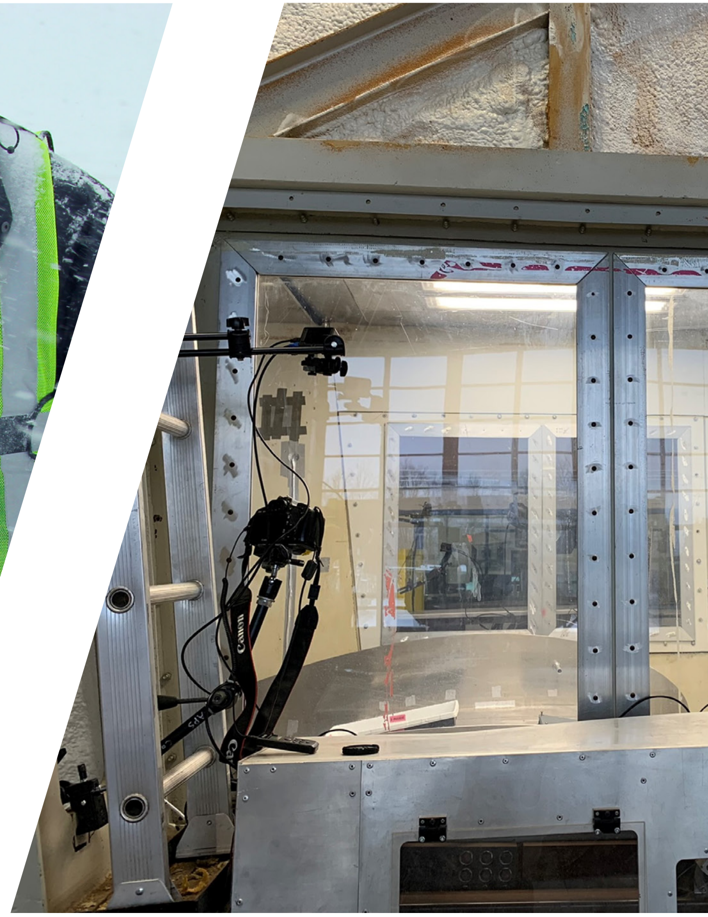


AIRCRAFT GROUND ICING GENERAL RESEARCH ACTIVITIES DURING THE 2021-22 WINTER

TP 15536E
Final Version 1.0
December 2022

Prepared for:

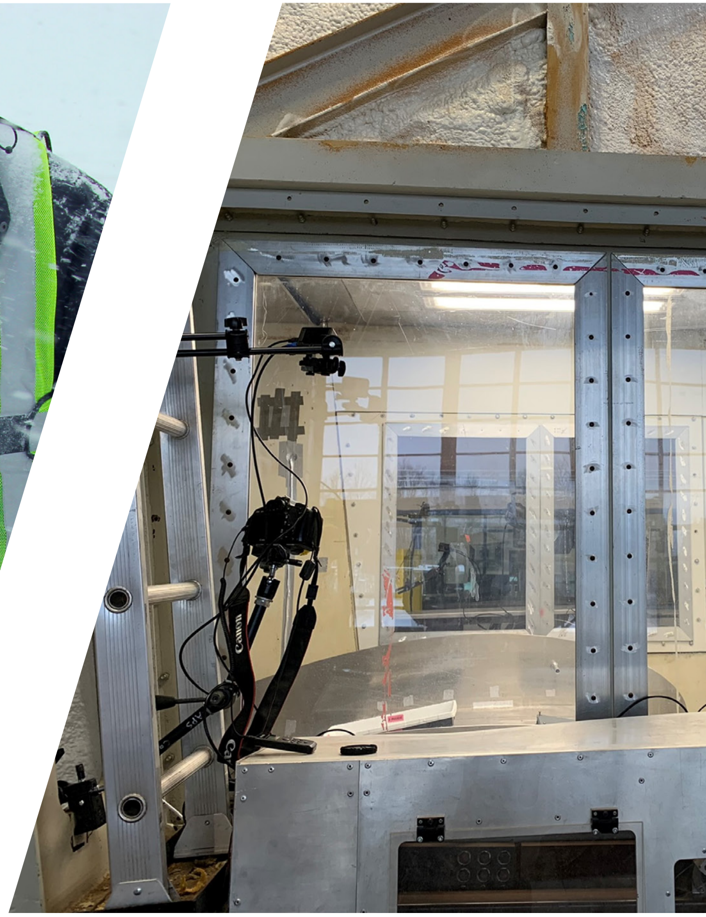
Transport Canada
Programs Group
Innovation Centre

In cooperation with:

Federal Aviation Administration
William J. Hughes Technical Center

Transport Canada
Civil Aviation

Federal Aviation Administration
Flight Standards – Air Carrier Operations



AIRCRAFT GROUND ICING GENERAL RESEARCH ACTIVITIES DURING THE 2021-22 WINTER

APS Aviation Inc.

TP 15536E
Final Version 1.0
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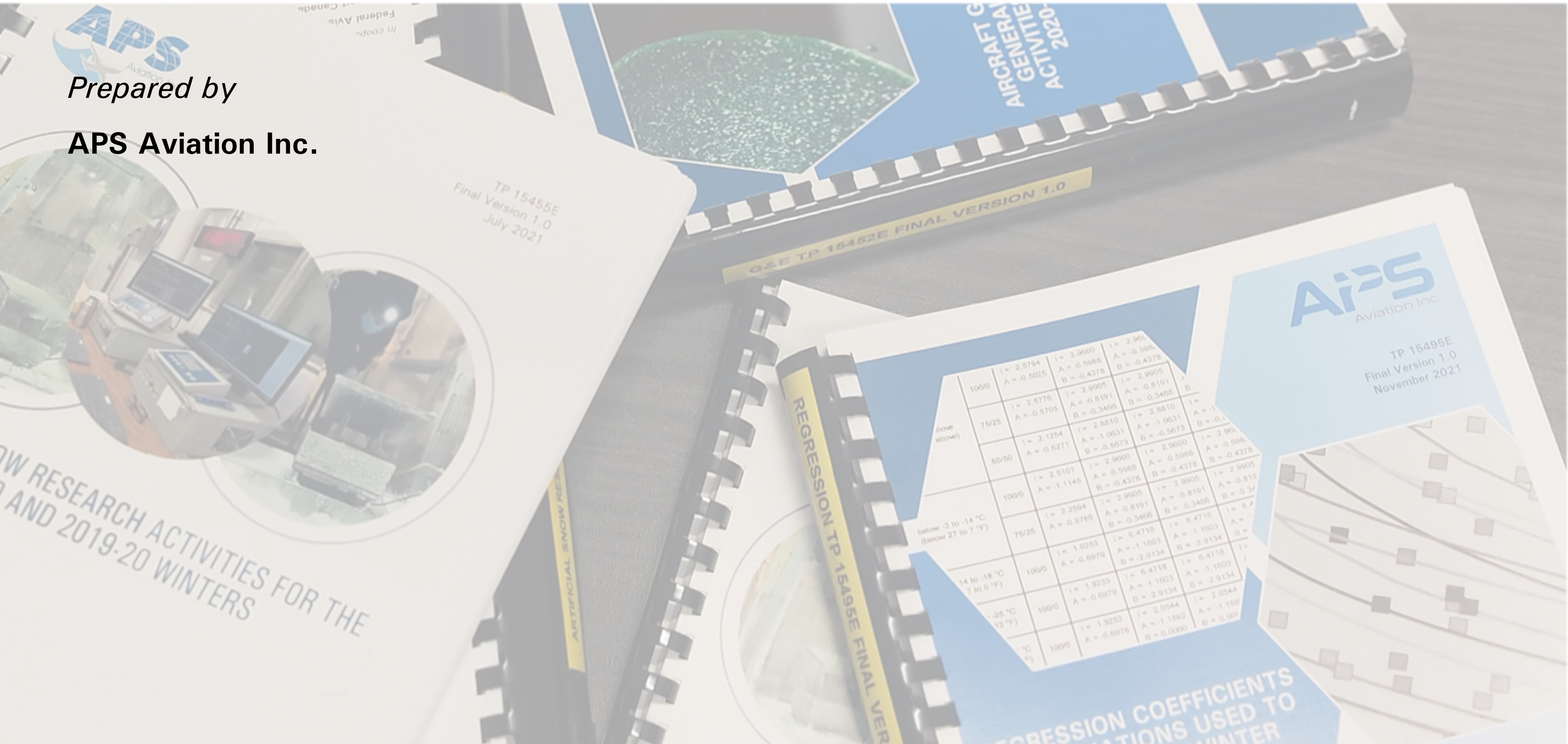

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APS Aviation Inc.

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Jun 9, 2023

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

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PREFACE

Under contract to the Transport Canada Programs Group 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 conduct wind tunnel testing with a vertical stabilizer common research model to evaluate contaminated fluid flow-off before and after a simulated takeoff;
- To conduct comparative endurance time testing and evaluate endurance times in mixed snow and freezing fog conditions;
- To conduct general and exploratory de/anti-icing research;
- To conduct analysis to support harmonization of the Transport Canada and the Federal Aviation Administration visibility table guidance;
- 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.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2021-22 are documented in seven reports. The titles of the reports are as follows:

- TP 15534E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2021-22 Winter;
- TP 15535E Regression Coefficients and Equations Used to Develop the Winter 2022-23 Aircraft Ground Deicing Holdover Time Tables;
- TP 15536E Aircraft Ground Icing General Research Activities During the 2021-22 Winter;
- TP 15537E Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2021-22;
- TP 15538E Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a Common Research Model Vertical Stabilizer;

- TP 15539E Artificial Snow Research Activities for the 2020-21 and 2021-22 Winters; and
- TP 15540E Evaluation of Fluid Endurance Times in Mixed Snow and Freezing Fog Conditions.

This report, TP 15536E, has the following objective:

- To document the exploratory research and general activities carried out during the winter of 2021-22.

PROGRAM ACKNOWLEDGEMENTS

This multi-year research program has been funded by the Transport Canada Programs Group 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, Steve Baker, David Beals, Stephanie Bendickson, Benjamin Bernier, Chloë Bernier, Christopher D'Avirro, John D’Avirro, Peter Dawson, Francine De Ladurantaye, Sean Devine, Ali Etemad, Noemie Gokhool, Kyra Kinderman-McCormick, Peter Kitchener, Diana Lalla, Shahdad Movaffagh, Shamim Nakhaei, William Ethan Payne, Dany Posteraro, Alex K. Raymond, Annaelle Reuveni, Marco Ruggi, Javad Safari, Alexa-Kiran Sareen-Diacoumacos, Niroshaan Sivarajah, Saba Tariq, Nicole Thomson, and Ian Wittmeyer.

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: Benjamin Bernier for *Review of “Snowfall Intensities as a Function of Prevailing Visibility” Holdover Time Guidance*; Dany Posteraro for *Evaluation of Mist and Freezing Fog Deposition Rates*; Diana Lalla for *Development of Guidance for Mixed Icing Conditions*; Dany Posteraro for *Continued Implementation of Video Streaming Technology for Remote Viewing of Deicing Research Tests*; Javad Safari for *Technical Review, Approval, and Publication of Historical Reports*; Chloë Bernier for *Publication of Holdover Time Guidance Materials*; Javad Safari for *Presentations, Fluid Manufacturer Reports, and Test Procedures for 2021-22.*

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

Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada (TC). These reports are available from the TC Programs Group 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 2021-22. The activities documented in this report were carried out in addition to the main research projects completed in the winter of 2021-22, which are documented in separate reports. The seven activities described in this report are listed below:

1) Review of "Snowfall Intensities as a Function of Prevailing Visibility" Holdover Time Guidance;
2) Evaluation of Mist and Freezing Fog Deposition Rates;
3) Development of Guidance for Mixed Icing Conditions;
4) Continued Implementation of Video Streaming Technology for Remote Viewing of Deicing Research Tests;
5) Technical Review, Approval, and Publication of Historical Reports;
6) Publication of Holdover Time Guidance Materials; and
7) Presentations, Fluid Manufacturer Reports, and Test Procedures for 2021-22.

17. Key Words METAR, Holdover Time, Guidelines, Mist, Freezing Fog, Degree-Specific, NRC, Visibility, Remote Viewing, Allowance Time, SAE, COVID-19, Reports, Presentations, Procedures	18. Distribution Statement Available from the Transport Canada Programs Group Innovation Centre

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

Plusieurs rapports de recherche sur des essais de technologies de dégivrage et d'antigivrage ont été produits au cours des hivers précédents pour le compte de Transports Canada (TC). Ils sont disponibles auprès du Centre d'innovation du groupe de programmes 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

Ce rapport fait état des activités générales menées par APS Aviation Inc. en matière de recherche sur le dégivrage d'aéronefs au sol au cours de l'hiver 2021-2022. Les activités dont fait état ce rapport ont été effectuées en plus des projets de recherche principale menés pendant l'hiver 2021-2022, qui sont documentés dans des rapports distincts. Les sept activités qui font l'objet du présent rapport sont énumérées ci-dessous.

1) Examen des lignes directrices relatives aux durées d'efficacité en ce qui concerne les intensités des chutes de neige en fonction de la visibilité dominante;
2) Évaluation des taux de dépôt de brume et de brouillard verglaçant;
3) Mise au point de lignes directrices relatives aux conditions de givrage mixtes;
4) Poursuite de la mise en œuvre de la technologie de diffusion vidéo en continu pour l'observation à distance des essais de recherche sur le dégivrage;
5) Examen technique, approbation et publication de rapports historiques;
6) Publication de documents d'orientation sur les durées d'efficacité;
7) Présentations, rapports aux fabricants de liquides et procédures d'essais pour 2021-2022.

17. Mots clés METAR, durées d'efficacité, lignes directrices, brume, brouillard verglaçant, selon le degré, CNRC, visibilité, observation à distance, marges de tolérance, SAE, COVID-19, rapports, présentations, procédures	18. Diffusion Disponible auprès du Centre d'innovation du groupe de programmes de Transports Canada

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EXECUTIVE SUMMARY

This report documents the exploratory research and general activities completed in the winter of 2021-22 by APS Aviation Inc. (APS) on behalf of Transport Canada (TC) and the Federal Aviation Administration (FAA). This work is part of the TC/FAA aircraft ground deicing research project. The major activities of the research project are documented in separate reports; this report documents seven activities that were carried out in addition to the main research projects in the winter of 2021-22.

Review of "Snowfall Intensities as a Function of Prevailing Visibility" Holdover Time Guidance (Section 2)

To support harmonization of the existing TC/FAA visibility table guidance, APS conducted a review of the guidance (including a data cleaning exercise involving the analysis upon which the recommended visibility table values were originally derived). An updated visibility table format (including modified guidance notes) was created, and an updated set of visibility table value recommendations was produced.

Both TC and the FAA agreed to adopt the updated table format and updated visibility guidance notes. TC also directly adopted the updated recommended visibility table values; the FAA partially adopted the updated recommended visibility table values but retained their previous values in several cells where the discrepancies related to previous policy decisions.

Both organizations published the updated visibility table guidance in their respective 2022-23 HOT Guidelines, resulting in a significant improvement in the harmonization status of the two organizations' visibility table guidance.

Evaluation of Mist and Freezing Fog Deposition Rates (Section 3)

Mist and freezing fog are commonly reported weather phenomena which can occur alone or in conjunction with other precipitation types. Although similar to fog, mist is said to be present when the visibility is between 0.6 and 1.2 statute miles (1-2 km), while fog reduces it to less than 0.6 statute miles (1 km). With respect to holdover times (HOT), mist deposition rates were first quantified, and guidance was introduced in the generic HOT tables in 2021. Information related to freezing fog indicates that deposition rates between 2 and 5 g/dm^2/h may be possible. In order to substantiate the rates, mist and freezing fog deposition rates were measured using the two similar methodologies which are related to the historical characterization of freezing fog. Since a comprehensive assessment is set to be documented in 2022-23 or in a subsequent year, only data obtained during the winter of 2021-22 is documented in this report; data from 2020-21 is documented in a previous report.

Development of Guidance for Mixed Icing Conditions (Section 4)

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. The objective of this ongoing project is to support the development of HOT or allowance time guidance for mixed icing conditions not currently included in the guidance material. To reach this objective, several research activities were undertaken by APS to support TC and the FAA which are detailed in this report.

Continued Implementation of Video Streaming Technology for Remote Viewing of Deicing Research Tests (Section 5)

The COVID-19 pandemic remained ongoing in Canada during the 2021-22 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 2021-22 winter testing was adapted to mitigate exposure risks through the implementation of a virtual remote camera viewing setup as a solution to allow stakeholder participation. This setup included Closed Circuit Television (CCTV) or GoPro® 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 implemented at the National Research Council Canada (NRC) climate chamber, NRC 3 m x 6 m Icing Wind Tunnel (IWT), APS test facility at Montréal–Pierre Elliott Trudeau International Airport (YUL), PMG Technologies Inc. (PMG) 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.

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

APS has conducted research related to ground icing, which involved writing and publishing over 218 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, 2022, 23 reports remain to be published, excluding the current year reports for 2021-22.

Publication of Holdover Time Guidance Materials (Section 7)

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

Presentations, Fluid Manufacturer Reports, and Test Procedures for 2021-22 (Section 8)

APS produced several presentations, fluid manufacturer reports, and test procedures for the Winter 2021-22 test program. These are documented in this report.

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SOMMAIRE

Ce rapport fait état de la recherche exploratoire et des activités générales menées au cours de l'hiver 2021-2022 par APS Aviation Inc. (APS), pour le compte de Transports Canada (TC) et de la Federal Aviation Administration (FAA). Ce travail a été effectué dans le cadre du projet de recherche de TC et de la FAA sur le dégivrage d'aéronefs au sol. Les principales activités du projet de recherche sont documentées dans des rapports distincts; le présent rapport documente les sept activités effectuées en plus des principaux projets de recherche de l'hiver 2021-2022.

Examen des lignes directrices relatives aux durées d'efficacité en ce qui concerne les intensités des chutes de neige en fonction de la visibilité dominante (Section 2)

Afin d'étayer l'harmonisation des lignes directrices actuelles du tableau de visibilité de TC et de la FAA, APS a procédé à un examen des lignes directrices (y compris un exercice de nettoyage des données comportant l'analyse sur laquelle les valeurs recommandées du tableau de visibilité se fondaient à l'origine). Un format de tableau de visibilité mis à jour (comprenant des notes d'orientation modifiées) a été produit, et un ensemble mis à jour des recommandations de valeurs du tableau de visibilité a été créé.

TC et la FAA ont convenu d'adopter le format de tableau et les notes d'orientation sur la visibilité mis à jour. TC a également adopté directement les valeurs recommandées du tableau de visibilité mis à jour; de son côté, la FAA a adopté en partie les valeurs recommandées du tableau de visibilité mis à jour, mais a conservé les valeurs adoptées précédemment dans plusieurs cellules où les écarts étaient liés à des décisions stratégiques antérieures.

Les deux organisations ont publié les lignes directrices du tableau de visibilité mis à jour dans leurs lignes directrices relatives aux durées d'efficacité 2022-2023 respectives, ce qui a grandement amélioré l'état d'harmonisation des lignes directrices du tableau de visibilité des deux organisations.

Évaluation des taux de dépôt de brume et de brouillard verglaçant (Section 3)

La brume et le brouillard verglaçant sont des phénomènes météorologiques couramment rapportés qui peuvent se produire seuls ou avec d'autres types de précipitations. Bien que la brume soit semblable au brouillard, on considère qu'il y a présence de brume lorsque la visibilité est comprise entre 0,6 et 1,2 mille terrestre (1 à 2 km), et qu'il y a présence de brouillard lorsque la visibilité est inférieure à 0,6 mille terrestre (1 km). C'est en 2021 qu'on a pour la première fois quantifié les taux de dépôt de brume et introduit des lignes directrices à ce sujet dans les tableaux

des durées d'efficacité génériques. Les informations relatives au brouillard verglaçant indiquent que des taux de dépôt compris entre 2 et 5 g/dm^2/h peuvent être possibles. Afin d'étayer ces valeurs, les taux de dépôt de brume et de brouillard verglaçant ont été mesurés à l'aide de deux méthodes semblables qui sont liées à la caractérisation historique du brouillard verglaçant. Étant donné qu'une évaluation complète doit être documentée en 2022-2023 ou au cours d'une année subséquente, seules les données obtenues au cours de l'hiver 2021-2022 sont documentées dans le présent rapport; les données obtenues en 2020-2021 sont documentées dans un rapport précédent.

Mise au point de lignes directrices relatives aux conditions de givrage mixtes (Section 4)

Lorsque les aéronefs volent en conditions hivernales défavorables, il se peut que les conditions météorologiques hivernales signalées par METAR ne correspondent pas toujours à une condition mentionnée dans les lignes directrices relatives aux durées d'efficacité afin de permettre un départ en toute sécurité, et particulièrement en présence de conditions mixtes. Ce projet en cours a pour objectif d'étayer la mise au point de lignes directrices relatives aux durées d'efficacité ou aux marges de tolérance en présence de conditions de givrage mixte qui ne sont pas incluses dans les lignes directrices actuelles. Afin d'atteindre cet objectif, APS a mené plusieurs activités de recherche en appui à TC et à la FAA, lesquelles sont présentées en détail dans le présent rapport.

Poursuite de la mise en œuvre de la technologie de diffusion vidéo en continu pour l'observation à distance des essais de recherche sur le dégivrage (Section 5)

La pandémie de COVID-19 s'est poursuivie au Canada tout au long de l'hiver 2021-2022. Par conséquent, de nombreuses lignes directrices relatives à la COVID-19 et restrictions concernant les déplacements et le personnel étaient en vigueur pendant la saison d'essai, et variaient au fil du temps et selon les régions. Compte tenu de ces restrictions, les essais réalisés au cours de l'hiver 2021-2022 ont été adaptés pour atténuer les risques d'exposition grâce à la mise en œuvre d'une installation d'observation à distance par caméra permettant la participation des parties prenantes. Cette installation comprenait l'intégration d'un système de caméras de télévision en circuit fermé (CCTV) ou d'un système de caméra GoPro[MD] avec une plateforme de vidéoconférence Web en ligne, ce qui permettait l'observation et l'évaluation d'essais critiques ainsi que la tenue de discussions techniques pendant ces séances d'essais. Les installations ont ensuite été mises en œuvre dans la chambre climatique du Conseil national de recherches Canada (CNRC), dans la soufflerie de givrage de 3 m sur 6 m du CNRC, à l'installation d'essai d'APS de l'aéroport international Montréal-Trudeau (YUL), à l'installation d'essai de PMG technologies Inc. (PMG) et dans le cadre des essais menés dans le Grand Nord et le Nord proche. Dans l'ensemble, l'installation d'observation à distance par caméra a bien fonctionné et a permis de fournir aux observateurs et participants une diffusion vidéo de haute qualité des essais effectués. Il est recommandé d'envisager d'autres améliorations afin d'accroître la qualité et l'efficacité des caméras pour la participation des parties prenantes virtuelles aux futures séances d'essais.

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

APS a effectué des études sur le givrage au sol qui ont supposé la rédaction et la publication de plus de 218 rapports pour le compte de TC et de la FAA depuis le début des années 1990. 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 2022, à l'exception des rapports annuels actuels de 2021-2022, 23 rapports doivent encore être publiés.

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

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

Présentations, rapports aux fabricants de liquides et procédures d'essais pour 2021-2022 (Section 8).

APS a produit plusieurs présentations, rapports aux fabricants de liquides et procédures d'essais pour le programme d'essais de l'hiver 2021-2022. Ceux-ci sont documentés dans le présent rapport.

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GLOSSARY

A4A	Airlines for America
APS	APS Aviation Inc.
AS	Aerospace Standard
AvN	Artificial vs. Natural
AWG	Aerodynamics Working Group
CCTV	Closed Circuit Television
CRM	Common Research Model
CSW	Cold-Soaked Wing
DSHOT	Degree-Specific Holdover Time
FAA	Federal Aviation Administration
FMH-1	Federal Meteorological Handbook No. 1
HOT	Holdover Time
HUPR	Highest Usable Precipitation Rate
IP	Internet Protocol
IWT	3 m x 6 m Icing Wind Tunnel
LED	Light-Emitting Diode
LOUT	Lowest Operational Use Temperature
LWC	Liquid Water Content
MANOBS	Manual of Surface Weather Observations Standards
MWG	METAR Working Group
NASA	National Aeronautics and Space Administration

NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
NVR	Network Video Recorder
OAT	Outside Air Temperature
PMG	PMG Technologies Inc.
READAC	Remote Environmental Automatic Data Acquisition Concept
SAE	SAE International
TC	Transport Canada
VCS	Very Cold Snow
YMX	Montréal–Mirabel International Airport
YUL	Montréal–Pierre Elliott Trudeau International Airport
ZD	Freezing Drizzle
ZF	Freezing Fog
ZR	Freezing Rain

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, enhance safety, and advance 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 Programs Group 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 2021-22 in support of the aircraft ground icing research program. Each major project completed as part of the 2021-22 research is documented in a separate individual report. This report documents the remaining general activities and smaller research projects.

1.1 Activities Completed in 2021-22

The general activities and smaller research projects completed in 2021-22 are documented in this report. Each activity is detailed in a separate section as follows (section number in parentheses):

a) Review of "Snowfall Intensities as a Function of Prevailing Visibility" Holdover Time Guidance (Section 2);

b) Evaluation of Mist and Freezing Fog Deposition Rates (Section 3);

c) Development of Guidance for Mixed Icing Conditions (Section 4);
d) Continued Implementation of Video Streaming Technology for Remote Viewing of Deicing Research Tests (Section 5);
e) Technical Review, Approval, and Publication of Historical Reports (Section 6);
f) Publication of Holdover Time Guidance Materials (Section 7); and
g) Presentations, Fluid Manufacturer Reports, and Test Procedures for 2021-22 (Section 8).

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

1.2 Activities Completed with Limited Scope

In addition to the activities referenced in Subsection 1.1, five activities with limited scope were completed during the winter of 2021-22. 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 2021-22, 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.

1.2.2 Support to the SAE G-12 Aerodynamics Working Group

APS provides support to the SAE G-12 Aerodynamics Working Group (AWG). 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 2021-22, APS attended several online meetings in conjunction with the G-12 bi-yearly meetings and participated in related group discussions by email.

1.2.3 Support to the METAR Working Group

APS provides support to the METAR Working Group (MWG), which includes technical experts and meteorologists from TC, the FAA, APS, and the National Center for Atmospheric Research (NCAR). This includes participation in all meetings, framing project objectives, discussing technical content, identifying areas of research, and directing research efforts. For the winter of 2021-22, APS attended several working group meetings and participated in related group discussions by email and through online meetings.

1.2.4 Holdover Time Committee

APS provides support to the SAE G-12 Holdover Time (HOT) Committee by providing a qualified individual to serve as the committee secretary. The role of this individual includes participating in the committee meetings, assisting the committee co-chairs with any preparation tasks, and recording and editing the meeting minutes for distribution.

1.2.5 Fluid Dry-Out and Longevity of Fluid on Wing

Anti-icing fluid is sometimes applied preventatively by operators, such as prior to an expected frost condition. However, when no frost or other precipitation occurs, the decision must be made whether it is safe to take off with the remaining fluid on the aircraft, which may have been applied several minutes or hours prior to departure. This activity is planned for completion in winter 2022-23.

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2. 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 2021-22 to review the existing snowfall intensity vs. visibility holdover time (HOT) guidance.

2.1 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* (1). The current FAA visibility table was developed using multiple sources of data and analysis (including TP 14151E [1]).

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.

2.2 Previous Work

This research is a continuation of work that was started in 2020-21. The previous work is documented in the TC report, TP 15496E, *Aircraft Ground Icing General Research Activities During the 2020-21 Winter* (2).

2.3 Objectives

The objectives of this project were as follows:

1) Completing a review of the TC and FAA visibility tables and to categorize the differences in the guidance;
2) Developing a harmonized table format for adoption by both organizations; and
3) Evaluating potential changes to the values within the visibility tables with the goal of harmonizing existing differences between the TC/FAA values.

2.4 Previous TC/FAA Visibility Guidance and Updated Format

The TC visibility table as it was published in the 2021-22 TC HOT Guidelines is shown below in Figure 2.1. The FAA visibility table as it was published in the 2021-22 FAA HOT Guidelines is shown in Figure 2.2.

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 2.1: TC Visibility Table from 2021-22 HOT Guidelines

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 2.2: FAA Visibility Table from 2021-22 HOT Guidelines

The above formats of the tables contain several differences in layout and data presentation. The format differences between the previous TC and FAA visibility table guidance are documented in detail within TP 15496E (2).

To reduce the number of differences in the TC/FAA visibility guidance, a new format incorporating elements of both previous tables was developed and presented to TC/FAA for consideration. The updated table formats are shown in Table 2.1 (TC) and Table 2.2 (FAA).

The new table formats eliminate most of the layout and data presentation differences that previously existed in the TC/FAA visibility tables. One exception is how the temperature of -1°C is categorized: the TC table includes -1°C within the warmer temperature category, whereas the FAA table includes -1°C within the colder temperature category.

Prior to adoption of the new format, TC sent out a copy of the proposed updated table to several organizations within the Canadian Civil Aviation industry for feedback. The consensus from the feedback received was that the new format laid out the information more clearly and that having a format that was better harmonized with the FAA table would also reduce the potential for confusion or misapplication of the guidance.

Table 2.1: Updated TC Visibility Table Format

Visibility								
				Day		Night		
Statute Miles		Meters		Below -1°C Below 30 °F	-1°C and above 30 °F and above	Below -1°C Below 30 °F	-1°C and above 30 °F and above
≤1/4	(≤3/8)	≤400	(≤600)	Heavy	Heavy	Heavy	Heavy
1/2	(>3/8 to ≤5/8)	800	(>600 to ≤1000)	Moderate	Heavy	Heavy	Heavy
3/4	(>5/8 to ≤7/8)	1200	(>1000 to ≤1400)	Moderate	Moderate	Heavy	Heavy
1	(>7/8 to ≤1 1/8)	1600	(>1400 to ≤1800)	Light	Light	Moderate	Heavy
1 ¼	(>1 1/8 to ≤1 3/8)	2000	(>1800 to ≤2200)	Light	Light	Moderate	Moderate
1 ½	(>1 3/8 to ≤1 5/8)	2400	(>2200 to ≤2600)	Light	Light	Moderate	Moderate
1 ¾	(>1 5/8 to ≤1 7/8)	2800	(>2600 to ≤3000)	Light	Light	Light	Light
2	(>1 7/8 to ≤2 ¼)	3200	(>3000 to ≤3600)	Very Light	Very Light	Light	Light
2 ½	(>2 ¼ to ≤2 ¾)	4000	(>3600 to ≤4400)	Very Light	Very Light	Light	Light
3	(>2 ¾ to ≤3 ¼)	4800	(>4400 to ≤5200)	Very Light	Very Light	Very Light	Light
≥3 ½	(>3 ¼)	≥5600	(>5200)	Very Light	Very Light	Very Light	Very Light

Table 2.2: Updated FAA Visibility Table Format

Visibility				Day		Night	
Statute Miles		Meters		-1°C and below 30 °F and below	Above -1°C Above 30 °F	-1°C and Below 30 °F and below	Above -1°C Above 30 °F
≤1/4	(≤3/8)	≤400	(≤600)	Heavy	Heavy	Heavy	Heavy
1/2	(>3/8 to ≤5/8)	800	(>600 to ≤1000)	Moderate	Heavy	Heavy	Heavy
3/4	(>5/8 to ≤7/8)	1200	(>1000 to ≤1400)	Moderate	Moderate	Moderate	Heavy
1	(>7/8 to ≤1 1/8)	1600	(>1400 to ≤1800)	Light	Light	Moderate	Moderate
1 ¼	(>1 1/8 to ≤1 3/8)	2000	(>1800 to ≤2200)	Light	Light	Moderate	Moderate
1 ½	(>1 3/8 to ≤1 5/8)	2400	(>2200 to ≤2600)	Light	Light	Moderate	Moderate
1 ¾	(>1 5/8 to ≤1 7/8)	2800	(>2600 to ≤3000)	Very Light	Light	Light	Light
2	(>1 7/8 to ≤2 ¼)	3200	(>3000 to ≤3600)	Very Light	Very Light	Light	Light
2 ½	(>2 ¼ to ≤2 ¾)	4000	(>3600 to ≤4400)	Very Light	Very Light	Very Light	Very Light
3	(>2 ¾ to ≤3 ¼)	4800	(>4400 to ≤5200)	Very Light	Very Light	Very Light	Very Light
≥3 ½	(>3 ¼)	≥5600	(>5200)	Very Light	Very Light	Very Light	Very Light

2.5 Review of TP 14151E Visibility Analysis

This subsection describes the analytical work that was completed in support of harmonizing the differences in the values within the TC and FAA visibility tables.

2.5.1 Analysis Background

The original TP 14151E (1) analysis was performed using a database of 7039 precipitation rate data points collected over seven years of endurance time testing conducted by APS at the Montréal–Pierre Elliot Trudeau International Airport (YUL) testing site. The precipitation rate data was paired with visibility data (provided by Meteorological Services Canada), which was gathered using a Belfort Forward Scatter Meter sensor.

This database was then analysed to determine which visibility limits were associated with differing levels of snowfall intensity (as defined in HOT terms). Visibility ranges were selected for the varying levels of snowfall intensity (ranging from very light to heavy snow) and used to populate the visibility table.

Due to the potential safety implications associated with underestimating snowfall intensity, the values for the visibility ranges were selected with the goal of minimizing the possibility that a pilot using the table would underestimate snowfall intensity (and consequently employ a HOT that was too long for the conditions).

Additional details concerning the original analysis can be found within TP 14151E (1).

2.5.2 Database Review and Data Cleaning

A detailed review of the underlying data used to create the TP 14151E (1) database was conducted to determine if a path towards harmonization could be discovered. As part of the review, historical weather data associated with each rate data point was verified. For each data point in the database, this verification included a check of the historical hourly Environment Canada data and minute-by-minute Remote Environmental Automatic Data Acquisition Concept (READAC) weather data associated with the time in which the rate/visibility data was collected.

During these weather verification checks, it was discovered that a portion of the data was associated with weather events where it could not be conclusively established that snow was the only precipitation type present. This included data points where the underlying weather data directly indicated the presence of non-snow precipitation types (either alone or in conjunction with snow) or where the precipitation type data was inconclusive in one or both data sources. Other data points were also flagged in the review because of misaligned timestamps associated with the data or due to other data entry issues resulting in an invalid rate and visibility pairing.

Of the 7039 data points in the original database, 1041 were flagged as either having weather data that indicated the presence of non-snow precipitation types (or inconclusive precipitation type) or having misaligned time data. Table 2.3 presents a breakdown of the data and the reason for which it was flagged in the database review.

Table 2.3: Data Flagged in TP 14151E Database Review by Category

Reason for Flagging Data	# of Data Points Flagged
Incorrect Timestamp on Data or Other Data Entry Issue	121
No Snow (Clear/No Precipitation)	23
Inconclusive Precipitation Type	497
Presence of Fog	100
Presence of Ice Pellets	156
Presence of Rain/Freezing Drizzle/Freezing Rain	109
Presence of Multiple Non-Snow Precipitation Types	35
Total	**1041**

The inclusion of mixed precipitation data within the snowfall database in the initial analysis resulted in lower than actual precipitation intensities being assigned to specific visibilities, as non-snow components of mixed precipitation events (i.e., ice pellets, rain) generally have less impact on visibility than does snow for an equivalent precipitation rate.

As such, it was decided that removal of the flagged data points was an appropriate data-cleaning exercise that would result in a database that would generate a more accurate set of visibility table values. An updated database (where the flagged data points were removed) was subsequently created. A visual depiction of which data points were retained and which were removed following the data-cleaning exercise is shown in Figure 2.3.

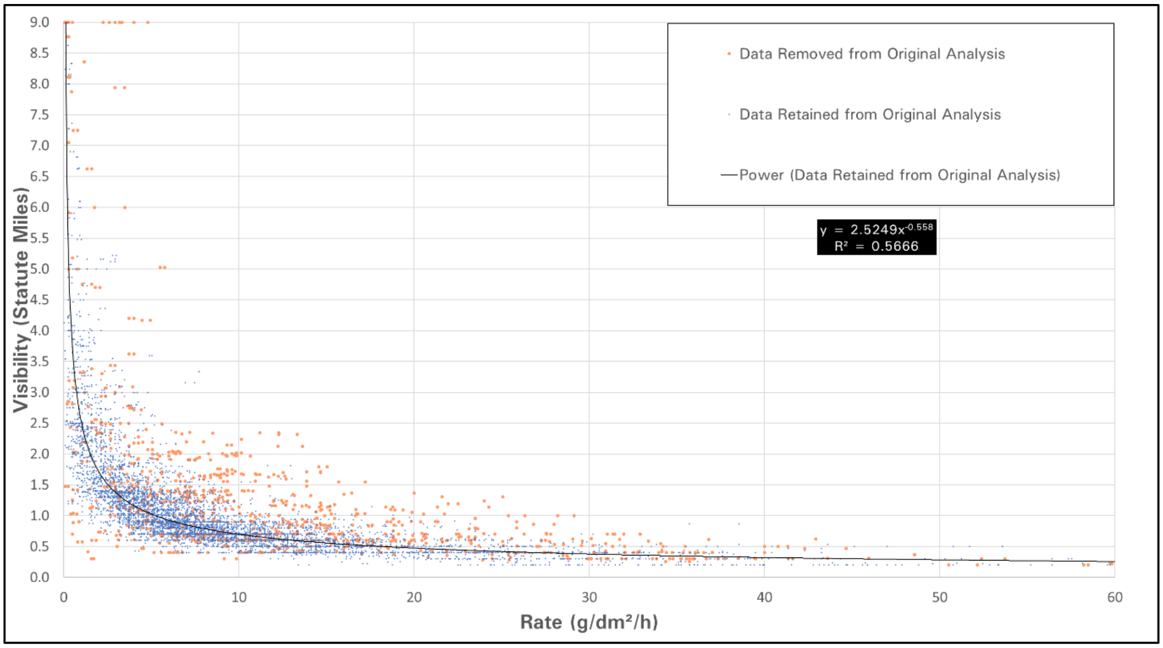

Figure 2.3: Visibility Analysis Database – Retained and Removed Data

Of the 1041 data points flagged for removal, 612 points belonged to the "-1°C and Above" data set. This is explained by the fact that a large proportion of the data flagged was due to the presence of non-snow precipitation types, which are more typically observed at higher temperatures. As such, the presence of this flagged data had a significant impact on the resulting visibility table values for the "-1°C and Above" data category.

2.5.3 Analysis of Updated Database

Following the removal of the flagged data, the analysis initially performed in TP 14151E (1) was repeated using the updated data set to determine the impact of the data removal on the resulting visibility table value recommendations.

This consisted of examining the snowfall intensity rates associated with each of the standard METAR-reported visibility values and assigning a snowfall intensity category to each visibility such that no more than 14 percent of the rate data points associated with that visibility would exceed the chosen snowfall intensity category. The 14 percent limit was chosen to reflect the same acceptable risk level employed in the original analysis.

The snowfall intensity categories and associated rate limits used were equivalent to the limits used in standard HOT development, as follows:

1) Heavy Snow: >25 g/dm²/h;
2) Moderate Snow: 10 to 25 g/dm²/h;
3) Light Snow: 4 to 10 g/dm²/h; and
4) Very Light Snow: 3 to 4 g/dm²/h.

As was done in the original analysis, separate evaluations were performed for data collected at -1°C and above and for data collected below -1°C. Summaries of these analyses are shown below in Table 2.4 (for data collected at -1°C and above) and in Table 2.5 (for data collected below -1°C).

For each commonly reported visibility value, the assigned snowfall intensity has been shown on the right. Cells representing snowfall rates that exceed the assigned snowfall intensity are shaded in red. The final column indicates the total percentage of the data points at each reported visibility value with a measured snowfall rate exceeding the assigned snowfall intensity.

Table 2.4: Visibilities and Associated Snow Precipitation Rates (-1°C and Above, Day)

Visibility Value (miles)	% of Associated Data Points by Rate Range (g/dm²/h)										Assigned Snowfall Intensity	# of Rate Data Points in Visibility Range	% of Rate Data Points Above Assigned Snowfall Intensity
	0-2	3	4	5-9	10	11-24	25	26-49	50	>50			
0.25	0%	0%	0%	0%	0%	25%	0%	63%	6%	6%	Heavy	16	0%
0.375	0%	0%	0%	0%	0%	42%	5%	53%	0%	0%	Heavy	60	0%
0.5	0%	0%	0%	9%	3%	51%	6%	31%	0%	0%	Heavy	68	0%
0.625	0%	0%	0%	26%	10%	56%	2%	6%	0%	0%	Moderate	82	6%
0.75	4%	0%	2%	39%	2%	54%	0%	0%	0%	0%	Moderate	57	0%
0.875	0%	10%	10%	54%	4%	23%	0%	0%	0%	0%	Moderate	52	0%
1	0%	18%	24%	59%	0%	0%	0%	0%	0%	0%	Light	34	0%
1.25	26%	22%	13%	34%	1%	3%	0%	0%	0%	0%	Light	68	3%
1.5	43%	25%	14%	18%	0%	0%	0%	0%	0%	0%	Light	44	0%
1.75	33%	19%	25%	22%	0%	0%	0%	0%	0%	0%	Light	36	0%
2	54%	37%	3%	6%	0%	0%	0%	0%	0%	0%	Very Light	35	6%
2.5	67%	18%	5%	10%	0%	0%	0%	0%	0%	0%	Very Light	39	10%
3	41%	14%	23%	23%	0%	0%	0%	0%	0%	0%	Very Light	22	23%*
3.5	40%	40%	0%	20%	0%	0%	0%	0%	0%	0%	Very Light	10	20%*
4+	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	Very Light	23	0%

* Due to the very limited amount of data points associated with these visibility values, these risk tolerances were accepted when establishing the assigned snowfall intensity.

Table 2.5: Visibilities and Associated Snow Precipitation Rates (Below -1°C, Day)

Visibility Value (miles)	% of Associated Data Points by Rate Range (g/dm²/h)										Assigned Snowfall Intensity	# of Rate Data Points in Visibility Range	% of Rate Data Points Above Assigned Snowfall Intensity
	0-2	3	4	5-9	10	11-24	25	26-49	50	>50			
0.25	0%	0%	0%	0%	0%	22%	5%	60%	0%	12%	Heavy	239	0%
0.375	0%	0%	0%	5%	2%	71%	4%	17%	0%	0%	Heavy	453	0%
0.5	0%	0%	0%	12%	6%	76%	1%	4%	0%	1%	Moderate	478	5%
0.625	0%	1%	2%	34%	11%	52%	0%	0%	0%	0%	Moderate	543	0%
0.75	0%	1%	4%	60%	11%	24%	0%	0%	0%	0%	Moderate	861	0%
0.875	2%	3%	9%	67%	6%	14%	0%	0%	0%	0%	Moderate	620	0%
1	4%	10%	14%	63%	2%	6%	0%	0%	0%	0%	Light	497	6%
1.25	8%	19%	22%	48%	1%	2%	0%	0%	0%	0%	Light	569	2%
1.5	30%	20%	19%	29%	0%	1%	0%	0%	0%	0%	Light	327	1%
1.75	40%	32%	11%	16%	0%	1%	0%	0%	0%	0%	Light	177	1%
2	73%	15%	4%	7%	0%	0%	0%	0%	0%	0%	Very Light	181	7%
2.5	83%	10%	3%	4%	0%	0%	0%	0%	0%	0%	Very Light	168	4%
3	80%	13%	7%	0%	0%	0%	0%	0%	0%	0%	Very Light	86	0%
3.5	93%	2%	0%	5%	0%	0%	0%	0%	0%	0%	Very Light	42	5%
4+	96%	4%	0%	0%	0%	0%	0%	0%	0%	0%	Very Light	114	0%

The recommended snowfall intensity values derived from this analysis are applicable only for the daylight condition as the sensor from which the visibility data in the database was obtained reports visibilities as a human observer would in daylight, regardless of the lighting condition when the data was collected.

At the time when the original TP 14151E (1) analysis was performed, Rasmussen et al. deduced a formula for converting daytime visibility values to the equivalent human observer night-time values. This formula was originally published in *The Estimation of Snowfall Rate Using Visibility*, (3), and in the TC report, TP 12893E, *Theoretical Considerations in the Estimation of Snowfall Rate Using Visibility* (4), and is shown below:

$$V_d = \frac{\ln(E)V_n}{\ln(C_{DB}V_n/I_O)}$$

where

V_d = Daytime visibility

E = Visual contrast threshold

V_n = Night-time visibility

C_{DB} = Constant of proportionality

I_O = Luminous intensity

This formula makes several assumptions, including the following:

a) $E = 0.055$;

b) $C_{DB} = 0.084\ mi^{-1}$; and

c) $I_0 = 25$ candles.

To determine the recommended snowfall intensity values for night-time visibility conditions, the visibility values within the updated database were converted to equivalent night-time values using the above formula, and the analysis was repeated on the converted "night" database. Summaries of these analyses are shown below in Table 2.6 (for data collected at -1°C and above) and in Table 2.7 (for data collected below -1°C).

Table 2.6: Visibilities and Associated Snow Precipitation Rates (-1°C and Above, Night)

Visibility Value (miles)	% of Associated Data Points by Rate Range (g/dm²/h)										Assigned Snowfall Intensity	# of Rate Data Points in Visibility Range	% of Rate Data Points Above Assigned Snowfall Intensity
	0-2	3	4	5-9	10	11-24	25	26-49	50	>50			
0.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Heavy	16	0%
0.375	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Heavy	60	0%
0.5	0%	0%	0%	0%	0%	0%	0%	50%	25%	25%	Heavy	68	0%
0.625	0%	0%	0%	0%	0%	31%	0%	69%	0%	0%	Heavy	82	0%
0.75	0%	0%	0%	0%	0%	67%	0%	33%	0%	0%	Heavy	57	0%
0.875	0%	0%	0%	0%	0%	39%	7%	54%	0%	0%	Heavy	52	0%
1	0%	0%	0%	10%	5%	51%	5%	29%	0%	0%	Heavy	34	0%
1.25	0%	0%	1%	31%	7%	58%	1%	2%	0%	0%	Moderate	68	2%
1.5	3%	5%	2%	53%	3%	35%	0%	0%	0%	0%	Moderate	44	0%
1.75	0%	22%	28%	50%	0%	0%	0%	0%	0%	0%	Light	36	0%
2	23%	17%	15%	40%	2%	3%	0%	0%	0%	0%	Light	35	3%
2.5	39%	24%	16%	20%	0%	0%	0%	0%	0%	0%	Light	39	0%
3	31%	31%	18%	21%	0%	0%	0%	0%	0%	0%	Light	22	0%
3.5	70%	25%	2%	2%	0%	0%	0%	0%	0%	0%	Very Light	10	2%
4+	63%	14%	9%	14%	0%	0%	0%	0%	0%	0%	Very Light	23	14%

Table 2.7: Visibilities and Associated Snow Precipitation Rates (Below -1°C, Night)

Visibility Value (miles)	% of Associated Data Points by Rate Range (g/dm²/h)										Assigned Snowfall Intensity	# of Rate Data Points in Visibility Range	% of Rate Data Points Above Assigned Snowfall Intensity
	0-2	3	4	5-9	10	11-24	25	26-49	50	>50			
0.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Heavy	239	0%
0.375	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Heavy	453	0%
0.5	0%	0%	0%	0%	0%	12%	2%	69%	0%	17%	Heavy	478	0%
0.625	0%	0%	0%	0%	0%	35%	9%	49%	1%	6%	Heavy	543	0%
0.75	0%	0%	0%	0%	0%	63%	3%	35%	0%	0%	Heavy	861	0%
0.875	0%	0%	0%	6%	3%	75%	3%	13%	0%	0%	Moderate	620	13%
1	0%	0%	0%	14%	6%	74%	1%	4%	0%	1%	Moderate	497	5%
1.25	0%	1%	3%	47%	13%	35%	0%	0%	0%	0%	Moderate	569	0%
1.5	1%	2%	7%	65%	6%	19%	0%	0%	0%	0%	Moderate	327	0%
1.75	3%	7%	15%	61%	4%	9%	0%	0%	0%	0%	Light	177	9%
2	7%	18%	19%	54%	1%	2%	0%	0%	0%	0%	Light	181	2%
2.5	28%	22%	20%	30%	0%	1%	0%	0%	0%	0%	Light	168	1%
3	54%	25%	8%	13%	0%	1%	0%	0%	0%	0%	Very Light	86	14%
3.5	83%	9%	4%	5%	0%	0%	0%	0%	0%	0%	Very Light	42	5%
4+	89%	8%	2%	1%	0%	0%	0%	0%	0%	0%	Very Light	114	1%

Table 2.8 presents a summary of the updated recommended visibility table values as derived from the updated database analyses.

Table 2.8: Recommended Visibility Table Values Derived from Updated Database

Visibility		Day		Night	
Statute Miles	Meters	Below -1°C Below 30°F	-1°C and Above 30°F and Above	Below -1°C Below 30°F	-1°C and Above 30°F and Above
≤1/4 (≤3/8)	**≤400** (≤600)	Heavy	Heavy	Heavy	Heavy
1/2 (>3/8 to ≤5/8)	**800** (>600 to ≤1000)	Moderate	Heavy	Heavy	Heavy
3/4 (>5/8 to ≤7/8)	**1200** (>1000 to ≤1400)	Moderate	Moderate	Heavy	Heavy
1 (>7/8 to ≤1 1/8)	**1600** (>1400 to ≤1800)	Light	Light	Moderate	Heavy
1 ¼ (>1 1/8 to ≤1 3/8)	**2000** (>1800 to ≤2200)	Light	Light	Moderate	Moderate
1 ½ (>1 3/8 to ≤1 5/8)	**2400** (>2200 to ≤2600)	Light	Light	Moderate	Moderate
1 ¾ (>1 5/8 to ≤1 7/8)	**2800** (>2600 to ≤3000)	Light	Light	Light	Light
2 (>1 7/8 to ≤2 ¼)	**3200** (>3000 to ≤3600)	Very Light	Very Light	Light	Light
2 ½ (>2 ¼ to ≤2 ¾)	**4000** (>3600 to ≤4400)	Very Light	Very Light	Light	Light
3 (>2 ¾ to ≤3 ¼)	**4800** (>4400 to ≤5200)	Very Light	Very Light	Very Light	Light
3 ½ (>3 ¼ to ≤3 ¾)	**5600** (>5200 to ≤6000)	Very Light	Very Light	Very Light	Very Light
≥4 (>3 ¾)	**≥6400** (> 6000)	Very Light	Very Light	Very Light	Very Light

The impact of the data-cleaning exercise on the analytical recommendations from the original TP 14151E (1) analysis is depicted below in Table 2.9.

Table 2.9: Changes from TP 14151E Analysis Recommendations After Data Cleaning

Visibility				Day		Night	
Statute Miles		Meters		Below -1°C Below 30°F	-1°C and Above 30°F and Above	Below -1°C Below 30°F	-1°C and Above 30°F and Above
≤1/4	(≤3/8)	≤400	(≤600)	Heavy	Heavy	Heavy	Heavy
1/2	(>3/8 to ≤5/8)	800	(>600 to ≤1000)	Moderate	Heavy	Heavy	Heavy
3/4	(>5/8 to ≤7/8)	1200	(>1000 to ≤1400)	Moderate	Moderate	Heavy	Heavy
1	(>7/8 to ≤1 1/8)	1600	(>1400 to ≤1800)	Light	Moderate ↑ Light	Moderate	Heavy
1 ¼	(>1 1/8 to ≤1 3/8)	2000	(>1800 to ≤2200)	Light	Moderate ↑ Light	Moderate	Moderate
1 ½	(>1 3/8 to ≤1 5/8)	2400	(>2200 to ≤2600)	Light	Moderate ↑ Light	Moderate	Moderate
1 ¾	(>1 5/8 to ≤1 7/8)	2800	(>2600 to ≤3000)	Light	Light	Light	Moderate ↑ Light
2	(>1 7/8 to ≤2 ¼)	3200	(>3000 to ≤3600)	↑ VLS	Light ↑ VLS	Light	Moderate ↑ Light
2 ½	(>2 ¼ to ≤2 ¾)	4000	(>3600 to ≤4400)	Very Light	↑ VLS	Light	Moderate ↑ Light
3	(>2 ¾ to ≤3 ¼)	4800	(>4400 to ≤5200)	Very Light	↑ VLS	↑ VLS	Light
3 ½	(>3 ¼ to ≤3 ¾)	5600	(>5200 to ≤6000)	Very Light	Very Light	Very Light	Light ↑ VLS
≥4	(>3 ¾)	≥6400	(> 6000)	Very Light	Very Light	Very Light	↑ VLS

In every instance where a change was made to the snowfall intensity value (as compared to the original analysis), the recommended change represented a move to a lighter snowfall intensity.

The most significant changes were noted in the "-1°C and Above" data category. This was expected as most of the data flagged in the database review belonged to this category.

2.6 Harmonization of Visibility Table Notes

In addition to the work that was done to harmonize the visibility table format and values, a separate exercise was performed to address differences in the guidance notes associated with the TC and FAA versions of the visibility tables.

The previous versions of the TC and FAA guidance notes contained largely similar information; however, the specific wording and placement of the information differed in many instances across the two publications. The TC/FAA visibility guidance notes prior to harmonization are shown in Figure 2.4 and Figure 2.5, respectively.

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.

HOW TO READ AND USE THE TABLE

The METAR/SPECI reported visibility or flight crew observed visibility will be used with this visibility table to establish snowfall intensity for Type I, II, III and IV holdover time guidelines, during snow, snow grain, or snow pellet precipitation conditions.

This visibility table will also be used when snow, snow grains or snow pellets are accompanied by blowing or drifting snow in the METAR/SPECI.

RVR values should not be used with this table.

Example: *CYVO 160200Z 15011G17KT 1SM -SN DRSN OVC009 M06/M08 A2948*

In the above METAR the snowfall intensity is reported as light. However, based upon the Transport Canada "Snowfall Intensities as a Function of Prevailing Visibility" table, with a visibility of 1 statute mile, in darkness and a temperature of -6°C, the snowfall intensity is classified as moderate. The snowfall intensity of moderate - not the METAR reported intensity of light - will be used to determine which holdover time guideline value is appropriate for the fluid in use.

Figure 2.4: TC Visibility Table Guidance Notes Before Harmonization

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 2.5: FAA Visibility Table Guidance Notes Before Harmonization

A harmonized version of the table notes was subsequently created, shown below in Figure 2.6.

NOTES

- The METAR/SPECI reported visibility or flight crew observed visibility will be used with this visibility table to establish snowfall intensity for Type I, II, III and IV holdover time guidelines, during snow, snow grain, or snow pellet precipitation conditions. This visibility table will also be used when snow, snow grains, or snow pellets are accompanied by blowing or drifting snow, or when snow is mixed with ice crystals or freezing fog in the METAR/SPECI.
- The use of Runway Visual Range (RVR) is not permitted for determining visibility used with the holdover tables.
- 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.

Example for how to read and use the table: *CYVO 160200Z 15011G17KT 1SM -SN DRSN OVC009 M06/M08 A2948*

In the above METAR the snowfall intensity is reported as light. However, based upon the "Snowfall Intensities as a Function of Prevailing Visibility" table, with a visibility of 1 statute mile, at night and a temperature of -6°C, the snowfall intensity is classified as moderate. The snowfall intensity of moderate - not the METAR reported intensity of light - will be used to determine which holdover time guideline value is appropriate for the fluid in use.

Figure 2.6: Harmonized TC/FAA Visibility Table Guidance Notes

During the review and harmonization process, several notes contained in one or both of TC/FAA's previous visibility tables were removed. These include statements indicating the analytical background from which the table was derived (removed for inconsistency with other guidance tables in the HOT Guidelines), a statement in the FAA guidance indicating how to interpret visibility values that do not directly align with METAR-reported values (no longer needed as the new table format provides visibility ranges), and finally a statement in the FAA guidance indicating that the METAR-reported snowfall intensity can be used when snow is being reported alongside forms of obscuration such as fog, haze, or smoke.

2.7 Changes to the HOT Guidelines and Harmonization Status

The updated visibility table guidance (including the revised format, updated table values, and updated guidance notes) was adopted and published by TC in their HOT Guidelines for the winter of 2022-23. The updated TC table and guidance is shown below in Figure 2.7.

TABLE 53: SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY

Visibility		Day		Night	
Statute Miles	**Meters**	**Below -1°C** Below 30 °F	**-1°C and above** 30 °F and above	**Below -1°C** Below 30 °F	**-1°C and above** 30 °F and above
≤1/4 (≤3/8)	**≤400** (≤600)	Heavy	Heavy	Heavy	Heavy
1/2 (>3/8 to ≤5/8)	**800** (>600 to ≤1000)	Moderate	Heavy	Heavy	Heavy
3/4 (>5/8 to ≤7/8)	**1200** (>1000 to ≤1400)	Moderate	Moderate	Heavy	Heavy
1 (>7/8 to ≤1 1/8)	**1600** (>1400 to ≤1800)	Light	Light	Moderate	Heavy
1 ¼ (>1 1/8 to ≤1 3/8)	**2000** (>1800 to ≤2200)	Light	Light	Moderate	Moderate
1 ½ (>1 3/8 to ≤1 5/8)	**2400** (>2200 to ≤2600)	Light	Light	Moderate	Moderate
1 ¾ (>1 5/8 to ≤1 7/8)	**2800** (>2600 to ≤3000)	Light	Light	Light	Light
2 (>1 7/8 to ≤2 ¼)	**3200** (>3000 to ≤3600)	Very Light	Very Light	Light	Light
2 ½ (>2 ¼ to ≤2 ¾)	**4000** (>3600 to ≤4400)	Very Light	Very Light	Light	Light
3 (>2 ¾ to ≤3 ¼)	**4800** (>4400 to ≤5200)	Very Light	Very Light	Very Light	Light
≥3 ½ (>3 ¼)	**≥5600** (>5200)	Very Light	Very Light	Very Light	Very Light

NOTES

- The METAR/SPECI reported visibility or flight crew observed visibility will be used with this visibility table to establish snowfall intensity for Type I, II, III and IV holdover time guidelines, during snow, snow grain, or snow pellet precipitation conditions. This visibility table will also be used when snow, snow grains, or snow pellets are accompanied by blowing or drifting snow, or when snow is mixed with ice crystals or freezing fog in the METAR/SPECI.
- The use of Runway Visual Range (RVR) is not permitted for determining visibility used with the holdover tables.
- 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.

Example for how to read and use the table: `CYVO 160200Z 15011G17KT 1SM -SN DRSN OVC009 M06/M08 A2948`

In the above METAR the snowfall intensity is reported as light. However, based upon the "Snowfall Intensities as a Function of Prevailing Visibility" table, with a visibility of 1 statute mile, at night and a temperature of -6°C, the snowfall intensity is classified as moderate. The snowfall intensity of moderate - not the METAR reported intensity of light - will be used to determine which holdover time guideline value is appropriate for the fluid in use.

Figure 2.7: TC Visibility Table Guidance for the 2022-23 HOT Guidelines

The FAA implemented the new visibility table format and guidance notes and partially adopted the recommended updates to the table values. The updated FAA table and guidance is shown below in Figure 2.8.

TABLE 53: SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY

Visibility		Day		Night	
Statute Miles	**Meters**	**-1°C and below** 30 °F and below	**Above -1°C** Above 30 °F	**-1°C and Below** 30 °F and below	**Above -1°C** Above 30 °F
≤1/4 (≤3/8)	**≤400** (≤600)	Heavy	Heavy	Heavy	Heavy
1/2 (>3/8 to ≤5/8)	**800** (>600 to ≤1000)	Moderate	Heavy	Heavy	Heavy
3/4 (>5/8 to ≤7/8)	**1200** (>1000 to ≤1400)	Moderate	Moderate	Moderate	Heavy
1 (>7/8 to ≤1 1/8)	**1600** (>1400 to ≤1800)	Light	Light	Moderate	Moderate
1 ¼ (>1 1/8 to ≤1 3/8)	**2000** (>1800 to ≤2200)	Light	Light	Moderate	Moderate
1 ½ (>1 3/8 to ≤1 5/8)	**2400** (>2200 to ≤2600)	Light	Light	Moderate	Moderate
1 ¾ (>1 5/8 to ≤1 7/8)	**2800** (>2600 to ≤3000)	Very Light	Light	Light	Light
2 (>1 7/8 to ≤2 ¼)	**3200** (>3000 to ≤3600)	Very Light	Very Light	Light	Light
2 ½ (>2 ¼ to ≤2 ¾)	**4000** (>3600 to ≤4400)	Very Light	Very Light	Very Light	Very Light
3 (>2 ¾ to ≤3 ¼)	**4800** (>4400 to ≤5200)	Very Light	Very Light	Very Light	Very Light
≥3 ½ (>3 ¼)	**≥5600** (>5200)	Very Light	Very Light	Very Light	Very Light

NOTES

- The METAR/SPECI reported visibility or flight crew observed visibility will be used with this visibility table to establish snowfall intensity for Type I, II, III and IV holdover time guidelines, during snow, snow grain, or snow pellet precipitation conditions. This visibility table will also be used when snow, snow grains, or snow pellets are accompanied by blowing or drifting snow, or when snow is mixed with ice crystals or freezing fog in the METAR/SPECI.
- The use of Runway Visual Range (RVR) is not permitted for determining visibility used with the holdover tables.
- 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.

Example for how to read and use the table: *CYVO 160200Z 15011G17KT 1SM -SN DRSN OVC009 M06/M08 A2948*

In the above METAR the snowfall intensity is reported as light. However, based upon the "Snowfall Intensities as a Function of Prevailing Visibility" table, with a visibility of 1 statute mile, at night and a temperature of -6°C, the snowfall intensity is classified as moderate. The snowfall intensity of moderate - not the METAR reported intensity of light - will be used to determine which holdover time guideline value is appropriate for the fluid in use.

Figure 2.8: FAA Visibility Table Guidance for the 2022-23 HOT Guidelines

The FAA elected to retain their previous visibility table values in several cells where they differed from the updated recommendations derived from the analysis in Subsection 2.5. This decision was made as the FAA visibility table was historically based on more than one data source (not just the analysis from TP 14151E [1]), and FAA opted not to reverse previous policy decisions related to these key cells.

As a result of the changes to the table formats and values, the TC and FAA visibility tables are now better harmonized, with the only remaining differences being the treatment of the -1°C temperature and the values in cells where the FAA opted not to reverse previous policy decisions. The remaining differences in the TC/FAA visibility table cell values are summarized in Figure 2.9.

TC/FAA Holdover Time Guidelines **Winter 20xx-20xx**

TABLE 50: SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY

Visibility		Day				Night			
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 (≤3/8)	≤400 (≤600)	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
1/2 (>3/8 to ≤5/8)	800 (>600 to ≤1000)	Mod	Mod	Heavy	Heavy	Heavy	Heavy	Heavy	Heavy
3/4 (>5/8 to ≤7/8)	1200 (>1000 to ≤1400)	Mod	Mod	Mod	Mod	Mod	Heavy	Heavy	Heavy
1 (>7/8 to ≤1 1/8)	1600 (>1400 to ≤1800)	Light	Light	Light	Light	Mod	Mod	Mod	Heavy
1 ¼ (>1 1/8 to ≤1 3/8)	2000 (>1800 to ≤2200)	Light	Light	Light	Light	Mod	Mod	Mod	Mod
1 ½ (>1 3/8 to ≤1 5/8)	2400 (>2200 to ≤2600)	Light	Light	Light	Light	Mod	Mod	Mod	Mod
1 ¾ (>1 5/8 to ≤1 7/8)	2800 (>2600 to ≤3000)	VLS	Light	Light	Light	Light	Light	Light	Light
2 (>1 7/8 to ≤2 ¼)	3200 (>3000 to ≤3600)	VLS	VLS	VLS	VLS	Light	Light	Light	Light
2 ½ (>2 ¼ to ≤2 ¾)	4000 (>3600 to ≤4400)	VLS	VLS	VLS	VLS	VLS	Light	VLS	Light
3 (>2 ¾ to ≤3 ¼)	4800 (>4400 to ≤5200)	VLS	VLS	VLS	VLS	VLS	VLS	VLS	Light
3 ½ (>3 ¼ to ≤3 ¾)	5600 (>5200 to ≤6000)	VLS	VLS	VLS	VLS	VLS	VLS	VLS	VLS
≥4 (>3 ¾)	≥6400 (> 6000)	VLS	VLS	VLS	VLS	VLS	VLS	VLS	VLS

Figure 2.9: Remaining Differences in TC/FAA Visibility Table Values After Changes

2.8 Conclusions

Following a review of the TC/FAA visibility table guidance and a data-cleaning exercise involving the analysis upon which the recommended visibility table values were originally derived, an updated visibility table format (including modified guidance notes) was created, and an updated set of visibility table value recommendations was produced.

Both TC and the FAA agreed to adopt the updated table format and updated visibility guidance notes. TC also fully adopted the updated recommended visibility table values; the FAA partially adopted the updated recommended visibility table values but retained their previous values in several cells where the discrepancies related to previous policy decisions.

Both organizations published the updated visibility table guidance in their respective 2022-23 HOT Guidelines, resulting in a significant improvement in the harmonization of the two organizations' visibility table guidance.

2.9 Recommendations

It is recommended that TC and the FAA continue to work to address the remaining differences between their respective visibility guidance tables to minimize the occurrence of situations where operators using different versions of the visibility tables would receive differing snowfall intensity guidance as a result.

The remaining differences that need to be addressed include the cells where differing snowfall intensities are assigned (particularly the corresponding cells where TC indicates "heavy snow" and FAA indicates "moderate snow") as well as the treatment of the -1°C temperature guidance.

It is recommended that additional snowfall precipitation rate and visibility data be collected at higher intensities to support further harmonization efforts in the above-mentioned cells where discrepancies remain.

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3. EVALUATION OF MIST AND FREEZING FOG DEPOSITION RATES

This section documents the work completed during the 2021-22 winter related to the investigation of mist and freezing fog deposition rates. The data provided in this report does not include the data obtained in 2020-21. Since a comprehensive assessment is set to be documented in 2022-23 or in a subsequent year, only the data obtained during the winter of 2021-22 is reported here. For more information regarding previous work completed related to this project, see Section 3 of the Transport Canada (TC) report, TP 15496E, *Aircraft Ground Icing General Research Activities During the 2020-21 Winter* (2).

The re-evaluation of freezing fog deposition rates began in the winter of 2021-22 and emerged from discussion within the G-12 Holdover Time (HOT) Committee (May 2021 Conference). The committee recommended that the substantiation of freezing fog deposition rates be conducted to provide an intensity comparison to those of mist.

3.1 Background

Mist (METAR code BR) and freezing fog (METAR code FZFG) are commonly reported weather phenomena. Both are considered forms of obscuration rather than precipitation types and can be reported alone or in conjunction with other weather conditions such as snow and freezing rain. In terms of visibility, mist can reduce visibility to between 0.6 and 1.2 statute miles (1-2 km), while fog can reduce it to less than 0.6 statute miles (1 km).

The deposition rates for mist were first quantified in 2020-21 while those for freezing fog were developed in the early 2000s. As a result, HOTs now exist for both mist and freezing fog. Historical research simulating an aircraft taxi in freezing fog indicated that the deposition rates can increase significantly when in motion; consequently, freezing fog rates of 2 to 5 $g/dm^2/h$ were selected for developing HOTs. For more information concerning this study, see Subsection 2.9 of the TC report, TP 13826E, *Aircraft Ground De/Anti-icing Fluid Holdover Time Development Program for the 2000-01 Winter* (5).

This research is set to continue in the winter of 2022-23 and is required to support the continued development of HOT guidance for both mist and freezing fog.

3.2 Objective

The objective of this study was to determine the range of deposition rates that occur naturally in conditions of mist or freezing fog alone. This research is required to support and develop guidance for the appropriate treatment of mist and freezing fog for HOT determination.

3.3 Mist and Freezing Fog Forecasting

The following list of winter weather conditions were targeted when trying to forecast mist or freezing fog conditions for testing purposes.

- Mist: Surface visibility greater than or equal to approximately one kilometer (five-eighths of a statute mile) and less than approximately eleven kilometers (seven miles).
- Freezing Fog: Surface visibility less than approximately one kilometer (five-eighths of a statute mile).
- Outside air temperature (OAT): Less than 2°C. Most mist and freezing fog observations are at temperatures above -4°C, with many occurring near 0°C. Mist and freezing fog are 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: Low ceiling suggests more robust mist or freezing fog below approximately 240 meters (800 ft.).
- Precipitation: Helpful if occurring before the expected period of mist but not concurrently with mist or freezing fog.
- Sustained wind speed: Less than approximately 15 km/h (9 knots).

An analysis of historical METAR reports from Montréal–Pierre Elliott Trudeau International Airport (YUL) 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 B.

3.4 Testing Procedure

During the winter of 2021-22, mist and fog tests were carried out at the APS Aviation Inc. (APS) test site facility in Montreal, Montréal–Mirabel International Airport (YMX), Chomedey (Laval), and Beaconsfield (Montreal). As this study was comparative in nature, mist deposition rates were captured simultaneously using two measurement methods. The first and second methods simulated a taxiing and a stationary aircraft, respectively. Both testing methods were conducted using the standard precipitation collection pan, which is used for standard HOT testing. For the first method (taxiing), the rate pan was mounted on the top of a test vehicle and driven for 30 minutes at approximately 30 km/h, as seen in Photo 3.1. 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 METAR reports indicated the presence of mist or fog, which was confirmed as visible by the researcher, as seen in Photo 3.3. However, in some instances, mist or fog was visually observed but not reported by METAR (e.g., Photo 3.4). Therefore, the decision was made to conduct testing for all events that forecasted mist or fog (within reason) regardless of mist or fog being reported by METAR if either condition was visually observed at the time of testing. For a more detailed description of the methodologies employed during mist or fog testing, refer to Appendix C.

3.4.1 Procedural Updates for Winter 2021-22

The results of the 2020-21 testing were presented to the G-12 HOT Committee at the May 2021 conference, and the stakeholders recommended the following changes/additions to the testing procedure:

- Addition of dry rate pans to determine if mist or freezing fog accretion rates are similar when comparing a dry wing to a fluid-covered wing (wet wing); and
- Addition of temperature loggers to determine freezing or non-freezing conditions.

3.5 Data Collected

The following subsections describe the data that was collected during the Winter 2021-22 testing season. In total, 40 tests were conducted at YUL, YMX, Chomedey (Laval), and the Beaconsfield suburb in Montreal. Of the 40 tests, 38 consisted of mist or fog being visibly present regardless of being reported by METAR. The remaining 2 tests were conducted on October 13, 2021, when no mist was visually present or reported by METAR. Collection for these tests was done due to preceding mist forecasts. The rates were 0 g/dm^2/h using both test methods. In addition, of the 38 valid tests, 1 test collected on April 7, 2022, was eliminated due to errors.

3.5.1 Tests with Visible Mist/Fog and Mist/Fog Reported by METAR

In total, 21 tests were conducted with mist being visible and reported by METAR during the 2021-22 testing year. Table 3.1 is a summary of the data collected.

3.5.2 Tests with Visible Mist/Fog and Mist/Fog NOT Reported by METAR

In total, 16 tests were conducted with mist being visible but not reported by METAR during the 2021-22 testing year. Table 3.2 is a summary of the data collected.

3.5.3 Omitted Tests

In total, three tests were omitted from the test logs in Table 3.1 and Table 3.2. For two of the tests, no mist or fog was observed or reported while the other was omitted due to errors. Table 3.3 is a summary of the data pertaining to these tests.

Table 3.1: Log of Data Collected – Tests with Visible Mist/Fog and Mist/Fog Reported by METAR – Winter of 2021-22

Test No.	Date	METAR Observed Weather	Wet (Fluid) or Dry (No Fluid) Pan	Visual Verification of Mist or Fog 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
42	8-Oct-21	Shallow Fog	Dry	Yes	6:29	7:00	14.2	28	**0.0**	6:28	7:02	**0.0**	**0.0**	8.0	100	16.1	6	YUL	–
43	8-Oct-21	Shallow Fog	Wet	Yes	6:29	7:00	14.2	28	**1.0**	6:28	7:02	**0.3**	**0.7**	8.0	100	16.1	6	YUL	–
44	8-Oct-21	Shallow Fog/Mist	Wet	Yes	7:34	8:07	21.3	44	**1.4**	7:33	8:08	**0.2**	**1.2**	9.0	100	10.0	6	YUL	–
45	8-Oct-21	Shallow Fog/Mist	Dry	Yes	7:34	8:07	21.3	44	**0.0**	7:33	8:08	**0.0**	**0.0**	9.0	100	10.0	6	YUL	–
46	8-Oct-21	Shallow Fog/Mist	Dry	Yes	8:46	9:16	21.0	44	**0.0**	8:45	9:17	**0.0**	**0.0**	10.0	100	24.1	0	YUL	–
47	8-Oct-21	Shallow Fog/Mist	Wet	Yes	8:45	9:16	21.0	44	**0.0**	8:45	9:16	**0.0**	**0.0**	10.0	100	24.1	0	YUL	–
48	7-Oct-21	Fog/Mist	Dry	Yes	n/a	n/a	n/a	n/a	**n/a**	5:00	8:00	**0.04**	**n/a**	9.6	98	10.5	0	Beaconsfield	–
49	7-Oct-21	Fog/Mist	Dry	Yes	n/a	n/a	n/a	n/a	**n/a**	5:00	8:00	**0.26**	**n/a**	9.6	98	10.5	0	Beaconsfield	–
50	7-Oct-21	Fog	Dry	Yes	n/a	n/a	n/a	n/a	**n/a**	5:00	8:00	**0.42**	**n/a**	7.0	100	38	4	Laval	–
61	15-Oct-21	Mist	Dry	Yes	9:14	9:35	6.9	27	**0.0**	9:13	9:37	**0.0**	**0.0**	17.0	94	3.6	9	YUL	Began Raining During Test
62	15-Oct-21	Mist	Wet	Yes	9:14	9:35	6.9	27	**0.7**	9:13	9:37	**0.3**	**0.4**	17.0	94	3.6	9	YUL	Began Raining During Test
63	21-Oct-21	Fog	Dry	Yes	21:30	22:04	14.6	29	**0.1**	21:30	22:04	**0.1**	**0.0**	10.0	100	0.4	7	YUL	–
64	21-Oct-21	Fog	Wet	Yes	21:31	22:04	14.6	29	**1.3**	21:30	22:05	**0.5**	**0.8**	10.0	100	0.4	7	YUL	–

Table 3.1: Log of Data Collected – Tests with Visible Mist/Fog and Mist/Fog Reported by METAR – Winter of 2021-22 (cont'd)

Test No.	Date	METAR Observed Weather	Wet (Fluid) or Dry (No Fluid) Pan	Visual Verification of Mist or Fog 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
65	21-Oct-21	Fog	Dry	Yes	22:26	23:03	14.7	28	**0.0**	22:25	23:03	**0.0**	**0.0**	10.0	100	0.6	19	YUL	–
66	21-Oct-21	Fog	Wet	Yes	22:26	23:03	14.7	28	**1.0**	22:25	23:04	**0.5**	**0.5**	10.0	100	0.6	19	YUL	–
67	21-Oct-21	Mist	Dry	Yes	23:20	23:38	6.7	28	**0.1**	23:20	23:39	**0.0**	**0.1**	11.0	100	8.0	7	YUL	Rain During Test
68	21-Oct-21	Mist	Wet	Yes	23:20	23:38	6.7	28	**0.6**	23:20	23:38	**0.3**	**0.3**	11.0	100	8.0	7	YUL	Rain During Test
69	21-Oct-21	Mist	Wet	Yes	23:54	00:27	14.6	28	**0.9**	23:53	00:27	**0.5**	**0.4**	11.0	100	8.0	6	YUL	Drizzle During Test
70	21-Oct-21	Mist	Dry	Yes	23:54	00:27	14.6	28	**0.0**	23:53	00:28	**0.0**	**0.0**	11.0	100	8.0	6	YUL	Drizzle During Test
71	25-Oct-22	Mist	Wet	Yes	12:18	12:51	14.9	28	**0.0**	12:18	12:51	**0.0**	**0.0**	2.0	93	12.9	4	YMX	–
72	7-Apr-22	Mist	Wet	Yes	n/a	n/a	n/a	n/a	**n/a**	12:30	13:00	**0.2**	**n/a**	2.3	96	n/a	14	YMX (PMG)	–

Table 3.2: Log of Data Collected – Tests with Visible Mist/Fog and Mist/Fog NOT Reported by METAR - Winter of 2021-22

Test No.	Date	METAR Observed Weather	Wet (Fluid) or Dry (No Fluid) Pan	Visual Verification of Mist or Fog 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
38	8-Oct-21	Nil	Wet	Yes	04:28	05:02	13.6	27.0	**1.10**	04:27	05:03	**0.40**	**0.70**	11.0	100	24.1	6	YUL	-
39	8-Oct-21	Nil	Dry	Yes	04:28	05:02	13.6	27.0	**0.10**	04:26	05:02	**0.10**	**0.00**	11.0	100	24.1	6	YUL	-
40	8-Oct-21	Nil	Dry	Yes	05:29	06:02	14.3	29.0	**0.20**	05:28	06:03	**0.10**	**0.10**	10.0	100	24.1	6	YUL	-
41	8-Oct-21	Nil	Wet	Yes	05:28	06:02	14.3	29.0	**1.30**	05:28	06:03	**0.30**	**1.00**	10.0	100	24.1	6	YUL	-
51	13-Oct-21	Nil	Dry	Yes	04:53	05:25	14.3	28.0	**0.20**	04:52	05:26	**0.10**	**0.10**	15.0	94	24.1	6	YUL	-
52	13-Oct-21	Nil	Wet	Yes	04:53	05:25	14.3	28.0	**1.50**	04:52	05:26	**0.40**	**1.10**	15.0	94	24.1	6	YUL	-
53	13-Oct-21	Nil	Dry	Yes	05:43	06:17	13.5	25.0	**0.0**	05:44	06:17	**0.10**	**-0.10**	14.0	94	24.1	6	YUL	-
54	13-Oct-21	Nil	Wet	Yes	05:44	06:17	13.5	25.0	**1.20**	05:45	06:18	**0.40**	**0.80**	14.0	94	24.1	6	YUL	-
55	13-Oct-21	Nil	Wet	Yes	06:45	07:18	14.8	29.0	**0.80**	06:44	07:19	**0.30**	**0.50**	14.0	100	24.1	7	YUL	-
56	13-Oct-21	Nil	Dry	Yes	06:45	07:19	14.8	29.0	**0.30**	06:44	07:19	**0.0**	**0.30**	14.0	100	24.1	7	YUL	-
57	13-Oct-21	Nil	Wet	Yes	7:48	8:19	14.7	28.0	**0.10**	7:45	8:20	**0.20**	**-0.10**	15.0	94	24.1	7	YUL	-
58	13-Oct-21	Nil	Dry	Yes	7:46	8:18	14.7	28.0	**0.0**	7:45	8:19	**0.0**	**0.0**	15.0	94	24.1	7	YUL	-
74	8-Apr-22	Nil	Dry	Yes	23:05	23:35	15.0	30.0	**0.0**	23:00	23:30	**0.09**	**-0.09**	3.5	95	6+	6	YUL	-
75	8-Apr-22	Nil	Wet	Yes	23:05	23:35	15.0	30.0	**0.51**	23:00	23:30	**0.24**	**0.27**	3.5	95	6+	6	YUL	-
76	9-Apr-22	Nil	Dry	Yes	23:58	00:28	15.0	30.0	**0.02**	23:50	00:30	**0.04**	**-0.02**	4.0	96	6+	4	YUL	-
77	9-Apr-22	Nil	Wet	Yes	23:58	00:28	15.0	30.0	**0.43**	23:50	00:30	**0.20**	**0.23**	4.0	96	6+	4	YUL	-

Table 3.3: Log of Data Collected – Omitted Tests - Winter of 2021-22

Test No.	Date	METAR Observed Weather	Wet (Fluid) or Dry (No Fluid) Pan	Visual Verification of Mist or Fog 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
59	13-Oct-21	Nil	Dry	No	8:46	9:19	14.8	28.0	**0.0**	8:45	9:21	**0.0**	**0.0**	14.0	94	24.1	0	YUL	Test Invalid
60	13-Oct-21	Nil	Wet	No	8:46	9:19	14.8	28.0	**0.0**	8:45	9:20	**0.0**	**0.0**	14.0	94	24.1	0	YUL	Test Invalid
73	7-Apr-22	Mist	Wet	Yes	n/a	n/a	n/a	n/a	**n/a**	13:00	13:30	**0.6**	**n/a**	2.4	97	n/a	13	YMX (PMG)	Test Invalid

3.6 Data Analysis

An analysis of the data obtained in 2021-22 will be performed in 2022-23 or a subsequent year so that a more comprehensive assessment for both mist and freezing fog can be conducted. This assessment will include all data collected from all years.

3.7 Recommendations

For the winter of 2022-23, it is recommended to continue collection of mist and freezing fog 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). 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.

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Photo 3.1: Method 1 – Simulated Taxiing Aircraft

Photo 3.2: Method 2 – Simulated Stationed Aircraft

Photo 3.3: Mist Visible – Reported by METAR

(January 15, 2021 – Ottawa, Ontario)

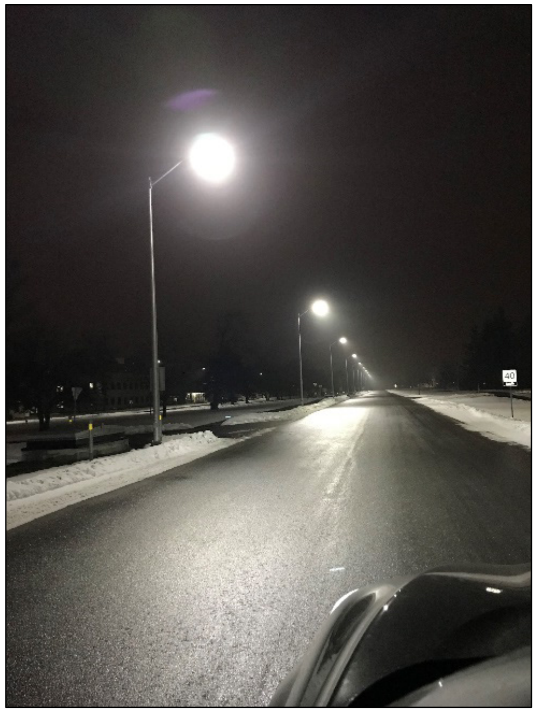
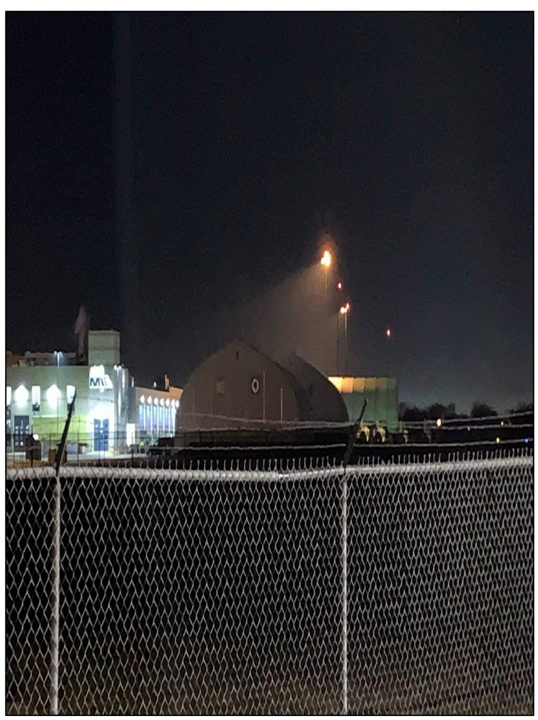


Photo 3.4: Mist Visible – Not Reported by METAR

(April 8-9, 2022 – Montreal, Quebec)



4. DEVELOPMENT OF GUIDANCE FOR MIXED ICING CONDITIONS

This section describes the ongoing work conducted by APS Aviation Inc. (APS) in 2021-22 to provide applicable holdover time (HOT) guidance for mixed icing conditions not currently addressed in the guidance material.

4.1 Background

When aircraft are operating in adverse winter conditions, METAR-reported weather conditions may not always have corresponding HOT guidance to allow for safe departure, and this is especially true for mixed conditions.

4.2 Previous Work

In 2019-20, 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* (6). This study examined a large sample of METAR data collected primarily at major airports in the United States and Canada that encounter winter precipitation including mixed precipitation conditions. In 2020-21, a METAR Working Group (MWG) was formed that included technical experts and meteorologists from the Federal Aviation Administration (FAA), TC, APS, and the National Center for Atmospheric Research (NCAR). The MWG utilised the data collected from the METAR analysis to develop a "master list" that groups similar conditions and organizes the groups (or "bins") by frequency of occurrence, level of effort required (from analytical to long-term research), and industry demand.

Changes to the HOT guidance for 2021-22 included the addition of "Freezing Mist" to the "Freezing Fog or Ice Crystals" column, which became the "Freezing Fog, Freezing Mist, or Ice Crystals" column, and the addition of "drizzle" in the note "Use light freezing rain HOTs in conditions of very light or light snow mixed with light rain or drizzle."

4.3 Objective

The objective of this ongoing project is to support the development of HOT or allowance time guidance for mixed icing conditions not currently included in the guidance material.

4.4 Research Activities 2021-22

To reach this objective, several research activities related to the following mixed conditions were undertaken by APS to support TC and the FAA:

1. Snow Mixed with Freezing Fog;
2. Moderate Ice Pellets and Moderate Snow;
3. Light Snow, Light Ice Pellets, and Light Freezing Rain;
4. Ice Crystals and Freezing Fog;
5. Ice Crystals and Mist; and
6. Ice Crystals and Snow.

These individual activities are described in Subsections 4.5 to 4.10.

4.5 Snow Mixed with Freezing Fog

Industry expressed concerns with HOT guidance related to reported mixed conditions of snow and freezing fog. Endurance time testing was conducted in mixed snow and freezing fog conditions to support the development of HOT guidance. The details of this research can be found in the TC report, TP 15540E, *Evaluation of Fluid Endurance Times in Mixed Snow and Freezing Fog Conditions* (7).

4.6 Moderate Ice Pellets and Moderate Snow

Preliminary exploratory testing was conducted for this condition at the National Research Council Canada (NRC) 3 m x 6 m Icing Wind Tunnel (IWT), providing some limited data indicating potential for future development. The details of this research can be found in the TC report, TP 15537E, *Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2021-22* (8).

4.7 Light Snow, Light Ice Pellets, and Light Freezing Rain

Preliminary exploratory testing was conducted for this condition at the NRC IWT, providing some limited data indicating potential for future development. The details of this research can be found in TP 15540E (7).

4.8 Ice Crystals and Freezing Fog

HOTs currently exist for ice crystals in the same column as freezing fog or freezing mist. The HOTs apply to the conditions occurring individually, and currently there is no HOT guidance for ice crystals and freezing fog, or mist, reported simultaneously. An example of the HOT table format is included below in Figure 4.1.

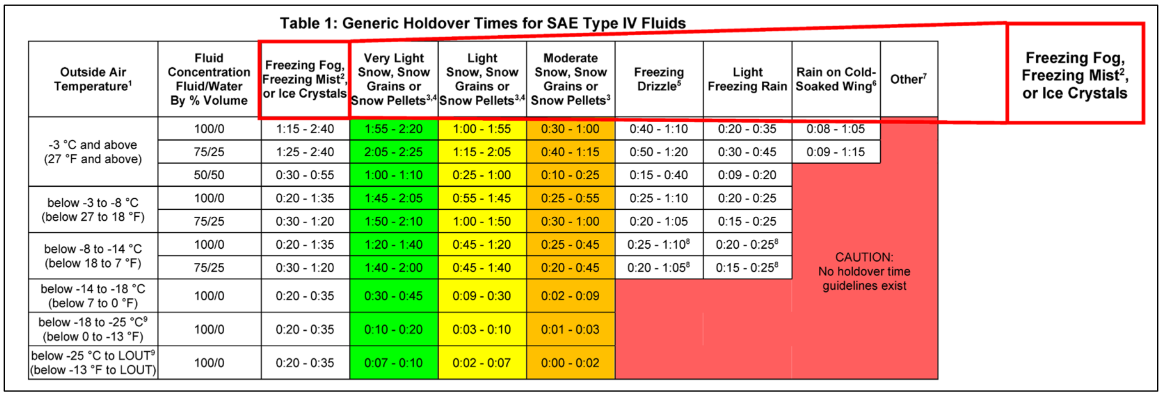


Table 1: Generic Holdover Times for SAE Type IV Fluids

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 4.1: Example of 2021-22 Holdover Time Table Format

4.8.1 Frequency

The "master list" of reports developed by the NCAR, comprising 20 years of data from airports worldwide, includes mixed conditions, all weather below 2ºC, and freezing/frozen precipitation above 2ºC. A summary of the number of weather events and hourly reports of ice crystals and freezing fog is included in Table 4.1 below.

Table 4.1: Number of Events and Reports in Master List per Mixed Condition

Weather Type	Number of Events	Number of Reports
-IC FZFG	47	63
IC FZFG	833	1838

4.8.2 Precipitation Rates Considered for HOT Guidance

4.8.2.1 Ice Crystals

Rate data was collected for ice crystals in 2012-14, and the majority of rates measured were less than 0.3 $g/dm^2/h$, with an average rate of 0.1 $g/dm^2/h$. The highest rate measured was 1.1 $g/dm^2/h$; however, a review of historical weather data revealed that blowing snow was reported during this and some of the other events included in the analysis, so the actual rates of ice crystals may be even lower. The average rate of 0.1 g/dm^2/h is similar in intensity to rates experienced in frost conditions. The rates were an order of magnitude less than the higher end of the freezing fog or very light snow intensities. Figure 4.2 below shows the frequency of rate data. More information can be found in the TC report, TP 15269E, *Aircraft Ground Icing General Research Activities During the 2013-14 Winter* (9).

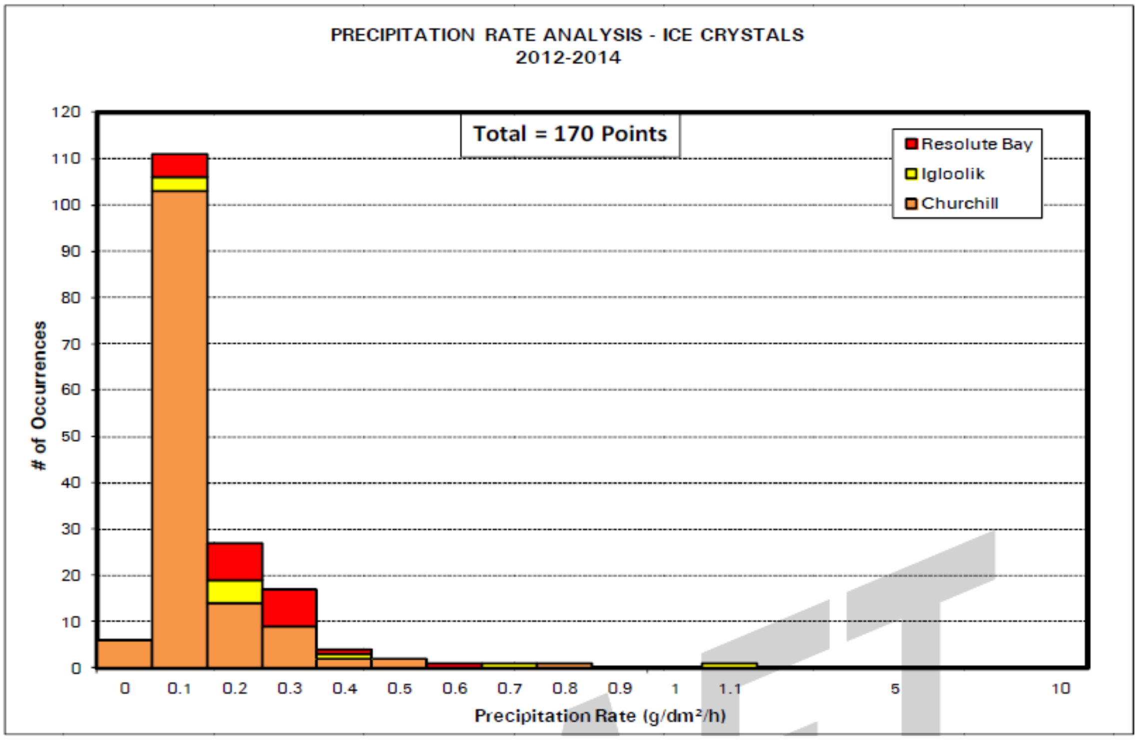


Figure 4.2: Precipitation Rate Analysis – Ice Crystals (from TP 15269E)

4.8.2.2 Freezing Fog

While fog is not considered a precipitation type, the droplets may deposit on aircraft surfaces and, for that reason, freezing fog HOTs were developed. At the 1997 Chicago SAE G-12 HOT Committee meeting, it was agreed that the lower and upper HOTs for freezing fog should be evaluated at rates of 5 g/dm^2/h and 2 g/dm^2/h, respectively. The fog deposition rates are based on an assumed liquid water content (LWC) of fog in the range of 0.2 to 0.6 g/m^3 and the following empirical expression:

Deposition = LWC x Wind Velocity x Sin 10° x Collection Efficiency

The “Sin 10º” value accounts for the 10º tilt of the test plates into the direction of the wind.

The higher limit of 5 g/dm^2/h is based on the upper LWC of 0.6 g/m^3, a wind velocity of 6 km/h, and a collection efficiency of 80 percent or an aircraft taxiing at 12 km/h relative to the same wind in a 0.6 g/m^3 fog and a collection efficiency of 40 percent.

A study to quantify freezing fog deposition rates was conducted by APS in 2002. The tests indicated that there is a relationship between visibility and deposition rates. As visibility dropped, a significant increase in deposition rate was observed. The rates measured ranged from 0.1 g/dm^2/h for 457 m (1500 ft.) of visibility to 2.5 g/dm^2/h for 46 m (150 ft.) of visibility. These results indicate that the selected rates for the laboratory tests of 2 g/dm^2/h (the lower rate used to measure endurance time) and 5 g/dm^2/h (the higher rate used to measure endurance time) appear to be conservative. Applicable regulations indicate that the lowest actual visibility limit for departures under instrument meteorological conditions is 183 m (600 ft.). At this visibility, the estimated rate of fog deposition is 0.7 g/dm^2/h. More information can be found in the TC report, TP 13993E, *Impact of Winter Weather on Holdover Time Table Format (1995-2002)* (10).

The respective rates measured and those used for the HOT guidance for each condition are summarized in Table 4.2 below.

Table 4.2: Summary of Rates Measured and Rates Used for HOTs

Rates Measured			
Condition	**Minimum Rate (g/dm²/h)**	**Maximum Rate (g/dm²/h)**	**Average Rate (g/dm²/h)**
Fog	0.1	2.5	1.1
Ice Crystals	0.01	1.1	0.1
Rates Used for HOTs			
Condition	**Minimum Rate (g/dm²/h)**	**Maximum Rate (g/dm²/h)**	**Average Rate (g/dm²/h)**
Freezing Fog, Freezing Mist, or Ice Crystals	2	5	3.5

4.8.3 Recommendations for Guidance

If the latent heat effect from the addition of ice crystals can be assumed to be negligible due to the rates being an order of magnitude less than those for fog on average, the HOT for the combined condition can be derived from the regression of freezing fog HOTs at the combined rate.

Table 4.3: Summary of Rates Measured and Adjusted for Fog and Ice Crystals

Rates Measured			
Condition	**Minimum Rate (g/dm²/h)**	**Maximum Rate (g/dm²/h)**	**Average Rate (g/dm²/h)**
Fog	0.1	2.5	1.1
Ice Crystals	0.01	1.1	0.1
Adjusted Rates for Combined Condition			
Condition	**Minimum Rate (g/dm²/h)**	**Estimated Maximum Rate (g/dm²/h)**	**Estimated Average Rate (g/dm²/h)**
Fog	0.1	1.0	0.6
Ice Crystals	0.01	0.5	0.3
Combined Rate	**0.11**	**1.5**	**0.9**

Table 4.3 above summarizes the rates of fog and ice crystals measured and those used to estimate the rates of the combined condition. As outlined in the previous section, the rates of 2 g/dm^2/h and 5 g/dm^2/h for freezing fog are conservative, as the maximum rate of fog measured by APS was 2.5 g/dm^2/h at a corresponding visibility of 46 m (150 ft.). As well, the higher rates measured (>1 g/dm^2/h) were collected at temperatures above 5°C. The rates (as shown in the Estimated Maximum Rate column) would be significantly lower at colder temperatures, as the maximum moisture content in air varies with temperature. Ice crystals most often occur at very low temperatures (below -18°C), where the fog rates would be the lowest.

The combined rate of ice crystals and freezing fog at the temperatures at which these events occur is expected to be below the lower rate of 2 g/dm^2/h used in the current "Freezing Fog, Freezing Mist or Ice Crystals" HOT guidance. Therefore, it would be possible to use the existing HOTs. It is recommended to perform testing next winter to validate.

A recommended option to address the mixed condition of ice crystals with freezing fog or mist would be to add a note to all applicable HOT tables stating, "Use freezing fog holdover times in conditions of ice crystals mixed with freezing fog or mist." An example is provided in Figure 4.3.

TABLE 21: GENERIC HOLDOVER TIMES FOR SAE TYPE IV FLUIDS[1]

Outside Air Temperature[2]	Fluid Concentration Fluid/Water By % Volume	Freezing Fog, Freezing Mist[3], or Ice Crystals[4]	Very Light Snow, Snow Grains or Snow Pellets[5,6,7]	Light Snow, Snow Grains or Snow Pellets[5,6,7]	Moderate Snow, Snow Grains or Snow Pellets[5,7]	Freezing Drizzle[8]	Light Freezing Rain	Rain on Cold-Soaked Wing[9]	Other[10]
-3°C and above (27°F and above)	100/0	1:15 - 2:40	1:55 - 2:00	1:00 - 1:55	0:30 - 1:00	0:40 - 1:10	0:20 - 0:35	0:08 - 1:05	
	75/25	1:25 - 2:40	2:00 - 2:00	1:15 - 2:00	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 - 2:00	0:55 - 1:45	0:25 - 0:55	0:25 - 1:10	0:20 - 0:25		
	75/25	0:30 - 1:20	1:50 - 2:00	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[11]	0:20 - 0:25[11]	CAUTION: No holdover time guidelines exist	
	75/25	0:30 - 1:20	1:40 - 2:00	0:45 - 1:40	0:20 - 0:45	0:20 - 1:05[11]	0:15 - 0:25[11]		
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[12] (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[12] (below -13°F to LOUT)	100/0	0:20 - 0:35	0:07 - 0:10	0:02 - 0:07	0:00 - 0:02				

NOTES

1 To use the HOTs in this table, ensure that the fluid and dilution being used is listed in the Type IV Fluids Tested for Anti-Icing Performance and Aerodynamic Acceptance table (Table 57). Any restrictions on the use of the fluid have to be identified and applied.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type IV fluid cannot be used.
3 Freezing mist is best confirmed by observation. It is never reported by METAR however it can occur when mist is present at 0 °C (32 °F) and below.
4 Use freezing fog holdover times in conditions of ice crystals mixed with freezing fog or mist.
5 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 53) is required.
6 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain or drizzle.
7 Use snow holdover times in conditions of very light, light, or moderate snow mixed with ice crystals.
8 Includes light, moderate and heavy freezing drizzle. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
9 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
10 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 51 provides allowance times for Type IV EG fluids and Table 52 provides allowance times for Type IV PG fluids in ice pellets and small hail. If the glycol type is unknown, the allowance times for SAE Type IV PG fluids should be used).
11 No holdover time guidelines exist for this condition below -10°C (14°F).
12 If the LOUT is unknown, no holdover time guidelines exist below -23.5°C (-10°F).

CAUTIONS

- The cautions that apply to the holdover times in the table above can be found on page 32.

Figure 4.3: Example of Potential Note Added to Holdover Time Tables

4.9 Ice Crystals and Mist

As stated in Subsection 4.8.3, the same guidance for ice crystals and freezing fog can be applied to ice crystals and mist. Mixed conditions of ice crystals and mist could be addressed by the same note: "Use freezing fog holdover times in conditions of ice crystals mixed with freezing fog or mist." By definition, the deposition rate of mist is lower than that of fog, as they are differentiated by the reduction in visibility: fog is reported for visibility below 5/8 SM and mist is reported for visibility between 5/8 SM and 6 or 7 SM according to Federal Meteorological Handbook No. 1 [FMH-1] and the Manual of Surface Weather Observations Standards [MANOBS], respectively). Therefore, it would be conservative to apply the same guidance for ice crystals mixed with mist as for ice crystals mixed with freezing fog.

4.10 Ice Crystals and Snow

HOTs currently exist for ice crystals in the same column as freezing fog or freezing mist. HOTs for snow are separated by intensity into "very light", "light," and "moderate" and include snow, snow grains, or snow pellets. The HOTs apply to the conditions occurring separately, and currently there is no HOT guidance for ice crystals and snow occurring simultaneously. An example of the current format for HOT guidance is provided below in Figure 4.4.

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 - 2:00	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	2:00 - 2:00	1:15 - 2:00	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 - 2:00	0:55 - 1:45	0:25 - 0:55	0:25 - 1:10	0:20 - 0:25		
	75/25	0:30 - 1:20	1:50 - 2:00	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				

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. Freezing mist is best confirmed by observation. It is never reported by METAR however it can occur when mist is present at 0 °C (32 °F) and below.
3. To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 50) is required.
4. Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain or drizzle.
5. Includes light, moderate and heavy freezing drizzle. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6. No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7. Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 48 provides allowance times for Type IV EG fluids and Table 49 provides allowance times for Type IV PG fluids in ice pellets and small hail. If the glycol type is unknown, the allowance times for SAE Type IV PG fluids should be used).
8. No holdover time guidelines exist for this condition below -10°C (14°F).
9. If the LOUT is unknown, no holdover time guidelines exist below -23.5°C (-10°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.

Figure 4.4: Example of Current Holdover Time Table Format

4.10.1 Frequency

The "master list" of reports developed by the NCAR, comprising 20 years of data from airports worldwide, includes mixed conditions, all weather below 2ºC, and freezing/frozen precipitation above 2ºC. A summary of the number of weather events and hourly reports of ice crystals and snow is included in Table 4.4.

Table 4.4: Number of Events and Reports in Master List per Mixed Condition

Weather Type	Number of Events	Number of Reports
-IC SN	28	65
IC SN	2085	3683
-SN IC	539	1629
SN IC	382	509

4.10.2 Precipitation Rates Considered for HOT Guidance

4.10.2.1 Ice Crystals

See Subsection 4.8.2.1.

4.10.2.2 Snow

The precipitation rate limits used to determine HOTs for Type II/III/IV fluids in snow are 3, 4, 10, and 25 g/dm²/h. These rate limits encompass very light, light, and moderate snow. A summary of the rates of snow and ice crystals used for HOT guidance are included in Table 4.5 below.

Table 4.5: Summary of Rates Measured and Rates Used for HOTs

Rates Measured			
Condition	**Minimum Rate (g/dm²/h)**	**Maximum Rate (g/dm²/h)**	**Average Rate (g/dm²/h)**
Ice Crystals	0.01	1.1	0.1

Rates Used for HOTs		
Condition	**Minimum Rate (g/dm²/h)**	**Maximum Rate (g/dm²/h)**
Freezing Fog, Freezing Mist, or Ice Crystals	2	5
Very Light Snow, Snow Grains, or Snow Pellets	3	4
Light Snow, Snow Grains, or Snow Pellets	4	10
Moderate Snow, Snow Grains, or Snow Pellets	10	25

4.10.3 Recommendations for Guidance

Ice crystals (diamond dust) and snow are both composed of ice crystals, where snow is mostly branched and ice crystals are unbranched. The two precipitation types are composed of similar particles, and the average rate for ice crystals is an order of magnitude less than that for snow. There are no latent heat effects on the fluid endurance time for the combined condition.

Use of the visibility table to determine the combined intensity of the snow and ice crystals is appropriate, as the ice crystals will have a reduction in visibility similar to that in snow.

It is recommended that a note be added to HOT tables reading, "Use snow holdover times in conditions of very light, light, or moderate snow mixed with ice crystals." An example of this note is provided below in Figure 4.5.

TABLE 21: GENERIC HOLDOVER TIMES FOR SAE TYPE IV FLUIDS[1]

Outside Air Temperature[2]	Fluid Concentration Fluid/Water By % Volume	Freezing Fog, Freezing Mist[3], or Ice Crystals[4]	Very Light Snow, Snow Grains or Snow Pellets[5,6,7]	Light Snow, Snow Grains or Snow Pellets[5,6,7]	Moderate Snow, Snow Grains or Snow Pellets[5,7]	Freezing Drizzle[8]	Light Freezing Rain	Rain on Cold-Soaked Wing[9]	Other[10]
-3°C and above (27°F and above)	100/0	1:15 - 2:40	1:55 - 2:00	1:00 - 1:55	0:30 - 1:00	0:40 - 1:10	0:20 - 0:35	0:08 - 1:05	
	75/25	1:25 - 2:40	2:00 - 2:00	1:15 - 2:00	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 - 2:00	0:55 - 1:45	0:25 - 0:55	0:25 - 1:10	0:20 - 0:25		
	75/25	0:30 - 1:20	1:50 - 2:00	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[11]	0:20 - 0:25[11]	CAUTION: No holdover time guidelines exist	
	75/25	0:30 - 1:20	1:40 - 2:00	0:45 - 1:40	0:20 - 0:45	0:20 - 1:05[11]	0:15 - 0:25[11]		
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[12] (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[12] (below -13°F to LOUT)	100/0	0:20 - 0:35	0:07 - 0:10	0:02 - 0:07	0:00 - 0:02				

NOTES

1 To use the HOTs in this table, ensure that the fluid and dilution being used is listed in the Type IV Fluids Tested for Anti-Icing Performance and Aerodynamic Acceptance table (Table 57). Any restrictions on the use of the fluid have to be identified and applied.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type IV fluid cannot be used.
3 Freezing mist is best confirmed by observation. It is never reported by METAR however it can occur when mist is present at 0 °C (32 °F) and below.
4 Use freezing fog holdover times in conditions of ice crystals mixed with freezing fog or mist.
5 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 53) is required.
6 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain or drizzle.
7 Use snow holdover times in conditions of very light, light, or moderate snow mixed with ice crystals.
8 Includes light, moderate and heavy freezing drizzle. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
9 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
10 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 51 provides allowance times for Type IV EG fluids and Table 52 provides allowance times for Type IV PG fluids in ice pellets and small hail. If the glycol type is unknown, the allowance times for SAE Type IV PG fluids should be used).
11 No holdover time guidelines exist for this condition below -10°C (14°F).
12 If the LOUT is unknown, no holdover time guidelines exist below -23.5°C (-10°F).

CAUTIONS

- The cautions that apply to the holdover times in the table above can be found on page 32.

Figure 4.5: Example of Potential Note Added to Holdover Time Tables

4.10.4 Recommendations

Mixed icing guidance development is an ongoing task that will continue to evolve as further analysis and research activities are accomplished. It is recommended that the MWG continue to collaborate on the further development of expanded HOT guidance for mixed precipitation conditions.

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5. CONTINUED 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 2021-22 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. The initial installation of these setups took place in the winter of 2020-21. All pertinent information related to this work can be found in the Transport Canada (TC) report, TP 15496E, *Aircraft Ground Icing General Research Activities During the 2020-21 Winter* (2). For this report, only notable changes in the winter of 2021-22 are documented here.

5.1 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 forced to temporarily shut down international travel and significantly reduce its domestic operations, the aviation industry, in particular the aviation safety sector, continued to operate with restrictions.

Pandemic-imposed restrictions forced APS to operate in exceptional ways. One major obstacle to solve 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 TC, the Federal Aviation Administration (FAA), and APS, could observe and provide insight into tests being conducted. Similarly, cameras were installed at the Montréal-Pierre Elliott Trudeau International Airport (YUL) test facility and at PMG Technologies Inc. (PMG). An iPhone® 12 Pro Max was used for Near/Far North testing to overcome the personnel capacity issues, and as well, to respond to situations when travel for certain staff members was not possible.

5.2 Objective

The primary objective of this project was to implement a remote viewing platform at all testing locations so that stakeholders, mainly TC, the FAA, and APS, could observe and provide insight into tests being conducted.

5.3 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 during fluid failures are as follows:

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

5.4 NRC Wind Tunnel

The following subsections describe the notable developments implemented in the winter of 2021-22 compared to the initial testing configuration used in 2020-21.

5.4.1 Overview of RJ Wing Testing

Four GoPro® cameras, one network video recorder (NVR) receiver, and five iPad® Pros were used to communicate and stream the live testing events. Streaming was made possible by using a Bell 5G Hotspot connected to the wiring setup, as depicted in Figure 5.1.

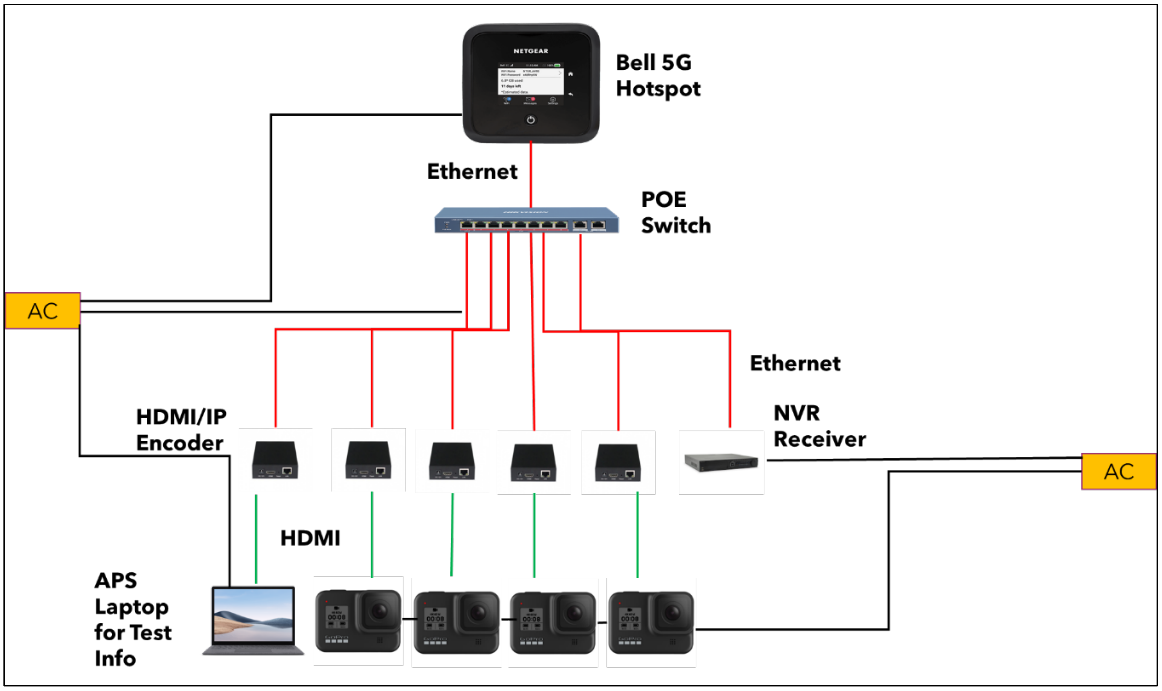

Figure 5.1: Remote Camera Wiring Diagram

The four GoPro® cameras, seen in Figure 5.2 and Figure 5.3, were strategically positioned outside of the wind tunnel as follows:

- Cameras 1 and 3 were positioned on the north side window viewing the wing; and
- Cameras 2 and 4 were positioned on the south side window viewing the wing.

To display the day's test plan to all stakeholders, an Internet Protocol (IP) box was connected to a computer, as shown in Figure 5.4.

5.4.2 Overview of Vertical Tail Testing

During vertical tail testing, the same setup described in Subsection 5.4.1 was used. However, instead of four GoPro® cameras, a combination of two GoPro's®, two closed-circuit televisions (CCTVs), two web cameras, and two high-resolution Osmo cameras were strategically installed inside the wind tunnel, as illustrated in Figure 5.5.

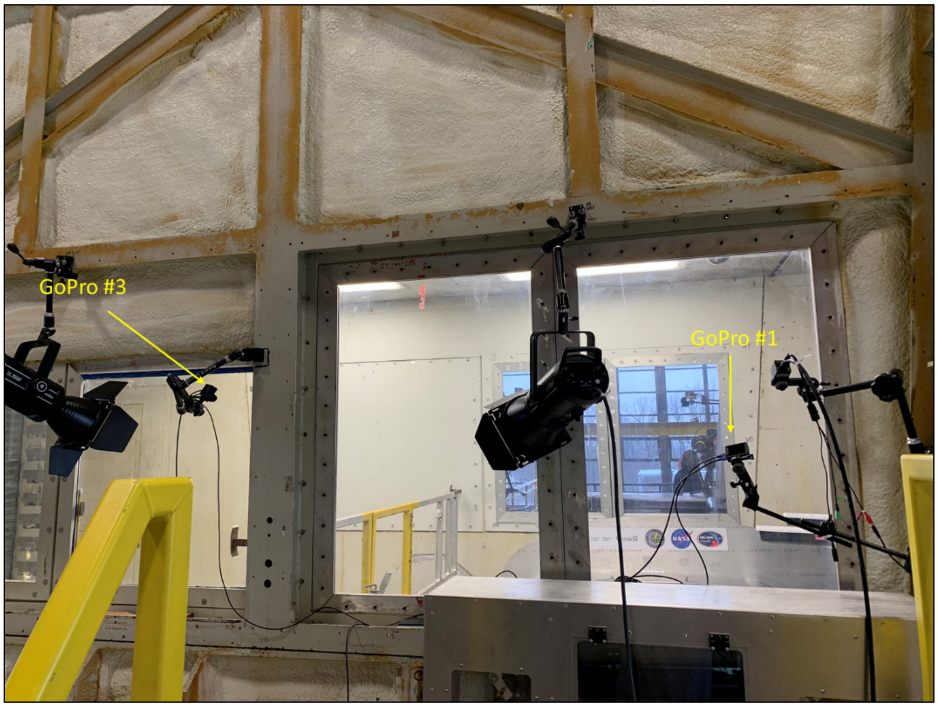

Figure 5.2: Location of Cameras – North Side of Wind Tunnel During RJ Wing Testing

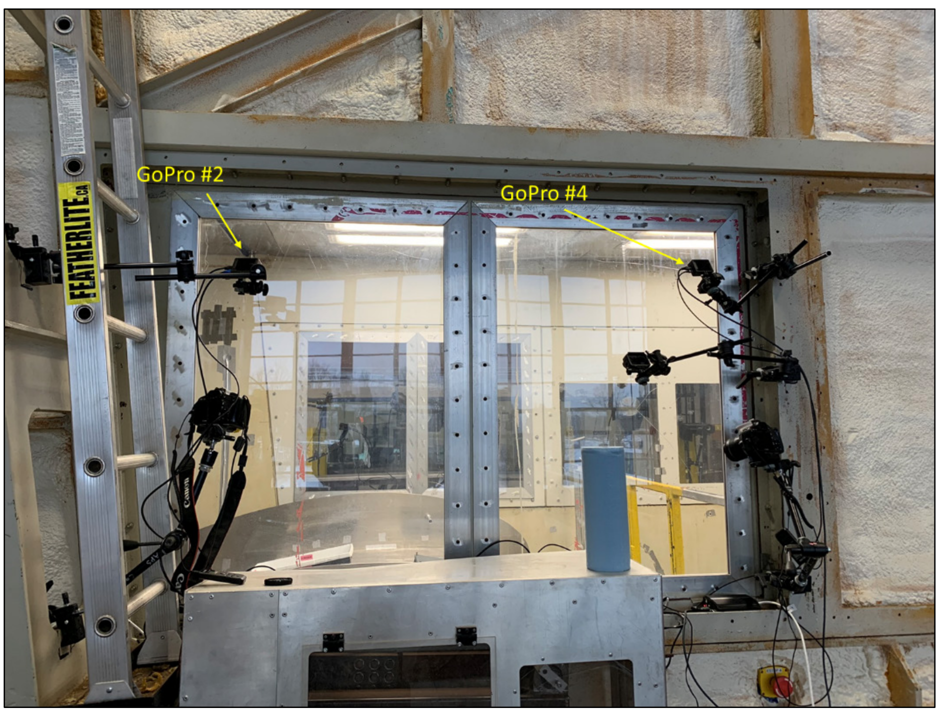

Figure 5.3: Location of Cameras – South Side of Wind Tunnel During RJ Wing Testing

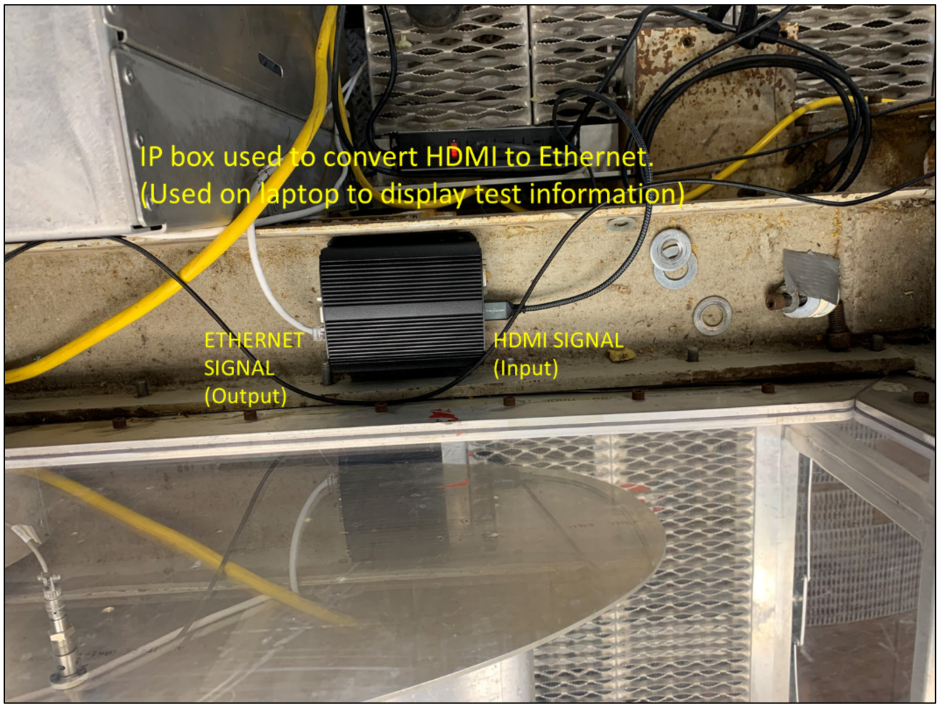

Figure 5.4: IP Box to Display the Day's Test Information During RJ Wing Testing

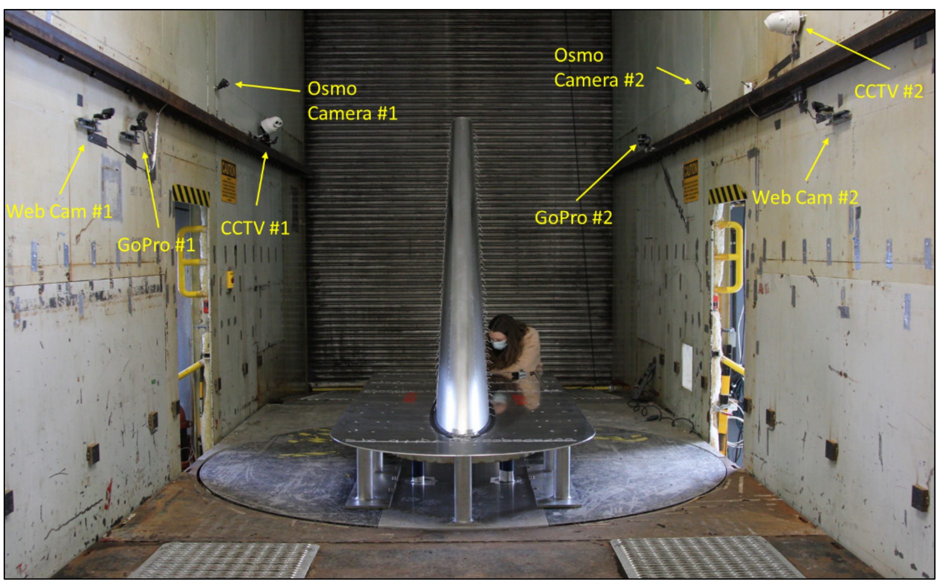

Figure 5.5: Location of Cameras During Vertical Stabilizer Testing

5.4.3 General Observations

Two minor technical issues were encountered while testing:

- Lighting; and
- Live-streaming issues.

The limited lighting available made the fluid flow-off during testing difficult to observe, especially toward the trailing edge of the RJ wing and over most of the vertical stabilizer.

The streaming issues encountered were mostly the "freezing" of screens, since the upload speeds from the internet connection could not keep up with the demand of multiple users. The process of streaming live feed through the internet places a high demand on the amount of data needed to be transferred to enable a high-resolution picture.

Although some issues were encountered, the camera system provided a suitable platform for active involvement in the testing process by those clients and personnel unable to attend live testing due to COVID-19 restrictions. Overall, all parties involved agreed that the system functioned very well. The high-quality resolution provided sufficient detail of the wings and fluid failures for all viewers.

5.4.4 Recommendations

Internet connections were the most problematic for the testing observed at the NRC wind tunnel. For this reason, it is recommended that an alternative internet provider be used for subsequent testing events. Camera upgrades and/or the reintroduction of CCTVs as done in 2020-21 should also be considered and may aid in resolving these issues.

5.5 NRC Climate Chamber

The following subsections describe the process used for the implementation of CCTV cameras at the NRC climate chamber during the winter of 2021-22 for both the Mixed Icing Conditions project (Mixed Snow and Freezing Fog) and the standard HOT testing.

5.5.1 Overview

Four cameras were used at the NRC climate chamber. Of the four cameras, two were 2.8 mm and two were of variable zoom in focal length. For the mixed snow and freezing fog project, all four cameras were positioned on the sides of the test stands, with both variable and 2.8 mm cameras positioned on the northwestern and southeastern direction of the chamber, respectively. Preliminary results showed that this setup was acceptable as it provided sufficient coverage of most test plates. Figure 5.6 displays the positions of the cameras at the NRC climate chamber.

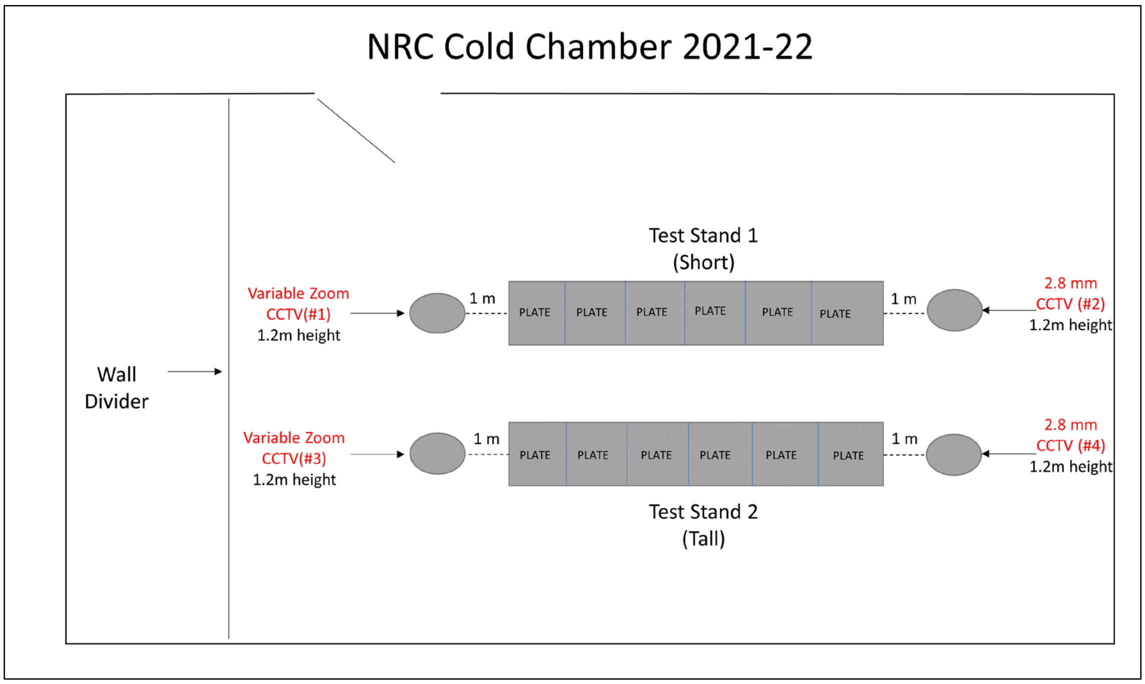

Figure 5.6: Camera Location at the NRC Climate Chamber During the Mixed Icing Condition Project (Mixed Snow and Freezing Fog)

During the standard HOT testing, all four camaras were positioned in front of Test Stand 1 (approximately 1.2 m) on a truss system approximately 2.5 m from the ground.

5.5.2 Observations

Although the camera system provided an excellent means of capturing all testing conducted at the NRC climate chamber, two issues were encountered during testing of both projects:

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

In general, the quality of the image was very good during all precipitation conditions (freezing rain [ZR], freezing drizzle [ZD], cold-soaked wing [CSW], and freezing fog [ZF]). However, testing with ZF sometimes posed a challenge. The image (feed) was at times unclear due to the dispersion of supercooled vapor particles in the air. In the future, this issue may be rectified by adding additional lighting to the area around the test stands.

5.5.3 Recommendations

While the camera system operated with near-perfect feeds, the following could still be considered in the future testing for both projects.

- The camera system could be positioned at better strategic locations to get better angles while testing.
- Lighting is particularly important if the feed is to be as clear as possible. It is recommended that additional and/or different types of lighting be incorporated into the setup.
- The image quality was very good. However, greater detail would be helpful, especially when dealing with fluid failures. It may be worth adding more cameras or mechanical arms to the setup so that the viewer can control the camera remotely while using zoom capabilities.

5.6 Natural Snow Testing at the YUL Test Facility

The following subsections describe the process used for the implementation of CCTV cameras at the YUL test facility. In some instances where the CCTV cameras did not provide the image details needed, an iPhone® 12 Pro Max was used as a backup.

5.6.1 Overview

Eight CCTV cameras were used at the YUL test facility. Five of the cameras had a focal length of 2.8 mm while the remining three had a focal length of 4 mm. The cameras were positioned at strategic locations so that the HOT and the artificial vs. natural (AvN) test stands were visible to provide support for fluid failure verifications. Figure 5.7 displays a schematic representation of the camera locations at the YUL test facility.

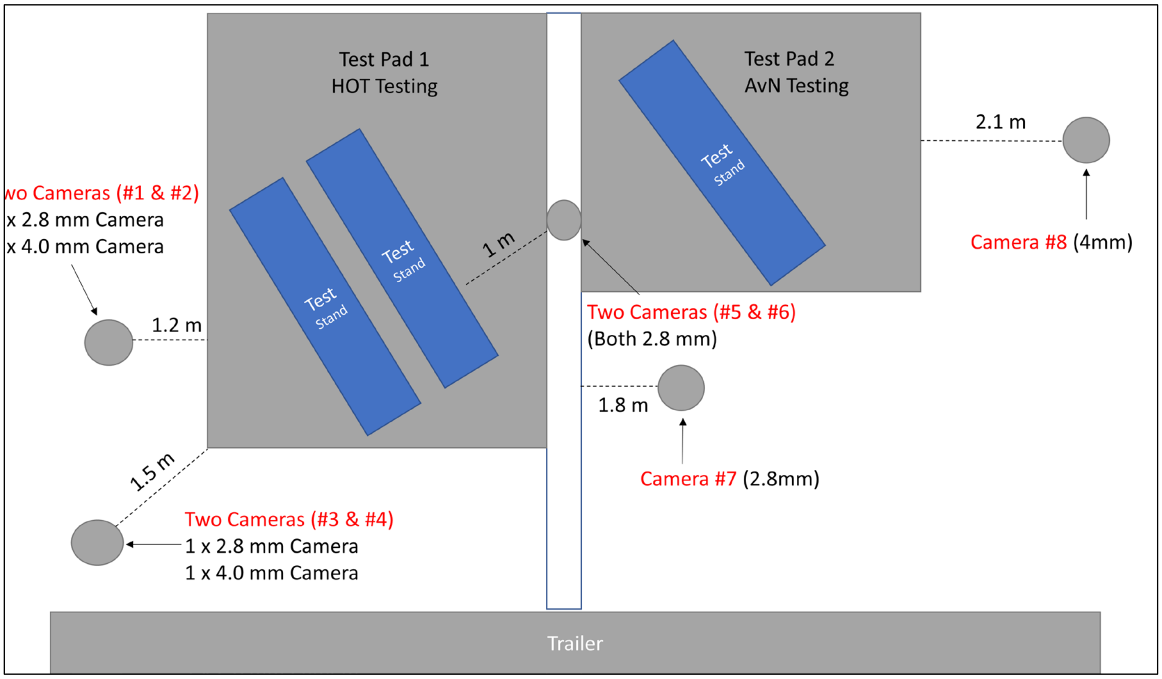

Figure 5.7: Schematic Representation of Camera Locations at the YUL Test Facility

5.6.2 Observations

Two issues were encountered while testing, as follows.

- Although four more cameras were added for the winter of 2021-22 compared to the winter of 2020-21, the camera setup did not have the complete capability of adapting 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.

Although the above issues were encountered during the winter of 2021-22, this setup did provide better capabilities and results compared to the setup of the previous year. Good-quality feeds were obtained, and guidance was easily provided remotely.

5.6.3 Recommendations

The camera system needs to be positioned at better strategic locations so that all test plates can be seen in both a zoomed configuration and as a whole while testing in any direction. This may be accomplished by placing cameras on tripods and repositioning when needed.

5.7 Near/Far North Testing

The following subsections describe the process used with the iPhone® 12 Pro Max during Near/Far North testing throughout Canada.

5.7.1 Overview

An iPhone® 12 Pro Max was used for video conferencing (Facetime®) during fluid failure verifications. The iPhone® made it possible to view the test plates at different angles, which is a key component when determining fluid failures.

5.7.2 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.

5.8 PMG Testing

The following subsections describe the process used for the implementation of CCTV cameras at the PMG test facility in Blainville, Quebec.

5.8.1 Overview

Three cameras were used, two of which had a variable optical focal length and one had a focal length of 2.8 mm.

Each variable camera was mounted on the inside of the artificial snow machine on an adjacent corner located midway from the ground to the top (where the top mount meets the bottom mount) to view the test plate and enable fluid failure verifications.

The third camera was positioned on a steel beam within the cold chamber to view the translator and ice core. Figure 5.8 displays the location of the cameras at PMG during testing.

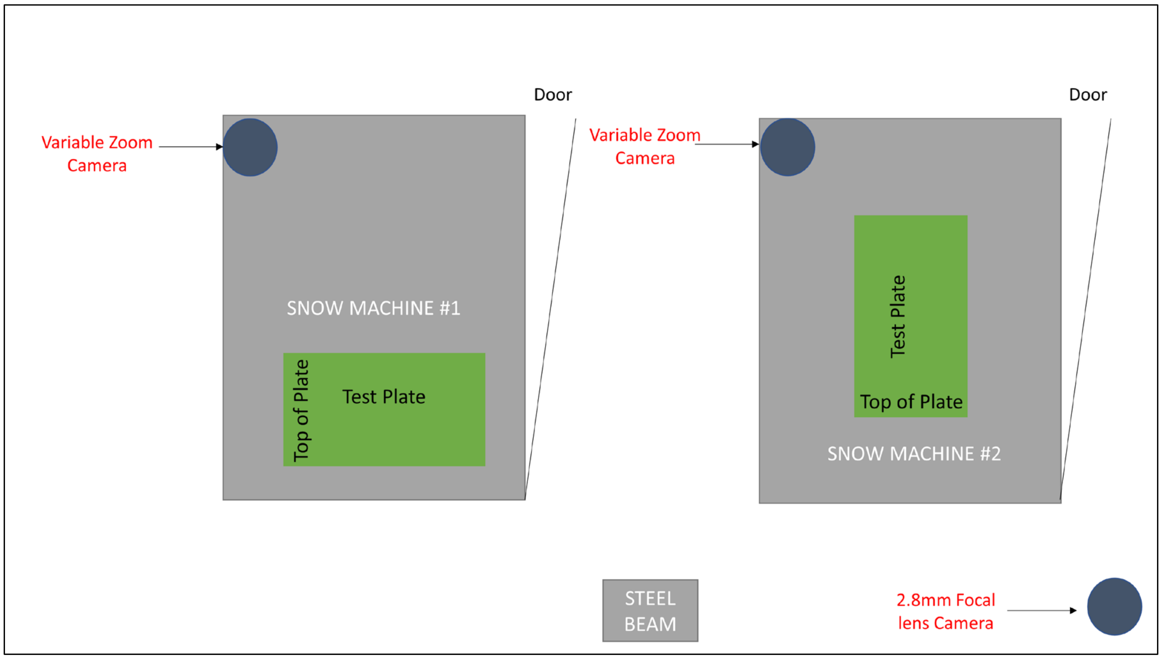

Figure 5.8: Schematic Representation of Camera Locations at PMG Technologies

5.8.2 Observations

The image clarity was the only issue encountered while testing. During some instances, the feed was too dark to view a clear image. The issue was rectified by adding additional light-emitting diode (LED) lighting to the area around the test plate.

5.8.3 Recommendations

The following recommendations are proposed for future testing.

- LED spotlights should be installed/used to increase image clarity. These lights should be placed around the test plate or within the enclosure.
- The camera placed within the enclosure may be repositioned to obtain a better view of the plate during testing.
- A smaller camera, if available, could be positioned inside the snow machine enclosure above the plate at a specific height and angle to provide better failure call verifications.

5.9 Side-by-Side Comparisons of Fluid Failures Using Remote Camera Technology

This subsection describes the process used for the implementation of CCTV cameras at the NRC Climate Chamber and PMG during the Mixed Icing Condition project (Mixed Snow and Freezing Fog) for the side-by-side comparisons of fluid failures.

By using the application DaVinci Resolve™, seven comparison videos of Snow versus Snow and Freezing Fog were produced, which significantly advanced the understanding of the fluid failure mechanisms. More information related to this work is described in the TC report, TP 15540E, *Evaluation of Fluid Endurance Times in Mixed Snow and Freezing Fog Conditions* (7).

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

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

6.1 Background

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

6.2 Objective

The objective of this project for 2021-22 was to handle up to 16 reports, with the aim to accelerate approximately 4 to 6 unpublished reports to the Final Draft 2.0 stage and to publish approximately 8 to 10 remaining reports as Final Version 1.0 (targets for subsequent years will be determined at the completion of each year).

6.3 Publication Process and Delivery of Technical Reports

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

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

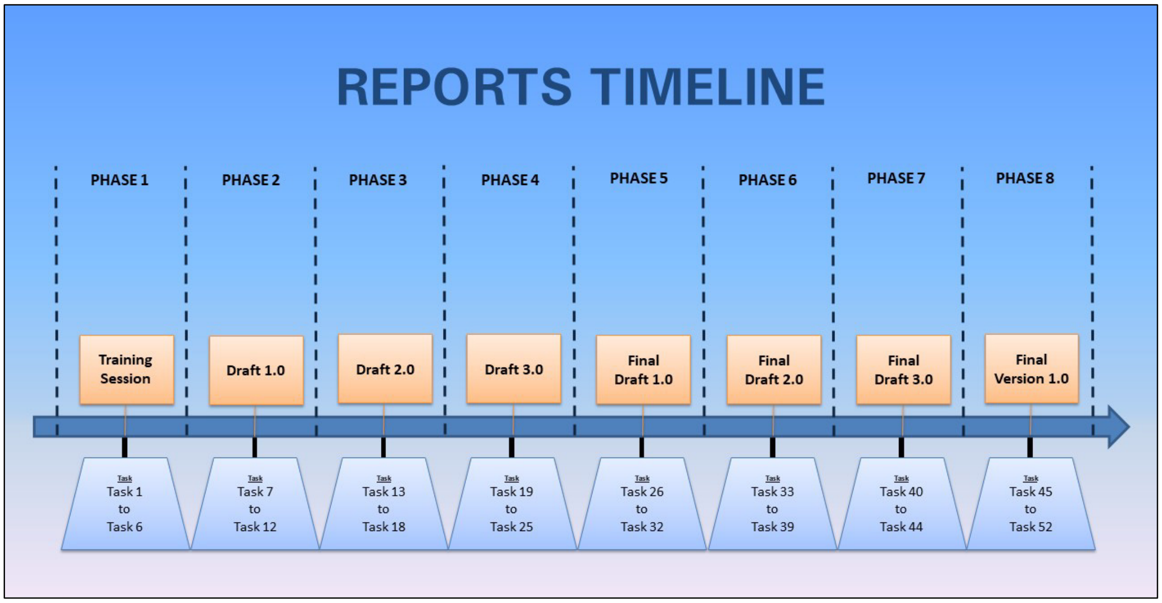

Figure 6.1: Reports Management Process

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* (11).

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* (12). 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 the reports published in 2018-19 are provided in the TC report, TP 15427E, *Aircraft Ground Icing General Research Activities During the 2018-19 Winter* (13). 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 advanced a total of six unpublished reports to the Final Draft 2.0 stage and published a total of 14 reports. The details of the reports published in 2019-20 are provided in the TC report, TP 15452E, *Aircraft Ground Icing General Research Activities During the 2019-20 Winter* (6). The 14 published reports were delivered to TC and the FAA as Final Version 1.0 via "WeTransfer" and USB drives.

For 2020-21, APS advanced a total of eight unpublished reports to the Final Draft 2.0 stage and published a total of 15 reports. The details of the reports published in 2020-21 are provided in the TC report, TP 15496E, *Aircraft Ground Icing General Research Activities During the 2020-21 Winter* (2) The 15 published reports were delivered to TC and the FAA as Final Version 1.0 via "WeTransfer" and USB drives.

For the year 2021-22, APS progressed a total of six unpublished reports to the Final Draft 2.0 stage and published a total of 10 reports; the published reports are displayed in Table 6.1. The 10 published reports were delivered to TC and the FAA as Final Version 1.0 via "WeTransfer" and USB drives.

6.4 Overall Publication Status of Technical Reports

The overall status of the reports as of October 31, 2021, was as follows:

- Published reports: 152;
- Non-published reports: 61; and
- Total reports: 213.

Detailed in Table 6.1, the following 10 reports were delivered to TC and the FAA as Final Version 1.0.

- One report from 1999-2000;
- One report from 2000-01;
- Three reports from 2002-03;
- One report from 2003-04; and
- Four reports from 2020-21.

The overall status of the reports as of October 31, 2022, was as follows:

- Published reports: 162;
- Non-published reports: 56; and
- Total reports: 218.

Table 6.1: List of Published Technical Reports (2021-22)

No.	TP Number	Year	Report Title	Category	Latest Version	Publication Date
1	TP 15494E	2020-21	Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2020-21 Winter	HOT	Final Version 1.0	July 15, 2022
2	TP 15495E	2020-21	Regression Coefficients and Equations Used to Develop the Winter 2021-22 Aircraft Ground Deicing Holdover Time Tables	Regression	Final Version 1.0	May 26, 2022
3	TP 15496E	2020-21	Aircraft Ground Icing General Research Activities During the 2020-21 Winter	G&E	Final Version 1.0	August 17, 2022
4	TP 15497E	2020-21	Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2020-21	Ice Pellet	Final Version 1.0	July 21, 2022
5	TP 13659E	1999-2000	Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 1999-2000 Winter	HOT	Final Version 1.0	September 25, 2022
6	TP 13831E	2000-01	Endurance Time Tests in Simulated Frost Conditions: 2001	Frost	Final Version 1.0	June 27, 2022
7	TP 14145E	2002-03	Laboratory Test Parameters for Frost Endurance Time Tests	Frost	Final Version 1.0	June 27, 2022
8	TP 14154E	2002-03	Aircraft Ground Icing Exploratory Research for the 2002-03 Winter	G&E	Final Version 1.0	July 21, 2022
9	TP 14155E	2002-03	Aircraft Ground Icing Research Support Activities for the 2002-03 Winter	Support Activities	Final Version 1.0	July 21, 2022
10	TP 14381E	2003-04	Aircraft Ground Icing General and Exploratory Research Activities for the 2003-04 Winter	G&E	Final Version 1.0	July 21, 2022

6.5 Conclusions

APS has been involved in writing and publishing technical reports on behalf of TC and the FAA since the early 1990s. Since 2016-17, APS was tasked with developing a prioritized list of unpublished reports that needed to be published.

For 2021-22, APS progressed some unpublished reports to the Final Draft 2.0 stage and published a total of 10 reports as Final Version 1.0.

6.6 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.

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7. PUBLICATION OF HOLDOVER TIME GUIDANCE MATERIALS

This section describes the work APS Aviation Inc. (APS) completed in the winter of 2021-22 in support of Transport Canada (TC) and the Federal Aviation Administration (FAA) holdover time (HOT) guidance materials.

7.1 Background

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

7.2 APS Contribution to Holdover Time Guidance Materials

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

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

b) Maintaining a Degree-Specific Holdover Times (DSHOTs) database for Type II, III, and IV 100/0 fluids in snow conditions (including snow, snow grains, snow pellets, snow mixed with freezing fog, and snow mixed with ice crystals);

c) Requesting, collecting, and reviewing 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) Recommending changes to the HOT guidance materials as a result of new research findings;

e) Maintaining an ongoing list of potential changes to the HOT guidance materials, scheduling and running meetings to review and discuss these changes with TC/FAA, and implementing changes as required;

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

g) Providing support for the update of the FAA N 8900 series document; and

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

7.3 Winter 2022-23 Holdover Time Guidance Materials

In August 2022, the 2022-23 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 15534E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2021-22 Winter* (14); and
2. **Holdover Time Regression Information:** TP 15535E, *Regression Coefficients and Equations Used to Develop the Winter 2022-23 Aircraft Ground Deicing Holdover Time Tables* (15).

The titles of the 2022-23 documents are listed in Table 7.1. Final drafts of the TC and FAA documents were provided to the TC and the FAA publications departments, respectively, for publication on August 3, 2022.

A revision to the TC and FAA HOT Guidelines was published on August 11 with corrections to the list of qualified fluids. A subsequent revision to the TC and FAA HOT Guidelines was published on August 31 and September 7, respectively, with corrections to the Snowfall Intensities as a Function of Prevailing Visibility table (TC only) and the Type IV PG allowance time table.

The FAA finalized and published its N 8900 series notice on July 29, 2022.

Table 7.1: Latest 2022-23 HOT Guidance Documents

HOT Guidelines	1. Transport Canada Holdover Time (HOT) Guidelines Winter 2022-2023, Revision 2.0, August 31, 2022
	2. Guide de Transports Canada sur les durées d'efficacité Hiver 2022-2023, révision 2.0, 31 août 2022
	3. FAA Holdover Time Guidelines Winter 2022-2023, Revision 1.1, September 7, 2022
DSHOTs Database	4. Transport Canada Degree-Specific Holdover Times, Winter 2022-2023, Original Issue, August 3, 2022
	5. Guide de Transports Canada sur les durées d'efficacité selon le degré Hiver 2022-2023, version originale, 3 août 2022
	6. FAA Degree-Specific Holdover Time Data, Winter 2022-2023, Original Issue, August 3, 2022
Regression Information	7. Transport Canada HOT Guidelines Regression Information Winter 2022-2023, Original Issue, August 3, 2022
	8. Transports Canada Guide des durées d'efficacité Information de régression Hiver 2022-2023, version originale, 3 août 2022
	9. FAA Holdover Time Regression Information Winter 2022-2023, Original Issue, August 3, 2022

7.4 Future Responsibilities

APS will continue contributing to the development of the TC and FAA HOT guidance materials in the winter of 2022-23. Specifically, APS will continue carrying out the tasks listed in Subsection 7.2.

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8. PRESENTATIONS, FLUID MANUFACTURER REPORTS, AND TEST PROCEDURES FOR 2021-22

This section contains an account of the presentations, fluid manufacturer reports, and test procedures prepared by APS Aviation Inc. (APS) in the winter of 2021-22.

8.1 Presentations

The 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 2021-22, APS gave presentations at the following meetings:

1) SAE G-12 Holdover Time (HOT) Committee Meeting, Online (via Webex), November 2021;
2) SAE G-12 HOT Committee Meeting, Online (via Webex), May 2022; and
3) Airlines for America (A4A) Ground Deicing Forum, Online (via Zoom), June 2022.

The presentations given by APS at these meetings are listed in the following subsections. Copies of each presentation listed are contained in Appendix D.

8.1.1 SAE G-12 Holdover Time Committee Meeting, Online (Via Webex), November 2021

The following two presentations were prepared and presented at the SAE G-12 HOT Committee meeting held virtually via Webex in November 2021:

1) 2021-22 Endurance Time Testing Program; and
2) SAE G-12 HOT Committee: Documents Status.

8.1.2 SAE G-12 Holdover Time Committee, Online (via Webex), May 2022

The following five presentations were prepared and presented at the SAE G-12 HOT Committee meeting held virtually via WebEx in May 2022:

1) Mixed Snow and Freezing Fog Conditions;
2) Winter 2021-22 Endurance Time Testing Update;
3) Icing Wind Tunnel Research Simulating Ice Pellet Conditions;
4) Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a CRM Vertical Stabilizer (presented jointly with National Research Council Canada [NRC] and National Aeronautics and Space Administration [NASA]); and
5) Upcoming Changes to the TC/FAA Visibility Tables (presented jointly with Transport Canada [TC] and the Federal Aviation Administration [FAA]).

8.1.3 Airlines for America (A4A) Ground Deicing Forum, Online (via Zoom), June 2022

The following five presentations were prepared and presented at the A4A Ground Deicing Forum held virtually via Zoom in June 2022:

1) Upcoming Changes to the TC/FAA Visibility Tables (presented jointly with TC and the FAA);
2) Winter 2021-22 Endurance Time Testing Update;
3) Mixed Snow and Freezing Fog Conditions;
4) Wind Tunnel Testing to Evaluate Contaminated Fluid Flow-Off from a CRM Vertical Stabilizer (presented jointly with NRC and NASA); and
5) Icing Wind Tunnel Research Simulating Ice Pellet Conditions.

8.2 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 TC report, TP 15534E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2021-22 Winter* (14), while the non-commercialized fluid reports are provided to the respective fluid manufacturers for their internal development purposes.

8.2.1 Holdover Time Testing Reports 2021-22

The following subsections describe the fluid manufacturer reports produced for fluids submitted in 2021-22.

8.2.1.1 Standard Holdover Time Testing Reports 2021-22

Four reports were prepared to document HOT testing conducted with fluids submitted in the winter of 2021-22. Copies of these reports were provided to the fluid manufacturers and to the TC and FAA project managers in July 2022.

Two of the reports were for commercialized fluids; these reports are included as appendices of TP 15534E (14). Two reports were for experimental fluids.

The reports were for the following fluids:

1) Type II: Ice Clear II;
2) Type II: COREICEPHOB Type II; and
3) Two 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 15534E (14).

8.2.1.2 Very Cold Snow Testing Reports 2021-22

Four reports were prepared to document very cold snow (VCS) testing. Copies of these reports were provided to the fluid manufacturers and to the TC and FAA project managers in July 2022.

The reports were for the following fluids:

1) Type II: Ice Clear II;
2) Type II: COREICEPHOB;
3) Type IV: 4Flite EG; and
4) Type IV: 4Flite PG.

The above list includes fluids that were initially submitted for testing in 2020-21 as well as fluids submitted for testing in 2021-22. Testing and analysis of the fluids submitted in 2020-21 (4Flite EG, 4Flite PG) was completed over two winter seasons due to late fluid receipt as well as the impact of the COVID-19 pandemic on endurance time testing activities in 2020-21.

8.2.1.3 Standard Holdover Time Testing Reports 2020-21 (Updated HUPRs)

Several testing reports initially published in 2020-21 were updated and republished in 2021-22 following supplemental testing that was conducted with retained samples of these fluids to support changes to their highest usable precipitation rates (HUPRs).

Updated reports were issued for the following fluids:

1) Type IV: 4Flite EG;
2) Type IV: 4Flite PG; and
3) Type IV: Defrost NORTH 4.

8.3 Test Procedures

Several procedures were developed to guide and support the research team in conducting tests in the winter of 2021-22. Table 8.1 provides the list of the procedures. The procedures have been included as appendices to the various Winter 2021-22 reports; the report with which each procedure is associated is listed in the last column of Table 8.1.

Table 8.1: List of Procedures 2021-22

Program Element #	ID#	Contract Program Element	Name of Procedure	Latest Version Details	Report
3	3.1	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
3	3.2	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
3	3.3	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
3	3.4	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	2.1	FREEZING FOG AND SNOW HOT GUIDANCE DEVELOPMENT – COMPARATIVE TESTING AND GUIDANCE DEVELOPMENT	Procedure: COMPARATIVE TESTING OF SIMULATED FREEZING FOG AND SNOW AT THE NRC	–	G&E
3	3.5	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2022	Final Version 1.0 March 16, 2021	HOT
3	3.6	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	OVERALL PROGRAM OF TESTS AT PMG, APRIL 2022	Final Version 1.0 March 11, 2021	HOT
4	4.1	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	10.15	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
10	10.15	WIND TUNNEL TESTING – VERTICAL STABILIZER	Procedure: WIND TUNNEL TESTS WITH THE VERTICAL STABILIZER CRM	Final Version 1.0 February 23, 2021	WT

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7. Bernier, B., Posteraro, D., *Evaluation of Fluid Endurance Times in Mixed Snow and Freezing Fog Conditions*, APS Aviation Inc., Transport Canada, Montreal, March 2023, TP 15540E, XX (to be published).

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9. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2013-14 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2014, TP 15269E, XX (to be published).

10. Alwaid, A., Moc, N., *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13993E, 86.

11. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2016-17 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, November 6017, TP 15374E, 52.

12. 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.

13. 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.

14. Bernier, B., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2021-22 Winter*, APS Aviation Inc., Transport Canada, Montreal, November 2022, TP 15534E, 58.

15. Lalla, D., *Regression Coefficients and Equations Used to Develop the Winter 2022-23 Aircraft Ground Deicing Holdover Time Tables*, APS Aviation Inc., Transport Canada, Montreal, November 2022, TP 15535E, 62.

APPENDIX A

TRANSPORT CANADA
STATEMENT OF WORK EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2021-22

TRANSPORT CANADA
STATEMENT OF WORK EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2021-22

1. Characterization of the Rate of Freezing Mist and Freezing Fog to Support HOT Guidance Development

a) Prepare project plan and coordinate testing activities.

b) Conduct a review of previously collected data related to freezing mist and freezing fog.

c) Collect data in the following conditions:

i. Natural Freezing Mist (Primary Activity); and

ii. Natural Freezing Fog.

d) Analyse the characterization of the rate of freezing mist and freezing fog.

e) Participate in meetings with TC/FAA to discuss the data, analysis, and recommended changes to guidance materials.

f) Prepare presentation for SAE G-12.

g) Prepare a report.

6. Exploratory Research and Standard (SAE Standards, AWG, MWG, 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) Provide support for further development of SAE aircraft ground deicing standards as needed.

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

c) Support activities of the SAE G-12 METAR Working Group.

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 November 18, 2021 based on TC/FAA request:

f) Develop a Position Paper to identify, Fluid Dry-Out & the Longevity of Fluid On-Wing.

g) Investigate the possibility of guidance development for Ice Crystals mixed with Freezing Fog & Ice Crystals mixed with Snow.

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. Conduct an independent technical evaluation of the ACE climatic testing facility.

ii. Support the development of new revisions of ARP5485, ARP5945, ARP5718, ARP6207 as part of the 5-year review due late 2022.

iii. Support development of guidance material for small airport and small operations.

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

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

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

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

viii. Evaluate the feasibility of developing degree-specific HOTs for freezing precipitation conditions.

ix. Evaluate the addition of heavy snow holdover times to HOT tables for 25-50 $g/dm^2/h$.

x. Conduct testing and analysis to evaluate the effects of intermittently starting and stopping precipitation on fluid integrity.

xi. Conduct testing and analysis to evaluate the effects of precipitation intensity fluctuations on fluid holdover times.

xii. Conduct testing and analysis to evaluate the effect of extended anti-icing fluid pre-treatment periods on fluid layer integrity.

xiii. Conduct testing and analysis to evaluate the impacts of vibration relative to fluid layer integrity on a vertical surface.

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

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

xvi. General research or activities related to weather, de/anti-icing fluids, aircraft performance, deicing operations, sensors, environment, research information dissemination, and testing facilities and infrastructures.

7. Maintenance and Update of Remote Camera Viewing System for Failure Call Remote VS. In-Person (Update Existing System for Wind Tunnel, Develop System for HOT Testing and Artificial Snow)

a) Review lessons learned from previous year and develop list of improvements for existing systems.

b) Evaluate project needs for different test locations (including wind tunnel, PET test site. NRC testing facility, PMG testing facility, and far north mobile testing).

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

d) Acquire equipment or engage long term rental.

e) Conduct initial trials of viewing system at different planned testing locations.

f) Make modifications as necessary.

g) Conduct additional trials (including fluid failure evaluation) during actual winter 2021-22 testing activities at wind tunnel, PET test site, NRC testing facility, PMG testing facility, and far north mobile test sites.

h) Modify or purchase additional equipment as required.

i) Launch remote viewing platform to clients and management.

j) Manage permissions and access rights for viewing systems.

k) Document a summary of activities conducted within a report.

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

a) Review the plan of potential changes to the TC/FAA visibility tables with the goal of harmonizing the TC/FAA tables. Meet with TC and FAA to review the plan, adjust accordingly, and refine the final list of modifications.

b) Continue 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.

c) Mock-up changes for incorporation into the HOT guidelines and participate in technical discussions with TC and FAA, and industry as required.

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

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 8 to 10 reports to be published as Final Version 1.0 and create and maintain schedule.

d) Coordinate technical review of approximately 4 to 6 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 and re-verify the TC and FAA degree-specific HOTs databases.

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

g) Provide support for publication of documents.

20. 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 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) 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) Evaluate current methods for measuring snowfall intensity or holdover times.
f) Develop improved, more efficient methods to measure snowfall intensity or holdover times, as required.
g) 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 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.

Preparation and Setup for Simulated Snow Testing at PMG

a) Prepare a general top-level plan to coordinate all simulated artificial snow testing required by the research program. Testing will be conducted at PMG Technologies in Blainville, Quebec.

b) Coordinate scheduling and test plans with PMG personnel.

c) Prepare an updated test procedure for the conduct of endurance time tests in simulated artificial snow at PMG, as required.

d) Arrange for support from NCAR personnel, as required during the testing session.

e) Arrange for the transport of equipment to and from the facility, as required.

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.

21. 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 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) 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) Evaluate current methods for measuring snowfall intensity or holdover times.

f) Develop improved, more efficient methods to measure snowfall intensity or holdover times, as required.

g) 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.

Preparation and Setup for Simulated Snow Testing at PMG

a) Prepare a general top-level plan to coordinate all simulated artificial snow testing required by the research program. Testing will be conducted at PMG Technologies in Blainville, Quebec.

b) Coordinate scheduling and test plans with PMG personnel.

c) Prepare an updated test procedure for the conduct of endurance time tests in simulated artificial snow at PMG, as required.

d) Arrange for support from NCAR personnel, as required during the testing session.

e) Arrange for the transport of equipment to and from the facility, as required.

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.

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APPENDIX B

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

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

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

APS/Library/Projects/300293 (TC Deicing 2020-21)/Analysis/MIST/Frequency of Fog and Mist (Final Version 1.1).docx
Final Version 1.1, November 21

4

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

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APPENDIX C

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

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 (≈1 km) and less than 7 miles (≈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. ≈240 m).
5. No precipitation concurrent with mist (for the purpose of this research).
6. Sustained wind speed < 9 knots (≈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

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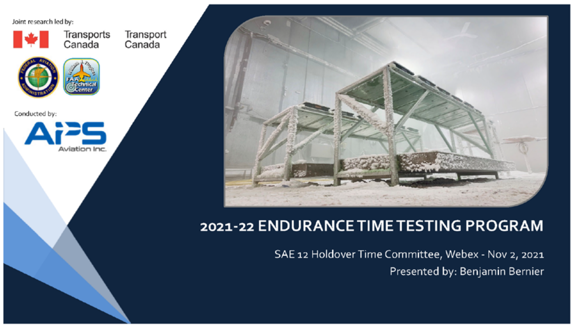
APPENDIX D

PRESENTATIONS, FLUID MANUFACTURER REPORTS, AND TEST PROCEDURES FOR 2021-2022

SAE G-12 HOLDOVER TIME COMMITTEE MEETING, ONLINE (VIA WEBEX), NOVEMBER 2021

**PRESENTATION:
2021-22 ENDURANCE TIME TESTING PROGRAM**

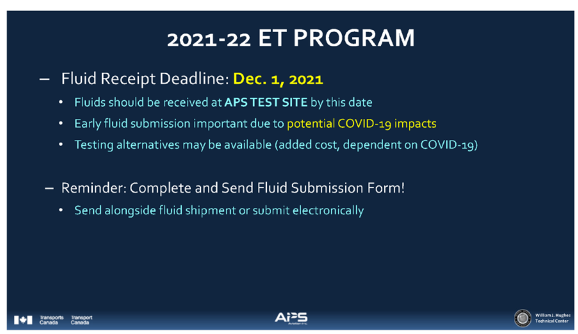

Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS Aviation Inc.
2021-22 ENDURANCE TIME TESTING PROGRAM
SAE 12 Holdover Time Committee, Webex - Nov 2, 2021
Presented by: Benjamin Bernier

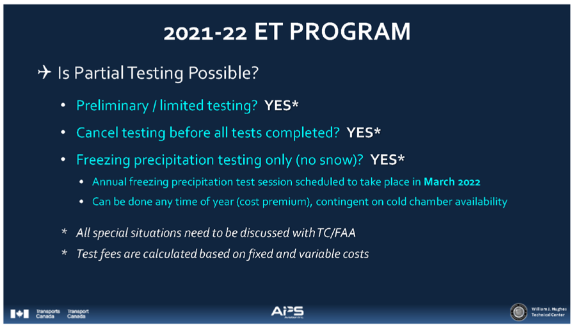

ENDURANCE TIME PROGRAM
APS Aviation is contracted to conduct
HOT Testing on behalf of TC/FAA

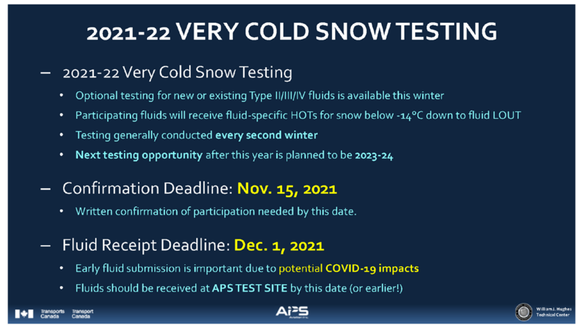

ENDURANCE TIME PROGRAM
Natural Snow and Natural Frost Testing
APS Test Site (Montreal, Canada)
Natural Snow
Natural Frost


ENDURANCE TIME PROGRAM
Simulated Freezing Precipitation Testing
NRC-CEF (Ottawa, Canada)
Simulated Freezing Precipitation


2021-22 ET PROGRAM
– 2021-22 testing season is starting soon!
– HOT Fluid Request Letter: emailed Sep 20, 2021
– Contains info on:
• Testing Fees
• Fluid Sample Preparation
• Shipping Details
• Plus: Fluid Submission Forms and FAQ Sheet


2021-22 ET PROGRAM
– Fluid Receipt Deadline: Dec. 1, 2021
• Fluids should be received 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)
– Reminder: Complete and Send Fluid Submission Form!
• Send alongside fluid shipment or submit electronically

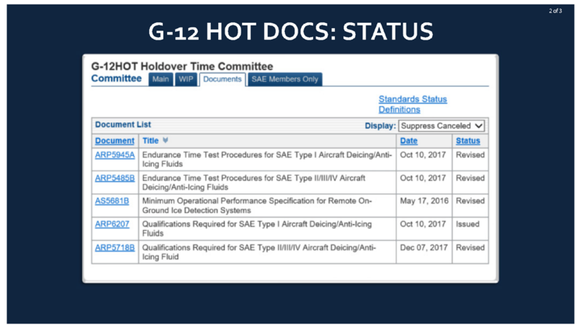

2021-22 ET PROGRAM
Is Partial Testing Possible?
Preliminary / limited testing? YES*
Cancel testing before all tests completed? YES*
Freezing precipitation testing only (no snow)? YES*
Annual freezing precipitation test session scheduled to take place in March 2022
Can be done any time of year (cost premium), 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


2021-22 VERY COLD SNOW TESTING
– 2021-22 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
Next testing opportunity after this year is planned to be 2023-24
– Confirmation Deadline: Nov. 15, 2021
Written confirmation of participation needed by this date.
– Fluid Receipt Deadline: Dec. 1, 2021
Early fluid submission is important due to potential COVID-19 impacts
Fluids should be received at APS TEST SITE by this date (or earlier!)

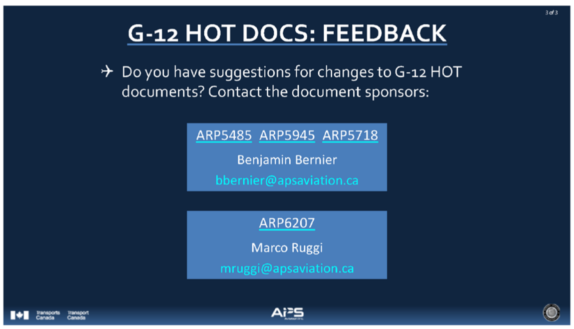

Questions?
APS Aviation Inc.
Benjamin Bernier
Leader, Icing & Technical
bbernier@apsaviation.ca

SAE G-12 HOLDOVER TIME COMMITTEE MEETING, ONLINE (VIA WEBEX), NOVEMBER 2021

PRESENTATION:
SAE G-12 HOT COMMITTEE: DOCUMENTS STATUS



Document	Title	Date	Status
ARP5945A	Endurance Time Test Procedures for SAE Type I Aircraft Deicing/Anti-Icing Fluids	Oct 10, 2017	Revised
ARP5485B	Endurance Time Test Procedures for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids	Oct 10, 2017	Revised
AS5681B	Minimum Operational Performance Specification for Remote On-Ground Ice Detection Systems	May 17, 2016	Revised
ARP6207	Qualifications Required for SAE Type I Aircraft Deicing/Anti-Icing Fluids	Oct 10, 2017	Issued
ARP5718B	Qualifications Required for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluid	Dec 07, 2017	Revised



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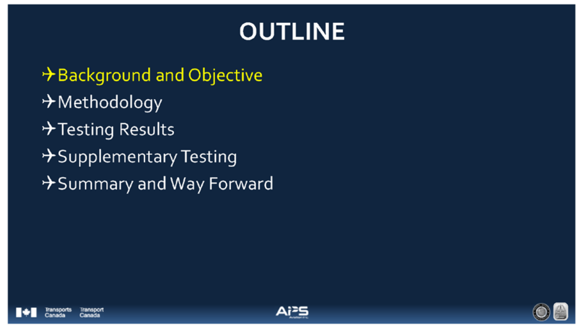
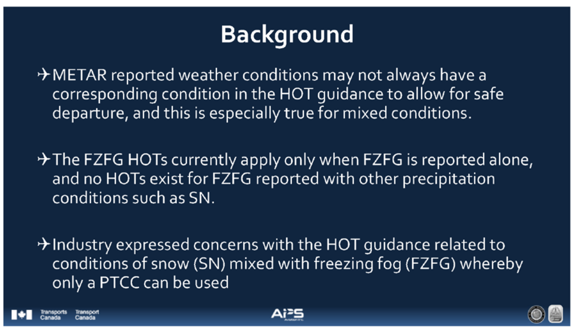
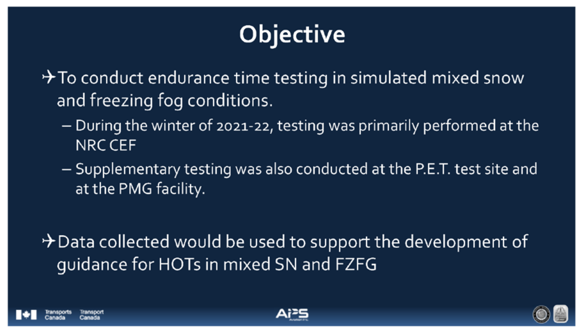
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2022

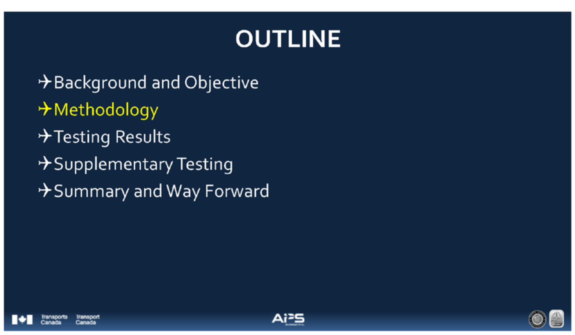
**PRESENTATION:
MIXED SNOW AND FREEZING FOG CONDITIONS**


Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS Aviation Inc.
MIXED SNOW AND FREEZING FOG CONDITIONS
SAE 12 Holdover Time Committee, Webex, May 17, 2022
Presented by: Marco Ruggi, Eng., M.B.A., Director


OUTLINE
Background and Objective
Methodology
Testing Results
Supplementary Testing
Summary and Way Forward


Background
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.
The FZFG HOTs currently apply only when FZFG is reported alone, and no HOTs exist for FZFG reported with other precipitation conditions such as SN.
Industry expressed concerns with the HOT guidance related to conditions of snow (SN) mixed with freezing fog (FZFG) whereby only a PTCC can be used


Objective
To conduct endurance time testing in simulated mixed snow and freezing fog conditions.
– During the winter of 2021-22, testing was primarily performed at the NRC CEF
– Supplementary testing was also conducted at the P.E.T. test site and at the PMG facility.
Data collected would be used to support the development of guidance for HOTs in mixed SN and FZFG


OUTLINE
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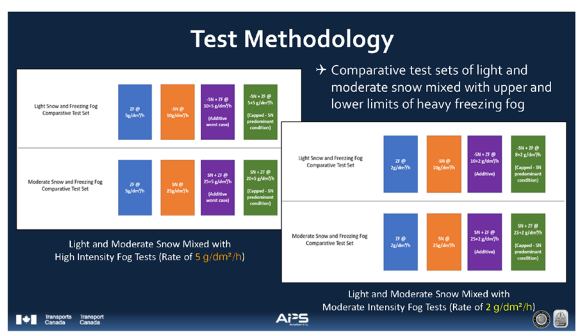
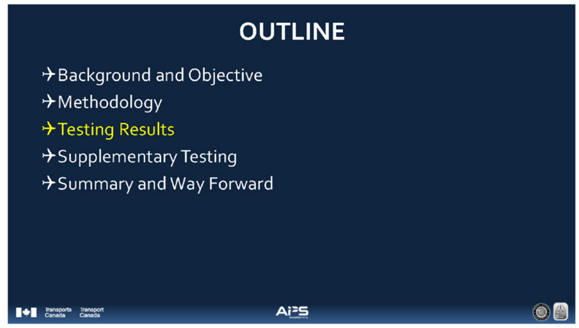

Test Methodology
Comparative test sets of light and moderate snow mixed with upper and lower limits of heavy freezing fog
Light Snow and Freezing Fog Comparative Test Set
Moderate Snow and Freezing Fog Comparative Test Set
Light and Moderate Snow Mixed with High Intensity Fog Tests (Rate of 5 g/dm²/h)
Light and Moderate Snow Mixed with Moderate Intensity Fog Tests (Rate of 2 g/dm²/h)


Test Methodology
AiPS


OUTLINE
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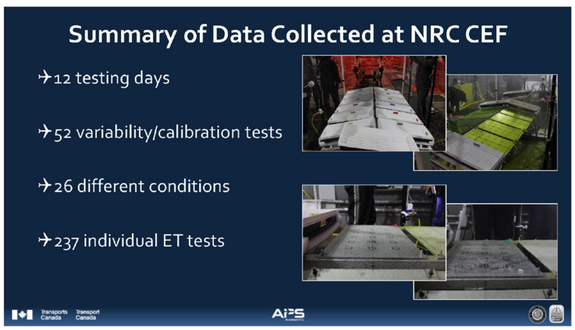
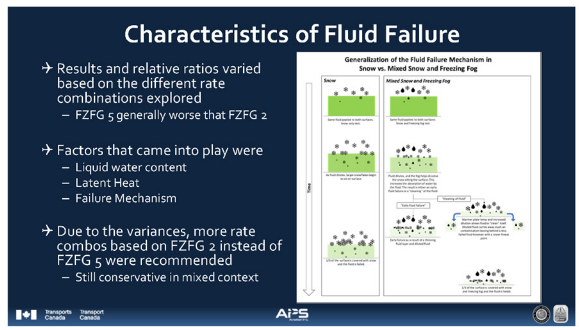
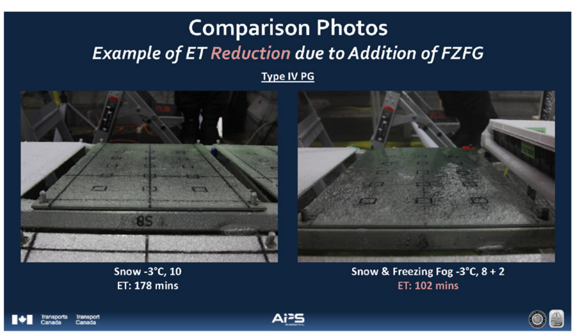
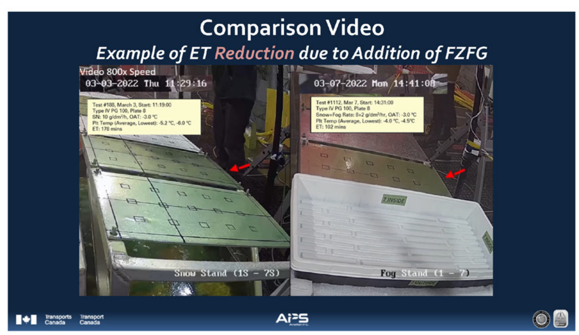
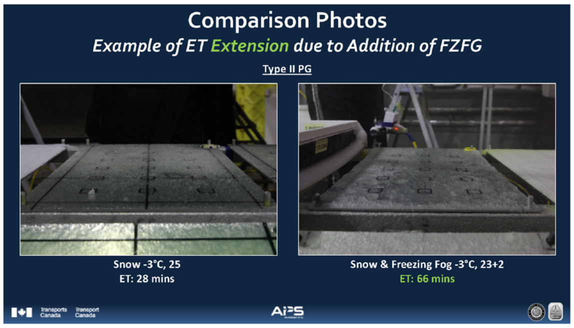
AiPS

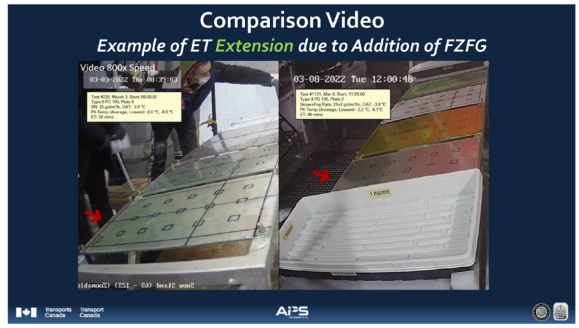

Summary of Data Collected at NRC CEF
12 testing days
52 variability/calibration tests
26 different conditions
237 individual ET tests
AiPS

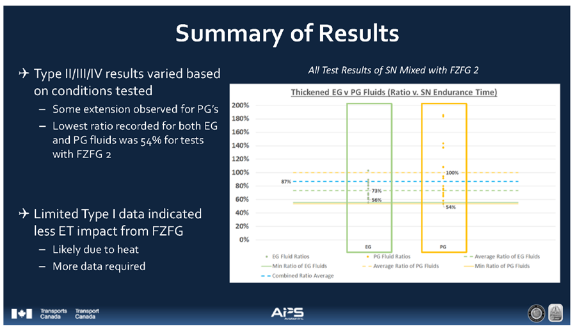

Characteristics of Fluid Failure
Results and relative ratios varied based on the different rate combinations explored
– FZFG 5 generally worse that FZFG 2
Factors that came into play were
– Liquid water content
– Latent Heat
– Failure Mechanism
Due to the variances, more rate combos based on FZFG 2 instead of FZFG 5 were recommended
– Still conservative in mixed context
Generalization of the Fluid Failure Mechanism in Snow vs. Mixed Snow and Freezing Fog
AiPS

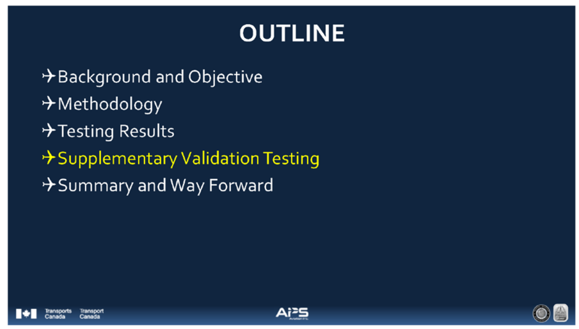

Comparison Photos
Example of ET Reduction due to Addition of FZFG
Type IV PG
Snow -3°C, 10
ET: 178 mins
Snow & Freezing Fog -3°C, 8 + 2
ET: 102 mins
AiPS


Comparison Video
Example of ET Reduction due to Addition of FZFG
Video 800x Speed
AiPS


Comparison Photos
Example of ET Extension due to Addition of FZFG
Type II PG
Snow -3°C, 25
ET: 28 mins
Snow & Freezing Fog -3°C, 23+2
ET: 66 mins
Transports Canada
Transport Canada


Comparison Video
Example of ET Extension due to Addition of FZFG
Video 800x Speed
03-03-2022 Thu 08:39:03
03-08-2022 Tue 12:00:48
Transports Canada
Transport Canada


Summary of Results
Type II/III/IV results varied based on conditions tested
– Some extension observed for PG's
– Lowest ratio recorded for both EG and PG fluids was 54% for tests with FZFG 2
Limited Type I data indicated less ET impact from FZFG
– Likely due to heat
– More data required
All Test Results of SN Mixed with FZFG 2
Thickened EG v PG Fluids (Ratio v. SN Endurance Time)
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
87%
73%
56%
100%
54%
EG
PG
EG Fluid Ratios
PG Fluid Ratios
Average Ratio of EG Fluids
Min Ratio of EG Fluids
Average Ratio of PG Fluids
Min Ratio of PG Fluids
Combined Ratio Average
Transports Canada
Transport Canada


OUTLINE
Background and Objective
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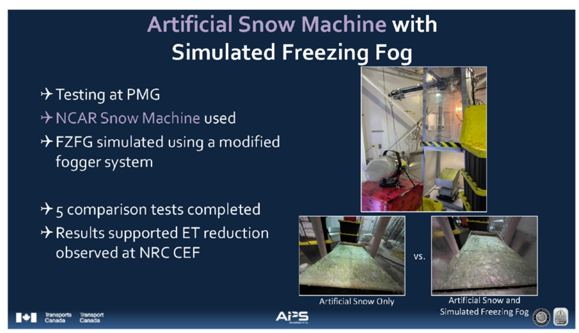
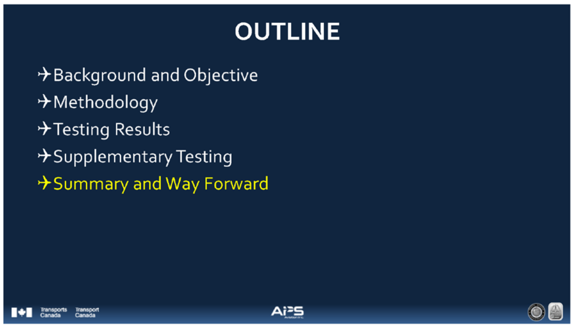
Supplementary Validation Testing
Summary and Way Forward
Transports Canada
Transport Canada


Natural Snow with Simulated Freezing Fog
Testing at P.E.T Airport Test Site
Natural snow events
FZFG simulated using a modified fogger system
5 comparison tests completed
Results supported ET reduction observed at NRC CEF
vs.
Natural Snow Only
Natural Snow and Simulated Freezing Fog
Transports Canada
Transport Canada


Artificial Snow Machine with Simulated Freezing Fog
Testing at PMG
NCAR Snow Machine used
FZFG simulated using a modified fogger system
5 comparison tests completed
Results supported ET reduction observed at NRC CEF
vs.
Artificial Snow Only
Artificial Snow and Simulated Freezing Fog
Transports Canada
Transport Canada


OUTLINE
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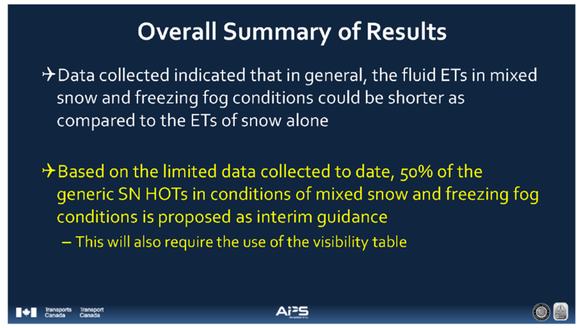
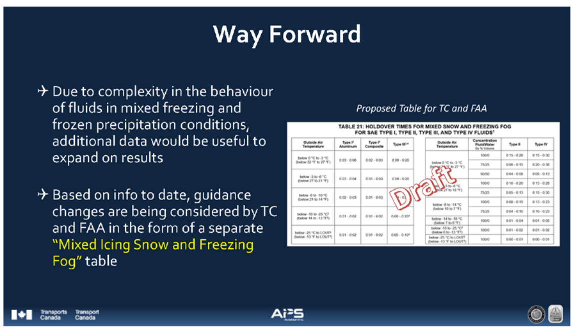

Overall Summary of Results
Data collected indicated that in general, the fluid ETs in mixed snow and freezing fog conditions could be shorter as compared to the ETs of snow alone
Based on the limited data collected to date, 50% of the generic SN HOTs in conditions of mixed snow and freezing fog conditions is proposed as interim guidance
– This will also require the use of the visibility table


Way Forward
Due to complexity in the behaviour of fluids in mixed freezing and frozen precipitation conditions, additional data would be useful to expand on results
Based on info to date, guidance changes are being considered by TC and FAA in the form of a separate "Mixed Icing Snow and Freezing Fog" table
Proposed Table for TC and FAA
Draft


Thank You
Marco Ruggi
mruggi@apsaviation.ca

SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2022

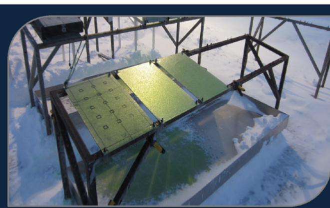
**PRESENTATION:
WINTER 2021-22 ENDURANCE TIME TESTING UPDATE**

Joint research led by:

Transports Canada Transport Canada

Conducted by:

APS Aviation Inc.



WINTER 2021-22
ENDURANCE TIME TESTING UPDATE

SAE G12 HOT Committee, Webex, May 17, 2022
Presented by: Benjamin Bernier

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Purpose

- To provide an overview of the new fluids tested for inclusion in the HOT guidelines
- 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.

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Outline

- 2021-22 Testing Overview
- Methodology
- Standard HOT Test Results Summary: 2 Fluids
- Very Cold Snow Test Results Summary: 4 Fluids
- Supplemental HUPR Testing
- Summary
- Appendix: Detailed Test Results

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Testing Overview

- 633 total endurance time (ET) tests were conducted with fluids submitted in 2021-22
- Two new fluids are expected to be added to the HOT Guidelines for the 2022-23 winter season

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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	177	16	24	16	16	8	7	264
	75/25	56	0	8	8	8	4	2	86
	50/50	17	0	4	4	4	0	1	30
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	190	8	12	8	8	4	23	253
	75/25	0	0	0	0	0	0	0	0
	50/50	0	0	0	0	0	0	0	0
Total		440	24	48	36	36	16	33	633

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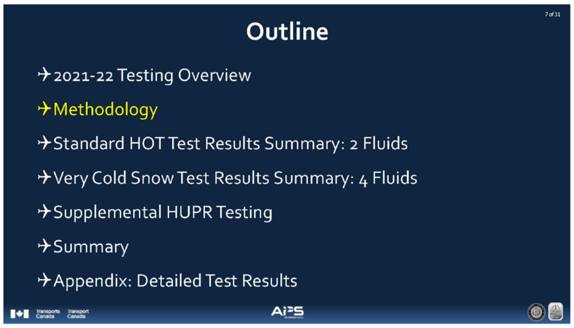
New Fluids

Kilfrost	Type II	Kilfrost Ice Clear II (fluid reformulated)
MKS DevO	Type II	COREICEPHOB TYPE-II



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2021-22 Testing Overview
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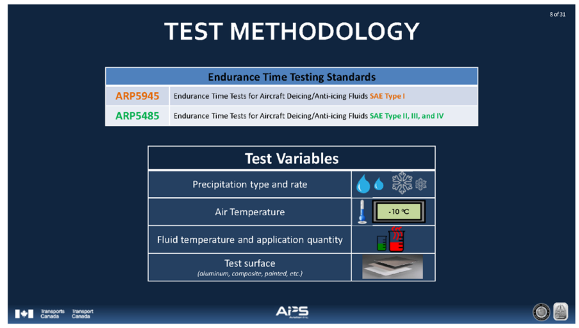
Supplemental HUPR Testing
Summary
Appendix: Detailed Test Results



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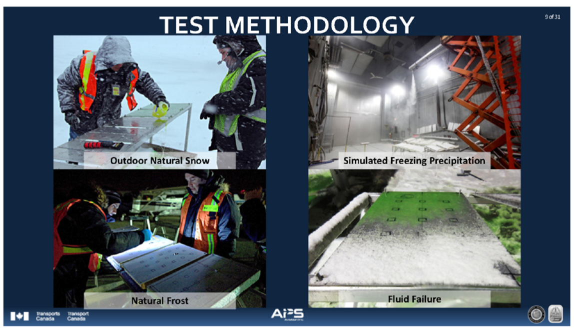
TEST METHODOLOGY
Endurance Time Testing Standards
ARP5945 Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Type I
ARP5485 Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Type II, III, and IV
Test Variables
Precipitation type and rate
Air Temperature
-10 °C
Fluid temperature and application quantity
Test surface
(aluminum, composite, painted, etc.)



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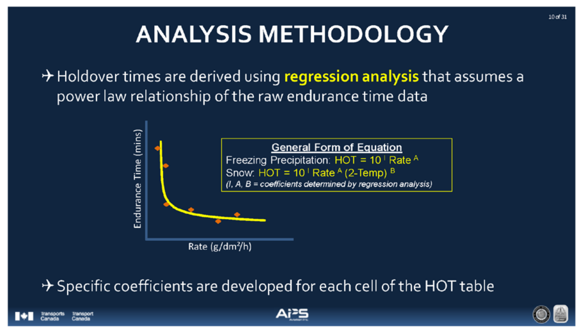
TEST METHODOLOGY
Outdoor Natural Snow
Simulated Freezing Precipitation
Natural Frost
Fluid Failure



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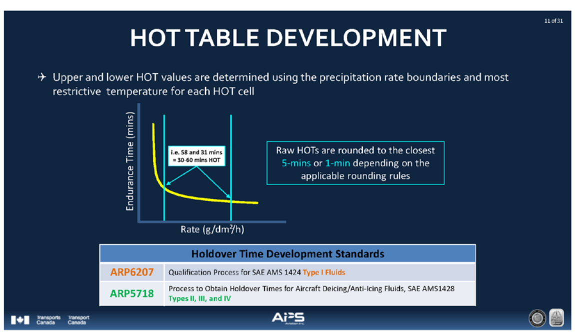
ANALYSIS METHODOLOGY
Holdover times are derived using regression analysis that assumes a power law relationship of the raw endurance time data
Endurance Time (mins)
Rate (g/dm²/h)
General Form of Equation
Freezing Precipitation: HOT = 10^I Rate^A
Snow: HOT = 10^I Rate^A (2-Temp)^B
(I, A, B = coefficients determined by regression analysis)
Specific coefficients are developed for each cell of the HOT table



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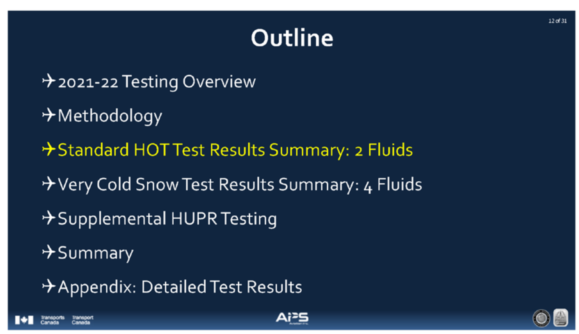
HOT TABLE DEVELOPMENT
Upper and lower HOT values are determined using the precipitation rate boundaries and most restrictive temperature for each HOT cell
Endurance Time (mins)
i.e. 58 and 31 mins = 30-60 mins HOT
Raw HOTs are rounded to the closest 5-mins or 1-min depending on the applicable rounding rules
Rate (g/dm²/h)
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



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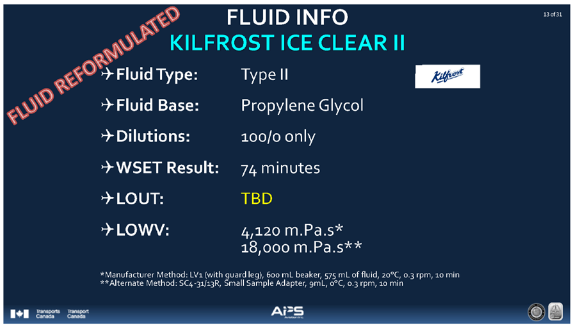
Outline
2021-22 Testing Overview
Methodology
Standard HOT Test Results Summary: 2 Fluids
Very Cold Snow Test Results Summary: 4 Fluids
Supplemental HUPR Testing
Summary
Appendix: Detailed Test Results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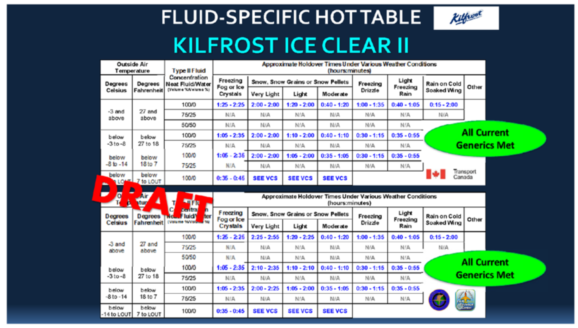
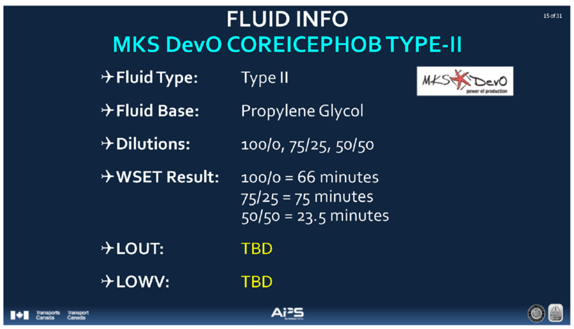
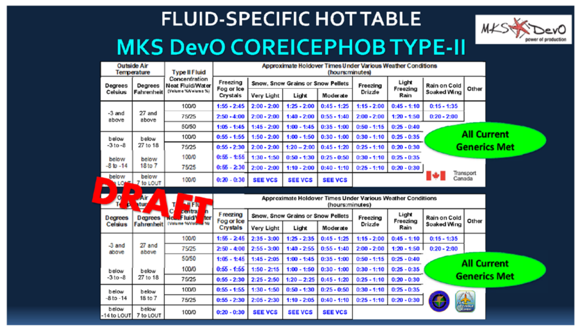
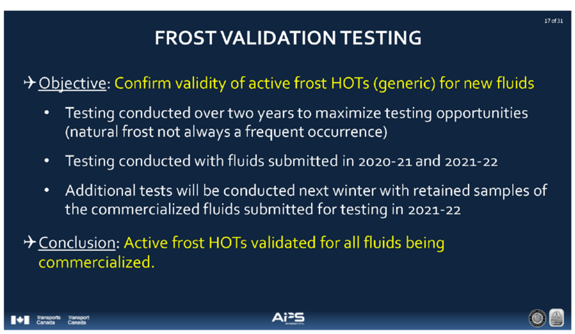
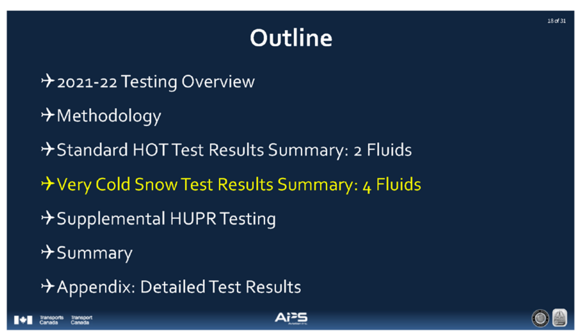
FLUID REFORMULATED
FLUID INFO
KILFROST ICE CLEAR II
Fluid Type: Type II
Fluid Base: Propylene Glycol
Dilutions: 100/0 only
WSET Result: 74 minutes
LOUT: TBD
LOWV: 4,120 m.Pa.s*
18,000 m.Pa.s**
*Manufacturer Method: LV1 (with guard leg), 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
**Alternate Method: SC4-31/13R, Small Sample Adapter, 9mL, 0°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


15 of 31
FLUID INFO
MKS DevO COREICEPHOB TYPE-II
Fluid Type: Type II
Fluid Base: Propylene Glycol
Dilutions: 100/0, 75/25, 50/50
WSET Result: 100/0 = 66 minutes
75/25 = 75 minutes
50/50 = 23.5 minutes
LOUT: TBD
LOWV: TBD
APS


FLUID-SPECIFIC HOT TABLE
MKS DevO COREICEPHOB TYPE-II
DRAFT
All Current Generics Met
All Current Generics Met


17 of 31
FROST VALIDATION TESTING
Objective: Confirm validity of active frost HOTs (generic) for new fluids
Testing conducted over two years to maximize testing opportunities (natural frost not always a frequent occurrence)
Testing conducted with fluids submitted in 2020-21 and 2021-22
Additional tests will be conducted next winter with retained samples of the commercialized fluids submitted for testing in 2021-22
Conclusion: Active frost HOTs validated for all fluids being commercialized.
APS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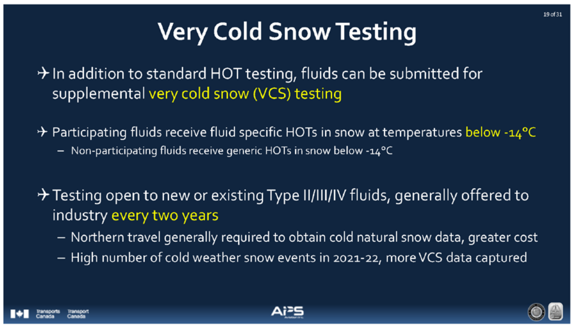
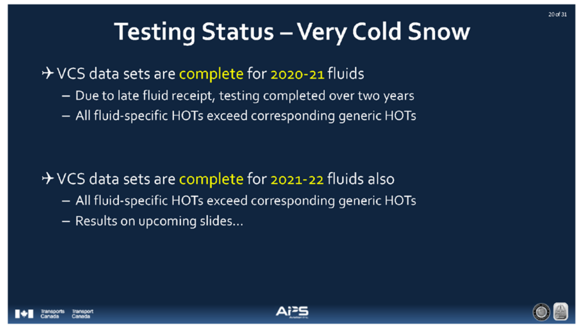
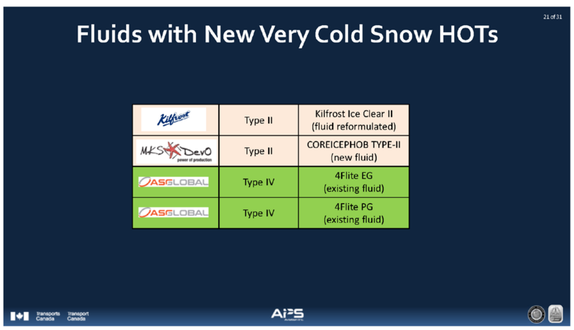
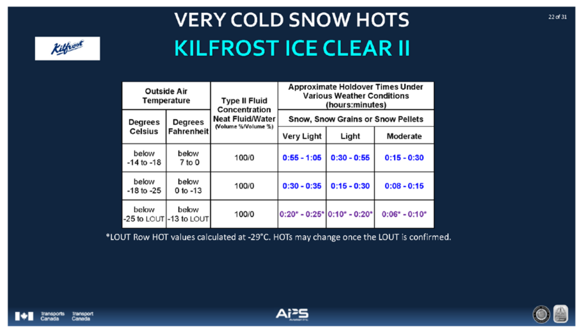




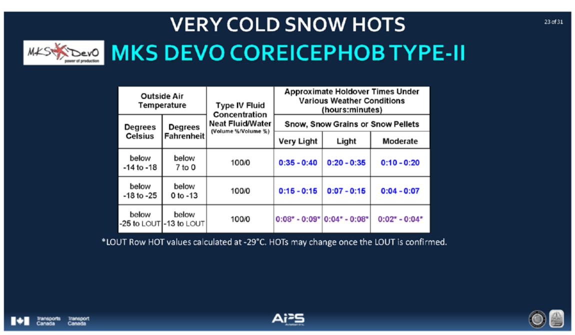


Kilfrost	Type II	Kilfrost Ice Clear II (fluid reformulated)
MKS DevO power of production	Type II	COREICEPHOB TYPE-II (new fluid)
ASGLOBAL	Type IV	4Flite EG (existing fluid)
ASGLOBAL	Type IV	4Flite PG (existing fluid)



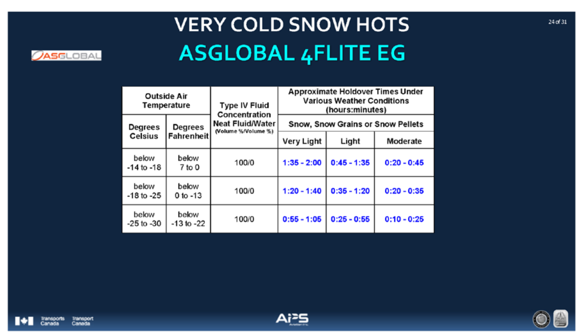
Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	0:55 - 1:05	0:30 - 0:55	0:15 - 0:30
below -18 to -25	below 0 to -13	100/0	0:30 - 0:35	0:15 - 0:30	0:08 - 0:15
below -25 to LOUT	below -13 to LOUT	100/0	0:20* - 0:25*	0:10* - 0:20*	0:06* - 0:10*

*LOUT Row HOT values calculated at -29°C. HOTs may change once the LOUT is confirmed.

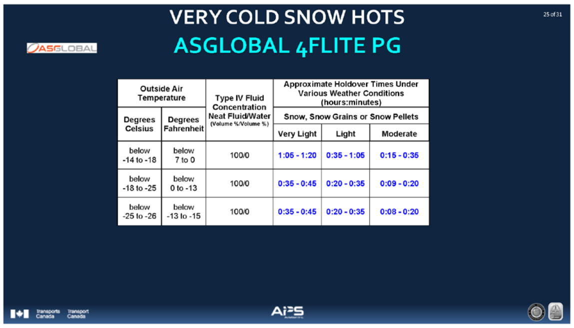


Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	0:35 - 0:40	0:20 - 0:35	0:10 - 0:20
below -18 to -25	below 0 to -13	100/0	0:15 - 0:15	0:07 - 0:15	0:04 - 0:07
below -25 to LOUT	below -13 to LOUT	100/0	0:08* - 0:09*	0:04* - 0:08*	0:02* - 0:04*

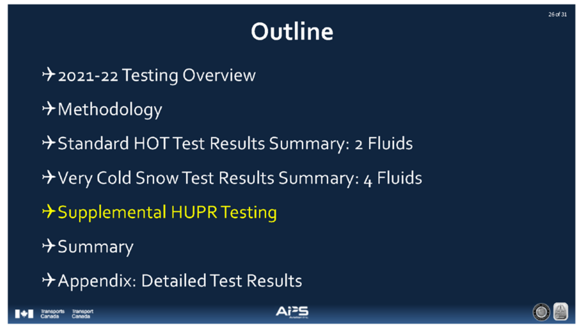
*LOUT Row HOT values calculated at -29°C. HOTs may change once the LOUT is confirmed.

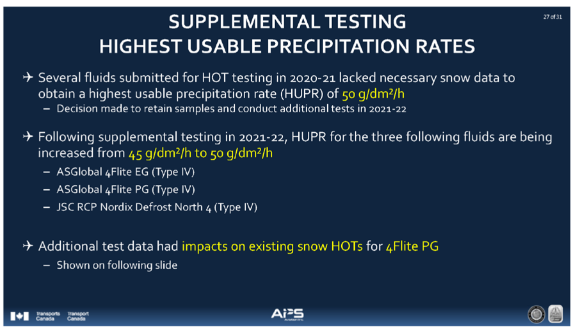


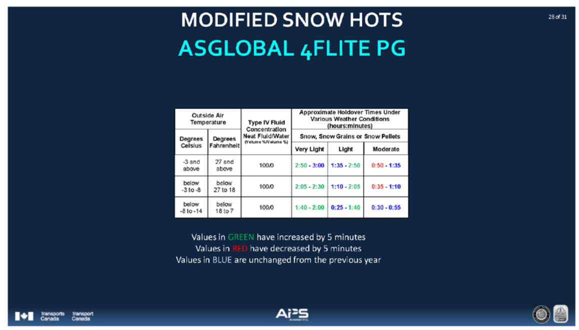
Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:35 - 2:00	0:45 - 1:35	0:20 - 0:45
below -18 to -25	below 0 to -13	100/0	1:20 - 1:40	0:35 - 1:20	0:20 - 0:35
below -25 to -30	below -13 to -22	100/0	0:55 - 1:05	0:25 - 0:55	0:10 - 0:25



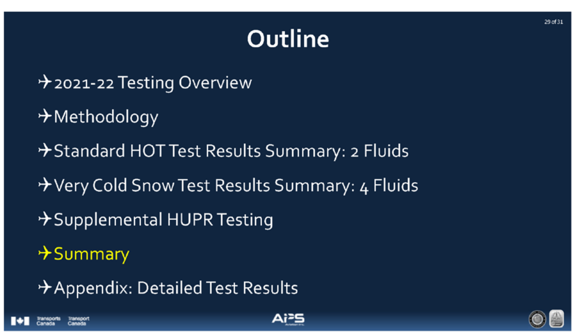
Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:05 - 1:20	0:35 - 1:05	0:15 - 0:35
below -18 to -25	below 0 to -13	100/0	0:35 - 0:45	0:20 - 0:35	0:09 - 0:20
below -25 to -26	below -13 to -15	100/0	0:35 - 0:45	0:20 - 0:35	0:08 - 0:20

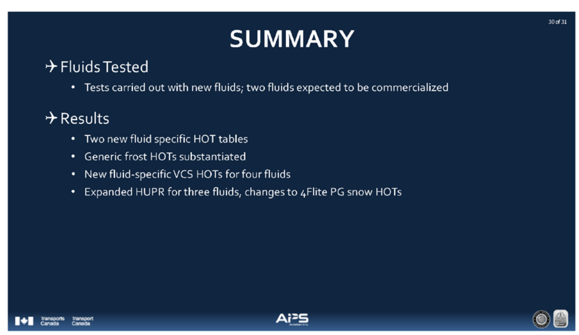






Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
-3 and above	27 and above	100/0	2:50 - 3:00	1:35 - 2:50	0:50 - 1:35
below -3 to -8	below 27 to 18	100/0	2:05 - 2:30	1:10 - 2:05	0:35 - 1:10
below -8 to -14	below 18 to 7	100/0	1:40 - 2:00	0:25 - 1:40	0:30 - 0:55



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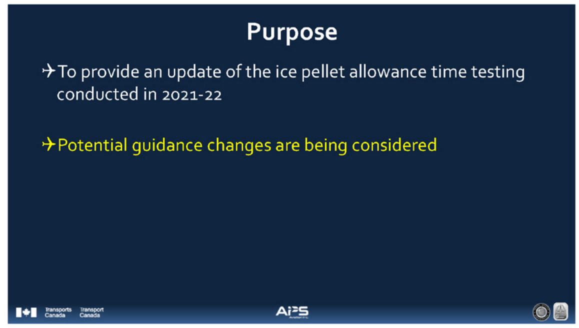
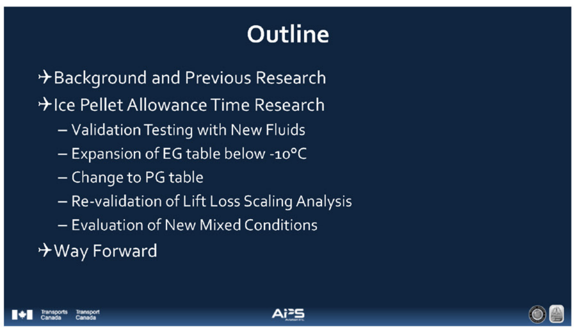
THANK YOU!!
Benjamin Bernier
bbernier@apsaviation.ca

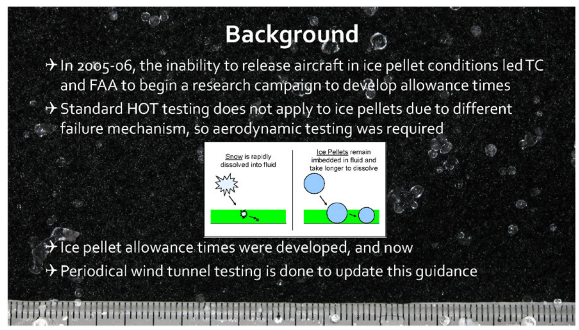
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2022

**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 G12 Holdover Time Committee, Webex, May 17, 2022
Marco Ruggi, Eng., M.B.A., Director


Purpose
To provide an update of the ice pellet allowance time testing conducted in 2021-22
Potential guidance changes are being considered


Outline
Background and Previous Research
Ice Pellet Allowance Time Research
– Validation Testing with New Fluids
– Expansion of EG table below -10°C
– Change to PG table
– Re-validation of Lift Loss Scaling Analysis
– Evaluation of New Mixed Conditions
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
AMIL
APS Aviation Inc.
SUPPORTERS
ABAX
ALLCLEAR SYSTEMS
CHEMCO
CLARIANT
CRYOTECH
DOW
Inland
Kilfrost
LNT Solutions
NEWANE
NORDIX
SAE INTERNATIONAL


2021-22 Research Team

2021-22 Summary of Test Runs

- 15 days of testing between Jan 9 – Jan 28, 2022

Objective #	Objective	# of Runs
1	Baseline Tests (Dry wing)	36
2	Ice Pellet Allowance Time Validation (New Fluids)	53
3	EG Fluids - Expansion of Allowance Times	28*
4	New Mixed Conditions	12
	Total	***129***

**Some also served as Validation tests*

Validation Testing Results

- 5 Type IV fluids recently added to the TC/FAA guidelines were tested
- Allowance times are generic, so systematic "spot checking" was done in order to identify any potential issues

Fluid	Status
AllClear Systems LLC - **ClearWing ECO**	Ongoing
CHEMCO Inc. - **ChemR Nordik IV**	✓ Validated
Cryotech Deicing Technology - **Polar Guard® Xtend**	✓ Validated
JSC RCP Nordix - **Defrost NORTH 4**	✓ Validated
Newave Aerochemical Co. Ltd. - **FCY-EGIV**	✓ Validated

EG Specific Allowance Times

- Industry requested EG specific fluid ice pellet allowance time tables be investigated
  - potential for longer allowance times
- Last year, a separate EG allowance time table was issued with longer times above -10°C
- Additional data was collected in 2021-22 with a focus on conditions below -10°C

EG Specific Allowance Time Data

- A total of 181 tests were analyzed
  - Data points meet or exceed allowance times
  - 46 of the 181 data points collected in 2021-22
- 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

- New data targeted primarily below -10°C conditions,
- However limited data is available below -16°C
- Some additional data in warmer temperatures was also collected

Distribution of Tests

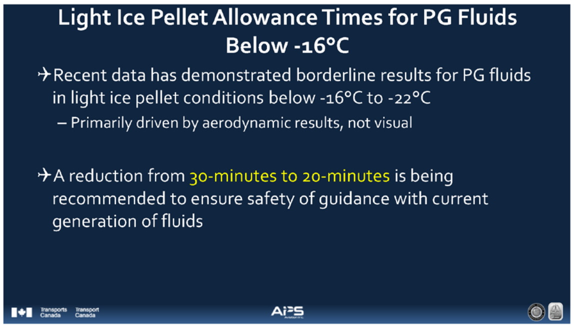
Precipitation Type	Outside Air Temperature			
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C
Light Ice Pellets	11 tests	8 tests	11 tests	6 tests
Light Ice Pellets Mixed with Light Snow	10 tests	7 tests	15 tests	2 tests
Light Ice Pellets Mixed with Light Freezing Drizzle or Moderate Freezing Drizzle	3 tests	3 tests		
Light Ice Pellets Mixed with Light Freezing Rain	15 tests	11 tests	2 tests	
Light Ice Pellets Mixed with Light Rain	3 tests			
Moderate Ice Pellets (or Small Hail)	15 tests	7 tests	13 tests	10 tests
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Freezing Drizzle	6 tests	6 tests		
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Rain	17 tests			

Changes to Allowance Times for EG Fluids

- The EG allowance times may be updated to include new longer times below -10°C

TABLE XX: ALLOWANCE TIMES FOR SAE TYPE IV ETHYLENE GLYCOL (EG) FLUIDS

Precipitation Type	Outside Air Temperature			
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C
Light Ice Pellets	70 minutes	50 minutes	~~20 minutes~~ 50 minutes	30 minutes
Light Ice Pellets Mixed with Light Snow	50 minutes	30 minutes	~~15 minutes~~ 25 minutes	
Light Ice Pellets Mixed with Light Freezing Drizzle or Moderate Freezing Drizzle	40 minutes	30 minutes	Caution: No allowance times currently exist	
Light Ice Pellets Mixed with Light Freezing Rain	40 minutes	30 minutes		
Light Ice Pellets Mixed with Light Rain	40 minutes			
Moderate Ice Pellets (or Small Hail)	35 minutes	25 minutes	~~10 minutes~~ 15 minutes	10 minutes
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Freezing Drizzle	20 minutes	10 minutes	Caution: No allowance times currently exist	
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Rain	15 minutes			


Light Ice Pellet Allowance Times for PG Fluids Below -16°C
Recent data has demonstrated borderline results for PG fluids in light ice pellet conditions below -16°C to -22°C
– Primarily driven by aerodynamic results, not visual
A reduction from 30-minutes to 20-minutes is being recommended to ensure safety of guidance with current generation of fluids
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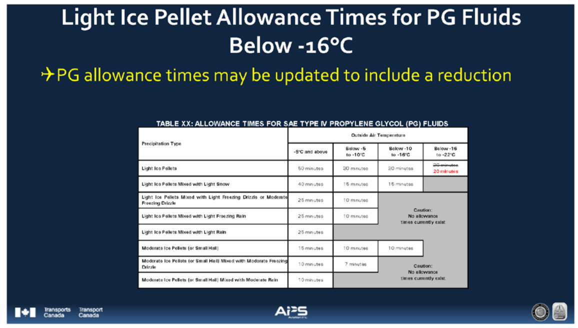
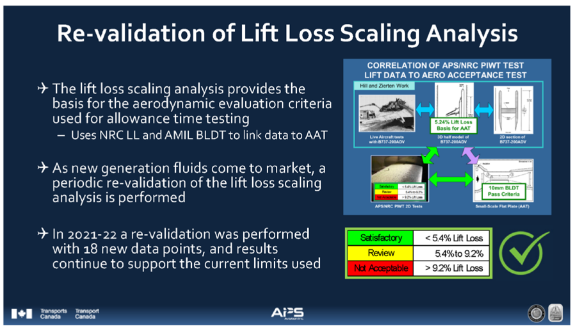
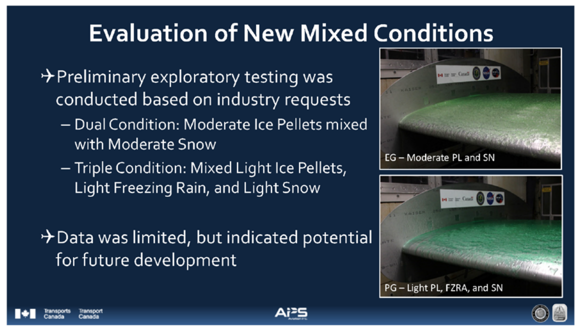

Light Ice Pellet Allowance Times for PG Fluids Below -16°C
PG allowance times may be updated to include a reduction
TABLE XX: ALLOWANCE TIMES FOR SAE TYPE IV PROPYLENE GLYCOL (PG) FLUIDS
Precipitation Type
Outside Air Temperature
-5°C and above
Below -5 to -10°C
Below -10 to -16°C
Below -16 to -22°C
Light Ice Pellets 50 minutes 30 minutes 30 minutes 30 minutes 20 minutes
Light Ice Pellets Mixed with Light Snow 40 minutes 15 minutes 15 minutes
Light Ice Pellets Mixed with Light Freezing Drizzle or Moderate Freezing Drizzle 25 minutes 10 minutes
Light Ice Pellets Mixed with Light Freezing Rain 25 minutes 10 minutes
Light Ice Pellets Mixed with Light Rain 25 minutes
Moderate Ice Pellets (or Small Hail) 15 minutes 10 minutes 10 minutes
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Freezing Drizzle 10 minutes 7 minutes
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Rain 10 minutes
Caution: No allowance times currently exist
Caution: No allowance times currently exist
AiPS


Re-validation of Lift Loss Scaling Analysis
The lift loss scaling analysis provides the basis for the aerodynamic evaluation criteria used for allowance time testing
– Uses NRC LL and AMIL BLDT to link data to AAT
As new generation fluids come to market, a periodic re-validation of the lift loss scaling analysis is performed
In 2021-22 a re-validation was performed with 18 new data points, and results continue to support the current limits used
CORRELATION OF APS/NRC PIWT TEST LIFT DATA TO AERO ACCEPTANCE TEST
Satisfactory < 5.4% Lift Loss
Review 5.4% to 9.2%
Not Acceptable > 9.2% Lift Loss
AiPS


Evaluation of New Mixed Conditions
Preliminary exploratory testing was conducted based on industry requests
– Dual Condition: Moderate Ice Pellets mixed with Moderate Snow
– Triple Condition: Mixed Light Ice Pellets, Light Freezing Rain, and Light Snow
Data was limited, but indicated potential for future development
EG – Moderate PL and SN
PG – Light PL, FZRA, and SN
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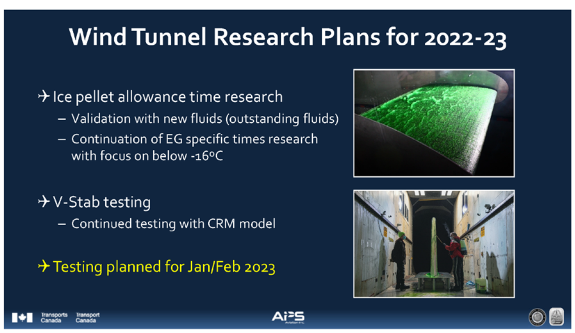
Wind Tunnel Research Plans for 2022-23
Ice pellet allowance time research
– Validation with new fluids (outstanding fluids)
– Continuation of EG specific times research with focus on below -16ºC
V-Stab testing
– Continued testing with CRM model
Testing planned for Jan/Feb 2023
AiPS


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?
Marco Ruggi
mruggi@apsaviation.ca

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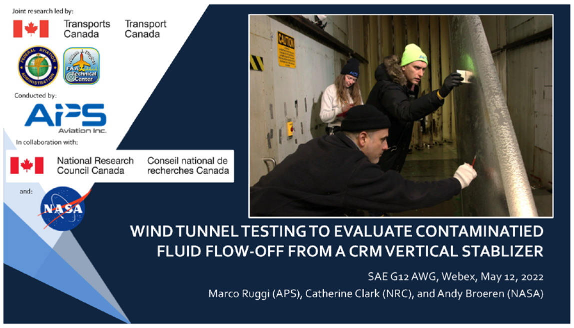
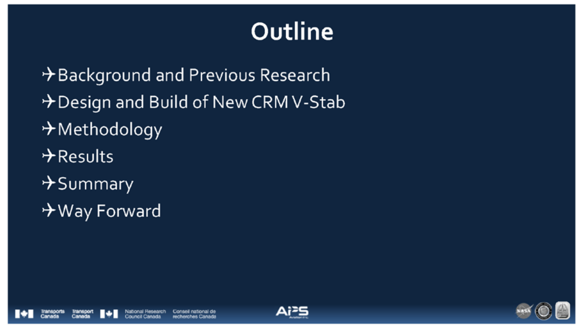
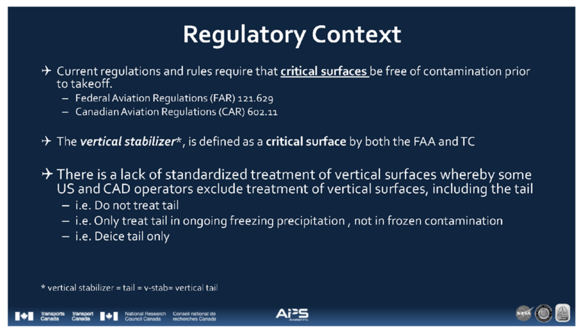
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2022

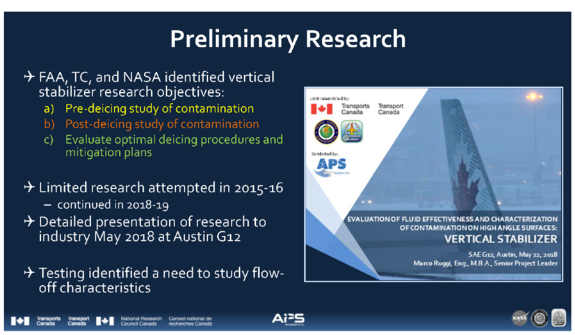
PRESENTATION:
WIND TUNNEL TESTING TO EVALUATE CONTAMINATED FLUID FLOW-OFF FROM A CRM VERTICAL STABILIZER (PRESENTED JOINTLY WITH NRC AND NASA)

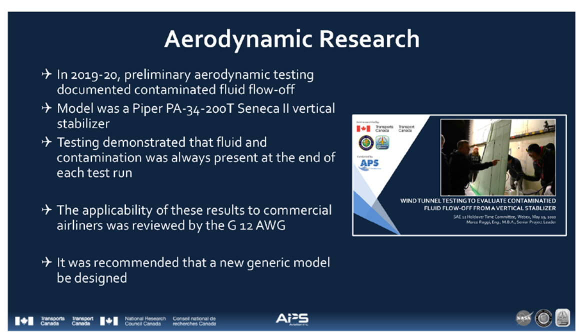

Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS Aviation Inc.
In collaboration with:
National Research Council Canada
Conseil national de recherches Canada
and:
NASA
WIND TUNNEL TESTING TO EVALUATE CONTAMINATIED FLUID FLOW-OFF FROM A CRM VERTICAL STABLIZER
SAE G12 AWG, Webex, May 12, 2022
Marco Ruggi (APS), Catherine Clark (NRC), and Andy Broeren (NASA)


Outline
Background and Previous Research
Design and Build of New CRM V-Stab
Methodology
Results
Summary
Way Forward

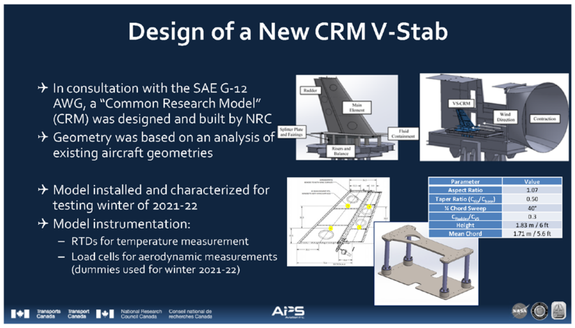

Background and Previous Research


Regulatory Context
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 both the FAA and TC
There is a lack of standardized treatment of vertical surfaces whereby some US and CAD operators exclude treatment of vertical surfaces, including the tail
– i.e. Do not treat tail
– i.e. Only treat tail in ongoing freezing precipitation , not in frozen contamination
– i.e. Deice tail only
* vertical stabilizer = tail = v-stab= vertical tail

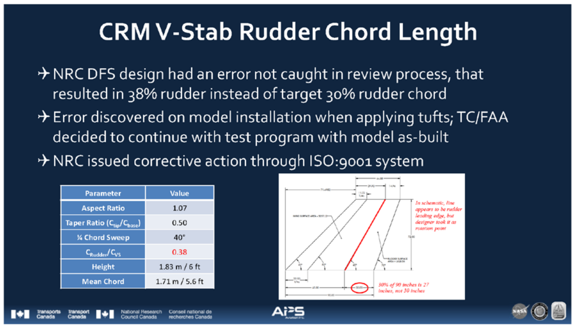

Preliminary Research
FAA, TC, and NASA identified vertical stabilizer research objectives:
a) Pre-deicing study of contamination
b) Post-deicing study of contamination
c) Evaluate optimal deicing procedures and mitigation plans
Limited research attempted in 2015-16
– continued in 2018-19
Detailed presentation of research to industry May 2018 at Austin G12
Testing identified a need to study flow-off characteristics
EVALUATION OF FLUID EFFECTIVENESS AND CHARACTERIZATION OF CONTAMINATION ON HIGH ANGLE SURFACES:
VERTICAL STABILIZER
SAE G12, Austin, May 22, 2018

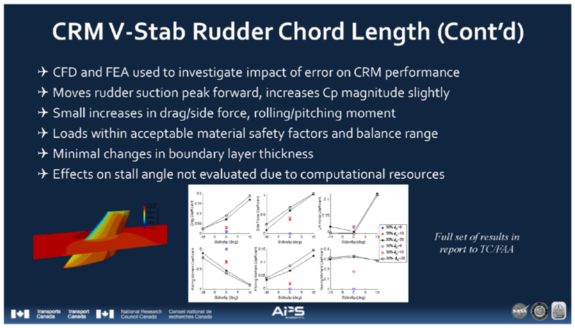

Aerodynamic Research
In 2019-20, preliminary aerodynamic testing documented contaminated fluid flow-off
Model was a Piper PA-34-200T Seneca II vertical stabilizer
Testing demonstrated that fluid and contamination was always present at the end of each test run
The applicability of these results to commercial airliners was reviewed by the G 12 AWG
It was recommended that a new generic model be designed
WIND TUNNEL TESTING TO EVALUATE CONTAMINATED FLUID FLOW-OFF FROM A VERTICAL STABLIZER

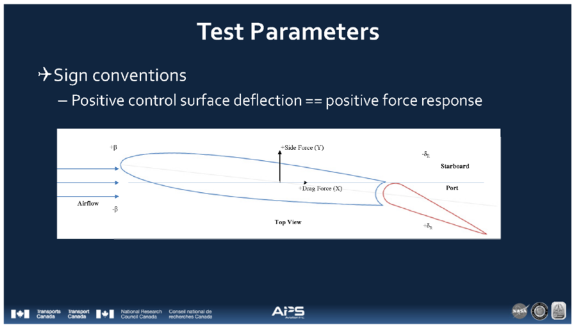

Design and Build of a New CRM V-Stab

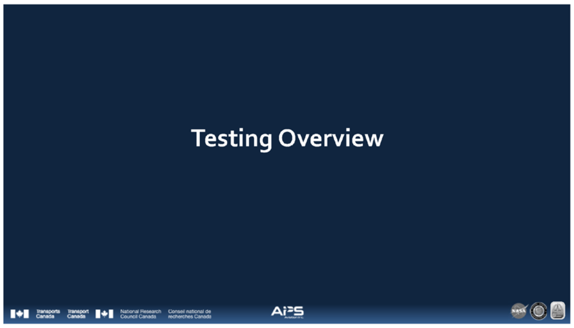

Design of a New CRM V-Stab
In consultation with the SAE G-12 AWG, a "Common Research Model" (CRM) was designed and built by NRC
Geometry was based on an analysis of existing aircraft geometries
Model installed and characterized for testing winter of 2021-22
Model instrumentation:
– RTDs for temperature measurement
– Load cells for aerodynamic measurements (dummies used for winter 2021-22)
Rudder
Main Element
Splinter Plate and Fairings
Fluid Containment
Risers and Balance
VS-CRM
Wind Direction
Contraction
Parameter | Value
Aspect Ratio | 1.07
Taper Ratio (C_{tip}/C_{base}) | 0.50
¼ Chord Sweep | 40°
C_{Rudder}/C_{VS} | 0.3
Height | 1.83 m / 6 ft
Mean Chord | 1.71 m / 5.6 ft

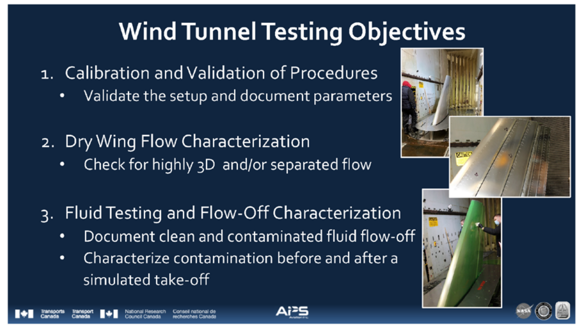

Fabrication and Installation of New CRM V-Stab

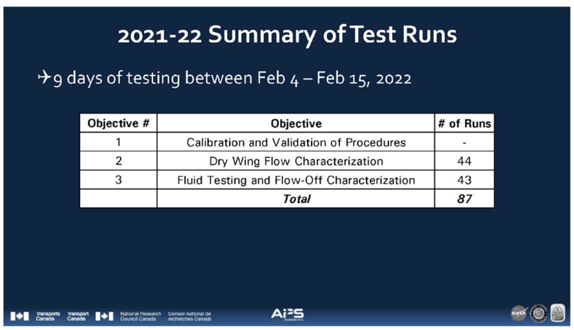

CRM V-Stab Rudder Chord Length
NRC DFS design had an error not caught in review process, that resulted in 38% rudder instead of target 30% rudder chord
Error discovered on model installation when applying tufts; TC/FAA decided to continue with test program with model as-built
NRC issued corrective action through ISO:9001 system
Parameter | Value
Aspect Ratio | 1.07
Taper Ratio (C_{tip}/C_{base}) | 0.50
¼ Chord Sweep | 40°
C_{Rudder}/C_{VS} | 0.38
Height | 1.83 m / 6 ft
Mean Chord | 1.71 m / 5.6 ft
In schematic, line appears to be rudder leading edge, but designer took it as rotation point
30% of 90 inches is 27 inches, not 30 inches


CRM V-Stab Rudder Chord Length (Cont'd)
CFD and FEA used to investigate impact of error on CRM performance
Moves rudder suction peak forward, increases Cp magnitude slightly
Small increases in drag/side force, rolling/pitching moment
Loads within acceptable material safety factors and balance range
Minimal changes in boundary layer thickness
Effects on stall angle not evaluated due to computational resources
Full set of results in report to TC/FAA

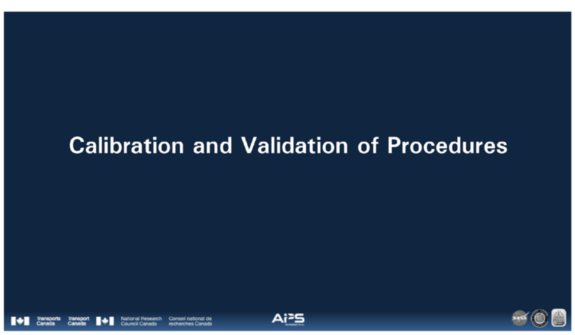

Test Parameters
Sign conventions
– Positive control surface deflection == positive force response
Side Force (Y)
Drag Force (X)
Starboard
Port
Airflow
Top View

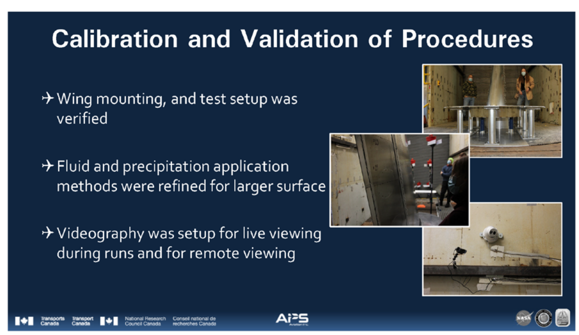


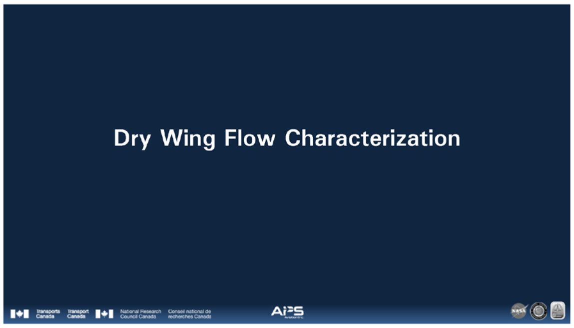


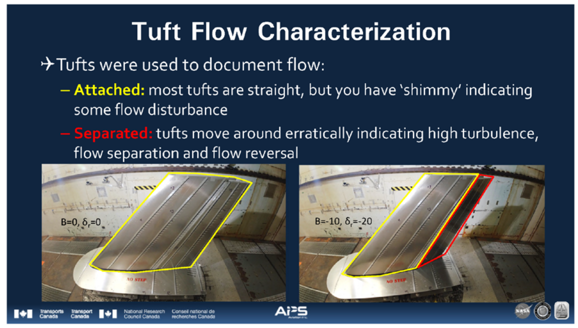


Objective #	Objective	# of Runs
1	Calibration and Validation of Procedures	-
2	Dry Wing Flow Characterization	44
3	Fluid Testing and Flow-Off Characterization	43
	Total	***87***






Dry Wing Flow Characterization
Transports Canada Transport Canada
National Research Council Canada Conseil national de recherches Canada
AiPS


Tuft Flow Characterization
Tufts were used to document flow:
– Attached: most tufts are straight, but you have 'shimmy' indicating some flow disturbance
– Separated: tufts move around erratically indicating high turbulence, flow separation and flow reversal
B=0, δr=0
B=-10, δr=-20
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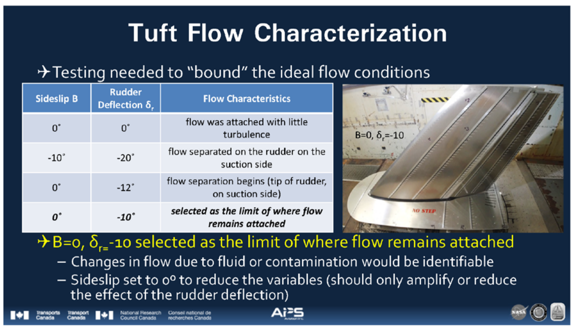
Tuft Flow Characterization
Testing needed to "bound" the ideal flow conditions
Sideslip B | Rudder Deflection δr | Flow Characteristics
0° | 0° | flow was attached with little turbulence
-10° | -20° | flow separated on the rudder on the suction side
0° | -12° | flow separation begins (tip of rudder, on suction side)
0° | -10° | selected as the limit of where flow remains attached
B=0, δr=-10
B=0, δr=-10 selected as the limit of where flow remains attached
– Changes in flow due to fluid or contamination would be identifiable
– Sideslip set to 0° to reduce the variables (should only amplify or reduce the effect of the rudder deflection)
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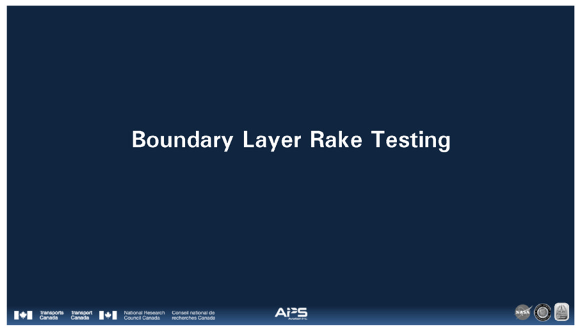
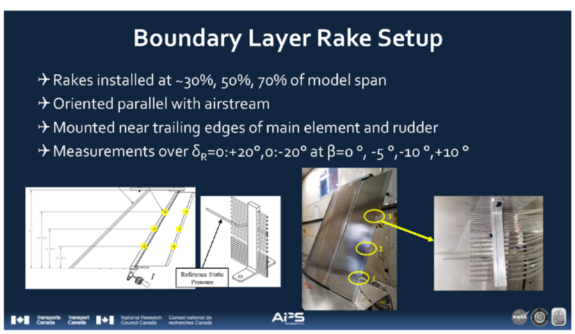
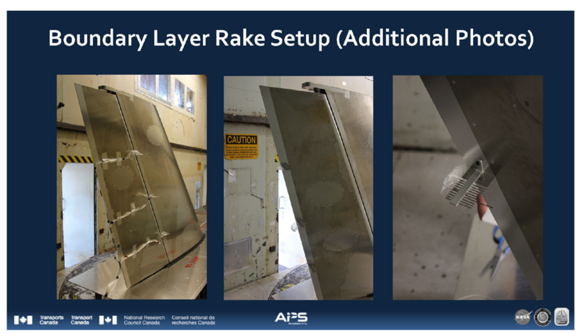
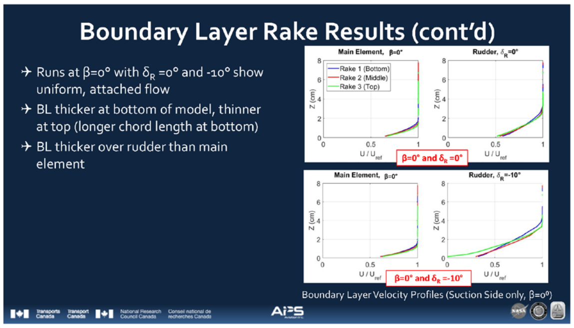
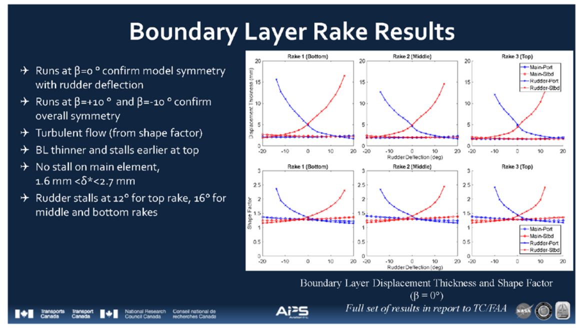
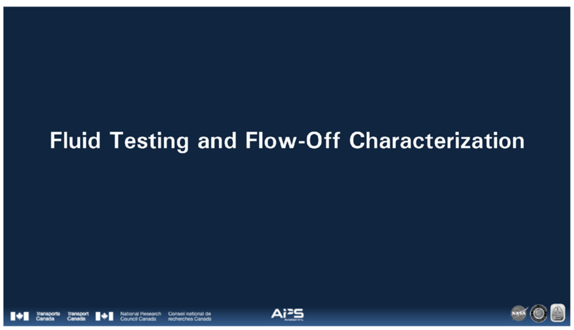

Boundary Layer Rake Testing
AiPS

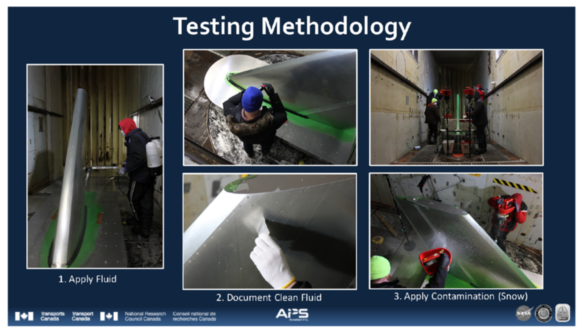

Boundary Layer Rake Setup
Rakes installed at ~30%, 50%, 70% of model span
Oriented parallel with airstream
Mounted near trailing edges of main element and rudder
Measurements over δR=0:+20°,0:-20° at β=0 °, -5 °,-10 °,+10 °
Reference Static Pressure
AiPS

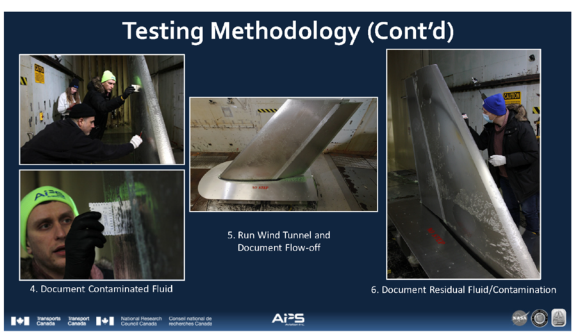

Boundary Layer Rake Setup (Additional Photos)
AiPS

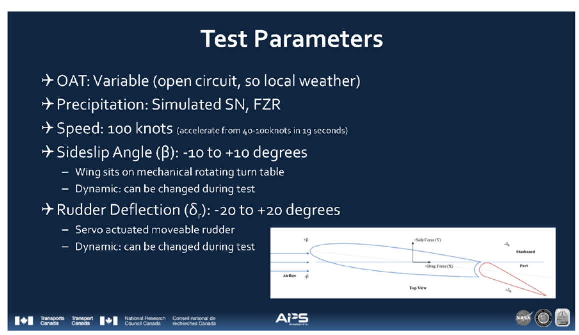

Boundary Layer Rake Results (cont'd)
Runs at β=0° with δR =0° and -10° show uniform, attached flow
BL thicker at bottom of model, thinner at top (longer chord length at bottom)
BL thicker over rudder than main element
Main Element, β=0°
Rudder, δR=0°
Rake 1 (Bottom)
Rake 2 (Middle)
Rake 3 (Top)
β=0° and δR =0°
β=0° and δR =-10°
Boundary Layer Velocity Profiles (Suction Side only, β=0°)

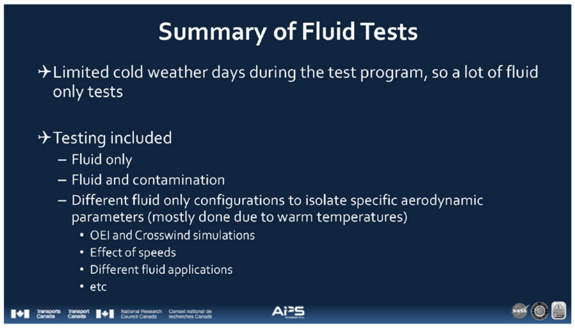

Boundary Layer Rake Results
Runs at β=0 ° confirm model symmetry with rudder deflection
Runs at β=+10 ° and β=-10 ° confirm overall symmetry
Turbulent flow (from shape factor)
BL thinner and stalls earlier at top
No stall on main element, 1.6 mm <δ*<2.7 mm
Rudder stalls at 12° for top rake, 16° for middle and bottom rakes
Boundary Layer Displacement Thickness and Shape Factor
(β = 0°)
Full set of results in report to TC/FAA


Fluid Testing and Flow-Off Characterization


Testing Methodology
1. Apply Fluid
2. Document Clean Fluid
3. Apply Contamination (Snow)


Testing Methodology (Cont'd)
4. Document Contaminated Fluid
5. Run Wind Tunnel and Document Flow-off
6. Document Residual Fluid/Contamination


Test Parameters
OAT: Variable (open circuit, so local weather)
Precipitation: Simulated SN, FZR
Speed: 100 knots (accelerate from 40-100knots in 19 seconds)
Sideslip Angle (β): -10 to +10 degrees
– Wing sits on mechanical rotating turn table
– Dynamic: can be changed during test
Rudder Deflection (δr): -20 to +20 degrees
– Servo actuated moveable rudder
– Dynamic: can be changed during test


Summary of Fluid Tests
Limited cold weather days during the test program, so a lot of fluid only tests
Testing included
– Fluid only
– Fluid and contamination
– Different fluid only configurations to isolate specific aerodynamic parameters (mostly done due to warm temperatures)
• OEI and Crosswind simulations
• Effect of speeds
• Different fluid applications
• etc
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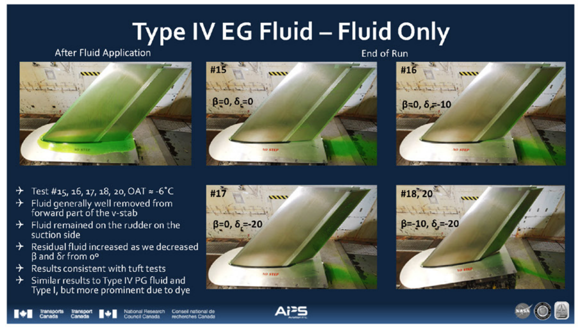
Type IV EG Fluid – Fluid Only
After Fluid Application
End of Run
#15
β=0, δr=0
#16
β=0, δr=-10
#17
β=0, δr=-20
#18, 20
β=-10, δr=-20
Test #15, 16, 17, 18, 20, OAT ≈ -6˚C
Fluid generally well removed from forward part of the v-stab
Fluid remained on the rudder on the suction side
Residual fluid increased as we decreased β and δr from 0º
Results consistent with tuft tests
Similar results to Type IV PG fluid and Type I, but more prominent due to dye
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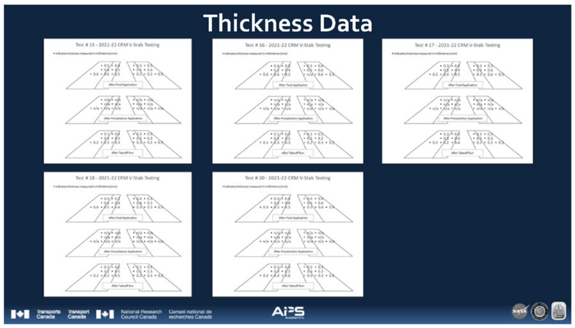
Thickness Data
Test # 15 - 2021-22 CRM V-Stab Testing
Test # 16 - 2021-22 CRM V-Stab Testing
Test # 17 - 2021-22 CRM V-Stab Testing
Test # 18 - 2021-22 CRM V-Stab Testing
Test # 20 - 2021-22 CRM V-Stab Testing
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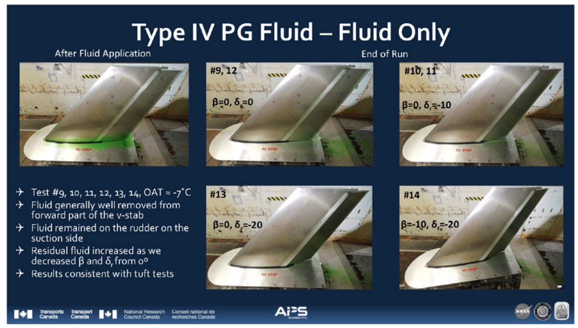
Type IV PG Fluid – Fluid Only
After Fluid Application
End of Run
#9, 12
β=0, δr=0
#10, 11
β=0, δr=-10
#13
β=0, δr=-20
#14
β=-10, δr=-20
Test #9, 10, 11, 12, 13, 14, OAT ≈ -7˚C
Fluid generally well removed from forward part of the v-stab
Fluid remained on the rudder on the suction side
Residual fluid increased as we decreased β and δr from 0º
Results consistent with tuft tests
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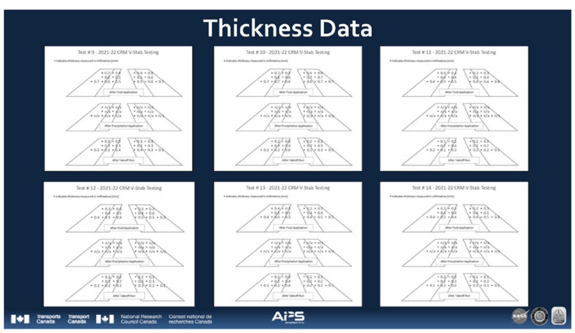
Thickness Data
Test # 9 - 2021-22 CRM V-Stab Testing
Test # 10 - 2021-22 CRM V-Stab Testing
Test # 11 - 2021-22 CRM V-Stab Testing
Test # 12 - 2021-22 CRM V-Stab Testing
Test # 13 - 2021-22 CRM V-Stab Testing
Test # 14 - 2021-22 CRM V-Stab Testing
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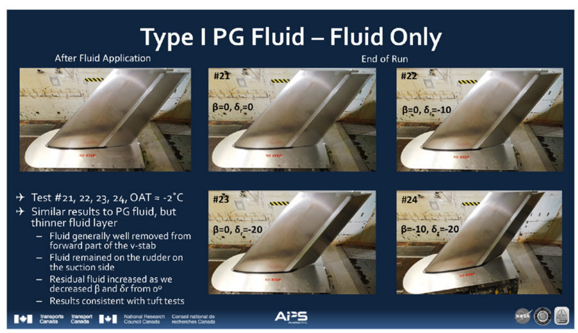
Type I PG Fluid – Fluid Only
After Fluid Application
End of Run
#21
β=0, δr=0
#22
β=0, δr=-10
#23
β=0, δr=-20
#24
β=-10, δr=-20
Test #21, 22, 23, 24, OAT ≈ -2˚C
Similar results to PG fluid, but thinner fluid layer
– Fluid generally well removed from forward part of the v-stab
– Fluid remained on the rudder on the suction side
– Residual fluid increased as we decreased β and δr from 0º
– Results consistent with tuft tests
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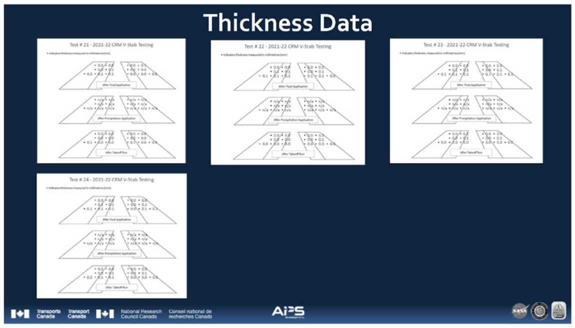
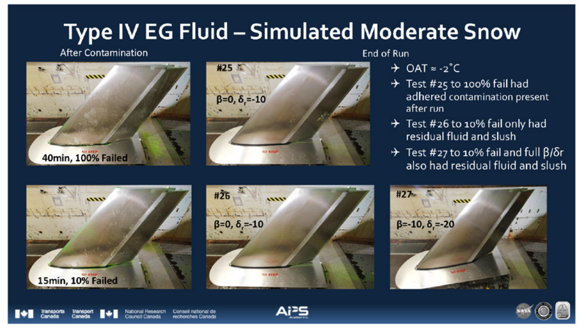
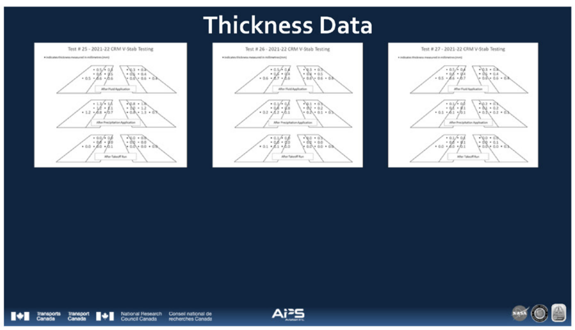
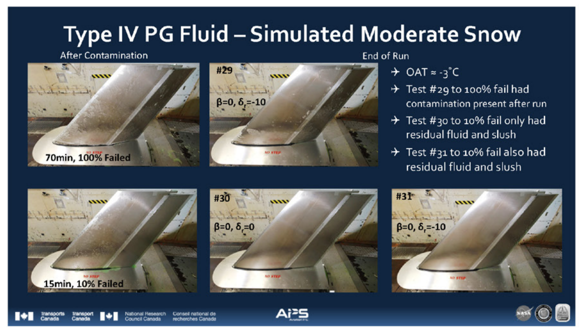
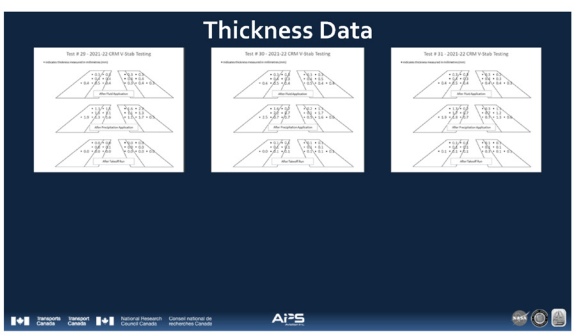
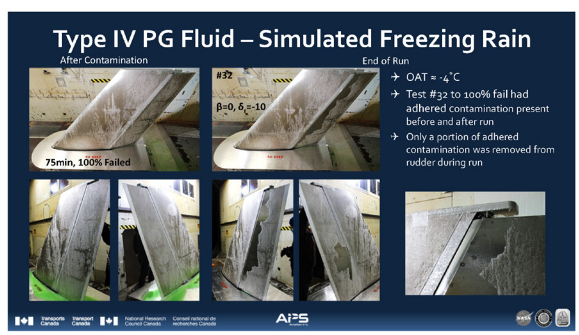

Thickness Data

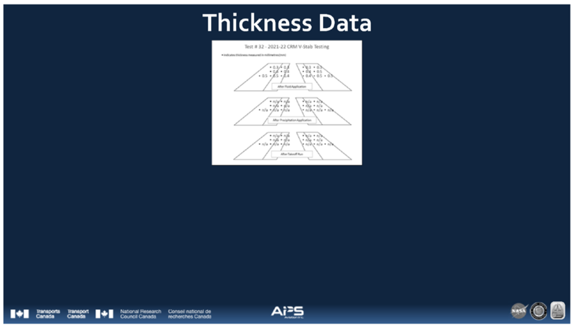

Type IV EG Fluid – Simulated Moderate Snow
After Contamination
End of Run
40min, 100% Failed
#25
β=0, δr=-10
OAT ≈ -2˚C
Test #25 to 100% fail had adhered contamination present after run
Test #26 to 10% fail only had residual fluid and slush
Test #27 to 10% fail and full β/δr also had residual fluid and slush
15min, 10% Failed
#26
β=0, δr=-10
#27
β=-10, δr=-20

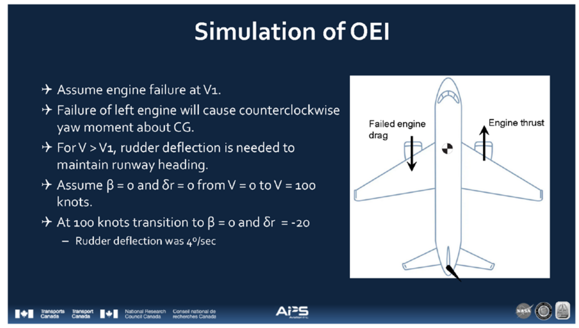

Thickness Data

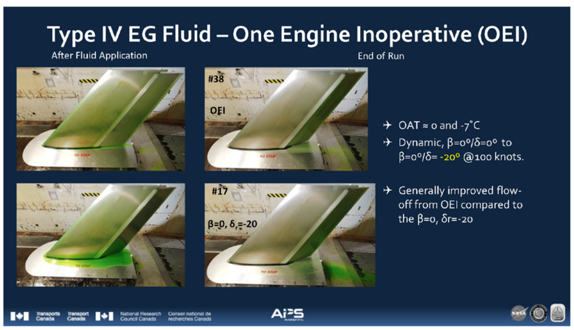

Type IV PG Fluid – Simulated Moderate Snow
After Contamination
End of Run
70min, 100% Failed
#29
β=0, δr=-10
OAT ≈ -3˚C
Test #29 to 100% fail had contamination present after run
Test #30 to 10% fail only had residual fluid and slush
Test #31 to 10% fail also had residual fluid and slush
15min, 10% Failed
#30
β=0, δr=0
#31
β=0, δr=-10

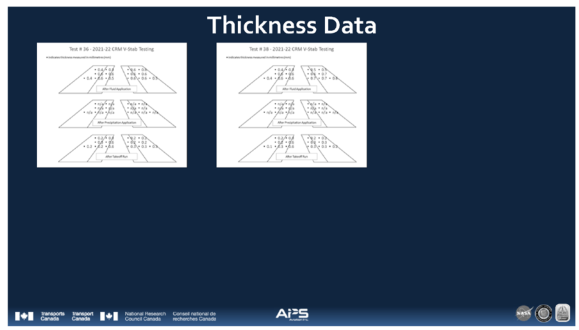

Thickness Data

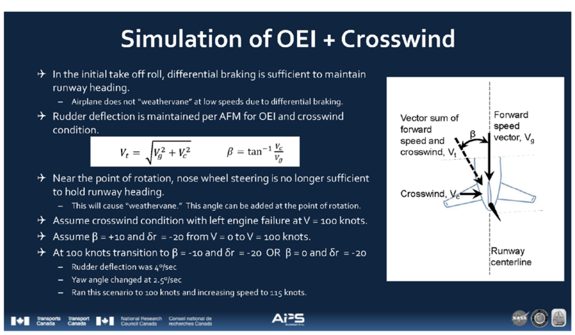

Type IV PG Fluid – Simulated Freezing Rain
After Contamination
End of Run
75min, 100% Failed
#32
β=0, δr=-10
OAT ≈ -4˚C
Test #32 to 100% fail had adhered contamination present before and after run
Only a portion of adhered contamination was removed from rudder during run

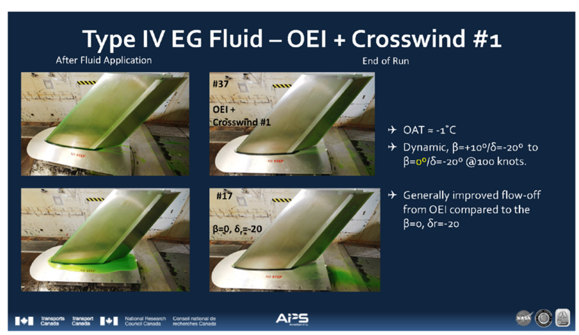

Thickness Data

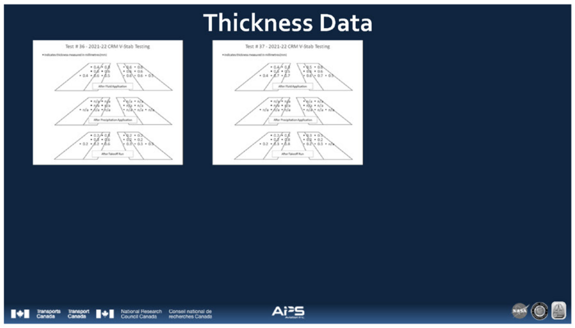

Simulation of OEI
Assume engine failure at V1.
Failure of left engine will cause counterclockwise yaw moment about CG.
For V > V1, rudder deflection is needed to maintain runway heading.
Assume β = 0 and δr = 0 from V = 0 to V = 100 knots.
At 100 knots transition to β = 0 and δr = -20
– Rudder deflection was 4°/sec
Failed engine drag
Engine thrust

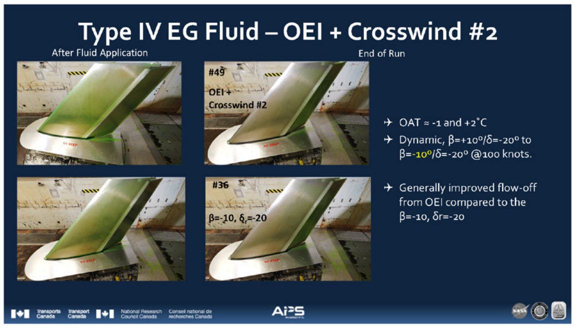

Type IV EG Fluid – One Engine Inoperative (OEI)
After Fluid Application
End of Run
#38
OEI
#17
β=0, δr=-20
OAT = 0 and -7˚C
Dynamic, β=0°/δ=0° to β=0°/δ= -20° @100 knots.
Generally improved flow-off from OEI compared to the β=0, δr=-20

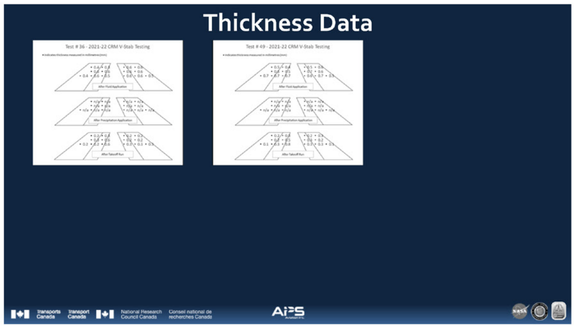

Thickness Data

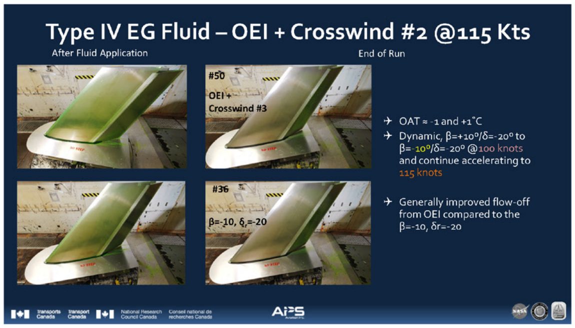

Simulation of OEI + Crosswind
In the initial take off roll, differential braking is sufficient to maintain runway heading.
– Airplane does not "weathervane" at low speeds due to differential braking.
Rudder deflection is maintained per AFM for OEI and crosswind condition.
$V_t = \sqrt{V_g^2 + V_c^2}$ $\beta = \tan^{-1}\frac{V_c}{V_g}$
Near the point of rotation, nose wheel steering is no longer sufficient to hold runway heading.
– This will cause "weathervane." This angle can be added at the point of rotation.
Assume crosswind condition with left engine failure at V = 100 knots.
Assume β = +10 and δr = -20 from V = 0 to V = 100 knots.
At 100 knots transition to β = -10 and δr = -20 OR β = 0 and δr = -20
– Rudder deflection was 4°/sec
– Yaw angle changed at 2.5°/sec
– Ran this scenario to 100 knots and increasing speed to 115 knots.
Vector sum of forward speed and crosswind, V_t
Forward speed vector, V_g
β
Crosswind, V_c
Runway centerline

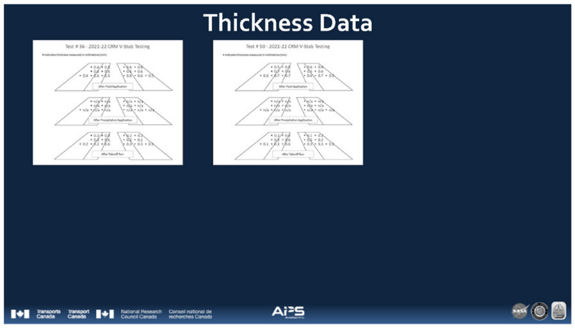

Type IV EG Fluid – OEI + Crosswind #1
After Fluid Application
End of Run
#37
OEI + Crosswind #1
#17
β=0, δr=-20
OAT = -1˚C
Dynamic, β=+10°/δ=-20° to β=0°/δ=-20° @100 knots.
Generally improved flow-off from OEI compared to the β=0, δr=-20

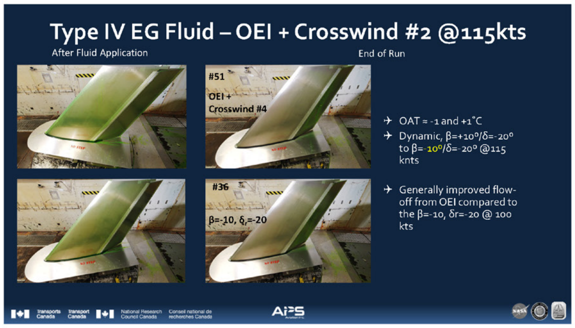

Thickness Data
Test # 36 - 2021-22 CRM V-Stab Testing
Test # 37 - 2021-22 CRM V-Stab Testing

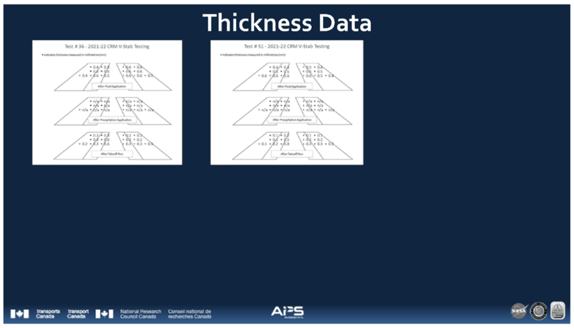

Type IV EG Fluid – OEI + Crosswind #2
After Fluid Application
End of Run
#49
OEI +
Crosswind #2
#36
β=-10, δr=-20
OAT ≈ -1 and +2˚C
Dynamic, β=+10º/δ=-20º to β=-10º/δ=-20º @100 knots.
Generally improved flow-off from OEI compared to the β=-10, δr=-20


Thickness Data
Test # 36 - 2021-22 CRM V-Stab Testing
Test # 49 - 2021-22 CRM V-Stab Testing


Type IV EG Fluid – OEI + Crosswind #2 @115 Kts
After Fluid Application
End of Run
#50
OEI +
Crosswind #3
#36
β=-10, δr=-20
OAT ≈ -1 and +1˚C
Dynamic, β=+10º/δ=-20º to β=-10º/δ=-20º @100 knots and continue accelerating to 115 knots
Generally improved flow-off from OEI compared to the β=-10, δr=-20


Thickness Data
Test # 36 - 2021-22 CRM V-Stab Testing
Test # 50 - 2021-22 CRM V-Stab Testing


Type IV EG Fluid – OEI + Crosswind #2 @115kts
After Fluid Application
End of Run
#51
OEI +
Crosswind #4
#36
β=-10, δr=-20
OAT ≈ -1 and +1˚C
Dynamic, β=+10º/δ=-20º to β=-10º/δ=-20º @115 knts
Generally improved flow-off from OEI compared to the β=-10, δr=-20 @ 100 kts


Thickness Data
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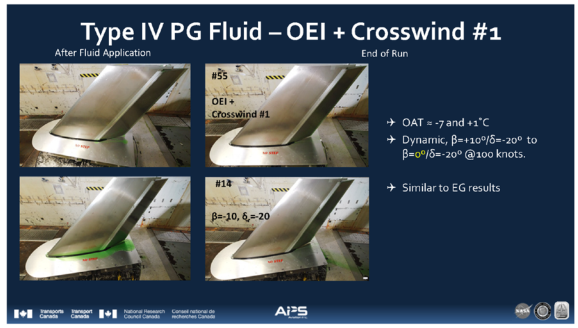
Type IV PG Fluid – OEI + Crosswind #1
After Fluid Application
End of Run
#55
OEI +
Crosswind #1
#14
β=-10, δr=-20
OAT ≈ -7 and +1˚C
Dynamic, β=+10º/δ=-20º to β=0º/δ=-20º @100 knots.
Similar to EG results
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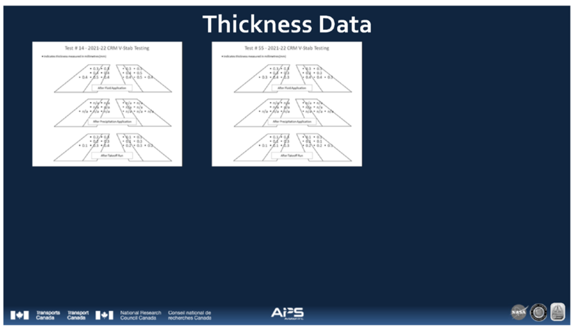
Thickness Data
Transports Canada
Transport Canada
National Research Council Canada
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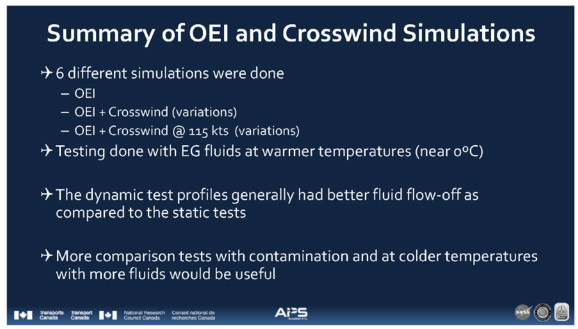
Summary of OEI and Crosswind Simulations
6 different simulations were done
– OEI
– OEI + Crosswind (variations)
– OEI + Crosswind @ 115 kts (variations)
Testing done with EG fluids at warmer temperatures (near 0ºC)
The dynamic test profiles generally had better fluid flow-off as compared to the static tests
More comparison tests with contamination and at colder temperatures with more fluids would be useful
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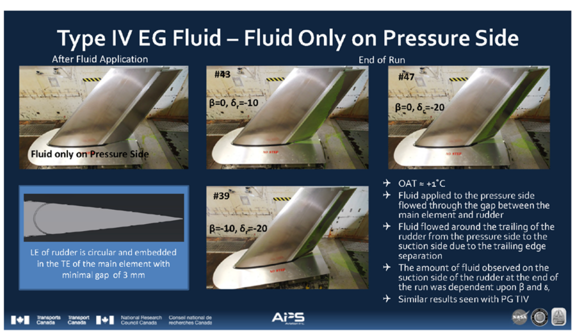
Type IV EG Fluid – Fluid Only on Pressure Side
After Fluid Application
End of Run
Fluid only on Pressure Side
#43
β=0, δr=-10
#47
β=0, δr=-20
LE of rudder is circular and embedded in the TE of the main element with minimal gap of 3 mm
#39
β=-10, δr=-20
OAT ≈ +1˚C
Fluid applied to the pressure side flowed through the gap between the main element and rudder
Fluid flowed around the trailing of the rudder from the pressure side to the suction side due to the trailing edge separation
The amount of fluid observed on the suction side of the rudder at the end of the run was dependent upon β and δr
Similar results seen with PG TIV
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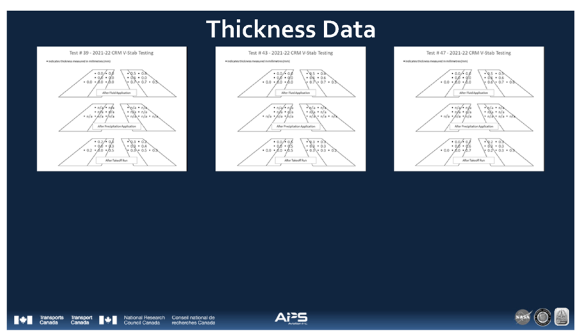
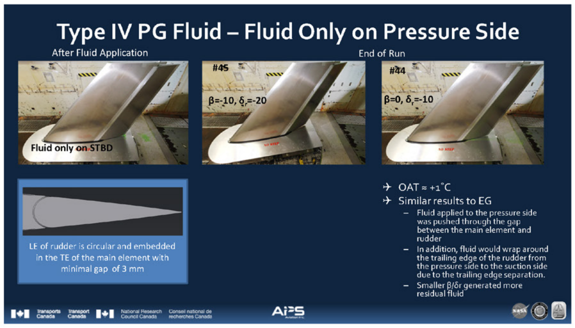
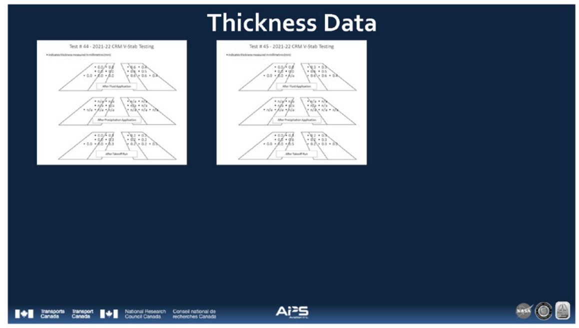
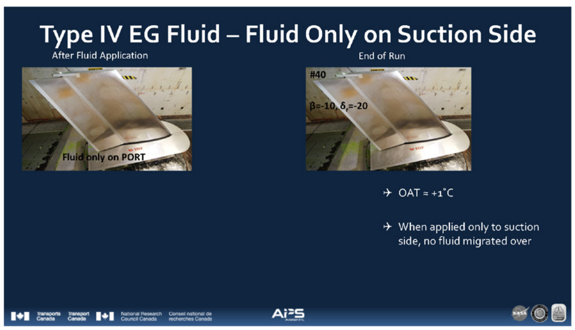
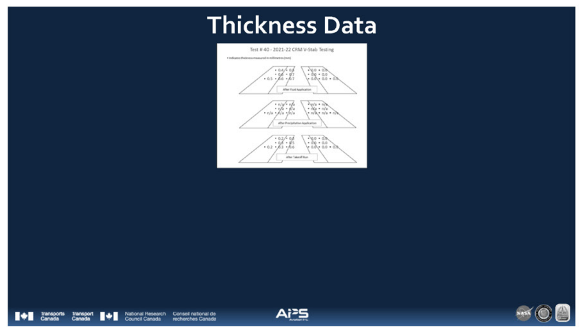
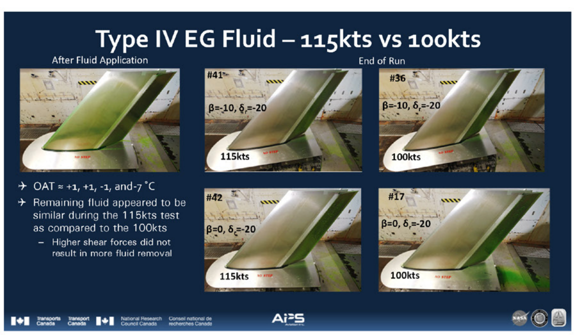

Thickness Data
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
APS

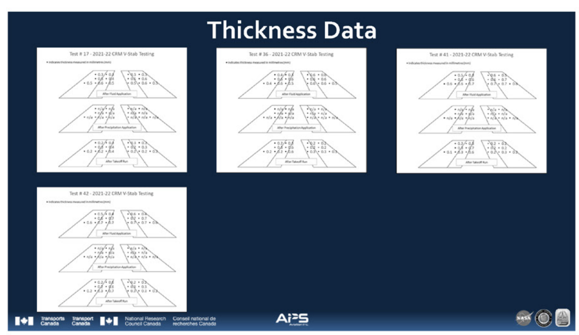

Type IV PG Fluid – Fluid Only on Pressure Side
After Fluid Application
End of Run
Fluid only on STBD
#45
β=-10, δr=-20
#44
β=0, δr=-10
LE of rudder is circular and embedded in the TE of the main element with minimal gap of 3 mm
OAT = +1˚C
Similar results to EG
– Fluid applied to the pressure side was pushed through the gap between the main element and rudder
– In addition, fluid would wrap around the trailing edge of the rudder from the pressure side to the suction side due to the trailing edge separation.
– Smaller β/δr generated more residual fluid

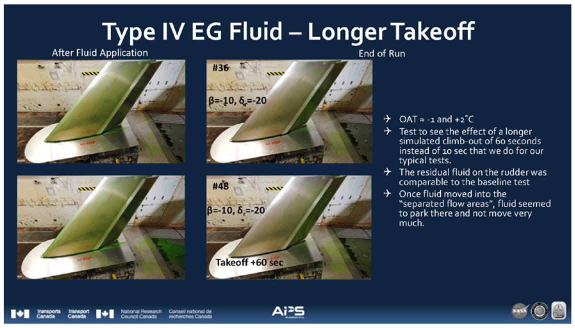

Thickness Data

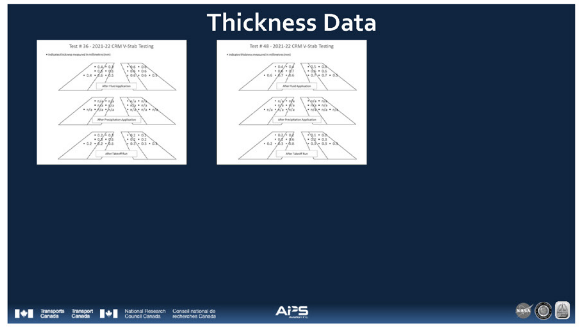

Type IV EG Fluid – Fluid Only on Suction Side
After Fluid Application
End of Run
Fluid only on PORT
#40
β=-10, δr=-20
OAT = +1˚C
When applied only to suction side, no fluid migrated over

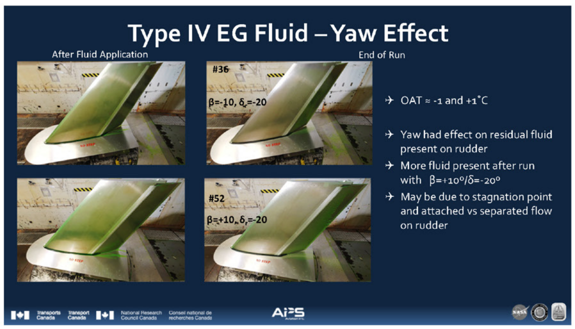

Thickness Data

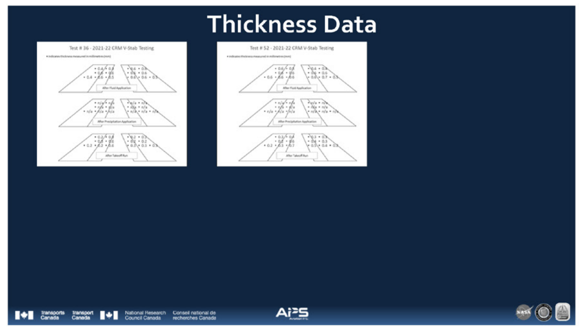

Type IV EG Fluid – 115kts vs 100kts
After Fluid Application
End of Run
#41
β=-10, δr=-20
115kts
#36
β=-10, δr=-20
100kts
#42
β=0, δr=-20
115kts
#17
β=0, δr=-20
100kts
OAT = +1, +1, -1, and -7 ˚C
Remaining fluid appeared to be similar during the 115kts test as compared to the 100kts
– Higher shear forces did not result in more fluid removal

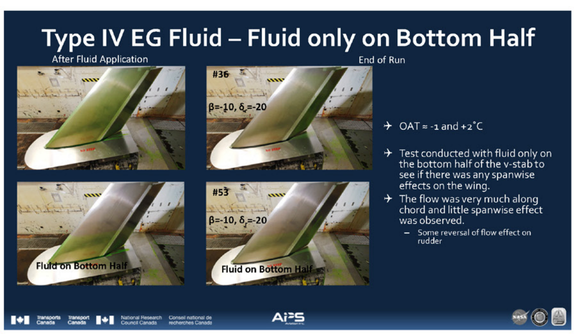

Thickness Data

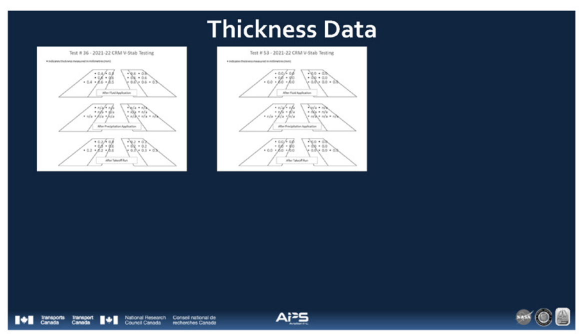

Type IV EG Fluid – Longer Takeoff
After Fluid Application
End of Run
#36
β=-10, δr=-20
#48
β=-10, δr=-20
Takeoff +60 sec
OAT ≈ -1 and +2˚C
Test to see the effect of a longer simulated climb-out of 60 seconds instead of 10 sec that we do for our typical tests.
The residual fluid on the rudder was comparable to the baseline test
Once fluid moved into the "separated flow areas", fluid seemed to park there and not move very much.
Transports Canada Transport Canada
National Research Council Canada Conseil national de recherches Canada


Thickness Data


Type IV EG Fluid – Yaw Effect
After Fluid Application
End of Run
#36
β=-10, δr=-20
#52
β=+10, δr=-20
OAT ≈ -1 and +1˚C
Yaw had effect on residual fluid present on rudder
More fluid present after run with β=+10º/δ=-20º
May be due to stagnation point and attached vs separated flow on rudder
Transports Canada Transport Canada
National Research Council Canada Conseil national de recherches Canada


Thickness Data


Type IV EG Fluid – Fluid only on Bottom Half
After Fluid Application
End of Run
#36
β=-10, δr=-20
#53
β=-10, δr=-20
Fluid on Bottom Half
Fluid on Bottom Half
OAT ≈ -1 and +2˚C
Test conducted with fluid only on the bottom half of the v-stab to see if there was any spanwise effects on the wing.
The flow was very much along chord and little spanwise effect was observed.
– Some reversal of flow effect on rudder
Transports Canada Transport Canada
National Research Council Canada Conseil national de recherches Canada


Thickness Data

Summary of Results

Summary of Results

- The dry wing flow characterization indicated separation beginning at the 0° side slip and -12° rudder deflection
- 0° side slip and -10° rudder deflection (the limit where flow remained attached) were selected as the standard test protocol parameters
- Some amount of fluid and contamination was always present at the end of each test run
- The amount of residual increased or decreased based on the severity of the condition tested
  - side slip and rudder deflection
  - Level of contamination
  - Temperature
  - Type of fluid
  - etc.

Summary of Results (cont'd)

- In snow conditions, failed fluid (slushy) had poor flow off
- In contrast, fluid that was not failed (either clean, or limited amounts of contamination) cleaned off better
- Vertical surface resulted in premature fluid failure due to gravity pulling fluid down and causing thinner protection layer
  - Well documented in previous research as well
- Freezing rain results were worse as compared to snow due to adhered contamination

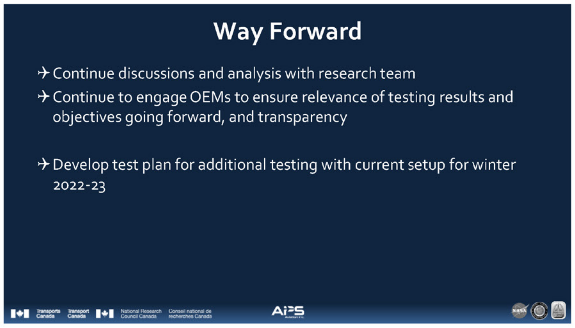
Summary of Results (cont'd)

- The dynamic test profiles (i.e. OEI simulations) generally seemed better as compared to the static configurations
  - The interpretation needs to be studied for impact on guidance
- The test campaign confirmed the desired performance of the new model and helped in the understanding the effects of sideslip and rudder deflection on pristine fluid flow off
- The tests conducted showed that the V-Stab CRM is a representative model for continued evaluation of ground icing situations

Future Considerations

- Explore asymmetric fluid/contamination scenarios
  - to be done in future
- Balances to be included in future tests to measure aerodynamic forces and moments
  - however interpretation and applicability of data can be complex
- More detailed photography/photogrammetry to support interpretation of results and potential implications for aerodynamic effects
- Painting the model to better identify ice and slush

Way Forward

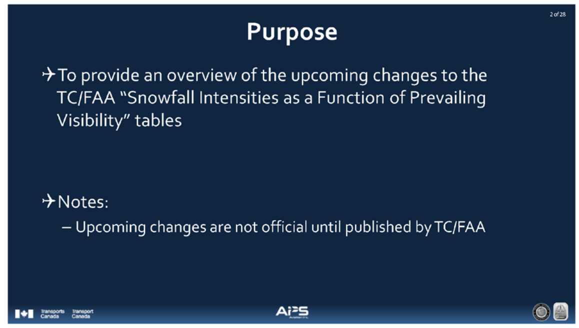

Way Forward
✈ Continue discussions and analysis with research team
✈ Continue to engage OEMs to ensure relevance of testing results and objectives going forward, and transparency
✈ Develop test plan for additional testing with current setup for winter 2022-23
APS

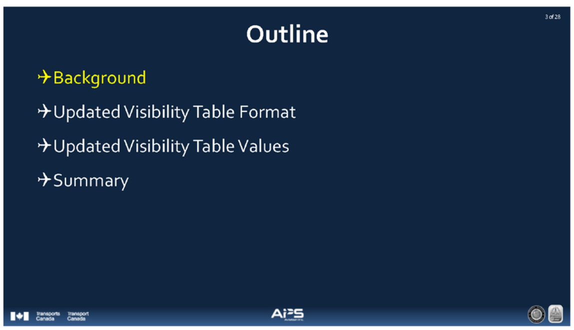

CAUTION
APS
Aviation Inc.
Marco Ruggi
mruggi@apsaviation.ca

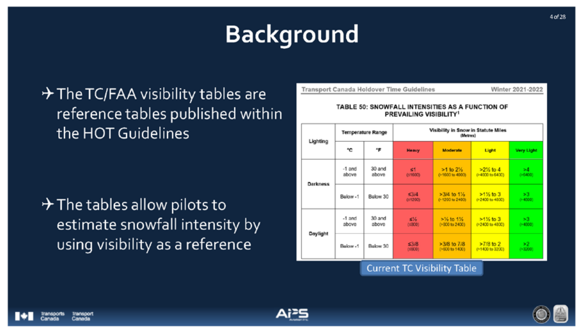
SAE G-12 HOLDOVER TIME COMMITTEE, ONLINE (VIA WEBEX), MAY 2022

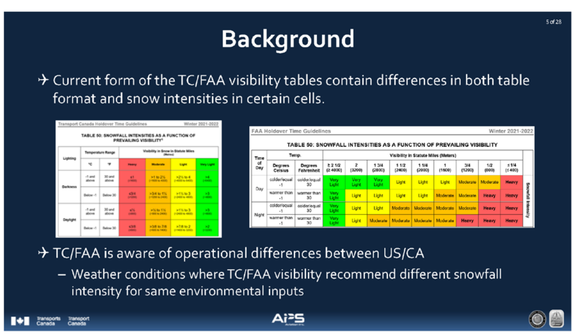
PRESENTATION:
UPCOMING CHANGES TO THE TC/FAA VISIBILITY TABLES (PRESENTED JOINTLY WITH TC AND THE FAA)

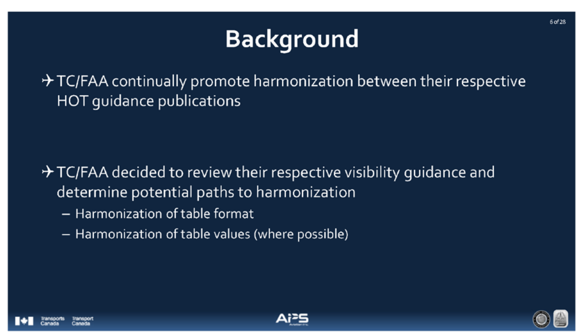

Joint research led and conducted by:
Transports Canada
Transport Canada
AIPS Aviation Inc.
UPCOMING CHANGES TO THE
TC/FAA VISIBILITY TABLES
SAE 12 Holdover Time Committee, Webex, May 17, 2022
Presented by: Benjamin Bernier, Yvan Chabot, Chuck Enders

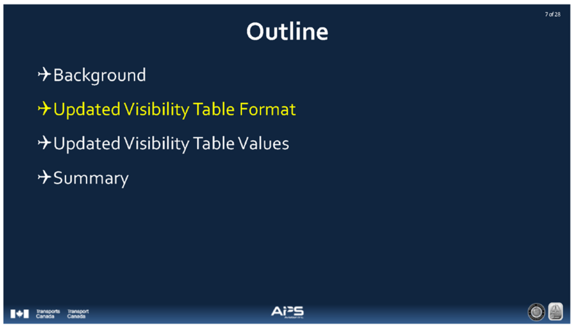

2 of 28
Purpose
To provide an overview of the upcoming changes to the TC/FAA "Snowfall Intensities as a Function of Prevailing Visibility" tables
Notes:
– Upcoming changes are not official until published by TC/FAA

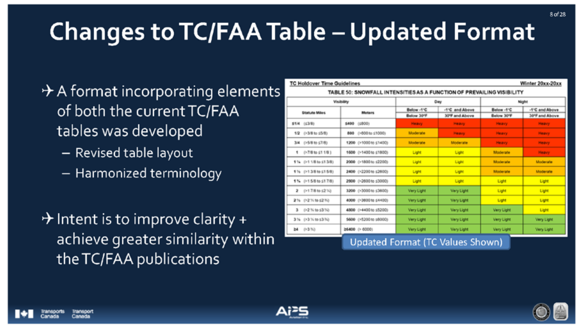

3 of 28
Outline
Background
Updated Visibility Table Format
Updated Visibility Table Values
Summary

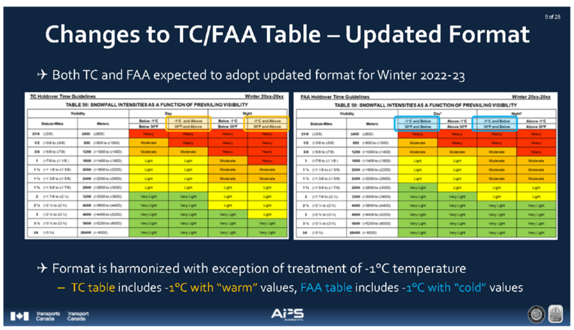

4 of 28
Background
The TC/FAA visibility tables are reference tables published within the HOT Guidelines
The tables allow pilots to estimate snowfall intensity by using visibility as a reference
Transport Canada Holdover Time Guidelines
Winter 2021-2022
TABLE 50: SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY
Current TC Visibility Table

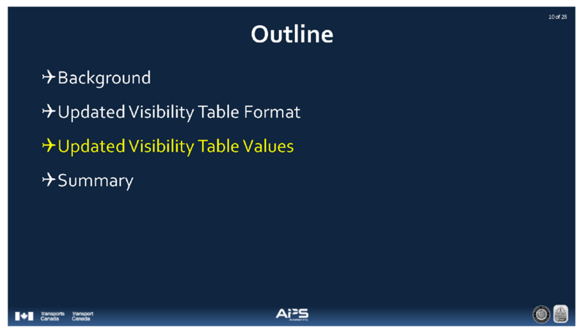

5 of 28
Background
Current form of the TC/FAA visibility tables contain differences in both table format and snow intensities in certain cells.
TC/FAA is aware of operational differences between US/CA
– Weather conditions where TC/FAA visibility recommend different snowfall intensity for same environmental inputs

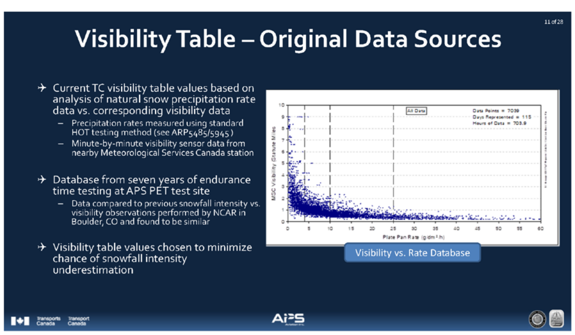

6 of 28
Background
TC/FAA continually promote harmonization between their respective HOT guidance publications
TC/FAA decided to review their respective visibility guidance and determine potential paths to harmonization
– Harmonization of table format
– Harmonization of table values (where possible)

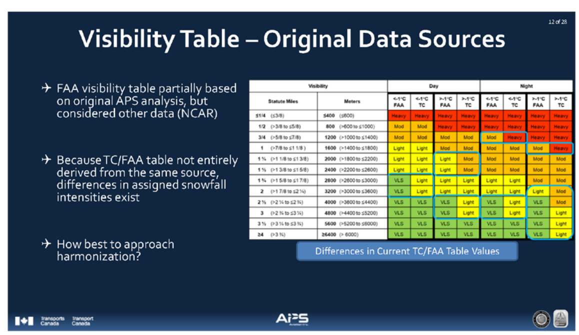

7 of 28
Outline
Background
Updated Visibility Table Format
Updated Visibility Table Values
Summary
APS

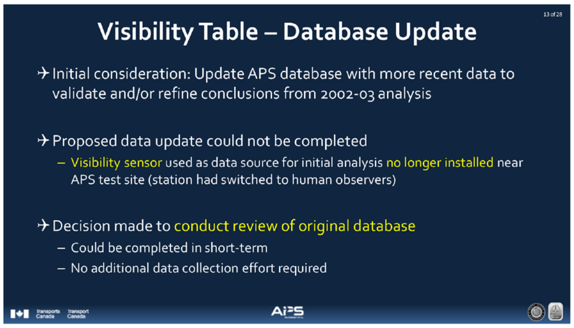

8 of 28
Changes to TC/FAA Table – Updated Format
A format incorporating elements of both the current TC/FAA tables was developed
– Revised table layout
– Harmonized terminology
Intent is to improve clarity + achieve greater similarity within the TC/FAA publications
Updated Format (TC Values Shown)
APS

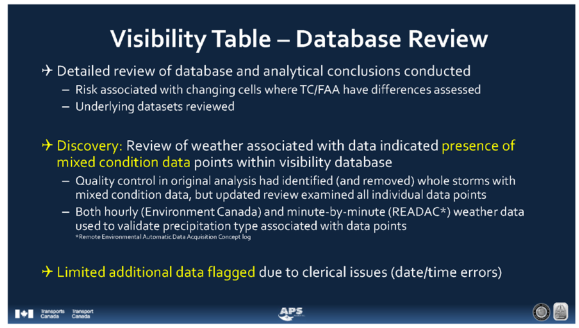

9 of 28
Changes to TC/FAA Table – Updated Format
Both TC and FAA expected to adopt updated format for Winter 2022-23
Format is harmonized with exception of treatment of -1°C temperature
– TC table includes -1°C with "warm" values, FAA table includes -1°C with "cold" values
APS

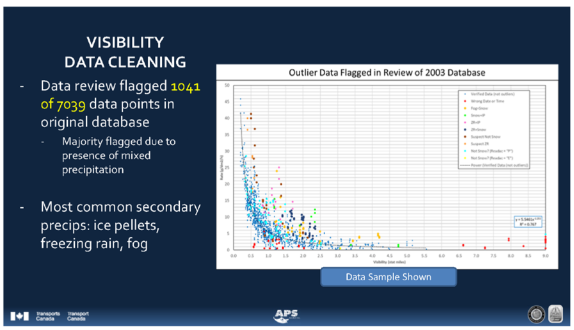

10 of 28
Outline
Background
Updated Visibility Table Format
Updated Visibility Table Values
Summary
APS

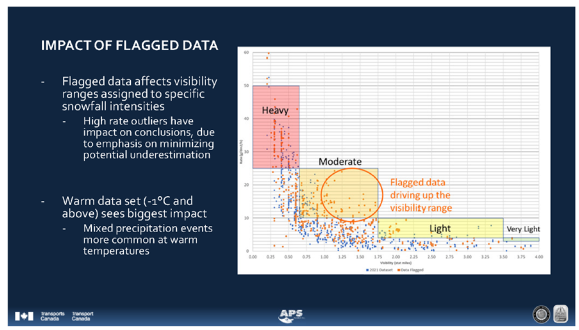

11 of 28
Visibility Table – Original Data Sources
Current TC visibility table values based on analysis of natural snow precipitation rate data vs. corresponding visibility data
– Precipitation rates measured using standard HOT testing method (see ARP5485/5945)
– Minute-by-minute visibility sensor data from nearby Meteorological Services Canada station
Database from seven years of endurance time testing at APS PET test site
– Data compared to previous snowfall intensity vs. visibility observations performed by NCAR in Boulder, CO and found to be similar
Visibility table values chosen to minimize chance of snowfall intensity underestimation
Visibility vs. Rate Database
APS

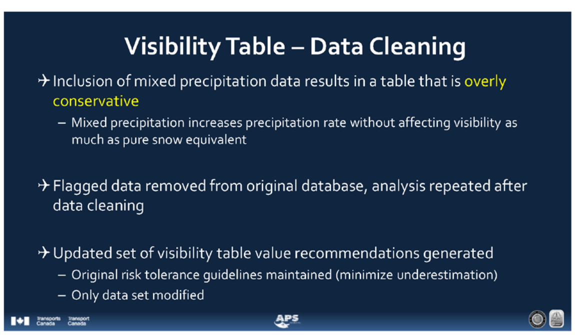

12 of 28
Visibility Table – Original Data Sources
FAA visibility table partially based on original APS analysis, but considered other data (NCAR)
Because TC/FAA table not entirely derived from the same source, differences in assigned snowfall intensities exist
How best to approach harmonization?
Differences in Current TC/FAA Table Values
APS

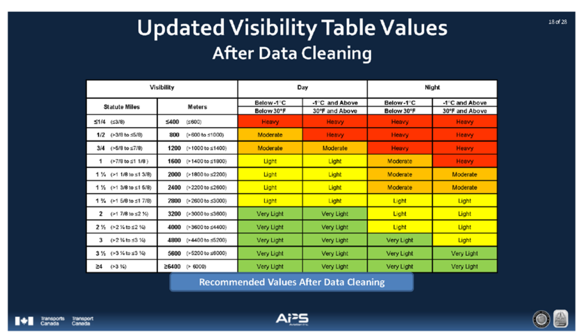




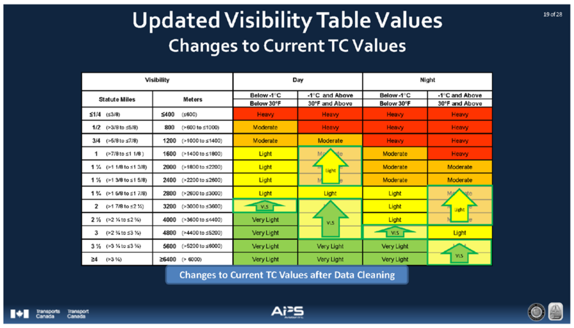


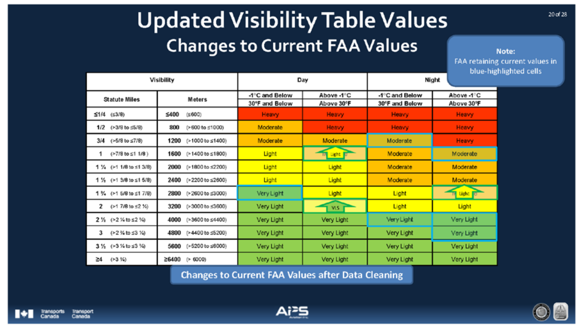


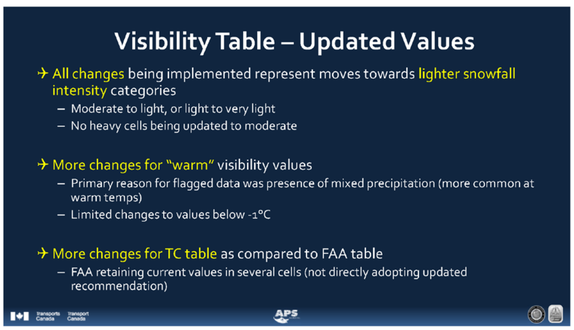


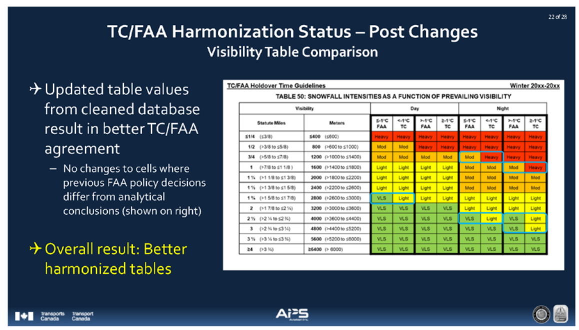


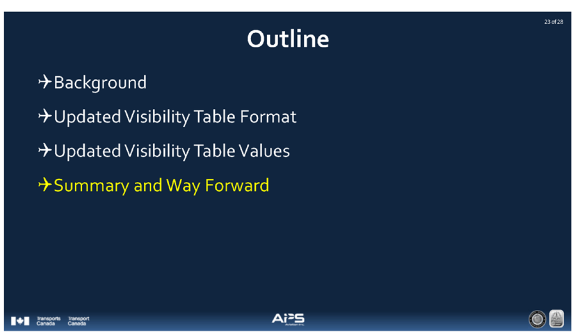
Visibility		Day		Night	
Statute Miles	Meters	Below -1°C Below 30°F	-1°C and Above 30°F and Above	Below -1°C Below 30°F	-1°C and Above 30°F and Above
≤1/4 (≤3/8)	≤400 (≤600)	Heavy	Heavy	Heavy	Heavy
1/2 (>3/8 to ≤5/8)	800 (>600 to ≤1000)	Moderate	Heavy	Heavy	Heavy
3/4 (>5/8 to ≤7/8)	1200 (>1000 to ≤1400)	Moderate	Moderate	Heavy	Heavy
1 (>7/8 to ≤1 1/8)	1600 (>1400 to ≤1800)	Light	Light	Moderate	Heavy
1 ¼ (>1 1/8 to ≤1 3/8)	2000 (>1800 to ≤2200)	Light	Light	Moderate	Moderate
1 ½ (>1 3/8 to ≤1 5/8)	2400 (>2200 to ≤2600)	Light	Light	Moderate	Moderate
1 ¾ (>1 5/8 to ≤1 7/8)	2800 (>2600 to ≤3000)	Light	Light	Light	Light
2 (>1 7/8 to ≤2 ¼)	3200 (>3000 to ≤3600)	Very Light	Very Light	Light	Light
2 ½ (>2 ¼ to ≤2 ¾)	4000 (>3600 to ≤4400)	Very Light	Very Light	Light	Light
3 (>2 ¾ to ≤3 ¼)	4800 (>4400 to ≤5200)	Very Light	Very Light	Very Light	Light
3 ½ (>3 ¼ to ≤3 ¾)	5600 (>5200 to ≤6000)	Very Light	Very Light	Very Light	Very Light
≥4 (>3 ¾)	≥6400 (> 6000)	Very Light	Very Light	Very Light	Very Light

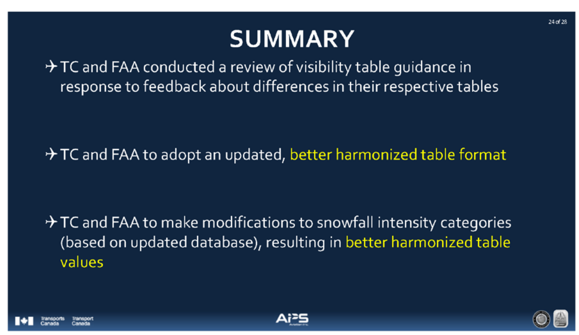

Updated Visibility Table Values
Changes to Current TC Values
19 of 28
Changes to Current TC Values after Data Cleaning

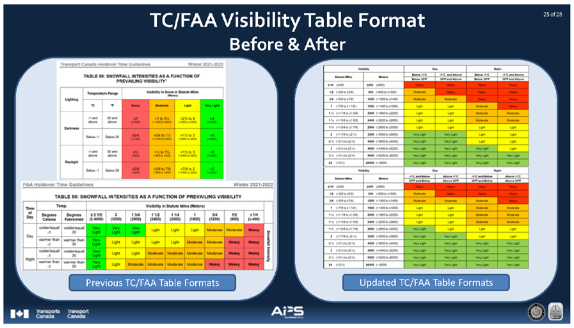

Updated Visibility Table Values
Changes to Current FAA Values
20 of 28
Note:
FAA retaining current values in blue-highlighted cells
Changes to Current FAA Values after Data Cleaning


Visibility Table – Updated Values
All changes being implemented represent moves towards lighter snowfall intensity categories
– Moderate to light, or light to very light
– No heavy cells being updated to moderate
More changes for "warm" visibility values
– Primary reason for flagged data was presence of mixed precipitation (more common at warm temps)
– Limited changes to values below -1°C
More changes for TC table as compared to FAA table
– FAA retaining current values in several cells (not directly adopting updated recommendation)

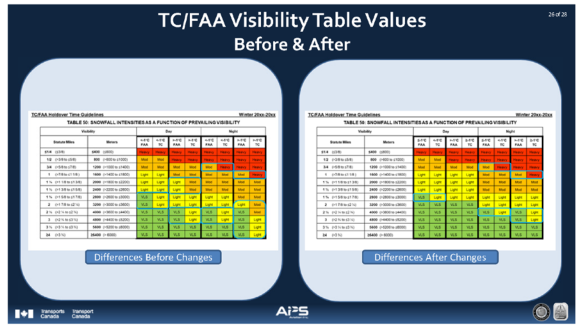

TC/FAA Harmonization Status – Post Changes
Visibility Table Comparison
22 of 28
Updated table values from cleaned database result in better TC/FAA agreement
– No changes to cells where previous FAA policy decisions differ from analytical conclusions (shown on right)
Overall result: Better harmonized tables


Outline
23 of 28
Background
Updated Visibility Table Format
Updated Visibility Table Values
Summary and Way Forward

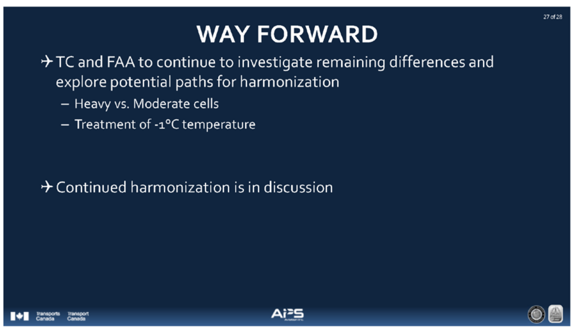

SUMMARY
24 of 28
TC and FAA conducted a review of visibility table guidance in response to feedback about differences in their respective tables
TC and FAA to adopt an updated, better harmonized table format
TC and FAA to make modifications to snowfall intensity categories (based on updated database), resulting in better harmonized table values



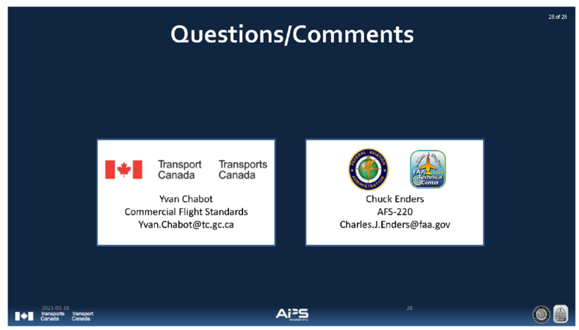
TC/FAA Visibility Table Format
Before & After
25 of 28
Previous TC/FAA Table Formats
Updated TC/FAA Table Formats



TC/FAA Visibility Table Values
Before & After
26 of 28
Differences Before Changes
Differences After Changes



WAY FORWARD
27 of 28
TC and FAA to continue to investigate remaining differences and explore potential paths for harmonization
– Heavy vs. Moderate cells
– Treatment of -1°C temperature
Continued harmonization is in discussion



Questions/Comments
28 of 28
Transport Canada Transports Canada
Yvan Chabot
Commercial Flight Standards
Yvan.Chabot@tc.gc.ca
Chuck Enders
AFS-220
Charles.J.Enders@faa.gov

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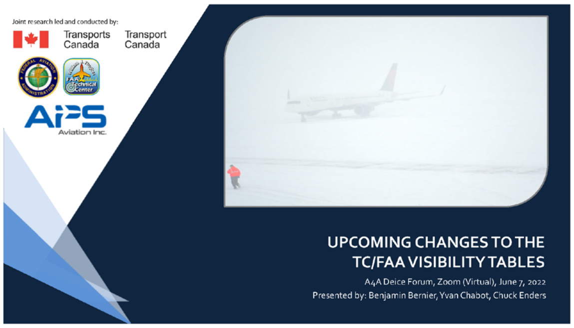
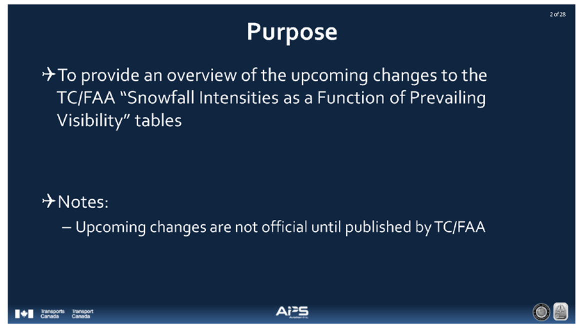
AIRLINES FOR AMERICA (A4A) GROUND DEICING FORUM, ONLINE (VIA ZOOM), JUNE 2022

PRESENTATION:
UPCOMING CHANGES TO THE TC/FAA VISIBILITY TABLES
(PRESENTED JOINTLY WITH TC AND THE FAA)


Joint research led and conducted by:
Transports Canada
Transport Canada
AiPS Aviation Inc.
UPCOMING CHANGES TO THE TC/FAA VISIBILITY TABLES
A4A Deice Forum, Zoom (Virtual), June 7, 2022
Presented by: Benjamin Bernier, Yvan Chabot, Chuck Enders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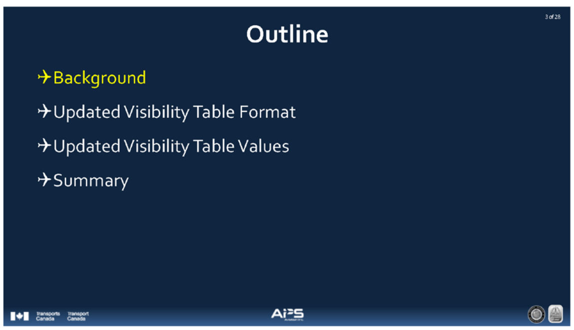
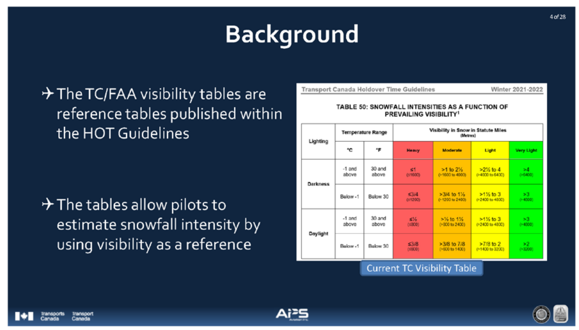
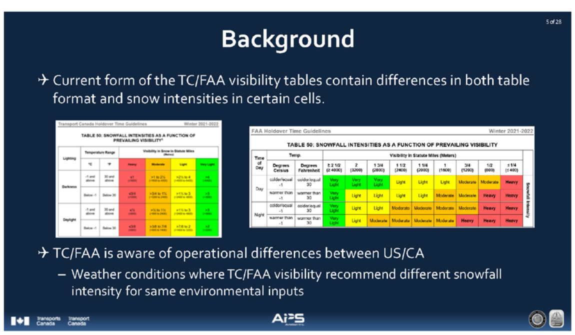
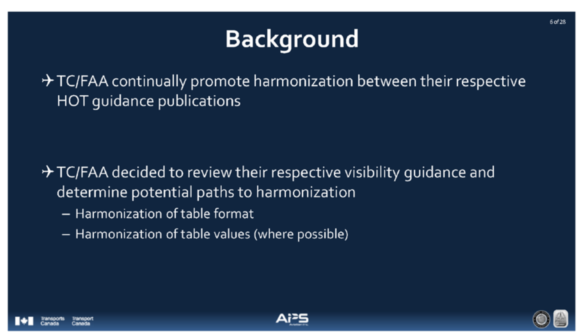
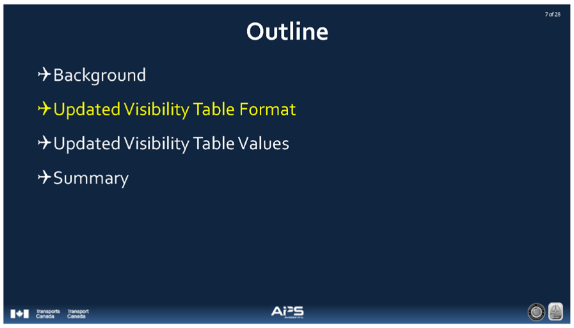
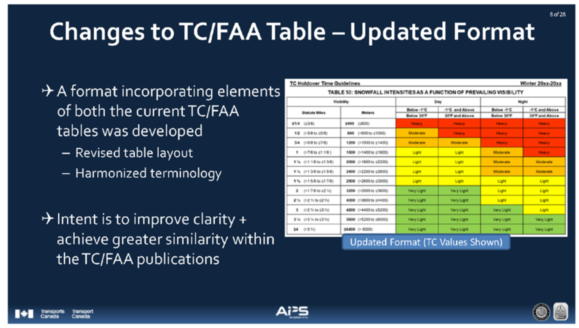

Outline
Background
Updated Visibility Table Format
Updated Visibility Table Values
Summary

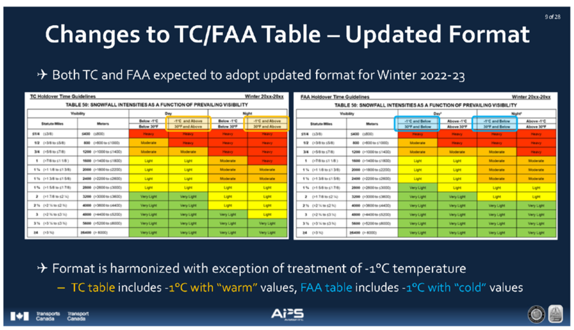

Background
The TC/FAA visibility tables are reference tables published within the HOT Guidelines
The tables allow pilots to estimate snowfall intensity by using visibility as a reference
Transport Canada Holdover Time Guidelines
Winter 2021-2022
TABLE 50: SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY
Current TC Visibility Table

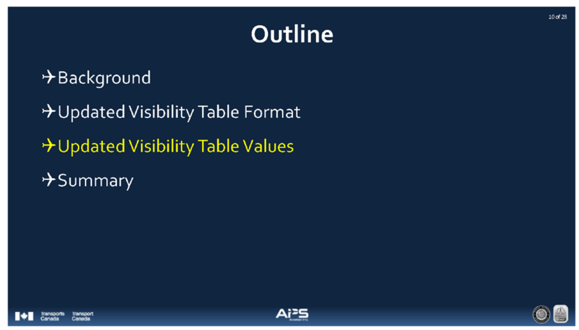

Background
Current form of the TC/FAA visibility tables contain differences in both table format and snow intensities in certain cells.
FAA Holdover Time Guidelines
Winter 2021-2022
TABLE 50. SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY
TC/FAA is aware of operational differences between US/CA
– Weather conditions where TC/FAA visibility recommend different snowfall intensity for same environmental inputs

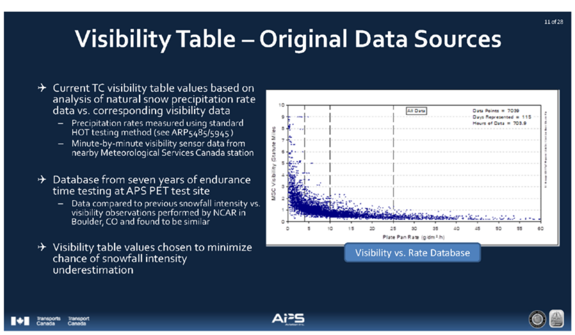

Background
TC/FAA continually promote harmonization between their respective HOT guidance publications
TC/FAA decided to review their respective visibility guidance and determine potential paths to harmonization
– Harmonization of table format
– Harmonization of table values (where possible)

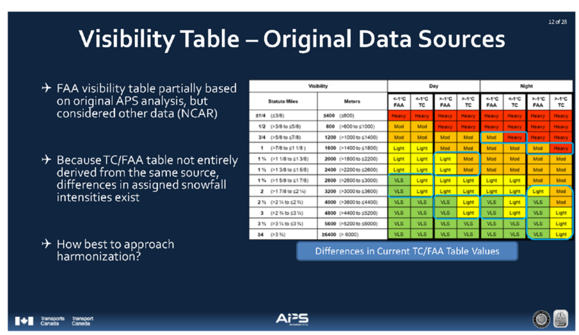

Outline
Background
Updated Visibility Table Format
Updated Visibility Table Values
Summary

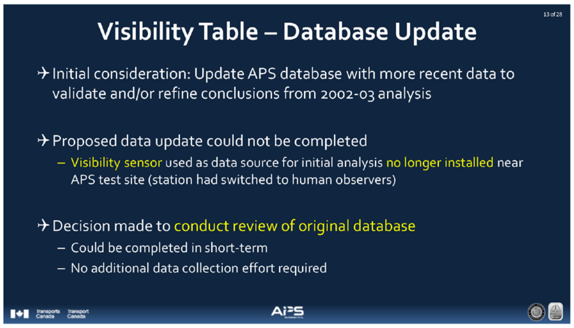

Changes to TC/FAA Table – Updated Format
A format incorporating elements of both the current TC/FAA tables was developed
– Revised table layout
– Harmonized terminology
Intent is to improve clarity + achieve greater similarity within the TC/FAA publications
Updated Format (TC Values Shown)

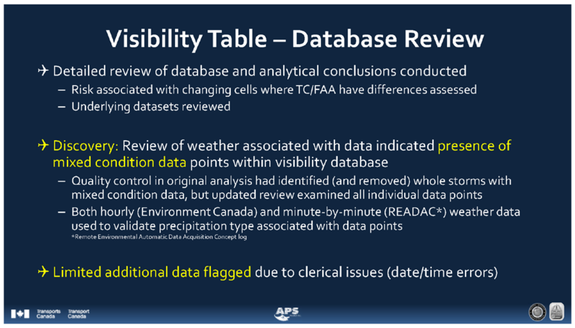

Changes to TC/FAA Table – Updated Format
Both TC and FAA expected to adopt updated format for Winter 2022-23
Format is harmonized with exception of treatment of -1°C temperature
– TC table includes -1°C with "warm" values, FAA table includes -1°C with "cold" values

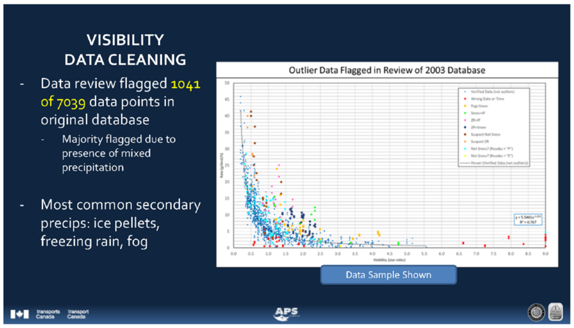

Outline
Background
Updated Visibility Table Format
Updated Visibility Table Values
Summary

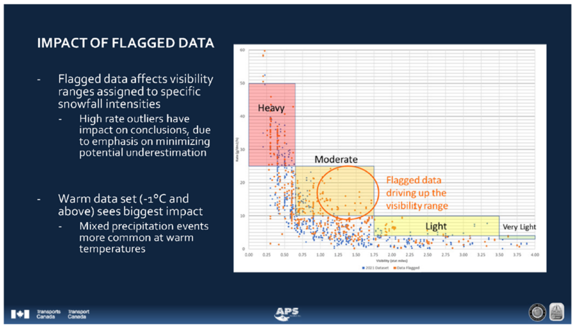

Visibility Table – Original Data Sources
Current TC visibility table values based on analysis of natural snow precipitation rate data vs. corresponding visibility data
– Precipitation rates measured using standard HOT testing method (see ARP5485/5945)
– Minute-by-minute visibility sensor data from nearby Meteorological Services Canada station
Database from seven years of endurance time testing at APS PET test site
– Data compared to previous snowfall intensity vs. visibility observations performed by NCAR in Boulder, CO and found to be similar
Visibility table values chosen to minimize chance of snowfall intensity underestimation
Visibility vs. Rate Database

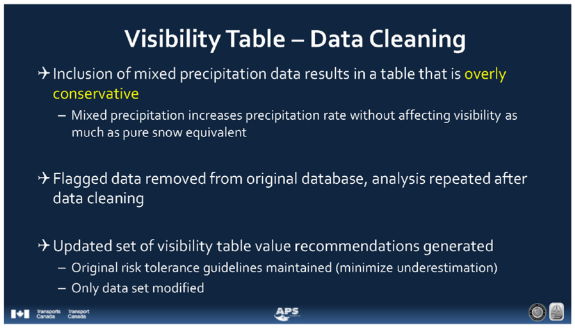

Visibility Table – Original Data Sources
FAA visibility table partially based on original APS analysis, but considered other data (NCAR)
Because TC/FAA table not entirely derived from the same source, differences in assigned snowfall intensities exist
How best to approach harmonization?
Differences in Current TC/FAA Table Values

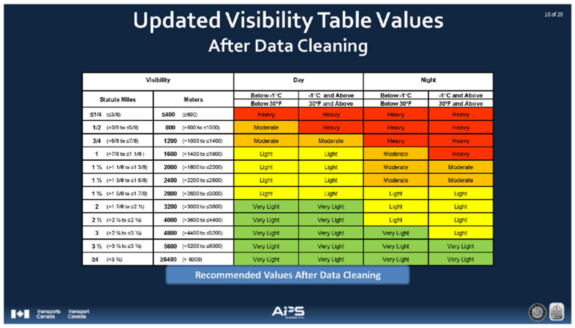




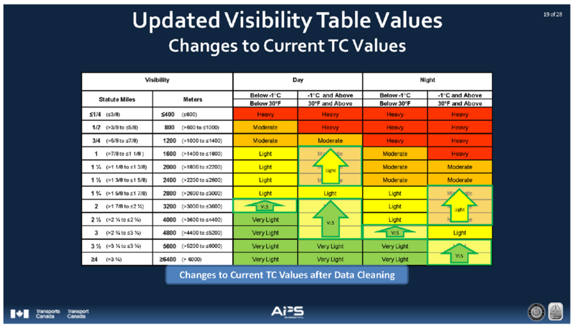


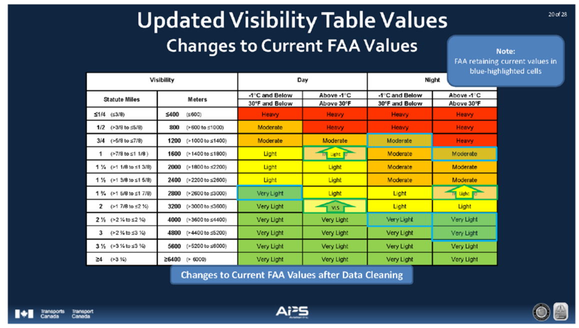


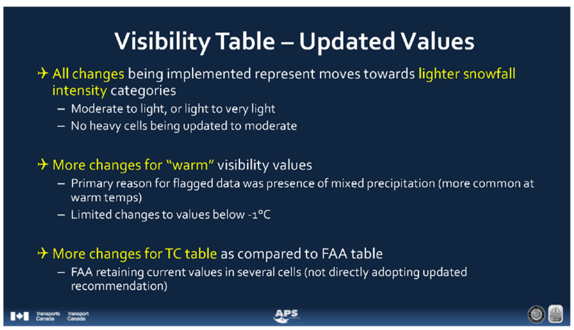


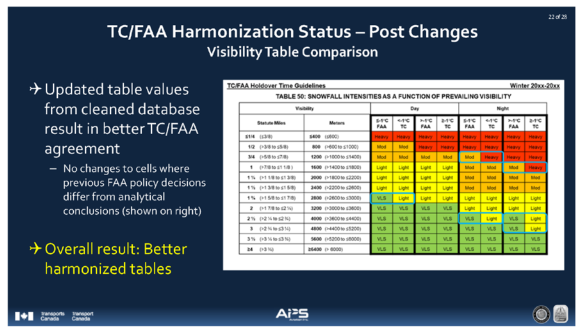


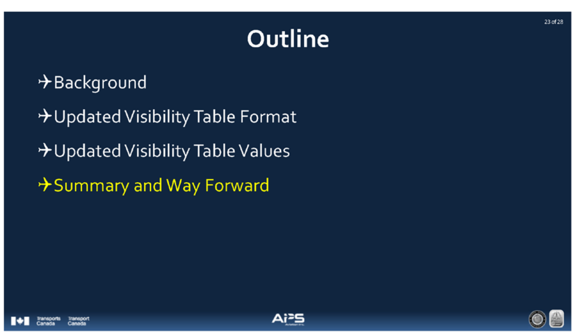
Visibility		Day		Night	
Statute Miles	Meters	Below -1°C Below 30°F	-1°C and Above 30°F and Above	Below -1°C Below 30°F	-1°C and Above 30°F and Above
≤1/4 (≤3/8)	≤400 (≤600)	Heavy	Heavy	Heavy	Heavy
1/2 (>3/8 to ≤5/8)	800 (>600 to ≤1000)	Moderate	Heavy	Heavy	Heavy
3/4 (>5/8 to ≤7/8)	1200 (>1000 to ≤1400)	Moderate	Moderate	Heavy	Heavy
1 (>7/8 to ≤1 1/8)	1600 (>1400 to ≤1800)	Light	Light	Moderate	Heavy
1 ¼ (>1 1/8 to ≤1 3/8)	2000 (>1800 to ≤2200)	Light	Light	Moderate	Moderate
1 ½ (>1 3/8 to ≤1 5/8)	2400 (>2200 to ≤2600)	Light	Light	Moderate	Moderate
1 ¾ (>1 5/8 to ≤1 7/8)	2800 (>2600 to ≤3000)	Light	Light	Light	Light
2 (>1 7/8 to ≤2 ¼)	3200 (>3000 to ≤3600)	Very Light	Very Light	Light	Light
2 ½ (>2 ¼ to ≤2 ¾)	4000 (>3600 to ≤4400)	Very Light	Very Light	Light	Light
3 (>2 ¾ to ≤3 ¼)	4800 (>4400 to ≤5200)	Very Light	Very Light	Very Light	Light
3 ½ (>3 ¼ to ≤3 ¾)	5600 (>5200 to ≤6000)	Very Light	Very Light	Very Light	Very Light
≥4 (>3 ¾)	≥6400 (> 6000)	Very Light	Very Light	Very Light	Very Light

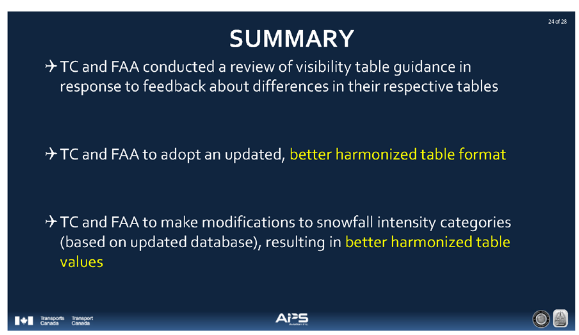

Updated Visibility Table Values
Changes to Current TC Values
Changes to Current TC Values after Data Cleaning

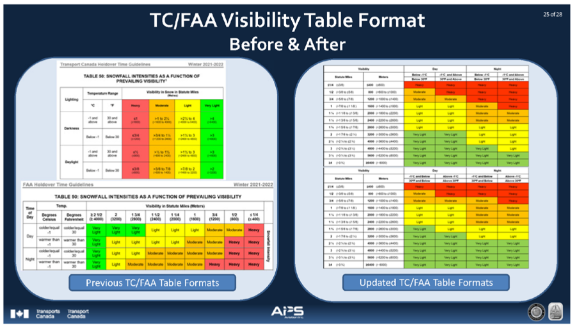

Updated Visibility Table Values
Changes to Current FAA Values
Note:
FAA retaining current values in blue-highlighted cells
Changes to Current FAA Values after Data Cleaning

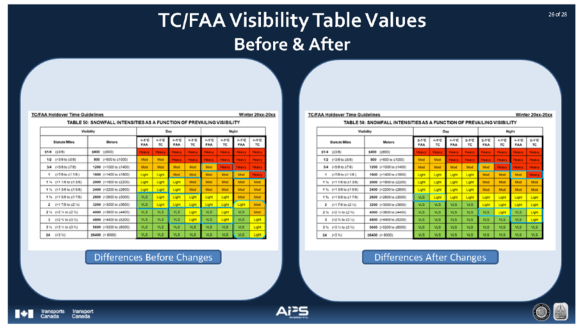

Visibility Table – Updated Values
All changes being implemented represent moves towards lighter snowfall intensity categories
– Moderate to light, or light to very light
– No heavy cells being updated to moderate
More changes for "warm" visibility values
– Primary reason for flagged data was presence of mixed precipitation (more common at warm temps)
– Limited changes to values below -1°C
More changes for TC table as compared to FAA table
– FAA retaining current values in several cells (not directly adopting updated recommendation)

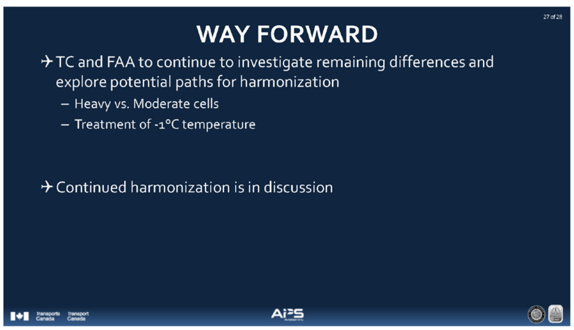

TC/FAA Harmonization Status – Post Changes
Visibility Table Comparison
Updated table values from cleaned database result in better TC/FAA agreement
– No changes to cells where previous FAA policy decisions differ from analytical conclusions (shown on right)
Overall result: Better harmonized tables
TABLE 50: SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY


Outline
Background
Updated Visibility Table Format
Updated Visibility Table Values
Summary and Way Forward


SUMMARY
TC and FAA conducted a review of visibility table guidance in response to feedback about differences in their respective tables
TC and FAA to adopt an updated, better harmonized table format
TC and FAA to make modifications to snowfall intensity categories (based on updated database), resulting in better harmonized table values


TC/FAA Visibility Table Format
Before & After
25 of 28
Previous TC/FAA Table Formats
Updated TC/FAA Table Formats
AiPS


TC/FAA Visibility Table Values
Before & After
26 of 28
Differences Before Changes
Differences After Changes
AiPS


WAY FORWARD
27 of 28
TC and FAA to continue to investigate remaining differences and explore potential paths for harmonization
– Heavy vs. Moderate cells
– Treatment of -1°C temperature
Continued harmonization is in discussion
AiPS


Questions/Comments
28 of 28
Transport Canada Transports Canada
Yvan Chabot
Commercial Flight Standards
Yvan.Chabot@tc.gc.ca
Chuck Enders
AFS-220
Charles.J.Enders@faa.gov
AiPS

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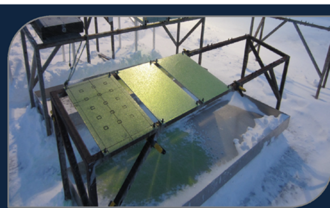
AIRLINES FOR AMERICA (A4A) GROUND DEICING FORUM, ONLINE (VIA ZOOM), JUNE 2022

**PRESENTATION:
WINTER 2021-22 ENDURANCE TIME TESTING UPDATE**

Joint research led by: Transports Canada Transport Canada

Conducted by: APS Aviation Inc.



WINTER 2021-22
ENDURANCE TIME TESTING UPDATE

A4A Deice Forum, Zoom (Virtual), June 7, 2022
Presented by: Benjamin Bernier, APS Aviation

Purpose

- To provide an overview of the new fluids tested for inclusion in the HOT guidelines
- Notes:
  - HOTs and fluid info are not official until published by TC/FAA

Outline

- 2021-22 Testing Overview
- Methodology
- Standard HOT Test Results Summary: 2 Fluids
- Very Cold Snow Test Results Summary: 4 Fluids
- Supplemental HUPR Testing
- Summary

Testing Overview

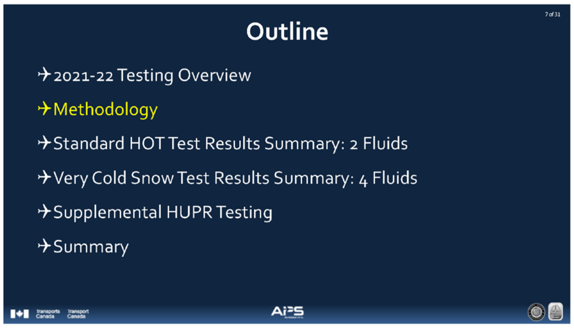
- 633 total endurance time (ET) tests were conducted with fluids submitted in 2021-22
- Two new fluids are expected to be added to the HOT Guidelines for the 2022-23 winter season

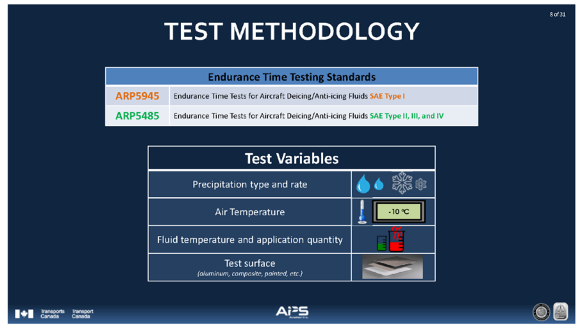
Tests Conducted

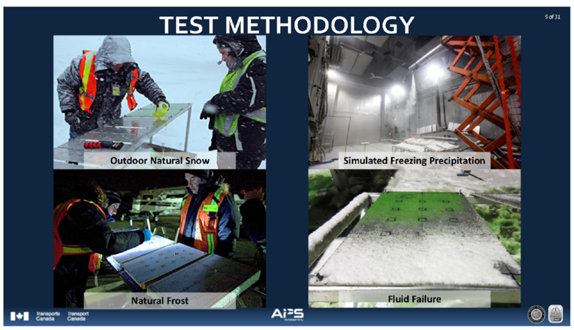
Fluid Type	Fluid Dilution	Natural Snow	Artificial Snow	Freezing Fog	Freezing Drizzle	Light Freezing Rain	Cold-Soak Surface	Frost	Total
Type I	Alum.	0	0	0	0	0	0	0	0
	Comp.	0	0	0	0	0	0	0	0
Type II	100/0	177	16	24	16	16	8	7	264
	75/25	56	0	8	8	8	4	2	86
	50/50	17	0	4	4	4	0	1	30
Type III	100/0	0	0	0	0	0	0	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	190	8	12	8	8	4	23	253
	75/25	0	0	0	0	0	0	0	0
	50/50	0	0	0	0	0	0	0	0
Total		440	24	48	36	36	16	33	633

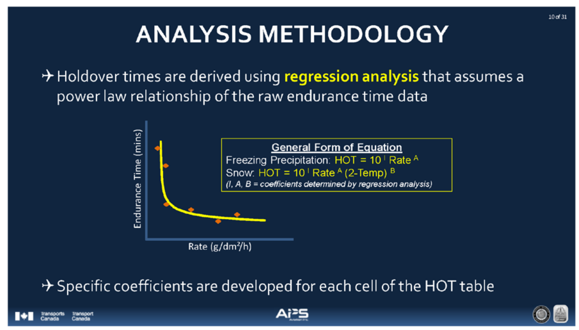
New Fluids

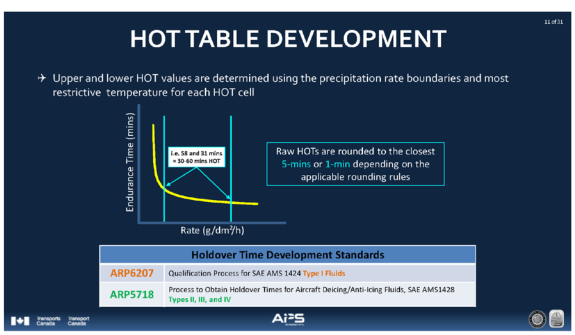
Kilfrost	Type II	Kilfrost Ice Clear II (fluid reformulated)
MKS DevO power of production	Type II	COREICEPHOB TYPE-II

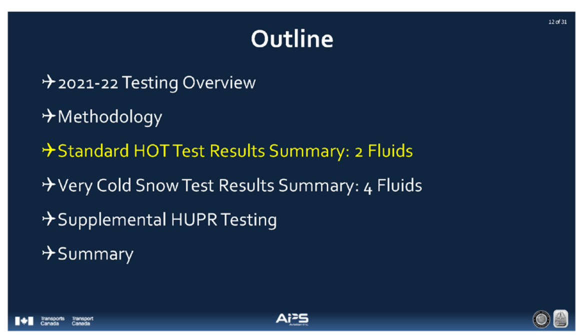

7 of 31
Outline
2021-22 Testing Overview
Methodology
Standard HOT Test Results Summary: 2 Fluids
Very Cold Snow Test Results Summary: 4 Fluids
Supplemental HUPR Testing
Summary
Transport Canada
AiPS

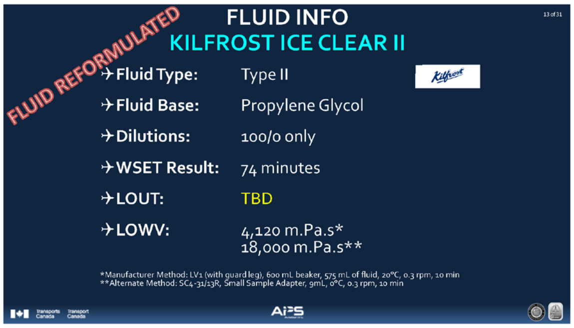

8 of 31
TEST METHODOLOGY
Endurance Time Testing Standards
ARP5945
Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Type I
ARP5485
Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Type II, III, and IV
Test Variables
Precipitation type and rate
Air Temperature
-10 °C
Fluid temperature and application quantity
Test surface
(aluminum, composite, painted, etc.)
Transport Canada
AiPS

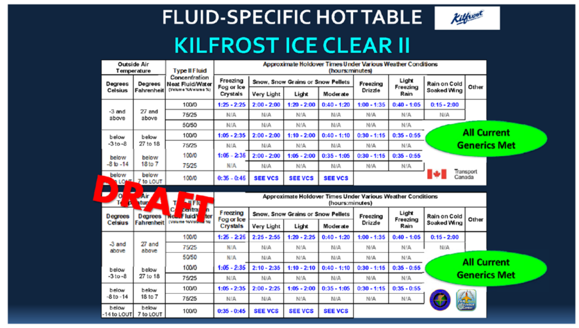

9 of 31
TEST METHODOLOGY
Outdoor Natural Snow
Simulated Freezing Precipitation
Natural Frost
Fluid Failure
Transport Canada
AiPS

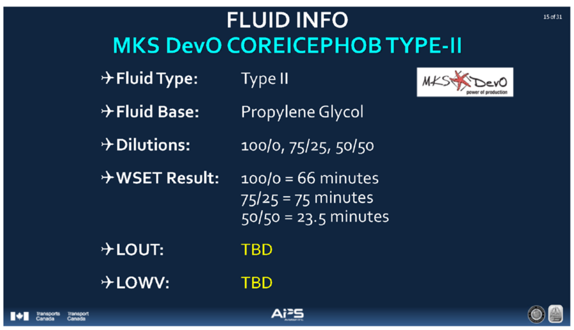

10 of 31
ANALYSIS METHODOLOGY
Holdover times are derived using regression analysis that assumes a power law relationship of the raw endurance time data
Endurance Time (mins)
Rate (g/dm²/h)
General Form of Equation
Freezing Precipitation: HOT = 10 I Rate A
Snow: HOT = 10 I Rate A (2-Temp) B
(I, A, B = coefficients determined by regression analysis)
Specific coefficients are developed for each cell of the HOT table
Transport Canada
AiPS

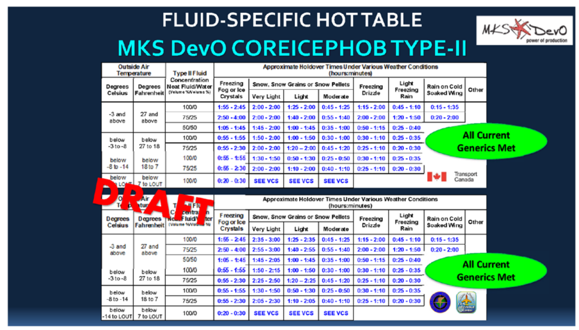

11 of 31
HOT TABLE DEVELOPMENT
Upper and lower HOT values are determined using the precipitation rate boundaries and most restrictive temperature for each HOT cell
Endurance Time (mins)
i.e. 58 and 31 mins = 30-60 mins HOT
Raw HOTs are rounded to the closest 5-mins or 1-min depending on the applicable rounding rules
Rate (g/dm²/h)
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
Transport Canada
AiPS

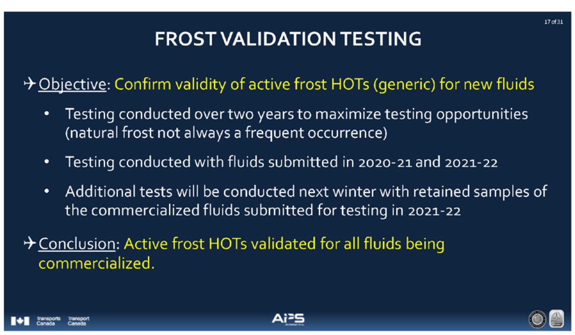

12 of 31
Outline
2021-22 Testing Overview
Methodology
Standard HOT Test Results Summary: 2 Fluids
Very Cold Snow Test Results Summary: 4 Fluids
Supplemental HUPR Testing
Summary
Transport Canada
AiPS

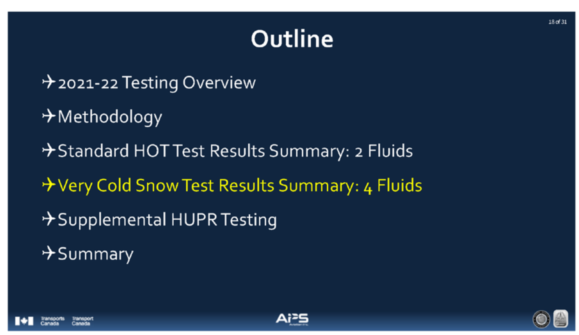

13 of 31
FLUID REFORMULATED
FLUID INFO
KILFROST ICE CLEAR II
Fluid Type: Type II
Fluid Base: Propylene Glycol
Dilutions: 100/0 only
WSET Result: 74 minutes
LOUT: TBD
LOWV: 4,120 m.Pa.s*
18,000 m.Pa.s**
*Manufacturer Method: LV1 (with guard leg), 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
**Alternate Method: SC4-31/13R, Small Sample Adapter, 9mL, 0°C, 0.3 rpm, 10 min
APS

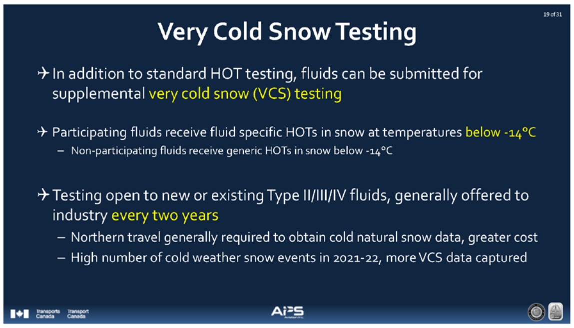

FLUID-SPECIFIC HOT TABLE
KILFROST ICE CLEAR II
DRAFT
All Current Generics Met
All Current Generics Met

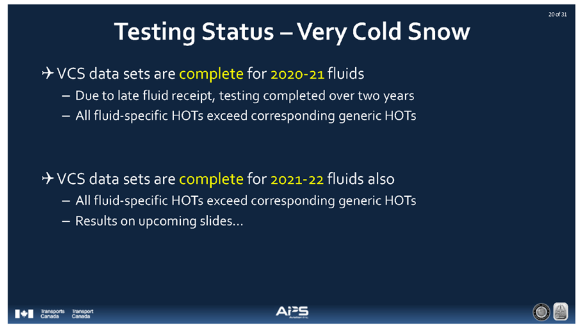

15 of 31
FLUID INFO
MKS DevO COREICEPHOB TYPE-II
Fluid Type: Type II
Fluid Base: Propylene Glycol
Dilutions: 100/0, 75/25, 50/50
WSET Result: 100/0 = 66 minutes
75/25 = 75 minutes
50/50 = 23.5 minutes
LOUT: TBD
LOWV: TBD
APS

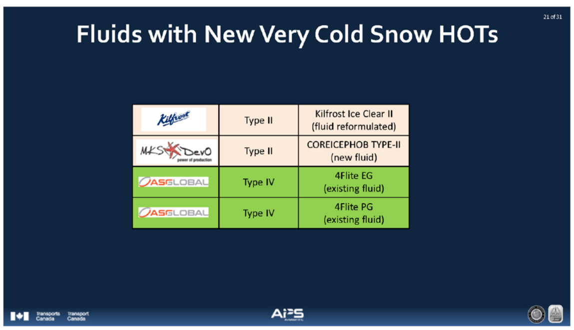

FLUID-SPECIFIC HOT TABLE
MKS DevO COREICEPHOB TYPE-II
DRAFT
All Current Generics Met
All Current Generics Met


17 of 31
FROST VALIDATION TESTING
Objective: Confirm validity of active frost HOTs (generic) for new fluids
Testing conducted over two years to maximize testing opportunities (natural frost not always a frequent occurrence)
Testing conducted with fluids submitted in 2020-21 and 2021-22
Additional tests will be conducted next winter with retained samples of the commercialized fluids submitted for testing in 2021-22
Conclusion: Active frost HOTs validated for all fluids being commercialized.
APS

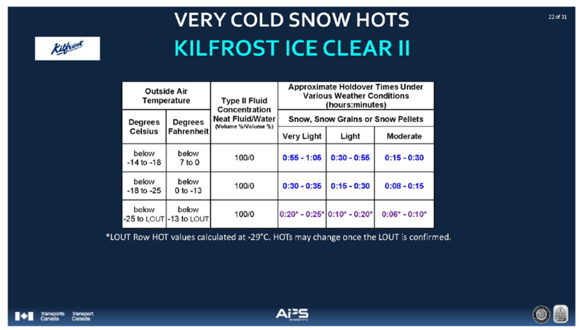

18 of 31
Outline
2021-22 Testing Overview
Methodology
Standard HOT Test Results Summary: 2 Fluids
Very Cold Snow Test Results Summary: 4 Fluids
Supplemental HUPR Testing
Summary
APS



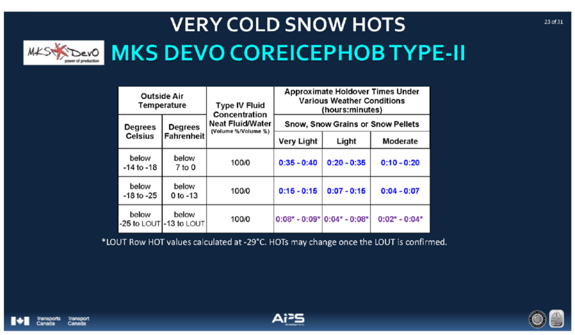




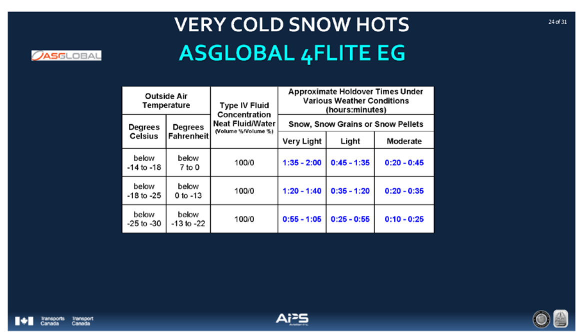
Kilfrost	Type II	Kilfrost Ice Clear II (fluid reformulated)
MKS DevO	Type II	COREICEPHOB TYPE-II (new fluid)
ASGLOBAL	Type IV	4Flite EG (existing fluid)
ASGLOBAL	Type IV	4Flite PG (existing fluid)



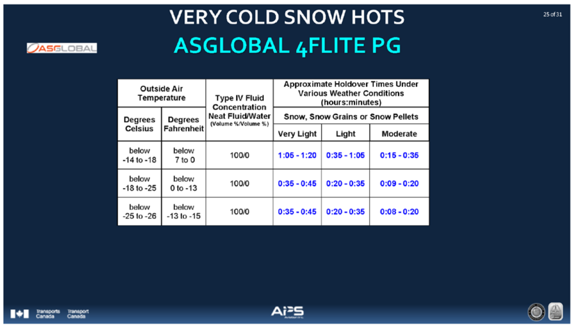
Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	0:55 - 1:05	0:30 - 0:55	0:15 - 0:30
below -18 to -25	below 0 to -13	100/0	0:30 - 0:35	0:15 - 0:30	0:08 - 0:15
below -25 to LOUT	below -13 to LOUT	100/0	0:20* - 0:25*	0:10* - 0:20*	0:06* - 0:10*



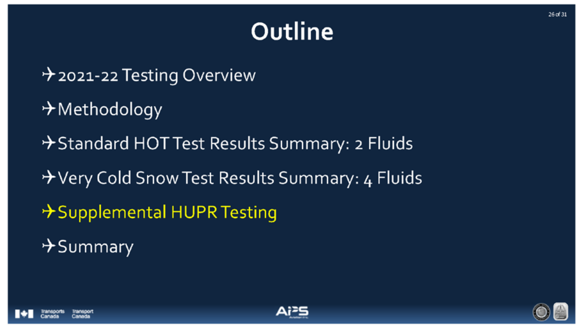
Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	0:35 - 0:40	0:20 - 0:35	0:10 - 0:20
below -18 to -25	below 0 to -13	100/0	0:15 - 0:15	0:07 - 0:15	0:04 - 0:07
below -25 to LOUT	below -13 to LOUT	100/0	0:08* - 0:09*	0:04* - 0:08*	0:02* - 0:04*

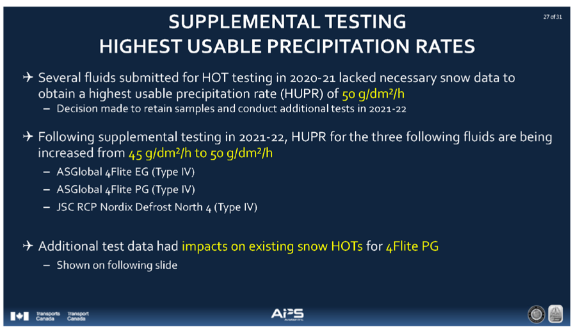


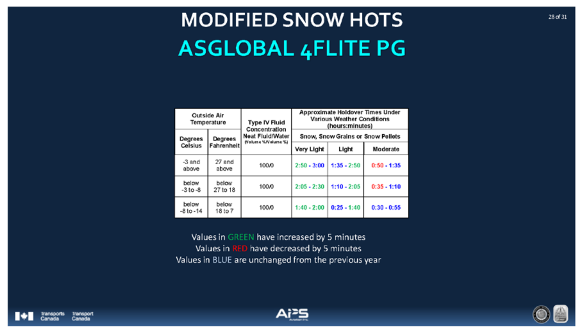
Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)		
			Snow, Snow Grains or Snow Pellets		
Degrees Celsius	Degrees Fahrenheit		Very Light	Light	Moderate
below -14 to -18	below 7 to 0	100/0	1:35 - 2:00	0:45 - 1:35	0:20 - 0:45
below -18 to -25	below 0 to -13	100/0	1:20 - 1:40	0:35 - 1:20	0:20 - 0:35
below -25 to -30	below -13 to -22	100/0	0:55 - 1:05	0:25 - 0:55	0:10 - 0:25


25 of 31
VERY COLD SNOW HOTS
ASGLOBAL 4FLITE 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	1:05 - 1:20	0:35 - 1:05	0:15 - 0:35
below -18 to -25	below 0 to -13	100/0	0:35 - 0:45	0:20 - 0:35	0:09 - 0:20
below -25 to -26	below -13 to -15	100/0	0:35 - 0:45	0:20 - 0:35	0:08 - 0:20

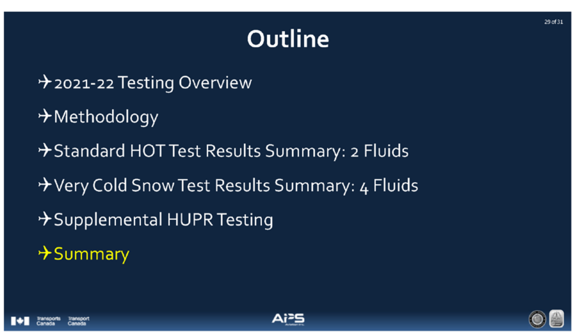

26 of 31
Outline
2021-22 Testing Overview
Methodology
Standard HOT Test Results Summary: 2 Fluids
Very Cold Snow Test Results Summary: 4 Fluids
Supplemental HUPR Testing
Summary

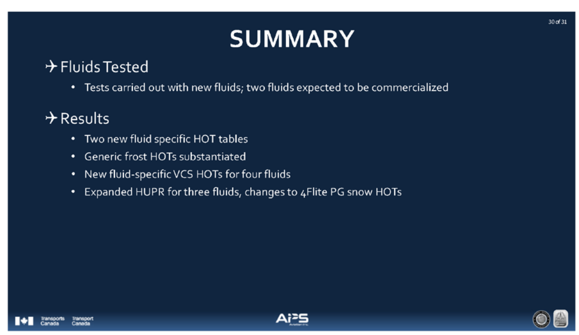

27 of 31
SUPPLEMENTAL TESTING
HIGHEST USABLE PRECIPITATION RATES
Several fluids submitted for HOT testing in 2020-21 lacked necessary snow data to obtain a highest usable precipitation rate (HUPR) of 50 g/dm²/h
– Decision made to retain samples and conduct additional tests in 2021-22
Following supplemental testing in 2021-22, HUPR for the three following fluids are being increased from 45 g/dm²/h to 50 g/dm²/h
– ASGlobal 4Flite EG (Type IV)
– ASGlobal 4Flite PG (Type IV)
– JSC RCP Nordix Defrost North 4 (Type IV)
Additional test data had impacts on existing snow HOTs for 4Flite PG
– Shown on following slide


28 of 31
MODIFIED SNOW HOTS
ASGLOBAL 4FLITE 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
-3 and above	27 and above	100/0	2:50 - 3:00	1:35 - 2:50	0:50 - 1:35
below -3 to -8	below 27 to 18	100/0	2:05 - 2:30	1:10 - 2:05	0:35 - 1:10
below -8 to -14	below 18 to 7	100/0	1:40 - 2:00	0:25 - 1:40	0:30 - 0:55

Values in GREEN have increased by 5 minutes
Values in RED have decreased by 5 minutes
Values in BLUE are unchanged from the previous year


29 of 31
Outline
2021-22 Testing Overview
Methodology
Standard HOT Test Results Summary: 2 Fluids
Very Cold Snow Test Results Summary: 4 Fluids
Supplemental HUPR Testing
Summary

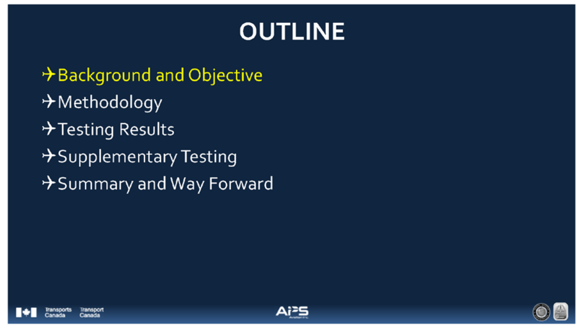

30 of 31
SUMMARY
Fluids Tested
• Tests carried out with new fluids; two fluids expected to be commercialized
Results
• Two new fluid specific HOT tables
• Generic frost HOTs substantiated
• New fluid-specific VCS HOTs for four fluids
• Expanded HUPR for three fluids, changes to 4Flite PG snow HOTs

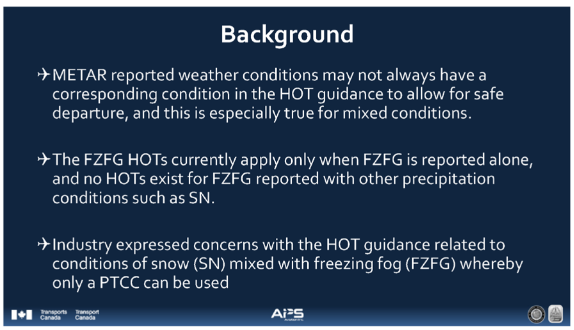

APS
Aviation Inc.
THANK YOU!!
Benjamin Bernier
bbernier@apsaviation.ca

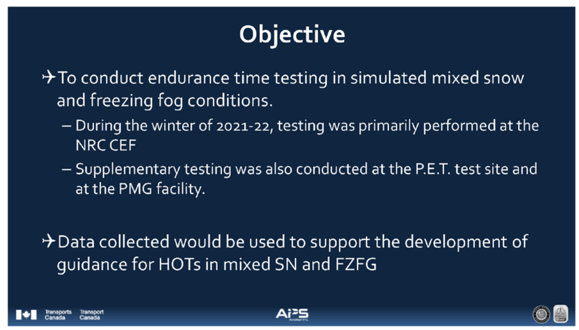
AIRLINES FOR AMERICA (A4A) GROUND DEICING FORUM, ONLINE (VIA ZOOM), JUNE 2022

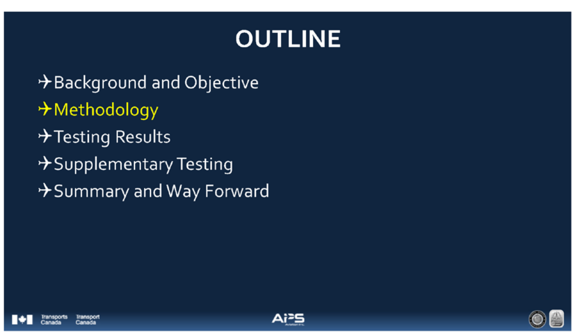
PRESENTATION:
MIXED SNOW AND FREEZING FOG CONDITIONS


Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS Aviation Inc.
MIXED SNOW AND FREEZING FOG CONDITIONS
Airlines for America Deice Forum, Virtual Meeting, June 7, 2022
Presented by: Marco Ruggi, Eng., M.B.A., Director


OUTLINE
Background and Objective
Methodology
Testing Results
Supplementary Testing
Summary and Way Forward


Background
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.
The FZFG HOTs currently apply only when FZFG is reported alone, and no HOTs exist for FZFG reported with other precipitation conditions such as SN.
Industry expressed concerns with the HOT guidance related to conditions of snow (SN) mixed with freezing fog (FZFG) whereby only a PTCC can be used


Objective
To conduct endurance time testing in simulated mixed snow and freezing fog conditions.
– During the winter of 2021-22, testing was primarily performed at the NRC CEF
– Supplementary testing was also conducted at the P.E.T. test site and at the PMG facility.
Data collected would be used to support the development of guidance for HOTs in mixed SN and FZFG


OUTLINE
Background and Objective
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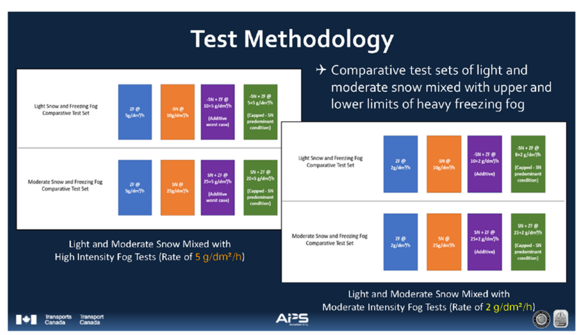
Test Methodology
Comparative test sets of light and moderate snow mixed with upper and lower limits of heavy freezing fog
Light and Moderate Snow Mixed with High Intensity Fog Tests (Rate of 5 g/dm²/h)
Light and Moderate Snow Mixed with Moderate Intensity Fog Tests (Rate of 2 g/dm²/h)


Test Methodology
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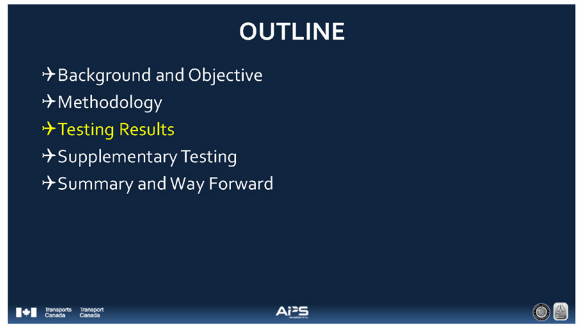
OUTLINE
Background and Objective
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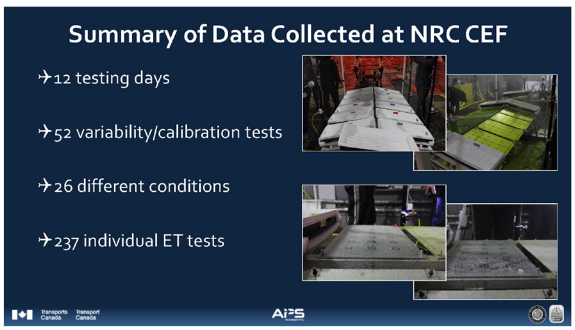
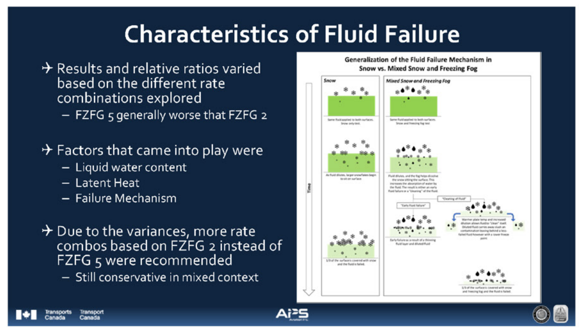
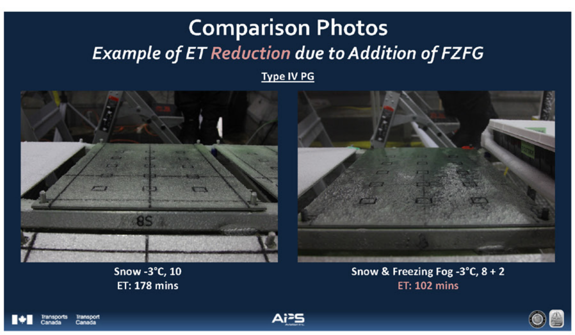
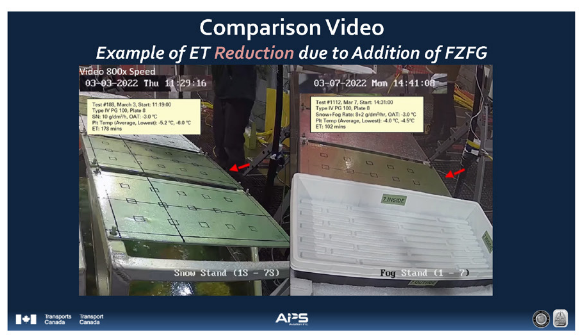
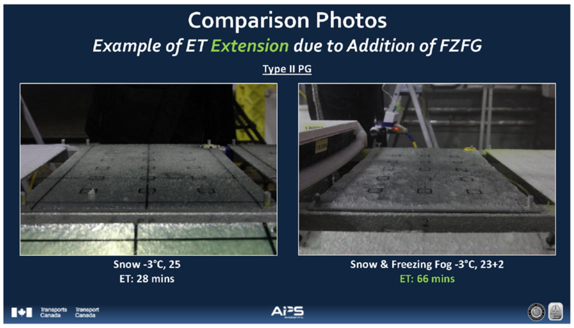
Summary and Way Forward
AiPS

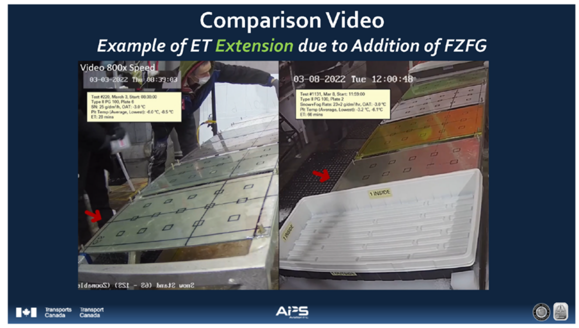

Summary of Data Collected at NRC CEF
12 testing days
52 variability/calibration tests
26 different conditions
237 individual ET tests
AiPS

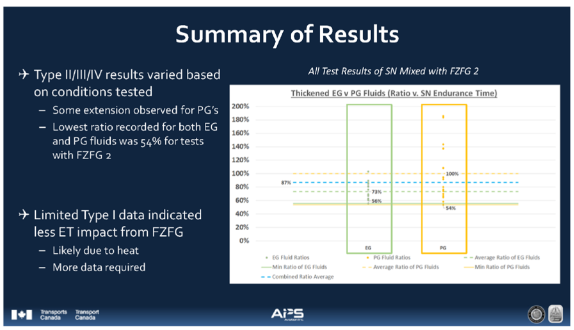

Characteristics of Fluid Failure
Results and relative ratios varied based on the different rate combinations explored
– FZFG 5 generally worse that FZFG 2
Factors that came into play were
– Liquid water content
– Latent Heat
– Failure Mechanism
Due to the variances, more rate combos based on FZFG 2 instead of FZFG 5 were recommended
– Still conservative in mixed context
Generalization of the Fluid Failure Mechanism in Snow vs. Mixed Snow and Freezing Fog
AiPS


Comparison Photos
Example of ET Reduction due to Addition of FZFG
Type IV PG
Snow -3°C, 10
ET: 178 mins
Snow & Freezing Fog -3°C, 8 + 2
ET: 102 mins
AiPS


Comparison Video
Example of ET Reduction due to Addition of FZFG
Video 800x Speed
Snow Stand (13 - 73)
Fog Stand (1 - 7)
AiPS


Comparison Photos
Example of ET Extension due to Addition of FZFG
Type II PG
Snow -3°C, 25
ET: 28 mins
Snow & Freezing Fog -3°C, 23+2
ET: 66 mins
AiPS


Comparison Video
Example of ET Extension due to Addition of FZFG
Video 800x Speed
03-08-2022 Tue 12:00:48
AiPS


Summary of Results
Type II/III/IV results varied based on conditions tested
Some extension observed for PG's
Lowest ratio recorded for both EG and PG fluids was 54% for tests with FZFG 2
Limited Type I data indicated less ET impact from FZFG
Likely due to heat
More data required
All Test Results of SN Mixed with FZFG 2
Thickened EG v PG Fluids (Ratio v. SN Endurance Time)
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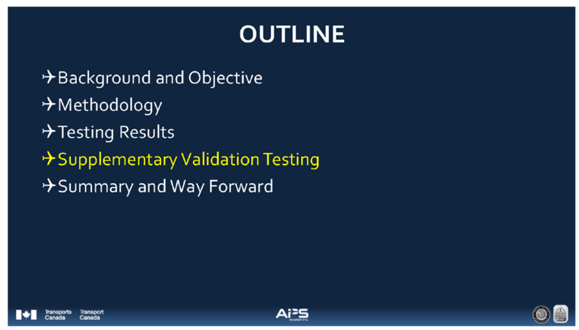
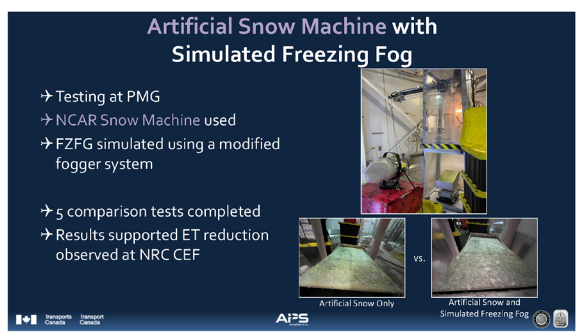
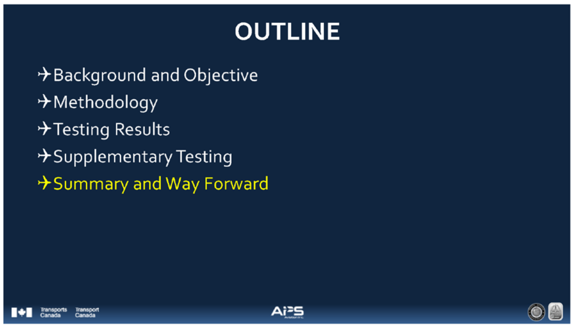
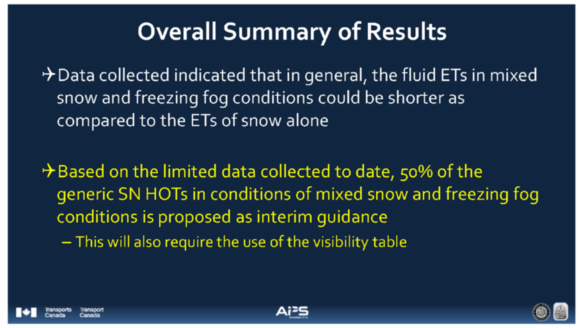

OUTLINE
Background and Objective
Methodology
Testing Results
Supplementary Validation Testing
Summary and Way Forward
AiPS


Natural Snow with Simulated Freezing Fog
Testing at P.E.T Airport Test Site
Natural snow events
FZFG simulated using a modified fogger system
5 comparison tests completed
Results supported ET reduction observed at NRC CEF
vs.
Natural Snow Only
Natural Snow and Simulated Freezing Fog
AiPS


Artificial Snow Machine with Simulated Freezing Fog
Testing at PMG
NCAR Snow Machine used
FZFG simulated using a modified fogger system
5 comparison tests completed
Results supported ET reduction observed at NRC CEF
vs.
Artificial Snow Only
Artificial Snow and Simulated Freezing Fog
AiPS


OUTLINE
Background and Objective
Methodology
Testing Results
Supplementary Testing
Summary and Way Forward
AiPS


Overall Summary of Results
Data collected indicated that in general, the fluid ETs in mixed snow and freezing fog conditions could be shorter as compared to the ETs of snow alone
Based on the limited data collected to date, 50% of the generic SN HOTs in conditions of mixed snow and freezing fog conditions is proposed as interim guidance
– This will also require the use of the visibility table
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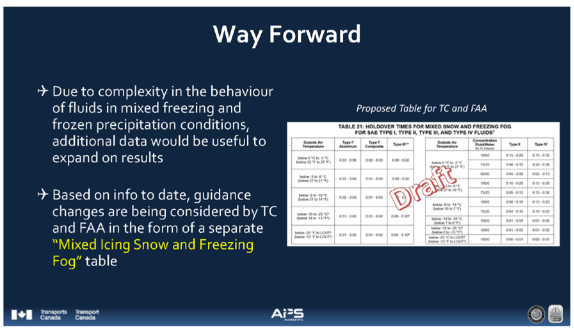
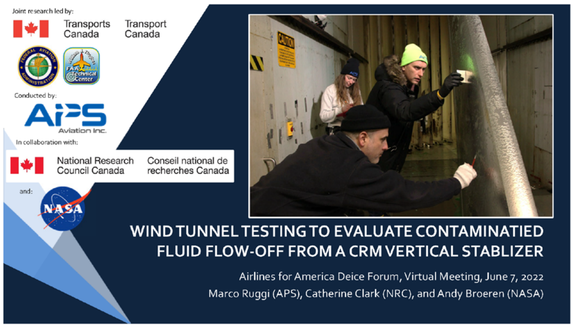
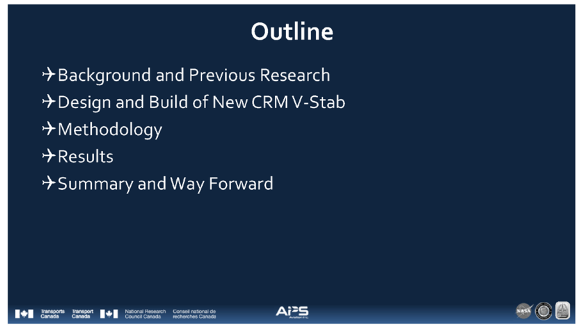

Way Forward
Due to complexity in the behaviour of fluids in mixed freezing and frozen precipitation conditions, additional data would be useful to expand on results
Based on info to date, guidance changes are being considered by TC and FAA in the form of a separate "Mixed Icing Snow and Freezing Fog" table
Proposed Table for TC and FAA
Draft
AiPS


AiPS
Thank You
Marco Ruggi
mruggi@apsaviation.ca

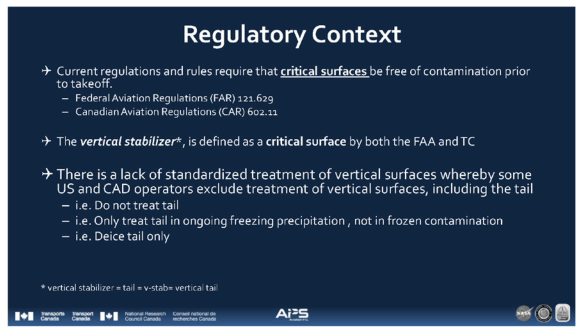
AIRLINES FOR AMERICA (A4A) GROUND DEICING FORUM, ONLINE (VIA ZOOM), JUNE 2022

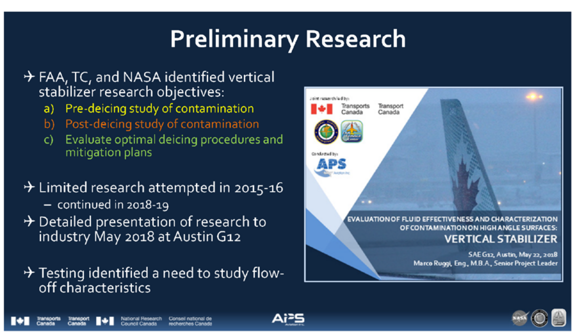
PRESENTATION:
WIND TUNNEL TESTING TO EVALUATE CONTAMINATED FLUID FLOW-OFF FROM A CRM VERTICAL STABILIZER
(PRESENTED JOINTLY WITH NRC AND NASA)

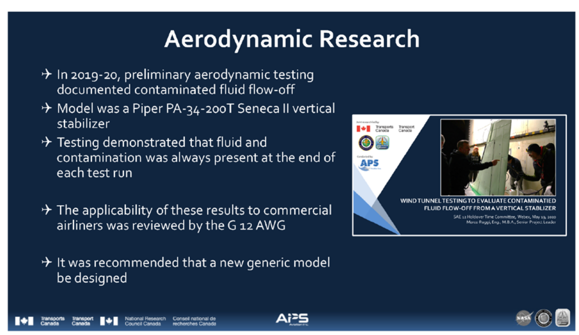

Joint research led by:
Transports Canada
Transport Canada
Conducted by:
APS Aviation Inc.
In collaboration with:
National Research Council Canada
Conseil national de recherches Canada
and:
NASA
WIND TUNNEL TESTING TO EVALUATE CONTAMINATIED FLUID FLOW-OFF FROM A CRM VERTICAL STABLIZER
Airlines for America Deice Forum, Virtual Meeting, June 7, 2022
Marco Ruggi (APS), Catherine Clark (NRC), and Andy Broeren (NASA)


Outline
Background and Previous Research
Design and Build of New CRM V-Stab
Methodology
Results
Summary and Way Forward


Background and Previous Research


Regulatory Context
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 both the FAA and TC
There is a lack of standardized treatment of vertical surfaces whereby some US and CAD operators exclude treatment of vertical surfaces, including the tail
– i.e. Do not treat tail
– i.e. Only treat tail in ongoing freezing precipitation , not in frozen contamination
– i.e. Deice tail only
* vertical stabilizer = tail = v-stab= vertical tail


Preliminary Research
FAA, TC, and NASA identified vertical stabilizer research objectives:
a) Pre-deicing study of contamination
b) Post-deicing study of contamination
c) Evaluate optimal deicing procedures and mitigation plans
Limited research attempted in 2015-16
– continued in 2018-19
Detailed presentation of research to industry May 2018 at Austin G12
Testing identified a need to study flow-off characteristics
EVALUATION OF FLUID EFFECTIVENESS AND CHARACTERIZATION OF CONTAMINATION ON HIGH ANGLE SURFACES:
VERTICAL STABILIZER
SAE G12, Austin, May 22, 2018
Marco Ruggi, Eng., M.B.A., Senior Project Leader


Aerodynamic Research
In 2019-20, preliminary aerodynamic testing documented contaminated fluid flow-off
Model was a Piper PA-34-200T Seneca II vertical stabilizer
Testing demonstrated that fluid and contamination was always present at the end of each test run
The applicability of these results to commercial airliners was reviewed by the G 12 AWG
It was recommended that a new generic model be designed
WIND TUNNEL TESTING TO EVALUATE CONTAMINATED FLUID FLOW-OFF FROM A VERTICAL STABILIZER


Design and Build of a New CRM V-Stab
Transports Canada Transport Canada
National Research Council Canada Conseil national de recherches Canada
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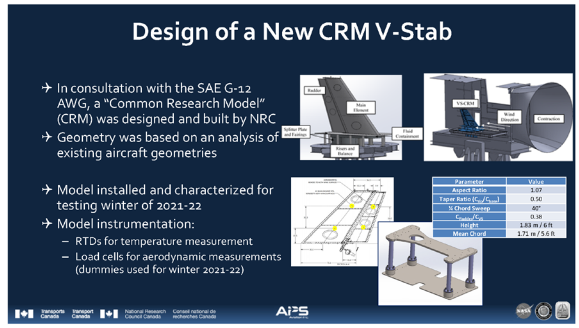
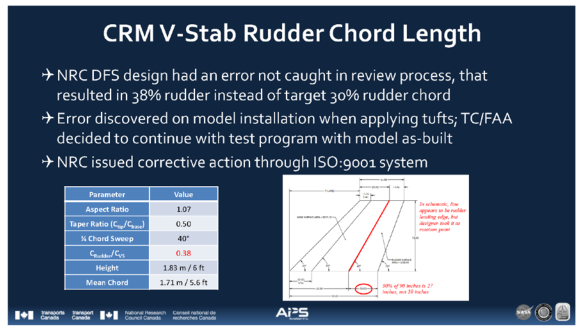
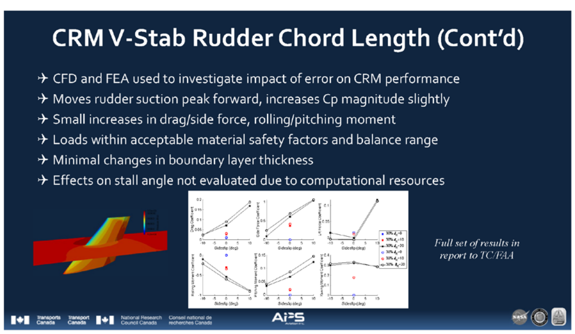
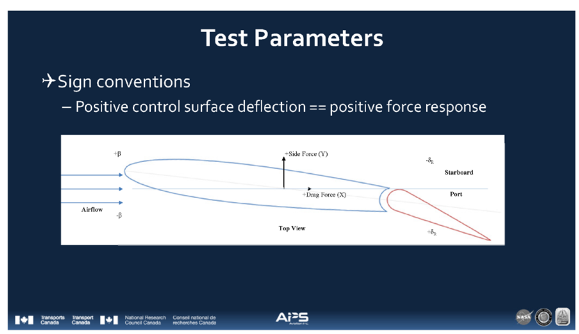
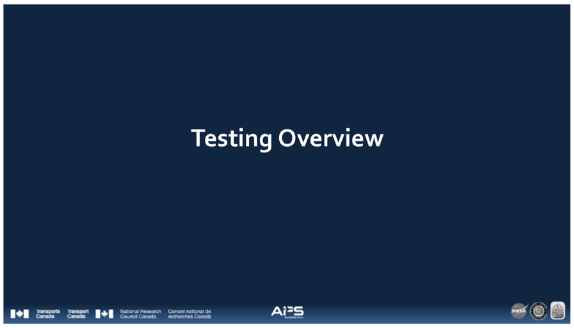

Design of a New CRM V-Stab
In consultation with the SAE G-12 AWG, a "Common Research Model" (CRM) was designed and built by NRC
Geometry was based on an analysis of existing aircraft geometries
Model installed and characterized for testing winter of 2021-22
Model instrumentation:
– RTDs for temperature measurement
– Load cells for aerodynamic measurements (dummies used for winter 2021-22)
Rudder
Main Element
Splitter Plate and Fairings
Fluid Containment
Risers and Balance
VS-CRM
Wind Direction
Contraction
Parameter | Value
Aspect Ratio | 1.07
Taper Ratio (C_{tip}/C_{base}) | 0.50
¼ Chord Sweep | 40°
C_{Rudder}/C_{VS} | 0.38
Height | 1.83 m / 6 ft
Mean Chord | 1.71 m / 5.6 ft

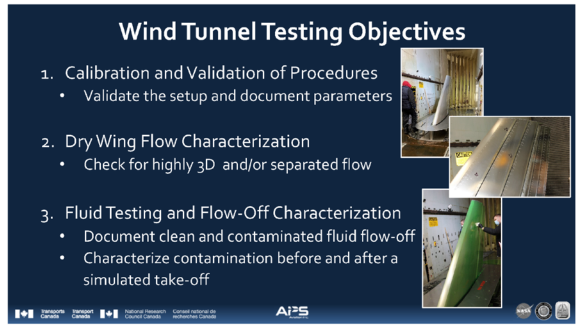

Fabrication and Installation of New CRM V-Stab

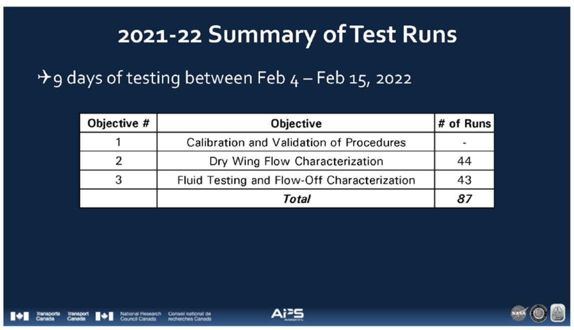

CRM V-Stab Rudder Chord Length
NRC DFS design had an error not caught in review process, that resulted in 38% rudder instead of target 30% rudder chord
Error discovered on model installation when applying tufts; TC/FAA decided to continue with test program with model as-built
NRC issued corrective action through ISO:9001 system
Parameter | Value
Aspect Ratio | 1.07
Taper Ratio (C_{tip}/C_{base}) | 0.50
¼ Chord Sweep | 40°
C_{Rudder}/C_{VS} | 0.38
Height | 1.83 m / 6 ft
Mean Chord | 1.71 m / 5.6 ft
In schematic, line appears to be rudder leading edge, but designer took it as rotation point
30% of 90 inches is 27 inches, not 30 inches


CRM V-Stab Rudder Chord Length (Cont'd)
CFD and FEA used to investigate impact of error on CRM performance
Moves rudder suction peak forward, increases Cp magnitude slightly
Small increases in drag/side force, rolling/pitching moment
Loads within acceptable material safety factors and balance range
Minimal changes in boundary layer thickness
Effects on stall angle not evaluated due to computational resources
Full set of results in report to TC/FAA

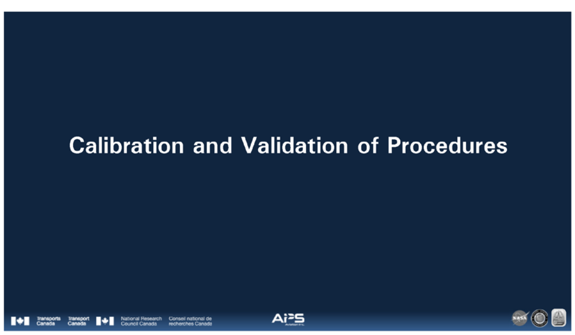

Test Parameters
Sign conventions
– Positive control surface deflection == positive force response
Side Force (Y)
Drag Force (X)
Starboard
Port
Airflow
Top View

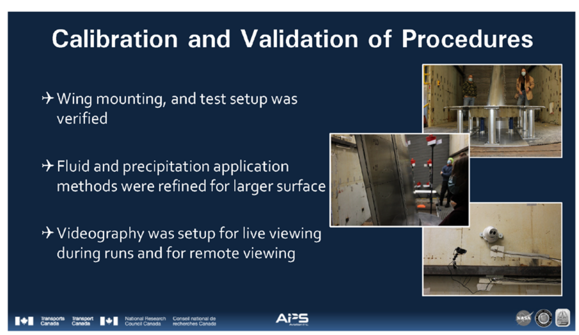


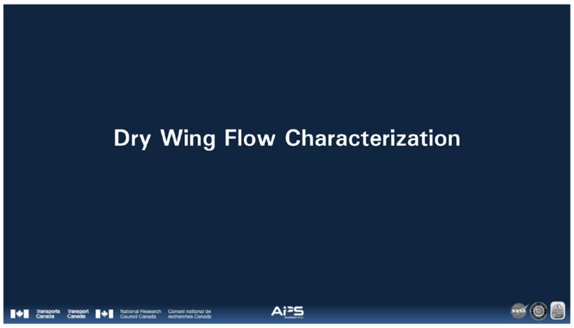


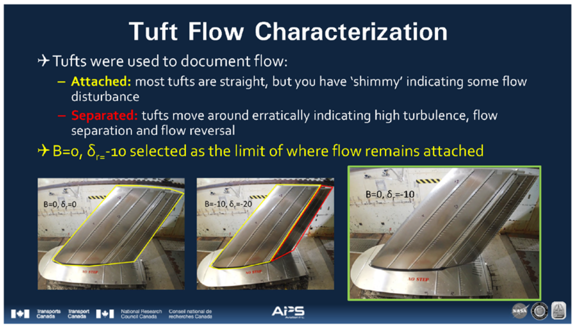


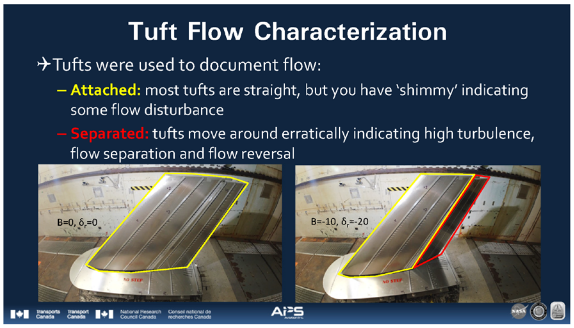
Objective #	Objective	# of Runs
1	Calibration and Validation of Procedures	-
2	Dry Wing Flow Characterization	44
3	Fluid Testing and Flow-Off Characterization	43
	Total	***87***

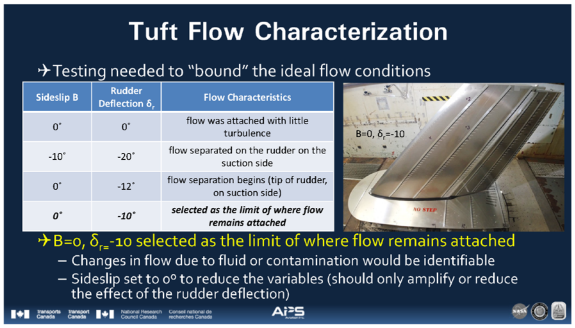




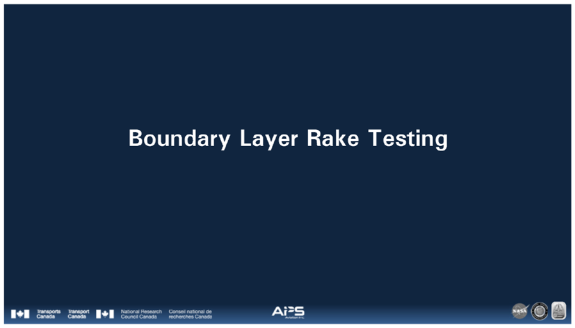


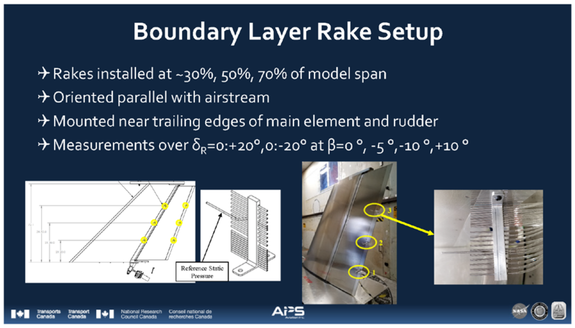


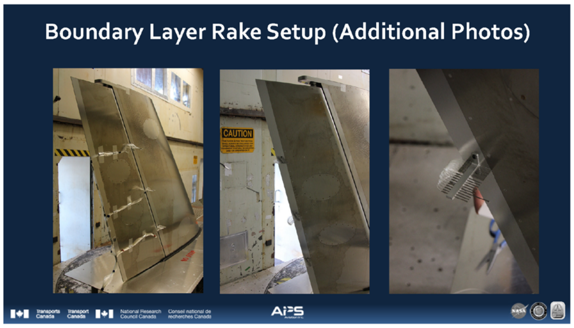


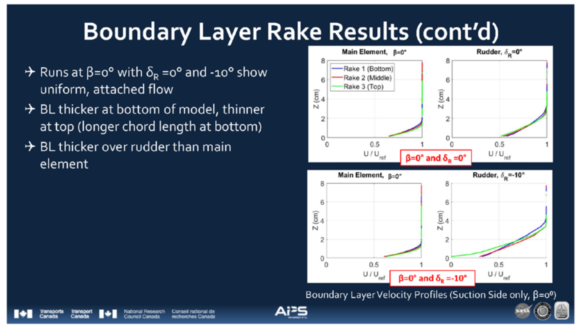


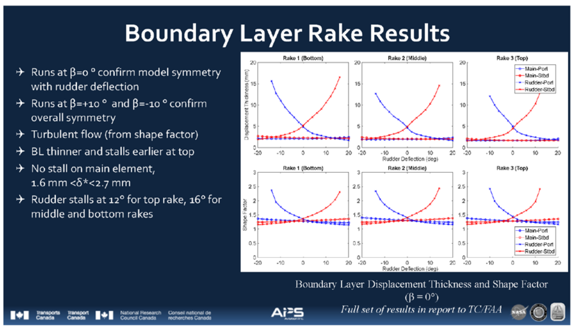
Sideslip B	Rudder Deflection δ_r	Flow Characteristics
0°	0°	flow was attached with little turbulence
-10°	-20°	flow separated on the rudder on the suction side
0°	-12°	flow separation begins (tip of rudder, on suction side)
0°	*-10°*	***selected as the limit of where flow remains attached***

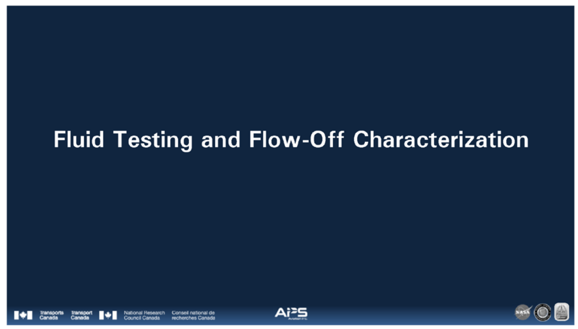


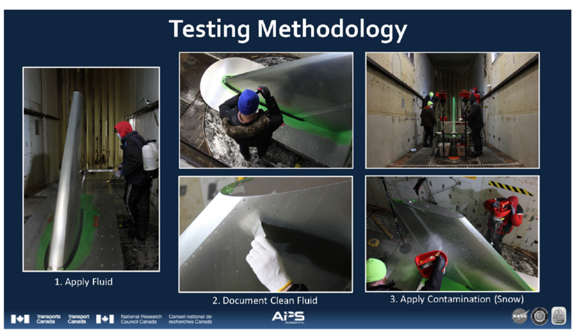


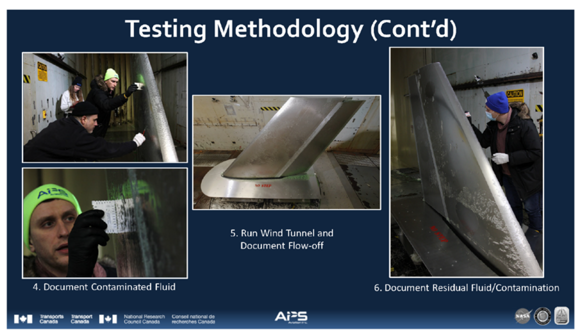

Boundary Layer Rake Setup (Additional Photos)
CAUTION
AiPS

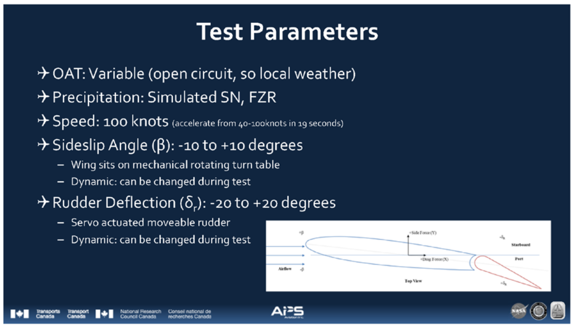

Boundary Layer Rake Results (cont'd)
Runs at β=0° with δ_R =0° and -10° show uniform, attached flow
BL thicker at bottom of model, thinner at top (longer chord length at bottom)
BL thicker over rudder than main element
Main Element, β=0°
Rudder, δ_R=0°
Rake 1 (Bottom)
Rake 2 (Middle)
Rake 3 (Top)
Z (cm)
U / U_{ref}
β=0° and δ_R =0°
Main Element, β=0°
Rudder, δ_R=-10°
β=0° and δ_R =-10°
Boundary Layer Velocity Profiles (Suction Side only, β=0°)
AiPS

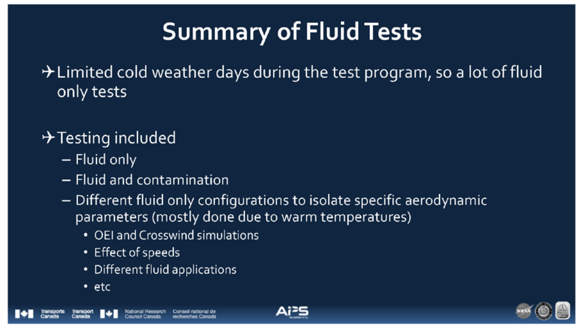

Boundary Layer Rake Results
Runs at β=0 ° confirm model symmetry with rudder deflection
Runs at β=+10 ° and β=-10 ° confirm overall symmetry
Turbulent flow (from shape factor)
BL thinner and stalls earlier at top
No stall on main element, 1.6 mm <δ*<2.7 mm
Rudder stalls at 12° for top rake, 16° for middle and bottom rakes
Rake 1 (Bottom)
Rake 2 (Middle)
Rake 3 (Top)
Rudder Deflection (deg)
Main-Port
Main-Stbd
Rudder-Port
Rudder-Stbd
Boundary Layer Displacement Thickness and Shape Factor
(β = 0°)
Full set of results in report to TC/FAA
AiPS

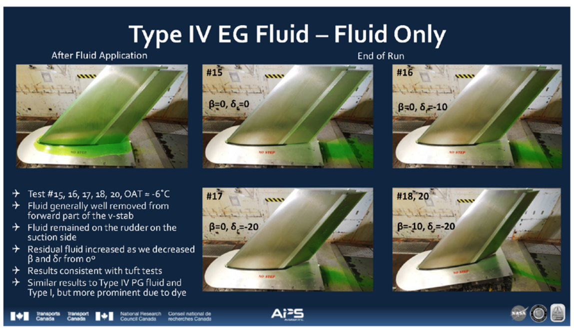

Fluid Testing and Flow-Off Characterization
AiPS

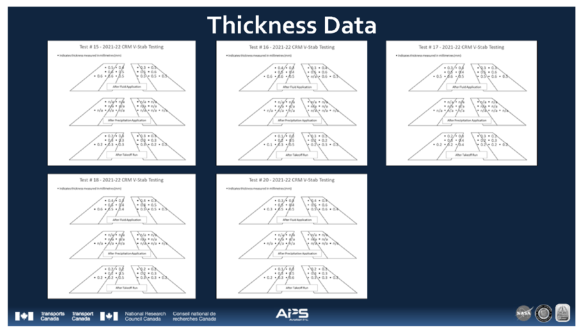

Testing Methodology
1. Apply Fluid
2. Document Clean Fluid
3. Apply Contamination (Snow)
AiPS

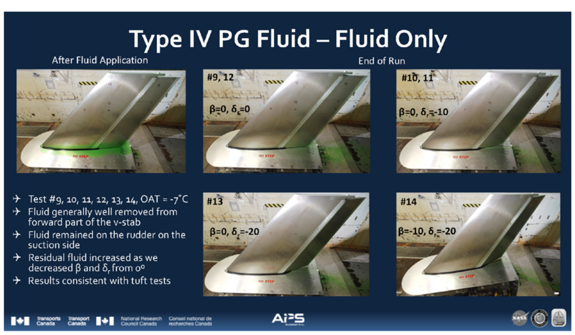

Testing Methodology (Cont'd)
4. Document Contaminated Fluid
5. Run Wind Tunnel and Document Flow-off
6. Document Residual Fluid/Contamination
AiPS

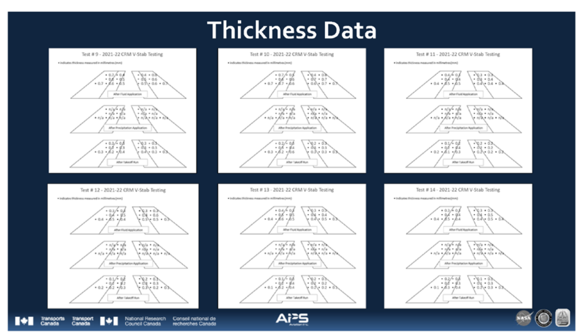

Test Parameters
OAT: Variable (open circuit, so local weather)
Precipitation: Simulated SN, FZR
Speed: 100 knots (accelerate from 40-100knots in 19 seconds)
Sideslip Angle (β): -10 to +10 degrees
– Wing sits on mechanical rotating turn table
– Dynamic: can be changed during test
Rudder Deflection (δr): -20 to +20 degrees
– Servo actuated moveable rudder
– Dynamic: can be changed during test
AiPS

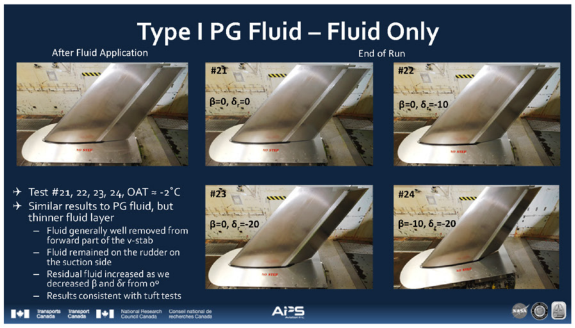

Summary of Fluid Tests
Limited cold weather days during the test program, so a lot of fluid only tests
Testing included
– Fluid only
– Fluid and contamination
– Different fluid only configurations to isolate specific aerodynamic parameters (mostly done due to warm temperatures)
• OEI and Crosswind simulations
• Effect of speeds
• Different fluid applications
• etc
AiPS

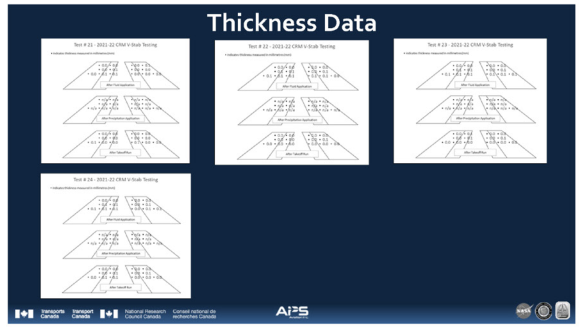

Type IV EG Fluid – Fluid Only
After Fluid Application
End of Run
#15
β=0, δr=0
#16
β=0, δr=-10
#17
β=0, δr=-20
#18, 20
β=-10, δr=-20
Test #15, 16, 17, 18, 20, OAT = -6°C
Fluid generally well removed from forward part of the v-stab
Fluid remained on the rudder on the suction side
Residual fluid increased as we decreased β and δr from 0°
Results consistent with tuft tests
Similar results to Type IV PG fluid and Type I, but more prominent due to dye
AiPS

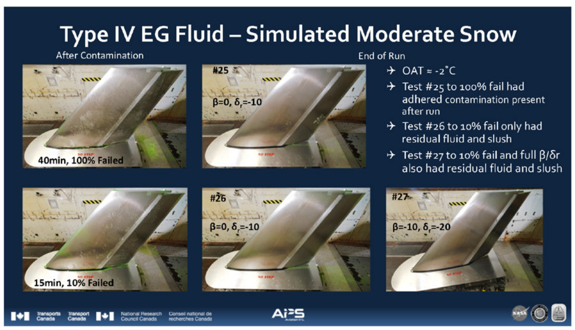

Thickness Data
AiPS

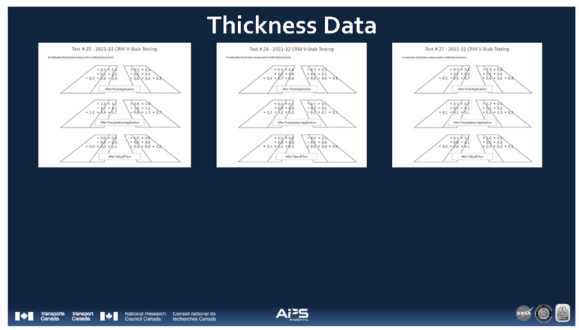

Type IV PG Fluid – Fluid Only
After Fluid Application
End of Run
#9, 12
β=0, δr=0
#10, 11
β=0, δr=-10
#13
β=0, δr=-20
#14
β=-10, δr=-20
Test #9, 10, 11, 12, 13, 14, OAT = -7°C
Fluid generally well removed from forward part of the v-stab
Fluid remained on the rudder on the suction side
Residual fluid increased as we decreased β and δr from 0°
Results consistent with tuft tests
AiPS

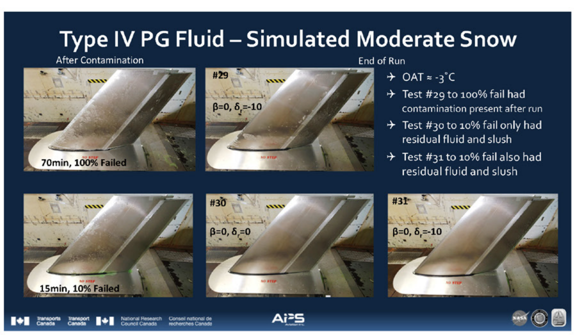

Thickness Data
AiPS

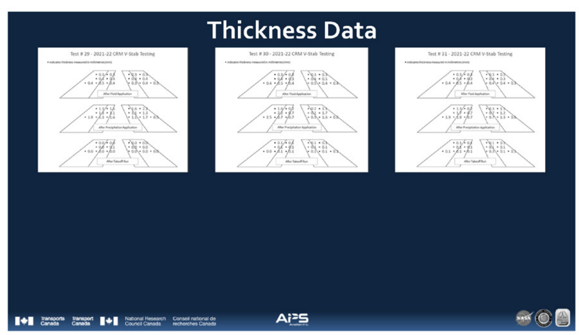

Type I PG Fluid – Fluid Only
After Fluid Application
End of Run
#21
$\beta=0, \delta_r=0$
#22
$\beta=0, \delta_r=-10$
#23
$\beta=0, \delta_r=-20$
#24
$\beta=-10, \delta_r=-20$
Test #21, 22, 23, 24, OAT ≈ -2˚C
Similar results to PG fluid, but thinner fluid layer
– Fluid generally well removed from forward part of the v-stab
– Fluid remained on the rudder on the suction side
– Residual fluid increased as we decreased β and δr from 0º
– Results consistent with tuft tests
AiPS

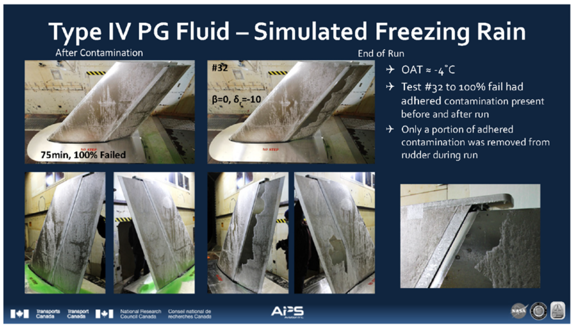

Thickness Data
AiPS

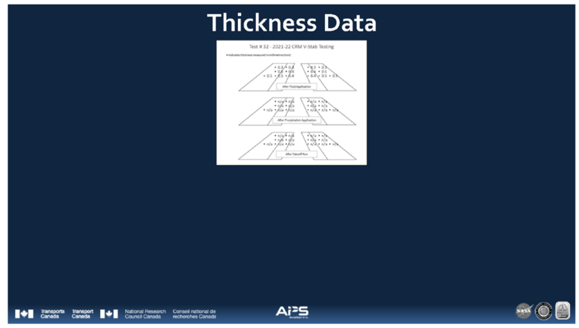

Type IV EG Fluid – Simulated Moderate Snow
After Contamination
End of Run
#25
$\beta=0, \delta_r=-10$
40min, 100% Failed
OAT ≈ -2˚C
Test #25 to 100% fail had adhered contamination present after run
Test #26 to 10% fail only had residual fluid and slush
Test #27 to 10% fail and full β/δr also had residual fluid and slush
#26
$\beta=0, \delta_r=-10$
#27
$\beta=-10, \delta_r=-20$
15min, 10% Failed
AiPS

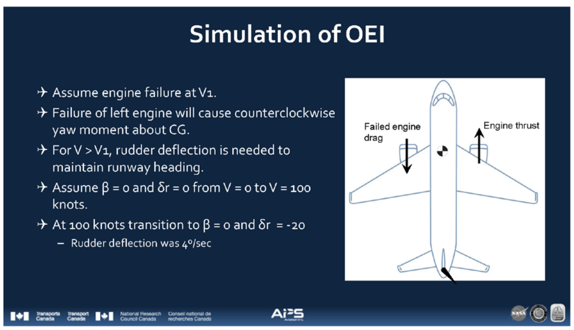

Thickness Data
AiPS

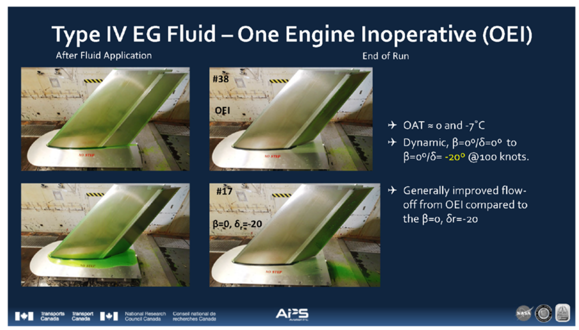

Type IV PG Fluid – Simulated Moderate Snow
After Contamination
End of Run
#29
$\beta=0, \delta_r=-10$
70min, 100% Failed
OAT ≈ -3˚C
Test #29 to 100% fail had contamination present after run
Test #30 to 10% fail only had residual fluid and slush
Test #31 to 10% fail also had residual fluid and slush
#30
$\beta=0, \delta_r=0$
#31
$\beta=0, \delta_r=-10$
15min, 10% Failed
AiPS

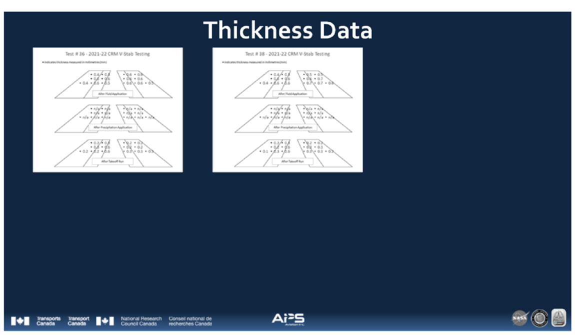

Thickness Data
AiPS

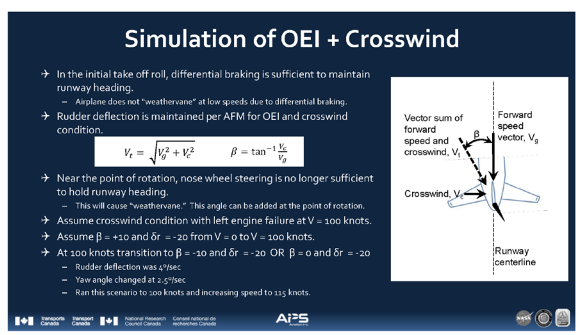

Type IV PG Fluid – Simulated Freezing Rain
After Contamination
End of Run
#32
β=0, δr=-10
75min, 100% Failed
OAT ≈ -4˚C
Test #32 to 100% fail had adhered contamination present before and after run
Only a portion of adhered contamination was removed from rudder during run

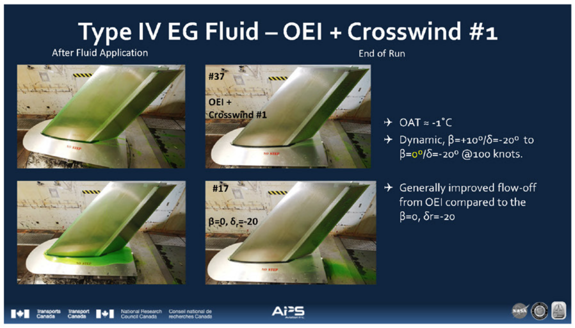

Thickness Data

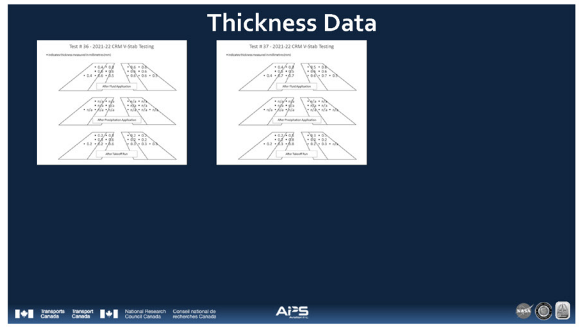

Simulation of OEI
Assume engine failure at V1.
Failure of left engine will cause counterclockwise yaw moment about CG.
For V > V1, rudder deflection is needed to maintain runway heading.
Assume β = 0 and δr = 0 from V = 0 to V = 100 knots.
At 100 knots transition to β = 0 and δr = -20
– Rudder deflection was 4°/sec
Failed engine drag
Engine thrust

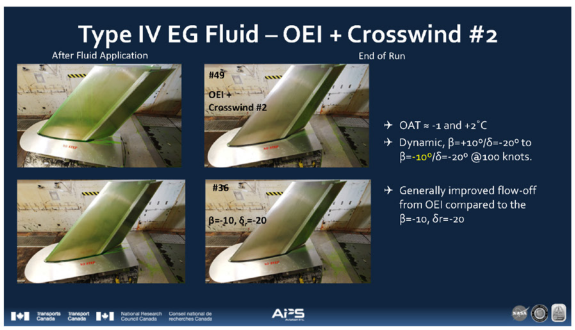

Type IV EG Fluid – One Engine Inoperative (OEI)
After Fluid Application
End of Run
#38
OEI
#17
β=0, δr=-20
OAT ≈ 0 and -7˚C
Dynamic, β=0°/δ=0° to β=0°/δ= -20° @100 knots.
Generally improved flow-off from OEI compared to the β=0, δr=-20

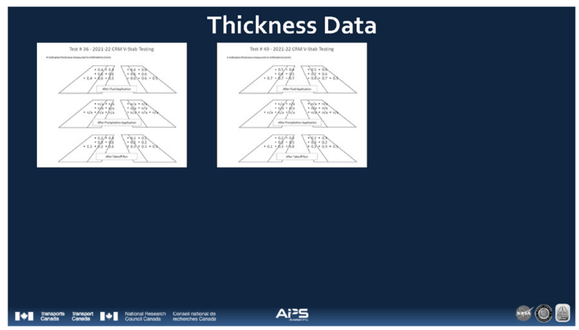

Thickness Data

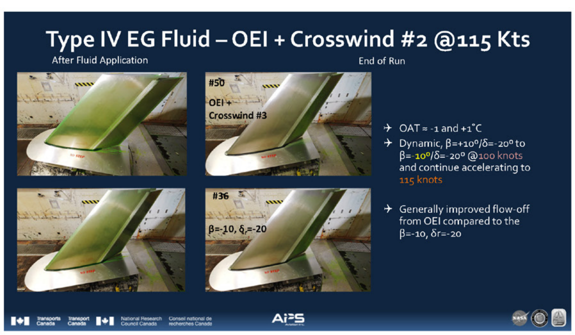

Simulation of OEI + Crosswind
In the initial take off roll, differential braking is sufficient to maintain runway heading.
– Airplane does not "weathervane" at low speeds due to differential braking.
Rudder deflection is maintained per AFM for OEI and crosswind condition.
$V_t = \sqrt{V_g^2 + V_c^2}$ $\beta = \tan^{-1}\frac{V_c}{V_g}$
Near the point of rotation, nose wheel steering is no longer sufficient to hold runway heading.
– This will cause "weathervane." This angle can be added at the point of rotation.
Assume crosswind condition with left engine failure at V = 100 knots.
Assume β = +10 and δr = -20 from V = 0 to V = 100 knots.
At 100 knots transition to β = -10 and δr = -20 OR β = 0 and δr = -20
– Rudder deflection was 4°/sec
– Yaw angle changed at 2.5°/sec
– Ran this scenario to 100 knots and increasing speed to 115 knots.
Vector sum of forward speed and crosswind, Vt
β
Forward speed vector, Vg
Crosswind, Vc
Runway centerline

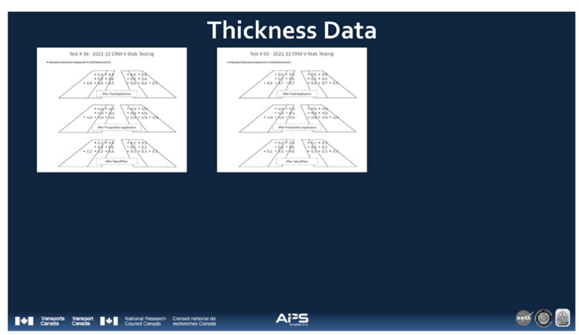

Type IV EG Fluid – OEI + Crosswind #1
After Fluid Application
End of Run
#37
OEI +
Crosswind #1
#17
β=0, δr=-20
OAT = -1˚C
Dynamic, β=+10º/δ=-20º to β=0º/δ=-20º @100 knots.
Generally improved flow-off from OEI compared to the β=0, δr=-20

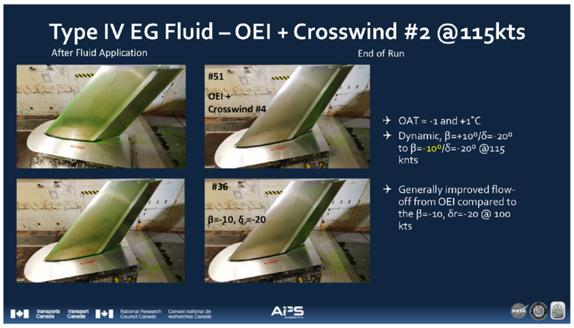

Thickness Data

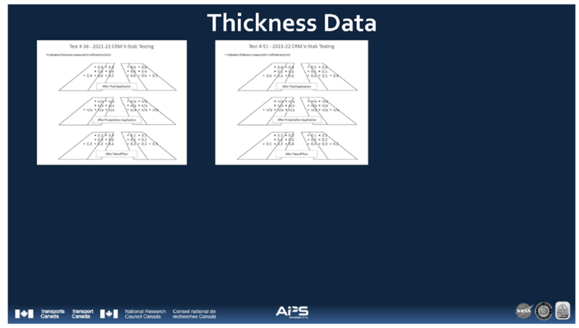

Type IV EG Fluid – OEI + Crosswind #2
After Fluid Application
End of Run
#49
OEI +
Crosswind #2
#36
β=-10, δr=-20
OAT = -1 and +2˚C
Dynamic, β=+10º/δ=-20º to β=-10º/δ=-20º @100 knots.
Generally improved flow-off from OEI compared to the β=-10, δr=-20

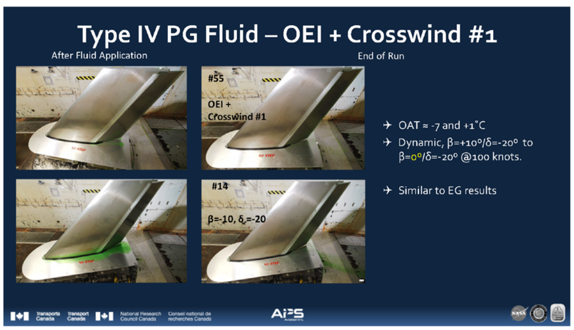

Thickness Data

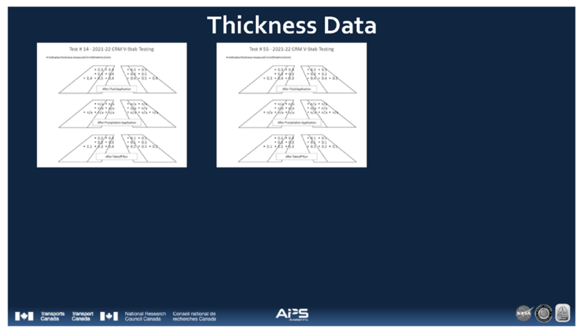

Type IV EG Fluid – OEI + Crosswind #2 @115 Kts
After Fluid Application
End of Run
#50
OEI +
Crosswind #3
#36
β=-10, δr=-20
OAT = -1 and +1˚C
Dynamic, β=+10º/δ=-20º to β=-10º/δ=-20º @100 knots and continue accelerating to 115 knots
Generally improved flow-off from OEI compared to the β=-10, δr=-20

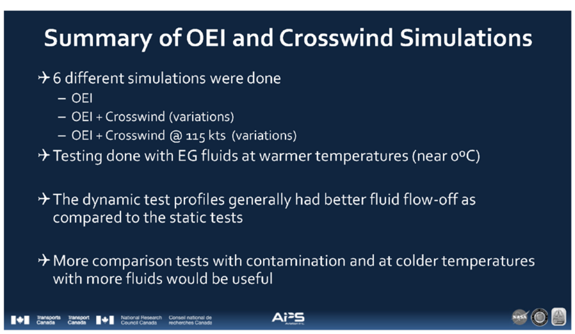

Thickness Data

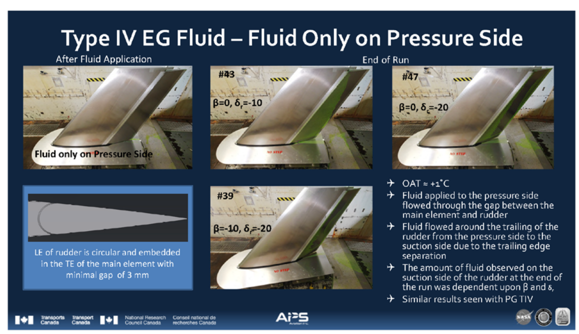

Type IV EG Fluid – OEI + Crosswind #2 @115kts
After Fluid Application
End of Run
#51
OEI + Crosswind #4
#36
β=-10, δr=-20
OAT ≈ -1 and +1˚C
Dynamic, β=+10º/δ=-20º to β=-10º/δ=-20º @115 knts
Generally improved flow-off from OEI compared to the β=-10, δr=-20 @ 100 kts
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
APS

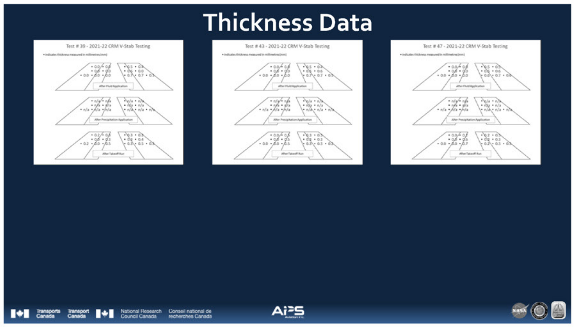

Thickness Data

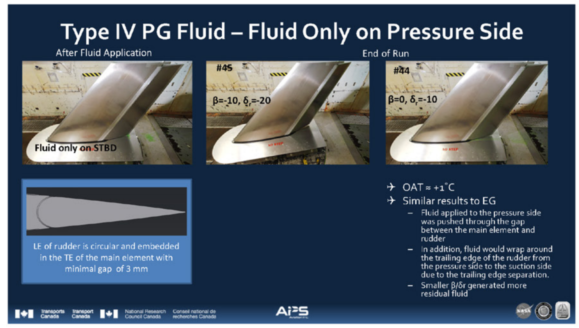

Type IV PG Fluid – OEI + Crosswind #1
After Fluid Application
End of Run
#55
OEI + Crosswind #1
#14
β=-10, δr=-20
OAT ≈ -7 and +1˚C
Dynamic, β=+10º/δ=-20º to β=0º/δ=-20º @100 knots.
Similar to EG results
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
APS

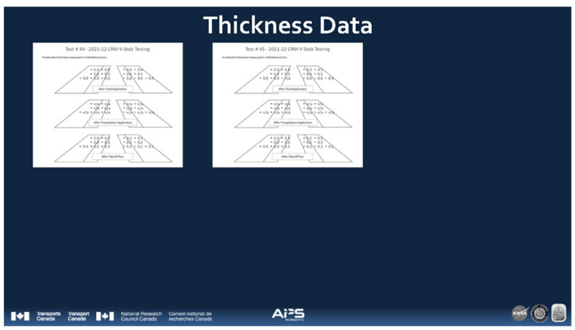

Thickness Data

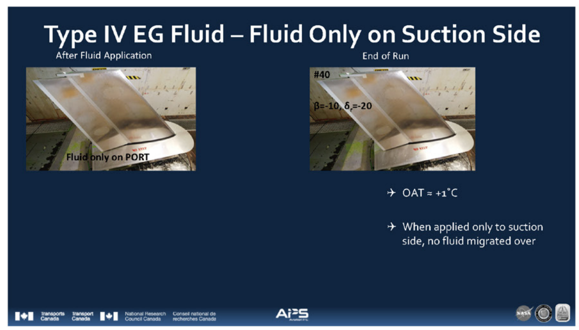

Summary of OEI and Crosswind Simulations
6 different simulations were done
– OEI
– OEI + Crosswind (variations)
– OEI + Crosswind @ 115 kts (variations)
Testing done with EG fluids at warmer temperatures (near 0ºC)
The dynamic test profiles generally had better fluid flow-off as compared to the static tests
More comparison tests with contamination and at colder temperatures with more fluids would be useful
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
APS

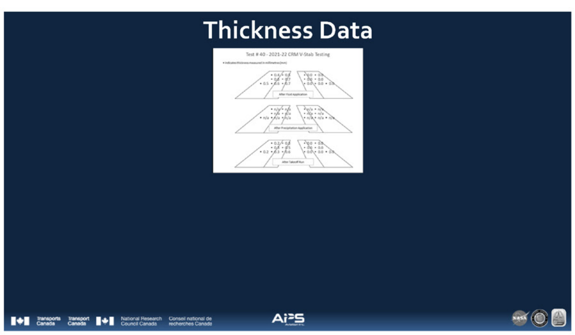

Type IV EG Fluid – Fluid Only on Pressure Side
After Fluid Application
End of Run
Fluid only on Pressure Side
#43
β=0, δr=-10
#47
β=0, δr=-20
LE of rudder is circular and embedded in the TE of the main element with minimal gap of 3 mm
#39
β=-10, δr=-20
OAT ≈ +1˚C
Fluid applied to the pressure side flowed through the gap between the main element and rudder
Fluid flowed around the trailing of the rudder from the pressure side to the suction side due to the trailing edge separation
The amount of fluid observed on the suction side of the rudder at the end of the run was dependent upon β and δr
Similar results seen with PG TIV
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
APS

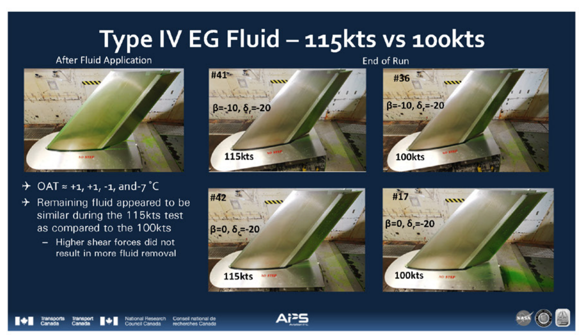

Thickness Data
Test # 39 - 2021-22 CRM V-Stab Testing
Test # 43 - 2021-22 CRM V-Stab Testing
Test # 47 - 2021-22 CRM V-Stab Testing

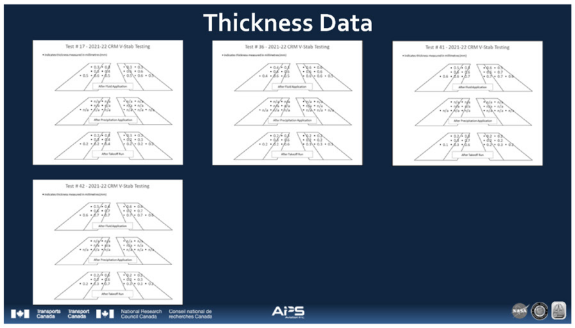

Type IV PG Fluid – Fluid Only on Pressure Side
After Fluid Application
End of Run
Fluid only on STBD
#45
β=-10, δr=-20
#44
β=0, δr=-10
LE of rudder is circular and embedded in the TE of the main element with minimal gap of 3 mm
OAT ≈ +1˚C
Similar results to EG
Fluid applied to the pressure side was pushed through the gap between the main element and rudder
In addition, fluid would wrap around the trailing edge of the rudder from the pressure side to the suction side due to the trailing edge separation.
Smaller β/δr generated more residual fluid

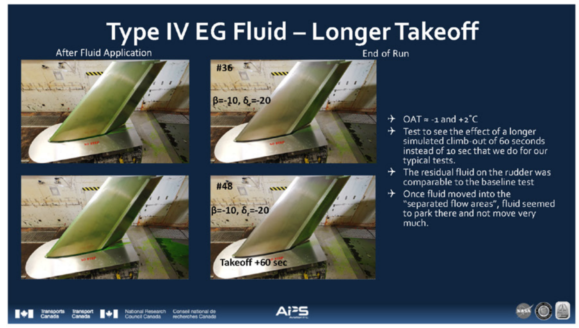

Thickness Data
Test # 44 - 2021-22 CRM V-Stab Testing
Test # 45 - 2021-22 CRM V-Stab Testing

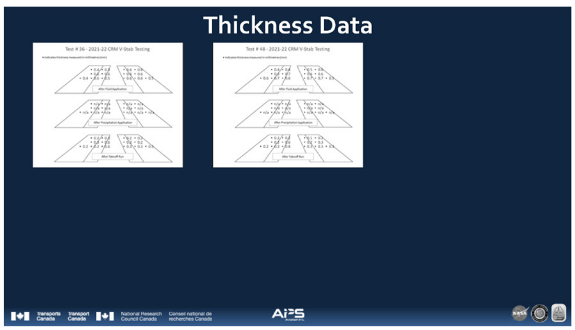

Type IV EG Fluid – Fluid Only on Suction Side
After Fluid Application
End of Run
Fluid only on PORT
#40
β=-10, δr=-20
OAT ≈ +1˚C
When applied only to suction side, no fluid migrated over

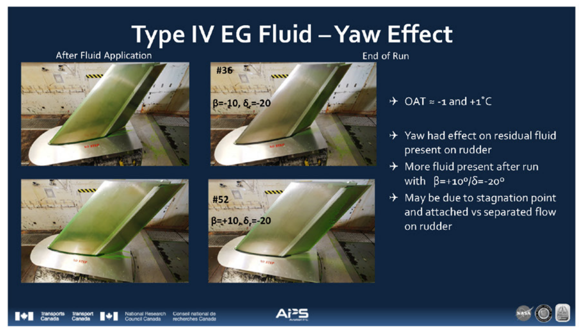

Thickness Data
Test # 40 - 2021-22 CRM V-Stab Testing

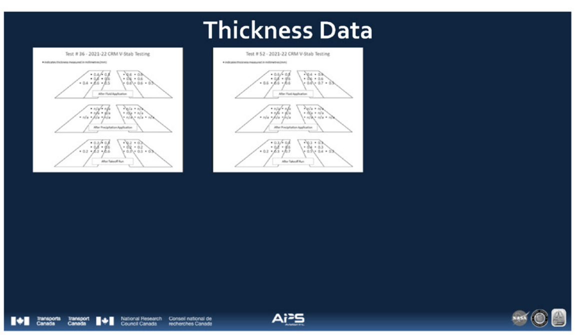

Type IV EG Fluid – 115kts vs 100kts
After Fluid Application
End of Run
#41
β=-10, δr=-20
115kts
#36
β=-10, δr=-20
100kts
#42
β=0, δr=-20
115kts
#17
β=0, δr=-20
100kts
OAT ≈ +1, +1, -1, and-7 ˚C
Remaining fluid appeared to be similar during the 115kts test as compared to the 100kts
Higher shear forces did not result in more fluid removal

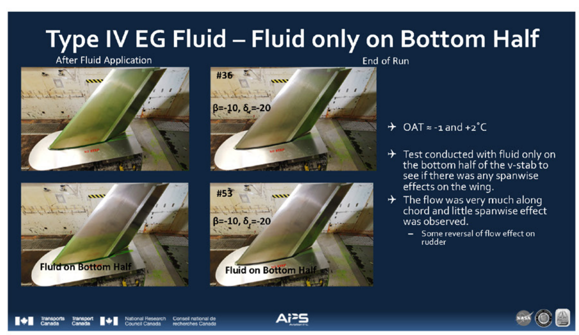

Thickness Data
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
AiPS


Type IV EG Fluid – Longer Takeoff
After Fluid Application
End of Run
#36
β=-10, δr=-20
#48
β=-10, δr=-20
Takeoff +60 sec
OAT ≈ -1 and +2˚C
Test to see the effect of a longer simulated climb-out of 60 seconds instead of 10 sec that we do for our typical tests.
The residual fluid on the rudder was comparable to the baseline test
Once fluid moved into the "separated flow areas", fluid seemed to park there and not move very much.
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
AiPS


Thickness Data
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
AiPS


Type IV EG Fluid – Yaw Effect
After Fluid Application
End of Run
#36
β=-10, δr=-20
#52
β=+10, δr=-20
OAT ≈ -1 and +1˚C
Yaw had effect on residual fluid present on rudder
More fluid present after run with β=+10º/δ=-20º
May be due to stagnation point and attached vs separated flow on rudder
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
AiPS


Thickness Data
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
AiPS


Type IV EG Fluid – Fluid only on Bottom Half
After Fluid Application
End of Run
#36
β=-10, δr=-20
Fluid on Bottom Half
#53
β=-10, δr=-20
Fluid on Bottom Half
OAT ≈ -1 and +2˚C
Test conducted with fluid only on the bottom half of the v-stab to see if there was any spanwise effects on the wing.
The flow was very much along chord and little spanwise effect was observed.
Some reversal of flow effect on rudder
Transports Canada
Transport Canada
National Research Council Canada
Conseil national de recherches Canada
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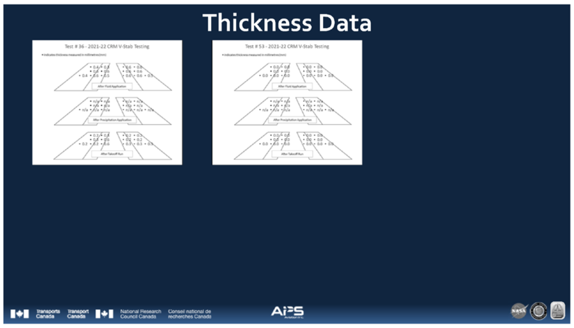
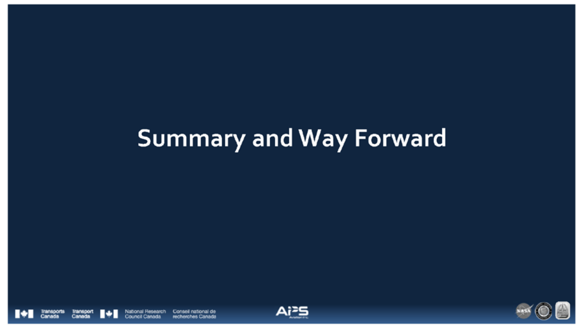
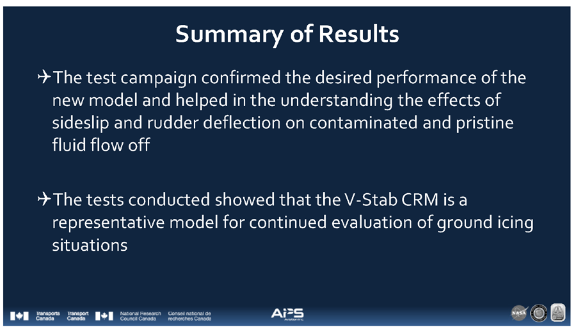
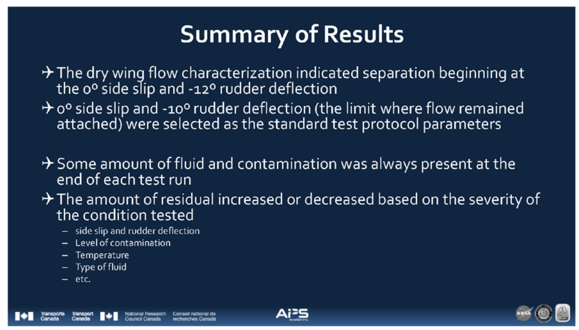
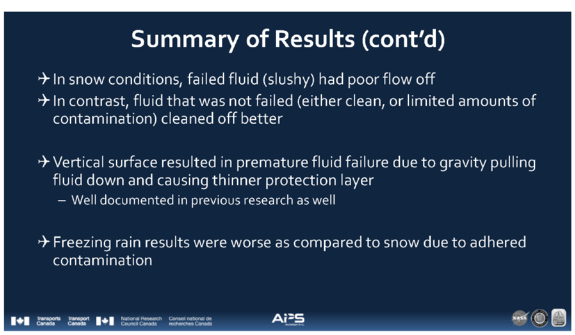
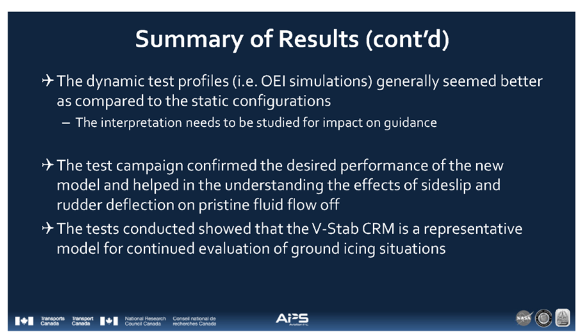

Thickness Data
AiPS

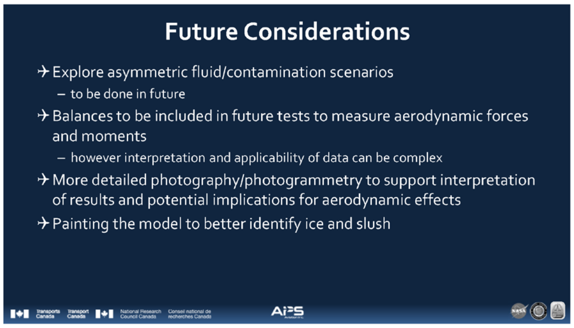

Summary and Way Forward
AiPS

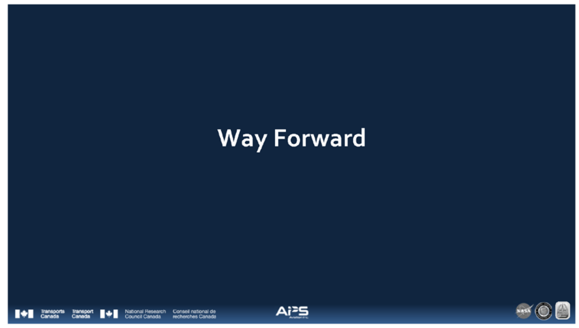

Summary of Results
The test campaign confirmed the desired performance of the new model and helped in the understanding the effects of sideslip and rudder deflection on contaminated and pristine fluid flow off
The tests conducted showed that the V-Stab CRM is a representative model for continued evaluation of ground icing situations
AiPS

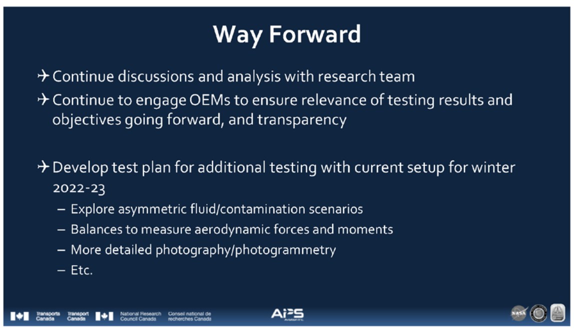

Summary of Results
The dry wing flow characterization indicated separation beginning at the 0° side slip and -12° rudder deflection
0° side slip and -10° rudder deflection (the limit where flow remained attached) were selected as the standard test protocol parameters
Some amount of fluid and contamination was always present at the end of each test run
The amount of residual increased or decreased based on the severity of the condition tested
– side slip and rudder deflection
– Level of contamination
– Temperature
– Type of fluid
– etc.
AiPS


Summary of Results (cont'd)
In snow conditions, failed fluid (slushy) had poor flow off
In contrast, fluid that was not failed (either clean, or limited amounts of contamination) cleaned off better
Vertical surface resulted in premature fluid failure due to gravity pulling fluid down and causing thinner protection layer
– Well documented in previous research as well
Freezing rain results were worse as compared to snow due to adhered contamination
AiPS


Summary of Results (cont'd)
The dynamic test profiles (i.e. OEI simulations) generally seemed better as compared to the static configurations
– The interpretation needs to be studied for impact on guidance
The test campaign confirmed the desired performance of the new model and helped in the understanding the effects of sideslip and rudder deflection on pristine fluid flow off
The tests conducted showed that the V-Stab CRM is a representative model for continued evaluation of ground icing situations
AiPS


Future Considerations
Explore asymmetric fluid/contamination scenarios
– to be done in future
Balances to be included in future tests to measure aerodynamic forces and moments
– however interpretation and applicability of data can be complex
More detailed photography/photogrammetry to support interpretation of results and potential implications for aerodynamic effects
Painting the model to better identify ice and slush


Way Forward

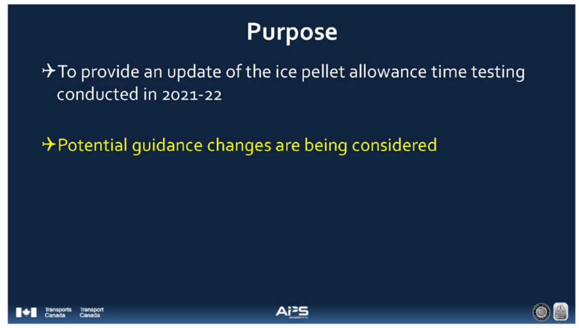

Way Forward
Continue discussions and analysis with research team
Continue to engage OEMs to ensure relevance of testing results and objectives going forward, and transparency
Develop test plan for additional testing with current setup for winter 2022-23
– Explore asymmetric fluid/contamination scenarios
– Balances to measure aerodynamic forces and moments
– More detailed photography/photogrammetry
– Etc.

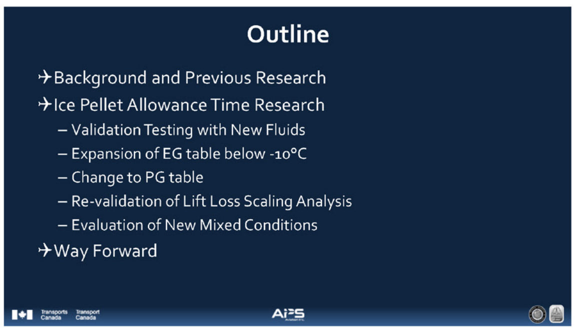

APS
Aviation Inc.
CAUTION
Marco Ruggi
mruggi@apsaviation.ca

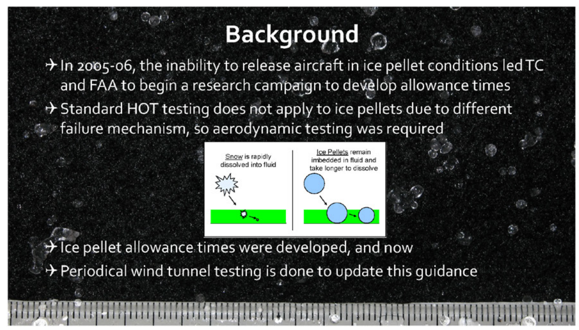
AIRLINES FOR AMERICA (A4A) GROUND DEICING FORUM, ONLINE (VIA ZOOM), JUNE 2022

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
Airlines for America Deice Forum, Virtual Meeting, June 7, 2022
Marco Ruggi, Eng., M.B.A., Director


Purpose
To provide an update of the ice pellet allowance time testing conducted in 2021-22
Potential guidance changes are being considered


Outline
Background and Previous Research
Ice Pellet Allowance Time Research
– Validation Testing with New Fluids
– Expansion of EG table below -10°C
– Change to PG table
– Re-validation of Lift Loss Scaling Analysis
– Evaluation of New Mixed Conditions
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
AMIL
APS Aviation Inc.
SUPPORTERS
ABAX
ALLCLEAR SYSTEMS
CHEMCO
CLARIANT
CRYOTECH
DOW
Inland
Kilfrost
LNT Solutions
NEWAVE
NORDIX
SAE INTERNATIONAL


2021-22
Research
Team

2021-22 Summary of Test Runs

- 15 days of testing between Jan 9 – Jan 28, 2022

Objective #	Objective	# of Runs
1	Baseline Tests (Dry wing)	36
2	Ice Pellet Allowance Time Validation (New Fluids)	53
3	EG Fluids - Expansion of Allowance Times	28*
4	New Mixed Conditions	12
	Total	*129*

**Some also served as Validation tests*

Validation Testing Results

- 5 Type IV fluids recently added to the TC/FAA guidelines were tested
- Allowance times are generic, so systematic "spot checking" was done in order to identify any potential issues

Fluid	Status
AllClear Systems LLC - **ClearWing ECO**	Ongoing
CHEMCO Inc. - **ChemR Nordik IV**	✓ Validated
Cryotech Deicing Technology - **Polar Guard® Xtend**	✓ Validated
JSC RCP Nordix - **Defrost NORTH 4**	✓ Validated
Newave Aerochemical Co. Ltd. - **FCY-EGIV**	✓ Validated

EG Specific Allowance Times

- Industry requested EG specific fluid ice pellet allowance time tables be investigated
  - potential for longer allowance times
- Last year, a separate EG allowance time table was issued with longer times above -10°C
- Additional data was collected in 2021-22 with a focus on conditions below -10°C

EG Specific Allowance Time Data

- A total of 181 tests were analyzed
  - Data points meet or exceed allowance times
  - 46 of the 181 data points collected in 2021-22
- 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

- New data targeted primarily below -10°C conditions,
- However limited data is available below -16°C
- Some additional data in warmer temperatures was also collected

Distribution of Tests

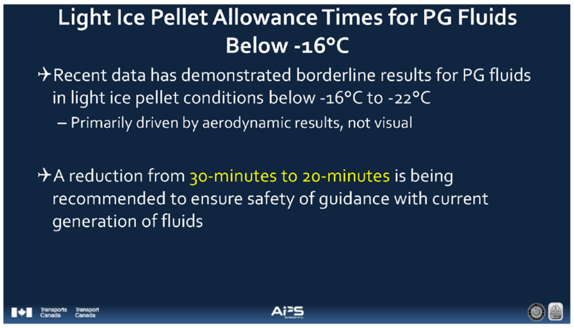
Precipitation Type	Outside Air Temperature			
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C
Light Ice Pellets	11 tests	8 tests	11 tests	6 tests
Light Ice Pellets Mixed with Light Snow	10 tests	7 tests	15 tests	2 tests
Light Ice Pellets Mixed with Light Freezing Drizzle or Moderate Freezing Drizzle	3 tests	3 tests		
Light Ice Pellets Mixed with Light Freezing Rain	15 tests	11 tests	2 tests	
Light Ice Pellets Mixed with Light Rain	3 tests			
Moderate Ice Pellets (or Small Hail)	15 tests	7 tests	13 tests	10 tests
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Freezing Drizzle	6 tests	6 tests		
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Rain	17 tests			

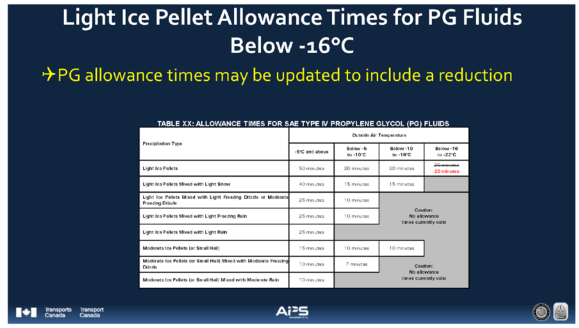
Changes to Allowance Times for EG Fluids

- The EG allowance times may be updated to include new longer times below -10°C

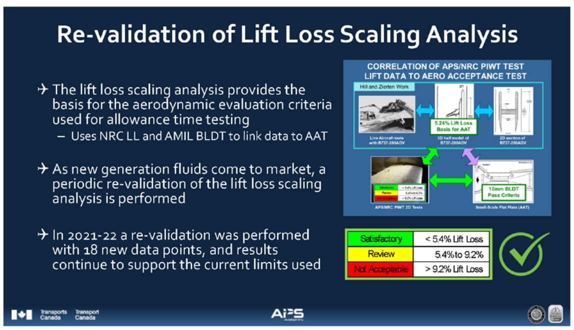
TABLE XX: ALLOWANCE TIMES FOR SAE TYPE IV ETHYLENE GLYCOL (EG) FLUIDS

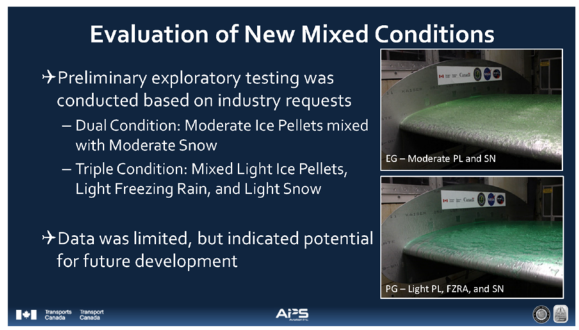
Precipitation Type	Outside Air Temperature			
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C
Light Ice Pellets	70 minutes	50 minutes	~~30 minutes~~ 50 minutes	30 minutes
Light Ice Pellets Mixed with Light Snow	50 minutes	30 minutes	~~15 minutes~~ 25 minutes	
Light Ice Pellets Mixed with Light Freezing Drizzle or Moderate Freezing Drizzle	40 minutes	30 minutes	Caution: No allowance times currently exist	
Light Ice Pellets Mixed with Light Freezing Rain	40 minutes	30 minutes		
Light Ice Pellets Mixed with Light Rain	40 minutes			
Moderate Ice Pellets (or Small Hail)	35 minutes	25 minutes	~~10 minutes~~ 15 minutes	10 minutes
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Freezing Drizzle	20 minutes	10 minutes	Caution: No allowance times currently exist	
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Rain	15 minutes			

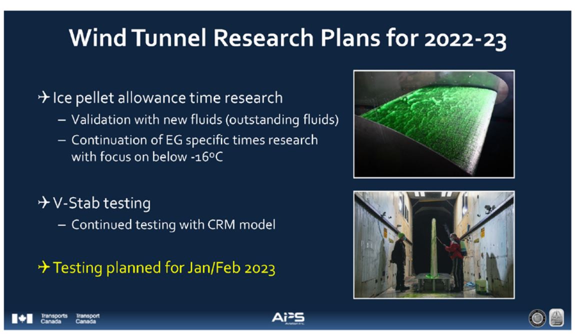


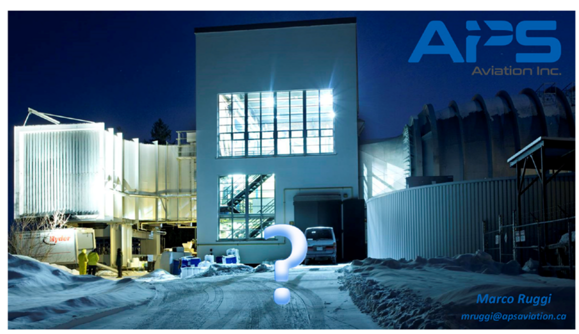


Precipitation Type	Outside Air Temperature			
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C
Light Ice Pellets	50 minutes	30 minutes	30 minutes	~~30 minutes~~ 20 minutes
Light Ice Pellets Mixed with Light Snow	40 minutes	15 minutes	15 minutes	
Light Ice Pellets Mixed with Light Freezing Drizzle or Moderate Freezing Drizzle	25 minutes	10 minutes	Caution: No allowance times currently exist	
Light Ice Pellets Mixed with Light Freezing Rain	25 minutes	10 minutes		
Light Ice Pellets Mixed with Light Rain	25 minutes			
Moderate Ice Pellets (or Small Hail)	15 minutes	10 minutes	10 minutes	
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Freezing Drizzle	10 minutes	7 minutes	Caution: No allowance times currently exist	
Moderate Ice Pellets (or Small Hail) Mixed with Moderate Rain	10 minutes			









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