AIRCRAFT GROUND ICING GENERAL RESEARCH ACTIVITIES DURING THE 2017-18 WINTER

TP 15398E

APS Aviation Inc.

Prepared for the

Transportation Development Centre

In cooperation with

Transport Canada Civil Aviation

and the

Federal Aviation Administration
William J. Hughes Technical Center

FINAL VERSION 1.0

NOVEMBER 2018

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Reviewed and Approved by:

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

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PREFACE

Under contract to the Transportation Development Centre of Transport Canada, with support from the Federal Aviation Administration, 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 evaluate fluid holdover times for snow at temperatures below -14°C;
- To review and analyse the use of artificial snow for holdover time development;
- To conduct wind tunnel testing to support the development of guidance material for operating in ice pellet conditions;
- To evaluate the effects of deploying flaps and slats prior to takeoff on fluid protection times;
- To conduct general and exploratory de/anti-icing research;
- To finalize publication of 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 2017-18 are documented in four reports. The titles of the reports are as follows:

- TP 15396E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2017-18 Winter;
- TP 15397E Regression Coefficients and Equations Used to Develop the Winter 2018-19 Aircraft Ground Deicing Holdover Time Tables;
- TP 15398E Aircraft Ground Icing General Research Activities During the 2017-18 Winter; and
- TP 15399E Artificial Snow Research Activities for the 2017-18 Winter.

This report, TP 15398E, has the following objective:

- To document the exploratory research and general activities carried out during the winter of 2017-18.

PROGRAM ACKNOWLEDGEMENTS

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

APS Aviation Inc. would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data, completion of data analysis, and preparation of reports. This includes the following people: Brandon Auclair, David Beals, Steven Baker, Stephanie Bendickson, Benjamin Bernier, Chloë Bernier, Andrea Cohen, Chris D'Avirro, John D'Avirro, Ben Falvo, Michael Hawdur, Gabriel Maatouk, Eric Perocchio, Dany Posteraro, Annaelle Reuveni, Marco Ruggi, Gordon Smith, Saba Tariq, David Youssef, and Nondas Zoitakis.

Special thanks are extended to Antoine Lacroix, Howard Posluns, Yvan Chabot, Warren Underwood and Charles J. Enders, who on behalf of the Transportation Development Centre 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 *Flaps and Slats: Wind Direction Sensitivity Testing with Airfoils*; Marco Ruggi for *Summary of Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times*, *Snow Allowance Times* and *Evaluation of Fluid Effectiveness and Characterization of Contamination on High Angle Surfaces: Vertical Stabilizer*; David Youssef for *Maintenance and Upgrade of Snow Machine*; Saba Tariq for *Technical Review, Approval, and Publication of Historical Reports*; Chloë Bernier for *Publication of Holdover Time Guidance Materials*; and Saba Tariq/Chloë Bernier for *Presentations, Fluid Manufacturer Reports, and Test Procedures for 2016-17*.

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Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada. These are available from the Transportation Development 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 2017-18. The activities documented in this report were carried out in addition to the main research projects completed in the winter of 2017-18, which are documented in separate reports. The eight activities described in this report are listed below:

1) Flaps and Slats: Wind Direction Sensitivity Testing with Airfoils;
2) Summary of Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times;
3) Snow Allowance Times;
4) Evaluation of Fluid Effectiveness and Characterization of Contamination on High Angle Surfaces: Vertical Stabilizer;
5) Maintenance and Upgrade of Snow Machine;
6) Technical Review, Approval, and Publication of Historical Reports;
7) Publication of Holdover Time Guidance Materials; and
8) Presentations, Fluid Manufacturer Reports, and Test Procedures for 2017-18.

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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. Ils sont disponibles au Centre de développement des transports. De nombreux rapports ont été rédigés dans le cadre du programme de recherche de cet hiver. Leur objet apparaît à l'avant-propos. Ce projet était coparrainé par la Federal Aviation Administration.

16. Résumé

Le présent rapport documente les activités d'ordre général réalisées par APS Aviation Inc. en matière de recherche sur le dégivrage d'aéronefs au sol au cours de l'hiver 2017-2018. Les activités dont fait état ce rapport ont été effectuées en plus des projets de la recherche principale menés pendant l'hiver 2017-2018, qui sont documentés dans des rapports distincts. Les huit activités qui font l'objet du présent rapport sont énumérées ci-dessous :

1) Volets et becs de bord d'attaque : essais de sensibilité à la direction du vent à l'aide de surfaces portantes ;
2) Sommaire des essais en soufflerie visant à appuyer le développement plus poussé de marges de tolérance pour les granules de glace ;
3) Marges de tolérance dans des conditions de neige ;
4) Évaluation de l'efficacité des liquides et caractérisation de la contamination sur des surfaces à angle élevé : stabilisateur vertical ;
5) Entretien et perfectionnement de l'appareil de fabrication de neige ;
6) Examen technique, approbation et publication de rapports historiques ;
7) Publication de documents d'orientation sur les durées d'efficacité ; et
8) Présentations, rapports aux fabricants de liquides et procédures d'essais pour 2017-2018.

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EXECUTIVE SUMMARY

This report documents the exploratory research and general activities completed in the winter of 2017-18 by APS Aviation Inc. (APS) on behalf of the Transportation Development Centre (TDC) 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 eight activities that were carried out in addition to the main research projects in the winter of 2017-18.

Flaps and Slats: Wind Direction Sensitivity Testing with Airfoils (Section 2)

To complete a supplemental research objective related to the recently completed deployed flaps and slats research program, APS conducted wind direction sensitivity tests to characterize the effect of specific airfoil orientations (relative to wind direction) on fluid endurance time performance on an airfoil model. Fluid endurance time performance was found to be generally improved by orienting the airfoil model out of the wind, with the magnitude of the improvement increasing significantly at angles of 90° and greater to the wind; this supported previous findings.

Summary of Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times (Section 3)

Testing during the winter of 2017-18 aimed at validating new-to-market fluids for use with ice pellet guidance, evaluating the extension of the current Type IV ice pellet allowance times for ethylene glycol fluids, and an evaluation of Type III ice pellet allowance times at 80 Knots. At the time of writing this report, analysis and technical discussions were still ongoing. Therefore, a brief testing summary was compiled rather than a detailed technical report. The detailed 2017-18 testing results will be included with the next wind tunnel trials report expected in the winter of 2018-19.

Snow Allowance Times (Section 4)

As a direct result of the ice pellet research, alternative ways for determining protection time for anti-icing fluids are being reviewed at the request of industry. A preliminary testing methodology was developed and proposed to industry and the SAE G-12 Aerodynamics Working Group for consideration. Proof-of-concept testing is recommended to identify the benefits to snow allowance times.

Evaluation of Fluid Effectiveness and Characterization of Contamination on High Angle Surfaces: Vertical Stabilizer (Section 5)

At the request of TC and the FAA, APS undertook a research plan during the winter of 2015-16 to evaluate de/anti-icing fluid effectiveness and characterize contamination on high angle surfaces. In 2017-18, APS prepared a presentation of the work conducted for formal dissemination of the information to industry.

Maintenance and Upgrade of Snow Machine (Section 6)

Recently, APS had the opportunity to conduct side-by-side testing with both the APS owned snow machine and the National Center for Atmospheric Research (NCAR) owned snow machine. This was completed when the NCAR machine was borrowed to supplement research. It was determined that the APS snow machine was not running as optimally as the NCAR machine. Upgrades to the weigh scale, carbide blades, and snow distribution system were required.

Technical Review, Approval, and Publication of Historical Reports (Section 7)

APS has been involved in writing and publishing 198 reports on behalf of TC since 1992. At the request of TC and the FAA, APS undertook the task to process and publish the draft reports backlogged in the system. At the beginning of this project, in 2016-17, 124 reports were identified as non-published. APS performed technical and editorial reviews on 16 reports at the Final Draft 1.0 stage and published them as Final Version 1.0 in October 2017. Following discussions that took place with TC and the FAA in the fall of 2017, APS published and delivered 22 reports to TC and the FAA as Final Version 1.0 in October 2018.

Publication of Holdover Time Guidance Materials (Section 8)

APS developed and implemented a website for the official TC holdover time guidelines in 2003 to eliminate the safety risks associated with discrepancies occurring as a result of holdover time information being published in multiple locations. Since then, APS has updated the website annually to reflect changes made to the guidelines and as well, assisted both TC and the FAA with the development of their guidance documents.

Presentations, Fluid Manufacturer Reports, and Test Procedures for 2017-18 (Section 9)

A number of presentations, fluid manufacturer reports, and test procedures were produced by APS for the winter 2017-18 test program. An account of these materials is included in this report.

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SOMMAIRE

Le présent rapport documente la recherche exploratoire et les activités d'ordre général effectuées au cours de l'hiver 2017-2018 par APS Aviation Inc. (APS), pour le compte du Centre de développement des transports (CDT) 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 huit activités effectuées en plus des principaux projets de recherche de l'hiver 2017-2018.

Volets et becs de bord d'attaque : essais de sensibilité à la direction du vent à l'aide de surfaces portantes (Section 2)

Dans le but de répondre à un autre objectif de recherche relié au programme de recherche récemment achevé sur les volets et les becs de bord d'attaque déployés, APS a mené, à l'aide d'une maquette de surface portante, des essais de sensibilité à la direction du vent afin de définir l'effet d'orientations prédéterminées (par rapport à la direction du vent) des surfaces portantes sur la durée d'endurance des liquides. De façon générale, une amélioration de la performance des liquides en ce qui a trait à la durée d'endurance a été observée lorsque la maquette de surface portante a été positionnée à l'abri du vent ; l'ampleur de cette amélioration s'est avérée particulièrement marquée lorsque la maquette a été placée à un angle de 90° ou plus par rapport au vent. Ces résultats viennent appuyer les constatations faites antérieurement.

Sommaire des essais en soufflerie visant à appuyer le développement plus poussé de marges de tolérance pour les granules de glace (Section 3)

Des tests effectués au cours de l'hiver 2017-2018 visaient à confirmer que des liquides nouvellement offerts sur le marché pouvaient être utilisés conformément aux lignes directrices relatives aux granules de glace, à étudier la possibilité que les marges de tolérance actuelles des liquides de type IV pour les granules de glace puissent être prolongées dans le cas des liquides à base d'éthylène glycol et à évaluer les marges de tolérance des liquides de type III pour les granules de glace à une vitesse de 80 nœuds. Au moment de la rédaction de ce rapport, des analyses et des discussions techniques étaient toujours en cours. Un bref compte rendu des essais effectués, plutôt qu'un rapport technique exhaustif, a donc été produit. Les résultats détaillés des tests menés en 2017-2018 seront inclus dans le prochain rapport sur les essais en soufflerie, prévu pour l'hiver 2018-2019.

Marges de tolérance dans des conditions de neige (Section 4)

En réponse à la recherche effectuée sur les granules de glace, d'autres moyens de déterminer la durée de protection des liquides d'antigivrage sont actuellement analysés, à la demande de l'industrie. Une méthode d'évaluation préliminaire a été mise au point et proposée pour examen aux acteurs de l'industrie ainsi qu'au groupe de travail G-12 de la SAE sur l'aérodynamisme. Un essai de validation est recommandé pour en déterminer les avantages en matière de marges de tolérance dans des conditions de neige.

Évaluation de l'efficacité des liquides et caractérisation de la contamination sur des surfaces à angle élevé : stabilisateur vertical (Section 5)

À la demande de TC et de la FAA, APS a entrepris, au cours de l'hiver 2015-2016, l'élaboration d'un plan de recherche visant à évaluer l'efficacité des liquides de dégivrage et d'antigivrage et à caractériser la contamination sur des surfaces à angle élevé. En 2017-2018, APS a préparé une présentation des travaux effectués aux fins de diffusion formelle de l'information au sein de l'industrie.

Entretien et perfectionnement de l'appareil de fabrication de neige (Section 6)

APS a récemment eu l'occasion d'effectuer des essais en parallèle sur son propre appareil de fabrication de neige et sur celui appartenant au National Center for Atmospheric Research (NCAR). Ces essais ont pu être réalisés grâce à l'emprunt de l'appareil du NCAR, qui a permis d'achever le travail de recherche mené. Il a été établi que l'appareil de fabrication de neige d'APS ne fonctionnait pas de manière aussi optimale que celui du NCAR. Des améliorations à la balance, aux lames au carbure et au système de répartition de la neige ont été requises.

Examen technique, approbation et publication de rapports historiques (Section 7)

Depuis 1992, APS a participé à la rédaction et à la publication de 198 rapports pour le compte de TC. 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. APS a effectué des examens techniques et éditoriaux de 16 rapports à l'étape de l'ébauche finale 1.0 et a publié leur version finale 1.0 en octobre 2017. À la suite de discussions avec TC et la FAA à l'automne 2017, APS a publié et remis, dans leur version finale 1.0, 22 rapports à TC et à la FAA en octobre 2018.

Publication de documents d'orientation sur les durées d'efficacité (Section 8)

En 2003, APS a conçu et mis en place un site Web présentant les lignes directrices officielles de TC sur les durées d'efficacité, afin d'éliminer les risques de sécurité associés à la possibilité de divergences lorsque l'information sur les durées d'efficacité est publiée à plusieurs endroits. Depuis lors, APS a procédé à la mise à jour annuelle de ce site Web, pour refléter les changements apportés aux lignes directrices et assister TC et la FAA dans l'élaboration de leurs documents d'orientation.

Présentations, rapports aux fabricants de liquides et procédures d'essais pour 2017-2018 (Section 9)

APS a produit un certain nombre de présentations, de rapports aux fabricants de liquides et de procédures d'essais pour le programme d'essais de l'hiver 2017-2018. Le présent rapport contient une description de cette documentation.

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GLOSSARY

A4A	Airlines for America
APS	APS Aviation Inc.
AWG	G-12 Aerodynamics Working Group
EG	Ethylene Glycol
FAA	Federal Aviation Administration
HOT	Holdover Time
LOUT	Lowest Operational Use Temperature
MSC	Meteorological Service of Canada
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
PIWT	Propulsion Icing Wind Tunnel
RJ	Regional Jet
SAE	SAE International
TC	Transport Canada
TDC	Transportation Development Centre
UPS	United Parcel Service
3D	Three-Dimensional

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1. INTRODUCTION

Under winter precipitation conditions, aircraft are cleaned with a freezing point depressant fluid and protected against further accumulation by an additional application of such a fluid, possibly thickened to extend the protection time. Prior to the 1990s, aircraft ground deicing had not been extensively researched. As a result of this need for advancement, the aircraft ground icing research program was developed with the aim of overcoming this lack of knowledge.

Since the early 1990s, the Transportation Development Centre (TDC) of Transport Canada (TC) has managed and conducted de/anti-icing related tests at various sites in Canada; it has also coordinated worldwide testing and evaluation of evolving technologies related to de/anti-icing operations with the co-operation of the United States Federal Aviation Administration (FAA), the National Research Council Canada (NRC), the Meteorological Service of Canada (MSC), several major airlines, and deicing fluid manufacturers. There is still an incomplete understanding of some aspects of the hazard and what further can be done to reduce remaining risks posed by the operation of aircraft in winter precipitation conditions. TDC is continuing its research and development program with support from the FAA.

Under contract to the TDC, with financial support from the FAA, APS Aviation Inc. (APS) undertook a research program in the winter of 2017-18 to further advance aircraft ground de/anti-icing research, technology, and information. Each major project completed as part of the 2017-18 research program is documented in a separate individual report. This report documents the remaining general activities and smaller research projects.

1.1 Activities Completed in 2017-18

The general activities and smaller research projects completed in 2017-18 are documented in this report. Each activity is detailed in a separate section as follows (section number in brackets):

a) Flaps and Slats: Wind Direction Sensitivity Testing with Airfoils (Section 2);
b) Summary of Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times (Section 3);
c) Snow Allowance Times (Section 4);
d) Evaluation of Fluid Effectiveness and Characterization of Contamination on High Angle Surfaces: Vertical Stabilizer (Section 5);
e) Maintenance and Upgrade of Snow Machine (Section 6);
f) Technical Review, Approval, and Publication of Historical Reports (Section 7);

g) Publication of Holdover Time Guidance Materials (Section 8); and
h) Presentations, Fluid Manufacturer Reports, and Test Procedures for 2017-18 (Section 9).

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

1.2 Activities Completed with Limited Scope

In addition to the activities described in Subsection 1.1, three activities with limited scope were completed during the winter of 2017-18. These activities are described in the subsections below.

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

1.2.1 Development of SAE Aircraft Ground Deicing Standards

APS provides support to the SAE International (SAE) G-12 Aircraft Ground Deicing industry group in its development of aerospace standards. In 2017-18, 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 Fluid Requalification Working Group

APS provides support to the SAE G-12 Fluid Requalification Working Group. This includes participation in all meetings and, when required, collecting/reviewing historical data, completing data analysis, reviewing changes to SAE standards drafted by the group, and providing expert opinion on specific topics. In the winter of 2017-18, APS attended two in-person meetings and several teleconferences held by this working group.

1.2.3 Support to the SAE G-12 Aerodynamics Working Group

APS provides support to the SAE G-12 Aerodynamics Working Group. This includes participation in all meetings and, when required, collecting data, completing data analysis, and providing expert opinion on specific topics. In the winter of 2017-18, APS attended two in-person meetings.

2. FLAPS AND SLATS: WIND DIRECTION SENSITIVITY TESTING WITH AIRFOILS

This section describes the supplementary work conducted to determine the sensitivity to wind direction of fluid endurance time performance on an airfoil model. This work is a continuation of a sensitivity study conducted during the 2016-17 testing season. This study is part of a multi-year research project which began in the winter of 2009-10.

2.1 Background

Recent research has indicated that early de/anti-icing fluid failure can occur on aircraft flaps and slats that are left deployed during the holdover time (HOT). The greater surface angles of these critical surfaces increase the precipitation catch factor and can cause the fluid to flow-off more readily; this potentially reduces HOTs for aircraft where flaps and slats are deployed prior to anti-icing.

Due to these operational concerns, a multi-year research project was conducted to determine and quantify the effects of deploying flaps and slats prior to anti-icing and to subsequently develop guidance for operators. This project included a variety of testing protocols and platforms, such as wind tunnel testing, flat plate testing, full-scale aircraft testing, and testing with airfoil models.

The primary research objectives were completed during the 2016-17 testing season and, at the conclusion of that year, regulators (through consultation with industry representatives) issued updated operational guidance relating to flap configuration and de/anti-icing. This work is documented in the TC report, TP 15375E, *Testing of Endurance Times on Extended Flaps and Slats (2016-17)* (1).

A wind direction sensitivity study was requested for inclusion by regulators as a supplemental research objective relating to this project. The intent of this study was to characterize the effects of specific airfoil orientations (relative to wind direction) on fluid endurance time performance. However, at the time of completion of the primary research objectives, only limited sensitivity study test runs had been completed, and a request was made by regulators that additional runs be performed in 2017-18 with the goal of bringing the sensitivity study to completion.

This report serves to document the additional sensitivity research conducted during the 2017-18 testing season and to summarize the findings of the study as a whole.

2.2 Objective

The objective of this project was to investigate the effect of specific airfoil orientations (relative to wind direction) on fluid performance, with the intent of characterizing and quantifying the effects of specific orientations.

2.3 Methodology

Testing was conducted using the same procedure that was employed for the wind direction sensitivity tests conducted in 2016-17. A copy of this procedure, *Flaps and Slats Research – Comparative Airfoil Testing*, is provided in Appendix B.

In order to determine the effects of different airfoil configurations on fluid endurance time performance, two equivalent airfoil models were used to conduct fluid endurance time tests in tandem. Each test run featured one static airfoil oriented in the headwind position, with a second static airfoil oriented in one of several fixed 45° increments (headwind, crosswind 45° / 90° / 135°, and tail 180° - one orientation per run). The airfoils were not rotated during the endurance time tests. Running the airfoils in tandem ensured that both surfaces experienced the same natural conditions (precipitation rate, wind speed etc.), leaving airfoil orientation to wind direction as the only variable across the two tests.

A test plan was created separately for testing during the 2017-18 testing season. This test plan was not included in the aforementioned procedure and is shown below in Table 2.1.

Table 2.1: 2017-18 Test Plan for Wind Direction Sensitivity Study

Test Plan #	Objective	Priority	Airfoil #1 Orientation	Airfoil #2 Orientation	Flat Plate Orientation	Fluid	Run Completed?
1	Sensitivity	1	Headwind 0º	Head/Cross 45º	Headwind 0º	Type IV PG - C	Yes
2	Sensitivity	2	Head/Cross 45º	Headwind 0º	Headwind 0º	Type IV PG - C	Yes
3	Sensitivity	1	Headwind 0º	Crosswind 90º	Headwind 0º	Type IV PG - C	Yes
4	Sensitivity	2	Crosswind 90º	Headwind 0º	Headwind 0º	Type IV PG - C	No
5	Sensitivity	1	Headwind 0º	Tail/Cross 135º	Headwind 0º	Type IV PG - C	Yes
6	Sensitivity	2	Tail/Cross 135º	Headwind 0º	Headwind 0º	Type IV PG - C	No
7	Sensitivity	1	Headwind 0º	Tailwind 180º	Headwind 0º	Type IV PG - C	Yes
8	Sensitivity	2	Tailwind 180º	Headwind 0º	Headwind 0º	Type IV PG - C	Yes
9	Calibration	2	Headwind 0º	Headwind 0º	Headwind 0º	Type IV PG - C	Yes
10	Calibration	2	Headwind 0º	Headwind 0º	Headwind 0º	Type IV PG - C	Yes
11	Sensitivity	2	Headwind 0º	Head/Cross 45º	Headwind 0º	Type IV EG - D	Yes
12	Sensitivity	1	Head/Cross 45º	Headwind 0º	Headwind 0º	Type IV EG - D	Yes
13	Sensitivity	2	Headwind 0º	Crosswind 90º	Headwind 0º	Type IV EG - D	Yes
14	Sensitivity	1	Crosswind 90º	Headwind 0º	Headwind 0º	Type IV EG - D	Yes
15	Sensitivity	2	Headwind 0º	Tail/Cross 135º	Headwind 0º	Type IV EG - D	Yes
16	Sensitivity	1	Tail/Cross 135º	Headwind 0º	Headwind 0º	Type IV EG - D	Yes
17	Sensitivity	2	Headwind 0º	Tailwind 180º	Headwind 0º	Type IV EG - D	Yes
18	Sensitivity	1	Tailwind 180º	Headwind 0º	Headwind 0º	Type IV EG - D	Yes
19	Calibration	2	Headwind 0º	Headwind 0º	Headwind 0º	Type IV EG - D	Yes
20	Calibration	2	Headwind 0º	Headwind 0º	Headwind 0º	Type IV EG - D	Yes

2.3.1 Fluids

All tests were conducted using mid-viscosity samples of commercially available anti-icing fluids. The viscosities of the fluids were checked to confirm that they fell within their respective production ranges. The fluids used for the 2016-17 sensitivity test runs had their viscosities checked in 2016-17; the fluids used in the 2017-18 sensitivity test runs had their viscosities checked, or re-checked, in 2017-18. The results of the viscosity tests are summarized below in Table 2.2.

Table 2.2: Testing Fluids – Viscosity Information

Manufacturer	Fluid	Dilution	Year Used	Batch #	Viscosity Details					
					Method Type	Method (a-n)	Production Min	Production Max	Mfr Stated Viscosity	APS Measured Viscosity
Clariant Produkte	Safewing MP II FLIGHT	100/0	2016-17	DEG4 145492	AS	a	6,000	14,000	10,920	11,200
Cryotech Deicing Technology	Polar Guard Advance 2nd Shipment	100/0	2017-18	PGA161216PA	AS	a	8,000	16,200	14,400	14,840
Dow Chemical Company	UCAR™ Endurance EG 106 2nd Shipment	100/0	2017-18	D268GAC000	MFR	h	29,500	47,800	43,390	40,200
Kilfrost Ltd.	ABC-S Plus	100/0	2016-17	WT.12.13.ABC-S+	*Info not available*					

2.4 Data

A total of 19 test runs were conducted in 2017-18. Six additional wind direction sensitivity test runs were previously conducted during the winter of 2016-17, bringing the total number of test runs to 25. Each test run is comprised of four individual tests run on different surfaces (Airfoil #1, Airfoil #2, 10° Plate and 20° Plate), for a total of 100 tests.

A log containing details on all wind direction sensitivity tests conducted in both 2016-17 and 2017-18 is provided in Appendix C.

2.5 Analysis

Each test run featured two static (non-rotating) airfoils, one in the headwind orientation and the other in a variety of orientations (headwind, crosswind 45° / 90° / 135°, and tail 180° – one orientation per run).

In order to determine the effect of specific airfoil orientations on fluid endurance time performance, the endurance time test results on the oriented airfoil were compared to the results from the headwind airfoil for each test run. Table 2.3 summarizes these results by oriented airfoil position.

Table 2.3: Oriented Airfoil Performance by Specific Orientation

Airfoil Orientations	Run Count	Average % Increase in Endurance Time (Oriented Airfoil vs. Headwind Airfoil)	StDev
Head 0° / Head 0°	4	-1%	7%
Cross 45° / Head 0°	6	6%	31%
Cross 90° / Head 0°	4	45%	42%
Cross 135° / Head 0°	4	101%	73%
Tail 180° / Head 0°	7	49%	57%

The Head 0° / Head 0° (both airfoils oriented into headwind) runs served as calibration runs; these were intended to establish the equivalence of both airfoils. On average, a 1 percent change in endurance time performance across the two airfoils was observed during these runs, which suggests that the surfaces are in fact equivalent.

The results were in line with what was observed in 2016-17. There is a general trend of improved fluid endurance time performance as the airfoil is oriented out of the headwind position, with a sharper improvement nearing the 90° threshold. The relationship between airfoil orientation and fluid endurance time performance is presented below in Figure 2.1.

This observed increase in performance is dependent on the environmental conditions at the time of a given test run, as evidenced by the high standard deviations seen in Table 2.3. Specifically, the performance increase observed in the tailwind 180° orientation tests (as compared to the cross 90° and cross 135° tests) was not as great as expected; this is likely linked to low wind speeds and/or very high precipitation rates experienced during a portion of these test runs, which may have skewed the results.

Nonetheless, a clear trend is observed: fluid endurance time performance on an airfoil model is generally improved by orienting the model out of the wind. The magnitude of the improvement increases significantly at angles equal to or greater than 90° to the wind.

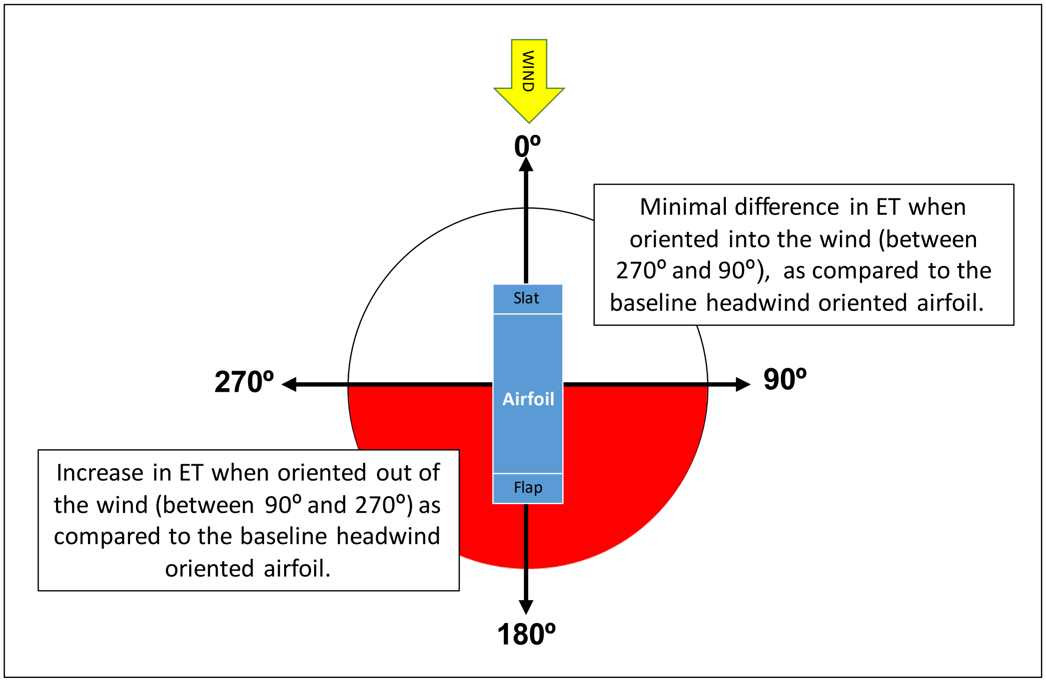

Figure 2.1: Simplified Summary of Wind Direction Sensitivity Results

2.6 Conclusions and Recommendations

Fluid endurance time performance on an airfoil model is generally improved by orienting the model out of the wind, with the magnitude of the improvement increasing significantly at angles of 90° and greater to the wind. The specific improvement observed in a given event is strongly affected by surrounding environmental factors: in particular, wind speed and rate of precipitation.

The results obtained are in-line with the findings from the limited tests conducted in 2016-17. As such, no changes to the existing guidance concerning HOTs and flap configuration are recommended at this time.

3. SUMMARY OF WIND TUNNEL TRIALS TO SUPPORT FURTHER DEVELOPMENT OF ICE PELLET ALLOWANCE TIMES

This section describes the 2017-18 wind tunnel trials to support further development of ice pellet allowance times.

NOTE: At the time of writing of this report, analysis and technical discussions were still ongoing. Therefore, this brief testing summary was compiled in place of a detailed technical report. The detailed 2017-18 testing results will be included with the next wind tunnel trials report, expected in the winter of 2018-19.

3.1 Background

Research at the National Research Council Canada (NRC) Propulsion Icing Wind Tunnel (PIWT) with and without ice pellets has been conducted on a yearly or bi-yearly basis since the winter of 2006-07. The testing has been performed by APS Aviation Inc. (APS), with support of the NRC, on behalf of Transport Canada (TC) and the Federal Aviation Administration (FAA). The focus of the research has been to further develop the ice pellet allowance time tables and to ensure that new fluids meet or exceed the generic times listed in those tables. In addition, the wind tunnel has served as a platform to explore other industry driven ground deicing projects.

3.2 Objective

A wind tunnel testing program was developed for the winter of 2017-18 with the primary objectives of conducting aerodynamic testing to:

a) Substantiate the current Type IV fluid ice pellet allowance times with new fluids and at temperatures close to the fluid lowest operational use temperature (LOUT) using the thin high-performance regional jet (RJ) airfoil;

b) Possibly extend the current Type IV fluid ice pellet allowance times for ethylene glycol (EG) fluids using the thin high-performance RJ airfoil; and

c) Evaluate the current Type III fluid ice pellet allowance times at 80 knots using the LS-0417 low speed airfoil, which required additional calibration / characterization testing with the support of National Aeronautics and Space Administration (NASA).

The statement of work for these tests is provided in Appendix A.

3.3 Test Methodology

The procedure for the wind tunnel trials is included in Appendix D. The procedure includes details regarding the test objectives, test plan, procedure and methodology, and pertinent information and documentation.

3.4 Fluids

Mid-viscosity fluid samples were used in the wind tunnel tests. The fluid information for the new samples received, as well as for the samples remaining from previous years' inventory is provided in Table 3.1. For reference, the table includes the viscosity information collected in 2017-18, and historical information for specific fluid batches in inventory at the start of the testing.

It should be noted that testing was conducted only with the following fluids:

- AllClear Systems LLC AeroClear MAX;
- CHEMCO Inc. ChemR EG IV; and
- Inland Technologies ECO-SHIELD®.

It should be noted that testing was also planned with the following two additional fluids. However, due to shipping logistics, the fluid was not received in time for the testing:

- Clariant Produkte (Deutschland) GmbH Max Flight AVIA; and
- Clariant Produkte (Deutschland) GmbH Max Flight SNEG.

Table 3.1: Wind Tunnel Fluid Inventory Information

						2012-13			2013-14			2014-15			2015-16			2017-18		
Sample Name	**Dilution**	**Batch #**	**Year Rec'd**	**2017-18 Receiving Qty (L)**	**Leftover Inventory Pre 2017-18 (L)**	**Measured Viscosity (cP)**	**Falling Ball Temp. (°C)**	**Falling Ball Time (mm:ss)**	**Measured Viscosity (cP)**	**Falling Ball Temp. (°C)**	**Falling Ball Time (mm:ss)**	**Measured Viscosity (cP)**	**Falling Ball Temp. (°C)**	**Falling Ball Time (mm:ss)**	**Measured Viscosity (cP)**	**Falling Ball Temp. (°C)**	**Falling Ball Time (mm:ss)**	**Measured Viscosity (cP)**	**Falling Ball Temp. (°C)**	**Falling Ball Time (mm:ss)**
Clariant Safewing MP II FLIGHT	100/0	DEG 4145408 (EASA)	2014-15		150							13,600	22.4	0:26		22.9	0:26			
Dow UCAR™ FlightGuard AD-49	75/25	L14-290 (EASA)	2014-15		140							36,000	22.0	0:48		20.2	0:47			
Cryotech Polar Guard Advance	50/50	12964 (EASA)	2014-15		100							5320	22.4	0:03						
Kilfrost ABC-S Plus	100/0	WT 13-14 ABC-S+	2013-14		200				19,800	21.7	0:37				27,100	19.5	0:32	36,200	19.7	0:49
Dow FlightGuard AD-49	100/0	WT 12-13 AD-49	2012-13		180	14,397	21.6	0:19	14,100	20.5	0:21				13,200	19.4	0:22	13,480	n/a	n/a
Cryotech Polar Guard Advance	100/0	WT 13-14 PGA	2013-14		140				15,400	20.6	0:25				16040	19.5	0:24	15,980	n/a	n/a
AllClear AeroClear MAX	100/0	TAB15-PB1112	2015-16												13,800	19.7	0:02			
LNT E450	100/0	WT.15.16.LNTE450	2015-16												47,400	20.5	0:42			
Newave FCY 9311	100/0	151113005	2015-16												24500	20.1	0:42			
AllClear AeroClear MAX	100/0	TAB17-1023	2017-18	400														16,500	19.0	0:02
Inland ECO-SHIELD	100/0	n/a	2017-18	300														n/a	n/a	n/a
CHEMCO ChemR EG IV	100/0	IV 35317-1	2017-18	400														46,000	19.6	0:13
Clariant MaxFlight AVIA	100/0	41	2017-18	400														1,838	19.6	0:08
Clariant MaxFlight SNEG	100/0	8	2017-18	400														18700	19.6	0:39

Note: Viscosity measured using manufacturer method.

3.5 Data

Two test logs have been included in Appendix E and Appendix F. They contain data for the tests conducted with the thin high-performance RJ airfoil, and the LS-0417 low speed airfoil, respectively.

3.6 Summary of Data Collected

The following sections provide a summary of the data collected.

3.6.1 Substantiation of the Current Type IV Fluid Ice Pellet Allowance Times

The Type IV fluid ice pellet allowance times are developed based on data collected using commercially available Type IV fluids. The Type IV fluid ice pellet allowance times are generic and therefore conservative. As new fluids are developed and become commercially available, it is important to evaluate these fluids against the current allowance times to ensure the validity of the generic guidance. Systematic "spot-checking" is used in order to identify any potential issues. In addition, testing is recommended with all available fluids to obtain data close to the fluid LOUT; this further allows the aerodynamic effects of ice pellet contamination at colder temperatures to be determined. To meet these requirements, testing during the winter of 2017-18 was conducted with two fluids:

- CHEMCO Inc. ChemR EG IV; and
- Inland Technologies ECO-SHIELD®.

Based on the results and on-site analysis conducted during the trials, both fluids demonstrated acceptable results. It should be noted that due to an issue with fluid batches received, the Inland Technologies ECO-SHIELD® will likely require some additional testing.

The details of these testing results will be included with the next wind tunnel trials report expected in the winter of 2018-19.

It should be noted that testing was also planned with the following two fluids. However, due to shipping logistics, the fluid was not received in time for the testing:

- Clariant Produkte (Deutschland) GmbH Max Flight AVIA; and
- Clariant Produkte (Deutschland) GmbH Max Flight SNEG.

The two fluid samples received will be stored and made available for the next wind tunnel trials report expected in the winter of 2018-19.

3.6.2 Possible Extension of Type IV Fluid Ice Pellet Allowance Times for EG Fluids

Type IV fluid ice pellet allowance times are intended to be conservative, and therefore generic guidance is developed based on data collected using commercially available Type IV fluids. Historically, both Type IV propylene glycol and ethylene glycol (EG) fluids have been grouped together; however, data has indicated that EG may have an operational advantage of longer ice pellet allowance times in specific conditions. Consequently, the industry requested that EG-specific fluid ice pellet allowance time tables be considered. This would allow operations to benefit from any potential longer allowance times specific to Type IV EG fluids.

Previously collected data from two EG fluids was reviewed and is included in Appendix G. The results indicated that there is a potential to extend the ice pellet allowance times for Type IV EG-based fluids.

In addition, a limited number of tests targeting longer allowance times for EG fluids were conducted during the winter of 2017-18 with a third fluid: CHEMCO Inc. ChemR EG IV. Based on the on-site analysis conducted during the trials, the results were in line with the previous findings and indicate a potential to extend the allowance times for EG fluids.

The results of this preliminary research, obtained through analysis and the collection of additional data, indicate the potential to extend the Type IV allowance times for EG fluids. In the future, guidance could be developed as either fluid-specific or generic for all EG fluids. Discussions with industry and the regulators will be required to determine the specific needs and format of the guidance moving forward.

The details of these testing results will be included with the next wind tunnel trials report expected in the winter of 2018-19.

3.6.3 Type III Fluid Ice Pellet Allowance Times at 80 Knots Using the LS-0417 Low Speed Airfoil

Type III fluid allowance times have recently been developed, but are limited to use with aircraft with rotation speeds of 100 knots or greater. Type III fluids can often be used with lower rotation speed aircraft, therefore, there is a requirement to have these allowance times validated for use at these lower speeds. The LS-0417 is a more representative airfoil to conduct low speed testing at 80 knots, however, the characteristics of the airfoil have yet to be fully investigated.

The testing conducted during the winter of 2017-18 was done primarily with AllClear Systems LLC AeroClear MAX, and included the following tests:

- Clean wing tests to evaluate performance through pitch pause, angle sweeps, and stall runs, and to verify repeatability;
- Tuft testing to better understand boundary layer separation and uniformity of flow;
- Boundary layer trip testing to establish wing sensitivity;
- Fluid testing with and without contamination to evaluate repeatability of results; and
- Fluid testing to determine the lift loss limits for the LS-0417 wing sections using the lift loss scaling technique.

This testing was done with the support of NASA. The results are currently being reviewed, analysed, and will be published in a separate report by NASA. The need for additional testing will be determined once the NASA analysis is complete.

The details of these testing results will also be included with the next wind tunnel trials report by APS expected in the winter of 2018-19.

3.7 Recommendations

The following recommendations have been derived.

3.7.1 Additional Analysis and Report Writing

It is recommended that the detailed analysis and report writing be completed. In addition, NASA will independently be conducting an analysis and report. It is anticipated that the results will be included with the next wind tunnel trials report expected in the winter of 2018-19 by APS.

3.7.2 Future Testing

It is anticipated that testing will continue for the winter of 2018-19. The following objectives should be targeted:

- Testing of new to market fluids (it is anticipated that one or two of these fluids will be submitted for testing);

- Clariant Produkte (Deutschland) GmbH Safewing EG IV NORTH;
- Oksayd Co. Ltd. Defrost ECO 4;
- Oksayd Co. Ltd. Defrost EG 4; and
- Shaanxi Cleanway Aviation Chemical Co., Ltd Cleansurface IV.

- Testing with the late-received fluids;
  - Clariant Produkte (Deutschland) GmbH Max Flight AVIA; and
  - Clariant Produkte (Deutschland) GmbH Max Flight SNEG.
- Re-testing of Inland Technologies ECO-SHIELD®;
- Testing to support continued development of the Type III fluid 80 knots table;
- Testing to support continued development of a Type IV EG-specific table; and
- Type IV fluid ice pellet allowance time testing at colder temperatures, higher rates, and different conditions in order to expand or extend the existing allowance times.

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4. SNOW ALLOWANCE TIMES

This section describes the 2017-18 activities related to snow allowance times. The section of the statement of work pertaining to this activity is provided in Appendix A.

4.1 Background

As a direct result of the ice pellet research conducted, alternative ways for determining protection time for anti-icing fluids are being reviewed at the request of industry. The focus has turned towards a term anecdotally referred to as “aerodynamic failure”; this refers to the point where an unacceptable aerodynamic degradation in performance is observed as a direct result of contaminated anti-icing fluid. As one would never want to operate at the “aerodynamic failure” point, moving forward we will refer to and use the term “aerodynamic limit.” The latter refers to a point before the “aerodynamic failure” that allows enough margin in operations to maintain safety of flight.

Holdover times (HOTs) are developed based on a visual evaluation of fluid failure on test plate surfaces measuring 30 cm x 50 cm (12” x 20”). In comparison, ice pellet allowance times are developed using a combination of both aerodynamic performance data and visual evaluations. In some cases, the ice pellet allowance times are limited by the visual evaluation rating (significant contamination is visible), but still perform well aerodynamically. The industry, through Airlines for America (A4A), has requested an investigation into the feasibility of using primarily the aerodynamic performance data to evaluate the integrity of the contaminated fluid rather than be limited by visual evaluations.

4.2 Previous Relevant Research

Wind tunnel testing has been conducted on a yearly or bi-yearly schedule since 2006-07 with the aim of further developing guidance for operations in ice pellets. In conjunction with this work, some preliminary data considering heavy snow, and extreme levels of contamination, have been conducted. Although indirectly relatable to snow allowance times, this research considered flow-off in conditions where fluid would be visibly failed and could provide some insight moving forward. This data has been reported on yearly and presented, accordingly, at annual SAE International (SAE) G-12 meetings.

In addition, a TC report, TP 14377E, *Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces* (2), was published, which investigated the conditions that prompt adherence after de/anti-icing. This research indicated that Type I can adhere in Snow conditions, but not Type II/IV.

4.3 Acknowledgments and Caveats

Transport Canada (TC) and the Federal Aviation Administration (FAA) agreed to support APS Aviation Inc. (APS) in the preparation of a presentation for the SAE G-12 Aerodynamics Working Group (AWG) and HOT Committee meeting in Austin, Texas in May 2018 to provide an outline for a basic testing methodology. This did not constitute an agreement from the regulators (TC and the FAA) to develop guidance or to support further research. The presentation was solely for discussion purposes, and not an endorsement by the regulators for the content or concepts described herein. The two presentations given by APS at the AWG and HOT Committee in Austin, Texas in May 2018 are provided in Appendix H.

The purpose of the presentation prepared by APS was to provide a structured testing methodology for discussion purposes in response to the requests made by A4A. A presentation that covered industry needs, as well as the request put forth by A4A, was given by the United Parcel Service (UPS) on industry's behalf. In addition, FAA presented their independent position with respect to the subject matter. The three presentations were provided at the AWG meeting in Austin, Texas in May 2018, and an abbreviated version was also presented at the HOT Committee in Austin in May 2018.

4.4 Snow Allowance Time Concept

The presentations given by APS at the AWG and HOT Committee in Austin, Texas in May 2018 proposed a basic methodology as the basis for developing snow allowance times. The concept would apply the ice pellet allowance time methodology to snow conditions. The following provides an overview of the proposed methodology:

- Determine aerodynamic limit using clean fluid as close to the lowest operational use temperature (LOUT) as possible;
- Test clean fluid and contaminated fluid, and compare performance against the aerodynamic limit (pass/fail);
- Repeat tests modifying contamination exposure times to determine what margins exist; and
- Determine snow allowance times based on the tests that pass.

Note that the "Lift-Loss Scaling" technique developed by National Aeronautics and Space Administration (NASA), National Research Council Canada (NRC), and APS [refer to the NASA report, NASA/TM—2012-217701 (3)] could be applied to overcome temperature limitations, or when a generic approach is preferred.

An example of how data could be collected and analysed as per the methodology described above is shown in Figure 4.1.

In order to use the snow allowance times, a change in operating procedures would need to be considered. This is because HOTs provide a range of times that can be extended using a pre-takeoff contamination inspection (PTCI) or a pre-takeoff contamination check (PTCC), whereas allowance times are single value times that cannot be extended.

Additional details are included in the presentations provided in Appendix H.

4.5 Recommendations

It is recommended that discussions with industry continue in order to better understand needs for guidance in snow, and to develop a plan with industry input on how best to move forward. With industry support, proof-of-concept testing that identifies the benefits of snow allowance times should be considered for the winter of 2018-19.

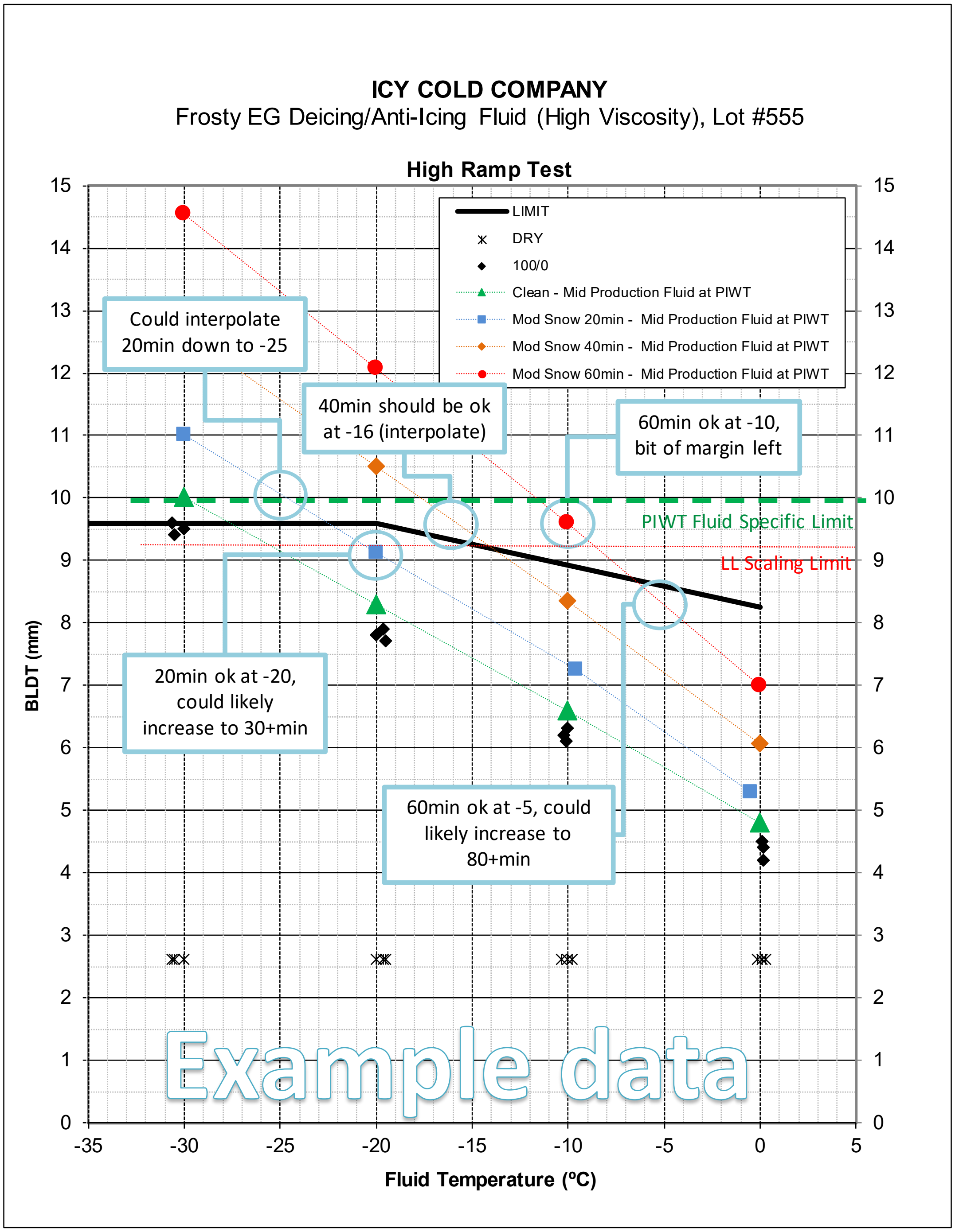

Figure 4.1: Snow Allowance Time Methodology Example

5. EVALUATION OF FLUID EFFECTIVENESS AND CHARACTERIZATION OF CONTAMINATION ON HIGH ANGLE SURFACES: VERTICAL STABILIZER

This section describes the 2017-18 activities related to the evaluation of fluid effectiveness and characterization of contamination on high angle surfaces including the vertical stabilizer. The section of the statement of work pertaining to this activity is provided in Appendix A.

5.1 Background

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

Current Transport Canada (TC) and Federal Aviation Administration (FAA) rules and regulations require that critical surfaces be free of contamination prior to takeoff. The vertical stabilizer is defined as a critical surface by both TC and the FAA. However, from a regulatory implementation and enforcement standpoint, there is currently no standardized guidance that offers inspectors a means to determine if an air operator is complying with operational rules. If current operational rules aim to achieve the clean aircraft concept – which requires the tail to have zero adhering frozen contamination – the question remains: How can this be adequately achieved, or appropriately mitigated by operators, to ensure a satisfactory level of safety (see Figure 5.1)?

5.2 Previous Work

Based on consultations held in 2015-16 with TC, the FAA, and National Aeronautics and Space Administration (NASA), the following research objectives were identified:

a) Verify if contamination is present on the vertical tail pre-deicing, and if so, under what conditions, and characterize (size, surface extent) that level of contamination;

b) Verify if contamination is present on the vertical tail post-deicing, and if so, under what conditions, and characterize (size, surface extent) that level of contamination; and

c) Identify and evaluate optimal deicing procedures and mitigation plans, and identify effectiveness of these methods or means.

The research objectives were intended to span over two research years or more. At the request of TC and the FAA, APS Aviation Inc. (APS) undertook a research plan to evaluate de/anti-icing fluid effectiveness and characterize contamination on high angle surfaces. Only research objectives a) and b) were attempted in 2015-16. The details of this research are included in the TC report, TP 15340E, *Aircraft Ground Icing General Research Activities During the 2015-16 Winter* (4).

Due to other priorities and limited funds, the research was discontinued in 2016-17 and 2017-18.

Figure 5.1: Regulation of Deicing Operations With Respect to Vertical Stabilizer

5.3 Information Dissemination

The research conducted during the winter of 2015-16 was informally discussed with industry at the SAE G-12 meetings in Savannah, Georgia (May 2016), and Athens, Greece (May 2017). In 2017-18, at the request of TC and the FAA, APS prepared a presentation of the work conducted for formal dissemination of the information to industry. The presentation was prepared and presented at the SAE G-12 Holdover Time Committee meeting held in May 2018 in Austin, Texas. A copy of the presentation has been included in Appendix H.

5.4 Recommendations

It is recommended that research resume for the winter of 2018-19. The plan originally set forth by TC, the FAA, and NASA for the winter of 2015-16 should be reviewed and adjusted as required. Research should focus on the characterization of contamination using three-dimensional (3D) scanning and/or wind tunnel testing. Research should also focus on identifying and evaluating optimal deicing procedures and mitigation plans, and identifying the effectiveness of these methods or means.

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6. MAINTENANCE AND UPGRADE OF SNOW MACHINE

This section provides an update on activities performed to maintain and upgrade the APS Aviation Inc. (APS) snow machine in 2017-18.

6.1 Background

Recently, APS had the opportunity to conduct side-by-side testing with two snow machines: the National Center for Atmospheric Research (NCAR) snow machine owned by APS, and the original machine operated by NCAR. The latter was borrowed to supplement previous research. Using the NCAR machine as a standard, it was determined that the APS snow machine was not running as optimally. Upgrades to the scales, carbide blades, and distribution system were required.

Moreover, the use of the APS snow machine was halted in April 2017, when the last of the original scales used for rate precipitation became unrepairable. Since the original scales are long obsolete, attempts to source an exact replacement proved to be impossible.

A separate contract was developed with NCAR in which a new scale and new computer were integrated into the APS snow machine. NCAR initially sourced a new scale; however, this scale proved to be unstable in the harsh environmental conditions the snow machine is used in. It was determined that a more robust scale should be used.

6.2 Objective

The objective of these activities is to support maintenance and upgrades to the snow machine to ensure optimal operation.

6.3 Activities Completed

As mentioned in Subsection 6.1, upgrade and repairs had to be made to the scales, carbide blades, and distribution system. Subsections 6.3.1 to 6.3.3 provide a summary of these upgrades and repairs.

6.3.1 Upgraded Weigh Scale

Subsection 6.1 discussed the need to source a new robust scale. After identifying the limitations of previous scales, an industrial scale that could withstand cold, wet conditions and significant vibration was selected. Before significant investment was made, APS borrowed the same model scale from the National Research Council Canada (NRC) as they had one on hand.

APS sourced a programmer to integrate this new scale into the snow machine system. Significant testing was performed to ensure that the new scale would operate with the same accuracy as the original scales. Once it was proved that this new scale would be suitable, two scales (one main scale and one back-up scale) were purchased and integrated into the system.

6.3.2 Maintenance of Carbide Blades

Side-by-side comparison testing of the APS and NCAR snow machines indicated that there were significant discrepancies in the snow size and shape produced from the two machines. It became apparent that the APS snow machine was not producing snow as optimally as the NCAR snow machine; at times producing broken bits of ice rather than snow. It was determined that the dullness of the carbide blades was causing this issue. The carbide blades were subsequently sent back to NCAR for re-sharpening. These re-sharpened blades provided optimum snow size and texture much more representative of natural snow.

The importance of the sharpness of the carbide blades became apparent. Efforts were made to catalogue the blades currently in APS inventory to track their use. To determine when and how often the carbide blades should be sharpened, comparative testing will be proposed for the development of an appropriate protocol.

6.3.3 Upgrade of Snow Distribution System (Fan Installation)

NCAR had a recent design change in which the original air jet distribution system was to be replaced with small fans. NCAR has indicated that using well positioned fans provide a better distribution of snow across the test plate then the original system. With instruction from NCAR, APS installed the fans to the same specifications. Three fans were added to control the distribution of snow.

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

This section describes the process used by APS Aviation Inc. (APS) to publish reports. It also details the status of the technical review of old reports in the publication process, and provides guidance for handling such reports subsequently.

7.1 Background

As of December 1, 2017, APS has prepared over 194 reports on aircraft ground icing research and development on behalf of Transport Canada (TC) and the Federal Aviation Administration (FAA). Of these 194 reports, 113 reports remained unpublished. This backlog is attributed to limited resources and shifting priorities within TC and the FAA.

7.2 Objective

To remedy this backlog, APS was tasked by TC and the FAA to develop a prioritized list of unpublished reports, accelerate these reports through the publication process and release them as Final Version 1.0. The objective of this project for winter 2017-18 was to complete these tasks for 20 reports (targets for subsequent years will be determined at the completion of each year).

This objective was achieved by utilising the following measures:

- Coordinate and outsource technical and editorial reviews of reports with technical experts;
- Perform technical and editorial reviews (to be done by technical and editorial experts), and make necessary updates to prepare reports for final editing and publishing; and
- Provide a status of progress within the monthly progress reports.

7.3 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 by utilising a detailed report management process that it has developed and continuously updates. Figure 7.1 displays the updated report timeline offering a global view of the entire process. It includes all the phases with their respective milestones and detailed tasks from initiation to publication.

The report management timeline is comprised of seven phases. The first three are internal to APS and labelled Internal Phase 1, 2, and 3, respectively. The following four phases are related to the publication of a report and are labelled Publication Phase 1, 2, 3, and 4, respectively. Reports typically undergo these phases prior to delivery of Final Version 1.0.

For the year 2016-17, APS surpassed the goal of 12 reports and published 16 reports in total. These reports were published and delivered to TC and the FAA as Final Version 1.0. The details of the reports published in 2016-17 are provided in TC report, TP 15374E, *Aircraft Ground Icing General Research Activities During the 2016-17 Winter* (5). For the year 2017-18, APS surpassed the goal of 20 reports and published 22 reports as shown in Table 7.1. These reports were published and delivered to TC and the FAA as Final Version 1.0 via "WeTransfer" and USB drives.

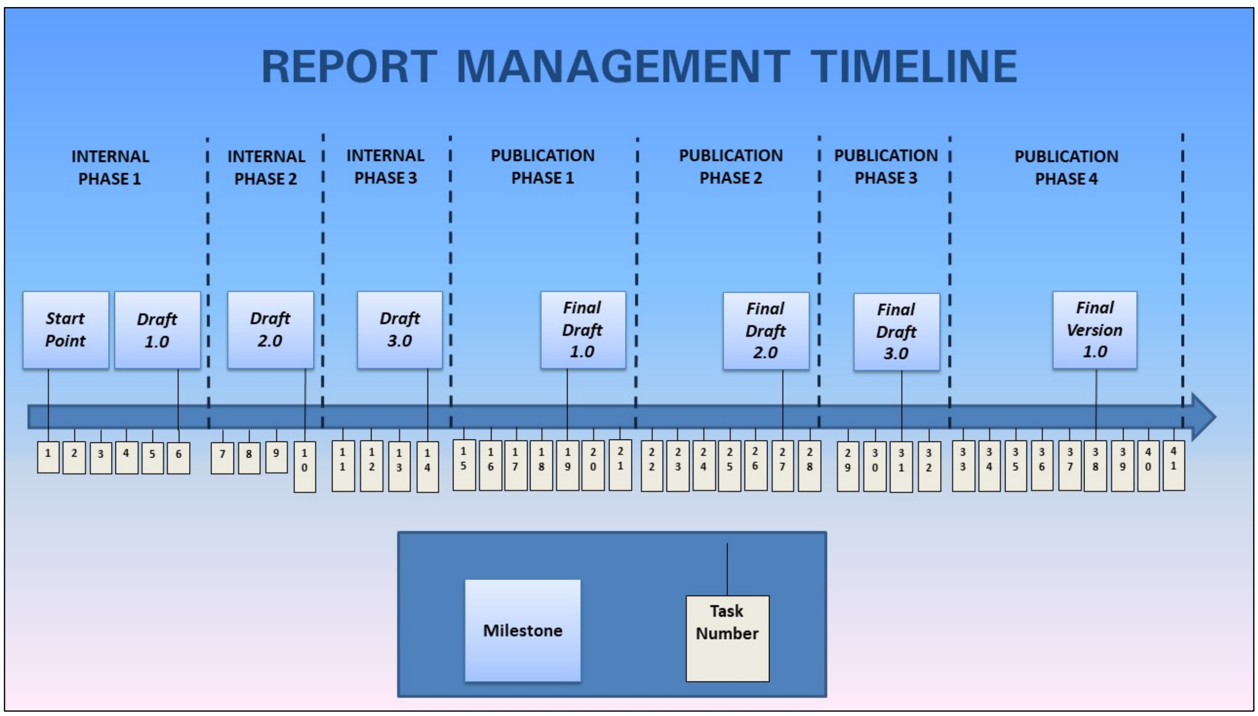

Figure 7.1: Report Management Timeline

Table 7.1: List of Technical Reports to be Published (2017-18)

No.	TP Number	Year	Report Title	Category	Priority	Latest Version	Publication Date
1	TP 14935E	2008-09	Research for Further Development of Ice Pellet Allowance Times: Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-off Characteristics Winter 2008-09	Ice Pellet	2	Final Version 1.0	January 19, 2018
2	TP 14452E	2006-07	Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681	ROGIDS	3	Final Version 1.0	February 2, 2018
3	TP 15375E	2016-17	Testing of Endurance Times on Extended Flaps and Slats (2016-17)	Deployed Flaps	1	Final Version 1.0	March 5, 2018
4	TP 14938E	2008-09	Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions	Frost	3	Final Version 1.0	March 29, 2018
5	TP 15372E	2016-17	Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2016-17 Winter	Hot	1	Final Version 1.0	June 28, 2018
6	TP 14447E	2004-05	Effect of Heat on Endurance Times of Anti-Icing Fluids	Hot vs. Cold	3	Final Version 1.0	July 31, 2018
7	TP 14377E	2003-04	Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces	Adhesion	3	Final Version 1.0	August 3, 2018
8	TP 14713E	2005-06	Aircraft Deicing Research in Natural and Simulated Ice Pellet Conditions	IP Research	3	Final Version 1.0	August 16, 2018
9	TP 14718E	2005-06	Preliminary Endurance Time Testing in Simulated Ice Pellet Conditions	IP Conditions	3	Final Version 1.0	August 16, 2018
10	TP 15374E	2016-17	Aircraft Ground Icing General Research Activities During the 2016-17 Winter	G & E	1	Final Version 1.0	August 31, 2018
11	TP 15373E	2016-17	Regression Coefficients and Equations Used to Develop the Winter 2017-18 Aircraft Ground Deicing Holdover Time Tables	Regressions	1	Final Version 1.0	September 13, 2018
12	TP 14782E	2006-07	Regressions Coefficients Used to Develop the Winter 2007-08 Type I Generic and Dow UCAR Endurance EG106 Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
13	TP 14873E	2007-08	Regressions Coefficients Used to Develop the Winter 2008-09 Aircraft Ground Deicing Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
14	TP 14937E	2008-09	Regressions Coefficients Used to Develop the Winter 2009-10 Aircraft Ground Deicing Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
15	TP 15054E	2009-10	Regressions Coefficients Used to Develop the Winter 2010-11 Aircraft Ground Deicing Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
16	TP 15159E	2010-11	Regressions Coefficients Used to Develop the Winter 2011-12 Aircraft Ground Deicing Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
17	TP 15198E	20011-12	Regressions Coefficients Used to Develop the Winter 2012-13 Aircraft Ground Deicing Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
18	TP 15229E	2012-13	Regressions Coefficients Used to Develop the Winter 2013-14 Aircraft Ground Deicing Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
19	TP 15270E	2013-14	Regressions Coefficients Used to Develop the Winter 2014-15 Aircraft Ground Deicing Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
20	TP 15322E	2014-15	Regressions Coefficients Used to Develop the Winter 2015-16 Aircraft Ground Deicing Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
21	TP 15339E	2015-16	Regressions Coefficients Used to Develop the Winter 2016-17 Aircraft Ground Deicing Holdover Time Tables	Regressions	3	Final Version 1.0	September 13, 2018
22	TP 14874E	2007-08	Effect of Heat on Endurance Times of Anti-Icing Fluids	Effect of Heat	3	Final Version 1.0	September 28, 2018

7.3.1 Overall Publication Status of Technical Reports

The overall status of the reports as of December 1, 2017 was as follows:

- Published reports: 81;
- Non-published reports: 113; and
- Total reports: 194.

During 2017-18, the following reports were delivered to TC and the FAA as Final Version 1.0:

- One report from 2003-04;
- One report from 2004-05;
- Two reports from 2005-06;
- Two reports from 2006-07;
- Two reports from 2007-08;
- Three reports from 2008-09;
- One report from 2009-10;
- One report from 2010-11;
- One report from 2011-12;
- One report from 2012-13;
- One report from 2013-14;
- One report from 2014-15;
- One report from 2015-16; and
- Four reports from 2016-17.

As stated in Subsection 7.3, 22 reports from past years were delivered to TC and the FAA as Final Version 1.0. Furthermore, a detailed analysis of all past APS reports was conducted and they were consequently re-categorized.

The overall status of the reports with the new categorization as of October 31, 2018 is presented in Table 7.2.

Table 7.2: Overall Status of Reports as of October 31, 2018

Category	Description	No.
Published Reports	TP reports that are published as Final Version 1.0.	103
Interim Reports	Reports that were initially produced as interim and subsequently incorporated into a TP report.	21
Interim Reports	Reports that have not been assigned TP numbers and will not be published; However, some information contained in these reports is included in a subsequent TP report.	2
Protected Reports	Reports that are not for distribution; 2 reports for the Department of National Defence and 1 Ops Survey report for TC.	3
Non-published Reports	TP reports that are still in Draft stages.	64
Interim Reports	Reports that have not been assigned TP numbers and may be published.	5
Total Reports	Total number of reports produced by APS.	**198**

In addition, APS is currently working on four reports for the winter 2017-18 research activities; these are not included in the totals as of October 31, 2018.

Assuming that APS will publish 20 reports per year (four current year reports, and 16 old reports), it will take approximately 4.5 years to clear the backlog.

7.4 Conclusions

APS has been involved in writing and publishing technical reports on behalf of TC and the FAA since 1992 and has prepared 198 reports. Due to TC and the FAA's limited resources, 124 reports were still outstanding in 2015-16, and APS was tasked with developing a prioritized list of unpublished reports that needed to be reviewed and published. In 2016-17, APS published 16 reports that were delivered to TC and the FAA as Final Version 1.0 in October 2017. In 2017-18, APS published 22 reports that were delivered to TC and the FAA as Final Version 1.0 in October 2018.

7.5 Recommendations

Since APS has taken a more active role in completing this project, it is recommended that proper resources be dedicated to publishing these reports on a yearly basis. It should also be noted that APS has contracted subject matter experts to fulfill the publication requirements and remains heavily involved in all phases of report publication.

8. PUBLICATION OF HOLDOVER TIME GUIDANCE MATERIALS

This section describes the work APS Aviation Inc. (APS) completed in the winter of 2017-18 in support of Transport Canada (TC) and the Federal Aviation Administration (FAA) holdover time (HOT) guidance materials.

8.1 Background

The development and use of HOT guidelines has represented 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.

8.2 APS Contribution to Holdover Time Guidance Materials

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

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

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

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

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

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

f) Provides support for the update of the FAA N8900 series document;

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

h) Updates the TC HOT guidelines website on an annual basis (or more frequently if updates to the HOT guidelines are more frequent); and

i) Hosts the TC HOT guidelines website, and monitors and maintains it on an annual basis.

As of August 7, 2018, the following tasks have been transferred to and are being handled by TC:

a) Updating the TC HOT guidelines website on an annual basis (or more frequently if updates to the HOT guidelines are more frequent); and

b) Hosting, monitoring, and maintaining the TC HOT guidelines website on an annual basis.

8.3 Winter 2018-19 Holdover Time Guidance Materials

In August 2018, the 2018-19 HOT Guidelines and Regression Information documents were finalized. The changes made to the documents are summarized in the documents themselves and are described in detail in two TC reports:

1. **Holdover Time Guidelines:** TP 15396E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2017-18 Winter* (6); and
2. **Holdover Time Regression Information:** TP 15397E, *Regression Coefficients and Equations Used to Develop the Winter 2018-19 Aircraft Ground Deicing Holdover Time Tables* (7).

The titles of the 2018-19 documents are listed in Table 8.1. Final drafts of TC and the FAA documents were provided to TC and the FAA publications departments, respectively for publication on August 7, 2018.

As intended, the FAA finalized and published its N8900 series notice along with the other HOT guidance materials, on August 7, 2018.

8.4 Transport Canada Holdover Time Guidelines Website

In the summer of 2003, TC tasked APS to develop and maintain a website for the TC HOT guidelines to serve as the single source location for HOT information. This was done to eliminate the safety risks associated with publishing information in multiple locations, which can result in information discrepancies.

The website was first made available when the 2003-04 HOT guidelines were published in July 2003, and has been updated regularly since that time (typically once per year). The website, which was used extensively by industry to access the HOT guidelines documents, is published in English and French, primarily for Canadian operators, although the information is made public for others to use.

As of August 7, 2018 the HOT Guidelines documents were moved onto TC servers and are now being hosted on a Government of Canada website.

Table 8.1: 2018-19 HOT Guidance Documents

HOT Guidelines	1. Transport Canada Holdover Time (HOT) Guidelines Winter 2018-2019
	2. Guide de Transports Canada sur les durées d'efficacité Hiver 2018-2019
	3. FAA Holdover Time Guidelines Winter 2018-2019
Regression Information	4. Transport Canada HOT Guidelines Regression Information Winter 2018-2019
	5. Transports Canada Guide des durées d'efficacité Information de régression Hiver 2018-2019
	6. FAA Holdover Time Regression Information Winter 2018-2019

8.5 Future Responsibilities

APS will continue contributing to the development of the TC and the FAA HOT guidance materials in the winter of 2018-19. Specifically, APS will continue carrying out the tasks listed in Subsection 8.2, with the exception of tasks h) and i).

In regards to the TC HOT Guidelines website, APS no longer hosts the website and as such, is no longer responsible for ensuring that it is operational. APS will, however, provide support to the TC publications department as needed.

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9. PRESENTATIONS, FLUID MANUFACTURER REPORTS, AND TEST PROCEDURES FOR 2017-18

This section contains an account of the test procedures, presentations, and fluid manufacturer reports prepared by APS Aviation Inc. (APS) in the winter of 2017-18.

9.1 Presentations

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

In 2017-18, APS gave presentations at the following meetings:

1) SAE G-12 Holdover Time (HOT) Committee, Montreal, Canada, November 2017;
2) SAE G-12 HOT Committee, Austin, USA, May 2018;
3) SAE G-12 Fluids Committee, Austin, USA, May 2018;
4) SAE G-12 Aerodynamics Working Group Committee, Austin, USA, May 2018; and
5) Airlines for America (A4A) Ground Deicing Forum, Washington, USA, June 2018.

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

9.1.1 SAE G-12 Holdover Time Committee Meeting, Montreal, Canada, November 2017

Three presentations were prepared for the SAE G-12 HOT Committee meeting held in Montreal, Canada in November 2017:

1) SAE G-12 HOT Committee: Document Updates;
2) Changes to HOT Guidance for Winter 2017-18; and
3) Linear Regression 101, HOT Data Analysis Methodology.

9.1.2 SAE G-12 Holdover Time Committee, Austin, USA, May 2018

Six presentations were prepared for the SAE G-12 HOT Committee meeting held in Austin, USA in May 2018:

1) Winter 2017-18 Endurance Time Testing Results;
2) SAE G-12 HOT Committee: Document Status;
3) Changes to HOT Guidelines for Winter 2018-19 [prepared by APS and presented by Yvan Chabot - Transport Canada (TC), and Charles Enders - Federal Aviation Administration (FAA)];
4) Snow Allowance Times;
5) Update: HOTs for Very Cold Snow; and
6) Evaluation of Fluid Effectiveness and Characterization of Contamination on High Angle Surfaces: Vertical Stabilizer.

9.1.3 SAE G-12 Fluids Committee, Austin, USA, May 2018

One presentation was prepared for the SAE G-12 Fluids Committee meeting held in Austin, USA in May 2018:

1) AIR6232: Aircraft After Market Coatings.

9.1.4 SAE G-12 Aerodynamics Working Group Committee, Austin, USA, May 2018

One presentation was prepared for the SAE G-12 Aerodynamics Working Group Committee meeting held in Austin, USA in May 2018:

1) Snow Allowance Times.

9.1.5 A4A Ground Deicing Forum, Washington, USA, June 2018

Two presentations were prepared for the A4A Ground Deicing Forum held in Washington, USA in June 2018:

1) Changes to HOT Guidelines for Winter 2018-19; and
2) Technical Briefing: Temperature-Specific HOTs.

9.2 Fluid Manufacturer Reports

As part of the HOT research program, several fluids are tested for holdover performance each year. The data from commercialized fluids is published in the related TC report, TP 15396E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2017-18 Winter* (6), while the non-commercialized fluid reports are maintained by the respective fluid manufacturers for research purposes.

9.2.1 Holdover Time Testing Reports

Six reports were prepared to document HOT testing conducted in the winter of 2017-18. Copies of these reports were provided to the fluid manufacturers, TC, and the FAA project managers.

Four of the reports are for commercialized fluids; these reports can be found in the appendices of TP 15396E (6). Two reports were for experimental fluids.

The six reports are:

1) Type II: Kilfrost Ice Clear II;
2) Type II: Oksayd Defrost PG 2;
3) Type II: Clariant Safewing MP II FLIGHT (supplemental heavy snow testing);
4) Type IV: Oksayd Defrost EG 4; and
5) Two non-commercialized experimental fluids.

A companion document outlining the methodologies used in endurance time testing of Type II, III, and IV fluid was also prepared and provided to the manufacturers.

9.3 Test Procedures

Several procedures were developed to guide and support the research team in conducting tests in the winter of 2017-18. It should be noted that some procedures used in the winter of 2017-18 were developed in previous years. Table 9.1 provides the list of the procedures. The procedures have been included as appendices to the winter 2017-18 reports; the specific reports are listed in the last column of Table 9.1.

Table 9.1: List of Procedures 2017-18

Program Element #	ID#	Contract Program Element	Name of Procedure	Latest Version Details	Report
1	1.1	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	PROCEDURE: TEST REQUIREMENTS FOR SIMULATED FREEZING PRECIPITATION FLAT PLATE TESTING	Version 1.0, Jan 15, 2004	HOT
1	1.2	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	PROCEDURE: TEST REQUIREMENTS FOR NATURAL PRECIPITATION FLAT PLATE TESTING	Version 1.0, Dec 23, 2004	HOT
1	1.3	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	PROCEDURE: DETERMINATION OF ENDURANCE TIMES OF TYPE I FLUIDS UNDER NATURAL SNOW PRECIPITATION AT DORVAL	Version 1.0, Dec 14, 2007	HOT
1	1.4	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	PROCEDURE: ENDURANCE TIME TEST REQUIREMENTS FOR SIMULATED SNOW FLAT PLATE TESTING WITH TYPE II, III AND IV FLUIDS	Final Version 1.2, January 23, 2008	HOT
1	1.5	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	PROCEDURE: ENDURANCE TIME TESTING IN FROST WITH TYPE I, II, III AND IV FLUIDS	Version 1.0, Nov 13, 2003 + Addendum Jan 4, 2013	HOT
1	1.6	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	ADDENDUM TO PROCEDURE: ENDURANCE TIME TESTING IN FROST WITH TYPE I, II, III AND IV FLUIDS VALIDATION OF FROST HOT'S WITH NEW FLUIDS	Final Version 1.0, January 4, 2013	HOT
1	1.7	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	OVERALL PROGRAM OF TESTS AT NRC, APRIL 2018	Final Version 1.0, March 30, 2018	HOT
1	1.8	ENDURANCE TIME TESTING FOR MAINTENANCE AND PUBLICATION OF HOT GUIDANCE MATERIAL	OVERALL PROGRAM OF TESTS AT PMG, APRIL 2018	Final Version 1.0, April 16, 2018	HOT
3	3.1	EVALUATION OF ENDURANCE TIMES ON DEPLOYED FLAPS AND SLATS - SENSITIVITY TESTING WITH AIRFOILS	PROCEDURE: FLAPS AND SLATS RESEARCH - COMPARATIVE AIRFOIL TESTING	Final Version 1.0, December 15, 2016	G&E
7	7.1	WIND TUNNEL TESTING - TYPE IV HIGH SPEED VALIDATON OF ALLOWANCE TIMES FOR NEW FLUIDS WITH THIN HIGH PERFORMANCE WING	PROCEDURE: WIND TUNNEL TESTING – TYPE IV HIGH SPEED VALIDATON OF ALLOWANCE TIMES FOR NEW FLUIDS WITH THIN HIGH PERFORMANCE WING	Final Version 2.0, August 6, 2018	G&E

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1. Bernier, B., Ruggi, M., *Testing of Endurance Times on Extended Flaps and Slats (2016-17)*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2017, TP 15375E, 52.

2. Moc, N., *Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces,* APS Aviation Inc., Transportation Development Centre, Montreal, December 2004, TP 14377E, 104.

3. Broeren, A., Riley, J., *Scaling of Lift Degradation Due to Anti-Icing Fluids Based Upon the Aerodynamic Acceptance Test*, National Aeronautics and Space Administration, Cleveland, August 2012, NASA/TM–2012-217701, 30.

4. Bendickson, S., Bernier, B., Bernier, C., Ruggi, M., Youssef, D., *Aircraft Ground Icing General Research Activities During the 2015-16 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, January 2017, TP 15340E, XX (to be published).

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

6. Bernier, B., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2017-18 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2018, TP 15396E, XX (to be published).

7. Bendickson, S., *Regression Coefficients and Equations Used to Develop the Winter 2018-19 Aircraft Ground Deicing Holdover Time Tables*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2018, TP 15397E, XX (to be published).

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE STATEMENT OF WORK EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2017-18

TRANSPORTATION DEVELOPMENT CENTRE
STATEMENT OF WORK EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2017-18

2) Exploratory Research and Standards

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 be performed (activities may be added at the discretion of TC/FAA).

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

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

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

d) Review previous work and develop a top-level future plan relating to vertical stabilizer icing;

e) Support the addition of the "Below -3°C to -8°C" temperature band in the Type II/IV HOT tables, including calculating snow HOTs, determining an approach for freezing precipitation cells, and identifying necessary corresponding changes to SAE standards;

f) Review historical snow allowance time data collected during past wind tunnel testing sessions and develop a framework for future development of snow allowance times for discussion with TC/FAA (and subsequently with SAE); and

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

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.

a) Address outstanding action items assigned to APS personnel relating to the rewrite of TP 14052;

b) Support the rewrite of TP 14052 through attendance of all meeting and consultations, and providing additional technical support, as needed;

c) Conduct additional analysis relating to rate tolerance in endurance time testing with the goal of further developing ARP5485;

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

e) Conduct additional testing to investigate vertical stabilizer icing;

f) Participate in discussions related to operators using HOTs not provided in the HOT Guidelines – these HOTs are derived for specific temperatures using the TC/FAA published regression information;

g) Conduct limited "proof-of-concept" wind tunnel testing (3 tests) for allowance times in snow, to be performed during the planned 5 day wind tunnel testing session; and

h) Investigate A319 engine icing issues experienced by a commercial operator.

3) Evaluation of Endurance Times on Deployed Flaps and Slats – Sensitivity Testing with Airfoils

a) Review previous results from limited airfoil sensitivity testing conducted in 2016-17 by APS;

b) Modify existing test procedure and analysis methodology, as needed, based on TC/FAA and industry consultations;

c) Order necessary fluid samples, as needed, and measure viscosities;

d) Conduct testing on airfoils at P.E.T. test site (the test matrix will be determined following consultations with TC and FAA and will consist of sensitivity testing based on wind direction with respect to the model);

e) Analyze the data collected;

f) Evaluate current guidance material regarding flap configuration against results obtained and develop/modify guidance material, if necessary;

g) Participate (as requested by TC/FAA) in any discussions with A4A relating to the testing results or guidance development; and

h) Report the findings and prepare presentation material for the SAE G-12 meetings, as needed.

7) Repairs and Updates to Existing APS Snow Machine

a) Determine the scope of the repairs and updates needed for the APS snow machine including but not limited to the scale, translator, enclosure, drill press, software and communication hardware;

b) Source the necessary parts and develop a schedule for repairs. The scale recommended by NCAR is not functional, therefore a new scale is required and must be programmed;

c) Perform the selected repairs and updates; and

d) Conduct calibration tests as needed to ensure proper snow machine function.

8) Wind Tunnel Testing – Type IV High Speed Validation of Allowance Times for New Fluids with Thin High Performance Wing

Note: The NRC facility costs associated with testing at M46 are not included in this task and are dealt with directly with TC through a M.O.U. agreement with NRC.

a) Coordinate with staff of NRC M-46 for scheduling and to organize any modifications to the wind tunnel, model, or related equipment;

b) Develop a procedure and test plan with the NRC staff that operates the PIWT. It is anticipated that testing will be conducted during overnight hours over a period of two weeks. The typical procedure is described as follows, but may be modified to address specific testing objectives. Prior to starting each test event, correlation testing is required to calibrate the TC model and to demonstrate repeatability. Wind tunnel tests will be performed with ethylene glycol and propylene glycol anti-icing fluids at below freezing temperatures. Tests will simulate low speed or high speed takeoffs in accordance with the speed and angle of attack profiles provided by TDC and airframe manufacturers. The simulated take-off profile may target the clean wing stall angle as the maximum angle of attack in order to obtain CLmax data. During contaminated test runs, a baseline fluid only case may be run immediately before, or after the contaminated test run to provide a direct correlation of the results. High resolution photos will be taken of the fluid motion at the leading and trailing edges of the wing at a rate of about 3 frames per second, with lighting adequate to see the fluid waves and ripples of about 1mm in height, even when the wing is at maximum angle of attack. Observers will document the appearance of fluid on the wing during the simulated takeoff run and climb of the aircraft by analyzing the photographic records. The testing team will collect, among other things, the following data during the tests: type and amount of fluid applied, type and rate of contamination applied, and extent of fluid contamination prior to the test run;

c) Perform wind tunnel tests (5 days) to validate the existing Type IV fluid allowance times for use with the newly certified anti-icing fluids, or with fluids for which data is lacking;

d) Analyze data; and

e) Report the findings, and prepare presentation material for the SAE G-12 meeting.

9) Update Source Documents for Maintenance and Publication of HOT Guidance Material

a) Maintain a log of proposed changes to the HOT guidelines;

b) In consultation with regulators, review long-lead issues during the winter months and recommend changes that should be made for the following season;

c) Coordinate, plan and lead discussions between TC, FAA and EASA to resolve outstanding issues, further harmonize guidance materials, and find appropriate ways to incorporate new guidance into the HOT guidance documents;

d) Update the TC and FAA HOT guidance documents (HOT Guidelines, Regression Information, N8900 series notice) with data/guidance from new testing and research, new information collected, changes made to SAE standards, and input from users;

e) Post the 2017-18 TC HOT guidelines documents online and post updates (not budgeted) that may be needed in special circumstances; and

f) Ensure the TC HOT guidelines website is operational, in terms of internet availability, for a one-year period.

11) Provision for Project Support Services Including Progress Reporting and Preparation of Current Year Technical Reports to Final Draft 1 Level

a) Provide support services to assist with program coordination and with reviewing, packaging and formatting reports, with the specific goal of bringing all current year technical reports to the Final Draft 1 level.

12) Technical Review, Approval, and Publishing of Technical Reports (20 Reports to Bring from Final Draft 1 to Final Publication)

a) Develop prioritized list of unpublished APS reports to be reviewed and published;

b) Coordinate technical reviews of reports;

c) Perform technical review, editorial review, and make necessary updates to the reports to prepare the document for final editing and publishing (target is to complete this for 20 reports per year; and

d) Provide a status of the progress within the monthly progress reports.

13) Infrastructure for FAA/TC Guideline Development

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

Fluid Management

a) Receive and catalogue fluids;
b) Verify viscosity of newly received fluids at time of receipt and prior to simulated precipitation testing;
c) At the request of TC/FAA, verify viscosity of fluids in inventory intended for testing use; and
d) Maintain log of fluid inventory and viscosity information.

Preparation and Setup for Natural and Artificial Snow Testing

a) Prepare the P.E.T. test site at Trudeau International Airport (YUL) for conducting tests;
b) Upgrade test site infrastructure (i.e.: trailer, shed, snow machine) to ensure personnel safety and adhere to environmental guidelines;
c) Prepare an updated procedure for testing fluids in natural snow;
d) Prepare an updated procedure for testing fluids in freezing precipitation;
e) Prepare an updated procedure for testing fluids in frost;
f) Prepare an updated procedure for testing fluids with the snow machine;
g) Evaluate current methods for measuring snowfall intensity or holdover times;
h) Develop improved, more efficient methods to measure snowfall intensity or holdover times, if appropriate; and
i) 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 a test procedure for the conduct of endurance time tests in simulated precipitation at the NRC CEF;

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

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

f) Update and maintain the NRC Rate Calculation software.

General Activities

a) Analyze individual fluid HOT data to develop generic Type II and Type IV HOTs;

b) Maintain data to ensure continuity;

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

d) Prepare report.

14) Infrastructure for FAA/TC 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 and, at the request of TC/FAA, verify viscosity of fluids in inventory intended for testing use; and

c) Maintain log of fluid inventory and viscosity information.

Preparation and Setup for Natural and Artificial Snow Testing at Trudeau International Airport

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

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

c) Prepare an updated procedures for testing fluids outdoors during snow events;

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

e) Develop improved, more efficient methods to measure snowfall intensity or holdover times, if appropriate.

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 a test procedure for the conduct of endurance time tests in simulated precipitation at the NRC CEF;

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

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.

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APPENDIX B

PROCEDURE:
FLAPS AND SLATS RESEARCH – COMPARATIVE AIRFOIL TESTING WINTER 2016-17

CM2480.003

PROCEDURE:

FLAPS AND SLATS RESEARCH – COMPARATIVE AIRFOIL TESTING

Winter 2016-17

Prepared for

Transportation Development Centre
Transport Canada

and

Federal Aviation Administration
William J. Hughes Technical Center

Prepared by: Ben Bernier and Marco Ruggi

Reviewed by: John D'Avirro

APS Aviation Inc.

December 15, 2016
Final Version 1.0

PROCEDURE:
FLAPS AND SLATS RESEARCH – COMPARATIVE AIRFOIL TESTING

Winter 2016-17

1. BACKGROUND

Anti-icing fluid applied to a wing with deployed flaps and slats can quickly flow off, resulting in a reduced fluid thickness layer, and consequently may shorten fluid holdover times (see Figure 1.1). In addition, the higher angles surfaces are subject to higher precipitation rate catch in wind conditions. Due to operational concerns, flaps and slats related testing has been ongoing since the winter of 2009-10 and has since included a multitude of testing protocols and platforms:

- Wind tunnel testing: High-performance wing model with hinged flap set to 20°;
- Flat plate testing: 10°/20°/35° plates in various configurations and orientations;
- Full-scale validation: Testing with A300 / B737 / A319 (with the support of UPS/SWA/Air Canada); and
- Airfoil model testing: Simple and slatted airfoil testing, both static and with a variety of rotation profiles.

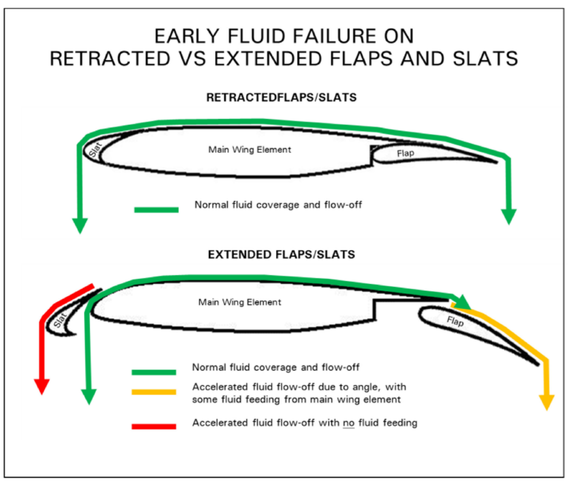


Figure 1.1: Fluid Failure Progression on Flaps and Slats

The data package available to date now contains flat plate, airfoil model and full-scale test data. For the winter of 2016-17, a new comparative airfoil testing approach using is being proposed to facilitate interpretation of results and to support development of guidance. The testing approach will include a wind direction sensitivity study as well as comparative static vs. rotating airfoil tests. This procedure includes the methodology and test plan for the testing to be conducted during the winter of 2016-17.

2. OBJECTIVE

The objective is to conduct comparative testing with two equivalent airfoil models to isolate and quantify the effect of orientation and rotation on endurance times.

3. METHODOLOGY

3.1 General Procedure

Comparative testing will be conducted using two airfoils which were built to be as close to identical as possible based on the materials and assembly procedures used. In addition, a baseline 10º plate (or box for Type I fluids) will be included in the test setup to record the endurance time according to ARP 5485 or ARP 5945. A 20º plate (or box for Type I fluids) will be included in the test setup and used as the surrogate plate model best representing the deployed wing protection time, and to add to the existing growing data set. General holdover time testing protocols will apply, however the following provides an overview of the specific testing procedure:

1. Ensure airfoils are correctly positioned with respect to the wind as per the test plan requirement;
2. Verify with a feeler gauge that the gap distance between the trailing edge of the slat and the hard leading edge is at least 1mm;
3. Ensure the 10º and 20º plates are positioned into the wind;
4. Ensure rate of precipitation is being measured approximately every 10-minutes just before, throughout, and just after the test (or every 5-minutes in moderate snow conditions);
5. Apply fluid to all surfaces simultaneously. Thickened fluids should be applied by pouring the fluid on the surface, Type I fluids should use a spreader or sprayer due to the large surface area. Note: Type III fluid testing is not

planned for 2016-17. Typically, it will require 14L of Type II/IV fluid to properly coat each airfoil (this may be as high as 20L if it is cold and the fluid is very viscous). For Type I fluids, 2.5L will be applied (this correlates to 1L/m²), however discussion is ongoing about increasing the quantity to be in line with the 0.5L applied to a cold soak box in outdoor snow testing which translates to 3.3L/m², or 8.25L on each airfoil;

6. Rotate the airfoils (if applicable) as per the test plan requirements. A looping PowerPoint show with has been developed and will be used to facilitate the timing of the rotations through sound and visual cues;

7. Measure fluid thickness 5-minutes after fluid application, and fluid brix at the time of failure;

8. Record the time of first failure, 10 percent failure, and full failure (if practical) on the airfoil models;

9. Record the time of standard plate failure (1/3 of the plate) for the 10º and 20º surfaces; and

10. Compare the results from the four different test models.

A diagram describing showing a top view of the general test setup is included in Figure 3.1.

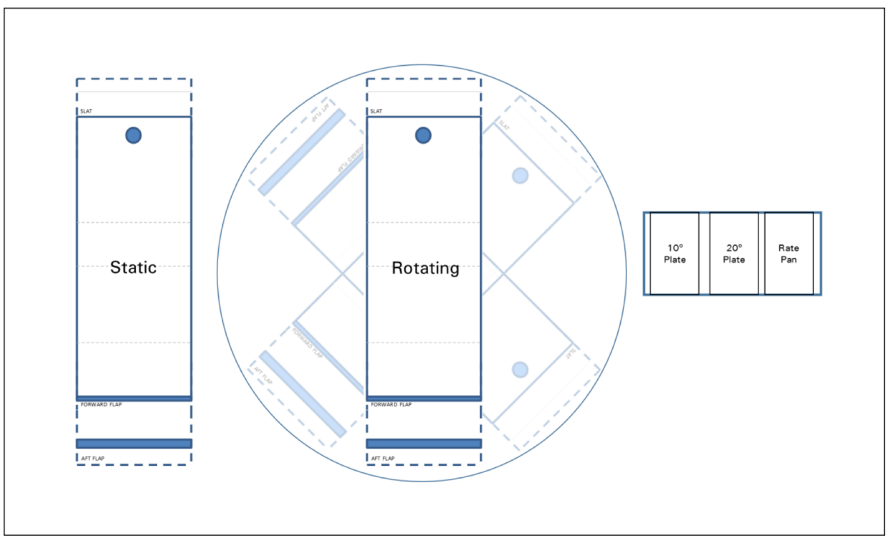


Figure 3.1: Top View of General Test Setup

3.2 Airfoil Calibration Testing

Testing will be conducted to verify that both airfoils are constructed equally, and that fluid applied to the two models will provide equal fluid protection times. Testing will be conducted using the two slatted airfoils in the same static orientations. Running two airfoils in tandem will ensure that natural factors remain the same for both airfoils (temperature, rate, wind speed, snowflake size etc.) The airfoils will not be rotated during these tests. A baseline 10º and 20º plate will also be included in the test setup.

3.3 Wind Direction Sensitivity Study

Testing will be conducted to determine the effect of specific airfoil orientations on fluid performance with the intent of identifying possible orientations that may be attributed to increased or decreased fluid protection times. Testing will be conducted using the two slatted airfoils in differing static orientations, the first in headwind configuration, and the second in different static orientations as per the test plan requirement. Running two airfoils in tandem will ensure that natural factors remain the same for both airfoils (temperature, rate, wind speed, snowflake size etc.) The airfoils will not be rotated during these tests. A baseline 10º and 20º plate will also be included in the test setup.

3.4 Comparative Static vs. Rotating Airfoil Testing

Testing will be conducted to isolate the effect of rotation on airfoil endurance time (while keeping other variables constant). Running two airfoils in tandem will ensure that natural factors remain the same for both airfoils (temperature, rate, wind speed, snowflake size etc.). One airfoil will remain in headwind position, while the second airfoil will be rotated throughout the test; one rotation profile will be used for all tests. The magnitude of rotating effect will be derived through comparison of static airfoil vs. rotating airfoil endurance time results. A baseline 10º and 20º plate will also be included in the test setup.

3.5 Airfoil Orientation Sequencing

An analysis conducted by Southwest Airlines provided a wind rose output of typical aircraft orientations following de/anti-icing until takeoff. APS conducted a post analysis and indicated that the general head / cross / tail orientation breakdown for the recorded operations could be simplified to 20 percent / 40 percent / 40 percent respectively for facilitate testing procedures.

To minimize this potential error in orientation sequencing due to under or over estimating the fluid HOT, the airfoil sequencing will be done in a continual 20-minute rotation cycle. The continuous 20-minute cycle will ensure the headwind 20 percent, crosswind 40 percent, and tailwind 40 percent orientation ratios are maintained. To do so, the rotations must be completed every 4, 8, and 8 minutes in order to maintain the 20/40/40 ratio for a 20-minute cycle. In the case of Type I fluids, if the expected HOT is less than 20-minute, consideration will be given to halving the rotation cycle to 10-minutes total (i.e. 2, 4, and 4 minutes) or shorter if required. Figure 3.2 demonstrates an example of the airfoil orientation for a test in which the expected HOT is 60-minutes.

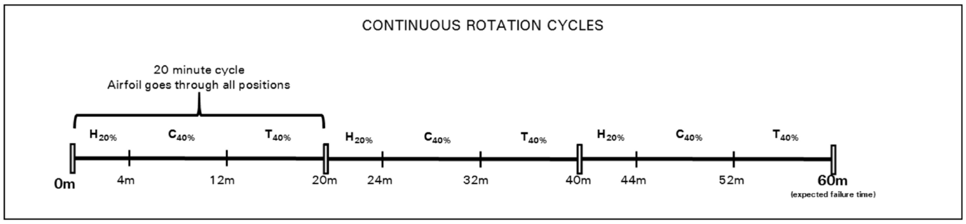


Figure 3.2: Airfoil Orientation Sequencing – Example of 60-minute Expected Holdover Time

4. TEST PLAN

Testing is to be conducted in natural snow conditions. It should be noted that the test runs are not specific to precipitation rate or outside temperature, however a variety of different conditions are preferred. The test plan for the winter of 2015-16 is included in Table 4.1. Tests #1-6 address the calibration testing objective, tests #7-16 address the wind direction sensitivity study, and tests #17-61 address the comparative static vs. rotating airfoil testing objective.

Consideration will be given to replacing the headwind airfoil in tests # 17-61 with a second rotating airfoil in order to collect a larger data set of rotating airfoil tests. The decision to proceed with this change will depend on the preliminary analysis of the static airfoil tests collected during tests #1-16.

PROCEDURE: FLAPS AND SLATS RESEARCH – COMPARATIVE AIRFOIL TESTING

Table 4.1: Test Plan for Winter 2016-17

TEST #	PRIORITY	OBJECTIVE	MODEL ORIENTATION OR ROTATION SEQUENCE			CODED FLUID	COMMENTS
			AIRFOIL #1	AIRFOIL #2	10° AND 20° PLATES		
1	1	Calibration	Headwind 0°	Headwind 0°	Headwind 0°	Type IV PG - C	Serves for sensitivity also
2	1	Calibration	Headwind 0°	Headwind 0°	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
3	1	Calibration	Crosswind 90°	Crosswind 90°	Headwind 0°	Type IV PG - C	
4	1	Calibration	Crosswind 90°	Crosswind 90°	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
5	1	Calibration	Tailwind 180°	Tailwind 180°	Headwind 0°	Type IV PG - C	
6	1	Calibration	Tailwind 180°	Tailwind 180°	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
7	3	Sensitivity	Headwind 0°	Headwind 0°	Headwind 0°	Type IV PG - C	Serves for calibration also
8	1	Sensitivity	Headwind 0°	45° to Wind	Headwind 0°	Type IV PG - C	
9	3	Sensitivity	Headwind 0°	45° to Wind	Headwind 0°	Type IV PG - C	
10	1	Sensitivity	Headwind 0°	Crosswind 90°	Headwind 0°	Type IV PG - C	
11	3	Sensitivity	Headwind 0°	Crosswind 90°	Headwind 0°	Type IV PG - C	
12	1	Sensitivity	Headwind 0°	135° to Wind	Headwind 0°	Type IV PG - C	
13	3	Sensitivity	Headwind 0°	135° to Wind	Headwind 0°	Type IV PG - C	
14	1	Sensitivity	Headwind 0°	Tailwind 180°	Headwind 0°	Type IV PG - C	
15	3	Sensitivity	Headwind 0°	Tailwind 180°	Headwind 0°	Type IV PG - C	
16	3	Sensitivity	Headwind 0°	45°, 90°, or 180° (TBD)	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
17	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
18	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
19	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
20	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
21	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
22	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
23	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
24	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
25	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
26	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	
27	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind
28	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind
29	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind
30	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind
31	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind
32	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind
33	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind
34	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind
35	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind
36	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - C	Consider pairing with EG106 and eliminate headwind

*** Consider replacing with second rotating airfoil test, pending analysis of head wind airfoil data.

PROCEDURE: FLAPS AND SLATS RESEARCH – COMPARATIVE AIRFOIL TESTING

Table 4.1: Test Plan for Winter 2016-17 (cont'd)

TEST #	PRIORITY	OBJECTIVE	MODEL ORIENTATION OR ROTATION SEQUENCE			FLUID	COMMENTS
			AIRFOIL #1	AIRFOIL #2	10° AND 20° PLATES		
37	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
38	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
39	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
40	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
41	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
42	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
43	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
44	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
45	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
46	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type IV PG - D	Consider pairing with PGA and eliminate headwind
47	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
48	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
49	1	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
50	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
51	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
52	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
53	2	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
54	3	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
55	3	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
56	3	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type I PG - A	Do in light snow when TII/IV not feasible
57	4	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type II PG - B	
58	4	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type II PG - B	
59	4	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type II PG - B	
60	4	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type II PG - B	
61	4	Static vs. Rotating	Headwind 0° ***	Rotating 20/40/40 - 20-min Cycles	Headwind 0°	Type II PG - B	

*** Consider replacing with second rotating airfoil test, pending analysis of head wind airfoil data.

5. EQUIPMENT

Standard holdover time testing equipment will be used for the conduct of these tests. In addition, the following specific items will be required:

- Two airfoils fitted with slats and flaps;
- Catch basins to collect fluid overflow during fluid application throughout the test (can use spare holdover time test stand catch pans);
- Large 3 litre jugs to apply anti-icing fluid; and
- Fluid spreader or backpack sprayer to apply deicing fluid.

6. PERSONNEL

A minimum of three people will be required for the conduct of these tests:

1. Overall coordinator, photography, and responsible for calling failures on all surfaces;
2. Fluid application on airfoil #1 and data documentation; and
3. Fluid application on airfoil #2 and measurements.

Ideally additional support from one or two persons is available at the start of the tests for fluid application.

7. FLUIDS

Testing will be performed with commercial fluids of production range viscosity (for comparative testing). The fluid selection was based on operator feedback regarding commonly used in U.S. and Canadian operations. Fluids quantities required have been ordered specifically for these tests and are described in Table 7.1. Fluid viscosity measurements will be conducted using the Brookfield viscometer and the falling ball upon receipt. Spot checks of fluid viscosity may be conducted periodically throughout the season as requested by Transport Canada or the Federal Aviation Administration; this will likely be done using only the falling ball method.

Table 7.1: Fluid Requirements

Fluid	Fluid Type	Dilution	Test Count	Fluid Required*
Type I PG - A	PG-Based Type I	10°B	14	168L
Type II PG - B	PG-Based Type II	100/0	5	200L
Type IV PG - C	PG-Based Type IV	100/0	20	800L**
Type IV PG - D	EG-Based Type IV	100/0	10	400L

*Prepared volume – not concentrate volume. Type II/IV approx. 40L per test, Type I approx. 12L per test.
**An additional 600L of fluid will be held on "reserve" by the fluid manufacturer in the event extra fluid is required.

8. DATA FORM

Comparative airfoil tests will require the use of a data form, which can be found in Attachment 1. Each test run will require the completion of this form.

9. PHOTOS

Photo documentation is an important part of the data collection. At the time of each plate failure, airfoil first failure, or airfoil 10 percent failure, nine photos should be taken as demonstrated in Figure 9.1. Special care should be given to taking photos in proper sequence to facilitate future analysis.

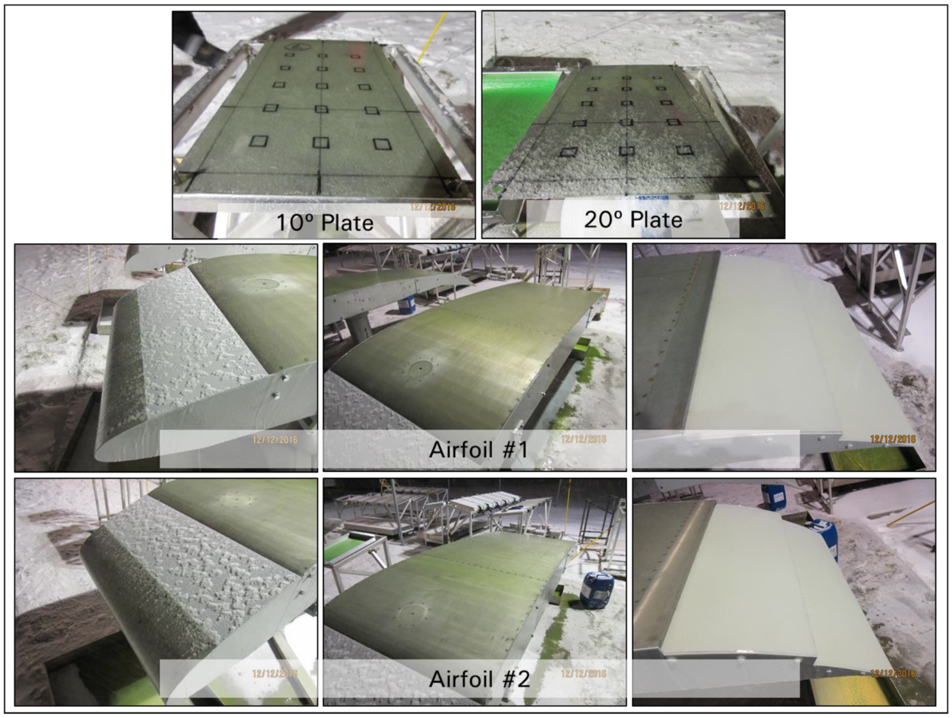


Figure 9.1: Example of Photos Required at Each Failure Event

Attachment 1: Airfoil End Condition Data Form

FLAPS AND SLATS RESEARCH
AIRFOIL END CONDITION DATA FORM

Test Plan # ________ Run # ________

EC HOURLY DATA
RECORDED AT END OF POUR TIME
TIME OF EC OBSERVATION
____
TEMP ______ °C
WIND SPEED _____km/h
WIND DIRECTION _______.

FLUID INFORMATION

Fluid Name:

Batch #:

Fluid Type:

Fluid Dilution:

Liters used:

Initial Brix:

Initial Temp:

ROTATION SEQUENCE
H = Headwind, C = Crosswind, T = Tailwind

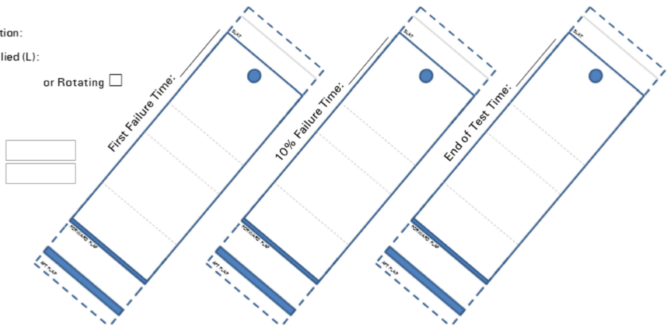
Start Time:

20-minute Rotation Sequence = Hx4-min, Cx8-min, Tx8-min

Orientation	Start Time	60-min Checklist
Headwind 4-min		
Crosswind 8-min		
Tailwind 8-min		
Headwind 4-min		
Crosswind 8-min		
Tailwind 8-min		
Headwind 4-min		
Crosswind 8-min		
Tailwind 8-min		

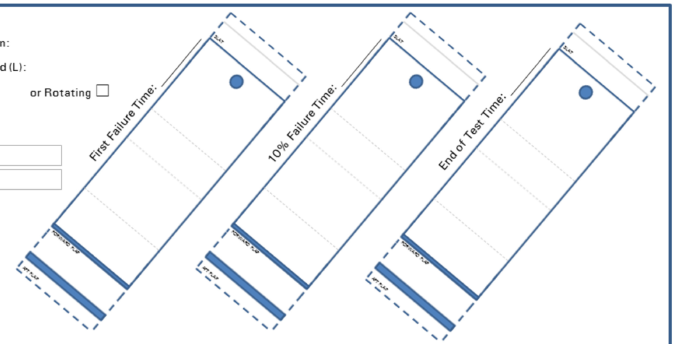
AIRFOIL #1
Time of Fluid Application:
Quantity of Fluid Applied (L):
Static (Position) ☐ or Rotating ☐

TH @ 5 MINS
BRIX @ FAILURE



AIRFOIL #2
Time of Fluid Application:
Quantity of Fluid Applied (L):
Static (Position) ☐ or Rotating ☐

TH @ 5 MINS
BRIX @ FAILURE



PLATES (Headwind) **Time of Fluid Application:**

	10°	20
Time of Fluid Failure:		
TH @ 5 MINS		
BRIX @ FAILURE		

Comments:__________________

☐Check if more on other side

Date: ___________
Recorded by: ___________
Testers: ___________

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APPENDIX C

WIND DIRECTION SENSITIVITY TESTING LOG

Wind Direction Sensitivity Testing Log

RUN	YEAR	DATE	TEST #	TEST PLAN #	CONDITION	LOCATION	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	ROTATION PROFILE	OBJECTIVE	PIVOT TABLE PARAMETER	SURFACE	Start Time (Local)	Fail Time (Local)	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	Baseline ET	PRECIP RATE (g/dm²/h)	Wind Speed (km/h)	OAT (°C)	Thickness @ 5 min (mm)	Brix @ Fail (°)
200	2016-17	12-Dec-16	SN639	1 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Calibration	10°	10°	0:49:10	3:08:00	138.8	138.8	138.8	6.9	19.3	-4.3	65	13.5
200	2016-17	12-Dec-16	SN640	1 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Calibration	20° Simple	20° Simple	0:48:30	2:23:00	94.5	73.2	138.8	5.4	20.7	-4.3	35	10
200	2016-17	12-Dec-16	SN641	1 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Calibration	Airfoil Static Head	Slatted Airfoil #1	0:47:40	2:09:00	81.3	57.7	138.8	4.9	20.9	-4.2	28	9.5
200	2016-17	12-Dec-16	SN642	1 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Calibration	Airfoil Static Head	Slatted Airfoil #2	0:47:30	2:14:00	86.5	64.0	138.8	5.1	20.8	-4.2	40	9
203	2016-17	12-Dec-16	SN651	10 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	6:08:30	9:30:00	201.5	201.5	N/A	6.4	11.4	-3.3	70	7.5
203	2016-17	12-Dec-16	SN652	10 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	6:09:15	8:23:00	133.8	125.0	N/A	6.0	12.6	-3.5	40	9.25
203	2016-17	12-Dec-16	SN653	10 (2016-17)	Snow	PET	II	Type II PG - B	100/0	CROSS (SB)	STATIC	Sensitivity	Airfoil Static Cross (SB)	Slatted Airfoil #1	6:06:30	8:00:00	113.5	94.2	N/A	5.3	13.2	-3.6	35	10.5
203	2016-17	12-Dec-16	SN654	10 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	6:07:30	7:52:00	104.5	85.2	N/A	5.2	13.3	-3.6	35	12
204	2016-17	12-Dec-16	SN655	8 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	8:57:00	13:22:00	265.0	265.0	88.2	3.5	14.7	-3.5	70	-
204	2016-17	12-Dec-16	SN656	8 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	8:56:30	12:12:00	195.5	177.5	88.2	3.2	13.4	-3.2	40	-
204	2016-17	12-Dec-16	SN657	8 (2016-17)	Snow	PET	II	Type II PG - B	100/0	CROSS 45° (SB)	STATIC	Sensitivity	Airfoil Static Cross 45° (SB)	Slatted Airfoil #1	8:56:00	11:39:00	163.0	144.7	88.2	3.1	12.4	-3.0	50	9.5
204	2016-17	12-Dec-16	SN658	8 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	8:55:00	11:55:00	180.0	159.8	88.2	3.1	12.9	-3.1	45	7.5
205	2016-17	12-Dec-16	SN659	14 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	13:16:00	15:26:00	130.0	130.0	82.7	8.7	16.2	-4.9	70	14.5
205	2016-17	12-Dec-16	SN660	14 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	13:15:00	14:54:00	99.0	89.1	82.7	7.8	17.0	-4.8	45	12
205	2016-17	12-Dec-16	SN661	14 (2016-17)	Snow	PET	II	Type II PG - B	100/0	TAIL	STATIC	Sensitivity	Airfoil Static Tail	Slatted Airfoil #1	13:12:00	15:18:00	126.0	119.9	82.7	8.3	16.5	-4.9	35	8.25
205	2016-17	12-Dec-16	SN662	14 (2016-17)	Snow	PET	II	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	13:13:00	14:20:00	67.0	54.8	82.7	7.1	17.8	-4.8	35	11.5

Wind Direction Sensitivity Testing Log (cont'd)

RUN	YEAR	DATE	TEST #	TEST PLAN #	CONDITION	LOCATION	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	ROTATION PROFILE	OBJECTIVE	PIVOT TABLE PARAMETER	SURFACE	Start Time (Local)	Fail Time (Local)	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	Baseline ET	PRECIP RATE ($g/dm^2/h$)	Wind Speed (km/h)	OAT (°C)	Thickness @ 5 min (mm)	Brix @ Fail (°)
206	2016-17	17-Dec-16	SN663	12 (2016-17)	Snow	PET	IV	Type IV PG - E	100/0	HEAD	STATIC	Sensitivity	10°	10°	8:30:45	10:14:15	103.5	103.5	90.8	5.5	21.7	-13.9	50	19.75
206	2016-17	17-Dec-16	SN664	12 (2016-17)	Snow	PET	IV	Type IV PG - E	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	8:31:00	9:26:00	55.0	51.4	90.8	5.2	21.5	-14.0	30	19
206	2016-17	17-Dec-16	SN665	12 (2016-17)	Snow	PET	IV	Type IV PG - E	100/0	CROSS 135° (P)	STATIC	Sensitivity	Airfoil Static Cross 135° (SB)	Slatted Airfoil #1	8:29:50	10:15:00	105.2	105.7	90.8	5.6	21.7	-13.9	35	27.25
206	2016-17	17-Dec-16	SN666	12 (2016-17)	Snow	PET	IV	Type IV PG - E	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	8:29:50	9:26:00	56.2	52.9	90.8	5.2	21.5	-14.0	35	19.5
207	2016-17	17-Dec-16	SN667	8 (2016-17)	Snow	PET	IV	Type IV PG - E	100/0	HEAD	STATIC	Sensitivity	10°	10°	10:30:00	13:00:00	N/A	150.0	62.9	4.2	21.2	-12.4	65	20
207	2016-17	17-Dec-16	SN668	8 (2016-17)	Snow	PET	IV	Type IV PG - E	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	10:30:00	11:48:00	78.0	77.6	62.9	4.2	22.7	-13.0	45	19.75
207	2016-17	17-Dec-16	SN669	8 (2016-17)	Snow	PET	IV	Type IV PG - E	100/0	CROSS 45° (P)	STATIC	Sensitivity	Airfoil Static Cross 45° (SB)	Slatted Airfoil #1	10:29:30	11:55:00	85.5	83.3	62.9	4.1	22.6	-12.9	35	18
207	2016-17	17-Dec-16	SN670	8 (2016-17)	Snow	PET	IV	Type IV PG - E	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	10:29:30	11:30:00	60.5	67.6	62.9	4.7	22.7	-13.1	40	21.75
258	2017-18	12-Dec-17	SN863	12	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	10°	10°	7:28:50	8:57:00	88.2	88.2	138.8	13.4	26.4	-10.1	96	13.5
258	2017-18	12-Dec-17	SN864	12	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	7:28:40	8:12:30	43.8	45.2	138.8	13.9	26.9	-10.3	65	14
258	2017-18	12-Dec-17	SN865	12	Snow	PET	IV	Type IV EG - D	100/0	CROSS 45° (P)	STATIC	Sensitivity	Airfoil Static Cross 45° (P)	Slatted Airfoil #1	7:28:25	8:02:40	34.3	37.2	138.8	14.6	26.9	-10.3	65	13.5
258	2017-18	12-Dec-17	SN866	12	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	7:28:10	8:05:00	36.8	39.8	138.8	14.5	26.9	-10.3	70	13.75
259	2017-18	12-Dec-17	SN867	16	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	10°	10°	9:28:20	10:51:00	82.7	82.7	82.7	16.2	27.2	-8.8	96	13.25
259	2017-18	12-Dec-17	SN868	16	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	9:28:10	10:08:30	40.3	42.2	82.7	16.9	26.9	-8.9	65	12.5
259	2017-18	12-Dec-17	SN869	16	Snow	PET	IV	Type IV EG - D	100/0	CROSS 135° (P)	STATIC	Sensitivity	Airfoil Static Cross 135° (P)	Slatted Airfoil #1	9:27:40	10:44:00	76.3	76.3	82.7	16.2	27.1	-8.8	70	12
259	2017-18	12-Dec-17	SN870	16	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	9:27:30	10:06:00	38.5	40.3	82.7	16.9	26.9	-8.9	70	12.75

Wind Direction Sensitivity Testing Log (cont'd)

RUN	YEAR	DATE	TEST #	TEST PLAN #	CONDITION	LOCATION	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	ROTATION PROFILE	OBJECTIVE	PIVOT TABLE PARAMETER	SURFACE	Start Time (Local)	Fail Time (Local)	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	Baseline ET	PRECIP RATE (g/dm²/h)	Wind Speed (km/h)	OAT (°C)	Thickness @ 5 min (mm)	Brix @ Fail (°)
260	2017-18	12-Dec-17	SN871	14	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	10°	10°	11:17:00	12:47:50	90.8	90.8	90.8	15.7	27.2	-7.8	96	11.5
260	2017-18	12-Dec-17	SN872	14	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	11:16:20	11:53:00	36.7	34.8	90.8	14.9	28.0	-8.1	60	12
260	2017-18	12-Dec-17	SN873	14	Snow	PET	IV	Type IV EG - D	100/0	CROSS (P)	STATIC	Sensitivity	Airfoil Static Cross (P)	Slatted Airfoil #1	11:15:50	12:29:00	73.2	65.7	90.8	14.1	28.0	-8.0	70	13
260	2017-18	12-Dec-17	SN874	14	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	11:15:30	11:49:00	33.5	33.0	90.8	15.5	28.0	-8.2	70	12.5
261	2017-18	23-Dec-17	SN875	18	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	10°	10°	15:10:00	16:12:55	62.9	62.9	62.9	21.4	15.6	-7.1	80	12.75
261	2017-18	23-Dec-17	SN876	18	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	15:09:40	15:40:45	31.1	31.4	62.9	21.6	17.3	-7.2	60	12.25
261	2017-18	23-Dec-17	SN877	18	Snow	PET	IV	Type IV EG - D	100/0	TAIL	STATIC	Sensitivity	Airfoil Static Tail	Slatted Airfoil #1	15:09:15	16:10:00	60.8	61.2	62.9	21.5	15.7	-7.1	65	11.75
261	2017-18	23-Dec-17	SN878	18	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	15:09:15	15:35:00	25.8	25.6	62.9	21.3	18.0	-7.2	65	12.25
262	2017-18	23-Dec-17	SN879	13	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	10°	10°	16:39:50	17:35:05	55.3	55.3	55.3	15.0	10.8	-6.5	96	11
262	2017-18	23-Dec-17	SN880	13	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	16:39:15	17:07:15	28.0	31.4	55.3	16.8	11.0	-6.6	65	12.25
262	2017-18	23-Dec-17	SN881	13	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #1	16:37:50	17:01:20	23.5	28.2	55.3	18.0	11.0	-6.6	65	12
262	2017-18	23-Dec-17	SN882	13	Snow	PET	IV	Type IV EG - D	100/0	CROSS (SB)	STATIC	Sensitivity	Airfoil Static Cross (SB)	Slatted Airfoil #2	16:38:50	17:08:45	29.9	33.4	55.3	16.8	11.0	-6.6	70	11.75
263	2017-18	04-Jan-18	SN883	11	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	10°	10°	19:02:30	20:53:30	111.0	111.0	111.0	7.8	20.0	-7.6	80	12.5
263	2017-18	04-Jan-18	SN884	11	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	19:02:15	20:08:10	65.9	51.4	111.0	6.1	19.7	-7.4	60	12.5
263	2017-18	04-Jan-18	SN885	11	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #1	19:02:00	19:56:55	54.9	32.4	111.0	4.6	19.5	-7.3	60	14
263	2017-18	04-Jan-18	SN886	11	Snow	PET	IV	Type IV EG - D	100/0	CROSS 45° (SB)	STATIC	Sensitivity	Airfoil Static Cross 45° (SB)	Slatted Airfoil #2	19:01:45	20:08:55	67.2	52.6	111.0	6.1	19.7	-7.4	60	12
264	2017-18	04-Jan-18	SN887	15	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	10°	10°	21:10:40	23:41:30	150.8	150.8	150.8	4.9	24.3	-9.7	80	15.25

Wind Direction Sensitivity Testing Log (cont'd)

RUN	YEAR	DATE	TEST #	TEST PLAN #	CONDITION	LOCATION	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	ROTATION PROFILE	OBJECTIVE	PIVOT TABLE PARAMETER	SURFACE	Start Time (Local)	Fail Time (Local)	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	Baseline ET	PRECIP RATE ($g/dm^2/h$)	Wind Speed (km/h)	OAT (°C)	Thickness @ 5 min (mm)	Brix @ Fail (°)
264	2017-18	04-Jan-18	SN888	15	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	21:10:20	22:15:00	64.7	78.1	150.8	5.9	22.1	-8.3	55	12.5
264	2017-18	04-Jan-18	SN889	15	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #1	21:09:50	21:58:00	48.2	58.7	150.8	5.9	21.7	-8.3	60	11
264	2017-18	04-Jan-18	SN890	15	Snow	PET	IV	Type IV EG - D	100/0	CROSS 135° (SB)	STATIC	Sensitivity	Airfoil Static Cross 135° (SB)	Slatted Airfoil #2	21:09:50	23:56:30	166.7	173.6	150.8	5.1	24.8	-9.9	65	14.5
266	2017-18	08-Jan-18	SN895	18R	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	10°	10°	10:19:30	11:53:30	94.0	94.0	94.0	8.3	15.7	-5.7	70	5.5
266	2017-18	08-Jan-18	SN896	18R	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	10:19:00	11:28:00	69.0	50.7	94.0	6.1	16.9	-5.8	45	4.5
266	2017-18	08-Jan-18	SN897	18R	Snow	PET	IV	Type IV EG - D	100/0	TAIL	STATIC	Sensitivity	Airfoil Static Tail	Slatted Airfoil #1	10:18:40	11:30:30	71.8	54.0	94.0	6.3	16.9	-5.8	55	4
266	2017-18	08-Jan-18	SN898	18R	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	10:18:15	11:28:00	69.8	51.0	94.0	6.1	16.8	-5.8	60	3.75
267	2017-18	08-Jan-18	SN899	19	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Calibration	10°	10°	12:12:25	12:59:55	47.5	47.5	47.5	21.8	8.2	-5.5	70	4.75
267	2017-18	08-Jan-18	SN900	19	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Calibration	20° Simple	20° Simple	12:12:15	12:37:00	24.8	23.4	47.5	20.6	10.3	-5.5	40	4.5
267	2017-18	08-Jan-18	SN901	19	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Calibration	Airfoil Static Head	Slatted Airfoil #1	12:11:45	12:34:00	22.3	21.3	47.5	20.9	10.9	-5.6	45	4
267	2017-18	08-Jan-18	SN902	19	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Calibration	Airfoil Static Head	Slatted Airfoil #2	12:11:40	12:34:00	22.3	21.4	47.5	20.9	10.9	-5.6	45	3.75
268	2017-18	08-Jan-18	SN903	17	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	10°	10°	13:12:50	13:58:30	45.7	45.7	45.7	20.5	2.9	-5.3	70	6.5
268	2017-18	08-Jan-18	SN904	17	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	13:12:25	13:35:00	22.6	24.7	45.7	22.4	4.9	-5.4	50	6.75
268	2017-18	08-Jan-18	SN905	17	Snow	PET	IV	Type IV EG - D	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #1	13:12:30	13:34:10	21.7	23.9	45.7	22.6	5.0	-5.4	55	5.5
268	2017-18	08-Jan-18	SN906	17	Snow	PET	IV	Type IV EG - D	100/0	TAIL	STATIC	Sensitivity	Airfoil Static Tail	Slatted Airfoil #2	13:11:50	13:35:45	23.9	26.2	45.7	22.4	4.8	-5.4	55	5.75
269	2017-18	12-Jan-18	SN907	1	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	22:25:00	23:28:15	63.3	63.3	63.3	24.2	15.2	-4.8	70	14
269	2017-18	12-Jan-18	SN908	1	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	22:25:10	23:07:30	42.3	39.3	63.3	22.5	15.2	-4.7	50	14
269	2017-18	12-Jan-18	SN909	1	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #1	22:25:15	23:06:20	41.1	34.7	63.3	20.5	15.2	-4.7	60	15

Wind Direction Sensitivity Testing Log (cont'd)

RUN	YEAR	DATE	TEST #	TEST PLAN #	CONDITION	LOCATION	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	ROTATION PROFILE	OBJECTIVE	PIVOT TABLE PARAMETER	SURFACE	Start Time (Local)	Fail Time (Local)	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	Baseline ET	PRECIP RATE (g/dm²/h)	Wind Speed (km/h)	OAT (°C)	Thickness @ 5 min (mm)	Brix @ Fail (°)
269	2017-18	12-Jan-18	SN910	1	Snow	PET	IV	Type II PG - B	100/0	CROSS 45° (SB)	STATIC	Sensitivity	Airfoil Static Cross 45° (SB)	Slatted Airfoil #2	22:24:05	23:01:50	37.8	29.6	63.3	19.0	15.3	-4.7	50	13.5
270	2017-18	12-Jan-18	SN911	3	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	23:46:30	0:35:00	49.2	49.2	49.2	21.2	15.0	-6.7	70	16.5
270	2017-18	12-Jan-18	SN912	3	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	23:46:50	0:22:40	36.5	34.3	49.2	20.0	15.0	-6.6	55	15.25
270	2017-18	12-Jan-18	SN913	3	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #1	23:46:05	0:23:20	37.9	36.0	49.2	20.2	15.0	-6.6	65	16
270	2017-18	12-Jan-18	SN914	3	Snow	PET	IV	Type II PG - B	100/0	CROSS (SB)	STATIC	Sensitivity	Airfoil Static Cross (SB)	Slatted Airfoil #2	23:46:05	0:29:00	43.6	42.4	49.2	20.7	15.0	-6.6	55	16
271	2017-18	13-Jan-18	SN915	5	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	1:00:30	1:32:00	31.5	31.5	31.5	39.7	15.0	-7.9	80	18
271	2017-18	13-Jan-18	SN916	5	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	1:00:05	1:23:45	23.7	22.4	31.5	37.5	15.0	-7.8	60	17.5
271	2017-18	13-Jan-18	SN917	5	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #1	0:59:45	1:20:25	20.7	19.1	31.5	36.6	15.0	-7.8	65	17.75
271	2017-18	13-Jan-18	SN918	5	Snow	PET	IV	Type II PG - B	100/0	CROSS 135° (SB)	STATIC	Sensitivity	Airfoil Static Cross 135° (SB)	Slatted Airfoil #2	0:59:30	1:23:35	24.1	22.6	31.5	37.3	15.0	-7.8	60	17.5
272	2017-18	13-Jan-18	SN919	7	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	2:28:55	2:49:45	20.8	20.8	20.8	43.6	15.0	-9.4	80	20.5
272	2017-18	13-Jan-18	SN920	7	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	2:29:30	2:43:00	13.5	12.8	20.8	41.3	15.0	-9.4	60	19
272	2017-18	13-Jan-18	SN921	7	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #1	2:28:35	2:45:45	17.2	16.5	20.8	41.9	15.0	-9.4	80	20.5
272	2017-18	13-Jan-18	SN922	7	Snow	PET	IV	Type II PG - B	100/0	TAIL	STATIC	Sensitivity	Airfoil Static Tail	Slatted Airfoil #2	2:28:20	2:45:00	16.7	15.8	20.8	41.4	15.0	-9.3	60	19
273	2017-18	13-Jan-18	SN923	9	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Calibration	10°	10°	3:25:55	3:47:30	21.6	21.6	21.6	42.7	16.6	-9.8	70	22.25
273	2017-18	13-Jan-18	SN924	9	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Calibration	20° Simple	20° Simple	3:26:10	3:41:00	14.8	14.8	21.6	42.6	16.5	-9.8	55	21
273	2017-18	13-Jan-18	SN925	9	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Calibration	Airfoil Static Head	Slatted Airfoil #1	3:25:45	3:39:00	13.3	13.6	21.6	43.9	16.4	-9.7	70	21.75
273	2017-18	13-Jan-18	SN926	9	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Calibration	Airfoil Static Head	Slatted Airfoil #2	3:25:30	3:38:00	12.5	13.1	21.6	44.7	16.3	-9.7	65	20.25

Wind Direction Sensitivity Testing Log (cont'd)

RUN	YEAR	DATE	TEST #	TEST PLAN #	CONDITION	LOCATION	FLUID TYPE	FLUID	DILUTION	STAND ORIENTATION	ROTATION PROFILE	OBJECTIVE	PIVOT TABLE PARAMETER	SURFACE	Start Time (Local)	Fail Time (Local)	ENDURANCE TIME (MIN)	ADJUSTED ENDURANCE TIME (MIN)	Baseline ET	PRECIP RATE ($g/dm^2/h$)	Wind Speed (km/h)	OAT (°C)	Thickness @ 5 min (mm)	Brix @ Fail (°)
274	2017-18	22-Jan-18	SN927	8	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	16:58:50	17:36:00	37.2	37.2	37.2	26.8	38.7	-6.8	35	16.5
274	2017-18	22-Jan-18	SN928	8	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	16:58:35	17:28:30	29.9	25.6	37.2	23.0	39.0	-6.7	28	15.5
274	2017-18	22-Jan-18	SN929	8	Snow	PET	IV	Type II PG - B	100/0	TAIL	STATIC	Sensitivity	Airfoil Static Tail	Slatted Airfoil #1	16:58:10	17:37:45	39.6	40.4	37.2	27.4	38.6	-6.8	30	16
274	2017-18	22-Jan-18	SN930	8	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	16:58:10	17:30:00	31.8	28.2	37.2	23.7	39.0	-6.7	35	16
275	2017-18	22-Jan-18	SN931	2	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	18:39:40	19:46:20	66.7	66.7	66.7	27.4	40.0	-7.2	70	N/A
275	2017-18	22-Jan-18	SN932	2	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	18:39:05	19:28:55	49.8	40.2	66.7	22.1	40.0	-7.2	55	14.25
275	2017-18	22-Jan-18	SN933	2	Snow	PET	IV	Type II PG - B	100/0	CROSS 45° (P)	STATIC	Sensitivity	Airfoil Static Cross 45° (P)	Slatted Airfoil #1	18:38:30	19:26:50	48.3	38.3	66.7	21.7	40.0	-7.2	55	14.5
275	2017-18	22-Jan-18	SN934	2	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	18:38:20	19:32:50	54.5	46.1	66.7	23.1	40.0	-7.2	60	14.5
276	2017-18	04-Feb-18	SN935	8R	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	10°	10°	9:53:05	12:18:00	144.9	144.9	144.9	9.7	26.0	-2.6	80	3.5
276	2017-18	04-Feb-18	SN936	8R	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	20° Simple	20° Simple	9:53:00	10:55:30	62.5	85.1	144.9	13.2	26.4	-3.2	45	5
276	2017-18	04-Feb-18	SN937	8R	Snow	PET	IV	Type II PG - B	100/0	TAIL	STATIC	Sensitivity	Airfoil Static Tail	Slatted Airfoil #1	9:52:15	11:25:00	92.7	107.8	144.9	11.3	25.6	-3.1	45	3.5
276	2017-18	04-Feb-18	SN938	8R	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Sensitivity	Airfoil Static Head	Slatted Airfoil #2	9:52:10	10:52:40	60.5	83.4	144.9	13.4	26.5	-3.2	45	4
277	2017-18	04-Feb-18	SN939	10	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Calibration	10°	10°	11:36:20	14:53:00	196.7	196.7	196.7	7.0	28.2	-1.1	70	N/A
277	2017-18	04-Feb-18	SN940	10	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Calibration	20° Simple	20° Simple	11:36:35	11:59:59	23.4	25.9	196.7	7.8	11.2	-0.8	45	2
277	2017-18	04-Feb-18	SN941	10	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Calibration	Airfoil Static Head	Slatted Airfoil #1	11:35:45	13:11:00	95.3	107.5	196.7	7.9	27.0	-1.5	45	2.5
277	2017-18	04-Feb-18	SN942	10	Snow	PET	IV	Type II PG - B	100/0	HEAD	STATIC	Calibration	Airfoil Static Head	Slatted Airfoil #2	11:35:45	13:05:45	90.0	103.0	196.7	8.1	27.0	-1.6	40	2

APPENDIX D

PROCEDURE:
WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS
WINTER 2017-18

CM2480.004

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

Winter 2017-18

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

APS Aviation Inc.

August 6, 2018
Final Version 2.0

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

Winter 2017-18

1. BACKGROUND

In 2005-06, the inability for operators to release aircraft in ice pellet conditions led TC and FAA to begin a research campaign to develop allowance times for these conditions. Developing holdover times was not feasible due to the properties of the ice pellets; they remain embedded in the fluid and take long to dissolve as compared to snow which is immediately absorbed and dissolved. Research was initiated by live aircraft testing with the NRC Falcon 20 in Ottawa Ontario, and later evolved to testing in a more controlled environment with the NRC Propulsion Icing Wind Tunnel also in Ottawa Ontario.

The early testing in 2005-06 with the Falcon 20 primarily used visual observations to evaluate fluid flow off. During the Falcon 20 work the wing was anti-iced, exposed to contamination, and aborted take-off runs were performed allowing researchers on-board to observe and evaluate the fluid flow-off. Testing in 2006-07 began in the propulsion icing wind tunnel (PIWT) allowing aerodynamic data to be used for evaluating fluid flow-off performance. The PIWT also allowed for a more controlled environment less susceptible to the elements.

The work continued each year, and the test methods and equipment improved allowing for real-time data analysis, better repeatability, and overall greater confidence in the results. The work conducted by FAA/TC was presented by APS to G-12 AWG and HOT Committee yearly since 2006. Additional presentations were also given at the AWG in May 2012 and May 2013 by NASA and NRC which focused on the extensive calibration and characterization work performed with a generic thin high performance airfoil. This work also helped increase confidence in how the data was used to help support TC/FAA rule-making. A detailed account of the more recent work conducted is included in the report, TP 15232E*, "Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics and to Support the Development of Ice Pellet Allowance Times, Winter 2009-10 to 2012-13"* (1).

The Ice Pellet Allowance Time research has helped further develop and improve the PIWT facility. As a result, a new medium is now available for aerodynamic testing of aircraft ground icing fluids with or without contamination in a full-scale format. Several other ground deicing projects have been ongoing as a result of industry requests and are expected to continue. The PIWT has evolved into a multidisciplinary facility; however it continues to be the primary source for the development and further refinement of the ground deicing ice pellet allowance time guidance material.

Research at the PIWT with and without ice pellets has continued on a yearly or bi-yearly basis and is performed by APS, with support of the NRC, on behalf of TC/FAA.

For the Winter 2017-18, the primary focus of testing will be on ice pellet allowance time validation.

2. OBJECTIVES AND TIMING

The following describes the objectives and timing of the research. 15 days of testing are being planned, however only 10 days will be done. The selection of which objectives are targeted will be at the discretion of the TC/FAA research team and decided on-site.

2.1 Type IV Allowance Time Validation Testing

The objective of this testing is to conduct aerodynamic testing with a thin high performance airfoil to:

- Substantiate the current Type IV ice pellet allowance times with new fluids and at temperatures close to the lowest operational use temperature (LOUT).

To satisfy this objectives, a thin high performance wing section (Figure 2.1) will be subjected to a series of tests in the NRC PIWT. The dimensions indicated are in inches. This wing section was constructed by NRC in 2009 specifically for the conduct of these tests following extensive consultations with an airframe manufacturer to ensure a representative thin high performance design.

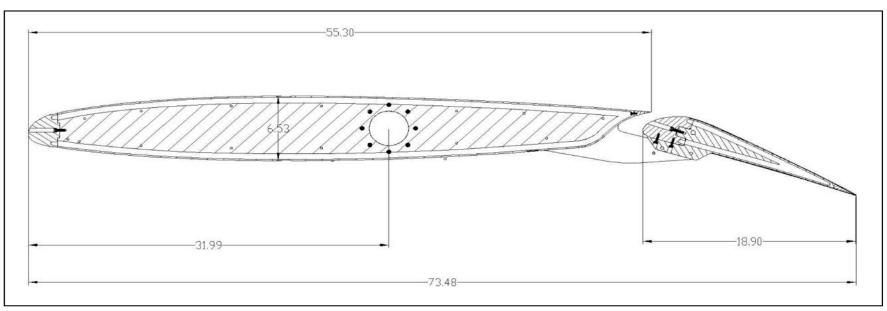

Figure 2.1: Thin High Performance Wing Section

Eight days of testing are required for the conduct of these tests.

2.2 Type IV Allowance Time Expansion for Ethylene Glycol (EG) Fluids

The objective of this testing is to conduct aerodynamic testing with a thin high performance airfoil to:

- Expand the current Type IV ice pellet allowance times for EG fluids.

To satisfy this objectives, a thin high performance wing section (described in Section 2.1 and shown in Figure 2.1) will be subjected to a series of tests in the NRC PIWT.

Two days of testing are required for the conduct of these tests.

2.3 Type III Low Speed Allowance Time Testing

Testing will be conducted to:

- Evaluate the current Type III ice pellet allowance times at 80 Knots using the LS-0417 low speed airfoil.

To satisfy this objective, the LS-0417 wing section (Figure 2.2) will be subjected to a series of tests in the NRC PIWT. The dimensions indicated are in inches. This wing section was constructed by NRC in the 1990's and was more recently used in 2008-09 for ice pellet wind tunnel testing. Time for the wing to be swapped is needed, testing efforts will be required to calibrate and characterize the wing section, and fluid only testing will be done prior to conducting any actual allowance time testing.

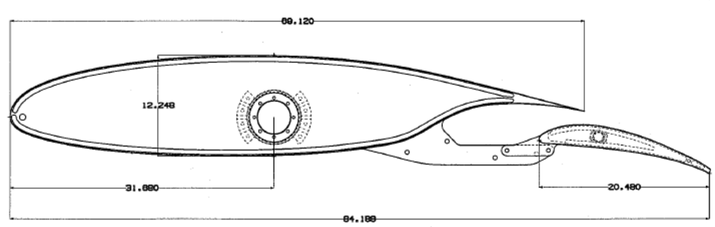

Figure 2.2: NASA LS-0417 Wing Section

An additional 5 days of testing are required for the conduct of these tests.

2.4 Timing

A total of 8 days are required for the "Type IV Allowance Time Validation Testing" (Section 2.1), 2 days are required for the "Type IV Allowance Time Expansion for EG Fluids" (Section 2.2) and an additional 5 days are required for the "Type III Low Speed Allowance Time Testing" (Section 2.3), time and funding permitting. This requires a total of 15 days of testing, however only 10 days of testing are available. The 10 days of testing will be conducted over a period of 3 weeks starting January 25th to February 9th (see Figure 2.3) Changing over of the wing sections may require some down-time which will need to be considered in the scheduling.

Testing will likely be conducted during overnight periods (i.e. 10 pm – 6 am), unless temperatures are suitable for day/evening testing. The weekends will be considered only if deemed necessary. The first 2 hours or more of the first day will be dedicated to setup and calibration of the rain sprayer and ice pellet and snow dispensers; time permitting testing will begin as per the test plan. The time required for the setup and calibration will be evenly deducted from the other objectives in order to still meet the 10 day testing plan. The precipitation conditions to be calibrated could include the following:

- ZR – 25g/dm²/h;
- R – 25g/dm²/h;
- R – 75g/dm²/h;
- ZD – 5g/dm²/h;
- ZD – 13g/dm²/h;
- SN – 10g/dm²/h;
- SN – 25g/dm²/h;
- IP – 25g/dm²/h; and
- IP – 75g/dm²/h.

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

JANUARY 2018

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Jan 14	15	16	17	18	19	20
Jan 21	22	23 Pack up truck in YUL	24 Leave YUL for YOW	25 TEST DAY 1 TESTING ACTIVITY TBD (only is Temps <-16C)	26 TEST DAY 2 TESTING ACTIVITY TBD (only is Temps <-16C)	27
28	29 TEST DAY 3 TESTING ACTIVITY TBD	30 TEST DAY 4 TESTING ACTIVITY TBD	31 TEST DAY 5 TESTING ACTIVITY TBD	February 1 TEST DAY 6 TESTING ACTIVITY TBD	2 TEST DAY 7 TESTING ACTIVITY TBD	3
4	5 TEST DAY 8 TESTING ACTIVITY TBD	6 TEST DAY 9 TESTING ACTIVITY TBD	7 TEST DAY 10 TESTING ACTIVITY TBD	8 SPARE DAY 1 TBD	9 SPARE DAY 2 TBD	10

NOTES

Anticipate Mon-Fri testing, however, weekend may be considered due to temperature.
Testing will be conducted during overnight periods (10:00 pm - 6:00 am)
Testing team will be JD, MR, BB, CB, BG & YOW x 4
Spare days available (Feb 8-9) should rescheduling be needed due to temperatures.

TESTING ACTIVITIES

SETUP & CALIBRATION of Rain Sprayer and IP/SN Dispensers (Will be done on first day. Time req'd to be deducted evenlyfrom other activities)	TEST DAY 1 IP VALIDATION - NEW FLUIDS (TIV) above -5 °C	TEST DAY 2 IP VALIDATION - NEW FLUIDS (TIV) above -5 °C	TEST DAY 3 IP VALIDATION - NEW FLUIDS (TIV) above -5 °C	TEST DAY 4 IP VALIDATION - NEW FLUIDS (TIV) below -5 to 16 °C	TEST DAY 5 IP VALIDATION - NEW FLUIDS (TIV) below -5 to 16°C
	TEST DAY 6 IP VALIDATION - NEW FLUIDS (TIV) below -5 to 16 °C	TEST DAY 7 IP VALIDATION - NEW FLUIDS (TIV) below -16 °C	TEST DAY 8 IP VALIDATION - NEW FLUIDS (TIV) below -16 °C	TEST DAY 9 EG IP EXPANSION (TIV) above -5°C	TEST DAY 10 EG IP EXPANSION (TIV) below -5 to -16 °C
	TEST DAY 11 Type III IP - LS0417 WING SWAP (done by NRC) Any temp	TEST DAY 12 TYPE III IP - LS0417 MODEL CALIBRATION & CHARACTERIZATION below 0ºC	TEST DAY 13 TYPE III IP - LS0417 MODEL CALIBRATION & CHARACTERIZATION below 0ºC	TEST DAY 14 TYPE III IP - LS0417 MODEL CALIBRATION & CHARACTERIZATION FLUID ONLY TESTING below 0ºC	TEST DAY 15 TYPE III IP VALIDATION AT 80KTS W/ LS0417 above -5ºC

Note: Each testing activity block represents one day of wind tunnel time.

Figure 2.3: Test Calendar

M:\Projects\PM2480.004 (TC Deicing 2017-18)\Procedures\Wind Tunnel\Final Version 2.0\Wind Tunnel Final Version 2.0.docx
Final Version 2.0, August 18

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3. TEST PLAN

The NRC wind tunnel is an open circuit tunnel. The temperature inside the wind tunnel is dependent on the outside ambient temperature. Prior to testing, the weather should be monitored to ensure proper temperatures for testing.

Representative Type I/II/III/IV propylene and ethylene fluids in Neat form (standard mix for Type I) shall be evaluated against their uncontaminated performance.

A preliminary list of test objectives is shown in Table 3.1 (only Priority 1 and 2 objectives will be attempted unless indicated otherwise by TC/FAA directive). It should be noted that the order in which the tests will be carried out will be depend on weather conditions and TC/FAA directive. A detailed test matrix (subject to change) is shown in Table 3.2. As some of this testing is exploratory, changes to the test plan may be made at the time of testing and will be confirmed by TC/FAA.

NOTE: The numbering of the test runs will be done in a sequential order starting with number 1.

A rating system has been developed for fluid and contamination tests, and will be filled out by the on-site experts when applicable. The overall rating will provide insight into the severity of the conditions observed. A test failure (failure to shed the fluid at time of rotation) shall be determined by the on-site experts based on residual contamination.

Table 3.1: Preliminary List of Testing Objectives for Winter 2017-18 Wind Tunnel Testing

Item #	Objective	Priority	Description	# of Days
0	Setup and Precipitation Calibration	1	Setup of equipment and calibration of the rain sprayer and the ice pellet and snow dispensers (to be done on the first day of testing)	-
1	Dry Wing Baseline Repeatability	1	Baseline test at beginning of each day to ensure repeatability (part of NRC shakedown tests so no days allotted)	N/A
2	Type IV IP AT Validation (New Fluids)	1	Substantiate current times with new fluids	8
3	EG Type IV AT Expansion	2	Conduct allowance time testing with the objective of extending times and potentially add new cells for EG fluids	2
4.1	Type III IP – LS-0417 Wing Swap	2	Replace the wing section in the tunnel with the LS-0417 model	1
4.2	Type III IP – LS-0417 Model Calibration and Characterization	2	Calibrate and characterize the LS-0417 wing model to support low speed ice pellet allowance time testing at 80 knots.	2
4.3	Type III IP – LS-0417 Model Calibration and Characterization Fluid Only Testing	2	Fluid only testing will be done to support BLDT correlation.	1
4.4	Type III IP AT Validation at 80 Knots with LS-0417 Wing Section	2	Validate the existing Type III allowance times for use at 80 knots using the LS-0417 wing section	1
5	Other R&D Activities	3	Could be selected from item # 5.1 to 8.16	0
5.1	Type III Allowance Time Expansion		Expand the current Type III allowance times to have increased times, or more cells.	-
5.2	Snow Allowance Times Using Aerodynamic Data		Investigate feasibility of developing snow allowance times using the same aerodynamic based methodology used for ice pellets	
5.3	Development of EG Specific IP Allowance Times		Support the development of an EG fluid specific ice pellet allowance time table to benefit of potential longer times	-
5.4	Heavy Snow	-	Continue Heavy Snow Research comparing lift losses with Light/Moderate Snow vs. Heavy Snow	-
5.5	Heavy Contamination (Aero vs. Visual Failure)	-	Continue work looking at aerodynamic failure vs. HOT defined failure, and effect of surface roughness on lift degradation	-
5.6	Tunnel Test Section Cooling System Evaluation	-	Evaluate effectiveness of new wind tunnel cooling system and potential effects on data results	-
5.7	Fluid + Cont @ LOUT	-	Effect of contamination on fluid performance at LOUT with IP, SN, ZF, Frost etc.	-
5.8	Simulate Frost in Wind Tunnel	-	Attempt to simulate frost conditions in wind tunnel.	-
5.9	130-150 Knots IP Testing	-	Conduct IP testing at 130-150 knots or validate feasibility MAY NEED TO MODIFY TUNNEL	-
5.10	2nd Wave of Fluid During Rotation	-	Investigate the aero effects of the 2nd wave of fluid created from fluid at the stagnation point which flows over the LE during rotation	-
5.11	Other	-	Any potential suggestions from industry	

Total # of Days for Priority 1 and Priority 2 Tests	**15**

**Note only 10 days of testing are planned. The time required for the setup and precipitation calibration will be evenly deducted from the other Priority 1 and 2 objectives in order to still meet the ten day testing plan.*

Table 3.2: Proposed Test Plan

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Test Priority	COMMENT
	P001	Baseline	1	Dry Wing	8	100	any	none	-	-	-	-	-	1	@start of day
	P002	Baseline	1	Dry Wing	22	80	any	none	-	-	-	-	-	1	@start of day
	P003	Type IV Validation and New Fuids	1	IP-	8	100	>-5	ChemR EG IV	25	-	-	-	50	1	
	P004	Type IV Validation and New Fuids	1	IP- / SN-	8	100	>-5	ChemR EG IV	25	10	-	-	40	1	
	P005	Type IV Validation and New Fuids	1	IP- / ZD	8	100	>-5	ChemR EG IV	25	-	13	-	25	2	
	P006	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	>-5	ChemR EG IV	25	-	25	-	25	1	
	P007	Type IV Validation and New Fuids	1	IP- / R-	8	100	>0	ChemR EG IV	25	-	-	25	25	2	
	P008	Type IV Validation and New Fuids	1	IP Mod	8	100	>-5	ChemR EG IV	75	-	-	-	25	1	
	P009	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	>-5	ChemR EG IV	75	-	13	-	10	1	
	P010	Type IV Validation and New Fuids	1	IP Mod / R	8	100	>0	ChemR EG IV	75	-	-	75	10	2	
	P011	Type IV Validation and New Fuids	1	IP-	8	100	-5 to -10	ChemR EG IV	25	-	-	-	30	2	
	P012	Type IV Validation and New Fuids	1	IP- / SN-	8	100	-5 to -10	ChemR EG IV	25	10	-	-	15	2	
	P013	Type IV Validation and New Fuids	1	IP- / ZD	8	100	-5 to -10	ChemR EG IV	25	-	13	-	10	2	
	P014	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	-5 to -10	ChemR EG IV	25	-	25	-	10	1	
	P015	Type IV Validation and New Fuids	1	IP Mod	8	100	-5 to -10	ChemR EG IV	75	-	-	-	10	2	
	P016	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	-5 to -10	ChemR EG IV	75	-	13	-	7	1	
	P017	Type IV Validation and New Fuids	1	IP-	8	100	-10 to -16	ChemR EG IV	25	-	-	-	30	1	
	P018	Type IV Validation and New Fuids	1	IP- / SN-	8	100	-10 to -16	ChemR EG IV	25	10	-	-	15	1	
	P019	Type IV Validation and New Fuids	1	IP Mod	8	100	-10 to -16	ChemR EG IV	75	-	-	-	10	1	
	P020	Type IV Validation and New Fuids	1	IP-	8	100	-16 to -22	ChemR EG IV	25	-	-	-	30	2	
	P021	Type IV Validation and New Fuids	1	IP Mod	8	100	-16 to -22	ChemR EG IV	75	-	-	-	10	2	
	P022	Type IV Validation and New Fuids	1	IP-	8	100	<-22	ChemR EG IV	25	-	-	-	30	2	
	P023	Type IV Validation and New Fuids	1	IP Mod	8	100	<-22	ChemR EG IV	75	-	-	-	10	2	
	P024	Type IV Validation and New Fuids	1	Fluid Only	8	100	-5 to -10	ChemR EG IV	-	-	-	-	-	1	Baseline Test
	P025	Type IV Validation and New Fuids	1	Fluid Only	8	100	-16 to -22	ChemR EG IV	-	-	-	-	-	1	Baseline Test
	P026	Type IV Validation and New Fuids	1	Fluid Only	8	100	<-22	ChemR EG IV	-	-	-	-	-	1	Baseline Test

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Test Priority	COMMENT
	P027	Type IV Validation and New Fuids	1	IP-	8	100	>-5	Max Flight AVIA	25	-	-	-	50	1	
	P028	Type IV Validation and New Fuids	1	IP- / SN-	8	100	>-5	Max Flight AVIA	25	10	-	-	40	1	
	P029	Type IV Validation and New Fuids	1	IP- / ZD	8	100	>-5	Max Flight AVIA	25	-	13	-	25	2	
	P030	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	>-5	Max Flight AVIA	25	-	25	-	25	1	
	P031	Type IV Validation and New Fuids	1	IP- / R-	8	100	>0	Max Flight AVIA	25	-	-	25	25	2	
	P032	Type IV Validation and New Fuids	1	IP Mod	8	100	>-5	Max Flight AVIA	75	-	-	-	25	1	
	P033	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	>-5	Max Flight AVIA	75	-	13	-	10	1	
	P034	Type IV Validation and New Fuids	1	IP Mod / R	8	100	>0	Max Flight AVIA	75	-	-	75	10	2	
	P035	Type IV Validation and New Fuids	1	IP-	8	100	-5 to -10	Max Flight AVIA	25	-	-	-	30	2	
	P036	Type IV Validation and New Fuids	1	IP- / SN-	8	100	-5 to -10	Max Flight AVIA	25	10	-	-	15	2	
	P037	Type IV Validation and New Fuids	1	IP- / ZD	8	100	-5 to -10	Max Flight AVIA	25	-	13	-	10	2	
	P038	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	-5 to -10	Max Flight AVIA	25	-	25	-	10	1	
	P039	Type IV Validation and New Fuids	1	IP Mod	8	100	-5 to -10	Max Flight AVIA	75	-	-	-	10	2	
	P040	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	-5 to -10	Max Flight AVIA	75	-	13	-	7	1	
	P041	Type IV Validation and New Fuids	1	IP-	8	100	-10 to -16	Max Flight AVIA	25	-	-	-	30	1	
	P042	Type IV Validation and New Fuids	1	IP- / SN-	8	100	-10 to -16	Max Flight AVIA	25	10	-	-	15	1	
	P043	Type IV Validation and New Fuids	1	IP Mod	8	100	-10 to -16	Max Flight AVIA	75	-	-	-	10	1	
	P044	Type IV Validation and New Fuids	1	IP-	8	100	-16 to -22	Max Flight AVIA	25	-	-	-	30	2	
	P045	Type IV Validation and New Fuids	1	IP Mod	8	100	-16 to -22	Max Flight AVIA	75	-	-	-	10	2	
	P046	Type IV Validation and New Fuids	1	IP-	8	100	<-22	Max Flight AVIA	25	-	-	-	30	2	
	P047	Type IV Validation and New Fuids	1	IP Mod	8	100	<-22	Max Flight AVIA	75	-	-	-	10	2	
	P048	Type IV Validation and New Fuids	1	Fluid Only	8	100	-5 to -10	Max Flight AVIA	-	-	-	-	-	1	Baseline Test
	P049	Type IV Validation and New Fuids	1	Fluid Only	8	100	-16 to -22	Max Flight AVIA	-	-	-	-	-	1	Baseline Test
	P050	Type IV Validation and New Fuids	1	Fluid Only	8	100	<-22	Max Flight AVIA	-	-	-	-	-	1	Baseline Test
	P051	Type IV Validation and New Fuids	1	IP-	8	100	>-5	Max Flight SNEG	25	-	-	-	50	1	

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Test Priority	COMMENT
	P052	Type IV Validation and New Fuids	1	IP- / SN-	8	100	>-5	Max Flight SNEG	25	10	-	-	40	1	
	P053	Type IV Validation and New Fuids	1	IP- / ZD	8	100	>-5	Max Flight SNEG	25	-	13	-	25	2	
	P054	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	>-5	Max Flight SNEG	25	-	25	-	25	1	
	P055	Type IV Validation and New Fuids	1	IP- / R-	8	100	>0	Max Flight SNEG	25	-	-	25	25	2	
	P056	Type IV Validation and New Fuids	1	IP Mod	8	100	>-5	Max Flight SNEG	75	-	-	-	15	1	15 min for PG
	P057	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	>-5	Max Flight SNEG	75	-	13	-	10	1	
	P058	Type IV Validation and New Fuids	1	IP Mod / R	8	100	>0	Max Flight SNEG	75	-	-	75	10	2	
	P059	Type IV Validation and New Fuids	1	IP-	8	100	-5 to -10	Max Flight SNEG	25	-	-	-	30	2	
	P060	Type IV Validation and New Fuids	1	IP- / SN-	8	100	-5 to -10	Max Flight SNEG	25	10	-	-	15	2	
	P061	Type IV Validation and New Fuids	1	IP- / ZD	8	100	-5 to -10	Max Flight SNEG	25	-	13	-	10	2	
	P062	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	-5 to -10	Max Flight SNEG	25	-	25	-	10	1	
	P063	Type IV Validation and New Fuids	1	IP Mod	8	100	-5 to -10	Max Flight SNEG	75	-	-	-	10	2	
	P064	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	-5 to -10	Max Flight SNEG	75	-	13	-	7	1	
	P065	Type IV Validation and New Fuids	1	IP-	8	115	-10 to -16	Max Flight SNEG	25	-	-	-	30	1	115knts for PG
	P066	Type IV Validation and New Fuids	1	IP- / SN-	8	115	-10 to -16	Max Flight SNEG	25	10	-	-	15	1	115knts for PG
	P067	Type IV Validation and New Fuids	1	IP Mod	8	115	-10 to -16	Max Flight SNEG	75	-	-	-	10	1	115knts for PG
	P068	Type IV Validation and New Fuids	1	IP-	8	115	-16 to -22	Max Flight SNEG	25	-	-	-	30	2	115knts for PG
	P069	Type IV Validation and New Fuids	1	IP Mod	8	115	-16 to -22	Max Flight SNEG	75	-	-	-	0	2	No Allowance Time
	P070	Type IV Validation and New Fuids	1	IP-	8	115	<-22	Max Flight SNEG	25	-	-	-	30	2	115knts for PG
	P071	Type IV Validation and New Fuids	1	IP Mod	8	115	<-22	Max Flight SNEG	75	-	-	-	0	2	No Allowance Time
	P072	Type IV Validation and New Fuids	1	Fluid Only	8	100	-5 to -10	Max Flight SNEG	-	-	-	-	-	1	Baseline Test
	P073	Type IV Validation and New Fuids	1	Fluid Only	8	100	-16 to -22	Max Flight SNEG	-	-	-	-	-	1	Baseline Test
	P074	Type IV Validation and New Fuids	1	Fluid Only	8	100	<-22	Max Flight SNEG	-	-	-	-	-	1	Baseline Test
	P075	Type IV Validation and New Fuids	1	IP-	8	100	>-5	ECO-SHIELD	25	-	-	-	50	1	
	P076	Type IV Validation and New Fuids	1	IP- / SN-	8	100	>-5	ECO-SHIELD	25	10	-	-	40	1	
	P077	Type IV Validation and New Fuids	1	IP- / ZD	8	100	>-5	ECO-SHIELD	25	-	13	-	25	2	

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Test Priority	COMMENT
	P078	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	>-5	ECO-SHIELD	25	-	25	-	25	1	
	P079	Type IV Validation and New Fuids	1	IP- / R-	8	100	>0	ECO-SHIELD	25	-	-	25	25	2	
	P080	Type IV Validation and New Fuids	1	IP Mod	8	100	>-5	ECO-SHIELD	75	-	-	-	15	1	15 min for PG
	P081	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	>-5	ECO-SHIELD	75	-	13	-	10	1	
	P082	Type IV Validation and New Fuids	1	IP Mod / R	8	100	>0	ECO-SHIELD	75	-	-	75	10	2	
	P083	Type IV Validation and New Fuids	1	IP-	8	100	-5 to -10	ECO-SHIELD	25	-	-	-	30	2	
	P084	Type IV Validation and New Fuids	1	IP- / SN-	8	100	-5 to -10	ECO-SHIELD	25	10	-	-	15	2	
	P085	Type IV Validation and New Fuids	1	IP- / ZD	8	100	-5 to -10	ECO-SHIELD	25	-	13	-	10	2	
	P086	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	-5 to -10	ECO-SHIELD	25	-	25	-	10	1	
	P087	Type IV Validation and New Fuids	1	IP Mod	8	100	-5 to -10	ECO-SHIELD	75	-	-	-	10	2	
	P088	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	-5 to -10	ECO-SHIELD	75	-	13	-	7	1	
	P089	Type IV Validation and New Fuids	1	IP-	8	115	-10 to -16	ECO-SHIELD	25	-	-	-	30	1	115knts for PG
	P090	Type IV Validation and New Fuids	1	IP- / SN-	8	115	-10 to -16	ECO-SHIELD	25	10	-	-	15	1	115knts for PG
	P091	Type IV Validation and New Fuids	1	IP Mod	8	115	-10 to -16	ECO-SHIELD	75	-	-	-	10	1	115knts for PG
	P092	Type IV Validation and New Fuids	1	IP-	8	115	-16 to -22	ECO-SHIELD	25	-	-	-	30	2	115knts for PG
	P093	Type IV Validation and New Fuids	1	IP Mod	8	115	-16 to -22	ECO-SHIELD	75	-	-	-	0	2	No Allowance Time
	P094	Type IV Validation and New Fuids	1	IP-	8	115	<-22	ECO-SHIELD	25	-	-	-	30	2	115knts for PG
	P095	Type IV Validation and New Fuids	1	IP Mod	8	115	<-22	ECO-SHIELD	75	-	-	-	0	2	No Allowance Time
	P096	Type IV Validation and New Fuids	1	Fluid Only	8	100	-5 to -10	ECO-SHIELD	-	-	-	-	-	1	Baseline Test
	P097	Type IV Validation and New Fuids	1	Fluid Only	8	100	-16 to -22	ECO-SHIELD	-	-	-	-	-	1	Baseline Test
	P098	Type IV Validation and New Fuids	1	Fluid Only	8	100	<-22	ECO-SHIELD	-	-	-	-	-	1	Baseline Test
	P099	Type IV Validation and New Fuids	1	IP-	8	100	>-5	Defrost ECO 4	25	-	-	-	50	1	
	P100	Type IV Validation and New Fuids	1	IP- / SN-	8	100	>-5	Defrost ECO 4	25	10	-	-	40	1	
	P101	Type IV Validation and New Fuids	1	IP- / ZD	8	100	>-5	Defrost ECO 4	25	-	13	-	25	2	
	P102	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	>-5	Defrost ECO 4	25	-	25	-	25	1	
	P103	Type IV Validation and New Fuids	1	IP- / R-	8	100	>0	Defrost ECO 4	25	-	-	25	25	2	

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate ($g/dm^2/h$)	SN Rate ($g/dm^2/h$)	ZR Rate ($g/dm^2/h$)	R Rate ($g/dm^2/h$)	Exposure Time	Test Priority	COMMENT
	P104	Type IV Validation and New Fuids	1	IP Mod	8	100	>-5	Defrost ECO 4	75	-	-	-	15	1	15 min for PG
	P105	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	>-5	Defrost ECO 4	75	-	13	-	10	1	
	P106	Type IV Validation and New Fuids	1	IP Mod / R	8	100	>0	Defrost ECO 4	75	-	-	75	10	2	
	P107	Type IV Validation and New Fuids	1	IP-	8	100	-5 to -10	Defrost ECO 4	25	-	-	-	30	2	
	P108	Type IV Validation and New Fuids	1	IP- / SN-	8	100	-5 to -10	Defrost ECO 4	25	10	-	-	15	2	
	P109	Type IV Validation and New Fuids	1	IP- / ZD	8	100	-5 to -10	Defrost ECO 4	25	-	13	-	10	2	
	P110	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	-5 to -10	Defrost ECO 4	25	-	25	-	10	1	
	P111	Type IV Validation and New Fuids	1	IP Mod	8	100	-5 to -10	Defrost ECO 4	75	-	-	-	10	2	
	P112	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	-5 to -10	Defrost ECO 4	75	-	13	-	7	1	
	P113	Type IV Validation and New Fuids	1	IP-	8	115	-10 to -16	Defrost ECO 4	25	-	-	-	30	1	115knts for PG
	P114	Type IV Validation and New Fuids	1	IP- / SN-	8	115	-10 to -16	Defrost ECO 4	25	10	-	-	15	1	115knts for PG
	P115	Type IV Validation and New Fuids	1	IP Mod	8	115	-10 to -16	Defrost ECO 4	75	-	-	-	10	1	115knts for PG
	P116	Type IV Validation and New Fuids	1	IP-	8	115	-16 to -22	Defrost ECO 4	25	-	-	-	30	2	115knts for PG
	P117	Type IV Validation and New Fuids	1	IP Mod	8	115	-16 to -22	Defrost ECO 4	75	-	-	-	0	2	No Allowance Time
	P118	Type IV Validation and New Fuids	1	IP-	8	115	<-22	Defrost ECO 4	25	-	-	-	30	2	115knts for PG
	P119	Type IV Validation and New Fuids	1	IP Mod	8	115	<-22	Defrost ECO 4	75	-	-	-	0	2	No Allowance Time
	P120	Type IV Validation and New Fuids	1	Fluid Only	8	100	-5 to -10	Defrost ECO 4	-	-	-	-	-	1	Baseline Test
	P121	Type IV Validation and New Fuids	1	Fluid Only	8	100	-16 to -22	Defrost ECO 4	-	-	-	-	-	1	Baseline Test
	P122	Type IV Validation and New Fuids	1	Fluid Only	8	100	<-22	Defrost ECO 4	-	-	-	-	-	1	Baseline Test
	P123	Type IV Validation and New Fuids	1	IP-	8	100	>-5	Cleansurface IV	25	-	-	-	50	1	
	P124	Type IV Validation and New Fuids	1	IP- / SN-	8	100	>-5	Cleansurface IV	25	10	-	-	40	1	
	P125	Type IV Validation and New Fuids	1	IP- / ZD	8	100	>-5	Cleansurface IV	25	-	13	-	25	2	
	P126	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	>-5	Cleansurface IV	25	-	25	-	25	1	
	P127	Type IV Validation and New Fuids	1	IP- / R-	8	100	>0	Cleansurface IV	25	-	-	25	25	2	
	P128	Type IV Validation and New Fuids	1	IP Mod	8	100	>-5	Cleansurface IV	75	-	-	-	15	1	15 min for PG
	P129	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	>-5	Cleansurface IV	75	-	13	-	10	1	

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate ($g/dm^2/h$)	SN Rate ($g/dm^2/h$)	ZR Rate ($g/dm^2/h$)	R Rate ($g/dm^2/h$)	Exposure Time	Test Priority	COMMENT
	P130	Type IV Validation and New Fuids	1	IP Mod / R	8	100	>0	Cleansurface IV	75	-	-	75	10	2	
	P131	Type IV Validation and New Fuids	1	IP-	8	100	-5 to -10	Cleansurface IV	25	-	-	-	30	2	
	P132	Type IV Validation and New Fuids	1	IP- / SN-	8	100	-5 to -10	Cleansurface IV	25	10	-	-	15	2	
	P133	Type IV Validation and New Fuids	1	IP- / ZD	8	100	-5 to -10	Cleansurface IV	25	-	13	-	10	2	
	P134	Type IV Validation and New Fuids	1	IP- / ZR-	8	100	-5 to -10	Cleansurface IV	25	-	25	-	10	1	
	P135	Type IV Validation and New Fuids	1	IP Mod	8	100	-5 to -10	Cleansurface IV	75	-	-	-	10	2	
	P136	Type IV Validation and New Fuids	1	IP Mod/ZD	8	100	-5 to -10	Cleansurface IV	75	-	13	-	7	1	
	P137	Type IV Validation and New Fuids	1	IP-	8	115	-10 to -16	Cleansurface IV	25	-	-	-	30	1	115knts for PG
	P138	Type IV Validation and New Fuids	1	IP- / SN-	8	115	-10 to -16	Cleansurface IV	25	10	-	-	15	1	115knts for PG
	P139	Type IV Validation and New Fuids	1	IP Mod	8	115	-10 to -16	Cleansurface IV	75	-	-	-	10	1	115knts for PG
	P140	Type IV Validation and New Fuids	1	IP-	8	115	-16 to -22	Cleansurface IV	25	-	-	-	30	2	115knts for PG
	P141	Type IV Validation and New Fuids	1	IP Mod	8	115	-16 to -22	Cleansurface IV	75	-	-	-	0	2	No Allowance Time
	P142	Type IV Validation and New Fuids	1	IP-	8	115	<-22	Cleansurface IV	25	-	-	-	30	2	115knts for PG
	P143	Type IV Validation and New Fuids	1	IP Mod	8	115	<-22	Cleansurface IV	75	-	-	-	0	2	No Allowance Time
	P144	Type IV Validation and New Fuids	1	Fluid Only	8	100	-5 to -10	Cleansurface IV	-	-	-	-	-	1	Baseline Test
	P145	Type IV Validation and New Fuids	1	Fluid Only	8	100	-16 to -22	Cleansurface IV	-	-	-	-	-	1	Baseline Test
	P146	Type IV Validation and New Fuids	1	Fluid Only	8	100	<-22	Cleansurface IV	-	-	-	-	-	1	Baseline Test
	P147	Type III LS Allowance Times	2	IP-	8	80	>-5	AeroClear MAX - Cold	25	-	-	-	10	1	
	P148	Type III LS Allowance Times	2	IP- / SN-	8	80	>-5	AeroClear MAX - Cold	25	10	-	-	10	1	
	P149	Type III LS Allowance Times	2	IP- / ZR-	8	80	>-5	AeroClear MAX - Cold	25	-	25	-	7	1	
	P150	Type III LS Allowance Times	2	IP- / R-	8	80	>0	AeroClear MAX - Cold	25	-	-	25	7	2	
	P151	Type III LS Allowance Times	2	IP Mod	8	80	>-5	AeroClear MAX - Cold	75	-	-	-	5	1	
	P152	Type III LS Allowance Times	2	IP-	8	80	-5 to -10	AeroClear MAX - Cold	25	-	-	-	10	1	
	P153	Type III LS Allowance Times	2	IP- / SN-	8	80	-5 to -10	AeroClear MAX - Cold	25	10	-	-	10	1	
	P154	Type III LS Allowance Times	2	IP- / ZR-	8	80	-5 to -10	AeroClear MAX - Cold	25	-	25	-	5	1	
	P155	Type III LS Allowance Times	2	IP Mod	8	80	-5 to -10	AeroClear MAX - Cold	75	-	-	-	5	1	

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time	Test Priority	COMMENT
	P156	Type III LS Allowance Times	2	IP-	8	80	-10 to -16	AeroClear MAX - Cold	25	-	-	-	10	2	
	P157	Type III LS Allowance Times	2	IP Mod	8	80	-10 to -16	AeroClear MAX - Cold	75	-	-	-	5	2	
	P158	Type III LS Allowance Times	2	IP-	8	80	-16 to -22	AeroClear MAX - Cold	25	-	-	-	10	2	
	P159	Type III LS Allowance Times	2	IP Mod	8	80	-16 to -22	AeroClear MAX - Cold	75	-	-	-	5	2	
	P160	Type III LS Allowance Times	2	IP-	8	80	<-22	AeroClear MAX - Cold	25	-	-	-	10	2	
	P161	Type III LS Allowance Times	2	IP Mod	8	80	<-22	AeroClear MAX - Cold	75	-	-	-	5	2	
	P162	Type III LS Allowance Times	2	Fluid Only	8	80	-5 to -10	AeroClear MAX - Cold	-	-	-	-	-	1	Baseline Test
	P163	Type III LS Allowance Times	2	Fluid Only	8	80	-16 to -22	AeroClear MAX - Cold	-	-	-	-	-	1	Baseline Test
	P164	Type III LS Allowance Times	2	IP-	8	100	>-5	AeroClear MAX - Cold	25	-	-	-	10	1	To be done with RJ wing
	P165	Type III LS Allowance Times	2	IP-	8	100	-5 to -10	AeroClear MAX - Cold	25	-	-	-	10	1	To be done with RJ wing
	P166	Type III LS Allowance Times	2	IP-	8	100	-10 to -16	AeroClear MAX - Cold	25	-	-	-	10	2	To be done with RJ wing
	P167	Type III LS Allowance Times	2	Fluid Only	8	100	-5 to -10	AeroClear MAX - Cold	-	-	-	-	-	1	To be done with RJ wing
	P168	Type III LS Allowance Times	2	Fluid Only	8	100	-16 to -22	AeroClear MAX - Cold	-	-	-	-	-	1	To be done with RJ wing
	P169	EG Type IV Expansion	2	IP-	8	100	>-5	ChemR EG IV	25	-	-	-	70	1	Current AT is 50 min
	P170	EG Type IV Expansion	2	IP- / SN-	8	100	>-5	ChemR EG IV	25	10	-	-	50	1	Current AT is 40 min
	P171	EG Type IV Expansion	2	IP- / ZD	8	100	>-5	ChemR EG IV	25	-	13	-	40	2	Current AT is 25 min
	P172	EG Type IV Expansion	2	IP- / ZR-	8	100	>-5	ChemR EG IV	25	-	25	-	40	1	Current AT is 25 min
	P173	EG Type IV Expansion	2	IP- / R-	8	100	>0	ChemR EG IV	25	-	-	25	40	2	Current AT is 25 min
	P174	EG Type IV Expansion	2	IP Mod	8	100	>-5	ChemR EG IV	75	-	-	-	35	1	Current AT is 25 min
	P175	EG Type IV Expansion	2	IP Mod/ZD	8	100	>-5	ChemR EG IV	75	-	13	-	20	1	Current AT is 10 min
	P176	EG Type IV Expansion	2	IP Mod / R	8	100	>0	ChemR EG IV	75	-	-	75	20	2	Current AT is 10 min
	P177	EG Type IV Expansion	2	IP-	8	100	-5 to -10	ChemR EG IV	25	-	-	-	50	2	Current AT is 30 min
	P178	EG Type IV Expansion	2	IP- / SN-	8	100	-5 to -10	ChemR EG IV	25	10	-	-	30	2	Current AT is 15 min
	P179	EG Type IV Expansion	2	IP- / ZD	8	100	-5 to -10	ChemR EG IV	25	-	13	-	30	2	Current AT is 10 min
	P180	EG Type IV Expansion	2	IP- / ZR-	8	100	-5 to -10	ChemR EG IV	25	-	25	-	30	1	Current AT is 10 min
	P181	EG Type IV Expansion	2	IP Mod	8	100	-5 to -10	ChemR EG IV	75	-	-	-	25	2	Current AT is 10 min

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Test Priority	COMMENT
	P182	EG Type IV Expansion	2	IP Mod/ZD	8	100	-5 to -10	ChemR EG IV	75	-	13	-	10	1	Current AT is 7 min
	P183	EG Type IV Expansion	2	IP-	8	100	-10 to -16	ChemR EG IV	25	-	-	-	50	1	Current AT is 30 min
	P184	EG Type IV Expansion	2	IP- / SN-	8	100	-10 to -16	ChemR EG IV	25	10	-	-	30	1	Current AT is 15 min
	P185	EG Type IV Expansion	2	IP Mod	8	100	-10 to -16	ChemR EG IV	75	-	-	-	25	1	Current AT is 10 min
	P186	EG Type IV Expansion	2	IP-	8	100	-16 to -22	ChemR EG IV	25	-	-	-	50	2	Current AT is 30 min
	P187	EG Type IV Expansion	2	IP- / SN-	8	100	-16 to -22	ChemR EG IV	25	10	-	-	30	1	No AT exists currently
	P188	EG Type IV Expansion	2	IP Mod	8	100	-16 to -22	ChemR EG IV	75	-	-	-	25	2	Current AT is 30 min
	P189	EG Type IV Expansion	2	IP-	8	100	<-22	ChemR EG IV	25	-	-	-	50	2	Current AT is 10 min
	P190	EG Type IV Expansion	2	IP Mod	8	100	<-22	ChemR EG IV	75	-	-	-	25	2	Current AT is - min
	P191	EG Type IV Expansion	2	Fluid Only	8	100	-5 to -10	ChemR EG IV	-	-	-	-	-	1	Baseline Test
	P192	EG Type IV Expansion	2	Fluid Only	8	100	-16 to -22	ChemR EG IV	-	-	-	-	-	1	Baseline Test
	P193	EG Type IV Expansion	2	Fluid Only	8	100	<-22	ChemR EG IV	-	-	-	-	-	1	Baseline Test
	P194	EG Type IV Expansion	2	IP-	8	100	>-5	Max Flight AVIA	25	-	-	-	70	1	Current AT is 50 min
	P195	EG Type IV Expansion	2	IP- / SN-	8	100	>-5	Max Flight AVIA	25	10	-	-	50	1	Current AT is 40 min
	P196	EG Type IV Expansion	2	IP- / ZD	8	100	>-5	Max Flight AVIA	25	-	13	-	40	2	Current AT is 25 min
	P197	EG Type IV Expansion	2	IP- / ZR-	8	100	>-5	Max Flight AVIA	25	-	25	-	40	1	Current AT is 25 min
	P198	EG Type IV Expansion	2	IP- / R-	8	100	>0	Max Flight AVIA	25	-	-	25	40	2	Current AT is 25 min
	P199	EG Type IV Expansion	2	IP Mod	8	100	>-5	Max Flight AVIA	75	-	-	-	35	1	Current AT is 25 min
	P200	EG Type IV Expansion	2	IP Mod/ZD	8	100	>-5	Max Flight AVIA	75	-	13	-	20	1	Current AT is 10 min
	P201	EG Type IV Expansion	2	IP Mod / R	8	100	>0	Max Flight AVIA	75	-	-	75	20	2	Current AT is 10 min
	P202	EG Type IV Expansion	2	IP-	8	100	-5 to -10	Max Flight AVIA	25	-	-	-	50	2	Current AT is 30 min
	P203	EG Type IV Expansion	2	IP- / SN-	8	100	-5 to -10	Max Flight AVIA	25	10	-	-	30	2	Current AT is 15 min
	P204	EG Type IV Expansion	2	IP- / ZD	8	100	-5 to -10	Max Flight AVIA	25	-	13	-	30	2	Current AT is 10 min
	P205	EG Type IV Expansion	2	IP- / ZR-	8	100	-5 to -10	Max Flight AVIA	25	-	25	-	30	1	Current AT is 10 min
	P206	EG Type IV Expansion	2	IP Mod	8	100	-5 to -10	Max Flight AVIA	75	-	-	-	25	2	Current AT is 10 min
	P207	EG Type IV Expansion	2	IP Mod/ZD	8	100	-5 to -10	Max Flight AVIA	75	-	13	-	10	1	Current AT is 7 min

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Test Priority	COMMENT
	P208	EG Type IV Expansion	2	IP-	8	100	-10 to -16	Max Flight AVIA	25	-	-	-	50	1	Current AT is 30 min
	P209	EG Type IV Expansion	2	IP- / SN-	8	100	-10 to -16	Max Flight AVIA	25	10	-	-	30	1	Current AT is 15 min
	P210	EG Type IV Expansion	2	IP Mod	8	100	-10 to -16	Max Flight AVIA	75	-	-	-	25	1	Current AT is 10 min
	P211	EG Type IV Expansion	2	IP-	8	100	-16 to -22	Max Flight AVIA	25	-	-	-	50	2	Current AT is 30 min
	P212	EG Type IV Expansion	2	IP- / SN-	8	100	-16 to -22	Max Flight AVIA	25	10	-	-	30	1	No AT exists currently
	P213	EG Type IV Expansion	2	IP Mod	8	100	-16 to -22	Max Flight AVIA	75	-	-	-	25	2	Current AT is 30 min
	P214	EG Type IV Expansion	2	IP-	8	100	<-22	Max Flight AVIA	25	-	-	-	50	2	Current AT is 10 min
	P215	EG Type IV Expansion	2	IP Mod	8	100	<-22	Max Flight AVIA	75	-	-	-	25	2	Current AT is - min
	P216	EG Type IV Expansion	2	Fluid Only	8	100	-5 to -10	Max Flight AVIA	-	-	-	-	-	1	Baseline Test
	P217	EG Type IV Expansion	2	Fluid Only	8	100	-16 to -22	Max Flight AVIA	-	-	-	-	-	1	Baseline Test
	P218	EG Type IV Expansion	2	Fluid Only	8	100	<-22	Max Flight AVIA	-	-	-	-	-	1	Baseline Test
	P219	Type III HS Allowance Times	3	IP-	8	100	>-5	AeroClear MAX - Cold	25	-	-	-	20	1	Current AT x2. To Revisit
	P220	Type III HS Allowance Times	3	IP- / SN-	8	100	>-5	AeroClear MAX - Cold	25	10	-	-	20	1	Current AT x2. To Revisit
	P221	Type III HS Allowance Times	3	IP- / ZR-	8	100	>-5	AeroClear MAX - Cold	25	-	25	-	14	1	Current AT x2. To Revisit
	P222	Type III HS Allowance Times	3	IP- / R-	8	100	>0	AeroClear MAX - Cold	25	-	-	25	14	2	Current AT x2. To Revisit
	P223	Type III HS Allowance Times	3	IP Mod	8	100	>-5	AeroClear MAX - Cold	75	-	-	-	10	1	Current AT x2. To Revisit
	P224	Type III HS Allowance Times	3	IP-	8	100	-5 to -10	AeroClear MAX - Cold	25	-	-	-	20	1	Current AT x2. To Revisit
	P225	Type III HS Allowance Times	3	IP- / SN-	8	100	-5 to -10	AeroClear MAX - Cold	25	10	-	-	20	1	Current AT x2. To Revisit
	P226	Type III HS Allowance Times	3	IP- / ZR-	8	100	-5 to -10	AeroClear MAX - Cold	25	-	25	-	10	1	Current AT x2. To Revisit
	P227	Type III HS Allowance Times	3	IP Mod	8	100	-5 to -10	AeroClear MAX - Cold	75	-	-	-	10	1	Current AT x2. To Revisit
	P228	Type III HS Allowance Times	3	IP-	8	100	-10 to -16	AeroClear MAX - Cold	25	-	-	-	20	2	Current AT x2. To Revisit
	P229	Type III HS Allowance Times	3	IP Mod	8	100	-10 to -16	AeroClear MAX - Cold	75	-	-	-	10	2	Current AT x2. To Revisit
	P230	Type III HS Allowance Times	3	IP-	8	100	-16 to -22	AeroClear MAX - Cold	25	-	-	-	20	2	Current AT x2. To Revisit
	P231	Type III HS Allowance Times	3	IP Mod	8	100	-16 to -22	AeroClear MAX - Cold	75	-	-	-	10	2	Current AT x2. To Revisit
	P232	Type III HS Allowance Times	3	IP-	8	100	<-22	AeroClear MAX - Cold	25	-	-	-	20	2	Current AT x2. To Revisit
	P233	Type III HS Allowance Times	3	IP Mod	8	100	<-22	AeroClear MAX - Cold	75	-	-	-	10	2	Current AT x2. To Revisit

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate ($g/dm^2/h$)	SN Rate ($g/dm^2/h$)	ZR Rate ($g/dm^2/h$)	R Rate ($g/dm^2/h$)	Exposure Time	Test Priority	COMMENT
	P234	Type III HS Allowance Times	3	Fluid Only	8	100	-5 to -10	AeroClear MAX - Cold	-	-	-	-	-	1	Baseline Test, needed for LS
	P235	Type III HS Allowance Times	3	Fluid Only	8	100	-16 to -22	AeroClear MAX - Cold	-	-	-	-	-	1	Baseline Test, needed for LS
	P236	R&D	3	TIII Expansion	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	TIII IP AT Expansion
	P237	R&D	3	Snow Aero	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	Snow Allowance Times
	P238	R&D	3	EG Aero	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	EG Fluid Allowance Times
	P239	R&D	3	S+++	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	Heavy snow
	P240	R&D	3	Heavy Cont	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	Heavy contamination
	P241	R&D	3	Tunnel Cooling	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	Tunnel Cooling Effects
	P242	R&D	3	LOUT w/ Cont.	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	Test w/ contamination @ LOUT
	P243	R&D	3	Sim. Frost	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	Simulated Frost
	P244	R&D	3	IP @ >130kts	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	IP testing a higher speeds
	P245	R&D	3	2nd Wave	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	2	2nd wave of fluid at rot.
	P246	Clean Wing		None	8	100	any	none							1.1
	P247	Clean Wing		None	8	100	any	none							1.6 (repeat)
	P248	Clean Wing		None	8	80	any	none							1.2
	P249	Clean Wing		None	8	80	any	none							1.6 (repeat)
	P250	Clean Wing		None	8, then stall	80	any	none							1.3
	P251	Clean Wing		None	8, then stall	80	any	none							1.6 (repeat)
	P252	Clean Wing		None	stall	80	any	none							1.4
	P253	Clean Wing		None	stall	80	any	none							1.6 (repeat)
	P254	Clean Wing		None	stall -4 to stall +4 PP@1	80	any	none							1.5
	P255	Clean Wing		None	stall -4 to stall +4 PP@1	80	any	none							1.6 (repeat)
	P256	Oil Flow Visualization		Oil	8 static	80	any	none							2.1
	P257	Oil Flow Visualization		Oil	4 or 6 static	80	any	none							2.2
	P258	Oil Flow Visualization		Oil	stall, static	80	any	none							2.3

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Test Priority	COMMENT
	P259	Oil Flow Visualization		Oil	stall-1, static	80	any	none							2.3
	P260	Oil Flow Visualization		Oil	stall-2, static	80	any	none							2.3
	P261	Oil Flow Visualization		Oil	stall-4, static	80	any	none							2.3
	P262	Oil Flow Visualization		Oil	stall-8, static	80	any	none							2.3
	P263	Roughness (Trips)		40-grit	stall	80	any	none							3.1
	P264	Roughness (Trips)		40-grit	stall -4 to stall +4 PP@1	80	any	none							3.1
	P265	Roughness (Trips)		150-grit	stall	80	any	none							3.2
	P266	Roughness (Trips)		150-grit	stall -4 to stall +4 PP@1	80	any	none							3.2
	P267	Roughness (Trips)		80-grit	stall	80	any	none							3.3
	P268	Roughness (Trips)		80-grit	stall -4 to stall +4 PP@1	80	any	none							3.3
	P269	Roughness (Trips)		Full Wing Grit (80?)	stall	80	any	none							3.4
	P270	Roughness (Trips)		Full Wing Grit (80?)	stall -4 to stall +4 PP@1	80	any	none							3.4
	P271	Roughness (Trips)		Grit (-30% grit on LE)	stall	80	any	none							3.5
	P272	Roughness (Trips)		Grit (-30% grit on LE)	stall -4 to stall +4 PP@1	80	any	none							3.5
	P273	Roughness (Trips)		Grit (-60% grit on LE)	stall	80	any	none							3.6
	P274	Roughness (Trips)		Grit (-60% grit on LE)	stall -4 to stall +4 PP@1	80	any	none							3.6
	P275	Roughness (Trips)		Grit (Flap Only)	stall	80	any	none							3.7

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Test Priority	COMMENT
	P276	Roughness (Trips)		Grit (Flap Only)	stall -4 to stall +4 PP@1	80	any	none							3.7
	P277	Roughness (Trips)		Diff. Grit (Flap Only)	stall	80	any	none							3.8
	P278	Roughness (Trips)		Diff. Grit (Flap Only)	stall -4 to stall +4 PP@1	80	any	none							3.8
	P279	Boundary-layer Rake Measurments		BL Rake TE Center	-2 to stall	TBD	TBD	none							4.1
	P280	Boundary-layer Rake Measurments		BL Rake TE Center -3ft	-2 to stall	TBD	TBD	none							4.2
	P281	Boundary-layer Rake Measurments		BL Rake TE Center +3ft	-2 to stall	TBD	TBD	none							4.3
	P282	Boundary-layer Rake Measurments		BL Rake Flap Center	-2 to stall	TBD	TBD	none							4.4
	P283	Boundary-layer Rake Measurments		BL Rake Flap Center - 3ft	-2 to stall	TBD	TBD	none							4.5
	P284	Boundary-layer Rake Measurments		BL Rake Flap Center +3ft	-2 to stall	TBD	TBD	none							4.6
	P285	Fluid Tests - Repeatibility		Fluid Only	8	100	TBD	2017-18 TIV #1?							5.1
	P286	Fluid Tests - Repeatibility		Fluid Only	8	100	TBD	2017-18 TIV #2?							5.1
	P287	Fluid Tests - Repeatibility		Fluid Only	8	100	TBD	AllClear TIII (100)							5.1
	P288	Fluid Tests - Repeatibility		IP-	8	100	TBD	2017-18 TIV #1?							5.2
	P289	Fluid Tests - Repeatibility		IP-	8	100	TBD	2017-18 TIV #2?							5.2
	P290	Fluid Tests - Repeatibility		IP-	8	100	TBD	AllClear TIII (100)							5.2
	P291	Fluid Tests - New BLDT		Fluid Only	8	80	below -25	AllClear TIII (100)							5.3
	P292	Fluid Tests - New BLDT		Fluid Only	8	80	below -25	AllClear TIII (100)							5.3
	P293	Fluid Tests - New BLDT		Fluid Only	8	80	below -20	AllClear TIII (100)							5.3
	P294	Fluid Tests - New BLDT		Fluid Only	8	80	below -20	AllClear TIII (100)							5.3

Table 3.2: Proposed Test Plan (Cont'd)

Test #	Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Test Priority	COMMENT
	P295	Fluid Tests - New BLDT		Fluid Only	8	80	-15 to -20	AllClear TIII (100)							5.3
	P296	Fluid Tests - New BLDT		Fluid Only	8	80	-15 to -20	AllClear TIII (100)							5.3
	P297	Fluid Tests - New BLDT		Fluid Only	8	80	-10 to -15	AllClear TIII (100)							5.3
	P298	Fluid Tests - New BLDT		Fluid Only	8	80	-10 to -15	AllClear TIII (100)							5.3
	P299	Fluid Tests - Repeatibility		Fluid Only	Stall, pause at 8	100	TBD	2017-18 TIV #1?							5.4
	P300	Fluid Tests - Repeatibility		Fluid Only	Stall, pause at 8	100	TBD	2017-18 TIV #2?							5.4
	P301	Fluid Tests - Repeatibility		Fluid Only	Stall, pause at 8	100	TBD	AllClear TIII (100)							5.4
	P302	Fluid Tests - Repeatibility		IP-	Stall, pause at 8	100	TBD	2017-18 TIV #1?							5.4
	P303	Fluid Tests - Repeatibility		IP-	Stall, pause at 8	100	TBD	2017-18 TIV #2?							5.4
	P304	Fluid Tests - Repeatibility		IP-	Stall, pause at 8	100	TBD	AllClear TIII (100)							5.4
	P305	Fluid Tests - Repeatibility		Fluid Only	Stall	100	TBD	2017-18 TIV #1?							5.5
	P306	Fluid Tests - Repeatibility		Fluid Only	Stall	100	TBD	2017-18 TIV #2?							5.5
	P307	Fluid Tests - Repeatibility		Fluid Only	Stall	100	TBD	AllClear TIII (100)							5.5
	P308	Fluid Tests - Repeatibility		IP-	Stall	100	TBD	2017-18 TIV #1?							5.5
	P309	Fluid Tests - Repeatibility		IP-	Stall	100	TBD	2017-18 TIV #2?							5.5
	P310	Fluid Tests - Repeatibility		IP-	Stall	100	TBD	AllClear TIII (100)							5.5
	P311	Fluid Tests - Repeatibility		Fluid Only	Stall	100	TBD	2017-18 TIV #1?							5.6
	P312	Fluid Tests - Repeatibility		Fluid Only	Stall	100	TBD	2017-18 TIV #2?							5.6
	P313	Fluid Tests - Repeatibility		Fluid Only	Stall	100	TBD	AllClear TIII (100)							5.6
	P314	Fluid Tests - Repeatibility		IP-	Stall	100	TBD	2017-18 TIV #1?							5.6
	P315	Fluid Tests - Repeatibility		IP-	Stall	100	TBD	2017-18 TIV #2?							5.6
	P316	Fluid Tests - Repeatibility		IP-	Stall	100	TBD	AllClear TIII (100)							5.6

4. PRE-TESTING SETUP ACTIVITIES

The activities to be performed for planning and preparation, on the first day of testing, and prior to each testing day thereafter, have been detailed in a list included in Attachment 1.

5. DATA FORMS

The following data forms are required for the January 2018 wind tunnel tests:

- Attachment 2: General Form;
- Attachment 3: Wing Temperature, Fluid Thickness and Fluid Brix Form;
- Attachment 4: Example Ice Pellet Dispensing Form;
- Attachment 5: Example Snow Dispensing Form;
- Attachment 6: Example Snow Dispensing Form (Manual Method);
- Attachment 7: Visual Evaluation Rating Form;
- Attachment 8: Fluid Receipt Form (Electronic Form); and
- Attachment 9: Log of Fluid Sample Bottles.

When and how the data forms will be used is described throughout Section 6.

6. PROCEDURE

The following sections describe the tasks to be performed during each test conducted. It should be noted that some sections (i.e. fluid application and contamination application) will be omitted depending on the objective of the test.

6.1 Initial Test Conditions Survey

- Record ambient conditions of the test (Attachment 2); and
- Record wing temperature (Attachment 3).

6.2 Fluid Application (Pour)

- Hand pour 20L of anti-icing fluid over the test area (fluid can be poured directly out of pails or transferred into smaller 3L jugs);

- Record fluid application times and quantities (Attachment 2);
- Let fluid settle for 5 minutes (as the wing section is relatively flat, last winter it required tilting the wing for 1-minute to enable fluid to be uniform);
- Measure fluid thickness at pre-determined locations on the wing (Attachment 3);
- Record wing temperature (Attachment 3);
- Measure fluid Brix value (Attachment 3);
- Photograph and videotape the appearance of the fluid on the wing; and
- Begin the time-lapse camera to gather photos of the precipitation application phase.

Note: At the request of TC/FAA, a standard aluminum test plate can be positioned on the wing in order to run a simultaneous endurance time test.

6.3 Application of Contamination

6.3.1 Ice Pellet/Snow Dispenser Calibration and Set-Up

Calibration work was performed during the winter of 2007-08 on the modified ice pellet/snow dispensers prior to testing with the Falcon 20. The purpose of this calibration work was to attain the dispenser's distribution footprint for both ice pellets and snow. A series of tests were performed in various conditions:

- Ice Pellets, Low Winds (0 to 5 km/h);
- Ice Pellets, Moderate Winds (10 km/h);
- Snow, Low Wind (0 to 5 km/h); and
- Snow, Moderate Wind (10 km/h).

These tests were conducted using 121 collection pans, each measuring 6 x 6 inches, over an area 11 x 11 feet. Pre-measured amounts of ice pellets/snow were dispersed over this area and the amount collected by each pan was recorded. A distribution footprint of the dispenser was attained and efficiency for the dispenser was computed.

6.3.2 Dispensing Ice Pellets/Snow for Wind Tunnel Tests

Using the results from these calibration tests, a decision was made to use two dispensers on each of the leading and trailing edges of wing; each of the four dispensers are moved to four different positions along each edge during the dispensing process. Figure 6.1, Figure 6.2, and Figure 6.3 demonstrate the setup of the dispensers in relation to the wing. Attachment 4 and Attachment 5 display the data sheets that will be used during testing in the wind tunnel. These data sheets will provide all the necessary information related to the amount of ice pellets/snow needed, effective rates and dispenser positions. During the winter of 2009-10, snow was also dispensed manually using sieves. This technique was used when higher rates of precipitation were required (for heavy snow) or when winds in the tunnel made dispensing difficult. The efficiency of this technique was estimated at 90% based on how much of the precipitation actually made it onto the wing and a form to be used for this dispensing process along with dispensing instructions is included in Attachment 6.

Note: Dispensing forms should be filled out and saved for each run and pertinent information shall be included in the general form (Attachment 2). Any comments regarding dispensing activities should be documented directly on the form.

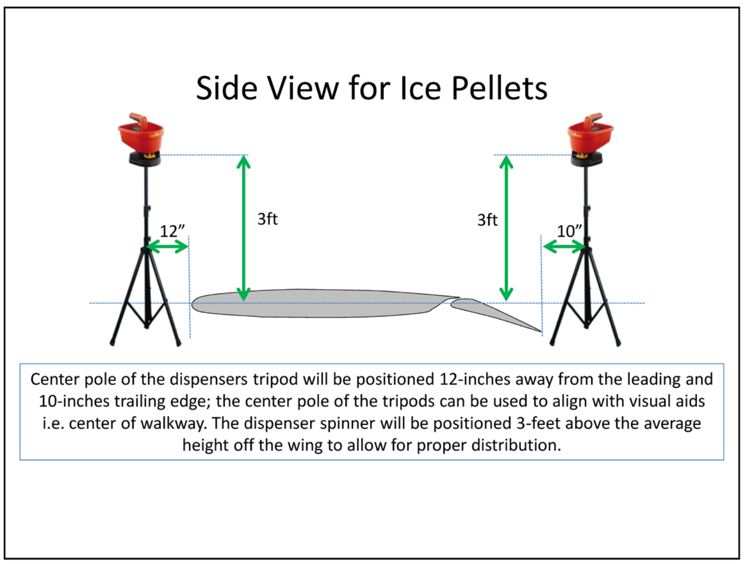


Figure 6.1: Side View of Positioning of Dispensers Relative to the Wing – Ice Pellets

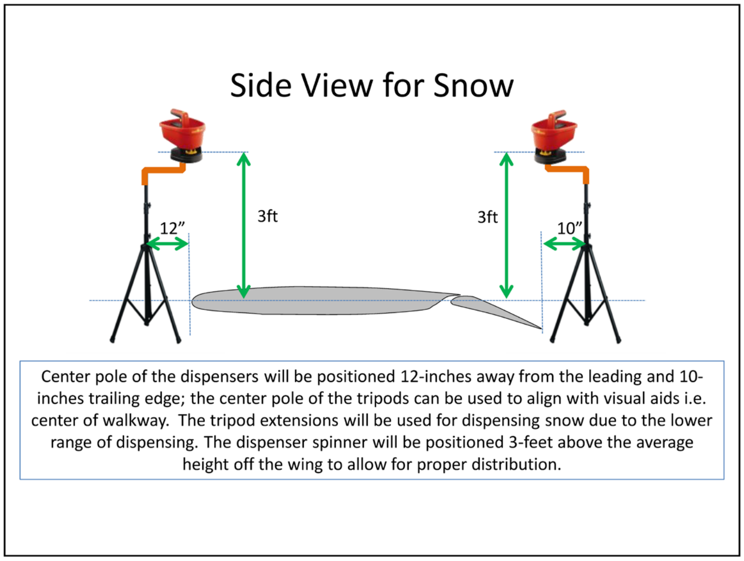


Figure 6.2: Side View of Positioning of Dispensers Relative to the Wing – Snow

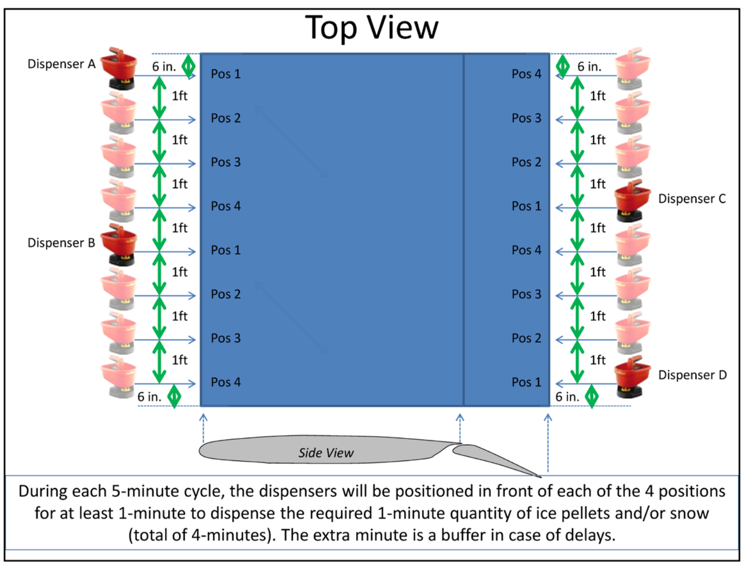


Figure 6.3: Top View of Positioning of Dispensers Relative to the Wing

6.3.3 New Ice Pellets/Snow Dispensing Systems for 2014 Onwards

Simulated ice pellets are distributed over a test surface using an ice pellet pitcher. The original ice pellet pitcher (Yardworks) was a modified handheld fertilizer dispenser. The rate of precipitation was controlled with the speed of rotation of the motor, as well as the size of the opening of the dispenser reservoir drop feeder.

In the winter of 2012-13, seed spreaders historically modified and used for applying ice pellets during wind tunnel and flat plate testing, were no longer available as the manufacturer stopped production of the model. A new replacement seed spreader system (Wolf Garten) was found which is similar (but not identical). Some calibration work was required to demonstrate an equivalency in the two systems; testing was conducted at the NRC CEF prior to the wind tunnel testing to verify the distribution of the historical system versus the new replacement system the details of which are included in the TC report TP 15230E Aircraft Ground Icing General Research Activities During the 2012-13 Winter (4).

The data collected demonstrated that the new system is very similar to old system; some small variation was present in distribution within the footprint, but equivalent efficiency on the overall footprint. Based on this it was concluded that for ice pellets, the new system can be used as a direct replacement. For snow, the new system was more efficient, therefore a reduction of 10% should be used for the snow mass requested.

Comparative wind tunnel testing was conducted in the winter of 2013-14 to further validate the equivalency of the systems, the details of which are included in the TC report TP 15274E Exploratory Wind Tunnel Aerodynamic Research. The results indicated that the differences in recorded lift losses were generally very small (less than 1.3%) when comparing back-to-back tests with no bias towards one system or the other. The differences were even smaller when looking at the average of the four comparative sequential tests (Test #330 to #337) which was 0.1%. In addition, the tests were visually evaluated to verify that the distribution of the ice pellets was similar, further supporting the similarity in aerodynamic results between the two dispenser systems.

In general, the wind tunnel results further supported the original distribution equivalency work conducted during the winter of 2012-13 and demonstrated that the new generation dispensers are suitable replacements for the older model dispensers.

6.4 Prior to Engines-On Wind Tunnel Test

- Measure fluid thickness at the pre-determined locations on the wing (Attachment 3);
- Measure fluid Brix value (Attachment 3);
- Record wing temperatures (Attachment 3);
- Record start time of test (Attachment 2); and
- Fill out visual evaluation rating form (Attachment 7).

Note: In order to minimize the measurement time post precipitation, temperature should be measured 5-minutes before the end of precipitation, thickness measured 3-minutes before the end of precipitation, and Brix measured when the precipitation ends. Also consideration has been given to reducing the number of measurements that are taken for this phase (i.e. locations 2 and 5 only).

6.5 During Wind Tunnel Test

- Take still pictures and video the behavior of the fluid on the wing during the takeoff run, capturing any movement of fluid/contamination;
- Fill out visual evaluation rating form at the time of rotation (Attachment 7); and
- Record wind tunnel operation start and stop times.

6.6 After the Wind Tunnel Test

- Measure fluid thickness at the pre-determined locations on the wing (Attachment 3);
- Measure fluid Brix value (Attachment 3);
- Record wing temperatures (Attachment 3);
- Observe and record the status of the fluid/contamination (Attachment 3);
- Fill out visual evaluation rating form (Attachment 7);
- Obtain lift data (excel file) from NRC; and
- Update APS test log with pertinent information.

6.7 Fluid Sample Collection for Viscosity Testing

Two liters of each fluid to be tested are to be collected on the first day of testing. The fluid receipt form (Attachment 8) should be completed indicating quantity of fluid and date received. Any samples extracted for viscosity purposes should be documented in the log of fluid samples data form (Attachment 9). A falling ball viscosity test should be performed on site to confirm that fluid viscosity is appropriate before testing.

6.8 At the End of Each Test Session

If required, APS personnel will collect the waste solution. At the end of the testing period, NRC will organize for a glycol recovery service provider to safely dispose of the waste glycol fluid.

6.9 Camera Setup

It is anticipated that the camera setup will be similar to the setup used during the winter of 2013-14. Modifications may be necessary and will be dealt with on-site. The flashes will be positioned on the control-room side of the tunnel, and the cameras will be positioned on the opposite side. The final positioning of the cameras and flashes should be documented to identify any deviation from the previous year's setup.

6.10 Demonstration of a Typical Wind Tunnel Test Sequence

Table 6.1 demonstrates a typical Wind Tunnel test sequence of activities, assuming the test starts at 08:00:00. Figure 6.4 demonstrates a typical wind tunnel run timeline.

Table 6.1: Typical Wind Tunnel Test

TIME	TASK
8:30:00	START OF TEST. ALL EQUIPMENT READY.
8:30:00	- Record test conditions.
8:35:00	- Prepare wing for fluid application (clean wing, etc).
8:45:00	- Measure wing temperature. - Ensure clean wing for fluid application
8:50:00	- Pour fluid over test area.
9:00:00	- Measure Brix, thickness, wing temperature. - Photograph test area.
9:05:00	- Apply contamination over test area. (i.e. 30 min)
9:35:00	- Measure Brix, thickness, wing temperature. - Photograph test area.
9:40:00	- Clear area and start wind tunnel
9:55:00	- Wind tunnel stopped
10:05:00	- Measure Brix, thickness, wing temperature. - Photograph test area. - Record test observations.
10:35:00	END OF TEST

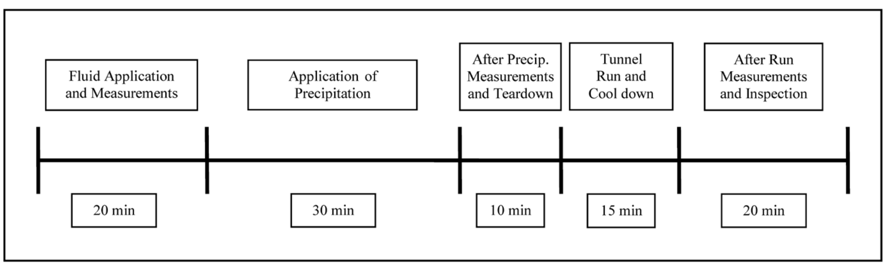


Figure 6.4: Typical Wind Tunnel Run Timeline

6.11 Procedures for Testing Objectives

Details for the testing objectives have been included in the following attachments:

- Attachment 10: Procedure - Dry Wing Performance;
- Attachment 11: Procedure – Type IV Ice Pellet Allowance Time Validation with New Fluids;
- Attachment 12: Procedure – Development of EG Specific Ice Pellet Allowance Time Table;
- Attachment 13: Procedure – Type III Low Speed Allowance Time Testing LS-0417 Wing Model Calibration and Characterization;
- Attachment 14: Procedure – Type III Ice Pellet Allowance Time Validation at 80 Knots with LS-0417 Wing Section;
- Attachment 15: Procedure – Type III Ice Pellet Allowance Time Expansion;
- Attachment 16: Procedure – Snow Allowance Times Using Aerodynamic Data;
- Attachment 17: Procedure - Heavy Snow;
- Attachment 18: Procedure - Heavy Contamination;
- Attachment 19: Procedure - Wind Tunnel Test Section Cooling;
- Attachment 20: Procedure - Fluid and Contamination at LOUT;
- Attachment 21: Procedure - Frost Simulation in the Wind Tunnel;
- Attachment 22: Procedure - Feasibility of Ice Pellet Testing at Higher Speeds; and
- Attachment 23: Procedure - 2nd Wave of Fluid during Rotation.

7. EQUIPMENT

Equipment to be employed is shown in Table 7.1.

Table 7.1: Equipment List

EQUIPMENT	STATUS		EQUIPMENT	STATUS
General Support and Testing Equipment			**Camera Equipment**	
20L containers x 12			AA Batteries x 48	
Adherence Probes Kit			C2032 Batteries x 10	
Barrel Opener (steel)			Digital still cameras x3 (two suitcases)	
Black Shelving Unit (or plastic)			Flashes and tripods (in APS storage)	
Blow Horns x 4			GoPro Cameras x 3 and related hardware	
Electrical tape x 5				
Envelopes and labels				
Exacto Knives x 2			**Ice Pellets Fabrication Equipment**	
Extension cords (power bars x 6 + reels x 4)			Blenders x 12 in good condition	
Falling Ball Viscometer			Folding tables (2 large, 1 small)	
Fluid pouring jugs x 60			Ice bags	
Fluids (ORDER and SHIP to Ottawa)			Ice bags storage freezer x 3	
Funnels(1 big + 1 small)			Ice pellets sieves (base, 1.4 mm, 4 mm)	
Gloves - black and yellow			Ice pellets Styrofoam containers x20	
Gloves - cotton (1 box)			Measuring cups (1L and smaller ones for dispensing)	
Gloves - latex (2 boxes)			NCAR Scale x 1	
Grid Section + Location docs			Refrigerated Truck	
Hard water chemicals x 3 premixes			Rubber Mats x all	
Horse and tap for fluid barrel x all			Wooden Spoons	
Hot Plate x 3 and Large Pots with rubber handles for Type III				
Ice pellet box supports for railing x4			**Freezing Rain Equipment**	
Ice Pellet control wires and boxes (all for new and old)			APS PC equipped with rate station software	
Ice pellets dispersers x 12 (6 new and 6 old)			NRC Freezing rain sprayer (NRC will provide)	
Inclinometer (yellow level) x 2			Rubber suction cup feet for wooden boards	
Isopropyl x 24			White plastic rate pans (1 to 8 x 2)	
Large and small tape measure			Wooden boards for rate pans (x8)	
Large Sharpies for Grid Section				
Long Ruler for marking wing x 2				
Marker for waste x 2			**Office Equipment**	
Paper towel x 48			APS Laptops x 6 with mouse and chargers	
Protective clothing (all) and personnel clothing			APS tuques x 10	
Sample bottles for viscosity measurement x 8			Calculators x 3	
Sartorius Weigh Scale x 1			Clip boards x 8	
Scrapers x 5			Data Forms	
Shop Vac			Dry eraser markers	
Speed tape x 1 small			Envelopes (9x12) x box	
Squeegees (5 small + 3 large floor)			File box x 2	
Stands for ice pellets dispensing devices x 6			Hard drive with all WT Photos	
Stop Watches x 4			Hard Drive x 2	
Temperature probes: immersion x 3			Pencils + sharpies/markers	
Temperature probes: surface x 3			Projector for laptop	
Temperature readers x 2 + spare batteries			Scissors	
Test Plate x 1			Small 90º aluminum ruler for wing	
Thermometer for Reefer Truck			Test Procedures x 8, printer paper	
Thickness Gauges (5 small, 5 big)			YOW employee contracts	
Vise grip (large) + rubber opener for containers				
Walkie Talkies x 12				
Water (2 x 18L) for hard water				
Watmans Paper and conversion charts				
Red Thermoses for Type III Transport				

8. FLUIDS

Mid-viscosity samples of ethylene glycol and propylene glycol IV fluid will be used in the wind tunnel tests. Although the number of tests conducted will be determined based on the results obtained, the fluid quantities available are shown in Table 8.1 (quantities to be confirmed once fluid is received). Up to 2960L of 100/0 Type IV and Type III fluid are expected to be available; an additional 404L of other fluids are also available if needed. Fluid application will be performed by pouring the fluid (rather than spraying) to reduce any shearing to the fluid.

Table 8.1: Fluid Available for Wind Tunnel Tests

FLUID	Type	DILUTION	ORDERED (L)	IN STOCK (L)	Estimated Remaining (L)	Full Containers	Partial Containers
ChemR EG IV	IV	100/0	400				
Max Flight AVIA	IV	100/0	400				
Max Flight SNEG	IV	100/0	300				
ECO-SHIELD	IV	100/0	300				
Defrost ECO 4	IV	100/0	300				
Cleansurface IV	IV	100/0	300				
UCAR™ FlightGuard AD-49	IV	100/0		180		6	3
ABC-S Plus	IV	100/0		200		5	3
Polar Guard® Advance	IV	100/0		140		5	2
AeroClear MAX	III	100/0	400	40		0	2
Safewing MP II FLIGHT	II	100/0		150		4	1
UCAR™ FlightGuard AD-49	IV	75/25		140		7	0
Polar Guard® Advance	IV	50/50		100		5	0
Lift-Off E-188	I	Brix 26.25		14		0	1 (at YUL site)

3600 L ordered for 2009-10 testing (18 days)
3200 L ordered for 2010-11 testing (15 days)
1800 L ordered for 2011-12 testing (7 of 15 days will be fluid testing)
4200 L ordered for 2012-13 testing (15 days)
1300L ordered for 2013-14 testing (15 days), 1900L previously in stock
1700L available for 2015-16 Testing (10 days)

9. PERSONNEL

Five APS staff members are required for the tests at the NRC wind tunnel. Four additional persons (with one back-up) will be required from Ottawa for making and dispensing the ice pellets and snow. One additional person from Ottawa will be required to photograph the testing. Table 9.1 demonstrates the personnel required and their associated tasks.

Fluid and ice pellets applications will be performed by APS/YOW personnel at the NRC wind tunnel. NRC personnel will operate the NRC wind tunnel and operate the freezing rain/drizzle sprayer (if requested).

Table 9.1: Personnel List

Wind Tunnel 2015-16 - Tentative	
Person	**Responsibility**
John	Director
Marco	Lead Engineer and Project Coordinator
Chloë	Data documentation (forms, logs, camera setup, etc) / IP Manager
Ben B	Data Collection / Fluid Manager (inventory and application) / YOW Pers. Manager
YOW Personnel	
Ben G	Photography / Camera Documentation
Steve	Fluids / IP / Dispensing / General Support
YOW 1	Fluids / IP / Dispensing
YOW 2	Fluids / IP / Dispensing
YOW 3	Fluids / IP / Dispensing
YOW 4	Back-up

NRC Institute of Aerospace Research Contacts

- Cory Bates: (613) 913-9720; and
- Marc MacMaster: (613) 998-6932.

10. SAFETY

- A safety briefing will be done on the first day of testing;
- Personnel should be familiar with NRC emergency procedures i.e. DO NOT CALL 9-1-1, instead call the NRC Emergency Center as they will contact and direct the necessary services;
- All personnel must be familiar with the Material Safety Data Sheets (MSDS) for fluids;
- Prior to operating the wind tunnel, loose objects should be removed from the vicinity;
- When wind tunnel is operating, ensure that ear plugs are worn if necessary and personnel keep safe distances;

- When working on ladders, ensure equipment is stable;
- CSA approved footwear and appropriate clothing for frigid temperatures are to be worn by all personnel;
- Caution should be taken when walking in the test section due to slippery floors, and dripping fluid from the wing section;
- If fluid comes into contact with skin, rinse hands under running water; and
- If fluid comes into contact with eyes, flush with the portable eye wash station.

Attachment 1: Task List for Setup and Actual Tests

No.	Task	Person	Status
	Planning and Preparation		
1	Co-ordinate with NRC wind tunnel personnel	MR/JD	
2	Ensure fluid is received by NRC and is stored outdoors	MR/JD	
3	Check with NRC the status of the testing site, tunnel etc	MR	
4	Arrange for hotel accommodations for APS personnel	ST	
5	Arrange truck rental	BB	
6	Arrange for ice and freezer delivery	ST	
7	Organize personnel travel to Ottawa;	MR	
8	Hire YOW personnel	CB	
9	Complete contract for YOW personnel	CB	
10	Co-ordinate with APS photographer	MR	
11	Ensure availability of freezing rain sprayer equipment;	MR	
12	Prepare and Arrange Office Materials for YOW	CB	
13	Prepare Data forms and procedure	CB	
14	Back up hard drives with all TC projects	CB	
15	Prepare Test Log and Merge Historical Logs for Reference	CB	
16	Prepare historical falling ball records spreadsheet	CB	
17	Finalize and complete list of equipment/materials required	MR	
18	Prepare and Arrange Site Equipment for YOW	BB/DY	
19	Ensure proper functioning of ice pellet dispenser equipment;	MR	
20	Review IP/ZR/SN dispersal techniques and location	CB/MR	
21	Update IP/SN Order Form (if necessary)	CB/MR	
22	Check weather prior to finalizing test dates and Day vs. Night Shift, Start Time	MR/JD	
23	Arrange for pallets to lift up 1000L totes (if applicable)	MR	
24	Purchase new 20 L containers (as necessary)	BB	
25	Complete purchase list and shopping	CB	
26	Pack and leave YUL for YOW	APS	
	Testing Day 1		
27	Safety Briefing & Training (APS/YOW)	MR	
28	Unload Truck and organize equipment in lower, middle, or office area	APS	
29	Verify and Organize Fluid Received (labels and fluid receipt forms)	BB/STB	
30	Transfer Fluids from 1000 L Totes to 20 L containers	BB/STB	
31	Collect fluid samples for viscosity at APS office and for Falling Ball	BB/CB	
32	Conduct falling ball verification	BB/CB	
33	Confirm ice and freezer delivery	BB	
34	Setup general office and testing equipment	CB	
35	Setup Projector	CB	
36	Setup Printer	CB	
37	Setup rate station (if necessary)	CB	
38	Setup IP/SN manufacturing material in reefer truck	BB/STB	
39	Test and prepare IP dispensing equipment	BB/STB	
40	Train IP making personnel (ongoing)	STB/YOW	
41	Co-ordinate fabrication of ice pellets/snow	CB/STB	
42	IP/SN/ZR Calibration (if necessary)	BB/CB/MR	
43	Start IP manufacturing	STB	
44	Mark wing (only if requested);	CB	
45	Setup Still and Video Cameras	BG/YOW	
46	Verify photo and video angles, resolution, etc,	BG/STBD/MR	
47	Document new final camera and flash locations	CB/BG/STBD	
48	General safety briefing and update on testing	APS/NRC/YOW	
49	Dry Run of tests with APS and NRC (if necessary)	APS/NRC	
50	Start Testing (Dry wing tests may be possible while setup occurs)	APS/NRC	
	Each Testing Day		
51	Check with NRC the status of the testing site, tunnel, weather etc	MR	
52	Deicide personnel requirements for following day for 24hr notice	MR/WU	
53	Prepare equipment and fluid to be used for test	BB	
54	Manufacture ice pellets	STB/YOW	
55	Prepare photography equipment	BG	
56	Prepare data forms for test	CB	
57	Conduct tests based on test plan	APS	
58	Modify test plan based on results obtained	WU/JD/MR	
59	Update ice pellet, snow, raw ice, and fluid Inventory (end of day)	CB/STB	
60	Update Test Log and Test Plan (ongoing and end of day)	CB	

Attachment 2: General Form

GENERAL FORM (EVERY TEST)

DATE: ____________ FLUID APPLIED: ____________ RUN # (Plan #): ____________

AIR TEMPERATURE (°C) BEFORE TEST: ____________ AIR TEMPERATURE (°C) AFTER TEST: ____________

TUNNEL TEMPERATURE (°C) BEFORE TEST: ____________ TUNNEL TEMPERATURE (°C) AFTER TEST: ____________

WIND TUNNEL START TIME: ____________ PROJECTED SPEED (S/KTS): ____________

ROTATION ANGLE: ____________ EXTRA RUN INFO: ____________

FLAP SETTING (20°, 0°): ____________

☐ Check if additional notes provided on a separate sheet

FLUID APPLICATION

Actual start time: ____________ Actual End Time: ____________

Fluid Brix: ____________ Amount of Fluid (L): ____________

Fluid Temperature (°C): ____________ Fluid Application Method: POUR

ICE PELLETS APPLICATION (if applicable)

Actual start time: ____________ Actual End Time: ____________

Rate of Ice Pellets Applied (g/dm²/h): ____________ Ice Pellets Size (mm): 1.4 - 4.0 mm

Exposure Time: ____________

Total IP Required per Dispenser: ____________

FREEZING RAIN/DRIZZLE APPLICATION (if applicable)

Actual start time: ____________ Actual End Time: ____________

Rate of Precipitation Applied (g/dm²/h): ____________ Droplet Size (mm): ____________

Exposure Time: ____________ Needle: ____________

Flow: ____________

Pressure: ____________

SNOW APPLICATION (if applicable)

Actual start time: ____________ Actual End Time: ____________

Rate of Snow Applied (g/dm²/h): ____________ Snow Size (mm): <1.4 mm

Exposure Time: ____________ Method: ☐ Dispenser ☐ Sieve

Total SN Required per Dispenser: ____________

COMMENTS

MEASUREMENTS BY: ____________ **HANDWRITTEN BY:** ____________

Attachment 3: Wing Temperature, Fluid Thickness and Fluid Brix Form

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

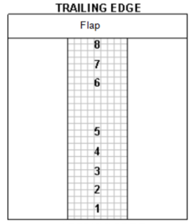
Date: ______________________ Run: ______________

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2				
T5				
TU				
Time:				

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2			
8			
Flap			
Time:			

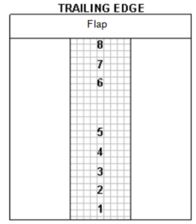
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2			
3			
4			
5			
6			
7			
8			
Flap			
Time:			

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

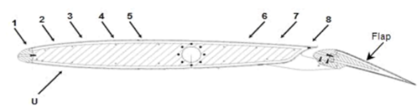


Comments:____________________
____
____
____

Wing and Plate Condition
After the Takeoff Run
Time: ___________



Comments:____________________
____
____
____



Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;

Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;

Wing Position 6: Approximately 30 cm from trailing edge;

Wing Position 7: Approximately 15 cm from trailing edge;

Wing Position 8: Approximately 2.5 cm from trailing edge; and

Wing Position 9: Midway up the flap

Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: ____________________
____
____
____

OBSERVER: ____________________
ASSISTED BY: ____________________

Attachment 4: Example Ice Pellet Dispensing Form

WING TRAILING EDGE

8 ft = 24.4 dm

6 ft = 18.3 dm

DISPENSER #3								DISPENSER #4							
1	1ft	2	1ft	3	1ft	4		1	1ft	2	1ft	3	1ft	4	
14.9	16.5	18.2	17.4	18.5	17.6	18.5	17.6	18.5	17.6	18.5	17.6	17.2	17.2	16.3	13.3
20.3	24.1	26.2	26.4	27.3	26.9	27.5	26.9	27.5	26.9	27.5	26.9	26.9	25.8	24.2	18.6
20.3	25.4	27.4	28.7	29.0	29.4	29.0	29.4	29.0	29.4	29.0	29.3	28.3	27.7	24.4	19.3
19.1	23.8	25.6	25.6	29.2	29.6	29.3	29.6	29.3	29.6	29.3	29.5	28.6	27.4	24.3	19.2
18.8	23.5	27.2	27.9	29.4	28.8	29.5	28.8	29.5	28.8	29.5	28.8	28.7	26.8	24.1	18.5
18.4	24.0	26.9	28.7	29.0	29.6	29.1	29.6	29.1	29.6	29.1	29.4	28.4	27.2	23.5	18.5
18.5	23.5	27.2	28.4	29.4	29.1	29.6	29.1	29.6	29.1	29.6	29.0	28.7	26.9	24.0	18.4
18.5	24.1	26.8	28.7	28.8	29.5	28.8	29.5	28.8	29.5	28.8	29.4	27.9	27.2	23.5	18.8
19.2	24.3	27.4	28.6	29.5	29.3	29.6	29.3	29.6	29.3	29.6	29.2	25.6	25.6	23.8	19.1
19.3	24.4	27.7	28.3	29.3	29.0	29.4	29.0	29.4	29.0	29.4	29.0	28.7	27.4	25.4	20.3
18.6	24.2	25.8	26.9	26.9	27.5	26.9	27.5	26.9	27.5	26.9	27.3	26.4	26.2	24.1	20.3
13.3	16.3	17.2	17.2	17.6	18.5	17.6	18.5	17.6	18.5	17.6	18.5	17.4	18.2	16.5	14.9
	4	1ft	3	1ft	2	1ft	1		4	1ft	3	1ft	2	1ft	1
	DISPENSER #2								DISPENSER #1						

WING LEADING EDGE

Precipitation Type	IP

Date	

Run #	

* ***Field to be manipulated***

Target Rate	**25**	**$g/dm^2/h$**
Duration	**5**	**minutes**

Footprint Rate	25	$g/dm^2/h$
Stdev of Rate (+/-)	5	$g/dm^2/h$

IP needed per 5min

In each position	81	g
In each Dispenser	323	g

IP needed for entire test

Total amount of IP in Each Dispenser	323	g
Total Amount IP Needed for Entire Test	1291	g

1. Enter "Date" and "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of IP Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of IP in Each Dispenser" in grams. **(Each Dispenser must be emptied at 5-minute intervals.)**
6. Dictate amount of IP needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispenser 1-foot to the left.
8. Once a Dispenser has completed its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals). (e.g: Position #1 -> Pos #2 -> Pos #3 -> Pos #4 -> Pos #4 -> Pos #3 -> Pos #2 -> Pos #1 -> Pos #1...)

NOTE:

- Leading Edge (LE): Centre Pole of the Dispenser Stands must be 1-foot (12 inches) from the Leading Edge (LE)

-Trailing Edge (TE): Centre Pole of the Dispenser Stands must be 10-inches from the Trailing Edge (TE) Flap.

- Dispenser Spinner must be 3-feet above the average height of the wing.

Attachment 5: Example Snow Dispensing Form

WING TRAILING EDGE

8 ft = 24.4 dm (width); 6 ft = 18.3 dm (depth)

DISPENSER #3								DISPENSER #4							
1 ←	1ft	→ 2 ←	1ft	→ 3 ←	1ft	→ 4		1 ←	1ft	→ 2 ←	1ft	→ 3 ←	1ft	→ 4	
23.1	24.8	27.2	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.4	26.6	19.7
27.1	35.5	34.9	36.7	35.1	36.7	35.1	36.7	35.1	36.7	35.1	36.7	35.0	36.3	33.9	29.8
24.6	39.4	36.4	41.4	36.8	41.5	36.8	41.5	36.8	41.5	36.8	41.5	36.7	41.1	35.5	35.2
14.4	26.3	25.3	28.6	25.7	28.7	25.7	28.7	25.7	28.7	25.7	28.7	25.6	28.4	24.7	24.3
8.8	15.2	16.4	17.4	17.0	17.6	17.2	17.6	17.2	17.6	17.2	17.6	17.0	17.2	15.9	14.2
6.1	9.4	10.6	11.2	11.1	11.4	11.2	11.4	11.2	11.4	11.2	11.3	11.0	10.9	9.8	7.9
7.9	9.8	10.9	11.0	11.3	11.2	11.4	11.2	11.4	11.2	11.4	11.1	11.2	10.6	9.4	6.1
14.2	15.9	17.2	17.0	17.6	17.2	17.6	17.2	17.6	17.2	17.6	17.0	17.4	16.4	15.2	8.8
24.3	24.7	28.4	25.6	28.7	25.7	28.7	25.7	28.7	25.7	28.7	25.7	28.6	25.3	26.3	14.4
35.2	35.5	41.1	36.7	41.5	36.8	41.5	36.8	41.5	36.8	41.5	36.8	41.4	36.4	39.4	24.6
29.8	33.9	36.3	35.0	36.7	35.1	36.7	35.1	36.7	35.1	36.7	35.1	36.7	34.9	35.5	27.1
19.7	26.6	25.4	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.2	24.8	23.1
	4 ←	1ft	→ 3 ←	1ft	→ 2 ←	1ft	→ 1		4 ←	1ft	→ 3 ←	1ft	→ 2 ←	1ft	→ 1
	DISPENSER #2								DISPENSER #1						

WING LEADING EDGE

Precipitation Type	Snow	Date		Run #	

* *Field to be manipulated*

Target Rate	**25**	**g/dm²/h**
Duration	**5**	**minutes**

Footprint Rate	25	g/dm²/h
Stdev of Rate	10	g/dm²/h

Snow needed per 5 minutes

In each position	84	76	g
In each Dispenser	336	305	g

Snow needed for entire test

In each Dispenser	336	305	g
Total Amount Snow Needed for Entire Test	1344	1222	g

1. Enter "Date" and "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of Snow Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of Snow in Each Dispensor" in grams. **(Each Dispensor must be emptied at 5-minute intervals.)**
6. Dictate amount of Snow needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispenser 1-foot to the left.
8. Once a Dispenser has completed its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals).

(e.g: Position #1 -> Pos #2 -> Pos #3 -> Pos #4 -> Pos #4 -> Pos #3 -> Pos #2 -> Pos #1 -> Pos #1...)

NOTE:

- Leading Edge (LE): Centre Pole of the Dispenser Stands must be 1-foot (12 inches) from the Leading Edge (LE)

-Trailing Edge (TE): Centre Pole of the Dispenser Stands must be 10-inches from the Trailing Edge (TE) Flap. The use of Dispensor Stand Extention is needed.

- Dispenser Spinner must be 3-feet above the average height of the wing.

Attachment 6: Example Snow Dispensing Form (Manual Method)

Precipitation Type	Sifted Snow

Date	

Run #	

* *Field to be manipulated*

Target Rate	**25**	**g/dm^2/h**
Duration	**5**	**minutes**

Footprint Rate	25	g/dm^2/h
Stdev of Rate	10	g/dm^2/h

Snow needed per 5 minutes

In each position	66
In each Dispenser	265

Snow needed for entire test

In each Dispenser	265
Total Amount Snow Needed for Entire Test	1062

1. Enter "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of Snow Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of Snow in Each Dispenser" in grams. **(Each Dispenser must be emptied at 5-minute intervals.)**
6. Dictate amount of Snow needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispenser 1-foot to the left.
8. Once a Dispensor has completed its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals).

(e.g: Position #1 -> Pos #2 -> Pos #3 -> Pos #4 -> Pos #4 -> Pos #3 -> Pos #2 -> Pos #1 -> Pos #1...)

- Since dispensing is done using a sieve, the percentage of snow loss is reduced. This efficiency is estimated at 90%, as per visual analysis in 2009-10.

Attachment 7: Visual Evaluation Rating Form

VISUAL EVALUATION RATING OF CONDITION OF WING

Date: ____________________ Run Number: _______

Ratings:

1 - Contamination not very visible, fluid still clean.
2 - Contamination is visible, but lots of fluid still present
3 - Contamination visible, spots of bridging contamination
4 - Contamination visible, lots of dry bridging present
5 - Contamination visible, adherence of contamination

Note: Ratings can include decimals i.e. 1.4 or 3.5

Before Take-off Run

Area	Visual Severity Rating (1-5)	
Leading Edge		*>3 = Review, >3.5=Bad*
Trailing Edge		*>3 = Review, >3.5=Bad*
Flap		*>4 = Review, >4.5=Bad*

At Rotation

Area	Visual Severity Rating (1-5)
Leading Edge	
Trailing Edge	
Flap	

>1= Review >1.5 = Bad

Expected Lift Loss (%) *>5.4 = Review* *>9.2 = Bad*

After Take-off Run

Area	Visual Severity Rating (1-5)
Leading Edge	
Trailing Edge	
Flap	

Additional Observations: ______________________________

____

____

OBSERVER: ______________________

Attachment 8: Fluid Receipt Form (Electronic Form)

FORM 1
GENERAL FORM FOR RECEIVING FLUID

Receiving Location: ☐ APS Site ☐ Other: ________________ **Date of Receipt:** ________________

Fluid Characteristics: Type: ___________ Colour: ____________ **Date of Production:** ________________

Manufacturer: ________________________________ **Batch #:** ________________

Fluid Name: ________________________________ **Project Task:** ________________

Fluid Quantities / Fluid Brix / Falling Ball Info:

Fluid Dilution: ____________	Fluid Dilution: ____________	Fluid Dilution: ____________
Fluid Quantity: ____ x ____ L = 0 L	Fluid Quantity: ____ x ____ L = 0 L	Fluid Quantity: ____ x ____ L = 0 L
Fluid Brix: _____°	Fluid Brix: _____°	Fluid Brix: _____°
Falling Ball Time: ___:___:___ (mm:ss:cs)	Falling Ball Time: ___:___:___ (mm:ss:cs)	Falling Ball Time: ___:___:___ (mm:ss:cs)
Falling Ball Temp: _____°C	Falling Ball Temp: _____°C	Falling Ball Temp: _____°C
Sample Collected From Container #: _____	Sample Collected From Container #: _____	Sample Collected From Container #: _____

Sample Collection:

HOT Fluids:	Extract 3 L 100 / 75 / 50 and 2 L Type I
Other Fluids:	Extract 2 L 100 / 75 / 50 / Type I

Sample Distribution:

Viscosity:	1 L 100 / 75 / 50 to third party for viscosity testing
WSET:	1 L 100 / 75 / 50 / Type I to AMIL for WSET (HOT samples only)
Office:	1 L 100 / 75 / 50 / Type I to be retained in office

Photo Documentation: (take photos of all that apply)

☐ Palette (as received) ☐ 100/0 MNF Fluid Label ☐ 75/25 MNF Fluid Label ☐ 50/50 MNF Fluid Label ☐ Type I MNF Fluid Label

Additional Info/Notes: (additional information included on fluid containers, paperwork received, etc.)

Received by: ______________________ **Date:** ______________________

Fluid Receipt Form (Nov 2017)

Attachment 9: Log of Fluid Sample Bottles

Date of Extraction	*Fluid and Dilution*	*Batch #*	*Sample Source (i.e. drum)*	*Falling Ball Fluid Temp (°C)*	*Falling Ball Time (sec)*	*Comments*

Attachment 10: Procedure - Dry Wing Performance

Background

A significant amount of work has been done in conjunction with NASA and NRC in order to calibrate and characterize the wind tunnel and airfoil model during the last two winter seasons. This work has further increased the confidence in the data produced, however ongoing verification is necessary in order to identify potential changes in the system performance.

Objective

Verify that clean model aerodynamic data agree with the data acquired in previous years with the same model. Given the various issues with repeatability and angle of attack offsets in the past, this is an important step prior to fluids testing.

Methodology

- Ensure the wing is clean and dry;
- Conduct a dry wing test using the regular take-off profile;
- Conduct a dry wing test using a take-off profile with rotation to stall;
- Compare lift performance to historical data; and
- Address potential discrepancies accordingly.

Test Plan

This testing should be conducted at the start of each testing day.

Attachment 11: Procedure – Type IV Ice Pellet Allowance Time Validation with New Fluids

Background

The Type IV ice pellet allowance times are conservative, generic guidance developed based on data collected using commercially available Type IV fluids. As new fluids are developed and become commercially available, it is important to evaluate these fluids against the current allowance times to ensure the validity of the generic guidance. Systematic "spot-checking" is used in order to identify any potential issues. In addition, testing is recommended with all fluids available to obtain data close to the fluid LOUT to determine the aerodynamic effects of ice pellet contamination at these colder temperatures.

Objective

To evaluate newly commercialized Type IV fluids against the existing allowance times, and to collect data close to the fluid LOUT.

Methodology

- Conduct testing with any new commercially available Type IV fluids in each of the cells of the ice pellet allowance times table;
- Record lift data, visual observations, and manually collected data;
- Adjust testing plan accordingly based on aerodynamic data collected; and
- Weather permitting, conduct testing close to the fluid LOUT (-25 to -30ºC) with appropriate conditions to address data gaps.

Test Plan

Eight days of testing are planned.

Attachment 12: Procedure – Development of EG Specific Ice Pellet Allowance Time Table

Background

Type IV ice pellet allowance times are also intended to be conservative, and therefore generic guidance is developed based on data collected using commercially available Type IV fluids. Historically both Type IV PG and EG fluids have been grouped together, however data has indicated that EG may have an operational advantage of longer ice pellet allowance times in specific conditions. The industry requested that EG specific fluid ice pellet allowance time tables be generated to be able to benefit from any potential linger allowance times specific to Type EG fluids.

Objective

To conduct testing to investigate the feasibility of developing an EG specific ice pellet allowance time table.

Methodology

- Determine what EG data exists and any potential data gaps which need to be filled;
- Conduct testing with commercially available EG Type IV fluids in each of the cells of the ice pellet allowance times table, as required;
- Record lift data, visual observations, and manually collected data; and
- Adjust testing plan accordingly based on aerodynamic data collected.

Test Plan

Two days of testing are planned.

Attachment 13: Procedure – Type III Low Speed Allowance Time Testing LS-0417 Wing Model Calibration and Characterization

Background

Type III fluid allowance times have recently been developed but are limited to use with aircraft with rotation speeds of 100 knots or greater. Type III fluids can often be used with lower rotation speed aircraft, therefore there is a requirement to have these allowance times validated for use at these lower speeds. The LS-0417 is a more representative airfoil to conduct low speed testing at 80 knots, however the characteristics of the airfoil have yet to be fully investigated.

Objective

Determine the baseline aerodynamic characteristics of the LS-0417 wing model configuration to improve the understanding and general applicability of the fluids and contamination tested on this wing model configuration for use with ice pellet allowance time testing at 80 knots.

Methodology

Testing will include a subset of the following:

- Thoroughly survey the clean wing performance through pitch pause, angle sweeps, and stall runs, and verify repeatability;
- Perform oil flow visualization to better understand boundary layer separation and uniformity of flow;
- Install boundary layer trips to establish wing sensitivity;
- Conduct fluid testing with and without contamination to evaluate repeatability of results; and
- Install larger end plates to evaluate potential 3D effects.

Test Plan

Three days of testing are planned, one of which will be fluid only testing. An additional day may be required to swap out the existing wing section in the wind tunnel for the LS-0417 wing.

Attachment 14: Procedure – Type III Ice Pellet Allowance Time Validation at 80 Knots with LS-0417 Wing Section

Background

Type III fluid allowance times have recently been developed but are limited to use with aircraft with rotation speeds of 100 knots or greater. Type III fluids can often be used with lower rotation speed aircraft, therefore these allowance times need to be validated for use at these lower speeds. The LS-0417 is a more representative airfoil to conduct low speed testing at 80 knots, therefore it is recommended that the Type III IP allowance times be validated using the LS-0417 wing model at lower speeds (80 knots).

Objective

To evaluate the Type III allowance times for use with lower rotation speeds (80 knots).

Methodology

- Conduct testing in each of the cells of the ice pellet allowance times table with commercially available Type III fluids in each of the cells of the ice pellet allowance times table at 80 knots rotation speed with the LS-0417 wing section;
- Record lift data, visual observations, and manually collected data; and
- Adjust testing plan accordingly based on aerodynamic data collected.

Test Plan

One day of testing is planned. This testing can only be completed once the LS-0417 wing section calibration and characterization work has been completed.

Attachment 15: Procedure – Type III Ice Pellet Allowance Time Expansion

Background

Allowance times for Type III fluids have just recently been developed. Similar to the Type IV ice pellet allowance times, the Type III allowance times are also intended to be conservative, generic guidance developed based on data collected using commercially available Type III fluids. In cases where the allowance times are too restrictive, additional data may be used to support an increase to the existing times, or new cells at different temperatures. This testing can be done at both 80 knots and 100 knots.

Objective

To conduct testing to support the expansion of the Type III ice pellet allowance times.

Methodology

- Conduct testing with commercially available Type III fluids in each of the cells of the ice pellet allowance times table at 80 knots and 100 knots rotation speed;
- Record lift data, visual observations, and manually collected data; and
- Adjust testing plan accordingly based on aerodynamic data collected.

Test Plan

Ten to twenty tests are anticipated.

Attachment 16: Procedure – Snow Allowance Times Using Aerodynamic Data

Background

Holdover times are developed based on a visual evaluation of fluid failure on test plate surfaces measuring 30x50cm (12x20in.). The industry requested an investigation into the feasibility of using the same aerodynamic testing methodology used to develop ice pellet allowance times, to develop snow allowance times. It is believed that using this methodology would provide longer "snow allowance times" as compared to the current existing snow holdover times.

Objective

To conduct testing to investigate the feasibility of developing snow allowance times.

Methodology

- Conduct testing with commercially available Type IV fluids using the current methodology used to develop ice pellet allowance times;
- Record lift data, visual observations, and manually collected data; and
- Adjust testing plan accordingly based on aerodynamic data collected.

Test Plan

Ten to twenty tests are anticipated.

Attachment 17: Procedure - Heavy Snow

Background

As a direct result of the ice pellet research conducted, the use of HOTs for determining the protection time provided by anti-icing fluids was questioned. The focus has turned towards "aerodynamic failure" which can be defined as a significant lift loss resulting from contaminated anti-icing fluid. Heavy snow conditions have been selected for this study for two reasons. First, snow conditions account for the most significant portion of de-icing operations globally. Secondly, there has been a recent industry interest for holdover time for heavy snow conditions. Preliminary aerodynamic testing was conducted during the winters of 2006-07 and 2008-2011.

Objective

To investigate the fluid aerodynamic flow-off characteristics of anti-icing fluid contaminated with simulated heavy snow versus moderate snow.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical snow condition tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating moderate snow conditions (rate of 25 g/dm²/h) for an exposure time derived from the HOT table based on the tunnel temperature at the time of the test;
- Record lift data, visual observations, and manually collected data;
- Conduct two comparative tests simulating heavy snow conditions (rate of 50 g/dm²/h or higher) for the same exposure time used during the moderate snow test;

  NOTE: Previous testing has indicated that using half, to ¾ of the moderate snow HOT generates similar end conditions; whereas using the full moderate HOT for heavy snow conditions generates a more sever fluid failure which behaves worse aerodynamically.
- Record lift data, visual observations, and manually collected data;
- Compare the heavy snow results to the moderate snow results. If the heavy snow results are worse, repeat the heavy snow test with a reduced exposure time, if the results are better, repeat the heavy snow test with an increased exposure time;
- Repeat until similar lift data, and visual observations are achieved for both heavy snow and moderate snow; and
- Document the percentage of the moderate snow HOT that is acceptable for heavy snow conditions.

Test Plan

Two to four comparative tests are anticipated. See previous reports for suggested test plan.

Attachment 18: Procedure - Heavy Contamination

Background

Previous testing in the wind tunnel demonstrated that although very heavy ice pellet and/or snow contamination was applied to a fluid covered wing section, significant lift losses were not apparent. The initial testing indicated that after a certain level of contamination, the dry loose ice pellets or snow no longer absorb into the fluid and easily fly off during the acceleration. The protection is due to a thin layer of fluid present underneath the contamination that prevents adherence. Questions of which point the lift losses become detrimental have been raised.

Objective

To continue previous research investigating heavy contamination effects on fluid flow off.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical ice pellet tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating ice pellets, snow, or freezing rain, for an exposure time far exceeding the recommended HOT or allowance time;
- Record lift data, visual observations, and manually collected data; and
- Compare aerodynamic performance results to fluid only or fluid and contamination tests at the same temperature.

Test Plan

One to four tests are anticipated. Previous work should be referenced to identify starting levels of heavy contamination.

Attachment 19: Procedure - Wind Tunnel Test Section Cooling

Background

Recent wind tunnel research has been limited by the ambient temperature in wind tunnel test section; in sunny conditions, the radiation will raise the temperature in the test section making testing difficult. To mitigate this effect, testing is often conducted overnight, however in some cases, even body heat from people working in the test area (specifically during long precipitation exposure tests) can affect the temperature. A new cooling system has been installed by the NRC to mitigate the effects of the radiation warming as well as from the heat generated by the personnel working in the test section. It was recommended that testing be conducted to evaluate the effects of the new cooling system on the test results.

Objective

To evaluate the effect of the cooling system on the aerodynamic test results produced.

Methodology

- Conduct a fluid only test without the cooling system. Have personnel standing on scaffolding for 20-minutes following fluid application to generate extra heat prior to running the wind tunnel;
- Conduct a second comparative fluid only test with the cooling system. Have personnel standing on scaffolding for 20-minutes following fluid application to generate extra heat prior to running the wind tunnel;
- Conduct a third comparative test at a suitable ambient temperature where the expected test area temperature with the cooling system is equal to the test area temperature of the test conducted without the cooling system; and
- Compare aerodynamic performance results.

EXAMPLE OF COMPARATIVE DATA TO BE COLLECTED

Test #	Cooling System Status	OAT ºC	Test Area Temp ºC	Lift Loss %
1	Off	-18	-14	6.3
2	On	-18	-17	7.5
3	On	-15*	-14	5.7

* To be selected based on efficiency of cooling system based on test #2

Test Plan

Three tests at a minimum are expected.

Attachment 20: Procedure - Fluid and Contamination at LOUT

Background

Recent changes to the frost HOT guidance material allowing fluids to be used to the LOUT have raised concerns about whether or not this is an appropriate practice. In frost the major concern was the effect of radiation cooling and how it could affect the LOUT, however the concern also includes contamination at LOUT. This issue was also raised from the AWG for the ice pellet testing which allows fluids to be used to LOUT: will the added ice pellet contamination at the LOUT not bust BLDT? It was recommended that some testing be conducted at the fluid LOUT to investigate how contamination can affect the aerodynamic performance of the fluid.

Objective

To investigate the fluid aerodynamic flow-off characteristics of anti-icing fluid with contamination at the LOUT.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical ice pellet tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating ice pellets, snow, freezing fog, or frost, for an exposure time derived from the HOT table at the fluid LOUT;
- Record lift data, visual observations, and manually collected data;
- Conduct a fluid only baseline test at the same temperature (at LOUT); and
- Compare the aerodynamic performance.

Test Plan

Four or more tests are anticipated at a minimum. If LOUT temperatures for neat fluids are not likely to occur, investigate the possibility of using diluted fluids to obtain a higher LOUT.

Attachment 21: Procedure - Frost Simulation in the Wind Tunnel

Background

Frost is an important consideration in aircraft deicing. The irregular and rough frost accretion patterns can result in a significant loss of lift on critical aircraft surfaces. This potential hazard is amplified by the frequent occurrence of frost accretion in winter operations. Frost is an area of research that has yet to be fully explored. Discussions regarding the aerodynamic effects of frost have been raised, and the possibility of doing wind tunnel testing has been considered. It was recommended that initial testing be performed to investigate whether it would be feasible to simulate frost conditions in the PIWT.

Objective

To investigate the feasibility of simulating frost conditions in the PIWT.

Methodology

This work is exploratory, so no exact procedure exists. It is recommended that the frost generating parameters be explored to try and stimulate frost accretion. This can be done by causing a negative temperature differential between the wing and the ambient air i.e. air is warmer than skin. A more specific methodology may be determined on site following a brain-storm with on-site technicians.

Test Plan

One or two tests are anticipated.

Attachment 22: Procedure - Feasibility of Ice Pellet Testing at Higher Speeds

Background

Historically, the ice pellet allowance time testing conducted in the wind tunnel simulated typical aircraft rotation of 100 knots, and more recently some limited work at 115 knots. As a result of some of the higher lift losses observed at colder temperatures with PG fluids applied to a thin high performance airfoil, it was recommended that higher speed testing be conducted to verify if the limitations in the allowance times would need to be applied to commercial aircraft with rotation speeds well above 115 knots. It was recommended that 130-150 knots be targeted, however modifications to the wind tunnel may be required as those higher speeds may increase stress on the wind tunnel engine and other structural systems.

Objective

To investigate the feasibility of conducting ice pellet testing at higher speeds of 130-150 knots.

Methodology

This work is exploratory, so no exact procedure exists. A more specific methodology may be determined on site following a brain-storm with on-site technicians. It is expected that a series of tests may be conducted to try and achieve speeds above 115 knots without rotating the wing model.

Test Plan

One or two tests are anticipated, however more tests may be required based on the results.

Attachment 23: Procedure - 2nd Wave of Fluid during Rotation

Background

Previous wind tunnel testing has shown that during a simulated take-off roll following de/anti-icing, fluid will shear off the wing section; however a small amount of fluid can remain trapped along the leading edge at the stagnation point. This "trapped" fluid begins to flow over the wing only once the wing is rotated; the stagnation point shifts below the leading edge, and the "trapped" fluid begins to shear off as a second wave. Previous testing was simulated in a static model using strips of speed tape and cork tape strategically located on the leading edge of the wing section (along the span where the separation bubble will typically occur). A separate set of dynamic tests simulated the second wave with actual anti-icing fluid; sheared fluid prior to rotation was left only in select areas either below or above the stagnation point and then the flow was observed during a typical rotation. The results showed the stalling characteristics of the wing with fluid (or fluid with contamination) appear to be driven by secondary wave effects near the leading edge; these effects are difficult to interpret on the two-dimensional model relative to a fully three-dimensional wing and should not be used in developing allowance times. Additional testing may be useful to better understand this effect.

Objective

To investigate the aerodynamic effects of the second wave of fluid flow during rotation.

Methodology

- Simulate the 2nd wave of fluid using strips of tape applied at specific areas at different thicknesses on the wing, or with fluid; and
- Compare the different results.

Test Plan

One to four tests are anticipated.

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APPENDIX E

LOG OF TESTS CONDUCTED WITH THIN HIGH PERFORMANCE WING SECTION – RJ WING

Log of Tests Conducted with Thin High Performance Wing Section – RJ Wing

Test #	Date	Test Plan #	Objective	Test Condition	Fluid Name	Fluid Batch #	Rotation Angle	Speed Kts	Flap Angle (0°, 20°)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Time from 40kts to Rotation (sec)	Max Speed At Approx. Time of Rot. (kts)	Target OAT (°C)	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)	AVG Wing Temp Before Fluid Appl. (°C)	AVG Wing Temp Before Test	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)	Rating Before Take-Off Run LE	Rating Before Take-Off Run TE	Rating Before Take-Off Run Flap	Rating At Rotation LE	Rating At Rotation TE	Rating At Rotation Flap	Rating After Take-Off Run LE	Rating After Take-Off Run TE	Rating After Take-Off Run Flap
1	28-Jan-18	P001	Baseline	Dry Wing	none	n/a	8	100	20	1.466	-0.32%	18.64	98.56	any	1.1	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2	28-Jan-18	P002	Baseline	Dry Wing	none	n/a	22	80	20	1.459	0.15%	51.08	86.61	any	-4.2	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3	29-Jan-18	P080	Type IV Validation and New Fluids	IP Mod	ECO-SHIELD	WT.17.18.IES	8	100	20	1.380	5.59%	19.34	97.84	>-5	-7.3	16	-9.9	-4.6	-4.2	75	-	-	-	15	2.0	2.0	3.7	1.0	1.7	2.2	1.0	1.0	1.0
4	29-Jan-18	P001	Baseline	Dry Wing	none	n/a	8	100	20	1.465	-0.26%	18.61	98.34	any	-4.4	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5	29-Jan-18	P002	Baseline	Dry Wing	none	n/a	22	80	20	1.465	-0.27%	50.8	82.3	any	-8.4	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6	29-Jan-18	P083	Type IV Validation and New Fluids	IP-	ECO-SHIELD	WT.17.18.IES	8	100	20	1.391	4.82%	18.5	98.44	-5 to -10	-7.4	16	-9.6	-6.8	-10.1	25	-	-	-	30	1.7	1.7	3.0	1.0	1.5	1.8	1.0	1.0	1.0
7	29-Jan-18	P086	Type IV Validation and New Fluids	IP- / ZR-	ECO-SHIELD	WT.17.18.IES	8	100	20	1.391	4.85%	18.75	98.59	-5 to -10	-8.1	16	-9.7	-8.0	-7.4	25	-	25	-	10	1.3	1.7	2.5	1.0	1.1	1.8	1.0	1.0	1.0
8	30-Jan-18	P014	Type IV Validation and New Fluids	IP- / ZR-	ChemR EG IV	WT.17.18.C HEM	8	100	20	1.415	3.21%	18.99	99.11	-5 to -10	-8.2	15	-9.6	-7.9	-8.5	25	-	25	-	10	1.3	1.5	2.2	1.0	1.0	1.5	1.0	1.0	1.2
9	30-Jan-18	P016	Type IV Validation and New Fluids	IP Mod/ ZD	ChemR EG IV	WT.17.18.C HEM	8	100	20	1.427	2.36%	18.9	99.62	-5 to -10	-7.9	15	-9.4	-8.4	-11.3	75	-	13	-	7	1.5	1.7	2.3	1.0	1.2	1.5	1.0	1.0	1.2
10	30-Jan-18	P088	Type IV Validation and New Fluids	IP Mod/ ZD	ECO-SHIELD	WT.17.18.IES	8	100	20	1.377	5.79%	18.8	99.15	-5 to -10	-7.1	16	-9.8	-8.3	-10.1	75	-	13	-	7	2.0	2.0	2.7	1.0	1.7	2.0	1.0	1.0	1.0
11	30-Jan-18	P084	Type IV Validation and New Fluids	IP- / SN-	ECO-SHIELD	WT.17.18.IES	8	100	20	1.389	4.96%	18.83	98.98	-5 to -10	-5.5	16	-10.1	-8.7	-10.2	25	10	-	-	15	1.8	1.8	2.8	1.1	1.7	2.3	1.0	1.0	1.0
12	30-Jan-18	P012	Type IV Validation and New Fluids	IP- / SN-	ChemR EG IV	WT.17.18.C HEM	8	100	20	1.425	2.48%	18.73	98.8	-5 to -10	-7.8	15	-10.4	-7.8	-11.6	25	10	-	-	15	1.8	1.7	3.3	1.0	1.2	1.5	1.0	1.0	1.0
13	30-Jan-18	P015	Type IV Validation and New Fluids	IP Mod	ChemR EG IV	WT.17.18.C HEM	8	100	20	1.434	1.86%	18.81	101.47	-5 to -10	-10.0	15	-11	-9.0	-13.1	75	-	-	-	10	1.8	2.0	2.3	1.0	1.3	1.5	1.0	1.0	1.2
14	30-Jan-18	P001	Baseline	Dry Wing	none	n/a	8	100	20	1.462	-0.06%	19.11	98.14	any	-11.9	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
15	30-Jan-18	P002	Baseline	Dry Wing	none	n/a	22	80	20	1.464	-0.19%	65.76	81.23	any	-12.6	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
16	30-Jan-18	P017	Type IV Validation and New Fluids	IP-	ChemR EG IV	WT.17.18.C HEM	8	100	20	1.423	2.60%	18.57	99	-10 to -16	-13.3	15	-14.2	-12.0	-15.1	25	-	-	-	30	2.0	2.0	2.8	1.0	1.2	1.4	1.0	1.0	1.2

Log of Tests Conducted with Thin High Performance Wing Section – RJ Wing (cont'd)

Test #	Date	Test Plan #	Objective	Test Condition	Fluid Name	Fluid Batch #	Rotation Angle	Speed Kts	Flap Angle (0°, 20°)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Time from 40kts to Rotation (sec)	Max Speed At Approx. Time of Rot. (kts)	Target OAT (°C)	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)	AVG Wing Temp Before Fluid Appl. (°C)	AVG Wing Temp Before Test	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)	Rating Before Take-Off Run LE	Rating Before Take-Off Run TE	Rating Before Take-Off Run Flap	Rating At Rotation LE	Rating At Rotation TE	Rating At Rotation Flap	Rating After Take-Off Run LE	Rating After Take-Off Run TE	Rating After Take-Off Run Flap
17	30-Jan-18	P018	Type IV Validation and New Fluids	IP- / SN-	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.412	3.36%	18.86	99.93	-10 to -16	-12.5	15	-15.2	-13.4	-15.2	25	10	-	-	15	2.0	2.0	2.8	1.0	1.3	1.5	1.0	1.0	1.2
18	31-Jan-18	P019	Type IV Validation and New Fluids	IP Mod	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.422	2.71%	18.77	99.62	-10 to -16	-14.8	15	-15.7	-13.8	-16.6	75	-	-	-	10	2.0	1.8	2.8	1.0	1.2	1.6	1.0	1.0	1.2
19	31-Jan-18	P025	Type IV Validation and New Fluids	Fluid Only	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.383	5.38%	18.91	99.53	-16 to -22	-14.5	15	-16.2	-14.5	-12.6	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
20	31-Jan-18	P089	Type IV Validation and New Fluids	IP-	ECO-SHIELD	WT.17.18. IES	8	115	20	1.366	6.54%	26	112.78	-10 to -16	-15.8	16	-16.8	-14.0	-15.4	25	-	-	-	30	2.5	2.3	3.3	1.0	1.8	2.3	1.0	1.0	1.1
21	31-Jan-18	P090	Type IV Validation and New Fluids	IP- / SN-	ECO-SHIELD	WT.17.18. IES	8	115	20	1.369	6.36%	24.87	114.01	-10 to -16	-13.6	16	-17.3	-15.4	-15.1	25	10	-	-	15	2.2	2.0	3.2	1.0	1.5	1.9	1.0	1.0	1.1
22	31-Jan-18	P091	Type IV Validation and New Fluids	IP Mod	ECO-SHIELD	WT.17.18. IES	8	115	20	1.333	8.79%	21.42	116	-10 to -16	-17.0	16	-17.7	-15.7	-16.7	75	-	-	-	10	2.2	2.0	3.7	1.0	1.7	2.3	1.0	1.0	1.2
23	31-Jan-18	P097	Type IV Validation and New Fluids	Fluid Only	ECO-SHIELD	WT.17.18. IES	8	100	20	1.373	6.05%	19.57	98.69	-16 to -22	-16.7	16	-17.7	-16.2	-14.3	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
24	31-Jan-18	P235	Type III HS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	8	100	20	1.414	3.27%	18.5	99.43	-16 to -22	-17.1	15	-18	-15.6	-14.8	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
25	31-Jan-18	P001	Baseline	Dry Wing	none	n/a	8	100	20	1.453	0.60%	18.66	98.57	any	-9.1	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
26	31-Jan-18	P002	Baseline	Dry Wing	none	n/a	22	80	20	1.451	0.71%	2.04	84.82	any	n/a	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
27	31-Jan-18	P001	Baseline	Dry Wing	none	n/a	8	100	20	1.461	0.03%	18.51	99.83	any	-9.8	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
28	31-Jan-18	P002	Baseline	Dry Wing	none	n/a	22	80	20	1.458	0.26%	17.06	80.88	any	n/a	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
29	31-Jan-18	P096	Type IV Validation and New Fluids	Fluid Only	ECO-SHIELD	WT.17.18. IES	8	100	20	1.376	5.81%	18.51	100.52	-5 to -10	-9.6	16	-11.8	-9.1	-9.5	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
30	31-Jan-18	P024	Type IV Validation and New Fluids	Fluid Only	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.389	4.97%	18.69	99.69	-5 to -10	-8.6	15	-11.5	-8.5	-9.3	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
31	31-Jan-18	P177	EG Type IV Expansion	IP-	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.435	1.80%	18.77	98.91	-5 to -10	-8.7	15	-10.8	-8.7	-12.3	25	-	-	-	50	2.3	2.7	3.9	1.0	1.2	1.6	1.0	1.0	1.0
32	1-Feb-18	P179	EG Type IV Expansion	IP- / ZD	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.382	5.43%	18.48	98.94	-5 to -10	-6.4	15	-10.2	-8.2	-10.0	25	-	13	-	30	2.5	2.5	4.0	1.0	1.0	5.0	1.0	1.0	1.5

Log of Tests Conducted with Thin High Performance Wing Section – RJ Wing (cont'd)

Test #	Date	Test Plan #	Objective	Test Condition	Fluid Name	Fluid Batch #	Rotation Angle	Speed Kts	Flap Angle (0°, 20°)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Time from 40kts to Rotation (sec)	Max Speed At Approx. Time of Rot. (kts)	Target OAT (°C)	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)	AVG Wing Temp Before Fluid Appl. (°C)	AVG Wing Temp Before Test	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)	Rating Before Take-Off Run LE	Rating Before Take-Off Run TE	Rating Before Take-Off Run Flap	Rating At Rotation LE	Rating At Rotation TE	Rating At Rotation Flap	Rating After Take-Off Run LE	Rating After Take-Off Run TE	Rating After Take-Off Run Flap
33	1-Feb-18	P178	EG Type IV Expansion	IP- / SN-	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.408	3.68%	18.98	99.74	-5 to -10	-5.2	15	-9.7	-7.1	-10.3	25	10	-	-	50	2.9	2.5	4.3	1.0	1.6	4.0	1.0	1.0	3.8
34	1-Feb-18	P087	Type IV Validation and New Fluids	IP Mod	ECO-SHIELD	WT.17.18. IES	8	100	20	1.361	6.89%	18.83	99.74	-5 to -10	-7.6	16	-9.4	-7.3	-11.2	75	-	-	-	10	2.3	2.3	3.0	1.0	1.6	2.0	1.0	1.0	1.1
35	1-Feb-18	P234	Type III HS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	8	100	20	1.423	2.65%	18.59	100.12	-5 to -10	-7.3	13	-9.2	-7.5	-8.5	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
36	1-Feb-18	P001	Baseline	Dry Wing	none	n/a	8	100	20	1.457	0.29%	18.75	99.58	any	-0.1	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
37	1-Feb-18	P002	Baseline	Dry Wing	none	n/a	22	80	20	1.463	-0.11%	1.97	82.77	any	n/a	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
38	1-Feb-18	P082	Type IV Validation and New Fluids	IP Mod / R	ECO-SHIELD	WT.17.18. IES	8	100	20	1.394	4.65%	18.37	100.27	>0	-1.6	16	-1.6	-0.6	-4.8	75	-	-	75	10	2.2	2.5	4.0	1.0	1.1	2.7	1.0	1.0	1.7
39	1-Feb-18	P010	Type IV Validation and New Fluids	IP Mod / R	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.356	7.21%	18.65	100.38	>0	-3.5	15	-4.2	-3.3	-7.0	75	-	-	75	10	2.2	2.2	4.7	1.0	1.0	5.0	1.0	1.0	5.0
40	1-Feb-18	P003	Type IV Validation and New Fluids	IP-	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.443	1.28%	18.47	99.42	>-5	-6.8	15	-7.4	-4.7	-10.5	25	-	-	-	50	2.5	2.5	3.5	1.0	1.1	1.3	1.0	1.0	1.2
41	1-Feb-18	P075	Type IV Validation and New Fluids	IP-	ECO-SHIELD	WT.17.18. IES	8	100	20	1.366	6.50%	18.65	99.24	>-5	-8.2	16	-9.1	-7.6	-10.3	25	-	-	-	50	2.3	2.5	4.0	1.0	1.8	2.2	1.0	1.0	1.0
42	2-Feb-18	P181	EG Type IV Expansion	IP Mod	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.428	2.29%	18.63	98.82	-5 to -10	-10.5	15	-11	-8.8	-14.2	75	-	-	-	25	2.6	2.8	4.0	1.0	1.1	1.7	1.0	1.0	1.1
43	2-Feb-18	P180	EG Type IV Expansion	IP- / ZR-	ChemR EG IV	WT.17.18. CHEM	8	100	20	1.377	5.76%	18.65	100.04	-5 to -10	-12.2	15	-13.3	-10.9	-10.7	25	-	25	-	30	3.3	2.8	5.0	1.8	1.1	5.0	1.0	1.0	5.0

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APPENDIX F

LOG OF TESTS CONDUCTED WITH LS-0417 WING SECTION

Log of Tests Conducted with LS-0417 Wing Section

Test #	Date	Test Plan #	Objective	Test Condition	Fluid Name	Fluid Batch #	Rotation Angle	Speed Kts	Flap Angle (0°, 20°)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Time from 40kts to Rotation (sec)	Max Speed At Approx. Time of Rot.(kts)	Target OAT (°C)	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)	AVG Wing Temp. Before Fluid Appl. (°C)	AVG Wing Temp. Before Test (°C)	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)	Rating Before Take-Off Run LE	Rating Before Take-Off Run TE	Rating Before Take-Off Run Flap	Rating At Rot. LE	Rating At Rot. TE	Rating At Rot. Flap	Rating After Take-Off Run LE	Rating After Take-Off Run TE	Rating After Take-Off Run Flap
1	5-Feb-18	P246	Clean Wing	None	none	n/a	8	100	20	1.517	0.59%	n/a	n/a	any	-13.4	n/a	-9.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2	05-Feb-18	P248	Clean Wing	None	none	n/a	8	80	20	1.522	0.25%	n/a	n/a	any	-13.4	n/a	-9.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3	05-Feb-18	P250	Clean Wing	None	none	n/a	8, then stall	80	20	1.527	-0.10%	n/a	n/a	any	-13.4	n/a	-9.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4	05-Feb-18	P252	Clean Wing	None	none	n/a	stall	80	20	1.528	-0.13%	n/a	n/a	any	-13.4	n/a	-9.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
5	05-Feb-18	P254	Clean Wing	None	none	n/a	Stall -4 to stall +23 PP@1	80	20	1.527	-0.07%	n/a	n/a	any	-13.4	n/a	-9.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
6	05-Feb-18	P247	Clean Wing	None	none	n/a	8	100	20	1.511	0.99%	n/a	n/a	any	-12.05	n/a	-9.0	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
7	05-Feb-18	P249	Clean Wing	None	none	n/a	8	80	20	1.528	-0.11%	n/a	n/a	any	-12.05	n/a	-9.0	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8	05-Feb-18	P251	Clean Wing	None	none	n/a	8, then stall	80	20	1.526	-0.04%	n/a	n/a	any	-12.05	n/a	-9.0	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9	05-Feb-18	P253	Clean Wing	None	none	n/a	stall	80	20	1.525	0.03%	n/a	n/a	any	-12.05	n/a	-9.0	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10	05-Feb-18	P255	Clean Wing	None	none	n/a	Stall -4 to stall +23 PP@1	80	20	1.530	-0.25%	n/a	n/a	any	-12.05	n/a	-9.0	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
11	05-Feb-18	P263	Roughness (Trips)	40-grit	none	n/a	stall	80	20	1.503	1.52%	17.68	79.28	any	-5.31	n/a	-9.6	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
12	05-Feb-18	P264	Roughness (Trips)	40-grit	none	n/a	Stall -4 to stall +23 PP@1	80	20	1.509	1.11%	n/a	n/a	any	-5.31	n/a	-9.6	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
13	05-Feb-18	P265	Roughness (Trips)	150-grit	none	n/a	stall	80	20	1.519	0.44%	n/a	n/a	any	-5.15	n/a	-9.0	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
14	05-Feb-18	P266	Roughness (Trips)	150-grit	none	n/a	stall -4 to stall +23 PP@1	80	20	1.518	0.48%	17.52	86.17	any	-5.15	n/a	-9.0	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
15	05-Feb-18	P267	Roughness (Trips)	80-grit	none	n/a	stall	80	20	1.516	0.64%	n/a	n/a	any	-2.49	n/a	-7.7	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Log of Tests Conducted with LS-0417 Wing Section (cont'd)

Test #	Date	Test Plan #	Objective	Test Condition	Fluid Name	Fluid Batch #	Rotation Angle	Speed Kts	Flap Angle (0°, 20°)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Time from 40kts to Rotation (sec)	Max Speed At Approx. Time of Rot.(kts)	Target OAT (°C)	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)	AVG Wing Temp. Before Fluid Appl. (°C)	AVG Wing Temp. Before Test (°C)	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)	Rating Before Take-Off Run LE	Rating Before Take-Off Run TE	Rating Before Take-Off Run Flap	Rating At Rot. LE	Rating At Rot. TE	Rating At Rot. Flap	Rating After Take-Off Run LE	Rating After Take-Off Run TE	Rating After Take-Off Run Flap
16	05-Feb-18	P268	Roughness (Trips)	80-grit	none	n/a	stall -4 to stall +23 PP@1	80	20	1.516	0.62%	17.55	84.41	any	-2.49	n/a	-7.7	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
17	06-Feb-18	P269	Roughness (Trips)	Full Wing Grit (80)	none	n/a	stall	80	20	1.475	3.35%	n/a	n/a	any	3.24	n/a	-6.4	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
18	06-Feb-18	P270	Roughness (Trips)	Full Wing Grit (80)	none	n/a	stall -4 to stall +23 PP@1	80	20	n/a	n/a	n/a	n/a	any	n/a	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
19	06-Feb-18	P270	Roughness (Trips)	Full Wing Grit (80)	none	n/a	stall -4 to stall +23 PP@1	80	20	1.478	3.14%	n/a	n/a	any	3.24	n/a	-4.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
20	06-Feb-18	P271	Roughness (Trips)	Grit (-30% grit on LE)	none	n/a	stall	80	20	1.491	2.31%	n/a	n/a	any	-2.75	n/a	-3.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
21	06-Feb-18	P272	Roughness (Trips)	Grit (-30% grit on LE)	none	n/a	stall -4 to stall +23 PP@1	80	20	1.489	2.44%	n/a	n/a	any	-2.75	n/a	-3.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
22	06-Feb-18	P273	Roughness (Trips)	Grit (-60% grit on LE)	none	n/a	stall	80	20	1.499	1.78%	n/a	n/a	any	-0.77	n/a	-3.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
23	06-Feb-18	P274	Roughness (Trips)	Grit (-60% grit on LE)	none	n/a	stall -4 to stall +23 PP@1	80	20	1.497	1.87%	n/a	n/a	any	-0.77	n/a	-3.9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
24	06-Feb-18	P275	Roughness (Trips)	Grit (Flap Only)	none	n/a	stall	80	20	1.509	1.13%	n/a	n/a	any	-2.25	n/a	-4.4	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
25	06-Feb-18	P276	Roughness (Trips)	Grit (Flap Only)	none	n/a	stall -4 to stall +23 PP@1	80	20	1.504	1.45%	n/a	n/a	any	-2.25	n/a	-4.4	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
26	06-Feb-18	P279	Boundary-layer Rake Measurements	BL Rake TE Center	none	n/a	stall -4 to stall +23 PP@1	80	20	1.478	3.10%	n/a	n/a	TBD	-3.62	n/a	-4.5	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
27	06-Feb-18	P280	Boundary-layer Rake Measurements	BL Rake TE Center -3ft	none	n/a	stall -4 to stall +23 PP@1	80	20	1.492	2.20%	n/a	n/a	TBD	-4.12	n/a	-4.7	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
28	06-Feb-18	P281	Boundary-layer Rake Measurements	BL Rake TE Center +3ft	none	n/a	stall -4 to stall +23 PP@1	80	20	1.475	3.34%	n/a	n/a	TBD	-3.51	n/a	-4.7	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
29	07-Feb-18	P284	Boundary-layer Rake Measurements	BL Rake Flap Center +3ft	none	n/a	stall -4 to stall +23 PP@1	80	20	1.500	1.66%	n/a	n/a	TBD	0.55	n/a	-15.1	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
30	07-Feb-18	P282	Boundary-layer Rake Measurements	BL Rake Flap Center	none	n/a	stall -4 to stall +23 PP@1	80	20	1.489	2.44%	n/a	n/a	TBD	-4.85	n/a	-14.6	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
31	07-Feb-18	P283	Boundary-layer Rake Measurements	BL Rake Flap Center -3ft	none	n/a	stall -4 to stall +23 PP@1	80	20	1.498	1.80%	n/a	n/a	TBD	-3.87	n/a	-13.7	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Log of Tests Conducted with LS-0417 Wing Section (cont'd)

Test #	Date	Test Plan #	Objective	Test Condition	Fluid Name	Fluid Batch #	Rotation Angle	Speed Kts	Flap Angle (0°, 20°)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Time from 40kts to Rotation (sec)	Max Speed At Approx. Time of Rot.(kts)	Target OAT (°C)	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)	AVG Wing Temp. Before Fluid Appl. (°C)	AVG Wing Temp. Before Test (°C)	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)	Rating Before Take-Off Run LE	Rating Before Take-Off Run TE	Rating Before Take-Off Run Flap	Rating At Rot. LE	Rating At Rot. TE	Rating At Rot. Flap	Rating After Take-Off Run LE	Rating After Take-Off Run TE	Rating After Take-Off Run Flap
32	07-Feb-18	P278	Roughness (Trips)	Diff. Grit (Flap Only)	none	n/a	stall -4 to stall +23 PP@1	80	20	1.478	3.16%	n/a	n/a	any	-1.7	n/a	-11.8	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
33	07-Feb-18	P277	Roughness (Trips)	Diff. Grit (Flap Only)	none	n/a	stall	80	20	1.470	3.68%	n/a	n/a	any	-1.7	n/a	-11.8	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
34	07-Feb-18	P263	Roughness (Trips)	40-grit	none	n/a	stall	80	20	1.488	2.51%	17.12	80.02	any	3.42	n/a	-10.6	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
35	07-Feb-18	P264	Roughness (Trips)	40-grit	none	n/a	stall -4 to stall +23 PP@1	80	20	1.498	1.80%	n/a	n/a	any	3.42	n/a	-10.6	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
36	07-Feb-18	P264	Roughness (Trips)	40-grit	none	n/a	stall -4 to stall +23 PP@1	80	20	-1.761	215.44%	n/a	n/a	any	0.0	n/a	-9.8	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
37	07-Feb-18	P279	Boundary-layer Rake Measurements	BL Rake TE Center	none	n/a	stall -4 to stall +23 PP@1	80	20	1.454	4.70%	n/a	n/a	TBD	1.13	n/a	-9.5	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
38	07-Feb-18	P279	Boundary-layer Rake Measurements	BL Rake TE Center	none	n/a	stall -4 to stall +23 PP@1	80	20	1.455	4.62%	n/a	n/a	TBD	-1.55	n/a	-9.4	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
39	07-Feb-18	P281	Boundary-layer Rake Measurements	BL Rake TE Center +3ft	none	n/a	stall -4 to stall +23 PP@1	80	20	1.398	8.39%	n/a	n/a	TBD	-3.94	n/a	-9.1	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
40	07-Feb-18	P280	Boundary-layer Rake Measurements	BL Rake TE Center -3ft	none	n/a	stall -4 to stall +23 PP@1	80	20	1.514	0.77%	n/a	n/a	TBD	-3.23	n/a	-9	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
41	07-Feb-18	P280	Boundary-layer Rake Measurements	BL Rake TE Center -3ft	none	n/a	stall -4 to stall +23 PP@1	80	20	1.514	0.77%	n/a	n/a	TBD	-3.99	n/a	-8.8	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
42	07-Feb-18	P281	Boundary-layer Rake Measurements	BL Rake TE Center +3ft	none	n/a	stall -4 to stall +23 PP@1	80	20	1.406	7.85%	n/a	n/a	TBD	1.89	n/a	-8.4	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
43	08-Feb-18	P001	Baseline	Dry Wing	none	n/a	8	100	20	1.517	0.54%	18.22	99.18	any	-12.72	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
44	08-Feb-18	P002	Baseline	Dry Wing	none	n/a	23	80	20	1.528	-0.12%	n/a	n/a	any	-12.72	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
45	08-Feb-18	P163	Type III LS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.469	3.71%	17.11	79.75	-16 to -22	-12.37	15	-13.6	-10.2	-9.8	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
46	08-Feb-18	P163	Type III LS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.466	3.90%	17.31	80.22	-16 to -22	-12.33	14	-12	-9.7	-9.0	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
47	08-Feb-18	P163	Type III LS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.489	2.43%	n/a	84.54	-16 to -22	-9.9	14	-7	-8.6	-7.9	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Log of Tests Conducted with LS-0417 Wing Section (cont'd)

Test #	Date	Test Plan #	Objective	Test Condition	Fluid Name	Fluid Batch #	Rotation Angle	Speed Kts	Flap Angle (0°, 20°)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Time from 40kts to Rotation (sec)	Max Speed At Approx. Time of Rot.(kts)	Target OAT (°C)	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)	AVG Wing Temp. Before Fluid Appl. (°C)	AVG Wing Temp. Before Test (°C)	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)	Rating Before Take-Off Run LE	Rating Before Take-Off Run TE	Rating Before Take-Off Run Flap	Rating At Rot. LE	Rating At Rot. TE	Rating At Rot. Flap	Rating After Take-Off Run LE	Rating After Take-Off Run TE	Rating After Take-Off Run Flap
48	08-Feb-18	P163	Type III LS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.476	3.26%	17.08	78.92	-16 to -22	-8.89	14	-5.9	-7.8	-7.1	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
49	08-Feb-18	P149	Type III LS Allowance Times	IP- / ZR-	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.490	2.32%	17.27	78.28	>-5	-7.88	14	-5.4	-6.1	-8.0	25	-	25	-	15	1.5	1.6	2.1	1.0	1.1	1.0	1.0	1.0	1.0
50	08-Feb-18	P168	Type III LS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	8	100	20	1.477	3.19%	18.79	99.91	-16 to -22	-7.27	14	-5.8	-6.7	-6.6	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
51	08-Feb-18	P025	Type IV Validation and New Fluids	Fluid Only	ChemR EG IV		8	100	20	1.463	4.08%	19.71	99.33	-16 to -22	-7.01	18	-5.7	-5.6	-6.4	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
52	08-Feb-18	P025	Type IV Validation and New Fluids	Fluid Only	ChemR EG IV		23	80	20	1.440	5.64%	17.2	78.96	-16 to -22	-6.54	18	-6	-5.0	-6.2	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
53	08-Feb-18	P147	Type III LS Allowance Times	IP-	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.491	2.31%	17.42	78.9	>-5	-6.01	14	-5.5	-4.8	-8.6	25	-	-	-	30	1.7	1.7	1.9	1.0	1.1	1.0	1.0	1.0	1.0
54	08-Feb-18	P151	Type III LS Allowance Times	IP Mod	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.502	1.58%	17.31	79.8	>-5	-6.52	14	-6.1	-5.6	-11.1	75	-	-	-	20	2.0	2.0	2.0	1.0	1.7	1.0	1.0	1.1	1.0
55	09-Feb-18	P001	Baseline	Dry Wing	none	n/a	8	100	20	1.519	0.47%	20	98.7	any	-9.83	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
56	09-Feb-18	P002	Baseline	Dry Wing	none	n/a	23	80	20	1.524	0.14%	2	82.34	any	-9.83	n/a	n/a	n/a	n/a	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
57	09-Feb-18	P163	Type III LS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.469	3.71%	18.2	78.56	-16 to -22	-10.94	15	-11.5	-6.9	-6.9	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
58	09-Feb-18	P168	Type III LS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	8	100	20	1.479	3.07%	20.47	99	-16 to -22	-10.81	13	-11	-8.0	-7.9	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
59	09-Feb-18	P153	Type III LS Allowance Times	IP- / SN-	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.473	3.44%	17.55	78.67	-5 to -10	-9.99	14	-9.6	-7.8	-12.5	25	10	-	-	20	1.8	1.8	2.0	1.0	1.7	1.0	1.0	1.2	1.0
60	09-Feb-18	P154	Type III LS Allowance Times	IP- / ZR-	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.478	3.13%	18.52	78.23	-5 to -10	-8.58	13	-7.3	-8.7	-8.3	25	-	25	-	20	1.7	1.7	2.9	1.0	1.1	1.0	1.0	1.1	1.0
61	09-Feb-18	P155	Type III LS Allowance Times	IP Mod	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.481	2.95%	17.37	79.21	-5 to -10	-7.99	14	-5.6	-6.8	-11.9	75	-	-	-	20	2.0	2.3	2.8	1.0	1.5	1.2	1.0	1.0	1.1
62	09-Feb-18	P152	Type III LS Allowance Times	IP-	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.496	1.94%	17.5	78.43	-5 to -10	-6.74	14	-5.4	-7.1	-10.1	25	-	-	-	40	1.3	1.5	1.8	1.0	1.3	1.0	1.0	1.0	1.0
63	09-Feb-18	P240	R&D	Heavy Cont	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.474	3.38%	17.64	79.06	TBD	-5.99	14	-5.6	-6.5	-7.0	220	-	25	-	25	5	5	5	1	1.5	1.166667	1	1	1
64	09-Feb-18	P162	Type III LS Allowance Times	Fluid Only	AeroClear MAX - Cold	TAB17-1023	23	80	20	1.471	3.62%	17.08	79.07	-5 to -10	-5.58	14	-5.4	-5.6	-5.0	-	-	-	-	-	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

APPENDIX G

EG WIND TUNNEL DATA ANALYSIS WITH THIN HIGH PERFORMANCE WING 2009-10 TO 2015-16

EG Wind Tunnel Data Analysis With Thin High Performance Wing
2009-10 to 2015-16

EG-A (Lift losses for this data in the range of **1 to 4%***, with exception of failed IP-/ZR- test at 7%)

Precipitation Type	Outside Air Temperature			
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C[2]
Light Ice Pellets	50 minutes 50+ minutes	30 minutes	30 minutes[3] 30+ minutes	30 minutes[3] 30+ minutes
Light Ice Pellets Mixed with Snow	40 minutes 40+ minutes	15 minutes	15 minutes[3] 25+ minutes	15+ minutes
Light Ice Pellets Mixed with Freezing Drizzle	25 minutes same as ↓	10 minutes Same as ↓	Caution: No allowance times currently exist	
Light Ice Pellets Mixed with Freezing Rain	25 minutes 25+ minutes, but by default could be 30-35 = or > than →	10 minutes 40 minutes just failed, 30-35 should be ok		
Light Ice Pellets Mixed with Rain	25 minutes[4] same as ↑			
Moderate Ice Pellets (or Small Hail)[5]	25 minutes[6] 25+ minutes	10 minutes	10 minutes[3]	10 minutes[7] 10+ minutes
Moderate Ice Pellets (or Small Hail)[5] Mixed with Freezing Drizzle	10 minutes	7 minutes	Caution: No allowance times currently exist	
Moderate Ice Pellets (or Small Hail)[5] Mixed with Rain	10 minutes[8]			

EG-B (Lift losses for this data in the range of **3 to 6%***)

Precipitation Type	Outside Air Temperature			
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C[2]
Light Ice Pellets	50 minutes	30 minutes	30 minutes[3] 30+ minutes	30 minutes[3]
Light Ice Pellets Mixed with Snow	40 minutes	15 minutes 15+ minutes	15 minutes[3]	
Light Ice Pellets Mixed with Freezing Drizzle	25 minutes same as↓	10 minutes same ↓	Caution: No allowance times currently exist	
Light Ice Pellets Mixed with Freezing Rain	25 minutes 25+ minutes	10 minutes 10+ minutes		
Light Ice Pellets Mixed with Rain	25 minutes[4] same as ↑			
Moderate Ice Pellets (or Small Hail)[5]	25 minutes[6] 25 minutes ok	10 minutes	10 minutes[3] 10+ minutes	10 minutes[7] 10+ minutes
Moderate Ice Pellets (or Small Hail)[5] Mixed with Freezing Drizzle	10 minutes	7 minutes	Caution: No allowance imes currently exist	
Moderate Ice Pellets (or Small Hail)[5] Mixed with Rain	10 minutes[8]			

** Note: Lift losses below 5.4% are good, between 5.4-9.2% are acceptable, and above 9.2% are bad.*

EG Wind Tunnel Data Analysis With Thin High Performance Wing
2009-10 to 2015-16

Notes on Analysis

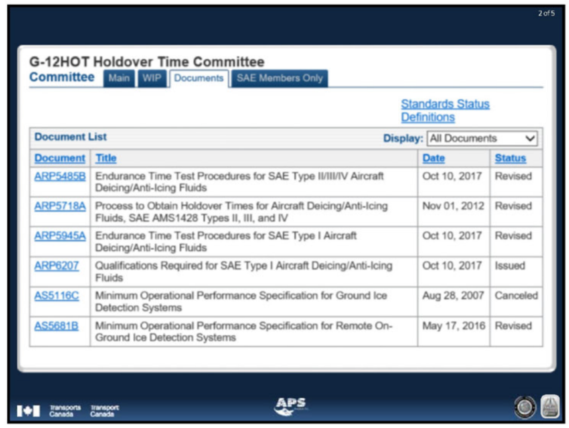
- Analysis based on the cumulative wind tunnel test log from 2009 to 2016.
- All tests were performed with the thin high performance wing section
- The tables below show every cell where we have data in a highlighted color:
  - The longest time tested is shown in highlight.
  - The + sign means there was still capacity to go beyond the longest time tested. This is based on lift loss performance and visual evaluation of contamination (as per usual wind tunnel procedure).
  - Highlight color of green if there is capacity to increase further, or yellow if we are nearing the ceiling for that cell.
- In addition is included the general lift loss (delta CL) for comparison and to scale the performance. This is based on looking at the set of contamination tests as a whole and generalizing the min and max lift losses observed. This is in context of the 5.4-9.2 lift loss limits developed and described at bottom of previous page.

APPENDIX H

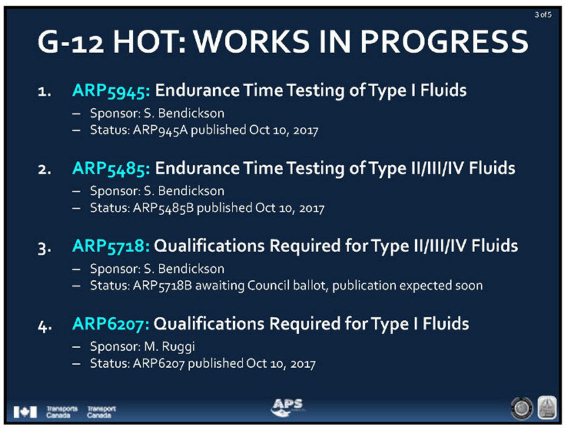
PRESENTATIONS, FLUID MANUFACTURER REPORTS, AND TEST PROCEDURES FOR 2017-18

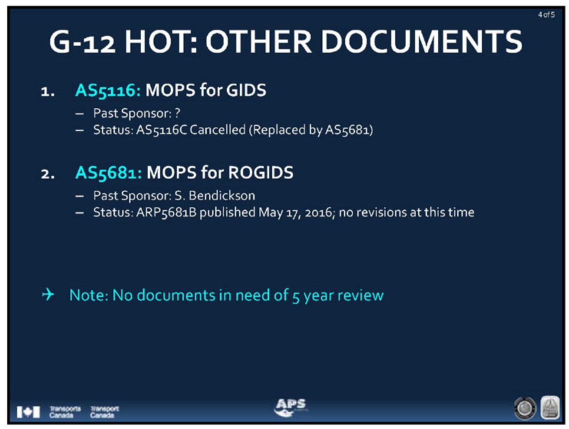
SAE G-12 HOLDOVER TIME COMMITTEE, MONTREAL, CANADA, NOVEMBER 2017

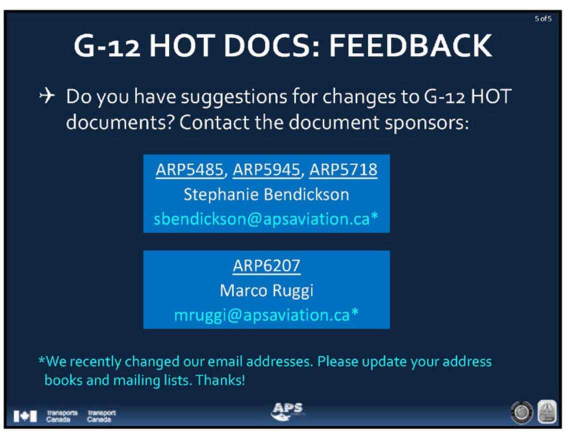
**PRESENTATION:
SAE G-12 HOT COMMITTEE: DOCUMENT UPDATES**



Document	Title	Date	Status
ARP5485B	Endurance Time Test Procedures for SAE Type II/III/IV Aircraft Deicing/Anti-Icing Fluids	Oct 10, 2017	Revised
ARP5718A	Process to Obtain Holdover Times for Aircraft Deicing/Anti-Icing Fluids, SAE AMS1428 Types II, III, and IV	Nov 01, 2012	Revised
ARP5945A	Endurance Time Test Procedures for SAE Type I Aircraft Deicing/Anti-Icing Fluids	Oct 10, 2017	Revised
ARP6207	Qualifications Required for SAE Type I Aircraft Deicing/Anti-Icing Fluids	Oct 10, 2017	Issued
AS5116C	Minimum Operational Performance Specification for Ground Ice Detection Systems	Aug 28, 2007	Canceled
AS5681B	Minimum Operational Performance Specification for Remote On-Ground Ice Detection Systems	May 17, 2016	Revised







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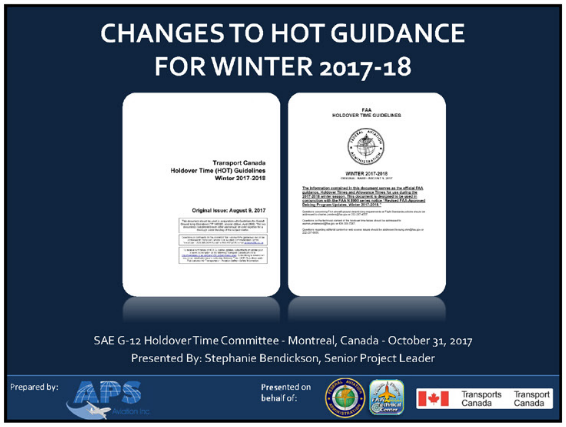
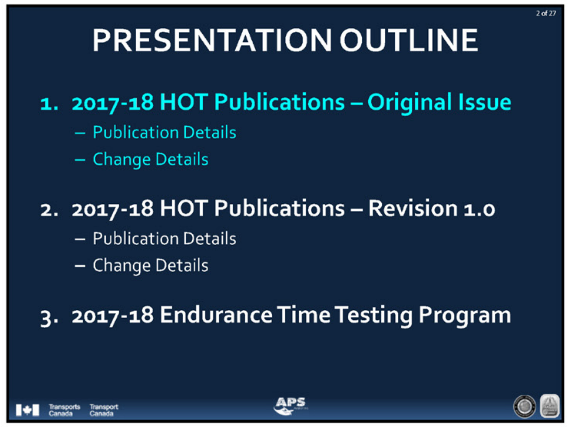
SAE G-12 HOLDOVER TIME COMMITTEE, MONTREAL, CANADA, NOVEMBER 2017

PRESENTATION:
CHANGES TO HOT GUIDANCE FOR WINTER 2017-18


CHANGES TO HOT GUIDANCE FOR WINTER 2017-18
Transport Canada Holdover Time (HOT) Guidelines Winter 2017-2018
FAA HOLDOVER TIME GUIDELINES
WINTER 2017-2018
SAE G-12 Holdover Time Committee - Montreal, Canada - October 31, 2017
Presented By: Stephanie Bendickson, Senior Project Leader
Prepared by:
APS
Presented on behalf of:
Transports Canada
Transport Canada


2 of 27
PRESENTATION OUTLINE
1. 2017-18 HOT Publications – Original Issue
– Publication Details
– Change Details
2. 2017-18 HOT Publications – Revision 1.0
– Publication Details
– Change Details
3. 2017-18 Endurance Time Testing Program


3 of 27
2017-18 HOT PUBLICATIONS
ORIGINAL ISSUE
Published August 9, 2017
Four Documents:
1. 2017-18 Holdover Time Guidelines, Original Issue (English)
2. 2017-18 Holdover Time Guidelines, Original Issue (French)
3. 2017-18 Regression Information, Original Issue (English)
4. 2017-18 Regression Information, Original Issue (French)
Available Online:
www.tc.gc.ca/eng/civilaviation/standards/commerce-holdovertime-menu-1877.htm
www.tc.gc.ca/fra/aviationcivile/normes/commerce-delaisdefficacite-menu-1877.htm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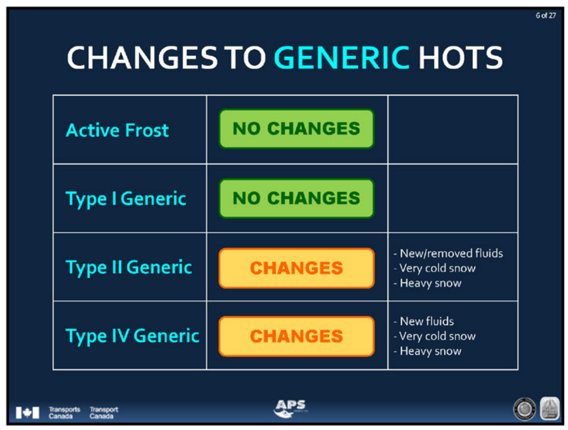
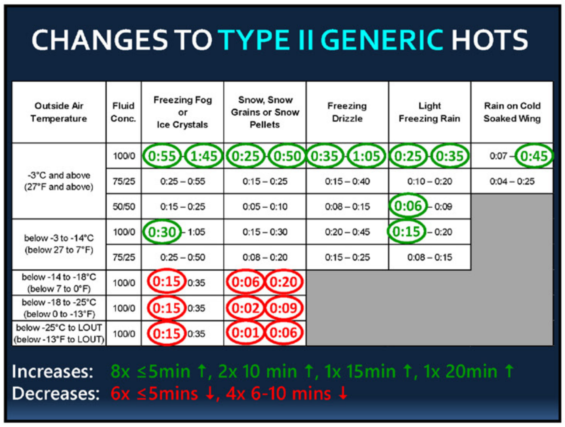
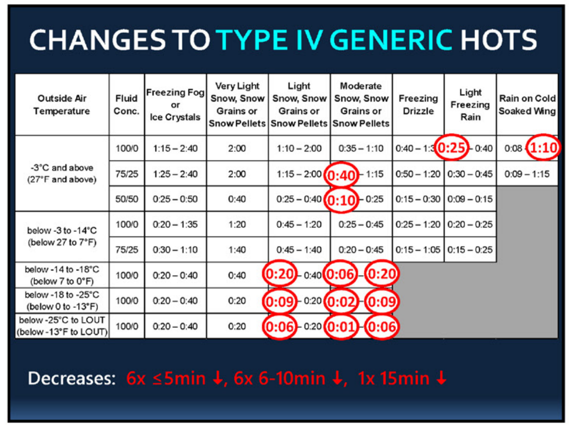
2017-18 HOT PUBLICATIONS
ORIGINAL ISSUE
Published August 9 & 11, 2017
Three Documents:
1. 2017-18 Holdover Time Guidelines, Original Issue Aug 9
2. 2017-18 Regression Information, Original Issue Aug 9
3. Revised FAA-Approved Deicing Program Updates, Winter 2017-2018 (N8900.431) Aug 11
Available Online:
www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/deicing/
www.faa.gov/documentLibrary/media/Notice/N_8900.431.pdf


2017-18 HOT PUBLICATIONS
FUN FACTS
7 Documents

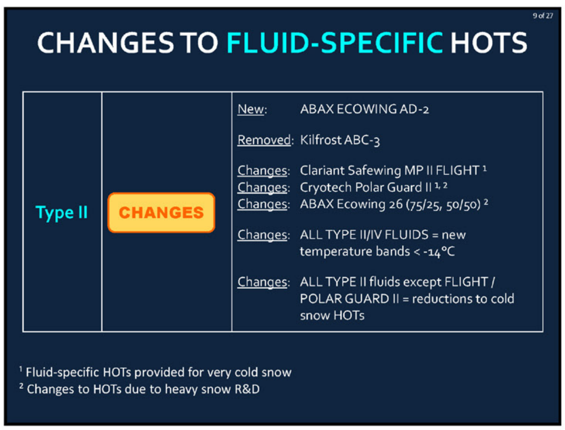

6 of 27
CHANGES TO GENERIC HOTS
Active Frost
NO CHANGES
Type I Generic
NO CHANGES
Type II Generic
CHANGES
- New/removed fluids
- Very cold snow
- Heavy snow
Type IV Generic
CHANGES
- New fluids
- Very cold snow
- Heavy snow

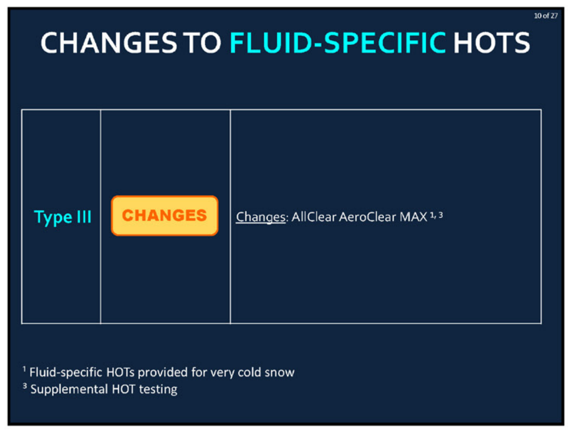


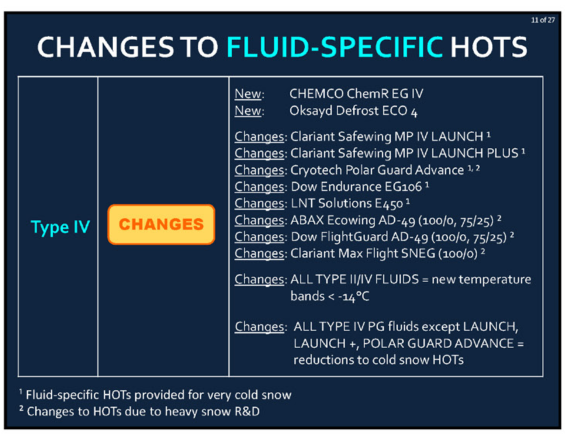
Outside Air Temperature	Fluid Conc.	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing
-3°C and above (27°F and above)	100/0	0:55 – 1:45	0:25 – 0:50	0:35 – 1:05	0:25 – 0:35	0:07 – 0:45
	75/25	0:25 – 0:55	0:15 – 0:25	0:15 – 0:40	0:10 – 0:20	0:04 – 0:25
	50/50	0:15 – 0:25	0:05 – 0:10	0:08 – 0:15	0:06 – 0:09	
below -3 to -14°C (below 27 to 7°F)	100/0	0:30 – 1:05	0:15 – 0:30	0:20 – 0:45	0:15 – 0:20	
	75/25	0:25 – 0:50	0:08 – 0:20	0:15 – 0:25	0:08 – 0:15	
below -14 to -18°C (below 7 to 0°F)	100/0	0:15 0:35	0:06 0:20			
below -18 to -25°C (below 0 to -13°F)	100/0	0:15 0:35	0:02 0:09			
below -25°C to LOUT (below -13°F to LOUT)	100/0	0:15 0:35	0:01 0:06			

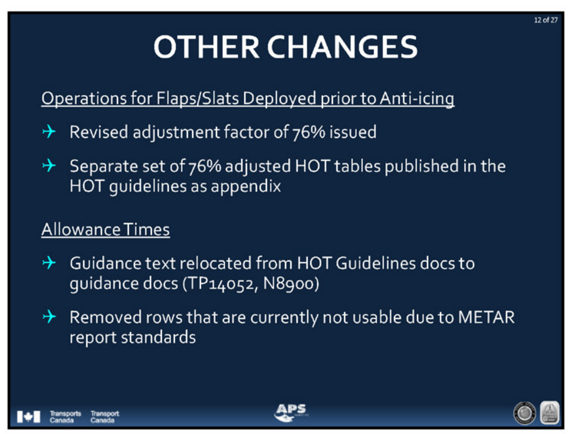


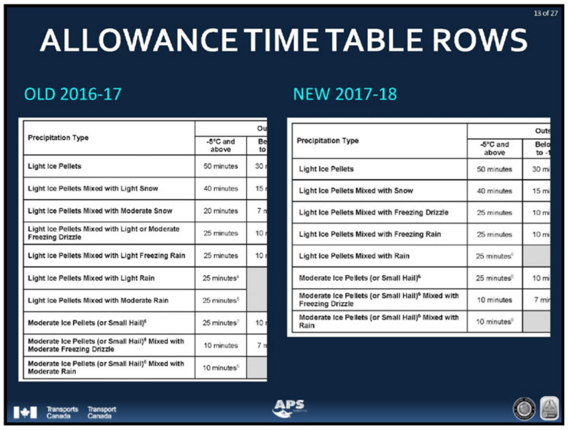
Outside Air Temperature	Fluid Conc.	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing
-3°C and above (27°F and above)	100/0	1:15 – 2:40	2:00	1:10 – 2:00	0:35 – 1:10	0:40 – 1:3	0:25 – 0:40	0:08 – 1:10
	75/25	1:25 – 2:40	2:00	1:15 – 2:00	0:40 – 1:15	0:50 – 1:20	0:30 – 0:45	0:09 – 1:15
	50/50	0:25 – 0:50	0:40	0:25 – 0:40	0:10 – 0:25	0:15 – 0:30	0:09 – 0:15	
below -3 to -14°C (below 27 to 7°F)	100/0	0:20 – 1:35	1:20	0:45 – 1:20	0:25 – 0:45	0:25 – 1:20	0:20 – 0:25	
	75/25	0:30 – 1:10	1:40	0:45 – 1:40	0:20 – 0:45	0:15 – 1:05	0:15 – 0:25	
below -14 to -18°C (below 7 to 0°F)	100/0	0:20 – 0:40	0:40	0:20 – 0:40	0:06 – 0:20			
below -18 to -25°C (below 0 to -13°F)	100/0	0:20 – 0:40	0:20	0:09 – 0:20	0:02 – 0:09			
below -25°C to LOUT (below -13°F to LOUT)	100/0	0:20 – 0:40	0:20	0:06 – 0:20	0:01 – 0:06			

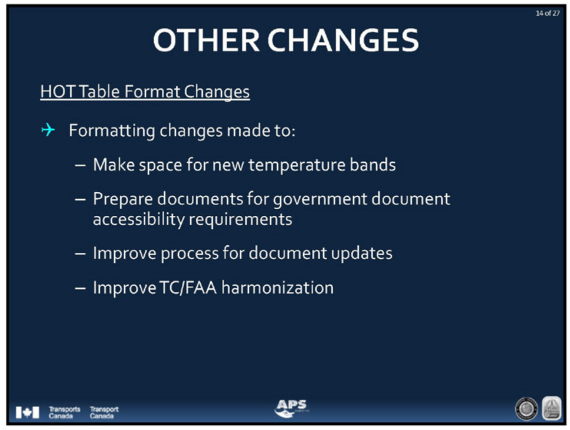


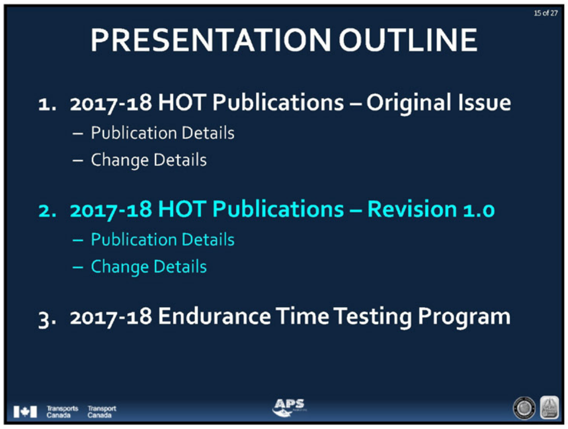


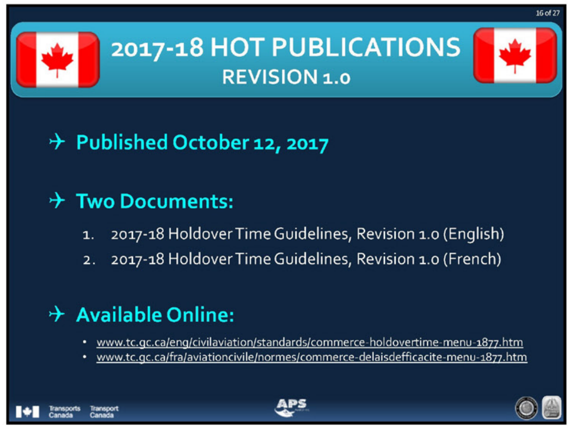


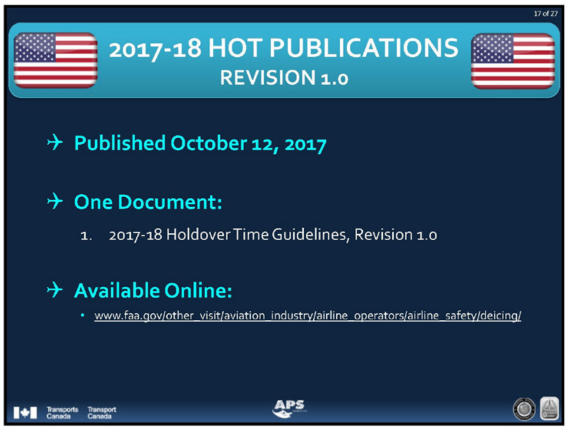


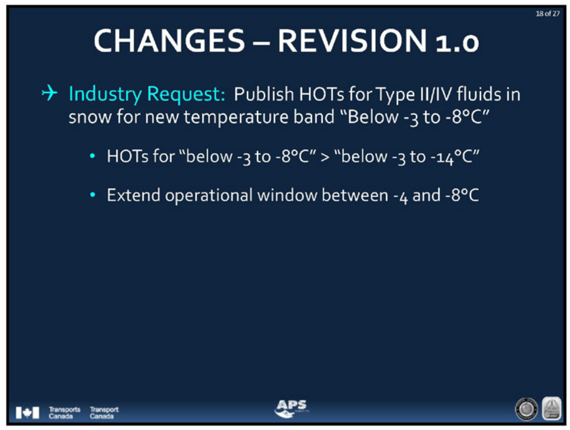

13 of 27
ALLOWANCE TIME TABLE ROWS
OLD 2016-17
Precipitation Type
-5°C and above
Light Ice Pellets | 50 minutes
Light Ice Pellets Mixed with Light Snow | 40 minutes
Light Ice Pellets Mixed with Moderate Snow | 20 minutes
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle | 25 minutes
Light Ice Pellets Mixed with Light Freezing Rain | 25 minutes
Light Ice Pellets Mixed with Light Rain | 25 minutes[4]
Light Ice Pellets Mixed with Moderate Rain | 25 minutes[5]
Moderate Ice Pellets (or Small Hail)[6] | 25 minutes[7]
Moderate Ice Pellets (or Small Hail)[6] Mixed with Moderate Freezing Drizzle | 10 minutes
Moderate Ice Pellets (or Small Hail)[6] Mixed with Moderate Rain | 10 minutes[5]
NEW 2017-18
Precipitation Type
-5°C and above
Light Ice Pellets | 50 minutes
Light Ice Pellets Mixed with Snow | 40 minutes
Light Ice Pellets Mixed with Freezing Drizzle | 25 minutes
Light Ice Pellets Mixed with Freezing Rain | 25 minutes
Light Ice Pellets Mixed with Rain | 25 minutes[4]
Moderate Ice Pellets (or Small Hail)[5] | 25 minutes[6]
Moderate Ice Pellets (or Small Hail)[5] Mixed with Freezing Drizzle | 10 minutes
Moderate Ice Pellets (or Small Hail)[5] Mixed with Rain | 10 minutes[8]
Transports Canada Transport Canada
APS

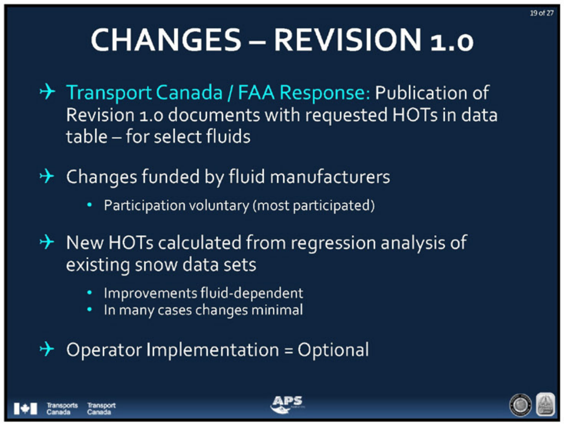

14 of 27
OTHER CHANGES
HOT Table Format Changes
Formatting changes made to:
– Make space for new temperature bands
– Prepare documents for government document accessibility requirements
– Improve process for document updates
– Improve TC/FAA harmonization
Transports Canada Transport Canada
APS


15 of 27
PRESENTATION OUTLINE
1. 2017-18 HOT Publications – Original Issue
– Publication Details
– Change Details
2. 2017-18 HOT Publications – Revision 1.0
– Publication Details
– Change Details
3. 2017-18 Endurance Time Testing Program
Transports Canada Transport Canada
APS


16 of 27
2017-18 HOT PUBLICATIONS
REVISION 1.0
Published October 12, 2017
Two Documents:
1. 2017-18 Holdover Time Guidelines, Revision 1.0 (English)
2. 2017-18 Holdover Time Guidelines, Revision 1.0 (French)
Available Online:
• www.tc.gc.ca/eng/civilaviation/standards/commerce-holdovertime-menu-1877.htm
• www.tc.gc.ca/fra/aviationcivile/normes/commerce-delaisdefficacite-menu-1877.htm
Transports Canada Transport Canada
APS


17 of 27
2017-18 HOT PUBLICATIONS
REVISION 1.0
Published October 12, 2017
One Document:
1. 2017-18 Holdover Time Guidelines, Revision 1.0
Available Online:
• www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/deicing/
Transports Canada Transport Canada
APS


18 of 27
CHANGES – REVISION 1.0
Industry Request: Publish HOTs for Type II/IV fluids in snow for new temperature band "Below -3 to -8°C"
• HOTs for "below -3 to -8°C" > "below -3 to -14°C"
• Extend operational window between -4 and -8°C
Transports Canada Transport Canada
APS



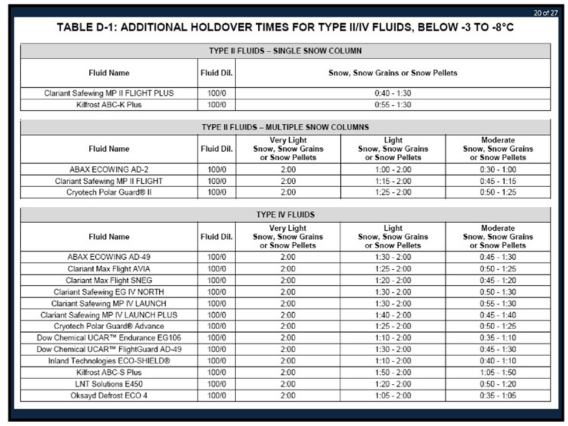
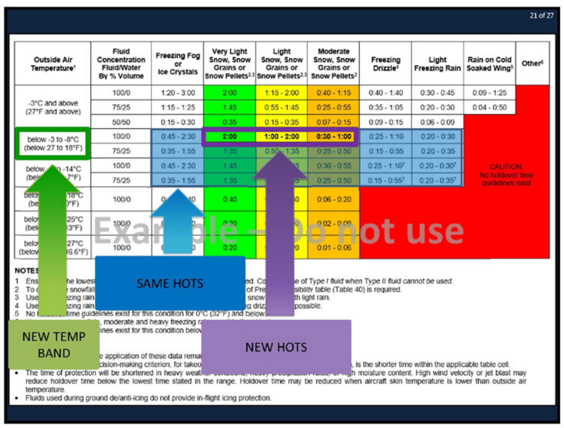


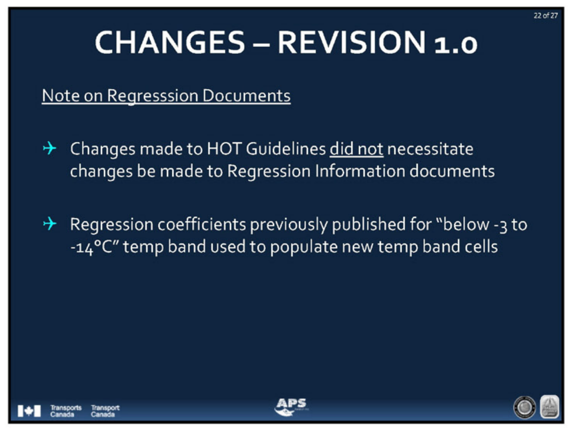
TABLE D-1: ADDITIONAL HOLDOVER TIMES FOR TYPE II/IV FLUIDS, BELOW -3 TO -8°C

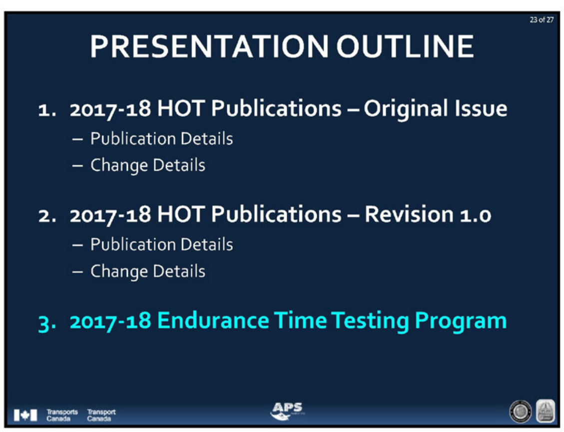
TYPE II FLUIDS – SINGLE SNOW COLUMN		
Fluid Name	Fluid Dil.	Snow, Snow Grains or Snow Pellets
Clariant Safewing MP II FLIGHT PLUS	100/0	0:40 - 1:30
Kilfrost ABC-K Plus	100/0	0:55 - 1:30

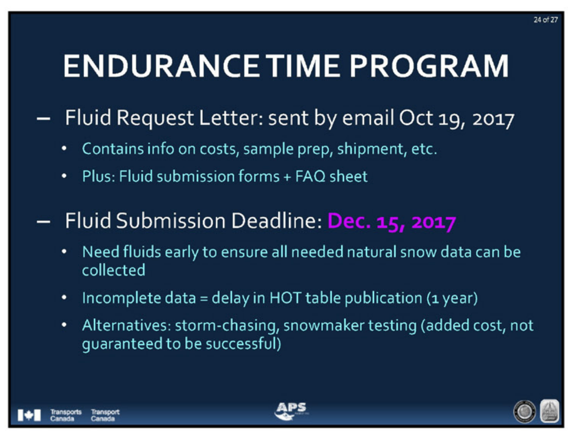
TYPE II FLUIDS – MULTIPLE SNOW COLUMNS				
Fluid Name	Fluid Dil.	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets
ABAX ECOWING AD-2	100/0	2:00	1:00 - 2:00	0:30 - 1:00
Clariant Safewing MP II FLIGHT	100/0	2:00	1:15 - 2:00	0:45 - 1:15
Cryotech Polar Guard® II	100/0	2:00	1:25 - 2:00	0:50 - 1:25

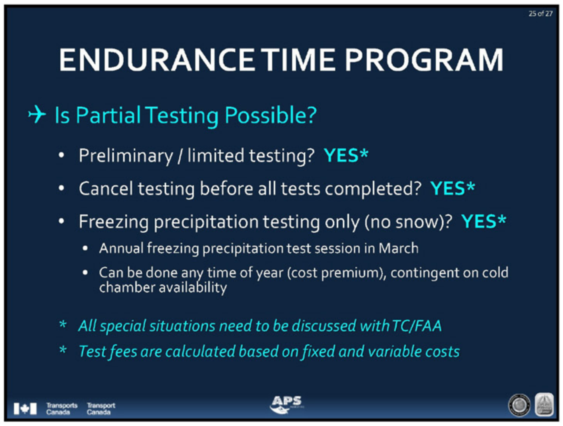
TYPE IV FLUIDS				
Fluid Name	Fluid Dil.	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets
ABAX ECOWING AD-49	100/0	2:00	1:30 - 2:00	0:45 - 1:30
Clariant Max Flight AVIA	100/0	2:00	1:25 - 2:00	0:50 - 1:25
Clariant Max Flight SNEG	100/0	2:00	1:20 - 2:00	0:45 - 1:20
Clariant Safewing EG IV NORTH	100/0	2:00	1:30 - 2:00	0:50 - 1:30
Clariant Safewing MP IV LAUNCH	100/0	2:00	1:30 - 2:00	0:55 - 1:30
Clariant Safewing MP IV LAUNCH PLUS	100/0	2:00	1:40 - 2:00	0:45 - 1:40
Cryotech Polar Guard® Advance	100/0	2:00	1:25 - 2:00	0:50 - 1:25
Dow Chemical UCAR™ Endurance EG106	100/0	2:00	1:10 - 2:00	0:35 - 1:10
Dow Chemical UCAR™ FlightGuard AD-49	100/0	2:00	1:30 - 2:00	0:45 - 1:30
Inland Technologies ECO-SHIELD®	100/0	2:00	1:10 - 2:00	0:40 - 1:10
Kilfrost ABC-S Plus	100/0	2:00	1:50 - 2:00	1:05 - 1:50
LNT Solutions E450	100/0	2:00	1:20 - 2:00	0:50 - 1:20
Oksayd Defrost ECO 4	100/0	2:00	1:05 - 2:00	0:35 - 1:05







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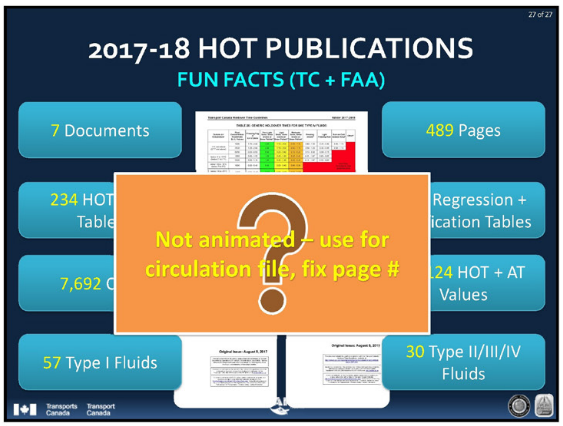
ENDURANCE TIME PROGRAM
Is Partial Testing Possible?
Preliminary / limited testing? YES*
Cancel testing before all tests completed? YES*
Freezing precipitation testing only (no snow)? YES*
Annual freezing precipitation test session in March
Can be done any time of year (cost premium), contingent on cold chamber availability
* All special situations need to be discussed with TC/FAA
* Test fees are calculated based on fixed and variable costs
Transports Canada Transport Canada
APS


Questions?
APS Aviation Inc.
Stephanie Bendickson
Project Leader, APS Aviation
sbendickson@apsaviation.ca*
*Note change
Transports Canada Transport Canada


27 of 27
2017-18 HOT PUBLICATIONS
FUN FACTS (TC + FAA)
7 Documents
489 Pages
234 HOT Table
Regression + ication Tables
7,692 C
24 HOT + AT Values
Not animated – use for circulation file, fix page #
57 Type I Fluids
30 Type II/III/IV Fluids
Transports Canada Transport Canada

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SAE G-12 HOLDOVER TIME COMMITTEE, MONTREAL, CANADA, NOVEMBER 2017

PRESENTATION:
LINEAR REGRESSION 101, HOT DATA ANALYSIS METHODOLOGY

Joint research led by:

Transports Canada Transport Canada

Conducted by:

APS Aviation Inc.

LINEAR REGRESSION 101
HOT DATA ANALYSIS METHODOLOGY

SAE G12 Holdover Time Committee, Montreal, Canada, Oct 31, 2017
Prepared By: Ben Bernier

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2 of 20

REGRESSION 101

- Regression analysis often-mentioned in APS HOT presentations, but details are not always discussed extensively
  - SAE membership has changed
  - Newer members may not be familiar with analysis protocol and its history
- How is the testing data gathered analyzed in order to develop HOTs?

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OUTLINE

- Background
- Regression 101
  - What is Linear Regression?
  - HOT Regression Analysis Protocol
- Questions?

---

4 of 20

OUTLINE

- Background
- Regression 101
  - What is Linear Regression?
  - HOT Regression Analysis Protocol
- Questions?

---

5 of 20

BACKGROUND

- In the mid-1990's, fluid-specific holdover time tables had not yet been developed.
  - Tables were type-specific and generic
  - Times were substantiated or changed based on the newly collected data each testing year
- Significant changes to Type IV fluid HOT table were proposed in 1997 at the G12 in Pittsburgh
  - Industry requested a better defined analytical protocol
- Linear regression protocol among those developed and evaluated by HOT committee

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BACKGROUND

- Linear regression protocol selected by committee to be standard analysis methodology for determining fluid specific HOTs.
  - Linear regression analysis method now included in ARP5485
- As of today, linear regression used to determine the fluid HOTs for all cells in fluid-specific HOT tables.

Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3°C and above (27°F and above)	100/0	1:20 - 3:00	2:00	1:15 - 2:00	0:40 - 1:15	0:40 - 1:40	0:30 - 0:45	0:09 - 1:25	CAUTION: No holdover time guidelines exist
	75/25	1:15 - 1:25	1:45	0:55 - 1:45	0:25 - 0:55	0:35 - 1:05	0:20 - 0:30	0:04 - 0:50	
	50/50	0:15 - 0:30	0:35	0:15 - 0:35	0:07 - 0:15	0:09 - 0:15	0:06 - 0:09		
below -3 to -14°C (below 27 to 7°F)	100/0	0:45 - 2:30	1:45	0:55 - 1:45	0:30 - 0:55	0:25 - 1:10	0:20 - 0:30		
	75/25	0:35 - 1:55	1:35	0:50 - 1:35	0:25 - 0:50	0:15 - 0:55	0:20 - 0:35		
below -14 to -18°C (below 7 to 0°F)	100/0	0:15 - 0:40	0:40	0:20 - 0:40	0:06 - 0:20				
below -18 to -25°C (below 0 to -13°F)	100/0	0:15 - 0:40	0:20	0:09 - 0:20	0:02 - 0:09				
below -25 to -27°C (below -13 to -16.6°F)	100/0	0:15 - 0:40	0:20	0:06 - 0:20	0:01 - 0:06				

HOTs in table the product of regression analysis!


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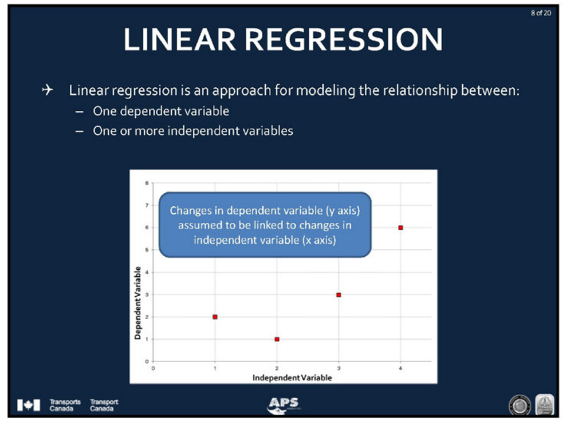
OUTLINE
Background
Regression 101
– What is Linear Regression?
– HOT Regression Analysis Protocol
Questions?
APS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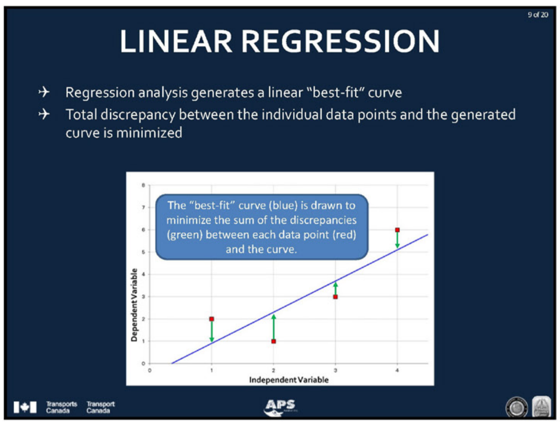
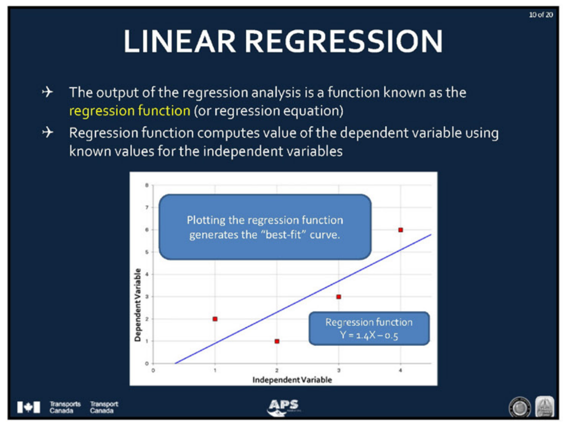
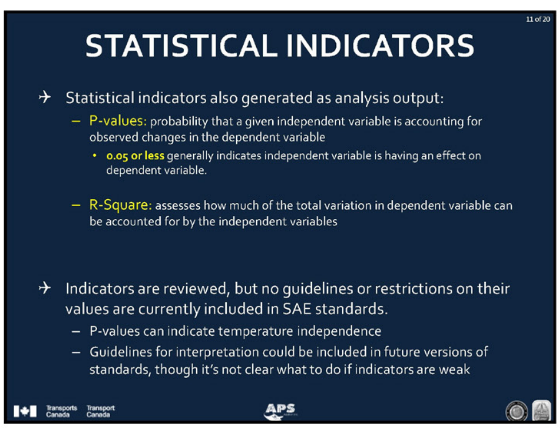
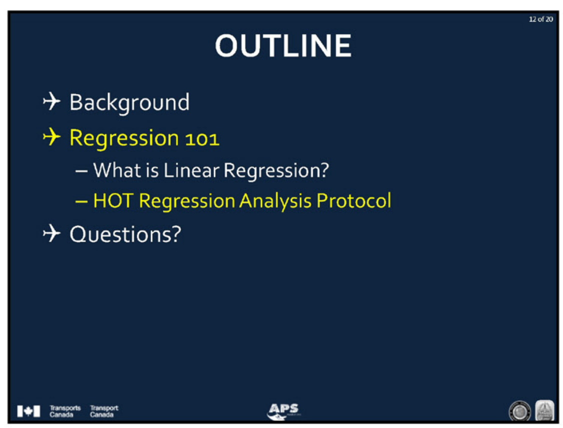
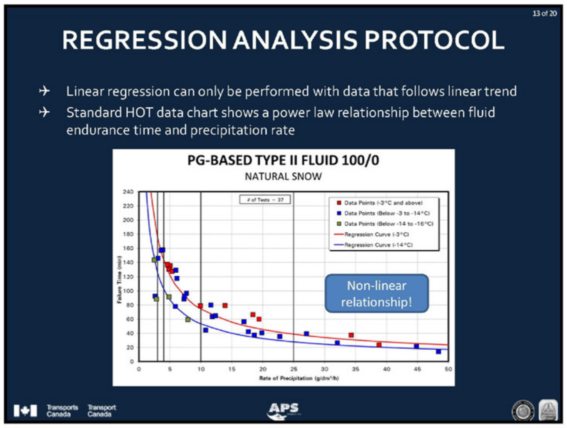
LINEAR REGRESSION
Linear regression is an approach for modeling the relationship between:
– One dependent variable
– One or more independent variables
Changes in dependent variable (y axis) assumed to be linked to changes in independent variable (x axis)
Dependent Variable
Independent Variable
APS

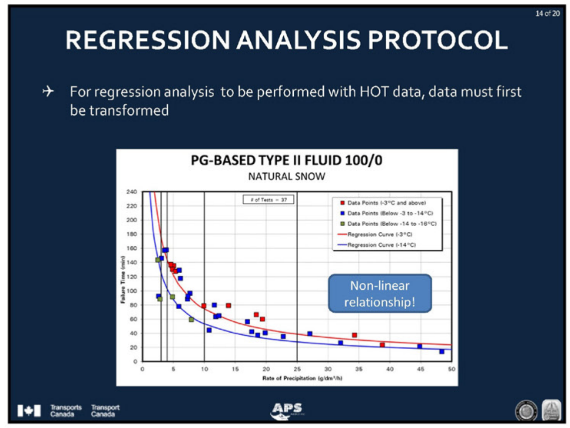

9 of 20
LINEAR REGRESSION
Regression analysis generates a linear "best-fit" curve
Total discrepancy between the individual data points and the generated curve is minimized
The "best-fit" curve (blue) is drawn to minimize the sum of the discrepancies (green) between each data point (red) and the curve.
Dependent Variable
Independent Variable
APS

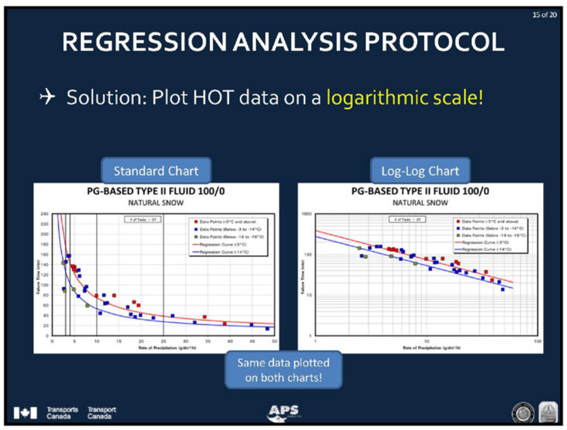

10 of 20
LINEAR REGRESSION
The output of the regression analysis is a function known as the regression function (or regression equation)
Regression function computes value of the dependent variable using known values for the independent variables
Plotting the regression function generates the "best-fit" curve.
Regression function
Y = 1.4X – 0.5
Dependent Variable
Independent Variable
APS

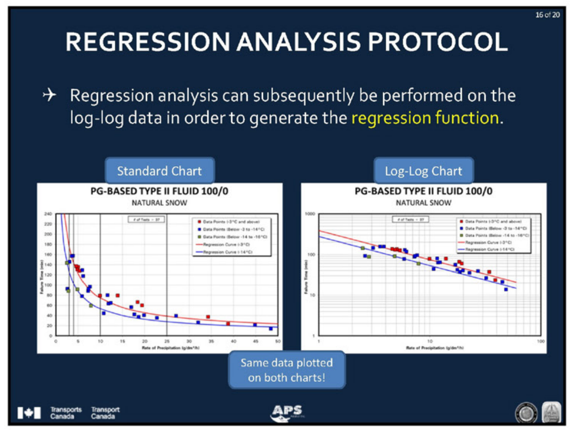

11 of 20
STATISTICAL INDICATORS
Statistical indicators also generated as analysis output:
– P-values: probability that a given independent variable is accounting for observed changes in the dependent variable
• 0.05 or less generally indicates independent variable is having an effect on dependent variable.
– R-Square: assesses how much of the total variation in dependent variable can be accounted for by the independent variables
Indicators are reviewed, but no guidelines or restrictions on their values are currently included in SAE standards.
– P-values can indicate temperature independence
– Guidelines for interpretation could be included in future versions of standards, though it's not clear what to do if indicators are weak
APS

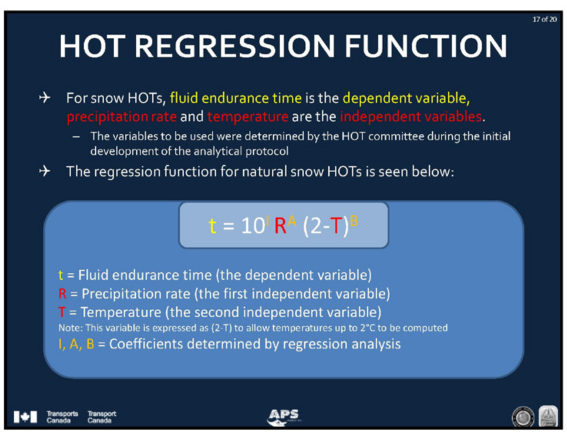

12 of 20
OUTLINE
Background
Regression 101
– What is Linear Regression?
– HOT Regression Analysis Protocol
Questions?
APS


13 of 20
REGRESSION ANALYSIS PROTOCOL
Linear regression can only be performed with data that follows linear trend
Standard HOT data chart shows a power law relationship between fluid endurance time and precipitation rate
PG-BASED TYPE II FLUID 100/0
NATURAL SNOW
Non-linear relationship!
Rate of Precipitation (g/dm²/h)
Transports Canada Transport Canada
APS


14 of 20
REGRESSION ANALYSIS PROTOCOL
For regression analysis to be performed with HOT data, data must first be transformed
PG-BASED TYPE II FLUID 100/0
NATURAL SNOW
Non-linear relationship!
Rate of Precipitation (g/dm²/h)
Transports Canada Transport Canada
APS


15 of 20
REGRESSION ANALYSIS PROTOCOL
Solution: Plot HOT data on a logarithmic scale!
Standard Chart
Log-Log Chart
PG-BASED TYPE II FLUID 100/0
NATURAL SNOW
Same data plotted on both charts!
Transports Canada Transport Canada
APS


16 of 20
REGRESSION ANALYSIS PROTOCOL
Regression analysis can subsequently be performed on the log-log data in order to generate the regression function.
Standard Chart
Log-Log Chart
PG-BASED TYPE II FLUID 100/0
NATURAL SNOW
Same data plotted on both charts!
Transports Canada Transport Canada
APS


17 of 20
HOT REGRESSION FUNCTION
For snow HOTs, fluid endurance time is the dependent variable, precipitation rate and temperature are the independent variables.
– The variables to be used were determined by the HOT committee during the initial development of the analytical protocol
The regression function for natural snow HOTs is seen below:
$t = 10^{I} R^{A} (2-T)^{B}$
t = Fluid endurance time (the dependent variable)
R = Precipitation rate (the first independent variable)
T = Temperature (the second independent variable)
Note: This variable is expressed as (2-T) to allow temperatures up to 2°C to be computed
I, A, B = Coefficients determined by regression analysis
Transports Canada Transport Canada
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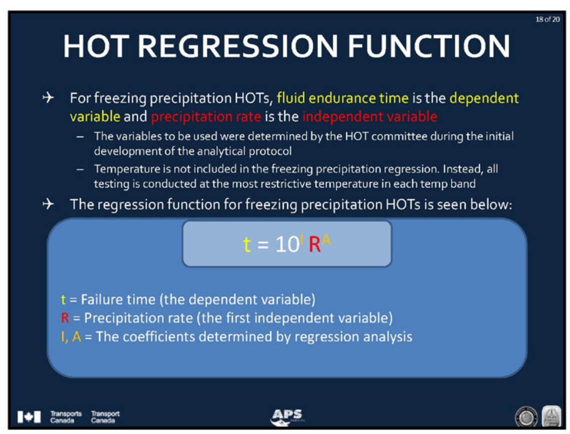
18 of 20
HOT REGRESSION FUNCTION
For freezing precipitation HOTs, fluid endurance time is the dependent variable and precipitation rate is the independent variable
– The variables to be used were determined by the HOT committee during the initial development of the analytical protocol
– Temperature is not included in the freezing precipitation regression. Instead, all testing is conducted at the most restrictive temperature in each temp band
The regression function for freezing precipitation HOTs is seen below:
$t = 10^{I} R^{A}$
t = Failure time (the dependent variable)
R = Precipitation rate (the first independent variable)
I, A = The coefficients determined by regression analysis
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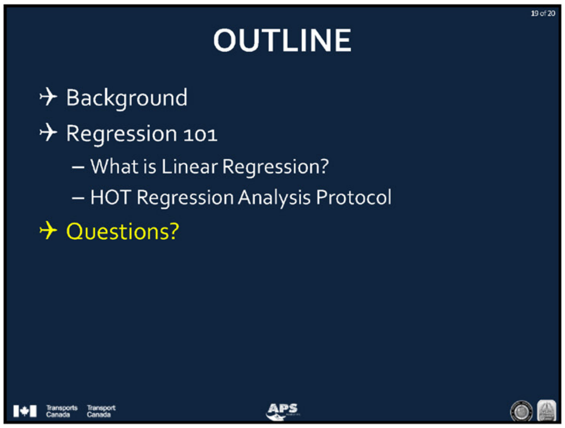
19 of 20
OUTLINE
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– HOT Regression Analysis Protocol
Questions?
Transports Canada
Transport Canada
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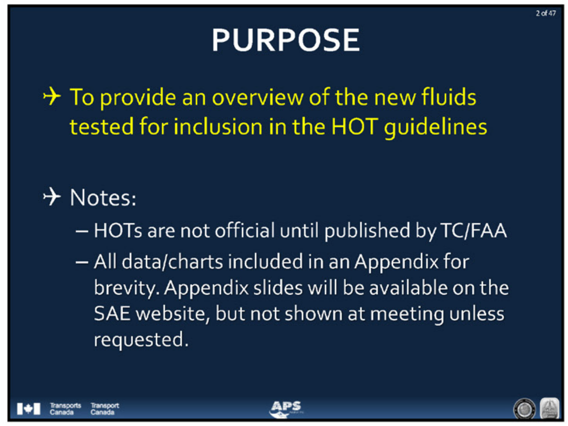
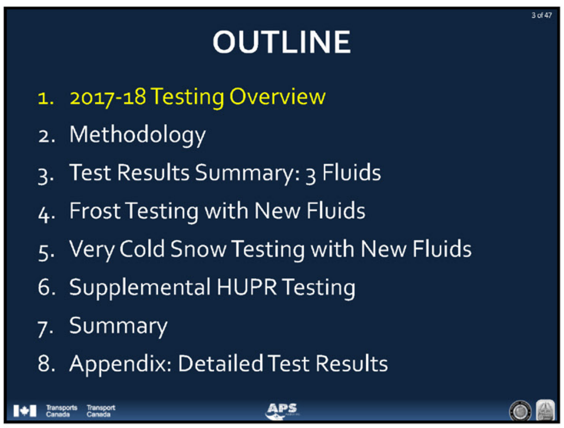
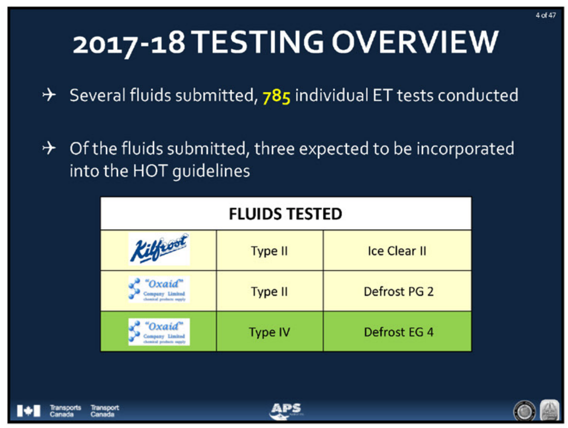
?
APS
Aviation Inc.
Benjamin Bernier
bbernier@apsaviation.ca

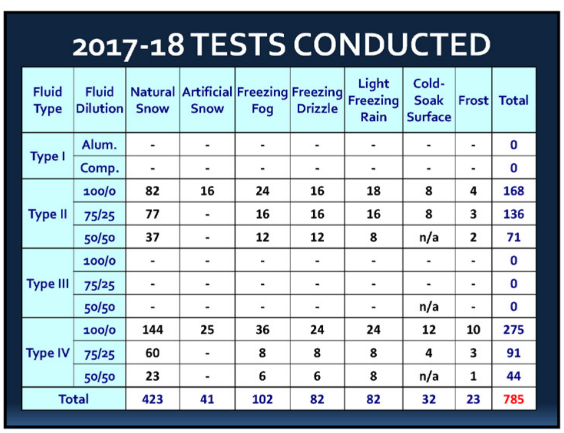
SAE G-12 HOLDOVER TIME COMMITTEE, AUSTIN, USA, MAY 2018

PRESENTATION:
WINTER 2017-18 ENDURANCE TIME TESTING RESULTS



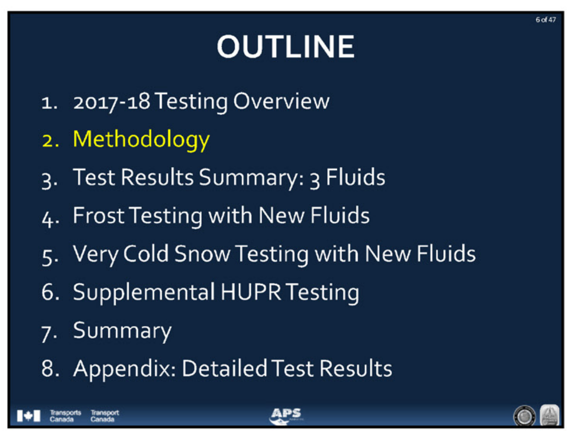


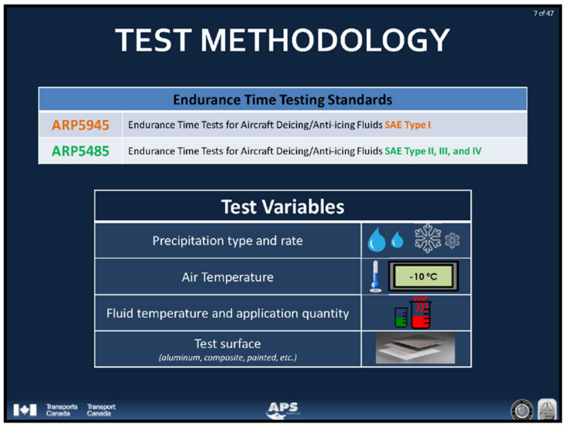


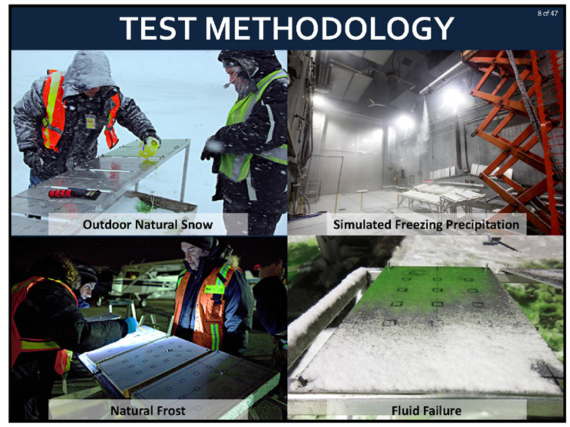


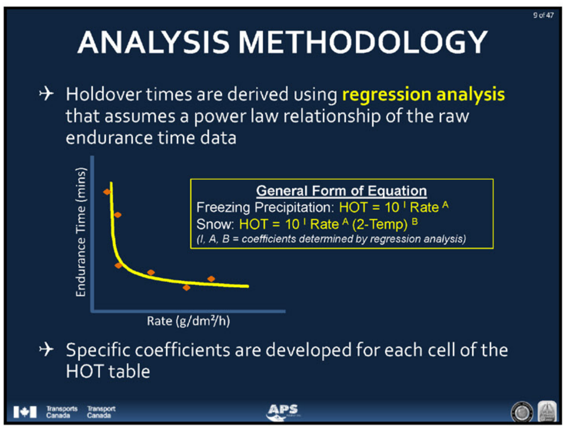
2017-18 TESTS CONDUCTED

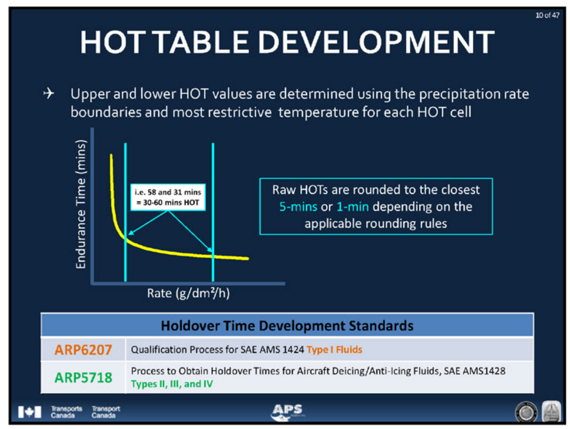
Fluid Type	Fluid Dilution	Natural Snow	Artificial Snow	Freezing Fog	Freezing Drizzle	Light Freezing Rain	Cold-Soak Surface	Frost	Total
Type I	Alum.	-	-	-	-	-	-	-	0
	Comp.	-	-	-	-	-	-	-	0
Type II	100/0	82	16	24	16	18	8	4	168
	75/25	77	-	16	16	16	8	3	136
	50/50	37	-	12	12	8	n/a	2	71
Type III	100/0	-	-	-	-	-	-	-	0
	75/25	-	-	-	-	-	-	-	0
	50/50	-	-	-	-	-	n/a	-	0
Type IV	100/0	144	25	36	24	24	12	10	275
	75/25	60	-	8	8	8	4	3	91
	50/50	23	-	6	6	8	n/a	1	44
Total		423	41	102	82	82	32	23	785




7 of 47
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.)
APS


8 of 47
TEST METHODOLOGY
Outdoor Natural Snow
Simulated Freezing Precipitation
Natural Frost
Fluid Failure


9 of 47
ANALYSIS METHODOLOGY
Holdover times are derived using regression analysis that assumes a power law relationship of the raw endurance time data
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)
Endurance Time (mins)
Rate (g/dm²/h)
Specific coefficients are developed for each cell of the HOT table
APS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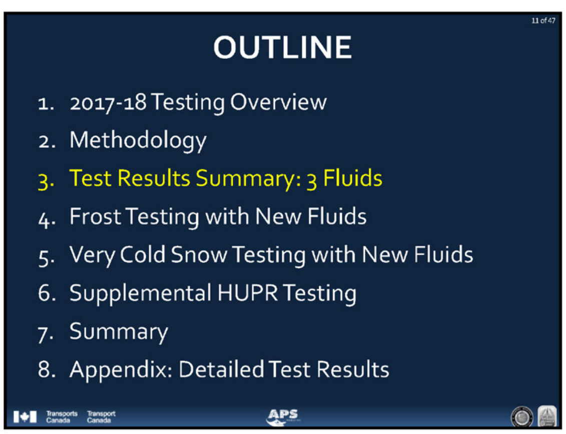
HOT TABLE DEVELOPMENT
Upper and lower HOT values are determined using the precipitation rate boundaries and most restrictive temperature for each HOT cell
i.e. 58 and 31 mins = 30-60 mins HOT
Raw HOTs are rounded to the closest 5-mins or 1-min depending on the applicable rounding rules
Endurance Time (mins)
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
APS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OUTLINE
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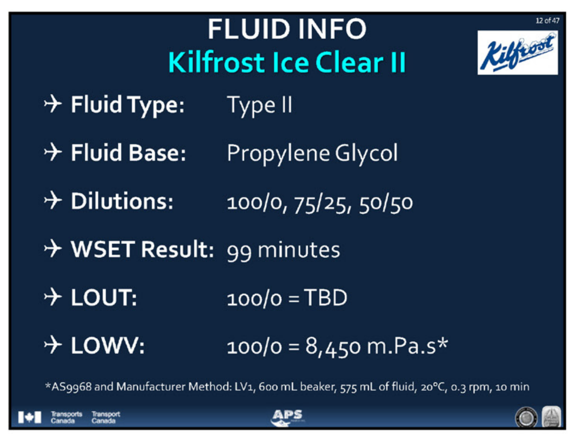
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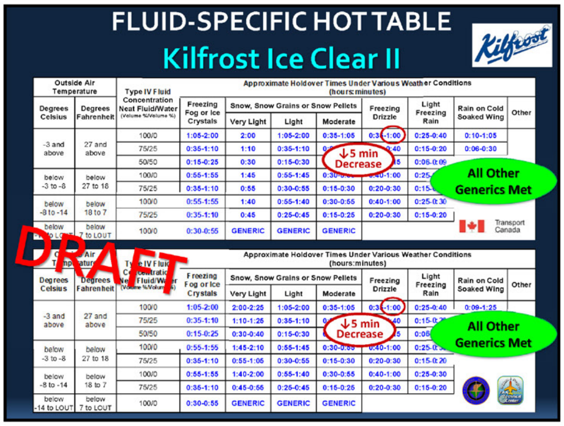
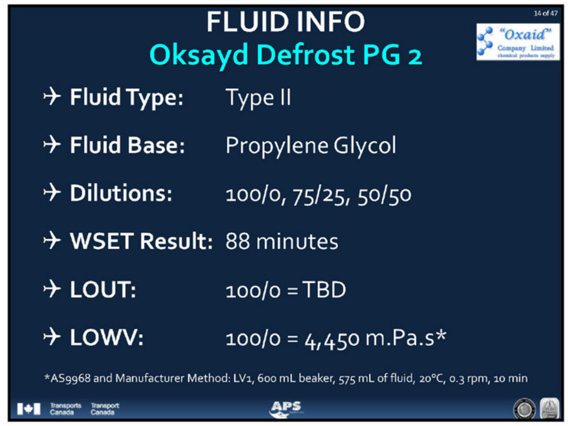
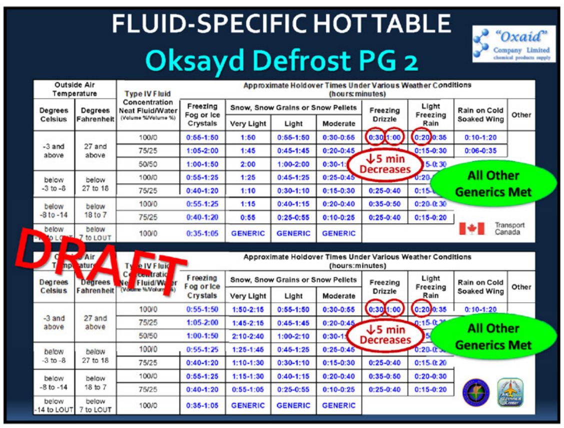
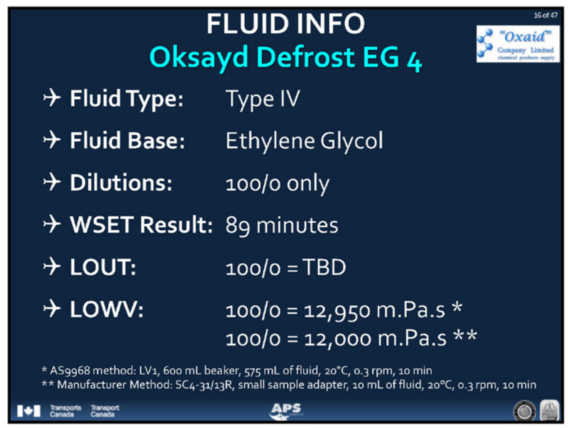
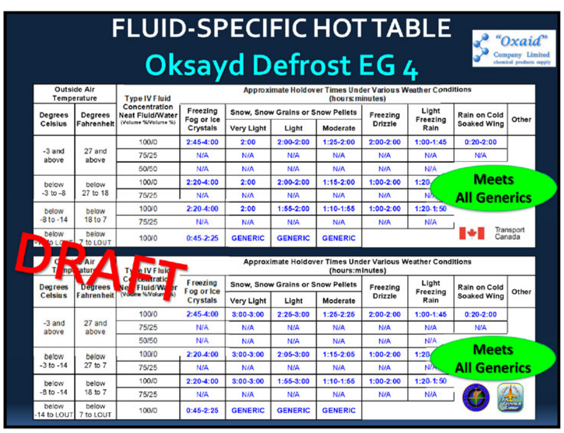
FLUID INFO
Kilfrost Ice Clear II
Kilfrost
Fluid Type: Type II
Fluid Base: Propylene Glycol
Dilutions: 100/0, 75/25, 50/50
WSET Result: 99 minutes
LOUT: 100/0 = TBD
LOWV: 100/0 = 8,450 m.Pa.s*
*AS9968 and Manufacturer Method: LV1, 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
APS

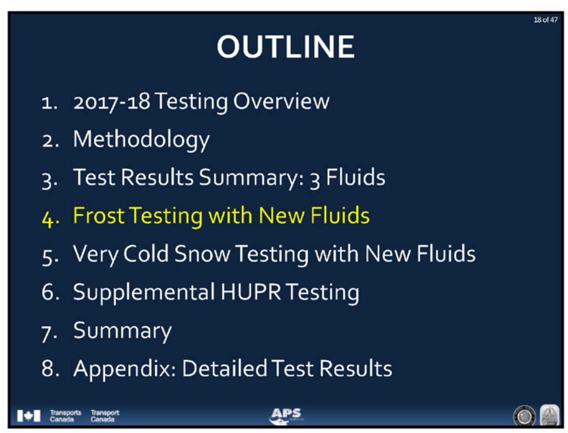

FLUID-SPECIFIC HOT TABLE
Kilfrost Ice Clear II
↓5 min Decrease
All Other Generics Met
DRAFT
↓5 min Decrease
All Other Generics Met


FLUID INFO
Oksayd Defrost PG 2
"Oxaid" Company Limited
Fluid Type: Type II
Fluid Base: Propylene Glycol
Dilutions: 100/0, 75/25, 50/50
WSET Result: 88 minutes
LOUT: 100/0 = TBD
LOWV: 100/0 = 4,450 m.Pa.s*
*AS9968 and Manufacturer Method: LV1, 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
APS


FLUID-SPECIFIC HOT TABLE
Oksayd Defrost PG 2
"Oxaid" Company Limited
↓5 min Decreases
All Other Generics Met
DRAFT
↓5 min Decreases
All Other Generics Met


FLUID INFO
Oksayd Defrost EG 4
"Oxaid" Company Limited
Fluid Type: Type IV
Fluid Base: Ethylene Glycol
Dilutions: 100/0 only
WSET Result: 89 minutes
LOUT: 100/0 = TBD
LOWV: 100/0 = 12,950 m.Pa.s *
100/0 = 12,000 m.Pa.s **
* AS9968 method: LV1, 600 mL beaker, 575 mL of fluid, 20°C, 0.3 rpm, 10 min
** Manufacturer Method: SC4-31/13R, small sample adapter, 10 mL of fluid, 20°C, 0.3 rpm, 10 min
APS


FLUID-SPECIFIC HOT TABLE
Oksayd Defrost EG 4
"Oxaid" Company Limited
Meets All Generics
DRAFT
Meets All Generics


OUTLINE
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FROST TESTING

- Objective: Verify validity of frost HOTs (generic) for new fluids
  - Testing conducted with three new fluids and fluids commercialized in 2017-18
  - All endurance times measured met current generic HOTs
  - Additional tests will be conducted next winter with retained samples of the three fluids expected to be commercialized
- Conclusion: Data collected does not indicate any issues with current generic active frost HOTs

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OUTLINE

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VERY COLD SNOW TESTING

- Objective: Verify validity of very cold snow HOTs (generic) for new fluids
  - Testing conducted with artificial snow maker in very cold snow boundary conditions (-18/-25°C and 3/4/10/25 g/dm²/h)
  - Data compared to similar data collected with other Type II/IV fluids
  - No large differences seen between new and historic data
  - Additional details will be provided in separate very cold snow presentation
- Conclusion: Data collected similar to historic data.

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OUTLINE

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HEAVY SNOW TESTING

- Objective: Collect supplemental data in heavy snow to improve HUPRS (highest usable precipitation rate)
  - Data collected in heavy snow conditions with one fluid: **Clariant Safewing MP II FLIGHT** (100/0 and 75/25)
  - Testing requested by (and funded by) the fluid manufacturer
  - HUPR analysis conducted on combined data set provides improved HUPRs of 50 g/dm²/h (up from 40 g/dm²/h)
  - Conformance analysis indicates new HUPRs can be used with existing regression information
- Conclusion: HUPRs of Clariant Safewing MP II FLIGHT 100/0 and 75/25 will increase to 50 g/dm²/h

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OUTLINE

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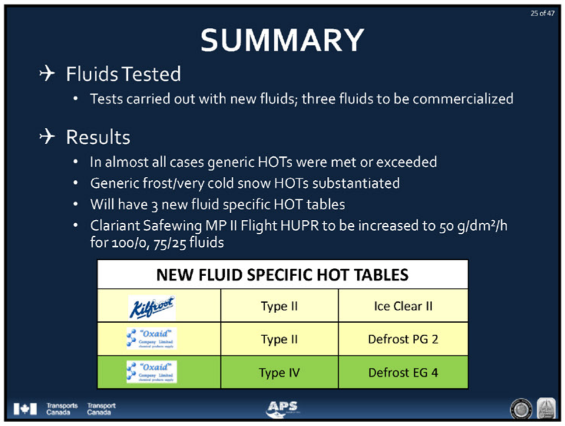
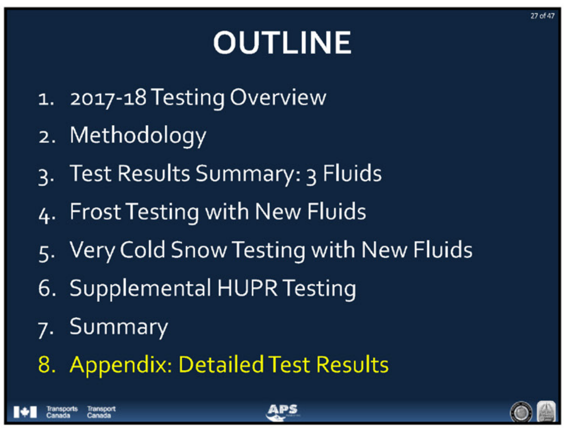

25 of 47
SUMMARY
Fluids Tested
Tests carried out with new fluids; three fluids to be commercialized
Results
In almost all cases generic HOTs were met or exceeded
Generic frost/very cold snow HOTs substantiated
Will have 3 new fluid specific HOT tables
Clariant Safewing MP II Flight HUPR to be increased to 50 g/dm²/h for 100/0, 75/25 fluids
NEW FLUID SPECIFIC HOT TABLES
Kilfrost | Type II | Ice Clear II
"Oxaid" | Type II | Defrost PG 2
"Oxaid" | Type IV | Defrost EG 4
Transport Canada
APS


APS
Aviation Inc.
?
Benjamin Bernier
email: bbernier@apsaviation.ca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KILFROST
ICE CLEAR II
Transport Canada
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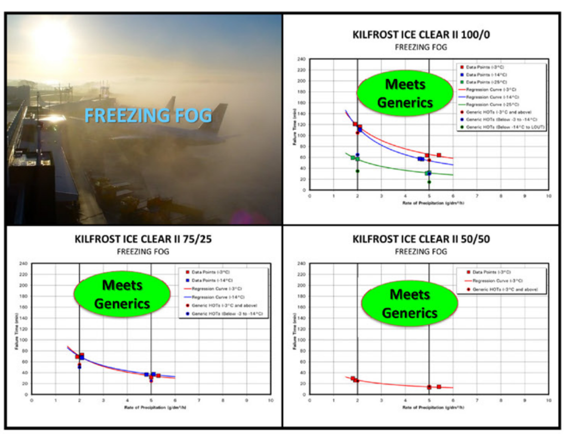
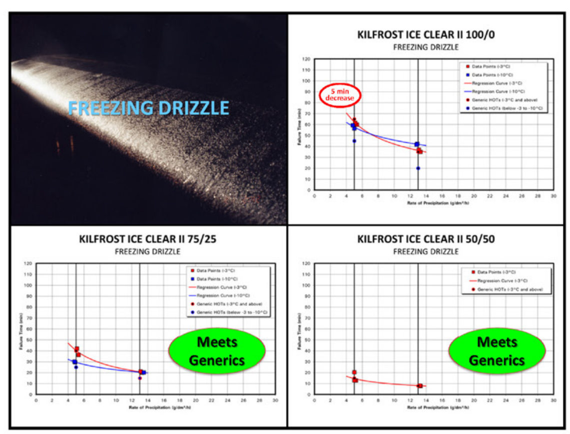
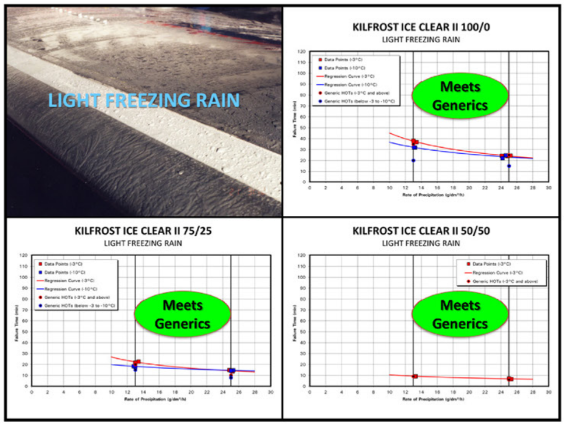
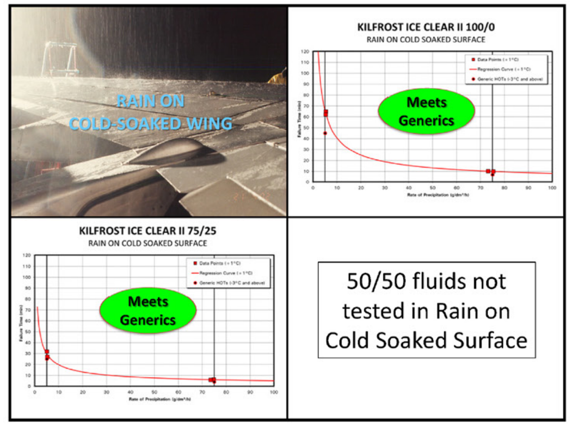
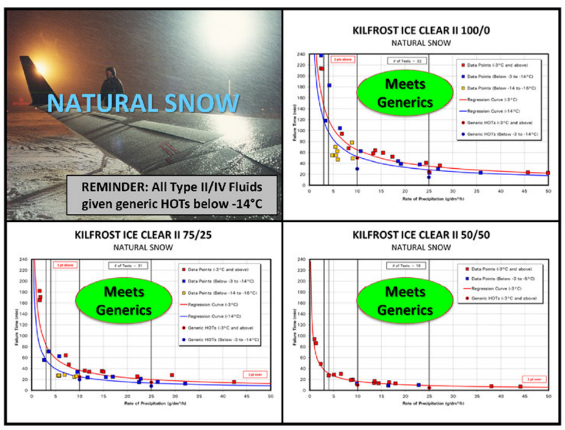
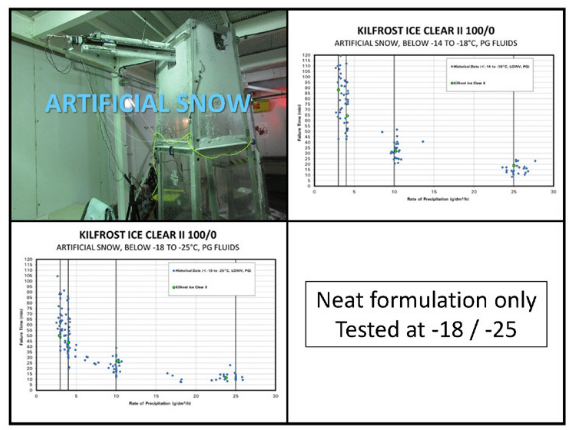

FREEZING FOG
KILFROST ICE CLEAR II 100/0
FREEZING FOG
Meets Generics
KILFROST ICE CLEAR II 75/25
FREEZING FOG
Meets Generics
KILFROST ICE CLEAR II 50/50
FREEZING FOG
Meets Generics

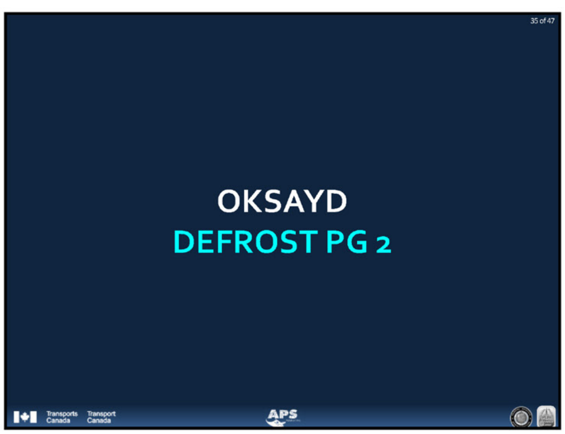

FREEZING DRIZZLE
KILFROST ICE CLEAR II 100/0
FREEZING DRIZZLE
5 min decrease
KILFROST ICE CLEAR II 75/25
FREEZING DRIZZLE
Meets Generics
KILFROST ICE CLEAR II 50/50
FREEZING DRIZZLE
Meets Generics


LIGHT FREEZING RAIN
KILFROST ICE CLEAR II 100/0
LIGHT FREEZING RAIN
Meets Generics
KILFROST ICE CLEAR II 75/25
LIGHT FREEZING RAIN
Meets Generics
KILFROST ICE CLEAR II 50/50
LIGHT FREEZING RAIN
Meets Generics


RAIN ON COLD-SOAKED WING
KILFROST ICE CLEAR II 100/0
RAIN ON COLD SOAKED SURFACE
Meets Generics
KILFROST ICE CLEAR II 75/25
RAIN ON COLD SOAKED SURFACE
Meets Generics
50/50 fluids not tested in Rain on Cold Soaked Surface


NATURAL SNOW
REMINDER: All Type II/IV Fluids given generic HOTs below -14°C
KILFROST ICE CLEAR II 100/0
NATURAL SNOW
Meets Generics
KILFROST ICE CLEAR II 75/25
NATURAL SNOW
Meets Generics
KILFROST ICE CLEAR II 50/50
NATURAL SNOW
Meets Generics


ARTIFICIAL SNOW
KILFROST ICE CLEAR II 100/0
ARTIFICIAL SNOW, BELOW -14 TO -18°C, PG FLUIDS
KILFROST ICE CLEAR II 100/0
ARTIFICIAL SNOW, BELOW -18 TO -25°C, PG FLUIDS
Neat formulation only Tested at -18 / -25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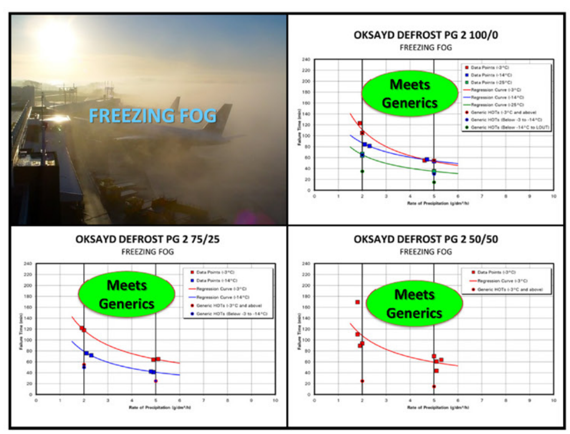
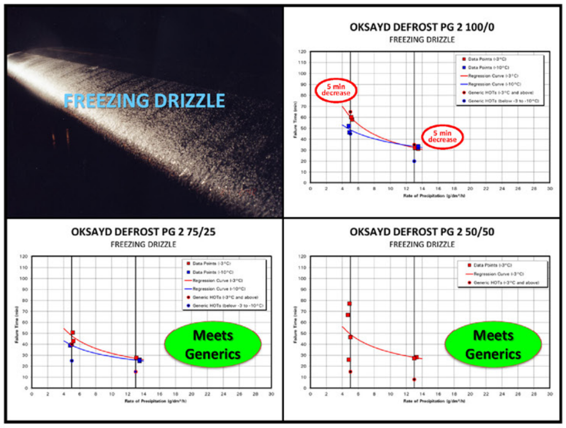
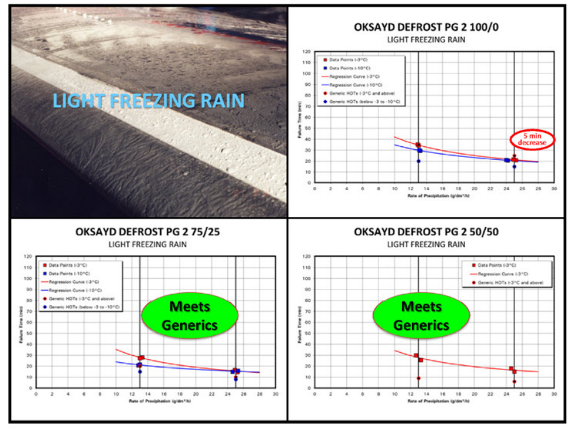
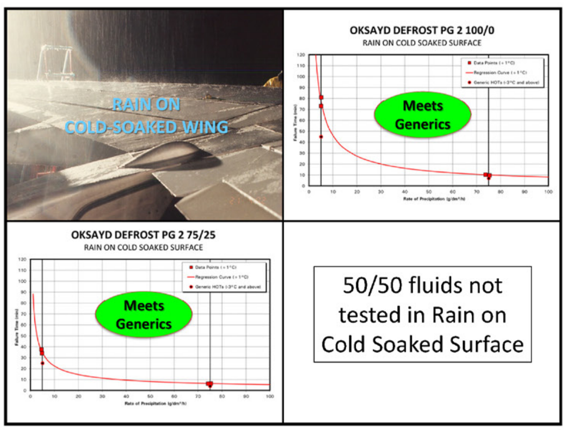
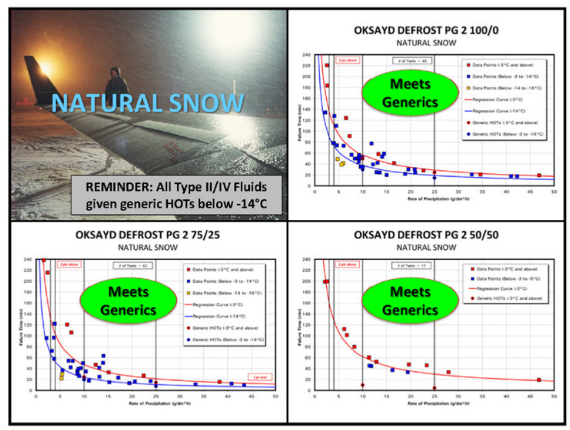
OKSAYD
DEFROST PG 2
Transports Canada
Transport Canada
APS

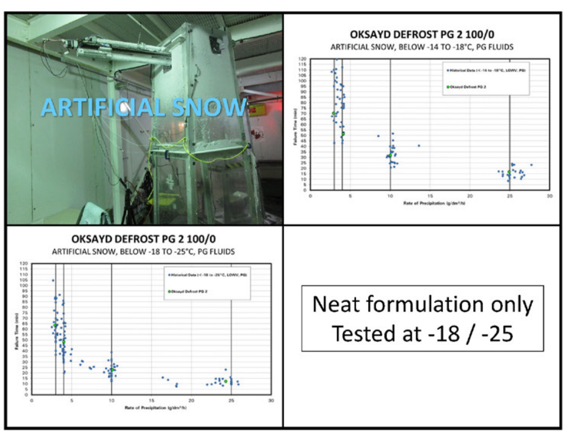

FREEZING FOG
OKSAYD DEFROST PG 2 100/0
FREEZING FOG
Meets Generics
OKSAYD DEFROST PG 2 75/25
FREEZING FOG
Meets Generics
OKSAYD DEFROST PG 2 50/50
FREEZING FOG
Meets Generics

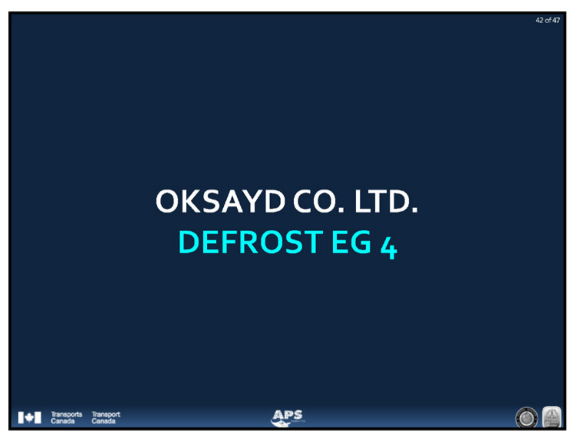

FREEZING DRIZZLE
OKSAYD DEFROST PG 2 100/0
FREEZING DRIZZLE
5 min decrease
5 min decrease
OKSAYD DEFROST PG 2 75/25
FREEZING DRIZZLE
Meets Generics
OKSAYD DEFROST PG 2 50/50
FREEZING DRIZZLE
Meets Generics


LIGHT FREEZING RAIN
OKSAYD DEFROST PG 2 100/0
LIGHT FREEZING RAIN
5 min decrease
OKSAYD DEFROST PG 2 75/25
LIGHT FREEZING RAIN
Meets Generics
OKSAYD DEFROST PG 2 50/50
LIGHT FREEZING RAIN
Meets Generics


RAIN ON COLD-SOAKED WING
OKSAYD DEFROST PG 2 100/0
RAIN ON COLD SOAKED SURFACE
Meets Generics
OKSAYD DEFROST PG 2 75/25
RAIN ON COLD SOAKED SURFACE
Meets Generics
50/50 fluids not tested in Rain on Cold Soaked Surface


NATURAL SNOW
REMINDER: All Type II/IV Fluids given generic HOTs below -14°C
OKSAYD DEFROST PG 2 100/0
NATURAL SNOW
Meets Generics
OKSAYD DEFROST PG 2 75/25
NATURAL SNOW
Meets Generics
OKSAYD DEFROST PG 2 50/50
NATURAL SNOW
Meets Generics


ARTIFICIAL SNOW
OKSAYD DEFROST PG 2 100/0
ARTIFICIAL SNOW, BELOW -14 TO -18°C, PG FLUIDS
OKSAYD DEFROST PG 2 100/0
ARTIFICIAL SNOW, BELOW -18 TO -25°C, PG FLUIDS
Neat formulation only Tested at -18 / -25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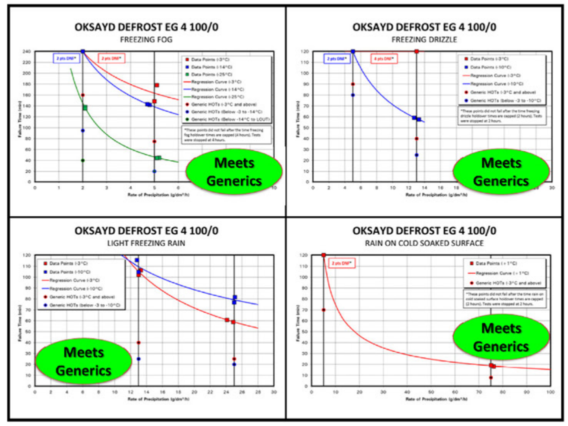
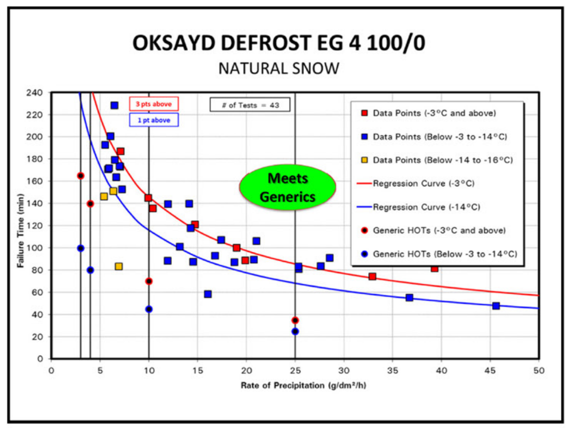
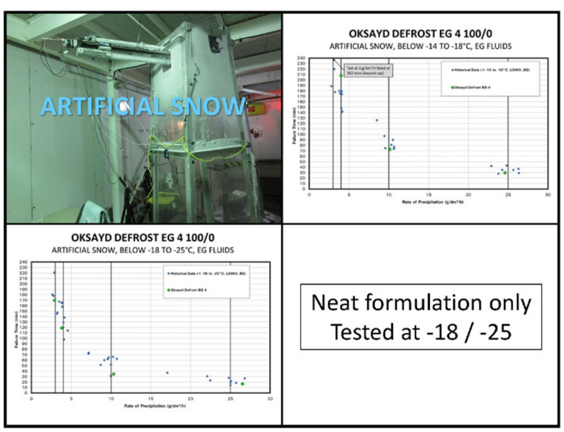
OKSAYD CO. LTD.
DEFROST EG 4
APS


FREEZING FOG
FREEZING DRIZZLE
LIGHT FREEZING RAIN
RAIN ON
COLD-SOAKED WING


OKSAYD DEFROST EG 4 100/0
FREEZING FOG
Meets
Generics
OKSAYD DEFROST EG 4 100/0
FREEZING DRIZZLE
Meets
Generics
OKSAYD DEFROST EG 4 100/0
LIGHT FREEZING RAIN
Meets
Generics
OKSAYD DEFROST EG 4 100/0
RAIN ON COLD SOAKED SURFACE
Meets
Generics

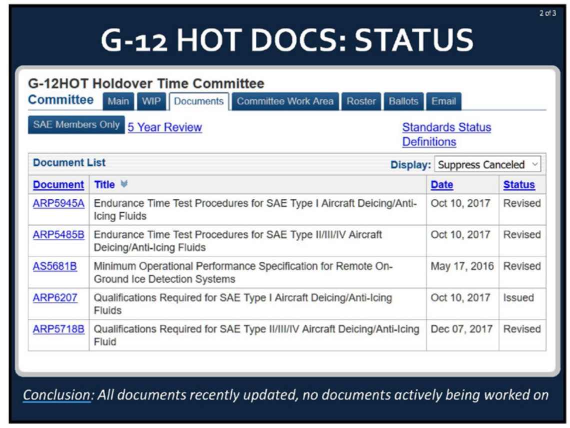

NATURAL SNOW


OKSAYD DEFROST EG 4 100/0
NATURAL SNOW
3 pts above
1 pt above
# of Tests = 43
Data Points (-3°C and above)
Data Points (Below -3 to -14°C)
Data Points (Below -14 to -16°C)
Regression Curve (-3°C)
Regression Curve (-14°C)
Generic HOTs (-3°C and above)
Generic HOTs (Below -3 to -14°C)
Meets
Generics
Failure Time (min)
Rate of Precipitation (g/dm²/h)

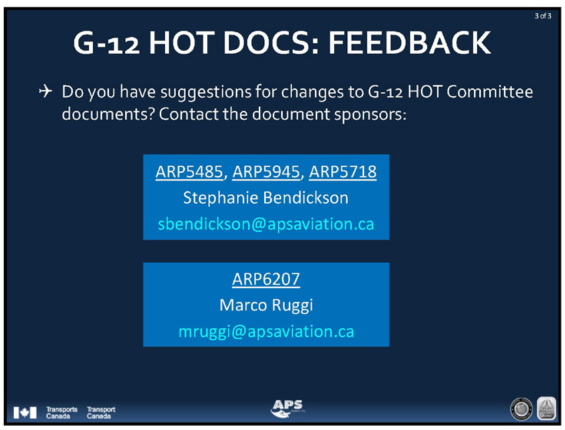

ARTIFICIAL SNOW
OKSAYD DEFROST EG 4 100/0
ARTIFICIAL SNOW, BELOW -14 TO -18°C, EG FLUIDS
OKSAYD DEFROST EG 4 100/0
ARTIFICIAL SNOW, BELOW -18 TO -25°C, EG FLUIDS
Neat formulation only
Tested at -18 / -25

SAE G-12 HOLDOVER TIME COMMITTEE, AUSTIN, USA, MAY 2018

PRESENTATION:
SAE G-12 HOT COMMITTEE: DOCUMENT 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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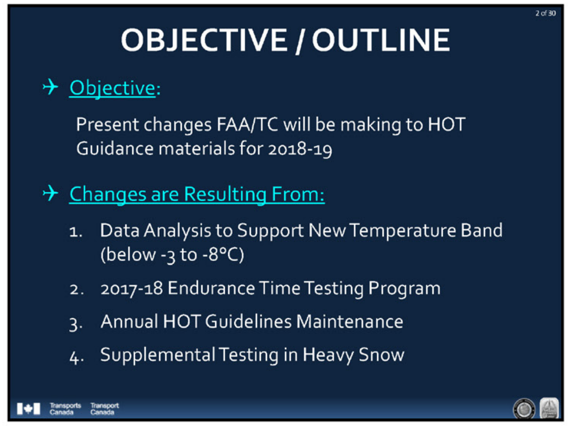
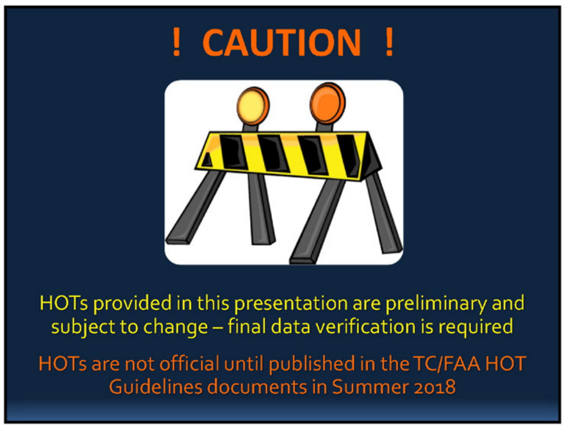
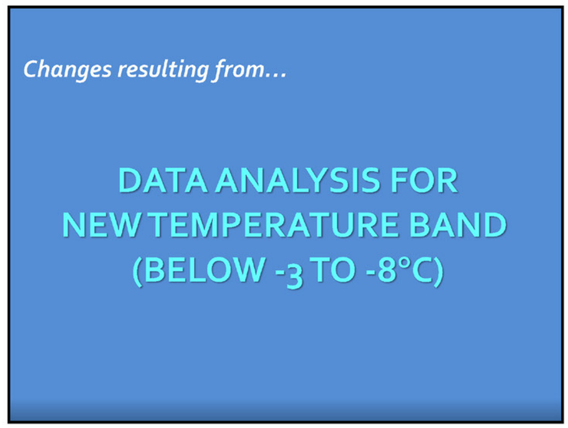
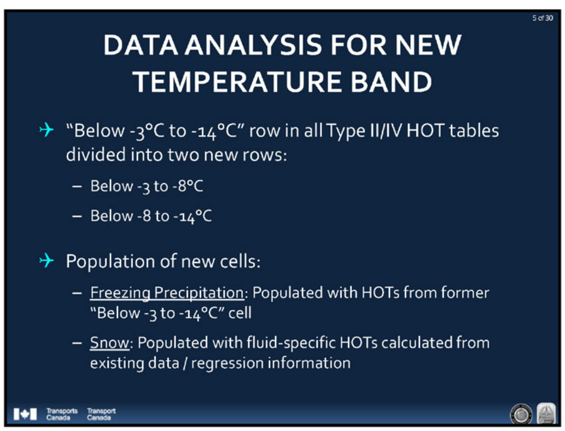
SAE G-12 HOLDOVER TIME COMMITTEE, AUSTIN, USA, MAY 2018

PRESENTATION:
CHANGES TO HOT GUIDELINES FOR WINTER 2018-19









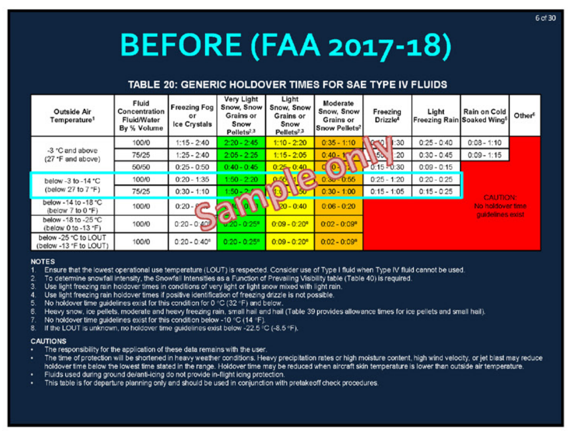


TABLE 20: GENERIC HOLDOVER TIMES FOR SAE TYPE IV FLUIDS

Outside Air Temperature[1]	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets[2,3]	Light Snow, Snow Grains or Snow Pellets[2,3]	Moderate Snow, Snow Grains or Snow Pellets[2]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 °C and above (27 °F and above)	100/0	1:15 - 2:40	2:20 - 2:45	1:10 - 2:20	0:35 - 1:10	[illegible]	0:25 - 0:40	0:08 - 1:10	
	75/25	1:25 - 2:40	2:05 - 2:25	1:15 - 2:05	[illegible]	[illegible]	0:30 - 0:45	0:09 - 1:15	
	50/50	0:25 - 0:50	0:40 - 0:45	0:25 - 0:40	[illegible]	0:15 - 0:30	0:09 - 0:15		
below -3 to -14 °C (below 27 to 7 °F)	100/0	0:20 - 1:35	1:50 - 2:20	[illegible]	[illegible]	0:25 - 1:20	0:20 - 0:25		
	75/25	0:30 - 1:10	[illegible]	[illegible]	0:30 - 1:00	0:15 - 1:05	0:15 - 0:25		
below -14 to -18 °C (below 7 to 0 °F)	100/0	[illegible]	[illegible]	[illegible]	0:06 - 0:20	CAUTION: No holdover time guidelines exist			
below -18 to -25 °C (below 0 to -13 °F)	100/0	[illegible]	[illegible]	0:09 - 0:20[8]	0:02 - 0:09[8]				
below -25 °C to LOUT (below -13 °F to LOUT)	100/0	0:20 - 0:40[8]	0:20 - 0:25[8]	0:09 - 0:20[8]	0:02 - 0:09[8]				

NOTES
1. Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type IV fluid cannot be used.
2. To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 40) is required.
3. Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5. No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
6. Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 39 provides allowance times for ice pellets and small hail).
7. No holdover time guidelines exist for this condition below -10 °C (14 °F).
8. If the LOUT is unknown, no holdover time guidelines exist below -22.5 °C (-8.5 °F).

CAUTIONS
- The responsibility for the application of these data remains with the user.
- 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.
- This table is for departure planning only and should be used in conjunction with pretakeoff check procedures.

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AFTER (DRAFT 2018-19)

TABLE 20: GENERIC HOLDOVER TIMES FOR SAE TYPE IV FLUIDS

Outside Air Temperature[1]	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets[2,3]	Light Snow, Snow Grains or Snow Pellets[2,3]	Moderate Snow, Snow Grains or Snow Pellets[2]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 °C and above (27 °F and above)	100/0	1:15 - 2:40	2:20 - 2:45	1:10 - 2:20	0:35 - 1:10	0:40 - 1:30	0:25 - 0:40	0:08 - 1:10	
	75/25	1:25 - 2:40	2:05 - 2:25	1:15 - 2:05	0:40 - 1:15	[illegible]	0:30 - 0:45	0:09 - 1:15	
	50/50	0:25 - 0:50	0:40 - 0:45	0:25 - 0:40	[illegible]	[illegible]	0:09 - 0:15		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:20 - 1:35	1:50 - 2:20	0:55 - 1:50	[illegible]	[illegible]	0:20 - 0:25		
	75/25	0:30 - 1:10	1:50 - 2:10	[illegible]	[illegible]	0:15 - 1:05	0:15 - 0:25		
below -8 to -14 °C (below 18 to 7 °F)	100/0	0:20 - 1:35	[illegible]	[illegible]	0:25 - 0:45	0:25 - 1:20[7]	0:20 - 0:25[7]	CAUTION: No holdover time guidelines exist	
	75/25	[illegible]	[illegible]	[illegible]	0:20 - 0:45	0:15 - 1:05[7]	0:15 - 0:25[7]		
below -14 to -18 °C (below 7 to 0 °F)	100/0	[illegible]	[illegible]	0:20 - 0:40	0:06 - 0:20				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:20 - 0:40[8]	0:20 - 0:25[8]	0:09 - 0:20[8]	0:02 - 0:09[8]				
below -25 °C to LOUT (below -13 °F to LOUT)	100/0	0:20 - 0:40[8]	0:20 - 0:25[8]	0:09 - 0:20[8]	0:02 - 0:09[8]				

Sample only

NOTES
1. Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type IV fluid cannot be used.
2. To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 40) is required.
3. Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4. Includes light, moderate and heavy freezing drizzle. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5. No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
6. Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 39 provides allowance times for ice pellets and small hail).
7. No holdover time guidelines exist for this condition below -10 °C (14 °F).
8. If the LOUT is unknown, no holdover time guidelines exist below -22.5 °C (-8.5 °F).

CAUTIONS
- The responsibility for the application of these data remains with the user.
- 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.
- This table is for departure planning only and should be used in conjunction with pretakeoff check procedures.

Changes resulting from…

2017-18 ENDURANCE TIME TESTING PROGRAM

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2017-18 ENDURANCE TIME TESTING PROGRAM

- Three new fluids will be added to the HOT Guidelines
  1. Kilfrost Ice Clear II (Type II)
  2. Oksayd Defrost PG 2 (Type II)
  3. Oksayd Defrost EG 4 (Type IV)

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FLUID-SPECIFIC HOT TABLE (TC) KILFROST ICE CLEAR II

Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	1:05-2:00	2:00	1:05-2:00	0:35-1:05	0:35-1:00	0:25-0:40	0:10-1:05	
	75/25	0:35-1:10	1:10	0:35-1:10	0:20-0:35	0:20-0:40	0:15-0:20	0:06-0:30	
	50/50	0:15-0:25	0:30	0:15-0:30	0:09-0:15	0:08-0:15	0:06-0:09		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:55-1:55	1:45	0:55-1:45	0:30-0:55	0:40-1:00	0:25-0:30	CAUTION: No holdover time guidelines exist	
	75/25	0:35-1:10	0:55	0:30-0:55	0:15-0:30	0:20-0:30	0:15-0:20		
below -8 to -14 °C (below 18 to 7 °F)	100/0	0:55-1:55	1:40	0:55-1:40	0:30-0:55	0:40-1:00	0:25-0:30		
	75/25	0:35-1:10	0:45	0:25-0:45	0:15-0:25	0:20-0:30	0:15-0:20		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:30-0:55	GENERIC	GENERIC	GENERIC				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:30-0:55	GENERIC	GENERIC	GENERIC				
below -25 to LOUT (below -13 to LOUT)	100/0	0:30-0:55	GENERIC	GENERIC	GENERIC				

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FLUID-SPECIFIC HOT TABLE (FAA) KILFROST ICE CLEAR II

Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	1:05-2:00	2:00-2:25	1:05-2:00	0:35-1:05	0:35-1:00	0:25-0:40	0:10-1:05	
	75/25	0:35-1:10	1:10-1:25	0:35-1:10	0:20-0:35	0:20-0:40	0:15-0:20	0:06-0:30	
	50/50	0:15-0:25	0:30-0:40	0:15-0:30	0:09-0:15	0:08-0:15	0:06-0:09		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:55-1:55	1:45-2:10	0:55-:1:45	0:30-0:55	0:40-1:00	0:25-0:30	CAUTION: No holdover time guidelines exist	
	75/25	0:35-1:10	0:55-1:05	0:30-0:55	0:15-0:30	0:20-0:30	0:15-0:20		
below -8 to -14 °C (below 18 to 7 °F)	100/0	0:55-1:55	1:40-2:00	0:55-1:40	0:30-0:55	0:40-1:00	0:25-0:30		
	75/25	0:35-1:10	0:45-0:55	0:25-0:45	0:15-0:25	0:20-0:30	0:15-0:20		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:30-0:55	GENERIC	GENERIC	GENERIC				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:30-0:55	GENERIC	GENERIC	GENERIC				
below -25 to LOUT (below -13 to LOUT)	100/0	0:30-0:55	GENERIC	GENERIC	GENERIC				

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FLUID-SPECIFIC HOT TABLE (TC) OKSAYD DEFROST PG 2

Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	0:55-1:50	1:50	0:55-1:50	0:30-0:55	0:30-1:00	0:20-0:35	0:10-1:20	
	75/25	1:05-2:00	1:45	0:45-1:45	0:20-0:45	0:25-0:50	0:15-0:30	0:06-0:35	
	50/50	1:00-1:50	2:00	1:00-2:00	0:30-1:00	0:30-0:50	0:15-0:30		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:55-1:25	1:25	0:45-1:25	0:25-0:45	0:35-0:50	0:20-0:30	CAUTION: No holdover time guidelines exist	
	75/25	0:40-1:20	1:10	0:30-1:10	0:15-0:30	0:25-0:40	0:15-0:20		
below -8 to -14 °C (below 18 to 7 °F)	100/0	0:55-1:25	1:15	0:40-1:15	0:20-0:40	0:35-0:50	0:20-0:30		
	75/25	0:40-1:20	0:55	0:25-0:55	0:10-0:25	0:25-0:40	0:15-0:20		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:35-1:05	GENERIC	GENERIC	GENERIC				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:35-1:05	GENERIC	GENERIC	GENERIC				
below -25 to LOUT (below -13 to LOUT)	100/0	0:35-1:05	GENERIC	GENERIC	GENERIC				

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FLUID-SPECIFIC HOT TABLE (FAA)
OKSAYD DEFROST PG 2

Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	0:55-1:50	1:50-2:15	0:55-1:50	0:30-0:55	0:30-1:00	0:20-0:35	0:10-1:20	
	75/25	1:05-2:00	1:45-2:15	0:45-1:45	0:20-0:45	0:25-0:50	0:15-0:30	0:06-0:35	
	50/50	1:00-1:50	2:10-2:40	1:00-2:10	0:30-1:00	0:30-0:50	0:15-0:30		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:55-1:25	1:25-1:45	0:45-1:25	0:25-0:45	0:35-0:50	0:20-0:30	CAUTION: No holdover time guidelines exist	
	75/25	0:40-1:20	1:10-1:30	0:30-1:10	0:15-0:30	0:25-0:40	0:15-0:20		
below -8 to -14 °C (below 18 to 7 °F)	100/0	0:55-1:25	1:15-1:30	0:40-1:15	0:20-0:40	0:35-0:50	0:20-0:30		
	75/25	0:40-1:20	0:55-1:05	0:25-0:55	0:10-0:25	0:25-0:40	0:15-0:20		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:35-1:05	GENERIC	GENERIC	GENERIC				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:35-1:05	GENERIC	GENERIC	GENERIC				
below -25 to LOUT (below -13 to LOUT)	100/0	0:35-1:05	GENERIC	GENERIC	GENERIC				

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FLUID-SPECIFIC HOT TABLE (TC)
OKSAYD DEFROST EG 4

Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	2:45-4:00	2:00	2:00-2:00	1:25-2:00	2:00-2:00	1:00-1:45	0:20-2:00	
	75/25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
	50/50	N/A	N/A	N/A	N/A	N/A	N/A		
below -3 to -8 °C (below 27 to 18 °F)	100/0	2:20-4:00	2:00	2:00-2:00	1:15-2:00	1:00-2:00	1:20-1:50	CAUTION: No holdover time guidelines exist	
	75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -8 to -14 °C (below 18 to 7 °F)	100/0	2:20-4:00	2:00	1:55-2:00	1:10-1:55	1:00-2:00	1:20-1:50		
	75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:45-2:25	GENERIC	GENERIC	GENERIC				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:45-2:25	GENERIC	GENERIC	GENERIC				
below -25 to LOUT (below -13 to LOUT)	100/0	0:45-2:25	GENERIC	GENERIC	GENERIC				

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FLUID-SPECIFIC HOT TABLE (FAA)
OKSAYD DEFROST EG 4

Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	2:45-4:00	3:00-3:00	2:25-3:00	1:25-2:25	2:00-2:00	1:00-1:45	0:20-2:00	
	75/25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
	50/50	N/A	N/A	N/A	N/A	N/A	N/A		
below -3 to -8 °C (below 27 to 18 °F)	100/0	2:20-4:00	3:00-3:00	2:05-3:00	1:15-2:05	1:00-2:00	1:20-1:50	CAUTION: No holdover time guidelines exist	
	75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -8 to -14 °C (below 18 to 7 °F)	100/0	2:20-4:00	3:00-3:00	1:55-3:00	1:10-1:55	1:00-2:00	1:20-1:50		
	75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:45-2:25	GENERIC	GENERIC	GENERIC				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:45-2:25	GENERIC	GENERIC	GENERIC				
below -25 to LOUT (below -13 to LOUT)	100/0	0:45-2:25	GENERIC	GENERIC	GENERIC				

DRAFT

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Changes resulting from…

2018-19
ANNUAL HOT GUIDELINES MAINTENANCE

17 of 30

Annual Maintenance:
REMOVED FLUIDS

- 3 fluids will be removed as a result of discussions between TC/FAA and manufacturers
  1. Kilfrost ABC-Ice Clear II (Type II)
  2. Clariant Safewing MP III 2031 ECO (Type III)
  3. Kilfrost ABC-3 (Formerly Type II, used as Type I)
- 75/25 and 50/50 dilutions will be removed for 2 fluids as a result of discussions between TC/FAA and manufacturers
  1. ABAX ECOWING AD-49 (Type IV)
  2. Dow UCAR FlightGuard AD-49 (Type IV)
- No fluids become obsolete -> no other removals

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TC/FAA TYPE II FLUID-SPECIFIC HOT GUIDELINES 2018-19

1) ABAX ECOWING 26
2) ABAX ECOWING AD-2
3) Aviation Shaanxi Cleanwing II
4) Beijing Yadilite YD-102
5) Clariant Safewing MP II FLIGHT
6) Clariant Safewing MP II FLIGHT PLUS
7) Cryotech Polar Guard II
8) Kilfrost ABC-K PLUS
9) **Kilfrost Ice Clear II (new)**
10) Newave Aerochemical FCY-2 Bio+
11) **Oksayd Defrost PG 2 (new)**

REMOVED:
Kilfrost ABC-Ice Clear II

TC/FAA TYPE III FLUID-SPECIFIC HOT GUIDELINES 2018-19

1) AllClear AeroClear MAX (High Speed)
2) AllClear AeroClear MAX (Low Speed)

REMOVED:

1) Clariant Safewing MP III 2031 ECO (High Speed)
2) Clariant Safewing MP III 2031 ECO (Low Speed)

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TC/FAA TYPE IV FLUID-SPECIFIC HOT GUIDELINES 2018-19

1) ABAX ECOWING AD-49**
2) CHEMCO ChemR EG IV*
3) Clariant Max Flight 04
4) Clariant Max Flight AVIA
5) Clariant Max Flight SNEG
6) Clariant Safewing EG IV NORTH
7) Clariant Safewing MP IV LAUNCH
8) Clariant Safewing MP IV LAUNCH PLUS
9) Cryotech Polar Guard Advance
10) Inland Technologies ECO-SHIELD
11) Dow UCAR Endurance EG106
12) Dow UCAR FlightGuard AD-49**
13) Kilfrost ABC-S PLUS
14) LNT Solutions E450
15) Newave Aerochemical FCY 9311
16) Oksayd Defrost ECO 4
17) Oksayd Defrost EG 4 (new)
18) Shaanxi Cleanway Cleansurface IV

**REMOVED DILUTIONS

Annual Maintenance: RECALCULATION OF GENERIC HOTS

Type II

- Added: Kilfrost Ice Clear II
- Added: Oksayd Defrost PG 2
- Removed: Kilfrost ABC-Ice Clear II

Type IV

- Added: Oksayd Defrost EG 4
- Removed: ABAX ECOWING AD-49 and Dow UCAR FlightGuard AD-49 72/25 and 50/50 dilutions

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CHANGES TO TYPE II GENERIC HOTS

Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	0:55 1:50	0:25 - 0:50	0:30 1:00	0:20 0:35	0:08 0:45	
	75/25	0:25 - 0:55	0:15 - 0:25	0:15 - 0:40	0:10 - 0:20	0:04 - 0:25	
	50/50	0:15 - 0:25	0:05 - 0:10	0:08 - 0:15	0:06 - 0:09		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:30 - 1:05	0:20 - 0:35	0:20 - 0:45	0:15 - 0:20		
	75/25	0:25 - 0:50	0:10 - 0:20	0:15 - 0:25	0:08 - 0:15		
below -8 to -14 °C (below 18 to 7 °F)	100/0	0:30 - 1:05	0:15 - 0:30	0:20 - 0:45	0:15 - 0:20	CAUTION: No holdover time guidelines exist	
	75/25	0:25 - 0:50	0:08 - 0:20	0:15 - 0:25	0:08 - 0:15		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:15 - 0:35	0:06 - 0:20				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:15 - 0:35	0:02 - 0:09				
below -25 °C to LOUT (below -13 °F to LOUT)	100/0	0:15 - 0:35	0:01 - 0:06				

DRAFT

1. Kilfrost Ice Clear II: 1x5min ↓
2. Oksayd Defrost PG 2: 2x5min ↓
3. Kilfrost ABC-Ice Clear II: 1x1min ↑, 1x5 min ↑

Note: Blue shaded cells have new HOTs populated from below -3 to -8°C analysis

CHANGES TO TYPE IV GENERIC HOTS

Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	1:15 - 2:40	2:20 - 2:45	1:10 - 2:20	0:35 - 1:10	0:40 - 1:30	0:25 - 0:40	0:08 - 1:10	
	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	1:50 - 2:20	0:55 - 1:50	0:30 - 0:55	0:25 - 1:20	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 - 1:20	0:20 - 0:25	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	0:15 - 0:25		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:20 - 0:40	0:40 - 0:50	0:20 - 0:40	0:06 - 0:20				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:20 - 0:40	0:20 - 0:25	0:09 - 0:20	0:02 - 0:09				
below -25 °C to LOUT (below -13 °F to LOUT)	100/0	0:20 - 0:40	0:20 - 0:25	0:06 - 0:20	0:01 - 0:06				

DRAFT

1. ABAX ECOWING / Dow FlightGuard AD-49: 4x5min ↑, 2x10min ↑, 2x20min ↑, 1x25min ↑
2. Oksayd Defrost EG 4: no impact

Note: Blue shaded cells have new HOTs populated from below -3 to -8°C analysis

Annual Maintenance: LOUT DEFINITION + ROUNDING

- Harmonization of LOUT definition with SAE standards
  - **Removed from LOUT definition** (list of fluids and fluid application tables): "For diluted Type II/III/IV fluids, the coldest temperature for which holdover times are published."
- Rounding LOUTs
  - LOUTs are now being rounded to the nearest half degree Celsius and to the nearest whole degree Fahrenheit. Changes have been made to LOUTs in fluid specific tables and in the list of fluids.
  - **Added to LOUT definition** (list of fluids and fluid application tables): "Note: LOUTs are rounded to the nearest half degree Celsius and the values in degrees Fahrenheit are converted to the nearest whole degree."

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Annual Maintenance: FREEZING DRIZZLE INTENSITY

- Clarification of HOT tables freezing drizzle intensity
  - Added intensity designator to note 5 (Type I/III) and note 4 (Type II/IV) in HOT tables.
  - From: *Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.*
  - To: *Includes light, moderate and heavy freezing drizzle. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.*

Annual Maintenance: CHANGES TO TP14052

- Changes to TP14052 (Appendix B) is being removed from HOT Guidelines
  - A 3rd Edition of the Guidelines for Aircraft Ground Icing Operations (TP14052E) will be published in 2018. The section "Changes to Guidelines for Aircraft Ground Icing Operations" will be incorporated into the new edition and removed from the HOT Guidelines.
- Applies to Transport Canada only

Changes resulting from…

SUPPLEMENTAL TESTING IN HEAVY SNOW

SUPPLEMENTAL TESTING IN HEAVY SNOW: HUPRS

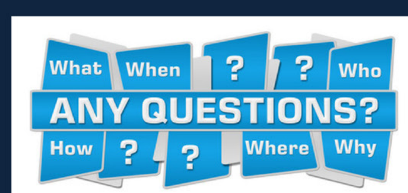
- Changes to the **HOT Guidelines** documents presented on previous slides will also be incorporated into the **Regression Information** documents
- One additional change will be made to the **Regression Information** documents (HOT Guidelines not affected)…
  - Highest usable precipitation rates (HUPRs) for two fluids will increase as a result of supplemental data collected in heavy snow
    - Clariant Safewing MP II FLIGHT: 100/0
    - Clariant Safewing MP II FLIGHT: 75/25

SUPPLEMENTAL TESTING IN HEAVY SNOW: HUPRS

TABLE 6: HIGHEST USABLE PRECIPITATION RATES IN SNOW[1]

TYPE II, TYPE III AND TYPE IV FLUIDS[2]

Type II De/Anti-Icing Fluids				
FLUID DILUTION	100/0		75/25	50/50
TEMPERATURE	*-14°C AND ABOVE*	*BELOW -14°C*	*-14°C AND ABOVE*	*-3°C AND ABOVE*
ABAX ECOWING 26	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	50 g/dm²/h
ABAX ECOWING AD-2	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	50 g/dm²/h
Aviation Shaanxi Hi-Tech Cleanwing II	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	50 g/dm²/h
Beijing Yadilite Aviation YD-102 Type II	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	50 g/dm²/h
Clariant Safewing MP II FLIGHT	~~40~~50 g/dm²/h	25 g/dm²/h	~~40~~50 g/dm²/h	40 g/dm²/h
Clariant Safewing MP II FLIGHT PLUS	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	40 g/dm²/h
Cryotech Polar Guard® II	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	50 g/dm²/h
Kilfrost ABC-Ice Clear II	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	50 g/dm²/h
Kilfrost ABC-K Plus	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	25 g/dm²/h
Newave Aerochemical FCY-2	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	50 g/dm²/h
Newave Aerochemical FCY-2 Bio+	50 g/dm²/h	25 g/dm²/h	50 g/dm²/h	50 g/dm²/h



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SAE G-12 HOLDOVER TIME COMMITTEE, AUSTIN, USA, MAY 2018

PRESENTATION:
SNOW ALLOWANCE TIMES

Background

- **Industry has requested we re-visit how fluid protection times are developed**
- Proposal:
  - Use primarily aerodynamic data to evaluate fluid protection times
  - Use visual failure indicators as a secondary, but not limiting, evaluation factor
- The underlying premise:
  - There is a useable delta between time at **visual failure time** vs the **aerodynamic limit**
  - This is anecdotally referred to as the "**conservative buffer**"

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Snow Allowance Time Concept

- Apply Ice Pellet Allowance time methodology to Snow Conditions
  - Determine aerodynamic limit using clean fluid and the aerodynamic acceptance limit
  - Test fluid + contamination and compare performance against the aerodynamic limit (pass/fail)
  - Repeat tests modifying contamination exposure times to determine what margins exist
  - Determine snow allowance times based on tests that pass

Note: "Lift-Loss Scaling" technique developed by NASA/APS/NRC could be applied to overcome temperature limitations, or if generic approach is preferred.

APS

Potential Guidance Format

Regulator's Holdover Time Guidelines — **Winter 20XX-20XX**

TABLE XX: SNOW ALLOWANCE TIMES FOR ICY COLD COMPANY FROSTY EG[1]

Precipitation Type	Outside Air Temperature				
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -25°C	Below -25°C
Very Light Snow	xx minutes	xx minutes	xx minutes	xx minutes	Caution: No allowance times currently exist
Light Snow	xx minutes	xx minutes	xx minutes	xx minutes	
Moderate Snow	80 minutes	60 minutes	40 minutes	20 minutes	
Heavy Snow	xx minutes	xx minutes	xx minutes	xx minutes	

NOTES
1 These allowance times are for use with undiluted (100/0) fluids applied on aircraft with rotation speeds of 100 knots or greater.

CAUTIONS
- The responsibility for the application of these data remains with the user.
- Fluids used during ground de/anti-icing do not provide in-flight icing protection.
- Allowance time cannot be extended by an inspection of the aircraft critical surfaces.
- Takeoff is allowed up to 90 minutes after start of fluid application if the precipitation stops at or before the allowance time expires and does not restart.

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Change in Operating Procedures

- Snow allowance times are developed differently than HOTs
- A change in operating procedures for snow conditions would need to be considered
  - HOTs provide a range of HOT's that can be extended using a PTCI or PTCC
  - Allowance times are single values that cannot be extended

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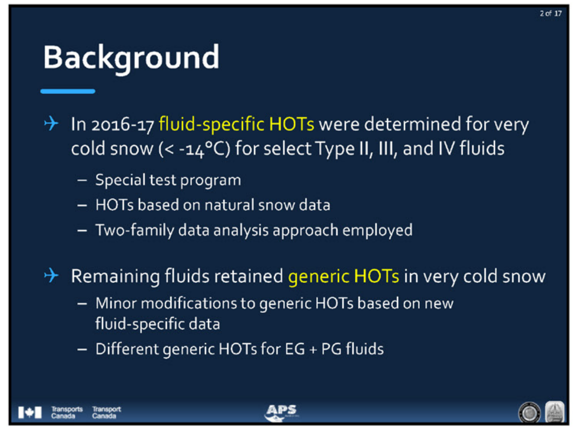
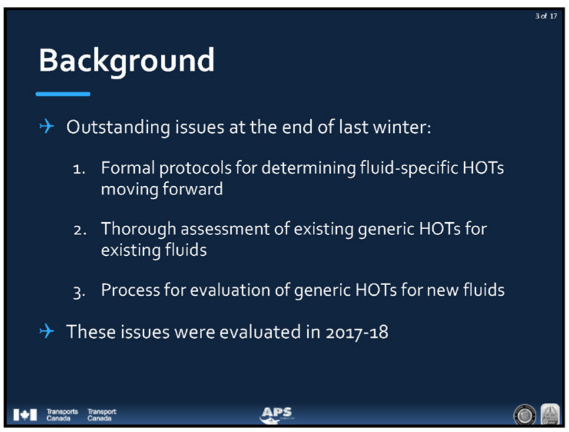
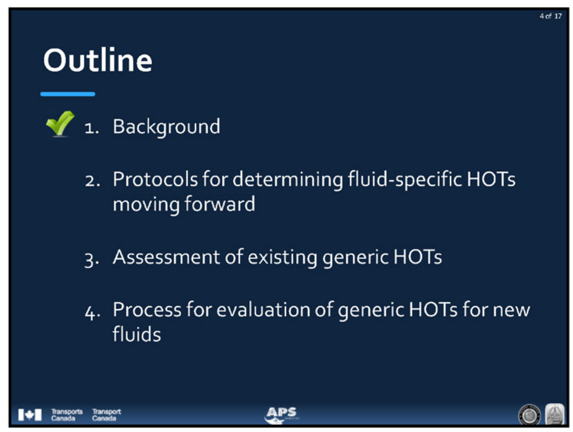
SAE G-12 HOLDOVER TIME COMMITTEE, AUSTIN, USA, MAY 2018

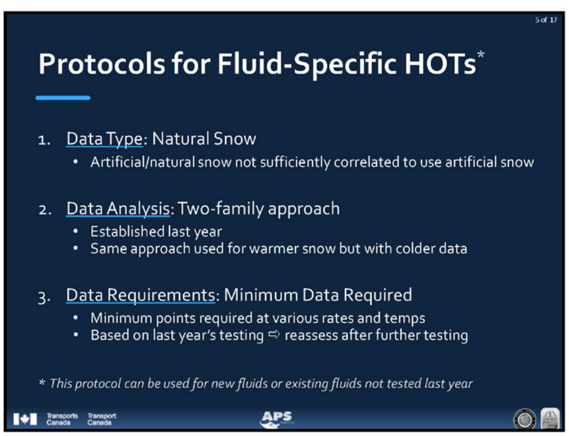
PRESENTATION:
UPDATE: HOTS FOR VERY COLD SNOW

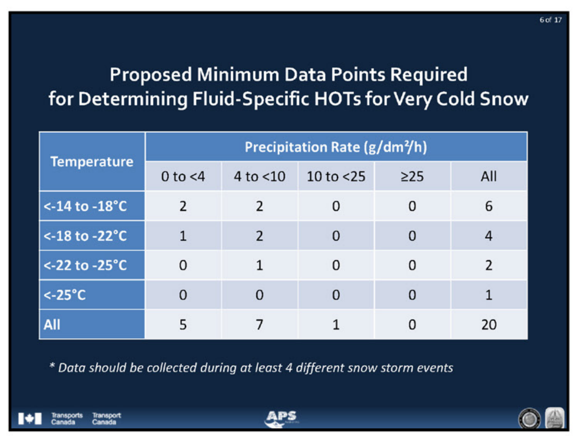

Joint research led by:
Transport Canada
Transports Canada
Conducted by:
APS
Aviation Inc.
UPDATE:
HOTS FOR VERY COLD SNOW
SAE G-12 Holdover Time Committee, Austin, Texas, May 23, 2018
Presented By: Stephanie Bendickson, Senior Project Leader


2 of 17
Background
In 2016-17 fluid-specific HOTs were determined for very cold snow (< -14°C) for select Type II, III, and IV fluids
– Special test program
– HOTs based on natural snow data
– Two-family data analysis approach employed
Remaining fluids retained generic HOTs in very cold snow
– Minor modifications to generic HOTs based on new fluid-specific data
– Different generic HOTs for EG + PG fluids


3 of 17
Background
Outstanding issues at the end of last winter:
1. Formal protocols for determining fluid-specific HOTs moving forward
2. Thorough assessment of existing generic HOTs for existing fluids
3. Process for evaluation of generic HOTs for new fluids
These issues were evaluated in 2017-18

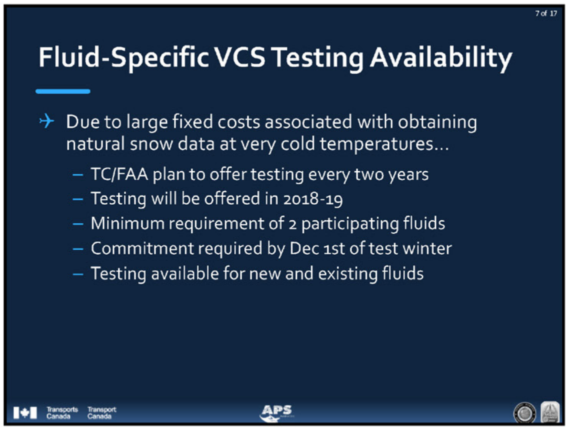

4 of 17
Outline
1. Background
2. Protocols for determining fluid-specific HOTs moving forward
3. Assessment of existing generic HOTs
4. Process for evaluation of generic HOTs for new fluids


5 of 17
Protocols for Fluid-Specific HOTs*
1. Data Type: Natural Snow
• Artificial/natural snow not sufficiently correlated to use artificial snow
2. Data Analysis: Two-family approach
• Established last year
• Same approach used for warmer snow but with colder data
3. Data Requirements: Minimum Data Required
• Minimum points required at various rates and temps
• Based on last year's testing ⇨ reassess after further testing
* This protocol can be used for new fluids or existing fluids not tested last year


6 of 17
Proposed Minimum Data Points Required
for Determining Fluid-Specific HOTs for Very Cold Snow

Temperature	Precipitation Rate (g/dm²/h)				
	0 to <4	4 to <10	10 to <25	≥25	All
<-14 to -18°C	2	2	0	0	6
<-18 to -22°C	1	2	0	0	4
<-22 to -25°C	0	1	0	0	2
<-25°C	0	0	0	0	1
All	5	7	1	0	20

* Data should be collected during at least 4 different snow storm events


7 of 17
Fluid-Specific VCS Testing Availability
Due to large fixed costs associated with obtaining natural snow data at very cold temperatures…
– TC/FAA plan to offer testing every two years
– Testing will be offered in 2018-19
– Minimum requirement of 2 participating fluids
– Commitment required by Dec 1st of test winter
– Testing available for new and existing fluids
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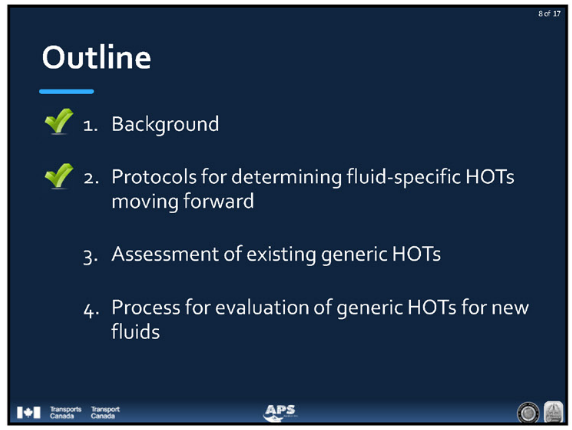
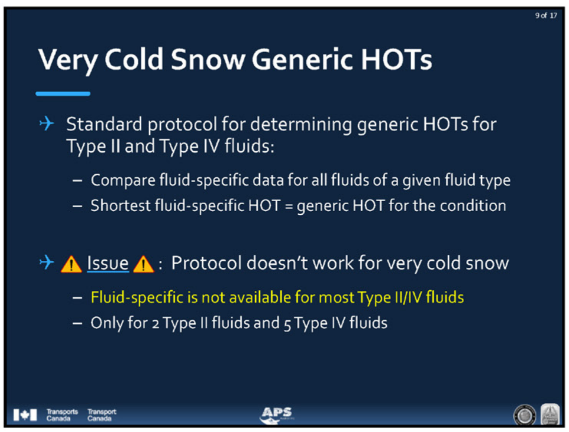

8 of 17
Outline
1. Background
2. Protocols for determining fluid-specific HOTs moving forward
3. Assessment of existing generic HOTs
4. Process for evaluation of generic HOTs for new fluids
APS


9 of 17
Very Cold Snow Generic HOTs
Standard protocol for determining generic HOTs for Type II and Type IV fluids:
– Compare fluid-specific data for all fluids of a given fluid type
– Shortest fluid-specific HOT = generic HOT for the condition
Issue : Protocol doesn't work for very cold snow
– Fluid-specific is not available for most Type II/IV fluids
– Only for 2 Type II fluids and 5 Type IV fluids
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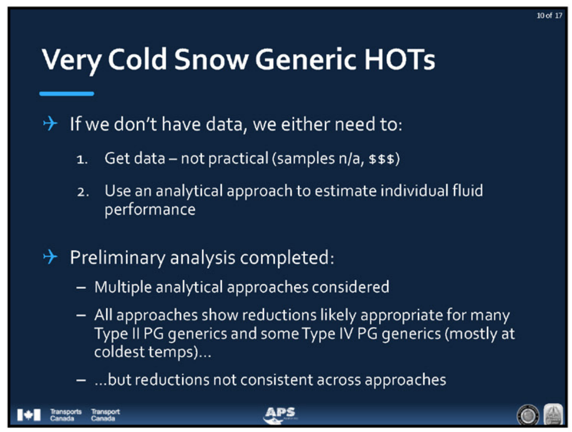
10 of 17
Very Cold Snow Generic HOTs
If we don't have data, we either need to:
1. Get data – not practical (samples n/a, $$$)
2. Use an analytical approach to estimate individual fluid performance
Preliminary analysis completed:
– Multiple analytical approaches considered
– All approaches show reductions likely appropriate for many Type II PG generics and some Type IV PG generics (mostly at coldest temps)…
– …but reductions not consistent across approaches
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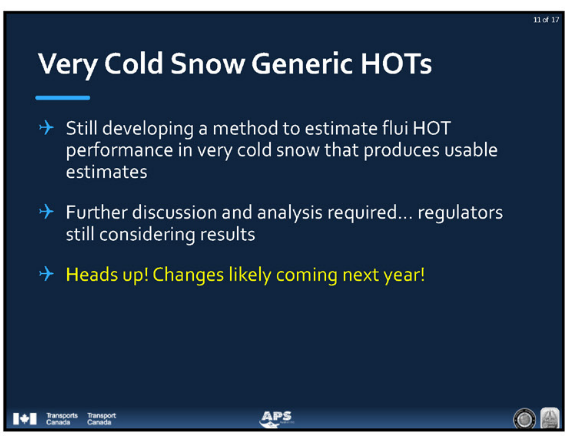
11 of 17
Very Cold Snow Generic HOTs
Still developing a method to estimate flui HOT performance in very cold snow that produces usable estimates
Further discussion and analysis required… regulators still considering results
Heads up! Changes likely coming next year!
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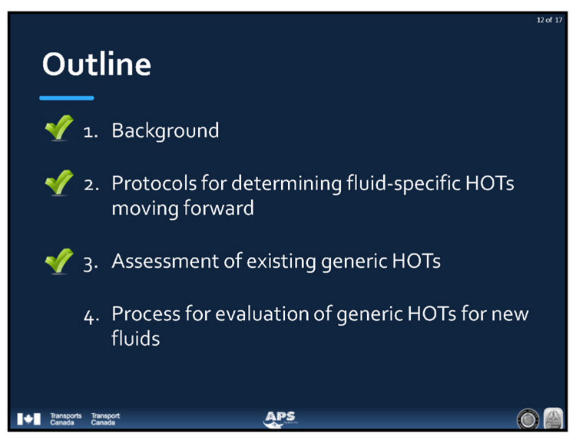
12 of 17
Outline
1. Background
2. Protocols for determining fluid-specific HOTs moving forward
3. Assessment of existing generic HOTs
4. Process for evaluation of generic HOTs for new fluids
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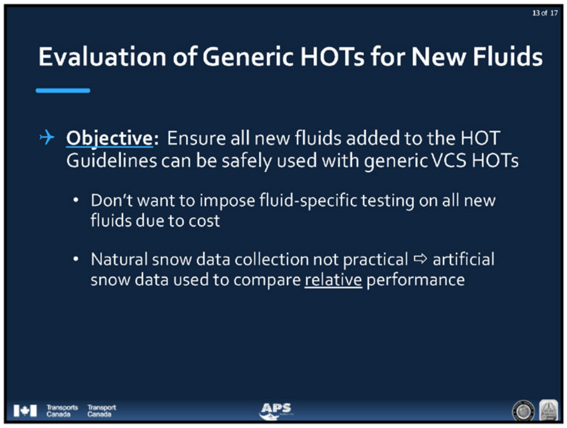
13 of 17
Evaluation of Generic HOTs for New Fluids
Objective: Ensure all new fluids added to the HOT Guidelines can be safely used with generic VCS HOTs
• Don't want to impose fluid-specific testing on all new fluids due to cost
• Natural snow data collection not practical ⇨ artificial snow data used to compare relative performance
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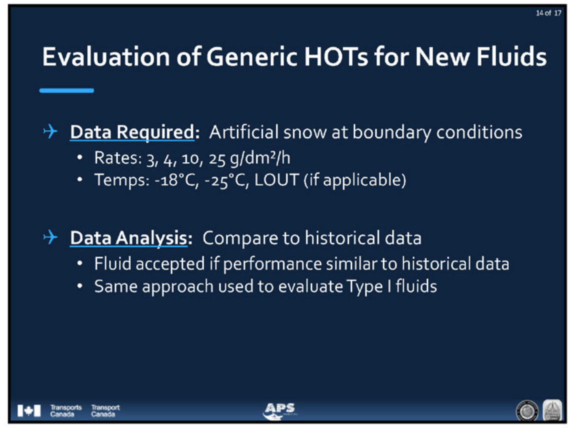
14 of 17
Evaluation of Generic HOTs for New Fluids
Data Required: Artificial snow at boundary conditions
• Rates: 3, 4, 10, 25 g/dm²/h
• Temps: -18°C, -25°C, LOUT (if applicable)
Data Analysis: Compare to historical data
• Fluid accepted if performance similar to historical data
• Same approach used to evaluate Type I fluids
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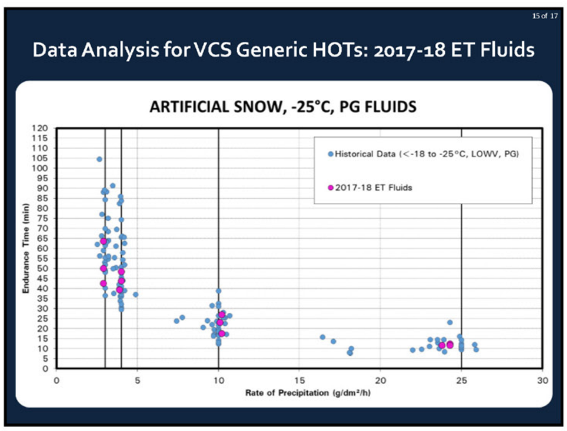
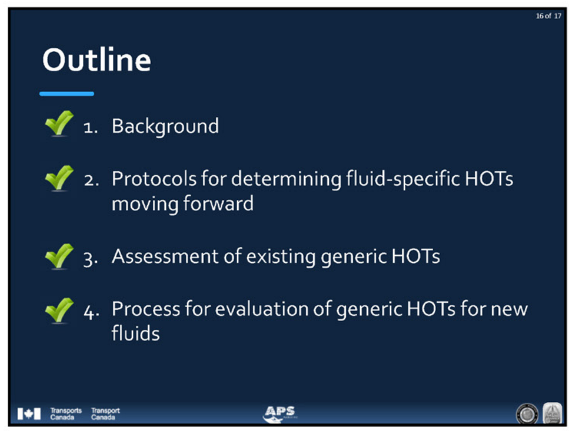

15 of 17
Data Analysis for VCS Generic HOTs: 2017-18 ET Fluids
ARTIFICIAL SNOW, -25°C, PG FLUIDS
Historical Data (<-18 to -25°C, LOWV, PG)
2017-18 ET Fluids
Endurance Time (min)
Rate of Precipitation (g/dm²/h)


16 of 17
Outline
1. Background
2. Protocols for determining fluid-specific HOTs moving forward
3. Assessment of existing generic HOTs
4. Process for evaluation of generic HOTs for new fluids
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SAE G-12 HOLDOVER TIME COMMITTEE, AUSTIN, USA, MAY 2018

PRESENTATION:
EVALUATION OF FLUID EFFECTIVENESS AND CHARACTERIZATION OF CONTAMINATION ON HIGH ANGLE SURFACES: VERTICAL STABILIZER

Joint research led by:
Transports Canada Transport Canada

Conducted by:
APS Aviation Inc.

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

Outline

1. Background
2. Overview of 1st Phase of Research
   - Survey: Condition of the Tail Prior to Deicing
   - Photo Documentation of the Tail Prior to Deicing
   - Construction of a Piper Seneca II Tail Section for Testing
   - Pre-Deicing and Post-Deicing Testing Using the Piper Seneca II Section and Flat Plates
3. Summary and Way Forward

Outline

1. Background
2. Overview of 1st Phase of Research
   - Survey: Condition of the Tail Prior to Deicing
   - Photo Documentation of the Tail Prior to Deicing
   - Construction of a Piper Seneca II Tail Section for Testing
   - Pre-Deicing and Post-Deicing Testing Using the Piper Seneca II Section and Flat Plates
3. Summary and Way Forward

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

* vertical stabilizer = tail = v-stab= vertical tail

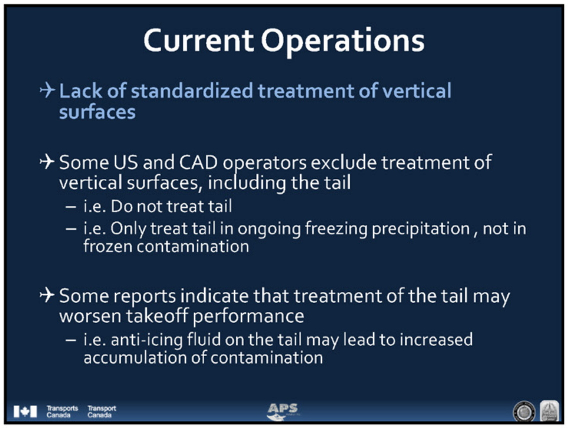
Regulatory Context Cont'd

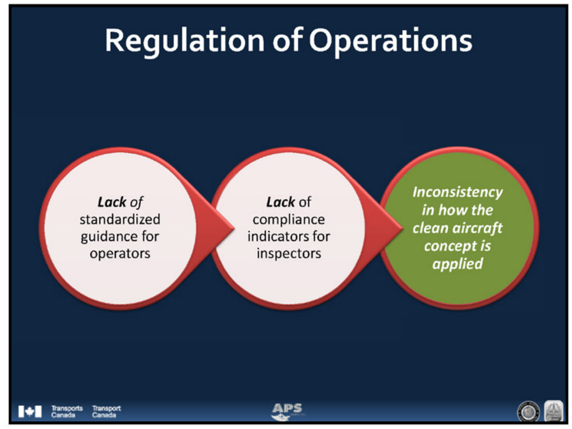
FAR 121.629(b)
No person may takeoff an aircraft when frost, ice, or snow is adhering to the wings, control surfaces, propellers, engine inlets, or other critical surfaces of the aircraft or when the takeoff would not be in compliance with paragraph (c) of this section. Takeoffs with frost under the wing in the area of the fuel tanks may be authorized by the Administrator.

CARs 602.11[1]
602.11 [1] In this section, "critical surfaces" means the wings, control surfaces, rotors, propellers, horizontal stabilizers, vertical stabilizers or any other stabilizing surface of an aircraft and, in the case of an aircraft that has rear-mounted engines, includes the upper surface of its fuselage.

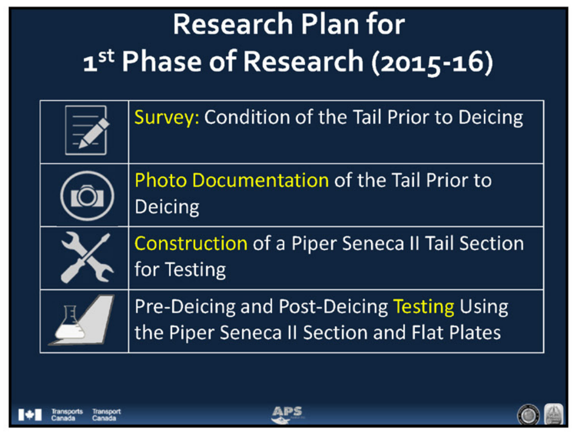
OEM Context

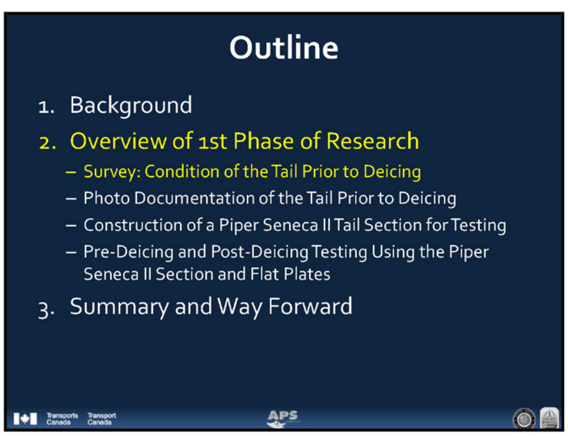
- Type certification is done considering **clean aircraft concept for ground icing**
- OEMs do not support a revision to operating rules permitting takeoff with frozen contamination adhering to the tail
  - Stated in a documents issued through SAE AWG
  - Airbus, Boeing, Cessna, Embraer, and SAAB
- OEMs position would only be reconsidered if:
  - Operational data indicates an adequate level of safety
  - Data is to the satisfaction of the regulatory agencies


Current Operations
Lack of standardized treatment of vertical surfaces
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
Some reports indicate that treatment of the tail may worsen takeoff performance
– i.e. anti-icing fluid on the tail may lead to increased accumulation of contamination
APS


Regulation of Operations
Lack of standardized guidance for operators
Lack of compliance indicators for inspectors
Inconsistency in how the clean aircraft concept is applied
APS


Research Program
FAA, TC, and NASA identified research objectives:
a) Pre-deicing study of contamination on on the tail
b) Post-deicing study of contamination on on the tail
c) Evaluate optimal deicing procedures and mitigation plans
The research objectives were intended to span over two research years or more. Limited research into a) and b) were attempted in 2015-16.
APS


Research Plan for 1st Phase of Research (2015-16)
Survey: Condition of the Tail Prior to Deicing
Photo Documentation of the Tail Prior to Deicing
Construction of a Piper Seneca II Tail Section for Testing
Pre-Deicing and Post-Deicing Testing Using the Piper Seneca II Section and Flat Plates
APS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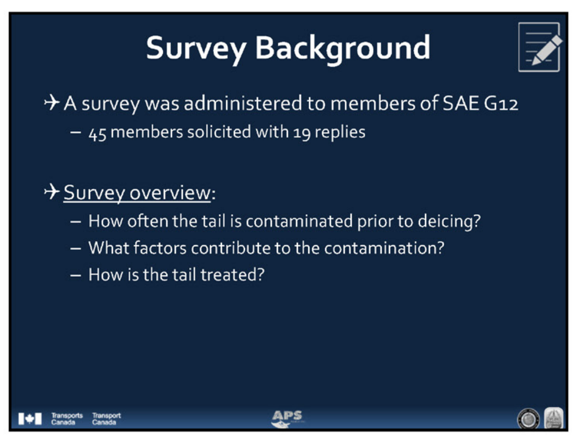
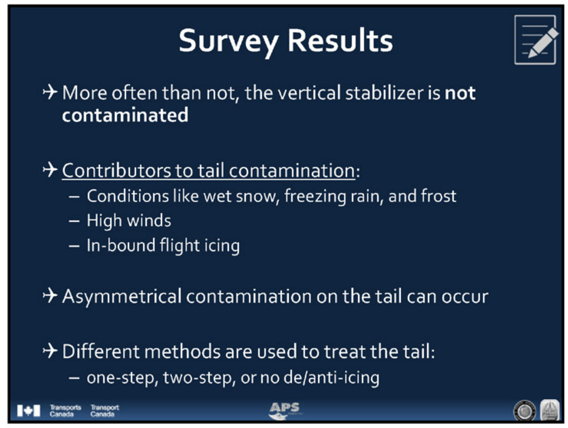
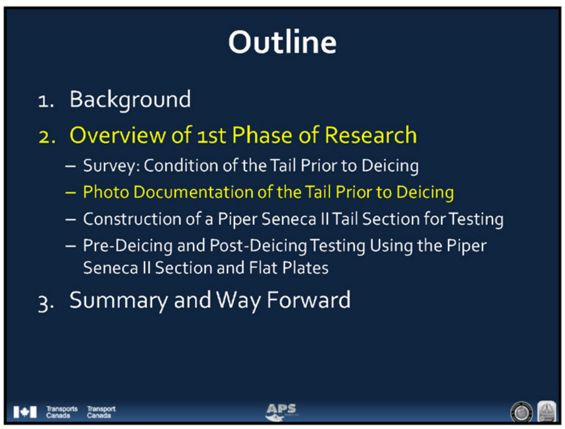

Survey Background
A survey was administered to members of SAE G12
– 45 members solicited with 19 replies
Survey overview:
– How often the tail is contaminated prior to deicing?
– What factors contribute to the contamination?
– How is the tail treated?
APS


Online Survey Snapshot
Survey conducted by:
APS
On behalf of:
Survey: Condition of Vertical Stabilizer Prior to Deicing
Introduction
This survey is being conducted by APS Aviation Inc. on behalf of Transport Canada and the Federal Aviation Administration. The results of this survey will be used to support and direct ground icing research into the subject of ground icing on aircraft vertical surfaces.
The purpose of this survey is to determine if contamination is present on the aircraft vertical stabilizer (including the rudder) prior to deicing, and if so, to characterize the conditions and the level of contamination present.
Please answer all questions. Note: You will only be allowed to complete the survey once.
Continue to the Survey
SurveyMonkey
APS


Survey Results
More often than not, the vertical stabilizer is not contaminated
Contributors to tail contamination:
– Conditions like wet snow, freezing rain, and frost
– High winds
– In-bound flight icing
Asymmetrical contamination on the tail can occur
Different methods are used to treat the tail:
– one-step, two-step, or no de/anti-icing
APS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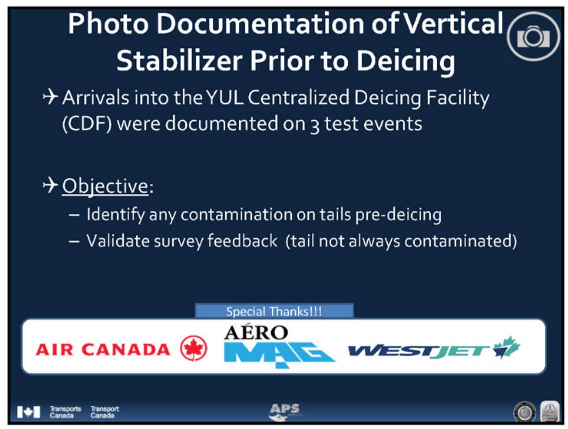
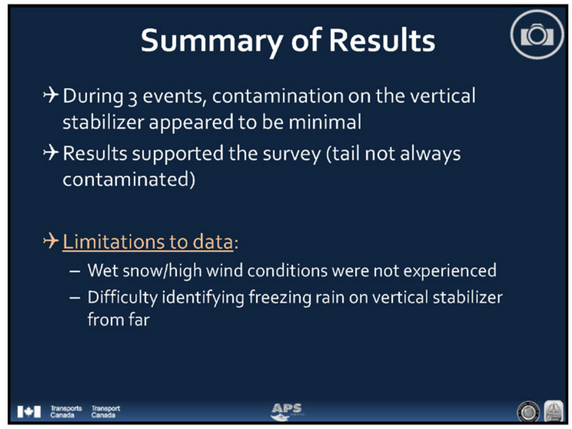


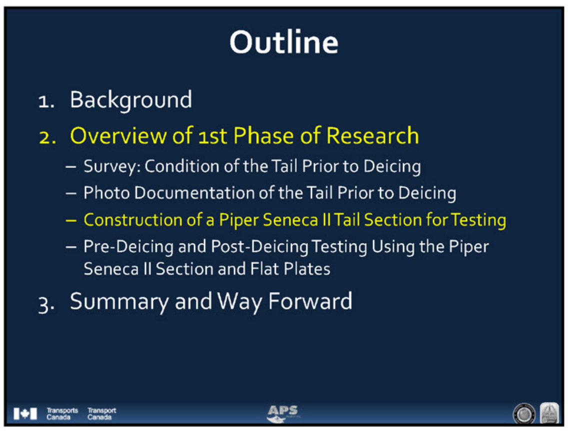
Photo Documentation of Vertical Stabilizer Prior to Deicing
Arrivals into the YUL Centralized Deicing Facility (CDF) were documented on 3 test events
Objective:
– Identify any contamination on tails pre-deicing
– Validate survey feedback (tail not always contaminated)
Special Thanks!!!
AIR CANADA
AÉRO MAG
WESTJET
APS


January 12, 2016 from 1pm to 4pm
Weather Conditions: Outside Ambient Temperature (OAT) was -5°C, winds about 15 knots, with light dry snow with periods of blowing snow.
C-GWBJ
View of Aeromag Parking Lot
APS


February 2, 2016 from 7am to 10am
Weather Conditions: OAT was -3°C at 7AM and went to 0 °C at 9AM, winds about 20+km, snow overnight turned into ice pellets at 7AM, then into freezing rain around 8AM, and then rain by 9AM.
View of Aeromag Parking Lot
APS


February 16, 2016 from 7am to 10:30am
Weather Conditions: OAT was -7ºC at 7AM and warmed to -6 ºC at 10AM, winds about 20+km winds, snow overnight turned into ice pellets and freezing rain at 10AM.
View of Aeromag Parking Lot


Summary of Results
During 3 events, contamination on the vertical stabilizer appeared to be minimal
Results supported the survey (tail not always contaminated)
Limitations to data:
– Wet snow/high wind conditions were not experienced
– Difficulty identifying freezing rain on vertical stabilizer from far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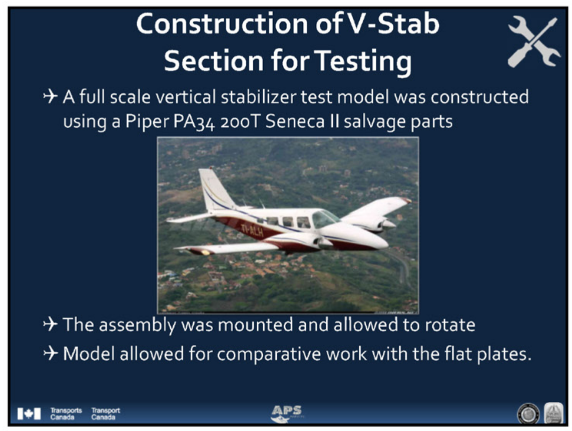
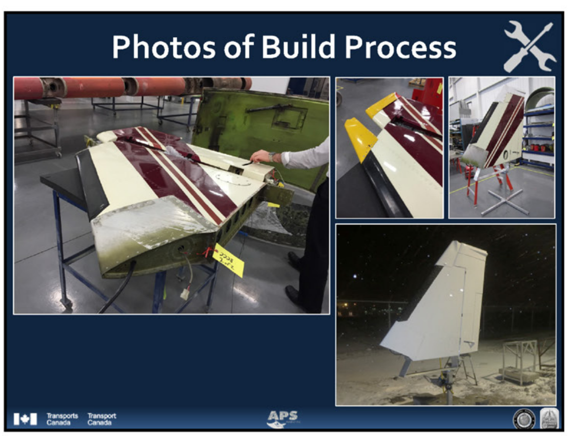
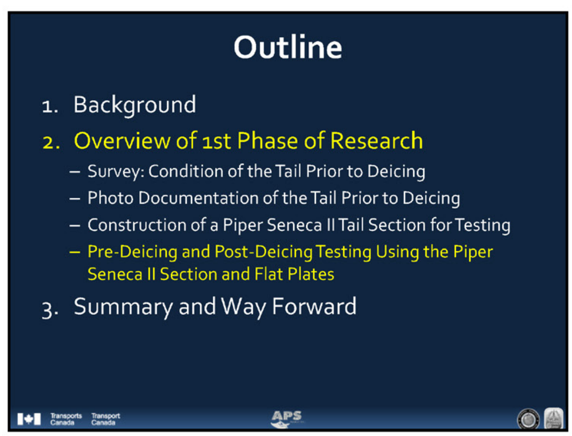

Construction of V-Stab Section for Testing
A full scale vertical stabilizer test model was constructed using a Piper PA34 200T Seneca II salvage parts
The assembly was mounted and allowed to rotate
Model allowed for comparative work with the flat plates.


Photos of Build Process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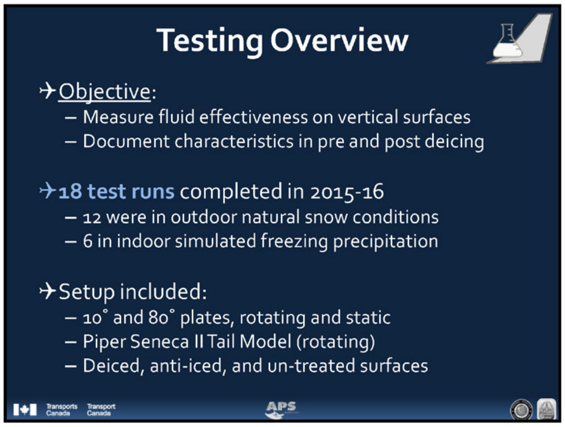
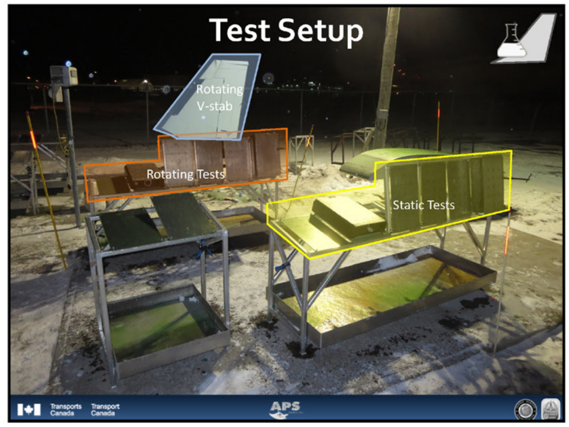
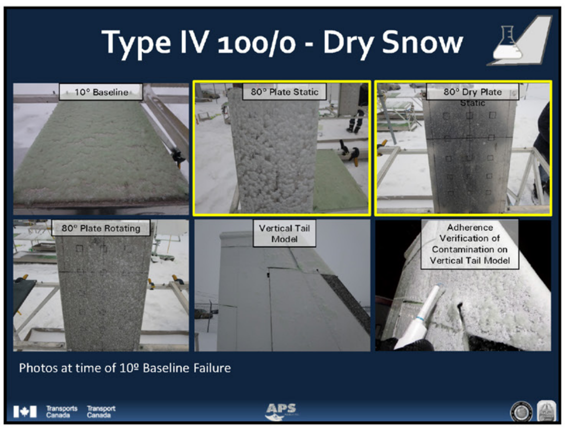
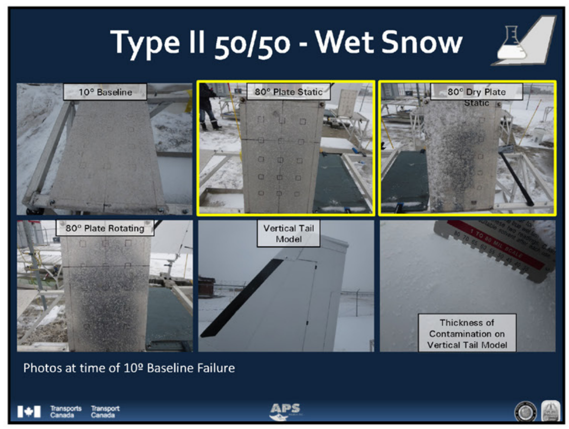
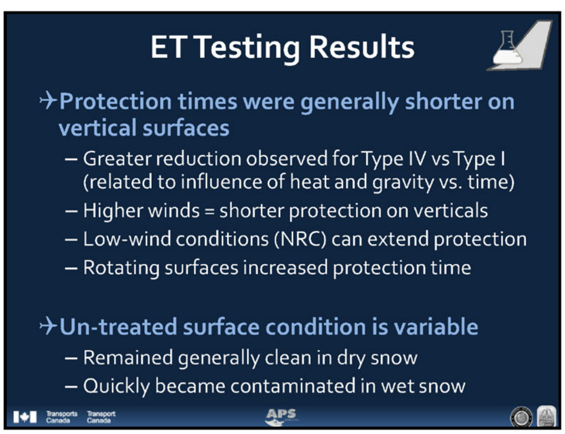
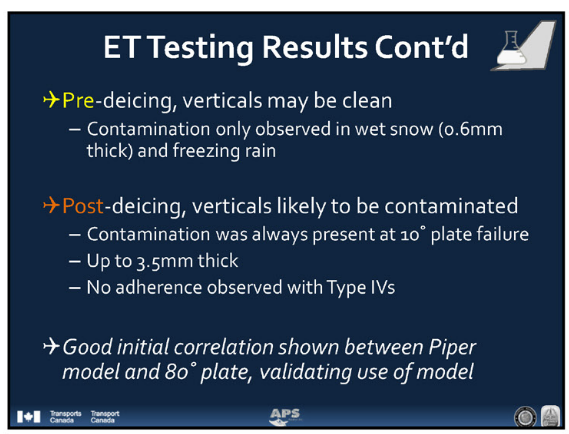

Testing Overview
Objective:
– Measure fluid effectiveness on vertical surfaces
– Document characteristics in pre and post deicing
18 test runs completed in 2015-16
– 12 were in outdoor natural snow conditions
– 6 in indoor simulated freezing precipitation
Setup included:
– 10˚ and 80˚ plates, rotating and static
– Piper Seneca II Tail Model (rotating)
– Deiced, anti-iced, and un-treated surfaces

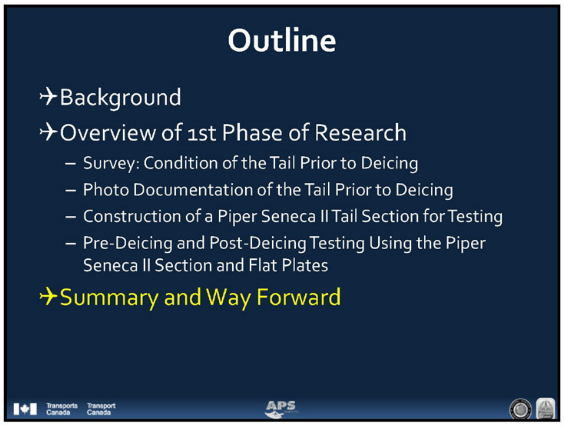

Test Setup
Rotating V-stab
Rotating Tests
Static Tests


Type IV 100/0 - Dry Snow
10° Baseline
80° Plate Static
80° Dry Plate Static
80° Plate Rotating
Vertical Tail Model
Adherence Verification of Contamination on Vertical Tail Model
Photos at time of 10º Baseline Failure


Type II 50/50 - Wet Snow
10° Baseline
80° Plate Static
80° Dry Plate Static
80° Plate Rotating
Vertical Tail Model
Thickness of Contamination on Vertical Tail Model
Photos at time of 10º Baseline Failure


ET Testing Results
Protection times were generally shorter on vertical surfaces
– Greater reduction observed for Type IV vs Type I (related to influence of heat and gravity vs. time)
– Higher winds = shorter protection on verticals
– Low-wind conditions (NRC) can extend protection
– Rotating surfaces increased protection time
Un-treated surface condition is variable
– Remained generally clean in dry snow
– Quickly became contaminated in wet snow


ET Testing Results Cont'd
Pre-deicing, verticals may be clean
– Contamination only observed in wet snow (0.6mm thick) and freezing rain
Post-deicing, verticals likely to be contaminated
– Contamination was always present at 10˚ plate failure
– Up to 3.5mm thick
– No adherence observed with Type IVs
Good initial correlation shown between Piper model and 80˚ plate, validating use of model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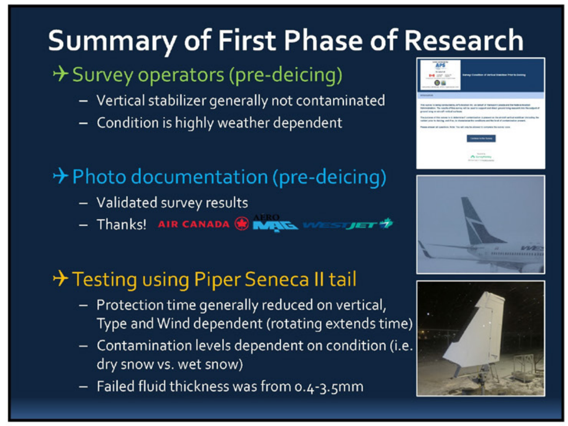
Summary of First Phase of Research
Survey operators (pre-deicing)
– Vertical stabilizer generally not contaminated
– Condition is highly weather dependent
Photo documentation (pre-deicing)
– Validated survey results
– Thanks! AIR CANADA
Testing using Piper Seneca II tail
– Protection time generally reduced on vertical, Type and Wind dependent (rotating extends time)
– Contamination levels dependent on condition (i.e. dry snow vs. wet snow)
– Failed fluid thickness was from 0.4-3.5mm


Way Forward
Continue research plan with focus on quantifying contamination and effects
Identify and evaluate optimal deicing procedures and mitigation plans
Maintain open discussion with OEMs and Operators to ensure operational relevance of research targets


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APS
Marco Ruggi
mruggi@apsaviation.ca

SAE G-12 FLUIDS COMMITTEE, AUSTIN, USA, MAY 2018

PRESENTATION:
AIR6232: AIRCRAFT AFTER MARKET COATINGS

OUTLINE

1. Background
2. AIR 6232 Overview
3. Industry Feedback on AIR6232
4. Current Initiatives
5. Summary and Way Forward

Purpose: To maintain the relevance of SAE AIR6232

Coatings Research

- Interest in coatings to protect aircraft critical surfaces
  - Civil and Military Aviation (wings, engines, UAV's)
- Early research by APS for TC/FAA and **AA** **raised awareness**
  - Some coatings negatively impacted fluid HOT's
- Concerns spread to coatings in general
  - Coatings for fuel savings, appearance enhancement, etc.
- TC/FAA led a **multi-year plan** executed by APS :
  - Tested more than 20 different coatings
  - Raised awareness in the deicing industry
  - Led to the development of AIR 6232

GENERAL OBSERVATIONS

- **All coatings behave differently**
- **Coatings tested have limitations to their icing protection and prevention**
- **Coatings have varying aerodynamic effects**
- **Synergies exist between coatings and traditional deicing and anti-icing fluids for aircraft ground icing protection**
- **The technologies are evolving**

G-12 SAE Involvement

- Industry agreed to develop SAE AIR to evaluate coating impact on aircraft de/anti-icing fluids

November 2011: Working group was formed → Document sponsored by APS → August 2013: AIR 6232 was published

SAE INTERNATIONAL

AEROSPACE INFORMATION REPORT	AIR6232
	Issued 2013-08

Aircraft Surface Coating Interaction with Aircraft Deicing/Anti-Icing Fluids

RATIONALE

This SAE Aerospace Information Report (AIR) provides a description of screening methods for verifying whether aircraft surface coatings have adverse effects on aircraft deicing/anti-icing fluid performance as published in the holdover time guidelines. The surface coatings include thin film coatings, typically less than 1 mil (0.0254 mm) thick and sometimes called paint sealants or protectants, as well as bulk coatings that are typically greater than 2 mils (0.0508 mm) thick. Although recommended performance criteria have been outlined, ultimately, the interpretation of the test results outlined in this document will be left to the discretion of the aircraft operator.

Major Sections of AIR 6232

- Section 3: Fluid Endurance Time Testing
  - Evaluate effect of coated surfaces on de/anti-icing fluid protection time
- Section 4: Fluid Aerodynamic Testing
  - Evaluate coated surface effects on de/anti-icing fluid flow-off
- Section 5: Additional Information Test Methods
  - Catch-all section for relative test methods for characterizing the coating properties
  (e.g. Compatibility with airplane surfaces, durability, weathering, etc.)

Major Sections of AIR 6232

5. ADDITIONAL INFORMATIONAL TEST METHODS
   - 5.1 Aircraft Surface Coating Compatibility and Integrity Tests
   - 5.2 Aerodynamic Drag Evaluation Test
   - 5.3 Ice Adhesion Test
   - 5.4 Ice Accumulation
   - 5.5 Contact Angle, Contact Angle Hysteresis, and Roll-Off Angle
   - 5.6 Droplet Impact Resistance
   - 5.7 Frost Endurance Test
   - 5.8 Thermal Conductivity
   - 5.9 Testing Organizations
   - ...

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Industry Feedback to SAE AIR6232

- AIR6232 was well received and addressed the immediate industry need for guidance

Recent Feedback Received

- "Needs pass/fail criteria."
- "How much or little of the AIR 6232 do we test?"
- "Coating durability is a big concern"
- "Interaction with fluids is only a small piece of the larger aviation safety need"

- Feedback is indicating that an update to the document may be warranted

APS

Current Research Initiatives

- Two new initiatives are being proposed as part of the H2020 and CRIAQ research programs with relevance to AIR6232
  - Other programs as well?
- Initiatives may provide information that will eventually support, or replace the current AIR6232 document
- Key experts in different fields of aviation are participating to provide a broader scope to the research, with a **focus on applied sciences**

European Commission | Horizon 2020 European Union funding for Research & Innovation

CRIAQ

APS

Other Interest and Drivers

- TC and FAA
  - Indicated interest in future research planned in this area
  - Intends to remain involved and may support as required
- SAE G8 Aerospace Organic Coatings Committee
  - Topic presented in April 2018 meeting
  - Positive feedback and interest received
- SAE AC-9C Aircraft Icing Technology Committee
  - Topic presented in May 2018 meeting
  - Positive feedback and interest received

SAE INTERNATIONAL G8 Committee

SAE INTERNATIONAL AC-9C Committee

APS

Summary

- AIR6232 continues to be a relevant document for:
  - Addressing coating interaction with de/anti-icing fluids
  - Providing a repository for recognized coating evaluation test methods
- A future update to the document may be warranted

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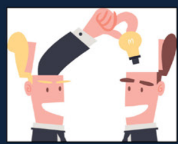
Way Forward

- Proposed research initiatives will be a good source of information for re-developing the AIR 6232 document
- Industry feedback during this process is welcome!



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APS
Aviation Inc.
Marco Ruggi
mruggi@apsaviation.ca

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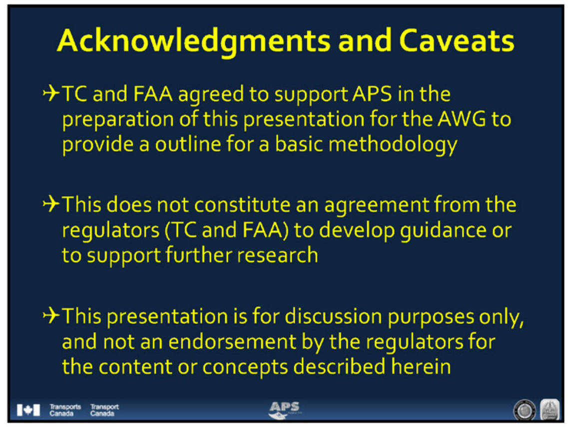
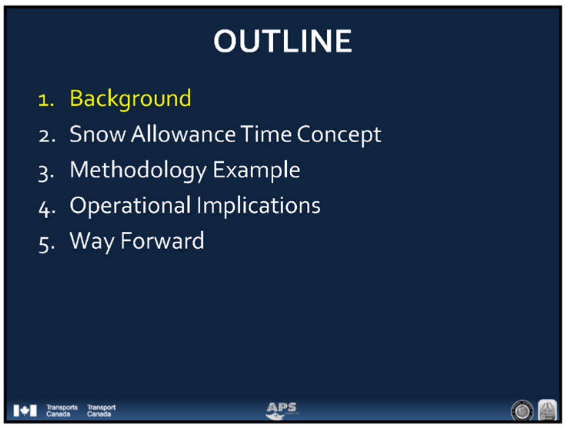
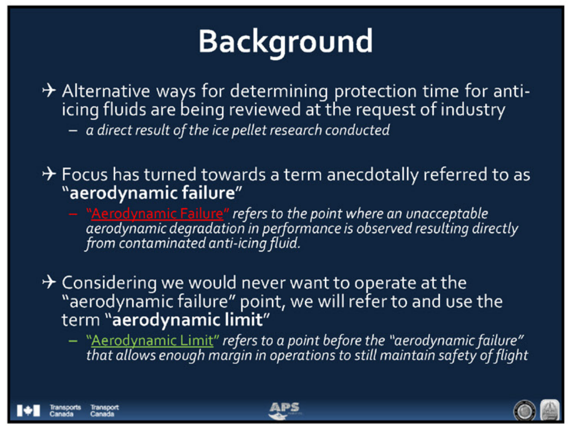
SAE G-12 AERODYNAMICS WORKING GROUP COMMITTEE, AUSTIN, USA, MAY 2018

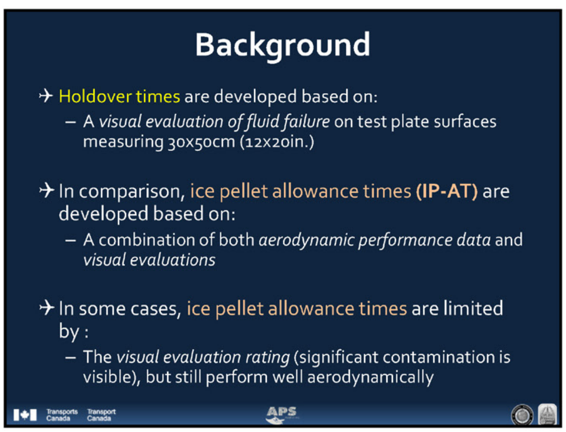
PRESENTATION:
SNOW ALLOWANCE TIMES

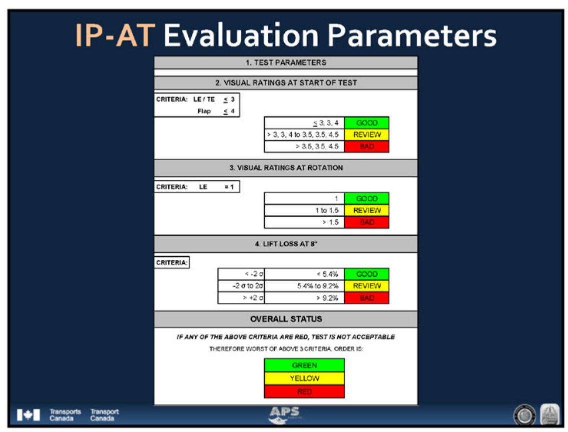

APS
Aviation Inc.
SNOW ALLOWANCE TIMES
SAE G12 Aerodynamics Working Group, Austin, May 22, 2018
Marco Ruggi, Eng., M.B.A., Senior Project Leader
RHEA
The views expressed here are those of APS Aviation Inc.,
and do not necessarily reflect those of TC, FAA, or any other organisation.


Acknowledgments and Caveats
TC and FAA agreed to support APS in the preparation of this presentation for the AWG to provide a outline for a basic methodology
This does not constitute an agreement from the regulators (TC and FAA) to develop guidance or to support further research
This presentation is for discussion purposes only, and not an endorsement by the regulators for the content or concepts described herein


OUTLINE
1. Background
2. Snow Allowance Time Concept
3. Methodology Example
4. Operational Implications
5. Way Forward


Background
Alternative ways for determining protection time for anti-icing fluids are being reviewed at the request of industry
– a direct result of the ice pellet research conducted
Focus has turned towards a term anecdotally referred to as "aerodynamic failure"
– "Aerodynamic Failure" refers to the point where an unacceptable aerodynamic degradation in performance is observed resulting directly from contaminated anti-icing fluid.
Considering we would never want to operate at the "aerodynamic failure" point, we will refer to and use the term "aerodynamic limit"
– "Aerodynamic Limit" refers to a point before the "aerodynamic failure" that allows enough margin in operations to still maintain safety of flight


Background
Holdover times are developed based on:
– A visual evaluation of fluid failure on test plate surfaces measuring 30x50cm (12x20in.)
In comparison, ice pellet allowance times (IP-AT) are developed based on:
– A combination of both aerodynamic performance data and visual evaluations
In some cases, ice pellet allowance times are limited by :
– The visual evaluation rating (significant contamination is visible), but still perform well aerodynamically


IP-AT Evaluation Parameters
1. TEST PARAMETERS
2. VISUAL RATINGS AT START OF TEST
CRITERIA: LE / TE ≤ 3
Flap ≤ 4
≤ 3, 3, 4 GOOD
> 3, 3, 4 to 3.5, 3.5, 4.5 REVIEW
> 3.5, 3.5, 4.5 BAD
3. VISUAL RATINGS AT ROTATION
CRITERIA: LE = 1
1 GOOD
1 to 1.5 REVIEW
> 1.5 BAD
4. LIFT LOSS AT 8°
CRITERIA:
< -2 σ < 5.4% GOOD
-2 σ to 2σ 5.4% to 9.2% REVIEW
> +2 σ > 9.2% BAD
OVERALL STATUS
IF ANY OF THE ABOVE CRITERIA ARE RED, TEST IS NOT ACCEPTABLE
THEREFORE WORST OF ABOVE 3 CRITERIA, ORDER IS:
GREEN
YELLOW
RED

Background

- Industry has requested we re-visit how fluid protection times are developed
- Proposal:
  - Use primarily aerodynamic data to evaluate fluid protection times
  - Use visual failure indicators as a secondary, but not limiting, evaluation factor
- The underlying premise:
  - There is a useable delta between time at visual failure time vs the aerodynamic limit
  - This is anecdotally referred to as the "conservative buffer"

Previous Relevant Research

- PIWT Ice Pellet Research
  - 2009-10 to 2012-13
  - NASA/APS/NRC Lift-loss scaling technique
- PIWT Heavy Snow and Heavy Contamination Research
  - 2006-07 to 2017-18
  - Aerodynamic research showing impacts of contamination

Note: Data has been shared yearly at G12

Research Collaborators:

Data Points from Heavy Snow Research

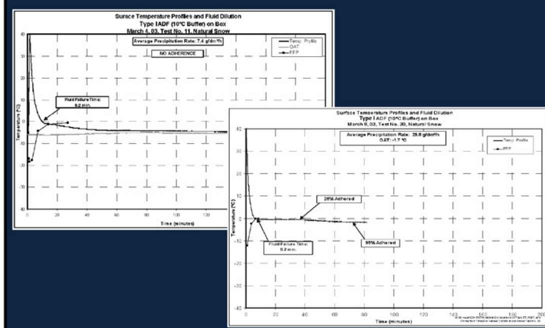
2009-10 and 2010-11

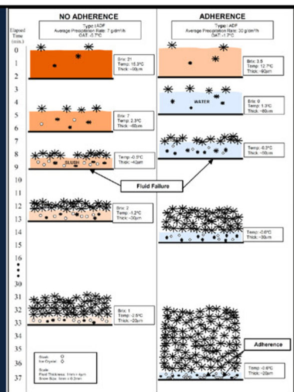
Test No.	Fluid	Condition	Precip. Rate (g/dm²/h)	Precip. Time (min.)	Moderate Snow HOT	Total LWE (g/dm²)	Tunnel Temp at Start of Test (°C)	Visual Cont. Rating Before Take off (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	% Lift Loss	Margin to Increase?
37	Type III	S	25	10	10	4	-0.9	2, 2, 3	1, 1, 1.5	4.72	Yes
38	Type III	S++	50	5	10	4	-2.5	1.7, 1.7, 3	1, 1, 2	4.84	Yes
39	Type III	S++	50	7.5	10	6	-2.9	3, 2.7, 3	1, 1.2, 1.5	5.13	Yes
40	Type III	S++	50	15	10	13	-3.1	4, 2, 4	1.5, 2.3, 3.8	7.40	Yes
83	Type IV EG- D	S	25	40	30	17	-4.2	2.4, 2.2, 4	1, 1.2, 1.3	1.64	Yes
84	Type IV EG- D	S++	50	30	30	25	-6.2	3, 2.3, 4	1, 1.7, 1.9	2.23	Yes
85	Type IV EG- D	S++	50	20	30	17	-6.8	2.6, 2.3, 4	1, 1.5, 1.9	1.41	Yes
86	Type IV PG-A	S	25	60	60	25	-8.5	3.7, 2.9, 4	1.5, 2.2, 3.5	12.16	No
87	Type IV PG-A	S++	50	30	60	25	-11.6	3.7, 2.9, 4	1.7, 2.2, 3.2	12.86	No
88	Type IV PG-A	S++	50	10	60	8	-12.6	2, 2, 2.8	1.5, 2, 2	8.56	Yes
90	Type IV PG-A	S++	50	10	60	8	-2.2	2.3, 2.2, 2.2	1.1, 1.5, 1.7	5.94	Yes
91	Type IV PG-A	S++	50	30	60	25	-3.8	2.8, 2.7, 3.7	1.5, 2.2, 2.7	8.44	Yes
92	Type IV PG-A	S	25	60	60	25	-4.7	2.5, 2.3, 3.8	1.5, 2, 2.7	8.38	Yes
108A	Type III	S	25	15	10	6	-11.5	3.5, 1.8, 4	1.25, 1.5, 2.25	6.40	Yes
109	Type III	S++	50	7.5	10	6	-11	3.25, 2.75, 3.75	1.1, 1.75, 2.35	6.47	Yes
110	Type III	S++	100	7.5	10	13	-10.3	3.5, 3, 4	1.1, 2.25, 2.5	8.09	Yes

Other Relevant Research

- Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces (TP14377E)
  - 2002-03 and 2003-04
  - Indicated that Type I can adhere in Snow conditions, but not Type II/IV

No Adherence vs. Adherence





OUTLINE

1. Background
2. Snow Allowance Time Concept
3. Methodology Example
4. Operational Implications
5. Way Forward

What we do know

Facts	What it means
All fluids are different	Need to test each specific fluids, or develop a generic test approach
Some conservative margins exist, and can be more or less depending on conditions	Increasing protection time is possible, but not constant across the board
Ice Pellet Allowance times are based on a combination of visual and aero data	A similar approach could be adopted for snow conditions
Clean fluids have an aerodynamic limit based on temperature (LOUT)	The aerodynamic limit can be applied to fluid + contamination

What we don't know

Unknown	What it means
What benefit actually exists if developing snow allowance times	Preliminary data indicates good for EG and ok for PG, but need testing
How aircraft performance degrades beyond the aerodynamic limit	Need to limit how times are used, i.e. allowance time with extension

Snow Allowance Time Concept

- Apply Ice Pellet Allowance time methodology to Snow Conditions
  - Determine aerodynamic limit using clean fluid and LOUT
  - Test fluid + contamination and compare performance against the aerodynamic limit (pass/fail)
  - Repeat tests modifying contamination exposure times to determine what margins exist
  - Determine snow allowance times based on tests that pass

Note: "Lift-Loss Scaling" technique developed by NASA/APS/NRC could be applied to overcome temperature limitations, or if generic approach is preferred.

OUTLINE

1. Background
2. Snow Allowance Time Concept
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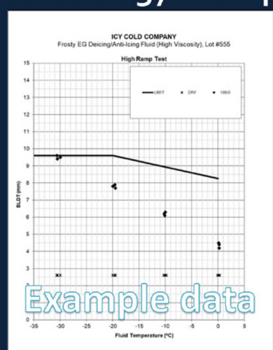
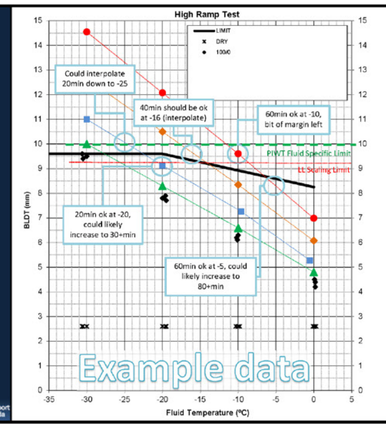
5. Way Forward

Methodology Example





Potential Guidance Format

Regulator's Holdover Time Guidelines **Winter 20XX-20XX**

TABLE XX: SNOW ALLOWANCE TIMES FOR ICY COLD COMPANY FROSTY EG[1]

Precipitation Type	Outside Air Temperature				
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -25°C	Below -25°C
Very Light Snow	xx minutes	xx minutes	xx minutes	xx minutes	Caution: No allowance times currently exist
Light Snow	xx minutes	xx minutes	xx minutes	xx minutes	
Moderate Snow	80 minutes	60 minutes	40 minutes	20 minutes	
Heavy Snow	xx minutes	xx minutes	xx minutes	xx minutes	

NOTES

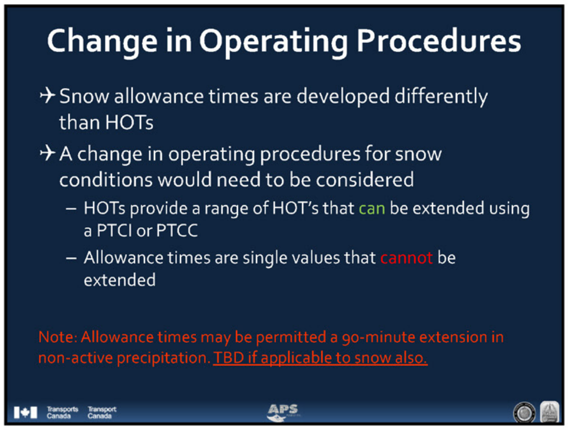
1 These allowance times are for use with undiluted (100/0) fluids applied on aircraft with rotation speeds of 100 knots or greater.

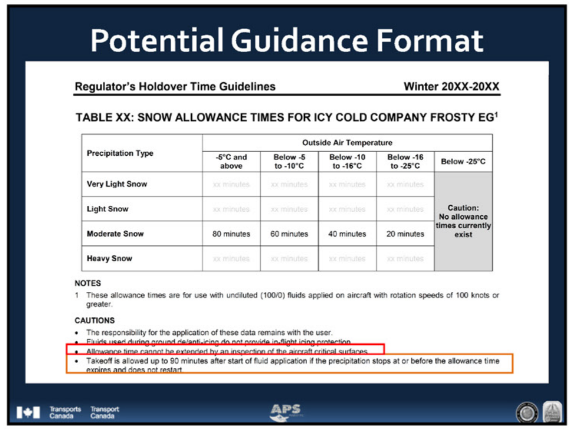
CAUTIONS

- The responsibility for the application of these data remains with the user.
- Fluids used during ground de/anti-icing do not provide in-flight icing protection.
- Allowance time cannot be extended by an inspection of the aircraft critical surfaces.
- Takeoff is allowed up to 90 minutes after start of fluid application if the precipitation stops at or before the allowance time expires and does not restart.

OUTLINE

1. Background
2. Snow Allowance Time Concept
3. Methodology Example
4. Operational Implications
5. Way Forward

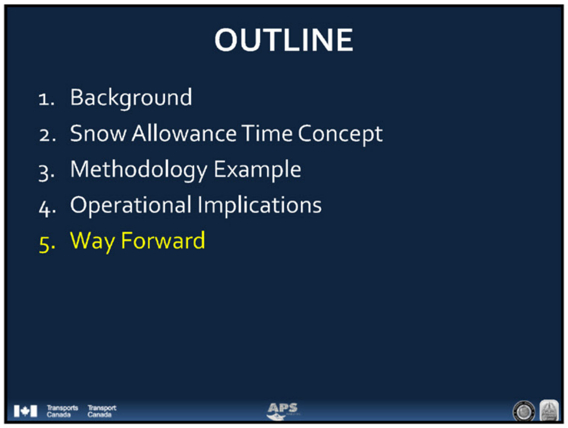


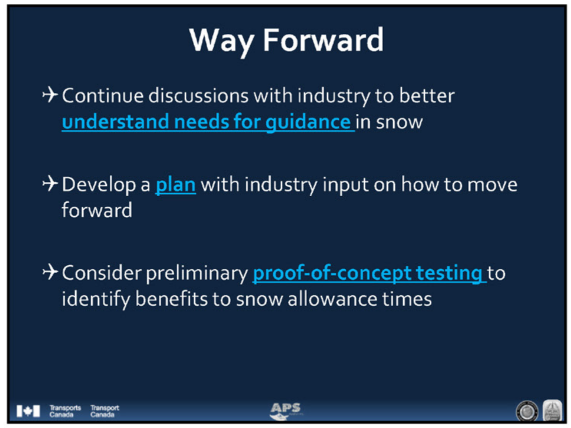


Precipitation Type	Outside Air Temperature				
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -25°C	Below -25°C
Very Light Snow	xx minutes	xx minutes	xx minutes	xx minutes	Caution: No allowance times currently exist
Light Snow	xx minutes	xx minutes	xx minutes	xx minutes	
Moderate Snow	80 minutes	60 minutes	40 minutes	20 minutes	
Heavy Snow	xx minutes	xx minutes	xx minutes	xx minutes	

NOTES
1 These allowance times are for use with undiluted (100/0) fluids applied on aircraft with rotation speeds of 100 knots or greater.

CAUTIONS
- The responsibility for the application of these data remains with the user.
- Fluids used during ground de/anti-icing do not provide in-flight icing protection.
- Allowance time cannot be extended by an inspection of the aircraft critical surfaces.
- Takeoff is allowed up to 90 minutes after start of fluid application if the precipitation stops at or before the allowance time expires and does not restart.





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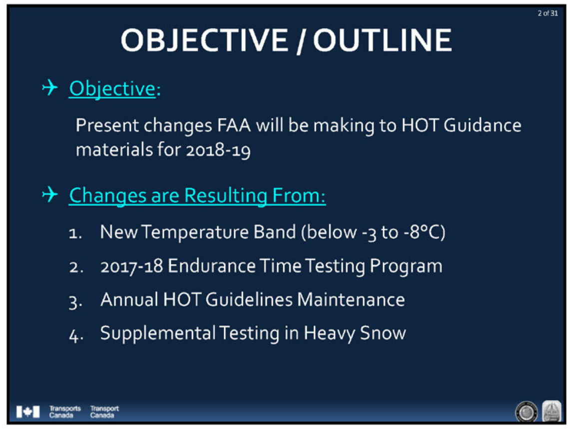
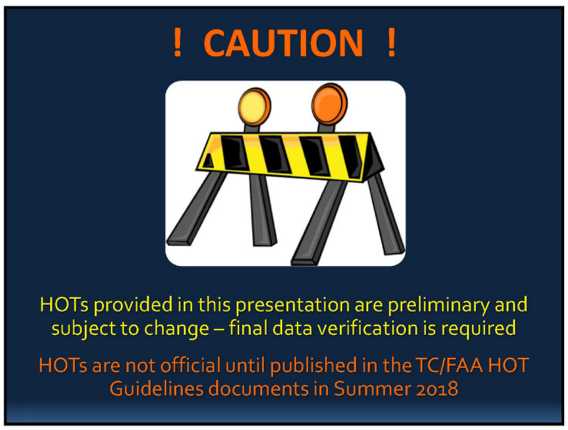
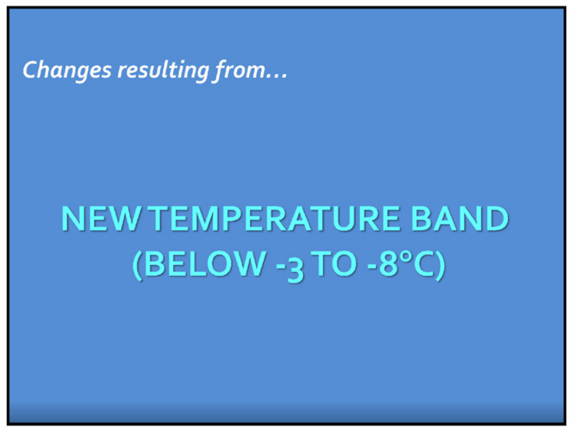
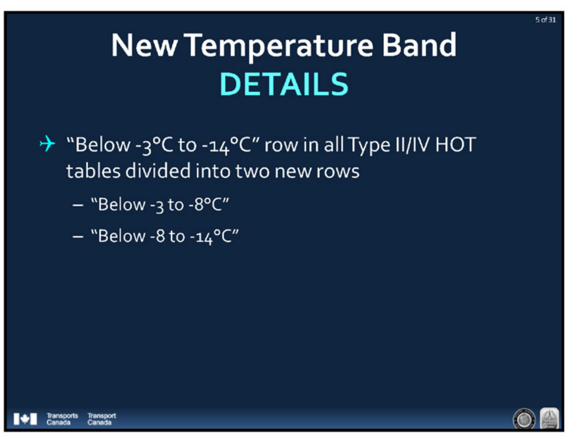
AIRLINES FOR AMERICA (A4A) GROUND DEICING FORUM, WASHINGTON, USA, JUNE 2018

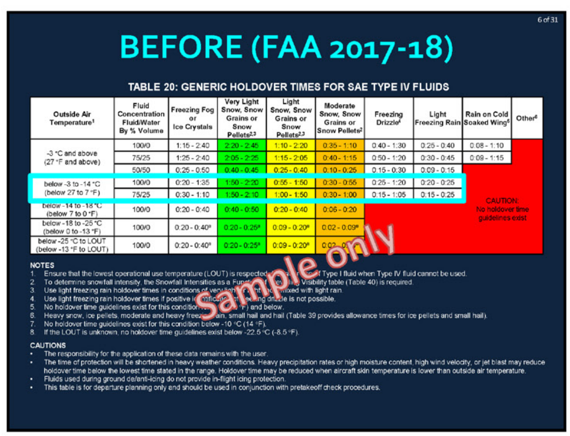
PRESENTATION:
CHANGES TO HOT GUIDELINES FOR WINTER 2018-19











Outside Air Temperature[1]	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets[2,3]	Light Snow, Snow Grains or Snow Pellets[2,3]	Moderate Snow, Snow Grains or Snow Pellets[2]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 °C and above (27 °F and above)	100/0	1:15 - 2:40	2:20 - 2:45	1:10 - 2:20	0:35 - 1:10	0:40 - 1:30	0:25 - 0:40	0:08 - 1:10	
	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	0:25 - 0:50	0:40 - 0:45	0:25 - 0:40	0:10 - 0:25	0:15 - 0:30	0:09 - 0:15		
below -3 to -14 °C (below 27 to 7 °F)	100/0	0:20 - 1:35	1:50 - 2:20	0:55 - 1:50	0:30 - 0:55	0:25 - 1:20	0:20 - 0:25		
	75/25	0:30 - 1:10	1:50 - 2:10	1:00 - 1:50	0:30 - 1:00	0:15 - 1:05	0:15 - 0:25		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:20 - 0:40	0:40 - 0:50	0:20 - 0:40	0:06 - 0:20				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:20 - 0:40[8]	0:20 - 0:25[8]	0:09 - 0:20[8]	0:02 - 0:09[8]				
below -25 °C to LOUT (below -13 °F to LOUT)	100/0	0:20 - 0:40[8]	0:20 - 0:25[8]	0:09 - 0:20[8]	0:02 - [illegible]				

NOTES
1. Ensure that the lowest operational use temperature (LOUT) is respected. [illegible] Type I fluid when Type IV fluid cannot be used.
2. To determine snowfall intensity, the Snowfall Intensities as a Fun[illegible] Visibility table (Table 40) is required.
3. Use light freezing rain holdover times in conditions of very ligh[illegible] mixed with light rain.
4. Use light freezing rain holdover times if positive i[illegible] drizzle is not possible.
5. No holdover time guidelines exist for this condition [illegible] °F) and below.
6. Heavy snow, ice pellets, moderate and heavy freez[illegible] rain, small hail and hail (Table 39 provides allowance times for ice pellets and small hail).
7. No holdover time guidelines exist for this condition below -10 °C (14 °F).
8. If the LOUT is unknown, no holdover time guidelines exist below -22.5 °C (-8.5 °F).

CAUTIONS
- The responsibility for the application of these data remains with the user.
- 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.
- This table is for departure planning only and should be used in conjunction with pretakeoff check procedures.

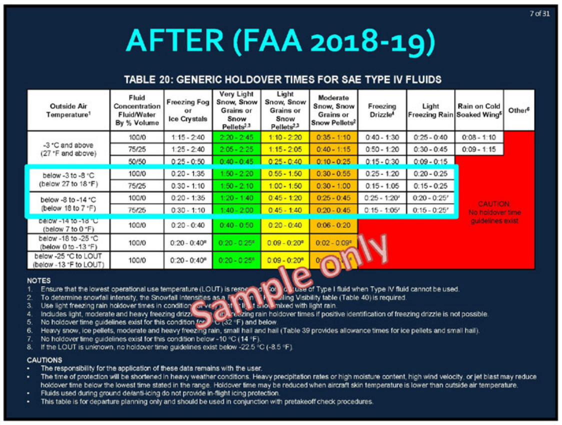
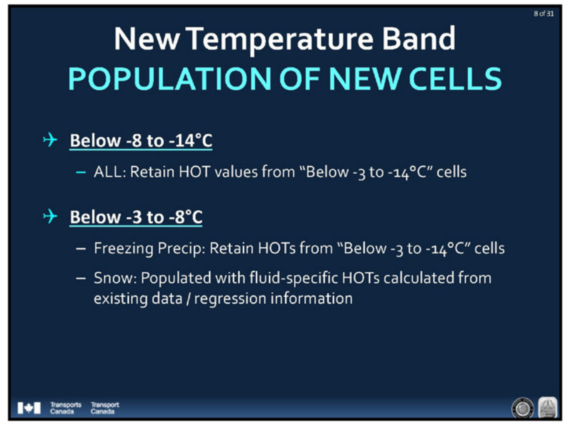


TABLE 20: GENERIC HOLDOVER TIMES FOR SAE TYPE IV FLUIDS

Outside Air Temperature[1]	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets[2,3]	Light Snow, Snow Grains or Snow Pellets[2,3]	Moderate Snow, Snow Grains or Snow Pellets[2]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 °C and above (27 °F and above)	100/0	1:15 - 2:40	2:20 - 2:45	1:10 - 2:20	0:35 - 1:10	0:40 - 1:30	0:25 - 0:40	0:08 - 1:10	
	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	0:25 - 0:50	0:40 - 0:45	0:25 - 0:40	0:10 - 0:25	0:15 - 0:30	0:09 - 0:15		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:20 - 1:35	1:50 - 2:20	0:55 - 1:50	0:30 - 0:55	0:25 - 1:20	0:20 - 0:25		
	75/25	0:30 - 1:10	1:50 - 2:10	1:00 - 1:50	0:30 - 1:00	0:15 - 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 - 1:20[7]	0:20 - 0:25[7]	CAUTION: No holdover time guidelines exist	
	75/25	0:30 - 1:10	1:40 - 2:00	0:45 - 1:40	0:20 - 0:45	0:15 - 1:05[7]	0:15 - 0:25[7]		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:20 - 0:40	0:40 - 0:50	0:20 - 0:40	0:06 - 0:20				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:20 - 0:40[8]	0:20 - 0:25[8]	0:09 - 0:20[8]	0:02 - 0:09[8]				
below -25 °C to LOUT (below -13 °F to LOUT)	100/0	0:20 - 0:40[8]	0:20 - 0:25[8]	0:09 - 0:20[8]	[illegible]				

NOTES
1. Ensure that the lowest operational use temperature (LOUT) is resp[illegible] use of Type I fluid when Type IV fluid cannot be used.
2. To determine snowfall intensity, the Snowfall Intensities as a [illegible] ailing Visibility table (Table 40) is required.
3. Use light freezing rain holdover times in condition[illegible] mixed with light rain.
4. Includes light, moderate and heavy freezing drizz[illegible] reezing rain holdover times if positive identification of freezing drizzle is not possible.
5. No holdover time guidelines exist for this condition fo[illegible] °C (32 °F) and below.
6. Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 39 provides allowance times for ice pellets and small hail).
7. No holdover time guidelines exist for this condition below -10 °C (14 °F).
8. If the LOUT is unknown, no holdover time guidelines exist below -22.5 °C (-8.5 °F).

CAUTIONS
- The responsibility for the application of these data remains with the user.
- 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.
- This table is for departure planning only and should be used in conjunction with pretakeoff check procedures.



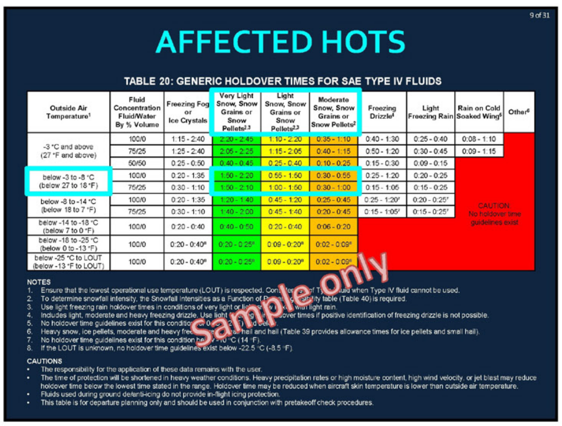


TABLE 20: GENERIC HOLDOVER TIMES FOR SAE TYPE IV FLUIDS

Outside Air Temperature[1]	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets[2,3]	Light Snow, Snow Grains or Snow Pellets[2,3]	Moderate Snow, Snow Grains or Snow Pellets[2]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 °C and above (27 °F and above)	100/0	1:15 - 2:40	2:20 - 2:45	1:10 - 2:20	0:35 - 1:10	0:40 - 1:30	0:25 - 0:40	0:08 - 1:10	
	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	0:25 - 0:50	0:40 - 0:45	0:25 - 0:40	0:10 - 0:25	0:15 - 0:30	0:09 - 0:15		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:20 - 1:35	1:50 - 2:20	0:55 - 1:50	0:30 - 0:55	0:25 - 1:20	0:20 - 0:25		
	75/25	0:30 - 1:10	1:50 - 2:10	1:00 - 1:50	0:30 - 1:00	0:15 - 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 - 1:20[7]	0:20 - 0:25[7]	CAUTION: No holdover time guidelines exist	
	75/25	0:30 - 1:10	1:40 - 2:00	0:45 - 1:40	0:20 - 0:45	0:15 - 1:05[7]	0:15 - 0:25[7]		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:20 - 0:40	0:40 - 0:50	0:20 - 0:40	0:06 - 0:20				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:20 - 0:40[8]	0:20 - 0:25[8]	0:09 - 0:20[8]	0:02 - 0:09[8]				
below -25 °C to LOUT (below -13 °F to LOUT)	100/0	0:20 - 0:40[8]	0:20 - 0:25[8]	0:09 - 0:20[8]	0:02 - 0:09[8]				

NOTES
1. Ensure that the lowest operational use temperature (LOUT) is respected. Cons[illegible] of Ty[illegible] when Type IV fluid cannot be used.
2. To determine snowfall intensity, the Snowfall Intensities as a Function of P[illegible] ibility table (Table 40) is required.
3. Use light freezing rain holdover times in conditions of very light or li[illegible] with light rain.
4. Includes light, moderate and heavy freezing drizzle. Use light [illegible] over times if positive identification of freezing drizzle is not possible.
5. No holdover time guidelines exist for this conditio[illegible]
6. Heavy snow, ice pellets, moderate and heavy fre[illegible] hail and hail (Table 39 provides allowance times for ice pellets and small hail).
7. No holdover time guidelines exist for this condition be[illegible] °C (14 °F).
8. If the LOUT is unknown, no holdover time guidelines exist below -22.5 °C (-8.5 °F).

CAUTIONS
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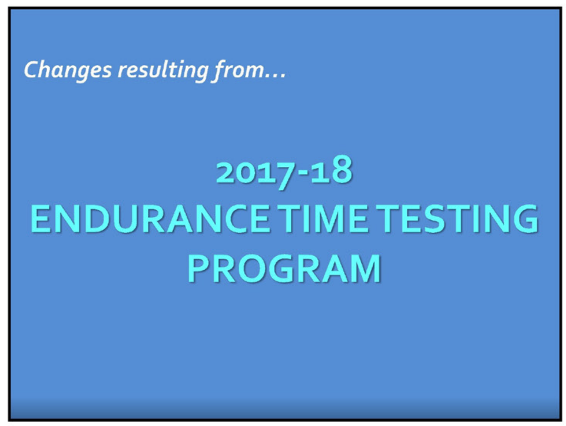
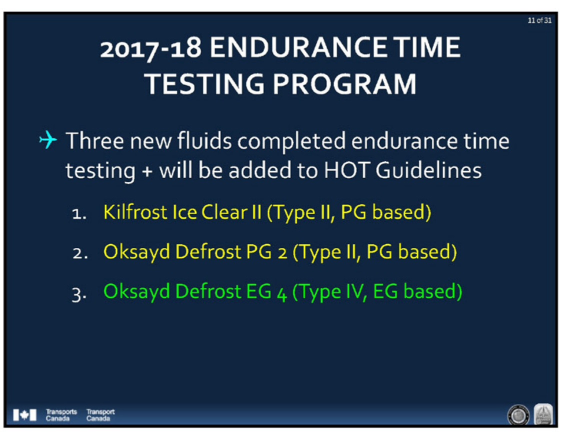
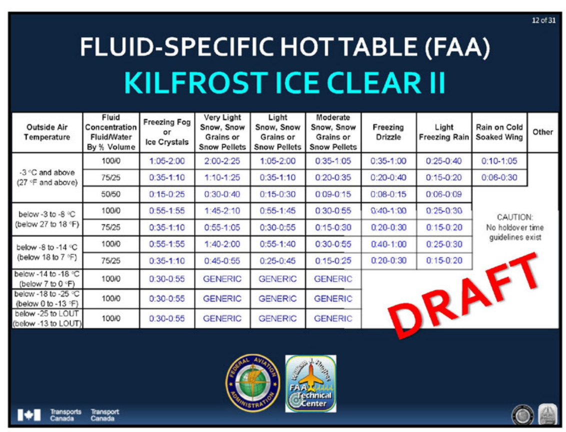
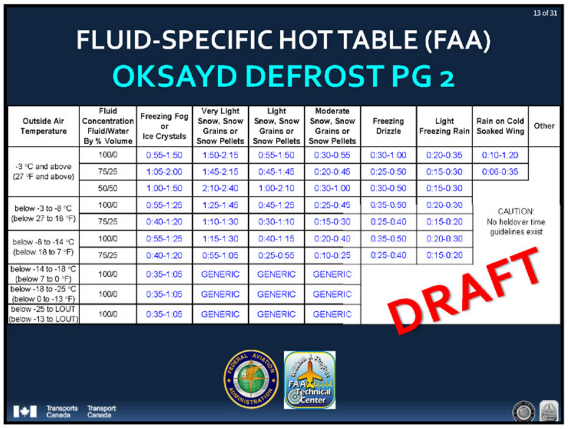


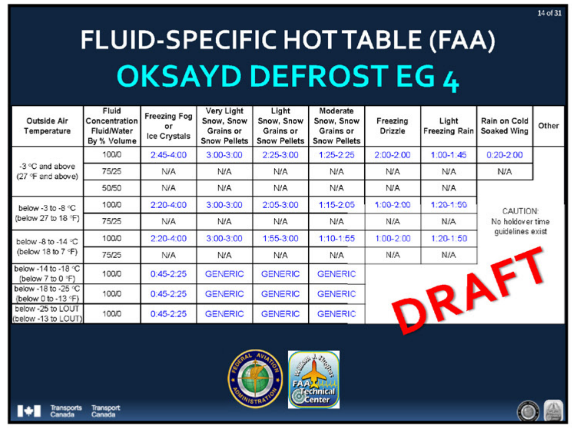




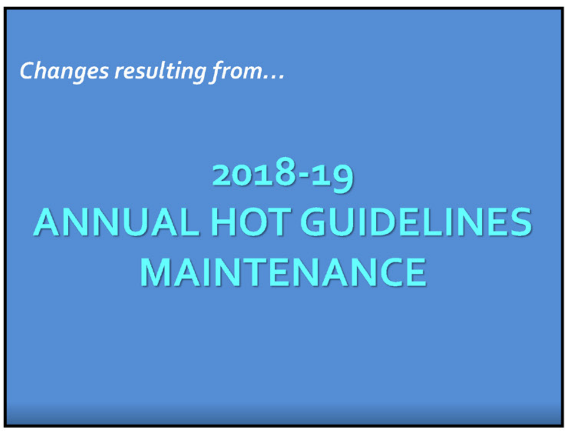
Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	1:05-2:00	2:00-2:25	1:05-2:00	0:35-1:05	0:35-1:00	0:25-0:40	0:10-1:05	
	75/25	0:35-1:10	1:10-1:25	0:35-1:10	0:20-0:35	0:20-0:40	0:15-0:20	0:06-0:30	
	50/50	0:15-0:25	0:30-0:40	0:15-0:30	0:09-0:15	0:08-0:15	0:06-0:09		
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:55-1:55	1:45-2:10	0:55-1:45	0:30-0:55	0:40-1:00	0:25-0:30	CAUTION: No holdover time guidelines exist	
	75/25	0:35-1:10	0:55-1:05	0:30-0:55	0:15-0:30	0:20-0:30	0:15-0:20		
below -8 to -14 °C (below 18 to 7 °F)	100/0	0:55-1:55	1:40-2:00	0:55-1:40	0:30-0:55	0:40-1:00	0:25-0:30		
	75/25	0:35-1:10	0:45-0:55	0:25-0:45	0:15-0:25	0:20-0:30	0:15-0:20		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:30-0:55	GENERIC	GENERIC	GENERIC				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:30-0:55	GENERIC	GENERIC	GENERIC				
below -25 to LOUT (below -13 to LOUT)	100/0	0:30-0:55	GENERIC	GENERIC	GENERIC				

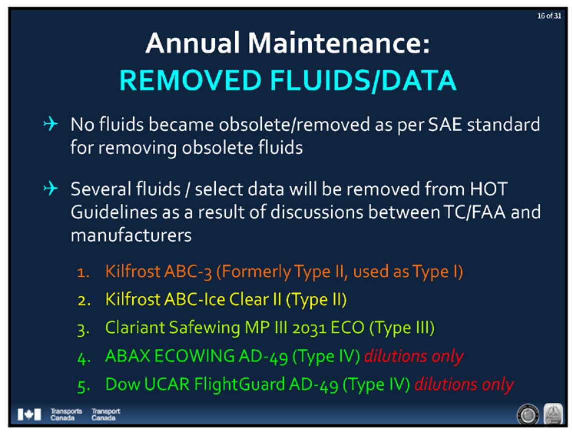


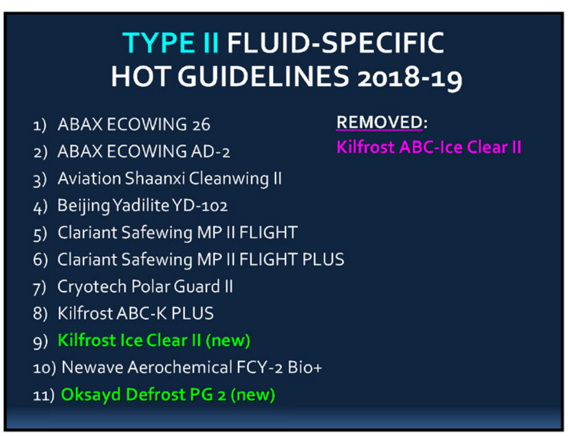
Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	0:55-1:50	1:50-2:15	0:55-1:50	0:30-0:55	0:30-1:00	0:20-0:35	0:10-1:20	
	75/25	1:05-2:00	1:45-2:15	0:45-1:45	0:20-0:45	0:25-0:50	0:15-0:30	0:06-0:35	
	50/50	1:00-1:50	2:10-2:40	1:00-2:10	0:30-1:00	0:30-0:50	0:15-0:30	CAUTION: No holdover time guidelines exist	
below -3 to -8 °C (below 27 to 18 °F)	100/0	0:55-1:25	1:25-1:45	0:45-1:25	0:25-0:45	0:35-0:50	0:20-0:30		
	75/25	0:40-1:20	1:10-1:30	0:30-1:10	0:15-0:30	0:25-0:40	0:15-0:20		
below -8 to -14 °C (below 18 to 7 °F)	100/0	0:55-1:25	1:15-1:30	0:40-1:15	0:20-0:40	0:35-0:50	0:20-0:30		
	75/25	0:40-1:20	0:55-1:05	0:25-0:55	0:10-0:25	0:25-0:40	0:15-0:20		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:35-1:05	GENERIC	GENERIC	GENERIC				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:35-1:05	GENERIC	GENERIC	GENERIC				
below -25 to LOUT (below -13 to LOUT)	100/0	0:35-1:05	GENERIC	GENERIC	GENERIC				

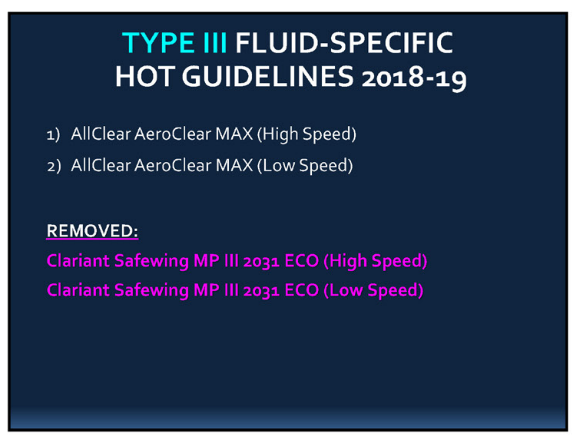


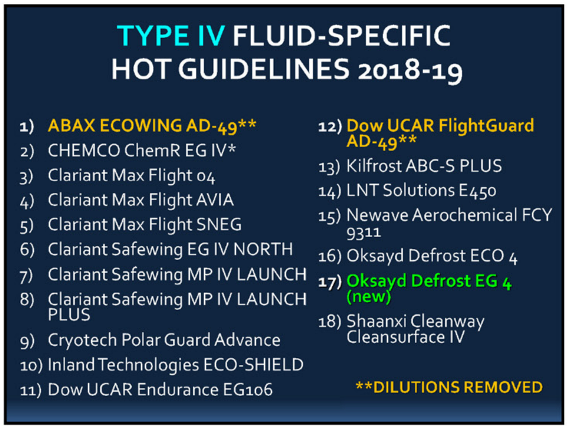
Outside Air Temperature	Fluid Concentration Fluid/Water By % Volume	Freezing Fog or Ice Crystals	Very Light Snow, Snow Grains or Snow Pellets	Light Snow, Snow Grains or Snow Pellets	Moderate Snow, Snow Grains or Snow Pellets	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 °C and above (27 °F and above)	100/0	2:45-4:00	3:00-3:00	2:25-3:00	1:25-2:25	2:00-2:00	1:00-1:45	0:20-2:00	
	75/25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
	50/50	N/A	N/A	N/A	N/A	N/A	N/A	CAUTION: No holdover time guidelines exist	
below -3 to -8 °C (below 27 to 18 °F)	100/0	2:20-4:00	3:00-3:00	2:05-3:00	1:15-2:05	1:00-2:00	1:20-1:50		
	75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -8 to -14 °C (below 18 to 7 °F)	100/0	2:20-4:00	3:00-3:00	1:55-3:00	1:10-1:55	1:00-2:00	1:20-1:50		
	75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -18 °C (below 7 to 0 °F)	100/0	0:45-2:25	GENERIC	GENERIC	GENERIC				
below -18 to -25 °C (below 0 to -13 °F)	100/0	0:45-2:25	GENERIC	GENERIC	GENERIC				
below -25 to LOUT (below -13 to LOUT)	100/0	0:45-2:25	GENERIC	GENERIC	GENERIC				

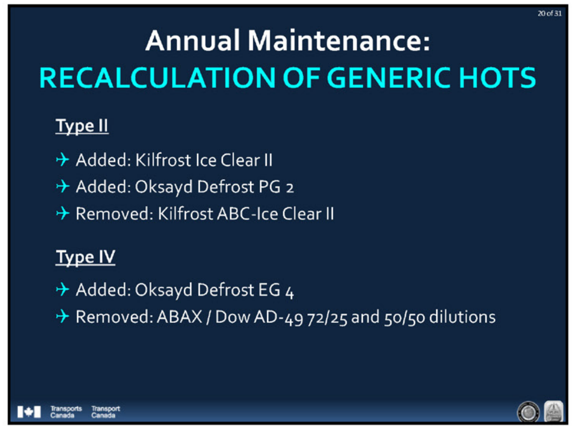


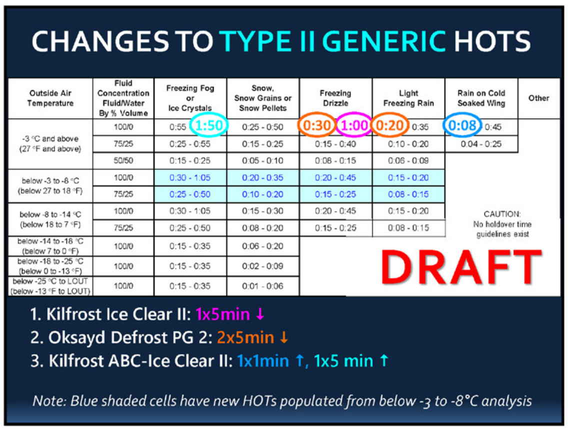


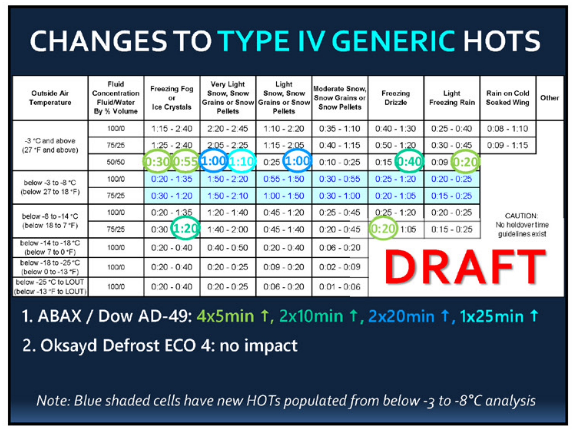


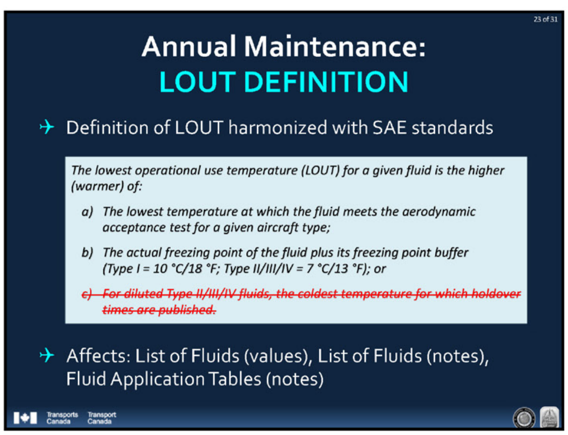


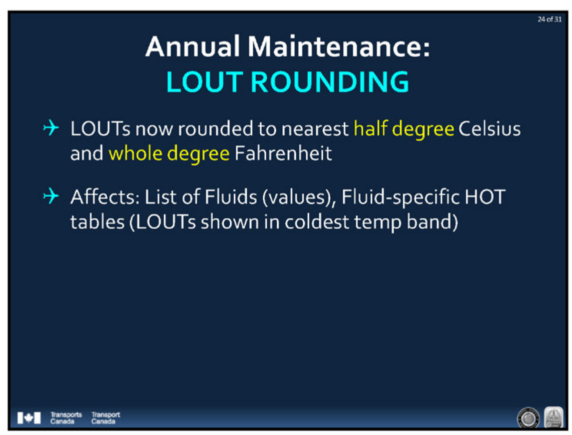

TYPE IV FLUID-SPECIFIC
HOT GUIDELINES 2018-19
1) ABAX ECOWING AD-49**
2) CHEMCO ChemR EG IV*
3) Clariant Max Flight 04
4) Clariant Max Flight AVIA
5) Clariant Max Flight SNEG
6) Clariant Safewing EG IV NORTH
7) Clariant Safewing MP IV LAUNCH
8) Clariant Safewing MP IV LAUNCH PLUS
9) Cryotech Polar Guard Advance
10) Inland Technologies ECO-SHIELD
11) Dow UCAR Endurance EG106
12) Dow UCAR FlightGuard AD-49**
13) Kilfrost ABC-S PLUS
14) LNT Solutions E450
15) Newave Aerochemical FCY 9311
16) Oksayd Defrost ECO 4
17) Oksayd Defrost EG 4 (new)
18) Shaanxi Cleanway Cleansurface IV
**DILUTIONS REMOVED


20 of 31
Annual Maintenance:
RECALCULATION OF GENERIC HOTS
Type II
Added: Kilfrost Ice Clear II
Added: Oksayd Defrost PG 2
Removed: Kilfrost ABC-Ice Clear II
Type IV
Added: Oksayd Defrost EG 4
Removed: ABAX / Dow AD-49 72/25 and 50/50 dilutions


CHANGES TO TYPE II GENERIC HOTS
Outside Air Temperature | Fluid Concentration Fluid/Water By % Volume | Freezing Fog or Ice Crystals | Snow, Snow Grains or Snow Pellets | Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing | Other
-3 °C and above (27 °F and above) | 100/0 | 0:55 - 1:50 | 0:25 - 0:50 | 0:30 - 1:00 | 0:20 - 0:35 | 0:08 - 0:45
75/25 | 0:25 - 0:55 | 0:15 - 0:25 | 0:15 - 0:40 | 0:10 - 0:20 | 0:04 - 0:25
50/50 | 0:15 - 0:25 | 0:05 - 0:10 | 0:08 - 0:15 | 0:06 - 0:09
below -3 to -8 °C (below 27 to 18 °F) | 100/0 | 0:30 - 1:05 | 0:20 - 0:35 | 0:20 - 0:45 | 0:15 - 0:20
75/25 | 0:25 - 0:50 | 0:10 - 0:20 | 0:15 - 0:25 | 0:08 - 0:15
below -8 to -14 °C (below 18 to 7 °F) | 100/0 | 0:30 - 1:05 | 0:15 - 0:30 | 0:20 - 0:45 | 0:15 - 0:20
75/25 | 0:25 - 0:50 | 0:08 - 0:20 | 0:15 - 0:25 | 0:08 - 0:15
below -14 to -18 °C (below 7 to 0 °F) | 100/0 | 0:15 - 0:35 | 0:06 - 0:20
below -18 to -25 °C (below 0 to -13 °F) | 100/0 | 0:15 - 0:35 | 0:02 - 0:09
below -25 °C to LOUT (below -13 °F to LOUT) | 100/0 | 0:15 - 0:35 | 0:01 - 0:06
CAUTION: No holdover time guidelines exist
DRAFT
1. Kilfrost Ice Clear II: 1x5min ↓
2. Oksayd Defrost PG 2: 2x5min ↓
3. Kilfrost ABC-Ice Clear II: 1x1min ↑, 1x5 min ↑
Note: Blue shaded cells have new HOTs populated from below -3 to -8°C analysis


CHANGES TO TYPE IV GENERIC HOTS
Outside Air Temperature | Fluid Concentration Fluid/Water By % Volume | Freezing Fog or Ice Crystals | Very Light Snow, Snow Grains or Snow Pellets | Light Snow, Snow Grains or Snow Pellets | Moderate Snow, Snow Grains or Snow Pellets | Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing | Other
-3 °C and above (27 °F and above) | 100/0 | 1:15 - 2:40 | 2:20 - 2:45 | 1:10 - 2:20 | 0:35 - 1:10 | 0:40 - 1:30 | 0:25 - 0:40 | 0:08 - 1:10
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 | 1:50 - 2:20 | 0:55 - 1:50 | 0:30 - 0:55 | 0:25 - 1:20 | 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 - 1:20 | 0:20 - 0:25
75/25 | 0:30 1:20 | 1:40 - 2:00 | 0:45 - 1:40 | 0:20 - 0:45 | 0:20 1:05 | 0:15 - 0:25
below -14 to -18 °C (below 7 to 0 °F) | 100/0 | 0:20 - 0:40 | 0:40 - 0:50 | 0:20 - 0:40 | 0:06 - 0:20
below -18 to -25 °C (below 0 to -13 °F) | 100/0 | 0:20 - 0:40 | 0:20 - 0:25 | 0:09 - 0:20 | 0:02 - 0:09
below -25 °C to LOUT (below -13 °F to LOUT) | 100/0 | 0:20 - 0:40 | 0:20 - 0:25 | 0:06 - 0:20 | 0:01 - 0:06
CAUTION: No holdover time guidelines exist
DRAFT
1. ABAX / Dow AD-49: 4x5min ↑, 2x10min ↑, 2x20min ↑, 1x25min ↑
2. Oksayd Defrost ECO 4: no impact
Note: Blue shaded cells have new HOTs populated from below -3 to -8°C analysis


23 of 31
Annual Maintenance:
LOUT DEFINITION
Definition of LOUT harmonized with SAE standards
The lowest operational use temperature (LOUT) for a given fluid is the higher (warmer) of:
a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type;
b) The actual freezing point of the fluid plus its freezing point buffer (Type I = 10 °C/18 °F; Type II/III/IV = 7 °C/13 °F); or
c) For diluted Type II/III/IV fluids, the coldest temperature for which holdover times are published.
Affects: List of Fluids (values), List of Fluids (notes), Fluid Application Tables (notes)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Annual Maintenance:
LOUT ROUNDING
LOUTs now rounded to nearest half degree Celsius and whole degree Fahrenheit
Affects: List of Fluids (values), Fluid-specific HOT tables (LOUTs shown in coldest temp band)

Annual Maintenance: FREEZING DRIZZLE INTENSITY

- Clarification of which intensities of freezing drizzle included in HOT tables
- Affects: HOT Tables (note on freezing drizzle column heading)
  - From: *Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.*
  - To: *Includes light, moderate and heavy freezing drizzle. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.*

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Changes resulting from…

SUPPLEMENTAL TESTING IN HEAVY SNOW

SUPPLEMENTAL TESTING IN HEAVY SNOW: HUPRS

- Changes to the **HOT Guidelines** documents presented on previous slides will also be incorporated into the **Regression Information** documents
- One additional change will be made to the **Regression Information** documents (HOT Guidelines not affected)
  - Two *Highest Usable Precipitation Rates* (HUPRs) will increase as a result of supplemental data collected in heavy snow
    - Clariant Safewing MP II FLIGHT: 100/0
    - Clariant Safewing MP II FLIGHT: 75/25

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SUPPLEMENTAL TESTING IN HEAVY SNOW: HUPRS

TABLE 6: HIGHEST USABLE PRECIPITATION RATES IN SNOW[1]

TYPE II, TYPE III AND TYPE IV FLUIDS[2]

Type II De/Anti-Icing Fluids				
FLUID DILUTION	100/0		75/25	50/50
TEMPERATURE	*-14°C AND ABOVE*	*BELOW -14°C*	*-14°C AND ABOVE*	*-3°C AND ABOVE*
ABAX ECOWING 26	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	50 $g/dm^2/h$
ABAX ECOWING AD-2	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	50 $g/dm^2/h$
Aviation Shaanxi Hi-Tech Cleanwing II	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	50 $g/dm^2/h$
Beijing Yadilite Aviation YD-102 Type II	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	50 $g/dm^2/h$
Clariant Safewing MP II FLIGHT	4050 $g/dm^2/h$	25 $g/dm^2/h$	4050 $g/dm^2/h$	40 $g/dm^2/h$
Clariant Safewing MP II FLIGHT PLUS	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	40 $g/dm^2/h$
Cryotech Polar Guard® II	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	50 $g/dm^2/h$
Kilfrost ABC-Ice Clear II	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	50 $g/dm^2/h$
Kilfrost ABC-K Plus	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	25 $g/dm^2/h$
Newave Aerochemical FCY-2	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	50 $g/dm^2/h$
Newave Aerochemical FCY-2 Bio+	50 $g/dm^2/h$	25 $g/dm^2/h$	50 $g/dm^2/h$	50 $g/dm^2/h$

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FUTURE CHANGES

Future Changes: GENERIC HOTS FOR VERY COLD SNOW

- Analysis completed winter 2017-18 indicates reductions to generic HOTS for very cold snow may be necessary
- Extent of reductions not yet know, TBD for winter 2018-19
- PG based Type II fluids at very coldest temperatures expected to be most affected
- Fluids with fluid-specific HOTS in very cold snow will not be affected

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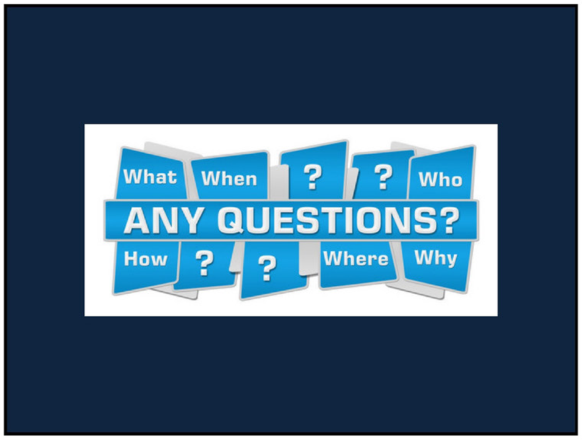
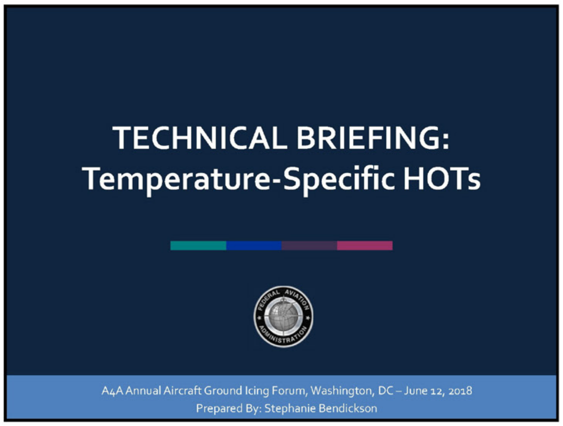
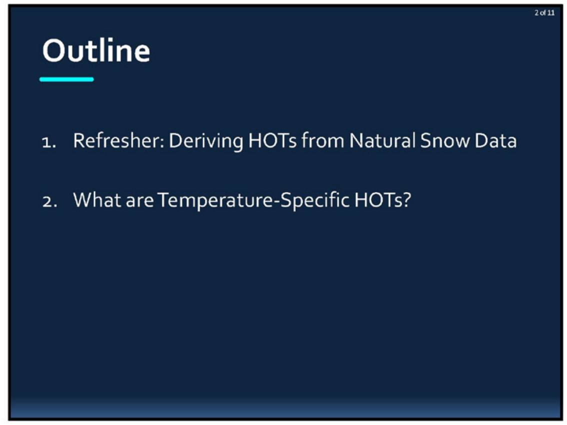
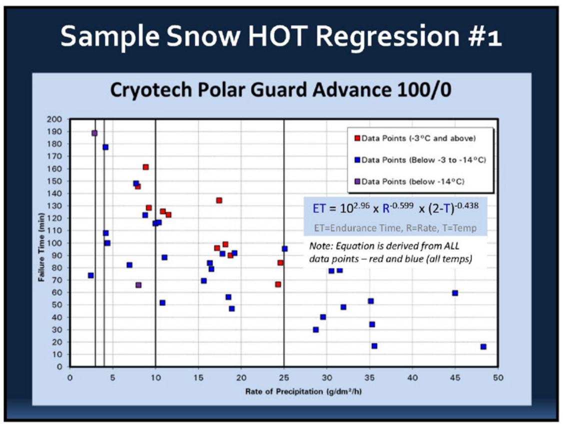

What
When
?
?
Who
ANY QUESTIONS?
How
?
?
Where
Why

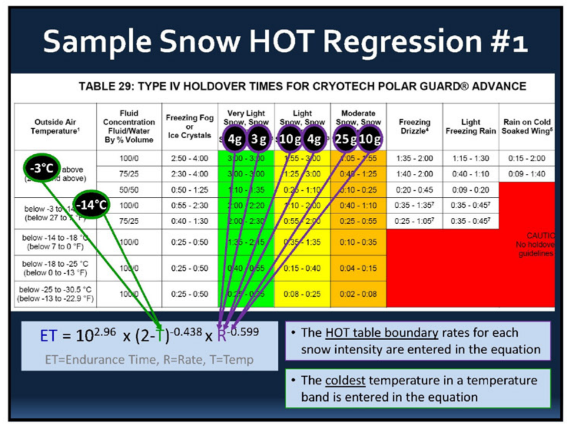
AIRLINES FOR AMERICA (A4A) GROUND DEICING FORUM, WASHINGTON, USA, JUNE 2018

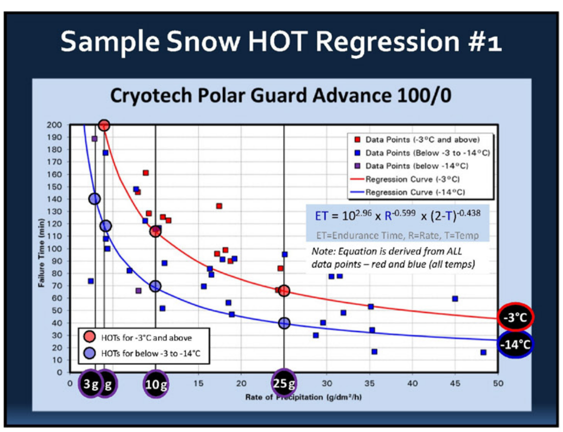
PRESENTATION:
TECHNICAL BRIEFING: TEMPERATURE-SPECIFIC HOTS

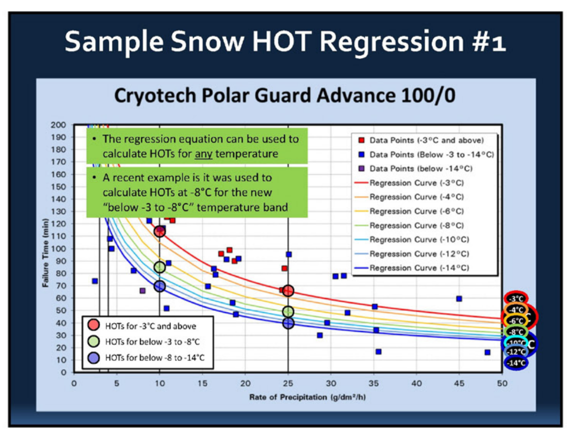

TECHNICAL BRIEFING:
Temperature-Specific HOTs
A4A Annual Aircraft Ground Icing Forum, Washington, DC – June 12, 2018
Prepared By: Stephanie Bendickson


2 of 11
Outline
1. Refresher: Deriving HOTs from Natural Snow Data
2. What are Temperature-Specific HOTs?


Sample Snow HOT Regression #1
Cryotech Polar Guard Advance 100/0
Data Points (-3°C and above)
Data Points (Below -3 to -14°C)
Data Points (below -14°C)
ET = 10^2.96 x R^-0.599 x (2-T)^-0.438
ET=Endurance Time, R=Rate, T=Temp
Note: Equation is derived from ALL data points – red and blue (all temps)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


Sample Snow HOT Regression #1
TABLE 29: TYPE IV HOLDOVER TIMES FOR CRYOTECH POLAR GUARD® ADVANCE
Outside Air Temperature
Fluid Concentration Fluid/Water By % Volume
Freezing Fog or Ice Crystals
Very Light Snow, Snow
Light Snow, Snow
Moderate Snow, Snow
Freezing Drizzle
Light Freezing Rain
Rain on Cold Soaked Wing
4g
3g
10g
4g
25g
10g
-3°C
-14°C
CAUTIO
No holdove
guidelines
ET = 10^2.96 x (2-T)^-0.438 x R^-0.599
ET=Endurance Time, R=Rate, T=Temp
• The HOT table boundary rates for each snow intensity are entered in the equation
• The coldest temperature in a temperature band is entered in the equation

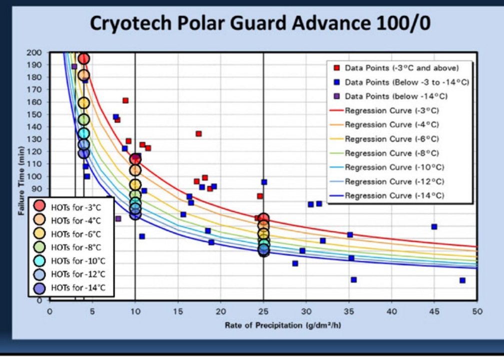

Sample Snow HOT Regression #1
Cryotech Polar Guard Advance 100/0
Data Points (-3°C and above)
Data Points (Below -3 to -14°C)
Data Points (below -14°C)
Regression Curve (-3°C)
Regression Curve (-14°C)
ET = 10^2.96 x R^-0.599 x (2-T)^-0.438
ET=Endurance Time, R=Rate, T=Temp
Note: Equation is derived from ALL data points – red and blue (all temps)
-3°C
-14°C
HOTs for -3°C and above
HOTs for below -3 to -14°C
3g
g
10g
25g
Failure Time (min)
Rate of Precipitation (g/dm²/h)


Sample Snow HOT Regression #1
Cryotech Polar Guard Advance 100/0
• The regression equation can be used to calculate HOTs for any temperature
• A recent example is it was used to calculate HOTs at -8°C for the new "below -3 to -8°C" temperature band
Data Points (-3°C and above)
Data Points (Below -3 to -14°C)
Data Points (below -14°C)
Regression Curve (-3°C)
Regression Curve (-4°C)
Regression Curve (-6°C)
Regression Curve (-8°C)
Regression Curve (-10°C)
Regression Curve (-12°C)
Regression Curve (-14°C)
HOTs for -3°C and above
HOTs for below -3 to -8°C
HOTs for below -8 to -14°C
Failure Time (min)
Rate of Precipitation (g/dm²/h)

What are Temperature Specific HOTs?

- HOTs that are calculated for specific temperatures based on published regression information
- Rate is not an input into the calculation, just temperature (HOT table boundary rates used)
- See example next slides

Sample Snow HOT Regression #1



Example

HOT Table Approach	
Temperature	**Moderate Snow**
-3°C and above	1:05 - 1:55
below -3 to -8°C	0:50 - 1:25
below -8 to -14°C	0:40 - 1:10

Temp-Specific Approach	
Temperature	**Moderate Snow**
-3°C	1:05 - 1:55
-4°C	1:00 - 1:45
-6°C	0:55 - 1:30
-8°C	0:50 - 1:25
-10°C	0:45 - 1:15
-12°C	0:40 - 1:10
-14°C	0:40 - 1:10

Cryotech Polar Guard Advance, 100/0, Moderate Snow

Details to Consider

- Rounding + capping rules
- Max and min temperature entries
- Provision of single HOT or HOT range
- Provision of notes and cautions
- Access to up to date temperature data