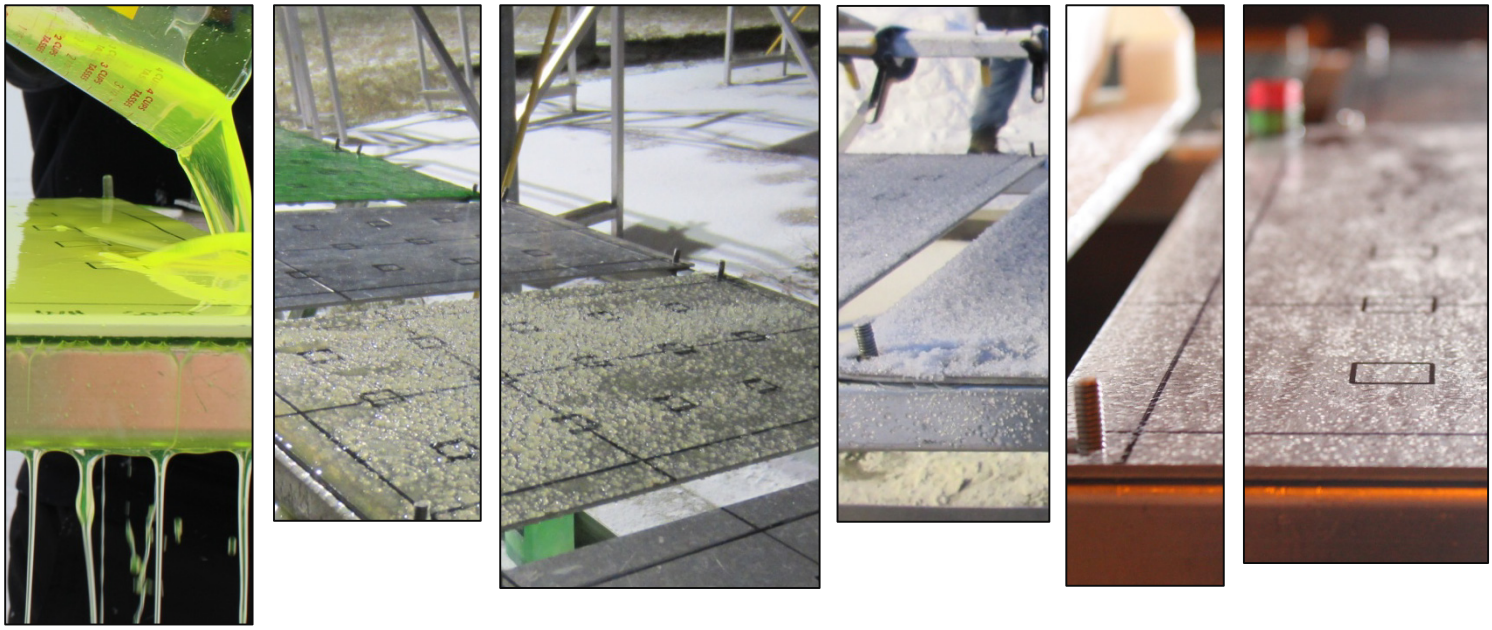
TP 15321E

Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2014-15 Winter



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and

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Prepared by

APS Aviation Inc.

December 2016
Final Version 1.0

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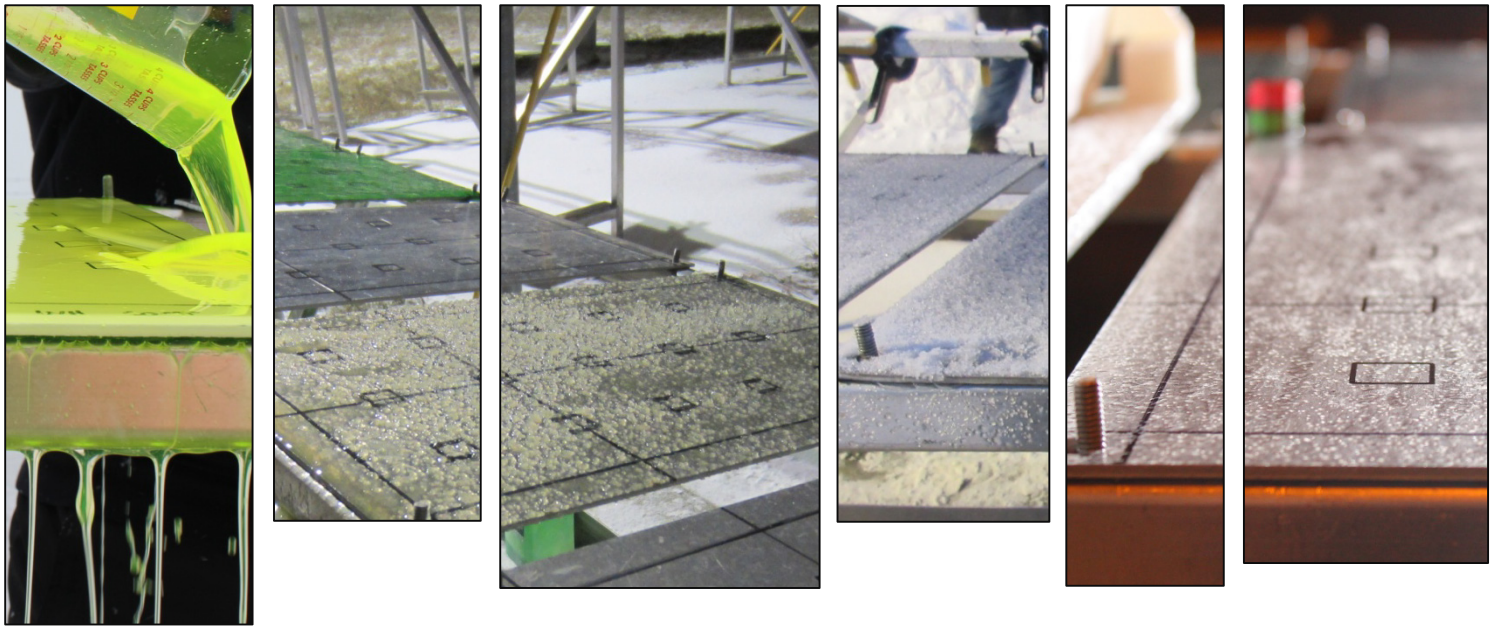

by

Stephanie Bendickson

December 2016
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The contents of this report reflect the views of APS Aviation Inc. and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

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Un sommaire français se trouve avant la table des matières.

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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 specific objectives of the APS Aviation Inc. test program are the following:

- To develop holdover time data for all newly-qualified de/anti-icing fluids and update and maintain the website for the holdover time guidelines;
- To evaluate weather data from previous winters that can have an impact on the format of the holdover time guidelines;
- To conduct general and exploratory de/anti-icing research;
- To conduct tests to evaluate the effect of coloured vs. uncoloured fluids on endurance times;
- To obtain full-scale operational documentation of anti-icing fluid flow-off, fluid freezing-in-flight, and residual fluid thickness;
- To conduct tests to evaluate the effect of deployed flaps and slats prior to anti-icing;
- To analyse historical data and/or conduct tests with the snowmaker to support ARP5485 changes;
- To analyse historical data and/or conduct tests to evaluate holdover times for heavy snow conditions;
- To continue research for development of ice detection capabilities for pre-deicing, engine deicing and departing aircraft at the runway threshold;
- To develop training and fluid failure photos/videos for global archive; and
- To update the regression coefficient report with the newly-qualified de/anti-icing fluids.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2014-15 are documented in four reports. The titles of the reports are as follows:

- TP 15320E Winter Weather Impact on Holdover Time Table Format (1995-2015);
- TP 15321E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2014-15 Winter;
- TP 15322E Regression Coefficients and Equations Used to Develop the Winter 2015-16 Aircraft Ground Deicing Holdover Time Tables; and
- TP 15323E Aircraft Ground Icing Research General Activities During the 2014-15 Winter.

In addition, the following interim report is being prepared:

- *Evaluation of Endurance Times on Extended Flaps and Slats.*

This report, TP 15321E has the following objective:

- To develop holdover time data for new de/anti-icing fluids and to document changes made to the holdover time guidelines.

This objective was met by conducting endurance time tests with fluids in simulated freezing precipitation at the National Research Council Canada Climatic Engineering Facility in Ottawa and in natural snow at the APS Aviation Inc. test site at Montreal-Trudeau Airport in Montreal.

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 several fluid manufacturers.

APS Aviation Inc. would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Yelyzaveta Asnytska, Steven Baker, Stephanie Bendickson, Benjamin Bernier, Chloë Bernier, Trevor Butler, Michael Carlucci, Matthew Budd-Kenny, John D'Avirro, Ben Falvo, Benjamin Guthrie, Jesse Moreland, Dany Posteraro, Marco Ruggi, Michael Stanton, David Youssef, Nondas Zoitakis and Victoria Zoitakis.

Special thanks are extended to Antoine Lacroix, Howard Posluns, Yvan Chabot, Doug Ingold, 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.

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

Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada. 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

The primary objective of the 2014-15 holdover time test program was to evaluate the performance of new deicing and anti-icing fluids over the entire range of conditions encompassed by the holdover time (HOT) guidelines. The objective was met by conducting endurance time tests. The procedure for these tests consisted of pouring fluids onto clean aluminum test surfaces inclined at 10º. The onset of failure was recorded as a function of time in natural frost, natural snow, artificial snow, simulated freezing fog, simulated freezing drizzle, simulated light freezing rain, and simulated rain on a cold-soaked wing. A total of 531 tests were conducted with ten fluids.

Changes to the HOT guidelines for the winter of 2015-16 include:

- Fluid-specific HOT guidelines were added for three new fluids: Kilfrost ABC-Ice Clear II (Type II), Newave Aerochemical FCY-2 Bio+ (Type II) and Deicing Solutions ECO-SHIELD (Type IV);
- Increases were made to snow holdover times for two fluids for which supplemental testing was conducted: LNT Solutions P250 (Type II) and LNT Solutions E450 (Type IV);
- Three fluids were removed from the guidelines as per the protocol for removal of obsolete data: Clariant Safewing MP II 1951 (Type II), ABAX AD-480 (Type IV) and Kilfrost ABC-S (Type IV);
- Six minor changes (increases and decreases of up to 5 minutes) were made to the Type II generic HOT guidelines as a result of the new and removed fluids;
- Significant changes (primarily increases) were made to the Type IV generic HOT guidelines as a result of the new and removed fluids;
- Fluid, application temperature, rotation speed-specific HOT guidelines were added for Type III fluids, specifically Clariant Safewing MP III 2031 ECO (applied heated) and AllClear AeroClear MAX (applied unheated); and
- The Type III generic HOT guidelines were removed due to the different application temperature requirements of the two Type III fluids.

It is recommended that any new Type I, Type II, Type III or Type IV fluids be evaluated over the entire range of conditions in the HOT guidelines. It is also recommended that if a new Type III fluid is submitted for heated application testing, further research be conducted to evaluate endurance times of Type III fluids applied heated to composite surfaces. Finally, it is recommended that further research be completed to evaluate the current holdover times provided for Type II, III and IV fluids in snow at very cold temperatures.

17. Key Words	18. Distribution Statement
Anti-icing, deicing, deicing fluid, holdover times, precipitation, endurance times, Type I, Type II, Type III, Type IV, aircraft, ground, test, winter	Limited number of copies available from the Transportation Development Centre

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

Plusieurs rapports de recherche sur des essais de technologies de dégivrage et d'antigivrage ont été produits au cours des hivers précédents pour le compte de Transports Canada. 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 principal objectif du programme d'essai sur les durées d'efficacité de l'hiver 2014-2015 était d'évaluer la performance de nouveaux liquides de dégivrage et d'antigivrage pour toute la gamme des conditions météorologiques couvertes par les lignes directrices relatives aux durées d'efficacité. Pour atteindre cet objectif, des essais d'endurance ont été menés. La procédure suivie pour ces essais consistait à verser les liquides sur des surfaces d'aluminium propres, inclinées à 10°. On notait ensuite l'amorce de la perte d'efficacité en fonction du temps, sous le givre naturel, la neige naturelle et artificielle, et dans des conditions artificielles simulant du brouillard verglaçant, de la bruine verglaçante, de la pluie verglaçante faible et de la pluie sur une aile imprégnée de froid. Un total de 531 essais ont été menés, avec dix liquides.

Parmi les changements apportés aux lignes directrices relatives aux durées d'efficacité pour l'hiver 2015-2016, on note ce qui suit :

- Des lignes directrices relatives aux durées d'efficacité spécifiques à trois nouveaux liquides, soit Kilfrost ABC-Ice Clear II (type II), Newave Aerochemical FCY-2 Bio+ (type II) et Deicing Solutions ECO-SHIELD (type IV), ont été ajoutées ;
- Des essais supplémentaires menés sur deux liquides, LNT Solutions P250 (type II) et LNT Solutions E450 (type IV), ont entraîné l'augmentation de leurs durées d'efficacité dans des conditions de neige ;
- Trois liquides, soit Clariant Safewing MP II 1951 (type II), ABAX AD-480 (type IV) et Kilfrost ABC-S (type IV) ont été retirés des lignes directrices, conformément au protocole régissant le retrait des données obsolètes ;
- À la suite du retrait de certains liquides et de l'ajout de nouveaux, six changements mineurs (des augmentations et des réductions pouvant aller jusqu'à 5 minutes) ont été apportés aux lignes directrices relatives aux durées d'efficacité génériques des liquides de type II ;
- À la suite du retrait de certains liquides et de l'ajout de nouveaux, des changements importants (principalement des augmentations) ont été apportés aux lignes directrices relatives aux durées d'efficacité génériques des liquides de type IV ;
- Des lignes directrices relatives aux durées d'efficacité spécifiques aux liquides, aux températures d'application et aux vitesses de rotation ont été ajoutées pour des liquides de type III, plus particulièrement pour les liquides Clariant Safewing MP III 2031 ECO (appliqué chauffé) et AllClear AeroClear MAX (appliqué non chauffé) ; et
- En raison des différentes exigences relatives aux températures d'application des deux liquides de type III, les lignes directrices relatives aux durées d'efficacité génériques des liquides de type III ont été retirées.

Il est recommandé que tout nouveau liquide de type I, de type II, de type III ou de type IV soit évalué pour toute la gamme des conditions couvertes par les tableaux des durées d'efficacité. Il est également recommandé que dans l'éventualité où un nouveau liquide de type III serait testé pour être appliqué lorsque chauffé, des essais supplémentaires soient menés dans le but d'évaluer les durées d'efficacité des liquides de type III appliqués chauffés sur des surfaces composites. Finalement, il est recommandé que des recherches supplémentaires soient menées afin d'évaluer les durées d'efficacité actuellement fournies pour les liquides de type II, de type III et de type IV dans des conditions de neige à des températures très froides.

17. Mots clés	18. Diffusion
Antigivrage, dégivrage, liquide de dégivrage, durées d'efficacité, précipitation, temps d'endurance, type I, type II, type III, type IV, aéronef, sol, essai, hiver	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada, with support from the Federal Aviation Administration (FAA), and several fluid manufacturers, APS Aviation Inc. (APS) has undertaken a testing and research program to further advance aircraft ground de/anti-icing technology. The program has a number of objectives, and work completed to address these objectives is documented in a series of related reports. The primary objective, the development of holdover time (HOT) guidelines for new de/anti-icing fluids, is addressed in this report. The objective was met by conducting holdover time tests with several de/anti-icing fluids. This report also documents changes made to the HOT guidelines for the winter of 2015-16.

Test Procedures

Test conditions, test parameters, and test bed specifications were determined based on the requirements of Aerospace Recommended Practice (ARP) 5485 and ARP5495, which were developed by the SAE International G-12 HOT Committee for Type II/III/IV and Type I fluids, respectively. The tests consisted of pouring freezing point depressant fluids onto clean, inclined (10°), standard flat aluminum plates. The plates were mounted on test stands and systematically exposed to a variety of natural or simulated icing conditions. For each plate, the elapsed time required to reach a predefined end condition was recorded.

The variables measured during testing included: failure time, type of precipitation, rate of precipitation, visibility, wind speed, wind direction, ambient temperature, test surface temperature, fluid brand, fluid type, and fluid concentration.

Data Collection and Testing

During the 2014-15 test season, data was collected during natural snow and natural frost events at the APS test site at Montreal-Trudeau Airport in Montreal and in simulated precipitation conditions (freezing drizzle, light freezing rain, freezing fog, rain on cold-soaked surface) at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

APS conducted 531 tests in the winter of 2014-15. The results of testing were incorporated into the winter 2015-16 HOT guidelines.

Changes to the HOT Guidelines

The changes below were made to the HOT guidelines for winter 2015-16.

1. Fluid-specific HOT guidelines were added for two new Type II fluids: Kilfrost ABC-Ice Clear II and Newave Aerochemical FCY-2 Bio+.
2. A fluid-specific HOT guideline was added for one new Type IV fluid: Deicing Solutions ECO-SHIELD.
3. Increases were made to snow holdover times for two fluids for which supplemental testing was conducted: LNT Solutions P250 (Type II) and LNT Solutions E450 (Type IV).
4. Clariant Safewing MP II 1951 (Type II), ABAX AD-480 (Type IV) and Kilfrost ABC-S (Type IV) were removed from the guidelines as per the protocol for removal of obsolete data.
5. Six minor changes (increases and decreases of up to 5 minutes) were made to the Type II generic HOT guidelines as a result of the addition of new and removed fluids.
6. Significant changes (primarily increases) were made to the Type IV generic HOT guidelines as a result of the new and removed fluids.
7. Fluid-specific HOT guidelines were added for Type III fluids. The Type III fluid-specific HOT guidelines are also application temperature and rotation speed specific. Low speed and high speed tables were added for Clariant Safewing MP III 2031 ECO (applied heated) and AllClear AeroClear MAX (applied unheated).
8. The Type III generic HOT guidelines were removed due to the different application temperature requirements of the two Type III fluids.

Recommendations

It is recommended that:

1. Any new Type I, Type II, Type III or Type IV fluids be evaluated over the entire range of conditions encompassed by the HOT tables;
2. If a new Type III fluid is submitted for heated application testing, further research be conducted to evaluate endurance times of Type III fluids applied heated to composite surfaces; and
3. Further research be completed to evaluate the current holdover times provided for Type II, III and IV fluids in snow at very cold temperatures.

SOMMAIRE

En vertu d'un contrat avec le Centre de développement des transports (CDT) de Transports Canada, avec l'appui de la Federal Aviation Administration (FAA) et de plusieurs fabricants de liquides, APS Aviation Inc. (APS) a entrepris des essais et un programme de recherches visant à approfondir la technologie de dégivrage et d'antigivrage d'aéronefs au sol. Le programme poursuivait plusieurs objectifs et les travaux effectués pour atteindre ces objectifs sont documentés dans une suite de rapports connexes. Le principal objectif, le développement de lignes directrices sur les durées d'efficacité (HOT) de nouveaux liquides de dégivrage et d'antigivrage, fait l'objet du présent rapport. Pour atteindre cet objectif, des essais sur les durées d'efficacité ont été menés avec plusieurs liquides de dégivrage et d'antigivrage. Le présent rapport documente également l'ensemble des changements apportés aux lignes directrices sur les durées d'efficacité pour l'hiver 2015-2016.

Procédures d'essai

Les conditions d'essai, les paramètres d'essai et les spécifications relatives au banc d'essai ont été déterminés en vertu des exigences des pratiques recommandées en aérospatiale ARP5485 et ARP5495, élaborées par le comité G-12 de la SAE International sur les durées d'efficacité pour les liquides de types II/III/IV et de type I, respectivement. Ces tests consistaient à verser des liquides abaisseurs du point de congélation sur des plaques en aluminium et en matériaux composites standards, plates, propres et inclinées (à 10°). Les plaques étaient montées sur un support d'essai et systématiquement exposées à une gamme de conditions de givrage, naturelles ou simulées. Pour chaque plaque, on notait le temps écoulé avant l'atteinte d'un état final prédéfini.

Parmi les variables mesurées dans le cadre de ces essais, on notait : temps de défaillance, type de précipitation, taux de précipitation, visibilité, vitesse du vent, direction du vent, température ambiante, température de la surface d'essai, marque de commerce du liquide, type de liquide et concentration du liquide.

Collecte de données et essais

Les données recueillies au cours de la saison d'essai 2014-2015 concernaient des tests sous neige naturelle et givre naturel menés à l'installation d'essai d'APS, à l'aéroport Montréal-Trudeau, à Montréal, de même que des essais effectués dans des conditions de précipitations simulées (bruine verglaçante, pluie verglaçante faible, brouillard verglaçant et pluie sur des surfaces imprégnées de froid) à l'installation de génie climatique du Conseil national de recherches du Canada (CNRC), à Ottawa.

Au cours de l'hiver 2014-2015, un total de 531 essais ont été menés par APS. Les résultats des essais effectués ont été inclus dans les lignes directrices relatives aux durées d'efficacité pour l'hiver 2015-2016.

Changements aux lignes directrices sur les durées d'efficacité

Les changements ci-dessous ont été apportés aux lignes directrices relatives aux durées d'efficacité pour l'hiver 2015-2016.

1. Des lignes directrices relatives aux durées d'efficacité spécifiques à deux nouveaux liquides de type II, soit Kilfrost ABC-Ice Clear II et Newave Aerochemical FCY-2 Bio+, ont été ajoutées.
2. Des lignes directrices relatives aux durées d'efficacité spécifiques à un nouveau liquide de type IV, Deicing Solutions ECO-SHIELD, ont été ajoutées.
3. Des essais supplémentaires menés sur deux liquides, LNT Solutions P250 (type II) et LNT Solutions E450 (type IV), ont entraîné l'augmentation de leurs durées d'efficacité dans des conditions de neige.
4. Les liquides Clariant Safewing MP II 1951 (type II), ABAX AD-480 (type IV) et Kilfrost ABC-S (type IV) ont été retirés des lignes directrices, conformément au protocole régissant le retrait des données obsolètes.
5. À la suite du retrait de certains liquides et de l'ajout de nouveaux, six changements mineurs (des augmentations et des réductions pouvant aller jusqu'à 5 minutes) ont été apportés aux lignes directrices relatives aux durées d'efficacité génériques des liquides de type II.
6. À la suite du retrait de certains liquides et de l'ajout de nouveaux, des changements importants (principalement des augmentations) ont été apportés aux lignes directrices relatives aux durées d'efficacité génériques des liquides de type IV.
7. Des lignes directrices relatives aux durées d'efficacité spécifiques aux liquides de type III ont été ajoutées. Ces lignes directrices relatives aux durées d'efficacité pour les liquides de type III sont également spécifiques à leurs températures d'application et aux vitesses de rotation. Des tableaux des durées d'efficacité à basse vitesse et à haute vitesse ont été ajoutés pour les liquides Clariant Safewing MP III 2031 ECO (appliqué chauffé) et AllClear AeroClear MAX (appliqué non chauffé).
8. En raison des différentes exigences relatives aux températures d'application des deux liquides de type III, les lignes directrices relatives aux durées d'efficacité génériques des liquides de type III ont été retirées.

Recommandations

Il est recommandé que :

1. Tout nouveau liquide de type I, de type II, de type III ou de type IV soit évalué pour toute la gamme des conditions couvertes par les tableaux des durées d'efficacité ;
2. Dans l'éventualité où un nouveau liquide de type III serait testé pour être appliqué lorsque chauffé, des essais supplémentaires soient menés dans le but d'évaluer les durées d'efficacité des liquides de type III appliqués chauffés sur des surfaces composites ; et
3. Des recherches supplémentaires soient menées afin d'évaluer les durées d'efficacité actuellement fournies pour les liquides de type II, de type III et de type IV dans des conditions de neige à des températures très froides.

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F Fluid Manufacturer Report: Newave Aerochemical FCY-2 Bio+ (Type II)

G Fluid Manufacturer Report: AllClear AeroClear MAX (Type III)

H Fluid Manufacturer Report: Deicing Solutions ECO-SHIELD® (Type IV)

I Fluid Manufacturer Report: LNT Solutions E450 (Type IV)

J Transport Canada and Federal Aviation Administration Holdover Time Guidelines, Winter 2015-2016

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L Addendum to Procedure: Test Requirements for Natural Precipitation Flat Plate Testing – Conduct HOT Testing in Northern Locations to Validate HOT Data at -25°C and Close to LOUT to Support Generic HOTs

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GLOSSARY

AMS	Aerospace Material Specification
APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
LOUT	Lowest Operational Use Temperature
LOWV	Lowest On-Wing Viscosity
LUPR	Lowest Usable Precipitation Rate
NRC	National Research Council Canada
SAE	SAE International
TDC	Transportation Development Centre
WSET	Water Spray Endurance Test

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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. Aircraft ground deicing had, until recently, never been researched and there is still an incomplete understanding of the hazard and of what can be done to reduce the risks posed by the operation of aircraft in winter precipitation conditions. This "winter operations contaminated aircraft – ground" program of research is aimed at overcoming this lack of knowledge.

Since the early 1990s, the Transportation Development Centre (TDC) of Transport Canada 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), several major airlines, and deicing fluid manufacturers. The TDC is continuing its research, development, testing and evaluation program.

Under contract to the TDC, with financial support from the FAA, APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology.

1.1 Background

APS has completed considerable testing related to de/anti-icing fluids on behalf of Transport Canada over the past two decades. Specifically, research has been conducted to determine fluid holdover times, to substantiate holdover time (HOT) tables, and to further the knowledge and development of deicing technology. A summary of the holdover time related research activities completed by APS is provided in Table 1.1.

1.2 Objectives

The primary objectives of the 2014-15 holdover time test program were to conduct flat plate tests under conditions of natural and simulated precipitation to determine de/anti-icing fluid endurance times for new fluids, to develop HOT guidelines based on samples of newly and previously qualified deicing and anti-icing fluids, and to document changes made to the HOT guidelines for the winter of 2015-16.

The detailed objectives of the 2014-15 test program are provided in the work statement excerpt in Appendix A.

Table 1.1: Summary of APS Holdover Time Testing Activities

Year	TDC Publication #	Conditions Tested	Fluids Tested	Test Locations
1990-91	TP 11206E	• Natural Precipitation (mostly snow)	• Type II (100%)	Mostly Montreal Worldwide
1991-92	TP 11454E	• Natural Precipitation (mostly snow)	• Type III (first gen)	Mostly Montreal St. John's
1992-93	TP 11836E	• Natural Snow • Simulated Freezing Drizzle (prelim) • Simulated Freezing Fog (outdoor) • Artificial Snow (prelim)	• Type I • Type II (100%) • Type III (first gen)	Montreal Ottawa (NRC) Rigaud
1993-94	TP 12915E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (outdoor)	• Primarily: Type II (dilutions) • Also: Type II (neat), Type I	Montreal Ottawa (NRC)
1994-95	TP 12654E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface (prelim)	• Type I • Type II • Type IV (prelim)	Montreal Ottawa (NRC)
1995-96	TP 12896E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	• Type I • Type II • Type IV	Montreal Ottawa (NRC)
1996-97	TP 13131E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	• Type I • Type II (100%) • Type III (first gen) • Type IV	Montreal Ottawa (NRC)
1997-98	TP 13318E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	• Type IV	Montreal Ottawa (NRC)
1998-99	TP 13477E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow	• Type I • Type II • Type IV (LV)	Montreal Ottawa (NRC)
1999-2000	TP 13659E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow • Preliminary Frost	• Type I • Type II • Type IV	Montreal Ottawa (NRC) Varennes (IREQ)

Table 1.1: Summary of APS Holdover Time Testing Activities (cont'd)

Year	TDC Publication #	Conditions Tested	Fluids Tested	Test Locations
2000-01	TP 13826E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow • Preliminary Frost	• Type I • Type II • Type IV	Montreal Ottawa (NRC) Varennes (IREQ)
2001-02	TP 13991E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow • Preliminary Frost	• Type I • Type II • Type IV	Montreal Ottawa (NRC) Val-d'Or North Bay Thompson
2002-03	TP 14144E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow • Preliminary Frost	• Type I • Type II • Type IV	Montreal Ottawa (NRC) Varennes (IREQ) St-Alexis
2003-04	TP 14374E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Natural Frost • Artificial Snow	• Type II • Type III	Montreal Ottawa (NRC) Val-d'Or Ste-Adele
2004-05	TP 14443E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Natural Frost	• Type II • Type III • Type IV	Montreal Ottawa (NRC)
2005-06	TP 14712E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Natural Frost • Ice Pellets / Mixed Conditions	• Type I • Type II • Type IV	Montreal Ottawa (NRC)
2006-07	TP 14776E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Natural Frost • Artificial Snow • Ice Pellets / Mixed Conditions	• Type I • Type II • Type IV	Montreal Ottawa (NRC)

Table 1.1: Summary of APS Holdover Time Testing Activities (cont'd)

Year	TDC Publication #	Conditions Tested	Fluids Tested	Test Locations
2007-08	TP 14869E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Natural Frost • Artificial Snow • Ice Pellets / Mixed Conditions • Snow Pellets	• Type II • Type III • Type IV	Montreal Ottawa (NRC)
2008-09	TP 14933E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Natural Frost • Ice Pellets / Mixed Conditions	• Type II • Type III • Type IV	Montreal Ottawa (NRC)
2009-10	TP 15050E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Ice Pellets / Mixed Conditions • Snow Pellets	• Type I • Type II • Type IV	Montreal Val-d'Or Dolbeau-Mistassini Thetford Mines St-Sauveur Ottawa (NRC)
2010-11	TP 15156E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow • Ice Pellets / Mixed Conditions	• Type I • Type II • Type IV	Montreal Ottawa (NRC)
2011-12	TP 15156E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow	• Type I • Type II • Type III	Montreal Gaspésie Rimouski St-Jovite Edmundston Ottawa (NRC)
2012-13	TP 15228E	• Natural Snow • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow	• Type I • Type II • Type III	Montreal Ottawa (NRC)
2013-14	TP 15271E	• Natural Snow/Frost • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow	• Type I • Type II • Type III • Type IV	Montreal Val-d'Or Timmins Kuujjuaq Ottawa (NRC)

Table 1.1: Summary of APS Holdover Time Testing Activities (cont'd)

Year	TDC Publication #	Conditions Tested	Fluids Tested	Test Locations
2014-15	TP 15321E	• Natural Snow/Frost • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Artificial Snow	• Type I • Type II • Type III • Type IV	Montreal Mirabel Morin Heights Beaconsfield Grand Prairie Ottawa (NRC)

1.3 Content of this Report

APS has written a report on the holdover time test program for each year it has been carried out. In 2003-04, the report was condensed to increase readability and to present the reader with, for the most part, only new and current information over the previous year's report.

Notably, the reader is now directed to Transport Canada report, TP 14144E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2002-03 Winter* (1), for the detailed test methodology and individual fluid test information is provided in appendices to the report rather than within the report itself.

In the winter of 2009-10, a decision was made to include detailed test information only for fluids that are expected to be qualified and commercialized. Test information for other fluids is not included.

1.4 Report Format

The subsequent sections of this report contain the following:

a) Section 2 summarizes 2014-15 testing;

b) Section 3 documents changes to the Type I HOT guidelines;

c) Section 4 documents changes to the Type II HOT guidelines;

d) Section 5 documents changes to the Type III HOT guidelines;

e) Section 6 documents changes to the Type IV HOT guidelines;

f) Section 7 documents changes to other HOT guidelines content;

g) Section 8 documents supplemental natural snow testing conducted at very low temperatures;

h) Section 9 presents conclusions derived from the test program; and

i) Section 10 lists recommendations for future testing.

1.5 Publication of HOT Guidelines

HOT guidelines are published annually by both Transport Canada and the FAA.

1.5.1 Transport Canada

The Transport Canada HOT guidelines are published on the following website:

- http://www.tc.gc.ca/eng/civilaviation/standards/commerce-holdovertime-menu-1877.htm

The Transport Canada HOT guidelines are intended to be used in conjunction with TP 14052E, *Guidelines for Aircraft Ground Icing Operations (Second Edition)* (2), which includes reference material related to ground icing operations. TP 14052E (2) is also available on the Transport Canada website.

1.5.2 FAA

The FAA HOT guidelines are published on the following website:

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

The FAA HOT guidelines are intended to be used in conjunction with the N 8900 series notice, *Revised FAA-Approved Deicing Program Updates, Winter 20xx-20xx* (3), which is published annually and provides additional guidance and reference material applicable to the current winter. The latest N 8900 series is also available on the FAA website.

2. TESTING IN 2014-15

An overview of the testing completed in the winter of 2014-15 is provided in this chapter.

2.1 Procedures

Test procedures for holdover time testing of Type II, III and IV fluids were developed in accordance with SAE International (SAE) Aerospace Recommended Practice (ARP) 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids: SAE Type II, III, and IV* (4). Test procedures for holdover time testing of Type I fluids were developed in accordance with ARP5945, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids: SAE Type I* (5).

Because this report serves as the publishing mechanism for the APS endurance time test program, all current endurance time test procedures are included in the report, even if they are not updated or used in a given year (for example, the Type I procedure is included even if no Type I fluids are tested). This is to ensure the most current procedure is available for reference.

The procedures valid for the 2014-15 winter are included in Appendix B. They include:

1. Test Requirements for Natural Precipitation Flat Plate Testing;
2. Determination of Endurance Times of Type I Fluids Under Natural Snow Precipitation at Dorval;
3. Test Requirements for Simulated Freezing Precipitation Flat Plate Testing; and
4. Overall Program of Tests at NRC, March/April 2015.

The first two procedures provide the detailed test methodology for natural snow testing. The third procedure provides the detailed test methodology for indoor simulated light freezing rain, freezing fog, freezing drizzle and rain on cold-soaked surface testing.

The fourth procedure was developed to coordinate holdover time testing and other aircraft ground icing research projects at the annual APS indoor simulated precipitation test session. Holdover time testing and other program element testing were conducted at the same session to maximize use of the facility and resources.

The endurance time test methodology is described in detail in the Transport Canada report, TP 14144E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2002-03 Winter* (1).

Over the winters of 2012-13 and 2013-14, two software projects were completed to improve the holdover time testing process.

1. A new interface was created for the freezing precipitation (indoor) rate management program. The new interface streamlines the process for measuring and managing precipitation rates in freezing precipitation.

2. An application was created to replace the paper-based end condition data form. It improves efficiency and accuracy in recording endurance times and adds new features to better manage the testing process.

Further details on these upgrades are provided in the Transport Canada report, TP 15269E, *Aircraft Ground Icing General Research Activities During the 2013-14 Winter* (6).

2.2 Test Sites

Simulated precipitation testing (freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surfaces) was conducted at the NRC Climatic Engineering Facility (CEF) in Ottawa.

Natural snow testing was conducted primarily at the APS test site at the Pierre Elliott Trudeau Airport in Montreal. Several tests were also conducted at remote locations using a mobile test site. The remote locations included Mirabel (Quebec), Morin Heights (Quebec), Beaconsfield (Quebec) and Grand Prairie (Alberta).

Artificial snow testing was required in the winter of 2014-15. It was conducted at the APS test site at the Montreal airport.

2.3 Fluids Tested

Ten fluids underwent endurance time testing in the winter of 2014-15. As described in Subsection 1.3, only the endurance time results of fluids that are expected to be commercialized are published in this report; the results of any other fluids that undergo testing are provided only to the fluid manufacturer(s).

Two Type I fluids were tested:

- Oksayd DEFROST ECO I: This new non-glycol Type I fluid underwent a complete set of testing in winter 2014-15 and is expected to be commercialized in future. The detailed test results are provided in Appendix C.

- Type I Experimental Fluid: A Type I experimental fluid was submitted for testing. This fluid will not be commercialized and therefore the detailed test results are not provided in this report.

Three Type II fluids were tested:

- Kilfrost ABC-Ice Clear II: This new Type II fluid underwent a complete set of testing in winter 2014-15 and is expected to be commercialized in future. The detailed test results are provided in Appendix D;

- LNT Solutions P250: This Type II fluid underwent a complete set of testing in winter 2013-14. Supplemental testing was conducted with the 50/50 dilution in the winter of 2014-15 to reduce its lowest usable precipitation rate (LUPR). The detailed test results are provided in Appendix E; and

- Newave Aerochemical FCY-2 Bio+: This new Type II fluid underwent a complete set of testing in winter 2014-15 and is expected to be commercialized in future. The detailed test results are provided in Appendix F.

Three Type III fluids were tested:

- AllClear AeroClear MAX: This new Type III fluid underwent endurance time testing in the winter of 2014-15 (100/0 only, no dilutions). The fluid was tested for use applied at ambient temperature. As it was submitted late in the season, very limited data was collected in natural snow and supplemental artificial snow testing was completed. The detailed test results are provided in Appendix G.

- Type III Experimental Fluid #1: A Type III experimental fluid was submitted for testing. This fluid will not be commercialized and therefore the detailed test results are not provided in this report.

- Type III Experimental Fluid #2: A second Type III experimental fluid was submitted for testing. This fluid was briefly commercialized in Canada at the end of winter 2014-15. However, as it will not be commercialized in future, the detailed test results are not provided in this report.

Two Type IV fluids were tested:

- Deicing Solutions ECO-SHIELD: This new Type IV fluid underwent testing in winter 2014-15 (100/0 fluid only) and is expected to be commercialized in future. The detailed test results are provided in Appendix H; and

- LNT Solutions E450: This Type II fluid underwent endurance time testing in winter 2013-14; however, natural snow testing was not completed due to the late submission of the fluid. Natural snow testing was therefore completed in the winter of 2014-15. The detailed test results from both winters are provided in Appendix I.

Additional relevant fluid receipt data for the commercialized fluids is provided in Table 2.1 (fluid receipt data) and Table 2.2 (fluid characteristic data).

Table 2.1: Fluid Receipt Data (Commercialized Fluids)

Fluid Manufacturer	Fluid Name	Fluid Type	Fluid Formulation	Date Received	Batch #	Dilutions Received (%)
Oksayd	DEFROST ECO I	I	Non Glycol	27-Feb-15	10	Concentrate
Kilfrost	ABC-Ice Clear II	II	Propylene Glycol	19-Feb-15	X/1/2/15	100, 75, 50
Newave Aerochemical	FCY-2 Bio+	II	Propylene Glycol	22-Jan-15	201412012 LS	100, 75, 50
LNT Solutions	P250	II	Propylene Glycol	12-Mar-14	C3/01/01	100, 75, 50
AllClear	AeroClear MAX	III	Ethylene Glycol	21-Mar-15	CB1-PB8000A	100
Deicing Solutions	ECO-SHIELD	IV	Propylene Glycol	24-Dec-14	141223D-CC	100
LNT Solutions	E450	IV	Ethylene Glycol	10-Apr-14	F4003 / 003/14	100, 75, 50

Table 2.2: Fluid Characteristic Data (Commercialized Fluids)

Fluid	Fluid Dil.	Brix (Measured)	WSET (mins)	Freeze Point (Stated, °C)	Aerodynamic LOUT (Stated, °C)	Viscosity (Measured, mPa.s)	
						Mfr. Method	AS9968 Method
Oksayd DEFROST ECO I	Conc.	44.75°	3.4	-23 (50/50) -34 (60/40) -46 (70/30)	-36[1]	n/a	n/a
Kilfrost ABC-Ice Clear II	100/0	35.5°	53	-37.0	-29.5	7,720[2]	7,720[2]
	75/25	28.5°	n/a	-21.7	-19.5	5,660[2]	5,660[2]
	50/50	19.25°	n/a	-11.1	-9.0	580[2]	558[3]
Newave Aerochemical FCY-2 Bio+	100/0	36.25°	77	-37.2	-28.5	7,210[2]	7,210[2]
	75/25	28.5°	n/a	-22.6	-19.5	21,400[4]	21,400[4]
	50/50	19.2°	n/a	-9.0	-9.0	1,900[2]	1,900[2]
LNT Solutions P250	100/0	36.25	78	not provided	not provided	2,400[5]	2,150[2]
	75/25	28.25	n/a			16,200[5]	15,200[2]
	50/50	19.25	n/a			8,150[5]	8,100[2]
AllClear AeroClear MAX	100/0	34.0°	18	-44.0	-16.0/-35.5[6]	7,300[7]	n/a
Deicing Solutions ECO-SHIELD	100/0	35.75	86	not provided	not provided	1,900[2]	1,900[2]
LNT Solutions E450	100/0	33.5	85	not provided	not provided	45,300[8]	n/a[9]
	75/25	26.0	n/a			16,000[8]	n/a[9]
	50/50	17.75	n/a			2,600[8]	n/a[9]

1 High speed ramp (70/30 dilution)
2 Spindle LV1 with guard leg, 600 mL low form beaker, ~575 mL of fluid, 20°C, 0.3 r/min, for 10.0 minutes
3 Spindle LV0, ULA, 16 mL, 20°C, 0.3 r/min, for 10.0 mins
4 Spindle LV2-disc with guard leg, 600 mL low form beaker, ~425 mL of fluid, 20°C, 0.3 r/min, for 10.0 minutes
5 Spindle LV2-disc with guard leg, 200 mL tall form beaker, ~155 mL of fluid, 20°C, 0.3 r/min, for 10.0 minutes
6 Low speed/high speed ramp
7 Spindle SC4-31, small sample adapter, 9 mL, 0°C, 0.3 r/min, for 30.0 mins
8 Spindle SC4-31, small sample adapter, 9 mL of fluid, 0°C, 0.3 r/min, for 10.0 minutes
9 Not available: stable, reliable results could not be measured using the AIR 9968 method

2.4 Description of Tests

In total, 531 endurance time tests were conducted during the winter of 2014-15. A summary of the total number of tests conducted is shown by precipitation condition in Table 2.3. Details for each test are included in the detailed reports provided to the manufacturers (see Subsection 2.5).

Table 2.3: Summary of Tests Conducted

Precipitation Condition	Tests Conducted
Natural Snow	211
Artificial Snow	34
Freezing Fog	100
Freezing Drizzle	72
Light Freezing Rain	64
Rain on Cold-Soaked Surface	32
Natural Frost	18
Total	**531**

2.5 Reporting

A comprehensive report was created for each fluid tested to document its performance in detail. These reports were provided to the fluid manufacturers. As per Subsection 1.3, copies of the reports for fluids which are expected to be qualified/commercialized have been included as appendices to this report. The relevant reports can be found in Appendices C, D, E, F, G, H and I.

2.6 Supplemental Testing – Very Cold Snow Research

Supplemental endurance time testing was conducted in snow at very cold temperatures in the winter of 2014-15. This research is documented in Section 8.

3. CHANGES TO THE TYPE I HOT GUIDELINES

Changes made to the Type I HOT guidelines for the winter of 2015-16 are documented in this chapter. The Transport Canada and FAA 2015-16 Type I HOT guidelines are included in Appendix J.

3.1 New Fluids/Data

A significant body of previous research and testing has indicated that all Type I fluids formulated with glycol perform in a similar manner from an endurance time perspective. As a result, regulators no longer require Type I deicing fluids formulated with propylene glycol, ethylene glycol or diethylene glycol to undergo endurance time testing. However, they do require testing of fluids formulated with other glycol bases or with non-glycol bases. This is to ensure the endurance time performance of these fluids is similar to that of the Type I fluids used to generate the current Type I holdover times.

Oksayd Defrost ECO I, a new non-glycol based Type I fluid, underwent testing in the winter of 2014-15. It performed similarly to Type I fluids tested in past years and therefore it was concluded it could be used with the generic Type I HOT guidelines. The detailed test results of testing with this fluid are provided in Appendix C.

3.2 Changes to HOT Guidelines Format

No changes were made to the format of the Type I HOT guidelines for winter 2015-16.

3.3 Type I Generic Holdover Time Values

No changes were made to the Type I generic holdover times for the winter of 2015-16.

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4. CHANGES TO THE TYPE II HOT GUIDELINES

Changes made to the Type II HOT guidelines for the winter of 2015-16 are documented in this chapter. The Transport Canada and FAA 2015-16 Type II HOT guidelines are included in Appendix J.

4.1 New Fluids/Data

Two new Type II fluids were added to the HOT guidelines for the winter of 2015-16: **Kilfrost ABC-Ice Clear II and Newave Aerochemical FCY-2 Bio+**. These fluids underwent endurance time testing in the winter of 2014-15.

In addition, supplemental natural snow testing was conducted with existing fluid **LNT Solutions P250** (50/50 dilution only). This testing was conducted to reduce the lowest usable precipitation rate (LUPR).

The detailed results of testing with these fluids are provided in Appendices D (ABC-Ice Clear II), E (P250), and F (FCY-2 Bio+).

4.2 Removed Fluids/Data

The protocol for removing obsolete holdover time data is given in ARP5718, *Qualification Process for SAE AMS1428 Type II, III, and IV Fluids* (7). As per the protocol, Clariant Safewing MP II 1951 was removed from the HOT guidelines for the winter of 2015-16. Although this fluid did not have a fluid-specific HOT table, its data was included in the generic Type II analysis and its removal did lead to changes in the generic Type II holdover times (see Subsection 4.4.1).

4.3 Changes to HOT Guidelines Format

No changes were made to the format of the Type II HOT Guidelines for winter 2015-16.

4.4 Type II Generic Holdover Time Values

The generic HOT guidelines for Type II fluid were developed prior to 1996-97 based on the results of endurance time tests with "grandfathered" fluids. Since 1999-2000, fluid-specific holdover times have been developed for each new Type II fluid tested,

and the generic Type II holdover times have been generated each year by taking the shortest holdover times of:

1. All fluids on the Transport Canada and FAA list of Type II fluids;

2. The "grandfathered" fluid data (included to account for the performance of grandfathered fluids which do not have fluid-specific holdover time data available, i.e. Kilfrost ABC-3); and

3. All fluids on the Transport Canada and FAA list of Type IV fluids (included because all Type IV fluids also qualify as Type II fluids).

It should be noted that the Transport Canada and FAA list of fluids contains fluids whose qualifications have recently expired (i.e. within four years). Fluids are only removed from the generic analysis when they are removed from the Transport Canada and FAA list.

4.4.1 Use of Generic Holdover Times in Very Cold Snow

Following the winter of 2003-04, a decision was made that fluid-specific holdover times would not be provided for Type II fluids in snow at temperatures below -14°C. This was due to the limited data that exits for most fluids at these temperatures. Instead, all Type II fluids are given pre-established "generic" holdover times in very cold snow. These holdover times were determined based on historical data and analysis.

4.4.2 Impact of New and Removed Fluids/Data

The addition of the new and removed Type II fluid/data led to six changes (increases and decreases of up to five minutes) to the Type II generic holdover times.

4.4.3 Fluids Responsible for Type II Generic Holdover Time Values

The fluids responsible for the values in the generic Type II HOT guidelines in 2015-16 are shown in Table 4.1. "Grandfather" is indicated where "grandfathered" fluids are responsible for times in the cells. "Type IV" is indicated where Type IV fluids are responsible for times in the cells. A "U" indicates the fluid is responsible for the upper value in the cell, an "L" indicates the fluid is responsible for the lower value in the cell, and a "B" indicates the fluid is responsible for both the upper and lower values in the cell.

Due to space limitations, the following abbreviations are used in the table:

- ABAX Ecowing 26 (A-E26);
- Clariant Safewing MP II Flight (C-Flight);
- Kilfrost ABC-Ice Clear II (K-ABC-IC);
- Kilfrost ABC-K Plus (K-ABC-K+);
- Newave Aerochemical FCY-2 (N-FCY-2); and
- Newave Aerochemical FCY-2 Bio+ (N-FCY-2B).

Table 4.1: Fluids Responsible for Type II Generic Holdover Time Values

OAT		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)				
°C	°F		Freezing Fog	Snow	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing
-3 and above	27 and above	100/0	Grandfather **(B)**	Grandfather **(B)**	Grandfather **(B)**	Grandfather **(B)**	K-ABC-IC **(L)** Grandfather **(U)**
		75/25	Grandfather **(B)**	Grandfather **(B)**	Grandfather **(B)** N-FCY-2 **(U)** K-ABC-IC **(U)**	Grandfather **(B)** N-FCY-2 **(U)** N-FCY-2B **(U)**	Grandfather **(B)** N-FCY-2 **(B)** K-ABC-IC **(L)**
		50/50	K-ABC-IC **(B)** N-FCY-2B **(B)** Grandfather **(L)**	Grandfather **(B)** K-ABC-K + **(U)** K-ABC-IC **(U)** N-FCY-2B **(U)** Type IV **(U)**	Grandfather **(B)** K-ABC-IC **(B)** N-FCY-2 **(B)** N-FCY-2B **(B)**	Grandfather **(B)** A-E26 **(U)** K-ABC-IC **(U)** N-FCY-2 **(U)** N-FCY-2B **(U)**	
below -3 to -14	below 27 to 7	100/0	Type IV **(L)** K-ABC-K + **(U)**	N-FCY-2 **(B)** N-FCY-2B **(B)** Grandfather **(L)**	N-FCY-2 **(B)**	Grandfather **(L)** N-FCY-2 **(U)**	
		75/25	Type IV **(B)** Grandfather **(L)** K-ABC-K + **(L)** C-Flight **(L)**	N-FCY-2B **(B)** N-FCY-2 **(U)**	N-FCY-2 **(B)** Type IV **(L)**	N-FCY-2 **(B)**	
below -14 to LOUT	below 7 to LOUT	100/0	Type IV **(L)** N-FCY-2 **(U)**	Historic Generic **(B)** Grandfather **(B)**			

LEGEND	L = DRIVES LOWER LIMIT U = DRIVES UPPER LIMIT B = DRIVES BOTH

4.4.4 Evolution of Type II Generic Holdover Time Values

The history of Type II fluid testing and the evolution of the fluid-specific and generic Type II holdover time values are illustrated in Tables 4.2 to 4.25. Each table represents one cell in the HOT guidelines and the title of the table links the table to the appropriate cell. Fluids that are no longer used in the generic analysis (see Subsection 4.2) are not included.

The first row in each table contains the generic values from testing in 1998-99, also known as the "grandfathered" fluid data. Each subsequent set of two rows represents a winter test season and the subsequent winter's HOT table values. The final line contains the generic and fluid-specific holdover time values for use in 2015-16 winter operations.

Underlined values indicate the fluid or fluids responsible for the generic holdover time. If the value in the first row is underlined, it indicates that the generic value is based on the "grandfathered" fluid data set.

Strikethrough values indicate endurance time test results that are not valid; this is typically a result of testing in multiple years (details are usually provided in the HOT report written in the most recent year the fluid underwent testing).

Due to space limitations, the following abbreviations are used in the tables:

- ABAX Ecowing 26 (A-E26);
- Aviation Shaanxi Hi-tech Cleanwing II (AS CII);
- Clariant Safewing MP II Flight (C-Flight);
- Clariant Safewing MP II Flight Plus (C-Flight+);
- Cryotech Polar Guard II (CR-PGII);
- Kilfrost ABC-Ice Clear II (K-ABC-IC);
- Kilfrost ABC-K Plus (K-ABC-K+);
- LNT Solutions P250 (L-P250);
- Newave Aerochemical FCY-2 (N-FCY-2); and
- Newave Aerochemical FCY-2 Bio+ (N-FCY-2B).

Table 4.2: Type II Neat Fluid, Snow, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:20-0:45										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:20-0:45										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:20-0:45										
2000-01 ET Test Results		0:40-1:00									
2001-02 HOT Table Values	0:20-0:45	0:40-1:00									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:20-0:45	0:40-1:00									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:20-0:45	0:40-1:00									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:20-0:45	0:40-1:00									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:20-0:45	0:40-1:00									
2005-06 ET Test Results			1:00-1:35								
2006-07 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35								
2006-07 ET Test Results				0:30-0:55							
2007-08 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35	0:30-0:55							
2007-08 ET Test Results					1:00-1:40						
2008-09 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35	0:30-0:55	1:00-1:40						
2008-09 ET Test Results						0:30-0:55					
2009-10 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35	0:30-0:55	1:00-1:40	0:30-0:55					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35	0:30-0:55	1:00-1:40	0:30-0:55					
2010-11 ET Test Results								1:20-1:50			
2011-12 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35	0:30-0:55	1:00-1:40	0:30-0:55					
2011-12 ET Test Results							~~1:05-2:00~~				
2012-13 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35	0:30-0:55	1:00-1:40	0:30-0:55	1:05-2:00				
2012-13 ET Test Results							0:50-1:50				
2013-14 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35	0:30-0:55	1:00-1:40	0:30-0:55	0:50-1:50	1:20-1:50			
2013-14 ET Test Results									0:55-1:45		
2014-15 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35	0:30-0:55	1:00-1:40	0:30-0:55	0:50-1:50	1:20-1:50	0:55-1:45		
2014-15 ET Test Results										0:25-0:50	0:30-1:05
2015-16 HOT Table Values	0:20-0:45	0:40-1:00	1:00-1:35	0:30-0:55	1:00-1:40	0:30-0:55	0:50-1:50	1:20-1:50	0:55-1:45	0:25-0:50	0:30-1:05

Table 4.3: Type II 75/25 Fluid, Snow, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:15-0:30										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:15-0:30										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:15-0:30										
2000-01 ET Test Results		0:25-0:45									
2001-02 HOT Table Values	0:15-0:30	0:25-0:45									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:15-0:30	0:25-0:45									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:15-0:30	0:25-0:45									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:15-0:30	0:25-0:45									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:15-0:30	0:25-0:45									
2005-06 ET Test Results			0:40-1:20								
2006-07 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20								
2006-07 ET Test Results				0:20-0:40							
2007-08 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20	0:20-0:40							
2007-08 ET Test Results					0:35-1:10						
2008-09 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20	0:20-0:40	0:35-1:10						
2008-09 ET Test Results						0:25-0:45					
2009-10 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20	0:20-0:40	0:35-1:10	0:25-0:45					
2009-10 ET Test Results			~~1:00-2:00~~								
2010-11 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20	0:20-0:40	0:35-1:10	0:25-0:45					
2010-11 ET Test Results								0:45-1:20			
2011-12 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20	0:20-0:40	0:35-1:10	0:25-0:45					
2011-12 ET Test Results							~~0:55-1:35~~				
2012-13 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20	0:20-0:40	0:35-1:10	0:25-0:45	0:55-1:35				
2012-13 ET Test Results							1:00-1:45				
2013-14 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20	0:20-0:40	0:35-1:10	0:25-0:45	1:00-1:45	0:45-1:20			
2013-14 ET Test Results									0:45-1:25		
2014-15 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20	0:20-0:40	0:35-1:10	0:25-0:45	1:00-1:45	0:45-1:20	0:45-1:25		
2014-15 ET Test Results										0:20-0:40	0:20-0:40
2015-16 HOT Table Values	0:15-0:30	0:25-0:45	0:40-1:20	0:20-0:40	0:35-1:10	0:25-0:45	1:00-1:45	0:45-1:20	0:45-1:25	0:20-0:40	0:20-0:40

Table 4.4: Type II 50/50 Fluid, Snow, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:05-0:15										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:05-0:15										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:05-0:15										
2000-01 ET Test Results		0:10-0:20									
2001-02 HOT Table Values	0:05-0:15	0:10-0:20									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:05-0:15	0:10-0:20									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:05-0:15	0:10-0:20									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:05-0:15	0:10-0:20									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:05-0:15	0:10-0:20									
2005-06 ET Test Results			0:10-0:25								
2006-07 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25								
2006-07 ET Test Results				0:15-0:25							
2007-08 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25	0:15-0:25							
2007-08 ET Test Results					0:07-0:15						
2008-09 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25	0:15-0:25	0:05-0:15						
2008-09 ET Test Results						0:15-0:30					
2009-10 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25	0:15-0:25	0:05-0:15	0:15-0:30					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25	0:15-0:25	0:05-0:15	0:15-0:30					
2010-11 ET Test Results								0:15-0:35			
2011-12 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25	0:15-0:25	0:07-0:15	0:15-0:30					
2011-12 ET Test Results							0:15-0:25				
2012-13 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25	0:15-0:25	0:07-0:15	0:15-0:30	0:15-0:25				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25	0:15-0:25	0:07-0:15	0:15-0:30	0:15-0:25	0:15-0:35			
2013-14 ET Test Results									~~0:15-0:30~~		
2014-15 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25	0:15-0:25	0:07-0:15	0:15-0:30	0:15-0:25	0:15-0:35	0:15-0:30		
2014-15 ET Test Results									0:15-0:30	0:08-0:15	0:08-0:15
2015-16 HOT Table Values	0:05-0:15	0:10-0:20	0:10-0:25	0:15-0:25	0:07-0:15	0:15-0:30	0:15-0:25	0:15-0:35	0:15-0:30	0:08-0:15	0:08-0:15

Table 4.5: Type II Neat Fluid, Snow, Below -3°C to -14°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:15-0:40										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:15-0:35										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:15-0:35										
2000-01 ET Test Results		0:35-0:55									
2001-02 HOT Table Values	0:15-0:35	0:35-0:55									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:15-0:35	0:35-0:55									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:15-0:35	0:35-0:55									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:15-0:35	0:35-0:55									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:15-0:35	0:35-0:55									
2005-06 ET Test Results			0:40-1:05								
2006-07 HOT Table Values	0:15-0:35	0:35-0:55	0:40-1:05								
2006-07 ET Test Results				0:15-0:30							
2007-08 HOT Table Values	0:15-0:30	0:35-0:55	0:40-1:05	0:15-0:30							
2007-08 ET Test Results					0:50-1:25						
2008-09 HOT Table Values	0:15-0:30	0:35-0:55	0:40-1:05	0:15-0:30	0:50-1:25						
2008-09 ET Test Results						0:30-0:55					
2009-10 HOT Table Values	0:15-0:30	0:35-0:55	0:40-1:05	0:15-0:30	0:50-1:25	0:30-0:55					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:15-0:30	0:35-0:55	0:40-1:05	0:15-0:30	0:50-1:25	0:30-0:55					
2010-11 ET Test Results								0:55-1:15			
2011-12 HOT Table Values	0:15-0:30	0:35-0:55	0:40-1:05	0:15-0:30	0:50-1:25	0:30-0:55					
2011-12 ET Test Results							~~0:15-0:30~~				
2012-13 HOT Table Values	0:15-0:30	0:35-0:55	0:40-1:05	0:15-0:30	0:50-1:25	0:30-0:55	0:15-0:30				
2012-13 ET Test Results							0:35-1:15				
2013-14 HOT Table Values	0:15-0:30	0:35-0:55	0:40-1:05	0:15-0:30	0:50-1:25	0:30-0:55	0:35-1:15	0:55-1:15			
2013-14 ET Test Results									0:50-1:40		
2014-15 HOT Table Values	0:15-0:30	0:35-0:55	0:40-1:05	0:15-0:30	0:50-1:25	0:30-0:55	0:35-1:15	0:55-1:15	0:50-1:40		
2014-15 ET Test Results										0:20-0:35	0:15-0:30
2015-16 HOT Table Values	0:15-0:30	0:35-0:55	0:40-1:05	0:15-0:30	0:50-1:25	0:30-0:55	0:35-1:15	0:55-1:15	0:50-1:40	0:20-0:35	0:15-0:30

Table 4.6: Type II 75/25 Fluid, Snow, Below -3°C to -14°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:15-0:30										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:15-0:25										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:15-0:25										
2000-01 ET Test Results		0:25-0:40									
2001-02 HOT Table Values	0:15-0:25	0:25-0:40									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:15-0:25	0:25-0:40									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:15-0:25	0:25-0:40									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:15-0:25	0:25-0:40									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:15-0:25	0:25-0:40									
2005-06 ET Test Results			0:20-0:40								
2006-07 HOT Table Values	0:15-0:25	0:25-0:40	0:20-0:40								
2006-07 ET Test Results				0:10-0:20							
2007-08 HOT Table Values	0:10-0:20	0:25-0:40	0:20-0:40	0:10-0:20							
2007-08 ET Test Results					0:35-1:05						
2008-09 HOT Table Values	0:10-0:20	0:25-0:40	0:20-0:40	0:10-0:20	0:35-1:05						
2008-09 ET Test Results						0:25-0:45					
2009-10 HOT Table Values	0:10-0:20	0:25-0:40	0:20-0:40	0:10-0:20	0:35-1:05	0:25-0:45					
2009-10 ET Test Results			~~1:00-2:00~~								
2010-11 HOT Table Values	0:10-0:20	0:25-0:40	0:20-0:40	0:10-0:20	0:35-1:05	0:25-0:45					
2010-11 ET Test Results								0:35-1:00			
2011-12 HOT Table Values	0:10-0:20	0:25-0:40	0:20-0:40	0:10-0:20	0:35-1:05	0:25-0:45					
2011-12 ET Test Results							~~0:10-0:20~~				
2012-13 HOT Table Values	0:10-0:20	0:25-0:40	0:20-0:40	0:10-0:20	0:35-1:05	0:25-0:45	0:10-0:20				
2012-13 ET Test Results							0:55-1:40				
2013-14 HOT Table Values	0:10-0:20	0:25-0:40	0:20-0:40	0:10-0:20	0:35-1:05	0:25-0:45	0:55-1:40	0:35-1:00			
2013-14 ET Test Results									0:45-1:25		
2014-15 HOT Table Values	0:10-0:20	0:25-0:40	0:20-0:40	0:10-0:20	0:35-1:05	0:25-0:45	0:55-1:40	0:35-1:00	0:45-1:25		
2014-15 ET Test Results										0:15-0:25	0:08-0:20
2015-16 HOT Table Values	0:08-0:20	0:25-0:40	0:20-0:40	0:10-0:20	0:35-1:05	0:25-0:45	0:55-1:40	0:35-1:00	0:45-1:25	0:15-0:25	0:08-0:20

Table 4.7: Type II Neat Fluid, Snow, Below -14°C to -25°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:15-0:30										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:15-0:30										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:15-0:30										
2000-01 ET Test Results		0:30-0:50									
2001-02 HOT Table Values	0:15-0:30	0:30-0:50									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:15-0:30	0:30-0:50									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:15-0:30	0:30-0:50									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:15-0:30	0:15-0:30*									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:15-0:30	0:15-0:30*									
2005-06 ET Test Results											
2006-07 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*								
2006-07 ET Test Results											
2007-08 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*							
2007-08 ET Test Results											
2008-09 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*						
2008-09 ET Test Results											
2009-10 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*					
2010-11 ET Test Results											
2011-12 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*					
2011-12 ET Test Results											
2012-13 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*			
2013-14 ET Test Results											
2014-15 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*		
2014-15 ET Test Results											
2015-16 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*

*Generic HOT values used in this cell

Table 4.8: Type II Neat Fluid, Freezing Drizzle, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:30-1:00										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:30-1:00										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:30-0:55										
2000-01 ET Test Results		0:50-1:35									
2001-02 HOT Table Values	0:30-0:55	0:50-1:35									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:30-0:55	0:50-1:35									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:30-0:55	0:50-1:35									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:30-0:55	0:50-1:35									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:30-0:55	0:50-1:35									
2005-06 ET Test Results			1:20-2:00								
2006-07 HOT Table Values	0:30-0:55	0:50-1:35	1:20-2:00								
2006-07 ET Test Results				0:35-1:05							
2007-08 HOT Table Values	0:30-0:55	0:50-1:35	1:20-2:00	0:35-1:05							
2007-08 ET Test Results					1:50-2:00						
2008-09 HOT Table Values	0:30-0:55	0:50-1:35	1:20-2:00	0:35-1:05	1:50-2:00						
2008-09 ET Test Results						0:35-1:05					
2009-10 HOT Table Values	0:30-0:55	0:50-1:35	1:20-2:00	0:35-1:05	1:50-2:00	0:35-1:05					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:30-0:55	0:50-1:35	1:20-2:00	0:35-1:05	1:50-2:00	0:35-1:05					
2010-11 ET Test Results								1:35-2:00			
2011-12 HOT Table Values	0:30-0:55	0:50-1:35	1:20-2:00	0:35-1:05	1:50-2:00	0:35-1:05					
2011-12 ET Test Results							1:25-2:00				
2012-13 HOT Table Values	0:30-0:55	0:50-1:35	1:20-2:00	0:35-1:05	1:50-2:00	0:35-1:05	1:25-2:00				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:30-0:55	0:50-1:35	1:20-2:00	0:35-1:05	1:50-2:00	0:35-1:05	1:25-2:00	1:35-2:00			
2013-14 ET Test Results									1:35-2:00		
2014-15 HOT Table Values	0:30-0:55	0:50-1:35	1:20-2:00	0:35-1:05	1:50-2:00	0:35-1:05	1:25-2:00	1:35-2:00	1:35-2:00		
2014-15 ET Test Results										0:40-1:05	0:50-1:20
2015-16 HOT Table Values	0:30-1:00	0:50-1:35	1:20-2:00	0:35-1:05	1:50-2:00	0:35-1:05	1:25-2:00	1:35-2:00	1:35-2:00	0:40-1:05	0:50-1:20

Table 4.9: Type II 75/25 Fluid, Freezing Drizzle, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:20-0:45										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:20-0:45										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:20-0:45										
2000-01 ET Test Results		0:45-1:05									
2001-02 HOT Table Values	0:20-0:45	0:45-1:05									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:20-0:45	0:45-1:05									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:20-0:45	0:45-1:05									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:20-0:45	0:45-1:05									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:20-0:45	0:45-1:05									
2005-06 ET Test Results			~~1:15-2:00~~								
2006-07 HOT Table Values	0:20-0:45	0:45-1:05	1:15-2:00								
2006-07 ET Test Results				0:25-0:45							
2007-08 HOT Table Values	0:20-0:45	0:45-1:05	1:15-2:00	0:25-0:45							
2007-08 ET Test Results					1:25-2:00						
2008-09 HOT Table Values	0:20-0:45	0:45-1:05	1:15-2:00	0:25-0:45	1:25-2:00						
2008-09 ET Test Results						0:35-1:00					
2009-10 HOT Table Values	0:20-0:45	0:45-1:05	1:15-2:00	0:25-0:45	1:25-2:00	0:35-1:00					
2009-10 ET Test Results			1:10-1:30								
2010-11 HOT Table Values	0:20-0:45	0:45-1:05	1:10-1:30	0:25-0:45	1:25-2:00	0:35-1:00					
2010-11 ET Test Results								1:40-2:00			
2011-12 HOT Table Values	0:20-0:45	0:45-1:05	1:10-1:30	0:25-0:45	1:25-2:00	0:35-1:00					
2011-12 ET Test Results							1:35-2:00				
2012-13 HOT Table Values	0:20-0:45	0:45-1:05	1:10-1:30	0:25-0:45	1:25-2:00	0:35-1:00	1:35-2:00				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:20-0:45	0:45-1:05	1:10-1:30	0:25-0:45	1:25-2:00	0:35-1:00	1:35-2:00	1:40-2:00			
2013-14 ET Test Results									1:20-1:35		
2014-15 HOT Table Values	0:20-0:45	0:45-1:05	1:10-1:30	0:25-0:45	1:25-2:00	0:35-1:00	1:35-2:00	1:40-2:00	1:20-1:35		
2014-15 ET Test Results										0:30-0:45	0:25-0:50
2015-16 HOT Table Values	0:20-0:45	0:45-1:05	1:10-1:30	0:25-0:45	1:25-2:00	0:35-1:00	1:35-2:00	1:40-2:00	1:20-1:35	0:30-0:45	0:25-0:50

Table 4.10: Type II 50/50 Fluid, Freezing Drizzle, -3ºC and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:10-0:20										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:05-0:20										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:05-0:15										
2000-01 ET Test Results		0:15-0:25									
2001-02 HOT Table Values	0:05-0:15	0:15-0:25									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:05-0:15	0:15-0:25									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:05-0:15	0:15-0:25									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:05-0:15	0:15-0:25									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:05-0:15	0:15-0:25									
2005-06 ET Test Results			0:20-0:30								
2006-07 HOT Table Values	0:05-0:15	0:15-0:25	0:20-0:30								
2006-07 ET Test Results				0:10-0:20							
2007-08 HOT Table Values	0:05-0:15	0:15-0:25	0:20-0:30	0:10-0:20							
2007-08 ET Test Results					0:20-0:30						
2008-09 HOT Table Values	0:05-0:15	0:15-0:25	0:20-0:30	0:10-0:20	0:20-0:30						
2008-09 ET Test Results						0:20-0:40					
2009-10 HOT Table Values	0:05-0:15	0:15-0:25	0:20-0:30	0:10-0:20	0:20-0:30	0:20-0:40					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:05-0:15	0:15-0:25	0:20-0:30	0:10-0:20	0:20-0:30	0:20-0:40					
2010-11 ET Test Results								0:20-0:45			
2011-12 HOT Table Values	0:08-0:15	0:15-0:25	0:20-0:30	0:10-0:20	0:20-0:30	0:20-0:40					
2011-12 ET Test Results							0:30-1:05				
2012-13 HOT Table Values	0:08-0:15	0:15-0:25	0:20-0:30	0:10-0:20	0:20-0:30	0:20-0:40	0:30-1:05				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:08-0:15	0:15-0:25	0:20-0:30	0:10-0:20	0:20-0:30	0:20-0:40	0:30-1:05	0:20-0:45			
2013-14 ET Test Results									0:20-0:35		
2014-15 HOT Table Values	0:08-0:15	0:15-0:25	0:20-0:30	0:10-0:20	0:20-0:30	0:20-0:40	0:30-1:05	0:20-0:45	0:20-0:35		
2014-15 ET Test Results										0:10-0:20	0:10-0:20
2015-16 HOT Table Values	0:10-0:20	0:15-0:25	0:20-0:30	0:10-0:20	0:20-0:30	0:20-0:40	0:30-1:05	0:20-0:45	0:20-0:35	0:10-0:20	0:10-0:20

Table 4.11: Type II Neat Fluid, Freezing Drizzle, Below -3°C to -10°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:30-1:00										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:15-0:45										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:15-0:45										
2000-01 ET Test Results		0:30-1:10									
2001-02 HOT Table Values	0:15-0:45	0:30-1:10									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:15-0:45	0:30-1:10									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:15-0:45	0:30-1:10									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:15-0:45	0:30-1:10									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:15-0:45	0:30-1:10									
2005-06 ET Test Results			0:35-1:30								
2006-07 HOT Table Values	0:15-0:45	0:30-1:10	0:35-1:30								
2006-07 ET Test Results				0:20-0:45							
2007-08 HOT Table Values	0:15-0:45	0:30-1:10	0:35-1:30	0:20-0:45							
2007-08 ET Test Results					0:25-1:00						
2008-09 HOT Table Values	0:15-0:45	0:30-1:10	0:35-1:30	0:20-0:45	0:25-1:00						
2008-09 ET Test Results						0:30-0:55					
2009-10 HOT Table Values	0:20-0:45	0:30-1:10	0:35-1:30	0:20-0:45	0:25-1:00	0:30-0:55					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:20-0:45	0:30-1:10	0:35-1:30	0:20-0:45	0:25-1:00	0:30-0:55					
2010-11 ET Test Results								0:35-1:35			
2011-12 HOT Table Values	0:20-0:45	0:30-1:10	0:35-1:30	0:20-0:45	0:25-1:00	0:30-0:55					
2011-12 ET Test Results							0:35-1:25				
2012-13 HOT Table Values	0:20-0:45	0:30-1:10	0:35-1:30	0:20-0:45	0:25-1:00	0:30-0:55	0:35-1:25				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:20-0:45	0:30-1:10	0:35-1:30	0:20-0:45	0:25-1:00	0:30-0:55	0:35-1:25	0:35-1:35			
2013-14 ET Test Results									0:25-1:20		
2014-15 HOT Table Values	0:20-0:45	0:30-1:10	0:35-1:30	0:20-0:45	0:25-1:00	0:30-0:55	0:35-1:25	0:35-1:35	0:25-1:20		
2014-15 ET Test Results										0:25-1:00	0:35-1:05
2015-16 HOT Table Values	0:20-0:45	0:30-1:10	0:35-1:30	0:20-0:45	0:25-1:00	0:30-0:55	0:35-1:25	0:35-1:35	0:25-1:20	0:25-1:00	0:35-1:05

Table 4.12: Type II 75/25 Fluid, Freezing Drizzle, Below -3°C to -10°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:20-0:45										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:15-0:30										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:15-0:30										
2000-01 ET Test Results		0:20-0:50									
2001-02 HOT Table Values	0:15-0:30	0:20-0:50									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:15-0:30	0:20-0:50									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:15-0:30	0:20-0:50									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:15-0:30	0:20-0:50									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:15-0:30	0:20-0:50									
2005-06 ET Test Results			0:25-1:10								
2006-07 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10								
2006-07 ET Test Results				0:15-0:30							
2007-08 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10	0:15-0:30							
2007-08 ET Test Results					0:20-0:55						
2008-09 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10	0:15-0:30	0:20-0:55						
2008-09 ET Test Results						0:35-0:40					
2009-10 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10	0:15-0:30	0:20-0:55	0:35-0:40					
2009-10 ET Test Results			~~0:25-1:15~~								
2010-11 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10	0:15-0:30	0:20-0:55	0:35-0:40					
2010-11 ET Test Results								0:25-1:05			
2011-12 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10	0:15-0:30	0:20-0:55	0:35-0:40					
2011-12 ET Test Results							0:25-1:10				
2012-13 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10	0:15-0:30	0:20-0:55	0:35-0:40	0:25-1:10				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10	0:15-0:30	0:20-0:55	0:35-0:40	0:25-1:10	0:25-1:05			
2013-14 ET Test Results									0:20-1:15		
2014-15 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10	0:15-0:30	0:20-0:55	0:35-0:40	0:25-1:10	0:25-1:05	0:20-1:15		
2014-15 ET Test Results										0:25-0:45	0:20-0:35
2015-16 HOT Table Values	0:15-0:30	0:20-0:50	0:25-1:10	0:15-0:30	0:20-0:55	0:35-0:40	0:25-1:10	0:25-1:05	0:20-1:15	0:25-0:45	0:20-0:35

Table 4.13: Type II Neat Fluid, Light Freezing Rain, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:15-0:30										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:15-0:30										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:15-0:30										
2000-01 ET Test Results		0:40-0:50									
2001-02 HOT Table Values	0:15-0:30	0:40-0:50									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:15-0:30	0:40-0:50									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:15-0:30	0:40-0:50									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:15-0:30	0:40-0:50									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:15-0:30	0:40-0:50									
2005-06 ET Test Results			0:45-1:25								
2006-07 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25								
2006-07 ET Test Results				0:25-0:35							
2007-08 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25	0:25-0:35							
2007-08 ET Test Results					1:00-1:25						
2008-09 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25	0:25-0:35	1:00-1:25						
2008-09 ET Test Results						0:25-0:35					
2009-10 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25	0:25-0:35	1:00-1:25	0:25-0:35					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25	0:25-0:35	1:00-1:25	0:25-0:35					
2010-11 ET Test Results								1:15-1:30			
2011-12 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25	0:25-0:35	1:00-1:25	0:25-0:35					
2011-12 ET Test Results							0:45-1:00				
2012-13 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25	0:25-0:35	1:00-1:25	0:25-0:35	0:45-1:00				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25	0:25-0:35	1:00-1:25	0:25-0:35	0:45-1:00	1:15-1:30			
2013-14 ET Test Results									0:50-1:25		
2014-15 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25	0:25-0:35	1:00-1:25	0:25-0:35	0:45-1:00	1:15-1:30	0:50-1:25		
2014-15 ET Test Results										0:25-0:35	0:25-0:45
2015-16 HOT Table Values	0:15-0:30	0:40-0:50	0:45-1:25	0:25-0:35	1:00-1:25	0:25-0:35	0:45-1:00	1:15-1:30	0:50-1:25	0:25-0:35	0:25-0:45

Table 4.14: Type II 75/25 Fluid, Light Freezing Rain, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:10-0:25										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:10-0:25										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:10-0:25										
2000-01 ET Test Results		0:25-0:35									
2001-02 HOT Table Values	0:10-0:25	0:25-0:35									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:10-0:25	0:25-0:35									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:10-0:25	0:25-0:35									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:10-0:25	0:25-0:35									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:10-0:25	0:25-0:35									
2005-06 ET Test Results			~~0:30-0:55~~								
2006-07 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55								
2006-07 ET Test Results				0:15-0:25							
2007-08 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55	0:15-0:25							
2007-08 ET Test Results					0:50-1:10						
2008-09 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55	0:15-0:25	0:50-1:10						
2008-09 ET Test Results						0:20-0:30					
2009-10 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55	0:15-0:25	0:50-1:10	0:20-0:30					
2009-10 ET Test Results			0:30-0:55								
2010-11 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55	0:15-0:25	0:50-1:10	0:20-0:30					
2010-11 ET Test Results								0:40-1:10			
2011-12 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55	0:15-0:25	0:50-1:10	0:20-0:30					
2011-12 ET Test Results							0:50-1:15				
2012-13 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55	0:15-0:25	0:50-1:10	0:20-0:30	0:50-1:15				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55	0:15-0:25	0:50-1:10	0:20-0:30	0:50-1:15	0:40-1:10			
2013-14 ET Test Results									0:40-1:00		
2014-15 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55	0:15-0:25	0:50-1:10	0:20-0:30	0:50-1:15	0:40-1:10	0:40-1:00		
2014-15 ET Test Results										0:20-0:30	0:15-0:25
2015-16 HOT Table Values	0:10-0:25	0:25-0:35	0:30-0:55	0:15-0:25	0:50-1:10	0:20-0:30	0:50-1:15	0:40-1:10	0:40-1:00	0:20-0:30	0:15-0:25

Table 4.15: Type II 50/50 Fluid, Light Freezing Rain, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:05-0:10										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:05-0:10										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:05-0:10										
2000-01 ET Test Results		0:08-0:10									
2001-02 HOT Table Values	0:05-0:10	0:05-0:10									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:05-0:10	0:05-0:10									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:05-0:10	0:05-0:10									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:05-0:10	0:05-0:10									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:05-0:10	0:05-0:10									
2005-06 ET Test Results			0:10-0:15								
2006-07 HOT Table Values	0:05-0:10	0:05-0:10	0:10-0:15								
2006-07 ET Test Results				0:07-0:10							
2007-08 HOT Table Values	0:05-0:10	0:05-0:10	0:10-0:15	0:05-0:10							
2007-08 ET Test Results					0:10-0:15						
2008-09 HOT Table Values	0:05-0:10	0:05-0:10	0:10-0:15	0:05-0:10	0:10-0:15						
2008-09 ET Test Results						0:10-0:20					
2009-10 HOT Table Values	0:05-0:10	0:05-0:10	0:10-0:15	0:05-0:10	0:10-0:15	0:10-0:20					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:05-0:10	0:05-0:10	0:10-0:15	0:05-0:10	0:10-0:15	0:10-0:20					
2010-11 ET Test Results								0:09-0:20			
2011-12 HOT Table Values	0:05-0:09	0:08-0:10	0:10-0:15	0:07-0:10	0:10-0:15	0:10-0:20					
2011-12 ET Test Results							0:15-0:20				
2012-13 HOT Table Values	0:05-0:09	0:08-0:10	0:10-0:15	0:07-0:10	0:10-0:15	0:10-0:20	0:15-0:20				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:05-0:09	0:08-0:10	0:10-0:15	0:07-0:10	0:10-0:15	0:10-0:20	0:15-0:20	0:09-0:20			
2013-14 ET Test Results									0:15-0:20		
2014-15 HOT Table Values	0:05-0:09	0:08-0:10	0:10-0:15	0:07-0:10	0:10-0:15	0:10-0:20	0:15-0:20	0:09-0:20	0:15-0:20		
2014-15 ET Test Results										0:07-0:10	0:08-0:10
2015-16 HOT Table Values	0:05-0:10	0:08-0:10	0:10-0:15	0:07-0:10	0:10-0:15	0:10-0:20	0:15-0:20	0:09-0:20	0:15-0:20	0:07-0:10	0:08-0:10

Table 4.16: Type II Neat Fluid, Light Freezing Rain, Below -3°C to -10°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:10-0:30										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:10-0:30										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:10-0:30										
2000-01 ET Test Results		0:15-0:35									
2001-02 HOT Table Values	0:10-0:25	0:15-0:35									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:10-0:25	0:15-0:35									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:10-0:25	0:15-0:35									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:10-0:25	0:15-0:35									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:10-0:25	0:15-0:35									
2005-06 ET Test Results			0:25-0:45								
2006-07 HOT Table Values	0:10-0:25	0:15-0:35	0:25-0:45								
2006-07 ET Test Results				0:15-0:20							
2007-08 HOT Table Values	0:10-0:20	0:15-0:35	0:25-0:45	0:15-0:20							
2007-08 ET Test Results					0:15-0:35						
2008-09 HOT Table Values	0:10-0:20	0:15-0:35	0:25-0:45	0:15-0:20	0:15-0:35						
2008-09 ET Test Results						0:20-0:25					
2009-10 HOT Table Values	0:10-0:20	0:15-0:35	0:25-0:45	0:15-0:20	0:15-0:35	0:20-0:25					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:10-0:20	0:15-0:35	0:25-0:45	0:15-0:20	0:15-0:35	0:20-0:25					
2010-11 ET Test Results								0:35-0:45			
2011-12 HOT Table Values	0:10-0:20	0:15-0:35	0:25-0:45	0:15-0:20	0:15-0:35	0:20-0:25					
2011-12 ET Test Results							0:35-0:55				
2012-13 HOT Table Values	0:10-0:20	0:15-0:35	0:25-0:45	0:15-0:20	0:15-0:35	0:20-0:25	0:35-0:55				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:10-0:20	0:15-0:35	0:25-0:45	0:15-0:20	0:15-0:35	0:20-0:25	0:35-0:55	0:35-0:45			
2013-14 ET Test Results									0:25-0:35		
2014-15 HOT Table Values	0:10-0:20	0:15-0:35	0:25-0:45	0:15-0:20	0:15-0:35	0:20-0:25	0:35-0:55	0:35-0:45	0:25-0:35		
2014-15 ET Test Results										0:15-0:30	0:15-0:30
2015-16 HOT Table Values	0:10-0:20	0:15-0:35	0:25-0:45	0:15-0:20	0:15-0:35	0:20-0:25	0:35-0:55	0:35-0:45	0:25-0:35	0:15-0:30	0:15-0:30

Table 4.17: Type II 75/25 Fluid, Light Freezing Rain, Below -3°C to -10°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:10-0:25										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:10-0:20										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:10-0:20										
2000-01 ET Test Results		0:15-0:25									
2001-02 HOT Table Values	0:10-0:20	0:15-0:25									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:10-0:20	0:15-0:25									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:10-0:20	0:15-0:25									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:10-0:20	0:15-0:25									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:10-0:20	0:15-0:25									
2005-06 ET Test Results			~~0:30-0:40~~								
2006-07 HOT Table Values	0:10-0:20	0:15-0:25	0:30-0:40								
2006-07 ET Test Results				0:08-0:15							
2007-08 HOT Table Values	0:05-0:15	0:15-0:25	0:30-0:40	0:05-0:15							
2007-08 ET Test Results					0:09-0:30						
2008-09 HOT Table Values	0:05-0:15	0:15-0:25	0:30-0:40	0:05-0:15	0:05-0:30						
2008-09 ET Test Results						0:20-0:25					
2009-10 HOT Table Values	0:05-0:15	0:15-0:25	0:30-0:40	0:05-0:15	0:05-0:30	0:20-0:25					
2009-10 ET Test Results			0:20-0:35								
2010-11 HOT Table Values	0:05-0:15	0:15-0:25	0:20-0:35	0:05-0:15	0:05-0:30	0:20-0:25					
2010-11 ET Test Results								0:35-0:45			
2011-12 HOT Table Values	0:08-0:15	0:15-0:25	0:20-0:35	0:08-0:15	0:09-0:30	0:20-0:25					
2011-12 ET Test Results							0:30-0:45				
2012-13 HOT Table Values	0:08-0:15	0:15-0:25	0:20-0:35	0:08-0:15	0:09-0:30	0:20-0:25	0:30-0:45				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:08-0:15	0:15-0:25	0:20-0:35	0:08-0:15	0:09-0:30	0:20-0:25	0:30-0:45	0:35-0:45			
2013-14 ET Test Results									0:20-0:30		
2014-15 HOT Table Values	0:08-0:15	0:15-0:25	0:20-0:35	0:08-0:15	0:09-0:30	0:20-0:25	0:30-0:45	0:35-0:45	0:20-0:30		
2014-15 ET Test Results										0:15-0:20	0:15-0:20
2015-16 HOT Table Values	0:08-0:15	0:15-0:25	0:20-0:35	0:08-0:15	0:09-0:30	0:20-0:25	0:30-0:45	0:35-0:45	0:20-0:30	0:15-0:20	0:15-0:20

Table 4.18: Type II Neat Fluid, Freezing Fog, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:35-1:30										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:35-1:30										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:35-1:30										
2000-01 ET Test Results		1:25-2:35									
2001-02 HOT Table Values	0:35-1:30	1:25-2:35									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:35-1:30	1:25-2:35									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:35-1:30	1:25-2:35									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:35-1:30	1:25-2:35									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:35-1:30	1:25-2:35									
2005-06 ET Test Results			3:30-4:00								
2006-07 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00								
2006-07 ET Test Results				1:15-2:25							
2007-08 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00	1:15-2:25							
2007-08 ET Test Results					2:15-3:45						
2008-09 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00	1:15-2:25	2:15-3:45						
2008-09 ET Test Results						0:55-1:50					
2009-10 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00	1:15-2:25	2:15-3:45	0:55-1:50					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00	1:15-2:25	2:15-3:45	0:55-1:50					
2010-11 ET Test Results								2:50-4:00			
2011-12 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00	1:15-2:25	2:15-3:45	0:55-1:50					
2011-12 ET Test Results							2:40-4:00				
2012-13 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00	1:15-2:25	2:15-3:45	0:55-1:50	2:40-4:00				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00	1:15-2:25	2:15-3:45	0:55-1:50	2:40-4:00	2:50-4:00			
2013-14 ET Test Results									2:10-4:00		
2014-15 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00	1:15-2:25	2:15-3:45	0:55-1:50	2:40-4:00	2:50-4:00	2:10-4:00		
2014-15 ET Test Results										1:00-1:45	1:25-2:30
2015-16 HOT Table Values	0:35-1:30	1:25-2:35	3:30-4:00	1:15-2:25	2:15-3:45	0:55-1:50	2:40-4:00	2:50-4:00	2:10-4:00	1:00-1:45	1:25-2:30

Table 4.19: Type II 75/25 Fluid, Freezing Fog, -3ºC and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:25-1:00										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:25-1:00										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:25-1:00										
2000-01 ET Test Results		1:05-1:55									
2001-02 HOT Table Values	0:25-1:00	1:05-1:55									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:25-1:00	1:05-1:55									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:25-1:00	1:05-1:55									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:25-1:00	1:05-1:55									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:25-1:00	1:05-1:55									
2005-06 ET Test Results			~~2:30-4:00~~								
2006-07 HOT Table Values	0:25-1:00	1:05-1:55	2:30-4:00								
2006-07 ET Test Results				0:50-1:30							
2007-08 HOT Table Values	0:25-1:00	1:05-1:55	2:30-4:00	0:50-1:30							
2007-08 ET Test Results					1:40-2:30						
2008-09 HOT Table Values	0:25-1:00	1:05-1:55	2:30-4:00	0:50-1:30	1:40-2:30						
2008-09 ET Test Results						0:50-1:20					
2009-10 HOT Table Values	0:25-1:00	1:05-1:55	2:30-4:00	0:50-1:30	1:40-2:30	0:50-1:20					
2009-10 ET Test Results			1:50-2:45								
2010-11 HOT Table Values	0:25-1:00	1:05-1:55	1:50-2:45	0:50-1:30	1:40-2:30	0:50-1:20					
2010-11 ET Test Results								2:30-4:00			
2011-12 HOT Table Values	0:25-1:00	1:05-1:55	1:50-2:45	0:50-1:30	1:40-2:30	0:50-1:20					
2011-12 ET Test Results							2:35-4:00				
2012-13 HOT Table Values	0:25-1:00	1:05-1:55	1:50-2:45	0:50-1:30	1:40-2:30	0:50-1:20	2:35-4:00				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:25-1:00	1:05-1:55	1:50-2:45	0:50-1:30	1:40-2:30	0:50-1:20	2:35-4:00	2:30-4:00			
2013-14 ET Test Results									1:50-2:35		
2014-15 HOT Table Values	0:25-1:00	1:05-1:55	1:50-2:45	0:50-1:30	1:40-2:30	0:50-1:20	2:35-4:00	2:30-4:00	1:50-2:35		
2014-15 ET Test Results										0:50-1:10	0:45-1:20
2015-16 HOT Table Values	0:25-1:00	1:05-1:55	1:50-2:45	0:50-1:30	1:40-2:30	0:50-1:20	2:35-4:00	2:30-4:00	1:50-2:35	0:50-1:10	0:45-1:20

Table 4.20: Type II 50/50 Fluid, Freezing Fog, -3°C and Above

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:15-0:45										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:15-0:35										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:15-0:30										
2000-01 ET Test Results		0:30-0:45									
2001-02 HOT Table Values	0:15-0:30	0:30-0:45									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:15-0:30	0:30-0:45									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:15-0:30	0:30-0:45									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:15-0:30	0:30-0:45									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:15-0:30	0:30-0:45									
2005-06 ET Test Results			0:55-1:45								
2006-07 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45								
2006-07 ET Test Results				0:25-0:35							
2007-08 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45	0:25-0:35							
2007-08 ET Test Results					0:35-1:05						
2008-09 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45	0:25-0:35	0:35-1:05						
2008-09 ET Test Results						0:35-1:00					
2009-10 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45	0:25-0:35	0:35-1:05	0:35-1:00					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45	0:25-0:35	0:35-1:05	0:35-1:00					
2010-11 ET Test Results								0:50-1:25			
2011-12 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45	0:25-0:35	0:35-1:05	0:35-1:00					
2011-12 ET Test Results							1:05-2:20				
2012-13 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45	0:25-0:35	0:35-1:05	0:35-1:00	1:05-2:20				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45	0:25-0:35	0:35-1:05	0:35-1:00	1:05-2:20	0:50-1:25			
2013-14 ET Test Results									0:35-0:50		
2014-15 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45	0:25-0:35	0:35-1:05	0:35-1:00	1:05-2:20	0:50-1:25	0:35-0:50		
2014-15 ET Test Results										0:15-0:30	0:15-0:30
2015-16 HOT Table Values	0:15-0:30	0:30-0:45	0:55-1:45	0:25-0:35	0:35-1:05	0:35-1:00	1:05-2:20	0:50-1:25	0:35-0:50	0:15-0:30	0:15-0:30

Table 4.21: Type II Neat Fluid, Freezing Fog, Below -3ºC to -14ºC

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:35-1:30										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:30-1:05										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:20*-1:05										
2000-01 ET Test Results		0:45-2:15									
2001-02 HOT Table Values	0:20*-1:05	0:45-2:15									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:20*-1:05	0:45-2:15									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:20*-1:05	0:45-2:15									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:20*-1:05	0:45-2:15									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:20*-1:05	0:45-2:15									
2005-06 ET Test Results			0:55-1:45								
2006-07 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45								
2006-07 ET Test Results				0:45-1:30							
2007-08 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45	0:45-1:30							
2007-08 ET Test Results					0:30-1:05						
2008-09 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45	0:45-1:30	0:30-1:05						
2008-09 ET Test Results						0:45-1:50					
2009-10 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45	0:45-1:30	0:30-1:05	0:45-1:50					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45	0:45-1:30	0:30-1:05	0:45-1:50					
2010-11 ET Test Results								0:55-2:30			
2011-12 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45	0:45-1:30	0:30-1:05	0:45-1:50					
2011-12 ET Test Results							0:40-2:20				
2012-13 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45	0:45-1:30	0:30-1:05	0:45-1:50	0:40-2:20				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45	0:45-1:30	0:30-1:05	0:45-1:50	0:40-2:20	0:55-2:30			
2013-14 ET Test Results									0:45-2:20		
2014-15 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45	0:45-1:30	0:30-1:05	0:45-1:50	0:40-2:20	0:55-2:30	0:45-2:20		
2014-15 ET Test Results										0:40-1:35	0:40-1:30
2015-16 HOT Table Values	0:20*-1:05	0:45-2:15	0:55-1:45	0:45-1:30	0:30-1:05	0:45-1:50	0:40-2:20	0:55-2:30	0:45-2:20	0:40-1:35	0:40-1:30

* Value in Type II generic table can not be more than value in Type IV generic table; values were reduced for this reason

Table 4.22: Type II 75/25 Fluid, Freezing Fog, Below -3°C to -14°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:25-1:00										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:20-0:55										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:20-0:55										
2000-01 ET Test Results		0:35-1:15									
2001-02 HOT Table Values	0:20-0:55	0:35-1:15									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:20-0:55	0:35-1:15									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:20-0:55	0:35-1:15									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:20-0:55	0:35-1:15									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:20-0:55	0:35-1:15									
2005-06 ET Test Results			~~0:40-1:10~~								
2006-07 HOT Table Values	0:20-0:55	0:35-1:15	0:40-1:10								
2006-07 ET Test Results				0:30-1:05							
2007-08 HOT Table Values	0:20-0:55	0:35-1:15	0:40-1:10	0:30-1:05							
2007-08 ET Test Results					0:25-1:25						
2008-09 HOT Table Values	0:20-0:55	0:35-1:15	0:40-1:10	0:30-1:05	0:25-1:25						
2008-09 ET Test Results						0:40-1:45					
2009-10 HOT Table Values	0:25-0:50*	0:35-1:15	0:40-1:10	0:30-1:05	0:25-1:25	0:40-1:45					
2009-10 ET Test Results			0:25-1:05								
2010-11 HOT Table Values	0:25-0:50*	0:35-1:15	0:25-1:05	0:30-1:05	0:25-1:25	0:40-1:45					
2010-11 ET Test Results								0:40-1:30			
2011-12 HOT Table Values	0:25-0:50*	0:35-1:15	0:25-1:05	0:30-1:05	0:25-1:25	0:40-1:45					
2011-12 ET Test Results							0:30-1:45				
2012-13 HOT Table Values	0:25-0:50*	0:35-1:15	0:25-1:05	0:30-1:05	0:25-1:25	0:40-1:45	0:30-1:45				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:25-0:50*	0:35-1:15	0:25-1:05	0:30-1:05	0:25-1:25	0:40-1:45	0:30-1:45	0:40-1:30			
2013-14 ET Test Results									0:35-1:45		
2014-15 HOT Table Values	0:25-0:50*	0:35-1:15	0:25-1:05	0:30-1:05	0:25-1:25	0:40-1:45	0:30-1:45	0:40-1:30	0:35-1:45		
2014-15 ET Test Results										0:40-1:20	0:30-1:05
2015-16 HOT Table Values	0:25-0:50*	0:35-1:15	0:25-1:05	0:30-1:05	0:25-1:25	0:40-1:45	0:30-1:45	0:40-1:30	0:35-1:45	0:40-1:20	0:30-1:05

* Value in Type II generic table can not be more than value in Type IV generic table; values were reduced for this reason

Table 4.23: Type II Neat Fluid, Freezing Fog, Below -14°C to -25°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:20-1:30										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:15-0:20										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:15-0:20										
2000-01 ET Test Results		0:25-0:45									
2001-02 HOT Table Values	0:15-0:20	0:25-0:45									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:15-0:20	0:25-0:45									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:15-0:20	0:25-0:45									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:15-0:20	0:25-0:45									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:15-0:20	0:25-0:45									
2005-06 ET Test Results			0:30-0:50								
2006-07 HOT Table Values	0:15-0:20	0:25-0:45	0:30-0:50								
2006-07 ET Test Results				0:25-0:35							
2007-08 HOT Table Values	0:15-0:20	0:25-0:45	0:30-0:50	0:25-0:35							
2007-08 ET Test Results					0:30-0:55						
2008-09 HOT Table Values	0:15-0:20	0:25-0:45	0:30-0:50	0:25-0:35	0:30-0:55						
2008-09 ET Test Results						0:20-0:50					
2009-10 HOT Table Values	0:15*-0:35	0:25-0:45	0:30-0:50	0:25-0:35	0:30-0:55	0:20-0:50					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:15*-0:35	0:25-0:45	0:30-0:50	0:25-0:35	0:30-0:55	0:20-0:50					
2010-11 ET Test Results								0:25-0:50			
2011-12 HOT Table Values	0:15*-0:35	0:25-0:45	0:30-0:50	0:25-0:35	0:30-0:55	0:20-0:50					
2011-12 ET Test Results							0:20-0:40				
2012-13 HOT Table Values	0:15*-0:35	0:25-0:45	0:30-0:50	0:25-0:35	0:30-0:55	0:20-0:50	0:20-0:40				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:15*-0:35	0:25-0:45	0:30-0:50	0:25-0:35	0:30-0:55	0:20-0:50	0:20-0:40	0:25-0:50			
2013-14 ET Test Results									0:20-0:50		
2014-15 HOT Table Values	0:15*-0:35	0:25-0:45	0:30-0:50	0:25-0:35	0:30-0:55	0:20-0:50	0:20-0:40	0:25-0:50	0:20-0:50		
2014-15 ET Test Results										0:20-0:40	0:20-1:00
2015-16 HOT Table Values	0:15*-0:35	0:25-0:45	0:30-0:50	0:25-0:35	0:30-0:55	0:20-0:50	0:20-0:40	0:25-0:50	0:20-0:50	0:20-0:40	0:20-1:00

* Value in Type II generic table can not be more than value in Type IV generic table; values were reduced for this reason

Table 4.24: Type II Neat Fluid, Rain on Cold-Soaked Wing, Above 0ºC

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:10-0:40										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:05-0:40										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:05-0:40										
2000-01 ET Test Results		0:20-1:25									
2001-02 HOT Table Values	0:05-0:40	0:20-1:25									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:05-0:40	0:20-1:25									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:05-0:40	0:20-1:25									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:05-0:40	0:20-1:25									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:05-0:40	0:20-1:25									
2005-06 ET Test Results			0:10-1:30								
2006-07 HOT Table Values	0:05-0:40	0:20-1:25	0:10-1:30								
2006-07 ET Test Results				0:08-0:45							
2007-08 HOT Table Values	0:05-0:40	0:20-1:25	0:10-1:30	0:05-0:45							
2007-08 ET Test Results					0:20-2:00						
2008-09 HOT Table Values	0:05-0:40	0:20-1:25	0:10-1:30	0:05-0:45	0:20-2:00						
2008-09 ET Test Results						0:10-0:55					
2009-10 HOT Table Values	0:05-0:40	0:20-1:25	0:10-1:30	0:05-0:45	0:20-2:00	0:10-0:55					
2009-10 ET Test Results											
2010-11 HOT Table Values	0:05-0:40	0:20-1:25	0:10-1:30	0:05-0:45	0:20-2:00	0:10-0:55					
2010-11 ET Test Results								0:15-2:00			
2011-12 HOT Table Values	0:08-0:40	0:20-1:25	0:10-1:30	0:08-0:45	0:20-2:00	0:10-0:55					
2011-12 ET Test Results							0:15-2:00				
2012-13 HOT Table Values	0:08-0:40	0:20-1:25	0:10-1:30	0:08-0:45	0:20-2:00	0:10-0:55	0:15-2:00				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:08-0:40	0:20-1:25	0:10-1:30	0:08-0:45	0:20-2:00	0:10-0:55	0:15-2:00	0:15-2:00			
2013-14 ET Test Results									0:15-2:00		
2014-15 HOT Table Values	0:08-0:40	0:20-1:25	0:10-1:30	0:08-0:45	0:20-2:00	0:10-0:55	0:15-2:00	0:15-2:00	0:15-2:00		
2014-15 ET Test Results										0:07-0:45	0:08-1:15
2015-16 HOT Table Values	0:07-0:40	0:20-1:25	0:10-1:30	0:08-0:45	0:20-2:00	0:10-0:55	0:15-2:00	0:15-2:00	0:15-2:00	0:07-0:45	0:08-1:15

Table 4.25: Type II 75/25 Fluid, Rain on Cold-Soaked Wing, Above 0°C

	GENERIC	A-E26	C-Flight	N-FCY-2	K-ABC-K+	AS CII	C-Flight+	CR-PGII	L-P250	K-ABC-IC	N-FCY-2B
1998-99 HOT Table Values	0:05-0:25										
1998-99 ET Test Results											
1999-00 HOT Table Values	0:05-0:25										
1999-00 ET Test Results											
2000-01 HOT Table Values	0:05-0:25										
2000-01 ET Test Results		0:10-1:00									
2001-02 HOT Table Values	0:05-0:25	0:10-1:00									
2001-02 ET Test Results											
2002-03 HOT Table Values	0:05-0:25	0:10-1:00									
2002-03 ET Test Results											
2003-04 HOT Table Values	0:05-0:25	0:10-1:00									
2003-04 ET Test Results											
2004-05 HOT Table Values	0:05-0:25	0:10-1:00									
2004-05 ET Test Results											
2005-06 HOT Table Values	0:05-0:25	0:10-1:00									
2005-06 ET Test Results			~~0:07-1:20~~								
2006-07 HOT Table Values	0:05-0:25	0:10-1:00	0:05-1:20								
2006-07 ET Test Results				0:05-0:25							
2007-08 HOT Table Values	0:05-0:25	0:10-1:00	0:05-1:20	0:05-0:25							
2007-08 ET Test Results					0:15-2:00						
2008-09 HOT Table Values	0:05-0:25	0:10-1:00	0:05-1:20	0:05-0:25	0:15-2:00						
2008-09 ET Test Results						0:07-0:50					
2009-10 HOT Table Values	0:05-0:25	0:10-1:00	0:05-1:20	0:05-0:25	0:15-2:00	0:05-0:50					
2009-10 ET Test Results			0:06-0:50								
2010-11 HOT Table Values	0:05-0:25	0:10-1:00	0:05-0:50	0:05-0:25	0:15-2:00	0:05-0:50					
2010-11 ET Test Results								0:09-1:40			
2011-12 HOT Table Values	0:05-0:25	0:10-1:00	0:06-0:50	0:05-0:25	0:15-2:00	0:07-0:50					
2011-12 ET Test Results							0:15-1:15				
2012-13 HOT Table Values	0:05-0:25	0:10-1:00	0:06-0:50	0:05-0:25	0:15-2:00	0:07-0:50	0:15-1:15				
2012-13 ET Test Results											
2013-14 HOT Table Values	0:05-0:25	0:10-1:00	0:06-0:50	0:05-0:25	0:15-2:00	0:07-0:50	0:15-1:15	0:09-1:40			
2013-14 ET Test Results									0:10-1:50		
2014-15 HOT Table Values	0:05-0:25	0:10-1:00	0:06-0:50	0:05-0:25	0:15-2:00	0:07-0:50	0:15-1:15	0:09-1:40	0:10-1:50		
2014-15 ET Test Results										0:05-0:35	0:06-0:35
2015-16 HOT Table Values	0:05-0:25	0:10-1:00	0:06-0:50	0:05-0:25	0:15-2:00	0:07-0:50	0:15-1:15	0:09-1:40	0:10-1:50	0:05-0:35	0:06-0:35

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5. CHANGES TO THE TYPE III HOT GUIDELINES

Changes made to the Type III HOT guidelines for the winter of 2015-16 are documented in this chapter. The Transport Canada and FAA 2015-16 Type III HOT guidelines are included in Appendix J.

5.1 New Fluids/Data

One new Type III fluid, **AllClear AeroClear MAX**, underwent endurance time testing in the winter of 2014-15. The fluid was tested for use applied at ambient temperature and two HOT tables were subsequently published for the fluid, as described in Subsection 5.2. Detailed test results for AllClear AeroClear MAX are provided in Appendix G.

In addition, previously collected heated application endurance time data for existing fluid **Clariant Safewing MP III 2031 ECO** was incorporated into the HOT guidelines, as described in Subsection 5.2. As this data has not previously been included in a published report, the detailed test results are provided in Appendix K.

5.2 Changes to HOT Guidelines Format

Past research concluded holdover times of Type III fluids can vary based on the fluid application temperature; either applied heated or applied unheated (at ambient temperature). A review of this research is documented in the Transport Canada report, TP 14936E, *Aircraft Ground Icing General Research Activities During the 2008-09 Winter* (8). The review concluded that Type III fluids should be tested applied at ambient temperature, applied heated, or both, depending on how the fluid will be used in operations, and that regulators should publish fluid-specific and application temperature-specific HOT tables for Type III fluids accordingly. Transport Canada and the FAA put this recommendation in place for the winter of 2015-16 by publishing Type III fluid-specific application temperature-specific HOT tables.

Fluid-specific HOT tables were created for two fluids: Clariant Safewing MP III 2031 Applied Heated (existing fluid/data) and AllClear AeroClear MAX (new fluid/data).

As Type III fluids are typically intended for use with low rotation speed aircraft, it was decided that low speed and high speed versions of the fluid-specific Type III HOT tables would be published. The low speed and high speed versions of the tables have the same holdover times, but different lowest temperature restrictions to account for the different fluid lowest operational use temperatures (LOUTs) for different rotation speeds. Separating the tables removes the clutter and possible

confusion of indicating the different temperature restrictions for different rotation speeds in the same table.

Therefore, in the winter of 2015-16, four Type III fluid-specific HOT tables were published:

1. AllClear AeroClear MAX, Applied Unheated, Low Speed;
2. AllClear AeroClear MAX, Applied Unheated, High Speed;
3. Clariant Safewing MP III 2031 ECO, Applied Heated, Low Speed; and
4. Clariant Safewing MP III 2031 ECO, Applied Heated, High Speed.

5.3 Type III Generic Holdover Time Values

As the two Type III fluids currently in the HOT Guidelines are intended for use with different application temperatures (and no data exists for the fluids for the other application temperature), it is not possible at this time to provide generic holdover times for Type III fluids. Therefore, a generic Type III HOT table is not included in the 2015-16 HOT Guidelines. This could change in future if the available fluids and/or data changes.

6. CHANGES TO THE TYPE IV HOT GUIDELINES

Changes made to the Type IV HOT guidelines for the winter of 2015-16 are documented in this chapter. The Transport Canada and FAA 2015-16 Type IV HOT guidelines are included in Appendix J.

6.1 New Fluids/Data

One new Type IV fluid was added to the HOT guidelines for the winter of 2015-16: **Deicing Solutions ECO-SHIELD**. This is a new fluid that underwent endurance time testing in the winter of 2014-15. It should be noted that no dilutions of this fluid were tested; therefore, holdover times are only provided for 100/0 fluid (not for 75/25 or 50/50). Detailed test results are provided in Appendix H.

In addition, supplemental natural snow testing was conducted with existing fluid **LNT Solutions E450**. This testing was conducted as insufficient data was collected in the winter of 2014-15 (when it was originally submitted) due to the late submission of the fluid in the winter season. This testing resulted in fluid-specific snow holdover times being added to the LNT Solutions E450 HOT table for winter 2015-16. Detailed test results are provided in Appendix I.

The addition of ECO-SHIELD resulted in several reductions to the generic Type IV holdover times (see Subsection 6.4.1). The changes to the E450 snow holdover times did not impact the generic Type IV holdover times.

6.2 Removed Fluids/Data

The protocol for removing obsolete holdover time data is given in ARP5718 (7). As per the protocol, ABAX AD-480 and Kilfrost ABC-S were removed from the HOT guidelines for the winter of 2015-16. The removal of Kilfrost ABC-S significantly impacted the generic Type IV holdover times (see Subsection 6.4.1). The removal of ABAX AD-480 did not impact the generic Type IV holdover times.

6.3 Changes to HOT Guidelines Format

No changes were made to the format of the Type IV HOT Guidelines for winter 2015-16.

6.4 Type IV Generic Holdover Time Values

The values in the Type IV generic HOT table are generated each year by taking the shortest holdover times of all fluids on the Transport Canada and FAA list of Type IV fluids. It should be noted that the Transport Canada and FAA list of fluids contains

fluids whose qualifications have recently expired (i.e. within four years). Fluids are only removed from the generic analysis when they are removed from the Transport Canada and FAA lists.

6.4.1 Use of Generic Holdover Times in Very Cold Snow

Following the winter of 2003-04, a decision was made that fluid-specific holdover times would not be provided for Type IV fluids in snow at temperatures below -14°C. This was due to the limited data that exits for most fluids at these temperatures. Instead, all Type IV fluids are given pre-established "generic" holdover times in very cold snow. These holdover times were determined based on historical data and analysis.

6.4.2 Impact of New and Removed Fluids/Data

The addition of ECO-SHIELD resulted in three decreases to the Type IV generic holdover times. The removal of ABC-S resulted in seventeen increases to the Type IV generic holdover times.

6.4.3 Fluids Responsible for the Type IV Generic Holdover Time Values

The fluids responsible for the values in the 2015-16 Type IV generic HOT guidelines are shown in Table 6.1. A "U" indicates a fluid is responsible for the upper value in the cell; an "L" indicates a fluid is responsible for the lower value in the cell; and a "B" indicates the fluid is responsible for both the upper and lower values in the cell.

Due to space limitations, the following abbreviations are used in the table:

- ABAX Ecowing AD-49 / Dow UCAR FlightGuard AD-49 (A/D-49);
- Clariant Safewing MP IV Launch Plus (C-L+);
- Clariant Max Flight 04 (C-Max-04);
- Clariant Max Flight Sneg (C-Max-S);
- Cryotech Polar Guard (CR-PG);
- Cryotech Polar Guard Advance (CR-PGA);
- Deicing Solutions ECO-SHIELD (DS-ES);
- Dow UCAR FlightGuard AD-480 (D-480);
- Kilfrost ABC-S PLUS (K-ABCS+); and
- Newave Aerochemical FCY 9311 (N-9311).

Table 6.1: Fluids Responsible for the Type IV Generic Holdover Time Values

OAT		Fluid Dilution	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)				
°C	°F		Freezing Fog	Snow	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing
-3 and above	27 and above	100/0	DS-ES **(B)**	N-9311 **(B)**	D-480 **(B)**	D-480 **(L)** DS-ES **(U)**	A/D-49 **(L)** CR-PG **(U)** N-9311 **(U)**
		75/25	K-ABCS + **(B)** CR-PG **(U)**	D-480 **(B)**	D-480 **(B)**	D-480 **(B)** K-ABCS + **(L)**	CR-PGA **(L)** CR-PG **(U)** D-480 **(U)**
		50/50	CR-PG **(B)** A/D-49 **(L)**	D-480 **(L)** CR-PG **(U)**	CR-PG **(B)** D-480 **(B)** A/D-49 **(L)** K-ABCS + **(L)**	D-480 **(B)** CR-PGA **(L)** A/D-49 **(U)** CR-PG **(U)**	
below -3 to -14	below 27 to 7	100/0	D-480 **(B)** A/D-49 **(L)**	N-9311 **(B)**	CR-PG **(B)** A/D-49 **(L)** C-L + **(L)** C-Max-04 **(L)** D-480 **(L)** K-ABCS + **(L)**	CR-PG **(L)** D-480 **(L)** A/D-49 **(U)**	
		75/25	D-480 **(B)**	CR-PG **(B)** D-480 **(L)**	A/D-49 **(B)** C-L + **(U)** C-Max-S **(U)** CR-PG **(U)** CR-PGA **(U)** D-480 **(U)**	A/D-49 **(B)** K-ABCS + **(B)** D-480 **(L)**	
below -14 to LOUT	below 7 to LOUT	100/0	D-480 **(B)** A/D-49 **(U)** CR-PG **(U)**	Historic Generic **(B)**			

LEGEND	L = DRIVES LOWER LIMIT U = DRIVES UPPER LIMIT B = DRIVES BOTH

6.4.4 Evolution of Type IV Generic Holdover Time Values

The history of testing with Type IV fluids and the evolution of the fluid-specific and generic Type IV holdover time values are illustrated through a series of tables given in Tables 6.2 to 6.25. Each table represents one cell in the HOT guidelines and the title of each table links the table to the appropriate cell. Fluids that are no longer used in the generic analysis (see Subsection 6.2) are not included.

The first row in each table contains the values obtained in testing in 1996-97. These values were used as the holdover time values in 1997-98 winter operations. Each subsequent set of two rows represents a winter test season and the subsequent winter's holdover time values. The final line contains the generic and fluid-specific holdover time values for use in 2015-16 winter operations. It should be noted that because no Type IV fluids were tested in the winter of 2001-02 and the generic values did not change, no line has been included for the 2001-02 winter test season or the 2002-03 holdover time values.

Underlined values indicate the fluid(s) responsible for the generic holdover time. Strikethrough values indicate endurance time test results that are no longer valid. If a fluid has been tested on multiple occasions, then only one test result, usually the shortest endurance time, is valid for a given fluid in a given cell. Details are typically provided in the HOT report written in the most recent year the fluid underwent testing.

Due to space limitations, the following abbreviations are used in the tables:

- ABAX Ecowing AD-49 / Dow UCAR FlightGuard AD-49 (A/D-49);
- Clariant Max Flight 04 (C-Max 04);
- Clariant Max Flight Sneg (C-Max-S);
- Clariant Safewing MP IV Launch (C-Launch);
- Clariant Safewing MP IV Launch Plus (C-L+);
- Cryotech Polar Guard (CR-PG);
- Cryotech Polar Guard Advance (CR-PGA);
- Dow UCAR Endurance EG106 (D-E106);
- Dow UCAR FlightGuard AD-480 (D-480);
- Deicing Solutions ECO-SHIELD (DS-ES);
- Kilfrost ABC-S PLUS (K-ABCS+);
- LNT Solutions E450 (L-E450); and
- Newave Aerochemical FCY 9311 (N-9311).

Table 6.2: Type IV Neat Fluid, Snow, -3°C and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:35-1:00													
1997-98 ET Test Results		~~1:05-2:00~~												
1998-99 HOT Table Values	0:35-1:00	1:05-2:00												
1998-99 ETTest Results		~~1:05-1:50~~												
1999-00 HOT Table Values	0:30-0:55	1:05-1:50												
1999-00 ET Test Results		0:40-1:20												
2000-01 HOT Table Values	0:30-0:55	0:40-1:20												
2000-01 ET Test Results			1:25-2:45											
2001-02 HOT Table Values	0:30-0:55	0:40-1:20												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:30-0:55	0:40-1:20												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:30-0:55	0:40-1:20	1:25-2:00											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:35-1:15	0:40-1:20	1:25-2:00											
2005-06 ET Test Results				~~1:00-1:35~~	0:40-1:20	~~0:45-1:25~~								
2006-07 HOT Table Values	0:35-1:15	0:40-1:20	1:25-2:00	1:00-1:35	0:40-1:20	0:45-1:25								
2006-07 ET Test Results				1:05-1:45		1:15-2:05								
2007-08 HOT Table Values	0:35-1:15	0:40-1:20	1:25-2:00	1:05-1:45	0:40-1:20	1:15-2:00								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:35-1:15	0:40-1:20	1:25-2:00	1:05-1:45	0:40-1:20	1:15-2:00								
2008-09 ET Test Results							1:10-1:50							
2009-10 HOT Table Values	0:35-1:15	0:40-1:20	1:25-2:00	1:05-1:45	0:40-1:20	1:15-2:00	1:10-1:50							
2009-10 ET Test Results								0:50-1:30						
2010-11 HOT Table Values	0:35-1:15	0:40-1:20	1:25-2:00	1:05-1:45	0:40-1:20	1:15-2:00	1:10-1:50	0:50-1:30						
2010-11 ET Test Results									1:20-1:50					
2011-12 HOT Table Values	0:35-1:15	0:40-1:20	1:25-2:00	1:05-1:45	0:40-1:20	1:15-2:00	1:10-1:50	0:50-1:30	1:20-1:50					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:40-1:20	0:40-1:20	1:25-2:00	1:05-1:45	0:40-1:20	1:15-2:00	1:10-1:50	0:50-1:30	1:20-1:50					
2012-13 ET Test Results										0:55-2:00				
2013-14 HOT Table Values (TC)	0:40-1:20	0:40-1:20	1:25-2:00	1:05-1:45	0:40-1:20	1:15-2:00	1:10-1:50	0:50-1:30	1:20-1:50	0:55-2:00				
2013-14 HOT Table Values (FAA)	0:40-1:20	0:40-1:20	1:25-2:45	1:05-1:45	0:40-1:20	1:15-2:05	1:10-1:50	0:50-1:30	1:20-1:50	0:55-2:05				
2013-14 ET Test Results											1:05-1:40		0:35-1:10	
2014-15 HOT Table Values (TC)	0:35-1:10	0:40-1:20	1:25-2:00	1:05-1:45	0:40-1:20	1:15-2:00	1:10-1:50	0:50-1:30	1:20-1:50	0:55-2:00	1:05-1:40	0:35-1:10	0:35-1:10	
2014-15 HOT Table Values (FAA)	0:35-1:10	0:40-1:20	1:25-2:45	1:05-1:45	0:40-1:20	1:15-2:05	1:10-1:50	0:50-1:30	1:20-1:50	0:55-2:05	1:05-1:40	0:35-1:10	0:35-1:10	
2014-15 ET Test Results												1:00-1:35		0:45-1:20
2015-16 HOT Table Values (TC)	0:35-1:10	0:40-1:20	1:25-2:00	1:05-1:45	0:40-1:20	1:15-2:00	1:10-1:50	0:50-1:30	1:20-1:50	0:55-2:00	1:05-1:40	1:00-1:35	0:35-1:10	0:45-1:20
2015-16 HOT Table Values (FAA)	0:35-1:10	0:40-1:20	1:25-2:45	1:05-1:45	0:40-1:20	1:15-2:05	1:10-1:50	0:50-1:30	1:20-1:50	0:55-2:05	1:05-1:40	1:00-1:35	0:35-1:10	0:45-1:20

Table 6.3: Type IV 75/25 Fluid, Snow, -3°C and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:20-0:35													
1997-98 ET Test Results		~~0:45-1:25~~												
1998-99 HOT Table Values	0:20-0:35	0:45-1:25												
1998-99 ETTest Results		~~0:45-1:25~~												
1999-00 HOT Table Values	0:20-0:35	0:45-1:25												
1999-00 ET Test Results		0:30-1:05												
2000-01 HOT Table Values	0:20-0:35	0:30-1:05												
2000-01 ET Test Results			~~1:05-2:00~~											
2001-02 HOT Table Values	0:25-0:50	0:30-1:05												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:25-0:50	0:30-1:05												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:25-0:50	0:30-1:05	1:05-2:00											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:20-0:55	0:30-1:05	1:05-2:00											
2005-06 ET Test Results				~~0:40-1:20~~		~~0:25-0:55~~								
2006-07 HOT Table Values	0:20-0:55	0:30-1:05	1:05-2:00	0:40-1:20		0:25-0:55								
2006-07 ET Test Results				1:00-1:45		0:45-1:15								
2007-08 HOT Table Values	0:20-0:55	0:30-1:05	1:05-2:00	1:00-1:45		0:45-1:15								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:20-0:55	0:30-1:05	1:05-2:00	1:00-1:45		0:45-1:15								
2008-09 ET Test Results							1:20-1:40							
2009-10 HOT Table Values	0:20-0:55	0:30-1:05	1:05-2:00	1:00-1:45		0:45-1:15	1:20-1:40							
2009-10 ET Test Results								0:35-1:10						
2010-11 HOT Table Values	0:20-0:55	0:30-1:05	1:05-2:00	1:00-1:45		0:45-1:15	1:20-1:40	0:35-1:10						
2010-11 ET Test Results									0:45-1:20					
2011-12 HOT Table Values	0:30-0:55	0:30-1:05	1:05-2:00	1:00-1:45		0:45-1:15	1:20-1:40	0:35-1:10	0:45-1:20					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:30-0:55	0:30-1:05	1:05-2:00	1:00-1:45		0:45-1:15	1:20-1:40	0:35-1:10	0:45-1:20					
2012-13 ET Test Results										0:50-1:55				
2013-14 HOT Table Values	0:30-0:55	0:30-1:05		1:00-1:45		0:45-1:15	1:20-1:40	0:35-1:10	0:45-1:20	0:50-1:55				
2013-14 ET Test Results											0:55-1:30			
2014-15 HOT Table Values	0:30-0:55	0:30-1:05		1:00-1:45		0:45-1:15	1:20-1:40	0:35-1:10	0:45-1:20	0:50-1:55	0:55-1:30			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:30-1:05	0:30-1:05		1:00-1:45		0:45-1:15	1:20-1:40	0:35-1:10	0:45-1:20	0:50-1:55	0:55-1:30			

Table 6.4: Type IV 50/50 Fluid, Snow, -3°C and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:05-0:15													
1997-98 ET Test Results		~~0:10-0:30~~												
1998-99 HOT Table Values	0:05-0:15	0:10-0:30												
1998-99 ETTest Results	0:05-0:15													
1999-00 HOT Table Values	0:05-0:15	0:10-0:30												
1999-00 ET Test Results		0:09-0:20												
2000-01 HOT Table Values	0:05-0:15	0:10-0:20												
2000-01 ET Test Results			~~0:25-1:15~~											
2001-02 HOT Table Values	0:05-0:15	0:10-0:20												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:05-0:15	0:10-0:20												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:05-0:15	0:10-0:20	0:25-1:15											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:05-0:15	0:10-0:20	0:25-1:15											
2005-06 ET Test Results				~~0:10-0:25~~		~~0:05-0:15~~								
2006-07 HOT Table Values	0:05-0:15	0:10-0:20	0:25-1:15	0:10-0:25		0:05-0:15								
2006-07 ET Test Results				0:25-0:45		0:15-0:30								
2007-08 HOT Table Values	0:05-0:15	0:10-0:20	0:25-1:15	0:25-0:45		0:15-0:30								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:05-0:15	0:10-0:20	0:25-1:15	0:25-0:45		0:15-0:30								
2008-09 ET Test Results							0:15-0:25							
2009-10 HOT Table Values	0:05-0:15	0:10-0:20	0:25-1:15	0:25-0:45		0:15-0:30	0:15-0:25							
2009-10 ET Test Results								0:10-0:15						
2010-11 HOT Table Values	0:05-0:15	0:10-0:20	0:25-1:15	0:25-0:45		0:15-0:30	0:15-0:25	0:10-0:15						
2010-11 ET Test Results									0:15-0:35					
2011-12 HOT Table Values	0:07-0:15	0:09-0:20	0:25-1:15	0:25-0:45		0:15-0:30	0:15-0:25	0:10-0:15	0:15-0:35					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:07-0:15	0:09-0:20	0:25-1:15	0:25-0:45		0:15-0:30	0:15-0:25	0:10-0:15	0:15-0:35					
2012-13 ET Test Results										0:20-0:45				
2013-14 HOT Table Values	0:07-0:15	0:09-0:20		0:25-0:45		0:15-0:30	0:15-0:25	0:10-0:15	0:15-0:35	0:20-0:45				
2013-14 ET Test Results											0:20-0:45			
2014-15 HOT Table Values	0:07-0:15	0:09-0:20		0:25-0:45		0:15-0:30	0:15-0:25	0:10-0:15	0:15-0:35	0:20-0:45	0:20-0:45			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:09-0:15	0:09-0:20		0:25-0:45		0:15-0:30	0:15-0:25	0:10-0:15	0:15-0:35	0:20-0:45	0:20-0:45			

Table 6.5: Type IV Neat Fluid, Snow, Below -3°C to -14°C

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:20-0:40													
1997-98 ET Test Results		~~0:20-0:40~~												
1998-99 HOT Table Values	0:20-0:40	0:20-0:40												
1998-99 ETTest Results		0:30-0:55												
1999-00 HOT Table Values	0:20-0:40	0:30-0:55												
1999-00 ET Test Results		0:30-0:55												
2000-01 HOT Table Values	0:20-0:40	0:30-0:55												
2000-01 ET Test Results			0:35-1:10											
2001-02 HOT Table Values	0:20-0:40	0:30-0:55												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:20-0:40	0:30-0:55												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:20-0:40	0:30-0:55	0:35-1:10											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:20-0:40	0:30-0:55	0:35-1:10											
2005-06 ET Test Results				~~0:40-1:05~~	0:30-1:05	~~0:35-1:00~~								
2006-07 HOT Table Values	0:20-0:40	0:30-0:55	0:35-1:10	0:40-1:05	0:30-1:05	0:35-1:00								
2006-07 ET Test Results				0:50-1:20		1:00-1:45								
2007-08 HOT Table Values	0:20-0:40	0:30-0:55	0:35-1:10	0:50-1:20	0:30-1:05	1:00-1:45								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:20-0:40	0:30-0:55	0:35-1:10	0:50-1:20	0:30-1:05	1:00-1:45								
2008-09 ET Test Results							1:10-1:50							
2009-10 HOT Table Values	0:20-0:40	0:30-0:55	0:35-1:10	0:50-1:20	0:30-1:05	1:00-1:45	1:10-1:50							
2009-10 ET Test Results								0:30-0:55						
2010-11 HOT Table Values	0:20-0:40	0:30-0:55	0:35-1:10	0:50-1:20	0:30-1:05	1:00-1:45	1:10-1:50	0:30-0:55						
2010-11 ET Test Results									0:55-1:15					
2011-12 HOT Table Values	0:25-0:50	0:30-0:55	0:35-1:10	0:50-1:20	0:30-1:05	1:00-1:45	1:10-1:50	0:30-0:55	0:55-1:15					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:30-0:55	0:30-0:55	0:35-1:10	0:50-1:20	0:30-1:05	1:00-1:45	1:10-1:50	0:30-0:55	0:55-1:15					
2012-13 ET Test Results										0:40-1:25				
2013-14 HOT Table Values	0:30-0:55	0:30-0:55	0:35-1:10	0:50-1:20	0:30-1:05	1:00-1:45	1:10-1:50	0:30-0:55	0:55-1:15	0:40-1:25				
2013-14 ET Test Results											0:45-1:15		0:25-0:50	
2014-15 HOT Table Values	0:25-0:50	0:30-0:55	0:35-1:10	0:50-1:20	0:30-1:05	1:00-1:45	1:10-1:50	0:30-0:55	0:55-1:15	0:40-1:25	0:45-1:15	0:25-0:50	0:25-0:50	
2014-15 ET Test Results												0:45-1:10		0:30-0:55
2015-16 HOT Table Values	0:25-0:50	0:30-0:55	0:35-1:10	0:50-1:20	0:30-1:05	1:00-1:45	1:10-1:50	0:30-0:55	0:55-1:15	0:40-1:25	0:45-1:15	0:45-1:10	0:25-0:50	0:30-0:55

Table 6.6: Type IV 75/25 Fluid, Snow, Below -3°C to -14°C

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:15-0:30													
1997-98 ET Test Results		~~0:15-0:25~~												
1998-99 HOT Table Values	0:15-0:25	0:15-0:25												
1998-99 ETTest Results		~~0:25-0:45~~												
1999-00 HOT Table Values	0:15-0:25	0:25-0:45												
1999-00 ET Test Results		0:20-0:45												
2000-01 HOT Table Values	0:15-0:25	0:20-0:45												
2000-01 ET Test Results			~~0:40-1:20~~											
2001-02 HOT Table Values	0:15-0:25	0:20-0:45												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:20-0:35	0:20-0:45												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:20-0:35	0:20-0:45	0:40-1:20											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:15-0:35	0:20-0:45	0:40-1:20											
2005-06 ET Test Results				~~0:20-0:40~~		~~0:25-0:50~~								
2006-07 HOT Table Values	0:15-0:35	0:20-0:45	0:40-1:20	0:20-0:40		0:25-0:50								
2006-07 ET Test Results				0:45-1:25		0:35-1:00								
2007-08 HOT Table Values	0:15-0:35	0:20-0:45	0:40-1:20	0:45-1:25		0:35-1:00								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:15-0:35	0:20-0:45	0:40-1:20	0:45-1:25		0:35-1:00								
2008-09 ET Test Results							1:20-1:40							
2009-10 HOT Table Values	0:15-0:35	0:20-0:45	0:40-1:20	0:45-1:25		0:35-1:00	1:20-1:40							
2009-10 ET Test Results								0:20-0:40						
2010-11 HOT Table Values	0:15-0:35	0:20-0:45	0:40-1:20	0:45-1:25		0:35-1:00	1:20-1:40	0:20-0:40						
2010-11 ET Test Results									0:35-1:00					
2011-12 HOT Table Values	0:20-0:35	0:20-0:45	0:40-1:20	0:45-1:25		0:35-1:00	1:20-1:40	0:20-0:40	0:35-1:00					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:20-0:40	0:20-0:45	0:40-1:20	0:45-1:25		0:35-1:00	1:20-1:40	0:20-0:40	0:35-1:00					
2012-13 ET Test Results										0:30-1:15				
2013-14 HOT Table Values	0:20-0:40	0:20-0:45		0:45-1:25		0:35-1:00	1:20-1:40	0:20-0:40	0:35-1:00	0:30-1:15				
2013-14 ET Test Results											0:40-1:00			
2014-15 HOT Table Values	0:20-0:40	0:20-0:45		0:45-1:25		0:35-1:00	1:20-1:40	0:20-0:40	0:35-1:00	0:30-1:15	0:40-1:00			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:20-0:40	0:20-0:45		0:45-1:25		0:35-1:00	1:20-1:40	0:20-0:40	0:35-1:00	0:30-1:15	0:40-1:00			

Table 6.7: Type IV Neat Fluid, Snow, Below -14ºC to -25ºC

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:15-0:30													
1997-98 ET Test Results		~~0:15-0:30~~												
1998-99 HOT Table Values	0:15-0:30	0:15-0:30												
1998-99 ETTest Results		0:25-0:40												
1999-00 HOT Table Values	0:15-0:30	0:25-0:40												
1999-00 ET Test Results		~~0:25-0:50~~												
2000-01 HOT Table Values	0:15-0:30	0:25-0:40												
2000-01 ET Test Results			0:25-0:50											
2001-02 HOT Table Values	0:15-0:30	0:25-0:40												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:15-0:30	0:25-0:40												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*											
2005-06 ET Test Results				~~0:35-0:55~~		~~0:30-0:50~~								
2006-07 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*								
2006-07 ET Test Results				~~0:45 1:10~~		~~0:55 1:35~~								
2007-08 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*								
2008-09 ET Test Results														
2009-10 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*							
2009-10 ET Test Results														
2010-11 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*						
2010-11 ET Test Results														
2011-12 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*					
2012-13 ET Test Results														
2013-14 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*				
2013-14 ET Test Results														
2014-15 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	
2014-15 ET Test Results														
2015-16 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*

*Generic HOT values used in this cell

Table 6.8: Type IV Neat Fluid, Freezing Drizzle, -3ºC and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:40-1:00													
1997-98 ET Test Results		~~1:05-2:00~~												
1998-99 HOT Table Values	0:40-1:00	1:05-2:00												
1998-99 ETTest Results														
1999-00 HOT Table Values	0:40-1:00	1:05-2:00												
1999-00 ET Test Results		0:50-1:30												
2000-01 HOT Table Values	0:40-1:00	0:50-1:30												
2000-01 ET Test Results			2:00-2:00											
2001-02 HOT Table Values	0:40-1:10	0:50-1:30												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:40-1:10	0:50-1:30												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:40-1:10	0:50-1:30	2:00-2:00											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:40-1:10	0:50-1:30	2:00-2:00											
2005-06 ET Test Results				1:30-2:00	1:10-2:00	~~1:15-1:55~~								
2006-07 HOT Table Values	0:40-1:10	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:15-1:55								
2006-07 ET Test Results						1:50-2:00								
2007-08 HOT Table Values	0:40-1:10	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:50-2:00								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:40-1:10	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:50-2:00								
2008-09 ET Test Results							1:25-2:00							
2009-10 HOT Table Values	0:40-1:10	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:50-2:00	1:25-2:00							
2009-10 ET Test Results								1:15-2:00						
2010-11 HOT Table Values	0:40-1:10	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:50-2:00	1:25-2:00	1:15-2:00						
2010-11 ET Test Results									1:35-2:00					
2011-12 HOT Table Values	0:45-1:30	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:50-2:00	1:25-2:00	1:15-2:00	1:35-2:00					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:50-1:30	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:50-2:00	1:25-2:00	1:15-2:00	1:35-2:00					
2012-13 ET Test Results										2:00-2:00				
2013-14 HOT Table Values	0:50-1:30	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:50-2:00	1:25-2:00	1:15-2:00	1:35-2:00	2:00-2:00				
2013-14 ET Test Results											2:00-2:00	1:35-2:00	1:10-2:00	
2014-15 HOT Table Values	0:50-1:30	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:50-2:00	1:25-2:00	1:15-2:00	1:35-2:00	2:00-2:00	2:00-2:00	1:35-2:00	1:10-2:00	
2014-15 ET Test Results														0:55-1:35
2015-16 HOT Table Values	0:50-1:30	0:50-1:30	2:00-2:00	1:30-2:00	1:10-2:00	1:50-2:00	1:25-2:00	1:15-2:00	1:35-2:00	2:00-2:00	2:00-2:00	1:35-2:00	1:10-2:00	0:55-1:35

Table 6.9: Type IV 75/25 Fluid, Freezing Drizzle, -3°C and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:30-1:00													
1997-98 ET Test Results		~~0:50-1:20~~												
1998-99 HOT Table Values	0:30-1:00	0:50-1:20												
1998-99 ETTest Results														
1999-00 HOT Table Values	0:30-1:00	0:50-1:20												
1999-00 ET Test Results		0:50-1:15												
2000-01 HOT Table Values	0:30-1:00	0:50-1:15												
2000-01 ET Test Results			~~1:50-2:00~~											
2001-02 HOT Table Values	0:35-0:50	0:50-1:15												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:35-0:50	0:50-1:15												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:35-0:50	0:50-1:15	1:50-2:00											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:35-0:50	0:50-1:15	1:50-2:00											
2005-06 ET Test Results				1:40-2:00		~~0:45-1:10~~								
2006-07 HOT Table Values	0:35-0:50	0:50-1:15	1:50-2:00	1:40-2:00		0:45-1:10								
2006-07 ET Test Results						1:00-1:20								
2007-08 HOT Table Values	0:35-0:50	0:50-1:15	1:50-2:00	1:40-2:00		1:00-1:20								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:35-0:50	0:50-1:15	1:50-2:00	1:40-2:00		1:00-1:20								
2008-09 ET Test Results							1:55-2:00							
2009-10 HOT Table Values	0:35-0:50	0:50-1:15	1:50-2:00	1:40-2:00		1:00-1:20	1:55-2:00							
2009-10 ET Test Results								1:05-1:25						
2010-11 HOT Table Values	0:35-0:50	0:50-1:15	1:50-2:00	1:40-2:00		1:00-1:20	1:55-2:00	1:05-1:25						
2010-11 ET Test Results									1:40-2:00					
2011-12 HOT Table Values	0:35-1:05	0:50-1:15	1:50-2:00	1:40-2:00		1:00-1:20	1:55-2:00	1:05-1:25	1:40-2:00					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:40-1:05	0:50-1:15	1:50-2:00	1:40-2:00		1:00-1:20	1:55-2:00	1:05-1:25	1:40-2:00					
2012-13 ET Test Results										2:00-2:00				
2013-14 HOT Table Values	0:45-1:10	0:50-1:15		1:40-2:00		1:00-1:20	1:55-2:00	1:05-1:25	1:40-2:00	2:00-2:00				
2013-14 ET Test Results											1:30-2:00			
2014-15 HOT Table Values	0:45-1:10	0:50-1:15		1:40-2:00		1:00-1:20	1:55-2:00	1:05-1:25	1:40-2:00	2:00-2:00	1:30-2:00			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:50-1:15	0:50-1:15		1:40-2:00		1:00-1:20	1:55-2:00	1:05-1:25	1:40-2:00	2:00-2:00	1:30-2:00			

Table 6.10: Type IV 50/50 Fluid, Freezing Drizzle, -3°C and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:10-0:20													
1997-98 ET Test Results		~~0:15-0:35~~												
1998-99 HOT Table Values	0:10-0:20	0:15-0:35												
1998-99 ETTest Results														
1999-00 HOT Table Values	0:10-0:20	0:15-0:35												
1999-00 ET Test Results		0:15-0:25												
2000-01 HOT Table Values	0:10-0:20	0:15-0:25												
2000-01 ET Test Results			~~0:35-1:10~~											
2001-02 HOT Table Values	0:10-0:20	0:15-0:25												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:10-0:20	0:15-0:25												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:10-0:20	0:15-0:25	0:35-1:10											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:10-0:20	0:15-0:25	0:35-1:10											
2005-06 ET Test Results				0:30-0:50		~~0:10-0:20~~								
2006-07 HOT Table Values	0:10-0:20	0:15-0:25	0:35-1:10	0:30-0:50		0:10-0:20								
2006-07 ET Test Results						0:15-0:40								
2007-08 HOT Table Values	0:10-0:20	0:15-0:25	0:35-1:10	0:30-0:50		0:15-0:40								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:10-0:20	0:15-0:25	0:35-1:10	0:30-0:50		0:15-0:40								
2008-09 ET Test Results							0:15-0:30							
2009-10 HOT Table Values	0:10-0:20	0:15-0:25	0:35-1:10	0:30-0:50		0:15-0:40	0:15-0:30							
2009-10 ET Test Results								0:15-0:25						
2010-11 HOT Table Values	0:10-0:20	0:15-0:25	0:35-1:10	0:30-0:50		0:15-0:40	0:15-0:30	0:15-0:25						
2010-11 ET Test Results									0:20-0:45					
2011-12 HOT Table Values	0:10-0:20	0:15-0:25	0:35-1:10	0:30-0:50		0:15-0:40	0:15-0:30	0:15-0:25	0:20-0:45					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:10-0:20	0:15-0:25	0:35-1:10	0:30-0:50		0:15-0:40	0:15-0:30	0:15-0:25	0:20-0:45					
2012-13 ET Test Results										0:25-1:00				
2013-14 HOT Table Values	0:15-0:20	0:15-0:25		0:30-0:50		0:15-0:40	0:15-0:30	0:15-0:25	0:20-0:45	0:25-1:00				
2013-14 ET Test Results											0:35-1:10			
2014-15 HOT Table Values	0:15-0:20	0:15-0:25		0:30-0:50		0:15-0:40	0:15-0:30	0:15-0:25	0:20-0:45	0:25-1:00	0:35-1:10			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:15-0:25	0:15-0:25		0:30-0:50		0:15-0:40	0:15-0:30	0:15-0:25	0:20-0:45	0:25-1:00	0:35-1:10			

Table 6.11: Type IV Neat Fluid, Freezing Drizzle, Below -3ºC to -10ºC

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:30-1:00													
1997-98 ET Test Results		0:25-1:20												
1998-99 HOT Table Values	0:25-1:00	0:25-1:20												
1998-99 ETTest Results														
1999-00 HOT Table Values	0:20-0:55	0:25-1:20												
1999-00 ET Test Results		0:25-1:20												
2000-01 HOT Table Values	0:20-0:55	0:25-1:20												
2000-01 ET Test Results			0:25-1:30											
2001-02 HOT Table Values	0:20-0:45	0:25-1:20												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:20-0:45	0:25-1:20												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:20-0:45	0:25-1:20	0:25-1:30											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:20-0:45	0:25-1:20	0:25-1:30											
2005-06 ET Test Results				0:35-1:40	0:55-1:50	~~0:30-1:35~~								
2006-07 HOT Table Values	0:20-0:45	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:30-1:35								
2006-07 ET Test Results						0:25-1:35								
2007-08 HOT Table Values	0:20-0:45	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:25-1:35								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:20-0:45	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:25-1:35								
2008-09 ET Test Results							0:25-1:25							
2009-10 HOT Table Values	0:20-0:45	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:25-1:35	0:25-1:25							
2009-10 ET Test Results								0:25-1:10						
2010-11 HOT Table Values	0:20-0:45	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:25-1:35	0:25-1:25	0:25-1:10						
2010-11 ET Test Results									0:35-1:35					
2011-12 HOT Table Values	0:20-1:00	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:25-1:35	0:25-1:25	0:25-1:10	0:35-1:35					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:20-1:00	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:25-1:35	0:25-1:25	0:25-1:10	0:35-1:35					
2012-13 ET Test Results										0:25-1:35				
2013-14 HOT Table Values	0:20-1:00	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:25-1:35	0:25-1:25	0:25-1:10	0:35-1:35	0:25-1:35				
2013-14 ET Test Results											0:30-1:25	1:45-2:00	0:35-1:20	
2014-15 HOT Table Values	0:20-1:00	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:25-1:35	0:25-1:25	0:25-1:10	0:35-1:35	0:25-1:35	0:30-1:25	1:45-2:00	0:35-1:20	
2014-15 ET Test Results														0:45-2:00
2015-16 HOT Table Values	0:25-1:10	0:25-1:20	0:25-1:30	0:35-1:40	0:55-1:50	0:25-1:35	0:25-1:25	0:25-1:10	0:35-1:35	0:25-1:35	0:30-1:25	1:45-2:00	0:35-1:20	0:45-2:00

Table 6.12: Type IV 75/25 Fluid, Freezing Drizzle, Below -3°C to -10°C

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:30-1:00													
1997-98 ET Test Results		~~0:30-1:15~~												
1998-99 HOT Table Values	0:30-1:00	0:30-1:15												
1998-99 ETTest Results														
1999-00 HOT Table Values	0:20-0:55	0:30-1:15												
1999-00 ET Test Results		0:25-1:05												
2000-01 HOT Table Values	0:20-0:50	0:25-1:05												
2000-01 ET Test Results			~~0:20-1:00~~											
2001-02 HOT Table Values	0:15-0:30	0:25-1:05												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:15-0:30	0:25-1:05												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:15-0:30	0:25-1:05	0:20-1:00											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:15-0:30	0:25-1:05	0:20-1:00											
2005-06 ET Test Results				0:25-1:10		~~0:25-1:15~~								
2006-07 HOT Table Values	0:15-0:30	0:25-1:05	0:20-1:00	0:25-1:10		0:25-1:15								
2006-07 ET Test Results						0:20-1:10								
2007-08 HOT Table Values	0:15-0:30	0:25-1:05	0:20-1:00	0:25-1:10		0:20-1:10								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:15-0:30	0:25-1:05	0:20-1:00	0:25-1:10		0:20-1:10								
2008-09 ET Test Results							0:15-1:05							
2009-10 HOT Table Values	0:15-0:30	0:25-1:05	0:20-1:00	0:25-1:10		0:20-1:10	0:15-1:05							
2009-10 ET Test Results								0:25-1:05						
2010-11 HOT Table Values	0:15-0:30	0:25-1:05	0:20-1:00	0:25-1:10		0:20-1:10	0:15-1:05	0:25-1:05						
2010-11 ET Test Results									0:25-1:05					
2011-12 HOT Table Values	0:15-1:00	0:25-1:05	0:20-1:00	0:25-1:10		0:20-1:10	0:15-1:05	0:25-1:05	0:25-1:05					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:15-1:00	0:25-1:05	0:20-1:00	0:25-1:10		0:20-1:10	0:15-1:05	0:25-1:05	0:25-1:05					
2012-13 ET Test Results										0:20-1:05				
2013-14 HOT Table Values	0:15-1:05	0:25-1:05		0:25-1:10		0:20-1:10	0:15-1:05	0:25-1:05	0:25-1:05	0:20-1:05				
2013-14 ET Test Results											0:20-1:05			
2014-15 HOT Table Values	0:15-1:05	0:25-1:05		0:25-1:10		0:20-1:10	0:15-1:05	0:25-1:05	0:25-1:05	0:20-1:05	0:20-1:05			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:15-1:05	0:25-1:05		0:25-1:10		0:20-1:10	0:15-1:05	0:25-1:05	0:25-1:05	0:20-1:05	0:20-1:05			

Table 6.13: Type IV Neat Fluid, Light Freezing Rain, -3ºC and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:35-0:55													
1997-98 ET Test Results		~~0:50-1:10~~												
1998-99 HOT Table Values	0:35-0:55	0:50-1:10												
1998-99 ETTest Results														
1999-00 HOT Table Values	0:25-0:40	0:50-1:10												
1999-00 ET Test Results		0:35-0:55												
2000-01 HOT Table Values	0:25-0:40	0:35-0:55												
2000-01 ET Test Results			1:10-1:30											
2001-02 HOT Table Values	0:25-0:40	0:35-0:55												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:25-0:40	0:35-0:55												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:25-0:40	0:35-0:55	1:10-1:30											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:25-0:40	0:35-0:55	1:10-1:30											
2005-06 ET Test Results				1:00-1:40	0:50-1:15	~~0:50-1:10~~								
2006-07 HOT Table Values	0:25-0:40	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	0:50-1:10								
2006-07 ET Test Results						1:05-2:00								
2007-08 HOT Table Values	0:25-0:40	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	1:05-2:00								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:25-0:40	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	1:05-2:00								
2008-09 ET Test Results							1:00-1:25							
2009-10 HOT Table Values	0:25-0:40	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	1:05-2:00	1:00-1:25							
2009-10 ET Test Results								0:50-1:15						
2010-11 HOT Table Values	0:25-0:40	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	1:05-2:00	1:00-1:25	0:50-1:15						
2010-11 ET Test Results									1:15-1:30					
2011-12 HOT Table Values	0:25-0:40	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	1:05-2:00	1:00-1:25	0:50-1:15	1:15-1:30					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:35-0:55	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	1:05-2:00	1:00-1:25	0:50-1:15	1:15-1:30					
2012-13 ET Test Results										1:00-2:00				
2013-14 HOT Table Values	0:35-0:55	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	1:05-2:00	1:00-1:25	0:50-1:15	1:15-1:30	1:00-2:00				
2013-14 ET Test Results											0:50-1:40	0:55-1:20	0:40-1:05	
2014-15 HOT Table Values	0:35-0:55	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	1:05-2:00	1:00-1:25	0:50-1:15	1:15-1:30	1:00-2:00	0:50-1:40	0:55-1:20	0:40-1:05	
2014-15 ET Test Results														0:40-0:50
2015-16 HOT Table Values	0:35-0:50	0:35-0:55	1:10-1:30	1:00-1:40	0:50-1:15	1:05-2:00	1:00-1:25	0:50-1:15	1:15-1:30	1:00-2:00	0:50-1:40	0:55-1:20	0:40-1:05	0:40-0:50

Table 6.14: Type IV 75/25 Fluid, Light Freezing Rain, -3°C and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:15-0:30													
1997-98 ET Test Results		~~0:35-0:50~~												
1998-99 HOT Table Values	0:15-0:30	0:35-0:50												
1998-99 ETTest Results														
1999-00 HOT Table Values	0:15-0:30	0:35-0:50												
1999-00 ET Test Results		0:30-0:45												
2000-01 HOT Table Values	0:15-0:30	0:30-0:45												
2000-01 ET Test Results			~~1:00-1:20~~											
2001-02 HOT Table Values	0:15-0:30	0:30-0:45												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:15-0:30	0:30-0:45												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:15-0:30	0:30-0:45	1:00-1:20											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:15-0:30	0:30-0:45	1:00-1:20											
2005-06 ET Test Results				0:45-1:15		~~0:30-0:45~~								
2006-07 HOT Table Values	0:15-0:30	0:30-0:45	1:00-1:20	0:45-1:15		0:30-0:45								
2006-07 ET Test Results						0:30-0:50								
2007-08 HOT Table Values	0:15-0:30	0:30-0:45	1:00-1:20	0:45-1:15		0:30-0:50								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:15-0:30	0:30-0:45	1:00-1:20	0:45-1:15		0:30-0:50								
2008-09 ET Test Results							0:50-1:30							
2009-10 HOT Table Values	0:15-0:30	0:30-0:45	1:00-1:20	0:45-1:15		0:30-0:50	0:50-1:30							
2009-10 ET Test Results								0:35-1:00						
2010-11 HOT Table Values	0:15-0:30	0:30-0:45	1:00-1:20	0:45-1:15		0:30-0:50	0:50-1:30	0:35-1:00						
2010-11 ET Test Results									0:40-1:10					
2011-12 HOT Table Values	0:25-0:35	0:30-0:45	1:00-1:20	0:45-1:15		0:30-0:50	0:50-1:30	0:35-1:00	0:40-1:10					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:25-0:40	0:30-0:45	1:00-1:20	0:45-1:15		0:30-0:50	0:50-1:30	0:35-1:00	0:40-1:10					
2012-13 ET Test Results										1:20-1:25				
2013-14 HOT Table Values	0:30-0:45	0:30-0:45		0:45-1:15		0:30-0:50	0:50-1:30	0:35-1:00	0:40-1:10	1:20-1:25				
2013-14 ET Test Results											1:05-1:20			
2014-15 HOT Table Values	0:30-0:45	0:30-0:45		0:45-1:15		0:30-0:50	0:50-1:30	0:35-1:00	0:40-1:10	1:20-1:25	1:05-1:20			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:30-0:45	0:30-0:45		0:45-1:15		0:30-0:50	0:50-1:30	0:35-1:00	0:40-1:10	1:20-1:25	1:05-1:20			

Table 6.15: Type IV 50/50 Fluid, Light Freezing Rain, -3°C and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:05-0:10													
1997-98 ET Test Results	0:05-0:10	~~0:10-0:25~~												
1998-99 HOT Table Values	0:05-0:10	0:10-0:25												
1998-99 ETTest Results	0:05-0:10													
1999-00 HOT Table Values	0:05-0:10	0:10-0:25												
1999-00 ET Test Results		0:09-0:15												
2000-01 HOT Table Values	0:05-0:10	0:05-0:15												
2000-01 ET Test Results			~~0:25-0:35~~											
2001-02 HOT Table Values	0:05-0:10	0:05-0:15												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:05-0:10	0:05-0:15												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:05-0:10	0:05-0:15	0:25-0:35											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:05-0:10	0:05-0:15	0:25-0:35											
2005-06 ET Test Results				0:20-0:25		~~0:05-0:10~~								
2006-07 HOT Table Values	0:05-0:10	0:05-0:15	0:25-0:35	0:20-0:25		0:05-0:10								
2006-07 ET Test Results						0:15-0:20								
2007-08 HOT Table Values	0:05-0:10	0:05-0:15	0:25-0:35	0:20-0:25		0:15-0:20								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:05-0:10	0:05-0:15	0:25-0:35	0:20-0:25		0:15-0:20								
2008-09 ET Test Results							0:10-0:15							
2009-10 HOT Table Values	0:05-0:10	0:05-0:15	0:25-0:35	0:20-0:25		0:15-0:20	0:10-0:15							
2009-10 ET Test Results								0:10-0:15						
2010-11 HOT Table Values	0:05-0:10	0:05-0:15	0:25-0:35	0:20-0:25		0:15-0:20	0:10-0:15	0:10-0:15						
2010-11 ET Test Results									0:09-0:20					
2011-12 HOT Table Values	0:07-0:10	0:09-0:15	0:25-0:35	0:20-0:25		0:15-0:20	0:10-0:15	0:10-0:15	0:09-0:20					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:07-0:10	0:09-0:15	0:25-0:35	0:20-0:25		0:15-0:20	0:10-0:15	0:10-0:15	0:09-0:20					
2012-13 ET Test Results										0:15-0:20				
2013-14 HOT Table Values	0:08-0:10	0:09-0:15		0:20-0:25		0:15-0:20	0:10-0:15	0:10-0:15	0:09-0:20	0:15-0:20				
2013-14 ET Test Results											0:15-0:30			
2014-15 HOT Table Values	0:08-0:10	0:09-0:15		0:20-0:25		0:15-0:20	0:10-0:15	0:10-0:15	0:09-0:20	0:15-0:20	0:15-0:30			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:09-0:15	0:09-0:15		0:20-0:25		0:15-0:20	0:10-0:15	0:10-0:15	0:09-0:20	0:15-0:20	0:15-0:30			

Table 6.16: Type IV Neat Fluid, Light Freezing Rain, Below -3°C to -10°C

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:30-0:45													
1997-98 ET Test Results		~~0:20-0:40~~												
1998-99 HOT Table Values	0:15-0:30	0:20-0:40												
1998-99 ETTest Results														
1999-00 HOT Table Values	0:10-0:30	0:20-0:40												
1999-00 ET Test Results		0:15-0:30												
2000-01 HOT Table Values	0:10-0:30	0:15-0:30												
2000-01 ET Test Results			0:20-0:40											
2001-02 HOT Table Values	0:10-0:25	0:15-0:30												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:10-0:25	0:15-0:30												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40											
2005-06 ET Test Results				0:25-0:45	0:45-1:10	~~0:25-0:35~~								
2006-07 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:25-0:35								
2006-07 ET Test Results						0:20-0:30								
2007-08 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:20-0:30								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:20-0:30								
2008-09 ET Test Results							0:20-0:25							
2009-10 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:20-0:30	0:20-0:25							
2009-10 ET Test Results								0:15-0:35						
2010-11 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:20-0:30	0:20-0:25	0:15-0:35						
2010-11 ET Test Results									0:35-0:45					
2011-12 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:20-0:30	0:20-0:25	0:15-0:35	0:35-0:45					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:20-0:30	0:20-0:25	0:15-0:35	0:35-0:45					
2012-13 ET Test Results										0:25-0:40				
2013-14 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:20-0:30	0:20-0:25	0:15-0:35	0:35-0:45	0:25-0:40				
2013-14 ET Test Results											0:25-0:40	1:05-1:40	0:20-0:35	
2014-15 HOT Table Values	0:10-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:20-0:30	0:20-0:25	0:15-0:35	0:35-0:45	0:25-0:40	0:25-0:40	1:05-1:40	0:20-0:35	
2014-15 ET Test Results														0:25-0:40
2015-16 HOT Table Values	0:15-0:25	0:15-0:30	0:20-0:40	0:25-0:45	0:45-1:10	0:20-0:30	0:20-0:25	0:15-0:35	0:35-0:45	0:25-0:40	0:25-0:40	1:05-1:40	0:20-0:35	0:25-0:40

Table 6.17: Type IV 75/25 Fluid, Light Freezing Rain, Below -3°C to -10°C

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:15-0:30													
1997-98 ET Test Results		~~0:20-0:35~~												
1998-99 HOT Table Values	0:15-0:30	0:20-0:35												
1998-99 ETTest Results														
1999-00 HOT Table Values	0:10-0:30	0:20-0:35												
1999-00 ET Test Results		0:15-0:30												
2000-01 HOT Table Values	0:10-0:25	0:15-0:30												
2000-01 ET Test Results			~~0:15-0:30~~											
2001-02 HOT Table Values	0:10-0:20	0:15-0:30												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:10-0:20	0:15-0:30												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:10-0:20	0:15-0:30	0:15-0:30											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:10-0:20	0:15-0:30	0:15-0:30											
2005-06 ET Test Results				0:25-0:45		~~0:30-0:40~~								
2006-07 HOT Table Values	0:10-0:20	0:15-0:30	0:15-0:30	0:25-0:45		0:30-0:40								
2006-07 ET Test Results						0:15-0:25								
2007-08 HOT Table Values	0:10-0:20	0:15-0:30	0:15-0:30	0:25-0:45		0:15-0:25								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:10-0:20	0:15-0:30	0:15-0:30	0:25-0:45		0:15-0:25								
2008-09 ET Test Results							0:15-0:25							
2009-10 HOT Table Values	0:10-0:20	0:15-0:30	0:15-0:30	0:25-0:45		0:15-0:25	0:15-0:25							
2009-10 ET Test Results								0:20-0:30						
2010-11 HOT Table Values	0:10-0:20	0:15-0:30	0:15-0:30	0:25-0:45		0:15-0:25	0:15-0:25	0:20-0:30						
2010-11 ET Test Results									0:35-0:45					
2011-12 HOT Table Values	0:10-0:25	0:15-0:30	0:15-0:30	0:25-0:45		0:15-0:25	0:15-0:25	0:20-0:30	0:35-0:45					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:10-0:25	0:15-0:30	0:15-0:30	0:25-0:45		0:15-0:25	0:15-0:25	0:20-0:30	0:35-0:45					
2012-13 ET Test Results										0:20-0:30				
2013-14 HOT Table Values	0:10-0:25	0:15-0:30		0:25-0:45		0:15-0:25	0:15-0:25	0:20-0:30	0:35-0:45	0:20-0:30				
2013-14 ET Test Results											0:20-0:40			
2014-15 HOT Table Values	0:10-0:25	0:15-0:30		0:25-0:45		0:15-0:25	0:15-0:25	0:20-0:30	0:35-0:45	0:20-0:30	0:20-0:40			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:15-0:25	0:15-0:30		0:25-0:45		0:15-0:25	0:15-0:25	0:20-0:30	0:35-0:45	0:20-0:30	0:20-0:40			

Table 6.18: Type IV Neat Fluid, Freezing Fog, -3°C and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	2:20-3:00													
1997-98 ET Test Results														
1998-99 HOT Table Values	2:00-3:00													
1998-99 ETTest Results														
1999-00 HOT Table Values	1:05-2:15	1:05-2:15												
1999-00 ET Test Results		2:00-3:30												
2000-01 HOT Table Values	1:05-2:15	2:00-3:30												
2000-01 ET Test Results			2:40-4:00											
2001-02 HOT Table Values	1:05-2:15	2:00-3:30												
2002-03 ET Test Results														
2003-04 HOT Table Values	1:05-2:15	2:00-3:30												
2003-04 ET Test Results														
2004-05 HOT Table Values	1:05-2:15	2:00-3:30	2:40-4:00											
2004-05 ET Test Results														
2005-06 HOT Table Values	1:15-2:30	2:00-3:30	2:40-4:00											
2005-06 ET Test Results				4:00-4:00	2:05-3:10	~~1:50-3:40~~								
2006-07 HOT Table Values	1:15-2:30	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	1:50-3:40								
2006-07 ET Test Results						2:10-4:00								
2007-08 HOT Table Values	1:15-2:30	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	2:10-4:00								
2007-08 ET Test Results														
2008-09 HOT Table Values	1:15-2:30	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	2:10-4:00								
2008-09 ET Test Results							3:20-4:00							
2009-10 HOT Table Values	1:15-2:30	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	2:10-4:00	3:20-4:00							
2009-10 ET Test Results								2:15-3:30						
2010-11 HOT Table Values	1:15-2:30	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	2:10-4:00	3:20-4:00	2:15-3:30						
2010-11 ET Test Results									2:50-4:00					
2011-12 HOT Table Values	1:20-3:10	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	2:10-4:00	3:20-4:00	2:15-3:30	2:50-4:00					
2011-12 ET Test Results														
2012-13 HOT Table Values	1:45-3:10	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	2:10-4:00	3:20-4:00	2:15-3:30	2:50-4:00					
2012-13 ET Test Results										3:55-4:00				
2013-14 HOT Table Values	1:55-3:10	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	2:10-4:00	3:20-4:00	2:15-3:30	2:50-4:00	3:55-4:00				
2013-14 ET Test Results											2:25-4:00	1:50-2:55	1:55-4:00	
2014-15 HOT Table Values	1:50-2:55	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	2:10-4:00	3:20-4:00	2:15-3:30	2:50-4:00	3:55-4:00	2:25-4:00	1:50-2:55	1:55-4:00	
2014-15 ET Test Results														1:30-2:25
2015-16 HOT Table Values	1:30-2:25	2:00-3:30	2:40-4:00	4:00-4:00	2:05-3:10	2:10-4:00	3:20-4:00	2:15-3:30	2:50-4:00	3:55-4:00	2:25-4:00	1:50-2:55	1:55-4:00	1:30-2:25

Table 6.19: Type IV 75/25 Fluid, Freezing Fog, -3ºC and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	1:05-2:00													
1997-98 ET Test Results														
1998-99 HOT Table Values	1:05-2:00													
1998-99 ETTest Results														
1999-00 HOT Table Values	1:05-1:45	1:05-1:45												
1999-00 ET Test Results		1:30-2:45												
2000-01 HOT Table Values	1:05-1:45	1:30-2:45												
2000-01 ET Test Results			~~2:05-3:15~~											
2001-02 HOT Table Values	1:05-1:45	1:30-2:45												
2002-03 ET Test Results														
2003-04 HOT Table Values	1:05-1:45	1:30-2:45												
2003-04 ET Test Results														
2004-05 HOT Table Values	1:05-1:45	1:30-2:45	2:05-3:15											
2004-05 ET Test Results														
2005-06 HOT Table Values	1:05-1:45	1:30-2:45	2:05-3:15											
2005-06 ET Test Results				3:40-4:00		~~1:10-2:10~~								
2006-07 HOT Table Values	1:05-1:45	1:30-2:45	2:05-3:15	3:40-4:00		1:10-2:10								
2006-07 ET Test Results						1:25-2:40								
2007-08 HOT Table Values	1:05-1:45	1:30-2:45	2:05-3:15	3:40-4:00		1:25-2:40								
2007-08 ET Test Results														
2008-09 HOT Table Values	1:05-1:45	1:30-2:45	2:05-3:15	3:40-4:00		1:25-2:40								
2008-09 ET Test Results							2:25-4:00							
2009-10 HOT Table Values	1:00-1:45	1:30-2:45	2:05-3:15	3:40-4:00		1:25-2:40	2:25-4:00							
2009-10 ET Test Results								1:40-2:40						
2010-11 HOT Table Values	1:00-1:45	1:30-2:45	2:05-3:15	3:40-4:00		1:25-2:40	2:25-4:00	1:40-2:40						
2010-11 ET Test Results									2:30-4:00					
2011-12 HOT Table Values	1:00-1:45	1:30-2:45	2:05-3:15	3:40-4:00		1:25-2:40	2:25-4:00	1:40-2:40	2:30-4:00					
2011-12 ET Test Results														
2012-13 HOT Table Values	1:00-1:45	1:30-2:45	2:05-3:15	3:40-4:00		1:25-2:40	2:25-4:00	1:40-2:40	2:30-4:00					
2012-13 ET Test Results										3:55-4:00				
2013-14 HOT Table Values	1:05-1:45	1:30-2:45		3:40-4:00		1:25-2:40	2:25-4:00	1:40-2:40	2:30-4:00	3:55-4:00				
2013-14 ET Test Results											4:00-4:00			
2014-15 HOT Table Values	1:05-1:45	1:30-2:45		3:40-4:00		1:25-2:40	2:25-4:00	1:40-2:40	2:30-4:00	3:55-4:00	4:00-4:00			
2014-15 ET Test Results														
2015-16 HOT Table Values	1:25-2:40	1:30-2:45		3:40-4:00		1:25-2:40	2:25-4:00	1:40-2:40	2:30-4:00	3:55-4:00	4:00-4:00			

Table 6.20: Type IV 50/50 Fluid, Freezing Fog, -3ºC and Above

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:20-0:45													
1997-98 ET Test Results														
1998-99 HOT Table Values	0:20-0:45													
1998-99 ETTest Results														
1999-00 HOT Table Values	0:20-0:35	0:20-0:35												
1999-00 ET Test Results		0:30-0:45												
2000-01 HOT Table Values	0:15-0:35	0:30-0:45												
2000-01 ET Test Results			~~0:55-1:45~~											
2001-02 HOT Table Values	0:15-0:35	0:30-0:45												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:15-0:35	0:30-0:45												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:15-0:35	0:30-0:45	0:55-1:45											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:15-0:35	0:30-0:45	0:55-1:45											
2005-06 ET Test Results				1:25-2:45		~~0:20-0:40~~								
2006-07 HOT Table Values	0:15-0:35	0:30-0:45	0:55-1:45	1:25-2:45		0:20-0:40								
2006-07 ET Test Results						0:30-0:55								
2007-08 HOT Table Values	0:15-0:35	0:30-0:45	0:55-1:45	1:25-2:45		0:30-0:55								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:15-0:35	0:30-0:45	0:55-1:45	1:25-2:45		0:30-0:55								
2008-09 ET Test Results							0:25-0:50							
2009-10 HOT Table Values	0:15-0:35	0:30-0:45	0:55-1:45	1:25-2:45		0:30-0:55	0:25-0:50							
2009-10 ET Test Results								0:25-0:40						
2010-11 HOT Table Values	0:15-0:35	0:30-0:45	0:55-1:45	1:25-2:45		0:30-0:55	0:25-0:50	0:25-0:40						
2010-11 ET Test Results									0:50-1:25					
2011-12 HOT Table Values	0:15-0:35	0:30-0:45	0:55-1:45	1:25-2:45		0:30-0:55	0:25-0:50	0:25-0:40	0:50-1:25					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:20-0:35	0:30-0:45	0:55-1:45	1:25-2:45		0:30-0:55	0:25-0:50	0:25-0:40	0:50-1:25					
2012-13 ET Test Results										1:15-1:50				
2013-14 HOT Table Values	0:20-0:35	0:30-0:45		1:25-2:45		0:30-0:55	0:25-0:50	0:25-0:40	0:50-1:25	1:15-1:50				
2013-14 ET Test Results											1:30-3:30			
2014-15 HOT Table Values	0:20-0:35	0:30-0:45		1:25-2:45		0:30-0:55	0:25-0:50	0:25-0:40	0:50-1:25	1:15-1:50	1:30-3:30			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:25-0:40	0:30-0:45		1:25-2:45		0:30-0:55	0:25-0:50	0:25-0:40	0:50-1:25	1:15-1:50	1:30-3:30			

Table 6.21: Type IV Neat Fluid, Freezing Fog, Below -3ºC to -14ºC

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:40-3:00													
1997-98 ET Test Results														
1998-99 HOT Table Values	0:40-3:00													
1998-99 ETTest Results														
1999-00 HOT Table Values	0:40-1:30	0:40-1:30												
1999-00 ET Test Results		0:20-1:20												
2000-01 HOT Table Values	0:20-1:20	0:20-1:20												
2000-01 ET Test Results			0:50-2:30											
2001-02 HOT Table Values	0:20-1:20	0:20-1:20												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:20-1:20	0:20-1:20												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30											
2005-06 ET Test Results				1:00-1:55	1:50-3:20	~~0:40-1:25~~								
2006-07 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:40-1:25								
2006-07 ET Test Results						0:55-3:30								
2007-08 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:55-3:30								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:55-3:30								
2008-09 ET Test Results							0:20-1:35							
2009-10 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:55-3:30	0:20-1:35							
2009-10 ET Test Results								0:45-1:45						
2010-11 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:55-3:30	0:20-1:35	0:45-1:45						
2010-11 ET Test Results									0:55-2:30					
2011-12 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:55-3:30	0:20-1:35	0:45-1:45	0:55-2:30					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:55-3:30	0:20-1:35	0:45-1:45	0:55-2:30					
2012-13 ET Test Results										0:55-2:15				
2013-14 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:55-3:30	0:20-1:35	0:45-1:45	0:55-2:30	0:55-2:15				
2013-14 ET Test Results											0:45-2:20	1:30-3:55	0:35-2:05	
2014-15 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:55-3:30	0:20-1:35	0:45-1:45	0:55-2:30	0:55-2:15	0:45-2:20	1:30-3:55	0:35-2:05	
2014-15 ET Test Results														1:10-2:30
2015-16 HOT Table Values	0:20-1:20	0:20-1:20	0:50-2:30	1:00-1:55	1:50-3:20	0:55-3:30	0:20-1:35	0:45-1:45	0:55-2:30	0:55-2:15	0:45-2:20	1:30-3:55	0:35-2:05	1:10-2:30

Table 6.22: Type IV 75/25 Fluid, Freezing Fog, Below -3°C to -14°C

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:35-2:00													
1997-98 ET Test Results														
1998-99 HOT Table Values	0:30-2:00													
1998-99 ETTest Results														
1999-00 HOT Table Values	0:25-1:00	0:25-1:00												
1999-00 ET Test Results		0:25-0:50												
2000-01 HOT Table Values	0:25-0:50	0:25-0:50												
2000-01 ET Test Results			~~0:30-1:05~~											
2001-02 HOT Table Values	0:25-0:50	0:25-0:50												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:25-0:50	0:25-0:50												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:25-0:50	0:25-0:50	0:30-1:05											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:25-0:50	0:25-0:50	0:30-1:05											
2005-06 ET Test Results				0:40-1:20		~~0:40-1:15~~								
2006-07 HOT Table Values	0:25-0:50	0:25-0:50	0:30-1:05	0:40-1:20		0:40-1:15								
2006-07 ET Test Results						0:45-1:50								
2007-08 HOT Table Values	0:25-0:50	0:25-0:50	0:30-1:05	0:40-1:20		0:45-1:50								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:25-0:50	0:25-0:50	0:30-1:05	0:40-1:20		0:45-1:50								
2008-09 ET Test Results							0:30-1:10							
2009-10 HOT Table Values	0:25-0:50	0:25-0:50	0:30-1:05	0:40-1:20		0:45-1:50	0:30-1:10							
2009-10 ET Test Results								0:35-1:30						
2010-11 HOT Table Values	0:25-0:50	0:25-0:50	0:30-1:05	0:40-1:20		0:45-1:50	0:30-1:10	0:35-1:30						
2010-11 ET Test Results									0:40-1:30					
2011-12 HOT Table Values	0:25-0:50	0:25-0:50	0:30-1:05	0:40-1:20		0:45-1:50	0:30-1:10	0:35-1:30	0:40-1:30					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:25-0:50	0:25-0:50	0:30-1:05	0:40-1:20		0:45-1:50	0:30-1:10	0:35-1:30	0:40-1:30					
2012-13 ET Test Results										0:40-2:00				
2013-14 HOT Table Values	0:25-0:50	0:25-0:50		0:40-1:20		0:45-1:50	0:30-1:10	0:35-1:30	0:40-1:30	0:40-2:00				
2013-14 ET Test Results											0:30-1:25			
2014-15 HOT Table Values	0:25-0:50	0:25-0:50		0:40-1:20		0:45-1:50	0:30-1:10	0:35-1:30	0:40-1:30	0:40-2:00	0:30-1:25			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:25-0:50	0:25-0:50		0:40-1:20		0:45-1:50	0:30-1:10	0:35-1:30	0:40-1:30	0:40-2:00	0:30-1:25			

Table 6.23: Type IV Neat Fluid, Freezing Fog, Below -14°C to -25°C

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	0:20-2:00													
1997-98 ET Test Results														
1998-99 HOT Table Values	0:20-2:00													
1998-99 ETTest Results														
1999-00 HOT Table Values	0:20-0:40	0:20-0:40												
1999-00 ET Test Results		0:15-0:40												
2000-01 HOT Table Values	0:15-0:40	0:15-0:40												
2000-01 ET Test Results			0:20-0:45											
2001-02 HOT Table Values	0:15-0:40	0:15-0:40												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:15-0:40	0:15-0:40												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45											
2005-06 ET Test Results				0:30-0:50	0:30-1:05	~~0:20-0:45~~								
2006-07 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:20-0:45								
2006-07 ET Test Results						0:40-1:00								
2007-08 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:40-1:00								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:40-1:00								
2008-09 ET Test Results							0:25-0:40							
2009-10 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:40-1:00	0:25-0:40							
2009-10 ET Test Results								0:20-0:40						
2010-11 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:40-1:00	0:25-0:40	0:20-0:40						
2010-11 ET Test Results									0:25-0:50					
2011-12 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:40-1:00	0:25-0:40	0:20-0:40	0:25-0:50					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:40-1:00	0:25-0:40	0:20-0:40	0:25-0:50					
2012-13 ET Test Results										0:25-0:50				
2013-14 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:40-1:00	0:25-0:40	0:20-0:40	0:25-0:50	0:25-0:50				
2013-14 ET Test Results											0:20-0:50	0:35-1:05	0:30-0:55	
2014-15 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:40-1:00	0:25-0:40	0:20-0:40	0:25-0:50	0:25-0:50	0:20-0:50	0:35-1:05	0:30-0:55	
2014-15 ET Test Results														0:30-0:55
2015-16 HOT Table Values	0:15-0:40	0:15-0:40	0:20-0:45	0:30-0:50	0:30-1:05	0:40-1:00	0:25-0:40	0:20-0:40	0:25-0:50	0:25-0:50	0:20-0:50	0:35-1:05	0:30-0:55	0:30-0:55

Table 6.24: Type IV Neat Fluid, Rain on a Cold-Soaked Wing, Above 0°C

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	~~0:10-0:50~~													
1997-98 ET Test Results														
1998-99 HOT Table Values	0:10-0:50													
1998-99 ETTest Results														
1999-00 HOT Table Values	0:10-0:50	0:10-0:50												
1999-00 ET Test Results		0:15-1:35												
2000-01 HOT Table Values	0:10-0:50	0:15-1:35												
2000-01 ET Test Results			0:20-2:00											
2001-02 HOT Table Values	0:10-0:50	0:15-1:35												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:10-0:50	0:15-1:35												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:10-0:50	0:15-1:35	0:20-2:00											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:10-0:50	0:15-1:35	0:20-2:00											
2005-06 ET Test Results				0:15-1:40	0:20-2:00	~~0:15-1:40~~								
2006-07 HOT Table Values	0:10-0:50	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:15-1:40								
2006-07 ET Test Results						0:25-2:00								
2007-08 HOT Table Values	0:10-0:50	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:25-2:00								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:10-1:05	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:25-2:00								
2008-09 ET Test Results							0:10-1:55							
2009-10 HOT Table Values	0:10-1:05	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:25-2:00	0:10-1:55							
2009-10 ET Test Results								0:15-1:25						
2010-11 HOT Table Values	0:10-1:05	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:25-2:00	0:10-1:55	0:15-1:25						
2010-11 ET Test Results									0:15-2:00					
2011-12 HOT Table Values	0:10-1:15	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:25-2:00	0:10-1:55	0:15-1:25	0:15-2:00					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:10-1:15	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:25-2:00	0:10-1:55	0:15-1:25	0:15-2:00					
2012-13 ET Test Results										0:20-2:00				
2013-14 HOT Table Values	0:10-1:15	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:25-2:00	0:10-1:55	0:15-1:25	0:15-2:00	0:20-2:00				
2013-14 ET Test Results											0:20-1:30	0:25-2:00	0:15-1:25	
2014-15 HOT Table Values	0:10-1:15	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:25-2:00	0:10-1:55	0:15-1:25	0:15-2:00	0:20-2:00	0:20-1:30	0:25-2:00	0:15-1:25	
2014-15 ET Test Results														0:15-1:55
2015-16 HOT Table Values	0:10-1:25	0:15-1:35	0:20-2:00	0:15-1:40	0:20-2:00	0:25-2:00	0:10-1:55	0:15-1:25	0:15-2:00	0:20-2:00	0:20-1:30	0:25-2:00	0:15-1:25	0:15-1:55

Table 6.25: Type IV 75/25 Fluid, Rain on a Cold-Soaked Wing, Above 0°C

	GENERIC	D-480	C-Max 04	C-Launch	D-E106	K-ABCS+	A/D-49	CR-PG	CR-PGA	C-L+	C-Max-S	L-E450	N-9311	DS-ES
1996-97 Test Results and Table Values used in 97-98	~~0:05-0:35~~													
1997-98 ET Test Results														
1998-99 HOT Table Values	0:05-0:35													
1998-99 ETTest Results														
1999-00 HOT Table Values	0:05-0:35	0:05-0:35												
1999-00 ET Test Results		0:10-1:15												
2000-01 HOT Table Values	0:05-0:35	0:10-1:15												
2000-01 ET Test Results			~~0:20-2:00~~											
2001-02 HOT Table Values	0:05-0:35	0:10-1:15												
2002-03 ET Test Results														
2003-04 HOT Table Values	0:05-0:35	0:10-1:15												
2003-04 ET Test Results														
2004-05 HOT Table Values	0:05-0:35	0:10-1:15	0:20-2:00											
2004-05 ET Test Results														
2005-06 HOT Table Values	0:05-0:35	0:10-1:15	0:20-2:00											
2005-06 ET Test Results				0:10-1:45		~~0:05-1:00~~								
2006-07 HOT Table Values	0:05-0:35	0:10-1:15	0:20-2:00	0:10-1:45		0:05-1:00								
2006-07 ET Test Results						0:10-1:20								
2007-08 HOT Table Values	0:05-0:35	0:10-1:15	0:20-2:00	0:10-1:45		0:10-1:20								
2007-08 ET Test Results														
2008-09 HOT Table Values	0:05-0:40	0:10-1:15	0:20-2:00	0:10-1:45		0:10-1:20								
2008-09 ET Test Results							0:10-1:40							
2009-10 HOT Table Values	0:05-0:40	0:10-1:15	0:20-2:00	0:10-1:45		0:10-1:20	0:10-1:40							
2009-10 ET Test Results								0:10-1:15						
2010-11 HOT Table Values	0:05-0:40	0:10-1:15	0:20-2:00	0:10-1:45		0:10-1:20	0:10-1:40	0:10-1:15						
2010-11 ET Test Results									0:09-1:40					
2011-12 HOT Table Values	0:09-0:50	0:10-1:15	0:20-2:00	0:10-1:45		0:10-1:20	0:10-1:40	0:10-1:15	0:09-1:40					
2011-12 ET Test Results														
2012-13 HOT Table Values	0:09-0:50	0:10-1:15	0:20-2:00	0:10-1:45		0:10-1:20	0:10-1:40	0:10-1:15	0:09-1:40					
2012-13 ET Test Results										0:20-1:50				
2013-14 HOT Table Values	0:09-0:50	0:10-1:15		0:10-1:45		0:10-1:20	0:10-1:40	0:10-1:15	0:09-1:40	0:20-1:50				
2013-14 ET Test Results											0:15-1:45			
2014-15 HOT Table Values	0:09-0:50	0:10-1:15		0:10-1:45		0:10-1:20	0:10-1:40	0:10-1:15	0:09-1:40	0:20-1:50	0:15-1:45			
2014-15 ET Test Results														
2015-16 HOT Table Values	0:09-1:15	0:10-1:15		0:10-1:45		0:10-1:20	0:10-1:40	0:10-1:15	0:09-1:40	0:20-1:50	0:15-1:45			

7. OTHER CHANGES TO HOT GUIDELINES CONTENT

In addition to the changes made to the Type I, II, III and IV fluid HOT Guidelines, a number of other changes were made to the HOT Guidelines for winter 2015-16. These changes are documented in this chapter.

7.1 Active Frost Holdover Time Guidelines

Endurance time testing in frost was conducted with all fluids submitted for endurance time testing in the winter of 2014-15. The test durations were compared to the related generic holdover times: all completed ("failed") tests surpassed the generic holdover times, as did all tests that were not completed (due to active frost ending before fluid failure could occur). This analysis indicates that the generic frost holdover times can be considered substantiated for all fluids added to the HOT guidelines for winter 2015-16.

No content or formatting changes were made to the active frost HOT guidelines for winter 2015-16.

7.2 Allowance Time Tables

No changes were made to the allowance time table values. However, several changes were made to the notes and cautions.

1. A note was added to the allowance time tables to indicate that if intensity is reported with small hail, the equivalent ice pellet condition can be used, e.g. if light small hail is reported, the light ice pellet allowance times can be used. If intensity is not reported, moderate ice pellet allowance times must be used.

2. Two cautions were added to the allowance time tables. These cautions provide important information directly on the allowance time tables, which was previously provided only in the allowance time operational guidance section. This is to highlight its importance to users.

7.3 List of Fluids

The list of fluids was merged with the list of lowest on-wing viscosities (LOWVs) and the list of lowest operational use temperatures (LOUTs) for the winter of 2015-16. The information in this table is updated annually based on new information provided by the fluid manufacturers. A number of changes were made to the table accordingly for winter 2015-16.

7.4 Transport Canada / FAA Harmonization Initiative

In late 2014, Transport Canada and the FAA initiated an effort to harmonize their HOT guidelines documents. Several changes were made to the 2015-16 HOT guidelines as a result of this initiative, including:

- Minor changes to wording of many HOT table notes and cautions;
- Rewording of some table titles, including HOT tables and the visibility table;
- Reordering of some document content; and
- Addition of background colours to the Transport Canada snow holdover time cells and visibility table cells – the colours are coordinated with snowfall intensities.

Harmonization efforts and discussions will continue over winter 2015-16 and further changes are expected in future.

8. SUPPLEMENTAL RESEARCH: ENDURANCE TIME TESTING IN NATURAL SNOW AT VERY COLD TEMPERATURES

In the winter of 2014-15, supplemental endurance time testing was conducted with Type I, II, III and IV fluids in natural snow at very cold temperatures. The testing is documented in this section.

8.1 Background

Until the winter of 2003-04, most Type II and Type IV fluids were given fluid-specific holdover times in snow in the coldest temperature band in the Type II/IV HOT tables (below -14ºC to LOUT). The fluid-specific holdover times were based on extrapolations of natural snow data collected at warmer temperatures. They were calculated this way because holdover time testing is conducted in Montreal, where natural snow rarely occurs below -14ºC, and therefore natural snow data below -14°C was typically not available.

At the May 2003 SAE G-12 HOT Committee meeting, it was recommended that this methodology be changed as it was felt it may not be providing appropriate holdover times. The alternative put forward was to collect data with artificial snow machines at -25°C and use this data to determine holdover times for snow for the below -14 to -25ºC temperature band (later changed to below -14ºC to LOUT).

The artificial snow data was subsequently collected during the winter of 2003-04 by APS and AMIL. As a result of this testing, the SAE G-12 HOT Committee introduced generic holdover times of 15 to 30 minutes for the coldest snow temperature band for all Type II and IV fluids, with the exception of one ethylene glycol based fluid which retained fluid-specific holdover times.

When cells were added for light snow and very light snow to the Type II/IV HOT tables in 2013-14, additional snow machine testing was conducted with select Type II and Type IV fluids to determine appropriate generic holdover time values for the new coldest temperature band cells (below -14ºC to LOUT). The holdover times that resulted were:

- Light snow = 30 to 40 minutes; and
- Very light snow = 40 to 50 minutes.

The Type II/IV generic snow holdover times in the coldest temperature band have never been validated using natural snow data. It was recommended this be done as no in-depth research has been completed to correlate artificial and natural snow data at very cold temperatures.

Furthermore, no artificial snow data has been collected to validate the use of the generic very cold snow holdover times for new Type II/IV fluids that have come to market since the artificial snow testing was completed.

8.2 Objective

The primary objective of the very cold snow research was to collect endurance time data in natural snow at very cold temperatures (below -14°C) with current Type II and Type IV fluids to validate the current Type II / Type IV generic snow holdover times in the coldest temperature band (below -14°C to LOUT).

A secondary objective was to do the same for Type I and Type III fluids.

8.3 Methodology

Tests were carried out according to the methodology described in the following subsections, which detail test locations, test procedures and fluids.

8.3.1 Test Locations

As the very cold temperatures needed for this project rarely occur in Montreal, APS planned to travel to the far north regions of Canada ("far north") to collect the necessary data.

APS analysed weather trends in various locations in the far north to find locations which offered very cold temperatures and sufficient snowfall to allow for a few days of testing at a time. Weather forecasts for these locations were monitored over the winter.

Due to unseasonably low temperatures in Montreal in the winter of 2014-15, testing was primarily conducted in Montreal. Additional testing was conducted in Grande Prairie, Alberta, in conjunction with another project.

8.3.2 Test Procedures

Tests were carried out according to standard endurance time testing procedures for natural snow, as detailed in Subsection 2.1. An additional test procedure was written to coordinate testing. A copy of this procedure is included in Appendix L.

Figure 8.1 depicts a collapsible test stand that was manufactured specifically for the testing. It was designed for testing in the far north, which requires personnel to travel by air on short notice with all required equipment and fluids. The collapsible test stand can easily be transported as checked luggage.

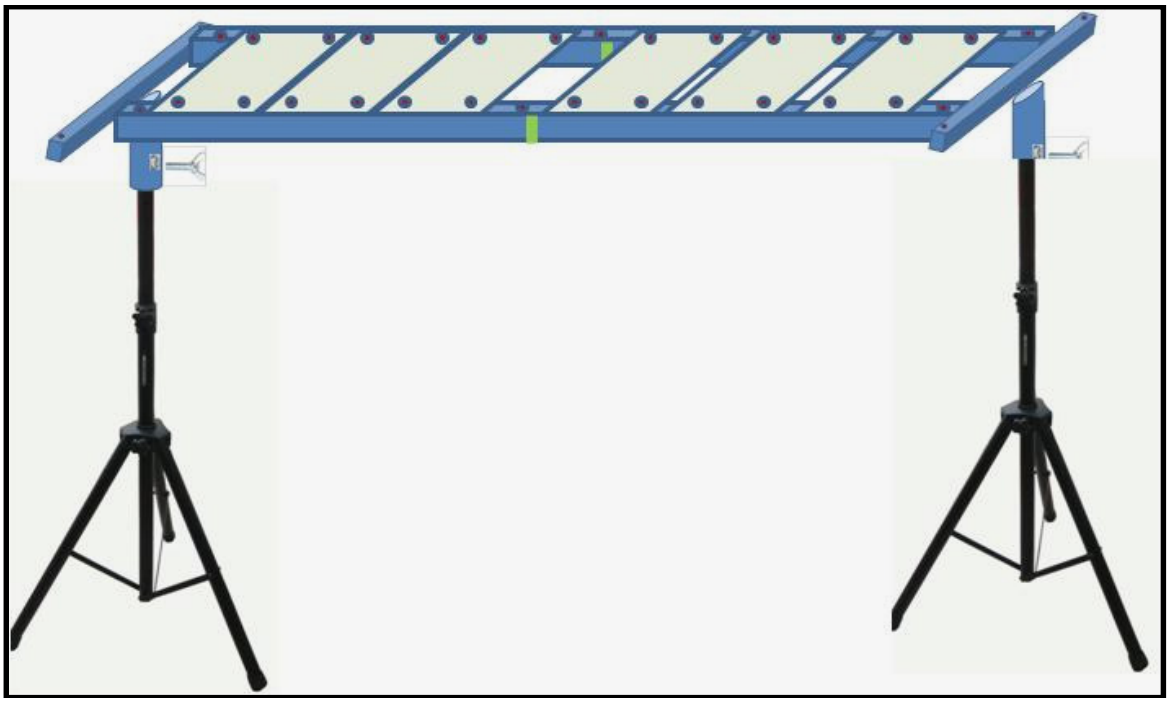

Figure 8.1: Rendering of Collapsible Test Stand

8.3.3 Fluids Tested

A selection of Type I, Type II, Type III and Type IV were tested. The fluids were obtained from available APS inventory. Fluids were predominantly commercially available fluids, but some experimental products were also tested. Most, but not all, of the Type II, Type III and Type IV fluid samples were LOWV samples.

Table 8.1 summarizes the number of fluids tested by fluid type. Table 8.2 provides details of the Type II, III and IV fluids tested. Fluids have been coded as results are intended to be analysed by fluid type, not on a fluid-specific basis.

It should be noted that the viscosities of most the fluids were checked midway through testing. Data from some fluids was scrapped because the viscosity was found to be below the LOWV. This data is not included in this report.

Table 8.1: Number of Fluids Tested

Fluid Type	Products Tested
Type I	2
Type II	3
Type III	1
Type IV	8
Total	**14**

Table 8.2: Details of Type II, III, IV Fluids Tested

Fluid Code	Fluid Type	Sample Type	Viscosity Checked
II-A	II	Mid Viscosity	No
III-A	III	LOWV	Yes
IV-B	IV	Mid Viscosity	No
IV-C	IV	LOWV	No
IV-D	IV	LOWV	Yes
IV-E	IV	LOWV	Yes
IV-F	IV	LOWV	Yes
II-G	II	LOWV	Yes
IV-H	IV	LOWV	No
IV-I	IV	LOWV	Yes
II-J	II	LOWV	Yes
IV-K	IV	LOWV	No

8.4 Data Collected

Table 8.3 provides a summary of testing events at which data was collected, including associated locations, temperatures and average precipitation rates.

A total of 49 tests were conducted. Table 8.4 provides a summary of tests conducted by fluid type.

Table 8.3: Summary of Testing Events

Event #	Location	Temperatures	Precipitation Rates
1	Grande Prairie, AB	-19°C	6 g/dm²/h
2	Montreal, QC	-19 to -23°C	5 to 9 g/dm²/h
3	Montreal, QC	-16 to -19°C	9 to 11 g/dm²/h
4	Montreal, QC	-16°C	1 g/dm²/h
5	Montreal, QC	-16°C	7 g/dm²/h

Table 8.4: Summary of Tests Conducted by Fluid Type

Fluid Type	Tests
Type I	5
Type II	10
Type III	14
Type IV	20
All	49

8.4.1 Type I Test Log

Table 8.5 provides a log of Type I tests completed. Five tests were conducted with Type I fluids. Tests were conducted on aluminum and composite surfaces.

8.4.2 Type III Test Log

Table 8.6 provides a log of Type III tests completed. Fourteen tests were conducted with Type III fluids. It should be noted that the Type III fluid sample tested was an LOWV sample.

8.4.3 Type II/IV Test Log

Table 8.7 provides a log of Type II and Type IV tests completed. Thirty tests were conducted, including 10 with Type II fluids and 20 with Type IV fluids. It should be noted that Fluids A and B were production viscosity samples; all other samples were LOWV.

Table 8.5: Log of Tests – Type I Fluids

#	Fluid Code	Test Surface	Endurance Time (Mins)	Average Precipitation Rate (g/dm²/h)	Average Temperature (°C)
1	I-O	Aluminum Box	7.0	8.8	-22.2
2	I-E	Aluminum Box	6.8	7.5	-22.4
3	I-E	Composite Box	5.4	10.6	-16.2
4	I-O	Composite Box	6.9	9.2	-15.9
5	I-E	Aluminum Box	9.2	9.5	-15.9

Table 8.6: Log of Tests – Type III Fluids

#	Fluid Code	Endurance Time (Mins)	Average Precipitation Rate (g/dm²/h)	Average Temperature (°C)
1	III-B	46.2	8.1	-17.9
2	III-B	55.0	7.0	-17.9
3	III-B	63.8	8.3	-18.1
4	III-B	57.3	6.2	-18.3
5	III-B	60.1	8.0	-18.4
6	III-B	55.8	6.4	-19.2
7	III-B	52.5	8.1	-22.2
8	III-B	78.2	8.1	-21.9
9	III-B	66.3	7.9	-19.6
10	III-B	66.1	7.9	-19.6
11	III-B	84.0	8.0	-19.2
12	III-B	83.8	8.0	-19.2
13	III-B	83.3	8.0	-19.2
14	III-B	83.1	8.0	-19.2

Table 8.7: Log of Tests – Type II/IV Fluids

#	Fluid Type	Fluid Code	Endurance Time (Mins)	Average Precipitation Rate (g/dm²/h)	Average Temperature (°C)
1	II	II-A	26.7	9.8	-16.7
2	II	II-A	26.4	9.8	-16.7
3	IV	IV-B	70.0	7.4	-21.3
4	IV	IV-C	63.0	8.3	-21.9
5	IV	IV-D	52.5	7.1	-21.0
6	IV	IV-D	31.0	8.5	-21.0
7	IV	IV-D	31.8	8.2	-16.2
8	IV	IV-E	23.0	7.4	-22.3
9	IV	IV-E	39.8	6.0	-21.0
10	IV	IV-F	41.0	8.4	-22.2
11	IV	IV-F	60.5	8.1	-19.2
12	IV	IV-F	63.8	8.9	-17.6
13	IV	IV-F	71.4	8.1	-16.7
14	IV	IV-F	274.8	0.8	-16.0
15	II	II-G	39.3	6.9	-15.7
16	IV	IV-H	60.1	7.9	-21.9
17	IV	IV-I	119.5	6.8	-18.8
18	IV	IV-I	129.3	6.5	-19.0
19	IV	IV-I	120.3	6.9	-19.1
20	IV	IV-I	111.3	6.8	-19.2
21	IV	IV-I	57.3	7.5	-22.3
22	IV	IV-I	131.2	8.0	-16.7
23	II	II-J	20.8	7.4	-21.9
24	II	II-J	44.0	6.5	-21.0
25	II	II-J	28.0	8.0	-21.0
26	II	II-J	30.1	10.1	-17.6
27	II	II-J	26.5	8.3	-17.1
28	II	II-J	19.9	10.3	-16.7
29	II	II-J	217.1	0.9	-16.4
30	IV	IV-K	40.5	8.1	-21.9

8.5 Results and Conclusions

The test results are analysed by fluid type in Subsections 8.5.1 to 8.5.3.

In each section, the data collected from the associated fluid type(s) is plotted on a chart of precipitation rate vs. endurance time as coloured data points. The generic holdover times for the fluid type(s) are plotted on the charts as black circles. The black lines drawn between the generic holdover time data points represent the generic holdover times at all rates.

Data points that are above the black generic holdover times line indicate data that is above the associated generic holdover times. Data points below the black line indicate data that did not meet the associated generic holdover times. This data is of concern.

8.5.1 Type I Fluid Results

Figure 8.2 shows the Type I data. The majority of data was collected in precipitation rates of 7 to 11 g/dm²/h. All data is above the generic holdover times, as indicated by the black curve. The limited data does not indicate an issue with the current Type I generic holdover times.

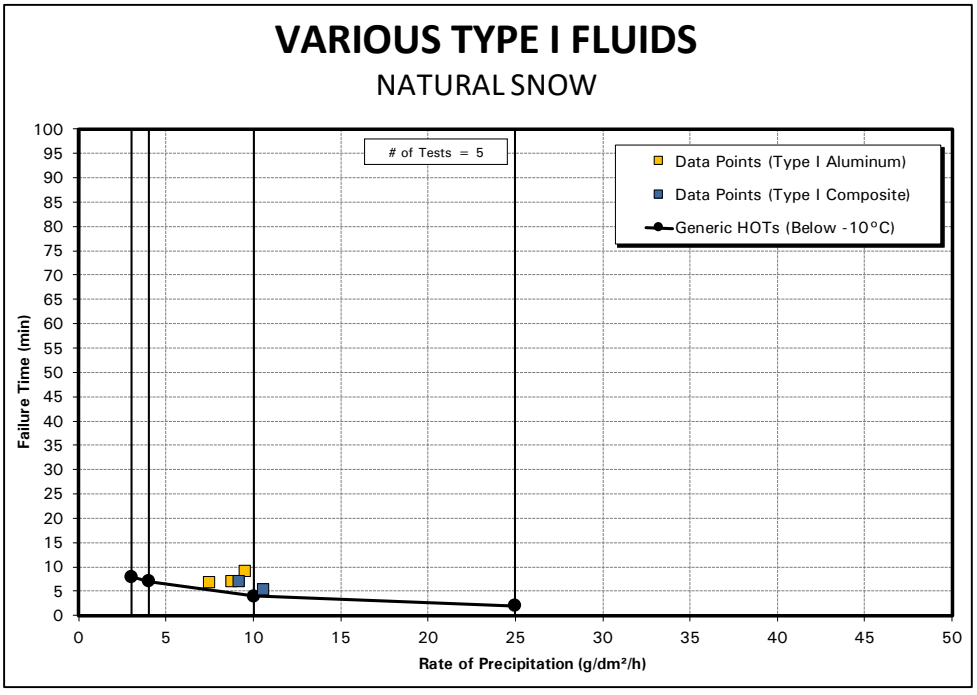

Figure 8.2: Type I Results

8.5.2 Type III Fluid Results

Figure 8.3 shows the Type III data. The majority of data was collected in precipitation rates of 6 to 9 g/dm²/h. All data is well above the generic holdover times, as indicated by the black curve. The data indicates that the current Type III generic holdover times are appropriate.

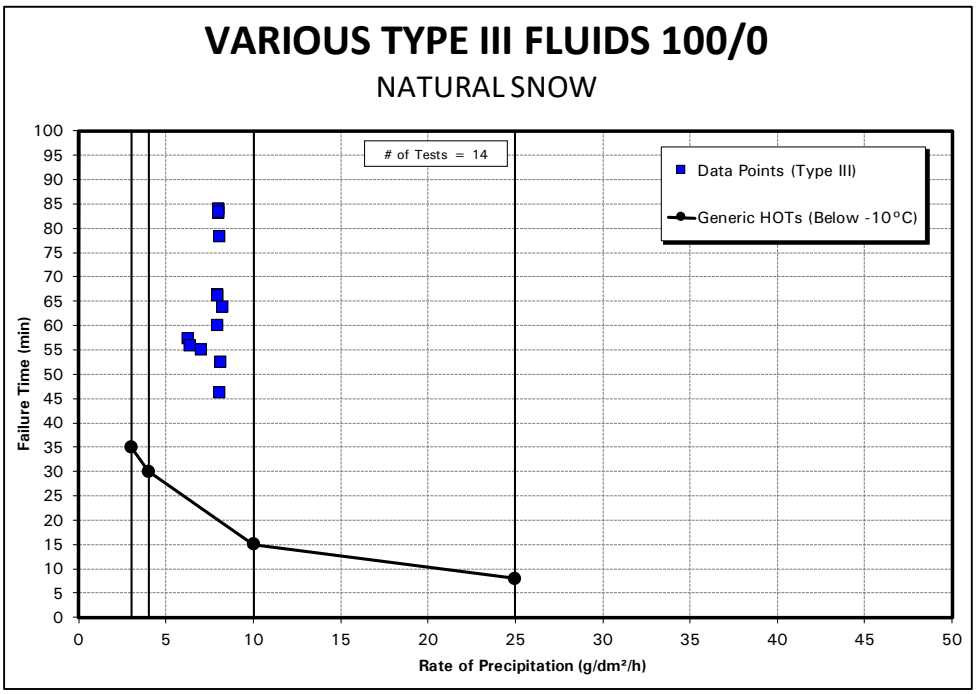

Figure 8.3: Type III Results

8.5.3 Type II/IV Fluid Results

Figure 8.4 shows the Type II and Type IV data. The majority of data was collected in precipitation rates below 9 g/dm²/h.

As can be seen in Figure 8.4, some data did not meet the generic holdover times, as indicated by the data points below the black curve. This data was surprising, as it was not expected that any data would be collected that did not meet the generic holdover times.

Both Type II and Type IV fluids are represented in the data below the generic line. Surprisingly, one mid-viscosity fluid sample did not meet the generic holdover times. It should be noted that the viscosities of all fluid samples which had data that did not meet the generic holdover times were checked. No data was retained from fluids

with viscosities below the LOWV. It should also be noted that much of the data collected was collected at temperatures at the higher end of the temperature band to which the plotted generic holdover times are applicable.

This data indicates that there is an issue with the validity of the current Type II/IV generic holdover times in snow at very cold temperatures for some fluids. These results were not expected. Because only a small number of tests was conducted with a small selection of currently available fluids, further data with additional fluids is required to further investigate this issue.

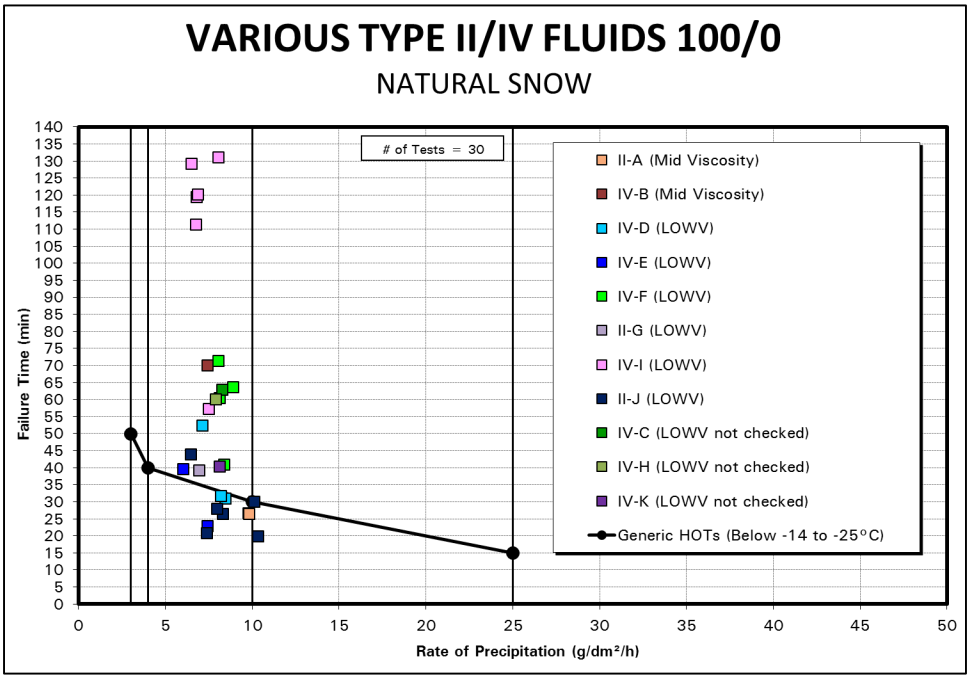

Figure 8.4: Type II/IV Results

8.6 Recommendations

It is recommended that further natural snow testing be conducted with Type II and IV fluids at very cold temperatures. A more comprehensive selection of fluids should be obtained from the fluid manufacturers. Ideally, all Type II and Type IV fluids currently in the HOT Guidelines would be tested.

LOWV fluid samples should be used for this testing as they will result in the most conservative endurance times. However, if these samples can not be obtained, production viscosity fluid samples can be used.

Testing will most likely require travel to colder regions of Canada, where snowfall at temperatures of -25°C and colder occurs with some regularity.

9. CONCLUSIONS

The conclusions derived from the testing conducted in the winter of 2014-15 are provided below.

9.1 Annual Testing

Endurance time testing was carried out with ten de/anti-icing fluids in the winter of 2014-15. The results of this testing resulted in several changes being made to the HOT guidelines. The changes, described below, were included in the winter 2015-16 HOT guidelines.

Type I Fluids

- No changes were made to the Type I fluid HOT guidelines.

Type II Fluids

- Fluid-specific HOT tables were added for the new fluids Kilfrost ABC-Ice Clear and Newave Aerochemical FCY-2 Bio+.
- Increases were made to the LNT Solutions P250 snow holdover times as the result of supplemental testing.
- Clariant Safewing MPII 1951 was removed as per the protocol for removing obsolete data.
- Six minor changes were made to the Type II generic fluid holdover times as a result of the new and removed Type II fluids.

Type III Fluids

- Fluid-specific, application temperature-specific, rotation speed-specific HOT tables were added for Type III fluids.
- The Type III generic HOT table was removed due to the different application temperature requirements of the two Type III fluids and subsequent lack of generic Type III holdover times.

Type IV Fluids

- A fluid-specific HOT table was added for the new fluid Deicing Solutions ECO-SHIELD.
- Increases were made to the LNT Solutions E450 snow holdover times as the result of supplemental testing.

- Obsolete fluids ABAX AD-480 and Kilfrost ABC-S were removed from the HOT guidelines.
- Significant changes, primarily increases, were made to the Type IV generic holdover times as a result of the new and removed Type II fluids.

Allowance Time Tables

- A note was added to the allowance time tables to indicate that if intensity is reported with small hail, the equivalent ice pellet condition can be used.
- Two cautions were added to the allowance time tables which provide important information which was previously provided only in the operational guidance section.

Active Frost Table

- No changes were made to the active frost HOT guidelines.

Other Changes

- The list of fluids was merged with the list of LOWVs and the list of LOUTs.
- Several minor changes were made as a result of the Transport Canada / FAA harmonization initiative.

9.2 Supplemental Testing

The supplemental testing conducted in natural snow at very cold temperatures did not indicate any issue with the current generic holdover times for Type I and Type III fluids. The testing indicates that Type II/IV generic holdover times in these conditions may not be sufficiently conservative. Further testing with additional fluids is required to support this conclusion.

10. RECOMMENDATIONS

It is recommended that:

1. Any new Type I, Type II, Type III or Type IV fluid be evaluated over the entire range of conditions encompassed by the HOT tables;
2. If a new Type III fluid is submitted for heated application testing, further research be conducted to evaluate endurance times of Type III fluids applied heated to composite surfaces; and
3. Further research be completed to evaluate the current holdover times provided for Type II, III and IV fluids in snow at very cold temperatures.

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REFERENCES

1. Bendickson, S., Campbell, R., Chaput, M., D'Avirro, J., Dawson, P., Mayodon, M., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2002-03 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2003, TP 14144E, XX (to be published).

2. *Guidelines for Aircraft Ground Icing Operations (Second Edition)*, Transport Canada, April 2005, TP 14052E.

3. *Revised FAA-Approved Deicing Program Updates, Winter 20xx-20xx,* Federal Aviation Administration, N8900.xxx.

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2014-15

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2014-15

2.3 Holdover Time Testing for New Fluids

This program element is funded by the fluid manufacturers. The extent of effort for this program element will be determined by the number of new fluids submitted for testing.

a) Conduct flat plate tests with samples of Type I, Type II, Type III and Type IV fluids supplied by fluid manufacturers. Testing will be conducted using the methodology provided in Aerospace Recommended Practice (ARP) 5485 and/or 5945 under conditions of:

   i. Natural snow and two frost events at the P.E.T. test site (under a wide range of temperature, precipitation rate, precipitation type, and wind conditions); and

   ii. Simulated freezing precipitation at the NRC CEF (in freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface).

b) Record individual fluid endurance times; and

c) Analyze the data collected, report the findings, and prepare presentation material for the SAE G-12 annual meeting.

2.20 Conduct HOT Testing in Northern Locations to Validate HOT Data at -25°C and Close to LOUT to Support Generic HOT's

a) Conduct flat plate tests with samples of Type I, Type II, Type III and Type IV fluids supplied by fluid manufacturers. Testing will be conducted using the methodology provided in Aerospace Recommended Practice (ARP) 5485 and/or 5945 under conditions of natural snow at temperatures close to -25°C; and

b) Analyze the data collected, report the findings, and prepare presentation material for the SAE G-12 annual meeting.

2.56.1 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.

Preparation and Setup for Natural 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) to ensure personnel safety and adhere to environmental guidelines;

c) Prepare an updated procedure 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 test 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.

General Activities

a) Analyze individual fluid HOT data for to develop generic table HOT's;

b) Maintain data to ensure continuity; and

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

APPENDIX B

PROCEDURES FOR HOLDOVER TIME TESTING

- Test Requirements for Natural Precipitation Flat Plate Testing
- Determination of Endurance Times of Type I Fluids Under Natural Snow Precipitation at Dorval
- Test Requirements for Simulated Freezing Precipitation Flat Plate Testing
- Overall Program of Tests at NRC, March/April 2015

TEST REQUIREMENTS
FOR NATURAL PRECIPITATION FLAT PLATE TESTING

CM1892.001

TEST REQUIREMENTS FOR NATURAL PRECIPITATION FLAT PLATE TESTING

Winter 2004-05

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Nicoara Moc

Reviewed by: John D'Avirro

APS Aviation Inc.

December 23, 2004
Version 1.0

TEST REQUIREMENTS FOR NATURAL PRECIPITATION FLAT PLATE TESTING

2004-05

This document provides a brief summary of the test requirements and data forms needed for natural precipitation flat plate tests in the 2004-05 winter season. The procedure containing a detailed description of the test parameters, snow measurement methods, testing procedure and test equipment for conducting endurance time tests for SAE Type II, III and IV de/anti-icing fluids is stored on APS's local network and can be found at the following location: M:\Groups\CM1892 (TC-Deicing 03-04)\Procedures\AS5485\

This document is based on the aforementioned procedure, and was developed for documentation purposes, to be inserted in the final report after the completion of endurance time testing, and to provide the latest data forms.

Also included in this document there is a list of steps required for testing (see Attachment 1).

1. TEST PLAN

The test plan, shown in Table 1.1 provides the temperature and requirements for fluid type testing. Test will be conducted at the Dorval test site located adjacent to the Meteorological Services of Canada. These tests shall be conducted during natural snow conditions.

Table 1.1: Natural Snow Precipitation Test Plan New Fluids

Temperature Range	Type II/IV Neat	Type II/IV 75/25	Type II/IV 50/50	Type III
>0°C	Yes	Yes	Yes	Yes
0 to -3°C	Yes	Yes	Yes	Yes
-3 to -14°C	Yes	Yes	No	Yes
-14 to -25°C	Yes	No	No	Yes
Below -25°C	Yes	No	No	Yes

2. DATA FORMS

The data forms are included in Tables 2.1 to 2.4. Table 2.1 represents the data form developed for the end-condition tester. Table 2.2 shows the data form for the meteo/video tester. Table 2.3 and Table 2.4 present two data forms to be filled in each testing session and winter season, respectively.

Table 2.1: End Condition Data Form for Natural Snow

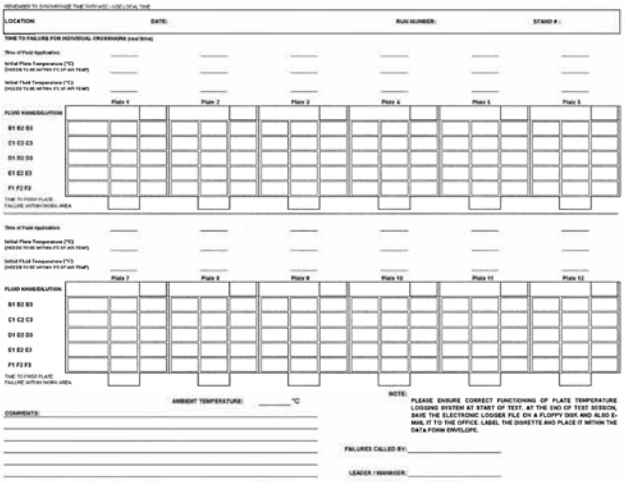

Table 2.2: Meteorological and Precipitation Rate Data Form

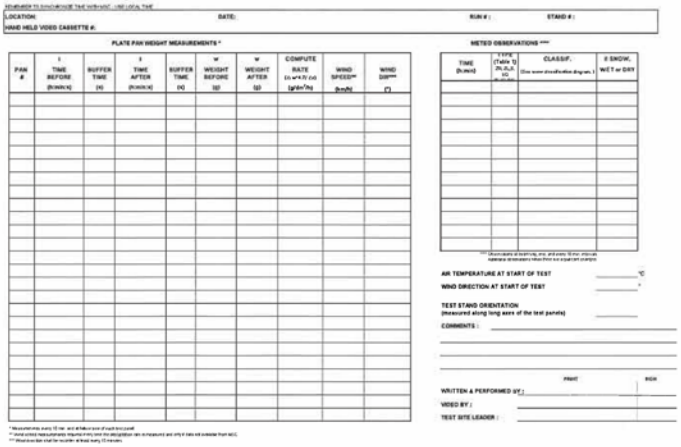

Table 2.3: General Form for Each Testing Session – Natural Snow

LOCATION: APS TEST SITE	DATE:

Angle of the Test Stands (°):
(the angle shall be within 10° ± 0.2)

PLATE 1 ☐ PLATE 6 ☐ PLATE 7 ☐ PLATE 12 ☐

Synchronize the timing devices and the computer clock with atomic time (www.time.gov): ☐
(check the box if the timing devices are synchronized)

Plate Temperature Files:
(to be recorded by APS at the end of the each test session, saved on floppy disks and included in the envelope along with the forms)
The plate temperature data is saved to the following files (provide filename and extension):

_____
_____
_____
_____
_____
_____

COMMENTS:

_____
_____
_____
_____

LEADER: _____

Table 2.4: General Form for Each Winter Season – Natural Snow

LOCATION: APS TEST SITE	DATE INTERVAL:

Safety Issues Discussed ☐

Test Plate Material: ☐
(check the box if material used is Aluminum alloy AMS 4037 or 4041)

Test Plate Dimensions: ☐
(check the box if the dimensions are 500mm long x 300mm wide x 3.2mm thick)

Surface Finish: ☐
(check the box if the average surface roughness is ≤ 1.0 µm)
Refer to Verification Procedure "A-Verif" for methodology

Ice-catch Pan Dimensions: ☐
(check the box if the dimensions are 30 cm by 43 cm)

COMMENTS:

_____
_____
_____
_____
_____

LEADER: _____

ATTACHMENT 1
SUMMARY OF STEPS TO CONDUCT TESTS

The following are the major steps required to conduct flat plate tests at Dorval.

Upon Entering Trailer

a) Turn on lights (outside and inside) and sign-in;

b) Determine tests to be conducted and fluids (Type II, III, IV to be placed outdoors);

c) Remove snow and clear access to stands; and

d) Synchronize all clocks and stop watches, if used.

For Each Test

a) Fill in general material on Table 2.3, and prepare plate pans for start of test;

b) Place fluids by stand;

c) Ensure stand is into wind;

d) Record end condition times of all panels (care to be taken for the 5th crosshair of each panel);

e) Measure plate pan weights over the course of the test;

f) Video record start of test, progression of failures, and when the end condition (5 of 15 crosshairs) is being called on each panel (OPTIONAL);

g) Ensure forms are properly completed and signed; and

h) Start a new test.

To Close Trailer

a) Replenish fluids;

b) Log and document date, times, test #'s, etc. on all media;

c) After major events (more than 10 tests), start new tapes for next occasion;

d) Place all media and test forms in large envelope for delivery to office;

e) Clean trailer and all garbage;

f) Ensure outdoor is left clean and presentable; and

g) Close lights and sign-out.

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DETERMINATION OF ENDURANCE TIMES OF TYPE I FLUIDS UNDER NATURAL SNOW PRECIPITATION AT DORVAL

CM2103.001 (07-08)

EXPERIMENTAL PROGRAM

DETERMINATION OF ENDURANCE TIMES OF TYPE I FLUIDS UNDER NATURAL SNOW PRECIPITATION AT DORVAL

Winter 2007-08

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: John D'Avirro

Reviewed by: John D'Avirro

APS Aviation Inc.

December 14, 2007
Version 1.0

EXPERIMENTAL PROGRAM
DETERMINATION OF ENDURANCE TIMES OF TYPE I FLUIDS
UNDER NATURAL SNOW PRECIPITATION AT DORVAL
Winter 2007-08

1. BACKGROUND

From the early 1990s, the Type I fluid holdover time range for snow conditions was 6 to 15 minutes. Based on a series of SAE Type I fluid endurance time trials on flat plates conducted in the 1999-2000 winter and discussions at a SAE G-12 Holdover Time Subcommittee meeting held in Toulouse, France in May 2000, the holdover times for snow were reduced to values significantly shorter than 6 to 15 minutes. The reduction in fluid endurance times coincided with the general realization that the test methodology was suspect.

As a result, APS was directed to develop a test protocol for measuring endurance times for SAE Type I fluids that would reflect real field operations. Following examination of several test surfaces and various procedures for fluid application, it was concluded that an insulated 7.5 cm cold-soak box, empty, when treated with 0.5 L of fluid at 60°C, was found to be a reasonable representation of the temperature decay rate demonstrated by wings in natural outdoor conditions. The fluid was applied along the top edge of the test surface using a specially designed 12-hole fluid spreader.

In the winter of 2001-02, a series of natural snow tests was conducted at Dorval Airport and at Chicoutimi, Quebec using the newly developed Type I protocol. Based on these tests, holdover time tables were produced and presented to the industry at the SAE G-12 Holdover Time Subcommittee meeting in Frankfurt, Germany in June 2002. A full account of these tests can be found in TP 13994E, *Generation of Holdover Times Using the New Type I Fluid Test Protocol*, November 2002.

2. OBJECTIVES

The objective of this project is to ensure that new Type I fluids do not behave inferior, from an endurance time perspective, to the fluids used to generate the currently accepted values in the holdover time table.

To achieve this objective, a series of tests will be conducted using new SAE Type I fluids, on the empty aluminum box surfaces.

3. PURPOSE

As stated in the objective, this project is to ensure new Type I fluids have endurance times greater than or equal to currently accepted holdover times. ARP 5945 describes procedures to carry out Type I tests in natural snow. While these tests are material, the tester cannot determine early on whether the fluid has reasonable performance or not.

This document describes additional tests that provide this missing information during testing. Comparing the new fluid, on a side-by-side basis, with a "grandfather" provides ongoing analysis of the performance of the new fluid,

4. PROCEDURE/TEST REQUIREMENTS

The 7.5 cm cold-soak box, insulated on all sides but the top, empty, will be used as the test surface for the outdoor tests.

The fluid temperature will be 60°C with an acceptance range of + 2°C and -0°C. The fluid quantity will be 0.5 L, and the fluid will be applied on the surface through a 12-hole spreader. The fluid used will be diluted to a freeze point 10°C below ambient temperature, unless otherwise specified by the fluid manufacturer.

For this experiment, two cold-soak boxes will be placed on the stand at the same time. In an attempt to keep the precipitation rate and temperature as constant as possible, the new fluids and the reference fluid will be run simultaneously. At least 20 tests will be conducted.

The tests will be conducted until the last fluid on the stand fails, and repeated following the same procedure.

In order to have a more accurate representation of the holdover time obtained in real field deicing operations, the trials need to be performed at different temperatures and rates, over several snowstorms.

The steps to be followed in conducting these tests are:

1. Synchronize computer and test clocks to atomic clock;
2. Follow standard procedures for ET tests except as described below;
3. Prepare surfaces on the stand in accordance with Table 3.1;
4. Prepare fluid (Section 4.2) for testing. The types of surfaces, positions and fluid amounts to be tested are shown in Table 3.1;

Table 3.1

Test Stand Positions

STAND POS.	SURFACE TYPE	FLUID		Fluid Conc.	Fluid Type
		AMOUNT (L)	TEMP (°C)		
1	RATE PAN				
2	7.5 cm box (empty)	0.5	60	10° Buffer	Battelle D3 ADF Type I
3	7.5 cm box (empty)	0.5	60	10° Buffer	Reference Fluid (E or P)*

* E – Ethylene (UCAR EG ADF)
P – Propylene (PG ADF)

5. Pour required amount of heated fluid into thermos containers for application;

6. Apply the fluid to the cold-soak boxes on the stand. Pour the fluid on the test surfaces in quick succession to avoid cooling of the spreader between pours. The spreader is modified (taped) to allow fluid to come out through only 12 holes. Just before pouring, the box surfaces should be cleaned according to the following procedure:

   - Clean the surface of all contamination with scraper and squeegee; and
   - Whenever surface wetting is found to be deficient, a clean wiper cloth with fluid at ambient temperature can be used to wipe the plate over its entire surface. (This is intended to ensure that the surface is wetted as well as clean, to assist in complete coverage with the applied fluid.)

7. Standing behind the stand, place a shield device to deflect the air and pour the test fluid from the thermos into the spreader. Remove the shield when the spreader has emptied;

8. Determine failure times on test surfaces, and record using standard ET data forms (Attachment I);

9. Measure precipitation rates and record using the Meteo/Plate data form (Attachment II); and

10. Record rates. As per Table 3.1, position 1 on the stand will be used for measuring snow deposition rates. Use two rate pans in a 5 minute routine. At the time that a measurement is required, the pan that needs to be weighed will be replaced on the stand by the other pan. This cycle will continue until the last surface failed. While pouring the fluid on the test surfaces care should be taken that no contamination falls in the rate pans (use a shield device if necessary). The bottom and sides of the pan MUST BE WETTED (before each pre-test weighing) with Type IV anti-icing fluid to prevent blowing snow from escaping the pan.

5. EQUIPMENT AND FLUIDS

5.1 Equipment

Use the same equipment that is used for ET trials. Candidate test surfaces used for these trials will be:

- Two 7.5 cm cold-soak boxes (empty)

A wind shield and fluid spreader device will be used for applying fluids.

5.2 Fluids

Tests shall be conducted with the following Type I fluids:

- Battelle D3 ADF Type I; and
- PG ADF or UCAR EG ADF (reference fluid).

Fluids are to be mixed to a freeze point 10ºC below OAT. The dilution table for these three fluids is presented in Attachment III.

Fluids to be applied to the cold soak box test surfaces will be heated to 60ºC.

6. PERSONNEL

Three technicians are needed to conduct the tests:

- First calls failures, prepares fluid samples;
- Second helps prepare and pour fluids; and
- Third measures rates and wind.

7. DATA FORMS

Use end condition forms from standard Endurance Time procedure (Attachment I). For rate measurements, see Attachment II.

ATTACHMENT I
END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH ATOMIC CLOCK - USE REAL TIME VERSION 1.0 Winter 2002/2003

LOCATION: DORVAL TEST SITE DATE: RUN #: STAND # :

LOCATION OF SURFACES ON THE STAND

1	2	3	4	5
Rate Pan	ColdSoak BOX	ColdSoak BOX	ColdSoak BOX	ColdSoak BOX

OTHER COMMENTS (Fluid Batch, etc):

FAILURES CALLED BY : PRINT SIGN

*TIME (After Fluid Application) TO FAILURE FOR INDIVIDUAL CROSSHAIRS (hr:min)

Time of Fluid Application: _____ hr:min:ss _____ hr:min:ss _____ hr:min:ss

	BOX ____			BOX ____			BOX ____		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									
BRIX / FLUID TEMPERATURE AT START	/			/			/		

Time of Fluid Application: _____ hr:min:ss _____ hr:min:ss _____ hr:min:ss

	BOX ____			BOX ____			BOX ____		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									
BRIX / FLUID TEMPERATURE AT START	/			/			/		

Cm1747\Procedures\Type I protocol\Type I ETV\Attachment I

M:\Groups\PM2103.001 (TC-Deicing 07-08)\Procedures\Type I Fluids (Nat. Snow)\Version 1.0.doc
Version 1.0,December 07

Page 6 of 8

ATTACHMENT II
METEO/PLATE PAN DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH ATOMIC CLOCK - USE REAL TIME — VERSION 1.0 Winter 2002/2003

LOCATION: DORVAL TEST SITE | DATE: | RUN # : | STAND # :

PLATE PAN WEIGHT MEASUREMENTS

PAN #	t TIME BEFORE (hh:mm:ss)	BUFFER TIME (Seconds)	t TIME AFTER (hh:mm:ss)	BUFFER TIME (Seconds)	w WEIGHT BEFORE (grams)	w WEIGHT AFTER (grams)	COMPUTE RATE (Δw*4.7/ Δt) ($g/dm^2/h$)

Precipitation rate will be measured every 5 minutes.

METEO OBSERVATIONS *

TIME (hr:min)	TYPE ZR, ZLS, SG IP, IC, BS, SP	SNOW CLASSIF. (See Fig. 3)

*observations at beginning, end, and every 5 min. intervals. Additional observations when there are significant changes.

Cm1747\Procedures\Type I protocol\Type I ETA ttachment 2

COMMENTS : _____

	PRINT	SIGN
WRITTEN & PERFORMED BY :		
PHOTO BY :		

ATTACHMENT III
FLUID DILUTION FOR TYPE I TESTING

OAT (°C)	FFP (°C)	Octagon Octaflo / EF				UCAR ADF (EG)				Battelle D3 1006A			
		% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres
5	-5	15	9.75	12.0	6.8	12	8	1.0	7.0				
4	-6					14.5	9.5	1.2	6.8	20	14.75	1.6	6.4
3	-7					16	10.5	1.3	6.7	25.9	18.50	2.1	5.9
2	-8					18.5	12	1.5	6.5	28	20	2.24	5.76
1	-9	27.5	18.5	2.2	5.8	21.5	13.5	1.7	6.3	29	21.25	2.32	5.68
0	-10	29	19	2.3	5.7	22	14	1.8	6.2	30	22.75	2.4	5.6
-1	-11	30	20	2.4	5.6	23	15	1.8	6.2	33	24	2.64	5.36
-2	-12	31	20.5	2.5	5.5	24.5	16	2.0	6.0	35	25.5	2.8	5.2
-3	-13	32	21.25	2.6	5.4	26	17	2.1	5.9	37	26.75	2.96	5.04
-4	-14	34	22.5	2.7	5.3	28	18	2.2	5.8	38	28	3.04	4.96
-5	-15	35	23	2.8	5.2	30	19	2.4	5.6	39	29	3.12	4.88
-6	-16	36	23.5	2.9	5.1	31	19.75	2.5	5.5	40	29.75	3.2	4.8
-7	-17	37	24	3.0	5.0	32	20.5	2.6	5.4	44	31.5	3.52	4.48
-8	-18	38.5	25	3.1	4.9	33.5	21.25	2.7	5.3	45	32.5	3.6	4.4
-9	-19	40	26	3.2	4.8	34.5	21.75	2.8	5.2	47	33.75	3.76	4.24
-10	-20	42	27	3.4	4.6	36	22.5	2.9	5.1	48	34.75	3.84	4.16
-11	-21	44	28	3.5	4.5	37	23	3.0	5.0	49	35.75	3.92	4.08
-12	-22	45	28.5	3.6	4.4	38	23.75	3.0	5.0	50	36.5	4	4
-13	-23	46	29	3.7	4.3	39	24.5	3.1	4.9	52	37.5	4.16	3.84
-14	-24	47	29.5	3.8	4.2	40	25	3.2	4.8	53	38.5	4.24	3.76
-15	-25	47.5	30	3.8	4.2	41	25.5	3.3	4.7	54	39.5	4.32	3.68
-16	-26	48.5	30.5	3.9	4.1	42	26	3.4	4.6	55	39.5	4.4	3.6
-17	-27	49	31	3.9	4.1	43	26.5	3.4	4.6	57	41	4.56	3.44
-18	-28	50	31.5	4.0	4.0	44	27	3.5	4.5	58	41.75	4.64	3.36
-19	-29	51	32	4.1	3.9	45	27.5	3.6	4.4	60	42.25	4.8	3.2
-20	-30	52	32.5	4.2	3.8	45.75	28	3.7	4.3	61	43	4.88	3.12
-22	-32	53.5	33.5	4.3	3.7	47	28.75	3.8	4.2	62	44.25	4.96	3.04
-25	-35	56	34.5	4.5	3.5	49	30	3.9	4.1	65	46	5.2	2.8
-30	-40	60	37	4.8	3.2	53	32	4.2	3.8	70	48.25	5.6	2.4

PM2020 (TC-Deicing 05-06)\Procedures\Type I ET\Fluid Dilution for Type I Testing

TEST REQUIREMENTS
FOR SIMULATED FREEZING PRECIPITATION FLAT PLATE TESTING

CM1892.001

TEST REQUIREMENTS
FOR SIMULATED FREEZING PRECIPITATION FLAT PLATE TESTING

- Freezing Fog
- Freezing Drizzle and Light Freezing Rain
- Rain on a Cold-Soaked Surface

Winter 2003-04

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Richard Campbell

Reviewed by: John D'Avirro



APS Aviation Inc.

January 15, 2004
Version 1.0

TEST REQUIREMENTS FOR SIMULATED FREEZING PRECIPITATION FLAT PLATE TESTING

Winter 2003-04

This document provides a brief summary of the test requirements and data forms needed for the conduct of simulated freezing fog, freezing drizzle, light freezing rain and rain on a cold-soaked surface holdover time tests. The list of tests and schedule of tests are described in the separate document "Overall Program of Tests at NRC, April, 2004". These tests will be conducted at NRC's Climatic Engineering Facility (CEF) in Ottawa. The procedure containing a detailed description of the test parameters, precipitation measurement methods, testing procedure and test equipment for conducting endurance time tests for SAE Type II, III and IV de/anti-icing fluids is stored on APS's local network and can be found at the following location: M:\Groups\CM1892 (TC-Deicing 03-04)\Procedures\AS5485\

This document is based on the aforementioned procedure, and was developed for documentation purposes, to be inserted in the final report after the completion of endurance time testing, and to provide the latest data forms.

1. CHARACTERISTICS OF SIMULATED PRECIPITATION PRODUCED

The following is a point-form summary of the set of test conditions under which data for freezing drizzle, light freezing rain, rain on a cold-soaked surface, and freezing fog are collected:

1. Freezing Drizzle:
   High precipitation rate: 13 g/dm²/h;
   Droplet median volume diameter: 350 μm;
   Air temperature: -3 and -10°C.

   Low Precipitation rate: 5 g/dm²/h;
   Droplet median volume diameter: 250 μm;
   Air temperature: -3 and -10°C.

2. Light Freezing Rain:
   High precipitation rate: 25 g/dm²/h;
   Droplet median volume diameter: 1 000 μm;
   Air temperature: -3 and -10°C.

   Low precipitation rate: 13 g/dm²/h;
   Droplet median volume diameter: 1 000 μm;
   Air temperature: -3 and -10°C.

3. Drizzle on Cold-Soaked Surface:
   Precipitation rate: 5 g/dm²/h;
   Droplet median volume diameter: 250 μm;
   Air temperature: +1°C.

4. Moderate Rain on Cold-Soaked Surface:
   Precipitation rate: 75 g/dm²/h;
   Droplet median volume diameter: 1 400 μm;
   Air temperature: +1°C.

5. Freezing Fog:
   Precipitation rate: 2 and 5 g/dm²/h;
   Droplet median volume diameter: 30 μm; and
   Air temperature: -3°C, -14°C and -25°C.

2. DATA FORMS

The data forms used for tests conducted in simulated conditions are as follows:

Figure 2.1: Test Stand Location for Each Condition at NRC;

Figure 2.2: General Form for Each Session at NRC;

Figure 2.3: General Form for Each Condition at NRC;

Figure 2.4: De/Anti-icing Data Form for Freezing Precipitation at NRC;

Figure 2.5: De/Anti-icing Data Form for Cold Soak Box;

Figure 2.6: Chamber Setting for Each Condition at NRC;

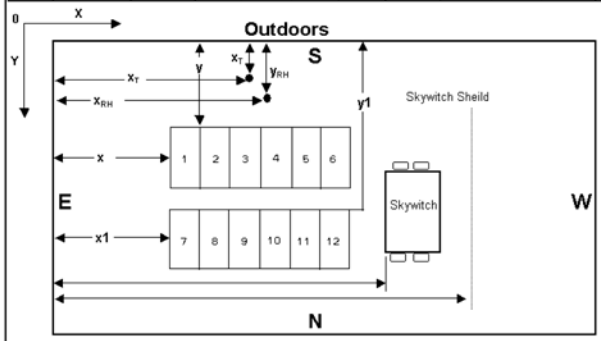
Figure 2.7: Rate Management Form at NRC, and;

Table 2.1: Condition Checklist

TEST REQUIREMENTS FOR SIMULATED FREEZING PRECIPITATION FLAT PLATE TESTING

LOCATION: CEF (Ottawa) DATE: CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL

Test	Date of Final Position	Condition	Sensor Position				Stand Position				Skywitch Position	Skywitch Sheild Position (")	Nozzle Position ("")	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						
1	04-Apr-01	ZR3H					24'2"	7'	22'7"	9'10"				Very Good		Top Stand 19' from snow fence
2	04-Apr-01	ZR3L					24'2"	7'	22'7"	9'10"				Very Good		Top Stand 19' from snow fence
3	02/04/2001	ZR10H					24'	6'9"	24'5"	9'6"				Very Good		Top stand is 20 ft. from snow fence
4	02-Apr-01	ZR10L					24'	6'9"	24'5"	9'6"				Very Good		Top stand is 20 ft. from snow fence
5	27-Mar-01	ZD3H					24'5"	6'6"	22'	10'4"				Very Good		
6	28-Mar-01	ZD3L					25'3"	7'3"	25'3"	9'6"				Good		
7	02-Apr-01	ZD10H					24'	7'11"	25'3"	9'6"				Very Good		
8	02-Apr-01	ZD10L					24'	7'7"	24'7"	9'11"				Good		20 ft. from Snow Fence
9	10-Apr-01	ZFog3H					24'	6'6"	21'11"	8'10"	34'2"from x	40'2" from x	top of plate 11	Good	144"	
10	10-Apr-01	ZFog3L					24'	6'6"	21'11"	8'10"	34'2"from x	40'2" from x	top of plate 11	Good	144"	
11	10-Apr-01	ZFog10H					24'	6'6"	21'11"	8'10"	34'2"from x	40'2" from x	top of plate 11	Good	144"	
12	10-Apr-01	ZFog10L					24'	6'6"	21'11"	8'10"	34'2"from x	40'2" from x	top of plate 11	Good	144"	
13	09-Apr-01	ZFog14H					24'	6'6"	21'11"	8'10"	34'2"from x	40'2" from x	top of plate 11	Good	144"	
14	09-Apr-01	ZFog14L					24'	6'6"	21'11"	8'10"	34'2"from x	40'2" from x	top of plate 11	Good	144"	
15	06-Apr-01	ZFog25H					24'	6'6"	21'11"	8'10"	34'2"from x	40'2" from x	top of plate 11	Good	144"	
16	06-Apr-01	ZFog25L					24'	6'6"	21'11"	8'10"	34'2"from x	40'2" from x	top of plate 11	Good	144"	
17	29-Mar-01	CSWH					25'3"		25'3"	9'6"						
18	29-Mar-01	CSWL					23'11"	7'3"	25'3"	9'6"						



Notes:

* - "From X" refers to the distance from the East wall.

** - The nozzle should be between positions 5 and 11

RH - Relative Humidity Sensor

T - Temperature Sensor

WEIGH SCALE TECHNICIAN: _____

LEADER: _____

NEW VALUES (IF DIFFERENT)

Test	Date of Final Position	Condition	Sensor Position				Stand Position				Skywitch Position	Skywitch Sheild Position (")	Nozzle Position ("")	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						

Figure 2.1: Test Stand Location for Each Condition at NRC

LOCATION: CEF (Ottawa)	DATE INTERVAL:	
Safety Issues Discussed		☐
Test Plate Material: (check the box if material used is Aluminum alloy AMS 4037 or 4041)		☐
Test Plate Dimensions: (check the box if the dimensions are 500mm long x 300mm wide x 3.2mm thick)		☐
Test Box Dimensions: (only for CSW, check the box if the dimensions are 500mm long x 300mm wide x 75mm thick)		☐
Surface Finish: (check the box if the average surface roughness is ≤ 0.5 µm) Refer to Verification Procedure "A-Verif" for methodology		☐
Ice-catch Pan Dimensions: (check the box if the dimensions are 27,7 cm by 54 cm)		☐
Water Supply to Nozzle: (check the box if the water supplied to nozzles conforms to ASTM D1193 Type IV water or a hardness of less than 300 ppm reported as $CaCO_3$)		☐
Weigh Scale verification: (see verification procedure)	2g ☐	50 g ☐
Air Temperature (°C): (to be recorded by the NRC at a sampling rate of minimum 1 datum per minute and handed in to APS at the end of the session on floppy disks) *The air temperature data is saved to the following files (provide filename and extension):*		
Relative humidity (%): (to be recorded by APS and saved at the end of the session on floppy disks) *The humidity data is saved to the following files (provide filename and extension):*		
COMMENTS:		
		LEADER:

Figure 2.2: General Form for Each Session at NRC

TEST REQUIREMENTS FOR SIMULATED FREEZING PRECIPITATION FLAT PLATE TESTING

LOCATION: CEF (Ottawa) **DATE:** **CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL**

Angle of the Test Stands (°): PLATE 1 ☐ PLATE 6 ☐ PLATE 7 ☐ PLATE 12 ☐

Distance between Nozzle and Test Plates: ☐
(check the box if distance is 7±0.5m for ZD, ZR and CSW)

Distance between Temperature Sensor and Test Plates: ☐
(check the box if distance is within 1.5 m)

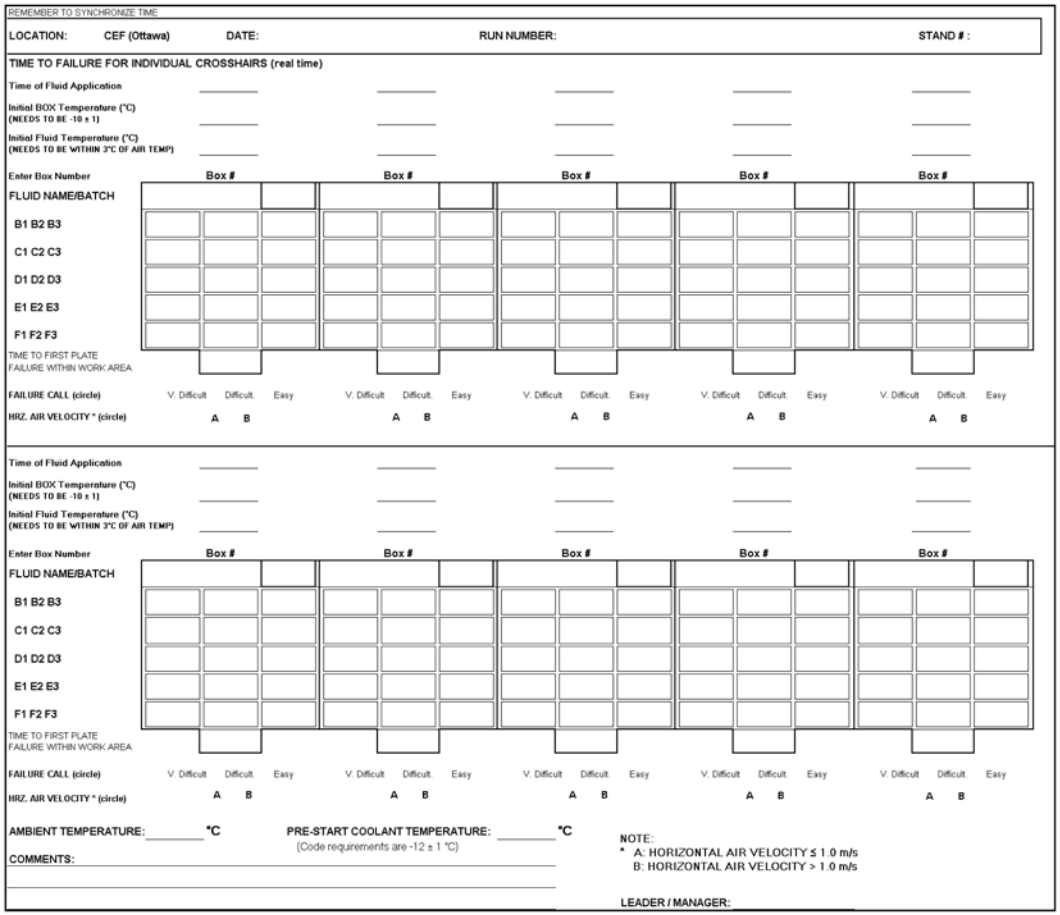
Plate Temperature (°C):
(to be recorded by APS at the end of the each condition, saved on floppy disks and included in the envelope along with the forms)
The plate temperature data is saved to the following files (provide filename and extension):

COMMENTS:

COMPUTER TECHNICIAN: _____

LEADER: _____

Figure 2.3: General Form for Each Condition at NRC



REMEMBER TO SYNCHRONIZE TIME

LOCATION: CEF (Ottawa) DATE: RUN NUMBER: STAND # :

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

Time of Fluid Application

Initial BOX Temperature (°C) (NEEDS TO BE -10 ± 1)

Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)

Enter Box Number — Box # | Box # | Box # | Box # | Box #

FLUID NAME/BATCH

B1 B2 B3

C1 C2 C3

D1 D2 D3

E1 E2 E3

F1 F2 F3

TIME TO FIRST PLATE FAILURE WITHIN WORK AREA

FAILURE CALL (circle) — V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy

HRZ. AIR VELOCITY * (circle) — A B | A B | A B | A B | A B

Time of Fluid Application

Initial BOX Temperature (°C) (NEEDS TO BE -10 ± 1)

Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)

Enter Box Number — Box # | Box # | Box # | Box # | Box #

FLUID NAME/BATCH

B1 B2 B3

C1 C2 C3

D1 D2 D3

E1 E2 E3

F1 F2 F3

TIME TO FIRST PLATE FAILURE WITHIN WORK AREA

FAILURE CALL (circle) — V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy

HRZ. AIR VELOCITY * (circle) — A B | A B | A B | A B | A B

AMBIENT TEMPERATURE: _____ °C

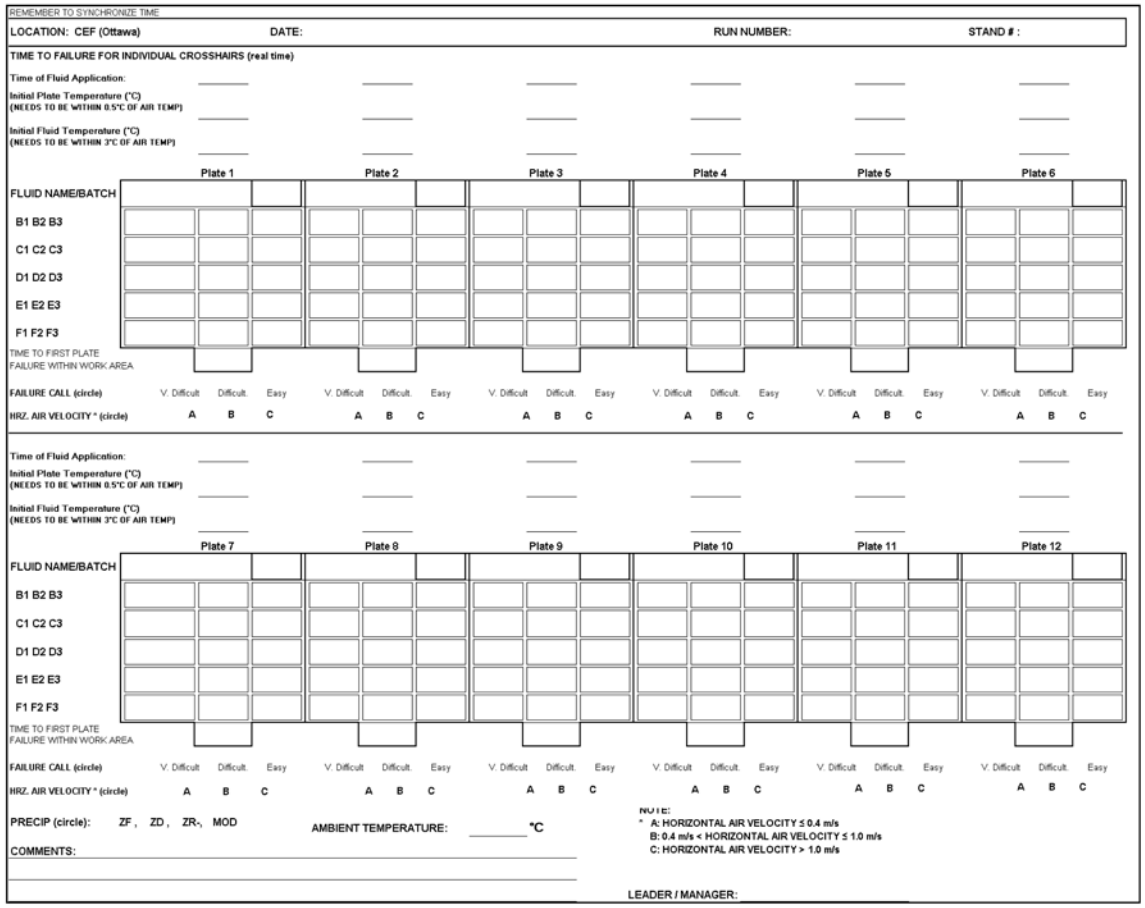
PRE-START COOLANT TEMPERATURE: _____ °C
(Code requirements are -12 ± 1 °C)

COMMENTS:

NOTE:
* A: HORIZONTAL AIR VELOCITY ≤ 1.0 m/s
B: HORIZONTAL AIR VELOCITY > 1.0 m/s

LEADER / MANAGER:

Figure 2.4: De/Anti-icing Data Form for Freezing Precipitation at NRC



REMEMBER TO SYNCHRONIZE TIME

LOCATION: CEF (Ottawa) DATE: RUN NUMBER: STAND # :

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

Time of Fluid Application:

Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 0.5°C OF AIR TEMP)

Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)

	Plate 1			Plate 2			Plate 3			Plate 4			Plate 5			Plate 6		
FLUID NAME/BATCH																		
B1 B2 B3																		
C1 C2 C3																		
D1 D2 D3																		
E1 E2 E3																		
F1 F2 F3																		
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA																		
FAILURE CALL (circle)	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy
HRZ. AIR VELOCITY * (circle)	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C

Time of Fluid Application:

Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 0.5°C OF AIR TEMP)

Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)

	Plate 7			Plate 8			Plate 9			Plate 10			Plate 11			Plate 12		
FLUID NAME/BATCH																		
B1 B2 B3																		
C1 C2 C3																		
D1 D2 D3																		
E1 E2 E3																		
F1 F2 F3																		
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA																		
FAILURE CALL (circle)	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy	V. Difficult	Difficult.	Easy
HRZ. AIR VELOCITY * (circle)	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C

PRECIP (circle): ZF , ZD , ZR-, MOD AMBIENT TEMPERATURE: _____ °C

COMMENTS:

NOTE:
* A: HORIZONTAL AIR VELOCITY ≤ 0.4 m/s
B: 0.4 m/s < HORIZONTAL AIR VELOCITY ≤ 1.0 m/s
C: HORIZONTAL AIR VELOCITY > 1.0 m/s

LEADER / MANAGER:

Figure 2.5: De/Anti-icing Data Form for Cold Soak Box

TEST REQUIREMENTS FOR SIMULATED FREEZING PRECIPITATION FLAT PLATE TESTING

LOCATION: CEF (Ottawa) **DATE:** **CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL**

CONDITION	Needles Used	Flow Rate of Water *	Line Air Pressure (psi)	Line Air Temperature (Celsius)	Line Water Pressure (psi)	Line Water Temperature (Celsius)	Relative Humidity (%)	X Axis Area	Speed	Y Axis Area	Speed	Brace Height (inches)	LTS on 1	2	3	4	5	6	MTS on 1	2	3	4	5	6	Last Date
ZR 3 L	**2x20**	**1 GPM**	**60**	**12.5**	**78**	**2**	**75**	**full**	**low**	**full**	**high**		**y**	**y**					**y**	**y**	**y**				**04-Apr-01**
ZR 10 L	2x20	1 GPM	60	12.5	82	2.5	75	full	low	full	high			y					y	y	y				03-Apr-01
ZR 3 H	**2x20**	**1 GPM**	**60**	**12.5**	**61**	**2**	**75**	**partial**	**low**	**full**	**high**								**y**	**y**	**y**				**04-Apr-01**
ZR 10 H	2x20	1 GPM	60	12.5	78	2.5	73	partial	low	full	high			y					y	y	y				03-Apr-01
ZD 3 L	2x24	1 GPM	60	13	65	2.5	75	partial	low	full	high								y	y	y				28-Mar-01
ZD 10 L	2x24	1 GPM	60	12	43	2	76	full	low	full	high			y					y	y	y				30-Mar-00
ZD 3 H	2x23	1 GPM	60	13	62	2.5	90	partial	low	full	high								y	y	y				27-Mar-01
ZD 10 H	2x23	1 GPM	60	12	55	2.5	72	partial	low	full	high			y	y				y	y	y				30-Mar-00
FOG 3 L	1 X 20/50/120	80	80	80	-	73.3	96	full	low	full	low	144							y	y	y				05-Apr-01
FOG 14 L	1 x 20/50/120	55	40	72	-	72.8	80	full	low	full	low	144							Y	Y	Y				11-Apr-01
FOG 25 L	1 x 20/50/120	50	40	72	-	72.8	80	full	low	full	low	144	y	y	y										06-Apr-01
FOG 3 H	1X 20/50/120	75	40	72	-	73.2	95	full	low	full	low	144							y	y	y				10-Apr-01
FOG 14 H	1 x 20/50/120	75	40	73	-	72.8	76	full	low	full	low		y						y	y	y				09-Apr-01
FOG 25 H	1 x 20/50/120	75	40	73	-	73.2	73	full	low	full	low	144	y	y	y										06-Apr-01
CSW 1 H	2x17	1 GPM	60	13.5	75	2	85	part	low	full	high											y	y	y	04-Jun-01
CSW 1 L	2 x 24	1 GPM	60	12.5	30	2.5	89	full	low	full	high											y	y		04-Jun-01
ZD 10 5	2 x 24	1 GPM	60	15	35	4.5	-												y	y	y				16-Jul-99
FOG 35 H	1 X 20/50	12	40	74	-	-	-	partial	low	partial	low	104	y	y	y	y									19-Jul-99
FOG 35 L	1 x 20/50	10	40	73	-	-	-	full	low	partial	low	104	y	y	y	y									19-Jul-99
FOG 30 L	1 x 20/50	10	40	73	-	-	-	full	low	partial	low	104	y	y	y	y									19-Jul-99
FOG 32 L	1 x 20/50	13	40	-	-	-	-	partial	low	full	low	104	y	y	y	y									20-Jul-99
FOG 32 H	1 x 20/50	24	40	-	-	-	-	full	low	full	low	144	y	y	y	y									20-Jul-99
FOG 10 H	1 x 20/50	75	40	74	-	72.6	-	full	low	full	low	144							y	y	y				09-Apr-01
FOG 10 L	1 X 20/50	55	40	-	-	-	-	full	low	full	low	144							y	y	y				09-Apr-01
FOG25L	1x20/50/120	15	40	73	-	70.9	-	full	low	full	low	144		y	y	y									31-Mar-00
FOG25h	1x20/50/120	24	40	79	-	72.9	-	full	low	full	low	144	y	y	y										04-Apr-00
ZR3H-2	2X20	1GPM	60	12.5	90	1.5	-	partial	low	full	high								y	y	y				06-Apr-00

* Dial Readings=X ⟶ Flow Rate for Fog (ml/min) = $0.0033*X^2 + 3.3605*X - 17.512$
Brace height 12"6"

NEW VALUES (IF DIFFERENT)

CONDITION	Needles Used	Flow Rate of Water*	Line Air Pressure (psi)	Line Air Temperature (Celsius)	Line Water Pressure (psi)	Line Water Temperature (Celsius)	Relative Humidity (%)	X Axis Area	Speed	Y Axis Area	Speed	Brace Height (inches)	LTS on 1	2	3	4	5	6	MTS on 1	2	3	4	5	6	Date

COMPUTER TECHNICIAN: _____ LEADER: _____

Figure 2.6: Chamber Setting for Each Condition at NRC

RATE MANAGEMENT FORM AT NRC

CONDITION: _____

DATE: _____ WEIGH SCALE TECHNICIAN: _____

PAN #	TIME OUT	1st or 2nd Rate	TIME*	Chamber Temperature	STDEV

Table 2.1: Condition Checklist

Beginning of the condition

TASKS	DONE - INITIALS
Start the computer and spreadsheet	
Start the scale program (Wedge software)	
Start, reset and level the scale	
Check that the scale is correctly verified to 2g and 50g	
Start the camera and video	
Verify the functionality of the walky-talky system	
Synchronize all clocks to atomic clock (computers, stopwatches)	
Prepare a dated envelope	

End of the condition

TASKS	DONE - INITIALS
Print all results (spreadsheet pages)	
Write on the envelope the tests that have been achieved	
Shut down the computer / Shut down the scale	
The coordinator should write a summary each night	
Stop and shut down the intercoms, camera and video	
Clean stand area (if needed)	
Prepare fluids for the next day	
Save all results on hard drive	
Zip all the results with *Winzip,* save them on a marked diskette	
Provide instructions to laboratory technician for the next day conditions	
Put all results sheets, checklists, and the diskette in the envelope. Forward the envelope to the office	

CO-ORDINATOR / MANAGER _____ **DATE** ___/___/_____

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OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2015

CM2265.004 (14-15)

OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2015

Winter 2014-15

Prepared for

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APS Aviation Inc.

March 20, 2015
Final Version 1.0

OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2015

Winter 2014-15

1. INTRODUCTION

This document was prepared to bring together several projects that require testing at the National Research Council Climactic Engineering Facility (NRC) in Ottawa. Tests will be carried out from March 25 to April 2, 2015.

The primary objective of the test session is to measure the endurance times of new de/anti-icing fluids. Testing for several other related research projects will be scheduled around the endurance time tests as time and space permit. This document provides the schedule, personnel, fluid, and equipment requirements for each of the projects involved.

A tentative test schedule is included in Figure 1.

2. PROJECTS, PROCEDURES AND OBJECTIVES

The projects that will be carried out at the March/April 2015 NRC test session are listed in this section. Each project has been given a shortened name (shown in brackets following full title) which is used in subsequent sections of this document. A description of each project, its objective and its test procedure are provided. The test procedures for several projects are provided in separate detailed documents, which are referenced in the appropriate subsection and listed in Section 9.

General comments on procedures and setup:

- Endurance time tests will be carried out according to the protocol provided in Aerospace Recommended Practice (ARP) 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type II, III, and IV* (1) and ARP 5945, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type I* (2), except as noted.
- There will be two test stands positioned under the sprayer (main stand with two 6-position stands and side stand with one 3-position stand) and a third stand that will be positioned outside the spray area in the small area of the climate chamber. The test stands should be situated in the cold chamber as per the measurements provided in Figure 2.
- A complex rate management program was developed in the early 2000s to assist in managing the measurement of precipitation rates. An update to the interface of this program was finalized in 2014. This program will be used. A guide to the rate management program is available to help with training of new rate station managers.

2.1 Endurance Times of New Fluids (New Fluid ETs)

The objective of this project is to measure endurance times of new fluids. This will include Type I, Type II and Type IV tests, as listed below. Each fluid will be tested over the entire range of freezing precipitation conditions encompassed by the relevant HOT table format, with the exception of the Type I fluid which may not be tested in the -6°C conditions. This decision will be made after the fourth day of testing. Schedules are provided for either outcome (see Figure 1).

- Oksayd Defrost ECO I Batch #10 (Type I)
- Newave Aerochemical FCY-2 Bio+ (Type II)
- Kilfrost P2595 (Type II)
- Deicing Solutions ECO-SHIELD® (Type IV, Neat only)

The procedure for conducting endurance time tests is given in the document *Test Requirements for Simulated Freezing Precipitation Flat Plate Testing* (3). Cold soak boxes should be prepared using the procedure provided in Attachment 1.

The test plan for new fluid endurance time tests is given in Table 1. All tests will be conducted on the main test stand.

2.2 Special Type III Endurance Time Tests (Type III CB1)

A full set of testing with the Type III fluid AllClear CB1 has been conducted over the last 4 months. Issues with the viscosity of the fluid have created a need for additional testing. Tests will be conducted with a new batch of CB1 with a lower viscosity. Due to the previously identified viscosity issues, a viscometer and a blender for additional shearing will be made available for potential use during the test session. A full set of Type III tests is planned for the new sample.

The Type III CB1 tests are included in the New Fluid ETs test plan in Table 1. All tests will be conducted on the main test stand.

2.3 Thickness of New Fluids (ET Thickness)

The objective of these tests is to measure the thickness new fluids on flat plates. The procedure for these tests is entitled *Experimental Program to Establish Film Thickness Profiles for De-Icing and Anti-Icing Fluids on Flat Plates* (4) and can be found in Transport Canada Report TP 13991E, Appendix I.

The test plan for Fluid Thickness tests is given in Table 2. The tests will be conducted at the small end of the chamber outside of the spray area.

2.4 Evaluation of Endurance Times on High Angle Surfaces: Comparative Fluid Thickness Tests (Winglet Thickness)

The FAA has acquired a portion of a full-scale winglet taken from a UPS aircraft that was damaged while in service. This winglet (currently under repair) has been made available for to support the aircraft ground deicing research program and will be used for this activity and the one described in Subsection 2.5.

The objective of this activity is to conduct tests to compare fluid thickness decay profiles following de/anti-icing on a winglet versus a 10° plate and 80° plate. Tests will be conducted with Type I and Type IV fluid (one run each) and measurements will be taken over a 30 minute period. The standard thickness procedure will be followed (see Subsection 2.3). In addition:

- The angle of the winglet shall be measured;
- After fluid application, fluid thickness will be measured at 5, 10, 15 and 30 minutes; and
- Fluid thickness will be measured at the 15 cm line of the plates and at 15 and 45 cm from the top of the winglet.

The test plan for the Winglet Thickness tests is given in Table 3. The tests will be conducted at the small end of the chamber outside of the spray area. It should be noted that tests are planned for -3°C but could also be done at -10°C.

2.5 Evaluation of Endurance Times on High Angle Surfaces: Comparative Endurance Time Tests (Winglet ETs)

The objective of this activity is to conduct tests to compare endurance times of de/anti-icing fluids on a winglet to those on 10° and 80° plates. Standard endurance time testing procedures will be followed; the only difference will be the test surfaces.

For tests being run in Freezing Rain, -10°C, 13 g/dm²/h the experimental set-up will include the winglet, simple airfoil, slatted airfoil and a test stand. The stand will include 10° and 20° aluminum plates related to the airfoil testing as well as an 80° aluminum plate related to the winglet testing. The experimental set-up is shown in Figure 3.

These tests will be conducted in conjunction with the Airfoil tests (Subsection 2.6) and will be conducted in the main stand area with the main stand removed. The combined test plan for Winglet ETs and Airfoil tests is given in Table 4.

2.6 Endurance Times on Flaps/Slats with Airfoil (Airfoil)

Preliminary testing with simulated deployed flaps has indicated a reduction in fluid protection time. However, recent industry discussions have indicated that the protection time could be increased during taxi as the changing aircraft direction relative to the wind direction could result in an increase to the protection time of deployed flaps, as they can be shielded from the wind during a segment of the taxi. Initial research conducted in 2013-14 demonstrated that there can be increased protection times as a result of taxi. It was recommended that further research be conducted using a simulated airfoil model during the winter of 2014-15. Initial testing was conducted outdoors in natural snow conditions, and it was recommended that limited testing indoors in simulated freezing precipitation conditions also be conducted to have a broader spectrum of conditions.

The fluid volumes being poured on the larger experimental surfaces are based upon the relative surface areas of these surfaces in relation to an aluminum test plate.

The objective of these tests is to compare the fluid protection time on the slatted and simple airfoil to the protection time on 10° and 20° test plates. This objective will be achieved by testing indoors simulating zero-wind conditions; therefore, rotating the model will not be necessary. The testing will utilize both airfoil models available (the simple airfoil and the airfoil with flaps and slats) and expose the anti-iced surfaces to freezing precipitation conditions. A 10° and 20° plate will also be required to provide the correlation to the historical plate data collected. Tests will be conducted in high and low rates of light freezing rain and freezing drizzle with various fluids at different dilutions. The experimental set-ups are shown in Figure 3.

These tests will be conducted in conjunction with the Winglet ETs tests (Subsection 2.5) and will be conducted in the main stand area with the main stand removed. The combined test plan for Airfoil and Winglet tests is given in Table 4.

2.7 Use of Aircraft Nose Cone as a Representative Surface for Evaluating Holdover Time (Nose Cone)

Preliminary testing with simulated deployed flaps has indicated a reduction in fluid protection time. Regulators and operators have been working together to develop mitigation tactics, one of which is the use of a pre-take-off contamination check. Unfortunately for cargo operators (without access to windows overlooking a wing), using a standard pre-take-off contamination check is not possible.

Nose cones have been proposed as an alternative location to use as a representative surface of fluid failure progression and overall condition of the wing while operating with the flaps and slats in extended configuration. Preliminary tests

have been conducted in natural snow. Additional tests in indoor simulated conditions were recommended.

The objective of the indoor tests is to evaluate how endurance times of Type I fluid applied to 20° surfaces (both with and without simulated nose cone heat) compare to endurance times of thickened fluids on 10° and 20° surfaces.

Testing will be conducted on four test surfaces:

1. Baseline plate with thickened fluid (10° plate);
2. Extended flaps/slats model with thickened fluid (20° plate);
3. Nose cone representative surface model with Type I fluid and no heat (20° plate); and
4. Nose cone representative surface model with Type I fluid and no heat (20° box).

Test surface #4 will be a box with a light bulb inside; this will simulate heat from instrumentation inside the nose cone. The temperature of the box will be 3°C warmer than ambient temperature.

The test plan for Nose Cone tests is given in Table 5. These tests will be conducted on the main stand.

2.8 Endurance Times on Deployed Flaps (Deployed Flaps)

The objective of this project is to continue the evaluation of endurance time performance of anti-icing fluids on wing surfaces with deployed flaps. Testing with Type I, Type II and Type III fluids will being carried out to supplement previously collected data.

The procedure for the conduct of these tests is provided in the document *Evaluation of Endurance Times on Deployed Flaps* (5). The procedure was written for testing in outdoor conditions; changes to the procedure required for indoor testing and the indoor test plan are provided herein.

Tests will be conducted using standard holdover time testing procedures. Each comparative test will include a baseline test (conducted on plate inclined to a 10° slope) and one non-nested flap test (conducted on a plate inclined to a 20° slope).

The test plan for Deployed Flaps tests is given in Table 6. The tests will be conducted on the main and/or side stand. Tests requiring plates oriented to 20° are better positioned on the lower main stand or on the side stand.

2.9 Effect of Thickened Fluid Freezing and Thawing on Fluid Integrity and Resulting Holdover Time (Freezing & Thawing)

The objective of this project is to evaluate the performance of anti-icing fluid that has frozen (gone below the fluid freeze point) and subsequently been thawed and returned to ambient temperature. There is reason to believe this change in state could have a negative impact on holdover time.

The procedure for the conduct of these tests is provided in the document *Effect of Thickened Fluid Freezing and Thawing on Fluid Integrity and Resulting Holdover Time* (6). The procedure requires that a fluid be subjected to freezing, returned to ambient, and then tested against an identical fluid sample that has not been subject to freezing.

The test plan for the Freezing & Thawing tests is given in Table 7. All tests will be conducted on the main and/or side test stands.

2.10 Effect of Fluid Colour on Endurance Times (Coloured vs. Uncoloured)

Aerospace Materials Specification (AMS 1428) provides the colour requirements for Type II, III, and IV fluids. The current version of the specification requires Type II fluids be water white/pale straw in color. However, consideration is being given to changing the colour requirement to straw yellow only, i.e. no longer allowing water white/uncoloured fluids.

The question has been asked if adding/removing a dye to a fluid impacts the endurance time performance of fluid. The objective of this project is to compare the holdover time performance of fluids in their coloured and un-coloured formulations.

ABAX Industries have a commercial Type II fluid that is available both with and without dye. They have provided samples of this fluid for this research.

A subset of the standard full set of holdover time tests will be conducted. Tests will be carried out using standard endurance time test protocol.

Additional information shall be collected for a few of the tests and documented on the end condition data form, as follows:

- Photo at failure;
- Brix at failure;
- Thickness after 5 minutes; and
- Smart buttons for plate temperatures.

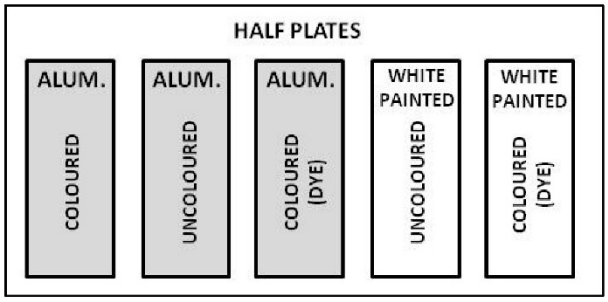
The test plan for the Coloured vs. Uncoloured tests is combined with the Visual Inspection project and is given in Table 8. All tests will be conducted on the main and/or side stands.

2.11 Ability to Identify Contamination on Surfaces Treated with Coloured or Uncoloured Fluids (Visual Inspection)

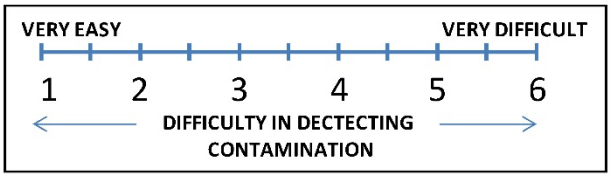
The objective of this project is to evaluate the difficulty in determining fluid failure with coloured fluids relative to uncoloured fluids. Different perspectives of a wing treated with coloured and uncoloured fluid will be simulated. This testing will be completed in conjunction with the Effect of Fluid Colour on Endurance Times project (see Subsection 2.10).

Testing will be conducted on standard aluminum plates and white painted aluminum plates and with uncoloured, coloured and dyed fluid. The dyed fluid is required as the coloured version of the only available coloured/ uncoloured fluid is somewhat pale in comparison to other coloured Type II/IV fluids. For this reason, a green dye (6 drops per litre of off-the-shelf green food colouring) will be added to some of the uncoloured sample to simulate a (typical) vibrant green fluid.

The test setup is shown below. Half plates will be used as fluid is limited. Tests will be run on all plates simultaneously.



One researcher will inspect the plates and, using the scale shown in the diagram below, rate his/her ability to identify the contamination on each test plate.

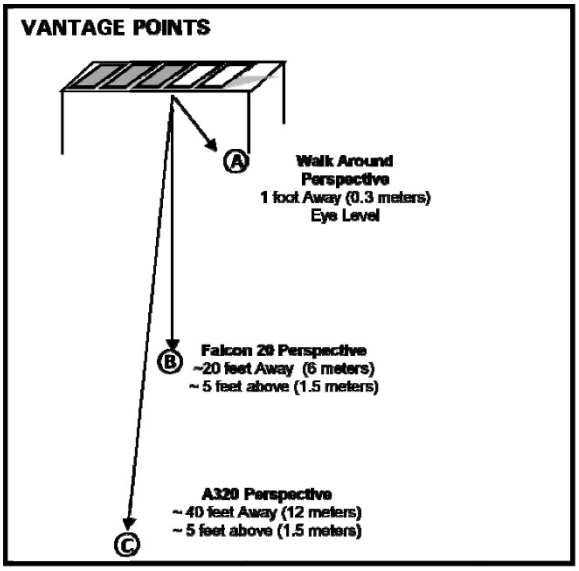


The visual inspection will be performed on each plate at two prescribed times:

1. Approximately halfway through the expected holdover time; and
2. When the first plate fails (all plates are expected to fail at approximately the same time).

The visual inspection and rating will be completed from three vantage points (see diagram below):

1. Walk Around Perspective: Approximately 0.3 m (1 foot) from test stand
2. Small Regional Jet Perspective: Approximately 6 m (20 feet) from test stand, 1.5 m (5 feet) elevated
3. Large Jet Perspective: Approximately 12 m (40 feet) from test stand, 1.5 m (5 feet) elevated



Lighting conditions may be altered to investigate differences between day and night time conditions.

The test plan for the Visual Inspection tests is combined with the test plan for the Coloured vs. Uncoloured ETs and is given in Table 8. All tests will be conducted on the main and/or side test stands.

2.12 Compatibility of Different Fluid Brands in Two-Step De/Anti-icing Procedures (Compatibility)

It is common practice to use a two-step de/anti-icing application where Type I fluid is applied (to deice) followed by a Type II or IV fluid (to anti-ice). This method provides longer holdover times than applying Type I fluid only.

Operators may choose to use a specific Type II or IV second step fluid in conjunction with various Type I first step fluids in order to minimize costs. Questions have been raised as to whether the use of different Type I fluids in a two-step application can have an adverse effect on the holdover time of the second step fluid.

The objective of this research is to compare the endurance times of various Type II/IV fluids when applied as part of a two-step procedure with different first step Type I fluids.

The test procedure is similar to the procedure used for standard endurance time testing except that fluids will be applied in two steps. First, one liter of Type I fluid will be applied at 20°C to the test surface. Three minutes later, one liter of Type II/IV fluid at ambient temperature will be applied. Plates will be allowed to run until failure occurs.

The test plan for the Compatibility tests is given in Table 9. All tests will be conducted on the main and/or side stands.

2.13 Documentation of Fluid Failure (Failure Photos)

A project was undertaken in winter 2013-14 to obtain photos of de/anti-icing fluid failure in all conditions encompassed by the holdover time guidelines. Review of existing materials indicated some of the needed photos do not exist. The objective of this project is to obtain the missing photos.

Photos will be taken at a 10° to 30° incident angle from three different perspectives: from the top end of the plate, from the bottom of the plate and from a 30° angle to the top of the plate. All photos should be taken within 1 minute of failure (failure of a plate is determined based on standard HOT procedure). Most of the photos will be taken of tests being conducted for other projects. Table 10 lists the tests to be photographed in each condition. The photographer will use the condition sheets as a data form, adding comments for individual tests to the sheets as needed.

The following is a summary of the steps to be completed for this project:

- Sync camera with clock at NRC;
- Take a picture of the condition sheet at the beginning (suggest writing beginning at the top of the sheet) and end (suggest writing end at the top of the sheet) of each condition;
- Put a nut on lower left bolt of plate once it has been poured to indicate photos are needed;
- Take photos at failure only (other photos not required);
- Circle test number on condition sheet as soon as plate fails and take a picture of the condition sheet after photos have been taken; and
- Download and sort photos by condition at the end of each day.

2.14 Separate Project: Preliminary Evaluation of Commercial Type IV Fluid vs. Generic Holdover Times (CC)

Tests for a non-TC/FAA funded project will be conducted concurrently with the other tests described in this procedure. The tests, conducted on behalf of a commercial fluid manufacturer, are being conducted at the test session to take advantage of cost sharing opportunities. The purpose is to conduct a series of preliminary endurance time tests to evaluate the HOT performance of the current formulation of their fluid. The plan for these tests is prepared in a separate document; the schedule and fluid requirements have been included in this procedure for planning purposes only.

3. PERSONNEL REQUIREMENTS/RESPONSIBILITIES

The personnel requirements and responsibilities are provided in Table 11.

4. FLUIDS

The required fluids and fluid quantities are shown in Table 12. Type I fluids will be diluted prior to testing using the dilution tables provided in Table 13. Fluids that will be used the first day of testing should be packed into coolers at the APS test site and plugged into power overnight.

5. EQUIPMENT

Table 14 provides a list of required equipment.

6. DATA FORMS

The data forms required for each project are listed below.

1. New Fluid ETs:
   - Freezing Precipitation Endurance Time Electronic Data Form
   - Rate Management Form (Figure 4)
   - NRC Continuous Rate Form (Figure 5)
2. Type III CB1:
   - Freezing Precipitation Endurance Time Electronic Data Form
3. ET Thickness:
   - Fluid Thickness Data Form (Figure 6)
4. Winglet Thickness:
   - Fluid Thickness Data Form (Figure 6). Additional notes shall be added to this data form to reflect the measurement procedure.
5. Winglet ETs:
   - Freezing Precipitation Endurance Time Data Form (Figure 7)
   - Winglet End Condition Data Form (Figure 8)
6. Airfoil:
   - Freezing Precipitation Endurance Time Data Form (Figure 7)
   - Airfoil End Condition Data Form (Figure 9)
7. Nose Cone:
   - Freezing Precipitation Endurance Time Electronic Data Form
8. Deployed Flaps:
   - Freezing Precipitation Endurance Time Electronic Data Form
9. Freezing & Thawing
   - Freezing Precipitation Endurance Time Electronic Data Form
10. Coloured vs. Un-coloured ETs:
    - Freezing Precipitation Endurance Time Electronic Data Form
    - Fluid Brix/Thickness Data Form (Figure 10)
11. Visual Inspection:
    - Freezing Precipitation Endurance Time Electronic Data Form
    - Visual Inspection Data Form (Figure 11)

12. Compatibility:
    - Type II/IV: Freezing Precipitation Endurance Time Electronic Data Form
    - Type I: Freezing Precipitation Endurance Time Data Form (Figure7)
13. Failure Photos:
    - Condition Sheets

7. PRE-TEST SET-UP ACTIVITIES

The following activities need to be completed prior to arrival at the NRC:

1. Mark plates with plate numbers on back and front. Also mark a set of half plates for positions 2 to 12 on back and front (if 11 sets not available, mark additional full plates that can be cut at NRC). Marking should be at bottom and half plates should be marked for example "4L and 4R". (MR/DP)
2. Mark plates with plate numbers (MR/DP)
3. Check rate pans: check quantity, check for holes, and check all pans are properly labelled (MR/DP)
4. Ensure plates and boxes are equipped with operational and verified thermistors or smart buttons (MR/DP)
5. Prepare labels for pour containers as per fluids list (CB)
6. Ensure fluids are prepared in advance according to Table 12 (DP)
7. Clean and label 1 litre pour containers (DP)
8. Check laptops (2) work for rate station (MR)
9. Rent cube van (EA)
10. Book hotel (EA)
11. Print data forms and procedures (SB/CB)
12. Print chamber condition sheets (SB/CB)
13. Contact Medhat (DY)
    - confirm availability of NRC camera system + black shelving unit
    - waste tote + floor mats in chamber for setup day

- cold soak fluid + wooden stand + pump in chamber for setup day
- coffee machine + cups + sugar
- rate monitoring system
- update chamber settings file with the latest data available
- make sure that the freezer works and is on the day before testing (fluids will be intentionally frozen over the weekend)
- set up test area temperature sensors for morning of test
- have the desks in the test area and in Medhat's office cleaned-up and available to avoid mixing up NRC/APS equipment
- ensure hallways and chamber free of clutter
- make sure dryer is operational and hooked up

14. Cut white plate on Friday March 20th (NRC)
15. Put 100/0 freezing/thawing fluids into CSW freezer at -40°C (MR)
16. Put CSW fluid into freezer at -40°C (MR)
17. Make all necessary purchases prior to NRC (MR/CB)
18. Ensure freezing/thawing project fluids are prepared in advance (DY)
19. Ensure fluids for research projects are available (DY)
20. Prepare fluids with dye requirements; and check thickness (DY)
21. Ensure photo equipment is ready for testing for photo project (CB)
22. Remove sensitive equipment, 50/50 fluids, 75/25 fluids if doing -25°C first day (MR)
23. Determine team travel plans (MR/JD)
24. Confirm lowest operational use temperature (LOUT) of all Type II, III and IV fluids (JD). If any LOUTs are -30°C or lower, schedule testing in freezing fog at the LOUT (CB/SB).
25. Provide final test plan to data form programmer (CB).
26. Make an easy prop to give plates a 20° incline (MR)
27. Determine new nose cone light bulb i.e. 10 watts or less to get 3°C warming (MR)

8. SAFETY ISSUES

Managers of each subproject must ensure that personnel involved in the set-up and conduct of their respective projects are aware of the following:

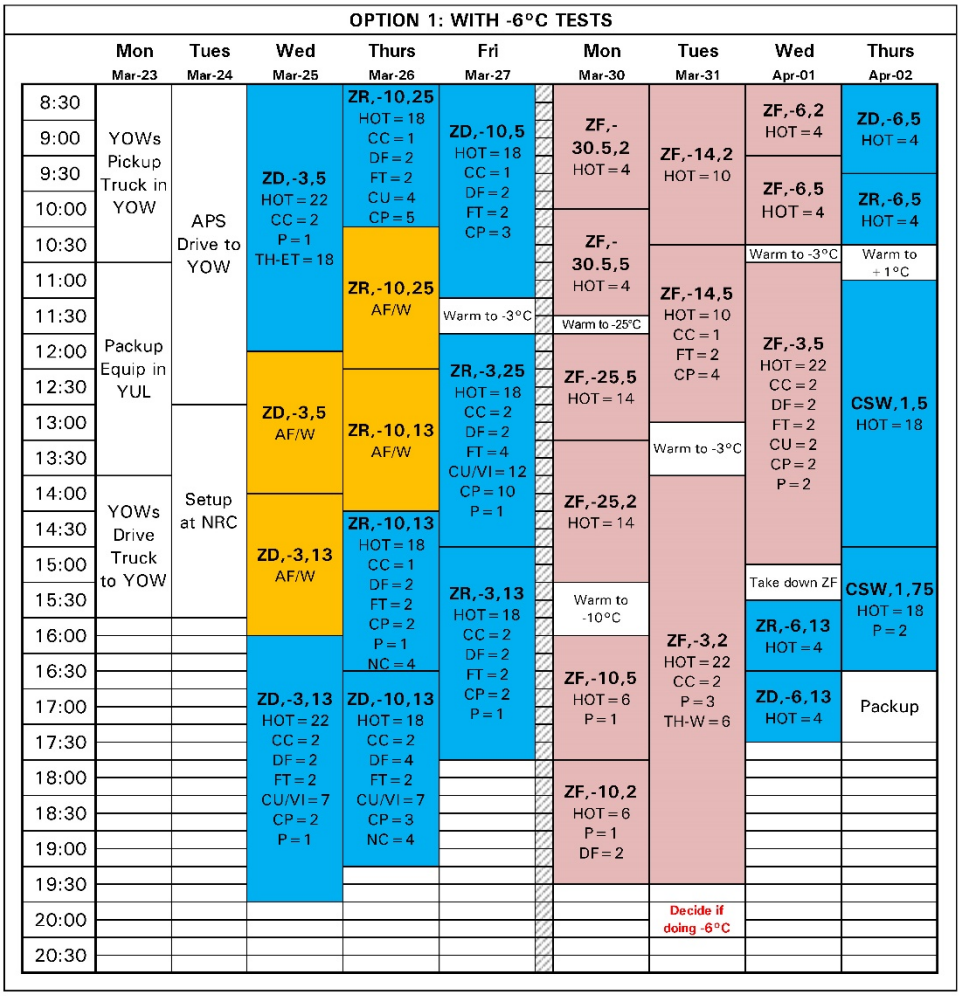
1. Fluid MSDS sheets are available for review.
2. Waterproof clothing and gloves are available.
3. Rubber mats must be properly placed in and around the test area and cleaned as necessary.
4. Care should be taken when circulating near the test stand due to slipperiness.
5. First aid kit, water and fire extinguisher are available.
6. All NRC safety guidelines must be followed.

9. REFERENCES

1. SAE Aerospace Recommended Practice 5485, Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Type II, III, and IV, July 2007.
2. SAE Aerospace Recommended Practice 5945, Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Type I, July 2007.
3. Test Requirements For Simulated Freezing Precipitation Flat Plate Testing, Version 1.0, January 15, 2004.
4. Experimental Program to Establish Film Thickness Profiles for De-Icing and Anti-Icing Fluids on Flat Plates, Version 1.0, April 3, 2002.
5. Evaluation of Endurance Times on Deployed Flaps, Final Version 1.0, January 25, 2012.
6. Effect of Thickened Fluid Freezing and Thawing on Fluid Integrity and Resulting Holdover Time, Final Version 1.0, March 5, 2015.

OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2015

FIGURE 1: TEST SCHEDULE



Project Abbreviations	
HOT = HOT of New Fluids	CC = Commercial Type IV vs. Generic HOTs
DF = Deployed Flaps	AF= Airfoil ET Testing
W = Winglet ET Testing	NC = Nose Cone
FT= Freezing & Thawing	CU = Coloured Vs. Uncoloured
VI = Visual Inspection	CP = Compatibility of Different Fluids
P = Photo Documentation of Failure	

FIGURE 1: TEST SCHEDULE (CONT'D)

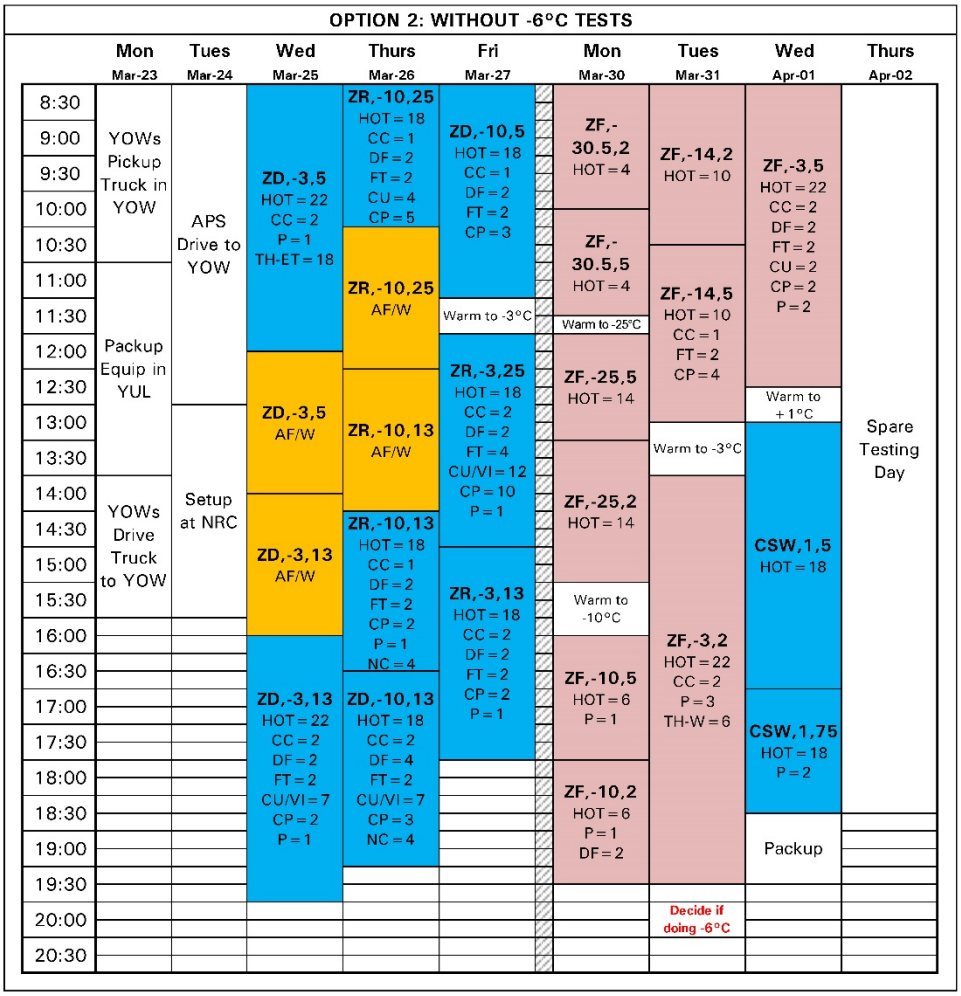


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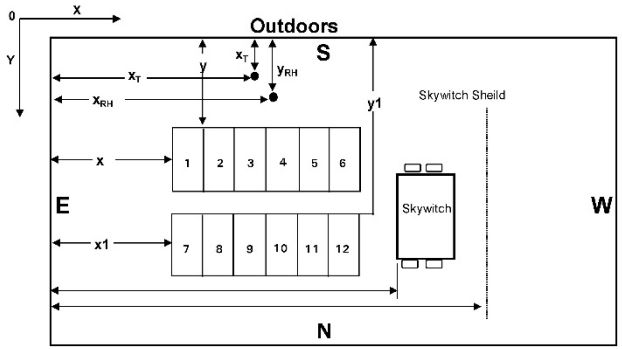
FIGURE 2: TEST STAND LOCATION MEASUREMENTS

LOCATION: CEF (Ottawa) DATE: CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL

Test	Date of Final Position	Condition	Sensor Position				Stand Position				Skywitch Position	Skywitch Sheild Position (*)	Nozzle Position (**)	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						
1	4-Apr-01	ZR3H					24' 2"	7'	22' 7"	9' 10"				Very Good		Top Stand 19' from snow fence
2	4-Apr-01	ZR3L					24' 2"	7'	22' 7"	9' 10"				Very Good		Top Stand 19' from snow fence
3	4/2/2001	ZR10H					24'	6' 9"	24' 5"	9' 6"				Very Good		Top stand is 20 ft. from snow fence
4	2-Apr-01	ZR10L					24'	6' 9"	24' 5"	9' 6"				Very Good		Top stand is 20 ft. from snow fence
5	27-Mar-01	ZD3H					24' 5"	6'6"	22'	10'4"				Very Good		
6	28-Mar-01	ZD3L					25' 3"	7'3"	25' 3"	9' 6"				Good		
7	2-Apr-01	ZD10H					24'	7'11"	25' 3"	9' 6"				Very Good		
8	2-Apr-01	ZD10L					24'	7' 7"	24' 7"	9' 11"				Good		20 ft. from Snow Fence
9	10-Apr-01	ZFog3H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
10	10-Apr-01	ZFog3L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
11	10-Apr-01	ZFog10H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
12	10-Apr-01	ZFog10L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
13	9-Apr-01	ZFog14H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
14	9-Apr-01	ZFog14L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
15	6-Apr-01	ZFog25H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
16	6-Apr-01	ZFog25L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
17	29-Mar-01	CSWH					25'3"		25'3"	9' 6"						
18	29-Mar-01	CSWL					23'11"	7'3"	25'3"	9' 6"						



Notes:

* - "From X" refers to the distance from the East wall.

** - The nozzle should be between positions 5 and 11

RH - Relative Humidity Sensor

T - Temperature Sensor

WEIGH SCALE TECHNICIAN: _____

LEADER: _____

NEW VALUES (IF DIFFERENT)

Test	Date of Final Position	Condition	Sensor Position				Stand Position				Skywitch Position	Skywitch Sheild Position (*)	Nozzle Position (**)	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						
							24'	7'	24'	9'						

ATTACHMENT 1: COLD SOAK BOX PREPARATION PROCEDURE

1. Put containers (20 L) of CSW box fluid (propylene 65/35) in cold (-30 ± 5 °C) freezer overnight. Freezers to be kept in large end of the chamber.

2. Put all filled CSW boxes in warmer (-11 ± 1 °C) freezer overnight.

3. Next morning, if freezer in step (2) does not provide fluid and box temperature of -11 ± 1 °C, then empty boxes in pail and achieve fluid at -12 ± 1 °C in pail.

4. Prepare step (3) in corner of large chamber that is at +1 °C; ensure boxes are cooled to about -11 °C. Go to step (6).

5. After first series of tests, empty fluid from boxes into separate pail. Put empty boxes in freezer to keep cool at -11 ± 2 °C.

6. Prepare fluid to -12 ± 1 °C by mixing (use small amounts of hot water and/or cold fluid). Agitate fluid mixture frequently.

7. Fill boxes, ensure -11 ± 1 °C on surface of box. This process shall be done while rates are being measured.

8. Position on stand with cover, but no insulation on top surface. Connect thermocouples.

9. Allow warming to -10 ± 0.5 °C. This process needs monitoring with rates measurement to not overshoot temperature (place insulation on top surface if required).

10. Start test.

11. At end of test, remove box from stand, measure rates, and go to step (5).

TABLE 1: NEW FLUID ENDURANCE TIMES TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
1	Freezing Fog	-3	2	Kilfrost P2595	100	Al. Plate	
2	Freezing Fog	-3	2	Kilfrost P2595	100	Al. Plate	
3	Freezing Fog	-3	2	Deicing Solutions ECO-SHIELD	100	Al. Plate	
4	Freezing Fog	-3	2	Deicing Solutions ECO-SHIELD	100	Al. Plate	
5	Freezing Fog	-3	2	AllClear CB1-PB8000A	100	Al. Plate	
6	Freezing Fog	-3	2	AllClear CB1-PB8000A	100	Al. Plate	
7	Freezing Fog	-3	2	Kilfrost P2595	75	Al. Plate	
8	Freezing Fog	-3	2	Kilfrost P2595	75	Al. Plate	
9	Freezing Fog	-3	2	Newave FCY-2 Bio +	100	Al. Plate	
10	Freezing Fog	-3	2	Newave FCY-2 Bio +	100	Al. Plate	
11	Freezing Fog	-3	2	Newave FCY-2 Bio +	75	Al. Plate	
12	Freezing Fog	-3	2	Newave FCY-2 Bio +	75	Al. Plate	
13	Freezing Fog	-3	2	Kilfrost P2595	50	Al. Plate	
14	Freezing Fog	-3	2	Kilfrost P2595	50	Al. Plate	
15	Freezing Fog	-3	2	Newave FCY-2 Bio +	50	Al. Plate	
16	Freezing Fog	-3	2	Newave FCY-2 Bio +	50	Al. Plate	
17	Freezing Fog	-3	2	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Al. Plate	
18	Freezing Fog	-3	2	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Al. Plate	
19	Freezing Fog	-3	2	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Comp. Plate	
20	Freezing Fog	-3	2	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Comp. Plate	
21	Freezing Fog	-3	5	Kilfrost P2595	100	Al. Plate	
22	Freezing Fog	-3	5	Kilfrost P2595	100	Al. Plate	
23	Freezing Fog	-3	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
24	Freezing Fog	-3	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
25	Freezing Fog	-3	5	Kilfrost P2595	75	Al. Plate	
26	Freezing Fog	-3	5	Kilfrost P2595	75	Al. Plate	
27	Freezing Fog	-3	5	Newave FCY-2 Bio +	100	Al. Plate	
28	Freezing Fog	-3	5	Newave FCY-2 Bio +	100	Al. Plate	
29	Freezing Fog	-3	5	AllClear CB1-PB8000A	100	Al. Plate	
30	Freezing Fog	-3	5	AllClear CB1-PB8000A	100	Al. Plate	
31	Freezing Fog	-3	5	Newave FCY-2 Bio +	75	Al. Plate	
32	Freezing Fog	-3	5	Newave FCY-2 Bio +	75	Al. Plate	
33	Freezing Fog	-3	5	Kilfrost P2595	50	Al. Plate	
34	Freezing Fog	-3	5	Kilfrost P2595	50	Al. Plate	
35	Freezing Fog	-3	5	Newave FCY-2 Bio +	50	Al. Plate	
36	Freezing Fog	-3	5	Newave FCY-2 Bio +	50	Al. Plate	
37	Freezing Fog	-3	5	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Al. Plate	
38	Freezing Fog	-3	5	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Al. Plate	
39	Freezing Fog	-3	5	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Comp. Plate	
40	Freezing Fog	-3	5	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Comp. Plate	
41	Freezing Fog	-6	2	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Al. Plate	
42	Freezing Fog	-6	2	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Al. Plate	
43	Freezing Fog	-6	2	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Comp. Plate	
44	Freezing Fog	-6	2	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Comp. Plate	
45	Freezing Fog	-6	5	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Al. Plate	
46	Freezing Fog	-6	5	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Al. Plate	
47	Freezing Fog	-6	5	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Comp. Plate	
48	Freezing Fog	-6	5	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Comp. Plate	

TABLE 1: NEW FLUID ENDURANCE TIMES TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
49	Freezing Fog	-10	2	AllClear CB1-PB8000A	100	Al. Plate	
50	Freezing Fog	-10	2	AllClear CB1-PB8000A	100	Al. Plate	
51	Freezing Fog	-10	2	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
52	Freezing Fog	-10	2	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
53	Freezing Fog	-10	2	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
54	Freezing Fog	-10	2	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
55	Freezing Fog	-10	5	AllClear CB1-PB8000A	100	Al. Plate	
56	Freezing Fog	-10	5	AllClear CB1-PB8000A	100	Al. Plate	
57	Freezing Fog	-10	5	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
58	Freezing Fog	-10	5	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
59	Freezing Fog	-10	5	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
60	Freezing Fog	-10	5	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
61	Freezing Fog	-14	2	Deicing Solutions ECO-SHIELD	100	Al. Plate	
62	Freezing Fog	-14	2	Deicing Solutions ECO-SHIELD	100	Al. Plate	
63	Freezing Fog	-14	2	Newave FCY-2 Bio +	100	Al. Plate	
64	Freezing Fog	-14	2	Newave FCY-2 Bio +	100	Al. Plate	
65	Freezing Fog	-14	2	Kilfrost P2595	75	Al. Plate	
66	Freezing Fog	-14	2	Kilfrost P2595	75	Al. Plate	
67	Freezing Fog	-14	2	Kilfrost P2595	100	Al. Plate	
68	Freezing Fog	-14	2	Kilfrost P2595	100	Al. Plate	
69	Freezing Fog	-14	2	Newave FCY-2 Bio +	75	Al. Plate	
70	Freezing Fog	-14	2	Newave FCY-2 Bio +	75	Al. Plate	
71	Freezing Fog	-14	5	Newave FCY-2 Bio +	100	Al. Plate	
72	Freezing Fog	-14	5	Newave FCY-2 Bio +	100	Al. Plate	
73	Freezing Fog	-14	5	Kilfrost P2595	100	Al. Plate	
74	Freezing Fog	-14	5	Kilfrost P2595	100	Al. Plate	
75	Freezing Fog	-14	5	Newave FCY-2 Bio +	75	Al. Plate	
76	Freezing Fog	-14	5	Newave FCY-2 Bio +	75	Al. Plate	
77	Freezing Fog	-14	5	Kilfrost P2595	75	Al. Plate	
78	Freezing Fog	-14	5	Kilfrost P2595	75	Al. Plate	
79	Freezing Fog	-14	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
80	Freezing Fog	-14	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
81	Freezing Fog	-25	2	AllClear CB1-PB8000A	100	Al. Plate	
82	Freezing Fog	-25	2	AllClear CB1-PB8000A	100	Al. Plate	
83	Freezing Fog	-25	2	Kilfrost P2595	100	Al. Plate	
84	Freezing Fog	-25	2	Kilfrost P2595	100	Al. Plate	
85	Freezing Fog	-25	2	Deicing Solutions ECO-SHIELD	100	Al. Plate	
86	Freezing Fog	-25	2	Deicing Solutions ECO-SHIELD	100	Al. Plate	
87	Freezing Fog	-25	2	Newave FCY-2 Bio +	100	Al. Plate	
88	Freezing Fog	-25	2	Newave FCY-2 Bio +	100	Al. Plate	
89	Freezing Fog	-25	2	Oksayd Defrost ECO I Batch #10	10°B (B = 29.5)	Al. Plate	
90	Freezing Fog	-25	2	Oksayd Defrost ECO I Batch #10	10°B (B = 29.5)	Al. Plate	
91	Freezing Fog	-25	2	Oksayd Defrost ECO I Batch #10	10°B (B = 29.5)	Comp. Plate	
92	Freezing Fog	-25	2	Oksayd Defrost ECO I Batch #10	10°B (B = 29.5)	Comp. Plate	
93	Freezing Fog	-25	5	Kilfrost P2595	100	Al. Plate	
94	Freezing Fog	-25	5	Kilfrost P2595	100	Al. Plate	
95	Freezing Fog	-25	5	Newave FCY-2 Bio +	100	Al. Plate	
96	Freezing Fog	-25	5	Newave FCY-2 Bio +	100	Al. Plate	

TABLE 1: NEW FLUID ENDURANCE TIMES TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
97	Freezing Fog	-25	5	AllClear CB1-PB8000A	100	Al. Plate	
98	Freezing Fog	-25	5	AllClear CB1-PB8000A	100	Al. Plate	
99	Freezing Fog	-25	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
100	Freezing Fog	-25	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
101	Freezing Fog	-25	5	Oksayd Defrost ECO I Batch #10	10°B (B = 29.5)	Al. Plate	
102	Freezing Fog	-25	5	Oksayd Defrost ECO I Batch #10	10°B (B = 29.5)	Al. Plate	
103	Freezing Fog	-25	5	Oksayd Defrost ECO I Batch #10	10°B (B = 29.5)	Comp. Plate	
104	Freezing Fog	-25	5	Oksayd Defrost ECO I Batch #10	10°B (B = 29.5)	Comp. Plate	
105	Freezing Fog	-35	2	LNT E450	100	Al. Plate	
106	Freezing Fog	-35	2	LNT E450	100	Al. Plate	
107	Freezing Fog	-35	2	AllClear CB1-PB8000A	100	Al. Plate	
108	Freezing Fog	-35	2	AllClear CB1-PB8000A	100	Al. Plate	
109	Freezing Fog	-35	5	LNT E450	100	Al. Plate	
110	Freezing Fog	-35	5	LNT E450	100	Al. Plate	
111	Freezing Fog	-35	5	AllClear CB1-PB8000A	100	Al. Plate	
112	Freezing Fog	-35	5	AllClear CB1-PB8000A	100	Al. Plate	
113	Freezing Drizzle	-3	5	Kilfrost P2595	100	Al. Plate	
114	Freezing Drizzle	-3	5	Kilfrost P2595	100	Al. Plate	
115	Freezing Drizzle	-3	5	Kilfrost P2595	75	Al. Plate	
116	Freezing Drizzle	-3	5	Kilfrost P2595	75	Al. Plate	
117	Freezing Drizzle	-3	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
118	Freezing Drizzle	-3	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
119	Freezing Drizzle	-3	5	Newave FCY-2 Bio +	100	Al. Plate	
120	Freezing Drizzle	-3	5	Newave FCY-2 Bio +	100	Al. Plate	
121	Freezing Drizzle	-3	5	AllClear CB1-PB8000A	100	Al. Plate	
122	Freezing Drizzle	-3	5	AllClear CB1-PB8000A	100	Al. Plate	
123	Freezing Drizzle	-3	5	Newave FCY-2 Bio +	75	Al. Plate	
124	Freezing Drizzle	-3	5	Newave FCY-2 Bio +	75	Al. Plate	
125	Freezing Drizzle	-3	5	Kilfrost P2595	50	Al. Plate	
126	Freezing Drizzle	-3	5	Kilfrost P2595	50	Al. Plate	
127	Freezing Drizzle	-3	5	Newave FCY-2 Bio +	50	Al. Plate	
128	Freezing Drizzle	-3	5	Newave FCY-2 Bio +	50	Al. Plate	
129	Freezing Drizzle	-3	5	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Al. Plate	
130	Freezing Drizzle	-3	5	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Al. Plate	
131	Freezing Drizzle	-3	5	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Comp. Plate	
132	Freezing Drizzle	-3	5	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Comp. Plate	
133	Freezing Drizzle	-3	13	Kilfrost P2595	100	Al. Plate	
134	Freezing Drizzle	-3	13	Kilfrost P2595	100	Al. Plate	
135	Freezing Drizzle	-3	13	Kilfrost P2595	75	Al. Plate	
136	Freezing Drizzle	-3	13	Kilfrost P2595	75	Al. Plate	
137	Freezing Drizzle	-3	13	Deicing Solutions ECO-SHIELD	100	Al. Plate	
138	Freezing Drizzle	-3	13	Deicing Solutions ECO-SHIELD	100	Al. Plate	
139	Freezing Drizzle	-3	13	Newave FCY-2 Bio +	100	Al. Plate	
140	Freezing Drizzle	-3	13	Newave FCY-2 Bio +	100	Al. Plate	
141	Freezing Drizzle	-3	13	AllClear CB1-PB8000A	100	Al. Plate	
142	Freezing Drizzle	-3	13	AllClear CB1-PB8000A	100	Al. Plate	
143	Freezing Drizzle	-3	13	Newave FCY-2 Bio +	75	Al. Plate	
144	Freezing Drizzle	-3	13	Newave FCY-2 Bio +	75	Al. Plate	

TABLE 1: NEW FLUID ENDURANCE TIMES TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
145	Freezing Drizzle	-3	13	Kilfrost P2595	50	Al. Plate	
146	Freezing Drizzle	-3	13	Kilfrost P2595	50	Al. Plate	
147	Freezing Drizzle	-3	13	Newave FCY-2 Bio +	50	Al. Plate	
148	Freezing Drizzle	-3	13	Newave FCY-2 Bio +	50	Al. Plate	
149	Freezing Drizzle	-3	13	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Al. Plate	
150	Freezing Drizzle	-3	13	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Al. Plate	
151	Freezing Drizzle	-3	13	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Comp. Plate	
152	Freezing Drizzle	-3	13	Oksayd Defrost ECO I Batch #10	10°B (B = 19.25)	Comp. Plate	
153	Freezing Drizzle	-6	5	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Al. Plate	
154	Freezing Drizzle	-6	5	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Al. Plate	
155	Freezing Drizzle	-6	5	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Comp. Plate	
156	Freezing Drizzle	-6	5	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Comp. Plate	
157	Freezing Drizzle	-6	13	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Al. Plate	
158	Freezing Drizzle	-6	13	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Al. Plate	
159	Freezing Drizzle	-6	13	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Comp. Plate	
160	Freezing Drizzle	-6	13	Oksayd Defrost ECO I Batch #10	10°B (B = 21.5)	Comp. Plate	
161	Freezing Drizzle	-10	5	AllClear CB1-PB8000A	100	Al. Plate	
162	Freezing Drizzle	-10	5	AllClear CB1-PB8000A	100	Al. Plate	
163	Freezing Drizzle	-10	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
164	Freezing Drizzle	-10	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
165	Freezing Drizzle	-10	5	Kilfrost P2595	100	Al. Plate	
166	Freezing Drizzle	-10	5	Kilfrost P2595	100	Al. Plate	
167	Freezing Drizzle	-10	5	Kilfrost P2595	75	Al. Plate	
168	Freezing Drizzle	-10	5	Kilfrost P2595	75	Al. Plate	
169	Freezing Drizzle	-10	5	Newave FCY-2 Bio +	100	Al. Plate	
170	Freezing Drizzle	-10	5	Newave FCY-2 Bio +	100	Al. Plate	
171	Freezing Drizzle	-10	5	Newave FCY-2 Bio +	75	Al. Plate	
172	Freezing Drizzle	-10	5	Newave FCY-2 Bio +	75	Al. Plate	
173	Freezing Drizzle	-10	5	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
174	Freezing Drizzle	-10	5	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
175	Freezing Drizzle	-10	5	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
176	Freezing Drizzle	-10	5	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
177	Freezing Drizzle	-10	13	AllClear CB1-PB8000A	100	Al. Plate	
178	Freezing Drizzle	-10	13	AllClear CB1-PB8000A	100	Al. Plate	
179	Freezing Drizzle	-10	13	Kilfrost P2595	100	Al. Plate	
180	Freezing Drizzle	-10	13	Kilfrost P2595	100	Al. Plate	
181	Freezing Drizzle	-10	13	Deicing Solutions ECO-SHIELD	100	Al. Plate	
182	Freezing Drizzle	-10	13	Deicing Solutions ECO-SHIELD	100	Al. Plate	
183	Freezing Drizzle	-10	13	Kilfrost P2595	75	Al. Plate	
184	Freezing Drizzle	-10	13	Kilfrost P2595	75	Al. Plate	
185	Freezing Drizzle	-10	13	Newave FCY-2 Bio +	100	Al. Plate	
186	Freezing Drizzle	-10	13	Newave FCY-2 Bio +	100	Al. Plate	
187	Freezing Drizzle	-10	13	Newave FCY-2 Bio +	75	Al. Plate	
188	Freezing Drizzle	-10	13	Newave FCY-2 Bio +	75	Al. Plate	
189	Freezing Drizzle	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
190	Freezing Drizzle	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
191	Freezing Drizzle	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
192	Freezing Drizzle	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	

TABLE 1: NEW FLUID ENDURANCE TIMES TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
193	Light Freezing Rain	-3	13	Kilfrost P2595	100	Al. Plate	
194	Light Freezing Rain	-3	13	Kilfrost P2595	100	Al. Plate	
195	Light Freezing Rain	-3	13	Kilfrost P2595	75	Al. Plate	
196	Light Freezing Rain	-3	13	Kilfrost P2595	75	Al. Plate	
197	Light Freezing Rain	-3	13	Deicing Solutions ECO-SHIELD	100	Al. Plate	
198	Light Freezing Rain	-3	13	Deicing Solutions ECO-SHIELD	100	Al. Plate	
199	Light Freezing Rain	-3	13	Newave FCY-2 Bio +	100	Al. Plate	
200	Light Freezing Rain	-3	13	Newave FCY-2 Bio +	100	Al. Plate	
201	Light Freezing Rain	-3	13	AllClear CB1-PB8000A	100	Al. Plate	
202	Light Freezing Rain	-3	13	AllClear CB1-PB8000A	100	Al. Plate	
203	Light Freezing Rain	-3	13	Newave FCY-2 Bio +	75	Al. Plate	
204	Light Freezing Rain	-3	13	Newave FCY-2 Bio +	75	Al. Plate	
205	Light Freezing Rain	-3	13	Kilfrost P2595	50	Al. Plate	
206	Light Freezing Rain	-3	13	Kilfrost P2595	50	Al. Plate	
207	Light Freezing Rain	-3	13	Newave FCY-2 Bio +	50	Al. Plate	
208	Light Freezing Rain	-3	13	Newave FCY-2 Bio +	50	Al. Plate	
209	Light Freezing Rain	-3	25	Kilfrost P2595	100	Al. Plate	
210	Light Freezing Rain	-3	25	Kilfrost P2595	100	Al. Plate	
211	Light Freezing Rain	-3	25	Kilfrost P2595	75	Al. Plate	
212	Light Freezing Rain	-3	25	Kilfrost P2595	75	Al. Plate	
213	Light Freezing Rain	-3	25	Deicing Solutions ECO-SHIELD	100	Al. Plate	
214	Light Freezing Rain	-3	25	Deicing Solutions ECO-SHIELD	100	Al. Plate	
215	Light Freezing Rain	-3	25	Newave FCY-2 Bio +	100	Al. Plate	
216	Light Freezing Rain	-3	25	Newave FCY-2 Bio +	100	Al. Plate	
217	Light Freezing Rain	-3	25	AllClear CB1-PB8000A	100	Al. Plate	
218	Light Freezing Rain	-3	25	AllClear CB1-PB8000A	100	Al. Plate	
219	Light Freezing Rain	-3	25	Newave FCY-2 Bio +	75	Al. Plate	
220	Light Freezing Rain	-3	25	Newave FCY-2 Bio +	75	Al. Plate	
221	Light Freezing Rain	-3	25	Kilfrost P2595	50	Al. Plate	
222	Light Freezing Rain	-3	25	Kilfrost P2595	50	Al. Plate	
223	Light Freezing Rain	-3	25	Newave FCY-2 Bio +	50	Al. Plate	
224	Light Freezing Rain	-3	25	Newave FCY-2 Bio +	50	Al. Plate	
225	Light Freezing Rain	-6	13	Oksayd Defrost ECO I Batch #10	10°B (B=21.5)	Al. Plate	
226	Light Freezing Rain	-6	13	Oksayd Defrost ECO I Batch #10	10°B (B=21.5)	Al. Plate	
227	Light Freezing Rain	-6	13	Oksayd Defrost ECO I Batch #10	10°B (B=21.5)	Comp. Plate	
228	Light Freezing Rain	-6	13	Oksayd Defrost ECO I Batch #10	10°B (B=21.5)	Comp. Plate	
229	Light Freezing Rain	-6	25	Oksayd Defrost ECO I Batch #10	10°B (B=21.5)	Al. Plate	
230	Light Freezing Rain	-6	25	Oksayd Defrost ECO I Batch #10	10°B (B=21.5)	Al. Plate	
231	Light Freezing Rain	-6	25	Oksayd Defrost ECO I Batch #10	10°B (B=21.5)	Comp. Plate	
232	Light Freezing Rain	-6	25	Oksayd Defrost ECO I Batch #10	10°B (B=21.5)	Comp. Plate	
233	Light Freezing Rain	-10	13	Kilfrost P2595	100	Al. Plate	
234	Light Freezing Rain	-10	13	Kilfrost P2595	100	Al. Plate	
235	Light Freezing Rain	-10	13	Deicing Solutions ECO-SHIELD	100	Al. Plate	
236	Light Freezing Rain	-10	13	Deicing Solutions ECO-SHIELD	100	Al. Plate	
237	Light Freezing Rain	-10	13	Kilfrost P2595	75	Al. Plate	
238	Light Freezing Rain	-10	13	Kilfrost P2595	75	Al. Plate	
239	Light Freezing Rain	-10	13	AllClear CB1-PB8000A	100	Al. Plate	
240	Light Freezing Rain	-10	13	AllClear CB1-PB8000A	100	Al. Plate	

TABLE 1: NEW FLUID ENDURANCE TIMES TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
241	Light Freezing Rain	-10	13	Newave FCY-2 Bio +	100	Al. Plate	
242	Light Freezing Rain	-10	13	Newave FCY-2 Bio +	100	Al. Plate	
243	Light Freezing Rain	-10	13	Newave FCY-2 Bio +	75	Al. Plate	
244	Light Freezing Rain	-10	13	Newave FCY-2 Bio +	75	Al. Plate	
245	Light Freezing Rain	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
246	Light Freezing Rain	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
247	Light Freezing Rain	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
248	Light Freezing Rain	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
249	Light Freezing Rain	-10	25	Kilfrost P2595	100	Al. Plate	
250	Light Freezing Rain	-10	25	Kilfrost P2595	100	Al. Plate	
251	Light Freezing Rain	-10	25	Newave FCY-2 Bio +	100	Al. Plate	
252	Light Freezing Rain	-10	25	Newave FCY-2 Bio +	100	Al. Plate	
253	Light Freezing Rain	-10	25	AllClear CB1-PB8000A	100	Al. Plate	
254	Light Freezing Rain	-10	25	AllClear CB1-PB8000A	100	Al. Plate	
255	Light Freezing Rain	-10	25	Deicing Solutions ECO-SHIELD	100	Al. Plate	
256	Light Freezing Rain	-10	25	Deicing Solutions ECO-SHIELD	100	Al. Plate	
257	Light Freezing Rain	-10	25	Kilfrost P2595	75	Al. Plate	
258	Light Freezing Rain	-10	25	Kilfrost P2595	75	Al. Plate	
259	Light Freezing Rain	-10	25	Newave FCY-2 Bio +	75	Al. Plate	
260	Light Freezing Rain	-10	25	Newave FCY-2 Bio +	75	Al. Plate	
261	Light Freezing Rain	-10	25	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
262	Light Freezing Rain	-10	25	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Al. Plate	
263	Light Freezing Rain	-10	25	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
264	Light Freezing Rain	-10	25	Oksayd Defrost ECO I Batch #10	10°B (B = 24.0)	Comp. Plate	
265	Cold Soak Box	1	5	Kilfrost P2595	100	Al. Plate	
266	Cold Soak Box	1	5	Kilfrost P2595	100	Al. Plate	
267	Cold Soak Box	1	5	Kilfrost P2595	75	Al. Plate	
268	Cold Soak Box	1	5	Kilfrost P2595	75	Al. Plate	
269	Cold Soak Box	1	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
270	Cold Soak Box	1	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	
271	Cold Soak Box	1	5	AllClear CB1-PB8000A	100	Al. Box	
272	Cold Soak Box	1	5	AllClear CB1-PB8000A	100	Al. Box	
273	Cold Soak Box	1	5	Newave FCY-2 Bio +	100	Al. Plate	
274	Cold Soak Box	1	5	Newave FCY-2 Bio +	100	Al. Plate	
275	Cold Soak Box	1	5	Newave FCY-2 Bio +	75	Al. Plate	
276	Cold Soak Box	1	5	Newave FCY-2 Bio +	75	Al. Plate	
277	Cold Soak Box	1	5	Oksayd Defrost ECO I Batch #10	10°B (B = 16.0)	Al. Plate	
278	Cold Soak Box	1	5	Oksayd Defrost ECO I Batch #10	10°B (B = 16.0)	Al. Plate	
279	Cold Soak Box	1	5	Oksayd Defrost ECO I Batch #10	10°B (B = 16.0)	Comp. Plate	
280	Cold Soak Box	1	5	Oksayd Defrost ECO I Batch #10	10°B (B = 16.0)	Comp. Plate	
281	Cold Soak Box	1	75	Kilfrost P2595	100	Al. Plate	
282	Cold Soak Box	1	75	Kilfrost P2595	100	Al. Plate	
283	Cold Soak Box	1	75	Kilfrost P2595	75	Al. Plate	
284	Cold Soak Box	1	75	Kilfrost P2595	75	Al. Plate	
285	Cold Soak Box	1	75	Deicing Solutions ECO-SHIELD	100	Al. Plate	
286	Cold Soak Box	1	75	Deicing Solutions ECO-SHIELD	100	Al. Plate	
287	Cold Soak Box	1	75	Newave FCY-2 Bio +	100	Al. Plate	
288	Cold Soak Box	1	75	Newave FCY-2 Bio +	100	Al. Plate	

TABLE 1: NEW FLUID ENDURANCE TIMES TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
289	Cold Soak Box	1	75	AllClear CB1-PB8000A	100	Al. Box	
290	Cold Soak Box	1	75	AllClear CB1-PB8000A	100	Al. Box	
291	Cold Soak Box	1	75	Newave FCY-2 Bio+	75	Al. Plate	
292	Cold Soak Box	1	75	Newave FCY-2 Bio+	75	Al. Plate	
293	Cold Soak Box	1	75	Oksayd Defrost ECO I Batch #10	10°B (B=16.0)	Al. Plate	
294	Cold Soak Box	1	75	Oksayd Defrost ECO I Batch #10	10°B (B=16.0)	Al. Plate	
295	Cold Soak Box	1	75	Oksayd Defrost ECO I Batch #10	10°B (B=16.0)	Comp. Plate	
296	Cold Soak Box	1	75	Oksayd Defrost ECO I Batch #10	10°B (B=16.0)	Comp. Plate	

TABLE 2: ET THICKNESS TEST PLAN

Test #	Fluid	Fluid Dilution	Fluid Temp	Test Surface	Ambient Air Temp
TH1	Oksayd Defrost ECO I Batch 10	10°B=(19.25)	20°C	Al. Plate	-3°C
TH2	Oksayd Defrost ECO I Batch 10	10°B=(19.25)	20°C	Al. Plate	-3°C
TH3	Newave FCY-2 Bio+	100/0	-3°C	Al. Plate	-3°C
TH4	Newave FCY-2 Bio+	100/0	-3°C	Al. Plate	-3°C
TH5	Newave FCY-2 Bio+	75/25	-3°C	Al. Plate	-3°C
TH6	Newave FCY-2 Bio+	75/25	-3°C	Al. Plate	-3°C
TH7	Newave FCY-2 Bio+	50/50	-3°C	Al. Plate	-3°C
TH8	Newave FCY-2 Bio+	50/50	-3°C	Al. Plate	-3°C
TH9	Kilfrost P2595	100/0	-3°C	Al. Plate	-3°C
TH10	Kilfrost P2595	100/0	-3°C	Al. Plate	-3°C
TH11	Kilfrost P2595	75/25	-3°C	Al. Plate	-3°C
TH12	Kilfrost P2595	75/25	-3°C	Al. Plate	-3°C
TH13	Kilfrost P2595	50/50	-3°C	Al. Plate	-3°C
TH14	Kilfrost P2595	50/50	-3°C	Al. Plate	-3°C
TH15	Deicing Solutions ECO-SHIELD	100/0	-3°C	Al. Plate	-3°C
TH16	Deicing Solutions ECO-SHIELD	100/0	-3°C	Al. Plate	-3°C
TH17	AllClear CB1-PB8000A	100/0	-3°C	Al. Plate	-3°C
TH18	AllClear CB1-PB8000A	100/0	-3°C	Al. Plate	-3°C

Notes:

- **The quantity of fluid that will be poured for each test is 1.0 L**
- **Measurements should be made at the 15-cm line at the time of fluid application, and after 2 minutes, 5 minutes, 15 minutes, and 30 minutes.**
- **If the results for one fluid vary by more than 10% repeat the two tests and disregard the highest and lowest values**

TABLE 3: WINGLET THICKNESS TEST PLAN

Test #	Fluid	Fluid Dilution	Fluid Temp	Test Surface	Ambient Air Temp	Fluid Quantity
W1	Oksayd Defrost ECO I Batch #10	10°B (B=19.25)	20°C	10° Al. Plate	-3°C	1 L
W2	Oksayd Defrost ECO I Batch #10	10°B (B=19.25)	20°C	80° Al. Plate	-3°C	1 L
W3	Oksayd Defrost ECO I Batch #10	10°B (B=19.25)	20°C	Winglet	-3°C	9 L / side (18 L total)
W4	Deicing Solutions Eco-Shield	100/0	-3°C	10° Al. Plate	-3°C	1 L
W5	Deicing Solutions Eco-Shield	100/0	-3°C	80° Al. Plate	-3°C	1 L
W6	Deicing Solutions Eco-Shield	100/0	-3°C	Winglet	-3°C	9 L on front side (9 L total)

Notes:

- **Fluid thickness to be measured at 15 cm line of plate**
- **Fluid thickness to be measured at 15 cm and 45 cm from the top of the winglet**
- **Fluid thickness to be measured at 5, 10, 15 and 30 minutes after pouring**
- **Winglet angle to be measured**

FIGURE 3: COMBINED AIRFOIL AND WINGLET EXPERIMENTAL SET-UP

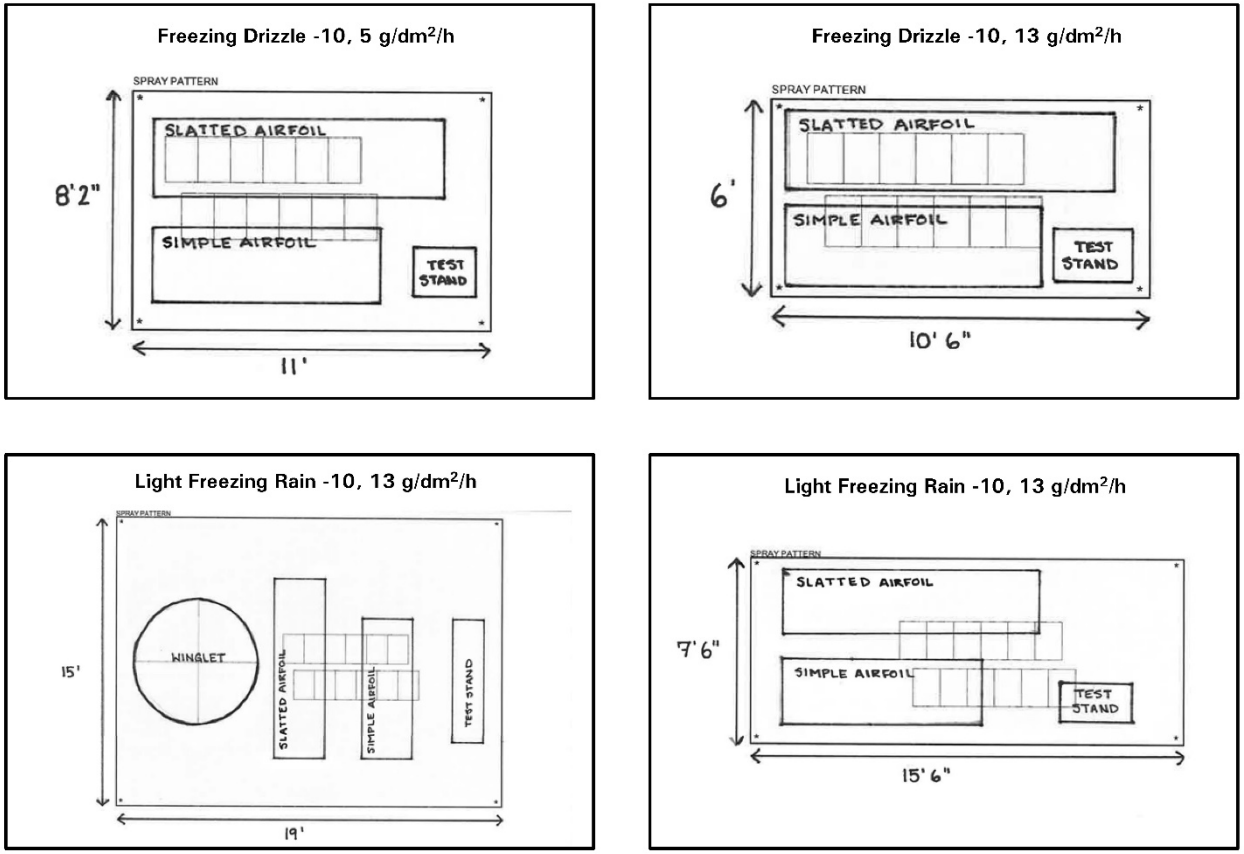


TABLE 4: COMBINED AIRFOIL AND WINGLET ENDURANCE TIMES TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
AF1	Light Freezing Rain	-10	13	Dow EG106	100	10° Al. Plate	
AF2	Light Freezing Rain	-10	13	Dow EG106	100	20° Al. Plate.	
W1	Light Freezing Rain	-10	13	Dow EG106	100	80° Al. Plate.	Only to be run if winglet fits in spray pattern
AF3	Light Freezing Rain	-10	13	Dow EG106	100	Slatted Airfoil	Pour 14.5L of fluid at OAT
AF4	Light Freezing Rain	-10	13	Dow EG106	100	Simple Airfoil	Pour 10.5L of fluid at OAT
W2	Light Freezing Rain	-10	13	Dow EG106	100	Winglet	Pour 18L Fluid @ OAT (9 L per side) Draw a sketch of failure once observed and note the time Only to be run if winglet fits in spray pattern
AF5	Light Freezing Rain	-10	13	Clariant MP I 1938 ECO	10°B (B=27.5)	10° Al. Plate	Pour 1L Fluid @ 20°C
AF6	Light Freezing Rain	-10	13	Clariant MP I 1938 ECO	10°B (B=27.5)	20° Al. Plate.	Pour 1L Fluid @ 20°C
AF7	Light Freezing Rain	-10	13	Clariant MP I 1938 ECO	10°B (B=27.5)	Slatted Airfoil	Pour 14.5L Fluid @ 20°C
AF8	Light Freezing Rain	-10	13	Clariant MP I 1938 ECO	10°B (B=27.5)	Simple Airfoil	Pour 10.5L Fluid @ 20°C
W3	Light Freezing Rain	-10	13	Cryotech Polar Plus	Premix	10° Al. Plate	Pour 1L Fluid @ 20°C
W4	Light Freezing Rain	-10	13	Cryotech Polar Plus	Premix	80° Al. Plate.	Pour 1L Fluid @ 20°C If winglet does not fit in spray, run as subsequent test
W5	Light Freezing Rain	-10	13	Cryotech Polar Plus	Premix	Winglet	Pour 18L Fluid @ 20°C (9L per side) Draw a sketch of failure once observed and note the time If winglet does not fit in spray, run as subsequent test
AF9	Light Freezing Rain	-10	25	ABAX AD-49	100	10° Al. Plate	
AF10	Light Freezing Rain	-10	25	ABAX AD-49	100	20° Al. Plate.	
AF11	Light Freezing Rain	-10	25	ABAX AD-49	100	Slatted Airfoil	Pour 14.5L of fluid at OAT
AF12	Light Freezing Rain	-10	25	ABAX AD-49	100	Simple Airfoil	Pour 10.5L of fluid at OAT
AF13	Freezing Drizzle	-3	5	Newave FCY 9311	50	10° Al. Plate	
AF14	Freezing Drizzle	-3	5	Newave FCY 9311	50	20° Al. Plate.	
AF15	Freezing Drizzle	-3	5	Newave FCY 9311	50	Slatted Airfoil	Pour 14.5L of fluid at OAT
AF16	Freezing Drizzle	-3	5	Newave FCY 9311	50	Simple Airfoil	Pour 10.5L of fluid at OAT
AF17	Freezing Drizzle	-3	13	Kilfrost ABC-S Plus	75	10° Al. Plate	
AF18	Freezing Drizzle	-3	13	Kilfrost ABC-S Plus	75	20° Al. Plate.	
AF19	Freezing Drizzle	-3	13	Kilfrost ABC-S Plus	75	Slatted Airfoil	Pour 14.5L of fluid at OAT
AF20	Freezing Drizzle	-3	13	Kilfrost ABC-S Plus	75	Simple Airfoil	Pour 10.5L of fluid at OAT

TABLE 5: NOSE CONE TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
NC1	Light Freezing Rain	-10	13	Newave FCY-2 BIO +	100	10° Al. Plate	
NC2	Light Freezing Rain	-10	13	Newave FCY-2 BIO +	100	20° Al. Plate	
NC3	Light Freezing Rain	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B=24)	20° Al. Plate	Pour 1L Fluid @ 20°C
NC4	Light Freezing Rain	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B=24)	20° Light Box	Pour 1L Fluid @ 20°C
NC5	Light Freezing Rain	-10	25	Deicing Solutions ECO-SHIELD	100	10° Al. Plate	
NC6	Light Freezing Rain	-10	25	Deicing Solutions ECO-SHIELD	100	20° Al. Plate	
NC7	Light Freezing Rain	-10	25	Oksayd Defrost ECO I Batch #10	10°B (B=24)	20° Al. Plate	Pour 1L Fluid @ 20°C
NC8	Light Freezing Rain	-10	25	Oksayd Defrost ECO I Batch #10	10°B (B=24)	20° Light Box	Pour 1L Fluid @ 20°C
NC9	Freezing Drizzle	-10	13	Kilfrost P2595	100	10° Al. Plate	
NC10	Freezing Drizzle	-10	13	Kilfrost P2595	100	20° Al. Plate	
NC11	Freezing Drizzle	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B=24)	20° Al. Plate	Pour 1L Fluid @ 20°C
NC12	Freezing Drizzle	-10	13	Oksayd Defrost ECO I Batch #10	10°B (B=24)	20° Light Box	Pour 1L Fluid @ 20°C

Notes:

- **Comparative sets outlined by thickened borders**

TABLE 6: DEPLOYED FLAPS ENDURANCE TIMES TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
DF1	Light Freezing Rain	-3	13	Clariant MP III 2031	100	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF2	Light Freezing Rain	-3	13	Clariant MP III 2031	100	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF3	Light Freezing Rain	-3	25	AllClear CB1-PB8000A	100	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF4	Light Freezing Rain	-3	25	AllClear CB1-PB8000A	100	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF5	Light Freezing Rain	-10	13	Newave FCY-2 BIO+	100	10° Al. Plate	
DF6	Light Freezing Rain	-10	13	Newave FCY-2 BIO+	100	20° Al. Plate	
DF7	Light Freezing Rain	-10	25	Deicing Solutions ECO-SHIELD	100	10° Al. Plate	
DF8	Light Freezing Rain	-10	25	Deicing Solutions ECO-SHIELD	100	20° Al. Plate	
DF9	Freezing Drizzle	-3	13	Clariant MP III 2031	75	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF10	Freezing Drizzle	-3	13	Clariant MP III 2031	75	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF11	Freezing Drizzle	-10	5	Clariant MP III 2031	75	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF12	Freezing Drizzle	-10	5	Clariant MP III 2031	75	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF13	Freezing Drizzle	-10	13	Kilfrost P2595	100	10° Al. Plate	
DF14	Freezing Drizzle	-10	13	Kilfrost P2595	100	20° Al. Plate	
DF15	Freezing Drizzle	-10	13	Clariant MP III 2031	75	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF16	Freezing Drizzle	-10	13	Clariant MP III 2031	75	20° Al. Plate	Unheated fluid - poured at ambient temperature
DF17	Freezing Fog	-3	5	Clariant MP III 2031	100	10° Al. Plate	Pour 1L Fluid @ 20°C
DF18	Freezing Fog	-3	5	Clariant MP III 2031	100	20° Al. Plate	Pour 1L Fluid @ 20°C
DF19	Freezing Fog	-10	5	AllClear CB1-PB8000A	100	10° Al. Plate	Unheated fluid - poured at ambient temperature
DF20	Freezing Fog	-10	5	AllClear CB1-PB8000A	100	20° Al. Plate	Unheated fluid - poured at ambient temperature

Notes:

- **Comparative sets outlined by thickened borders**

TABLE 7: FREEZING & THAWING TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
FT1	Freezing Drizzle	-10	5	Clariant MaxFlight 04	75	Al. Plate	Baseline -No Freeze
FT2	Freezing Drizzle	-10	5	Clariant MaxFlight 04	75	Al. Plate	48 Hour Freeze
FT3	Freezing Drizzle	-10	13	Newave FCY-2 Bio +	75	Al. Plate	Baseline -No Freeze
FT4	Freezing Drizzle	-10	13	Newave FCY-2 Bio +	75	Al. Plate	48 Hour Freeze
FT5	Freezing Drizzle	-3	13	Clariant Launch	75	Al. Plate	Baseline -No Freeze
FT6	Freezing Drizzle	-3	13	Clariant Launch	75	Al. Plate	48 Hour Freeze
FT7	Freezing Fog	-14	5	Kilfrost ABC-S Plus	75	Al. Plate	Baseline -No Freeze
FT8	Freezing Fog	-14	5	Kilfrost ABC-S Plus	75	Al. Plate	48 Hour Freeze
FT9	Freezing Fog	-3	5	Cryotech Polar Guard Advance	75	Al. Plate	Baseline -No Freeze
FT10	Freezing Fog	-3	5	Cryotech Polar Guard Advance	75	Al. Plate	48 Hour Freeze
FT11	Light Freezing Rain	-10	13	ABAX AD-49	75	Al. Plate	Baseline -No Freeze
FT12	Light Freezing Rain	-10	13	ABAX AD-49	75	Al. Plate	Repeated 48 Hour Freeze
FT13	Light Freezing Rain	-10	25	ABAX AD-49	75	Al. Plate	Baseline -No Freeze
FT14	Light Freezing Rain	-10	25	ABAX AD-49	75	Al. Plate	48 Hour Freeze
FT15	Light Freezing Rain	-3	13	Newave FCY-2 Bio +	100	Al. Plate	Baseline -No Freeze
FT16	Light Freezing Rain	-3	13	Newave FCY-2 Bio +	100	Al. Plate	48 Hour Freeze
FT17	Light Freezing Rain	-3	25	Clariant MP III 2031	75	Al. Plate	Baseline -No Freeze
FT18	Light Freezing Rain	-3	25	Clariant MP III 2031	75	Al. Plate	48 Hour Freeze
FT19	Light Freezing Rain	-3	25	Deicing Solutions ECO-SHIELD®	100	Al. Plate	Baseline -No Freeze
FT20	Light Freezing Rain	-3	25	Deicing Solutions ECO-SHIELD®	100	Al. Plate	48 Hour Freeze

TABLE 8: COMBINED COLOURED VS. UNCOLOURED AND VISUAL INSPECTION TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	ABAX Ecowing 26	Fluid Dilution (%)	Test Surface	Comments
CU1	Freezing Drizzle	-10	13	Coloured	100	Al. Plate	Half Plate (side stand)
CU2	Freezing Drizzle	-10	13	Un-Coloured	100	Al. Plate	Half Plate (side stand)
VI1	Freezing Drizzle	-10	13	Dye	100	Al. Plate	Half Plate (side stand)
VI2	Freezing Drizzle	-10	13	Un-Coloured	100	White Plate	Half Plate (side stand)
VI3	Freezing Drizzle	-10	13	Dye	100	White Plate	Half Plate (side stand)
CU3	Freezing Drizzle	-10	13	Coloured	75	Al. Plate	Half Plate Suggested
CU4	Freezing Drizzle	-10	13	Un-Coloured	75	Al. Plate	Half Plate Suggested
CU5	Freezing Drizzle	-3	13	Coloured	100	Al. Plate	1/2 Plate, Thick @ 5 mins, Brix at fail
CU6	Freezing Drizzle	-3	13	Un-Coloured	100	Al. Plate	1/2 Plate, Thick @ 5 mins, Brix at fail
CU7	Freezing Drizzle	-3	13	Coloured	75	Al. Plate	Half Plate (side stand)
CU8	Freezing Drizzle	-3	13	Un-Coloured	75	Al. Plate	Half Plate (side stand)
VI4	Freezing Drizzle	-3	13	Dye	75	Al. Plate	Half Plate (side stand)
VI5	Freezing Drizzle	-3	13	Un-Coloured	75	White Plate	Half Plate (side stand)
VI6	Freezing Drizzle	-3	13	Dye	75	White Plate	Half Plate (side stand)
CU9	Freezing Fog	-3	5	Coloured	50	Al. Plate	Half Plate Suggested
CU10	Freezing Fog	-3	5	Un-Coloured	50	Al. Plate	Half Plate Suggested
CU11	Light Freezing Rain	-10	25	Coloured	100	Al. Plate	Half Plate Suggested
CU12	Light Freezing Rain	-10	25	Un-Coloured	100	Al. Plate	Half Plate Suggested
CU13	Light Freezing Rain	-10	25	Coloured	75	Al. Plate	Half Plate Suggested
CU14	Light Freezing Rain	-10	25	Un-Coloured	75	Al. Plate	Half Plate Suggested
CU15	Light Freezing Rain	-3	25	Coloured	100	Al. Plate	Half Plate Suggested
CU16	Light Freezing Rain	-3	25	Un-Coloured	100	Al. Plate	Half Plate Suggested
CU17	Light Freezing Rain	-3	25	Coloured	75	Al. Plate	Half Plate (side stand)
CU18	Light Freezing Rain	-3	25	Un-Coloured	75	Al. Plate	Half Plate (side stand)
VI7	Light Freezing Rain	-3	25	Dye	75	Al. Plate	Half Plate (side stand)
VI8	Light Freezing Rain	-3	25	Un-Coloured	75	White Plate	Half Plate (side stand)
VI9	Light Freezing Rain	-3	25	Dye	75	White Plate	Half Plate (side stand)
CU19	Light Freezing Rain	-3	25	Coloured	50	Al. Plate	Half Plate (side stand)
CU20	Light Freezing Rain	-3	25	Un-Coloured	50	Al. Plate	Half Plate (side stand)
VI10	Light Freezing Rain	-3	25	Dye	50	Al. Plate	Half Plate (side stand)
VI11	Light Freezing Rain	-3	25	Un-Coloured	50	White Plate	Half Plate (side stand)
VI12	Light Freezing Rain	-3	25	Dye	50	White Plate	Half Plate (side stand)

TABLE 9: COMPATIBILITY TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	1st Step Fluid	2nd Step Fluid	Fluid Dilution (%)	Test Surface	Comments
CP1	Freezing Drizzle	-10	5	Inland EG (B = 22.9)	Newave FCY-2 Bio +	75	Al. Plate	3 min. wait
CP2	Freezing Drizzle	-10	5	Clariant 1938 (B = 27.5)	Newave FCY-2 Bio +	75	Al. Plate	3 min. wait
CP3	Freezing Drizzle	-10	5	Oksayd #10 (B = 24.0)	Newave FCY-2 Bio +	75	Al. Plate	3 min. wait
CP4	Freezing Drizzle	-10	13	Dow EG (B = 22.9)	Deicing Solutions ECO-SHIELD®	100	Al. Plate	3 min. wait
CP5	Freezing Drizzle	-10	13	Dow PG (B = 27.0)	Deicing Solutions ECO-SHIELD®	100	Al. Plate	3 min. wait
CP6	Freezing Drizzle	-10	13	Oksayd #10 (B = 24.0)	Deicing Solutions ECO-SHIELD®	100	Al. Plate	3 min. wait
CP7	Freezing Drizzle	-3	13	Inland EG (B = 17.6)	Newave FCY-2 Bio +	75	Al. Plate	3 min. wait
CP8	Freezing Drizzle	-3	13	Clariant 1938 (B = 21.7)	Newave FCY-2 Bio +	75	Al. Plate	3 min. wait
CP9	Freezing Fog	-14	5	Dow EG (B = 25.2)	Newave FCY-2 Bio +	100	Al. Plate	3 min. wait
CP10	Freezing Fog	-14	5	Dow PG (B = 29.3)	Newave FCY-2 Bio +	100	Al. Plate	3 min. wait
CP11	Freezing Fog	-14	5	Dow EG (B = 25.2)	Kilfrost P2595	100	Al. Plate	3 min. wait
CP12	Freezing Fog	-14	5	Dow PG (B = 29.3)	Kilfrost P2595	100	Al. Plate	3 min. wait
CP13	Freezing Fog	-3	5	Inland EG (B = 17.6)	Deicing Solutions ECO-SHIELD®	100	Al. Plate	3 min. wait
CP14	Freezing Fog	-3	5	Clariant 1938 (B = 21.7)	Deicing Solutions ECO-SHIELD®	100	Al. Plate	3 min. wait
CP15	Light Freezing Rain	-10	13	Inland EG (B = 22.9)	Kilfrost P2595	100	Al. Plate	3 min. wait
CP16	Light Freezing Rain	-10	13	Clariant 1938 (B = 27.5)	Kilfrost P2595	100	Al. Plate	3 min. wait
CP17	Light Freezing Rain	-10	25	Inland EG (B = 22.9)	Kilfrost P2595	75	Al. Plate	3 min. wait
CP18	Light Freezing Rain	-10	25	Dow EG (B = 22.9)	Kilfrost P2595	75	Al. Plate	3 min. wait
CP19	Light Freezing Rain	-10	25	Clariant 1938 (B = 27.5)	Kilfrost P2595	75	Al. Plate	3 min. wait
CP20	Light Freezing Rain	-10	25	Dow PG (B = 27.0)	Kilfrost P2595	75	Al. Plate	3 min. wait
CP21	Light Freezing Rain	-10	25	Oksayd #10 (B = 24.0)	Kilfrost P2595	75	Al. Plate	3 min. wait
CP22	Light Freezing Rain	-3	13	Dow EG (B = 17.6)	Deicing Solutions ECO-SHIELD®	100	Al. Plate	3 min. wait
CP23	Light Freezing Rain	-3	13	Dow PG (B = 21.8)	Deicing Solutions ECO-SHIELD®	100	Al. Plate	3 min. wait
CP24	Light Freezing Rain	-3	25	Dow EG (B = 17.6)	Newave FCY-2 Bio +	50	Al. Plate	3 min. wait
CP25	Light Freezing Rain	-3	25	Dow PG (B = 21.8)	Newave FCY-2 Bio +	50	Al. Plate	3 min. wait
CP26	Light Freezing Rain	-3	25	Oksayd #10 (B = 19.25)	Newave FCY-2 Bio +	50	Al. Plate	3 min. wait
CP27	Light Freezing Rain	-3	25	Inland EG (B = 17.6)	Newave FCY-2 Bio +	50	Al. Plate	3 min. wait
CP28	Light Freezing Rain	-3	25	Clariant 1938 (B = 21.7)	Newave FCY-2 Bio +	50	Al. Plate	3 min. wait
CP29	Light Freezing Rain	-3	25	Dow EG (B = 17.6)	Kilfrost P2595	50	Al. Plate	3 min. wait
CP30	Light Freezing Rain	-3	25	Dow PG (B = 21.8)	Kilfrost P2595	50	Al. Plate	3 min. wait
CP31	Light Freezing Rain	-3	25	Oksayd #10 (B = 19.25)	Kilfrost P2595	50	Al. Plate	3 min. wait
CP32	Light Freezing Rain	-3	25	Inland EG (B = 17.6)	Kilfrost P2595	50	Al. Plate	3 min. wait
CP33	Light Freezing Rain	-3	25	Clariant 1938 (B = 21.7)	Kilfrost P2595	50	Al. Plate	3 min. wait

TABLE 10: FLUID FAILURE PHOTOS TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
P1	Freezing Drizzle	-10	5	AllClear CB1-PB	100	Al. Plate	Priority 1
P2	Freezing Drizzle	-10	5	Clariant MP III 2031	75	Al. Plate	Priority 1
P3	Freezing Drizzle	-10	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	Priority 1
P4	Freezing Drizzle	-3	5	Oksayd Defrost ECO I	10°B (B = 19.25)	Al. Plate	Priority 1
P5	Freezing Drizzle	-3	5	Kilfrost P2595	100	Al. Plate	Priority 1
P6	Freezing Drizzle	-3	5	Kilfrost P2595	50	Al. Plate	Priority 1
P7	Freezing Drizzle	-3	5	Clariant MP III 2031	75	Al. Plate	Priority 2
P8	Freezing Drizzle	-3	13	Kilfrost P2595	75	Al. Plate	Priority 1
P9	Freezing Drizzle	-3	13	Kilfrost P2595	50	Al. Plate	Priority 1
P10	Freezing Drizzle	-3	13	AllClear CB1-PB	100	Al. Plate	Priority 1
P11	Freezing Drizzle	-3	13	Clariant MP III 2031	50	Al. Plate	Priority 2
P12	Freezing Fog	-25	2	Oksayd Defrost ECO I	10°B (B = 29.5)	Al. Plate	Priority 1
P13	Freezing Fog	-25	2	AllClear CB1-PB	100	Al. Plate	Priority 1
P14	Freezing Fog	-14	5	Kilfrost P2595	100	Al. Plate	Priority 1
P15	Freezing Fog	-14	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	Priority 1
P16	Freezing Fog	-14	5	Kilfrost ABC-S Plus	75	Al. Plate	Priority 1
P17	Freezing Fog	-10	2	Oksayd Defrost ECO I	10°B (B = 24.0)	Al. Plate	Priority 1
P18	Freezing Fog	-10	2	AllClear CB1-PB	100	Al. Plate	Priority 1
P19	Freezing Fog	-10	2	Clariant MP III 2031	75	Al. Plate	Priority 2
P20	Freezing Fog	-10	5	Oksayd Defrost ECO I	10°B (B = 24.0)	Al. Plate	Priority 1
P21	Freezing Fog	-10	5	AllClear CB1-PB	100	Al. Plate	Priority 1
P22	Freezing Fog	-10	5	Clariant MP III 2031	75	Al. Plate	Priority 2
P23	Freezing Fog	-3	2	Clariant MP III 2031	50	Al. Plate	Priority 1
P24	Freezing Fog	-3	2	Deicing Solutions ECO-SHIELD	100	Al. Plate	Priority 1
P25	Freezing Fog	-3	2	Polar Guard Advance	75	Al. Plate	Priority 2
P26	Freezing Fog	-3	2	Polar Guard Advance	50	Al. Plate	Priority 1
P27	Freezing Fog	-3	5	Oksayd Defrost ECO I	10°B (B = 19.25)	Al. Plate	Priority 1
P28	Freezing Fog	-3	5	Kilfrost P2595	50	Al. Plate	Priority 1
P29	Freezing Fog	-3	5	Clariant MP III 2031	75	Al. Plate	Priority 2
P30	Freezing Fog	-3	5	Clariant MP III 2031	50	Al. Plate	Priority 2
P31	Freezing Fog	-3	5	Deicing Solutions ECO-SHIELD	100	Al. Plate	Priority 1
P32	Freezing Fog	-3	5	Polar Guard Advance	75	Al. Plate	Priority 1
P33	Light Freezing Rain	-10	13	Clariant MP III 2031	75	Al. Plate	Priority 2
P34	Light Freezing Rain	-10	25	Clariant MP III 2031	75	Al. Plate	Priority 1
P35	Light Freezing Rain	-3	13	Kilfrost P2595	75	Al. Plate	Priority 1
P36	Light Freezing Rain	-3	13	Clariant MP III 2031	50	Al. Plate	Priority 2
P37	Light Freezing Rain	-3	25	AllClear CB1-PB	100	Al. Plate	Priority 1
P38	Light Freezing Rain	-3	25	Clariant MP III 2031	75	Al. Plate	Priority 1
P39	Light Freezing Rain	-3	25	Clariant MP III 2031	50	Al. Plate	Priority 2
P40	Light Freezing Rain	-3	25	Deicing Solutions ECO-SHIELD	100	Al. Plate	Priority 1
P41	Cold Soak Box	1	5	AllClear CB1-PB	100	Al. Plate	Priority 1
P42	Cold Soak Box	1	75	Oksayd Defrost ECO I	10°B (B = 16.0)	Al. Plate	Priority 1
P43	Cold Soak Box	1	75	Clariant MP III 2031	75	Al. Plate	Priority 2
P44	Cold Soak Box	1	75	Polar Guard Advance	75	Al. Plate	Priority 1

TABLE 11: PERSONNEL REQUIREMENTS / RESPONSIBILITIES

PERSONNEL ASSIGNMENTS	MAIN STAND - HOT		MAIN/SIDE STANDS - R&D						
	HOT + Type III	CC	Photos	Flaps/Slats	Freeze/Thaw	Coloured/ Uncoloured	Visual Inspection	Compatibility	Nosecone
Manager	JD	JD	BB	DY	DY	DY	BB	DY	BB
Assistant	YOW2	YOW2	CB/JD/YOW2	MR/BB	MR/BB	MR/BB	MR/DY	MR/BB	MR/DY
Data Forms	CB	CB	CB	CB	CB	CB	CB	CB	CB
Rate Station Manager	SB	SB	SB	SB	SB	SB	SB	SB	SB
Rate Station Asst	YOW1	YOW1	YOW1	YOW1	YOW1	YOW1	YOW1	YOW1	YOW1
Dedicated Photographer	-	-	BB	-	-	-	-	-	-
R&D Manager*	-	-	MR	MR	MR	MR	MR	MR	MR

PERSONNEL ASSIGNMENTS	SMALL END CHAMBER		STANDS REMOVED
	ET Thickness	Winglet Thickness	Airfoil + Winglet ETs
Manager	BB	MR	MR
Assistant	MR	BB	DY/BB/YOW2
Data Forms	BB/MR	MR/BB	CB
Rate Station Manager	-	-	SB
Rate Station Asst	-	-	YOW1
Dedicated Photographer	-	-	-
R&D Manager*	-	-	-

* manages timing of projects and assignment of test positions to R&D projects in each condition

PERSONNEL ASSIGNMENTS	OTHER TASKS
Pre-Test Setup	JD/DP
Equipment Manager	MR/DY
Fluid Management	MR/DY
Data Form Filing	CB
Box Prep (in CSW)	MR/DY/YOW2
Fluid Collection + Filling	YOW1/YOW2
Viscosity/Shearing	DP
Relief Rate Station Mgr	DY

TABLE 12: LIST OF FLUIDS

Fluid	Viscosity Type	Batch #	Fluid Temp	Fluid Dil or Brix (FFP)	Litres Required per Project											Total Litres	Pour Bottles	Notes
					ET/ CB1	TH-ET	TH-W	AF/W	NC	DF	FT	CU/ VI	CP	P	CC			
Type I																		
Oksayd Defrost ECO I (B=16.0)**	n/a	10	20°C	16.0 (-9°C)	8	-	-	-	-	-	-	-	-	-	-	8	4	1 jug @ 5L
Oksayd Defrost ECO I (B=19.3)**	n/a	10	20°C	19.3 (-13°C)	16	2	20	-	-	-	-	-	2	-	-	40	4	2 jugs @ 20L each
Oksayd Defrost ECO I (B=21.5)**	n/a	10	20°C	21.5 (-16°C)	24	-	-	-	-	-	-	-	-	-	-	24	4	1 jug @ 20L
Oksayd Defrost ECO I (B=24.0)**	n/a	10	20°C	24.0 (-20°C)	24	-	-	-	6	-	-	-	3	-	-	33	4	2 jugs @ 20L each
Oksayd Defrost ECO I (B=29.5)**	n/a	10	20°C	29.5 (-35°C)	8	-	-	-	-	-	-	-	-	-	-	8	4	1 jug @ 5L
Dow EG (B=17.6)	n/a	Inland Dow Type I	20°C	17.6 (-13°C)	-	-	-	-	-	-	-	-	3	-	-	3	3	no jug
Dow EG (B=22.9)	n/a	Inland Dow Type I	20°C	22.9 (-20°C)	-	-	-	-	-	-	-	-	2	-	-	2	2	no jug
Dow EG (B=25.2)	n/a	Inland Dow Type I	20°C	25.2 (-24°C)	-	-	-	-	-	-	-	-	2	-	-	2	2	no jug
Dow PG (B=21.8)	n/a	XL0519G8G	20°C	21.8 (-13°C)	-	-	-	-	-	-	-	-	3	-	-	3	3	no jug
Dow PG (B=27.0)	n/a	XL0519G8G	20°C	27.0 (-20°C)	-	-	-	-	-	-	-	-	2	-	-	2	2	no jug
Dow PG (B=29.3)	n/a	XL0519G8G	20°C	29.3 (-24°C)	-	-	-	-	-	-	-	-	2	-	-	2	2	no jug
Inland Duragly-E (B=17.6)	n/a	?	20°C	17.6 (-13°C)	-	-	-	-	-	-	-	-	4	-	-	4	4	no jug
Inland Duragly-E (B=22.9)	n/a	?	20°C	22.9 (-20°C)	-	-	-	-	-	-	-	-	3	-	-	3	3	no jug
Cryotech Polar Plus Premix**	n/a	?	20°C	Premix	-	-	-	20	-	-	-	-	-	-	-	20	4	1 jug @ 20L
Clariant MP I 1938 ECO (B=21.7)	n/a	?	20°C	21.7 (-13°C)	-	-	-	-	-	-	-	-	7	-	-	7	4	1 jug @ 3L
Clariant MP I 1938 ECO (B=27.5)**	n/a	?	20°C	27.5 (-20°C)	-	-	-	27	-	-	-	-	7	-	-	34	4	2 jugs @ 20L each
Type II, III, IV (HOT)																		
AllClear CB1 PB-8000A	LOWV	TBD	OAT	100	36	2	-	-	-	4	-	-	-	-	-	42	8*+2~	2 jugs
Deicing Solutions ECO SHIELD	LOWV	141223D-CC	OAT	100	32	2	11	-	2	2	1	-	7	-	-	57	8*+2~	3 jugs
Kilfrost P2595	LOWV	X/1/2/15	OAT	100	32	2	-	-	2	2	-	-	4	-	-	42	8*+2~	2 jugs
Kilfrost P2595	LOWV	X/1/2/15	OAT	75	28	2	-	-	-	-	-	-	5	-	-	35	8*+2~	2 jugs
Kilfrost P2595	LOWV	X/1/2/15	OAT	50	12	2	-	-	-	-	-	-	5	-	-	19	8*+2~	1 jug
Newave FCY-2 Bio+	LOWV	201412012	OAT	100	32	2	-	-	2	2	1	-	2	-	-	41	8*+2~	2 jugs
Newave FCY-2 Bio+	LOWV	201412012	OAT	75	28	2	-	-	-	-	1	-	5	-	-	36	8*+2~	2 jugs
Newave FCY-2 Bio+	LOWV	201412012	OAT	50	12	2	-	-	-	-	-	-	5	-	-	19	8*+2~	1 jug
LNT Solutions E450	LOWV	003/14	OAT	100	4	-	-	-	-	-	-	-	-	-	-	4	4	no jug
Commercial Fluid (CC)																		
Commercial Fluid (CC)	LOWV	TBD	OAT	100	-	-	-	-	-	-	-	-	-	-	6	6	2	1 jug @ 5L
Commercial Fluid (CC)	LOWV	TBD	OAT	75	-	-	-	-	-	-	-	-	-	-	6	6	2	1 jug @ 5L
Commercial Fluid (CC)	LOWV	TBD	OAT	50	-	-	-	-	-	-	-	-	-	-	6	6	2	1 jug @ 5L

TABLE 12: LIST OF FLUIDS (CONT'D)

Fluid	Viscosity Type	Batch #	Fluid Temp	Fluid Dil or Brix (FFP)	Litres Required per Project											Total Litres	Pour Bottles	Notes
					ET/ CB1	TH-ET	TH-W	AF/W	NC	DF	FT	CU/ VI	CP	P	CC			
Type II, III, IV (R&D)																		
AllClear CB1 (G or H)	LOWV	CB1	OAT	100	5	-	-	-	-	-	-	-	-	-	-	5	5	no jug
Clariant Safewing MP III (WARM)	Mid	6V40159	20°C	100	-	-	-	-	-	2	-	-	-	-	-	2	2	no jug
Clariant Safewing MP III (COLD)	Mid	6V40159	OAT	100	-	-	-	-	-	2	-	-	-	-	-	2	2	no jug
Clariant Safewing MP III (COLD)	Mid	6V40159	OAT	75	-	-	-	-	-	2	-	-	-	7	-	9	2	1 jug @ 7L
Clariant Safewing MP III (COLD)	LOWV	USHA03583	OAT	75	-	-	-	-	-	4	1	-	-	-	-	5	5	no jug
Clariant Safewing MP III (COLD)	LOWV	USHA03583	OAT	50	-	-	-	-	-	-	-	-	-	5	-	5	5	no jug
ABAX AD-49	Mid	L12-328	OAT	100	-	-	-	27	-	-	-	-	-	-	-	27	0	2 (bring current jugs)
ABAX AD-49	LOWV	L12-319	OAT	75	-	-	-	-	-	-	2	-	-	-	-	2	2	no jug
Newave FCY 9311	LOWV	201311002	OAT	50	-	-	-	27	-	-	-	-	-	-	-	27	0	2 (bring current jugs)
Clariant Launch	Mid	WT-11-12	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
Clariant Max Flight 04	LOWV	U49E001966	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
Cryotech PG Advance	LOWV	13102	OAT	75	-	-	-	-	-	-	1	-	-	2	-	3	3	no jug
Cryotech PG Advance	LOWV	13102	OAT	50	-	-	-	-	-	-	-	-	-	1	-	1	1	no jug
Dow EG106	Mid	1302 1G1K0R+WT1112	OAT	100	-	-	-	46	-	-	-	-	-	-	-	46	0	2 (bring current jugs)
Kilfrost ABC-S Plus	Mid	B/13/12/11	OAT	75	-	-	-	27	-	-	1	-	-	-	-	28	1	2 (bring current jugs)
ABAX AD-49 (48 hr freeze)	n/a	APS	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
ABAX AD-49 (repeat 48 hr freeze)	n/a	APS	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
Clariant Launch (48 hr freeze)	n/a	APS	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
Clariant Max Flight 04 (48 hr freeze)	n/a	APS	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
Clariant MP III 2031 (48 hr freeze)	n/a	APS	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
Cryotech PG Advance (48 hr freeze)	n/a	APS	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
DS ECO-SHIELD (48 hr freeze)	n/a	APS	OAT	100	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
Kilfrost ABC-S Plus (48 hr freeze)	n/a	APS	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
Newave FCY-2 Bio + (48 hr freeze)	n/a	APS	OAT	100	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
Newave FCY-2 Bio + (48 hr freeze)	n/a	APS	OAT	75	-	-	-	-	-	-	1	-	-	-	-	1	1	no jug
ABAX E-26 (Coloured)	High	L14324/2	OAT	100	-	-	-	-	-	-	-	2	-	-	-	2	1	bring current jug
ABAX E-26 (Coloured)	High	L14324/2	OAT	75	-	-	-	-	-	-	-	2	-	-	-	2	1	bring current jug
ABAX E-26 (Coloured)	High	L14324/2	OAT	50	-	-	-	-	-	-	-	1	-	-	-	1	1	bring current jug
ABAX E-26 (Un-Coloured)	High	L14324/1	OAT	100	-	-	-	-	-	-	-	2.5	-	-	-	2.5	1	bring current jug
ABAX E-26 (Un-Coloured)	High	L14324/1	OAT	75	-	-	-	-	-	-	-	3	-	-	-	3	1	bring current jug
ABAX E-26 (Un-Coloured)	High	L14324/1	OAT	50	-	-	-	-	-	-	-	1.5	-	-	-	1.5	1	bring current jug
ABAX E-26 (Dye)	High	APS	OAT	100	-	-	-	-	-	-	-	1	-	-	-	1	1	no jug
ABAX E-26 (Dye)	High	APS	OAT	75	-	-	-	-	-	-	-	2	-	-	-	2	2	no jug
ABAX E-26 (Dye)	High	APS	OAT	50	-	-	-	-	-	-	-	1	-	-	-	1	1	no jug
All Fluids					317	18	31	174	12	20	20	16	73	15	18	714	117	

* pour bottles already exist at site, pack them (leave ~ 2 bottles at the site for natural snow testing) ** bring concentrate jug Cold Storage Fluid Warm Storage Fluid

TABLE 13: TYPE I DILUTION TABLES

FFP (°C)	Test Temp (°C)	Clariant Safewing MP I 1938 ECO (PG)				Dow UCAR™ Aircraft Deicing Fluid Concentrate (EG)			
		% Fluid	Brix	Fluid (L) for 4 L	Water (L) for 4 L	% Fluid	Brix	Fluid (L) for 4 L	Water (L) for 4 L
-9	1	26.0	16.8	1.0	3.0	20.8	13.6	0.8	3.2
-13	-3	33.9	21.7	1.4	2.6	27.4	17.6	1.1	2.9
-16	-6	38.7	24.6	1.5	2.5	31.5	20.1	1.3	2.7
-20	-10	44.0	27.6	1.8	2.2	36.3	22.9	1.5	2.5
-24	-14	48.3	30.0	1.9	2.1	40.5	25.2	1.6	2.4
-35	-25	58.9	35.8	2.4	1.6	50.3	30.5	2.0	2.0

FFP (°C)	Test Temp (°C)	Dow UCAR™ PG Aircraft Deicing Fluid Concentrate (PG)				Inland Technologies Duragly-E (EG)			
		% Fluid	° Brix	Fluid (L) for 4 L	Water (L) for 4 L	% Fluid	° Brix	Fluid (L) for 4 L	Water (L) for 4 L
-9	1	27	18.1	1.1	2.9	20.8	13.60	0.8	3.2
-13	-3	33	21.8	1.3	2.7	27.4	17.60	1.1	2.9
-16	-6	37	24.2	1.5	2.5	31.5	20.10	1.3	2.7
-20	-10	42	27.0	1.7	2.3	36.3	22.90	1.5	2.5
-24	-14	46	29.3	1.8	2.2	40.5	25.20	1.6	2.4
-35	-25	n/a	n/a	n/a	n/a	50.3	30.50	2.0	2.0

FFP (°C)	Test Temp (°C)	Oksayd Defrost ECO I (NG)			
		% Fluid	Brix	Fluid (L) for 4 L	Water (L) for 4 L
-9	1	29.2	16.00	1.2	2.8
-13	-3	37.2	19.25	1.5	2.5
-16	-6	42.0	21.50	1.7	2.3
-20	-10	47.4	24.00	1.9	2.1
-24	-14	51.6	25.75	2.1	1.9
-35	-25	60.3	29.50	2.4	1.6

TABLE 14: GENERAL EQUIPMENT LIST

HOT AND GENERAL EQUIPMENT
LOCATION: TEST SITE
Barrel Opener
Bins for mixing CSW fluid x 5 (60L rubbermaids)
Brixometer x 3
Calculators x 2
Camera x3 (small Canon) with accessories
Cart (IKEA) x2
Clipboards x 10
Clock (Large digital) x 2
Cold-soak boxes (aluminum) x 10
Cold-soak boxes (composite) x 3
Extension Cords x 4
Flashlights x 2
Fluids (separate table)
Folding table x 1 (small)
Freezers (portable) x2
Funnels x 4 (big and small)
Gloves - black and yellow x4
Gloves - cotton (1 large box)
Gloves - latex (2 boxes)
Hard water chemicals x 3 premixes
Ice Pic
Inclinometer (yellow level) x 2
Isopropyl x 15
Jigaloo x1 and Scotchguard x1
Lock for truck
Marker for Waste x 2
Measuring Cups x 3
Nuts to separate plates x 100 (full box)
Pails x 4 (Empty 18L cont. for -30C CSW fluid)
Paper Towels (4 packs)
Personnel clothing + SB box
Pour containers (1-litre) - 6 empty
Pour containers (1-litre) - see separate list
Power bars x 4
Printer & Ink Cartridge
Rain Suits (all)
Rate Pan (aluminum HOT) x1
Rate Pans(white plastic) x all
Sample bottles x 6
Scrapers x 14
Shop Vac + 2x18L open top pails
Smart button kits x 2 + extension wire
Speed tape x 1 and electrical tape x 5
Squeegees x 4 (small)
Tape measure (large yellow + small)
Temperature probes: immersion x 3
Temperature probes: surface x 3
Temperature readers (blue box)x 2
Test plate covers (white plastic) x 15
Test plate covers (wooden boards) x 12
Test Plates - Half plates x 11 (22 halves)
Test Plates (Aluminum): 12 w/buttons + 6 w/out

HOT AND GENERAL EQUIPMENT
LOCATION: TEST SITE
Test Plates (Composite) x 4 w/smart buttons
Test Stand Collection Pans (one per stand)
Test Stand Shims (poker chips) x 1 box
Test Stands: 1 x 6 position (small end)
Test Stands: 2 x 6-position (main stand)
Test Stands: 3 position (side stand) (2 + 1)
Test Stands: 3 position (spare) (2 + 1)
Thickness Gauges (4 x small 4 x large)
Tuques x10
Type I PG Concentrate (CSW) x 10L
USB Extension cables x3
Vise grip (large) + rubber opener
Washers x 1 box
Water (1 x 18L) for hard water
Weigh Scale x 2 (sartorius) + wiring
White poster board panels for water run-off
Yellow Carrying Cases x4
LOCATION: OFFICE
Accordian Folder
Blank Waterproof labels (1 page)
Camera Gear (2 suitcases + gopro)
Coffee x 140 (K-Cups)
Data Forms (on water phobic paper)
Envelopes (9x12) x box
Falling Ball Viscometer + Syringes
Hard Drive (if necessary)
iPads x 3
Laptop for smart button (MR)
Laptop x5 (CB,DY,SB,MR,BB)
Mouse for Rate Station and keypad
Paper for printer (1 pack)
Pencils (sharpened) + pens + markers
Test Procedures x 2 (1 sided)
Walkie Talkies x 4
Waterproof paper (40sheets)
LOCATION: NRC
Cold-soak box filling stand
Cold-soak fluid pump
Copper tubing insulation (for passing wires)
Fluid for cold-soak boxes (barrel)
Rubber Mats
Shelving unit x 1 (black one)
Tie wraps
Tools
Tote for Waste Fluid
NRC Auto Rate Form with Historical #'s

TABLE 14: GENERAL EQUIPMENT LIST (CONT'D)

OTHER RESEARCH PROJECTS
LOCATION: VARIOUS
Flaps/Slats (Plates)
Empty 1L pour containers to prop plates to 20º x 4
Electrical tape
Flaps/Slats (Airfoil)
Slatted airfoil on stand
Simple airfoil
Table to support simple airfoil
Fluid collection pans (use wtv available @NRC)
3L pour container
Winglets
Winglet on stand
Fluid collection pans (use wtv available @NRC)
80º test stand x1 with plate
Nose Cone
Empty CSW box (use wtv available @NRC)
light bulb, socket, and extension chord
Empty 1L pour containers to prop plates to 20º x 4
Electrical tape
Freezing Thawing
NRC freezer
Effect of Color/Visual Inspection
Food colouring
Camera (already accounted for in HOT)
Fluid Compatability
n/a
Documentation of Fluid Failure
Camera (already accounted for in HOT)
HOT
Viscometer/Blender Kit

Note: Pack coolers with first day fluids and plug into power overnight

OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2015

FIGURE 4: NRC RATE MANAGEMENT FORM

DATE: _____

CONDITION: _____ TECHNICIAN: _____

PAN #	TAB	TIME OUT	1st or 2nd Rate

FIGURE 5: NRC CONTINUOUS RATE FORM

Condition	Date	Historical Average Calculated Rate - Position 1	Historical Standard Deviation	Previous Session Standard Deviation	Average Visual Rate	Was Stand Moved? (Where?)	Condition Difficulty (Easy, OK, Hard)	Comments
ZF, -3, 2		1.6	0.2	0.5				
ZF, -3, 5		4.5	0.3	0.8				
ZF, -10, 2		1.6	n/a	0.5				
ZF, -10, 5		5.2	1.8	0.6				
ZF, -14, 2		1.9	n/a	n/a				
ZF, -14, 5		4.5	n/a	n/a				
ZF, -25, 2		2.4	0.1	1.6				
ZF, -25, 5		4.7	0.8	1.3				
ZD, -3, 5		5.5	0.2	0.8				
ZD, -3, 13		14.6	0.4	0.9				
ZD, -6, 5		n/a	n/a	n/a				
ZD, -6, 13		n/a	n/a	n/a				
ZD, -10, 5		5.5	n/a	1.0				
ZD, -10, 13		14.4	0.4	1.3				
ZR, -3, 13		13.2	0.2	1.1				
ZR, -3, 25		25.1	0.4	1.1				
ZR, -6, 13		n/a	n/a	n/a				
ZR, -6, 25		n/a	n/a	n/a				
ZR, -10, 13		13.5	0.6	0.9				
ZR, -10, 25		26.3	0.8	1.3				
CS, 1, 5		4.9	0.2	0.9				
CS, 1, 75		80.5	n/a	n/a				

FIGURE 6: FLUID THICKNESS DATA FORM

DATE: _____ TEMPERATURE °C (beg.): _____ PERFORMED BY: _____

TEST #: ____to____ WIND SPEED, kph (beg.): _____ WRITTEN BY: _____

STAND: _____ LOCATION: CEF (NRC)

THICKNESS (mil)											
Plate: U Run #: Fluid: Application Time:		Plate: V Run #: Fluid: Application Time:		Plate: W Run #: Fluid: Application Time:		Plate: X Run #: Fluid: Application Time:		Plate: Y Run #: Fluid: Application Time:		Plate: Z Run #: Fluid: Application Time:	
TIME	6" LINE	TIME	6" LINE	TIME	6" LINE	TIME	6" LINE	TIME	6" LINE	TIME	6" LINE

I:\Groups\Cm1680 (01-02)\Procedures\Thickness\Thickness Form

Notes:

- The quantity of fluid that will be poured for each test is 1.0 L
- Measurements should be made at the 15-cm line at the time of fluid application, and after 2, 5, 15 and 30 minutes
- If the results for one fluid vary by more than 10% repeat the two tests and disregard the highest and lowest values

FIGURE 7: FREEZING PRECIPITATION ENDURANCE TIME DATA FORM

REMEMBER TO SYNCHRONIZE TIME

LOCATION: CEF (Ottawa) **DATE:** **RUN NUMBER:** **STAND # :**

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 0.5°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/BATCH						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						
FAILURE CALL (circle)	V. Difficult Difficult Easy	V. Difficult Difficult Easy	V. Difficult Difficult Easy	V. Difficult Difficult Easy	V. Difficult Difficult Easy	V. Difficult Difficult Easy
HRZ. AIR VELOCITY * (circle)	A B C	A B C	A B C	A B C	A B C	A B C

	Plate 7	Plate 8	Plate 9	Plate 10	Plate 11	Plate 12
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 0.5°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/BATCH						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						
FAILURE CALL (circle)	V. Difficult Difficult Easy	V. Difficult Difficult Easy	V. Difficult Difficult Easy	V. Difficult Difficult Easy	V. Difficult Difficult Easy	V. Difficult Difficult Easy
HRZ. AIR VELOCITY * (circle)	A B C	A B C	A B C	A B C	A B C	A B C

PRECIP (circle): ZF , ZD , ZR-, MOD

AMBIENT TEMPERATURE: _____ °C

COMMENTS: _____

NOTE:
* A: HORIZONTAL AIR VELOCITY ≤ 0.4 m/s
B: 0.4 m/s < HORIZONTAL AIR VELOCITY ≤ 1.0 m/s
C: HORIZONTAL AIR VELOCITY > 1.0 m/s

LEADER / MANAGER: _____

FIGURE 8: WINGLET END CONDITION DATA FORM

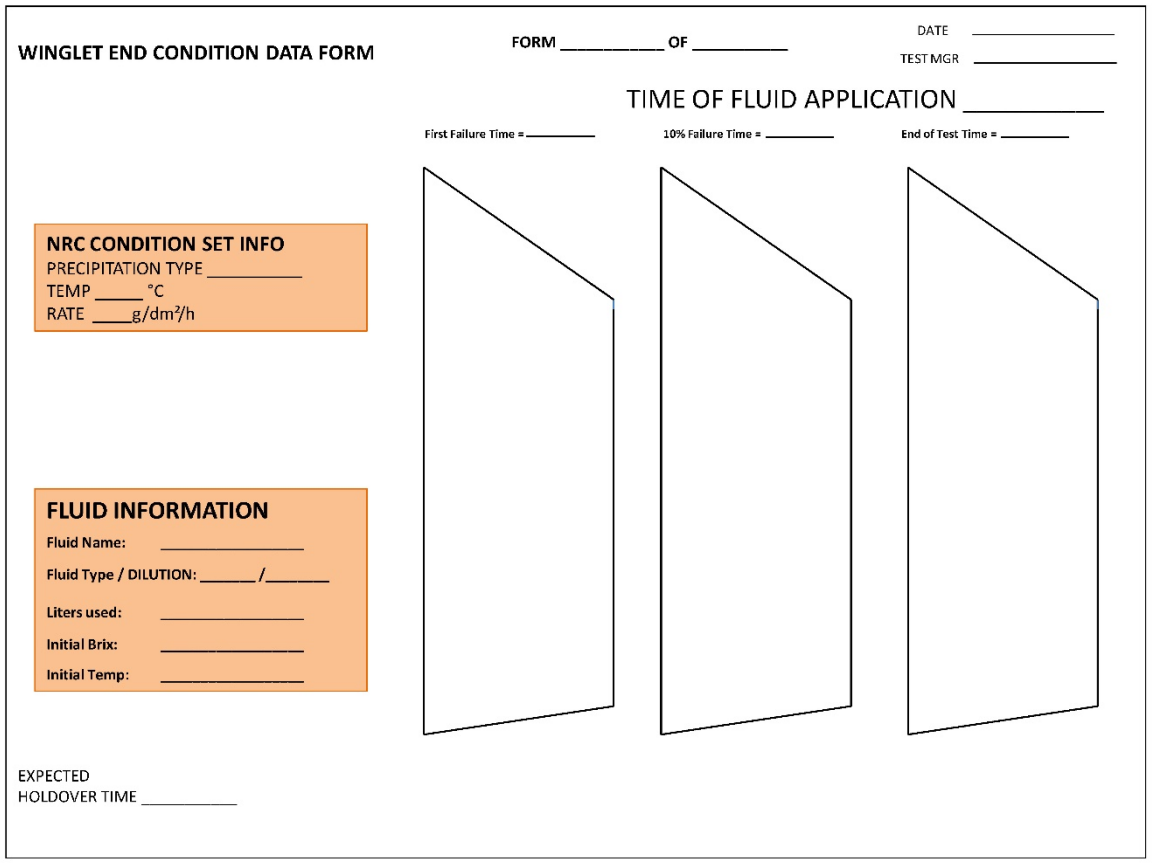
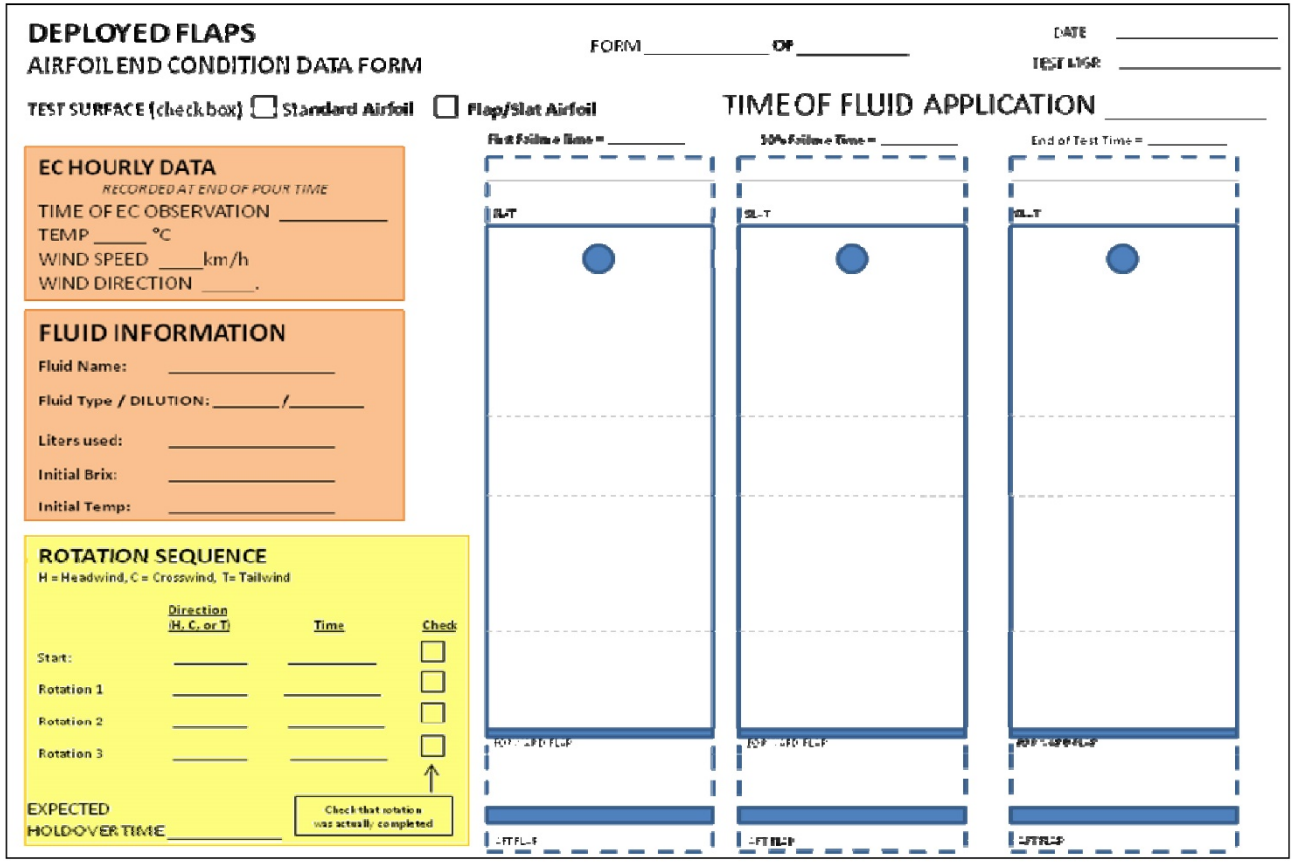


FIGURE 9: AIRFOIL END CONDITION DATA FORM



OVERALL PROGRAM OF TESTS AT NRC, MARCH/APRIL 2015

FIGURE 10: FLUID BRIX/THICKNESS DATA FORM

FLUID BRIX/THICKNESS DATA FORM

DATE: _____ PERFORMED BY: _____

RUN #: _____ WRITTEN BY: _____

STAND: _____ LOCATION: _____

Plate/BOX: Fluid:			Plate/BOX: Fluid:			Plate/BOX: Fluid:			Plate/BOX: Fluid:		
TIME	Brix at 15 cm Line	Thick. at 15 cm Line	TIME	Brix at 15 cm Line	Thick. at 15 cm Line	TIME	Brix at 15 cm Line	Thick. at 15 cm Line	TIME	Brix at 15 cm Line	Thick. at 15 cm Line

FIGURE 11: VISUAL INSPECTION DATA FORM

VISUAL INSPECTION OF CONTAMINATION
COLOURED VS UNCOLOURED

Date: _____

Condition: _____

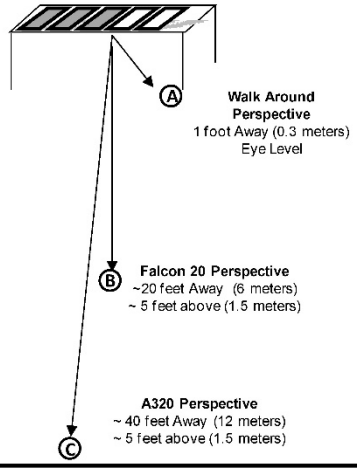
Observer: _____

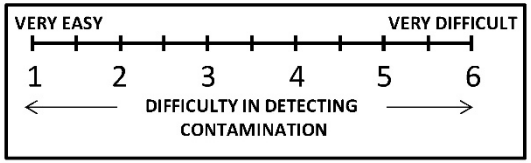


HALF PLATES

ALUM. COLOURED	ALUM. UNCOLOURED	ALUM. COLOURED (DYE)	WHITE PAINTED UNCOLOURED	WHITE PAINTED COLOURED (DYE)

VANTAGE POINTS





RATING #1 INDICATE RATING HALFWAY THROUGH EXPECTED HOT

TIME: _____

POSITION	ALUMINUM COLOURED	ALUMINUM UNCOLOURED	ALUMINUM COLOURED (DYE)	WHITE PAINTED UNCOLOURED	WHITE PAINTED COLOURED (DYE)
A					
B					
C					

RATING #2 INDICATE RATING AT FAILURE

TIME: _____

POSITION	ALUMINUM COLOURED	ALUMINUM UNCOLOURED	ALUMINUM COLOURED (DYE)	WHITE PAINTED UNCOLOURED	WHITE PAINTED COLOURED (DYE)
A					
B					
C					

COMMENTS:

_____

_____

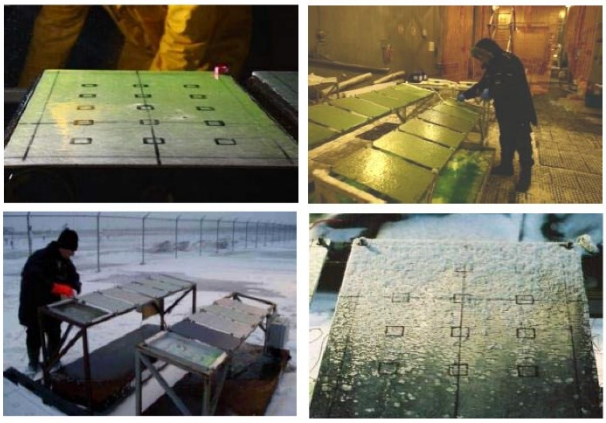
_____

APPENDIX C

FLUID MANUFACTURER REPORT: OKSAYD DEFROST ECO 1 (TYPE I)

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Oksayd DEFROST ECO 1 (Type I)



Prepared for

Oksayd Co. Ltd.

by

APS Aviation Inc.

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 1.0
Report No. O-DE1-10 2014-15

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Oksayd DEFROST ECO 1 (Type I)

Prepared for

Oksayd Co. Ltd.

Prepared by:

Stephanie Bendickson
Project Analyst

June 12, 2015
Date

And by:

Chloë Bernier
Research Assistant

June 12, 2015
Date

Reviewed by:

John D'Avirro, Eng.
Program Manager

June 12, 2015
Date

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 1.0
Report No. O-DE1-10 2014-15

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer:	Oksayd Co. Ltd.
Fluid Test Name:	DEFROST ECO 1 (Batch 10)
Fluid Commercial Name:	DEFROST ECO 1
Fluid Type / Colour:	Type I / Orange
Fluid Formulation:	Non-glycol
Batch #:	10
Date of Receipt:	February 27, 2015
Brix (Measured):	Concentrate: 44.75°
WSET (from AMIL):	3.4 minutes

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SUMMARY

The primary objective of this project was to measure the endurance time performance of Oksayd DEFROST ECO 1 over the entire range of conditions encompassed by the Type I Holdover Time (HOT) tables. This report contains the results of these measurements and was completed with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada and the Federal Aviation Administration (FAA).

The fluid manufacturer provided a batch of this fluid (Batch 1) early in the winter but subsequently asked APS to stop testing with that formulation. Data that was collected with Batch 1 is documented in a separate report. The data described in this report is for tests conducted with the replacement batch (Batch 10).

Tests were carried out according to the protocol provided in Aerospace Recommended Practice (ARP) 5945. The test procedure consisted of pouring fluids onto clean aluminum and composite test surfaces inclined at 10°; the onset of failure was recorded as a function of time in simulated freezing fog, freezing drizzle, light freezing rain, rain on cold soaked wing and snow. Tests were performed at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa, Ontario and at the APS Aviation Inc. (APS) test facility located at the Pierre-Elliott-Trudeau International Airport in Montreal, Quebec.

The endurance times measured with this fluid were similar to those of Type I fluids tested in past years. As a result, it was concluded that Oksayd DEFROST ECO 1 can be used with the Type I generic HOT guidelines.

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GLOSSARY

APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LWC	Liquid Water Content
MVD	Median Volume Diameter
MANOBS	Manual of Surface Weather Observations
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

Aircraft ground de/anti-icing has been the subject of concentrated industry attention in recent years due to the occurrence of several fatal icing-related aircraft accidents. Notably, attention has been placed on the enhancement of anti-icing fluids in order to provide an extended period of protection against further contamination following initial deicing. This emphasis has led to the development of de/anti-icing fluid holdover time (HOT) tables. These tables, accepted by regulatory authorities, are used by aircraft operators for departure planning in adverse winter conditions. Specifically, they provide the duration of time that qualified fluids provide protection against ice formation under specific weather conditions.

Testing has shown that Type II and Type IV fluid endurance time performance varies considerably by fluid. As a result, endurance time testing is carried out with all Type II and Type IV fluids and fluid-specific HOT tables are developed for each Type II/IV fluid based on the results of the testing.

In contrast, a significant body of previous research and testing has indicated the endurance time performance of all Type I fluids formulated with glycol is similar. As a result, all Type I fluids are used with the Type I generic holdover times (no fluid-specific holdover times are provided) and regulators no longer require endurance time testing be conducted with Type I fluids formulated with propylene glycol, ethylene glycol or diethylene glycol. However, they do require the endurance time performance of fluids formulated with other glycol bases or with non-glycol bases be measured. This is to ensure the endurance time performance of these fluids is similar to the performance of the Type I fluids that were used to generate the current Type I generic holdover times.

This report provides a detailed account of the endurance time testing APS Aviation Inc. (APS) carried out with **Oksayd DEFROST ECO 1**, a new Type I fluid formulated with a non-glycol base. It describes the test methodology used, endurance time data collected, and conclusions derived from the results.

This report has been created with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada and the Federal Aviation Administration (FAA).

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2

2. METHODOLOGY

SAE Aerospace Recommended Practice (ARP) 5945 provides the procedure and requirements for endurance time testing with Type I fluids under natural and simulated conditions. This chapter summarizes some of aspects of the test methodology included in ARP5945, and some aspects which are not included in ARP5945. The chapter includes sections for test sites, equipment, procedures, precipitation rates and ambient temperatures used in Type I endurance time testing, and freezing precipitation droplet sizes. The final subsection describes the analysis methodology used to evaluate Type I endurance time data.

2.1 Test Sites

Natural and artificial snow and natural frost testing is performed at the APS test site located at the Montréal-Pierre-Elliott-Trudeau International Airport. The test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station, as shown in Figure 2.1 on a plan view of the airport. The APS test site consists of two trailers and three outdoor locations for test stands. One of the trailers is equipped with a refrigeration unit to enable indoor testing at controlled temperatures. Photos 2.1 and 2.2 show the test site as seen from the test pads and main trailer, respectively.

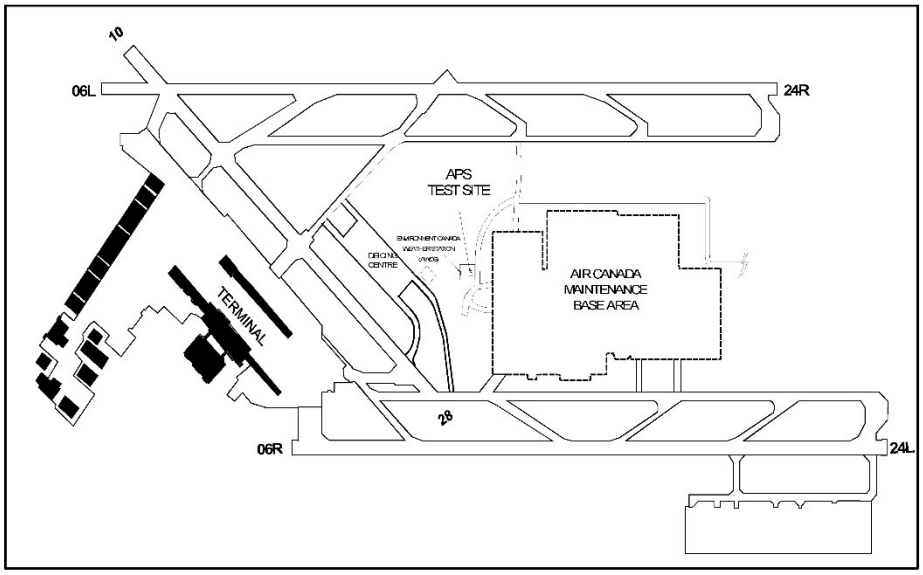

Figure 2.1: APS Test Site at Montréal-Pierre-Elliott-Trudeau International Airport

Tests under conditions of simulated freezing fog, freezing drizzle, light freezing rain and rain on cold soaked wing are conducted indoors at the National Research Council (NRC) Climatic Engineering Facility (CEF), where precipitation is artificially produced. Photo 2.3 provides an outdoor view of the facility giving a general indication of its size (30 m by 5.4 m, height 8 m). The facility was originally designed for the testing of locomotives; Photo 2.4 provides an interior view of the CEF set up for endurance time testing.

2.2 Test Equipment

The key equipment used in endurance time testing is described in this section, as are the calibration procedures APS follows for ensuring the accuracy of its test equipment.

2.2.1 Calibration

APS measurement instruments and test equipment are calibrated and/or verified on an annual basis. This calibration is carried out according to a calibration plan based upon approved International Organization for Standardization (ISO) 9001:2000 standards, and developed internally by APS.

2.2.2 Environmental Chamber Equipment

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) was as stipulated in the requirements set out in ARP5945.

2.2.3 Test Surface Structures

The majority of endurance time testing is carried out on standard flat plates. A schematic of a standard flat plate is provided in Figure 2.2. It depicts the size and surface markings of a standard flat plate. Three parallel lines are positioned at 2.5 cm (1″), 15 cm (6″) and 30 cm (12″) from the top of the plate. The plates are marked with 15 crosshairs, which are used in determining when end conditions (see Subsection 2.3.3) are achieved. Photo 2.5, taken outdoors at the APS test site, shows six test plates mounted on a test stand.

Figure 2.3 shows a schematic of the sealed boxes used for tests simulating a cold soaked wing and in natural snow testing with Type I fluids. The top of the box consists of a flat plate identical to the standard flat plate. A box shaped

reservoir is welded to the bottom of the plate. Photo 2.6 shows a picture of a sealed box, which is referred to as a cold-soak box when filled for simulated rain on cold soaked wing tests and a leading edge thermal equivalent box when used empty for testing Type I fluids in natural snow conditions.

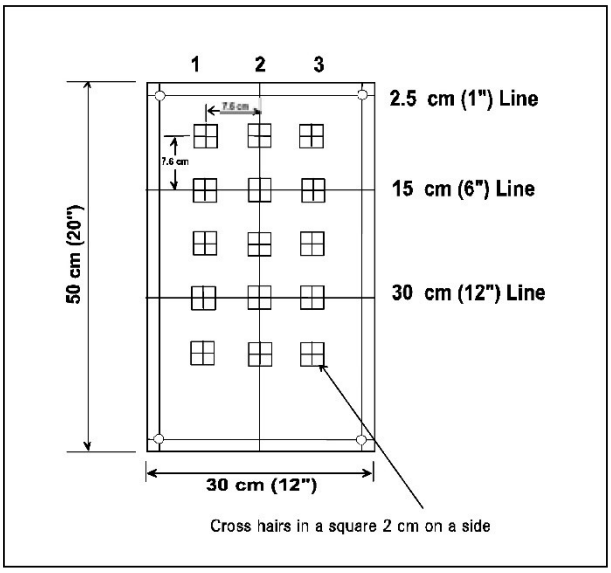

Figure 2.2: Standard Test Plate Schematic

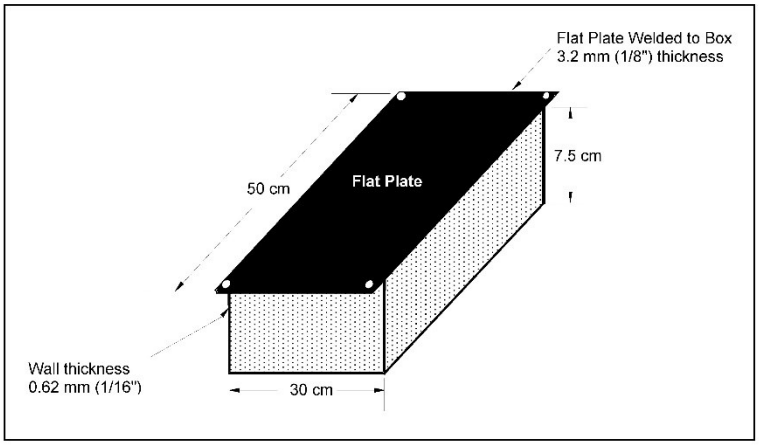

Figure 2.3: Cold Soak Box Schematic

In natural frost, tests are conducted on frosticator plates. The frosticator plates are constructed by attaching a Styrofoam insulation backing to the back of the test surface (either aluminum or composite). The insulation prevents heat exchange via the underside of the flat plate and allows for effective radiative cooling during active frost conditions. Photo 2.7 shows a white-painted aluminum frosticator plate.

2.2.4 Test Surface Materials

Research has shown endurance times of Type I fluids can be shorter on composite surfaces than on aluminum surfaces. For many years all test surfaces used in endurance time testing were constructed of aluminum. However, since Transport Canada and the FAA implemented new holdover times for composite surfaces in the winter of 2010-11, all Type I fluids evaluated for endurance time performance are tested on both aluminum and composite surfaces. The details of the test surface materials are as follows:

- Aluminum: Alclad 2024 T3 aluminum, 0.32 cm thick; and
- Composite: Carbon fibre cross weave fabric, 0.32 cm thick.

Previous research has shown this composite material produces endurance time results representative of many composite aircraft materials.

2.2.5 Test Stands

Figure 2.4 shows a schematic of the test platform used for HOT testing. For natural snow tests, six test plates are normally mounted on the test stand, which has a working surface inclined at 10° to the horizontal. During normal winter operations two six-position stands are used in combination. Each plate represents a flat plate test. For simulated freezing precipitation tests at the NRC, 12 plates are mounted on 2 six-position stands. Photos 2.4 and 2.5 show the test stands set up for indoor and outdoor testing, respectively.

2.2.6 Collection Pans

Figure 2.5 shows a schematic of the collection pan used for precipitation rate measurement in outdoor testing. It is the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.8 shows the collection pans used for measuring precipitation rates indoors at the NRC.

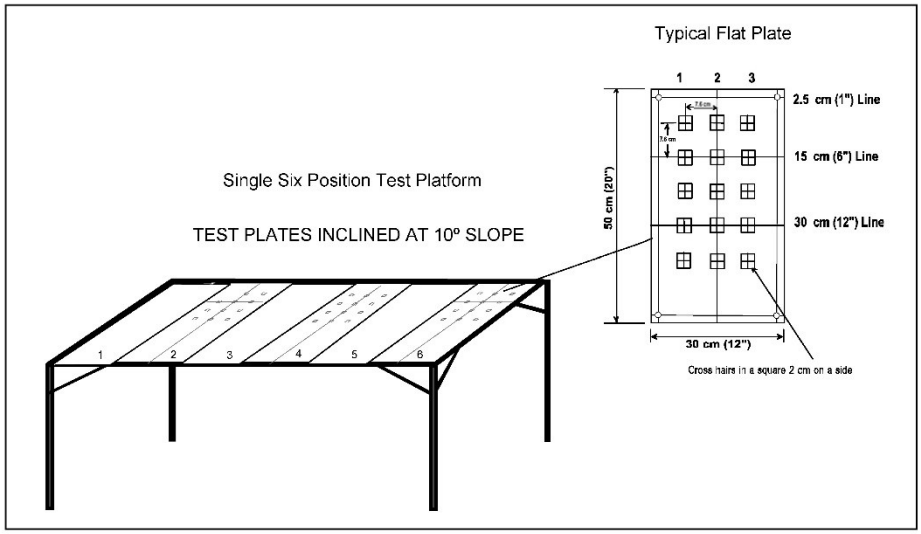

Figure 2.4: Test Stand Setup Schematic

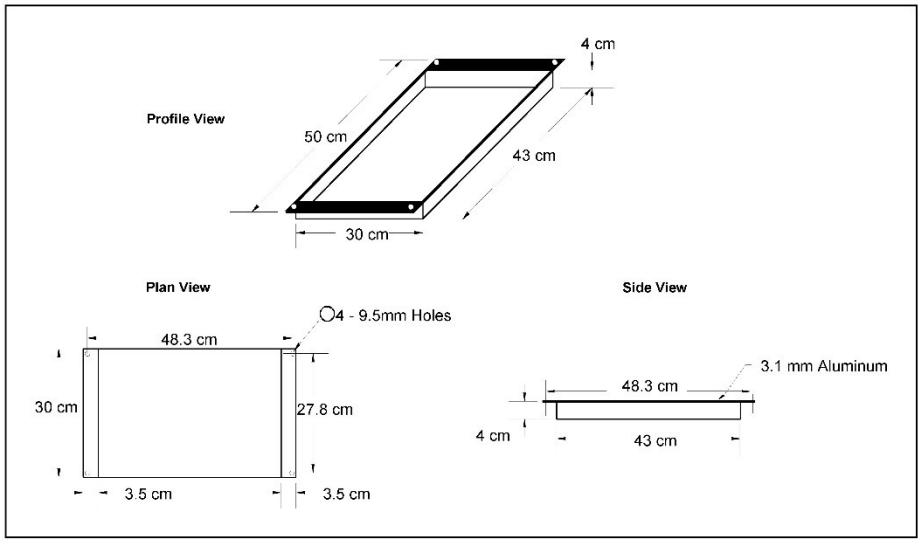

Figure 2.5: Schematic of Outdoor Precipitation Measurement Pan

2.2.7 NRC Sprayer Assembly

NRC developed an improved sprayer assembly, shown in Photos 2.9 and 2.10, in 1997-98. The improved sprayer provides a larger scan area and improved spray uniformity over the test bed area. The scanner consists of a horizontal main shaft supported by two bearings. The actual spray head assembly is shaft-mounted on a rotating scanner, so that one scan covers a lateral running strip of the test bed area. A stepper motor is synchronized to index the relative angle of the spray head between scans along an axis perpendicular to the scan axis. This provides two axes of rotation, essentially an x-y plane; one along each axis. Each scan is consecutively indexed in order to complete the precipitation coverage of the test bed area. This defines one cycle of the spray unit. The scan rate, index angle, and the number of scans per cycle are adjusted, along with the fluid delivery pressures (water and air) to obtain appropriate droplet sizes and precipitation rates. The spray nozzle is shown in Photo 2.11.

2.2.8 Refractometer

Freeze points were measured using a hand-held Misco refractometer with a Brix scale (see Photo 2.12)

2.2.9 Fluids

Testing was carried out using fluid diluted to a freeze point 10°C below the ambient temperature. Information provided by the manufacturer was used to develop the dilution table shown in Table 2.1, which was used to mix the fluid to the appropriate freeze point for each test.

Table 2.1: Oksayd DEFROST ECO 1 Dilution Table

Test Temp. (°C)	FFP (°C)	Fluid %	Brix (°)	Fluid for 4 L	Water for 4 L
+1	-9	29.2	16.00	1.2	2.8
-3	-13	37.2	19.25	1.5	2.5
-6	-16	42.0	21.50	1.7	2.3
-10	-20	47.4	24.00	1.9	2.1
-25	-35	60.3	29.50	2.4	1.6

2.2.10 12-Hole Spreader

A 12-hole spreader is used to apply fluids during natural snow and natural frost tests (see Photo 2.13).

2.3 Test Procedures

ARP5945 provides the procedure for endurance time testing of Type I fluids under natural and simulated precipitation conditions. The procedure generally consists of pouring de/anti-icing fluids onto clean flat plates exposed to various winter precipitation conditions, and recording the elapsed time for the test to reach the defined end condition (see Subsection 2.3.3), when a specified degree of freezing occurs.

The following subsections provide summaries of the test procedures followed for testing in natural snow, artificial snow and simulated freezing precipitation.

2.3.1 Test Protocol – Natural Snow Tests

APS developed a specific procedure for Type I testing in natural snow based on the requirements outlined in ARP5945. Key details of the procedure include:

- Tests are conducted on empty leading edge thermal equivalent boxes (see Subsection 2.2.3);
- Fluid is applied at a temperature of 60°C;
- 0.5 L of fluid is applied to the test surface with a 12-hole spreader; and
- For each test with a new Type I fluid, a test with a Type I reference fluid is conducted simultaneously. The reference fluid is a Type I fluid that was used in the determination of the current Type I generic holdover times.

2.3.2 Test Protocol – Simulated Precipitation Tests

APS developed a specific procedure for Type I testing in natural snow based on the requirements outlined in ARP5945. Key details of the procedure include:

- Freezing fog, freezing drizzle and light freezing rain tests are conducted on standard flat plates (see Section 2.2.3);
- Rain on cold-soaked surface tests are conducted on filled cold-soak boxes (see Section 2.2.3);

- Fluid is applied at a temperature of 20°C; and
- 1 L of fluid is hand-poured on the test surface.

2.3.3 Test Protocol – Artificial Snow Tests

APS developed a specific procedure for Type I testing in artificial snow based on the requirements outlined in ARP5485 (ARP5945 does not currently include a procedure for artificial snow testing). Key details of the procedure include:

- Tests are conducted on a standard test plate with insulated tray (see Photo 2.14);
- Fluid is applied at a temperature of 60°C;
- 0.5 L of fluid is applied to the test surface with a 12-hole spreader; and
- For each test with a new Type I fluid, a test with a Type I reference fluid is also conducted. The reference fluid is a Type I fluid that was used in the determination of the current Type I generic holdover times.

2.3.4 Test Protocol – Natural Frost Tests

APS developed a specific procedure for Type I testing in natural frost. Key details of the procedure include:

- Tests are conducted on frosticator plates (see Section 2.2.3);
- Fluid is applied at 20°C; and
- 0.5 L of fluid is applied to the test surface with a 12-hole spreader.

2.3.5 End Condition Definitions

Failure is called when 30 percent (1/3) of the plate or 5 cross-hairs are covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

a) Ice front;
b) Ice sheet;
c) Slush, in clusters or as a front;
d) Disseminated fine ice crystals;
e) Frost on surface;
f) Clear ice pieces partially or totally imbedded in fluid; and
g) Snow bridges on top of the fluid.

2.3.6 Precipitation Rate Measurement Procedures

The procedures for measuring and determining precipitation rates during simulated precipitation and natural precipitation conditions are provided below.

2.3.6.1 Simulated precipitation conditions

Prior to the start of the rate collection period, the proper needles and nozzles are installed in the spray unit, and both the air and water pressures are adjusted. Water spray calibration is performed by placing catch pans on the test stand, each pan marked with a number identifying the collection location on the test stand, and exposing the pans to a predetermined precipitation collection period.

The pans are weighed prior to exposure to precipitation and the weights are recorded in a customized Excel spreadsheet by using the print function on the digital weigh scale. Prior to the start of the precipitation catch period, the exact time (hh:mm:ss) is recorded using a pre-programmed time macro in the Excel spreadsheet. The pans are re-weighed following this collection period and the precipitation rates over the area of the test stand are examined. If the rates are unacceptable, re-calibration of the water spray is necessary. If the rates are deemed to be acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period has expired, the pans are again re-weighed and the rates computed.

Once two rates have been collected at each test location, the catch rates of the first and second collection are compared. If the average catch rate for any location is deemed to be acceptable for the test condition, the pouring of fluids may begin at this location.

Rates are continuously monitored at a minimum of two locations during a test in order to ensure there are no significant rate fluctuations. Pans will be placed at these locations and be re-weighed at fixed intervals (15 minutes, typically) during the course of a test. If a rate fluctuation occurs, the test is stopped.

Following the failure of a test plate, a rate collection pan is weighed and placed at the plate location for a predetermined time interval. It is then re-weighed and placed again on the stand to collect a minimum of two additional rates at this location.

The rate of precipitation for any location on the stand is calculated by averaging the two rates collected prior to the test and the two rates collected following the test.

2.3.6.2 Natural precipitation conditions

Two rate collection pans per test stand are used to determine precipitation rates in natural conditions. Prior to the rate collection period, both pans are marked (upper and lower), and the inner bottom and sides of the each pan are wetted with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The wetted pans are then weighed to the nearest gram. The start time of the rate collection period is recorded (h/min/sec) using a customized Excel spreadsheet in which the weight is also recorded by pressing the print function on the digital weigh scale.

The pans are positioned in locations 6 and 7 (see Figure 2.4) and are allowed to collect precipitation for 10-minute intervals in normal conditions and 5-minute intervals in periods of high precipitation rates and high winds. Prior to removal of the plate pans from the test stand for re-weighing, any accumulated precipitation on the lips and outer sides of each plate pan is carefully removed. The plate pans are then carried to the rate station for re-weighing. Upon entering the trailer, the exact time is noted. The new weights of the plate pans are recorded and the pans are brought back outside. This procedure is continued until the final plate on the test stand has failed.

The rate for any HOT test in natural snow is obtained by computing the time-weighted average of the rates collected in the upper and lower pans over the duration of this particular test. To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.6. Typically, two collections pans are used for each test. The start and end times of the test shown in Figure 206 are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t1, t2, and t3 (minutes). The calculated rates for each collection period are indicated by R1, R2, and R3 (g/dm²/h). In order to calculate the average rate for this pan, the following formula is then used:

$$\frac{(R_1 \times t_1 + R_2 \times t_2 + R_3 \times t_3)}{t_1 + t_2 + t_3}$$

In the example shown in Figure 2.6, the rate is calculated as follows:

$$\frac{(25 \times 10 + 22 \times 8 + 34 \times 5)}{10 + 8 + 5}$$

The calculated average rate for this pan is 25.9 g/dm²/h. The average rate for the other collection pan is calculated in similar fashion, and the average of the two rates is then taken.

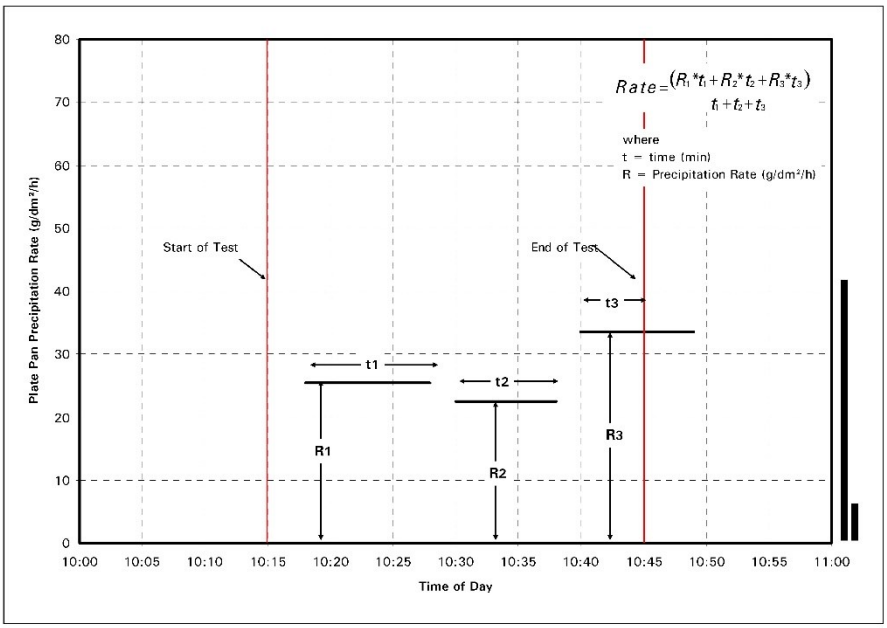

Figure 2.6: Calculation of Outdoor Precipitation Rate

2.4 Precipitation Rate Limits in Type I Endurance Time Testing

Upper and lower precipitation rate limits are an important part of the test methodology for measuring fluid endurance times. Table 2.2 provides the meteorologically accepted definitions of weather phenomenon / precipitation types. It also includes the criteria used to determine precipitation intensity. This table was compiled by the National Centre for Atmospheric Research (NCAR) from the *World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation* (1983) and from the *American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS) (3/94).*

The precipitation rate limits established for Type I endurance time testing are provided in ARP5945 and represented graphically in Figure 2.7. Subsections 2.4.1 to 2.4.5 provide detailed definitions and explanations of the precipitation types and rate boundaries used in Type I endurance time testing. It should be noted that in many cases these limits are not the same as the meteorologically accepted definitions provided in Table 2.2.

Table 2.2: Definition of Weather Phenomenon

Weather Phenomenon*	Definition*
FROST (No METAR code) Note: No Intensity is assigned to FROST	Ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.
FREEZING FOG (FZFG) Note: No Intensity is assigned to FRZ FOG	A suspension of numerous minute water droplets which freezes upon impact with ground or other exposed objects, generally reducing the horizontal
SNOW (SN)	Precipitation of ice crystals, most of which are branched, star-shaped, or mixed with unbranched crystals. At temperatures higher than about -5°C
FRZING DRIZZLE (FZDZ)	Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0.02 in.)] very close together which freezes upon impact with
FREEZING RAIN (FZRA)	Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5
RAIN (RA)	Precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 in.) diameter or of smaller widely scattered drops.
SNOW PELLETS (GS) and/or SMALL HAIL	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is
HAIL (GR)	Precipitation of small balls or pieces of ice with a diame-
ICE PELLETS (PE)	Precipitation of transparent (sleet or grains of ice), or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 in.)

Intensity Criteria**

Estimated Intensity	Snow(SN),Pellets(GS),Grains(SG): Horizontal Visibility (statute mile)	Snow(SN),Pellets(GS),Grains(SG): Liquid Equivalent Snow (SN) Intensity***	Ice Pellets (PE): Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm/hr or 10 gr/dm²/hr)	Scattered pellets on the ground. Visibility not affected.
Moderate	If visibility is: < 5/8 to 5/16 mi (< 1.0 to 0.5 km)	> 0.05 to 0.10 in/hr (> 1.0 to 2.5 mm/hr) (> 10.0 to 25.0 gr/dm²/hr)	Slow accumulation on the ground. Visibility reduced to less than 7 mi.
Heavy (+)	If visibility is: < 5/16 mi (< 0.5 km)	More than 0.10 in/hr (> 2.5 mm/hr or 25 gr/dm²/hr)	Rapid accumulation on the ground. Visibility reduced to less than 3 mi.

Note: Horizontal visibility is only an estimation of snow and freezing drizzle intensity. Measurements and observations have

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm/hr or 2.54 gr/dm²/hr)
Moderate	From 0.01 to 0.02 in/hr (2.54 to 5.08 gr/dm²/hr)
Heavy(+)	More than 0.02 in/hr (> 5.08 gr/dm²/hr) Note: Drizzle > 0.04 in/hr is usually in the form of rain.

	Rain (RA), Freezing Rain (FZRA), Ice Pellets (PE)
Measured Intensity: Light (-)	Up to 0.10 in/hr (2.5 mm/hr or 25 gr/dm²/hr) Maximum 0.01 inch in 6 minutes
Estimated Intensity: Light (-)	From scattered drops that, regardless of duration, do not completely wet an
Measured Intensity: Moderate	0.11 in to 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.01 to 0.03 inch in 6 minutes
Estimated Intensity: Moderate	Individual drops are not clearly identifiable; spray is observable just above
Measured Intensity: Heavy (+)	More than 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.03 inch in 6 minutes
Estimated Intensity: Heavy (+)	Rain seemingly falls in sheets; individual drops are not identifiable; heavy

* From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
** From American Meteorological Society, Glossary of Meteorology WSCH #7 MA3GB5 (3/94)
*** NCAR/ISAE Proposed Definition for Liquid Equivalent Snowfall Intensity

1) gr/dm² = 0.01 cm = 0.1 mm = 0.0039 in
2) in = 2.54 cm = 25.4 mm = 254 gr/dm²

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP Sept 8, 1999 (Updated for METAR codes)

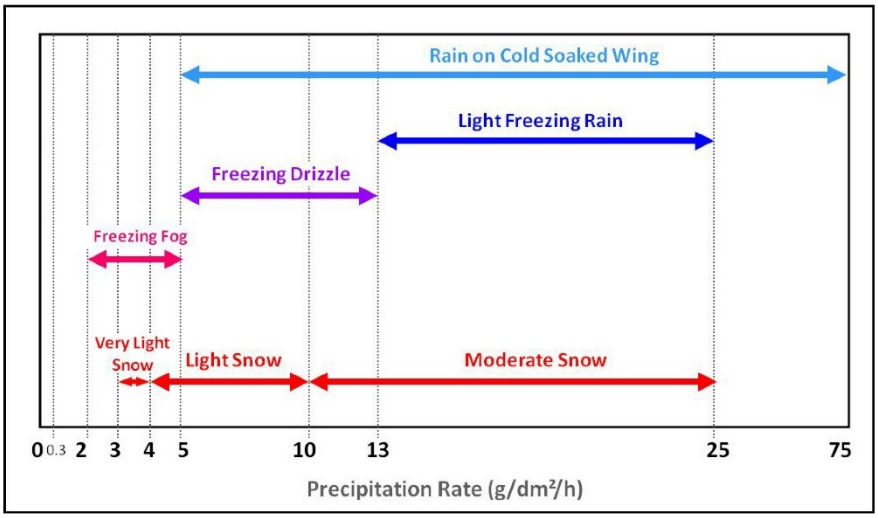

Figure 2.7: Precipitation Rate Limits Used in Endurance Time Testing

2.4.1 Freezing Fog

The precipitation rate limits for endurance time testing in freezing fog were set in 1997 at rates of 2 and 5 g/dm^2/h. These limits were determined with input from NRC meteorologists, who helped define an important parameter in the study of fog referred to as the *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic meter of air, can generally assume values in the range of 0.2 to 0.6 g/m^3.

2.4.2 Freezing Drizzle

The precipitation rate limits for endurance time testing in freezing drizzle are 5 and 13 g/dm^2/h. The upper limit in this range was adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Committee. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety.

2.4.3 Light Freezing Rain

The precipitation rate limits for endurance time testing in light freezing rain are 13 and 25 g/dm^2/h. This range corresponds to the category of light freezing rain and is the only freezing rain category considered, as operations in periods of moderate or heavy freezing rain are deemed unsafe.

2.4.4 Rain on a Cold-Soaked Surface

The precipitation rate limits for rain on cold soaked surface are 5 and 75 g/dm^2/h. This range encompasses drizzle (5 to 13 g/dm^2/h), light rain (13 to 25 g/dm^2/h), and moderate rain (25 to 75 g/dm^2/h).

2.4.5 Snow

The precipitation rate limits used to determine snow holdover times are:

a) Very light snow: 3 and 4 g/dm²/h;

b) Light snow: 4 and 10 g/dm²/h; and

c) Moderate snow: 10 and 25 g/dm²/h.

2.5 Ambient Temperatures in Type I Endurance Time Testing

The Type I generic holdover time tables provide holdover times for four temperature ranges:

- -3°C and above
- Below -3 to -6°C
- Below -6 to -10°C
- Below -10°C

In natural snow testing, endurance time testing is carried out under a range of temperatures. In simulated freezing precipitation and artificial snow testing, endurance time testing is typically conducted at the lower limit of each temperature band.

- Freezing Fog: -3°C, -6°C, -10°C and -25°C
- Freezing Drizzle: -3°C, -6°C and -10°C
- Light Freezing Rain: -6°C and -10°C (see note below)
- Rain on Cold Soaked Surface: +1°C

Note: Testing is not carried out with Type I fluids in light freezing rain at -3°C as the latent heat of freezing in calm test conditions produces artificially long endurance times.

2.6 Freezing Precipitation Droplet Sizes

Research has shown that median volume diameter (MVD) of rain droplets is related to rate of precipitation as follows:

$$MVD = (\text{precipitation rate}/10)^{0.23},$$ where MVD is in mm and rate of precipitation is in g/dm²/h

The theoretical MVDs for rain at various rates of precipitation were determined based on this equation. These values are listed in Table 2.2 beside the experimental MVDs for each precipitation condition.

To determine whether droplets produced at the NRC resembled droplets from natural precipitation, a test was conducted during natural light freezing rain conditions in 1997-98 at the APS test site. The droplet sizes were compared to those obtained in simulated light freezing rain at the NRC. The results of these tests are shown below:

a) *For the outdoor test:*

Location:	Montreal P.E.T. Airport
Precipitation:	Natural Light Freezing Rain
Precipitation Rate:	20 g/dm²/h
Calibrated MVD:	1.0 mm

b) *For the indoor test:*

Location:	National Research Council
Precipitation:	Simulated Light Freezing Rain
Precipitation Rate:	25 g/dm²/h
Calibrated MVD:	1.0 mm

The MVD for both natural and simulated light freezing rain was 1 mm, indicating that the NRC produced droplets simulate natural precipitation. As a result of this testing, the MVDs for freezing precipitation testing were established as follows:

- Freezing Fog, high precipitation rate (5 g/dm²/h): 30 μm
- Freezing Fog, low precipitation rate (2 g/dm²/h): 30 μm
- Freezing Drizzle, high precipitation rate (13 g/dm²/h): 350 μm
- Freezing Drizzle, low precipitation rate (5 g/dm²/h): 250 μm
- Light Freezing Rain, high precipitation rate (25 g/dm²/h): 1,000 μm
- Light Freezing Rain, low precipitation rate (13 g/dm²/h): 1,000 μm
- Rain on Cold-Soaked Surface, low precipitation rate (5 g/dm²/h): 250 μm
- Rain on Cold-Soaked Surface, high precipitation rate (75 g/dm²/h): 1,400 μm

Table 2.3: Theoretical and Experimental MVDs

Precipitation Condition	Experimental MVD (mm)	Theoretical MVD (mm)
Moderate Rain (High rate: 75 g/dm²/h)	1.4	1.6
Light Rain (Low rate: 13 g/dm²/h)	1.0	< 1.1
Light Rain (High rate: 25 g/dm²/h)	1.0	1.2
Drizzle (Low rate: 5 g/dm²/h)	0.25	< 0.5
Drizzle (High rate: 13 g/dm²/h)	0.35	< 0.5
Fog		< 0.1

2.7 Summary of Freezing Precipitation Test Conditions

The precipitation types/rates, ambient temperatures and droplet sizes for freezing precipitation testing with Type I fluids were described in the previous subsections. In summary, freezing precipitation tests are carried out under each of the 20 weather conditions listed in Table 2.4.

2.8 Analysis Methodology

The endurance time performance of Type I fluids is evaluated by comparing the data collected to the performance of historical Type I fluids (i.e. the Type I fluids the generic Type I holdover times are based on). In order for the endurance time performance of a new Type I fluid to be considered acceptable, the endurance time results need to be similar or superior to the historical fluid data.

Table 2.4: Summary of Freezing Precipitation Test Conditions (Type I Fluids)

Precipitation Type	Ambient Temperature	Precipitation Rate (Droplet Size)
Freezing Fog	-3°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-6°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-10°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-25°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
Freezing Drizzle	-3°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
	-6°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
	-10°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
Light Freezing Rain	-6°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
	-10°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
Rain on Cold-Soaked Surface	+1°C	5 g/dm²/h (250 μm)
		75 g/dm²/h (1,400 μm)

Photo 2.1: APS Test Site - View from Test Pad



Photo 2.2: APS Test Site - View from Trailer



Photo 2.3: Outdoor View of NRC Climatic Engineering Facility



Photo 2.4: Inside View of NRC Climatic Engineering Facility

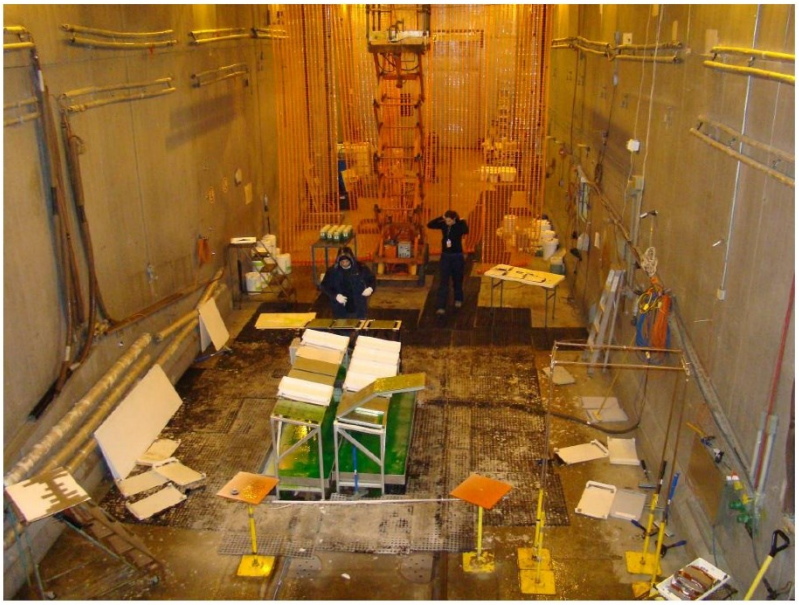

Photo 2.5: Test Plates Mounted on Stand

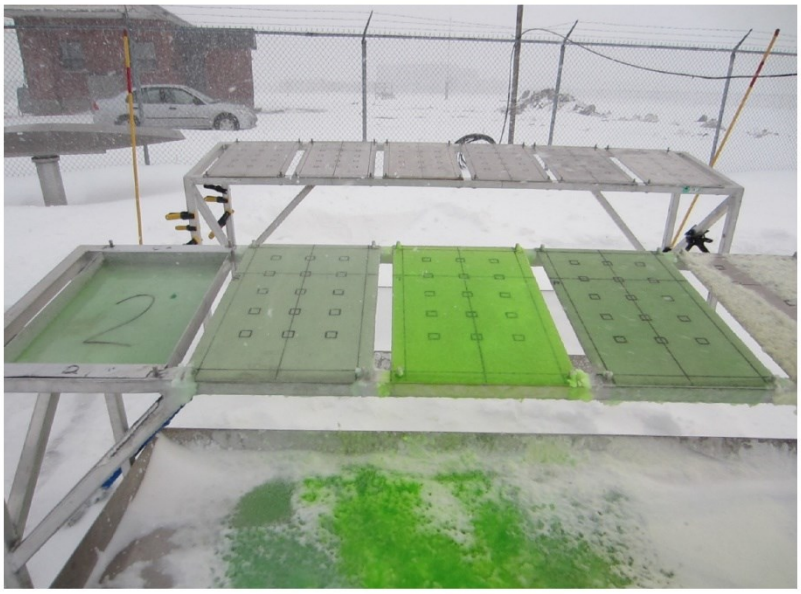

Photo 2.6: Cold-Soak / Leading Edge Thermal Equivalent Box

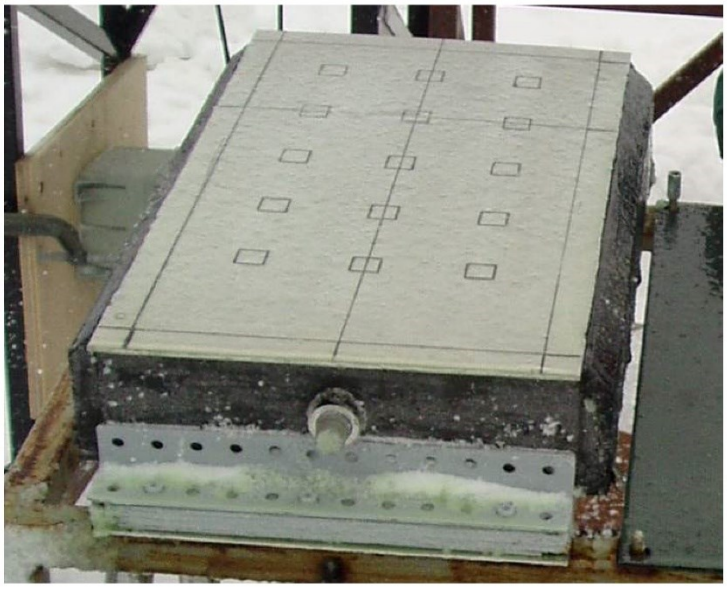

Photo 2.7: Frost Plate with Insulated Backing



Photo 2.8: Collection Pans Used Indoors at the NRC



Photo 2.9: Sprayer Assembly



Photo 2.10: Sprayer Assembly in Use

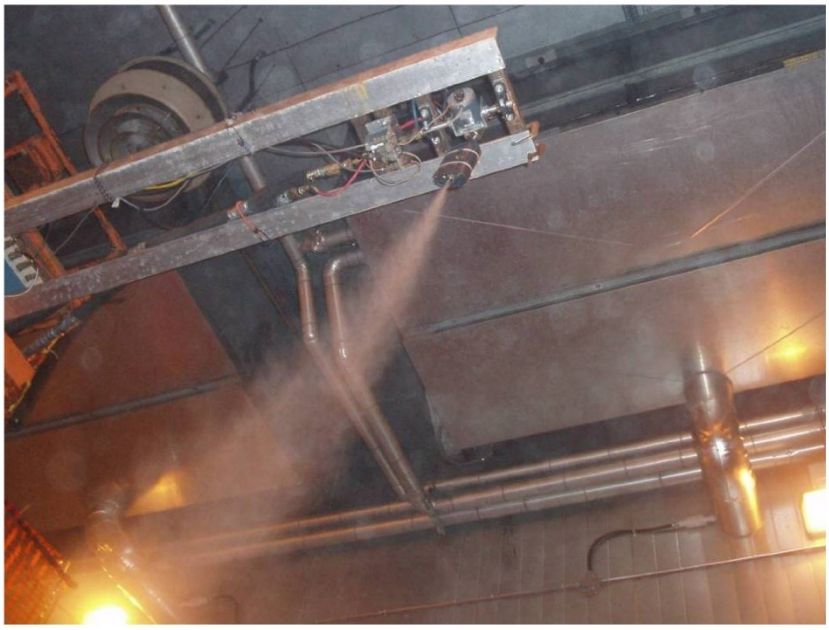

Photo 2.11: Sprayer Nozzle

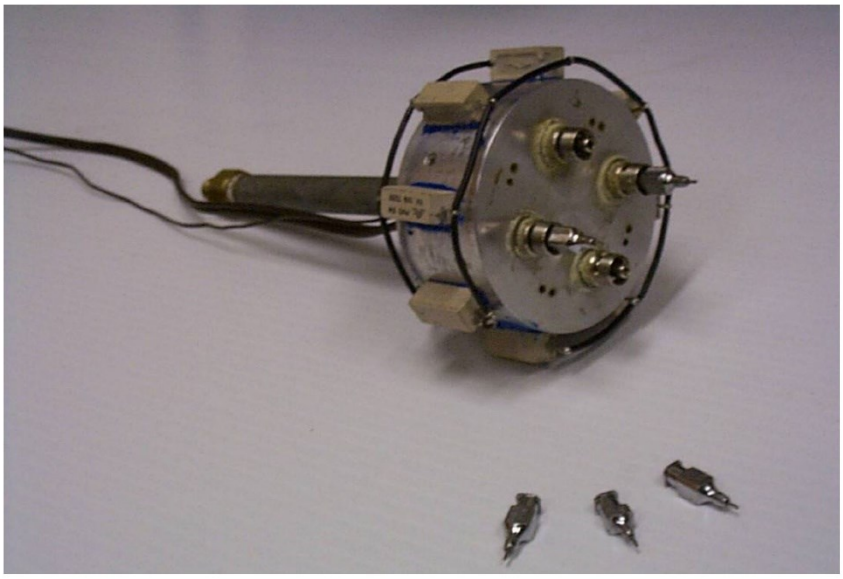

Photo 2.12: Hand Held Brixometer



Photo 2.13: Twelve Hole Spreader Used for Fluid Application



Photo 2.14: Standard Plate Setup for Type I Testing with Artificial Snowmaker



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted. Breakdowns are provided for the quantity of tests performed by precipitation type, test surface, and test temperature. A list of the tests conducted is provided in Section 3.9.

3.1 Natural Frost Tests

Four tests were conducted in natural frost at the APS test site. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

Test Surface	≥-1°C	<-1 to -3°C	<-3 to -10°C	<-10°C
Aluminum	0	2	0	0
Composite	0	2	0	0

3.2 Natural Snow Tests

Sixteen natural snow tests were conducted at the APS test site. The number of tests conducted is summarized below by temperature and test surface. For comparison purposes, simultaneous tests were conducted with a baseline Type I fluid.

Test Surface	≥ -3°C	-3 to -6°C	-6 to -10°C	< -10°C
Aluminum	5	3	0	0
Composite	5	3	0	0

3.3 Freezing Fog Tests

Twenty-four tests were conducted in freezing fog at the NRC CEF. The number of tests conducted is shown below by test surface and temperature.

Test Surface	-3°C	-6°C	-10°C	-25°C
Aluminum	4	0	4	4
Composite	4	0	4	4

3.4 Freezing Drizzle Tests

Sixteen tests were conducted in freezing drizzle at the NRC CEF. The number of tests conducted is shown below by test surface and temperature.

Test Surface	-3°C	-6°C	-10°C
Aluminum	4	0	4
Composite	4	0	4

3.5 Light Freezing Rain Tests

Eight tests were conducted in light freezing rain at the NRC CEF. The number of tests conducted is shown below by test surface and temperature. It should be noted that Type I fluids are not tested in light freezing rain at -3°C because the latent heat of freezing in calm test conditions produces artificially long endurance times.

Test Surface	-3°C	-6°C	-10°C
Aluminum	0	0	4
Composite	0	0	4

3.6 Rain on Cold-Soaked Surface Tests

Eight tests were conducted in rain on cold-soaked surface conditions at the NRC CEF. The number of tests conducted is shown below by test surface and temperature.

Test Surface	+ 1°C
Aluminum	4
Composite	4

3.7 Fluid Thickness Tests

Fluid thickness tests were conducted at the NRC CEF. The purpose of these tests was to measure the film thickness profile of Oksayd DEFROST ECO 1

under dry conditions. Two tests were performed at an ambient temperature of -3°C. The measurements are displayed below.

For each test, one litre of fluid was poured onto a flat plate mounted at 10° to the horizontal. Film thickness measurements were taken at the 15-cm (6") line at pre-selected time intervals over a 30-minute interval. The thickness after 30 minutes was <0.04 mm.

Measurement	Time after Application (mins)	Thickness (mm)	
		Run 1	Run 2
1	2	0.04	0.06
2	5	0.04	0.04
3	15	<0.04	<0.04
4	30	<0.04	<0.04

3.8 Summary of Tests Performed

Details of the tests performed are provided in Tables 3.1 (frost), Table 3.2 (snow), and Table 3.3 (freezing precipitation).

Table 3.1: Summary of Tests Performed (Frost)

Test No.	Date	Fluid Name	Fluid Dilution	Precipitation Type	Test Surface	Temp (°C)	Average Rate (g/dm²/h)	Wind Speed (km/h)	Average RH (%)	Endurance Time (min)	Final Brix (°)	Comments
65	6-May-15	Oksayd Defrost ECO 1	10°Buffer	Frost	Al. Plate	2.6	0.140	0.0	84.0	95	3.50	Failed
66	6-May-15	Oksayd Defrost ECO 1	10°Buffer	Frost	Al. Plate	2.6	0.130	0.0	84.0	96	3.00	Failed
67	6-May-15	Oksayd Defrost ECO 1	10°Buffer	Frost	Comp. Plate	2.6	0.140	0.0	84.0	114	2.00	Failed
68	6-May-15	Oksayd Defrost ECO 1	10°Buffer	Frost	Comp. Plate	2.6	0.150	0.0	84.0	113	1.25	Failed

Table 3.2: Summary of Tests Performed (Snow)

Test No.	Date	Fluid Name	Fluid Dil.	Precipitation Type	Test Surface	Temp. (°C)	Precip. Rate (g/dm²/h)	Endurance Time (min)
279	3-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Alum. Box	-5.9	33.3	3.0
280	3-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Comp. Box	-5.9	32.8	2.3
300	3-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Alum. Box	-5.5	12.8	6.4
301	3-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Comp. Box	-5.5	12.8	4.5
308	3-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Alum. Box	-5.0	6.8	8.7
309	3-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Comp. Box	-5.0	6.7	7.5
325	14-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Alum. Box	-1.5	6.2	16.1
326	14-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Comp. Box	-1.5	6.3	15.4
340	14-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Alum. Box	-1.9	18.7	7.6
341	14-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Comp. Box	-1.9	18.7	4.4
391	17-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Alum. Box	-1.9	8.3	17.3
392	17-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Comp. Box	-1.9	8.2	9.9
440	8-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Alum. Box	0.5	7.3	46.8
442	8-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Comp. Box	0.5	7.9	9.3
446	8-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Alum. Box	0.6	5.4	43.0
448	8-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Natural Snow	Comp. Box	0.6	7.4	11.9

Table 3.3: Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dil.	Precipitation Type	Test Surface	Temp. (°C)	Precip. Rate (g/dm²/h)	Endurance Time (min)
17	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-3.3	2.0	16.5
18	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-3.3	1.7	17.1
19	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-3.3	1.9	16.1
20	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-3.3	1.8	16.1
37	31-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-3.1	5.3	12.7
38	31-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-3.1	5.1	12.7
39	31-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-3.1	5.1	10.2
40	31-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-3.1	4.8	10.7
51	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-9.8	2.1	11.8
52	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-9.8	2.3	10.9
53	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-9.7	2.2	8.9
54	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-9.7	2.0	8.8
57	31-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-10.1	4.8	7.0
58	31-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-10.1	5.0	7.0
59	31-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-10.0	4.8	5.1
60	31-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-10.0	5.0	5.2
89	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-25.2	2.0	9.3
90	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-25.2	2.0	9.2
91	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-25.2	2.0	7.5
92	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-25.2	2.0	7.6
101	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-25.1	5.1	4.8
102	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Al. Plate	-25.1	4.9	5.2
103	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-25.1	5.2	4.3
104	30-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Fog	Comp. Plate	-25.1	5.2	3.8
129	25-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Al. Plate	-3.0	5.3	13.8
130	25-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Al. Plate	-3.0	5.0	13.9
131	25-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Comp. Plate	-3.0	5.3	14.8
131R	25-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Comp. Plate	-2.9	4.9.	14.0

Table 3.3 (cont'd): Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dil.	Precipitation Type	Test Surface	Temp. (°C)	Precip. Rate (g/dm²/h)	Endurance Time (min)
149	25-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Al. Plate	-3.1	10.8	13.2
150	25-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Al. Plate	-3.1	12.4	13.3
151	25-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Comp. Plate	-3.3	9.9	13.5
152	25-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Comp. Plate	-3.1	10.3	13.0
173	27-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Al. Plate	-10.1	8.5	4.8
174	27-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Al. Plate	-10.1	8.2	4.7
175	27-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Comp. Plate	-10.2	7.9	4.8
176	27-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Comp. Plate	-10.3	8.7	4.7
189	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Al. Plate	-10.1	6.7	12.8
190	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Al. Plate	-10.1	6.3	13.0
191	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Comp. Plate	-10.1	6.3	12.8
192	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Freezing Drizzle	Comp. Plate	-10.1	5.7	13.0
245	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Light Freezing Rain	Al. Plate	-10.4	6.7	13.0
246	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Light Freezing Rain	Al. Plate	-10.5	6.5	13.5
247	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Light Freezing Rain	Comp. Plate	-10.2	5.5	13.0
248	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Light Freezing Rain	Comp. Plate	-10.5	5.3	13.5
261	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Light Freezing Rain	Al. Plate	-10.3	6.1	24.5
262	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Light Freezing Rain	Al. Plate	-10.1	5.5	24.8
263	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Light Freezing Rain	Comp. Plate	-10.1	3.6	24.8
264	26-Mar-15	Oksayd Defrost ECO 1	10°Buffer	Light Freezing Rain	Comp. Plate	-10.1	4.1	24.5
277	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Cold Soak Box	Al. Box	1.0	4.9	4.9
278	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Cold Soak Box	Al. Box	1.0	4.6	5.1
279	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Cold Soak Box	Comp. Box	1.1	5.9	4.7
280	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Cold Soak Box	Comp. Box	1.0	6.2	5.4
293	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Cold Soak Box	Al. Box	0.8	1.6	75.7
294	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Cold Soak Box	Al. Box	0.7	2.3	75.1
295	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Cold Soak Box	Comp. Box	0.8	1.8	76.5
296	1-Apr-15	Oksayd Defrost ECO 1	10°Buffer	Cold Soak Box	Comp. Box	0.8	1.6	73.7

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4. RESULTS AND DISCUSSION

The endurance time test results of Oksayd DEFROST ECO 1 are presented in this section. To assess the performance of the fluid, the endurance time results are compared to historic Type I fluid endurance times.

4.1 Results

Figures 4.1 to 4.14 show the results of testing in simulated freezing precipitation. There is one chart for each freezing precipitation cell in the Type I generic holdover time tables, with the exception of the "-3°C and above" light freezing rain cells (see note in Subsection 2.5). Each chart contains the Oksayd DEFROST ECO 1 endurance times (represented with solid diamonds), the endurance times of other Type I fluids (represented with hollow diamonds) and the current Type I generic holdover times (represented by solid squares).

Figures 4.15 and 4.16 show the results of testing in natural snow. The Oksayd DEFROST ECO 1 endurance times are represented with solid shapes and the endurance times of other Type I fluids are represented with hollow shapes.

The natural frost data was presented in Table 3.3. All tests, including those where fluid failure did not occur (due to active frost ending before fluid failure could occur), surpassed the Type I holdover times.

4.2 Discussion

The data collected shows the endurance times of Oksayd DEFROST ECO 1 are similar or superior to the endurance times of Type I fluids tested in past years and to the current Type I generic holdover times. These results indicate this non-glycol based fluid performs similar to glycol based Type I fluids from an endurance time perspective and therefore can be used with the generic Type I HOT guidelines.

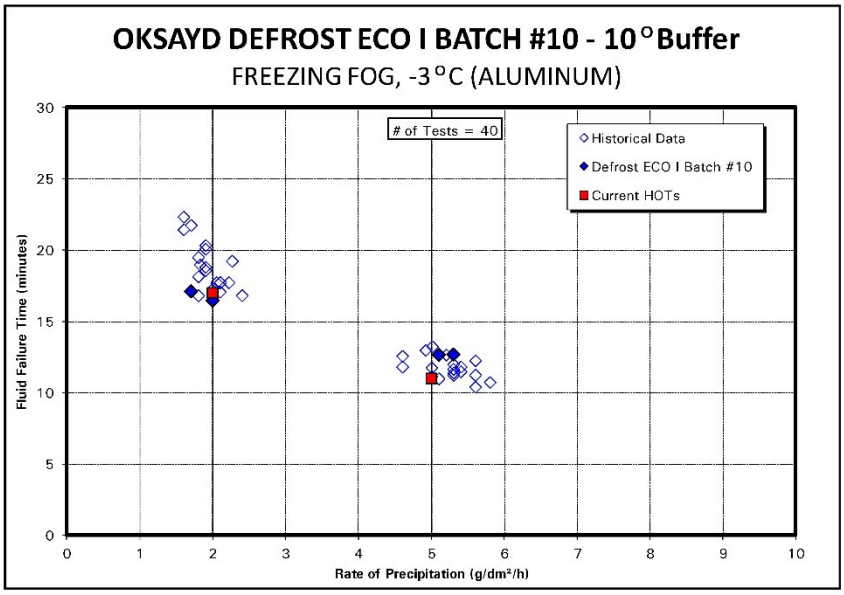

Figure 4.1: Freezing Fog, -3°C and Above, Aluminum Surface

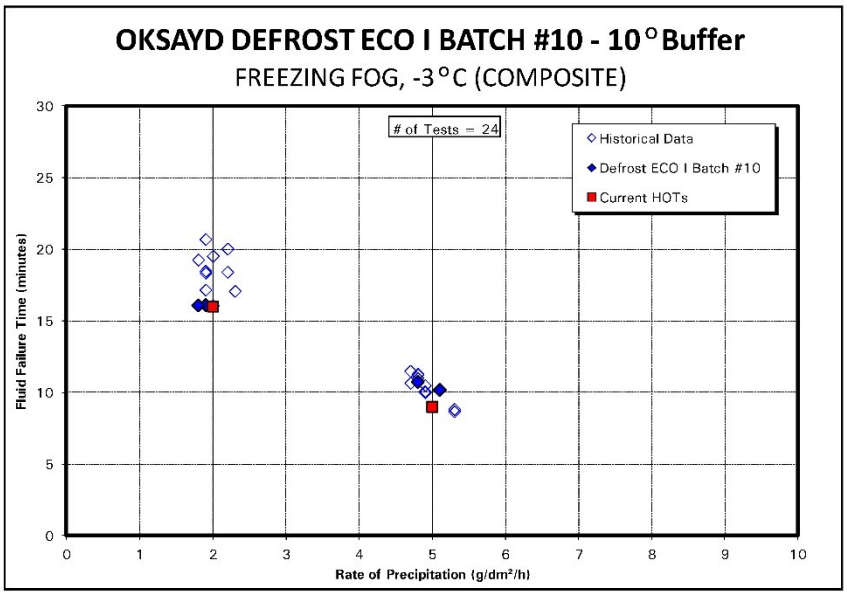

Figure 4.2: Freezing Fog, -3°C and Above, Composite Surface

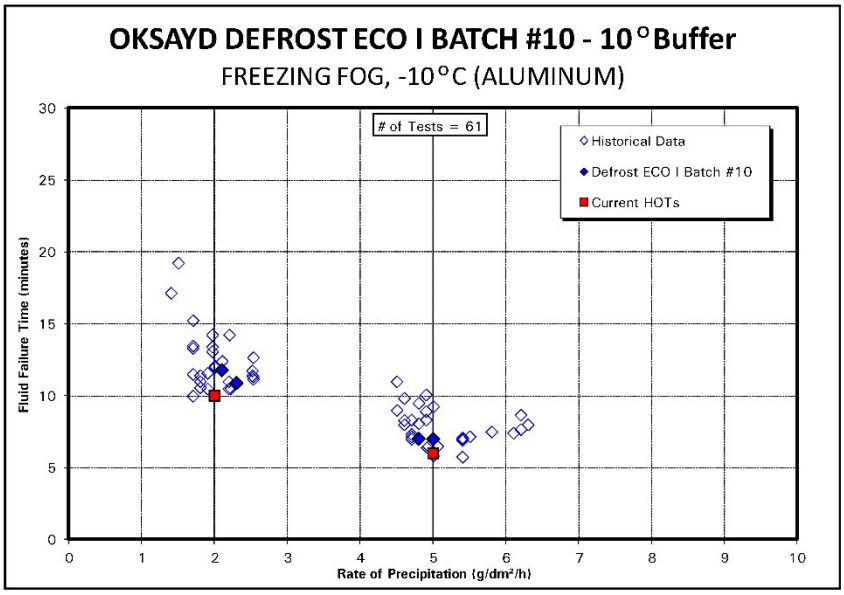

Figure 4.3: Freezing Fog, Below -6 to -10°C, Aluminum Surface

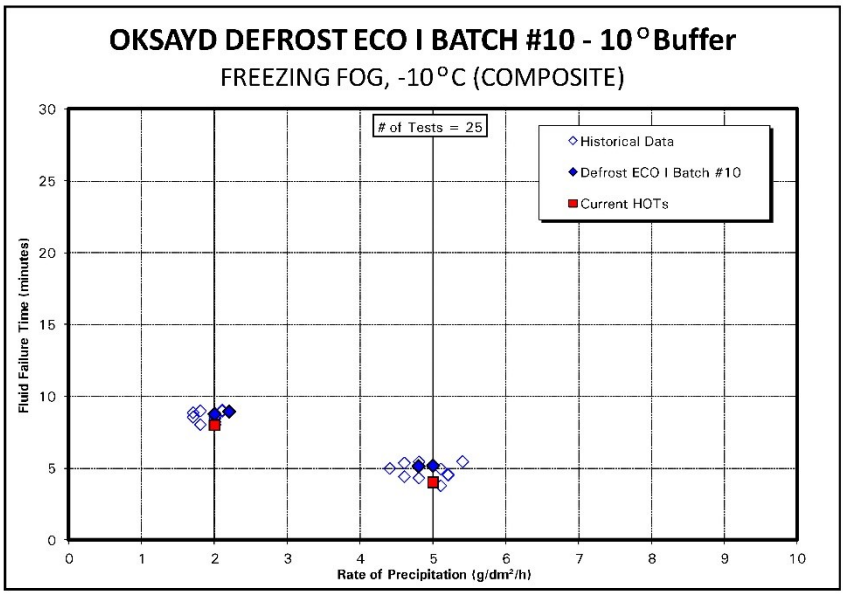

Figure 4.4: Freezing Fog, Below -6 to -10°C, Composite Surface

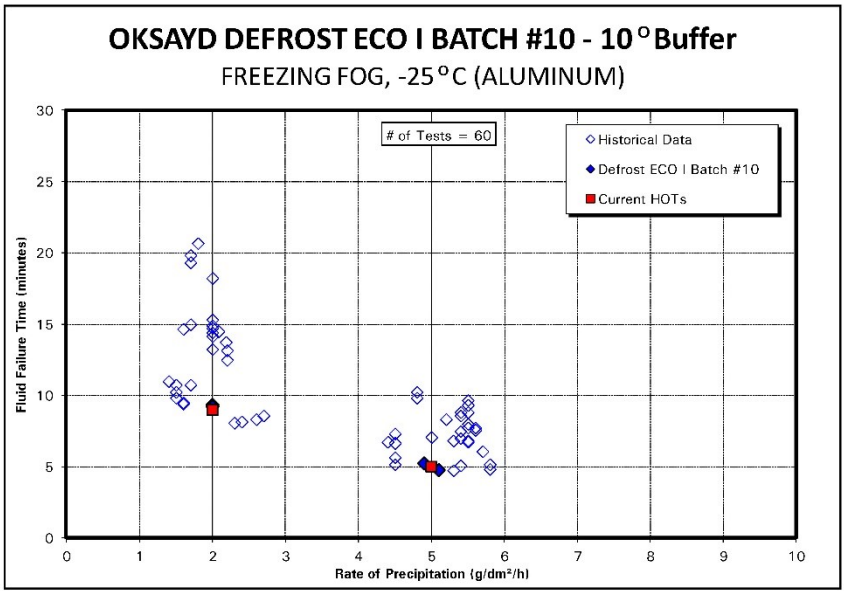

Figure 4.5: Freezing Fog, Below -10°C, Aluminum Surface

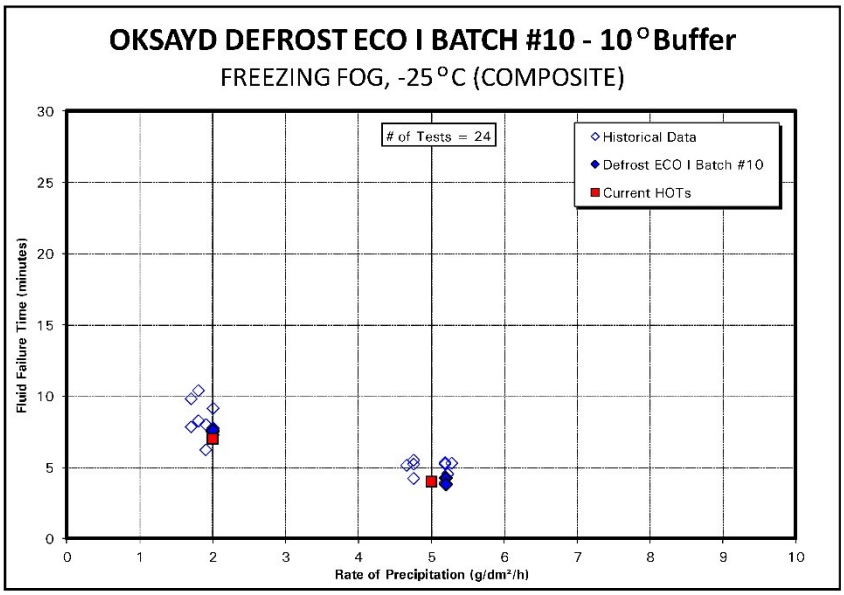

Figure 4.6: Freezing Fog, Below -10°C, Composite Surface

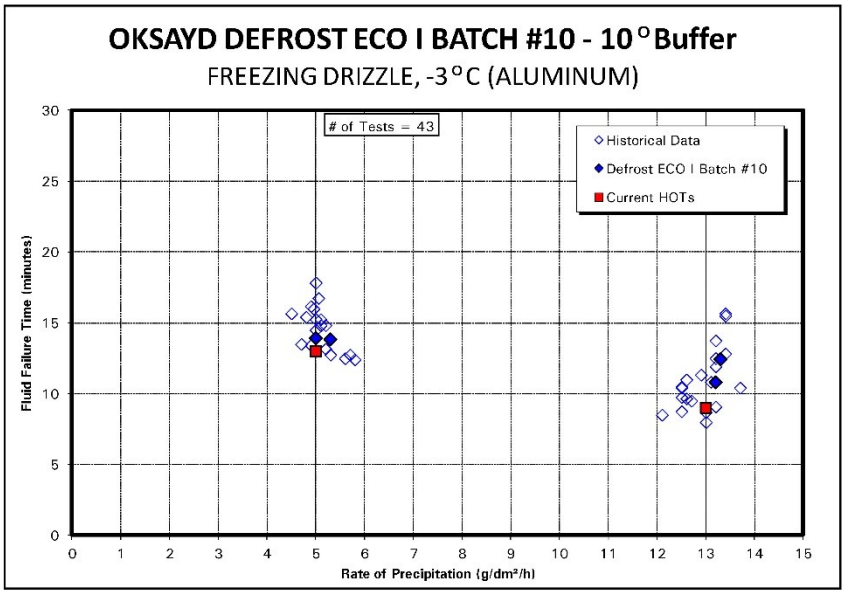

Figure 4.7: Freezing Drizzle, -3°C and Above, Aluminum Surface

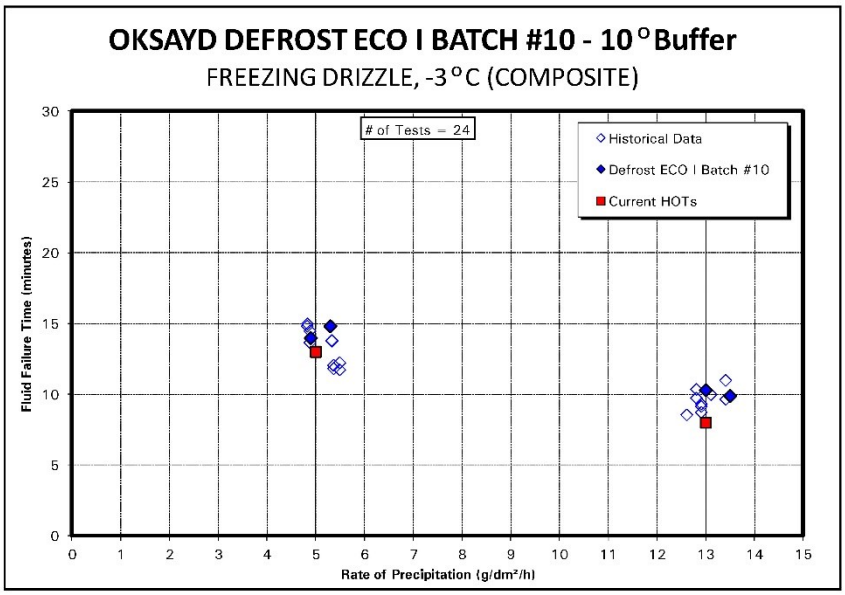

Figure 4.8: Freezing Drizzle, -3°C and Above, Composite Surface

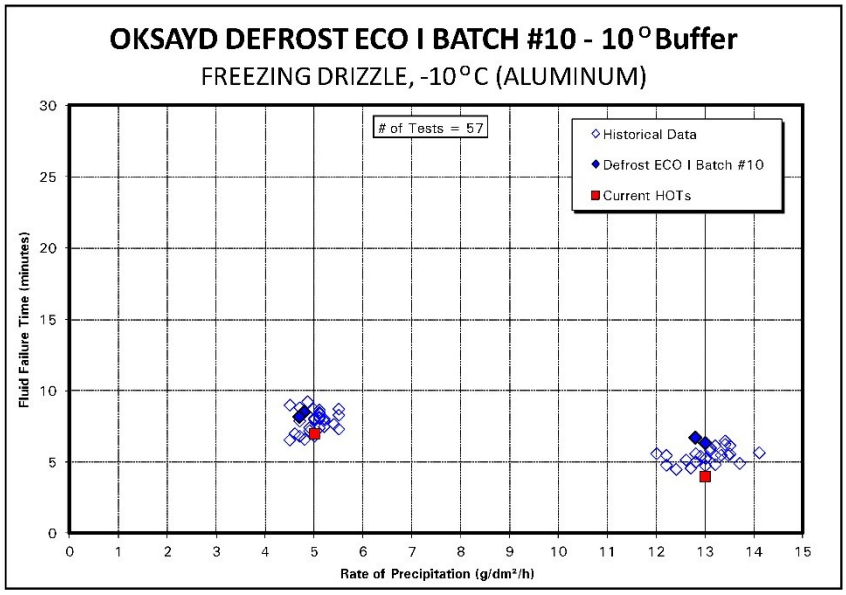

Figure 4.9: Freezing Drizzle, Below -6 to -10°C, Aluminum Surface

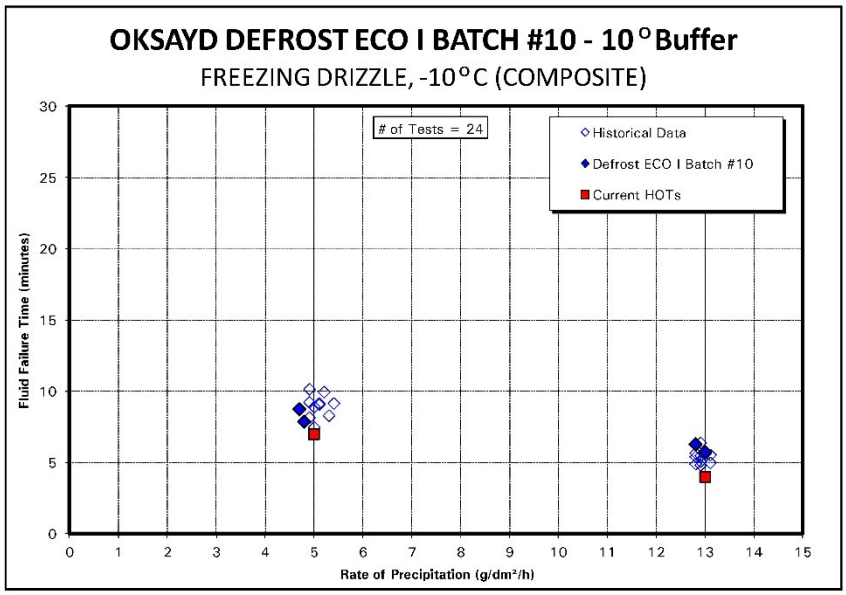

Figure 4.10: Freezing Drizzle, Below -6 to -10°C, Composite Surface

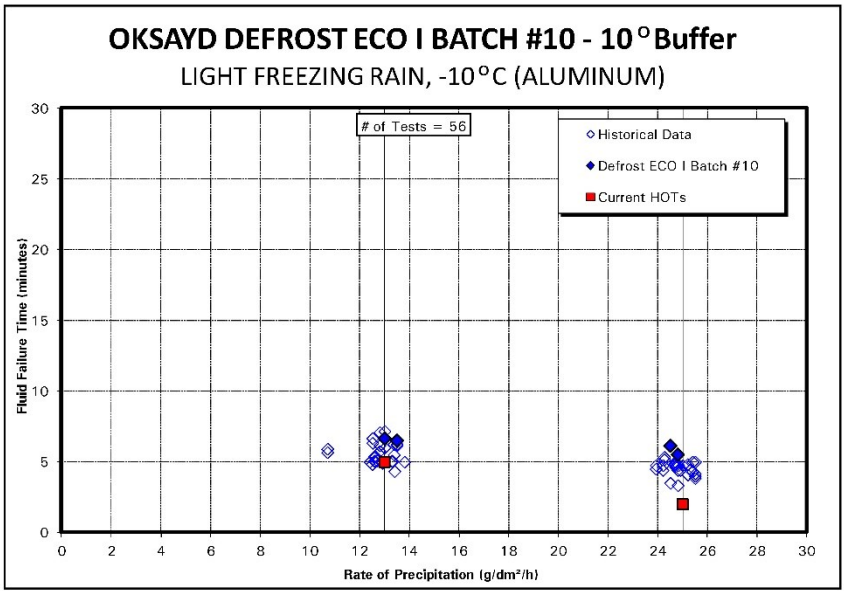

Figure 4.11: Light Freezing Rain, Below -6 to -10°C, Aluminum Surface

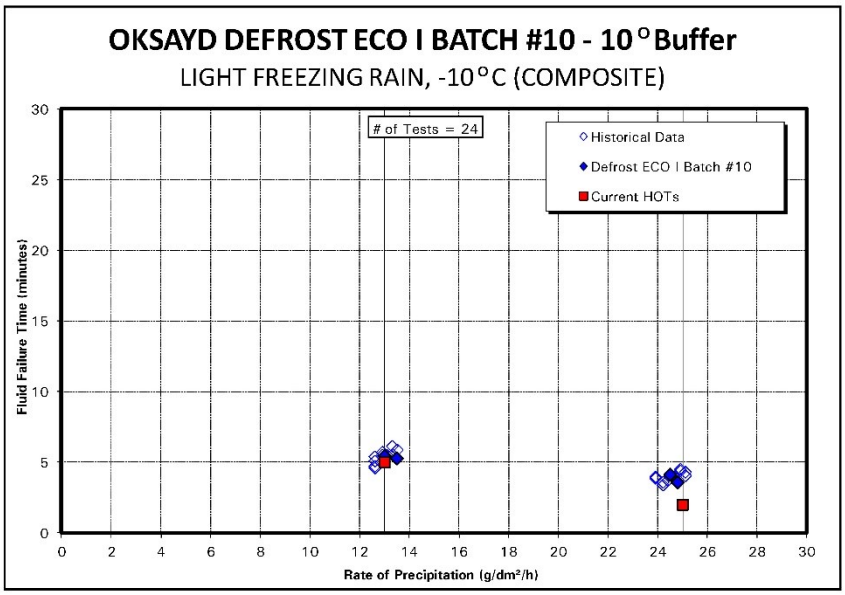

Figure 4.12: Light Freezing Rain, Below -6 to -10°C, Composite Surface

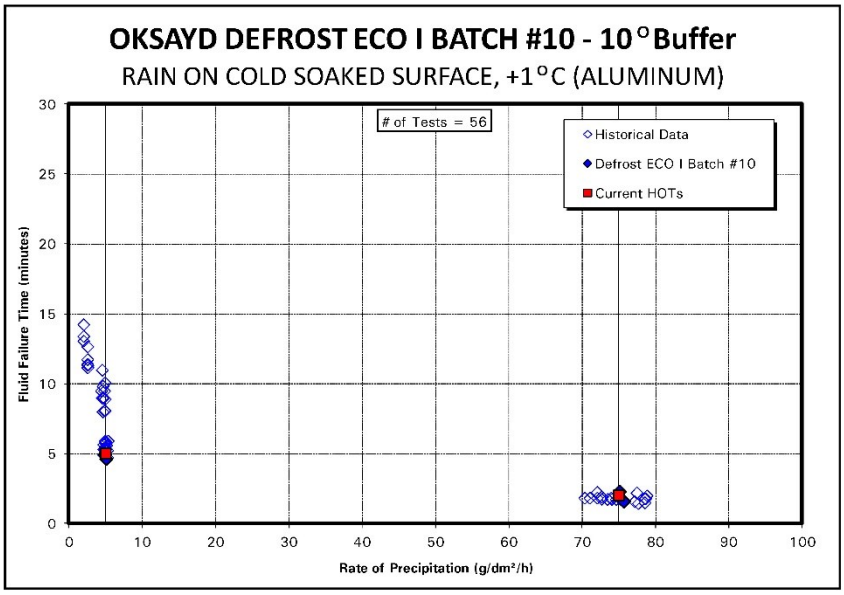

Figure 4.13: Rain on Cold-Soaked Surface, -3°C and Above, Aluminum Surface

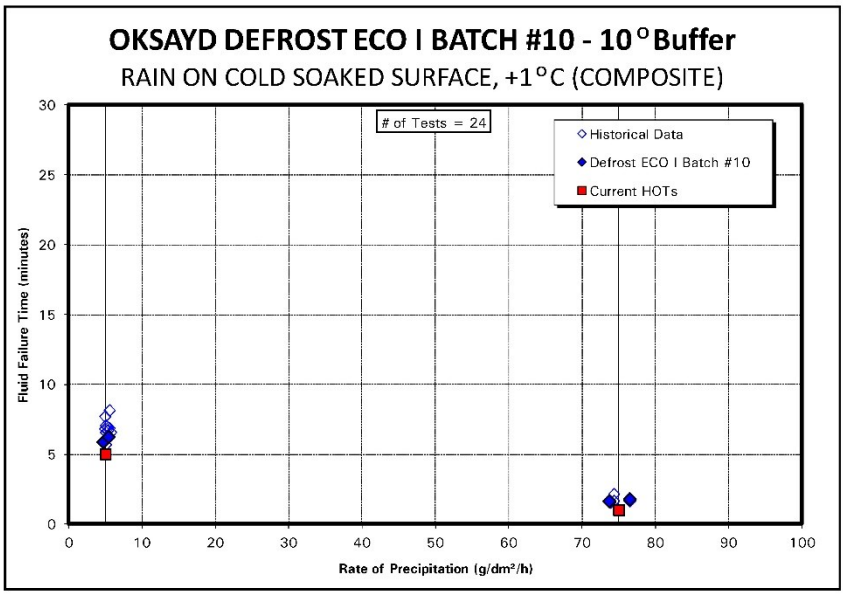

Figure 4.14: Rain on Cold-Soaked Surface, -3°C and Above, Composite Surface

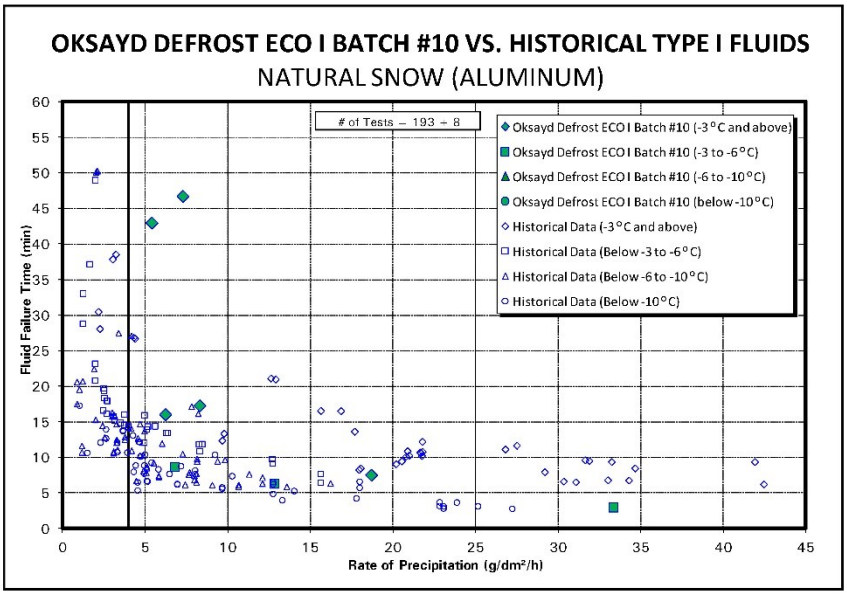

Figure 4.15: Natural Snow, Aluminum Surface

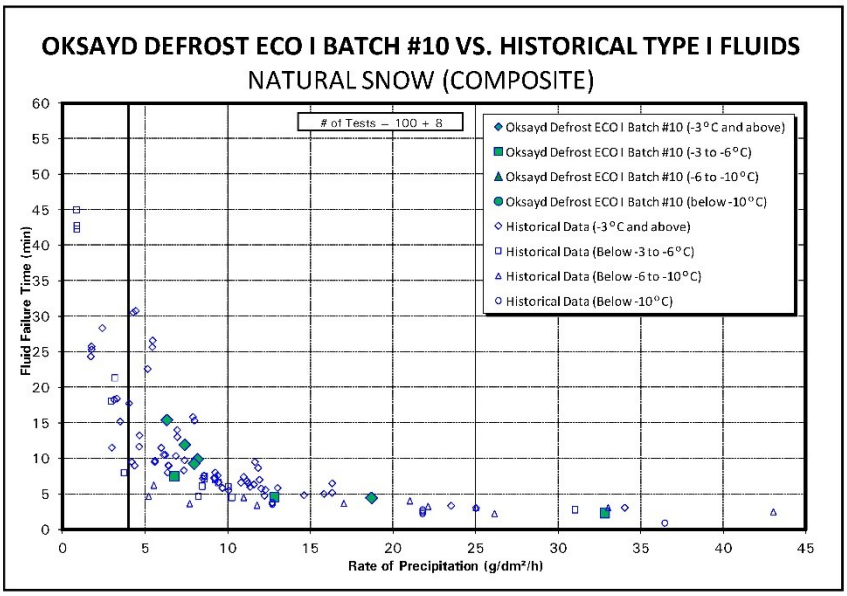

Figure 4.16: Natural Snow, Composite Surface

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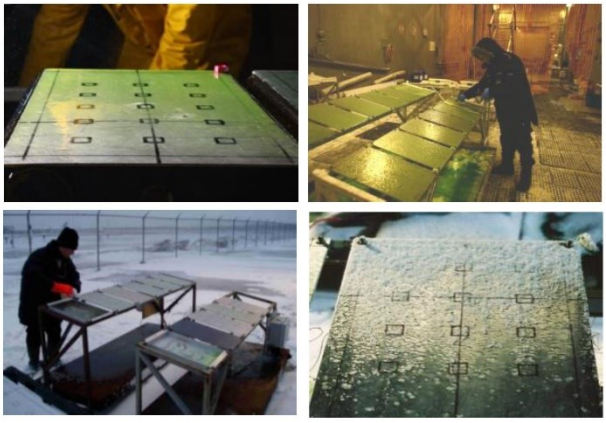
APPENDIX D

FLUID MANUFACTURER REPORT:
KILFROST ABC-ICE CLEAR II (TYPE II)

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Kilfrost ABC-Ice Clear II (Type II)



Prepared for

Kilfrost Ltd.

by

APS Aviation Inc.

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 1.0
Report No. K-P2595 2014-15

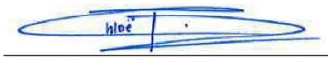
AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Kilfrost ABC-Ice Clear II (Type II)

Prepared for

Kilfrost Ltd.

Prepared by:



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John D'Avirro, Eng.
Program Manager

June 26, 2015
Date

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 1.0
Report No. K-P2595 2014-15

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer:	Kilfrost Ltd.		
Fluid Test Name:	P2595		
Fluid Commercial Name:	ABC-Ice Clear II		
Fluid Type / Base / Colour:	Type II / Propylene Glycol / Yellow		
Batch #:	X/1/2/15		
Date of Receipt:	February 19, 2015		
Brix (Measured):	Neat fluid:	35.5°	
	75/25 dilution:	28.5°	
	50/50 dilution:	19.25°	
Freeze Point (Stated):	Neat fluid:	-37.0°C	
	75/25 dilution:	-21.7°C	
	50/50 dilution:	-11.1°C	
Aerodynamic LOUT (AMIL):	Neat fluid:	-29.5°C	
	75/25 dilution:	-19.5°C	
	50/50 dilution:	-9°C	
Viscosity:	**Mfr Method**	**Stated**	**Measured**
	Neat fluid[1]:	8,160 cP	7,720 cP
	75/25 dilution[1]:	5,700 cP	5,660 cP
	50/50 dilution[1]:	525 cP	580 cP
	AIR 9968 Method	**Stated**	**Measured**
	Neat fluid[1]:	8,160 cP	7,720 cP
	75/25 dilution[1]:	5,700 cP	5,660 cP
	50/50 dilution[2]:	not given	558 cP
WSET (from AMIL):	Neat fluid:	53 minutes	

[1] Spindle LV1 (with guard leg), 600 mL Griffin, ~575 mL, 20°C, 0.3 rpm, 10 mins
[2] Spindle LV0, ULA, 16 mL, 20°C, 0.3 rpm, 10 mins

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SUMMARY

The primary objective of this project was to measure the endurance time performance of **Kilfrost ABC-Ice Clear II** over the entire range of conditions encompassed by the Holdover Time (HOT) tables. This report contains the results of these measurements and was completed with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

Tests were carried out according to the protocol provided in Aerospace Recommended Practice (ARP) 5485. The test procedure consisted of pouring fluids onto clean aluminum test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural and simulated precipitation.

Tests were performed at the APS Aviation Inc. (APS) test facility at Montréal-Pierre-Elliott-Trudeau International Airport and the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were derived from the data collected using multi-variable regression analysis. This resulted in the generation of the fluid-specific holdover times shown in the tables on the next page. These holdover times will be published by regulators for use in the winter 2015-16 operating season.

SUMMARY

Kilfrost ABC-Ice Clear II Type II Fluid Holdover Times (Transport Canada Format)

Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume % /Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:00-1:45	1:45	0:50-1:45	0:25-0:50	0:40-1:05	0:25-0:35	0:07-0:45	
		75/25	0:50-1:10	1:20	0:40-1:20	0:20-0:40	0:30-0:45	0:20-0:30	0:05-0:35	
		50/50	0:15-0:30	0:20	0:15-0:20	0:08-0:15	0:10-0:20	0:07-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40-1:35	1:15	0:35-1:15	0:20-0:35	0:25-1:00	0:15-0:30		
		75/25	0:40-1:20	0:55	0:25-0:55	0:15-0:25	0:25-0:45	0:15-0:20		
below -14 to -29.5	below 7 to -21.1	100/0	0:20-0:40	0:40	0:30-0:40	0:15-0:30				

Kilfrost ABC-Ice Clear II Type II Fluid Holdover Times (FAA Format)

Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume % /Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:00-1:45	1:45-2:10	0:50-1:45	0:25-0:50	0:40-1:05	0:25-0:35	0:07-0:45	
		75/25	0:50-1:10	1:20-1:45	0:40-1:20	0:20-0:40	0:30-0:45	0:20-0:30	0:05-0:35	
		50/50	0:15-0:30	0:20-0:25	0:15-0:20	0:08-0:15	0:10-0:20	0:07-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40-1:35	1:15-1:35	0:35-1:15	0:20-0:35	0:25-1:00	0:15-0:30		
		75/25	0:40-1:20	0:55-1:10	0:25-0:55	0:15-0:25	0:25-0:45	0:15-0:20		
below -14 to -29.5	below 7 to -21.1	100/0	0:20-0:40	0:40-0:50	0:30-0:40	0:15-0:30				

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GLOSSARY

APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LOUT	Lowest Operational Use Temperature
LOWV	Lowest On-Wing Viscosity
LUPR	Lowest Usable Precipitation Rate
LWC	Liquid Water Content
MVD	Median Volume Diameter
MANOBS	Manual of Surface Weather Observations
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

This report has been created with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

Aircraft ground de/anti-icing has been the subject of concentrated industry attention in recent years due to the occurrence of several fatal icing-related aircraft accidents. Notably, attention has been placed on the enhancement of anti-icing fluids in order to provide an extended period of protection against further contamination following initial deicing. This emphasis has led to the development of fluid-specific de/anti-icing fluid holdover time (HOT) tables for Type II and Type IV fluids. These tables, accepted by regulatory authorities, are used by aircraft operators for departure planning in adverse winter conditions. Specifically, they provide the duration of time that qualified fluids provide protection against ice formation under specific weather conditions.

New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid holdover times without compromising the aerodynamic features of the airfoil. The purpose of the endurance time testing program is to measure the endurance times of these new fluids and develop fluid-specific HOT tables that provide guidance for their use.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop HOT values for new fluids. These tests are carried out according to SAE Aerospace Recommended Practice (ARP) ARP5485, which provides the test protocols for measuring endurance times of Type II, III and IV fluids. Along with its counterpart for measuring endurance times of Type I fluids ARP5945, ARP5485 has evolved into a refined procedure for measuring the duration of de/anti-icing fluid protection against ice formation.

The current data analysis protocol for developing HOT values from endurance time data was developed in 1996-97 and uses multi-variable regression to obtain HOT values. HOT values are derived for all cells of the Type II/IV HOT tables using this protocol and are used to create a fluid-specific HOT table for each Type II/IV fluid tested.

This report provides a detailed account of the endurance time testing conducted by APS Aviation Inc. (APS) with **Kilfrost ABC-Ice Clear II**, a new Type II fluid. It describes the test methodology used, endurance time data collected, and analysis completed to derive fluid-specific holdover times for the fluid.

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2

2. METHODOLOGY

SAE Aerospace Recommended Practice (ARP) 5485 provides the procedure and requirements for endurance time testing with Type II, III and IV fluids under natural and simulated conditions. This chapter summarizes some of aspects of the test methodology included in ARP5485, and some aspects which are not included in ARP5485. The chapter includes sections for test sites, equipment, procedures, precipitation rates and ambient temperatures used in Type II/IV endurance time testing, and freezing precipitation droplet sizes. The final subsection describes the analysis methodology used to evaluate Type II/IV endurance time data.

2.1 Test Sites

2.1.1 Natural Snow, Natural Frost and Artificial Snow

Natural snow, natural frost and artificial snow testing is typically performed at the APS test site located at the Montréal-Pierre-Elliott-Trudeau International Airport. The test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station, as shown in Figure 2.1 on a plan view of the airport.

The APS test site consists of two trailers and three outdoor locations for test stands. One of the trailers is equipped with a refrigeration unit to enable indoor testing at controlled temperatures; artificial snow testing is conducted inside this trailer. Photos 2.1 and 2.2 show the test site as seen from the test pads and main trailer, respectively.

In winter 2014-15, additional natural snow mobile testing was conducted in Mirabel, Québec and Beaconsfield, Québec.

2.1.2 Freezing Precipitation

Tests under conditions of freezing fog, rain on cold-soaked surface, freezing drizzle, and light freezing rain were conducted indoors at the NRC Climatic Engineering Facility (CEF), where precipitation was artificially produced.

Photo 2.3 provides an outdoor view of the facility giving a general indication of its size (30 m by 5.4 m, height 8 m). The facility was originally designed for the testing of locomotives; Photo 2.4 provides an interior view of the CEF set up for endurance time testing. The lowest temperature achievable in the CEF is -46°C.

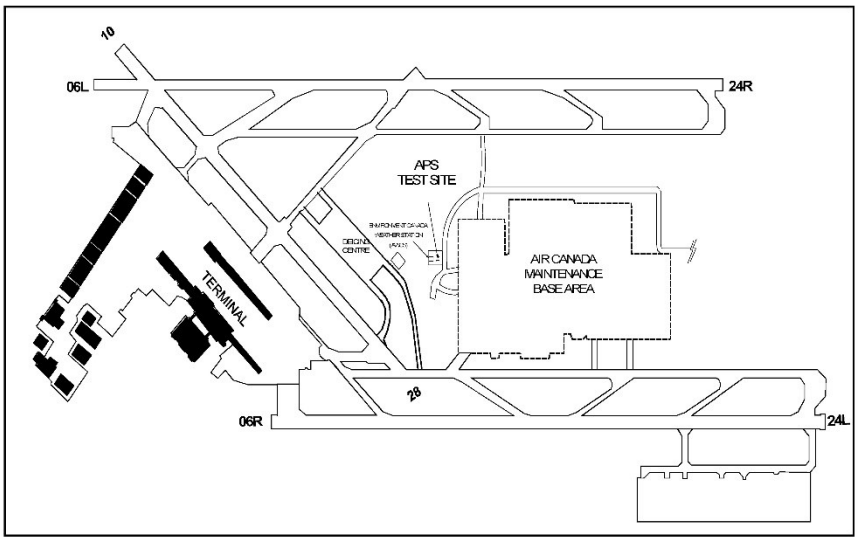


Figure 2.1: APS Test Site at Montréal-Pierre-Elliott-Trudeau International Airport

2.2 Test Equipment

The key equipment used in endurance time testing is described in this section, as are the calibration procedures APS follows for ensuring the accuracy of its test equipment.

2.2.1 Calibration

APS measurement instruments and test equipment are calibrated and/or verified on an annual basis. This calibration is carried out according to a calibration plan based upon approved International Organization for Standardization (ISO) 9001:2000 standards, and developed internally by APS.

2.2.2 Environmental Chamber Equipment

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) was as stipulated in the requirements set out in ARP5485.

2.2.3 Test Surface Structures

The majority of endurance time testing is carried out on standard flat plates. A schematic of a standard flat plate is provided in Figure 2.2. It depicts the size and surface markings of a standard flat plate. Three parallel lines are positioned at 2.5 cm (1"), 15 cm (6") and 30 cm (12") from the top of the plate. The plates are marked with 15 crosshairs, which are used in determining when end conditions (see Subsection 2.3.5) are achieved. Photo 2.5, taken outdoors at the APS test site, shows six test plates mounted on a test stand.

Figure 2.3 shows a schematic of the sealed boxes used for tests simulating a cold soaked wing. The top of the box consists of a flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate. Photo 2.6 shows a picture of a sealed box, which is referred to as a cold-soak box when filled for simulated rain on cold soaked wing tests.

In natural frost, tests are conducted on frosticator plates, which are the current standard test surface used in frost holdover time testing. The frosticator plates were constructed by attaching a Styrofoam insulation backing to the back of the test surface (either aluminum or composite). The insulation prevents heat exchange via the underside of the flat plate and allows for effective radiative cooling during active frost conditions. Photo 2.7 shows a white-painted aluminum frosticator plate.

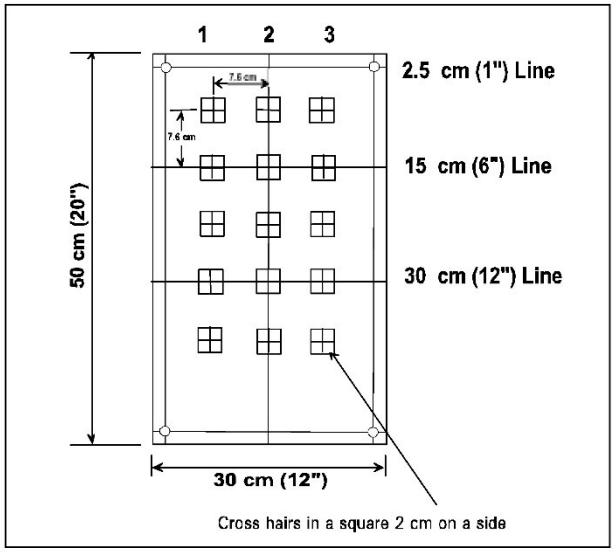


Figure 2.2: Standard Test Plate Schematic

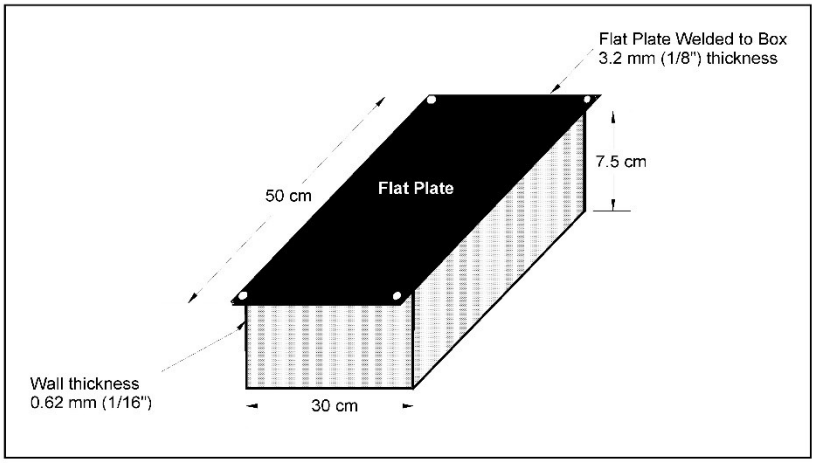


Figure 2.3: Cold Soak Box Schematic

2.2.4 Test Surface Materials

Testing of Type II, III and IV fluids is carried out exclusively on aluminum surfaces. The aluminum used is 0.32 cm thick Alclad 2024 T3 aluminum.

2.2.5 Test Stands

Figure 2.4 shows a schematic of the test platform used for HOT testing. For natural snow tests, six test plates are normally mounted on the test stand, which has a working surface inclined at 10° to the horizontal. During normal winter operations two six-position stands are used in combination. Each plate represents a flat plate test. For simulated freezing precipitation tests at the NRC, 12 plates are mounted on 2 six-position stands. Photos 2.4 and 2.5 show the test stands set up for indoor and outdoor testing, respectively.

2.2.6 Collection Pans

Figure 2.5 shows a schematic of the collection pan used for precipitation rate measurement in outdoor testing. It is the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.8 shows the collection pans used for measuring precipitation rates indoors at the NRC.

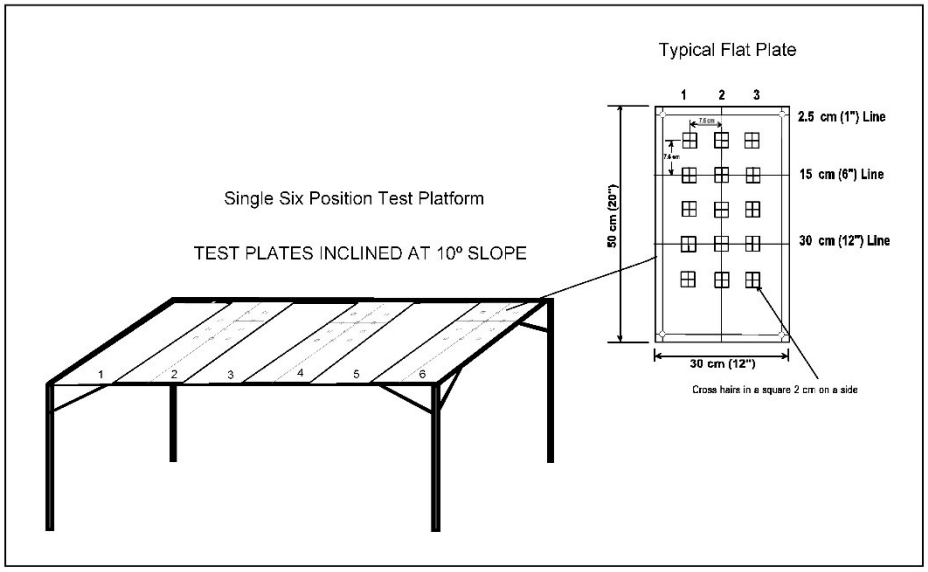


Figure 2.4: Test Stand Setup Schematic

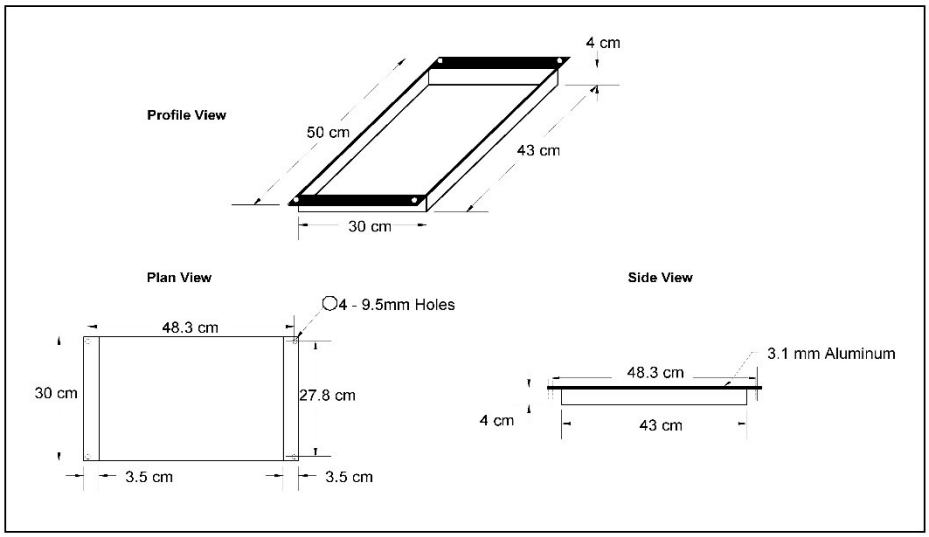


Figure 2.5: Schematic of Outdoor Precipitation Measurement Pan

2.2.7 NRC Sprayer Assembly

NRC developed an improved sprayer assembly, shown in Photos 2.9 and 2.10, in 1997-98. The improved sprayer provides a larger scan area and improved spray uniformity over the test bed area. The scanner consists of a horizontal main shaft supported by two bearings. The actual spray head assembly is shaft-mounted on a rotating scanner, so that one scan covers a lateral running strip of the test bed area. A stepper motor is synchronized to index the relative angle of the spray head between scans along an axis perpendicular to the scan axis. This provides two axes of rotation, essentially an x-y plane; one along each axis. Each scan is consecutively indexed in order to complete the precipitation coverage of the test bed area. This defines one cycle of the spray unit. The scan rate, index angle, and the number of scans per cycle are adjusted, along with the fluid delivery pressures (water and air) to obtain appropriate droplet sizes and precipitation rates. The spray nozzle is shown in Photo 2.11.

2.2.8 Fluids

Testing was carried out with Kilfrost ABC-Ice Clear II in the standard Type II, III and IV fluid test dilutions: neat, 75/25 and 50/50. The fluid sample was diluted by the manufacturer.

2.3 Test Procedures

ARP5485 provides the procedure for endurance time testing of Type II, III and IV fluids under natural and simulated precipitation conditions.

The procedure generally consists of pouring de/anti-icing fluids onto clean flat plates exposed to various winter precipitation conditions, and recording the elapsed time for the test to reach the defined end condition (see Subsection 2.3.5), when a specified degree of freezing occurs. The following subsections provide summaries of the test procedures followed for natural snow, natural frost, artificial snow and simulated freezing precipitation testing.

2.3.1 Test Protocol – Natural Snow Tests

APS developed a specific procedure for Type II, III and IV fluid testing in natural snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted are conducted on standard flat plates (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.2 Test Protocol – Natural Frost Tests

APS developed a specific procedure for Type II/III/IV testing in natural frost. Key details of the procedure include:

- Tests are conducted on frosticator plates (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.3 Test Protocol – Artificial Snow Tests

APS developed a specific procedure for testing in artificial snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted on a standard plate (shown mounted on the snowmaker scale in Photo 2.12);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.4 Test Protocol – Simulated Precipitation Tests

APS developed a specific procedure for Type II/III/IV testing in simulated precipitation based on the requirements outlined in ARP5485. Key details of the procedure include:

- Freezing fog, freezing drizzle and light freezing rain tests are conducted on standard flat plates (see Section 2.2.3);
- Rain on cold-soak surface tests are conducted on filled cold-soak boxes (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.5 End Condition Definitions

Failure is called when 30 percent (1/3) of the plate or 5 cross-hairs are covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

a) Ice front;
b) Ice sheet;
c) Slush, in clusters or as a front;
d) Disseminated fine ice crystals;
e) Frost on surface;
f) Clear ice pieces partially or totally imbedded in fluid; and
g) Snow bridges on top of the fluid.

2.3.6 Precipitation Rate Measurement Procedures

The procedures for measuring and determining precipitation rates during simulated precipitation and natural precipitation conditions are provided below.

2.3.6.1 Simulated precipitation conditions

Prior to the start of the rate collection period, the proper needles and nozzles are installed in the spray unit, and both the air and water pressures are adjusted. Water spray calibration is performed by placing catch pans on the test stand, each pan marked with a number identifying the collection location on the test stand, and exposing the pans to a predetermined precipitation collection period.

The pans are weighed prior to exposure to precipitation and the weights are recorded in a customized Excel spreadsheet by using the print function on the digital weigh scale. Prior to the start of the precipitation catch period, the exact time (hh:mm:ss) is recorded using a pre-programmed time macro in the Excel spreadsheet. The pans are re-weighed following this collection period and the precipitation rates over the area of the test stand are examined. If the rates are unacceptable, re-calibration of the water spray is necessary. If the rates are deemed to be acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period has expired, the pans are again re-weighed and the rates computed.

Once two rates have been collected at each test location, the catch rates of the first and second collection are compared. If the average catch rate for any location

is deemed to be acceptable for the test condition, then the pouring of fluids may begin at this location.

Rates are continuously monitored at a minimum of two locations during a test in order to ensure there are no significant rate fluctuations. Pans will be placed at these locations and be re-weighed at fixed intervals (15 minutes, typically) during the course of a test. If a rate fluctuation occurs, the test is stopped.

Following the failure of a test plate, a rate collection pan is weighed and placed at the plate location for a predetermined time interval. It is then re-weighed and placed again on the stand to collect a minimum of two additional rates at this location.

The rate of precipitation for any location on the stand is calculated by averaging the two rates collected prior to the test and the two rates collected following the test.

2.3.6.2 Natural precipitation conditions

Two rate collection pans per test stand are used to determine precipitation rates in natural conditions. Prior to the rate collection period, both pans are marked (upper and lower), and the inner bottom and sides of the each pan are wetted with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The wetted pans are then weighed to the nearest gram. The start time of the rate collection period is recorded (h/min/sec) using a customized Excel spreadsheet in which the weight is also recorded by pressing the print function on the digital weigh scale.

The pans are positioned in locations 6 and 7 (see Figure 2.4) and are allowed to collect precipitation for 10-minute intervals in normal conditions and 5-minute intervals in periods of high precipitation rates and high winds. Prior to removal of the plate pans from the test stand for re-weighing, any accumulated precipitation on the lips and outer sides of each plate pan is carefully removed. The plate pans are then carried to the rate station for re-weighing. Upon entering the trailer, the exact time is noted. The new weights of the plate pans are recorded and the pans are brought back outside. This procedure is continued until the final plate on the test stand has failed.

The rate for any HOT test in natural snow is obtained by computing the time-weighted average of the rates collected in the upper and lower pans over the duration of this particular test. To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.6. Typically, two collections pans are used for each test. The start and end times of the test shown in Figure 2.6 are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t1, t2, and t3 (minutes). The calculated rates for each collection period are indicated by R1, R2, and R3 (g/dm²/h). In order to calculate the average rate for this pan, the following formula is then used:

$$\frac{(R_1 \times t_1 + R_2 \times t_2 + R_3 \times t_3)}{t_1 + t_2 + t_3}$$

In the example shown in Figure 2.6, the rate is calculated as follows:

$$\frac{(25 \times 10 + 22 \times 8 + 34 \times 5)}{10 + 8 + 5}$$

The calculated average rate for this pan is 25.9 g/dm²/h. The average rate for the other collection pan is calculated in similar fashion, and the average of the two rates is then taken.

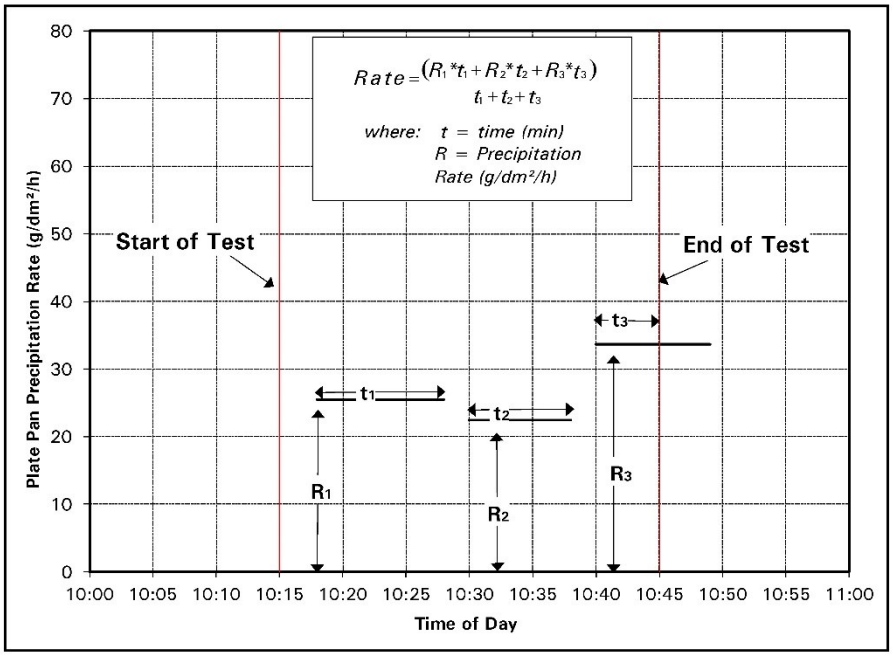


Figure 2.6: Calculation of Outdoor Precipitation Rate

2.4 Precipitation Rate Limits in Type II/IV Endurance Time Testing

Upper and lower precipitation rate limits are an important part of the test methodology for measuring fluid endurance times. Table 2.1 provides the meteorologically accepted definitions of weather phenomenon / precipitation types. It also includes the criteria used to determine precipitation intensity. This table was compiled by the National Centre for Atmospheric Research (NCAR) from the *World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation* (1983) and from the *American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS*) (3/94).

The precipitation rate limits established for Type II/IV endurance time testing are provided in ARP5485 and represented graphically in Figure 2.7. Subsections 2.4.1 to 2.4.5 provide detailed definitions and explanations of the precipitation types and rate boundaries used in Type II/IV endurance time testing. It should be noted that in many cases these limits are not the same as the meteorologically accepted definitions provided in Table 2.1.

Table 2.1: Definition of Weather Phenomenon

Weather Phenomenon*	Definition*
FROST (No METAR code) Note: No Intensity is assigned to FROST.	Ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.
FREEZING FOG (FZFG) Note: No Intensity is assigned to FRZ FOG	A suspension of numerous minute water droplets which freezes upon impact with ground or other exposed objects, generally reducing the horizontal
SNOW (SN)	Precipitation of ice crystals, most of which are branched, star-shaped, or mixed with unbranched crystals. At temperatures higher than about -5°C
FRZING DRIZZLE (FZDZ)	Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0.02 in.)] very close together which freezes upon impact with
FREEZING RAIN (FZRA)	Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5
RAIN (RA)	Precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 in.) diameter or of smaller widely scattered drops.
SNOW PELLETS (GS) and/or SMALL HAIL	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is
HAIL (GR)	Precipitation of small balls or pieces of ice with a diame-
ICE PELLETS (PE)	Precipitation of transparent (sleet or grains of ice), or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 in.)

Intensity Criteria**

	Snow(SN),Pellets(GS),Grains(SG)		Ice Pellets (PE)
Estimated Intensity	**Horizontal Visibility (statute mile)**	**Liquid Equivalent Snow (SN) Intensity*** **	**Definition and Horizontal Visibility**
Light (-)	If visibility is: **≥ 5/8 mi** (≥ 1.0 km)	**Trace to 0.05 in/hr** (≤ 1.0 mm/hr or 10 gr/dm²/hr)	Scattered pellets on the ground. Visibility not affected.
Moderate	If visibility is: **< 5/8 to 5/16 mi** (< 1.0 to 0.5 km)	**> 0.05 to 0.10 in/hr** (> 1.0 to 2.5 mm/hr) (> 10.0 to 25.0 gr/dm²/hr)	Slow accumulation on the ground. Visibility reduced to less than 7 mi.
Heavy (+)	If visibility is: **< 5/16 mi** (< 0.5 km)	**More than 0.10 in/hr** (> 2.5 mm/hr or 25 gr/dm²/hr)	Rapid accumulation on the ground. Visibility reduced to less than 3 mi.

Note: Horizontal visibility is only an estimation of snow and freezing drizzle intensity. Measurements and observations have

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm/hr or 2.54 gr/dm²/hr)
Moderate	From 0.01 to 0.02 in/hr (2.54 to 5.08 gr/dm²/hr)
Heavy(+)	More than 0.02 in/hr (> 5.08 gr/dm²/hr) Note: Drizzle > 0.04 in/hr is usually in the form of rain.

	Rain (RA), Freezing Rain (FZRA), Ice Pellets (PE)
Measured Intensity	Up to 0.10 in/hr (2.5 mm/hr or 25 gr/dm²/hr) Maximum 0.01 inch in 6 minutes
Light (-)	
Estimated Intensity	From scattered drops that, regardless of duration, do not completely wet an
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.01 to 0.03 inch in 6 minutes
Moderate	
Estimated Intensity	Individual drops are not clearly identifiable; spray is observable just above
Measured Intensity	More than 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.03 inch in 6 minutes
Heavy (+)	
Estimated Intensity	Rain seemingly falls in sheets; individual drops are not identifiable; heavy

*From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
**From American Meteorological Society, Glossary of Meteorology WSOH #7 MANOBS (3/94)
***NCAR/UAE Proposed Definition for Liquid Equivalent Snowfall Intensity

1) gr/dm² = 0.01 cm = 0.1 mm = 1.0 kPa or
2) cm = 2.54 cm = 25.4 mm = 254 gr/dm²

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP Sept 8, 1999
(Updated for METAR codes)

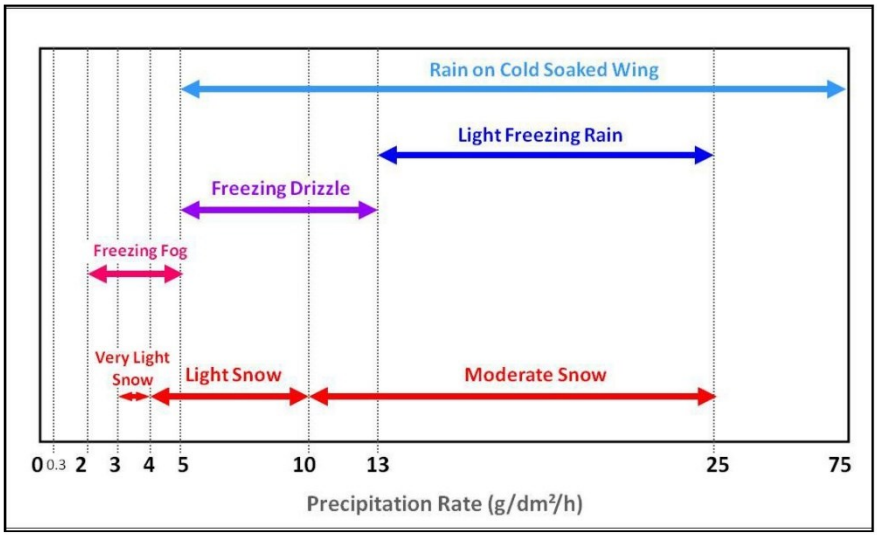


Figure 2.7: Precipitation Rate Limits Used in Endurance Time Testing

2.4.1 Freezing Fog

The precipitation rate limits for endurance time testing in freezing fog were set in 1997 at rates of 2 and 5 g/dm^2/h. These limits were determined with input from NRC meteorologists, who helped define an important parameter in the study of fog referred to as the *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic meter of air, can generally assume values in the range of 0.2 to 0.6 g/m^3.

2.4.2 Freezing Drizzle

The precipitation rate limits for endurance time testing in freezing drizzle are 5 and 13 g/dm^2/h. The upper limit in this range was adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Committee. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety.

2.4.3 Light Freezing Rain

The precipitation rate limits for endurance time testing in light freezing rain are 13 and 25 g/dm^2/h. This range corresponds to the category of light freezing rain and is the only freezing rain category considered, as operations in periods of moderate or heavy freezing rain are deemed unsafe.

2.4.4 Rain on a Cold-Soaked Surface

The precipitation rate limits for rain on cold soaked surface are 5 and 75 g/dm^2/h. This range encompasses drizzle (5 to 13 g/dm^2/h), light rain (13 to 25 g/dm^2/h), and moderate rain (25 to 75 g/dm^2/h).

2.4.5 Snow

The precipitation rate limits used to determine holdover times for Type II/IV fluids in snow are 3, 4, 10 and 25 g/dm^2/h. These rate limits encompass very light, light and moderate snow.

2.5 Ambient Temperatures in Type II/IV Endurance Time Testing

The Type II/IV holdover time tables provide holdover times for three temperature ranges:

- -3°C and above;
- Below -3 to -10°C (freezing drizzle, light freezing rain, cold soak wing) or Below -3 to -14°C (freezing fog, snow); and
- Below -14°C to LOUT

In natural snow testing, endurance time testing is carried out under a range of temperatures. In simulated freezing precipitation and artificial snow testing, endurance time testing is typically conducted at the lower limit of each temperature band.

- Freezing Fog: -3°C, -14°C and -25°C
- Freezing Drizzle: -3°C and -10°C
- Light Freezing Rain: -3°C and -10°C
- Rain on Cold Soaked Surface: +1°C
- Artificial Snow: -3, -14 and/or -25°C

2.6 Freezing Precipitation Droplet Sizes

Research has shown that median volume diameter (MVD) of rain droplets is related to rate of precipitation as follows:

- MVD = (precipitation rate/10) $^{0.23}$, where MVD is in mm and rate of precipitation is in g/dm²/h

The theoretical MVDs for rain at various rates of precipitation were determined based on this equation. These values are listed in Table 2.2 beside the experimental MVDs for each precipitation condition.

Table 2.2: Theoretical and Experimental MVDs

Precipitation Condition	Experimental MVD (mm)	Theoretical MVD (mm)
Moderate Rain (High rate: 75 g/dm²/h)	1.4	1.6
Light Rain (Low rate: 13 g/dm²/h)	1.0	< 1.1
Light Rain (High rate: 25 g/dm²/h)	1.0	1.2
Drizzle (Low rate: 5 g/dm²/h)	0.25	< 0.5
Drizzle (High rate: 13 g/dm²/h)	0.35	< 0.5
Fog		< 0.1

To determine whether droplets produced at the NRC resembled droplets from natural precipitation, a test was conducted during natural light freezing rain conditions in 1997-98 at the APS test site. The droplet sizes were compared to those obtained in simulated light freezing rain at the NRC. The results of these tests are shown below.

a) *For the outdoor test:*

Location:	Montreal P.E.T. Airport
Precipitation:	Natural Light Freezing Rain
Precipitation Rate:	20 g/dm²/h
Calibrated MVD:	1.0 mm

b) *For the indoor test:*

Location:	National Research Council
Precipitation:	Simulated Light Freezing Rain
Precipitation Rate:	25 g/dm²/h
Calibrated MVD:	1.0 mm

The MVD for both natural and simulated light freezing rain was 1 mm, indicating that the NRC produced droplets simulate natural precipitation.
As a result of this testing, the MVDs for freezing precipitation testing were established as follows:

- Freezing Fog, high precipitation rate (5 g/dm²/h): 30 μm
- Freezing Fog, low precipitation rate (2 g/dm²/h): 30 μm
- Freezing Drizzle, high precipitation rate (13 g/dm²/h): 350 μm
- Freezing Drizzle, low precipitation rate (5 g/dm²/h): 250 μm
- Light Freezing Rain, high precipitation rate (25 g/dm²/h): 1,000 μm
- Light Freezing Rain, low precipitation rate (13 g/dm²/h): 1,000 μm
- Rain on Cold-Soaked Surface, low precipitation rate (5 g/dm²/h): 250 μm
- Rain on Cold-Soaked Surface, high precipitation rate (75 g/dm²/h): 1,400 μm

2.7 Summary of Freezing Precipitation Test Conditions

The precipitation types/rates, ambient temperatures and droplet sizes for freezing precipitation testing with Type II/IV fluids were described in the previous subsections. In summary, freezing precipitation tests are carried out under each of the 16 weather conditions listed in Table 2.3.

Table 2.3: Summary of Freezing Precipitation Test Conditions (Type II/IV Fluids)

Precipitation Type	Ambient Temperature	Precipitation Rate (Droplet Size)
Freezing Fog	-3°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-14°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-25°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
Freezing Drizzle	-3°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
	-10°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
Light Freezing Rain	-3°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
	-10°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
Rain on Cold-Soaked Surface	+1°C	5 g/dm²/h (250 μm)
		75 g/dm²/h (1,400 μm)

2.8 Analysis Methodology

A multi-variable regression procedure is used to derive fluid-specific holdover times for Type II/IV fluids. The procedure is based on the refinement of an equation for a curve which best represents the test data, and then solving that equation at the upper and lower limits established for the precipitation type. These precipitation rate limits, set by the SAE G-12 HOT Committee and detailed in ARP5485, were described in Subsection 0. This approach was developed in the winter of 1996-97 (see TC report, TP 13131E) and has since been used to derive fluid holdover times. There are some differences in the way the methodology is applied to freezing precipitation and natural snow data.

2.8.1 Freezing Precipitation Data

For each related freezing precipitation HOT table cell, four tests are conducted at the most restrictive (lowest) temperature in the temperature range for that cell: two tests at the low precipitation rate limit and two tests at the high precipitation rate limit (limits are detailed in Subsection 0). The equation used to treat freezing precipitation data is:

- $t = 10^{I}R^{a}$, where

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.2 Natural Snow Data

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural snow tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather data under all temperatures and precipitation rates encompassed by the HOT tables.

The general form of the regression equation is modified for natural snow to incorporate the variable of temperature and also to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C. The equation used to treat natural snow data is:

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

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a, b = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, using the most restrictive (lowest) temperature for that cell. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.3 Natural Frost Data

Regression analysis is not used in the determination of frost holdover times. The current Type II/III/IV generic frost holdover times were determined based on several years of testing using all fluids which were commercially available at the time. A "minimum values" analysis methodology was used to determine appropriate holdover times from the test data.

The purpose of natural frost testing with new fluids is to verify the fluids can be used with the generic frost holdover times. The analysis methodology is to compare the frost test data collected with the new fluid to the current generic holdover times. If the test data provides holdover times equal to or greater than the generic holdover times then the generic holdover times have been validated for the new fluid.

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural frost tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather several data points with each fluid/dilution.

2.8.4 Rounding and Capping Protocols

Regression-generated holdover times are subject to rounding and capping protocols. For Type II/IV fluids they are as follows:

- Rounding Protocol: Holdover times are rounded to the nearest whole "5" minute, i.e. 55.1 to 57.4 minutes is rounded down to 55 minutes; 57.5 to 59.9 minutes is rounded up to 60 minutes. In cases where the regression-generated holdover times are below 10 minutes, the numbers are rounded down to the nearest whole minute as a precautionary measure. For example, 9.6 minutes is rounded down to 9 minutes.

- Capping Protocol: All holdover time values are capped at maximum values. The caps differ by precipitation type, and in the case of snow, by regulator. The caps are as follows:
  - Freezing Fog holdover time values are capped at 4 hours;
  - Freezing Drizzle, Light Freezing Rain, Rain on Cold Soaked Wing holdover times are capped at 2 hours; and
  - Snow holdover times are capped at 2 hours by Transport Canada and 3 hours by FAA.

2.8.5 Regression Example

Sample plots of **Log t** versus **Log R** are shown in Figure 2.8. The plots contain data for one Neat Type IV fluid, in one temperature range (-10°C), in light freezing rain conditions. The best-fit regression line is superimposed onto the plot and was obtained from the analysis using the lowest temperature in the temperature range from which the data were chosen.

The same data plotted on a linear scale (failure time **t** versus precipitation rate **R**) are shown in Figure 2.9. The curve, generated from the power law form of the equation using the coefficients determined from the fit, is superimposed onto the plot. The HOT range is determined from the intersections of the curve with the precipitation rate limits defined for light freezing rain.

The holdover times for this fluid at -10°C are 20 minutes at 13 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid in the light freezing rain, neat fluid, below -3 to -10°C cell. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

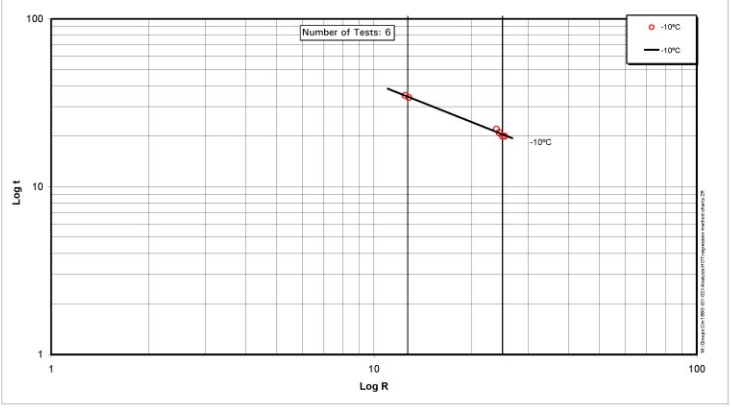


Figure 2.8: Regression Method on Log-Log Chart – Type IV Neat, Freezing Rain

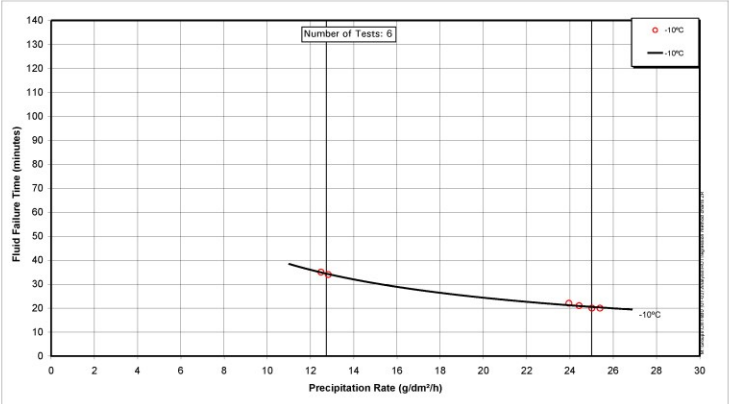


Figure 2.9: Regression Method on Standard Chart – Type IV Neat, Freezing Rain

2.8.6 Lowest Usable Precipitation Rates in Snow

A detailed analysis methodology was developed to determine if a snow data set is sufficient to determine holdover times for light and very light snow. Specifically, the analysis determines the lowest usable precipitation rate (LUPR), which is the lowest rate at which the data set is considered robust.

The methodology is a five-factor weighted analysis. The five factors are:

1. Total number of data points;
2. Number of data points with air temperatures below -3°C;
3. Number of data points with precipitation rates below 10 g/dm²/h;
4. Number of data points with precipitation rates less than or equal to 0.5 g/dm²/h above the precipitation rate being examined; and
5. Scatter from regression curve of low precipitation rate data points (average absolute percent difference between fail time and regression calculated fail time for all points less than or equal to 10 g/dm²/h).

The weights given to each of the five factors are:

1. Total Data Points = 5%;
2. Data Points Below -3°C = 20%;
3. Data Points Below 10 g/dm²/h = 20%;
4. Data Points ≤ Precipitation Rate = 40%; and
5. Low Rate Data Scatter = 15%.

Each data set is given a score of 0, 10, 20, 30 or 40 for each factor. The scoring system is shown in Table 2.4.

This approach provides a score for each data set for each precipitation rate below 10 g/dm²/h. The scores are compared to the minimum acceptance scores:

- 100/0 = 28
- 75/25 = 28
- 50/50 = 19 (lower due to a 0 score for data points below -3°C)

The LUPR is the lowest precipitation rate at which a data set has a passing score.

Table 2.4: LUPR Factor Scoring System

Factor #1: Total Data Points (Weight = 5%)	
Rating = 40	≥20 data points in data set
Rating = 30	15-19 data points in data set
Rating = 20	10-14 data points in data set
Rating = 10	5-9 data points in data set
Rating = 0	<5 data points in data set

Factor #2: Data Points Below -3°C (Weight = 20%)	
Rating = 40	≥15 data points from -3 to -14°C
Rating = 30	12-14 data points -3 to -14°C
Rating = 20	9-11 data points -3 to -14°C
Rating = 10	6-8 data points -3 to -14°C
Rating = 0	<6 data points -3 to -14°C

Factor #3: Data Points Below 10 g/dm²/h (Weight = 20%)	
Rating = 40	≥10 data points <10 g/dm²/h
Rating = 30	7-9 data points <10 g/dm²/h
Rating = 20	5-6 data points <10 g/dm²/h
Rating = 10	3-4 data points <10 g/dm²/h
Rating = 0	<3 data points <10 g/dm²/h

Factor #4: Data Points ≤ Precipitation Rate (Weight = 40%)	
Rating = 40	≥3 data points ≤ rate limit +0.5
Rating = 30	2 data points ≤ rate limit +0.5
Rating = 20	1 data points ≤ rate limit +0.5
Rating = 10	n/a
Rating = 0	0 data points ≤ rate limit +0.5

Factor #5: Low Rate Data Scatter (Weight = 15%)	
Rating = 40	Average actual-calculated error <10%
Rating = 30	Average actual-calculated error 10-19%
Rating = 20	Average actual-calculated error 20-29%
Rating = 10	Average actual-calculated error 30-39%
Rating = 0	Average actual-calculated error ≥40%

Photo 2.1: APS Test Site - View from Test Pad



Photo 2.2: APS Test Site - View from Trailer



Photo 2.3: Outdoor View of NRC Climatic Engineering Facility



Photo 2.4: Inside View of NRC Climatic Engineering Facility

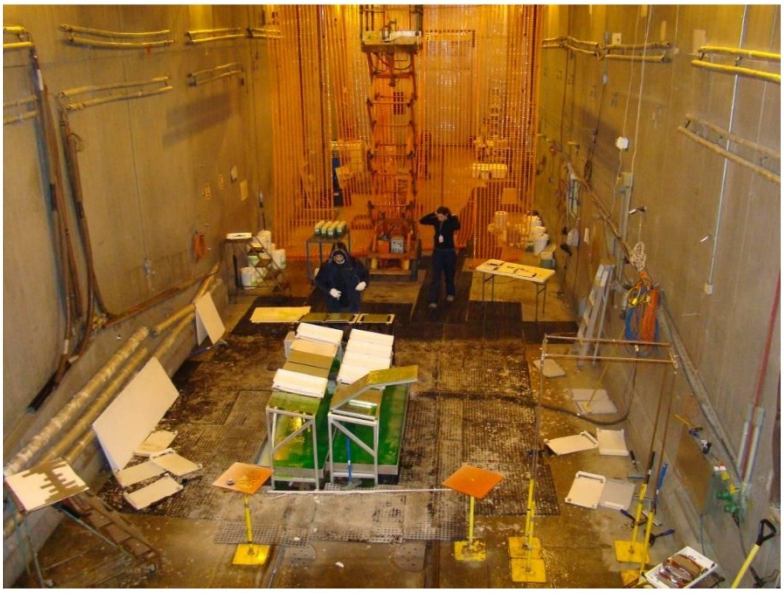


Photo 2.5: Test Plates Mounted on Stand

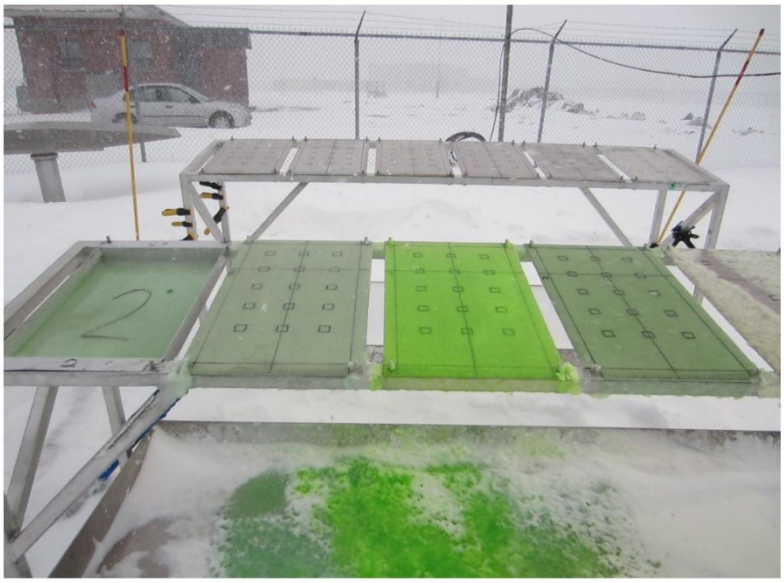


Photo 2.6: Cold-Soak / Leading Edge Thermal Equivalent Box

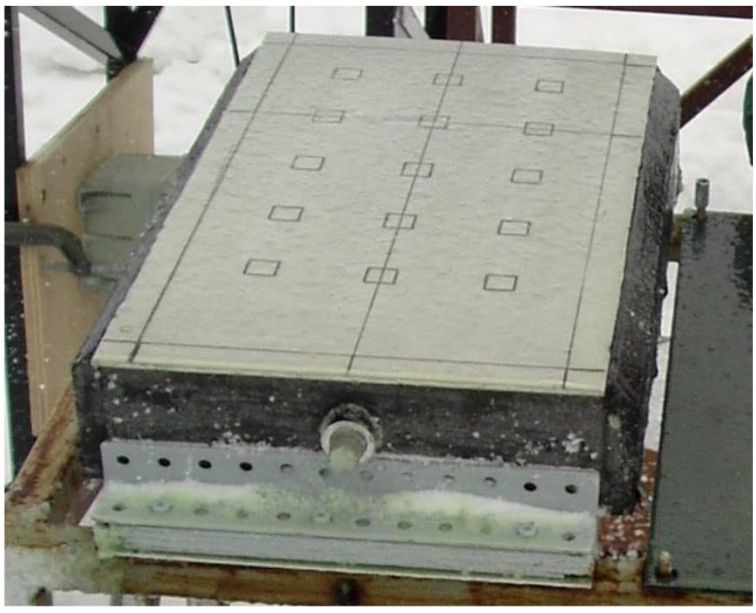


Photo 2.7: Frost Plate with Insulated Backing



Photo 2.8: Collection Pans Used Indoors at the NRC



Photo 2.9: Sprayer Assembly



Photo 2.10: Sprayer Assembly in Use

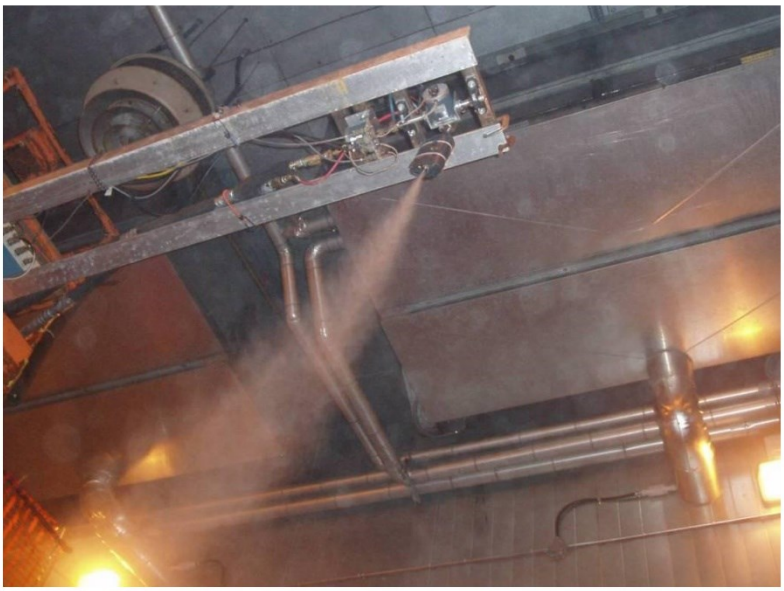


Photo 2.11: Sprayer Nozzle

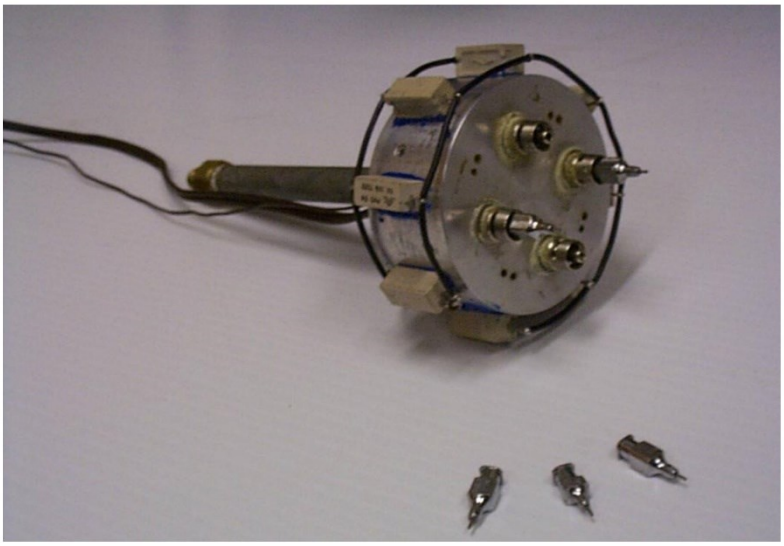
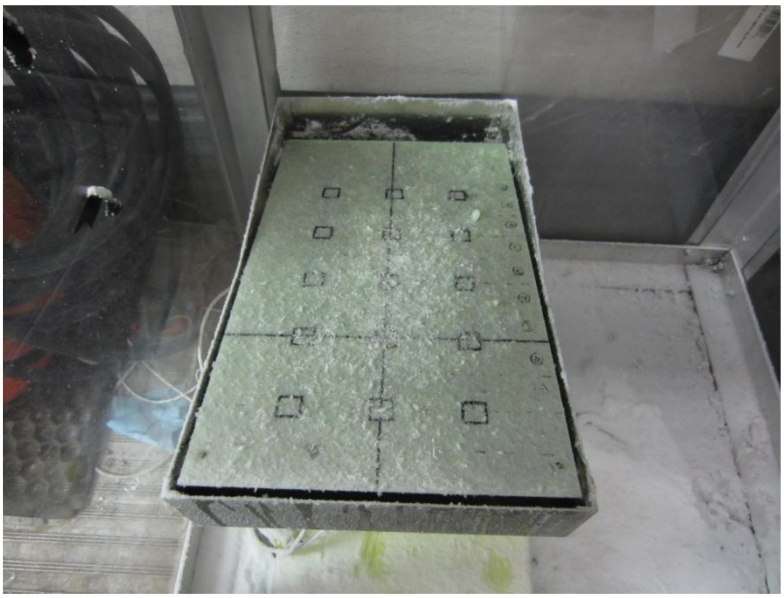


Photo 2.12: Standard Plate Setup for Testing with Artificial Snowmaker



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted. Breakdowns are provided for the number of tests performed by test type, precipitation type, fluid dilution and test temperature.

3.1 Natural and Artificial Snow Tests

Tests were conducted in natural snow conditions at the APS test site and at several mobile test sites (see Subsection 2.1.1). No artificial snow tests were conducted. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

Fluid Dilution	Natural Snow			Artificial Snow		
	≥ -3°C	-3 to -14°C	<-14°C	-3°C	-14°C	-25°C
Neat	13	9	1	0	0	0
75/25	11	12	0	0	0	0
50/50	15	1	0	0	0	0

3.2 Freezing Precipitation Tests

Tests were conducted in freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface conditions at the NRC CEF. The number of tests conducted is summarized below by precipitation type, fluid dilution and test temperature.

Fluid Dilution	Freezing Drizzle		Light Freezing Rain		Freezing Fog			Cold Soak
	-3°C	-10°C	-3°C	-10°C	-3°C	-14°C	-25°C	+1°C
Neat	4	4	4	4	4	4	4	4
75/25	4	4	4	4	4	4	0	4
50/50	4	0	4	0	4	0	0	0

3.3 Natural Frost Tests

Tests were conducted in natural frost at the APS test site. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

Fluid Dilution	Natural Frost			
	≥-1°C	<-1 to -3°C	<-3 to -10°C	<-10°C
Neat	0	0	1	1
75/25	0	0	1	1
50/50	1	0	1	0

3.4 Fluid Thickness Tests

Fluid thickness tests were conducted to measure the film thickness profiles of the fluid under dry conditions. Two tests were performed for each dilution. For each test, 1 litre of fluid was poured onto a flat plate mounted on a test stand inclined by 10°. Thickness measurements were taken at the 15-cm (6″) line at select time intervals over a 30-minute period. Tests were conducted at -3°C.

3.5 Test Logs

Details of each test conducted are provided in the test logs included as Table 3.1 (snow) Table 3.2 (freezing precipitation), and Table 3.3 (frost).

Table 3.1: Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
251	19-Feb-15	Natural Snow	ABC-Ice Clear II	100%	-15.7	6.9	39.3
252	19-Feb-15	Natural Snow	ABC-Ice Clear II	75%	-15.7	7.0	28.8
253	21-Feb-15	Natural Snow	ABC-Ice Clear II	75%	-9.2	8.8	31.5
254	21-Feb-15	Natural Snow	ABC-Ice Clear II	100%	-9.2	7.9	51.1
255	21-Feb-15	Natural Snow	ABC-Ice Clear II	75%	-8.8	5.3	47.3
256	21-Feb-15	Natural Snow	ABC-Ice Clear II	100%	-8.8	5.4	65.6
257	21-Feb-15	Natural Snow	ABC-Ice Clear II	75%	-8.2	7.4	38.0
258	21-Feb-15	Natural Snow	ABC-Ice Clear II	100%	-8.2	7.6	58.3
263	21-Feb-15	Natural Snow	ABC-Ice Clear II	100%	-9.0	2.7	124.9
264	21-Feb-15	Natural Snow	ABC-Ice Clear II	75%	-8.6	3.3	79.9
265	3-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-5.1	15.1	18.7
266	3-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-5.5	14.6	34.5
271	3-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-5.1	15.2	5.7
273	3-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-5.5	17.2	21.1
277	3-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-5.9	26.5	16.9
283	3-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-5.8	9.6	53.2
287	3-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-5.8	8.6	48.8
290	3-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-5.7	16.3	19.9
295	3-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-5.5	13.2	42.1
299	3-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-5.5	12.1	35.6
307	3-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-5.0	6.2	85.2
321	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-1.5	18.3	47.6
322	14-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-1.5	17.3	35.9
323	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-1.5	9.6	22.8
330	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-1.7	25.4	14.1
335	14-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-1.9	21.0	32.7
336	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-1.9	21.4	45.5
345	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-2.1	18.2	42.0
348	14-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-2.4	15.0	34.4
352	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-2.4	12.7	30.5
353	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-2.4	24.5	10.2
356	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-2.7	29.5	8.3
358	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-2.8	13.7	57.0
359	14-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-2.8	13.5	42.0
360	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-2.8	8.2	17.0
364	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-3.0	26.0	24.0

Table 3.1 (cont'd): Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
366	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-3.0	38.8	18.0
367	14-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-3.0	27.1	20.0
368	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-2.9	13.4	24.0
374	14-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-3.0	40.2	14.0
375	14-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-3.0	50.3	7.0
376	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-3.0	26.7	8.0
378	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-3.0	48.7	14.0
380	14-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-3.0	47.8	11.0
381	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-3.0	37.2	5.0
383	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-3.0	44.7	15.0
384	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-2.9	48.5	4.0
385	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-2.9	50.3	15.0
386	14-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-3.0	47.0	11.0
387	14-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-2.9	51.3	3.0
389	14-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-2.9	47.4	11.0
390	17-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-0.1	0.1	103.8
409	21-Mar-15	Natural Snow	ABC-Ice Clear II	100%	-0.1	2.3	156.0
410	21-Mar-15	Natural Snow	ABC-Ice Clear II	75%	-0.1	2.7	109.8
411	21-Mar-15	Natural Snow	ABC-Ice Clear II	50%	-0.8	3.0	32.8
413	21-Mar-15	Natural Snow	ABC-Ice Clear II	50%	0.3	2.7	51.0
419	4-Apr-15	Natural Snow	ABC-Ice Clear II	50%	-3.5	16.6	14.0
422	4-Apr-15	Natural Snow	ABC-Ice Clear II	100%	-3.5	13.9	34.0
423	4-Apr-15	Natural Snow	ABC-Ice Clear II	50%	-2.7	2.9	32.5
425	4-Apr-15	Natural Snow	ABC-Ice Clear II	75%	-3.5	13.2	24.0
438	8-Apr-15	Natural Snow	ABC-Ice Clear II	100%	0.5	6.3	96.0
439	8-Apr-15	Natural Snow	ABC-Ice Clear II	75%	0.5	6.0	83.3

Table 3.2: Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
1	1-Apr-15	Freezing Fog	ABC-Ice Clear II	100	-3.4	2.0	101.9
2	1-Apr-15	Freezing Fog	ABC-Ice Clear II	100	-3.4	2.2	102.3
7	1-Apr-15	Freezing Fog	ABC-Ice Clear II	75	-3.5	2.1	68.3
8	1-Apr-15	Freezing Fog	ABC-Ice Clear II	75	-3.5	2.0	66.3
13	1-Apr-15	Freezing Fog	ABC-Ice Clear II	50	-3.2	2.1	27.3
14	1-Apr-15	Freezing Fog	ABC-Ice Clear II	50	-3.1	2.0	27.1
21	31-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-3.7	4.8	63.2
22	31-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-3.7	4.9	63.6
25	31-Mar-15	Freezing Fog	ABC-Ice Clear II	75	-3.7	4.8	50.0
26	31-Mar-15	Freezing Fog	ABC-Ice Clear II	75	-3.7	4.9	49.4
33	31-Mar-15	Freezing Fog	ABC-Ice Clear II	50	-3.4	4.8	18.2
34	31-Mar-15	Freezing Fog	ABC-Ice Clear II	50	-3.4	4.8	17.2
65	31-Mar-15	Freezing Fog	ABC-Ice Clear II	75	-14.1	2.1	78.0
66	31-Mar-15	Freezing Fog	ABC-Ice Clear II	75	-14.1	2.0	78.4
67	31-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-14.1	2.1	94.3
68	31-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-14.1	1.9	93.1
73	31-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-14.0	5.0	43.3
74	31-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-14.1	5.1	37.8
77	31-Mar-15	Freezing Fog	ABC-Ice Clear II	75	-13.9	5.1	40.2
78	31-Mar-15	Freezing Fog	ABC-Ice Clear II	75	-14.0	5.1	38.8
83	30-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-25.2	2.2	35.1
84	30-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-25.2	2.1	36.1
93	30-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-25.0	5.2	16.7
94	30-Mar-15	Freezing Fog	ABC-Ice Clear II	100	-25.0	5.3	17.6
113	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	100	-3.1	5.0	62.0
114	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	100	-3.1	4.9	64.7
115	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	75	-3.1	5.1	45.6
116	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	75	-3.1	4.9	49.1
125	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	50	-3.1	4.8	19.8
126	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	50	-3.1	4.9	18.1
133	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	100	-3.1	12.8	38.3
134	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	100	-3.1	12.7	41.9
135	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	75	-3.2	12.5	30.4
136	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	75	-3.2	13.3	28.8
145	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	50	-3.4	12.8	10.5
146	25-Mar-15	Freezing Drizzle	ABC-Ice Clear II	50	-3.5	13.5	9.6

Table 3.2 (cont'd): Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
165R	27-Mar-15	Freezing Drizzle	ABC-Ice Clear II	100	-10.2	4.8	62.2
166R	27-Mar-15	Freezing Drizzle	ABC-Ice Clear II	100	-10.2	5.0	59.0
167	27-Mar-15	Freezing Drizzle	ABC-Ice Clear II	75	-10.1	4.8	46.2
168	27-Mar-15	Freezing Drizzle	ABC-Ice Clear II	75	-10.2	5.0	48.9
179	26-Mar-15	Freezing Drizzle	ABC-Ice Clear II	100	-10.1	13.5	26.0
180	26-Mar-15	Freezing Drizzle	ABC-Ice Clear II	100	-10.1	13.3	26.9
183	26-Mar-15	Freezing Drizzle	ABC-Ice Clear II	75	-10.2	13.1	28.0
184	26-Mar-15	Freezing Drizzle	ABC-Ice Clear II	75	-10.2	12.8	26.5
193	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	100	-2.9	12.8	32.0
194	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	100	-2.9	13.3	35.9
195	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	75	-2.9	12.5	29.7
196	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	75	-2.9	13.1	30.1
205	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	50	-2.9	12.8	10.7
206	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	50	-2.9	13.1	10.7
209	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	100	-3.0	24.6	28.0
210	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	100	-3.0	24.4	27.0
211	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	75	-3.0	24.7	20.2
212	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	75	-2.9	25.1	21.3
221	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	50	-2.9	24.7	7.8
222	27-Mar-15	Light Freezing Rain	ABC-Ice Clear II	50	-2.9	24.4	7.9
233	26-Mar-15	Light Freezing Rain	ABC-Ice Clear II	100	-10.5	13.2	30.8
234	26-Mar-15	Light Freezing Rain	ABC-Ice Clear II	100	-10.5	13.0	30.1
237	26-Mar-15	Light Freezing Rain	ABC-Ice Clear II	75	-10.6	12.9	20.2
238	26-Mar-15	Light Freezing Rain	ABC-Ice Clear II	75	-10.6	13.0	18.1
249	26-Mar-15	Light Freezing Rain	ABC-Ice Clear II	100	-10.0	24.3	18.7
250	26-Mar-15	Light Freezing Rain	ABC-Ice Clear II	100	-9.9	24.4	16.9
257	26-Mar-15	Light Freezing Rain	ABC-Ice Clear II	75	-10.1	25.0	15.0
258	26-Mar-15	Light Freezing Rain	ABC-Ice Clear II	75	-10.1	24.4	14.7
265	1-Apr-15	Cold Soak Box	ABC-Ice Clear II	100	1.1	5.0	49.3
266	1-Apr-15	Cold Soak Box	ABC-Ice Clear II	100	1.1	5.2	43.3
267	1-Apr-15	Cold Soak Box	ABC-Ice Clear II	75	1.0	4.8	32.3
268	1-Apr-15	Cold Soak Box	ABC-Ice Clear II	75	0.9	5.3	39.1
281	1-Apr-15	Cold Soak Box	ABC-Ice Clear II	100	0.7	75.1	8.4
282	1-Apr-15	Cold Soak Box	ABC-Ice Clear II	100	0.7	74.7	7.3
283	1-Apr-15	Cold Soak Box	ABC-Ice Clear II	75	0.8	75.0	5.7
284	1-Apr-15	Cold Soak Box	ABC-Ice Clear II	75	0.7	73.5	5.9

Table 3.3: Summary of Tests Performed (Natural Frost)

Test No.	Date	Precip. Type	Fluid Name	Fluid Dilution	Test Duration (min.)	Average Rate (g/dm²/h)	Temp (°C)	Wind Speed (km/h)	Average RH (%)	Comments
52	15-Mar-15	Natural Frost	ABC-Ice Clear II	50%	113	0.080	-5.6	4.3	87.0	Failed
53	15-Mar-15	Natural Frost	ABC-Ice Clear II	100%	620	0.080	-8.0	3.5	89.0	Did Not Fail
57	15-Mar-15	Natural Frost	ABC-Ice Clear II	75%	619	0.080	-8.0	3.5	89.0	Did Not Fail
59	23-Mar-15	Natural Frost	ABC-Ice Clear II	100%	464	0.010	-11.3	8.3	66.6	Did Not Fail
60	23-Mar-15	Natural Frost	ABC-Ice Clear II	75%	463	0.010	-11.3	8.3	66.6	Did Not Fail
73	6-May-2015	Natural Frost	ABC-Ice Clear II	50%	180	0.160	2.3	0.0	84.7	Failed

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4. RESULTS AND DISCUSSION

The methods used to evaluate the test data were reviewed in Subsection 2.8. The results of the data analyses and a discussion of the findings are presented in this section.

4.1 Results

The results of the endurance time and thickness tests are described in this section.

4.1.1 Endurance Time Tests – Natural Snow and Freezing Precipitation

Figures 4.1 to 4.14 present the endurance time data collected in natural snow and freezing precipitation (freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface).

These figures show the effect of temperature, precipitation type and precipitation rate on fluid endurance time in the conditions encompassed by the Type II HOT guidelines. The figures include the current Type II generic holdover times for comparative purposes.

Multi-variable regression analysis was performed on these data sets as described in Subsection 2.8. Table 4.1 provides the outputs from the multi-variable regression analyses. These outputs were used to derive fluid-specific holdover times for all conditions encompassed by Type II fluid-specific HOT tables. One exception is the coldest temperature band snow cells (see Subsection 4.2.2).

4.1.2 Endurance Time Tests – Natural Frost

The natural frost data was presented in Table 3.3. The test durations were compared to the Type II generic holdover times. Tests that were not completed (due to active frost ending before fluid failure could occur) surpassed the generic holdover times. This analysis indicates the Type II generic frost holdover times can be considered substantiated for Kilfrost ABC-Ice Clear II.

4.1.3 Fluid Thickness Tests

Figure 4.15 shows the fluid thickness test data. As described in Subsection 3.4, two tests were conducted at an ambient temperature of -3°C. The final fluid thicknesses are displayed in Figure 4.16.

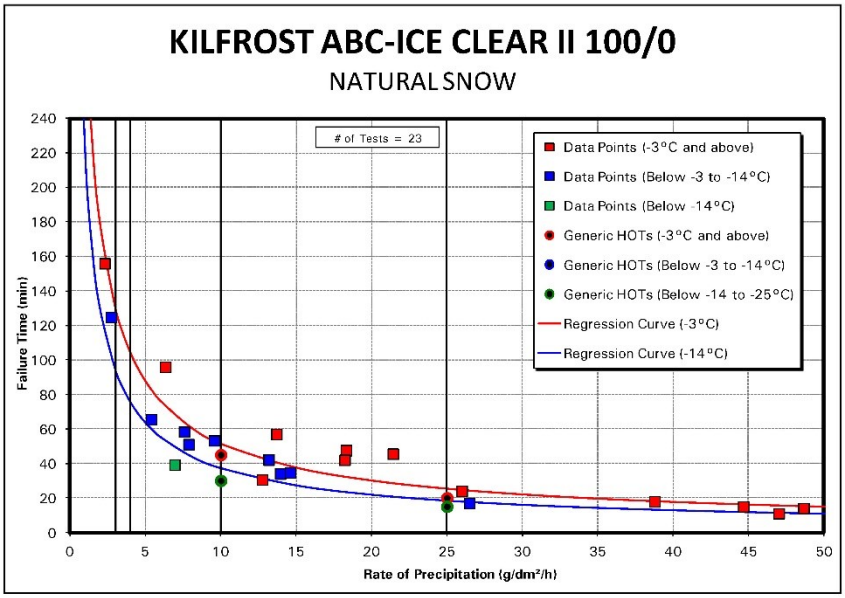

Figure 4.1: Type II Neat – Natural Snow

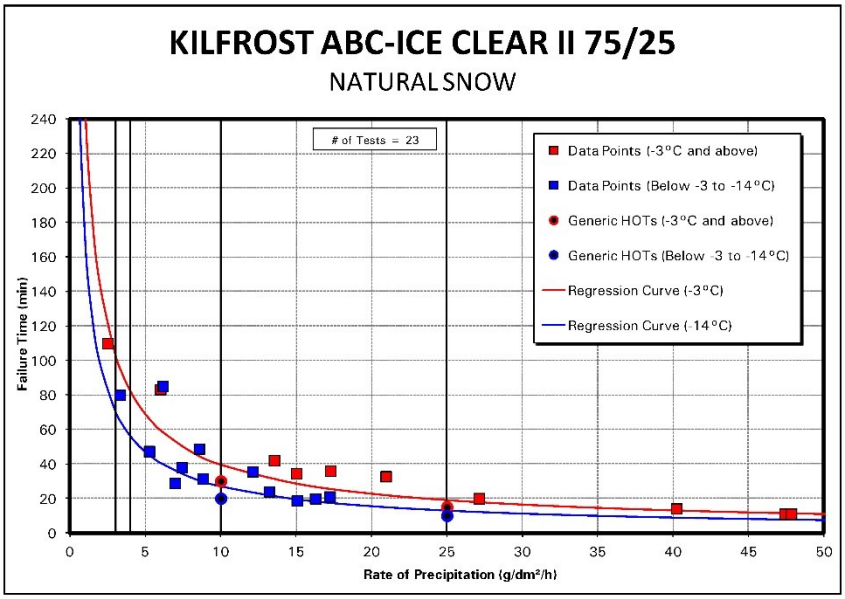

Figure 4.2: Type II 75/25 – Natural Snow

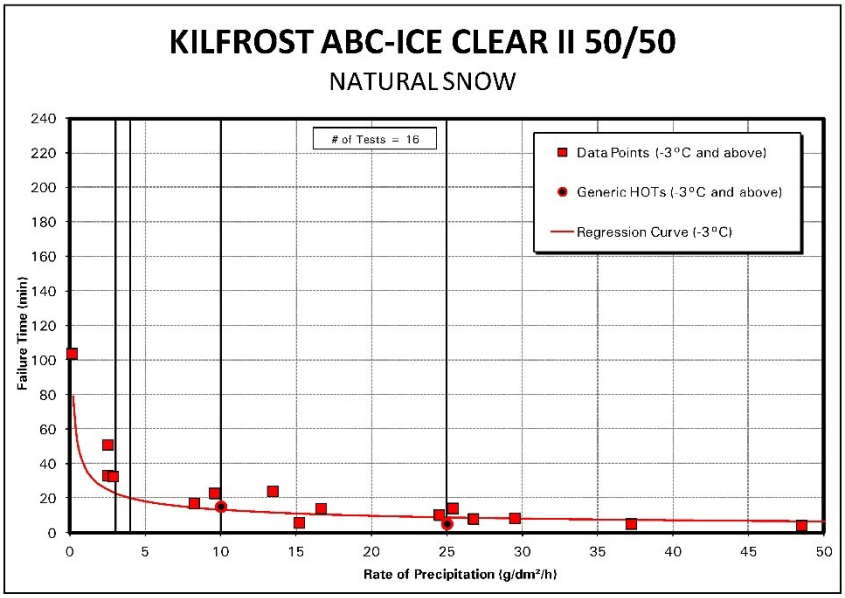

Figure 4.3: Type II 50/50 – Natural Snow

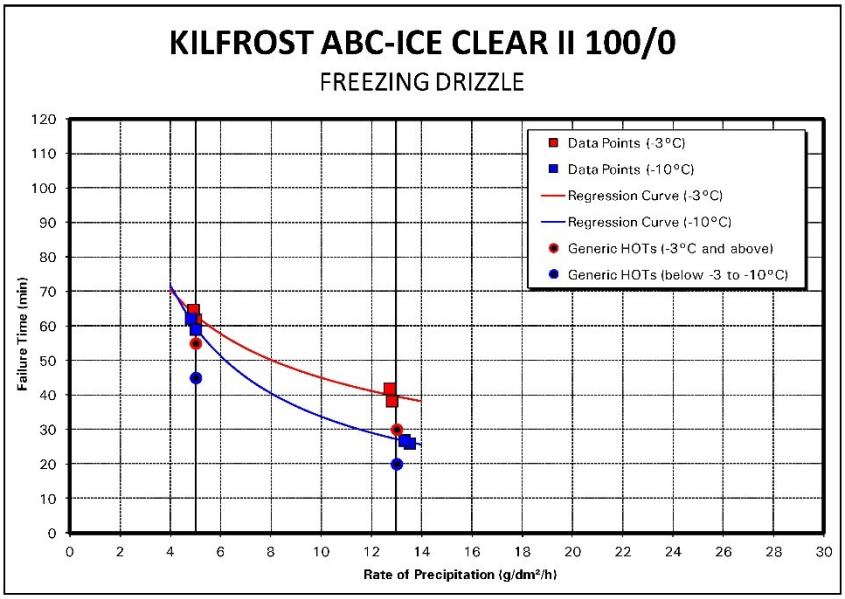

Figure 4.4: Type II Neat – Freezing Drizzle

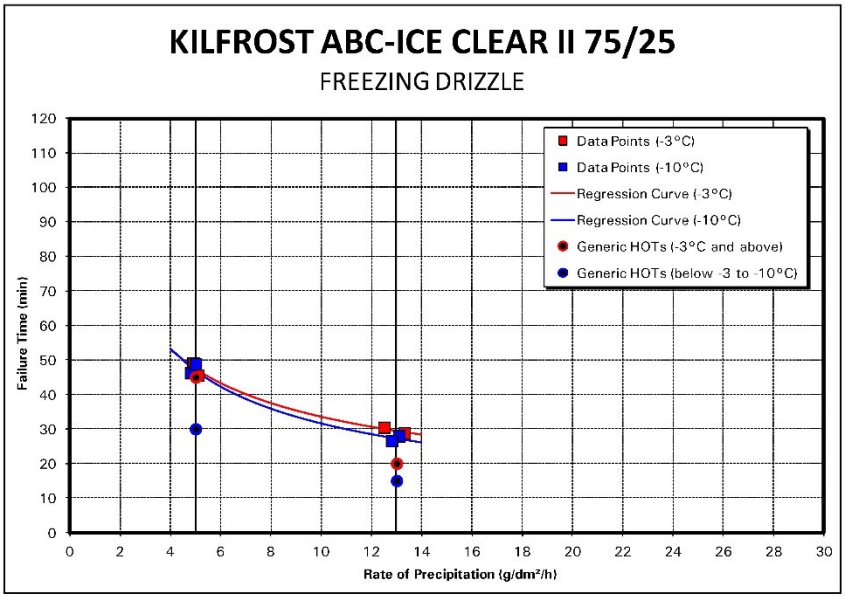

Figure 4.5: Type II 75/25 – Freezing Drizzle

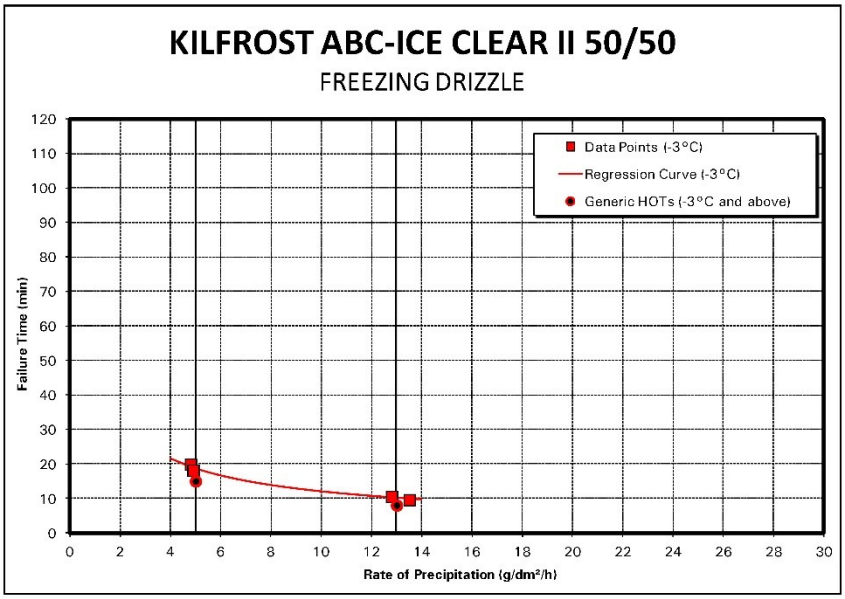

Figure 4.6: Type II 50/50 – Freezing Drizzle

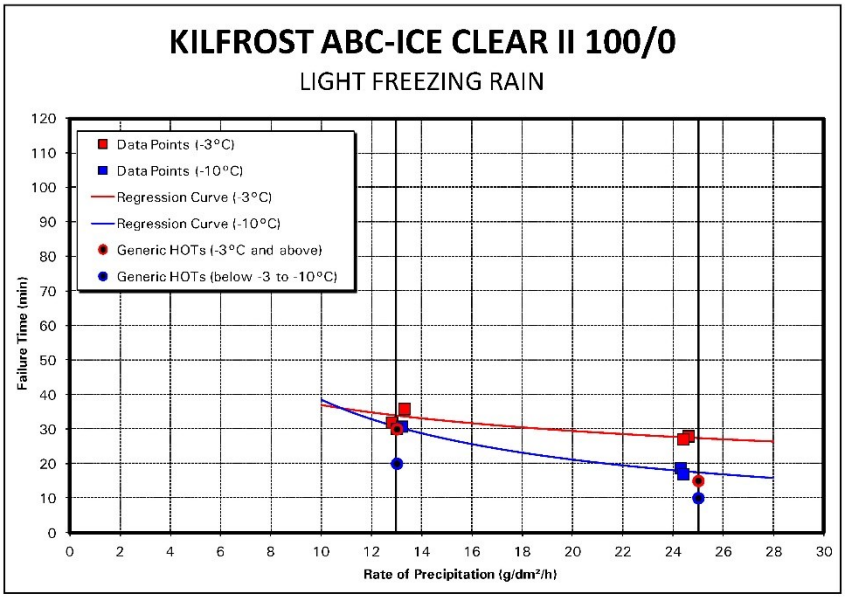

Figure 4.7: Type II Neat – Light Freezing Rain

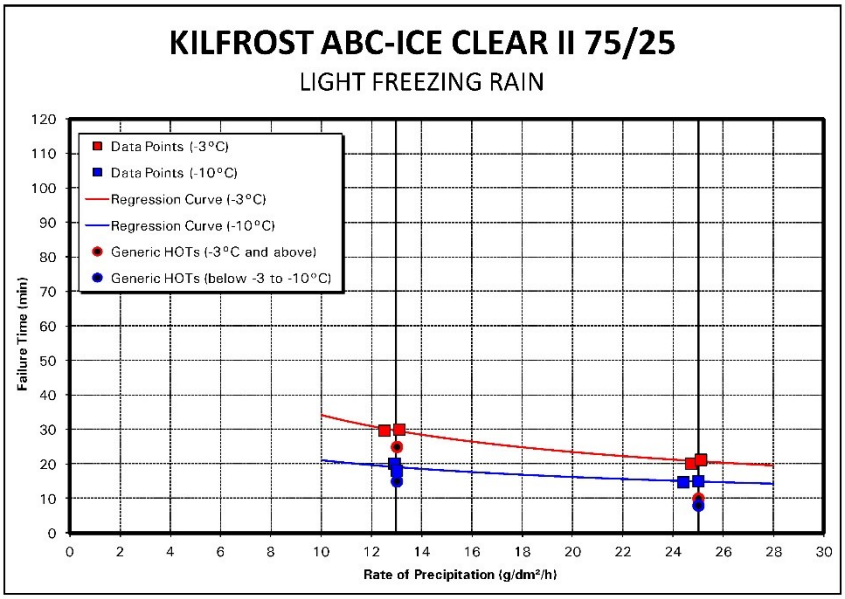

Figure 4.8: Type II 75/25 – Light Freezing Rain

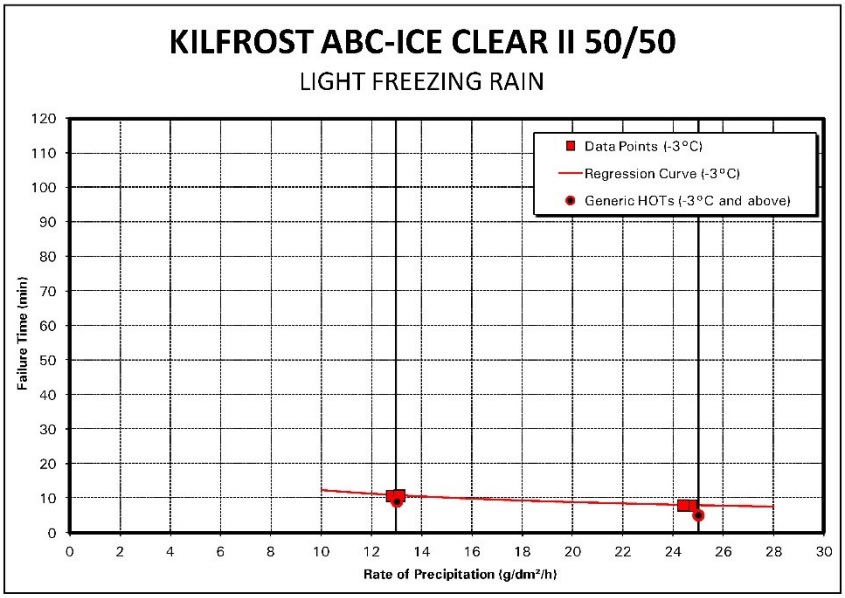

Figure 4.9: Type II 50/50 – Light Freezing Rain

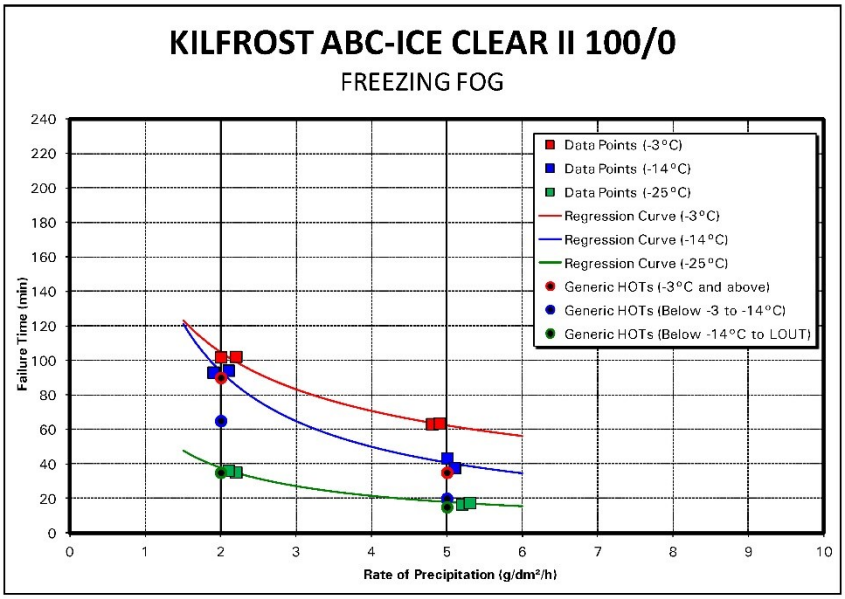

Figure 4.10: Type II Neat – Freezing Fog

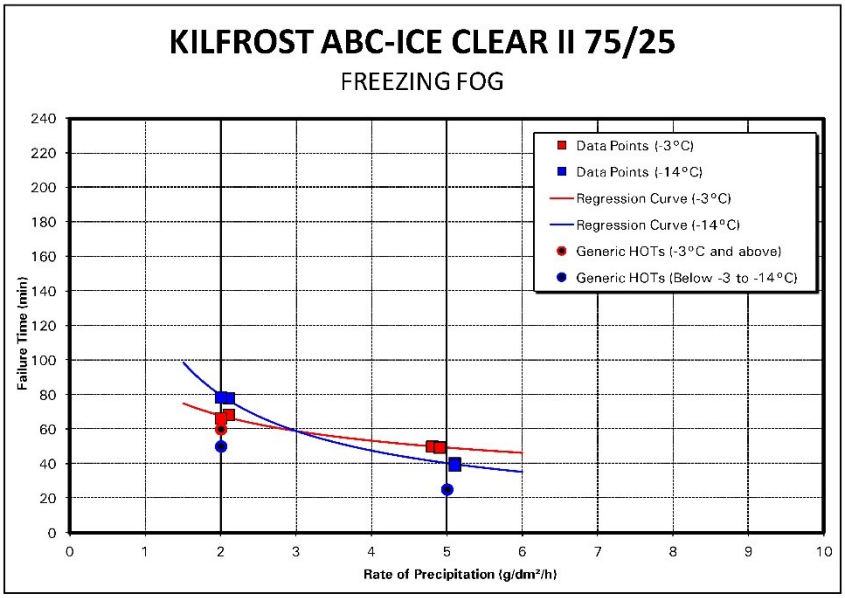

Figure 4.11: Type II 75/25 – Freezing Fog

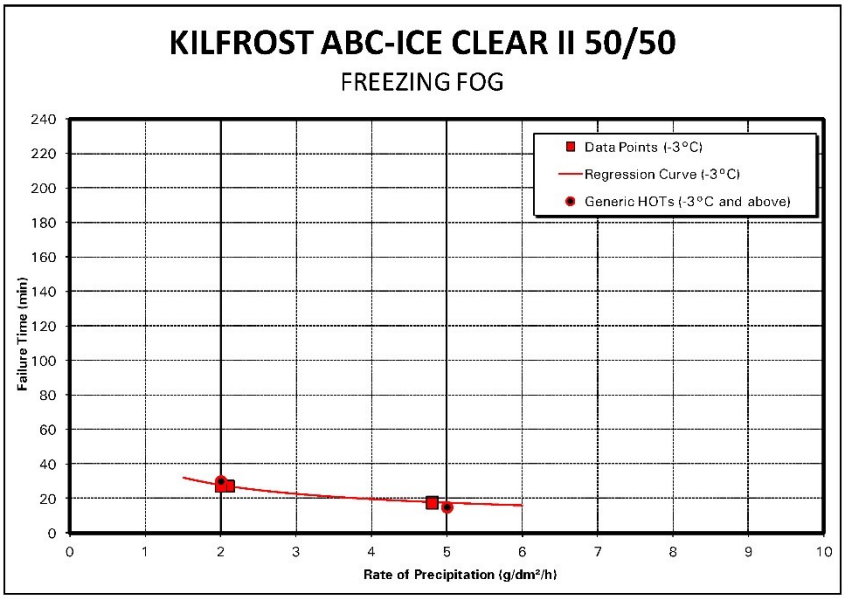

Figure 4.12: Type II 50/50 – Freezing Fog

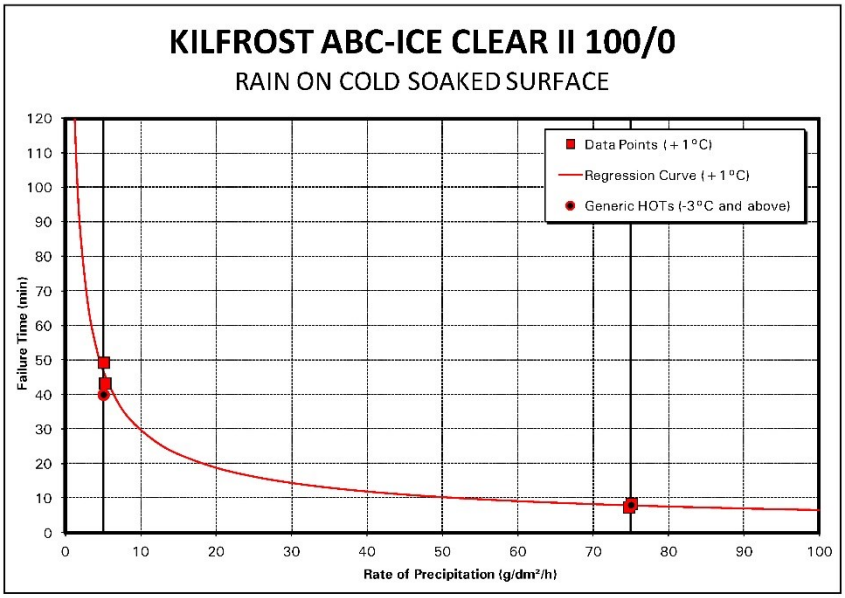

Figure 4.13: Type II Neat – Rain on Cold-Soaked Surface

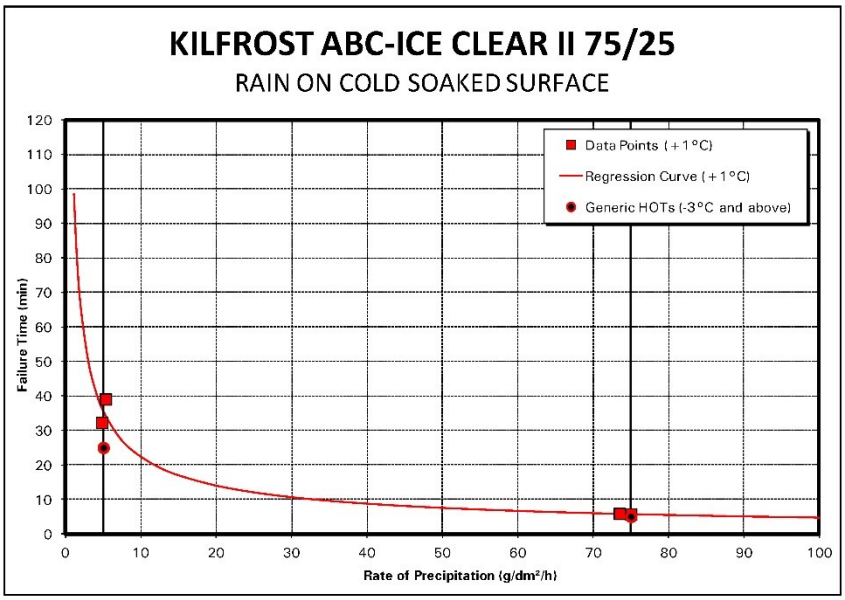

Figure 4.14: Type II 75/25 – Rain on Cold-Soaked Surface

Table 4.1: Regression Equation Coefficients for Kilfrost ABC-Ice Clear II

Natural Snow

Fluid	Dil	R^2	Intercept (I)	Coeff. Rate (A)	Coeff. Tem (B)	Total Pts.
Kilfrost ABC-Ice Clear II	Neat	92%	2.6781	-0.7750	-0.2769	23
Kilfrost ABC-Ice Clear II	75%	89%	2.6264	-0.8000	-0.3280	23
Kilfrost ABC-Ice Clear II	50%	83%	1.9548	-0.4632	-0.5448	16

General Equation $t = 10^{I} R^{A} (2\text{-}T)^{B}$

Simulated Freezing Fog

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-Ice Clear II	Neat	-3°C	99%	2.1900	-0.5648	4
Kilfrost ABC-Ice Clear II	75/25	-3°C	99%	1.9366	-0.3504	4
Kilfrost ABC-Ice Clear II	50/50	-3°C	99%	1.5907	-0.5021	4
Kilfrost ABC-Ice Clear II	Neat	-14°C	98%	2.2416	-0.9015	4
Kilfrost ABC-Ice Clear II	75/25	-14°C	100%	2.1257	-0.7471	4
Kilfrost ABC-Ice Clear II	Neat	-25°C	100%	1.8242	-0.8203	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-Ice Clear II	Neat	-3°C	98%	2.1391	-0.4856	4
Kilfrost ABC-Ice Clear II	75/25	-3°C	99%	2.0223	-0.4964	4
Kilfrost ABC-Ice Clear II	50/50	-3°C	99%	1.7170	-0.6398	4
Kilfrost ABC-Ice Clear II	Neat	-10°C	100%	2.3510	-0.8239	4
Kilfrost ABC-Ice Clear II	75/25	-10°C	98%	2.0701	-0.5702	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-Ice Clear II	Neat	-3°C	83%	1.8902	-0.3241	4
Kilfrost ABC-Ice Clear II	75/25	-3°C	98%	2.0814	-0.5477	4
Kilfrost ABC-Ice Clear II	50/50	-3°C	100%	1.5657	-0.4822	4
Kilfrost ABC-Ice Clear II	Neat	-10°C	98%	2.4513	-0.8666	4
Kilfrost ABC-Ice Clear II	75/25	-10°C	91%	1.7116	-0.3870	4

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-Ice Clear II	Neat	+1°C	99%	2.1321	-0.6607	4
Kilfrost ABC-Ice Clear II	75%	+1°C	99%	2.0217	-0.6724	4

General Equation $t = 10^{I} R^{A}$

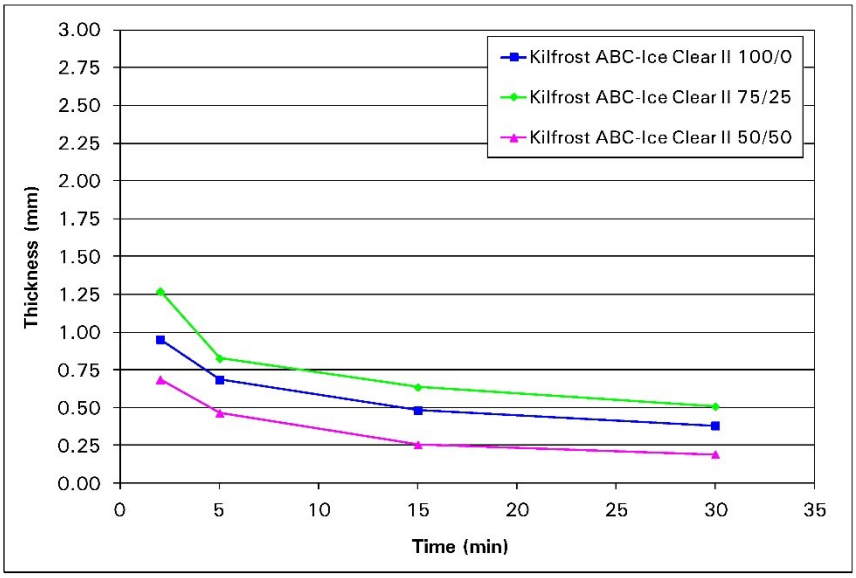

Figure 4.15: Fluid Thickness Profiles of Kilfrost ABC-Ice Clear II

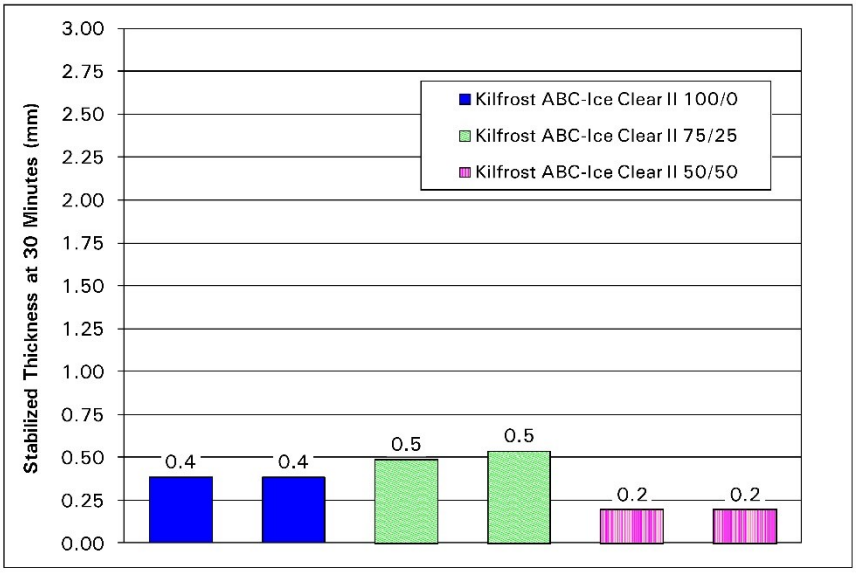

Figure 4.16: Final Fluid Thickness of Kilfrost ABC-Ice Clear II

4.2 Discussion

4.2.1 Holdover Time Table

The holdover times described in Subsection 4.1 were used to populate a fluid-specific HOT table for Kilfrost ABC-Ice Clear. The HOT table is shown in both the TC format (Table 4.2) and FAA format (Table 4.3) at the end of this chapter.

4.2.2 Holdover Times in Snow, Below -14°C to LOUT

Very little endurance time data has been collected in natural snow at temperatures below -14°C. In the winter of 2003-04, testing was conducted with artificial snowmakers to collect additional data below -14°C. As a result of this testing, it was decided all Type II/IV fluids would be given generic values in the "Below -14 to LOUT" snow cells. Accordingly, Kilfrost ABC-Ice Clear II has been given generic values in the "Below -14°C to LOUT" snow cells.

4.2.3 Holdover Times in Frost

It should be noted that frost holdover times are not included in the fluid-specific HOT tables. This is due to a decision made by TC and the FAA in May 2009 to move frost holdover times from the generic and fluid-specific HOT tables to a separate frost HOT table. Accordingly, frost holdover times have not been included in the Kilfrost ABC-Ice Clear II fluid-specific HOT table.

4.2.4 Fluid Viscosity

The viscosities of the fluid samples used in this testing were measured using both the AS 9968 method and the manufacturer's designated method. The APS measured viscosities appear at the beginning of this document and will be published as the lowest on-wing viscosity (LOWV) values for the fluid. In order for the fluid-specific holdover times provided in this document to be valid, operators must ensure that the viscosity of the fluid being used is equal or greater than the published LOWV.

4.2.5 Lowest Operational Use Temperatures (LOUTs)

The LOUT for Type II/III/IV fluids is determined by the higher of:

- The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
- The actual freezing point of the fluid plus its freezing point buffer of 7°C (13°F).

For fluid dilutions, the LOUT may also be limited by the coldest temperature for which holdover times are published (-3°C for 50/50; -14°C for 75/25).

The aerodynamic acceptance and freezing point information for this fluid is provided at the beginning of this document. The LOUTs for Kilfrost ABC-Ice Clear II are:

- 100/0: -29.5°C (-21.1°F)
- 75/25: -14°C (7°F)
- 50/50: -3°C (27°F)

4.2.6 Lowest Usable Precipitation Rates in Snow

The LUPRs for Kilfrost ABC-Ice Clear were determined by analysing the natural snow data sets using the analysis methodology described in Subsection 2.8.6. The resulting statistics are shown in Table 4.4. The analysis determined the LUPRs for Kilfrost ABC-Ice Clear II are:

- 100/0 = 3 g/dm²/h;
- 75/25 = 3 g/dm²/h; and
- 50/50 = 2 g/dm²/h.

4.2.7 Publication of Holdover Times

As Kilfrost intends to commercialize ABC-Ice Clear II, TC and FAA will publish its fluid-specific HOT table in their 2015-16 Holdover Time Guidelines. The guidelines will also include the LOWV and LOUT information; the LUPR data will be published in the related TC and FAA Regression Information documents.

Table 4.2: Fluid Specific Holdover Time Guidelines – Kilfrost ABC-Ice Clear II (Transport Canada Format)

TABLE 2-K-ABC-IC

TYPE II FLUID HOLDOVER TIME GUIDELINES[1]
KILFROST ABC-ICE CLEAR II

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

Outside Air Temperature[2]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:00 – 1:45	1:45	0:50 – 1:45	0:25 – 0:50	0:40 – 1:05	0:25 – 0:35	0:07 – 0:45	
		75/25	0:50 – 1:10	1:20	0:40 – 1:20	0:20 – 0:40	0:30 – 0:45	0:20 – 0:30	0:05 – 0:35	
		50/50	0:15 – 0:30	0:20	0:15 – 0:20	0:08 – 0:15	0:10 – 0:20	0:07 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40 – 1:35	1:15	0:35 – 1:15	0:20 – 0:35	0:25 – 1:00[8]	0:15 – 0:30[8]		
		75/25	0:40 – 1:20	0:55	0:25 – 0:55	0:15 – 0:25	0:25 – 0:45[8]	0:15 – 0:20[8]		
below -14 to -29.5	below 7 to -21.1	100/0	0:20 – 0:40	0:40	0:30 – 0:40	0:15 – 0:30				

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

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

Table 4.3: Fluid Specific Holdover Time Guidelines – Kilfrost ABC-Ice Clear II (FAA Format)

TABLE 2F. TYPE II HOLDOVER TIME GUIDELINES FOR KILFROST ABC-ICE CLEAR II

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:00-1:45	1:45-2:10	0:50-1:45	0:25-0:50	0:40-1:05	0:25-0:35	0:07-0:45	
		75/25	0:50-1:10	1:20-1:45	0:40-1:20	0:20-0:40	0:30-0:45	0:20-0:30	0:05-0:35	
		50/50	0:15-0:30	0:20-0:25	0:15-0:20	0:08-0:15	0:10-0:20	0:07-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40-1:35	1:15-1:35	0:35-1:15	0:20-0:35	0:25-1:00[7]	0:15-0:30[7]		
		75/25	0:40-1:20	0:55-1:10	0:25-0:55	0:15-0:25	0:25-0:45[7]	0:15-0:20[7]		
Below -14 to -29.5	Below 7 to -21.1	100/0	0:20-0:40	0:40-0:50	0:30-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4.4: LUPR Statistics – Kilfrost ABC-Ice Clear II

Data Measure	100/0		75/25		50/50	
	Stat	Rating	Stat	Rating	Stat	Rating
Total Data Points	23	40	23	40	16	30
Data Points -3 to -14°C	10	20	12	30	n/a	0
Data Points < 10.0	8	30	9	30	6	20
Data Points < = 9.5	7	40	9	40	5	40
Data Points < = 8.5	7	40	7	40	5	40
Data Points < = 7.5	5	40	7	40	4	40
Data Points < = 6.5	4	40	5	40	4	40
Data Points < = 5.5	3	40	3	40	4	40
Data Points < = 4.5	2	30	2	30	4	40
Data Points < = 3.5	2	30	2	30	4	40
Data Points < = 2.5	1	20	1	20	3	40
Scatter 0-10 g	11%	30	19%	30	30%	10

Rate	100/0		75/25		50/50	
	Score	Pass/Fail	Score	Pass/Fail	Score	Pass/Fail
9 g/dm²/h	33	pass	35	pass	23	pass
8 g/dm²/h	33	pass	35	pass	23	pass
7 g/dm²/h	33	pass	35	pass	23	pass
6 g/dm²/h	33	pass	35	pass	23	pass
5 g/dm²/h	33	pass	35	pass	23	pass
4 g/dm²/h	29	pass	31	pass	23	pass
3 g/dm²/h	29	pass	31	pass	23	pass
2 g/dm²/h	25	fail	27	fail	23	pass

LUPR	100/0	75/25	50/50
	3 g/dm²/h	3 g/dm²/h	2 g/dm²/h

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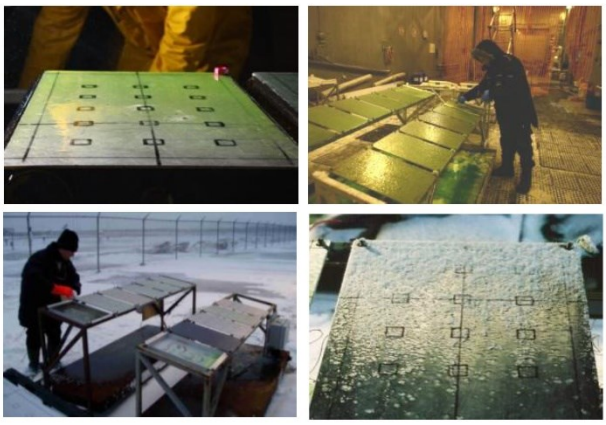
APPENDIX E

FLUID MANUFACTURER REPORT:
LNT SOLUTIONS P250 (TYPE II)

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

LNT Solutions P250 (Type II)



Prepared for

LNT Solutions

by

APS Aviation Inc.

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 2.0
Report No. L-250 2014-15

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

LNT Solutions P250 (Type II)

Prepared for

LNT Solutions

Prepared by:



Stephanie Bendickson
Project Analyst

June 26, 2015
Date

And by:



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June 26, 2015
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Reviewed by:



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Program Manager

June 26, 2015
Date

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 2.0
Report No. L-250 2014-15

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer:	LNT Solutions		
Fluid Test Name:	Type II / P250 / P250-2		
Fluid Commercial Name:	P250		
Fluid Type / Base / Colour:	Type II / Propylene Glycol / Straw		
Batch #:	C3/01/01		
Date of Receipt:	March 12, 2014		
Brix (Measured):	Neat fluid:	36.25°	
	75/25 dilution:	28.25°	
	50/50 dilution:	19.25°	
Freeze Point (Stated):	Neat fluid:	-37.0°C	
	75/25 dilution:	-21.4°C	
	50/50 dilution:	-10.6°C	
LOUT (Stated):	Neat fluid:	not provided	
	75/25 dilution:	not provided	
	50/50 dilution:	not provided	
Viscosity:	**Mfr Method[1]**	**Stated**	**Measured**
	Neat fluid:	2,400 cP	2,400 cP
	75/25 dilution:	14,700 cP	16,200 cP
	50/50 dilution:	8,400 cP	8,150 cP
	AIR 9968 Method[2]	**Stated**	**Measured**
	Neat fluid:	2,400 cP	2,150 cP
	75/25 dilution:	14,700 cP	15,200 cP
	50/50 dilution:	8,300 cP	8,100 cP
WSET (from AMIL):	Neat fluid:	78 minutes	

[1] Spindle LV2-disc with guard leg, 200 mL tall form beaker, ~155 mL of fluid, 20°C, 0.3 rpm, for 10.0 minutes
[2] Spindle LV1 with guard leg, 600 mL low form beaker, ~575 mL of fluid, 20°C, 0.3 rpm, for 10.0 minutes

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SUMMARY

The primary objective of this project was to measure the endurance time performance of **LNT Solutions P250** over the entire range of conditions encompassed by the Holdover Time (HOT) tables. This objective was met by conducting endurance time tests over the winters of 2013-14 and 2014-15.

This report contains the results of these measurements and was completed with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA). Version 1.0 of this report contained only the results of the 2013-14 testing. This report, Version 2.0, contains the results of the 2013-14 and 2014-15 testing.

Tests were carried out according to the protocol provided in Aerospace Recommended Practice (ARP) 5485. The test procedure consisted of pouring fluids onto clean aluminum test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural and simulated precipitation.

Tests were performed at the APS Aviation Inc. (APS) test facility at Montréal-Pierre-Elliott-Trudeau International Airport and the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were derived from the data collected using multi-variable regression analysis. This resulted in the generation of the fluid-specific holdover times shown in the tables on the next page.

Insufficient data was collected in light/very light snow in winter 2013-14 due to the late submission of the fluid in the winter. This resulted in a lowest usable precipitation rate (LUPR) which limited the 50/50 snow holdover times for the 2014-15 operating season. Additional natural snow data was collected in the winter of 2014-15; this data reduced the LUPR to a rate which does not limit the light and very light snow holdover times. The updated holdover times, as shown in the tables on the following page, will be published by regulators for use in the winter 2015-16 operating season.

SUMMARY

LNT Solutions P250 Type II Fluid Holdover Times (Transport Canada Format)

Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume % /Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	2:10-4:00	2:00	1:45-2:00	0:55-1:45	1:35-2:00	0:50 - 1:25	0:15-2:00	
		75/25	1:50-2:35	2:00	1:25-2:00	0:45-1:25	1:20-1:35	0:40-1:00	0:10-1:50	
		50/50	0:35-0:50	1:05	0:30-1:05	0:15-0:30	0:20-0:35	0:15-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45-2:20	2:00	1:40-2:00	0:50-1:40	0:25-1:20	0:25-0:35		
		75/25	0:35-1:45	2:00	1:25-2:00	0:45-1:25	0:20-1:15	0:20-0:30		
below -14 to LOUT	below 7 to LOUT	100/0	0:20-0:50	0:40	0:30-0:40	0:15-0:30				

LNT Solutions P250 Type II Fluid Holdover Times (FAA Format)

Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume % /Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	2:10-4:00	3:00-3:00	1:45-3:00	0:55-1:45	1:35-2:00	0:50-1:25	0:15-2:00	
		75/25	1:50-2:35	2:50-3:00	1:25-2:50	0:45-1:25	1:20-1:35	0:40-1:00	0:10-1:50	
		50/50	0:35-0:50	1:05-1:25	0:30-1:05	0:15-0:30	0:20-0:35	0:15-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45-2:20	3:00-3:00	1:40-3:00	0:50-1:40	0:25-1:20	0:25-0:35		
		75/25	0:35-1:45	2:50-3:00	1:25-2:50	0:45-1:25	0:20-1:15	0:20-0:30		
below -14 to LOUT	below 7 to LOUT	100/0	0:20-0:50	0:40-0:50	0:30-0:40	0:15-0:30				

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GLOSSARY

APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LOUT	Lowest Operational Use Temperature
LOWV	Lowest On-Wing Viscosity
LUPR	Lowest Usable Precipitation Rate
LWC	Liquid Water Content
MVD	Median Volume Diameter
MANOBS	Manual of Surface Weather Observations
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

This report has been created with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

Aircraft ground de/anti-icing has been the subject of concentrated industry attention in recent years due to the occurrence of several fatal icing-related aircraft accidents. Notably, attention has been placed on the enhancement of anti-icing fluids in order to provide an extended period of protection against further contamination following initial deicing. This emphasis has led to the development of fluid-specific de/anti-icing fluid holdover time (HOT) tables for Type II and Type IV fluids. These tables, accepted by regulatory authorities, are used by aircraft operators for departure planning in adverse winter conditions. Specifically, they provide the duration of time that qualified fluids provide protection against ice formation under specific weather conditions.

New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid holdover times without compromising the aerodynamic features of the airfoil. The purpose of the endurance time testing program is to measure the endurance times of these new fluids and develop fluid-specific HOT tables that provide guidance for their use.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop HOT values for new fluids. These tests are carried out according to SAE Aerospace Recommended Practice (ARP) ARP5485, which provides the test protocols for measuring endurance times of Type II, III and IV fluids. Along with its counterpart for measuring endurance times of Type I fluids ARP5945, ARP5485 has evolved into a refined procedure for measuring the duration of de/anti-icing fluid protection against ice formation.

The current data analysis protocol for developing HOT values from endurance time data was developed in 1996-97 and uses multi-variable regression to obtain HOT values. HOT values are derived for all cells of the Type II/IV HOT tables using this protocol and are used to create a fluid-specific HOT table for each Type II/IV fluid tested.

This report provides a detailed account of the endurance time testing conducted by APS Aviation Inc. (APS) with **LNT Solutions P250**, a new Type II fluid. It describes the test methodology used, endurance time data collected, and analysis completed to derive fluid-specific holdover times for the fluid.

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2

2. METHODOLOGY

SAE Aerospace Recommended Practice (ARP) 5485 provides the procedure and requirements for endurance time testing with Type II, III and IV fluids under natural and simulated conditions. This chapter summarizes some of aspects of the test methodology included in ARP5485, and some aspects which are not included in ARP5485. The chapter includes sections for test sites, equipment, procedures, precipitation rates and ambient temperatures used in Type II/IV endurance time testing, and freezing precipitation droplet sizes. The final subsection describes the analysis methodology used to evaluate Type II/IV endurance time data.

2.1 Test Sites

2.1.1 Natural Snow and Natural Frost

Natural snow and natural frost testing is typically performed at the APS test site located at the Montréal-Pierre-Elliott-Trudeau International Airport. The test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station, as shown in Figure 2.1 on a plan view of the airport.

The APS test site consists of two trailers and three outdoor locations for test stands. One of the trailers is equipped with a refrigeration unit to enable indoor testing at controlled temperatures. Photos 2.1 and 2.2 show the test site as seen from the test pads and main trailer, respectively.

In winter 2013-14, additional natural snow testing was conducted in Val d'Or, Quebec and Ottawa, Ontario.

2.1.2 Freezing Precipitation

Tests under conditions of freezing fog, rain on cold-soaked surface, freezing drizzle, and light freezing rain were conducted indoors at the NRC Climatic Engineering Facility (CEF), where precipitation was artificially produced.

Photo 2.3 provides an outdoor view of the facility giving a general indication of its size (30 m by 5.4 m, height 8 m). The facility was originally designed for the testing of locomotives; Photo 2.4 provides an interior view of the CEF set up for endurance time testing. The lowest temperature achievable in the CEF is -46°C.

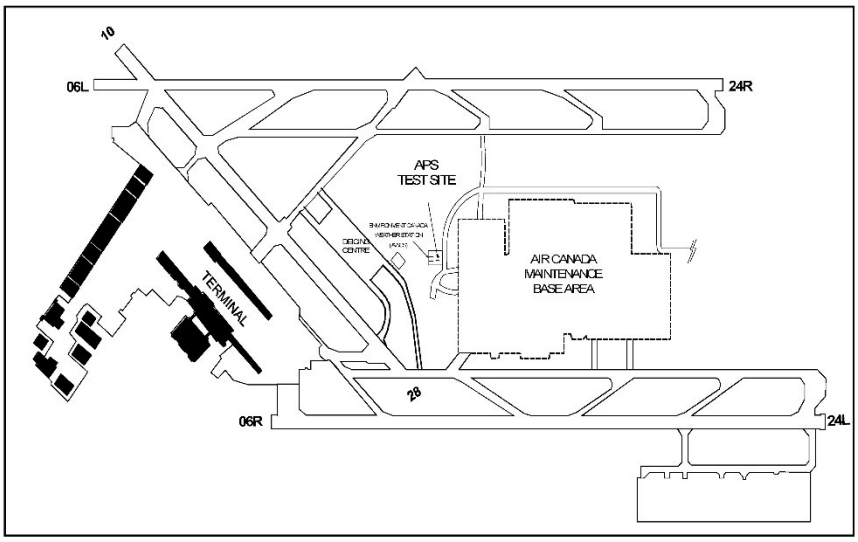


Figure 2.1: APS Test Site at Montréal-Pierre-Elliott-Trudeau International Airport

2.2 Test Equipment

The key equipment used in endurance time testing is described in this section, as are the calibration procedures APS follows for ensuring the accuracy of its test equipment.

2.2.1 Calibration

APS measurement instruments and test equipment are calibrated and/or verified on an annual basis. This calibration is carried out according to a calibration plan based upon approved International Organization for Standardization (ISO) 9001:2000 standards, and developed internally by APS.

2.2.2 Environmental Chamber Equipment

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) was as stipulated in the requirements set out in ARP5485.

2.2.3 Test Surface Structures

The majority of endurance time testing is carried out on standard flat plates. A schematic of a standard flat plate is provided in Figure 2.2. It depicts the size and surface markings of a standard flat plate. Three parallel lines are positioned at 2.5 cm (1"), 15 cm (6") and 30 cm (12") from the top of the plate. The plates are marked with 15 crosshairs, which are used in determining when end conditions (see Subsection 2.3.4) are achieved. Photo 2.5, taken outdoors at the APS test site, shows six test plates mounted on a test stand.

Figure 2.3 shows a schematic of the sealed boxes used for tests simulating a cold soaked wing. The top of the box consists of a flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate. Photo 2.6 shows a picture of a sealed box, which is referred to as a cold-soak box when filled for simulated rain on cold soaked wing tests.

In natural frost, tests are conducted on frosticator plates, which are the current standard test surface used in frost holdover time testing. The frosticator plates were constructed by attaching a Styrofoam insulation backing to the back of the test surface (either aluminum or composite). The insulation prevents heat exchange via the underside of the flat plate and allows for effective radiative cooling during active frost conditions. Photo 2.7 shows a white-painted aluminum frosticator plate.

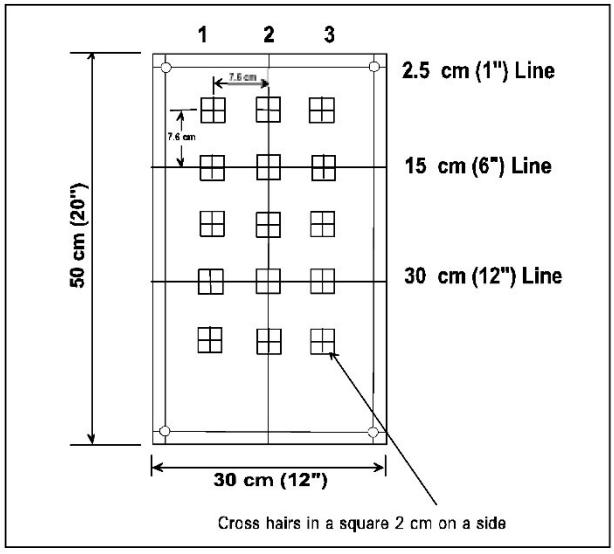


Figure 2.2: Standard Test Plate Schematic

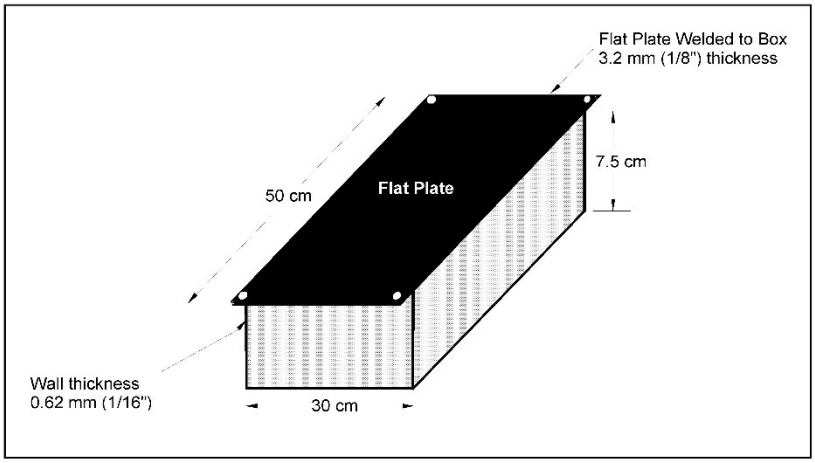


Figure 2.3: Cold Soak Box Schematic

2.2.4 Test Surface Materials

Testing of Type II, III and IV fluids is carried out exclusively on aluminum surfaces. The aluminum used is 0.32 cm thick Alclad 2024 T3 aluminum.

2.2.5 Test Stands

Figure 2.4 shows a schematic of the test platform used for HOT testing. For natural snow tests, six test plates are normally mounted on the test stand, which has a working surface inclined at 10° to the horizontal. During normal winter operations two six-position stands are used in combination. Each plate represents a flat plate test. For simulated freezing precipitation tests at the NRC, 12 plates are mounted on 2 six-position stands. Photos 2.4 and 2.5 show the test stands set up for indoor and outdoor testing, respectively.

2.2.6 Collection Pans

Figure 2.5 shows a schematic of the collection pan used for precipitation rate measurement in outdoor testing. It is the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.8 shows the collection pans used for measuring precipitation rates indoors at the NRC.

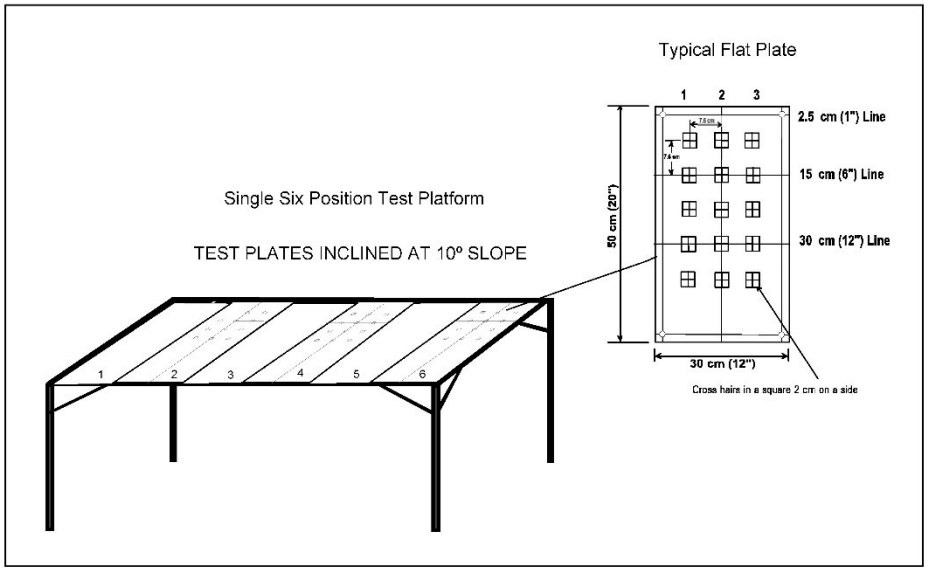


Figure 2.4: Test Stand Setup Schematic

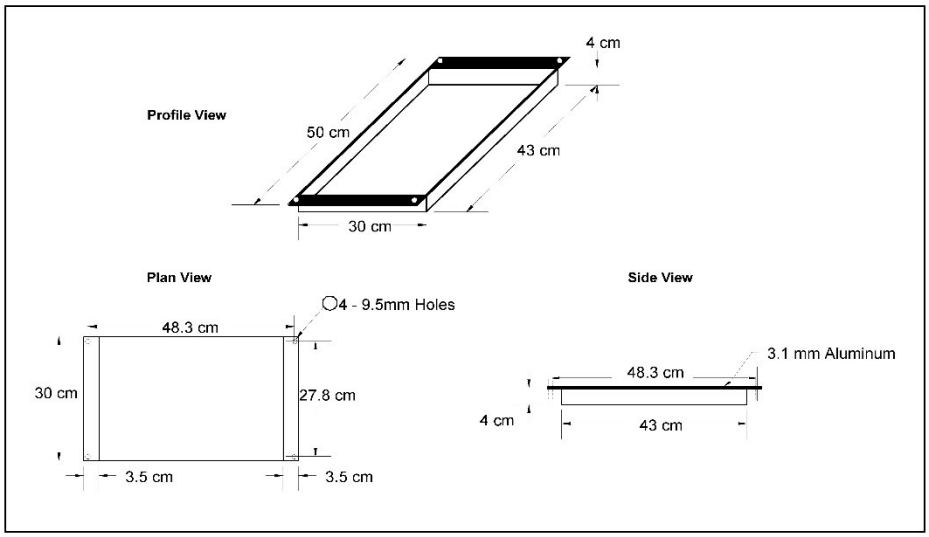


Figure 2.5: Schematic of Outdoor Precipitation Measurement Pan

2.2.7 NRC Sprayer Assembly

NRC developed an improved sprayer assembly, shown in Photos 2.9 and 2.10, in 1997-98. The improved sprayer provides a larger scan area and improved spray uniformity over the test bed area. The scanner consists of a horizontal main shaft supported by two bearings. The actual spray head assembly is shaft-mounted on a rotating scanner, so that one scan covers a lateral running strip of the test bed area. A stepper motor is synchronized to index the relative angle of the spray head between scans along an axis perpendicular to the scan axis. This provides two axes of rotation, essentially an x-y plane; one along each axis. Each scan is consecutively indexed in order to complete the precipitation coverage of the test bed area. This defines one cycle of the spray unit. The scan rate, index angle, and the number of scans per cycle are adjusted, along with the fluid delivery pressures (water and air) to obtain appropriate droplet sizes and precipitation rates. The spray nozzle is shown in Photo 2.11.

2.2.8 Fluids

Testing was carried out with LNT Solutions P250 in the standard Type II, III and IV fluid test dilutions: neat, 75/25 and 50/50. The fluid sample was diluted by the manufacturer.

2.3 Test Procedures

ARP5485 provides the procedure for endurance time testing of Type II, III and IV fluids under natural and simulated precipitation conditions.

The procedure generally consists of pouring de/anti-icing fluids onto clean flat plates exposed to various winter precipitation conditions, and recording the elapsed time for the test to reach the defined end condition (see Subsection 2.3.4), when a specified degree of freezing occurs. The following subsections provide summaries of the test procedures followed for natural snow, natural frost and simulated freezing precipitation testing.

2.3.1 Test Protocol – Natural Snow Tests

APS developed a specific procedure for Type II, III and IV fluid testing in natural snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted are conducted on standard flat plates (see Section 2.2.3);

- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.2 Test Protocol – Natural Frost Tests

APS developed a specific procedure for Type II/III/IV testing in natural frost. Key details of the procedure include:

- Tests are conducted on frosticator plates (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.3 Test Protocol – Simulated Precipitation Tests

APS developed a specific procedure for Type II/III/IV testing in simulated precipitation based on the requirements outlined in ARP5485. Key details of the procedure include:

- Freezing fog, freezing drizzle and light freezing rain tests are conducted on standard flat plates (see Section 2.2.3);
- Rain on cold-soak surface tests are conducted on filled cold-soak boxes (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.4 End Condition Definitions

Failure is called when 30 percent (1/3) of the plate or 5 cross-hairs are covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

a) Ice front;
b) Ice sheet;
c) Slush, in clusters or as a front;
d) Disseminated fine ice crystals;
e) Frost on surface;
f) Clear ice pieces partially or totally imbedded in fluid; and
g) Snow bridges on top of the fluid.

2.3.5 Precipitation Rate Measurement Procedures

The procedures for measuring and determining precipitation rates during simulated precipitation and natural precipitation conditions are provided below.

2.3.5.1 Simulated precipitation conditions

Prior to the start of the rate collection period, the proper needles and nozzles are installed in the spray unit, and both the air and water pressures are adjusted. Water spray calibration is performed by placing catch pans on the test stand, each pan marked with a number identifying the collection location on the test stand, and exposing the pans to a predetermined precipitation collection period.
The pans are weighed prior to exposure to precipitation and the weights are recorded in a customized Excel spreadsheet by using the print function on the digital weigh scale. Prior to the start of the precipitation catch period, the exact time (hh:mm:ss) is recorded using a pre-programmed time macro in the Excel spreadsheet. The pans are re-weighed following this collection period and the precipitation rates over the area of the test stand are examined. If the rates are unacceptable, re-calibration of the water spray is necessary. If the rates are deemed to be acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period has expired, the pans are again re-weighed and the rates computed.

Once two rates have been collected at each test location, the catch rates of the first and second collection are compared. If the average catch rate for any location is deemed to be acceptable for the test condition, then the pouring of fluids may begin at this location.
Rates are continuously monitored at a minimum of two locations during a test in order to ensure there are no significant rate fluctuations. Pans will be placed at these locations and be re-weighed at fixed intervals (15 minutes, typically) during the course of a test. If a rate fluctuation occurs, the test is stopped.

Following the failure of a test plate, a rate collection pan is weighed and placed at the plate location for a predetermined time interval. It is then re-weighed and placed again on the stand to collect a minimum of two additional rates at this location.

The rate of precipitation for any location on the stand is calculated by averaging the two rates collected prior to the test and the two rates collected following the test.

2.3.5.2 Natural precipitation conditions

Two rate collection pans per test stand are used to determine precipitation rates in natural conditions. Prior to the rate collection period, both pans are marked (upper and lower), and the inner bottom and sides of the each pan are wetted with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The wetted pans are then weighed to the nearest gram. The start time of the rate collection period is recorded (h/min/sec) using a customized Excel spreadsheet in which the weight is also recorded by pressing the print function on the digital weigh scale.

The pans are positioned in locations 6 and 7 (see Figure 2.4) and are allowed to collect precipitation for 10-minute intervals in normal conditions and 5-minute intervals in periods of high precipitation rates and high winds. Prior to removal of the plate pans from the test stand for re-weighing, any accumulated precipitation on the lips and outer sides of each plate pan is carefully removed. The plate pans are then carried to the rate station for re-weighing. Upon entering the trailer, the exact time is noted. The new weights of the plate pans are recorded and the pans are brought back outside. This procedure is continued until the final plate on the test stand has failed.

The rate for any HOT test in natural snow is obtained by computing the time-weighted average of the rates collected in the upper and lower pans over the duration of this particular test. To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.6. Typically, two collections pans are used for each test. The start and end times of the test shown in Figure 2.6 are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t1, t2, and t3 (minutes). The calculated rates for each collection period are indicated by R1, R2, and R3 (g/dm²/h). In order to calculate the average rate for this pan, the following formula is then used:

$$\frac{(R_1 \times t_1 + R_2 \times t_2 + R_3 \times t_3)}{t_1 + t_2 + t_3}$$

In the example shown in Figure 2.6, the rate is calculated as follows:

$$\frac{(25 \times 10 + 22 \times 8 + 34 \times 5)}{10 + 8 + 5}$$

The calculated average rate for this pan is 25.9 g/dm²/h. The average rate for the other collection pan is calculated in similar fashion, and the average of the two rates is then taken.

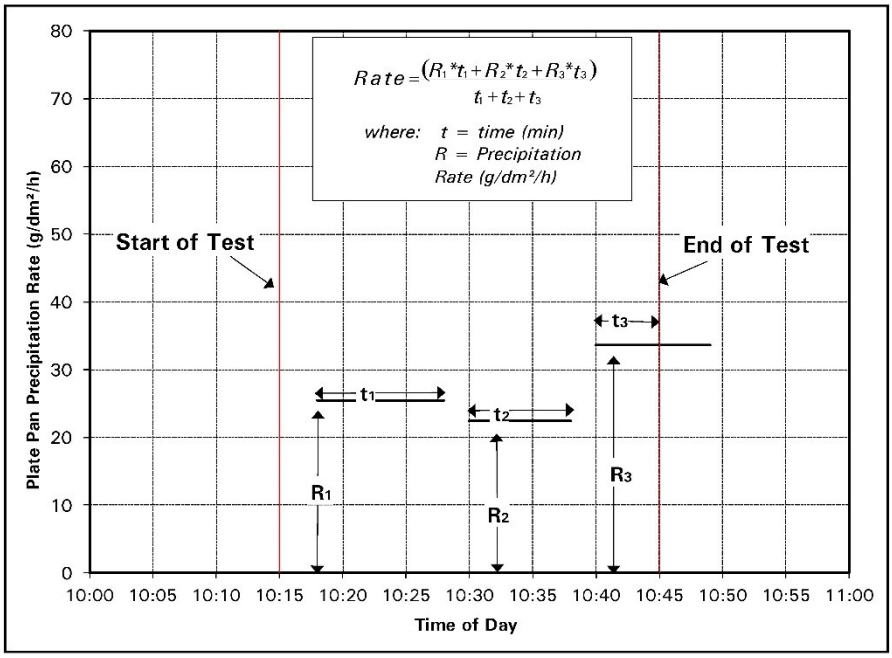


Figure 2.6: Calculation of Outdoor Precipitation Rate

2.4 Precipitation Rate Limits in Type II/IV Endurance Time Testing

Upper and lower precipitation rate limits are an important part of the test methodology for measuring fluid endurance times. Table 2.1 provides the meteorologically accepted definitions of weather phenomenon / precipitation types. It also includes the criteria used to determine precipitation intensity. This table was compiled by the National Centre for Atmospheric Research (NCAR) from the *World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation* (1983) and from the *American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS)* (3/94).

The precipitation rate limits established for Type II/IV endurance time testing are provided in ARP5485 and represented graphically in Figure 2.7. Subsections 2.4.1 to 2.4.5 provide detailed definitions and explanations of the precipitation types and rate boundaries used in Type II/IV endurance time testing. It should be noted that in many cases these limits are not the same as the meteorologically accepted definitions provided in Table 2.1.

Table 2.1: Definition of Weather Phenomenon

Weather Phenomenon*	Definition*
FROST (No METAR code) Note: No Intensity is assigned to FROST.	Ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.
FREEZING FOG (FZFG) Note: No Intensity is assigned to FRZ FOG	A suspension of numerous minute water droplets which freezes upon impact with ground or other exposed objects, generally reducing the horizontal
SNOW (SN)	Precipitation of ice crystals, most of which are branched, star-shaped, or mixed with unbranched crystals. At temperatures higher than about -5°C
FRZING DRIZZLE (FZDZ)	Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0.02 in.)] very close together which freezes upon impact with
FREEZING RAIN (FZRA)	Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5
RAIN (RA)	Precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 in.) diameter or of smaller widely scattered drops.
SNOW PELLETS (GS) and/or SMALL HAIL	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is
HAIL (GR)	Precipitation of small balls or pieces of ice with a diame-
ICE PELLETS (PE)	Precipitation of transparent (sleet or grains of ice), or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 in.)

Intensity Criteria**

	Snow(SN),Pellets(GS),Grains(SG)		Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (SN) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm/hr or 10 gr/dm²/hr)	Scattered pellets on the ground. Visibility not affected.
Moderate	If visibility is: < 5/8 to 5/16 mi (< 1.0 to 0.5 km)	> 0.05 to 0.10 in/hr (> 1.0 to 2.5 mm/hr) (> 10.0 to 25.0 gr/dm²/hr)	Slow accumulation on the ground. Visibility reduced to less than 7 mi.
Heavy (+)	If visibility is: < 5/16 mi (< 0.5 km)	More than 0.10 in/hr (> 2.5 mm/hr or 25 gr/dm²/hr)	Rapid accumulation on the ground. Visibility reduced to less than 3 mi.

Note: Horizontal visibility is only an estimation of snow and freezing drizzle intensity. Measurements and observations have

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm/hr or 2.54 gr/dm²/hr)
Moderate	From 0.01 to 0.02 in/hr (2.54 to 5.08 gr/dm²/hr)
Heavy(+)	More than 0.02 in/hr (> 5.08 gr/dm²/hr) Note: Drizzle > 0.04 in/hr is usually in the form of rain

	Rain (RA), Freezing Rain (FZRA), Ice Pellets (PE)
Measured Intensity: Light (-)	Up to 0.10 in/hr (2.5 mm/hr or 25 gr/dm²/hr) Maximum 0.01 inch in 6 minutes
Estimated Intensity: Light (-)	From scattered drops that, regardless of duration, do not completely wet an
Measured Intensity: Moderate	0.11 in to 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.01 to 0.03 inch in 6 minutes
Estimated Intensity: Moderate	Individual drops are not clearly identifiable; spray is observable just above
Measured Intensity: Heavy (+)	More than 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.03 inch in 6 minutes
Estimated Intensity: Heavy (+)	Rain seemingly falls in sheets; individual drops are not identifiable; heavy

*From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
**From American Meteorological Society, Glossary of Meteorology WSOH #7 MAJORS (3/94)
***HCAR/ISAE Proposed Definition for Liquid Equivalent Snowfall Intensity

1 gram/dm² = 0.01 cm = 0.1 mm = 0.0039 in
2 in = 2.54 cm = 25.4 mm = 254 gr/dm²

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP Sept 8, 1999 (Updated for METAR codes)

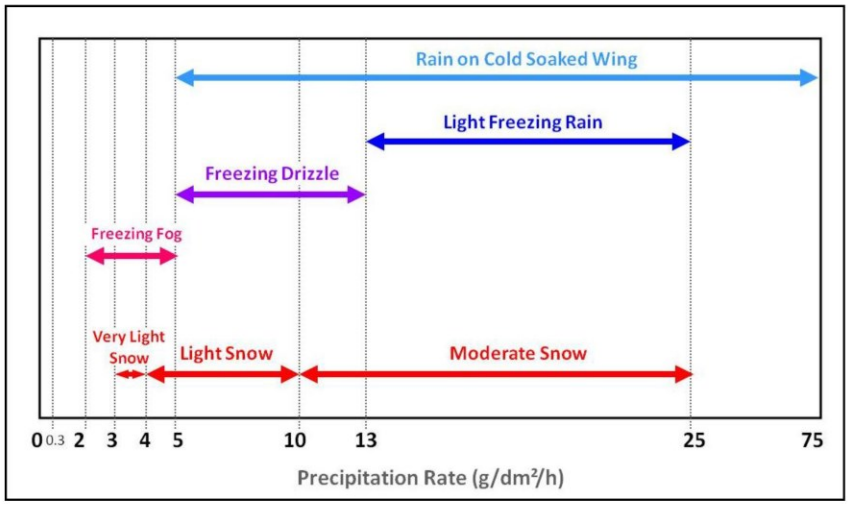


Figure 2.7: Precipitation Rate Limits Used in Endurance Time Testing

2.4.1 Freezing Fog

The precipitation rate limits for endurance time testing in freezing fog were set in 1997 at rates of 2 and 5 g/dm^2/h. These limits were determined with input from NRC meteorologists, who helped define an important parameter in the study of fog referred to as the *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic meter of air, can generally assume values in the range of 0.2 to 0.6 g/m^3.

2.4.2 Freezing Drizzle

The precipitation rate limits for endurance time testing in freezing drizzle are 5 and 13 g/dm^2/h. The upper limit in this range was adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Committee. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety.

2.4.3 Light Freezing Rain

The precipitation rate limits for endurance time testing in light freezing rain are 13 and 25 g/dm^2/h. This range corresponds to the category of light freezing rain and is the only freezing rain category considered, as operations in periods of moderate or heavy freezing rain are deemed unsafe.

2.4.4 Rain on a Cold-Soaked Surface

The precipitation rate limits for rain on cold soaked surface are 5 and 75 g/dm^2/h. This range encompasses drizzle (5 to 13 g/dm^2/h), light rain (13 to 25 g/dm^2/h), and moderate rain (25 to 75 g/dm^2/h).

2.4.5 Snow

The precipitation rate limits used to determine holdover times for Type II/IV fluids in snow are 3, 4, 10 and 25 g/dm²/h. These rate limits encompass very light, light and moderate snow.

2.5 Ambient Temperatures in Type II/IV Endurance Time Testing

The Type II/IV holdover time tables provide holdover times for three temperature ranges:

- -3°C and above;
- Below -3 to -10°C (freezing drizzle, light freezing rain, cold soak wing) or Below -3 to -14°C (freezing fog, snow); and
- Below -14°C to LOUT

In natural snow testing, endurance time testing is carried out under a range of temperatures. In simulated freezing precipitation testing, endurance time testing is typically conducted at the lower limit of each temperature band.

- Freezing Fog: -3°C, -14°C and -25°C
- Freezing Drizzle: -3°C and -10°C
- Light Freezing Rain: -3°C and -10°C
- Rain on Cold Soaked Surface: +1°C

2.6 Freezing Precipitation Droplet Sizes

Research has shown that median volume diameter (MVD) of rain droplets is related to rate of precipitation as follows:

- MVD = (precipitation rate/10) $^{0.23}$, where MVD is in mm and rate of precipitation is in g/dm²/h

The theoretical MVDs for rain at various rates of precipitation were determined based on this equation. These values are listed in Table 2.2 beside the experimental MVDs for each precipitation condition.

Table 2.2: Theoretical and Experimental MVDs

Precipitation Condition	Experimental MVD (mm)	Theoretical MVD (mm)
Moderate Rain (High rate: 75 g/dm²/h)	1.4	1.6
Light Rain (Low rate: 13 g/dm²/h)	1.0	< 1.1
Light Rain (High rate: 25 g/dm²/h)	1.0	1.2
Drizzle (Low rate: 5 g/dm²/h)	0.25	< 0.5
Drizzle (High rate: 13 g/dm²/h)	0.35	< 0.5
Fog		< 0.1

To determine whether droplets produced at the NRC resembled droplets from natural precipitation, a test was conducted during natural light freezing rain conditions in 1997-98 at the APS test site. The droplet sizes were compared to those obtained in simulated light freezing rain at the NRC. The results of these tests are shown below:

a) *For the outdoor test:*

Location:	Montreal P.E.T. Airport
Precipitation:	Natural Light Freezing Rain
Precipitation Rate:	20 g/dm²/h
Calibrated MVD:	1.0 mm

b) *For the indoor test:*

Location:	National Research Council
Precipitation:	Simulated Light Freezing Rain
Precipitation Rate:	25 g/dm²/h
Calibrated MVD:	1.0 mm

The MVD for both natural and simulated light freezing rain was 1 mm, indicating that the NRC produced droplets simulate natural precipitation.
As a result of this testing, the MVDs for freezing precipitation testing were established as follows:

- Freezing Fog, high precipitation rate (5 g/dm²/h): 30 μm
- Freezing Fog, low precipitation rate (2 g/dm²/h): 30 μm

- Freezing Drizzle, high precipitation rate (13 g/dm²/h): 350 μm
- Freezing Drizzle, low precipitation rate (5 g/dm²/h): 250 μm

- Light Freezing Rain, high precipitation rate (25 g/dm²/h): 1,000 μm
- Light Freezing Rain, low precipitation rate (13 g/dm²/h): 1,000 μm

- Rain on Cold-Soaked Surface, low precipitation rate (5 g/dm²/h): 250 μm
- Rain on Cold-Soaked Surface, high precipitation rate (75 g/dm²/h): 1,400 μm

2.7 Summary of Freezing Precipitation Test Conditions

The precipitation types/rates, ambient temperatures and droplet sizes for freezing precipitation testing with Type II/IV fluids were described in the previous subsections. In summary, freezing precipitation tests are carried out under each of the 16 weather conditions listed in Table 2.3.

Table 2.3: Summary of Freezing Precipitation Test Conditions (Type II/IV Fluids)

Precipitation Type	Ambient Temperature	Precipitation Rate (Droplet Size)
Freezing Fog	-3°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-14°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-25°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
Freezing Drizzle	-3°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
	-10°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
Light Freezing Rain	-3°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
	-10°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
Rain on Cold-Soaked Surface	+1°C	5 g/dm²/h (250 μm)
		75 g/dm²/h (1,400 μm)

2.8 Analysis Methodology

A multi-variable regression procedure is used to derive fluid-specific holdover times for Type II/IV fluids. The procedure is based on the refinement of an equation for a curve which best represents the test data, and then solving that equation at the upper and lower limits established for the precipitation type. These precipitation rate limits, set by the SAE G-12 HOT Committee and detailed in ARP5485, were described in Subsection 2.4. This approach was developed in the winter of 1996-97 (see TC report, TP 13131E) and has since been used to derive fluid holdover times. There are some differences in the way the methodology is applied to freezing precipitation and natural snow data.

2.8.1 Freezing Precipitation Data

For each related freezing precipitation HOT table cell, four tests are conducted at the most restrictive (lowest) temperature in the temperature range for that cell: two tests at the low precipitation rate limit and two tests at the high precipitation rate limit (limits are detailed in Subsection 2.4). The equation used to treat freezing precipitation data is:

- $t = 10^{I}R^{a}$, where

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.2 Natural Snow Data

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural snow tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather data under all temperatures and precipitation rates encompassed by the HOT tables.

The general form of the regression equation is modified for natural snow to incorporate the variable of temperature and also to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C. The equation used to treat natural snow data is:

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

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a, b = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, using the most restrictive (lowest) temperature for that cell. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.3 Natural Frost Data

Regression analysis is not used in the determination of frost holdover times. The current Type II/III/IV generic frost holdover times were determined based on several years of testing using all fluids which were commercially available at the time. A "minimum values" analysis methodology was used to determine appropriate holdover times from the test data.

The purpose of natural frost testing with new fluids is to verify the fluids can be used with the generic frost holdover times. The analysis methodology is to compare the frost test data collected with the new fluid to the current generic holdover times. If the test data provides holdover times equal to or greater than the generic holdover times then the generic holdover times have been validated for the new fluid.

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural frost tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather several data points with each fluid/dilution.

2.8.4 Rounding and Capping Protocols

Regression-generated holdover times are subject to rounding and capping protocols. For Type II/IV fluids they are as follows:

- Rounding Protocol: Holdover times are rounded to the nearest whole "5" minute, i.e. 55.1 to 57.4 minutes is rounded down to 55 minutes; 57.5 to 59.9 minutes is rounded up to 60 minutes. In cases where the regression-generated holdover times are below 10 minutes, the numbers are rounded down to the nearest whole minute as a precautionary measure. For example, 9.6 minutes is rounded down to 9 minutes.

- Capping Protocol: All holdover time values are capped at maximum values. The caps differ by precipitation type, and in the case of snow, by regulator. The caps are as follows:
  - Freezing Fog holdover time values are capped at 4 hours;
  - Freezing Drizzle, Light Freezing Rain, Rain on Cold Soaked Wing holdover times are capped at 2 hours; and
  - Snow holdover times are capped at 2 hours by Transport Canada and 3 hours by FAA.

2.8.5 Regression Example

Sample plots of **Log t** versus **Log R** are shown in Figure 2.8. The plots contain data for one Neat Type IV fluid, in one temperature range (-10°C), in light freezing rain conditions. The best-fit regression line is superimposed onto the plot and was obtained from the analysis using the lowest temperature in the temperature range from which the data were chosen.

The same data plotted on a linear scale (failure time **t** versus precipitation rate **R**) are shown in Figure 2.9. The curve, generated from the power law form of the equation using the coefficients determined from the fit, is superimposed onto the plot. The HOT range is determined from the intersections of the curve with the precipitation rate limits defined for light freezing rain.

The holdover times for this fluid at -10°C are 20 minutes at 13 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid in the light freezing rain, neat fluid, below -3 to -10°C cell. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

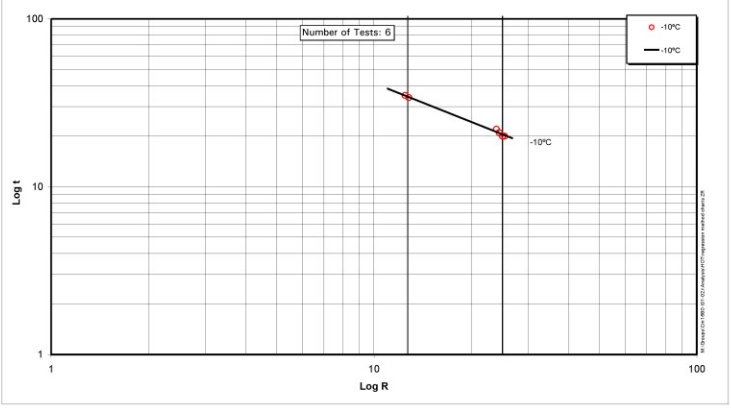


Figure 2.8: Regression Method on Log-Log Chart – Type IV Neat, Freezing Rain

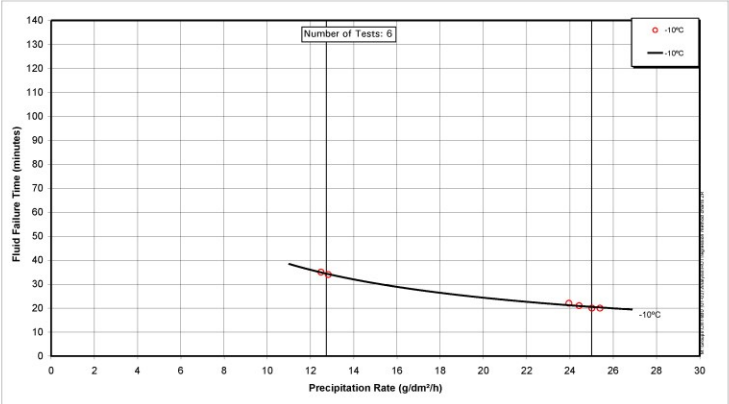


Figure 2.9: Regression Method on Standard Chart – Type IV Neat, Freezing Rain

2.8.6 Lowest Usable Precipitation Rates in Snow

A detailed analysis methodology was developed to determine if a snow data set is sufficient to determine holdover times for light and very light snow. Specifically, the analysis determines the lowest usable precipitation rate (LUPR), which is the lowest rate at which the data set is considered robust.

The methodology is a five-factor weighted analysis. The five factors are:

1. Total number of data points;
2. Number of data points with air temperatures below -3°C;
3. Number of data points with precipitation rates below 10 g/dm²/h;
4. Number of data points with precipitation rates less than or equal to 0.5 g/dm²/h above the precipitation rate being examined; and
5. Scatter from regression curve of low precipitation rate data points (average absolute percent difference between fail time and regression calculated fail time for all points less than or equal to 10 g/dm²/h).

The weights given to each of the five factors are:

1. Total Data Points = 5%;
2. Data Points Below -3°C = 20%;
3. Data Points Below 10 g/dm²/h = 20%;
4. Data Points ≤ Precipitation Rate = 40%; and
5. Low Rate Data Scatter = 15%.

Each data set is given a score of 0, 10, 20, 30 or 40 for each factor. The scoring system is shown in Table 2.4.

This approach provides a score for each data set for each precipitation rate below 10 g/dm²/h. The scores are compared to the minimum acceptance scores:

- 100/0 = 28
- 75/25 = 28
- 50/50 = 19 (lower due to a 0 score for data points below -3°C)

The LUPR is the lowest precipitation rate at which a data set has a passing score.

Table 2.4: LUPR Factor Scoring System

Factor #1: Total Data Points (Weight = 5%)	
Rating = 40	≥20 data points in data set
Rating = 30	15-19 data points in data set
Rating = 20	10-14 data points in data set
Rating = 10	5-9 data points in data set
Rating = 0	<5 data points in data set

Factor #2: Data Points Below -3°C (Weight = 20%)	
Rating = 40	≥15 data points from -3 to -14°C
Rating = 30	12-14 data points -3 to -14°C
Rating = 20	9-11 data points -3 to -14°C
Rating = 10	6-8 data points -3 to -14°C
Rating = 0	<6 data points -3 to -14°C

Factor #3: Data Points Below 10 g/dm²/h (Weight = 20%)	
Rating = 40	≥10 data points <10 g/dm²/h
Rating = 30	7-9 data points <10 g/dm²/h
Rating = 20	5-6 data points <10 g/dm²/h
Rating = 10	3-4 data points <10 g/dm²/h
Rating = 0	<3 data points <10 g/dm²/h

Factor #4: Data Points ≤ Precipitation Rate (Weight = 40%)	
Rating = 40	≥3 data points ≤ rate limit +0.5
Rating = 30	2 data points ≤ rate limit +0.5
Rating = 20	1 data points ≤ rate limit +0.5
Rating = 10	n/a
Rating = 0	0 data points ≤ rate limit +0.5

Factor #5: Low Rate Data Scatter (Weight = 15%)	
Rating = 40	Average actual-calculated error <10%
Rating = 30	Average actual-calculated error 10-19%
Rating = 20	Average actual-calculated error 20-29%
Rating = 10	Average actual-calculated error 30-39%
Rating = 0	Average actual-calculated error ≥40%

Photo 2.1: APS Test Site - View from Test Pad



Photo 2.2: APS Test Site - View from Trailer



Photo 2.3: Outdoor View of NRC Climatic Engineering Facility



Photo 2.4: Inside View of NRC Climatic Engineering Facility



Photo 2.5: Test Plates Mounted on Stand

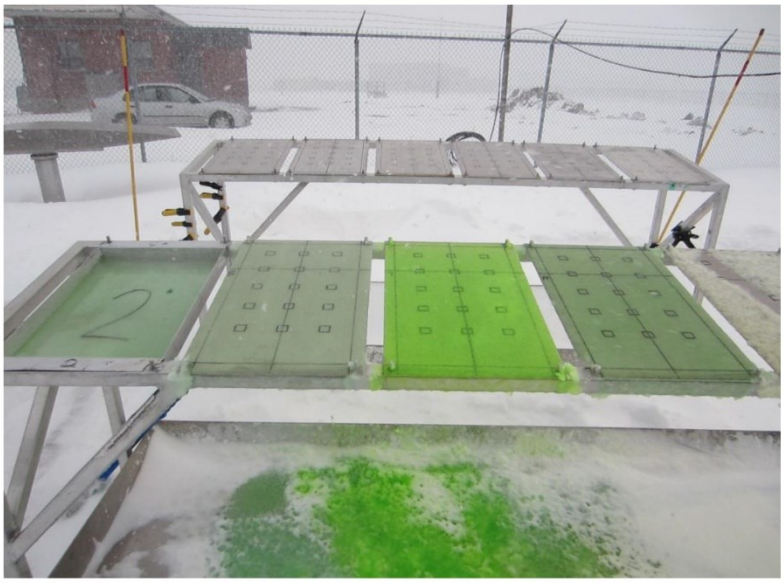


Photo 2.6: Cold-Soak / Leading Edge Thermal Equivalent Box

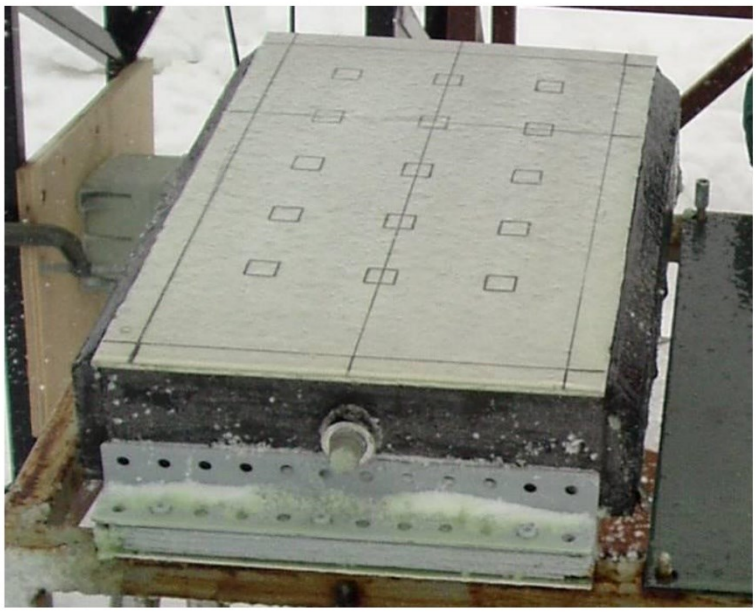


Photo 2.7: Frost Plate with Insulated Backing



Photo 2.8: Collection Pans Used Indoors at the NRC



Photo 2.9: Sprayer Assembly



Photo 2.10: Sprayer Assembly in Use

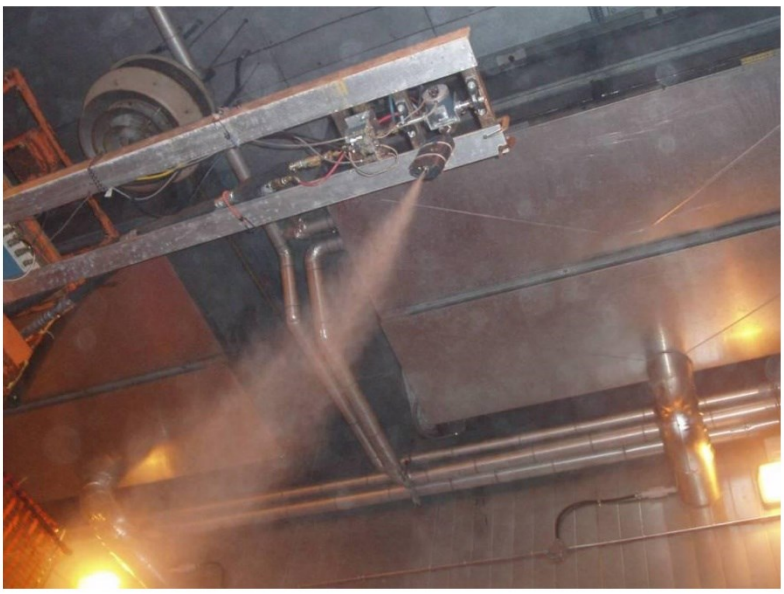
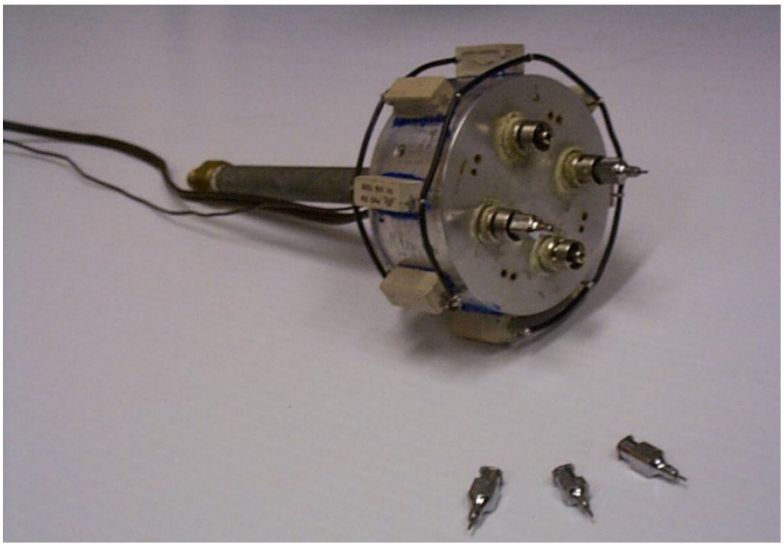


Photo 2.11: Sprayer Nozzle



3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted. Breakdowns are provided for the number of tests performed by test type, precipitation type, fluid dilution and test temperature.

Logs of the tests conducted are provided at the end of this section as follows: Table 3.1 (snow), Table 3.2 (freezing precipitation), and Table 3.3 (frost). The logs provide details of each test conducted.

3.1 Natural Snow Tests

Tests were conducted in natural snow conditions at the APS test site and at several mobile test sites (see Subsection 2.1.1). The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	≥ -3°C	-3 to -14°C	<-14°C
Neat	12	9	0
75/25	12	13	0
50/50	21	2	0

3.2 Freezing Drizzle and Light Freezing Rain Tests

Tests were conducted in freezing drizzle and light freezing rain conditions at the NRC CEF. The breakdown of tests conducted is summarized below by precipitation type, fluid dilution and temperature.

	Freezing Drizzle		Light Freezing Rain	
	-3°C	-10°C	-3°C	-10°C
Neat	4	4	4	4
75/25	4	4	4	4
50/50	4	0	4	0

3.3 Freezing Fog Tests

Tests were conducted in freezing fog conditions at the NRC CEF. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	-3°C	-14°C	-25°C
Neat	4	4	4
75/25	4	4	0
50/50	4	0	0

3.4 Rain on Cold-Soaked Surface Tests

Tests were conducted in rain on cold-soaked surface conditions at the NRC CEF with Neat and 75/25 diluted fluids. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	+1°C
Neat	4
75/25	4
50/50	0

3.5 Natural Frost Tests

Tests were conducted in natural frost at the APS test site. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	≥-1°C	<-1 to -3°C	<-3 to -10°C	<-10°C
Neat	0	2	0	0
75/25	0	2	0	0
50/50	0	2	0	0

3.6 Fluid Thickness Tests

Fluid thickness tests were conducted to measure the film thickness profiles of the fluid under dry conditions. Two tests were performed for each dilution. For each test, 1 litre of fluid was poured onto a flat plate mounted on a test stand inclined by 10°. Thickness measurements were taken at the 15-cm (6") line at select time intervals over a 30-minute period. Tests were conducted at -3°C.

The film thickness profiles are displayed in Figure 3.1. The final fluid thicknesses are displayed in Figure 3.2.

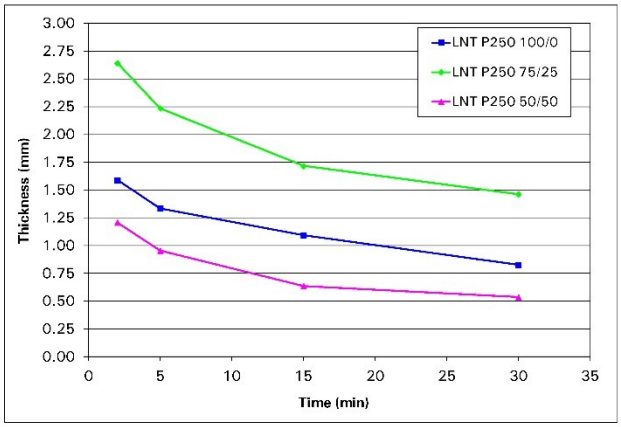


Figure 3.1: Fluid Thickness Profiles of LNT Solutions P250

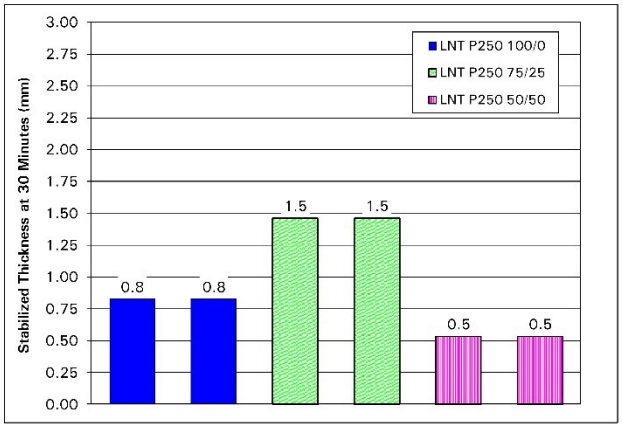


Figure 3.2: Final Fluid Thickness of LNT Solutions P250

Table 3.1: Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
187	12-Mar-14	Natural Snow	LNT Solutions P250	75%	-10.8	14.2	77.2
197	12-Mar-14	Natural Snow	LNT Solutions P250	75%	-10.9	26.5	48.0
198	12-Mar-14	Natural Snow	LNT Solutions P250	100%	-12.1	13.9	68.1
199	12-Mar-14	Natural Snow	LNT Solutions P250	75%	-12.1	14.1	56.6
202	19-Mar-14	Natural Snow	LNT Solutions P250	50%	0.8	29.9	7.7
205	19-Mar-14	Natural Snow	LNT Solutions P250	100%	0.8	25.1	64.9
209	19-Mar-14	Natural Snow	LNT Solutions P250	50%	0.8	35.2	4.9
212	19-Mar-14	Natural Snow	LNT Solutions P250	50%	0.8	19.5	24.2
215	19-Mar-14	Natural Snow	LNT Solutions P250	50%	0.8	24.0	11.9
216	19-Mar-14	Natural Snow	LNT Solutions P250	75%	0.8	21.0	51.5
218	19-Mar-14	Natural Snow	LNT Solutions P250	100%	1.2	4.3	181.0
220	19-Mar-14	Natural Snow	LNT Solutions P250	50%	1.2	1.8	144.2
222	19-Mar-14	Natural Snow	LNT Solutions P250	75%	1.2	4.0	174.5
223	19-Mar-14	Natural Snow	LNT Solutions P250	100%	0.9	10.1	140.7
224	19-Mar-14	Natural Snow	LNT Solutions P250	75%	0.9	14.5	73.9
225	19-Mar-14	Natural Snow	LNT Solutions P250	50%	0.7	13.3	21.8
227	20-Mar-14	Natural Snow	LNT Solutions P250	50%	0.7	15.7	17.9
229	20-Mar-14	Natural Snow	LNT Solutions P250	50%	1.0	6.7	73.5
230	22-Mar-14	Natural Snow	LNT Solutions P250	50%	-3.4	34.2	15.1
231	22-Mar-14	Natural Snow	LNT Solutions P250	100%	-3.4	43.8	40.5
232	22-Mar-14	Natural Snow	LNT Solutions P250	75%	-3.5	47.3	29.5
233	22-Mar-14	Natural Snow	LNT Solutions P250	50%	-3.5	44.8	13.6
237	22-Mar-14	Natural Snow	LNT Solutions P250	50%	-3.0	40.6	12.8
238	22-Mar-14	Natural Snow	LNT Solutions P250	75%	-3.2	23.3	72.7
239	22-Mar-14	Natural Snow	LNT Solutions P250	100%	-3.2	18.8	107.9
245	22-Mar-14	Natural Snow	LNT Solutions P250	100%	-3.3	25.5	53.5
246	22-Mar-14	Natural Snow	LNT Solutions P250	75%	-3.3	30.6	27.1
247	22-Mar-14	Natural Snow	LNT Solutions P250	50%	-3.4	20.0	7.6
254	22-Mar-14	Natural Snow	LNT Solutions P250	50%	-3.4	16.4	17.7
255	22-Mar-14	Natural Snow	LNT Solutions P250	75%	-3.4	23.7	58.1
256	22-Mar-14	Natural Snow	LNT Solutions P250	100%	-3.4	26.0	65.2
260	22-Mar-14	Natural Snow	LNT Solutions P250	50%	-3.2	20.7	19.5
263	27-Mar-14	Natural Snow	LNT Solutions P250	100%	-9.2	3.3	232.7
264	27-Mar-14	Natural Snow	LNT Solutions P250	75%	-11.3	4.3	151.6
265	27-Mar-14	Natural Snow	LNT Solutions P250	100%	-9.2	3.0	240.6
266	27-Mar-14	Natural Snow	LNT Solutions P250	75%	-9.2	3.0	239.8

Table 3.1 (cont'd): Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
269	27-Mar-14	Natural Snow	LNT Solutions P250	100%	-5.5	4.9	152.6
270	27-Mar-14	Natural Snow	LNT Solutions P250	75%	-5.5	4.3	132.3
271	27-Mar-14	Natural Snow	LNT Solutions P250	50%	-5.1	7.6	27.9
273	27-Mar-14	Natural Snow	LNT Solutions P250	75%	-5.7	4.8	139.9
279	28-Mar-14	Natural Snow	LNT Solutions P250	100%	-4.6	18.2	50.1
280	28-Mar-14	Natural Snow	LNT Solutions P250	75%	-4.6	15.9	44.8
281	28-Mar-14	Natural Snow	LNT Solutions P250	100%	-4.6	28.9	34.1
282	28-Mar-14	Natural Snow	LNT Solutions P250	75%	-4.6	28.2	30.1
283	28-Mar-14	Natural Snow	LNT Solutions P250	100%	-4.3	21.6	63.9
284	28-Mar-14	Natural Snow	LNT Solutions P250	75%	-4.3	22.3	55.3
285	28-Mar-14	Natural Snow	LNT Solutions P250	100%	-4.0	12.6	122.2
286	28-Mar-14	Natural Snow	LNT Solutions P250	75%	-4.3	17.9	61.2
287	28-Mar-14	Natural Snow	LNT Solutions P250	100%	-4.0	10.0	109.9
288	28-Mar-14	Natural Snow	LNT Solutions P250	75%	-4.0	10.0	92.4
291	28-Mar-14	Natural Snow	LNT Solutions P250	50%	-3.3	8.6	30.2
293	28-Mar-14	Natural Snow	LNT Solutions P250	50%	-3.0	10.7	31.6
300	28-Mar-14	Natural Snow	LNT Solutions P250	50%	-0.3	34.6	8.7
301	28-Mar-14	Natural Snow	LNT Solutions P250	100%	-0.1	33.2	47.7
302	28-Mar-14	Natural Snow	LNT Solutions P250	75%	-0.3	35.2	30.0
305	28-Mar-14	Natural Snow	LNT Solutions P250	50%	-0.3	36.8	9.7
308	28-Mar-14	Natural Snow	LNT Solutions P250	100%	0.3	28.0	59.8
309	28-Mar-14	Natural Snow	LNT Solutions P250	100%	0.3	29.5	52.7
310	28-Mar-14	Natural Snow	LNT Solutions P250	75%	0.3	24.6	44.3
311	28-Mar-14	Natural Snow	LNT Solutions P250	50%	0.2	21.4	15.0
312	28-Mar-14	Natural Snow	LNT Solutions P250	50%	-0.3	28.1	12.9
313	28-Mar-14	Natural Snow	LNT Solutions P250	75%	-0.1	28.4	41.8
315	28-Mar-14	Natural Snow	LNT Solutions P250	100%	-0.1	26.9	40.0
316	28-Mar-14	Natural Snow	LNT Solutions P250	75%	-0.1	28.5	22.8
318	28-Mar-14	Natural Snow	LNT Solutions P250	50%	0.3	42.3	11.0
321	30-Mar-14	Natural Snow	LNT Solutions P250	75%	-1.1	13.5	77.5
324	30-Mar-14	Natural Snow	LNT Solutions P250	75%	-0.8	8.5	95.1
328	30-Mar-14	Natural Snow	LNT Solutions P250	100%	-1.1	10.1	111.5
92	17-Dec-14	Natural Snow	LNT P250	50%	0.2	1.1	204.8

Table 3.2: Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
5	24-Mar-14	Freezing Fog	LNT Solutions P250	100	-25	2.2	43.9
6	24-Mar-14	Freezing Fog	LNT Solutions P250	100	-25	2.3	41.6
11	24-Mar-14	Freezing Fog	LNT Solutions P250	100	-25	5.0	20.0
12	24-Mar-14	Freezing Fog	LNT Solutions P250	100	-25	5.1	21.0
17	24-Mar-14	Freezing Fog	LNT Solutions P250	100	-14	1.8	156.5
18	24-Mar-14	Freezing Fog	LNT Solutions P250	100	-14	1.9	155.7
23	24-Mar-14	Freezing Fog	LNT Solutions P250	75	-14	1.9	111.8
24	24-Mar-14	Freezing Fog	LNT Solutions P250	75	-14	1.9	110.9
29	24-Mar-14	Freezing Fog	LNT Solutions P250	100	-14	5.2	44.5
30	24-Mar-14	Freezing Fog	LNT Solutions P250	100	-14	5.4	44.0
35	24-Mar-14	Freezing Fog	LNT Solutions P250	75	-14	4.8	33.3
36	24-Mar-14	Freezing Fog	LNT Solutions P250	75	-14	4.9	35.4
41	25-Mar-14	Freezing Fog	LNT Solutions P250	100	-3	2.0	268.4
42	25-Mar-14	Freezing Fog	LNT Solutions P250	100	-3	2.1	220.6
47	25-Mar-14	Freezing Fog	LNT Solutions P250	75	-3	1.9	175.4
48	25-Mar-14	Freezing Fog	LNT Solutions P250	75	-3	1.9	144.1
53	25-Mar-14	Freezing Fog	LNT Solutions P250	50	-3.2	2.1	53.4
54	25-Mar-14	Freezing Fog	LNT Solutions P250	50	-3.2	2.0	43.9
59	25-Mar-14	Freezing Fog	LNT Solutions P250	100	-3	4.9	120.9
60	25-Mar-14	Freezing Fog	LNT Solutions P250	100	-3	5.1	135.0
65	25-Mar-14	Freezing Fog	LNT Solutions P250	75	-3	5.0	111.0
66	25-Mar-14	Freezing Fog	LNT Solutions P250	75	-3	4.7	111.7
71	25-Mar-14	Freezing Fog	LNT Solutions P250	50	-3	5.2	31.5
72	25-Mar-14	Freezing Fog	LNT Solutions P250	50	-3	5.1	34.1
77	20-Mar-14	Freezing Drizzle	LNT Solutions P250	100	-10	4.7	87.5
78	20-Mar-14	Freezing Drizzle	LNT Solutions P250	100	-10	4.6	88.5
83	20-Mar-14	Freezing Drizzle	LNT Solutions P250	75	-10	4.9	75.1
84	20-Mar-14	Freezing Drizzle	LNT Solutions P250	75	-10	5.1	75.3
89	20-Mar-14	Freezing Drizzle	LNT Solutions P250	100	-10	13.3	24.8
90	20-Mar-14	Freezing Drizzle	LNT Solutions P250	100	-10	12.8	25.6
95	20-Mar-14	Freezing Drizzle	LNT Solutions P250	75	-10	13.6	16.8
96	20-Mar-14	Freezing Drizzle	LNT Solutions P250	75	-10	12.8	18.9
101	21-Mar-14	Freezing Drizzle	LNT Solutions P250	100	-3	5.2	137.0
102	21-Mar-14	Freezing Drizzle	LNT Solutions P250	100	-3	4.8	>120
107	21-Mar-14	Freezing Drizzle	LNT Solutions P250	75	-3	4.7	89.8
108	21-Mar-14	Freezing Drizzle	LNT Solutions P250	75	-3	4.8	107.7
113	21-Mar-14	Freezing Drizzle	LNT Solutions P250	50	-3	4.7	34.5

Table 3.2 (cont'd): Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
114	21-Mar-14	Freezing Drizzle	LNT Solutions P250	50	-3	4.6	33.8
119	19-Mar-14	Freezing Drizzle	LNT Solutions P250	100	-3	13.7	91.5
120	19-Mar-14	Freezing Drizzle	LNT Solutions P250	100	-3	13.2	96.7
125	19-Mar-14	Freezing Drizzle	LNT Solutions P250	75	-3	13.2	88.4
126	19-Mar-14	Freezing Drizzle	LNT Solutions P250	75	-3	13.5	72.6
131	19-Mar-14	Freezing Drizzle	LNT Solutions P250	50	-3	13.0	18.9
132	19-Mar-14	Freezing Drizzle	LNT Solutions P250	50	-3	13.5	18.3
137	20-Mar-14	Light Freezing Rain	LNT Solutions P250	100	-10	13.3	35.6
138	20-Mar-14	Light Freezing Rain	LNT Solutions P250	100	-10	13.5	36.4
143	20-Mar-14	Light Freezing Rain	LNT Solutions P250	75	-10	12.6	29.5
144	20-Mar-14	Light Freezing Rain	LNT Solutions P250	75	-10	12.9	30.3
149	20-Mar-14	Light Freezing Rain	LNT Solutions P250	100	-10	24.8	22.3
150	20-Mar-14	Light Freezing Rain	LNT Solutions P250	100	-10	25.7	23.5
155	20-Mar-14	Light Freezing Rain	LNT Solutions P250	75	-10	24.8	16.4
156	20-Mar-14	Light Freezing Rain	LNT Solutions P250	75	-10	24.6	19.6
161	19-Mar-14	Light Freezing Rain	LNT Solutions P250	100	-3	12.8	90.8
162	19-Mar-14	Light Freezing Rain	LNT Solutions P250	100	-3	12.7	85.4
167	19-Mar-14	Light Freezing Rain	LNT Solutions P250	75	-3	12.8	56.7
168	19-Mar-14	Light Freezing Rain	LNT Solutions P250	75	-3	12.6	68.7
173	19-Mar-14	Light Freezing Rain	LNT Solutions P250	50	-3	12.8	22.0
174	19-Mar-14	Light Freezing Rain	LNT Solutions P250	50	-3	12.8	18.6
179	21-Mar-14	Light Freezing Rain	LNT Solutions P250	100	-3	25.0	48.0
180	21-Mar-14	Light Freezing Rain	LNT Solutions P250	100	-3	25.3	49.6
185	21-Mar-14	Light Freezing Rain	LNT Solutions P250	75	-3	24.4	37.8
186	21-Mar-14	Light Freezing Rain	LNT Solutions P250	75	-3	24.7	44.7
191	21-Mar-14	Light Freezing Rain	LNT Solutions P250	50	-3	24.7	12.7
192	21-Mar-14	Light Freezing Rain	LNT Solutions P250	50	-3	25.3	12.8
197	26-Mar-14	Cold Soak Box	LNT Solutions P250	100	1.0	5.3	111.7
198	26-Mar-14	Cold Soak Box	LNT Solutions P250	100	1.0	5.2	120.0
203	26-Mar-14	Cold Soak Box	LNT Solutions P250	75	1.0	5.4	112.0
204	26-Mar-14	Cold Soak Box	LNT Solutions P250	75	1.1	5.4	93.5
209	26-Mar-14	Cold Soak Box	LNT Solutions P250	100	0.7	75.6	15.9
210	26-Mar-14	Cold Soak Box	LNT Solutions P250	100	1.3	74.7	18.2
215	26-Mar-14	Cold Soak Box	LNT Solutions P250	75	1.1	75.2	12.6
216	26-Mar-14	Cold Soak Box	LNT Solutions P250	75	1.1	73.2	12.1

Table 3.3: Summary of Tests Performed (Natural Frost)

Test No.	Date	Precip. Type	Fluid Name	Fluid Dilution	Test Duration (min.)	Average Rate ($g/dm^2/h$)	Temp (°C)	Wind Speed (km/h)	Average RH (%)	Comments
25	16-Apr-14	Natural Frost	LNT Solutions P250	100%	694	0.03	-2.9	4	75	Did Not Fail
26	16-Apr-14	Natural Frost	LNT Solutions P250	75%	563	0.03	-3.2	3	78	Did Not Fail
27	16-Apr-14	Natural Frost	LNT Solutions P250	50%	456	0.03	-3.5	3	81	Did Not Fail
36	17-Apr-14	Natural Frost	LNT Solutions P250	100%	659	0.09	-2.1	8	64	Did Not Fail
37	17-Apr-14	Natural Frost	LNT Solutions P250	75%	381	0.11	-2.7	8	69	Did Not Fail
38	17-Apr-14	Natural Frost	LNT Solutions P250	50%	380	0.11	-2.7	8	69	Did Not Fail

4. RESULTS AND DISCUSSION

The methods used to evaluate the test data were reviewed in Subsection 2.8. The results of the data analyses are presented in this section.

4.1 Natural Snow and Freezing Precipitation

Figures 4.1 to 4.14 present the data collected in natural snow and simulated freezing precipitation (freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface). These figures show the effect of temperature, precipitation type and precipitation rate on fluid endurance time in the conditions encompassed by the Type II HOT guidelines.

Multi-variable regression analysis was performed on these data sets as described in Subsection 2.8. Table 4.1 provides the outputs from the multi-variable regression analyses. These outputs were used to derive fluid-specific holdover times for all conditions encompassed by Type II fluid-specific HOT table, with the exception of the coldest temperature band snow cells (see Subsection 4.3.1).

4.2 Natural Frost

The natural frost data was presented in Table 3.3. The test durations were compared to the generic holdover times. All completed ("failed") tests surpassed the generic holdover times, as did all tests that were not completed (due to active frost ending before fluid failure could occur). This analysis indicates the generic frost holdover times have been substantiated for LNT Solutions P250.

4.3 Holdover Time Table

The holdover times described in Subsection 4.1 were used to populate a fluid-specific HOT table for LNT Solutions P250. The HOT table is shown in both the TC format (Table 4.2) and FAA format (Table 4.3) at the end of this chapter.

4.3.1 Holdover Times in Snow, Below -14°C to LOUT

Very little endurance time data has been collected in natural snow at temperatures below -14°C. In the winter of 2003-04, testing was conducted with artificial snowmakers to collect additional data below -14°C. As a result of this testing, the existing propylene Type II/IV fluids were given generic values in the "Below -14 to

LOUT" snow cell. It was also decided that all new Type II/IV fluids would be given generic values. Accordingly, LNT Solutions P250 has been given generic values in the "Below -14°C to LOUT" snow cells.

4.3.2 Holdover Times in Frost

It should be noted that frost holdover times are not included in the fluid-specific HOT table. This is due to a decision made by TC and the FAA in May 2009 to move frost holdover times from the generic and fluid-specific HOT tables to a separate frost HOT table. Accordingly, frost holdover times have not been included in the LNT Solutions P250 fluid-specific HOT table.

4.3.3 Fluid Viscosity

The viscosities of the fluid samples used in this testing were measured using both the AIR 9968 method and the manufacturer's designated method. The APS measured viscosities appear at the beginning of this document and will be published as the lowest on-wing viscosity (LOWV) values for the fluid. In order for the fluid-specific holdover times provided in this document to be valid, operators must ensure that the viscosity of the fluid being used is equal or greater than the published LOWV.

4.4 Lowest Usable Precipitation Rates in Snow

The LUPRs for LNT Solutions P250 were determined by analysing the natural snow data sets using the analysis methodology described in Subsection 2.8.6. The resulting statistics are shown in Table 4.4. The analysis determined the LUPRs for LNT Solutions P250 are:

- 100/0 = 3 g/dm²/h;
- 75/25 = 3 g/dm²/h; and
- 50/50 = 2 g/dm²/h.

4.5 Discussion

As LNT Solutions intends to commercialize P250, TC and FAA will publish its updated fluid-specific HOT table in their 2015-16 Holdover Time Guidelines. The guidelines will also include the LOWV and LOUT information; the LUPR data will be published in the related TC and FAA Regression Information documents.

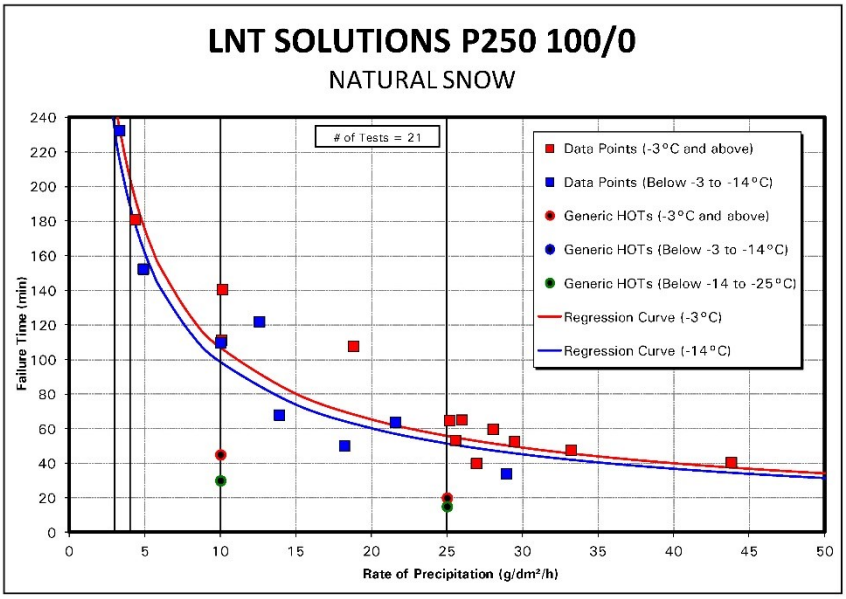


Figure 4.1: Type II Neat – Natural Snow

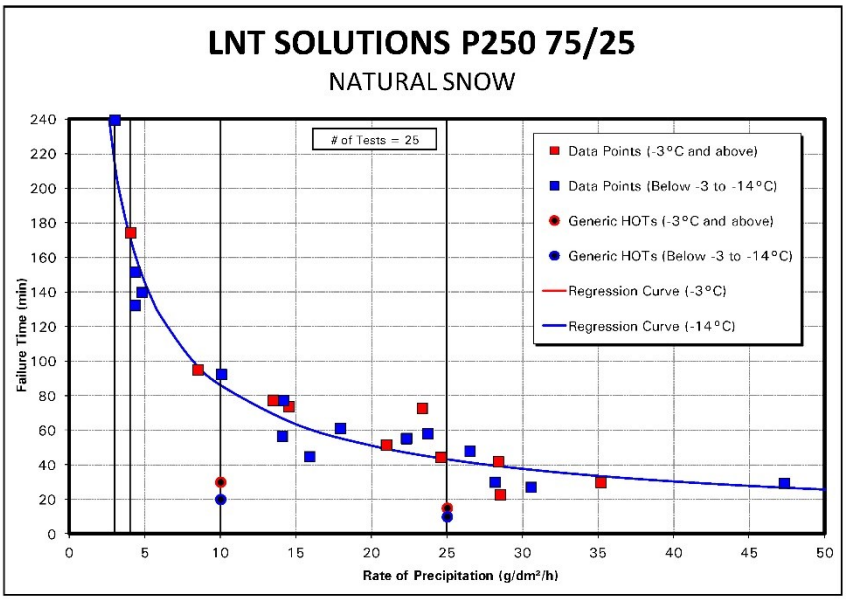


Figure 4.2: Type II 75/25 – Natural Snow

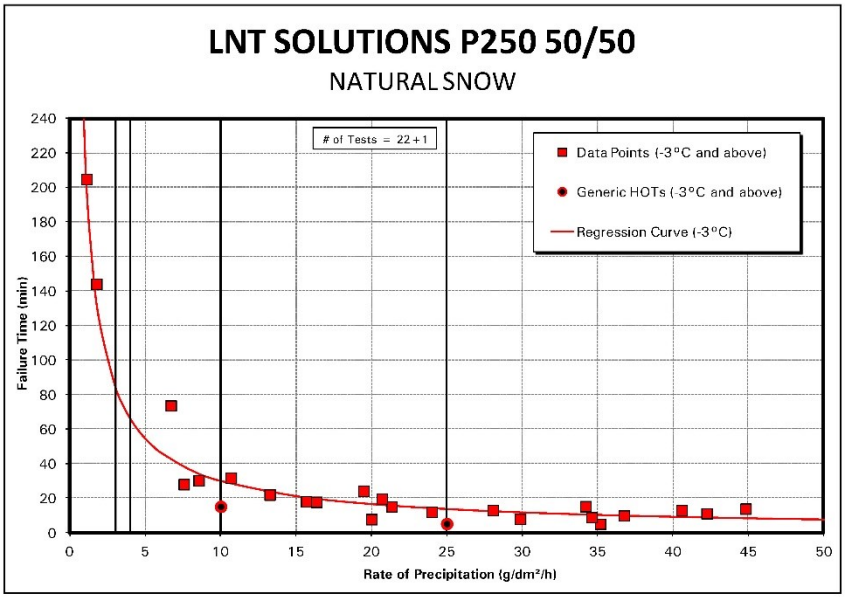


Figure 4.3: Type II 50/50 – Natural Snow

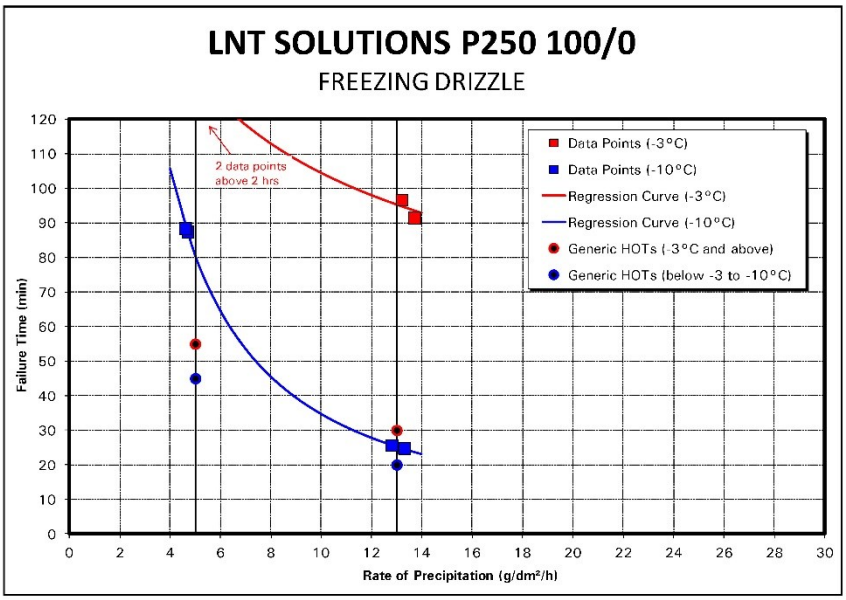


Figure 4.4: Type II Neat – Freezing Drizzle

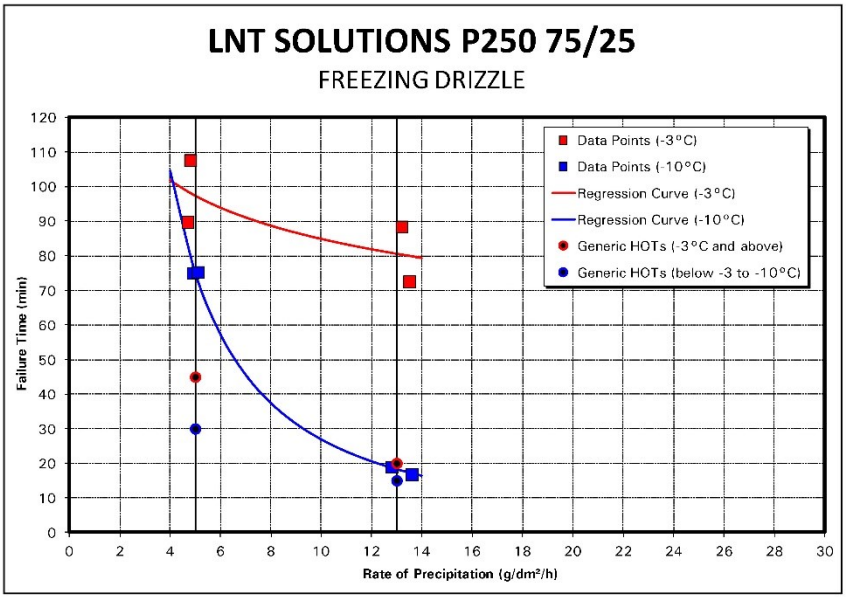


Figure 4.5: Type II 75/25 – Freezing Drizzle

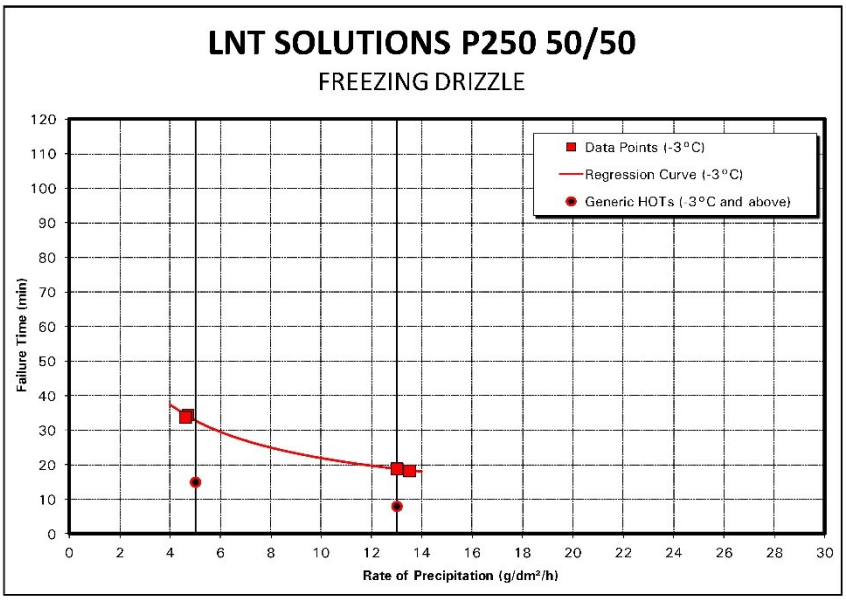


Figure 4.6: Type II 50/50 – Freezing Drizzle

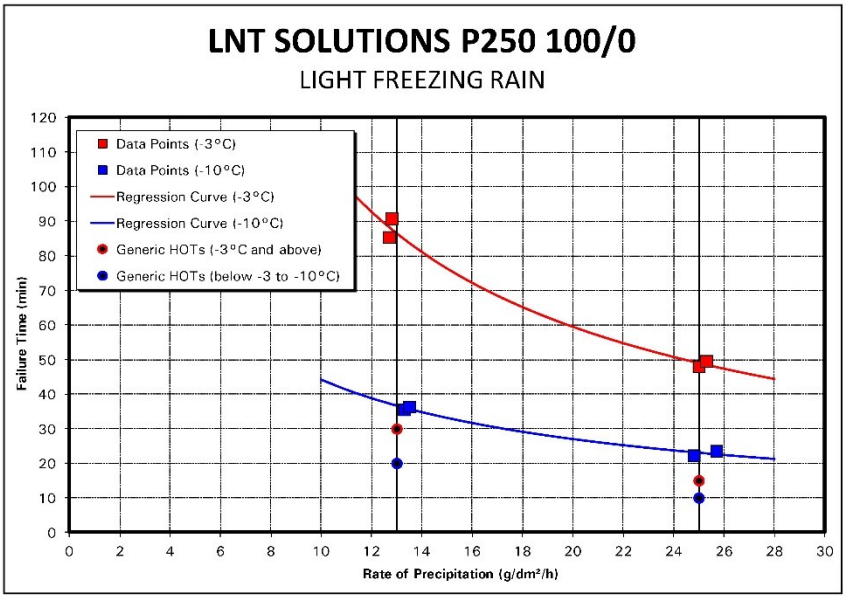


Figure 4.7: Type II Neat – Light Freezing Rain

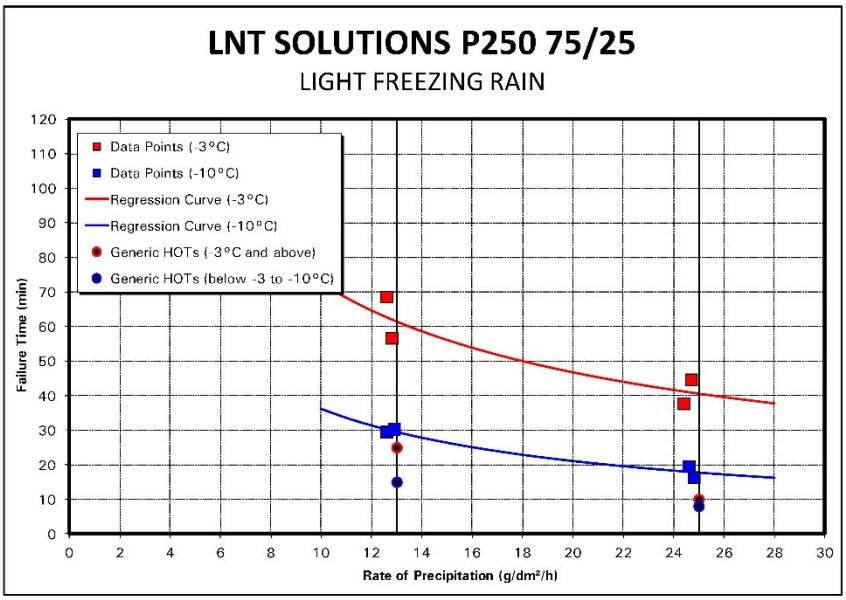


Figure 4.8: Type II 75/25 – Light Freezing Rain

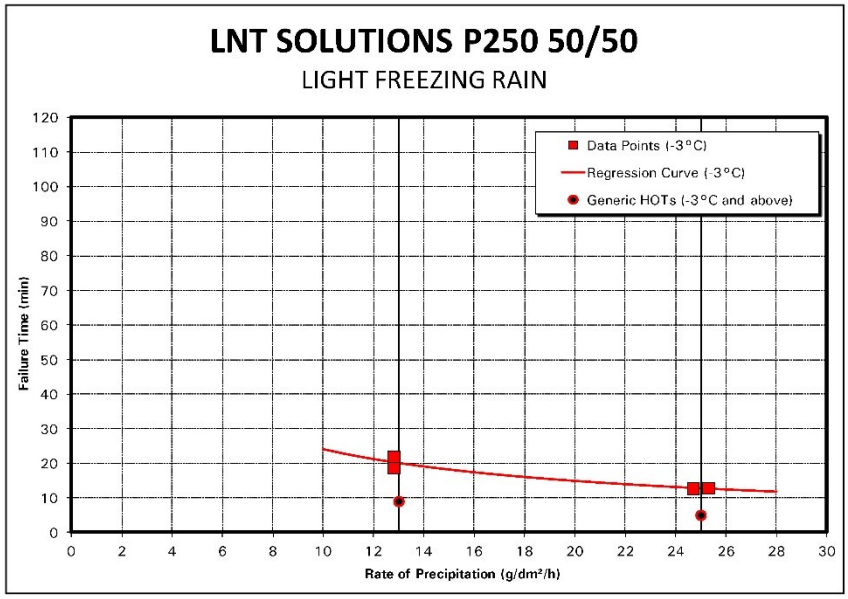


Figure 4.9: Type II 50/50 – Light Freezing Rain

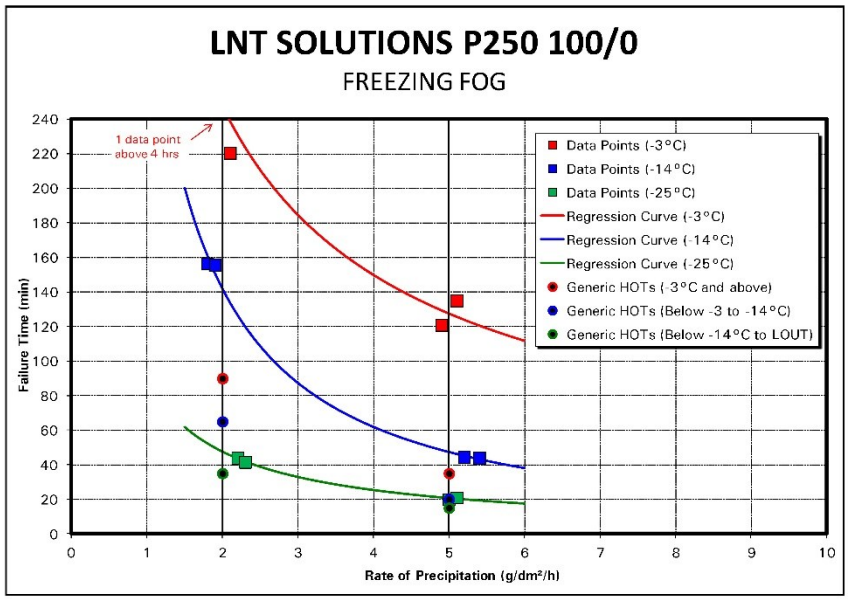


Figure 4.10: Type II Neat – Freezing Fog

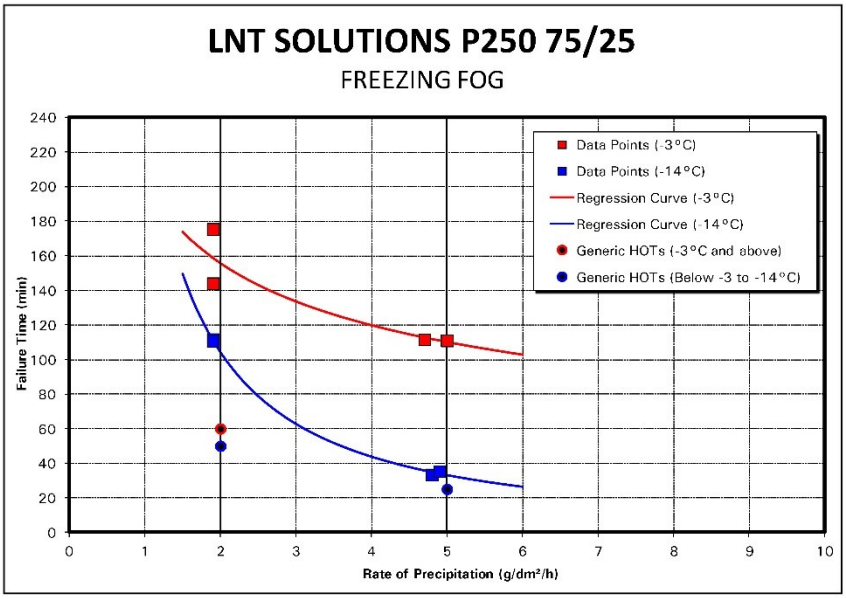


Figure 4.11: Type II 75/25 – Freezing Fog

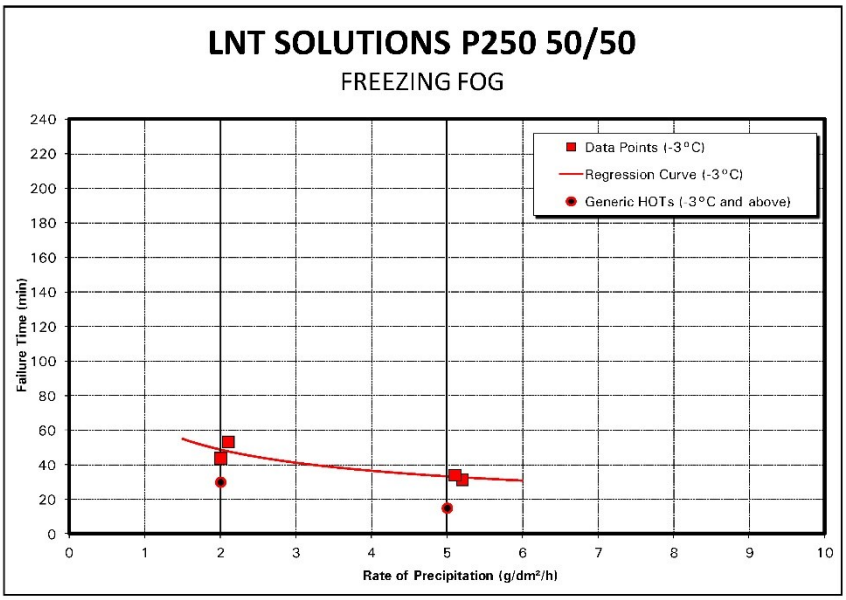


Figure 4.12: Type II 50/50 – Freezing Fog

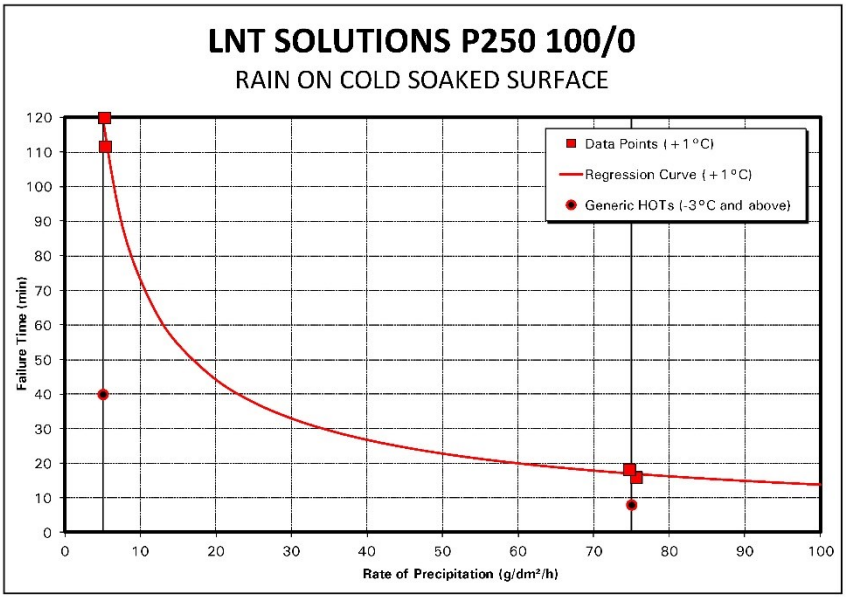


Figure 4.13: Type II Neat – Rain on Cold-Soaked Surface

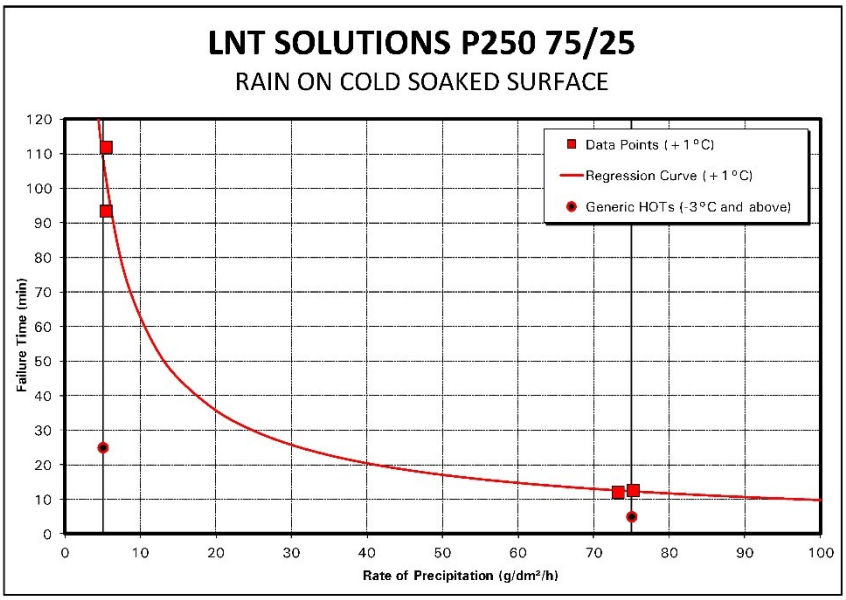


Figure 4.14: Type II 75/25 – Rain on Cold-Soaked Surface

Table 4.1: Regression Equation Coefficients for LNT Solutions P250

Natural Snow Conditions

Fluid	Dil	R^2	Intercept (I)	Coeff. Rate (A)	Coeff. Tem (B)	Total Pts.
LNT Solutions P250	Neat	88%	2.7865	-0.7100	-0.0686	21
LNT Solutions P250	75%	88%	2.6894	-0.7555	0.0000	25
LNT Solutions P250	50%	86%	2.3406	-0.8670	0.0000	23

General Equation $t = 10^{I} R^{A} (2\text{-}T)^{B}$

Simulated Freezing Fog

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
LNT Solutions P250	Neat	-3°C	95%	2.6120	-0.7237	4
LNT Solutions P250	75/25	-3°C	87%	2.3071	-0.3797	4
LNT Solutions P250	50/50	-3°C	85%	1.8141	-0.4176	4
LNT Solutions P250	Neat	-14°C	100%	2.5125	-1.1965	4
LNT Solutions P250	75/25	-14°C	100%	2.3960	-1.2541	4
LNT Solutions P250	Neat	-25°C	100%	1.9517	-0.9112	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
LNT Solutions P250	Neat	-3°C	97%	2.3698	-0.3507	4
LNT Solutions P250	75/25	-3°C	54%	2.1265	-0.1979	4
LNT Solutions P250	50/50	-3°C	100%	1.9204	-0.5800	4
LNT Solutions P250	Neat	-10°C	100%	2.7526	-1.2111	4
LNT Solutions P250	75/25	-10°C	100%	2.9133	-1.4840	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
LNT Solutions P250	Neat	-3°C	99%	2.9042	-0.8680	4
LNT Solutions P250	75/25	-3°C	85%	2.4972	-0.6358	4
LNT Solutions P250	50/50	-3°C	94%	2.0671	-0.6870	4
LNT Solutions P250	Neat	-10°C	98%	2.3546	-0.7092	4
LNT Solutions P250	75/25	-10°C	94%	2.3372	-0.7789	4

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
LNT Solutions P250	Neat	+1°C	100%	2.5822	-0.7200	4
LNT Solutions P250	75/25	+1°C	100%	2.6004	-0.8062	4

General Equation $t = 10^{I} R^{A}$

Table 4.2: Fluid Specific Holdover Time Guidelines – LNT Solutions P250 (Transport Canada Format)

TABLE 2-L-P250

TYPE II FLUID HOLDOVER TIME GUIDELINES
LNT SOLUTIONS P250

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:10 – 4:00	2:00	1:45 – 2:00	0:55 – 1:45	1:35 – 2:00	0:50 - 1:25	0:15 – 2:00	
		75/25	1:50 – 2:35	2:00	1:25 – 2:00	0:45 – 1:25	1:20 – 1:35	0:40 – 1:00	0:10 – 1:50	
		50/50	0:35 – 0:50	1:05	0:30 – 1:05	0:15 – 0:30	0:20 – 0:35	0:15 – 0:20		
below -3 to -14	below 27 to 7	100/0	0:45 – 2:20	2:00	1:40 – 2:00	0:50 – 1:40	0:25 – 1:20[7]	0:25 – 0:35[7]	CAUTION: No holdover time guidelines exist	
		75/25	0:35 – 1:45	2:00	1:25 – 2:00	0:45 – 1:25	0:20 – 1:15[7]	0:20 – 0:30[7]		
below -14 to LOUT	below 7 to LOUT	100/0	0:20 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES
1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility (Table 5) 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 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

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

Table 4.3: Fluid Specific Holdover Time Guidelines – LNT Solutions P250 (FAA Format)

TABLE 2H. TYPE II HOLDOVER TIME GUIDELINES FOR LNT SOLUTIONS P250

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:10-4:00	3:00-3:00	1:45-3:00	0:55-1:45	1:35-2:00	0:50-1:25	0:15-2:00	
		75/25	1:50-2:35	2:50-3:00	1:25-2:50	0:45-1:25	1:20-1:35	0:40-1:00	0:10-1:50	
		50/50	0:35-0:50	1:05-1:25	0:30-1:05	0:15-0:30	0:20-0:35	0:15-0:20	CAUTION No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45-2:20	3:00-3:00	1:40-3:00	0:50-1:40	0:25-1:20[7]	0:25-0:35[7]		
		75/25	0:35-1:45	2:50-3:00	1:25-2:50	0:45-1:25	0:20-1:15[7]	0:20-0:30[7]		
Below -14 to LOUT	Below 7 to LOUT	100/0	0:20-0:50	0:40-0:50	0:30-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4.4: LUPR Statistics – LNT Solutions P250

Data Measure	100/0		75/25		50/50	
	Stat	Rating	Stat	Rating	Stat	Rating
Total Data Points	21	40	25	40	23	40
Data Points -3 to -14°C	13	30	16	40	n/a	0
Data Points < 10.0	4	10	6	20	5	20
Data Points < = 9.5	4	40	6	40	5	40
Data Points < = 8.5	4	40	6	40	4	40
Data Points < = 7.5	4	40	5	40	3	40
Data Points < = 6.5	4	40	5	40	2	30
Data Points < = 5.5	4	40	5	40	2	30
Data Points < = 4.5	3	40	4	40	2	30
Data Points < = 3.5	2	30	1	20	2	30
Data Points < = 2.5	0	0	0	0	2	30
Scatter 0-10 g	9%	40	8%	40	24%	20

Rate	100/0		75/25		50/50	
	Score	Pass/Fail	Score	Pass/Fail	Score	Pass/Fail
9 g/dm²/h	32	pass	36	pass	25	pass
8 g/dm²/h	32	pass	36	pass	25	pass
7 g/dm²/h	32	pass	36	pass	25	pass
6 g/dm²/h	32	pass	36	pass	21	pass
5 g/dm²/h	32	pass	36	pass	21	pass
4 g/dm²/h	32	pass	36	pass	21	pass
3 g/dm²/h	28	pass	28	pass	21	pass
2 g/dm²/h	16	fail	20	fail	21	pass

LUPR	100/0	75/25	50/50
	3 g/dm²/h	3 g/dm²/h	2 g/dm²/h

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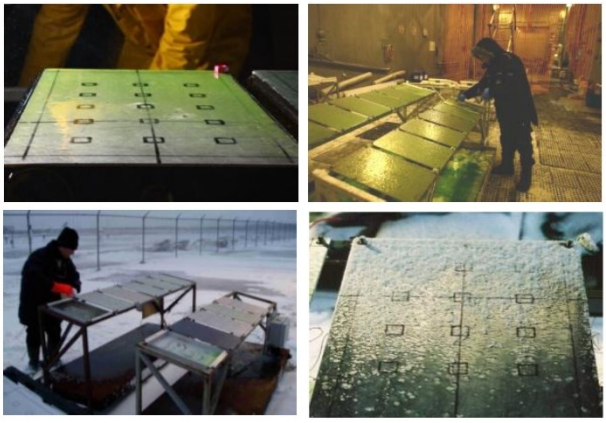
APPENDIX F

FLUID MANUFACTURER REPORT:
NEWAVE AEROCHEMICAL FCY-2 BIO + (TYPE II)

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Newave Aerochemical FCY-2 Bio + (Type II)



Prepared for

Newave Aerochemical Co. Ltd.

by

APS Aviation Inc.

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 1.0
Report No. NW-FCY2B 2014-15

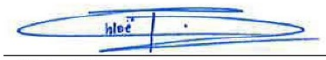
AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Newave Aerochemical FCY-2 Bio + (Type II)

Prepared for

Newave Aerochemical Co. Ltd.

Prepared by:



Chloë Bernier
Research Assistant

June 26, 2015
Date

And by:



Stephanie Bendickson
Project Analyst

June 26, 2015
Date

Reviewed by:



John D'Avirro, Eng.
Program Manager

June 26, 2015
Date

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 1.0
Report No. NW-FCY2B 2014-15

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer:	Newave Aerochemical Co. Ltd.		
Fluid Test Name:	FCY-2 Bio +		
Fluid Commercial Name:	FCY-2 Bio +		
Fluid Type / Base / Colour:	Type II / Propylene Glycol / Straw		
Batch #:	201412012 LS		
Date of Receipt:	January 22, 2015		
Brix (Measured):	Neat fluid:	36.25°	
	75/25 dilution:	28.5°	
	50/50 dilution:	19.5°	
Freeze Point (Stated):	Neat fluid:	-37.2°C	
	75/25 dilution:	-22.6°C	
	50/50 dilution:	-12.7°C	
Aerodynamic LOUT (AMIL):	Neat fluid:	-28.5°C	
	75/25 dilution:	-19.5°C	
	50/50 dilution:	-9.0°C	
Viscosity:	**Mfr Method**	**Stated**	**Measured**
	Neat fluid[1]:	5,800 cP	7,210 cP
	75/25 dilution[2]:	21,800 cP	21,400 cP
	50/50 dilution[1]:	1,870 cP	1,900 cP
	AIR 9968 Method	**Stated**	**Measured**
	Neat fluid[1]:	5,800 cP	7,210 cP
	75/25 dilution[2]:	21,800 cP	21,400 cP
	50/50 dilution[1]:	1,870 cP	1,900 cP
	50/50 dilution[3]:	not provided	544 cP
WSET (from AMIL):	Neat fluid:	77 minutes	

[1] Spindle LV1 (with guard leg), 600 mL Griffin, ~575 mL, 20°C, 0.3 rpm, 10 mins
[2] Spindle LV2 (with guard leg), 600 mL Griffin, ~425 mL, 20°C, 0.3 rpm, 10 mins
[3] Spindle LV0, ULA, 16 mL, 20°C, 0.3 rpm, 10 mins

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SUMMARY

The primary objective of this project was to measure the endurance time performance of **Newave Aerochemical FCY-2 Bio+** over the entire range of conditions encompassed by the Holdover Time (HOT) tables. This report contains the results of these measurements and was completed with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

Tests were carried out according to the protocol provided in Aerospace Recommended Practice (ARP) 5485. The test procedure consisted of pouring fluids onto clean aluminum test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural and simulated precipitation.

Tests were performed at the APS Aviation Inc. (APS) test facility at Montréal-Pierre-Elliott-Trudeau International Airport and the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were derived from the data collected using multi-variable regression analysis. This resulted in the generation of the fluid-specific holdover times shown in the tables on the next page. These holdover times will be published by regulators for use in the winter 2015-16 operating season.

Newave Aerochemical FCY-2 Bio+ Type II Fluid Holdover Times (Transport Canada Format)

Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume % /Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:25-2:30	2:00	1:05-2:00	0:30-1:05	0:50-1:20	0:25-0:45	0:08-1:15	
		75/25	0:45-1:20	1:20	0:40-1:20	0:20-0:40	0:25-0:50	0:15-0:25	0:06-0:35	
		50/50	0:15-0:30	0:25	0:15-0:25	0:08-0:15	0:10-0:20	0:08-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40-1:30	1:00	0:30-1:00	0:15-0:30	0:35-0:105	0:15-0:30		
		75/25	0:30-1:05	0:35	0:20-0:35	0:08-0:20	0:20-0:35	0:15-0:20		
below -14 to -28.5	below 7 to -19.3	100/0	0:20-1:00	0:40	0:30-0:40	0:15-0:30				

Newave Aerochemical FCY-2 Bio+ Type II Fluid Holdover Times (FAA Format)

Outside Air Temperature		Type II Fluid Concentration Neat Fluid/Water (Volume % /Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:25-2:30	2:20-2:55	1:05-2:20	0:30-1:05	0:50-1:20	0:25-0:45	0:08-1:15	
		75/25	0:45-1:20	1:20-1:40	0:40-1:20	0:20-0:40	0:25-0:50	0:15-0:25	0:06-0:35	
		50/50	0:15-0:30	0:25-0:30	0:15-0:25	0:08-0:15	0:10-0:20	0:08-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40-1:30	1:00-1:15	0:30-1:00	0:15-0:30	0:35-0:105	0:15-0:30		
		75/25	0:30-1:05	0:35-0:45	0:20-0:35	0:08-0:20	0:20-0:35	0:15-0:20		
below -14 to -28.5	below 7 to -19.3	100/0	0:20-1:00	0:40-0:50	0:30-0:40	0:15-0:30				

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GLOSSARY

APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LOUT	Lowest Operational Use Temperature
LOWV	Lowest On-Wing Viscosity
LUPR	Lowest Usable Precipitation Rate
LWC	Liquid Water Content
MVD	Median Volume Diameter
MANOBS	Manual of Surface Weather Observations
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

This report has been created with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

Aircraft ground de/anti-icing has been the subject of concentrated industry attention in recent years due to the occurrence of several fatal icing-related aircraft accidents. Notably, attention has been placed on the enhancement of anti-icing fluids in order to provide an extended period of protection against further contamination following initial deicing. This emphasis has led to the development of fluid-specific de/anti-icing fluid holdover time (HOT) tables for Type II and Type IV fluids. These tables, accepted by regulatory authorities, are used by aircraft operators for departure planning in adverse winter conditions. Specifically, they provide the duration of time that qualified fluids provide protection against ice formation under specific weather conditions.

New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid holdover times without compromising the aerodynamic features of the airfoil. The purpose of the endurance time testing program is to measure the endurance times of these new fluids and develop fluid-specific HOT tables that provide guidance for their use.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop HOT values for new fluids. These tests are carried out according to SAE Aerospace Recommended Practice (ARP) ARP5485, which provides the test protocols for measuring endurance times of Type II, III and IV fluids. Along with its counterpart for measuring endurance times of Type I fluids ARP5945, ARP5485 has evolved into a refined procedure for measuring the duration of de/anti-icing fluid protection against ice formation.

The current data analysis protocol for developing HOT values from endurance time data was developed in 1996-97 and uses multi-variable regression to obtain HOT values. HOT values are derived for all cells of the Type II/IV HOT tables using this protocol and are used to create a fluid-specific HOT table for each Type II/IV fluid tested.

This report provides a detailed account of the endurance time testing conducted by APS Aviation Inc. (APS) with **Newave Aerochemical FCY-2 Bio+**, a new Type II fluid. It describes the test methodology used, endurance time data collected, and analysis completed to derive fluid-specific holdover times for the fluid.

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2

2. METHODOLOGY

SAE Aerospace Recommended Practice (ARP) 5485 provides the procedure and requirements for endurance time testing with Type II, III and IV fluids under natural and simulated conditions. This chapter summarizes some of aspects of the test methodology included in ARP5485, and some aspects which are not included in ARP5485. The chapter includes sections for test sites, equipment, procedures, precipitation rates and ambient temperatures used in Type II/IV endurance time testing, and freezing precipitation droplet sizes. The final subsection describes the analysis methodology used to evaluate Type II/IV endurance time data.

2.1 Test Sites

2.1.1 Natural Snow, Natural Frost and Artificial Snow

Natural snow, natural frost and artificial snow testing is typically performed at the APS test site located at the Montréal-Pierre-Elliott-Trudeau International Airport. The test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station, as shown in Figure 2.1 on a plan view of the airport.

The APS test site consists of two trailers and three outdoor locations for test stands. One of the trailers is equipped with a refrigeration unit to enable indoor testing at controlled temperatures; artificial snow testing is conducted inside this trailer. Photos 2.1 and 2.2 show the test site as seen from the test pads and main trailer, respectively.

In winter 2014-15, additional natural snow mobile testing was conducted in Mirabel, Québec and Beaconsfield, Québec.

2.1.2 Freezing Precipitation

Tests under conditions of freezing fog, rain on cold-soaked surface, freezing drizzle, and light freezing rain were conducted indoors at the NRC Climatic Engineering Facility (CEF), where precipitation was artificially produced.

Photo 2.3 provides an outdoor view of the facility giving a general indication of its size (30 m by 5.4 m, height 8 m). The facility was originally designed for the testing of locomotives; Photo 2.4 provides an interior view of the CEF set up for endurance time testing. The lowest temperature achievable in the CEF is -46°C.

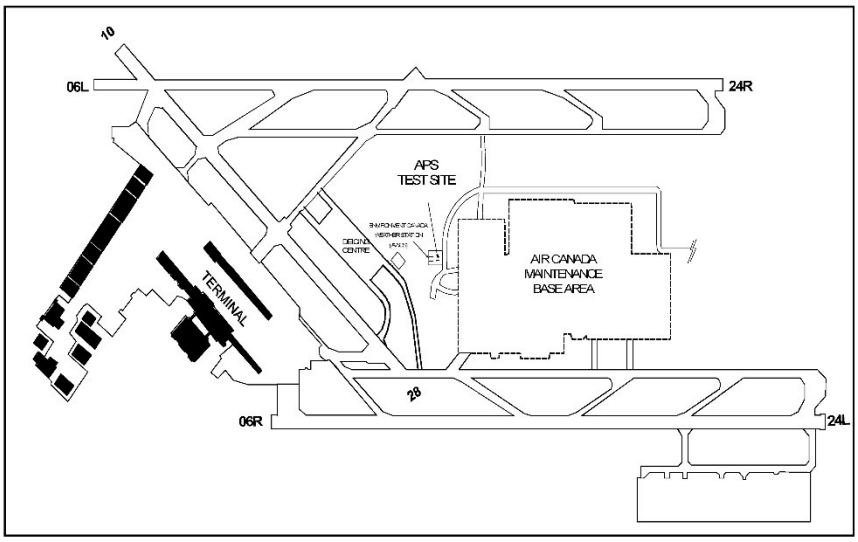


Figure 2.1: APS Test Site at Montréal-Pierre-Elliott-Trudeau International Airport

2.2 Test Equipment

The key equipment used in endurance time testing is described in this section, as are the calibration procedures APS follows for ensuring the accuracy of its test equipment.

2.2.1 Calibration

APS measurement instruments and test equipment are calibrated and/or verified on an annual basis. This calibration is carried out according to a calibration plan based upon approved International Organization for Standardization (ISO) 9001:2000 standards, and developed internally by APS.

2.2.2 Environmental Chamber Equipment

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) was as stipulated in the requirements set out in ARP5485.

2.2.3 Test Surface Structures

The majority of endurance time testing is carried out on standard flat plates. A schematic of a standard flat plate is provided in Figure 2.2. It depicts the size and surface markings of a standard flat plate. Three parallel lines are positioned at 2.5 cm (1"), 15 cm (6") and 30 cm (12") from the top of the plate. The plates are marked with 15 crosshairs, which are used in determining when end conditions (see Subsection 2.3.5) are achieved. Photo 2.5, taken outdoors at the APS test site, shows six test plates mounted on a test stand.

Figure 2.3 shows a schematic of the sealed boxes used for tests simulating a cold soaked wing. The top of the box consists of a flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate. Photo 2.6 shows a picture of a sealed box, which is referred to as a cold-soak box when filled for simulated rain on cold soaked wing tests.

In natural frost, tests are conducted on frosticator plates, which are the current standard test surface used in frost holdover time testing. The frosticator plates were constructed by attaching a Styrofoam insulation backing to the back of the test surface (either aluminum or composite). The insulation prevents heat exchange via the underside of the flat plate and allows for effective radiative cooling during active frost conditions. Photo 2.7 shows a white-painted aluminum frosticator plate.

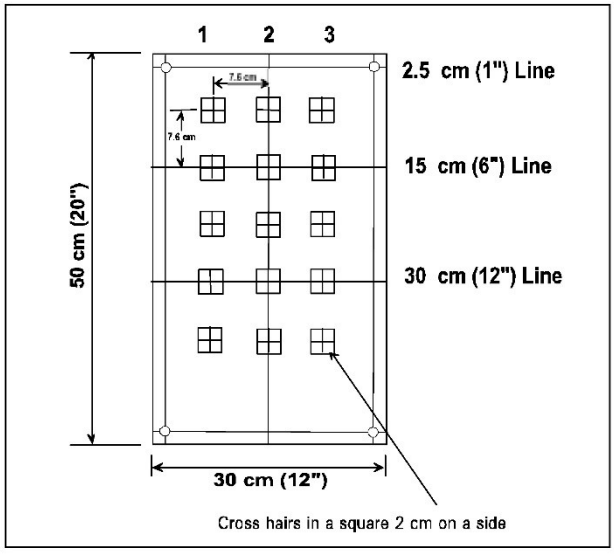


Figure 2.2: Standard Test Plate Schematic

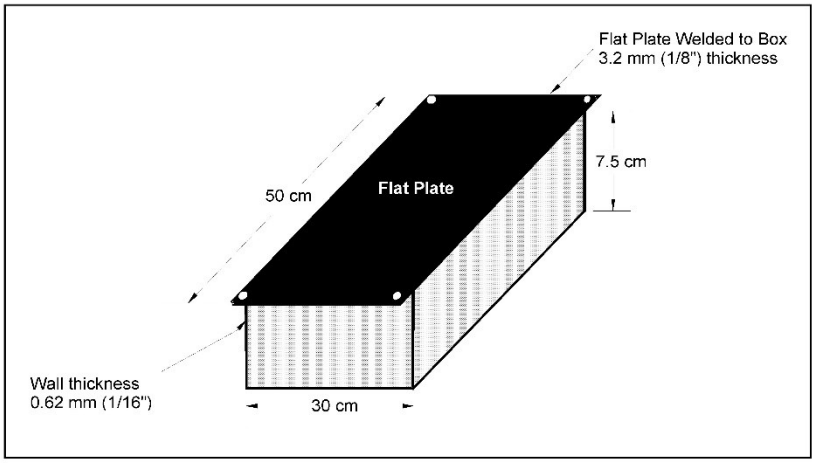


Figure 2.3: Cold Soak Box Schematic

2.2.4 Test Surface Materials

Testing of Type II, III and IV fluids is carried out exclusively on aluminum surfaces. The aluminum used is 0.32 cm thick Alclad 2024 T3 aluminum.

2.2.5 Test Stands

Figure 2.4 shows a schematic of the test platform used for HOT testing. For natural snow tests, six test plates are normally mounted on the test stand, which has a working surface inclined at 10° to the horizontal. During normal winter operations two six-position stands are used in combination. Each plate represents a flat plate test. For simulated freezing precipitation tests at the NRC, 12 plates are mounted on 2 six-position stands. Photos 2.4 and 2.5 show the test stands set up for indoor and outdoor testing, respectively.

2.2.6 Collection Pans

Figure 2.5 shows a schematic of the collection pan used for precipitation rate measurement in outdoor testing. It is the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.8 shows the collection pans used for measuring precipitation rates indoors at the NRC.

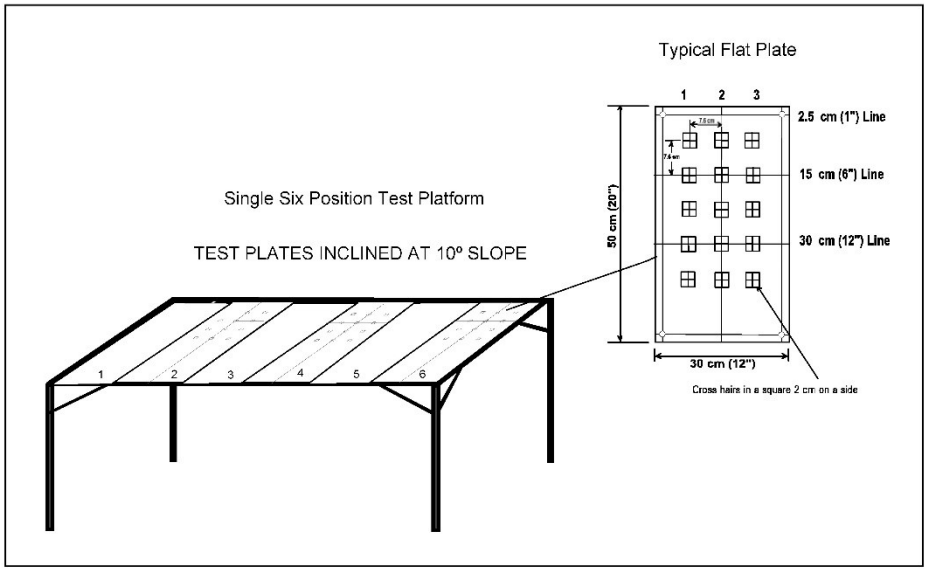


Figure 2.4: Test Stand Setup Schematic

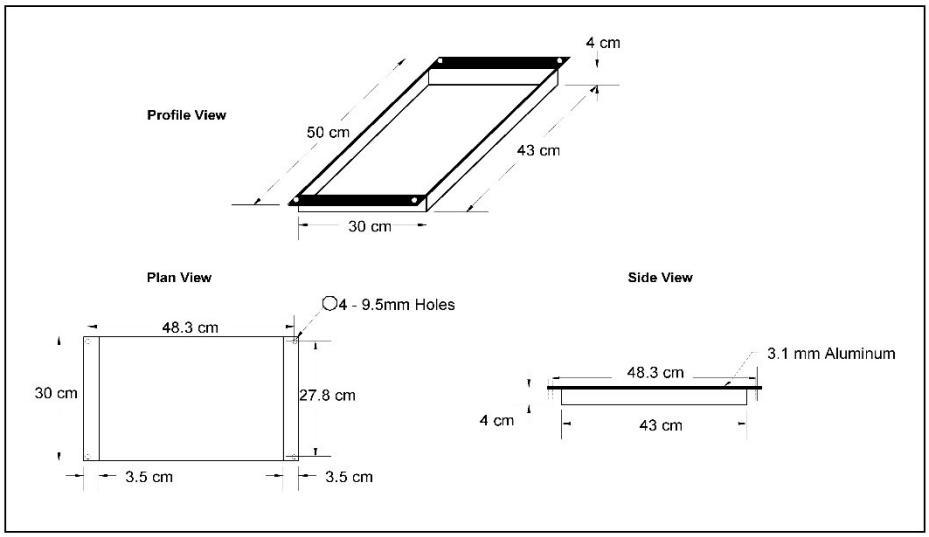


Figure 2.5: Schematic of Outdoor Precipitation Measurement Pan

2.2.7 NRC Sprayer Assembly

NRC developed an improved sprayer assembly, shown in Photos 2.9 and 2.10, in 1997-98. The improved sprayer provides a larger scan area and improved spray uniformity over the test bed area. The scanner consists of a horizontal main shaft supported by two bearings. The actual spray head assembly is shaft-mounted on a rotating scanner, so that one scan covers a lateral running strip of the test bed area. A stepper motor is synchronized to index the relative angle of the spray head between scans along an axis perpendicular to the scan axis. This provides two axes of rotation, essentially an x-y plane; one along each axis. Each scan is consecutively indexed in order to complete the precipitation coverage of the test bed area. This defines one cycle of the spray unit. The scan rate, index angle, and the number of scans per cycle are adjusted, along with the fluid delivery pressures (water and air) to obtain appropriate droplet sizes and precipitation rates. The spray nozzle is shown in Photo 2.11.

2.2.8 Fluids

Testing was carried out with Newave Aerochemical FCY-2 Bio+ in the standard Type II, III and IV fluid test dilutions: neat, 75/25 and 50/50. The fluid sample was diluted by the manufacturer.

2.3 Test Procedures

ARP5485 provides the procedure for endurance time testing of Type II, III and IV fluids under natural and simulated precipitation conditions.

The procedure generally consists of pouring de/anti-icing fluids onto clean flat plates exposed to various winter precipitation conditions, and recording the elapsed time for the test to reach the defined end condition (see Subsection 2.3.5), when a specified degree of freezing occurs. The following subsections provide summaries of the test procedures followed for natural snow, natural frost, artificial snow and simulated freezing precipitation testing.

2.3.1 Test Protocol – Natural Snow Tests

APS developed a specific procedure for Type II, III and IV fluid testing in natural snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted are conducted on standard flat plates (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.2 Test Protocol – Natural Frost Tests

APS developed a specific procedure for Type II/III/IV testing in natural frost. Key details of the procedure include:

- Tests are conducted on frosticator plates (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.3 Test Protocol – Artificial Snow Tests

APS developed a specific procedure for testing in artificial snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted on a standard plate (shown mounted on the snowmaker scale in Photo 2.12);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.4 Test Protocol – Simulated Precipitation Tests

APS developed a specific procedure for Type II/III/IV testing in simulated precipitation based on the requirements outlined in ARP5485. Key details of the procedure include:

- Freezing fog, freezing drizzle and light freezing rain tests are conducted on standard flat plates (see Section 2.2.3);
- Rain on cold-soak surface tests are conducted on filled cold-soak boxes (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.5 End Condition Definitions

Failure is called when 30 percent (1/3) of the plate or 5 cross-hairs are covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

a) Ice front;
b) Ice sheet;
c) Slush, in clusters or as a front;
d) Disseminated fine ice crystals;
e) Frost on surface;
f) Clear ice pieces partially or totally imbedded in fluid; and
g) Snow bridges on top of the fluid.

2.3.6 Precipitation Rate Measurement Procedures

The procedures for measuring and determining precipitation rates during simulated precipitation and natural precipitation conditions are provided below.

2.3.6.1 Simulated precipitation conditions

Prior to the start of the rate collection period, the proper needles and nozzles are installed in the spray unit, and both the air and water pressures are adjusted. Water spray calibration is performed by placing catch pans on the test stand, each pan marked with a number identifying the collection location on the test stand, and exposing the pans to a predetermined precipitation collection period.

The pans are weighed prior to exposure to precipitation and the weights are recorded in a customized Excel spreadsheet by using the print function on the digital weigh scale. Prior to the start of the precipitation catch period, the exact time (hh:mm:ss) is recorded using a pre-programmed time macro in the Excel spreadsheet. The pans are re-weighed following this collection period and the precipitation rates over the area of the test stand are examined. If the rates are unacceptable, re-calibration of the water spray is necessary. If the rates are deemed to be acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period has expired, the pans are again re-weighed and the rates computed.

Once two rates have been collected at each test location, the catch rates of the first and second collection are compared. If the average catch rate for any location

is deemed to be acceptable for the test condition, then the pouring of fluids may begin at this location.

Rates are continuously monitored at a minimum of two locations during a test in order to ensure there are no significant rate fluctuations. Pans will be placed at these locations and be re-weighed at fixed intervals (15 minutes, typically) during the course of a test. If a rate fluctuation occurs, the test is stopped.

Following the failure of a test plate, a rate collection pan is weighed and placed at the plate location for a predetermined time interval. It is then re-weighed and placed again on the stand to collect a minimum of two additional rates at this location.

The rate of precipitation for any location on the stand is calculated by averaging the two rates collected prior to the test and the two rates collected following the test.

2.3.6.2 Natural precipitation conditions

Two rate collection pans per test stand are used to determine precipitation rates in natural conditions. Prior to the rate collection period, both pans are marked (upper and lower), and the inner bottom and sides of the each pan are wetted with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The wetted pans are then weighed to the nearest gram. The start time of the rate collection period is recorded (h/min/sec) using a customized Excel spreadsheet in which the weight is also recorded by pressing the print function on the digital weigh scale.

The pans are positioned in locations 6 and 7 (see Figure 2.4) and are allowed to collect precipitation for 10-minute intervals in normal conditions and 5-minute intervals in periods of high precipitation rates and high winds. Prior to removal of the plate pans from the test stand for re-weighing, any accumulated precipitation on the lips and outer sides of each plate pan is carefully removed. The plate pans are then carried to the rate station for re-weighing. Upon entering the trailer, the exact time is noted. The new weights of the plate pans are recorded and the pans are brought back outside. This procedure is continued until the final plate on the test stand has failed.

The rate for any HOT test in natural snow is obtained by computing the time-weighted average of the rates collected in the upper and lower pans over the duration of this particular test. To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.6. Typically, two collections pans are used for each test. The start and end times of the test shown in Figure 2.6 are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t1, t2, and t3 (minutes). The calculated rates for each collection period are indicated by R1, R2, and R3 (g/dm²/h). In order to calculate the average rate for this pan, the following formula is then used:

$$\frac{(R_1 \times t_1 + R_2 \times t_2 + R_3 \times t_3)}{t_1 + t_2 + t_3}$$

In the example shown in Figure 2.6, the rate is calculated as follows:

$$\frac{(25 \times 10 + 22 \times 8 + 34 \times 5)}{10 + 8 + 5}$$

The calculated average rate for this pan is 25.9 g/dm²/h. The average rate for the other collection pan is calculated in similar fashion, and the average of the two rates is then taken.

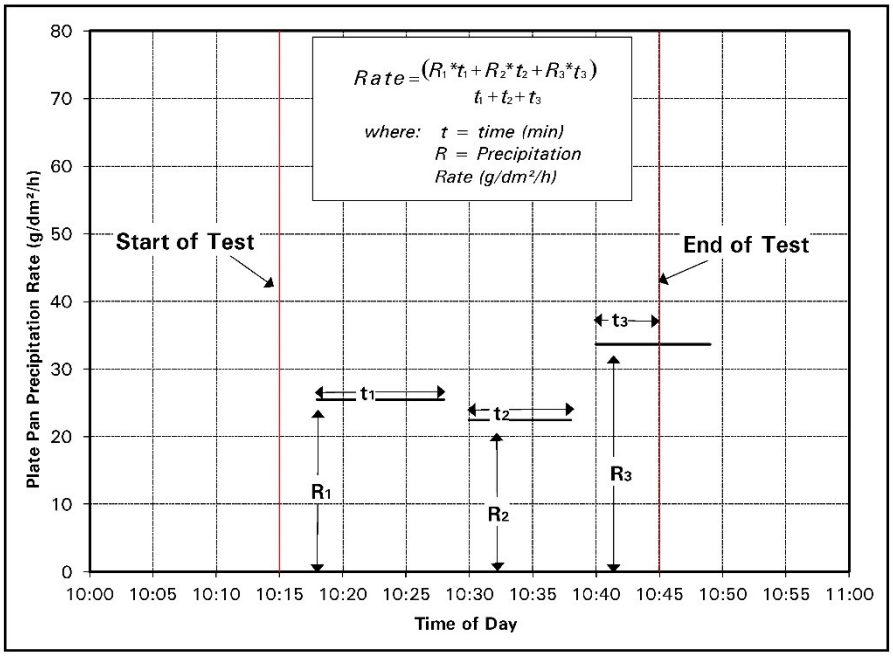


Figure 2.6: Calculation of Outdoor Precipitation Rate

2.4 Precipitation Rate Limits in Type II/IV Endurance Time Testing

Upper and lower precipitation rate limits are an important part of the test methodology for measuring fluid endurance times. Table 2.1 provides the meteorologically accepted definitions of weather phenomenon / precipitation types. It also includes the criteria used to determine precipitation intensity. This table was compiled by the National Centre for Atmospheric Research (NCAR) from the *World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation* (1983) and from the *American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS*) (3/94).

The precipitation rate limits established for Type II/IV endurance time testing are provided in ARP5485 and represented graphically in Figure 2.7. Subsections 2.4.1 to 2.4.5 provide detailed definitions and explanations of the precipitation types and rate boundaries used in Type II/IV endurance time testing. It should be noted that in many cases these limits are not the same as the meteorologically accepted definitions provided in Table 2.1.

Table 2.1: Definition of Weather Phenomenon

Weather Phenomenon*	Definition*
FROST (No METAR code) Note: No Intensity is assigned to FROST.	Ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.
FREEZING FOG (FZFG) Note: No Intensity is assigned to FRZ FOG	A suspension of numerous minute water droplets which freezes upon impact with ground or other exposed objects, generally reducing the horizontal
SNOW (SN)	Precipitation of ice crystals, most of which are branched, star-shaped, or mixed with unbranched crystals. At temperatures higher than about -5°C
FRZING DRIZZLE (FZDZ)	Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0.02 in.)] very close together which freezes upon impact with
FREEZING RAIN (FZRA)	Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5
RAIN (RA)	Precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 in.) diameter or of smaller widely scattered drops.
SNOW PELLETS (GS) and/or SMALL HAIL	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is
HAIL (GR)	Precipitation of small balls or pieces of ice with a diame-
ICE PELLETS (PE)	Precipitation of transparent (sleet or grains of ice), or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 in.)

Intensity Criteria**

	Snow(SN),Pellets(GS),Grains(SG)		Ice Pellets (PE)
Estimated Intensity	**Horizontal Visibility (statute mile)**	**Liquid Equivalent Snow (SN) Intensity*** **	**Definition and Horizontal Visibility**
Light (-)	If visibility is: **≥ 5/8 mi** (≥ 1.0 km)	**Trace to 0.05 in/hr** (≤ 1.0 mm/hr or 10 gr/dm²/hr)	Scattered pellets on the ground. Visibility not affected.
Moderate	If visibility is: **< 5/8 to 5/16 mi** (< 1.0 to 0.5 km)	**> 0.05 to 0.10 in/hr** (> 1.0 to 2.5 mm/hr) (> 10.0 to 25.0 gr/dm²/hr)	Slow accumulation on the ground. Visibility reduced to less than 7 mi.
Heavy (+)	If visibility is: **< 5/16 mi** (< 0.5 km)	**More than 0.10 in/hr** (> 2.5 mm/hr or 25 gr/dm²/hr)	Rapid accumulation on the ground. Visibility reduced to less than 3 mi.

Note: Horizontal visibility is only an estimation of snow and freezing drizzle intensity. Measurements and observations have

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm/hr or 2.54 gr/dm²/hr)
Moderate	From 0.01 to 0.02 in/hr (2.54 to 5.08 gr/dm²/hr)
Heavy(+)	More than 0.02 in/hr (> 5.08 gr/dm²/hr) Note: Drizzle > 0.04 in/hr is usually in the form of rain.

	Rain (RA), Freezing Rain (FZRA), Ice Pellets (PE)
Measured Intensity	Up to 0.10 in/hr (2.5 mm/hr or 25 gr/dm²/hr) Maximum 0.01 inch in 6 minutes
Light (-)	
Estimated Intensity	From scattered drops that, regardless of duration, do not completely wet an
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.01 to 0.03 inch in 6 minutes
Moderate	
Estimated Intensity	Individual drops are not clearly identifiable; spray is observable just above
Measured Intensity	More than 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.03 inch in 6 minutes
Heavy (+)	
Estimated Intensity	Rain seemingly falls in sheets; individual drops are not identifiable; heavy

*From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
**From American Meteorological Society, Glossary of Meteorology WSOH #7 MANOBS (3/94)
***NCAR/UAE Proposed Definition for Liquid Equivalent Snowfall Intensity

1) gr/dm² = 0.01 cm = 0.1 mm = 0.0039 in
2) in = 2.54 cm = 25.4 mm = 254 gr/dm²

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP Sept 8, 1999 (Updated for METAR codes)

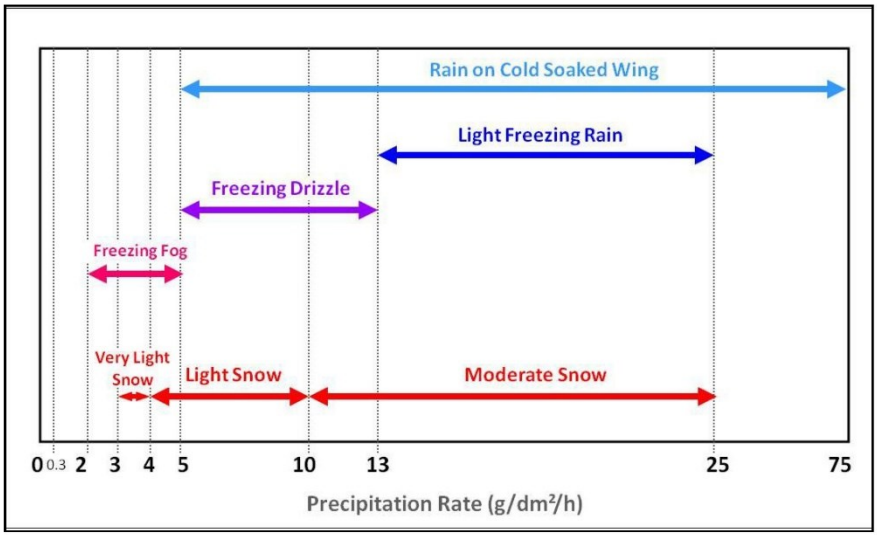


Figure 2.7: Precipitation Rate Limits Used in Endurance Time Testing

2.4.1 Freezing Fog

The precipitation rate limits for endurance time testing in freezing fog were set in 1997 at rates of 2 and 5 g/dm^2/h. These limits were determined with input from NRC meteorologists, who helped define an important parameter in the study of fog referred to as the *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic meter of air, can generally assume values in the range of 0.2 to 0.6 g/m^3.

2.4.2 Freezing Drizzle

The precipitation rate limits for endurance time testing in freezing drizzle are 5 and 13 g/dm^2/h. The upper limit in this range was adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Committee. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety.

2.4.3 Light Freezing Rain

The precipitation rate limits for endurance time testing in light freezing rain are 13 and 25 g/dm^2/h. This range corresponds to the category of light freezing rain and is the only freezing rain category considered, as operations in periods of moderate or heavy freezing rain are deemed unsafe.

2.4.4 Rain on a Cold-Soaked Surface

The precipitation rate limits for rain on cold soaked surface are 5 and 75 g/dm^2/h. This range encompasses drizzle (5 to 13 g/dm^2/h), light rain (13 to 25 g/dm^2/h), and moderate rain (25 to 75 g/dm^2/h).

2.4.5 Snow

The precipitation rate limits used to determine holdover times for Type II/IV fluids in snow are 3, 4, 10 and 25 g/dm^2/h. These rate limits encompass very light, light and moderate snow.

2.5 Ambient Temperatures in Type II/IV Endurance Time Testing

The Type II/IV holdover time tables provide holdover times for three temperature ranges:

- -3°C and above;
- Below -3 to -10°C (freezing drizzle, light freezing rain, cold soak wing) or Below -3 to -14°C (freezing fog, snow); and
- Below -14°C to LOUT

In natural snow testing, endurance time testing is carried out under a range of temperatures. In simulated freezing precipitation and artificial snow testing, endurance time testing is typically conducted at the lower limit of each temperature band.

- Freezing Fog: -3°C, -14°C and -25°C
- Freezing Drizzle: -3°C and -10°C
- Light Freezing Rain: -3°C and -10°C
- Rain on Cold Soaked Surface: +1°C
- Artificial Snow: -3, -14 and/or -25°C

2.6 Freezing Precipitation Droplet Sizes

Research has shown that median volume diameter (MVD) of rain droplets is related to rate of precipitation as follows:

- MVD = (precipitation rate/10) $^{0.23}$, where MVD is in mm and rate of precipitation is in g/dm²/h

The theoretical MVDs for rain at various rates of precipitation were determined based on this equation. These values are listed in Table 2.2 beside the experimental MVDs for each precipitation condition.

Table 2.2: Theoretical and Experimental MVDs

Precipitation Condition	Experimental MVD (mm)	Theoretical MVD (mm)
Moderate Rain (High rate: 75 g/dm²/h)	1.4	1.6
Light Rain (Low rate: 13 g/dm²/h)	1.0	< 1.1
Light Rain (High rate: 25 g/dm²/h)	1.0	1.2
Drizzle (Low rate: 5 g/dm²/h)	0.25	< 0.5
Drizzle (High rate: 13 g/dm²/h)	0.35	< 0.5
Fog		< 0.1

To determine whether droplets produced at the NRC resembled droplets from natural precipitation, a test was conducted during natural light freezing rain conditions in 1997-98 at the APS test site. The droplet sizes were compared to those obtained in simulated light freezing rain at the NRC. The results of these tests are shown below.

a) *For the outdoor test:*

Location:	Montreal P.E.T. Airport
Precipitation:	Natural Light Freezing Rain
Precipitation Rate:	20 g/dm²/h
Calibrated MVD:	1.0 mm

b) *For the indoor test:*

Location:	National Research Council
Precipitation:	Simulated Light Freezing Rain
Precipitation Rate:	25 g/dm²/h
Calibrated MVD:	1.0 mm

The MVD for both natural and simulated light freezing rain was 1 mm, indicating that the NRC produced droplets simulate natural precipitation.
As a result of this testing, the MVDs for freezing precipitation testing were established as follows:

- Freezing Fog, high precipitation rate (5 g/dm²/h): 30 μm
- Freezing Fog, low precipitation rate (2 g/dm²/h): 30 μm
- Freezing Drizzle, high precipitation rate (13 g/dm²/h): 350 μm
- Freezing Drizzle, low precipitation rate (5 g/dm²/h): 250 μm
- Light Freezing Rain, high precipitation rate (25 g/dm²/h): 1,000 μm
- Light Freezing Rain, low precipitation rate (13 g/dm²/h): 1,000 μm
- Rain on Cold-Soaked Surface, low precipitation rate (5 g/dm²/h): 250 μm
- Rain on Cold-Soaked Surface, high precipitation rate (75 g/dm²/h): 1,400 μm

2.7 Summary of Freezing Precipitation Test Conditions

The precipitation types/rates, ambient temperatures and droplet sizes for freezing precipitation testing with Type II/IV fluids were described in the previous subsections. In summary, freezing precipitation tests are carried out under each of the 16 weather conditions listed in Table 2.3.

Table 2.3: Summary of Freezing Precipitation Test Conditions (Type II/IV Fluids)

Precipitation Type	Ambient Temperature	Precipitation Rate (Droplet Size)
Freezing Fog	-3°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-14°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-25°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
Freezing Drizzle	-3°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
	-10°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
Light Freezing Rain	-3°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
	-10°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
Rain on Cold-Soaked Surface	+1°C	5 g/dm²/h (250 μm)
		75 g/dm²/h (1,400 μm)

2.8 Analysis Methodology

A multi-variable regression procedure is used to derive fluid-specific holdover times for Type II/IV fluids. The procedure is based on the refinement of an equation for a curve which best represents the test data, and then solving that equation at the upper and lower limits established for the precipitation type. These precipitation rate limits, set by the SAE G-12 HOT Committee and detailed in ARP5485, were described in Subsection 0. This approach was developed in the winter of 1996-97 (see TC report, TP 13131E) and has since been used to derive fluid holdover times. There are some differences in the way the methodology is applied to freezing precipitation and natural snow data.

2.8.1 Freezing Precipitation Data

For each related freezing precipitation HOT table cell, four tests are conducted at the most restrictive (lowest) temperature in the temperature range for that cell: two tests at the low precipitation rate limit and two tests at the high precipitation rate limit (limits are detailed in Subsection 0). The equation used to treat freezing precipitation data is:

- $t = 10^{I}R^{a}$, where

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.2 Natural Snow Data

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural snow tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather data under all temperatures and precipitation rates encompassed by the HOT tables.

The general form of the regression equation is modified for natural snow to incorporate the variable of temperature and also to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C. The equation used to treat natural snow data is:

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

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a, b = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, using the most restrictive (lowest) temperature for that cell. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.3 Natural Frost Data

Regression analysis is not used in the determination of frost holdover times. The current Type II/III/IV generic frost holdover times were determined based on several years of testing using all fluids which were commercially available at the time. A "minimum values" analysis methodology was used to determine appropriate holdover times from the test data.

The purpose of natural frost testing with new fluids is to verify the fluids can be used with the generic frost holdover times. The analysis methodology is to compare the frost test data collected with the new fluid to the current generic holdover times. If the test data provides holdover times equal to or greater than the generic holdover times then the generic holdover times have been validated for the new fluid.

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural frost tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather several data points with each fluid/dilution.

2.8.4 Rounding and Capping Protocols

Regression-generated holdover times are subject to rounding and capping protocols. For Type II/IV fluids they are as follows:

- Rounding Protocol: Holdover times are rounded to the nearest whole "5" minute, i.e. 55.1 to 57.4 minutes is rounded down to 55 minutes; 57.5 to 59.9 minutes is rounded up to 60 minutes. In cases where the regression-generated holdover times are below 10 minutes, the numbers are rounded down to the nearest whole minute as a precautionary measure. For example, 9.6 minutes is rounded down to 9 minutes.

- Capping Protocol: All holdover time values are capped at maximum values. The caps differ by precipitation type, and in the case of snow, by regulator. The caps are as follows:
  - Freezing Fog holdover time values are capped at 4 hours;
  - Freezing Drizzle, Light Freezing Rain, Rain on Cold Soaked Wing holdover times are capped at 2 hours; and
  - Snow holdover times are capped at 2 hours by Transport Canada and 3 hours by FAA.

2.8.5 Regression Example

Sample plots of **Log t** versus **Log R** are shown in Figure 2.8. The plots contain data for one Neat Type IV fluid, in one temperature range (-10°C), in light freezing rain conditions. The best-fit regression line is superimposed onto the plot and was obtained from the analysis using the lowest temperature in the temperature range from which the data were chosen.

The same data plotted on a linear scale (failure time **t** versus precipitation rate **R**) are shown in Figure 2.9. The curve, generated from the power law form of the equation using the coefficients determined from the fit, is superimposed onto the plot. The HOT range is determined from the intersections of the curve with the precipitation rate limits defined for light freezing rain.

The holdover times for this fluid at -10°C are 20 minutes at 13 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid in the light freezing rain, neat fluid, below -3 to -10°C cell. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

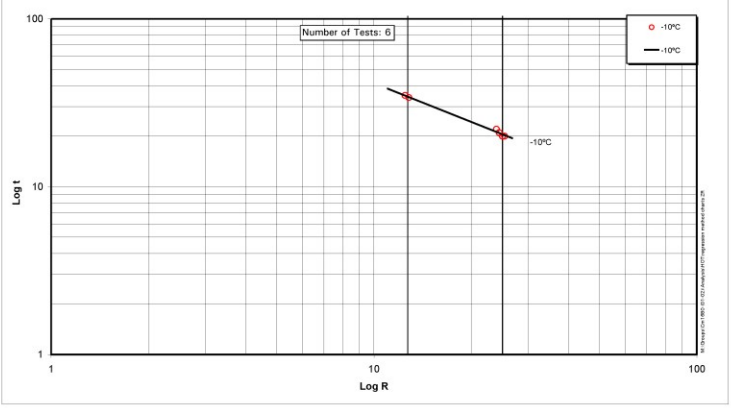


Figure 2.8: Regression Method on Log-Log Chart – Type IV Neat, Freezing Rain

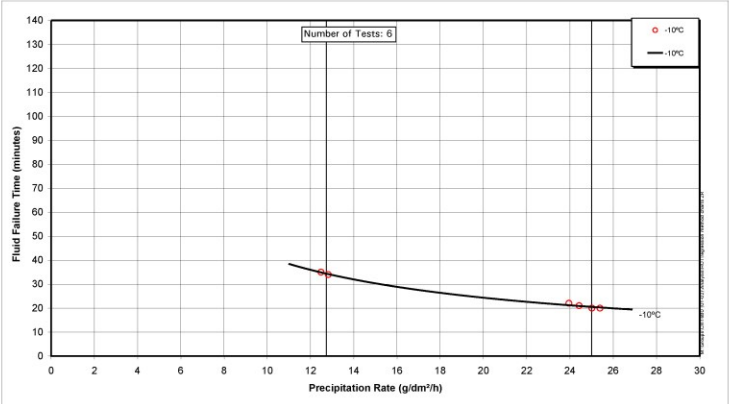


Figure 2.9: Regression Method on Standard Chart – Type IV Neat, Freezing Rain

2.8.6 Lowest Usable Precipitation Rates in Snow

A detailed analysis methodology was developed to determine if a snow data set is sufficient to determine holdover times for light and very light snow. Specifically, the analysis determines the lowest usable precipitation rate (LUPR), which is the lowest rate at which the data set is considered robust.

The methodology is a five-factor weighted analysis. The five factors are:

1. Total number of data points;
2. Number of data points with air temperatures below -3°C;
3. Number of data points with precipitation rates below 10 g/dm²/h;
4. Number of data points with precipitation rates less than or equal to 0.5 g/dm²/h above the precipitation rate being examined; and
5. Scatter from regression curve of low precipitation rate data points (average absolute percent difference between fail time and regression calculated fail time for all points less than or equal to 10 g/dm²/h).

The weights given to each of the five factors are:

1. Total Data Points = 5%;
2. Data Points Below -3°C = 20%;
3. Data Points Below 10 g/dm²/h = 20%;
4. Data Points ≤ Precipitation Rate = 40%; and
5. Low Rate Data Scatter = 15%.

Each data set is given a score of 0, 10, 20, 30 or 40 for each factor. The scoring system is shown in Table 2.4.

This approach provides a score for each data set for each precipitation rate below 10 g/dm²/h. The scores are compared to the minimum acceptance scores:

- 100/0 = 28
- 75/25 = 28
- 50/50 = 19 (lower due to a 0 score for data points below -3°C)

The LUPR is the lowest precipitation rate at which a data set has a passing score.

Table 2.4: LUPR Factor Scoring System

Factor #1: Total Data Points (Weight = 5%)	
Rating = 40	≥20 data points in data set
Rating = 30	15-19 data points in data set
Rating = 20	10-14 data points in data set
Rating = 10	5-9 data points in data set
Rating = 0	<5 data points in data set

Factor #2: Data Points Below -3°C (Weight = 20%)	
Rating = 40	≥15 data points from -3 to -14°C
Rating = 30	12-14 data points -3 to -14°C
Rating = 20	9-11 data points -3 to -14°C
Rating = 10	6-8 data points -3 to -14°C
Rating = 0	<6 data points -3 to -14°C

Factor #3: Data Points Below 10 g/dm²/h (Weight = 20%)	
Rating = 40	≥10 data points <10 g/dm²/h
Rating = 30	7-9 data points <10 g/dm²/h
Rating = 20	5-6 data points <10 g/dm²/h
Rating = 10	3-4 data points <10 g/dm²/h
Rating = 0	<3 data points <10 g/dm²/h

Factor #4: Data Points ≤ Precipitation Rate (Weight = 40%)	
Rating = 40	≥3 data points ≤ rate limit +0.5
Rating = 30	2 data points ≤ rate limit +0.5
Rating = 20	1 data points ≤ rate limit +0.5
Rating = 10	n/a
Rating = 0	0 data points ≤ rate limit +0.5

Factor #5: Low Rate Data Scatter (Weight = 15%)	
Rating = 40	Average actual-calculated error <10%
Rating = 30	Average actual-calculated error 10-19%
Rating = 20	Average actual-calculated error 20-29%
Rating = 10	Average actual-calculated error 30-39%
Rating = 0	Average actual-calculated error ≥40%

Photo 2.1: APS Test Site - View from Test Pad



Photo 2.2: APS Test Site - View from Trailer



Photo 2.3: Outdoor View of NRC Climatic Engineering Facility



Photo 2.4: Inside View of NRC Climatic Engineering Facility

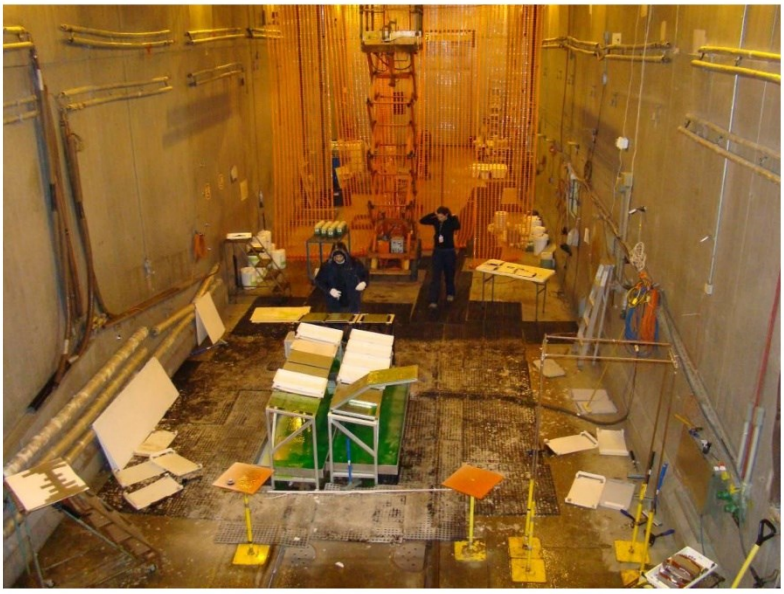


Photo 2.5: Test Plates Mounted on Stand

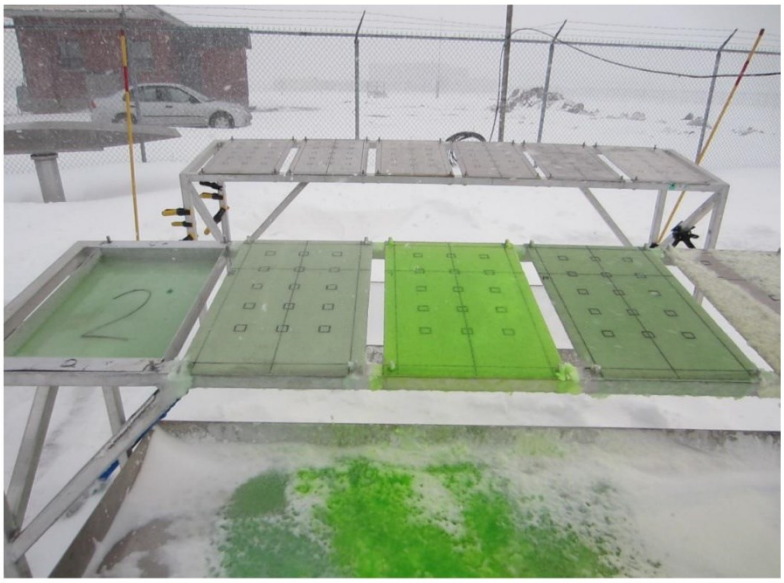


Photo 2.6: Cold-Soak / Leading Edge Thermal Equivalent Box

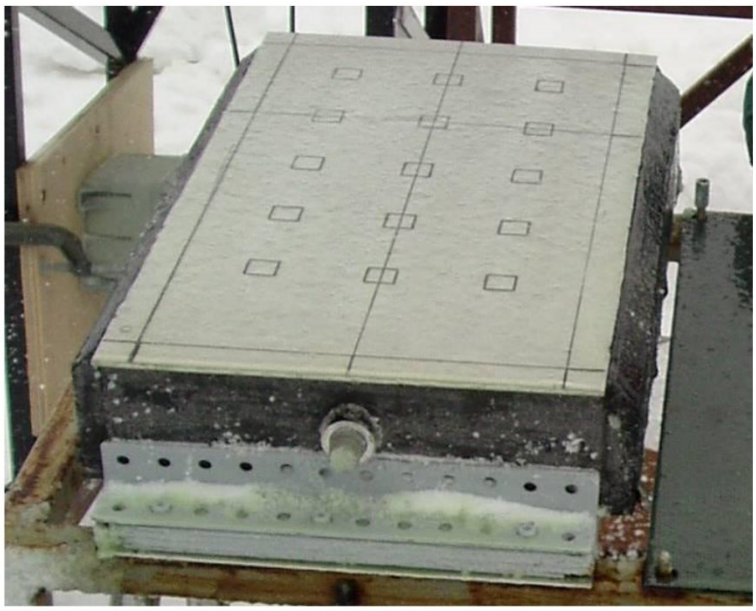


Photo 2.7: Frost Plate with Insulated Backing



Photo 2.8: Collection Pans Used Indoors at the NRC



Photo 2.9: Sprayer Assembly



Photo 2.10: Sprayer Assembly in Use

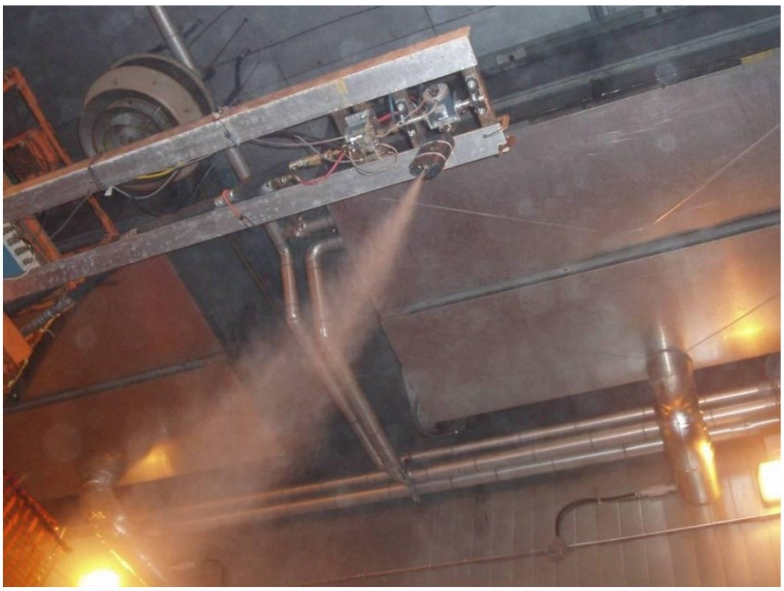


Photo 2.11: Sprayer Nozzle

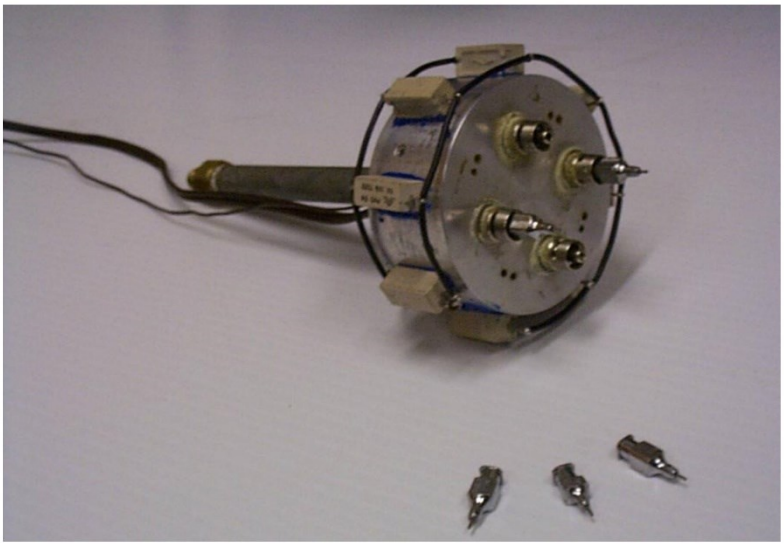
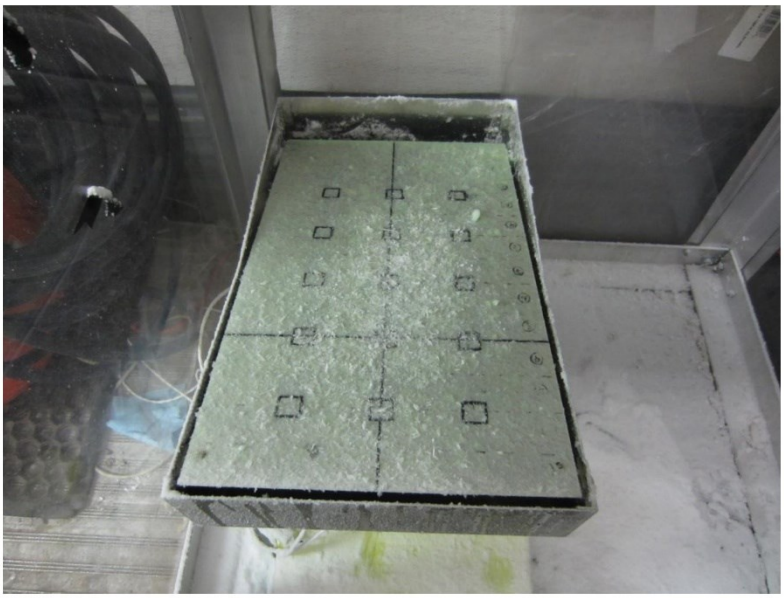


Photo 2.12: Standard Plate Setup for Testing with Artificial Snowmaker



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted. Breakdowns are provided for the number of tests performed by test type, precipitation type, fluid dilution and test temperature.

3.1 Natural and Artificial Snow Tests

Tests were conducted in natural snow conditions at the APS test site and at several mobile test sites (see Subsection 2.1.1). No artificial snow tests were conducted. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

Fluid Dilution	Natural Snow			Artificial Snow		
	≥ -3°C	-3 to -14°C	<-14°C	-3°C	-14°C	-25°C
Neat	7	17	7	0	0	0
75/25	8	19	0	0	0	0
50/50	19	1	0	0	0	0

3.2 Freezing Precipitation Tests

Tests were conducted in freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface conditions at the NRC CEF. The number of tests conducted is summarized below by precipitation type, fluid dilution and test temperature.

Fluid Dilution	Freezing Drizzle		Light Freezing Rain		Freezing Fog			Cold Soak
	-3°C	-10°C	-3°C	-10°C	-3°C	-14°C	-25°C	+1°C
Neat	4	4	4	4	4	4	4	4
75/25	4	4	4	4	4	4	0	4
50/50	4	0	4	0	4	0	0	0

3.3 Natural Frost Tests

Tests were conducted in natural frost at the APS test site. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

Fluid Dilution	Natural Frost			
	≥-1°C	<-1 to -3°C	<-3 to -10°C	<-10°C
Neat	0	0	1	3
75/25	0	0	1	1
50/50	1	0	1	0

3.4 Fluid Thickness Tests

Fluid thickness tests were conducted to measure the film thickness profiles of the fluid under dry conditions. Two tests were performed for each dilution. For each test, 1 litre of fluid was poured onto a flat plate mounted on a test stand inclined by 10°. Thickness measurements were taken at the 15-cm (6″) line at select time intervals over a 30-minute period. Tests were conducted at -3°C.

3.5 Test Logs

Details of each test conducted are provided in the test logs included as Table 3.1 (snow) Table 3.2 (freezing precipitation), and Table 3.3 (frost).

Table 3.1: Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
151	29-Jan-15	Natural Snow	FCY-2 Bio+	75%	-6.9	17.4	13.8
152	29-Jan-15	Natural Snow	FCY-2 Bio+	100%	-6.9	19.2	16.9
166	29-Jan-15	Natural Snow	FCY-2 Bio+	75%	-4.5	27.0	13.0
167	29-Jan-15	Natural Snow	FCY-2 Bio+	100%	-2.1	3.5	162.7
175	29-Jan-15	Natural Snow	FCY-2 Bio+	50%	-1.6	5.3	19.0
176	29-Jan-15	Natural Snow	FCY-2 Bio+	75%	-2.4	6.3	46.2
177	29-Jan-15	Natural Snow	FCY-2 Bio+	100%	-2.3	1.9	273.1
179	29-Jan-15	Natural Snow	FCY-2 Bio+	50%	-2.4	4.4	23.0
180	30-Jan-15	Natural Snow	FCY-2 Bio+	75%	-2.8	7.6	42.0
181	30-Jan-15	Natural Snow	FCY-2 Bio+	50%	-2.8	7.6	19.7
183	2-Feb-15	Natural Snow	FCY-2 Bio+	100%	-21.9	7.4	20.8
188	2-Feb-15	Natural Snow	FCY-2 Bio+	100%	-21.0	6.5	44.0
189	2-Feb-15	Natural Snow	FCY-2 Bio+	100%	-21.0	8.0	28.0
198	4-Feb-15	Natural Snow	FCY-2 Bio+	75%	-6.0	2.2	139.6
199	4-Feb-15	Natural Snow	FCY-2 Bio+	100%	-5.9	2.3	165.1
201	4-Feb-15	Natural Snow	FCY-2 Bio+	100%	-5.1	2.3	172.1
202	4-Feb-15	Natural Snow	FCY-2 Bio+	75%	-5.3	2.5	112.2
210	4-Feb-15	Natural Snow	FCY-2 Bio+	75%	-4.8	2.2	107.1
211	4-Feb-15	Natural Snow	FCY-2 Bio+	100%	-4.6	2.5	154.1
214	4-Feb-15	Natural Snow	FCY-2 Bio+	100%	-4.4	4.4	111.3
215	4-Feb-15	Natural Snow	FCY-2 Bio+	75%	-4.5	3.6	64.7
223	4-Feb-15	Natural Snow	FCY-2 Bio+	100%	-5.0	4.7	86.6
224	4-Feb-15	Natural Snow	FCY-2 Bio+	75%	-4.0	4.2	56.9
225	4-Feb-15	Natural Snow	FCY-2 Bio+	100%	-7.3	3.7	98.7
226	4-Feb-15	Natural Snow	FCY-2 Bio+	75%	-7.2	3.5	57.8
228	8-Feb-15	Natural Snow	FCY-2 Bio+	100%	-17.6	10.1	30.1
230	8-Feb-15	Natural Snow	FCY-2 Bio+	100%	-17.1	8.3	26.5
231	8-Feb-15	Natural Snow	FCY-2 Bio+	100%	-16.7	10.3	19.9
235	11-Feb-15	Natural Snow	FCY-2 Bio+	100%	-12.4	6.0	44.8
236	11-Feb-15	Natural Snow	FCY-2 Bio+	75%	-12.3	5.4	36.7
237	11-Feb-15	Natural Snow	FCY-2 Bio+	75%	-12.4	6.9	19.3
238	11-Feb-15	Natural Snow	FCY-2 Bio+	100%	-12.4	5.5	46.5
241	11-Feb-15	Natural Snow	FCY-2 Bio+	100%	-12.4	6.3	58.9
242	11-Feb-15	Natural Snow	FCY-2 Bio+	75%	-12.4	6.4	27.0
244	12-Feb-15	Natural Snow	FCY-2 Bio+	100%	-12.4	2.6	79.8
245	12-Feb-15	Natural Snow	FCY-2 Bio+	75%	-12.4	2.3	67.0

Table 3.1 (cont'd): Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
246	14-Feb-15	Natural Snow	FCY-2 Bio+	100%	-16.4	0.9	217.1
248	19-Feb-15	Natural Snow	FCY-2 Bio+	75%	-8.6	1.7	105.0
249	19-Feb-15	Natural Snow	FCY-2 Bio+	100%	-9.1	1.7	149.8
259	21-Feb-15	Natural Snow	FCY-2 Bio+	100%	-8.2	7.8	50.9
260	21-Feb-15	Natural Snow	FCY-2 Bio+	75%	-8.2	8.1	25.6
262	21-Feb-15	Natural Snow	FCY-2 Bio+	75%	-7.7	3.4	47.0
268	3-Mar-15	Natural Snow	FCY-2 Bio+	100%	-5.5	14.7	36.0
269	3-Mar-15	Natural Snow	FCY-2 Bio+	75%	-5.1	14.9	21.3
270	3-Mar-15	Natural Snow	FCY-2 Bio+	50%	-5.1	15.2	7.1
274	3-Mar-15	Natural Snow	FCY-2 Bio+	75%	-5.5	17.5	20.5
278	3-Mar-15	Natural Snow	FCY-2 Bio+	100%	-5.9	28.9	21.0
285	3-Mar-15	Natural Snow	FCY-2 Bio+	100%	-5.8	9.6	52.7
286	3-Mar-15	Natural Snow	FCY-2 Bio+	75%	-5.8	9.0	33.0
297	3-Mar-15	Natural Snow	FCY-2 Bio+	100%	-5.5	13.9	43.9
298	3-Mar-15	Natural Snow	FCY-2 Bio+	75%	-5.5	12.2	33.5
319	14-Mar-15	Natural Snow	FCY-2 Bio+	100%	-1.5	18.2	52.6
320	14-Mar-15	Natural Snow	FCY-2 Bio+	75%	-1.5	16.6	36.2
329	14-Mar-15	Natural Snow	FCY-2 Bio+	50%	-1.7	32.8	9.6
333	14-Mar-15	Natural Snow	FCY-2 Bio+	50%	-1.9	21.1	12.6
339	14-Mar-15	Natural Snow	FCY-2 Bio+	75%	-1.9	21.8	25.3
346	14-Mar-15	Natural Snow	FCY-2 Bio+	100%	-2.4	18.7	53.2
351	14-Mar-15	Natural Snow	FCY-2 Bio+	50%	-2.4	15.2	13.9
355	14-Mar-15	Natural Snow	FCY-2 Bio+	50%	-2.7	29.6	9.4
361	14-Mar-15	Natural Snow	FCY-2 Bio+	100%	-2.8	14.7	62.0
362	14-Mar-15	Natural Snow	FCY-2 Bio+	75%	-2.8	13.4	46.0
363	14-Mar-15	Natural Snow	FCY-2 Bio+	50%	-2.8	9.1	16.0
369	14-Mar-15	Natural Snow	FCY-2 Bio+	100%	-3.0	30.1	21.0
370	14-Mar-15	Natural Snow	FCY-2 Bio+	75%	-3.0	28.8	17.0
371	14-Mar-15	Natural Snow	FCY-2 Bio+	50%	-2.9	13.4	24.0
372	14-Mar-15	Natural Snow	FCY-2 Bio+	100%	-3.0	47.6	15.0
377	14-Mar-15	Natural Snow	FCY-2 Bio+	50%	-3.0	37.5	7.0
379	14-Mar-15	Natural Snow	FCY-2 Bio+	50%	-3.0	27.4	7.0
382	14-Mar-15	Natural Snow	FCY-2 Bio+	75%	-3.0	47.6	11.0
388	14-Mar-15	Natural Snow	FCY-2 Bio+	50%	-2.9	49.2	4.0
400	17-Mar-15	Natural Snow	FCY-2 Bio+	50%	-1.9	7.8	21.2
401	17-Mar-15	Natural Snow	FCY-2 Bio+	75%	-1.9	2.3	114.3

Table 3.1 (cont'd): Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
412	21-Mar-15	Natural Snow	FCY-2 Bio+	50%	-0.8	2.9	31.5
414	21-Mar-15	Natural Snow	FCY-2 Bio+	50%	0.3	2.7	44.5
416	4-Apr-15	Natural Snow	FCY-2 Bio+	50%	-2.8	15.0	10.3
421	4-Apr-15	Natural Snow	FCY-2 Bio+	50%	-2.7	3.6	25.0
444	8-Apr-15	Natural Snow	FCY-2 Bio+	50%	0.5	6.5	25.7
450	8-Apr-15	Natural Snow	FCY-2 Bio+	50%	0.6	4.7	33.3

Table 3.2: Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
9	1-Apr-15	Freezing Fog	FCY-2 Bio+	100	-3.3	2.0	150.0
10	1-Apr-15	Freezing Fog	FCY-2 Bio+	100	-3.3	1.7	171.9
11	1-Apr-15	Freezing Fog	FCY-2 Bio+	75	-3.4	2.0	77.4
12	1-Apr-15	Freezing Fog	FCY-2 Bio+	75	-3.4	1.8	86.0
15	1-Apr-15	Freezing Fog	FCY-2 Bio+	50	-3.0	2.0	31.0
16	1-Apr-15	Freezing Fog	FCY-2 Bio+	50	-3.0	1.8	30.7
27	31-Mar-15	Freezing Fog	FCY-2 Bio+	100	-3.6	4.8	87.6
28	31-Mar-15	Freezing Fog	FCY-2 Bio+	100	-3.6	4.9	82.5
31	31-Mar-15	Freezing Fog	FCY-2 Bio+	75	-3.7	4.8	45.8
32	31-Mar-15	Freezing Fog	FCY-2 Bio+	75	-3.7	4.8	46.1
35	31-Mar-15	Freezing Fog	FCY-2 Bio+	50	-3.4	4.8	17.6
36	31-Mar-15	Freezing Fog	FCY-2 Bio+	50	-3.4	4.9	17.3
63	31-Mar-15	Freezing Fog	FCY-2 Bio+	100	-14.1	2.1	87.8
64	31-Mar-15	Freezing Fog	FCY-2 Bio+	100	-14.1	2.2	86.8
69	31-Mar-15	Freezing Fog	FCY-2 Bio+	75	-14.1	2.1	67.2
70	31-Mar-15	Freezing Fog	FCY-2 Bio+	75	-14.1	1.9	67.0
71	31-Mar-15	Freezing Fog	FCY-2 Bio+	100	-14.1	5.3	43.9
72	31-Mar-15	Freezing Fog	FCY-2 Bio+	100	-14.1	4.9	38.4
75	31-Mar-15	Freezing Fog	FCY-2 Bio+	75	-14.1	4.9	34.3
76	31-Mar-15	Freezing Fog	FCY-2 Bio+	75	-14.1	5.1	29.9
87	30-Mar-15	Freezing Fog	FCY-2 Bio+	100	-25.3	2.2	53.3
88	30-Mar-15	Freezing Fog	FCY-2 Bio+	100	-25.3	2.1	55.0
95	30-Mar-15	Freezing Fog	FCY-2 Bio+	100	-25.0	5.2	20.5
96	30-Mar-15	Freezing Fog	FCY-2 Bio+	100	-25.0	5.3	20.7
119	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	100	-3.1	4.6	84.3
120	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	100	-3.1	4.8	83.2
123	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	75	-3.1	4.8	50.6
124	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	75	-3.1	5.4	51.4
127	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	50	-2.9	4.7	19.3
128	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	50	-2.9	4.7	19.0
139	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	100	-3.1	12.5	50.6
140	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	100	-3.1	13.3	49.9
143	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	75	-3.1	12.5	24.7
144	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	75	-3.2	13.3	26.1
147	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	50	-3.4	12.8	11.0
148	25-Mar-15	Freezing Drizzle	FCY-2 Bio+	50	-3.4	13.5	10.4

Table 3.2 (cont'd): Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
169	27-Mar-15	Freezing Drizzle	FCY-2 Bio+	100	-10.2	5.0	63.3
170	27-Mar-15	Freezing Drizzle	FCY-2 Bio+	100	-10.2	5.0	64.3
171	27-Mar-15	Freezing Drizzle	FCY-2 Bio+	75	-10.2	5.2	33.8
172	27-Mar-15	Freezing Drizzle	FCY-2 Bio+	75	-10.2	4.8	31.9
185	26-Mar-15	Freezing Drizzle	FCY-2 Bio+	100	-10.0	13.1	35.2
186	26-Mar-15	Freezing Drizzle	FCY-2 Bio+	100	-10.0	12.8	33.6
187	26-Mar-15	Freezing Drizzle	FCY-2 Bio+	75	-10.1	13.5	18.4
188	26-Mar-15	Freezing Drizzle	FCY-2 Bio+	75	-10.1	13.3	19.3
199	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	100	-2.9	12.8	46.3
200	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	100	-2.9	12.5	42.6
203	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	75	-2.9	13.1	24.0
204	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	75	-3.0	12.5	23.9
207	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	50	-2.9	12.8	12.3
208	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	50	-2.9	13.1	12.4
215	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	100	-3.0	24.6	25.1
216	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	100	-3.0	24.4	24.8
219	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	75	-3.1	24.7	16.0
220	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	75	-2.9	24.5	18.5
223	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	50	-2.9	24.7	8.2
224	27-Mar-15	Light Freezing Rain	FCY-2 Bio+	50	-2.9	24.4	8.4
241	26-Mar-15	Light Freezing Rain	FCY-2 Bio+	100	-10.3	13.2	29.0
242	26-Mar-15	Light Freezing Rain	FCY-2 Bio+	100	-10.3	13.0	29.3
243	26-Mar-15	Light Freezing Rain	FCY-2 Bio+	75	-10.6	12.9	18.6
244	26-Mar-15	Light Freezing Rain	FCY-2 Bio+	75	-10.6	13.0	19.1
251	26-Mar-15	Light Freezing Rain	FCY-2 Bio+	100	-10.3	25.0	16.2
252	26-Mar-15	Light Freezing Rain	FCY-2 Bio+	100	-10.3	24.4	17.3
259	26-Mar-15	Light Freezing Rain	FCY-2 Bio+	75	-10.1	25.0	13.3
260	26-Mar-15	Light Freezing Rain	FCY-2 Bio+	75	-10.1	24.4	14.5
273	1-Apr-15	Cold Soak Box	FCY-2 Bio+	100	0.9	5.3	64.6
274	1-Apr-15	Cold Soak Box	FCY-2 Bio+	100	0.9	5.5	77.3
275	1-Apr-15	Cold Soak Box	FCY-2 Bio+	75	1.0	5.4	30.2
276	1-Apr-15	Cold Soak Box	FCY-2 Bio+	75	1.0	5.3	35.7
287	1-Apr-15	Cold Soak Box	FCY-2 Bio+	100	0.7	74.9	8.4
288	1-Apr-15	Cold Soak Box	FCY-2 Bio+	100	0.7	74.4	8.6
291	1-Apr-15	Cold Soak Box	FCY-2 Bio+	75	0.8	76.2	6.4
292	1-Apr-15	Cold Soak Box	FCY-2 Bio+	75	0.8	75.1	7.2

Table 3.3: Summary of Tests Performed (Natural Frost)

Test No.	Date	Precip. Type	Fluid Name	Fluid Dilution	Test Duration (min.)	Average Rate (g/dm²/h)	Temp (°C)	Wind Speed (km/h)	Average RH (%)	Comments
26	17-Feb-15	Natural Frost	FCY-2 Bio+	100%	217	0.010	-22.3	3.0	59.2	Did Not Fail
39	18-Feb-15	Natural Frost	FCY-2 Bio+	100%	361	0.060	-17.7	5.6	68.9	Did Not Fail
54	15-Mar-15	Natural Frost	FCY-2 Bio+	100%	618	0.080	-8.0	3.5	89.0	Did Not Fail
56	15-Mar-15	Natural Frost	FCY-2 Bio+	50%	125	0.090	-5.6	4.3	87.0	Failed
58	15-Mar-15	Natural Frost	FCY-2 Bio+	75%	617	0.080	-8.0	3.5	89.0	Did Not Fail
61	23-Mar-15	Natural Frost	FCY-2 Bio+	100%	462	0.010	-11.3	8.3	66.6	Did Not Fail
62	23-Mar-15	Natural Frost	FCY-2 Bio+	75%	461	0.010	-11.3	8.3	66.6	Did Not Fail
72	6-May-2015	Natural Frost	FCY-2 Bio+	50%	183	0.160	2.3	0.0	84.7	TH @ fail=4

4. RESULTS AND DISCUSSION

The methods used to evaluate the test data were reviewed in Subsection 2.8. The results of the data analyses and a discussion of the findings are presented in this section.

4.1 Results

The results of the endurance time and thickness tests are described in this section.

4.1.1 Endurance Time Tests – Natural Snow and Freezing Precipitation

Figures 4.1 to 4.14 present the endurance time data collected in natural snow and freezing precipitation (freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface).

These figures show the effect of temperature, precipitation type and precipitation rate on fluid endurance time in the conditions encompassed by the Type II HOT guidelines. The figures include the current Type II generic holdover times for comparative purposes.

Multi-variable regression analysis was performed on these data sets as described in Subsection 2.8. Table 4.1 provides the outputs from the multi-variable regression analyses. These outputs were used to derive fluid-specific holdover times for all conditions encompassed by Type II fluid-specific HOT tables. One exception is the coldest temperature band snow cells (see Subsection 4.2.2).

4.1.2 Endurance Time Tests – Natural Frost

The natural frost data was presented in Table 3.3. The test durations were compared to the Type II generic holdover times. Tests that were not completed (due to active frost ending before fluid failure could occur) surpassed the generic holdover times. This analysis indicates the Type II generic frost holdover times can be considered substantiated for Newave FCY-2 Bio+.

4.1.3 Fluid Thickness Tests

Figure 4.15 shows the fluid thickness test data. As described in Subsection 3.4, two tests were conducted at an ambient temperature of -3°C. The final fluid thicknesses are displayed in Figure 4.16.

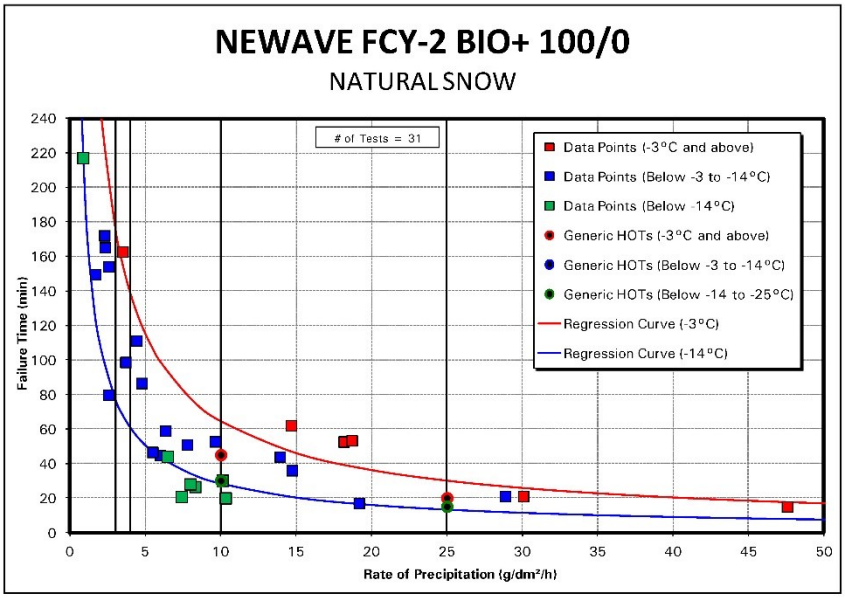

Figure 4.1: Type II Neat – Natural Snow

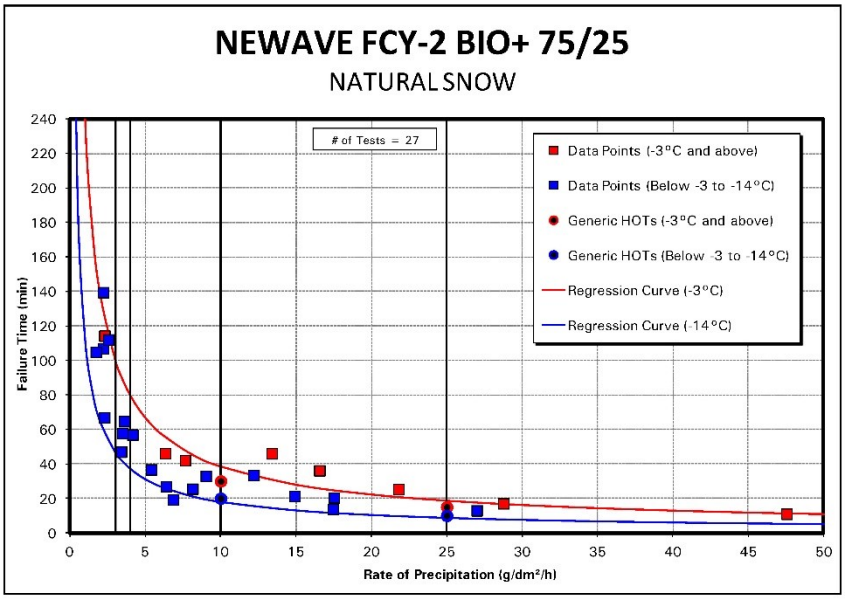

Figure 4.2: Type II 75/25 – Natural Snow

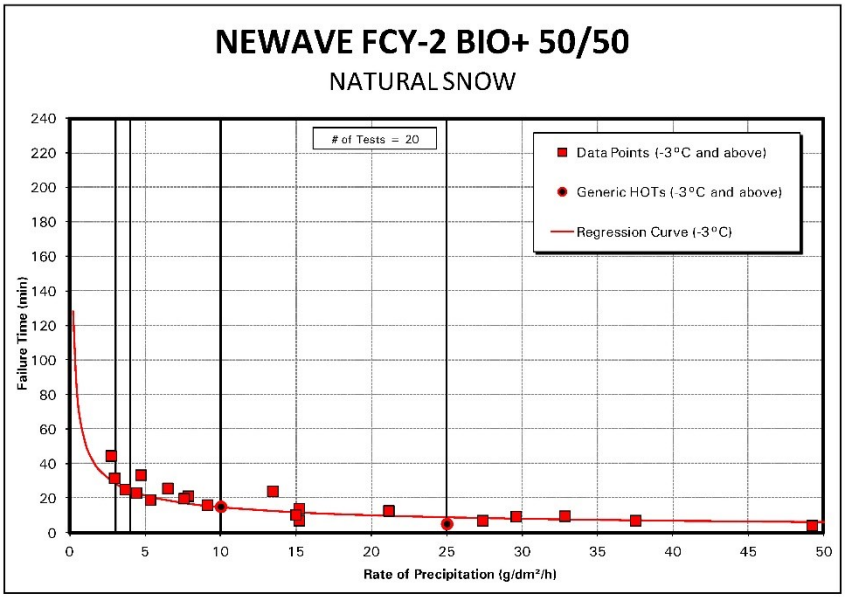

Figure 4.3: Type II 50/50 – Natural Snow

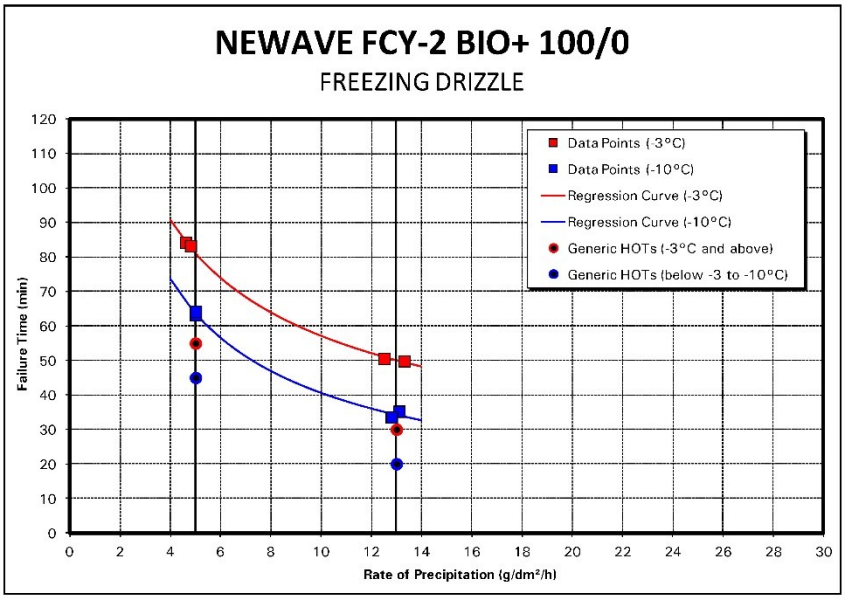

Figure 4.4: Type II Neat – Freezing Drizzle

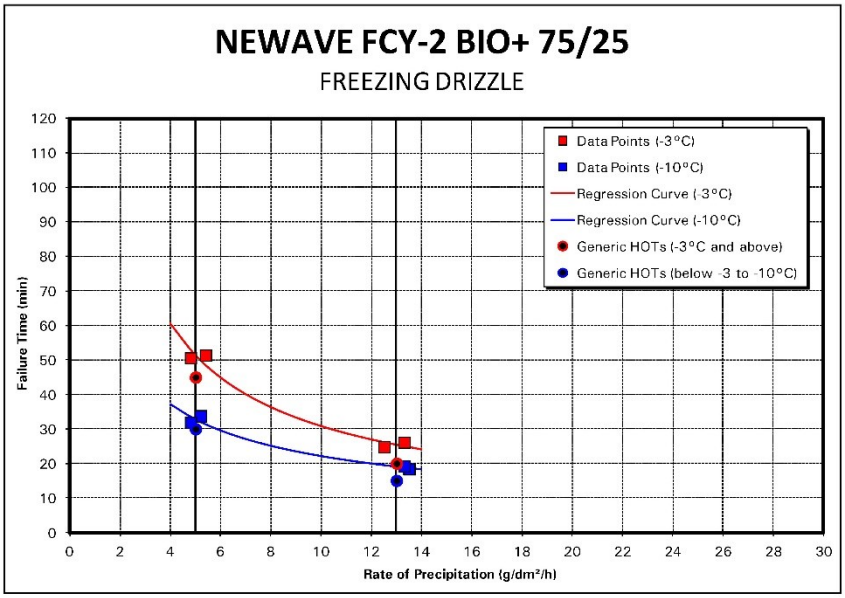

Figure 4.5: Type II 75/25 – Freezing Drizzle

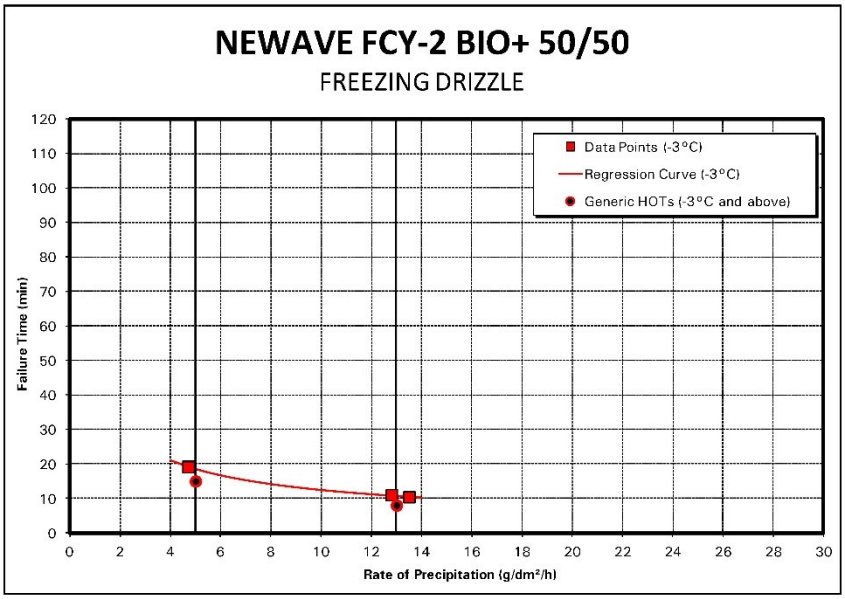

Figure 4.6: Type II 50/50 – Freezing Drizzle

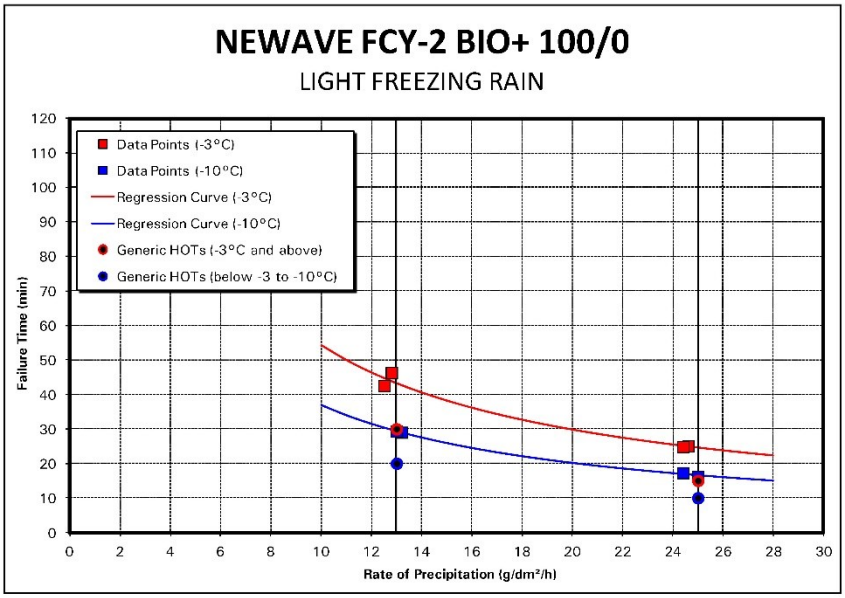

Figure 4.7: Type II Neat – Light Freezing Rain

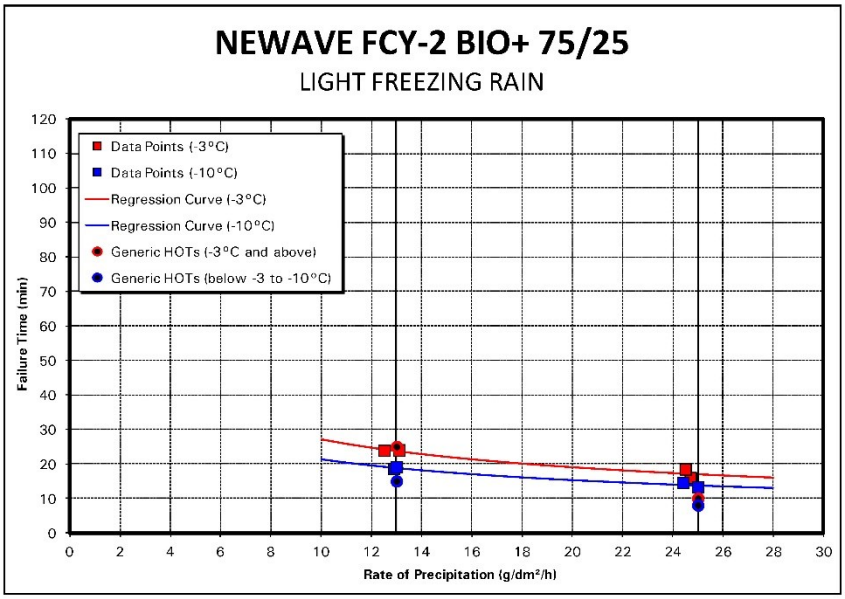

Figure 4.8: Type II 75/25 – Light Freezing Rain

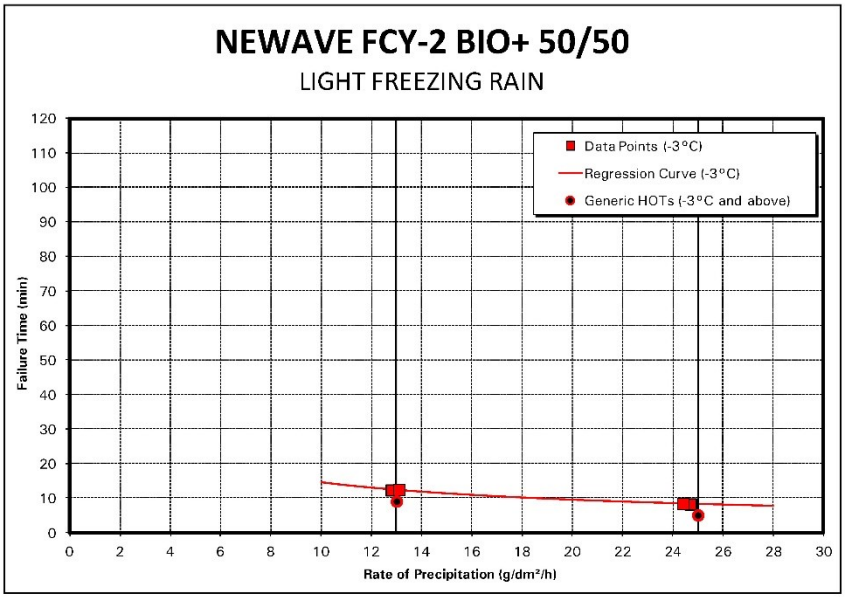

Figure 4.9: Type II 50/50 – Light Freezing Rain

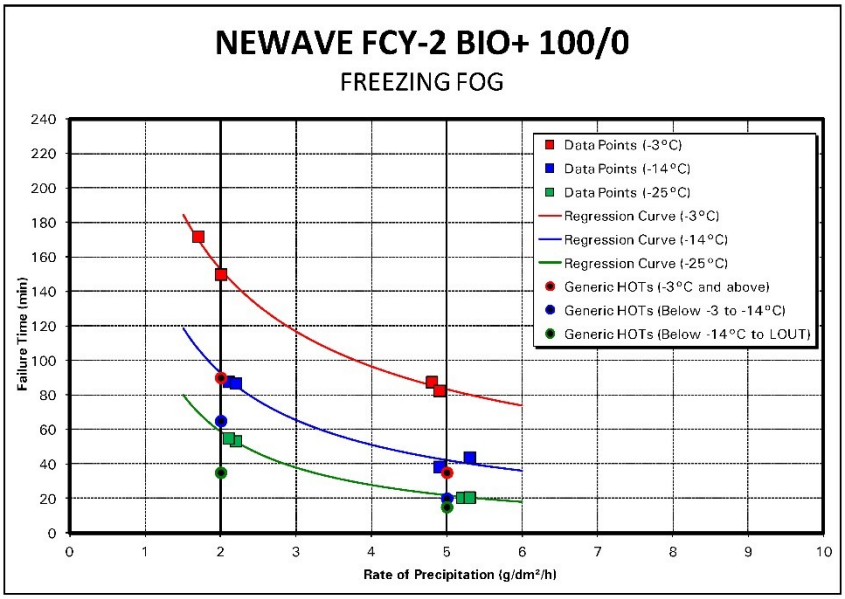

Figure 4.10: Type II Neat – Freezing Fog

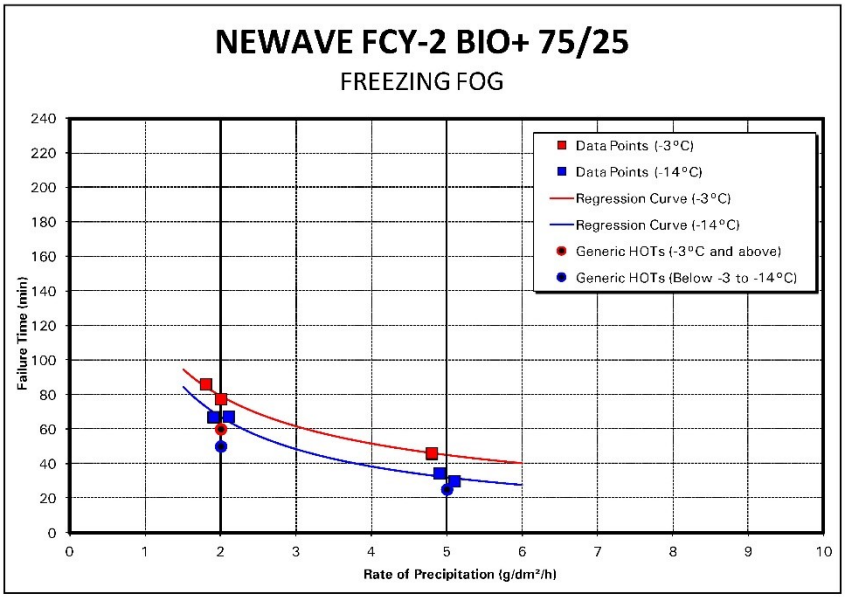

Figure 4.11: Type II 75/25 – Freezing Fog

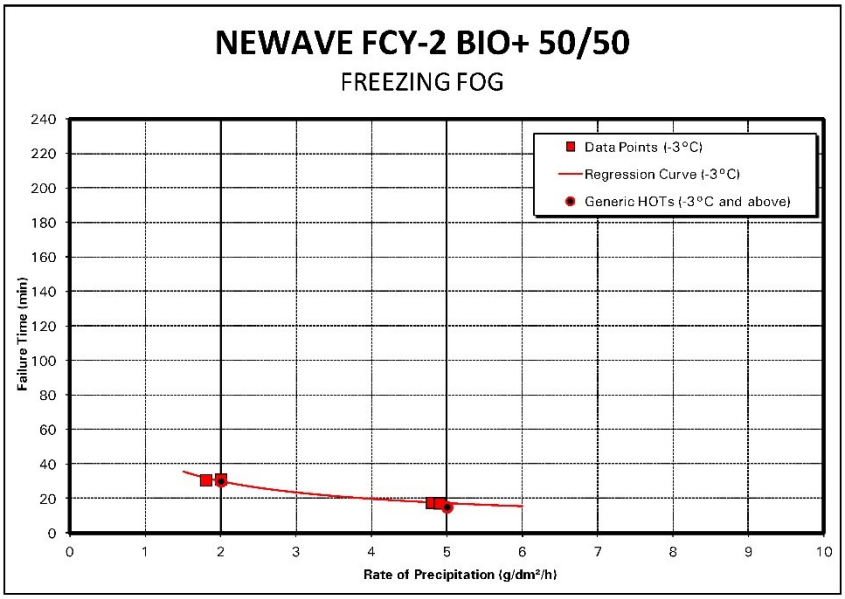

Figure 4.12: Type II 50/50 – Freezing Fog

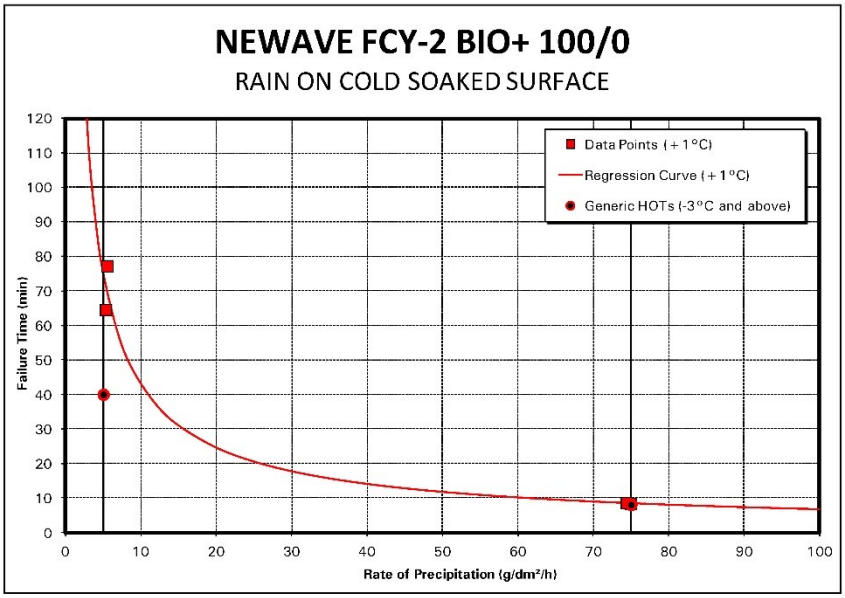

Figure 4.13: Type II Neat – Rain on Cold-Soaked Surface

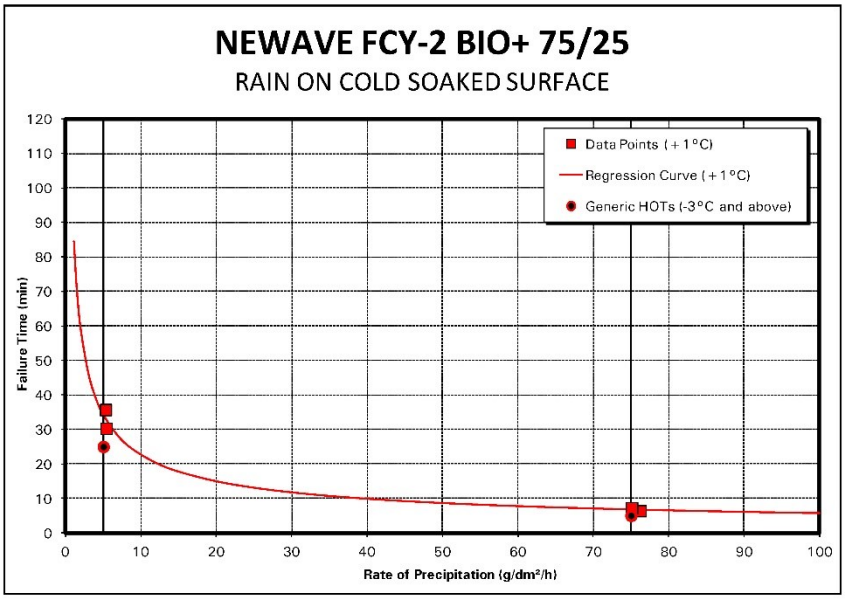

Figure 4.14: Type II 75/25 – Rain on Cold-Soaked Surface

Table 4.1: Regression Equation Coefficients for Newave Aerochemical FCY-2 Bio+

Natural Snow

Fluid	Dil	R^2	Intercept (I)	Coeff. Rate (A)	Coeff. Tem (B)	Total Pts.
Newave Aerochemical FCY-2 Bio+	Neat	96%	3.1420	-0.8361	-0.7102	31
Newave Aerochemical FCY-2 Bio+	75%	93%	2.8399	-0.7994	-0.6556	27
Newave Aerochemical FCY-2 Bio+	50%	87%	1.9658	-0.5568	-0.3538	20

General Equation $t = 10^{I} R^{A} (2\text{-}T)^{B}$

Simulated Freezing Fog

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Newave Aerochemical FCY-2 Bio+	Neat	-3°C	100%	2.3819	-0.6607	4
Newave Aerochemical FCY-2 Bio+	75/25	-3°C	100%	2.0853	-0.6218	4
Newave Aerochemical FCY-2 Bio+	50/50	-3°C	99%	1.6563	-0.6034	4
Newave Aerochemical FCY-2 Bio+	Neat	-14°C	96%	2.2250	-0.8616	4
Newave Aerochemical FCY-2 Bio+	75/25	-14°C	98%	2.0676	-0.8031	4
Newave Aerochemical FCY-2 Bio+	Neat	-25°C	100%	2.0929	-1.0828	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Newave Aerochemical FCY-2 Bio+	Neat	-3°C	100%	2.2626	-0.5057	4
Newave Aerochemical FCY-2 Bio+	75/25	-3°C	98%	2.2267	-0.7378	4
Newave Aerochemical FCY-2 Bio+	50/50	-3°C	100%	1.6641	-0.5675	4
Newave Aerochemical FCY-2 Bio+	Neat	-10°C	99%	2.2571	-0.6478	4
Newave Aerochemical FCY-2 Bio+	75/25	-10°C	98%	1.9065	-0.5604	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Newave Aerochemical FCY-2 Bio+	Neat	-3°C	98%	2.6041	-0.8687	4
Newave Aerochemical FCY-2 Bio+	75/25	-3°C	91%	1.9393	-0.5060	4
Newave Aerochemical FCY-2 Bio+	50/50	-3°C	100%	1.7844	-0.6234	4
Newave Aerochemical FCY-2 Bio+	Neat	-10°C	100%	2.4418	-0.8745	4
Newave Aerochemical FCY-2 Bio+	75/25	-10°C	97%	1.8028	-0.4737	4

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Newave Aerochemical FCY-2 Bio+	Neat	+1°C	100%	2.4390	-0.8058	4
Newave Aerochemical FCY-2 Bio+	75/25	+1°C	99%	1.9514	-0.5966	4

General Equation $t = 10^{I} R^{A}$

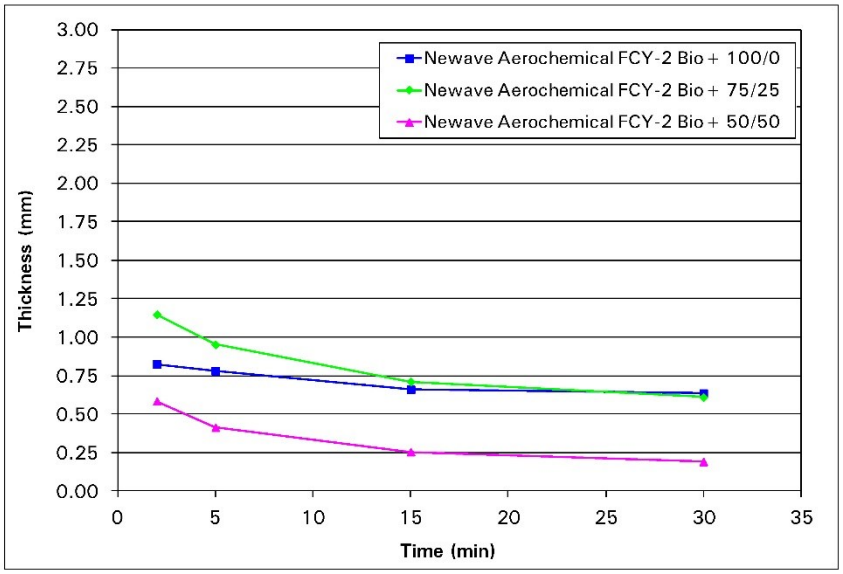

Figure 4.15: Fluid Thickness Profiles of Newave Aerochemical FCY-2 Bio +

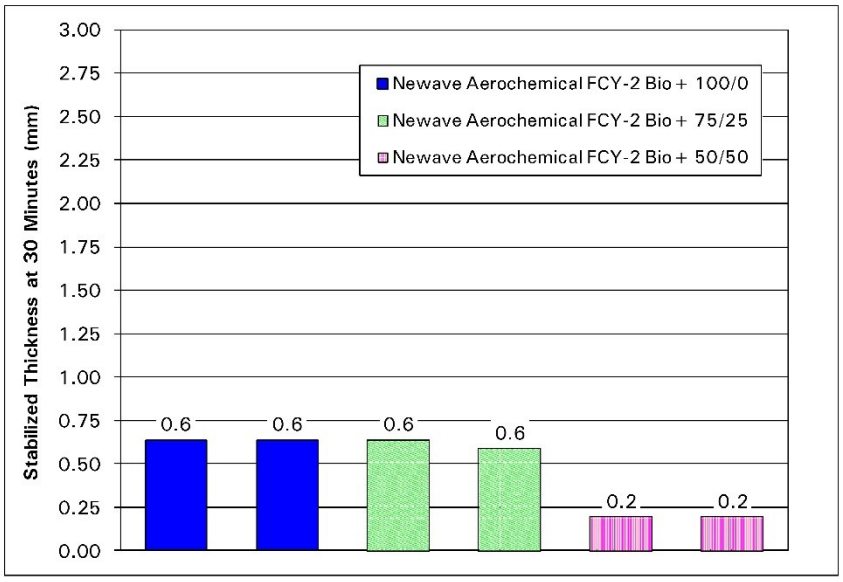

Figure 4.16: Final Fluid Thickness of Newave Aerochemical FCY-2 Bio +

4.2 Discussion

4.2.1 Holdover Time Table

The holdover times described in Subsection 4.1 were used to populate a fluid-specific HOT table for Newave Aerochemical FCY-2 Bio+. The HOT table is shown in both the TC format (Table 4.2) and FAA format (Table 4.3) at the end of this chapter.

4.2.2 Holdover Times in Snow, Below -14°C to LOUT

Very little endurance time data has been collected in natural snow at temperatures below -14°C. In the winter of 2003-04, testing was conducted with artificial snowmakers to collect additional data below -14°C. As a result of this testing, it was decided all Type II/IV fluids would be given generic values in the "Below -14 to LOUT" snow cells. Accordingly, Newave Aerochemical FCY-2 Bio+ has been given generic values in the "Below -14°C to LOUT" snow cells.

4.2.3 Holdover Times in Frost

It should be noted that frost holdover times are not included in the fluid-specific HOT tables. This is due to a decision made by TC and the FAA in May 2009 to move frost holdover times from the generic and fluid-specific HOT tables to a separate frost HOT table. Accordingly, frost holdover times have not been included in the Newave Aerochemical FCY-2 Bio+ fluid-specific HOT table.

4.2.4 Fluid Viscosity

The viscosities of the fluid samples used in this testing were measured using both the AS9968 method and the manufacturer's designated method. The APS measured viscosities appear at the beginning of this document and will be published as the lowest on-wing viscosity (LOWV) values for the fluid. In order for the fluid-specific holdover times provided in this document to be valid, operators must ensure that the viscosity of the fluid being used is equal or greater than the published LOWV.

4.2.5 Lowest Operational Use Temperatures (LOUTs)

The LOUT for Type II/III/IV fluids is determined by the higher of:

- The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
- The actual freezing point of the fluid plus its freezing point buffer of 7°C (13°F).

For fluid dilutions, the LOUT may also be limited by the coldest temperature for which holdover times are published (-3°C for 50/50; -14°C for 75/25).

The aerodynamic acceptance and freezing point information for this fluid is provided at the beginning of this document. The LOUTs for Newave Aerochemical FCY-2 Bio+ are:

- 100/0: -28.5°C (-19.3°F)
- 75/25: -14°C (7°F)
- 50/50: -3°C (27°F)

4.2.6 Lowest Usable Precipitation Rates in Snow

The LUPRs for Newave Aerochemical FCY-2 Bio+ were determined by analysing the natural snow data sets using the analysis methodology described in Subsection 2.8.6. The resulting statistics are shown in Table 4.4. The analysis determined the LUPRs for Newave Aerochemical FCY-2 Bio+ are:

- 100/0 = 2 g/dm²/h;
- 75/25 = 2 g/dm²/h; and
- 50/50 = 3 g/dm²/h.

4.2.7 Publication of Holdover Times

As Newave Aerochemical intends to commercialize FCY-2 Bio+, TC and FAA will publish its fluid-specific HOT table in their 2015-16 Holdover Time Guidelines. The guidelines will also include the LOWV and LOUT information; the LUPR data will be published in the related TC and FAA Regression Information documents.

Table 4.2: Fluid Specific Holdover Time Guidelines – Newave Aerochemical FCY-2 Bio + (Transport Canada Format)

TABLE 2-N-FCY-2B+

TYPE II FLUID HOLDOVER TIME GUIDELINES[1]
NEWAVE AEROCHEMICAL FCY-2 BIO+

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

Outside Air Temperature[2]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:25 – 2:30	2:00	1:05 – 2:00	0:30 – 1:05	0:50 – 1:20	0:25 – 0:45	0:08 – 1:15	
		75/25	0:45 – 1:20	1:20	0:40 – 1:20	0:20 – 0:40	0:25 – 0:50	0:15 – 0:25	0:06 – 0:35	
		50/50	0:15 – 0:30	0:25	0:15 – 0:25	0:08 – 0:15	0:10 – 0:20	0:08 – 0:10		
below -3 to -14	below 27 to 7	100/0	0:40 – 1:30	1:00	0:30 – 1:00	0:15 – 0:30	0:35 – 1:05[8]	0:15 – 0:30[8]	CAUTION: No holdover time guidelines exist	
		75/25	0:30 – 1:05	0:35	0:20 – 0:35	0:08 – 0:20	0:20 – 0:35[8]	0:15 – 0:20[8]		
below -14 to -28.5	below 7 to -19.3	100/0	0:20 – 1:00	0:40	0:30 – 0:40	0:15 – 0:30				

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

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

Table 4.3: Fluid Specific Holdover Time Guidelines – Newave Aerochemical FCY-2 Bio+ (FAA Format)

TABLE 2J. TYPE II HOLDOVER TIME GUIDELINES FOR NEWAVE AEROCHEMICAL FYC-2 BIO+

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:25-2:30	2:20-2:55	1:05-2:20	0:30-1:05	0:50-1:20	0:25-0:45	0:08-1:15	
		75/25	0:45-1:20	1:20-1:40	0:40-1:20	0:20-0:40	0:25-0:50	0:15-0:25	0:06-0:35	
		50/50	0:15-0:30	0:25-0:30	0:15-0:25	0:08-0:15	0:10-0:20	0:08-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40-1:30	1:00-1:15	0:30-1:00	0:15-0:30	0:35-1:05[7]	0:15-0:30[7]		
		75/25	0:30-1:05	0:35-0:45	0:20-0:35	0:08-0:20	0:20-0:35[7]	0:15-0:20[7]		
below -14 to -28.5	below 7 to -19.3	100/0	0:20-1:00	0:40-0:50	0:30-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4.4: LUPR Statistics – Newave Aerochemical FCY-2 Bio+

Data Measure	100/0		75/25		50/50	
	Stat	Rating	Stat	Rating	Stat	Rating
Total Data Points	31	40	27	40	20	40
Data Points -3 to -14°C	24	40	19	40	n/a	0
Data Points < 10.0	20	40	17	40	10	40
Data Points < = 9.5	19	40	17	40	10	40
Data Points < = 8.5	19	40	16	40	9	40
Data Points < = 7.5	16	40	14	40	7	40
Data Points < = 6.5	15	40	13	40	7	40
Data Points < = 5.5	12	40	11	40	6	40
Data Points < = 4.5	10	40	10	40	4	40
Data Points < = 3.5	8	40	8	40	2	30
Data Points < = 2.5	6	40	6	40	0	0
Scatter 0-10 g	10%	30	15%	30	9%	40

Rate	100/0		75/25		50/50	
	Score	Pass/Fail	Score	Pass/Fail	Score	Pass/Fail
9 g/dm²/h	39	pass	39	pass	32	pass
8 g/dm²/h	39	pass	39	pass	32	pass
7 g/dm²/h	39	pass	39	pass	32	pass
6 g/dm²/h	39	pass	39	pass	32	pass
5 g/dm²/h	39	pass	39	pass	32	pass
4 g/dm²/h	39	pass	39	pass	32	pass
3 g/dm²/h	39	pass	39	pass	28	pass
2 g/dm²/h	39	pass	39	pass	16	fail

LUPR	100/0	75/25	50/50
	2 g/dm²/h	2 g/dm²/h	3 g/dm²/h

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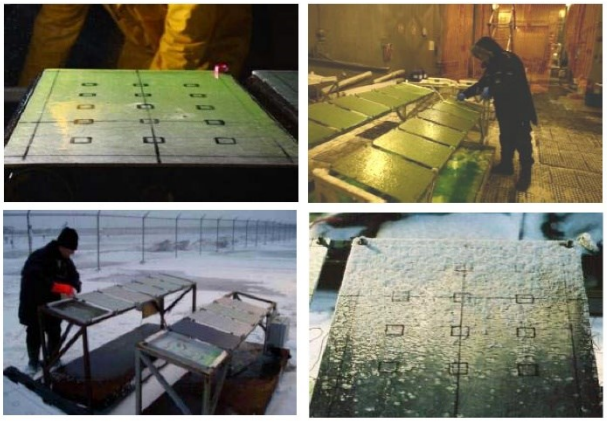
APPENDIX G

FLUID MANUFACTURER REPORT:
ALLCLEAR AEROCLEAR MAX (TYPE III)

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

AllClear AeroClear MAX (Type III)
Batch # CB1-PB8000A



Prepared for

AllClear Systems LLC

by

APS Aviation Inc

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

September 2015
Version 1.0
Report No. AC-ACM-PB8000A 2014-15

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

AllClear AeroClear MAX (Type III) Batch # CB1-PB8000A

Prepared for

AllClear Systems LLC

Prepared by: 

Chloë Bernier
Research Assistant

Sept. 28, 2015
Date

And by: 

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Sept. 28, 2015
Date

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Program Manager

Sept. 28, 2015
Date

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

September 2015
Version 1.0
Report No. AC-ACM-PB8000A 2014-15

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer:	AllClear Systems LLC
Fluid Test Name:	CB1-PB8000A
Fluid Commercial Name:	AeroClear MAX
Fluid Type / Base / Colour:	Type III / Ethylene Glycol / Yellow
Dilutions Submitted:	100/0
Batch #:	CB1-PB8000A
Date of Receipt:	March 21, 2015
Brix (Measured):	34.0°
Fluid Freeze Point (Stated):	-44°C
WSET (from AMIL):	18 minutes

Aerodynamic LOUT (from AMIL):

Low Speed Test:	-16.0°C
High Speed Test:	-35.5°C

Viscosity:	**Stated**	**Measured**
Manufacturer Method[1]	8,000 cP	7,300 cP
AS 9968 Method	not provided	not available[2]
Alternate Method[3]	not provided	3,160 cP

[1] *Spindle SC4-31, SSA, 9 mL, 0°C, 0.3 rpm, 30 mins*
[2] *Appropriate results could not be measured using the AIR 9968 method*
[3] *Spindle SC4-18, SSA, 6.7 mL, 0°C, 0.3 rpm, 30 mins*

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SUMMARY

The primary objective of this project was to measure the endurance time performance of the AllClear Type III fluid **AeroClear MAX (sample CB1-PB8000A)** over the entire range of conditions encompassed by the Holdover Time (HOT) tables. Testing was carried out with this sample due to due complications with the previously submitted sample **(sample CB1)**. The project was completed with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada and the Federal Aviation Administration (FAA).

Tests were carried out according to the protocol provided in Aerospace Recommended Practice 5485, with fluid applied at ambient temperature. The test procedure consisted of pouring fluids onto clean aluminum test surfaces inclined at 10 degrees; the onset of failure was recorded as a function of time in natural and simulated precipitation.

Tests were performed at the APS Aviation Inc. (APS) test facility at Montréal-Pierre-Elliott-Trudeau International Airport, at the National Research Council Canada Climatic Engineering Facility in Ottawa and at a mobile test site in Beaconsfield, Quebec.

The freezing precipitation data collected was subjected to multi-variable regression analysis to derive fluid-specific endurance times. This resulted in the generation of fluid-specific holdover times for AeroClear MAX in freezing precipitation conditions. Due to the late submission of this fluid in the winter, insufficient data was collected in natural snow to determine fluid-specific holdover times for snow. Supplemental testing with an artificial snowmaker proved that AeroClear MAX could be used with the 2014-15 Type III generic holdover times.

The result of the 2015-16 testing and analysis is the fluid-specific holdover time table shown on the next page, which includes fluid-specific holdover times for freezing precipitation and generic holdover times for snow. This table will be published by regulators for use in the winter of 2015-16. Additional natural snow data will be collected in the winter of 2015-16 to allow fluid-specific snow holdover times to be generated for use in the winter of 2016-17.

It should be noted that AeroClear MAX can be used with the generic frost holdover guidelines; however, as no ice pellet / small hail data exists for this fluid, it cannot be used with the Type III allowance time table.

As no dilutions of this fluid were tested, no holdover times are provided for 75/25 or 50/50 dilutions.

SUMMARY

AllClear AeroClear MAX Type III Fluid Holdover Times (Transport Canada Format)

Outside Air Temperature		Type III Fluid Concentration Neat Fluid/Water (Vol %/Vol %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:00 – 2:15	0:35	0:20 – 0:35	0:10 – 0:20	0:40 – 1:20	0:25 – 0:30	0:09 – 1:00	
		75/25								
		50/50								
below -3 to -10	below 27 to 14	100/0	1:00 – 1:45	0:30	0:15 – 0:30	0:09 – 0:15	0:40 – 1:10	0:30 – 0:40		
		75/25								
below -10 to -25	below 14 to -13	100/0	0:30 – 1:05	0:30	0:15 – 0:30	0:08 – 0:15				
below -25 to -35	below -13 to -31	100/0	0:18 – 0:55							

CAUTION: No holdover time guidelines exist

AllClear AeroClear MAX Type III Fluid Holdover Times (FAA Format)

Outside Air Temperature		Type III Fluid Concentration Neat Fluid/Water (Vol %/Vol %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:00-2:15	0:35-0:40	0:20-0:35	0:10-0:20	0:40-1:20	0:25-0:30	0:09-1:00	
		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 -10	below 27 to 14	100/0	1:00-1:45	0:30-0:35	0:15-0:30	0:09-0:15	0:40-1:10	0:30-0:40		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -10 to -25	below 14 to -13	100/0	0:30-1:05	0:30-0:35	0:15-0:30	0:08-0:15				
below -25 to -35	below -13 to -31	100/0	0:18-0:55							

CAUTION: No holdover time guidelines exist

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GLOSSARY

APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LOUT	Lowest Operational Use Temperature
LOWV	Lowest On-Wing Viscosity
LUPR	Lowest Usable Precipitation Rate
LWC	Liquid Water Content
MVD	Median Volume Diameter
MANOBS	Manual of Surface Weather Observations
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

This report has been created with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

1.1 Background – De/Anti-icing Fluid Endurance Time Research

Aircraft ground de/anti-icing has been the subject of concentrated industry attention in recent years due to the occurrence of several fatal icing-related aircraft accidents. Notably, attention has been placed on the enhancement of anti-icing fluids in order to provide an extended period of protection against further contamination following initial deicing.

This emphasis has led to the development of fluid-specific de/anti-icing fluid holdover time (HOT) tables for Type II, Type III and Type IV fluids. These tables, accepted by regulatory authorities, are used by aircraft operators for departure planning in adverse winter conditions. Specifically, they provide the duration of time that qualified fluids provide protection against ice formation under specific weather conditions.

New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid holdover times without compromising the aerodynamic features of the airfoil. The purpose of the endurance time testing program is to measure the endurance times of these new fluids and develop fluid-specific HOT tables that provide guidance for their use.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop HOT values for new fluids. These tests are carried out according to SAE Aerospace Recommended Practice (ARP) ARP5485, which provides the test protocols for measuring endurance times of Type II/III/IV fluids, and ARP5945, which provides the test protocols for measuring endurance times of Type I fluids. These documents have evolved to provide a refined procedure for measuring the duration of de/anti-icing fluid protection against ice formation.

The current data analysis protocol for developing HOT values from endurance time data was developed in 1996-97 and uses multi-variable regression analysis to obtain HOT values. HOT values are derived for all cells of the Type II/III/IV HOT tables using this protocol and are used to create a fluid-specific HOT table for each Type II/III/IV fluid tested.

1.2 Project Objective

The primary objective of this project was to measure the endurance time performance of the AllClear Type III fluid **AeroClear MAX (sample CB1-PB8000A)** over the entire range of conditions encompassed by the Holdover Time (HOT) tables. Testing was carried out with this sample due to due complications with the previously submitted sample **(sample CB1)**.

2. METHODOLOGY

SAE Aerospace Recommended Practice (ARP) 5485 provides the procedure and requirements for endurance time testing with Type II, III and IV fluids under natural and simulated conditions. This chapter summarizes some of aspects of the test methodology included in ARP5485, and some aspects which are not included in ARP5485. The chapter includes sections for test sites, equipment, procedures, precipitation rates and ambient temperatures used in Type II, III and IV endurance time testing, and freezing precipitation droplet sizes. The final subsection describes the analysis methodology used to evaluate Type II, III and IV endurance time data.

2.1 Test Sites

2.1.1 Natural Snow, Natural Frost and Artificial Snow

Natural snow, natural frost and artificial snow testing is typically performed at the APS test site located at the Montréal-Pierre-Elliott-Trudeau International Airport. The test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station, as shown in Figure 2.1 on a plan view of the airport.

The APS test site consists of two trailers and three outdoor locations for test stands. One of the trailers is equipped with a refrigeration unit to enable indoor testing at controlled temperatures; artificial snow testing is conducted inside this trailer. Photos 2.1 and 2.2 show the test site as seen from the test pads and main trailer, respectively.

Additional natural snow testing was conducted with AeroClear MAX in Beaconsfield, Quebec.

2.1.2 Freezing Precipitation

Tests under conditions of freezing fog, rain on cold-soaked surface, freezing drizzle, and light freezing rain were conducted indoors at the NRC Climatic Engineering Facility (CEF), where precipitation was artificially produced.

Photo 2.3 provides an outdoor view of the facility giving a general indication of its size (30 m by 5.4 m, height 8 m). The facility was originally designed for the testing of locomotives; Photo 2.4 provides an interior view of the CEF set up for endurance time testing. The lowest temperature achievable in the CEF is -46°C.

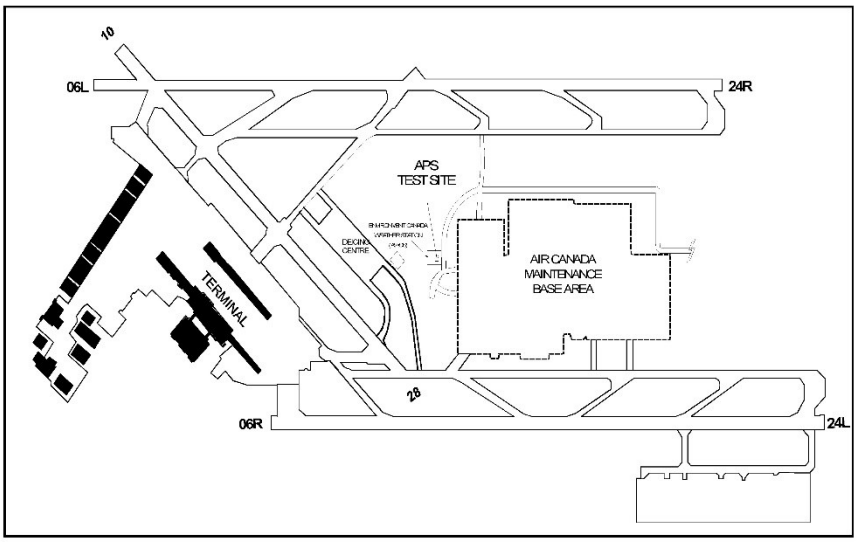


Figure 2.1: APS Test Site at Montréal-Pierre-Elliott-Trudeau International Airport

2.2 Test Equipment

The key equipment used in endurance time testing is described in this section, as are the calibration procedures APS follows for ensuring the accuracy of its test equipment.

2.2.1 Calibration

APS measurement instruments and test equipment are calibrated and/or verified on an annual basis. This calibration is carried out according to a calibration plan based upon approved International Organization for Standardization (ISO) 9001:2000 standards, and developed internally by APS.

2.2.2 Environmental Chamber Equipment

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) was as stipulated in the requirements set out in ARP5485.

2.2.3 Test Surface Structures

The majority of endurance time testing is carried out on standard flat plates. A schematic of a standard flat plate is provided in Figure 2.2. It depicts the size and surface markings of a standard flat plate. Three parallel lines are positioned at 2.5 cm (1″), 15 cm (6″) and 30 cm (12″) from the top of the plate. The plates are marked with 15 crosshairs, which are used in determining when end conditions (see Subsection 0) are achieved. Photo 2.5, taken outdoors at the APS test site, shows six test plates mounted on a test stand.

Figure 2.3 shows a schematic of the sealed boxes used for tests simulating a cold soaked wing. The top of the box consists of a flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate. Photo 2.6 shows a picture of a sealed box, which is referred to as a cold-soak box when filled for simulated rain on cold soaked wing tests.

In natural frost, tests are conducted on frosticator plates, which are the current standard test surface used in frost holdover time testing. The frosticator plates were constructed by attaching a Styrofoam insulation backing to the back of the test surface (either aluminum or composite). The insulation prevents heat exchange via the underside of the flat plate and allows for effective radiative cooling during active frost conditions. Photo 2.7 shows a white-painted aluminum frosticator plate.

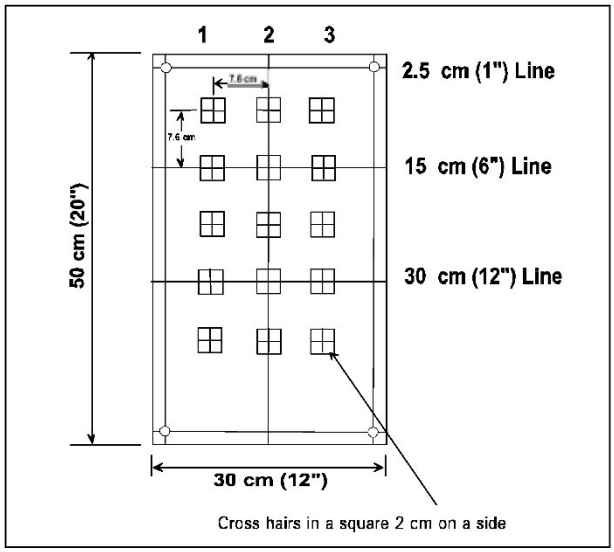


Figure 2.2: Standard Test Plate Schematic

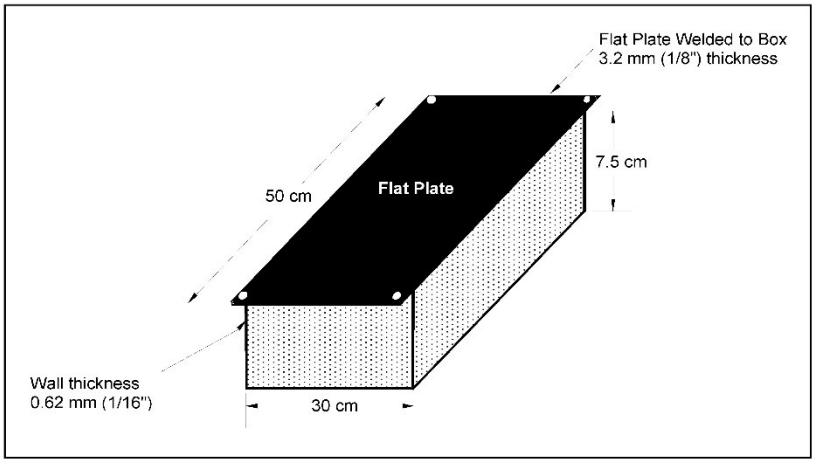


Figure 2.3: Cold Soak Box Schematic

2.2.4 Test Surface Materials

Testing of Type II, III and IV fluids is carried out exclusively on aluminum surfaces. The aluminum used is 0.32 cm thick Alclad 2024 T3 aluminum.

2.2.5 Test Stands

Figure 2.4 shows a schematic of the test platform used for HOT testing. For natural snow tests, six test plates are normally mounted on the test stand, which has a working surface inclined at 10° to the horizontal. During normal winter operations two six-position stands are used in combination. Each plate represents a flat plate test. For simulated freezing precipitation tests at the NRC, 12 plates are mounted on 2 six-position stands. Photos 2.4 and 2.5 show the test stands set up for indoor and outdoor testing, respectively.

2.2.6 Collection Pans

Figure 2.5 shows a schematic of the collection pan used for precipitation rate measurement in outdoor testing. It is the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.8 shows the collection pans used for measuring precipitation rates indoors at the NRC.

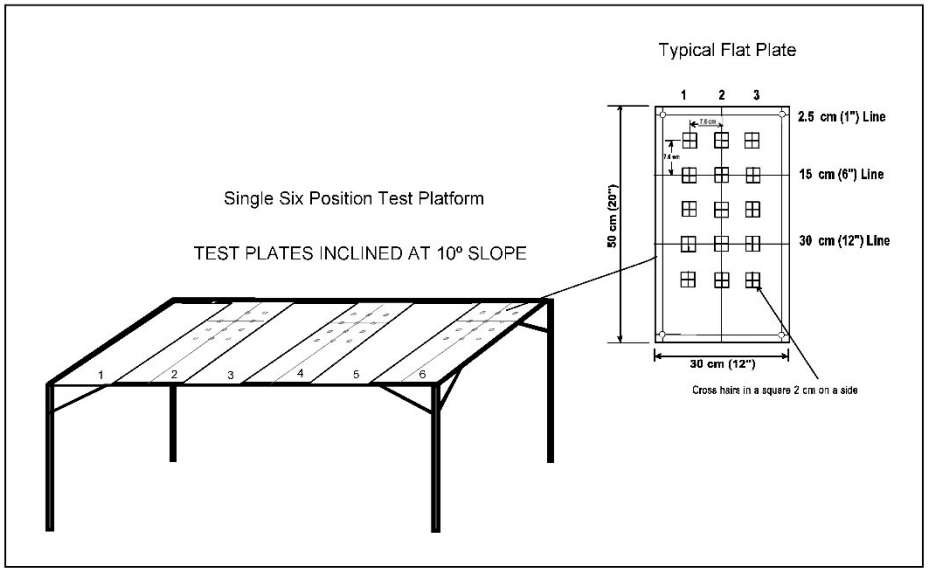


Figure 2.4: Test Stand Setup Schematic

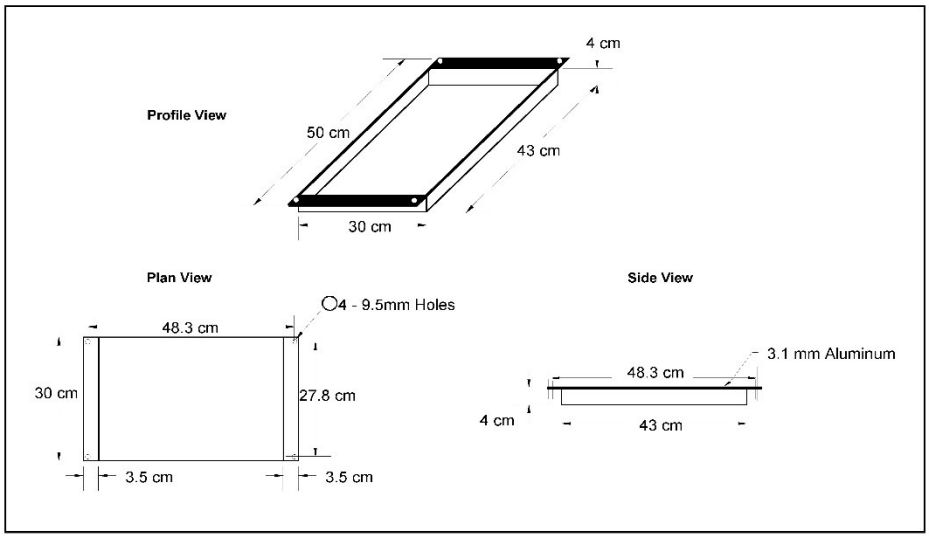


Figure 2.5: Schematic of Outdoor Precipitation Measurement Pan

2.2.7 NRC Sprayer Assembly

NRC developed an improved sprayer assembly, shown in Photos 2.9 and 2.10, in 1997-98. The improved sprayer provides a larger scan area and improved spray uniformity over the test bed area. The scanner consists of a horizontal main shaft supported by two bearings. The actual spray head assembly is shaft-mounted on a rotating scanner, so that one scan covers a lateral running strip of the test bed area. A stepper motor is synchronized to index the relative angle of the spray head between scans along an axis perpendicular to the scan axis. This provides two axes of rotation, essentially an x-y plane; one along each axis. Each scan is consecutively indexed in order to complete the precipitation coverage of the test bed area. This defines one cycle of the spray unit. The scan rate, index angle, and the number of scans per cycle are adjusted, along with the fluid delivery pressures (water and air) to obtain appropriate droplet sizes and precipitation rates. The spray nozzle is shown in Photo 2.11.

2.2.8 Fluids

Testing was carried out with AeroClear Max, a Type III ethylene glycol based fluid. Testing was conducted only with the neat fluid; no dilutions were tested.

2.3 Test Procedures

ARP5485 provides the procedure for endurance time testing of Type II, III and IV fluids under natural and simulated precipitation conditions.

The procedure generally consists of pouring de/anti-icing fluids onto clean flat plates exposed to various winter precipitation conditions, and recording the elapsed time for the test to reach the defined end condition (see Subsection 0), when a specified degree of freezing occurs. The following subsections provide summaries of the test procedures followed for natural snow, natural frost, artificial snow and simulated freezing precipitation testing.

2.3.1 Test Protocol – Natural Snow Tests

APS developed a specific procedure for Type II, III and IV fluid testing in natural snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted are conducted on standard flat plates (see Section 2.2.3);

- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.2 Test Protocol – Natural Frost Tests

APS developed a specific procedure for Type II/III/IV testing in natural frost. Key details of the procedure include:

- Tests are conducted on frosticator plates (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.3 Test Protocol – Artificial Snow Tests

APS developed a specific procedure for testing in artificial snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted on a standard plate (shown mounted on the snowmaker scale in Photo 2.12);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.4 Test Protocol – Simulated Precipitation Tests

APS developed a specific procedure for Type II/III/IV testing in simulated precipitation based on the requirements outlined in ARP5485. Key details of the procedure include:

- Freezing fog, freezing drizzle and light freezing rain tests are conducted on standard flat plates (see Section 2.2.3);
- Rain on cold-soak surface tests are conducted on filled cold-soak boxes (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.5 End Condition Definitions

Failure is called when 30 percent (1/3) of the plate or 5 cross-hairs are covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

a) Ice front;
b) Ice sheet;
c) Slush, in clusters or as a front;
d) Disseminated fine ice crystals;
e) Frost on surface;
f) Clear ice pieces partially or totally imbedded in fluid; and
g) Snow bridges on top of the fluid.

2.3.6 Precipitation Rate Measurement Procedures

The procedures for measuring and determining precipitation rates during simulated precipitation and natural precipitation conditions are provided below.

2.3.6.1 Simulated precipitation conditions

Prior to the start of the rate collection period, the proper needles and nozzles are installed in the spray unit, and both the air and water pressures are adjusted. Water spray calibration is performed by placing catch pans on the test stand, each pan marked with a number identifying the collection location on the test stand, and exposing the pans to a predetermined precipitation collection period.
The pans are weighed prior to exposure to precipitation and the weights are recorded in a customized Excel spreadsheet by using the print function on the digital weigh scale. Prior to the start of the precipitation catch period, the exact time (hh:mm:ss) is recorded using a pre-programmed time macro in the Excel spreadsheet. The pans are re-weighed following this collection period and the precipitation rates over the area of the test stand are examined. If the rates are unacceptable, re-calibration of the water spray is necessary. If the rates are deemed to be acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period has expired, the pans are again re-weighed and the rates computed.

Once two rates have been collected at each test location, the catch rates of the first and second collection are compared. If the average catch rate for any location is deemed to be acceptable for the test condition, then the pouring of fluids may begin at this location.

Rates are continuously monitored at a minimum of two locations during a test in order to ensure there are no significant rate fluctuations. Pans will be placed at these locations and be re-weighed at fixed intervals (15 minutes, typically) during the course of a test. If a rate fluctuation occurs, the test is stopped.

Following the failure of a test plate, a rate collection pan is weighed and placed at the plate location for a predetermined time interval. It is then re-weighed and placed again on the stand to collect a minimum of two additional rates at this location.

The rate of precipitation for any location on the stand is calculated by averaging the two rates collected prior to the test and the two rates collected following the test.

2.3.6.2 Natural precipitation conditions

Two rate collection pans per test stand are used to determine precipitation rates in natural conditions. Prior to the rate collection period, both pans are marked (upper and lower), and the inner bottom and sides of the each pan are wetted with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The wetted pans are then weighed to the nearest gram. The start time of the rate collection period is recorded (h/min/sec) using a customized Excel spreadsheet in which the weight is also recorded by pressing the print function on the digital weigh scale.

The pans are positioned in locations 6 and 7 (see Figure 2.4) and are allowed to collect precipitation for 10-minute intervals in normal conditions and 5-minute intervals in periods of high precipitation rates and high winds. Prior to removal of the plate pans from the test stand for re-weighing, any accumulated precipitation on the lips and outer sides of each plate pan is carefully removed. The plate pans are then carried to the rate station for re-weighing. Upon entering the trailer, the exact time is noted. The new weights of the plate pans are recorded and the pans are brought back outside. This procedure is continued until the final plate on the test stand has failed.

The rate for any HOT test in natural snow is obtained by computing the time-weighted average of the rates collected in the upper and lower pans over the duration of this particular test. To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.6. Typically, two collections pans are used for each test. The start and end times of the test shown in Figure 2.6 are 10:15 and 10:45,

respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t1, t2, and t3 (minutes). The calculated rates for each collection period are indicated by R1, R2, and R3 (g/dm²/h). In order to calculate the average rate for this pan, the following formula is then used:

$$\frac{(R_1 \times t_1 + R_2 \times t_2 + R_3 \times t_3)}{t_1 + t_2 + t_3}$$

In the example shown in Figure 2.6, the rate is calculated as follows:

$$\frac{(25 \times 10 + 22 \times 8 + 34 \times 5)}{10 + 8 + 5}$$

The calculated average rate for this pan is 25.9 g/dm²/h. The average rate for the other collection pan is calculated in similar fashion, and the average of the two rates is then taken.

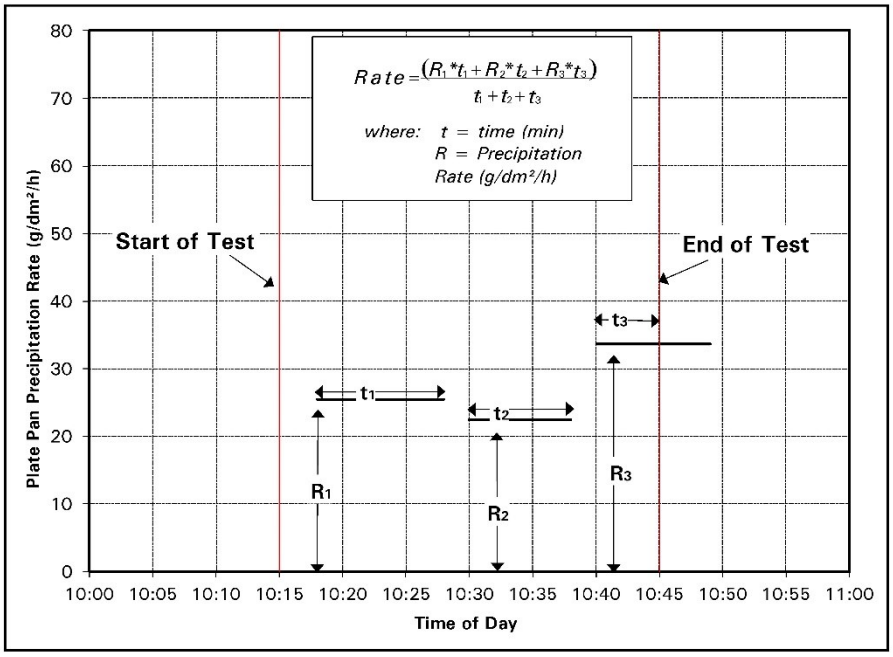


Figure 2.6: Calculation of Outdoor Precipitation Rate

2.4 Precipitation Rate Limits in Type II/III/IV Endurance Time Testing

Upper and lower precipitation rate limits are an important part of the test methodology for measuring fluid endurance times. Table 2.1 provides the meteorologically accepted definitions of weather phenomenon / precipitation types. It also includes the criteria used to determine precipitation intensity. This table was compiled by the National Centre for Atmospheric Research (NCAR) from the *World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation* (1983) and from the *American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS*) (3/94).

The precipitation rate limits established for Type II/III/IV endurance time testing are provided in ARP5485 and represented graphically in Figure 2.7. Subsections 2.4.1 to 2.4.5 provide detailed definitions and explanations of the precipitation types and rate boundaries used in Type II/III/IV endurance time testing. It should be noted that in many cases these limits are not the same as the meteorologically accepted definitions provided in Table 2.1.

Table 2.1: Definition of Weather Phenomenon

Weather Phenomenon*	Definition*
FROST (No METAR code) Note: No Intensity is assigned to FROST.	Ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.
FREEZING FOG (FZFG) Note: No Intensity is assigned to FRZ FOG	A suspension of numerous minute water droplets which freezes upon impact with ground or other exposed objects, generally reducing the horizontal
SNOW (SN)	Precipitation of ice crystals, most of which are branched, star-shaped, or mixed with unbranched crystals. At temperatures higher than about -5°C
FRZING DRIZZLE (FZDZ)	Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0.02 in.)] very close together which freezes upon impact with
FREEZING RAIN (FZRA)	Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5
RAIN (RA)	Precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 in.) diameter or of smaller widely scattered drops.
SNOW PELLETS (GS) and/or SMALL HAIL	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is
HAIL (GR)	Precipitation of small balls or pieces of ice with a diame-
ICE PELLETS (PE)	Precipitation of transparent (sleet or grains of ice), or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 in.)

Intensity Criteria**

	Snow(SN),Pellets(GS),Grains(SG)		Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (SN) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm/hr or 10 gr/dm²/hr)	Scattered pellets on the ground. Visibility not affected.
Moderate	If visibility is: < 5/8 to 5/16 mi (< 1.0 to 0.5 km)	> 0.05 to 0.10 in/hr (> 1.0 to 2.5 mm/hr), (> 10.0 to 25.0 gr/dm²/hr)	Slow accumulation on the ground. Visibility reduced to less than 7 mi.
Heavy (+)	If visibility is: < 5/16 mi (< 0.5 km)	More than 0.10 in/hr (> 2.5 mm/hr or 25 gr/dm²/hr)	Rapid accumulation on the ground. Visibility reduced to less than 3 mi.
Note: Horizontal visibility is only an estimation of snow and freezing drizzle intensity. Measurements and observations have			

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm/hr or 2.54 gr/dm²/hr)
Moderate	From 0.01 to 0.02 in/hr (2.54 to 5.08 gr/dm²/hr)
Heavy(+)	More than 0.02 in/hr (> 5.08 gr/dm²/hr) Note: Drizzle > 0.04 in/hr is usually in the form of rain.

	Rain (RA), Freezing Rain (FZRA), Ice Pellets (PE)
Measured Intensity	Up to 0.10 in/hr (2.5 mm/hr or 25 gr/dm²/hr) Maximum 0.01 inch in 6 minutes
Light (-) Estimated Intensity	From scattered drops that, regardless of duration, do not completely wet an
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.01 to 0.03 inch in 6 minutes
Moderate Estimated Intensity	Individual drops are not clearly identifiable; spray is observable just above
Measured Intensity	More than 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.03 inch in 6 minutes
Heavy (+) Estimated Intensity	Rain seemingly falls in sheets; individual drops are not identifiable; heavy

*From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
**From American Meteorological Society, Glossary of Meteorology WSOH #7 MANOBS (3/94)
***NCAR/RAE Proposed Definition for Liquid Equivalent Snowfall Intensity

1) gr/dm² = 0.01 mm = 0.1 mm = 0.0039 in
2) in = 2.54 cm = 25.4 mm = 254 gr/dm²

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP Sept 8, 1999 (Updated for METAR codes)

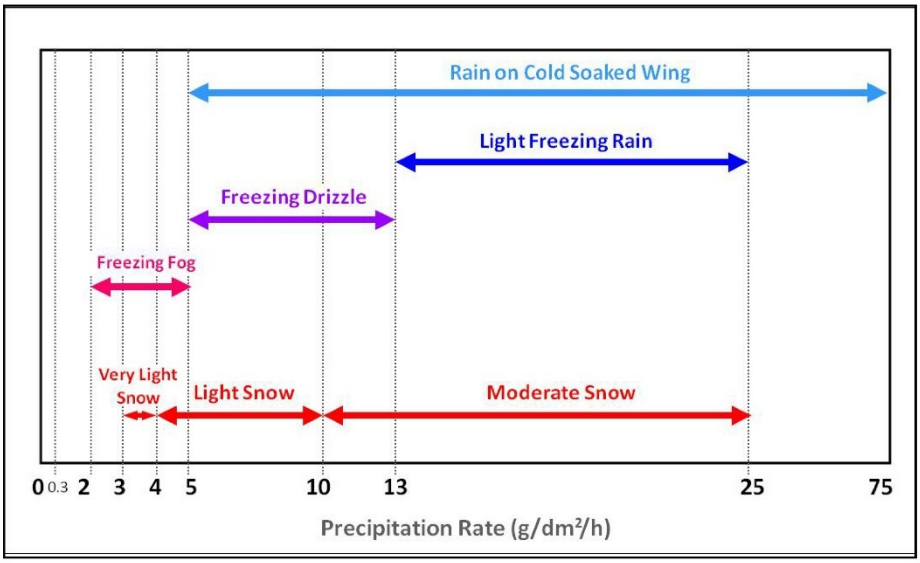


Figure 2.7: Precipitation Rate Limits Used in Endurance Time Testing

2.4.1 Freezing Fog

The precipitation rate limits for endurance time testing in freezing fog were set in 1997 at rates of 2 and 5 g/dm^2/h. These limits were determined with input from NRC meteorologists, who helped define an important parameter in the study of fog referred to as the *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic meter of air, can generally assume values in the range of 0.2 to 0.6 g/m^3.

2.4.2 Freezing Drizzle

The precipitation rate limits for endurance time testing in freezing drizzle are 5 and 13 g/dm^2/h. The upper limit in this range was adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Committee. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety.

2.4.3 Light Freezing Rain

The precipitation rate limits for endurance time testing in light freezing rain are 13 and 25 g/dm^2/h. This range corresponds to the category of light freezing rain and is the only freezing rain category considered, as operations in periods of moderate or heavy freezing rain are deemed unsafe.

2.4.4 Rain on a Cold-Soaked Surface

The precipitation rate limits for rain on cold soaked surface are 5 and 75 g/dm^2/h. This range encompasses drizzle (5 to 13 g/dm^2/h), light rain (13 to 25 g/dm^2/h), and moderate rain (25 to 75 g/dm^2/h).

2.4.5 Snow

The precipitation rate limits used to determine holdover times for Type II/II/IV fluids in snow are 3, 4, 10 and 25 g/dm^2/h. These rate limits encompass very light, light and moderate snow.

2.5 Ambient Temperatures in Type II/III/IV Endurance Time Testing

The Type II/IV holdover time tables have several temperature ranges:

- -3°C and above;
- Below -3 to -10°C (freezing drizzle, light freezing rain, cold soak wing);
- Below -3 to -14°C (freezing fog, snow); and
- Below -14°C to LOUT

The Type III holdover time tables have similar temperature ranges:

- -3°C and above;
- Below -3 to -10°C; and
- Below -10°C

In natural snow testing, endurance time testing is carried out under a range of temperatures. In simulated freezing precipitation and artificial snow testing, endurance time testing is typically conducted at the lower limit of each temperature band.

- Freezing Fog: -3°C, -10°C (Type III) / -14°C (Type II/IV) and -25°C
- Freezing Drizzle: -3°C and -10°C
- Light Freezing Rain: -3°C and -10°C
- Rain on Cold Soaked Surface: +1°C
- Artificial Snow: -3, -10°C (Type III) / -14°C (Type II/IV) and/or -25°C

2.6 Freezing Precipitation Droplet Sizes

Research has shown that median volume diameter (MVD) of rain droplets is related to rate of precipitation as follows:

- MVD = (precipitation rate/10) $^{0.23}$, where MVD is in mm and rate of precipitation is in g/dm²/h

The theoretical MVDs for rain at various rates of precipitation were determined based on this equation. These values are listed in Table 2.2 beside the experimental MVDs for each precipitation condition.

Table 2.2: Theoretical and Experimental MVDs

Precipitation Condition	Experimental MVD (mm)	Theoretical MVD (mm)
Moderate Rain (High rate: 75 g/dm²/h)	1.4	1.6
Light Rain (Low rate: 13 g/dm²/h)	1.0	< 1.1
Light Rain (High rate: 25 g/dm²/h)	1.0	1.2
Drizzle (Low rate: 5 g/dm²/h)	0.25	< 0.5
Drizzle (High rate: 13 g/dm²/h)	0.35	< 0.5
Fog		< 0.1

To determine whether droplets produced at the NRC resembled droplets from natural precipitation, a test was conducted during natural light freezing rain

conditions in 1997-98 at the APS test site. The droplet sizes were compared to those obtained in simulated light freezing rain at the NRC. The results of these tests are shown below.

a) *For the outdoor test:*

Location:	Montreal P.E.T. Airport
Precipitation:	Natural Light Freezing Rain
Precipitation Rate:	20 g/dm²/h
Calibrated MVD:	1.0 mm

b) *For the indoor test:*

Location:	National Research Council
Precipitation:	Simulated Light Freezing Rain
Precipitation Rate:	25 g/dm²/h
Calibrated MVD:	1.0 mm

The MVD for both natural and simulated light freezing rain was 1 mm, indicating that the NRC produced droplets simulate natural precipitation.
As a result of this testing, the MVDs for freezing precipitation testing were established as follows:

- Freezing Fog, high precipitation rate (5 g/dm²/h): 30 μm
- Freezing Fog, low precipitation rate (2 g/dm²/h): 30 μm
- Freezing Drizzle, high precipitation rate (13 g/dm²/h): 350 μm
- Freezing Drizzle, low precipitation rate (5 g/dm²/h): 250 μm
- Light Freezing Rain, high precipitation rate (25 g/dm²/h): 1,000 μm
- Light Freezing Rain, low precipitation rate (13 g/dm²/h): 1,000 μm
- Rain on Cold-Soaked Surface, low precipitation rate (5 g/dm²/h): 250 μm
- Rain on Cold-Soaked Surface, high precipitation rate (75 g/dm²/h): 1,400 μm

2.7 Summary of Freezing Precipitation Test Conditions

The precipitation types/rates, ambient temperatures and droplet sizes for freezing precipitation testing with Type II/III/IV fluids were described in the previous subsections. In summary, freezing precipitation tests are carried out in the weather conditions listed in Table 2.3.

Table 2.3: Summary of Freezing Precipitation Test Conditions (Type II//III/IV Fluids)

Precipitation Type	Fluid Type	Ambient Temperature	Precipitation Rate (Droplet Size)
Freezing Fog	Type II/III/IV	-3°C	2 g/dm²/h (30 μm)
			5 g/dm²/h (30 μm)
	Type III	-10°C	2 g/dm²/h (30 μm)
			5 g/dm²/h (30 μm)
	Type II/IV	-14°C	2 g/dm²/h (30 μm)
			5 g/dm²/h (30 μm)
	Type II/III/IV	-25°C	2 g/dm²/h (30 μm)
			5 g/dm²/h (30 μm)
Freezing Drizzle	Type II/III/IV	-3°C	5 g/dm²/h (250 μm)
			13 g/dm²/h (350 μm)
		-10°C	5 g/dm²/h (250 μm)
			13 g/dm²/h (350 μm)
Light Freezing Rain	Type II/III/IV	-3°C	13 g/dm²/h (1,000 μm)
			25 g/dm²/h (1,000 μm)
		-10°C	13 g/dm²/h (1,000 μm)
			25 g/dm²/h (1,000 μm)
Rain on Cold-Soaked Surface	Type II/III/IV	+1°C	5 g/dm²/h (250 μm)
			75 g/dm²/h (1,400 μm)

2.8 Analysis Methodology

A multi-variable regression procedure is used to derive fluid-specific holdover times for Type II/III/IV fluids. The procedure is based on the refinement of an equation for a curve which best represents the test data, and then solving that equation at the upper and lower limits established for the precipitation type. These precipitation rate limits, set by the SAE G-12 HOT Committee and detailed in ARP5485, were described in Subsection 2.4. This approach was developed in the winter of 1996-97 (see TC report, TP 13131E) and has since been used to derive fluid holdover times. There are some differences in the way the methodology is applied to freezing precipitation and natural snow data.

2.8.1 Freezing Precipitation Data

For each related freezing precipitation HOT table cell, four tests are conducted at the most restrictive (lowest) temperature in the temperature range for that cell: two tests at the low precipitation rate limit and two tests at the high precipitation rate limit (limits are detailed in Subsection 2.4). The equation used to treat freezing precipitation data is:

- $t = 10^{l}R^{a}$, where

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  l, a = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.2 Natural Snow Data

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural snow tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather data under all temperatures and precipitation rates encompassed by the HOT tables.

The general form of the regression equation is modified for natural snow to incorporate the variable of temperature and also to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C. The equation used to treat natural snow data is:

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

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a, b = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, using the most restrictive (lowest) temperature for that cell. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.3 Natural Frost Data

Regression analysis is not used in the determination of frost holdover times. The current Type II/III/IV generic frost holdover times were determined based on several years of testing using all fluids which were commercially available at the time. A "minimum values" analysis methodology was used to determine appropriate holdover times from the test data.

The purpose of natural frost testing with new fluids is to verify the fluids can be used with the generic frost holdover times. The analysis methodology is to compare the frost test data collected with the new fluid to the current generic holdover times. If the test data provides holdover times equal to or greater than the generic holdover times then the generic holdover times have been validated for the new fluid.

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural frost tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather several data points with each fluid/dilution.

2.8.4 Rounding and Capping Protocols

Regression-generated holdover times are subject to rounding and capping protocols.

The rounding protocols are as follows:

- Type II/IV: Holdover times are rounded to the nearest whole "5" minute, i.e. 55.1 to 57.4 minutes is rounded down to 55 minutes; 57.5 to 59.9 minutes is rounded up to 60 minutes. In cases where the regression-generated holdover times are below 10 minutes, the numbers are rounded down to the

nearest whole minute as a precautionary measure. For example, 9.6 minutes is rounded down to 9 minutes.

- Type III: Holdover times are rounded to the nearest whole "5" minute. In cases where the regression-generated holdover times are below 20 minutes, the numbers are rounded down to the nearest whole minute as a precautionary measure.

The capping protocols are:

- Type II/III/IV: All holdover time values are capped at maximum values. The caps differ by precipitation type, and in the case of snow, by regulator. The caps are as follows:
  - Freezing Fog holdover time values are capped at 4 hours;
  - Freezing Drizzle, Light Freezing Rain, Rain on Cold Soaked Wing holdover times are capped at 2 hours; and
  - Snow holdover times are capped at 2 hours by Transport Canada and 3 hours by FAA.

2.8.5 Regression Example

Sample plots of **Log t** versus **Log R** are shown in Figure 2.8. The plots contain data for one Neat Type IV fluid, in one temperature range (-10°C), in light freezing rain conditions. The best-fit regression line is superimposed onto the plot and was obtained from the analysis using the lowest temperature in the temperature range from which the data were chosen.

The same data plotted on a linear scale (failure time **t** versus precipitation rate **R**) are shown in Figure 2.9. The curve, generated from the power law form of the equation using the coefficients determined from the fit, is superimposed onto the plot. The HOT range is determined from the intersections of the curve with the precipitation rate limits defined for light freezing rain.

The holdover times for this fluid at -10°C are 20 minutes at 13 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid in the light freezing rain, neat fluid, below -3 to -10°C cell. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

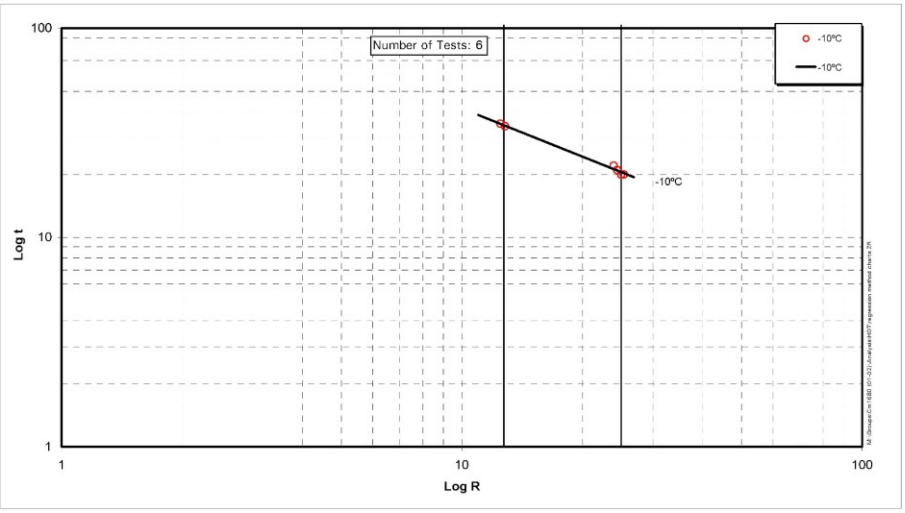


Figure 2.8: Regression Method on Log-Log Chart – Type IV Neat, Freezing Rain

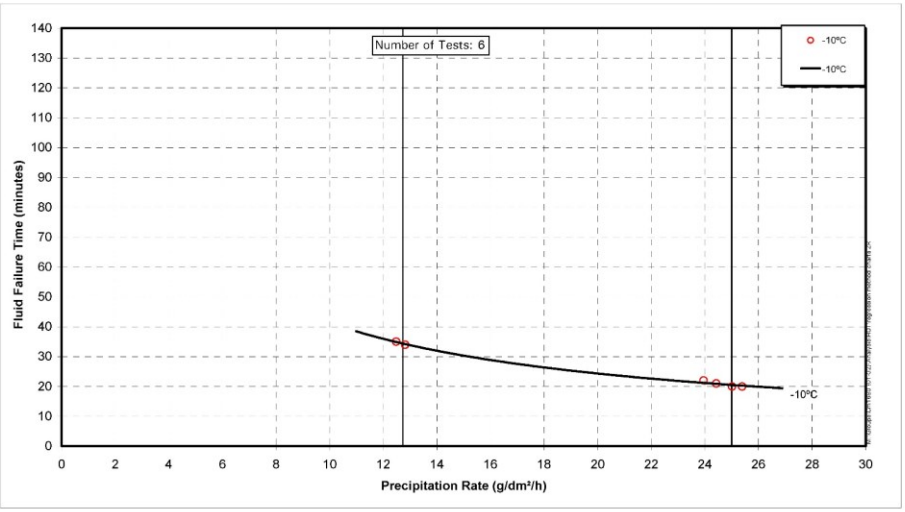


Figure 2.9: Regression Method on Standard Chart – Type IV Neat, Freezing Rain

2.8.6 Lowest Usable Precipitation Rates in Snow

A detailed analysis methodology was developed to determine if a snow data set is sufficient to determine holdover times for light and very light snow. Specifically, the analysis determines the lowest usable precipitation rate (LUPR), which is the lowest rate at which the data set is considered robust.

The methodology is a five-factor weighted analysis. The five factors are:

1. Total number of data points;
2. Number of data points with air temperatures below -3°C;
3. Number of data points with precipitation rates below 10 g/dm²/h;
4. Number of data points with precipitation rates less than or equal to 0.5 g/dm²/h above the precipitation rate being examined; and
5. Scatter from regression curve of low precipitation rate data points (average absolute percent difference between fail time and regression calculated fail time for all points less than or equal to 10 g/dm²/h).

The weights given to each of the five factors are:

1. Total Data Points = 5%;
2. Data Points Below -3°C = 20%;
3. Data Points Below 10 g/dm²/h = 20%;
4. Data Points ≤ Precipitation Rate = 40%; and
5. Low Rate Data Scatter = 15%.

Each data set is given a score of 0, 10, 20, 30 or 40 for each factor. The scoring system is shown in Table 2.4.

This approach provides a score for each data set for each precipitation rate below 10 g/dm²/h. The scores are compared to the minimum acceptance scores:

- 100/0 = 28
- 75/25 = 28
- 50/50 = 19 (lower due to a 0 score for data points below -3°C)

The LUPR is the lowest precipitation rate at which a data set has a passing score.

Table 2.4: LUPR Factor Scoring System

Factor #1: Total Data Points (Weight = 5%)	
Rating = 40	≥20 data points in data set
Rating = 30	15-19 data points in data set
Rating = 20	10-14 data points in data set
Rating = 10	5-9 data points in data set
Rating = 0	<5 data points in data set

Factor #2: Data Points Below -3°C (Weight = 20%)	
Rating = 40	≥15 data points from -3 to -14°C
Rating = 30	12-14 data points -3 to -14°C
Rating = 20	9-11 data points -3 to -14°C
Rating = 10	6-8 data points -3 to -14°C
Rating = 0	<6 data points -3 to -14°C

Factor #3: Data Points Below 10 g/dm²/h (Weight = 20%)	
Rating = 40	≥10 data points <10 g/dm²/h
Rating = 30	7-9 data points <10 g/dm²/h
Rating = 20	5-6 data points <10 g/dm²/h
Rating = 10	3-4 data points <10 g/dm²/h
Rating = 0	<3 data points <10 g/dm²/h

Factor #4: Data Points ≤ Precipitation Rate (Weight = 40%)	
Rating = 40	≥3 data points ≤ rate limit +0.5
Rating = 30	2 data points ≤ rate limit +0.5
Rating = 20	1 data points ≤ rate limit +0.5
Rating = 10	n/a
Rating = 0	0 data points ≤ rate limit +0.5

Factor #5: Low Rate Data Scatter (Weight = 15%)	
Rating = 40	Average actual-calculated error <10%
Rating = 30	Average actual-calculated error 10-19%
Rating = 20	Average actual-calculated error 20-29%
Rating = 10	Average actual-calculated error 30-39%
Rating = 0	Average actual-calculated error ≥40%

Photo 2.1: APS Test Site - View from Test Pad



Photo 2.2: APS Test Site - View from Trailer



Photo 2.3: Outdoor View of NRC Climatic Engineering Facility



Photo 2.4: Inside View of NRC Climatic Engineering Facility

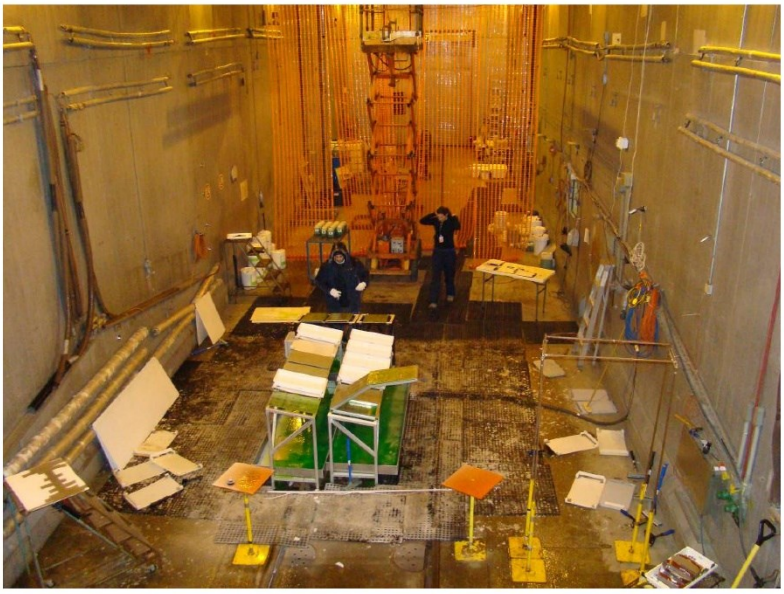


Photo 2.5: Test Plates Mounted on Stand

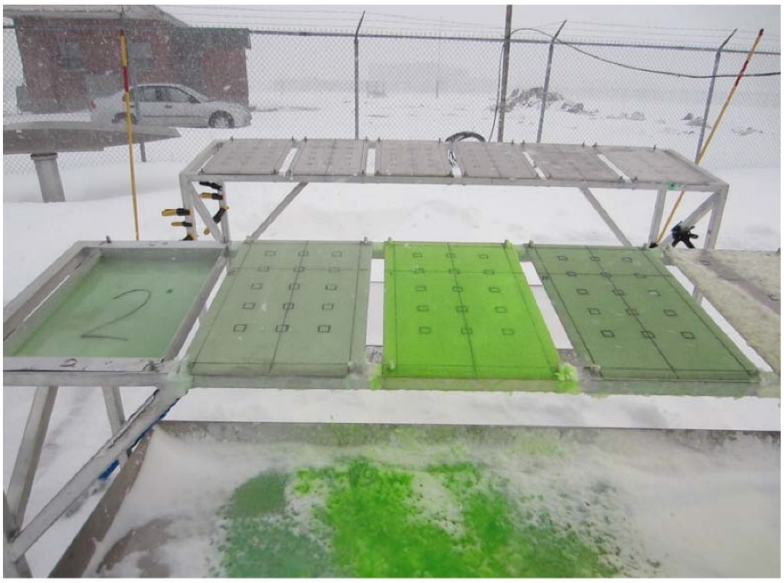


Photo 2.6: Cold-Soak / Leading Edge Thermal Equivalent Box

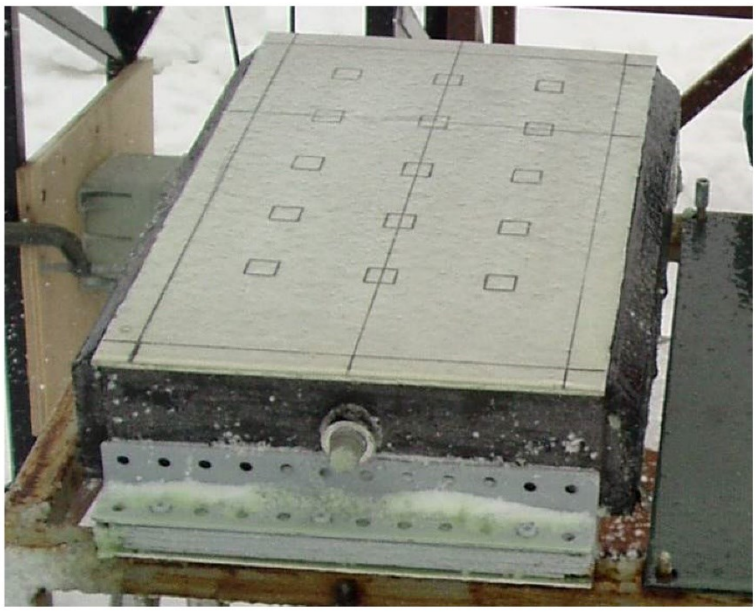


Photo 2.7: Frost Plate with Insulated Backing



Photo 2.8: Collection Pans Used Indoors at the NRC



Photo 2.9: Sprayer Assembly



Photo 2.10: Sprayer Assembly in Use

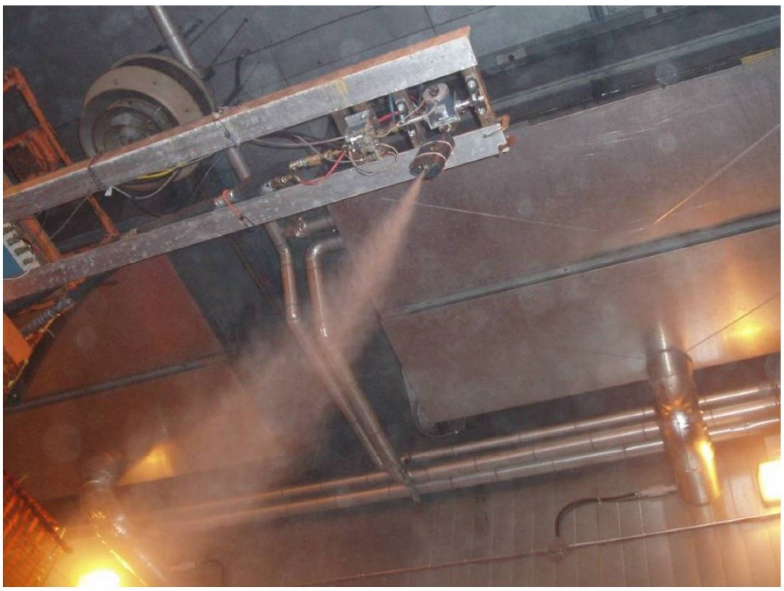


Photo 2.11: Sprayer Nozzle

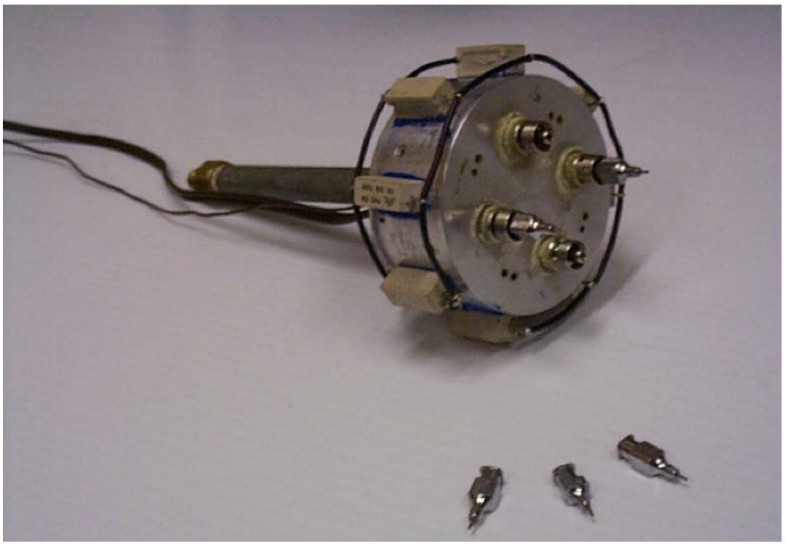
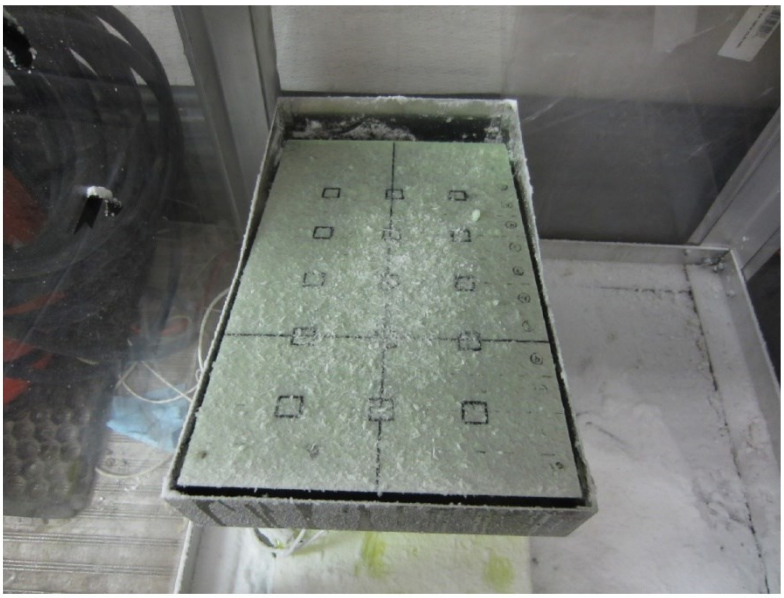


Photo 2.12: Standard Plate Setup for Testing with Artificial Snowmaker



3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted. Breakdowns are provided for the number of tests performed by precipitation type, fluid dilution and test temperature.

Logs of the tests conducted are provided at the end of this section as follows: Table 3.1 (snow), Table 3.2 (freezing precipitation) and Table 3.3 (frost). The logs provide details about each test conducted.

3.1 Natural and Artificial Snow Tests

Tests were conducted in natural snow conditions at the APS test site and at several mobile test sites (see Subsection 2.1.1). Artificial snow tests were conducted to supplement the limited natural snow data collected. These tests were conducted at the APS test site and at the NCAR test site in Boulder, CO. The number of tests conducted is summarized below by snow type, fluid dilution and test temperature.

Fluid Dilution	Natural Snow		
	≥ -3°C	-3 to -10°C	<-10°C
Neat	5	3	0

Fluid Dilution	Artificial Snow			
	-3°C	-10°C	-15°C	-25°C
Neat	9	9	8	8

3.2 Freezing Precipitation Tests

Tests were conducted in freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface conditions at the NRC CEF. The number of tests conducted is summarized below by precipitation type, fluid dilution and test temperature.

Fluid Dilution	Freezing Drizzle		Light Freezing Rain	
	-3°C	-10°C	-3°C	-10°C
Neat	4	4	4	4

Fluid Dilution	Freezing Fog				Cold Soak
	-3°C	-14°C	-25°C	-35°C	+1°C
Neat	4	4	4	4	4

3.3 Natural Frost Tests

Tests were conducted in natural frost conditions at the APS test site. The number of tests conducted is summarized below by fluid dilution and test temperature.

Fluid Dilution	Natural Frost			
	≥-1°C	<-1 to -3°C	<-3 to -10°C	<-10°C
Neat	3	0	0	1

3.4 Fluid Thickness Tests

Fluid thickness tests were conducted to measure the film thickness profiles of the fluid under dry conditions. Two tests were performed for each dilution. For each test, 1 litre of fluid was poured onto a flat plate mounted on a test stand inclined by 10°. Thickness measurements were taken at the 15-cm (6″) line at select time intervals over a 30-minute period. Tests were conducted at -3°C.

3.5 Viscosity Tests

Viscosity tests were conducted to determine the viscosity of the sample submitted for endurance time testing. This measurement is important as it establishes the lowest on-wing viscosity for the fluid.

Tests were conducted using the manufacturer's recommended method: Spindle SC4-31, small sample adapter, 9 mL, 0°C, 0.3 rpm, 30 minutes. No AIR9968 method viscosity measurements were taken due to the viscosity of the fluid at the AIR9968 measurement method temperature (20°C) being higher for the sheared fluid than the unsheared fluid.

Tests were also conducted using Spindle SC4-18 and 6.7 mL of fluid. This measurement was taken as the viscosity range of Spindle SC4-18 at 0.3 rpm (1,000 to 10,000 mPa.s) is more appropriate for the sample than the manufacturer's recommended method spindle (SC4-31; 10,000 to 100,000 mPa.s). The manufacturer is considering using this method in future.

Table 3.1: Summary of Tests Performed (Snow)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
415	4-Apr-15	Natural Snow	AeroClear MAX	100%	-2.8	14.2	28.8
418	4-Apr-15	Natural Snow	AeroClear MAX	100%	-3.5	9.7	41.0
420	4-Apr-15	Natural Snow	AeroClear MAX	100%	-3.9	10.8	41.5
424	4-Apr-15	Natural Snow	AeroClear MAX	100%	-4.7	13.7	29.0
436	8-Apr-15	Natural Snow	AeroClear MAX	100%	0.5	16.1	37.3
437	8-Apr-15	Natural Snow	AeroClear MAX	100%	0.5	7.2	73.7
445	8-Apr-15	Natural Snow	AeroClear MAX	100%	0.5	7.8	70.0
451	8-Apr-15	Natural Snow	AeroClear MAX	100%	0.6	5.7	86.0
AS1	7-Apr-15	Artificial Snow	AeroClear MAX	100%	-3.0	3.0	131.8
AS5	7-Apr-15	Artificial Snow	AeroClear MAX	100%	-3.0	10.0	42.7
AS7	7-Apr-15	Artificial Snow	AeroClear MAX	100%	-3.0	25.0	21.7
AS3	8-Apr-15	Artificial Snow	AeroClear MAX	100%	-3.0	4.0	115.0
AS9	8-Apr-15	Artificial Snow	AeroClear MAX	100%	-10.0	3.0	134.4
AS11	8-Apr-15	Artificial Snow	AeroClear MAX	100%	-10.0	4.0	110.0
AS13	8-Apr-15	Artificial Snow	AeroClear MAX	100%	-10.0	10.0	47.2
AS15	8-Apr-15	Artificial Snow	AeroClear MAX	100%	-10.0	25.0	23.9
AS17	9-Apr-15	Artificial Snow	AeroClear MAX	100%	-15.0	3.0	128.9
AS19	9-Apr-15	Artificial Snow	AeroClear MAX	100%	-15.0	4.0	98.8
AS21	9-Apr-15	Artificial Snow	AeroClear MAX	100%	-15.0	10.0	49.0
AS18	16-Apr-15	Artificial Snow	AeroClear MAX	100%	-15.0	3.0	157.0
AS20	16-Apr-15	Artificial Snow	AeroClear MAX	100%	-15.0	4.0	104.5
AS22	16-Apr-15	Artificial Snow	AeroClear MAX	100%	-15.0	10.0	48.0
AS10	17-Apr-15	Artificial Snow	AeroClear MAX	100%	-10.0	3.0	129.8
AS12	17-Apr-15	Artificial Snow	AeroClear MAX	100%	-10.0	4.0	106.9
AS14	17-Apr-15	Artificial Snow	AeroClear MAX	100%	-10.0	10.0	49.7
AS16	17-Apr-15	Artificial Snow	AeroClear MAX	100%	-10.0	25.0	27.9
AS2	20-Apr-15	Artificial Snow	AeroClear MAX	100%	-3.0	3.0	127.6
AS6	20-Apr-15	Artificial Snow	AeroClear MAX	100%	-3.0	10.0	43.2
AS8	20-Apr-15	Artificial Snow	AeroClear MAX	100%	-3.0	25.0	26.6
AS4	21-Apr-15	Artificial Snow	AeroClear MAX	100%	-3.0	4.0	131.5
AS23R	21-Apr-15	Artificial Snow	AeroClear MAX	100%	-15.0	25.0	25.0
AS39	21-Apr-15	Artificial Snow	AeroClear MAX	100%	-25.0	25.0	18.0
AS37	21-Apr-15	Artificial Snow	AeroClear MAX	100%	-25.0	10.0	40.9
AS33	21-Apr-15	Artificial Snow	AeroClear MAX	100%	-25.0	3.0	135.3
AS35	21-Apr-15	Artificial Snow	AeroClear MAX	100%	-25.0	4.0	100.0
AS7R	22-Apr-15	Artificial Snow	AeroClear MAX	100%	-3.0	25.0	25.8
AS15R	22-Apr-15	Artificial Snow	AeroClear MAX	100%	-10.0	25.0	28.8
AS24R	22-Apr-15	Artificial Snow	AeroClear MAX	100%	-15.0	25.0	24.0
AS34	22-Apr-15	Artificial Snow	AeroClear MAX	100%	-25.0	3.0	129.2
AS36	22-Apr-15	Artificial Snow	AeroClear MAX	100%	-25.0	4.0	98.9
AS38	22-Apr-15	Artificial Snow	AeroClear MAX	100%	-25.0	10.0	39.2
AS40	22-Apr-15	Artificial Snow	AeroClear MAX	100%	-25.0	25.0	16.5

Table 3.2: Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
5	1-Apr-15	Freezing Fog	AeroClear MAX	100	-3	2.0	133.3
6	1-Apr-15	Freezing Fog	AeroClear MAX	100	-3	2.0	141.1
29	31-Mar-15	Freezing Fog	AeroClear MAX	100	-3	5.2	58.2
30	31-Mar-15	Freezing Fog	AeroClear MAX	100	-3	5.1	62.4
49	30-Mar-15	Freezing Fog	AeroClear MAX	100	-10	2.0	103.7
50	30-Mar-15	Freezing Fog	AeroClear MAX	100	-10	2.1	103.4
55	31-Mar-15	Freezing Fog	AeroClear MAX	100	-10	5.1	61.4
56	31-Mar-15	Freezing Fog	AeroClear MAX	100	-10	5.1	61.6
81	30-Mar-15	Freezing Fog	AeroClear MAX	100	-25	1.9	67.4
82	30-Mar-15	Freezing Fog	AeroClear MAX	100	-25	1.9	68.2
97	30-Mar-15	Freezing Fog	AeroClear MAX	100	-25	5.4	25.9
98	30-Mar-15	Freezing Fog	AeroClear MAX	100	-25	5.4	25.9
107	30-Mar-15	Freezing Fog	AeroClear MAX	100	-35	2.2	49.2
108	30-Mar-15	Freezing Fog	AeroClear MAX	100	-35	2.2	51.9
111	30-Mar-15	Freezing Fog	AeroClear MAX	100	-35	4.7	19.7
112	30-Mar-15	Freezing Fog	AeroClear MAX	100	-35	4.9	19.5
121	25-Mar-15	Freezing Drizzle	AeroClear MAX	100	-3	4.7	80.7
122	25-Mar-15	Freezing Drizzle	AeroClear MAX	100	-3	5.4	78.6
141	25-Mar-15	Freezing Drizzle	AeroClear MAX	100	-3	12.8	39.7
142	25-Mar-15	Freezing Drizzle	AeroClear MAX	100	-3	12.7	38.1
161	27-Mar-15	Freezing Drizzle	AeroClear MAX	100	-10	5.2	70.5
162	27-Mar-15	Freezing Drizzle	AeroClear MAX	100	-10	4.8	72.3
177	26-Mar-15	Freezing Drizzle	AeroClear MAX	100	-10	12.8	38.8
178	26-Mar-15	Freezing Drizzle	AeroClear MAX	100	-10	12.9	38.1
201	27-Mar-15	Light Freezing Rain	AeroClear MAX	100	-3	12.8	32.7
202	27-Mar-15	Light Freezing Rain	AeroClear MAX	100	-3	13.3	31.4
217	27-Mar-15	Light Freezing Rain	AeroClear MAX	100	-3	24.5	26.5
218	27-Mar-15	Light Freezing Rain	AeroClear MAX	100	-3	25.1	23.7
239	26-Mar-15	Light Freezing Rain	AeroClear MAX	100	-10	13.2	41.8
240	26-Mar-15	Light Freezing Rain	AeroClear MAX	100	-10	13.0	42.4
253	26-Mar-15	Light Freezing Rain	AeroClear MAX	100	-10	25.0	27.4
254	26-Mar-15	Light Freezing Rain	AeroClear MAX	100	-10	24.4	28.1
271	1-Apr-15	Cold Soak Box	AeroClear MAX	100	1	5.3	59.4
272	1-Apr-15	Cold Soak Box	AeroClear MAX	100	1	5.2	56.1
289	1-Apr-15	Cold Soak Box	AeroClear MAX	100	1	76.8	9.4
290	1-Apr-15	Cold Soak Box	AeroClear MAX	100	1	76.3	8.9

Table 3.3: Summary of Tests Performed (Natural Frost)

Test No.	Date	Precip. Type	Fluid Name	Fluid Dilution	Test Duration (min.)	Average Rate (g/dm²/h)	Temp (°C)	Wind Speed (km/h)	Average RH (%)
64	23-Mar-15	Natural Frost	AeroClear MAX	100%	459	0.01	-11.3	8.3	66.6
69	6-May-15	Natural Frost	AeroClear MAX	100%	152	0.16	2.3	0.0	84.7
70	6-May-15	Natural Frost	AeroClear MAX	100%	151	0.16	2.3	0.0	84.7
71	6-May-15	Natural Frost	AeroClear MAX	100%	145	0.16	2.3	0.0	84.7

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4. RESULTS AND DISCUSSION

The methods used to evaluate the test data were reviewed in Subsection 2.8. The results of the data analyses and discussions of the implications of the findings are presented in this section.

4.1 Results

The results of the endurance time tests, thickness tests and viscosity tests are described in this section.

4.1.1 Endurance Time Tests – Freezing Precipitation

Figures 4.1 to 4.4 present the endurance time data collected in freezing precipitation (freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface).

These figures show the effect of temperature, precipitation type and precipitation rate on fluid endurance time in the conditions encompassed by the Type III HOT guidelines. The figures include the current Type III generic holdover times for comparative purposes.

Multi-variable regression analysis was performed on these data sets as described in Subsection 2.8. Table 4.1 provides the outputs from the multi-variable regression analyses. These outputs were used to derive fluid-specific holdover times for all conditions encompassed by Type III fluid-specific HOT tables, except snow (see Subsection 4.1.2 and 4.1.3).

4.1.2 Endurance Time Tests – Natural Snow

Figure 4.5 presents the endurance time data collected in natural snow. This figure shows the effect of temperature, precipitation type and precipitation rate on fluid endurance time in the conditions encompassed by the Type III HOT guidelines. The figure includes the current Type III generic holdover times for comparative purposes.

Due to the late submission of the fluid in the winter test season, limited natural snow data was collected; the data collected was insufficient to determine fluid-specific holdover times.

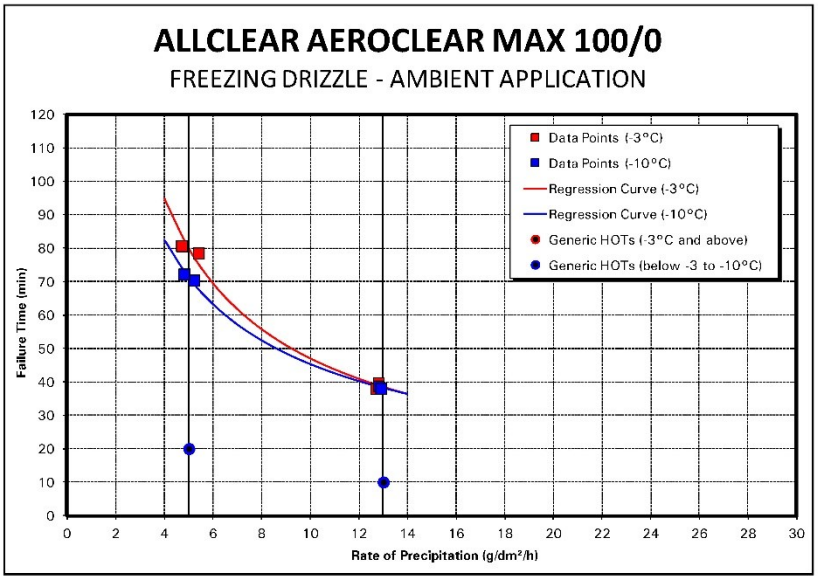

Figure 4.1: Type III Neat – Freezing Drizzle

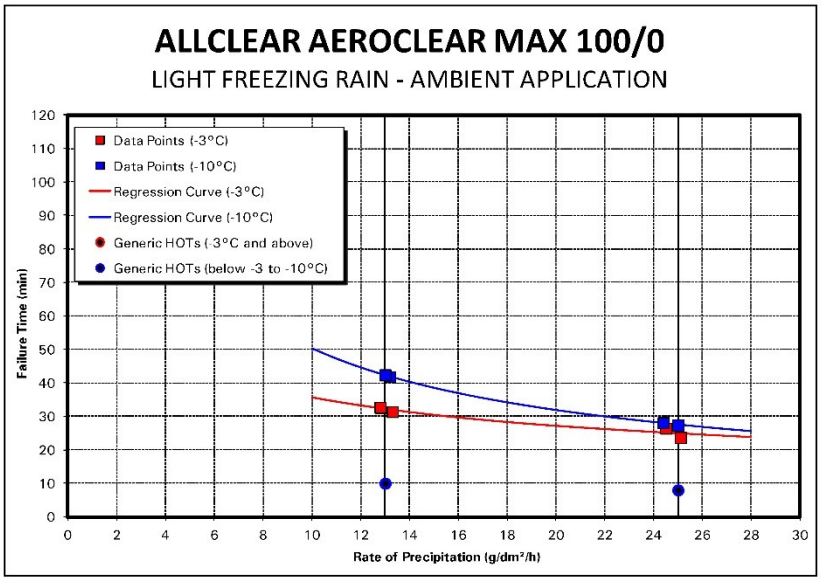

Figure 4.2: Type III Neat – Light Freezing Rain

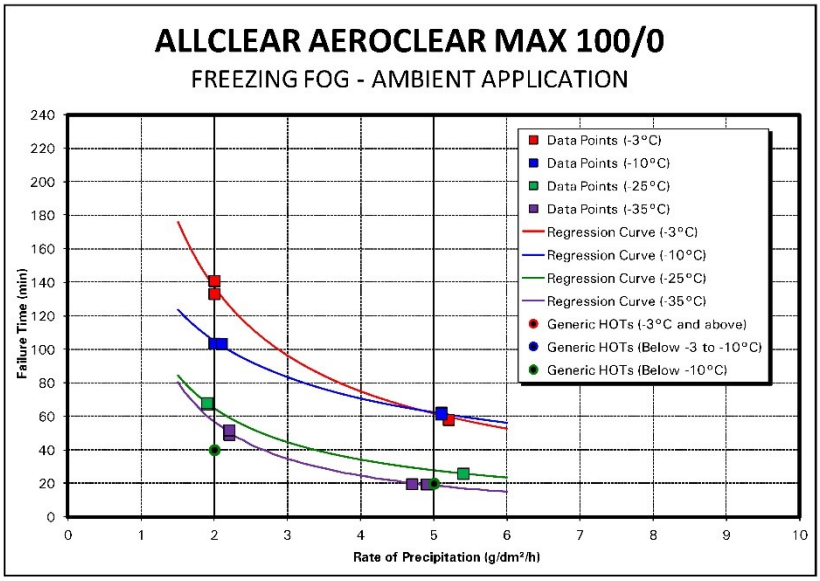

Figure 4.3: Type III Neat – Freezing Fog

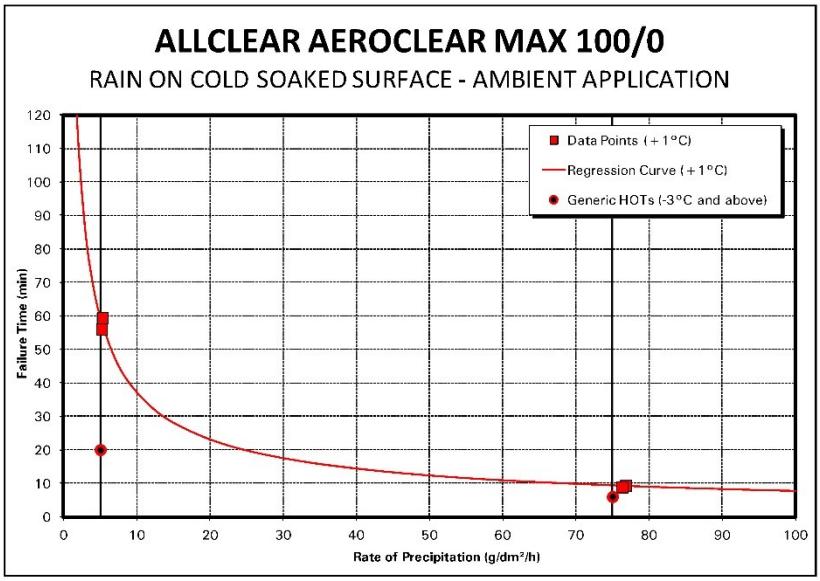

Figure 4.4: Type III Neat – Rain on Cold-Soaked Surface

Table 4.1: Regression Equation Coefficients for AllClear AeroClear MAX

Precipitation Type	Dilution	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Freezing Fog	Neat	-3°C	100%	2.3993	-0.8704	4
Freezing Fog	Neat	-10°C	100%	2.1931	-0.5714	4
Freezing Fog	Neat	-25°C	100%	2.0874	-0.9193	4
Freezing Fog	Neat	-35°C	100%	2.1187	-1.2127	4
Freezing Drizzle	Neat	-3°C	99%	2.4376	-0.7660	4
Freezing Drizzle	Neat	-10°C	100%	2.3105	-0.6543	4
Light Freezing Rain	Neat	-3°C	92%	1.9386	-0.3880	4
Light Freezing Rain	Neat	-10°C	100%	2.3607	-0.6591	4
Rain on Cold Soaked Wing	Neat	+1°C	100%	2.2567	-0.6880	4

General Equation $t = 10^{I} R^{A}$

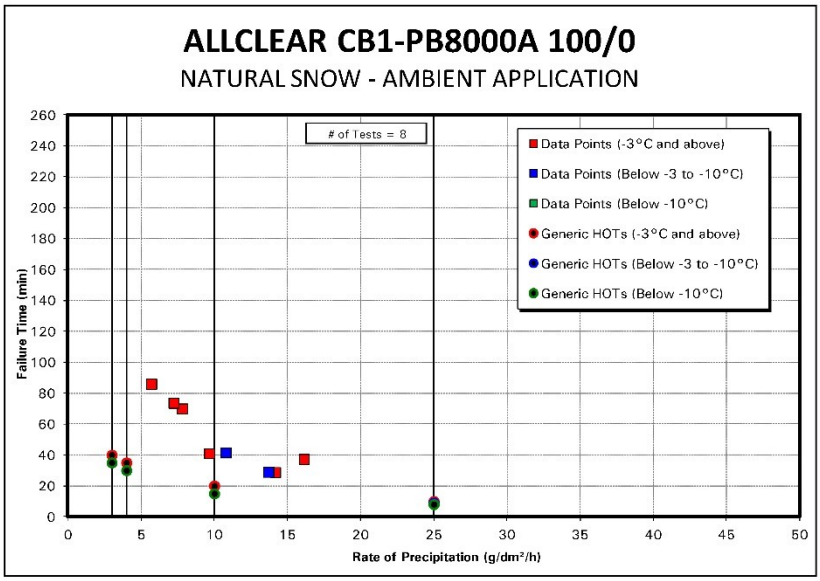

Figure 4.5: Type III Neat – Natural Snow

4.1.3 Endurance Time Tests – Artificial Snow

Due to the late submission of this fluid in the winter, it was not possible to collect sufficient data in natural snow to derive fluid-specific holdover times from the data. Data was collected in artificial snow to supplement the limited natural snow data. Figures 4.6 and 4.7 show the artificial snow data plotted against the Type III generic snow holdover times and the holdover times derived from the 2014-15 Type III regression coefficients.

All data points met or exceeded the generic holdover times and the holdover times derived from the 2014-15 Type III regression coefficients. It was concluded from these tests that AllClear AeroClear MAX can be used with the generic snow holdover times and the 2014-15 Type III regression coefficients for the winter 2015-16 operating season. The fluid can not be used in snow below the coldest temperature at which tests were conducted: -25°C.

4.1.4 Fluid Thickness Tests

As described in Subsection 3.4, two thickness tests were conducted at an ambient temperature of -3°C. The resulting film thickness profiles are displayed in Figure 4.8. The final fluid thickness (both tests) was 0.7 mm.

4.1.5 Endurance Time Tests – Natural Frost

The natural frost data was presented in Table 3.3. The test durations were compared to the Type III generic holdover times. Tests that were not completed (due to active frost ending before fluid failure could occur) surpassed the generic holdover times. This analysis indicates the Type III generic frost holdover times can be considered substantiated for AeroClear MAX.

4.1.6 Viscosity Tests

The viscosity was measured as follows:

- Manufacturer Method: 7,300 cP (Spindle SC4-31, SSA, 9 mL, 0°C, 0.3 rpm, 30 mins)
- Alternate Method: 3,160 cP (Spindle SC4-18, SSA, 6.7 mL, 0°C, 0.3 rpm, 30 mins)

No unusual behaviour was observed during the viscosity tests.

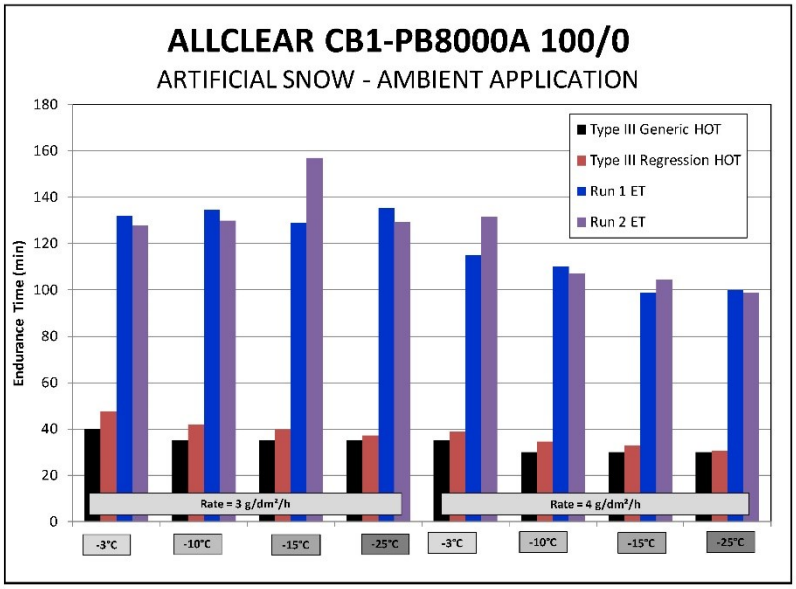

Figure 4.6: Type III Neat – Artificial Snow (Rate = 3, 4 g/dm²/h)

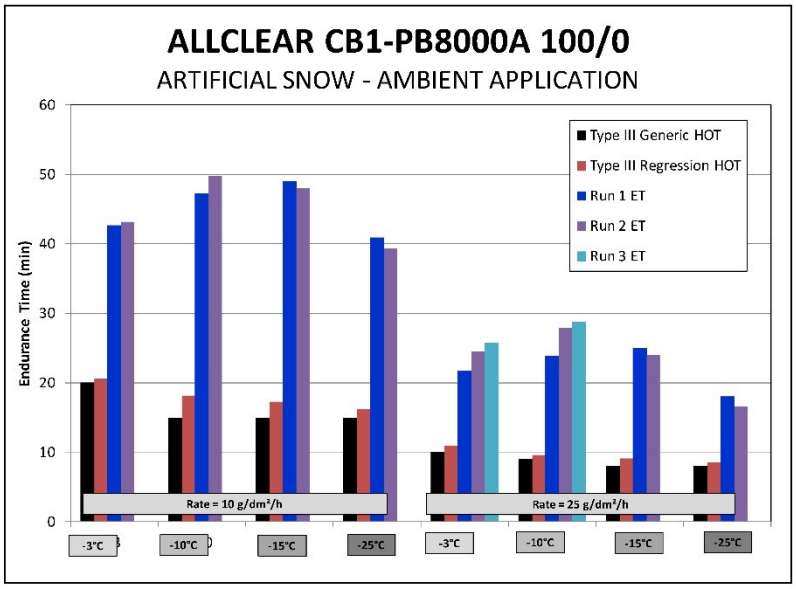

Figure 4.7: Type III Neat – Artificial Snow (Rate = 10, 25 g/dm²/h)

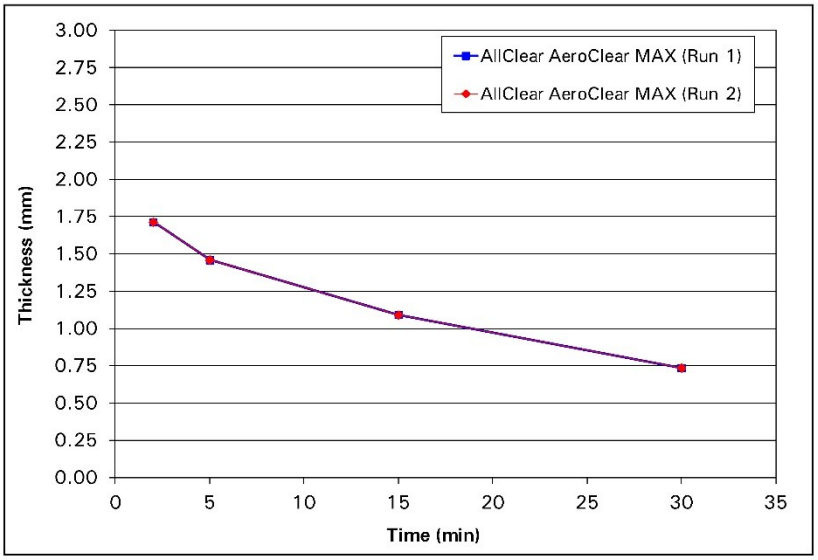

Figure 4.8: Fluid Thickness Profile of AeroClear MAX

4.2 Discussion

4.2.1 Fluid-Specific Holdover Time Tables

The holdover times described in Subsection 4.1.1 were used to populate the freezing precipitation cells of a fluid-specific HOT table for AllClear AeroClear MAX. As detailed in Subsection 4.1.3, the 2014-15 generic Type III holdover times were used to populate the snow cells.

In addition, several other factors impact the holdover times published:

- Snow holdover times are only provided down to the lowest temperature at which the fluid underwent testing in artificial snow (-25°C);
- Freezing fog holdover times are only provided down to the lowest temperature at which the fluid underwent testing in freezing fog (-35°C);
- No holdover times are provided for 75/25 and 50/50 dilutions of AeroClear MAX as only the 100/0 concentration was tested;
- Separate high speed and low speed versions of the HOT table will be published. The difference between the tables is the coldest temperature they

encompass; holdover times are provided down to the lowest operational use temperature specific to high speed and low speed aircraft;

- The holdover times provided in the AeroClear MAX HOT tables are only valid for unheated fluid applications. This is because the fluid was not tested for heated applications;
- As no testing has been conducted to date with AeroClear MAX in ice pellet conditions, it cannot be used with the Type III generic ice pellet/small hail allowance times; and
- Frost holdover times are not included in fluid-specific HOT tables. Generic holdover times are provided for frost in the separate frost HOT table published by TC and FAA. AeroClear MAX can be used in frost with the Type III generic frost holdover times.

The AeroClear MAX HOT tables are shown in both the TC format (Tables 4.2 and 4.3) and FAA format (Tables 4.4 and 4.5) at the end of this chapter.

4.2.2 Regression Information

Regression information was provided in Table 4.1 for freezing precipitation conditions. Table 4.1 does not include regression information for snow, as limited natural snow testing was completed (see Subsection 4.1.2) and regression analysis could not be completed. Regulators have agreed to provide this fluid with the 2014-15 Type III regression coefficients for the winter of 2015-16. This is supported by the data collected in artificial snow (see Subsection 4.1.3).

4.2.1 Lowest Operational Use Temperatures (LOUTs)

The LOUT for Type III fluids is determined for each rotation speed (low speed, high speed) by the higher of:

- The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
- The actual freezing point of the fluid plus its freezing point buffer of 7°C (13°F).

The aerodynamic test and fluid freeze point information for this fluid appears at the beginning of this report. The low speed LOUT is -16°C. The high speed LOUT was set at -35°C. This was due to the unusual situation that the coldest temperature at which holdover time testing was conducted was above the LOUT calculated using the method described above.

4.2.2 Lowest Usable Precipitation Rates in Snow

The LUPR analysis was not completed as the natural snow data set was not completed. For the winter of 2014-15, the LUPR is the higher of:

- The lowest rate at which AeroClear Max underwent artificial snow testing (3 g/dm²/h); and
- The LUPR for the 2014-15 Type III regression coefficients (2 g/dm²/h for -10°C and above; 4 g/dm²/h for below -10°C)

4.2.3 Water Spray Endurance Test (WSET) Result

The Water Spray Endurance Test (WSET) result for this fluid was marginally (2 minutes) below the current SAE WSET acceptance criteria for a Type III fluid. The SAE acceptance criteria is provided in SAE AMS1428G. The fluid has nevertheless been accepted as a Type III fluid by TC and FAA. It should be noted that TC and FAA have proposed a change for this requirement to the SAE G-12.

4.2.4 Viscosity

The viscosity of the fluid sample used in this testing was measured using the manufacturer's designated method. The APS measured viscosity appears at the beginning of this document and will be published as the lowest on-wing viscosity (LOWV) value for the fluid. In order for the fluid-specific holdover times provided in this document to be valid, operators must ensure that the viscosity of the fluid being used is equal or greater than the published LOWV.

4.2.5 Publication of Holdover Times

As AllClear intends to commercialize AeroClear MAX, TC and FAA will publish its fluid-specific HOT tables in their 2015-16 Holdover Time Guidelines. The guidelines will also include the LOWV and LOUT information; the regression and LUPR data will be published in the related TC and FAA Regression Information documents.

4.2.6 Future Developments

This fluid will undergo further testing in natural snow in the winter of 2015-16. It is expected this testing will enable the development of fluid-specific snow holdover times, which will be published by regulators for the winter of 2016-17.

Table 4.2: Holdover Time Table – Low Speed (Transport Canada Format)

TABLE 3LS-A-ACM

LOW SPEED TYPE III FLUID HOLDOVER TIME GUIDELINES
ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]
FOR AIRCRAFT CONFORMING TO THE SAE AS5900 LOW SPEED AERODYNAMIC TEST CRITERION
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:00 – 2:15	0:35	0:20 – 0:35	0:10 – 0:20	0:40 – 1:20	0:25 – 0:30	0:09 – 1:00	
		75/25								
		50/50								
below -3 to -10	below 27 to 14	100/0	1:00 – 1:45	0:30	0:15 – 0:30	0:09 – 0:15	0:40 – 1:10	0:30 – 0:40	CAUTION: No holdover time guidelines exist	
		75/25								
below -10 to -16	below 14 to 3.2	100/0	0:30 – 1:05	0:30	0:15 – 0:30	0:08 – 0:15				

NOTES
1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

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

Table 4.3: Holdover Time Table – High Speed (Transport Canada Format)

TABLE 3HS-A-ACM

HIGH SPEED TYPE III FLUID HOLDOVER TIME GUIDELINES
ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]
FOR AIRCRAFT CONFORMING TO THE SAE AS5900 HIGH SPEED AERODYNAMIC TEST CRITERION
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:00 – 2:15	0:35	0:20 – 0:35	0:10 – 0:20	0:40 – 1:20	0:25 – 0:30	0:09 – 1:00	
		75/25								
		50/50								
below -3 to -10	below 27 to 14	100/0	1:00 – 1:45	0:30	0:15 – 0:30	0:09 – 0:15	0:40 – 1:10	0:30 – 0:40	CAUTION: No holdover time guidelines exist	
		75/25								
below -10 to -25	below 14 to -13	100/0	0:30 – 1:05	0:30	0:15 – 0:30	0:08 – 0:15				
below -25 to -35	below -13 to -31	100/0	0:18 – 0:55							

NOTES
1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

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

Table 4.4: Holdover Time Table – Low Speed (FAA Format)

TABLE 3A-LS. LOW SPEED TYPE III HOLDOVER TIME GUIDELINES FOR ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 LOW SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:00-2:15	0:35-0:40	0:20-0:35	0:10-0:20	0:40-1:20	0:25-0:30	0:09-1:00	CAUTION No holdover time guidelines exist
		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 -10	below 27 to 14	100/0	1:00-1:45	0:30-0:35	0:15-0:30	0:09-0:15	0:40-1:10	0:30-0:40		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -10 to -16	below 14 to 3.2	100/0	0:30-1:05	0:30-0:35	0:15-0:30	0:08-0:15				

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

1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid when applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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 4.5: Holdover Time Table – High Speed (FAA Format)

TABLE 3A-HS. HIGH SPEED TYPE III HOLDOVER TIME GUIDELINES FOR ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 HIGH SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:00-2:15	0:35-0:40	0:20-0:35	0:10-0:20	0:40-1:20	0:25-0:30	0:09-1:00	CAUTION No holdover time guidelines exist
		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 -10	below 27 to 14	100/0	1:00-1:45	0:30-0:35	0:15-0:30	0:09-0:15	0:40-1:10	0:30-0:40		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -10 to -25	below 14 to -13	100/0	0:30-1:05	0:30-0:35	0:15-0:30	0:08-0:15				
below -25 to -35	below -13 to -31	100/0	0:18-0:55							

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

1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid when applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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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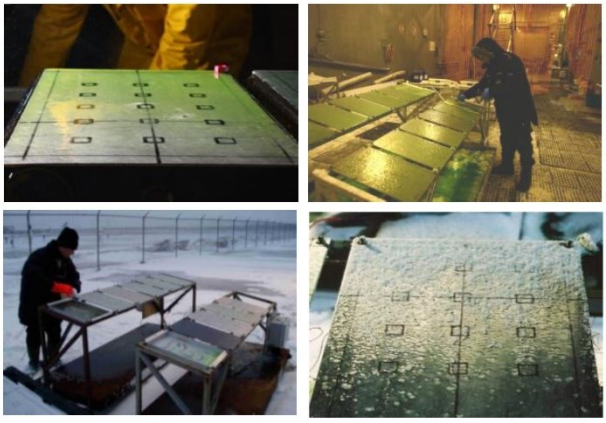
APPENDIX H

FLUID MANUFACTURER REPORT:
DEICING SOLUTIONS ECO-SHIELD® (TYPE IV)

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Deicing Solutions ECO-SHIELD® (Type IV)



Prepared for

Deicing Solutions LLC

by

APS Aviation Inc.

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 1.0
Report No. DS-ES 2014-15

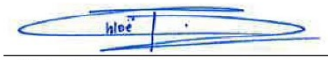
AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Deicing Solutions ECO-SHIELD® (Type IV)

Prepared for

Deicing Solutions LLC

Prepared by:



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Reviewed by:



John D'Avirro, Eng.
Program Manager

June 26, 2015
Date

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 1.0
Report No. DS-ES 2014-15

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer:	Deicing Solutions LLC
Fluid Test Name:	ECO-SHIELD®
Fluid Commercial Name:	ECO-SHIELD®
Fluid Type / Base / Colour:	Type IV / Propylene Glycol / Green
Dilutions Submitted:	100/0
Batch #:	141223D-CC
Date of Receipt:	December 24, 2014
Brix (Measured):	35.75°
Fluid Freeze Point (Stated):	not provided
Aerodynamic LOUT (AMIL)	-24.5°C
WSET (from AMIL):	86 minutes

Viscosity:	**Stated**	**Measured**
Manufacturer Method[1]	1,900 cP	1,900 cP
AS9968 Method[1]	1,900 cP	1,900 cP
Alternate Method[2]	not provided	816 cP

[1] *Spindle LV1 (with guard leg), 600 mL Griffin, ~575 mL, 20°C, 0.3 rpm, 10 mins*
[2] *Spindle LV0, ULA, 16 mL, 20°C, 0.3 rpm, 10 mins*

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SUMMARY

The primary objective of this project was to measure the endurance time performance of **Deicing Solutions ECO-SHIELD**® over the entire range of conditions encompassed by the Holdover Time (HOT) tables. This report contains the results of these measurements and was completed with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

Tests were carried out according to the protocol provided in Aerospace Recommended Practice (ARP) 5485. The test procedure consisted of pouring fluids onto clean aluminum test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural and simulated precipitation.

Tests were performed at the APS Aviation Inc. (APS) test facility at Montréal-Pierre-Elliott-Trudeau International Airport and the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were derived from the data collected using multi-variable regression analysis. This resulted in the generation of the fluid-specific holdover times shown in the tables on the next page. These holdover times will be published by regulators for use in the winter 2015-16 operating season.

SUMMARY

Deicing Solutions ECO-SHIELD® Type IV Fluid Holdover Times (Transport Canada Format)

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume % /Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:30-2:25	2:00	1:20-2:00	0:45-1:20	0:55-1:35	0:40-0:50	0:15-1:55	
		75/25								
		50/50								
below -3 to -14	below 27 to 7	100/0	1:10-2:30	1:45	0:55-1:45	0:30-0:55	0:45-2:00	0:25-0:40	CAUTION: No holdover time guidelines exist	
		75/25								
below -14 to -24.5	below 7 to -12.1	100/0	0:30-0:55	0:40	0:30-0:40	0:15-0:30				

Deicing Solutions ECO-SHIELD® Type IV Fluid Holdover Times (FAA Format)

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume % /Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:30-2:25	2:25-2:55	1:20-2:25	0:45-1:20	0:55-1:35	0:40-0:50	0:15-1:55	
		75/25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
		50/50	N/A	N/A	N/A	N/A	N/A	N/A		
below -3 to -14	below 27 to 7	100/0	1:10-2:30	1:45-2:05	0:55-1:45	0:30-0:55	0:45-2:00	0:25-0:40	CAUTION: No holdover time guidelines exist	
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -24.5	below 7 to -12.1	100/0	0:30-0:55	0:40-0:50	0:30-0:40	0:15-0:30				

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GLOSSARY

APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LOUT	Lowest Operational Use Temperature
LOWV	Lowest On-Wing Viscosity
LUPR	Lowest Usable Precipitation Rate
LWC	Liquid Water Content
MVD	Median Volume Diameter
MANOBS	Manual of Surface Weather Observations
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

This report has been created with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

Aircraft ground de/anti-icing has been the subject of concentrated industry attention in recent years due to the occurrence of several fatal icing-related aircraft accidents. Notably, attention has been placed on the enhancement of anti-icing fluids in order to provide an extended period of protection against further contamination following initial deicing. This emphasis has led to the development of fluid-specific de/anti-icing fluid holdover time (HOT) tables for Type II and Type IV fluids. These tables, accepted by regulatory authorities, are used by aircraft operators for departure planning in adverse winter conditions. Specifically, they provide the duration of time that qualified fluids provide protection against ice formation under specific weather conditions.

New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid holdover times without compromising the aerodynamic features of the airfoil. The purpose of the endurance time testing program is to measure the endurance times of these new fluids and develop fluid-specific HOT tables that provide guidance for their use.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop HOT values for new fluids. These tests are carried out according to SAE Aerospace Recommended Practice (ARP) ARP5485, which provides the test protocols for measuring endurance times of Type II, III and IV fluids. Along with its counterpart for measuring endurance times of Type I fluids ARP5945, ARP5485 has evolved into a refined procedure for measuring the duration of de/anti-icing fluid protection against ice formation.

The current data analysis protocol for developing HOT values from endurance time data was developed in 1996-97 and uses multi-variable regression to obtain HOT values. HOT values are derived for all cells of the Type II/IV HOT tables using this protocol and are used to create a fluid-specific HOT table for each Type II/IV fluid tested.

This report provides a detailed account of the endurance time testing conducted by APS Aviation Inc. (APS) with **Deicing Solutions ECO-SHIELD®**, a new Type IV fluid. It describes the test methodology used, endurance time data collected, and analysis completed to derive fluid-specific holdover times for the fluid.

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2

2. METHODOLOGY

SAE Aerospace Recommended Practice (ARP) 5485 provides the procedure and requirements for endurance time testing with Type II, III and IV fluids under natural and simulated conditions. This chapter summarizes some of aspects of the test methodology included in ARP5485, and some aspects which are not included in ARP5485. The chapter includes sections for test sites, equipment, procedures, precipitation rates and ambient temperatures used in Type II/IV endurance time testing, and freezing precipitation droplet sizes. The final subsection describes the analysis methodology used to evaluate Type II/IV endurance time data.

2.1 Test Sites

2.1.1 Natural Snow, Natural Frost and Artificial Snow

Natural snow, natural frost and artificial snow testing is typically performed at the APS test site located at the Montréal-Pierre-Elliott-Trudeau International Airport. The test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station, as shown in Figure 2.1 on a plan view of the airport.

The APS test site consists of two trailers and three outdoor locations for test stands. One of the trailers is equipped with a refrigeration unit to enable indoor testing at controlled temperatures; artificial snow testing is conducted inside this trailer. Photos 2.1 and 2.2 show the test site as seen from the test pads and main trailer, respectively.

In winter 2014-15, additional natural snow mobile testing was conducted in Mirabel, Québec and Beaconsfield, Québec.

2.1.2 Freezing Precipitation

Tests under conditions of freezing fog, rain on cold-soaked surface, freezing drizzle, and light freezing rain were conducted indoors at the NRC Climatic Engineering Facility (CEF), where precipitation was artificially produced.

Photo 2.3 provides an outdoor view of the facility giving a general indication of its size (30 m by 5.4 m, height 8 m). The facility was originally designed for the testing of locomotives; Photo 2.4 provides an interior view of the CEF set up for endurance time testing. The lowest temperature achievable in the CEF is -46°C.

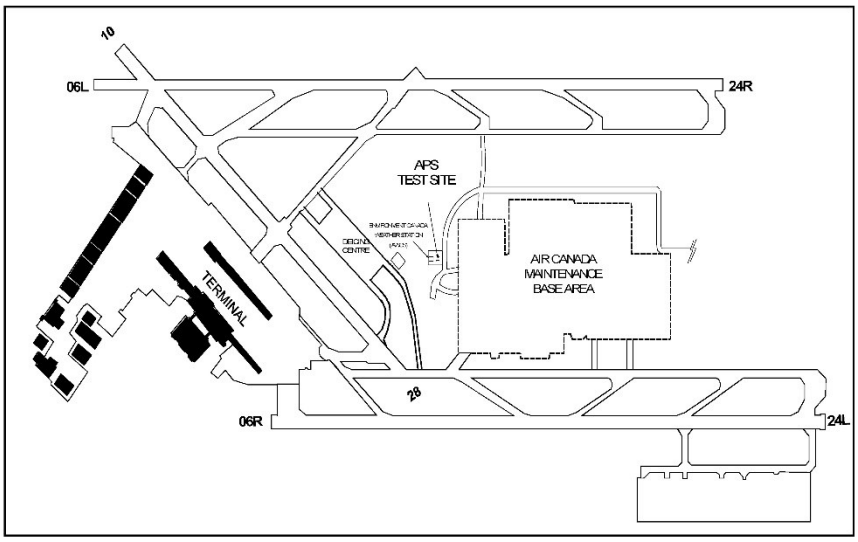


Figure 2.1: APS Test Site at Montréal-Pierre-Elliott-Trudeau International Airport

2.2 Test Equipment

The key equipment used in endurance time testing is described in this section, as are the calibration procedures APS follows for ensuring the accuracy of its test equipment.

2.2.1 Calibration

APS measurement instruments and test equipment are calibrated and/or verified on an annual basis. This calibration is carried out according to a calibration plan based upon approved International Organization for Standardization (ISO) 9001:2000 standards, and developed internally by APS.

2.2.2 Environmental Chamber Equipment

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) was as stipulated in the requirements set out in ARP5485.

2.2.3 Test Surface Structures

The majority of endurance time testing is carried out on standard flat plates. A schematic of a standard flat plate is provided in Figure 2.2. It depicts the size and surface markings of a standard flat plate. Three parallel lines are positioned at 2.5 cm (1"), 15 cm (6") and 30 cm (12") from the top of the plate. The plates are marked with 15 crosshairs, which are used in determining when end conditions (see Subsection 2.3.5) are achieved. Photo 2.5, taken outdoors at the APS test site, shows six test plates mounted on a test stand.

Figure 2.3 shows a schematic of the sealed boxes used for tests simulating a cold soaked wing. The top of the box consists of a flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate. Photo 2.6 shows a picture of a sealed box, which is referred to as a cold-soak box when filled for simulated rain on cold soaked wing tests.

In natural frost, tests are conducted on frosticator plates, which are the current standard test surface used in frost holdover time testing. The frosticator plates were constructed by attaching a Styrofoam insulation backing to the back of the test surface (either aluminum or composite). The insulation prevents heat exchange via the underside of the flat plate and allows for effective radiative cooling during active frost conditions. Photo 2.7 shows a white-painted aluminum frosticator plate.

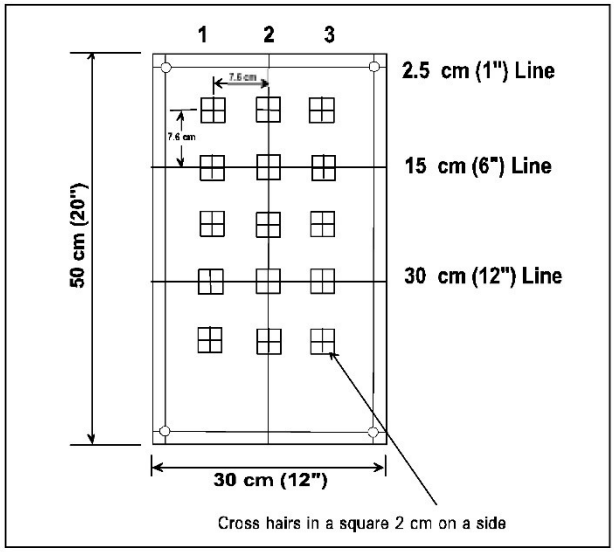


Figure 2.2: Standard Test Plate Schematic

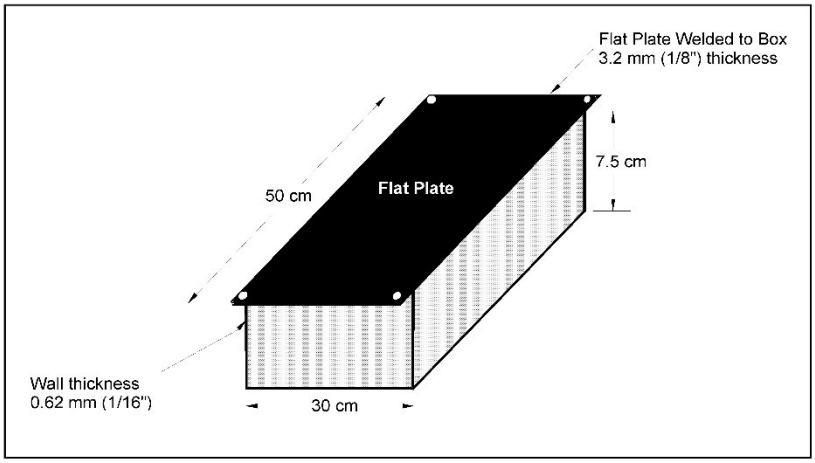


Figure 2.3: Cold Soak Box Schematic

2.2.4 Test Surface Materials

Testing of Type II, III and IV fluids is carried out exclusively on aluminum surfaces. The aluminum used is 0.32 cm thick Alclad 2024 T3 aluminum.

2.2.5 Test Stands

Figure 2.4 shows a schematic of the test platform used for HOT testing. For natural snow tests, six test plates are normally mounted on the test stand, which has a working surface inclined at 10° to the horizontal. During normal winter operations two six-position stands are used in combination. Each plate represents a flat plate test. For simulated freezing precipitation tests at the NRC, 12 plates are mounted on 2 six-position stands. Photos 2.4 and 2.5 show the test stands set up for indoor and outdoor testing, respectively.

2.2.6 Collection Pans

Figure 2.5 shows a schematic of the collection pan used for precipitation rate measurement in outdoor testing. It is the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.8 shows the collection pans used for measuring precipitation rates indoors at the NRC.

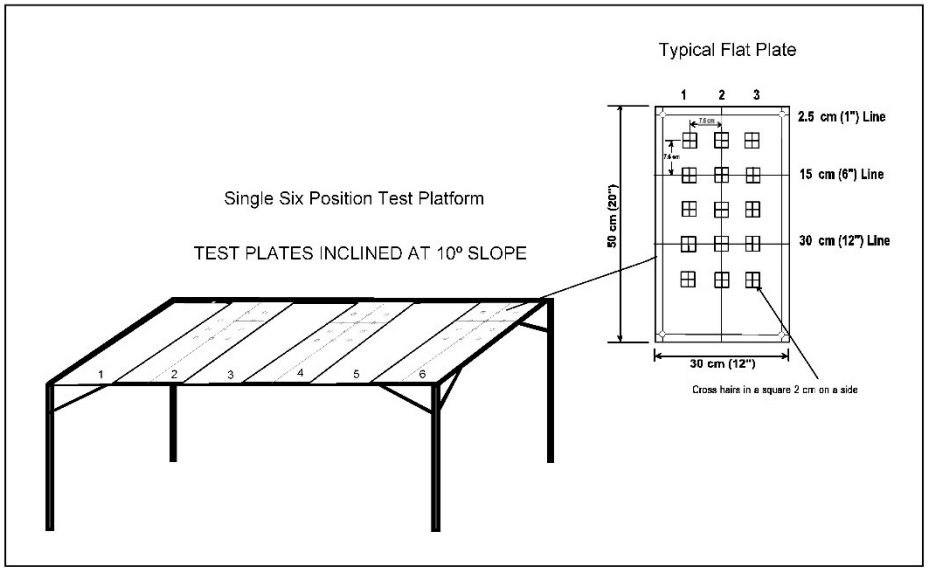


Figure 2.4: Test Stand Setup Schematic

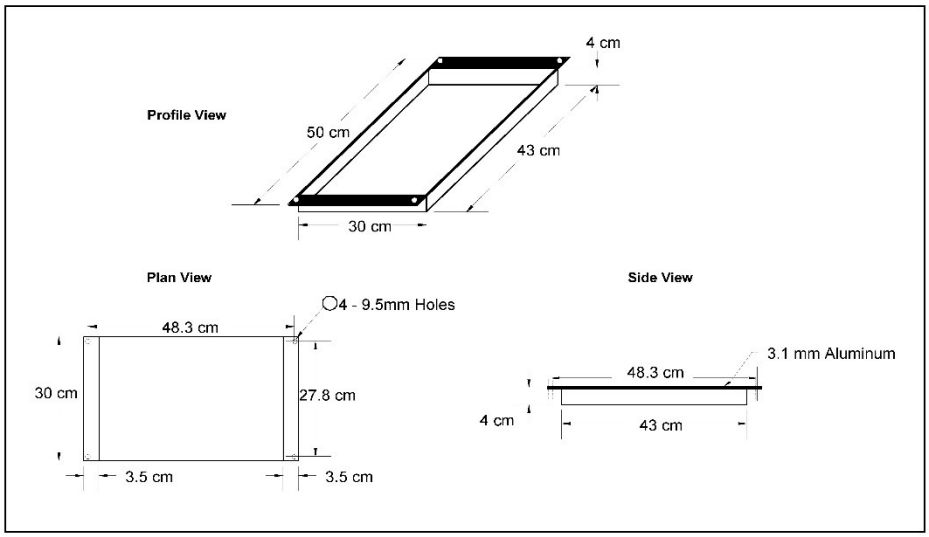


Figure 2.5: Schematic of Outdoor Precipitation Measurement Pan

2.2.7 NRC Sprayer Assembly

NRC developed an improved sprayer assembly, shown in Photos 2.9 and 2.10, in 1997-98. The improved sprayer provides a larger scan area and improved spray uniformity over the test bed area. The scanner consists of a horizontal main shaft supported by two bearings. The actual spray head assembly is shaft-mounted on a rotating scanner, so that one scan covers a lateral running strip of the test bed area. A stepper motor is synchronized to index the relative angle of the spray head between scans along an axis perpendicular to the scan axis. This provides two axes of rotation, essentially an x-y plane; one along each axis. Each scan is consecutively indexed in order to complete the precipitation coverage of the test bed area. This defines one cycle of the spray unit. The scan rate, index angle, and the number of scans per cycle are adjusted, along with the fluid delivery pressures (water and air) to obtain appropriate droplet sizes and precipitation rates. The spray nozzle is shown in Photo 2.11.

2.2.8 Fluids

Testing was carried out with Deicing Solutions ECO-SHIELD®, a Type IV propylene glycol based fluid. Testing was conducted with the neat fluid only; no dilutions were tested.

2.3 Test Procedures

ARP5485 provides the procedure for endurance time testing of Type II, III and IV fluids under natural and simulated precipitation conditions.

The procedure generally consists of pouring de/anti-icing fluids onto clean flat plates exposed to various winter precipitation conditions, and recording the elapsed time for the test to reach the defined end condition (see Subsection 2.3.5), when a specified degree of freezing occurs. The following subsections provide summaries of the test procedures followed for natural snow, natural frost, artificial snow and simulated freezing precipitation testing.

2.3.1 Test Protocol – Natural Snow Tests

APS developed a specific procedure for Type II, III and IV fluid testing in natural snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted are conducted on standard flat plates (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.2 Test Protocol – Natural Frost Tests

APS developed a specific procedure for Type II/III/IV testing in natural frost. Key details of the procedure include:

- Tests are conducted on frosticator plates (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.3 Test Protocol – Artificial Snow Tests

APS developed a specific procedure for testing in artificial snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted on a standard plate (shown mounted on the snowmaker scale in Photo 2.12);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.4 Test Protocol – Simulated Precipitation Tests

APS developed a specific procedure for Type II/III/IV testing in simulated precipitation based on the requirements outlined in ARP5485. Key details of the procedure include:

- Freezing fog, freezing drizzle and light freezing rain tests are conducted on standard flat plates (see Section 2.2.3);
- Rain on cold-soak surface tests are conducted on filled cold-soak boxes (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.5 End Condition Definitions

Failure is called when 30 percent (1/3) of the plate or 5 cross-hairs are covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

a) Ice front;
b) Ice sheet;
c) Slush, in clusters or as a front;
d) Disseminated fine ice crystals;
e) Frost on surface;
f) Clear ice pieces partially or totally imbedded in fluid; and
g) Snow bridges on top of the fluid.

2.3.6 Precipitation Rate Measurement Procedures

The procedures for measuring and determining precipitation rates during simulated precipitation and natural precipitation conditions are provided below.

2.3.6.1 Simulated precipitation conditions

Prior to the start of the rate collection period, the proper needles and nozzles are installed in the spray unit, and both the air and water pressures are adjusted. Water spray calibration is performed by placing catch pans on the test stand, each pan marked with a number identifying the collection location on the test stand, and exposing the pans to a predetermined precipitation collection period.

The pans are weighed prior to exposure to precipitation and the weights are recorded in a customized Excel spreadsheet by using the print function on the digital weigh scale. Prior to the start of the precipitation catch period, the exact time (hh:mm:ss) is recorded using a pre-programmed time macro in the Excel spreadsheet. The pans are re-weighed following this collection period and the precipitation rates over the area of the test stand are examined. If the rates are unacceptable, re-calibration of the water spray is necessary. If the rates are deemed to be acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period has expired, the pans are again re-weighed and the rates computed.

Once two rates have been collected at each test location, the catch rates of the first and second collection are compared. If the average catch rate for any location

is deemed to be acceptable for the test condition, then the pouring of fluids may begin at this location.

Rates are continuously monitored at a minimum of two locations during a test in order to ensure there are no significant rate fluctuations. Pans will be placed at these locations and be re-weighed at fixed intervals (15 minutes, typically) during the course of a test. If a rate fluctuation occurs, the test is stopped.

Following the failure of a test plate, a rate collection pan is weighed and placed at the plate location for a predetermined time interval. It is then re-weighed and placed again on the stand to collect a minimum of two additional rates at this location.

The rate of precipitation for any location on the stand is calculated by averaging the two rates collected prior to the test and the two rates collected following the test.

2.3.6.2 Natural precipitation conditions

Two rate collection pans per test stand are used to determine precipitation rates in natural conditions. Prior to the rate collection period, both pans are marked (upper and lower), and the inner bottom and sides of the each pan are wetted with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The wetted pans are then weighed to the nearest gram. The start time of the rate collection period is recorded (h/min/sec) using a customized Excel spreadsheet in which the weight is also recorded by pressing the print function on the digital weigh scale.

The pans are positioned in locations 6 and 7 (see Figure 2.4) and are allowed to collect precipitation for 10-minute intervals in normal conditions and 5-minute intervals in periods of high precipitation rates and high winds. Prior to removal of the plate pans from the test stand for re-weighing, any accumulated precipitation on the lips and outer sides of each plate pan is carefully removed. The plate pans are then carried to the rate station for re-weighing. Upon entering the trailer, the exact time is noted. The new weights of the plate pans are recorded and the pans are brought back outside. This procedure is continued until the final plate on the test stand has failed.

The rate for any HOT test in natural snow is obtained by computing the time-weighted average of the rates collected in the upper and lower pans over the duration of this particular test. To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.6. Typically, two collections pans are used for each test. The start and end times of the test shown in Figure 2.6 are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t1, t2, and t3 (minutes). The calculated rates for each collection period are indicated by R1, R2, and R3 (g/dm²/h). In order to calculate the average rate for this pan, the following formula is then used:

$$\frac{(R_1 \times t_1 + R_2 \times t_2 + R_3 \times t_3)}{t_1 + t_2 + t_3}$$

In the example shown in Figure 2.6, the rate is calculated as follows:

$$\frac{(25 \times 10 + 22 \times 8 + 34 \times 5)}{10 + 8 + 5}$$

The calculated average rate for this pan is 25.9 g/dm²/h. The average rate for the other collection pan is calculated in similar fashion, and the average of the two rates is then taken.

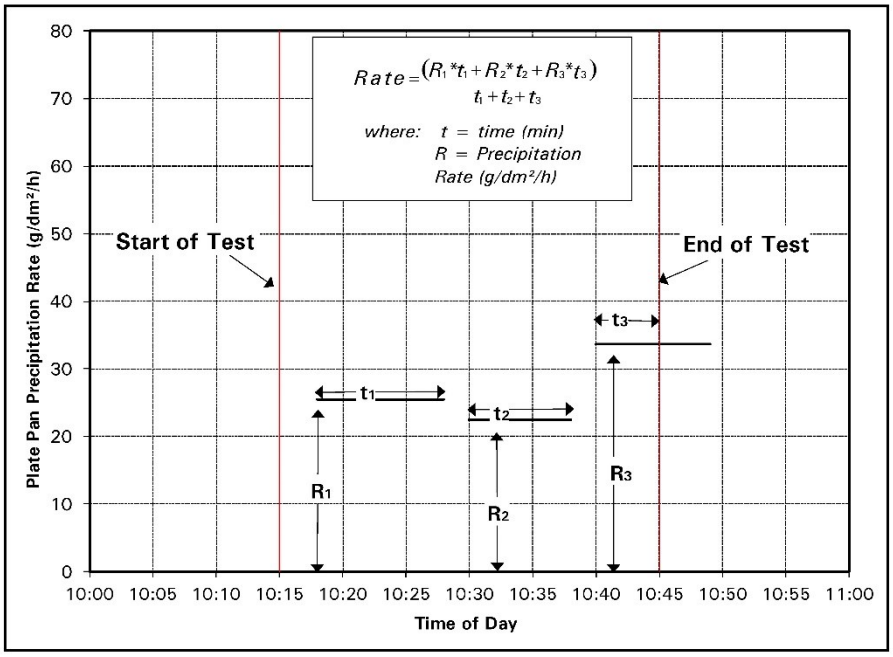


Figure 2.6: Calculation of Outdoor Precipitation Rate

2.4 Precipitation Rate Limits in Type II/IV Endurance Time Testing

Upper and lower precipitation rate limits are an important part of the test methodology for measuring fluid endurance times. Table 2.1 provides the meteorologically accepted definitions of weather phenomenon / precipitation types. It also includes the criteria used to determine precipitation intensity. This table was compiled by the National Centre for Atmospheric Research (NCAR) from the *World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation* (1983) and from the *American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS)* (3/94).

The precipitation rate limits established for Type II/IV endurance time testing are provided in ARP5485 and represented graphically in Figure 2.7. Subsections 2.4.1 to 2.4.5 provide detailed definitions and explanations of the precipitation types and rate boundaries used in Type II/IV endurance time testing. It should be noted that in many cases these limits are not the same as the meteorologically accepted definitions provided in Table 2.1.

Table 2.1: Definition of Weather Phenomenon

Weather Phenomenon*	Definition*
FROST (No METAR code) Note: No Intensity is assigned to FROST.	Ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.
FREEZING FOG (FZFG) Note: No Intensity is assigned to FRZ FOG	A suspension of numerous minute water droplets which freezes upon impact with ground or other exposed objects, generally reducing the horizontal
SNOW (SN)	Precipitation of ice crystals, most of which are branched, star-shaped, or mixed with unbranched crystals. At temperatures higher than about -5°C
FRZING DRIZZLE (FZDZ)	Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0.02 in.)] very close together which freezes upon impact with
FREEZING RAIN (FZRA)	Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5
RAIN (RA)	Precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 in.) diameter or of smaller widely scattered drops.
SNOW PELLETS (GS) and/or SMALL HAIL	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is
HAIL (GR)	Precipitation of small balls or pieces of ice with a diame-
ICE PELLETS (PE)	Precipitation of transparent (sleet or grains of ice), or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 in.)

Intensity Criteria**

	Snow(SN),Pellets(GS),Grains(SG)		Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (SN) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm/hr or 10 gr/dm²/hr)	Scattered pellets on the ground. Visibility not affected.
Moderate	If visibility is: < 5/8 to 5/16 mi (< 1.0 to 0.5 km)	> 0.05 to 0.10 in/hr (> 1.0 to 2.5 mm/hr) (> 10.0 to 25.0 gr/dm²/hr)	Slow accumulation on the ground. Visibility reduced to less than 7 mi.
Heavy (+)	If visibility is: < 5/16 mi (< 0.5 km)	More than 0.10 in/hr (> 2.5 mm/hr or 25 gr/dm²/hr)	Rapid accumulation on the ground. Visibility reduced to less than 3 mi.

Note: Horizontal visibility is only an estimation of snow and freezing drizzle intensity. Measurements and observations have

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm/hr or 2.54 gr/dm²/hr)
Moderate	From 0.01 to 0.02 in/hr (2.54 to 5.08 gr/dm²/hr)
Heavy(+)	More than 0.02 in/hr (> 5.08 gr/dm²/hr) Note: Drizzle > 0.04 in/hr is usually in the form of rain.

	Rain (RA), Freezing Rain (FZRA), Ice Pellets (PE)
Measured Intensity	Up to 0.10 in/hr (2.5 mm/hr or 25 gr/dm²/hr) Maximum 0.01 inch in 6 minutes
Light (-) Estimated Intensity	From scattered drops that, regardless of duration, do not completely wet an
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.01 to 0.03 inch in 6 minutes
Moderate Estimated Intensity	Individual drops are not clearly identifiable; spray is observable just above
Measured Intensity	More than 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.03 inch in 6 minutes
Heavy (+) Estimated Intensity	Rain seemingly falls in sheets; individual drops are not identifiable; heavy

* From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
** From American Meteorological Society, Glossary of Meteorology WSOH #7 MANOBS (3/94)
*** NCAR/FAE Proposed Definition for Liquid Equivalent Snowfall Intensity

1) gr/dm² = 0.01 cm = 0.1 mm = 0.0039 in
2) in = 2.54 cm = 25.4 mm = 254 gr/dm²

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP Sept 8, 1999 (Updated for METAR codes)

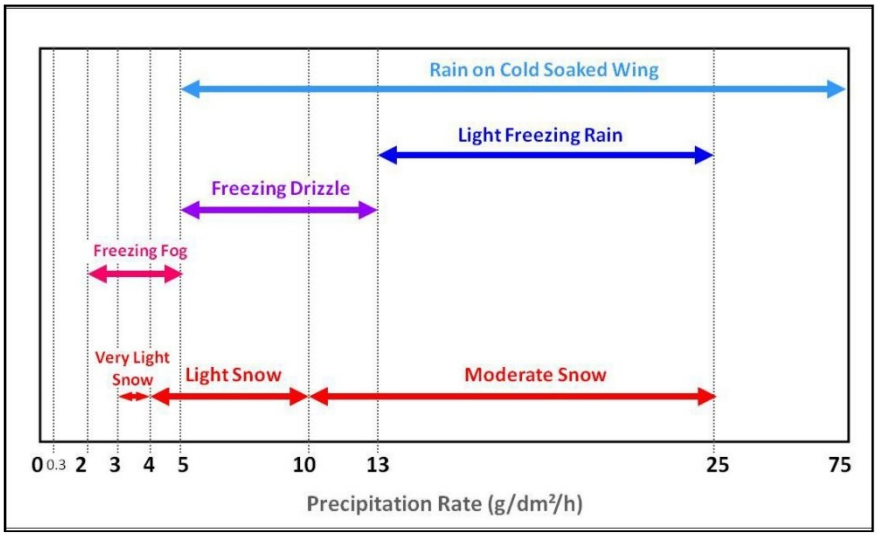


Figure 2.7: Precipitation Rate Limits Used in Endurance Time Testing

2.4.1 Freezing Fog

The precipitation rate limits for endurance time testing in freezing fog were set in 1997 at rates of 2 and 5 g/dm^2/h. These limits were determined with input from NRC meteorologists, who helped define an important parameter in the study of fog referred to as the *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic meter of air, can generally assume values in the range of 0.2 to 0.6 g/m^3.

2.4.2 Freezing Drizzle

The precipitation rate limits for endurance time testing in freezing drizzle are 5 and 13 g/dm^2/h. The upper limit in this range was adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Committee. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety.

2.4.3 Light Freezing Rain

The precipitation rate limits for endurance time testing in light freezing rain are 13 and 25 g/dm^2/h. This range corresponds to the category of light freezing rain and is the only freezing rain category considered, as operations in periods of moderate or heavy freezing rain are deemed unsafe.

2.4.4 Rain on a Cold-Soaked Surface

The precipitation rate limits for rain on cold soaked surface are 5 and 75 g/dm^2/h. This range encompasses drizzle (5 to 13 g/dm^2/h), light rain (13 to 25 g/dm^2/h), and moderate rain (25 to 75 g/dm^2/h).

2.4.5 Snow

The precipitation rate limits used to determine holdover times for Type II/IV fluids in snow are 3, 4, 10 and 25 g/dm^2/h. These rate limits encompass very light, light and moderate snow.

2.5 Ambient Temperatures in Type II/IV Endurance Time Testing

The Type II/IV holdover time tables provide holdover times for three temperature ranges:

- -3°C and above;
- Below -3 to -10°C (freezing drizzle, light freezing rain, cold soak wing) or Below -3 to -14°C (freezing fog, snow); and
- Below -14°C to LOUT

In natural snow testing, endurance time testing is carried out under a range of temperatures. In simulated freezing precipitation and artificial snow testing, endurance time testing is typically conducted at the lower limit of each temperature band.

- Freezing Fog: -3°C, -14°C and -25°C
- Freezing Drizzle: -3°C and -10°C
- Light Freezing Rain: -3°C and -10°C
- Rain on Cold Soaked Surface: +1°C
- Artificial Snow: -3, -14 and/or -25°C

2.6 Freezing Precipitation Droplet Sizes

Research has shown that median volume diameter (MVD) of rain droplets is related to rate of precipitation as follows:

- MVD = (precipitation rate/10) $^{0.23}$, where MVD is in mm and rate of precipitation is in g/dm²/h

The theoretical MVDs for rain at various rates of precipitation were determined based on this equation. These values are listed in Table 2.2 beside the experimental MVDs for each precipitation condition.

Table 2.2: Theoretical and Experimental MVDs

Precipitation Condition	Experimental MVD (mm)	Theoretical MVD (mm)
Moderate Rain (High rate: 75 g/dm²/h)	1.4	1.6
Light Rain (Low rate: 13 g/dm²/h)	1.0	< 1.1
Light Rain (High rate: 25 g/dm²/h)	1.0	1.2
Drizzle (Low rate: 5 g/dm²/h)	0.25	< 0.5
Drizzle (High rate: 13 g/dm²/h)	0.35	< 0.5
Fog		< 0.1

To determine whether droplets produced at the NRC resembled droplets from natural precipitation, a test was conducted during natural light freezing rain conditions in 1997-98 at the APS test site. The droplet sizes were compared to those obtained in simulated light freezing rain at the NRC. The results of these tests are shown below.

a) *For the outdoor test:*

Location:	Montreal P.E.T. Airport
Precipitation:	Natural Light Freezing Rain
Precipitation Rate:	20 g/dm²/h
Calibrated MVD:	1.0 mm

b) *For the indoor test:*

Location:	National Research Council
Precipitation:	Simulated Light Freezing Rain
Precipitation Rate:	25 g/dm²/h
Calibrated MVD:	1.0 mm

The MVD for both natural and simulated light freezing rain was 1 mm, indicating that the NRC produced droplets simulate natural precipitation.
As a result of this testing, the MVDs for freezing precipitation testing were established as follows:

- Freezing Fog, high precipitation rate (5 g/dm²/h): 30 μm
- Freezing Fog, low precipitation rate (2 g/dm²/h): 30 μm
- Freezing Drizzle, high precipitation rate (13 g/dm²/h): 350 μm
- Freezing Drizzle, low precipitation rate (5 g/dm²/h): 250 μm
- Light Freezing Rain, high precipitation rate (25 g/dm²/h): 1,000 μm
- Light Freezing Rain, low precipitation rate (13 g/dm²/h): 1,000 μm
- Rain on Cold-Soaked Surface, low precipitation rate (5 g/dm²/h): 250 μm
- Rain on Cold-Soaked Surface, high precipitation rate (75 g/dm²/h): 1,400 μm

2.7 Summary of Freezing Precipitation Test Conditions

The precipitation types/rates, ambient temperatures and droplet sizes for freezing precipitation testing with Type II/IV fluids were described in the previous subsections. In summary, freezing precipitation tests are carried out under each of the 16 weather conditions listed in Table 2.3.

Table 2.3: Summary of Freezing Precipitation Test Conditions (Type II/IV Fluids)

Precipitation Type	Ambient Temperature	Precipitation Rate (Droplet Size)
Freezing Fog	-3°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-14°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-25°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
Freezing Drizzle	-3°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
	-10°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
Light Freezing Rain	-3°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
	-10°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
Rain on Cold-Soaked Surface	+1°C	5 g/dm²/h (250 μm)
		75 g/dm²/h (1,400 μm)

2.8 Analysis Methodology

A multi-variable regression procedure is used to derive fluid-specific holdover times for Type II/IV fluids. The procedure is based on the refinement of an equation for a curve which best represents the test data, and then solving that equation at the upper and lower limits established for the precipitation type. These precipitation rate limits, set by the SAE G-12 HOT Committee and detailed in ARP5485, were described in Subsection 0. This approach was developed in the winter of 1996-97 (see TC report, TP 13131E) and has since been used to derive fluid holdover times. There are some differences in the way the methodology is applied to freezing precipitation and natural snow data.

2.8.1 Freezing Precipitation Data

For each related freezing precipitation HOT table cell, four tests are conducted at the most restrictive (lowest) temperature in the temperature range for that cell: two tests at the low precipitation rate limit and two tests at the high precipitation rate limit (limits are detailed in Subsection 0). The equation used to treat freezing precipitation data is:

- $t = 10^{I}R^{a}$, where

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.2 Natural Snow Data

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural snow tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather data under all temperatures and precipitation rates encompassed by the HOT tables.

The general form of the regression equation is modified for natural snow to incorporate the variable of temperature and also to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C. The equation used to treat natural snow data is:

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

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a, b = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, using the most restrictive (lowest) temperature for that cell. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.3 Natural Frost Data

Regression analysis is not used in the determination of frost holdover times. The current Type II/III/IV generic frost holdover times were determined based on several years of testing using all fluids which were commercially available at the time. A "minimum values" analysis methodology was used to determine appropriate holdover times from the test data.

The purpose of natural frost testing with new fluids is to verify the fluids can be used with the generic frost holdover times. The analysis methodology is to compare the frost test data collected with the new fluid to the current generic holdover times. If the test data provides holdover times equal to or greater than the generic holdover times then the generic holdover times have been validated for the new fluid.

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural frost tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather several data points with each fluid/dilution.

2.8.4 Rounding and Capping Protocols

Regression-generated holdover times are subject to rounding and capping protocols. For Type II/IV fluids they are as follows:

- Rounding Protocol: Holdover times are rounded to the nearest whole "5" minute, i.e. 55.1 to 57.4 minutes is rounded down to 55 minutes; 57.5 to 59.9 minutes is rounded up to 60 minutes. In cases where the regression-generated holdover times are below 10 minutes, the numbers are rounded down to the nearest whole minute as a precautionary measure. For example, 9.6 minutes is rounded down to 9 minutes.

- Capping Protocol: All holdover time values are capped at maximum values. The caps differ by precipitation type, and in the case of snow, by regulator. The caps are as follows:
  - Freezing Fog holdover time values are capped at 4 hours;
  - Freezing Drizzle, Light Freezing Rain, Rain on Cold Soaked Wing holdover times are capped at 2 hours; and
  - Snow holdover times are capped at 2 hours by Transport Canada and 3 hours by FAA.

2.8.5 Regression Example

Sample plots of **Log t** versus **Log R** are shown in Figure 2.8. The plots contain data for one Neat Type IV fluid, in one temperature range (-10°C), in light freezing rain conditions. The best-fit regression line is superimposed onto the plot and was obtained from the analysis using the lowest temperature in the temperature range from which the data were chosen.

The same data plotted on a linear scale (failure time **t** versus precipitation rate **R**) are shown in Figure 2.9. The curve, generated from the power law form of the equation using the coefficients determined from the fit, is superimposed onto the plot. The HOT range is determined from the intersections of the curve with the precipitation rate limits defined for light freezing rain.

The holdover times for this fluid at -10°C are 20 minutes at 13 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid in the light freezing rain, neat fluid, below -3 to -10°C cell. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

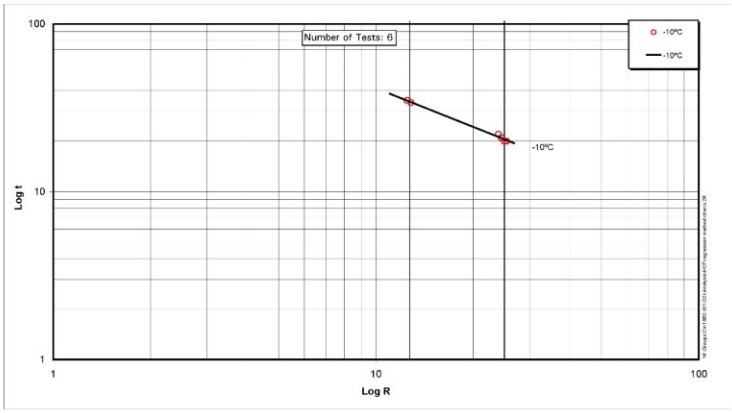


Figure 2.8: Regression Method on Log-Log Chart – Type IV Neat, Freezing Rain

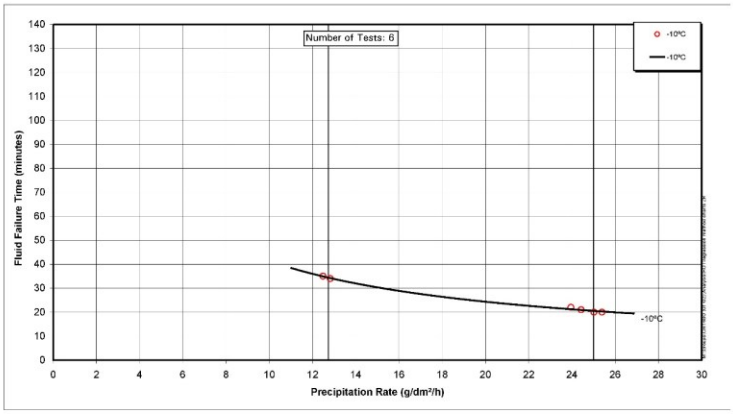


Figure 2.9: Regression Method on Standard Chart – Type IV Neat, Freezing Rain

2.8.6 Lowest Usable Precipitation Rates in Snow

A detailed analysis methodology was developed to determine if a snow data set is sufficient to determine holdover times for light and very light snow. Specifically, the analysis determines the lowest usable precipitation rate (LUPR), which is the lowest rate at which the data set is considered robust.

The methodology is a five-factor weighted analysis. The five factors are:

1. Total number of data points;
2. Number of data points with air temperatures below -3°C;
3. Number of data points with precipitation rates below 10 g/dm²/h;
4. Number of data points with precipitation rates less than or equal to 0.5 g/dm²/h above the precipitation rate being examined; and
5. Scatter from regression curve of low precipitation rate data points (average absolute percent difference between fail time and regression calculated fail time for all points less than or equal to 10 g/dm²/h).

The weights given to each of the five factors are:

1. Total Data Points = 5%;
2. Data Points Below -3°C = 20%;
3. Data Points Below 10 g/dm²/h = 20%;
4. Data Points ≤ Precipitation Rate = 40%; and
5. Low Rate Data Scatter = 15%.

Each data set is given a score of 0, 10, 20, 30 or 40 for each factor. The scoring system is shown in Table 2.4.

This approach provides a score for each data set for each precipitation rate below 10 g/dm²/h. The scores are compared to the minimum acceptance scores:

- 100/0 = 28
- 75/25 = 28
- 50/50 = 19 (lower due to a 0 score for data points below -3°C)

The LUPR is the lowest precipitation rate at which a data set has a passing score.

Table 2.4: LUPR Factor Scoring System

Factor #1: Total Data Points (Weight = 5%)	
Rating = 40	≥20 data points in data set
Rating = 30	15-19 data points in data set
Rating = 20	10-14 data points in data set
Rating = 10	5-9 data points in data set
Rating = 0	<5 data points in data set

Factor #2: Data Points Below -3°C (Weight = 20%)	
Rating = 40	≥15 data points from -3 to -14°C
Rating = 30	12-14 data points -3 to -14°C
Rating = 20	9-11 data points -3 to -14°C
Rating = 10	6-8 data points -3 to -14°C
Rating = 0	<6 data points -3 to -14°C

Factor #3: Data Points Below 10 g/dm²/h (Weight = 20%)	
Rating = 40	≥10 data points <10 g/dm²/h
Rating = 30	7-9 data points <10 g/dm²/h
Rating = 20	5-6 data points <10 g/dm²/h
Rating = 10	3-4 data points <10 g/dm²/h
Rating = 0	<3 data points <10 g/dm²/h

Factor #4: Data Points ≤ Precipitation Rate (Weight = 40%)	
Rating = 40	≥3 data points ≤ rate limit +0.5
Rating = 30	2 data points ≤ rate limit +0.5
Rating = 20	1 data points ≤ rate limit +0.5
Rating = 10	n/a
Rating = 0	0 data points ≤ rate limit +0.5

Factor #5: Low Rate Data Scatter (Weight = 15%)	
Rating = 40	Average actual-calculated error <10%
Rating = 30	Average actual-calculated error 10-19%
Rating = 20	Average actual-calculated error 20-29%
Rating = 10	Average actual-calculated error 30-39%
Rating = 0	Average actual-calculated error ≥40%

Photo 2.1: APS Test Site - View from Test Pad



Photo 2.2: APS Test Site - View from Trailer



Photo 2.3: Outdoor View of NRC Climatic Engineering Facility



Photo 2.4: Inside View of NRC Climatic Engineering Facility

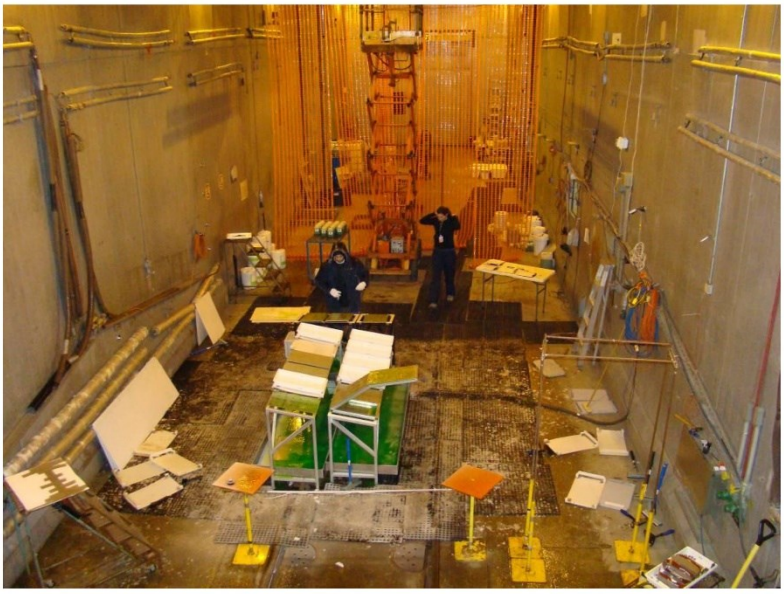


Photo 2.5: Test Plates Mounted on Stand

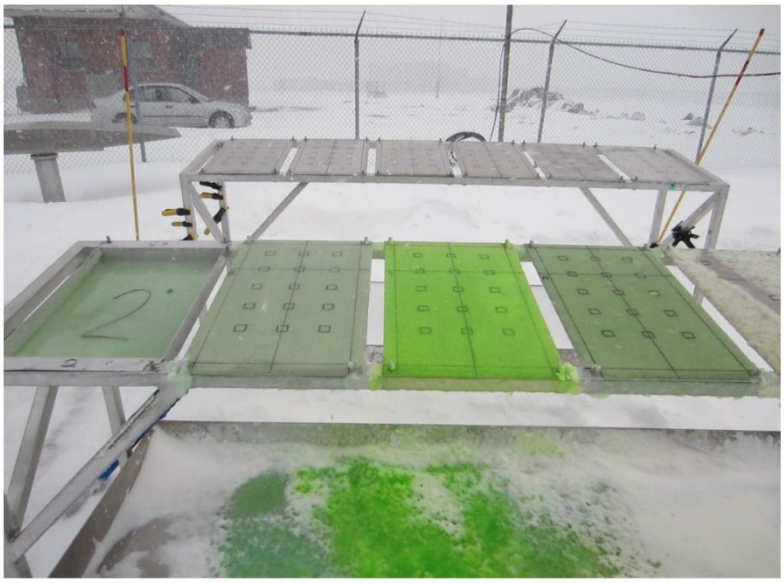


Photo 2.6: Cold-Soak / Leading Edge Thermal Equivalent Box

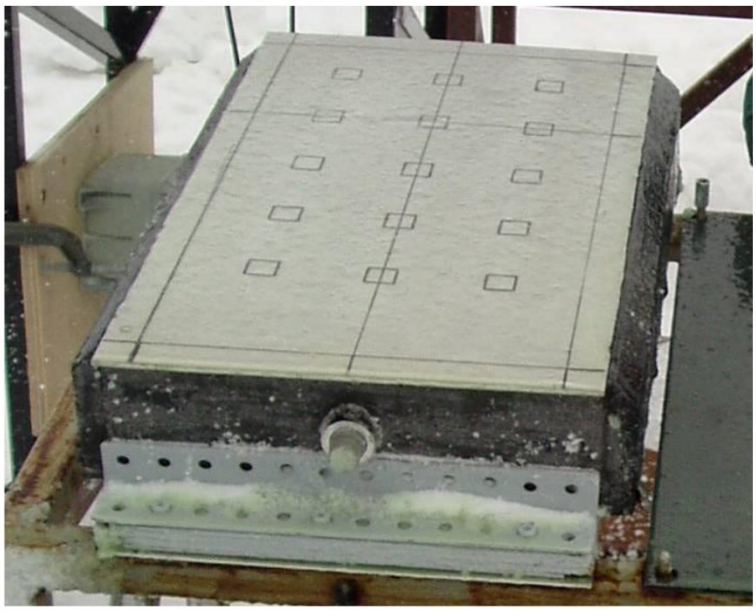


Photo 2.7: Frost Plate with Insulated Backing



Photo 2.8: Collection Pans Used Indoors at the NRC



Photo 2.9: Sprayer Assembly



Photo 2.10: Sprayer Assembly in Use

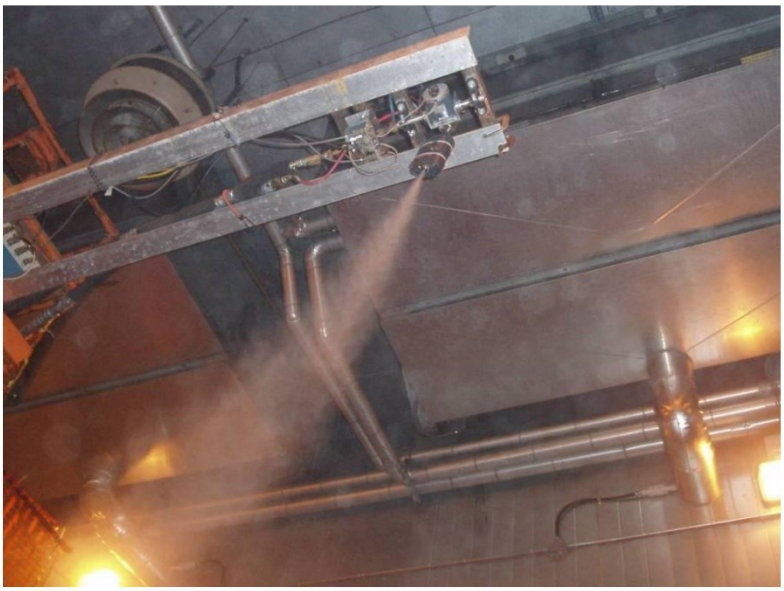


Photo 2.11: Sprayer Nozzle

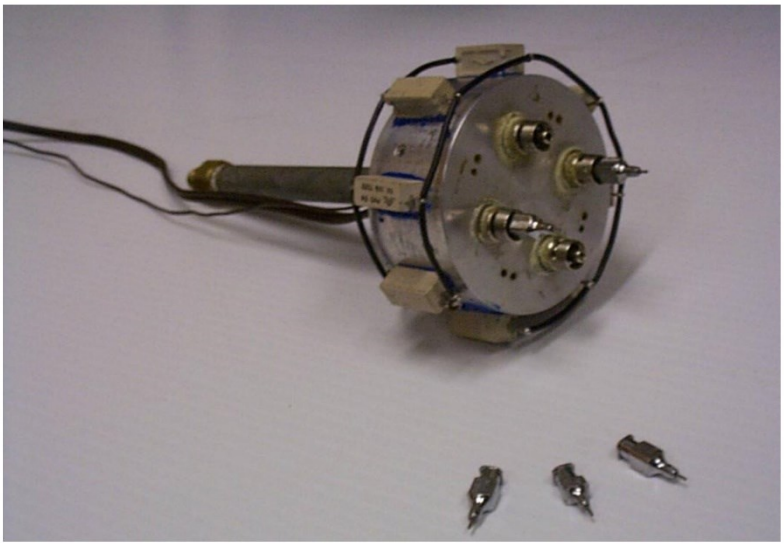
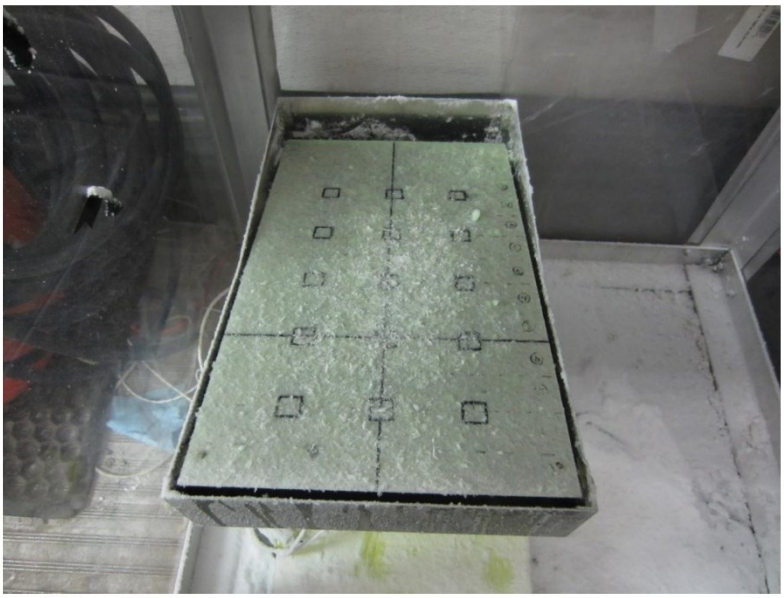


Photo 2.12: Standard Plate Setup for Testing with Artificial Snowmaker



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted. Breakdowns are provided for the number of tests performed by test type, precipitation type, fluid dilution and test temperature.

3.1 Natural and Artificial Snow Tests

Tests were conducted in natural snow conditions at the APS test site and at several mobile test sites (see Subsection 2.1.1). No artificial snow tests were conducted. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

Fluid Dilution	Natural Snow			Artificial Snow		
	≥ -3°C	-3 to -14°C	<-14°C	-3°C	-14°C	-25°C
Neat	7	18	5	0	0	0
75/25	0	0	0	0	0	0
50/50	0	0	0	0	0	0

3.2 Freezing Precipitation Tests

Tests were conducted in freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface conditions at the NRC CEF. The number of tests conducted is summarized below by precipitation type, fluid dilution and test temperature.

Fluid Dilution	Freezing Drizzle		Light Freezing Rain		Freezing Fog			Cold Soak
	-3°C	-10°C	-3°C	-10°C	-3°C	-14°C	-25°C	+1°C
Neat	4	4	4	4	4	4	4	4
75/25	0	0	0	0	0	0	0	0
50/50	0	0	0	0	0	0	0	0

3.3 Natural Frost Tests

Tests were conducted in natural frost at the APS test site. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

Fluid Dilution	Natural Frost			
	≥-1°C	<-1 to -3°C	<-3 to -10°C	<-10°C
Neat	0	0	1	2
75/25	0	0	0	0
50/50	0	0	0	0

3.4 Fluid Thickness Tests

Fluid thickness tests were conducted to measure the film thickness profiles of the fluid under dry conditions. Two tests were performed for each dilution. For each test, 1 litre of fluid was poured onto a flat plate mounted on a test stand inclined by 10°. Thickness measurements were taken at the 15-cm (6″) line at select time intervals over a 30-minute period. Tests were conducted at -3°C.

3.5 Test Logs

Details of each test conducted are provided in the test logs included as Table 3.1 (snow) Table 3.2 (freezing precipitation), and Table 3.3 (frost).

Table 3.1: Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
153	29-Jan-15	Natural Snow	ECO-SHIELD®	100%	-5.7	23.6	32.0
168	29-Jan-15	Natural Snow	ECO-SHIELD®	100%	-2.2	3.6	191.9
178	29-Jan-15	Natural Snow	ECO-SHIELD®	100%	-2.3	1.9	267.4
185	2-Feb-15	Natural Snow	ECO-SHIELD®	100%	-22.2	8.4	41.0
196	2-Feb-15	Natural Snow	ECO-SHIELD®	100%	-19.2	8.1	60.5
200	4-Feb-15	Natural Snow	ECO-SHIELD®	100%	-5.9	2.3	167.3
203	4-Feb-15	Natural Snow	ECO-SHIELD®	100%	-5.1	2.2	163.7
212	4-Feb-15	Natural Snow	ECO-SHIELD®	100%	-4.6	2.6	156.0
213	4-Feb-15	Natural Snow	ECO-SHIELD®	100%	-4.4	4.7	124.7
222	4-Feb-15	Natural Snow	ECO-SHIELD®	100%	-5.6	4.5	148.8
227	4-Feb-15	Natural Snow	ECO-SHIELD®	100%	-7.4	3.5	187.8
229	8-Feb-15	Natural Snow	ECO-SHIELD®	100%	-17.6	8.9	63.8
232	8-Feb-15	Natural Snow	ECO-SHIELD®	100%	-16.7	8.1	71.4
234	11-Feb-15	Natural Snow	ECO-SHIELD®	100%	-12.4	5.8	92.2
239	11-Feb-15	Natural Snow	ECO-SHIELD®	100%	-12.4	6.1	96.4
240	11-Feb-15	Natural Snow	ECO-SHIELD®	100%	-12.4	3.7	158.1
243	12-Feb-15	Natural Snow	ECO-SHIELD®	100%	-12.5	3.5	144.6
247	14-Feb-15	Natural Snow	ECO-SHIELD®	100%	-16.0	0.8	274.8
250	19-Feb-15	Natural Snow	ECO-SHIELD®	100%	-9.1	1.7	148.7
261	21-Feb-15	Natural Snow	ECO-SHIELD®	100%	-8.0	7.3	70.6
267	3-Mar-15	Natural Snow	ECO-SHIELD®	100%	-5.5	16.2	48.3
284	3-Mar-15	Natural Snow	ECO-SHIELD®	100%	-5.8	12.8	58.9
296	3-Mar-15	Natural Snow	ECO-SHIELD®	100%	-5.5	15.4	54.1
314	3-Mar-15	Natural Snow	ECO-SHIELD®	100%	-4.6	4.4	81.7
316	14-Mar-15	Natural Snow	ECO-SHIELD®	100%	-1.7	17.6	65.8
338	14-Mar-15	Natural Snow	ECO-SHIELD®	100%	-2.2	19.5	79.4
357	14-Mar-15	Natural Snow	ECO-SHIELD®	100%	-2.8	15.8	75.0
365	14-Mar-15	Natural Snow	ECO-SHIELD®	100%	-3.0	43.1	32.0
373	14-Mar-15	Natural Snow	ECO-SHIELD®	100%	-3.0	47.3	25.0
417	4-Apr-15	Natural Snow	ECO-SHIELD®	100%	-3.5	10.3	59.0

Table 3.2: Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
3	1-Apr-15	Freezing Fog	ECO-SHIELD®	100	-3.3	2.1	144.0
4	1-Apr-15	Freezing Fog	ECO-SHIELD®	100	-3.3	2.0	142.4
23	31-Mar-15	Freezing Fog	ECO-SHIELD®	100	-3.5	5.2	89.8
24	31-Mar-15	Freezing Fog	ECO-SHIELD®	100	-3.6	5.2	87.7
61	31-Mar-15	Freezing Fog	ECO-SHIELD®	100	-14.1	2.1	140.9
62	31-Mar-15	Freezing Fog	ECO-SHIELD®	100	-14.1	2.2	139.5
79	31-Mar-15	Freezing Fog	ECO-SHIELD®	100	-14.0	5.1	68.5
80	31-Mar-15	Freezing Fog	ECO-SHIELD®	100	-14.0	5.3	69.7
85	30-Mar-15	Freezing Fog	ECO-SHIELD®	100	-25.3	1.9	59.0
86	30-Mar-15	Freezing Fog	ECO-SHIELD®	100	-25.3	2.0	57.0
99	30-Mar-15	Freezing Fog	ECO-SHIELD®	100	-25.0	5.4	29.5
100	30-Mar-15	Freezing Fog	ECO-SHIELD®	100	-25.0	5.4	31.9
117	25-Mar-15	Freezing Drizzle	ECO-SHIELD®	100	-3.1	4.7	103.2
118	25-Mar-15	Freezing Drizzle	ECO-SHIELD®	100	-3.1	4.6	93.1
137	25-Mar-15	Freezing Drizzle	ECO-SHIELD®	100	-3.1	12.5	54.9
138	25-Mar-15	Freezing Drizzle	ECO-SHIELD®	100	-3.1	13.3	50.7
163	27-Mar-15	Freezing Drizzle	ECO-SHIELD®	100	-10.2	5.0	130.0
164	27-Mar-15	Freezing Drizzle	ECO-SHIELD®	100	-10.2	5.0	121.7
181	26-Mar-15	Freezing Drizzle	ECO-SHIELD®	100	-10.0	13.1	45.0
182	26-Mar-15	Freezing Drizzle	ECO-SHIELD®	100	-10.1	12.8	44.2
197	27-Mar-15	Light Freezing Rain	ECO-SHIELD®	100	-2.9	12.8	51.7
198	27-Mar-15	Light Freezing Rain	ECO-SHIELD®	100	-2.9	12.5	50.0
213R	27-Mar-15	Light Freezing Rain	ECO-SHIELD®	100	-2.7	24.5	41.4
214R	27-Mar-15	Light Freezing Rain	ECO-SHIELD®	100	-2.7	24.7	40.5
235	26-Mar-15	Light Freezing Rain	ECO-SHIELD®	100	-10.3	13.2	41.7
236	26-Mar-15	Light Freezing Rain	ECO-SHIELD®	100	-10.4	13.0	40.8
255	26-Mar-15	Light Freezing Rain	ECO-SHIELD®	100	-10.0	24.3	26.5
256	26-Mar-15	Light Freezing Rain	ECO-SHIELD®	100	-10.0	24.4	27.7
269	1-Apr-15	Cold Soak Box	ECO-SHIELD®	100	1.0	5.3	109.2
270	1-Apr-15	Cold Soak Box	ECO-SHIELD®	100	1.0	5.1	110.9
285	1-Apr-15	Cold Soak Box	ECO-SHIELD®	100	0.8	76.5	13.4
286	1-Apr-15	Cold Soak Box	ECO-SHIELD®	100	0.8	73.7	13.2

Table 3.3: Summary of Tests Performed (Natural Frost)

Test No.	Date	Precip. Type	Fluid Name	Fluid Dilution	Test Duration (min.)	Average Rate (g/dm²/h)	Temp (°C)	Wind Speed (km/h)	Average RH (%)	Comments
47	18-Feb-15	Natural Frost	ECO-SHIELD®	100%	369	0.060	-17.7	5.6	68.9	Did Not Fail
55	15-Mar-15	Natural Frost	ECO-SHIELD®	100%	662	0.080	-8.0	3.5	89.0	Did Not Fail
63	23-Mar-15	Natural Frost	ECO-SHIELD®	100%	460	0.010	-11.3	8.3	66.6	Did Not Fail

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4. RESULTS AND DISCUSSION

The methods used to evaluate the test data were reviewed in Subsection 2.8. The results of the data analyses and a discussion of the findings are presented in this section.

4.1 Results

The results of the endurance time and thickness tests are described in this section.

4.1.1 Endurance Time Tests – Natural Snow and Freezing Precipitation

Figures 4.1 to 4.5 present the endurance time data collected in natural snow and freezing precipitation (freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface).

These figures show the effect of temperature, precipitation type and precipitation rate on fluid endurance time in the conditions encompassed by the Type IV HOT guidelines. The figures include the current Type IV generic holdover times for comparative purposes.

Multi-variable regression analysis was performed on these data sets as described in Subsection 2.8. Table 4.1 provides the outputs from the multi-variable regression analyses. These outputs were used to derive fluid-specific holdover times for all conditions encompassed by Type IV fluid-specific HOT tables. One exception is the coldest temperature band snow cells (see Subsection 4.2.24.2.2).

4.1.2 Endurance Time Tests – Natural Frost

The natural frost data was presented in Table 3.3. The test durations were compared to the Type IV generic holdover times. Tests that were not completed (due to active frost ending before fluid failure could occur) surpassed the generic holdover times. This analysis indicates the Type IV generic frost holdover times can be considered substantiated for Deicing Solutions Eco-Shield®.

4.1.3 Fluid Thickness Tests

Figure 4.6 shows the fluid thickness test data. As described in Subsection 3.4, two tests were conducted at an ambient temperature of -3°C. The final fluid thickness after 30 minutes was 1.3 mm.

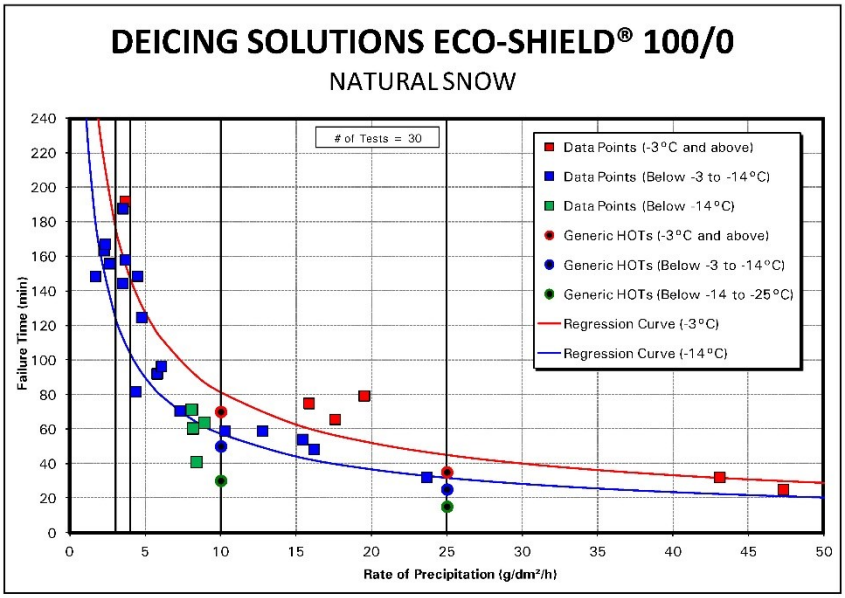


Figure 4.1: Type IV Neat – Natural Snow

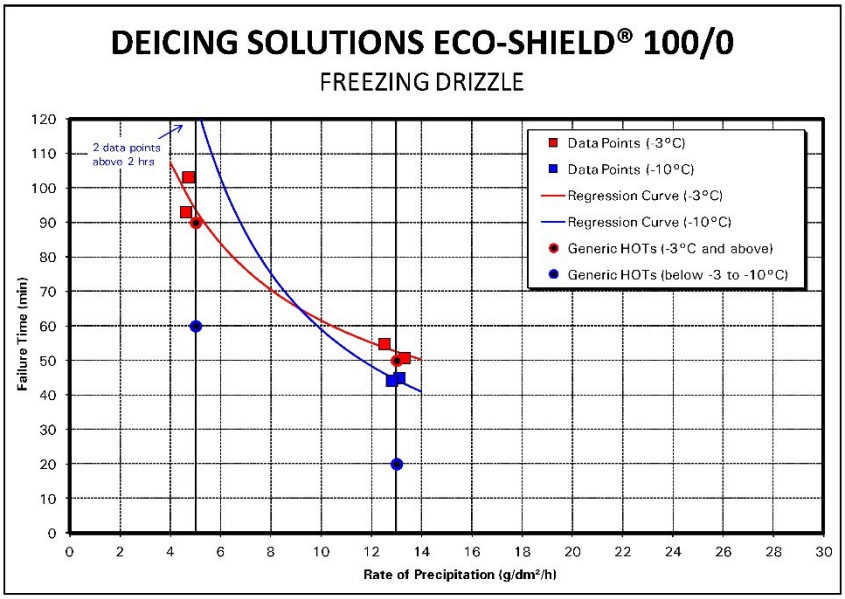


Figure 4.2: Type IV Neat – Freezing Drizzle

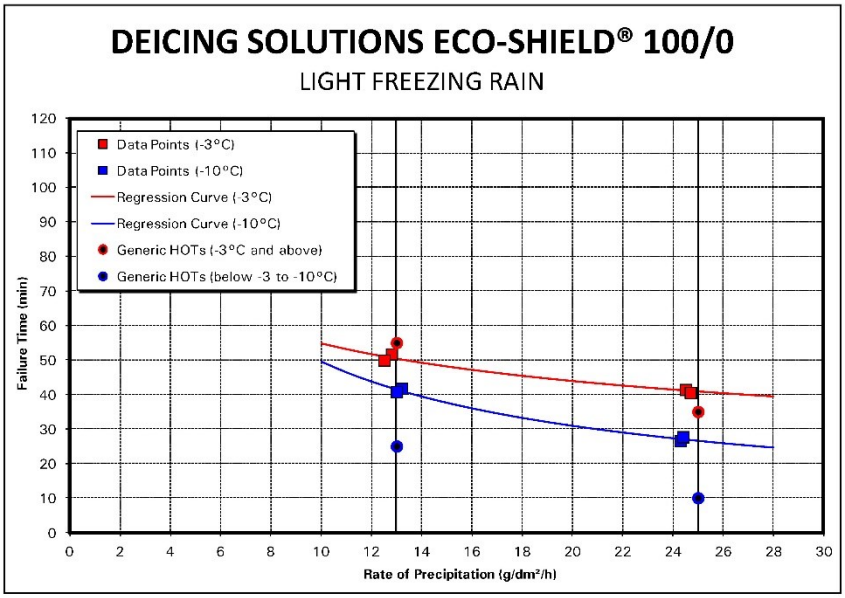


Figure 4.3: Type IV Neat – Light Freezing Rain

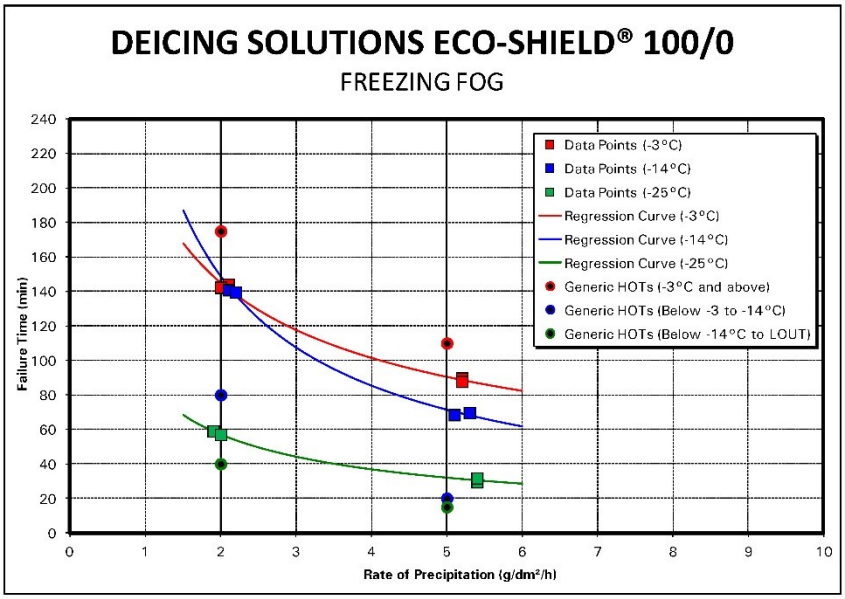


Figure 4.4: Type IV Neat – Freezing Fog

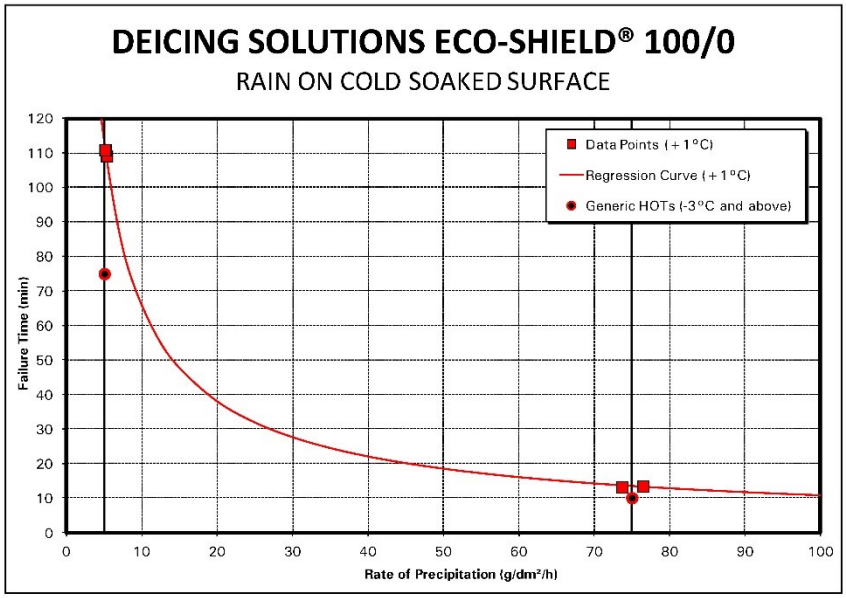


Figure 4.5: Type IV Neat – Rain on Cold-Soaked Surface

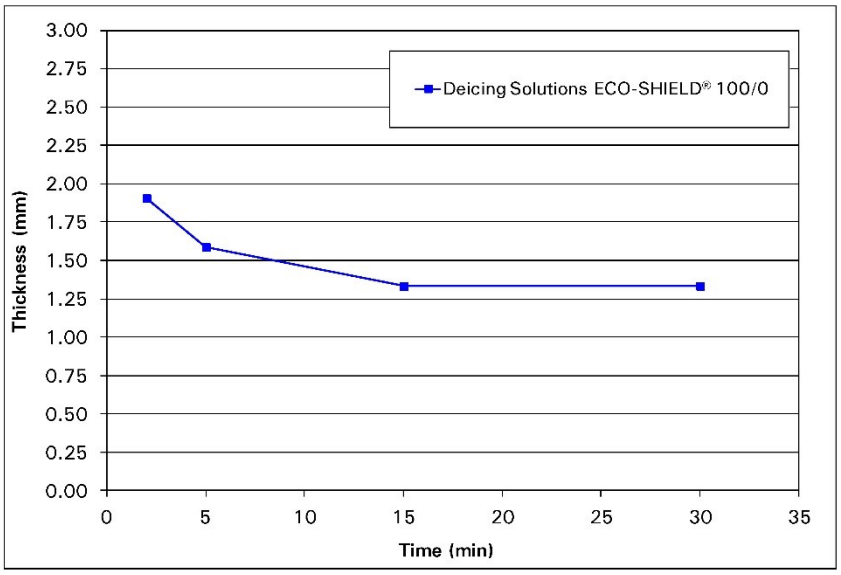


Figure 4.6: Fluid Thickness Profile of Deicing Solutions ECO-SHIELD®

Table 4.1: Regression Equation Coefficients for Deicing Solutions ECO-SHIELD®

Natural Snow

Fluid	Dil	R^2	Intercept (I)	Coeff. Rate (A)	Coeff. Tem (B)	Total Pts.
Deicing Solutions ECO-SHIELD®	Neat	89%	2.7690	-0.6488	-0.3016	30
Deicing Solutions ECO-SHIELD®	75%	N/A	N/A	N/A	N/A	N/A
Deicing Solutions ECO-SHIELD®	50%	N/A	N/A	N/A	N/A	N/A

General Equation $t = 10^{I} R^{A} (2\text{-}T)^{B}$

Simulated Freezing Fog

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Deicing Solutions ECO-SHIELD®	Neat	-3°C	100%	2.3155	-0.5128	4
Deicing Solutions ECO-SHIELD®	75/25	-3°C	N/A	N/A	N/A	N/A
Deicing Solutions ECO-SHIELD®	50/50	-3°C	N/A	N/A	N/A	N/A
Deicing Solutions ECO-SHIELD®	Neat	-14°C	100%	2.4123	-0.8001	4
Deicing Solutions ECO-SHIELD®	75/25	-14°C	N/A	N/A	N/A	N/A
Deicing Solutions ECO-SHIELD®	Neat	-25°C	99%	1.9446	-0.6255	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Deicing Solutions ECO-SHIELD®	Neat	-3°C	98%	2.3968	-0.6075	4
Deicing Solutions ECO-SHIELD®	75/25	-3°C	N/A	N/A	N/A	N/A
Deicing Solutions ECO-SHIELD®	50/50	-3°C	N/A	N/A	N/A	N/A
Deicing Solutions ECO-SHIELD®	Neat	-10°C	100%	2.8606	-1.0888	4
Deicing Solutions ECO-SHIELD®	75/25	-10°C	N/A	N/A	N/A	N/A

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Deicing Solutions ECO-SHIELD®	Neat	-3°C	98%	2.0619	-0.3231	4
Deicing Solutions ECO-SHIELD®	75/25	-3°C	N/A	N/A	N/A	N/A
Deicing Solutions ECO-SHIELD®	50/50	-3°C	N/A	N/A	N/A	N/A
Deicing Solutions ECO-SHIELD®	Neat	-10°C	99%	2.3709	-0.6766	4
Deicing Solutions ECO-SHIELD®	75/25	-10°C	N/A	N/A	N/A	N/A

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Deicing Solutions ECO-SHIELD®	Neat	+1°C	100%	2.6079	-0.7913	4
Deicing Solutions ECO-SHIELD®	75/25	+1°C	N/A	N/A	N/A	N/A

General Equation $t = 10^{I} R^{A}$

4.2 Discussion

4.2.1 Holdover Time Table

The holdover times described in Subsection 4.1 were used to populate a fluid-specific HOT table for Deicing Solutions ECO-SHIELD®. The HOT table is shown in both the TC format (Table 4.2) and FAA format (Table 4.3) at the end of this chapter.

4.2.2 Holdover Times in Snow, Below -14°C to LOUT

Very little endurance time data has been collected in natural snow at temperatures below -14°C. In the winter of 2003-04, testing was conducted with artificial snowmakers to collect additional data below -14°C. As a result of this testing, it was decided all Type II/IV fluids would be given generic values in the "Below -14 to LOUT" snow cells. Accordingly, Deicing Solutions ECO-SHIELD® has been given generic values in the "Below -14°C to LOUT" snow cells.

4.2.3 Holdover Times in Frost

It should be noted that frost holdover times are not included in the fluid-specific HOT tables. This is due to a decision made by TC and the FAA in May 2009 to move frost holdover times from the generic and fluid-specific HOT tables to a separate frost HOT table. Accordingly, frost holdover times have not been included in the Deicing Solutions ECO-SHIELD® fluid-specific HOT table.

4.2.4 Fluid Viscosity

The viscosities of the fluid samples used in this testing were measured using both the AS9968 method and the manufacturer's designated method. The APS measured viscosities appear at the beginning of this document and will be published as the lowest on-wing viscosity (LOWV) values for the fluid. In order for the fluid-specific holdover times provided in this document to be valid, operators must ensure that the viscosity of the fluid being used is equal or greater than the published LOWV.

4.2.5 Lowest Operational Use Temperatures (LOUTs)

The LOUT for Type II/III/IV fluids is determined by the higher of:

- The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
- The actual freezing point of the fluid plus its freezing point buffer of 7°C (13°F).

This aerodynamic LOUT and fluid freeze point information for this fluid appears at the beginning of this document. The LOUT for this fluid is -24.5°C.

4.2.6 Lowest Usable Precipitation Rates in Snow

The LUPR for Deicing Solutions ECO-SHIELD® was determined by analysing the natural snow data set using the analysis methodology described in Subsection 2.8.6. The resulting statistics are shown in Table 4.4. The analysis determined the LUPR for Deicing Solutions ECO-SHIELD® is 2 g/dm²/h.

4.2.7 Publication of Holdover Times

As Deicing Solutions intends to commercialize ECO-SHIELD®, TC and FAA will publish its fluid-specific HOT table in their 2015-16 Holdover Time Guidelines. The guidelines will also include the LOWV and LOUT information; the LUPR data will be published in the related TC and FAA Regression Information documents.

Table 4.2: Fluid Specific Holdover Time Guidelines – Deicing Solutions ECO-SHIELD® (Transport Canada Format)

TABLE 4-DS-ES

TYPE IV FLUID HOLDOVER TIME GUIDELINES[1]
DEICING SOLUTIONS ECO-SHIELD®

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

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:30 – 2:25	2:00	1:20 – 2:00	0:45 – 1:20	0:55 – 1:35	0:40 – 0:50	0:15 – 1:55	
		75/25								
		50/50							CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:10 – 2:30	1:45	0:55 – 1:45	0:30 – 0:55	0:45 – 2:00[8]	0:25 – 0:40[8]		
		75/25								
below -14 to -24.5	below 7 to -12.1	100/0	0:30 – 0:55	0:40	0:30 – 0:40	0:15 – 0:30				

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

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

Table 4.3: Fluid Specific Holdover Time Guidelines – Deicing Solutions ECO-SHIELD® (FAA Format)

TABLE 4H. TYPE IV HOLDOVER TIME GUIDELINES FOR DEICING SOLUTIONS ECO-SHIELD®

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:30-2:25	2:25-2:55	1:20-2:25	0:45-1:20	0:55-1:35	0:40-0:50	0:15-1:55	
		75/25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
		50/50	N/A	N/A	N/A	N/A	N/A	N/A	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:10-2:30	1:45-2:05	0:55-1:45	0:30-0:55	0:45-2:00[7]	0:25-0:40[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -24.5	below 7 to -12.1	100/0	0:30-0:55	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4.4: LUPR Statistics – Deicing Solutions ECO-SHIELD®

Data Measure	100/0		75/25		50/50	
	Stat	Rating	Stat	Rating	Stat	Rating
Total Data Points	30	40	N/A	N/A	N/A	N/A
Data Points -3 to -14°C	23	40	N/A	N/A	N/A	N/A
Data Points < 10.0	20	40	N/A	N/A	N/A	N/A
Data Points < = 9.5	20	40	N/A	N/A	N/A	N/A
Data Points < = 8.5	19	40	N/A	N/A	N/A	N/A
Data Points < = 7.5	16	40	N/A	N/A	N/A	N/A
Data Points < = 6.5	15	40	N/A	N/A	N/A	N/A
Data Points < = 5.5	13	40	N/A	N/A	N/A	N/A
Data Points < = 4.5	12	40	N/A	N/A	N/A	N/A
Data Points < = 3.5	8	40	N/A	N/A	N/A	N/A
Data Points < = 2.5	5	40	N/A	N/A	N/A	N/A
Scatter 0-10 g	17%	30	N/A	N/A	N/A	N/A

Rate	100/0		75/25		50/50	
	Score	Pass/Fail	Score	Pass/Fail	Score	Pass/Fail
9 g/dm²/h	39	pass	N/A	N/A	N/A	N/A
8 g/dm²/h	39	pass	N/A	N/A	N/A	N/A
7 g/dm²/h	39	pass	N/A	N/A	N/A	N/A
6 g/dm²/h	39	pass	N/A	N/A	N/A	N/A
5 g/dm²/h	39	pass	N/A	N/A	N/A	N/A
4 g/dm²/h	39	pass	N/A	N/A	N/A	N/A
3 g/dm²/h	39	pass	N/A	N/A	N/A	N/A
2 g/dm²/h	39	pass	N/A	N/A	N/A	N/A

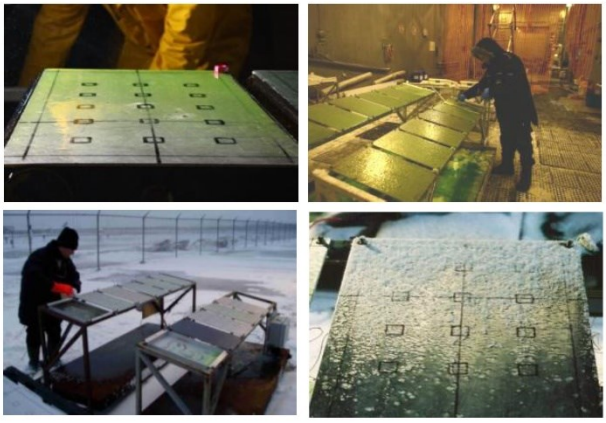
LUPR	100/0	75/25	50/50
	2 g/dm²/h	N/A	N/A

APPENDIX I

FLUID MANUFACTURER REPORT:
LNT SOLUTIONS E450 (TYPE IV)

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

LNT Solutions E450 (Type IV)



Prepared for

LNT Solutions

by

APS Aviation Inc.

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 2.0
Report No. L-450 2014-15

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

LNT Solutions E450 (Type IV)

Prepared for

LNT Solutions

Prepared by:



Stephanie Bendickson
Project Analyst

June 26, 2015
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Program Manager

June 26, 2015
Date

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

June 2015
Version 2.0
Report No. L-450 2014-15

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer:	LNT Solutions		
Fluid Test Name:	Type IV / E450		
Fluid Commercial Name:	E450		
Fluid Type / Base / Colour:	Type IV / Ethylene Glycol / Green		
Batch #:	F4003 / 003/14		
Date of Receipt:	April 10, 2014		
Brix (Measured):	Neat fluid:	33.5°	
	75/25 dilution:	26.0°	
	50/50 dilution:	17.75°	
Freeze Point (Stated):	Neat fluid:	-36°C	
	75/25 dilution:	not provided	
	50/50 dilution:	not provided	
Aerodynamic LOUT (Stated):	Neat fluid:	-26.5°C	
	75/25 dilution:	not provided	
	50/50 dilution:	not provided	
Viscosity:	**Mfr Method**	**Stated**	**Measured**
	Neat fluid:	47,000 cP[1]	45,300 cP[1]
	75/25 dilution:	not provided	16,000 cP[1]
	50/50 dilution:	not provided	2,600 cP[1]
	AIR 9968 Method	**Stated**	**Measured**
	Neat fluid:	13,200 cP[2]	Not available[4]
	75/25 dilution:	4,850 cP[3]	Not available[4]
	50/50 dilution:	1,580 cP[3]	Not available[4]
WSET (from AMIL):	Neat fluid:	85 minutes	

[1] Spindle SC4-31/13R, small sample adapter, 9 mL of fluid, 0°C, 0.3 rpm, for 10.0 minutes
[2] Spindle LV2-disc with guard leg, 600 mL low form beaker, ~425 mL of fluid, 20°C, 0.3 rpm, for 10.0 minutes
[3] Spindle LV1 with guard leg, 600 mL low form beaker, ~575 mL of fluid, 20°C, 0.3 rpm, for 10.0 minutes
[4] Stable, reliable results could not be measured using the AIR 9968 method

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SUMMARY

The primary objective of this project was to measure the endurance time performance of **LNT Solutions E450** over the entire range of conditions encompassed by the Holdover Time (HOT) tables. This objective was met by conducting endurance time tests over the winters of 2013-14 and 2014-15.

This report contains the results of this testing and was completed with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA). Version 1.0 of this report contained only the results of the 2013-14 testing. This report, Version 2.0, contains the results of the 2013-14 and 2014-15 testing.

Tests were carried out according to the protocol provided in Aerospace Recommended Practice (ARP) 5485. The test procedure consisted of pouring fluids onto clean aluminum test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural and simulated precipitation.

Tests were performed at the APS Aviation Inc. (APS) test facility at Montréal-Pierre-Elliott-Trudeau International Airport and the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were derived from the data collected using multi-variable regression analysis. This resulted in the generation of fluid-specific holdover times. At the request of the manufacturer, only the 100/0 holdover times will be published by regulators; holdover times for 75/25 and 50/50 fluids will not be published. The 100/0 holdover times are shown in the tables on the next page.

Due to the late submission of the fluid in winter 2013-14, insufficient data was collected to determine fluid-specific snow holdover times for winter 2014-15. Supplemental testing with an artificial snowmaker enabled the snow cells to be populated with generic holdover times for winter 2014-15. Additional natural snow data collected in the winter of 2014-15 enabled fluid-specific snow holdover times to be generated for winter 2015-16.

LNT Solutions E450 Type IV Fluid Holdover Times (Transport Canada Format)

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:50 – 2:55	2:00	1:35 – 2:00	1:00 – 1:35	1:35 – 2:00	0:55 – 1:20	0:25 – 2:00	
		75/25								
		50/50								
below -3 to -14	below 27 to 7	100/0	1:30 – 3:55	1:50	1:10 – 1:50	0:45 – 1:10	1:45 – 2:00	1:05 – 1:40		
		75/25								
below -14 to -26.5	below 7 to -15.7	100/0	0:35 – 1:05	0:40	0:30 – 0:40	0:15 – 0:30				

LNT Solutions E450 Type IV Fluid Holdover Times (FAA Format)

Outside Air Temperature		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	1:50 – 2:55	2:25 – 2:45	1:35 – 2:25	1:00 – 1:35	1:35 – 2:00	0:55 – 1:20	0:25 – 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 -14	below 27 to 7	100/0	1:30 – 3:55	1:50 – 2:05	1:10 – 1:50	0:45 – 1:10	1:45 – 2:00	1:05 – 1:40		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -26.5	below 7 to -15.7	100/0	0:35 – 1:05	0:40 – 0:50	0:30 – 0:40	0:15 – 0:30				

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GLOSSARY

APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LOUT	Lowest Operational Use Temperature
LOWV	Lowest On-Wing Viscosity
LUPR	Lowest Usable Precipitation Rate
LWC	Liquid Water Content
MVD	Median Volume Diameter
MANOBS	Manual of Surface Weather Observations
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

This report has been created with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

Aircraft ground de/anti-icing has been the subject of concentrated industry attention in recent years due to the occurrence of several fatal icing-related aircraft accidents. Notably, attention has been placed on the enhancement of anti-icing fluids in order to provide an extended period of protection against further contamination following initial deicing. This emphasis has led to the development of fluid-specific de/anti-icing fluid holdover time (HOT) tables for Type II and Type IV fluids. These tables, accepted by regulatory authorities, are used by aircraft operators for departure planning in adverse winter conditions. Specifically, they provide the duration of time that qualified fluids provide protection against ice formation under specific weather conditions.

New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid holdover times without compromising the aerodynamic features of the airfoil. The purpose of the endurance time testing program is to measure the endurance times of these new fluids and develop fluid-specific HOT tables that provide guidance for their use.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop HOT values for new fluids. These tests are carried out according to SAE Aerospace Recommended Practice (ARP) ARP5485, which provides the test protocols for measuring endurance times of Type II, III and IV fluids. Along with its counterpart for measuring endurance times of Type I fluids ARP5945, ARP5485 has evolved into a refined procedure for measuring the duration of de/anti-icing fluid protection against ice formation.

The current data analysis protocol for developing HOT values from endurance time data was developed in 1996-97 and uses multi-variable regression to obtain HOT values. HOT values are derived for all cells of the Type II/IV HOT tables using this protocol and are used to create a fluid-specific HOT table for each Type II/IV fluid tested.

This report provides a detailed account of the endurance time testing conducted by APS Aviation Inc. (APS) with **LNT Solutions E450**, a new Type IV fluid. It describes the test methodology used, endurance time data collected, and analysis completed to derive fluid-specific holdover times for the fluid.

Version 1.0 of this report documented the testing completed in the winter of 2013-14 and the HOT table published for the winter of 2014-15. Version 2.0 of

this report includes the additional natural snow and natural frost testing conducted in the winter of 2014-15 and the resulting updated snow holdover times. These holdover times are expected to be published by regulators for use in the winter 2015-16 operating season.

2. METHODOLOGY

SAE Aerospace Recommended Practice (ARP) 5485 provides the procedure and requirements for endurance time testing with Type II, III and IV fluids under natural and simulated conditions. This chapter summarizes some of aspects of the test methodology included in ARP5485, and some aspects which are not included in ARP5485. The chapter includes sections for test sites, equipment, procedures, precipitation rates and ambient temperatures used in Type II/IV endurance time testing, and freezing precipitation droplet sizes. The final subsection describes the analysis methodology used to evaluate Type II/IV endurance time data.

2.1 Test Sites

2.1.1 Natural Snow, Natural Frost and Artificial Snow

Natural snow, natural frost and artificial snow testing is typically performed at the APS test site located at the Montréal-Pierre-Elliott-Trudeau International Airport. The test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station, as shown in Figure 2.1 on a plan view of the airport.

The APS test site consists of two trailers and three outdoor locations for test stands. One of the trailers is equipped with a refrigeration unit to enable indoor testing at controlled temperatures; artificial snow testing is conducted inside this trailer. Photos 2.1 and 2.2 show the test site as seen from the test pads and main trailer, respectively.

In winter 2013-14, additional natural snow testing was conducted in Timmins, Ontario and Kuujjuak, Quebec.

2.1.2 Freezing Precipitation

Tests under conditions of freezing fog, rain on cold-soaked surface, freezing drizzle, and light freezing rain were conducted indoors at the NRC Climatic Engineering Facility (CEF), where precipitation was artificially produced.

Photo 2.3 provides an outdoor view of the facility giving a general indication of its size (30 m by 5.4 m, height 8 m). The facility was originally designed for the testing of locomotives; Photo 2.4 provides an interior view of the CEF set up for endurance time testing. The lowest temperature achievable in the CEF is -46°C.

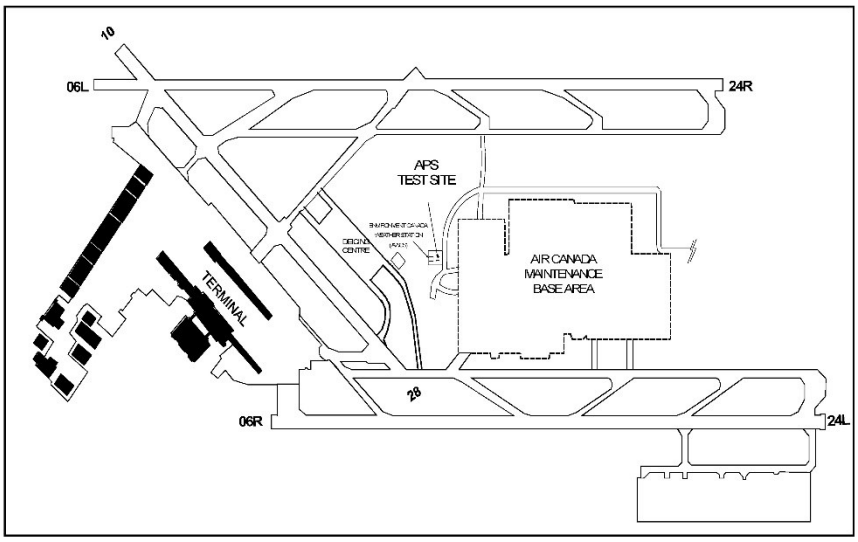


Figure 2.1: APS Test Site at Montréal-Pierre-Elliott-Trudeau International Airport

2.2 Test Equipment

The key equipment used in endurance time testing is described in this section, as are the calibration procedures APS follows for ensuring the accuracy of its test equipment.

2.2.1 Calibration

APS measurement instruments and test equipment are calibrated and/or verified on an annual basis. This calibration is carried out according to a calibration plan based upon approved International Organization for Standardization (ISO) 9001:2000 standards, and developed internally by APS.

2.2.2 Environmental Chamber Equipment

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) was as stipulated in the requirements set out in ARP5485.

2.2.3 Test Surface Structures

The majority of endurance time testing is carried out on standard flat plates. A schematic of a standard flat plate is provided in Figure 2.2. It depicts the size and surface markings of a standard flat plate. Three parallel lines are positioned at 2.5 cm (1"), 15 cm (6") and 30 cm (12") from the top of the plate. The plates are marked with 15 crosshairs, which are used in determining when end conditions (see Subsection 2.3.5) are achieved. Photo 2.5, taken outdoors at the APS test site, shows six test plates mounted on a test stand.

Figure 2.3 shows a schematic of the sealed boxes used for tests simulating a cold soaked wing. The top of the box consists of a flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate. Photo 2.6 shows a picture of a sealed box, which is referred to as a cold-soak box when filled for simulated rain on cold soaked wing tests.

In natural frost, tests are conducted on frosticator plates, which are the current standard test surface used in frost holdover time testing. The frosticator plates were constructed by attaching a Styrofoam insulation backing to the back of the test surface (either aluminum or composite). The insulation prevents heat exchange via the underside of the flat plate and allows for effective radiative cooling during active frost conditions. Photo 2.7 shows a white-painted aluminum frosticator plate.

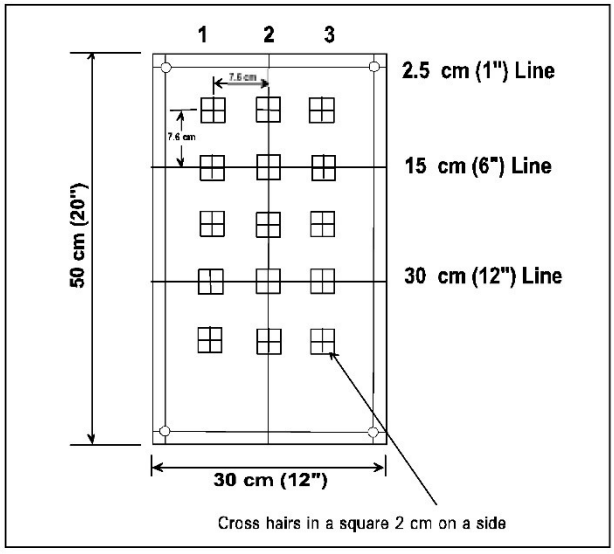


Figure 2.2: Standard Test Plate Schematic

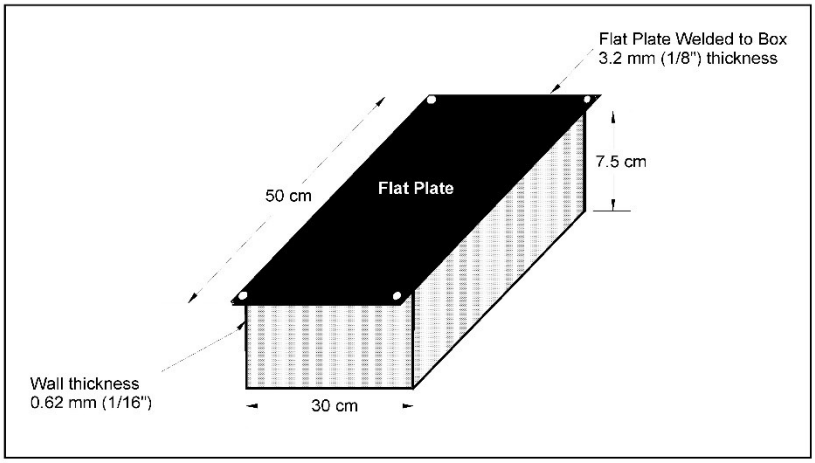


Figure 2.3: Cold Soak Box Schematic

2.2.4 Test Surface Materials

Testing of Type II, III and IV fluids is carried out exclusively on aluminum surfaces. The aluminum used is 0.32 cm thick Alclad 2024 T3 aluminum.

2.2.5 Test Stands

Figure 2.4 shows a schematic of the test platform used for HOT testing. For natural snow tests, six test plates are normally mounted on the test stand, which has a working surface inclined at 10° to the horizontal. During normal winter operations two six-position stands are used in combination. Each plate represents a flat plate test. For simulated freezing precipitation tests at the NRC, 12 plates are mounted on 2 six-position stands. Photos 2.4 and 2.5 show the test stands set up for indoor and outdoor testing, respectively.

2.2.6 Collection Pans

Figure 2.5 shows a schematic of the collection pan used for precipitation rate measurement in outdoor testing. It is the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.8 shows the collection pans used for measuring precipitation rates indoors at the NRC.

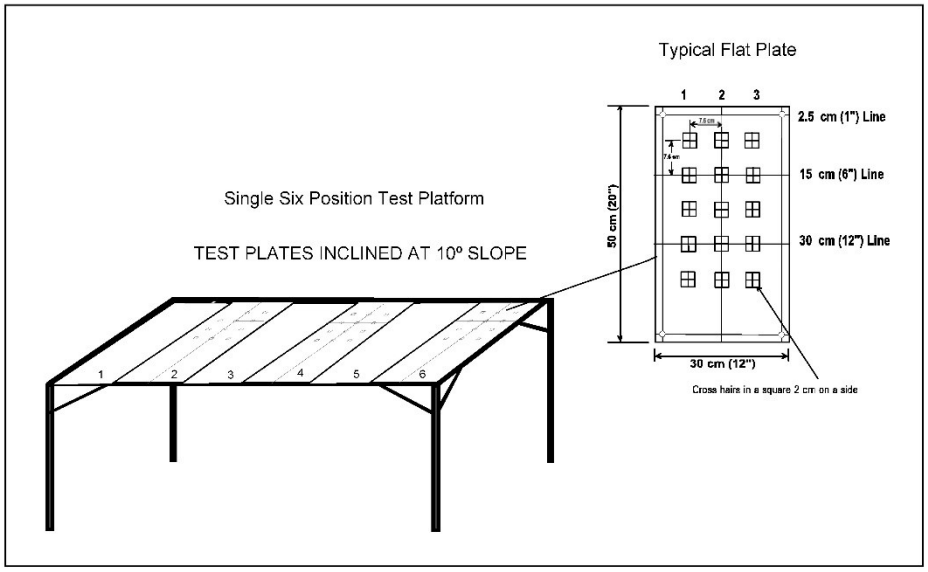


Figure 2.4: Test Stand Setup Schematic

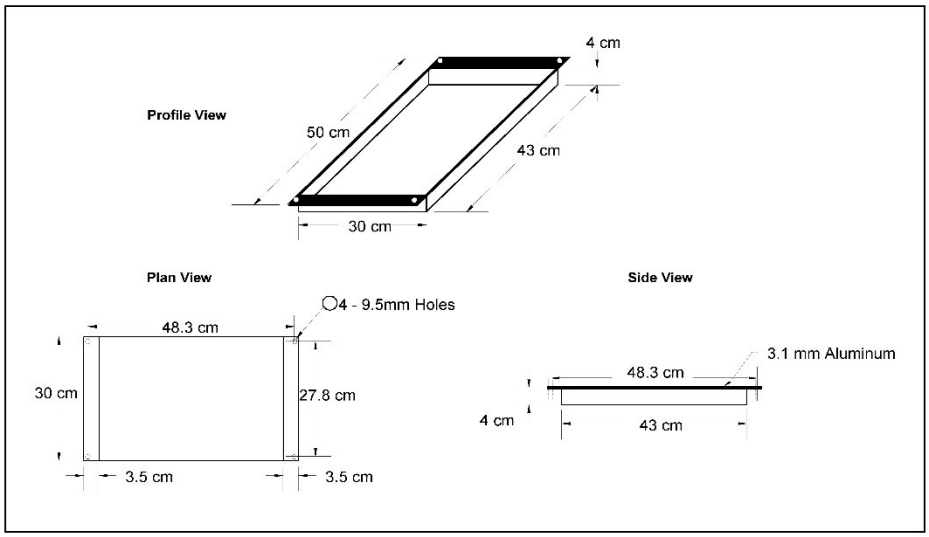


Figure 2.5: Schematic of Outdoor Precipitation Measurement Pan

2.2.7 NRC Sprayer Assembly

NRC developed an improved sprayer assembly, shown in Photos 2.9 and 2.10, in 1997-98. The improved sprayer provides a larger scan area and improved spray uniformity over the test bed area. The scanner consists of a horizontal main shaft supported by two bearings. The actual spray head assembly is shaft-mounted on a rotating scanner, so that one scan covers a lateral running strip of the test bed area. A stepper motor is synchronized to index the relative angle of the spray head between scans along an axis perpendicular to the scan axis. This provides two axes of rotation, essentially an x-y plane; one along each axis. Each scan is consecutively indexed in order to complete the precipitation coverage of the test bed area. This defines one cycle of the spray unit. The scan rate, index angle, and the number of scans per cycle are adjusted, along with the fluid delivery pressures (water and air) to obtain appropriate droplet sizes and precipitation rates. The spray nozzle is shown in Photo 2.11.

2.2.8 Fluids

Testing was carried out with LNT Solutions E450 in the standard Type II, III and IV fluid test dilutions: neat, 75/25 and 50/50. The fluid sample was diluted by the manufacturer.

2.3 Test Procedures

ARP5485 provides the procedure for endurance time testing of Type II, III and IV fluids under natural and simulated precipitation conditions.

The procedure generally consists of pouring de/anti-icing fluids onto clean flat plates exposed to various winter precipitation conditions, and recording the elapsed time for the test to reach the defined end condition (see Subsection 2.3.5), when a specified degree of freezing occurs. The following subsections provide summaries of the test procedures followed for natural snow, natural frost, artificial snow and simulated freezing precipitation testing.

2.3.1 Test Protocol – Natural Snow Tests

APS developed a specific procedure for Type II, III and IV fluid testing in natural snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted are conducted on standard flat plates (see Section 2.2.3);

- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.2 Test Protocol – Natural Frost Tests

APS developed a specific procedure for Type II/III/IV testing in natural frost. Key details of the procedure include:

- Tests are conducted on frosticator plates (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.3 Test Protocol – Artificial Snow Tests

APS developed a specific procedure for testing in artificial snow based on the requirements outlined in ARP5485. Key details of the procedure include:

- Tests are conducted on a standard plate (shown mounted on the snowmaker scale in Photo 2.12);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.4 Test Protocol – Simulated Precipitation Tests

APS developed a specific procedure for Type II/III/IV testing in simulated precipitation based on the requirements outlined in ARP5485. Key details of the procedure include:

- Freezing fog, freezing drizzle and light freezing rain tests are conducted on standard flat plates (see Section 2.2.3);
- Rain on cold-soak surface tests are conducted on filled cold-soak boxes (see Section 2.2.3);
- Fluid is applied at ambient temperature; and
- 1 L of fluid is hand-poured on the test surface.

2.3.5 End Condition Definitions

Failure is called when 30 percent (1/3) of the plate or 5 cross-hairs are covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

a) Ice front;
b) Ice sheet;
c) Slush, in clusters or as a front;
d) Disseminated fine ice crystals;
e) Frost on surface;
f) Clear ice pieces partially or totally imbedded in fluid; and
g) Snow bridges on top of the fluid.

2.3.6 Precipitation Rate Measurement Procedures

The procedures for measuring and determining precipitation rates during simulated precipitation and natural precipitation conditions are provided below.

2.3.6.1 Simulated precipitation conditions

Prior to the start of the rate collection period, the proper needles and nozzles are installed in the spray unit, and both the air and water pressures are adjusted. Water spray calibration is performed by placing catch pans on the test stand, each pan marked with a number identifying the collection location on the test stand, and exposing the pans to a predetermined precipitation collection period.
The pans are weighed prior to exposure to precipitation and the weights are recorded in a customized Excel spreadsheet by using the print function on the digital weigh scale. Prior to the start of the precipitation catch period, the exact time (hh:mm:ss) is recorded using a pre-programmed time macro in the Excel spreadsheet. The pans are re-weighed following this collection period and the precipitation rates over the area of the test stand are examined. If the rates are unacceptable, re-calibration of the water spray is necessary. If the rates are deemed to be acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period has expired, the pans are again re-weighed and the rates computed.

Once two rates have been collected at each test location, the catch rates of the first and second collection are compared. If the average catch rate for any location is deemed to be acceptable for the test condition, then the pouring of fluids may begin at this location.

Rates are continuously monitored at a minimum of two locations during a test in order to ensure there are no significant rate fluctuations. Pans will be placed at these locations and be re-weighed at fixed intervals (15 minutes, typically) during the course of a test. If a rate fluctuation occurs, the test is stopped.

Following the failure of a test plate, a rate collection pan is weighed and placed at the plate location for a predetermined time interval. It is then re-weighed and placed again on the stand to collect a minimum of two additional rates at this location.

The rate of precipitation for any location on the stand is calculated by averaging the two rates collected prior to the test and the two rates collected following the test.

2.3.6.2 Natural precipitation conditions

Two rate collection pans per test stand are used to determine precipitation rates in natural conditions. Prior to the rate collection period, both pans are marked (upper and lower), and the inner bottom and sides of the each pan are wetted with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The wetted pans are then weighed to the nearest gram. The start time of the rate collection period is recorded (h/min/sec) using a customized Excel spreadsheet in which the weight is also recorded by pressing the print function on the digital weigh scale.

The pans are positioned in locations 6 and 7 (see Figure 2.4) and are allowed to collect precipitation for 10-minute intervals in normal conditions and 5-minute intervals in periods of high precipitation rates and high winds. Prior to removal of the plate pans from the test stand for re-weighing, any accumulated precipitation on the lips and outer sides of each plate pan is carefully removed. The plate pans are then carried to the rate station for re-weighing. Upon entering the trailer, the exact time is noted. The new weights of the plate pans are recorded and the pans are brought back outside. This procedure is continued until the final plate on the test stand has failed.

The rate for any HOT test in natural snow is obtained by computing the time-weighted average of the rates collected in the upper and lower pans over the duration of this particular test. To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.6. Typically, two collections pans are used for each test. The start and end times of the test shown in Figure 2.6 are 10:15 and 10:45,

respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t1, t2, and t3 (minutes). The calculated rates for each collection period are indicated by R1, R2, and R3 (g/dm²/h). In order to calculate the average rate for this pan, the following formula is then used:

$$\frac{(R_1 \times t_1 + R_2 \times t_2 + R_3 \times t_3)}{t_1 + t_2 + t_3}$$

In the example shown in Figure 2.6, the rate is calculated as follows:

$$\frac{(25 \times 10 + 22 \times 8 + 34 \times 5)}{10 + 8 + 5}$$

The calculated average rate for this pan is 25.9 g/dm²/h. The average rate for the other collection pan is calculated in similar fashion, and the average of the two rates is then taken.

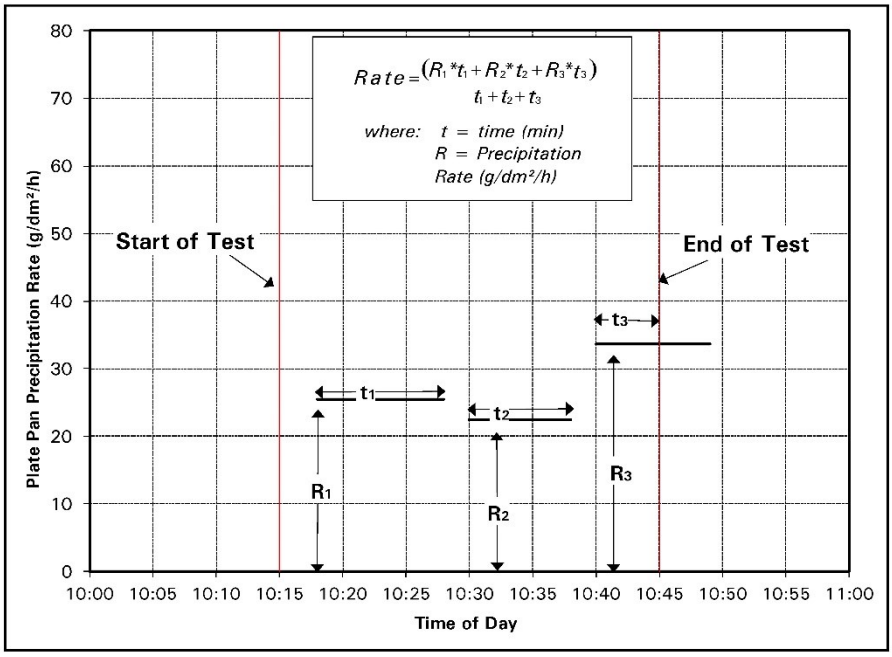


Figure 2.6: Calculation of Outdoor Precipitation Rate

2.4 Precipitation Rate Limits in Type II/IV Endurance Time Testing

Upper and lower precipitation rate limits are an important part of the test methodology for measuring fluid endurance times. Table 2.1 provides the meteorologically accepted definitions of weather phenomenon / precipitation types. It also includes the criteria used to determine precipitation intensity. This table was compiled by the National Centre for Atmospheric Research (NCAR) from the *World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation* (1983) and from the *American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS)* (3/94).

The precipitation rate limits established for Type II/IV endurance time testing are provided in ARP5485 and represented graphically in Figure 2.7. Subsections 2.4.1 to 2.4.5 provide detailed definitions and explanations of the precipitation types and rate boundaries used in Type II/IV endurance time testing. It should be noted that in many cases these limits are not the same as the meteorologically accepted definitions provided in Table 2.1.

Table 2.1: Definition of Weather Phenomenon

Weather Phenomenon*	Definition*
FROST (No METAR code) Note: No Intensity is assigned to FROST.	Ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.
FREEZING FOG (FZFG) Note: No Intensity is assigned to FRZ FOG	A suspension of numerous minute water droplets which freezes upon impact with ground or other exposed objects, generally reducing the horizontal
SNOW (SN)	Precipitation of ice crystals, most of which are branched, star-shaped, or mixed with unbranched crystals. At temperatures higher than about -5°C
FRZING DRIZZLE (FZDZ)	Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0.02 in.)] very close together which freezes upon impact with
FREEZING RAIN (FZRA)	Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5
RAIN (RA)	Precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 in.) diameter or of smaller widely scattered drops.
SNOW PELLETS (GS) and/or SMALL HAIL	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is
HAIL (GR)	Precipitation of small balls or pieces of ice with a diame-
ICE PELLETS (PE)	Precipitation of transparent (sleet or grains of ice), or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 in.)

Intensity Criteria**

	Snow(SN),Pellets(GS),Grains(SG)		Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (SN) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm/hr or 10 gr/dm²/hr)	Scattered pellets on the ground. Visibility not affected.
Moderate	If visibility is: < 5/8 to 5/16 mi (< 1.0 to 0.5 km)	> 0.05 to 0.10 in/hr (> 1.0 to 2.5 mm/hr) (> 10.0 to 25.0 gr/dm²/hr)	Slow accumulation on the ground. Visibility reduced to less than 7 mi.
Heavy (+)	If visibility is: < 5/16 mi (< 0.5 km)	More than 0.10 in/hr (> 2.5 mm/hr or 25 gr/dm²/hr)	Rapid accumulation on the ground. Visibility reduced to less than 3 mi.

Note: Horizontal visibility is only an estimation of snow and freezing drizzle intensity. Measurements and observations have

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm/hr or 2.54 gr/dm²/hr)
Moderate	From 0.01 to 0.02 in/hr (2.54 to 5.08 gr/dm²/hr)
Heavy(+)	More than 0.02 in/hr (> 5.08 gr/dm²/hr) Note: Drizzle > 0.04 in/hr is usually in the form of rain.

	Rain (RA), Freezing Rain (FZRA), Ice Pellets (PE)
Measured Intensity	Up to 0.10 in/hr (2.5 mm/hr or 25 gr/dm²/hr) Maximum 0.01 inch in 6 minutes
Light (-) Estimated Intensity	From scattered drops that, regardless of duration, do not completely wet an
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.01 to 0.03 inch in 6 minutes
Moderate Estimated Intensity	Individual drops are not clearly identifiable; spray is observable just above
Measured Intensity	More than 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.03 inch in 6 minutes
Heavy (+) Estimated Intensity	Rain seemingly falls in sheets; individual drops are not identifiable; heavy

* From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
** From American Meteorological Society, Glossary of Meteorology WSOH #7 MANOBS (3/94)
*** NCAR/ISAE Proposed Definition for Liquid Equivalent Snowfall Intensity

1) gr/dm² = 0.01 cm = 0.1 mm = 0.0039 in
2) in = 2.54 cm = 25.4 mm = 254 gr/dm²

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP Sept 8, 1999 (Updated for METAR codes)

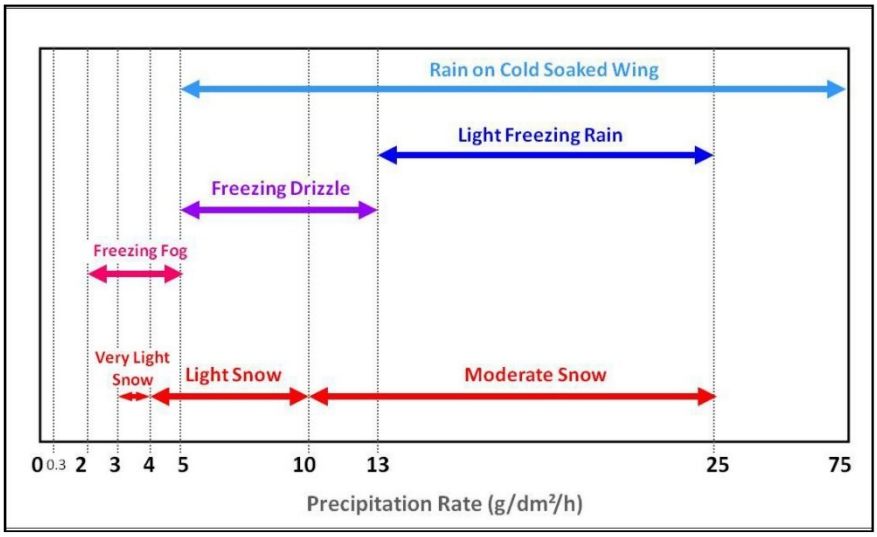


Figure 2.7: Precipitation Rate Limits Used in Endurance Time Testing

2.4.1 Freezing Fog

The precipitation rate limits for endurance time testing in freezing fog were set in 1997 at rates of 2 and 5 g/dm^2/h. These limits were determined with input from NRC meteorologists, who helped define an important parameter in the study of fog referred to as the *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic meter of air, can generally assume values in the range of 0.2 to 0.6 g/m^3.

2.4.2 Freezing Drizzle

The precipitation rate limits for endurance time testing in freezing drizzle are 5 and 13 g/dm^2/h. The upper limit in this range was adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Committee. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety.

2.4.3 Light Freezing Rain

The precipitation rate limits for endurance time testing in light freezing rain are 13 and 25 g/dm^2/h. This range corresponds to the category of light freezing rain and is the only freezing rain category considered, as operations in periods of moderate or heavy freezing rain are deemed unsafe.

2.4.4 Rain on a Cold-Soaked Surface

The precipitation rate limits for rain on cold soaked surface are 5 and 75 g/dm^2/h. This range encompasses drizzle (5 to 13 g/dm^2/h), light rain (13 to 25 g/dm^2/h), and moderate rain (25 to 75 g/dm^2/h).

2.4.5 Snow

The precipitation rate limits used to determine holdover times for Type II/IV fluids in snow are 3, 4, 10 and 25 g/dm^2/h. These rate limits encompass very light, light and moderate snow.

2.5 Ambient Temperatures in Type II/IV Endurance Time Testing

The Type II/IV holdover time tables provide holdover times for three temperature ranges:

- -3°C and above;
- Below -3 to -10°C (freezing drizzle, light freezing rain, cold soak wing) or Below -3 to -14°C (freezing fog, snow); and
- Below -14°C to LOUT

In natural snow testing, endurance time testing is carried out under a range of temperatures. In simulated freezing precipitation and artificial snow testing, endurance time testing is typically conducted at the lower limit of each temperature band.

- Freezing Fog: -3°C, -14°C and -25°C
- Freezing Drizzle: -3°C and -10°C
- Light Freezing Rain: -3°C and -10°C
- Rain on Cold Soaked Surface: +1°C
- Artificial Snow: -3, -14 and/or -25°C

2.6 Freezing Precipitation Droplet Sizes

Research has shown that median volume diameter (MVD) of rain droplets is related to rate of precipitation as follows:

- MVD = (precipitation rate/10) $^{0.23}$, where MVD is in mm and rate of precipitation is in g/dm²/h

The theoretical MVDs for rain at various rates of precipitation were determined based on this equation. These values are listed in Table 2.2 beside the experimental MVDs for each precipitation condition.

Table 2.2: Theoretical and Experimental MVDs

Precipitation Condition	Experimental MVD (mm)	Theoretical MVD (mm)
Moderate Rain (High rate: 75 g/dm²/h)	1.4	1.6
Light Rain (Low rate: 13 g/dm²/h)	1.0	< 1.1
Light Rain (High rate: 25 g/dm²/h)	1.0	1.2
Drizzle (Low rate: 5 g/dm²/h)	0.25	< 0.5
Drizzle (High rate: 13 g/dm²/h)	0.35	< 0.5
Fog		< 0.1

To determine whether droplets produced at the NRC resembled droplets from natural precipitation, a test was conducted during natural light freezing rain conditions in 1997-98 at the APS test site. The droplet sizes were compared to those obtained in simulated light freezing rain at the NRC. The results of these tests are shown below.

a) *For the outdoor test:*

Location:	Montreal P.E.T. Airport
Precipitation:	Natural Light Freezing Rain
Precipitation Rate:	20 g/dm²/h
Calibrated MVD:	1.0 mm

b) *For the indoor test:*

Location:	National Research Council
Precipitation:	Simulated Light Freezing Rain
Precipitation Rate:	25 g/dm²/h
Calibrated MVD:	1.0 mm

The MVD for both natural and simulated light freezing rain was 1 mm, indicating that the NRC produced droplets simulate natural precipitation.
As a result of this testing, the MVDs for freezing precipitation testing were established as follows:

- Freezing Fog, high precipitation rate (5 g/dm²/h): 30 μm
- Freezing Fog, low precipitation rate (2 g/dm²/h): 30 μm
- Freezing Drizzle, high precipitation rate (13 g/dm²/h): 350 μm
- Freezing Drizzle, low precipitation rate (5 g/dm²/h): 250 μm
- Light Freezing Rain, high precipitation rate (25 g/dm²/h): 1,000 μm
- Light Freezing Rain, low precipitation rate (13 g/dm²/h): 1,000 μm
- Rain on Cold-Soaked Surface, low precipitation rate (5 g/dm²/h): 250 μm
- Rain on Cold-Soaked Surface, high precipitation rate (75 g/dm²/h): 1,400 μm

2.7 Summary of Freezing Precipitation Test Conditions

The precipitation types/rates, ambient temperatures and droplet sizes for freezing precipitation testing with Type II/IV fluids were described in the previous subsections. In summary, freezing precipitation tests are carried out under each of the 16 weather conditions listed in Table 2.3.

Table 2.3: Summary of Freezing Precipitation Test Conditions (Type II/IV Fluids)

Precipitation Type	Ambient Temperature	Precipitation Rate (Droplet Size)
Freezing Fog	-3°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-14°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-25°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
Freezing Drizzle	-3°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
	-10°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
Light Freezing Rain	-3°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
	-10°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
Rain on Cold-Soaked Surface	+1°C	5 g/dm²/h (250 μm)
		75 g/dm²/h (1,400 μm)

2.8 Analysis Methodology

A multi-variable regression procedure is used to derive fluid-specific holdover times for Type II/IV fluids. The procedure is based on the refinement of an equation for a curve which best represents the test data, and then solving that equation at the upper and lower limits established for the precipitation type. These precipitation rate limits, set by the SAE G-12 HOT Committee and detailed in ARP5485, were described in Subsection 2.4. This approach was developed in the winter of 1996-97 (see TC report, TP 13131E) and has since been used to derive fluid holdover times. There are some differences in the way the methodology is applied to freezing precipitation and natural snow data.

2.8.1 Freezing Precipitation Data

For each related freezing precipitation HOT table cell, four tests are conducted at the most restrictive (lowest) temperature in the temperature range for that cell: two tests at the low precipitation rate limit and two tests at the high precipitation rate limit (limits are detailed in Subsection 2.4). The equation used to treat freezing precipitation data is:

- $t = 10^{I}R^{a}$, where

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.2 Natural Snow Data

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural snow tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather data under all temperatures and precipitation rates encompassed by the HOT tables.

The general form of the regression equation is modified for natural snow to incorporate the variable of temperature and also to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C. The equation used to treat natural snow data is:

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

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  I, a, b = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, using the most restrictive (lowest) temperature for that cell. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.4.

2.8.3 Natural Frost Data

Regression analysis is not used in the determination of frost holdover times. The current Type II/III/IV generic frost holdover times were determined based on several years of testing using all fluids which were commercially available at the time. A "minimum values" analysis methodology was used to determine appropriate holdover times from the test data.

The purpose of natural frost testing with new fluids is to verify the fluids can be used with the generic frost holdover times. The analysis methodology is to compare the frost test data collected with the new fluid to the current generic holdover times. If the test data provides holdover times equal to or greater than the generic holdover times then the generic holdover times have been validated for the new fluid.

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural frost tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather several data points with each fluid/dilution.

2.8.4 Rounding and Capping Protocols

Regression-generated holdover times are subject to rounding and capping protocols. For Type II/IV fluids they are as follows:

- Rounding Protocol: Holdover times are rounded to the nearest whole "5" minute, i.e. 55.1 to 57.4 minutes is rounded down to 55 minutes; 57.5 to 59.9 minutes is rounded up to 60 minutes. In cases where the regression-generated holdover times are below 10 minutes, the numbers are rounded down to the nearest whole minute as a precautionary measure. For example, 9.6 minutes is rounded down to 9 minutes.

- Capping Protocol: All holdover time values are capped at maximum values. The caps differ by precipitation type, and in the case of snow, by regulator. The caps are as follows:
  - Freezing Fog holdover time values are capped at 4 hours;
  - Freezing Drizzle, Light Freezing Rain, Rain on Cold Soaked Wing holdover times are capped at 2 hours; and
  - Snow holdover times are capped at 2 hours by Transport Canada and 3 hours by FAA.

2.8.5 Regression Example

Sample plots of **Log t** versus **Log R** are shown in Figure 2.8. The plots contain data for one Neat Type IV fluid, in one temperature range (-10°C), in light freezing rain conditions. The best-fit regression line is superimposed onto the plot and was obtained from the analysis using the lowest temperature in the temperature range from which the data were chosen.

The same data plotted on a linear scale (failure time **t** versus precipitation rate **R**) are shown in Figure 2.9. The curve, generated from the power law form of the equation using the coefficients determined from the fit, is superimposed onto the plot. The HOT range is determined from the intersections of the curve with the precipitation rate limits defined for light freezing rain.

The holdover times for this fluid at -10°C are 20 minutes at 13 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid in the light freezing rain, neat fluid, below -3 to -10°C cell. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

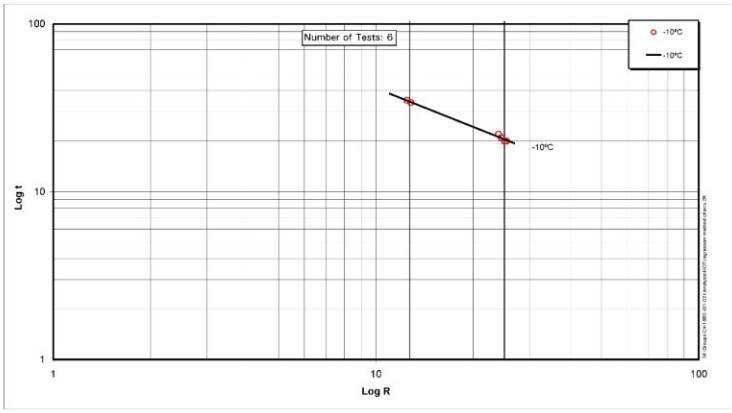


Figure 2.8: Regression Method on Log-Log Chart – Type IV Neat, Freezing Rain

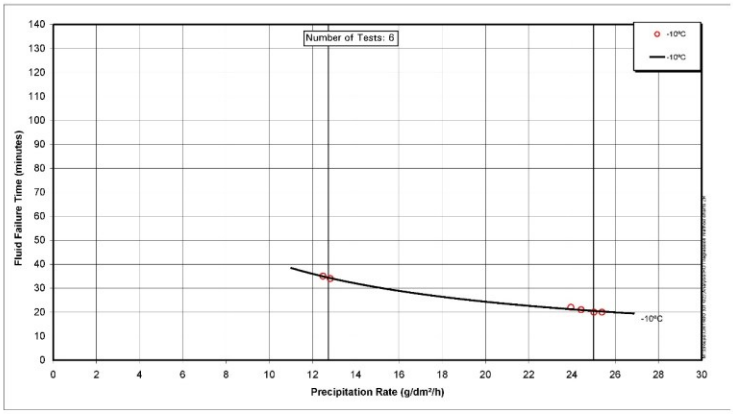


Figure 2.9: Regression Method on Standard Chart – Type IV Neat, Freezing Rain

2.8.6 Lowest Usable Precipitation Rates in Snow

A detailed analysis methodology was developed to determine if a snow data set is sufficient to determine holdover times for light and very light snow. Specifically, the analysis determines the lowest usable precipitation rate (LUPR), which is the lowest rate at which the data set is considered robust.

The methodology is a five-factor weighted analysis. The five factors are:

1. Total number of data points;
2. Number of data points with air temperatures below -3°C;
3. Number of data points with precipitation rates below 10 g/dm²/h;
4. Number of data points with precipitation rates less than or equal to 0.5 g/dm²/h above the precipitation rate being examined; and
5. Scatter from regression curve of low precipitation rate data points (average absolute percent difference between fail time and regression calculated fail time for all points less than or equal to 10 g/dm²/h).

The weights given to each of the five factors are:

1. Total Data Points = 5%;
2. Data Points Below -3°C = 20%;
3. Data Points Below 10 g/dm²/h = 20%;
4. Data Points ≤ Precipitation Rate = 40%; and
5. Low Rate Data Scatter = 15%.

Each data set is given a score of 0, 10, 20, 30 or 40 for each factor. The scoring system is shown in Table 2.4.

This approach provides a score for each data set for each precipitation rate below 10 g/dm²/h. The scores are compared to the minimum acceptance scores:

- 100/0 = 28
- 75/25 = 28
- 50/50 = 19 (lower due to a 0 score for data points below -3°C)

The LUPR is the lowest precipitation rate at which a data set has a passing score.

Table 2.4: LUPR Factor Scoring System

Factor #1: Total Data Points (Weight = 5%)	
Rating = 40	≥20 data points in data set
Rating = 30	15-19 data points in data set
Rating = 20	10-14 data points in data set
Rating = 10	5-9 data points in data set
Rating = 0	<5 data points in data set

Factor #2: Data Points Below -3°C (Weight = 20%)	
Rating = 40	≥15 data points from -3 to -14°C
Rating = 30	12-14 data points -3 to -14°C
Rating = 20	9-11 data points -3 to -14°C
Rating = 10	6-8 data points -3 to -14°C
Rating = 0	<6 data points -3 to -14°C

Factor #3: Data Points Below 10 g/dm²/h (Weight = 20%)	
Rating = 40	≥10 data points <10 g/dm²/h
Rating = 30	7-9 data points <10 g/dm²/h
Rating = 20	5-6 data points <10 g/dm²/h
Rating = 10	3-4 data points <10 g/dm²/h
Rating = 0	<3 data points <10 g/dm²/h

Factor #4: Data Points ≤ Precipitation Rate (Weight = 40%)	
Rating = 40	≥3 data points ≤ rate limit +0.5
Rating = 30	2 data points ≤ rate limit +0.5
Rating = 20	1 data points ≤ rate limit +0.5
Rating = 10	n/a
Rating = 0	0 data points ≤ rate limit +0.5

Factor #5: Low Rate Data Scatter (Weight = 15%)	
Rating = 40	Average actual-calculated error <10%
Rating = 30	Average actual-calculated error 10-19%
Rating = 20	Average actual-calculated error 20-29%
Rating = 10	Average actual-calculated error 30-39%
Rating = 0	Average actual-calculated error ≥40%

Photo 2.1: APS Test Site - View from Test Pad



Photo 2.2: APS Test Site - View from Trailer



Photo 2.3: Outdoor View of NRC Climatic Engineering Facility



Photo 2.4: Inside View of NRC Climatic Engineering Facility



Photo 2.5: Test Plates Mounted on Stand

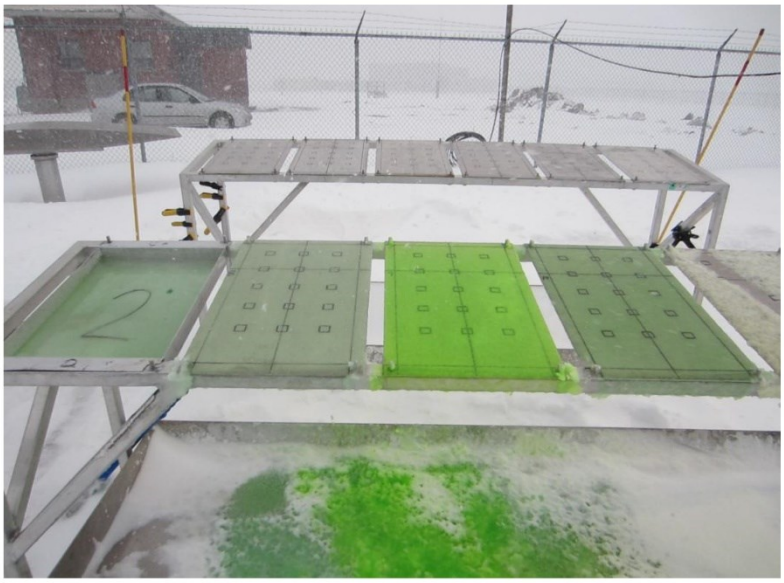


Photo 2.6: Cold-Soak / Leading Edge Thermal Equivalent Box

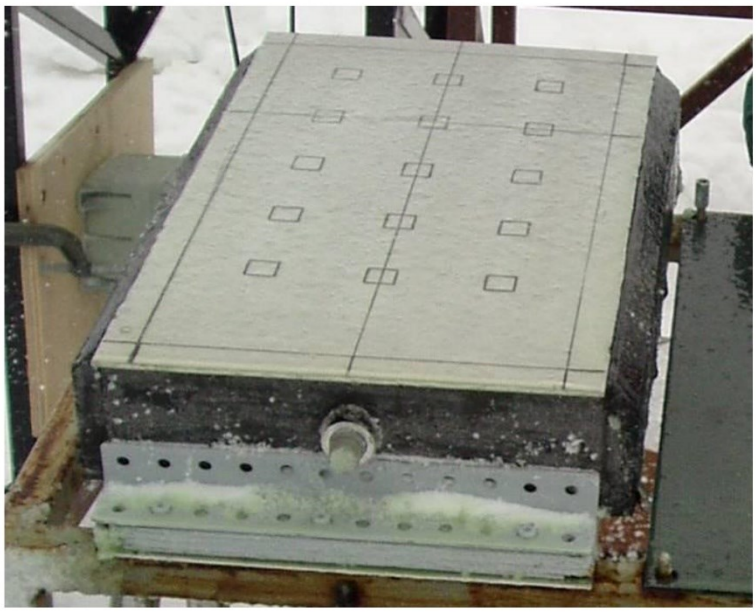


Photo 2.7: Frost Plate with Insulated Backing



Photo 2.8: Collection Pans Used Indoors at the NRC



Photo 2.9: Sprayer Assembly



Photo 2.10: Sprayer Assembly in Use

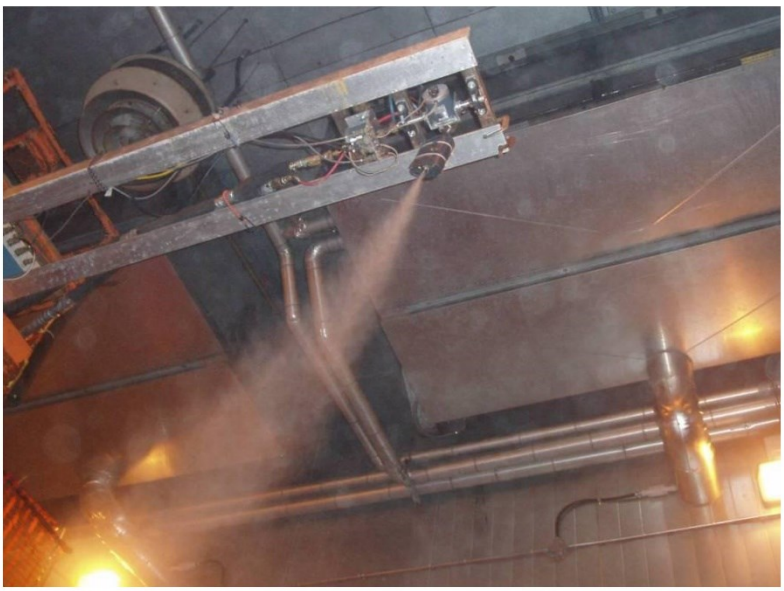


Photo 2.11: Sprayer Nozzle

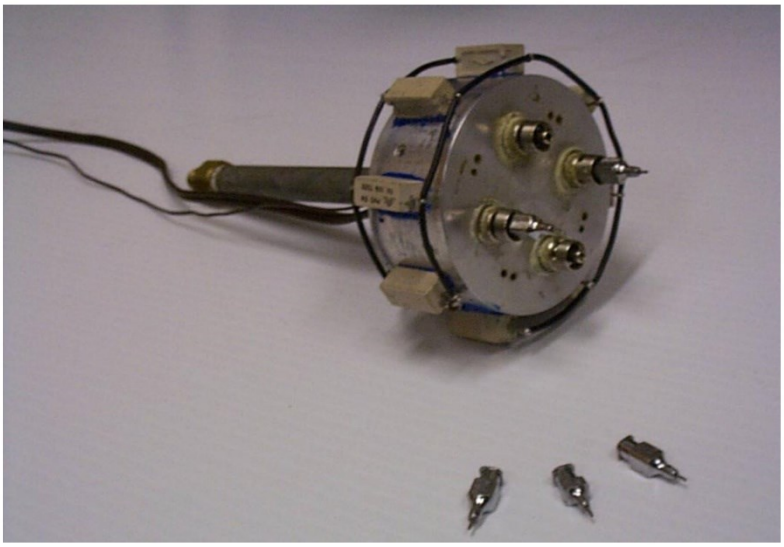
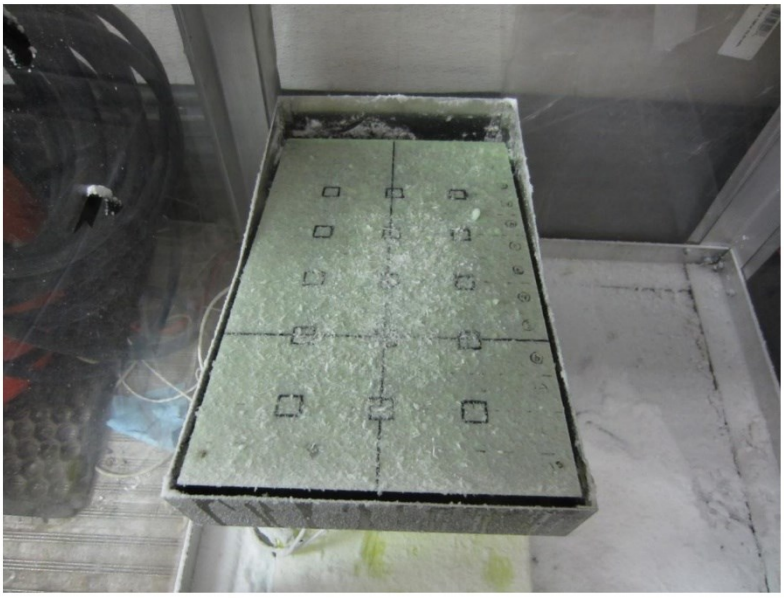


Photo 2.12: Standard Plate Setup for Testing with Artificial Snowmaker



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted. Breakdowns are provided for the number of tests performed by test type, precipitation type, fluid dilution and test temperature.

Logs of the tests conducted are provided at the end of this section as follows: Table 3.1 (snow), Table 3.2 (freezing precipitation), and Table 3.3 (frost). The logs provide details of each test conducted.

3.1 Natural and Artificial Snow Tests

Tests were conducted in natural snow conditions at the APS test site and at several mobile test sites (see Subsection 2.1.1). The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	Natural Snow			Artificial Snow		
	≥ -3°C	-3 to -14°C	<-14°C	-3°C	-14°C	-25°C
Neat	16	9	1	4	4	0
75/25	13	9	0	4	4	0
50/50	14	3	0	4	0	0

3.2 Freezing Drizzle and Light Freezing Rain Tests

Tests were conducted in freezing drizzle and light freezing rain conditions at the NRC CEF. The breakdown of tests conducted is summarized below by precipitation type, fluid dilution and temperature.

	Freezing Drizzle		Light Freezing Rain	
	-3°C	-10°C	-3°C	-10°C
Neat	4	4	4	4
75/25	4	4	5	4
50/50	4	0	5	0

3.3 Freezing Fog Tests

Tests were conducted in freezing fog conditions at the NRC CEF. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	-3°C	-14°C	-25°C
Neat	4	4	4
75/25	4	4	0
50/50	4	0	0

3.4 Rain on Cold-Soaked Surface Tests

Tests were conducted in rain on cold-soaked surface conditions at the NRC CEF with Neat and 75/25 diluted fluids. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	+1°C
Neat	4
75/25	4
50/50	0

3.5 Natural Frost Tests

Tests were conducted in natural frost at the APS test site. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	≥-1°C	<-1 to -3°C	<-3 to -10°C	<-10°C
Neat	0	0	0	2
75/25	0	2	0	0
50/50	0	2	0	0

3.6 Fluid Thickness Tests

Fluid thickness tests were conducted to measure the film thickness profiles of the fluid under dry conditions. Two tests were performed for each dilution. For each test, 1 litre of fluid was poured onto a flat plate mounted on a test stand inclined by 10°. Thickness measurements were taken at the 15-cm (6") line at select time intervals over a 30-minute period. Tests were conducted at -3°C.

The film thickness profiles are displayed in Figure 3.1. The final fluid thicknesses are displayed in Figure 3.2.

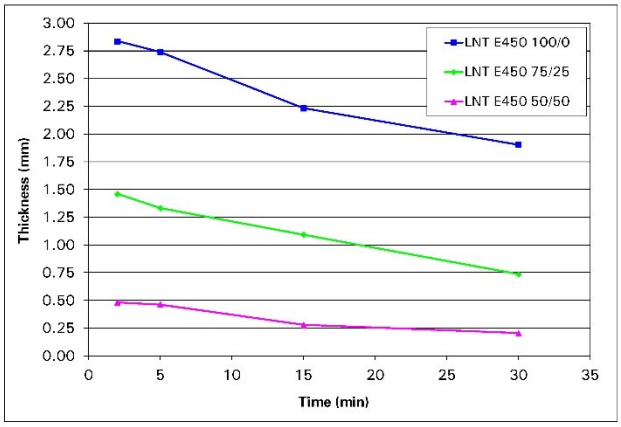

Figure 3.1: Fluid Thickness Profiles of LNT Solutions E450

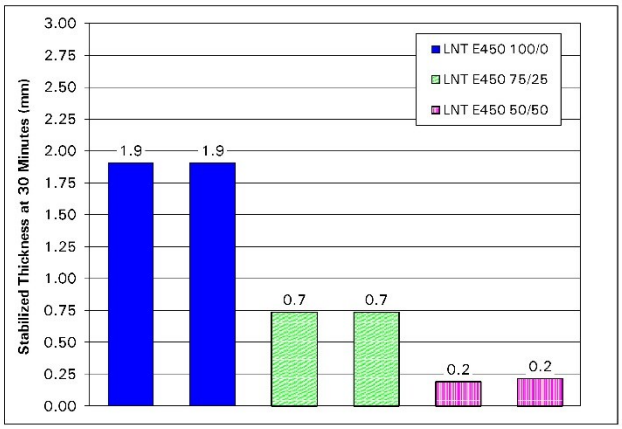

Figure 3.2: Final Fluid Thickness of LNT Solutions E450

Table 3.1: Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
329	14-Apr-14	Natural Snow	LNT E450	100%	-1.0	37.7	48.6
330	14-Apr-14	Natural Snow	LNT E450	100%	0.0	31.6	54.2
331	14-Apr-14	Natural Snow	LNT E450	50%	-1.0	30.0	9.7
332	14-Apr-14	Natural Snow	LNT E450	50%	-1.0	40.8	6.4
333	14-Apr-14	Natural Snow	LNT E450	75%	-1.0	38.2	19.8
334	14-Apr-14	Natural Snow	LNT E450	75%	-1.0	42.5	19.7
335	14-Apr-14	Natural Snow	LNT E450	75%	-1.0	36.4	21.9
336	14-Apr-14	Natural Snow	LNT E450	75%	0.0	31.0	18.6
337	14-Apr-14	Natural Snow	LNT E450	50%	-1.0	40.7	5.4
338	14-Apr-14	Natural Snow	LNT E450	50%	-1.0	33.3	5.7
339	14-Apr-14	Natural Snow	LNT E450	100%	-1.0	41.9	46.1
340	14-Apr-14	Natural Snow	LNT E450	100%	-1.0	44.2	46.7
341	14-Apr-14	Natural Snow	LNT E450	100%	-5.5	3.5	258.7
344	14-Apr-14	Natural Snow	LNT E450	75%	-5.5	4.4	65.8
345	14-Apr-14	Natural Snow	LNT E450	75%	-5.0	12.8	42.0
348	14-Apr-14	Natural Snow	LNT E450	75%	-7.0	0.8	207.5
349	15-Apr-14	Natural Snow	LNT E450	100%	-1.8	1.6	289.8
350	15-Apr-14	Natural Snow	LNT E450	50%	-0.4	2.5	71.0
351	15-Apr-14	Natural Snow	LNT E450	75%	-1.8	1.5	198.8
352	15-Apr-14	Natural Snow	LNT E450	75%	-1.1	2.3	161.4
353	15-Apr-14	Natural Snow	LNT E450	100%	-2.2	1.5	270.3
354	15-Apr-14	Natural Snow	LNT E450	50%	-1.1	2.7	81.0
355	15-Apr-14	Natural Snow	LNT E450	50%	-3.4	10.0	14.8
356	15-Apr-14	Natural Snow	LNT E450	75%	-2.6	1.1	194.5
358	15-Apr-14	Natural Snow	LNT E450	100%	-2.9	1.8	216.0
359	24-Apr-14	Natural Snow	LNT E450	100%	-2.6	2.3	176.5
361	24-Apr-14	Natural Snow	LNT E450	75%	-2.4	1.4	102.5
366	24-Apr-14	Natural Snow	LNT E450	50%	-2.2	0.5	47.0
367	24-Apr-14	Natural Snow	LNT E450	50%	-3.3	1.3	19.5
369	24-Apr-14	Natural Snow	LNT E450	100%	-3.3	1.4	114.0
371	24-Apr-14	Natural Snow	LNT E450	100%	-3.7	1.4	172.0
375	24-Apr-14	Natural Snow	LNT E450	50%	-3.3	4.3	19.6
376	24-Apr-14	Natural Snow	LNT E450	75%	-3.3	4.3	58.0
377	25-Apr-14	Natural Snow	LNT E450	100%	-4.1	4.0	123.0
378	25-Apr-14	Natural Snow	LNT E450	50%	-3.6	3.3	18.0
380	25-Apr-14	Natural Snow	LNT E450	75%	-3.8	3.6	49.3

Table 3.1 (cont'd): Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
383	25-Apr-14	Natural Snow	LNT E450	100%	-3.2	4.4	111.0
384	25-Apr-14	Natural Snow	LNT E450	50%	-3.8	5.4	14.0
388	25-Apr-14	Natural Snow	LNT E450	75%	-3.6	4.3	59.3
391	25-Apr-14	Natural Snow	LNT E450	50%	-3.6	4.1	18.5
394	25-Apr-14	Natural Snow	LNT E450	100%	-3.0	4.4	95.7
395	25-Apr-14	Natural Snow	LNT E450	100%	-1.7	1.8	409.8
396	25-Apr-14	Natural Snow	LNT E450	100%	-2.1	3.3	131.0
402	25-Apr-14	Natural Snow	LNT E450	75%	-1.8	2.3	130.3
1	28-Apr-14	Artificial Snow	LNT E450	100%	-14.0	10.0	90.0
2	28-Apr-14	Artificial Snow	LNT E450	100%	-14.0	25.0	47.5
3	02-May-14	Artificial Snow	LNT E450	75%	-14.0	10.0	50.1
4	02-May-14	Artificial Snow	LNT E450	75%	-14.0	25.0	20.9
9	01-May-14	Artificial Snow	LNT E450	100%	-3.0	10.0	87.5
10	01-May-14	Artificial Snow	LNT E450	100%	-3.0	25.0	46.0
11	01-May-14	Artificial Snow	LNT E450	75%	-3.0	10.0	54.2
12	01-May-14	Artificial Snow	LNT E450	75%	-3.0	25.0	26.7
13	01-May-14	Artificial Snow	LNT E450	50%	-3.0	10.0	17.8
14	01-May-14	Artificial Snow	LNT E450	50%	-3.0	25.0	6.9
21	16-Jul-14	Artificial Snow	LNT E450	100%	-14.0	10.0	85.0
22	16-Jul-14	Artificial Snow	LNT E450	100%	-14.0	25.0	43.7
23	15-Jul-14	Artificial Snow	LNT E450	75%	-14.0	10.0	46.0
24	15-Jul-14	Artificial Snow	LNT E450	75%	-14.0	25.0	23.0
29	11-Jul-14	Artificial Snow	LNT E450	100%	-3.0	10.0	98.2
30	11-Jul-14	Artificial Snow	LNT E450	100%	-3.0	25.0	52.0
31	03-May-14	Artificial Snow	LNT E450	75%	-3.0	10.0	56.2
32	02-May-14	Artificial Snow	LNT E450	75%	-3.0	25.0	23.4
33	02-May-14	Artificial Snow	LNT E450	50%	-3.0	10.0	23.0
34	02-May-14	Artificial Snow	LNT E450	50%	-3.0	25.0	8.2
24	2-Dec-14	Natural Snow	LNT E450	75%	-8.2	18.1	24.3
25	2-Dec-15	Natural Snow	LNT E450	100%	-5.6	1.4	143.1
35	2-Dec-14	Natural Snow	LNT E450	75%	-9.2	10.4	32.9
36	2-Dec-14	Natural Snow	LNT E450	100%	-9.2	15.8	52.6
69	10-Dec-14	Natural Snow	LNT E450	50%	-0.3	20.5	10.9
77	10-Dec-14	Natural Snow	LNT E450	50%	-0.1	15.9	15.2
104	3-Jan-15	Natural Snow	LNT E450	100%	-11.4	21.9	58.7
108	3-Jan-15	Natural Snow	LNT E450	100%	-11.2	29.2	53.2

Table 3.1 (cont'd): Summary of Tests Performed (Natural Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
109	3-Jan-15	Natural Snow	LNT E450	75%	-11.2	31.2	24.5
133	12-Jan-15	Natural Snow	LNT E450	100%	-2.9	4.3	151.1
143	18-Jan-15	Natural Snow	LNT E450	75%	-1.3	12.3	28.8
144	18-Jan-15	Natural Snow	LNT E450	50%	-1.3	11.1	14.8
149	18-Jan-15	Natural Snow	LNT E450	75%	-1.4	8.8	41.0
150	18-Jan-15	Natural Snow	LNT E450	50%	-1.4	12.3	11.2
164	29-Jan-15	Natural Snow	LNT E450	100%	-2.2	4.1	200.2
165	29-Jan-15	Natural Snow	LNT E450	75%	-4.5	26.8	18.7
182	30-Jan-15	Natural Snow	LNT E450	75%	-2.8	7.7	38.8
186	2-Feb-15	Natural Snow	LNT E450	100%	-22.3	7.5	57.3
272	3-Mar-15	Natural Snow	LNT E450	100%	-5.5	18.0	76.7
294	3-Mar-15	Natural Snow	LNT E450	100%	-5.3	12.9	97.8
331	14-Mar-15	Natural Snow	LNT E450	100%	-1.9	19.3	84.6

Table 3.2: Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
1	28-Apr-14	Freezing Fog	LNT E450	100	-25.1	2.0	69.0
2	28-Apr-14	Freezing Fog	LNT E450	100	-25.1	1.9	66.7
5	28-Apr-14	Freezing Fog	LNT E450	100	-25.2	4.8	34.0
6	28-Apr-14	Freezing Fog	LNT E450	100	-25.2	4.8	33.0
9	28-Apr-14	Freezing Fog	LNT E450	100	-14.0	2.0	228.8
10	28-Apr-14	Freezing Fog	LNT E450	100	-14.0	2.1	228.4
13	28-Apr-14	Freezing Fog	LNT E450	75	-14.0	2.0	111.2
14	28-Apr-14	Freezing Fog	LNT E450	75	-14.0	1.9	110.1
17	28-Apr-14	Freezing Fog	LNT E450	100	-14.1	5.3	84.9
18	28-Apr-14	Freezing Fog	LNT E450	100	-14.1	5.2	83.1
21	28-Apr-14	Freezing Fog	LNT E450	75	-14.1	4.7	49.9
22	28-Apr-14	Freezing Fog	LNT E450	75	-14.1	5.0	48.7
25	29-Apr-14	Freezing Fog	LNT E450	100	-3.2	5.1	111.0
26	29-Apr-14	Freezing Fog	LNT E450	100	-3.2	5.1	109.4
29	29-Apr-14	Freezing Fog	LNT E450	75	-3.2	5.2	50.9
30	29-Apr-14	Freezing Fog	LNT E450	75	-3.1	4.8	58.1
33	29-Apr-14	Freezing Fog	LNT E450	50	-3.1	5.1	18.3
34	29-Apr-14	Freezing Fog	LNT E450	50	-3.1	5.2	18.0
37	29-Apr-14	Freezing Fog	LNT E450	100	-3.3	1.9	170.3
38	29-Apr-14	Freezing Fog	LNT E450	100	-3.3	2.2	182.4
41	29-Apr-14	Freezing Fog	LNT E450	75	-3.3	2.1	83.6
42	29-Apr-14	Freezing Fog	LNT E450	75	-3.3	2.0	85.7
45	29-Apr-14	Freezing Fog	LNT E450	50	-3.3	1.7	33.4
46	29-Apr-14	Freezing Fog	LNT E450	50	-3.3	1.8	33.7
49	24-Apr-14	Freezing Drizzle	LNT E450	100	-10.1	5.0	>120
50	24-Apr-14	Freezing Drizzle	LNT E450	100	-10.1	5.0	>120
53	24-Apr-14	Freezing Drizzle	LNT E450	75	-10.2	5.0	61.5
54	24-Apr-14	Freezing Drizzle	LNT E450	75	-10.2	4.9	66.1
57	24-Apr-14	Freezing Drizzle	LNT E450	100	-10.3	13.0	103.8
58	24-Apr-14	Freezing Drizzle	LNT E450	100	-10.2	12.8	107.4
61	24-Apr-14	Freezing Drizzle	LNT E450	75	-10.3	13.3	35.7
62	24-Apr-14	Freezing Drizzle	LNT E450	75	-10.3	12.9	36.5
65	25-Apr-14	Freezing Drizzle	LNT E450	100	-3.2	4.8	>120
66	25-Apr-14	Freezing Drizzle	LNT E450	100	-3.2	4.9	>120
69	25-Apr-14	Freezing Drizzle	LNT E450	75	-3.2	5.2	51.7
70	25-Apr-14	Freezing Drizzle	LNT E450	75	-3.2	4.7	63.3
73	25-Apr-14	Freezing Drizzle	LNT E450	50	-3.2	4.8	23.3

Table 3.2 (cont'd): Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
74	25-Apr-14	Freezing Drizzle	LNT E450	50	-3.2	5.3	22.2
77	23-Apr-14	Freezing Drizzle	LNT E450	100	-3.2	13.2	97.2
78	23-Apr-14	Freezing Drizzle	LNT E450	100	-3.2	13.2	90.6
81	23-Apr-14	Freezing Drizzle	LNT E450	75	-3.2	13.0	33.1
82	23-Apr-14	Freezing Drizzle	LNT E450	75	-3.2	13.5	30.9
85	23-Apr-14	Freezing Drizzle	LNT E450	50	-3.1	13.0	10.3
86	23-Apr-14	Freezing Drizzle	LNT E450	50	-3.1	13.2	9.8
89	24-Apr-14	Light Freezing Rain	LNT E450	100	-10.2	12.7	100.6
90	24-Apr-14	Light Freezing Rain	LNT E450	100	-10.2	13.2	100.8
93	24-Apr-14	Light Freezing Rain	LNT E450	75	-10.3	12.9	38.9
94	24-Apr-14	Light Freezing Rain	LNT E450	75	-10.3	12.5	37.5
97	24-Apr-14	Light Freezing Rain	LNT E450	100	-9.9	24.7	60.9
98	24-Apr-14	Light Freezing Rain	LNT E450	100	-9.9	24.9	66.8
101	24-Apr-14	Light Freezing Rain	LNT E450	75	-9.8	24.1	22.7
102	24-Apr-14	Light Freezing Rain	LNT E450	75	-9.8	24.3	22.7
105	23-Apr-14	Light Freezing Rain	LNT E450	100	-3.1	12.7	83.4
106	23-Apr-14	Light Freezing Rain	LNT E450	100	-3.1	12.6	75.1
109	23-Apr-14	Light Freezing Rain	LNT E450	75	-3.0	12.9	29.9
110	23-Apr-14	Light Freezing Rain	LNT E450	75	-3.0	13.0	28.4
110R	23-Apr-14	Light Freezing Rain	LNT E450	75	-3.1	12.5	28.7
113	23-Apr-14	Light Freezing Rain	LNT E450	50	-3.1	13.1	10.8
113R	23-Apr-14	Light Freezing Rain	LNT E450	50	-3.1	12.9	12.0
114	23-Apr-14	Light Freezing Rain	LNT E450	50	-3.1	13.2	11.0
117	23-Apr-14	Light Freezing Rain	LNT E450	100	-3.0	24.7	55.2
118	23-Apr-14	Light Freezing Rain	LNT E450	100	-3.0	24.9	59.7
121	23-Apr-14	Light Freezing Rain	LNT E450	75	-3.0	24.5	20.9
122	23-Apr-14	Light Freezing Rain	LNT E450	75	-3.0	24.6	19.6
125	23-Apr-14	Light Freezing Rain	LNT E450	50	-3.1	24.5	8.2
126	23-Apr-14	Light Freezing Rain	LNT E450	50	-3.1	24.6	8.0
129	25-Apr-14	Cold Soak Box	LNT E450	100	1.0	5.4	120.1
130	25-Apr-14	Cold Soak Box	LNT E450	100	1.0	5.4	119.3
133	25-Apr-14	Cold Soak Box	LNT E450	75	1.0	4.8	62.5
134	25-Apr-14	Cold Soak Box	LNT E450	75	1.0	5.0	58.1
137	25-Apr-14	Cold Soak Box	LNT E450	100	0.7	77.6	22.5
138	25-Apr-14	Cold Soak Box	LNT E450	100	0.7	77.1	22.1
141	25-Apr-14	Cold Soak Box	LNT E450	75	0.7	77.8	8.6
142	25-Apr-14	Cold Soak Box	LNT E450	75	0.8	72.3	9.7

Table 3.3: Summary of Tests Performed (Natural Frost)

Test No.	Date	Precip. Type	Fluid Name	Fluid Dilution	Test Duration (min.)	Average Rate (g/dm²/h)	Temp (°C)	Wind Speed (km/h)	Average RH (%)	Comments
23	16-Apr-14	Natural Frost	LNT E450	75%	564	0.03	-3.2	3	78	Did Not Fail
24	16-Apr-14	Natural Frost	LNT E450	50%	457	0.03	-3.5	3	81	Did Not Fail
34	17-Apr-14	Natural Frost	LNT E450	75%	384	0.11	-2.7	8	69	Did Not Fail
35	17-Apr-14	Natural Frost	LNT E450	50%	204	0.08	-2.7	8	69	Failed
17	14-Jan-15	Natural Frost	LNT E450	100%	247	0.080	-21.3	5.7	77.2	Did Not Fail
44	18-Feb-15	Natural Frost	LNT E450	100%	379	0.060	-17.7	5.6	68.9	Did Not Fail

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4. RESULTS AND DISCUSSION

The methods used to evaluate the test data were reviewed in Subsection 2.8. The results of the data analyses are presented in this section.

4.1 Freezing Precipitation and Natural Snow

Figures 4.1 to 4.14 present the data collected in simulated freezing precipitation (freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface) and in natural snow. These figures show the effect of temperature, precipitation type and precipitation rate on fluid endurance time in the freezing precipitation conditions encompassed by the Type IV HOT guidelines.

Multi-variable regression analysis was performed on these data sets as described in Subsection 2.8. Table 4.1 provides the outputs from the multi-variable regression analyses. These outputs were used to derive fluid-specific holdover times for all conditions encompassed by Type IV fluid-specific HOT tables, with the exception of the coldest temperature band snow cells (see Subsection 4.3.1).

4.2 Artificial Snow

Data was collected in artificial snow to supplement the limited natural snow data collected in the first winter of testing. Figures 4.15 to 4.17 show the artificial snow data plotted against the Type IV generic snow holdover times.

All 100/0 and 50/50 data points met or exceeded the generic holdover times. Several 75/25 data points did not meet the generic holdover times. These results were used to provide generic snow holdover times for the 100/0 fluid for the winter 2014-15 operating season.

4.3 Natural Frost

The natural frost data was presented in Table 3.3. The test durations were compared to the generic holdover times. All completed ("failed") tests surpassed the generic holdover times, as did all tests that were not completed (due to active frost ending before fluid failure could occur). This analysis indicates the generic frost holdover times have been substantiated for LNT Solutions E450.

4.4 Holdover Time Table

A fluid-specific HOT table was created for LNT Solutions E450 based on the results of the endurance time testing. At the request of LNT Solutions, the 75/25 and 50/50 holdover times were not included in the table.

The holdover times described in Subsection 4.1 were used to populate the HOT table cells. The resulting fluid-specific HOT table is shown in both the TC format (Table 4.2) and FAA format (Table 4.3) at the end of this chapter.

4.4.1 Holdover Times in Snow, Below -14°C to LOUT

Very little endurance time data has been collected in natural snow at temperatures below -14°C. In the winter of 2003-04, testing was conducted with artificial snowmakers to collect additional data below -14°C. As a result of this testing, the existing propylene Type II/IV fluids were given generic values in the "Below -14 to LOUT" snow cell. It was also decided that all new Type II/IV fluids would be given generic values. Accordingly, LNT Solutions P250 has been given generic values in the "Below -14°C to LOUT" snow cells.

4.4.2 Holdover Times in Frost

It should be noted that frost holdover times are not included in the fluid-specific HOT table. This is due to a decision made by TC and the FAA in May 2009 to move frost holdover times from the generic and fluid-specific HOT tables to a separate frost HOT table. Accordingly, frost holdover times have not been included in the LNT Solutions E450 fluid-specific HOT table.

4.4.3 Fluid Viscosity

The viscosities of the fluid samples used in this testing were measured using both the AS 9968 method and the manufacturer's designated method. The APS measured viscosities appear at the beginning of this document and will be published as the lowest on-wing viscosity (LOWV) values for the fluid. In order for the fluid-specific holdover times provided in this document to be valid, operators must ensure that the viscosity of the fluid being used is equal or greater than the published LOWV.

4.5 Lowest Usable Precipitation Rates in Snow

The LUPRs for LNT E450 were determined by analysing the natural snow data sets using the analysis methodology described in Subsection **Error! Reference source not found.**. The resulting statistics are shown in Table 4.4. The analysis determined the LUPRs for LNT E450 are:

- 100/0 = 2 g/dm²/h;
- 75/25 = 2 g/dm²/h; and
- 50/50 = 2 g/dm²/h.

4.6 Discussion

As LNT Solutions intends to commercialize E450, TC and FAA will publish its updated fluid-specific HOT table in their 2015-16 Holdover Time Guidelines. The update will include the new fluid-specific snow holdover times. The guidelines will also include the LOWV and LOUT information; the LUPR data will be published in the related TC and FAA Regression Information documents. At the request of LNT Solutions, the information for 75/25 and 50/50 dilutions will not be included.

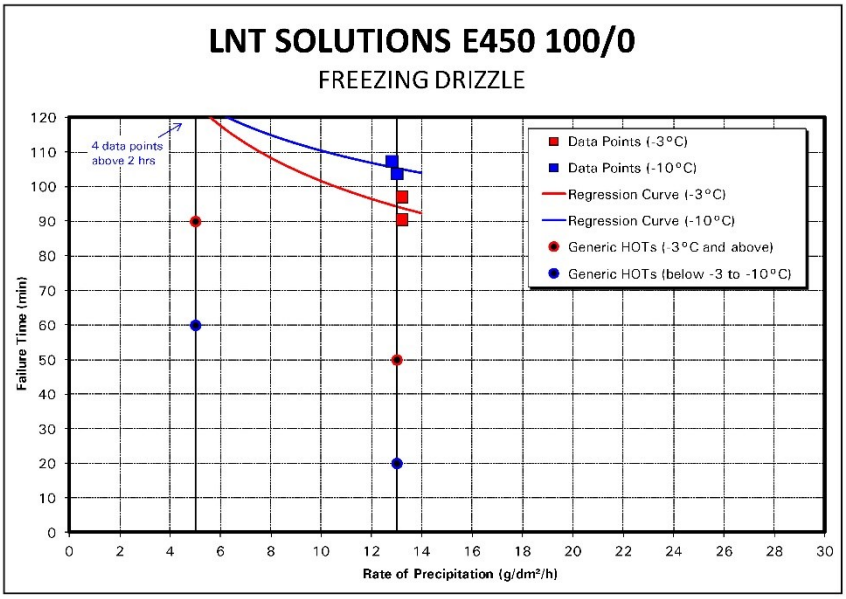

Figure 4.1: Type IV Neat – Freezing Drizzle

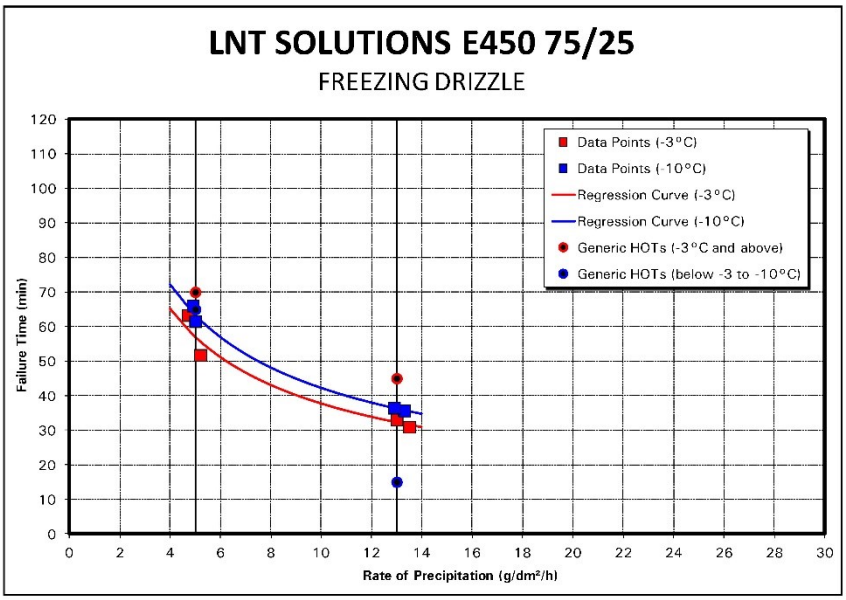

Figure 4.2: Type IV 75/25 – Freezing Drizzle

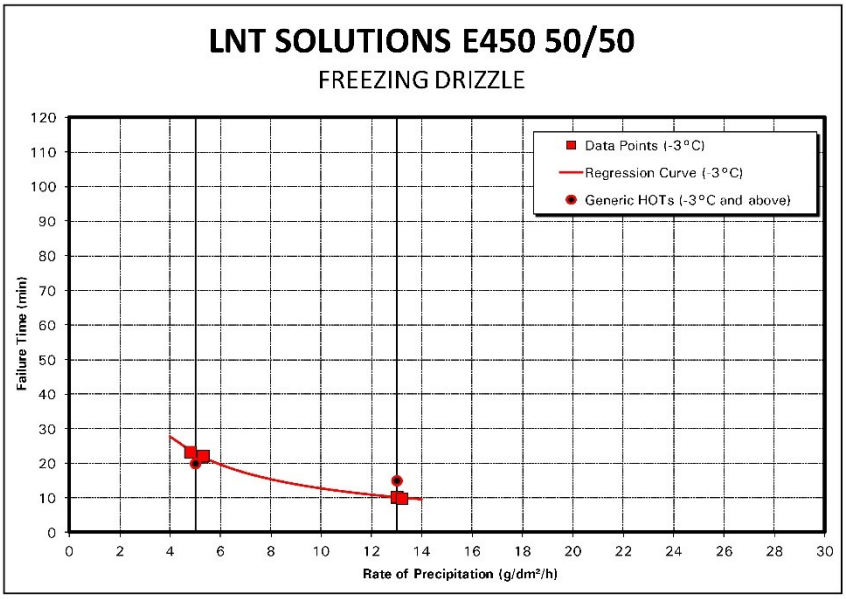

Figure 4.3: Type IV 50/50 – Freezing Drizzle

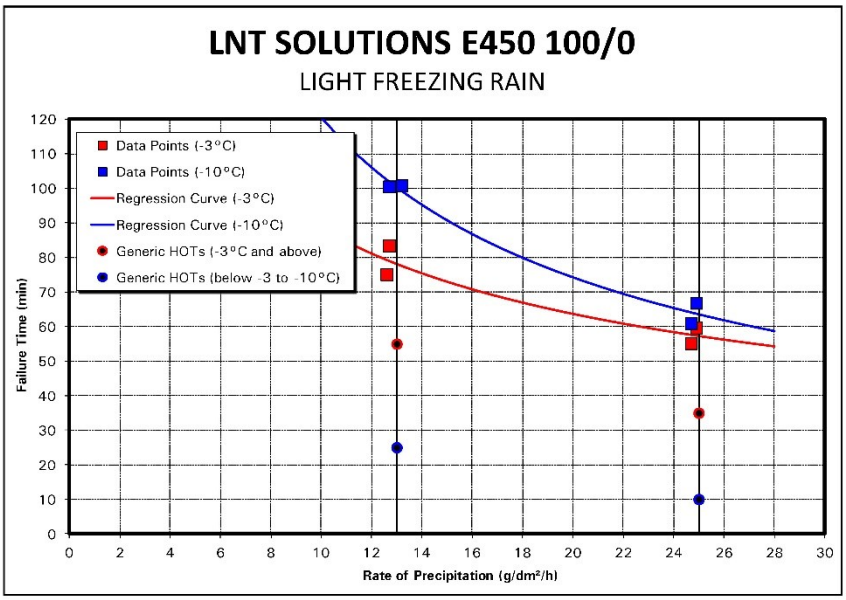

Figure 4.4: Type IV Neat – Light Freezing Rain

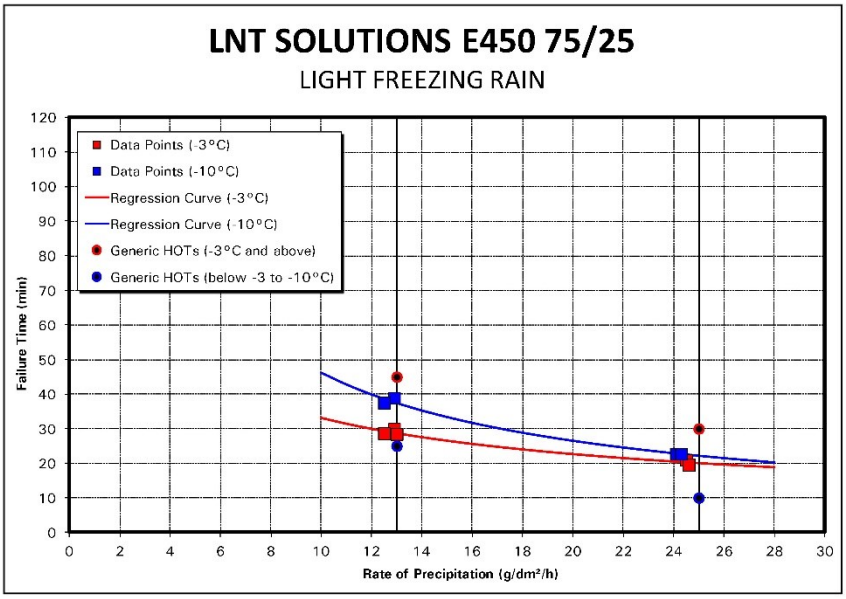

Figure 4.5: Type IV 75/25 – Light Freezing Rain

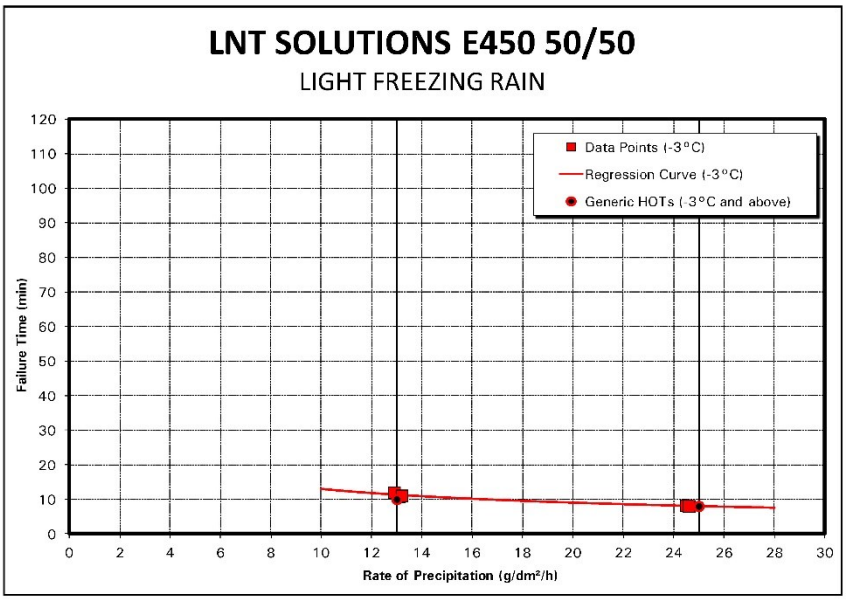

Figure 4.6: Type IV 50/50 – Light Freezing Rain

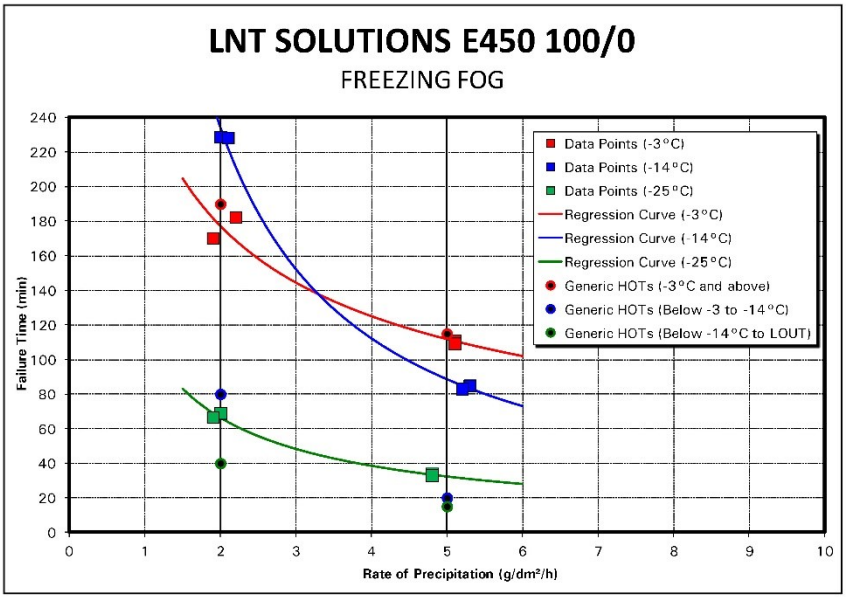

Figure 4.7: Type IV Neat – Freezing Fog

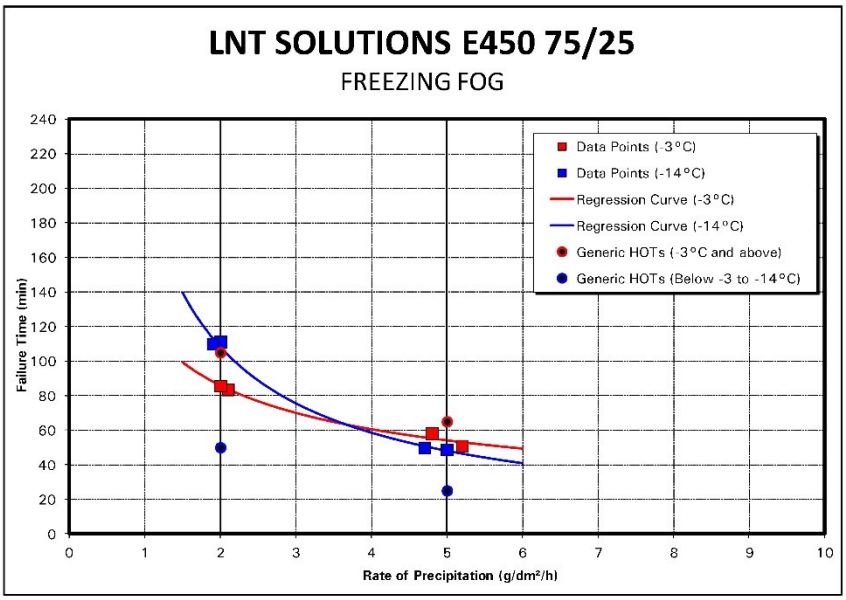

Figure 4.8: Type IV 75/25 – Freezing Fog

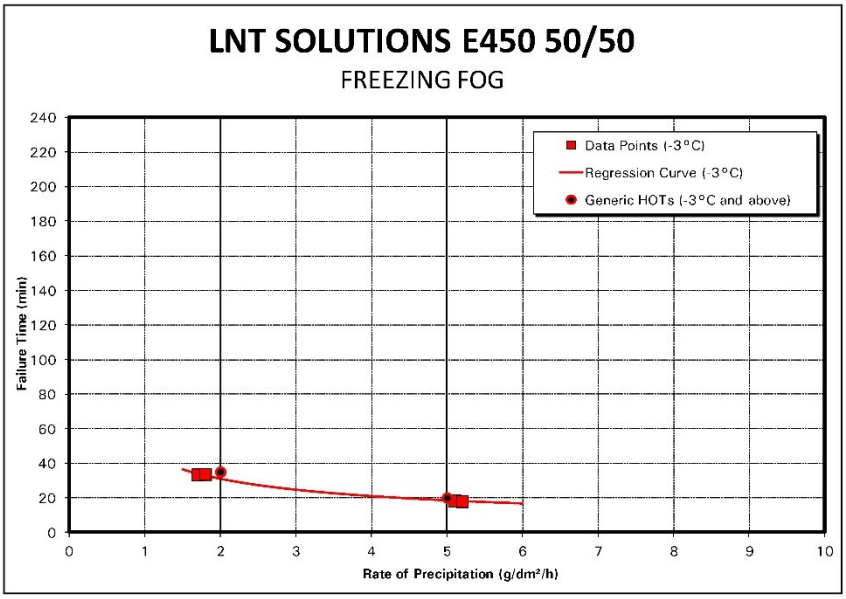

Figure 4.9: Type IV 50/50 – Freezing Fog

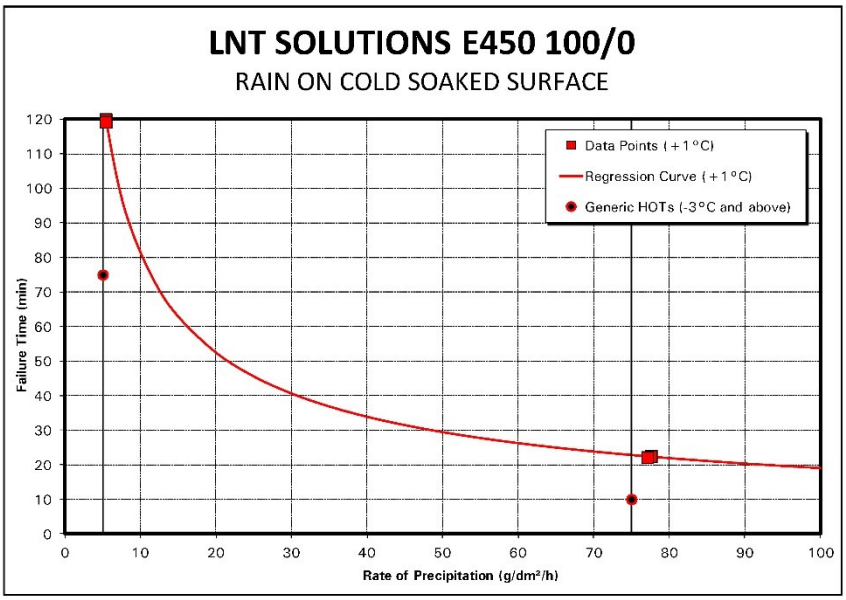

Figure 4.10: Type IV Neat – Rain on Cold-Soaked Surface

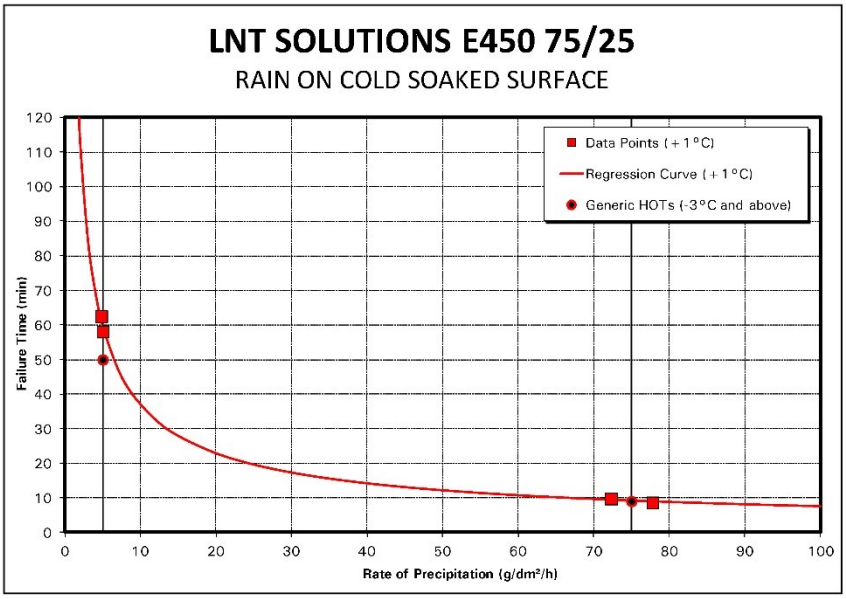

Figure 4.11: Type IV 75/25 – Rain on Cold-Soaked Surface

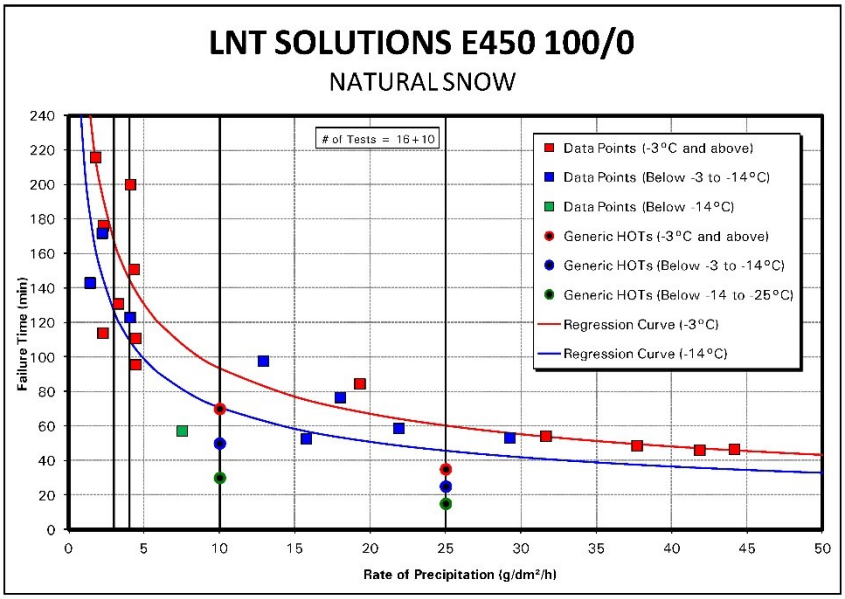

Figure 4.12: Type IV Neat – Natural Snow

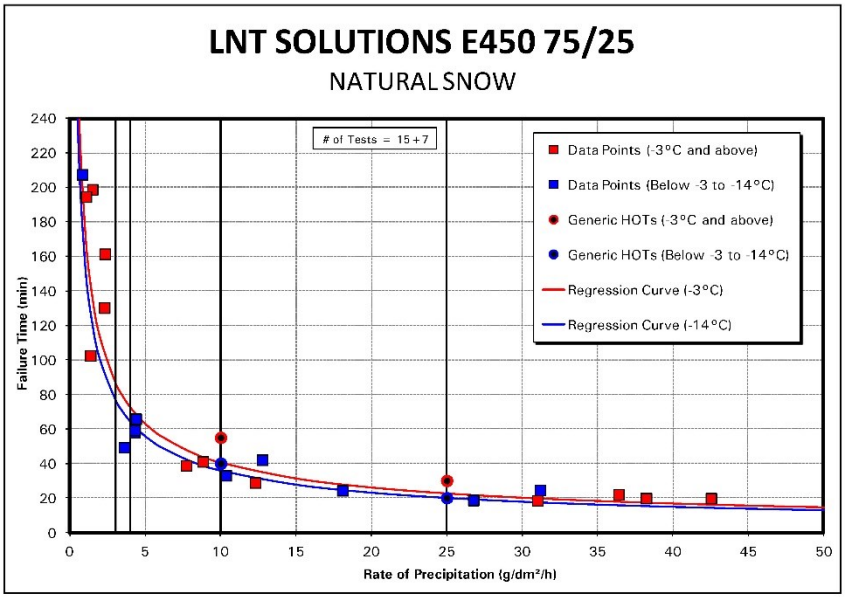

Figure 4.13: Type IV 75/25 – Natural Snow

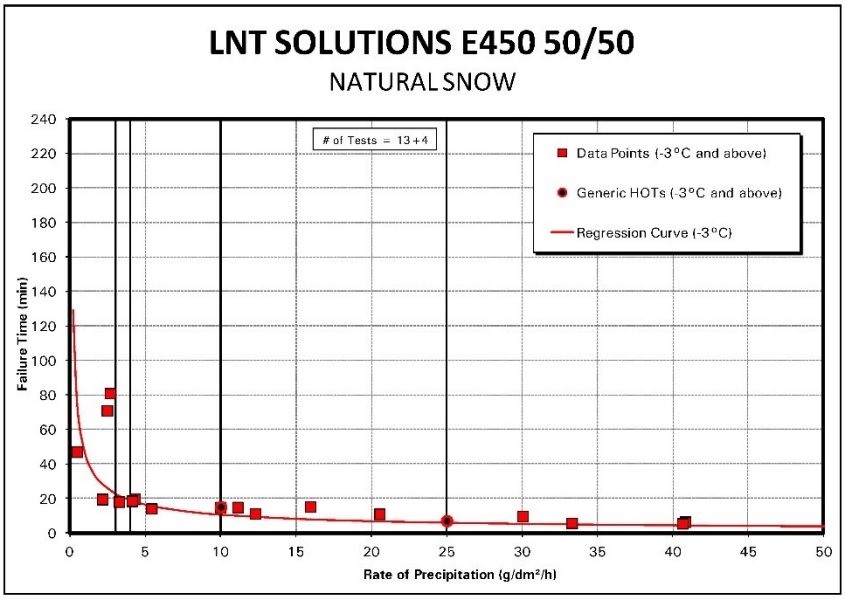

Figure 4.14: Type IV 50/50 – Natural Snow

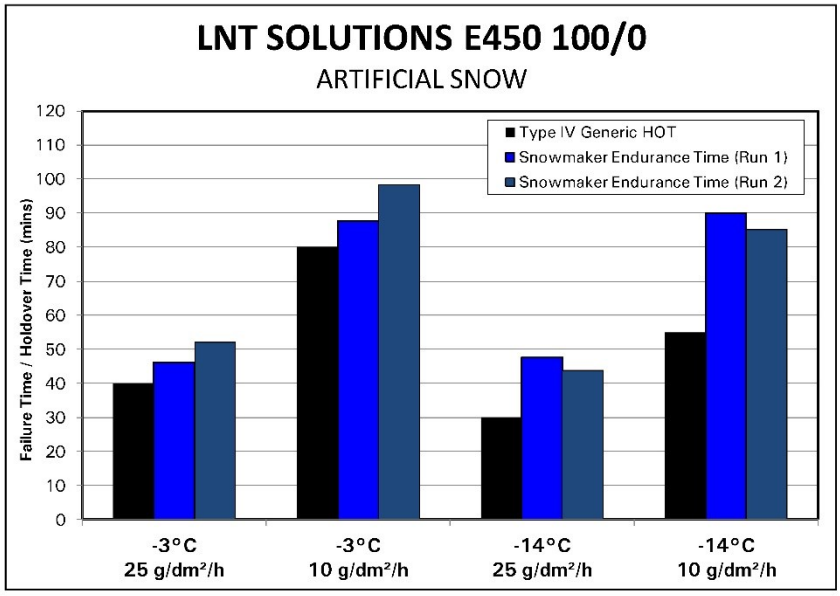

Figure 4.15: Type IV Neat – Artificial Snow

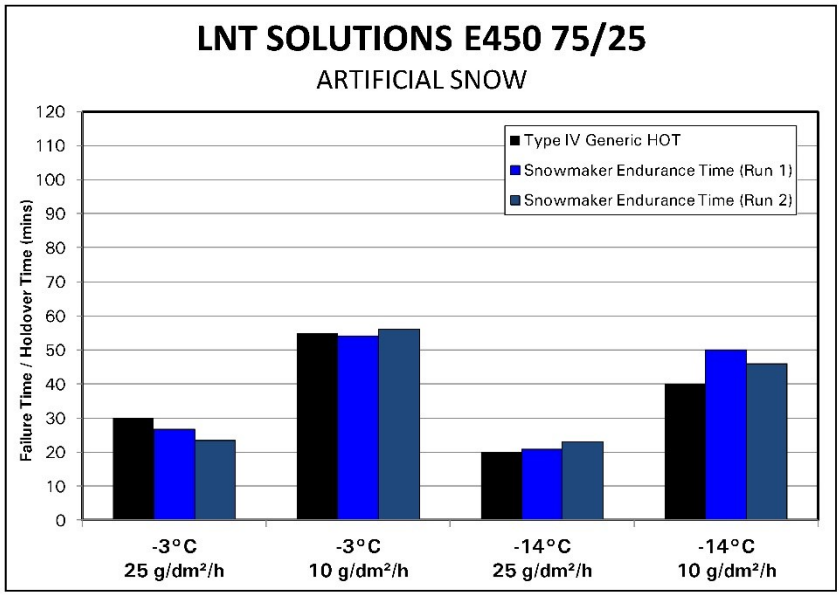

Figure 4.16: Type IV 75/25 – Artificial Snow

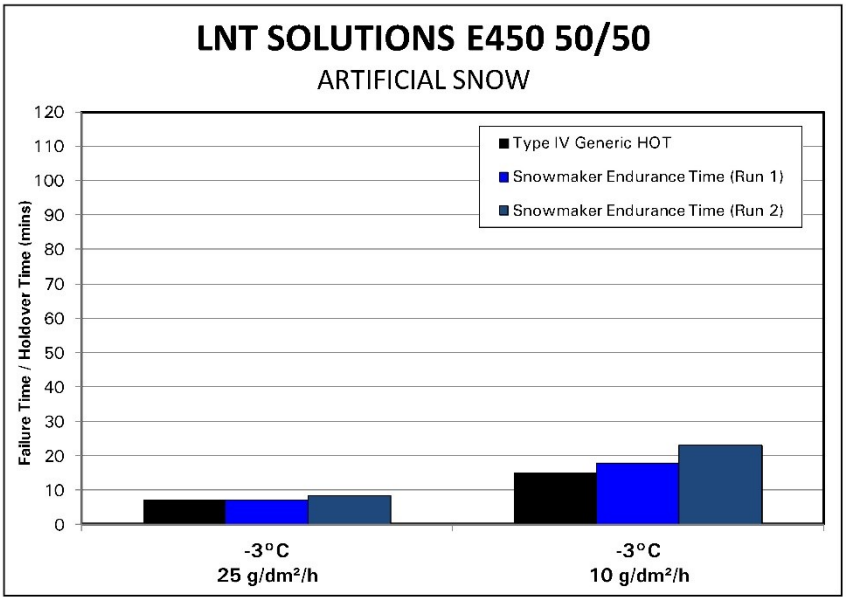

Figure 4.17: Type IV 50/50 – Artificial Snow

Table 4.1: Regression Equation Coefficients for LNT Solutions E450

Natural Snow Conditions

Fluid	Dil	R^2	Intercept (I)	Coeff. Rate (A)	Coeff. Tem (B)	Total Pts.
LNT Solutions E450	Neat	78%	2.6188	-0.4800	-0.2407	26
LNT Solutions E450	75%	92%	2.3175	-0.6376	-0.1042	22
LNT Solutions E450	50%	83%	2.2933	-0.6429	-0.9044	17

General Equation $t = 10^{I} R^{A} (2\text{-}T)^{B}$

Simulated Freezing Fog

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
LNT Solutions E450	Neat	-3°C	95%	2.3993	-0.5014	4
LNT Solutions E450	75/25	-3°C	98%	2.0846	-0.5009	4
LNT Solutions E450	50/50	-3°C	100%	1.6632	-0.5675	4
LNT Solutions E450	Neat	-14°C	100%	2.6898	-1.0623	4
LNT Solutions E450	75/25	-14°C	100%	2.2999	-0.8851	4
LNT Solutions E450	Neat	-25°C	99%	2.0571	-0.7805	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
LNT Solutions E450	Neat	-3°C	97%	2.2934	-0.2865	4
LNT Solutions E450	75/25	-3°C	97%	2.1746	-0.5983	4
LNT Solutions E450	50/50	-3°C	100%	1.9556	-0.8531	4
LNT Solutions E450	Neat	-10°C	98%	2.2217	-0.1785	4
LNT Solutions E450	75/25	-10°C	99%	2.2119	-0.5863	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
LNT Solutions E450	Neat	-3°C	92%	2.4233	-0.4763	4
LNT Solutions E450	75/25	-3°C	97%	2.0715	-0.5506	5
LNT Solutions E450	50/50	-3°C	96%	1.6334	-0.5205	5
LNT Solutions E450	Neat	-10°C	98%	2.7806	-0.6994	4
LNT Solutions E450	75/25	-10°C	99%	2.4725	-0.8070	4

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
LNT Solutions E450	Neat	+1°C	100%	2.5400	-0.6311	4
LNT Solutions E450	75/25	+1°C	100%	2.2576	-0.6915	4

General Equation $t = 10^{I} R^{A}$

Table 4.2: Fluid Specific Holdover Time Guidelines – LNT Solutions E450 (Transport Canada Format)

TABLE 4-L-E450

TYPE IV FLUID HOLDOVER TIME GUIDELINES
LNT SOLUTIONS E450

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:50 – 2:55	2:00	1:35 – 2:00	1:00 – 1:35	1:35 – 2:00	0:55 – 1:20	0:25 – 2:00	
		75/25								
		50/50							CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:30 – 3:55	1:50	1:10 – 1:50	0:45 – 1:10	1:45 – 2:00[7]	1:05 – 1:40[7]		
		75/25								
below -14 to -26.5	below 7 to -15.7	100/0	0:35 – 1:05	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. igh 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.**

Table 4.3: Fluid Specific Holdover Time Guidelines – LNT Solutions E450 (FAA Format)

TABLE 4M. TYPE IV HOLDOVER TIME GUIDELINES FOR LNT SOLUTIONS E450

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:50-2:55	2:25-2:45	1:35-2:25	1:00-1:35	1:35-2:00	0:55-1:20	0:25-2:00	
		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 -14	below 27 to 7	100/0	1:30-3:55	1:50-2:05	1:10-1:50	0:45-1:10	1:45-2:00[7]	1:05-1:40[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -26.5	below 7 to -15.7	100/0	0:35-1:05	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4.4: LUPR Statistics – LNT Solutions E450

Data Measure	100/0		75/25		50/50	
	Stat	Rating	Stat	Rating	Stat	Rating
Total Data Points	26	40	22	40	17	30
Data Points -3 to -14°C	12	30	10	20	n/a	0
Data Points < 10.0	16	40	12	40	8	30
Data Points < = 9.5	16	40	12	40	8	40
Data Points < = 8.5	16	40	11	40	8	40
Data Points < = 7.5	16	40	10	40	8	40
Data Points < = 6.5	15	40	10	40	8	40
Data Points < = 5.5	15	40	10	40	8	40
Data Points < = 4.5	15	40	10	40	7	40
Data Points < = 3.5	10	40	6	40	5	40
Data Points < = 2.5	7	40	6	40	3	40
Scatter 0-10 g	30%	10	22%	20	33%	10

Rate	100/0		75/25		50/50	
	Score	Pass/Fail	Score	Pass/Fail	Score	Pass/Fail
9 g/dm²/h	34	pass	33	pass	25	pass
8 g/dm²/h	34	pass	33	pass	25	pass
7 g/dm²/h	34	pass	33	pass	25	pass
6 g/dm²/h	34	pass	33	pass	25	pass
5 g/dm²/h	34	pass	33	pass	25	pass
4 g/dm²/h	34	pass	33	pass	25	pass
3 g/dm²/h	34	pass	33	pass	25	pass
2 g/dm²/h	34	pass	33	pass	25	pass

LUPR	100/0	75/25	50/50
	2 g/dm²/h	2 g/dm²/h	2 g/dm²/h

APPENDIX J

TRANSPORT CANADA AND FEDERAL AVIATION ADMINISTRATION HOLDOVER TIME GUIDELINES, WINTER 2015-2016

TRANSPORT CANADA
HOLDOVER TIME (HOT) GUIDELINES
WINTER 2015-2016

Transport Canada
Holdover Time (HOT) Guidelines
Winter 2015-2016

Original Issue, July 2015

This document should be used in conjunction with *Guidelines for Aircraft Ground-Icing Operations* (TP 14052E, second edition, April 2005).

The two documents complement each other and should be used together for a thorough understanding of the subject matter.

Questions or comments on the content of the holdover time guidelines should be addressed to
Transport Canada Civil Aviation Communication Centre
Telephone 1-800-305-2059 Facsimile 613-957-4208 E-mail services@tc.gc.ca

To receive notification of HOT Guideline updates, subscribe to or update your e-news subscription at the following Transport Canada Web site: http://wwwapps.tc.gc.ca/Comm/5/ListServ/menu.aspx
Subscribing to e-news will require an email address and selecting Holdover Time (HOT) Guidelines under Publications / Air Transportation / Aviation Safety - Safety Information.

CHANGE CONTROL RECORDS

This page indicates any changes made to individual pages within the document. Changed pages have the appropriate revision date in the footer. Sidebars are shown to assist in identifying where significant changes have been made on these pages.

It is the responsibility of the end user to periodically check the following website for updates on Holdover Time Guidelines: http://www.tc.gc.ca/eng/civilaviation/standards/commerce-holdovertime-menu-1877.htm.

REVISION	*DATE*	*DESCRIPTION OF CHANGES*	*AFFECTED PAGES*	*AUTHOR*

SUMMARY OF CHANGES FROM PREVIOUS YEAR

The principal changes from the previous year are briefly indicated herein.

Active Frost

- The active frost holdover time (HOT) guidelines are unchanged.

Type I Fluid

- The Type I HOT guidelines are unchanged.

Type II Fluid

- Fluid-specific HOT guidelines have been created for two new Type II fluids: Kilfrost ABC-Ice Clear II and Newave Aerochemical FCY-2 Bio+.
- Several of the LNT Solutions P250 snow holdover times have been increased as a result of supplemental testing.
- Clariant Safewing MP II 1951 has been removed from the Type II guidelines as per the protocol for removing obsolete fluids.
- Six changes (increases and decreases of up to five minutes) have been made to the Type II generic holdover times as a result of the new and removed Type II fluids.

Type III Fluid

- Fluid-specific, application temperature-specific, and aircraft rotation speed profile-specific HOT guidelines have been added for Type III fluids. This includes guidelines for the existing Type III fluid Clariant Safewing MP III 2031 ECO (applied heated) and for the new Type III fluid AllClear AeroClear MAX (applied unheated).
- Due to the different application temperature requirements of the two Type III fluids it is not possible to determine generic Type III holdover times. As a result, the Type III generic HOT guideline has been removed. Users must know which fluid brand is being used and use the appropriate Type III fluid-specific HOT guidelines when using Type III fluid.

Type IV Fluid

- Fluid-specific HOT guidelines have been created for the new Type IV fluid Deicing Solutions ECO-SHIELD®.
- Most of the LNT Solutions E450 snow holdover times have been increased as a result of supplemental testing.
- ABAX AD-480 and Kilfrost ABC-S have been removed from the Type IV guidelines as per the protocol for removing obsolete fluids.
- Significant changes, primarily increases, have been made to the Type IV generic holdover times as a result of the new and removed Type IV fluids.

Ice Pellet and Small Hail Allowance Times

- A new note has been added to the allowance time tables to indicate that if intensity is reported with small hail, the equivalent ice pellet condition can be used, i.e. if light small hail is reported, the light ice pellet allowance times can be used. If intensity is not reported, the moderate ice pellet allowance times must be used.
- Two new cautions have been added to the allowance time tables. These cautions provide important information directly on the allowance time tables, which was previously provided only in the allowance time operational guidance section. This is to highlight its importance to users.

Transport Canada / FAA Harmonization Initiative

- In late 2014, Transport Canada and the United States Federal Aviation Administration (FAA) initiated an effort to harmonize their holdover time guidelines documents. Several changes have been made as a result of this initiative, including:
  - Minor changes to wording of many holdover time table notes and cautions;
  - Rewording of some table titles, including holdover time tables and the visibility table;
  - Reordering of some document content;
  - Addition of background colours to the snow holdover time cells and visibility table cells – the colours are coordinated with snowfall intensities; and
  - Merging of the information previously provided in the list of fluids tested, table of lowest operational use temperatures (LOUTs) and table of lowest on-wing viscosities (LOWVs) into a single table (Table 8). The LOUT values in degrees Fahrenheit (°F) and fluid base information have also been added to this table.
- Harmonization efforts and discussions will continue over winter 2015-2016 and further changes are expected in future versions of this document.

Interpretation of METAR Codes GS/SHGS

- In winter 2014-2015, a section was added to TP 14052E (12.1.10) to provide guidance for determining which holdover times/allowance times should be used with METAR code GS. Further information has since been gained on this topic. The related guidance in TP 14052E has been updated accordingly. Notably:
  - When operating in Canada: snow holdover times can be used when METAR code GS is reported. Ice pellet / small hail allowance times must be used when METAR code SHGS is reported.
  - When operating outside of Canada: ice pellet / small hail allowance times must be used when GS or SHGS are reported.
  - If no intensity is reported with small hail, the moderate ice pellet allowance times must be used. If intensity is reported with small hail, the allowance times for the ice pellet condition with the equivalent intensity should be used.

Split Scimitar Wingtip Devices and Strakes

- Guidance has been added to TP 14052E related to split scimitar wingtip devices and strakes. This guidance is provided as additional text in section 10.6.2.4, “Areas to be Sprayed” and in new section 11.2.3.5, “Split Scimitar Wingtip Devices and Strakes.”

Note on Operations with Deployed Flaps/Slats

- Transport Canada is conducting research to provide additional guidance for aircraft operations with deployed flaps/slats. Transport Canada has determined that further research is necessary, therefore no changes to the operational and HOT guidelines with respect to deployed flaps/slats have been made for winter 2015-2016. Further guidance is available in the *Changes to TP14052E* (Section 12.3) provided in this document.

CHANGES TO *Guidelines for Aircraft Ground-Icing Operations* (TP 14052E, SECOND ED., APRIL 2005)

The following changes will be incorporated into TP 14052E at its next revision. They are recorded here in advance due to the longer life cycle time associated with the updating and publication of TP 14052E and are for immediate use.

Replace Sub-Paragraph 8.1.2 (2nd paragraph), "Fluid Description", with the following:

Anti-icing fluids are similar in composition except that they also contain polymeric thickeners. They are formulated to prevent formation of unabsorbed frozen contamination for a longer period of time than deicing fluids; however, the protection is still for a limited period of time. Although Type I fluids may be used for anti-icing, Type II, III and IV fluids are typically used in the anti-icing role because they can last for a significantly longer period of time than the Type I fluids.

Replace entire contents of Sub-Paragraph 8.1.4, "Certification Applicable to Qualified Fluids", with the following:

8.1.4 Acceptable Fluids

Transport Canada does not approve or qualify de/anti-icing fluids.

The aircraft manufacturer will generally indicate in the Aircraft Maintenance Manual the applicable industry specification for aircraft consumable materials. The industry fluid specifications for de/anti-icing fluids was discussed in Section 8.1.3.

The SAE specifications require numerous chemical and physical tests at a specialized laboratory. These tests are principally for measuring the compatibility of materials used in aircraft construction and the physical properties of the fluid against the appropriate SAE specification.

Also, the SAE specifications require a series of anti-icing and aerodynamic performance tests. The aerodynamic performance tests are conducted in a calibrated wind tunnel, in a specialized laboratory, for the purpose of measuring the aerodynamic and "flow off" characteristics of the fluid against the appropriate SAE specification.

Further, fluids undergo HOT evaluation to assess their HOT characteristics and establish the values for the HOT guidelines for that particular fluid.

Add the following Paragraph to 10.6.2.4, "Areas to be Sprayed", between item (e) and paragraph beginning "Care must be taken…":

Wingtip devices have various names including winglets, strakes, sharklets, or raked wingtips; these devices are considered critical surfaces given they are part of the wing surface. A new wingtip device element, the strake has been introduced and is part of the split scimitar. The strake is installed outboard of the vertical component of the wingtip device and extends downward and therefore cannot be observed from inside the aircraft.

Replace Sub-Paragraph 10.4 (6th paragraph), "Procedure Selection", with the following:

The temperature of cold soaked wings can be considerably below the ambient temperature; therefore frost can build up in localized areas. When active frost is anticipated, the holdover times will be shortened when the wings are cold soaked, particularly when using Type I fluids. Consider applying SAE Type II or IV fluid to the surfaces as these will provide greater holdover times than Type I, along with better safety margins to prevent frost accumulation. Both wings should receive a symmetrical treatment for aerodynamic reasons.

Replace Sub-Paragraph 10.4.2 (2nd paragraph), "Two Step De/Anti-Icing", with the following:

If a two-step procedure is used, the first step is typically performed using a deicing fluid; however, alternate deicing technology or mechanical methods may be used depending on the circumstances. The selection of fluid

type and concentration depends on the ambient temperature, the weather conditions and the desired holdover time. When performing a two-step process, the freezing point of a fluid used for the first step must not be more than 3°C above ambient temperature. The freezing point of an SAE Type I fluid used for a one-step process, or as the second step of a two-step operation, must be at least 10°C below the ambient temperature. The second step is to be performed before the first step freezes, typically within 3 minutes. This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area. When deicing fluid is used in step 1, the application of the second step fluid will flush away the first step fluid and leave a film of anti-icing fluid, which is designed to be of adequate thickness. If freezing of the deicing fluid has occurred, step 1 must be repeated. Refer to the SAE ARP 4737 document for additional details.

Add Sub-Paragraph 10.8.1, "De/Anti-icing Fluid Compatibility with Runway Deicer", as follows:

Recent research showed that when thickened aircraft anti-icing fluid came in contact with minimal amounts of runway deicing fluids (formate or acetate based), anti-icing protection provided by the aircraft anti-icing fluid could be diminished. The separation of the thickening agents in this fluid consequently reduce holdover time.

This can occur when fluids from the runway are splashed onto the wing by the nose gear wheels or from the use of engine thrust reversers at landing prior to when the aircraft is anti-iced using a one-step process as protection for the next flight. Additional tests also showed that when using a two-step de/anti-icing process, the application of the first step cleans off the contamination from the runway deicing fluid so that the anti-ice protection provided with the second step is not affected by the runway deicing fluids. Therefore, it is recommended that de/anti-icing applications be performed using a two-step process.

Replace Sub-Paragraph 10.11, "Applying Anti-Icing Fluid in a Hangar", with the following:

There are operational conditions when air operators may choose to anti-ice their aircraft while the aircraft is in a heated hangar. This is one way to reduce the consumption of deicing fluid and to minimize the environmental impact of deicing.

The period of time after fluid application and the air temperature in the hangar both have an effect on the ability of the fluid to protect the aircraft when it is pulled out of the hangar and into freezing/frozen precipitation. The HOT for a fluid is based largely on the fluid's thickness on the surface. The fluid thickness varies with time and temperature. Unless otherwise approved in an air operator's program, the holdover time clock must be started at the time of the first application of anti-icing fluid onto a clean wing. It may not be started when the aircraft is first exposed to freezing/frozen precipitation.

Replace Sub-Paragraph 10.12.1 (5th paragraph), "Brooms", with the following:

Using the wing broom to remove contamination does not always mean that the wing surface is clean and safe for flight. Every time a broom is used to remove contamination, a tactile inspection must be performed.

Replace Sub-Paragraph 10.13.3, "Hot Water", with the following:

Hot water may be used to remove large amounts of contamination (such as ice) from an aircraft, provided that the Outside Air Temperature is -3°C and above as per the application procedures for SAE Type I, II, III and IV fluids described in tables 6 and 7 of the Transport Canada HOT Guidelines document.

Delete Sub-Paragraph 10.13.3.1 Item g) only.

Replace entire contents of 10.13.5 to 10.13.5.4 with the following:

10.13.5 Ground Ice Detection Systems (GIDS)

The development of ground ice detection sensors has been stimulated by the difficulty in determining whether an aircraft is free of frozen contaminants prior to takeoff. Humans have a limited ability to accurately evaluate the condition of an aircraft's critical surface during ground icing operations. Impediments to ensuring the aircraft

is free of frozen contaminants include poor lighting conditions, visibility restrictions due to blowing snow, and the difficulty in determining whether clear ice is present.

For the purposes of this document, these sensors are referred to as Remote on Ground Ice Detection Systems (ROGIDS). A Minimum Operational Performance Specification (MOPS) for these systems is identified in the SAE document AS 5681.

Air operators or service providers seeking authorization to incorporate ROGIDS into their operations should consult Transport Canada Advisory Circular AC 602-001, "Operational Use of Remote on Ground Ice Detection Systems (ROGIDS) for Post De-icing Applications". This document is available at the following website:

https://www.tc.gc.ca/eng/civilaviation/opssvs/managementservices-referencecentre-acs-600-602-001-492.htm

Add the following paragraph to the end of Sub-Paragraph 11.1.1:

The values in the Type II and Type IV generic holdover time guidelines (Table 2-Generic, Table 4-Generic) are the shortest (worst case) holdover times of all Type II or all Type IV fluids included on the Transport Canada List of Fluids. These values are specific to precipitation condition, temperature range, fluid concentration, and precipitation rate. An analysis of all available Type II and Type IV fluids is done annually to determine these values. The generic holdover times must be used if the specific Type II or Type IV fluid being used cannot be positively determined. Note: The lowest on-wing viscosity (LOWV) of the fluid being used must always be respected, even when the generic Type II or Type IV holdover times are used.

Replace Sub-Paragraph 11.1.2, "Current Holdover Time Guidelines", with the following:

Current HOT Guidelines can be found at the following website:
http://www.tc.gc.ca/eng/civilaviation/standards/commerce-holdovertime-menu-1877.htm

The following information can be found at the above website:

a) Active Frost HOT Guidelines;
b) Type I Fluid Generic HOT Guidelines;
c) Type II Fluid HOT Guidelines;
d) Type III Fluid HOT Guidelines;
e) Type IV Fluid HOT Guidelines;
f) Snowfall Intensities as a Function of Prevailing Visibility;
g) Ice Pellet and Small Hail Allowance Times.
h) List of Fluids Tested for Anti-Icing Performance and Aerodynamic Acceptance;
i) SAE Type I De/Anti-Icing Fluid Application Procedures;
j) SAE Types II, Type III and Type IV De/Anti-Icing Fluid Application Procedures;

Replace Sub-Paragraph 11.1.4.1 a) "Estimating the Precipitation Rate" with the following:

The METAR/SPECI reported snowfall intensity is based only on observed visibility in accordance with the Environment Canada MANOBS. Scientific research has demonstrated that the use of observed visibility in snow as the sole criteria in the MANOBS, for establishing snow intensity is not accurate enough for use with the holdover time guidelines. The evidence indicates that a visibility and temperature pair needs to be used for establishing the more accurate snowfall intensity required for use with the holdover time guidelines.

The highest snowfall intensities occur near 0°C. It has also been determined that during night time snowfall conditions, for the same snowfall intensity, visibility is about twice as good as it is during the day (i.e. one can see further at night than during the day for the same snowfall intensity). This factor must be considered in estimating the snowfall intensity.

The relationship between visibility and snowfall intensity was analyzed and is documented in TP14151E. The relevant information from TP14151E is contained in the Transport Canada "Snowfall Intensities as a Function of Prevailing Visibility" table contained in the holdover time guidelines.

The METAR/SPECI reported visibility or flight crew observed visibility will be used with the "Snowfall Intensities as a Function of Prevailing Visibility" table to establish snowfall intensity for Type I, II, III and IV holdover time

guidelines, during snow, snow grain, or snow pellet precipitation conditions.

The "Snowfall Intensities as a Function of Prevailing Visibility" table, should also be used when snow, snow grains or snow pellets are accompanied by blowing or drifting snow in the METAR/SPECI.

Examples:

CYUY 161300Z 26005KT 1SM -SN OVC015 M01/M05 A2964

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

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

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

Rarely, there may be circumstances where the METAR/SPECI reported visibility or flight crew observed visibility is substantially reduced due to obscuration conditions such as fog, mist, freezing fog, dust, haze, or smoke. These obscuration conditions contribute very little to the overall catch rate at the wing surface and using the "Snowfall Intensities as a Function of Prevailing Visibility" table, would likely over estimate the snow fall intensity.

Under these conditions and with a careful assessment by the flight crew to ensure that the obscuration conditions are not concealing significant snowfall intensities, the METAR/SPECI reported snowfall intensity can be used.

Example:

CYTS 231000Z 21003KT ½ SM SN FZFG OVC003 M03/M03 A2969

In the above METAR, the snowfall intensity is reported as moderate. Based on the Transport Canada "Snowfall Intensities as a Function of Prevailing Visibility" table, with a visibility of ½ statute mile, in darkness and a temperature of -3°C, the snowfall intensity is classified as heavy. However, since freezing fog is present as an obscuring condition, a moderate snowfall intensity (as reported in the METAR) can be used to determine which HOT Guideline value is appropriate for the fluid in use, provided the crew can ensure that the obscuration is not concealing significant snowfall intensities.

NOTE: The Transport Canada "Snowfall Intensities as a Function of Prevailing Visibility" table can be found along with the current HOT Guidelines through the Transport Canada website: www.tc.gc.ca.

Use of Runway Visual Range (RVR) with the Snowfall Intensities as a Function of Prevailing Visibility Table

There has been some confusion regarding the values indicated below the visibility (in parentheses) in the Snowfall Intensity table. The values indicated in parentheses refer to the visibility in metres and not an RVR.

RVR should not be used to determine visibility for the following reasons:

a) RVR transmissometers were never intended to measure visibility with respect to snowfall intensity for use with holdover time guidelines.

b) The RVR equipment is designed to provide pilots with an expected visual range along the runway, based on an associated runway edge and centerline lighting intensity. For a given obscuration phenomenon and precipitation intensity (fog, snow, etc.) the RVR will vary based on the selected runway lighting level. Therefore multiple RVR are possible for a given condition even though the meteorological conditions remain the same.

c) Furthermore RVR's in excess of 6000 ft are simply reported as 6000+. This level of resolution, only allows limited use of the Snowfall Intensity table (for example in darkness and at a temperature of -1°C and an RVR of 6000+, the only conclusion that can be drawn from the Snowfall Intensity table is that we are not in heavy snow, and that we could be in Moderate, Light or Very Light Snow conditions).

Varying Weather Conditions After Completion of Anti-Icing Procedure

During periods when the weather conditions are varying after completion of the anti-icing procedure, crews should reassess the previously selected holdover time. When doing so crews need to consider the following:

1) Improving weather conditions – if the snowfall intensity decreases, the original HOT should be retained;

2) Worsening weather conditions – if the snowfall intensity increases, a new lower HOT should be established and used.

Replace Sub-Paragraph 11.1.5, "Elapsed time is less than the lowest time in the HOT cell", with the following:

Transport Canada has previously considered that, under an approved ground icing program, if the lowest time in a cell has NOT been exceeded for conditions covered by the Guidelines, there is no requirement to inspect the aircraft's critical surfaces prior to commencing a takeoff.

This position was based on evidence gained during fluids testing. The HOT values are conservative for the lowest number in the cell, if:

a) The conditions present are NOT in excess of those conditions represented by the table (e.g. for snow, it would be a moderate snow condition); and

b) The impact of other factors (e.g. jet blast) has been considered and deemed not to affect the HOT.

If there is doubt surrounding the conditions associated with using the lowest time as a decision-making criterion, an inspection prior to takeoff would be prudent. This inspection should be conducted in accordance with the procedures described in the Air Operator's Approved Ground Icing Program.

Replace Sub-Paragraph 11.1.8, "Meteorological Conditions for which the HOT Guidelines are not applicable", with the following:

The HOT Guidelines do not include guidelines for all meteorological conditions. Holdover time guidelines have not been assessed for the following conditions: a) Hail; b) Moderate and Heavy Freezing Rain; and c) Heavy Snow.

Note: Operators need to assess whether operations can be safely conducted under these conditions.

Additionally, holdover time guidelines have not been assessed for Ice Pellets or Small Hail, since a formal protocol for this testing has not yet been developed and included in standard SAE testing methodologies and no visual failure criteria have yet been identified for these conditions. Instead, allowance times have been developed for operations during ice pellet conditions as a result of research carried out by Transport Canada and the FAA. As it has been determined small hail is equivalent to ice pellets, allowance times are also provided for small hail conditions.

Replace entire contents of Sub-Paragraph 11.1.9, "Use of approved fluids", with the following:

11.1.9 Use of De/Anti-icing Fluids

The operator is ultimately responsible for ensuring that only fluids tested to SAE AMS 1424 or SAE AMS 1428 are applied when the HOT Guidelines will be utilized operationally.

The Transport Canada Holdover Time Guidelines document, published on an annual basis, contains lists of fluids that have been tested with respect to anti-icing performance (SAE AMS 1424 or SAE AMS 1428) and aerodynamic acceptance (SAE AMS 1424 or SAE AMS 1428) only.

Therefore, the end user is cautioned that they must confirm that other SAE AMS 1424 or SAE AMS 1428 technical requirement tests such as fluid stability, toxicity, materials compatibility, etc. have been conducted. The fluid manufacturer will supply all samples for testing and, is responsible for obtaining independent laboratory confirmation of conformance to these requirements of AMS 1424 or AMS 1428. The fluid manufacturer should provide certificates of conformance upon request.

Add Sub-Paragraph 11.1.12, "Type I HOT Guidelines for Aircraft with Critical Surfaces Constructed Using Composite Materials", as follows:

The recent introduction of new aircraft constructed primarily with composite materials required a review of Type I fluid holdover time performance when used on these aircraft. This review has shown that the holdover time performance of Type I fluids on composite surfaces is reduced when compared to aluminum surfaces. Type I fluid holdover time evaluations were conducted and holdover times have been developed for use with aircraft critical surfaces constructed primarily with composite materials.

It is not the intent that the composite holdover times be used on aircraft where previous experience has shown the acceptable use of aluminum holdover times (unless those aircraft have predominately or entirely composite critical surfaces). If there is any doubt, consult with the aircraft manufacturer to determine whether to use aluminum or composite holdover times.

Add Sub-Paragraph 11.1.13, "Longer Holdover Times for 75/25 Dilutions", as follows:

For some brand-specific fluids, protection is increased in some cells when fluid concentration is reduced. The addition of certain quantities of water to some neat fluids can enhance their performance up to a certain point. Without knowing about this particular fluid mix phenomenon, an operator may think that the data presented in the tables are in error.

Add Sub-Paragraph 11.1.14, "Holdover Times for Non-Standard Dilutions of Type II, III and IV fluids", as follows:

When a Type II, III, or IV fluid is diluted to other than the published 100/0, 75/25 or 50/50 dilutions, the more conservative holdover time and LOUT associated with either the dilution above or below the selected dilution are applicable.

For example:

1) The holdover time and LOUT of a 80/20 dilution would be the more conservative holdover time and LOUT of either the 100/0 or 75/25 dilutions;
2) The holdover time and LOUT of a 60/40 dilution would be the more conservative holdover time and LOUT of either the 75/25 or 50/50 dilutions.

Add Subparagraph 11.2.3.5, "Split Scimitar Wingtip Devices and Strakes", as follows:

Wingtip devices have various names including winglets, strakes, sharklets, or raked wingtips; these devices are considered critical surfaces given they are part of the wing surface. A new wingtip device element, the strake, has been introduced and is part of the split scimitar. The strake is installed outboard of the vertical component of the wingtip device and extends downward and therefore cannot be observed from inside the aircraft.

Manufacturers may designate the upper inboard surface of the vertical element of the wingtip device as a representative surface to assure no frozen contamination is present. The anti-icing procedures specified require this inboard surface to be anti-iced first starting at the top and working downward. The strake is anti-iced after the inboard surface application is completed. A visual scan of the designated representative surface (upper inboard surface of the vertical element of both wingtips) is required prior to take-off as part of the pre-take-off inspection. This paragraph applies only to aircraft with split scimitar wingtip devices. This guidance will be revised when new wingtip types become available.

Replace Sub-Paragraph 12.1.2, "Ice Pellet Conditions", with the following:

Holdover time guidelines have not been assessed for ice pellets, since a formal protocol for ice pellet testing has not yet been developed and included in standard SAE testing methodologies and no visual failure criteria have been identified for ice pellet conditions.

However, comprehensive ice pellet research was conducted jointly by the research teams of the FAA and Transport Canada. This research consisted of extensive climatic chamber, wind tunnel, and live aircraft testing with ice pellets (light and moderate) and light ice pellets mixed with other forms of precipitation. Results of this research provide the basis for allowance times for operations in light and moderate ice pellets, as well as allowance times for operations in light ice pellets mixed with other forms of precipitation.

Replace Sub-Paragraph 12.1.6, "Cold Dry Snow Falling on a Cold Dry Wing", with the following:

12.1.6 Cold Dry Snow (or Ice Crystals) Falling on a Cold Dry Wing

Conditions are encountered whereby cold dry snow (or ice crystals) is falling onto the cold wing of an aircraft. The wind often causes the snow (or ice crystals) to swirl and move across the surface of the wing and it is evident that the snow (or ice crystals) is not adhering to the wing surface. Under these circumstances the application of deicing/anti-icing fluid to the wing of the aircraft would likely result in the snow (or ice crystals) sticking to the fluid. Under such operational conditions it may not be prudent to apply fluids to the wing.

However, if snow or ice crystals have accumulated at any location on the wing surface it must be removed prior to take-off. It cannot be assumed that snow or ice crystals on a wing will "blow off" during the take-off. For example, refueling with fuel warmer than the wing skin temperature may create a condition whereby previously non adhering contaminants may adhere to the wing surfaces.

Replace entire contents of Sub-Paragraph 12.1.7 "Frost", with the following:

12.1.7 Frost

Frost occurs frequently during winter operating conditions. Frost due to radiation cooling is a uniform thin white deposit of fine crystalline texture, which forms on exposed surfaces that are below freezing, generally on calm cloudless nights where the air at the surface is close to saturation. When the deposit is thin enough for surface features underneath the frost, such as paint lines, markings and lettering, to be distinguished it is often referred to as hoarfrost. Frost can also form on the upper or lower surfaces of the wing due to cold soaked fuel. Frost has the appearance of being a minor contaminant and therefore does not offer the same obvious signal of danger as do other types of contamination such as snow or ice. However, frost is an insidious threat to the safety of aircraft operations because it always adheres to the aircraft surface, is rough and causes significant lift degradation and increased drag.

12.1.7.1 Active Frost

Active frost is a condition when frost is forming. During active frost conditions, frost will form on an unprotected surface or re-form on a surface protected with de/anti-icing fluid where the holdover time has expired.

Frost forms whenever the exposed surface temperature cools below OAT to, or below, the frost point (not dew point). The mechanisms for cooling include:

1) radiation cooling; or

2) conductive cooling (due to cold soaked fuel).

If the exposed surface temperature is equal to or below the frost point, frost will begin to accrete on the surface. Once formed, residual accreted frost may remain after the active frost phase if the exposed surface temperature remains below freezing.

12.1.7.2 Dew Point and Frost Point

The dew point is the temperature at a given pressure to which air must be cooled to cause saturation. The dew point can occur below or above 0°C.

The frost point is the temperature, at or below 0°C (32°F), at which moisture in the air will condense as a layer of frost on an exposed surface. The frost point occurs between the OAT and dew point.

METAR does not report frost point; however, it does report dew point. The frost point is higher (warmer) than the dew point for a given humidity in the air. The frost point and the dew point are the same at 0°C; at a dew point of -40°C, the frost point is 3.2°C warmer (-36.8°C). The following table provides further examples of the correlation between dew point and frost point.

Dew Point Temperature (°C)	Frost Point Temperature (°C)
0	0.0
-5	-4.4
-10	-8.9
-15	-13.5
-20	-18.0
-25	-22.7
-30	-27.3
-35	-32.1
-40	-36.8

12.1.7.3 Radiation Cooling

Radiation cooling will generally occur during clear sky (e.g. SKC, high FEW or high SCT), low wind (e.g. less than 10 knots), and low light (e.g. shade, at night or in low angle / obscured sun) conditions. These conditions will cause the exposed surface temperature to cool below the OAT. Once the exposed surface temperature cools to the frost point or below, active frost occurs.

Certain surface finishes and material compositions may be more susceptible to radiation cooling, and as a result, different areas of an aircraft may begin to accrete frost at different times. Radiation cooling can cause an exposed surface to cool several degrees below the OAT; therefore, frost can form on an exposed surface at an OAT several degrees above 0°C.

Depending on conditions, time to frost formation may range from minutes to hours. As a result, a surface that appears free of frost during an early inspection may become contaminated later. When conditions are favorable for active frost formation, a direct inspection of critical surfaces conducted as close as possible to the departure time is recommended.

12.1.7.4 Cold Soaked Fuel Cooling

Cold soaked fuel cooling results from conductive cooling due to very cold fuel on board at destination or from refueling with fuel that may be cooler than the OAT. Cold soaked fuel conditions are highly variable and therefore, only direct surface temperature readings are accurate, but not available at most stations. Fuel temperature does not accurately predict cold soaked fuel conditions but may provide an initial indication, particularly in the period after landing and prior to fuelling. The presence of frost under the wing is a good indication of cold soaked fuel conditions.

In extreme cases, cold soaking may reduce the surface temperature below the fluid LOUT and cause aerodynamic performance degradation due to fluid freezing or the inability of the fluid to adequately flow off the treated surface.

12.1.7.5 Combined Radiation and Cold Soaked Fuel Cooling Effects

Cold soaked fuel cooling combined with radiation cooling effects can cause reductions in active frost holdover times. This is particularly true for Type I fluid holdover times as these are shorter in duration, and therefore use of a thickened anti-icing fluid should be considered.

12.1.7.6 De/Anti-Icing in Active Frost Conditions

Frost reforming after removal is an indication of active frost. During active frost, anti-icing protection is required and operations should be conducted in accordance with holdover time guidelines and minimum fluid quantity and temperature application procedures therein. Applications such as misting or mopping of Type I fluid may not provide adequate heat or fluid quantity to use the holdover times in active frost conditions.

In active frost conditions, deicing alone is insufficient, therefore, once the frost has been removed, a preventative anti-icing coating is required.

12.1.7.7 Fluid Holdover Times for Active Frost Conditions

Fluid holdover times in active frost conditions differ from holdover times in other conditions as they incorporate an allowance for the temperature differential (typically 6 to 8°C) between the OAT and the exposed surface temperature due to radiation cooling. As a result of this allowance, the OAT should be used to determine the appropriate active frost holdover time.

Active frost holdover times may be reduced in the presence of combined cooling effects or extreme surface cooling. In extreme cases, the surface temperature may be below the fluid LOUT and cause aerodynamic performance degradation due to fluid freezing or the inability of the fluid to adequately flow off the treated surface.

12.1.7.8 Frost on the Underside of the Wing

CAR 602.11(3) states: Notwithstanding subsection (12.1.7.9), a person may conduct a take-off in an aircraft that has frost adhering to the underside of its wings that is caused by cold-soaked fuel, if the take-off is conducted in accordance with the aircraft manufacturer's instructions for take-off under those conditions.

12.1.7.9 Frost on the Fuselage

Despite the requirement to clean contamination from critical surfaces, it is acceptable for aircraft, including those with aft fuselage mounted engines, to take-off when hoarfrost is adhering to the upper surface of the fuselage if it is the only remaining contaminant, provided all vents and ports are clear. Contact the aircraft manufacturer for further details.

Add Sub-Paragraph 12.1.9, "Hail and Small Hail", as follows:

The meteorological conditions "Hail" and "Small Hail" are different. Hail is a more intense condition for which holdover times do not exist. Small hail is a lighter condition, meteorologically equivalent to ice pellets, for which allowance times are provided.

Add Sub-Paragraph 12.1.10, "Small Hail / Snow Pellets (METAR Codes GS/SHGS)", as follows:

The World Meteorological Organization (WMO) states METAR code GS is used for two meteorological conditions: "snow pellets" and "small hail." Different holdover times/allowance times apply in these two weather conditions. If the weather condition is snow pellets, the snow holdover times are applicable. If the weather condition is small hail, the ice pellet and small hail allowance times are applicable. Furthermore, the ice pellet and small hail allowance times are applicable if the prevailing weather condition between "snow pellets" and "small hail" cannot be determined given that these are more restrictive than the snow holdover times.

It has been determined that Canada does not follow the WMO standard for reporting these two weather conditions. In Canada, METAR code GS is used exclusively for snow pellets; METAR code SHGS with remarks is used to report small hail (METAR code SHGS without remarks is snow pellet showers). Therefore, different holdover times / allowance times apply when these METAR codes are reported in Canada as compared to other countries including the United States.

In addition, there are differences between countries in whether or not intensity is reported with small hail. in Canada, the United States and most other countries, no intensity is reported with small hail. In some other countries, e.g. Japan, intensity is reported with small hail.

Based on this information and Canadian air operator feedback, the following guidance must be followed.

When operating in Canada:

- When METAR code GS is reported: the condition is snow pellets and the snow holdover times should be used.
- When METAR code SHGS (with or without remarks) is reported: the condition is either snow pellet showers or small hail and the appropriate ice pellet and small hail allowance times should be used.

When operating in the United States / International:

- When METAR code GS or SHGS is reported: the condition could be snow pellets or small hail; the ice pellet/small hail allowance times should be used.

Determining appropriate allowance times for Small Hail:

- If no intensity is reported with small hail, the moderate ice pellet allowance times must be used. If an intensity is reported with small hail, the allowance times for the ice pellet condition with the equivalent intensity should be used, e.g. light small hail = light ice pellets, moderate small hail = moderate ice pellets.

Replace Sub-Paragraph 12.3 (5th paragraph), "Configuration During Deicing Procedures", with the following:

Two possible options are: delaying slat/flap deployment until just prior to take-off; or deploying the devices prior to de/anti-icing so that the surfaces under these devices are treated. With the second option, the holdover time and allowance time will be reduced due to the steeper angles of the slat/flap in the deployed configuration.

Delaying the slat/flap deployment may be the preferred option for optimum protection from ice buildup. If it is necessary to remove contamination from the slats/flaps, it may be best to deploy the slats/flaps for deicing and anti-icing and then retract them prior to taxi. Consult the Aircraft Operating Manual and/or aircraft manufacturer for more details.

Replace Sub-Paragraph 12.6.7 (e), "Recommended "Clean Aircraft Concept" Practices", with the following:

e) The general rule for ground icing procedures is that the deicing and anti-icing processes must be done symmetrically. That is, whatever final treatment (i.e. same brand name fluid) is administered on one wing must be applied to the other wing for aerodynamic symmetry reasons.

Add the following definitions to Section 18 "Glossary":

Lowest On-Wing Viscosity
Lowest viscosity of a fluid for which the applicable holdover time table can still be used.

Maximum On-Wing Viscosity
Maximum viscosity of a fluid which is still aerodynamically acceptable.

HOLDOVER TIME (HOT) GUIDELINES FOR WINTER 2015-2016

Table 0	Active Frost Holdover Time Guidelines
Table 1-A	SAE Type I Fluid Holdover Time Guidelines on Aluminum Wing Surfaces
Table 1-C	SAE Type I Fluid Holdover Time Guidelines on Composite Wing Surfaces
Table 2-Generic	SAE Type II Fluid Holdover Time Guidelines
Table 2-A-E26	Type II Fluid Holdover Time Guidelines - ABAX Ecowing 26
Table 2-AS-CW II	Type II Fluid Holdover Time Guidelines - Aviation Shaanxi Hi-Tech Cleanwing II
Table 2-C-FLIGHT	Type II Fluid Holdover Time Guidelines - Clariant Safewing MP II FLIGHT
Table 2-C-FLIGHT+	Type II Fluid Holdover Time Guidelines - Clariant Safewing MP II FLIGHT PLUS
Table 2-CR-PG-II	Type II Fluid Holdover Time Guidelines - Cryotech Polar Guard® II
Table 2-K-ABC-IC	Type II Fluid Holdover Time Guidelines - Kilfrost ABC-Ice Clear II
Table 2-K-ABC-K+	Type II Fluid Holdover Time Guidelines - Kilfrost ABC-K Plus
Table 2-L-P250	Type II Fluid Holdover Time Guidelines - LNT Solutions P250
Table 2-N-FCY-2	Type II Fluid Holdover Time Guidelines - Newave Aerochemical FCY-2
Table 2-N-FCY-2B+	Type II Fluid Holdover Time Guidelines - Newave Aerochemical FCY-2 Bio+
Table 3LS-A-ACM	Low Speed Type III Fluid Holdover Time Guidelines - AllClear AeroClear MAX
Table 3HS-A-ACM	High Speed Type III Fluid Holdover Time Guidelines - AllClear AeroClear MAX
Table 3LS-C-2031	Low Speed Type III Fluid Holdover Time Guidelines - Clariant Safewing MP III 2031 ECO
Table 3HS-C-2031	High Speed Type III Fluid Holdover Time Guidelines - Clariant Safewing MP III 2031 ECO
Table 4-Generic	SAE Type IV Fluid Holdover Time Guidelines
Table 4-A-E-AD-49	Type IV Fluid Holdover Time Guidelines - ABAX Ecowing AD-49
Table 4-C-MF-04	Type IV Fluid Holdover Time Guidelines - Clariant Max Flight 04
Table 4-C-MF-SNEG	Type IV Fluid Holdover Time Guidelines - Clariant Max Flight SNEG
Table 4-C-LAUNCH	Type IV Fluid Holdover Time Guidelines - Clariant Safewing MP IV LAUNCH
Table 4-C-LAUNCH+	Type IV Fluid Holdover Time Guidelines - Clariant Safewing MP IV LAUNCH PLUS
Table 4-CR-PG	Type IV Fluid Holdover Time Guidelines - Cryotech Polar Guard®
Table 4-CR-PG-A	Type IV Fluid Holdover Time Guidelines - Cryotech Polar Guard® Advance
Table 4-DS-ES	Type IV Fluid Holdover Time Guidelines – Deicing Solutions ECO-SHIELD®
Table 4-D-E106	Type IV Fluid Holdover Time Guidelines - Dow Chemical UCAR™ Endurance EG106
Table 4-D-AD-480	Type IV Fluid Holdover Time Guidelines - Dow Chemical UCAR™ FlightGuard AD-480
Table 4-D-AD-49	Type IV Fluid Holdover Time Guidelines - Dow Chemical UCAR™ FlightGuard AD-49
Table 4-K-ABC-S+	Type IV Fluid Holdover Time Guidelines - Kilfrost ABC-S Plus
Table 4-L-E450	Type IV Fluid Holdover Time Guidelines - LNT Solutions E450
Table 4-N-F-9311	Type IV Fluid Holdover Time Guidelines - Newave Aerochemical FCY 9311
Table 5	Snowfall Intensities as a Function of Prevailing Visibility
Table 6	SAE Type III Ice Pellet and Small Hail Allowance Times
Table 7	SAE Type IV Ice Pellet and Small Hail Allowance Times
Table 8	List of Fluids Tested for Anti-Icing Performance and Aerodynamic Acceptance
Table 9	SAE Type I De/Anti-icing Fluid Application Procedures
Table 10	SAE Type II, Type III and Type IV De/Anti-Icing Fluid Application Procedures

TABLE 0

SAE TYPE I, TYPE II, TYPE III, AND TYPE IV FLUID ACTIVE FROST HOLDOVER TIME GUIDELINES

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

Outside Air Temperature[1,2]		Approximate Holdover Times (hours:minutes)
Degrees Celsius	Degrees Fahrenheit	Active Frost
		Type I
-1 and above	30 and above	0:45 *(0:35)*[4]
below -1 to -3	below 30 to 27	
below -3 to -10	below 27 to 14	
below -10 to -14	below 14 to 7	
below -14 to -21	below 7 to -6	
below -21 to LOUT	below -6 to LOUT	

Outside Air Temperature[2]		Concentration Neat Fluid/Water (Volume %/ Volume %)	Approximate Holdover Times (hours:minutes)		
Degrees Celsius	Degrees Fahrenheit		Active Frost		
			Type II	Type III[3]	Type IV
-1 and above	30 and above	100/0	8:00	2:00	12:00
		75/25	5:00	1:00	5:00
		50/50	3:00	0:30	3:00
below -1 to -3	below 30 to 27	100/0	8:00	2:00	12:00
		75/25	5:00	1:00	5:00
		50/50	1:30	0:30	3:00
below -3 to -10	below 27 to 14	100/0	8:00	2:00	10:00
		75/25	5:00	1:00	5:00
below -10 to -14	below 14 to 7	100/0	6:00	2:00	6:00
		75/25	1:00	1:00	1:00
below -14 to -21	below 7 to -6	100/0	6:00	2:00	6:00
below -21 to -25	below -6 to -13	100/0	2:00	2:00	4:00
Below -25	below -13	100/0	No Holdover Time Guidelines Exist		

NOTES

1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To use the Type III fluid frost holdover times, the fluid brand being used must be known. AllClear AeroClear MAX must be applied unheated. Clariant Safewing MP III 2031 ECO must be applied heated.
4 Value in parentheses is for aircraft with critical surfaces that are predominantly or entirely constructed of composite materials.

CAUTIONS

- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 1-A

SAE TYPE I FLUID HOLDOVER TIME GUIDELINES ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF ALUMINUM[1]

This table applies to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

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

NOTES
1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

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

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Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 1-C

SAE TYPE I FLUID HOLDOVER TIME GUIDELINES ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF COMPOSITES[1]

These holdover times apply to newer aircraft with critical surfaces constructed predominantly or entirely of composite materials.
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
			Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	9 – 16	12	6 – 12	3 – 6	8 – 13	4 – 6	1 – 5	
below -3 to -6	below 27 to 21	6 – 8	11	5 – 11	2 – 5	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	4 – 8	9	5 – 9	2 – 5	4 – 7	2 – 5		
below -10	below 14	4 – 7	7	4 – 7	2 – 4				

NOTES
1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

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

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TABLE 2-Generic

SAE TYPE II FLUID HOLDOVER TIME GUIDELINES

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	0:35 – 1:30	0:20 – 0:45	0:30 – 1:00	0:15 – 0:30	0:07 – 0:40	
		75/25	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	0:15 – 0:30	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	0:20 – 1:05	0:15 – 0:30	0:20 – 0:45[7]	0:10 – 0:20[7]	CAUTION: No holdover time guidelines exist	
		75/25	0:25 – 0:50	0:08 – 0:20	0:15 – 0:30[7]	0:08 – 0:15[7]		
below -14 to LOUT	below 7 to LOUT	100/0	0:15 – 0:35[8]	0:15 – 0:30[8]				

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
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 -25°C (-13°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 2-A-E26

TYPE II FLUID HOLDOVER TIME GUIDELINES
ABAX ECOWING 26

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:25 – 2:35	1:35	1:00 – 1:35	0:40 – 1:00	0:50 – 1:35	0:40 – 0:50	0:20 – 1:25	
		75/25	1:05 – 1:55	1:15	0:45 – 1:15	0:25 – 0:45	0:45 – 1:05	0:25 – 0:35	0:10 – 1:00	
		50/50	0:30 – 0:45	0:40	0:20 – 0:40	0:10 – 0:20	0:15 – 0:25	0:08 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45 – 2:15	1:25	0:55 – 1:25	0:35 – 0:55	0:30 – 1:10[7]	0:15 – 0:35[7]		
		75/25	0:35 – 1:15	0:55	0:40 – 0:55	0:25 – 0:40	0:20 – 0:50[7]	0:15 – 0:25[7]		
below -14 to -25	below 7 to -13	100/0	0:25 – 0:45	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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TABLE 2-AS-CW II

TYPE II FLUID HOLDOVER TIME GUIDELINES
AVIATION SHAANXI HI-TECH CLEANWING II

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	0:55 – 1:50	0:30 – 0:55	0:35 – 1:05	0:25 – 0:35	0:10 – 0:55	
		75/25	0:50 – 1:20	0:25 – 0:45	0:35 – 1:00	0:20 – 0:30	0:07 – 0:50	
		50/50	0:35 – 1:00	0:15 – 0:30	0:20 – 0:40	0:10 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45 – 1:50	0:30 – 0:55	0:30 – 0:55[7]	0:20 – 0:25[7]		
		75/25	0:40 – 1:45	0:25 – 0:45	0:35 – 0:40[7]	0:20 – 0:25[7]		
below -14 to -29	below 7 to -20.2	100/0	0:20 – 0:50	0:15 – 0:30				

NOTES
1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 2-C-FLIGHT

TYPE II FLUID HOLDOVER TIME GUIDELINES
CLARIANT SAFEWING MP II FLIGHT

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:30 – 4:00	2:00	1:35 – 2:00	1:00 – 1:35	1:20 – 2:00	0:45 – 1:25	0:10 – 1:30	
		75/25	1:50 – 2:45	2:00	1:20 – 2:00	0:40 – 1:20	1:10 – 1:30	0:30 – 0:55	0:06 – 0:50	
		50/50	0:55 – 1:45	0:45	0:25 – 0:45	0:10 – 0:25	0:20 – 0:30	0:10 – 0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55 – 1:45	1:50	1:05 – 1:50	0:40 – 1:05	0:35 – 1:30[7]	0:25 – 0:45[7]		
		75/25	0:25 – 1:05	1:20	0:40 – 1:20	0:20 – 0:40	0:25 – 1:10[7]	0:20 – 0:35[7]		
below -14 to -29	below 7 to -20.2	100/0	0:30 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 2-C-FLIGHT+

TYPE II FLUID HOLDOVER TIME GUIDELINES
CLARIANT SAFEWING MP II FLIGHT PLUS

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:40 – 4:00	0:50 – 1:50	1:25 – 2:00	0:45 – 1:00	0:15 – 2:00	
		75/25	2:35 – 4:00	1:00 – 1:45	1:35 – 2:00	0:50 – 1:15	0:15 – 1:15	
		50/50	1:05 – 2:20	0:15 – 0:25	0:30 – 1:05	0:15 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40 – 2:20	0:35 – 1:15	0:35 – 1:25[7]	0:35 – 0:55[7]		
		75/25	0:30 – 1:45	0:55 – 1:40	0:25 – 1:10[7]	0:30 – 0:45[7]		
below -14 to -29	below 7 to -20.2	100/0	0:20 – 0:40	0:15 – 0:30				

NOTES
1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 2-CR-PG-II

TYPE II FLUID HOLDOVER TIME GUIDELINES
CRYOTECH POLAR GUARD® II

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:50 – 4:00	2:00	1:50 – 2:00	1:20 – 1:50	1:35 – 2:00	1:15 – 1:30	0:15 – 2:00	
		75/25	2:30 – 4:00	2:00	1:20 – 2:00	0:45 – 1:20	1:40 – 2:00	0:40 – 1:10	0:09 – 1:40	
		50/50	0:50 – 1:25	1:20	0:35 – 1:20	0:15 – 0:35	0:20 – 0:45	0:09 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55 – 2:30	1:45	1:15 – 1:45	0:55 – 1:15	0:35 – 1:35[7]	0:35 – 0:45[7]		
		75/25	0:40 – 1:30	1:45	1:00 – 1:45	0:35 – 1:00	0:25 – 1:05[7]	0:35 – 0:45[7]		
below -14 to -30.5	below 7 to -22.9	100/0	0:25 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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TABLE 2-K-ABC-IC

TYPE II FLUID HOLDOVER TIME GUIDELINES
KILFROST ABC-ICE CLEAR II

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:00 – 1:45	1:45	0:50 – 1:45	0:25 – 0:50	0:40 – 1:05	0:25 – 0:35	0:07 – 0:45	
		75/25	0:50 – 1:10	1:20	0:40 – 1:20	0:20 – 0:40	0:30 – 0:45	0:20 – 0:30	0:05 – 0:35	
		50/50	0:15 – 0:30	0:20	0:15 – 0:20	0:08 – 0:15	0:10 – 0:20	0:07 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40 – 1:35	1:15	0:35 – 1:15	0:20 – 0:35	0:25 – 1:00[7]	0:15 – 0:30[7]		
		75/25	0:40 – 1:20	0:55	0:25 – 0:55	0:15 – 0:25	0:25 – 0:45[7]	0:15 – 0:20[7]		
below -14 to -29.5	below 7 to -21.1	100/0	0:20 – 0:40	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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TABLE 2-K-ABC-K+

TYPE II FLUID HOLDOVER TIME GUIDELINES
KILFROST ABC-K PLUS

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:15 – 3:45	1:00 – 1:40	1:50 – 2:00	1:00 – 1:25	0:20 – 2:00	
		75/25	1:40 – 2:30	0:35 – 1:10	1:25 – 2:00	0:50 – 1:10	0:15 – 2:00	
		50/50	0:35 – 1:05	0:07 – 0:15	0:20 – 0:30	0:10 – 0:15		
below -3 to -14	below 27 to 7	100/0	0:30 – 1:05	0:50 – 1:25	0:25 – 1:00[7]	0:15 – 0:35[7]	CAUTION: No holdover time guidelines exist	
		75/25	0:25 – 1:25	0:35 – 1:05	0:20 – 0:55[7]	0:09 – 0:30[7]		
below -14 to -29	below 7 to -20.2	100/0	0:30 – 0:55	0:15 – 0:30				

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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TABLE 2-L-P250

TYPE II FLUID HOLDOVER TIME GUIDELINES
LNT SOLUTIONS P250

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:10 – 4:00	2:00	1:45 – 2:00	0:55 – 1:45	1:35 – 2:00	0:50 – 1:25	0:15 – 2:00	
		75/25	1:50 – 2:35	2:00	1:25 – 2:00	0:45 – 1:25	1:20 – 1:35	0:40 – 1:00	0:10 – 1:50	
		50/50	0:35 – 0:50	1:05	0:30 – 1:05	0:15 – 0:30	0:20 – 0:35	0:15 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45 – 2:20	2:00	1:40 – 2:00	0:50 – 1:40	0:25 – 1:20[7]	0:25 – 0:35[7]		
		75/25	0:35 – 1:45	2:00	1:25 – 2:00	0:45 – 1:25	0:20 – 1:15[7]	0:20 – 0:30[7]		
below -14 to LOUT	below 7 to LOUT	100/0	0:20 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES
1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

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

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TABLE 2-N-FCY-2

TYPE II FLUID HOLDOVER TIME GUIDELINES
NEWAVE AEROCHEMICAL FCY-2

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	1:15 – 2:25	0:30 – 0:55	0:35 – 1:05	0:25 – 0:35	0:08 – 0:45	
		75/25	0:50 – 1:30	0:20 – 0:40	0:25 – 0:45	0:15 – 0:25	0:05 – 0:25	
		50/50	0:25 – 0:35	0:15 – 0:25	0:10 – 0:20	0:07 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45 – 1:30	0:15 – 0:30	0:20 – 0:45[7]	0:15 – 0:20[7]		
		75/25	0:30 – 1:05	0:10 – 0:20	0:15 – 0:30[7]	0:08 – 0:15[7]		
below -14 to -28	below 7 to -18.4	100/0	0:25 – 0:35	0:15 – 0:30				

NOTES
1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

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

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TABLE 2-N-FCY-2B+

TYPE II FLUID HOLDOVER TIME GUIDELINES
NEWAVE AEROCHEMICAL FCY-2 BIO+

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

Outside Air Temperature[1]		Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:25 – 2:30	2:00	1:05 – 2:00	0:30 – 1:05	0:50 – 1:20	0:25 – 0:45	0:08 – 1:15	
		75/25	0:45 – 1:20	1:20	0:40 – 1:20	0:20 – 0:40	0:25 – 0:50	0:15 – 0:25	0:06 – 0:35	
		50/50	0:15 – 0:30	0:25	0:15 – 0:25	0:08 – 0:15	0:10 – 0:20	0:08 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40 – 1:30	1:00	0:30 – 1:00	0:15 – 0:30	0:35 – 1:05[7]	0:15 – 0:30[7]		
		75/25	0:30 – 1:05	0:35	0:20 – 0:35	0:08 – 0:20	0:20 – 0:35[7]	0:15 – 0:20[7]		
below -14 to -28.5	below 7 to -19.3	100/0	0:20 – 1:00	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 3LS-A-ACM

LOW SPEED TYPE III FLUID HOLDOVER TIME GUIDELINES
ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 LOW SPEED AERODYNAMIC TEST CRITERION

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

Outside Air Temperature[2]		Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:00 – 2:15	0:35	0:20 – 0:35	0:10 – 0:20	0:40 – 1:20	0:25 – 0:30	0:09 – 1:00	
		75/25								
		50/50							CAUTION: No holdover time guidelines exist	
below -3 to -10	below 27 to 14	100/0	1:00 – 1:45	0:30	0:15 – 0:30	0:09 – 0:15	0:40 – 1:10	0:30 – 0:40		
		75/25								
below -10 to -16	below 14 to 3.2	100/0	0:30 – 1:05	0:30	0:15 – 0:30	0:08 – 0:15				

NOTES

1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 3HS-A-ACM

HIGH SPEED TYPE III FLUID HOLDOVER TIME GUIDELINES
ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 HIGH SPEED AERODYNAMIC TEST CRITERION

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

Outside Air Temperature[2]		Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:00 – 2:15	0:35	0:20 – 0:35	0:10 – 0:20	0:40 – 1:20	0:25 – 0:30	0:09 – 1:00	
		75/25								
		50/50							CAUTION: No holdover time guidelines exist	
below -3 to -10	below 27 to 14	100/0	1:00 – 1:45	0:30	0:15 – 0:30	0:09 – 0:15	0:40 – 1:10	0:30 – 0:40		
		75/25								
below -10 to -25	below 14 to -13	100/0	0:30 – 1:05	0:30	0:15 – 0:30	0:08 – 0:15				
below -25 to -35	below -13 to -31	100/0	0:18 – 0:55							

NOTES

1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 3LS-C-2031

LOW SPEED TYPE III FLUID HOLDOVER TIME GUIDELINES
CLARIANT SAFEWING MP III 2031 ECO, APPLIED HEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 LOW SPEED AERODYNAMIC TEST CRITERION

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

Outside Air Temperature[2]		Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	0:25 – 0:50	0:40	0:20 – 0:40	0:10 – 0:20	0:17 – 0:30	0:10 – 0:14	0:05 – 0:30	
		75/25	0:19 – 0:40	0:35	0:16 – 0:35	0:07 – 0:16	0:13 – 0:20	0:08 – 0:09	0:03 – 0:18	
		50/50	0:13 – 0:18	0:25	0:13 – 0:25	0:07 – 0:13	0:13 – 0:14	0:07 – 0:07	CAUTION: No holdover time guidelines exist	
below -3 to -10	below 27 to 14	100/0	0:35 – 1:15	0:40	0:20 – 0:40	0:10 – 0:20	0:14 – 0:30	0:09 – 0:13		
		75/25	0:19 – 0:45[8]	0:25[8]	0:12 – 0:25[8]	0:05 – 0:12[8]	0:09 – 0:16[8]	0:06 – 0:08[8]		
below -10 to -16.5	below 14 to 2.3	100/0	0:25 – 0:45	0:40	0:19 – 0:40	0:09 – 0:19				

NOTES

1 Fluid must be applied heated to use these holdover times. No holdover times exist for this fluid applied unheated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 6 provides allowance times for ice pellets and small hail).
8 No holdover time guidelines exist for 75/25 fluid below -9°C (15.8°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 3HS-C-2031

HIGH SPEED TYPE III FLUID HOLDOVER TIME GUIDELINES
CLARIANT SAFEWING MP III 2031 ECO, APPLIED HEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 HIGH SPEED AERODYNAMIC TEST CRITERION

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

Outside Air Temperature[2]		Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	0:25 – 0:50	0:40	0:20 – 0:40	0:10 – 0:20	0:17 – 0:30	0:10 – 0:14	0:05 – 0:30	
		75/25	0:19 – 0:40	0:35	0:16 – 0:35	0:07 – 0:16	0:13 – 0:20	0:08 – 0:09	0:03 – 0:18	
		50/50	0:13 – 0:18	0:25	0:13 – 0:25	0:07 – 0:13	0:13 – 0:14	0:07 – 0:07	CAUTION: No holdover time guidelines exist	
below -3 to -10	below 27 to 14	100/0	0:35 – 1:15	0:40	0:20 – 0:40	0:10 – 0:20	0:14 – 0:30	0:09 – 0:13		
		75/25	0:19 – 0:45	0:25	0:12 – 0:25	0:05 – 0:12	0:09 – 0:16	0:06 – 0:08		
below -10 to -25	below 14 to -13	100/0	0:25 – 0:45	0:40	0:19 – 0:40	0:09 – 0:19				
below -25 to -29	below -13 to -20.2	100/0	0:25 – 0:45	0:40	0:19 – 0:40	0:09 – 0:19				

NOTES

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

CAUTIONS

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

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TABLE 4-Generic

SAE TYPE IV FLUID HOLDOVER TIME GUIDELINES

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	1:30 – 2:25	0:35 – 1:10	0:50 – 1:30	0:35 – 0:50	0:10 – 1:25	
		75/25	1:25 – 2:40	0:30 – 1:05	0:50 – 1:15	0:30 – 0:45	0:09 – 1:15	
		50/50	0:25 – 0:40	0:09 – 0:15	0:15 – 0:25	0:09 – 0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20 – 1:20	0:25 – 0:50	0:25 – 1:10[7]	0:15 – 0:25[7]		
		75/25	0:25 – 0:50[8]	0:20 – 0:40[8]	0:15 – 1:05[7,8]	0:15 – 0:25[7,8]		
below -14 to LOUT	below 7 to LOUT	100/0	0:15 – 0:40[9]	0:15 – 0:30[9]				

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 5) 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 7 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 -5.5°C (22.1°F).
9 If the LOUT is unknown, no holdover time guidelines exist below -23.5°C (-10.3°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-A-E-AD-49

TYPE IV FLUID HOLDOVER TIME GUIDELINES
ABAX ECOWING AD-49

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:20 – 4:00	2:00	1:50 – 2:00	1:10 – 1:50	1:25 – 2:00	1:00 – 1:25	0:10 – 1:55	
		75/25	2:25 – 4:00	2:00	1:40 – 2:00	1:20 – 1:40	1:55 – 2:00	0:50 – 1:30	0:10 – 1:40	
		50/50	0:25 – 0:50	0:40	0:25 – 0:40	0:15 – 0:25	0:15 – 0:30	0:10 – 0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20 – 1:35	2:00	1:50 – 2:00	1:10 – 1:50	0:25 – 1:25[7]	0:20 – 0:25[7]		
		75/25	0:30 – 1:10	2:00	1:40 – 2:00	1:20 – 1:40	0:15 – 1:05[7]	0:15 – 0:25[7]		
below -14 to -26	below 7 to -14.8	100/0	0:25 – 0:40	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

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

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Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-C-MF-04

TYPE IV FLUID HOLDOVER TIME GUIDELINES
CLARIANT MAX FLIGHT 04

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:40 – 4:00	2:00	2:00 – 2:00	1:25 – 2:00	2:00 – 2:00	1:10 – 1:30	0:20 – 2:00	
		75/25								
		50/50							CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:50 – 2:30	2:00	1:10 – 2:00	0:35 – 1:10	0:25 – 1:30[7]	0:20 – 0:40[7]		
		75/25								
below -14 to -23.5	below 7 to -10.3	100/0	0:20 – 0:45	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-C-MF-SNEG

TYPE IV FLUID HOLDOVER TIME GUIDELINES
CLARIANT MAX FLIGHT SNEG

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:25 – 4:00	2:00	1:40 – 2:00	1:05 – 1:40	2:00 – 2:00	0:50 – 1:40	0:20 – 1:30	
		75/25	4:00 – 4:00	2:00	1:30 – 2:00	0:55 – 1:30	1:30 – 2:00	1:05 – 1:20	0:15 – 1:45	
		50/50	1:30 – 3:30	1:45	0:45 – 1:45	0:20 – 0:45	0:35 – 1:10	0:15 – 0:30	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45 – 2:20	2:00	1:15 – 2:00	0:45 – 1:15	0:30 – 1:25[7]	0:25 – 0:40[7]		
		75/25	0:30 – 1:25	1:40	1:00 – 1:40	0:40 – 1:00	0:20 – 1:05[7]	0:20 – 0:40[7]		
below -14 to -29	below 7 to -20.2	100/0	0:20 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-C-LAUNCH

TYPE IV FLUID HOLDOVER TIME GUIDELINES
CLARIANT SAFEWING MP IV LAUNCH

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	4:00 – 4:00	2:00	1:45 – 2:00	1:05 – 1:45	1:30 – 2:00	1:00 – 1:40	0:15 – 1:40	
		75/25	3:40 – 4:00	2:00	1:45 – 2:00	1:00 – 1:45	1:40 – 2:00	0:45 – 1:15	0:10 – 1:45	
		50/50	1:25 – 2:45	1:25	0:45 – 1:25	0:25 – 0:45	0:30 – 0:50	0:20 – 0:25	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:00 – 1:55	2:00	1:20 – 2:00	0:50 – 1:20	0:35 – 1:40[7]	0:25 – 0:45[7]		
		75/25	0:40 – 1:20	2:00	1:25 – 2:00	0:45 – 1:25	0:25 – 1:10[7]	0:25 – 0:45[7]		
below -14 to -28.5	below 7 to -19.3	100/0	0:30 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-C-LAUNCH+

TYPE IV FLUID HOLDOVER TIME GUIDELINES
CLARIANT SAFEWING MP IV LAUNCH PLUS

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:55 – 4:00	2:00	2:00 – 2:00	0:55 – 2:00	2:00 – 2:00	1:00 – 2:00	0:20 – 2:00	
		75/25	3:55 – 4:00	2:00	1:55 – 2:00	0:50 – 1:55	2:00 – 2:00	1:20 – 1:25	0:20 – 1:50	
		50/50	1:15 – 1:50	1:35	0:45 – 1:35	0:20 – 0:45	0:25 – 1:00	0:15 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55 – 2:15	2:00	1:25 – 2:00	0:40 – 1:25	0:25 – 1:35[7]	0:25 – 0:40[7]		
		75/25	0:40 – 2:00	2:00	1:15 – 2:00	0:30 – 1:15	0:20 – 1:05[7]	0:20 – 0:30[7]		
below -14 to -29	below 7 to -20.2	100/0	0:25 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-CR-PG

TYPE IV FLUID HOLDOVER TIME GUIDELINES
CRYOTECH POLAR GUARD®

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:15 – 3:30	0:50 – 1:30	1:15 – 2:00	0:50 – 1:15	0:15 – 1:25	
		75/25	1:40 – 2:40	0:35 – 1:10	1:05 – 1:25	0:35 – 1:00	0:10 – 1:15	
		50/50	0:25 – 0:40	0:10 – 0:15	0:15 – 0:25	0:10 – 0:15		
below -3 to -14	below 27 to 7	100/0	0:45 – 1:45	0:30 – 0:55	0:25 – 1:10[7]	0:15 – 0:35[7]	CAUTION: No holdover time guidelines exist	
		75/25	0:35 – 1:30[8]	0:20 – 0:40[8]	0:25 – 1:05[8]	0:20 – 0:30[8]		
below -14 to -23.5	below 7 to -10.3	100/0	0:20 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).
8 These holdover times only apply to outside air temperatures to -5.5°C (22.1°F) and above.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-CR-PG-A

TYPE IV FLUID HOLDOVER TIME GUIDELINES
CRYOTECH POLAR GUARD® ADVANCE

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:50 – 4:00	2:00	1:50 – 2:00	1:20 – 1:50	1:35 – 2:00	1:15 – 1:30	0:15 – 2:00	
		75/25	2:30 – 4:00	2:00	1:20 – 2:00	0:45 – 1:20	1:40 – 2:00	0:40 – 1:10	0:09 – 1:40	
		50/50	0:50 – 1:25	1:20	0:35 – 1:20	0:15 – 0:35	0:20 – 0:45	0:09 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55 – 2:30	1:45	1:15 – 1:45	0:55 – 1:15	0:35 – 1:35[7]	0:35 – 0:45[7]		
		75/25	0:40 – 1:30	1:45	1:00 – 1:45	0:35 – 1:00	0:25 – 1:05[7]	0:35 – 0:45[7]		
below -14 to -30.5	below 7 to -22.9	100/0	0:25 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-DS-ES

TYPE IV FLUID HOLDOVER TIME GUIDELINES
DEICING SOLUTIONS ECO-SHIELD®

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:30 – 2:25	2:00	1:20 – 2:00	0:45 – 1:20	0:55 – 1:35	0:40 – 0:50	0:15 – 1:55	
		75/25								
		50/50							CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:10 – 2:30	1:45	0:55 – 1:45	0:30 – 0:55	0:45 – 2:00[7]	0:25 – 0:40[7]		
		75/25								
below -14 to -24.5	below 7 to -12.1	100/0	0:30 – 0:55	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-D-E106

TYPE IV FLUID HOLDOVER TIME GUIDELINES
DOW CHEMICAL UCAR™ ENDURANCE EG106

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:05 – 3:10	2:00	1:20 – 2:00	0:40 – 1:20	1:10 – 2:00	0:50 – 1:15	0:20 – 2:00	
		75/25							CAUTION: No holdover time guidelines exist	
		50/50								
below -3 to -14	below 27 to 7	100/0	1:50 – 3:20	2:00	1:05 – 2:00	0:30 – 1:05	0:55 – 1:50[7]	0:45 – 1:10[7]		
		75/25								
below -14 to -27	below 7 to -16.6	100/0	0:30 – 1:05	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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TABLE 4-D-AD-480

TYPE IV FLUID HOLDOVER TIME GUIDELINES
DOW CHEMICAL UCAR™ FLIGHTGUARD AD-480

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:00 – 3:30	0:40 – 1:20	0:50 – 1:30	0:35 – 0:55	0:15 – 1:35	
		75/25	1:30 – 2:45	0:30 – 1:05	0:50 – 1:15	0:30 – 0:45	0:10 – 1:15	
		50/50	0:30 – 0:45	0:09 – 0:20	0:15 – 0:25	0:09 – 0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20 – 1:20	0:30 – 0:55	0:25 – 1:20[7]	0:15 – 0:30[7]		
		75/25	0:25 – 0:50	0:20 – 0:45	0:25 – 1:05[7]	0:15 – 0:30[7]		
below -14 to -26	below 7 to -14.8	100/0	0:15 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-D-AD-49

TYPE IV FLUID HOLDOVER TIME GUIDELINES
DOW CHEMICAL UCAR™ FLIGHTGUARD AD-49

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:20 – 4:00	2:00	1:50 – 2:00	1:10 – 1:50	1:25 – 2:00	1:00 – 1:25	0:10 – 1:55	
		75/25	2:25 – 4:00	2:00	1:40 – 2:00	1:20 – 1:40	1:55 – 2:00	0:50 – 1:30	0:10 – 1:40	
		50/50	0:25 – 0:50	0:40	0:25 – 0:40	0:15 – 0:25	0:15 – 0:30	0:10 – 0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20 – 1:35	2:00	1:50 – 2:00	1:10 – 1:50	0:25 – 1:25[7]	0:20 – 0:25[7]		
		75/25	0:30 – 1:10	2:00	1:40 – 2:00	1:20 – 1:40	0:15 – 1:05[7]	0:15 – 0:25[7]		
below -14 to -26	below 7 to -14.8	100/0	0:25 – 0:40	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-K-ABC-S+

TYPE IV FLUID HOLDOVER TIME GUIDELINES
KILFROST ABC-S PLUS

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:10 – 4:00	2:00	2:00 – 2:00	1:15 – 2:00	1:50 – 2:00	1:05 – 2:00	0:25 – 2:00	
		75/25	1:25 – 2:40	2:00	1:15 – 2:00	0:45 – 1:15	1:00 – 1:20	0:30 – 0:50	0:10 – 1:20	
		50/50	0:30 – 0:55	1:00	0:30 – 1:00	0:15 – 0:30	0:15 – 0:40	0:15 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55 – 3:30	2:00	1:45 – 2:00	1:00 – 1:45	0:25 – 1:35[7]	0:20 – 0:30[7]		
		75/25	0:45 – 1:50	1:45	1:00 – 1:45	0:35 – 1:00	0:20 – 1:10[7]	0:15 – 0:25[7]		
below -14 to -28	below 7 to -18.4	100/0	0:40 – 1:00	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-L-E450

TYPE IV FLUID HOLDOVER TIME GUIDELINES
LNT SOLUTIONS E450

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:50 – 2:55	2:00	1:35 – 2:00	1:00 – 1:35	1:35 – 2:00	0:55 – 1:20	0:25 – 2:00	
		75/25								
		50/50							CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:30 – 3:55	1:50	1:10 – 1:50	0:45 – 1:10	1:45 – 2:00[7]	1:05 – 1:40[7]		
		75/25								
below -14 to LOUT	below 7 to LOUT	100/0	0:35 – 1:05	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 4-N-F-9311

TYPE IV FLUID HOLDOVER TIME GUIDELINES
NEWAVE AEROCHEMICAL FCY 9311

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

Outside Air Temperature[1]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:55 – 4:00	2:00	1:10 – 2:00	0:35 – 1:10	1:10 – 2:00	0:40 – 1:05	0:15 – 1:25	
		75/25								
		50/50							CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:35 – 2:05	1:35	0:50 – 1:35	0:25 – 0:50	0:35 – 1:20[7]	0:20 – 0:35[7]		
		75/25								
below -14 to -29.5	below 7 to -21.1	100/0	0:30 – 0:55	0:40	0:30 – 0:40	0:15 – 0:30				

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10°C (14°F).

CAUTIONS

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

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Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 5

SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY[1]

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

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

HOW TO READ AND USE THE TABLE

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

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

RVR values should not be used with this table.

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

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

ICE PELLET AND SMALL HAIL ALLOWANCE TIMES FOR WINTER 2015-2016

Comprehensive ice pellet research was conducted jointly by the research teams of the FAA and Transport Canada. This research consisted of extensive climatic chamber, wind tunnel, and live aircraft testing with ice pellets (light or moderate) and light ice pellets mixed with other forms of precipitation.

Results of this research provide the basis for allowance times for operations in ice pellets (light or moderate) and operations in light ice pellets mixed with other forms of precipitation. Allowance times for small hail are also provided as it has been determined small hail is meteorologically equivalent to moderate ice pellets.

In 2014-2015, allowance times were published for undiluted (100/0) Type III fluid applied unheated. Further testing is required to expand allowance times in other conditions, such as temperatures below -10°C. No testing has been conducted with AllClear AeroClear MAX; therefore, no allowance times currently exist for this fluid.

Additionally, Type IV anti-icing fluid with ice pellets embedded was evaluated for its aging qualities over periods of time beyond the allowance times, when the active precipitation time was limited to the allowance times.

Operational Guidelines

1) Tests have shown that ice pellets generally remain in a frozen state embedded in Type III or Type IV anti-icing fluid and are not dissolved by the fluid in the same manner as other forms of precipitation. Using current guidelines for determining anti-icing fluid failure, the presence of a contaminant not dissolved by the fluid (i.e. remaining embedded) is an indication that the fluid has failed. These embedded ice pellets are generally not readily detectable by the human eye during pre-takeoff contamination inspection procedures.

2) The research data have also shown that after proper deicing and anti-icing, the accumulation of light ice pellets, moderate ice pellets, and light ice pellets mixed with other forms of precipitation in Type III or Type IV fluid will not prevent the fluid from flowing off of the aerodynamic surfaces during takeoff.

3) The allowance times were developed based on this aerodynamic testing and are contained in Table 6 and Table 7.

4) Research has also shown that Type IV propylene glycol (PG) and Type IV ethylene glycol (EG) fluids behave differently under certain temperature and ice pellet precipitation conditions. Currently all Type IV fluids are PG based with the exception of Dow Chemical EG106 and LNT Solutions E450 which are EG based. Higher aircraft rotation speeds are required to effectively remove Type IV PG fluid contaminated with light or moderate ice pellets at temperatures below -10°C. Therefore, there are no allowance times associated with the use of Type IV PG fluids on aircraft with rotation speeds of less than 115 knots in conditions of light or moderate ice pellets at temperatures below -10°C.

5) Research has indicated that Type IV propylene glycol (PG) fluids are removed less effectively when contaminated with moderate ice pellets at temperatures below -16°C; operations in these conditions are not recommended. Therefore, there are no allowance times associated with the use of PG fluids in conditions of moderate ice pellets at temperatures below -16°C, irrespective of aircraft rotation speed.

6) Furthermore, recent research with newer generation type airfoils has shown that the allowance times are shorter when using Type IV PG fluids under certain conditions. Since it is challenging to determine exactly which aircraft may be affected, the allowance time when using Type IV PG fluids at temperatures of -5°C and above is limited to 15 minutes in moderate ice pellets.

7) The ice pellet allowances are contingent on the operator's approved ground icing program being updated to incorporate the ice pellet information contained herein, including the following conditions and restrictions that must be satisfied:

   a) The aircraft critical surfaces must be properly deiced before the application of Type III or Type IV anti-icing fluid;

b) The allowance time is valid only if the aircraft is anti-iced with undiluted Type III or Type IV fluid;

c) The Type III allowance times are only applicable for un-heated anti-icing fluid applications;

d) These allowance times are applicable from the start of the Type III or Type IV anti-icing fluid application;

e) The allowance time is limited to aircraft with a rotation speed of 100 knots or greater (subject to 4) above);

f) If the takeoff is not accomplished within the applicable allowance time in Table 6 or 7, the aircraft must be completely deiced, and if precipitation is still present, anti-iced again prior to a subsequent takeoff;

g) The allowance time cannot be extended by an inspection of the aircraft critical surfaces from either inside or outside the aircraft;

h) If the temperature decreases below the temperature on which the allowance time was based, where the new lower temperature has an associated allowance time for the precipitation condition and the present time is within the new allowance time, then that new time must be used as the allowance time limit;

i) If ice pellet precipitation becomes heavier than moderate or if the light ice pellets mixed with other forms of allowable precipitation exceeds the listed intensities or temperature range, the allowance time cannot be used;

j) If the precipitation condition stops at, or before, the time limit of the applicable allowance time in Table 6 or 7 and does not restart, the aircraft may take off up to 90 minutes after the start of the application of the Type III or Type IV anti-icing fluid. To use this guidance in the following conditions, the OAT must remain constant or increase during the 90-minute period:

- light ice pellets mixed with light or moderate freezing drizzle;
- light ice pellets mixed with light freezing rain;
- light ice pellets mixed with light rain; and
- light ice pellets mixed with moderate rain.

8) Examples:

a) Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0°C, light ice pellets fall until 10:20 and stop and do not restart. The allowance time stops at 10:50; however, provided that no precipitation restarts after the allowance time of 10:50; the aircraft may take off without any further action until 11:30.

b) Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0°C, light ice pellets mixed with freezing drizzle falls until 10:10, stops and restarts at 10:15, and stops at 10:20. The allowance time stops at 10:25; however, provided that the OAT remains constant or increases and no precipitation restarts after the end of the allowance time at 10:25, the aircraft may take off without any further action until 11:30.

c) Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0°C, light ice pellets mixed with light freezing rain falls until 10:10, stops and restarts at 10:15, and stops at 10:20. The allowance time stops at 10:25; however, provided that the OAT remains constant or increases and no precipitation restarts after the end of the allowance time at 10:25, the aircraft may take off without any further action until 11:30.

d) On the other hand, if Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0°C, light ice pellets mixed with freezing drizzle falls until 10:10, stops and restarts at 10:30, with the allowance time stopping at 10:25, the aircraft may not take off, no matter how short the time or type of precipitation after 10:25, without being deiced and anti-iced if precipitation is present.

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 6

SAE TYPE III FLUID ICE PELLET AND SMALL HAIL ALLOWANCE TIMES

This table is for use with SAE Type III undiluted (100/0) fluids applied unheated only[1]

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

Precipitation Type	Outside Air Temperature		
	-5°C and above	Below -5 to -10°C	Below -10°C[2]
Light Ice Pellets	10 minutes	10 minutes	Caution: No allowance times currently exist
Moderate Ice Pellets or Small Hail[3]	5 minutes	5 minutes	
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	7 minutes	5 minutes	
Light Ice Pellets Mixed with Light Freezing Rain	7 minutes	5 minutes	
Light Ice Pellets Mixed with Light Rain	7 minutes[4]		
Light Ice Pellets Mixed with Moderate Rain			
Light Ice Pellets Mixed with Light Snow	10 minutes	10 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes	10 minutes	

NOTES

1 No allowance times exist for AllClear AeroClear MAX.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 If no intensity is reported with small hail, moderate ice pellets allowance times apply. However, if an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. light small hail = light ice pellets, moderate small hail = moderate ice pellets.
4 No allowance times exist in this condition for temperatures below 0°C; consider use of light ice pellets mixed with light freezing rain.

CAUTIONS

- **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.**
- **Take off 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. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, or light rain.**

Transport Canada Holdover Time Guidelines — Winter 2015-2016

TABLE 7

SAE TYPE IV FLUID ICE PELLET AND SMALL HAIL ALLOWANCE TIMES

This table is for use with SAE Type IV undiluted (100/0) fluids only. All Type IV fluids are propylene glycol based with the exception of Dow EG106 and LNT Solutions E450 which are ethylene glycol based.

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

Precipitation Type	Outside Air Temperature		
	-5°C and above	Below -5 to -10°C	Below -10°C[1]
Light Ice Pellets	50 minutes	30 minutes	30 minutes[2]
Moderate Ice Pellets or Small Hail[3]	25 minutes[4]	10 minutes	10 minutes[2,5]
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	25 minutes	10 minutes	**Caution: No allowance times currently exist**
Light Ice Pellets Mixed with Light Freezing Rain	25 minutes	10 minutes	
Light Ice Pellets Mixed with Light Rain	25 minutes[6]		
Light Ice Pellets Mixed with Moderate Rain	25 minutes[7]		
Light Ice Pellets Mixed with Light Snow	25 minutes	15 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes	7 minutes	

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected.
2 No allowance times exist for propylene glycol (PG) fluids when used on aircraft with rotation speeds less than 115 knots. (For these aircraft, if the fluid type is not known, assume zero allowance time.)
3 If no intensity is reported with small hail, moderate ice pellets allowance times apply. However, if an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. light small hail = light ice pellets, moderate small hail = moderate ice pellets.
4 Allowance time is 15 minutes for propylene glycol (PG) fluids or when the fluid type is unknown.
5 No allowance times exist for propylene glycol (PG) fluids in this condition for temperatures below -16°C.
6 No allowance times exist in this condition for temperatures below 0°C; consider use of light ice pellets mixed with light freezing rain.
7 No allowance times exist in this condition for temperatures below 0°C.

CAUTIONS

- **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.**
- **Take off 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. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, light rain, or moderate rain.**

TABLE 8-1

LIST OF TYPE I FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 62)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	LOWEST OPERATIONAL USE TEMPERATURE[3]				
				DILUTION[4,5] (FLUID/WATER)	LOW SPEED AERODYNAMIC TEST[6]		HIGH SPEED AERODYNAMIC TEST[6]	
					°C	°F	°C	°F
ABAX Industries	DE-950	PG	18-05-01	71/29	-26	-14.8	-31	-23.8
ABAX Industries	*DE-950 Colorless*	*PG*	*12-06-26*[9]	*60/40*	*Not tested*[10]	*Not tested*[10]	*-24*	*-11.2*
ADDCON EUROPE GmbH	IceFree I.80	PG	17-05-20	70/30	-26	-14.8	-32	-25.6
AllClear Systems LLC	Lift-Off P-88	PG	18-06-11	70/30	-24.5	-12.1	-29.5	-21.1
AllClear Systems LLC	Lift-Off E-188	EG	18-07-15	70/30	-40	-40	-41.5	-42.7
Arcton Ltd.[11]	Arctica DG ready-to-use	DEG	17-07-15	as supplied	-26	-14.8	-26	-14.8
Arcton Ltd.[11]	*Arctica DG 91 Concentrate*	*DEG*	*15-07-25*[9]	*75/25*	*-25*	*-13*	*-25*	*-13*
AVIAFLUID International Ltd.	AVIAFLO EG	EG	16-11-28	70/30	-40.5	-40.9	-44	-47.2
Aviation Shaanxi Hi-Tech Physical Chemical Co. Ltd.	Cleanwing I	PG	15-12-19	75/25	Not tested[10]	Not tested[10]	-39.5	-39.1
Aviation Xi'an High-Tech Physical Chemical Co. Ltd.	KHF-1	PG	19-05-22	75/25	Not available[12]	Not available[12]	-38.5	-37.3
Baltic Ground Services[11]	*DEFROSOL ADF*	*NG*	*15-03-18*[9]	*65/35*	*-25*	*-13*	*-30*	*-22*
Beijing Phoenix Air Traffic Product Development and Trading Co.[11]	*CBSX-I*	*PG*	*12-04-21*[9]	*Not available*[12]	*Not available*[12]	*Not available*[12]	*Not available*[12]	*Not available*[12]
Beijing Wangye Aviation Chemical Product Co Ltd.[11]	KLA-1	EG	15-08-25	60/40	Not available[12]	Not available[12]	-30.5	-22.9
Beijing Yadilite Aviation Advanced Materials Corporation	YD-101 Type I	PG	17-05-27	60/40	Not tested[10]	Not tested[10]	-30	-22
CHEMCO Inc.	CHEMR EG I	EG	16-03-25	70/30	-37	-34.6	-43	-45.4
CHEMCO Inc.	CHEMR REG I	EG	16-07-08	75/25	-36	-32.8	-40.5	-40.9
Clariant Produkte (Deutschland) GmbH	*EcoFlo Concentrate*	*NG*	*13-07-06*[9]	*65/35*	*Not tested*[10]	*Not tested*[10]	*-30.5*	*-22.9*
Clariant Produkte (Deutschland) GmbH	*EcoFlo 2 Concentrate*	*NG*	*13-07-25*[9]	*65/35*	*Not tested*[10]	*Not tested*[10]	*-29*	*-20.2*
Clariant Produkte (Deutschland) GmbH	Octaflo EF Concentrate	PG	18-03-20	65/35	-25	-13	-33	-27.4
Clariant Produkte (Deutschland) GmbH	*Octaflo EF-80*	*PG*	*13-12-21*[9]	*70/30*	*-25*	*-13*	*-33*	*-27.4*
Clariant Produkte (Deutschland) GmbH	Octaflo EG Concentrate	EG	17-07-23	70/30	-40.5	-40.9	-44	-47.2
Clariant Produkte (Deutschland) GmbH	Octaflo LYOD	EG	16-02-11	70/30	-40	-40	-45.5	-49.9
Clariant Produkte (Deutschland) GmbH	*Safewing EG I 1996*	*EG*	*12-06-10*[9]	*75/25*	*-35.5*	*-31.9*	*-43*	*-45.4*
Clariant Produkte (Deutschland) GmbH	Safewing EG I 1996 (88)	EG	15-10-19	70/30	-39.5	-39.1	-41.5	-42.7

TABLE 8-1 (cont'd)

LIST OF TYPE I FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 62)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	LOWEST OPERATIONAL USE TEMPERATURE[3]				
				DILUTION[4,5] (FLUID/WATER)	LOW SPEED AERODYNAMIC TEST[6]		HIGH SPEED AERODYNAMIC TEST[6]	
					°C	°F	°C	°F
Clariant Produkte (Deutschland) GmbH	Safewing MP I 1938 ECO	PG	16-06-26	65/35	-25.5	-13.9	-32	-25.6
Clariant Produkte (Deutschland) GmbH	Safewing MP I 1938 ECO (80)	PG	16-07-09	71/29	-25	-13	-32.5	-26.5
Clariant Produkte (Deutschland) GmbH	Safewing MP I 1938 ECO (80) Premix 55% i.g. ready-to-use	PG	17-03-13	as supplied	Not tested[10]	Not tested[10]	-19	-2.2
Clariant Produkte (Deutschland) GmbH	Safewing MP I ECO PLUS (80)	PG	19-03-13	71/29	-25	-13	-33	-27.4
Cryotech Deicing Technology	Polar Plus®	PG	16-01-16	63/37	-27	-16.6	-32	-25.6
Cryotech Deicing Technology	Polar Plus® LT	PG	16-03-13	63/37	-27	-16.6	-33	-27.4
Cryotech Deicing Technology	Polar Plus® LT (80)	PG	16-09-15	70/30	-27	-16.6	-33	-27.4
Cryotech Deicing Technology	Polar Plus® (80)	PG	17-09-12	70/30	-24.5	-12.1	-32.5	-26.5
Deicing Solutions LLC	Safetemp® ES Plus (Multiple Location)	PG	18-08-29	65/35	-25.5	-13.9	-31	-23.8
Dow Chemical Company	UCAR™ ADF Concentrate	EG	19-05-11	75/25	-36	-32.8	-45	-49
Dow Chemical Company	UCAR™ ADF XL54	EG	17-01-18	as supplied	-33	-27.4	-33	-27.4
Dow Chemical Company	UCAR™ PG ADF Concentrate	PG	19-05-11	65/35	-25	-13	-32	-25.6
Dow Chemical Company	*UCAR™ PG ADF Dilute 55/45*	*PG*	*12-02-05[9]*	*as supplied*	*-24*	*-11.2*	*-25*	*-13*
Heilongjiang Hangjie Aero-chemical Technology Co. Ltd.	HJF-1	EG	17-10-02	65/35	Not tested[10]	Not tested[10]	-42	-43.6
Heilongjiang Hangjie Aero-chemical Technology Co. Ltd.	HJF-1A	EG	16-09-02	75/25	Not tested[10]	Not tested[10]	-40.5	-40.9
HOC Industries	SafeTemp® ES Plus	PG	16-08-07	65/35	-25.5	-13.9	-29	-20.2
Inland Technologies CANADA Inc.	DuraGly-E Type I ADF Concentrate	EG	19-01-13	60/40	-33	-27.4	-33	-27.4
Inland Technologies CANADA Inc.	DuraGly-P Type I ADF Concentrate	PG	15-02-04[13]	60/40	-25	-13	-25	-13
Kilfrost Limited	Kilfrost DF Plus	PG	15-08-30	69/31	-25.5	-13.9	-32	-25.6
Kilfrost Limited	Kilfrost DF Plus (80)	PG	16-07-13	69/31	-26	-14.8	-31.5	-24.7
Kilfrost Limited	Kilfrost DF Plus (88)	PG	15-08-30	63/37	-25.5	-13.9	-32	-25.6
Kilfrost Limited	Kilfrost DF^{Sustain}	PDO	15-08-08	68/32	-34	-29.2	-41	-41.8
LNT Solutions	LNT E188	EG	17-10-01	70/30	-30.5	-22.9	-41	-41.8
LNT Solutions	LNT P180	PG	17-10-04	69/31	-26	-14.8	-32	-25.6
LNT Solutions	LNT P188	PG	18-11-28	70/30	-24.5	-12.1	-31.5	-24.7

TABLE 8-1 (cont'd)

LIST OF TYPE I FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 62)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	LOWEST OPERATIONAL USE TEMPERATURE[3]				
				DILUTION[4,5] (FLUID/WATER)	LOW SPEED AERODYNAMIC TEST[6]		HIGH SPEED AERODYNAMIC TEST[6]	
					°C	°F	°C	°F
Newave Aerochemical Co. Ltd.	FCY-1A	EG	19-02-20	75/25	-40	-40	-40	-40
Newave Aerochemical Co. Ltd.	FCY-1Bio+	EG	16-07-08	75/25	Not tested[10]	Not tested[10]	-40.5	-40.9
Oksayd Co. Ltd.	DEFROST ECO 1	NG	16-07-09	70/30	Not tested[10]	Not tested[10]	-36	-32.8
Shaanxi Cleanway Aviation Chemical Co., Ltd	Cleansurface I	EG	17-09-12	75/25	-32.5[14]	-26.5[14]	-40.5	-40.9
Shaanxi Cleanway Aviation Chemical Co., Ltd	Cleansurface I-BIO	EG	18-07-11	75/25	Not tested[10]	Not tested[10]	-37	-34.6
Velvana a.s.	AIRVEL OK 1	PG	17-01-28	70/30	-26	-14.8	-30	-22

TABLE 8-2

LIST OF TYPE II FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 62)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	DILUTION (FLUID/WATER)	LOWEST OPERATIONAL USE TEMPERATURE[3] HIGH SPEED AERODYNAMIC TEST[6] °C	LOWEST OPERATIONAL USE TEMPERATURE[3] HIGH SPEED AERODYNAMIC TEST[6] °F	LOWEST ON-WING VISCOSITY[7,8] (mPa.s) MANUFACTURER METHOD	LOWEST ON-WING VISCOSITY[7,8] (mPa.s) AS 9968 METHOD
ABAX Industries	Ecowing 26	PG	17-04-28	100/0	-25	-13	4 900 (h)	4 600 (a)
				75/25	-14	7	2 200 (a)	2 200 (a)
				50/50	-3	27	50 (a)	50 (a)
Aviation Shaanxi Hi-Tech Physical Chemical Co. Ltd.	Cleanwing II	PG	17-05-20	100/0	-29	-20.2	4 650 (f)	4 500 (a)
				75/25	-14	7	9 450 (f)	10 000 (a)
				50/50	-3	27	10 150 (f)	10 200 (a)
Clariant Produkte (Deutschland) GmbH	Safewing MP II FLIGHT	PG	16-05-14	100/0	-29	-20.2	3 340 (a)	3 340 (a)
				75/25	-14	7	12 900 (c)	12 900 (c)
				50/50	-3	27	11 500 (a)	11 500 (a)
Clariant Produkte (Deutschland) GmbH	Safewing MP II FLIGHT PLUS	PG	16-02-28	100/0	-29	-20.2	3 650 (o)	3 100 (a)
				75/25	-14	7	12 400 (o)	10 450 (a)
				50/50	-3	27	7 800 (o)	7 050 (a)
Cryotech Deicing Technology	Polar Guard® II	PG	17-03-11	100/0	-30.5	-22.9	4 400 (g)	4 050 (a)
				75/25	-14	7	11 600 (g)	9 750 (a)
				50/50	-3	27	80 (a)	80 (a)
Kilfrost Limited	ABC-3	PG	16-10-08	100/0	-27	-16.6	2 500 (f)	2 500 (a)
				75/25	-14	7	2 000 (f)	2 000 (a)
				50/50	-3	27	400 (f)	400 (a)
Kilfrost Limited	ABC-Ice Clear II	PG	17-05-13	100/0	-29.5	-21.1	7 720 (a)	7 720 (a)
				75/25	-14	7	5 660 (a)	5 660 (a)
				50/50	-3	27	580 (a)	558 (n)
Kilfrost Limited	ABC-K Plus	PG	16-11-24	100/0	-29	-20.2	2 850 (f)	2 640 (a)
				75/25	-14	7	12 650 (f)	12 650 (c)
				50/50	-3	27	4 200 (f)	5 260 (a)
LNT Solutions	LNT P250	PG	Y-M-D[13]	100/0	Not available[12]	Not available[12]	2 400 (e)	2 150 (a)
				75/25	Not available[12]	Not available[12]	16 200 (e)	15 200 (a)
				50/50	Not available[12]	Not available[12]	8 150 (e)	8 100 (a)
Newave Aerochemical Co. Ltd.	FCY-2	PG	17-02-20	100/0	-28	-18.4	7 000 (f)	8 920 (a)
				75/25	-14	7	18 550 (f)	18 550 (f)
				50/50	-3	27	6 750 (f)	7 030 (a)

TABLE 8-2 (cont'd)

LIST OF TYPE II FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 62)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	DILUTION (FLUID/WATER)	LOWEST OPERATIONAL USE TEMPERATURE[3]		LOWEST ON-WING VISCOSITY[7,8] (mPa.s)	
					HIGH SPEED AERODYNAMIC TEST[6]		MANUFACTURER METHOD	AS 9968 METHOD
					°C	°F		
Newave Aerochemical Co. Ltd.	FCY-2 Bio+	PG	17-05-06	100/0	-28.5	-19.3	7 210 (a)	7 210 (a)
				75/25	-14	7	21 400 (c)	21 400 (c)
				50/50	-3	27	1 900 (a)	1 900 (a)

TABLE 8-3

LIST OF TYPE III FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 62)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	DILUTION (FLUID/WATER)	LOWEST OPERATIONAL USE TEMPERATURE[3]				LOWEST ON-WING VISCOSITY[7,8] (mPa.s)	
					LOW SPEED AERODYNAMIC TEST[6]		HIGH SPEED AERODYNAMIC TEST[6]		MANUFACTURER METHOD	AS 9968 METHOD
					°C	°F	°C	°F		
AllClear Systems LLC	AeroClear MAX	EG	16-12-22[15]	100/0	-16	3.2	-35	-31	7 300 (m)	Not Available[16]
				75/25	Dilution Not Applicable		Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable		Dilution Not Applicable	
Clariant Produkte (Deutschland) GmbH	Safewing MP III 2031 ECO	PG	15-08-15	100/0	-16.5	2.3	-29	-20.2	120 (n)	120 (n)
				75/25	-9	15.8	-10	14	86 (n)	86 (n)
				50/50	-3	27	-3	27	16 (n)	16 (n)

TABLE 8-4

LIST OF TYPE IV FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 62)

Company Name	Fluid Name	Type of Glycol[1]	Expiry[2] (Y-M-D)	Dilution (fluid/water)	Lowest Operational Use Temperature[3]		Lowest On-Wing Viscosity[7,8] (mPa.s)	
					High Speed Aerodynamic Test[6]		Manufacturer Method	AS 9968 Method
					°C	°F		
ABAX Industries	Ecowing AD-49	PG	16-06-02	100/0	-26	-14.8	12 150 (i)	11 000 (a)
				75/25	-14	7	30 700 (i)	32 350 (c)
				50/50	-3	27	19 450 (i)	21 150 (c)
Clariant Produkte (Deutschland) GmbH	Max Flight 04	PG	16-07-23	100/0	-23.5	-10.3	5 540 (b)	5 540 (a)
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	
Clariant Produkte (Deutschland) GmbH	Max Flight SNEG	PG	16-02-20	100/0	-29	-20.2	8 700 (p)	8 050 (a)
				75/25	-14	7	20 200 (q)	21 800 (c)
				50/50	-3	27	13 600(q)	15 000 (c)
Clariant Produkte (Deutschland) GmbH	Safewing MP IV LAUNCH	PG	16-06-02	100/0	-28.5	-19.3	7 550 (a)	7 550 (a)
				75/25	-14	7	18 000 (a)	18 000 (a)
				50/50	-3	27	17 800 (a)	17 800 (a)
Clariant Produkte (Deutschland) GmbH	Safewing MP IV LAUNCH PLUS	PG	17-03-24	100/0	-29	-20.2	8 700 (p)	8 450 (a)
				75/25	-14	7	18 800 (q)	17 200 (c)
				50/50	-3	27	9 700 (p)	12 150 (a)
Cryotech Deicing Technology	*Polar Guard®*	*PG*	*12-08-30[9]*	*100/0*	*-23.5*	*-10.3*	*32 100 (k)*	*36 300 (c)*
				75/25	*-5.5*	*22.1*	*24 200 (k)*	*27 800 (c)*
				50/50	*-3*	*27*	*6 200 (k)*	*7 500 (a)*
Cryotech Deicing Technology	Polar Guard® Advance	PG	17-03-11	100/0	-30.5	-22.9	4 400 (g)	4 050 (a)
				75/25	-14	7	11 600 (g)	9 750 (a)
				50/50	-3	27	80 (a)	80 (a)
Deicing Solutions LLC	ECO-SHIELD®	PG	17-01-26	100/0	-24.5	-12.1	1 900 (a)	1 900 (a)
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	
Dow Chemical Company	UCAR™ Endurance EG106 De/Anti-Icing Fluid	EG	17-05-20	100/0	-27	-16.6	24 850 (j)	2 230 (a)
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	
Dow Chemical Company	*UCAR™ FlightGuard AD-480*	*PG*	*12-06-15[9]*	*100/0*	*-26*	*-14.8*	*15 200 (h)*	*12 800 (d)*
				75/25	*-14*	*7*	*16 000 (h)*	*12 400 (d)*
				50/50	*-3*	*27*	*4 000 (h)*	*3 800 (a)*

TABLE 8-4 (cont'd)

LIST OF TYPE IV FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 62)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	DILUTION (FLUID/WATER)	LOWEST OPERATIONAL USE TEMPERATURE[3] HIGH SPEED AERODYNAMIC TEST[6] °C	LOWEST OPERATIONAL USE TEMPERATURE[3] HIGH SPEED AERODYNAMIC TEST[6] °F	LOWEST ON-WING VISCOSITY[7,8] (mPa.s) MANUFACTURER METHOD	LOWEST ON-WING VISCOSITY[7,8] (mPa.s) AS 9968 METHOD
Dow Chemical Company	UCAR™ FlightGuard AD-49	PG	17-05-20	100/0	-26	-14.8	12 150 (i)	11 000 (a)
				75/25	-14	7	30 700 (i)	32 350 (c)
				50/50	-3	27	19 450 (i)	21 150 (c)
Kilfrost Limited	ABC-S Plus	PG	17-06-16	100/0	-28	-18.4	17 900 (f)	17 900 (c)
				75/25	-14	7	18 300 (f)	18 300 (c)
				50/50	-3	27	7 500 (f)	7 500 (a)
LNT Solutions	LNT E450	EG	Y-M-D[13]	100/0	Not available[12]	Not available[12]	45 300 (l)	Not Available[16]
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	
Newave Aerochemical Co. Ltd.	FCY 9311	PG	15-12-20	100/0	-29.5	-21.1	14 100 (c)	14 100 (c)
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	

CAUTIONS AND NOTES FOR TABLES 8-1, 8-2, 8-3, 8-4

CAUTIONS

- This table lists fluids that have been tested with respect to anti-icing performance and aerodynamic acceptance (Type I: SAE AMS1424 §3.5.2 and §3.5.3; Type II, III, IV: SAE AMS1428 §3.2.4 and §3.2.5) only. These tests were conducted by Anti-icing Materials International Laboratory: www.uqac.ca/amil. The end user is responsible for contacting the fluid manufacturer to confirm all other SAE AMS1424/1428 technical requirement tests, such as fluid stability, toxicity, materials compatibility, etc. have been conducted.
- LOUT data provided in these tables is based strictly on the manufacturer's data; the end user is responsible for verifying the validity of this data.
- Type I fluids supplied in concentrated form must not be used in that form and must be diluted.

NOTES

1 PG = propylene glycol; PDO = propylene glycol (propane-1, 3-diol); EG = ethylene glycol; DEG = diethylene glycol; NG = non-glycol.

2 Expiry date is the earlier expiry date of the Aerodynamic Test(s) or Water Spray Endurance Test. Fluids that are tested after the issuance of this list will appear in a later update.

3 The values in this table were determined using test results from pre-production fluid samples when available. In some cases, the fluid manufacturer requested the publication of a more conservative value than the pre-production test value. The lowest operational use temperature (LOUT) for a given fluid is the higher of:

a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type;
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.

4 The LOUT for Type I fluids that are intended to be diluted is derived from a dilution that provides the lowest operational use temperature. For other Type I dilutions, determine the freezing point of the fluid and add a 10°C freezing point buffer, as a dilution will usually yield a higher and more restrictive operational use temperature. Consult the fluid manufacturer or fluid documentation for further clarification and guidance on establishing the appropriate operational use temperature of a diluted fluid.

5 Type I concentrate fluids have also been tested at 50/50 (glycol/water) dilution.

6 If uncertain whether the aircraft to be treated conforms to the low speed or the high speed aerodynamic test, consult the aircraft manufacturer. The aerodynamic test is defined in SAE AS5900 (latest version).

7 The viscosity values in this table are those of the fluids provided by the manufacturers for holdover time testing. For the holdover times to be valid, the viscosity of the fluid on the wing shall not be lower than that in this table. The user should periodically ensure that the viscosity of a fluid sample taken from the wing surface is not lower than that listed.

8 The SAE AS9968 viscosity method should only be used for field verification and auditing purposes; when in doubt as to which method is appropriate, use the manufacturer method. Viscosity measurement methods are indicated as letters (in parentheses) beside each viscosity value. Details of each measurement method are shown in the table below. The exact measurement method (spindle, container, fluid volume, temperature, speed, duration) must be used to compare the viscosity of a sample to a viscosity given in this table.

Method	Brookfield Spindle	Container	Fluid Volume	Temp.	Speed	Duration
a	LV1 (with guard leg)	600 mL low form (Griffin) beaker	575 mL*	20°C	0.3 rpm	10.0 minutes
b	LV1 (with guard leg)	600 mL low form (Griffin) beaker	575 mL*	20°C	0.3 rpm	33.3 minutes
c	LV2-disc (with guard leg)	600 mL low form (Griffin) beaker	425 mL*	20°C	0.3 rpm	10.0 minutes
d	LV2-disc (with guard leg)	250 mL tall form (Berzelius) beaker	200 mL*	20°C	0.3 rpm	10.0 minutes
e	LV2-disc (with guard leg)	200 mL tall form (Berzelius) beaker	155 mL*	20°C	0.3 rpm	10.0 minutes
f	LV2-disc (with guard leg)	150 mL tall form (Berzelius) beaker	135 mL*	20°C	0.3 rpm	10.0 minutes
g	SC4-34/13R	small sample adapter	10 mL	20°C	0.3 rpm	10.0 minutes
h	SC4-34/13R	small sample adapter	10 mL	20°C	0.3 rpm	30.0 minutes
i	SC4-31/13R	small sample adapter	10 mL	20°C	0.3 rpm	10.0 minutes
j	SC4-31/13R	small sample adapter	10 mL	0°C	0.3 rpm	10.0 minutes
k	SC4-31/13R	small sample adapter	9 mL	20°C	0.3 rpm	10.0 minutes
l	SC4-31/13R	small sample adapter	9 mL	0°C	0.3 rpm	10.0 minutes
m	SC4-31/13R	small sample adapter	9 mL	0°C	0.3 rpm	30.0 minutes
n	LV0	UL adapter	16 mL	20°C	0.3 rpm	10.0 minutes
o	LV1	big sample adapter	50 mL	20°C	0.3 rpm	10.0 minutes
p	LV1	big sample adapter	55 mL	20°C	0.3 rpm	10.0 minutes
q	LV2-disc	big sample adapter	60 mL	20°C	0.3 rpm	10.0 minutes

*If necessary, adjust fluid volume to ensure fluid is level with notch on the spindle shaft

9 Fluids listed in italics have expired and will be removed from this listing four years after expiry.

10 Manufacturer has indicated fluid was not tested.

11 Manufacturer has not provided fluid information as required in SAE ARP5718A; fluid may be removed from this listing in subsequent revisions.

12 Manufacturer had not provided LOUT information at the time of publication.

13 Currently in the test/re-retest process.

14 Fluid was not retested for low speed aerodynamics. This data will be removed four years after the expiry of the last low speed test.

15 Fluid did not meet the minimum Water Spray Endurance Test requirement for a Type III fluid in AMS1428G; Transport Canada and the FAA have proposed a change to the SAE G-12 for this requirement.

16 Measurements using the SAE AS9968 method do not provide stable, reliable results. Use the manufacturer method to evaluate viscosity.

TABLE 9

SAE TYPE I DE/ANTI-ICING FLUID APPLICATION PROCEDURES

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

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

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

NOTES

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

CAUTION

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

TABLE 10

SAE TYPE II, TYPE III and TYPE IV DE/ANTI-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type II, III and IV fluid mixtures
(minimum concentrations in % by volume) as a function of outside air temperature (OAT)

Outside Air Temperature (OAT)[1]	One-Step Procedure De/Anti-icing	Two-Step Procedure	
		First Step: Deicing	Second Step: Anti-icing[2]
-3°C (27°F) and above	50/50 Heated[3] Type II/III/IV	Heated water or a heated mix of Type I, II, III or IV with water	50/50 Type II/III/IV
-14°C (7°F) and above	75/25 Heated[3] Type II/III/IV	Heated suitable mix of Type I, Type II/III/IV and water with FP not more than 3°C (5°F) above actual OAT	75/25 Type II/III/IV
-25°C (-13°F) and above	100/0 Heated[3] Type II/III/IV	Heated suitable mix of Type I, Type II/III/IV and water with FP not more than 3°C (5°F) above actual OAT	100/0 Type II/III/IV
Below -25°C (-13°F)	Type II/III/IV fluid may be used below -25°C (-13°F) provided that the OAT is at or above the LOUT. Consider the use of Type I when Type II/III/IV fluid cannot be used (see Table 9).		

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes. (This time may be higher than 3 minutes in some conditions, but potentially lower in heavy precipitation, in colder temperatures, or for critical surfaces constructed of composite materials. If necessary, the second step shall be applied area by area.)
3 Clean aircraft may be anti-iced with unheated fluid, unless the related holdover time table requires a heated application to obtain holdover times.

NOTES

- For heated fluids, a fluid temperature not less than 60°C (140°F) at the nozzle is desirable. When the first step is performed using a fluid/water mix with a freezing point above OAT, the temperature at the nozzle shall be at least 60°C and at least 1 litre/m^2 (2 gal./100 sq. ft.) shall be applied to the surfaces to be deiced. For fluids which require a heated application to obtain holdover times (this is stated in the applicable holdover time table), the temperature at the nozzle shall be at least 60°C and at least 1 litre/m^2 (2 gal./100 sq. ft.) shall be applied.
- Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- The lowest operational use temperature (LOUT) for a given Type II/III/IV fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type; or
  b) The actual freezing point of the fluid plus its freezing point buffer of 7°C (13°F).

CAUTIONS

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**
- **Whenever frost or ice occurs on the lower surface of the wing in the area of the fuel tank, indicating a cold soaked wing, the 50/50 dilutions of Type II, III or IV shall not be used for the anti-icing step because fluid freezing may occur.**
- **An insufficient amount of anti-icing fluid may cause a substantial loss of holdover time. This is particularly true when using a Type I fluid mixture for the first step in a two-step procedure.**

FAA
HOLDOVER TIME GUIDELINES
WINTER 2015-2016

FAA
HOLDOVER TIME GUIDELINES

WINTER 2015-2016
ORIGINAL ISSUE

The information contained in this document serves as the official FAA guidance, Holdover Times and Allowance Times for use during the 2015-2016 winter season. This document is designed to be used in conjunction with the FAA N 8900 series notice "Revised FAA-Approved Deicing Program Updates, Winter 2015-2016."

Questions concerning FAA aircraft ground de/anti-icing requirements or Flight Standards policies should be addressed to charles.j.enders@faa.gov or 202-267-4557.

Questions on the technical content of the holdover time tables should be addressed to warren.underwood@faa.gov or 404-305-6652.

Questions regarding editorial content or web access issues should be addressed to sung.shin@faa.gov or 202-267-8086.

CHANGE CONTROL RECORDS

This page indicates any changes made to individual pages within the document. Changed pages have the appropriate revision date in the header. Sidebars are shown to assist in identifying where changes have been made on these pages.

It is the responsibility of the end user to periodically check the following website for updates: https://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/deicing/.

REVISION	DATE	DESCRIPTION OF CHANGES	AFFECTED PAGES	AUTHOR

SUMMARY OF CHANGES FOR WINTER 2015-2016

The principal changes from the previous year are briefly indicated herein.

ACTIVE FROST

- The active frost holdover time (HOT) guidelines are unchanged.

TYPE I FLUIDS

- The Type I HOT guidelines are unchanged.

TYPE II FLUIDS

- Fluid-specific HOT guidelines have been created for two new Type II fluids: Kilfrost ABC-Ice Clear II and Newave Aerochemical FCY-2 Bio+.
- Several of the LNT Solutions P250 snow holdover times have been increased as a result of supplemental testing.
- Clariant Safewing MP II 1951 has been removed from the Type II guidelines as per the protocol for removing obsolete fluids.
- Six changes (increases and decreases of up to five minutes) have been made to the Type II generic holdover times as a result of the new and removed Type II fluids.

TYPE III FLUIDS

- Fluid-specific, application temperature-specific, and aircraft rotation speed profile-specific HOT guidelines have been added for Type III fluids. This includes guidelines for the existing Type III fluid Clariant Safewing MP III 2031 ECO (applied heated) and for the new Type III fluid AllClear AeroClear MAX (applied unheated).
- Due to the different application temperature requirements of the two Type III fluids it is not possible to determine generic Type III holdover times. As a result, the Type III generic HOT guideline has been removed. Users must know which fluid brand is being used and use the appropriate Type III fluid-specific HOT guidelines when using Type III fluid.

TYPE IV FLUIDS

- Fluid-specific HOT guidelines have been created for the new Type IV fluid Deicing Solutions ECO-SHIELD®.
- Most of the LNT Solutions E450 snow holdover times have been increased as a result of supplemental testing.
- ABAX AD-480 and Kilfrost ABC-S have been removed from the Type IV guidelines as per the protocol for removing obsolete fluids.
- Significant changes, primarily increases, have been made to the Type IV generic holdover times as a result of the new and removed Type IV fluids.

ICE PELLET AND SMALL HAIL ALLOWANCE TIMES

- A new note has been added to the allowance time tables to indicate that if an intensity is reported with small hail, the equivalent ice pellet condition can be used, i.e. if light small hail is reported, the light ice pellet allowance times can be used. If an intensity is not reported, the moderate ice pellet allowance times must be used.

- Two new cautions have been added to the allowance time tables. These cautions provide important information within the allowance time tables, which was previously provided only in the allowance time operational guidance section. This is to highlight its importance to users.

FAA / TRANSPORT CANADA HARMONIZATION INITIATIVE

- In late 2014, FAA and Transport Canada initiated an effort to harmonize their holdover time guidelines documents. Several changes have been made as a result of this initiative, including:
  - Minor changes to wording of many holdover time table notes and cautions
  - Rewording of holdover time table titles
  - Reordering of some document content
  - Merging of the information previously provided in the list of fluids tested, table of lowest operational use temperatures (LOUTs) and table of lowest on-wing viscosities (LOWVs) into a single table (Table 8). Fluid expiry date and fluid base information has also been added to this table.
  - Separating the content previously provided in the Summary of Changes section into two sections: the Summary of Changes section provides details of revisions made to the document for the current winter and the Key Guidance section provides important guidance which remains in the document from year to year.
- Harmonization efforts and discussions will continue over winter 2015-2016 and further changes are expected in future versions of this document.

EARLY FLUID FAILURE ON EXTENDED SLATS AND FLAPS

- Research has determined that fluid degradation is accelerated by the steeper angles of the flaps/slats in the takeoff configuration. The degree of potential degradation is significantly affected by the specific aircraft design. For the winter of 2014-2015, holdover time and allowance time tables were published which include 90% adjusted holdover / allowance times. These adjusted tables will continue to be used for winter 2015-2016.
- The 90% adjusted tables provide holdover / allowance times that must be used when flaps and slats are deployed prior to de/anti-icing. Standard holdover / allowance times can be used if flaps and slats are deployed as close to departure as safety allows. Additional guidance is provided in the FAA N 8900 series notice “Revised FAA-Approved Deicing Program Updates, Winter 2015-2016.”

INTERPRETATION OF METAR CODE GS

- The World Meteorological Organization (WMO) states METAR code GS is used for two meteorological conditions: “snow pellets” and “small hail.” However, investigation has determined that not all countries follow these guidelines, notably Canada. The use of the reported GS code can potentially lead to difficulties in determining which condition (snow pellets or small hail) is occurring and therefore in establishing the appropriate holdover time/allowance time. The related section in the FAA N 8900 series notice “Revised FAA-Approved Deicing Program Updates, Winter 2015-2016” has been updated to provide proper guidance for determining which holdover times/allowance times should be used with METAR code GS.

KEY GUIDANCE FOR WINTER 2015-2016

TYPE I FLUID HOLDOVER TIMES. The Type I fluid holdover times for composite surfaces, Table 1C, and applicable sections of Table 0, must be applied to aircraft with all critical surfaces that are predominantly or entirely constructed of composite materials. However, the Type I fluid holdover times for composite surfaces do not need to be applied to aircraft that are currently in service, have a demonstrated safe operating history using Type I fluid aluminum structure holdover times, and have critical surfaces only partially constructed of composite material. The aluminum values also apply to other metals used in aircraft construction such as titanium. If there is any doubt, consult with the aircraft manufacturer to determine whether aluminum or composite holdover times are appropriate for the specific aircraft.

TYPE II AND TYPE IV GENERIC FLUID HOLDOVER TIMES. The values in the Type II and Type IV generic holdover time guidelines (Table 2-GENERIC, Table 4-GENERIC) are the shortest (worst case) holdover times of all Type II (Table 2-GENERIC) or all Type IV (Table 4-GENERIC) fluids included on the FAA List of Fluids. These values are specific to precipitation condition, temperature range, fluid concentration, and precipitation rate. An analysis of all available Type II and Type IV fluids is done annually to determine these values. The generic holdover times must be used if the specific Type II or Type IV fluid being used cannot positively be determined.

Note: The lowest on-wing viscosity (LOWV) of the fluid being used must always be respected, even when the generic Type II or Type IV holdover times are used.

HOLDOVER TIMES FOR NON-STANDARD DILUTIONS OF TYPE II, III, AND IV FLUIDS. When a Type II, III, or IV fluid is diluted to other than the published 100/0, 75/25 or 50/50 dilutions, the more conservative holdover time and LOUT associated with either the dilution above or below the selected dilution are applicable. For example:

1) The holdover time and LOUT of a 80/20 dilution would be the more conservative holdover time and LOUT of either the 100/0 or 75/25 dilutions;
2) The holdover time and LOUT of a 60/40 dilution would be the more conservative holdover time and LOUT of either the 75/25 or 50/50 dilutions.

SNOWFALL VISIBILITY TABLE. Table 5, Snowfall Intensities as a Function of Prevailing Visibility, is unchanged for 2015-2016. For simplification purposes, portions of the table may be included in an air carrier's winter operations plan in non-table format. An example would be: "Since very light snow is being added to some of the Type II and Type IV tables, and since the METAR and the associated ATIS do not report very light snow, a METAR reported visibility of 2.5 miles or higher can be used as an indication that the snowfall intensity is very light." An air carrier certainly would also have the option of providing a more detailed description utilizing lower METAR reported visibilities for specific day/night and temperature conditions.

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

USE OF RUNWAY VISUAL RANGE (RVR). The use of RVR is not permitted for determining visibility used with the holdover tables.

USE OF ELECTRONIC HAND HELD DEVICES TO DETERMINE HOLDOVER TIMES (eHOT). Electronic devices to determine HOTs may be used as part of an air operator's Title 14 of the Code of Federal Regulations (14 CFR) part 121, § 121.629 winter operations plan submitted to the FAA for approval. If for any reason the device or application fails or if the user has any concern regarding the

accuracy of the data being displayed, printed tables sourced from the FAA HOTS must be used as a fall back information source. Questions regarding the use of these devices should be submitted to charles.j.enders@faa.gov, 202-267-4557.

LOWEST OPERATIONAL USE TEMPERATURE (LOUT) TABLE. Lowest Operational Use Temperature (LOUT) information for Type I, II, III and IV fluids is provided in Table 8 and is updated for each version of this document. This information is derived by the FAA based on data provided by the fluid manufacturers. Contact the fluid manufacturer if further clarification with respect to the information in these tables is required.

The Lowest Operational Use Temperature, or LOUT, is the lowest temperature at which a de/anti-icing fluid will adequately flow off aircraft critical surfaces and maintain the required anti-icing freezing point buffer which is 7 °C (13 °F) below outside air temperature (OAT) for SAE Type II, Type III, and Type IV fluids and 10 °C (18 °F) below (OAT) for SAE Type I fluids.

For example, if a Type IV fluid has been aerodynamically tested and demonstrated adequate flow-off capability down to -30 °C (-22 °F), and the freezing point of this fluid is -35 °C (-31 °F), the LOUT would be -28 °C (-18.4 °F) to account for the required 7 °C (13 °F) freezing point buffer. In this case, the freezing point buffer requirement is the LOUT limiting factor.

Similarly if a Type I fluid has been found to adequately flow off down to -29 °C (-20.2 °F), and the freezing point is -40 °C (-40 °F), the LOUT would be -29 °C (-20.2 °F) to account for the lowest temperature at which the fluid adequately flows off the aircraft. Here, in this example, the fluid aerodynamic flow-off capability limits the LOUT.

There are two aerodynamic fluid flow-off test protocols: the high speed test for aircraft with rotation speeds generally greater than 100 or 110 knots and the low speed test is for aircraft with rotation speeds generally less than 100 knots. Type II, and Type IV fluids typically do not pass the low speed test. Therefore in order for these fluids to be used on a low rotation speed aircraft, the aircraft manufacturer must conduct testing to determine if these fluids can be safely applied on these aircraft and to identify operational procedures that must be implemented to insure the safe operation when these fluids have been applied.

The LOUTs for Type I fluids provided in Table 8-1 also include the manufacturer specified fluid/water concentration used to establish the LOUT for each fluid. This concentration should not be exceeded.

As previously stated, in the cases of Types II, III, and IV fluids, there can be multiple LOUTs to account for the undiluted fluid (100/0) and the 50/50 and 75/25 dilutions. In addition to being provided in Table 8, the LOUTs are also listed in their brand-specific holdover tables

FLIGHT CREW AWARENESS OF CONDITIONS AFFECTING THE AIRCRAFT ANTI-ICING TREATMENT FOLLOWING DEICING AND ANTI-ICING OPERATIONS. The operator's deicing plan must provide a process that informs the captain of the time of the deicing/anti-icing treatment and conditions that have affected the aircraft anti-icing treatment since that time. If the flight crew is not present at the time of the deicing/anti-icing application, the crew will review this information before calculating the holdover time.

STANDARDIZED INTERNATIONAL AIRCRAFT GROUND DEICING PROGRAM (SIAGDP). For those air carriers participating in the SIAGDP one change was agreed upon after the 2010-2011 winter revisions were made to the SIAGDP. This change was included in the 2011-2012 revision. This change addresses a concern that the air carriers have expressed over the completion of the annual audits within the anniversary month. In addition to the scheduling difficulties that this has generated, it has also necessitated that many of the audits be conducted in late summer and early fall prior to the service providers being in a full operational mode. In many cases this has limited the auditor's effectiveness and has not been conducive to the high quality audit that is fundamental to the success

of the SIAGDP. Therefore it was agreed upon by the member air carriers participating in the SIAGDP and the FAA policy office that the grace month concept that is currently applied to the training/qualification annual requirements under the SIAGDP will be also applied to the annual audit requirements. This allows a three month period in which the audit can be conducted and credited as though it was conducted in the month it was originally due. For example if the audit in 2009 was completed in September the next audit would be due in September 2010. The 2010 audit could be completed in either August, September or October 2010 and credited as completed in its original due month of September 2010. The next audit would be due in September 2011 regardless of which of the three months the audit was completed in 2010. The same grace month rational will apply for the 2011 audit as well. If the recurring audit is not completed in the three month applicable period then the service provider would be considered as a new service provider under the SIAGDP and an initial detailed qualification audit would need to be completed prior to any SIAGDP participating air carrier utilizing their services under the SIAGDP. Policy development is continuing in 2015-2016.

OPERATIONS IN HEAVY SNOW

Tactile and Visual Checks of Aircraft. No holdover times (HOT) exist for heavy snow conditions in the current HOT tables. Review of existing data from past testing has indicated takeoffs may be safely conducted with proper tactile and/or visual checks, as appropriate for the aircraft, and a determination that the fluid has not failed. A tactile and/or visual check in heavy snow conditions must be accomplished in a manner that provides an assessment that can be accurately accomplished. It is imperative that the tactile and/or visual check procedures to determine if the anti-icing fluid has failed in heavy snow conditions be at least as comprehensive as the authorized procedures for the operator's pretakeoff contamination check (when HOTs have been exceeded) for those precipitation conditions for which HOTs exist. Anti-icing fluids dissolve the snow and absorb the resulting moisture into the fluid. When the fluid begins to fail it starts to change in appearance (e.g., less glossy and more opaque) and the snow starts to accumulate on and in the fluid. At this stage, the fluid has failed and takeoff is not authorized. If the operator's procedure to accomplish this check is different from the operator's approved pretakeoff contamination check procedures for other precipitation conditions, this check procedure must be verified and approved by the operator's Principal Operations Inspector (POI).

Takeoff in Heavy Snow Conditions. Operators with a deicing program approved in accordance with 14 CFR part 121, § 121.629, will be allowed to takeoff in heavy snow conditions subject to the following restrictions:

1) The aircraft must be anti-iced with undiluted Type IV fluid.
2) The aircraft critical surfaces must be free of contaminants, or the aircraft must be properly deiced before the application of the anti-icing fluid.
3) When appropriate, the operator must accomplish an approved tactile and/or visual check of the aircraft critical surfaces within 5 minutes of takeoff.
4) If this check is accomplished visually from within the aircraft, the view must be such that it is not obscured by de/anti-icing fluid, dirt, or fogging. If the critical surfaces cannot be seen due to snowfall, distance from the viewing position, or inadequate lighting, or for any other reason, the check must be a visual or tactile check conducted from outside the aircraft.
5) If a definitive fluid failure determination cannot be made using the checks prescribed, takeoff is not authorized. The aircraft must be completely deiced, and if precipitation is still present, anti-iced again before a subsequent takeoff.

Note: Current aircraft certification standards only require testing of flight instrument sensing devices and engine anti-icing systems in moderate snow levels. Ground operations in heavy snow conditions may exceed the capabilities or limitations of these systems and devices to adequately provide anti-icing.

HOLDOVER TIME (HOT) GUIDELINES FOR WINTER 2015-2016

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HOT Guidelines - SAE Type I, II, III, and IV Fluids in Active Frost ..... Table 0
Type I HOT Guidelines - SAE Type I Fluid on Critical Aircraft Surfaces Composed Predominantly of Aluminum ..... Table 1A
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Type II HOT Guidelines - SAE Type II Fluids ..... Table 2-Generic
Type II HOT Guidelines - ABAX ECOWING 26 ..... Table 2A
Type II HOT Guidelines - AVIATION SHAANXI HI-TECH CLEANWING II ..... Table 2B
Type II HOT Guidelines - CLARIANT SAFEWING MP II FLIGHT ..... Table 2C
Type II HOT Guidelines - CLARIANT SAFEWING MP II FLIGHT PLUS ..... Table 2D
Type II HOT Guidelines - CRYOTECH POLAR GUARD® II ..... Table 2E
Type II HOT Guidelines - KILFROST ABC-ICE CLEAR II ..... Table 2F
Type II HOT Guidelines - KILFROST ABC-K PLUS ..... Table 2G
Type II HOT Guidelines - LNT SOLUTIONS P250 ..... Table 2H
Type II HOT Guidelines - NEWAVE AEROCHEMICAL FCY-2 ..... Table 2I
Type II HOT Guidelines - NEWAVE AEROCHEMICAL FCY-2 BIO+ ..... Table 2J
Type III HOT Guidelines - ALLCLEAR AEROCLEAR MAX, Low Speed ..... Table 3A-LS
Type III HOT Guidelines - ALLCLEAR AEROCLEAR MAX, High Speed ..... Table 3A-HS
Type III HOT Guidelines - CLARIANT SAFEWING MP III 2031 ECO, Low Speed ..... Table 3B-LS
Type III HOT Guidelines - CLARIANT SAFEWING MP III 2031 ECO, High Speed ..... Table 3B-HS
Type IV HOT Guidelines - SAE Type IV Fluids ..... Table 4-Generic
Type IV HOT Guidelines - ABAX ECOWING AD-49 ..... Table 4A
Type IV HOT Guidelines - CLARIANT MAX FLIGHT 04 ..... Table 4B
Type IV HOT Guidelines - CLARIANT MAX FLIGHT SNEG ..... Table 4C
Type IV HOT Guidelines - CLARIANT SAFEWING MP IV LAUNCH ..... Table 4D
Type IV HOT Guidelines - CLARIANT SAFEWING MP IV LAUNCH PLUS ..... Table 4E
Type IV HOT Guidelines - CRYOTECH POLAR GUARD® ..... Table 4F
Type IV HOT Guidelines - CRYOTECH POLAR GUARD® ADVANCE ..... Table 4G
Type IV HOT Guidelines - DEICING SOLUTIONS ECO-SHIELD® ..... Table 4H
Type IV HOT Guidelines - DOW CHEMICAL UCAR™ ENDURANCE EG106 ..... Table 4I
Type IV HOT Guidelines - DOW CHEMICAL UCAR™ FLIGHTGUARD AD-480 ..... Table 4J
Type IV HOT Guidelines - DOW CHEMICAL UCAR™ FLIGHTGUARD AD-49 ..... Table 4K
Type IV HOT Guidelines - KILFROST ABC-S PLUS ..... Table 4L
Type IV HOT Guidelines - LNT SOLUTIONS E450 ..... Table 4M
Type IV HOT Guidelines - NEWAVE AEROCHEMICAL FCY 9311 ..... Table 4N

Supplemental Guidance

Snowfall Intensities as a Function of Prevailing Visibility ..... Table 5
Ice Pellet and Small Hail Allowance Times - SAE Type III Fluids ..... Table 6
Ice Pellet and Small Hail Allowance Times - SAE Type IV Fluids ..... Table 7
Fluids Tested for Anti-icing Performance and Aerodynamic Acceptance ..... Table 8
Guidelines for the Application of SAE Type I Fluid ..... Table 9
Guidelines for the Application of SAE Type II, Type III, and Type IV Fluid ..... Table 10

90% Adjusted HOT Guidelines

90% Adjusted HOT Guidelines - SAE Type I, II, III, and IV Fluids in Active Frost ..... Table 0-90%
90% Adjusted Type I HOT Guidelines - SAE Type I Fluid on Critical Aircraft Surfaces Composed Predominantly of Aluminum ..... Table 1A-90%
90% Adjusted Type I HOT Guidelines - SAE Type I Fluid on Critical Aircraft Surfaces Composed Predominantly of Composites ..... Table 1C-90%
90% Adjusted Type II HOT Guidelines - SAE Type II Fluid ..... Table 2-Generic-90%
90% Adjusted Type II HOT Guidelines - ABAX ECOWING 26 ..... Table 2A-90%
90% Adjusted Type II HOT Guidelines - AVIATION SHAANXI HI-TECH CLEANWING II ..... Table 2B-90%
90% Adjusted Type II HOT Guidelines - CLARIANT SAFEWING MP II FLIGHT ..... Table 2C-90%
90% Adjusted Type II HOT Guidelines - CLARIANT SAFEWING MP II FLIGHT PLUS ..... Table 2D-90%
90% Adjusted Type II HOT Guidelines - CRYOTECH POLAR GUARD® II ..... Table 2E-90%
90% Adjusted Type II HOT Guidelines - KILFROST ABC-ICE CLEAR II ..... Table 2F-90%
90% Adjusted Type II HOT Guidelines - KILFROST ABC-K PLUS ..... Table 2G-90%
90% Adjusted Type II HOT Guidelines - LNT SOLUTIONS P250 ..... Table 2H-90%
90% Adjusted Type II HOT Guidelines - NEWAVE AEROCHEMICAL FCY-2 ..... Table 2I-90%
90% Adjusted Type II HOT Guidelines - NEWAVE AEROCHEMICAL FCY-2 BIO+ ..... Table 2J-90%
90% Adjusted Type III HOT Guidelines - ALLCLEAR AEROCLEAR MAX, Low Speed ..... Table 3A-LS-90%
90% Adjusted Type III HOT Guidelines - ALLCLEAR AEROCLEAR MAX, High Speed ..... Table 3A-HS-90%
90% Adjusted Type III HOT Guidelines - CLARIANT SAFEWING MP III 2031 ECO, Low Speed ..... Table 3B-LS-90%
90% Adjusted Type III HOT Guidelines - CLARIANT SAFEWING MP III 2031 ECO, High Speed ..... Table 3B-HS-90%
90% Adjusted Type IV HOT Guidelines - SAE Type IV Fluids ..... Table 4-Generic-90%
90% Adjusted Type IV HOT Guidelines - ABAX ECOWING AD-49 ..... Table 4A-90%
90% Adjusted Type IV HOT Guidelines - CLARIANT MAX FLIGHT 04 ..... Table 4B-90%
90% Adjusted Type IV HOT Guidelines - CLARIANT MAX FLIGHT SNEG ..... Table 4C-90%
90% Adjusted Type IV HOT Guidelines - CLARIANT SAFEWING MP IV LAUNCH ..... Table 4D-90%
90% Adjusted Type IV HOT Guidelines - CLARIANT SAFEWING MP IV LAUNCH PLUS ..... Table 4E-90%
90% Adjusted Type IV HOT Guidelines - CRYOTECH POLAR GUARD® ..... Table 4F-90%
90% Adjusted Type IV HOT Guidelines - CRYOTECH POLAR GUARD® ADVANCE ..... Table 4G-90%
90% Adjusted Type IV HOT Guidelines - DEICING SOLUTIONS ECO-SHIELD® ..... Table 4H-90%
90% Adjusted Type IV HOT Guidelines - DOW CHEMICAL UCAR™ ENDURANCE EG106 .. Table 4I-90%
90% Adjusted Type IV HOT Guidelines - DOW CHEMICAL UCAR™ FLIGHTGUARD AD-480 ..... Table 4J-90%
90% Adjusted Type IV HOT Guidelines - DOW CHEMICAL UCAR™ FLIGHTGUARD AD-49 ..... Table 4K-90%
90% Adjusted Type IV HOT Guidelines - KILFROST ABC-S PLUS ..... Table 4L-90%
90% Adjusted Type IV HOT Guidelines - LNT SOLUTIONS E450 ..... Table 4M-90%
90% Adjusted Type IV HOT Guidelines - NEWAVE AEROCHEMICAL FCY 9311 ..... Table 4N-90%

90% Adjusted Allowance Times

90% Adjusted Ice Pellet and Small Hail Allowance Times - SAE Type III Fluids ..... Table 6-90%
90% Adjusted Ice Pellet and Small Hail Allowance Times - SAE Type IV Fluids ..... Table 7-90%

TABLE 0. HOLDOVER TIME GUIDELINES FOR SAE TYPE I, TYPE II, TYPE III, AND TYPE IV FLUIDS IN ACTIVE FROST

Outside Air Temperature[1,2]		Approximate Holdover Times (hours:minutes)
Degrees Celsius	Degrees Fahrenheit	Active Frost
		Type I
-1 and above	30 and above	0:45 (0:35)[4]
below -1 to -3	below 30 to 27	
below -3 to -10	below 27 to 14	
below -10 to -14	below 14 to 7	
below -14 to -21	below 7 to -6	
below -21 to LOUT	below -6 to LOUT	

Outside Air Temperature[2]		Concentration Neat Fluid/Water (Volume %/ Volume %)	Approximate Holdover Times (hours:minutes)		
Degrees Celsius	Degrees Fahrenheit		Active Frost		
			Type II	Type III[3]	Type IV
-1 and above	30 and above	100/0	8:00	2:00	12:00
		75/25	5:00	1:00	5:00
		50/50	3:00	0:30	3:00
below -1 to -3	below 30 to 27	100/0	8:00	2:00	12:00
		75/25	5:00	1:00	5:00
		50/50	1:30	0:30	3:00
below -3 to -10	below 27 to 14	100/0	8:00	2:00	10:00
		75/25	5:00	1:00	5:00
below -10 to -14	below 14 to 7	100/0	6:00	2:00	6:00
		75/25	1:00	1:00	1:00
below -14 to -21	below 7 to -6	100/0	6:00	2:00	6:00
below -21 to -25	below -6 to -13	100/0	2:00	2:00	4:00
Below -25	Below -13	No holdover time guidelines exist			

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

1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10 °C (18 °F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To use the Type III fluid frost holdover times, the fluid brand being used must be known. AllClear AeroClear MAX must be applied unheated. Clariant Safewing MP III 2031 ECO must be applied heated.
4 Value in parentheses is for aircraft with critical surfaces that are predominantly or entirely constructed of composite materials.

CAUTIONS:

- **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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FAA 2015-2016 Holdover Time Guidelines 07/31/15

TABLE 1A. HOLDOVER TIME GUIDELINES FOR SAE TYPE I FLUID ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF ALUMINUM

Outside Air Temperature[1,2]		Wing Surface	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	Aluminum	0:11-0:17	0:18-0:22	0:11-0:18	0:06-0:11	0:09-0:13	0:02-0:05	0:02-0:05	
below -3 to -6	below 27 to 21	Aluminum	0:08-0:13	0:14-0:17	0:08-0:14	0:05-0:08	0:05-0:09	0:02-0:05	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	Aluminum	0:06-0:10	0:11-0:13	0:06-0:11	0:04-0:06	0:04-0:07	0:02-0:05		
Below -10	below 14	Aluminum	0:05-0:09	0:07-0:08	0:04-0:07	0:02-0:04				

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

1 Type I fluid / water mixture must be selected so that the freezing point of the mixture is at least 10 °C (18 °F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The 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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TABLE 1C. HOLDOVER TIME GUIDELINES FOR SAE TYPE I FLUID ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF COMPOSITES

Outside Air Temperature[1,2]		Wing Surface	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	Composite	0:09-0:16	0:12-0:15	0:06-0:12	0:03-0:06	0:08-0:13	0:02-0:05	0:01-0:05	
below -3 to -6	below 27 to 21	Composite	0:06-0:08	0:11-0:13	0:05-0:11	0:02-0:05	0:05-0:09	0:02-0:05	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	Composite	0:04-0:08	0:09-0:12	0:05-0:09	0:02-0:05	0:04-0:07	0:02-0:05		
Below -10	below 14	Composite	0:04-0:07	0:07-0:08	0:04-0:07	0:02-0:04				

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

1 Type I fluid / water mixture must be selected so that the freezing point of the mixture is at least 10 °C (18 °F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The 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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TABLE 2-GENERIC. TYPE II HOLDOVER TIME GUIDELINES FOR SAE TYPE II FLUIDS

Outside Air Temperature[1]		Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	0:35-1:30	0:20-0:45	0:30-1:00	0:15-0:30	0:07-0:40	
		75/25	0:25-1:00	0:15-0:30	0:20-0:45	0:10-0:25	0:05-0:25	
		50/50	0:15-0:30	0:05-0:15	0:10-0:20	0:05-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20-1:05	0:15-0:30	0:20-0:45[7]	0:10-0:20[7]		
		75/25	0:25-0:50	0:08-0:20	0:15-0:30[7]	0:08-0:15[7]		
Below -14 to LOUT	Below 7 to LOUT	100/0	0:15-0:35[8]	0:15-0:30[8]				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
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 -25° C (-13 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 2A. TYPE II HOLDOVER TIME GUIDELINES FOR ABAX ECOWING 26

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:25-2:35	1:35-1:50	1:00-1:35	0:40-1:00	0:50-1:35	0:40-0:50	0:20-1:25	
		75/25	1:05-1:55	1:15-1:25	0:45-1:15	0:25-0:45	0:45-1:05	0:25-0:35	0:10-1:00	
		50/50	0:30-0:45	0:40-0:50	0:20-0:40	0:10-0:20	0:15-0:25	0:08-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45-2:15	1:25-1:40	0:55-1:25	0:35-0:55	0:30-1:10[7]	0:15-0:35[7]		
		75/25	0:35-1:15	0:55-1:05	0:40-0:55	0:25-0:40	0:20-0:50[7]	0:15-0:25[7]		
below -14 to -25	below 7 to -13	100/0	0:25-0:45	0:40-0:50	0:30-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 2B. TYPE II HOLDOVER TIME GUIDELINES FOR AVIATION SHAANXI HI-TECH CLEANWING II

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	0:55-1:50	0:30-0:55	0:35-1:05	0:25-0:35	0:10-0:55	
		75/25	0:50-1:20	0:25-0:45	0:35-1:00	0:20-0:30	0:07-0:50	
		50/50	0:35-1:00	0:15-0:30	0:20-0:40	0:10-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45-1:50	0:30-0:55	0:30-0:55[7]	0:20-0:25[7]		
		75/25	0:40-1:45	0:25-0:45	0:35-0:40[7]	0:20-0:25[7]		
below -14 to -29	below 7 to -20.2	100/0	0:20-0:50	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 2C. TYPE II HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP II FLIGHT

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:30-4:00	2:35-3:00	1:35-2:35	1:00-1:35	1:20-2:00	0:45-1:25	0:10-1:30	
		75/25	1:50-2:45	2:35-3:00	1:20-2:35	0:40-1:20	1:10-1:30	0:30-0:55	0:06-0:50	
		50/50	0:55-1:45	0:45-0:55	0:25-0:45	0:10-0:25	0:20-0:30	0:10-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55-1:45	1:50-2:10	1:05-1:50	0:40-1:05	0:35-1:30[7]	0:25-0:45[7]		
		75/25	0:25-1:05	1:20-1:40	0:40-1:20	0:20-0:40	0:25-1:10[7]	0:20-0:35[7]		
Below -14 to -29	Below 7 to -20.2	100/0	0:30-0:50	0:40-0:50	0:30-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 2D. TYPE II HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP II FLIGHT PLUS

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:40-4:00	0:50-1:50	1:25-2:00	0:45-1:00	0:15-2:00	
		75/25	2:35-4:00	1:00-1:45	1:35-2:00	0:50-1:15	0:15-1:15	
		50/50	1:05-2:20	0:15-0:25	0:30-1:05	0:15-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40-2:20	0:35-1:15	0:35-1:25[7]	0:35-0:55[7]		
		75/25	0:30-1:45	0:55-1:40	0:25-1:10[7]	0:30-0:45[7]		
Below -14 to -29	Below 7 to -20.2	100/0	0:20-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 2E. TYPE II HOLDOVER TIME GUIDELINES FOR CRYOTECH POLAR GUARD® II

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:50-4:00	2:35-2:50	1:50-2:35	1:20-1:50	1:35-2:00	1:15-1:30	0:15-2:00	
		75/25	2:30-4:00	2:25-2:55	1:20-2:25	0:45-1:20	1:40-2:00	0:40-1:10	0:09-1:40	
		50/50	0:50-1:25	1:20-1:45	0:35-1:20	0:15-0:35	0:20-0:45	0:09-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55-2:30	1:45-1:55	1:15-1:45	0:55-1:15	0:35-1:35[7]	0:35-0:45[7]		
		75/25	0:40-1:30	1:45-2:05	1:00-1:45	0:35-1:00	0:25-1:05[7]	0:35-0:45[7]		
Below -14 to -30.5	Below 7 to -22.9	100/0	0:25-0:50	0:40-0:50	0:30-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 2F. TYPE II HOLDOVER TIME GUIDELINES FOR KILFROST ABC-ICE CLEAR II

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:00-1:45	1:45-2:10	0:50-1:45	0:25-0:50	0:40-1:05	0:25-0:35	0:07-0:45	
		75/25	0:50-1:10	1:20-1:45	0:40-1:20	0:20-0:40	0:30-0:45	0:20-0:30	0:05-0:35	
		50/50	0:15-0:30	0:20-0:25	0:15-0:20	0:08-0:15	0:10-0:20	0:07-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40-1:35	1:15-1:35	0:35-1:15	0:20-0:35	0:25-1:00[7]	0:15-0:30[7]		
		75/25	0:40-1:20	0:55-1:10	0:25-0:55	0:15-0:25	0:25-0:45[7]	0:15-0:20[7]		
Below -14 to -29.5	Below 7 to -21.1	100/0	0:20-0:40	0:40-0:50	0:30-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 2G. TYPE II HOLDOVER TIME GUIDELINES FOR KILFROST ABC-K PLUS

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:15-3:45	1:00-1:40	1:50-2:00	1:00-1:25	0:20-2:00	
		75/25	1:40-2:30	0:35-1:10	1:25-2:00	0:50-1:10	0:15-2:00	
		50/50	0:35-1:05	0:07-0:15	0:20-0:30	0:10-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:30-1:05	0:50-1:25	0:25-1:00[7]	0:15-0:35[7]		
		75/25	0:25-1:25	0:35-1:05	0:20-0:55[7]	0:09-0:30[7]		
below -14 to -29	below 7 to -20.2	100/0	0:30-0:55	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 2H. TYPE II HOLDOVER TIME GUIDELINES FOR LNT SOLUTIONS P250

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:10-4:00	3:00-3:00	1:45-3:00	0:55-1:45	1:35-2:00	0:50-1:25	0:15-2:00	
		75/25	1:50-2:35	2:50-3:00	1:25-2:50	0:45-1:25	1:20-1:35	0:40-1:00	0:10-1:50	
		50/50	0:35-0:50	1:05-1:25	0:30-1:05	0:15-0:30	0:20-0:35	0:15-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45-2:20	3:00-3:00	1:40-3:00	0:50-1:40	0:25-1:20[7]	0:25-0:35[7]		
		75/25	0:35-1:45	2:50-3:00	1:25-2:50	0:45-1:25	0:20-1:15[7]	0:20-0:30[7]		
Below -14 to LOUT	Below 7 to LOUT	100/0	0:20-0:50	0:40-0:50	0:30-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 2I. TYPE II HOLDOVER TIME GUIDELINES FOR NEWAVE AEROCHEMICAL FCY-2

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	1:15-2:25	0:30-0:55	0:35-1:05	0:25-0:35	0:08-0:45	
		75/25	0:50-1:30	0:20-0:40	0:25-0:45	0:15-0:25	0:05-0:25	
		50/50	0:25-0:35	0:15-0:25	0:10-0:20	0:07-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45-1:30	0:15-0:30	0:20-0:45[7]	0:15-0:20[7]		
		75/25	0:30-1:05	0:10-0:20	0:15-0:30[7]	0:08-0:15[7]		
below -14 to -28	below 7 to -18.4	100/0	0:25-0:35	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 2J. TYPE II HOLDOVER TIME GUIDELINES FOR NEWAVE AEROCHEMICAL FCY-2 BIO+

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:25-2:30	2:20-2:55	1:05-2:20	0:30-1:05	0:50-1:20	0:25-0:45	0:08-1:15	
		75/25	0:45-1:20	1:20-1:40	0:40-1:20	0:20-0:40	0:25-0:50	0:15-0:25	0:06-0:35	
		50/50	0:15-0:30	0:25-0:30	0:15-0:25	0:08-0:15	0:10-0:20	0:08-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:40-1:30	1:00-1:15	0:30-1:00	0:15-0:30	0:35-1:05[7]	0:15-0:30[7]		
		75/25	0:30-1:05	0:35-0:45	0:20-0:35	0:08-0:20	0:20-0:35[7]	0:15-0:20[7]		
below -14 to -28.5	below 7 to -19.3	100/0	0:20-1:00	0:40-0:50	0:30-0:40	0:15-0:30				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 3A-LS. LOW SPEED TYPE III HOLDOVER TIME GUIDELINES FOR ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 LOW SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:00-2:15	0:35-0:40	0:20-0:35	0:10-0:20	0:40-1:20	0:25-0:30	0:09-1:00	
		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 -10	below 27 to 14	100/0	1:00-1:45	0:30-0:35	0:15-0:30	0:09-0:15	0:40-1:10	0:30-0:40		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -10 to -16	below 14 to 3.2	100/0	0:30-1:05	0:30-0:35	0:15-0:30	0:08-0:15				

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

1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid when applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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 3A-HS. HIGH SPEED TYPE III HOLDOVER TIME GUIDELINES FOR ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 HIGH SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	1:00-2:15	0:35-0:40	0:20-0:35	0:10-0:20	0:40-1:20	0:25-0:30	0:09-1:00	
		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 -10	below 27 to 14	100/0	1:00-1:45	0:30-0:35	0:15-0:30	0:09-0:15	0:40-1:10	0:30-0:40		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -10 to -25	below 14 to -13	100/0	0:30-1:05	0:30-0:35	0:15-0:30	0:08-0:15				
below -25 to -35	below -13 to -31	100/0	0:18-0:55							

CAUTION: No holdover time guidelines exist

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

1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid when applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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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TABLE 3B-LS. LOW SPEED TYPE III HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP III 2031 ECO, APPLIED HEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 LOW SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	0:25-0:50	0:40-0:55	0:20-0:40	0:10-0:20	0:17-0:30	0:10-0:14	0:05-0:30	
		75/25	0:19-0:40	0:35-0:45	0:16-0:35	0:07-0:16	0:13-0:20	0:08-0:09	0:03-0:18	
		50/50	0:13-0:18	0:25-0:30	0:13-0:25	0:07-0:13	0:13-0:14	0:07-0:07	CAUTION: No holdover time guidelines exist	
below -3 to -10	below 27 to 14	100/0	0:35-1:15	0:40-0:50	0:20-0:40	0:10-0:20	0:14-0:30	0:09-0:13		
		75/25	0:19-0:45[8]	0:25-0:35[8]	0:12-0:25[8]	0:05-0:12[8]	0:09-0:16[8]	0:06-0:08[8]		
below -10 to -16.5	below 14 to 2.3	100/0	0:25-0:45	0:40-0:45	0:19-0:40	0:09-0:19				

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

1 Fluid must be applied heated to use these holdover times. No holdover times exist for this fluid applied unheated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 6 provides allowance times for ice pellets and small hail).
8 No holdover time guidelines exist for 75/25 fluid below -9 °C (15.8 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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 3B-HS. HIGH SPEED TYPE III HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP III 2031 ECO, APPLIED HEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 HIGH SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	0:25-0:50	0:40-0:55	0:20-0:40	0:10-0:20	0:17-0:30	0:10-0:14	0:05-0:30	CAUTION: No holdover time guidelines exist
		75/25	0:19-0:40	0:35-0:45	0:16-0:35	0:07-0:16	0:13-0:20	0:08-0:09	0:03-0:18	
		50/50	0:13-0:18	0:25-0:30	0:13-0:25	0:07-0:13	0:13-0:14	0:07-0:07		
below -3 to -10	below 27 to 14	100/0	0:35-1:15	0:40-0:50	0:20-0:40	0:10-0:20	0:14-0:30	0:09-0:13		
		75/25	0:19-0:45	0:25-0:35	0:12-0:25	0:05-0:12	0:09-0:16	0:06-0:08		
below -10 to -25	below 14 to -13	100/0	0:25-0:45	0:40-0:45	0:19-0:40	0:09-0:19				
below -25 to -29	below -13 to -20.2	100/0	0:25-0:45	0:40-0:45	0:19-0:40	0:09-0:19				

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

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

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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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TABLE 4-GENERIC. TYPE IV HOLDOVER TIME GUIDELINES FOR SAE TYPE IV FLUIDS

Outside Air Temperature[1]		Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	1:30-2:25	0:35-1:10	0:50-1:30	0:35-0:50	0:10-1:25	
		75/25	1:25-2:40	0:30-1:05	0:50-1:15	0:30-0:45	0:09-1:15	
		50/50	0:25-0:40	0:09-0:15	0:15-0:25	0:09-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20-1:20	0:25-0:50	0:25-1:10[7]	0:15-0:25[7]		
		75/25	0:25-0:50[8]	0:20-0:40[8]	0:15-1:05[7,8]	0:15-0:25[7,8]		
below -14 to LOUT	below 7 to LOUT	100/0	0:15-0:40[9]	0:15-0:30[9]				

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

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 5) 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 7 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 -5.5 °C (22.1 °F).
9 If the LOUT is unknown, no holdover time guidelines exist below -23.5 °C (-10.3 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4A. TYPE IV HOLDOVER TIME GUIDELINES FOR ABAX ECOWING AD-49

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:20-4:00	2:50-3:00	1:50-2:50	1:10-1:50	1:25-2:00	1:00-1:25	0:10-1:55	
		75/25	2:25-4:00	2:05-2:15	1:40-2:05	1:20-1:40	1:55-2:00	0:50-1:30	0:10-1:40	
		50/50	0:25-0:50	0:40-0:45	0:25-0:40	0:15-0:25	0:15-0:30	0:10-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20-1:35	2:50-3:00	1:50-2:50	1:10-1:50	0:25-1:25[7]	0:20-0:25[7]		
		75/25	0:30-1:10	2:05-2:15	1:40-2:05	1:20-1:40	0:15-1:05[7]	0:15-0:25[7]		
below -14 to -26	below 7 to -14.8	100/0	0:25-0:40	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 4B. TYPE IV HOLDOVER TIME GUIDELINES FOR CLARIANT MAX FLIGHT 04

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:40-4:00	3:00-3:00	2:45-3:00	1:25-2:45	2:00-2:00	1:10-1:30	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 -14	below 27 to 7	100/0	0:50-2:30	2:20-2:50	1:10-2:20	0:35-1:10	0:25-1:30[7]	0:20-0:40[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -23.5	below 7 to -10.3	100/0	0:20-0:45	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4C. TYPE IV HOLDOVER TIME GUIDELINES FOR CLARIANT MAX FLIGHT SNEG

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:25-4:00	2:45-3:00	1:40-2:45	1:05-1:40	2:00-2:00	0:50-1:40	0:20-1:30	
		75/25	4:00-4:00	2:25-2:50	1:30-2:25	0:55-1:30	1:30-2:00	1:05-1:20	0:15-1:45	
		50/50	1:30-3:30	1:45-2:20	0:45-1:45	0:20-0:45	0:35-1:10	0:15-0:30	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45-2:20	2:00-2:20	1:15-2:00	0:45-1:15	0:30-1:25[7]	0:25-0:40[7]		
		75/25	0:30-1:25	1:40-2:00	1:00-1:40	0:40-1:00	0:20-1:05[7]	0:20-0:40[7]		
below -14 to -29	below 7 to -20.2	100/0	0:20-0:50	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 4D. TYPE IV HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP IV LAUNCH

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	4:00-4:00	2:50-3:00	1:45-2:50	1:05-1:45	1:30-2:00	1:00-1:40	0:15-1:40	
		75/25	3:40-4:00	3:00-3:00	1:45-3:00	1:00-1:45	1:40-2:00	0:45-1:15	0:10-1:45	
		50/50	1:25-2:45	1:25-1:40	0:45-1:25	0:25-0:45	0:30-0:50	0:20-0:25	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:00-1:55	2:10-2:30	1:20-2:10	0:50-1:20	0:35-1:40[7]	0:25-0:45[7]		
		75/25	0:40-1:20	2:25-2:55	1:25-2:25	0:45-1:25	0:25-1:10[7]	0:25-0:45[7]		
below -14 to -28.5	below 7 to -19.3	100/0	0:30-0:50	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4E. TYPE IV HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP IV LAUNCH PLUS

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:55-4:00	3:00-3:00	2:05-3:00	0:55-2:05	2:00-2:00	1:00-2:00	0:20-2:00	
		75/25	3:55-4:00	3:00-3:00	1:55-3:00	0:50-1:55	2:00-2:00	1:20-1:25	0:20-1:50	
		50/50	1:15-1:50	1:35-2:00	0:45-1:35	0:20-0:45	0:25-1:00	0:15-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55-2:15	3:00-3:00	1:25-3:00	0:40-1:25	0:25-1:35[7]	0:25-0:40[7]		
		75/25	0:40-2:00	2:55-3:00	1:15-2:55	0:30-1:15	0:20-1:05[7]	0:20-0:30[7]		
below -14 to -29	below 7 to -20.2	100/0	0:25-0:50	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 4F. TYPE IV HOLDOVER TIME GUIDELINES FOR CRYOTECH POLAR GUARD®

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:15-3:30	0:50-1:30	1:15-2:00	0:50-1:15	0:15-1:25	
		75/25	1:40-2:40	0:35-1:10	1:05-1:25	0:35-1:00	0:10-1:15	
		50/50	0:25-0:40	0:10-0:15	0:15-0:25	0:10-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:45-1:45	0:30-0:55	0:25-1:10[7]	0:15-0:35[7]		
		75/25[8]	0:35-1:30[8]	0:20-0:40[8]	0:25-1:05[8]	0:20-0:30[8]		
Below -14 to -23.5	Below 7 to -10.3	100/0	0:20-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).
8 Temperature is limited to -5.5 °C (22 °F) when using 75/25 dilution of this fluid.

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4G. TYPE IV HOLDOVER TIME GUIDELINES FOR CRYOTECH POLAR GUARD® ADVANCE

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:50-4:00	2:35-2:50	1:50-2:35	1:20-1:50	1:35-2:00	1:15-1:30	0:15-2:00	
		75/25	2:30-4:00	2:25-2:55	1:20-2:25	0:45-1:20	1:40-2:00	0:40-1:10	0:09-1:40	
		50/50	0:50-1:25	1:20-1:45	0:35-1:20	0:15-0:35	0:20-0:45	0:09-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55-2:30	1:45-1:55	1:15-1:45	0:55-1:15	0:35-1:35[7]	0:35-0:45[7]		
		75/25	0:40-1:30	1:45-2:05	1:00-1:45	0:35-1:00	0:25-1:05[7]	0:35-0:45[7]		
Below -14 to -30.5	Below 7 to -22.9	100/0	0:25-0:50	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 4H. TYPE IV HOLDOVER TIME GUIDELINES FOR DEICING SOLUTIONS ECO-SHIELD®

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:30-2:25	2:25-2:55	1:20-2:25	0:45-1:20	0:55-1:35	0:40-0:50	0:15-1:55	
		75/25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
		50/50	N/A	N/A	N/A	N/A	N/A	N/A	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:10-2:30	1:45-2:05	0:55-1:45	0:30-0:55	0:45-2:00[7]	0:25-0:40[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -24.5	below 7 to -12.1	100/0	0:30-0:55	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4I. TYPE IV HOLDOVER TIME GUIDELINES FOR DOW CHEMICAL UCAR™ ENDURANCE EG106

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:05-3:10	2:45-3:00	1:20-2:45	0:40-1:20	1:10-2:00	0:50-1:15	0:20-2:00	
		75/25	N/A	N/A	N/A	N/A	N/A	N/A	CAUTION: No holdover time guidelines exist	
		50/50	N/A	N/A	N/A	N/A	N/A	N/A		
below -3 to -14	below 27 to 7	100/0	1:50-3:20	2:10-2:45	1:05-2:10	0:30-1:05	0:55-1:50[7]	0:45-1:10[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -27	below 7 to -16.6	100/0	0:30-1:05	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 4J. TYPE IV HOLDOVER TIME GUIDELINES FOR DOW CHEMICAL UCAR™ FLIGHTGUARD AD-480

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:00-3:30	0:40-1:20	0:50-1:30	0:35-0:55	0:15-1:35	
		75/25	1:30-2:45	0:30-1:05	0:50-1:15	0:30-0:45	0:10-1:15	
		50/50	0:30-0:45	0:09-0:20	0:15-0:25	0:09-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20-1:20	0:30-0:55	0:25-1:20[7]	0:15-0:30[7]		
		75/25	0:25-0:50	0:20-0:45	0:25-1:05[7]	0:15-0:30[7]		
below -14 to -26	below 7 to -14.8	100/0	0:15-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 4K. TYPE IV HOLDOVER TIME GUIDELINES FOR DOW CHEMICAL UCAR™ FLIGHTGUARD AD-49

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:20-4:00	2:50-3:00	1:50-2:50	1:10-1:50	1:25-2:00	1:00-1:25	0:10-1:55	
		75/25	2:25-4:00	2:05-2:15	1:40-2:05	1:20-1:40	1:55-2:00	0:50-1:30	0:10-1:40	
		50/50	0:25-0:50	0:40-0:45	0:25-0:40	0:15-0:25	0:15-0:30	0:10-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20-1:35	2:50-3:00	1:50-2:50	1:10-1:50	0:25-1:25[7]	0:20-0:25[7]		
		75/25	0:30-1:10	2:05-2:15	1:40-2:05	1:20-1:40	0:15-:1:05[7]	0:15-0:25[7]		
below -14 to -26	below 7 to -14.8	100/0	0:25-0:40	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 4L. TYPE IV HOLDOVER TIME GUIDELINES FOR KILFROST ABC-S PLUS

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:10-4:00	3:00-3:00	2:05-3:00	1:15-2:05	1:50-2:00	1:05-2:00	0:25-2:00	
		75/25	1:25-2:40	2:05-2:25	1:15-2:05	0:45-1:15	1:00-1:20	0:30-0:50	0:10-1:20	
		50/50	0:30-0:55	1:00-1:10	0:30-1:00	0:15-0:30	0:15-0:40	0:15-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:55-3:30	2:55-3:00	1:45-2:55	1:00-1:45	0:25-1:35[7]	0:20-0:30[7]		
		75/25	0:45-1:50	1:45-2:00	1:00-1:45	0:35-1:00	0:20-1:10[7]	0:15-0:25[7]		
below -14 to -28	below 7 to -18.4	100/0	0:40-1:00	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 4M. TYPE IV HOLDOVER TIME GUIDELINES FOR LNT SOLUTIONS E450

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:50-2:55	2:25-2:45	1:35-2:25	1:00-1:35	1:35-2:00	0:55-1:20	0:25-2:00	
		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 -14	below 27 to 7	100/0	1:30-3:55	1:50-2:05	1:10-1:50	0:45-1:10	1:45-2:00[7]	1:05-1:40[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to LOUT	below 7 to LOUT	100/0	0:35-1:05	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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TABLE 4N. TYPE IV HOLDOVER TIME GUIDELINES FOR NEWAVE AEROCHEMICAL FCY 9311

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:55-4:00	2:20-2:55	1:10-2:20	0:35-1:10	1:10-2:00	0:40-1:05	0:15-1:25	
		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 -14	below 27 to 7	100/0	0:35-2:05	1:35-2:00	0:50-1:35	0:25-0:50	0:35-1:20[7]	0:20-0:35[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -29.5	below 7 to -21.1	100/0	0:30-0:55	0:40-0:50	0:30-0:40	0:15-0:30				

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

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 5) 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 7 provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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 5. SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY

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

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

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

NOTE 3: If visibility from a source other than the METAR is used, round to the nearest visibility in the table, rounding down if it is right in between two values. For example, .6 and .625 (5/8) would both be rounded to .5 (1/2).

HEAVY = Caution—No Holdover Time Guidelines Exist

During snow conditions alone, the use of Table 5 in determining snowfall intensities does not require pilot company coordination or company reporting procedures since this table is more conservative than the visibility table used by official weather observers in determining snowfall intensities.

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

ICE PELLET AND SMALL HAIL ALLOWANCE TIMES 2015-2016

1. Background

During the winter of 2006-2007, operations in ice pellets were approved for "light ice pellets" with an allowance time of 25 minutes. That time was based on limited research conducted late in the winter of 2005-2006 at the request of various industry groups. Additional and more comprehensive ice pellet research was conducted jointly by the research teams of the FAA and Transport Canada during the 2007-2008 winter season.

This research consisted of extensive climatic chamber and wind tunnel testing with ice pellets (light and moderate) and light ice pellets mixed with other forms of precipitation. Additionally, Type IV anti-icing fluid with ice pellets embedded was evaluated for its aging qualities over periods of time beyond the allowance times, when the active precipitation time was limited to the allowance times. Results of this research provide the basis for extended allowance times for operations in light ice pellets, as well as allowance times for operations in moderate ice pellets and light ice pellets mixed with other forms of precipitation. Additional ice pellet research was conducted during the winter season of 2008-2009 which further expanded the ice pellet allowance times under specified conditions. Guidance was also provided for Type IV anti-icing fluid with embedded ice pellets "aged" beyond its allowance time when the precipitation stops at or prior to the expiration of the allowance time.

During the winter of 2009-2010, wind tunnel research conducted with a newer generation type airfoil showed that Propylene Glycol (PG) and Ethylene Glycol (EG) fluids behave differently under certain temperature and ice pellet conditions. Specifically, higher aircraft rotation speeds are required to effectively remove PG fluid contaminated with light or moderate ice pellets at temperatures less than -10 °C. Therefore, there are no allowance times associated with the use of PG fluids on aircraft with rotation speeds of less than 115 knots in conditions of light or moderate ice pellets at temperatures below -10 °C.

Furthermore, research with this newer generation type airfoil has shown that the allowance times are shorter when using PG fluids under certain conditions for all aircraft regardless of the rotation speed. This research resulted in the allowance time when using PG fluids at temperatures of -5 °C and above being limited to 15 minutes in moderate ice pellets. Currently all Type IV fluids are PG based with the exception of Dow EG106 and LNT Solutions E450 which are EG based.

Research has indicated that Type IV PG fluids are removed less effectively when contaminated with moderate ice pellets at temperatures below -16 °C; operations in these conditions are not recommended. Therefore, there are no allowance times associated with the use of PG fluids in conditions of moderate ice pellets at temperatures below -16 °C, irrespective of aircraft rotation speed.

In 2014-2015, allowance times were published for undiluted (100/0) Type III fluid applied unheated in select conditions. Further testing is required to expand Type III allowance times in other conditions, such as temperatures below -10 °C. No testing has been conducted with AllClear AeroClear MAX; therefore, no allowance times currently exist for this fluid. Allowance times for small hail were also added in 2014-2015, as it was determined small hail is meteorologically equivalent to moderate ice pellets.

2. Operations in Light and Moderate Ice Pellets and Light Ice Pellets mixed with other forms of precipitation.

A. Tests have shown that ice pellets generally remain in the frozen state imbedded in Type III and Type IV anti-icing fluid, and are not absorbed by the fluid in the same manner as other forms of precipitation. Using current guidelines for determining anti-icing fluid failure, the presence of a

contaminant not absorbed by the fluid (remaining imbedded) would be an indication that the fluid has failed. These imbedded ice pellets are generally not readily detectable by the human eye during pre-takeoff contamination check procedures. Therefore, a visual pre-takeoff contamination check in ice pellet conditions may not be of value and is not required.

B. The research data have also shown that after proper deicing and anti-icing, the accumulation of light ice pellets, moderate ice pellets, and ice pellets mixed with other forms of precipitation in Type III or Type IV fluid will not prevent the fluid from flowing off the aerodynamic surfaces during takeoff except as noted above. This flow-off due to the shearing forces occurs with rotation speeds consistent with Type III or Type IV anti-icing fluid recommended applications, and up to the applicable allowance time listed in Table 6 and Table 7 below. These allowance times are from the start of the Type III/IV anti-icing fluid application. Additionally, if the ice pellet condition stops, and the allowance time has not been exceeded, the operator is permitted to consider the Type III or Type IV anti-icing fluid effective without any further action up to 90 minutes after the start of the application time of the Type III or Type IV anti icing fluid. To use this guidance in the following conditions, the outside air temperature (OAT) must remain constant or increase during the 90 minute period:

- light ice pellets mixed with light or moderate freezing drizzle;
- light ice pellets mixed with light freezing rain;
- light ice pellets mixed with light rain; and
- light ice pellets mixed with moderate rain.

Examples:

1) Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0 °C, light ice pellets fall until 10:20 and stop and do not restart. The allowance time stops at 10:50; however, provided that no precipitation restarts after the allowance time of 10:50 the aircraft may takeoff without any further action up to 11:30.

2) Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0 °C, light ice pellets mixed with freezing drizzle falls until 10:10 and stops and restarts at 10:15 and stops at 10:20. The allowance time stops at 10:25, however provided that the OAT remains constant or increases and that no precipitation restarts after the allowance time of 10:25, the aircraft may takeoff without any further action up to 11:30.

3) Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0 °C, light ice pellets mixed with light freezing rain falls until 10:10, stops and restarts at 10:15, and stops at 10:20. The allowance time stops at 10:25; however, provided that the OAT remains constant or increases and no precipitation restarts after the end of the allowance time at 10:25, the aircraft may take off without any further action until 11:30.

4) On the other hand, if Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0 °C, light ice pellets mixed with freezing drizzle falls until 10:10 and stops and restarts at 10:30 with the allowance time stopping at 10:25 the aircraft may not takeoff, no matter how short the time or type of precipitation after 10:25, without being deiced and anti-iced if precipitation is present.

C. Operators with a deicing program approved in accordance with Title 14 of the Code of Federal Regulations 14 CFR part 121, § 121.629, will be allowed, in the specified ice pellet and small hail conditions listed in Tables 6 and 7, up to the specific allowance time, to commence the takeoff with the following restrictions:

1) The aircraft critical surfaces must be free of contaminants before applying Type III or Type IV anti-icing fluid. If not, the aircraft must be properly deiced and checked to be free of contaminants before the application of Type III or Type IV anti-icing fluid.

2) The allowance time is valid only if the aircraft is anti-iced with undiluted Type III or Type IV fluid.

3) The Type III allowance times are only applicable for unheated anti-icing fluid applications.

4) Due to the shearing qualities of Type III and Type IV fluids with imbedded ice pellets, this allowance is limited to aircraft with a rotation speed of 100 knots or greater or 115 knots as indicated in the Ice Pellet Allowance Table below.

5) If the takeoff is not accomplished within the applicable allowance time in Table 6 or Table 7, the aircraft must be completely deiced, and if precipitation is still present, anti-iced again prior to a subsequent takeoff. If the precipitation stops at or before the time limits of the applicable allowance time and does not restart, the aircraft may takeoff up to 90 minutes after the start of the application of the Type III or Type IV anti-icing fluid, subject to the restrictions in 2.B. on the previous page.

6) A pre-takeoff contamination check is not required. The allowance time cannot be extended by an internal or external check of the aircraft critical surfaces.

7) If ice pellet precipitation becomes heavier than moderate or if the light ice pellets mixed with other forms of allowable precipitation exceeds the listed intensities or temperature range, the allowance time cannot be used.

8) If the temperature decreases below the temperature on which the allowance time was based,

   a) and the new lower temperature has an associated allowance time for the precipitation condition and the present time is within the new allowance time, then that new time must be used as the allowance time limit.

   b) and the allowance time has expired (within the 90 minute post anti-icing window if the precipitation has stopped within the allowance time), the aircraft may not takeoff and must be completely deiced and, if applicable, anti-iced before a subsequent takeoff.

TABLE 6. ICE PELLET AND SMALL HAIL ALLOWANCE TIMES FOR SAE TYPE III FLUIDS

This table is for use with SAE Type III undiluted (100/0) fluids applied unheated only[1]

Precipitation Type	Outside Air Temperature		
	-5°C and above	Below -5 to -10°C	Below -10°C[2]
Light Ice Pellets	10 minutes	10 minutes	**Caution: No allowance times currently exist**
Moderate Ice Pellets or Small Hail[3]	5 minutes	5 minutes	
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	7 minutes	5 minutes	
Light Ice Pellets Mixed with Light Freezing Rain	7 minutes	5 minutes	
Light Ice Pellets Mixed with Light Rain	7 minutes[4]		
Light Ice Pellets Mixed with Moderate Rain			
Light Ice Pellets Mixed with Light Snow	10 minutes	10 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes	10 minutes	

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

NOTES

1 No allowance times exist for AllClear AeroClear MAX.

2 Ensure that the lowest operational use temperature (LOUT) is respected.

3 If no intensity is reported with small hail, moderate ice pellets allowance times apply. However, if an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. light small hail = light ice pellets, moderate small hail = moderate ice pellets.

4 No allowance times exist in this condition for temperatures below 0 °C; consider use of light ice pellets mixed with light freezing rain.

CAUTIONS:

- **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.**
- **Allowance time cannot be extended by an inspection of the aircraft critical surfaces.**
- **Take off 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. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, or light rain.**

TABLE 7. ICE PELLET AND SMALL HAIL ALLOWANCE TIMES FOR SAE TYPE IV FLUIDS

This table is for use with SAE Type IV undiluted (100/0) fluids only. All Type IV fluids are propylene glycol based with the exception of Dow EG106 and LNT E450 which are ethylene glycol based.

Precipitation Type	Outside Air Temperature		
	-5°C and above	Below -5 to -10°C	Below -10°C[1]
Light Ice Pellets	50 minutes	30 minutes	30 minutes[2]
Moderate Ice Pellets or Small Hail[3]	25 minutes[4]	10 minutes	10 minutes[2,5]
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	25 minutes	10 minutes	**Caution: No allowance times currently exist**
Light Ice Pellets Mixed with Light Freezing Rain	25 minutes	10 minutes	
Light Ice Pellets Mixed with Light Rain	25 minutes[6]		
Light Ice Pellets Mixed with Moderate Rain	25 minutes[7]		
Light Ice Pellets Mixed with Light Snow	25 minutes	15 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes	7 minutes	

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

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected.

2 No allowance times exist for propylene glycol (PG) fluids when used on aircraft with rotation speeds less than 115 knots. (For these aircraft, if the fluid type is not known, assume zero allowance time.)

3 If no intensity is reported with small hail, moderate ice pellets allowance times apply. However, if an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. light small hail = light ice pellets, moderate small hail = moderate ice pellets.

4 Allowance time is 15 minutes for propylene glycol (PG) fluids or when the fluid type is unknown.

5 No allowance times exist for propylene glycol (PG) fluids in this condition for temperatures below -16 °C.

6 No allowance times exist in this condition for temperatures below 0 °C; consider use of light ice pellets mixed with light freezing rain.

7 No allowance times exist in this condition for temperatures below 0 °C.

CAUTIONS:

- **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.**
- **Allowance time cannot be extended by an inspection of the aircraft critical surfaces.**
- **Take off 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. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, light rain, or moderate rain.**

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TABLE 8-1.
LIST OF TYPE I FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE
(see cautions and notes on page 57)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	LOWEST OPERATIONAL USE TEMPERATURE[3]				
				DILUTION[4,5] (FLUID/WATER)	LOW SPEED AERODYNAMIC TEST[6]		HIGH SPEED AERODYNAMIC TEST[6]	
					°C	°F	°C	°F
ABAX Industries	DE-950	PG	18-05-01	71/29	-26	-14.8	-31	-23.8
ABAX Industries	*DE-950 Colorless*	*PG*	*12-06-26*[9]	*60/40*	*Not tested*[10]	*Not tested*[10]	*-24*	*-11.2*
ADDCON EUROPE GmbH	IceFree I.80	PG	17-05-20	70/30	-26	-14.8	-32	-25.6
AllClear Systems LLC	Lift-Off P-88	PG	18-06-11	70/30	-24.5	-12.1	-29.5	-21.1
AllClear Systems LLC	Lift-Off E-188	EG	18-07-15	70/30	-40	-40	-41.5	-42.7
Arcton Ltd.[11]	Arctica DG ready-to-use	DEG	17-07-15	as supplied	-26	-14.8	-26	-14.8
Arcton Ltd.[11]	*Arctica DG 91 Concentrate*	*DEG*	*15-07-25*[9]	*75/25*	*-25*	*-13*	*-25*	*-13*
AVIAFLUID International Ltd.	AVIAFLO EG	EG	16-11-28	70/30	-40.5	-40.9	-44	-47.2
Aviation Shaanxi Hi-Tech Physical Chemical Co. Ltd.	Cleanwing I	PG	15-12-19	75/25	Not tested[10]	Not tested[10]	-39.5	-39.1
Aviation Xi'an High-Tech Physical Chemical Co. Ltd.	KHF-1	PG	19-05-22	75/25	Not available[12]	Not available[12]	-38.5	-37.3
Baltic Ground Services[11]	*DEFROSOL ADF*	*NG*	*15-03-18*[9]	*65/35*	*-25*	*-13*	*-30*	*-22*
Beijing Phoenix Air Traffic Product Development and Trading Co.[11]	*CBSX-I*	*PG*	*12-04-21*[9]	*Not available*[12]	*Not available*[12]	*Not available*[12]	*Not available*[12]	*Not available*[12]
Beijing Wangye Aviation Chemical Product Co Ltd.[11]	KLA-1	EG	15-08-25	60/40	Not available[12]	Not available[12]	-30.5	-22.9
Beijing Yadilite Aviation Advanced Materials Corporation	YD-101 Type I	PG	17-05-27	60/40	Not tested[10]	Not tested[10]	-30	-22
CHEMCO Inc.	CHEMR EG I	EG	16-03-25	70/30	-37	-34.6	-43	-45.4
CHEMCO Inc.	CHEMR REG I	EG	16-07-08	75/25	-36	-32.8	-40.5	-40.9
Clariant Produkte (Deutschland) GmbH	*EcoFlo Concentrate*	*NG*	*13-07-06*[9]	*65/35*	*Not tested*[10]	*Not tested*[10]	*-30.5*	*-22.9*
Clariant Produkte (Deutschland) GmbH	*EcoFlo 2 Concentrate*	*NG*	*13-07-25*[9]	*65/35*	*Not tested*[10]	*Not tested*[10]	*-29*	*-20.2*
Clariant Produkte (Deutschland) GmbH	Octaflo EF Concentrate	PG	18-03-20	65/35	-25	-13	-33	-27.4
Clariant Produkte (Deutschland) GmbH	*Octaflo EF-80*	*PG*	*13-12-21*[9]	*70/30*	*-25*	*-13*	*-33*	*-27.4*
Clariant Produkte (Deutschland) GmbH	Octaflo EG Concentrate	EG	17-07-23	70/30	-40.5	-40.9	-44	-47.2
Clariant Produkte (Deutschland) GmbH	Octaflo LYOD	EG	16-02-11	70/30	-40	-40	-45.5	-49.9
Clariant Produkte (Deutschland) GmbH	*Safewing EG I 1996*	*EG*	*12-06-10*[9]	*75/25*	*-35.5*	*-31.9*	*-43*	*-45.4*
Clariant Produkte (Deutschland) GmbH	Safewing EG I 1996 (88)	EG	15-10-19	70/30	-39.5	-39.1	-41.5	-42.7

TABLE 8-1 (CONT'D).
LIST OF TYPE I FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 57)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	LOWEST OPERATIONAL USE TEMPERATURE[3]				
				DILUTION[4,5] (FLUID/WATER)	LOW SPEED AERODYNAMIC TEST[6]		HIGH SPEED AERODYNAMIC TEST[6]	
					°C	°F	°C	°F
Clariant Produkte (Deutschland) GmbH	Safewing MP I 1938 ECO	PG	16-06-26	65/35	-25.5	-13.9	-32	-25.6
Clariant Produkte (Deutschland) GmbH	Safewing MP I 1938 ECO (80)	PG	16-07-09	71/29	-25	-13	-32.5	-26.5
Clariant Produkte (Deutschland) GmbH	Safewing MP I 1938 ECO (80) Premix 55% i.g. ready-to-use	PG	17-03-13	as supplied	Not tested[10]	Not tested[10]	-19	-2.2
Clariant Produkte (Deutschland) GmbH	Safewing MP I ECO PLUS (80)	PG	19-03-13	71/29	-25	-13	-33	-27.4
Cryotech Deicing Technology	Polar Plus®	PG	16-01-16	63/37	-27	-16.6	-32	-25.6
Cryotech Deicing Technology	Polar Plus® LT	PG	16-03-13	63/37	-27	-16.6	-33	-27.4
Cryotech Deicing Technology	Polar Plus® LT (80)	PG	16-09-15	70/30	-27	-16.6	-33	-27.4
Cryotech Deicing Technology	Polar Plus® (80)	PG	17-09-12	70/30	-24.5	-12.1	-32.5	-26.5
Deicing Solutions LLC	Safetemp® ES Plus (Multiple Location)	PG	18-08-29	65/35	-25.5	-13.9	-31	-23.8
Dow Chemical Company	UCAR™ ADF Concentrate	EG	19-05-11	75/25	-36	-32.8	-45	-49
Dow Chemical Company	UCAR™ ADF XL54	EG	17-01-18	as supplied	-33	-27.4	-33	-27.4
Dow Chemical Company	UCAR™ PG ADF Concentrate	PG	19-05-11	65/35	-25	-13	-32	-25.6
Dow Chemical Company	*UCAR™ PG ADF Dilute 55/45*	*PG*	*12-02-05[9]*	*as supplied*	*-24*	*-11.2*	*-25*	*-13*
Heilongjiang Hangjie Aero-chemical Technology Co. Ltd.	HJF-1	EG	17-10-02	65/35	Not tested[10]	Not tested[10]	-42	-43.6
Heilongjiang Hangjie Aero-chemical Technology Co. Ltd.	HJF-1A	EG	16-09-02	75/25	Not tested[10]	Not tested[10]	-40.5	-40.9
HOC Industries	SafeTemp® ES Plus	PG	16-08-07	65/35	-25.5	-13.9	-29	-20.2
Inland Technologies CANADA Inc.	DuraGly-E Type I ADF Concentrate	EG	19-01-13	60/40	-33	-27.4	-33	-27.4
Inland Technologies CANADA Inc.	DuraGly-P Type I ADF Concentrate	PG	15-02-04[13]	60/40	-25	-13	-25	-13
Kilfrost Limited	Kilfrost DF Plus	PG	15-08-30	69/31	-25.5	-13.9	-32	-25.6
Kilfrost Limited	Kilfrost DF Plus (80)	PG	16-07-13	69/31	-26	-14.8	-31.5	-24.7
Kilfrost Limited	Kilfrost DF Plus (88)	PG	15-08-30	63/37	-25.5	-13.9	-32	-25.6
Kilfrost Limited	Kilfrost DF^{Sustain}	PDO	15-08-08	68/32	-34	-29.2	-41	-41.8
LNT Solutions	LNT E188	EG	17-10-01	70/30	-30.5	-22.9	-41	-41.8
LNT Solutions	LNT P180	PG	17-10-04	69/31	-26	-14.8	-32	-25.6
LNT Solutions	LNT P188	PG	18-11-28	70/30	-24.5	-12.1	-31.5	-24.7

TABLE 8-1 (CONT'D).
LIST OF TYPE I FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 57)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	LOWEST OPERATIONAL USE TEMPERATURE[3]				
				DILUTION[4,5] (FLUID/WATER)	LOW SPEED AERODYNAMIC TEST[6]		HIGH SPEED AERODYNAMIC TEST[6]	
					°C	°F	°C	°F
Newave Aerochemical Co. Ltd.	FCY-1A	EG	19-02-20	75/25	-40	-40	-40	-40
Newave Aerochemical Co. Ltd.	FCY-1Bio+	EG	16-07-08	75/25	Not tested[10]	Not tested[10]	-40.5	-40.9
Oksayd Co. Ltd.	DEFROST ECO 1	NG	16-07-09	70/30	Not tested[10]	Not tested[10]	-36	-32.8
Shaanxi Cleanway Aviation Chemical Co., Ltd	Cleansurface I	EG	17-09-12	75/25	-32.5[14]	-26.5[14]	-40.5	-40.9
Shaanxi Cleanway Aviation Chemical Co., Ltd	Cleansurface I-BIO	EG	18-07-11	75/25	Not tested[10]	Not tested[10]	-37	-34.6
Velvana a.s.	AIRVEL OK 1	PG	17-01-28	70/30	-26	-14.8	-30	-22

TABLE 8-2.
LIST OF TYPE II FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE

(see cautions and notes on page 57)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	DILUTION (FLUID/WATER)	LOWEST OPERATIONAL USE TEMPERATURE[3]		LOWEST ON-WING VISCOSITY[7,8] (mPa.s)	
					HIGH SPEED AERODYNAMIC TEST[6]		MANUFACTURER METHOD	AS 9968 METHOD
					°C	°F		
ABAX Industries	Ecowing 26	PG	17-04-28	100/0	-25	-13	4 900 (h)	4 600 (a)
				75/25	-14	7	2 200 (a)	2 200 (a)
				50/50	-3	27	50 (a)	50 (a)
Aviation Shaanxi Hi-Tech Physical Chemical Co. Ltd.	Cleanwing II	PG	17-05-20	100/0	-29	-20.2	4 650 (f)	4 500 (a)
				75/25	-14	7	9 450 (f)	10 000 (a)
				50/50	-3	27	10 150 (f)	10 200 (a)
Clariant Produkte (Deutschland) GmbH	Safewing MP II FLIGHT	PG	16-05-14	100/0	-29	-20.2	3 340 (a)	3 340 (a)
				75/25	-14	7	12 900 (c)	12 900 (c)
				50/50	-3	27	11 500 (a)	11 500 (a)
Clariant Produkte (Deutschland) GmbH	Safewing MP II FLIGHT PLUS	PG	16-02-28	100/0	-29	-20.2	3 650 (o)	3 100 (a)
				75/25	-14	7	12 400 (o)	10 450 (a)
				50/50	-3	27	7 800 (o)	7 050 (a)
Cryotech Deicing Technology	Polar Guard® II	PG	17-03-11	100/0	-30.5	-22.9	4 400 (g)	4 050 (a)
				75/25	-14	7	11 600 (g)	9 750 (a)
				50/50	-3	27	80 (a)	80 (a)
Kilfrost Limited	ABC-3	PG	16-10-08	100/0	-27	-16.6	2 500 (f)	2 500 (a)
				75/25	-14	7	2 000 (f)	2 000 (a)
				50/50	-3	27	400 (f)	400 (a)
Kilfrost Limited	ABC-Ice Clear II	PG	17-05-13	100/0	-29.5	-21.1	7 720 (a)	7 720 (a)
				75/25	-14	7	5 660 (a)	5 660 (a)
				50/50	-3	27	580 (a)	558 (n)
Kilfrost Limited	ABC-K Plus	PG	16-11-24	100/0	-29	-20.2	2 850 (f)	2 640 (a)
				75/25	-14	7	12 650 (f)	12 650 (c)
				50/50	-3	27	4 200 (f)	5 260 (a)
LNT Solutions	LNT P250	PG	Y-M-D[13]	100/0	Not available[12]	Not available[12]	2 400 (e)	2 150 (a)
				75/25	Not available[12]	Not available[12]	16 200 (e)	15 200 (a)
				50/50	Not available[12]	Not available[12]	8 150 (e)	8 100 (a)
Newave Aerochemical Co. Ltd.	FCY-2	PG	17-02-20	100/0	-28	-18.4	7 000 (f)	8 920 (a)
				75/25	-14	7	18 550 (f)	18 550 (f)
				50/50	-3	27	6 750 (f)	7 030 (a)

TABLE 8-2 (CONT'D).
LIST OF TYPE II FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE
(see cautions and notes on page 57)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	DILUTION (FLUID/WATER)	LOWEST OPERATIONAL USE TEMPERATURE[3]		LOWEST ON-WING VISCOSITY[7,8] (mPa.s)	
					HIGH SPEED AERODYNAMIC TEST[6]		MANUFACTURER METHOD	AS 9968 METHOD
					°C	°F		
Newave Aerochemical Co. Ltd.	FCY-2 Bio+	PG	17-05-06	100/0	-28.5	-19.3	7 210 (a)	7 210 (a)
				75/25	-14	7	21 400 (c)	21 400 (c)
				50/50	-3	27	1 900 (a)	1 900 (a)

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TABLE 8-3.
LIST OF TYPE III FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE
(see cautions and notes on page 57)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	DILUTION (FLUID/WATER)	LOWEST OPERATIONAL USE TEMPERATURE[3]				LOWEST ON-WING VISCOSITY[7,8] (mPa.s)	
					LOW SPEED AERODYNAMIC TEST[6]		HIGH SPEED AERODYNAMIC TEST[6]		MANUFACTURER METHOD	AS 9968 METHOD
					°C	°F	°C	°F		
AllClear Systems LLC	AeroClear MAX	EG	16-12-22[15]	100/0	-16	3.2	-35	-31	7 300 (m)	Not Available[16]
				75/25	Dilution Not Applicable		Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable		Dilution Not Applicable	
Clariant Produkte (Deutschland) GmbH	Safewing MP III 2031 ECO	PG	15-08-15	100/0	-16.5	2.3	-29	-20.2	120 (n)	120 (n)
				75/25	-9	15.8	-10	14	86 (n)	86 (n)
				50/50	-3	27	-3	27	16 (n)	16 (n)

TABLE 8-4.
LIST OF TYPE IV FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE
(see cautions and notes on page 57)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	DILUTION (FLUID/WATER)	LOWEST OPERATIONAL USE TEMPERATURE[3] HIGH SPEED AERODYNAMIC TEST[6] °C	LOWEST OPERATIONAL USE TEMPERATURE[3] HIGH SPEED AERODYNAMIC TEST[6] °F	LOWEST ON-WING VISCOSITY[7,8] (mPa.s) MANUFACTURER METHOD	LOWEST ON-WING VISCOSITY[7,8] (mPa.s) AS 9968 METHOD
ABAX Industries	Ecowing AD-49	PG	16-06-02	100/0	-26	-14.8	12 150 (i)	11 000 (a)
				75/25	-14	7	30 700 (i)	32 350 (c)
				50/50	-3	27	19 450 (i)	21 150 (c)
Clariant Produkte (Deutschland) GmbH	Max Flight 04	PG	16-07-23	100/0	-23.5	-10.3	5 540 (b)	5 540 (a)
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	
Clariant Produkte (Deutschland) GmbH	Max Flight SNEG	PG	16-02-20	100/0	-29	-20.2	8 700 (p)	8 050 (a)
				75/25	-14	7	20 200 (q)	21 800 (c)
				50/50	-3	27	13 600(q)	15 000 (c)
Clariant Produkte (Deutschland) GmbH	Safewing MP IV LAUNCH	PG	16-06-02	100/0	-28.5	-19.3	7 550 (a)	7 550 (a)
				75/25	-14	7	18 000 (a)	18 000 (a)
				50/50	-3	27	17 800 (a)	17 800 (a)
Clariant Produkte (Deutschland) GmbH	Safewing MP IV LAUNCH PLUS	PG	17-03-24	100/0	-29	-20.2	8 700 (p)	8 450 (a)
				75/25	-14	7	18 800 (q)	17 200 (c)
				50/50	-3	27	9 700 (p)	12 150 (a)
Cryotech Deicing Technology	*Polar Guard®*	*PG*	*12-08-30[9]*	*100/0*	*-23.5*	*-10.3*	*32 100 (k)*	*36 300 (c)*
				75/25	*-5.5*	*22.1*	*24 200 (k)*	*27 800 (c)*
				50/50	*-3*	*27*	*6 200 (k)*	*7 500 (a)*
Cryotech Deicing Technology	Polar Guard® Advance	PG	17-03-11	100/0	-30.5	-22.9	4 400 (g)	4 050 (a)
				75/25	-14	7	11 600 (g)	9 750 (a)
				50/50	-3	27	80 (a)	80 (a)
Deicing Solutions LLC	ECO-SHIELD®	PG	17-01-26	100/0	-24.5	-12.1	1 900 (a)	1 900 (a)
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	
Dow Chemical Company	UCAR™ Endurance EG106 De/Anti-Icing Fluid	EG	17-05-20	100/0	-27	-16.6	24 850 (j)	2 230 (a)
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	
Dow Chemical Company	*UCAR™ FlightGuard AD-480*	*PG*	*12-06-15[9]*	*100/0*	*-26*	*-14.8*	*15 200 (h)*	*12 800 (d)*
				75/25	*-14*	*7*	*16 000 (h)*	*12 400 (d)*
				50/50	*-3*	*27*	*4 000 (h)*	*3 800 (a)*

TABLE 8-4 (CONT'D).
LIST OF TYPE IV FLUIDS TESTED FOR ANTI-ICING PERFORMANCE AND AERODYNAMIC ACCEPTANCE
(see cautions and notes on page 57)

COMPANY NAME	FLUID NAME	TYPE OF GLYCOL[1]	EXPIRY[2] (Y-M-D)	DILUTION (FLUID/WATER)	LOWEST OPERATIONAL USE TEMPERATURE[3] HIGH SPEED AERODYNAMIC TEST[6] °C	LOWEST OPERATIONAL USE TEMPERATURE[3] HIGH SPEED AERODYNAMIC TEST[6] °F	LOWEST ON-WING VISCOSITY[7,8] (mPa.s) MANUFACTURER METHOD	LOWEST ON-WING VISCOSITY[7,8] (mPa.s) AS 9968 METHOD
Dow Chemical Company	UCAR™ FlightGuard AD-49	PG	17-05-20	100/0	-26	-14.8	12 150 (i)	11 000 (a)
				75/25	-14	7	30 700 (i)	32 350 (c)
				50/50	-3	27	19 450 (i)	21 150 (c)
Kilfrost Limited	ABC-S Plus	PG	17-06-16	100/0	-28	-18.4	17 900 (f)	17 900 (c)
				75/25	-14	7	18 300 (f)	18 300 (c)
				50/50	-3	27	7 500 (f)	7 500 (a)
LNT Solutions	LNT E450	EG	Y-M-D[13]	100/0	Not available[12]	Not available[12]	45 300 (l)	Not Available[16]
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	
Newave Aerochemical Co. Ltd.	FCY 9311	PG	15-12-20	100/0	-29.5	-21.1	14 100 (c)	14 100 (c)
				75/25	Dilution Not Applicable		Dilution Not Applicable	
				50/50	Dilution Not Applicable		Dilution Not Applicable	

CAUTIONS AND NOTES FOR TABLES 8-1, 8-2, 8-3, 8-4

CAUTIONS

- This table lists fluids that have been tested with respect to anti-icing performance and aerodynamic acceptance (Type I: SAE AMS1424 §3.5.2 and §3.5.3; Type II, III, IV: SAE AMS1428 §3.2.4 and §3.2.5) only. These tests were conducted by Anti-icing Materials International Laboratory: www.uqac.ca/amil. The end user is responsible for contacting the fluid manufacturer to confirm all other SAE AMS1424/1428 technical requirement tests, such as fluid stability, toxicity, materials compatibility, etc. have been conducted.
- LOUT data provided in these tables is based strictly on the manufacturer's data; the end user is responsible for verifying the validity of this data.
- Type I fluids supplied in concentrated form must not be used in that form and must be diluted.

NOTES

1 PG = propylene glycol; PDO = propylene glycol (propane-1, 3-diol); EG = ethylene glycol; DEG = diethylene glycol; NG = non-glycol.

2 Expiry date is the earlier expiry date of the Aerodynamic Test(s) or Water Spray Endurance Test. Fluids that are tested after the issuance of this list will appear in a later update.

3 The values in this table were determined using test results from pre-production fluid samples when available. In some cases, the fluid manufacturer requested the publication of a more conservative value than the pre-production test value. The lowest operational use temperature (LOUT) for a given fluid is the higher of:

a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type;
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.

4 The LOUT for Type I fluids that are intended to be diluted is derived from a dilution that provides the lowest operational use temperature. For other Type I dilutions, determine the freezing point of the fluid and add a 10°C freezing point buffer, as a dilution will usually yield a higher and more restrictive operational use temperature. Consult the fluid manufacturer or fluid documentation for further clarification and guidance on establishing the appropriate operational use temperature of a diluted fluid.

5 Type I concentrate fluids have also been tested at 50/50 (glycol/water) dilution.

6 If uncertain whether the aircraft to be treated conforms to the low speed or the high speed aerodynamic test, consult the aircraft manufacturer. The aerodynamic test is defined in SAE AS5900 (latest version).

7 The viscosity values in this table are those of the fluids provided by the manufacturers for holdover time testing. For the holdover times to be valid, the viscosity of the fluid on the wing shall not be lower than that in this table. The user should periodically ensure that the viscosity of a fluid sample taken from the wing surface is not lower than that listed.

8 The SAE AS9968 viscosity method should only be used for field verification and auditing purposes; when in doubt as to which method is appropriate, use the manufacturer method. Viscosity measurement methods are indicated as letters (in parentheses) beside each viscosity value. Details of each measurement method are shown in the table below. The exact measurement method (spindle, container, fluid volume, temperature, speed, duration) must be used to compare the viscosity of a sample to a viscosity given in this table.

Method	Brookfield Spindle	Container	Fluid Volume	Temp.	Speed	Duration
a	LV1 (with guard leg)	600 mL low form (Griffin) beaker	575 mL*	20°C	0.3 rpm	10.0 minutes
b	LV1 (with guard leg)	600 mL low form (Griffin) beaker	575 mL*	20°C	0.3 rpm	33.3 minutes
c	LV2-disc (with guard leg)	600 mL low form (Griffin) beaker	425 mL*	20°C	0.3 rpm	10.0 minutes
d	LV2-disc (with guard leg)	250 mL tall form (Berzelius) beaker	200 mL*	20°C	0.3 rpm	10.0 minutes
e	LV2-disc (with guard leg)	200 mL tall form (Berzelius) beaker	155 mL*	20°C	0.3 rpm	10.0 minutes
f	LV2-disc (with guard leg)	150 mL tall form (Berzelius) beaker	135 mL*	20°C	0.3 rpm	10.0 minutes
g	SC4-34/13R	small sample adapter	10 mL	20°C	0.3 rpm	10.0 minutes
h	SC4-34/13R	small sample adapter	10 mL	20°C	0.3 rpm	30.0 minutes
i	SC4-31/13R	small sample adapter	10 mL	20°C	0.3 rpm	10.0 minutes
j	SC4-31/13R	small sample adapter	10 mL	0°C	0.3 rpm	10.0 minutes
k	SC4-31/13R	small sample adapter	9 mL	20°C	0.3 rpm	10.0 minutes
l	SC4-31/13R	small sample adapter	9 mL	0°C	0.3 rpm	10.0 minutes
m	SC4-31/13R	small sample adapter	9 mL	0°C	0.3 rpm	30.0 minutes
n	LV0	UL adapter	16 mL	20°C	0.3 rpm	10.0 minutes
o	LV1	big sample adapter	50 mL	20°C	0.3 rpm	10.0 minutes
p	LV1	big sample adapter	55 mL	20°C	0.3 rpm	10.0 minutes
q	LV2-disc	big sample adapter	60 mL	20°C	0.3 rpm	10.0 minutes

*If necessary, adjust fluid volume to ensure fluid is level with notch on the spindle shaft

9 Fluids listed in italics have expired and will be removed from this listing four years after expiry.

10 Manufacturer has indicated fluid was not tested.

11 Manufacturer has not provided fluid information as required in SAE ARP5718A; fluid may be removed from this listing in subsequent revisions.

12 Manufacturer had not provided LOUT information at the time of publication.

13 Currently in the test/re-retest process.

14 Fluid was not retested for low speed aerodynamics. This data will be removed four years after the expiry of the last low speed test.

15 Fluid did not meet the minimum Water Spray Endurance Test requirement for a Type III fluid in AMS1428G; Transport Canada and the FAA have proposed a change to the SAE G-12 for this requirement.

16 Measurements using the SAE AS9968 method do not provide stable, reliable results. Use the manufacturer method to evaluate viscosity.

TABLE 9. GUIDELINES FOR THE APPLICATION OF SAE TYPE I FLUID MIXTURE MINIMUM CONCENTRATIONS AS A FUNCTION OF OUTSIDE AIR TEMPERATURE

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

1) Fluids must only be used at temperatures at or above their lowest operational use temperature (LOUT).

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

NOTES:

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

CAUTION:

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

TABLE 10. GUIDELINES FOR THE APPLICATION OF SAE TYPE II, TYPE III, AND TYPE IV FLUID MIXTURES MINIMUM CONCENTRATIONS AS A FUNCTION OF OUTSIDE AIR TEMPERATURE (CONCENTRATIONS IN % VOLUME)

Outside Air Temperature (OAT) [1]	One-step Procedure Deicing/Anti-icing	Two-step Procedure	
		First step: Deicing	Second step: Anti-icing[2]
-3 °C (27 °F) and above	50/50 Heated[3] Types II, III or IV	Heated water or a heated mix of Type I, II, III or IV, and water	50/50 Type II, III, or IV
Below -3 °C (27 °F) to -14 °C (7 °F)	75/25 Heated[3] Types II, III or IV	Heated suitable mix of Type I, II, III or IV, and water with a freezing point not more than 3 °C (5 °F) above actual OAT	75/25 Type II, III, or IV
below -14 °C (7 °F) to -25 °C (-13 °F)	100/0 Heated[3] Types II, III or IV	Heated suitable mix of Type I, II, III or IV, and water with a freezing point not more than 3 °C (5 °F) above actual OAT	100/0 Type II, III, or IV
Below -25 °C (-13 °F)	**SAE Type II/IV fluid** may be used below -25 °C (-13 °F) provided that the OAT is at or above the LOUT. **SAE Type III fluid** may be used below -10 °C (14 °F) provided that the OAT is at or above the LOUT. Consider the use of **SAE Type I fluid** (Table 9) when **Type II, III, or IV** fluid cannot be used.		

1) Fluids must only be used at temperatures at or above their lowest operational use temperature (LOUT).

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

3) Clean aircraft may be anti-iced with unheated Type II, III, or IV fluid, unless the related holdover time table requires a heated application to obtain holdover times.

NOTES:

- For heated fluids, a fluid temperature not less than 60 °C (140 °F) at the nozzle is desirable. For fluids which require a heated application to obtain holdover times (this is stated in the applicable holdover time table), the temperature at the nozzle shall be at least 60 °C and at least 1 liter/m^2 (2 gal./100 sq. ft.) shall be applied. Upper temperature limit shall not exceed fluid and aircraft manufacturer's recommendations.
- The lowest operational use temperature (LOUT) for a given Type II, III, or IV fluid is the higher of:
  a) The lowest temperature at which the fluid meets the aerodynamic acceptance test for a given aircraft type, or
  b) The actual freezing point of the fluid plus a freezing point buffer of 7 °C (13 °F).

CAUTIONS:

- **Wing skin temperatures may differ and in some cases may be lower than OAT. A stronger mix (more glycol) may be needed under these conditions.**
- **As fluid freezing may occur, 50/50 Types II, III, or IV fluid shall not be used for the anti-icing step of a cold-soaked wing as indicated by frost or ice on the lower surface of the wing in the area of the fuel tank.**
- **An insufficient amount of anti-icing fluid, especially in the second step of a two-step procedure, may cause a substantial loss of holdover time, particularly when using a Type I fluid mixture for the first step (deicing) of a two-step procedure.**
- **Repeated deicing/anti-icing with heated thickened fluids without the frequent use of Type I fluid/water mixtures for deicing can lead to the buildup of residue which can re-hydrate and freeze on control surfaces, hinges, and associated actuators during flight and restrict movement of these devices, leading to an unsafe condition. If repeated deicing/anti-icing with heated thickened fluids occurs, periodic inspections and removal of residue in accordance with the aircraft manufacturer's instructions and procedures should be followed.**

THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 0-90%. 90 PERCENT ADJUSTED HOLDOVER TIME GUIDELINES FOR SAE TYPE I, TYPE II, TYPE III, AND TYPE IV FLUIDS IN ACTIVE FROST

Outside Air Temperature[1,2]		Approximate Holdover Times (hours:minutes)
Degrees Celsius	Degrees Fahrenheit	Active Frost
		Type I
-1 and above	30 and above	0:41 (0:32)[4]
below -1 to -3	below 30 to 27	
below -3 to -10	below 27 to 14	
below -10 to -14	below 14 to 7	
below -14 to -21	below 7 to -6	
below -21 to LOUT	below -6 to LOUT	

Outside Air Temperature[2]		Concentration Neat Fluid/Water (Volume %/ Volume %)	Approximate Holdover Times (hours:minutes)		
Degrees Celsius	Degrees Fahrenheit		Active Frost		
			Type II	Type III[3]	Type IV
-1 and above	30 and above	100/0	7:12	1:48	10:48
		75/25	4:30	0:54	4:30
		50/50	2:42	0:27	2:42
below -1 to -3	below 30 to 27	100/0	7:12	1:48	10:48
		75/25	4:30	0:54	4:30
		50/50	1:21	0:27	2:42
below -3 to -10	below 27 to 14	100/0	7:12	1:48	9:00
		75/25	4:30	0:54	4:30
below -10 to -14	below 14 to 7	100/0	5:24	1:48	5:24
		75/25	0:54	0:54	0:54
below -14 to -21	below 7 to -6	100/0	5:24	1:48	5:24
below -21 to -25	below -6 to -13	100/0	1:48	1:48	3:36
Below -25	Below -13	No holdover time guidelines exist			

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

1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10 °C (18 °F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To use the Type III fluid frost holdover times, the fluid brand being used must be known. AllClear AeroClear MAX must be applied unheated. Clariant Safewing MP III 2031 ECO must be applied heated.
4 Value in parentheses is for aircraft with critical surfaces that are predominantly or entirely constructed of composite materials.

CAUTIONS:

- **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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 1A-90%. 90 PERCENT ADJUSTED HOLDOVER TIME GUIDELINES FOR SAE TYPE I FLUID ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF ALUMINUM

Outside Air Temperature[1,2]		Wing Surface	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	Aluminum	0:10-0:15	0:16-0:20	0:10-0:16	0:05-0:10	0:08-0:12	0:02-0:05	0:02-0:05	
below -3 to -6	below 27 to 21	Aluminum	0:07-0:12	0:13-0:15	0:07-0:13	0:05-0:07	0:05-0:08	0:02-0:05	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	Aluminum	0:05-0:09	0:10-0:12	0:05-0:10	0:04-0:05	0:04-0:06	0:02-0:05		
Below -10	below 14	Aluminum	0:05-0:08	0:06-0:07	0:04-0:06	0:02-0:04				

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

1 Type I fluid / water mixture must be selected so that the freezing point of the mixture is at least 10 °C (18 °F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 1C-90%. 90 PERCENT ADJUSTED HOLDOVER TIME GUIDELINES FOR SAE TYPE I FLUID ON CRITICAL AIRCRAFT SURFACES COMPOSED PREDOMINANTLY OF COMPOSITES

Outside Air Temperature[1,2]		Wing Surface	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	Composite	0:08-0:14	0:11-0:14	0:05-0:11	0:03-0:05	0:07-0:12	0:02-0:05	0:01-0:05	
below -3 to -6	below 27 to 21	Composite	0:05-0:07	0:10-0:12	0:05-0:10	0:02-0:05	0:05-0:08	0:02-0:05	CAUTION: No holdover time guidelines exist	
below -6 to -10	below 21 to 14	Composite	0:04-0:07	0:08-0:11	0:05-0:08	0:02-0:05	0:04-0:06	0:02-0:05		
Below -10	below 14	Composite	0:04-0:06	0:06-0:07	0:04-0:06	0:02-0:04				

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

1 Type I fluid / water mixture must be selected so that the freezing point of the mixture is at least 10 °C (18 °F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2-GENERIC-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR SAE TYPE II FLUID

Outside Air Temperature[1]		Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	0:32-1:21	0:18-0:41	0:27-0:54	0:14-0:27	0:06-0:36	
		75/25	0:23-0:54	0:14-0:27	0:18-0:41	0:09-0:23	0:05-0:23	
		50/50	0:14-0:27	0:05-0:14	0:09-0:18	0:05-0:09	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:18-0:59	0:14-0:27	0:18-0:41[7]	0:09-0:18[7]		
		75/25	0:23-0:45	0:07-0:18	0:14-0:27[7]	0:07-0:14[7]		
Below -14 to LOUT	Below 7 to LOUT	100/0	0:14-0:32[8]	0:14-0:27[8]				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
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 -25° C (-13 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2A-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR ABAX ECOWING 26

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:17-2:20	1:26-1:39	0:54-1:26	0:36-0:54	0:45-1:26	0:36-0:45	0:18-1:17	CAUTION: No holdover time guidelines exist
		75/25	0:59-1:44	1:08-1:17	0:41-1:08	0:23-0:41	0:41-0:59	0:23-0:32	0:09-0:54	
		50/50	0:27-0:41	0:36-0:45	0:18-0:36	0:09-0:18	0:14-0:23	0:07-0:09		
below -3 to -14	below 27 to 7	100/0	0:41-2:02	1:17-1:30	0:50-1:17	0:32-0:50	0:27-1:03[7]	0:14-0:32[7]		
		75/25	0:32-1:08	0:50-0:59	0:36-0:50	0:23-0:36	0:18-0:45[7]	0:14-0:23[7]		
below -14 to -25	below 7 to -13	100/0	0:23-0:41	0:36-0:45	0:27-0:36	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2B-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR AVIATION SHAANXI HI-TECH CLEANWING II

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	0:50-1:39	0:27-0:50	0:32-0:59	0:23-0:32	0:09-0:50	
		75/25	0:45-1:12	0:23-0:41	0:32-0:54	0:18-0:27	0:06-0:45	
		50/50	0:32-0:54	0:14-0:27	0:18-0:36	0:09-0:18	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:41-1:39	0:27-0:50	0:27-0:50[7]	0:18-0:23[7]		
		75/25	0:36-1:35	0:23-0:41	0:32-0:36[7]	0:18-0:23[7]		
below -14 to -29	below 7 to -20.2	100/0	0:18-0:45	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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FAA 2015-2016 Holdover Time Guidelines 07/31/15

THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2C-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP II FLIGHT

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:09-3:36	2:20-2:47	1:26-2:20	0:54-1:26	1:12-1:48	0:41-1:17	0:09-1:21	
		75/25	1:39-2:29	2:20-2:51	1:12-2:20	0:36-1:12	1:03-1:21	0:27-0:50	0:05-0:45	
		50/50	0:50-1:35	0:41-0:50	0:23-0:41	0:09-0:23	0:18-0:27	0:09-0:14	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:50-1:35	1:39-1:57	0:59-1:39	0:36-0:59	0:32-1:21[7]	0:23-0:41[7]		
		75/25	0:23-0:59	1:12-1:30	0:36-1:12	0:18-0:36	0:23-1:03[7]	0:18-0:32[7]		
Below -14 to -29	Below 7 to -20.2	100/0	0:27-0:45	0:36-0:45	0:27-0:36	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2D-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP II FLIGHT PLUS

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:24-3:36	0:45-1:39	1:17-1:48	0:41-0:54	0:14-1:48	
		75/25	2:20-3:36	0:54-1:35	1:26-1:48	0:45-1:08	0:14-1:08	
		50/50	0:59-2:06	0:14-0:23	0:27-0:59	0:14-0:18	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:36-2:06	0:32-1:08	0:32-1:17[7]	0:32-0:50[7]		
		75/25	0:27-1:35	0:50-1:30	0:23-1:03[7]	0:27-0:41[7]		
Below -14 to -29	Below 7 to -20.2	100/0	0:18-0:36	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2E-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR CRYOTECH POLAR GUARD® II

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:33-3:36	2:20-2:33	1:39-2:20	1:12-1:39	1:26-1:48	1:08-1:21	0:14-1:48	
		75/25	2:15-3:36	2:11-2:38	1:12-2:11	0:41-1:12	1:30-1:48	0:36-1:03	0:08-1:30	
		50/50	0:45-1:17	1:12-1:35	0:32-1:12	0:14-0:32	0:18-0:41	0:08-0:18	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:50-2:15	1:35-1:44	1:08-1:35	0:50-1:08	0:32-1:26[7]	0:32-0:41[7]		
		75/25	0:36-1:21	1:35-1:53	0:54-1:35	0:32-0:54	0:23-0:59[7]	0:32-0:41[7]		
Below -14 to -30.5	Below 7 to -22.9	100/0	0:23-0:45	0:36-0:45	0:27-0:36	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2F-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR KILFROST ABC-ICE CLEAR II

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	0:54-1:35	1:35-1:57	0:45-1:35	0:23-0:45	0:36-0:59	0:23-0:32	0:06-0:41	
		75/25	0:45-1:03	1:121:35	0:36-1:12	0:18-0:36	0:27-0:41	0:18-0:27	0:05-0:32	
		50/50	0:14-0:27	0:18-0:23	0:14-0:18	0:07-0:14	0:09-0:18	0:06-0:09	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:36-1:26	1:08-1:26	0:32-1:08	0:18-0:32	0:23-0:54[7]	0:14-0:27[7]		
		75/25	0:36-1:12	0:50-1:03	0:23-0:50	0:14-0:23	0:23-0:41[7]	0:14-0:18[7]		
Below -14 to -29.5	Below 7 to -21.1	100/0	0:18-0:36	0:36-0:45	0:27-0:36	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2G-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR KILFROST ABC-K PLUS

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:02-3:23	0:54-1:30	1:39-1:48	0:54-1:17	0:18-1:48	
		75/25	1:30-2:15	0:32-1:03	1:17-1:48	0:45-1:03	0:14-1:48	
		50/50	0:32-0:59	0:06-0:14	0:18-0:27	0:09-0:14	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:27-0:59	0:45-1:17	0:23-0:54[7]	0:14-0:32[7]		
		75/25	0:23-1:17	0:32-0:59	0:18-0:50[7]	0:08-0:27[7]		
below -14 to -29	below 7 to -20.2	100/0	0:27-0:50	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2H-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR LNT SOLUTIONS P250

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:57-3:36	3:00-3:00	1:35-3:00	0:50-1:35	1:26-1:48	0:45-1:17	0:14-1:48	CAUTION: No holdover time guidelines exist
		75/25	1:39-2:20	2:33-3:00	1:17-2:33	0:41-1:17	1:12-1:26	0:36-0:54	0:09-1:39	
		50/50	0:32-0:45	0:59-1:17	0:27-0:59	0:14-0:27	0:18-0:32	0:14-0:18		
below -3 to -14	below 27 to 7	100/0	0:41-2:06	2:51-3:00	1:30-2:51	0:45-1:30	0:23-1:12[7]	0:23-0:32[7]		
		75/25	0:32-1:35	2:33-3:00	1:17-2:33	0:41-1:17	0:18-1:08[7]	0:18-0:27[7]		
Below -14 to LOUT	Below 7 to LOUT	100/0	0:18-0:45	0:36-0:45	0:27-0:36	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2I-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR NEWAVE AEROCHEMICAL FCY-2

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	1:08-2:11	0:27-0:50	0:32-0:59	0:23-0:32	0:07-0:41	
		75/25	0:45-1:21	0:18-0:36	0:23-0:41	0:14-0:23	0:05-0:23	
		50/50	0:23-0:32	0:14-0:23	0:09-0:18	0:06-0:09	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:41-1:21	0:14-0:27	0:18-0:41[7]	0:14-0:18[7]		
		75/25	0:27-0:59	0:09-0:18	0:14-0:27[7]	0:07-0:14[7]		
below -14 to -28	below 7 to -18.4	100/0	0:23-0:32	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 2J-90%. 90 PERCENT ADJUSTED TYPE II HOLDOVER TIME GUIDELINES FOR NEWAVE AEROCHEMICAL FCY-2 BIO+

Outside Air Temperature[1]		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:17-2:15	2:06-2:38	0:59-2:06	0:27-0:59	0:45-1:12	0:23-0:41	0:07-1:08	
		75/25	0:41-1:12	1:12-1:30	0:36-1:12	0:18-0:36	0:23-0:45	0:14-0:23	0:05-0:32	
		50/50	0:14-0:27	0:23-0:27	0:14-0:23	0:07-0:14	0:09-0:18	0:07-0:09	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:36-1:21	0:54-1:08	0:27-0:54	0:14-0:27	0:32-0:59[7]	0:14-0:27[7]		
		75/25	0:27-0:59	0:32-0:41	0:18-0:32	0:07-0:18	0:18-0:32[7]	0:14-0:18[7]		
below -14 to -28.5	below 7 to -19.3	100/0	0:18-0:54	0:36-0:45	0:27-0:36	0:14-0:27				

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

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type II fluid cannot be used.
2 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) 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.
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 3A-LS-90%. 90 PERCENT ADJUSTED LOW SPEED TYPE III HOLDOVER TIME GUIDELINES FOR ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 LOW SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	0:54-2:02	0:32-0:36	0:18-0:32	0:09-0:18	0:36-1:12	0:23-0:27	0:08-0:54	
		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 -10	below 27 to 14	100/0	0:54-1:35	0:27-0:32	0:14-0:27	0:08-0:14	0:36-1:03	0:27-0:36		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -10 to -16	below 14 to 3.2	100/0	0:27-0:59	0:27-0:32	0:14-0:27	0:07-0:14				

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

1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 3A-HS-90%. 90 PERCENT ADJUSTED HIGH SPEED TYPE III HOLDOVER TIME GUIDELINES FOR ALLCLEAR AEROCLEAR MAX, APPLIED UNHEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 HIGH SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	0:54-2:02	0:32-0:36	0:18-0:32	0:09-0:18	0:36-1:12	0:23-0:27	0:08-0:54	
		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 -10	below 27 to 14	100/0	0:54-1:35	0:27-0:32	0:14-0:27	0:08-0:14	0:36-1:03	0:27-0:36		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -10 to -25	below 14 to -13	100/0	0:27-0:59	0:27-0:32	0:14-0:27	0:07-0:14				
below -25 to -35	below -13 to -31	100/0	0:16-0:50							

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

1 Fluid must be applied unheated to use these holdover times. No holdover times exist for this fluid applied heated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail.

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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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FAA 2015-2016 Holdover Time Guidelines 07/31/15

THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 3B-LS-90%. 90 PERCENT ADJUSTED LOW SPEED TYPE III HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP III 2031 ECO, APPLIED HEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 LOW SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	0:23-0:45	0:36-0:50	0:18-0:36	0:09-0:18	0:15-0:27	0:09-0:13	0:05-0:27	
		75/25	0:17-0:36	0:32-0:41	0:14-0:32	0:06-0:14	0:12-0:18	0:07-0:08	0:03-0:16	
		50/50	0:12-0:16	0:23-0:27	0:12-0:23	0:06-0:12	0:12-0:13	0:06-0:06	CAUTION: No holdover time guidelines exist	
below -3 to -10	below 27 to 14	100/0	0:32-1:08	0:36-0:45	0:18-0:36	0:09-0:18	0:13-0:27	0:08-0:12		
		75/25	0:17-0:41[8]	0:23-0:32[8]	0:11-0:23[8]	0:05-0:11[8]	0:08-0:14[8]	0:05-0:07[8]		
below -10 to -16.5	below 14 to 2.3	100/0	0:23-0:41	0:36-0:41	0:17-0:36	0:08-0:17				

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

1 Fluid must be applied heated to use these holdover times. No holdover times exist for this fluid applied unheated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 6-90% provides allowance times for ice pellets and small hail).
8 No holdover time guidelines exist for 75/25 fluid below -9 °C (15.8 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 3B-HS-90%. 90 PERCENT ADJUSTED HIGH SPEED TYPE III HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP III 2031 ECO, APPLIED HEATED[1]

FOR AIRCRAFT CONFORMING TO THE SAE AS5900 HIGH SPEED AERODYNAMIC TEST CRITERION

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[3]			Freezing Drizzle[5]	Light Freezing Rain	Rain on Cold Soaked Wing[6]	Other[7]
				Very Light[4]	Light[4]	Moderate				
-3 and above	27 and above	100/0	0:23-0:45	0:36-0:50	0:18-0:36	0:09-0:18	0:15-0:27	0:09-0:13	0:05-0:27	
		75/25	0:17-0:36	0:32-0:41	0:14-0:32	0:06-0:14	0:12-0:18	0:07-0:08	0:03-0:16	
		50/50	0:12-0:16	0:23-0:27	0:12-0:23	0:06-0:12	0:12-0:13	0:06-0:06	CAUTION: No holdover time guidelines exist	
below -3 to -10	below 27 to 14	100/0	0:32-1:08	0:36-0:45	0:18-0:36	0:09-0:18	0:13-0:27	0:08-0:12		
		75/25	0:17-0:41	0:23-0:32	0:11-0:23	0:05-0:11	0:08-0:14	0:05-0:07		
below -10 to -25	below 14 to-13	100/0	0:23-0:41	0:36-0:41	0:17-0:36	0:08-0:17				
below -25 to -29	below -13 to 20.2	100/0	0:23-0:41	0:36-0:41	0:17-0:36	0:08-0:17				

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

1 Fluid must be applied heated to use these holdover times. No holdover times exist for this fluid applied unheated.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I fluid when Type III fluid cannot be used.
3 To determine snowfall intensity, the Snowfall Intensities as a Function of Prevailing Visibility table (Table 5) is required.
4 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
5 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
6 No holdover time guidelines exist for this condition for 0 °C (32 °F) and below.
7 Heavy snow, ice pellets, moderate and heavy freezing rain, small hail and hail (Table 6-90% provides allowance times for ice pellets and small hail).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast will 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4-GENERIC-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR SAE TYPE IV FLUIDS

Outside Air Temperature[1]		Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	1:21-2:11	0:32-1:03	0:45-1:21	0:32-0:45	0:09-1:17	
		75/25	1:17-2:24	0:27-0:59	0:45-1:08	0:27-0:41	0:08-1:08	
		50/50	0:23-0:36	0:08-0:14	0:14-0:23	0:08-0:14	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:18-1:12	0:23-0:45	0:23-1:03[7]	0:14-0:23[7]		
		75/25	0:23-0:45[8]	0:18-0:36[8]	0:14-0:59[7,8]	0:14-0:23[7,8]		
below -14 to LOUT	below 7 to LOUT	100/0	0:14-0:36[9]	0:14-0:27[9]				

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

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 5) 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 7-90% 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 -5.5 °C (22 °F).
9 If the LOUT is unknown, no holdover time guidelines exist below -23.5 °C (-10.3 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4A-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR ABAX ECOWING AD-49

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:00-3:36	2:33-2:51	1:39-2:33	1:03-1:39	1:17-1:48	0:54-1:17	0:09-1:44	
		75/25	2:11-3:36	1:53-2:02	1:30-1:53	1:12-1:30	1:44-1:48	0:45-1:21	0:09-1:30	
		50/50	0:23-0:45	0:36-0:41	0:23-0:36	0:14-0:23	0:14-0:27	0:09-0:14	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:18-1:26	2:33-2:51	1:39-2:33	1:03-1:39	0:23-1:17[7]	0:18-0:23[7]		
		75/25	0:27-1:03	1:53-2:02	1:30-1:53	1:12-1:30	0:14-0:59[7]	0:14-0:23[7]		
below -14 to -26	below 7 to -14.8	100/0	0:23-0:36	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4B-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR CLARIANT MAX FLIGHT 04

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:24-3:36	3:00-3:00	2:29-3:00	1:17-2:29	1:48-1:48	1:03-1:21	0:18-1:48	
		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 -14	below 27 to 7	100/0	0:45-2:15	2:06-2:33	1:03-2:06	0:32-1:03	0:23-1:21[7]	0:18-0:36[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -23.5	below 7 to -10.3	100/0	0:18-0:41	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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FAA 2015-2016 Holdover Time Guidelines 07/31/15

THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4C-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR CLARIANT MAX FLIGHT SNEG

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:11-3:36	2:29-2:51	1:30-2:29	0:59-1:30	1:48-1:48	0:45-1:30	0:18-1:21	
		75/25	3:36-3:36	2:11-2:33	1:21-2:11	0:50-1:21	1:21-1:48	0:59-1:12	0:14-1:35	
		50/50	1:21-3:09	1:35-2:06	0:41-1:35	0:18-0:41	0:32-1:03	0:14-0:27	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:41-2:06	1:48-2:06	1:08-1:48	0:41-1:08	0:27-1:17[7]	0:23-0:36[7]		
		75/25	0:27-1:17	1:30-1:48	0:54-1:30	0:36-0:54	0:18-0:59[7]	0:18-0:36[7]		
below -14 to -29	below 7 to -20.2	100/0	0:18-0:45	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4D-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP IV LAUNCH

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:36-3:36	2:33-3:00	1:35-2:33	0:59-1:35	1:21-1:48	0:54-1:30	0:14-1:30	
		75/25	3:18-3:36	2:47-3:00	1:35-2:47	0:54-1:35	1:30-1:48	0:41-1:08	0:09-1:35	
		50/50	1:17-2:29	1:17-1:30	0:41-1:17	0:23-0:41	0:27-0:45	0:18-0:23	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:54-1:44	1:57-2:15	1:12-1:57	0:45-1:12	0:32-1:30[7]	0:23-0:41[7]		
		75/25	0:36-1:12	2:11-2:38	1:17-2:11	0:41-1:17	0:23-1:03[7]	0:23-0:41[7]		
below -14 to -28.5	below 7 to -19.3	100/0	0:27-0:45	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4E-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR CLARIANT SAFEWING MP IV LAUNCH PLUS

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:32-3:36	3:00-3:00	1:53-3:00	0:50-1:53	1:48-1:48	0:54-1:48	0:18-1:48	
		75/25	3:32-3:36	3:00-3:00	1:44-3:00	0:45-1:44	1:48-1:48	1:12-1:17	0:18-1:39	
		50/50	1:08-1:39	1:26-1:48	0:41-1:26	0:18-0:41	0:23-0:54	0:14-0:18	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:50-2:02	2:56-3:00	1:17-2:56	0:36-1:17	0:23-1:26[7]	0:23-0:36[7]		
		75/25	0:36-1:48	2:38-3:00	1:08-2:38	0:27-1:08	0:18-0:59[7]	0:18-0:27[7]		
below -14 to -29	below 7 to -20.2	100/0	0:23-0:45	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4F-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR CRYOTECH POLAR GUARD®

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:02-3:09	0:45-1:21	1:08-1:48	0:45-1:08	0:14-1:17	
		75/25	1:30-2:24	0:32-1:03	0:59-1:17	0:32-0:54	0:09-1:08	
		50/50	0:23-0:36	0:09-0:14	0:14-0:23	0:09-0:14	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:41-1:35	0:27-0:50	0:23-1:03[7]	0:14-0:32[7]		
		75/25[8]	0:32-1:21[8]	0:18-0:36[8]	0:23-0:59[8]	0:18-0:27[8]		
Below -14 to -23.5	Below 7 to -10.3	100/0	0:18-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).
8 Temperature is limited to -5.5 °C (22 °F) when using 75/25 dilution of this fluid.

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4G-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR CRYOTECH POLAR GUARD® ADVANCE

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	2:33-3:36	2:20-2:33	1:39-2:20	1:12-1:39	1:26-1:48	1:08-1:21	0:14-1:48	
		75/25	2:15-3:36	2:11-2:38	1:12-2:11	0:41-1:12	1:30-1:48	0:36-1:03	0:08-1:30	
		50/50	0:45-1:17	1:12-1:35	0:32-1:12	0:14-0:32	0:18-0:41	0:08-0:18	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:50-2:15	1:35-1:44	1:08-1:35	0:50-1:08	0:32-1:26[7]	0:32-0:41[7]		
		75/25	0:36-1:21	1:35-1:53	0:54-1:35	0:32-0:54	0:23-0:59[7]	0:32-0:41[7]		
Below -14 to -30.5	Below 7 to -22.9	100/0	0:23-0:45	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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FAA 2015-2016 Holdover Time Guidelines 07/31/15

THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4H-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR DEICING SOLUTIONS ECO-SHIELD®

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:21-2:11	2:11-2:38	1:12-2:11	0:41-1:12	0:45-1:26	0:36-0:45	0:14-1:44	
		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 -14	below 27 to 7	100/0	1:03-2:15	1:35-1:53	0:50-1:35	0:27-0:50	0:41-1:48[7]	0:23-0:36[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -24.5	below 7 to -12.1	100/0	0:27-0:50	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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FAA 2015-2016 Holdover Time Guidelines 07/31/15

THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4I-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR DOW CHEMICAL UCAR™ ENDURANCE EG106

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:53-2:51	2:29-3:00	1:12-2:29	0:36-1:12	1:03-1:48	0:45-1:08	0:18-1:48	
		75/25	N/A	N/A	N/A	N/A	N/A	N/A	CAUTION: No holdover time guidelines exist	
		50/50	N/A	N/A	N/A	N/A	N/A	N/A		
below -3 to -14	below 27 to 7	100/0	1:39-3:00	1:57-2:29	0:59-1:57	0:27-0:59	0:50-1:39[7]	0:41-1:03[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -27	below 7 to -16.6	100/0	0:27-0:59	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4J-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR DOW CHEMICAL UCAR™ FLIGHTGUARD AD-480

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2,3]	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	1:48-3:09	0:36-1:12	0:45-1:21	0:32-0:50	0:14-1:26	
		75/25	1:21-2:29	0:27-0:59	0:45-1:08	0:27-0:41	0:09-1:08	
		50/50	0:27-0:41	0:08-0:18	0:14-0:23	0:08-0:14	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:18-1:12	0:27-0:50	0:23-1:12[7]	0:14-0:27[7]		
		75/25	0:23-0:45	0:18-0:41	0:23-0:59[7]	0:14-0:27[7]		
below -14 to -26	below 7 to -14.8	100/0	0:14-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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.**

THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4K-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR DOW CHEMICAL UCAR™ FLIGHTGUARD AD-49

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:00-3:36	2:33-2:51	1:39-2:33	1:03-1:39	1:17-1:48	0:54-1:17	0:09-1:44	
		75/25	2:11-3:36	1:53-2:02	1:30-1:53	1:12-1:30	1:44-1:48	0:45-1:21	0:09-1:30	
		50/50	0:23-0:45	0:36-0:41	0:23-0:36	0:14-0:23	0:14-0:27	0:09-0:14	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:18-1:26	2:33-2:51	1:39-2:33	1:03-1:39	0:23-1:17[7]	0:18-0:23[7]		
		75/25	0:27-1:03	1:53-2:02	1:30-1:53	1:12-1:30	0:14-0:59[7]	0:14-0:23[7]		
below -14 to -26	below 7 to -14.8	100/0	0:23-0:36	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4L-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR KILFROST ABC-S PLUS

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:57-3:36	3:00-3:00	1:53-3:00	1:08-1:53	1:39-1:48	0:59-1:48	0:23-1:48	
		75/25	1:17-2:24	1:53-2:11	1:08-1:53	0:41-1:08	0:54-1:12	0:27-0:45	0:09-1:12	
		50/50	0:27-0:50	0:54-1:03	0:27-0:54	0:14-0:27	0:14-0:36	0:14-0:18	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:50-3:09	2:38-3:00	1:35-2:38	0:54-1:35	0:23-1:26[7]	0:18-0:27[7]		
		75/25	0:41-1:39	1:35-1:48	0:54-1:35	0:32-0:54	0:18-1:03[7]	0:14-0:23[7]		
below -14 to -28	below 7 to -18.4	100/0	0:36-0:54	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4M-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR LNT SOLUTIONS E450

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:39-2:38	2:11-2:29	1:26-2:11	0:54-1:26	1:26-1:48	0:50-1:12	0:23-1:48	
		75/25	N/A				N/A	N/A	N/A	
		50/50	N/A				N/A	N/A	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:21-3:32	1:39-1:53	1:03-1:39	0:41-1:03	1:35-1:48[7]	0:59-1:30[7]		
		75/25	N/A				N/A	N/A		
below -14 to LOUT	below 7 to LOUT	100/0	0:32-0:59	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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FAA 2015-2016 Holdover Time Guidelines 07/31/15

THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 4N-90%. 90 PERCENT ADJUSTED TYPE IV HOLDOVER TIME GUIDELINES FOR NEWAVE AEROCHEMICAL FCY 9311

Outside Air Temperature[1]		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets[2]			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	1:44-3:36	2:06-2:38	1:03-2:06	0:32-1:03	1:03-1:48	0:36-0:59	0:14-1:17	
		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 -14	below 27 to 7	100/0	0:32-1:53	1:26-1:48	0:45-1:26	0:23-0:45	0:32-1:12[7]	0:18-0:32[7]		
		75/25	N/A	N/A	N/A	N/A	N/A	N/A		
below -14 to -29.5	below 7 to -21.1	100/0	0:27-0:50	0:36-0:45	0:27-0:36	0:14-0:27				

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

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 5) 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 7-90% provides allowance times for ice pellets and small hail).
7 No holdover time guidelines exist for this condition below -10 °C (14 °F).

CAUTIONS:

- **The time of protection will be shortened in heavy weather conditions. Heavy precipitation rates or high moisture content, high wind velocity, or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may 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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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 6-90%. 90 PERCENT ADJUSTED ICE PELLET AND SMALL HAIL ALLOWANCE TIMES FOR SAE TYPE III FLUIDS

This table is for use with SAE Type III undiluted (100/0) fluids applied unheated only[1]

Precipitation Type	Outside Air Temperature		
	-5°C and above	Below -5 to -10°C	Below -10°C[2]
Light Ice Pellets	9 minutes	9 minutes	**Caution: No allowance times currently exist**
Moderate Ice Pellets or Small Hail[3]	5 minutes	5 minutes	
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	6 minutes	5 minutes	
Light Ice Pellets Mixed with Light Freezing Rain	6 minutes	5 minutes	
Light Ice Pellets Mixed with Light Rain	6 minutes[4]		
Light Ice Pellets Mixed with Moderate Rain			
Light Ice Pellets Mixed with Light Snow	9 minutes	9 minutes	
Light Ice Pellets Mixed with Moderate Snow	9 minutes	9 minutes	

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

NOTES

1 No allowance times exist for AllClear AeroClear MAX.

2 Ensure that the lowest operational use temperature (LOUT) is respected.

3 If no intensity is reported with small hail, moderate ice pellets allowance times apply. However, if an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. light small hail = light ice pellets, moderate small hail = moderate ice pellets.

4 No allowance times exist in this condition for temperatures below 0 °C; consider use of light ice pellets mixed with light freezing rain.

CAUTIONS:

- **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.**
- **Allowance time cannot be extended by an inspection of the aircraft critical surfaces.**
- **Take off 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. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, or light rain.**

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THIS TABLE IS FOR USE WHEN FLAPS/SLATS ARE DEPLOYED PRIOR TO DE/ANTI-ICING

TABLE 7-90%. 90 PERCENT ADJUSTED ICE PELLET AND SMALL HAIL ALLOWANCE TIMES FOR SAE TYPE IV FLUIDS

This table is for use with SAE Type IV undiluted (100/0) fluids only. All Type IV fluids are propylene glycol based with the exception of Dow EG106 and LNT E450 which are ethylene glycol based.

Precipitation Type	Outside Air Temperature		
	-5°C and above	Below -5 to -10°C	Below -10°C[1]
Light Ice Pellets	45 minutes	27 minutes	27 minutes[2]
Moderate Ice Pellets or Small Hail[3]	23 minutes[4]	9 minutes	9 minutes[2,5]
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	23 minutes	9 minutes	**Caution: No allowance times currently exist**
Light Ice Pellets Mixed with Light Freezing Rain	23 minutes	9 minutes	
Light Ice Pellets Mixed with Light Rain	23 minutes[6]		
Light Ice Pellets Mixed with Moderate Rain	23 minutes[7]		
Light Ice Pellets Mixed with Light Snow	23 minutes	14 minutes	
Light Ice Pellets Mixed with Moderate Snow	9 minutes	6 minutes	

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

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected.

2 No allowance times exist for propylene glycol (PG) fluids when used on aircraft with rotation speeds less than 115 knots. (For these aircraft, if the fluid type is not known, assume zero allowance time.)

3 If no intensity is reported with small hail, moderate ice pellets allowance times apply. However, if an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. light small hail = light ice pellets, moderate small hail = moderate ice pellets.

4 Allowance time is 14 minutes for propylene glycol (PG) fluids or when the fluid type is unknown.

5 No allowance times exist for propylene glycol (PG) fluids in this condition for temperatures below -16 °C.

6 No allowance times exist in this condition for temperatures below 0 °C; consider use of light ice pellets mixed with light freezing rain.

7 No allowance times exist in this condition for temperatures below 0 °C.

CAUTIONS:

- **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.**
- **Allowance time cannot be extended by an inspection of the aircraft critical surfaces.**
- **Take off 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. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, light rain, or moderate rain.**

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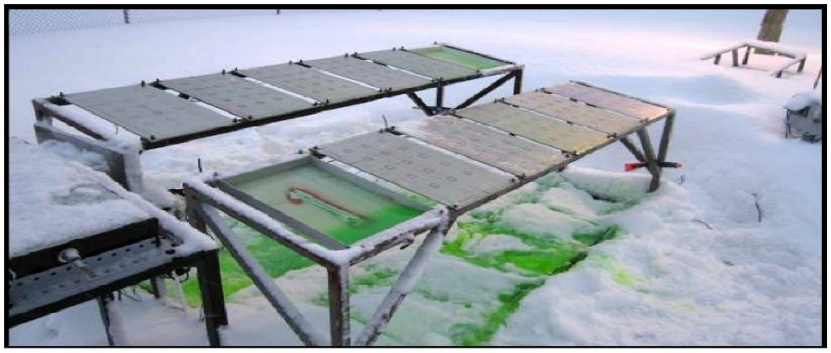
APPENDIX K

FLUID MANUFACTURER REPORT:
CLARIANT SAFEWING MP III 2031 ECO (TYPE III)

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Clariant Safewing MP III 2031 ECO (Type III)

Testing Using Type I Protocol



Prepared for

Clariant GmbH

by

APS Aviation Inc.

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

November 2014
Version 2.0
Report No. C-2031 2013-14

AIRCRAFT GROUND ANTI-ICING FLUID ENDURANCE TIME TEST RESULTS

Clariant Safewing MP III 2031 ECO (Type III)

Testing Using Type I Protocol

Prepared for

Clariant GmbH

Prepared by:

Stephanie Bendickson
Project Analyst

Nov. 24, 2014
Date

Reviewed by:

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Program Manager

Nov. 24, 2014
Date

These tests were made possible with the guidance, participation and contribution of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration.

November 2014
Version 2.0
Report No. C-2031 2013-14

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer:	Clariant GmbH		
Fluid Test Name:	Safewing MP III 2031 ECO		
Fluid Commercial Name:	Safewing MP III 2031 ECO		
Fluid Type / Base / Colour:	Type III / Propylene Glycol / Yellow		
Batch #:	USHA 035838		
Date of Receipt:	February 27, 2013		
Brix (Measured):	Neat fluid:	35.00°	
	75/25 dilution:	27.25°	
	50/50 dilution:	19.00°	
Viscosity:	**Mfr Method[1]**	**Stated**	**Measured**
	Neat fluid:	118 cP	120 cP
	75/25 dilution:	74 cP	86 cP
	50/50 dilution:	16 cP	16 cP
WSET (from AMIL):	Neat fluid:	24 minutes	

[1] *Spindle LV0, ultra low adapter, 16 mL of fluid, 20°C, 0.3 rpm, for 10 minutes 0 seconds*

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SUMMARY

This report provides a detailed account of the endurance time testing conducted in the winters of 2012-13 and 2013-14 with **Clariant Safewing MP III 2031 ECO** using the Type I test protocol. It describes the test methodology used, endurance time data collected, and analysis completed to derive a fluid-specific endurance times for the fluid. This report was completed with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

The testing described in this report was carried out as a result of supplemental research conducted with Type III fluids, which showed fluid application temperature has an impact on Type III fluid endurance times, and changes to Aerospace Recommended Practice (ARP) 5718, which include publication of fluid-specific and application temperature specific holdover time tables. As a result of the supplemental research and ARP5718 changes, it was mutually decided by regulators and the manufacturer that Safewing MP III 2031 ECO should undergo endurance time testing using the Type I test protocol.

Preliminary testing was conducted in the winter of 2011-12; the results from this testing were discarded due to an unfavourable water spray endurance test (WSET) result. A new sample was submitting for testing in the winter of 2012-13. This report documents the testing conducted with the new sample.

Tests were carried out according to the Type I test protocol provided in ARP5945. The test procedure consisted of pouring fluids onto clean aluminum test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural and simulated precipitation.

Tests were performed at the APS Aviation Inc. (APS) test facility at Montréal-Pierre-Elliott-Trudeau International Airport and at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa. Testing was conducted over two winters: freezing precipitation and preliminary natural snow and natural frost tests were conducted in the winter of 2012-13; natural snow and natural frost testing was completed in the winter of 2013-14.

De/anti-icing fluid endurance times were derived from the data collected using multi-variable regression analysis. This resulted in the generation of the fluid-specific endurance times shown below.

Due to the manufacturer's decision to discontinue manufacturing this fluid, it was mutually agreed by regulators and the manufacturer (after the May 2014 SAE meetings) that these results would not be incorporated into the holdover time guidelines.

SUMMARY

Table ES-1: Endurance Times of Clariant Safewing MP III 2031 ECO Applied Heated

Outside Air Temp.	Type III Fluid Concentration Neat Fluid/Water (Vol %/Vol %)	Endurance Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
			Very Light	Light	Moderate				
-3 and above	100/0	25–50	40–55	20–40	10–20	17–30	10–14	5–30	
	75/25	19–40	35–45	16–35	7–16	13–20	8–9	3–18	
	50/50	13–18	25–30	13–25	7–13	13–14	7–7		
below -3 to -10	100/0	35–75	40–50	20–40	10–20	14–30	9–13	CAUTION: No holdover time guidelines exist	
	75/25	19–45	25–35	12–25	5–12	9-16	6–8		
below -10	100/0	25–45	40–45	19–40	9–19				

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GLOSSARY

AMIL	Anti-Icing Materials International Laboratory
APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LWC	Liquid Water Content
MVD	Median Volume Diameter
MANOBS	Manual of Surface Weather Observations
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
TC	Transport Canada
TDC	Transportation Development Centre

1. INTRODUCTION

This report has been created with the support of the fluid manufacturer, the Transport Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA).

This report provides a detailed account of the endurance time testing conducted with **Clariant Safewing MP III 2031 ECO** in the winters of 2012-13 and 2013-14 using the Type I test protocol. It describes the test methodology used, endurance time data collected, and analysis completed to derive a fluid-specific endurance times for the fluid.

The testing described in this report was carried out as a result of supplemental research conducted with Type III fluids and changes to Aerospace Recommended Practice (ARP) 5718, as described below. It was mutually decided by regulators and the manufacturer that this testing should be completed.

1.1 Supplemental Endurance Time Research with Type III Fluids

Clariant Safewing MP III 2031 ECO was the first next-generation Type III de/anti-icing fluid to come to market when it was commercialized in the winter of 2004-05. When it was submitted for endurance time testing, there was no standard protocol in place for measuring endurance times of Type III fluids; test protocols were only in place for Type I fluids and for Type II/IV fluids. Because the new Type III fluid was thickened, it was felt that the test protocol for thickened fluids (Type II/IV) was more appropriate than the test protocol for unthickened fluids (Type I fluids).

The primary difference between the Type I and Type II/IV test protocols is the temperature at which fluids are applied to the test surface: Type II/IV fluids are applied at ambient temperature and Type I fluids are applied heated. This difference replicates the different ways the fluids are applied in operations.

Since the original endurance time testing of Safewing MP III 2031 ECO, additional research has been conducted that shows the temperature at which Type III fluids are applied can have an impact on fluid endurance times.

As Clariant Safewing MP III 2031 ECO is predominantly being applied heated in operations, it is now felt that the Type I protocol is more appropriate for measuring endurance times of Type III fluids applied heated. This necessitates that a complete set of endurance time tests be carried out with the fluid using the Type I test protocol.

1.2 Changes to ARP5718

ARP5718A was published in the fall of 2013 and included changes related to Type III holdover time (HOT) tables. Specifically, it stipulates that fluid-specific and application temperature specific HOT tables will be published for Type III fluids. Currently, there is only a generic Type III HOT table, which contains values which are roughly 10 percent lower than the fluid-specific holdover times for Safewing MP III 2031.

The original endurance time test results for Safewing MP III 2031 ECO will enable a fluid-specific, ambient temperature fluid application table to be produced. However, additional testing using the Type I protocol is required to produce a fluid-specific, heated fluid application table.

Regulators have indicated their intent to publish the fluid-specific and application temperature HOT tables in the near future. Therefore endurance time testing of Safewing MP III 2031 ECO using the Type I test protocol is required.

1.3 Preliminary Testing (Winter 2011-12)

Preliminary testing was conducted with Safewing MP III 2031 ECO using the Type I test protocol in the winter of 2011-12. The endurance time testing was completed and results were acceptable. However, the endurance time testing results were discarded due to an unfavourable water spray endurance test (WSET) result.

1.4 Current Testing (Winters 2012-13 and 2013-14)

A new sample of Safewing MP III 2031 ECO was submitting for testing in the winter of 2012-13. This report documents the testing conducted with the new fluid sample. Testing with this sample was not completed in the winter of 2012-13 due to the late submission of the sample in the winter and lack of favourable weather conditions for natural snow testing following its receipt. Testing was completed in the winter of 2013-14.

2. METHODOLOGY

Testing was carried out using the SAE Aerospace Recommended Practice (ARP) for endurance time testing of Type I fluids, ARP5945. ARP5945 provides the procedure and requirements for endurance time testing of Type I fluids under natural and simulated conditions. This chapter summarizes the test methodology employed in the testing of Clariant Safewing MP III 2031 ECO. The chapter includes sections for test sites, equipment, procedures, precipitation rates and ambient temperatures used in Type III endurance time testing, and freezing precipitation droplet sizes. The final subsection describes the analysis methodology used to evaluate the Type III endurance time data.

2.1 Test Sites

2.1.1 Natural Snow and Natural Frost

Natural snow and natural frost testing was performed at the APS test site located at the Montréal-Pierre-Elliott-Trudeau International Airport. The test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station, as shown in Figure 2.1 on a plan view of the airport. The APS test site consists of two trailers and three outdoor locations for test stands. One of the trailers is equipped with a refrigeration unit to enable indoor testing at controlled temperatures. Photos 2.1 and 2.2 show the test site as seen from the test pads and main trailer, respectively.

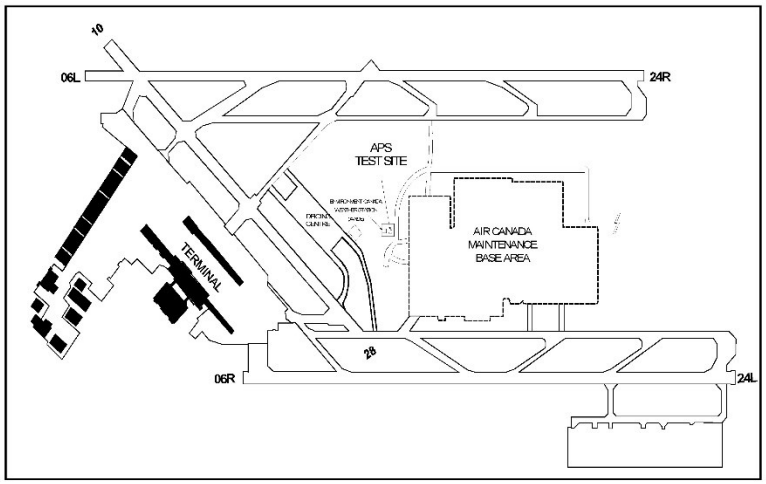


Figure 2.1: APS Test Site at Montréal-Pierre-Elliott-Trudeau International Airport

2.1.2 Freezing Precipitation

Tests under conditions of freezing fog, rain on cold-soaked surface, freezing drizzle, and light freezing rain were conducted indoors at the NRC Climatic Engineering Facility (CEF), where precipitation was artificially produced.

Photo 2.4 provides an outdoor view of the facility giving a general indication of its size (30 m by 5.4 m, height 8 m). The facility was originally designed for the testing of locomotives; Photo 2.5 provides an interior view of the CEF set up for endurance time testing. The lowest temperature achievable in the CEF is -46°C.

2.2 Test Equipment

The key equipment used in endurance time testing is described in this section, as are the calibration procedures APS follows for ensuring the accuracy of its test equipment.

2.2.1 Calibration

APS measurement instruments and test equipment are calibrated and/or verified on an annual basis. This calibration is carried out according to a calibration plan based upon approved International Organization for Standardization (ISO) 9001:2000 standards, and developed internally by APS.

2.2.2 Environmental Chamber Equipment

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) was as stipulated in the requirements set out in ARP5945.

2.2.3 Test Surface Structures

The majority of endurance time testing is carried out on standard flat plates. A schematic of a standard flat plate is provided in Figure 2.2. It depicts the size and surface markings of a standard flat plate. Three parallel lines are positioned at 2.5 cm (1"), 15 cm (6") and 30 cm (12") from the top of the plate. The plates are marked with 15 crosshairs, which are used in determining when end conditions (see Subsection 2.3.4) are achieved. Photo 2.6, taken outdoors at the APS test site, shows six test plates mounted on a test stand.

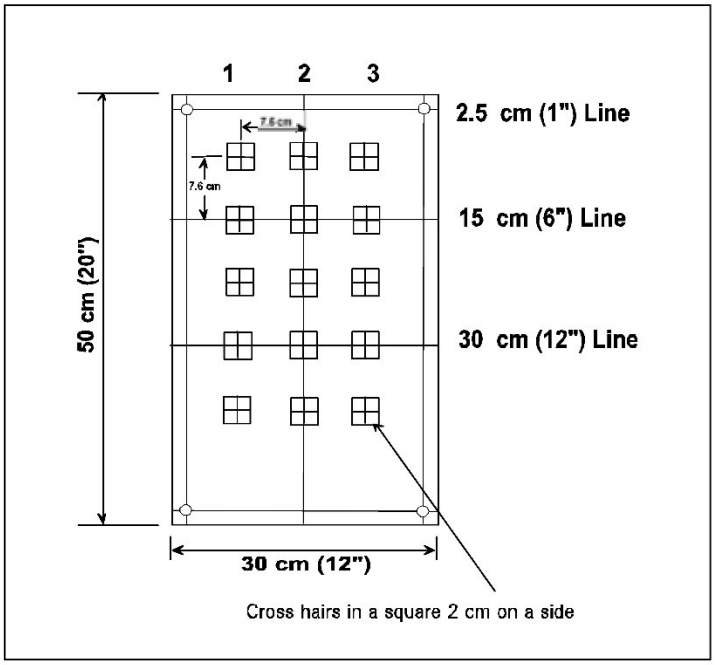


Figure 2.2: Standard Test Plate Schematic

Figure 2.3 shows a schematic of the sealed boxes used for tests simulating a cold soaked wing. The top of the box consists of a flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate. Photo 2.7 shows a picture of a sealed box, which is referred to as a cold-soak box when filled for simulated rain on cold soaked wing tests and a leading edge thermal equivalent box when used empty for testing heated fluids in natural snow conditions.

In natural frost, tests are conducted on frosticator plates, which are the current standard test surface used in frost holdover time testing. The frosticator plates were constructed by attaching a Styrofoam insulation backing to the back of the test surface (either aluminum or composite). The insulation prevents heat exchange via the underside of the flat plate and allows for effective radiative cooling during active frost conditions. Photo 2.8 shows a white-painted aluminum frosticator plate.

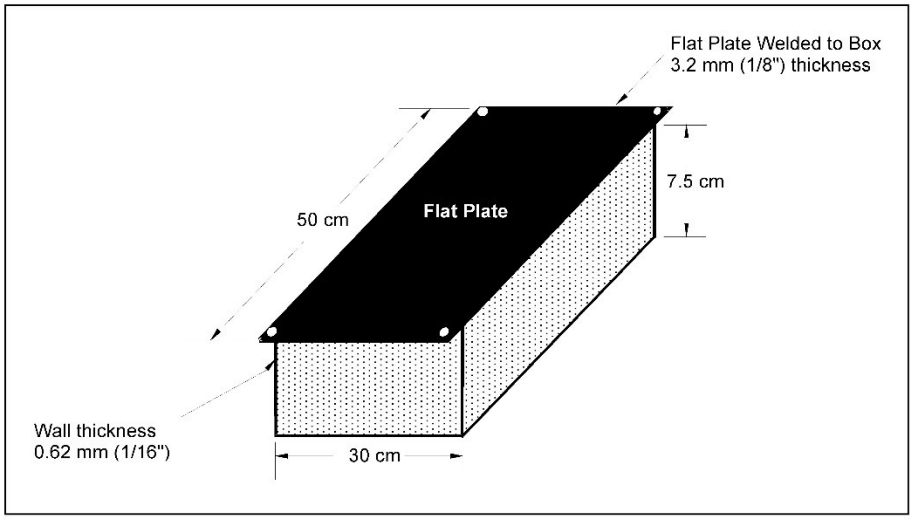


Figure 2.3: Cold Soak Box Schematic

2.2.4 Test Surface Materials

Testing of Type II, III and IV fluids is carried out exclusively on aluminum surfaces. The aluminum used is 0.32 cm thick Alclad 2024 T3 aluminum.

2.2.5 Test Stands

Figure 2.4 shows a schematic of the test platform used for HOT testing. For natural snow tests, six test plates are normally mounted on the test stand, which has a working surface inclined at 10° to the horizontal. During normal winter operations two six-position stands are used in combination. Each plate represents a flat plate test. For simulated freezing precipitation tests at the NRC, 12 plates are mounted on 2 six-position stands. Photos 2.5 and 2.6 show the test stands set up for indoor and outdoor testing, respectively.

2.2.6 Collection Pans

Figure 2.5 shows a schematic of the collection pan used for precipitation rate measurement in outdoor testing. It is the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.8 shows the collection pans used for measuring precipitation rates indoors at the NRC.

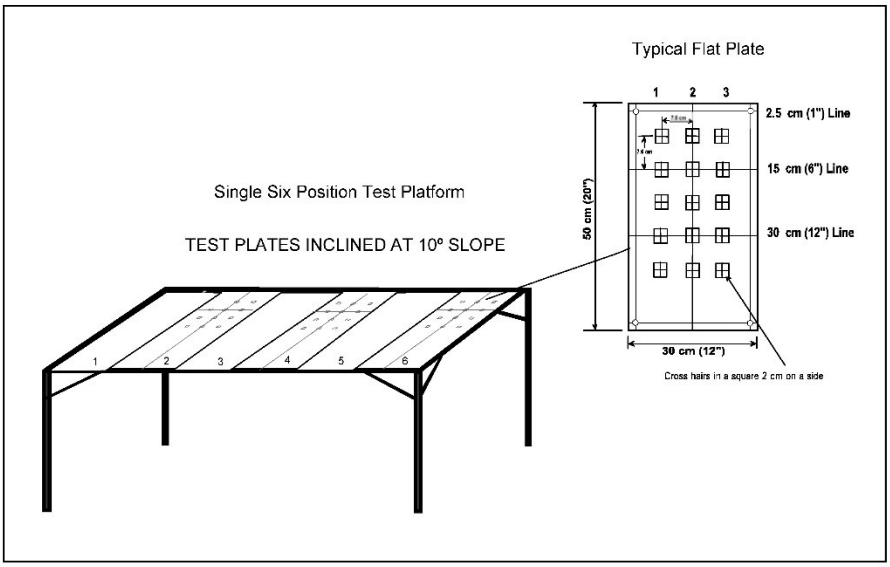


Figure 2.4: Test Stand Setup Schematic

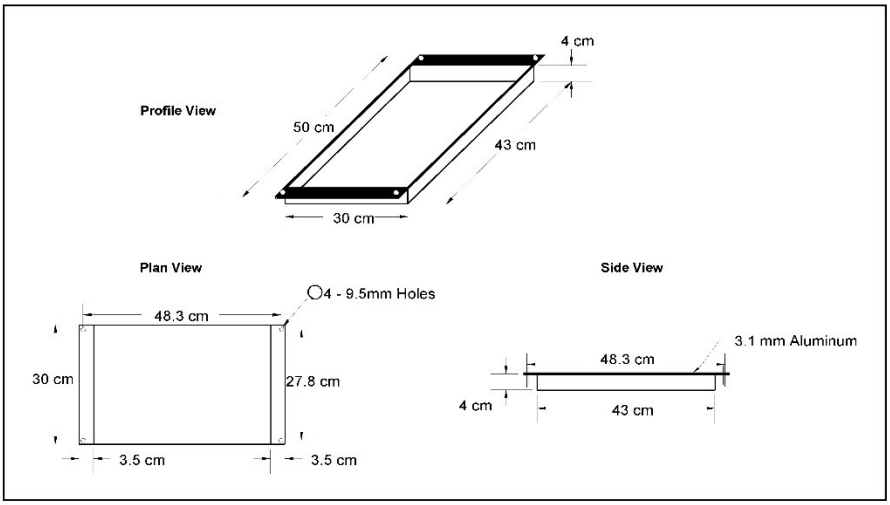


Figure 2.5: Schematic of Outdoor Precipitation Measurement Pan

2.2.7 NRC Sprayer Assembly

NRC developed an improved sprayer assembly, shown in Photos 2.9 and 2.10, in 1997-98. The improved sprayer provides a larger scan area and improved spray uniformity over the test bed area. The scanner consists of a horizontal main shaft supported by two bearings. The actual spray head assembly is shaft-mounted on a rotating scanner, so that one scan covers a lateral running strip of the test bed area. A stepper motor is synchronized to index the relative angle of the spray head between scans along an axis perpendicular to the scan axis. This provides two axes of rotation, essentially an x-y plane; one along each axis. Each scan is consecutively indexed in order to complete the precipitation coverage of the test bed area. This defines one cycle of the spray unit. The scan rate, index angle, and the number of scans per cycle are adjusted, along with the fluid delivery pressures (water and air) to obtain appropriate droplet sizes and precipitation rates. The spray nozzle is shown in Photo 2.11.

2.2.8 Fluids

Testing was carried out with Clariant Safewing MP III 2031 ECO in the standard Type II, III and IV fluid test dilutions: neat, 75/25 and 50/50. The fluid sample was diluted by the manufacturer.

2.3 Test Procedures

Tests were carried out using the Type I fluid endurance time testing protocol, which is provided in ARP5945 and includes protocols for endurance time testing under both natural and simulated precipitation conditions.

The procedure generally consists of pouring de/anti-icing fluids onto clean flat plates exposed to various winter precipitation conditions, and recording the elapsed time for the test to reach the defined end condition (see Subsection 2.3.4), when a specified degree of freezing occurs. The following subsections provide summaries of the test procedures followed for natural snow and simulated freezing precipitation testing.

2.3.1 Test Protocol – Natural Snow Tests

APS developed a specific procedure for Type III heated fluid testing in natural snow based on the requirements outlined in ARP5945. Key details of the procedure include:

- Tests are conducted on empty leading edge thermal equivalent boxes (see Subsection 2.2.3);

- Fluid is applied at a temperature of 60°C; and
- 0.5 L of fluid is applied to the test surface with a 12-hole spreader;

2.3.2 Test Protocol – Simulated Precipitation Tests

APS developed a specific procedure for Type III heated fluid testing in simulated precipitation based on the requirements outlined in ARP5945. Key details of the procedure include:

- Freezing fog, freezing drizzle and light freezing rain tests are conducted on standard flat plates (see Section 2.2.3);
- Cold-soak surface tests are conducted on filled cold-soak boxes (see Section 2.2.3);
- Fluid is applied at a temperature of 20°C; and
- 1 L of fluid is hand-poured on the test surface.

2.3.3 Test Protocol – Natural Frost Tests

APS developed a specific procedure for heated Type III testing in natural frost. Key details of the procedure include:

- Tests are conducted on frosticator plates (see Section 2.2.3);
- Fluid is applied at 20°C; and
- 0.5 L of fluid is hand-poured on the test surface.

2.3.4 End Condition Definitions

Failure is called when 30 percent (1/3) of the plate or 5 cross-hairs are covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

a) Ice front;
b) Ice sheet;
c) Slush, in clusters or as a front;
d) Disseminated fine ice crystals;
e) Frost on surface;

f) Clear ice pieces partially or totally imbedded in fluid; and
g) Snow bridges on top of the fluid.

2.3.5 Precipitation Rate Measurement Procedures

The procedures for measuring and determining precipitation rates during simulated precipitation and natural precipitation conditions are provided below.

2.3.5.1 Simulated precipitation conditions

Prior to the start of the rate collection period, the proper needles and nozzles are installed in the spray unit, and both the air and water pressures are adjusted. Water spray calibration is performed by placing catch pans on the test stand, each pan marked with a number identifying the collection location on the test stand, and exposing the pans to a predetermined precipitation collection period.

The pans are weighed prior to exposure to precipitation and the weights are recorded. Prior to the start of the precipitation catch period, the exact time (hh:mm:ss) is recorded. The pans are re-weighed following this collection period and the precipitation rates over the area of the test stand are examined. If the rates are unacceptable, re-calibration of the water spray is necessary. If the rates are deemed to be acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period has expired, the pans are again re-weighed and the rates computed.

Once two rates have been collected at each test location, the catch rates of the first and second collection are compared. If the average catch rate for any location is deemed to be acceptable for this condition, then the pouring of fluids may begin at this location.

Rates are continuously monitored at a minimum of two locations during a test in order to ensure there are no significant rate fluctuations. Pans will be placed at these locations and be re-weighed at fixed intervals (15 minutes, typically) during the course of a test. If a rate fluctuation occurs, the test is stopped.

Following the failure of a test plate, a rate collection pan is weighed and placed at the plate location for a predetermined time interval. It is then re-weighed and placed again on the stand to collect a minimum of two additional rates at this location.

The rate of precipitation for any location on the stand is calculated by averaging the two rates collected prior to the test and the two rates collected following the test.

2.3.5.2 Natural precipitation conditions

Two rate collection pans per test stand are used to determine precipitation rates in natural conditions. Prior to the rate collection period, both pans are marked (upper and lower), and the inner bottom and sides of the each pan are wetted with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The wetted pans are then weighed to the nearest gram. The start time of the rate collection period is recorded (h/min/sec) using a customized Excel spreadsheet in which the weight is also recorded by pressing the print function on the digital weigh scale.

The pans are positioned in locations 6 and 7 (see Figure 2.4) and are allowed to collect precipitation for 10-minute intervals in normal conditions and 5-minute intervals in periods of high precipitation rates and high winds. Prior to removal of the plate pans from the test stand for re-weighing, any accumulated precipitation on the lips and outer sides of each plate pan is carefully removed. The plate pans are then carried to the rate station for re-weighing. Upon entering the trailer, the exact time is noted. The new weights of the plate pans are recorded and the pans are brought back outside. This procedure is continued until the final plate on the test stand has failed.

The rate for any HOT test in natural snow is obtained by computing the time-weighted average of the rates collected in the upper and lower pans over the duration of this particular test. To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.6. Typically, two collections pans are used for each test. The start and end times of the test shown in Figure 2.6 are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t1, t2, and t3 (minutes). The calculated rates for each collection period are indicated by R1, R2, and R3 (g/dm²/h). In order to calculate the average rate for this pan, the following formula is then used:

$$\frac{(R_1 \times t_1 + R_2 \times t_2 + R_3 \times t_3)}{t_1 + t_2 + t_3}$$

In the example shown in Figure 2.6, the rate is calculated as follows:

$$\frac{(25 \times 10 + 22 \times 8 + 34 \times 5)}{10 + 8 + 5}$$

The calculated average rate for this pan is 25.9 g/dm²/h. The average rate for the other collection pan is calculated in similar fashion, and the average of the two rates is then taken.

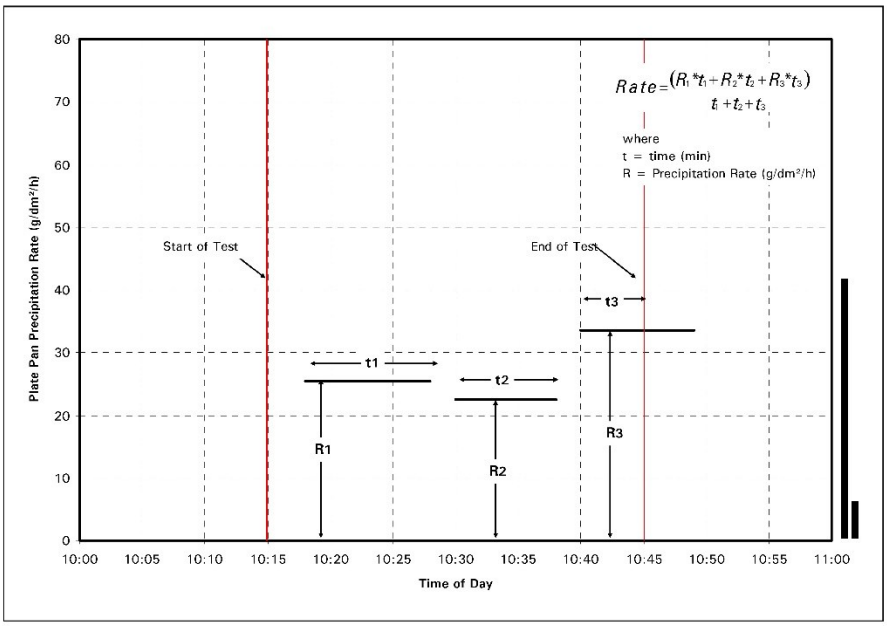


Figure 2.6: Calculation of Outdoor Precipitation Rate

2.4 Precipitation Rate Limits in Type III Endurance Time Testing

Upper and lower precipitation rate limits are an important part of the test methodology for measuring fluid endurance times. Table 2.1 provides the meteorologically accepted definitions of weather phenomenon / precipitation types. It also includes the criteria used to determine precipitation intensity. This table was compiled by the National Centre for Atmospheric Research (NCAR) from the *World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation* (1983) and from the *American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS)* (3/94).

The precipitation rate limits established for Type III endurance time testing are represented graphically in Figure 2.7. Subsections 2.4.1 to 2.4.5 provide detailed definitions and explanations of the precipitation types and rate boundaries used in Type II/IV endurance time testing. It should be noted that in many cases these limits are not the same as the meteorologically accepted definitions provided in Table 2.1.

Table 2.1: Definition of Weather Phenomenon

Weather Phenomenon*	Definition*
FROST (No METAR code) Note: No Intensity is assigned to FROST.	Ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.
FREEZING FOG (FZFG) Note: No Intensity is assigned to FRZ FOG	A suspension of numerous minute water droplets which freezes upon impact with ground or other exposed objects, generally reducing the horizontal
SNOW (SN)	Precipitation of ice crystals, most of which are branched, star-shaped, or mixed with unbranched crystals. At temperatures higher than about -5°C
FRZING DRIZZLE (FZDZ)	Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0.02 in.)] very close together which freezes upon impact with
FREEZING RAIN (FZRA)	Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5
RAIN (RA)	Precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 in.) diameter or of smaller widely scattered drops.
SNOW PELLETS (GS) and/or SMALL HAIL	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is
HAIL (GR)	Precipitation of small balls or pieces of ice with a diame-
ICE PELLETS (PE)	Precipitation of transparent (sleet or grains of ice), or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 in.)

Intensity Criteria**

	Snow(SN),Pellets(GS),Grains(SG)		Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (SN) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm/hr or 10 gr/dm²/hr)	Scattered pellets on the ground. Visibility not affected
Moderate	If visibility is: < 5/8 to 5/16 mi (< 1.0 to 0.5 km)	> 0.05 to 0.10 in/hr (> 1.0 to 2.5 mm/hr) (> 10.0 to 25.0 gr/dm²/hr)	Slow accumulation on the ground. Visibility reduced to less than 7 mi.
Heavy (+)	If visibility is: < 5/16 mi (< 0.5 km)	More than 0.10 in/hr (> 2.5 mm/hr or 25 gr/dm²/hr)	Rapid accumulation on the ground. Visibility reduced to less than 3 mi.

Note: Horizontal visibility is only an estimation of snow and freezing drizzle intensity. Measurements and observations have

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm/hr or 2.54 gr/dm²/hr)
Moderate	From 0.01 to 0.02 in/hr (2.54 to 5.08 gr/dm²/hr)
Heavy(+)	More than 0.02 in/hr (> 5.08 gr/dm²/hr) Note: Drizzle > 0.04 in/hr is usually in the form of rain.

	Rain (RA), Freezing Rain (FZRA), Ice Pellets (PE)
Measured Intensity: Light (-)	Up to 0.10 in/hr (2.5 mm/hr or 25 gr/dm²/hr) Maximum 0.01 inch in 6 minutes
Estimated Intensity: Light (-)	From scattered drops that, regardless of duration, do not completely wet an
Measured Intensity: Moderate	0.11 in to 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.01 to 0.03 inch in 6 minutes
Estimated Intensity: Moderate	Individual drops are not clearly identifiable; spray is observable just above
Measured Intensity: Heavy (+)	More than 0.30 in/hr (7.6 mm/hr or 76 gr/dm²/hr) More than 0.03 inch in 6 minutes
Estimated Intensity: Heavy (+)	Rain seemingly falls in sheets; individual drops are not identifiable; heavy

*From World Meteorological Organization, Guide to Meteorological Instruments and Methods of Observation (1983)
**From American Meteorological Society, Glossary of Meteorology WSCH #7 MA1CB5 (3/94)
***HCAR/HAE Proposed Definition for Liquid Equivalent Snowfall Intensity

1) gm/dm² = 0.01 cm = 0.1 mm = 0.0039 in
2) cm = 2.54 cm = 25.4 mm = 254 gm/dm²

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP Sept 8, 1999 (Updated for METAR codes)

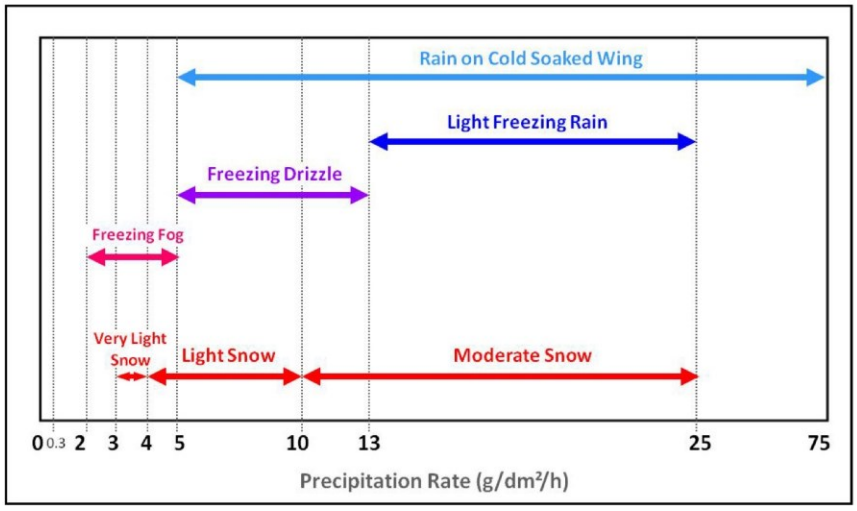


Figure 2.7: Precipitation Rate Limits Used in Endurance Time Testing

2.4.1 Freezing Fog

The precipitation rate limits for endurance time testing in freezing fog were set in 1997 at rates of 2 and 5 g/dm^2/h. These limits were determined with input from NRC meteorologists, who helped define an important parameter in the study of fog referred to as the *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic meter of air, can generally assume values in the range of 0.2 to 0.6 g/m^3.

2.4.2 Freezing Drizzle

The precipitation rate limits for endurance time testing in freezing drizzle are 5 and 13 g/dm^2/h. The upper limit in this range was adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Committee. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety.

2.4.3 Light Freezing Rain

The precipitation rate limits for endurance time testing in light freezing rain are 13 and 25 g/dm^2/h. This range corresponds to the category of light freezing rain and is the only freezing rain category considered, as operations in periods of moderate or heavy freezing rain are deemed unsafe.

2.4.4 Rain on a Cold-Soaked Surface

The precipitation rate limits for rain on cold soaked surface are 5 and 75 g/dm^2/h. This range encompasses drizzle (5 to 13 g/dm^2/h), light rain (13 to 25 g/dm^2/h), and moderate rain (25 to 75 g/dm^2/h).

2.4.5 Snow

The precipitation rate limits used to determine holdover times for Type I/II/III/IV fluids in snow are 3, 4, 10 and 25 g/dm²/h. These rate limits encompass very light, light and moderate snow.

2.5 Ambient Temperatures in Type IIII Endurance Time Testing

The Type III holdover time tables provide holdover times for three temperature ranges:

- -3°C and above;
- Below -3 to -10°C; and
- Below -10°C

In natural snow testing, endurance time testing is carried out under a range of temperatures. In simulated freezing precipitation testing, endurance time testing is typically conducted at the lower limit of each temperature band.

- Freezing Fog: -3°C, -10°C and -25°C
- Freezing Drizzle: -6°C* and -10°C
- Light Freezing Rain: -3°C and -10°C
- Rain on Cold Soaked Surface: +1°C

*Testing is not carried out with heated fluids in light freezing rain at -3°C as the latent heat of freezing in calm test conditions produces artificially long endurance times. Tests may be conducted at -6°C to determine -3°C HOTs.

2.6 Freezing Precipitation Droplet Sizes

Research has shown that median volume diameter (MVD) of rain droplets is related to rate of precipitation as follows:

- MVD = (precipitation rate/10) $^{0.23}$, where MVD is in mm and rate of precipitation is in g/dm²/h

The theoretical MVDs for rain at various rates of precipitation were determined based on this equation. These values are listed in Table 2.2 beside the experimental MVDs for each precipitation condition.

Table 2.2: Theoretical and Experimental MVDs

Precipitation Condition	Experimental MVD (mm)	Theoretical MVD (mm)
Moderate Rain (High rate: 75 g/dm²/h)	1.4	1.6
Light Rain (Low rate: 13 g/dm²/h)	1.0	< 1.1
Light Rain (High rate: 25 g/dm²/h)	1.0	1.2
Drizzle (Low rate: 5 g/dm²/h)	0.25	< 0.5
Drizzle (High rate: 13 g/dm²/h)	0.35	< 0.5
Fog		< 0.1

To determine whether droplets produced at the NRC resembled droplets from natural precipitation, a test was conducted during natural light freezing rain conditions in 1997-98 at the APS test site. The droplet sizes were compared to those obtained in simulated light freezing rain at the NRC. The results of these tests are shown below:

a) *For the outdoor test:*

Location:	Montreal P.E.T. Airport
Precipitation:	Natural Light Freezing Rain
Precipitation Rate:	20 g/dm²/h
Calibrated MVD:	1.0 mm

b) *For the indoor test:*

Location:	National Research Council
Precipitation:	Simulated Light Freezing Rain
Precipitation Rate:	25 g/dm²/h
Calibrated MVD:	1.0 mm

The MVD for both natural and simulated light freezing rain was 1 mm, indicating that the NRC produced droplets simulate natural precipitation.
As a result of this testing, the MVDs for freezing precipitation testing were established as follows:

- Freezing Fog, high precipitation rate (5 g/dm²/h): 30 μm
- Freezing Fog, low precipitation rate (2 g/dm²/h): 30 μm
- Freezing Drizzle, high precipitation rate (13 g/dm²/h): 350 μm
- Freezing Drizzle, low precipitation rate (5 g/dm²/h): 250 μm
- Light Freezing Rain, high precipitation rate (25 g/dm²/h): 1,000 μm
- Light Freezing Rain, low precipitation rate (13 g/dm²/h): 1,000 μm
- Rain on Cold-Soaked Surface, low precipitation rate (5 g/dm²/h): 250 μm
- Rain on Cold-Soaked Surface, high precipitation rate (75 g/dm²/h): 1,400 μm

2.7 Summary of Freezing Precipitation Test Conditions

The precipitation types/rates, ambient temperatures and droplet sizes for freezing precipitation testing with Type III fluids were described in the previous subsections. In summary, freezing precipitation tests are carried out under each of the 16 weather conditions listed in Table 2.3.

Table 2.3: Summary of Freezing Precipitation Test Conditions (Type II/IV Fluids)

Precipitation Type	Ambient Temperature	Precipitation Rate (Droplet Size)
Freezing Fog	-3°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-10°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
	-25°C	2 g/dm²/h (30 μm)
		5 g/dm²/h (30 μm)
Freezing Drizzle	-3°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
	-10°C	5 g/dm²/h (250 μm)
		13 g/dm²/h (350 μm)
Light Freezing Rain	-3°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
	-10°C	13 g/dm²/h (1,000 μm)
		25 g/dm²/h (1,000 μm)
Rain on Cold-Soaked Surface	+1°C	5 g/dm²/h (250 μm)
		75 g/dm²/h (1,400 μm)

2.8 Analysis Methodology

A multi-variable regression procedure is used to derive fluid-specific holdover times for de/anti-icing fluids. The procedure is based on the refinement of an equation for a curve which best represents the test data, and then solving that equation at the upper and lower limits established for the precipitation type. These precipitation rate limits, set by the SAE G-12 HOT Committee, were described in Subsection 2.4. This approach was developed in the winter of 1996-97 (see TC report, TP 13131E) and has since been used to derive fluid holdover times. There are some differences in the way the methodology is applied to freezing precipitation and natural snow data.

2.8.1 Freezing Precipitation Data

For each related freezing precipitation HOT table cell, four tests are conducted at the most restrictive (lowest) temperature in the temperature range for that cell: two tests at the low precipitation rate limit and two tests at the high precipitation rate limit (limits are detailed in Subsection 2.4).The equation used to treat freezing precipitation data is:

- $t = 10^{l}R^{a}$, where

  t = Time (minutes)
  R = Rate of precipitation (g/dm²/h)
  l, a = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.3.

2.8.2 Natural Snow Data

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural snow tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather data under all temperatures and precipitation rates encompassed by the HOT tables.

The general form of the regression equation is modified for natural snow to incorporate the variable of temperature and also to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C. The equation used to treat natural snow data is:

- $t = 10^{l} R^{a} (2-T)^{b}$

where

t = Time (minutes)
R = Rate of precipitation (g/dm²/h)
l, a, b = coefficients determined from the regression.

The upper and lower HOT values for each cell are determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, using the most restrictive (lowest) temperature for that cell. The calculated holdover times derived from this analysis are subject to the rounding and capping rules detailed in Subsection 2.8.3.

2.8.3 Natural Frost Tests

As outside air temperature and precipitation rate can not be controlled under natural test conditions, natural frost tests are carried out at a variety of temperatures and precipitation rates. An attempt is made to gather data under all temperatures encompassed by the frost HOT table.

Regression analysis is not used in the determination of frost holdover times. The current Type II/III/IV generic frost holdover times were determined based on several years of testing using all fluids which were commercially available at the time. A "minimum values" analysis methodology was used to determine appropriate holdover times from the test data.

The purpose of natural frost testing with new fluids is to verify the fluids can be used with the current generic frost holdover times. The analysis methodology is to compare the frost test data collected with the new fluid to the current generic holdover times. If the test data provides holdover times equal to or greater than the generic holdover times then the generic holdover times have been validated for the new fluid.

2.8.4 Rounding and Capping Protocols

Regression-generated holdover times are subject to rounding and capping protocols. For Type III fluids they are as follows:

- Rounding Protocol: Holdover times are rounded to the nearest whole "5" minute, i.e. 55.1 to 57.4 minutes is rounded down to 55 minutes; 57.5 to 59.9 minutes is rounded up to 60 minutes. In cases where the regression-generated holdover times are below 20 minutes, the numbers are rounded down to the nearest whole minute as a precautionary measure. For example, 9.6 minutes is rounded down to 9 minutes.

- Capping Protocol: All holdover time values are capped at maximum values. The caps differ by precipitation type, and in the case of snow, by regulator. The caps are as follows:
  - Freezing fog holdover time values are capped at 4 hours;
  - Freezing drizzle, light freezing rain, rain on cold soaked wing holdover times are capped at 2 hours; and
  - Snow holdover times are capped at 2 hours by Transport Canada and 3 hours by FAA.

2.8.5 Example

Sample plots of **Log t** versus **Log R** are shown in Figure 2.8. The plots contain data for one Neat Type IV fluid, in one temperature range (-10°C), in light freezing rain conditions. The best-fit regression line is superimposed onto the plot and was obtained from the analysis using the lowest temperature in the temperature range from which the data were chosen.

The same data plotted on a linear scale (failure time **t** versus precipitation rate **R**) are shown in Figure 2.9. The curve, generated from the power law form of the equation using the coefficients determined from the fit, is superimposed onto the plot. The HOT range is determined from the intersections of the curve with the precipitation rate limits defined for light freezing rain.

The holdover times for this fluid at -10°C are 20 minutes at 13 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid in the light freezing rain, neat fluid, below -3 to -10°C cell. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

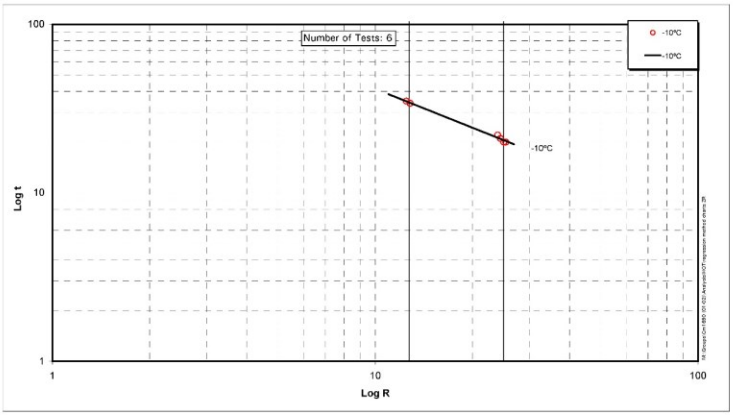


Figure 2.8: Regression Method on Log-Log Chart – Type IV Neat, Freezing Rain

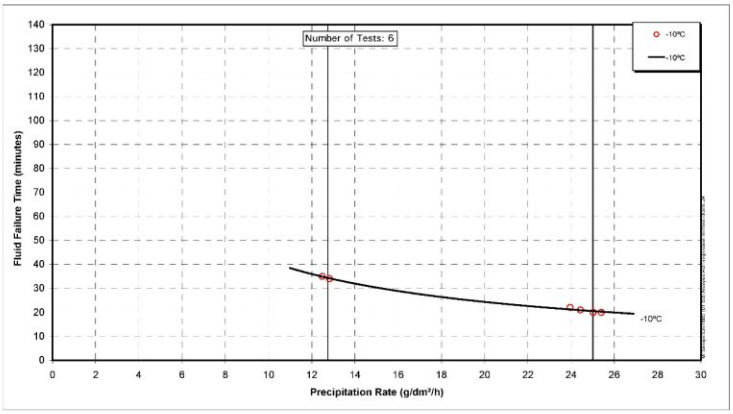


Figure 2.9: Regression Method on Standard Chart – Type IV Neat, Freezing Rain

Photo 2.1: APS Test Site - View from Test Pad



Photo 2.2: APS Test Site - View from Trailer



Photo 2.3: Outdoor View of NRC Climatic Engineering Facility



Photo 2.4: Inside View of NRC Climatic Engineering Facility



Photo 2.5: Test Plates Mounted on Stand



Photo 2.6: Cold-Soak / Leading Edge Thermal Equivalent Box

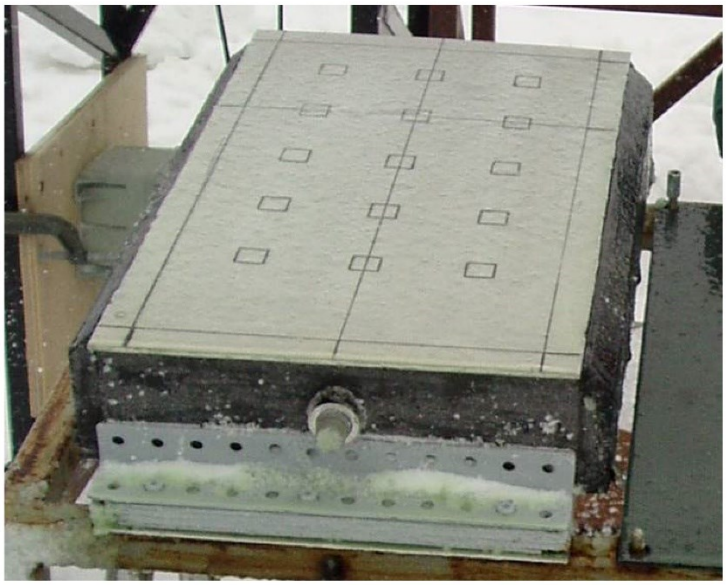


Photo 2.7: Frost Plate with Insulated Backing



Photo 2.8: Collection Pans Used Indoors at the NRC



Photo 2.9: Sprayer Assembly



Photo 2.10: Sprayer Assembly in Use

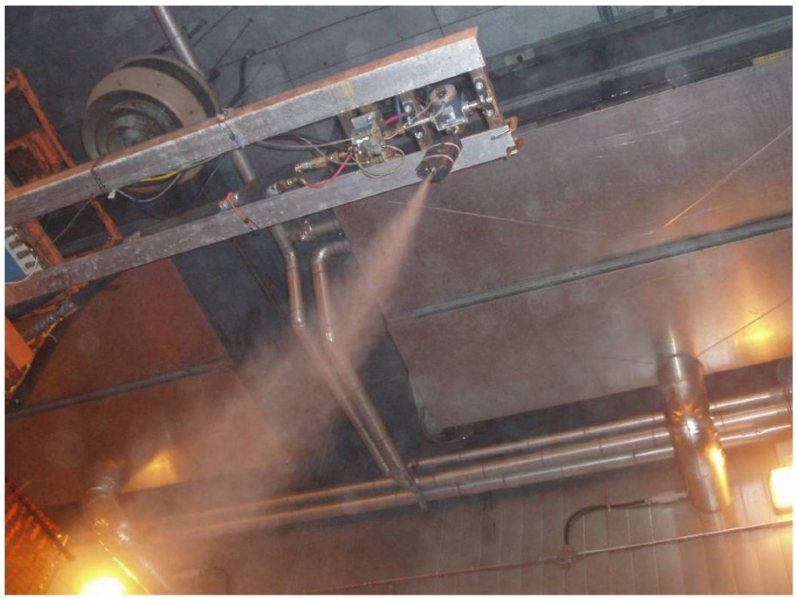
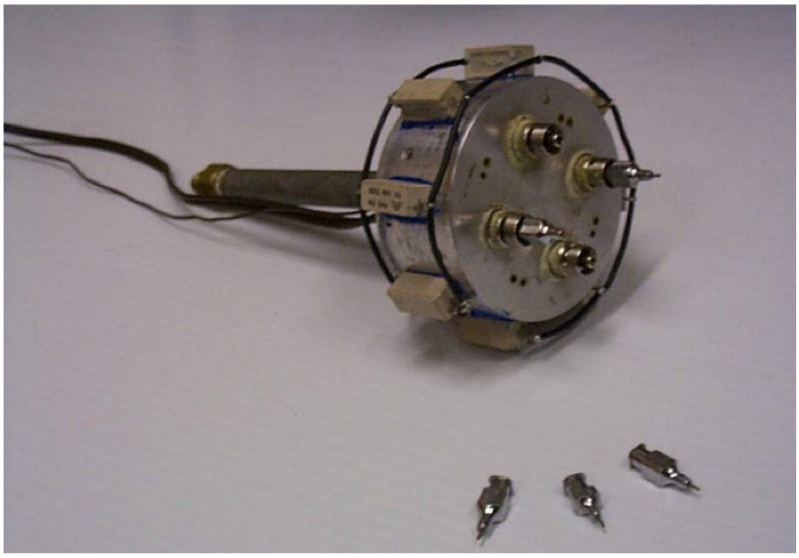


Photo 2.11: Sprayer Nozzle



3. DESCRIPTION OF DATA

This section provides a summary of the number of tests. Breakdowns are provided for the number of tests performed by precipitation type, fluid dilution and temperature.

Logs of the tests conducted are provided at the end of this section as follows: Table 3.1 (snow), Table 3.2 (freezing precipitation), Table 3.3 (frost) and Table 3.4 (supplemental tests). The logs provide details of each test conducted.

3.1 Freezing Fog Tests

Tests were conducted in freezing fog conditions at the NRC CEF. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

Dilution	-3°C	-10°C	-25°C
Neat	4	4	4
75/25	4	4	0
50/50	4	0	0

3.2 Light Freezing Rain Tests

Tests were conducted in light freezing rain conditions at the NRC CEF. Tests were initially conducted at -3°C and -10°C. Tests were later conducted at -6°C when it was determined that, similar to Type I fluids, the latent heat of freezing in calm test conditions produces artificially long endurance times when testing Type III fluids applied heated in light freezing rain at -3°C.

The breakdown of tests conducted is summarized below by precipitation type, fluid dilution and temperature.

Dilution	-3°C	-6°C	-10°C
Neat	4	4	4
75/25	4	4	5
50/50	4	4	0

3.3 Freezing Drizzle

Tests were conducted in freezing drizzle conditions at the NRC CEF. The breakdown of tests conducted is summarized below by precipitation type, fluid dilution and temperature.

Dilution	-3°C	-10°C
Neat	4	4
75/25	4	4
50/50	4	0

3.4 Rain on Cold-Soaked Surface Tests

Tests were conducted in rain on cold-soaked surface conditions at the NRC CEF with Neat and 75/25 diluted fluids. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

Dilution	+1°C
Neat	4
75/25	5
50/50	0

3.5 Natural Snow Tests

Tests were conducted in natural snow conditions at the APS test site and at several mobile test sites (see Subsection 2.2.1). The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	≥ -3°C	-3 to -10°C	<-10°C
Neat	9	13	2
75/25	10	11	0
50/50	14	0	0

3.6 Natural Frost Tests

Tests were conducted in natural frost at the APS test site. The breakdown of tests conducted is summarized below by fluid dilution and temperature.

	≥-1°C	<-1 to -3°C	<-3 to -10°C	<-10°C
Neat	1	0	1	3
75/25	0	0	1	0
50/50	2	0	0	0

3.7 Fluid Thickness Tests

Fluid thickness tests were conducted to measure the film thickness profiles of the fluid under dry conditions. Two tests were performed for each dilution. Tests were conducted at an ambient air temperature of -3°C with fluid applied at 20°C. For each test, 1 litre of fluid was poured onto a flat plate mounted on a test stand inclined by 10°. Thickness measurements were taken at the 15-cm (6″) line at select time intervals over a 30-minute period.

The film thickness profiles are displayed in Figure 3.1. The final fluid thicknesses are displayed in Figure 3.2.

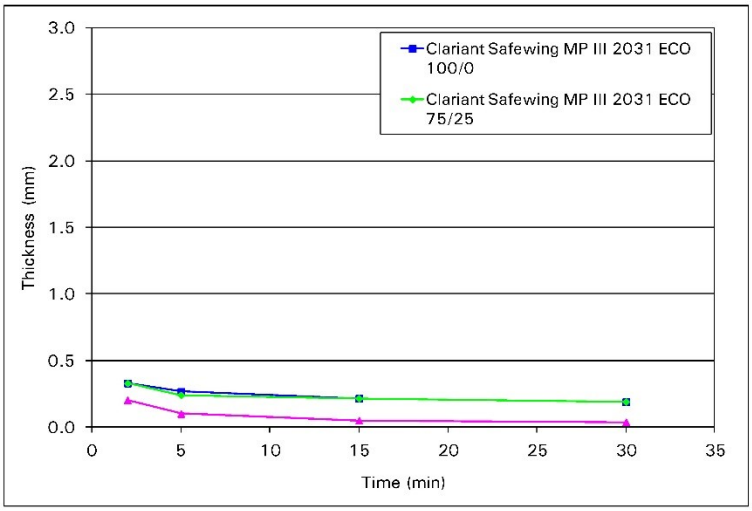


Figure 3.1: Fluid Thickness Profiles of Clariant Safewing MP III 2031 at 20°C

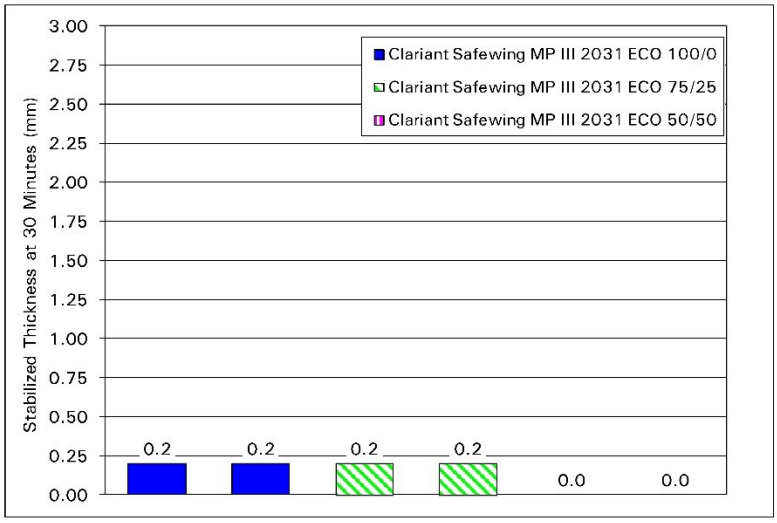


Figure 3.2: Final Fluid Thickness of Clariant Safewing MP III 2031 at 20°C

3.8 Supplemental Tests: Type II/IV Test Protocol

Supplemental tests were conducted with Clariant Safewing MP III 2031 ECO using the standard Type II/IV test protocol. The objective of the tests was to compare the endurance times of the fluid applied with the Type I protocol (heated application) and the Type II/IV protocol (ambient temperature application).

The differences in the natural snow test protocols are as follows:

- Type I Protocol: 1 litre of fluid; fluid applied at ambient temperature; leading edge thermal equivalent box test surface.
- Type II/IV Protocol: 0.5 litre of fluid; fluid applied at 60°C; standard flat plate test surface.

The differences in the freezing precipitation test protocols are as follows:

- Type I Protocol: Fluid applied at 20°C.
- Type II/IV Protocol: Fluid applied at ambient temperature.

In total 12 of these tests were conducted, including 6 tests in natural snow and 6 tests in freezing precipitation. The number of tests is summarized below by precipitation type and fluid dilution. Further details from these tests are provided

in the supplemental log of tests (Table 3.4) at the end of this chapter. The tests are identified by their test numbers, which are prefaced by "CD".

In general, the tests showed similar endurance times to the baseline tests. However, there were some tests where endurance times differed by up to 51%.

	Natural Snow	Freezing Fog	Freezing Drizzle	Light Freezing Rain
Neat	3	0	1	1
75/25	2	1	0	1
50/50	1	1	1	0

3.9 Supplemental Tests: Composite Surfaces

Supplemental tests were conducted with Clariant Safewing MP III 2031 ECO on composite surfaces. The objective of the tests was to collect preliminary data with this fluid applied heated on composite surfaces.

The only difference in the test protocol for these tests and the standard tests was the test surface, which was the standard composite material used in Type I fluid testing on composite surfaces (0.32 cm thick carbon fibre cross weave fabric).

In total 20 of these tests were conducted, including 11 tests in natural snow and 9 tests in freezing precipitation. The number of tests is summarized below by precipitation type and fluid dilution. Further details from these tests are provided in the supplemental log of tests (Table 3.4) at the end of this chapter. The tests are identified by their test numbers, which are prefaced by "CP".

Due to the limited number of tests performed, no final conclusions can be drawn from the tests conducted. However, it appears that endurance times on composite surfaces are similar to those on aluminum surfaces in freezing precipitation conditions and slightly shorter in natural snow conditions.

	Natural Snow	Freezing Fog	Freezing Drizzle	Light Freezing Rain
Neat	5	3	1	1
75/25	3	1	0	1
50/50	3	1	1	0

Table 3.1: Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
Winter 2012-13							
221	27-Feb-13	Natural Snow	MP III 2031 ECO	100%	0.2	31.9	11.5
222	27-Feb-13	Natural Snow	MP III 2031 ECO	75%	0.2	32.3	8.8
223	27-Feb-13	Natural Snow	MP III 2031 ECO	50%	0.2	32.3	6.8
245	2-Mar-13	Natural Snow	MP III 2031 ECO	50%	-3.5	2.1	23.7
246	2-Mar-13	Natural Snow	MP III 2031 ECO	75%	-3.5	1.3	81.7
247	2-Mar-13	Natural Snow	MP III 2031 ECO	100%	-3.5	1.4	96.4
257	2-Mar-13	Natural Snow	MP III 2031 ECO	100%	-3.7	5.8	29.6
258	2-Mar-13	Natural Snow	MP III 2031 ECO	75%	-3.7	5.1	25.5
259	2-Mar-13	Natural Snow	MP III 2031 ECO	100%	-4.4	6.3	23.8
260	2-Mar-13	Natural Snow	MP III 2031 ECO	75%	-4.4	5.4	25.2
261	2-Mar-13	Natural Snow	MP III 2031 ECO	100%	-4.4	6.2	31.6
262	2-Mar-13	Natural Snow	MP III 2031 ECO	75%	-4.4	7.4	18.5
267	2-Mar-13	Natural Snow	MP III 2031 ECO	100%	-5.8	3.5	51.9
268	2-Mar-13	Natural Snow	MP III 2031 ECO	75%	-5.8	3.3	39.8
269	2-Mar-13	Natural Snow	MP III 2031 ECO	100%	-5.7	4.1	49.0
270	2-Mar-13	Natural Snow	MP III 2031 ECO	75%	-5.7	4.2	31.5
277	15-Mar-13	Natural Snow	MP III 2031 ECO	100%	-3.1	2.7	63.4
278	15-Mar-13	Natural Snow	MP III 2031 ECO	75%	-3.1	2.8	51.8
279	15-Mar-13	Natural Snow	MP III 2031 ECO	50%	-3.1	2.8	52.4
287	15-Mar-13	Natural Snow	MP III 2031 ECO	100%	-2.4	1.5	82.1
288	15-Mar-13	Natural Snow	MP III 2031 ECO	75%	-2.4	1.6	80.7
289	15-Mar-13	Natural Snow	MP III 2031 ECO	50%	-2.4	1.6	82.6
308	19-Mar-13	Natural Snow	MP III 2031 ECO	100%	-2.3	16.5	13.1
309	19-Mar-13	Natural Snow	MP III 2031 ECO	75%	-2.3	16.4	11.1
310	19-Mar-13	Natural Snow	MP III 2031 ECO	50%	-2.3	16.3	9.5
326	19-Mar-13	Natural Snow	MP III 2031 ECO	100%	-2.6	13.6	15.2
327	19-Mar-13	Natural Snow	MP III 2031 ECO	75%	-2.6	14.4	11.2
328	19-Mar-13	Natural Snow	MP III 2031 ECO	50%	-2.6	14.5	10.7
332	19-Mar-13	Natural Snow	MP III 2031 ECO	100%	-3.0	6.7	27.9
333	19-Mar-13	Natural Snow	MP III 2031 ECO	75%	-3.0	8.5	18.1
334	19-Mar-13	Natural Snow	MP III 2031 ECO	50%	-3.0	9.2	14.0
336	12-Apr-13	Natural Snow	MP III 2031 ECO	75%	-1.3	8.2	21.8
337	12-Apr-13	Natural Snow	MP III 2031 ECO	50%	-1.3	6.7	17.1
339	12-Apr-13	Natural Snow	MP III 2031 ECO	100%	-0.2	51.1	7.4
340	12-Apr-13	Natural Snow	MP III 2031 ECO	75%	-0.2	53.4	5.4
341	12-Apr-13	Natural Snow	MP III 2031 ECO	50%	-0.2	53.8	4.1
342	12-Apr-13	Natural Snow	MP III 2031 ECO	100%	-0.2	65.6	5.7
343	12-Apr-13	Natural Snow	MP III 2031 ECO	75%	-0.2	65.0	4.8
344	12-Apr-13	Natural Snow	MP III 2031 ECO	50%	-0.2	64.1	4.4

Table 3.1 (cont'd): Summary of Tests Performed (Snow)

Test No.	Date	Snow Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
Winter 2013-14							
21	9-Dec-13	Natural Snow	MP III 2031 ECO	100%	-4.9	19.4	12.2
22	9-Dec-13	Natural Snow	MP III 2031 ECO	75%	-4.9	22.0	7.7
23	9-Dec-13	Natural Snow	MP III 2031 ECO	100%	-4.0	7.4	21.4
24	9-Dec-13	Natural Snow	MP III 2031 ECO	75%	-4.0	7.5	14.0
25	14-Dec-13	Natural Snow	MP III 2031 ECO	100%	-16.9	5.8	36.8
32	15-Dec-13	Natural Snow	MP III 2031 ECO	100%	-16.2	14.8	15.8
43	20-Dec-13	Natural Snow	MP III 2031 ECO	100%	-7.7	11.6	16.4
44	20-Dec-13	Natural Snow	MP III 2031 ECO	75%	-7.7	11.5	11.1
47	20-Dec-13	Natural Snow	MP III 2031 ECO	100%	-8.3	9.1	19.2
48	20-Dec-13	Natural Snow	MP III 2031 ECO	75%	-8.3	8.9	13.1
55	20-Dec-13	Natural Snow	MP III 2031 ECO	100%	-7.0	4.1	46.7
56	20-Dec-13	Natural Snow	MP III 2031 ECO	75%	-7.0	3.3	38.1
63	25-Jan-14	Natural Snow	MP III 2031 ECO	100%	-9.5	4.0	35.9
80	1-Feb-14	Natural Snow	MP III 2031 ECO	50%	-3.1	2.7	27.4
82	1-Feb-14	Natural Snow	MP III 2031 ECO	50%	-2.5	4.4	19.9
90	1-Feb-14	Natural Snow	MP III 2031 ECO	50%	-1.4	16.7	11.8
132	5-Feb-14	Natural Snow	MP III 2031 ECO	100%	-9.7	7.2	25.0
235	22-Mar-14	Natural Snow	MP III 2031 ECO	50%	-3.5	41.1	5.4
236	22-Mar-14	Natural Snow	MP III 2031 ECO	100%	-3.0	28.5	11.3
240	22-Mar-14	Natural Snow	MP III 2031 ECO	75%	-3.2	13.3	18.8

Table 3.2: Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
7	4-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-3.0	2.1	47.6
8	4-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-3.1	2.1	50.8
9R	4-Apr-13	Freezing Fog	MP III 2031 ECO	75%	-3.2	2.0	38.7
10	4-Apr-13	Freezing Fog	MP III 2031 ECO	75%	-3.1	2.3	38.2
11	4-Apr-13	Freezing Fog	MP III 2031 ECO	50%	-3.1	2.3	17.1
12	4-Apr-13	Freezing Fog	MP III 2031 ECO	50%	-3.1	2.1	18.9
19	4-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-3.0	4.8	26.5
20	4-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-3.1	4.8	26.6
21	4-Apr-13	Freezing Fog	MP III 2031 ECO	75%	-3.2	5.0	18.9
22	4-Apr-13	Freezing Fog	MP III 2031 ECO	75%	-3.2	4.9	20.2
23	4-Apr-13	Freezing Fog	MP III 2031 ECO	50%	-3.0	5.1	13.2
24	4-Apr-13	Freezing Fog	MP III 2031 ECO	50%	-3.0	5.1	13.1
25	5-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-10.1	1.9	74.1
26	5-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-10.1	2.0	79.0
27	5-Apr-13	Freezing Fog	MP III 2031 ECO	75%	-10.0	2.0	46.9
28	5-Apr-13	Freezing Fog	MP III 2031 ECO	75%	-10.0	2.0	46.5
29	5-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-10.1	5.0	35.2
30	5-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-10.1	5.1	34.9
31	5-Apr-13	Freezing Fog	MP III 2031 ECO	75%	-10.1	5.1	18.9
32	5-Apr-13	Freezing Fog	MP III 2031 ECO	75%	-10.1	4.8	21.3
43	8-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-25.2	2.0	44.8
44	8-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-25.2	1.9	50.7
47	8-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-25.2	5.1	23.7
48	8-Apr-13	Freezing Fog	MP III 2031 ECO	100%	-25.2	5.0	25.0
55	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	-3.2	12.9	14.9
56	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	-3.2	12.9	14.5
57	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	-3.1	13.2	13.2
58	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	-3.1	13.3	13.5
59	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	50%	-3.1	13.5	11.3
60	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	50%	-3.1	13.3	12.0
67	11-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	-3.0	24.7	14.1
68	11-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	-3.0	24.5	13.7
69	11-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	-3.0	24.3	12.6
70	11-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	-3.0	24.3	11.5
71	11-Apr-13	Light Freezing Rain	MP III 2031 ECO	50%	-3.3	25.0	10.0
72	11-Apr-13	Light Freezing Rain	MP III 2031 ECO	50%	-3.3	24.4	9.2
77	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	-10.2	13.5	14.4
78	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	-10.5	12.6	12.2
79	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	-10.1	13.0	9.2
80	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	-10.2	12.9	7.5

Table 3.2 (cont'd): Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
80R	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	-10.4	12.9	7.8
85	8-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	-9.8	25.5	8.7
86	8-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	-9.8	25.5	8.9
87	8-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	-10.3	25.2	7.0
88	8-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	-10.3	25.7	6.3
95	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	-3.2	5.0	29.8
96	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	-3.2	5.2	29.5
97	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	75%	-3.2	4.8	22.3
98	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	75%	-3.2	4.6	21.7
99	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	50%	-3.1	5.1	16.1
100	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	50%	-3.1	5.4	13.6
107	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	-3.2	13.5	18.7
108	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	-3.3	13.0	15.9
109	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	75%	-3.2	13.1	14.4
110	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	75%	-3.3	13.0	12.0
111	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	50%	-3.3	13.1	14.4
112	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	50%	-3.3	13.1	11.9
117	9-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	-10.0	5.4	27.5
118	9-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	-10.0	5.3	26.4
119	9-Apr-13	Freezing Drizzle	MP III 2031 ECO	75%	-10.0	5.1	15.0
120	9-Apr-13	Freezing Drizzle	MP III 2031 ECO	75%	-10.2	5.1	18.0
125	8-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	-10.4	12.5	14.4
126	8-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	-10.3	13.5	13.7
127	8-Apr-13	Freezing Drizzle	MP III 2031 ECO	75%	-10.1	12.5	9.4
128	8-Apr-13	Freezing Drizzle	MP III 2031 ECO	75%	-10.2	13.3	10.0
133	11-Apr-13	Cold Soak Box	MP III 2031 ECO	100%	0.8	5.3	30.0
134	11-Apr-13	Cold Soak Box	MP III 2031 ECO	100%	0.8	5.1	30.2
135	11-Apr-13	Cold Soak Box	MP III 2031 ECO	75%	0.8	5.0	16.4
135R	11-Apr-13	Cold Soak Box	MP III 2031 ECO	75%	1.0	5.2	18.2
136	11-Apr-13	Cold Soak Box	MP III 2031 ECO	75%	0.9	4.9	20.7
141	11-Apr-13	Cold Soak Box	MP III 2031 ECO	100%	0.9	76.5	5.2
142	11-Apr-13	Cold Soak Box	MP III 2031 ECO	100%	0.9	75.5	4.6
143	11-Apr-13	Cold Soak Box	MP III 2031 ECO	75%	0.9	75.0	3.0
144	11-Apr-13	Cold Soak Box	MP III 2031 ECO	75%	0.9	74.4	3.1
81	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	100%	-6.2	12.9	14.6
82	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	100%	-6.2	13.0	13.8
83	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	75%	-6.3	13.1	9.8
84	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	75%	-6.3	12.7	9.5
85	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	50%	-6.2	13.1	7.6
86	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	50%	-6.2	13.4	7.6

Table 3.2 (cont'd): Summary of Tests Performed (Freezing Precipitation)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)
87	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	100%	-6.1	25.3	10.1
88	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	100%	-6.1	24.6	10.1
89	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	75%	-6.1	25.3	7.8
90	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	75%	-6.3	24.6	8.5
91	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	50%	-6.3	25.2	8.1
92	18-Sep-13	Light Freezing Rain	MP III 2031 ECO	50%	-6.3	25.1	7.1

Table 3.3: Summary of Tests Performed (Natural Frost)

Test No.	Date	Precipitation	Fluid Name	Fluid Dilution	Endurance Time (min.)	Average Rate (g/dm²/h)	Temp (°C)	Wind Speed (km/h)	Average RH (%)	Comments
41	8-Mar-13	Natural Frost	MP III 2031 ECO	75%	442	0.16	-4.0	81	4	failed
50	8-Mar-13	Natural Frost	MP III 2031 ECO	100%	556	0.14	-3.1	77	4	failed
51	8-Mar-13	Natural Frost	MP III 2031 ECO	50%	114	0.10	-0.8	69	3	failed
65	9-Mar-13	Natural Frost	MP III 2031 ECO	100%	335	0.05	-0.3	4	72	not failed
66	9-Mar-13	Natural Frost	MP III 2031 ECO	50%	335	0.05	-0.3	4	72	not failed
3	11-Feb-14	Natural Frost	MP III 2031 ECO	100%	324	0.06	-15.8	12	71	not failed
7	11-Feb-14	Natural Frost	MP III 2031 ECO	100%	599	0.05	-18.5	3	67	failed
15	5-Mar-14	Natural Frost	MP III 2031 ECO	100%	306	0.06	-15.2	7	65	not failed

Table 3.4: Summary of Tests Performed (Supplemental Testing)

Test No.	Date	Precipitation Type	Fluid Name	Fluid Dilution	Test Surface	Fluid App. Temp (°C)	Test Temp. (°C)	Icing Intensity (g/dm²/h)	Endurance Time (min)	
									Test	Baseline
CD314	19-Mar-13	Natural Snow	MP III 2031 ECO	50%	Alum. Plate	Ambient	-2.3	16.2	4.7	9.5
CD331	19-Mar-13	Natural Snow	MP III 2031 ECO	100%	Alum. Plate	Ambient	-2.6	13.0	19.8	15.2
CD335	19-Mar-13	Natural Snow	MP III 2031 ECO	75%	Alum. Plate	Ambient	-3.0	8.3	18.9	18.1
CD024	4-Apr-13	Freezing Fog	MP III 2031 ECO	50%	Alum. Plate	Ambient	-2.9	5.1	11.4	36.8
CD028	5-Apr-13	Freezing Fog	MP III 2031 ECO	75%	Alum. Plate	Ambient	-10.0	1.9	35.4	15.8
CD058	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	Alum. Plate	Ambient	-3.0	13.5	10.9	11.1
CD118	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	Alum. Plate	Ambient	-10.0	5.1	27.0	13.1
CD112	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	50%	Alum. Plate	Ambient	-3.3	13.5	5.8	46.5
CD068	11-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	Alum. Plate	Ambient	-3.2	24.5	10.4	13.5
CD27	14-Dec-13	Natural Snow	MP III 2031 ECO	100%	Alum. Plate	Ambient	-17.2	6.7	19.7	26.4
CD34	15-Dec-13	Natural Snow	MP III 2031 ECO	100%	Alum. Plate	Ambient	-16.2	14.9	13.8	11.9
CD46	20-Dec-13	Natural Snow	MP III 2031 ECO	75%	Alum. Plate	Ambient	-7.7	11.4	12.3	13.7
CP024	4-Apr-13	Freezing Fog	MP III 2031 ECO	50%	Comp. Plate	20	-3.0	5.0	11.9	13.1
CP028	5-Apr-13	Freezing Fog	MP III 2031 ECO	75%	Comp. Plate	20	-10.0	1.8	46.4	46.7
CP058	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	75%	Comp. Plate	20	-3.2	13.5	14.0	13.3
CP118	9-Apr-13	Light Freezing Rain	MP III 2031 ECO	100%	Comp. Plate	20	-10.1	5.5	27.1	26.9
CP112	10-Apr-13	Freezing Drizzle	MP III 2031 ECO	50%	Comp. Plate	20	-3.3	13.5	9.7	13.2
CP068	11-Apr-13	Freezing Drizzle	MP III 2031 ECO	100%	Comp. Plate	20	-3.3	24.7	10.9	13.9
CP-T7	26-Mar-14	Freezing Fog	MP III 2031 ECO	100%	Comp. Plate	20	-10	4.9	33.6	35.1
CP-T9	25-Mar-14	Freezing Fog	MP III 2031 ECO	100%	Comp. Plate	20	-3	4.9	28.8	25.6
CP-T11	25-Mar-14	Freezing Fog	MP III 2031 ECO	100%	Comp. Plate	20	-3	2.2	53.7	45.5
CP26	14-Dec-13	Natural Snow	MP III 2031 ECO	100%	Comp. Box	60	-16.9	6.2	28.3	36.8
CP33	15-Dec-13	Natural Snow	MP III 2031 ECO	100%	Comp. Box	60	-16.2	14.9	12.0	15.8
CP45	20-Dec-13	Natural Snow	MP III 2031 ECO	75%	Comp. Box	60	-7.7	11.5	7.4	11.1
CP49	20-Dec-13	Natural Snow	MP III 2031 ECO	100%	Comp. Box	60	-8.3	9.0	16.4	19.2
CP50	20-Dec-13	Natural Snow	MP III 2031 ECO	75%	Comp. Box	60	-8.3	8.9	11.1	13.1
CP57	20-Dec-13	Natural Snow	MP III 2031 ECO	100%	Comp. Box	60	-7.0	4.1	46.4	46.7
CP58	20-Dec-13	Natural Snow	MP III 2031 ECO	75%	Comp. Box	60	-7.0	2.8	32.8	38.1
CP81	1-Feb-14	Natural Snow	MP III 2031 ECO	50%	Comp. Box	60	-3.1	2.9	23.5	27.4
CP83	1-Feb-14	Natural Snow	MP III 2031 ECO	50%	Comp. Box	60	-2.5	4.4	12.4	19.9
CP91	1-Feb-14	Natural Snow	MP III 2031 ECO	50%	Comp. Box	60	-1.4	15.6	8.7	11.8
CP131	5-Feb-14	Natural Snow	MP III 2031 ECO	100%	Comp. Box	60	-9.7	7.4	23.3	25.0

4. RESULTS AND DISCUSSION

The methods used to evaluate the test data were reviewed in Subsection 2.6. The data used to generate endurance times for Clariant Safewing MP III 2031 ECO using the Type I protocol are presented in this section.

4.1 Results

Figures 4.1 to 4.14 present the data collected in natural snow, freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface. These figures show the effect of temperature, precipitation type and precipitation rate on fluid endurance time in the conditions encompassed by the Type III HOT guidelines.

The natural frost data was presented in Table 3.3. All tests, including those where fluid failure did not occur (due to active frost ending before fluid failure could occur), surpassed the generic holdover times indicating the generic frost holdover times have been substantiated for MP III 2031 ECO applied heated.

Table 4.1 illustrates the outputs from the multi-variable regression analyses performed on the freezing fog, freezing drizzle, freezing rain and cold soak data. These outputs were used to derive fluid-specific endurance times for all cells in the fluid-specific HOT table.

4.2 Endurance Time Table

A table of endurance times for Clariant Safewing MP III 2031 ECO applied heated is shown in Table 4.2 at the end of this section. The values in the table were derived from regression analysis of the endurance time data collected.

In May 2009, a decision was made by TC and the FAA to move frost holdover times from the generic and fluid-specific HOT tables to a separate frost HOT table. Accordingly, frost holdover times have not been included in the fluid-specific HOT table for Clariant Safewing MP III 2031 ECO.

Due to the manufacturer's decision to discontinue manufacturing this fluid, it was mutually agreed by regulators and the manufacturer that these results would not be incorporated into the holdover time guidelines.

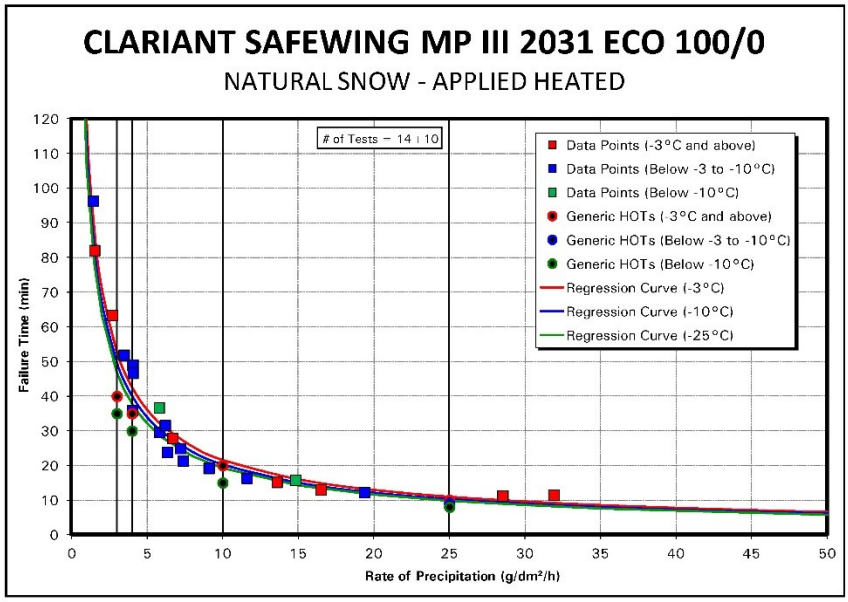


Figure 4.1: Type III Neat – Natural Snow

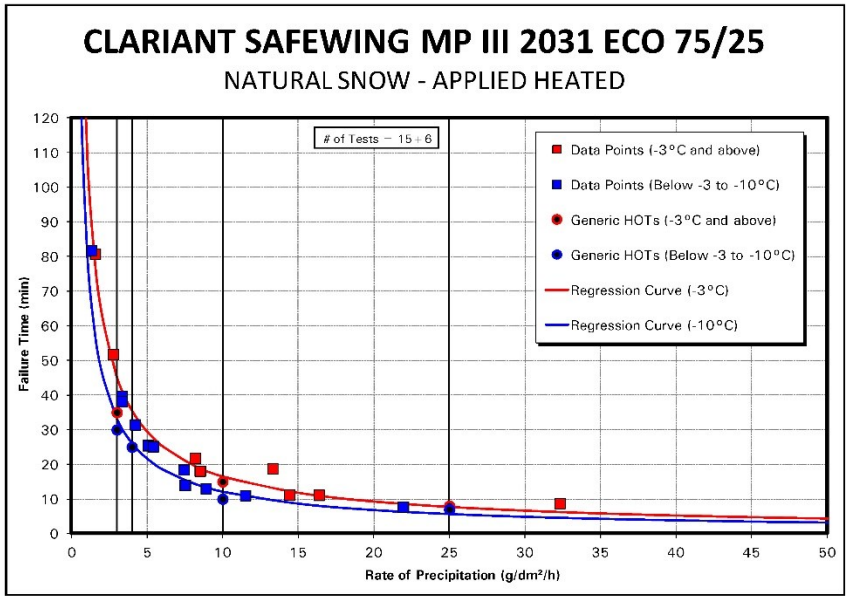


Figure 4.2: Type III 75/25 – Natural Snow

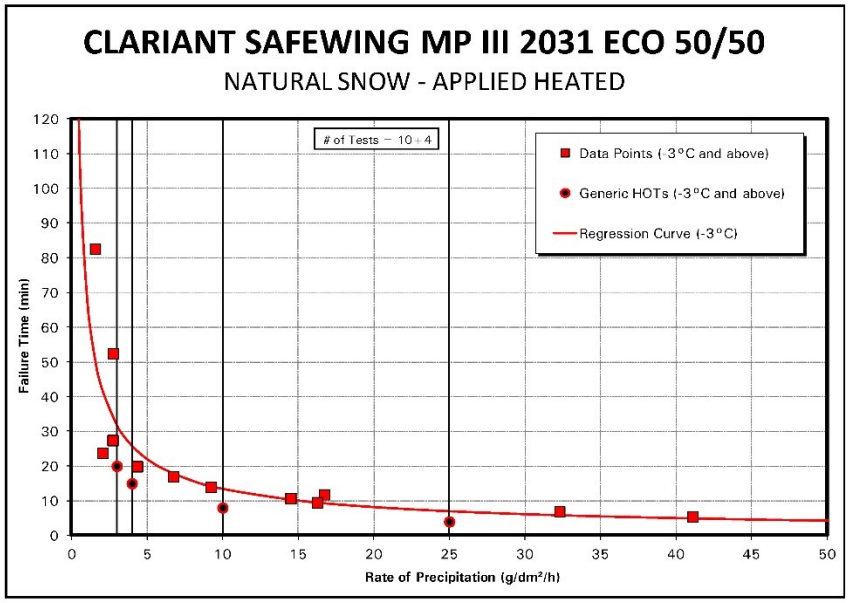


Figure 4.3: Type III 50/50 – Natural Snow

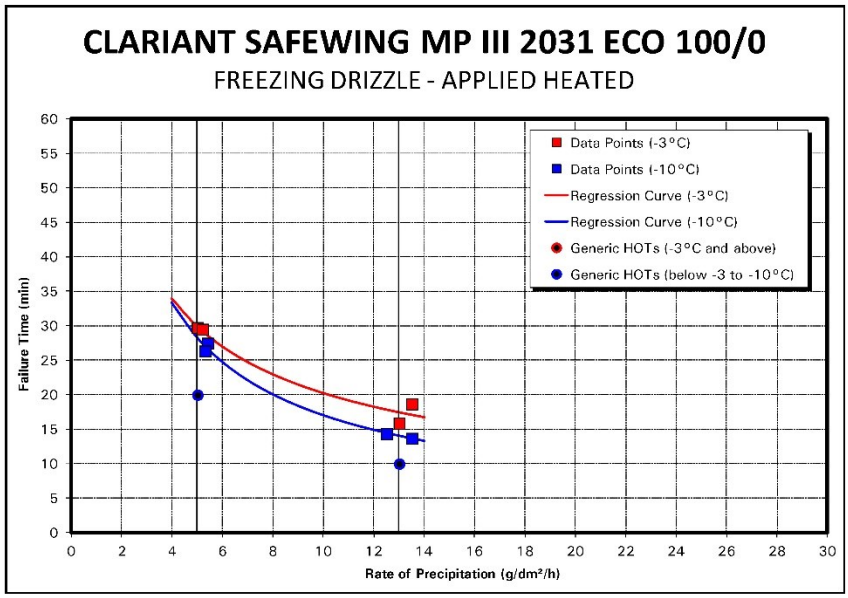


Figure 4.4: Type III Neat – Freezing Drizzle

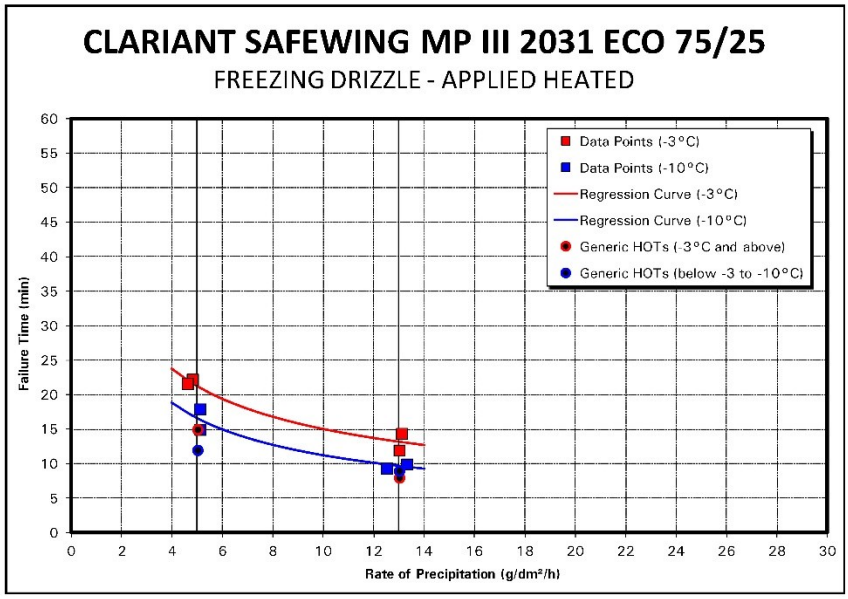


Figure 4.5: Type III 75/25 – Freezing Drizzle

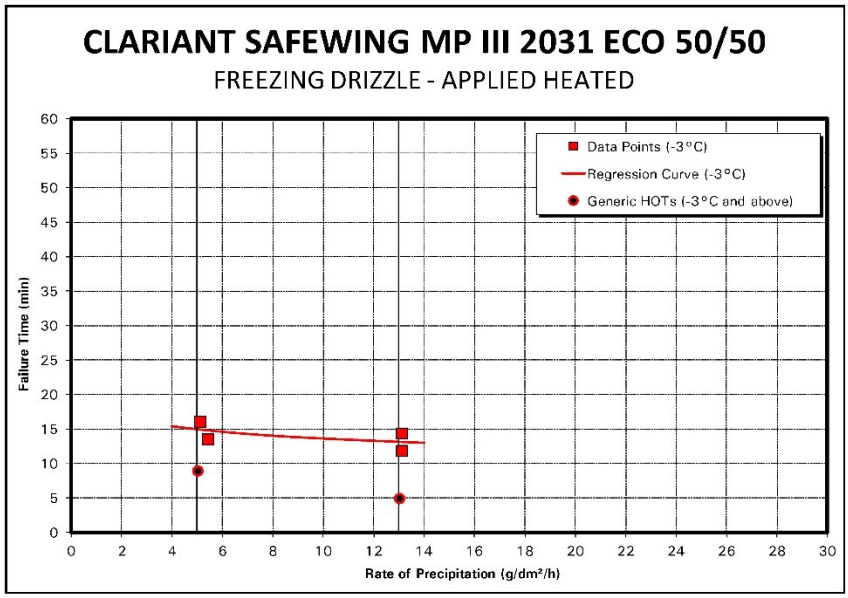


Figure 4.6: Type III 50/50 – Freezing Drizzle

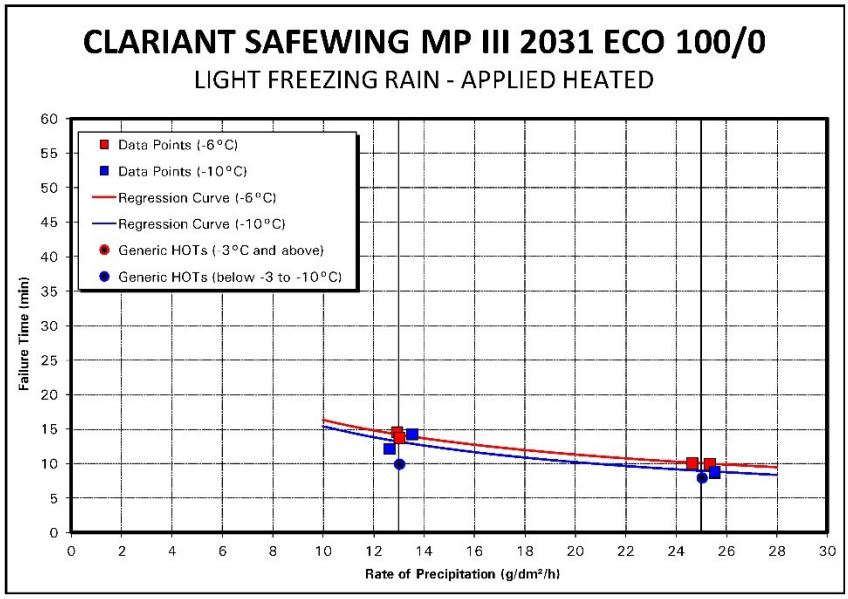


Figure 4.7: Type III Neat – Light Freezing Rain

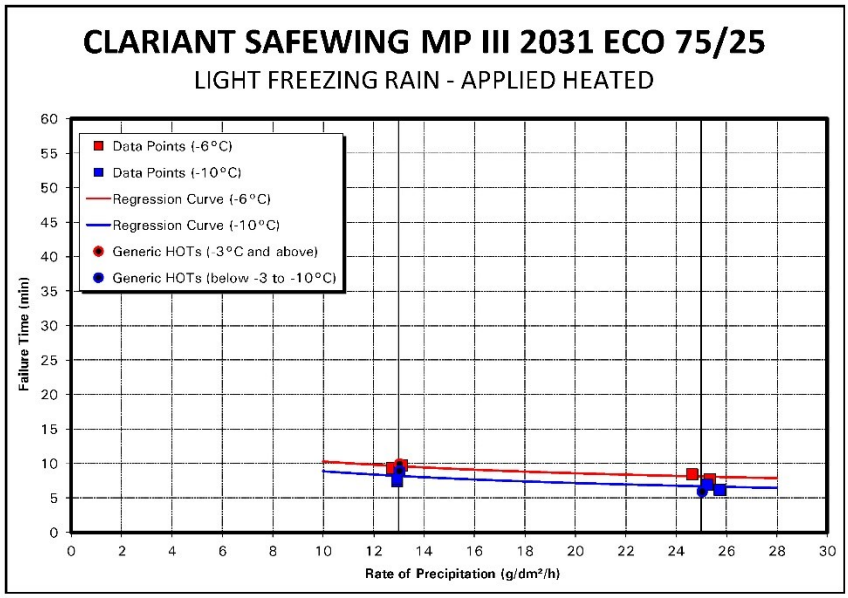


Figure 4.8: Type III 75/25 – Light Freezing Rain

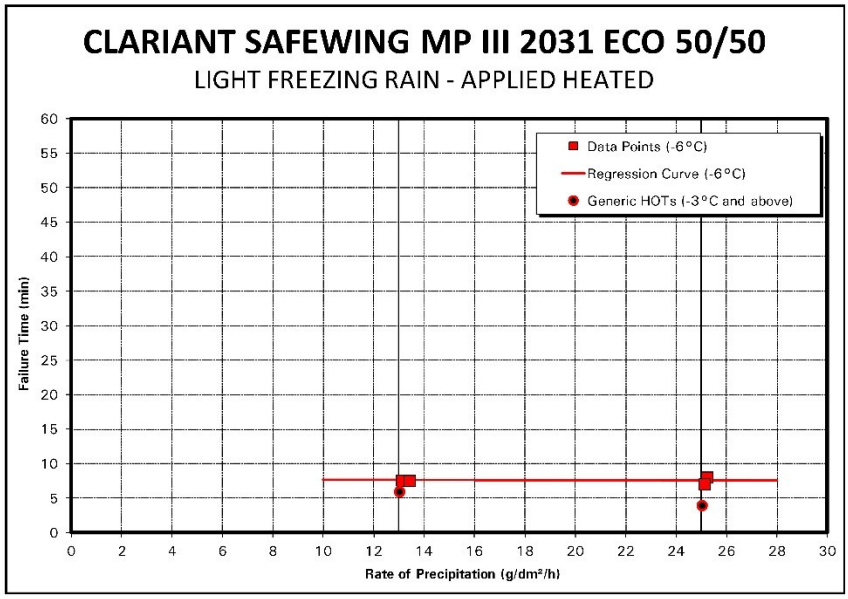


Figure 4.9: Type III 50/50 – Light Freezing Rain

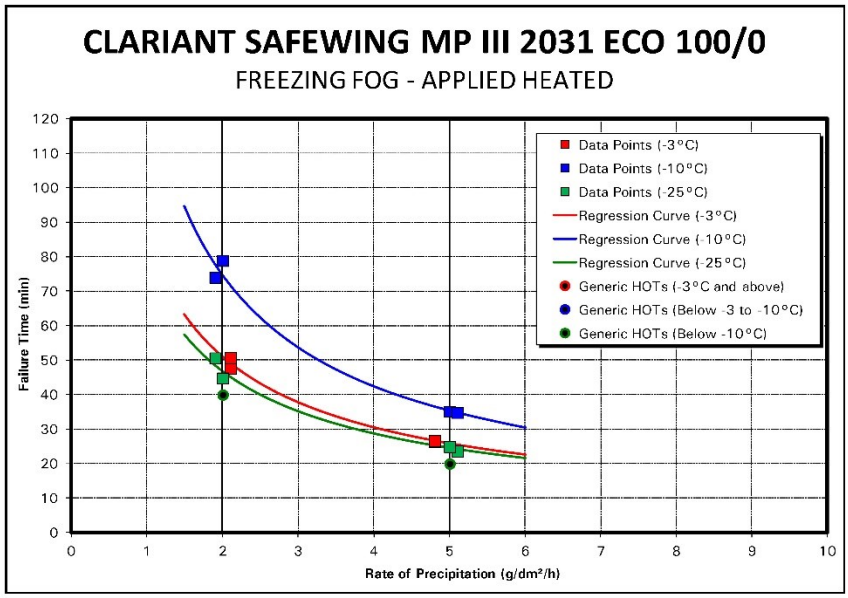


Figure 4.10: Type III Neat – Freezing Fog

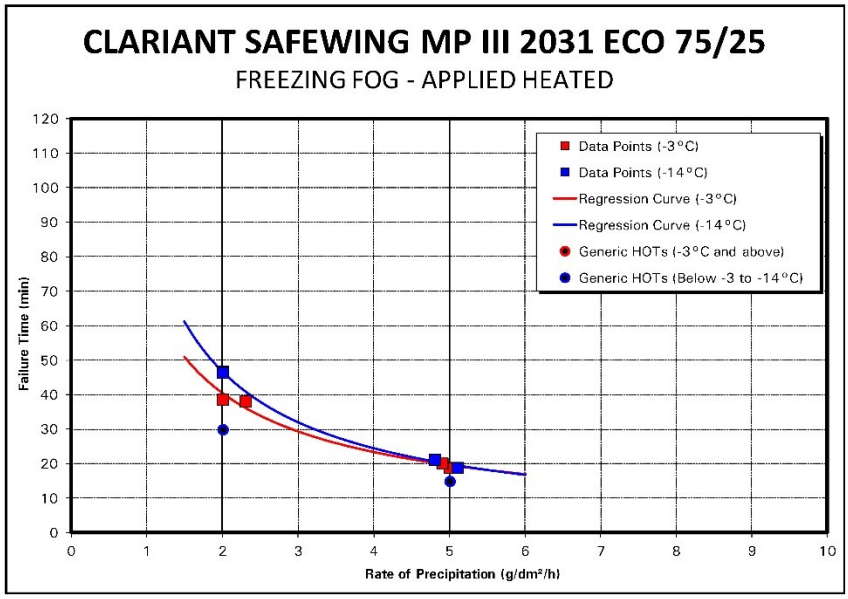


Figure 4.11: Type III 75/25 – Freezing Fog

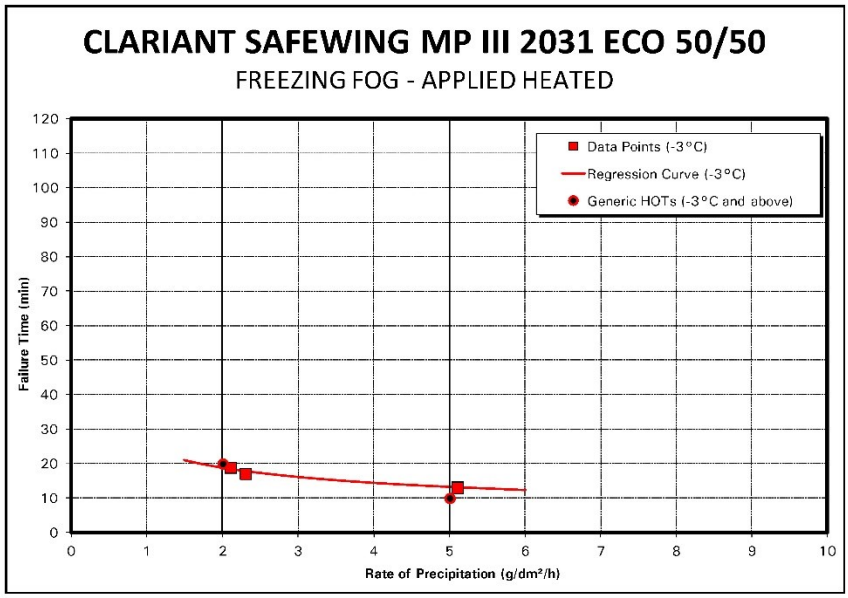


Figure 4.12: Type III 50/50 – Freezing Fog

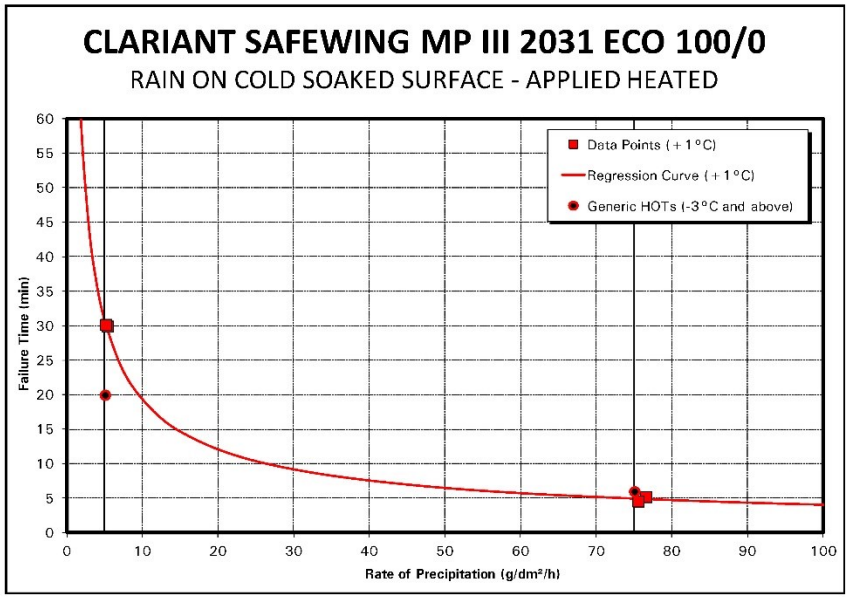


Figure 4.13: Type III Neat – Rain on Cold-Soaked Surface

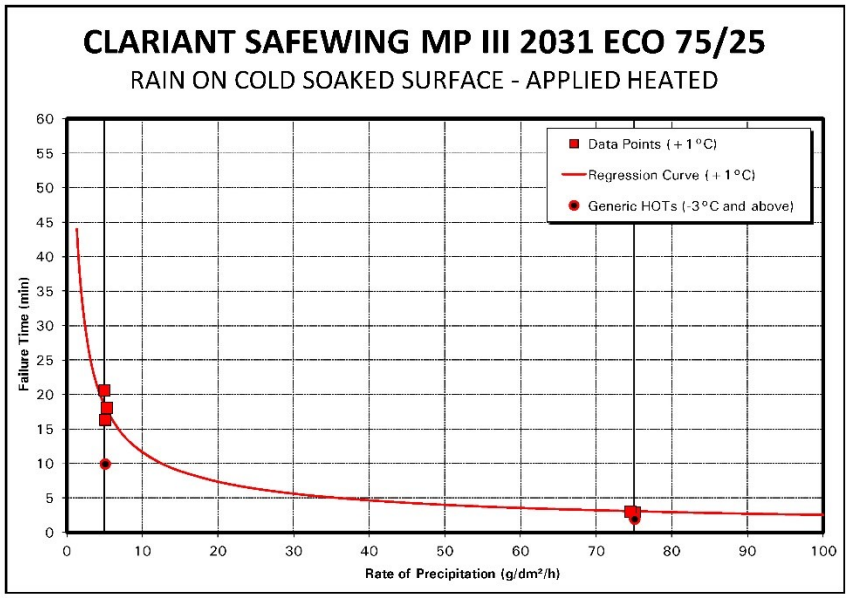


Figure 4.14: Type III 75/25 – Rain on Cold-Soaked Surface

Table 4.1: Regression Equation Coefficients for Clariant Safewing MP III 2031 ECO (Applied Heated)

Natural Snow

Fluid	Dil	R^2	Intercept (I)	Coeff. Rate (A)	Coeff. Temp (B)	Total Pts.
Clariant Safewing MP III 2031	Neat	97%	2.1207	-0.7409	-0.0669	24
Clariant Safewing MP III 2031	75/25	97%	2.2969	-0.8365	-0.3501	21
Clariant Safewing MP III 2031	50/50	91%	1.9716	-0.7146	-0.1861	14

General Equation: $t = 10^{I} RA^{(2-T)B}$

Simulated Freezing Fog

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant Safewing MP III 2031	Neat	-3°C	99%	1.9317	-0.7452	4
Clariant Safewing MP III 2031	75/25	-3°C	99%	1.8484	-0.8000	4
Clariant Safewing MP III 2031	50/50	-3°C	98%	1.3864	-0.3800	4
Clariant Safewing MP III 2031	Neat	-14°C	99%	2.1198	-0.8173	4
Clariant Safewing MP III 2031	75/25	-14°C	100%	1.9517	-0.9364	4
Clariant Safewing MP III 2031	Neat	-25°C	99%	1.8844	-0.7096	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant Safewing MP III 2031	Neat	-3°C	94%	1.8697	-0.5638	4
Clariant Safewing MP III 2031	75/25	-3°C	93%	1.6784	-0.5016	4
Clariant Safewing MP III 2031	50/50	-3°C	33%	1.2707	-0.1382	4
Clariant Safewing MP III 2031	Neat	-10°C	100%	1.9646	-0.7345	4
Clariant Safewing MP III 2031	75/25	-10°C	93%	1.6166	-0.5685	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant Safewing MP III 2031	Neat	-3°C	99%	1.7375	-0.5253	4
Clariant Safewing MP III 2031	75/25	-3°C	86%	1.2679	-0.2558	4
Clariant Safewing MP III 2031	50/50	-3°C	0%	0.8903	-0.0081	4
Clariant Safewing MP III 2031	Neat	-10°C	89%	1.7804	-0.5922	4
Clariant Safewing MP III 2031	75/25	-10°C	63%	1.2506	-0.3056	5

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	Temp.	R^2	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant Safewing MP III 2031	Neat	+1°C	100%	1.9621	-0.6759	4
Clariant Safewing MP III 2031	75/25	+1°C	99%	1.7300	-0.6644	5

General Equation $t = 10^{I} R^{A}$

Table 4.2: Fluid Specific Endurance Times – Clariant Safewing MP III 2031 ECO (Applied Heated)

Outside Air Temperature		Type III Fluid Concentration Neat Fluid/Water (Vol %/Vol %)	Endurance Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	Snow, Snow Grains or Snow Pellets			Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
				Very Light	Light	Moderate				
-3 and above	27 and above	100/0	25–50	40–55	20–40	10–20	17–30	10–14	5-30	
		75/25	19–40	35–45	16–35	7–16	13–20	8–9	3-18	
		50/50	13–18	25–30	13–25	7–13	13–14	7–7		
below -3 to -10	below 27 to 14	100/0	35–75	40–50	20–40	10–20	14–30	9–13		CAUTION: No holdover time guidelines exist
		75/25	19–45	25–35	12–25	5–12	9-16	6–8		
below -10	below 14	100/0	25–45	40–45	19–40	9–19				

APPENDIX L

ADDENDUM TO PROCEDURE: TEST REQUIREMENTS FOR NATURAL PRECIPITATION FLAT PLATE TESTING – CONDUCT HOT TESTING IN NORTHERN LOCATIONS TO VALIDATE HOT DATA AT -25ºC AND CLOSE TO LOUT TO SUPPORT GENERIC HOTS

CM2265.004

ADDENDUM TO PROCEDURE:

TEST REQUIREMENTS FOR NATURAL PRECIPITATION FLAT PLATE TESTING

CONDUCT HOT TESTING IN NORTHERN LOCATIONS TO VALIDATE HOT DATA AT -25°C AND CLOSE TO LOUT TO SUPPORT GENERIC HOTs

Winter 2014-15

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: David Youssef

Reviewed by: John D'Avirro

APS Aviation Inc.

January 28, 2015
Final Version 1.0

ADDENDUM TO PROCEDURE
TEST REQUIREMENTS
FOR NATURAL PRECIPITATION FLAT PLATE TESTING

1. OBJECTIVE

To conduct holdover time testing in northern locations to validate the generic holdover time data at -25 °C and close to the LOUT in the evaluation of generic holdover times.

APS plans to track the weather trends in various locations in the far North, in order to find an opportunity for testing around -25 °C, with enough snowfall to allow for a few days of testing.

2. PROCEDURE

Endurance time tests will be conducted using the procedures outlined in the program procedure: *Test Requirements: For Natural Precipitation Flat Plate Testing, December 23rd 2004.* In addition the following criteria will be followed:

- Transport Canada and the FAA should be present for this testing;
- More stringent Brix and thickness measurements should be recorded;
- All tests will be with Neat Dilutions; and
- Ideally rates higher than 5g/dm^2/hr should be targeted.

The test plan is as follows:

FLUID TYPE	FLUID (Batch #)	Viscosity	# of Tests Expected
I	DOW EG[1]	-	2
	DOW PG[1]	-	2
II	LNT P250 (C3/01/01-P250)	LOWV	4
	ABAX Ecowing 26 (L 8-343)	LOWV	4
III	All Clear CB1(CB-1 Sheared)	LOWV	4
IV	LNT E450 (F4003)	LOWV	4
	FCY 9311 (201311002 LS)	LOWV	4
	Polar Guard Advance (13102)	LOWV	2
	MaxFlight 04 (U49E001966)	LOWV	2

FLUID TYPE	FLUID (Batch #)	Viscosity	# of Tests Expected
IV	Clariant Launch (DEG4146139)	LOWV	1
	Clariant Launch (DEG4146164)	LOWV	1
	ABAX AD-49 (L12-318)	LOWV	2
TOTAL			32

1. *Hard water chemicals required*

3. PERSONNEL

Two employees will be required to travel for this testing including one senior individual.

4. EQUIPMENT

A detailed list of equipment will be required prior to departure. This is based upon the standard holdover time testing equipment. It is also recommended to review the list of equipment that is used for northern travel.

5. DATA FORMS

The following data form will be used to document fluid endurance time, Brix, and thickness data:

- Attachment I: End Condition Data Form

Rate measurements will be recorded using the electronic rate form typically used for endurance time testing.

TEST REQUIREMENTS: FOR NATURAL PRECIPITATION FLAT PLATE TESTING

ATTACHMENT I: END CONDITION FORM FOR ENDURANCE TIME TESTING

REMEMBER TO SYNCHRONIZE TIME WITH MSC - USE LOCAL TIME

LOCATION: **DATE:** **RUN NUMBER:** **STAND # :**

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 2°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

	Plate 7	Plate 8	Plate 9	Plate 10	Plate 11	Plate 12
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 2°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

AMBIENT TEMPERATURE: _____ °C

COMMENTS:

NOTE:
PLEASE ENSURE CORRECT FUNCTIONING OF PLATE TEMPERATURE LOGGING SYSTEM AT START OF TEST. AT THE END OF TEST SESSION, SAVE THE ELECTRONIC LOGGER FILE ON A FLOPPY DISK AND ALSO E-MAIL IT TO THE OFFICE. LABEL THE DISKETTE AND PLACE IT WITHIN THE DATA FORM ENVELOPE.

FAILURES CALLED BY: _____

LEADER / MANAGER: _____

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Final Version 1.0, January 15

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