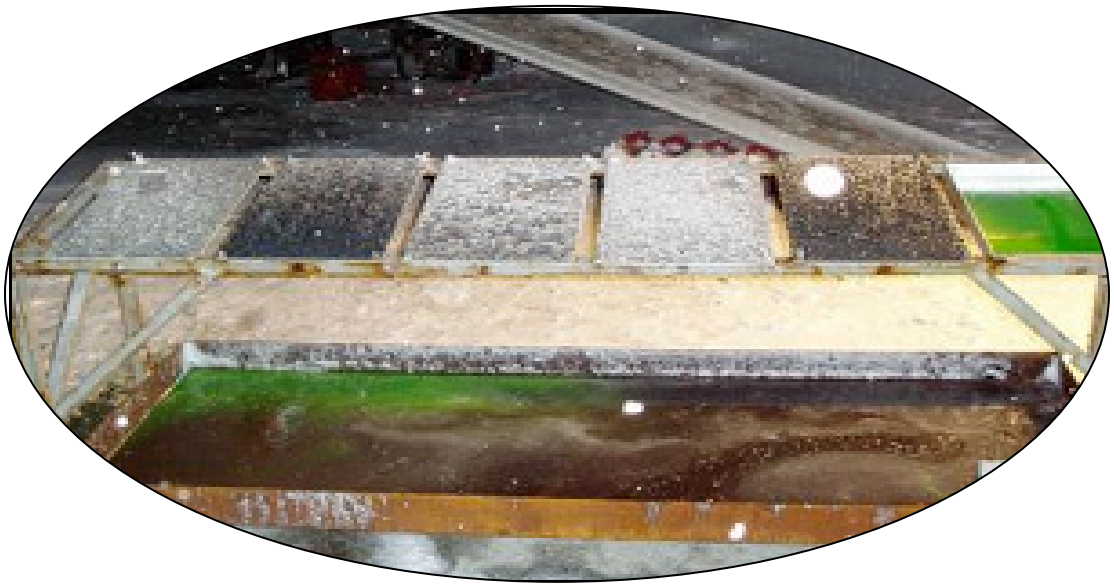
TP 14712E

Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2005-06 Winter



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and

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William J. Hughes Technical Center

Prepared by

APS Aviation Inc.

October 2006
Final Version 1.0

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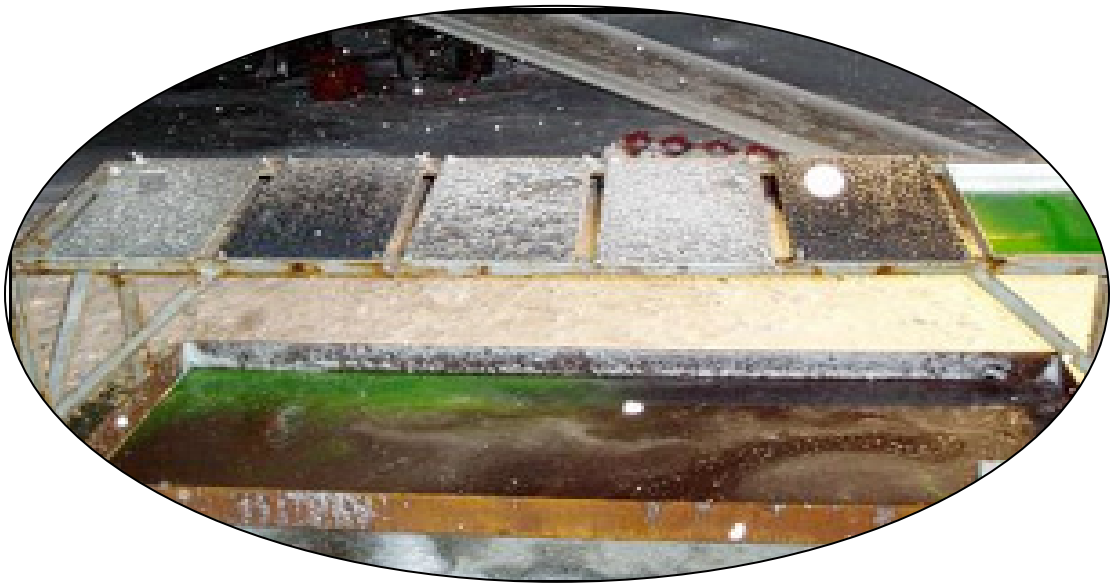

by

Stephanie Bendickson

October 2006
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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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PREFACE

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. has undertaken a research program to advance aircraft ground de/anti-icing technology. The 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;
- To evaluate whether holdover times should be developed for ice pellet conditions;
- To examine the effect of heated fluids on Type II, III and IV fluid endurance times;
- To evaluate if it is appropriate to apply fluid with a -3°C buffer (fluid with a freeze point 3°C above the ambient temperature) for the 1st step of a two-step application;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To assist in the testing of flow of contaminated fluid from aircraft wings during takeoff;
- To validate the laboratory snow test protocol with Type II and IV fluids;
- To develop performance specifications for an integrated weather system that measures holdover time;
- To provide support for the development of a standard that evaluates remote on-ground ice detection systems;
- To conduct general and exploratory de/anti-icing research;
- To conduct endurance time tests on non-aluminum plates; and
- To conduct endurance time tests in frost on various test surfaces.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2005-06 are documented in nine reports. The titles of the reports are as follows:

- TP 14712E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2005-06 Winter;
- TP 14713E Aircraft Deicing Research in Natural and Simulated Ice Pellet Conditions;
- TP 14714E Evaluation of Fluid Freeze Points in First-Step Application of Type I Fluids;
- TP 14715E Winter Weather Impact on Holdover Time Table Format (1995-2006);
- TP 14716E Falcon 20 Trials To Examine Fluid Removed From Aircraft During Takeoff With Ice Pellets;
- TP 14717E Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2005-06;
- TP 14718E Preliminary Endurance Time Testing in Simulated Ice Pellet Conditions;
- TP 14719E Aircraft Ground Icing General Research Activities During the 2005-06 Winter; and
- TP 14720E Effect of Heat on Fluid Endurance Times Using Composite Surfaces.

In addition, the following three interim reports are being prepared:

- *Implementation of Holdover Time Determination Systems (not for distribution)*;
- *Effect of Heat on Endurance Times of Anti-Icing Fluids; and*
- *Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions.*

This report, TP 14712E, has the following objective:

- To develop holdover time data for all newly qualified de/anti-icing fluids.

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

PROGRAM ACKNOWLEDGEMENTS

This multi-year research program has been funded by the Civil Aviation Group, 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, the Meteorological Service of 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: George Balaban, Katrina Bell, Kim Bendickson, Stephanie Bendickson, Nicolas Blais, Michael Chaput, Sami Chebil, John D'Avirro, Jan Goraczkowski, Chris McCormack, Rob Petermann, Marco Ruggi, Joey Tiano, Larry Turner, and David Youssef.

Special thanks are extended to Barry Myers, Frank Eyre and Yagusha Bodnar, who on behalf of the Transportation Development Centre, have participated, contributed and provided guidance in the preparation of these documents.

PROJECT ACKNOWLEDGEMENTS

APS Aviation Inc. would like to acknowledge the contributions of the following organizations to this project: Meteorological Services Canada and Aéroports de Montréal for providing a location for outdoor testing; AéroMag 2000 for providing fluid disposal services; and the fluid manufacturers for providing support and funding for this project.

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Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada. These are available from the Transportation Development Centre. Nine reports (including this one) 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 2005-06 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 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 snow and artificial conditions including simulated freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. APS conducted a total of 618 endurance time tests with seven fluids, including one non-glycol Type I fluid, three Type II fluids and three Type IV fluids.

Changes to the holdover time guidelines for the winter of 2006-07 include the introduction of fluid-specific tables for Clariant Safewing MP II Flight (Type II), Kilfrost ABC-TF2 (Type II), Clariant Safewing MP IV Launch (Type IV), Kilfrost ABC-S PLUS (Type IV) and Dow UCAR Endurance EG106 (Type IV). The introduction of the new fluids did not affect the Type II or Type IV generic holdover time tables. No changes were made to the Type I or Type III holdover time guidelines. One non-glycol Type I fluid, Battelle D3: Degradable by Design DeicerTM 1006A, was qualified in the winter of 2005-06.

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 holdover time tables.

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

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
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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. Neufs rapports (dont celui-ci) 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 2005-2006 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 la neige naturelle 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 618 essais d'endurance ont ainsi été réalisés par APS avec sept liquides, soit un liquide de type I sans glycol, trois liquides de type II et trois liquides de type IV.

Parmi les changements apportés aux lignes directrices relatives aux durées d'efficacité pour l'hiver 2006-2007, notons la création de tableaux spécifiques aux liquides Clariant Safewing MP II Flight (type II), Kilfrost ABC-TF2 (type II), Clariant Safewing MP IV Launch (type IV), Kilfrost ABC-S PLUS (type IV) et Dow UCAR Endurance EG106 (type IV). L'introduction de ces nouveaux liquides n'a pas eu pour effet de modifier les tableaux génériques des durées d'efficacité des liquides de type II ou de type IV. Aucun changement n'a été apporté aux lignes directrices relatives aux durées d'efficacité pour les liquides de type I ou de type III. Un liquide de type I sans glycol, le liquide Battelle D3 : Degradable by Design DeicerMC 1006A, a été qualifié au cours de l'hiver 2005-2006.

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.

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

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
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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) tables for new de/anti-icing fluids, is addressed in this report.

The objective was met by conducting HOT tests. 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 Society of Automotive Engineers (SAE) G-12 HOT Subcommittee. 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 every 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 2005-06 test season, data was collected for tests conducted during natural precipitation events at the APS test site at Montreal-Trudeau Airport in Montreal. Data was also collected in simulated precipitation conditions including freezing drizzle, light freezing rain, freezing fog, and rain on cold-soaked surfaces at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

APS conducted 618 tests in 2005-06. Seven fluids were tested including one non-glycol Type I fluid, three Type II fluids and three Type IV fluids. The distribution of tests is listed in Table ES-1 by precipitation condition and fluid type.

TABLE ES-1: Summary of Tests Conducted

Fluid Type	Precipitation Condition					
	Natural Snow	Freezing Drizzle	Light Freezing Rain	Freezing Fog	Rain on Cold-Soaked Wing	Total
Type I	4	8	4	12	4	**32**
Type II Neat	40	24	22	23	8	**117**
Type II 75/25	45	24	22	16	8	**115**
Type II 50/50	27	12	10	10	0	**59**
Type IV Neat	20	24	24	16	12	**96**
Type IV 75/25	32	24	24	24	12	**116**
Type IV 50/50	23	13	12	35	0	**83**
Total	**191**	**129**	**118**	**136**	**44**	**618**

Changes to the Holdover Time Guidelines

The changes below were made to the HOT guidelines for the winter of 2006-07.

1. Type IV fluid-specific tables were produced for three new fluids: Clariant Safewing MP IV Launch, Kilfrost ABC-S PLUS and Dow UCAR Endurance EG106. Clariant Safewing MP IV Launch and Dow UCAR Endurance EG106 have been qualified; Kilfrost ABC-S PLUS is currently in the qualification process.

2. Type II fluid-specific tables were produced for two new fluids: Clariant Safewing MP II Flight and Kilfrost ABC-TF2. Clariant Safewing MP II Flight has been qualified; Kilfrost ABC-TF2 is currently in the qualification process.

3. One new non-glycol Type I fluid, Battelle D^3: Degradable by Design Deicer™ 1006A, was introduced.

No new Type III fluids were introduced for the winter of 2006-07, nor were any changes made to the values in the generic Type II or Type IV tables.

Recommendations

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 tables.

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 réaliser cet objectif, des essais sur les durées d'efficacité ont été effectués. Les conditions d'essai, les paramètres d'essai et les spécifications relatives au banc d'essai ont été déterminés en vertu des exigences de la pratique recommandée en aérospatiale ARP5485 et ARP5495, élaborées par le sous-comité G-12 de la Society of Automotive Engineers (SAE) sur les durées d'efficacité. Les essais consistaient à verser des liquides abaisseurs du point de congélation sur des plaques d'aluminium standards, 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 2005-2006 concernaient des tests sous précipitations naturelles menés à l'installation d'essai d'APS, à l'aéroport Montréal-Trudeau, à Montréal. Des données ont également été collectées dans des conditions de précipitations simulées incluant de la bruine verglaçante, de la pluie verglaçante faible, du brouillard verglaçant et de la pluie sur des surfaces imprégnées de froid à l'installation de génie climatique du Conseil national de recherches du Canada (CNRC), à Ottawa.

En 2005-2006, un total de 618 essais ont été menés par APS. Sept liquides ont fait l'objet de tests, soit un liquide de type I sans glycol, trois liquides de type II et trois liquides de type IV. Le tableau ES-1 présente la répartition des essais réalisés, selon la précipitation et le type de liquide.

TABLEAU ES-1: Sommaire des essais

Type de liquide	Condition de précipitation					
	Neige naturelle	**Bruine verglaçante**	**Pluie verglaçante faible**	**Brouillard verglaçant**	**Pluie sur aile imprégnée de froid**	**Total**
Type I	4	8	4	12	4	**32**
Type II pur	40	24	22	23	8	**117**
Type II 75/25	45	24	22	16	8	**115**
Type II 50/50	27	12	10	10	0	**59**
Type IV pur	20	24	24	16	12	**96**
Type IV 75/25	32	24	24	24	12	**116**
Type IV 50/50	23	13	12	35	0	**83**
Total	**191**	**129**	**118**	**136**	**44**	**618**

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 2006-2007.

1. Des tableaux spécifiques ont été créés pour trois nouveaux liquides de type IV, soit Clariant Safewing MP IV Launch, Kilfrost ABC-S PLUS et Dow UCAR Endurance EG106. Clariant Safewing MP IV Launch et Dow UCAR Endurance EG106 ont été qualifiés, alors que le processus de qualification du liquide Kilfrost ABC-S PLUS suit actuellement son cours.

2. Des tableaux spécifiques ont été créés pour deux nouveaux liquides de type II, soit Clariant Safewing MP II Flight et Kilfrost ABC-TF2. Clariant Safewing MP II Flight a été qualifié, alors que le processus de qualification du liquide Kilfrost ABC-TF2 suit actuellement son cours.

3. Un nouveau liquide de type I sans glycol, le liquide Battelle D^3 : Degradable by Design Deicer^{MC} 1006A, a été introduit.

Aucun nouveau liquide de type III n'a été introduit pour l'hiver 2006-2007, et aucun changement n'a été apporté aux valeurs des tableaux génériques des liquides de type II ou de type IV.

Recommandations

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.

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GLOSSARY

AMS	Aerospace Material Specification
APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
CEF	Climatic Engineering Facility
EG	Ethylene Glycol
FAA	Federal Aviation Administration
HOT	Holdover Time
MSC	Meteorological Service of Canada
NRC	National Research Council Canada
PG	Propylene Glycol
SAE	Society of Automotive Engineers
TDC	Transportation Development Centre

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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), the Meteorological Service of Canada (MSC), 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

Over the past 16 winters, APS has completed considerable testing related to de/anti-icing fluids on behalf of Transport Canada. Specifically, research has been conducted to determine fluid holdover times (HOTs), to substantiate HOT tables, and to further the knowledge and development of deicing technology. A summary of the research activities related to fluid HOT testing is provided in Table 1.1.

1.2 Objectives

The detailed objectives of the HOT test program for the 2005-06 winter season are provided in the work statement given in Appendix A. The primary objective of the test program was to conduct flat plate tests under conditions of natural and simulated precipitation to determine de/anti-icing fluid endurance times for new fluids and to develop HOT guidelines based on samples of newly and previously qualified deicing and anti-icing fluids.

Table 1.1: Summary of APS Holdover Time Testing Activities

Year	Transport Canada Publication #	Conditions Tested	Primary Fluids Tested	Location of Testing
1990-91	TP 11206E	• Natural Precipitation (mostly snow)	• Type II (100%)	Mostly Dorval, worldwide
1991-92	TP 11454E	• Natural Precipitation (mostly snow)	• Type III	Mostly Dorval, St. John's
1992-93	TP 11836E	• Natural Precipitation (snow) • Simulated Freezing Drizzle (preliminary) • Simulated Freezing Fog (outdoor)	• Type I (Standard)	Dorval and Ottawa (NRC)
1993-94	Summary Report Available	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (outdoor)	• Type II (75/25, 50/50)	Dorval and Ottawa (NRC)
1994-95	TP 12654E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface (preliminary)	• Type IV (Preliminary)	Dorval and Ottawa (NRC)
1995-96	TP 12896E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	• Type IV	Dorval and Ottawa (NRC)
1996/97	TP 13131E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	• New Type IVs • Type III	Dorval and Ottawa (NRC)
1997-98	TP 13318E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	• New Type IVs	Dorval and Ottawa (NRC)
1998-99	TP 13477E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Simulated Snow	• Low Viscosity Type IVs • Type II • Type I	Dorval and Ottawa (NRC)
1999-2000	TP 13659E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Simulated Snow • Preliminary Frost	• Type IV • Type II • Type I	Dorval and Ottawa (NRC) Varennes (IREQ)
2000-01	TP 13826E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Simulated Snow • Preliminary Frost	• Type IV • Type II • Type I	Dorval and Ottawa (NRC) Varennes (IREQ)

M:\Groups\CM2020\Reports\HOT\Working Documents\Table 1.1

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

Year	Transport Canada Publication #	Conditions Tested	Primary Fluids Tested	Location of Testing
2001-02	TP 13991E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Simulated Snow	• Type IV • Type II • Type I	Dorval and Ottawa (NRC) Val D'Or North Bay
2002-03	TP 14144E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Simulated Snow	• Type IV • Type II • Type I	Dorval and Ottawa (NRC)
2003-04	TP 14374E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface • Simulated Snow	• Type III • Type II	Dorval and Ottawa (NRC) Val D'Or Ste-Adele
2004-05	TP 14443E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	• Type IV • Type III • Type II	Dorval and Ottawa (NRC)
2005-06	TP 14712E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	• Type IV • Type II • Type I	Dorval and Ottawa (NRC)

M:\Groups\CM2020\Reports\HOT\Working Documents\Table 1.1

1.3 Content of this Report

APS has written a report on the HOT test program for each year it has been carried out. Over the years, the HOT report grew in size considerably as additional information was added each year. In 2004, the report was condensed in order to increase its readability and present the reader with, for the most part, only new and current information. Key changes are listed below.

- Removal of the methodology section. The reader is instead directed to the 2002-03 HOT report, TP 14144E (1), where this information is contained. Any changes from the 2002-03 methodology are addressed in the current report.

- Removal of individual fluid data. This information is contained in the reports provided to the fluid manufacturers. Reports for any fluids that are qualified or expected to be qualified are included as appendices to the HOT report.

- Removal of the fluid thickness section. This information is now included in the individual fluid reports provided to the fluid manufacturers.

The report for the 2005-06 season will be presented this way, as will future versions of the report.

1.4 Report Format

The following list provides short descriptions of subsequent sections of this report:

a) Section 2 summarizes 2005-06 testing;

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

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

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

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

f) Section 7 presents conclusions derived from the test program; and

g) Section 8 lists recommendations for future testing.

1.5 Publication of Holdover Time Guidelines

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

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

For a thorough understanding of the subject matter, the HOT guidelines should 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.

2. TESTING IN 2005-06

2.1 Methodology

Test procedures for Type II, Type III and Type IV HOT testing were developed in accordance with the Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids: SAE Type II, III, and IV* (3). Test procedures for Type I HOT testing were developed in accordance with the proposed SAE testing standard for endurance time testing with Type I fluids (ARP5945).

All of the procedures used during the 2005-06 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;
4. Overall Program of Tests at NRC, April 2006; and
5. Additional Program of Tests at NRC, April 2006.

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 wing testing.

The fourth procedure was developed to coordinate HOT testing and other aircraft ground icing projects at the annual APS indoor simulated precipitation test session. HOT testing and other program element testing are conducted at the same session in order to maximize use of the facility and resources. The procedure provides detailed test plans, personnel assignments, fluid requirements and the precipitation schedule for this session.

Following the initial indoor test session, Kilfrost decided to submit an additional fluid sample for testing and agreed to fund an additional indoor test session. The fifth procedure was written for these tests. Additional program elements were again piggybacked onto HOT testing.

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).

2.2 Test Sites

During the 2005-06 test season, data was collected for tests conducted during natural snow events at the APS test site at Montreal-Trudeau Airport in Montreal.

Data was also collected in simulated precipitation conditions including freezing drizzle, light freezing rain, freezing fog, and rain on cold-soaked surfaces at the NRC Climatic Engineering Facility (CEF) in Ottawa.

2.3 Fluids Tested

During the winter of 2005-06, one Type I fluid, three Type II fluids and three Type IV fluids were tested. Most of the fluids were propylene glycol (PG) based, although one ethylene glycol (EG) and one non-glycol based fluid were tested.

Type I: Battelle D^3: Degradable by Design Deicer™ 1006A (non-glycol)

Type II: Clariant Safewing MP II Flight (PG)
Kilfrost ABC-TF2 (PG)
Kilfrost P1792-1 (PG)

Type IV: Clariant Safewing MP IV Launch (PG)
Kilfrost ABC-S PLUS (PG)
Dow UCAR Endurance EG106 (EG)

Additional relevant data for these fluids is given in Table 2.1. Detailed reports on the performance of individual fluids were provided to the fluid manufacturers. The reports of the fluids that will be commercialized are included as appendices to this report. Kilfrost P1792-1 will not be commercialized and therefore its report is not included.

2.4 Description of Tests

In total, 618 endurance time tests were conducted during the 2005-06 winter. A log of endurance time tests for each fluid is included in the individual fluid reports. The reports for the fluids that will be commercialized are given in Appendices C to H.

A summary of the total number of tests conducted by precipitation condition, fluid type and fluid dilution is shown in Table 2.2.

Table 2.1: List of Fluids Received

Fluid Manufacturer	Brand Name	Fluid Type	Date Received	Batch #	APS Measured Brix	Stated Viscosity (mPa.s)	Measured Viscosity[1] (mPa.s)	Measured Viscosity[2] (mPa.s)	Manufacturer Viscosity Method
Clariant	Safewing MP II Flight	II-100%	20-Jan-06	TV428	35.00	3,500	3,340	3,340	Spindle LV1, 20°C, 0.3 rpm, 10 minutes
Clariant	Safewing MP II Flight	II-75%	20-Jan-06	TV428	27.00	17,500	17,080	17,080	Spindle LV1, 20°C, 0.3 rpm, 10 minutes
Clariant	Safewing MP II Flight	II-50%	20-Jan-06	TV428	19.00	15,500	18,230	18,230	Spindle LV1, 20°C, 0.3 rpm, 10 minutes
Kilfrost	ABC-S PLUS	IV-100%	02-Feb-06	1797	37.00	12,500	10,450	11,040	Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
Kilfrost	ABC-S PLUS	IV-75%	02-Feb-06	1797	27.25	not given	14,400	19,740	Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
Kilfrost	ABC-S PLUS	IV-50%	02-Feb-06	1797	19.00	not given	4,500	2,440	Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
Kilfrost	P1792-1	II-100%	02-Feb-06	1792-1	35.50	2,500	3,040	3,230	Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
Kilfrost	P1792-1	II-75%	02-Feb-06	1792-1	27.50	not given	4,100	4,330	Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
Kilfrost	P1792-1	II-50%	02-Feb-06	1792-1	18.75	not given	1,040	1,140	Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
Battelle	D3: Degradable by Design DeicerTM 1006A	I	23-Feb-06	51381	>50	n/a	n/a	n/a	n/a
Dow Chemical	UCAR Endurance EG106	IV-100%	23-Feb-06	200600147-12	31.50	28,700 to 30,400	24,850	2,230	Spindle 31, 0°C, 0.3 rpm, 10 minutes
Dow Chemical	UCAR Endurance EG106	IV-75%	23-Feb-06	200600147-12	24.00	22,600 to 23,400	16,850	1,170	Spindle 31, 0°C, 0.3 rpm, 10 minutes
Dow Chemical	UCAR Endurance EG106	IV-50%	23-Feb-06	200600147-12	17.00	1,200 to 1,400	350	20	Spindle 31, 0°C, 0.3 rpm, 10 minutes
Clariant	Safewing MP IV Launch	IV-100%	10-Mar-06	TV431	35.00	8,000	7,550	7,550	Spindle LV1, 20°C, 0.3 rpm, 10 minutes
Clariant	Safewing MP IV Launch	IV-75%	10-Mar-06	TV431	27.25	18,000	17,680	17,680	Spindle LV1, 20°C, 0.3 rpm, 10 minutes
Clariant	Safewing MP IV Launch	IV-50%	10-Mar-06	TV431	19.00	17,800	18,500	18,500	Spindle LV1, 20°C, 0.3 rpm, 10 minutes
Kilfrost	ABC-TF2	II-100%	21-Apr-06	1792-2	35.25	3,400	3,550	3,460	Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
Kilfrost	ABC-TF2	II-75%	21-Apr-06	1792-2	28.00	not given	11,100	10,300	Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
Kilfrost	ABC-TF2	II-50%	21-Apr-06	1792-2	19.00	not given	9,400	10,120	Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes

[1]Manufacturer Method

[2]AIR 9968 Method

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Table 2.2: Summary of Tests Conducted

Fluid Type	Precipitation Condition					
	Natural Snow	Freezing Drizzle	Light Freezing Rain	Freezing Fog	Rain on Cold-Soaked Wing	Total
Type I	4	8	4	12	4	**32**
Type II Neat	40	24	22	23	8	**117**
Type II 75/25	45	24	22	16	8	**115**
Type II 50/50	27	12	10	10	0	**59**
Type IV Neat	20	24	24	16	12	**96**
Type IV 75/25	32	24	24	24	12	**116**
Type IV 50/50	23	13	12	35	0	**83**
Total	**191**	**129**	**118**	**136**	**44**	**618**

2.5 Artificial Snow Tests

A number of tests were also conducted in artificial snow. These tests are documented in a separate Transport Canada report, TP 14717E, *Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2005-06* (4).

2.6 Ice Pellet Research

Transport Canada is currently conducting research to provide additional guidance for aircraft operations during ice pellet conditions. The work completed in 2005-06 is documented in the Transport Canada report, TP 14713E, *Aircraft Deicing Research in Natural and Simulated Ice Pellet Conditions* (5). Transport Canada has deemed further research is necessary and therefore has not made changes at this time to its operational or HOT guidelines with respect to ice pellet conditions.

The FAA, however, has provided guidelines on operations in ice pellets in its holdover time guidance material. The guidelines allow operators with approved deicing programs to takeoff in conditions of ice pellets up to 25 minutes after application of undiluted Type IV fluid. There are five restrictions on this allowance. These restrictions, and the complete FAA ice pellets guidance material, are included on page I-38 in Appendix I.

3. TYPE I ENDURANCE TIME RESULTS AND HOLDOVER TIME GUIDELINES

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 the endurance times of Type I deicing fluids formulated with propylene glycol, ethylene glycol or diethylene glycol to be measured. However, they do require that the endurance times 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 are similar to the performance of the Type I fluids used to generate the currently accepted values in the Type I HOT table.

3.1 New Fluids

One non-glycol based Type I fluid was submitted for testing in 2005-06. Details and analysis of tests carried out with Battelle D^3: Degradable by Design Deicer™ 1006A are included in the report provided to the fluid manufacturer. A copy of this report has been included in Appendix C.

The report concludes that Battelle D^3 performs similarly to glycol based Type I fluids from an endurance time perspective and therefore can be used as a Type I fluid with the generic Type I HOT guidelines.

3.2 Changes to Holdover Time Guidelines

No changes were made to the values in the Type I HOT guidelines for 2006-07. The Transport Canada and FAA generic Type I HOT guidelines are included in Appendix I.

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4. TYPE II ENDURANCE TIME RESULTS AND HOLDOVER TIME GUIDELINES

Three Type II fluids were tested in 2005-06: Clariant Safewing MP II Flight, Kilfrost ABC-TF2 and Kilfrost P1792-1. Fluid-specific HOT tables were created for Clariant Safewing MP II Flight and Kilfrost ABC-TF2 and added to the 2006-07 Type II HOT guidelines. Kilfrost P1792-1 was not commercialized and therefore detailed test results have not been included in this report.

The Transport Canada and FAA Type II HOT guidelines are included in Appendix I.

4.1 New Fluids

Two Type II fluids tested in the winter of 2005-06 will be introduced for the winter 2006-07 operating season: Clariant Safewing MP II Flight and Kilfrost ABC-TF2. At the time of writing, Clariant Safewing MP II Flight had been qualified and Kilfrost ABC-TF2 was in the qualification process. Based on the expectation that both fluids would be qualified, fluid-specific HOT tables were created for the 2006-07 HOT guidelines based on the results of these fluids' HOT test results.

Because Kilfrost ABC-TF2 was submitted for testing late in the winter, testing in natural snow was not possible and the fluid was conservatively given generic HOTs in the snow column based on data collected from an artificial snow machine. If the test procedure to use snow machines is approved, the data from the artificial snow machine may be used in the future to produce fluid-specific values in the snow column. Details of these and other artificial snow tests conducted by APS on behalf of Transport Canada in the winter of 2005-06 are documented in the Transport Canada report TP 14717E (4).

The detailed test results and analysis for each fluid are included in the fluid-specific reports provided to the fluid manufacturers. Copies of these reports are included in Appendix D (Clariant Safewing MP II Flight) and Appendix E (Kilfrost ABC-TF2).

The introduction of the new Type II fluids did not impact the generic Type II HOT guidelines.

4.2 Changes to Holdover Time Guidelines Format

Transport Canada is conducting research to provide additional guidance for aircraft operations during ice pellet conditions. Since further research is necessary, no

changes will be made to the operational and HOT guidelines with respect to ice pellet conditions for the 2006-07 guidelines.

4.3 Evolution of 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, such as Kilfrost ABC-3. Since then, the data from all new fluids tested has been used to modify the generic HOT guidelines as required. There are several notable exceptions.

1. A fluid-specific table is no longer produced for Clariant Safewing MP II 1951, but the fluid is still available for use with the generic HOT guidelines and therefore is still used in the calculation of generic Type II values.

2. 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.

The history of Type II fluid testing and the evolution of the fluid-specific and generic Type II HOT values are illustrated through a series of tables presented in Tables 4.1 to 4.24. Each table represents one cell in the HOT guidelines and the title of the table links the table to the appropriate cell. The first row in each table contains the generic values from testing in 1998-99. Each subsequent set of two rows represents a winter test season and the subsequent winter's HOT values. The final line contains the generic and fluid-specific HOT values for use in 2006-07 winter operations. Underlined values indicate the fluid or fluids responsible for the generic holdover time. If no value is underlined, it implies that the generic value is based on the results of "grandfathered" fluids.

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

- Kilfrost ABC-II PLUS (ABC-II+);
- Clariant Safewing MP II 1951 (C-1951);
- SPCA Ecowing 26 (S E26);
- Kilfrost ABC-2000 (K2000);
- Octagon E Max II (E II);
- Clariant Safewing MP II 2025 ECO (C-2025);
- Clariant Safewing MP II Flight (C-Flight); and
- Kilfrost ABC-TF2 (K-TF2).

Table 4.1: Type II Neat Fluid, Snow, -3°C and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:20-0:45								
	1998-99 Endurance Time Test Results		0:25-0:55							
	1999-00 HOT Table Values	0:20-0:45	0:25-0:55							
	1999-00 Endurance Time Test Results			0:20-0:45						
	2000-01 HOT Table Values	0:20-0:45	0:25-0:55	0:20-0:45						
	2000-01 Endurance Time Test Results				0:40-1:00					
	2001-02 HOT Table Values	0:20-0:45	0:25-0:55	0:20-0:45	0:40-1:00					
	2001-02 Endurance Time Test Results					0:30-1:00	0:40-1:20			
	2002-03 HOT Table Values	0:20-0:45	0:25-0:55		0:40-1:00	0:30-1:00	0:40-1:20			
	2002-03 Endurance Time Test Results							0:40-1:10		
	2003-04 HOT Table Values	0:20-0:45	0:25-0:55		0:40-1:00	0:30-1:00	0:40-1:20	0:40-1:10		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:20-0:45	0:25-0:55		0:40-1:00	0:30-1:00	0:40-1:20	0:40-1:10		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:20-0:45	0:25-0:55		0:40-1:00	0:30-1:00	0:40-1:20	0:40-1:10		
CURRENT	2005-06 Endurance Time Test Results								1:00-1:35	
	2006-07 HOT Table Values	0:20-0:45	0:25-0:55		0:40-1:00	0:30-1:00	0:40-1:20	0:40-1:10	1:00-1:35	0:20-0:45

Table 4.2: Type II 75/25 Fluid, Snow, -3°C and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:15-0:30								
	1998-99 Endurance Time Test Results		0:25-0:50							
	1999-00 HOT Table Values	0:15-0:30	0:25-0:50							
	1999-00 Endurance Time Test Results			0:15-0:35						
	2000-01 HOT Table Values	0:15-0:30	0:25-0:50	0:15-0:35						
	2000-01 Endurance Time Test Results				0:25-0:45					
	2001-02 HOT Table Values	0:15-0:30	0:25-0:50	0:15-0:35	0:25-0:45					
	2001-02 Endurance Time Test Results					0:30-1:05	0:25-0:55			
	2002-03 HOT Table Values	0:15-0:30	0:25-0:50		0:25-0:45	0:30-1:05	0:25-0:55			
	2002-03 Endurance Time Test Results							0:25-0:45		
	2003-04 HOT Table Values	0:15-0:30	0:25-0:50		0:25-0:45	0:30-1:05	0:25-0:55	0:25-0:45		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:15-0:30	0:25-0:50		0:25-0:45	0:30-1:05	0:25-0:55	0:25-0:45		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:15-0:30	0:25-0:50		0:25-0:45	0:30-1:05	0:25-0:55	0:25-0:45		
CURRENT	2005-06 Endurance Time Test Results								0:40-1:20	
	2006-07 HOT Table Values	0:15-0:30	0:25-0:50		0:25-0:45	0:30-1:05	0:25-0:55	0:25-0:45	0:40-1:20	0:15-0:30

Table 4.3: Type II 50/50 Fluid, Snow, -3ºC and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:05-0:15								
	1998-99 Endurance Time Test Results		0:15-0:35							
	1999-00 HOT Table Values	0:05-0:15	0:15-0:35							
	1999-00 Endurance Time Test Results			0:05-0:15						
	2000-01 HOT Table Values	0:05-0:15	0:15-0:35	0:05-0:15						
	2000-01 Endurance Time Test Results				0:10-0:20					
	2001-02 HOT Table Values	0:05-0:15	0:15-0:35	0:05-0:15	0:10-0:20					
	2001-02 Endurance Time Test Results					0:15-0:30	0:10-0:25			
	2002-03 HOT Table Values	0:05-0:15	0:15-0:35		0:10-0:20	0:15-0:30	0:10-0:25			
	2002-03 Endurance Time Test Results							0:05-0:15		
	2003-04 HOT Table Values	0:05-0:15	0:15-0:35		0:10-0:20	0:15-0:30	0:10-0:25	0:05-0:15		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:05-0:15	0:15-0:35		0:10-0:20	0:15-0:30	0:10-0:25	0:05-0:15		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:05-0:15	0:15-0:35		0:10-0:20	0:15-0:30	0:10-0:25	0:05-0:15		
CURRENT	2005-06 Endurance Time Test Results								0:10-0:25	
	2006-07 HOT Table Values	0:05-0:15	0:15-0:35		0:10-0:20	0:15-0:30	0:10-0:25	0:05-0:15	0:10-0:25	0:05-0:15

Table 4.4: Type II Neat Fluid, Snow, Below -3ºC to -14ºC

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:15-0:40								
	1998-99 Endurance Time Test Results		0:15-0:35							
	1999-00 HOT Table Values	0:15-0:35	0:15-0:35							
	1999-00 Endurance Time Test Results			0:20-0:40						
	2000-01 HOT Table Values	0:15-0:35	0:15-0:35	0:20-0:40						
	2000-01 Endurance Time Test Results				0:35-0:55					
	2001-02 HOT Table Values	0:15-0:35	0:15-0:35	0:20-0:40	0:35-0:55					
	2001-02 Endurance Time Test Results					0:25-0:45	0:35-1:10			
	2002-03 HOT Table Values	0:15-0:35	0:15-0:35		0:35-0:55	0:25-0:45	0:35-1:10			
	2002-03 Endurance Time Test Results							0:35-1:00		
	2003-04 HOT Table Values	0:15-0:35	0:15-0:35		0:35-0:55	0:25-0:45	0:35-1:10	0:35-1:00		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:15-0:35	0:15-0:35		0:35-0:55	0:25-0:45	0:35-1:10	0:35-1:00		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:15-0:35	0:15-0:35		0:35-0:55	0:25-0:45	0:35-1:10	0:35-1:00		
CURRENT	2005-06 Endurance Time Test Results								0:40-1:05	
	2006-07 HOT Table Values	0:15-0:35	0:15-0:35		0:35-0:55	0:25-0:45	0:35-1:10	0:35-1:00	0:40-1:05	0:15-0:35

Table 4.5: Type II 75/25 Fluid, Snow, Below -3°C to -14°C

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:15-0:30								
	1998-99 Endurance Time Test Results		0:15-0:35							
	1999-00 HOT Table Values	0:15-0:25	0:15-0:35							
	1999-00 Endurance Time Test Results			0:15-0:25						
	2000-01 HOT Table Values	0:15-0:25	0:15-0:35	0:15-0:25						
	2000-01 Endurance Time Test Results				0:25-0:40					
	2001-02 HOT Table Values	0:15-0:25	0:15-0:35	0:15-0:25	0:25-0:40					
	2001-02 Endurance Time Test Results					0:25-0:50	0:25-0:50			
	2002-03 HOT Table Values	0:15-0:25	0:15-0:35		0:25-0:40	0:25-0:50	0:25-0:50			
	2002-03 Endurance Time Test Results							0:25-0:45		
	2003-04 HOT Table Values	0:15-0:25	0:15-0:35		0:25-0:40	0:25-0:50	0:25-0:50	0:25-0:45		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:15-0:25	0:15-0:35		0:25-0:40	0:25-0:50	0:25-0:50	0:25-0:45		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:15-0:25	0:15-0:35		0:25-0:40	0:25-0:50	0:25-0:50	0:25-0:45		
CURRENT	2005-06 Endurance Time Test Results								0:20-0:40	
	2006-07 HOT Table Values	0:15-0:25	0:15-0:35		0:25-0:40	0:25-0:50	0:25-0:50	0:25-0:45	0:20-0:40	0:15-0:25

Table 4.6: Type II Neat Fluid, Snow, Below -14°C to -25°C

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:15-0:30								
	1998-99 Endurance Time Test Results		0:15-0:30							
	1999-00 HOT Table Values	0:15-0:30	0:15-0:30							
	1999-00 Endurance Time Test Results			0:20-0:35						
	2000-01 HOT Table Values	0:15-0:30	0:15-0:30	0:20-0:35						
	2000-01 Endurance Time Test Results				0:30-0:50					
	2001-02 HOT Table Values	0:15-0:30	0:15-0:30	0:20-0:35	0:30-0:50					
	2001-02 Endurance Time Test Results					0:20-0:40	0:35-1:05			
	2002-03 HOT Table Values	0:15-0:30	0:15-0:30		0:30-0:50	0:15-0:30	0:15-0:30			
	2002-03 Endurance Time Test Results							0:15-0:30		
	2003-04 HOT Table Values	0:15-0:30	0:15-0:30		0:30-0:50	0:15-0:30	0:15-0:30	0:15-0:30		
	2003-04 Endurance Time Test Results									
	2004-05 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*		
	2004-05 Endurance Time Test Results									
	2005-06 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*		
CURRENT	2005-06 Endurance Time Test Results								0:35-0:55	
	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*	0:15-0:30*	0:15-0:30*

*Generic HOT values were used for this cell

Table 4.7: Type II Neat Fluid, Freezing Drizzle, -3ºC and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:30-1:00								
	1998-99 Endurance Time Test Results		0:35-1:10							
	1999-00 HOT Table Values	0:30-1:00	0:35-1:10							
	1999-00 Endurance Time Test Results			0:35-0:55						
	2000-01 HOT Table Values	0:30-0:55	0:35-1:10	0:35-0:55						
	2000-01 Endurance Time Test Results				0:50-1:35					
	2001-02 HOT Table Values	0:30-0:55	0:35-1:10	0:35-0:55	0:50-1:35					
	2001-02 Endurance Time Test Results					0:55-1:35	0:45-1:35			
	2002-03 HOT Table Values	0:30-0:55	0:35-1:10		0:50-1:35	0:55-1:35	0:45-1:35			
	2002-03 Endurance Time Test Results							0:40-1:00		
	2003-04 HOT Table Values	0:30-0:55	0:35-1:10		0:50-1:35	0:55-1:35	0:45-1:35	0:40-1:00		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:30-0:55	0:35-1:10		0:50-1:35	0:55-1:35	0:45-1:35	0:40-1:00		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:30-0:55	0:35-1:10		0:50-1:35	0:55-1:35	0:45-1:35	0:40-1:00		
CURRENT	2005-06 Endurance Time Test Results								1:20-2:00	0:40-1:20
	2006-07 HOT Table Values	0:30-0:55	0:35-1:10		0:50-1:35	0:55-1:35	0:45-1:35	0:40-1:00	1:20-2:00	0:40-1:20

Table 4.8: Type II 75/25 Fluid, Freezing Drizzle, -3ºC and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:20-0:45								
	1998-99 Endurance Time Test Results		0:30-1:00							
	1999-00 HOT Table Values	0:20-0:45	0:30-1:00							
	1999-00 Endurance Time Test Results			0:25-0:45						
	2000-01 HOT Table Values	0:20-0:45	0:30-1:00	0:25-0:45						
	2000-01 Endurance Time Test Results				0:45-1:05					
	2001-02 HOT Table Values	0:20-0:45	0:30-1:00	0:25-0:45	0:45-1:05					
	2001-02 Endurance Time Test Results					0:45-1:15	0:40-1:10			
	2002-03 HOT Table Values	0:20-0:45	0:30-1:00		0:45-1:05	0:45-1:15	0:40-1:10			
	2002-03 Endurance Time Test Results							0:25-0:45		
	2003-04 HOT Table Values	0:20-0:45	0:30-1:00		0:45-1:05	0:45-1:15	0:40-1:10	0:25-0:45		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:20-0:45	0:30-1:00		0:45-1:05	0:45-1:15	0:40-1:10	0:25-0:45		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:20-0:45	0:30-1:00		0:45-1:05	0:45-1:15	0:40-1:10	0:25-0:45		
CURRENT	2005-06 Endurance Time Test Results								1:15-2:00	0:45-1:25
	2006-07 HOT Table Values	0:20-0:45	0:30-1:00		0:45-1:05	0:45-1:15	0:40-1:10	0:25-0:45	1:15-2:00	0:45-1:25

Table 4.9: Type II 50/50 Fluid, Freezing Drizzle, -3°C and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:10-0:20								
	1998-99 Endurance Time Test Results		0:05-0:25							
	1999-00 HOT Table Values	0:05-0:20	0:05-0:25							
	1999-00 Endurance Time Test Results			0:05-0:15						
	2000-01 HOT Table Values	0:05-0:15	0:05-0:25	0:05-0:15						
	2000-01 Endurance Time Test Results				0:15-0:25					
	2001-02 HOT Table Values	0:05-0:15	0:05-0:25	0:05-0:15	0:15-0:25					
	2001-02 Endurance Time Test Results					0:15-0:25	0:15-0:30			
	2002-03 HOT Table Values	0:05-0:15	0:05-0:25		0:15-0:25	0:15-0:25	0:15-0:30			
	2002-03 Endurance Time Test Results							0:10-0:15		
	2003-04 HOT Table Values	0:05-0:15	0:05-0:25		0:15-0:25	0:15-0:25	0:15-0:30	0:10-0:15		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:05-0:15	0:05-0:25		0:15-0:25	0:15-0:25	0:15-0:30	0:10-0:15		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:05-0:15	0:05-0:25		0:15-0:25	0:15-0:25	0:15-0:30	0:10-0:15		
CURRENT	2005-06 Endurance Time Test Results								0:20-0:30	0:20-0:40
	2006-07 HOT Table Values	0:05-0:15	0:05-0:25		0:15-0:25	0:15-0:25	0:15-0:30	0:10-0:15	0:20-0:30	0:20-0:40

Table 4.10: Type II Neat Fluid, Freezing Drizzle, Below -3°C to -10°C

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:30-1:00								
	1998-99 Endurance Time Test Results		0:15-0:45							
	1999-00 HOT Table Values	0:15-0:45	0:15-0:45							
	1999-00 Endurance Time Test Results			0:25-0:50						
	2000-01 HOT Table Values	0:15-0:45	0:15-0:45	025-0:50						
	2000-01 Endurance Time Test Results				0:30-1:10					
	2001-02 HOT Table Values	0:15-0:45	0:15-0:45	025-0:50	0:30-1:10					
	2001-02 Endurance Time Test Results					0:25-0:50	0:35-1:00			
	2002-03 HOT Table Values	0:15-0:45	0:15-0:45		0:30-1:10	0:25-0:50	0:35-1:00			
	2002-03 Endurance Time Test Results							0:35-1:05		
	2003-04 HOT Table Values	0:15-0:45	0:15-0:45		0:30-1:10	0:25-0:50	0:35-1:00	0:35-1:05		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:15-0:45	0:15-0:45		0:30-1:10	0:25-0:50	0:35-1:00	0:35-1:05		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:15-0:45	0:15-0:45		0:30-1:10	0:25-0:50	0:35-1:00	0:35-1:05		
CURRENT	2005-06 Endurance Time Test Results								0:35-1:30	0:35-1:15
	2006-07 HOT Table Values	0:15-0:45	0:15-0:45		0:30-1:10	0:25-0:50	0:35-1:00	0:35-1:05	0:35-1:30	0:35-1:15

Table 4.11: Type II 75/25 Fluid, Freezing Drizzle, Below -3°C to -10°C

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:20-0:45								
	1998-99 Endurance Time Test Results		0:15-0:30							
	1999-00 HOT Table Values	0:15-0:30	0:15-0:30							
	1999-00 Endurance Time Test Results			0:20-0:35						
	2000-01 HOT Table Values	0:15-0:30	0:15-0:30	0:20-0:35						
	2000-01 Endurance Time Test Results				0:20-0:50					
	2001-02 HOT Table Values	0:15-0:30	0:15-0:30	0:20-0:35	0:20-0:50					
	2001-02 Endurance Time Test Results					0:25-0:55	0:35-1:10			
	2002-03 HOT Table Values	0:15-0:30	0:15-0:30		0:20-0:50	0:25-0:55	0:35-1:10			
	2002-03 Endurance Time Test Results							0:30-0:40		
	2003-04 HOT Table Values	0:15-0:30	0:15-0:30		0:20-0:50	0:25-0:55	0:35-1:05	0:30-0:40		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:15-0:30	0:15-0:30		0:20-0:50	0:25-0:55	0:35-1:05	0:30-0:40		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:15-0:30	0:15-0:30		0:20-0:50	0:25-0:55	0:35-1:05	0:30-0:40		
CURRENT	2005-06 Endurance Time Test Results								0:25-1:10	0:30-1:30
	2006-07 HOT Table Values	0:15-0:30	0:15-0:30		0:20-0:50	0:25-0:55	0:35-1:05	0:30-0:40	0:25-1:10	0:30-1:30

Table 4.12: Type II Neat Fluid, Light Freezing Rain, -3°C and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:15-0:30								
	1998-99 Endurance Time Test Results		0:30-0:40							
	1999-00 HOT Table Values	0:15-0:30	0:30-0:40							
	1999-00 Endurance Time Test Results			0:20-0:30						
	2000-01 HOT Table Values	0:15-0:30	0:30-0:40	0:20-0:30						
	2000-01 Endurance Time Test Results				0:40-0:50					
	2001-02 HOT Table Values	0:15-0:30	0:30-0:40	0:20-0:30	0:40-0:50					
	2001-02 Endurance Time Test Results					0:40-0:50	0:30-0:40			
	2002-03 HOT Table Values	0:15-0:30	0:30-0:40		0:40-0:50	0:40-0:50	0:30-0:40			
	2002-03 Endurance Time Test Results							0:25-0:35		
	2003-04 HOT Table Values	0:15-0:30	0:30-0:40		0:40-0:50	0:40-0:50	0:30-0:40	0:25-0:35		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:15-0:30	0:30-0:40		0:40-0:50	0:40-0:50	0:30-0:40	0:25-0:35		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:15-0:30	0:30-0:40		0:40-0:50	0:40-0:50	0:30-0:40	0:25-0:35		
CURRENT	2005-06 Endurance Time Test Results								0:45-1:25	0:30-0:45
	2006-07 HOT Table Values	0:15-0:30	0:30-0:40		0:40-0:50	0:40-0:50	0:30-0:40	0:25-0:35	0:45-1:25	0:30-0:45

Table 4.13: Type II 75/25 Fluid, Light Freezing Rain, -3°C and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:10-0:25								
	1998-99 Endurance Time Test Results		0:20-0:40							
	1999-00 HOT Table Values	0:10-0:25	0:20-0:40							
	1999-00 Endurance Time Test Results			015-0:25						
	2000-01 HOT Table Values	0:10-0:25	0:20-0:40	0:15-0:25						
	2000-01 Endurance Time Test Results				0:25-0:35					
	2001-02 HOT Table Values	0:10-0:25	0:20-0:40	0:15-0:25	0:25-0:35					
	2001-02 Endurance Time Test Results					0:40-0:50	0:20-0:30			
	2002-03 HOT Table Values	0:10-0:25	0:20-0:40		0:25-0:35	0:40-0:50	0:20-0:30			
	2002-03 Endurance Time Test Results							0:20-0:25		
	2003-04 HOT Table Values	0:10-0:25	0:20-0:40		0:25-0:35	0:40-0:50	0:20-0:30	0:20-0:25		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:10-0:25	0:20-0:40		0:25-0:35	0:40-0:50	0:20-0:30	0:20-0:25		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:10-0:25	0:20-0:40		0:25-0:35	0:40-0:50	0:20-0:30	0:20-0:25		
CURRENT	2005-06 Endurance Time Test Results								0:30-0:55	0:30-0:45
	2006-07 HOT Table Values	0:10-0:25	0:20-0:40		0:25-0:35	0:40-0:50	0:20-0:30	0:20-0:25	0:30-0:55	0:30-0:45

Table 4.14: Type II 50/50 Fluid, Light Freezing Rain, -3°C and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:05-0:10								
	1998-99 Endurance Time Test Results		0:05-0:15							
	1999-00 HOT Table Values	0:05-0:10	0:05-0:15							
	1999-00 Endurance Time Test Results			0:05-0:10						
	2000-01 HOT Table Values	0:05-0:10	0:05-0:15	0:05-0:10						
	2000-01 Endurance Time Test Results				0:05-0:10					
	2001-02 HOT Table Values	0:05-0:10	0:05-0:15	0:05-0:10	0:05-0:10					
	2001-02 Endurance Time Test Results					0:05-0:15	0:10-0:15			
	2002-03 HOT Table Values	0:05-0:10	0:05-0:15		0:05-0:10	0:05-0:15	0:10-0:15			
	2002-03 Endurance Time Test Results							0:05-0:10		
	2003-04 HOT Table Values	0:05-0:10	0:05-0:15		0:05-0:10	0:05-0:15	0:10-0:15	0:05-0:10		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:05-0:10	0:05-0:15		0:05-0:10	0:05-0:15	0:10-0:15	0:05-0:10		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:05-0:10	0:05-0:15		0:05-0:10	0:05-0:15	0:10-0:15	0:05-0:10		
CURRENT	2005-06 Endurance Time Test Results								0:10-0:15	0:15-0:20
	2006-07 HOT Table Values	0:05-0:10	0:05-0:15		0:05-0:10	0:05-0:15	0:10-0:15	0:05-0:10	0:10-0:15	0:15-0:20

Table 4.15: Type II Neat Fluid, Light Freezing Rain, Below -3ºC to -10ºC

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:10-0:30								
	1998-99 Endurance Time Test Results		0:10-0:30							
	1999-00 HOT Table Values	0:10-0:30	0:10-0:30							
	1999-00 Endurance Time Test Results			0:15-0:30						
	2000-01 HOT Table Values	0:10-0:30	0:10-0:30	0:15-0:30						
	2000-01 Endurance Time Test Results				0:15-0:35					
	2001-02 HOT Table Values	0:10-0:25*	0:10-0:30	0:15-0:30	0:15-0:35					
	2001-02 Endurance Time Test Results					0:10-0:30	0:20-0:30			
	2002-03 HOT Table Values	0:10-0:25*	0:10-0:30		0:15-0:35	0:10-0:30	0:20-0:30			
	2002-03 Endurance Time Test Results							0:20-0:35		
	2003-04 HOT Table Values	0:10-0:25*	0:10-0:30		0:15-0:35	0:10-0:30	0:20-0:30	0:20-0:35		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:10-0:25*	0:10-0:30		0:15-0:35	0:10-0:30	0:20-0:30	0:20-0:35		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:10-0:25*	0:10-0:30		0:15-0:35	0:10-0:30	0:20-0:30	0:20-0:35		
CURRENT	2005-06 Endurance Time Test Results								0:25-0:45	0:30-0:40
	2006-07 HOT Table Values	0:10-0:25*	0:10-0:30		0:15-0:35	0:10-0:30	0:20-0:30	0:20-0:35	0:25-0:45	0:30-0:40

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

Table 4.16: Type II 75/25 Fluid, Light Freezing Rain, Below -3ºC to -10ºC

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:10-0:25								
	1998-99 Endurance Time Test Results		0:10-0:20							
	1999-00 HOT Table Values	0:10-0:20	0:10-0:20							
	1999-00 Endurance Time Test Results			0:15-0:20						
	2000-01 HOT Table Values	0:10-0:20	0:10-0:20	0:15-0:20						
	2000-01 Endurance Time Test Results				0:15-0:25					
	2001-02 HOT Table Values	0:10-0:20	0:10-0:20	0:15-0:20	0:15-0:25					
	2001-02 Endurance Time Test Results					0:15-0:30	0:15-0:30			
	2002-03 HOT Table Values	0:10-0:20	0:10-0:20		0:15-0:25	0:15-0:30	0:15-0:30			
	2002-03 Endurance Time Test Results							0:15-0:25		
	2003-04 HOT Table Values	0:10-0:20	0:10-0:20		0:15-0:25	0:15-0:30	0:15-0:30	0:15-0:25		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:10-0:20	0:10-0:20		0:15-0:25	0:15-0:30	0:15-0:30	0:15-0:25		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:10-0:20	0:10-0:20		0:15-0:25	0:15-0:30	0:15-0:30	0:15-0:25		
CURRENT	2005-06 Endurance Time Test Results								0:30-0:40	0:30-0:40
	2006-07 HOT Table Values	0:10-0:20	0:10-0:20		0:15-0:25	0:15-0:30	0:15-0:30	0:15-0:25	0:30-0:40	0:30-0:40

Table 4.17: Type II Neat Fluid, Freezing Fog, -3ºC and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:35-1:30								
	1998-99 Endurance Time Test Results		1:10-2:25							
	1999-00 HOT Table Values	0:35-1:30	1:10-2:25							
	1999-00 Endurance Time Test Results			0:55-1:40						
	2000-01 HOT Table Values	0:35-1:30	1:10-2:25	0:55-1:40						
	2000-01 Endurance Time Test Results				1:25-2:35					
	2001-02 HOT Table Values	0:35-1:30	1:10-2:25	0:55-1:40	1:25-2:35					
	2001-02 Endurance Time Test Results					1:30-3:05	2:05-3:45			
	2002-03 HOT Table Values	0:35-1:30	1:10-2:25		1:25-2:35	1:30-3:05	2:05-3:45			
	2002-03 Endurance Time Test Results							1:30-2:05		
	2003-04 HOT Table Values	0:35-1:30	1:10-2:25		1:25-2:35	1:30-3:05	2:05-3:45	1:30-2:05		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:35-1:30	1:10-2:25		1:25-2:35	1:30-3:05	2:05-3:45	1:30-2:05		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:35-1:30	1:10-2:25		1:25-2:35	1:30-3:05	2:05-3:45	1:30-2:05		
CURRENT	2005-06 Endurance Time Test Results								3:30-4:00	1:10-2:25
	2006-07 HOT Table Values	0:35-1:30	1:10-2:25		1:25-2:35	1:30-3:05	2:05-3:45	1:30-2:05	3:30-4:00	1:10-2:25

Table 4.18: Type II 75/25 Fluid, Freezing Fog, -3ºC and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:25-1:00								
	1998-99 Endurance Time Test Results		1:10-2:25							
	1999-00 HOT Table Values	0:25-1:00	1:10-2:25							
	1999-00 Endurance Time Test Results			0:45-1:15						
	2000-01 HOT Table Values	0:25-1:00	1:10-2:25	0:45-1:15						
	2000-01 Endurance Time Test Results				1:05-1:55					
	2001-02 HOT Table Values	0:25-1:00	1:10-2:25	0:45-1:15	1:05-1:55					
	2001-02 Endurance Time Test Results					1:40-3:30	1:25-2:50			
	2002-03 HOT Table Values	0:25-1:00	1:10-2:25		1:05-1:55	1:40-3:30	1:25-2:50			
	2002-03 Endurance Time Test Results							0:55-1:45		
	2003-04 HOT Table Values	0:25-1:00	1:10-2:25		1:05-1:55	1:40-3:30	1:25-2:50	0:55-1:45		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:25-1:00	1:10-2:25		1:05-1:55	1:40-3:30	1:25-2:50	0:55-1:45		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:25-1:00	1:10-2:25		1:05-1:55	1:40-3:30	1:25-2:50	0:55-1:45		
CURRENT	2005-06 Endurance Time Test Results								2:30-4:00	1:20-2:25
	2006-07 HOT Table Values	0:25-1:00	1:10-2:25		1:05-1:55	1:40-3:30	1:25-2:50	0:55-1:45	2:30-4:00	1:20-2:25

Table 4.19: Type II 50/50 Fluid, Freezing Fog, -3ºC and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:15-0:45								
	1998-99 Endurance Time Test Results		0:15-0:45							
	1999-00 HOT Table Values	0:15-0:35	0:15-0:45							
	1999-00 Endurance Time Test Results			0:20-0:30						
	2000-01 HOT Table Values	0:15-0:30	0:15-0:45	0:20-0:30						
	2000-01 Endurance Time Test Results				0:30-0:45					
	2001-02 HOT Table Values	0:15-0:30	0:15-0:45	0:20-0:30	0:30-0:45					
	2001-02 Endurance Time Test Results					1:00-2:10	0:30-0:55			
	2002-03 HOT Table Values	0:15-0:30	0:15-0:45		0:30-0:45	1:00-2:10	0:30-0:55			
	2002-03 Endurance Time Test Results							0:20-0:35		
	2003-04 HOT Table Values	0:15-0:30	0:15-0:45		0:30-0:45	1:00-2:10	0:30-0:55	0:20-0:35		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:15-0:30	0:15-0:45		0:30-0:45	1:00-2:10	0:30-0:55	0:20-0:35		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:15-0:30	0:15-0:45		0:30-0:45	1:00-2:10	0:30-0:55	0:20-0:35		
CURRENT	2005-06 Endurance Time Test Results								0:55-1:45	0:45-1:25
	2006-07 HOT Table Values	0:15-0:30	0:15-0:45		0:30-0:45	1:00-2:10	0:30-0:55	0:20-0:35	0:55-1:45	0:45-1:25

Table 4.20: Type II Neat Fluid, Freezing Fog, Below -3ºC to -14ºC

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:35-1:30								
	1998-99 Endurance Time Test Results		0:30-1:05							
	1999-00 HOT Table Values	0:30-1:05	0:30-1:05							
	1999-00 Endurance Time Test Results			0:45-1:25						
	2000-01 HOT Table Values	0:20*-1:05	0:30-1:05	0:45-1:25						
	2000-01 Endurance Time Test Results				0:45-2:15					
	2001-02 HOT Table Values	0:20*-1:05	0:30-1:05	0:45-1:25	0:45-2:15					
	2001-02 Endurance Time Test Results					0:35-1:25	0:50-1:45			
	2002-03 HOT Table Values	0:20*-1:05	0:30-1:05		0:45-2:15	0:35-1:25	0:50-1:45			
	2002-03 Endurance Time Test Results							0:45-1:50		
	2003-04 HOT Table Values	0:20*-1:05	0:30-1:05		0:45-2:15	0:35-1:25	0:50-1:45	0:45-1:50		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:20*-1:05	0:30-1:05		0:45-2:15	0:35-1:25	0:50-1:45	0:45-1:50		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:20*-1:05	0:30-1:05		0:45-2:15	0:35-1:25	0:50-1:45	0:45-1:50		
CURRENT	2005-06 Endurance Time Test Results								0:55-1:45	0:50-1:40
	2006-07 HOT Table Values	0:20*-1:05	0:30-1:05		0:45-2:15	0:35-1:25	0:50-1:45	0:45-1:50	0:55-1:45	0:50-1:40

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

Table 4.21: Type II 75/25 Fluid, Freezing Fog, Below -3ºC to -14ºC

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:25-1:00								
	1998-99 Endurance Time Test Results		0:20-0:55							
	1999-00 HOT Table Values	0:20-0:55	0:20-0:55							
	1999-00 Endurance Time Test Results			0:35-1:00						
	2000-01 HOT Table Values	0:20-0:55	0:20-0:55	0:35-1:00						
	2000-01 Endurance Time Test Results				0:35-1:15					
	2001-02 HOT Table Values	0:20-0:55	0:20-0:55	0:35-1:00	0:35-1:15					
	2001-02 Endurance Time Test Results					0:35-1:15	0:30-1:20			
	2002-03 HOT Table Values	0:20-0:55	0:20-0:55		0:35-1:15	0:35-1:15	0:30-1:20			
	2002-03 Endurance Time Test Results							0:40-1:20		
	2003-04 HOT Table Values	0:20-0:55	0:20-0:55		0:35-1:15	0:35-1:15	0:30-1:20	0:40-1:20		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:20-0:55	0:20-0:55		0:35-1:15	0:35-1:15	0:30-1:20	0:40-1:20		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:20-0:55	0:20-0:55		0:35-1:15	0:35-1:15	0:30-1:20	0:40-1:20		
CURRENT	2005-06 Endurance Time Test Results								0:40-1:10	0:35-1:25
	2006-07 HOT Table Values	0:20-0:55	0:20-0:55		0:35-1:15	0:35-1:15	0:30-1:20	0:40-1:20	0:40-1:10	0:35-1:25

Table 4.22: Type II Neat Fluid, Freezing Fog, Below -14ºC to -25ºC

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:20-1:30								
	1998-99 Endurance Time Test Results		0:15-0:20							
	1999-00 HOT Table Values	0:15-0:20	0:15-0:20							
	1999-00 Endurance Time Test Results			0:20-0:40						
	2000-01 HOT Table Values	0:15-0:20	0:15-0:20	0:20-0:40						
	2000-01 Endurance Time Test Results				0:25-0:45					
	2001-02 HOT Table Values	0:15-0:20	0:15-0:20	0:20-0:40	0:25-0:45					
	2001-02 Endurance Time Test Results					0:20-0:45	0:20-0:35			
	2002-03 HOT Table Values	0:15-0:20	0:15-0:20		0:25-0:45	0:20-0:45	0:20-0:35			
	2002-03 Endurance Time Test Results							0:25-0:45		
	2003-04 HOT Table Values	0:15-0:20	0:15-0:20		0:25-0:45	0:20-0:45	0:20-0:35	0:25-0:45		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:15-0:20	0:15-0:20		0:25-0:45	0:20-0:45	0:20-0:35	0:25-0:45		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:15-0:20	0:15-0:20		0:25-0:45	0:20-0:45	0:20-0:35	0:25-0:45		
CURRENT	2005-06 Endurance Time Test Results								0:30-0:50	0:30-1:00
	2006-07 HOT Table Values	0:15-0:20	0:15-0:20		0:25-0:45	0:20-0:45	0:20-0:35	0:25-0:45	0:30-0:50	0:30-1:00

Table 4.23: Type II Neat Fluid, Cold-Soaked Wing, -3ºC and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:10-0:40								
	1998-99 Endurance Time Test Results		0:05-1:00							
	1999-00 HOT Table Values	0:05-0:40	0:05-1:00							
	1999-00 Endurance Time Test Results			0:10-0:50						
	2000-01 HOT Table Values	0:05-0:40	0:05-1:00	0:10-0:50						
	2000-01 Endurance Time Test Results				0:20-1:25					
	2001-02 HOT Table Values	0:05-0:40	0:05-1:00	0:10-0:50	0:20-1:25					
	2001-02 Endurance Time Test Results					0:15-1:10	0:15-1:30			
	2002-03 HOT Table Values	0:05-0:40	0:05-1:00		0:20-1:25	0:15-1:10	0:15-1:30			
	2002-03 Endurance Time Test Results							0:10-1:15		
	2003-04 HOT Table Values	0:05-0:40	0:05-1:00		0:20-1:25	0:15-1:10	0:15-1:30	0:10-1:15		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:05-0:40	0:05-1:00		0:20-1:25	0:15-1:10	0:15-1:30	0:10-1:15		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:05-0:40	0:05-1:00		0:20-1:25	0:15-1:10	0:15-1:30	0:10-1:15		
CURRENT	2005-06 Endurance Time Test Results								0:10-1:30	0:10-1:10
	2006-07 HOT Table Values	0:05-0:40	0:05-1:00		0:20-1:25	0:15-1:10	0:15-1:30	0:10-1:15	0:10-1:30	0:10-1:10

Table 4.24: Type II 75/25 Fluid, Cold-Soaked Wing, -3ºC and Above

		GENERIC	ABC-II +	C-1951	S E26	K2000	E II	C-2025	C-Flight	K-TF2
HISTORICAL	1998-99 HOT Table Values	0:05-0:25								
	1998-99 Endurance Time Test Results		0:05-0:50							
	1999-00 HOT Table Values	0:05-0:25	0:05-0:50							
	1999-00 Endurance Time Test Results			0:05-0:40						
	2000-01 HOT Table Values	0:05-0:25	0:05-0:50	0:05-0:40						
	2000-01 Endurance Time Test Results				0:10-1:00					
	2001-02 HOT Table Values	0:05-0:25	0:05-0:50	0:05-0:40	0:10-1:00					
	2001-02 Endurance Time Test Results					0:15-1:40	0:10-1:05			
	2002-03 HOT Table Values	0:05-0:25	0:05-0:50		0:10-1:00	0:15-1:40	0:10-1:05			
	2002-03 Endurance Time Test Results							0:05-0:50		
	2003-04 HOT Table Values	0:05-0:25	0:05-0:50		0:10-1:00	0:15-1:40	0:10-1:05	0:05-0:50		
	2003-04 Endurance Time Test Results									
	2004-05 HOT Table Values	0:05-0:25	0:05-0:50		0:10-1:00	0:15-1:40	0:10-1:05	0:05-0:50		
	2004-05 Endurance Time Test Results									
	2005-06 HOT Table Values	0:05-0:25	0:05-0:50		0:10-1:00	0:15-1:40	0:10-1:05	0:05-0:50		
CURRENT	2005-06 Endurance Time Test Results								0:05-1:20	0:10-1:25
	2006-07 HOT Table Values	0:05-0:25	0:05-0:50		0:10-1:00	0:15-1:40	0:10-1:05	0:05-0:50	0:05-1:20	0:10-1:25

4.4 Fluids Responsible for the Type II Generic Holdover Time Values

The fluids responsible for the values in each cell of the generic Type II HOT guidelines in 2006-07 are shown in Table 4.25. "Grandfather" is indicated where "grandfathered" fluids are responsible for the 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.

Table 4.25: Fluids Responsible for Type II Generic Holdover Time Values

OAT		Type II Fluid Concentration	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
°C	°F	Neat Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD-SOAKED WING
-3 and above	27 and above	100/0		Grandfather **(B)**	Grandfather **(B)** C-1951 **(B)**	Grandfather **(L)** C-1951 **(U)**	Grandfather **(B)** C-1951 **(U)**	Grandfather **(U)** ABC II + **(L)**
		75/25		Grandfather **(B)**	Grandfather **(B)** C-1951 **(L)**	Grandfather **(B)** C-1951 **(U)** C-2025 **(U)**	Grandfather **(B)** C-1951 **(U)** C-2025 **(U)**	Grandfather **(B)** ABC II + **(L)** C-1951 **(L)** C-2025 **(L)** C-Flight **(L)**
		50/50		Grandfather **(L)** ABC II + **(L)** C-1951 **(U)**	Grandfather **(B)** C-1951 **(B)** C-2025 **(B)**	C-1951 **(B)** ABC II + **(L)** C-2025 **(U)**	Grandfather **(B)** C-1951 **(B)** S E26 **(B)** C-2025 **(B)** ABC II + **(L)** K2000 **(L)**	
below -3 to -14	below 27 to 7	100/0		Type IV **(L)*** ABC II + **(U)**	ABC II + **(B)** Grandfather **(L)**	ABC II + **(B)**	Grandfather **(L)** ABC II + **(L)** K2000 **(L)** Type IV **(U)***	
		75/25		ABC II + **(B)**	C-1951 **(B)** Grandfather **(L)** ABC II + **(L)**	ABC II + **(B)**	ABC II + **(B)** Grandfather **(L)** C-1951 **(U)**	
below -14 to -25	below 7 to -13	100/0		ABC II + **(B)**	Grandfather **(B)** ABC II + **(B)** C-2025 **(B)**			
below -25	below -13	100/0	SAE TYPE II fluid may be used below -25ºC (-13ºF), provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.				**LEGEND** **L = DRIVES LOWER LIMIT** **U = DRIVES UPPER LIMIT** **B = DRIVES BOTH**	

M:\Groups\PM2020\Reports\HOT\Working Documents\Fluids Responsible for Generic Table Values At: Type II

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

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5. TYPE III ENDURANCE TIME RESULTS AND HOLDOVER TIME GUIDELINES

No tests were conducted with Type III fluids in 2005-06. No changes were made to the values in the Type III HOT guidelines for 2006-07.

5.1 New Fluids

No new Type III fluids were tested in 2005-06.

5.2 Changes to Holdover Time Guidelines

No changes were made to the values in the Type III HOT guidelines for 2006-07. The Transport Canada and FAA generic Type III HOT guidelines are included in Appendix I.

5.3 Evolution of Type III Holdover Times

Following the winter of 1999-2000, the need for a de/anti-icing fluid for aircraft with slower rotation speeds was identified. The new fluid needed to have longer holdover times than Type I fluids but a lower viscosity than Type II or Type IV fluids.

During the next several winters, Transport Canada, the FAA, APS, American Eagle and Clariant worked together to determine the precise requirements of this new fluid. During this process, it was decided that any new fluid created to meet these requirements would be classified as a new Type III.

In 2004, Clariant Safewing MP III 2031 ECO was submitted for endurance time testing and subsequently became the first fluid qualified to Aerospace Material Specification (AMS) 1428 as a new Type III fluid. As a result, Transport Canada and the FAA produced new generic Type III HOT guidelines for use in the winter of 2004-05.

The new Type III guidelines were based on the endurance times of Clariant Safewing MP III 2031 ECO. The following protocol was used to obtain the values:

- Endurance time results of Clariant 2031 were reduced by 10 percent; and
- The reduced values were changed to reasonably round values.

When the Type III test results and guidelines were presented at the SAE G-12 Holdover Subcommittee meeting in May 2004, several companies showed an interest in using Type III fluids in dilute form. As a result, 75/25 and 50/50 samples of Clariant Safewing MP III 2031 ECO were tested the following winter and the same protocol used to generate the neat fluid values was employed to generate 75/25 and 50/50 values. These values were incorporated in the winter 2005-06 HOT guidelines.

No changes have been made to the complete generic Type III HOT guidelines since they were introduced for the winter of 2005-06. Neither the FAA nor Transport Canada has intentions of publishing fluid-specific tables for Type III fluids.

6. TYPE IV ENDURANCE TIME RESULTS AND HOLDOVER TIME GUIDELINES

Three Type IV fluids were tested in 2005-06: Dow UCAR Endurance EG106, Clariant Safewing MP IV Launch and Kilfrost ABC-S PLUS. Fluid-specific HOT tables were created for each fluid and added to the 2006-07 Type IV HOT guidelines. The Transport Canada and FAA Type IV HOT guidelines are included in Appendix I.

6.1 New Fluids

Three Type IV fluids were tested in the winter of 2005-06 and will be introduced for the winter 2006-07 operating season: Clariant Safewing MP IV Launch, Dow UCAR Endurance EG106 and Kilfrost ABC-S PLUS. At the time of writing, Dow UCAR Endurance EG106 and Clariant Safewing MP IV Launch had been qualified and Kilfrost ABC-S PLUS was in the qualification process. Based on the expectation that all three fluids would be qualified, fluid-specific HOT tables were created for the 2006-07 HOT guidelines based on the results of HOT tests conducted with these fluids.

Because Clariant Safewing MP IV Launch was submitted for testing late in the winter, testing in natural snow was not possible and therefore conservative holdover times were derived analytically using data from an artificial snow machine and from an alternate sample. Details of these and other artificial snow tests conducted by APS on behalf of Transport Canada in the winter of 2005-06 are documented in the Transport Canada report TP 14717E (4). The fluid manufacturer intends to test the fluid in natural snow during the winter of 2006-07.

The detailed test results and analysis for each fluid are included in the fluid-specific reports provided to the fluid manufacturers. Copies of these reports are included in Appendix F (Clariant Safewing MP IV Launch), Appendix G (Dow UCAR Endurance EG106) and Appendix H (Kilfrost ABC-S PLUS).

The introduction of the new Type IV fluids did not impact the generic Type IV HOT guidelines.

6.2 Changes to Holdover Time Guidelines Format

Transport Canada is conducting research to provide additional guidance for aircraft operations during ice pellet conditions. Since further research is necessary, no changes will be made to the operational and HOT guidelines with respect to ice pellet conditions for the 2006-07 guidelines.

6.3 Evolution of Type IV Generic Holdover Time Values

The Type IV generic HOT guidelines are developed each year using data from Type IV fluids tested since 1996-97. At the SAE G-12 HOT Subcommittee meeting held in New Orleans in May 2001, it was decided that data from fluids that have not been commercially available for four years or more (and which have not been re-qualified) would be eliminated from the analysis. Since then, Hoechst MP IV 1957, diluted forms of Dow UCAR Ultra+, SPCA AD-404, Clariant Safewing Four and Clariant Safewing MP IV 1957 have been eliminated from the analysis for this reason. No fluids were removed this year.

It should be noted that 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. An exception was made for the only ethylene glycol based fluid on the market, Dow UCAR Ultra+, which retains fluid-specific holdover times in very cold snow.

The history of testing with Type IV fluids and the evolution of the fluid-specific and generic Type II HOT values are illustrated through a series of tables presented in Tables 6.1 to 6.24. 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 above) are not included.

The first row in each table contains the HOT values obtained in testing in 1996-97. These values were used as the HOT values in 1997-98 winter operations. Each subsequent set of two rows represents a winter test season and the subsequent winter's HOT values. The final line contains the generic and fluid-specific HOT values for use in 2006-07 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 HOT values.

Underlined values indicate the fluid or fluids responsible for the generic holdover time. If no value is underlined, it implies that the 1997-98 SAE Type IV values are responsible.

Strikethrough values indicate endurance time test results that are no longer valid. If a fluid is no longer qualified, such as the Dow UCAR Ultra+ dilutions and the Octagon Max-Flight 1998-99 low viscosity sample, the test results become invalid. Alternately, 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:

- Octagon Max-Flight (O-Max);
- Kilfrost ABC-S (K-ABC-S);
- Dow UCAR Ultra+ (Ultra+);
- SPCA AD-480 (S-480);
- Clariant MP IV 2001 (C-2001);
- Octagon Max-Flight 04 (O-Max 04);
- Clariant Safewing MP IV Protect 2012 (C-2012);
- Clariant Safewing MP IV 2030 ECO (C-2030);
- Octagon MaxFlo (O-MFlo);
- Clariant Safewing MP IV Launch (C-Launch);
- Dow UCAR Endurance EG106 (D-E106); and
- Kilfrost ABC-S PLUS (K-ABCS+).

6.4 Fluids Responsible for the Type IV Generic Holdover Time Values

The fluids responsible for the values in each cell of the generic Type IV HOT guidelines in 2006-07 are shown in Table 6.25, along with the year they were tested. 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.

Table 6.1: Type IV Neat Fluid, Snow, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:35-1:00	0:50-1:35	1:00-1:40	0:35-1:15									
	1997-98 Endurance Time Test Results					~~1:05-2:00~~	1:00-1:55							
	1998-99 HOT Table Values	0:35-1:00	0:50-1:35	1:00-1:40	0:35-1:15	1:05-2:00	1:00-1:55							
	1998-99 Endurance TimeTest Results		~~0:50 1:20~~	1:00-1:40	0:35-1:15	~~1:05 1:50~~								
	1999-2000 HOT Table Values	0:30-0:55	0:50-1:20	1:00-1:40	0:35-1:15	1:05-1:50	1:00-1:55							
	1999-2000 Endurance Time Test Results					0:40-1:20								
	2000-01 HOT Table Values	0:30-0:55	0:50-1:20	1:00-1:40	0:35-1:15	0:40-1:20	1:00-1:55							
	2000-01 Endurance Time Test Results		~~1:25-2:00~~					1:25-2:00	0:40-1:15					
	2001-02 HOT Table Values	0:30-0:55	0:50-1:35	1:00-1:40	0:35-1:15	0:40-1:20	1:00-1:55		0:40-1:15					
	2002-03 Endurance Time Test Results									0:50-1:30				
	2003-04 HOT Table Values	0:30-0:55	0:50-1:35	1:00-1:40	0:35-1:15	0:40-1:20	1:00-1:55		0:40-1:15	0:50-1:30				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:30-0:55	0:50-1:35	1:00-1:40	0:35-1:15	0:40-1:20	1:00-1:55	1:25-2:00	0:40-1:15	0:50-1:30				
	2004-05 Endurance Time Test Results										0:40-1:30			
	2005-06 HOT Table Values	0:35-1:15	0:50-1:35	1:00-1:40	0:35-1:15	0:40-1:20	1:00-1:55	1:25-2:00	0:40-1:15	0:50-1:30	0:40-1:30			
CURRENT	2005-06 Endurance Time Test Results											1:00-1:35	0:40-1:20	0:45-1:25
	2006-07 HOT Table Values	0:35-1:15	0:50-1:35	1:00-1:40	0:35-1:15	0:40-1:20	1:00-1:55	1:25-2:00	0:40-1:15	0:50-1:30	0:40-1:30	1:00-1:35	0:40-1:20	0:45-1:25

Table 6.2: Type IV 75/25 Fluid, Snow, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:20-0:35	0:45-1:45	~~0:35-1:05~~	~~0:20-0:35~~									
	1997-98 Endurance Time Test Results					~~0:45-1:25~~	0:35-1:00							
	1998-99 HOT Table Values	0:20-0:35	0:45-1:45	0:35-1:05		0:45-1:25	0:35-1:00							
	1998-99 Endurance TimeTest Results		~~0:30 1:00~~	0:30-0:55		~~0:45 1:25~~								
	1999-2000 HOT Table Values	0:20-0:35	0:30-1:00	0:30-0:55		0:45-1:25	0:35-1:00							
	1999-2000 Endurance Time Test Results					0:30-1:05								
	2000-01 HOT Table Values	0:20-0:35	0:30-1:00	0:30-0:55		0:30-1:05	0:35-1:00							
	2000-01 Endurance Time Test Results		~~1:05-2:00~~					1:05-2:00	0:25-0:55					
	2001-02 HOT Table Values	0:25-0:50	0:45-1:45	0:30-0:55		0:30-1:05	0:35-1:00		0:25-0:55					
	2002-03 Endurance Time Test Results									0:35-1:05				
	2003-04 HOT Table Values	0:25-0:50	0:45-1:45	0:30-0:55		0:30-1:05	0:35-1:00		0:25-0:55	0:35-1:05				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:25-0:50	0:45-1:45	0:30-0:55		0:30-1:05	0:35-1:00	1:05-2:00	0:25-0:55	0:35-1:05				
	2004-05 Endurance Time Test Results										0:20-0:55			
	2005-06 HOT Table Values	0:20-0:55	0:45-1:45	0:30-0:55		0:30-1:05	0:35-1:00	1:05-2:00	0:25-0:55	0:35-1:05	0:20-0:55			
CURRENT	2005-06 Endurance Time Test Results											0:40-1:20		0:25-0:55
	2006-07 HOT Table Values	0:20-0:55	0:45-1:45	0:30-0:55		0:30-1:05	0:35-1:00	1:05-2:00	0:25-0:55	0:35-1:05	0:20-0:55	0:40-1:20		0:25-0:55

Table 6.3: Type IV 50/50 Fluid, Snow, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:05-0:15	~~0:40-1:20~~	0:05-0:15	~~0:05-0:15~~									
	1997-98 Endurance Time Test Results		~~0:40-1:20~~	0:05-0:15		~~0:10-0:30~~	0:10-0:20							
	1998-99 HOT Table Values	0:05-0:15	0:40-1:20	0:05-0:15		0:10-0:30	0:10-0:20							
	1998-99 Endurance TimeTest Results	0:05-0:15	~~0:15-0:30~~	0:05-0:15										
	1999-2000 HOT Table Values	0:05-0:15	0:15-0:30	0:05-0:15		0:10-0:30	0:10-0:20							
	1999-2000 Endurance Time Test Results					0:10-0:20								
	2000-01 HOT Table Values	0:05-0:15	0:15-0:30	0:05-0:15		0:10-0:20	0:10-0:20							
	2000-01 Endurance Time Test Results		0:25-1:15					0:25-1:15	0:15-0:25					
	2001-02 HOT Table Values	0:05-0:15	0:25-1:15	0:05-0:15		0:10-0:20	0:10-0:20		0:15-0:25					
	2002-03 Endurance Time Test Results									0:15-0:25				
	2003-04 HOT Table Values	0:05-0:15	0:25-1:15	0:05-0:15		0:10-0:20	0:10-0:20		0:15-0:25	0:15-0:25				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:05-0:15	0:25-1:15	0:05-0:15		0:10-0:20	0:10-0:20	0:25-1:15	0:15-0:25	0:15-0:25				
	2004-05 Endurance Time Test Results										0:05-0:15			
	2005-06 HOT Table Values	0:05-0:15	0:25-1:15	0:05-0:15		0:10-0:20	0:10-0:20	0:25-1:15	0:15-0:25	0:15-0:25	0:05-0:15			
CURRENT	2005-06 Endurance Time Test Results											0:10-0:25		0:05-0:15
	2006-07 HOT Table Values	0:05-0:15	0:25-1:15	0:05-0:15		0:10-0:20	0:10-0:20	0:25-1:15	0:15-0:25	0:15-0:25	0:05-0:15	0:10-0:25		0:05-0:15

Table 6.4: Type IV Neat Fluid, Snow, Below -3°C to -14°C

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:20-0:40	0:25-0:50	0:45-1:20	0:25-0:55									
	1997-98 Endurance Time Test Results					~~0:20-0:40~~	0:30-0:50							
	1998-99 HOT Table Values	0:20-0:40	0:25-0:50	0:45-1:20	0:25-0:55	0:20-0:40	0:30-0:50							
	1998-99 Endurance TimeTest Results		~~0:45 1:05~~	0:45-1:20	~~0:30 1:00~~	0:30-0:55								
	1999-2000 HOT Table Values	0:20-0:40	0:25-0:50	0:45-1:20	0:25-0:55	0:30-0:55	0:30-0:50							
	1999-2000 Endurance Time Test Results					0:30-0:55								
	2000-01 HOT Table Values	0:20-0:40	0:25-0:50	0:45-1:20	0:25-0:55	0:30-0:55	0:30-0:50							
	2000-01 Endurance Time Test Results		~~0:35-1:10~~					0:35-1:10	0:20-0:40					
	2001-02 HOT Table Values	0:20-0:40	0:25-0:50	0:45-1:20	0:25-0:55	0:30-0:55	0:30-0:50		0:20-0:40					
	2002-03 Endurance Time Test Results									0:45-1:25				
	2003-04 HOT Table Values	0:20-0:40	0:25-0:50	0:45-1:20	0:25-0:55	0:30-0:55	0:30-0:50		0:20-0:40	0:45-1:25				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:20-0:40	0:25-0:50	0:45-1:20	0:25-0:55	0:30-0:55	0:30-0:50	0:35-1:10	0:20-0:40	0:45-1:25				
	2004-05 Endurance Time Test Results										0:25-1:00			
	2005-06 HOT Table Values	0:20-0:40	0:25-0:50	0:45-1:20	0:25-0:55	0:30-0:55	0:30-0:50	0:35-1:10	0:20-0:40	0:45-1:25	0:25-1:00			
CURRENT	2005-06 Endurance Time Test Results											0:40-1:05	0:30-1:05	0:35-1:00
	2006-07 HOT Table Values	0:20-0:40	0:25-0:50	0:45-1:20	0:25-0:55	0:30-0:55	0:30-0:50	0:35-1:10	0:20-0:40	0:45-1:25	0:25-1:00	0:40-1:05	0:30-1:05	0:35-1:00

Table 6.5: Type IV 75/25 Fluid, Snow, Below -3°C to -14°C

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:15-0:30	0:20-0:50	~~0:35-1:05~~	~~0:15-0:30~~									
	1997-98 Endurance Time Test Results					~~0:15-0:25~~	0:20-0:35							
	1998-99 HOT Table Values	0:15-0:25	0:20-0:50	0:35-1:05		0:15-0:25	0:20-0:35							
	1998-99 Endurance TimeTest Results		~~0:20-0:40~~	0:25-0:50		~~0:25-0:45~~								
	1999-2000 HOT Table Values	0:15-0:25	0:20-0:40	0:25-0:50		0:25-0:45	0:20-0:35							
	1999-2000 Endurance Time Test Results					0:20-0:45								
	2000-01 HOT Table Values	0:15-0:25	0:20-0:40	0:25-0:50		0:20-0:45	0:20-0:35							
	2000-01 Endurance Time Test Results		~~0:40-1:20~~					0:40-1:20	0:20-0:40					
	2001-02 HOT Table Values	0:15-0:25	0:20-0:50	0:25-0:50		0:20-0:45	0:20-0:35		0:20-0:40					
	2002-03 Endurance Time Test Results									0:35-1:05				
	2003-04 HOT Table Values	0:20-0:35	0:20-0:50	0:25-0:50		0:20-0:45	0:20-0:35		0:20-0:40	0:35-1:05				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:20-0:35	0:20-0:50	0:25-0:50		0:20-0:45	0:20-0:35	0:40-1:20	0:20-0:40	0:35-1:05				
	2004-05 Endurance Time Test Results										0:15-0:40			
	2005-06 HOT Table Values	0:15-0:35	0:20-0:50	0:25-0:50		0:20-0:45	0:20-0:35	0:40-1:20	0:20-0:40	0:35-1:05	0:15-0:40			
CURRENT	2005-06 Endurance Time Test Results											0:20-0:40		0:25-0:50
	2006-07 HOT Table Values	0:15-0:35	0:20-0:50	0:25-0:50		0:20-0:45	0:20-0:35	0:40-1:20	0:20-0:40	0:35-1:05	0:15-0:40	0:20-0:40		0:25-0:50

Table 6.6: Type IV Neat Fluid, Snow, Below -14°C to -25°C

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:15-0:30	0:20-0:40	0:40-1:10	0:20-0:45									
	1997-98 Endurance Time Test Results					~~0:15-0:30~~	0:20-0:35							
	1998-99 HOT Table Values	0:15-0:30	0:20-0:40	0:40-1:10	0:20-0:45	0:15-0:30	0:20-0:35							
	1998-99 Endurance TimeTest Results		~~0:40 1:00~~	0:40-1:10	~~0:30 0:55~~	0:25-0:40								
	1999-2000 HOT Table Values	0:15-0:30	0:20-0:40	0:40-1:10	0:20-0:45	0:25-0:40	0:20-0:35							
	1999-2000 Endurance Time Test Results					~~0:25-0:50~~								
	2000-01 HOT Table Values	0:15-0:30	0:20-0:40	0:40-1:10	0:20-0:45	0:25-0:40	0:20-0:35							
	2000-01 Endurance Time Test Results		~~0:25-0:50~~					0:25-0:50	0:15-0:30					
	2001-02 HOT Table Values	0:15-0:30	0:20-0:40	0:40-1:10	0:20-0:45	0:25-0:40	0:20-0:35		0:15-0:30					
	2002-03 Endurance Time Test Results									0:15-0:30				
	2003-04 HOT Table Values	0:15-0:30	0:20-0:40	0:40-1:10	0:20-0:45	0:25-0:40	0:20-0:35		0:15-0:30	0:15-0:30				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:20-0:45	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*				
	2004-05 Endurance Time Test Results										0:20-0:50			
	2005-06 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:20-0:45	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*	0:15-0:30*			
CURRENT	2005-06 Endurance Time Test Results											0:35-0:55	0:25-0:55	0:30-0:50
	2006-07 HOT Table Values	0:15-0:30	0:15-0:30*	0:15-0:30*	0:20-0:45	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*

*The generic HOT values were used for this cell

Table 6.7: Type IV Neat Fluid, Freezing Drizzle, -3ºC and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:40-1:00	0:55-2:00	1:20-1:50	~~1:00-2:00~~									
	1997-98 Endurance Time Test Results		~~1:10-2:00~~	~~1:55-2:00~~		~~1:05-2:00~~	0:55-1:55							
	1998-99 HOT Table Values	0:40-1:00	0:55-2:00	1:20-1:50	1:00-2:00	1:05-2:00	0:55-1:55							
	1998-99 Endurance TimeTest Results		~~1:00 1:55~~	~~2:00 2:00~~	0:45-1:35									
	1999-2000 HOT Table Values	0:40-1:00	0:55-1:55	1:20-1:50	0:45-1:35	1:05-2:00	0:55-1:55							
	1999-2000 Endurance Time Test Results					0:50-1:30								
	2000-01 HOT Table Values	0:40-1:00	0:55-1:55	1:20-1:50	0:45-1:35	0:50-1:30	0:55-1:55							
	2000-01 Endurance Time Test Results		~~2:00-2:00~~					2:00-2:00	0:40-1:10					
	2001-02 HOT Table Values	0:40-1:10	0:55-2:00	1:20-1:50	0:45-1:35	0:50-1:30	0:55-1:55		0:40-1:10					
	2002-03 Endurance Time Test Results									0:55-2:00				
	2003-04 HOT Table Values	0:40-1:10	0:55-2:00	1:20-1:50	0:45-1:35	0:50-1:30	0:55-1:55		0:40-1:10	0:55-2:00				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:40-1:10	0:55-2:00	1:20-1:50	0:45-1:35	0:50-1:30	0:55-1:55	2:00-2:00	0:40-1:10	0:55-2:00				
	2004-05 Endurance Time Test Results										1:20-2:05			
	2005-06 HOT Table Values	0:40-1:10	0:55-2:00	1:20-1:50	0:45-1:35	0:50-1:30	0:55-1:55	2:00-2:00	0:40-1:10	0:55-2:00	1:20-2:00			
CURRENT	2005-06 Endurance Time Test Results											1:30-2:00	1:10-2:00	1:15-1:55
	2006-07 HOT Table Values	0:40-1:10	0:55-2:00	1:20-1:50	0:45-1:35	0:50-1:30	0:55-1:55	2:00-2:00	0:40-1:10	0:55-2:00	1:20-2:00	1:30-2:00	1:10-2:00	1:15-1:55

Table 6.8: Type IV 75/25 Fluid, Freezing Drizzle, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:30-1:00	1:15-2:00	~~0:50-1:25~~	~~0:30-1:00~~									
	1997-98 Endurance Time Test Results		~~1:20-2:00~~	~~0:50~~-1:10		~~0:50-1:20~~	0:35-1:10							
	1998-99 HOT Table Values	0:30-1:00	1:15-2:00	0:50-1:10		0:50-1:20	0:35-1:10							
	1998-99 Endurance TimeTest Results		~~0:50 1:20~~	0:45-1:10										
	1999-2000 HOT Table Values	0:30-1:00	0:50-1:20	0:45-1:10		0:50-1:20	0:35-1:10							
	1999-2000 Endurance Time Test Results					0:50-1:15								
	2000-01 HOT Table Values	0:30-1:00	0:50-1:20	0:45-1:10		0:50-1:15	0:35-1:10							
	2000-01 Endurance Time Test Results		~~1:50-2:00~~					1:50-2:00	0:35-0:50					
	2001-02 HOT Table Values	0:35-0:50	1:15-2:00	0:45-1:10		0:50-1:15	0:35-1:10		0:35-0:50					
	2002-03 Endurance Time Test Results									0:40-1:05				
	2003-04 HOT Table Values	0:35-0:50	1:15-2:00	0:45-1:10		0:50-1:15	0:35-1:10		0:35-0:50	0:40-1:05				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:35-0:50	1:15-2:00	0:45-1:10		0:50-1:15	0:35-1:10	1:50-2:00	0:35-0:50	0:40-1:05				
	2004-05 Endurance Time Test Results										0:40-1:05			
	2005-06 HOT Table Values	0:35-0:50	1:15-2:00	0:45-1:10		0:50-1:15	0:35-1:10	1:50-2:00	0:35-0:50	0:40-1:05	0:40-1:05			
CURRENT	2005-06 Endurance Time Test Results											1:40-2:00		0:45-1:10
	2006-07 HOT Table Values	0:35-0:50	1:15-2:00	0:45-1:10		0:50-1:15	0:35-1:10	1:50-2:00	0:35-0:50	0:40-1:05	0:40-1:05	1:40-2:00		0:45-1:10

Table 6.9: Type IV 50/50 Fluid, Freezing Drizzle, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:10-0:20	~~0:55-1:40~~	0:15-~~0:25~~	~~0:10-0:20~~									
	1997-98 Endurance Time Test Results		0:35-1:00	0:15-0:20		~~0:15-0:35~~	0:10-0:20							
	1998-99 HOT Table Values	0:10-0:20	0:35-1:00	0:15-0:20		0:15-0:35	0:10-0:20							
	1998-99 Endurance TimeTest Results		~~0:15-0:25~~	0:15-0:20										
	1999-2000 HOT Table Values	0:10-0:20	0:15-0:25	0:15-0:20		0:15-0:35	0:10-0:20							
	1999-2000 Endurance Time Test Results					0:15-0:25								
	2000-01 HOT Table Values	0:10-0:20	0:15-0:25	0:15-0:20		0:15-0:25	0:10-0:20							
	2000-01 Endurance Time Test Results		~~0:35-1:10~~					0:35-1:10	0:15-0:20					
	2001-02 HOT Table Values	0:10-0:20	0:35-1:00	0:15-0:20		0:15-0:25	0:10-0:20		0:15-0:20					
	2002-03 Endurance Time Test Results									0:15-0:25				
	2003-04 HOT Table Values	0:10-0:20	0:35-1:00	0:15-0:20		0:15-0:25	0:10-0:20		0:15-0:20	0:15-0:25				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:10-0:20	0:35-1:00	0:15-0:20		0:15-0:25	0:10-0:20	0:35-1:10	0:15-0:20	0:15-0:25				
	2004-05 Endurance Time Test Results										0:10-0:20			
	2005-06 HOT Table Values	0:10-0:20	0:35-1:00	0:15-0:20		0:15-0:25	0:10-0:20	0:35-1:10	0:15-0:20	0:15-0:25	0:10-0:20			
CURRENT	2005-06 Endurance Time Test Results											0:30-0:50		0:10-0:20
	2006-07 HOT Table Values	0:10-0:20	0:35-1:00	0:15-0:20		0:15-0:25	0:10-0:20	0:35-1:10	0:15-0:20	0:15-0:25	0:10-0:20	0:30-0:50		0:10-0:20

Table 6.10: Type IV Neat Fluid, Freezing Drizzle, Below -3°C to -10°C

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:30-1:00	~~0:30~~-1:10	~~0:35~~-1:00	~~0:50-1:35~~									
	1997-98 Endurance Time Test Results		~~0:30-1:25~~	~~0:40-1:20~~		0:25-1:20	0:55-1:35							
	1998-99 HOT Table Values	0:25-1:00	0:30-1:10	0:35-1:00	0:50-1:35	0:25-1:20	0:55-1:35							
	1998-99 Endurance TimeTest Results		~~0:25-1:15~~	0:20~~-1:30~~	0:45-1:25									
	1999-2000 HOT Table Values	0:20-0:55	0:25-1:10	0:20-1:00	0:45-1:25	0:25-1:20	0:55-1:35							
	1999-2000 Endurance Time Test Results					0:25-1:20								
	2000-01 HOT Table Values	0:20-0:55	0:25-1:10	0:20-1:00	0:45-1:25	0:25-1:20	0:55-1:35							
	2000-01 Endurance Time Test Results		0:25~~-1:30~~					0:25-1:30	0:25-0:45					
	2001-02 HOT Table Values	0:20-0:45	0:25-1:10	0:20-1:00	0:45-1:25	0:25-1:20	0:55-1:35		0:25-0:45					
	2002-03 Endurance Time Test Results									0:30-1:10				
	2003-04 HOT Table Values	0:20-0:45	0:25-1:10	0:20-1:00	0:45-1:25	0:25-1:20	0:55-1:35		0:25-0:45	0:30-1:10				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:20-0:45	0:25-1:10	0:20-1:00	0:45-1:25	0:25-1:20	0:55-1:35	0:25-1:30	0:25-0:45	0:30-1:10				
	2004-05 Endurance Time Test Results										0:35-1:45			
	2005-06 HOT Table Values	0:20-0:45	0:25-1:10	0:20-1:00	0:45-1:25	0:25-1:20	0:55-1:35	0:25-1:30	0:25-0:45	0:30-1:10	0:35-1:45			
CURRENT	2005-06 Endurance Time Test Results											0:35-1:40	0:55-1:50	0:30-1:35
	2006-07 HOT Table Values	0:20-0:45	0:25-1:10	0:20-1:00	0:45-1:25	0:25-1:20	0:55-1:35	0:25-1:30	0:25-0:45	0:30-1:10	0:35-1:45	0:35-1:40	0:55-1:50	0:30-1:35

Table 6.11: Type IV 75/25 Fluid, Freezing Drizzle, Below -3°C to -10°C

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:30-1:00	~~0:30-1:05~~	~~0:50-1:25~~										
	1997-98 Endurance Time Test Results		~~0:25-1:20~~	~~0:30~~-1:10		~~0:30-1:15~~	0:40-1:10							
	1998-99 HOT Table Values	0:30-1:00	0:25-1:05	0:30-1:10		0:30-1:15	0:40-1:10							
	1998-99 Endurance TimeTest Results		~~0:20-1:00~~	0:20~~-1:30~~										
	1999-2000 HOT Table Values	0:20-0:55	0:20-1:00	0:20-1:10		0:30-1:15	0:40-1:10							
	1999-2000 Endurance Time Test Results					0:25-1:05								
	2000-01 HOT Table Values	0:20-0:50	0:20-1:00	0:20-1:10		0:25-1:05	0:40-1:10							
	2000-01 Endurance Time Test Results		0:20-1:00					0:20-1:00	0:15-0:30					
	2001-02 HOT Table Values	0:15-0:30	0:20-1:00	0:20-1:10		0:25-1:05	0:40-1:10		0:15-0:30					
	2002-03 Endurance Time Test Results									0:35-1:20				
	2003-04 HOT Table Values	0:15-0:30	0:20-1:00	0:20-1:10		0:25-1:05	0:40-1:10		0:15-0:30	0:35-1:20				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:15-0:30	0:20-1:00	0:20-1:10		0:25-1:05	0:40-1:10	0:20-1:00	0:15-0:30	0:35-1:20				
	2004-05 Endurance Time Test Results										0:35-1:15			
	2005-06 HOT Table Values	0:15-0:30	0:20-1:00	0:20-1:10		0:25-1:05	0:40-1:10	0:20-1:00	0:15-0:30	0:35-1:20	0:35-1:15			
CURRENT	2005-06 Endurance Time Test Results											0:25-1:10		0:25-1:15
	2006-07 HOT Table Values	0:15-0:30	0:20-1:00	0:20-1:10		0:25-1:05	0:40-1:10	0:20-1:00	0:15-0:30	0:35-1:20	0:35-1:15	0:25-1:10		0:25-1:15

Table 6.12: Type IV Neat Fluid, Light Freezing Rain, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:35-0:55	~~0:40-1:15~~	1:00-1:25	~~0:35-1:00~~									
	1997-98 Endurance Time Test Results		0:35-1:00	~~1:20-2:00~~		~~0:50-1:10~~	0:40-1:00							
	1998-99 HOT Table Values	0:35-0:55	0:35-1:00	1:00-1:25	0:35-1:00	0:50-1:10	0:40-1:00							
	1998-99 Endurance TimeTest Results		~~0:30 0:50~~	~~1:20 2:00~~	0:25-0:40									
	1999-2000 HOT Table Values	0:25-0:40	0:30-0:50	1:00-1:25	0:25-0:40	0:50-1:10	0:40-1:00							
	1999-2000 Endurance Time Test Results					0:35-0:55								
	2000-01 HOT Table Values	0:25-0:40	0:30-0:50	1:00-1:25		0:35-0:55	0:40-1:00							
	2000-01 Endurance Time Test Results		~~1:10-1:30~~					1:10-1:30	0:25-0:45					
	2001-02 HOT Table Values	0:25-0:40	0:35-1:00	1:00-1:25	0:25-0:40	0:35-0:55	0:40-1:00		0:25-0:45					
	2002-03 Endurance Time Test Results									0:40-0:50				
	2003-04 HOT Table Values	0:25-0:40	0:35-1:00	1:00-1:25	0:25-0:40	0:35-0:55	0:40-1:00		0:25-0:45	0:40-0:50				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:25-0:40	0:35-1:00	1:00-1:25	0:25-0:40	0:35-0:55	0:40-1:00	1:10-1:30	0:25-0:45	0:40-0:50				
	2004-05 Endurance Time Test Results										0:30-1:00			
	2005-06 HOT Table Values	0:25-0:40	0:35-1:00	1:00-1:25	0:25-0:40	0:35-0:55	0:40-1:00	1:10-1:30	0:25-0:45	0:40-0:50	0:30-1:00			
CURRENT	2005-06 Endurance Time Test Results											1:00-1:40	0:50-1:15	0:50-1:10
	2006-07 HOT Table Values	0:25-0:40	0:35-1:00	1:00-1:25	0:25-0:40	0:35-0:55	0:40-1:00	1:10-1:30	0:25-0:45	0:40-0:50	0:30-1:00	1:00-1:40	0:50-1:15	0:50-1:10

Table 6.13: Type IV 75/25 Fluid, Light Freezing Rain, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:15-0:30	~~0:50-1:15~~	0:35-0:50	~~0:15-0:30~~									
	1997-98 Endurance Time Test Results		0:35-1:10	~~0:40-0:55~~		~~0:35-0:50~~	0:25-0:35							
	1998-99 HOT Table Values	0:15-0:30	0:35-1:10	0:35-0:50		0:35-0:50	0:25-0:35							
	1998-99 Endurance TimeTest Results		~~0:20 0:40~~	0:35-0:50										
	1999-2000 HOT Table Values	0:15-0:30	0:20-0:40	0:35-0:50		0:35-0:50	0:25-0:35							
	1999-2000 Endurance Time Test Results					0:30-0:45								
	2000-01 HOT Table Values	0:15-0:30	0:20-0:40	0:35-0:50		0:30-0:45	0:25-0:35							
	2000-01 Endurance Time Test Results		~~1:00-1:20~~					1:00-1:20	0:15-0:30					
	2001-02 HOT Table Values	0:15-0:30	0:35-1:10	0:35-0:50		0:30-0:45	0:25-0:35		0:15-0:30					
	2002-03 Endurance Time Test Results									0:25-0:35				
	2003-04 HOT Table Values	0:15-0:30	0:35-1:10	0:35-0:50		0:30-0:45	0:25-0:35		0:15-0:30	0:25-0:35				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:15-0:30	0:35-1:10	0:35-0:50		0:30-0:45	0:25-0:35	1:00-1:20	0:15-0:30	0:25-0:35				
	2004-05 Endurance Time Test Results										0:20-0:35			
	2005-06 HOT Table Values	0:15-0:30	0:35-1:10	0:35-0:50		0:30-0:45	0:25-0:35	1:00-1:20	0:15-0:30	0:25-0:35	0:20-0:35			
CURRENT	2005-06 Endurance Time Test Results											0:45-1:15		0:30-0:45
	2006-07 HOT Table Values	0:15-0:30	0:35-1:10	0:35-0:50		0:30-0:45	0:25-0:35	1:00-1:20	0:15-0:30	0:25-0:35	0:20-0:35	0:45-1:15		0:30-0:45

Table 6.14: Type IV 50/50 Fluid, Light Freezing Rain, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:05-0:10	~~0:30-0:55~~	~~0:10-0:15~~	~~0:05-0:10~~									
	1997-98 Endurance Time Test Results	0:05-0:10	0:15-0:30	~~0:10 0:15~~		~~0:10 0:25~~	0:05-0:15							
	1998-99 HOT Table Values	0:05-0:10	0:15-0:30	0:10-0:15		0:10-0:25	0:10-0:15*							
	1998-99 Endurance TimeTest Results	0:05-0:10	~~0:05 0:15~~	0:05-0:10										
	1999-2000 HOT Table Values	0:05-0:10	0:05-0:15	0:05-0:10		0:10-0:25	0:05-0:15							
	1999-2000 Endurance Time Test Results					0:05-0:15								
	2000-01 HOT Table Values	0:05-0:10	0:05-0:15	0:05-0:10		0:05-0:15	0:05-0:15							
	2000-01 Endurance Time Test Results		~~0:25 0:35~~					0:25-0:35	0:05-0:10					
	2001-02 HOT Table Values	0:05-0:10	0:15-0:30	0:05-0:10		0:05-0:15	0:05-0:15		0:05-0:10					
	2002-03 Endurance Time Test Results									0:05-0:10				
	2003-04 HOT Table Values	0:05-0:10	0:15-0:30	0:05-0:10		0:05-0:15	0:05-0:15		0:05-0:10	0:05-0:10				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:05-0:10	0:15-0:30	0:05-0:10		0:05-0:15	0:05-0:15	0:25-0:35	0:05-0:10	0:05-0:10				
	2004-05 Endurance Time Test Results										0:05-0:10			
	2005-06 HOT Table Values	0:05-0:10	0:15-0:30	0:05-0:10		0:05-0:15	0:05-0:15	0:25-0:35	0:05-0:10	0:05-0:10	0:05-0:10			
CURRENT	2005-06 Endurance Time Test Results											0:20-0:25		0:05-0:10
	2006-07 HOT Table Values	0:05-0:10	0:15-0:30	0:05-0:10		0:05-0:15	0:05-0:15	0:25-0:35	0:05-0:10	0:05-0:10	0:05-0:10	0:20-0:25		0:05-0:10

*Values were rounded to 0:10-0:15 in 1998-99 and 0:05-0:15 in subsequent years

Table 6.15: Type IV Neat Fluid, Light Freezing Rain, Below -3°C to -10°C

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:30-0:45	~~0:30-0:55~~	~~0:30-0:45~~	~~0:30-0:50~~									
	1997-98 Endurance Time Test Results		0:20-0:40	~~0:20-0:40~~		~~0:20-0:40~~	0:30-0:45							
	1998-99 HOT Table Values	0:15-0:30	0:20-0:40	0:20-0:40	0:30-0:50	0:20-0:40	0:30-0:45							
	1998-99 Endurance TimeTest Results		~~0:15-0:40~~	0:10-0:30	0:30-0:45									
	1999-2000 HOT Table Values	0:10-0:30	0:15-0:40	0:10-0:30	0:30-0:45	0:20-0:40	0:30-0:45							
	1999-2000 Endurance Time Test Results					0:15-0:30								
	2000-01 HOT Table Values	0:10-0:30	0:15-0:40	0:10-0:30	0:30-0:45	0:15-0:30	0:30-0:45							
	2000-01 Endurance Time Test Results		0:20-0:40					0:20-0:40	0:15-0:25					
	2001-02 HOT Table Values	0:10-0:25	0:20-0:40	0:10-0:30	0:30-0:45	0:15-0:30	0:30-0:45		0:15-0:25					
	2002-03 Endurance Time Test Results									0:20-0:35				
	2003-04 HOT Table Values	0:10-0:25	0:20-0:40	0:10-0:30	0:30-0:45	0:15-0:30	0:30-0:45		0:15-0:25	0:20-0:35				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:10-0:25	0:20-0:40	0:10-0:30	0:30-0:45	0:15-0:30	0:30-0:45	0:20-0:40	0:15-0:25	0:20-0:35				
	2004-05 Endurance Time Test Results										0:30-0:50			
	2005-06 HOT Table Values	0:10-0:25	0:20-0:40	0:10-0:30	0:30-0:45	0:15-0:30	0:30-0:45	0:20-0:40	0:15-0:25	0:20-0:35	0:30-0:50			
CURRENT	2005-06 Endurance Time Test Results											0:25-0:45	0:45-1:10	0:25-0:35
	2006-07 HOT Table Values	0:10-0:25	0:20-0:40	0:10-0:30	0:30-0:45	0:15-0:30	0:30-0:45	0:20-0:40	0:15-0:25	0:20-0:35	0:30-0:50	0:25-0:45	0:45-1:10	0:25-0:35

Table 6.16: Type IV 75/25 Fluid, Light Freezing Rain, Below -3°C to -10°C

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:15-0:30	~~0:25-0:35~~	~~0:35-0:50~~	~~0:15-0:30~~									
	1997-98 Endurance Time Test Results		~~0:20-0:30~~	~~0:25~~-0:35		~~0:20-0:35~~	0:20-0:30							
	1998-99 HOT Table Values	0:15-0:30	0:20-0:30	0:25-0:35		0:20-0:35	0:20-0:30							
	1998-99 Endurance TimeTest Results		~~0:15-0:30~~	0:10-0:35										
	1999-2000 HOT Table Values	0:10-0:30	0:15-0:30	0:10-0:35		0:20-0:35	0:20-0:30							
	1999-2000 Endurance Time Test Results					0:15-0:30								
	2000-01 HOT Table Values	0:10-0:25	0:15-0:30	0:10-0:35		0:15-0:30	0:20-0:30							
	2000-01 Endurance Time Test Results		0:15-0:30					0:15-0:30	0:10-0:20					
	2001-02 HOT Table Values	0:10-0:20	0:15-0:30	0:10-0:35		0:15-0:30	0:20-0:30		0:10-0:20					
	2002-03 Endurance Time Test Results									0:15-0:30				
	2003-04 HOT Table Values	0:10-0:20	0:15-0:30	0:10-0:35		0:15-0:30	0:20-0:30		0:10-0:20	0:15-0:30				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:10-0:20	0:15-0:30	0:10-0:35		0:15-0:30	0:20-0:30	0:15-0:30	0:10-0:20	0:15-0:30				
	2004-05 Endurance Time Test Results										0:15-0:30			
	2005-06 HOT Table Values	0:10-0:20	0:15-0:30	0:10-0:35		0:15-0:30	0:20-0:30	0:15-0:30	0:10-0:20	0:15-0:30	0:15-0:30			
CURRENT	2005-06 Endurance Time Test Results											0:25-0:45		0:30-0:40
	2006-07 HOT Table Values	0:10-0:20	0:15-0:30	0:10-0:35		0:15-0:30	0:20-0:30	0:15-0:30	0:10-0:20	0:15-0:30	0:15-0:30	0:25-0:45		0:30-0:40

Table 6.17: Type IV Neat Fluid, Freezing Fog, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	2:20-3:00												
	1997-98 Endurance Time Test Results													
	1998-99 HOT Table Values	2:00-3:00												
	1998-99 Endurance TimeTest Results		~~2:15-4:00~~	2:35-4:00	1:35-3:35									
	1999-2000 HOT Table Values	1:05-2:15	2:15-4:00	2:35-4:00	1:35-3:35	1:05-2:15	1:05-2:15							
	1999-2000 Endurance Time Test Results					2:00-3:30	1:20-3:20							
	2000-01 HOT Table Values	1:05-2:15	2:15-4:00	2:35-4:00	1:35-3:35	2:00-3:30	1:20-3:20							
	2000-01 Endurance Time Test Results		2:40-4:00					2:40-4:00	1:15-2:30					
	2001-02 HOT Table Values	1:05-2:15	2:40-4:00	2:35-4:00	1:35-3:35	2:00-3:30	1:20-3:20		1:15-2:30					
	2002-03 Endurance Time Test Results									1:55-3:20				
	2003-04 HOT Table Values	1:05-2:15	2:40-4:00	2:35-4:00	1:35-3:35	2:00-3:30	1:20-3:20		1:15-2:30	1:55-3:20				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	1:05-2:15	2:40-4:00	2:35-4:00	1:35-3:35	2:00-3:30	1:20-3:20	2:40-4:00	1:15-2:30	1:55-3:20				
	2004-05 Endurance Time Test Results										2:20-3:35			
	2005-06 HOT Table Values	1:15-2:30	2:40-4:00	2:35-4:00	1:35-3:35	2:00-3:30	1:20-3:20	2:40-4:00	1:15-2:30	1:55-3:20	2:20-3:35			
CURRENT	2005-06 Endurance Time Test Results											4:00-4:00	2:05-3:10	1:50-3:40
	2006-07 HOT Table Values	1:15-2:30	2:40-4:00	2:35-4:00	1:35-3:35	2:00-3:30	1:20-3:20	2:40-4:00	1:15-2:30	1:55-3:20	2:20-3:35	4:00-4:00	2:05-3:10	1:50-3:40

Table 6.18: Type IV 75/25 Fluid, Freezing Fog, -3ºC and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	1:05-2:00												
	1997-98 Endurance Time Test Results													
	1998-99 HOT Table Values	1:05-2:00												
	1998-99 Endurance TimeTest Results		~~1:30 2:50~~	1:05-1:45										
	1999-2000 HOT Table Values	1:05-1:45	1:30-2:50	1:05-1:45		1:05-1:45	1:05-1:45							
	1999-2000 Endurance Time Test Results					1:30-2:45	1:20-2:00							
	2000-01 HOT Table Values	1:05-1:45	1:30-2:50	1:05-1:45		1:30-2:45	1:20-2:00							
	2000-01 Endurance Time Test Results		2:05-3:15					2:05-3:15	1:10-2:05					
	2001-02 HOT Table Values	1:05-1:45	2:05-3:15	1:05-1:45		1:30-2:45	1:20-2:00		1:10-2:05					
	2002-03 Endurance Time Test Results									1:15-2:05				
	2003-04 HOT Table Values	1:05-1:45	2:05-3:15	1:05-1:45		1:30-2:45	1:20-2:00		1:10-2:05	1:15-2:05				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	1:05-1:45	2:05-3:15	1:05-1:45		1:30-2:45	1:20-2:00	2:05-3:15	1:10-2:05	1:15-2:05				
	2004-05 Endurance Time Test Results										1:25-2:00			
	2005-06 HOT Table Values	1:05-1:45	2:05-3:15	1:05-1:45		1:30-2:45	1:20-2:00	2:05-3:15	1:10-2:05	1:15-2:05	1:25-2:00			
CURRENT	2005-06 Endurance Time Test Results											3:40-4:00		1:10-2:10
	2006-07 HOT Table Values	1:05-1:45	2:05-3:15	1:05-1:45		1:30-2:45	1:20-2:00	2:05-3:15	1:10-2:05	1:15-2:05	1:25-2:00	3:40-4:00		1:10-2:10

Table 6.19: Type IV 50/50 Fluid, Freezing Fog, -3ºC and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:20-0:45												
	1997-98 Endurance Time Test Results													
	1998-99 HOT Table Values	0:20-0:45												
	1998-99 Endurance TimeTest Results		~~0:30 0:50~~	0:20-0:35										
	1999-2000 HOT Table Values	0:20-0:35	0:30-0:50	0:20-0:35		0:20-0:35	0:20-0:35							
	1999-2000 Endurance Time Test Results					0:30-0:45	0:15-0:40							
	2000-01 HOT Table Values	0:15-0:35	0:30-0:50	0:20-0:35		0:30-0:45	0:15-0:40							
	2000-01 Endurance Time Test Results		0:55-1:45					0:55-1:45	0:25-0:45					
	2001-02 HOT Table Values	0:15-0:35	0:55-1:45	0:20-0:35		0:30-0:45	0:15-0:40		0:25-0:45					
	2002-03 Endurance Time Test Results									0:30-0:45				
	2003-04 HOT Table Values	0:15-0:35	0:55-1:45	0:20-0:35		0:30-0:45	0:15-0:40		0:25-0:45	0:30-0:45				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:15-0:35	0:55-1:45	0:20-0:35		0:30-0:45	0:15-0:40	0:55-1:45	0:25-0:45	0:30-0:45				
	2004-05 Endurance Time Test Results										0:20-0:40			
	2005-06 HOT Table Values	0:15-0:35	0:55-1:45	0:20-0:35		0:30-0:45	0:15-0:40	0:55-1:45	0:25-0:45	0:30-0:45	0:20-0:40			
CURRENT	2005-06 Endurance Time Test Results											1:25-2:45		0:20-0:40
	2006-07 HOT Table Values	0:15-0:35	0:55-1:45	0:20-0:35		0:30-0:45	0:15-0:40	0:55-1:45	0:25-0:45	0:30-0:45	0:20-0:40	1:25-2:45		0:20-0:40

Table 6.20: Type IV Neat Fluid, Freezing Fog, Below -3ºC to -14ºC

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:40-3:00												
	1997-98 Endurance Time Test Results													
	1998-99 HOT Table Values	0:40-3:00												
	1998-99 Endurance TimeTest Results		~~0:45 1:55~~	0:45-2:05	1:25-3:00									
	1999-2000 HOT Table Values	0:40-1:30	0:45-1:55	0:45-2:05	1:25-3:00	0:40-1:30	0:40-1:30							
	1999-2000 Endurance Time Test Results					0:20-1:20	0:45-1:35							
	2000-01 HOT Table Values	0:20-1:20	0:45-1:55	0:45-2:05	1:25-3:00	0:20-1:20	0:45-1:35							
	2000-01 Endurance Time Test Results		0:50-2:30					0:50-2:30	0:45-1:45					
	2001-02 HOT Table Values	0:20-1:20	0:50-2:30	0:45-2:05	1:25-3:00	0:20-1:20	0:45-1:35		0:45-1:45					
	2002-03 Endurance Time Test Results									0:50-2:00				
	2003-04 HOT Table Values	0:20-1:20	0:50-2:30	0:45-2:05	1:25-3:00	0:20-1:20	0:45-1:35		0:45-1:35	0:50-2:00				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:20-1:20	0:50-2:30	0:45-2:05	1:25-3:00	0:20-1:20	0:45-1:35	0:50-2:30	0:45-1:35	0:50-2:00				
	2004-05 Endurance Time Test Results										1:10-2:20			
	2005-06 HOT Table Values	0:20-1:20	0:50-2:30	0:45-2:05	1:25-3:00	0:20-1:20	0:45-1:35	0:50-2:30	0:45-1:35	0:50-2:00	1:10-2:20			
CURRENT	2005-06 Endurance Time Test Results											1:00-1:55	1:50-3:20	0:40-1:25
	2006-07 HOT Table Values	0:20-1:20	0:50-2:30	0:45-2:05	1:25-3:00	0:20-1:20	0:45-1:35	0:50-2:30	0:45-1:35	0:50-2:00	1:10-2:20	1:00-1:55	1:50-3:20	0:40-1:25

Table 6.21: Type IV 75/25 Fluid, Freezing Fog, Below -3°C to -14°C

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:35-2:00												
	1997-98 Endurance Time Test Results													
	1998-99 HOT Table Values	0:30-2:00												
	1998-99 Endurance TimeTest Results		~~0:30 1:10~~	0:25-1:00										
	1999-2000 HOT Table Values	0:25-1:00	0:30-1:10	0:25-1:00		0:25-1:00	0:25-1:00							
	1999-2000 Endurance Time Test Results					0:25-0:50	0:30-1:00							
	2000-01 HOT Table Values	0:25-0:50	0:30-1:10	0:25-1:00		0:25-0:50	0:30-1:00							
	2000-01 Endurance Time Test Results		030-1:05					030-1:05	0:25-1:05					
	2001-02 HOT Table Values	0:25-0:50	0:30-1:05	0:25-1:00		0:25-0:50	0:30-1:00		0:25-1:05					
	2002-03 Endurance Time Test Results									0:40-1:30				
	2003-04 HOT Table Values	0:25-0:50	0:30-1:05	0:25-1:00		0:25-0:50	0:30-1:00		0:25-1:05	0:40-1:30				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:25-0:50	0:30-1:05	0:25-1:00		0:25-0:50	0:30-1:00	0:30-1:05	0:25-1:05	0:40-1:30				
	2004-05 Endurance Time Test Results										0:40-1:25			
	2005-06 HOT Table Values	0:25-0:50	0:30-1:05	0:25-1:00		0:25-0:50	0:30-1:00	0:30-1:05	0:25-1:05	0:40-1:30	0:40-1:25			
CURRENT	2005-06 Endurance Time Test Results											0:40-1:20		0:40-1:15
	2006-07 HOT Table Values	0:25-0:50	0:30-1:05	0:25-1:00		0:25-0:50	0:30-1:00	0:30-1:05	0:25-1:05	0:40-1:30	0:40-1:25	0:40-1:20		0:40-1:15

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

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:20-2:00												
	1997-98 Endurance Time Test Results													
	1998-99 HOT Table Values	0:20-2:00												
	1998-99 Endurance TimeTest Results		~~0:20 0:40~~	0:20-0:40	0:40-2:10									
	1999-2000 HOT Table Values	0:20-0:40	0:20-0:40	0:20-0:40	0:40-2:10	0:20-0:40	0:20-0:40							
	1999-2000 Endurance Time Test Results					0:15-0:40	0:20-0:45							
	2000-01 HOT Table Values	0:15-0:40	0:20-0:40	0:20-0:40	0:40-2:10	0:15-0:40	0:20-0:45							
	2000-01 Endurance Time Test Results		0:20-0:45					0:20-0:45	0:20-0:45					
	2001-02 HOT Table Values	0:15-0:40	0:20-0:45	0:20-0:40	0:40-2:10	0:15-0:40	0:20-0:45		0:20-0:45					
	2002-03 Endurance Time Test Results									0:25-0:45				
	2003-04 HOT Table Values	0:15-0:40	0:20-0:45	0:20-0:40	0:40-2:10	0:15-0:40	0:20-0:45		0:20-0:45	0:25-0:45				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:15-0:40	0:20-0:45	0:20-0:40	0:40-2:10	0:15-0:40	0:20-0:45	0:20-0:45	0:20-0:45	0:25-0:45				
	2004-05 Endurance Time Test Results										0:30-1:00			
	2005-06 HOT Table Values	0:15-0:40	0:20-0:45	0:20-0:40	0:40-2:10	0:15-0:40	0:20-0:45	0:20-0:45	0:20-0:45	0:25-0:45	0:30-1:00			
CURRENT	2005-06 Endurance Time Test Results											0:30-0:50	0:30-1:05	0:20-0:45
	2006-07 HOT Table Values	0:15-0:40	0:20-0:45	0:20-0:40	0:40-2:10	0:15-0:40	0:20-0:45	0:20-0:45	0:20-0:45	0:25-0:45	0:30-1:00	0:30-0:50	0:30-1:05	0:20-0:45

Table 6.23: Type IV Neat Fluid, Cold-Soaked Wing, -3°C and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:10-0:50												
	1997-98 Endurance Time Test Results		0:15-1:15	0:20-1:15										
	1998-99 HOT Table Values	0:10-0:50												
	1998-99 Endurance TimeTest Results		~~0:10 2:00~~	~~0:30 2:00~~	0:10-1:20									
	1999-2000 HOT Table Values	0:10-0:50	0:10-1:15	0:20-1:15	0:10-1:20	0:10-0:50	0:10-0:50							
	1999-2000 Endurance Time Test Results					0:15-1:35	0:15-2:00							
	2000-01 HOT Table Values	0:10-0:50	0:10-1:15	0:20-1:15	0:10-1:20	0:15-1:35	0:15-2:00							
	2000-01 Endurance Time Test Results		~~0:20 2:00~~					0:20-2:00	0:10-1:05					
	2001-02 HOT Table Values	0:10-0:50	0:15-1:15	0:20-1:15	0:10-1:20	0:15-1:35	0:15-2:00		0:10-1:05					
	2002-03 Endurance Time Test Results									0:15-1:40				
	2003-04 HOT Table Values	0:10-0:50	0:15-1:15	0:20-1:15	0:10-1:20	0:15-1:35	0:15-2:00		0:10-1:05	0:15-1:40				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:10-0:50	0:15-1:15	0:20-1:15	0:10-1:20	0:15-1:35	0:15-2:00	0:20-2:00	0:10-1:05	0:15-1:40				
	2004-05 Endurance Time Test Results										0:10-2:00			
	2005-06 HOT Table Values	0:10-0:50	0:15-1:15	0:20-1:15	0:10-1:20	0:15-1:35	0:15-2:00	0:20-2:00	0:10-1:05	0:15-1:40	0:10-2:00			
CURRENT	2005-06 Endurance Time Test Results											0:15-1:40	0:20-2:00	0:15-1:40
	2006-07 HOT Table Values	0:10-0:50	0:15-1:15	0:20-1:15	0:10-1:20	0:15-1:35	0:15-2:00	0:20-2:00	0:10-1:05	0:15-1:40	0:10-2:00	0:15-1:40	0:20-2:00	0:15-1:40

Table 6.24: Type IV 75/25 Fluid, Cold-Soaked Wing, -3ºC and Above

		GENERIC	O-Max	K-ABC-S	Ultra+	S-480	C-2001	O-Max 04	C-2012	C-2030	O-MFlo	C-Launch	D-E106	K-ABCS+
HISTORICAL	1996-97 Test Results and Table Values used in 1997-98	0:05-0:35												
	1997-98 Endurance Time Test Results		0:10-0:40	0:10-0:50										
	1998-99 HOT Table Values	0:05-0:35												
	1998-99 Endurance TimeTest Results		~~0:05 1:15~~	~~0:10 1:15~~										
	1999-2000 HOT Table Values	0:05-0:35	0:05-0:40	0:10-0:50		0:05-0:35	0:05-0:35							
	1999-2000 Endurance Time Test Results					0:10-1:15	0:10-1:25							
	2000-01 HOT Table Values	0:05-0:35	0:05-0:40	0:10-0:50		0:10-1:15	0:10-1:25							
	2000-01 Endurance Time Test Results		~~0:20 2:00~~					0:20-2:00	0:05-0:40					
	2001-02 HOT Table Values	0:05-0:35	0:10-0:40	0:10-0:50		0:10-1:15	0:10-1:25		0:05-0:40					
	2002-03 Endurance Time Test Results									0:10-1:00				
	2003-04 HOT Table Values	0:05-0:35	0:10-0:40	0:10-0:50		0:10-1:15	0:10-1:25		0:05-0:40	0:10-1:00				
	2003-04 Endurance Time Test Results													
	2004-05 HOT Table Values	0:05-0:35	0:10-0:40	0:10-0:50		0:10-1:15	0:10-1:25	0:20-2:00	0:05-0:40	0:10-1:00				
	2004-05 Endurance Time Test Results										0:05-1:15			
	2005-06 HOT Table Values	0:05-0:35	0:10-0:40	0:10-0:50		0:10-1:15	0:10-1:25	0:20-2:00	0:05-0:40	0:10-1:00	0:05-1:15			
CURRENT	2005-06 Endurance Time Test Results											0:10-1:45		0:05-1:00
	2006-07 HOT Table Values	0:05-0:35	0:10-0:40	0:10-0:50		0:10-1:15	0:10-1:25	0:20-2:00	0:05-0:40	0:10-1:00	0:05-1:15	0:10-1:45		0:05-1:00

Table 6.25: Fluids Responsible for the Type IV Generic Holdover Time Values

OAT		Type IV Fluid Concentration	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
°C	°F	Neat Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD-SOAKED WING
-3 and above	27 and above	100/0		C-2012 (00/01) **B**	Ultra+ (98/99) **B** C-2012 (00/01) **U**	C-2012 (00/01) **B**	Ultra+ (98/99) **B** C-2012 (00/01) **L**	C-2012 (00/01) **L** Ultra+ (98/99) **L** O-MFlo (04/05) **L** Old data **B**
		75/25		ABC-S (98/99) **B**	ABC-S (98/99) **U** C-2012 (00/01) **U** O-MFlo (04/05) **B** ABC-S+ (05/06) **U**	C-2012 (00/01) **B** C-2001 (97/98) **L**	C-2012 (00/01) **B**	C-2012 (00/01) **L** O-MFlo (04/05) **L** Old data **B**
		50/50		ABC-S (98/99) **U** C-2001 (99/00) **L**	ABC-S (98/99) **B** O-MFlo (04/05) **B** ABC-S+ (05/06) **B**	C-2012 (00/01) **U** C-2001 (97/98) **B** ABC-S (98/99) **U** O-MFlo (04/05) **B** ABC-S+ (05/06) **B**	C-2012 (00/01) **B** O-MFlo (04/05) **B** ABC-S (98/99) **B** ABC-S+ (05-06) **B** C-2030 (02/03) **B** S 480 (99/00) **L** C-2001(97-98) **L**	
below -3 to -14	below 27 to 7	100/0		S 480 (99/00) **B**	C-2012 (00/01) **B**	ABC-S (98/99) **L** C-2012 (00/01) **U**	ABC-S (98/99) **L** C-2012 (00/01) **U**	
		75/25		C-2012 (00/01) **L** ABC-S (98/99) **L** S 480 (99/00) **B**	C-2001 (97/98) **U** O-MFlo (04/05) **L**	C-2012 (00/01) **B**	ABC-S (98/99) **L** C-2012 (00/01) **B**	
below -14 to -25	below 7 to -13	100/0		S 480 (99/00) **B** ABC-S (98/99) **U**	C-2012 (00/01) **B** C-2030 (02/03) **B**			
below -25	below -13	100/0	SAE TYPE IV fluid may be used below -25ºC (-13ºF), provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.				**LEGEND** **L = DRIVES LOWER LIMIT** **U = DRIVES UPPER LIMIT** **B = DRIVES BOTH**	

M:\Groups\PM2020\Reports\HOT\Working Documents\Fluids Responsible for Generic Table Values At:

7. CONCLUSIONS

7.1 Type I Fluids

One non-glycol Type I fluid, Battelle D^3: Degradable by Design Deicer™ 1006A, was qualified in the winter of 2005-06. No changes were made to the values in the Type I fluid HOT guidelines this year.

7.2 Type II Fluids

Two new fluid-specific tables, for Clariant Safewing MP II Flight and Kilfrost ABC-TF2, were added to the Type II HOT guidelines for 2006-07. No changes were made to the values in the Type II generic HOT guidelines this year.

7.3 Type III Fluids

No changes were made to the values in the Type III fluid HOT guidelines this year.

7.4 Type IV Fluids

Three new fluid-specific tables, for Clariant Safewing MP IV Launch, Dow UCAR Endurance EG106 and Kilfrost ABC-S PLUS, were added to the Type IV HOT guidelines for 2006-07. No changes were made to the values in the Type IV generic HOT guidelines this year.

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8. RECOMMENDATIONS

It is recommended that any new Type I, II, III or IV fluids be evaluated over the entire range of conditions of the HOT tables.

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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. Society of Automotive Engineers Aerospace Recommended Practice 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids: SAE Type II, III, and IV*, July 2004.

4. Balaban, G., *Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2005-06,* APS Aviation Inc., Transportation Development Centre, Montreal, December 2006, TP 14717E, XX (to be published).

5. Ruggi, M., *Aircraft Deicing Research in Natural and Simulated Ice Pellet Conditions,* APS Aviation Inc., Transportation Development Centre, Montreal, January 2007, TP 14713E, 104.

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2005-06

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2005-06

5.2 FLUID PERFORMANCE RESEARCH

5.2.2 Aircraft De-Anti-Icing Fluid Endurance Time Testing

Note: This program element will ultimately be charged entirely to the manufacturers of fluids and other agencies external to Transport Canada.

5.2.2.1 Natural Snow Tests at Trudeau

a) Prepare a procedure for testing outdoors during snowfalls;

b) Conduct flat plate tests under conditions of natural snow mainly at the Dorval Airport test site to record fluid endurance times. All testing will be performed using the methodology developed in the conduct of similar tests for Transport Canada in past years (ARP5485 and/or proposed ARP5945);

c) Record individual fluid endurance times for snow, based on samples of newly certified or re-certified Type I, Type II, Type III (including dilutions) and Type IV fluids supplied by fluid manufacturers, under as wide a range of temperature, precipitation rate, precipitation type, and wind conditions as can be experienced. (Testing is anticipated with three anti-icing fluids, as well as one Type I fluid); and

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

5.2.2.2 Endurance Time Tests in Simulated Precipitation at NRC

a) Prepare a test procedure for the conduct of endurance time tests in simulated precipitation at NRC Climatic Environment Facility;

b) Conduct flat plate tests under conditions of freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface at the National Research Council Climatic Engineering Facility in Ottawa to record fluid holdover times. All testing will be performed using the methodology developed in the conduct of similar tests for Transport Canada in past years (ARP 5485 and/or ARP 5945);

c) Testing is anticipated with three anti-icing fluids, as well as one Type I fluid;

d) Record individual fluid endurance times for all simulated precipitation conditions based on samples of newly certified or re-certified fluids supplied by fluid manufacturers under defined test parameters, such as temperature and precipitation rate; and

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

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, April 2006
- Additional Program of Tests at NRC, April 2006

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.

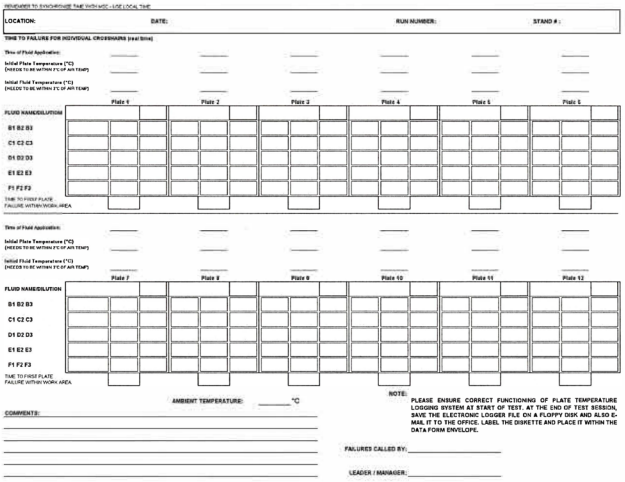
Table 1.1: Natural Snow Precipitation Test Plan New Fluids

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



REMEMBER TO SYNCHRONISE TIME WITH MOC - USE LOCAL TIME

LOCATION: DATE: RUN NUMBER: STAND # :

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

Time of Fluid Application:
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 3°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/DILUTION
B1 B2 B3
C1 C2 C3
D1 D2 D3
E1 E2 E3
F1 F2 F3
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA

Time of Fluid Application:
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 3°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/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

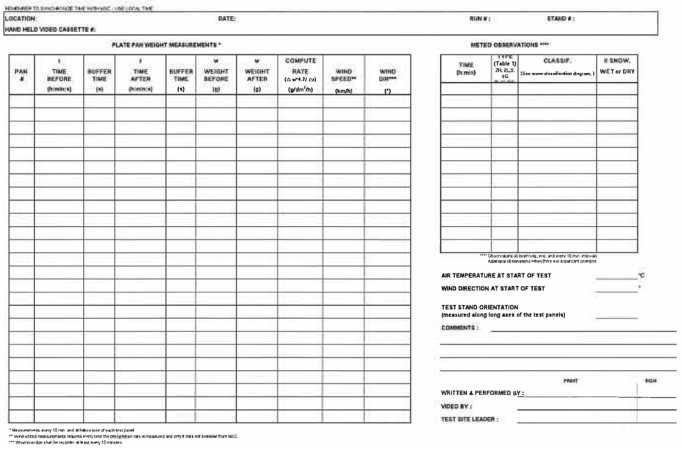
NOTE: PLEASE ENSURE CORRECT FUNCTIONING OF PLATE TEMPERATURE LOGGING SYSTEM AT START OF TEST. AT THE END OF TEST SESSION, SAVE THE ELECTRONIC LOGGER FILE ON A FLOPPY DISK AND ALSO E-MAIL IT TO THE OFFICE. LABEL THE DISKETTE AND PLACE IT WITHIN THE DATA FORM ENVELOPE.

COMMENTS:

FAILURES CALLED BY: _____

LEADER / MANAGER: _____

Table 2.2: Meteorological and Precipitation Rate Data Form



REMEMBER TO SYNCHRONISE TIME WITH MOC - USE LOCAL TIME

LOCATION: DATE: RUN # : STAND # :

HAND HELD VIDEO CASSETTE #:

PLATE PAN WEIGHT MEASUREMENTS *

PAN #	t TIME BEFORE (h:min:s)	BUFFER TIME (s)	t TIME AFTER (h:min:s)	BUFFER TIME (s)	w WEIGHT BEFORE (g)	w WEIGHT AFTER (g)	COMPUTE RATE (Δ w-1 / Δ t) (g/m²/h)	WIND SPEED** (km/h)	WIND DIR** (°)

METEO OBSERVATIONS ***

TIME (h:min)	TYPE (Table 1) (N, D, S, IG etc.)	CLASSIF. (Use www.climatlas.ca/precip_1.html)	If SNOW, WET or DRY

*** Observations at beginning, mid, and every 10 min. intervals. Additional observations when there are significant changes.

AIR TEMPERATURE AT START OF TEST _____ °C

WIND DIRECTION AT START OF TEST _____ °

TEST STAND ORIENTATION (measured along long axis of the test panels) _____

COMMENTS : _____

PRINT SIGN

WRITTEN & PERFORMED BY : _____

VIDEO BY : _____

TEST SITE LEADER : _____

* Measurements every 10 min. and at failure (one of each test panel)
** WIND DATA FROM AUTOMATIC WEATHER STATION (AWS) FROM THE PRECIPITATION GAUGE SITE IS PREFERRED AND ONLY IF DATA NOT AVAILABLE FROM MOC
*** Observations shall be recorded at least every 10 minutes

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

CM2020.002 (2006)

EXPERIMENTAL PROGRAM

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

Winter 2005-06

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: John D'Avirro

Reviewed by: Jean Valiquette

APS Aviation Inc.

February 27, 2006
Version 1.0

EXPERIMENTAL PROGRAM
DETERMINATION OF ENDURANCE TIMES OF TYPE I FLUIDS
UNDER NATURAL SNOW PRECIPITATION AT DORVAL
Winter 2005-06

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. 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.

4. EQUIPMENT AND FLUIDS

4.1 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.

4.2 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 10°C 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 60°C.

5. PERSONNEL

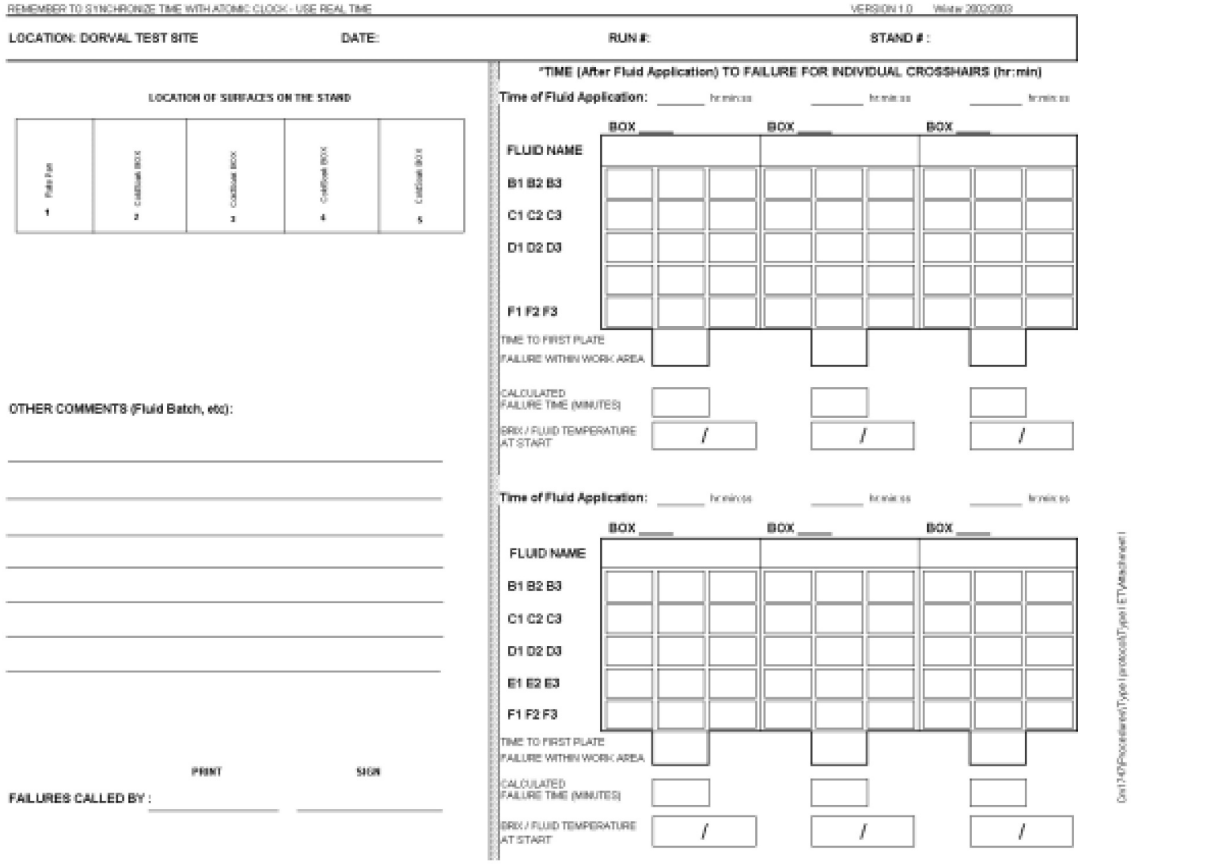
Three technicians are needed to conduct the tests:

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

6. 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
Plate Pan	Calibrak BOX	Calibrak BOX	Calibrak BOX	Calibrak 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

FLUID NAME	BOX ____			BOX ____			BOX ____		
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

FLUID NAME	BOX ____			BOX ____			BOX ____		
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	/			/			/		

Doc1147\Procedures\Type I protocol\Type I ET\Attachment I

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, ZL, S, SG IP, IC, BS, SP	SNOW CLASSIF. (See Fig. 3)

Cm1747\Procedures\Type I protocol\Type I ET\Attachment 2

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

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





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;

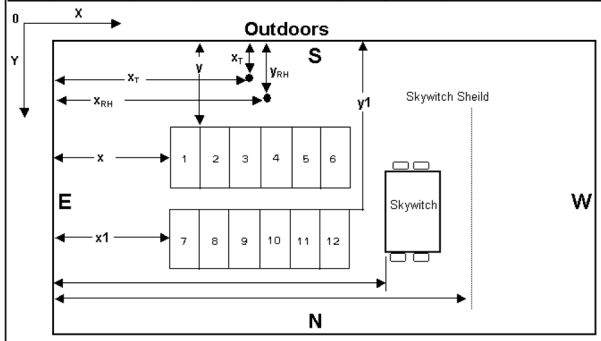
Figure 2.7: Rate Management Form at NRC, and;

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: 2g ☐ 50 g ☐
(see verification procedure)

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

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

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

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):

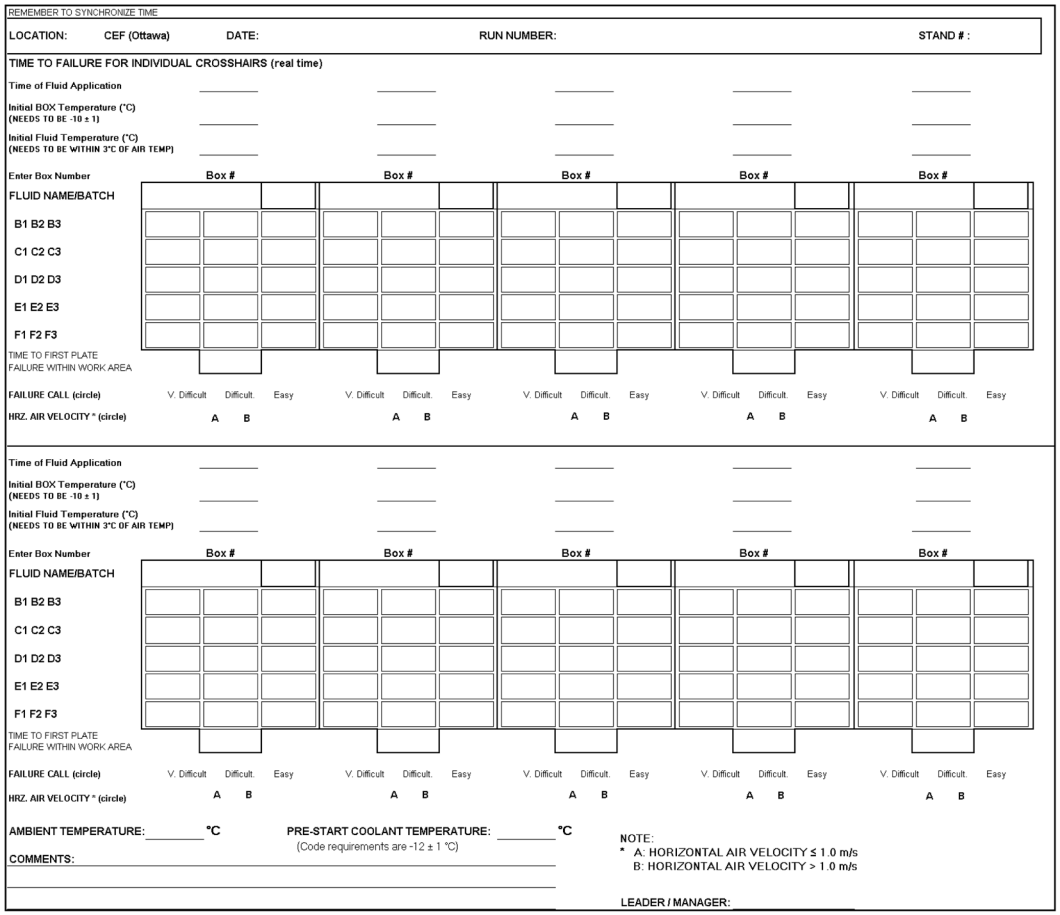
COMMENTS:

COMPUTER TECHNICIAN: _____

LEADER: _____

Figure 2.3: General Form for Each Condition at NRC

TEST REQUIREMENTS FOR SIMULATED FREEZING PRECIPITATION FLAT PLATE TESTING



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

HRZ. AIR VELOCITY * (circle) — 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

HRZ. AIR VELOCITY * (circle) — A | B

AMBIENT TEMPERATURE: _____ °C

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

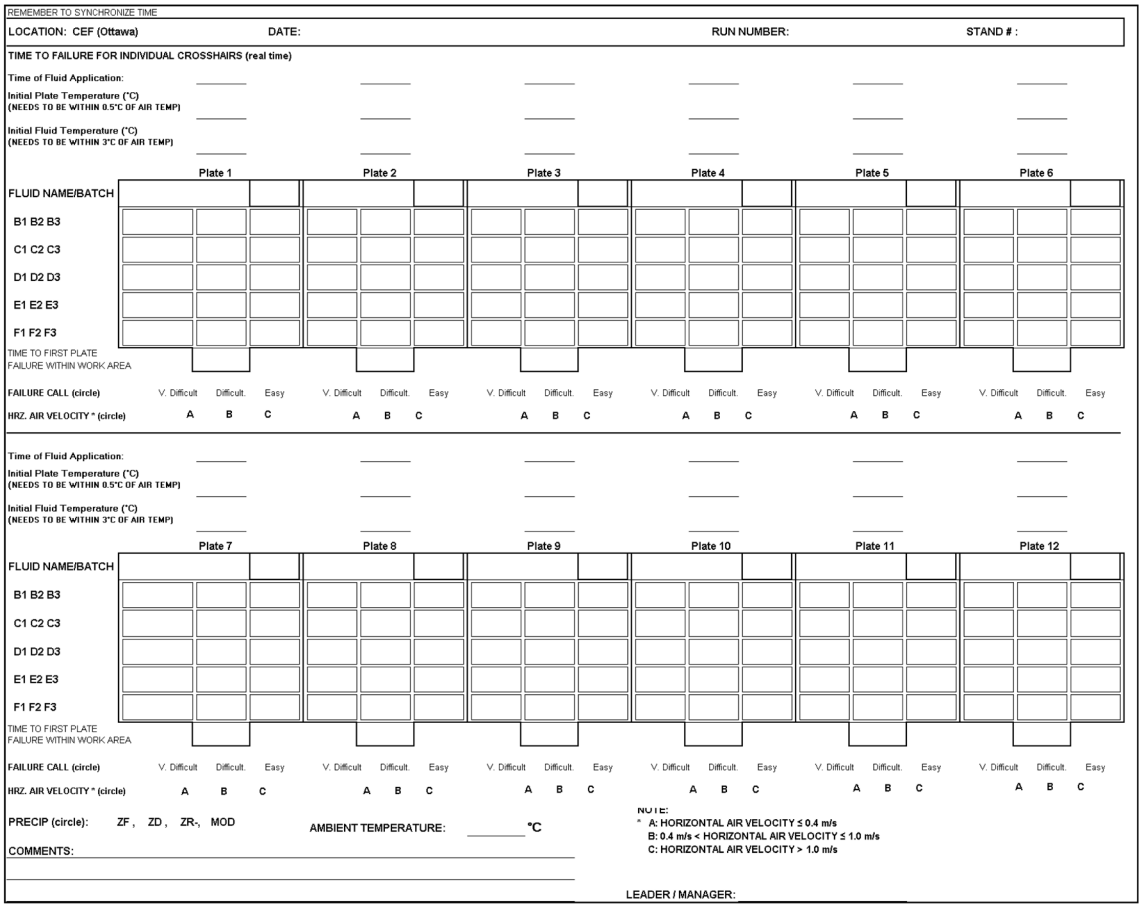
COMMENTS:

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

TEST REQUIREMENTS FOR SIMULATED FREEZING PRECIPITATION FLAT PLATE TESTING



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)	LT'S on 1	2	3	4	5	6	MT'S 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)	LT'S on 1	2	3	4	5	6	MT'S 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

* One reading every 30 minutes (Check procedure for air temp. STDEV requirements).
This form is for guidance to manage the sequencing of pans measurement and to verify the chamber temperature STDEV.
(At the end of condition file this form in the same envelope with the endurance time data form)

Figure 2.7: Rate Management Form at NRC

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, APRIL 2006

CM2020.002 (05-06)

OVERALL PROGRAM OF TESTS AT NRC, APRIL 2006

Winter 2005-06

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Stephanie Bendickson

Reviewed by: John D'Avirro

APS Aviation Inc.

March 31, 2006
Version 1.0

OVERALL PROGRAM OF TESTS AT NRC, APRIL 2006
Winter 2005-06

1. INTRODUCTION

This document was prepared to bring together several projects that require tests be conducted at the National Research Council (NRC) Climactic Engineering Facility in Ottawa. The primary project is testing the endurance times of new de/anti-icing fluids. Other projects will be scheduled around the endurance time tests as time and space permit. This document refers to a number of other procedures. A detailed list of these procedures is given in Section 9.

Tests will be conducted from April 3rd to 7th, and April 10th to 13th, 2006. A tentative schedule is included in Attachment I.

2. PROJECTS, PROCEDURES AND OBJECTIVES

2.1 Endurance Times of New Fluids

The objective of this project is to measure endurance times of new fluids in simulated freezing precipitation. Six fluids will be tested:

- Batelle D3 ADF (Type I)
- Kilfrost P1792 (Type II)
- Clariant Safewing Launch (Type IV)
- Clariant Safewing Launch (Type IV)
- Dow 200600147-10 (Type IV)
- Kilfrost P1797 (Type IV)

Specific details of the procedure to be followed for these tests can be found in the separate procedure entitled *Test Requirements for Simulated Freezing Precipitation Flat Plate Testing* (1).

One change will be made to the standard Type I test protocol. Due to time limitations, the Type I fluid will not be tested in freezing fog at -6°C or -10°C. Instead, it will be tested at freezing fog at -14°C and interpolation will be used to ascertain the fluid endurance times in freezing fog at -6°C and -10°C. All other standard Type I test protocol will be followed; test temperatures in other precipitation types will not be altered. This decision has been made in conjunction with Transport Canada.

The test plan for endurance time tests is given in Attachment II.

2.2 Thickness of New Fluids

The objective of these tests is to measure thicknesses of 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* (2) and can be found in Transport Canada Report TP 13991E, Appendix I. The test plan is given in Attachment III.

2.3 Effect of Heat on Endurance Times

The objective of this project is to investigate the impact of application method on endurance time performance. Specifically, the use of heated or non-heated fluids will be examined. Details can be found in the separate procedure entitled *Effect of Heat on Endurance Time of Anti-Icing Fluids* (3). The test plan is given in Attachment IV. These tests will be run concurrently with endurance time tests, but will be conducted on a side stand positioned perpendicular to the holdover time test stand.

2.4 Effect of Surface Material on Endurance Times

The objective of this project is to investigate the impact non-aluminum test plate material has on fluid endurance time. Comparative testing will be conducted to evaluate fluid endurance times on a standard plate, white painted aluminium plate, and white painted cross weave carbon fibre test plate (Carbon 05). Details can be found in the separate procedure entitled *Indoor Endurance Time Testing on Non-Aluminum Plates* (4). The test plan is given in Attachment V. These tests will be run concurrently with endurance time tests, but will be conducted on a side stand positioned perpendicular to the holdover time test stand. Endurance time tests will be used, as indicated in the test plan, as the standard plate tests.

2.5 NCAR Indoor Snow

The objective of the NCAR indoor snow testing is to generate holdover times in artificial snow for new fluids. The detailed test procedure is given in a separate document entitled *Fluid Endurance Time Testing with Artificial Snow* (5). The test plan is given in Attachment VI. The number of tests completed will be determined by the amount of time the chamber is at each required temperature.

It is not expected that there will be time to complete all tests; test priorities are given in the test plan.

2.6 Negative 3°C Buffer

The objective of this test program is to conduct testing with fluid mixed to a -3°C buffer and compare results with fluids mixed to 0°C and +10°C buffers. Details of this project are given in the separate procedure entitled *Comparison of Freezing Times with -3°C, 0°C and +10°C Buffer Type I Fluids* (6). Tests are numbered B1 to B15 and are included in the endurance time test plan given in Attachment II. Tests will be conducted on the endurance time test stands at the end of each condition as test positions become available.

2.7 Ice Pellets

The objective of this project is to investigate if endurance time testing conducted during ice pellet conditions will demonstrate signs of fluid adhesion to aluminum test surfaces. Preliminary testing will be conducted during conditions most likely to exhibit adhesion. Details of this project are given in the separate procedure entitled *Adhesion of Aircraft De/Anti-icing Fluids on Aluminum Surfaces during Simulated Ice Pellet Conditions* (7). The test plan given in that document has changed to include additional tests; the updated test plan is given in Attachment VII.

2.8 Far vs. Near - Pilots Perspective in Ice Pellets

The objective of this project is to document simultaneous perspectives representing close in and pilot views of an airfoil subjected to snow and ice pellet precipitation conditions, and to obtain an adequate representation of the human perspective when viewing an aircraft wing. Details of this project are given in the separate procedure entitled *Video Documentation of Pilot's Perspective in Ice pellets (8).*

Testing should be conducted as per the procedure with the following exceptions:

- Application of the desired quantity of ice pellets should be done all at once (no continuous rates);
- Human observations should only be recorded once all the ice pellets have been applied; and
- Distances from the airfoil should representative of common aircraft.

The test plan is given in Attachment VIII and is subject to change based on the results obtained. Common aircraft specifications are included at the end of this report in Annex A.

2.9 Airsilk

Airsilk is a combination of silicone emulsions in an aqueous solution created by General Electric. It is designed for application to aircraft wing surfaces to reduce skin friction and to reduce the adherence of ice crystals to aircraft exterior surfaces by creating a water-repellent microfilm. The objective of testing airsilk at this test session is to evalulate its ability to reduce adherence of ice crystals. Several tests will be conducted. They are numbered AS1 to AS12 and are included in the endurance time test plan given in Attachment II.

The procedure to prepare the airsilk plate is as follows:

1. Shake airsilk well;
2. Cover the top of a clean, dry test plate with Airsilk using a paintbrush: cover the top completely once, and then continue brushing slowly for 2 to 3 minutes to achieve a near cure of the surface; and
3. Allow to dry for 15 minutes to achieve a full cure of protective film.

2.10 Negative 3°C Buffer on Airfoil

The purpose of this project is to conduct preliminary observations into the hypothesis that a Type I fluid with a negative buffer can form a layer that, if it is not displaced by the Type II or IV fluid, will remain underneath the thickened fluid and can freeze as temperature goes down.

Type I fluid mixed to a -3°C buffer will be applied to an airfoil when the chamber is at below freezing temperatures. The fluid will be allowed to partially or fully freeze and then Type II or IV fluid will be gently applied to it, possibly using a spreader. Visual observations will be recorded.

3. PERSONNEL REQUIREMENTS/RESPONSIBILITIES

Personnel requirements for specific projects are detailed in Attachment IX and are as follows:

1. Endurance Times of New Fluids: MC and rates team. DY, GB and JG will prepare boxes in the cold soak wing conditions;

2. Thickness of New Fluids: SB;
3. Effect of Heat on Endurance Times: DY/JG and rates team;
4. Effect of Surface Material on Endurance Times: DY/JG and rates team;
5. NCAR Indoor Snow: GB and SB (part-time);
6. Negative 3ºC Buffer: SB and rates team;
7. Ice Pellets: MR, JT, SB and rates team;
8. Pilot's Perspective: DY/JG or GB;
9. Airsilk: SB; and
10. Negative 3°C Buffer on Airfoil: SB.

In addition, personnel will be designated responsible for rates, equipment, data forms and pre-test setup activities:

Rates Team:
- CM: rate manager;
- YOW 1: rate assistant; and
- SB: fluid management.

Equipment:
- DY: equipment manager; and
- SB, JG: equipment assistants.

Data Forms:
- SB: data form manager.

Pre-test Setup:
- JG: setup manager.

4. FLUIDS

The required fluids and fluid quantities are shown in Attachment X. The brix values and glycol/water proportions for diluting Type I fluids are given in Attachment XI.

5. EQUIPMENT

A complete list of equipment required for testing is given in Attachment XII.

6. DATA FORMS

1. Endurance Times of New Fluids: The freezing precipitation endurance time data form is required for these tests. It is included as Attachment XIII. The cold-soak wing endurance time data form, included as Attachment XIV, is also required.

2. Thickness of New Fluids: The fluid thickness data form, included as Attachment XV, is required.

3. Effect of Heat on Endurance Times: The freezing precipitation endurance time data form (Attachment XIII) and the brix and thickness data form (Attachment XVI) are required.

4. Effect of Surface Material on Endurance Times: The freezing precipitation endurance time data form (Attachment XIII) and the brix and thickness data form (Attachment XVI) are required.

5. NCAR Indoor Snow: The NCAR data form is included as Attachment XVII.

6. Negative 3°C Buffer: The freezing precipitation endurance time data form (Attachment XIII) is required.

7. Ice Pellets: The freezing precipitation endurance time data form (Attachment XIII), the brix and thickness data form (Attachment XVI), and the adherence of fluid failure data form (Attachment XVIII) are required.

8. Pilot's Perspective: The airfoil failure observation form is included in Attachment XIX.

9. Airsilk: Freezing precipitation endurance time data form (Attachment XIII) and the adherence of fluid failure data form (Attachment XVIII) are required.

10. Negative 3°C Buffer on Airfoil: The data form for this project is given in Attachment XX.

7. 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. Care should be taken when circulating near test stand due to slipperiness;
4. First aid kit, water and fire extinguisher are available; and
5. All NRC safety guidelines must be followed.

8. PRE-TEST SET-UP ACTIVITIES

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

1. Mark plates;
2. Mark boxes;
3. Ensure plates are equipped with operational and verified thermistors;
4. Ensure boxes are equipped with operational and verified thermistors;
5. Install thermistors on cold soak boxes and verify the number of box supports (plywood about the same size area as the box and used to support it on the stand);
6. Determine number of loggers required (loggers are on stands already);
7. Install software on rate desktop PC and on backup laptop;
8. Prepare PC for logging plate temperatures;
9. Ensure fluids are prepared in advance (see Attachmnet XI);
10. Empty 1 litre containers must be labelled and cleaned for pouring; and
11. Rate pans must be checked: 4 sets for each #1-12, check for holes, check properly labelled.

The following items should be purchased prior to arrival at the NRC:

1. Ice melt (NRC standard) – 5 boxes;
2. Paper towels;
3. White gloves (3 packs of 10); and
4. Paint brushes (3 mid-sized).

9. REFERENCES

1. Test Requirements For Simulated Freezing Precipitation Flat Plate Testing, Version 1.0, January 15, 2004.
2. Experimental Program to Establish Film Thickness Profiles for De-Icing and Anti-Icing Fluids on Flat Plates, Version 1.0, April 3, 2002.
3. Effect of Heat on Endurance Times of Anti-icing Fluids, Version 1.0, November 4, 2005.
4. Indoor Endurance Time Testing on Non-Aluminum Plates, Version 1.0, March 31, 2006.
5. Fluid Endurance Time Testing with Artificial Snow, Version 1.0, February 13, 2006.
6. Comparison of Freezing Times with -3°C, 0°C and +10°C Buffer Type I Fluids, Version 1.0, December 15, 2005.
7. Adhesion of Aircraft De/Anti-icing Fluids on Aluminum Surfaces during Simulated Ice Pellet Conditions, Version 1.1, January 23, 2006.
8. Video Documentation of Pilot's Perspective in Ice Pellets, Version 1.0, December 12, 2005.

ATTACHMENT I: TEST SCHEDULE

	Mon Apr 3	Tue Apr 4	Wed Apr 5	Thu Apr 6	Fri Apr 7	Mon Apr 10	Tue Apr 11	Wed Apr 12	Thu Apr 13
8:00	Packup	ZR, -3, 13 Composite Heat NCAR* Thickness*	ZD, -10, 5 Composite Heat IP Airsilk	ZD, -3, 13 Composite Heat NCAR* IP Airsilk	ZF, -3, 2 IP* NCAR* PP* Airsilk	ZF, -25, 5 NCAR*, IP*	ZF, -14, 5 NCAR* IP* PP* Airsilk	CSW, 1, 5 PP*	
8:30									
9:00									
9:30						ZF, -25, 2 Buffer NCAR*, IP*			
10:00									
10:30							Warm to -3° ↓ ↓		
11:00	Drive to Ottawa								
11:30			ZR, -10, 25 Composite Heat Buffer, IP*			Warm to -14° ↓ ↓			
12:00		ZD, -3, 5 Composite Heat Buffer NCAR* Thickness*					ZF, -3, 5 NCAR* IP** PP* Airsilk	CSW, 1, 75 PP*	
12:30									
13:00	Setup					ZF, -14, 2 NCAR* IP* PP*			
13:30			ZR, -10, 13 Composite Heat Buffer IP	ZR, -3, 25 Composite Heat NCAR* IP Airsilk					
14:00								Packup	
14:30									
15:00									
15:30									
16:00			ZD, -10, 13 Composite Heat IP*					Drive to Montreal	
16:30									
17:00									
17:30									
18:00								Unpack	
18:30									
19:00									

*These projects do not require the spray pattern, just the temperature

**If necessary

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution (BRIX)	Test Surface	Comments
1	Freezing Drizzle	-3	13	Batelle D3 ADF	10°buf. (26.75)	Plate	Apply fluid at 20±5°C, is also Test C4c
2	Freezing Drizzle	-3	13	Batelle D3 ADF	10°buf. (26.75)	Plate	Apply fluid at 20±5°C
3	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch	100	Plate	
4	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch	100	Plate	
5	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch	75	Plate	
6	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch	75	Plate	
7	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch	50	Plate	
8	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch	50	Plate	
9	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch 2	100	Plate	
10	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch 2	100	Plate	
11	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch 2	75	Plate	
12	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch 2	75	Plate	
13	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch 2	50	Plate	
14	Freezing Drizzle	-3	13	Clariant Safewing MP IV Launch 2	50	Plate	
15	Freezing Drizzle	-3	13	Dow 200600147-10 (Type IV)	100	Plate	
16	Freezing Drizzle	-3	13	Dow 200600147-10 (Type IV)	100	Plate	
17	Freezing Drizzle	-3	13	Dow 200600147-10 (Type IV)	75	Plate	
18	Freezing Drizzle	-3	13	Dow 200600147-10 (Type IV)	75	Plate	
19	Freezing Drizzle	-3	13	Dow 200600147-10 (Type IV)	50	Plate	
20	Freezing Drizzle	-3	13	Dow 200600147-10 (Type IV)	50	Plate	
21	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)	100	Plate	
22	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)	100	Plate	
23	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)	75	Plate	
24	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)	75	Plate	
25	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)	50	Plate	Doubles as Test C3c
26	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)	50	Plate	
27	Freezing Drizzle	-3	13	Kilfrost P1797 (Type IV)	100	Plate	
28	Freezing Drizzle	-3	13	Kilfrost P1797 (Type IV)	100	Plate	
29	Freezing Drizzle	-3	13	Kilfrost P1797 (Type IV)	75	Plate	
30	Freezing Drizzle	-3	13	Kilfrost P1797 (Type IV)	75	Plate	
31	Freezing Drizzle	-3	13	Kilfrost P1797 (Type IV)	50	Plate	
32	Freezing Drizzle	-3	13	Kilfrost P1797 (Type IV)	50	Plate	
33	Freezing Drizzle	-3	5	Batelle D3 ADF	10°buf. (26.75)	Plate	Apply fluid at 20±5°C, is also Test C2c
34	Freezing Drizzle	-3	5	Batelle D3 ADF	10°buf. (26.75)	Plate	Apply fluid at 20±5°C
35	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch	100	Plate	
36	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch	100	Plate	
37	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch	75	Plate	
38	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch	75	Plate	
39	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch	50	Plate	
40	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch	50	Plate	
41	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch 2	100	Plate	
42	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch 2	100	Plate	
43	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch 2	75	Plate	
44	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch 2	75	Plate	
45	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch 2	50	Plate	
46	Freezing Drizzle	-3	5	Clariant Safewing MP IV Launch 2	50	Plate	
47	Freezing Drizzle	-3	5	Dow 200600147-10 (Type IV)	100	Plate	
48	Freezing Drizzle	-3	5	Dow 200600147-10 (Type IV)	100	Plate	
49	Freezing Drizzle	-3	5	Dow 200600147-10 (Type IV)	75	Plate	
50	Freezing Drizzle	-3	5	Dow 200600147-10 (Type IV)	75	Plate	
51	Freezing Drizzle	-3	5	Dow 200600147-10 (Type IV)	50	Plate	
52	Freezing Drizzle	-3	5	Dow 200600147-10 (Type IV)	50	Plate	
53	Freezing Drizzle	-3	5	Kilfrost P1792 (Type II)	100	Plate	
54	Freezing Drizzle	-3	5	Kilfrost P1792 (Type II)	100	Plate	

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
55	Freezing Drizzle	-3	5	Kilfrost P1792 (Type II)	75	Plate	
56	Freezing Drizzle	-3	5	Kilfrost P1792 (Type II)	75	Plate	
57	Freezing Drizzle	-3	5	Kilfrost P1792 (Type II)	50	Plate	Doubles as Test C1c
58	Freezing Drizzle	-3	5	Kilfrost P1792 (Type II)	50	Plate	
59	Freezing Drizzle	-3	5	Kilfrost P1797 (Type IV)	100	Plate	
60	Freezing Drizzle	-3	5	Kilfrost P1797 (Type IV)	100	Plate	
61	Freezing Drizzle	-3	5	Kilfrost P1797 (Type IV)	75	Plate	
62	Freezing Drizzle	-3	5	Kilfrost P1797 (Type IV)	75	Plate	
63	Freezing Drizzle	-3	5	Kilfrost P1797 (Type IV)	50	Plate	
64	Freezing Drizzle	-3	5	Kilfrost P1797 (Type IV)	50	Plate	
65	Freezing Drizzle	-10	13	Batelle D3 ADF	10°buf. (34.75)	Plate	Apply fluid at 20±5°C, is also Test C8c
66	Freezing Drizzle	-10	13	Batelle D3 ADF	10°buf. (34.75)	Plate	Apply fluid at 20±5°C
67	Freezing Drizzle	-10	13	Clariant Safewing MP IV Launch	100	Plate	
68	Freezing Drizzle	-10	13	Clariant Safewing MP IV Launch	100	Plate	
69	Freezing Drizzle	-10	13	Clariant Safewing MP IV Launch	75	Plate	
70	Freezing Drizzle	-10	13	Clariant Safewing MP IV Launch	75	Plate	
71	Freezing Drizzle	-10	13	Clariant Safewing MP IV Launch 2	100	Plate	
72	Freezing Drizzle	-10	13	Clariant Safewing MP IV Launch 2	100	Plate	
73	Freezing Drizzle	-10	13	Clariant Safewing MP IV Launch 2	75	Plate	
74	Freezing Drizzle	-10	13	Clariant Safewing MP IV Launch 2	75	Plate	
75	Freezing Drizzle	-10	13	Dow 200600147-10 (Type IV)	100	Plate	
76	Freezing Drizzle	-10	13	Dow 200600147-10 (Type IV)	100	Plate	
77	Freezing Drizzle	-10	13	Dow 200600147-10 (Type IV)	75	Plate	
78	Freezing Drizzle	-10	13	Dow 200600147-10 (Type IV)	75	Plate	
79	Freezing Drizzle	-10	13	Kilfrost P1792 (Type II)	100	Plate	
80	Freezing Drizzle	-10	13	Kilfrost P1792 (Type II)	100	Plate	
81	Freezing Drizzle	-10	13	Kilfrost P1792 (Type II)	75	Plate	Doubles as Test C7c
82	Freezing Drizzle	-10	13	Kilfrost P1792 (Type II)	75	Plate	
83	Freezing Drizzle	-10	13	Kilfrost P1797 (Type IV)	100	Plate	
84	Freezing Drizzle	-10	13	Kilfrost P1797 (Type IV)	100	Plate	
85	Freezing Drizzle	-10	13	Kilfrost P1797 (Type IV)	75	Plate	
86	Freezing Drizzle	-10	13	Kilfrost P1797 (Type IV)	75	Plate	
87	Freezing Drizzle	-10	5	Batelle D3 ADF	10°buf. (34.75)	Plate	Apply fluid at 20±5°C, is also Test C6c
88	Freezing Drizzle	-10	5	Batelle D3 ADF	10°buf. (34.75)	Plate	Apply fluid at 20±5°C
89	Freezing Drizzle	-10	5	Clariant Safewing MP IV Launch	100	Plate	
90	Freezing Drizzle	-10	5	Clariant Safewing MP IV Launch	100	Plate	
91	Freezing Drizzle	-10	5	Clariant Safewing MP IV Launch	75	Plate	
92	Freezing Drizzle	-10	5	Clariant Safewing MP IV Launch	75	Plate	
93	Freezing Drizzle	-10	5	Clariant Safewing MP IV Launch 2	100	Plate	
94	Freezing Drizzle	-10	5	Clariant Safewing MP IV Launch 2	100	Plate	
95	Freezing Drizzle	-10	5	Clariant Safewing MP IV Launch 2	75	Plate	
96	Freezing Drizzle	-10	5	Clariant Safewing MP IV Launch 2	75	Plate	
97	Freezing Drizzle	-10	5	Dow 200600147-10 (Type IV)	100	Plate	
98	Freezing Drizzle	-10	5	Dow 200600147-10 (Type IV)	100	Plate	
99	Freezing Drizzle	-10	5	Dow 200600147-10 (Type IV)	75	Plate	
100	Freezing Drizzle	-10	5	Dow 200600147-10 (Type IV)	75	Plate	
101	Freezing Drizzle	-10	5	Kilfrost P1792 (Type II)	100	Plate	
102	Freezing Drizzle	-10	5	Kilfrost P1792 (Type II)	100	Plate	
103	Freezing Drizzle	-10	5	Kilfrost P1792 (Type II)	75	Plate	Doubles as Test C5c
104	Freezing Drizzle	-10	5	Kilfrost P1792 (Type II)	75	Plate	
105	Freezing Drizzle	-10	5	Kilfrost P1797 (Type IV)	100	Plate	
106	Freezing Drizzle	-10	5	Kilfrost P1797 (Type IV)	100	Plate	
107	Freezing Drizzle	-10	5	Kilfrost P1797 (Type IV)	75	Plate	
108	Freezing Drizzle	-10	5	Kilfrost P1797 (Type IV)	75	Plate	

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
109	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch	100	Plate	
110	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch	100	Plate	
111	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch	75	Plate	
112	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch	75	Plate	
113	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch	50	Plate	
114	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch	50	Plate	
115	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch 2	100	Plate	
116	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch 2	100	Plate	
117	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch 2	75	Plate	Doubles as Test C10c
118	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch 2	75	Plate	
119	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch 2	50	Plate	
120	Light Freezing Rain	-3	25	Clariant Safewing MP IV Launch 2	50	Plate	
121	Light Freezing Rain	-3	25	Dow 200600147-10 (Type IV)	100	Plate	
122	Light Freezing Rain	-3	25	Dow 200600147-10 (Type IV)	100	Plate	
123	Light Freezing Rain	-3	25	Dow 200600147-10 (Type IV)	75	Plate	
124	Light Freezing Rain	-3	25	Dow 200600147-10 (Type IV)	75	Plate	
125	Light Freezing Rain	-3	25	Dow 200600147-10 (Type IV)	50	Plate	
126	Light Freezing Rain	-3	25	Dow 200600147-10 (Type IV)	50	Plate	
127	Light Freezing Rain	-3	25	Kilfrost P1792 (Type II)	100	Plate	
128	Light Freezing Rain	-3	25	Kilfrost P1792 (Type II)	100	Plate	
129	Light Freezing Rain	-3	25	Kilfrost P1792 (Type II)	75	Plate	
130	Light Freezing Rain	-3	25	Kilfrost P1792 (Type II)	75	Plate	
131	Light Freezing Rain	-3	25	Kilfrost P1792 (Type II)	50	Plate	
132	Light Freezing Rain	-3	25	Kilfrost P1792 (Type II)	50	Plate	
133	Light Freezing Rain	-3	25	Kilfrost P1797 (Type IV)	100	Plate	
134	Light Freezing Rain	-3	25	Kilfrost P1797 (Type IV)	100	Plate	
135	Light Freezing Rain	-3	25	Kilfrost P1797 (Type IV)	75	Plate	
136	Light Freezing Rain	-3	25	Kilfrost P1797 (Type IV)	75	Plate	
137	Light Freezing Rain	-3	25	Kilfrost P1797 (Type IV)	50	Plate	
138	Light Freezing Rain	-3	25	Kilfrost P1797 (Type IV)	50	Plate	
139	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch	100	Plate	
140	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch	100	Plate	
141	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch	75	Plate	
142	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch	75	Plate	
143	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch	50	Plate	
144	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch	50	Plate	
145	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch 2	100	Plate	
146	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch 2	100	Plate	
147	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch 2	75	Plate	Doubles as Test C9c
148	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch 2	75	Plate	
149	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch 2	50	Plate	
150	Light Freezing Rain	-3	13	Clariant Safewing MP IV Launch 2	50	Plate	
151	Light Freezing Rain	-3	13	Dow 200600147-10 (Type IV)	100	Plate	
152	Light Freezing Rain	-3	13	Dow 200600147-10 (Type IV)	100	Plate	
153	Light Freezing Rain	-3	13	Dow 200600147-10 (Type IV)	75	Plate	
154	Light Freezing Rain	-3	13	Dow 200600147-10 (Type IV)	75	Plate	
155	Light Freezing Rain	-3	13	Dow 200600147-10 (Type IV)	50	Plate	
156	Light Freezing Rain	-3	13	Dow 200600147-10 (Type IV)	50	Plate	
157	Light Freezing Rain	-3	13	Kilfrost P1792 (Type II)	100	Plate	
158	Light Freezing Rain	-3	13	Kilfrost P1792 (Type II)	100	Plate	
159	Light Freezing Rain	-3	13	Kilfrost P1792 (Type II)	75	Plate	
160	Light Freezing Rain	-3	13	Kilfrost P1792 (Type II)	75	Plate	
161	Light Freezing Rain	-3	13	Kilfrost P1792 (Type II)	50	Plate	
162	Light Freezing Rain	-3	13	Kilfrost P1792 (Type II)	50	Plate	

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
163	Light Freezing Rain	-3	13	Kilfrost P1797 (Type IV)	100	Plate	
164	Light Freezing Rain	-3	13	Kilfrost P1797 (Type IV)	100	Plate	
165	Light Freezing Rain	-3	13	Kilfrost P1797 (Type IV)	75	Plate	
166	Light Freezing Rain	-3	13	Kilfrost P1797 (Type IV)	75	Plate	
167	Light Freezing Rain	-3	13	Kilfrost P1797 (Type IV)	50	Plate	
168	Light Freezing Rain	-3	13	Kilfrost P1797 (Type IV)	50	Plate	
169	Light Freezing Rain	-10	25	Batelle D3 ADF	10°buf. (34.75)	Plate	Apply fluid at 20±5°C, isalso Test C14c
170	Light Freezing Rain	-10	25	Batelle D3 ADF	10°buf. (34.75)	Plate	Apply fluid at 20±5°C
171	Light Freezing Rain	-10	25	Clariant Safewing MP IV Launch	100	Plate	
172	Light Freezing Rain	-10	25	Clariant Safewing MP IV Launch	100	Plate	
173	Light Freezing Rain	-10	25	Clariant Safewing MP IV Launch	75	Plate	
174	Light Freezing Rain	-10	25	Clariant Safewing MP IV Launch	75	Plate	
175	Light Freezing Rain	-10	25	Clariant Safewing MP IV Launch 2	100	Plate	Doubles as Test C13c
176	Light Freezing Rain	-10	25	Clariant Safewing MP IV Launch 2	100	Plate	
177	Light Freezing Rain	-10	25	Clariant Safewing MP IV Launch 2	75	Plate	
178	Light Freezing Rain	-10	25	Clariant Safewing MP IV Launch 2	75	Plate	
179	Light Freezing Rain	-10	25	Dow 200600147-10 (Type IV)	100	Plate	
180	Light Freezing Rain	-10	25	Dow 200600147-10 (Type IV)	100	Plate	
181	Light Freezing Rain	-10	25	Dow 200600147-10 (Type IV)	75	Plate	
182	Light Freezing Rain	-10	25	Dow 200600147-10 (Type IV)	75	Plate	
183	Light Freezing Rain	-10	25	Kilfrost P1792 (Type II)	100	Plate	
184	Light Freezing Rain	-10	25	Kilfrost P1792 (Type II)	100	Plate	
185	Light Freezing Rain	-10	25	Kilfrost P1792 (Type II)	75	Plate	
186	Light Freezing Rain	-10	25	Kilfrost P1792 (Type II)	75	Plate	
187	Light Freezing Rain	-10	25	Kilfrost P1797 (Type IV)	100	Plate	
188	Light Freezing Rain	-10	25	Kilfrost P1797 (Type IV)	100	Plate	
189	Light Freezing Rain	-10	25	Kilfrost P1797 (Type IV)	75	Plate	
190	Light Freezing Rain	-10	25	Kilfrost P1797 (Type IV)	75	Plate	
191	Light Freezing Rain	-10	13	Batelle D3 ADF	10°buf. (34.75)	Plate	Apply fluid at 20±5°C, is also Test C12c
192	Light Freezing Rain	-10	13	Batelle D3 ADF	10°buf. (34.75)	Plate	Apply fluid at 20±5°C
193	Light Freezing Rain	-10	13	Clariant Safewing MP IV Launch	100	Plate	
194	Light Freezing Rain	-10	13	Clariant Safewing MP IV Launch	100	Plate	
195	Light Freezing Rain	-10	13	Clariant Safewing MP IV Launch	75	Plate	
196	Light Freezing Rain	-10	13	Clariant Safewing MP IV Launch	75	Plate	
197	Light Freezing Rain	-10	13	Clariant Safewing MP IV Launch 2	100	Plate	Doubles as Test C11c
198	Light Freezing Rain	-10	13	Clariant Safewing MP IV Launch 2	100	Plate	
199	Light Freezing Rain	-10	13	Clariant Safewing MP IV Launch 2	75	Plate	
200	Light Freezing Rain	-10	13	Clariant Safewing MP IV Launch 2	75	Plate	
201	Light Freezing Rain	-10	13	Dow 200600147-10 (Type IV)	100	Plate	
202	Light Freezing Rain	-10	13	Dow 200600147-10 (Type IV)	100	Plate	
203	Light Freezing Rain	-10	13	Dow 200600147-10 (Type IV)	75	Plate	
204	Light Freezing Rain	-10	13	Dow 200600147-10 (Type IV)	75	Plate	
205	Light Freezing Rain	-10	13	Kilfrost P1792 (Type II)	100	Plate	
206	Light Freezing Rain	-10	13	Kilfrost P1792 (Type II)	100	Plate	
207	Light Freezing Rain	-10	13	Kilfrost P1792 (Type II)	75	Plate	
208	Light Freezing Rain	-10	13	Kilfrost P1792 (Type II)	75	Plate	
209	Light Freezing Rain	-10	13	Kilfrost P1797 (Type IV)	100	Plate	
210	Light Freezing Rain	-10	13	Kilfrost P1797 (Type IV)	100	Plate	
211	Light Freezing Rain	-10	13	Kilfrost P1797 (Type IV)	75	Plate	
212	Light Freezing Rain	-10	13	Kilfrost P1797 (Type IV)	75	Plate	
213	Freezing Fog	-3	5	Batelle D3 ADF	10°buf. (26.75)	Plate	Apply fluid at 20±5°C
214	Freezing Fog	-3	5	Batelle D3 ADF	10°buf. (26.75)	Plate	Apply fluid at 20±5°C
215	Freezing Fog	-3	5	Clariant Safewing MP IV Launch	100	Plate	
216	Freezing Fog	-3	5	Clariant Safewing MP IV Launch	100	Plate	

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
217	Freezing Fog	-3	5	Clariant Safewing MP IV Launch	75	Plate	
218	Freezing Fog	-3	5	Clariant Safewing MP IV Launch	75	Plate	
219	Freezing Fog	-3	5	Clariant Safewing MP IV Launch	50	Plate	
220	Freezing Fog	-3	5	Clariant Safewing MP IV Launch	50	Plate	
221	Freezing Fog	-3	5	Clariant Safewing MP IV Launch 2	100	Plate	
222	Freezing Fog	-3	5	Clariant Safewing MP IV Launch 2	100	Plate	
223	Freezing Fog	-3	5	Clariant Safewing MP IV Launch 2	75	Plate	
224	Freezing Fog	-3	5	Clariant Safewing MP IV Launch 2	75	Plate	
225	Freezing Fog	-3	5	Clariant Safewing MP IV Launch 2	50	Plate	
226	Freezing Fog	-3	5	Clariant Safewing MP IV Launch 2	50	Plate	
227	Freezing Fog	-3	5	Dow 200600147-10 (Type IV)	100	Plate	
228	Freezing Fog	-3	5	Dow 200600147-10 (Type IV)	100	Plate	
229	Freezing Fog	-3	5	Dow 200600147-10 (Type IV)	75	Plate	
230	Freezing Fog	-3	5	Dow 200600147-10 (Type IV)	75	Plate	
231	Freezing Fog	-3	5	Dow 200600147-10 (Type IV)	50	Plate	
232	Freezing Fog	-3	5	Dow 200600147-10 (Type IV)	50	Plate	
233	Freezing Fog	-3	5	Kilfrost P1792 (Type II)	100	Plate	
234	Freezing Fog	-3	5	Kilfrost P1792 (Type II)	100	Plate	
235	Freezing Fog	-3	5	Kilfrost P1792 (Type II)	75	Plate	
236	Freezing Fog	-3	5	Kilfrost P1792 (Type II)	75	Plate	
237	Freezing Fog	-3	5	Kilfrost P1792 (Type II)	50	Plate	
238	Freezing Fog	-3	5	Kilfrost P1792 (Type II)	50	Plate	
239	Freezing Fog	-3	5	Kilfrost P1797 (Type IV)	100	Plate	
240	Freezing Fog	-3	5	Kilfrost P1797 (Type IV)	100	Plate	
241	Freezing Fog	-3	5	Kilfrost P1797 (Type IV)	75	Plate	
242	Freezing Fog	-3	5	Kilfrost P1797 (Type IV)	75	Plate	
243	Freezing Fog	-3	5	Kilfrost P1797 (Type IV)	50	Plate	
244	Freezing Fog	-3	5	Kilfrost P1797 (Type IV)	50	Plate	
245	Freezing Fog	-3	2	Batelle D3 ADF	10°buf. (26.75)	Plate	Apply fluid at 20±5°C
246	Freezing Fog	-3	2	Batelle D3 ADF	10°buf. (26.75)	Plate	Apply fluid at 20±5°C
247	Freezing Fog	-3	2	Clariant Safewing MP IV Launch	100	Plate	
248	Freezing Fog	-3	2	Clariant Safewing MP IV Launch	100	Plate	
249	Freezing Fog	-3	2	Clariant Safewing MP IV Launch	75	Plate	
250	Freezing Fog	-3	2	Clariant Safewing MP IV Launch	75	Plate	
251	Freezing Fog	-3	2	Clariant Safewing MP IV Launch	50	Plate	
252	Freezing Fog	-3	2	Clariant Safewing MP IV Launch	50	Plate	
253	Freezing Fog	-3	2	Clariant Safewing MP IV Launch 2	100	Plate	
254	Freezing Fog	-3	2	Clariant Safewing MP IV Launch 2	100	Plate	
255	Freezing Fog	-3	2	Clariant Safewing MP IV Launch 2	75	Plate	
256	Freezing Fog	-3	2	Clariant Safewing MP IV Launch 2	75	Plate	
257	Freezing Fog	-3	2	Clariant Safewing MP IV Launch 2	50	Plate	
258	Freezing Fog	-3	2	Clariant Safewing MP IV Launch 2	50	Plate	
259	Freezing Fog	-3	2	Dow 200600147-10 (Type IV)	100	Plate	
260	Freezing Fog	-3	2	Dow 200600147-10 (Type IV)	100	Plate	
261	Freezing Fog	-3	2	Dow 200600147-10 (Type IV)	75	Plate	
262	Freezing Fog	-3	2	Dow 200600147-10 (Type IV)	75	Plate	
263	Freezing Fog	-3	2	Dow 200600147-10 (Type IV)	50	Plate	
264	Freezing Fog	-3	2	Dow 200600147-10 (Type IV)	50	Plate	
265	Freezing Fog	-3	2	Kilfrost P1792 (Type II)	100	Plate	
266	Freezing Fog	-3	2	Kilfrost P1792 (Type II)	100	Plate	
267	Freezing Fog	-3	2	Kilfrost P1792 (Type II)	75	Plate	
268	Freezing Fog	-3	2	Kilfrost P1792 (Type II)	75	Plate	
269	Freezing Fog	-3	2	Kilfrost P1792 (Type II)	50	Plate	
270	Freezing Fog	-3	2	Kilfrost P1792 (Type II)	50	Plate	

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
271	Freezing Fog	-3	2	Kilfrost P1797 (Type IV)	100	Plate	
272	Freezing Fog	-3	2	Kilfrost P1797 (Type IV)	100	Plate	
273	Freezing Fog	-3	2	Kilfrost P1797 (Type IV)	75	Plate	
274	Freezing Fog	-3	2	Kilfrost P1797 (Type IV)	75	Plate	
275	Freezing Fog	-3	2	Kilfrost P1797 (Type IV)	50	Plate	
276	Freezing Fog	-3	2	Kilfrost P1797 (Type IV)	50	Plate	
277	Freezing Fog	-14	5	Batelle D3 ADF	10°buf. (38.50)	Plate	Apply fluid at 20±5°C
278	Freezing Fog	-14	5	Batelle D3 ADF	10°buf. (38.50)	Plate	Apply fluid at 20±5°C
279	Freezing Fog	-14	5	Clariant Safewing MP IV Launch	100	Plate	
280	Freezing Fog	-14	5	Clariant Safewing MP IV Launch	100	Plate	
281	Freezing Fog	-14	5	Clariant Safewing MP IV Launch	75	Plate	
282	Freezing Fog	-14	5	Clariant Safewing MP IV Launch	75	Plate	
283	Freezing Fog	-14	5	Clariant Safewing MP IV Launch 2	100	Plate	
284	Freezing Fog	-14	5	Clariant Safewing MP IV Launch 2	100	Plate	
285	Freezing Fog	-14	5	Clariant Safewing MP IV Launch 2	75	Plate	
286	Freezing Fog	-14	5	Clariant Safewing MP IV Launch 2	75	Plate	
287	Freezing Fog	-14	5	Dow 200600147-10 (Type IV)	100	Plate	
288	Freezing Fog	-14	5	Dow 200600147-10 (Type IV)	100	Plate	
289	Freezing Fog	-14	5	Dow 200600147-10 (Type IV)	75	Plate	
290	Freezing Fog	-14	5	Dow 200600147-10 (Type IV)	75	Plate	
291	Freezing Fog	-14	5	Kilfrost P1792 (Type II)	100	Plate	
292	Freezing Fog	-14	5	Kilfrost P1792 (Type II)	100	Plate	
293	Freezing Fog	-14	5	Kilfrost P1792 (Type II)	75	Plate	
294	Freezing Fog	-14	5	Kilfrost P1792 (Type II)	75	Plate	
295	Freezing Fog	-14	5	Kilfrost P1797 (Type IV)	100	Plate	
296	Freezing Fog	-14	5	Kilfrost P1797 (Type IV)	100	Plate	
297	Freezing Fog	-14	5	Kilfrost P1797 (Type IV)	75	Plate	
298	Freezing Fog	-14	5	Kilfrost P1797 (Type IV)	75	Plate	
299	Freezing Fog	-14	2	Batelle D3 ADF	10°buf. (38.50)	Plate	Apply fluid at 20±5°C
300	Freezing Fog	-14	2	Batelle D3 ADF	10°buf. (38.50)	Plate	Apply fluid at 20±5°C
301	Freezing Fog	-14	2	Clariant Safewing MP IV Launch	100	Plate	
302	Freezing Fog	-14	2	Clariant Safewing MP IV Launch	100	Plate	
303	Freezing Fog	-14	2	Clariant Safewing MP IV Launch	75	Plate	
304	Freezing Fog	-14	2	Clariant Safewing MP IV Launch	75	Plate	
305	Freezing Fog	-14	2	Clariant Safewing MP IV Launch 2	100	Plate	
306	Freezing Fog	-14	2	Clariant Safewing MP IV Launch 2	100	Plate	
307	Freezing Fog	-14	2	Clariant Safewing MP IV Launch 2	75	Plate	
308	Freezing Fog	-14	2	Clariant Safewing MP IV Launch 2	75	Plate	
309	Freezing Fog	-14	2	Dow 200600147-10 (Type IV)	100	Plate	
310	Freezing Fog	-14	2	Dow 200600147-10 (Type IV)	100	Plate	
311	Freezing Fog	-14	2	Dow 200600147-10 (Type IV)	75	Plate	
312	Freezing Fog	-14	2	Dow 200600147-10 (Type IV)	75	Plate	
313	Freezing Fog	-14	2	Kilfrost P1792 (Type II)	100	Plate	
314	Freezing Fog	-14	2	Kilfrost P1792 (Type II)	100	Plate	
315	Freezing Fog	-14	2	Kilfrost P1792 (Type II)	75	Plate	
316	Freezing Fog	-14	2	Kilfrost P1792 (Type II)	75	Plate	
317	Freezing Fog	-14	2	Kilfrost P1797 (Type IV)	100	Plate	
318	Freezing Fog	-14	2	Kilfrost P1797 (Type IV)	100	Plate	
319	Freezing Fog	-14	2	Kilfrost P1797 (Type IV)	75	Plate	
320	Freezing Fog	-14	2	Kilfrost P1797 (Type IV)	75	Plate	
321	Freezing Fog	-25	5	Batelle D3 ADF	10°buf. (46.00)	Plate	Apply fluid at 20±5°C
322	Freezing Fog	-25	5	Batelle D3 ADF	10°buf. (46.00)	Plate	Apply fluid at 20±5°C
323	Freezing Fog	-25	5	Clariant Safewing MP IV Launch	100	Plate	
324	Freezing Fog	-25	5	Clariant Safewing MP IV Launch	100	Plate	

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
325	Freezing Fog	-25	5	Clariant Safewing MP IV Launch 2	100	Plate	
326	Freezing Fog	-25	5	Clariant Safewing MP IV Launch 2	100	Plate	
327	Freezing Fog	-25	5	Dow 200600147-10 (Type IV)	100	Plate	
328	Freezing Fog	-25	5	Dow 200600147-10 (Type IV)	100	Plate	
329	Freezing Fog	-25	5	Kilfrost P1792 (Type II)	100	Plate	
330	Freezing Fog	-25	5	Kilfrost P1792 (Type II)	100	Plate	
331	Freezing Fog	-25	5	Kilfrost P1797 (Type IV)	100	Plate	
332	Freezing Fog	-25	5	Kilfrost P1797 (Type IV)	100	Plate	
333	Freezing Fog	-25	2	Batelle D3 ADF	10°buf. (46.00)	Plate	Apply fluid at 20±5°C
334	Freezing Fog	-25	2	Batelle D3 ADF	10°buf. (46.00)	Plate	Apply fluid at 20±5°C
335	Freezing Fog	-25	2	Clariant Safewing MP IV Launch	100	Plate	
336	Freezing Fog	-25	2	Clariant Safewing MP IV Launch	100	Plate	
337	Freezing Fog	-25	2	Clariant Safewing MP IV Launch 2	100	Plate	
338	Freezing Fog	-25	2	Clariant Safewing MP IV Launch 2	100	Plate	
339	Freezing Fog	-25	2	Dow 200600147-10 (Type IV)	100	Plate	
340	Freezing Fog	-25	2	Dow 200600147-10 (Type IV)	100	Plate	
341	Freezing Fog	-25	2	Kilfrost P1792 (Type II)	100	Plate	
342	Freezing Fog	-25	2	Kilfrost P1792 (Type II)	100	Plate	
343	Freezing Fog	-25	2	Kilfrost P1797 (Type IV)	100	Plate	
344	Freezing Fog	-25	2	Kilfrost P1797 (Type IV)	100	Plate	
345	Cold Soak Box	1	75	Batelle D3 ADF	10°buf. (21.25)	Plate	Apply fluid at 20±5°C
346	Cold Soak Box	1	75	Batelle D3 ADF	10°buf. (21.25)	Plate	Apply fluid at 20±5°C
347	Cold Soak Box	1	75	Clariant Safewing MP IV Launch	100	Box	
348	Cold Soak Box	1	75	Clariant Safewing MP IV Launch	100	Box	
349	Cold Soak Box	1	75	Clariant Safewing MP IV Launch	75	Box	
350	Cold Soak Box	1	75	Clariant Safewing MP IV Launch	75	Box	
351	Cold Soak Box	1	75	Clariant Safewing MP IV Launch 2	100	Box	
352	Cold Soak Box	1	75	Clariant Safewing MP IV Launch 2	100	Box	
353	Cold Soak Box	1	75	Clariant Safewing MP IV Launch 2	75	Box	
354	Cold Soak Box	1	75	Clariant Safewing MP IV Launch 2	75	Box	
355	Cold Soak Box	1	75	Dow 200600147-10 (Type IV)	100	Box	
356	Cold Soak Box	1	75	Dow 200600147-10 (Type IV)	100	Box	
357	Cold Soak Box	1	75	Dow 200600147-10 (Type IV)	75	Box	
358	Cold Soak Box	1	75	Dow 200600147-10 (Type IV)	75	Box	
359	Cold Soak Box	1	75	Kilfrost P1792 (Type II)	100	Box	
360	Cold Soak Box	1	75	Kilfrost P1792 (Type II)	100	Box	
361	Cold Soak Box	1	75	Kilfrost P1792 (Type II)	75	Box	
362	Cold Soak Box	1	75	Kilfrost P1792 (Type II)	75	Box	
363	Cold Soak Box	1	75	Kilfrost P1797 (Type IV)	100	Box	
364	Cold Soak Box	1	75	Kilfrost P1797 (Type IV)	100	Box	
365	Cold Soak Box	1	75	Kilfrost P1797 (Type IV)	75	Box	
366	Cold Soak Box	1	75	Kilfrost P1797 (Type IV)	75	Box	
367	Cold Soak Box	1	5	Batelle D3 ADF	10°buf. (21.25)	Plate	Apply fluid at 20±5°C
368	Cold Soak Box	1	5	Batelle D3 ADF	10°buf. (21.25)	Plate	Apply fluid at 20±5°C
369	Cold Soak Box	1	5	Clariant Safewing MP IV Launch	100	Box	
370	Cold Soak Box	1	5	Clariant Safewing MP IV Launch	100	Box	
371	Cold Soak Box	1	5	Clariant Safewing MP IV Launch	75	Box	
372	Cold Soak Box	1	5	Clariant Safewing MP IV Launch	75	Box	
373	Cold Soak Box	1	5	Clariant Safewing MP IV Launch 2	100	Box	
374	Cold Soak Box	1	5	Clariant Safewing MP IV Launch 2	100	Box	
375	Cold Soak Box	1	5	Clariant Safewing MP IV Launch 2	75	Box	
376	Cold Soak Box	1	5	Clariant Safewing MP IV Launch 2	75	Box	
377	Cold Soak Box	1	5	Dow 200600147-10 (Type IV)	100	Box	
378	Cold Soak Box	1	5	Dow 200600147-10 (Type IV)	100	Box	

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
379	Cold Soak Box	1	5	Dow 200600147-10 (Type IV)	75	Box	
380	Cold Soak Box	1	5	Dow 200600147-10 (Type IV)	75	Box	
381	Cold Soak Box	1	5	Kilfrost P1792 (Type II)	100	Box	
382	Cold Soak Box	1	5	Kilfrost P1792 (Type II)	100	Box	
383	Cold Soak Box	1	5	Kilfrost P1792 (Type II)	75	Box	
384	Cold Soak Box	1	5	Kilfrost P1792 (Type II)	75	Box	
385	Cold Soak Box	1	5	Kilfrost P1797 (Type IV)	100	Box	
386	Cold Soak Box	1	5	Kilfrost P1797 (Type IV)	100	Box	
387	Cold Soak Box	1	5	Kilfrost P1797 (Type IV)	75	Box	
388	Cold Soak Box	1	5	Kilfrost P1797 (Type IV)	75	Box	
B1	Freezing Drizzle	-3	5	Octagon Octaflo EF (PG Type I)	10°buf. (21.25)	Plate	Run B1, B2, B3 concurrently
B2	Freezing Drizzle	-3	5	Octagon Octaflo EF (PG Type I)	0°buf. (6)	Plate	Run B1, B2, B3 concurrently
B3	Freezing Drizzle	-3	5	Octagon Octaflo EF (PG Type I)	-3°buf. (0)	Plate	Run B1, B2, B3 concurrently
B4	Freezing Drizzle	-10	13	Dow UCAR ADF (EG Type I)	10°buf. (22.5)	Plate	Run B4, B5, B6 concurrently
B5	Freezing Drizzle	-10	13	Dow UCAR ADF (EG Type I)	0°buf. (14)	Plate	Run B4, B5, B6 concurrently
B6	Freezing Drizzle	-10	13	Dow UCAR ADF (EG Type I)	-3°buf. (10.5)	Plate	Run B4, B5, B6 concurrently
B7	Light Freezing Rain	-10	25	Octagon Octaflo EF (PG Type I)	10°buf. (27)	Plate	Run B7, B8, B9 concurrently
B8	Light Freezing Rain	-10	25	Octagon Octaflo EF (PG Type I)	0°buf. (19)	Plate	Run B7, B8, B9 concurrently
B9	Light Freezing Rain	-10	25	Octagon Octaflo EF (PG Type I)	-3°buf. (24)	Plate	Run B7, B8, B9 concurrently
B10	Light Freezing Rain	-3	13	Dow UCAR ADF (EG Type I)	10°buf. (17)	Plate	Run B10, B11, B12 concurrently
B11	Light Freezing Rain	-3	13	Dow UCAR ADF (EG Type I)	0°buf. (4.75)	Plate	Run B10, B11, B12 concurrently
B12	Light Freezing Rain	-3	13	Dow UCAR ADF (EG Type I)	-3°buf. (0)	Plate	Run B10, B11, B12 concurrently
B13	Freezing Fog	-25	2	Octagon Octaflo EF (PG Type I)	10°buf. (34.5)	Plate	Run B13, B14, B15 concurrently
B14	Freezing Fog	-25	2	Octagon Octaflo EF (PG Type I)	0°buf. (30)	Plate	Run B13, B14, B15 concurrently
B15	Freezing Fog	-25	2	Octagon Octaflo EF (PG Type I)	-3°buf. (28.5)	Plate	Run B13, B14, B15 concurrently
AS1	Freezing Drizzle	-10	25	Clariant Safewing MP IV Launch	100	A/S Plate	
AS2	Freezing Drizzle	-10	25	Kilfrost P1792 (Type II)	50	A/S Plate	
AS3	Freezing Fog	-3	2	Batelle D3 ADF	10°buf. (26.75)	A/S Plate	
AS4	Freezing Fog	-3	2	Clariant Safewing MP IV Launch	100	A/S Plate	
AS5	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)	100	A/S Plate	
AS6	Freezing Drizzle	-3	13	Batelle D3 ADF	10°buf. (26.75)	A/S Plate	
AS7	Freezing Fog	-14	5	Batelle D3 ADF	10°buf. (38.50)	A/S Plate	
AS8	Freezing Fog	-14	5	Kilfrost P1792 (Type II)	100	A/S Plate	
AS9	Freezing Fog	-3	5	Clariant Safewing MP IV Launch	75	A/S Plate	
AS10	Freezing Fog	-3	5	Kilfrost P1792 (Type II)	75	A/S Plate	
AS11	Freezing Rain	-3	25	Batelle D3 ADF	10°buf. (26.75)	A/S Plate	
AS12	Freezing Rain	-3	25	Clariant Safewing MP IV Launch	75	A/S Plate	

Note: A/S = Airsilk

ATTACHMENT III: FLUID THICKNESS TEST PLAN

Test #	Fluid Manufacturer	Fluid Name	Fluid Dilution	Ambient Air Temperature
TH1	Kilfrost	P1797 (Type IV)	100/0	-3°C
TH2	Kilfrost	P1797 (Type IV)	100/0	-3°C
TH3	Kilfrost	P1797 (Type IV)	75/25	-3°C
TH4	Kilfrost	P1797 (Type IV)	75/25	-3°C
TH5	Kilfrost	P1797 (Type IV)	50/50	-3°C
TH6	Kilfrost	P1797 (Type IV)	50/50	-3°C
TH7	Dow	200600147-10 (Type IV)	100/0	-3°C
TH8	Dow	200600147-10 (Type IV)	100/0	-3°C
TH9	Dow	200600147-10 (Type IV)	75/25	-3°C
TH10	Dow	200600147-10 (Type IV)	75/25	-3°C
TH11	Dow	200600147-10 (Type IV)	50/50	-3°C
TH12	Dow	200600147-10 (Type IV)	50/50	-3°C
TH13	Clariant	Safewing MP IV Launch	100/0	-3°C
TH14	Clariant	Safewing MP IV Launch	100/0	-3°C
TH15	Clariant	Safewing MP IV Launch	75/25	-3°C
TH16	Clariant	Safewing MP IV Launch	75/25	-3°C
TH17	Clariant	Safewing MP IV Launch	50/50	-3°C
TH18	Clariant	Safewing MP IV Launch	50/50	-3°C
TH19	Clariant	Safewing MP IV Launch 2	100/0	-3°C
TH20	Clariant	Safewing MP IV Launch 2	100/0	-3°C
TH21	Clariant	Safewing MP IV Launch 2	75/25	-3°C
TH22	Clariant	Safewing MP IV Launch 2	75/25	-3°C
TH23	Clariant	Safewing MP IV Launch 2	50/50	-3°C
TH24	Clariant	Safewing MP IV Launch 2	50/50	-3°C
TH25	Kilfrost	P1792 (Type II)	100/0	-3°C
TH26	Kilfrost	P1792 (Type II)	100/0	-3°C
TH27	Kilfrost	P1792 (Type II)	75/25	-3°C
TH28	Kilfrost	P1792 (Type II)	75/25	-3°C
TH29	Kilfrost	P1792 (Type II)	50/50	-3°C
TH30	Kilfrost	P1792 (Type II)	50/50	-3°C
TH31	Batelle	D3 ADF	10°buf. (26.75)	-3°C
TH32	Batelle	D3 ADF	10°buf. (26.75)	-3°C

Notes:

- If the results for one fluid vary by more than 10% repeat the two tests and disregard the highest and lowest values
- The quantity of fluid that will be poured for each test is 1.0 L

ATTACHMENT IV: EFFECT OF HEAT TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
H1a	Freezing Drizzle	-10	5	Clariant Safewing MP III 2031 ECO	100	Plate	Heat fluid to 60°C, use spreader
H1b	Freezing Drizzle	-10	5	Clariant Safewing MP III 2031 ECO	100	Plate	Apply fluid at OAT
H2a	Freezing Drizzle	-10	5	Octagon MaxFlo	75	Plate	Heat fluid to 60°C, use spreader
H2b	Freezing Drizzle	-10	5	Octagon MaxFlo	75	Plate	Apply fluid at OAT
H3a	Freezing Drizzle	-10	5	Kilfrost ABC 2000	100	Plate	Heat fluid to 60°C, use spreader
H3b	Freezing Drizzle	-10	5	Kilfrost ABC 2000	100	Plate	Apply fluid at OAT
H4a	Freezing Drizzle	-10	13	Clariant Safewing MP III 2031 ECO	75	Plate	Heat fluid to 60°C, use spreader
H4b	Freezing Drizzle	-10	13	Clariant Safewing MP III 2031 ECO	75	Plate	Apply fluid at OAT
H5a	Freezing Drizzle	-10	13	Octagon MaxFlo	100	Plate	Heat fluid to 60°C, use spreader
H5b	Freezing Drizzle	-10	13	Octagon MaxFlo	100	Plate	Apply fluid at OAT
H6a	Freezing Drizzle	-10	13	Kilfrost ABC 2000	75	Plate	Heat fluid to 60°C, use spreader
H6b	Freezing Drizzle	-10	13	Kilfrost ABC 2000	75	Plate	Apply fluid at OAT
H7a	Freezing Drizzle	-10	13	Kilfrost ABC 2000	100	Plate	Heat fluid to 60°C, use spreader
H7b	Freezing Drizzle	-10	13	Kilfrost ABC 2000	100	Plate	Apply fluid at OAT
H8a	Light Freezing Rain	-3	13	Clariant Safewing MP III 2031 ECO	75	Plate	Heat fluid to 60°C, use spreader
H8b	Light Freezing Rain	-3	13	Clariant Safewing MP III 2031 ECO	75	Plate	Apply fluid at OAT
H9a	Light Freezing Rain	-3	13	Octagon MaxFlo	50	Plate	Heat fluid to 60°C, use spreader
H9b	Light Freezing Rain	-3	13	Octagon MaxFlo	50	Plate	Apply fluid at OAT
H10a	Light Freezing Rain	-3	13	Kilfrost ABC 2000	75	Plate	Heat fluid to 60°C, use spreader
H10b	Light Freezing Rain	-3	13	Kilfrost ABC 2000	75	Plate	Apply fluid at OAT
H11a	Light Freezing Rain	-3	13	Clariant Safewing MP III 2031 ECO	100	Plate	Heat fluid to 60°C, use spreader
H11b	Light Freezing Rain	-3	13	Clariant Safewing MP III 2031 ECO	100	Plate	Apply fluid at OAT
H12a	Light Freezing Rain	-3	13	Octagon MaxFlo	100	Plate	Heat fluid to 60°C, use spreader
H12b	Light Freezing Rain	-3	13	Octagon MaxFlo	100	Plate	Apply fluid at OAT
H13a	Light Freezing Rain	-3	13	Kilfrost ABC 2000	50	Plate	Heat fluid to 60°C, use spreader
H13b	Light Freezing Rain	-3	13	Kilfrost ABC 2000	50	Plate	Apply fluid at OAT
H14a	Light Freezing Rain	-3	13	Clariant Safewing MP III 2031 ECO	50	Plate	Heat fluid to 60°C, use spreader
H14b	Light Freezing Rain	-3	13	Clariant Safewing MP III 2031 ECO	50	Plate	Apply fluid at OAT
H15a	Freezing Drizzle	-3	5	Clariant Safewing MP III 2031 ECO	50	Plate	Heat fluid to 60°C, use spreader
H15b	Freezing Drizzle	-3	5	Clariant Safewing MP III 2031 ECO	50	Plate	Apply fluid at OAT
H16a	Freezing Drizzle	-3	5	Kilfrost ABC 2000	75	Plate	Heat fluid to 60°C, use spreader
H16b	Freezing Drizzle	-3	5	Kilfrost ABC 2000	75	Plate	Apply fluid at OAT
H17a	Freezing Drizzle	-3	5	Dow/UCAR Ultra+	100	Plate	Heat fluid to 60°C, use spreader
H17b	Freezing Drizzle	-3	5	Dow/UCAR Ultra+	100	Plate	Apply fluid at OAT
H18a	Freezing Drizzle	-3	5	Kilfrost ABC 2000	100	Plate	Heat fluid to 60°C, use spreader
H18b	Freezing Drizzle	-3	5	Kilfrost ABC 2000	100	Plate	Apply fluid at OAT
H19a	Freezing Drizzle	-3	5	Kilfrost ABC 2000	50	Plate	Heat fluid to 60°C, use spreader
H19b	Freezing Drizzle	-3	5	Kilfrost ABC 2000	50	Plate	Apply fluid at OAT
H20a	Freezing Drizzle	-3	13	Clariant Safewing MP III 2031 ECO	100	Plate	Heat fluid to 60°C, use spreader
H20b	Freezing Drizzle	-3	13	Clariant Safewing MP III 2031 ECO	100	Plate	Apply fluid at OAT
H21a	Freezing Drizzle	-3	13	Clariant Safewing MP III 2031 ECO	75	Plate	Heat fluid to 60°C, use spreader
H21b	Freezing Drizzle	-3	13	Clariant Safewing MP III 2031 ECO	75	Plate	Apply fluid at OAT
H22a	Freezing Drizzle	-3	13	Octagon MaxFlo	50	Plate	Heat fluid to 60°C, use spreader
H22b	Freezing Drizzle	-3	13	Octagon MaxFlo	50	Plate	Apply fluid at OAT
H23a	Freezing Drizzle	-3	13	Kilfrost ABC 2000	50	Plate	Heat fluid to 60°C, use spreader
H23b	Freezing Drizzle	-3	13	Kilfrost ABC 2000	50	Plate	Apply fluid at OAT
H24a	Freezing Drizzle	-3	13	Kilfrost ABC 2000	100	Plate	Heat fluid to 60°C, use spreader
H24b	Freezing Drizzle	-3	13	Kilfrost ABC 2000	100	Plate	Apply fluid at OAT
H25a	Freezing Drizzle	-3	13	Octagon MaxFlo	100	Plate	Heat fluid to 60°C, use spreader
H25b	Freezing Drizzle	-3	13	Octagon MaxFlo	100	Plate	Apply fluid at OAT
H26a	Freezing Drizzle	-3	13	Dow/UCAR Ultra+	100	Plate	Heat fluid to 60°C, use spreader
H26b	Freezing Drizzle	-3	13	Dow/UCAR Ultra+	100	Plate	Apply fluid at OAT
H27a	Freezing Drizzle	-3	13	Octagon MaxFlo	75	Plate	Heat fluid to 60°C, use spreader
H27b	Freezing Drizzle	-3	13	Octagon MaxFlo	75	Plate	Apply fluid at OAT

ATTACHMENT IV: EFFECT OF HEAT TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
H28a	Light Freezing Rain	-10	25	Dow/UCAR Ultra+	100	Plate	Heat fluid to 60°C, use spreader
H28b	Light Freezing Rain	-10	25	Dow/UCAR Ultra+	100	Plate	Apply fluid at OAT
H29a	Light Freezing Rain	-10	25	Clariant Safewing MP III 2031 ECO	100	Plate	Heat fluid to 60°C, use spreader
H29b	Light Freezing Rain	-10	25	Clariant Safewing MP III 2031 ECO	100	Plate	Apply fluid at OAT
H30a	Light Freezing Rain	-10	25	Octagon MaxFlo	75	Plate	Heat fluid to 60°C, use spreader
H30b	Light Freezing Rain	-10	25	Octagon MaxFlo	75	Plate	Apply fluid at OAT
H31a	Light Freezing Rain	-10	25	Kilfrost ABC 2000	100	Plate	Heat fluid to 60°C, use spreader
H31b	Light Freezing Rain	-10	25	Kilfrost ABC 2000	100	Plate	Apply fluid at OAT
H32a	Light Freezing Rain	-10	25	Octagon MaxFlo	75	Plate	Heat fluid to 60°C, use spreader
H32b	Light Freezing Rain	-10	25	Octagon MaxFlo	75	Plate	Apply fluid at OAT
H33a	Light Freezing Rain	-10	13	Clariant Safewing MP III 2031 ECO	100	Plate	Heat fluid to 60°C, use spreader
H33b	Light Freezing Rain	-10	13	Clariant Safewing MP III 2031 ECO	100	Plate	Apply fluid at OAT
H34a	Light Freezing Rain	-10	13	Clariant Safewing MP III 2031 ECO	75	Plate	Heat fluid to 60°C, use spreader
H34b	Light Freezing Rain	-10	13	Clariant Safewing MP III 2031 ECO	75	Plate	Apply fluid at OAT
H35a	Light Freezing Rain	-10	13	Octagon MaxFlo	75	Plate	Heat fluid to 60°C, use spreader
H35b	Light Freezing Rain	-10	13	Octagon MaxFlo	75	Plate	Apply fluid at OAT
H36a	Light Freezing Rain	-10	13	Dow/UCAR Ultra+	100	Plate	Heat fluid to 60°C, use spreader
H36b	Light Freezing Rain	-10	13	Dow/UCAR Ultra+	100	Plate	Apply fluid at OAT
H37a	Light Freezing Rain	-3	25	Octagon MaxFlo	100	Plate	Heat fluid to 60°C, use spreader
H37b	Light Freezing Rain	-3	25	Octagon MaxFlo	100	Plate	Apply fluid at OAT
H38a	Light Freezing Rain	-3	25	Kilfrost ABC 2000	100	Plate	Heat fluid to 60°C, use spreader
H38b	Light Freezing Rain	-3	25	Kilfrost ABC 2000	100	Plate	Apply fluid at OAT
H39a	Light Freezing Rain	-3	25	Dow/UCAR Ultra+	100	Plate	Heat fluid to 60°C, use spreader
H39b	Light Freezing Rain	-3	25	Dow/UCAR Ultra+	100	Plate	Apply fluid at OAT
H40a	Light Freezing Rain	-3	25	Clariant Safewing MP III 2031 ECO	100	Plate	Heat fluid to 60°C, use spreader
H40b	Light Freezing Rain	-3	25	Clariant Safewing MP III 2031 ECO	100	Plate	Apply fluid at OAT
H41a	Light Freezing Rain	-3	25	Clariant Safewing MP III 2031 ECO	75	Plate	Heat fluid to 60°C, use spreader
H41b	Light Freezing Rain	-3	25	Clariant Safewing MP III 2031 ECO	75	Plate	Apply fluid at OAT
H42a	Light Freezing Rain	-3	25	Clariant Safewing MP III 2031 ECO	50	Plate	Heat fluid to 60°C, use spreader
H42b	Light Freezing Rain	-3	25	Clariant Safewing MP III 2031 ECO	50	Plate	Apply fluid at OAT
H43a	Light Freezing Rain	-3	25	Kilfrost ABC 2000	75	Plate	Heat fluid to 60°C, use spreader
H43b	Light Freezing Rain	-3	25	Kilfrost ABC 2000	75	Plate	Apply fluid at OAT
H44a	Light Freezing Rain	-3	25	Octagon MaxFlo	75	Plate	Heat fluid to 60°C, use spreader
H44b	Light Freezing Rain	-3	25	Octagon MaxFlo	75	Plate	Apply fluid at OAT
H45a	Light Freezing Rain	-3	25	Octagon MaxFlo	50	Plate	Heat fluid to 60°C, use spreader
H45b	Light Freezing Rain	-3	25	Octagon MaxFlo	50	Plate	Apply fluid at OAT
H46a	Light Freezing Rain	-3	25	Kilfrost ABC 2000	50	Plate	Heat fluid to 60°C, use spreader
H46b	Light Freezing Rain	-3	25	Kilfrost ABC 2000	50	Plate	Apply fluid at OAT

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ATTACHMENT V: EFFECT OF SURFACE MATERIAL TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution (BRIX)	Test Surface	Comments
C1a	Freezing Drizzle	-3	5	Kilfrost P1792 (Type II)*	50/50	White Al.	1 L, 12-hole spreader, 60°C
C1b	Freezing Drizzle	-3	5	Kilfrost P1792 (Type II)*	50/50	Comp 05	1 L, 12-hole spreader, 60°C
C1c	Freezing Drizzle	-3	5	Kilfrost P1792 (Type II)*	50/50	Plate	Do not run, see ET Test 57***
C2a	Freezing Drizzle	-3	5	Batelle D3 ADF**	10°buf (26.75)	White Al.	1 L, 12-hole spreader, 20°C
C2b	Freezing Drizzle	-3	5	Batelle D3 ADF**	10°buf (26.75)	Comp 05	1 L, 12-hole spreader, 20°C
C2c	Freezing Drizzle	-3	5	Batelle D3 ADF**	10°buf (26.75)	Plate	Do not run, see ET Test 33***
C3a	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)*	50/50	White Al.	1 L, 12-hole spreader, 60°C
C3b	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)*	50/50	Comp 05	1 L, 12-hole spreader, 60°C
C3c	Freezing Drizzle	-3	13	Kilfrost P1792 (Type II)*	50/50	Plate	Do not run, see ET Test 25***
C4a	Freezing Drizzle	-3	13	Batelle D3 ADF**	10°buf (26.75)	White Al.	1 L, 12-hole spreader, 20°C
C4b	Freezing Drizzle	-3	13	Batelle D3 ADF**	10°buf (26.75)	Comp 05	1 L, 12-hole spreader, 20°C
C4c	Freezing Drizzle	-3	13	Batelle D3 ADF**	10°buf (26.75)	Plate	Do not run, see ET Test 1***
C5a	Freezing Drizzle	-10	5	Kilfrost P1792 (Type II)*	75/25	White Al.	1 L, 12-hole spreader, 60°C
C5b	Freezing Drizzle	-10	5	Kilfrost P1792 (Type II)*	75/25	Comp 05	1 L, 12-hole spreader, 60°C
C5c	Freezing Drizzle	-10	5	Kilfrost P1792 (Type II)*	75/25	Plate	Do not run, see ET Test 103***
C6a	Freezing Drizzle	-10	5	Batelle D3 ADF**	10°buf (34.75)	White Al.	1 L, 12-hole spreader, 20°C
C6b	Freezing Drizzle	-10	5	Batelle D3 ADF**	10°buf (34.75)	Comp 05	1 L, 12-hole spreader, 20°C
C6c	Freezing Drizzle	-10	5	Batelle D3 ADF**	10°buf (34.75)	Plate	Do not run, see ET Test 87***
C7a	Freezing Drizzle	-10	13	Kilfrost P1792 (Type II)*	75/25	White Al.	1 L, 12-hole spreader, 60°C
C7b	Freezing Drizzle	-10	13	Kilfrost P1792 (Type II)*	75/25	Comp 05	1 L, 12-hole spreader, 60°C
C7c	Freezing Drizzle	-10	13	Kilfrost P1792 (Type II)*	75/25	Plate	Do not run, see ET Test 81***
C8a	Freezing Drizzle	-10	13	Batelle D3 ADF**	10°buf (34.75)	White Al.	1 L, 12-hole spreader, 20°C
C8b	Freezing Drizzle	-10	13	Batelle D3 ADF**	10°buf (34.75)	Comp 05	1 L, 12-hole spreader, 20°C
C8c	Freezing Drizzle	-10	13	Batelle D3 ADF**	10°buf (34.75)	Plate	Do not run, see ET Test 65***
C9a	Light Freezing Rain	-3	13	Clariant Safewing MPIV Launch 2	75/25	White Al.	1 L, 12-hole spreader, 60°C
C9b	Light Freezing Rain	-3	13	Clariant Safewing MPIV Launch 2	75/25	Comp 05	1 L, 12-hole spreader, 60°C
C9c	Light Freezing Rain	-3	13	Clariant Safewing MPIV Launch 2	75/25	Plate	Do not run, see ET Test 147***
C10a	Light Freezing Rain	-3	25	Clariant Safewing MPIV Launch 2	75/25	White Al.	1 L, 12-hole spreader, 60°C
C10b	Light Freezing Rain	-3	25	Clariant Safewing MPIV Launch 2	75/25	Comp 05	1 L, 12-hole spreader, 60°C
C10c	Light Freezing Rain	-3	25	Clariant Safewing MPIV Launch 2	75/25	Plate	Do not run, see ET Test 117***
C11a	Light Freezing Rain	-10	13	Clariant Safewing MPIV Launch 2	100/0	White Al.	1 L, 12-hole spreader, 60°C
C11b	Light Freezing Rain	-10	13	Clariant Safewing MPIV Launch 2	100/0	Comp 05	1 L, 12-hole spreader, 60°C
C11c	Light Freezing Rain	-10	13	Clariant Safewing MPIV Launch 2	100/0	Plate	Do not run, see ET Test 197***
C12a	Light Freezing Rain	-10	13	Batelle D3 ADF**	10°buf (34.75)	White Al.	1 L, 12-hole spreader, 20°C
C12b	Light Freezing Rain	-10	13	Batelle D3 ADF**	10°buf (34.75)	Comp 05	1 L, 12-hole spreader, 20°C
C12c	Light Freezing Rain	-10	13	Batelle D3 ADF**	10°buf (34.75)	Plate	Do not run, see ET Test 191***
C13a	Light Freezing Rain	-10	25	Clariant Safewing MPIV Launch 2	100/0	White Al.	1 L, 12-hole spreader, 60°C
C13b	Light Freezing Rain	-10	25	Clariant Safewing MPIV Launch 2	100/0	Comp 05	1 L, 12-hole spreader, 60°C
C13c	Light Freezing Rain	-10	25	Clariant Safewing MPIV Launch 2	100/0	Plate	Do not run, see ET Test 175***
C14a	Light Freezing Rain	-10	25	Batelle D3 ADF**	10°buf (34.75)	White Al.	1 L, 12-hole spreader, 20°C
C14b	Light Freezing Rain	-10	25	Batelle D3 ADF**	10°buf (34.75)	Comp 05	1 L, 12-hole spreader, 20°C
C14c	Light Freezing Rain	-10	25	Batelle D3 ADF**	10°buf (34.75)	Plate	Do not run, see ET Test 169***

* If Kilfrost P1792 Type II fluid is not available, replace with Clariant Launch 2
** If Battelle Type I is not available, replace with UCAR EG ADF and omit standard HOT test
*** Standard HOT tests will be used in place of test "c"s and can be conducted independantly from the composite tests

ATTACHMENT VI: NCAR SNOW TEST PLAN

Test #	Run #	Fluid	Dilution	Temp. (°C)	Precip. Rate (g/dm²/h)	Estimated Duration (min)	Priority
N1	1	Clariant Safewing MPIV Launch	75/25	-3	25	40	1
N2	1	Clariant Safewing MPIV Launch	50/50	-3	25	15	1
N3	1	Clariant Safewing MPIV Launch	100/0	-3	25	45	1
N4	1	Clariant Safewing MPIV Launch 2	75/25	-3	25	40	1
N5	1	Clariant Safewing MPIV Launch 2	50/50	-3	25	15	1
N6	1	Clariant Safewing MPIV Launch 2	100/0	-3	25	45	1
N7	1	Dow 200600147-10 (Type IV)	100/0	-3	25	45	1
N8	1	Dow 200600147-10 (Type IV)	75/25	-3	25	40	1
N9	1	Dow 200600147-10 (Type IV)	50/50	-3	25	15	1
N10	1	Kilfrost P1792 (Type II)	100/0	-3	25	45	1
N11	1	Kilfrost P1792 (Type II)	75/25	-3	25	40	1
N12	1	Kilfrost P1792 (Type II)	50/50	-3	25	15	1
N13	1	Kilfrost P1797 (Type IV)	100/0	-3	25	45	1
N14	1	Kilfrost P1797 (Type IV)	75/25	-3	25	40	1
N15	1	Kilfrost P1797 (Type IV)	50/50	-3	25	15	1
N16	1	Clariant Safewing MPIV Launch	50/50	-3	10	15	2
N17	1	Clariant Safewing MPIV Launch	100/0	-3	10	75	2
N18	1	Clariant Safewing MPIV Launch	75/25	-3	10	65	2
N19	1	Clariant Safewing MPIV Launch 2	100/0	-3	10	75	2
N20	1	Clariant Safewing MPIV Launch 2	75/25	-3	10	65	2
N21	1	Clariant Safewing MPIV Launch 2	50/50	-3	10	15	2
N22	1	Dow 200600147-10 (Type IV)	100/0	-3	10	75	2
N23	1	Dow 200600147-10 (Type IV)	75/25	-3	10	65	2
N24	1	Dow 200600147-10 (Type IV)	50/50	-3	10	15	2
N25	1	Kilfrost P1792 (Type II)	100/0	-3	10	75	2
N26	1	Kilfrost P1792 (Type II)	75/25	-3	10	65	2
N27	1	Kilfrost P1792 (Type II)	50/50	-3	10	15	2
N28	1	Kilfrost P1797 (Type IV)	100/0	-3	10	75	2
N29	1	Kilfrost P1797 (Type IV)	75/25	-3	10	65	2
N30	1	Kilfrost P1797 (Type IV)	50/50	-3	10	15	2
N31	2	Clariant Safewing MPIV Launch	75/25	-3	25	40	3
N32	2	Clariant Safewing MPIV Launch	50/50	-3	25	15	3
N33	2	Clariant Safewing MPIV Launch	100/0	-3	25	45	3
N34	2	Clariant Safewing MPIV Launch 2	75/25	-3	25	40	3
N35	2	Clariant Safewing MPIV Launch 2	50/50	-3	25	15	3
N36	2	Clariant Safewing MPIV Launch 2	100/0	-3	25	45	3
N37	2	Dow 200600147-10 (Type IV)	100/0	-3	25	45	3
N38	2	Dow 200600147-10 (Type IV)	75/25	-3	25	40	3
N39	2	Dow 200600147-10 (Type IV)	50/50	-3	25	15	3
N40	2	Kilfrost P1792 (Type II)	100/0	-3	25	45	3
N41	2	Kilfrost P1792 (Type II)	75/25	-3	25	40	3
N42	2	Kilfrost P1792 (Type II)	50/50	-3	25	15	3
N43	2	Kilfrost P1797 (Type IV)	100/0	-3	25	45	3
N44	2	Kilfrost P1797 (Type IV)	75/25	-3	25	40	3
N45	2	Kilfrost P1797 (Type IV)	50/50	-3	25	15	3
N46	2	Clariant Safewing MPIV Launch	75/25	-3	10	65	4
N47	2	Clariant Safewing MPIV Launch	50/50	-3	10	15	4
N48	2	Clariant Safewing MPIV Launch	100/0	-3	10	75	4
N49	2	Clariant Safewing MPIV Launch 2	75/25	-3	10	65	4
N50	2	Clariant Safewing MPIV Launch 2	100/0	-3	10	75	4
N51	2	Clariant Safewing MPIV Launch 2	50/50	-3	10	15	4
N52	2	Dow 200600147-10 (Type IV)	100/0	-3	10	75	4
N53	2	Dow 200600147-10 (Type IV)	75/25	-3	10	65	4
N54	2	Dow 200600147-10 (Type IV)	50/50	-3	10	15	4
N55	2	Kilfrost P1792 (Type II)	100/0	-3	10	75	4

ATTACHMENT VI: NCAR SNOW TEST PLAN (CONT'D)

Test #	Run #	Fluid	Dilution	Temp. (°C)	Precip. Rate (g/dm2/h)	Estimated Duration (min)	Priority
N56	2	Kilfrost P1792 (Type II)	75/25	-3	10	65	4
N57	2	Kilfrost P1792 (Type II)	50/50	-3	10	15	4
N58	2	Kilfrost P1797 (Type IV)	100/0	-3	10	75	4
N59	2	Kilfrost P1797 (Type IV)	75/25	-3	10	65	4
N60	2	Kilfrost P1797 (Type IV)	50/50	-3	10	15	4
N61	1	Clariant Safewing MPIV Launch	75/25	-14	25	30	1
N62	1	Clariant Safewing MPIV Launch	100/0	-14	25	30	1
N63	1	Clariant Safewing MPIV Launch 2	75/25	-14	25	30	1
N64	1	Clariant Safewing MPIV Launch 2	100/0	-14	25	30	1
N65	1	Dow 200600147-10 (Type IV)	100/0	-14	25	30	1
N66	1	Dow 200600147-10 (Type IV)	75/25	-14	25	30	1
N67	1	Kilfrost P1792 (Type II)	100/0	-14	25	30	1
N68	1	Kilfrost P1792 (Type II)	75/25	-14	25	30	1
N69	1	Kilfrost P1797 (Type IV)	100/0	-14	25	30	1
N70	1	Kilfrost P1797 (Type IV)	75/25	-14	25	30	1
N71	1	Clariant Safewing MPIV Launch	75/25	-14	10	60	2
N72	1	Clariant Safewing MPIV Launch	100/0	-14	10	55	2
N73	1	Clariant Safewing MPIV Launch 2	75/25	-14	10	60	2
N74	1	Clariant Safewing MPIV Launch 2	100/0	-14	10	55	2
N75	1	Dow 200600147-10 (Type IV)	100/0	-14	10	55	2
N76	1	Dow 200600147-10 (Type IV)	75/25	-14	10	60	2
N77	1	Kilfrost P1792 (Type II)	100/0	-14	10	55	2
N78	1	Kilfrost P1792 (Type II)	75/25	-14	10	60	2
N79	1	Kilfrost P1797 (Type IV)	100/0	-14	10	55	2
N80	1	Kilfrost P1797 (Type IV)	75/25	-14	10	60	2
N81	2	Clariant Safewing MPIV Launch	75/25	-14	25	30	3
N82	2	Clariant Safewing MPIV Launch	100/0	-14	25	30	3
N83	2	Clariant Safewing MPIV Launch 2	75/25	-14	25	30	3
N84	2	Clariant Safewing MPIV Launch 2	100/0	-14	25	30	3
N85	2	Dow 200600147-10 (Type IV)	100/0	-14	25	30	3
N86	2	Dow 200600147-10 (Type IV)	75/25	-14	25	30	3
N87	2	Kilfrost P1792 (Type II)	100/0	-14	25	30	3
N88	2	Kilfrost P1792 (Type II)	75/25	-14	25	30	3
N89	2	Kilfrost P1797 (Type IV)	100/0	-14	25	30	3
N90	2	Kilfrost P1797 (Type IV)	75/25	-14	25	30	3
N91	2	Clariant Safewing MPIV Launch	75/25	-14	10	60	4
N92	2	Clariant Safewing MPIV Launch	100/0	-14	10	55	4
N93	2	Clariant Safewing MPIV Launch 2	75/25	-14	10	60	4
N94	2	Clariant Safewing MPIV Launch 2	100/0	-14	10	55	4
N95	2	Dow 200600147-10 (Type IV)	100/0	-14	10	55	4
N96	2	Dow 200600147-10 (Type IV)	75/25	-14	10	60	4
N97	2	Kilfrost P1792 (Type II)	100/0	-14	10	55	4
N98	2	Kilfrost P1792 (Type II)	75/25	-14	10	60	4
N99	2	Kilfrost P1797 (Type IV)	100/0	-14	10	55	4
N100	2	Kilfrost P1797 (Type IV)	75/25	-14	10	60	4
N101	1	Clariant Safewing MPIV Launch	100/0	-25	10	40	1
N102	1	Clariant Safewing MPIV Launch 2	100/0	-25	10	40	1
N103	1	Dow 200600147-10 (Type IV)	100/0	-25	10	40	1
N104	1	Kilfrost P1792 (Type II)	100/0	-25	10	40	1
N105	1	Kilfrost P1797 (Type IV)	100/0	-25	10	40	1
N106	2	Clariant Safewing MPIV Launch	100/0	-25	25	25	2
N107	2	Clariant Safewing MPIV Launch 2	100/0	-25	25	25	2
N108	2	Dow 200600147-10 (Type IV)	100/0	-25	25	25	2
N109	2	Kilfrost P1792 (Type II)	100/0	-25	25	25	2
N110	2	Kilfrost P1797 (Type IV)	100/0	-25	25	25	2

ATTACHMENT VII: ICE PELLETS TEST PLAN

Test #	Priority	Fluid Type	Fluid Brand	Dilution (Brix)	Fluid Temp. [°C]	Precip Type	Test Temp. [°C]	Ice Pellet Precip Rate [g/dm²/h]	Freezing Rain Precip Rate [g/dm²/h]	NRC Condition	Objective
IP1	1	I	Batelle D3 ADF*	10°buf. (26.75)	60	IP	-3	25	N/A	ZD,3,13	Type I Heated
IP2	2	I	Batelle D3 ADF*	3° buf. (14.75	60	IP	-3	25	N/A	ZD,3,13	Type I Heated
IP3	3	I	Batelle D3 ADF*	10°buf. (26.75)	60	IP	-3	75	N/A	ZD,3,13	Type I Heated
IP4	2	I	Batelle D3 ADF*	10°buf (34.75)	60	IP	-10	75	N/A	ZR,10,25	Type I Heated
IP5	1	I	Batelle D3 ADF*	10°buf. (38.50)	60	IP	-14	75	N/A	ZF,14,2	Type I Heated
IP6	1	I	Batelle D3 ADF*	10°buf. (46.00)	60	IP	-25	75	N/A	ZF,25,5	Type I Heated
IP7	1	IV	Octagon Maxflo	50/50	15	IP	-3	75	N/A	ZR,3,25	Type II/III/IV - Fluid Room Temp.
IP8	2	IV	Octagon Maxflo	75/25	15	IP	-14	75	N/A	ZF,14,2	Type II/III/IV - Fluid Room Temp.
IP9	1	II	Kilfrost P1792 (Type II)*	75/25	15	IP	-14	75	N/A	ZF,14,2	Type II/III/IV - Fluid Room Temp.
IP10	1	IV	Octagon Maxflo	50/50	60	IP	-3	75	N/A	ZR,3,25	Type II/III/IV - Fluid Heated 60°C
IP11	2	IV	Octagon Maxflo	50/50	60	IP	-3	25	N/A	ZF,3,2	Type II/III/IV - Fluid Heated 60°C
IP12	1	IV	Octagon Maxflo	75/25	60	IP	-14	75	N/A	ZF,14,5	Type II/III/IV - Fluid Heated 60°C
IP13	2	II	Kilfrost P1792 (Type II)*	75/25	60	IP	-14	75	N/A	ZF,14,5	Type II/III/IV - Fluid Heated 60°C
IP14	1	IV	Octagon Maxflo	Neat	60	IP	-25	75	N/A	ZF,25,2	Type II/III/IV - Fluid Heated 60°C
IP15	1	IV	Octagon Maxflo	50/50	-3	IP	-3	75	N/A	ZF,3,2	Type II/III/IV - Exceeded HOT
IP16	3	II	Kilfrost P1792 (Type II)*	50/50	-3	IP	-3	75	N/A	ZF,3,2	Type II/III/IV - Exceeded HOT
IP17	2	IV	Octagon Maxflo	75/25	-10	IP	-10	75	N/A	ZD,10,13	Type II/III/IV - Exceeded HOT
IP18	2	IV	Octagon Maxflo	50/50	-3	IP/ZD	-3	25	13	ZD,3,13	Type II/III/IV - Mixed Precip.
IP19	2	IV	Octagon Maxflo	75/25	-10	IP/ZD	-10	25	5	ZD,10,5	Type II/III/IV - Mixed Precip.
IP20	1	IV	Octagon Maxflo	50/50	-3	IP/ZR	-3	25	25	ZR,3,25	Type II/III/IV - Mixed Precip.
IP21	1	IV	Octagon Maxflo	75/25	-10	IP/ZR	-10	25	13	ZR,10,13	Type II/III/IV - Mixed Precip.

* If Battelle Type I is not available, replace with UCAR EG ADF
** If Kilfrost Type II fluid is not available, replace with Clariant Launch 2

Note: Test #IP18 -21 must be done using simulated ice pellets in conjunction with simulated freezing drizzle at the NRC test chamber. All other tests require only simulated ice pellets (tests can be done in separate section of NRC chamber).

ATTACHMENT VIII: FAR VS. NEAR PILOT'S PERSPECTIVE TEST PLAN

Test #	Run#	Priority	Aircraft Representation	Fluid Type	Fluid Name	Fluid Quantity	Pellet Size	Ice Pellet Quantity	Ice Pellet Condition*
FVN-1	1	2	Falcon 20	Type IV	Maxflo	5L	3mm	0.45 Kg	Light
FVN-2	1	1	Falcon 20	Type IV	Maxflo	5L	3mm	0.85 Kg	Moderate
FVN-3	1	1	Falcon 20	Type IV	Maxflo	5L	3mm	2.5 Kg	Heavy
FVN-4	1	2	Falcon 20	Type IV	Maxflo	5L	3mm	0.45 Kg	Light (w/ tracer pellets)
FVN-5	1	1	Falcon 20	Type IV	Maxflo	5L	3mm	0.85 Kg	Moderate (w/ tracer pellets)
FVN-6	1	1	Falcon 20	Type IV	Maxflo	5L	3mm	2.5 Kg	Heavy (w/ tracer pellets)
FVN-1	2	2	Falcon 20	Type IV	Maxflo	5L	5mm	0.45 Kg	Light
FVN-2	2	1	Falcon 20	Type IV	Maxflo	5L	5mm	0.85 Kg	Moderate
FVN-3	2	1	Falcon 20	Type IV	Maxflo	5L	5mm	2.5 Kg	Heavy
FVN-4	2	2	Falcon 20	Type IV	Maxflo	5L	5mm	0.45 Kg	Light (w/ tracer pellets)
FVN-5	2	1	Falcon 20	Type IV	Maxflo	5L	5mm	0.85 Kg	Moderate (w/ tracer pellets)
FVN-6	2	1	Falcon 20	Type IV	Maxflo	5L	5mm	2.5 Kg	Heavy (w/ tracer pellets)
FVN-7	3	3	A 320	Type IV	Maxflo	5L	3mm	0.45 Kg	Light (w/ tracer pellets)
FVN-8	3	2	A 320	Type IV	Maxflo	5L	3mm	0.85 Kg	Moderate (w/ tracer pellets)
FVN-9	3	2	A 320	Type IV	Maxflo	5L	3mm	2.5 Kg	Heavy (w/ tracer pellets)
FVN-10	4	2	CRJ	Type IV	Maxflo	5L	3mm	0.45 Kg	Light (w/ tracer pellets)
FVN-11	4	1	CRJ	Type IV	Maxflo	5L	3mm	0.85 Kg	Moderate (w/ tracer pellets)
FVN-12	4	1	CRJ	Type IV	Maxflo	5L	3mm	2.5 Kg	Heavy (w/ tracer pellets)
FVN-13	5	3	B-737	Type IV	Maxflo	5L	3mm	0.45 Kg	Light (w/ tracer pellets)
FVN-14	5	2	B-737	Type IV	Maxflo	5L	3mm	0.85 Kg	Moderate (w/ tracer pellets)
FVN-15	5	2	B-737	Type IV	Maxflo	5L	3mm	2.5 Kg	Heavy (w/ tracer pellets)
FVN-16	6	3	Falcon 20	Type II	ABC-2000	5L	3mm	0.45 Kg	Light (w/ tracer pellets)
FVN-17	6	2	Falcon 20	Type II	ABC-2000	5L	3mm	0.85 Kg	Moderate (w/ tracer pellets)
FVN-18	6	2	Falcon 20	Type II	ABC-2000	5L	3mm	2.5 Kg	Heavy (w/ tracer pellets)
FVN-19	7	2	Falcon 20	Type I	UCAR EG ADF	5L	3mm	0.45 Kg	Light
FVN-20	7	1	Falcon 20	Type I	UCAR EG ADF	5L	3mm	0.85 Kg	Moderate
FVN-21	7	1	Falcon 20	Type I	UCAR EG ADF	5L	3mm	2.5 Kg	Heavy
FVN-22	7	2	Falcon 20	Type I	UCAR EG ADF	5L	3mm	0.45 Kg	Light (w/ tracer pellets)
FVN-23	7	1	Falcon 20	Type I	UCAR EG ADF	5L	3mm	0.85 Kg	Moderate (w/ tracer pellets)
FVN-24	7	1	Falcon 20	Type I	UCAR EG ADF	5L	3mm	2.5 Kg	Heavy (w/ tracer pellets)

Note: Tests are not temperature dependant, however each complete "Run" of tests should be conducted during similar temperatures.
*Light IP =20min @ 13g/dm²/h, Moderate IP =20 min @ 25 g/dm²/h, Heavy IP =20 min @ 75 g/dm²/h

ATTACHMENT IX: PERSONNEL REQUIREMENTS

	RATES			HOT			HEAT/COMP			NCAR	
	Rates Mgr	Rates Ass.	Fluid Mgr	Mgr	Rates	CSW Prep	Mgr	Brix / Thick	Rates	Mgr	Ass.
CM	x				x				x		
YOW1		x			x				x		
MC				x							
JD											
SB			x								x
DY						x	x				
MR											
JT						x					
GB						x				x	
JG						x		x			

	-3ºC BUFFER		ICE PELLETS				PILOT PERS.	AIR SILK		-3ºC B. AIRFOIL	THICK
	Mgr	Rates	Mgr	Brix / Thick	Ice Pellets	Rates	Mgr	Mgr	Rates	Mgr	Mgr
CM		x				x			x		
YOW1		x				x			x		
MC											
JD											
SB	x			x				x		x	x
DY							x				
MR			x								
JT					x						
GB											
JG							x				

ATTACHMENT X: LIST OF FLUIDS

Fluid Name	Dilution	Litres Required									
		HOT	THICK	HEAT	COMP	NCAR	BUFF	A/SILK	PP	ICE P	Total
Batelle D3 ADF	10° buffer	28	2	-	18	-	-	4	-	6	**58**
Clariant Safewing MP IV Launch	100	32	2	-	-	10	-	2	-	-	**46**
Clariant Safewing MP IV Launch	75	28	2	-	-	8	-	1	-	-	**39**
Clariant Safewing MP IV Launch	50	12	2	-	-	4	-	1	-	-	**19**
Clariant Safewing MP IV Launch 2	100	32	2	-	6	10	-	-	-	-	**50**
Clariant Safewing MP IV Launch 2	75	28	2	-	6	8	-	-	-	-	**44**
Clariant Safewing MP IV Launch 2	50	12	2	-	-	4	-	-	-	-	**18**
Dow 200600147-10 (Type IV)	100	32	2	-	-	10	-	-	-	-	**44**
Dow 200600147-10 (Type IV)	75	28	2	-	-	8	-	-	-	-	**38**
Dow 200600147-10 (Type IV)	50	12	2	-	-	4	-	-	-	-	**18**
Kilfrost P1792 (Type II)	100	32	2	-	-	10	-	2	-	-	**46**
Kilfrost P1792 (Type II)	75	28	2	-	6	8	-	1	-	2	**47**
Kilfrost P1792 (Type II)	50	12	2	-	6	4	-	1	-	1	**26**
Kilfrost P1797 (Type IV)	100	32	2	-	-	10	-	-	-	-	**44**
Kilfrost P1797 (Type IV)	75	28	2	-	-	8	-	-	-	-	**38**
Kilfrost P1797 (Type IV)	50	12	2	-	-	4	-	-	-	-	**18**
Clariant Safewing MP III 2031	100	-	-	12	-	-	-	-	-	-	**12**
Clariant Safewing MP III 2031	75	-	-	10	-	-	-	-	-	-	**10**
Clariant Safewing MP III 2031	50	-	-	6	-	-	-	-	-	-	**6**
Dow UCAR Ultra+	100	-	-	10	-	-	-	-	-	-	**10**
Kilfrost ABC 2000	100	-	-	12	-	-	-	-	15	-	**27**
Kilfrost ABC 2000	75	-	-	8	-	-	-	-	-	-	**8**
Kilfrost ABC 2000	50	-	-	8	-	-	-	-	-	-	**8**
Octagon Maxflo	100	-	-	8	-	-	-	-	105	1	**114**
Octagon Maxflo	75	-	-	12	-	-	-	-	-	5	**17**
Octagon Maxflo	50	-	-	6	-	-	-	-	-	6	**12**
Octagon Octaflo EF (PG Type I)	various	-	-	-	-	-	9	-	-	-	**9**
Dow UCAR ADF (EG Type I)	various	-	-	-	-	-	6	-	30	-	**36**
		388	**32**	**92**	**42**	**110**	**15**	**12**	**150**	**21**	**862**

ATTACHMMENT XI: TYPE I DILUTION TABLES

OAT (°C)	FFP (°C)	Batelle D3				Octaflo EF (PG)				UCAR ADF (EG)			
		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
10	0					0	0.00	0.0	8.0	0	0.00	0.0	8.0
9	-1					4	2.75	0.3	7.7	3	1.50	0.2	7.8
8	-2					7.75	5.25	0.6	7.4	4.5	3.00	0.4	7.6
7	-3					8.25	6.00	0.7	7.3	7.5	4.75	0.6	7.4
6	-4					10	6.75	0.8	7.2	**10**	**6.50**	0.8	7.2
5	-5					15	9.75	1.2	6.8	12	8.00	1.0	7.0
4	-6	**20**	**14.75**	1.6	6.4	**20**	**12.75**	1.6	6.4	14.5	9.50	1.2	6.8
3	-7	26	18.50	2.1	5.9	22	15.00	1.8	6.2	16	10.50	1.3	6.7
2	-8	28	20.00	2.2	5.8	25	16.50	2.0	6.0	18.5	12.00	1.5	6.5
1	-9	29	21.25	2.3	5.7	28	18.50	2.2	5.8	21.5	13.50	1.7	6.3
0	-10	**30**	**22.75**	2.4	5.6	29	19.00	2.3	5.7	22	14.00	1.8	6.2
-1	-11	33	24.00	2.6	5.4	**30**	**20.00**	2.4	5.6	23	15.00	1.8	6.2
-2	-12	35	25.50	2.8	5.2	31	20.50	2.5	5.5	24.5	16.00	2.0	6.0
-3	-13	37	26.75	3.0	5.0	32	21.25	2.6	5.4	26	17.00	2.1	5.9
-4	-14	38	28.00	3.0	5.0	34	22.50	2.7	5.3	28	18.00	2.2	5.8
-5	-15	39	29.00	3.1	4.9	35	23.00	2.8	5.2	**30**	**19.00**	2.4	5.6
-6	-16	**40**	**29.75**	3.2	4.8	36	23.50	2.9	5.1	31	19.75	2.5	5.5
-7	-17	44	31.50	3.5	4.5	37	24.00	3.0	5.0	32	20.50	2.6	5.4
-8	-18	45	32.50	3.6	4.4	38.5	25.00	3.1	4.9	33.5	21.25	2.7	5.3
-9	-19	47	33.75	3.8	4.2	**40**	**26.00**	3.2	4.8	34.5	21.75	2.8	5.2
-10	-20	48	34.75	3.8	4.2	42	27.00	3.4	4.6	36	22.50	2.9	5.1
-11	-21	49	35.75	3.9	4.1	44	28.00	3.5	4.5	37	23.00	3.0	5.0
-12	-22	**50**	**36.50**	4.0	4.0	45	28.50	3.6	4.4	38	23.75	3.0	5.0
-13	-23	52	37.50	4.2	3.8	46	29.00	3.7	4.3	39	24.50	3.1	4.9
-14	-24	53	38.50	4.2	3.8	47	29.50	3.8	4.2	**40**	**25.00**	3.2	4.8
-15	-25	54	39.50	4.3	3.7	47.5	30.00	3.8	4.2	41	25.50	3.3	4.7
-16	-26	**55**	**39.50**	4.4	3.6	48.5	30.50	3.9	4.1	42	26.00	3.4	4.6
-17	-27	57	41.00	4.6	3.4	49	31.00	3.9	4.1	43	26.50	3.4	4.6
-18	-28	58	41.75	4.6	3.4	**50**	**31.50**	4.0	4.0	44	27.00	3.5	4.5
-19	-29	**60**	**42.25**	4.8	3.2	51	32.00	4.1	3.9	45	27.50	3.6	4.4
-20	-30	61	43.00	4.9	3.1	52	32.50	4.2	3.8	45.75	28.00	3.7	4.3
-22	-32	62	44.25	5.0	3.0	53.5	33.50	4.3	3.7	47	28.75	3.8	4.2
-25	-35	65	46.00	5.2	2.8	56	34.50	4.5	3.5	49	30.00	3.9	4.1
-30	-40	**70**	**48.25**	5.6	2.4	**60**	**37.00**	4.8	3.2	53	32.00	4.2	3.8
Std. Mix						63	38.30	5.0	3.0	57	33.50	4.6	3.4

ATTACHMENT XII: EQUIPMENT LIST

ALL PROJECTS	LOCATION	STATUS
Test Stands (4 x 6-plate stands)	Site	
4-plate stand (or 3-plate + 1-plate)	Site	
Desktop Computer x 1	Site	
Diskettes	Site	
Rags	Site	
Video Tapes	Site	
Batteries AA, 9V	Site	
Still Digital Camera	Site	
Weigh Scale x 2 (sartorius) + wiring	Site	
Time lapse video camera	Site	
Boards for cold-soak test	Site	
Clamps x 12	Site	
VCR for time lapse	Site	
Monitor for time lapse	Site	
Plates (wing nuts) x10 (w/logging capability)	Site	
Red containers with LIDS	Site	
Insulation for weigh scale	Site	
Large Precipitation Pans x 100	Site	
Metal cold-soak box covers	Site	
Large calculator	Site	
Fluids	Site	
Clipboards x 10	Site	
Pencils + pens + markers	Site	
Paper Towels (lots)	Site	
Rubber squeegees x 4	Site	
Waste containers x 8	Site	
Funnels	Site	
Electrical Extension Cords	Site	
Lighting x 2	Site	
Stop watches x 4	Site	
Storage bins for small equipment	Site	
Protective clothing (6)	Site	
Brixometer X 4	Site	
Tie wraps	Site	
Funnels	Site	
Hand-held Temperture Probes (Wahl)	Site	
Thickness Gauges x 8 (both types)	Site	
Scrapers	Site	
Plate covers x 10	Site	
Spray paint	Site	
Tape measure	Site	
Cold-Soaked Boxes 7.5 cm X 6	Site	
Thermistor Kit + Logger	Site	
Inclinometer (yellow level)	Site	
Printer Epson @ site	Site	
Paper for printer (1 packs)	Site	
Washers	Site	
Hard Water for Type I tests x 50 litres	Site	
Hard Water Chemicals	Site	
1 litre pour containers x 100 (if possible)	Site	
Large digital clock x 2	Site	
Cotton gloves	Site	
Laptop Computer	Office?	
Time Cards, Invoices, Expense forms	Office	
Data Forms for plates	Office	
Precipitation rate Data Forms	Office	
Reports + HOT Tables	Office	
Dilution curves for Type I fluids	Office	
Test Procedures X2	Office	
Fluid for cold-soak boxes	NRC?	
Black shelving units x 2	NRC?	

NCAR	LOCATION	STATUS
Snow making machine and related equipment	Site	
Aluminum plates with heating pads	Site	
Aluminum Rate Pan 300mm X 500mm	Site	
Snow Distribution Pans 100mm X 150mm	Site	
Electronic balance for snow distribution trials	Site	
Electronic NCAR files	Site	
Squeegee/scraper	Site	
Extension cord	Site	
Flood lights	Site	
Wet vacuum	Site	

ICE PELLETS / PILOT PERSPECTIVE	LOCATION	STATUS
Smart Reader 8 channel	Site	
Smart reader interface	Site	
Thermistors	Site	
1/4" cable for interface (30ft)	Site	
Campbell Scientific	Site	
NCAR weigh scale	Site	
Laptop	Site?	
Ice Pellet Pitcher (2006)	Site	
Ice Pellet Pitcher (2005) as backup	Site	
Tripod for IP Pitcher	Site	
NCAR Bucket and Plate	Site	
12 hole spreader (x3)	Site	
Tarp	Site	
Squeegee	Site	
Hand Held IP Pitchers (x4)	Site	
Airfoil	Site	
20L Ultra+ (or any other Type IV)	Site	
Digital Cameras (x2)	Site?	
Camera tripods (x2)	Site	
Storage freezer	Site	
Ice Cubes	Site	
Blender (x4)	Site	
Sieves (x12)	Site	
Sieve collection dish (x2)	Site	
Styrofoam Containers (x10)	Site	
>5mm rectangular Screen	Site	
1.5 mm rectangular screen	Site	
Big Table	Site	
Small table	Site	
Neon light	Site	
1 litre measuring cups (x2)	Site	
Food Coloring (Blue and Red)	Site	
Extension Cables (x3)	Site	
Power bars (x2)	Site	
Microwave (x2)	Site	
Rubber gloves (x2)	Site	
Grey Duck Tape	Site	
Thermos (x6)	Site	
Thermos Carrier (x2)	Site	
Step Ladder	Site	

COMPOSITE		
Painted Aluminum Plate	Site	
White Painted Cross Weave Carbon Fibre Test Plate	Site	

AIRSILK		
Airsilk (8 Litres)	Site	
Paint brushes (2)	Purchase	

ATTACHMENT XIII: 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: _____

ATTACHMENT XIV: COLD-SOAK WING ENDURANCE TIME DATA FORM

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)

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

COMMENTS: _____

LEADER / MANAGER: _____

ATTACHMENT XV: 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

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ATTACHMENT XVI: 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

ATTACHMENT XVII: NCAR DATA FORM

Version 1.0 Winter 2003-04

LOCATION: DATE: RUN # : STAND # : NCAR

OUTPUT FILENAME:_____.txt

OAT: _____ °C

PRECIPITATION RATE: _____ g/dm²/h

FLUID TEMPERATURE: _____ °C

FLUID QUANTITY APPLIED: _____ Litres

PLATE WASHING METHOD: _____

PLATE TEMPERATURE (OMEGA): _____ °C

OTHER COMMENTS (Fluid Batch, etc):

_____

_____

_____

_____

_____

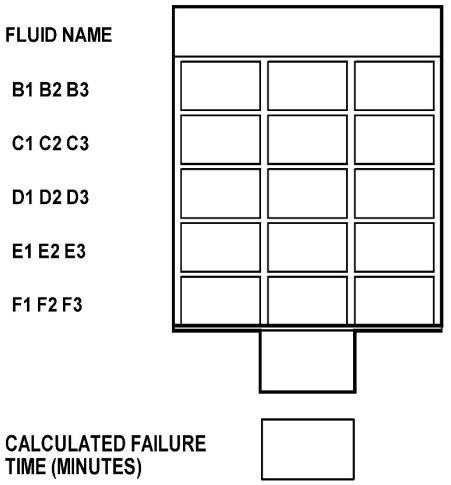
_____

_____

	PRINT	SIGN
FAILURES CALLED BY :		
HAND WRITTTEN BY :		
LEADER :		

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

Time of Fluid Application: _____ h:min



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Version 1.0, March 06

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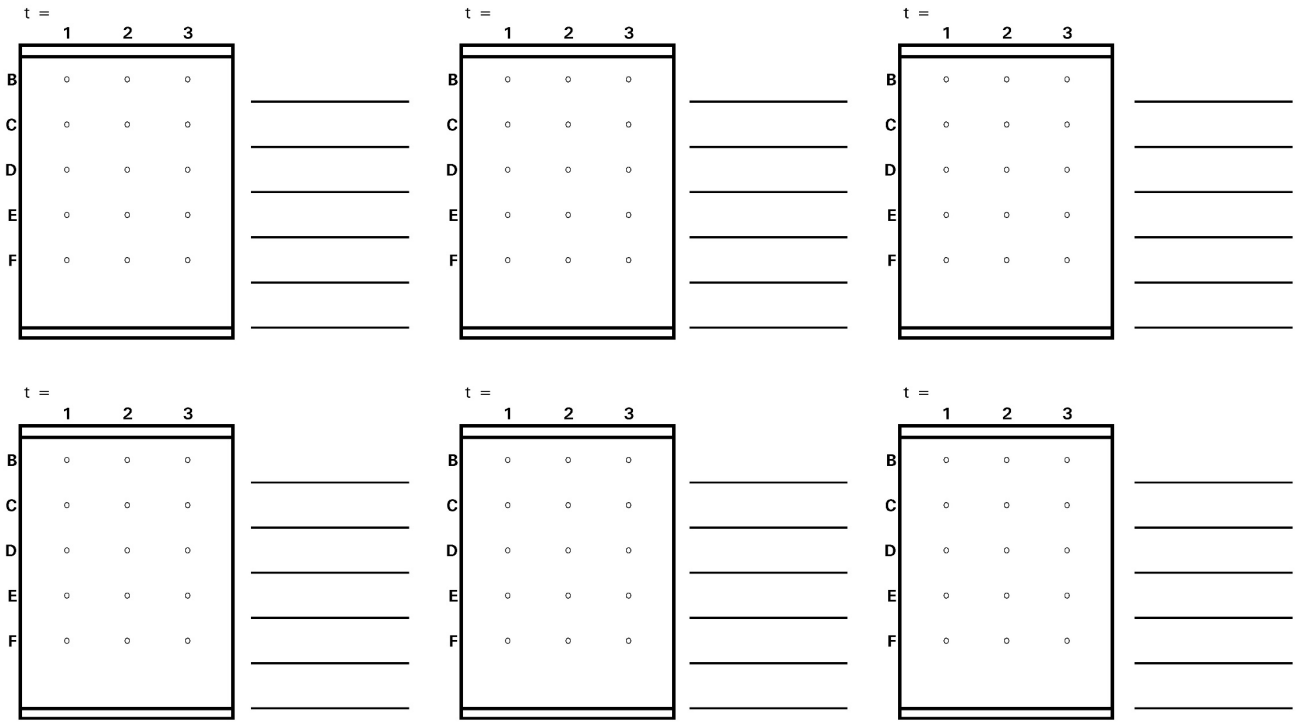
ATTACHMENT XVIII: ADHERENCE OF FLUID FAILURE DATA FORM

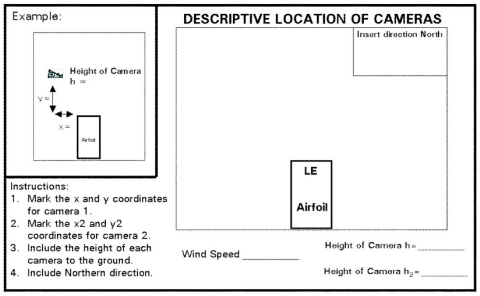
Date: _____ Time: _____ Plate Location: _____

Run #: _____ Fluid Name: _____ Fluid Dilution: _____



ATTACHMENT XIX: AIRFOIL FAILURE OBSERVATION DATA FORM

Date:	
Test Observed by:	
Fluid Name:	
Fluid Type:	**Dilution:**
Time of Start:	
Time of Finish:	



Time	% Airfoil Failed	Picture Taken (Y/N)	Observations

- Approximately ten observations should be recorded per test.
- The time interval between observations can be approximated by taking the expected HOT of the fluid being tested and dividing by ten.
- A final observation should be recorded once fluid failure has been confirmed.

Comments

Name: _____ Signature: _____

ATTACHMENT XX: -3°C BUFFER AIRFOIL DATA FORM

Date: _____

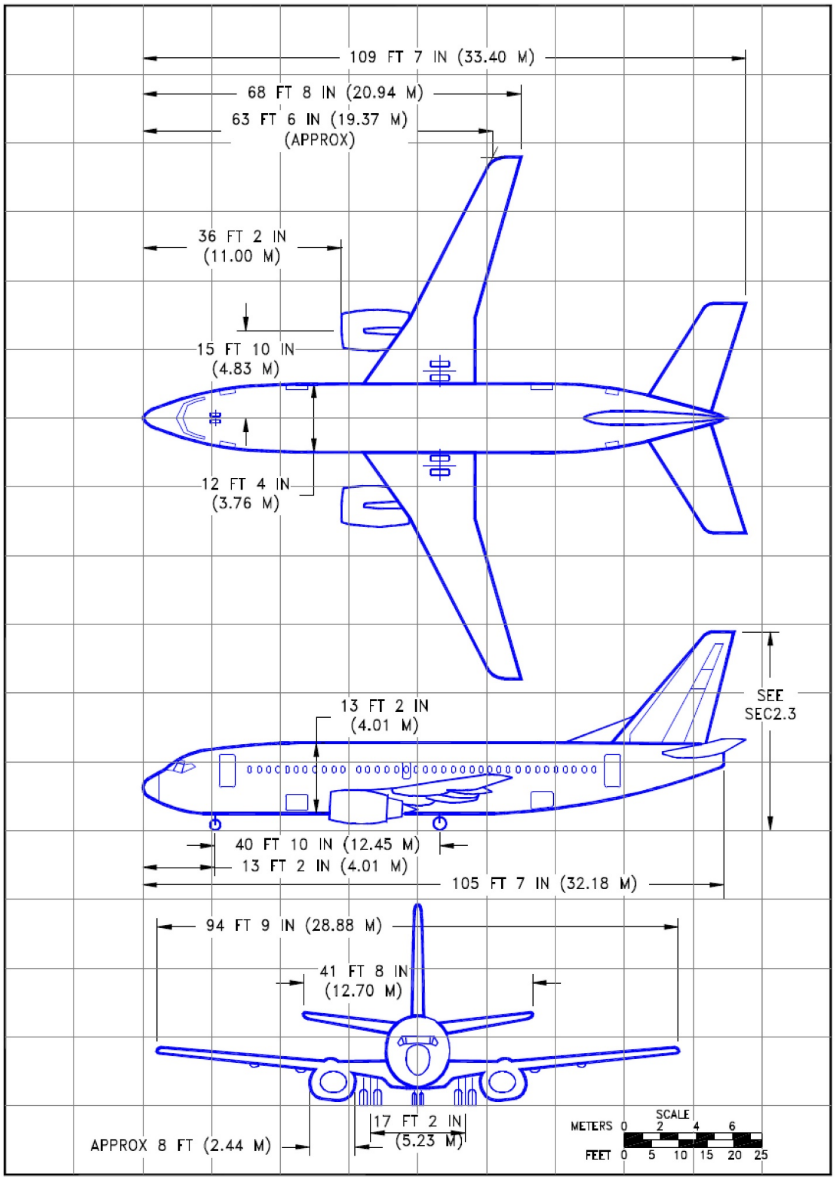
Location: _____

Observer: _____

Description of Airfoil Treatment:

Observations:

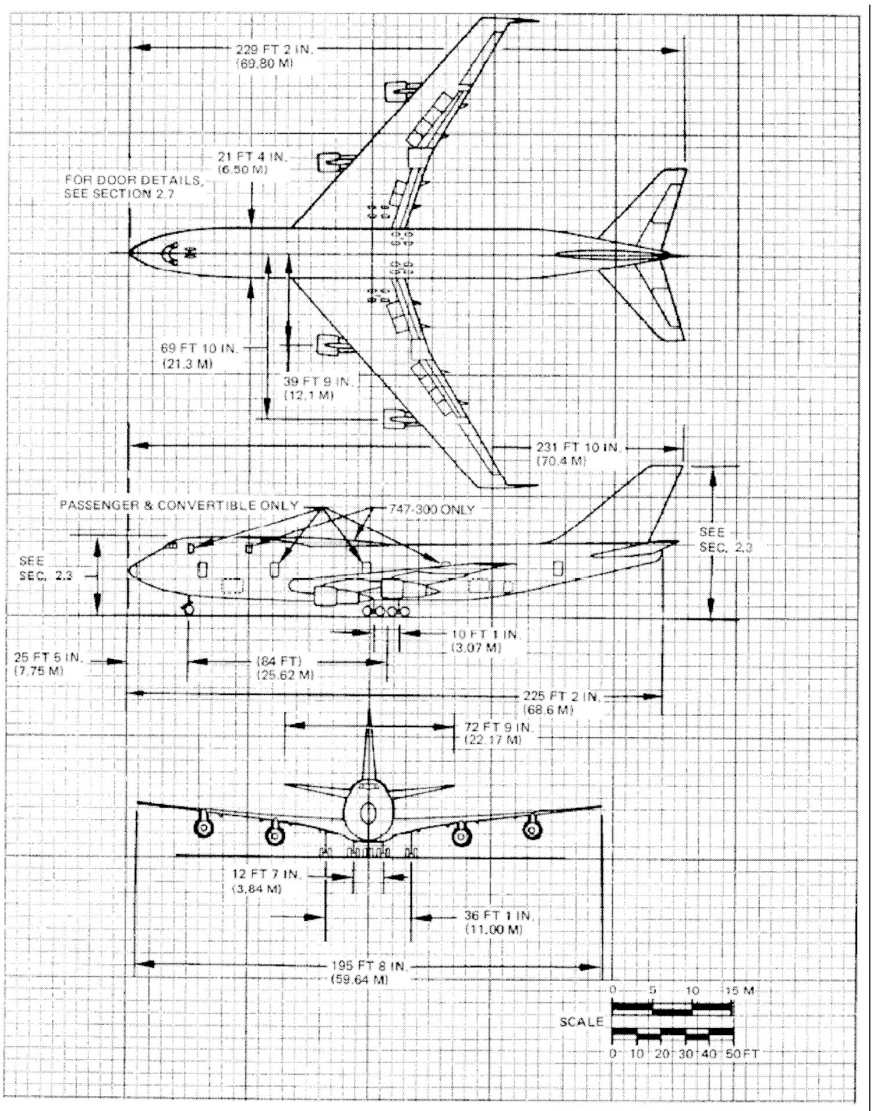
ANNEX A
COMMON AIRCRAFT SPECIFICATIONS



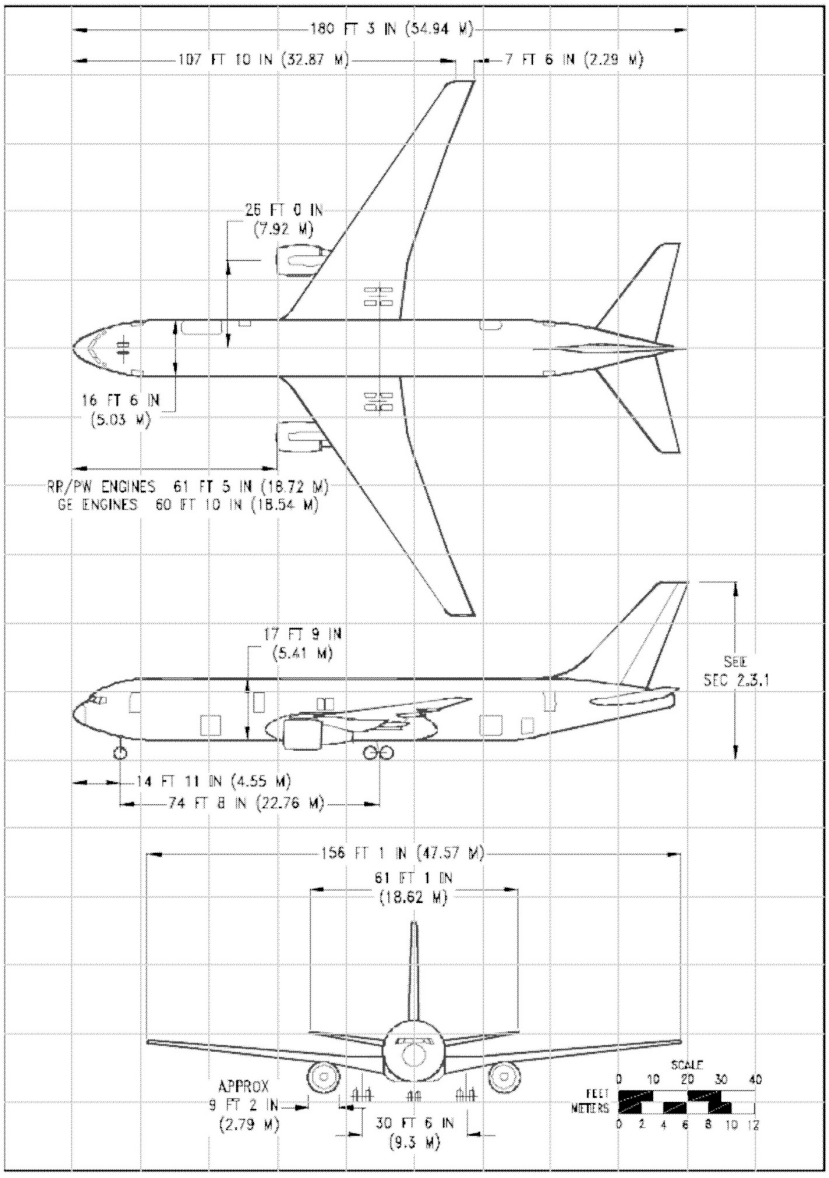
2.2.3 GENERAL DIMENSIONS

MODEL 737-300

OVERALL PROGRAM OF TESTS AT NRC, APRIL 2006



2.2.1 GENERAL DIMENSIONS
MODELS 747-100B, -200, -300



2.2.2 GENERAL DIMENSIONS

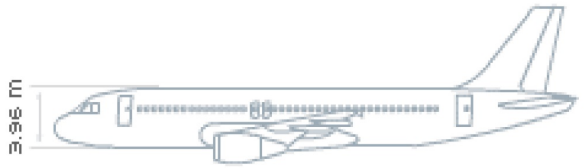
MODEL 767-300, -300ER

OVERALL PROGRAM OF TESTS AT NRC, APRIL 2006



External: CRJ 700	
Length overall	32.51 m
Wingspan	23.24 m
Wing area (net)	70.61 m^2
Height overall	7.57 m
Fuselage max diameter	2.69 m
Turning Circle	22.86 m

OVERALL PROGRAM OF TESTS AT NRC, APRIL 2006



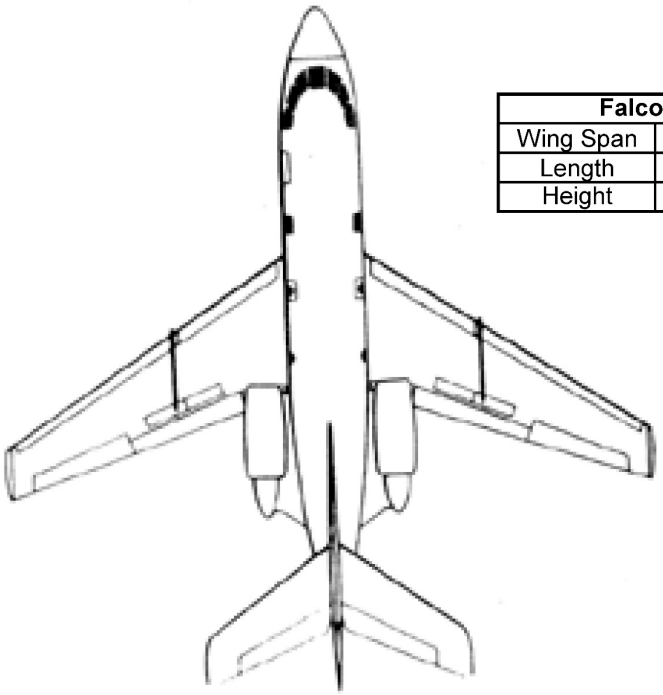


A320	
Overall length	37.57 m.
Height	11.76 m.
Fuselage diameter	3.96 m.
Maximum cabin width	3.70 m.
Cabin length	27.50 m.
Wingspan (geometric)	34.09 m.
Wing area (reference)	122.6 m2
Wing sweep (25% chord)	25 degrees
Wheelbase	12.65 m.
Wheel track	7.59 m.

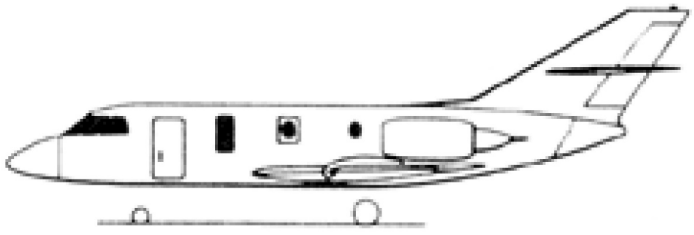


OVERALL PROGRAM OF TESTS AT NRC, APRIL 2006





Falcon 20	
Wing Span	15.4 m
Length	17.15
Height	5.32



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ADDITIONAL PROGRAM OF TESTS AT NRC, APRIL 2006

CM2020.002 (05-06)

ADDITIONAL PROGRAM OF TESTS AT NRC, APRIL 2006

Winter 2005-06

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Stephanie Bendickson

Reviewed by: John D'Avirro

April 21, 2006
Version 1.0

ADDITIONAL PROGRAM OF TESTS AT NRC, APRIL 2006
Winter 2005-06

1. INTRODUCTION

This document was prepared as an addition to the procedure "Overall Program of Tests at NRC, April 2006". An additional fluid was received for endurance time testing after the first test session had been completed. Therefore a second test session will take place at the National Research Council (NRC) Climatic Engineering Facility (CEF) in Ottawa from April 24th to 27th, 2006. A tentative schedule is included in Attachment I.

2. PROJECTS, PROCEDURES AND OBJECTIVES

Specific details are given in the document "Overall Program of Tests at NRC, April 2006".

2.1 Endurance Times of New Fluids

The objective of this project is to measure endurance times of one Type II fluid, Kilfrost P1792 Batch 2. Retests of some tests conducted at the first test session may be conducted. The test plan for endurance time tests is given in Attachment II.

2.2 Thickness of New Fluids

The objective of these tests is to measure the thickness of Kilfrost P1792 Batch 2. The test plan is given in Attachment III.

2.3 NCAR Indoor Snow

The objective of the NCAR indoor snow testing is to generate holdover times in artificial snow for Kilfrost P1792 Batch 2. Additional tests may be conducted if time allows. The test plan is given in Attachment IV.

2.4 Ice Pellets

The objective of this project is to investigate if endurance time testing conducted during ice pellet conditions will demonstrate signs of fluid adhesion to aluminum test surfaces. Preliminary testing was conducted at the first NRC test session. The test plan is given in Attachment V.

2.5 Effect of Surface Material on Endurance Times

The objective of this project is to investigate the impact non-aluminum test plate material has on fluid endurance time. Testing was conducted at the first NRC test session. Several tests will be repeated at the second test session. The test plan is given in Attachment VI.

2.6 Effect of Heat on Endurance Times

The objective of this project is to investigate the impact of application method on endurance time performance. Testing was conducted at the first NRC test session. Several tests will be repeated at the second test session. The test plan is given in Attachment VII.

3. PERSONNEL REQUIREMENTS/RESPONSIBILITIES

Personnel requirements are detailed in Attachment I and are as follows:

1. Endurance Times of New Fluids: MC and rates team. DY, GB and JG will prepare boxes in the cold soak wing conditions.
2. Thickness of New Fluids: DY
3. NCAR Indoor Snow: GB
4. Ice Pellets: DY, JG and YOW
5. Effect of Surface Material: DY
6. Effect of Heat: DY

Rates Team:

- RP: rate manager
- DY/YOW: rate assistant

4. FLUIDS

The required fluids and fluid quantities are shown in Attachment VIII. The brix values and glycol/water proportions for diluting Type I fluids are given in Attachment IX.

5. EQUIPMENT

A complete list of equipment required for testing is given in the procedure "Overall Program of Tests at NRC, April 2006".

6. DATA FORMS

1. Endurance Times of New Fluids:
   - Freezing precipitation endurance time data form (Attachment X); and
   - Cold-soak wing endurance time data form (Attachment XI).
2. Thickness of New Fluids:
   - Fluid thickness data form (Attachment XII).
3. NCAR Indoor Snow:
   - NCAR data form (Attachment XIII).
4. Ice Pellets:
   - Freezing precipitation endurance time data form (Attachment X);
   - Brix and thickness data form (Attachment XIV); and
   - Adherence of fluid failure data form (Attachment XV).
5. Effect of Surface Material:
   - Freezing precipitation endurance time data form (Attachment X); and
   - Brix and thickness data form (Attachment XIV).
6. Effect of Heat:
   - Freezing precipitation endurance time data form (Attachment X); and
   - Brix and thickness data form (Attachment XIV).

7. 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. Care should be taken when circulating near test stand due to slipperiness;
4. First aid kit, water and fire extinguisher are available; and
5. All NRC safety guidelines must be followed.

ATTACHMENT I: TEST SCHEDULE AND PERSONNEL REQUIREMENTS

TEST SCHEDULE

	Mon Apr 24	Tue Apr 25	Wed Apr 26	Thu Apr 27	Fri Apr 28
8:00	rates	rates	rates	rates	Pack up
8:30	rates	rates	rates	rates	
9:00	ZF, -25, 2	ZD, -10, 5 Heat	ZF, -3, 2	ZD, -3, 5	
9:30					
10:00	rates	rates			
10:30	rates	rates			
11:00	ZF, -25, 5	ZD, -10, 13 Composite		rates	Drive to Montreal
11:30	rates			rates	
12:00	Warm to -14°	rates		CSW, 1, 5	
12:30	↓	rates	rates		
13:00	rates	ZR, -10, 25	rates		
13:30	ZF, -14, 5	rates	ZR, -3, 25 Composite		Unpack
14:00		rates			
14:30	rates	ZR, -10, 13 Composite Heat	rates		
15:00	rates		rates		
15:30	ZF, -14, 2	rates	ZR, -3, 13	rates	
16:00		Warm to -3°		rates	
16:30		rates		CSW, 1, 75	
17:00	rates	ZF, -3, 5 Thickness	rates		
17:30			rates	rates	
18:00			ZD, -3, 13 Composite Heat		
18:30					
19:00		rates			
19:30			rates		

PERSONNEL REQUIREMENTS

	Mon Apr 24	Tue Apr 25	Wed Apr 26	Thu Apr 27	Fri Apr 28
DY	RATES	RATES/C/H/Thick	IP/Comp/Heat	IP/CSW	Packup
RP	RATES	RATES	RATES	RATES	Packup
MC	HOT	HOT	HOT	HOT	Packup
GB	NCAR	NCAR	NCAR	NCAR / CSW	Packup
JG		C/H/Thick	IP	IP/CSW	Packup
YOW	IP	IP	RATES	RATES	

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid Brand	Dilution (BRIX)	Test Surface	Comments
501	Freezing Fog	-25	2	Kilfrost P1792 Batch 2	100	Plate	
502	Freezing Fog	-25	2	Kilfrost P1792 Batch 2	100	Plate	
503	Freezing Fog	-25	5	Kilfrost P1792 Batch 2	100	Plate	
504	Freezing Fog	-25	5	Kilfrost P1792 Batch 2	100	Plate	
505	Freezing Fog	-14	5	Kilfrost P1792 Batch 2	100	Plate	
506	Freezing Fog	-14	5	Kilfrost P1792 Batch 2	100	Plate	
507	Freezing Fog	-14	5	Kilfrost P1792 Batch 2	75	Plate	
508	Freezing Fog	-14	5	Kilfrost P1792 Batch 2	75	Plate	
509	Freezing Fog	-14	2	Kilfrost P1792 Batch 2	100	Plate	
510	Freezing Fog	-14	2	Kilfrost P1792 Batch 2	100	Plate	
511	Freezing Fog	-14	2	Kilfrost P1792 Batch 2	75	Plate	
512	Freezing Fog	-14	2	Kilfrost P1792 Batch 2	75	Plate	
513	Freezing Fog	-3	5	Kilfrost P1792 Batch 2	100	Plate	
514	Freezing Fog	-3	5	Kilfrost P1792 Batch 2	100	Plate	
515	Freezing Fog	-3	5	Kilfrost P1792 Batch 2	75	Plate	
516	Freezing Fog	-3	5	Kilfrost P1792 Batch 2	75	Plate	
517	Freezing Fog	-3	5	Kilfrost P1792 Batch 2	50	Plate	
518	Freezing Fog	-3	5	Kilfrost P1792 Batch 2	50	Plate	
519	Freezing Fog	-3	2	Kilfrost P1792 Batch 2	100	Plate	
520	Freezing Fog	-3	2	Kilfrost P1792 Batch 2	100	Plate	
521	Freezing Fog	-3	2	Kilfrost P1792 Batch 2	75	Plate	
522	Freezing Fog	-3	2	Kilfrost P1792 Batch 2	75	Plate	
523	Freezing Fog	-3	2	Kilfrost P1792 Batch 2	50	Plate	
524	Freezing Fog	-3	2	Kilfrost P1792 Batch 2	50	Plate	
525	Freezing Drizzle	-10	13	Kilfrost P1792 Batch 2	100	Plate	
526	Freezing Drizzle	-10	13	Kilfrost P1792 Batch 2	100	Plate	
527	Freezing Drizzle	-10	13	Kilfrost P1792 Batch 2	75	Plate	Doubles as Test C7c
528	Freezing Drizzle	-10	13	Kilfrost P1792 Batch 2	75	Plate	
529	Freezing Drizzle	-10	5	Kilfrost P1792 Batch 2	100	Plate	
530	Freezing Drizzle	-10	5	Kilfrost P1792 Batch 2	100	Plate	
531	Freezing Drizzle	-10	5	Kilfrost P1792 Batch 2	75	Plate	
532	Freezing Drizzle	-10	5	Kilfrost P1792 Batch 2	75	Plate	
533	Light Freezing Rain	-10	25	Kilfrost P1792 Batch 2	100	Plate	
534	Light Freezing Rain	-10	25	Kilfrost P1792 Batch 2	100	Plate	
535	Light Freezing Rain	-10	25	Kilfrost P1792 Batch 2	75	Plate	
536	Light Freezing Rain	-10	25	Kilfrost P1792 Batch 2	75	Plate	
537	Light Freezing Rain	-10	13	Kilfrost P1792 Batch 2	100	Plate	
538	Light Freezing Rain	-10	13	Kilfrost P1792 Batch 2	100	Plate	
539	Light Freezing Rain	-10	13	Kilfrost P1792 Batch 2	75	Plate	
540	Light Freezing Rain	-10	13	Kilfrost P1792 Batch 2	75	Plate	
541	Freezing Drizzle	-3	13	Kilfrost P1792 Batch 2	100	Plate	
542	Freezing Drizzle	-3	13	Kilfrost P1792 Batch 2	100	Plate	
543	Freezing Drizzle	-3	13	Kilfrost P1792 Batch 2	75	Plate	
544	Freezing Drizzle	-3	13	Kilfrost P1792 Batch 2	75	Plate	

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
545	Freezing Drizzle	-3	13	Kilfrost P1792 Batch 2	50	Plate	Doubles as Test C3c
546	Freezing Drizzle	-3	13	Kilfrost P1792 Batch 2	50	Plate	
547	Freezing Drizzle	-3	5	Kilfrost P1792 Batch 2	100	Plate	
548	Freezing Drizzle	-3	5	Kilfrost P1792 Batch 2	100	Plate	
549	Freezing Drizzle	-3	5	Kilfrost P1792 Batch 2	75	Plate	
550	Freezing Drizzle	-3	5	Kilfrost P1792 Batch 2	75	Plate	
551	Freezing Drizzle	-3	5	Kilfrost P1792 Batch 2	50	Plate	
552	Freezing Drizzle	-3	5	Kilfrost P1792 Batch 2	50	Plate	
553	Light Freezing Rain	-3	25	Kilfrost P1792 Batch 2	100	Plate	
554	Light Freezing Rain	-3	25	Kilfrost P1792 Batch 2	100	Plate	
555	Light Freezing Rain	-3	25	Kilfrost P1792 Batch 2	75	Plate	
556	Light Freezing Rain	-3	25	Kilfrost P1792 Batch 2	75	Plate	
557	Light Freezing Rain	-3	25	Kilfrost P1792 Batch 2	50	Plate	
558	Light Freezing Rain	-3	25	Kilfrost P1792 Batch 2	50	Plate	
559	Light Freezing Rain	-3	13	Kilfrost P1792 Batch 2	100	Plate	
560	Light Freezing Rain	-3	13	Kilfrost P1792 Batch 2	100	Plate	
561	Light Freezing Rain	-3	13	Kilfrost P1792 Batch 2	75	Plate	
562	Light Freezing Rain	-3	13	Kilfrost P1792 Batch 2	75	Plate	
563	Light Freezing Rain	-3	13	Kilfrost P1792 Batch 2	50	Plate	
564	Light Freezing Rain	-3	13	Kilfrost P1792 Batch 2	50	Plate	
565	Cold Soak Box	1	75	Batelle D3 ADF	10°buf. (21.25)	Plate	Apply fluid at 20±5°C
566	Cold Soak Box	1	75	Batelle D3 ADF	10°buf. (21.25)	Plate	Apply fluid at 20±5°C
567	Cold Soak Box	1	75	Clariant Safewing MP IV Launch	100	Box	
568	Cold Soak Box	1	75	Clariant Safewing MP IV Launch	100	Box	
569	Cold Soak Box	1	75	Clariant Safewing MP IV Launch	75	Box	
570	Cold Soak Box	1	75	Clariant Safewing MP IV Launch	75	Box	
571	Cold Soak Box	1	75	Clariant Safewing MP IV Launch 2	100	Box	
572	Cold Soak Box	1	75	Clariant Safewing MP IV Launch 2	100	Box	
573	Cold Soak Box	1	75	Clariant Safewing MP IV Launch 2	75	Box	
574	Cold Soak Box	1	75	Clariant Safewing MP IV Launch 2	75	Box	
575	Cold Soak Box	1	75	Dow 200600147-10 (Type IV)	100	Box	
576	Cold Soak Box	1	75	Dow 200600147-10 (Type IV)	100	Box	
577	Cold Soak Box	1	75	Dow 200600147-10 (Type IV)	75	Box	
578	Cold Soak Box	1	75	Dow 200600147-10 (Type IV)	75	Box	
579	Cold Soak Box	1	75	Kilfrost P1792 Batch 2	100	Box	
580	Cold Soak Box	1	75	Kilfrost P1792 Batch 2	100	Box	
581	Cold Soak Box	1	75	Kilfrost P1792 Batch 2	75	Box	
582	Cold Soak Box	1	75	Kilfrost P1792 Batch 2	75	Box	
583	Cold Soak Box	1	75	Kilfrost P1797 (Type IV)	100	Box	
584	Cold Soak Box	1	75	Kilfrost P1797 (Type IV)	100	Box	
585	Cold Soak Box	1	75	Kilfrost P1797 (Type IV)	75	Box	
586	Cold Soak Box	1	75	Kilfrost P1797 (Type IV)	75	Box	
587	Cold Soak Box	1	5	Batelle D3 ADF	10°buf. (21.25)	Plate	Apply fluid at 20±5°C
588	Cold Soak Box	1	5	Batelle D3 ADF	10°buf. (21.25)	Plate	Apply fluid at 20±5°C

ATTACHMENT II: DETAILED ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
589	Cold Soak Box	1	5	Clariant Safewing MP IV Launch	100	Box	
590	Cold Soak Box	1	5	Clariant Safewing MP IV Launch	100	Box	
591	Cold Soak Box	1	5	Clariant Safewing MP IV Launch	75	Box	
592	Cold Soak Box	1	5	Clariant Safewing MP IV Launch	75	Box	
593	Cold Soak Box	1	5	Clariant Safewing MP IV Launch 2	100	Box	
594	Cold Soak Box	1	5	Clariant Safewing MP IV Launch 2	100	Box	
595	Cold Soak Box	1	5	Clariant Safewing MP IV Launch 2	75	Box	
596	Cold Soak Box	1	5	Clariant Safewing MP IV Launch 2	75	Box	
597	Cold Soak Box	1	5	Dow 200600147-10 (Type IV)	100	Box	
598	Cold Soak Box	1	5	Dow 200600147-10 (Type IV)	100	Box	
599	Cold Soak Box	1	5	Dow 200600147-10 (Type IV)	75	Box	
600	Cold Soak Box	1	5	Dow 200600147-10 (Type IV)	75	Box	
601	Cold Soak Box	1	5	Kilfrost P1797 (Type IV)	100	Box	
602	Cold Soak Box	1	5	Kilfrost P1797 (Type IV)	100	Box	
603	Cold Soak Box	1	5	Kilfrost P1797 (Type IV)	75	Box	
604	Cold Soak Box	1	5	Kilfrost P1797 (Type IV)	75	Box	
605	Cold Soak Box	1	5	Kilfrost P1792 Batch 2	100	Box	
606	Cold Soak Box	1	5	Kilfrost P1792 Batch 2	100	Box	
607	Cold Soak Box	1	5	Kilfrost P1792 Batch 2	75	Box	
608	Cold Soak Box	1	5	Kilfrost P1792 Batch 2	75	Box	

ATTACHMENT III: FLUID THICKNESS TEST PLAN

Test #	Fluid Manufacturer	Fluid Name	Fluid Dilution	Ambient Air Temperature
TH1	Kilfrost	P1792 Batch 2	100/0	-3°C
TH2	Kilfrost	P1792 Batch 2	100/0	-3°C
TH3	Kilfrost	P1792 Batch 2	75/25	-3°C
TH4	Kilfrost	P1792 Batch 2	75/25	-3°C
TH5	Kilfrost	P1792 Batch 2	50/50	-3°C
TH6	Kilfrost	P1792 Batch 2	50/50	-3°C

Notes:

- If the results for one fluid vary by more than 10% repeat the two tests and disregard the highest and lowest values
- The quantity of fluid that will be poured for each test is 1.0 L

ATTACHMENT IV: NCAR SNOW TEST PLAN

Test #	Fluid	Dilution	Temp. (°C)	Precip. Rate (g/dm2/h)	Natural Snow (min)	Priority	Test Status**	Prev NCAR Test Time (min)	Fluid Set Temp ±3 (°C)	Room Set Temp Low (°C)***	Room Set Temp High (°C)***	Plate Set Temp ±0.5 (°C)
NCAR1	Kilfrost P1792 (Type II) Batch2	100/0	-3	25	21.7*	1	N	N/A	-6	-7.1	-4.6	-5.1
NCAR2	Kilfrost P1792 (Type II) Batch2	75/25	-3	25	13.1*	1	N	N/A	-6	-7.1	-4.6	-5.1
NCAR3	Kilfrost P1792 (Type II) Batch1	75/25	-3	25	13.1	1	N	N/A	-6	-7.1	-4.6	-5.1
NCAR4	Kilfrost P1792 (Type II) Batch2	50/50	-3	25	8.4*	1	N	N/A	-6	-7.1	-4.6	-5.1
NCAR5	Kilfrost P1792 (Type II) Batch1	50/50	-3	25	8.4	1	N	N/A	-6	-7.1	-4.6	-5.1
NCAR6	Kilfrost P1792 (Type II) Batch2	100/0	-3	10	42*	1	N	N/A	-5	-6.2	-3.7	-4.2
NCAR7	Kilfrost P1792 (Type II) Batch1	100/0	-3	10	42.0	1	N	N/A	-5	-6.2	-3.7	-4.2
NCAR8	Kilfrost P1792 (Type II) Batch2	75/25	-3	10	28.9*	1	N	N/A	-5	-6.2	-3.7	-4.2
NCAR9	Kilfrost P1792 (Type II) Batch1	75/25	-3	10	28.9	1	N	N/A	-5	-6.2	-3.7	-4.2
NCAR10	Kilfrost P1792 (Type II) Batch2	50/50	-3	10	16.1*	1	N	N/A	-5	-6.2	-3.7	-4.2
NCAR11	Kilfrost P1792 (Type II) Batch1	50/50	-3	10	16.1	1	N	N/A	-5	-6.2	-3.7	-4.2
NCAR22	Kilfrost P1797 (Type IV)	75/25	-3	10	52.0	2	N	N/A	-5	-6.2	-3.7	-4.2
NCAR12	Dow 200600147-10 (Type IV)	75/25	-3	25	15.0	3	R	21.00	-6	-7.1	-4.6	-5.1
NCAR13	Dow 200600147-10 (Type IV)	50/50	-3	25	5.7	3	R	7.00	-6	-7.1	-4.6	-5.1
NCAR14	Clariant Safewing MPIV Launch	50/50	-3	25	12.3	3	R	39.25	-6	-7.1	-4.6	-5.1
NCAR15	Clariant Safewing MPIV Launch 2	50/50	-3	25	N/A	3	R	87.00	-6	-7.1	-4.6	-5.1
NCAR16	Dow 200600147-10 (Type IV)	100/0	-3	25	38.4	3	R	100.00	-6	-7.1	-4.6	-5.1
NCAR17	Kilfrost P1797 (Type IV)	100/0	-3	25	46.7	3	R	50.25	-6	-7.1	-4.6	-5.1
NCAR18	Clariant Safewing MPIV Launch	50/50	-3	10	23.6	4	R	14.50	-5	-6.2	-3.7	-4.2
NCAR19	Clariant Safewing MPIV Launch	100/0	-3	10	95.7	4	R	20.00	-5	-6.2	-3.7	-4.2
NCAR20	Clariant Safewing MPIV Launch 2	100/0	-3	10	N/A	4	R	46.00	-5	-6.2	-3.7	-4.2
NCAR21	Clariant Safewing MPIV Launch 2	50/50	-3	10	N/A	4	R	39.25	-5	-6.2	-3.7	-4.2
NCAR23	Clariant Safewing MPIV Launch	75/25	-3	10	80.9	4	R	89.50	-5	-6.2	-3.7	-4.2
NCAR24	Clariant Safewing MPIV Launch 2	75/25	-3	10	N/A	4	R	107.00	-5	-6.2	-3.7	-4.2
NCAR25	Kilfrost P1792 (Type II) Batch2	100/0	-14	25	15*	1	N	N/A	-17	-18.1	-15.6	-16.1
NCAR26	Kilfrost P1792 (Type II) Batch1	100/0	-14	25	15.0	1	N	N/A	-17	-18.1	-15.6	-16.1
NCAR27	Kilfrost P1792 (Type II) Batch2	75/25	-14	25	8.1*	1	N	N/A	-17	-18.1	-15.6	-16.1

ATTACHMENT IV: NCAR SNOW TEST PLAN (CONT'D)

Test #	Fluid	Dilution	Temp. (ºC)	Precip. Rate (g/dm^2/h)	Natural Snow (min)	Priority	Test Status**	Prev NCAR Test Time (min)	Fluid Set Temp ±3 (°C)	Room Set Temp Low (°C)***	Room Set Temp High (°C)***	Plate Set Temp ±0.5 (°C)
NCAR28	Kilfrost P1792 (Type II) Batch2	100/0	-14	10	28.1*	1	N	N/A	-16	-17.2	-14.7	-15.2
NCAR29	Kilfrost P1792 (Type II) Batch1	100/0	-14	10	28.1	1	N	N/A	-16	-17.2	-14.7	-15.2
NCAR30	Kilfrost P1792 (Type II) Batch2	75/25	-14	10	17.9*	1	N	N/A	-16	-17.2	-14.7	-15.2
NCAR31	Kilfrost P1792 (Type II) Batch1	75/25	-14	10	17.9	1	N	N/A	-16	-17.2	-14.7	-15.2
NCAR32	Clariant Safewing MPIV Launch	75/25	-14	25	21.8	2	N	N/A	-17	-18.1	-15.6	-16.1
NCAR33	Kilfrost P1797 (Type IV)	100/0	-14	10	61.1	2	N	N/A	-16	-17.2	-14.7	-15.2
NCAR34	Clariant Safewing MPIV Launch	100/0	-14	25	40.5	3	R	13.25	-17	-18.1	-15.6	-16.1
NCAR35	Clariant Safewing MPIV Launch 2	100/0	-14	25	N/A	3	R	13.25	-17	-18.1	-15.6	-16.1
NCAR36	Clariant Safewing MPIV Launch 2	75/25	-14	25	N/A	3	R	11.75	-17	-18.1	-15.6	-16.1
NCAR37	Kilfrost P1797 (Type IV)	100/0	-14	25	33.1	3	R	14.50	-17	-18.1	-15.6	-16.1
NCAR38	Kilfrost P1797 (Type IV)	75/25	-14	25	22.6	3	R	14.50	-17	-18.1	-15.6	-16.1
NCAR39	Clariant Safewing MPIV Launch	100/0	-14	10	66.6	4	R	45.25	-16	-17.2	-14.7	-15.2
NCAR40	Clariant Safewing MPIV Launch 2	100/0	-14	10	N/A	4	R	46.50	-16	-17.2	-14.7	-15.2
NCAR41	Dow 200600147-10 (Type IV)	75/25	-14	10	28.3	4	R	37.25	-16	-17.2	-14.7	-15.2
NCAR42	Kilfrost P1797 (Type IV)	75/25	-14	10	50.1	4	R	34.00	-16	-17.2	-14.7	-15.2
NCAR43	Kilfrost P1792 (Type II) Batch2	100/0	-25	10	N/A	1	N	N/A	-27	-28.2	-25.7	-26.2
NCAR44	Kilfrost P1792 (Type II) Batch2	100/0	-25	25	N/A	1	N	N/A	-28	-29.1	-26.6	-27.1
NCAR45	Dow 200600147-10 (Type IV)	100/0	-25	10	N/A	2	R	28.50	-27	-28.2	-25.7	-26.2

* For Kilfrost TII Batch 2, natural snow times are based on Batch 1 tests

** Test Status: N= New Test, R = Repeated Test

*** The room temperature should be in the interval between Room Temp Set Low and Room Set Temp High

ATTACHMENT V: ICE PELLETS TEST PLAN

Test #	Priority	Fluid Type	First Step Fluid Brand	First Step Dilution	First Step Fluid Quantity	First Step Fluid Temp. [° C]	Second Step Fluid Brand	Second Step Dilution	Second Step Fluid Quantity	Second Step Fluid Temp. [° C]	Precip Type	Test Temp. [° C]	Ice Pellet Precip Rate [g/dm²/h]	Objective
IP22	1	I and II	UCAR ADF EG	10° Buffer	1L	60	Maxflo	50/50	1L	60	IP	-3	75	Two Step Application, on Box
IP23	3	I and II	UCAR ADF EG	10° Buffer	1L	60	Maxflo	50/50	1L	20	IP	-3	75	Two Step Application, on Box
IP24	4	I and II	UCAR ADF EG	10° Buffer	1L	60	Maxflo	50/50	1L	-3	IP	-3	75	Two Step Application, on Box
IP25	2	I and II	UCAR ADF EG	10° Buffer	1L	60	Maxflo	100/0	1L	60	IP	-3	75	Two Step Application, on Box
IP26	1	I and IV	UCAR ADF EG	10° Buffer	1L	60	Ultra+	50/50	1L	60	IP	-3	75	Two Step Application, on Box
IP27	3	I and IV	UCAR ADF EG	10° Buffer	1L	60	Ultra+	50/50	1L	20	IP	-3	75	Two Step Application, on Box
IP28	4	I and IV	UCAR ADF EG	10° Buffer	1L	60	Ultra+	50/50	1L	-3	IP	-3	75	Two Step Application, on Box
IP29	2	I and IV	UCAR ADF EG	10° Buffer	1L	60	Ultra+	100/0	1L	60	IP	-3	75	Two Step Application, on Box
IP30	1	IV	Maxflo	50/50	2L	60	N/A	N/A	N/A	N/A	IP	-3	75	2 Litres of Heated Fluid, on Box
IP31	2	IV	Ultra+	50/50	2L	60	N/A	N/A	N/A	N/A	IP	-3	75	2 Litres of Heated Fluid, on Box
IP32	1	IV	UCAR ADF EG	10° Buffer	1L	60	Ultra+	100/0	1L (degraded)	OAT	IP	-3	75	2-Step, 1L EG Fluid mixed with few drops of Sodium Hydroxide (or Vinegar if not available), on Box
IP33	1	IV	UCAR ADF EG	10° Buffer	1L	60	Maxflo	100/0	1L (Sheared)	OAT	IP	-3	75	2-Step, 1L PG Fluid sheared to 40% of LOWV, on Box

Note: All tests require only simulated ice pellets (tests can be done is separate section of NRC chamber)

ATTACHMENT VI: EFFECT OF SURFACE MATERIAL TEST PLAN

Test #	Priority	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid Brand	Dilution (BRIX)	Test Surface	Comments
C3a	2	Freezing Drizzle	-3	13	Kilfrost P1792 Batch 2	50/50	White Al.	1 L, 12-hole spreader, 60° C
C3b	2	Freezing Drizzle	-3	13	Kilfrost P1792 Batch 2	50/50	Comp 05	1 L, 12-hole spreader, 60° C
C3c	2	Freezing Drizzle	-3	13	Kilfrost P1792 Batch 2	50/50	Plate	Do not run, see ET Test 545*
C4a	1	Freezing Drizzle	-3	13	Batelle D3 ADF	10° buf (26.75)	White Al.	1 L, 12-hole spreader, 20° C
C4b	1	Freezing Drizzle	-3	13	Batelle D3 ADF	10° buf (26.75)	Comp 05	1 L, 12-hole spreader, 20° C
C7a	2	Freezing Drizzle	-10	13	Kilfrost P1792 Batch 2	75/25	White Al.	1 L, 12-hole spreader, 60° C
C7b	2	Freezing Drizzle	-10	13	Kilfrost P1792 Batch 2	75/25	Comp 05	1 L, 12-hole spreader, 60° C
C7c	2	Freezing Drizzle	-10	13	Kilfrost P1792 Batch 2	75/25	Plate	Do not run, see ET Test 527*
C10a	1	Light Freezing Rain	-3	25	Clariant Safew ing MPIV Launch 2	75/25	White Al.	1 L, 12-hole spreader, 60° C
C10b	1	Light Freezing Rain	-3	25	Clariant Safew ing MPIV Launch 2	75/25	Comp 05	1 L, 12-hole spreader, 60° C
C12a	2	Light Freezing Rain	-10	13	Batelle D3 ADF	10° buf (34.75)	White Al.	1 L, 12-hole spreader, 20° C
C12b	2	Light Freezing Rain	-10	13	Batelle D3 ADF	10° buf (34.75)	Comp 05	1 L, 12-hole spreader, 20° C

* Standard HOT tests will be used in place of this test and can be run independently

ATTACHMENT VII: EFFECT OF HEAT TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid Brand	Dilution or BRIX	Test Surface	Comments
H1a	Freezing Drizzle	-10	5	Clariant Safewing MP III 2031 ECO	100	Plate	Heat fluid to 60°C, use spreader
H1b	Freezing Drizzle	-10	5	Clariant Safewing MP III 2031 ECO	100	Plate	Apply fluid at OAT
H2a	Freezing Drizzle	-10	5	Octagon MaxFlo	75	Plate	Heat fluid to 60°C, use spreader
H2b	Freezing Drizzle	-10	5	Octagon MaxFlo	75	Plate	Apply fluid at OAT
H12a	Light Freezing Rain	-3	13	Octagon MaxFlo	100	Plate	Heat fluid to 60°C, use spreader
H12b	Light Freezing Rain	-3	13	Octagon MaxFlo	100	Plate	Apply fluid at OAT
H35a	Light Freezing Rain	-10	13	Octagon MaxFlo	75	Plate	Heat fluid to 60°C, use spreader
H35b	Light Freezing Rain	-10	13	Octagon MaxFlo	75	Plate	Apply fluid at OAT

ATTACHMENT VIII: LIST OF FLUIDS

Fluid Name	Dilution	Litres Required						
		HOT	THICK	COMP	HEAT	NCAR	ICE P	Total
Kilfrost P1792 (Type II) Batch 2	100	32	2	-	-	6	-	**40**
Kilfrost P1792 (Type II) Batch 2	75	28	2	2	-	4	-	**36**
Kilfrost P1792 (Type II) Batch 2	50	12	2	2	-	2	-	**18**
Batelle D3 ADF	10° buffer	6	-	4	-	-	-	**10**
Clariant Safewing MP IV Launch	100	4	-	-	-	3	-	**7**
Clariant Safewing MP IV Launch	75	5	-	-	-	2	-	**7**
Clariant Safewing MP IV Launch	50	-	-	-	-	2	-	**2**
Clariant Safewing MP IV Launch 2	100	4	-	-	-	3	-	**7**
Clariant Safewing MP IV Launch 2	75	4	-	2	-	2	-	**8**
Clariant Safewing MP IV Launch 2	50	-	-	-	-	2	-	**2**
Dow 200600147-10 (Type IV)	100	6	-	-	-	2	-	**8**
Dow 200600147-10 (Type IV)	75	5	-	-	-	2	-	**7**
Dow 200600147-10 (Type IV)	50	-	-	-	-	1	-	**1**
Kilfrost P1792 (Type II) Batch 1	100	-	-	-	-	3	-	**3**
Kilfrost P1792 (Type II) Batch 1	75	-	-	-	-	3	-	**3**
Kilfrost P1792 (Type II) Batch 1	50	-	-	-	-	2	-	**2**
Kilfrost P1797 (Type IV)	100	4	-	-	-	3	-	**7**
Kilfrost P1797 (Type IV)	75	6	-	-	-	3	-	**9**
Kilfrost P1797 (Type IV)	50	1	-	-	-	-	-	**1**
Clariant Safewing MP III 2031	100	-	-	-	2	-	-	**2**
Dow UCAR Ultra+	100	-	-	-	-	-	4	**4**
Dow UCAR Ultra+	50	-	-	-	-	-	2	**2**
Octagon Maxflo	100	-	-	-	2	-	2	**4**
Octagon Maxflo	75	-	-	-	4	-	-	**4**
Octagon Maxflo	50	-	-	-	-	-	4	**4**
Dow UCAR ADF (EG Type I)	10° buffer	-	-	-	-	-	10	**10**
		117	**6**	**10**	**8**	**45**	**22**	**208**

ATTACHMENT IX: TYPE I DILUTION TABLES

OAT (°C)	FFP (°C)	Batelle D3				Octaflo EF (PG)				UCAR ADF (EG)			
		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
10	0					0	0.00	0.0	8.0	0	0.00	0.0	8.0
9	-1					4	2.75	0.3	7.7	3	1.50	0.2	7.8
8	-2					7.75	5.25	0.6	7.4	4.5	3.00	0.4	7.6
7	-3					8.25	6.00	0.7	7.3	7.5	4.75	0.6	7.4
6	-4					10	6.75	0.8	7.2	**10**	**6.50**	0.8	7.2
5	-5					15	9.75	1.2	6.8	12	8.00	1.0	7.0
4	-6	**20**	**14.75**	1.6	6.4	**20**	**12.75**	1.6	6.4	14.5	9.50	1.2	6.8
3	-7	26	18.50	2.1	5.9	22	15.00	1.8	6.2	16	10.50	1.3	6.7
2	-8	28	20.00	2.2	5.8	25	16.50	2.0	6.0	18.5	12.00	1.5	6.5
1	-9	29	21.25	2.3	5.7	28	18.50	2.2	5.8	21.5	13.50	1.7	6.3
0	-10	**30**	**22.75**	2.4	5.6	29	19.00	2.3	5.7	22	14.00	1.8	6.2
-1	-11	33	24.00	2.6	5.4	**30**	**20.00**	2.4	5.6	23	15.00	1.8	6.2
-2	-12	35	25.50	2.8	5.2	31	20.50	2.5	5.5	24.5	16.00	2.0	6.0
-3	-13	37	26.75	3.0	5.0	32	21.25	2.6	5.4	26	17.00	2.1	5.9
-4	-14	38	28.00	3.0	5.0	34	22.50	2.7	5.3	28	18.00	2.2	5.8
-5	-15	39	29.00	3.1	4.9	35	23.00	2.8	5.2	**30**	**19.00**	2.4	5.6
-6	-16	**40**	**29.75**	3.2	4.8	36	23.50	2.9	5.1	31	19.75	2.5	5.5
-7	-17	44	31.50	3.5	4.5	37	24.00	3.0	5.0	32	20.50	2.6	5.4
-8	-18	45	32.50	3.6	4.4	38.5	25.00	3.1	4.9	33.5	21.25	2.7	5.3
-9	-19	47	33.75	3.8	4.2	**40**	**26.00**	3.2	4.8	34.5	21.75	2.8	5.2
-10	-20	48	34.75	3.8	4.2	42	27.00	3.4	4.6	36	22.50	2.9	5.1
-11	-21	49	35.75	3.9	4.1	44	28.00	3.5	4.5	37	23.00	3.0	5.0
-12	-22	**50**	**36.50**	4.0	4.0	45	28.50	3.6	4.4	38	23.75	3.0	5.0
-13	-23	52	37.50	4.2	3.8	46	29.00	3.7	4.3	39	24.50	3.1	4.9
-14	-24	53	38.50	4.2	3.8	47	29.50	3.8	4.2	**40**	**25.00**	3.2	4.8
-15	-25	54	39.50	4.3	3.7	47.5	30.00	3.8	4.2	41	25.50	3.3	4.7
-16	-26	**55**	**39.50**	4.4	3.6	48.5	30.50	3.9	4.1	42	26.00	3.4	4.6
-17	-27	57	41.00	4.6	3.4	49	31.00	3.9	4.1	43	26.50	3.4	4.6
-18	-28	58	41.75	4.6	3.4	**50**	**31.50**	4.0	4.0	44	27.00	3.5	4.5
-19	-29	**60**	**42.25**	4.8	3.2	51	32.00	4.1	3.9	45	27.50	3.6	4.4
-20	-30	61	43.00	4.9	3.1	52	32.50	4.2	3.8	45.75	28.00	3.7	4.3
-22	-32	62	44.25	5.0	3.0	53.5	33.50	4.3	3.7	47	28.75	3.8	4.2
-25	-35	65	46.00	5.2	2.8	56	34.50	4.5	3.5	49	30.00	3.9	4.1
-30	-40	**70**	**48.25**	5.6	2.4	**60**	**37.00**	4.8	3.2	53	32.00	4.2	3.8
Std. Mix						63	38.30	5.0	3.0	57	33.50	4.6	3.4

ATTACHMENT X: 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

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

COMMENTS: _____

LEADER / MANAGER: _____

ATTACHMENT XI: COLD-SOAK WING ENDURANCE TIME DATA FORM

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: _____

ATTACHMENT XII: 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

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ATTACHMENT XIII: NCAR DATA FORM

Version 1.0 Winter 2003-04

LOCATION: DATE: RUN # : STAND # : NCAR

OUTPUT FILENAME:_____.txt

OAT: _____ °C

PRECIPITATION RATE: _____ g/dm²/h

FLUID TEMPERATURE: _____ °C

FLUID QUANTITY APPLIED: _____ Litres

PLATE WASHING METHOD: _____

PLATE TEMPERATURE (OMEGA): _____ °C

OTHER COMMENTS (Fluid Batch, etc):

_____

_____

_____

_____

_____

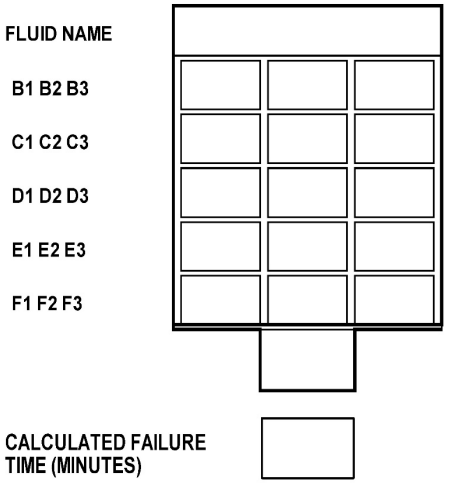
_____

_____

	PRINT	SIGN
FAILURES CALLED BY :		
HAND WRITTTEN BY :		
LEADER :		

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

Time of Fluid Application: _____ h:min



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Version 1.0, April 06

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ATTACHMENT XIV: FLUID BRIX / THICKNESS DATA FORM

DATE: _____ **PERFORMED BY:** _____

RUN #: _____ **WRITTEN BY:** _____

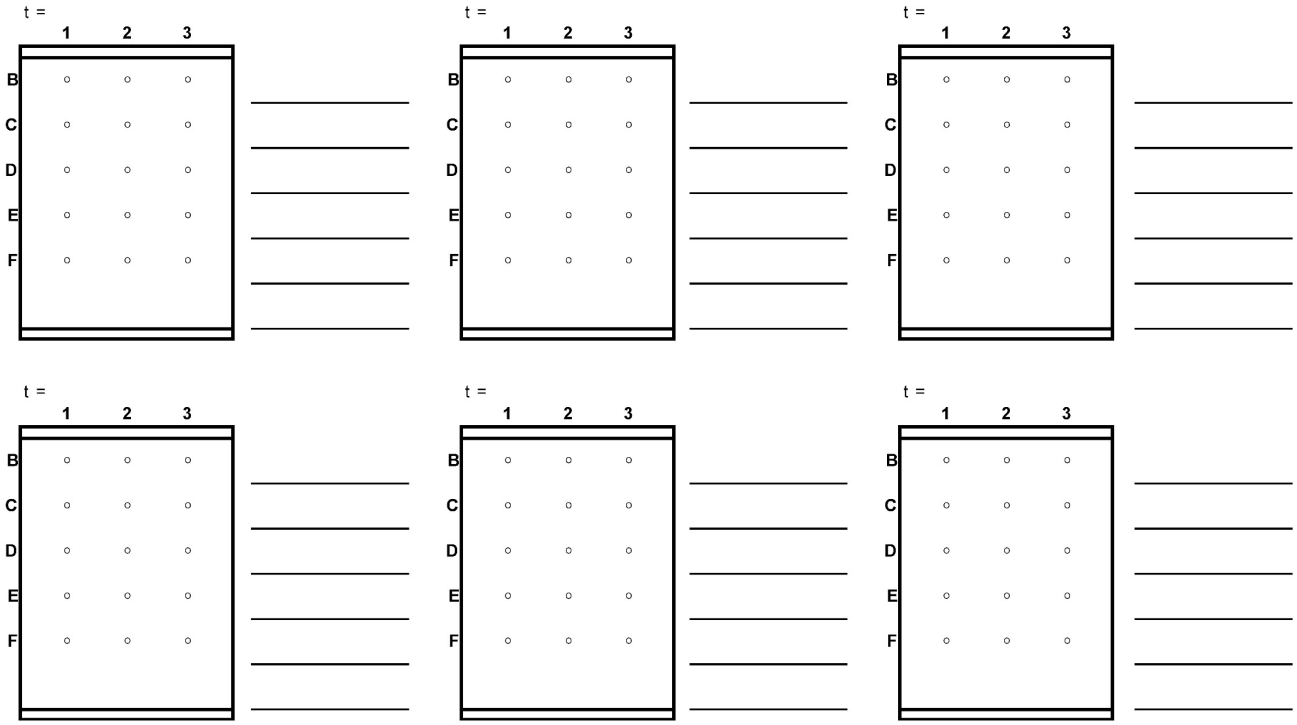
STAND: _____ **LOCATION:** _____

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

ATTACHMENT XV: ADHERENCE OF FLUID FAILURE DATA FORM

Date: _____ Time: _____ Plate Location: _____

Run #: _____ Fluid Name: _____ Fluid Dilution: _____



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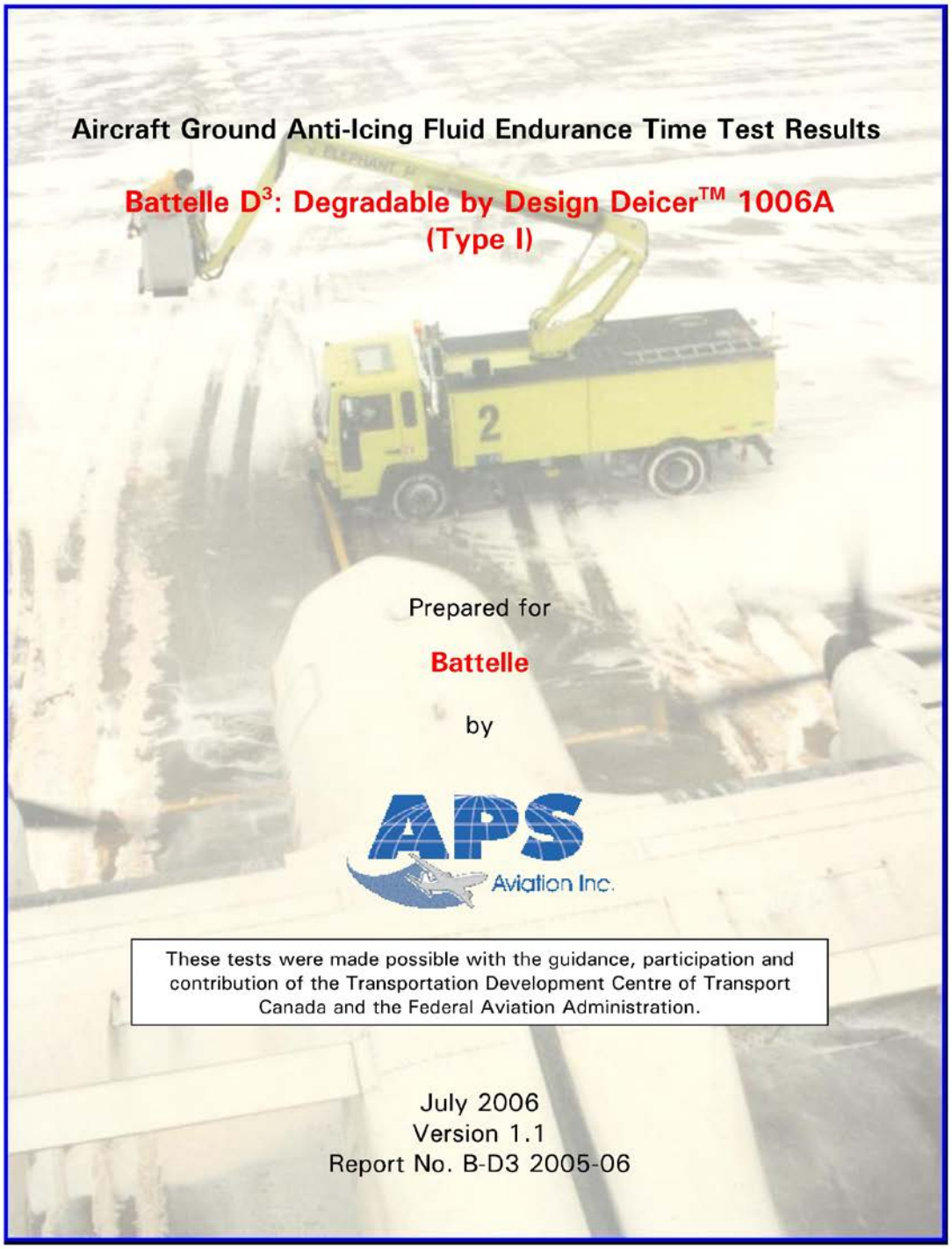
APPENDIX C

FLUID MANUFACTURER REPORT:
BATTELLE D^3: DEGRADABLE BY DESIGN DEICER™ 1006A (TYPE I)


Aircraft Ground Anti-Icing Fluid Endurance Time Test Results
Battelle D3: Degradable by Design Deicer™ 1006A
(Type I)
Prepared for
Battelle
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.
July 2006
Version 1.1
Report No. B-D3 2005-06

Aircraft Ground Anti-Icing Fluid Endurance Time Test Results

Battelle D^3: Degradable by Design Deicer^{TM} 1006A (Type I)

Prepared for

Battelle

Prepared by: _____ July 7, 2006
Stephanie Bendickson — Date
Project Analyst

Reviewed by: _____ July 7, 2006
John D'Avirro — Date
Program Manager, Eng.



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

July 2006
Version 1.1
Report No. B-D3 2005-06

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer:	Battelle
Fluid:	D^3: Degradable by Design Deicer™ 1006A
Fluid Type / Colour:	Type I / Orange
Fluid Formulation:	Non-glycol
Batch #:	51381
Date of Receipt:	February 23, 2006
Brix Measured:	Concentrate: >50°
WSET provided by AMIL:	50/50: 4.6 minutes

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SUMMARY

The primary objective of this project was to measure the endurance time performance of Battelle D^3: Degradable by Design Deicer™ 1006A over the entire range of conditions encompassed by the Holdover Time (HOT) tables and compare it to the performance of other Type I fluids. 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).

The HOT test procedure consisted of pouring fluids onto clean aluminium test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural snow and simulated freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. Endurance time tests were performed at the APS Aviation Inc. (APS) test facility located within the Montréal-Pierre-Elliott-Trudeau International Airport and at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

The endurance time results of this fluid in simulated freezing precipitation were similar or superior to Type I fluids tested in past years. The endurance time results of this fluid in snow were similar or superior to other Type I fluids that were tested simultaneously.

The endurance time test results indicate that this fluid, Battelle D^3: Degradable by Design Deicer™ 1006A, can be used as a Type I fluid with the generic Type I HOT guidelines.

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GLOSSARY

APS	APS Aviation Inc.
ARP	Aerospace Recommended Practice
Battelle D^3	Battelle D^3: Degradable by Design Deicer™ 1006A
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LWC	Liquid Water Content
MVD	Median Volume Diameter
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
SAE	Society of Automotive Engineers, Inc.
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

Aircraft ground de/anti-icing has been the subject of concentrated industry attention over the past decade due the occurrence of several fatal icing-related aircraft accidents. Recent attention has been placed upon 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 used by aircraft operators in departure planning in adverse winter weather conditions. These guidelines are accepted by regulatory authorities and provide the HOT ranges for aircraft treated with any qualified deicing or anti-icing fluid.

Testing has shown that Type II and Type IV fluid endurance time performance varies considerably by fluid. As a result, fluid-specific HOT tables have been developed for each certified Type II and Type IV fluid based on the results of endurance time tests carried out by APS Aviation (APS).

In contrast, 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, only one Type I HOT table is provided in the HOT guidelines and it is used with all certified Type I fluids. Furthermore, regulators no longer require Type I deicing fluids formulated with propylene glycol, ethylene glycol or diethylene glycol be tested for endurance times. However, they do require that the endurance times of fluids formulated with other glycol bases or with non-glycol bases be measured. This is to ensure the endurance time performance of the fluid is similar to the performance of the Type I fluids used to generate the currently accepted values in the Type I HOT table.

Battelle D^3: Degradable by Design Deicer™ 1006A (Battelle D^3) is a non-glycol based fluid and therefore regulators required its endurance time performance be measured and compared to the performance of other Type I fluids. This report documents the data collected and the methods used to measure the fluid endurance times for Battelle D^3. The content and format of the report is based on the standard Type II/IV report; however, it has been adapted to document the performance of a Type I non-glycol based fluid.

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).

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2

2. METHODOLOGY

This chapter contains a description of the weather conditions, test sites, test conditions, equipment, test procedures, and precipitation data ranges used in de/anti-icing fluid testing.

2.1 Definition of Weather Conditions

HOTs are provided as a function of *weather condition*, fluid mixture and outside air temperature. The objective of the winter test program was to substantiate these HOT or develop new ones based on the most recent test data.

Table 2.1 provides definitions of most weather conditions experienced in winter operations and includes the criteria used to determine precipitation intensity (light, moderate, heavy). 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).

Table 2.1 includes definitions for the *weather conditions* described in the HOT tables (frost, freezing fog, snow, freezing drizzle, light freezing rain and rain). Definitions for snow pellets, hail and ice pellets are also presented, however these are conditions for which HOT guidelines do not exist.

The test methodology used to determine fluid endurance times has included the generally accepted upper and lower limits for precipitation rates for each type of precipitation. These limits were discussed in detail at a 1997 meeting of the Society of Automotive Engineers (SAE) G-12 HOT Subcommittee where standard definitions of upper and lower precipitation rate limits were approved for each category of precipitation. These limits are documented and discussed in Subsection 2.6.

2.1.1 Snow

Table 2.1 contains the criteria that were used in the past to estimate the intensity of snow. These criteria are based upon horizontal visibility with three intensity levels. For light snow, visibility is greater than or equal to 1.0 km, moderate snow visibility is 0.5 km to less than 1.0 km, and heavy snow, visibility is less than 0.5 km.

As stated in a cautionary note in Table 2.1, visibility is only an indicator of snow intensity, and the two parameters are not always correlated.

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 visibility at the earth's surface to less than 1 km (5/8 mile).
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 (23°F), the crystals are generally agglomerated into snowflakes.
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 the ground or other exposed objects.
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 mm (0.02 in.) or smaller drops which, in contrast to drizzle, are widely separated.
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)	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter is about 2-5 mm (0.1-0.2 in.). Grains are brittle, easily crushed; they bounce and break on hard ground.
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is less than 1 mm (0.04 in.). When the grains hit hard ground, they do not bounce or shatter.
HAIL (GR)	Precipitation of small balls or pieces of ice with a diameter ranging from 5 to > 50 mm (0.2 to 2.0 in.) falling either separately or agglomerated.
ICE PELLETS (PE) Note: Includes Sleet and Small Hail	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.) or less. The pellets of ice usually bounce when hitting hard ground.

Intensity Criteria**

Snow(SN),Pellets(GS),Grains(SG),Fra Drizzle(FZDZ)			Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (SI) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm or 10.0 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 or 25.0 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 shown that visibility and precipitation intensity are not always directly correlated.

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm 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 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 exposed surface up to a condition where individual drops are easily seen.
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm 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 pavement and other hard surfaces.
Measured Intensity	More than 0.30 in/hr (7.6 mm 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 spray to height of several inches is observed over hard surfaces.

* From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
** From American Meteorological Society, Glossary of Meteorology W/SOH #7 MANOBS (5/94)
*** NCAR Proposed Definition for Liquid Equivalent Snowfall Intensity

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

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP June 17, 1997
(Updated for METAR codes)

Table 2.2 is based on more recent data than Table 2.1 and provides more detail about snowfall intensity and visibility. APS, NCAR and TC all had input into the formation of this table, which is based on NCAR field data and theoretical work on classes of snow and on extensive field data compiled by APS. The table categorizes snowfall into one of four intensities based on visibility and lighting condition.

TC publishes a visibility table annually for use in winter operations. This table was first used in the winter of 2003-04. The FAA visibility table differs slightly from the TC visibility table, but is based on the same data set.

Table 2.2: Visibility in Snow vs. Snowfall Intensity Chart[1]

Lighting	Temperature Range		Visibility in Snow (Statute Miles)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤ 1	> 1 to 2½	> 2½ to 4	> 4
	Below -1	Below 30	≤ 3/4	> 3/4 to 1½	> 1½ to 3	> 3
Daylight	-1 and above	30 and above	≤ ½	> ½ to 1½	> 1½ to 3	> 3
	Below -1	Below 30	≤ 3/8	> 3/8 to 7/8	> 7/8 to 2	> 2

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.

2.1.2 Freezing Drizzle

Freezing drizzle is composed of closely spaced fine water droplets with a diameter less than 0.5 mm (see Table 2.1). The intensity of freezing drizzle is estimated, as for snow, through the measurement of horizontal visibility. The HOT table has one column for freezing drizzle, but Table 2.1 shows three intensity levels (light, moderate and heavy). For example, under moderate freezing drizzle, the rate of precipitation should range between 2.5 and 5.1 g/dm²/h. For heavy freezing drizzle, the definition indicates that the intensity is greater than 5 g/dm²/h. Discussions between United Airlines, NCAR and the National Research Council Canada (NRC) led to the upper limit value of 13 g/dm²/h for freezing drizzle. This value was also used as the lower limit for light freezing rain.

2.1.3 Freezing Rain

This form of precipitation exists either in the form of drops with diameters greater than 0.5 mm, or smaller drops which, in contrast to drizzle, are widely separated. For each of the three intensities of freezing rain given in Table 2.1, a visual description is supplied to provide a subjective guideline for the purpose of estimating rain intensity. However, the following definitions apply when an instrument is available to measure the intensity of precipitation:

- Light Precipitation rate is ≤ 25 g/dm²/h
- Moderate Precipitation rate is >25 g/dm²/h but ≤75 g/dm²/h
- Heavy Precipitation rate is >75 g/dm²/h

2.1.4 Freezing Fog

Freezing fog is defined as suspended minute water droplets that freeze upon impact with the ground or exposed objects. Table 2.1 does not provide any indication of intensity or liquid water content (LWC) of the fog other than that the horizontal visibility is reduced to less than 1 km.

2.2 Test Sites

Normal natural snow test operations are performed at the APS test site located within the Montréal-Pierre-Elliott-Trudeau International Airport. The location of the test site is shown on the plan view of the airport shown in Figure 2.1. Photo 2.1 shows the test site trailer and test stands, the site consists of two trailers and three locations for test stands. The APS test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station (Photo 2.2).

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.

The CEF is partitioned into two sections, separated by an insulated dividing door. Each partition can be separately controlled, permitting different tests to be conducted simultaneously. Photo 2.3 provides a general indication of the size of the facility. Photos 2.4 and 2.5 provide interior images of the small and large ends of the facility. The facility was designed and built for the testing of locomotives. The size of the chamber is 30 m by 5.4 m and its total height is 8 m. The lowest temperature achievable is -46°C.

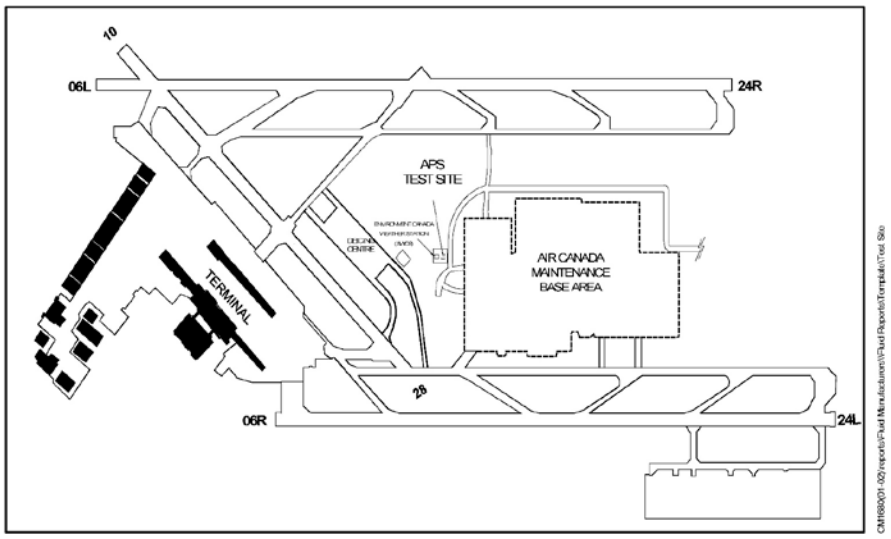


Figure 2.1: Test Site at the Montréal-Pierre-Elliott-Trudeau International Airport

2.3 Test Conditions

Outdoor testing was conducted during natural precipitation events. Supplementary tests to simulate freezing precipitation were carried out at the NRC CEF (see Photo 2.4). Subsections 2.3.1 and 2.3.2 provide descriptions of the spray assembly (see Photo 2.6) and of the methods used to produce and calibrate the fine water droplets in these artificial precipitation tests. Subsection 2.3.3 provides a summary of the categories and characteristics of each precipitation type produced for these tests.

2.3.1 Droplet Size and Rate of Precipitation

In the past few years, more industry attention has been given to the influence of droplet size on HOT. To explore this relationship further, experiments were performed to measure droplet sizes produced by different nozzles (gauge of hypodermic needle) at various water and air pressures in the spray delivery unit. Although the gauge of the needles is an important factor in the production of water droplets with appropriate dimensions, the air and water pressure levels in the sprayer system are equally important.

An improved sprayer assembly was developed in 1997-98 by the NRC and is shown in Photo 2.6. The new 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 2.7.

Prior to 1995, calibration experiments conducted by the NRC used an optical gauge manufactured by HSS (Biral UK acquired the HSS technology) to verify that the simulation of freezing fog, freezing drizzle, and light freezing rain provided adequate droplet sizes.

Since 1995, the APS team has carried out droplet size calibration using a manual dye-stain technique employed by personnel at the NRC. This technique consists of dusting Whatman #1 filter paper discs with a water-activated, very finely-divided powder form of methylene blue dye. The prepared discs are manually positioned under simulated precipitation for a fixed time to acquire a droplet size pattern. A calibration curve is then used to convert the measured diameter of the droplets on the pattern to the experimental median volume diameter (MVD).

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:	Dorval 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.

Figures 2.2 and 2.3 show an example of the distribution of simulated light freezing rain droplets obtained at the NRC.

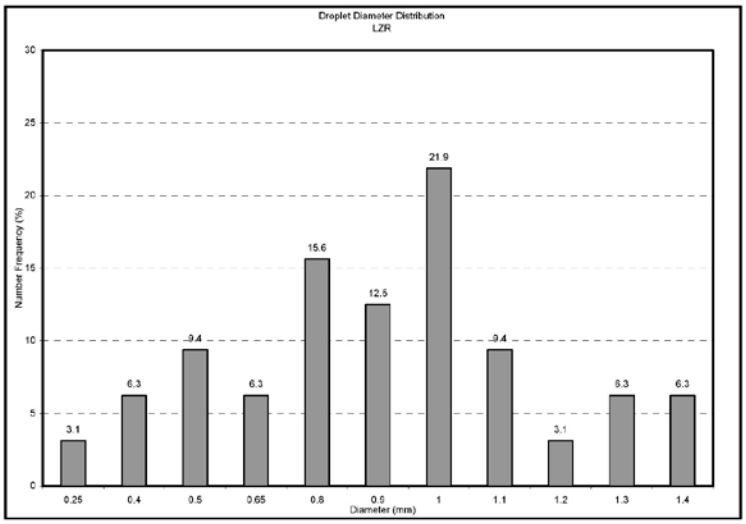


Figure 2.2: Droplet Diameter Distribution, Sample

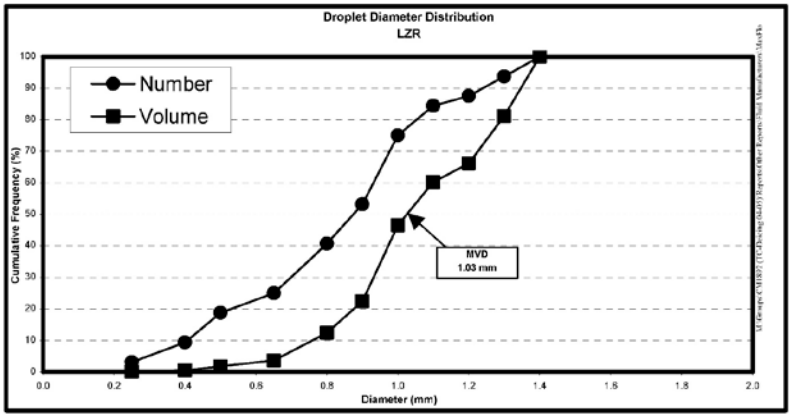


Figure 2.3: Cumulative Frequency of Droplet Diameter, Sample

2.3.2 Median Volume Diameter of Rain Drops

The MVD of a rain droplet was researched and found to be related to the precipitation rate 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 2.3 beside the experimental MVDs for each precipitation condition.

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

2.3.3 Characteristics of 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 were collected:

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

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

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

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

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

4. Moderate Rain on Cold Soaked Surface:
   Precipitation rate: 75 g/dm²/h;
   Droplet median volume diameter: 1 400 μm; and
   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.

2.4 Equipment

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.

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) meets the requirements set out in the test protocol.

Figure 2.4 shows a schematic of the test platform used for HOT testing. During normal operations, six test plates are normally mounted on the test stand, which has a working surface inclined at 10° to the horizontal. Each plate represents a flat plate test.

Figure 2.4 also depicts the size and surface markings of the standard flat plate used for freezing fog, freezing drizzle and light freezing rain tests. 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 were marked with 15 crosshairs used in determining

whether end conditions (see Subsection 2.5.2 for definition) were achieved. Photo 2.8, taken outdoors at APS test site, shows six test plates mounted on a stand. For simulated freezing precipitation tests at the NRC, 12 plates were mounted on 2 six-position stands, as shown in Figure 2.4.

Figure 2.5 shows the collection (plate) pan, which is of the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.9 shows the collection pans used for measuring precipitation rates indoors at the NRC.

Figure 2.5 also depicts the sealed boxes (7.5 cm deep) which were used for natural snow and simulated cold-soaked wing tests (see Figure 2.5). The top of the cold-soak box consists of an aluminium flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate. The boxes remain empty for natural snow tests and are filled with fluid for cold-soaked wing tests.

Freeze points were measured using a hand-held Misco refractometer with a Brix scale.

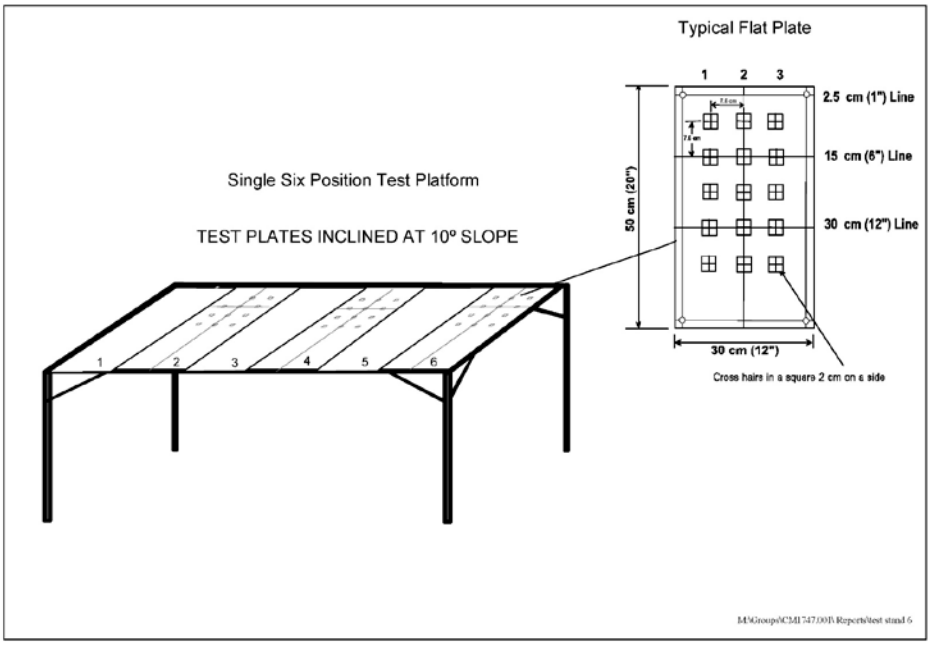
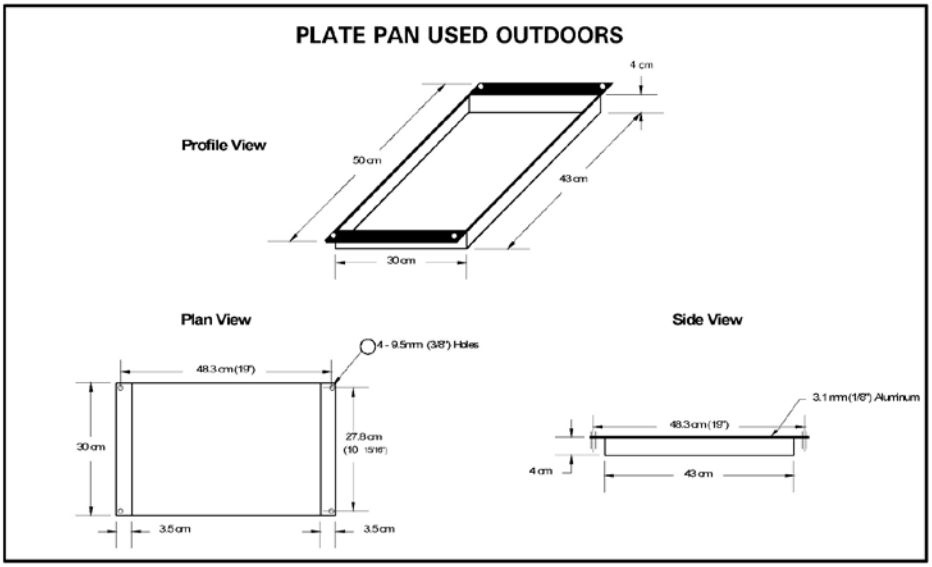


Figure 2.4: Flat Plate Test Set-Up



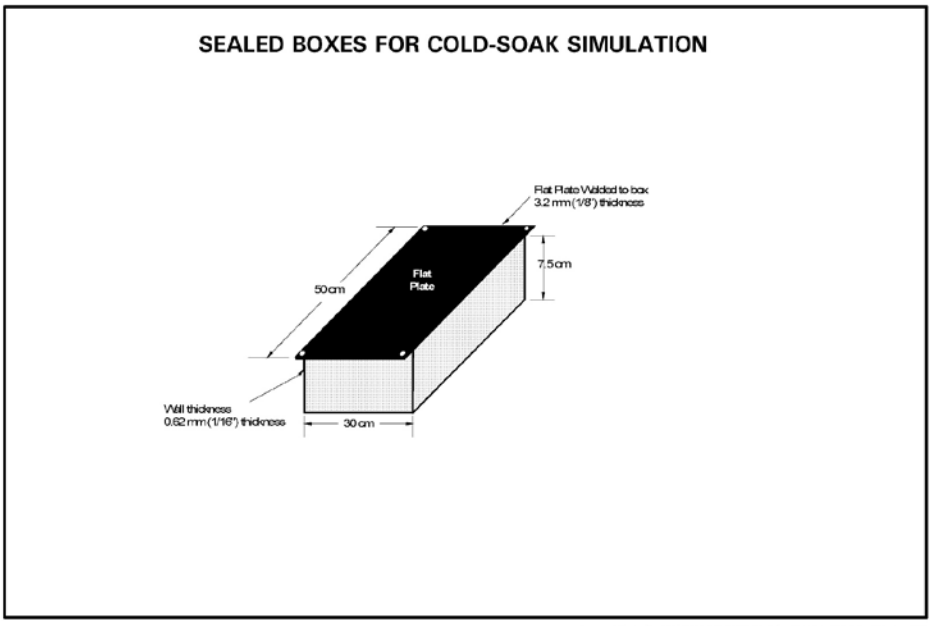


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Figure 2.5: Schematics of Plate Pan and Sealed Boxes

2.5 Test Procedures

The SAE Aerospace Recommended Practice (ARP) 5945 provides the procedure and requirements for Type I testing. This procedure addresses testing conducted under natural precipitation conditions and under simulated freezing precipitation conditions.

The procedure for endurance time testing is to apply fluid to test plates exposed to natural snow and simulated freezing fog, freezing drizzle, light freezing rain and rain on cold soaked wing. Endurance times are evaluated by measuring the amount of time that passes before a specified degree of freezing occurs.

During the conduct of these tests a series of test parameters are recorded. The test parameters are grouped into two categories: generic and specific test parameters. Generic test parameters are recorded once per winter season (or test session, in laboratory testing) and include: discussion of safety issues, test plate material, test plate dimensions, surface finish and ice-catch pan dimensions. Specific test parameters are recorded during each testing session (or weather condition, in laboratory testing) and include: angle of the test stand, synchronization of timing devices, plate and ambient temperature profile files, icing intensity, etc.

2.5.1 Test Protocol – Snow Tests

APS developed a specific procedure for Type I testing in natural snow based on the requirements outlined in ARP 5945. This procedure has been included in Appendix A.

Key details of the procedure include:

- Tests were conducted on empty aluminum boxes (see Section 2.4);
- Fluid was diluted to a freeze point 10°C below ambient temperature using information provided by the fluid manufacturer (see Table 2.4);
- Fluid was applied at a temperature of 60°C;
- 0.5 L of fluid was applied to the test surface with a 12-hole spreader; and
- For each Battelle D^3 test, a test with a Type I reference fluid was conducted simultaneously.

2.5.2 Test Protocol – Simulated Precipitation Tests

ARP 5945 was used as the procedure for simulated precipitation tests.

Key details of the procedure include:

- Freezing fog, freezing drizzle and light freezing rain tests were conducted on standard flat plates (see Section 2.4);
- Cold-soak surface tests were conducted on fluid-filled aluminum boxes (see Section 2.4);
- Fluid was diluted to a freeze point 10°C below ambient temperature using information provided by the manufacturer (see Table 2.4);
- Fluid was applied at a temperature of 20°C; and
- 1 L of fluid was poured on the test surface.

Table 2.4: Battelle D³ Dilution Table[1]

OAT (°C)	FFP (°C)	Polyol %	Brix (°)	OAT (°C)	FFP (°C)	Polyol %	Brix (°)
4	-6	20	14.75	-10	-20	48	34.75
3	-7	26	18.50	-11	-21	49	35.75
2	-8	**28**	**20.00**	-12	-22	**50**	**36.50**
1	-9	29	21.25	-13	-23	52	37.50
0	-10	30	22.75	-14	-24	53	38.50
-1	-11	33	24.00	-15	-25	54	39.50
-2	-12	**35**	**25.50**	-16	-26	**55**	**39.50**
-3	-13	37	26.75	-17	-27	57	41.00
-4	-14	38	28.00	-18	-28	58	41.75
-5	-15	**39**	**29.00**	-19	-29	**60**	**42.25**
-6	-16	40	29.75	-20	-30	61	43.00
-7	-17	44	31.50	-22	-32	62	44.25
-8	-18	45	32.50	-25	-35	65	46.00
-9	-19	**47**	**33.75**	-30	-40	**70**	**48.25**

[1] *Based on information provided by the fluid manufacturer*

2.5.3 End Condition Definitions

The determination of defined end conditions has evolved from the experience the APS test team has accumulated over more than a decade of winter test programs. The following description provides the general guidelines that observers use to judge when fluid failure occurs:

Failure is called when 30 percent (1/3) of the plate is 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.

2.5.4 Precipitation Rate Procedures

2.5.4.1 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; the weights are recorded. The exact start of the precipitation catch period 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 acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period, the pans are 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 are 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 rates at this location.

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

2.5.4.2 Precipitation rate distribution in simulated conditions

Clean test plates are placed on the test stand prior to the rate collection period, and are exposed to the simulated precipitation to verify that an even ice formation occurs over the entire test bed. If this visual inspection proves satisfactory, the rate collection period will begin. If this visual inspection proves unsatisfactory, the test stand must be repositioned under the spray device and the process is then repeated.

In order to verify the rate distribution on the test stand, a continuous rate-monitoring pan is replaced with a detailed rate distribution pan, which consists of 4 small pans of equivalent size. The area of the 4 small pans combined is similar to that of a standard rate collection pan. The small pans are weighed and placed at these locations and re-weighed at fixed intervals. The typical collection period for rate distribution is 60 minutes, however this interval may be shorter if all tests have been completed within 60 minutes. The variation between the rate of any of the 4 small pans and that of the average rate of that location should not be greater than 10 percent.

Two examples of the detailed rate distributions are shown in Table 2.5. Both rate distributions were conducted in freezing drizzle, one at the low rate (5 g/dm^2/h), the other at the high rate (13 g/dm^2/h). The average precipitation rate over the entire position in the low rate example in Table 2.5 was 5.1 g/dm^2/h. The individual rates of the four smaller pans were 5.0, 4.9, 5.2 and 5.3 g/dm^2/h, suggesting a maximum variation of 4.1 percent from the average rate over the entire position.

Table 2.5: Detailed Rate Distribution

Freezing Drizzle (low rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	2-top left	14:02	14:34	81.6	88.8	7.2	31.9	5.0
4	2-top right	14:02	14:34	81.6	88.6	7	31.9	4.9
5	2-bottom left	14:02	14:34	81.8	89.2	7.4	31.9	5.2
6	2-bottom right	14:02	14:34	81.6	89.2	7.6	31.9	5.3

		3	4		5.1		STD DEV	
		5.0	4.9		-1.4%	-4.1%	0.181	
		5.2	5.3		1.4%	4.1%		
		5	6					

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

Freezing Drizzle (high rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	5-top left	12:12	12:43	81.8	98.8	17	30.8	12.3
4	5-top right	12:12	12:43	81.6	98.8	17.2	30.8	12.5
5	5-bottom left	12:12	12:43	81.6	100.2	18.6	30.8	13.5
6	5-bottom right	12:12	12:43	81.6	100.2	18.6	30.8	13.5

		3	4		12.9		STD DEV	
		12.3	12.5		-4.8%	-3.6%	0.631	
		13.5	13.5		4.2%	4.2%		
		5	6					

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

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2.5.4.3 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) from the timepiece located near the rate station before leaving the trailer to place the pans on the test stand. The person responsible for collecting precipitation rate data take the time delay necessary to proceed outside from the rate station into consideration.

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.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.7. Typically, two collections pans are used for each test. The start and end times of the test are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t_1, t_2, and t_3 (minutes). The calculated rates for each collection period are indicated by R_1, R_2, and R_3 (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 2.4, 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.

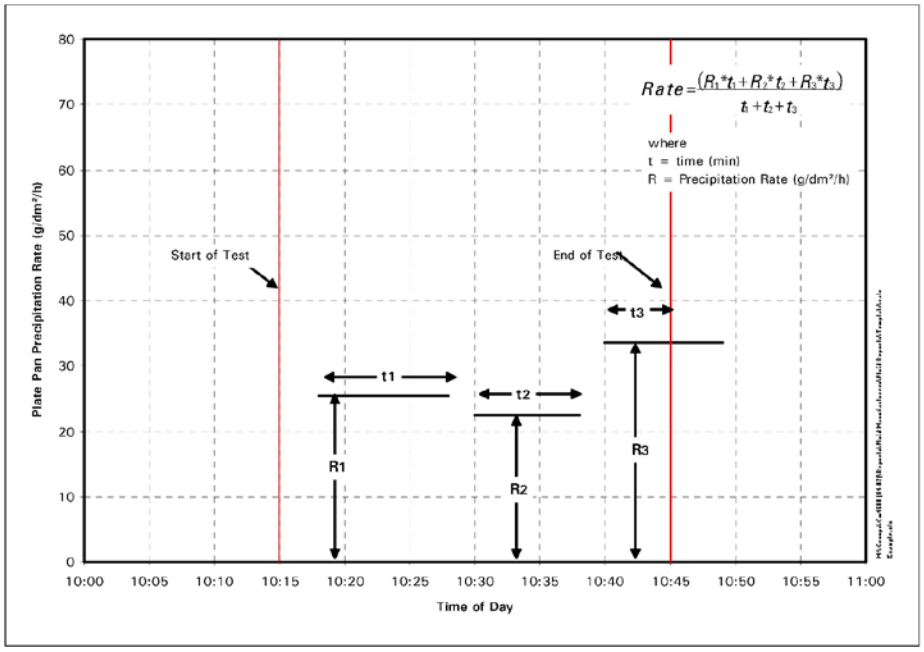

Figure 2.6: Calculation of Outdoor Precipitation Rate

2.6 Precipitation Data Ranges

Endurance time tests are conducted over temperature and precipitation rate ranges specific to each category of precipitation. The specific precipitation rate limits presented in this section are used to calculate fluid-specific HOTs for Type II and Type IV fluids, but they also define precipitation categories for all fluids. Simulated precipitation testing is typically conducted at the lower and upper rate limits of each category.

The precipitation rate limits are represented schematically in Figure 2.8. Detailed definitions and explanations of the data types and ranges are described in the following subsections. Meteorologically accepted definitions of these conditions were outlined in Table 2.1.

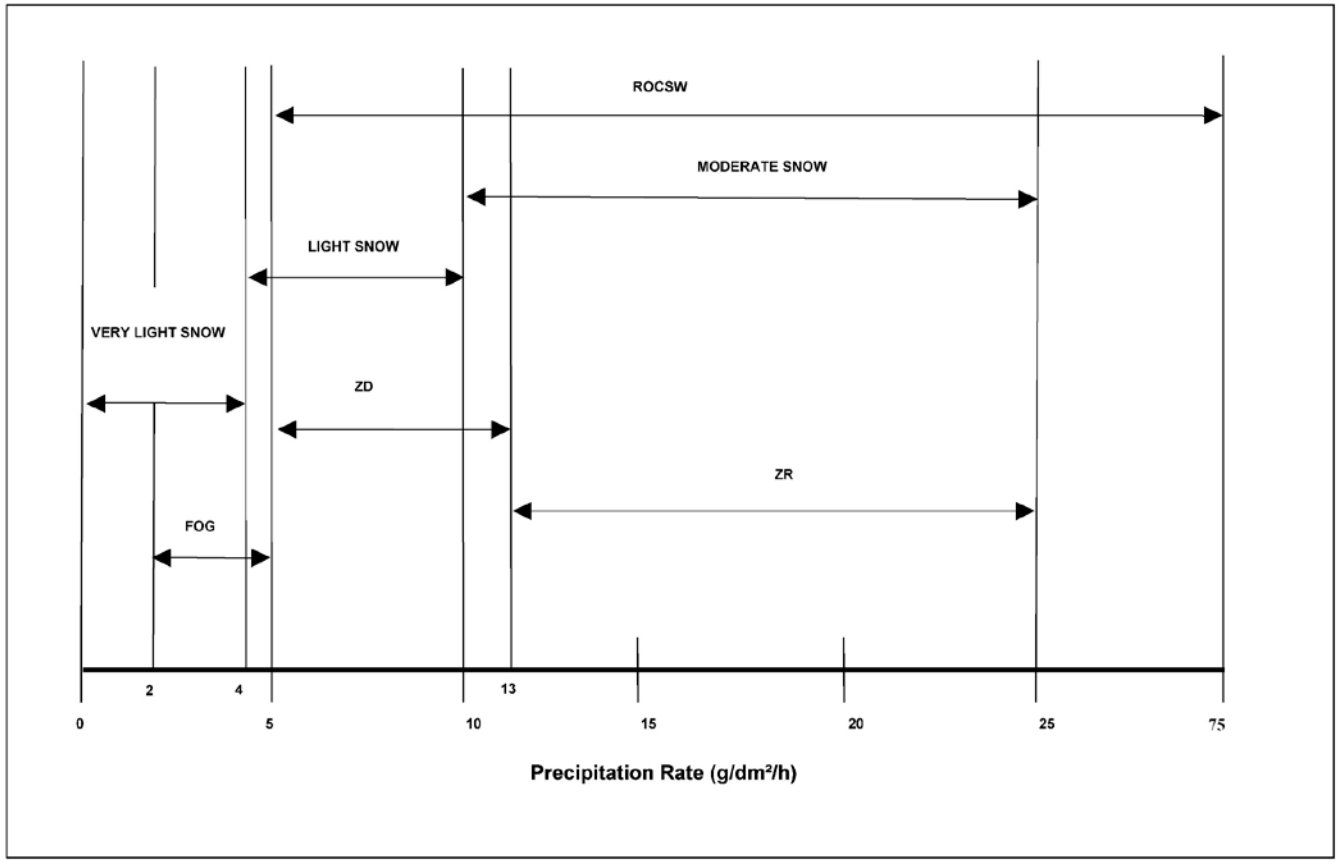

Figure 2.7: Data Range Used for Evaluation of Holdover Time Limits

2.6.1 Natural Snow

For Type I fluids, the precipitation rate limits for the snow column are as follows:

a) Very light snow: 4 g/dm²/h;
b) Light snow: 4 g/dm²/h and 10 g/dm²/h; and
c) Moderate snow: 10 g/dm²/h and 25 g/dm²/h.

The upper precipitation rate limit (25 g/dm^2/h) corresponds to the onset of heavy snow. Above this rate, it is standard practice to refer to the cautionary note included in the HOT tables indicating that the time of protection will be shortened in heavy weather conditions, (i.e., heavy precipitation, or high moisture content).

2.6.2 Freezing Drizzle

Freezing drizzle is considered to occur over the range of 0 to 13 g/dm^2/h. The upper limit in this range, while not specifically defined in Table 2.1, has been adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Subcommittee.

For test purposes, the precipitation rate spectrum for freezing drizzle is constrained to rates between 5 and 13 g/dm^2/h, inclusively. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety. A caution note is included in the HOT tables indicating that if positive identification of freezing drizzle is not possible, the light freezing rain HOTs is recommended for use.

2.6.3 Light Freezing Rain

With reference to the HOT tables, freezing rain conditions span the range of precipitation rates from 13 to 25 g/dm^2/h, inclusively. This range falls in 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.

2.6.4 Freezing Fog

The precipitation rate limits for freezing fog were selected with input from meteorologists from the NRC, 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.

The precipitation rate for fog, referred to as *fog deposition* or simply as *deposition*, is given by the empirical expression,

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

where the Sin 10° term accounts for the 10° inclination of the test plates into the direction of the wind.

The meteorological circumstances (LWC value and wind speed), and the speed and orientation of the airfoil relative to the wind (stationary or taxiing), contribute to uncertainties in the values that the variables in the equation can assume.

The upper and lower HOTs for freezing fog were determined subjectively from the test data in previous years. It has been agreed upon by the SAE G-12 HOT Subcommittee that the lower and upper HOTs for fog be evaluated at rates of 5 g/dm^2/h and 2 g/dm^2/h, respectively.

2.6.5 Rain on a Cold-soaked Surface

Data used for the evaluation of HOTs for this category of precipitation is limited to precipitation rates ranging from 5 to 75 g/dm^2/h, which 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). The heavy rain category is covered by the caution note at the bottom of the HOT table regarding heavy weather conditions.

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Photo 2.1: View of Test Site and Associated Equipment



Photo 2.2: Meteorological Services of Canada Weather Observation Station at Montréal-Pierre-Elliott-Trudeau International Airport



Photo 2.3: Outdoor View of National Research Council Climatic Engineering Facility



Photo 2.4: Inside View of Small End of Climatic Engineering Facility



Photo 2.5: Inside View of Large End of Climatic Engineering Facility



Photo 2.6: Sprayer Assembly Used at National Research Council

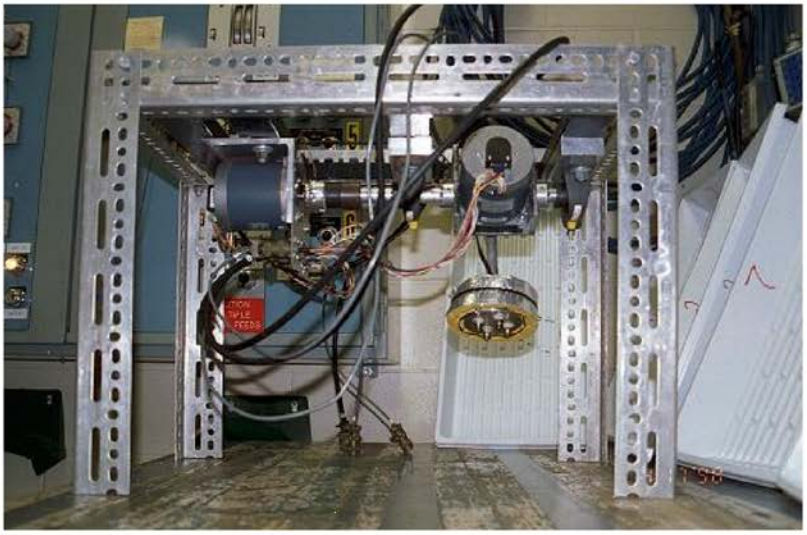

Photo 2.7: Sprayer Nozzle

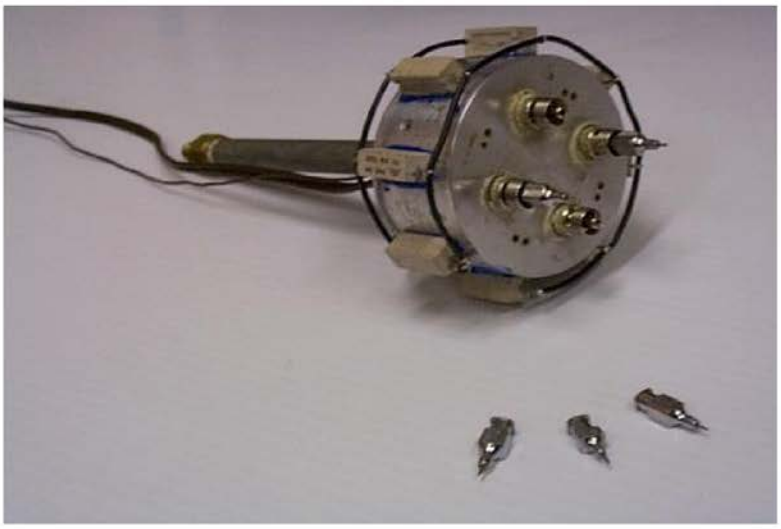

Photo 2.8: Test Plates Mounted on Stand



Photo 2.9: Collection Pans Used Indoors at the National Research Council



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted in each precipitation type including natural snow, freezing drizzle, light freezing rain, freezing fog and rain on a cold-soaked surface. A log of tests conducted is provided in Table 3.1. The thickness test data is also provided in this section.

3.1 Natural Snow Tests

The number of tests conducted in snow was limited by the lack of snow events that occurred in Montreal following the receipt of the fluid sample. A total of 4 tests were conducted at the APS test site in natural snow. The number of tests conducted is summarized below by temperature.

	Above -3°C	-3 to -14°C	-14 to -25°C
10°C Buffer	0	4	0

3.2 Freezing Drizzle and Light Freezing Rain Tests

A total of 12 tests were conducted in freezing drizzle and light freezing rain. Due to time limitations at the NRC CEF test session, tests were conducted at select temperatures only. This decision was made in conjunction with, and approved by, Transport Canada. The number of tests conducted is summarized below by temperature.

	Freezing Drizzle		Light Freezing Rain	
	-3°C	-10°C	-3°C	-10°C
10°C Buffer	4	4	*	4

** Type I fluids are not tested in freezing rain at -3°C because the latent heat of freezing in calm test conditions produces artificially long endurance times.*

3.3 Freezing Fog Tests

A total of 12 tests were conducted in freezing fog. Due to time limitations at the NRC CEF test session, tests were conducted at select temperatures only. This decision was made in conjunction with, and approved by, Transport Canada. The number of tests conducted is summarized below by temperature.

	-3°C	-14°C	-25°C
10°C Buffer	4	4	4

3.4 Rain on Cold-Soaked Surface Tests

A total of 4 cold-soak tests were conducted using 7.5 cm deep sealed boxes at an ambient temperature of +1°C. Tests were conducted at the NRC CEF.

Table 3.1: Summary of Tests Performed in 2005-06

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/hr)	Test Temp. (°C)	Precipitation Type
1	06-Apr-06	Battelle D³	10° buffer	8.7	12.5	-3.0	Freezing Drizzle
2	06-Apr-06	Battelle D³	10° buffer	9.1	13.2	-3.0	Freezing Drizzle
R1	27-Apr-06	Battelle D³	10° buffer	15.4	4.8	-3.0	Freezing Drizzle
R2	27-Apr-06	Battelle D³	10° buffer	15.3	5.0	-3.0	Freezing Drizzle
65	06-Apr-06	Battelle D³	10° buffer	4.8	13.2	-9.9	Freezing Drizzle
66	06-Apr-06	Battelle D³	10° buffer	5.0	12.8	-9.9	Freezing Drizzle
87	05-Apr-06	Battelle D³	10° buffer	7.5	5.2	-10.3	Freezing Drizzle
88	05-Apr-06	Battelle D³	10° buffer	7.7	5.4	-10.3	Freezing Drizzle
169	05-Apr-06	Battelle D³	10° buffer	4.7	24.2	-10.2	Light Freezing Rain
170	05-Apr-06	Battelle D³	10° buffer	4.4	24.2	-10.3	Light Freezing Rain
191	05-Apr-06	Battelle D³	10° buffer	5.1	13.3	-10.0	Light Freezing Rain
192	05-Apr-06	Battelle D³	10° buffer	5.0	13.3	-10.1	Light Freezing Rain
213	11-Apr-06	Battelle D³	10° buffer	12.6	4.6	-2.9	Freezing Fog
214	11-Apr-06	Battelle D³	10° buffer	11.8	4.6	-3.0	Freezing Fog
245	12-Apr-06	Battelle D³	10° buffer	19.3	2.3	-3.0	Freezing Fog
246	12-Apr-06	Battelle D³	10° buffer	17.8	2.2	-2.9	Freezing Fog
277	11-Apr-06	Battelle D³	10° buffer	7.0	5.4	-14.1	Freezing Fog
278	11-Apr-06	Battelle D³	10° buffer	7.0	4.7	-14.1	Freezing Fog
299	10-Apr-06	Battelle D³	10° buffer	14.2	2.2	-14.1	Freezing Fog
300	10-Apr-06	Battelle D³	10° buffer	15.3	1.7	-14.1	Freezing Fog
321	10-Apr-06	Battelle D³	10° buffer	8.6	5.4	-25.5	Freezing Fog
322	10-Apr-06	Battelle D³	10° buffer	8.3	5.2	-25.6	Freezing Fog
333	10-Apr-06	Battelle D³	10° buffer	19.8	1.7	-25.5	Freezing Fog
334	10-Apr-06	Battelle D³	10° buffer	19.3	1.7	-25.5	Freezing Fog
565	27-Apr-06	Battelle D³	10° buffer	2.2	72.0	1.3	Cold Soak Wing
566	27-Apr-06	Battelle D³	10° buffer	1.8	72.0	1.1	Cold Soak Wing
587	27-Apr-06	Battelle D³	10° buffer	5.3	4.9	1.0	Cold Soak Wing
588	27-Apr-06	Battelle D³	10° buffer	5.5	4.9	1.0	Cold Soak Wing
S1	25-Feb-06	Battelle D³	10° buffer	12.6	5.0	-13.7	Natural Snow
S3	25-Feb-06	Battelle D³	10° buffer	6.8	10.3	-13.6	Natural Snow
S5	25-Feb-06	Battelle D³	10° buffer	18.0	3.8	-12.9	Natural Snow
S7	03-Mar-06	Battelle D³	10° buffer	17.6	5.6	-9.7	Natural Snow

3.5 Fluid Thickness Tests

The purpose of these tests was to measure the film thickness of the fluid under dry conditions. Two tests were performed at an ambient temperature of -3°C. The fluid was mixed to a 10° buffer, as per Table 2.4.

For each test, one litre of fluid was poured onto a flat plate mounted on a test stand inclined 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 less than 0.03 mm. The measurements are displayed in Table 3.2.

Table 3.2: Fluid Thickness Measurements

Measurement	Time After Application (mins)	Thickness (mm)	
		Run 1	Run 2
1	0	0.20	0.20
2	2	0.10	0.10
3	5	0.08	0.08
4	15	0.05	0.05
5	30	<0.03	<0.03

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4. RESULTS AND DISCUSSION

The results of endurance time tests with Battelle D^3 are presented in this section. To assess the performance of Battelle D^3, the endurance time results are compared to the current Type I generic HOT values and to the endurance times of other Type I fluids.

4.1 Data

Figures 4.1 to 4.13 present the endurance time data collected. The figures show the effect of temperature and precipitation rate on fluid endurance time in each condition. The data is presented in three formats.

Figures 4.1 to 4.5 show the Battelle D^3 endurance times and the current Type I generic HOT table values by weather condition. The test results are represented by hollow shapes and the HOT table values are represented by solid shapes.

Figures 4.6 to 4.12 show the Battelle D^3 endurance times and the endurance times of other Type I fluids in simulated freezing precipitation. Other Type I fluid data points are represented with hollow shapes; Battelle D^3 data points are represented with solid shapes.

Figure 4.13 shows the endurance times of Battelle D^3 in snow along with the endurance times of the Type I reference fluid that was tested simultaneously.

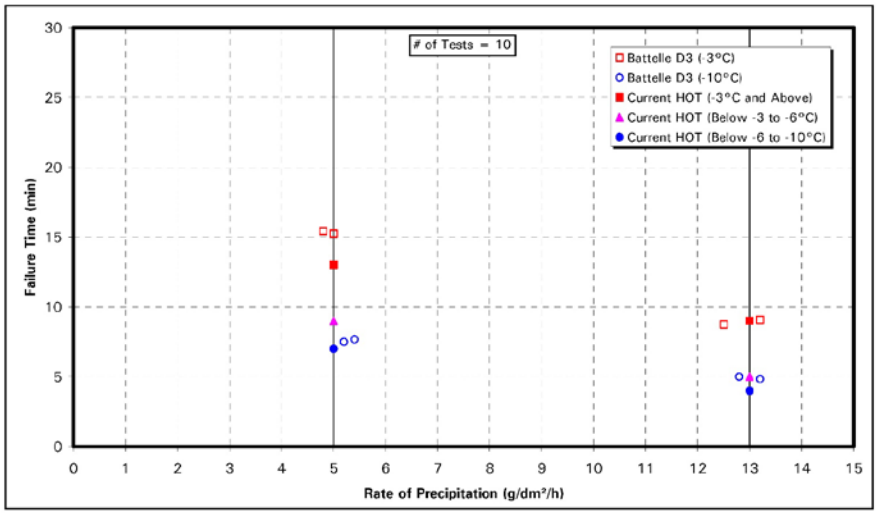


Figure 4.1: Battelle D^3 – Freezing Drizzle

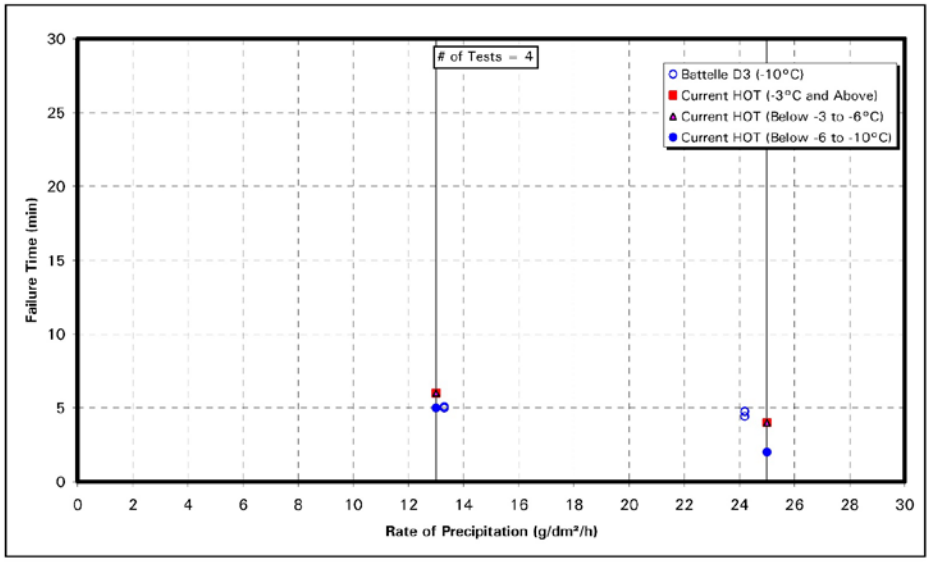


Figure 4.2: Battelle D³ – Light Freezing Rain

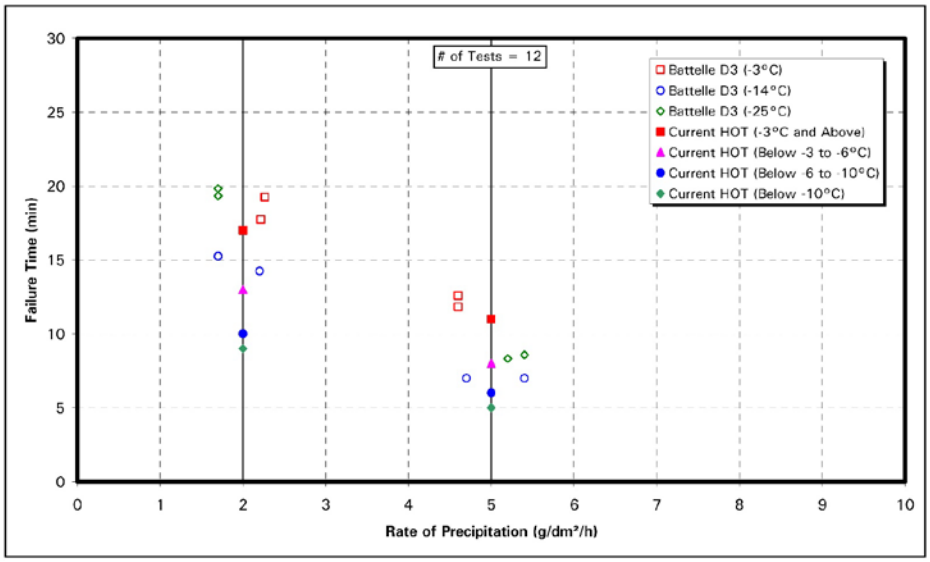


Figure 4.3: Battelle D³ – Freezing Fog

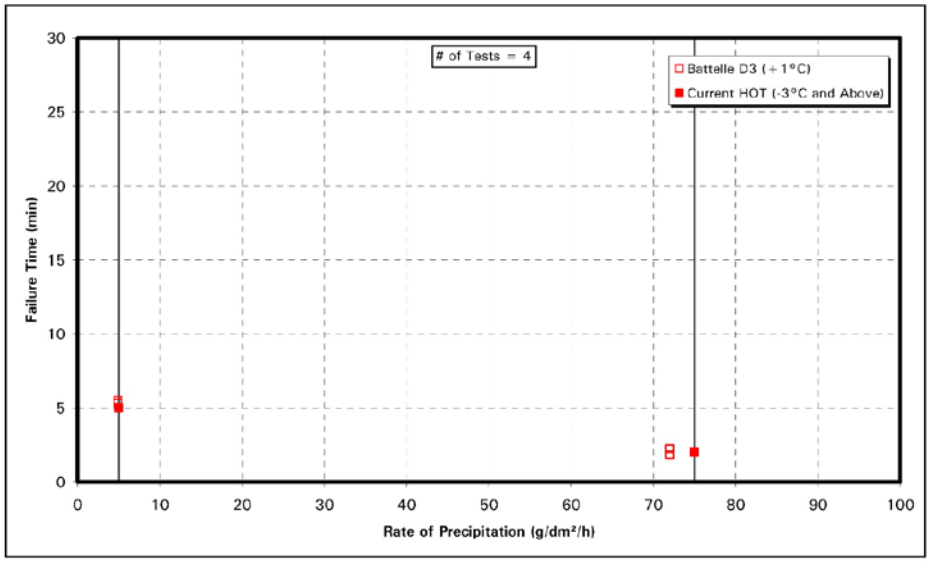


Figure 4.4: Battelle D³ – Rain on Cold-Soaked Surface

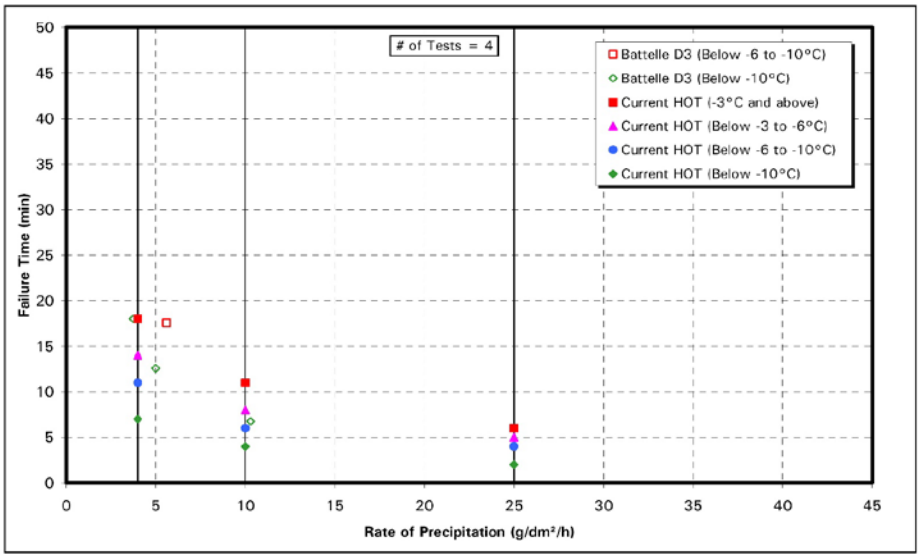


Figure 4.5: Battelle D³ – Natural Snow

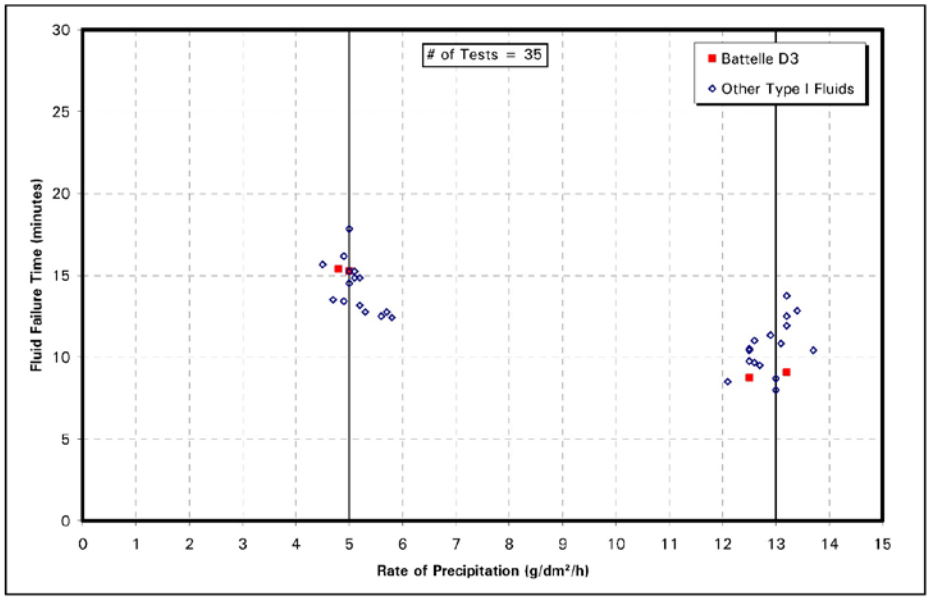


Figure 4.6: Type I Fluids – Freezing Drizzle, -3°C

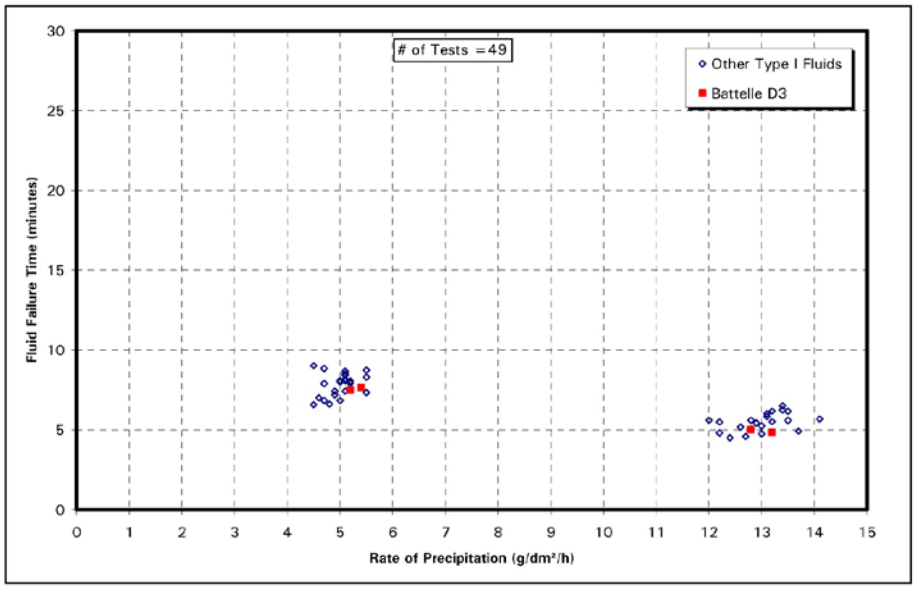


Figure 4.7: Type I Fluids – Freezing Drizzle, -10°C

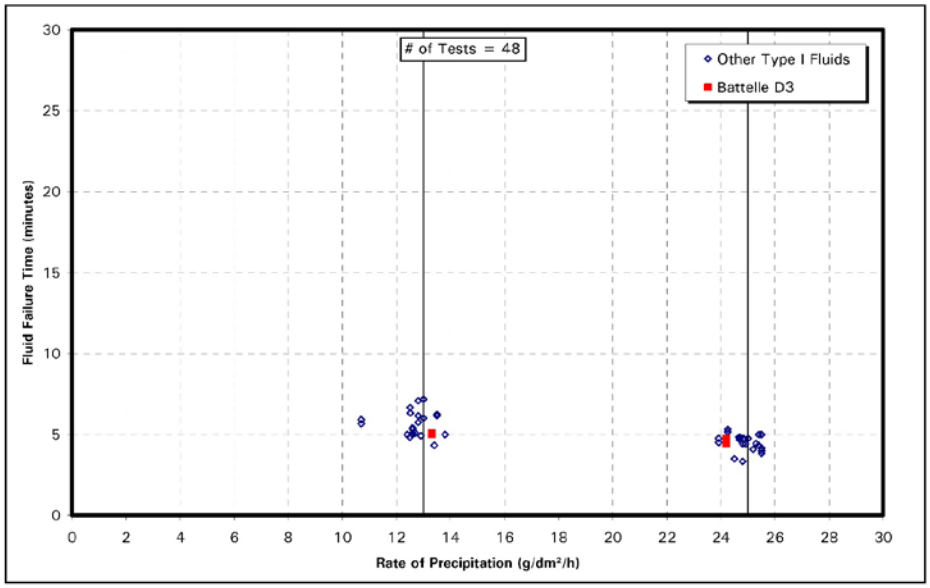


Figure 4.8: Type I Fluids – Light Freezing Rain, -10°C

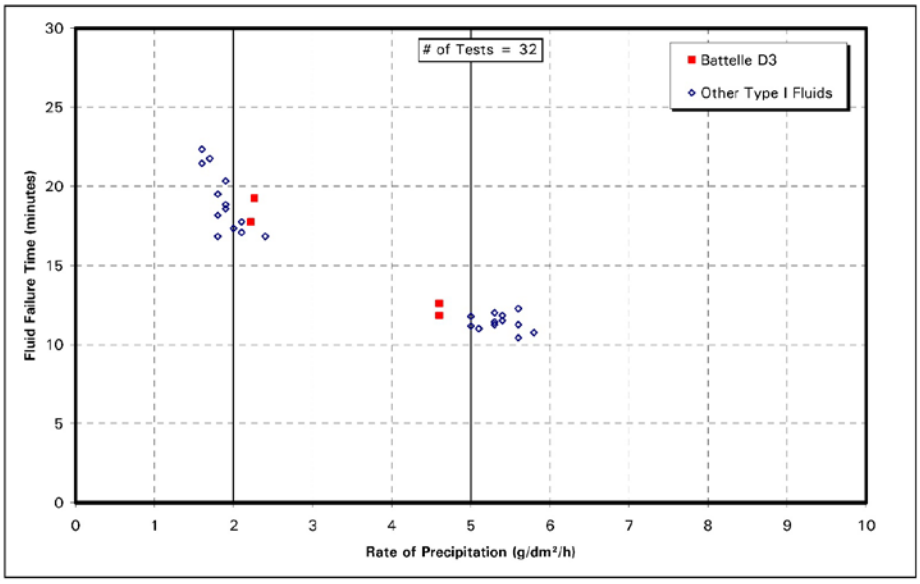


Figure 4.9: Type I Fluids – Freezing Fog, -3°C

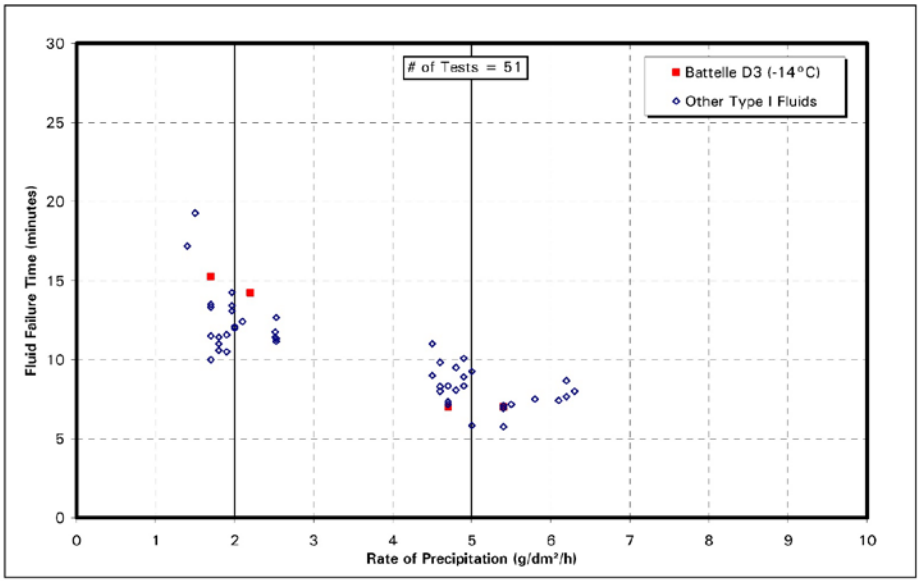


Figure 4.10: Type I Fluids – Freezing Fog, -10°C

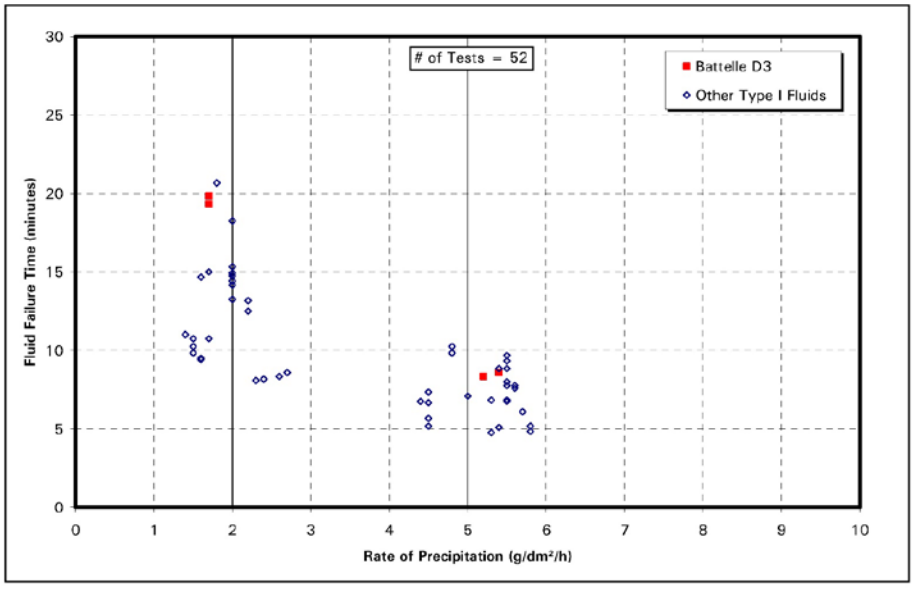


Figure 4.11: Type I Fluids – Freezing Fog, -25°C

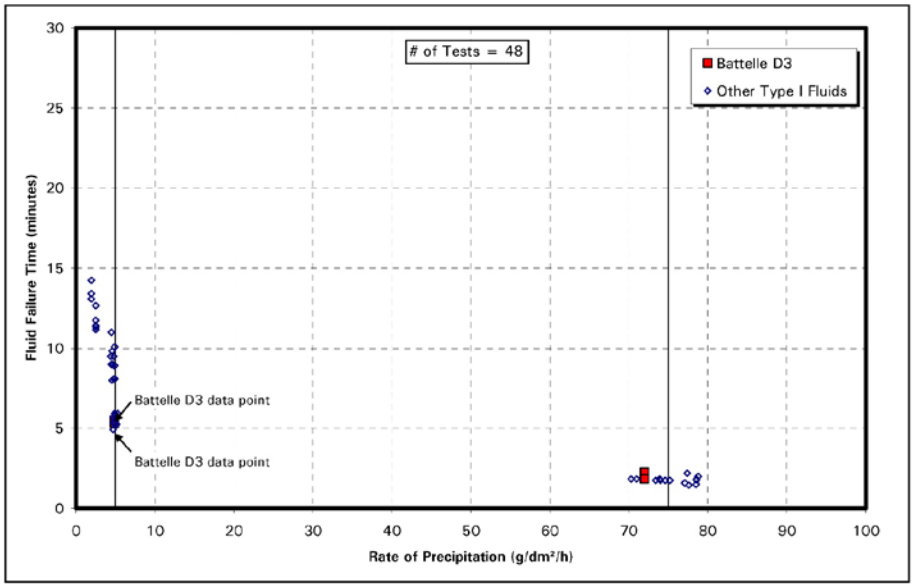


Figure 4.12: Type I Fluids – Rain on Cold-Soaked Surface, +1°C

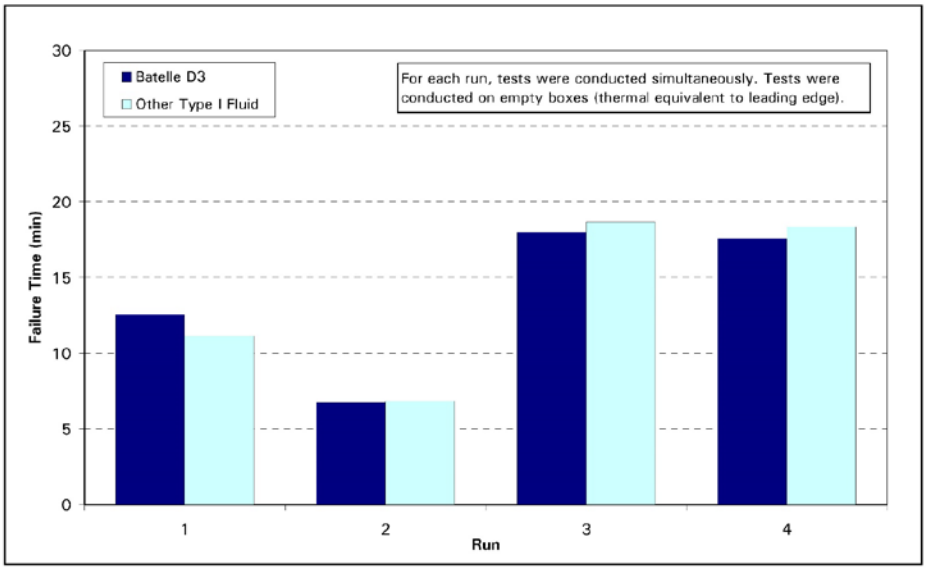


Figure 4.13: Battelle D^3 vs. Baseline Type I Fluid – Natural Snow

4.2 Discussion

The endurance time results of Battelle D^3 in simulated freezing precipitation are similar or superior to Type I fluids tested in past years. The endurance time results of this fluid in snow are similar or superior to the Type I reference fluid that was tested simultaneously.

This can be seen, for example, by looking at the data for freezing drizzle at -10°C. When the endurance time results are compared to the current generic HOT values (see Figure 4.1), the Battelle D^3 results are superior:

Condition	Current Type I Generic HOT (minutes)	Measured Battelle D^3 Endurance Times (minutes)
Freezing drizzle, -10°C, high rate	4	4.8, 5.0
Freezing drizzle, -10°C, low rate	7	7.5, 7.7

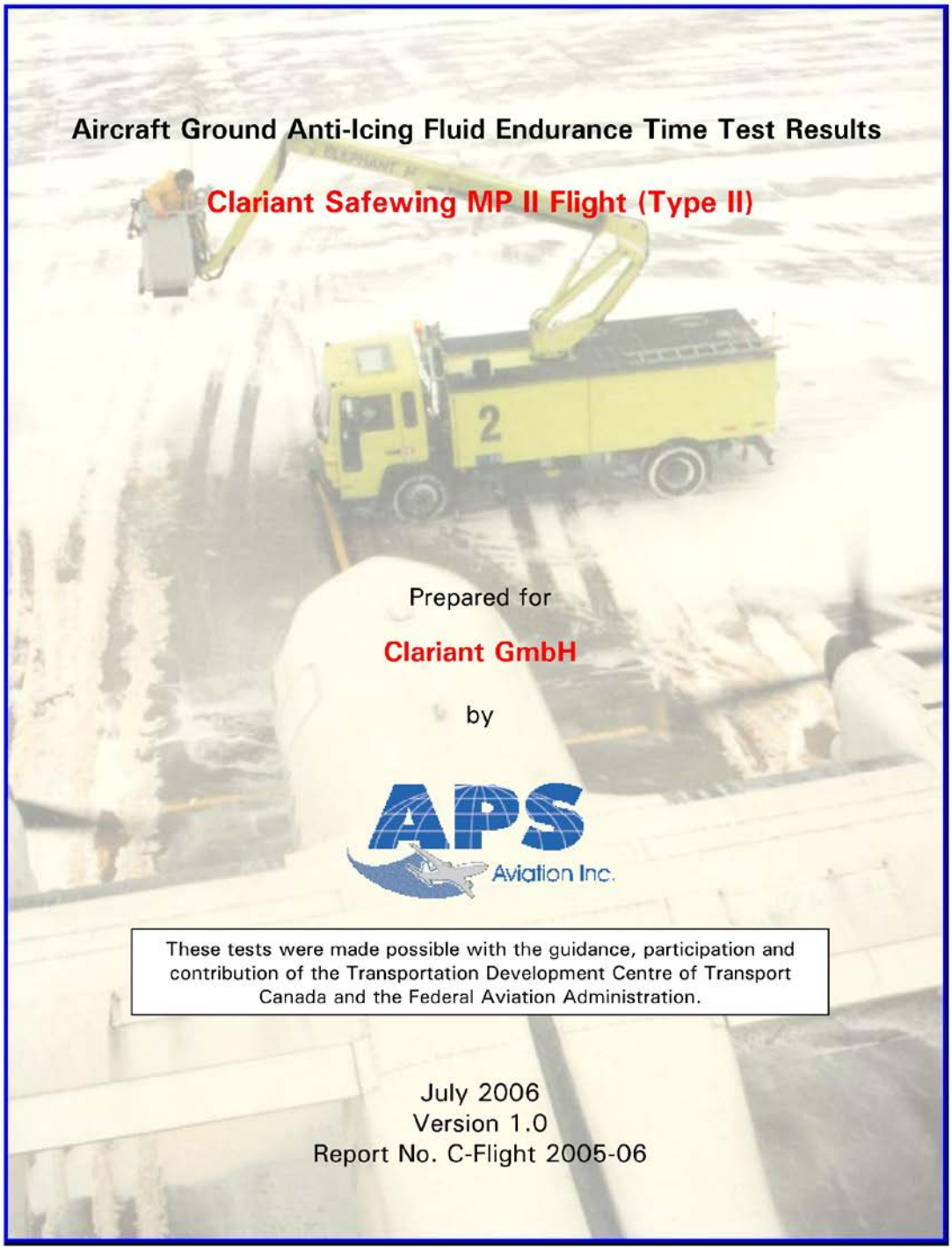
In addition, when the Battelle D^3 data is plotted along with other Type I fluid data (see Figure 4.7), it can be seen that the Battelle D^3 endurance times are within the range of the results of the other fluids:

Condition	Other Type I Endurance Times (minutes)	Measured Battelle D^3 Endurance Times (minutes)
Freezing drizzle, -10°C, high rate	4.5 to 6.5	4.8, 5.0
Freezing drizzle, -10°C, low rate	6 to 9	7.5, 7.7

These results indicate that the non-glycol based Battelle D^3 fluid performs similarly to glycol based Type I fluids from an endurance time perspective and therefore can be used as a Type I fluid with the generic Type I HOT guidelines.

APPENDIX D

FLUID MANUFACTRURER REPORT:
CLARIANT SAFEWING MP II FLIGHT (TYPE II)


Aircraft Ground Anti-Icing Fluid Endurance Time Test Results
Clariant Safewing MP II Flight (Type II)
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.
July 2006
Version 1.0
Report No. C-Flight 2005-06

Aircraft Ground Anti-Icing Fluid Endurance Time Test Results

Clariant Safewing MP II Flight (Type II)

Prepared for

Clariant GmbH

Prepared by: _____ July 10, 2006
Stephanie Bendickson — Date
Project Analyst

Reviewed by: _____ July 10, 2006
John D'Avirro — Date
Program Manager, Eng.



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

July 2006
Version 1.0
Report No. C-Flight 2005-06

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer: Clariant

Fluid: MP II Flight

Fluid Type / Colour: Type II / Green

Batch #: TV428

Date of Receipt: January 20, 2006

Brix Measured:

Neat fluid:	35.00°
75/25 dilution:	27.00°
50/50 dilution:	19.00°

Viscosity Stated by Manufacturer[1]:

Neat fluid:	3,500 cP
75/25 dilution:	17,500 cP
50/50 dilution:	15,500 cP

Viscosity Measured by APS (Manufacturer Method)[1]:

Neat fluid:	3,340 cP
75/25 dilution:	17,080 cP
50/50 dilution:	18,230 cP

Viscosity Measured by APS (AIR 9968 Method)[2]:

Neat fluid:	3,340 cP
75/25 dilution:	17,080 cP
50/50 dilution:	18,230 cP

WSET provided by AMIL:

Neat fluid:	58 minutes

[1]Manufacturer Method: Spindle LV1, 20°C, 0.3 rpm, 10 minutes
[2]AIR 9968 Method: Spindle LV1, 20°C, 0.3 rpm, 10 minutes

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SUMMARY

The primary objective of this project was to measure the endurance time performance of Clariant Safewing MP II Flight 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).

The HOT test procedure consisted of pouring fluids onto clean aluminium test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural snow and simulated freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. Endurance time tests were performed at the APS Aviation Inc. (APS) test facility located within the Montréal-Pierre-Elliott-Trudeau International Airport and at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were determined using a multi-variable regression analysis, resulting in the generation of the fluid-specific HOT table shown below.

Clariant Safewing MP II Flight Type II Fluid Holdover Times

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 and above	27 and above	100/0	8:00	3:30 – 4:00	1:00 – 1:35	1:20 – 2:00	0:45 – 1:25	0:10 – 1:30	
		75/25	5:00	2:30 – 4:00	0:40 – 1:20	1:15 – 2:00	0:30 – 0:55	0:05 – 1:20	
		50/50	3:00	0:55 – 1:45	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	8:00	0:55 – 1:45	0:40 – 1:05	0:35 – 1:30	0:25 – 0:45		
		75/25	5:00	0:40 – 1:10	0:20 – 0:40	0:25 – 1:10	0:30 – 0:40		
below -14 to -25	below 7 to -13	100/0	8:00	0:30 – 0:50	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

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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
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
SAE	Society of Automotive Engineers, Inc.
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-icing/anti-icing has been the subject of concentrated industry attention over the past decade due the occurrence of several fatal icing-related aircraft accidents. Recent attention has been placed upon 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 for use by aircraft operators and accepted by regulatory authorities. New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid HOTs without compromising the aerodynamic features of the airfoil.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop and substantiate fluid HOT tables for current fluids and new formulations. Test procedures to measure the duration of fluid protection against ice formation have evolved into a refined Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 5485 that is followed by APS Aviation Inc. (APS).

Testing of aircraft ground de/ant-icing fluids has resulted in the generation of HOT tables. These tables provide guidelines for use in departure planning in adverse winter conditions. They provide the HOT ranges for aircraft treated with any particular qualified deicing or anti-icing fluid.

A new data analysis protocol was developed in 1996-97 wherein the endurance time data for each fluid brand in each cell of the HOT tables was subject to a multi-variable regression treatment. Type II and Type IV fluid HOTs are determined using this method of analysis, resulting in the generation of generic and fluid-specific HOT tables.

This report provides the data and analysis used to determine the fluid HOTs for Clariant Safewing MP II Flight.

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2

2. METHODOLOGY

This chapter contains a description of the tests, equipment and procedures used to conduct endurance time tests. It is divided into sections dealing with the definition of weather, test sites, test conditions, equipment, procedures, and analysis methodology. A 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 was developed by APS for this testing, based upon the requirements of ARP 5485.

2.1 Definition of Weather Conditions

HOTs are provided as a function of weather condition, fluid dilution and outside air temperature. The objective of the winter test program was to develop HOTs for new fluids based on the most recent test data.

Table 2.1 provides definitions of most weather conditions experienced in winter operations and includes the criteria used to determine precipitation intensity (light, moderate, heavy). 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).

Table 2.1 includes definitions for the weather conditions described in the HOT tables (frost, freezing fog, snow, freezing drizzle, light freezing rain and rain). Definitions for snow pellets, hail and ice pellets are also presented, however these are conditions for which HOT guidelines do not exist.

The test methodology used to determine fluid endurance times has included the generally accepted upper and lower limits for precipitation rates for each type of precipitation. These limits were discussed in detail at a 1997 meeting of the SAE G-12 HOT Subcommittee where standard definitions of upper and lower precipitation rate limits were approved for each category of precipitation. These limits are documented and discussed in Subsection 2.6.

2.1.1 Snow

Table 2.1 contains the criteria that were used in the past to estimate the intensity of snow. These criteria are based upon horizontal visibility with three

intensity levels. For light snow, visibility is greater than or equal to 1.0 km, moderate snow visibility is 0.5 km to less than 1.0 km, and heavy snow, visibility is less than 0.5 km.

As stated in a cautionary note in Table 2.1, visibility is only an indicator of snow intensity, and the two parameters are not always correlated.

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 visibility at the earth's surface to less than 1 km (5/8 mile).
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 (23°F), the crystals are generally agglomerated into snowflakes.
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 the ground or other exposed objects.
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 mm (0.02 in.) or smaller drops which, in contrast to drizzle, are widely separated.
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)	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter is about 2-5 mm (0.1-0.2 in.). Grains are brittle, easily crushed; they bounce and break on hard ground.
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is less than 1 mm (0.04 in.). When the grains hit hard ground, they do not bounce or shatter.
HAIL (GR)	Precipitation of small balls or pieces of ice with a diameter ranging from 5 to > 50 mm (0.2 to 2.0 in.) falling either separately or agglomerated.
ICE PELLETS (PE) Note: Includes Sleet and Small Hail	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.) or less. The pellets of ice usually bounce when hitting hard ground.

* 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 Proposed Definition for Liquid Equivalent Snowfall Intensity

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

Intensity Criteria**

Snow(SN),Pellets(CS),Grains(SG),Frz Drizzle(FZDZ)			Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (S) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm or 10.0 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 or 25.0 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 shown that visibility and precipitation intensity are not always directly correlated.

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm 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 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 exposed surface up to a condition where individual drops are easily seen.
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm 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 pavement and other hard surfaces.
Measured Intensity	More than 0.30 in/hr (7.6 mm 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 spray to height of several inches is observed over hard surfaces.

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP June 17, 1997 (Updated for METAR codes)

Table 2.2 is the visibility table which has been published annually by TC since the winter of 2003-04 for use in winter operations. It is based on more recent data than Table 2.1 and provides more detail about snowfall intensity and visibility. APS, NCAR and TC all had input into the formation of this table, which is based on NCAR field data and theoretical work on classes of snow and on extensive field data compiled by APS. The table categorizes snowfall into one of four intensities based on visibility and lighting condition.

The FAA also publishes a visibility, which differs slightly from the TC visibility table, but is based on the same data set.

Table 2.2: Visibility in Snow vs. Snowfall Intensity Chart[1]

Lighting	Temperature Range		Visibility in Snow (Statute Miles)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1	>1 to 2½	>2½ to 4	>4
	Below -1	Below 30	≤3/4	>3/4 to 1½	>1½ to 3	>3
Daylight	-1 and above	30 and above	≤½	>½ to 1½	>1½ to 3	>3
	Below -1	Below 30	≤3/8	>3/8 to 7/8	>7/8 to 2	>2

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.

2.1.2 Freezing Drizzle

Freezing drizzle is composed of closely spaced fine water droplets with a diameter less than 0.5 mm (see Table 2.1). The intensity of freezing drizzle is estimated, as it is for snow, through the measurement of horizontal visibility.

HOT tables have one column for freezing drizzle; however, Table 2.1 shows three intensity levels (light, moderate and heavy). For example, under moderate freezing drizzle, the rate of precipitation should range between 2.5 and 5.1 g/dm²/h. For heavy freezing drizzle, the definition indicates that the intensity is greater than 5 g/dm²/h. Discussions between United Airlines, NCAR and the National Research Council Canada (NRC) led to the upper limit value of 13 g/dm²/h for freezing drizzle. This value is also used as the lower limit for light freezing rain.

2.1.3 Freezing Rain

This form of precipitation exists either in the form of drops with diameters greater than 0.5 mm, or smaller drops which, in contrast to drizzle, are widely separated. For each of the three intensities of freezing rain given in Table 2.1, a visual description is supplied to provide a subjective guideline for the purpose of estimating rain intensity. However, the following definitions apply when an instrument is available to measure the intensity of precipitation:

- Light Precipitation rate is ≤ 25 g/dm²/h
- Moderate Precipitation rate is >25 g/dm²/h but ≤75 g/dm²/h
- Heavy Precipitation rate is >75 g/dm²/h

2.1.4 Freezing Fog

Freezing fog is defined as suspended minute water droplets that freeze upon impact with the ground or exposed objects. Table 2.1 does not provide any indication of intensity or liquid water content (LWC) of the fog other than that the horizontal visibility is reduced to less than 1 km.

2.2 Test Sites

Normal natural snow test operations are performed at the APS test site located within the Montréal-Pierre-Elliott-Trudeau International Airport. The location of the test site is shown on the plan view of the airport shown in Figure 2.1. Photo 2.1 shows the test site trailer and test stands, the site consists of two trailers and three locations for test stands. The APS test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station (Photo 2.2).

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.

The CEF is partitioned into two sections, separated by an insulated dividing door. Each partition can be separately controlled, permitting different tests to be conducted simultaneously. Photo 2.3 provides a general indication of the size of the facility. Photos 2.4 and 2.5 provide interior images of the small and large ends of the facility. The facility was designed and built for the testing of locomotives. The size of the chamber is 30 m by 5.4 m and its total height is 8 m. The lowest temperature achievable is -46°C.

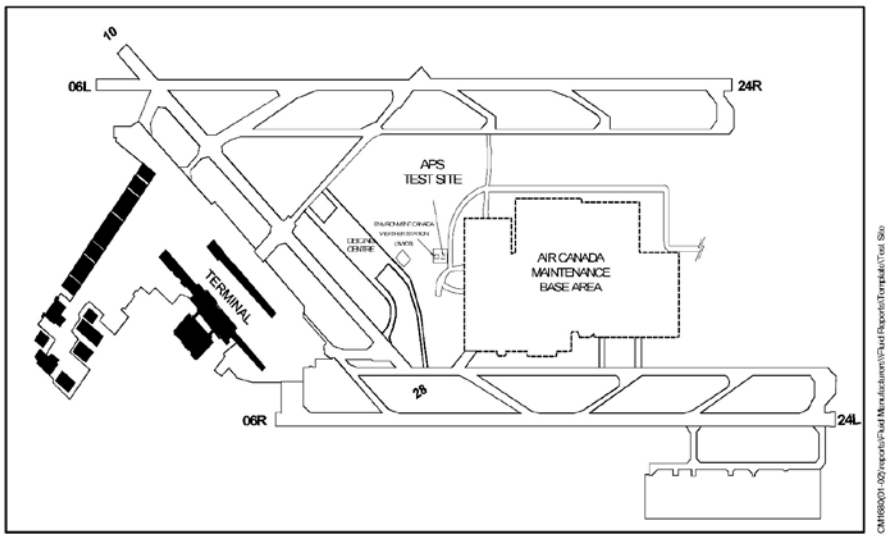


Figure 2.1: Test Site at the Montréal-Pierre-Elliott-Trudeau International Airport

2.3 Test Conditions

Outdoor testing was conducted during natural precipitation events. Supplementary tests to simulate freezing precipitation were carried out at the NRC CEF (see Photo 2.4). Subsections 2.3.1 and 2.3.2 provide descriptions of the spray assembly (see Photo 2.6) and of the methods used to produce and calibrate the fine water droplets in these artificial precipitation tests. Subsection 2.3.3 provides a summary of the categories and characteristics of each precipitation type produced for these tests.

2.3.1 Droplet Size and Rate of Precipitation

In the past few years, more industry attention has been given to the influence of droplet size on HOT. To explore this relationship further, experiments were performed to measure droplet sizes produced by different nozzles (gauge of hypodermic needle) at various water and air pressures in the spray delivery unit. Although the gauge of the needles is an important factor in the production of water droplets with appropriate dimensions, the air and water pressure levels in the sprayer system are equally important.

An improved sprayer assembly was developed in 1997-98 by the NRC and is shown in Photo 2.6. 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 2.7.

Prior to 1995, calibration experiments conducted by the NRC used an optical gauge manufactured by HSS (Biral UK acquired the HSS technology) to verify that the simulation of freezing fog, freezing drizzle, and light freezing rain provided adequate droplet sizes according to ARP 5485.

Since 1995, the APS team using a manual dye-stain technique employed by personnel at the NRC has carried out droplet size calibration. This technique consists of dusting Whatman #1 filter paper discs with a water-activated, very finely-divided powder form of methylene blue dye. The prepared discs are manually positioned under simulated precipitation for a fixed time to acquire a droplet size pattern. A calibration curve is then used to convert the measured diameter of the droplets on the pattern to the experimental median volume diameter (MVD).

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:	Dorval 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.

Figures 2.2 and 2.3 show an example of the distribution of simulated light freezing rain droplets obtained at the NRC.

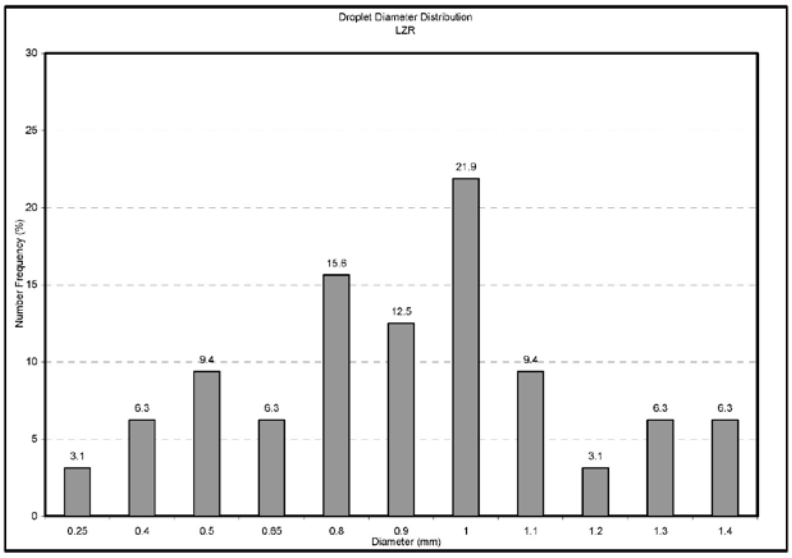


Figure 2.2: Droplet Diameter Distribution, Sample

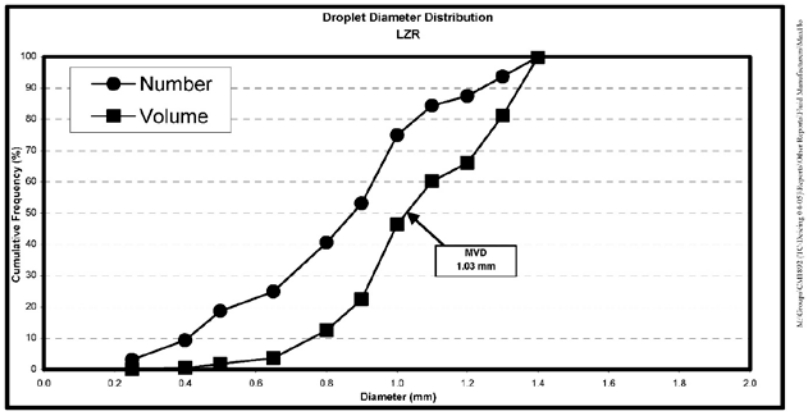


Figure 2.3: Cumulative Frequency of Droplet Diameter, Sample

2.3.2 Median Volume Diameter of Rain Drops

The MVD of a rain droplet was researched and found to be related to the precipitation rate 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 2.3 beside the experimental MVDs for each precipitation condition.

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

2.3.3 Characteristics of 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 were collected:

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

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

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

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

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

4. Moderate Rain on Cold Soaked Surface:
   Precipitation rate: 75 g/dm²/h;
   Droplet median volume diameter: 1 400 μm; and
   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.

2.4 Equipment

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.

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) is in accordance with the requirements set out in the ARP 5485.

Figure 2.4 shows a schematic of the test platform used for in 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.

Figure 2.4 also 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 were marked with 15 crosshairs used in determining whether end conditions (see Subsection 2.5.2 for definition) were achieved. Photo 2.8, taken outdoors at APS test site, shows six test plates mounted on a stand. For simulated freezing precipitation tests at the NRC, 12 plates were mounted on 2 six-position stands, as shown in Figure 2.4.

Figure 2.5 shows the collection (plate) pan, which is of the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.9 shows the collection pans used for measuring precipitation rates indoors at the NRC.

Sealed boxes (7.5 cm deep) were used for simulating a cold-soaked wing (see Figure 2.5). The top of the cold-soak box consists of an aluminium flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate.

Freeze points were measured using a hand-held Misco refractometer with a Brix scale.

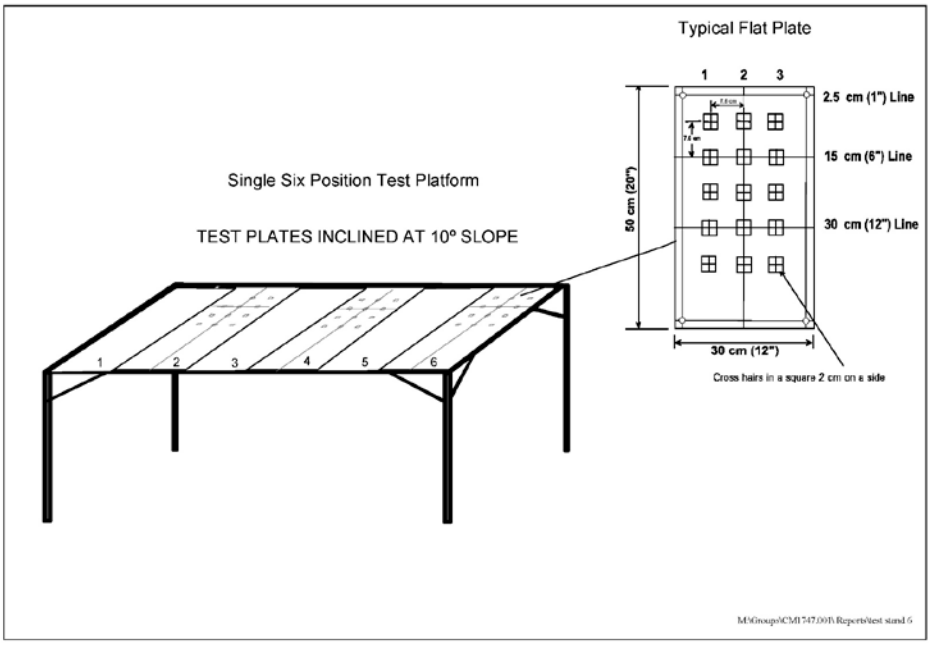
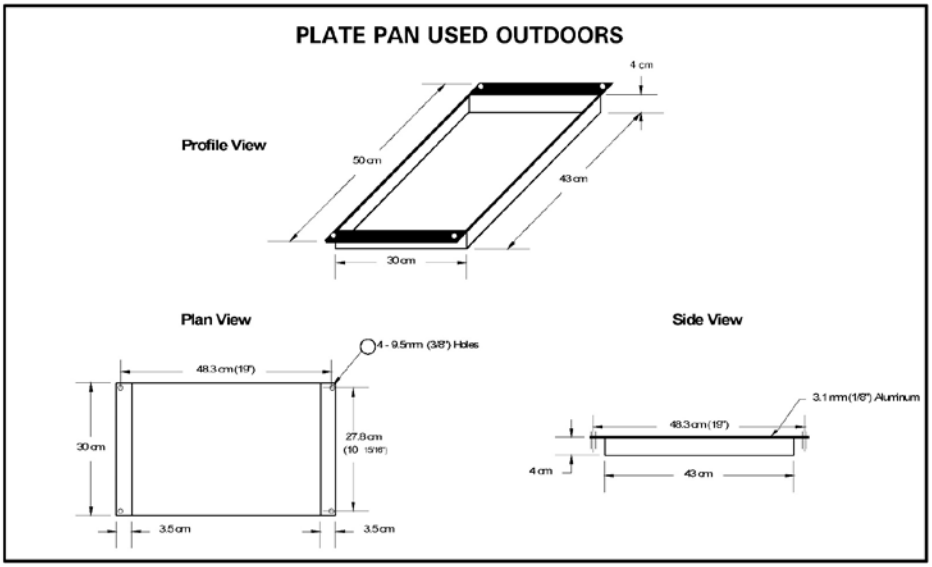


Figure 2.4: Flat Plate Test Set-Up



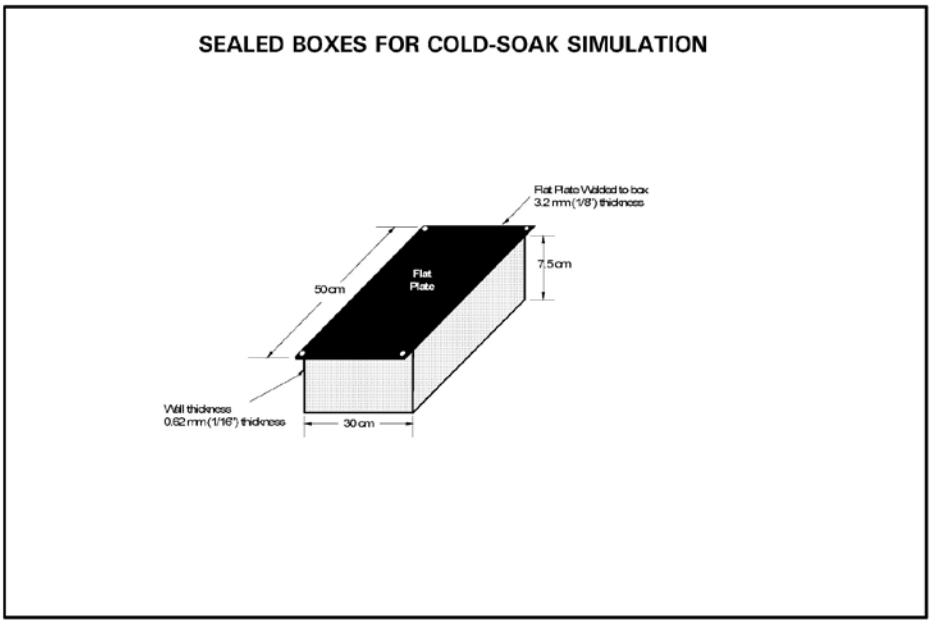


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Figure 2.5: Schematics of Plate Pan and Sealed Boxes

2.5 Test Procedures

Tests consisted of pouring anti-icing fluids directly onto clean test panels (exposed to various winter precipitation conditions) and recording the elapsed time for each crosshair to fail until the test panels reached the defined end condition (see Subsection 2.5.2 below).

2.5.1 Test Protocol (ARP 5485)

A plan 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 was developed by APS, based upon the requirements of ARP 5485. This procedure addresses testing conducted under natural precipitation conditions as well as under simulated freezing precipitation conditions.

Fluids to be evaluated are applied to test plates exposed to natural snow and simulated freezing fog, freezing drizzle, light freezing rain and rain on cold soaked wing. Endurance times are evaluated by measuring the minimum exposure time before a specified degree of freezing occurs.

During the conduct of these tests a series of test parameters are recorded. All test parameters specified in ARP 5485 are addressed in the procedure developed by APS. The test parameters are grouped into two categories: generic and specific test parameters.

Generic test parameters are recorded once per winter season (or test session, in laboratory testing) and include: discussion of safety issues, test plate material, test plate dimensions, surface finish and ice-catch pan dimensions. Specific test parameters are recorded during each testing session (or weather condition, in laboratory testing) and include: angle of the test stand, synchronization of timing devices, plate and ambient temperature profile files, icing intensity, etc.

As per ARP 5485 requirements, the test surface and ambient temperatures were recorded at a minimum sampling rate of one datum per minute. Figure 2.6 presents an example of a typical endurance time test conducted under simulated freezing drizzle conditions. The graph shows the test surface and chamber temperature profiles over the duration of the test and beyond failure time.

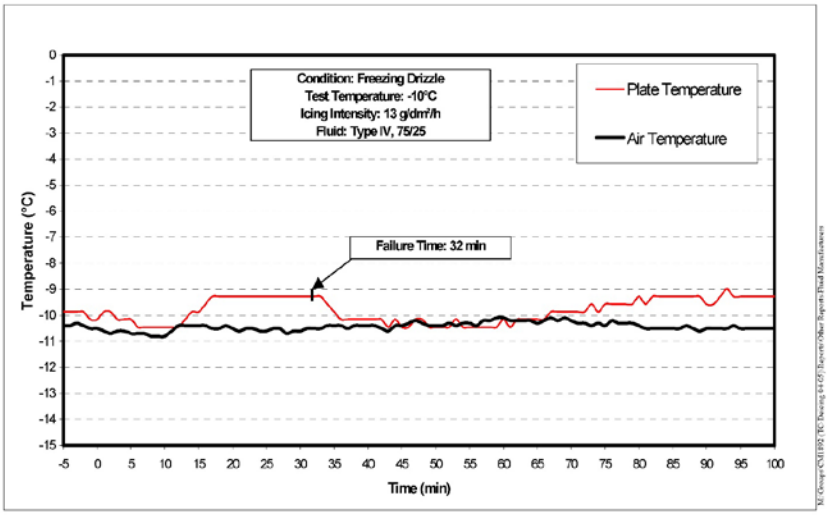

Figure 2.6: Temperature Profiles During a Typical Endurance Time Test

2.5.2 Test Protocol

The SAE G-12 HOT Subcommittee developed the procedure for natural snow flat plate tests.

The major steps in the natural snow flat plate test procedure are:

- Synchronize all timepieces;
- Clean panels and start;
- Apply (pour) fluids to test panels. Type II, Type III, and Type IV fluid are applied at the outdoor ambient temperature. Fluids are poured using a single-step fluid application;
- Record crosshair end condition times;
- Continue testing until at least five crosshairs or 30 percent (1/3) of the plate have failed;
- Record weather conditions; and
- Clean panels and restart.

2.5.3 End Condition Definitions

The test procedures and the determination of defined end conditions evolved from the experience the APS test team has accumulated from previous winter season test programs. Any of the following descriptions provide the general guidelines that observers use to judge when fluid failure occurs and to judge the extent of contamination or failure:

Failure is called when 30 percent (1/3) of the plate is 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.

2.5.4 Precipitation Rate Procedures

2.5.4.1 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 (h: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.

2.5.4.2 Precipitation rate distribution in simulated conditions

Clean test plates are placed on the test stand prior to the rate collection period, and are exposed to the simulated precipitation to verify that an even ice formation occurs over the entire test bed. If this visual inspection proves satisfactory, the rate collection period will begin. If this visual inspection proves unsatisfactory, the test stand must be repositioned under the spray device and the process is then repeated.

In order to verify the rate distribution on the test stand, a continuous rate-monitoring pan is replaced with a detailed rate distribution pan, which consists of 4 small pans of equivalent size. The area of the 4 small pans combined is similar to that of a standard rate collection pan. The small pans are weighed and placed at these locations and re-weighed at fixed intervals. The typical collection period for rate distribution is 60 minutes, however this interval may be shorter if all tests have been completed within 60 minutes. The variation between the rate of any of the 4 small pans and that of the average rate of that location should not be greater than 10 percent.

Two examples of the detailed rate distributions are shown in Table 2.4. Both rate distributions were conducted in freezing drizzle, one at the low rate (5 g/dm^2/h), the other at the high rate (13 g/dm^2/h). The average precipitation rate over the entire position in the low rate example in Table 2.4 was 5.1 g/dm^2/h. The individual rates of the four smaller pans were 5.0, 4.9, 5.2 and 5.3 g/dm^2/h, suggesting a maximum variation of 4.1 percent from the average rate over the entire position.

Table 2.4: Detailed Rate Distribution

Freezing Drizzle (low rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	2-top left	14:02	14:34	81.6	88.8	7.2	31.9	5.0
4	2-top right	14:02	14:34	81.6	88.6	7	31.9	4.9
5	2-bottom left	14:02	14:34	81.8	89.2	7.4	31.9	5.2
6	2-bottom right	14:02	14:34	81.6	89.2	7.6	31.9	5.3

3	4	5		STDDEV
5.0	4.9	-1.4%	-4.1%	0.181
5.2	5.3	1.4%	4.1%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

Freezing Drizzle (high rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	5-top left	12:12	12:43	81.8	98.8	17	30.8	12.3
4	5-top right	12:12	12:43	81.6	98.8	17.2	30.8	12.5
5	5-bottom left	12:12	12:43	81.6	100.2	18.6	30.8	13.5
6	5-bottom right	12:12	12:43	81.6	100.2	18.6	30.8	13.5

3	4	12.9		STDDEV
12.3	12.5	-4.8%	-3.6%	0.631
13.5	13.5	4.2%	4.2%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

CM1B0 (D:\C2)\eport s\Fluid Manufacturers Fluid Reports\Template\Detailed Rate Distribution

2.5.4.3 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) from the timepiece located near the rate station before leaving the trailer to place the pans on the test stand. The person responsible for collecting precipitation rate data take the time delay necessary to proceed outside from the rate station into consideration.

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.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.7. Typically, two collections pans are used for each test. The start and end times of the test are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t_1, t_2, and t_3 (minutes). The calculated rates for each collection period are indicated by R_1, R_2, and R_3 (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 2.4, 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.

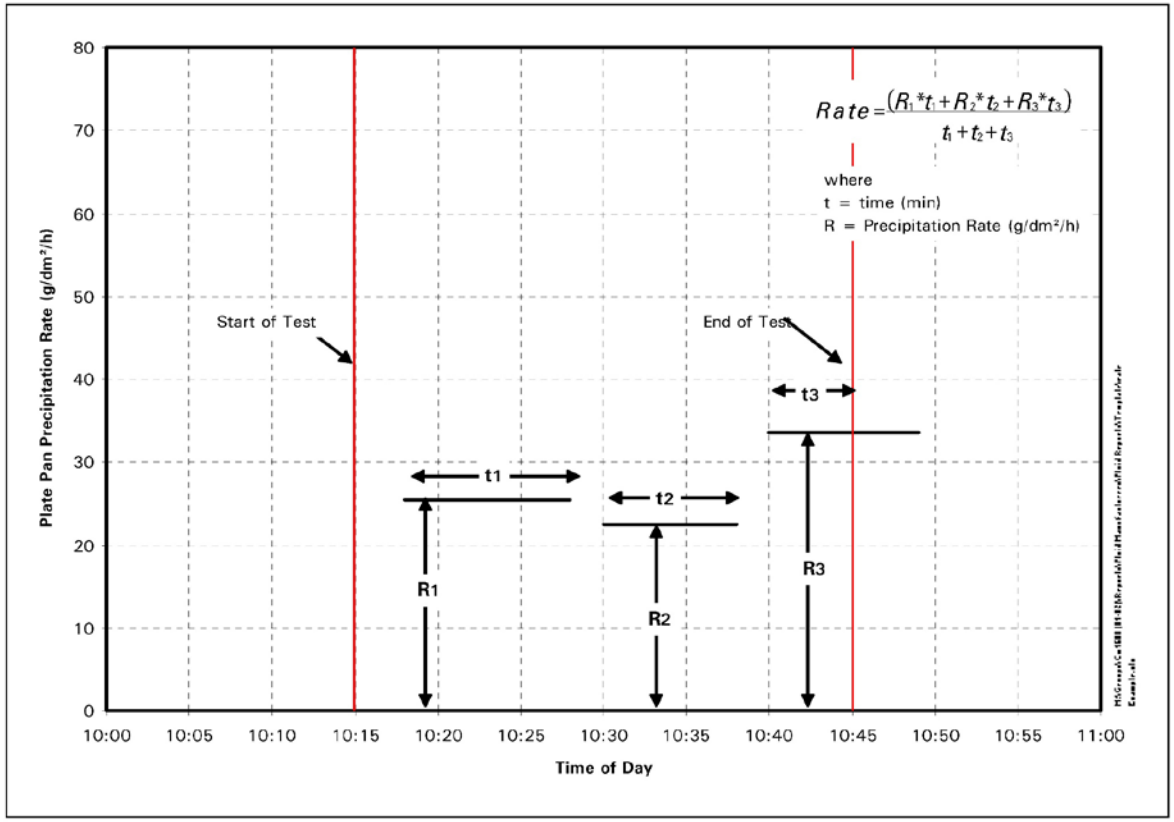

Figure 2.7: Calculation of Outdoor Precipitation Rate

2.6 Analysis Methodology

2.6.1 General

This section of the report describes the various categories of precipitation and the precipitation rate limits used during the course of endurance time testing. The process of data analysis used in the determination of fluid HOTs is also described.

2.6.2 Descriptions of Data Ranges and Precipitation Definitions

The test program developed to measure fluid failure times was carried out under five general categories of precipitation:

- Natural snow;
- Freezing drizzle;
- Light freezing rain;
- Freezing fog; and
- Rain on a cold-soaked surface.

Tests were conducted over temperature and precipitation rate ranges specific to each category of precipitation. A multi-variable regression procedure was used to evaluate fluid HOTs (first presented in TC report, TP 13131E) and is based on the refinement of an equation for a curve which best represents the fluid failure time test data, and then solving that equation at the upper and lower limits of a defined precipitation range. To support this procedure, precipitation rate limits for each specific category of precipitation were defined, reviewed and approved.

The precipitation rate limits used for the evaluation of HOT's are represented schematically in Figure 2.8. Detailed definitions and explanations of the data types and ranges are described in the following subsections. Meteorologically accepted definitions of these conditions were outlined in Table 2.1.

2.6.2.1 Natural snow

All fluid failure tests in natural snow were conducted at the APS Dorval Airport test site. Data were collected for precipitation rates that ranged from less than 4 g/dm²/h to greater than 25 g/dm²/h. For Type II and Type IV fluids, upper and lower limits for the snow column were set at rates of 10 and 25 g/dm²/h, respectively.

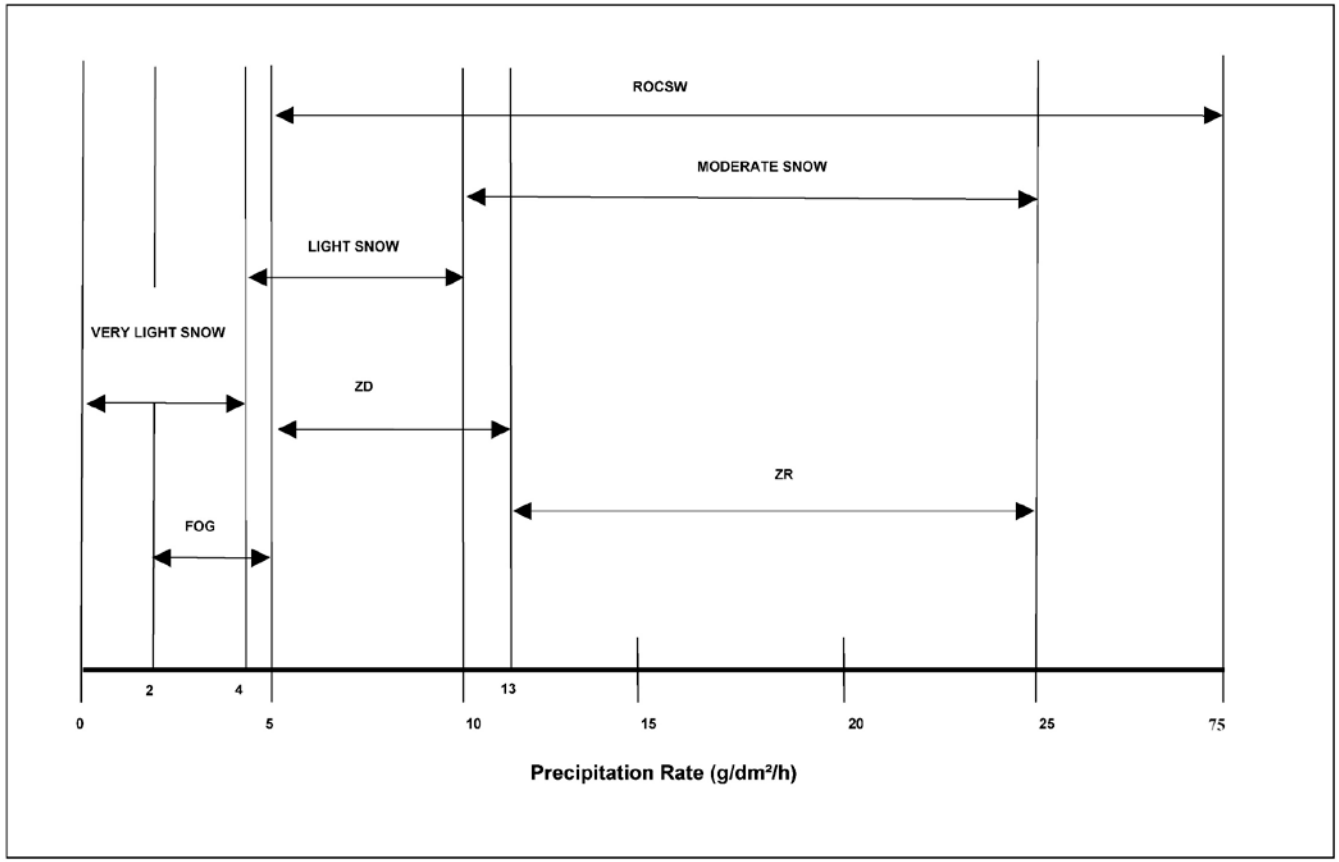

Figure 2.8: Data Range Used for Evaluation of Holdover Time Limits

The upper precipitation rate limit (25 g/dm^2/h) corresponds to the onset of heavy snow. Above this rate, it is standard practice to refer to the cautionary note included in the HOT tables indicating that the time of protection will be shortened in heavy weather conditions, (i.e., heavy precipitation, or high moisture content).

2.6.2.2 Freezing drizzle

Freezing drizzle is considered to occur over the range of 0 to 13 g/dm^2/h. The upper limit in this range, while not specifically defined in Table 2.1, has been adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Subcommittee.

For test purposes, the precipitation rate spectrum for freezing drizzle is constrained to rates between 5 and 13 g/dm^2/h, inclusively. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety. A caution note is included in the HOT tables indicating that if positive identification of freezing drizzle is not possible, the light freezing rain HOT is recommended for use.

2.6.2.3 Light freezing rain

With reference to the HOT tables, freezing rain conditions span the range of precipitation rates from 13 to 25 g/dm^2/h, inclusively. This range falls in 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.

2.6.2.4 Freezing fog

The precipitation rate limits for freezing fog were arrived at with input from meteorologists from the NRC, 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.

The precipitation rate for fog, referred to as *fog deposition* or simply as *deposition*, is given by the empirical expression,

$$\textbf{\textit{Deposition = LWC x Wind Velocity x Sin 10° x Collection Efficiency}}$$

where the Sin 10° term accounts for the 10° inclination of the test plates into the direction of the wind.

The meteorological circumstances (LWC value and wind speed), and the speed and orientation of the airfoil relative to the wind (stationary or taxiing), contribute to uncertainties in the values that the variables in the equation can assume.

Since 1997, the upper and lower HOTs for freezing fog have been evaluated at rates of 5 g/dm^2/h and 2 g/dm^2/h, respectively. In Vienna, during the 1998 SAE G-12 HOT Subcommittee meeting, it was felt that 2 g/dm²/h was not indicative of low rate natural fog. However, during a meeting of the Workgroup on Laboratory Methods to Derive HOT Guidelines in Montreal in March 1999, it was again agreed upon that the rate of 2 g/dm^2/h would be used in subsequent HOT testing in order to determine the upper HOT limit in freezing fog conditions.

2.6.2.5 Rain on a cold-soaked surface

Data used for the evaluation of HOTs for this category of precipitation were limited to precipitation rates ranging from 5 to 75 g/dm^2/h, which 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). The heavy rain category is covered by the caution note at the bottom of the HOT table regarding heavy weather conditions.

2.6.3 Protocol for the Determination of Holdover Times

Each cell in a HOT table represents a range of time during which a fluid at a specified concentration will provide protection for a particular temperature range in a particular category of precipitation. The Type II and Type IV HOT tables are composed of a maximum of 30 cells. Each cell contains a lower and upper time limit (except in frost) for a maximum of 54 time values.

Cell HOT values are determined by plotting *Failure Time* versus *Rate of Precipitation* and recording the failure time at two pre-selected rate limits. In previous years, several protocols were employed in the determination of HOTs. Due to the subjective natures of these different protocols, different interpretations of the data were possible. A multi-variable regression approach was subsequently devised in 1996/97 (see TC report, TP 13131E) and has since been used to evaluate fluid holdover times.

Data corresponding to each cell in the HOT table were assembled and sorted according to precipitation type, fluid dilution and temperature range. The data for each cell in the HOT table were plotted.

The data points on each plot were used to fit an equation of the form:

$$t = cR^a$$

where

t = Time (minutes)
R = Rate of precipitation (g/dm^2/h)
a,c = coefficients determined from the regression.

The coefficient a gives the rate dependency of the failure time.

Sample plots of **Log t** versus **Log R** are shown in Figure 2.9. The plots contain data from one temperature range, for one Neat Type IV fluid 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 2.10. 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 snow.

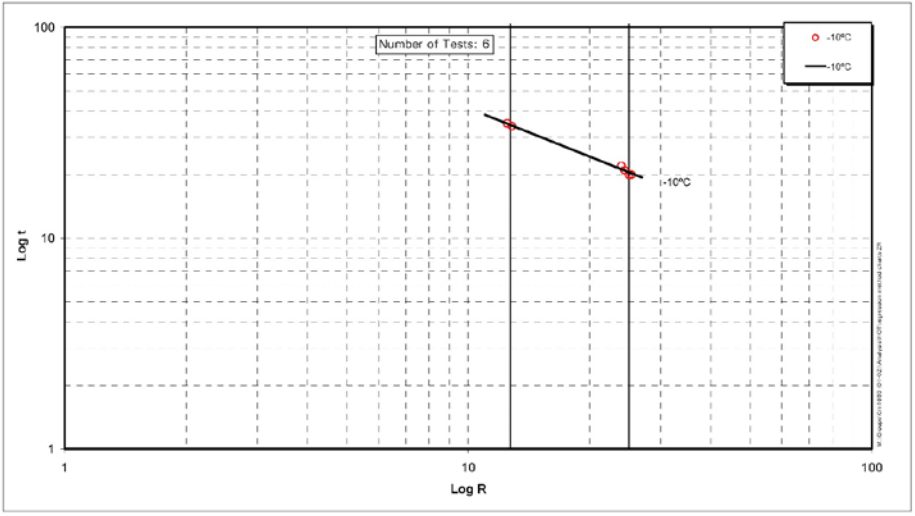

Figure 2.9: Regression Method on Log-Log Chart – Sample Type IV Neat, Freezing Rain

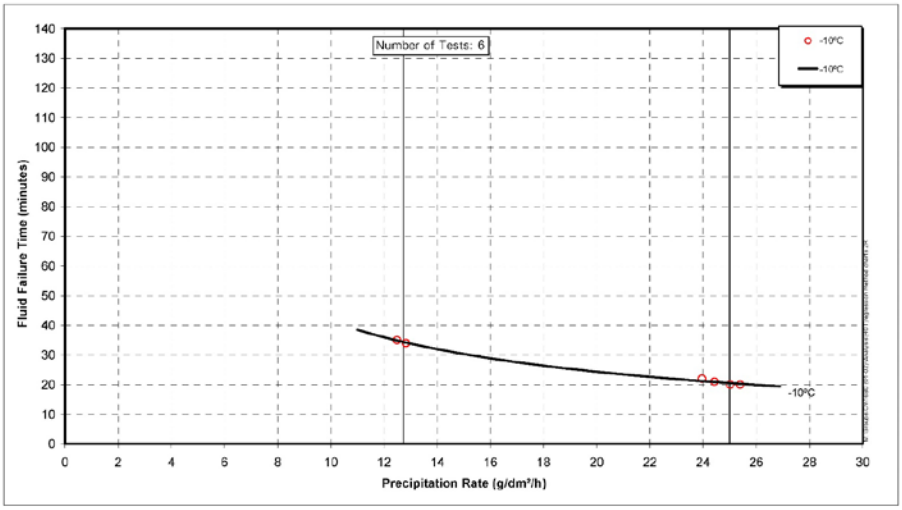

Figure 2.10: Regression Method on Standard Chart – Sample Type IV Neat, Freezing Rain

The HOTs for this fluid at -10°C are 20 minutes at 10 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

The categories of precipitation are separated into five groups: natural snow, freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface. Each group was subject to a slightly modified version of the general equation given above, as described in the following subsections.

2.6.3.1 Light freezing rain and freezing drizzle

The equation used to treat the data in these categories of precipitation is given by the expression below:

$$t = cR^a$$

- Tests in freezing drizzle and light freezing rain were conducted at predetermined temperature limits (-3 and -10°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were also obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.2 Simulated freezing fog

The equation used to treat freezing fog data is given by the expression below:

$$t = cR^a$$

- Tests in freezing fog were conducted at predetermined temperature limits (-3, -14 and -25°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.3 Natural snow

The general form of the regression equation was modified for natural snow by substituting 2-T for the variable T, in order to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C.

$$t = cR^a(2-T)^b.$$

- Best-fit curves were plotted for each fluid in each cell of the snow column using the most restrictive (lowest) temperature for that cell. For example, in cases of natural snow tests conducted at ambient temperatures above -3°C, the value of temperature used in the fitting procedure was -3°C.

- The upper and lower HOT values were determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively.

2.6.3.4 Rain on a cold-soaked wing

The same method for the evaluation of HOTs in light freezing rain and freezing drizzle was used for this category of precipitation.

2.6.4 Determination of Generic and Fluid Specific Holdover Times

At the SAE HOT Subcommittee meeting in Chicago in July 1997, Type IV fluid HOTs obtained using the multi-variable regression protocol of data analysis were presented. Wide variations in fluid performance among the different Type IV fluid brands forced the development of generic Type II and IV HOT tables as well as fluid-specific Type II and IV HOT tables.

2.6.4.1 *Fluid-specific holdover time tables*

Fluid-specific HOT table development was prompted by the fact that certain Type IV fluid brands were observed to significantly outperform other fluids under conditions corresponding to specific cells in the HOT tables. In general, any one fluid brand does not globally outperform the other fluid brands, but rather does so at a specific dilution, temperature range, and/or category of precipitation.

At the Chicago meeting in 1997, most members of the SAE G-12 HOT Subcommittee did not favour fluid-specific tables. However, significant reductions to HOTs for the cells corresponding to the most common Type IV fluid usage convinced the committee of the need to consider the development of fluid-specific and generic tables. Furthermore, some members wanted to take advantage of the significant benefits exhibited by some fluids in certain conditions.

A summary of the steps to follow to determine fluid specific values for a Type II or IV fluid is provided below:

- The method used to determine HOTs is generally the same as was agreed upon in Chicago in 1997 at the SAE G-12 HOT Subcommittee meeting;
- For each cell of the HOT tables, four tests are typically conducted at the lowest temperature in the temperature range for that cell. Two tests are conducted at the low precipitation rate condition and at the high precipitation rate condition, for a total of four tests per cell;
- For each cell of the HOT table (except frost), a best-fit power law curve for each fluid is developed from the tests conducted at the low and high precipitation rate condition of that cell;
- Regression-generated HOTs are rounded off to the nearest whole "5" digit. For example, 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 HOTs are below 10 minutes, the numbers are rounded down as a precautionary measure. For example, 9 minutes is rounded down to 5 minutes; and
- Values are capped at 2 hours for all precipitation conditions except freezing fog, which are capped at 4 hours.

Photo 2.1: View of Test Site and Associated Equipment



Photo 2.2: Meteorological Services of Canada Weather Observation Station at Montréal-Pierre-Elliott-Trudeau International Airport



Photo 2.3: Outdoor View of National Research Council Climatic Engineering Facility



Photo 2.4: Inside View of Small End of Climatic Engineering Facility



Photo 2.5: Inside View of Large End of Climatic Engineering Facility



Photo 2.6: Sprayer Assembly Used at National Research Council

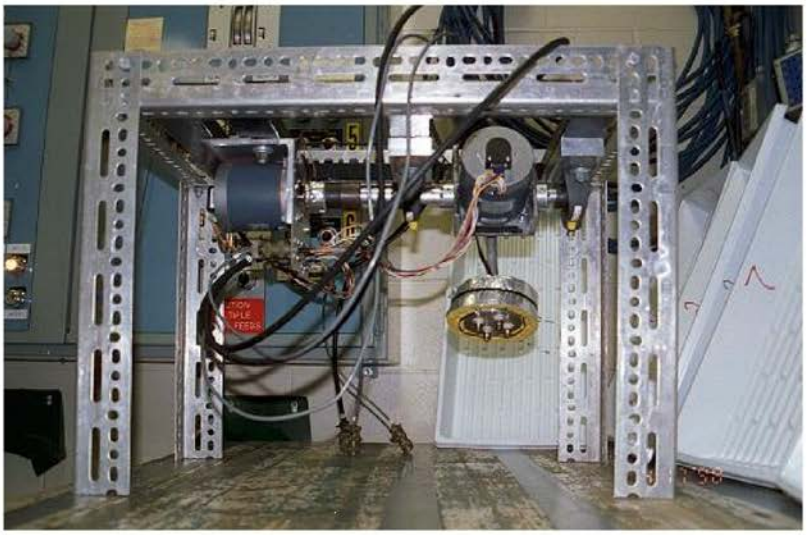

Photo 2.7: Sprayer Nozzle

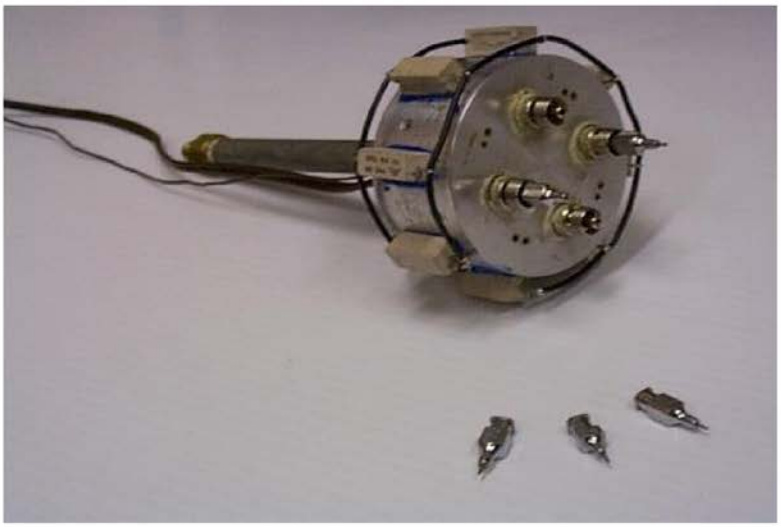

Photo 2.8: Test Plates Mounted on Stand



Photo 2.9: Collection Pans Used Indoors at the National Research Council



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted for natural snow, simulated light freezing rain, simulated freezing drizzle, simulated freezing fog, and rain on cold-soaked surfaces. Breakdowns are provided for quantity of tests performed by fluid type and temperature.

Summaries of the tests conducted in natural snow and in freezing precipitation are provided in Tables 3.1 and 3.2 at the end of this section.

3.1 Natural Snow Tests

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

	Above -3°C	-3 to -14°C	-14 to -25°C	Total
Neat	10	12	0	22
75/25	13	14	0	27
50/50	18	1	0	19
				68

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 the tests conducted is summarized below by 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 condition at the NRC CEF. The breakdown of the tests conducted is summarized below by fluid dilution and temperature.

	-3°C	-14°C	-25°C
Neat	3	4	4
75/25	4	4	0
50/50	6	0	0

3.4 Rain on Cold-Soaked Surface Tests

Cold-soak tests were conducted with Neat and 75/25 dilutions using 7.5 cm deep sealed boxes. Tests were conducted at an ambient temperature of +1°C at the NRC CEF. Duplicate tests were conducted with each dilution at each precipitation rate.

3.5 Fluid Thickness Tests

The purpose of these tests was to measure the film thickness profiles of the fluid in all dilutions, under dry conditions.

Two tests were performed for each standard dilution (Neat, 75/25 and 50/50). For each test, one litre of fluid was poured onto a flat plate mounted on a test stand inclined 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. Tests were conducted at an ambient temperature of -3°C.

The results are displayed in Figure 3.1.

3. DESCRIPTION OF DATA

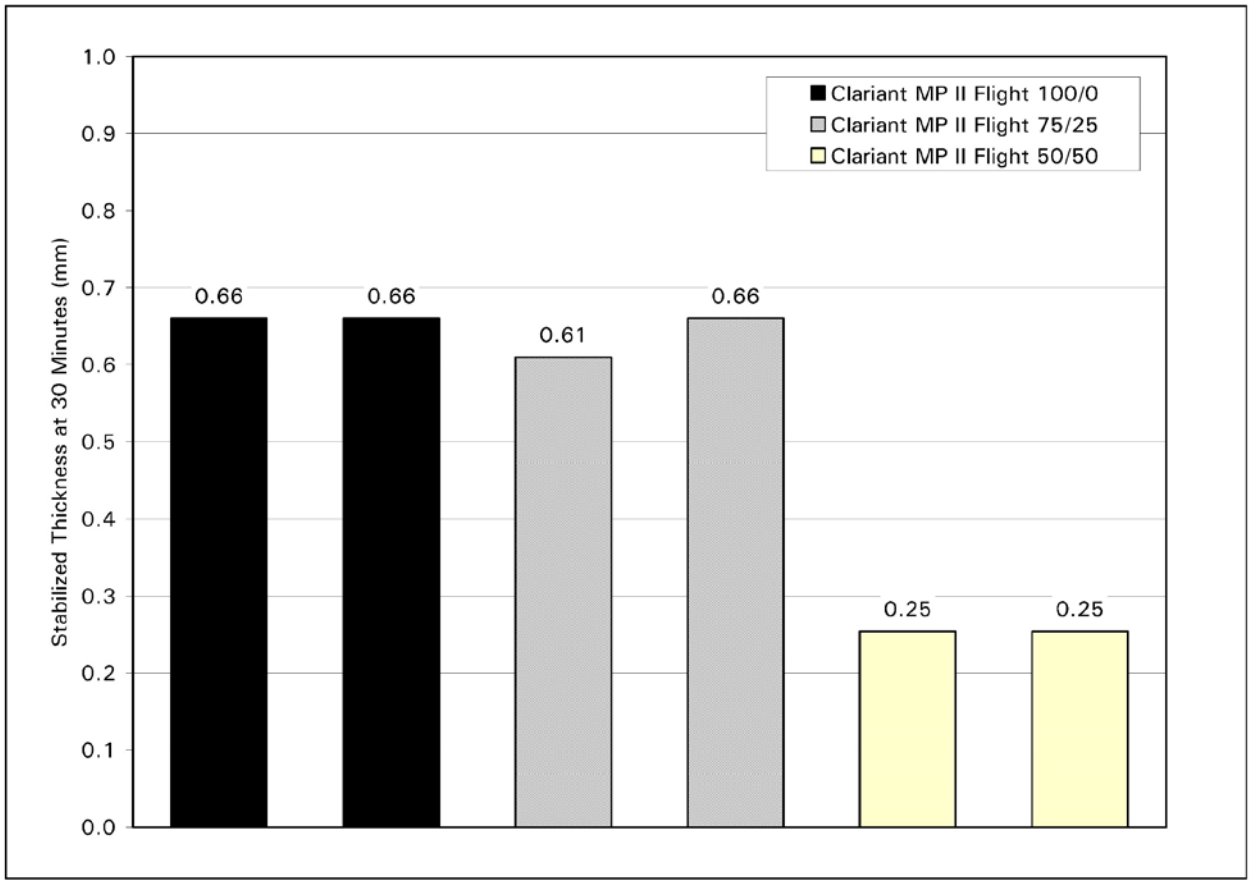

Figure 3.1: Fluid Thickness of Clariant Safewing MP II Flight

Table 3.1: Summary of Tests Performed in 2005-06 (Snow)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
1	21-Jan-06	Clariant MP II Flight	50%	17.0	27.0	-0.1	Natural Snow
2	21-Jan-06	Clariant MP II Flight	50%	19.5	17.7	-0.2	Natural Snow
3	21-Jan-06	Clariant MP II Flight	50%	19.2	26.6	0.0	Natural Snow
4	21-Jan-06	Clariant MP II Flight	75%	69.3	25.9	-0.2	Natural Snow
5	21-Jan-06	Clariant MP II Flight	100%	73.0	26.9	-0.3	Natural Snow
6	21-Jan-06	Clariant MP II Flight	100%	83.0	26.5	-0.3	Natural Snow
7	21-Jan-06	Clariant MP II Flight	75%	56.7	26.0	-0.2	Natural Snow
8	21-Jan-06	Clariant MP II Flight	50%	16.0	27.7	-1.0	Natural Snow
9	21-Jan-06	Clariant MP II Flight	50%	22.0	19.1	-1.3	Natural Snow
11	21-Jan-06	Clariant MP II Flight	50%	16.3	30.0	-0.6	Natural Snow
12	21-Jan-06	Clariant MP II Flight	75%	76.7	25.7	-1.0	Natural Snow
14	21-Jan-06	Clariant MP II Flight	75%	63.0	23.4	-1.2	Natural Snow
15	21-Jan-06	Clariant MP II Flight	100%	80.0	25.5	-1.0	Natural Snow
16	24-Jan-06	Clariant MP II Flight	50%	24.3	10.5	-0.7	Natural Snow
17	24-Jan-06	Clariant MP II Flight	50%	21.5	13.0	-0.7	Natural Snow
18	24-Jan-06	Clariant MP II Flight	100%	126.5	9.1	-0.7	Natural Snow
19	24-Jan-06	Clariant MP II Flight	75%	118.0	8.7	-0.7	Natural Snow
20	24-Jan-06	Clariant MP II Flight	100%	87.7	15.2	-0.5	Natural Snow
21	24-Jan-06	Clariant MP II Flight	75%	79.3	15.8	-0.5	Natural Snow
22	24-Jan-06	Clariant MP II Flight	100%	88.0	14.3	-0.5	Natural Snow
23	24-Jan-06	Clariant MP II Flight	75%	73.5	14.9	-0.6	Natural Snow
24	24-Jan-06	Clariant MP II Flight	50%	16.5	18.4	-0.7	Natural Snow
25	25-Jan-06	Clariant MP II Flight	50%	23.8	11.6	-0.5	Natural Snow
26	24-Jan-06	Clariant MP II Flight	50%	23.7	13.1	-0.7	Natural Snow
27	24-Jan-06	Clariant MP II Flight	50%	19.8	13.2	-0.7	Natural Snow
29	24-Jan-06	Clariant MP II Flight	75%	103.7	11.5	-0.6	Natural Snow
30	24-Jan-06	Clariant MP II Flight	100%	146.5	10.1	-0.7	Natural Snow
31	24-Jan-06	Clariant MP II Flight	75%	124.2	9.4	-0.7	Natural Snow
32	24-Jan-06	Clariant MP II Flight	100%	126.5	5.7	-0.7	Natural Snow
33	24-Jan-06	Clariant MP II Flight	75%	96.8	10.0	-0.7	Natural Snow
34	24-Jan-06	Clariant MP II Flight	50%	48.0	5.0	-0.7	Natural Snow
35	29-Jan-06	Clariant MP II Flight	100%	53.8	23.7	-6.0	Natural Snow
36	29-Jan-06	Clariant MP II Flight	75%	43.7	23.4	-6.0	Natural Snow
37	29-Jan-06	Clariant MP II Flight	75%	45.0	22.4	-5.7	Natural Snow
38	29-Jan-06	Clariant MP II Flight	100%	52.7	22.0	-5.7	Natural Snow
39	29-Jan-06	Clariant MP II Flight	100%	88.0	17.6	-4.9	Natural Snow
40	29-Jan-06	Clariant MP II Flight	75%	81.7	17.5	-4.9	Natural Snow
41	29-Jan-06	Clariant MP II Flight	100%	99.2	7.5	-4.0	Natural Snow
42	29-Jan-06	Clariant MP II Flight	75%	88.0	7.2	-4.0	Natural Snow
43	16-Feb-06	Clariant MP II Flight	75%	26.3	20.7	-8.4	Natural Snow
44	16-Feb-06	Clariant MP II Flight	100%	41.3	23.6	-8.5	Natural Snow

Table 3.1 (cont'd): Summary of Tests Performed in 2005-06 (Snow)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
51	16-Feb-06	Clariant MP II Flight	75%	21.5	32.4	-9.2	Natural Snow
52	16-Feb-06	Clariant MP II Flight	100%	47.0	30.6	-9.3	Natural Snow
59	16-Feb-06	Clariant MP II Flight	75%	14.2	28.8	-9.3	Natural Snow
60	16-Feb-06	Clariant MP II Flight	100%	24.5	29.7	-9.3	Natural Snow
67	16-Feb-06	Clariant MP II Flight	75%	64.8	8.3	-9.0	Natural Snow
68	16-Feb-06	Clariant MP II Flight	100%	85.1	10.6	-9.0	Natural Snow
94	21-Feb-06	Clariant MP II Flight	50%	73.2	2.6	-3.4	Natural Snow
103	22-Feb-06	Clariant MP II Flight	100%	132.3	5.7	-1.6	Natural Snow
104	22-Feb-06	Clariant MP II Flight	75%	125.0	5.6	-1.6	Natural Snow
115	23-Feb-06	Clariant MP II Flight	75%	149.7	9.6	-2.1	Natural Snow
124	22-Feb-06	Clariant MP II Flight	50%	17.0	12.5	-1.7	Natural Snow
131	22-Feb-06	Clariant MP II Flight	50%	66.4	3.1	-1.6	Natural Snow
136	23-Feb-06	Clariant MP II Flight	50%	25.1	9.3	-1.4	Natural Snow
139	23-Feb-06	Clariant MP II Flight	50%	51.8	3.9	-2.2	Natural Snow
144	23-Feb-06	Clariant MP II Flight	75%	44.6	16.4	-1.2	Natural Snow
145	23-Feb-06	Clariant MP II Flight	100%	69.2	16.6	-1.1	Natural Snow
160	23-Feb-06	Clariant MP II Flight	50%	12.1	15.9	-1.2	Natural Snow
174	25-Feb-06	Clariant MP II Flight	100%	107.0	5.1	-13.7	Natural Snow
175	25-Feb-06	Clariant MP II Flight	75%	78.6	3.7	-13.6	Natural Snow
185	25-Feb-06	Clariant MP II Flight	100%	72.3	8.9	-13.6	Natural Snow
186	25-Feb-06	Clariant MP II Flight	75%	50.2	9.7	-13.7	Natural Snow
187	25-Feb-06	Clariant MP II Flight	75%	59.3	5.9	-13.2	Natural Snow
188	25-Feb-06	Clariant MP II Flight	75%	58.8	5.9	-13.3	Natural Snow
189	25-Feb-06	Clariant MP II Flight	75%	32.5	10.1	-13.6	Natural Snow
194	25-Feb-06	Clariant MP II Flight	100%	73.5	9.8	-13.6	Natural Snow
205	03-Mar-06	Clariant MP II Flight	100%	129.6	3.4	-9.1	Natural Snow
206	03-Mar-06	Clariant MP II Flight	75%	137.1	3.6	-9.1	Natural Snow

Table 3.2: Summary of Tests Performed in 2005-06 (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
3	06-Apr-06	Clariant MP II Flight	100%	79.0	12.9	-3.2	Freezing Drizzle
4	06-Apr-06	Clariant MP II Flight	100%	83.3	13.0	-3.2	Freezing Drizzle
5	06-Apr-06	Clariant MP II Flight	75%	77.3	12.5	-3.2	Freezing Drizzle
6	06-Apr-06	Clariant MP II Flight	75%	75.0	12.6	-3.2	Freezing Drizzle
7	06-Apr-06	Clariant MP II Flight	50%	21.5	12.5	-3.1	Freezing Drizzle
8	06-Apr-06	Clariant MP II Flight	50%	21.5	13.1	-3.1	Freezing Drizzle
35	07-Apr-06	Clariant MP II Flight	100%	157.8	4.6	-3.3	Freezing Drizzle
36	07-Apr-06	Clariant MP II Flight	100%	167.0	4.6	-3.2	Freezing Drizzle
37	07-Apr-06	Clariant MP II Flight	75%	136.3	5.0	-3.2	Freezing Drizzle
38	07-Apr-06	Clariant MP II Flight	75%	139.8	4.9	-3.2	Freezing Drizzle
39	07-Apr-06	Clariant MP II Flight	50%	31.3	5.4	-3.1	Freezing Drizzle
40	07-Apr-06	Clariant MP II Flight	50%	28.0	5.4	-3.2	Freezing Drizzle
67	06-Apr-06	Clariant MP II Flight	100%	36.0	13.0	-10.3	Freezing Drizzle
68	06-Apr-06	Clariant MP II Flight	100%	36.2	13.0	-10.3	Freezing Drizzle
69	06-Apr-06	Clariant MP II Flight	75%	26.0	12.9	-10.1	Freezing Drizzle
70	06-Apr-06	Clariant MP II Flight	75%	25.5	12.8	-10.1	Freezing Drizzle
89	05-Apr-06	Clariant MP II Flight	100%	87.7	5.1	-10.1	Freezing Drizzle
90	05-Apr-06	Clariant MP II Flight	100%	85.7	5.3	-10.1	Freezing Drizzle
91	05-Apr-06	Clariant MP II Flight	75%	69.2	5.1	-10.4	Freezing Drizzle
92	05-Apr-06	Clariant MP II Flight	75%	67.8	5.3	-10.4	Freezing Drizzle
109	13-Apr-06	Clariant MP II Flight	100%	46.8	24.7	-3.0	Freezing Rain
110	13-Apr-06	Clariant MP II Flight	100%	47.3	24.9	-3.1	Freezing Rain
111	13-Apr-06	Clariant MP II Flight	75%	33.4	25.2	-3.0	Freezing Rain
112	13-Apr-06	Clariant MP II Flight	75%	30.8	25.4	-3.0	Freezing Rain
113	13-Apr-06	Clariant MP II Flight	50%	9.7	24.9	-3.1	Freezing Rain
114	13-Apr-06	Clariant MP II Flight	50%	10.6	24.9	-3.1	Freezing Rain
139	04-Apr-06	Clariant MP II Flight	100%	79.8	13.1	-3.3	Freezing Rain
140	04-Apr-06	Clariant MP II Flight	100%	86.0	13.1	-3.3	Freezing Rain
141	04-Apr-06	Clariant MP II Flight	75%	52.3	13.5	-3.3	Freezing Rain
142	04-Apr-06	Clariant MP II Flight	75%	55.8	13.5	-3.3	Freezing Rain
143	04-Apr-06	Clariant MP II Flight	50%	14.9	13.0	-3.2	Freezing Rain
144	04-Apr-06	Clariant MP II Flight	50%	16.2	12.6	-3.2	Freezing Rain
171	05-Apr-06	Clariant MP II Flight	100%	26.8	25.0	-10.0	Freezing Rain
172	05-Apr-06	Clariant MP II Flight	100%	28.3	24.9	-10.2	Freezing Rain
173	05-Apr-06	Clariant MP II Flight	75%	28.3	24.5	-10.0	Freezing Rain
174	05-Apr-06	Clariant MP II Flight	75%	29.2	25.0	-10.0	Freezing Rain
193	05-Apr-06	Clariant MP II Flight	100%	47.5	12.8	-10.2	Freezing Rain
194	05-Apr-06	Clariant MP II Flight	100%	47.2	12.7	-10.2	Freezing Rain
195	05-Apr-06	Clariant MP II Flight	75%	42.0	12.7	-10.1	Freezing Rain
196	05-Apr-06	Clariant MP II Flight	75%	43.2	13.0	-10.1	Freezing Rain

Table 3.2 (cont'd): Summary of Tests Performed in 2005-06 (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
215	11-Apr-06	Clariant MP II Flight	100%	207.5	4.7	-3.3	Freezing Fog
216	11-Apr-06	Clariant MP II Flight	100%	218.5	4.6	-3.3	Freezing Fog
217	11-Apr-06	Clariant MP II Flight	75%	143.8	5.0	-3.1	Freezing Fog
218	11-Apr-06	Clariant MP II Flight	75%	151.8	5.3	-3.1	Freezing Fog
220	11-Apr-06	Clariant MP II Flight	50%	66.0	4.9	-3.0	Freezing Fog
247	12-Apr-06	Clariant MP II Flight	100%	>246.3[1]	1.9	-3.2	Freezing Fog
249	12-Apr-06	Clariant MP II Flight	75%	>246.0[1]	1.7	-3.2	Freezing Fog
250	12-Apr-06	Clariant MP II Flight	75%	>245.5[1]	1.8	-3.2	Freezing Fog
251	12-Apr-06	Clariant MP II Flight	50%	97.0	2.0	-3.1	Freezing Fog
252	12-Apr-06	Clariant MP II Flight	50%	112.2	2.0	-3.0	Freezing Fog
279	11-Apr-06	Clariant MP II Flight	100%	56.0	5.0	-14.2	Freezing Fog
280	11-Apr-06	Clariant MP II Flight	100%	55.0	5.0	-14.2	Freezing Fog
281	11-Apr-06	Clariant MP II Flight	75%	38.0	5.1	-14.2	Freezing Fog
282	11-Apr-06	Clariant MP II Flight	75%	40.0	4.9	-14.2	Freezing Fog
301	10-Apr-06	Clariant MP II Flight	100%	111.0	1.7	-14.3	Freezing Fog
302	10-Apr-06	Clariant MP II Flight	100%	110.2	2.0	-14.3	Freezing Fog
303	10-Apr-06	Clariant MP II Flight	75%	72.2	1.9	-14.1	Freezing Fog
304	10-Apr-06	Clariant MP II Flight	75%	71.8	2.0	-14.1	Freezing Fog
323	10-Apr-06	Clariant MP II Flight	100%	28.7	4.9	-25.6	Freezing Fog
324	10-Apr-06	Clariant MP II Flight	100%	27.7	5.3	-25.6	Freezing Fog
335	10-Apr-06	Clariant MP II Flight	100%	53.2	1.8	-25.3	Freezing Fog
336	10-Apr-06	Clariant MP II Flight	100%	54.3	1.9	-25.3	Freezing Fog
567	27-Apr-06	Clariant MP II Flight	100%	10.8	75.3	0.9	Cold Soak
568	27-Apr-06	Clariant MP II Flight	100%	12.0	76.4	0.9	Cold Soak
569	27-Apr-06	Clariant MP II Flight	75%	6.5	72.5	0.8	Cold Soak
570	27-Apr-06	Clariant MP II Flight	75%	6.0	72.4	0.8	Cold Soak
589	27-Apr-06	Clariant MP II Flight	100%	84.3	5.2	0.7	Cold Soak
590	27-Apr-06	Clariant MP II Flight	100%	89.2	5.2	0.7	Cold Soak
591	27-Apr-06	Clariant MP II Flight	75%	80.5	4.8	1.0	Cold Soak
592	27-Apr-06	Clariant MP II Flight	75%	87.3	5.0	1.0	Cold Soak
804	11-Apr-06	Clariant MP II Flight	50%	56.0	5.2	-3.0	Freezing Fog
805	11-Apr-06	Clariant MP II Flight	50%	51.7	4.8	-3.0	Freezing Fog
809	11-Apr-06	Clariant MP II Flight	50%	58.2	4.6	-3.1	Freezing Fog

[1]Tests stopped when fluid failure had not occurred after 4 hours.

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4. RESULTS AND DISCUSSION

The methods used to evaluate the test data have been reviewed in Subsection 2.6. In this section, the data used to generate the endurance times will be presented.

4.1 Data

Endurance time values, for all conditions, are those of the tests conducted in 2005-06. 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 and precipitation on fluid endurance times for each condition. Table 4.1 illustrates the outputs from the regression equations run for this fluid under natural snow, freezing fog, freezing drizzle, freezing rain and cold soak conditions.

4.2 Holdover Time Table

A fluid specific HOT table for Clariant Safewing MP II Flight is shown in Table 4.2 at the end of this section.

4.2.1 Holdover Times in Snow, Below -14 to -25°C

In the winter of 2003-04, testing was conducted with artificial snowmakers at temperatures below -14°C. This was done as very limited endurance time data existed for fluids at these temperatures. As a result of this testing, the current propylene Type II and Type IV fluids were given generic values in the -14 to -25°C snow cell. Because no natural snow tests were conducted below -14°C with Clariant Safewing MP II Flight in the winter of 2005-06, generic values have been used in the -14 to -25°C snow cell.

4.2.2 Fluid Viscosity

The viscosity of the fluid sample used in HOT testing, as measured by APS personnel, appears at the front of this document. The viscosity measurement method is also documented. In order for the fluid specific values of a fluid to be valid, operators must ensure that the viscosity of the fluid used is superior to the published viscosity of that fluid, using the same viscosity measurement method published.

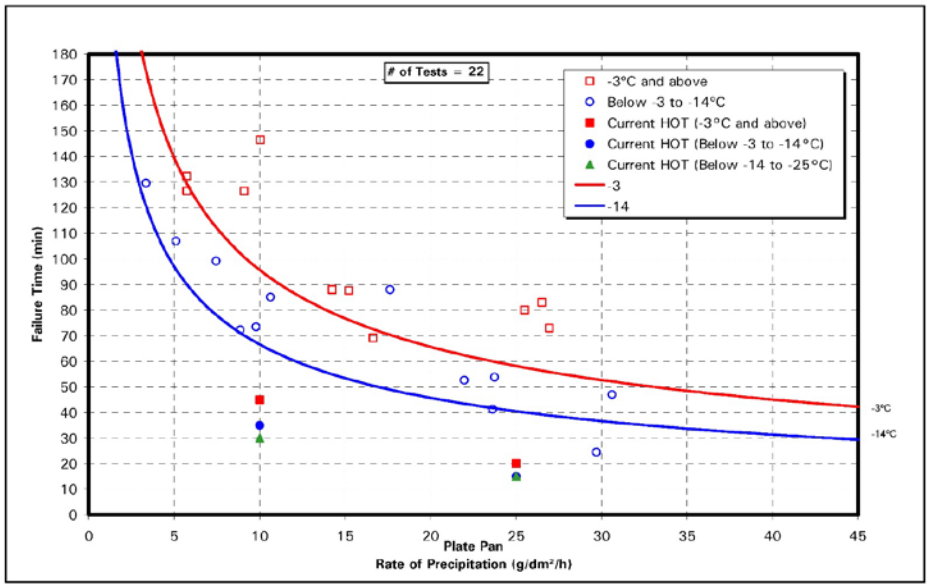


Figure 4.1: Type II Neat – Natural Snow

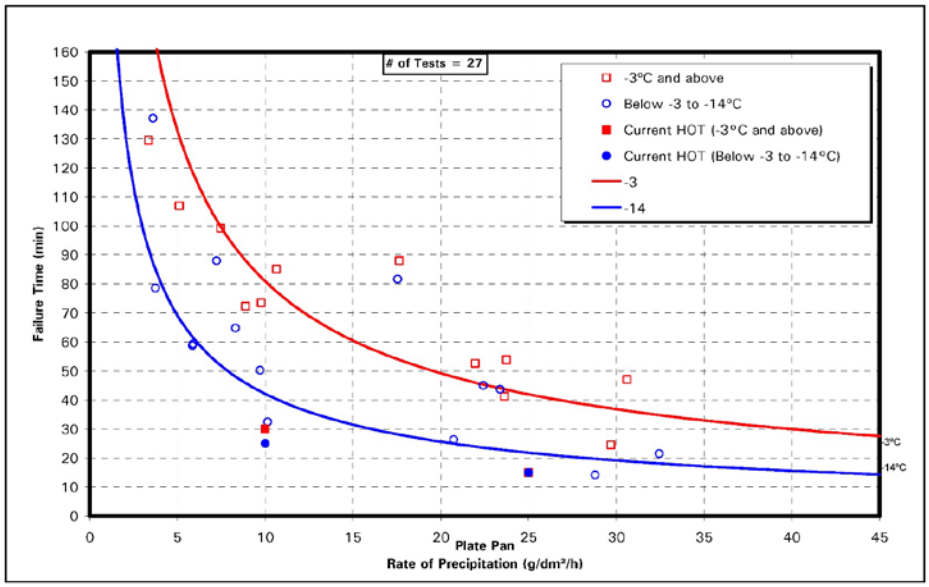


Figure 4.2: Type II 75/25 – Natural Snow

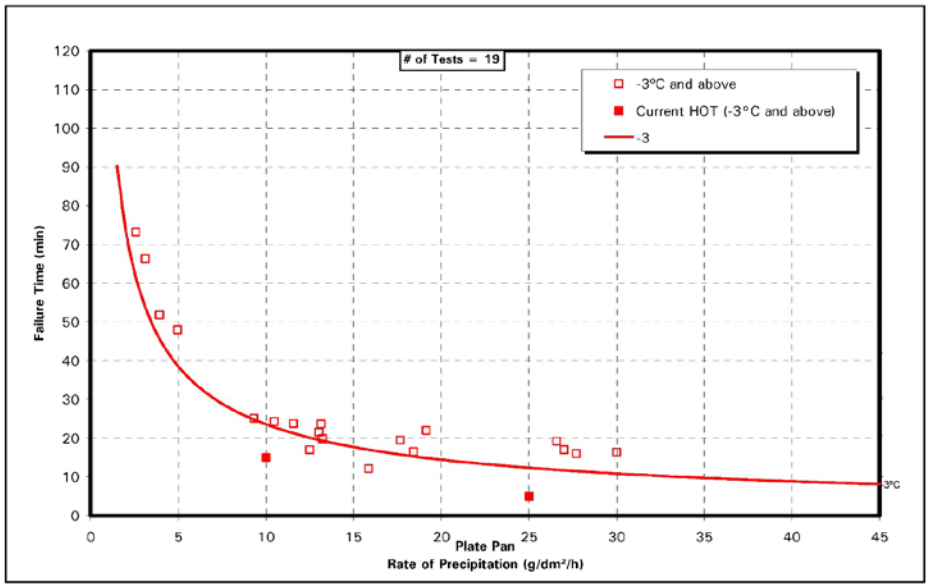


Figure 4.3: Type II 50/50 – Natural Snow

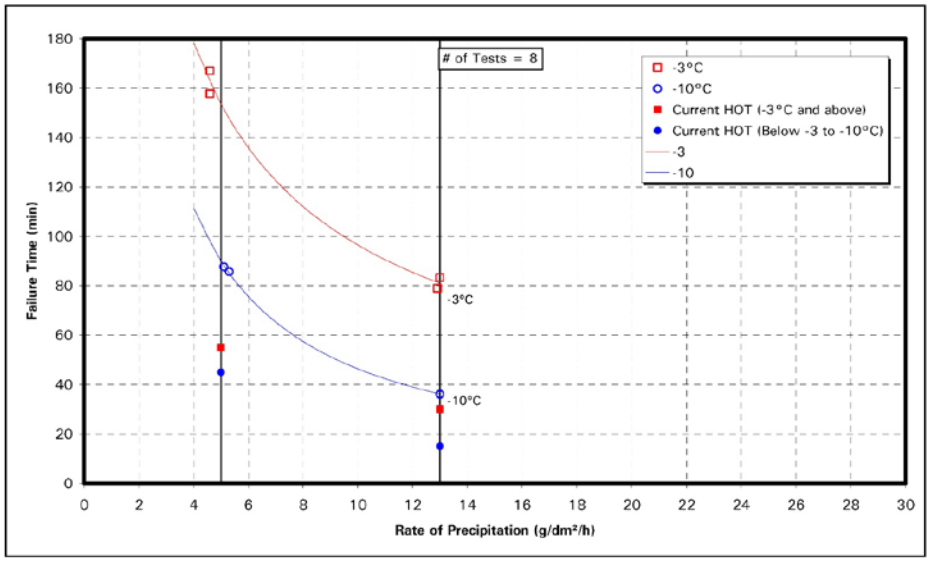


Figure 4.4: Type II Neat – Freezing Drizzle

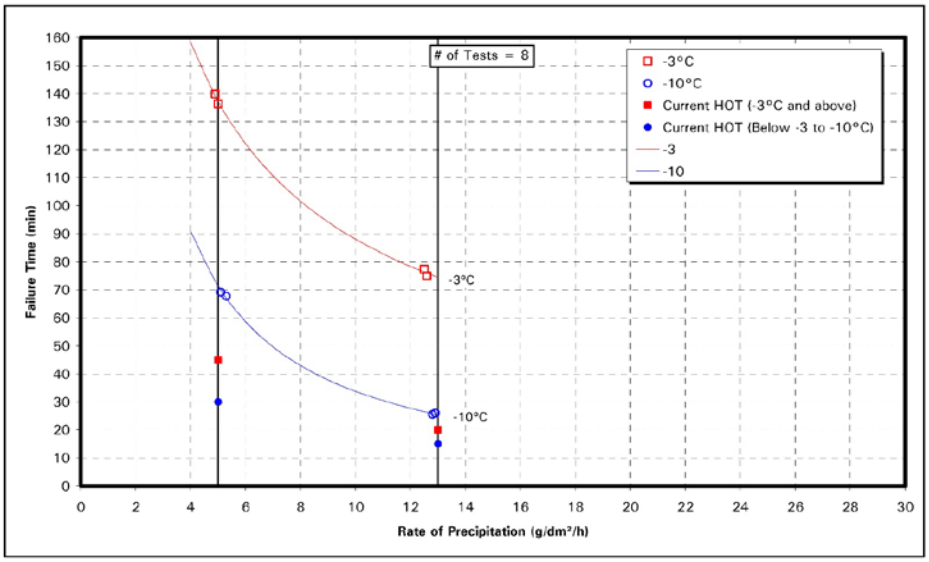


Figure 4.5: Type II 75/25 – Freezing Drizzle

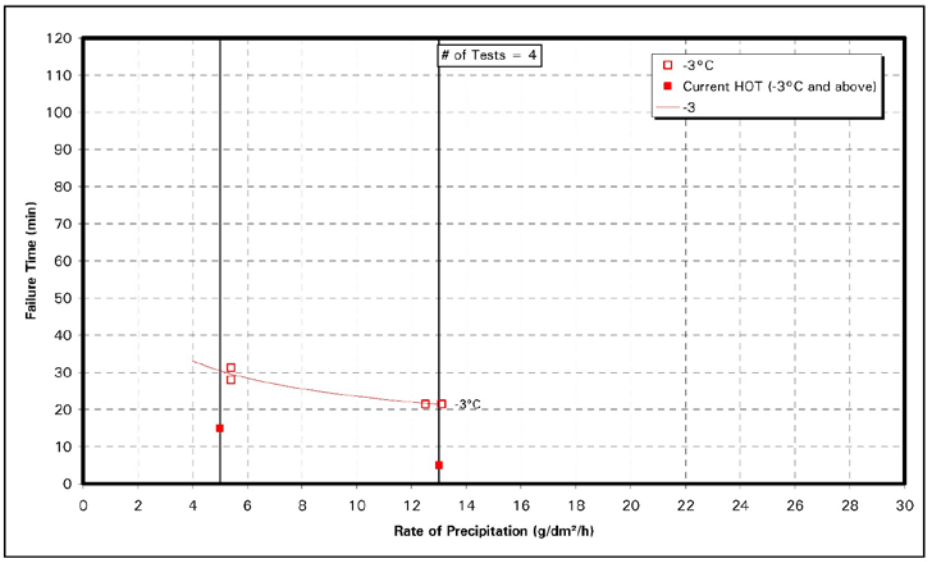


Figure 4.6: Type II 50/50 – Freezing Drizzle

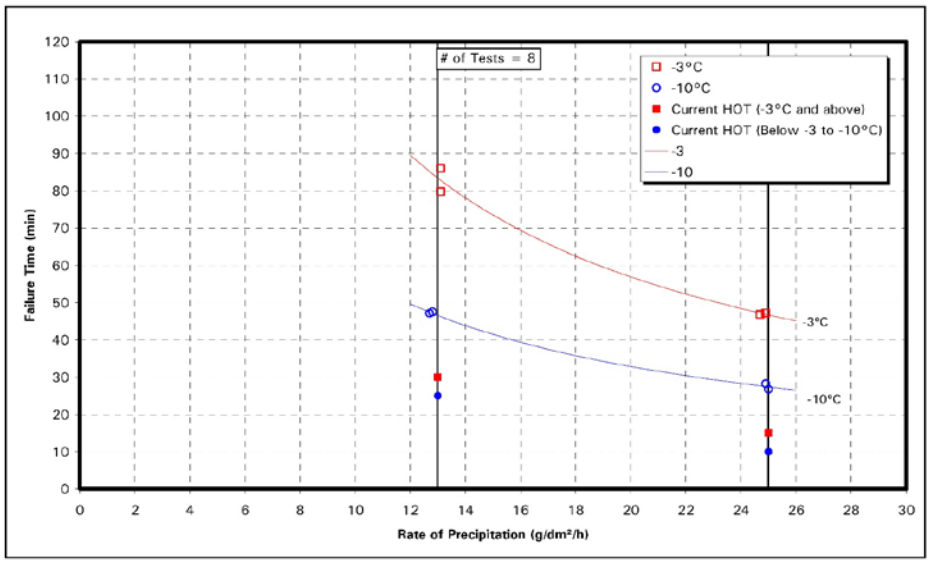


Figure 4.7: Type II Neat – Light Freezing Rain

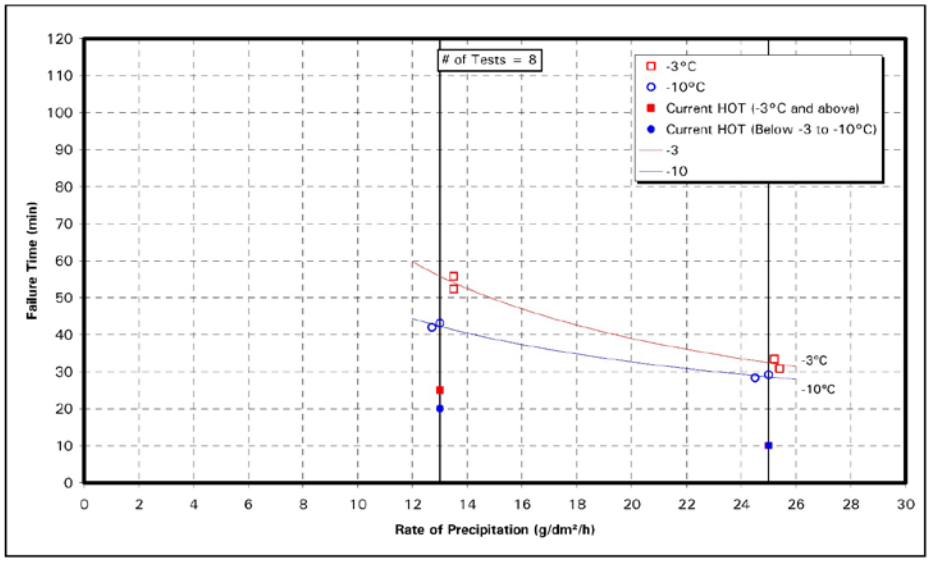


Figure 4.8: Type II 75/25 – Light Freezing Rain

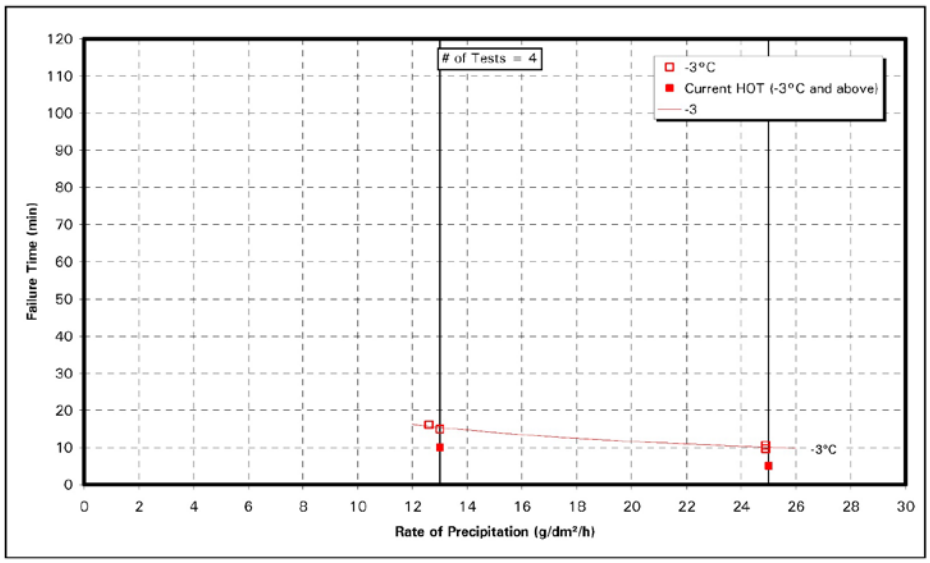


Figure 4.9: Type II 50/50 – Light Freezing Rain

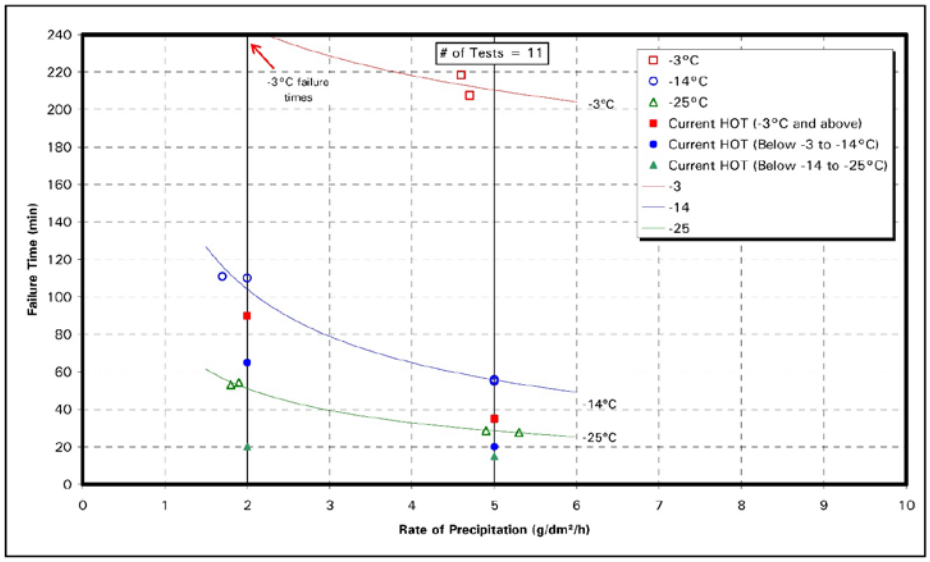


Figure 4.10: Type II Neat – Freezing Fog

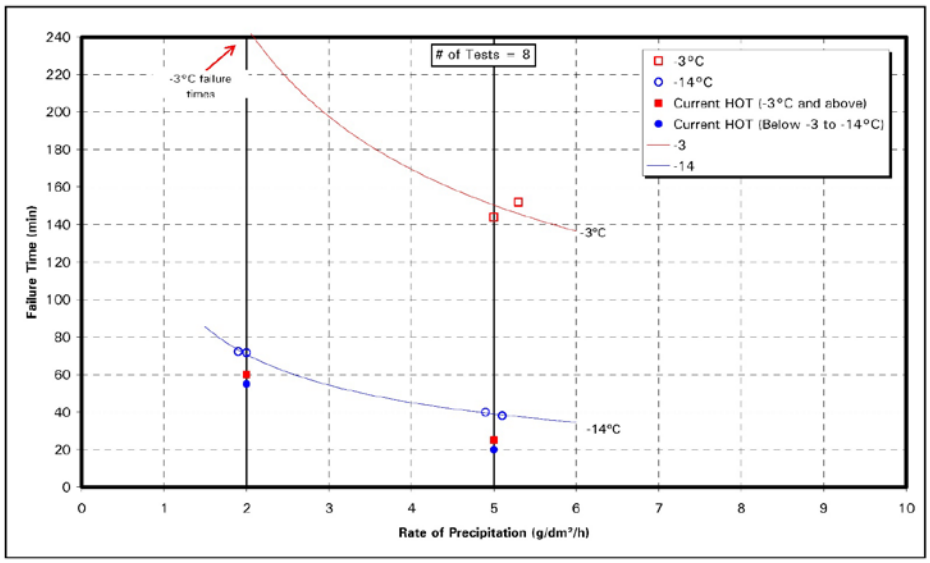


Figure 4.11: Type II 75/25 – Freezing Fog

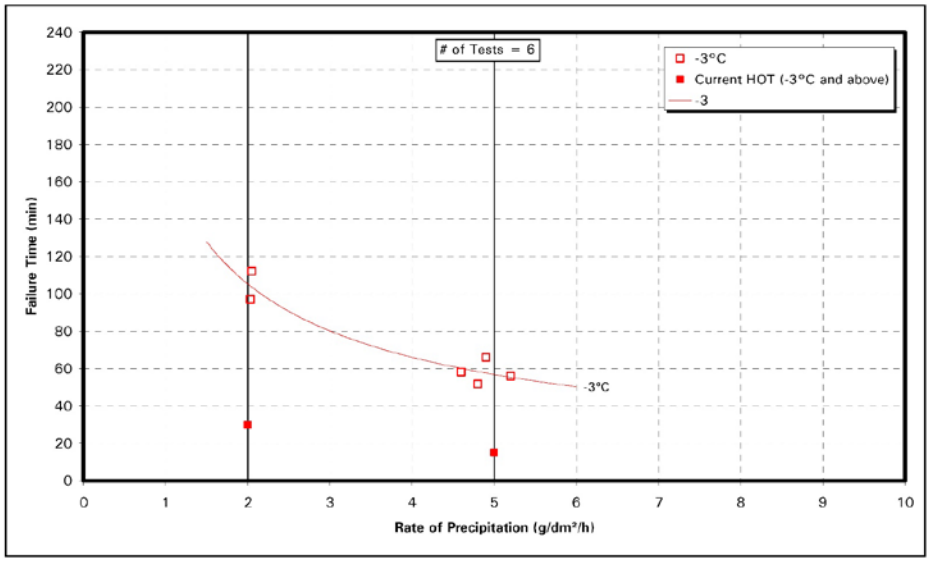


Figure 4.12: Type II 50/50 – Freezing Fog

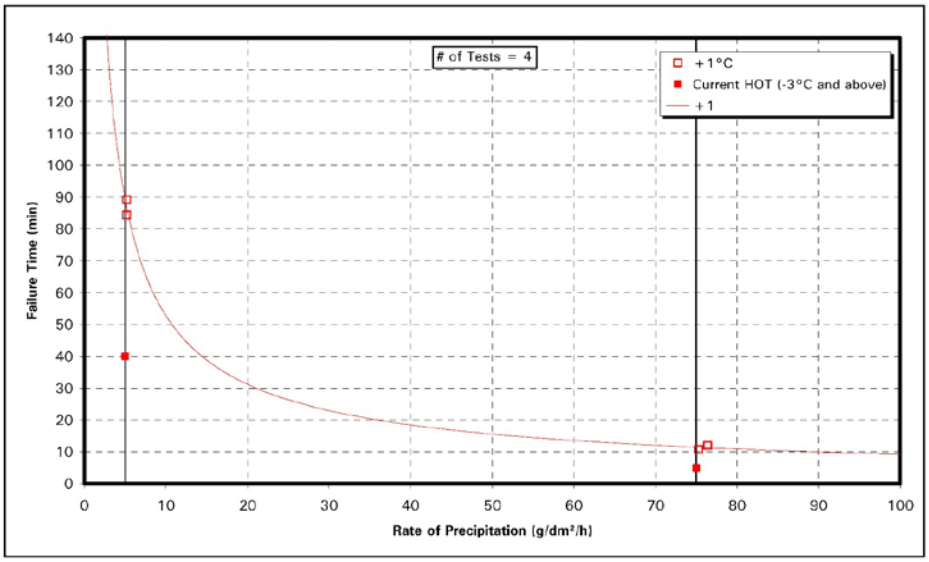


Figure 4.13: Type II Neat – Rain on Cold-Soaked Surface

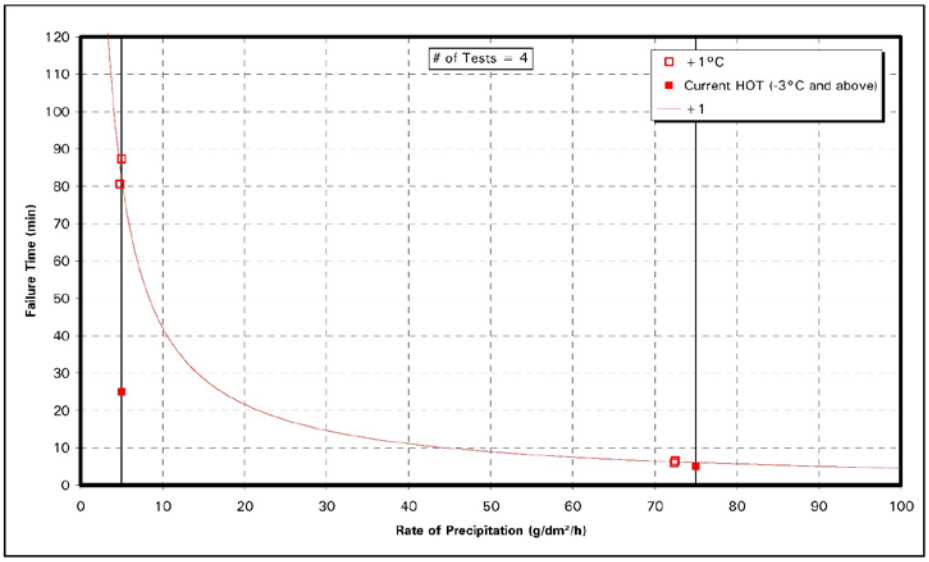


Figure 4.14: Type II 75/25 – Rain on Cold-Soaked Surface

Table 4.1: Summary of Regression Equation Coefficients for Clariant Safewing MP II Flight

Natural Snow Conditions

Fluid	Dil	R^2	Intercept (I)	Coeff. Rate (A)	Coeff. Tem (B)	Total Pts.
Clariant MP II Flight	Neat	83%	2.7	-0.54	-0.31	22
Clariant MP II Flight	75%	80%	3.0	-0.72	-0.56	27
Clariant MP II Flight	50%	86%	2.3	-0.71	-0.30	19

General Equation $t = 10^{I} R^{A} (2\text{-}T)^{B}$

Simulated Freezing Fog

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant MP II Flight	Neat	93%	-3°C	2.4	-0.2	3
Clariant MP II Flight	75%	99%	-3°C	2.6	-0.5	4
Clariant MP II Flight	50%	91%	-3°C	2.2	-0.7	6
Clariant MP II Flight	Neat	99%	-14°C	2.2	-0.7	4
Clariant MP II Flight	75%	100%	-14°C	2.0	-0.7	4
Clariant MP II Flight	Neat	100%	-25°C	1.9	-0.6	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant MP II Flight	Neat	99%	-3°C	2.7	-0.67	4
Clariant MP II Flight	75%	100%	-3°C	2.6	-0.64	4
Clariant MP II Flight	50%	94%	-3°C	1.7	-0.37	4
Clariant MP II Flight	Neat	100%	-10°C	2.6	-0.96	4
Clariant MP II Flight	75%	100%	-10°C	2.6	-1.08	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant MP II Flight	Neat	99%	-3°C	2.9	-0.89	4
Clariant MP II Flight	75%	98%	-3°C	2.7	-0.83	4
Clariant MP II Flight	50%	97%	-3°C	1.9	-0.65	4
Clariant MP II Flight	Neat	100%	-10°C	2.6	-0.81	4
Clariant MP II Flight	75%	99%	-10°C	2.3	-0.60	4

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant MP II Flight	Neat	100%	+1°C	2.5	-0.76	4
Clariant MP II Flight	75%	100%	+1°C	2.6	-0.96	4

General Equation $t = 10^{I} R^{A}$

Table 4.2: Fluid Specific Type II Fluid Holdover Time Guidelines

CLARIANT TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
SAFEWING MP II FLIGHT

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	3:30 – 4:00	1:00 – 1:35	1:20 – 2:00	0:45 – 1:25	0:10 – 1:30	
		75/25	5:00	2:30 – 4:00	0:40 – 1:20	1:15 – 2:00	0:30 – 0:55	0:05 – 1:20	
		50/50	3:00	0:55 –1:45	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	8:00	0:55 – 1:45	0:40 – 1:05	0:35 – 1:30[3]	0:25 – 0:45[3]		
		75/25	5:00	0:40 – 1:10	0:20 – 0:40	0:25 – 1:10[3]	0:30 – 0:40[3]		
below -14 to -25	below 7 to -13	100/0	8:00	0:30 – 0:50	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES

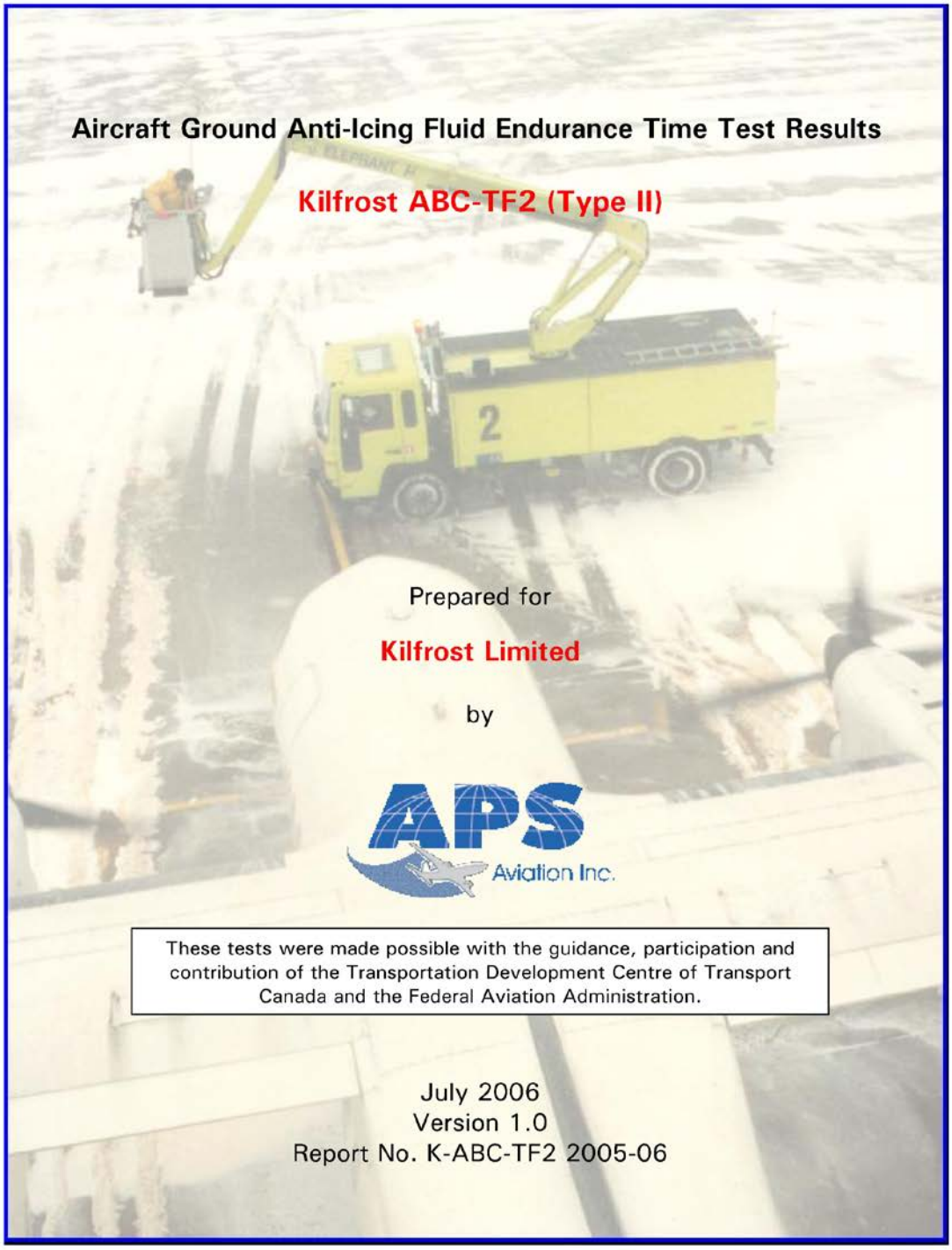
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

APPENDIX E

FLUID MANUFACTURER REPORT: KILFROST ABC-TF2 (TYPE II)


Aircraft Ground Anti-Icing Fluid Endurance Time Test Results
Kilfrost ABC-TF2 (Type II)
Prepared for
Kilfrost Limited
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.
July 2006
Version 1.0
Report No. K-ABC-TF2 2005-06

Aircraft Ground Anti-Icing Fluid Endurance Time Test Results

Kilfrost ABC-TF2 (Type II)

Prepared for

Kilfrost Limited

Prepared by: Stephanie Bendickson, Project Analyst — July 10, 2006 (Date)

Reviewed by: John D'Avirro, Program Manager, Eng. — July 10, 2006 (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.

July 2006
Version 1.0
Report No. K-ABC-TF2 2005-06

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer: Kilfrost

Fluid: ABC-TF2

Fluid Type / Colour: Type II / Straw

Batch #: P1792-2

Date of Receipt: April 21, 2006

Brix Measured:

Neat fluid:	35.25°
75/25 dilution:	28.00°
50/50 dilution:	19.00°

Viscosity Stated by Manufacturer[1]:

Neat fluid:	3,400 cP
75/25 dilution:	not given
50/50 dilution:	not given

Viscosity Measured by APS (Manufacturer Method)[1]:

Neat fluid:	3,550 cP
75/25 dilution:	11,100 cP
50/50 dilution:	9,400 cP

Viscosity Measured by APS (AIR 9968 Method)[2]:

Neat fluid:	3,460 cP
75/25 dilution:	10,300 cP
50/50 dilution:	10,120 cP

WSET provided by AMIL:

Neat fluid:	58 minutes

[1]Manufacturer Method: Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
[2]AIR 9968 Method: Spindle LV1, 20°C, 0.3 rpm, 10 minutes

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SUMMARY

The primary objective of this project was to measure the endurance time performance of Kilfrost ABC-TF2 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).

The HOT test procedure consisted of pouring fluids onto clean aluminium test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural snow and simulated freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. Endurance time tests were performed at the APS Aviation Inc. (APS) test facility located within the Montréal-Pierre-Elliott-Trudeau International Airport and at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were determined using a multi-variable regression analysis, resulting in the generation of the fluid-specific HOT table shown below. Because Kilfrost ABC-TF2 was submitted for testing late in the winter and testing in natural snow was not possible, the fluid was conservatively assigned generic Type II holdover times in the snow column based on data collected from an artificial snowmaker. If the test procedure to use snowmakers is approved, the data from the artificial snowmaker may be used to produce fluid-specific values in snow.

Kilfrost ABC-TF2 Type II Fluid Holdover Times

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 and above	27 and above	100/0	8:00	1:10 – 2:25	0:20 – 0:45	0:40 – 1:20	0:30 – 0:45	0:10 – 1:10	
		75/25	5:00	1:20 – 2:25	0:15 – 0:30	0:45 – 1:25	0:30 – 0:45	0:10 – 1:25	
		50/50	3:00	0:45 – 1:25	0:05 – 0:15	0:20 – 0:40	0:15 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:50 – 1:40	0:15 – 0:35	0:35 – 1:15	0:30 – 0:40		
		75/25	5:00	0:35 – 1:25	0:15 – 0:25	0:30 – 1:30	0:30 – 0:40		
below -14 to -25	below 7 to -13	100/0	8:00	0:30 – 1:00	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

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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
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
SAE	Society of Automotive Engineers, Inc.
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-icing/anti-icing has been the subject of concentrated industry attention over the past decade due the occurrence of several fatal icing-related aircraft accidents. Recent attention has been placed upon 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 for use by aircraft operators and accepted by regulatory authorities. New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid HOTs without compromising the aerodynamic features of the airfoil.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop and substantiate fluid HOT tables for current fluids and new formulations. Test procedures to measure the duration of fluid protection against ice formation have evolved into a refined Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 5485 that is followed by APS Aviation Inc. (APS).

Testing of aircraft ground de/ant-icing fluids has resulted in the generation of HOT tables. These tables provide guidelines for use in departure planning in adverse winter conditions. They provide the HOT ranges for aircraft treated with any particular qualified deicing or anti-icing fluid.

A new data analysis protocol was developed in 1996-97 wherein the endurance time data for each fluid brand in each cell of the HOT tables was subject to a multi-variable regression treatment. Type II and Type IV fluid HOTs are determined using this method of analysis, resulting in the generation of generic and fluid-specific HOT tables.

This report provides the data and analysis used to determine the fluid HOTs for Kilfrost ABC-TF2.

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2

2. METHODOLOGY

This chapter contains a description of the tests, equipment and procedures used to conduct endurance time tests. It is divided into sections dealing with the definition of weather, test sites, test conditions, equipment, procedures, and analysis methodology. A 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 was developed by APS for this testing, based upon the requirements of ARP 5485.

2.1 Definition of Weather Conditions

HOTs are provided as a function of weather condition, fluid dilution and outside air temperature. The objective of the winter test program was to develop HOTs for new fluids based on the most recent test data.

Table 2.1 provides definitions of most weather conditions experienced in winter operations and includes the criteria used to determine precipitation intensity (light, moderate, heavy). 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).

Table 2.1 includes definitions for the weather conditions described in the HOT tables (frost, freezing fog, snow, freezing drizzle, light freezing rain and rain). Definitions for snow pellets, hail and ice pellets are also presented, however these are conditions for which HOT guidelines do not exist.

The test methodology used to determine fluid endurance times has included the generally accepted upper and lower limits for precipitation rates for each type of precipitation. These limits were discussed in detail at a 1997 meeting of the SAE G-12 HOT Subcommittee where standard definitions of upper and lower precipitation rate limits were approved for each category of precipitation. These limits are documented and discussed in Subsection 2.6.

2.1.1 Snow

Table 2.1 contains the criteria that were used in the past to estimate the intensity of snow. These criteria are based upon horizontal visibility with three

intensity levels. For light snow, visibility is greater than or equal to 1.0 km, moderate snow visibility is 0.5 km to less than 1.0 km, and heavy snow, visibility is less than 0.5 km.

As stated in a cautionary note in Table 2.1, visibility is only an indicator of snow intensity, and the two parameters are not always correlated.

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 visibility at the earth's surface to less than 1 km (5/8 mile).
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 (23°F), the crystals are generally agglomerated into snowflakes.
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 the ground or other exposed objects.
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 mm (0.02 in.) or smaller drops which, in contrast to drizzle, are widely separated.
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)	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter is about 2-5 mm (0.1-0.2 in.). Grains are brittle, easily crushed; they bounce and break on hard ground.
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is less than 1 mm (0.04 in.). When the grains hit hard ground, they do not bounce or shatter.
HAIL (GR)	Precipitation of small balls or pieces of ice with a diameter ranging from 5 to > 50 mm (0.2 to 2.0 in.) falling either separately or agglomerated.
ICE PELLETS (PE) Note: Includes Sleet and Small Hail	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.) or less. The pellets of ice usually bounce when hitting hard ground.

Intensity Criteria**

Snow(SN),Pellets(CS),Grains(SG),Frz Drizzle(FZDZ)			Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (S) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm or 10.0 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 or 25.0 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 shown that visibility and precipitation intensity are not always directly correlated.

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm 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 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 exposed surface up to a condition where individual drops are easily seen.
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm 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 pavement and other hard surfaces.
Measured Intensity	More than 0.30 in/hr (7.6 mm 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 spray to height of several inches is observed over hard surfaces.

* 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 Proposed Definition for Liquid Equivalent Snowfall Intensity

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

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP June 17, 1997
(Updated for METAR codes)

Table 2.2 is the visibility table which has been published annually by TC since the winter of 2003-04 for use in winter operations. It is based on more recent data than Table 2.1 and provides more detail about snowfall intensity and visibility. APS, NCAR and TC all had input into the formation of this table, which is based on NCAR field data and theoretical work on classes of snow and on extensive field data compiled by APS. The table categorizes snowfall into one of four intensities based on visibility and lighting condition.

The FAA also publishes a visibility, which differs slightly from the TC visibility table, but is based on the same data set.

Table 2.2: Visibility in Snow vs. Snowfall Intensity Chart[1]

Lighting	Temperature Range		Visibility in Snow (Statute Miles)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1	>1 to 2½	>2½ to 4	>4
	Below -1	Below 30	≤3/4	>3/4 to 1½	>1½ to 3	>3
Daylight	-1 and above	30 and above	≤½	>½ to 1½	>1½ to 3	>3
	Below -1	Below 30	≤3/8	>3/8 to 7/8	>7/8 to 2	>2

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.

2.1.2 Freezing Drizzle

Freezing drizzle is composed of closely spaced fine water droplets with a diameter less than 0.5 mm (see Table 2.1). The intensity of freezing drizzle is estimated, as it is for snow, through the measurement of horizontal visibility.

HOT tables have one column for freezing drizzle; however, Table 2.1 shows three intensity levels (light, moderate and heavy). For example, under moderate freezing drizzle, the rate of precipitation should range between 2.5 and 5.1 g/dm²/h. For heavy freezing drizzle, the definition indicates that the intensity is greater than 5 g/dm²/h. Discussions between United Airlines, NCAR and the National Research Council Canada (NRC) led to the upper limit value of 13 g/dm²/h for freezing drizzle. This value is also used as the lower limit for light freezing rain.

2.1.3 Freezing Rain

This form of precipitation exists either in the form of drops with diameters greater than 0.5 mm, or smaller drops which, in contrast to drizzle, are widely separated. For each of the three intensities of freezing rain given in Table 2.1, a visual description is supplied to provide a subjective guideline for the purpose of estimating rain intensity. However, the following definitions apply when an instrument is available to measure the intensity of precipitation:

- Light Precipitation rate is ≤ 25 g/dm²/h
- Moderate Precipitation rate is >25 g/dm²/h but ≤75 g/dm²/h
- Heavy Precipitation rate is >75 g/dm²/h

2.1.4 Freezing Fog

Freezing fog is defined as suspended minute water droplets that freeze upon impact with the ground or exposed objects. Table 2.1 does not provide any indication of intensity or liquid water content (LWC) of the fog other than that the horizontal visibility is reduced to less than 1 km.

2.2 Test Sites

Normal natural snow test operations are performed at the APS test site located within the Montréal-Pierre-Elliott-Trudeau International Airport. The location of the test site is shown on the plan view of the airport shown in Figure 2.1. Photo 2.1 shows the test site trailer and test stands, the site consists of two trailers and three locations for test stands. The APS test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station (Photo 2.2).

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.

The CEF is partitioned into two sections, separated by an insulated dividing door. Each partition can be separately controlled, permitting different tests to be conducted simultaneously. Photo 2.3 provides a general indication of the size of the facility. Photos 2.4 and 2.5 provide interior images of the small and large ends of the facility. The facility was designed and built for the testing of locomotives. The size of the chamber is 30 m by 5.4 m and its total height is 8 m. The lowest temperature achievable is -46°C.

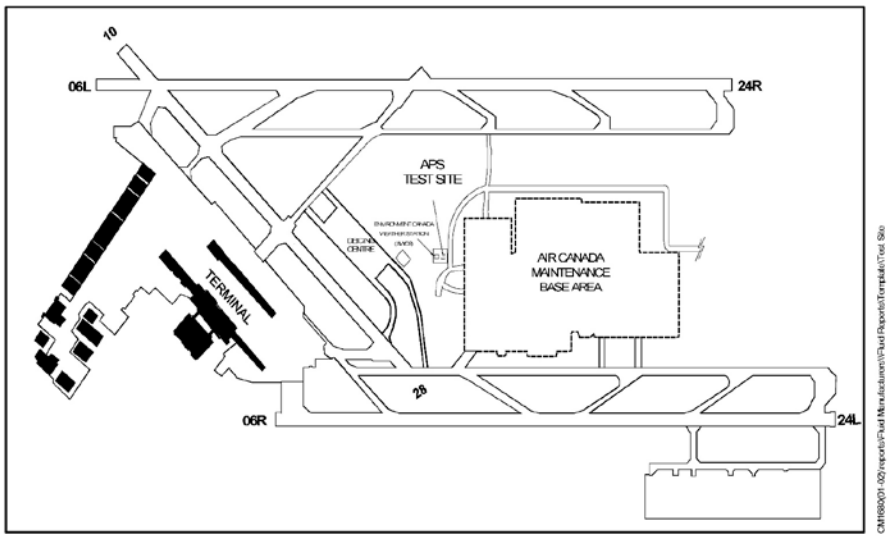


Figure 2.1: Test Site at the Montréal-Pierre-Elliott-Trudeau International Airport

2.3 Test Conditions

Outdoor testing was conducted during natural precipitation events. Supplementary tests to simulate freezing precipitation were carried out at the NRC CEF (see Photo 2.4). Subsections 2.3.1 and 2.3.2 provide descriptions of the spray assembly (see Photo 2.6) and of the methods used to produce and calibrate the fine water droplets in these artificial precipitation tests. Subsection 2.3.3 provides a summary of the categories and characteristics of each precipitation type produced for these tests.

2.3.1 Droplet Size and Rate of Precipitation

In the past few years, more industry attention has been given to the influence of droplet size on HOT. To explore this relationship further, experiments were performed to measure droplet sizes produced by different nozzles (gauge of hypodermic needle) at various water and air pressures in the spray delivery unit. Although the gauge of the needles is an important factor in the production of water droplets with appropriate dimensions, the air and water pressure levels in the sprayer system are equally important.

An improved sprayer assembly was developed in 1997-98 by the NRC and is shown in Photo 2.6. 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 2.7.

Prior to 1995, calibration experiments conducted by the NRC used an optical gauge manufactured by HSS (Biral UK acquired the HSS technology) to verify that the simulation of freezing fog, freezing drizzle, and light freezing rain provided adequate droplet sizes according to ARP 5485.

Since 1995, the APS team using a manual dye-stain technique employed by personnel at the NRC has carried out droplet size calibration. This technique consists of dusting Whatman #1 filter paper discs with a water-activated, very finely-divided powder form of methylene blue dye. The prepared discs are manually positioned under simulated precipitation for a fixed time to acquire a droplet size pattern. A calibration curve is then used to convert the measured diameter of the droplets on the pattern to the experimental median volume diameter (MVD).

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:	Dorval 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.

Figures 2.2 and 2.3 show an example of the distribution of simulated light freezing rain droplets obtained at the NRC.

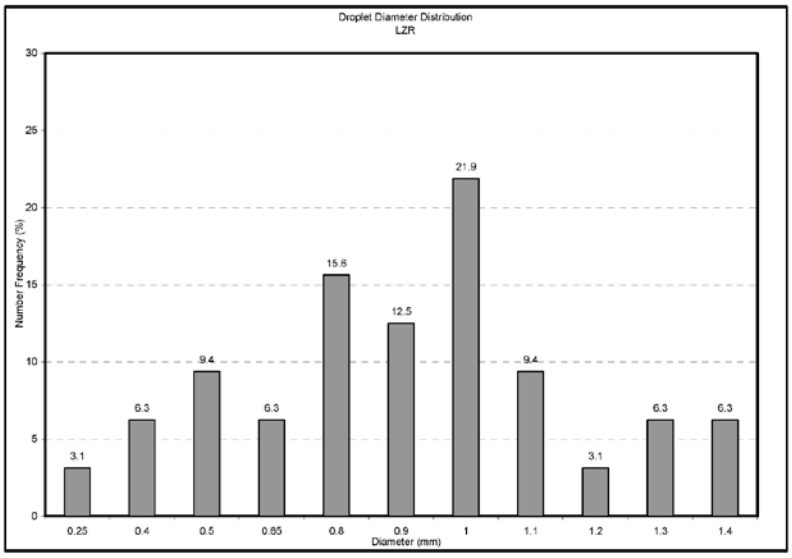


Figure 2.2: Droplet Diameter Distribution, Sample

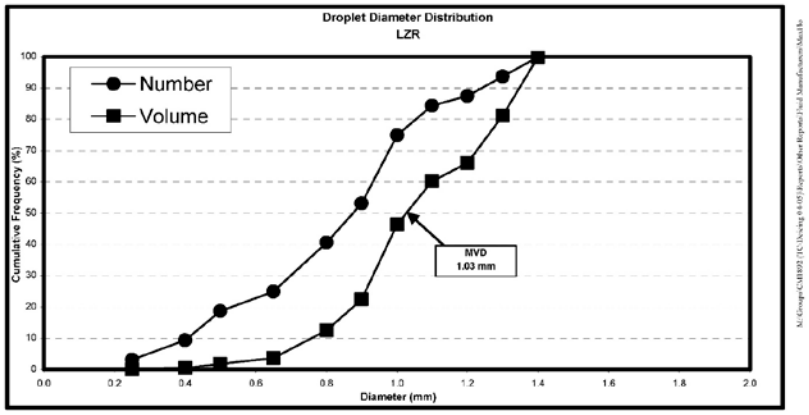


Figure 2.3: Cumulative Frequency of Droplet Diameter, Sample

2.3.2 Median Volume Diameter of Rain Drops

The MVD of a rain droplet was researched and found to be related to the precipitation rate 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 2.3 beside the experimental MVDs for each precipitation condition.

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

2.3.3 Characteristics of 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 were collected:

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

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

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

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

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

4. Moderate Rain on Cold Soaked Surface:
   Precipitation rate: 75 g/dm²/h;
   Droplet median volume diameter: 1 400 μm; and
   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.

2.4 Equipment

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.

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) is in accordance with the requirements set out in the ARP 5485.

Figure 2.4 shows a schematic of the test platform used for in 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.

Figure 2.4 also 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 were marked with 15 crosshairs used in determining whether end conditions (see Subsection 2.5.2 for definition) were achieved. Photo 2.8, taken outdoors at APS test site, shows six test plates mounted on a stand. For simulated freezing precipitation tests at the NRC, 12 plates were mounted on 2 six-position stands, as shown in Figure 2.4.

Figure 2.5 shows the collection (plate) pan, which is of the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.9 shows the collection pans used for measuring precipitation rates indoors at the NRC.

Sealed boxes (7.5 cm deep) were used for simulating a cold-soaked wing (see Figure 2.5). The top of the cold-soak box consists of an aluminium flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate.

Freeze points were measured using a hand-held Misco refractometer with a Brix scale.

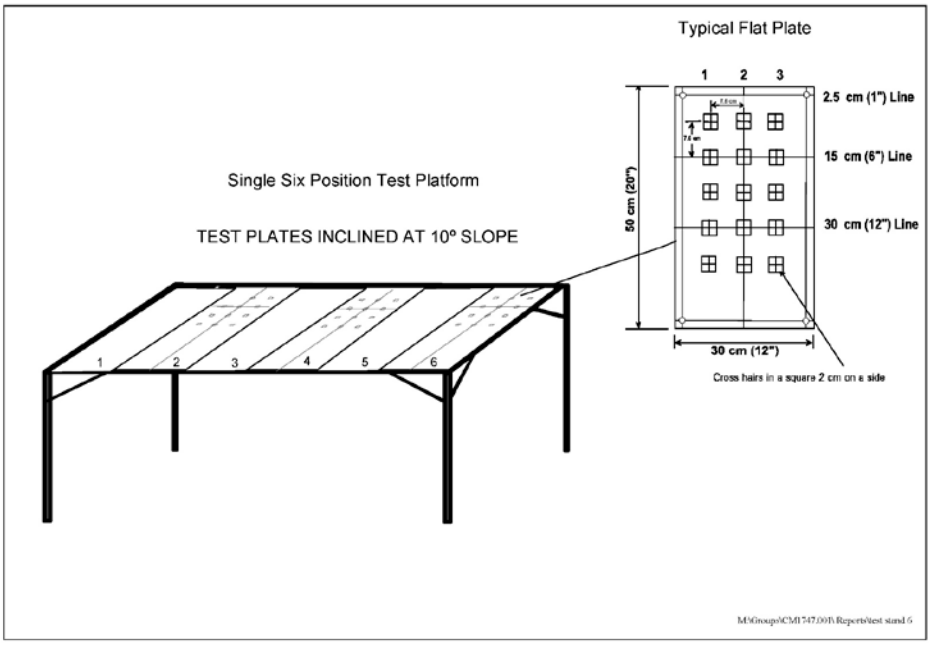
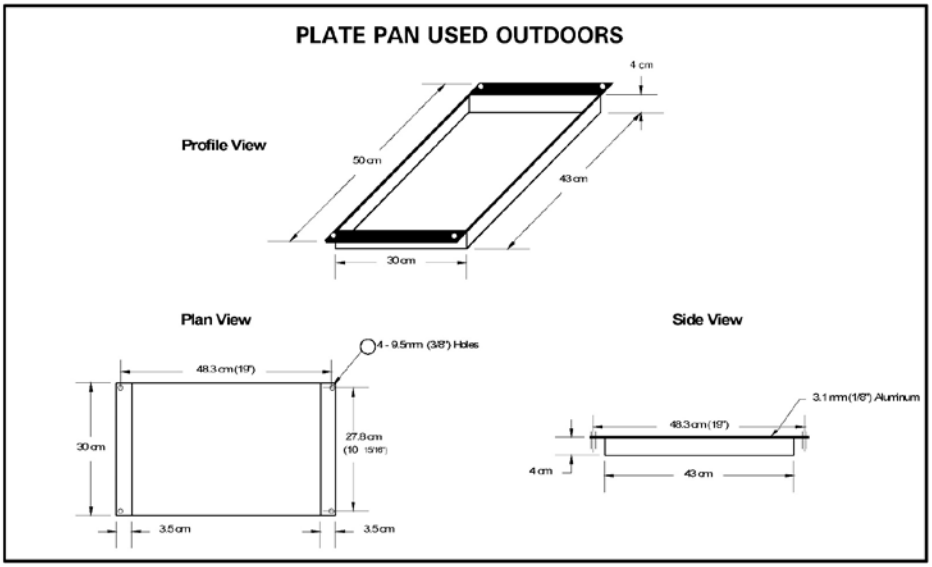
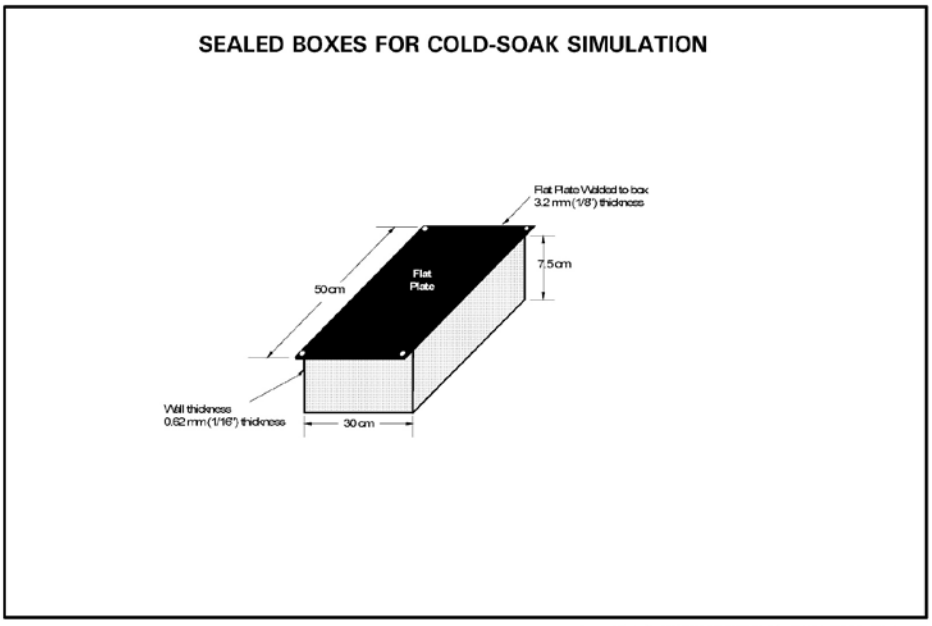


Figure 2.4: Flat Plate Test Set-Up





C:\M980\01-02\Reports\Fluid Manufacturers\Fluid Reports\Template\Pan and Boxes

Figure 2.5: Schematics of Plate Pan and Sealed Boxes

2.5 Test Procedures

Tests consisted of pouring anti-icing fluids directly onto clean test panels (exposed to various winter precipitation conditions) and recording the elapsed time for each crosshair to fail until the test panels reached the defined end condition (see Subsection 2.5.2 below).

2.5.1 Test Protocol (ARP 5485)

A plan 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 was developed by APS, based upon the requirements of ARP 5485. This procedure addresses testing conducted under natural precipitation conditions as well as under simulated freezing precipitation conditions.

Fluids to be evaluated are applied to test plates exposed to natural snow and simulated freezing fog, freezing drizzle, light freezing rain and rain on cold soaked wing. Endurance times are evaluated by measuring the minimum exposure time before a specified degree of freezing occurs.

During the conduct of these tests a series of test parameters are recorded. All test parameters specified in ARP 5485 are addressed in the procedure developed by APS. The test parameters are grouped into two categories: generic and specific test parameters.

Generic test parameters are recorded once per winter season (or test session, in laboratory testing) and include: discussion of safety issues, test plate material, test plate dimensions, surface finish and ice-catch pan dimensions. Specific test parameters are recorded during each testing session (or weather condition, in laboratory testing) and include: angle of the test stand, synchronization of timing devices, plate and ambient temperature profile files, icing intensity, etc.

As per ARP 5485 requirements, the test surface and ambient temperatures were recorded at a minimum sampling rate of one datum per minute. Figure 2.6 presents an example of a typical endurance time test conducted under simulated freezing drizzle conditions. The graph shows the test surface and chamber temperature profiles over the duration of the test and beyond failure time.

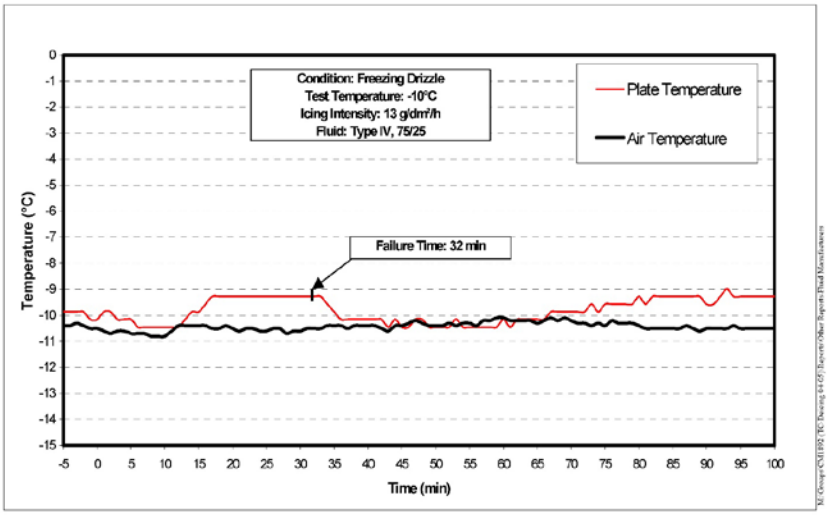


Figure 2.6: Temperature Profiles During a Typical Endurance Time Test

2.5.2 Test Protocol

The SAE G-12 HOT Subcommittee developed the procedure for natural snow flat plate tests.

The major steps in the natural snow flat plate test procedure are:

- Synchronize all timepieces;
- Clean panels and start;
- Apply (pour) fluids to test panels. Type II, Type III, and Type IV fluid are applied at the outdoor ambient temperature. Fluids are poured using a single-step fluid application;
- Record crosshair end condition times;
- Continue testing until at least five crosshairs or 30 percent (1/3) of the plate have failed;
- Record weather conditions; and
- Clean panels and restart.

2.5.3 End Condition Definitions

The test procedures and the determination of defined end conditions evolved from the experience the APS test team has accumulated from previous winter season test programs. Any of the following descriptions provide the general guidelines that observers use to judge when fluid failure occurs and to judge the extent of contamination or failure:

Failure is called when 30 percent (1/3) of the plate is 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.

2.5.4 Precipitation Rate Procedures

2.5.4.1 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 (h: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.

2.5.4.2 Precipitation rate distribution in simulated conditions

Clean test plates are placed on the test stand prior to the rate collection period, and are exposed to the simulated precipitation to verify that an even ice formation occurs over the entire test bed. If this visual inspection proves satisfactory, the rate collection period will begin. If this visual inspection proves unsatisfactory, the test stand must be repositioned under the spray device and the process is then repeated.

In order to verify the rate distribution on the test stand, a continuous rate-monitoring pan is replaced with a detailed rate distribution pan, which consists of 4 small pans of equivalent size. The area of the 4 small pans combined is similar to that of a standard rate collection pan. The small pans are weighed and placed at these locations and re-weighed at fixed intervals. The typical collection period for rate distribution is 60 minutes, however this interval may be shorter if all tests have been completed within 60 minutes. The variation between the rate of any of the 4 small pans and that of the average rate of that location should not be greater than 10 percent.

Two examples of the detailed rate distributions are shown in Table 2.4. Both rate distributions were conducted in freezing drizzle, one at the low rate (5 g/dm^2/h), the other at the high rate (13 g/dm^2/h). The average precipitation rate over the entire position in the low rate example in Table 2.4 was 5.1 g/dm^2/h. The individual rates of the four smaller pans were 5.0, 4.9, 5.2 and 5.3 g/dm^2/h, suggesting a maximum variation of 4.1 percent from the average rate over the entire position.

Table 2.4: Detailed Rate Distribution

Freezing Drizzle (low rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	2-top left	14:02	14:34	81.6	88.8	7.2	31.9	5.0
4	2-top right	14:02	14:34	81.6	88.6	7	31.9	4.9
5	2-bottom left	14:02	14:34	81.8	89.2	7.4	31.9	5.2
6	2-bottom right	14:02	14:34	81.6	89.2	7.6	31.9	5.3

3	4	5		STDDEV
5.0	4.9	-1.4%	-4.1%	0.181
5.2	5.3	1.4%	4.1%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

Freezing Drizzle (high rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	5-top left	12:12	12:43	81.8	98.8	17	30.8	12.3
4	5-top right	12:12	12:43	81.6	98.8	17.2	30.8	12.5
5	5-bottom left	12:12	12:43	81.6	100.2	18.6	30.8	13.5
6	5-bottom right	12:12	12:43	81.6	100.2	18.6	30.8	13.5

3	4	12.9		STDDEV
12.3	12.5	-4.8%	-3.6%	0.631
13.5	13.5	4.2%	4.2%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

CM1E30 (01-02) \reports\Fluid Manufacturers\Fluid Reports\Template\Detailed Rate Distribution

2.5.4.3 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) from the timepiece located near the rate station before leaving the trailer to place the pans on the test stand. The person responsible for collecting precipitation rate data take the time delay necessary to proceed outside from the rate station into consideration.

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.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.7. Typically, two collections pans are used for each test. The start and end times of the test are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t_1, t_2, and t_3 (minutes). The calculated rates for each collection period are indicated by R_1, R_2, and R_3 (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 2.4, 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.

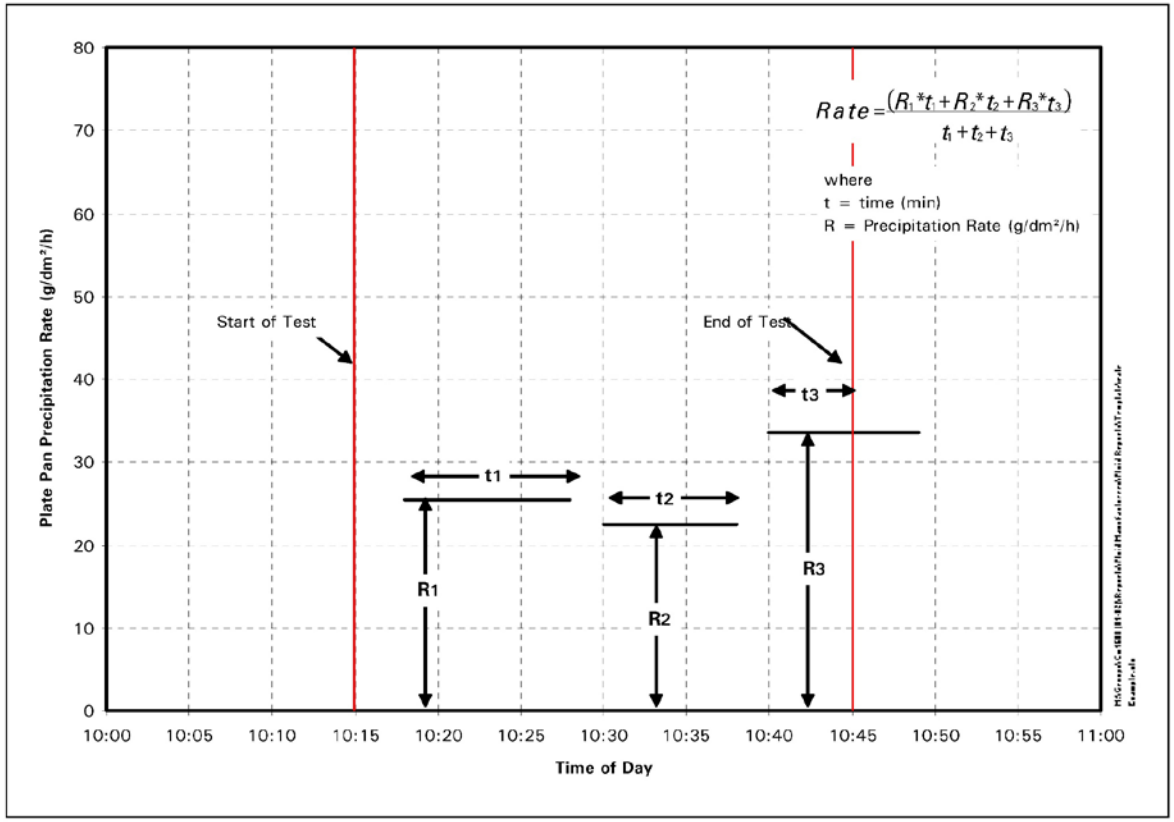


Figure 2.7: Calculation of Outdoor Precipitation Rate

2.6 Analysis Methodology

2.6.1 General

This section of the report describes the various categories of precipitation and the precipitation rate limits used during the course of endurance time testing. The process of data analysis used in the determination of fluid HOTs is also described.

2.6.2 Descriptions of Data Ranges and Precipitation Definitions

The test program developed to measure fluid failure times was carried out under five general categories of precipitation:

- Natural snow;
- Freezing drizzle;
- Light freezing rain;
- Freezing fog; and
- Rain on a cold-soaked surface.

Tests were conducted over temperature and precipitation rate ranges specific to each category of precipitation. A multi-variable regression procedure was used to evaluate fluid HOTs (first presented in TC report, TP 13131E) and is based on the refinement of an equation for a curve which best represents the fluid failure time test data, and then solving that equation at the upper and lower limits of a defined precipitation range. To support this procedure, precipitation rate limits for each specific category of precipitation were defined, reviewed and approved.

The precipitation rate limits used for the evaluation of HOT's are represented schematically in Figure 2.8. Detailed definitions and explanations of the data types and ranges are described in the following subsections. Meteorologically accepted definitions of these conditions were outlined in Table 2.1.

2.6.2.1 Natural snow

All fluid failure tests in natural snow were conducted at the APS Dorval Airport test site. Data were collected for precipitation rates that ranged from less than 4 g/dm²/h to greater than 25 g/dm²/h. For Type II and Type IV fluids, upper and lower limits for the snow column were set at rates of 10 and 25 g/dm²/h, respectively.

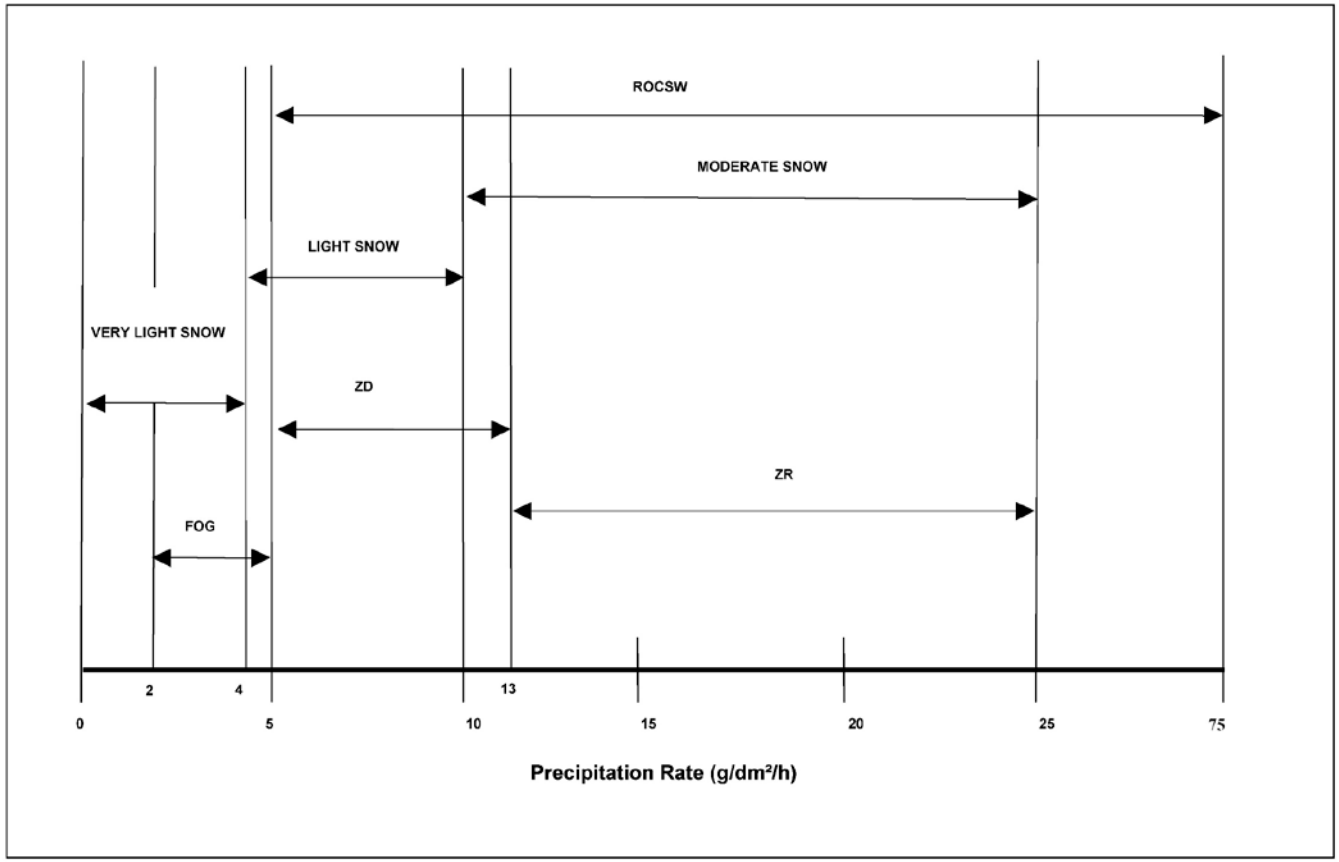


Figure 2.8: Data Range Used for Evaluation of Holdover Time Limits

The upper precipitation rate limit (25 g/dm^2/h) corresponds to the onset of heavy snow. Above this rate, it is standard practice to refer to the cautionary note included in the HOT tables indicating that the time of protection will be shortened in heavy weather conditions, (i.e., heavy precipitation, or high moisture content).

2.6.2.2 Freezing drizzle

Freezing drizzle is considered to occur over the range of 0 to 13 g/dm^2/h. The upper limit in this range, while not specifically defined in Table 2.1, has been adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Subcommittee.

For test purposes, the precipitation rate spectrum for freezing drizzle is constrained to rates between 5 and 13 g/dm^2/h, inclusively. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety. A caution note is included in the HOT tables indicating that if positive identification of freezing drizzle is not possible, the light freezing rain HOT is recommended for use.

2.6.2.3 Light freezing rain

With reference to the HOT tables, freezing rain conditions span the range of precipitation rates from 13 to 25 g/dm^2/h, inclusively. This range falls in 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.

2.6.2.4 Freezing fog

The precipitation rate limits for freezing fog were arrived at with input from meteorologists from the NRC, 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.

The precipitation rate for fog, referred to as *fog deposition* or simply as *deposition*, is given by the empirical expression,

$$\textbf{\textit{Deposition = LWC x Wind Velocity x Sin 10° x Collection Efficiency}}$$

where the Sin 10° term accounts for the 10° inclination of the test plates into the direction of the wind.

The meteorological circumstances (LWC value and wind speed), and the speed and orientation of the airfoil relative to the wind (stationary or taxiing), contribute to uncertainties in the values that the variables in the equation can assume.

Since 1997, the upper and lower HOTs for freezing fog have been evaluated at rates of 5 g/dm^2/h and 2 g/dm^2/h, respectively. In Vienna, during the 1998 SAE G-12 HOT Subcommittee meeting, it was felt that 2 g/dm²/h was not indicative of low rate natural fog. However, during a meeting of the Workgroup on Laboratory Methods to Derive HOT Guidelines in Montreal in March 1999, it was again agreed upon that the rate of 2 g/dm^2/h would be used in subsequent HOT testing in order to determine the upper HOT limit in freezing fog conditions.

2.6.2.5 Rain on a cold-soaked surface

Data used for the evaluation of HOTs for this category of precipitation were limited to precipitation rates ranging from 5 to 75 g/dm^2/h, which 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). The heavy rain category is covered by the caution note at the bottom of the HOT table regarding heavy weather conditions.

2.6.3 Protocol for the Determination of Holdover Times

Each cell in a HOT table represents a range of time during which a fluid at a specified concentration will provide protection for a particular temperature range in a particular category of precipitation. The Type II and Type IV HOT tables are composed of a maximum of 30 cells. Each cell contains a lower and upper time limit (except in frost) for a maximum of 54 time values.

Cell HOT values are determined by plotting *Failure Time* versus *Rate of Precipitation* and recording the failure time at two pre-selected rate limits. In previous years, several protocols were employed in the determination of HOTs. Due to the subjective natures of these different protocols, different interpretations of the data were possible. A multi-variable regression approach was subsequently devised in 1996/97 (see TC report, TP 13131E) and has since been used to evaluate fluid holdover times.

Data corresponding to each cell in the HOT table were assembled and sorted according to precipitation type, fluid dilution and temperature range. The data for each cell in the HOT table were plotted.

The data points on each plot were used to fit an equation of the form:

$$t = cR^a$$

where

t = Time (minutes)
R = Rate of precipitation (g/dm^2/h)
a,c = coefficients determined from the regression.

The coefficient a gives the rate dependency of the failure time.

Sample plots of **Log t** versus **Log R** are shown in Figure 2.9. The plots contain data from one temperature range, for one Neat Type IV fluid 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 2.10. 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 snow.

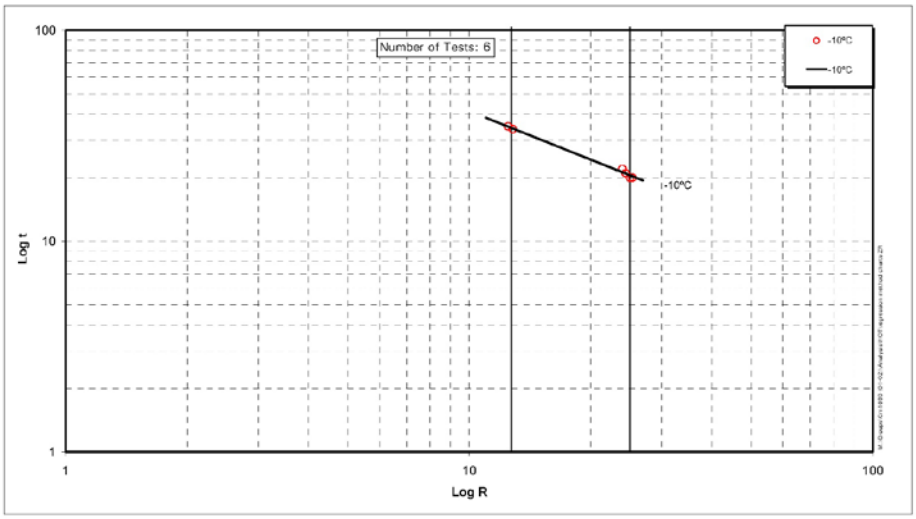


Figure 2.9: Regression Method on Log-Log Chart – Sample Type IV Neat, Freezing Rain

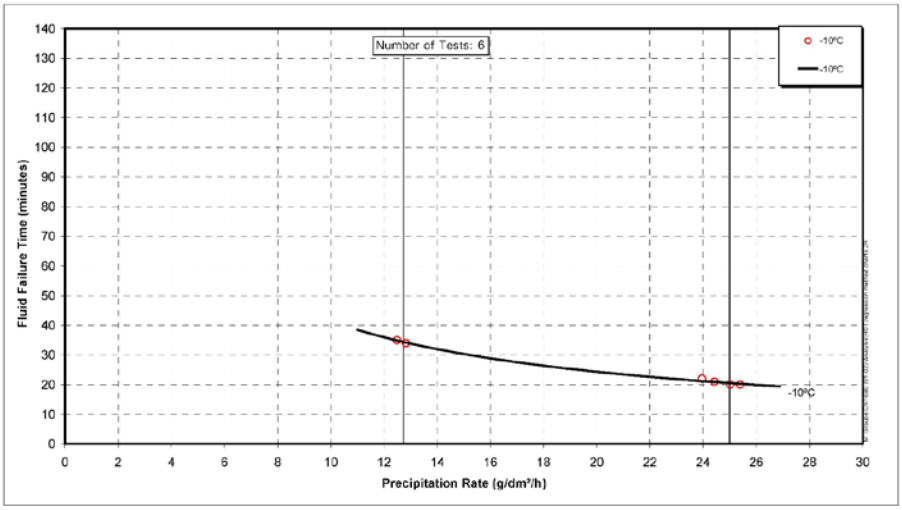


Figure 2.10: Regression Method on Standard Chart – Sample Type IV Neat, Freezing Rain

The HOTs for this fluid at -10°C are 20 minutes at 10 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

The categories of precipitation are separated into five groups: natural snow, freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface. Each group was subject to a slightly modified version of the general equation given above, as described in the following subsections.

2.6.3.1 Light freezing rain and freezing drizzle

The equation used to treat the data in these categories of precipitation is given by the expression below:

$$t = cR^a$$

- Tests in freezing drizzle and light freezing rain were conducted at predetermined temperature limits (-3 and -10°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were also obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.2 Simulated freezing fog

The equation used to treat freezing fog data is given by the expression below:

$$t = cR^a$$

- Tests in freezing fog were conducted at predetermined temperature limits (-3, -14 and -25°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.3 Natural snow

The general form of the regression equation was modified for natural snow by substituting 2-T for the variable T, in order to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C.

$$t = cR^a(2-T)^b.$$

- Best-fit curves were plotted for each fluid in each cell of the snow column using the most restrictive (lowest) temperature for that cell. For example, in cases of natural snow tests conducted at ambient temperatures above -3°C, the value of temperature used in the fitting procedure was -3°C.

- The upper and lower HOT values were determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively.

2.6.3.4 Rain on a cold-soaked wing

The same method for the evaluation of HOTs in light freezing rain and freezing drizzle was used for this category of precipitation.

2.6.4 Determination of Generic and Fluid Specific Holdover Times

At the SAE HOT Subcommittee meeting in Chicago in July 1997, Type IV fluid HOTs obtained using the multi-variable regression protocol of data analysis were presented. Wide variations in fluid performance among the different Type IV fluid brands forced the development of generic Type II and IV HOT tables as well as fluid-specific Type II and IV HOT tables.

2.6.4.1 Fluid-specific holdover time tables

Fluid-specific HOT table development was prompted by the fact that certain Type IV fluid brands were observed to significantly outperform other fluids under conditions corresponding to specific cells in the HOT tables. In general, any one fluid brand does not globally outperform the other fluid brands, but rather does so at a specific dilution, temperature range, and/or category of precipitation.

At the Chicago meeting in 1997, most members of the SAE G-12 HOT Subcommittee did not favour fluid-specific tables. However, significant reductions to HOTs for the cells corresponding to the most common Type IV fluid usage convinced the committee of the need to consider the development of fluid-specific and generic tables. Furthermore, some members wanted to take advantage of the significant benefits exhibited by some fluids in certain conditions.

A summary of the steps to follow to determine fluid specific values for a Type II or IV fluid is provided below:

- The method used to determine HOTs is generally the same as was agreed upon in Chicago in 1997 at the SAE G-12 HOT Subcommittee meeting;
- For each cell of the HOT tables, four tests are typically conducted at the lowest temperature in the temperature range for that cell. Two tests are conducted at the low precipitation rate condition and at the high precipitation rate condition, for a total of four tests per cell;
- For each cell of the HOT table (except frost), a best-fit power law curve for each fluid is developed from the tests conducted at the low and high precipitation rate condition of that cell;
- Regression-generated HOTs are rounded off to the nearest whole "5" digit. For example, 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 HOTs are below 10 minutes, the numbers are rounded down as a precautionary measure. For example, 9 minutes is rounded down to 5 minutes; and
- Values are capped at 2 hours for all precipitation conditions except freezing fog, which are capped at 4 hours.

Photo 2.1: View of Test Site and Associated Equipment



Photo 2.2: Meteorological Services of Canada Weather Observation Station at Montréal-Pierre-Elliott-Trudeau International Airport



Photo 2.3: Outdoor View of National Research Council Climatic Engineering Facility



Photo 2.4: Inside View of Small End of Climatic Engineering Facility



Photo 2.5: Inside View of Large End of Climatic Engineering Facility



Photo 2.6: Sprayer Assembly Used at National Research Council

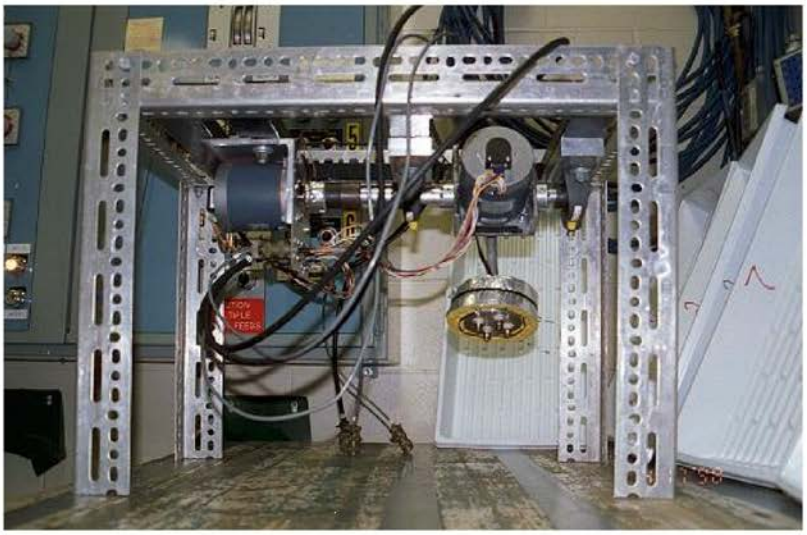


Photo 2.7: Sprayer Nozzle

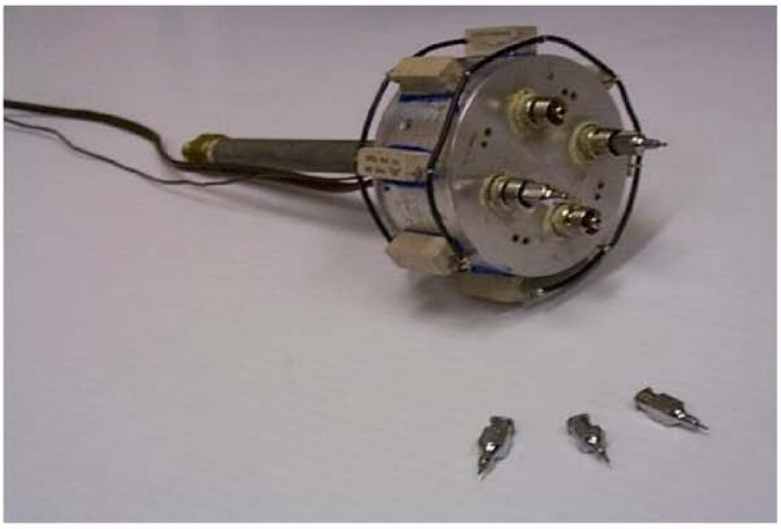


Photo 2.8: Test Plates Mounted on Stand



Photo 2.9: Collection Pans Used Indoors at the National Research Council



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted in snow, simulated light freezing rain, simulated freezing drizzle, simulated freezing fog, and rain on cold-soaked surfaces. Breakdowns are provided for quantity of tests performed by fluid type and temperature. As the fluid was received near the end of the winter test season, no natural snow tests were possible. However, some tests in artificial snow were conducted.

A summary of the tests conducted at the NRC is provided in Table 3.1 at the end of this section.

3.1 Snow Tests

Tests in natural snow could not be conducted with this fluid as it was submitted for testing at the end of the winter season. However, tests were conducted in artificial snow at the NRC CEF. The breakdown of artificial snow tests is given below by fluid dilution and temperature.

	-3°C	-14°C	-25°C
Neat	2	2	0
75/25	2	2	0
50/50	2	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 given below by 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 condition at the NRC CEF. The breakdown of tests conducted is given 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

Cold-soak tests were conducted with Neat and 75/25 dilutions using 7.5 cm deep sealed boxes. Tests were conducted at an ambient temperature of +1°C at the NRC CEF. Duplicate tests were conducted with each dilution at each precipitation rate.

3.5 Fluid Thickness Tests

The purpose of these tests was to measure the film thickness profiles of the fluid in all dilutions, under dry conditions.

Two tests were performed for each standard dilution (Neat, 75/25 and 50/50). For each test, one litre of fluid was poured onto a flat plate mounted on a test stand inclined 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. Tests were conducted at an ambient temperature of -3°C.

The results are displayed in Figure 3.1.

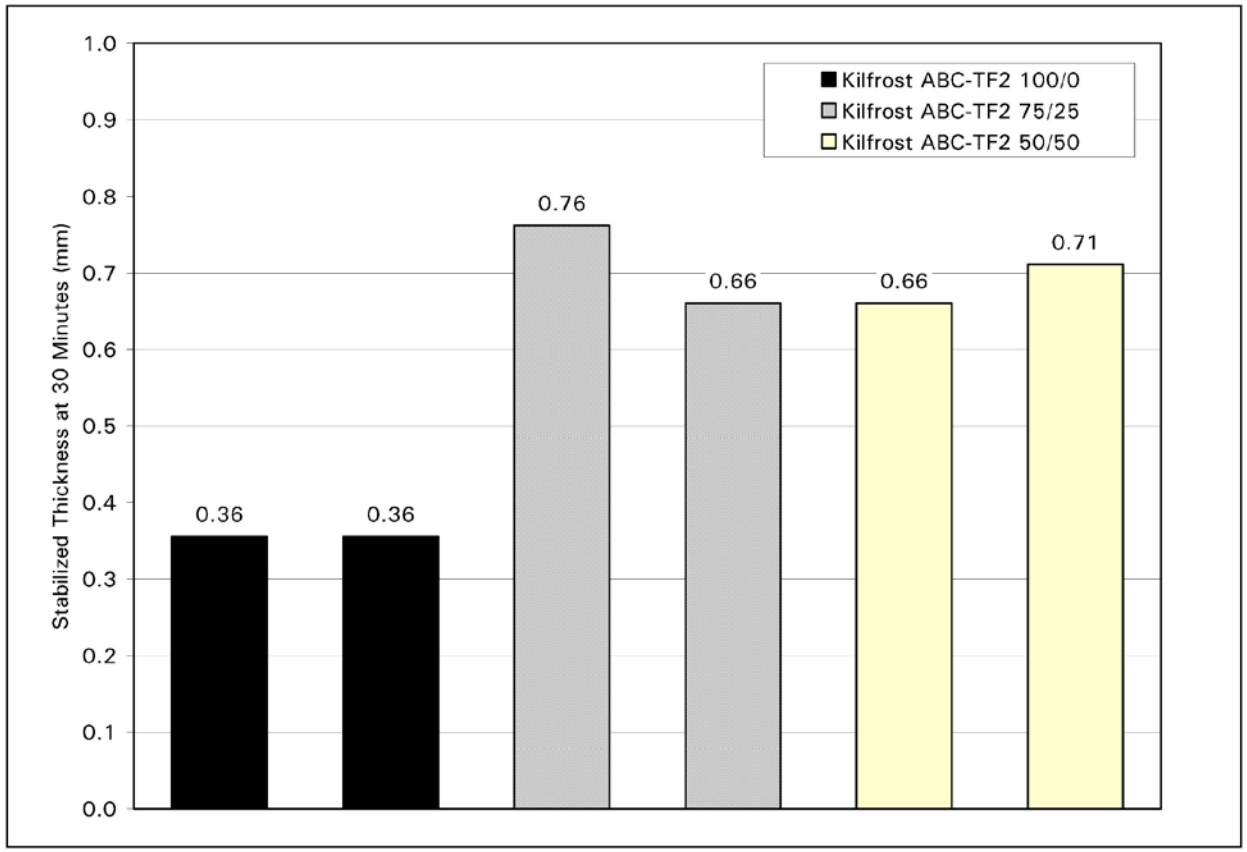

Figure 3.1: Fluid Thickness of Kilfrost ABC-TF2

Table 3.1: Log of Tests Performed in 2005-06

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
NCAR1	25-Apr-06	Kilfrost ABC-TF2	100/0	32.3	25*	-3	Artificial snow
NCAR2	25-Apr-06	Kilfrost ABC-TF2	75/25	33.0	25*	-3	Artificial snow
NCAR4	26-Apr-06	Kilfrost ABC-TF2	50/50	14.3	25*	-3	Artificial snow
NCAR6	25-Apr-06	Kilfrost ABC-TF2	100/0	68.0	10*	-3	Artificial snow
NCAR8	25-Apr-06	Kilfrost ABC-TF2	75/25	60.5	10*	-3	Artificial snow
NCAR10	26-Apr-06	Kilfrost ABC-TF2	50/50	23.8	10*	-3	Artificial snow
NCAR25	24-Apr-06	Kilfrost ABC-TF2	100/0	17.5	25*	-14	Artificial snow
NCAR27	24-Apr-06	Kilfrost ABC-TF2	75/25	15.0	25*	-14	Artificial snow
NCAR28	24-Apr-06	Kilfrost ABC-TF2	100/0	35.0	10*	-14	Artificial snow
NCAR30	24-Apr-06	Kilfrost ABC-TF2	75/25	37.0	10*	-14	Artificial snow
501	24-Apr-06	Kilfrost ABC-TF2	100%	63.3	1.9	-25.1	Freezing Fog
502	24-Apr-06	Kilfrost ABC-TF2	100%	62.8	2.0	-25.1	Freezing Fog
503	24-Apr-06	Kilfrost ABC-TF2	100%	31.7	4.9	-24.7	Freezing Fog
504	24-Apr-06	Kilfrost ABC-TF2	100%	32.9	4.9	-24.7	Freezing Fog
505	24-Apr-06	Kilfrost ABC-TF2	100%	50.0	4.7	-14.0	Freezing Fog
506	24-Apr-06	Kilfrost ABC-TF2	100%	49.0	4.8	-14.0	Freezing Fog
507	24-Apr-06	Kilfrost ABC-TF2	75%	37.0	4.9	-14.0	Freezing Fog
508	24-Apr-06	Kilfrost ABC-TF2	75%	36.0	4.7	-14.0	Freezing Fog
509	24-Apr-06	Kilfrost ABC-TF2	100%	106.0	1.9	-14.1	Freezing Fog
510	24-Apr-06	Kilfrost ABC-TF2	100%	105.0	1.8	-14.1	Freezing Fog
511	24-Apr-06	Kilfrost ABC-TF2	75%	85.0	2.0	-14.1	Freezing Fog
512	24-Apr-06	Kilfrost ABC-TF2	75%	84.7	2.0	-14.1	Freezing Fog
513	26-Apr-06	Kilfrost ABC-TF2	100%	68.0	5.0	-3.3	Freezing Fog
514	26-Apr-06	Kilfrost ABC-TF2	100%	69.0	5.2	-3.3	Freezing Fog
515	26-Apr-06	Kilfrost ABC-TF2	75%	80.0	5.1	-3.3	Freezing Fog
516	26-Apr-06	Kilfrost ABC-TF2	75%	77.0	4.8	-3.3	Freezing Fog
517	26-Apr-06	Kilfrost ABC-TF2	50%	45.0	4.8	-3.3	Freezing Fog
518	26-Apr-06	Kilfrost ABC-TF2	50%	46.0	4.8	-3.3	Freezing Fog
519	26-Apr-06	Kilfrost ABC-TF2	100%	145.5	1.9	-3.3	Freezing Fog
520	26-Apr-06	Kilfrost ABC-TF2	100%	141.0	2.1	-3.3	Freezing Fog
521	26-Apr-06	Kilfrost ABC-TF2	75%	150.5	2.0	-3.3	Freezing Fog
522	26-Apr-06	Kilfrost ABC-TF2	75%	142.0	2.0	-3.3	Freezing Fog
523	26-Apr-06	Kilfrost ABC-TF2	50%	80.0	2.2	-3.3	Freezing Fog
524	26-Apr-06	Kilfrost ABC-TF2	50%	85.0	1.9	-3.3	Freezing Fog
525	25-Apr-06	Kilfrost ABC-TF2	100%	33.0	13.2	-10.0	Freezing Drizzle
526	25-Apr-06	Kilfrost ABC-TF2	100%	32.5	13.0	-10.0	Freezing Drizzle
527	25-Apr-06	Kilfrost ABC-TF2	75%	29.0	13.0	-10.1	Freezing Drizzle
528	25-Apr-06	Kilfrost ABC-TF2	75%	28.5	13.3	-10.1	Freezing Drizzle
529	25-Apr-06	Kilfrost ABC-TF2	100%	76.0	5.0	-10.2	Freezing Drizzle
530	25-Apr-06	Kilfrost ABC-TF2	100%	75.0	5.0	-10.2	Freezing Drizzle
531	25-Apr-06	Kilfrost ABC-TF2	75%	86.0	5.1	-10.2	Freezing Drizzle

*Artificial snow icing intensity values are estimates. For actual values, refer to the Transport Canada report on winter 2005-06 artificial snow tests (to be completed November 2006).

Table 3.1 (cont'd): Log of Tests Performed in 2005-06

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
532	25-Apr-06	Kilfrost ABC-TF2	75%	85.5	5.3	-10.2	Freezing Drizzle
533	25-Apr-06	Kilfrost ABC-TF2	100%	27.5	24.2	-9.8	Freezing Rain
534	25-Apr-06	Kilfrost ABC-TF2	100%	29.0	24.1	-9.8	Freezing Rain
535	25-Apr-06	Kilfrost ABC-TF2	75%	29.5	24.1	-9.8	Freezing Rain
536	25-Apr-06	Kilfrost ABC-TF2	75%	31.0	24.1	-9.8	Freezing Rain
537	25-Apr-06	Kilfrost ABC-TF2	100%	39.5	13.3	-10.1	Freezing Rain
538	25-Apr-06	Kilfrost ABC-TF2	100%	39.0	13.2	-10.1	Freezing Rain
539	25-Apr-06	Kilfrost ABC-TF2	75%	41.0	12.8	-10.1	Freezing Rain
540	25-Apr-06	Kilfrost ABC-TF2	75%	40.0	12.8	-10.1	Freezing Rain
541	26-Apr-06	Kilfrost ABC-TF2	100%	37.5	13.4	-3.2	Freezing Drizzle
542	26-Apr-06	Kilfrost ABC-TF2	100%	39.5	12.6	-3.2	Freezing Drizzle
543	26-Apr-06	Kilfrost ABC-TF2	75%	47.0	13.3	-3.2	Freezing Drizzle
544	26-Apr-06	Kilfrost ABC-TF2	75%	46.0	13.3	-3.2	Freezing Drizzle
545	26-Apr-06	Kilfrost ABC-TF2	50%	22.7	12.7	-3.2	Freezing Drizzle
546	26-Apr-06	Kilfrost ABC-TF2	50%	22.3	13.1	-3.2	Freezing Drizzle
547	27-Apr-06	Kilfrost ABC-TF2	100%	82.5	4.7	-3.4	Freezing Drizzle
548	27-Apr-06	Kilfrost ABC-TF2	100%	79.8	5.0	-3.4	Freezing Drizzle
549	27-Apr-06	Kilfrost ABC-TF2	75%	79.5	5.2	-3.4	Freezing Drizzle
550	27-Apr-06	Kilfrost ABC-TF2	75%	81.0	5.3	-3.4	Freezing Drizzle
551	27-Apr-06	Kilfrost ABC-TF2	50%	37.5	5.2	-3.5	Freezing Drizzle
552	27-Apr-06	Kilfrost ABC-TF2	50%	37.0	5.3	-3.5	Freezing Drizzle
553	26-Apr-06	Kilfrost ABC-TF2	100%	28.0	24.4	-3.3	Freezing Rain
554	26-Apr-06	Kilfrost ABC-TF2	100%	28.8	24.4	-3.3	Freezing Rain
555	26-Apr-06	Kilfrost ABC-TF2	75%	31.2	25.1	-3.3	Freezing Rain
556	26-Apr-06	Kilfrost ABC-TF2	75%	32.8	24.2	-3.3	Freezing Rain
557	26-Apr-06	Kilfrost ABC-TF2	50%	15.0	24.0	-3.3	Freezing Rain
558	26-Apr-06	Kilfrost ABC-TF2	50%	14.5	24.2	-3.3	Freezing Rain
559	26-Apr-06	Kilfrost ABC-TF2	100%	43.0	13.5	-3.1	Freezing Rain
560	26-Apr-06	Kilfrost ABC-TF2	100%	44.5	13.4	-3.1	Freezing Rain
561	26-Apr-06	Kilfrost ABC-TF2	75%	44.5	13.2	-3.1	Freezing Rain
562	26-Apr-06	Kilfrost ABC-TF2	75%	44.8	13.2	-3.1	Freezing Rain
563	26-Apr-06	Kilfrost ABC-TF2	50%	21.5	12.9	-3.1	Freezing Rain
564	26-Apr-06	Kilfrost ABC-TF2	50%	21.0	13.0	-3.1	Freezing Rain
579	27-Apr-06	Kilfrost ABC-TF2	100%	13.0	74.1	0.8	Cold Soak
580	27-Apr-06	Kilfrost ABC-TF2	100%	11.5	72.6	0.8	Cold Soak
581	27-Apr-06	Kilfrost ABC-TF2	75%	12.2	76.3	0.8	Cold Soak
582	27-Apr-06	Kilfrost ABC-TF2	75%	11.0	75.0	0.8	Cold Soak
605	27-Apr-06	Kilfrost ABC-TF2	100%	75.0	4.7	1.0	Cold Soak
606	27-Apr-06	Kilfrost ABC-TF2	100%	68.5	5.1	1.1	Cold Soak
607	27-Apr-06	Kilfrost ABC-TF2	75%	88.7	4.9	1.0	Cold Soak
608	27-Apr-06	Kilfrost ABC-TF2	75%	84.0	5.0	1.0	Cold Soak

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4. RESULTS AND DISCUSSION

The data used to generate the endurance times will be presented in this section by precipitation type and fluid dilution.

4.1 Freezing Precipitation

Figures 4.1 to 4.11 present the data collected in freezing drizzle, light freezing rain, freezing fog and rain on cold-soaked surface. These figures show the effect of temperature and precipitation on fluid endurance times for each condition.

The methods used to evaluate the test data and calculate fluid specific HOTs in each precipitation condition were reviewed in Subsection 2.6. Table 4.1 gives the outputs from the regression equations run for this fluid under freezing fog, freezing drizzle, freezing rain and cold soak conditions.

4.2 Snow

Kilfrost ABC-TF2 was submitted too late in the winter season to be tested in natural snow. However, artificial snow tests were conducted. The endurance times of Kilfrost ABC-TF2 in artificial snow are shown in Figures 4.12 to 4.14. The generic Type II endurance times have been included for comparison purposes. In all cases the endurance times of Kilfrost ABC-TF2 meet or exceed the generic Type II values.

In addition, tests were conducted in both natural and artificial snow with a different sample of Kilfrost ABC-TF2 (batch P1792-1). The relationship between natural and artificial snow endurance times with the P1792-1 sample was found to be close to 1:1. As it is likely the relationship between natural and artificial snow endurance times with the certified sample is also close to 1:1, and as the artificial snow endurance times meet or exceed the Type II generic values, it was deduced that the endurance times of ABC-TF2 in snow meet or exceed the Type II generic values.

A detailed analysis of the artificial snow testing conducted with this fluid and others can be found in the TC report on artificial snow testing for the winter of 2005-06.

4.3 Holdover Time Table

A fluid-specific HOT table for Kilfrost ABC-TF2 is shown in Table 4.2. The fluid was conservatively given generic holdover times in the snow column based on analysis of tests conducted with an artificial snowmaker. However, if the test procedure to use snowmakers is approved, the data from the artificial snowmaker may be used to produce fluid specific values for this fluid in snow.

4.3.1 Fluid Viscosity

The viscosity of the fluid sample used in HOT testing, as measured by APS personnel, appears at the front of this document. The viscosity measurement method is also documented. In order for the fluid specific values of a fluid to be valid, operators must ensure that the viscosity of the fluid used is superior to the published viscosity of that fluid, using the same viscosity measurement method published.

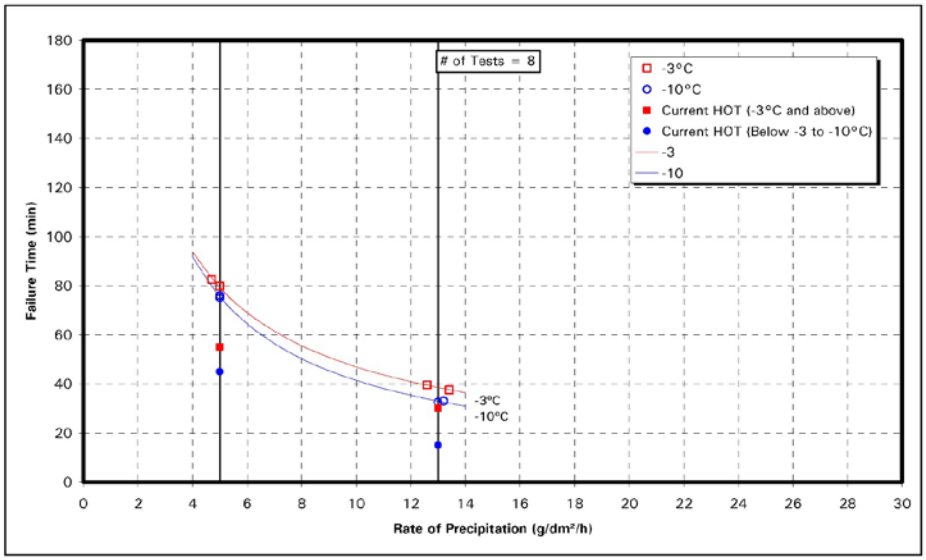

Figure 4.1: Type II Neat – Freezing Drizzle

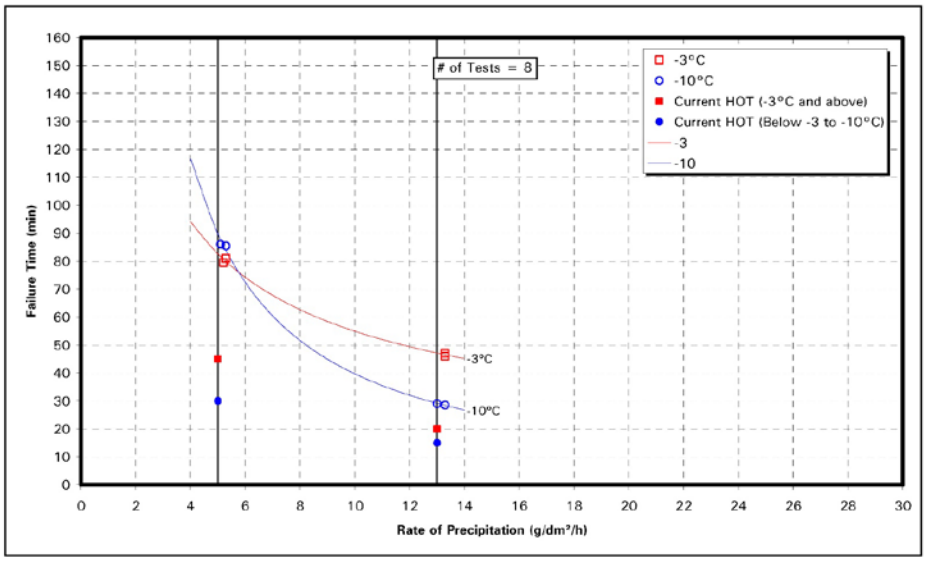

Figure 4.2: Type II 75/25 – Freezing Drizzle

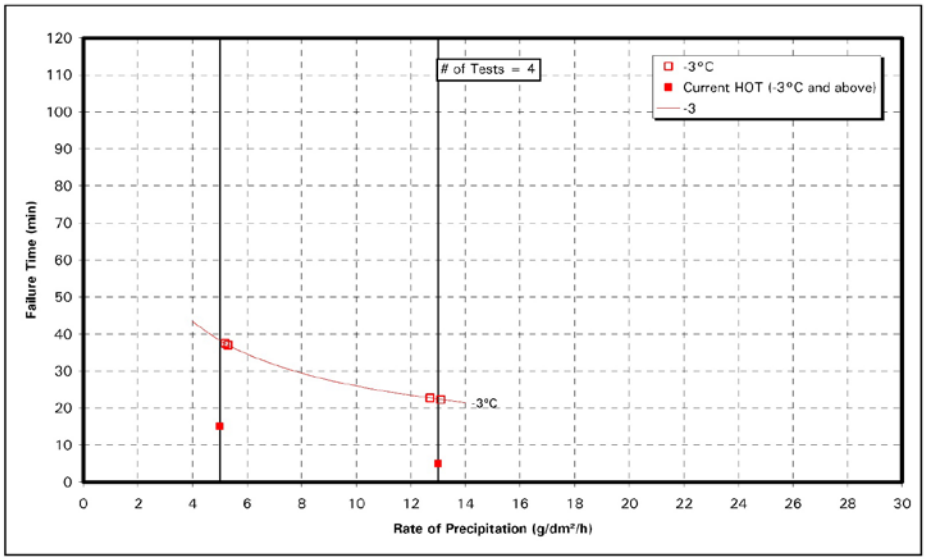

Figure 4.3: Type II 50/50 – Freezing Drizzle

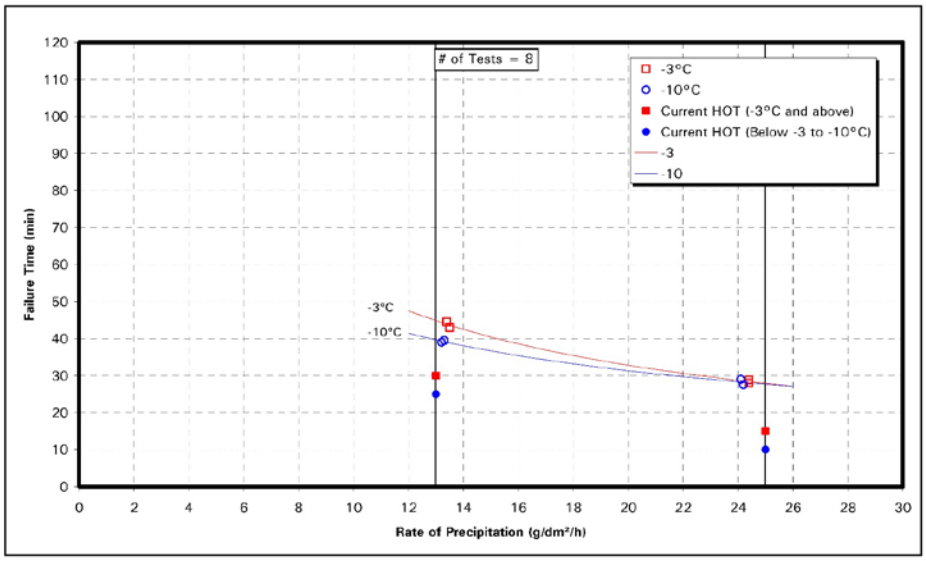

Figure 4.4: Type II Neat – Light Freezing Rain

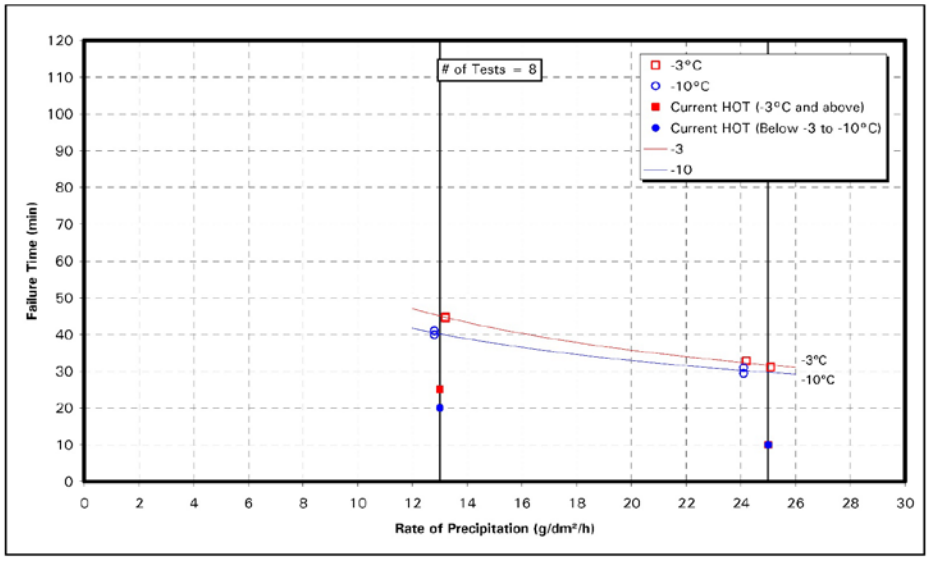

Figure 4.5: Type II 75/25 – Light Freezing Rain

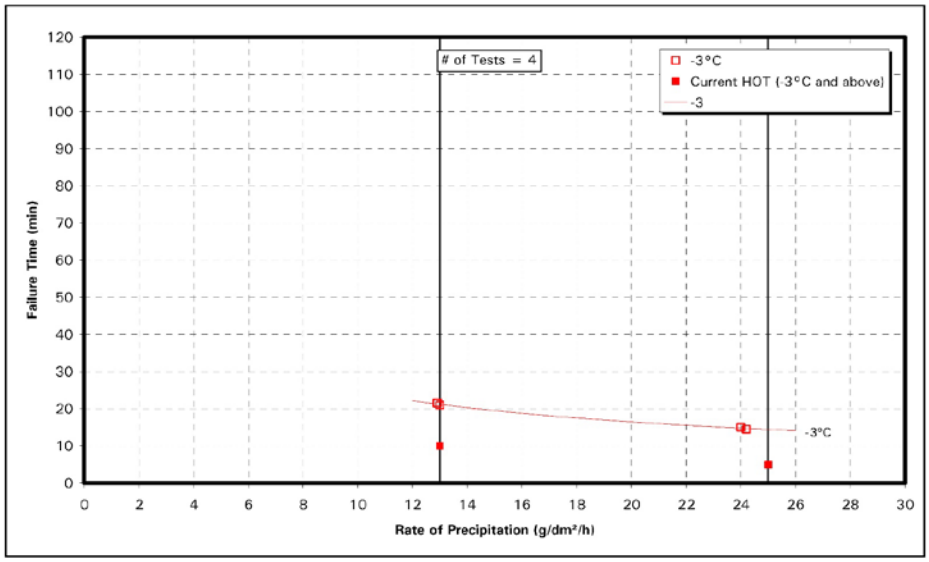

Figure 4.6: Type II 50/50 – Light Freezing Rain

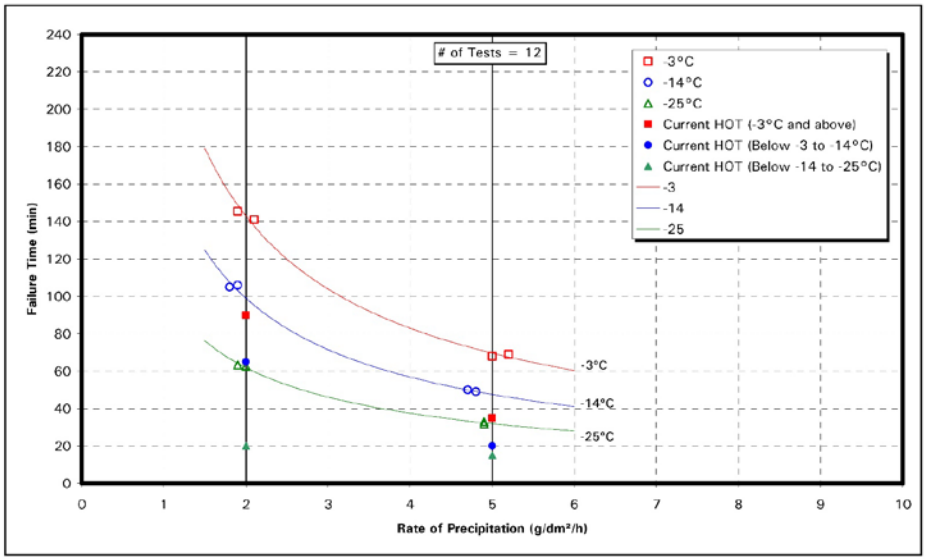

Figure 4.7: Type II Neat – Freezing Fog

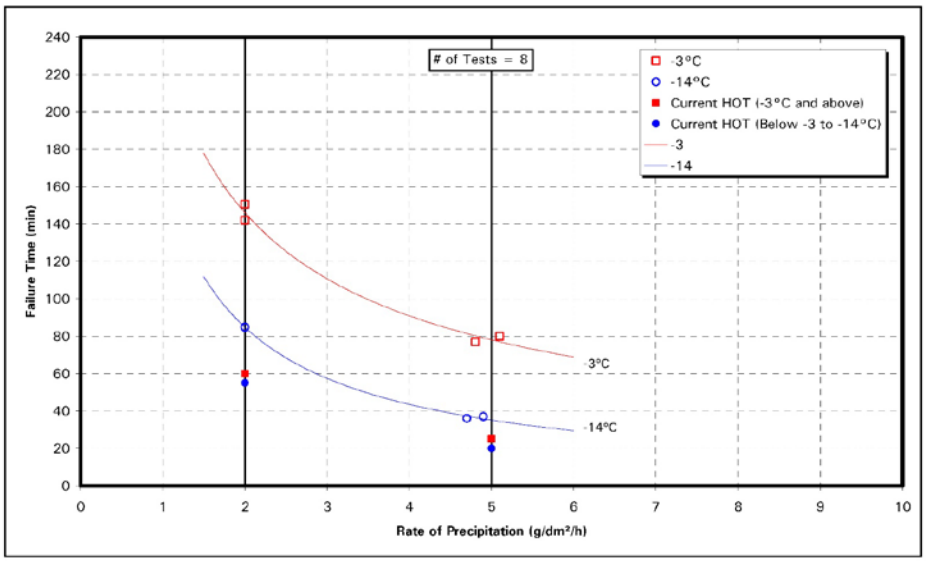

Figure 4.8: Type II 75/25 – Freezing Fog

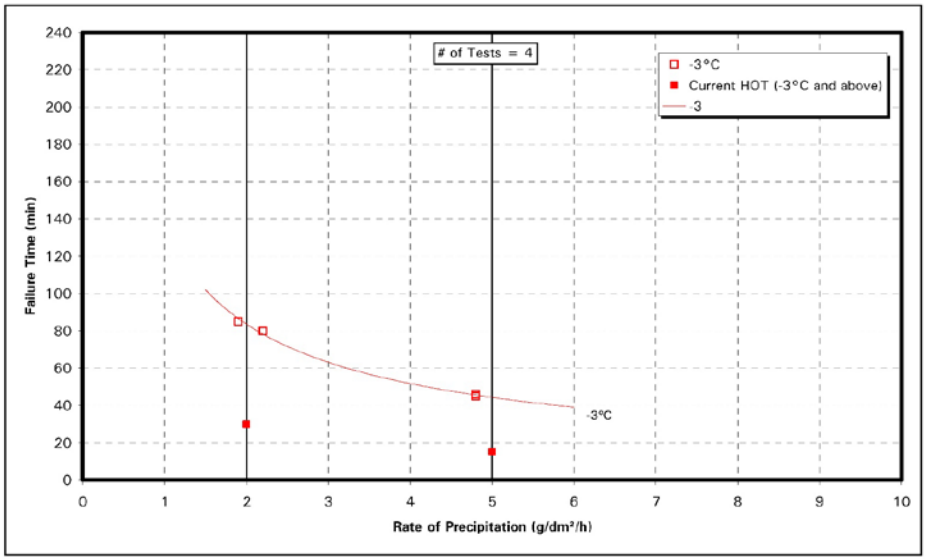

Figure 4.9: Type II 50/50 – Freezing Fog

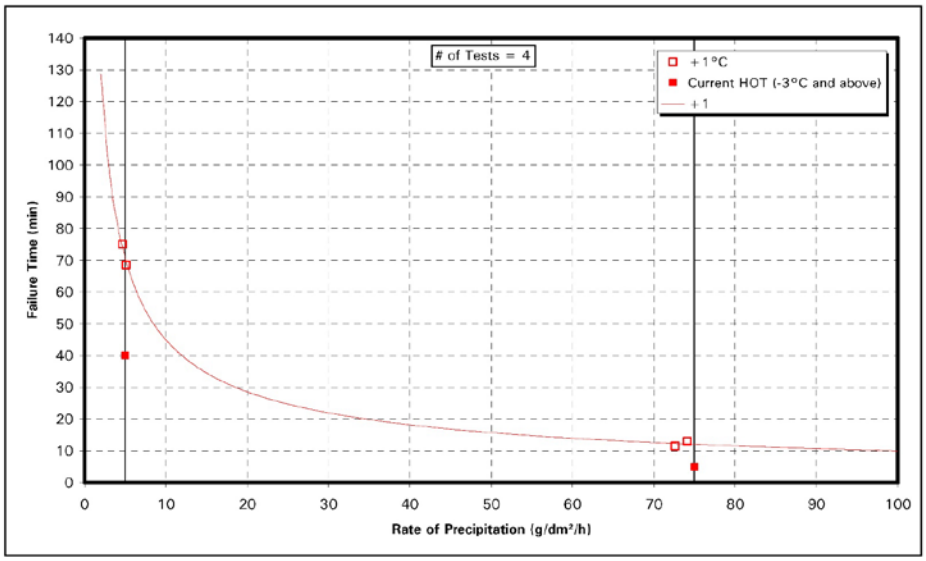

Figure 4.10: Type II Neat – Rain on Cold-Soaked Surface

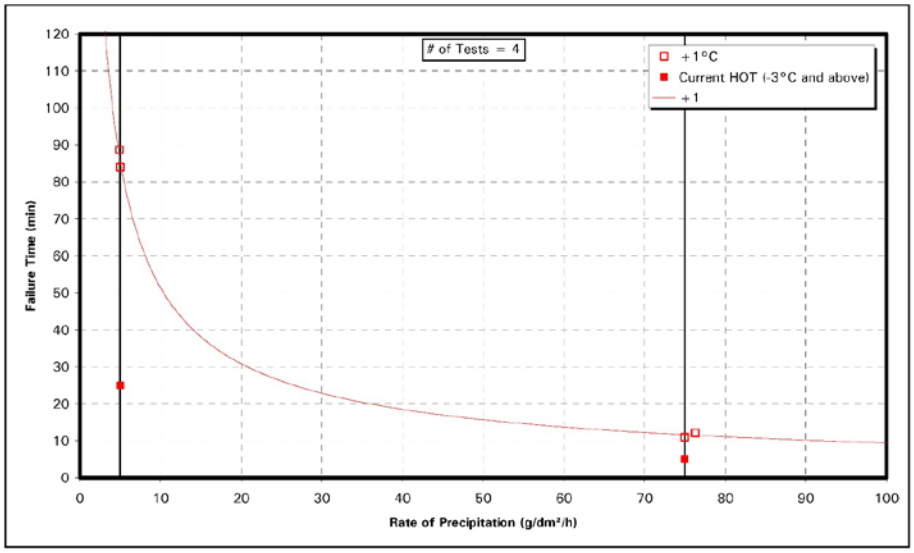

Figure 4.11: Type II 75/25 – Rain on Cold-Soaked Surface

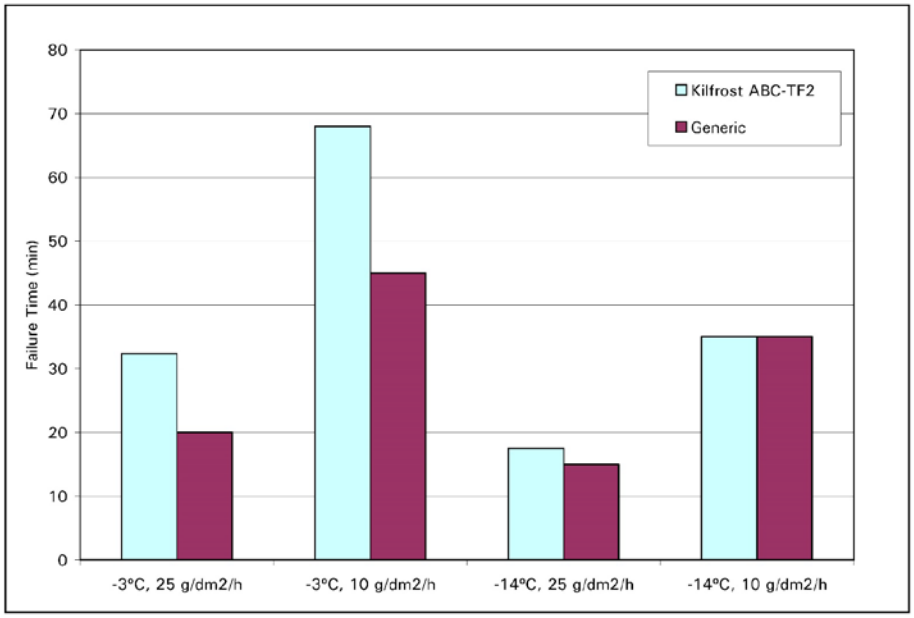

Figure 4.12: Type II Neat – Artificial Snow

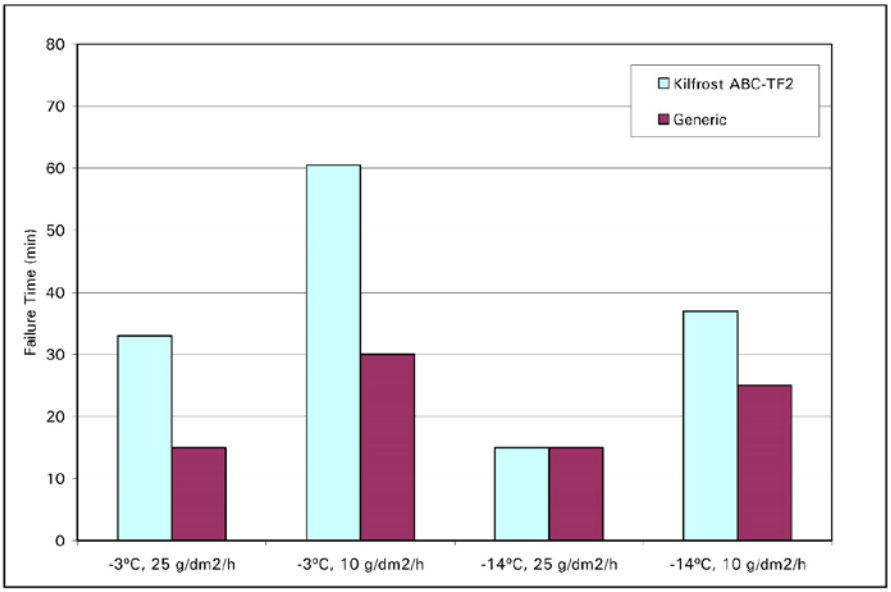

Figure 4.13: Type II 75/25 – Artificial Snow

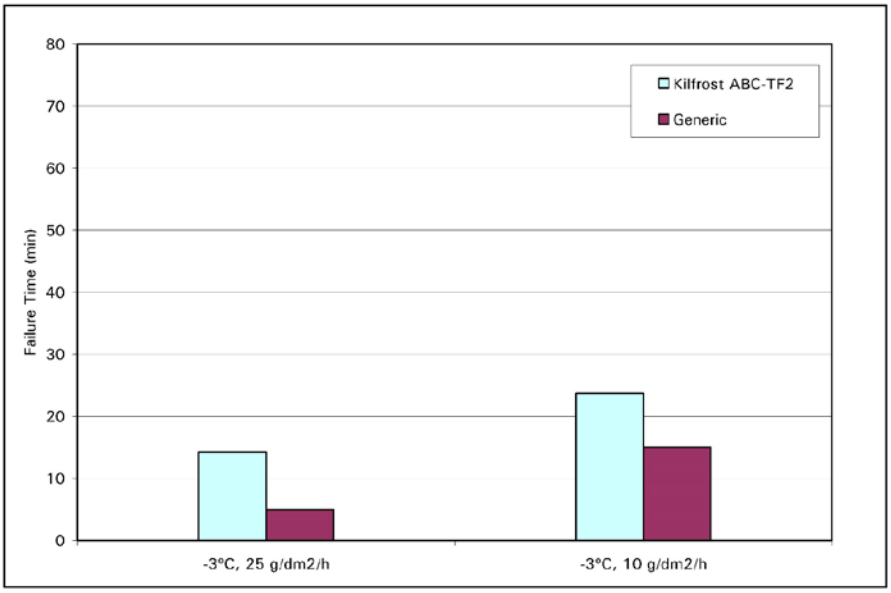

Figure 4.14: Type II 50/50 – Artificial Snow

Table 4.1: Summary of Regression Equation Coefficients for Kilfrost ABC-TF2

Simulated Freezing Fog

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-TF2	Neat	100%	-3°C	2.4	-0.78	4
Kilfrost ABC-TF2	75%	99%	-3°C	2.4	-0.68	4
Kilfrost ABC-TF2	50%	100%	-3°C	2.1	-0.69	4
Kilfrost ABC-TF2	Neat	100%	-14°C	2.2	-0.80	4
Kilfrost ABC-TF2	75%	100%	-14°C	2.2	-0.96	4
Kilfrost ABC-TF2	Neat	100%	-25°C	2.0	-0.72	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-TF2	Neat	100%	-3°C	2.4	-0.76	4
Kilfrost ABC-TF2	75%	100%	-3°C	2.3	-0.59	4
Kilfrost ABC-TF2	50%	100%	-3°C	2.0	-0.56	4
Kilfrost ABC-TF2	Neat	100%	-10°C	2.5	-0.87	4
Kilfrost ABC-TF2	75%	100%	-10°C	2.8	-1.18	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-TF2	Neat	100%	-3°C	2.5	-0.72	4
Kilfrost ABC-TF2	75%	100%	-3°C	2.3	-0.54	4
Kilfrost ABC-TF2	50%	100%	-3°C	2.0	-0.59	4
Kilfrost ABC-TF2	Neat	99%	-10°C	2.2	-0.55	4
Kilfrost ABC-TF2	75%	98%	-10°C	2.1	-0.46	4

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-TF2	Neat	100%	+1°C	2.3	-0.65	4
Kilfrost ABC-TF2	75%	100%	+1°C	2.4	-0.74	4

General Equation $t = 10^{I} R^{A}$

Table 4.2: Fluid Specific Type II Fluid Holdover Time Guidelines

KILFROST TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
ABC-TF2

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	1:10 – 2:25	0:20 – 0:45	0:40 – 1:20	0:30 – 0:45	0:10 – 1:10	
		75/25	5:00	1:20 – 2:25	0:15 – 0:30	0:45 – 1:25	0:30 – 0:45	0:10 – 1:25	
		50/50	3:00	0:45 – 1:25	0:05 – 0:15	0:20 – 0:40	0:15 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:50 – 1:40	0:15 – 0:35	0:35 – 1:15[3]	0:30 – 0:40[3]		
		75/25	5:00	0:35 – 1:25	0:15 – 0:25	0:30 – 1:30[3]	0:30 – 0:40[3]		
below -14 to -25	below 7 to -13	100/0	8:00	0:30 – 1:00	0:15 – 0:30[5]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

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

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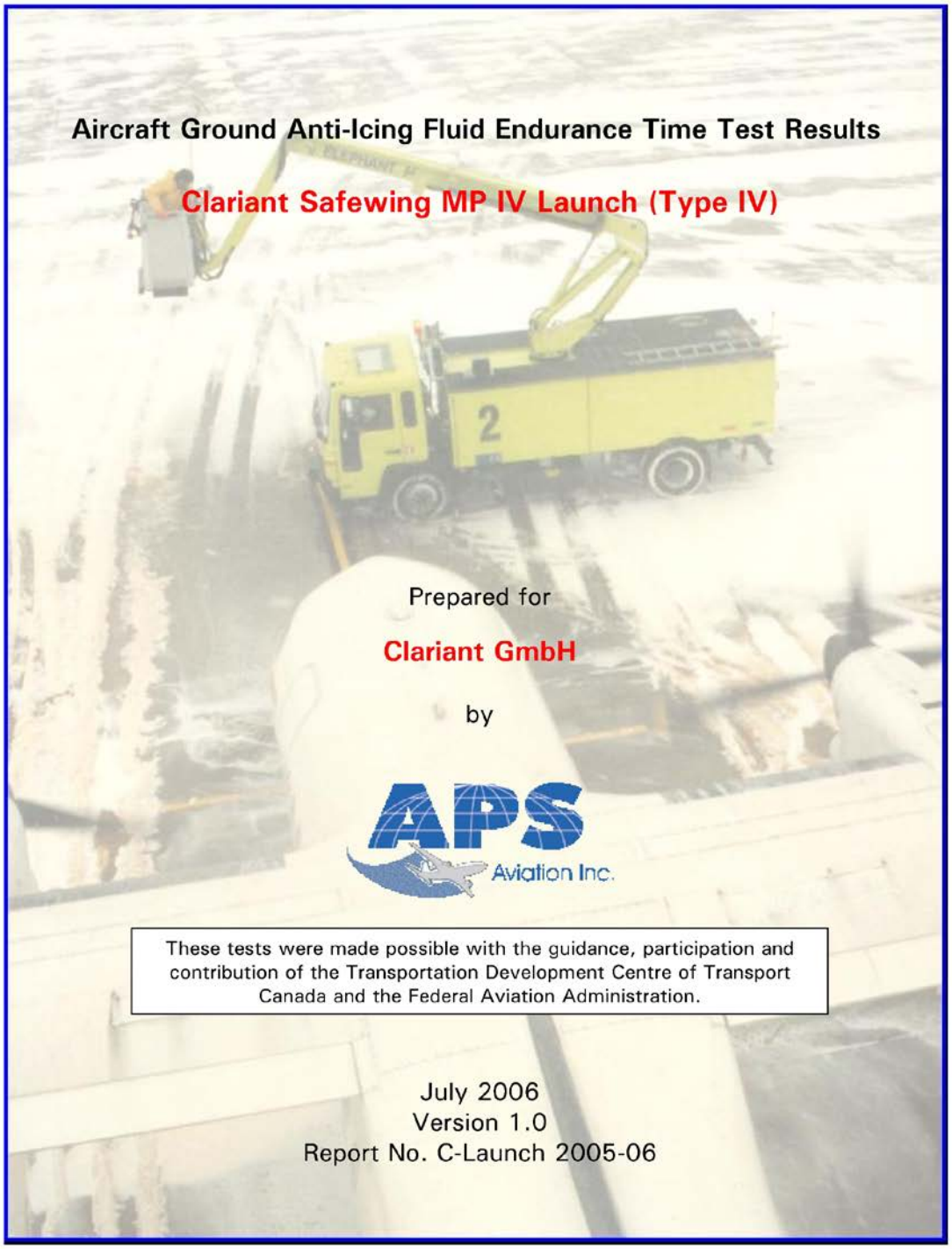
APPENDIX F

FLUID MANUFACTURER REPORT:
CLARIANT SAFEWING MP IV LAUNCH (TYPE IV)


Aircraft Ground Anti-Icing Fluid Endurance Time Test Results
Clariant Safewing MP IV Launch (Type IV)
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.
July 2006
Version 1.0
Report No. C-Launch 2005-06

Aircraft Ground Anti-Icing Fluid Endurance Time Test Results

Clariant Safewing MP IV Launch (Type IV)

Prepared for

Clariant GmbH

Prepared by: Stephanie Bendickson, Project Analyst — July 10, 2006 (Date)

Reviewed by: John D'Avirro, Program Manager, Eng. — July 10, 2006 (Date)

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.

July 2006
Version 1.0
Report No. C-Launch 2005-06

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer: Clariant

Fluid: MP IV Launch

Fluid Type / Colour: Type IV / Green

Batch #: TV431

Date of Receipt: March 10, 2006

Brix Measured:

Neat fluid:	35.00°
75/25 dilution:	27.25°
50/50 dilution:	19.00°

Viscosity Stated by Manufacturer[1]:

Neat fluid:	not given
75/25 dilution:	not given
50/50 dilution:	not given

Viscosity Measured by APS (Manufacturer Method)[1]:

Neat fluid:	7,550 cP
75/25 dilution:	17,680 cP
50/50 dilution:	18,500 cP

Viscosity Measured by APS (AIR 9968 Method)[2]:

Neat fluid:	7,550 cP
75/25 dilution:	17,680 cP
50/50 dilution:	18,500 cP

WSET provided by AMIL:

Neat fluid:	87 minutes

[1]Manufacturer Method: Spindle LV1, 20°C, 0.3 rpm, 10 minutes
[2]AIR 9968 Method: Spindle LV1, 20°C, 0.3 rpm, 10 minutes

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SUMMARY

The primary objective of this project was to measure the endurance time performance of Clariant Safewing MP IV Launch 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).

The HOT test procedure consisted of pouring fluids onto clean aluminium test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural snow and simulated freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. Endurance time tests were performed at the APS Aviation Inc. (APS) test facility located within the Montréal-Pierre-Elliott-Trudeau International Airport and at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were determined using a multi-variable regression analysis, resulting in the generation of the fluid-specific HOT table shown below. Since Clariant Safewing MP IV Launch was submitted for testing late in the winter and testing in natural snow was not possible, conservative holdover times in snow were derived analytically using data from an artificial snowmaker and from an alternate sample. The manufacturer intends to test the fluid in natural snow during the winter of 2006-2007.

Clariant Safewing MP IV Launch Type IV Fluid Holdover Times

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 and above	27 and above	100/0	12:00	4:00 – 4:00	1:00 – 1:35	1:30 – 2:00	1:00 – 1:40	0:15 – 1:40	
		75/25	5:00	3:40 – 4:00	0:40 – 1:20	1:40 – 2:00	0:45 – 1:15	0:10 – 1:45	
		50/50	3:00	1:25 – 2:45	0:10 – 0:25	0:30 – 0:50	0:20 – 0:25	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	1:00 – 1:55	0:40 – 1:05	0:35 – 1:40	0:25 – 0:45		
		75/25	5:00	0:40 – 1:20	0:20 – 0:40	0:25 – 1:10	0:25 – 0:45		
below -14 to -25	below 7 to -13	100/0	12:00	0:30 – 0:50	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

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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
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
SAE	Society of Automotive Engineers, Inc.
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-icing/anti-icing has been the subject of concentrated industry attention over the past decade due the occurrence of several fatal icing-related aircraft accidents. Recent attention has been placed upon 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 for use by aircraft operators and accepted by regulatory authorities. New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid HOTs without compromising the aerodynamic features of the airfoil.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop and substantiate fluid HOT tables for current fluids and new formulations. Test procedures to measure the duration of fluid protection against ice formation have evolved into a refined Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 5485 that is followed by APS Aviation Inc. (APS).

Testing of aircraft ground de/ant-icing fluids has resulted in the generation of HOT tables. These tables provide guidelines for use in departure planning in adverse winter conditions. They provide the HOT ranges for aircraft treated with any particular qualified deicing or anti-icing fluid.

A new data analysis protocol was developed in 1996-97 wherein the endurance time data for each fluid brand in each cell of the HOT tables was subject to a multi-variable regression treatment. Type II and Type IV fluid HOTs are determined using this method of analysis, resulting in the generation of generic and fluid-specific HOT tables.

This report provides the data and analysis used to determine the fluid HOTs for Clariant Safewing MP IV Launch.

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2

2. METHODOLOGY

This chapter contains a description of the tests, equipment and procedures used to conduct endurance time tests. It is divided into sections dealing with the definition of weather, test sites, test conditions, equipment, procedures, and analysis methodology. A 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 was developed by APS for this testing, based upon the requirements of ARP 5485.

2.1 Definition of Weather Conditions

HOTs are provided as a function of weather condition, fluid dilution and outside air temperature. The objective of the winter test program was to develop HOTs for new fluids based on the most recent test data.

Table 2.1 provides definitions of most weather conditions experienced in winter operations and includes the criteria used to determine precipitation intensity (light, moderate, heavy). 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).

Table 2.1 includes definitions for the weather conditions described in the HOT tables (frost, freezing fog, snow, freezing drizzle, light freezing rain and rain). Definitions for snow pellets, hail and ice pellets are also presented, however these are conditions for which HOT guidelines do not exist.

The test methodology used to determine fluid endurance times has included the generally accepted upper and lower limits for precipitation rates for each type of precipitation. These limits were discussed in detail at a 1997 meeting of the SAE G-12 HOT Subcommittee where standard definitions of upper and lower precipitation rate limits were approved for each category of precipitation. These limits are documented and discussed in Subsection 2.6.

2.1.1 Snow

Table 2.1 contains the criteria that were used in the past to estimate the intensity of snow. These criteria are based upon horizontal visibility with three

intensity levels. For light snow, visibility is greater than or equal to 1.0 km, moderate snow visibility is 0.5 km to less than 1.0 km, and heavy snow, visibility is less than 0.5 km.

As stated in a cautionary note in Table 2.1, visibility is only an indicator of snow intensity, and the two parameters are not always correlated.

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 visibility at the earth's surface to less than 1 km (5/8 mile).
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 (23°F), the crystals are generally agglomerated into snowflakes.
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 the ground or other exposed objects.
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 mm (0.02 in.) or smaller drops which, in contrast to drizzle, are widely separated.
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)	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter is about 2-5 mm (0.1-0.2 in.). Grains are brittle, easily crushed; they bounce and break on hard ground.
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is less than 1 mm (0.04 in.). When the grains hit hard ground, they do not bounce or shatter.
HAIL (GR)	Precipitation of small balls or pieces of ice with a diameter ranging from 5 to > 50 mm (0.2 to 2.0 in.) falling either separately or agglomerated.
ICE PELLETS (PE) Note: Includes Sleet and Small Hail	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.) or less. The pellets of ice usually bounce when hitting hard ground.

Intensity Criteria**

Snow(SN),Pellets(CS),Grains(SG),Frz Drizzle(FZDZ)			Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (S) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm or 10.0 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 or 25.0 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 shown that visibility and precipitation intensity are not always directly correlated.

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm 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 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 exposed surface up to a condition where individual drops are easily seen.
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm 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 pavement and other hard surfaces.
Measured Intensity	More than 0.30 in/hr (7.6 mm 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 spray to height of several inches is observed over hard surfaces.

* 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 Proposed Definition for Liquid Equivalent Snowfall Intensity

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

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP June 17, 1997
(Updated for METAR codes)

Table 2.2 is the visibility table which has been published annually by TC since the winter of 2003-04 for use in winter operations. It is based on more recent data than Table 2.1 and provides more detail about snowfall intensity and visibility. APS, NCAR and TC all had input into the formation of this table, which is based on NCAR field data and theoretical work on classes of snow and on extensive field data compiled by APS. The table categorizes snowfall into one of four intensities based on visibility and lighting condition.

The FAA also publishes a visibility, which differs slightly from the TC visibility table, but is based on the same data set.

Table 2.2: Visibility in Snow vs. Snowfall Intensity Chart[1]

Lighting	Temperature Range		Visibility in Snow (Statute Miles)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1	>1 to 2½	>2½ to 4	>4
	Below -1	Below 30	≤3/4	>3/4 to 1½	>1½ to 3	>3
Daylight	-1 and above	30 and above	≤½	>½ to 1½	>1½ to 3	>3
	Below -1	Below 30	≤3/8	>3/8 to 7/8	>7/8 to 2	>2

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.

2.1.2 Freezing Drizzle

Freezing drizzle is composed of closely spaced fine water droplets with a diameter less than 0.5 mm (see Table 2.1). The intensity of freezing drizzle is estimated, as it is for snow, through the measurement of horizontal visibility.

HOT tables have one column for freezing drizzle; however, Table 2.1 shows three intensity levels (light, moderate and heavy). For example, under moderate freezing drizzle, the rate of precipitation should range between 2.5 and 5.1 g/dm²/h. For heavy freezing drizzle, the definition indicates that the intensity is greater than 5 g/dm²/h. Discussions between United Airlines, NCAR and the National Research Council Canada (NRC) led to the upper limit value of 13 g/dm²/h for freezing drizzle. This value is also used as the lower limit for light freezing rain.

2.1.3 Freezing Rain

This form of precipitation exists either in the form of drops with diameters greater than 0.5 mm, or smaller drops which, in contrast to drizzle, are widely separated. For each of the three intensities of freezing rain given in Table 2.1, a visual description is supplied to provide a subjective guideline for the purpose of estimating rain intensity. However, the following definitions apply when an instrument is available to measure the intensity of precipitation:

- Light Precipitation rate is ≤ 25 g/dm²/h
- Moderate Precipitation rate is >25 g/dm²/h but ≤75 g/dm²/h
- Heavy Precipitation rate is >75 g/dm²/h

2.1.4 Freezing Fog

Freezing fog is defined as suspended minute water droplets that freeze upon impact with the ground or exposed objects. Table 2.1 does not provide any indication of intensity or liquid water content (LWC) of the fog other than that the horizontal visibility is reduced to less than 1 km.

2.2 Test Sites

Normal natural snow test operations are performed at the APS test site located within the Montréal-Pierre-Elliott-Trudeau International Airport. The location of the test site is shown on the plan view of the airport shown in Figure 2.1. Photo 2.1 shows the test site trailer and test stands, the site consists of two trailers and three locations for test stands. The APS test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station (Photo 2.2).

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.

The CEF is partitioned into two sections, separated by an insulated dividing door. Each partition can be separately controlled, permitting different tests to be conducted simultaneously. Photo 2.3 provides a general indication of the size of the facility. Photos 2.4 and 2.5 provide interior images of the small and large ends of the facility. The facility was designed and built for the testing of locomotives. The size of the chamber is 30 m by 5.4 m and its total height is 8 m. The lowest temperature achievable is -46°C.

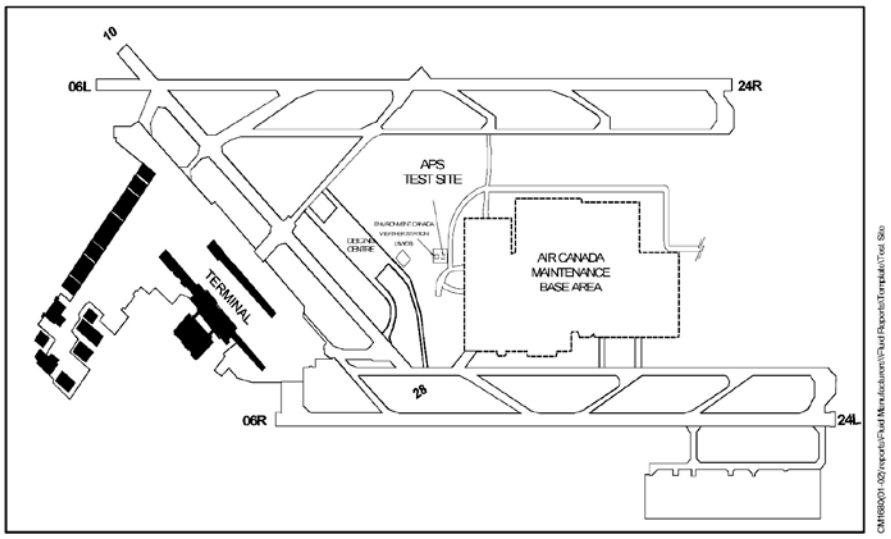


Figure 2.1: Test Site at the Montréal-Pierre-Elliott-Trudeau International Airport

2.3 Test Conditions

Outdoor testing was conducted during natural precipitation events. Supplementary tests to simulate freezing precipitation were carried out at the NRC CEF (see Photo 2.4). Subsections 2.3.1 and 2.3.2 provide descriptions of the spray assembly (see Photo 2.6) and of the methods used to produce and calibrate the fine water droplets in these artificial precipitation tests. Subsection 2.3.3 provides a summary of the categories and characteristics of each precipitation type produced for these tests.

2.3.1 Droplet Size and Rate of Precipitation

In the past few years, more industry attention has been given to the influence of droplet size on HOT. To explore this relationship further, experiments were performed to measure droplet sizes produced by different nozzles (gauge of hypodermic needle) at various water and air pressures in the spray delivery unit. Although the gauge of the needles is an important factor in the production of water droplets with appropriate dimensions, the air and water pressure levels in the sprayer system are equally important.

An improved sprayer assembly was developed in 1997-98 by the NRC and is shown in Photo 2.6. 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 2.7.

Prior to 1995, calibration experiments conducted by the NRC used an optical gauge manufactured by HSS (Biral UK acquired the HSS technology) to verify that the simulation of freezing fog, freezing drizzle, and light freezing rain provided adequate droplet sizes according to ARP 5485.

Since 1995, the APS team using a manual dye-stain technique employed by personnel at the NRC has carried out droplet size calibration. This technique consists of dusting Whatman #1 filter paper discs with a water-activated, very finely-divided powder form of methylene blue dye. The prepared discs are manually positioned under simulated precipitation for a fixed time to acquire a droplet size pattern. A calibration curve is then used to convert the measured diameter of the droplets on the pattern to the experimental median volume diameter (MVD).

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:	Dorval 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.

Figures 2.2 and 2.3 show an example of the distribution of simulated light freezing rain droplets obtained at the NRC.

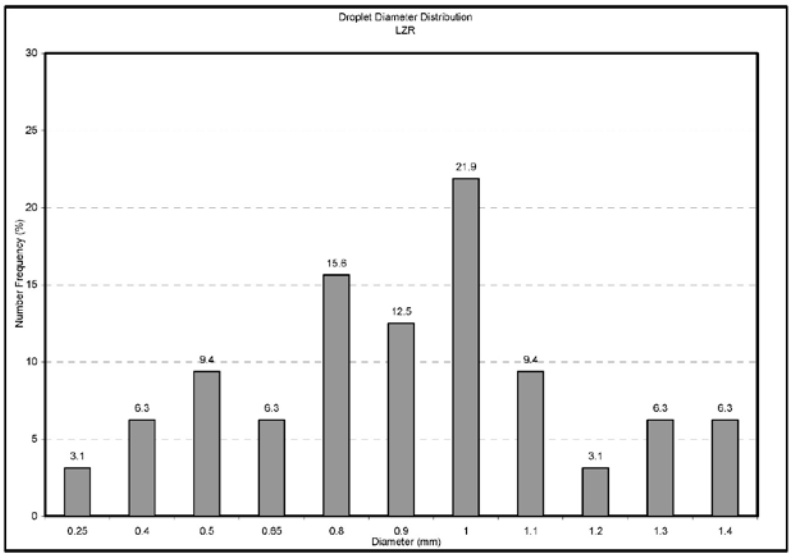


Figure 2.2: Droplet Diameter Distribution, Sample

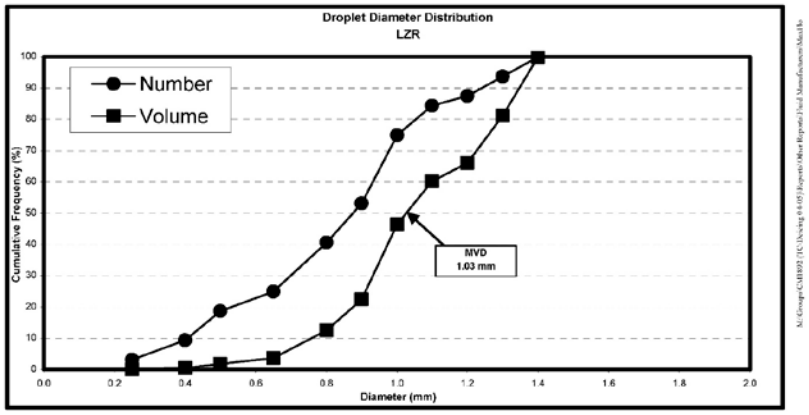


Figure 2.3: Cumulative Frequency of Droplet Diameter, Sample

2.3.2 Median Volume Diameter of Rain Drops

The MVD of a rain droplet was researched and found to be related to the precipitation rate 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 2.3 beside the experimental MVDs for each precipitation condition.

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

2.3.3 Characteristics of 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 were collected:

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

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

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

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

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

4. Moderate Rain on Cold Soaked Surface:
   Precipitation rate: 75 g/dm²/h;
   Droplet median volume diameter: 1 400 μm; and
   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.

2.4 Equipment

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.

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) is in accordance with the requirements set out in the ARP 5485.

Figure 2.4 shows a schematic of the test platform used for in 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.

Figure 2.4 also 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 were marked with 15 crosshairs used in determining whether end conditions (see Subsection 2.5.2 for definition) were achieved. Photo 2.8, taken outdoors at APS test site, shows six test plates mounted on a stand. For simulated freezing precipitation tests at the NRC, 12 plates were mounted on 2 six-position stands, as shown in Figure 2.4.

Figure 2.5 shows the collection (plate) pan, which is of the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.9 shows the collection pans used for measuring precipitation rates indoors at the NRC.

Sealed boxes (7.5 cm deep) were used for simulating a cold-soaked wing (see Figure 2.5). The top of the cold-soak box consists of an aluminium flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate.

Freeze points were measured using a hand-held Misco refractometer with a Brix scale.

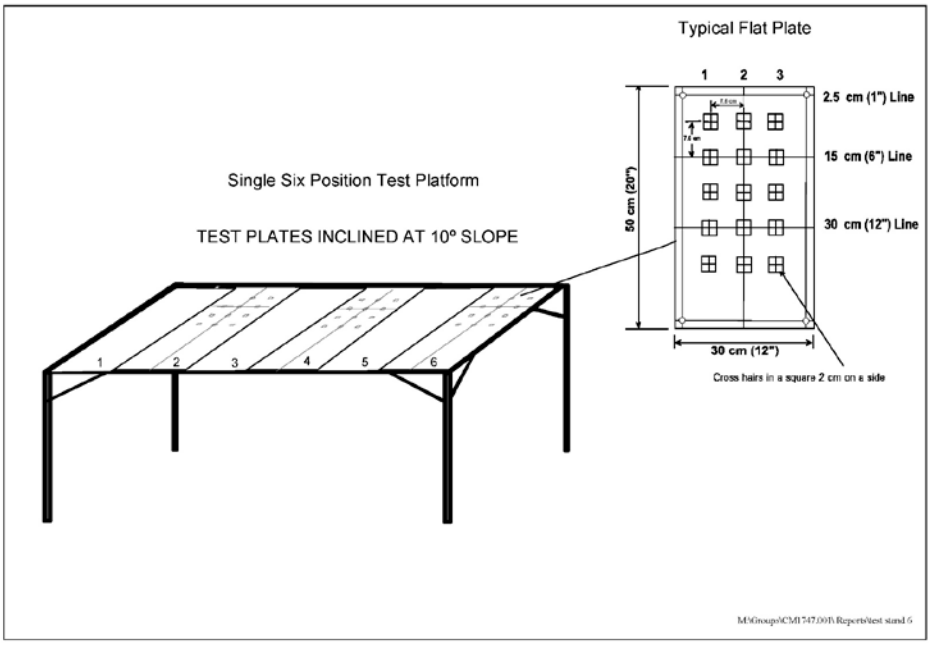
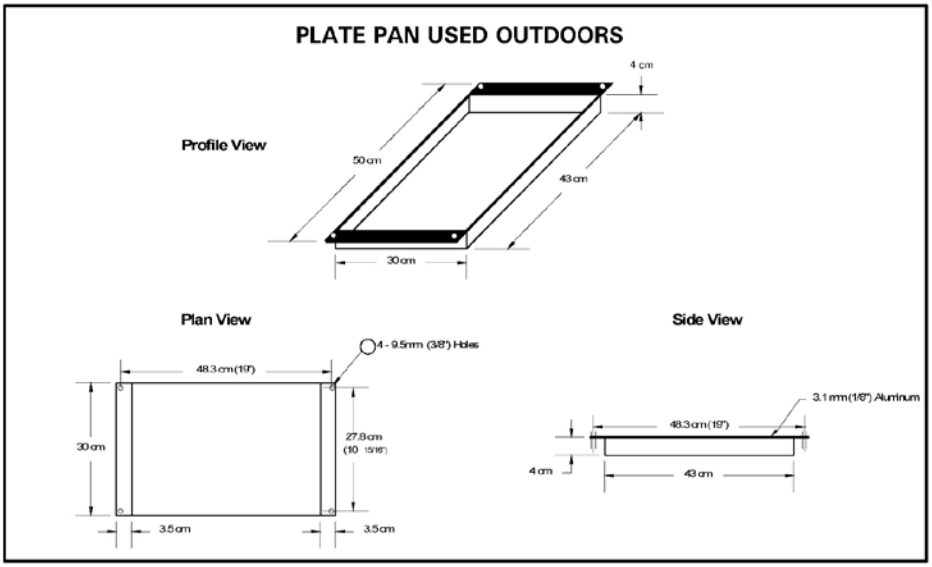
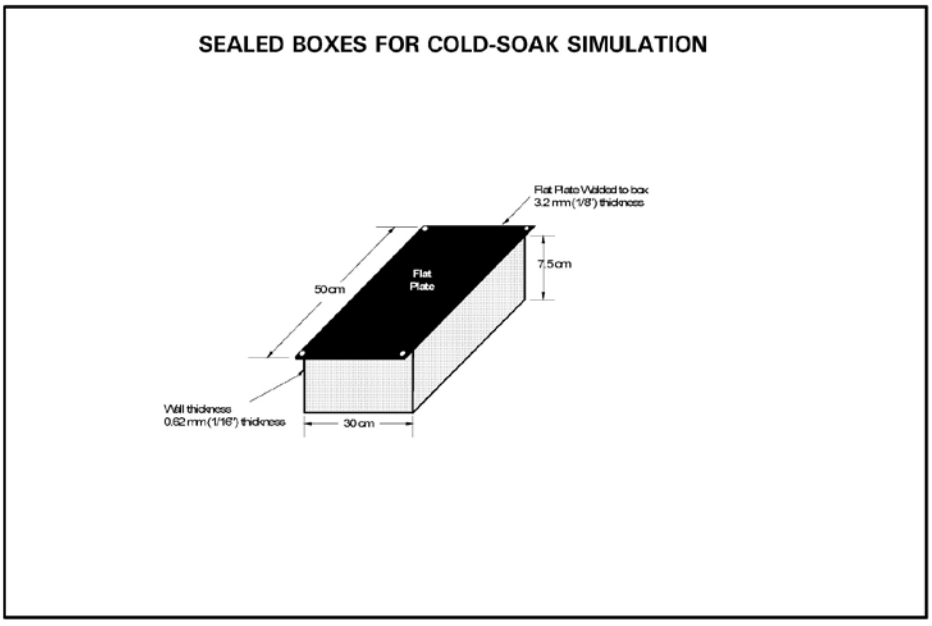


Figure 2.4: Flat Plate Test Set-Up





C:\M980\01-02\Reports\Fluid Manufacturers\Fluid Reports\Template\Pan and Boxes

Figure 2.5: Schematics of Plate Pan and Sealed Boxes

2.5 Test Procedures

Tests consisted of pouring anti-icing fluids directly onto clean test panels (exposed to various winter precipitation conditions) and recording the elapsed time for each crosshair to fail until the test panels reached the defined end condition (see Subsection 2.5.2 below).

2.5.1 Test Protocol (ARP 5485)

A plan 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 was developed by APS, based upon the requirements of ARP 5485. This procedure addresses testing conducted under natural precipitation conditions as well as under simulated freezing precipitation conditions.

Fluids to be evaluated are applied to test plates exposed to natural snow and simulated freezing fog, freezing drizzle, light freezing rain and rain on cold soaked wing. Endurance times are evaluated by measuring the minimum exposure time before a specified degree of freezing occurs.

During the conduct of these tests a series of test parameters are recorded. All test parameters specified in ARP 5485 are addressed in the procedure developed by APS. The test parameters are grouped into two categories: generic and specific test parameters.

Generic test parameters are recorded once per winter season (or test session, in laboratory testing) and include: discussion of safety issues, test plate material, test plate dimensions, surface finish and ice-catch pan dimensions. Specific test parameters are recorded during each testing session (or weather condition, in laboratory testing) and include: angle of the test stand, synchronization of timing devices, plate and ambient temperature profile files, icing intensity, etc.

As per ARP 5485 requirements, the test surface and ambient temperatures were recorded at a minimum sampling rate of one datum per minute. Figure 2.6 presents an example of a typical endurance time test conducted under simulated freezing drizzle conditions. The graph shows the test surface and chamber temperature profiles over the duration of the test and beyond failure time.

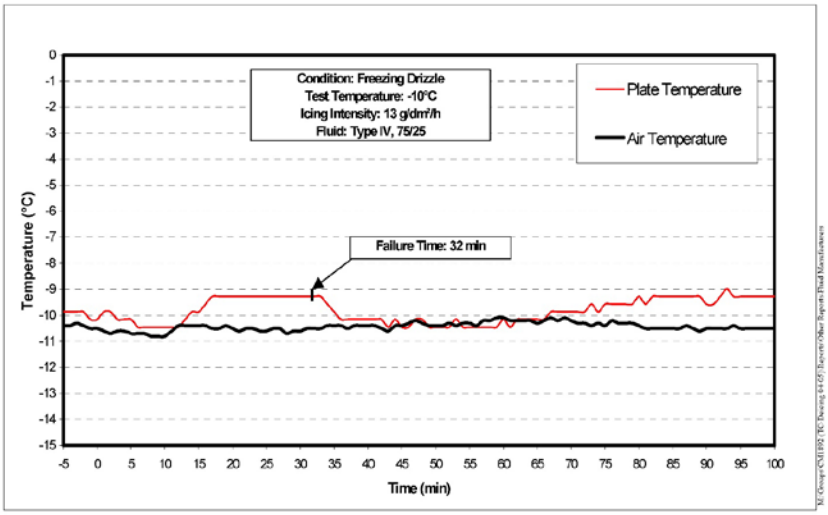


Figure 2.6: Temperature Profiles During a Typical Endurance Time Test

2.5.2 Test Protocol

The SAE G-12 HOT Subcommittee developed the procedure for natural snow flat plate tests.

The major steps in the natural snow flat plate test procedure are:

- Synchronize all timepieces;
- Clean panels and start;
- Apply (pour) fluids to test panels. Type II, Type III, and Type IV fluid are applied at the outdoor ambient temperature. Fluids are poured using a single-step fluid application;
- Record crosshair end condition times;
- Continue testing until at least five crosshairs or 30 percent (1/3) of the plate have failed;
- Record weather conditions; and
- Clean panels and restart.

2.5.3 End Condition Definitions

The test procedures and the determination of defined end conditions evolved from the experience the APS test team has accumulated from previous winter season test programs. Any of the following descriptions provide the general guidelines that observers use to judge when fluid failure occurs and to judge the extent of contamination or failure:

Failure is called when 30 percent (1/3) of the plate is 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.

2.5.4 Precipitation Rate Procedures

2.5.4.1 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 (h: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.

2.5.4.2 Precipitation rate distribution in simulated conditions

Clean test plates are placed on the test stand prior to the rate collection period, and are exposed to the simulated precipitation to verify that an even ice formation occurs over the entire test bed. If this visual inspection proves satisfactory, the rate collection period will begin. If this visual inspection proves unsatisfactory, the test stand must be repositioned under the spray device and the process is then repeated.

In order to verify the rate distribution on the test stand, a continuous rate-monitoring pan is replaced with a detailed rate distribution pan, which consists of 4 small pans of equivalent size. The area of the 4 small pans combined is similar to that of a standard rate collection pan. The small pans are weighed and placed at these locations and re-weighed at fixed intervals. The typical collection period for rate distribution is 60 minutes, however this interval may be shorter if all tests have been completed within 60 minutes. The variation between the rate of any of the 4 small pans and that of the average rate of that location should not be greater than 10 percent.

Two examples of the detailed rate distributions are shown in Table 2.4. Both rate distributions were conducted in freezing drizzle, one at the low rate (5 g/dm^2/h), the other at the high rate (13 g/dm^2/h). The average precipitation rate over the entire position in the low rate example in Table 2.4 was 5.1 g/dm^2/h. The individual rates of the four smaller pans were 5.0, 4.9, 5.2 and 5.3 g/dm^2/h, suggesting a maximum variation of 4.1 percent from the average rate over the entire position.

Table 2.4: Detailed Rate Distribution

Freezing Drizzle (low rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	2-top left	14:02	14:34	81.6	88.8	7.2	31.9	5.0
4	2-top right	14:02	14:34	81.6	88.6	7	31.9	4.9
5	2-bottom left	14:02	14:34	81.8	89.2	7.4	31.9	5.2
6	2-bottom right	14:02	14:34	81.6	89.2	7.6	31.9	5.3

3	4	5		STDDEV
5.0	4.9	-1.4%	-4.1%	0.181
5.2	5.3	1.4%	4.1%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

Freezing Drizzle (high rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	5-top left	12:12	12:43	81.8	98.8	17	30.8	12.3
4	5-top right	12:12	12:43	81.6	98.8	17.2	30.8	12.5
5	5-bottom left	12:12	12:43	81.6	100.2	18.6	30.8	13.5
6	5-bottom right	12:12	12:43	81.6	100.2	18.6	30.8	13.5

3	4	12.9		STDDEV
12.3	12.5	-4.8%	-3.6%	0.631
13.5	13.5	4.2%	4.2%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

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2.5.4.3 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) from the timepiece located near the rate station before leaving the trailer to place the pans on the test stand. The person responsible for collecting precipitation rate data take the time delay necessary to proceed outside from the rate station into consideration.

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.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.7. Typically, two collections pans are used for each test. The start and end times of the test are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t_1, t_2, and t_3 (minutes). The calculated rates for each collection period are indicated by R_1, R_2, and R_3 (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 2.4, 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.

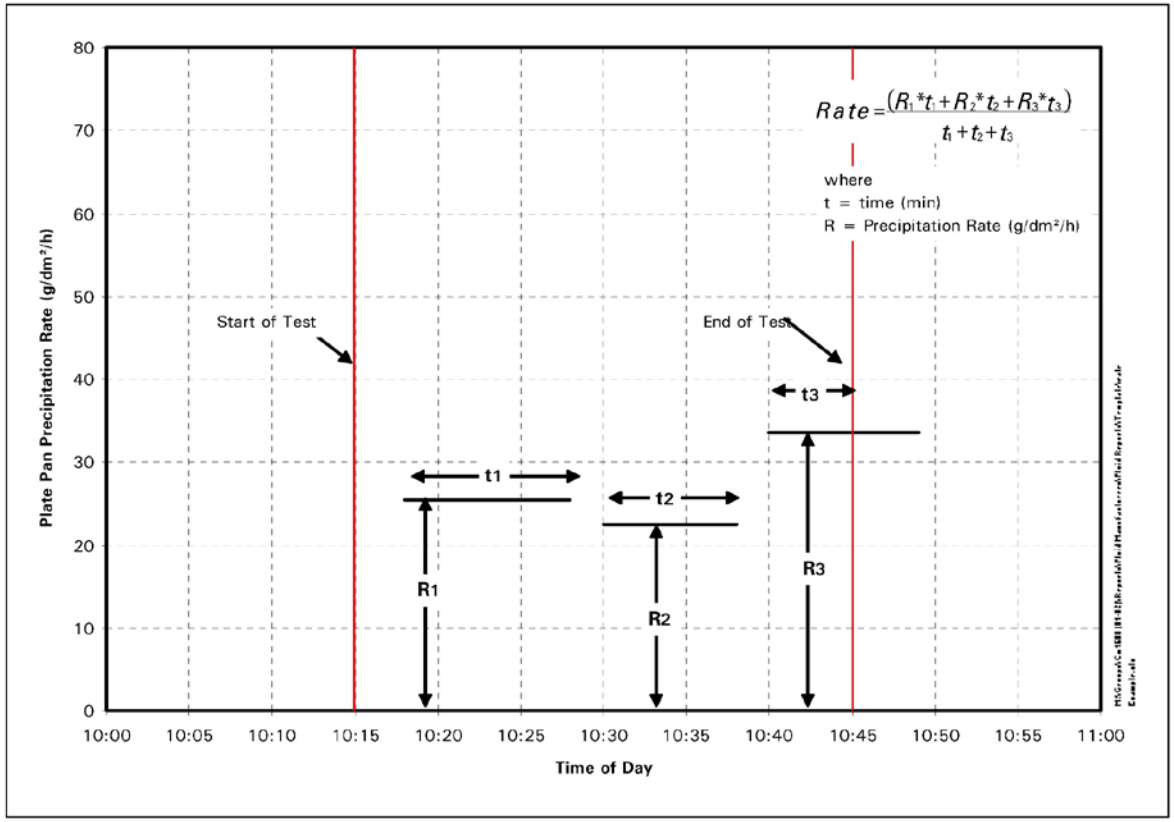

Figure 2.7: Calculation of Outdoor Precipitation Rate

2.6 Analysis Methodology

2.6.1 General

This section of the report describes the various categories of precipitation and the precipitation rate limits used during the course of endurance time testing. The process of data analysis used in the determination of fluid HOTs is also described.

2.6.2 Descriptions of Data Ranges and Precipitation Definitions

The test program developed to measure fluid failure times was carried out under five general categories of precipitation:

- Natural snow;
- Freezing drizzle;
- Light freezing rain;
- Freezing fog; and
- Rain on a cold-soaked surface.

Tests were conducted over temperature and precipitation rate ranges specific to each category of precipitation. A multi-variable regression procedure was used to evaluate fluid HOTs (first presented in TC report, TP 13131E) and is based on the refinement of an equation for a curve which best represents the fluid failure time test data, and then solving that equation at the upper and lower limits of a defined precipitation range. To support this procedure, precipitation rate limits for each specific category of precipitation were defined, reviewed and approved.

The precipitation rate limits used for the evaluation of HOT's are represented schematically in Figure 2.8. Detailed definitions and explanations of the data types and ranges are described in the following subsections. Meteorologically accepted definitions of these conditions were outlined in Table 2.1.

2.6.2.1 Natural snow

All fluid failure tests in natural snow were conducted at the APS Dorval Airport test site. Data were collected for precipitation rates that ranged from less than 4 g/dm²/h to greater than 25 g/dm²/h. For Type II and Type IV fluids, upper and lower limits for the snow column were set at rates of 10 and 25 g/dm²/h, respectively.

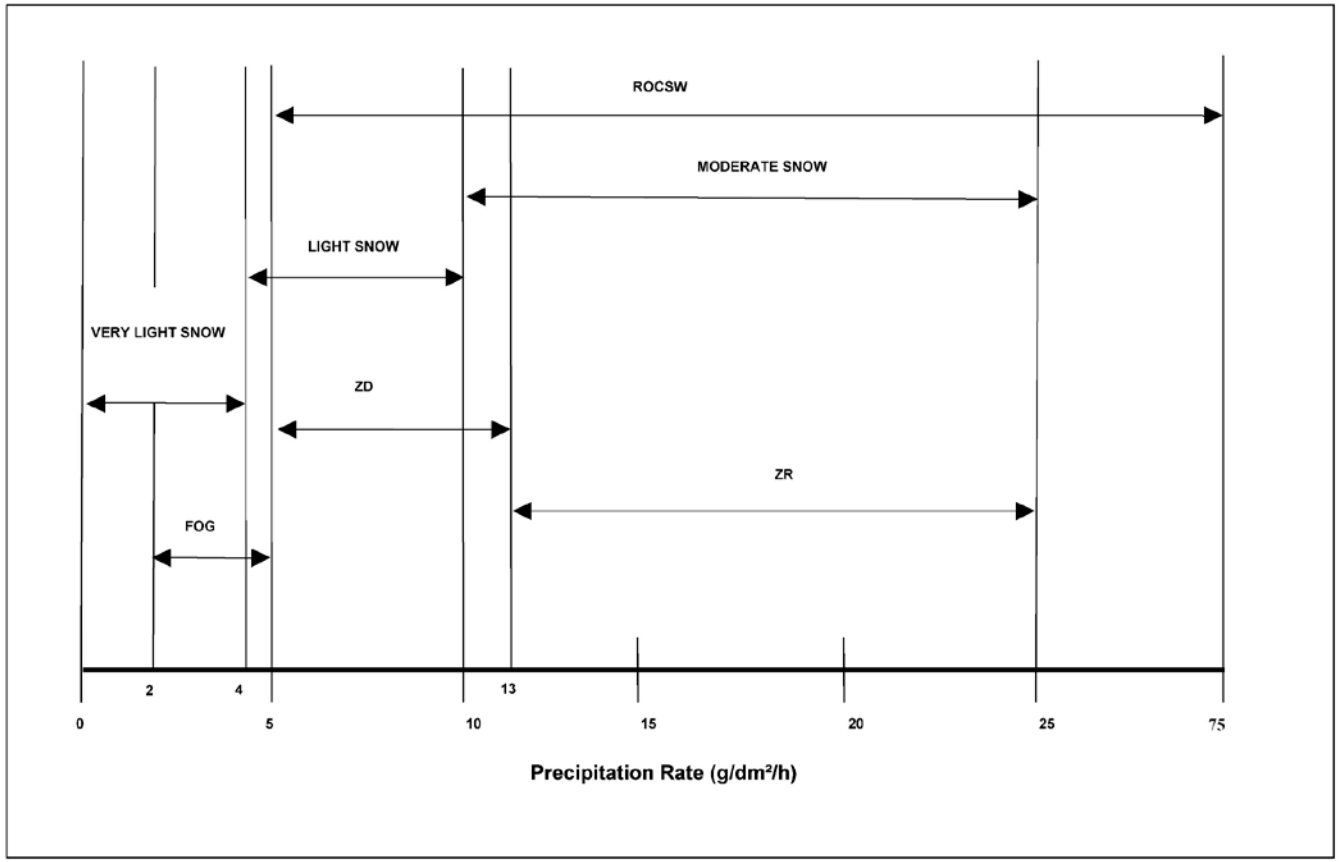

Figure 2.8: Data Range Used for Evaluation of Holdover Time Limits

The upper precipitation rate limit (25 g/dm^2/h) corresponds to the onset of heavy snow. Above this rate, it is standard practice to refer to the cautionary note included in the HOT tables indicating that the time of protection will be shortened in heavy weather conditions, (i.e., heavy precipitation, or high moisture content).

2.6.2.2 Freezing drizzle

Freezing drizzle is considered to occur over the range of 0 to 13 g/dm^2/h. The upper limit in this range, while not specifically defined in Table 2.1, has been adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Subcommittee.

For test purposes, the precipitation rate spectrum for freezing drizzle is constrained to rates between 5 and 13 g/dm^2/h, inclusively. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety. A caution note is included in the HOT tables indicating that if positive identification of freezing drizzle is not possible, the light freezing rain HOT is recommended for use.

2.6.2.3 Light freezing rain

With reference to the HOT tables, freezing rain conditions span the range of precipitation rates from 13 to 25 g/dm^2/h, inclusively. This range falls in 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.

2.6.2.4 Freezing fog

The precipitation rate limits for freezing fog were arrived at with input from meteorologists from the NRC, 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.

The precipitation rate for fog, referred to as *fog deposition* or simply as *deposition*, is given by the empirical expression,

$$\textbf{\textit{Deposition = LWC x Wind Velocity x Sin 10° x Collection Efficiency}}$$

where the Sin 10° term accounts for the 10° inclination of the test plates into the direction of the wind.

The meteorological circumstances (LWC value and wind speed), and the speed and orientation of the airfoil relative to the wind (stationary or taxiing), contribute to uncertainties in the values that the variables in the equation can assume.

Since 1997, the upper and lower HOTs for freezing fog have been evaluated at rates of 5 g/dm^2/h and 2 g/dm^2/h, respectively. In Vienna, during the 1998 SAE G-12 HOT Subcommittee meeting, it was felt that 2 g/dm²/h was not indicative of low rate natural fog. However, during a meeting of the Workgroup on Laboratory Methods to Derive HOT Guidelines in Montreal in March 1999, it was again agreed upon that the rate of 2 g/dm^2/h would be used in subsequent HOT testing in order to determine the upper HOT limit in freezing fog conditions.

2.6.2.5 Rain on a cold-soaked surface

Data used for the evaluation of HOTs for this category of precipitation were limited to precipitation rates ranging from 5 to 75 g/dm^2/h, which 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). The heavy rain category is covered by the caution note at the bottom of the HOT table regarding heavy weather conditions.

2.6.3 Protocol for the Determination of Holdover Times

Each cell in a HOT table represents a range of time during which a fluid at a specified concentration will provide protection for a particular temperature range in a particular category of precipitation. The Type II and Type IV HOT tables are composed of a maximum of 30 cells. Each cell contains a lower and upper time limit (except in frost) for a maximum of 54 time values.

Cell HOT values are determined by plotting *Failure Time* versus *Rate of Precipitation* and recording the failure time at two pre-selected rate limits. In previous years, several protocols were employed in the determination of HOTs. Due to the subjective natures of these different protocols, different interpretations of the data were possible. A multi-variable regression approach was subsequently devised in 1996/97 (see TC report, TP 13131E) and has since been used to evaluate fluid holdover times.

Data corresponding to each cell in the HOT table were assembled and sorted according to precipitation type, fluid dilution and temperature range. The data for each cell in the HOT table were plotted.

The data points on each plot were used to fit an equation of the form:

$$t = cR^a$$

where

t = Time (minutes)
R = Rate of precipitation (g/dm^2/h)
a,c = coefficients determined from the regression.

The coefficient a gives the rate dependency of the failure time.

Sample plots of **Log t** versus **Log R** are shown in Figure 2.9. The plots contain data from one temperature range, for one Neat Type IV fluid 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 2.10. 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 snow.

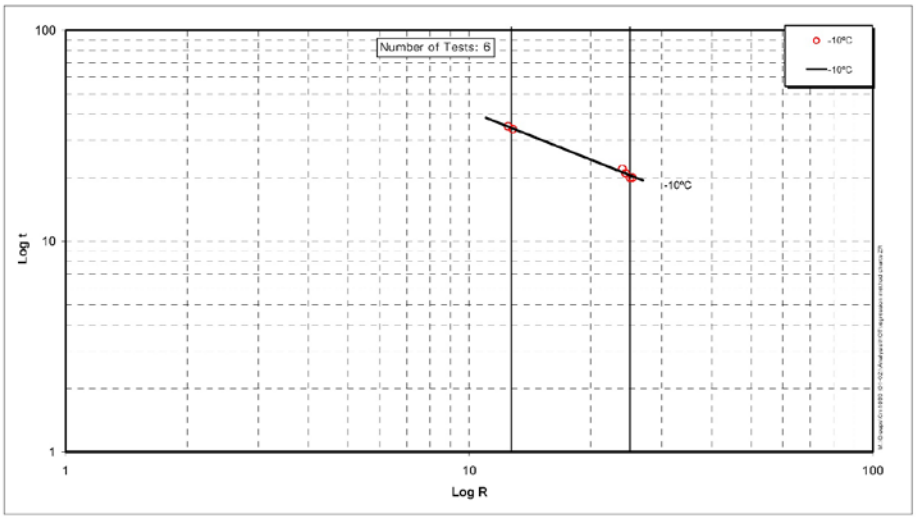

Figure 2.9: Regression Method on Log-Log Chart – Sample Type IV Neat, Freezing Rain

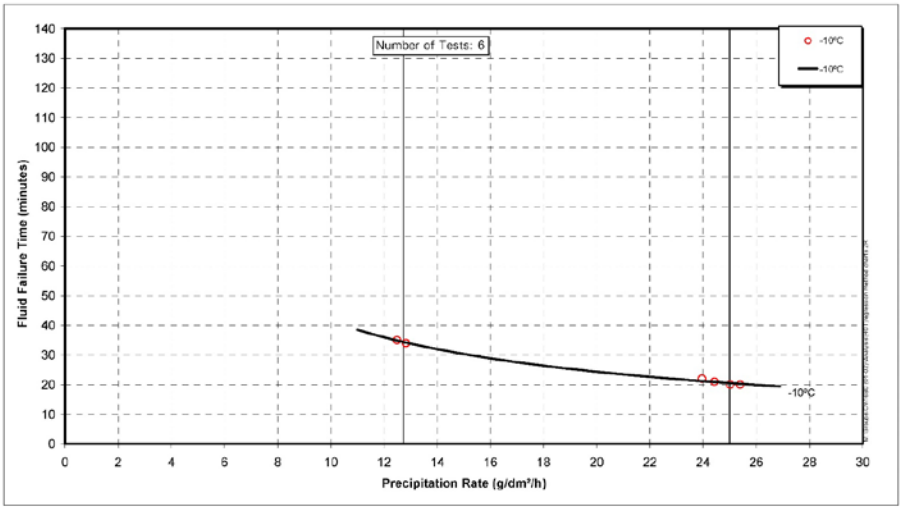

Figure 2.10: Regression Method on Standard Chart – Sample Type IV Neat, Freezing Rain

The HOTs for this fluid at -10°C are 20 minutes at 10 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

The categories of precipitation are separated into five groups: natural snow, freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface. Each group was subject to a slightly modified version of the general equation given above, as described in the following subsections.

2.6.3.1 Light freezing rain and freezing drizzle

The equation used to treat the data in these categories of precipitation is given by the expression below:

$$t = cR^a$$

- Tests in freezing drizzle and light freezing rain were conducted at predetermined temperature limits (-3 and -10°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were also obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.2 Simulated freezing fog

The equation used to treat freezing fog data is given by the expression below:

$$t = cR^a$$

- Tests in freezing fog were conducted at predetermined temperature limits (-3, -14 and -25°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.3 Natural snow

The general form of the regression equation was modified for natural snow by substituting 2-T for the variable T, in order to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C.

$$t = cR^a(2-T)^b.$$

- Best-fit curves were plotted for each fluid in each cell of the snow column using the most restrictive (lowest) temperature for that cell. For example, in cases of natural snow tests conducted at ambient temperatures above -3°C, the value of temperature used in the fitting procedure was -3°C.

- The upper and lower HOT values were determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively.

2.6.3.4 Rain on a cold-soaked wing

The same method for the evaluation of HOTs in light freezing rain and freezing drizzle was used for this category of precipitation.

2.6.4 Determination of Generic and Fluid Specific Holdover Times

At the SAE HOT Subcommittee meeting in Chicago in July 1997, Type IV fluid HOTs obtained using the multi-variable regression protocol of data analysis were presented. Wide variations in fluid performance among the different Type IV fluid brands forced the development of generic Type II and IV HOT tables as well as fluid-specific Type II and IV HOT tables.

2.6.4.1 Fluid-specific holdover time tables

Fluid-specific HOT table development was prompted by the fact that certain Type IV fluid brands were observed to significantly outperform other fluids under conditions corresponding to specific cells in the HOT tables. In general, any one fluid brand does not globally outperform the other fluid brands, but rather does so at a specific dilution, temperature range, and/or category of precipitation.

At the Chicago meeting in 1997, most members of the SAE G-12 HOT Subcommittee did not favour fluid-specific tables. However, significant reductions to HOTs for the cells corresponding to the most common Type IV fluid usage convinced the committee of the need to consider the development of fluid-specific and generic tables. Furthermore, some members wanted to take advantage of the significant benefits exhibited by some fluids in certain conditions.

A summary of the steps to follow to determine fluid-specific values for a Type II or IV fluid is provided below:

- The method used to determine HOTs is generally the same as was agreed upon in Chicago in 1997 at the SAE G-12 HOT Subcommittee meeting;
- For each cell of the HOT tables, four tests are typically conducted at the lowest temperature in the temperature range for that cell. Two tests are conducted at the low precipitation rate condition and at the high precipitation rate condition, for a total of four tests per cell;
- For each cell of the HOT table (except frost), a best-fit power law curve for each fluid is developed from the tests conducted at the low and high precipitation rate condition of that cell;
- Regression-generated HOTs are rounded off to the nearest whole "5" digit. For example, 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 HOTs are below 10 minutes, the numbers are rounded down as a precautionary measure. For example, 9 minutes is rounded down to 5 minutes; and
- Values are capped at 2 hours for all precipitation conditions except freezing fog, which are capped at 4 hours.

Photo 2.1: View of Test Site and Associated Equipment



Photo 2.2: Meteorological Services of Canada Weather Observation Station at Montréal-Pierre-Elliott-Trudeau International Airport



Photo 2.3: Outdoor View of National Research Council Climatic Engineering Facility



Photo 2.4: Inside View of Small End of Climatic Engineering Facility



Photo 2.5: Inside View of Large End of Climatic Engineering Facility



Photo 2.6: Sprayer Assembly Used at National Research Council

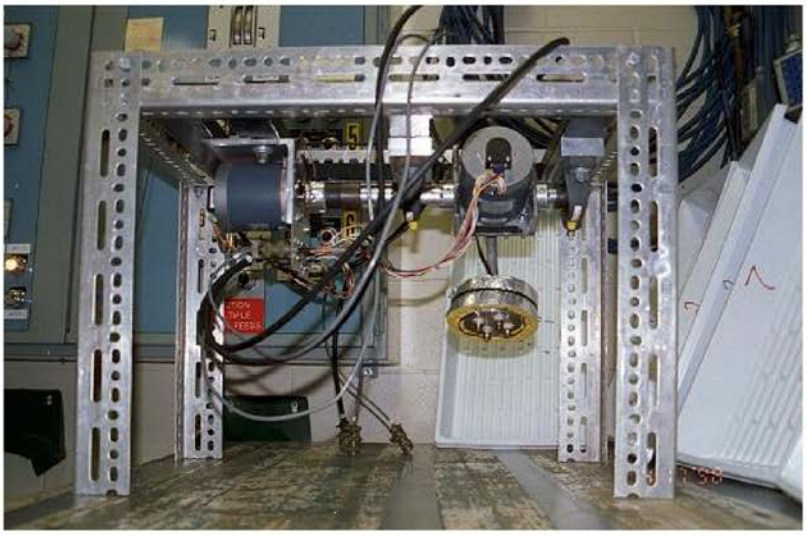

Photo 2.7: Sprayer Nozzle

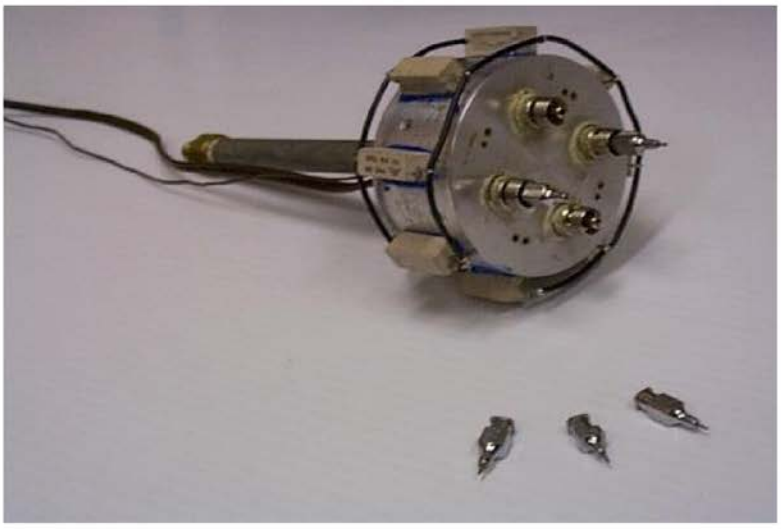

Photo 2.8: Test Plates Mounted on Stand



Photo 2.9: Collection Pans Used Indoors at the National Research Council



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted in natural snow, simulated light freezing rain, simulated freezing drizzle, simulated freezing fog, and rain on cold-soaked surfaces. Breakdowns are provided for quantity of tests performed by fluid type and temperature.

Two samples of Clariant Safewing MP IV Launch were provided for testing. The first sample, batch # TV428, was tested in all conditions. The second sample, batch # TV431, was received after natural snow testing was completed and was tested in freezing precipitation conditions only. TV431 will be commercialized as Clariant Safewing MP IV Launch; however, natural snow data from TV428 will be used to produce the fluid specific values in snow. Further analysis and discussion on this topic will be provided in Section 4.

Summaries of the tests conducted in natural snow and in freezing precipitation are provided in Tables 3.1 and 3.2 at the end of this section. Tests conducted with sample TV 431 are listed as "Clariant MP IV Launch". Tests conducted with sample TV428 are listed as "Clariant MP IV Launch (428)".

3.1 Natural Snow Tests

Tests were conducted in natural snow conditions at the APS test site. Tests were conducted with sample TV428. The breakdown of the tests conducted is summarized below by fluid dilution and temperature.

	Above -3°C	-3 to -14°C	-14 to -25°C	Total
Neat	10	12	0	22
75/25	13	14	0	27
50/50	18	1	0	19
				68

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 the tests conducted is summarized below by fluid dilution and temperature. Tests were conducted with sample TV431.

	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 condition at the NRC CEF. The breakdown of the tests conducted is summarized below by fluid dilution and temperature. Tests were conducted with sample TV431.

	-3°C	-14°C	-25°C
Neat	3	4	4
75/25	4	4	0
50/50	6	0	0

3.4 Rain on Cold-Soaked Surface Tests

Cold-soak tests were conducted with Neat and 75/25 dilutions using 7.5 cm deep sealed boxes. Tests were conducted at an ambient temperature of +1°C at the NRC CEF. Duplicate tests were conducted with each dilution at each precipitation rate. Tests were conducted with sample TV431.

3.5 Fluid Thickness Tests

The purpose of these tests was to measure the film thickness profiles of the fluid in all dilutions, under dry conditions.

Two tests were performed for each standard dilution (Neat, 75/25 and 50/50). For each test, one litre of fluid was poured onto a flat plate mounted on a test stand inclined 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. Tests were conducted at an ambient temperature of -3°C.

The results are displayed in Figure 3.1.

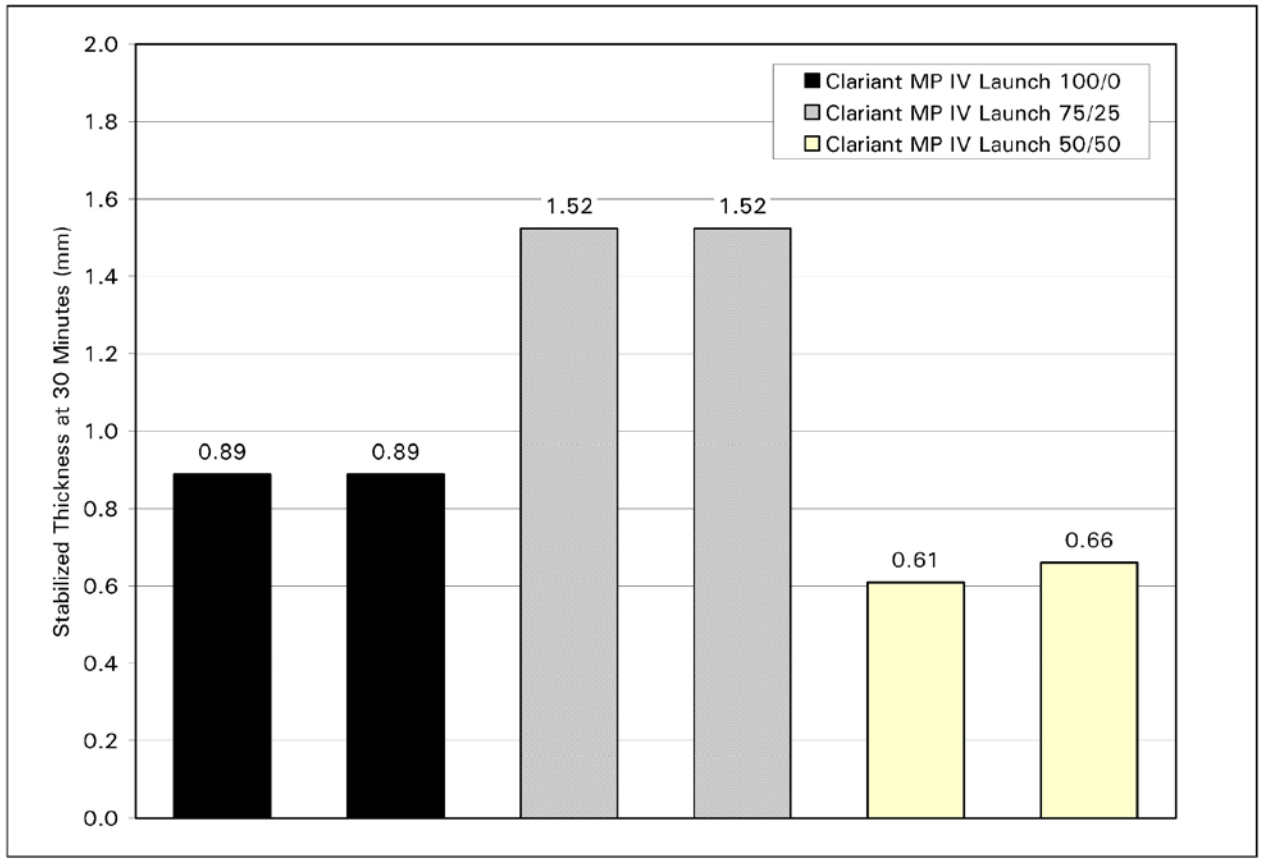

Figure 3.1: Fluid Thickness of Clariant Safewing MP IV Launch

Table 3.1: Summary of Tests Performed in 2005-06 (Snow)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
1	21-Jan-06	Clariant MP IV Launch (428)	50%	17.0	27.0	-0.1	Natural Snow
2	21-Jan-06	Clariant MP IV Launch (428)	50%	19.5	17.7	-0.2	Natural Snow
3	21-Jan-06	Clariant MP IV Launch (428)	50%	19.2	26.6	0.0	Natural Snow
4	21-Jan-06	Clariant MP IV Launch (428)	75%	69.3	25.9	-0.2	Natural Snow
5	21-Jan-06	Clariant MP IV Launch (428)	100%	73.0	26.9	-0.3	Natural Snow
6	21-Jan-06	Clariant MP IV Launch (428)	100%	83.0	26.5	-0.3	Natural Snow
7	21-Jan-06	Clariant MP IV Launch (428)	75%	56.7	26.0	-0.2	Natural Snow
8	21-Jan-06	Clariant MP IV Launch (428)	50%	16.0	27.7	-1.0	Natural Snow
9	21-Jan-06	Clariant MP IV Launch (428)	50%	22.0	19.1	-1.3	Natural Snow
11	21-Jan-06	Clariant MP IV Launch (428)	50%	16.3	30.0	-0.6	Natural Snow
12	21-Jan-06	Clariant MP IV Launch (428)	75%	76.7	25.7	-1.0	Natural Snow
14	21-Jan-06	Clariant MP IV Launch (428)	75%	63.0	23.4	-1.2	Natural Snow
15	21-Jan-06	Clariant MP IV Launch (428)	100%	80.0	25.5	-1.0	Natural Snow
16	24-Jan-06	Clariant MP IV Launch (428)	50%	24.3	10.5	-0.7	Natural Snow
17	24-Jan-06	Clariant MP IV Launch (428)	50%	21.5	13.0	-0.7	Natural Snow
18	24-Jan-06	Clariant MP IV Launch (428)	100%	126.5	9.1	-0.7	Natural Snow
19	24-Jan-06	Clariant MP IV Launch (428)	75%	118.0	8.7	-0.7	Natural Snow
20	24-Jan-06	Clariant MP IV Launch (428)	100%	87.7	15.2	-0.5	Natural Snow
21	24-Jan-06	Clariant MP IV Launch (428)	75%	79.3	15.8	-0.5	Natural Snow
22	24-Jan-06	Clariant MP IV Launch (428)	100%	88.0	14.3	-0.5	Natural Snow
23	24-Jan-06	Clariant MP IV Launch (428)	75%	73.5	14.9	-0.6	Natural Snow
24	24-Jan-06	Clariant MP IV Launch (428)	50%	16.5	18.4	-0.7	Natural Snow
25	25-Jan-06	Clariant MP IV Launch (428)	50%	23.8	11.6	-0.5	Natural Snow
26	24-Jan-06	Clariant MP IV Launch (428)	50%	23.7	13.1	-0.7	Natural Snow
27	24-Jan-06	Clariant MP IV Launch (428)	50%	19.8	13.2	-0.7	Natural Snow
29	24-Jan-06	Clariant MP IV Launch (428)	75%	103.7	11.5	-0.6	Natural Snow
30	24-Jan-06	Clariant MP IV Launch (428)	100%	146.5	10.1	-0.7	Natural Snow
31	24-Jan-06	Clariant MP IV Launch (428)	75%	124.2	9.4	-0.7	Natural Snow
32	24-Jan-06	Clariant MP IV Launch (428)	100%	126.5	5.7	-0.7	Natural Snow
33	24-Jan-06	Clariant MP IV Launch (428)	75%	96.8	10.0	-0.7	Natural Snow
34	24-Jan-06	Clariant MP IV Launch (428)	50%	48.0	5.0	-0.7	Natural Snow
35	29-Jan-06	Clariant MP IV Launch (428)	100%	53.8	23.7	-6.0	Natural Snow
36	29-Jan-06	Clariant MP IV Launch (428)	75%	43.7	23.4	-6.0	Natural Snow
37	29-Jan-06	Clariant MP IV Launch (428)	75%	45.0	22.4	-5.7	Natural Snow
38	29-Jan-06	Clariant MP IV Launch (428)	100%	52.7	22.0	-5.7	Natural Snow
39	29-Jan-06	Clariant MP IV Launch (428)	100%	88.0	17.6	-4.9	Natural Snow
40	29-Jan-06	Clariant MP IV Launch (428)	75%	81.7	17.5	-4.9	Natural Snow
41	29-Jan-06	Clariant MP IV Launch (428)	100%	99.2	7.5	-4.0	Natural Snow
42	29-Jan-06	Clariant MP IV Launch (428)	75%	88.0	7.2	-4.0	Natural Snow
43	16-Feb-06	Clariant MP IV Launch (428)	75%	26.3	20.7	-8.4	Natural Snow
44	16-Feb-06	Clariant MP IV Launch (428)	100%	41.3	23.6	-8.5	Natural Snow

Table 3.1 (cont'd): Summary of Tests Performed in 2005-06 (Snow)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
51	16-Feb-06	Clariant MP IV Launch (428)	75%	21.5	32.4	-9.2	Natural Snow
52	16-Feb-06	Clariant MP IV Launch (428)	100%	47.0	30.6	-9.3	Natural Snow
59	16-Feb-06	Clariant MP IV Launch (428)	75%	14.2	28.8	-9.3	Natural Snow
60	16-Feb-06	Clariant MP IV Launch (428)	100%	24.5	29.7	-9.3	Natural Snow
67	16-Feb-06	Clariant MP IV Launch (428)	75%	64.8	8.3	-9.0	Natural Snow
68	16-Feb-06	Clariant MP IV Launch (428)	100%	85.1	10.6	-9.0	Natural Snow
94	21-Feb-06	Clariant MP IV Launch (428)	50%	73.2	2.6	-3.4	Natural Snow
103	22-Feb-06	Clariant MP IV Launch (428)	100%	132.3	5.7	-1.6	Natural Snow
104	22-Feb-06	Clariant MP IV Launch (428)	75%	125.0	5.6	-1.6	Natural Snow
115	23-Feb-06	Clariant MP IV Launch (428)	75%	149.7	9.6	-2.1	Natural Snow
124	22-Feb-06	Clariant MP IV Launch (428)	50%	17.0	12.5	-1.7	Natural Snow
131	22-Feb-06	Clariant MP IV Launch (428)	50%	66.4	3.1	-1.6	Natural Snow
136	23-Feb-06	Clariant MP IV Launch (428)	50%	25.1	9.3	-1.4	Natural Snow
139	23-Feb-06	Clariant MP IV Launch (428)	50%	51.8	3.9	-2.2	Natural Snow
144	23-Feb-06	Clariant MP IV Launch (428)	75%	44.6	16.4	-1.2	Natural Snow
145	23-Feb-06	Clariant MP IV Launch (428)	100%	69.2	16.6	-1.1	Natural Snow
160	23-Feb-06	Clariant MP IV Launch (428)	50%	12.1	15.9	-1.2	Natural Snow
174	25-Feb-06	Clariant MP IV Launch (428)	100%	107.0	5.1	-13.7	Natural Snow
175	25-Feb-06	Clariant MP IV Launch (428)	75%	78.6	3.7	-13.6	Natural Snow
185	25-Feb-06	Clariant MP IV Launch (428)	100%	72.3	8.9	-13.6	Natural Snow
186	25-Feb-06	Clariant MP IV Launch (428)	75%	50.2	9.7	-13.7	Natural Snow
187	25-Feb-06	Clariant MP IV Launch (428)	75%	59.3	5.9	-13.2	Natural Snow
188	25-Feb-06	Clariant MP IV Launch (428)	75%	58.8	5.9	-13.3	Natural Snow
189	25-Feb-06	Clariant MP IV Launch (428)	75%	32.5	10.1	-13.6	Natural Snow
194	25-Feb-06	Clariant MP IV Launch (428)	100%	73.5	9.8	-13.6	Natural Snow
205	03-Mar-06	Clariant MP IV Launch (428)	100%	129.6	3.4	-9.1	Natural Snow
206	03-Mar-06	Clariant MP IV Launch (428)	75%	137.1	3.6	-9.1	Natural Snow

Table 3.2: Summary of Tests Performed in 2005-06 (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
9	06-Apr-06	Clariant MP IV Launch	100%	89.3	12.5	-3.2	Freezing Drizzle
10	06-Apr-06	Clariant MP IV Launch	100%	95.0	12.5	-3.2	Freezing Drizzle
11	06-Apr-06	Clariant MP IV Launch	75%	100.5	13.2	-3.1	Freezing Drizzle
12	06-Apr-06	Clariant MP IV Launch	75%	98.0	13.4	-3.1	Freezing Drizzle
13	06-Apr-06	Clariant MP IV Launch	50%	26.8	12.8	-3.0	Freezing Drizzle
14	06-Apr-06	Clariant MP IV Launch	50%	28.8	13.1	-3.0	Freezing Drizzle
41	07-Apr-06	Clariant MP IV Launch	100%	194.5	4.6	-3.2	Freezing Drizzle
42	07-Apr-06	Clariant MP IV Launch	100%	186.5	4.8	-3.2	Freezing Drizzle
43	07-Apr-06	Clariant MP IV Launch	75%	203.0	4.9	-3.2	Freezing Drizzle
44	07-Apr-06	Clariant MP IV Launch	75%	184.2	5.5	-3.2	Freezing Drizzle
46	07-Apr-06	Clariant MP IV Launch	50%	50.5	4.9	-3.2	Freezing Drizzle
801	07-Apr-06	Clariant MP IV Launch	50%	48.0	4.7	-3.2	Freezing Drizzle
71	06-Apr-06	Clariant MP IV Launch	100%	34.3	12.9	-10.3	Freezing Drizzle
72	06-Apr-06	Clariant MP IV Launch	100%	35.0	13.3	-10.3	Freezing Drizzle
73	06-Apr-06	Clariant MP IV Launch	75%	24.3	13.2	-10.5	Freezing Drizzle
74	06-Apr-06	Clariant MP IV Launch	75%	25.5	13.1	-10.5	Freezing Drizzle
93	05-Apr-06	Clariant MP IV Launch	100%	102.5	4.8	-10.1	Freezing Drizzle
94	05-Apr-06	Clariant MP IV Launch	100%	101.8	4.8	-10.1	Freezing Drizzle
95	05-Apr-06	Clariant MP IV Launch	75%	67.0	5.3	-10.4	Freezing Drizzle
96	05-Apr-06	Clariant MP IV Launch	75%	66.2	5.4	-10.4	Freezing Drizzle
115	13-Apr-06	Clariant MP IV Launch	100%	57.0	24.8	-3.1	Freezing Rain
116	13-Apr-06	Clariant MP IV Launch	100%	59.0	25.1	-3.1	Freezing Rain
117	13-Apr-06	Clariant MP IV Launch	75%	44.3	24.2	-3.1	Freezing Rain
118	13-Apr-06	Clariant MP IV Launch	75%	46.5	24.5	-3.1	Freezing Rain
119	13-Apr-06	Clariant MP IV Launch	50%	19.0	25.2	-3.0	Freezing Rain
120	13-Apr-06	Clariant MP IV Launch	50%	17.8	24.7	-3.0	Freezing Rain
145	04-Apr-06	Clariant MP IV Launch	100%	104.5	13.0	-3.3	Freezing Rain
146	04-Apr-06	Clariant MP IV Launch	100%	96.0	13.2	-3.3	Freezing Rain
147	04-Apr-06	Clariant MP IV Launch	75%	79.0	13.0	-3.2	Freezing Rain
148	04-Apr-06	Clariant MP IV Launch	75%	71.5	12.8	-3.2	Freezing Rain
149	04-Apr-06	Clariant MP IV Launch	50%	24.4	13.5	-3.1	Freezing Rain
150	04-Apr-06	Clariant MP IV Launch	50%	21.8	13.2	-3.2	Freezing Rain
175	05-Apr-06	Clariant MP IV Launch	100%	26.5	24.3	-9.9	Freezing Rain
176	05-Apr-06	Clariant MP IV Launch	100%	24.7	24.9	-10.0	Freezing Rain
178	05-Apr-06	Clariant MP IV Launch	75%	24.7	25.9	-10.3	Freezing Rain
800	05-Apr-06	Clariant MP IV Launch	75%	26.2	25.3	-10.4	Freezing Rain
197	05-Apr-06	Clariant MP IV Launch	100%	46.5	12.6	-10.2	Freezing Rain
198	05-Apr-06	Clariant MP IV Launch	100%	45.5	12.7	-10.2	Freezing Rain
199	05-Apr-06	Clariant MP IV Launch	75%	43.5	12.9	-10.2	Freezing Rain
200	05-Apr-06	Clariant MP IV Launch	75%	41.8	13.2	-10.2	Freezing Rain

Table 3.2 (cont'd): Summary of Tests Performed in 2005-06 (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
221	11-Apr-06	Clariant MP IV Launch	100%	>254.0[1]	4.9	-3.2	Freezing Fog
222	11-Apr-06	Clariant MP IV Launch	100%	>253.8[1]	4.9	-3.2	Freezing Fog
223	11-Apr-06	Clariant MP IV Launch	75%	218.0	5.2	-3.2	Freezing Fog
224	11-Apr-06	Clariant MP IV Launch	75%	217.0	5.0	-3.2	Freezing Fog
226	11-Apr-06	Clariant MP IV Launch	50%	85.5	4.7	-3.1	Freezing Fog
806	11-Apr-06	Clariant MP IV Launch	50%	82.5	5.0	-3.0	Freezing Fog
807	11-Apr-06	Clariant MP IV Launch	50%	85.5	4.7	-3.0	Freezing Fog
808	11-Apr-06	Clariant MP IV Launch	50%	87.7	4.9	-3.1	Freezing Fog
253	12-Apr-06	Clariant MP IV Launch	100%	>250.0[1]	1.8	-3.2	Freezing Fog
255	12-Apr-06	Clariant MP IV Launch	75%	>249.3[1]	2.0	-3.2	Freezing Fog
256	12-Apr-06	Clariant MP IV Launch	75%	>248.3[1]	2.0	-3.2	Freezing Fog
257	12-Apr-06	Clariant MP IV Launch	50%	160.3	1.9	-3.0	Freezing Fog
258	12-Apr-06	Clariant MP IV Launch	50%	171.8	2.0	-3.0	Freezing Fog
283	11-Apr-06	Clariant MP IV Launch	100%	57.3	5.3	-14.2	Freezing Fog
284	11-Apr-06	Clariant MP IV Launch	100%	55.5	5.3	-14.2	Freezing Fog
285	11-Apr-06	Clariant MP IV Launch	75%	39.0	5.3	-14.1	Freezing Fog
286	11-Apr-06	Clariant MP IV Launch	75%	39.6	5.4	-14.1	Freezing Fog
305	10-Apr-06	Clariant MP IV Launch	100%	109.7	2.1	-14.3	Freezing Fog
306	10-Apr-06	Clariant MP IV Launch	100%	109.0	2.2	-14.3	Freezing Fog
307	10-Apr-06	Clariant MP IV Launch	75%	74.0	2.2	-14.3	Freezing Fog
308	10-Apr-06	Clariant MP IV Launch	75%	73.0	2.3	-14.2	Freezing Fog
325	10-Apr-06	Clariant MP IV Launch	100%	28.0	5.4	-25.6	Freezing Fog
326	10-Apr-06	Clariant MP IV Launch	100%	27.0	4.8	-25.6	Freezing Fog
337	10-Apr-06	Clariant MP IV Launch	100%	51.7	1.9	-25.4	Freezing Fog
338	10-Apr-06	Clariant MP IV Launch	100%	51.8	1.9	-25.4	Freezing Fog
571	27-Apr-06	Clariant MP IV Launch	100%	14.0	72.2	1.0	Cold Soak
572	27-Apr-06	Clariant MP IV Launch	100%	14.8	73.6	0.9	Cold Soak
573	27-Apr-06	Clariant MP IV Launch	75%	11.0	74.5	0.8	Cold Soak
574	27-Apr-06	Clariant MP IV Launch	75%	10.3	75.3	0.8	Cold Soak
593	27-Apr-06	Clariant MP IV Launch	100%	103.0	4.8	0.7	Cold Soak
594	27-Apr-06	Clariant MP IV Launch	100%	99.3	5.3	0.7	Cold Soak
595	27-Apr-06	Clariant MP IV Launch	75%	104.0	5.2	0.8	Cold Soak
596	27-Apr-06	Clariant MP IV Launch	75%	97.8	5.4	0.9	Cold Soak

[1]Tests stopped when fluid failure had not occurred after 4 hours.

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4. RESULTS AND DISCUSSION

The methods used to evaluate the test data have been reviewed in Subsection 2.6. In this section, the data used to generate the endurance times will be presented.

4.1 Data

Endurance time values, for all conditions, are those of tests conducted in 2005-06. 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 and precipitation on fluid endurance times for each condition. Table 4.1 illustrates the outputs from the regression equations run for this fluid under natural snow, freezing fog, freezing drizzle, freezing rain and cold soak conditions.

4.1.1 Snow Data

As mentioned in Section 3, two samples of Clariant Safewing MP IV Launch were provided for testing. Sample TV428 was submitted for testing early in the winter and was tested in all weather conditions. Sample TV431 was submitted for testing late in the winter and was tested in freezing precipitation but could not be tested in natural snow. The manufacturer selected TV431 to be commercialized as Clariant Safewing MP IV Launch.

Artificial snow tests were completed with TV431 and TV428 to ascertain if their performance in snow was similar. The results (see Figures 4.15 to 4.17) show that TV431 has consistently longer endurance times in artificial snow than TV428. It was deduced that the endurance times of TV431 would also be longer than the endurance times of TV428 in natural snow, and therefore that the endurance time data collected with TV428 in natural snow could safely be used to determined the fluid specific snow HOTs for Clariant Safewing MP IV Launch.

These values will be conservative. The manufacturer intends to test the fluid in natural snow during the winter of 2006-07. The values of Clariant Safewing MP IV Launch will therefore likely increase in the HOT guidelines published for the winter of 2007-08.

A detailed analysis of artificial snow testing conducted with this fluid can be found in the TC report on artificial snow testing for the winter of 2005-06.

4.2 Holdover Time Table

A fluid-specific HOT table for Clariant Safewing MP IV Launch is shown in Table 4.2 at the end of this section.

4.2.1 Holdover Times in Snow, Below -14 to -25°C

In the winter of 2003-04, testing was conducted with artificial snowmakers at temperatures below -14°C. This was done as very limited endurance time data existed for fluids at these temperatures. As a result of this testing, the current propylene Type II and Type IV fluids were given generic values in the -14 to -25°C snow cell. Because no natural snow tests were conducted below -14°C with Clariant Safewing MP IV Launch in the winter of 2005-06, generic values have been used in the -14 to -25°C snow cell.

4.2.2 Fluid Viscosity

The viscosity of the fluid sample used in HOT testing, as measured by APS personnel, appears at the front of this document. The viscosity measurement method is also documented. In order for the fluid specific values of a fluid to be valid, operators must ensure that the viscosity of the fluid used is superior to the published viscosity of that fluid, using the same viscosity measurement method published.

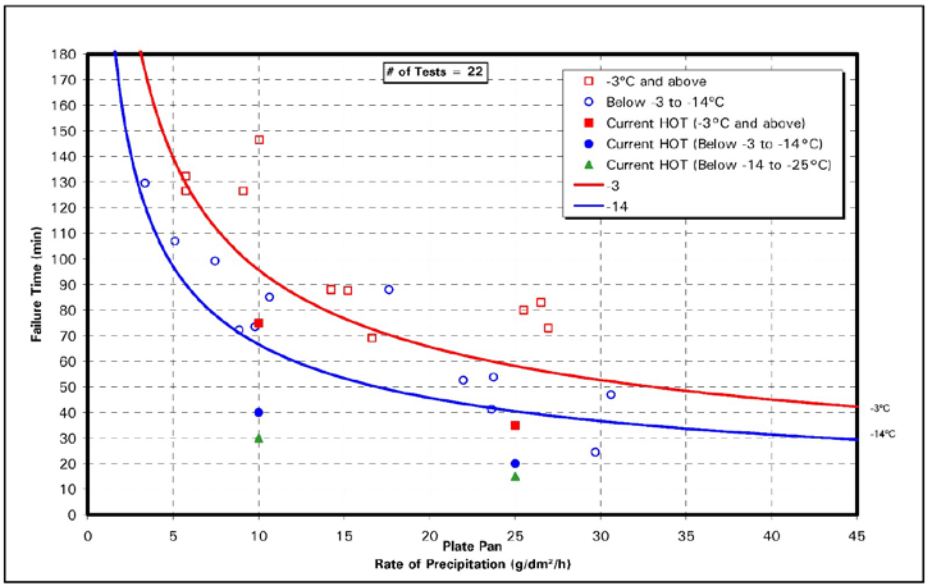


Figure 4.1: Type IV Neat – Natural Snow (Batch #TV428)

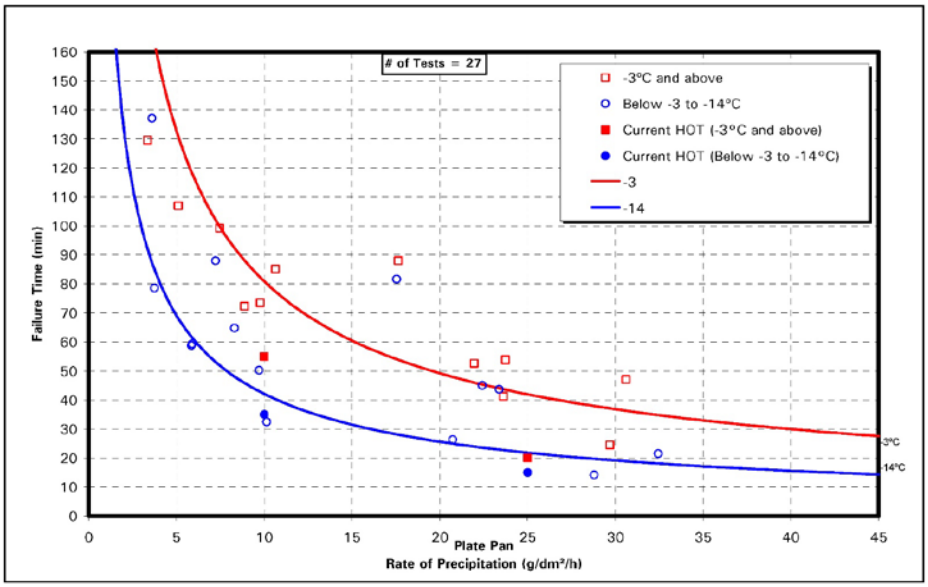


Figure 4.2: Type IV 75/25 – Natural Snow (Batch #TV428)

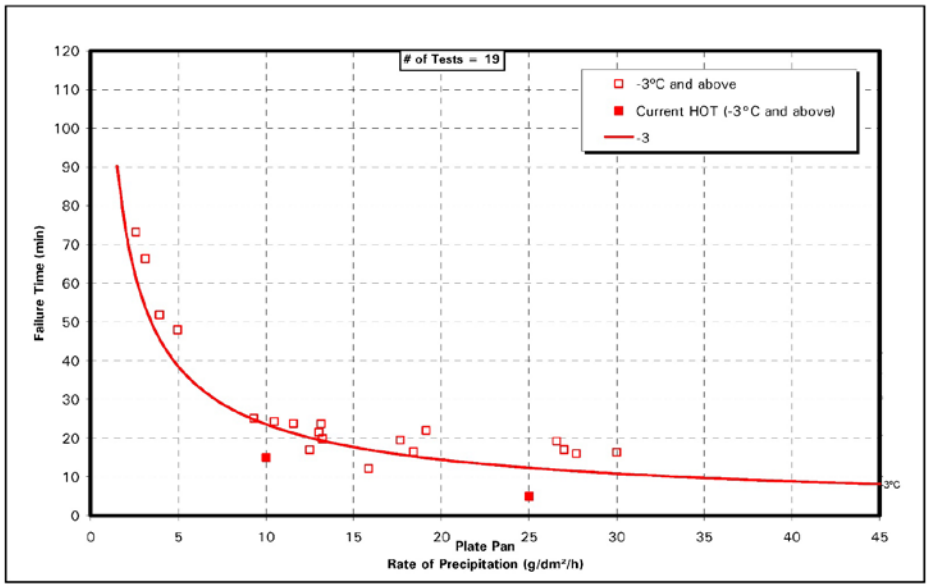


Figure 4.3: Type IV 50/50 – Natural Snow (Batch #TV428)

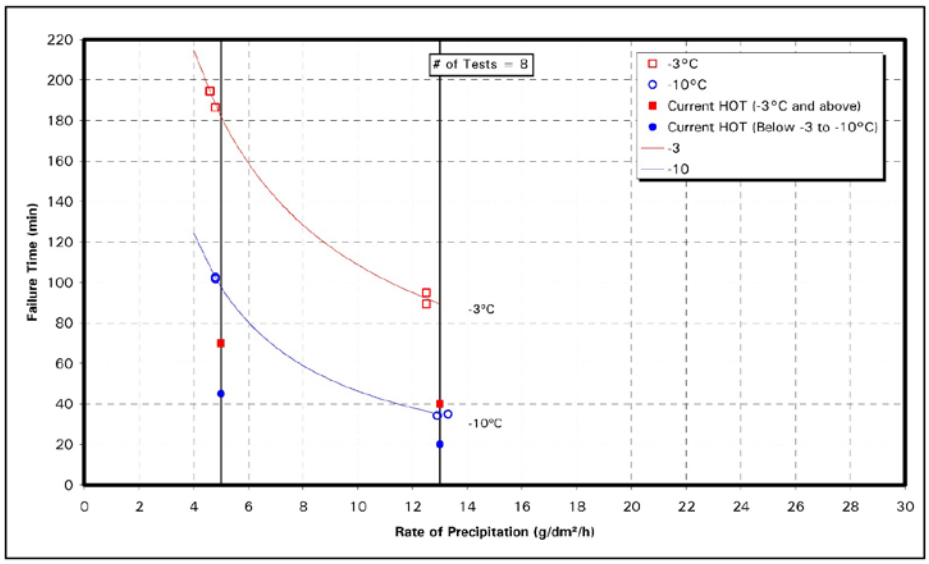


Figure 4.4: Type IV Neat – Freezing Drizzle

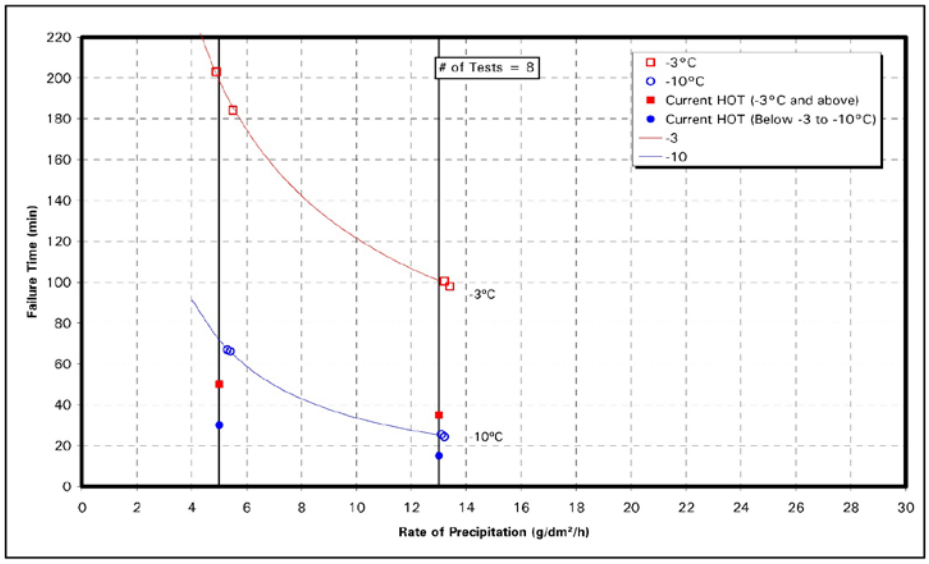


Figure 4.5: Type IV 75/25 – Freezing Drizzle

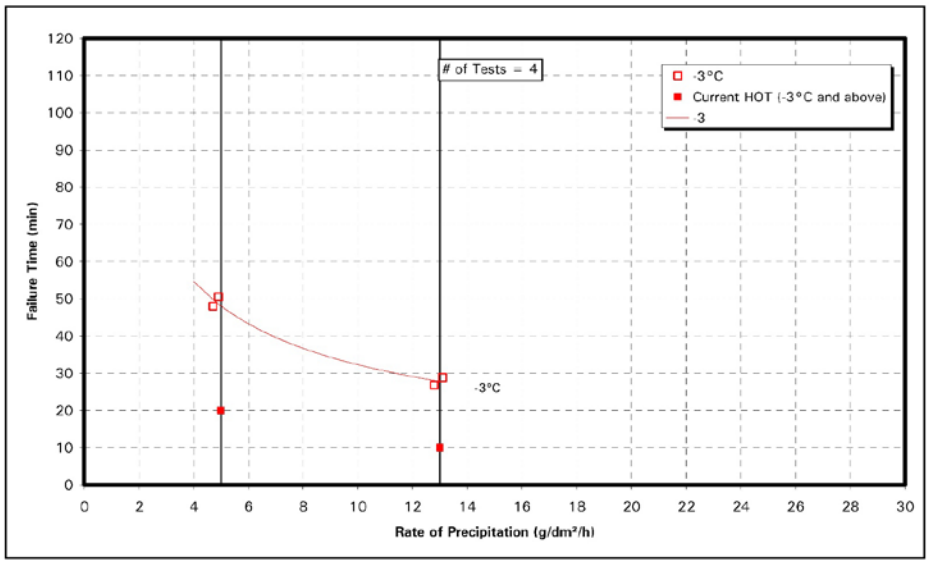


Figure 4.6: Type IV 50/50 – Freezing Drizzle

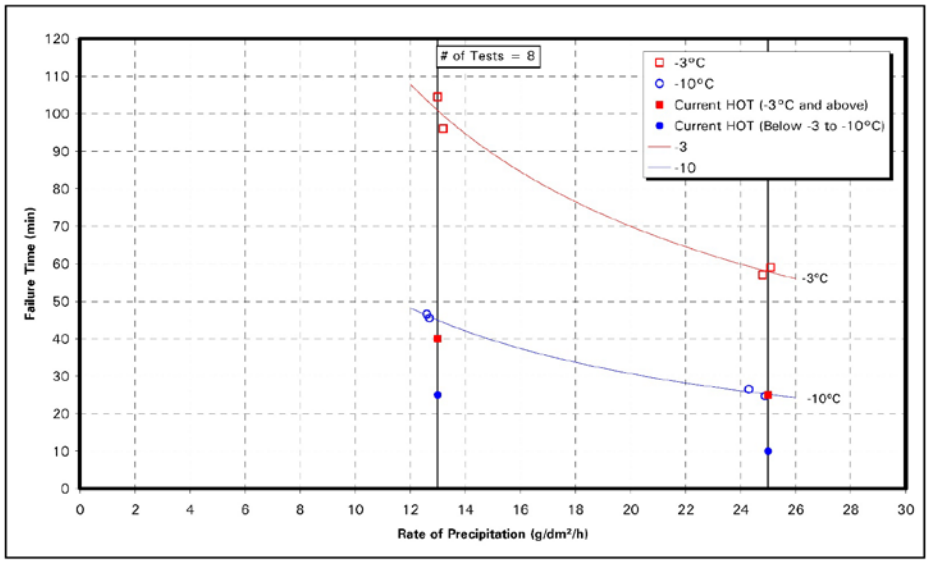


Figure 4.7: Type IV Neat – Light Freezing Rain

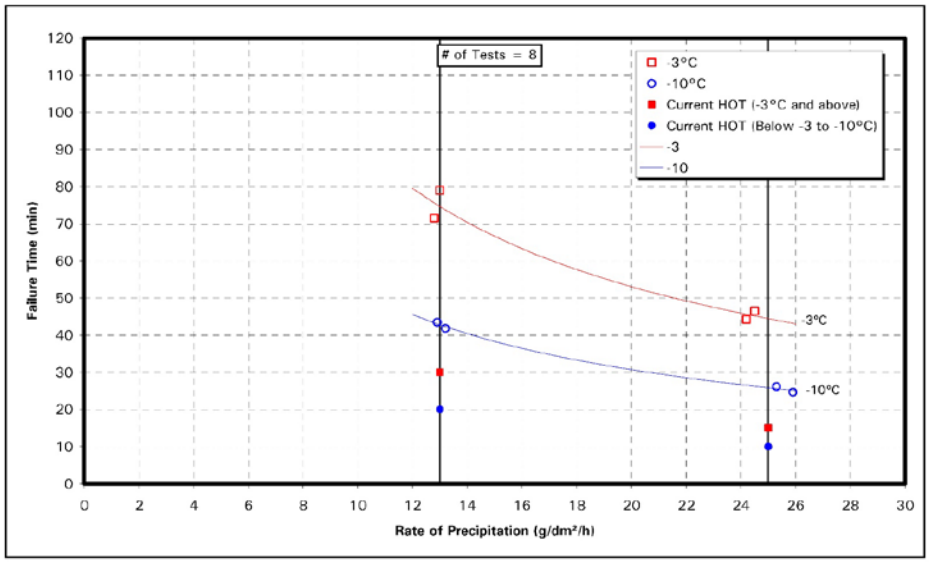


Figure 4.8: Type IV 75/25 – Light Freezing Rain

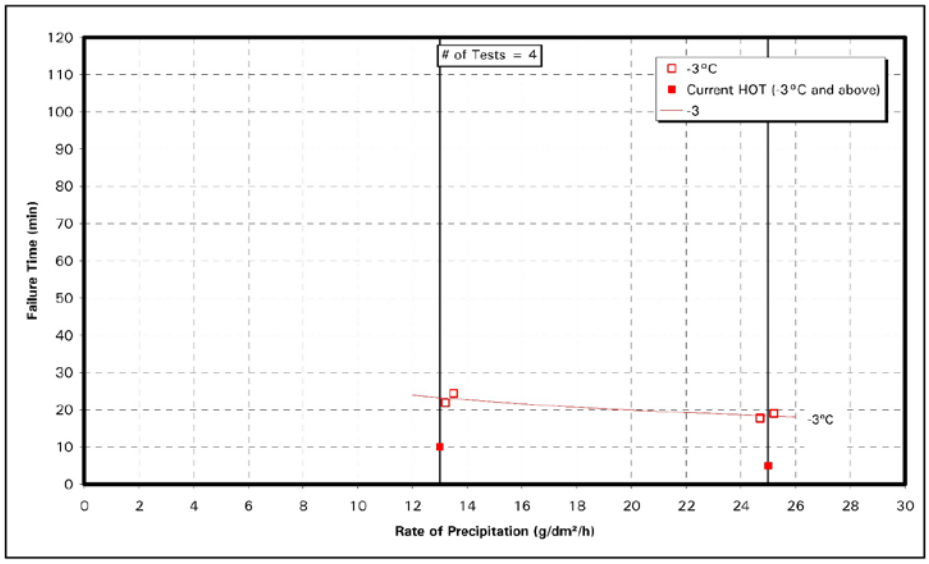


Figure 4.9: Type IV 50/50 – Light Freezing Rain

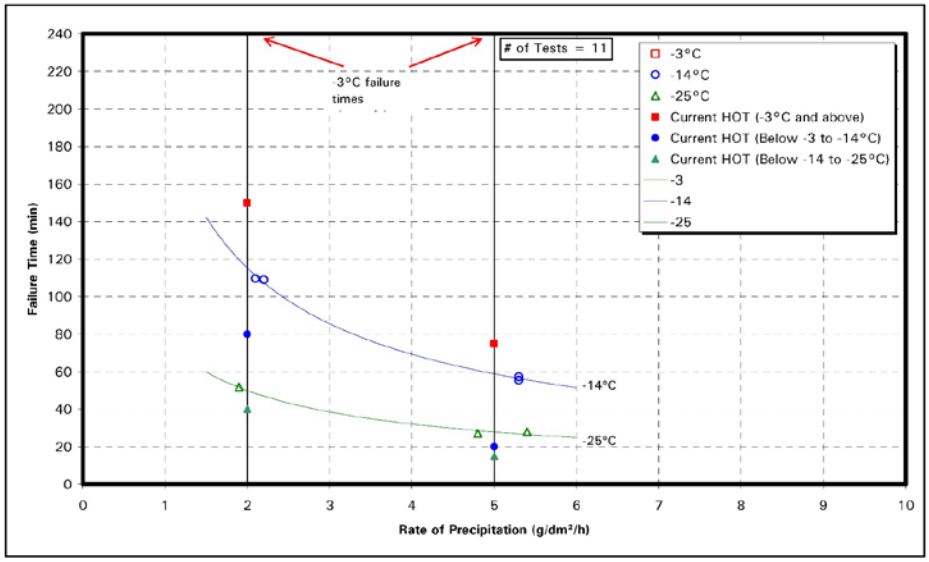


Figure 4.10: Type IV Neat – Freezing Fog

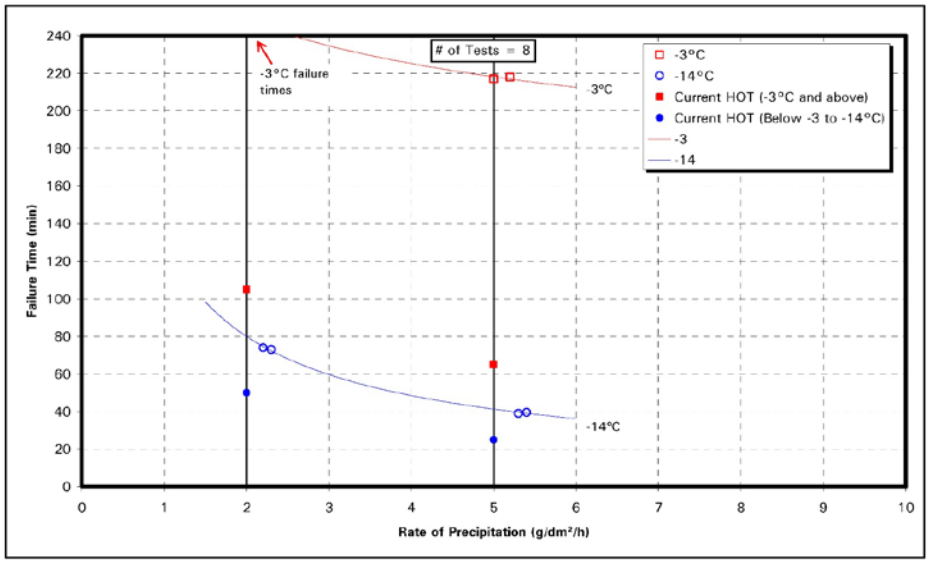


Figure 4.11: Type IV 75/25 – Freezing Fog

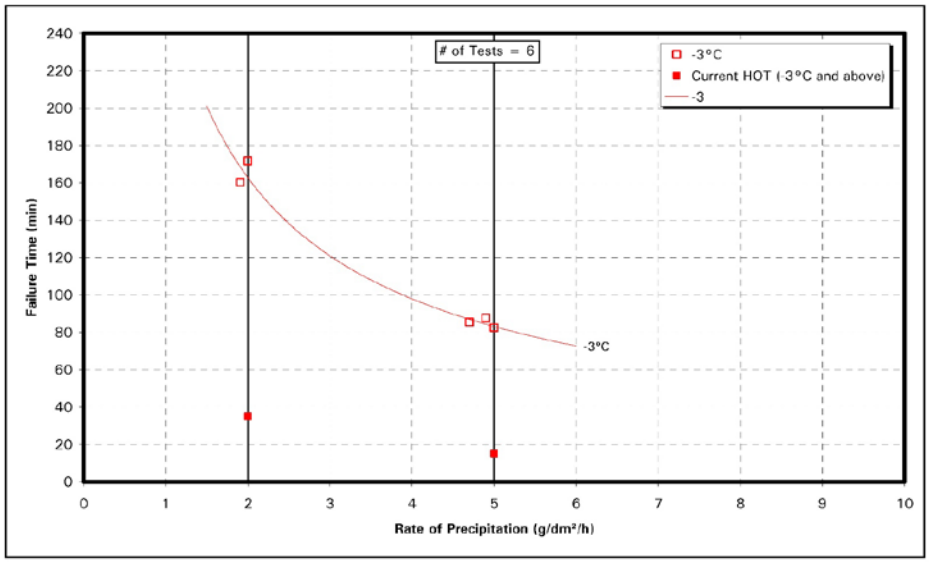


Figure 4.12: Type IV 50/50 – Freezing Fog

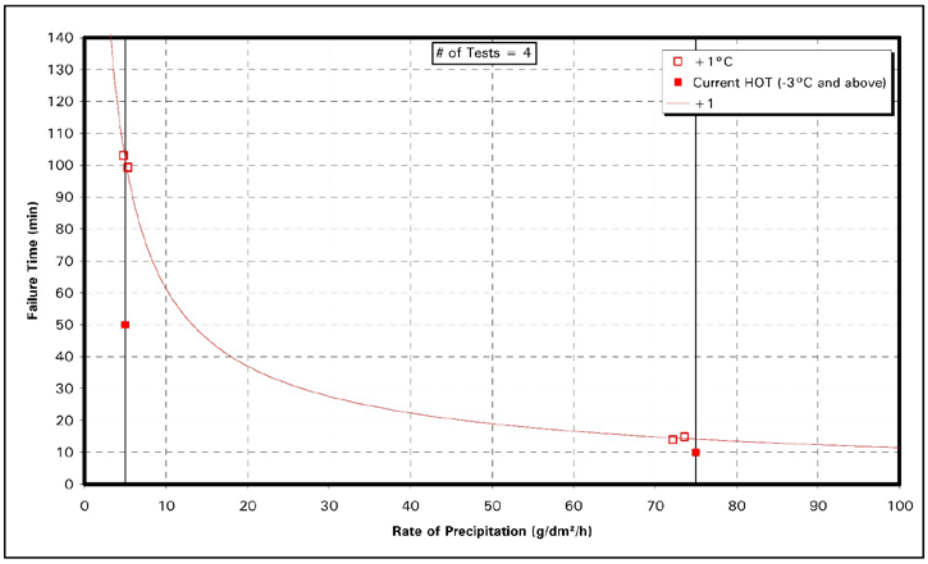


Figure 4.13: Type IV Neat – Rain on Cold-Soaked Surface

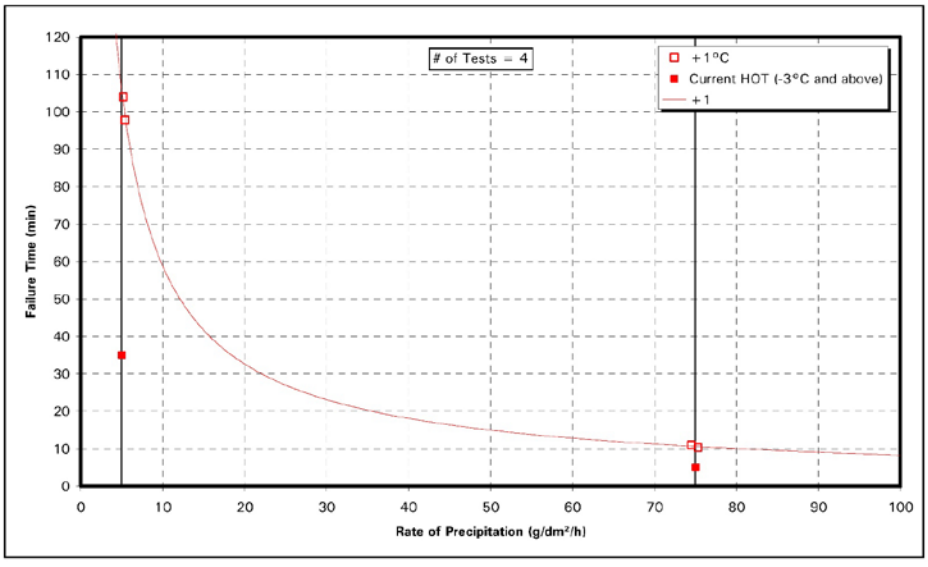


Figure 4.14: Type IV 75/25 – Rain on Cold-Soaked Surface

Table 4.1: Summary of Regression Equation Coefficients for Clariant Safewing MP IV Launch

Natural Snow Conditions

Fluid	Dil	R^2	Intercept I	Coeff. Rate (A)	Coeff. Tem (B)	Total Pts.
Clariant MP IV Launch A	Neat	83%	2.7	-0.54	-0.31	22
Clariant MP IV Launch A	75%	80%	3.0	-0.72	-0.56	27
Clariant MP IV Launch A	50%	86%	2.3	-0.71	-0.30	19

General Equation $t = 10^{I} R^{A} (2\text{-}T)^{B}$

Simulated Freezing Fog

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant MP IV Launch	Neat	100%	-3°C	2.4	0.02	3
Clariant MP IV Launch	75%	100%	-3°C	2.4	-0.14	4
Clariant MP IV Launch	50%	99%	-3°C	2.4	-0.73	6
Clariant MP IV Launch	Neat	100%	-14°C	2.3	-0.73	4
Clariant MP IV Launch	75%	100%	-14°C	2.1	-0.72	4
Clariant MP IV Launch	Neat	98%	-25°C	1.9	-0.63	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant MP IV Launch	Neat	100%	-3°C	2.8	-0.74	4
Clariant MP IV Launch	75%	100%	-3°C	2.8	-0.71	4
Clariant MP IV Launch	50%	98%	-3°C	2.1	-0.57	4
Clariant MP IV Launch	Neat	100%	-10°C	2.7	-1.08	4
Clariant MP IV Launch	75%	100%	-10°C	2.6	-1.09	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant MP IV Launch	Neat	99%	-3°C	2.9	-0.85	4
Clariant MP IV Launch	75%	97%	-3°C	2.8	-0.79	4
Clariant MP IV Launch	50%	84%	-3°C	1.8	-0.36	4
Clariant MP IV Launch	Neat	100%	-10°C	2.6	-0.88	4
Clariant MP IV Launch	75%	100%	-10°C	2.5	-0.77	4

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Clariant MP IV Launch	Neat	100%	+1°C	2.5	-0.73	4
Clariant MP IV Launch	75%	100%	+1°C	2.6	-0.85	4

General Equation $t = 10^{I} R^{A}$

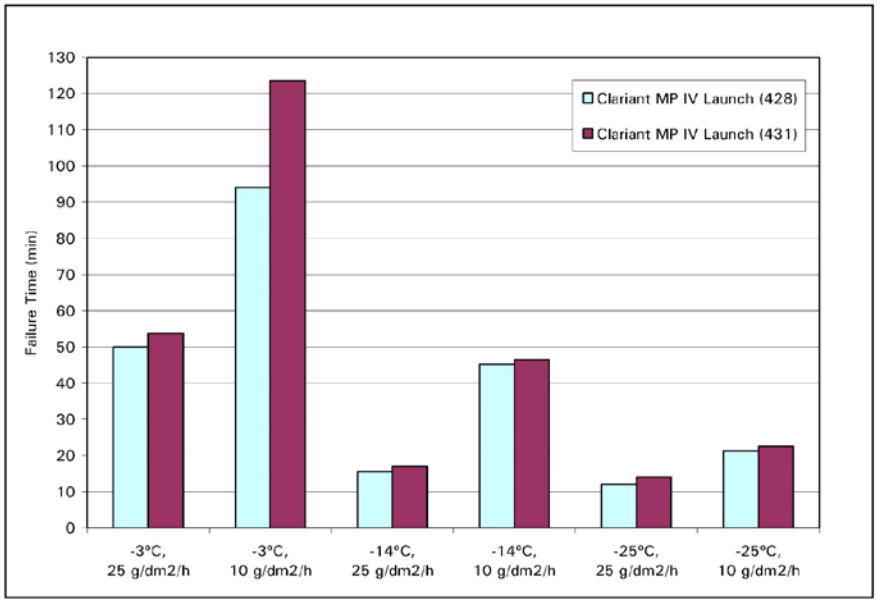


Figure 4.15: Type IV Neat – Artificial Snow

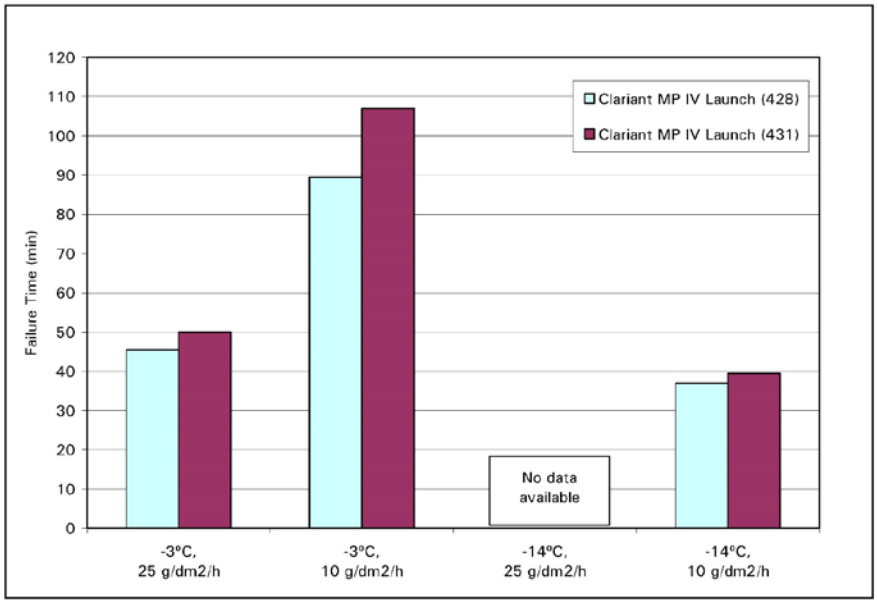


Figure 4.16: Type IV 75/25 – Artificial Snow

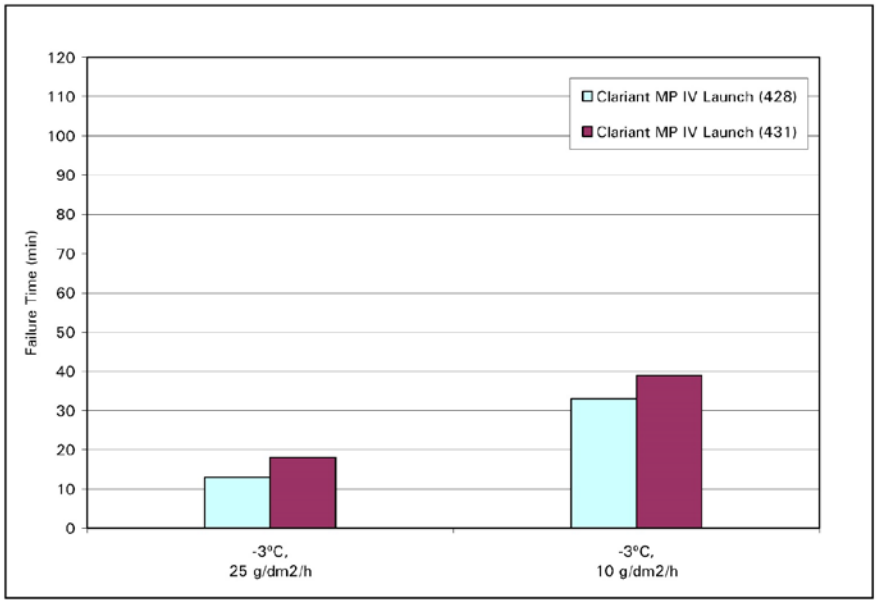


Figure 4.17: Type IV 50/50 – Artificial Snow

Table 4.2: Fluid Specific Type IV Fluid Holdover Time Guidelines

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
SAFEWING MP IV LAUNCH

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	4:00 – 4:00	1:00 – 1:35	1:30 – 2:00	1:00 – 1:40	0:15 – 1:40	
		75/25	5:00	3:40 – 4:00	0:40 – 1:20	1:40 – 2:00	0:45 – 1:15	0:10 – 1:45	
		50/50	3:00	1:25 – 2:45	0:10 – 0:25	0:30 – 0:50	0:20 – 0:25	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	1:00 – 1:55	0:40 – 1:05	0:35 – 1:40[3]	0:25 – 0:45[3]		
		75/25	5:00	0:40 – 1:20	0:20 – 0:40	0:25 – 1:10[3]	0:25 – 0:45[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:30 – 0:50	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

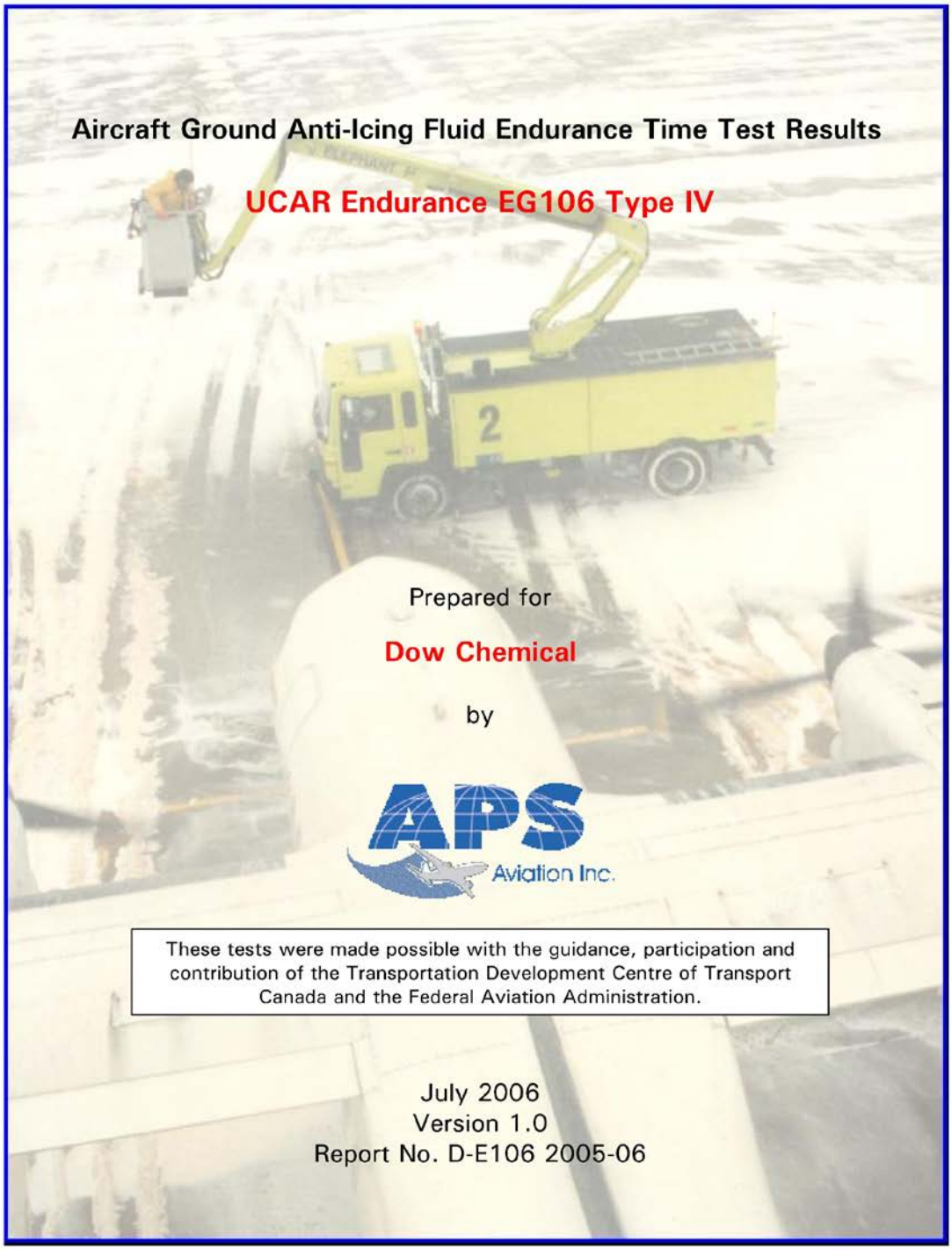
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

APPENDIX G

FLUID MANUFACTURER REPORT:
DOW CHEMICAL UCAR™ ENDURANCE EG106 (TYPE IV)


Aircraft Ground Anti-Icing Fluid Endurance Time Test Results
UCAR Endurance EG106 Type IV
Prepared for
Dow Chemical
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.
July 2006
Version 1.0
Report No. D-E106 2005-06

Aircraft Ground Anti-Icing Fluid Endurance Time Test Results

UCAR Endurance EG106 Type IV

Prepared for

Dow Chemical

Prepared by: Stephanie Bendickson, Project Analyst — July 10, 2006 (Date)

Reviewed by: John D'Avirro, Program Manager, Eng. — July 10, 2006 (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.

July 2006
Version 1.0
Report No. D-E106 2005-06

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer: Dow Chemical

Fluid: UCAR Endurance EG106 Type IV

Fluid Type / Colour: Type IV / Green

Batch #: 200600147-12

Date of Receipt: February 23, 2006

Brix Measured:

Neat fluid:	31.50°
75/25 dilution:	24.00°
50/50 dilution:	17.00°

Viscosity Stated by Manufacturer[1]:

Neat fluid:	28,700 to 30,400 cP
75/25 dilution:	22,600 to 23,400 cP
50/50 dilution:	1,200 to 1,400 cP

Viscosity Measured by APS (Manufacturer Method)[1]:

Neat fluid:	24,850 cP
75/25 dilution:	16,850 cP
50/50 dilution:	350 cP

Viscosity Measured by APS (AIR 9968 Method)[2]:

Neat fluid:	2,230 cP
75/25 dilution:	1,170 cP
50/50 dilution:	20 cP

WSET provided by AMIL:

Neat fluid:	125 minutes

[1]Manufacturer Method: Spindle 31, 10 mL fluid, 0°C, 0.3 rpm, 10 minutes
[2]AIR 9968 Method: Spindle LV1, 20°C, 0.3 rpm, 10 minutes

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SUMMARY

The primary objective of this project was to measure the endurance time performance of UCAR Endurance EG106 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).

The HOT test procedure consisted of pouring fluids onto clean aluminium test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural snow and simulated freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. Endurance time tests were performed at the APS Aviation Inc. (APS) test facility located within the Montréal-Pierre-Elliott-Trudeau International Airport and at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were determined using a multi-variable regression analysis, resulting in the generation of the fluid-specific HOT table shown below. At the request of the fluid manufacturer, values for only the neat fluid were provided.

Dow Chemical UCAR Endurance EG106 Type IV Fluid Holdover Times

Outside Air Temperature		Type IV Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit	Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 and above	27 and above	100/0	12:00	2:05 – 3:10	0:40 – 1:20	1:10 – 2:00	0:50 – 1:15	0:20 – 2:00	
		75/25							
		50/50							CAUTION: No holdover time guidelines exist
below -3 to -14	below 27 to 7	100/0	12:00	1:50 – 3:20	0:30 – 1:05	0:55 – 1:50	0:45 – 1:10		
		75/25							
below -14 to -25	below 7 to -13	100/0	12:00	0:30 – 1:05	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

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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
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
SAE	Society of Automotive Engineers, Inc.
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-icing/anti-icing has been the subject of concentrated industry attention over the past decade due the occurrence of several fatal icing-related aircraft accidents. Recent attention has been placed upon 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 for use by aircraft operators and accepted by regulatory authorities. New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid HOTs without compromising the aerodynamic features of the airfoil.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop and substantiate fluid HOT tables for current fluids and new formulations. Test procedures to measure the duration of fluid protection against ice formation have evolved into a refined Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 5485 that is followed by APS Aviation Inc. (APS).

Testing of aircraft ground de/ant-icing fluids has resulted in the generation of HOT tables. These tables provide guidelines for use in departure planning in adverse winter conditions. They provide the HOT ranges for aircraft treated with any particular qualified deicing or anti-icing fluid.

A new data analysis protocol was developed in 1996-97 wherein the endurance time data for each fluid brand in each cell of the HOT tables was subject to a multi-variable regression treatment. Type II and Type IV fluid HOTs are determined using this method of analysis, resulting in the generation of generic and fluid-specific HOT tables.

This report provides the data and analysis used to determine the fluid HOTs for UCAR Endurance EG106.

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2

2. METHODOLOGY

This chapter contains a description of the tests, equipment and procedures used to conduct endurance time tests. It is divided into sections dealing with the definition of weather, test sites, test conditions, equipment, procedures, and analysis methodology. A 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 was developed by APS for this testing, based upon the requirements of ARP 5485.

2.1 Definition of Weather Conditions

HOTs are provided as a function of weather condition, fluid dilution and outside air temperature. The objective of the winter test program was to develop HOTs for new fluids based on the most recent test data.

Table 2.1 provides definitions of most weather conditions experienced in winter operations and includes the criteria used to determine precipitation intensity (light, moderate, heavy). 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).

Table 2.1 includes definitions for the weather conditions described in the HOT tables (frost, freezing fog, snow, freezing drizzle, light freezing rain and rain). Definitions for snow pellets, hail and ice pellets are also presented, however these are conditions for which HOT guidelines do not exist.

The test methodology used to determine fluid endurance times has included the generally accepted upper and lower limits for precipitation rates for each type of precipitation. These limits were discussed in detail at a 1997 meeting of the SAE G-12 HOT Subcommittee where standard definitions of upper and lower precipitation rate limits were approved for each category of precipitation. These limits are documented and discussed in Subsection 2.6.

2.1.1 Snow

Table 2.1 contains the criteria that were used in the past to estimate the intensity of snow. These criteria are based upon horizontal visibility with three

intensity levels. For light snow, visibility is greater than or equal to 1.0 km, moderate snow visibility is 0.5 km to less than 1.0 km, and heavy snow, visibility is less than 0.5 km.

As stated in a cautionary note in Table 2.1, visibility is only an indicator of snow intensity, and the two parameters are not always correlated.

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 visibility at the earth's surface to less than 1 km (5/8 mile).
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 (23°F), the crystals are generally agglomerated into snowflakes.
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 the ground or other exposed objects.
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 mm (0.02 in.) or smaller drops which, in contrast to drizzle, are widely separated.
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)	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter is about 2-5 mm (0.1-0.2 in.). Grains are brittle, easily crushed; they bounce and break on hard ground.
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is less than 1 mm (0.04 in.). When the grains hit hard ground, they do not bounce or shatter.
HAIL (GR)	Precipitation of small balls or pieces of ice with a diameter ranging from 5 to > 50 mm (0.2 to 2.0 in.) falling either separately or agglomerated.
ICE PELLETS (PE) Note: Includes Sleet and Small Hail	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.) or less. The pellets of ice usually bounce when hitting hard ground.

Intensity Criteria**

Snow(SN),Pellets(CS),Grains(SG),Frz Drizzle(FZDZ)			Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (S) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm or 10.0 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 or 25.0 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 shown that visibility and precipitation intensity are not always directly correlated.

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm 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 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 exposed surface up to a condition where individual drops are easily seen.
Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm 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 pavement and other hard surfaces.
Measured Intensity	More than 0.30 in/hr (7.6 mm 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 spray to height of several inches is observed over hard surfaces.

* 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 Proposed Definition for Liquid Equivalent Snowfall Intensity

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

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP June 17, 1997
(Updated for METAR codes)

Table 2.2 is the visibility table which has been published annually by TC since the winter of 2003-04 for use in winter operations. It is based on more recent data than Table 2.1 and provides more detail about snowfall intensity and visibility. APS, NCAR and TC all had input into the formation of this table, which is based on NCAR field data and theoretical work on classes of snow and on extensive field data compiled by APS. The table categorizes snowfall into one of four intensities based on visibility and lighting condition.

The FAA also publishes a visibility, which differs slightly from the TC visibility table, but is based on the same data set.

Table 2.2: Visibility in Snow vs. Snowfall Intensity Chart[1]

Lighting	Temperature Range		Visibility in Snow (Statute Miles)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1	>1 to 2½	>2½ to 4	>4
	Below -1	Below 30	≤3/4	>3/4 to 1½	>1½ to 3	>3
Daylight	-1 and above	30 and above	≤½	>½ to 1½	>1½ to 3	>3
	Below -1	Below 30	≤3/8	>3/8 to 7/8	>7/8 to 2	>2

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.

2.1.2 Freezing Drizzle

Freezing drizzle is composed of closely spaced fine water droplets with a diameter less than 0.5 mm (see Table 2.1). The intensity of freezing drizzle is estimated, as it is for snow, through the measurement of horizontal visibility.

HOT tables have one column for freezing drizzle; however, Table 2.1 shows three intensity levels (light, moderate and heavy). For example, under moderate freezing drizzle, the rate of precipitation should range between 2.5 and 5.1 g/dm²/h. For heavy freezing drizzle, the definition indicates that the intensity is greater than 5 g/dm²/h. Discussions between United Airlines, NCAR and the National Research Council Canada (NRC) led to the upper limit value of 13 g/dm²/h for freezing drizzle. This value is also used as the lower limit for light freezing rain.

2.1.3 Freezing Rain

This form of precipitation exists either in the form of drops with diameters greater than 0.5 mm, or smaller drops which, in contrast to drizzle, are widely separated. For each of the three intensities of freezing rain given in Table 2.1, a visual description is supplied to provide a subjective guideline for the purpose of estimating rain intensity. However, the following definitions apply when an instrument is available to measure the intensity of precipitation:

- Light Precipitation rate is ≤ 25 g/dm²/h
- Moderate Precipitation rate is >25 g/dm²/h but ≤75 g/dm²/h
- Heavy Precipitation rate is >75 g/dm²/h

2.1.4 Freezing Fog

Freezing fog is defined as suspended minute water droplets that freeze upon impact with the ground or exposed objects. Table 2.1 does not provide any indication of intensity or liquid water content (LWC) of the fog other than that the horizontal visibility is reduced to less than 1 km.

2.2 Test Sites

Normal natural snow test operations are performed at the APS test site located within the Montréal-Pierre-Elliott-Trudeau International Airport. The location of the test site is shown on the plan view of the airport shown in Figure 2.1. Photo 2.1 shows the test site trailer and test stands, the site consists of two trailers and three locations for test stands. The APS test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station (Photo 2.2).

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.

The CEF is partitioned into two sections, separated by an insulated dividing door. Each partition can be separately controlled, permitting different tests to be conducted simultaneously. Photo 2.3 provides a general indication of the size of the facility. Photos 2.4 and 2.5 provide interior images of the small and large ends of the facility. The facility was designed and built for the testing of locomotives. The size of the chamber is 30 m by 5.4 m and its total height is 8 m. The lowest temperature achievable is -46°C.

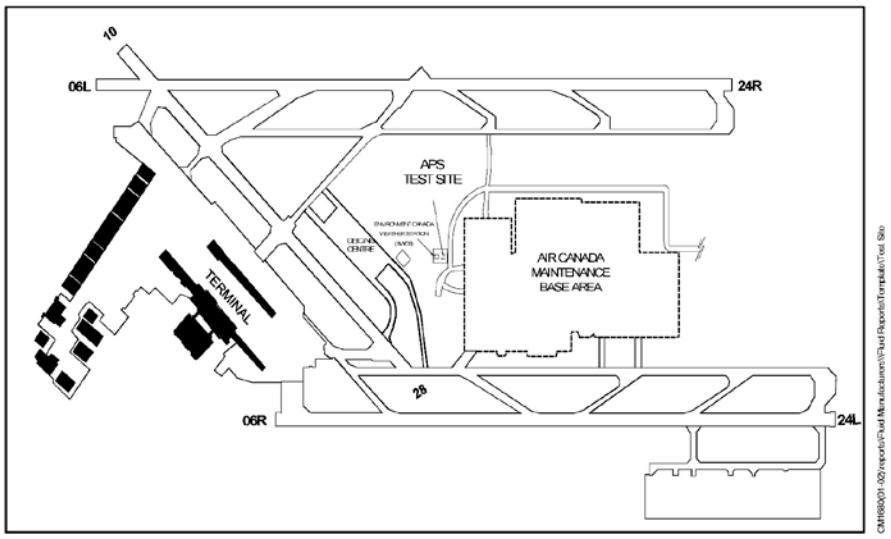


Figure 2.1: Test Site at the Montréal-Pierre-Elliott-Trudeau International Airport

2.3 Test Conditions

Outdoor testing was conducted during natural precipitation events. Supplementary tests to simulate freezing precipitation were carried out at the NRC CEF (see Photo 2.4). Subsections 2.3.1 and 2.3.2 provide descriptions of the spray assembly (see Photo 2.6) and of the methods used to produce and calibrate the fine water droplets in these artificial precipitation tests. Subsection 2.3.3 provides a summary of the categories and characteristics of each precipitation type produced for these tests.

2.3.1 Droplet Size and Rate of Precipitation

In the past few years, more industry attention has been given to the influence of droplet size on HOT. To explore this relationship further, experiments were performed to measure droplet sizes produced by different nozzles (gauge of hypodermic needle) at various water and air pressures in the spray delivery unit. Although the gauge of the needles is an important factor in the production of water droplets with appropriate dimensions, the air and water pressure levels in the sprayer system are equally important.

An improved sprayer assembly was developed in 1997-98 by the NRC and is shown in Photo 2.6. 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 2.7.

Prior to 1995, calibration experiments conducted by the NRC used an optical gauge manufactured by HSS (Biral UK acquired the HSS technology) to verify that the simulation of freezing fog, freezing drizzle, and light freezing rain provided adequate droplet sizes according to ARP 5485.

Since 1995, the APS team using a manual dye-stain technique employed by personnel at the NRC has carried out droplet size calibration. This technique consists of dusting Whatman #1 filter paper discs with a water-activated, very finely-divided powder form of methylene blue dye. The prepared discs are manually positioned under simulated precipitation for a fixed time to acquire a droplet size pattern. A calibration curve is then used to convert the measured diameter of the droplets on the pattern to the experimental median volume diameter (MVD).

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:	Dorval 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.

Figures 2.2 and 2.3 show an example of the distribution of simulated light freezing rain droplets obtained at the NRC.

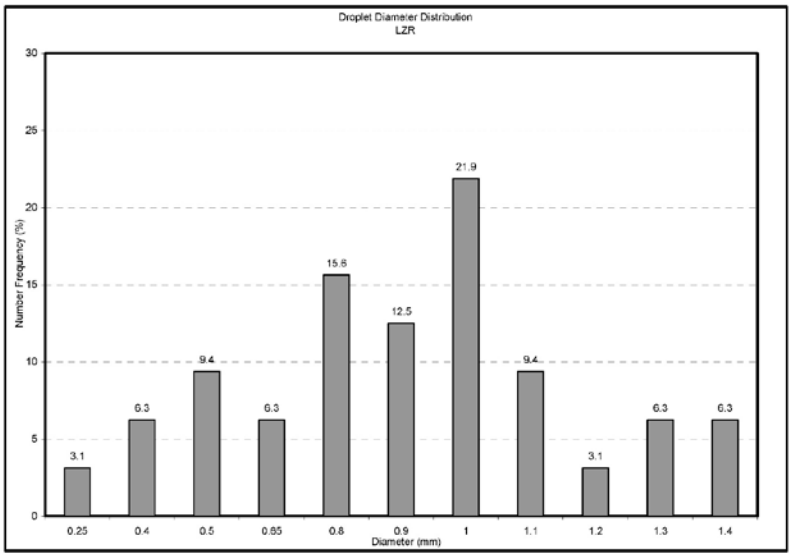


Figure 2.2: Droplet Diameter Distribution, Sample

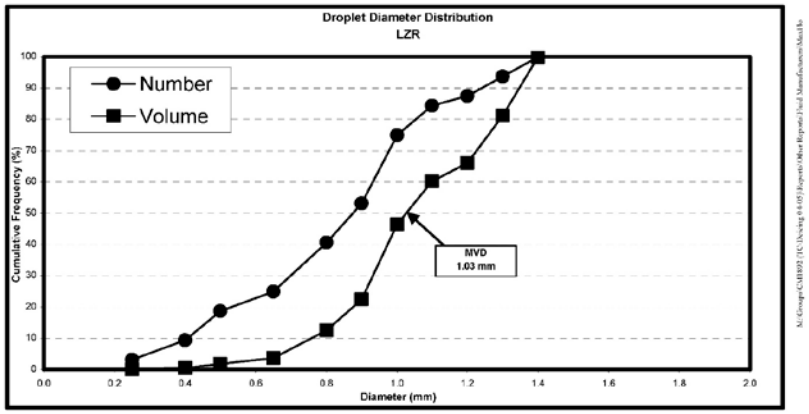


Figure 2.3: Cumulative Frequency of Droplet Diameter, Sample

2.3.2 Median Volume Diameter of Rain Drops

The MVD of a rain droplet was researched and found to be related to the precipitation rate 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 2.3 beside the experimental MVDs for each precipitation condition.

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

2.3.3 Characteristics of 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 were collected:

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

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

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

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

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

4. Moderate Rain on Cold Soaked Surface:
   Precipitation rate: 75 g/dm²/h;
   Droplet median volume diameter: 1 400 μm; and
   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.

2.4 Equipment

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.

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) is in accordance with the requirements set out in the ARP 5485.

Figure 2.4 shows a schematic of the test platform used for in 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.

Figure 2.4 also 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 were marked with 15 crosshairs used in determining whether end conditions (see Subsection 2.5.2 for definition) were achieved. Photo 2.8, taken outdoors at APS test site, shows six test plates mounted on a stand. For simulated freezing precipitation tests at the NRC, 12 plates were mounted on 2 six-position stands, as shown in Figure 2.4.

Figure 2.5 shows the collection (plate) pan, which is of the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.9 shows the collection pans used for measuring precipitation rates indoors at the NRC.

Sealed boxes (7.5 cm deep) were used for simulating a cold-soaked wing (see Figure 2.5). The top of the cold-soak box consists of an aluminium flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate.

Freeze points were measured using a hand-held Misco refractometer with a Brix scale.

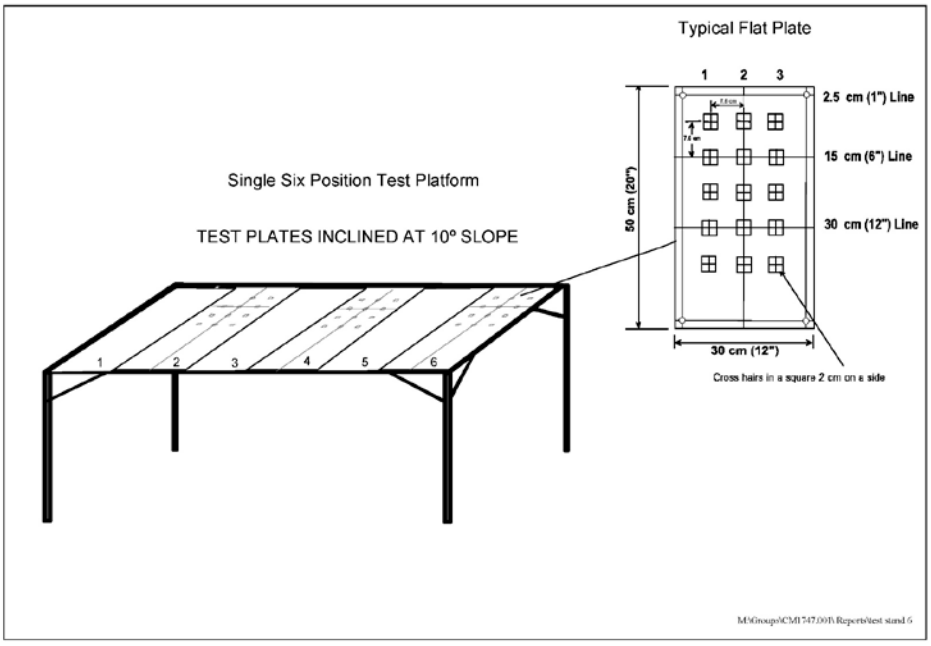
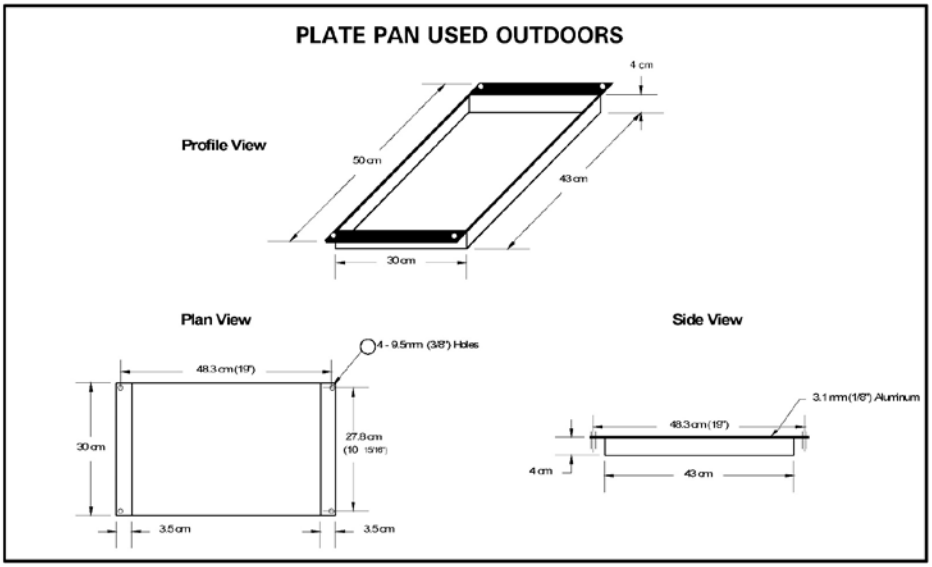
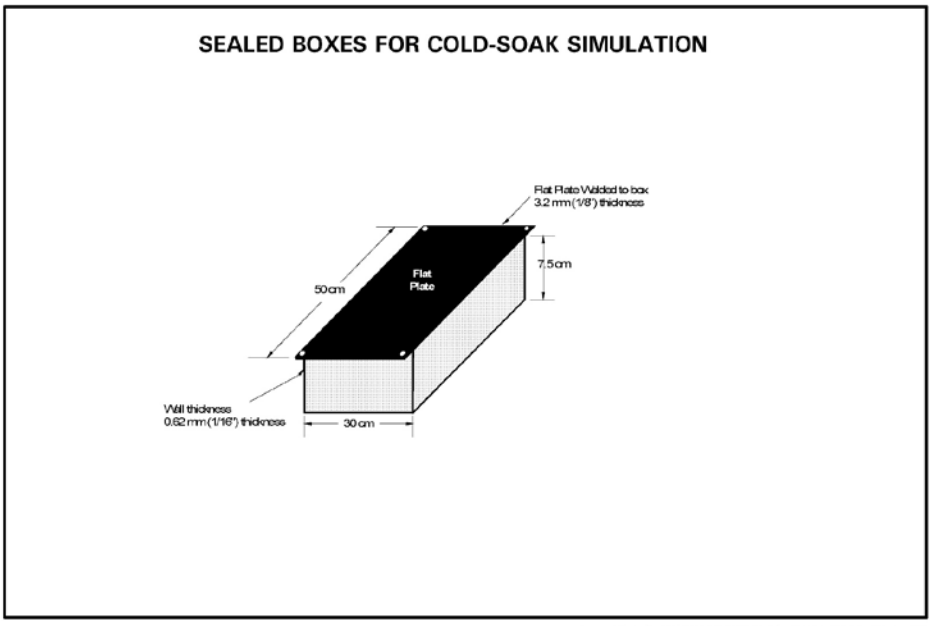


Figure 2.4: Flat Plate Test Set-Up





C:\M980\01-02\Reports\Fluid Manufacturers\Fluid Reports\Template\Pan and Boxes

Figure 2.5: Schematics of Plate Pan and Sealed Boxes

2.5 Test Procedures

Tests consisted of pouring anti-icing fluids directly onto clean test panels (exposed to various winter precipitation conditions) and recording the elapsed time for each crosshair to fail until the test panels reached the defined end condition (see Subsection 2.5.2 below).

2.5.1 Test Protocol (ARP 5485)

A plan 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 was developed by APS, based upon the requirements of ARP 5485. This procedure addresses testing conducted under natural precipitation conditions as well as under simulated freezing precipitation conditions.

Fluids to be evaluated are applied to test plates exposed to natural snow and simulated freezing fog, freezing drizzle, light freezing rain and rain on cold soaked wing. Endurance times are evaluated by measuring the minimum exposure time before a specified degree of freezing occurs.

During the conduct of these tests a series of test parameters are recorded. All test parameters specified in ARP 5485 are addressed in the procedure developed by APS. The test parameters are grouped into two categories: generic and specific test parameters.

Generic test parameters are recorded once per winter season (or test session, in laboratory testing) and include: discussion of safety issues, test plate material, test plate dimensions, surface finish and ice-catch pan dimensions. Specific test parameters are recorded during each testing session (or weather condition, in laboratory testing) and include: angle of the test stand, synchronization of timing devices, plate and ambient temperature profile files, icing intensity, etc.

As per ARP 5485 requirements, the test surface and ambient temperatures were recorded at a minimum sampling rate of one datum per minute. Figure 2.6 presents an example of a typical endurance time test conducted under simulated freezing drizzle conditions. The graph shows the test surface and chamber temperature profiles over the duration of the test and beyond failure time.

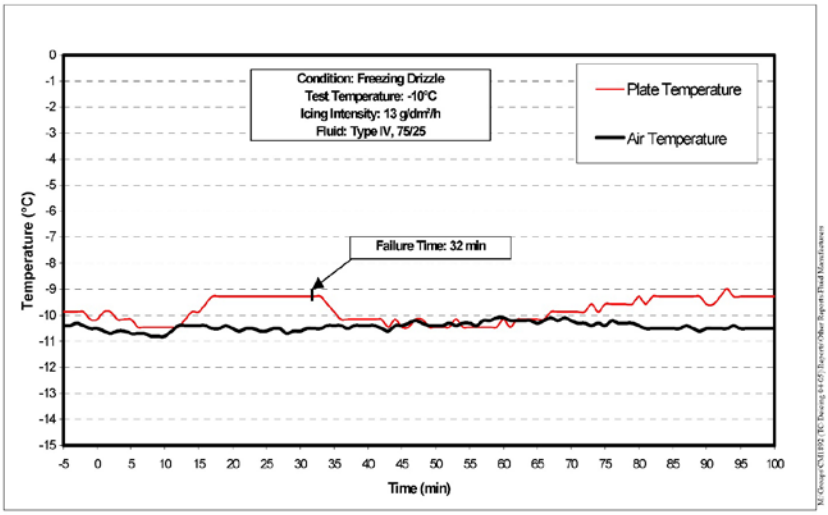


Figure 2.6: Temperature Profiles During a Typical Endurance Time Test

2.5.2 Test Protocol

The SAE G-12 HOT Subcommittee developed the procedure for natural snow flat plate tests.

The major steps in the natural snow flat plate test procedure are:

- Synchronize all timepieces;
- Clean panels and start;
- Apply (pour) fluids to test panels. Type II, Type III, and Type IV fluid are applied at the outdoor ambient temperature. Fluids are poured using a single-step fluid application;
- Record crosshair end condition times;
- Continue testing until at least five crosshairs or 30 percent (1/3) of the plate have failed;
- Record weather conditions; and
- Clean panels and restart.

2.5.3 End Condition Definitions

The test procedures and the determination of defined end conditions evolved from the experience the APS test team has accumulated from previous winter season test programs. Any of the following descriptions provide the general guidelines that observers use to judge when fluid failure occurs and to judge the extent of contamination or failure:

Failure is called when 30 percent (1/3) of the plate is 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.

2.5.4 Precipitation Rate Procedures

2.5.4.1 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 (h: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.

2.5.4.2 Precipitation rate distribution in simulated conditions

Clean test plates are placed on the test stand prior to the rate collection period, and are exposed to the simulated precipitation to verify that an even ice formation occurs over the entire test bed. If this visual inspection proves satisfactory, the rate collection period will begin. If this visual inspection proves unsatisfactory, the test stand must be repositioned under the spray device and the process is then repeated.

In order to verify the rate distribution on the test stand, a continuous rate-monitoring pan is replaced with a detailed rate distribution pan, which consists of 4 small pans of equivalent size. The area of the 4 small pans combined is similar to that of a standard rate collection pan. The small pans are weighed and placed at these locations and re-weighed at fixed intervals. The typical collection period for rate distribution is 60 minutes, however this interval may be shorter if all tests have been completed within 60 minutes. The variation between the rate of any of the 4 small pans and that of the average rate of that location should not be greater than 10 percent.

Two examples of the detailed rate distributions are shown in Table 2.4. Both rate distributions were conducted in freezing drizzle, one at the low rate (5 g/dm^2/h), the other at the high rate (13 g/dm^2/h). The average precipitation rate over the entire position in the low rate example in Table 2.4 was 5.1 g/dm^2/h. The individual rates of the four smaller pans were 5.0, 4.9, 5.2 and 5.3 g/dm^2/h, suggesting a maximum variation of 4.1 percent from the average rate over the entire position.

Table 2.4: Detailed Rate Distribution

Freezing Drizzle (low rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	2-top left	14:02	14:34	81.6	88.8	7.2	31.9	5.0
4	2-top right	14:02	14:34	81.6	88.6	7	31.9	4.9
5	2-bottom left	14:02	14:34	81.8	89.2	7.4	31.9	5.2
6	2-bottom right	14:02	14:34	81.6	89.2	7.6	31.9	5.3

3	4	5		STDDEV
5.0	4.9	-1.4%	-4.1%	0.181
5.2	5.3	1.4%	4.1%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

Freezing Drizzle (high rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	5-top left	12:12	12:43	81.8	98.8	17	30.8	12.3
4	5-top right	12:12	12:43	81.6	98.8	17.2	30.8	12.5
5	5-bottom left	12:12	12:43	81.6	100.2	18.6	30.8	13.5
6	5-bottom right	12:12	12:43	81.6	100.2	18.6	30.8	13.5

3	4	12.9		STDDEV
12.3	12.5	-4.8%	-3.6%	0.631
13.5	13.5	4.2%	4.2%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

CM1B0 (D:\C2)\eport s\Fluid Manufacturers\Fluid Reports\Template\Detailed Rate Distribution

2.5.4.3 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) from the timepiece located near the rate station before leaving the trailer to place the pans on the test stand. The person responsible for collecting precipitation rate data take the time delay necessary to proceed outside from the rate station into consideration.

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.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.7. Typically, two collections pans are used for each test. The start and end times of the test are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t_1, t_2, and t_3 (minutes). The calculated rates for each collection period are indicated by R_1, R_2, and R_3 (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 2.4, 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.

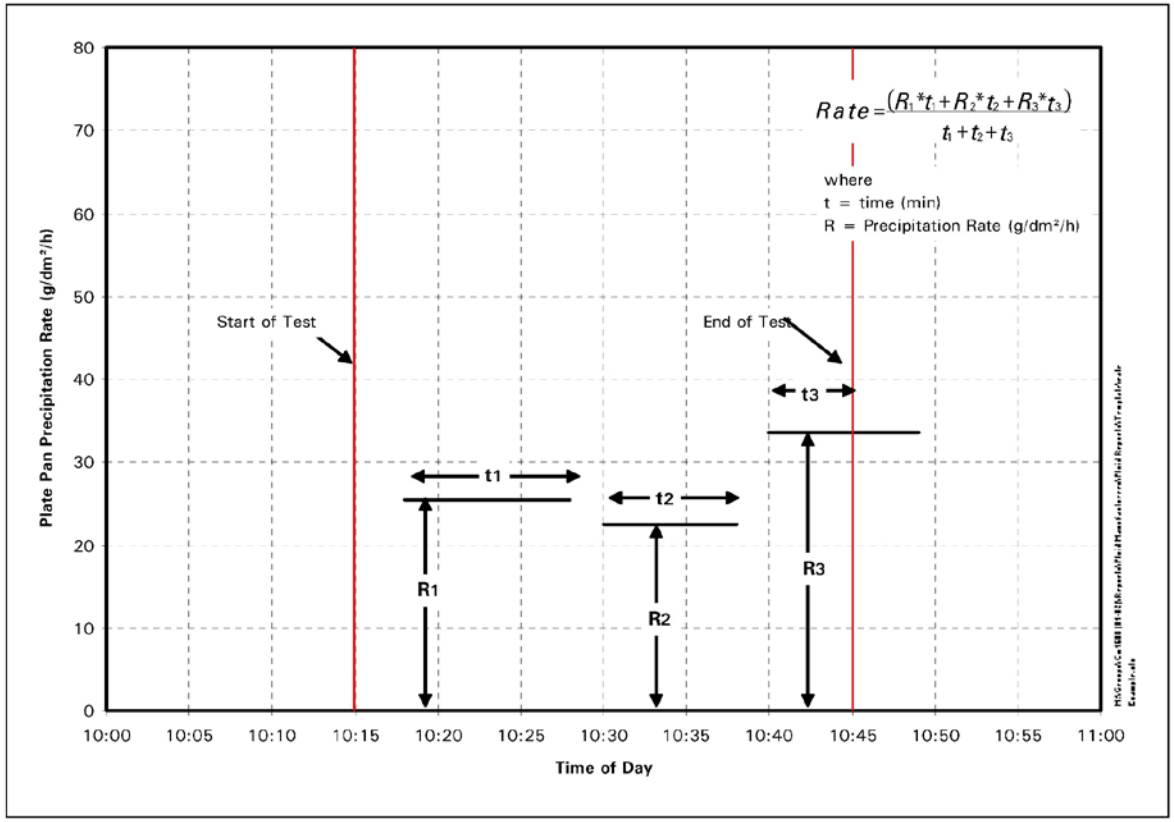


Figure 2.7: Calculation of Outdoor Precipitation Rate

2.6 Analysis Methodology

2.6.1 General

This section of the report describes the various categories of precipitation and the precipitation rate limits used during the course of endurance time testing. The process of data analysis used in the determination of fluid HOTs is also described.

2.6.2 Descriptions of Data Ranges and Precipitation Definitions

The test program developed to measure fluid failure times was carried out under five general categories of precipitation:

- Natural snow;
- Freezing drizzle;
- Light freezing rain;
- Freezing fog; and
- Rain on a cold-soaked surface.

Tests were conducted over temperature and precipitation rate ranges specific to each category of precipitation. A multi-variable regression procedure was used to evaluate fluid HOTs (first presented in TC report, TP 13131E) and is based on the refinement of an equation for a curve which best represents the fluid failure time test data, and then solving that equation at the upper and lower limits of a defined precipitation range. To support this procedure, precipitation rate limits for each specific category of precipitation were defined, reviewed and approved.

The precipitation rate limits used for the evaluation of HOT's are represented schematically in Figure 2.8. Detailed definitions and explanations of the data types and ranges are described in the following subsections. Meteorologically accepted definitions of these conditions were outlined in Table 2.1.

2.6.2.1 Natural snow

All fluid failure tests in natural snow were conducted at the APS Dorval Airport test site. Data were collected for precipitation rates that ranged from less than 4 g/dm²/h to greater than 25 g/dm²/h. For Type II and Type IV fluids, upper and lower limits for the snow column were set at rates of 10 and 25 g/dm²/h, respectively.

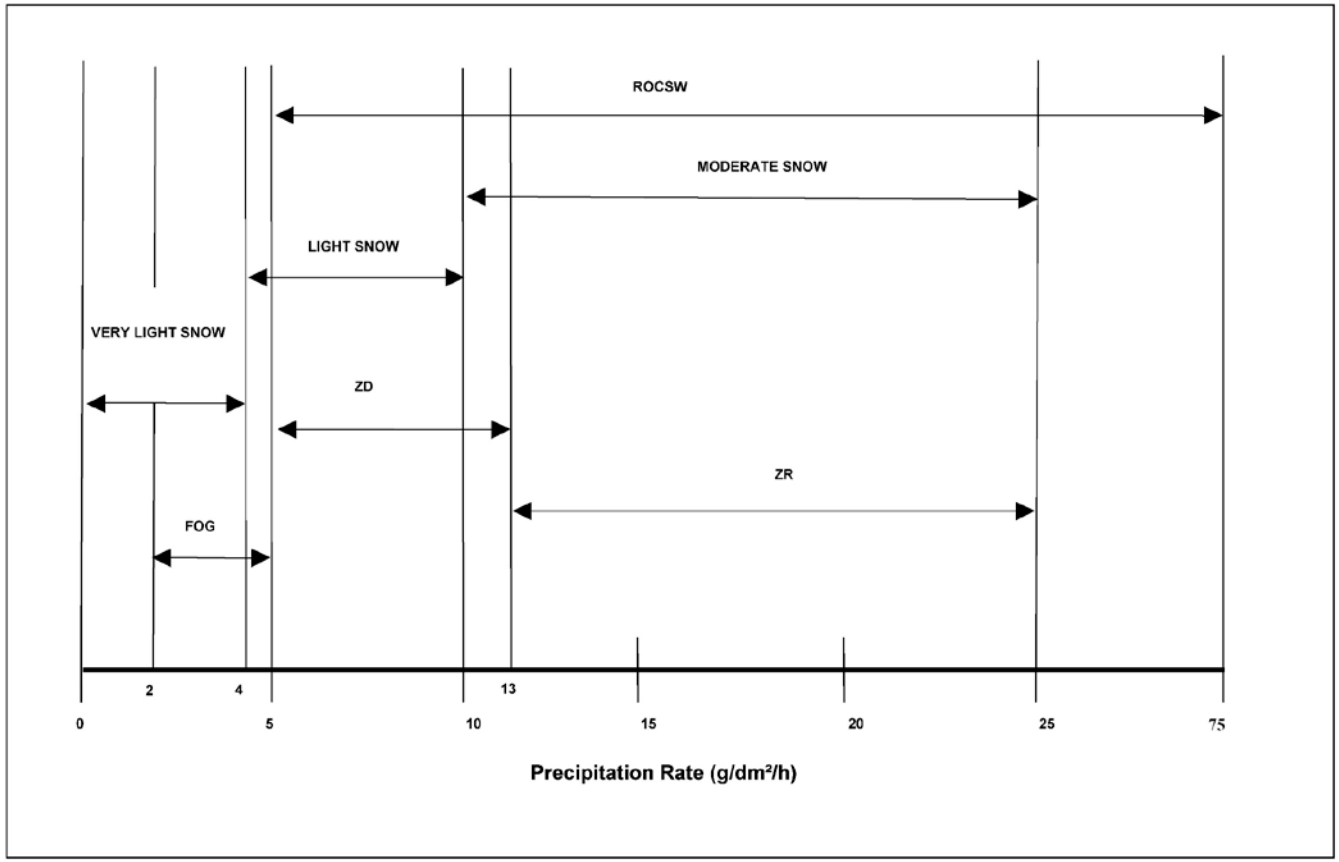


Figure 2.8: Data Range Used for Evaluation of Holdover Time Limits

The upper precipitation rate limit (25 g/dm^2/h) corresponds to the onset of heavy snow. Above this rate, it is standard practice to refer to the cautionary note included in the HOT tables indicating that the time of protection will be shortened in heavy weather conditions, (i.e., heavy precipitation, or high moisture content).

2.6.2.2 Freezing drizzle

Freezing drizzle is considered to occur over the range of 0 to 13 g/dm^2/h. The upper limit in this range, while not specifically defined in Table 2.1, has been adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Subcommittee.

For test purposes, the precipitation rate spectrum for freezing drizzle is constrained to rates between 5 and 13 g/dm^2/h, inclusively. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety. A caution note is included in the HOT tables indicating that if positive identification of freezing drizzle is not possible, the light freezing rain HOT is recommended for use.

2.6.2.3 Light freezing rain

With reference to the HOT tables, freezing rain conditions span the range of precipitation rates from 13 to 25 g/dm^2/h, inclusively. This range falls in 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.

2.6.2.4 Freezing fog

The precipitation rate limits for freezing fog were arrived at with input from meteorologists from the NRC, 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.

The precipitation rate for fog, referred to as *fog deposition* or simply as *deposition*, is given by the empirical expression,

$$\textbf{\textit{Deposition = LWC x Wind Velocity x Sin 10° x Collection Efficiency}}$$

where the Sin 10° term accounts for the 10° inclination of the test plates into the direction of the wind.

The meteorological circumstances (LWC value and wind speed), and the speed and orientation of the airfoil relative to the wind (stationary or taxiing), contribute to uncertainties in the values that the variables in the equation can assume.

Since 1997, the upper and lower HOTs for freezing fog have been evaluated at rates of 5 g/dm^2/h and 2 g/dm^2/h, respectively. In Vienna, during the 1998 SAE G-12 HOT Subcommittee meeting, it was felt that 2 g/dm²/h was not indicative of low rate natural fog. However, during a meeting of the Workgroup on Laboratory Methods to Derive HOT Guidelines in Montreal in March 1999, it was again agreed upon that the rate of 2 g/dm^2/h would be used in subsequent HOT testing in order to determine the upper HOT limit in freezing fog conditions.

2.6.2.5 Rain on a cold-soaked surface

Data used for the evaluation of HOTs for this category of precipitation were limited to precipitation rates ranging from 5 to 75 g/dm^2/h, which 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). The heavy rain category is covered by the caution note at the bottom of the HOT table regarding heavy weather conditions.

2.6.3 Protocol for the Determination of Holdover Times

Each cell in a HOT table represents a range of time during which a fluid at a specified concentration will provide protection for a particular temperature range in a particular category of precipitation. The Type II and Type IV HOT tables are composed of a maximum of 30 cells. Each cell contains a lower and upper time limit (except in frost) for a maximum of 54 time values.

Cell HOT values are determined by plotting *Failure Time* versus *Rate of Precipitation* and recording the failure time at two pre-selected rate limits. In previous years, several protocols were employed in the determination of HOTs. Due to the subjective natures of these different protocols, different interpretations of the data were possible. A multi-variable regression approach was subsequently devised in 1996/97 (see TC report, TP 13131E) and has since been used to evaluate fluid holdover times.

Data corresponding to each cell in the HOT table were assembled and sorted according to precipitation type, fluid dilution and temperature range. The data for each cell in the HOT table were plotted.

The data points on each plot were used to fit an equation of the form:

$$t = cR^a$$

where

t = Time (minutes)
R = Rate of precipitation (g/dm^2/h)
a,c = coefficients determined from the regression.

The coefficient a gives the rate dependency of the failure time.

Sample plots of **Log t** versus **Log R** are shown in Figure 2.9. The plots contain data from one temperature range, for one Neat Type IV fluid 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 2.10. 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 snow.

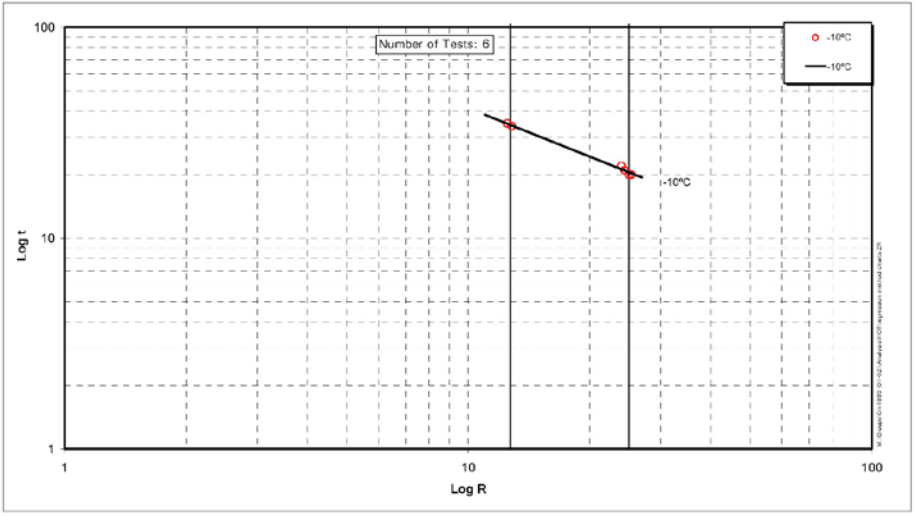


Figure 2.9: Regression Method on Log-Log Chart – Sample Type IV Neat, Freezing Rain

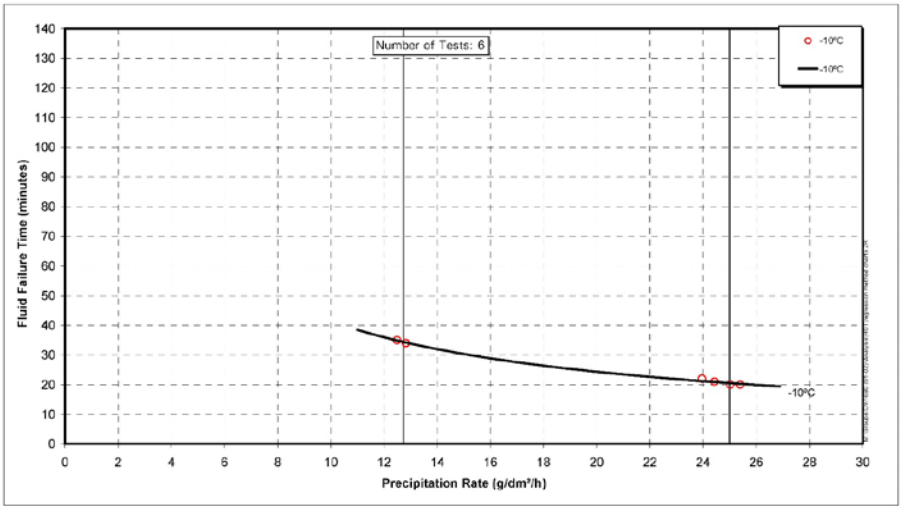


Figure 2.10: Regression Method on Standard Chart – Sample Type IV Neat, Freezing Rain

The HOTs for this fluid at -10°C are 20 minutes at 10 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

The categories of precipitation are separated into five groups: natural snow, freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface. Each group was subject to a slightly modified version of the general equation given above, as described in the following subsections.

2.6.3.1 Light freezing rain and freezing drizzle

The equation used to treat the data in these categories of precipitation is given by the expression below:

$$t = cR^a$$

- Tests in freezing drizzle and light freezing rain were conducted at predetermined temperature limits (-3 and -10°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were also obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.2 Simulated freezing fog

The equation used to treat freezing fog data is given by the expression below:

$$t = cR^a$$

- Tests in freezing fog were conducted at predetermined temperature limits (-3, -14 and -25°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.3 Natural snow

The general form of the regression equation was modified for natural snow by substituting 2-T for the variable T, in order to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C.

$$t = cR^a(2-T)^b.$$

- Best-fit curves were plotted for each fluid in each cell of the snow column using the most restrictive (lowest) temperature for that cell. For example, in cases of natural snow tests conducted at ambient temperatures above -3°C, the value of temperature used in the fitting procedure was -3°C.

- The upper and lower HOT values were determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively.

2.6.3.4 Rain on a cold-soaked wing

The same method for the evaluation of HOTs in light freezing rain and freezing drizzle was used for this category of precipitation.

2.6.4 Determination of Generic and Fluid Specific Holdover Times

At the SAE HOT Subcommittee meeting in Chicago in July 1997, Type IV fluid HOTs obtained using the multi-variable regression protocol of data analysis were presented. Wide variations in fluid performance among the different Type IV fluid brands forced the development of generic Type II and IV HOT tables as well as fluid-specific Type II and IV HOT tables.

2.6.4.1 Fluid-specific holdover time tables

Fluid-specific HOT table development was prompted by the fact that certain Type IV fluid brands were observed to significantly outperform other fluids under conditions corresponding to specific cells in the HOT tables. In general, any one fluid brand does not globally outperform the other fluid brands, but rather does so at a specific dilution, temperature range, and/or category of precipitation.

At the Chicago meeting in 1997, most members of the SAE G-12 HOT Subcommittee did not favour fluid-specific tables. However, significant reductions to HOTs for the cells corresponding to the most common Type IV fluid usage convinced the committee of the need to consider the development of fluid-specific and generic tables. Furthermore, some members wanted to take advantage of the significant benefits exhibited by some fluids in certain conditions.

A summary of the steps to follow to determine fluid-specific values for a Type II or IV fluid is provided below:

- The method used to determine HOTs is generally the same as was agreed upon in Chicago in 1997 at the SAE G-12 HOT Subcommittee meeting;
- For each cell of the HOT tables, four tests are typically conducted at the lowest temperature in the temperature range for that cell. Two tests are conducted at the low precipitation rate condition and at the high precipitation rate condition, for a total of four tests per cell;
- For each cell of the HOT table (except frost), a best-fit power law curve for each fluid is developed from the tests conducted at the low and high precipitation rate condition of that cell;
- Regression-generated HOTs are rounded off to the nearest whole "5" digit. For example, 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 HOTs are below 10 minutes, the numbers are rounded down as a precautionary measure. For example, 9 minutes is rounded down to 5 minutes; and
- Values are capped at 2 hours for all precipitation conditions except freezing fog, which are capped at 4 hours.

Photo 2.1: View of Test Site and Associated Equipment



Photo 2.2: Meteorological Services of Canada Weather Observation Station at Montréal-Pierre-Elliott-Trudeau International Airport



Photo 2.3: Outdoor View of National Research Council Climatic Engineering Facility



Photo 2.4: Inside View of Small End of Climatic Engineering Facility



Photo 2.5: Inside View of Large End of Climatic Engineering Facility



Photo 2.6: Sprayer Assembly Used at National Research Council

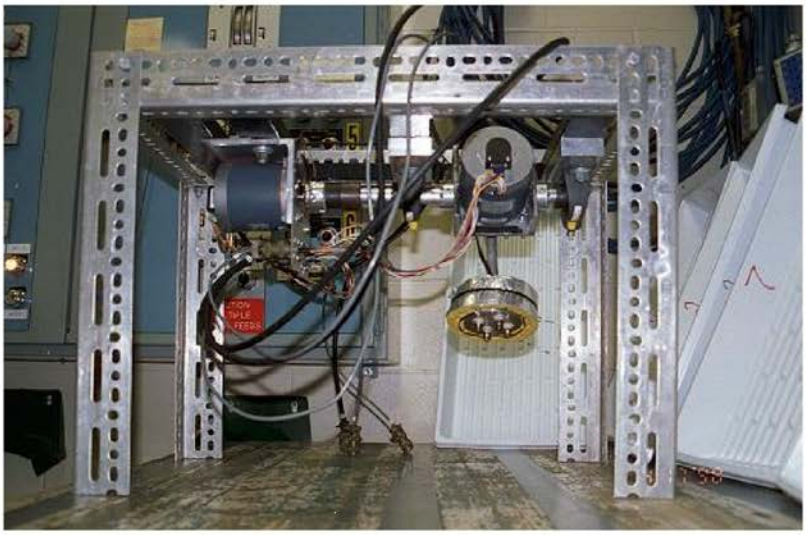


Photo 2.7: Sprayer Nozzle

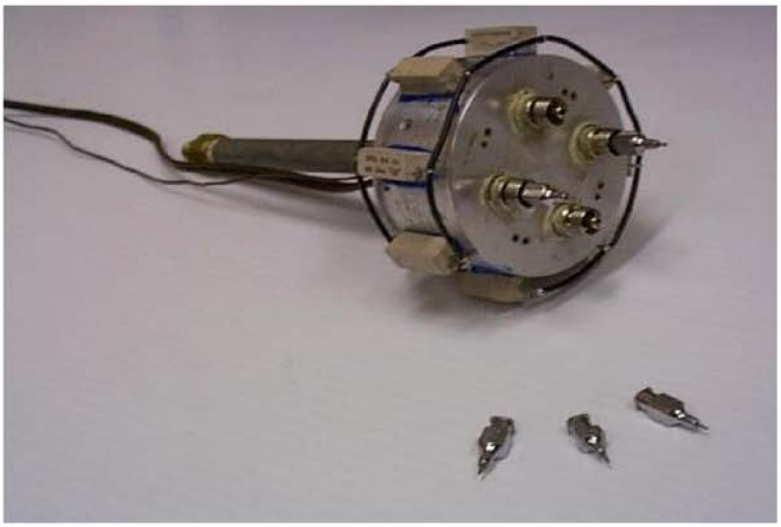


Photo 2.8: Test Plates Mounted on Stand



Photo 2.9: Collection Pans Used Indoors at the National Research Council



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted in natural snow, simulated light freezing rain, simulated freezing drizzle, simulated freezing fog, and rain on cold-soaked surfaces. Breakdowns are provided for quantity of tests performed by fluid type and temperature.

Summaries of the tests conducted in natural snow and in freezing precipitation are provided in Tables 3.1 and 3.2 at the end of this section.

3.1 Natural Snow Tests

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

	Above -3°C	-3 to -14°C	-14 to -25°C	Total
Neat	3	9	0	12
75/25	5	12	0	17
50/50	9	1	0	10
				39

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 the tests conducted is summarized below by 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 condition at the NRC CEF. The breakdown of the 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	6	0	0

3.4 Rain on Cold-Soaked Surface Tests

Cold-soak tests were conducted with Neat and 75/25 dilutions using 7.5 cm deep sealed boxes. Tests were conducted at an ambient temperature of +1°C at the NRC CEF. Duplicate tests were conducted with each dilution at each precipitation rate.

3.5 Fluid Thickness Tests

The purpose of these tests was to measure the film thickness profiles of the fluid in all dilutions, under dry conditions.

Two tests were performed for each standard dilution (Neat, 75/25 and 50/50). For each test, one litre of fluid was poured onto a flat plate mounted on a test stand inclined 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. Tests were conducted at an ambient temperature of -3°C.

The results are displayed in Figure 3.1.

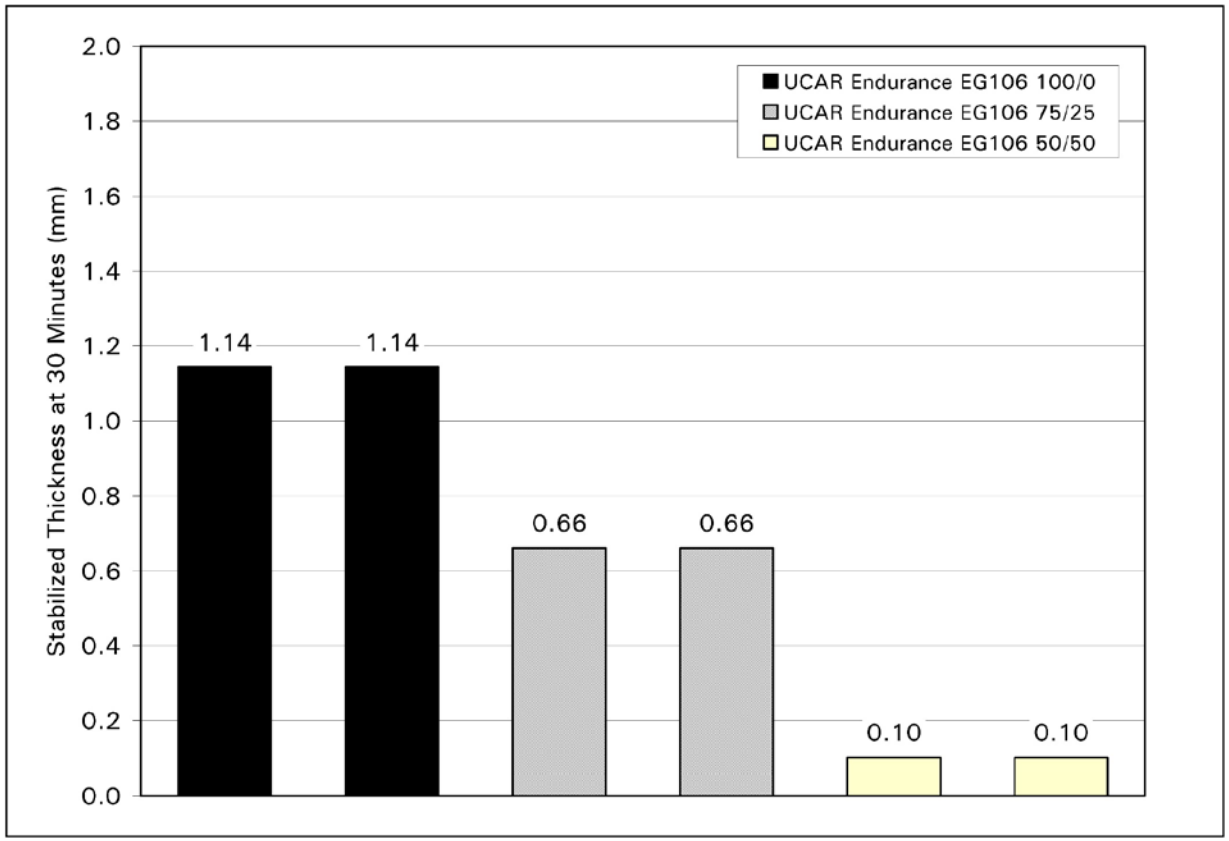


Figure 3.1: Fluid Thickness of UCAR Endurance EG106

Table 3.1: Summary of Tests Performed in 2005-06 (Snow)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
45	16-Feb-06	UCAR Endurance EG106	100%	35.6	23.1	-8.4	Natural Snow
46	16-Feb-06	UCAR Endurance EG106	75%	16.0	20.6	-8.3	Natural Snow
53	16-Feb-06	UCAR Endurance EG106	100%	27.5	32.0	-9.2	Natural Snow
54	16-Feb-06	UCAR Endurance EG106	75%	10.9	32.6	-9.2	Natural Snow
61	16-Feb-06	UCAR Endurance EG106	100%	23.9	29.9	-9.3	Natural Snow
62	16-Feb-06	UCAR Endurance EG106	75%	8.3	28.3	-9.3	Natural Snow
69	16-Feb-06	UCAR Endurance EG106	100%	77.4	9.8	-9.0	Natural Snow
70	16-Feb-06	UCAR Endurance EG106	75%	39.8	5.3	-9.0	Natural Snow
78	16-Feb-06	UCAR Endurance EG106	75%	30.0	10.0	-8.4	Natural Snow
83	21-Feb-06	UCAR Endurance EG106	50%	18.0	5.2	-3.6	Natural Snow
86	21-Feb-06	UCAR Endurance EG106	100%	217.8	2.6	-3.2	Natural Snow
87	21-Feb-06	UCAR Endurance EG106	75%	136.2	2.9	-3.5	Natural Snow
107	22-Feb-06	UCAR Endurance EG106	50%	10.1	11.9	-1.6	Natural Snow
111	22-Feb-06	UCAR Endurance EG106	100%	123.3	5.7	-1.6	Natural Snow
112	22-Feb-06	UCAR Endurance EG106	75%	41.3	7.3	-1.6	Natural Snow
118	22-Feb-06	UCAR Endurance EG106	50%	8.3	12.9	-1.7	Natural Snow
122	23-Feb-06	UCAR Endurance EG106	100%	189.6	3.3	-2.5	Natural Snow
123	22-Feb-06	UCAR Endurance EG106	75%	74.0	4.0	-1.6	Natural Snow
130	23-Feb-06	UCAR Endurance EG106	75%	38.5	8.7	-1.4	Natural Snow
133	23-Feb-06	UCAR Endurance EG106	50%	11.9	9.0	-1.4	Natural Snow
137	23-Feb-06	UCAR Endurance EG106	50%	8.6	9.9	-1.4	Natural Snow
140	23-Feb-06	UCAR Endurance EG106	50%	13.1	8.6	-1.4	Natural Snow
142	23-Feb-06	UCAR Endurance EG106	50%	13.3	6.6	-1.5	Natural Snow
143	23-Feb-06	UCAR Endurance EG106	50%	35.3	1.8	-2.5	Natural Snow
146	23-Feb-06	UCAR Endurance EG106	75%	29.5	11.6	-1.0	Natural Snow
147	23-Feb-06	UCAR Endurance EG106	100%	65.8	16.8	-1.1	Natural Snow
148	23-Feb-06	UCAR Endurance EG106	50%	13.3	8.2	-1.0	Natural Snow
157	23-Feb-06	UCAR Endurance EG106	75%	18.5	25.0	-1.6	Natural Snow
159	23-Feb-06	UCAR Endurance EG106	50%	8.7	14.7	-1.2	Natural Snow
173	25-Feb-06	UCAR Endurance EG106	75%	40.0	8.2	-13.7	Natural Snow
176	25-Feb-06	UCAR Endurance EG106	100%	115.9	5.6	-13.7	Natural Snow
177	25-Feb-06	UCAR Endurance EG106	75%	64.0	3.5	-13.6	Natural Snow
178	25-Feb-06	UCAR Endurance EG106	100%	79.7	7.6	-13.7	Natural Snow
184	25-Feb-06	UCAR Endurance EG106	100%	63.0	9.3	-13.6	Natural Snow
201	25-Feb-06	UCAR Endurance EG106	75%	44.0	5.8	-13.4	Natural Snow
202	25-Feb-06	UCAR Endurance EG106	100%	134.1	3.8	-12.8	Natural Snow
203	25-Feb-06	UCAR Endurance EG106	75%	31.2	10.3	-13.6	Natural Snow
208	03-Mar-06	UCAR Endurance EG106	75%	40.4	7.8	-9.7	Natural Snow
215	03-Mar-06	UCAR Endurance EG106	75%	40.7	9.5	-8.4	Natural Snow

Table 3.2: Summary of Tests Performed in 2005-06 (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
15	06-Apr-06	UCAR Endurance EG106	100%	70.2	13.2	-3.2	Freezing Drizzle
16	06-Apr-06	UCAR Endurance EG106	100%	71.7	13.4	-3.2	Freezing Drizzle
17	06-Apr-06	UCAR Endurance EG106	75%	29.8	13.0	-3.1	Freezing Drizzle
18	06-Apr-06	UCAR Endurance EG106	75%	29.8	13.0	-3.2	Freezing Drizzle
19	06-Apr-06	UCAR Endurance EG106	50%	8.0	13.0	-3.2	Freezing Drizzle
20	06-Apr-06	UCAR Endurance EG106	50%	8.4	13.3	-3.1	Freezing Drizzle
47	07-Apr-06	UCAR Endurance EG106	100%	120.5	5.0	-3.3	Freezing Drizzle
48	07-Apr-06	UCAR Endurance EG106	100%	116.5	5.1	-3.3	Freezing Drizzle
49	07-Apr-06	UCAR Endurance EG106	75%	53.5	4.7	-3.3	Freezing Drizzle
50	07-Apr-06	UCAR Endurance EG106	75%	59.0	5.1	-3.1	Freezing Drizzle
51	07-Apr-06	UCAR Endurance EG106	50%	12.5	4.8	-3.2	Freezing Drizzle
52	07-Apr-06	UCAR Endurance EG106	50%	12.8	4.8	-3.2	Freezing Drizzle
75	06-Apr-06	UCAR Endurance EG106	100%	57.8	12.8	-10.2	Freezing Drizzle
76	06-Apr-06	UCAR Endurance EG106	100%	56.8	12.6	-10.2	Freezing Drizzle
77	06-Apr-06	UCAR Endurance EG106	75%	27.7	13.1	-10.5	Freezing Drizzle
78	06-Apr-06	UCAR Endurance EG106	75%	26.0	13.2	-10.5	Freezing Drizzle
97	05-Apr-06	UCAR Endurance EG106	100%	102.2	5.4	-10.2	Freezing Drizzle
98	05-Apr-06	UCAR Endurance EG106	100%	102.5	5.4	-10.2	Freezing Drizzle
99	05-Apr-06	UCAR Endurance EG106	75%	40.6	5.0	-10.5	Freezing Drizzle
100	05-Apr-06	UCAR Endurance EG106	75%	43.2	5.0	-10.5	Freezing Drizzle
121	13-Apr-06	UCAR Endurance EG106	100%	50.8	24.5	-3.1	Freezing Rain
122	13-Apr-06	UCAR Endurance EG106	100%	52.3	24.7	-3.1	Freezing Rain
123	13-Apr-06	UCAR Endurance EG106	75%	19.0	25.0	-3.0	Freezing Rain
124	13-Apr-06	UCAR Endurance EG106	75%	19.7	25.1	-3.0	Freezing Rain
125	13-Apr-06	UCAR Endurance EG106	50%	6.0	25.3	-3.1	Freezing Rain
126	13-Apr-06	UCAR Endurance EG106	50%	5.5	24.7	-3.1	Freezing Rain
151	04-Apr-06	UCAR Endurance EG106	100%	73.8	13.5	-3.3	Freezing Rain
152	04-Apr-06	UCAR Endurance EG106	100%	71.4	13.4	-3.3	Freezing Rain
153	04-Apr-06	UCAR Endurance EG106	75%	26.3	13.0	-3.2	Freezing Rain
154	04-Apr-06	UCAR Endurance EG106	75%	27.3	12.8	-3.2	Freezing Rain
155	04-Apr-06	UCAR Endurance EG106	50%	8.3	13.3	-3.2	Freezing Rain
156	04-Apr-06	UCAR Endurance EG106	50%	9.1	12.9	-3.0	Freezing Rain
179	05-Apr-06	UCAR Endurance EG106	100%	44.7	24.3	-10.0	Freezing Rain
180	05-Apr-06	UCAR Endurance EG106	100%	47.2	24.4	-10.0	Freezing Rain
181	05-Apr-06	UCAR Endurance EG106	75%	17.3	25.4	-10.0	Freezing Rain
182	05-Apr-06	UCAR Endurance EG106	75%	18.3	25.0	-10.0	Freezing Rain
201	05-Apr-06	UCAR Endurance EG106	100%	71.3	13.1	-10.2	Freezing Rain
202	05-Apr-06	UCAR Endurance EG106	100%	72.8	12.8	-10.2	Freezing Rain
203	05-Apr-06	UCAR Endurance EG106	75%	19.7	13.0	-10.1	Freezing Rain
204	05-Apr-06	UCAR Endurance EG106	75%	21.8	13.2	-10.1	Freezing Rain

Table 3.2 (cont'd): Summary of Tests Performed in 2005-06 (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
227	11-Apr-06	UCAR Endurance EG106	100%	127.5	4.7	-3.3	Freezing Fog
228	11-Apr-06	UCAR Endurance EG106	100%	121.8	5.2	-3.3	Freezing Fog
229	11-Apr-06	UCAR Endurance EG106	75%	61.0	4.9	-3.1	Freezing Fog
230	11-Apr-06	UCAR Endurance EG106	75%	58.3	5.2	-3.1	Freezing Fog
231	11-Apr-06	UCAR Endurance EG106	50%	15.0	5.3	-2.9	Freezing Fog
232	11-Apr-06	UCAR Endurance EG106	50%	15.2	5.1	-2.9	Freezing Fog
259	12-Apr-06	UCAR Endurance EG106	100%	192.5	1.8	-3.2	Freezing Fog
260	12-Apr-06	UCAR Endurance EG106	100%	197.8	2.0	-3.2	Freezing Fog
261	12-Apr-06	UCAR Endurance EG106	75%	114.0	2.1	-3.0	Freezing Fog
262	12-Apr-06	UCAR Endurance EG106	75%	109.5	2.0	-3.1	Freezing Fog
263	12-Apr-06	UCAR Endurance EG106	50%	27.3	1.9	-3.1	Freezing Fog
264	12-Apr-06	UCAR Endurance EG106	50%	28.0	2.2	-3.1	Freezing Fog
R	12-Apr-06	UCAR Endurance EG106	50%	30.2	2.0	-3.1	Freezing Fog
RR	12-Apr-06	UCAR Endurance EG106	50%	29.8	2.0	-3.1	Freezing Fog
287	11-Apr-06	UCAR Endurance EG106	100%	111.3	4.7	-14.2	Freezing Fog
288	11-Apr-06	UCAR Endurance EG106	100%	110.8	4.9	-14.2	Freezing Fog
R289	24-Apr-06	UCAR Endurance EG106	75%	51.0	4.8	-14.0	Freezing Fog
290	11-Apr-06	UCAR Endurance EG106	75%	50.4	5.4	-14.2	Freezing Fog
309	10-Apr-06	UCAR Endurance EG106	100%	185.3	2.2	-14.2	Freezing Fog
310	10-Apr-06	UCAR Endurance EG106	100%	191.8	2.1	-14.2	Freezing Fog
311	10-Apr-06	UCAR Endurance EG106	75%	100.3	1.9	-14.1	Freezing Fog
312	10-Apr-06	UCAR Endurance EG106	75%	93.7	2.1	-14.1	Freezing Fog
327	10-Apr-06	UCAR Endurance EG106	100%	31.5	5.4	-25.6	Freezing Fog
328	10-Apr-06	UCAR Endurance EG106	100%	29.0	5.3	-25.6	Freezing Fog
339	10-Apr-06	UCAR Endurance EG106	100%	66.5	2.0	-25.4	Freezing Fog
340	10-Apr-06	UCAR Endurance EG106	100%	65.7	2.0	-25.4	Freezing Fog
575	27-Apr-06	UCAR Endurance EG106	100%	18.5	73.5	0.9	Cold Soak
576	27-Apr-06	UCAR Endurance EG106	100%	18.0	75.2	0.9	Cold Soak
577	27-Apr-06	UCAR Endurance EG106	75%	7.7	76.8	0.8	Cold Soak
578	27-Apr-06	UCAR Endurance EG106	75%	7.3	76.0	0.8	Cold Soak
597	27-Apr-06	UCAR Endurance EG106	100%	119.2	5.1	1.0	Cold Soak
598	27-Apr-06	UCAR Endurance EG106	100%	124.0	5.2	1.0	Cold Soak
599	27-Apr-06	UCAR Endurance EG106	75%	52.3	5.0	1.0	Cold Soak
600	27-Apr-06	UCAR Endurance EG106	75%	53.0	5.1	1.0	Cold Soak

4. RESULTS AND DISCUSSIONS

The methods used to evaluate the test data have been reviewed in Subsection 2.6. In this section, the data used to generate the endurance times will be presented.

4.1 Data

Endurance time values, for all conditions, are those of the tests conducted in 2005-06. 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 and precipitation on fluid endurance times for each condition. Table 4.1 illustrates the outputs from the regression equations run for this fluid under natural snow, freezing fog, freezing drizzle, freezing rain and cold soak conditions.

4.2 Holdover Time Table

A fluid-specific HOT table for UCAR Endurance EG106 is shown in Table 4.2 at the end of this section. Dow Chemical will not commercialize dilutions of UCAR Endurance EG106 and therefore HOTs are not provided in the fluid-specific table for 75/25 or 50/50 dilutions.

4.2.1 Holdover Times in Snow, Below -14 to -25°C

In the winter of 2003-04, testing was conducted with artificial snowmakers at temperatures below -14°C. This was done as very limited endurance time data existed for fluids at these temperatures. As a result of this testing, the current propylene Type II and Type IV fluids were given generic values in the -14 to -25°C snow cell. Because no natural snow tests were conducted below -14°C with UCAR Endurance EG106 in the winter of 2005-06, generic values have been used in the -14 to -25°C snow cell.

4.2.2 Fluid Viscosity

The viscosity of the fluid sample used in HOT testing, as measured by APS personnel, appears at the front of this document. The viscosity measurement method is also documented. In order for the fluid specific values of a fluid to be valid, operators must ensure that the viscosity of the fluid used is superior to the published viscosity of that fluid, using the same viscosity measurement method published.

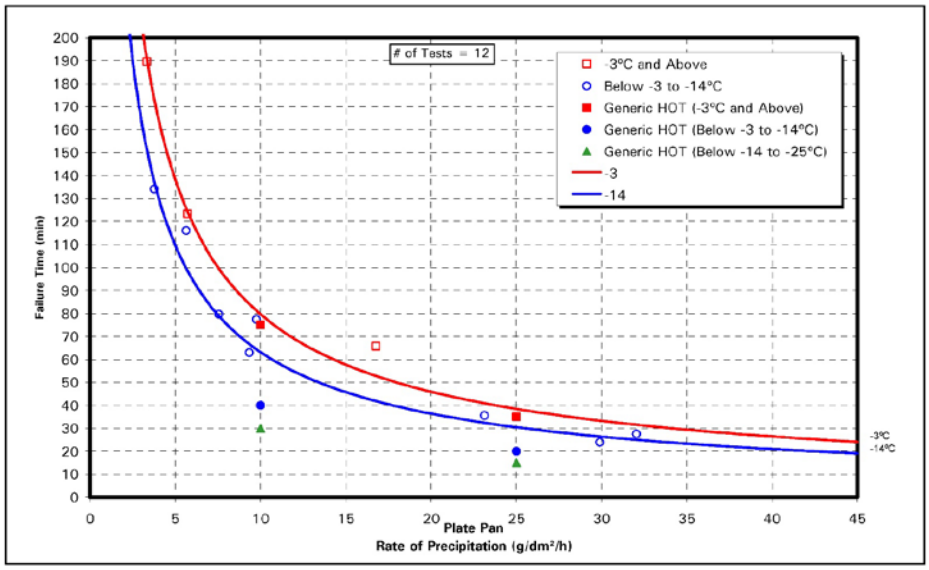


Figure 4.1: Type IV Neat – Natural Snow

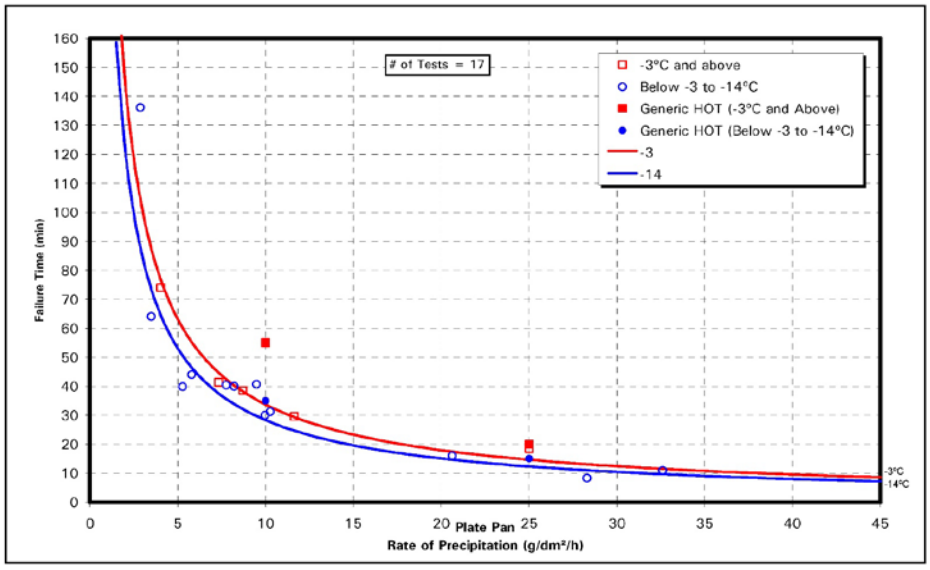


Figure 4.2: Type IV 75/25 – Natural Snow

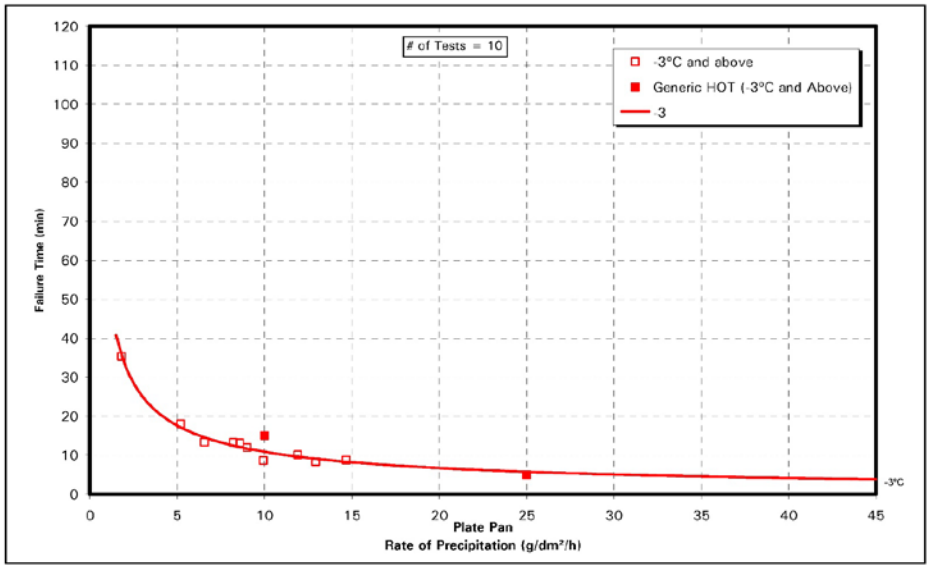


Figure 4.3: Type IV 50/50 – Natural Snow

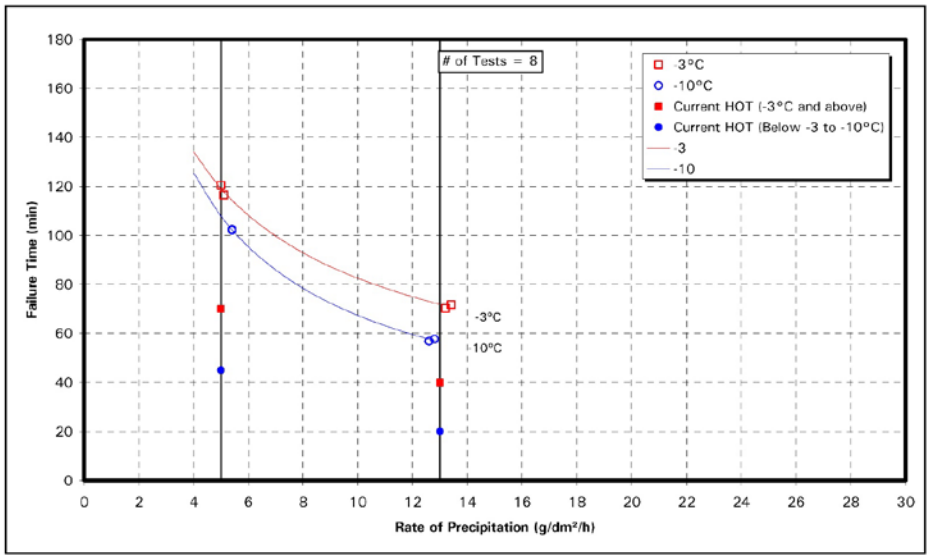


Figure 4.4: Type IV Neat – Freezing Drizzle

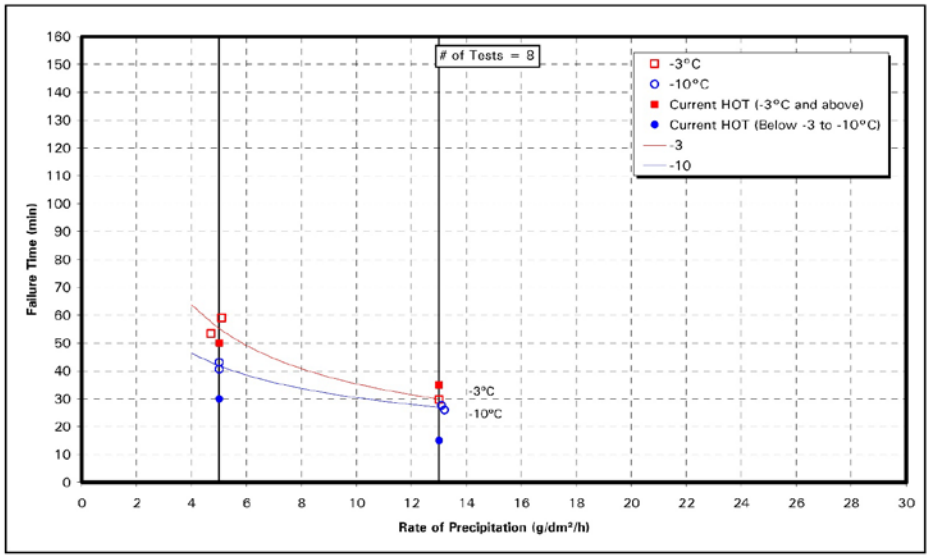


Figure 4.5: Type IV 75/25 – Freezing Drizzle

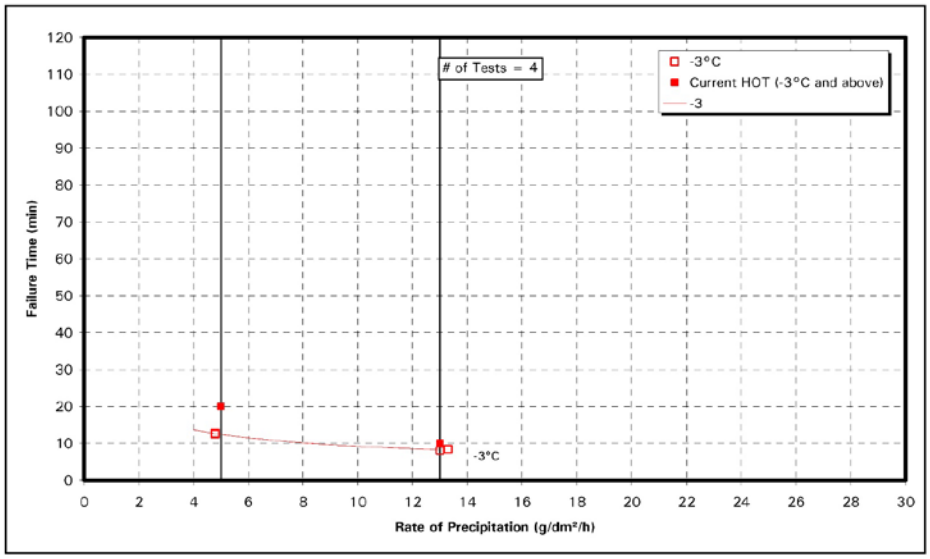


Figure 4.6: Type IV 50/50 – Freezing Drizzle

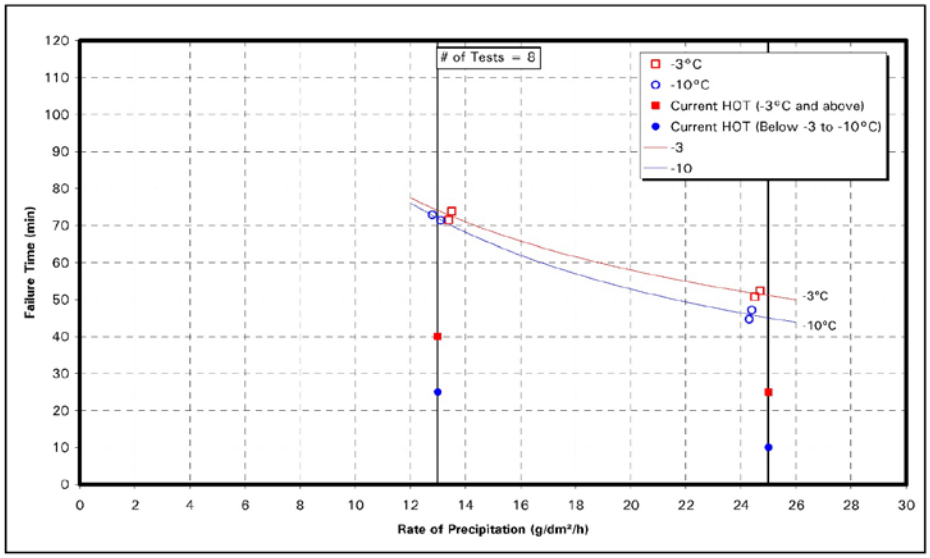


Figure 4.7: Type IV Neat – Light Freezing Rain

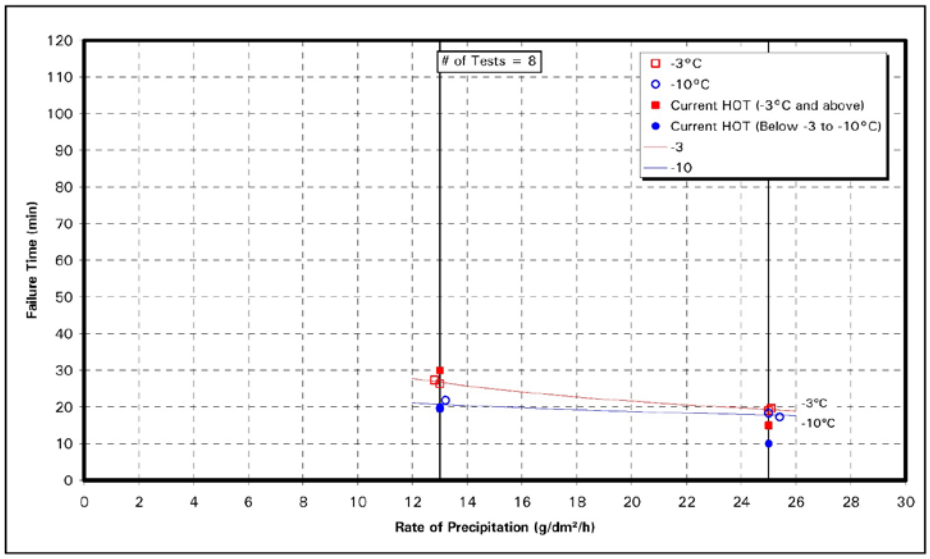


Figure 4.8: Type IV 75/25 – Light Freezing Rain

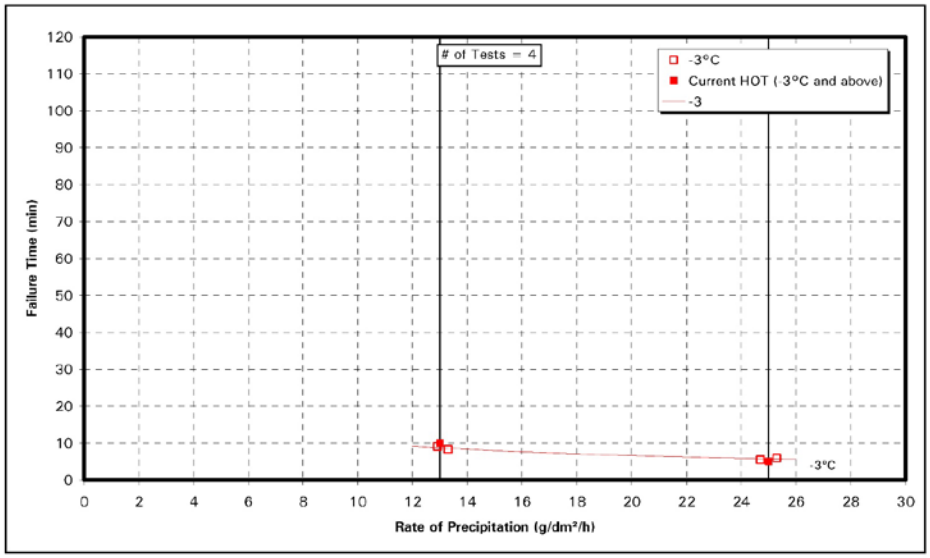


Figure 4.9: Type IV 50/50 – Light Freezing Rain

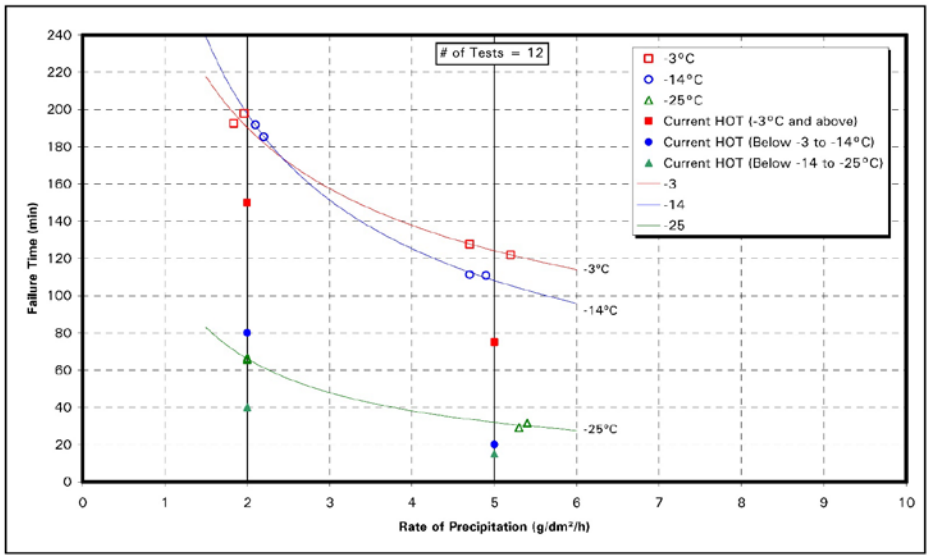


Figure 4.10: Type IV Neat – Freezing Fog

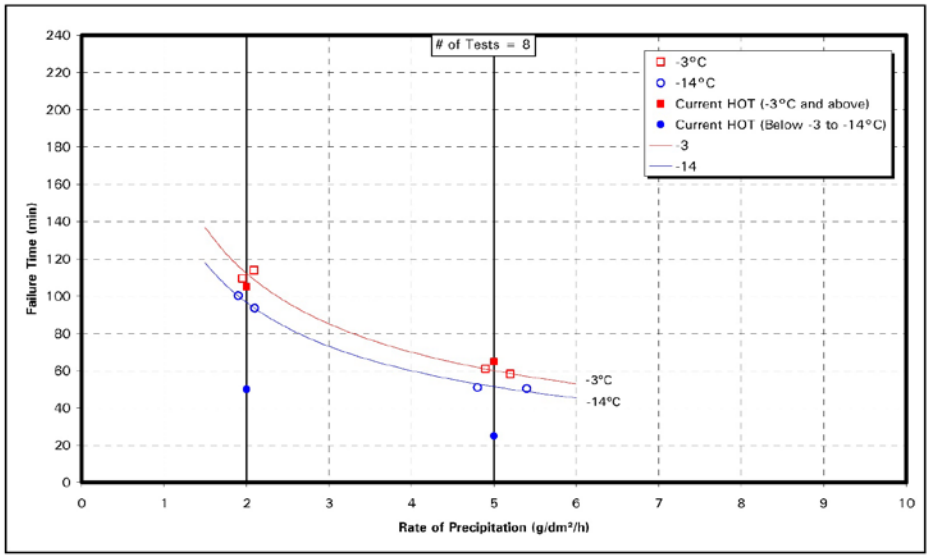


Figure 4.11: Type IV 75/25 – Freezing Fog

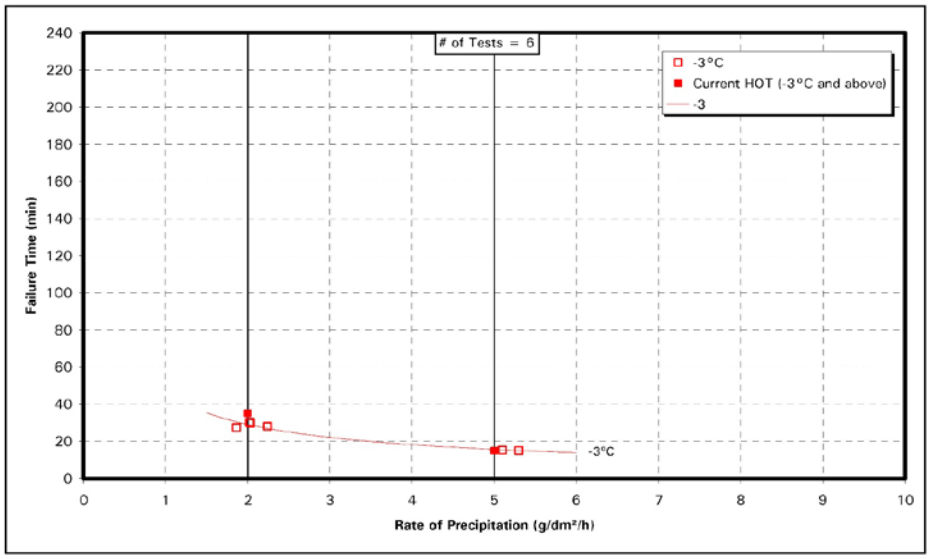


Figure 4.12: Type IV 50/50 – Freezing Fog

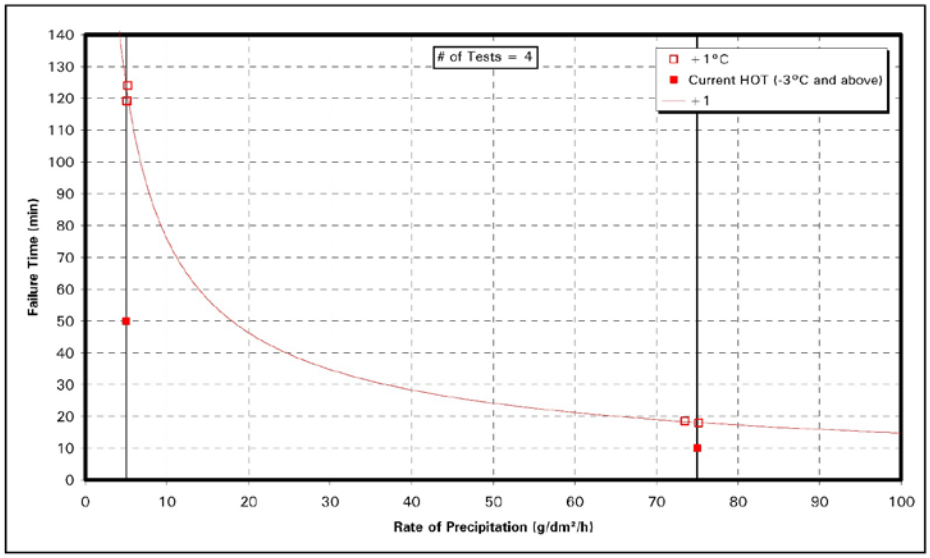


Figure 4.13: Type IV Neat – Rain on Cold-Soaked Surface

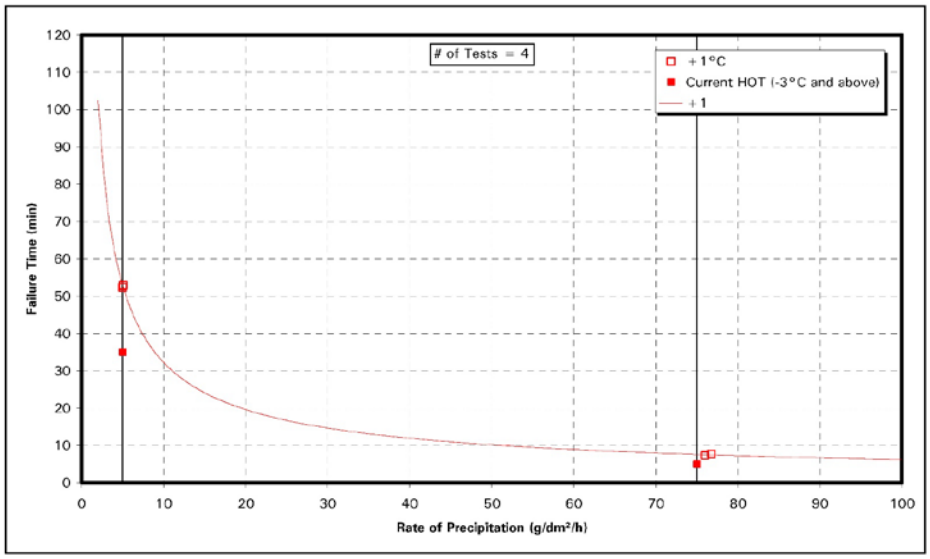


Figure 4.14: Type IV 75/25 – Rain on Cold-Soaked Surface

Table 4.1: UCAR Endurance EG106 Regression Equation Coefficient Summary

Natural Snow Conditions

Fluid	Dil	R^2	Intercept (I)	Coeff. Rate (A)	Coeff. Tem (B)	Total Pts.
UCAR Endurance EG106	Neat	98%	2.8	-0.80	-0.20	12
UCAR Endurance EG106	75%	94%	2.5	-0.91	-0.15	17
UCAR Endurance EG106	50%	95%	1.7	-0.70	0.03	10

General Equation $t = 10^{I} R^{A} (2\text{-}T)^{B}$

Simulated Freezing Fog

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
UCAR Endurance EG106	Neat	99%	-3°C	2.4	-0.47	4
UCAR Endurance EG106	75%	99%	-3°C	2.3	-0.68	4
UCAR Endurance EG106	50%	97%	-3°C	1.7	-0.68	6
UCAR Endurance EG106	Neat	100%	-14°C	2.5	-0.66	4
UCAR Endurance EG106	75%	99%	-14°C	2.2	-0.69	4
UCAR Endurance EG106	Neat	99%	-25°C	2.1	-0.79	4

General Equation $t = 10$

Simulated Freezing Drizzle

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
UCAR Endurance EG106	Neat	100%	-3°C	2.4	-0.53	4
UCAR Endurance EG106	75%	97%	-3°C	2.2	-0.64	4
UCAR Endurance EG106	50%	99%	-3°C	1.4	-0.43	4
UCAR Endurance EG106	Neat	100%	-10°C	2.5	-0.68	4
UCAR Endurance EG106	75%	98%	-10°C	1.9	-0.46	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
UCAR Endurance EG106	Neat	99%	-3°C	2.5	-0.57	4
UCAR Endurance EG106	75%	99%	-3°C	2.0	-0.49	4
UCAR Endurance EG106	50%	96%	-3°C	1.7	-0.64	4
UCAR Endurance EG106	Neat	99%	-10°C	2.7	-0.71	4
UCAR Endurance EG106	75%	76%	-10°C	1.6	-0.23	4

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
UCAR Endurance EG106	Neat	100%	+1°C	2.6	-0.71	4
UCAR Endurance EG106	75%	100%	+1°C	2.2	-0.72	4

General Equation $t = 10^{I} R^{A}$

Table 4.2: Fluid Specific Type IV Fluid Holdover Time Guidelines

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
UCAR™ ENDURANCE EG106

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	2:05 – 3:10	0:40 – 1:20	1:10 – 2:00	0:50 – 1:15	0:20 – 2:00	
		75/25							
		50/50						CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	1:50 – 3:20	0:30 – 1:05	0:55 – 1:50[3]	0:45 – 1:10[3]		
		75/25							
below -14 to -25	below 7 to -13	100/0	12:00	0:30 – 1:05	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

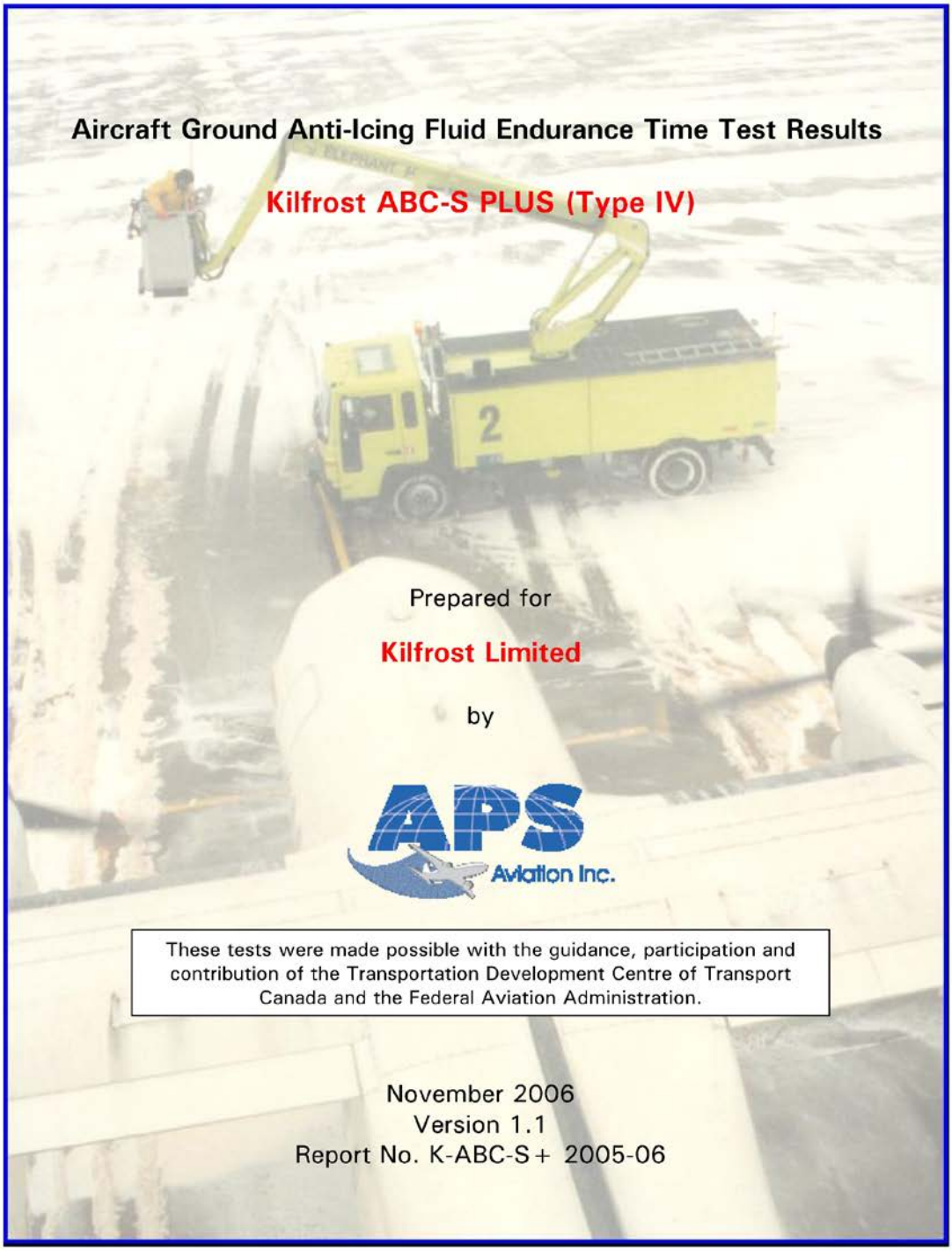
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

APPENDIX H

FLUID MANUFACTURER REPORT:
KILFROST ABC-S PLUS (TYPE IV)


Aircraft Ground Anti-Icing Fluid Endurance Time Test Results
Kilfrost ABC-S PLUS (Type IV)
Prepared for
Kilfrost Limited
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 2006
Version 1.1
Report No. K-ABC-S+ 2005-06

Aircraft Ground Anti-Icing Fluid Endurance Time Test Results

Kilfrost ABC-S PLUS (Type IV)

Prepared for

Kilfrost Limited

Prepared by: _____ November 28, 2006
Stephanie Bendickson — Date
Project Analyst

Reviewed by: _____ Nov 28, 06
John D'Avirro — Date
Program Manager, Eng.

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 2006
Version 1.1
Report No. K-ABC-S+ 2005-06

FLUID IDENTIFICATION AND CHARACTERISTICS

Manufacturer: Kilfrost Limited

Fluid: ABC-S PLUS

Fluid Type / Colour: Type IV / Green

Batch #: P1797

Date of Receipt: February 2, 2006

Brix Measured:

Neat fluid:	37.00°
75/25 dilution:	27.25°
50/50 dilution:	19.00°

Viscosity Stated by Manufacturer[1]:

Neat fluid:	12,500 cP
75/25 dilution:	not given
50/50 dilution:	not given

Viscosity Measured by APS (Manufacturer Method)[1]:

Neat fluid:	10,450 cP
75/25 dilution:	14,400 cP
50/50 dilution:	4,500 cP

Viscosity Measured by APS (AIR 9968 Method)[2]:

Neat fluid:	11,040 cP
75/25 dilution:	19,740 cP
50/50 dilution:	2,440 cP

WSET provided by AMIL:

Neat fluid:	80 minutes

[1]Manufacturer Method: Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes
[2]AIR 9968 Method: Spindle LV1, 20°C, 0.3 rpm, 10 minutes

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SUMMARY

The primary objective of this project was to measure the endurance time performance of Kilfrost ABC-S PLUS 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).

The HOT test procedure consisted of pouring fluids onto clean aluminium test surfaces inclined at 10°; the onset of failure was recorded as a function of time in natural snow and simulated freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. Endurance time tests were performed at the APS Aviation Inc. (APS) test facility located within the Montréal-Pierre-Elliott-Trudeau International Airport and at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa.

De/anti-icing fluid endurance times were determined using a multi-variable regression analysis, resulting in the generation of the fluid-specific HOT table shown below.

Kilfrost ABC-S PLUS Type IV Fluid Holdover Times

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 and above	27 and above	100/0	12:00	1:50 – 3:40	0:45 – 1:25	1:15 – 1:55	0:50 – 1:10	0:15 – 1:40	
		75/25	5:00	1:10 – 2:10	0:20 – 0:55	0:45 – 1:10	0:30 – 0:45	0:05 – 1:00	
		50/50	3:00	0:20 – 0:40	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	12:00	0:40 – 1:25	0:35 – 1:00	0:30 – 1:35	0:25 – 0:35	CAUTION: No holdover time guidelines exist	
		75/25	5:00	0:40 – 1:15	0:20 – 0:50	0:25 – 1:15	0:30 – 0:40		
below -14 to -25	below 7 to -13	100/0	12:00	0:20 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

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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
NCAR	National Center for Atmospheric Research
NRC	National Research Council Canada
SAE	Society of Automotive Engineers, Inc.
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-icing/anti-icing has been the subject of concentrated industry attention over the past decade due the occurrence of several fatal icing-related aircraft accidents. Recent attention has been placed upon 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 for use by aircraft operators and accepted by regulatory authorities. New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid HOTs without compromising the aerodynamic features of the airfoil.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop and substantiate fluid HOT tables for current fluids and new formulations. Test procedures to measure the duration of fluid protection against ice formation have evolved into a refined Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 5485 that is followed by APS Aviation Inc. (APS).

Testing of aircraft ground de/ant-icing fluids has resulted in the generation of HOT tables. These tables provide guidelines for use in departure planning in adverse winter conditions. They provide the HOT ranges for aircraft treated with any particular qualified deicing or anti-icing fluid.

A new data analysis protocol was developed in 1996-97 wherein the endurance time data for each fluid brand in each cell of the HOT tables was subject to a multi-variable regression treatment. Type II and Type IV fluid HOTs are determined using this method of analysis, resulting in the generation of generic and fluid-specific HOT tables.

This report provides the data and analysis used to determine the fluid HOTs for Kilfrost ABC-S PLUS.

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2

2. METHODOLOGY

This chapter contains a description of the tests, equipment and procedures used to conduct endurance time tests. It is divided into sections dealing with the definition of weather, test sites, test conditions, equipment, procedures, and analysis methodology. A 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 was developed by APS for this testing, based upon the requirements of ARP 5485.

2.1 Definition of Weather Conditions

HOTs are provided as a function of weather condition, fluid dilution and outside air temperature. The objective of the winter test program was to develop HOTs for new fluids based on the most recent test data.

Table 2.1 provides definitions of most weather conditions experienced in winter operations and includes the criteria used to determine precipitation intensity (light, moderate, heavy). 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).

Table 2.1 includes definitions for the weather conditions described in the HOT tables (frost, freezing fog, snow, freezing drizzle, light freezing rain and rain). Definitions for snow pellets, hail and ice pellets are also presented, however these are conditions for which HOT guidelines do not exist.

The test methodology used to determine fluid endurance times has included the generally accepted upper and lower limits for precipitation rates for each type of precipitation. These limits were discussed in detail at a 1997 meeting of the SAE G-12 HOT Subcommittee where standard definitions of upper and lower precipitation rate limits were approved for each category of precipitation. These limits are documented and discussed in Subsection 2.6.

2.1.1 Snow

Table 2.1 contains the criteria that were used in the past to estimate the intensity of snow. These criteria are based upon horizontal visibility with three

intensity levels. For light snow, visibility is greater than or equal to 1.0 km, moderate snow visibility is 0.5 km to less than 1.0 km, and heavy snow, visibility is less than 0.5 km.

As stated in a cautionary note in Table 2.1, visibility is only an indicator of snow intensity, and the two parameters are not always correlated.

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 visibility at the earth's surface to less than 1 km (5/8 mile).
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 (23°F), the crystals are generally agglomerated into snowflakes.
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 the ground or other exposed objects.
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 mm (0.02 in.) or smaller drops which, in contrast to drizzle, are widely separated.
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)	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter is about 2-5 mm (0.1-0.2 in.). Grains are brittle, easily crushed; they bounce and break on hard ground.
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is less than 1 mm (0.04 in.). When the grains hit hard ground, they do not bounce or shatter.
HAIL (GR)	Precipitation of small balls or pieces of ice with a diameter ranging from 5 to > 50 mm (0.2 to 2.0 in.) falling either separately or agglomerated.
ICE PELLETS (PE) Note: Includes Sleet and Small Hail	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.) or less. The pellets of ice usually bounce when hitting hard ground.

Intensity Criteria**

Snow(SN),Pellets(CS),Grains(SG),Frz Drizzle(FZDZ)			Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (S) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm or 10.0 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 or 25.0 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 shown that visibility and precipitation intensity are not always directly correlated.

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm 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 (-) Estimated Intensity	Up to 0.10 in/hr (2.5 mm or 25 gr/dm²/hr); Maximum 0.01 inch in 6 minutes From scattered drops that, regardless of duration, do not completely wet an exposed surface up to a condition where individual drops are easily seen.
Measured Intensity Moderate Estimated Intensity	0.11 in to 0.30 in/hr (7.6 mm or 76 gr/dm²/hr); More than 0.01 to 0.03 inch in 6 minutes Individual drops are not clearly identifiable; spray is observable just above pavement and other hard surfaces.
Measured Intensity Heavy (+) Estimated Intensity	More than 0.30 in/hr (7.6 mm or 76 gr/dm²/hr); More than 0.03 inch in 6 minutes Rain seemingly falls in sheets; individual drops are not identifiable; heavy spray to height of several inches is observed over hard surfaces.

* From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
** From American Meteorological Society, Glossary of Meteorology WSOH #7 MANOBS (5/94)
*** NCAR Proposed Definition for Liquid Equivalent Snowfall Intensity

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

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP June 17, 1997 (Updated for METAR codes)

Table 2.2 is the visibility table which has been published annually by TC since the winter of 2003-04 for use in winter operations. It is based on more recent data than Table 2.1 and provides more detail about snowfall intensity and visibility. APS, NCAR and TC all had input into the formation of this table, which is based on NCAR field data and theoretical work on classes of snow and on extensive field data compiled by APS. The table categorizes snowfall into one of four intensities based on visibility and lighting condition.

The FAA also publishes a visibility, which differs slightly from the TC visibility table, but is based on the same data set.

Table 2.2: Visibility in Snow vs. Snowfall Intensity Chart[1]

Lighting	Temperature Range		Visibility in Snow (Statute Miles)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1	>1 to 2½	>2½ to 4	>4
	Below -1	Below 30	≤3/4	>3/4 to 1½	>1½ to 3	>3
Daylight	-1 and above	30 and above	≤½	>½ to 1½	>1½ to 3	>3
	Below -1	Below 30	≤3/8	>3/8 to 7/8	>7/8 to 2	>2

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.

2.1.2 Freezing Drizzle

Freezing drizzle is composed of closely spaced fine water droplets with a diameter less than 0.5 mm (see Table 2.1). The intensity of freezing drizzle is estimated, as it is for snow, through the measurement of horizontal visibility.

HOT tables have one column for freezing drizzle; however, Table 2.1 shows three intensity levels (light, moderate and heavy). For example, under moderate freezing drizzle, the rate of precipitation should range between 2.5 and 5.1 g/dm²/h. For heavy freezing drizzle, the definition indicates that the intensity is greater than 5 g/dm²/h. Discussions between United Airlines, NCAR and the National Research Council Canada (NRC) led to the upper limit value of 13 g/dm²/h for freezing drizzle. This value is also used as the lower limit for light freezing rain.

2.1.3 Freezing Rain

This form of precipitation exists either in the form of drops with diameters greater than 0.5 mm, or smaller drops which, in contrast to drizzle, are widely separated. For each of the three intensities of freezing rain given in Table 2.1, a visual description is supplied to provide a subjective guideline for the purpose of estimating rain intensity. However, the following definitions apply when an instrument is available to measure the intensity of precipitation:

- Light Precipitation rate is $\leq$ 25 g/dm²/h
- Moderate Precipitation rate is $>$25 g/dm²/h but $\leq$75 g/dm²/h
- Heavy Precipitation rate is $>$75 g/dm²/h

2.1.4 Freezing Fog

Freezing fog is defined as suspended minute water droplets that freeze upon impact with the ground or exposed objects. Table 2.1 does not provide any indication of intensity or liquid water content (LWC) of the fog other than that the horizontal visibility is reduced to less than 1 km.

2.2 Test Sites

Normal natural snow test operations are performed at the APS test site located within the Montréal-Pierre-Elliott-Trudeau International Airport. The location of the test site is shown on the plan view of the airport shown in Figure 2.1. Photo 2.1 shows the test site trailer and test stands, the site consists of two trailers and three locations for test stands. The APS test site is located near Environment Canada's Meteorological Services of Canada automated weather observation station (Photo 2.2).

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.

The CEF is partitioned into two sections, separated by an insulated dividing door. Each partition can be separately controlled, permitting different tests to be conducted simultaneously. Photo 2.3 provides a general indication of the size of the facility. Photos 2.4 and 2.5 provide interior images of the small and large ends of the facility. The facility was designed and built for the testing of locomotives. The size of the chamber is 30 m by 5.4 m and its total height is 8 m. The lowest temperature achievable is -46°C.

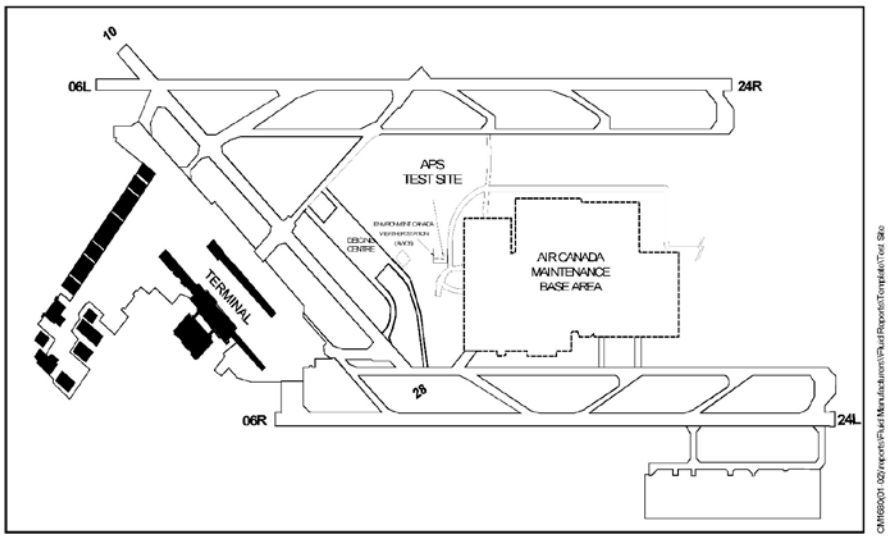


Figure 2.1: Test Site at the Montréal-Pierre-Elliott-Trudeau International Airport

2.3 Test Conditions

Outdoor testing was conducted during natural precipitation events. Supplementary tests to simulate freezing precipitation were carried out at the NRC CEF (see Photo 2.4). Subsections 2.3.1 and 2.3.2 provide descriptions of the spray assembly (see Photo 2.6) and of the methods used to produce and calibrate the fine water droplets in these artificial precipitation tests. Subsection 2.3.3 provides a summary of the categories and characteristics of each precipitation type produced for these tests.

2.3.1 Droplet Size and Rate of Precipitation

In the past few years, more industry attention has been given to the influence of droplet size on HOT. To explore this relationship further, experiments were performed to measure droplet sizes produced by different nozzles (gauge of hypodermic needle) at various water and air pressures in the spray delivery unit. Although the gauge of the needles is an important factor in the production of water droplets with appropriate dimensions, the air and water pressure levels in the sprayer system are equally important.

An improved sprayer assembly was developed in 1997-98 by the NRC and is shown in Photo 2.6. 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 2.7.

Prior to 1995, calibration experiments conducted by the NRC used an optical gauge manufactured by HSS (Biral UK acquired the HSS technology) to verify that the simulation of freezing fog, freezing drizzle, and light freezing rain provided adequate droplet sizes according to ARP 5485.

Since 1995, the APS team using a manual dye-stain technique employed by personnel at the NRC has carried out droplet size calibration. This technique consists of dusting Whatman #1 filter paper discs with a water-activated, very finely-divided powder form of methylene blue dye. The prepared discs are manually positioned under simulated precipitation for a fixed time to acquire a droplet size pattern. A calibration curve is then used to convert the measured diameter of the droplets on the pattern to the experimental median volume diameter (MVD).

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:	Dorval 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.

Figures 2.2 and 2.3 show an example of the distribution of simulated light freezing rain droplets obtained at the NRC.

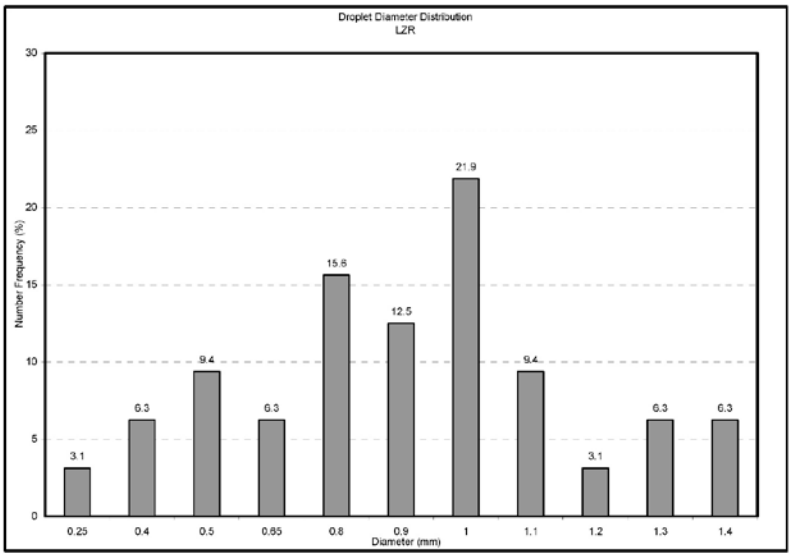


Figure 2.2: Droplet Diameter Distribution, Sample

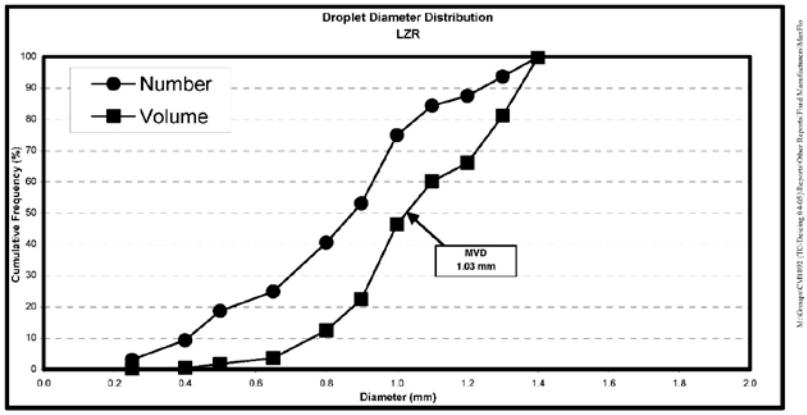


Figure 2.3: Cumulative Frequency of Droplet Diameter, Sample

2.3.2 Median Volume Diameter of Rain Drops

The MVD of a rain droplet was researched and found to be related to the precipitation rate 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 2.3 beside the experimental MVDs for each precipitation condition.

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

2.3.3 Characteristics of 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 were collected:

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

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

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

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

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

4. Moderate Rain on Cold Soaked Surface:
   Precipitation rate: 75 g/dm²/h;
   Droplet median volume diameter: 1 400 μm; and
   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.

2.4 Equipment

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.

The general environmental chamber equipment used during tests (including air temperature sensor, data acquisition system, temperature control equipment, etc.) is in accordance with the requirements set out in the ARP 5485.

Figure 2.4 shows a schematic of the test platform used for in 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.

Figure 2.4 also 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 were marked with 15 crosshairs used in determining whether end conditions (see Subsection 2.5.2 for definition) were achieved. Photo 2.8, taken outdoors at APS test site, shows six test plates mounted on a stand. For simulated freezing precipitation tests at the NRC, 12 plates were mounted on 2 six-position stands, as shown in Figure 2.4.

Figure 2.5 shows the collection (plate) pan, which is of the same size as a standard flat plate and is used to make precipitation rate measurements during outdoor tests. Photo 2.9 shows the collection pans used for measuring precipitation rates indoors at the NRC.

Sealed boxes (7.5 cm deep) were used for simulating a cold-soaked wing (see Figure 2.5). The top of the cold-soak box consists of an aluminium flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate.

Freeze points were measured using a hand-held Misco refractometer with a Brix scale.

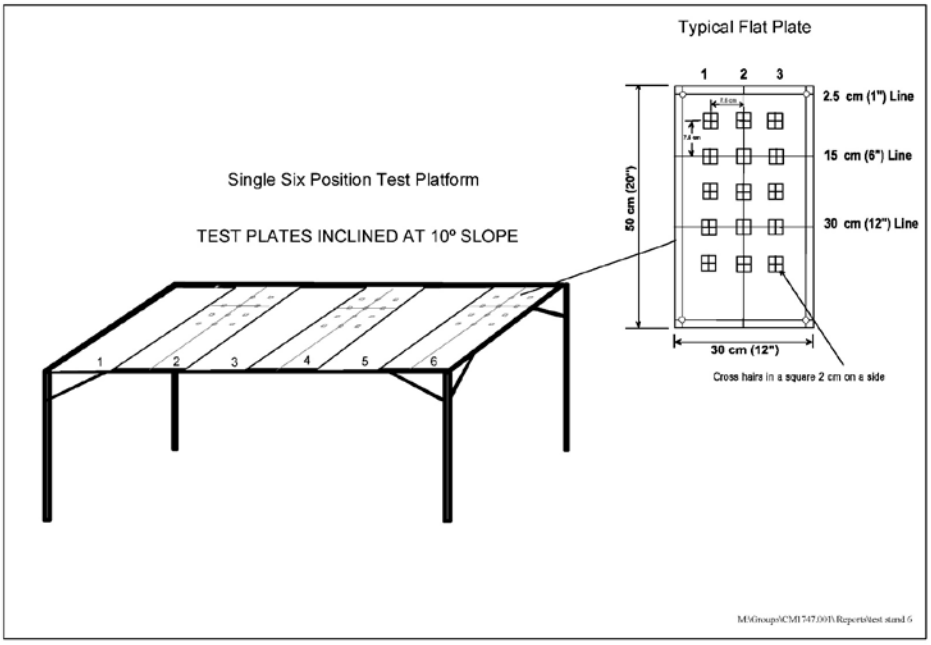
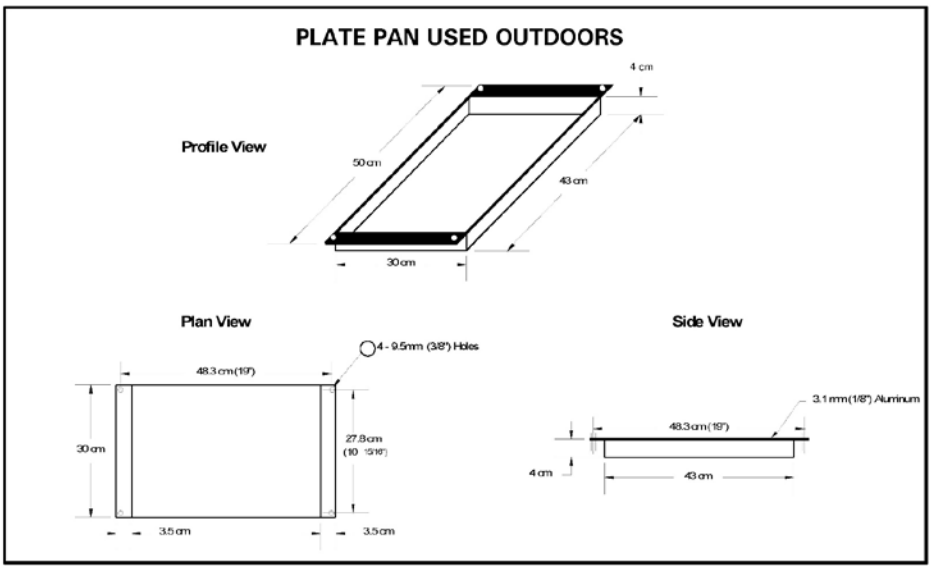
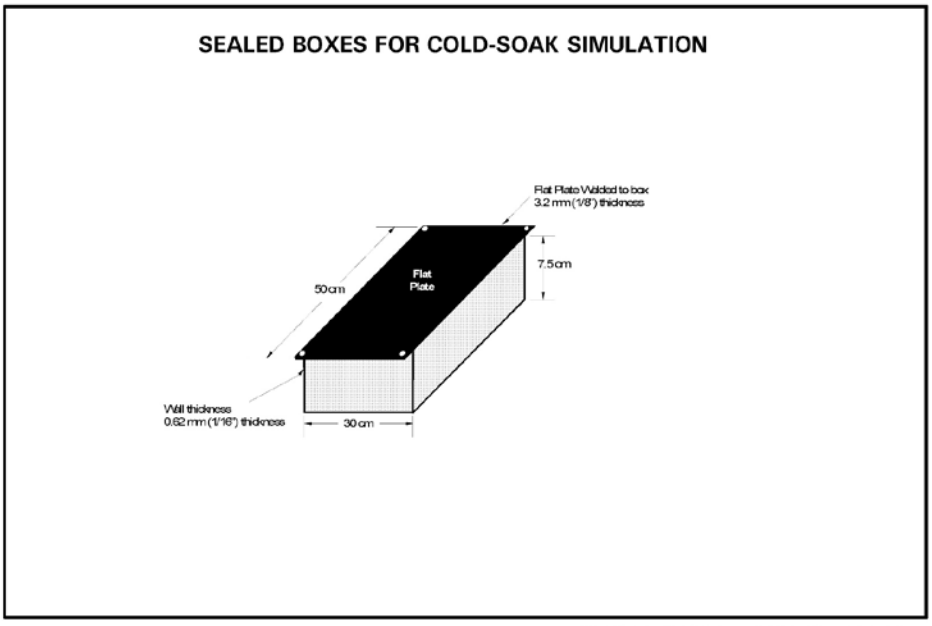


Figure 2.4: Flat Plate Test Set-Up





CM1680(01-02)\Reports\Fluid Manufacturers\Fluid Reports\Template\Pan and Boxes

Figure 2.5: Schematics of Plate Pan and Sealed Boxes

2.5 Test Procedures

Tests consisted of pouring anti-icing fluids directly onto clean test panels (exposed to various winter precipitation conditions) and recording the elapsed time for each crosshair to fail until the test panels reached the defined end condition (see Subsection 2.5.2 below).

2.5.1 Test Protocol (ARP 5485)

A plan 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 was developed by APS, based upon the requirements of ARP 5485. This procedure addresses testing conducted under natural precipitation conditions as well as under simulated freezing precipitation conditions.

Fluids to be evaluated are applied to test plates exposed to natural snow and simulated freezing fog, freezing drizzle, light freezing rain and rain on cold soaked wing. Endurance times are evaluated by measuring the minimum exposure time before a specified degree of freezing occurs.

During the conduct of these tests a series of test parameters are recorded. All test parameters specified in ARP 5485 are addressed in the procedure developed by APS. The test parameters are grouped into two categories: generic and specific test parameters.

Generic test parameters are recorded once per winter season (or test session, in laboratory testing) and include: discussion of safety issues, test plate material, test plate dimensions, surface finish and ice-catch pan dimensions. Specific test parameters are recorded during each testing session (or weather condition, in laboratory testing) and include: angle of the test stand, synchronization of timing devices, plate and ambient temperature profile files, icing intensity, etc.

As per ARP 5485 requirements, the test surface and ambient temperatures were recorded at a minimum sampling rate of one datum per minute. Figure 2.6 presents an example of a typical endurance time test conducted under simulated freezing drizzle conditions. The graph shows the test surface and chamber temperature profiles over the duration of the test and beyond failure time.

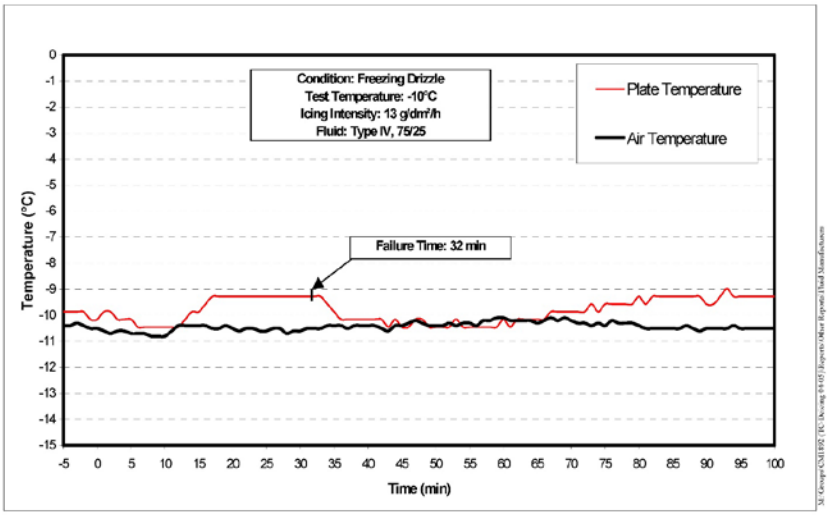


Figure 2.6: Temperature Profiles During a Typical Endurance Time Test

2.5.2 Test Protocol

The SAE G-12 HOT Subcommittee developed the procedure for natural snow flat plate tests.

The major steps in the natural snow flat plate test procedure are:

- Synchronize all timepieces;
- Clean panels and start;
- Apply (pour) fluids to test panels. Type II, Type III, and Type IV fluid are applied at the outdoor ambient temperature. Fluids are poured using a single-step fluid application;
- Record crosshair end condition times;
- Continue testing until at least five crosshairs or 30 percent (1/3) of the plate have failed;
- Record weather conditions; and
- Clean panels and restart.

2.5.3 End Condition Definitions

The test procedures and the determination of defined end conditions evolved from the experience the APS test team has accumulated from previous winter season test programs. Any of the following descriptions provide the general guidelines that observers use to judge when fluid failure occurs and to judge the extent of contamination or failure:

Failure is called when 30 percent (1/3) of the plate is 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.

2.5.4 Precipitation Rate Procedures

2.5.4.1 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 (h: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.

2.5.4.2 Precipitation rate distribution in simulated conditions

Clean test plates are placed on the test stand prior to the rate collection period, and are exposed to the simulated precipitation to verify that an even ice formation occurs over the entire test bed. If this visual inspection proves satisfactory, the rate collection period will begin. If this visual inspection proves unsatisfactory, the test stand must be repositioned under the spray device and the process is then repeated.

In order to verify the rate distribution on the test stand, a continuous rate-monitoring pan is replaced with a detailed rate distribution pan, which consists of 4 small pans of equivalent size. The area of the 4 small pans combined is similar to that of a standard rate collection pan. The small pans are weighed and placed at these locations and re-weighed at fixed intervals. The typical collection period for rate distribution is 60 minutes, however this interval may be shorter if all tests have been completed within 60 minutes. The variation between the rate of any of the 4 small pans and that of the average rate of that location should not be greater than 10 percent.

Two examples of the detailed rate distributions are shown in Table 2.4. Both rate distributions were conducted in freezing drizzle, one at the low rate (5 g/dm^2/h), the other at the high rate (13 g/dm^2/h). The average precipitation rate over the entire position in the low rate example in Table 2.4 was 5.1 g/dm^2/h. The individual rates of the four smaller pans were 5.0, 4.9, 5.2 and 5.3 g/dm^2/h, suggesting a maximum variation of 4.1 percent from the average rate over the entire position.

Table 2.4: Detailed Rate Distribution

Freezing Drizzle (low rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	2-top left	14:02	14:34	81.6	88.8	7.2	31.9	5.0
4	2-top right	14:02	14:34	81.6	88.6	7	31.9	4.9
5	2-bottom left	14:02	14:34	81.8	89.2	7.4	31.9	5.2
6	2-bottom right	14:02	14:34	81.6	89.2	7.6	31.9	5.3

3	4	5		STDDEV
5.0	4.9	-1.4%	-4.1%	0.181
5.2	5.3	1.4%	4.1%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

Freezing Drizzle (high rate)

ZD AT NRC (-3°C)
DETAILED RATE OF PRECIPITATION

FORM: 1

PAN #	Plate Loc.	t1 TIME BEFORE	t2 TIME AFTER	w1 WEIGHT BEFORE	w2 WEIGHT AFTER	w2-w1 (g)	t2-t1 (min)	RATE (g/dm²/h)
3	5-top left	12:12	12:43	81.8	98.8	17	30.8	12.3
4	5-top right	12:12	12:43	81.6	98.8	17.2	30.8	12.5
5	5-bottom left	12:12	12:43	81.6	100.2	18.6	30.8	13.5
6	5-bottom right	12:12	12:43	81.6	100.2	18.6	30.8	13.5

3	4	12.9		STDDEV
12.3	12.5	-4.8%	-3.6%	0.631
13.5	13.5	4.2%	4.2%	
5	6			

X Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	
Y Axis	Area	Full	Y
		Partial	
	Speed	High	Y
		Low	

CM1880 (31-02) \report & Fluid Manufacturers Fluid Reports\Template\Detailed Rate Distribution

2.5.4.3 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) from the timepiece located near the rate station before leaving the trailer to place the pans on the test stand. The person responsible for collecting precipitation rate data take the time delay necessary to proceed outside from the rate station into consideration.

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.

An example of the rate calculation method for tests in natural snow conditions is displayed in Figure 2.7. Typically, two collections pans are used for each test. The start and end times of the test are 10:15 and 10:45, respectively. Precipitation rates for one pan were collected at three periods during this test, indicated by t_1, t_2, and t_3 (minutes). The calculated rates for each collection period are indicated by R_1, R_2, and R_3 (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 2.4, 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.

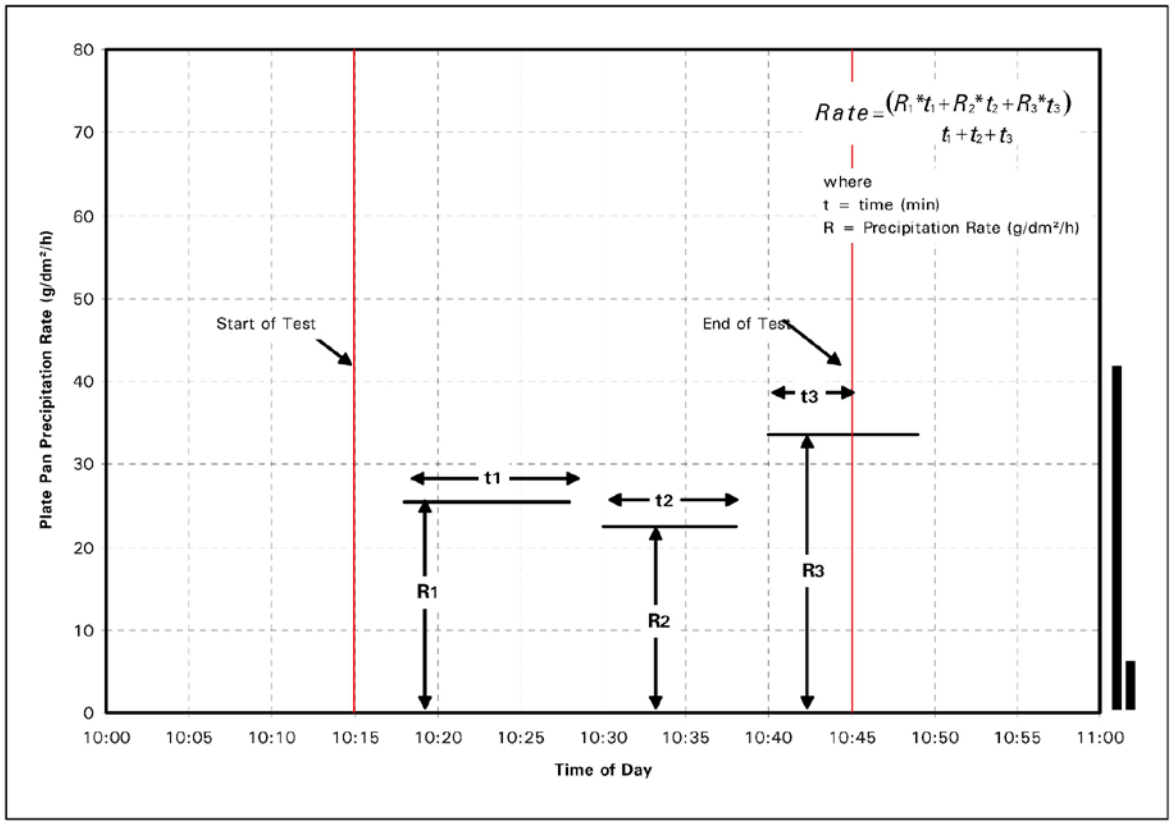


Figure 2.7: Calculation of Outdoor Precipitation Rate

2.6 Analysis Methodology

2.6.1 General

This section of the report describes the various categories of precipitation and the precipitation rate limits used during the course of endurance time testing. The process of data analysis used in the determination of fluid HOTs is also described.

2.6.2 Descriptions of Data Ranges and Precipitation Definitions

The test program developed to measure fluid failure times was carried out under five general categories of precipitation:

- Natural snow;
- Freezing drizzle;
- Light freezing rain;
- Freezing fog; and
- Rain on a cold-soaked surface.

Tests were conducted over temperature and precipitation rate ranges specific to each category of precipitation. A multi-variable regression procedure was used to evaluate fluid HOTs (first presented in TC report, TP 13131E) and is based on the refinement of an equation for a curve which best represents the fluid failure time test data, and then solving that equation at the upper and lower limits of a defined precipitation range. To support this procedure, precipitation rate limits for each specific category of precipitation were defined, reviewed and approved.

The precipitation rate limits used for the evaluation of HOT's are represented schematically in Figure 2.8. Detailed definitions and explanations of the data types and ranges are described in the following subsections. Meteorologically accepted definitions of these conditions were outlined in Table 2.1.

2.6.2.1 Natural snow

All fluid failure tests in natural snow were conducted at the APS Dorval Airport test site. Data were collected for precipitation rates that ranged from less than 4 g/dm²/h to greater than 25 g/dm²/h. For Type II and Type IV fluids, upper and lower limits for the snow column were set at rates of 10 and 25 g/dm²/h, respectively.

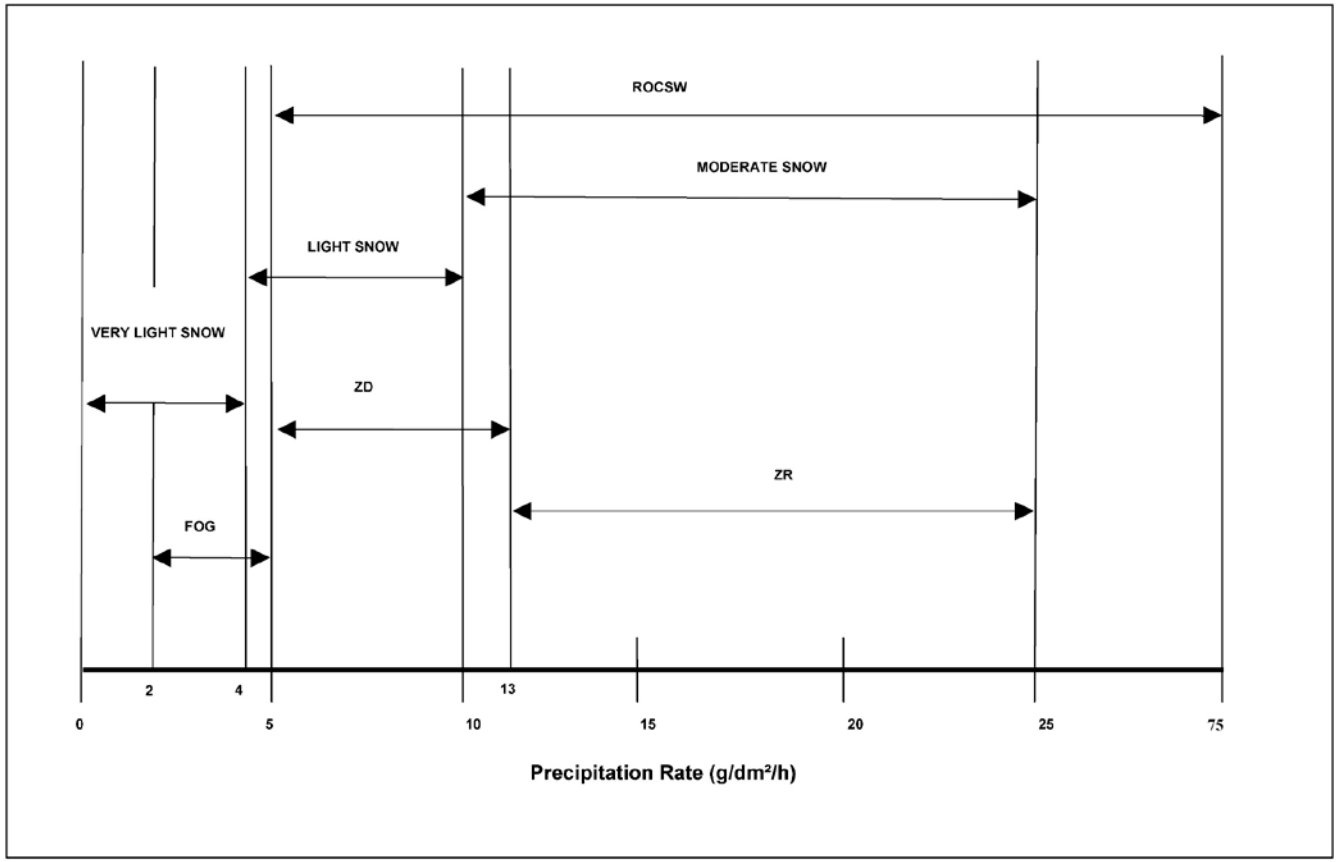


Figure 2.8: Data Range Used for Evaluation of Holdover Time Limits

The upper precipitation rate limit (25 g/dm^2/h) corresponds to the onset of heavy snow. Above this rate, it is standard practice to refer to the cautionary note included in the HOT tables indicating that the time of protection will be shortened in heavy weather conditions, (i.e., heavy precipitation, or high moisture content).

2.6.2.2 Freezing drizzle

Freezing drizzle is considered to occur over the range of 0 to 13 g/dm^2/h. The upper limit in this range, while not specifically defined in Table 2.1, has been adopted based on discussions with meteorological experts and aircraft operators on the SAE G-12 HOT Subcommittee.

For test purposes, the precipitation rate spectrum for freezing drizzle is constrained to rates between 5 and 13 g/dm^2/h, inclusively. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety. A caution note is included in the HOT tables indicating that if positive identification of freezing drizzle is not possible, the light freezing rain HOT is recommended for use.

2.6.2.3 Light freezing rain

With reference to the HOT tables, freezing rain conditions span the range of precipitation rates from 13 to 25 g/dm^2/h, inclusively. This range falls in 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.

2.6.2.4 Freezing fog

The precipitation rate limits for freezing fog were arrived at with input from meteorologists from the NRC, 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.

The precipitation rate for fog, referred to as *fog deposition* or simply as *deposition*, is given by the empirical expression,

$$\textbf{\textit{Deposition = LWC x Wind Velocity x Sin 10° x Collection Efficiency}}$$

where the Sin 10° term accounts for the 10° inclination of the test plates into the direction of the wind.

The meteorological circumstances (LWC value and wind speed), and the speed and orientation of the airfoil relative to the wind (stationary or taxiing), contribute to uncertainties in the values that the variables in the equation can assume.

Since 1997, the upper and lower HOTs for freezing fog have been evaluated at rates of 5 g/dm^2/h and 2 g/dm^2/h, respectively. In Vienna, during the 1998 SAE G-12 HOT Subcommittee meeting, it was felt that 2 g/dm²/h was not indicative of low rate natural fog. However, during a meeting of the Workgroup on Laboratory Methods to Derive HOT Guidelines in Montreal in March 1999, it was again agreed upon that the rate of 2 g/dm^2/h would be used in subsequent HOT testing in order to determine the upper HOT limit in freezing fog conditions.

2.6.2.5 Rain on a cold-soaked surface

Data used for the evaluation of HOTs for this category of precipitation were limited to precipitation rates ranging from 5 to 75 g/dm^2/h, which 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). The heavy rain category is covered by the caution note at the bottom of the HOT table regarding heavy weather conditions.

2.6.3 Protocol for the Determination of Holdover Times

Each cell in a HOT table represents a range of time during which a fluid at a specified concentration will provide protection for a particular temperature range in a particular category of precipitation. The Type II and Type IV HOT tables are composed of a maximum of 30 cells. Each cell contains a lower and upper time limit (except in frost) for a maximum of 54 time values.

Cell HOT values are determined by plotting *Failure Time* versus *Rate of Precipitation* and recording the failure time at two pre-selected rate limits. In previous years, several protocols were employed in the determination of HOTs. Due to the subjective natures of these different protocols, different interpretations of the data were possible. A multi-variable regression approach was subsequently devised in 1996/97 (see TC report, TP 13131E) and has since been used to evaluate fluid holdover times.

Data corresponding to each cell in the HOT table were assembled and sorted according to precipitation type, fluid dilution and temperature range. The data for each cell in the HOT table were plotted.

The data points on each plot were used to fit an equation of the form:

$$t = cR^a$$

where

t = Time (minutes)
R = Rate of precipitation (g/dm^2/h)
a,c = coefficients determined from the regression.

The coefficient a gives the rate dependency of the failure time.

Sample plots of **Log t** versus **Log R** are shown in Figure 2.9. The plots contain data from one temperature range, for one Neat Type IV fluid 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 2.10. 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 snow.

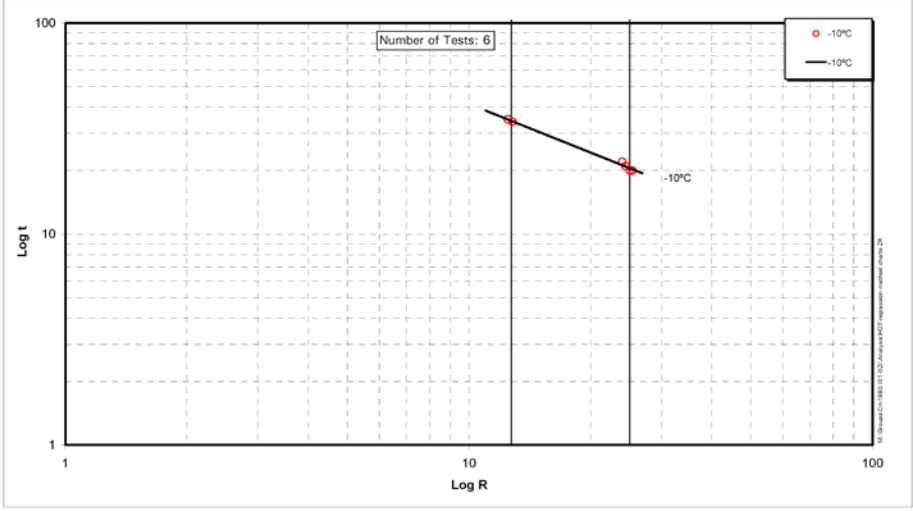


Figure 2.9: Regression Method on Log-Log Chart – Sample Type IV Neat, Freezing Rain

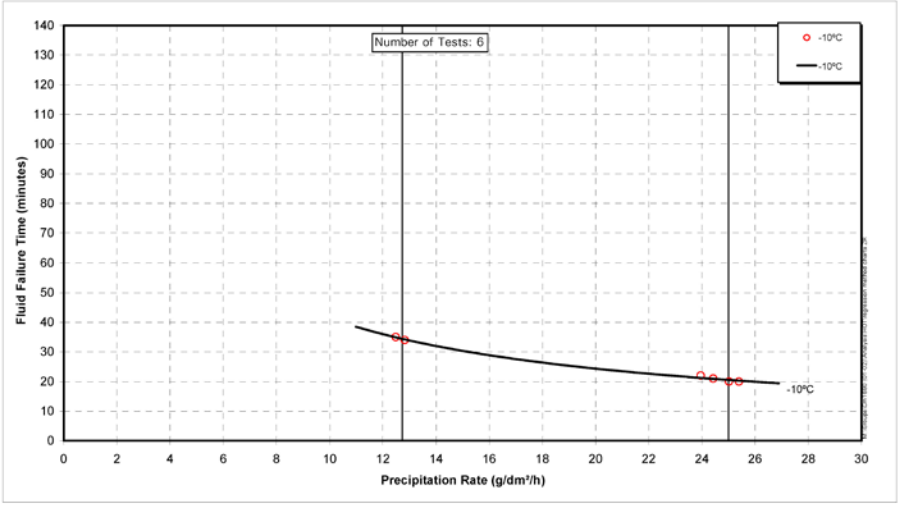


Figure 2.10: Regression Method on Standard Chart – Sample Type IV Neat, Freezing Rain

The HOTs for this fluid at -10°C are 20 minutes at 10 g/dm^2/h and 35 minutes at 25 g/dm^2/h, establishing the HOT range for this particular fluid. This illustrates the general approach used in the determination of a fluid HOT range for any given cell in the HOT table.

The categories of precipitation are separated into five groups: natural snow, freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface. Each group was subject to a slightly modified version of the general equation given above, as described in the following subsections.

2.6.3.1 Light freezing rain and freezing drizzle

The equation used to treat the data in these categories of precipitation is given by the expression below:

$$t = cR^a$$

- Tests in freezing drizzle and light freezing rain were conducted at predetermined temperature limits (-3 and -10°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were also obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.2 Simulated freezing fog

The equation used to treat freezing fog data is given by the expression below:

$$t = cR^a$$

- Tests in freezing fog were conducted at predetermined temperature limits (-3, -14 and -25°C). The best-fit curves for data corresponding to a given cell in the HOT table in these conditions were obtained by using the most restrictive (lowest) cell range temperature.

2.6.3.3 Natural snow

The general form of the regression equation was modified for natural snow by substituting 2-T for the variable T, in order to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C.

$$t = cR^a(2-T)^b.$$

- Best-fit curves were plotted for each fluid in each cell of the snow column using the most restrictive (lowest) temperature for that cell. For example, in cases of natural snow tests conducted at ambient temperatures above -3°C, the value of temperature used in the fitting procedure was -3°C.

- The upper and lower HOT values were determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively.

2.6.3.4 Rain on a cold-soaked wing

The same method for the evaluation of HOTs in light freezing rain and freezing drizzle was used for this category of precipitation.

2.6.4 Determination of Generic and Fluid Specific Holdover Times

At the SAE HOT Subcommittee meeting in Chicago in July 1997, Type IV fluid HOTs obtained using the multi-variable regression protocol of data analysis were presented. Wide variations in fluid performance among the different Type IV fluid brands forced the development of generic Type II and IV HOT tables as well as fluid-specific Type II and IV HOT tables.

2.6.4.1 Fluid-specific holdover time tables

Fluid-specific HOT table development was prompted by the fact that certain Type IV fluid brands were observed to significantly outperform other fluids under conditions corresponding to specific cells in the HOT tables. In general, any one fluid brand does not globally outperform the other fluid brands, but rather does so at a specific dilution, temperature range, and/or category of precipitation.

At the Chicago meeting in 1997, most members of the SAE G-12 HOT Subcommittee did not favour fluid-specific tables. However, significant reductions to HOTs for the cells corresponding to the most common Type IV fluid usage convinced the committee of the need to consider the development of fluid-specific and generic tables. Furthermore, some members wanted to take advantage of the significant benefits exhibited by some fluids in certain conditions.

A summary of the steps to follow to determine fluid specific values for a Type II or IV fluid is provided below:

- The method used to determine HOTs is generally the same as was agreed upon in Chicago in 1997 at the SAE G-12 HOT Subcommittee meeting;
- For each cell of the HOT tables, four tests are typically conducted at the lowest temperature in the temperature range for that cell. Two tests are conducted at the low precipitation rate condition and at the high precipitation rate condition, for a total of four tests per cell;
- For each cell of the HOT table (except frost), a best-fit power law curve for each fluid is developed from the tests conducted at the low and high precipitation rate condition of that cell;
- Regression-generated HOTs are rounded off to the nearest whole "5" digit. For example, 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 HOTs are below 10 minutes, the numbers are rounded down as a precautionary measure. For example, 9 minutes is rounded down to 5 minutes; and
- Values are capped at 2 hours for all precipitation conditions except freezing fog, which are capped at 4 hours.

Photo 2.1: View of Test Site and Associated Equipment



Photo 2.2: Meteorological Services of Canada Weather Observation Station at Montréal-Pierre-Elliott-Trudeau International Airport



Photo 2.3: Outdoor View of National Research Council Climatic Engineering Facility



Photo 2.4: Inside View of Small End of Climatic Engineering Facility



Photo 2.5: Inside View of Large End of Climatic Engineering Facility



Photo 2.6: Sprayer Assembly Used at National Research Council



Photo 2.7: Sprayer Nozzle

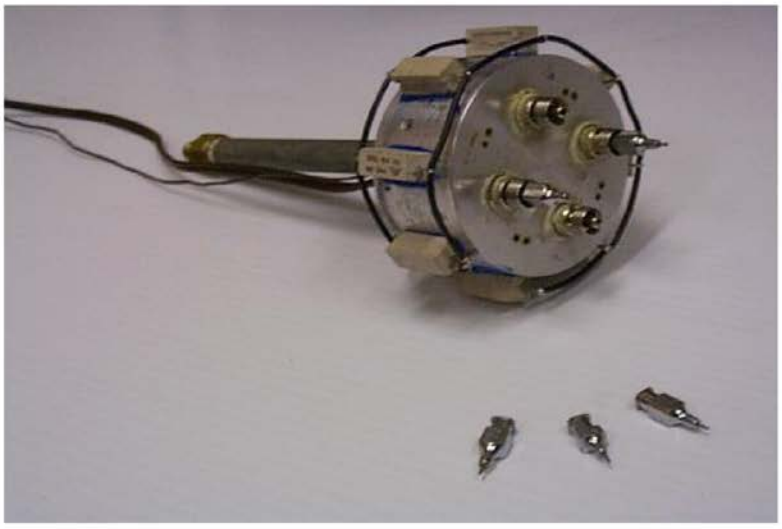


Photo 2.8: Test Plates Mounted on Stand



Photo 2.9: Collection Pans Used Indoors at the National Research Council



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3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted in natural snow, simulated light freezing rain, simulated freezing drizzle, simulated freezing fog, and rain on cold-soaked surfaces. Breakdowns are provided for quantity of tests performed by fluid type and temperature.

Summaries of tests conducted in natural snow and in freezing precipitation are provided in Tables 3.1 and 3.2 at the end of this section.

3.1 Natural Snow Tests

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

	Above -3°C	-3 to -14°C	-14 to -25°C	Total
Neat	2	9	0	11
75/25	5	10	0	15
50/50	8	2	0	10
				36

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 the tests conducted is summarized below by 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	5	0	4	0

3.3 Freezing Fog Tests

Tests were conducted in freezing fog condition at the NRC CEF. The breakdown of the 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

Cold-soak tests were conducted with Neat and 75/25 dilutions using 7.5 cm deep sealed boxes. Tests were conducted at an ambient temperature of +1°C at the NRC CEF. Duplicate tests were conducted with each dilution at each precipitation rate.

3.5 Fluid Thickness Tests

The purpose of these tests was to measure the film thickness profiles of the fluid in all dilutions, under dry conditions.

Two tests were performed for each standard dilution (Neat, 75/25 and 50/50). For each test, one litre of fluid was poured onto a flat plate mounted on a test stand inclined 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. Tests were conducted at an ambient temperature of -3°C.

The results are displayed in Figure 3.1.

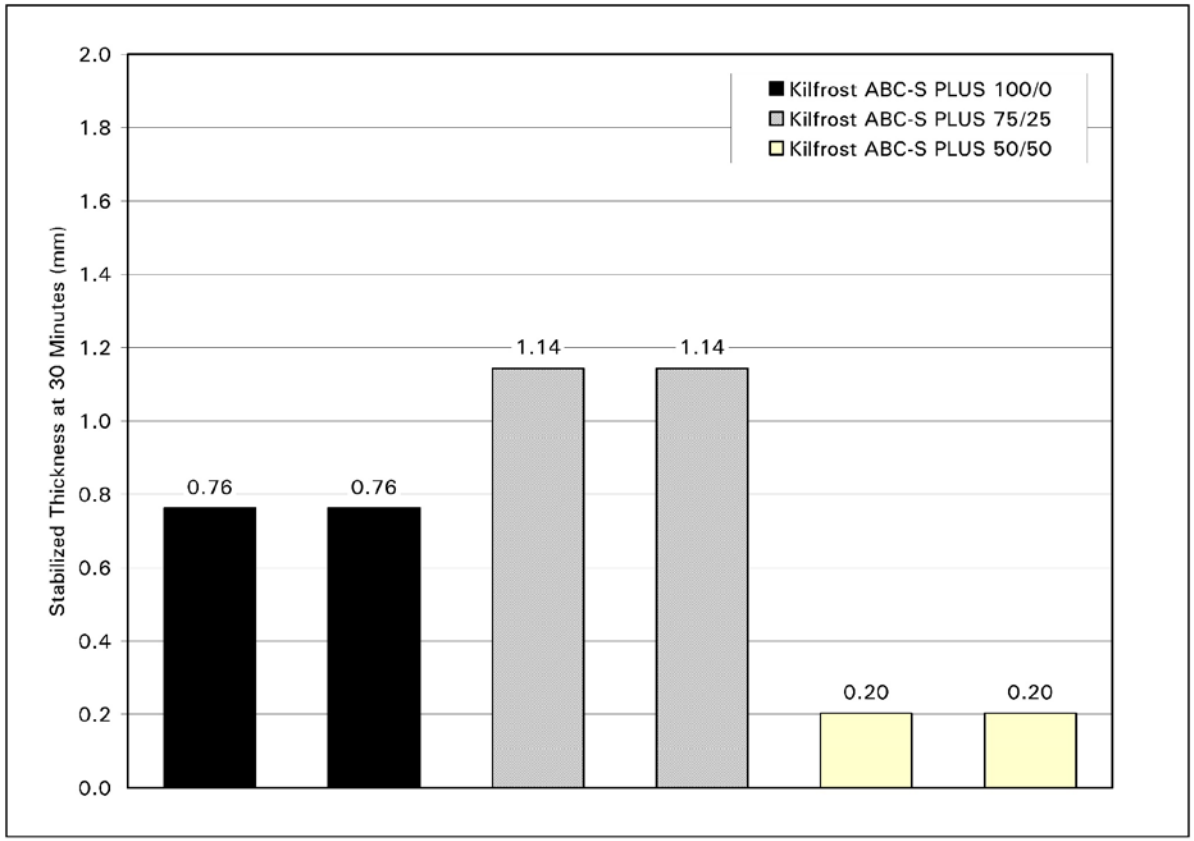

Figure 3.1: Fluid Thickness of Kilfrost ABC-S PLUS

Table 3.1: Summary of Tests Performed in 2005-06 (Snow)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
47	16-Feb-06	Kilfrost ABC-S PLUS	100%	36.1	24.0	-8.4	Natural Snow
48	16-Feb-06	Kilfrost ABC-S PLUS	75%	24.5	23.3	-8.4	Natural Snow
55	16-Feb-06	Kilfrost ABC-S PLUS	100%	42.4	30.7	-9.3	Natural Snow
56	16-Feb-06	Kilfrost ABC-S PLUS	75%	20.8	32.4	-9.2	Natural Snow
63	16-Feb-06	Kilfrost ABC-S PLUS	100%	26.6	30.2	-9.3	Natural Snow
64	16-Feb-06	Kilfrost ABC-S PLUS	75%	17.0	30.7	-9.3	Natural Snow
71	16-Feb-06	Kilfrost ABC-S PLUS	100%	85.1	10.6	-9.0	Natural Snow
72	16-Feb-06	Kilfrost ABC-S PLUS	75%	60.7	7.4	-9.0	Natural Snow
88	21-Feb-06	Kilfrost ABC-S PLUS	50%	33.8	4.3	-3.6	Natural Snow
93	21-Feb-06	Kilfrost ABC-S PLUS	75%	153.4	3.1	-3.5	Natural Snow
96	21-Feb-06	Kilfrost ABC-S PLUS	50%	105.5	1.9	-3.2	Natural Snow
108	22-Feb-06	Kilfrost ABC-S PLUS	50%	16.0	10.4	-1.6	Natural Snow
109	22-Feb-06	Kilfrost ABC-S PLUS	100%	133.9	5.9	-1.6	Natural Snow
110	22-Feb-06	Kilfrost ABC-S PLUS	75%	53.9	8.6	-1.6	Natural Snow
119	22-Feb-06	Kilfrost ABC-S PLUS	50%	54.0	2.1	-1.4	Natural Snow
121	22-Feb-06	Kilfrost ABC-S PLUS	75%	92.4	4.8	-1.5	Natural Snow
128	23-Feb-06	Kilfrost ABC-S PLUS	50%	14.3	8.9	-1.4	Natural Snow
129	23-Feb-06	Kilfrost ABC-S PLUS	75%	84.9	4.8	-2.0	Natural Snow
134	23-Feb-06	Kilfrost ABC-S PLUS	50%	18.3	9.3	-1.4	Natural Snow
138	23-Feb-06	Kilfrost ABC-S PLUS	50%	16.1	6.9	-1.4	Natural Snow
149	23-Feb-06	Kilfrost ABC-S PLUS	50%	12.1	11.4	-1.0	Natural Snow
150	23-Feb-06	Kilfrost ABC-S PLUS	75%	36.1	15.3	-1.2	Natural Snow
151	23-Feb-06	Kilfrost ABC-S PLUS	100%	62.8	17.1	-1.1	Natural Snow
161	23-Feb-06	Kilfrost ABC-S PLUS	75%	49.9	13.9	-1.3	Natural Snow
167	24-Feb-06	Kilfrost ABC-S PLUS	50%	9.4	23.4	-1.5	Natural Snow
171	24-Feb-06	Kilfrost ABC-S PLUS	50%	11.0	16.0	-1.3	Natural Snow
179	25-Feb-06	Kilfrost ABC-S PLUS	100%	85.1	4.3	-13.7	Natural Snow
180	25-Feb-06	Kilfrost ABC-S PLUS	75%	89.7	4.6	-13.7	Natural Snow
183	25-Feb-06	Kilfrost ABC-S PLUS	100%	66.3	6.9	-13.7	Natural Snow
190	25-Feb-06	Kilfrost ABC-S PLUS	100%	56.2	10.2	-13.7	Natural Snow
191	25-Feb-06	Kilfrost ABC-S PLUS	75%	48.8	10.3	-13.7	Natural Snow
196	25-Feb-06	Kilfrost ABC-S PLUS	100%	118.0	4.4	-12.9	Natural Snow
197	25-Feb-06	Kilfrost ABC-S PLUS	75%	98.7	4.8	-12.9	Natural Snow
200	25-Feb-06	Kilfrost ABC-S PLUS	75%	51.5	8.9	-13.5	Natural Snow
209	03-Mar-06	Kilfrost ABC-S PLUS	100%	149.3	4.4	-9.0	Natural Snow
210	03-Mar-06	Kilfrost ABC-S PLUS	75%	141.8	4.0	-9.1	Natural Snow

Table 3.2: Summary of Tests Performed in 2005-06 (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
27	06-Apr-06	Kilfrost ABC-S PLUS	100%	73.9	13.3	-3.2	Freezing Drizzle
28	06-Apr-06	Kilfrost ABC-S PLUS	100%	72.2	13.3	-3.2	Freezing Drizzle
29	06-Apr-06	Kilfrost ABC-S PLUS	75%	43.7	12.7	-3.2	Freezing Drizzle
30	06-Apr-06	Kilfrost ABC-S PLUS	75%	49.4	13.2	-3.1	Freezing Drizzle
31	06-Apr-06	Kilfrost ABC-S PLUS	50%	10.3	13.5	-3.0	Freezing Drizzle
32	06-Apr-06	Kilfrost ABC-S PLUS	50%	10.2	12.8	-3.0	Freezing Drizzle
59	07-Apr-06	Kilfrost ABC-S PLUS	100%	117.5	4.9	-3.3	Freezing Drizzle
60	07-Apr-06	Kilfrost ABC-S PLUS	100%	117.0	5.0	-3.3	Freezing Drizzle
61	07-Apr-06	Kilfrost ABC-S PLUS	75%	74.5	5.1	-3.2	Freezing Drizzle
62	07-Apr-06	Kilfrost ABC-S PLUS	75%	65.5	5.2	-3.3	Freezing Drizzle
63	07-Apr-06	Kilfrost ABC-S PLUS	50%	20.5	5.2	-3.2	Freezing Drizzle
64	07-Apr-06	Kilfrost ABC-S PLUS	50%	19.4	5.3	-3.2	Freezing Drizzle
R64	27-Apr-06	Kilfrost ABC-S PLUS	50%	21.5	5.4	-3.1	Freezing Drizzle
83	06-Apr-06	Kilfrost ABC-S PLUS	100%	31.0	12.8	-10.3	Freezing Drizzle
84	06-Apr-06	Kilfrost ABC-S PLUS	100%	30.2	12.9	-10.3	Freezing Drizzle
85	06-Apr-06	Kilfrost ABC-S PLUS	75%	26.0	13.0	-9.9	Freezing Drizzle
86	06-Apr-06	Kilfrost ABC-S PLUS	75%	25.5	13.1	-9.9	Freezing Drizzle
105	05-Apr-06	Kilfrost ABC-S PLUS	100%	92.0	4.9	-10.1	Freezing Drizzle
106	05-Apr-06	Kilfrost ABC-S PLUS	100%	91.3	5.3	-10.1	Freezing Drizzle
107	05-Apr-06	Kilfrost ABC-S PLUS	75%	68.5	5.4	-10.4	Freezing Drizzle
108	05-Apr-06	Kilfrost ABC-S PLUS	75%	66.5	5.4	-10.4	Freezing Drizzle
133	13-Apr-06	Kilfrost ABC-S PLUS	100%	53.5	24.6	-3.1	Freezing Rain
134	13-Apr-06	Kilfrost ABC-S PLUS	100%	52.0	24.4	-3.1	Freezing Rain
135	13-Apr-06	Kilfrost ABC-S PLUS	75%	32.0	25.2	-3.0	Freezing Rain
136	13-Apr-06	Kilfrost ABC-S PLUS	75%	31.0	24.8	-3.0	Freezing Rain
137	13-Apr-06	Kilfrost ABC-S PLUS	50%	7.3	24.6	-3.0	Freezing Rain
138	13-Apr-06	Kilfrost ABC-S PLUS	50%	8.3	25.6	-3.1	Freezing Rain
163	04-Apr-06	Kilfrost ABC-S PLUS	100%	68.8	13.3	-3.2	Freezing Rain
164	04-Apr-06	Kilfrost ABC-S PLUS	100%	71.2	13.5	-3.2	Freezing Rain
165	04-Apr-06	Kilfrost ABC-S PLUS	75%	43.5	13.3	-3.2	Freezing Rain
166	04-Apr-06	Kilfrost ABC-S PLUS	75%	43.3	13.2	-3.2	Freezing Rain
167	04-Apr-06	Kilfrost ABC-S PLUS	50%	11.8	13.4	-3.1	Freezing Rain
168	04-Apr-06	Kilfrost ABC-S PLUS	50%	12.0	13.0	-3.1	Freezing Rain
187	05-Apr-06	Kilfrost ABC-S PLUS	100%	24.6	24.9	-9.9	Freezing Rain
188	05-Apr-06	Kilfrost ABC-S PLUS	100%	22.7	25.0	-9.9	Freezing Rain
189	05-Apr-06	Kilfrost ABC-S PLUS	75%	27.5	24.6	-10.3	Freezing Rain
190	05-Apr-06	Kilfrost ABC-S PLUS	75%	28.3	24.8	-10.3	Freezing Rain
209	05-Apr-06	Kilfrost ABC-S PLUS	100%	37.8	12.8	-10.2	Freezing Rain
210	05-Apr-06	Kilfrost ABC-S PLUS	100%	36.8	12.9	-10.2	Freezing Rain
211	05-Apr-06	Kilfrost ABC-S PLUS	75%	39.8	13.1	-10.1	Freezing Rain

Table 3.2 (cont'd): Summary of Tests Performed in 2005-06 (Freezing Precipitation)

Test No.	Date	Fluid Name	Fluid Dilution	Endurance Time (min)	Icing Intensity (g/dm²/h)	Test Temp. (°C)	Precipitation Type
212	05-Apr-06	Kilfrost ABC-S PLUS	75%	39.2	13.2	-10.1	Freezing Rain
239	11-Apr-06	Kilfrost ABC-S PLUS	100%	112.7	4.8	-3.4	Freezing Fog
240	11-Apr-06	Kilfrost ABC-S PLUS	100%	108.3	5.1	-3.4	Freezing Fog
241	11-Apr-06	Kilfrost ABC-S PLUS	75%	72.0	4.8	-3.2	Freezing Fog
242	11-Apr-06	Kilfrost ABC-S PLUS	75%	71.0	4.8	-3.0	Freezing Fog
243	11-Apr-06	Kilfrost ABC-S PLUS	50%	21.8	5.0	-2.9	Freezing Fog
244	11-Apr-06	Kilfrost ABC-S PLUS	50%	22.0	5.1	-3.0	Freezing Fog
271	12-Apr-06	Kilfrost ABC-S PLUS	100%	229.5	2.0	-3.2	Freezing Fog
272	12-Apr-06	Kilfrost ABC-S PLUS	100%	213.2	1.9	-3.2	Freezing Fog
273	12-Apr-06	Kilfrost ABC-S PLUS	75%	129.2	2.0	-3.1	Freezing Fog
274	12-Apr-06	Kilfrost ABC-S PLUS	75%	131.8	2.0	-3.1	Freezing Fog
275	12-Apr-06	Kilfrost ABC-S PLUS	50%	40.5	2.0	-3.0	Freezing Fog
276	12-Apr-06	Kilfrost ABC-S PLUS	50%	40.2	2.2	-3.0	Freezing Fog
295	11-Apr-06	Kilfrost ABC-S PLUS	100%	39.0	4.8	-14.2	Freezing Fog
296	11-Apr-06	Kilfrost ABC-S PLUS	100%	40.0	5.2	-14.2	Freezing Fog
297	11-Apr-06	Kilfrost ABC-S PLUS	75%	40.5	5.1	-14.1	Freezing Fog
298	11-Apr-06	Kilfrost ABC-S PLUS	75%	41.5	4.8	-14.1	Freezing Fog
317	10-Apr-06	Kilfrost ABC-S PLUS	100%	82.2	2.0	-14.3	Freezing Fog
318	10-Apr-06	Kilfrost ABC-S PLUS	100%	84.7	2.2	-14.3	Freezing Fog
319	10-Apr-06	Kilfrost ABC-S PLUS	75%	68.0	2.2	-14.1	Freezing Fog
320	10-Apr-06	Kilfrost ABC-S PLUS	75%	67.5	2.3	-14.1	Freezing Fog
331	10-Apr-06	Kilfrost ABC-S PLUS	100%	20.8	5.2	-25.6	Freezing Fog
332	10-Apr-06	Kilfrost ABC-S PLUS	100%	19.7	5.4	-25.6	Freezing Fog
343	10-Apr-06	Kilfrost ABC-S PLUS	100%	48.2	1.9	-25.4	Freezing Fog
344	10-Apr-06	Kilfrost ABC-S PLUS	100%	47.4	1.9	-25.4	Freezing Fog
583	27-Apr-06	Kilfrost ABC-S PLUS	100%	16.0	77.3	0.8	Cold Soak
584	27-Apr-06	Kilfrost ABC-S PLUS	100%	15.5	75.9	0.8	Cold Soak
585	27-Apr-06	Kilfrost ABC-S PLUS	75%	9.2	72.0	0.9	Cold Soak
586	27-Apr-06	Kilfrost ABC-S PLUS	75%	8.5	72.0	1.2	Cold Soak
601	27-Apr-06	Kilfrost ABC-S PLUS	100%	101.3	5.1	1.0	Cold Soak
602	27-Apr-06	Kilfrost ABC-S PLUS	100%	97.0	5.1	1.0	Cold Soak
603	27-Apr-06	Kilfrost ABC-S PLUS	75%	62.3	5.2	1.0	Cold Soak
604	27-Apr-06	Kilfrost ABC-S PLUS	75%	58.0	5.2	1.0	Cold Soak

4. RESULTS AND DISCUSSION

The methods used to evaluate the test data have been reviewed in Subsection 2.6. In this section, the data used to generate the endurance times will be presented.

4.1 Data

Endurance time values, for all conditions, are those of the tests conducted in 2005-06. 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 and precipitation on fluid endurance times for each condition. Table 4.1 illustrates the outputs from the regression equations run for this fluid under natural snow, freezing fog, freezing drizzle, freezing rain and cold soak conditions.

4.2 Holdover Time Table

A fluid-specific HOT table for Kilfrost ABC-S PLUS is shown in Table 4.2 at the end of this section.

4.2.1 Holdover Times in Snow, Below -14 to -25°C

In the winter of 2003-04, testing was conducted with artificial snowmakers at temperatures below -14°C. This was done as very limited endurance time data existed for fluids at these temperatures. As a result of this testing, the current propylene Type II and Type IV fluids were given generic values in the -14 to -25°C snow cell. Because no natural snow tests were conducted below -14°C with Kilfrost ABC-S PLUS in the winter of 2005-06, generic values have been used in the -14 to -25°C snow cell.

4.2.2 Fluid Viscosity

The viscosity of the fluid sample used in HOT testing, as measured by APS personnel, appears at the front of this document. The viscosity measurement method is also documented. In order for the fluid specific values of a fluid to be valid, operators must ensure that the viscosity of the fluid used is superior to the published viscosity of that fluid, using the same viscosity measurement method published.

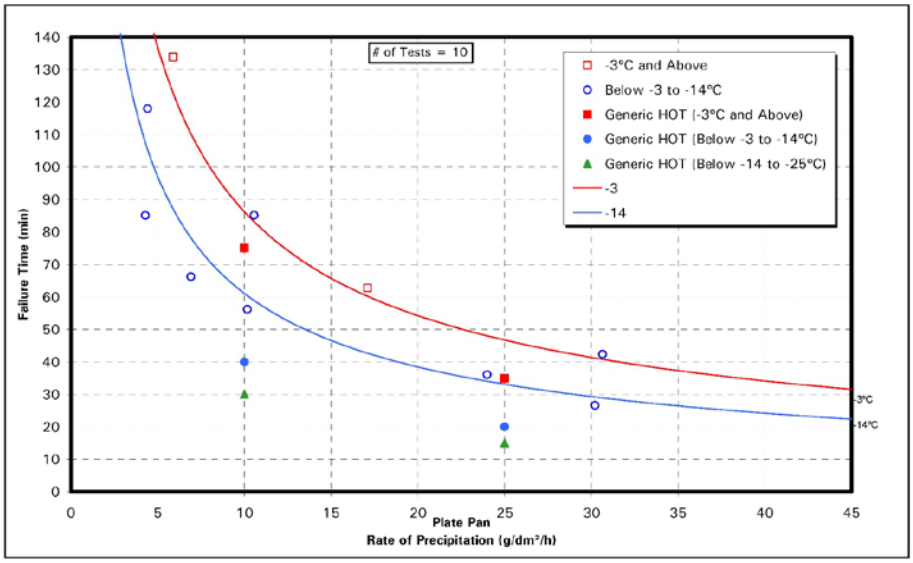

Figure 4.1: Type IV Neat – Natural Snow

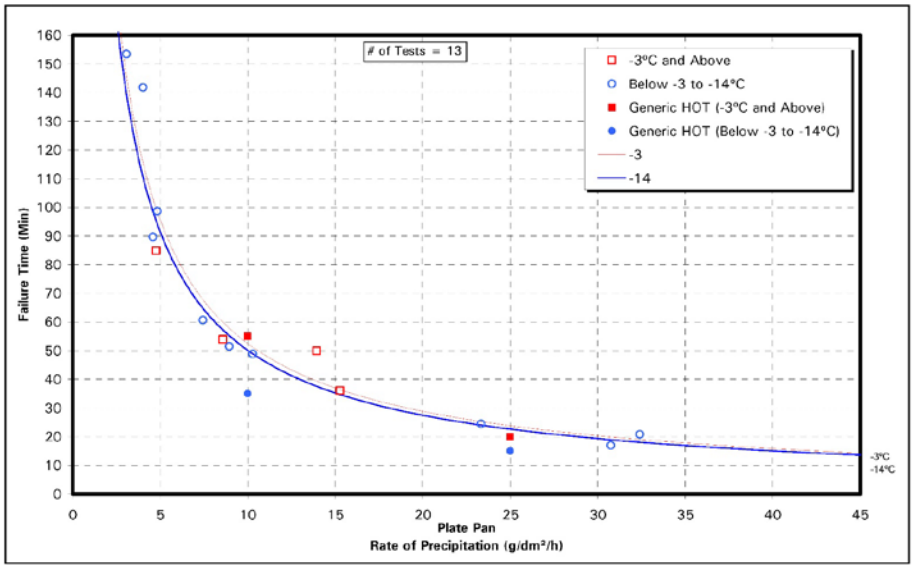

Figure 4.2: Type IV 75/25 – Natural Snow

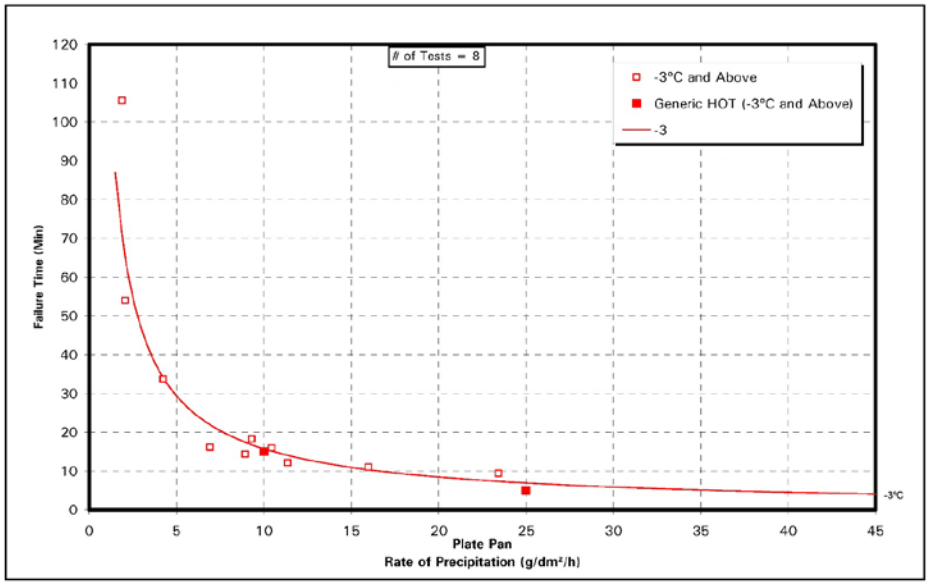

Figure 4.3: Type IV 50/50 – Natural Snow

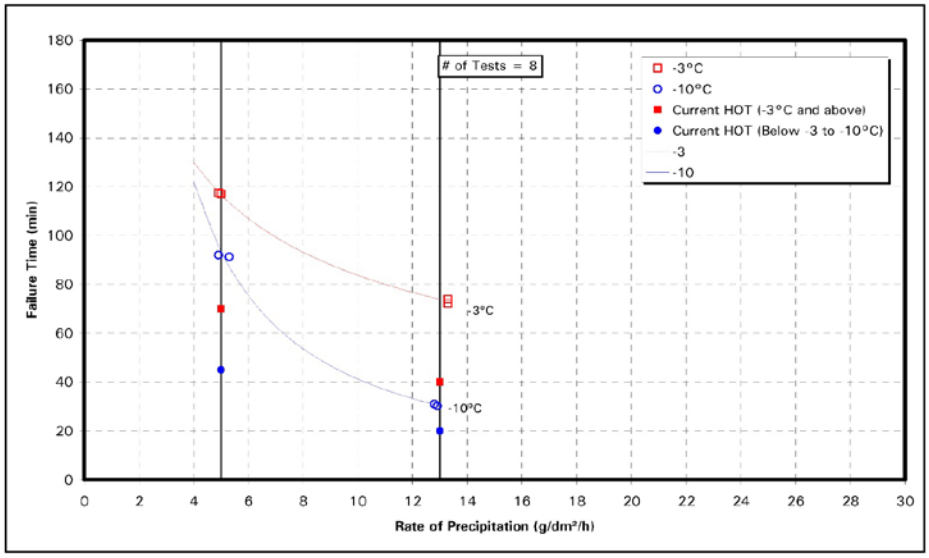

Figure 4.4: Type IV Neat – Freezing Drizzle

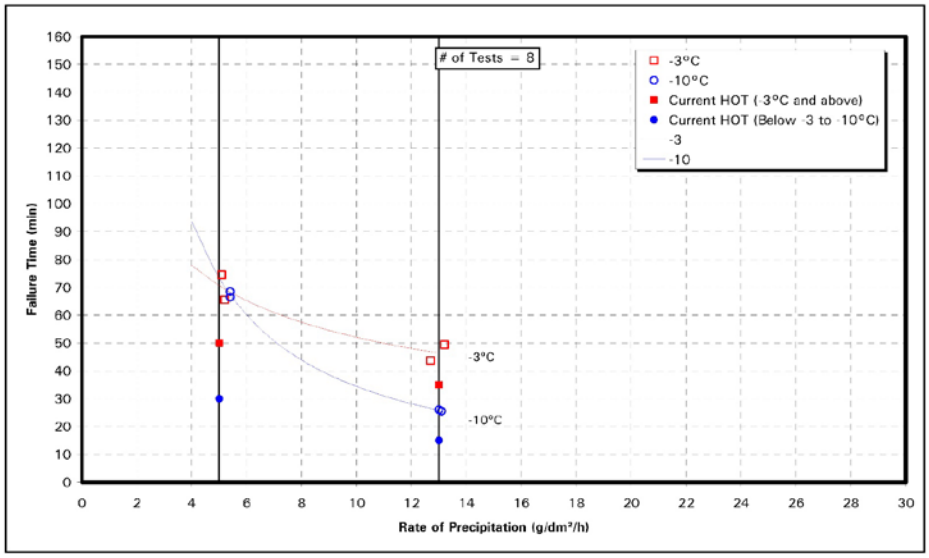

Figure 4.5: Type IV 75/25 – Freezing Drizzle

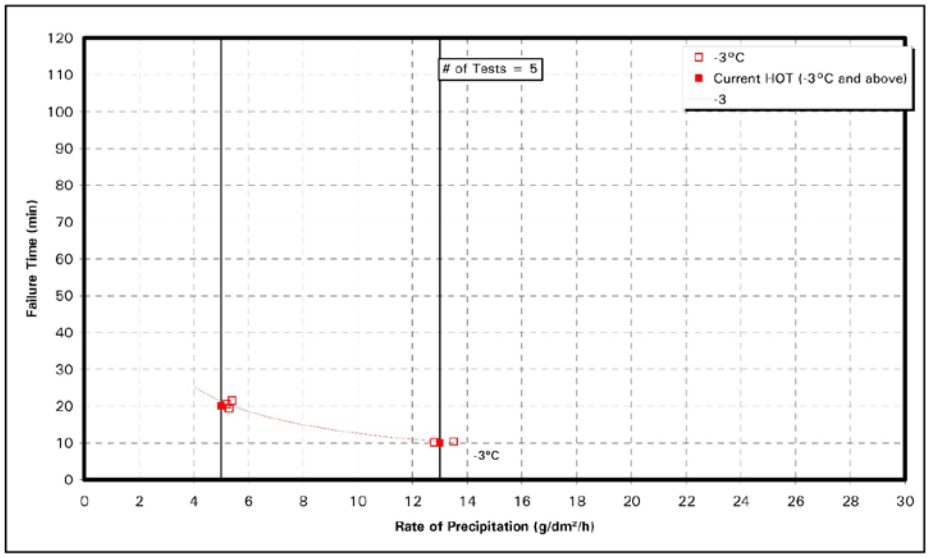

Figure 4.6: Type IV 50/50 – Freezing Drizzle

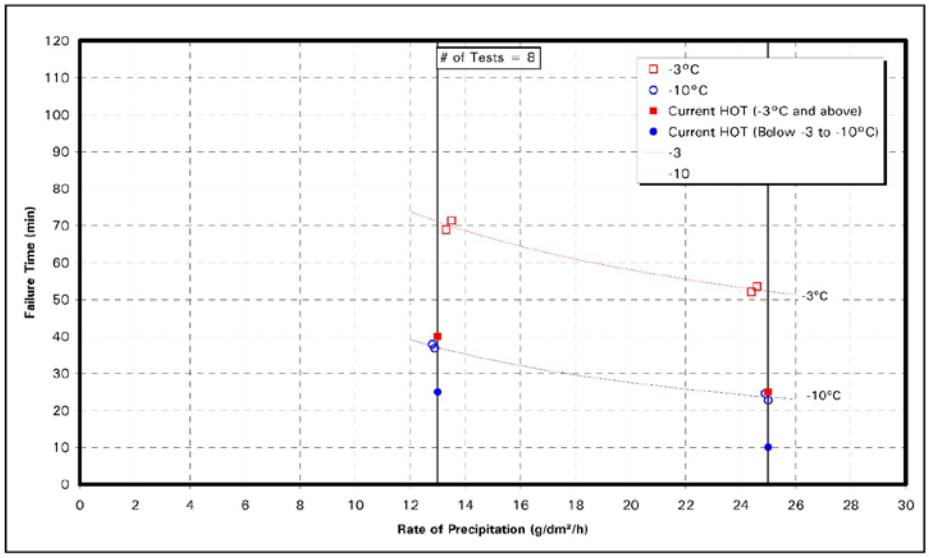

Figure 4.7: Type IV Neat – Light Freezing Rain

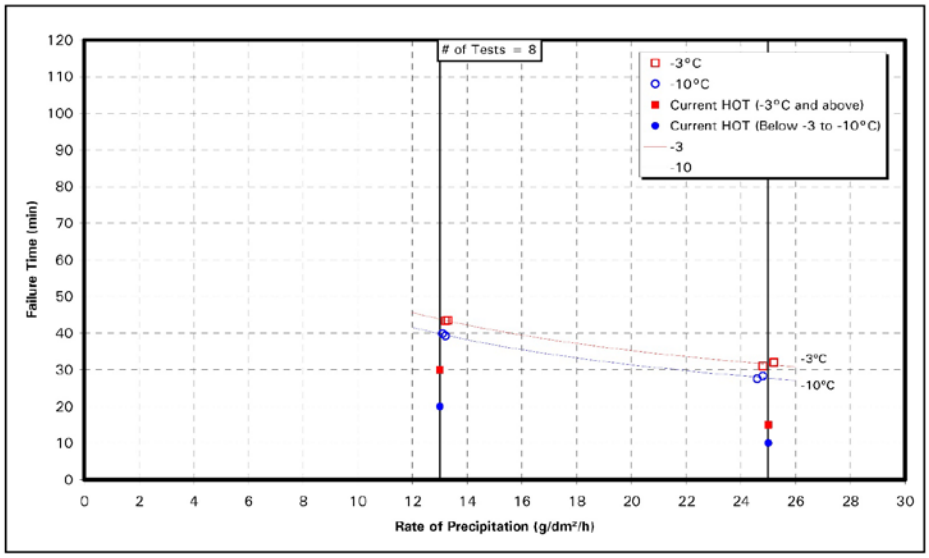

Figure 4.8: Type IV 75/25 – Light Freezing Rain

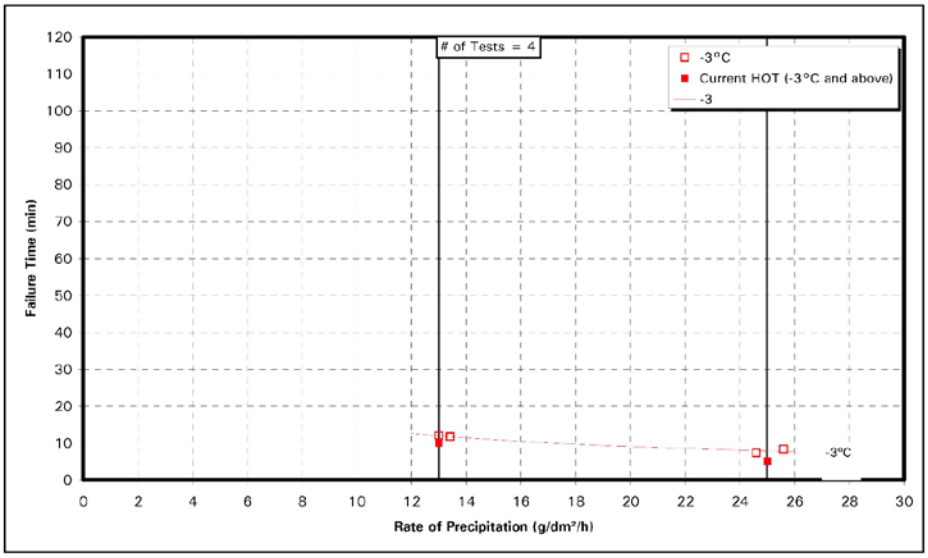

Figure 4.9: Type IV 50/50 – Light Freezing Rain

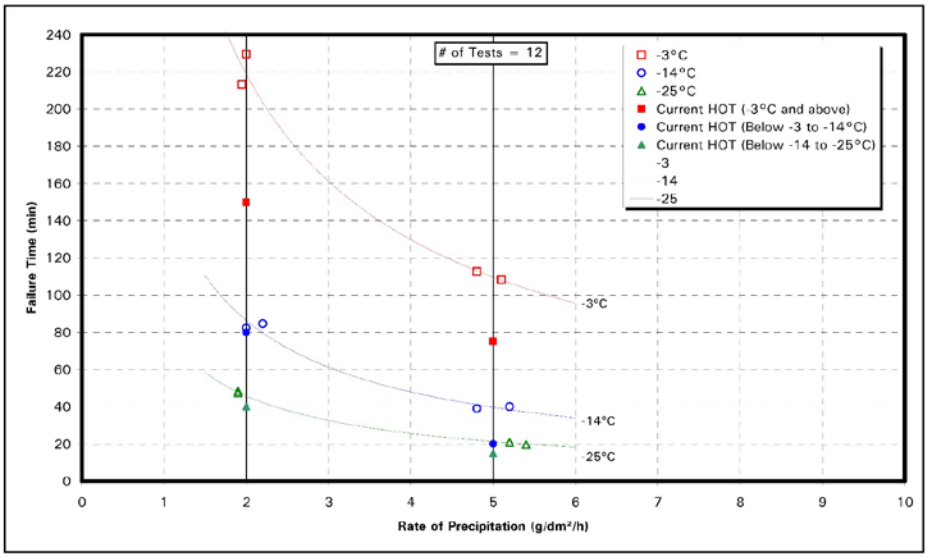

Figure 4.10: Type IV Neat – Freezing Fog

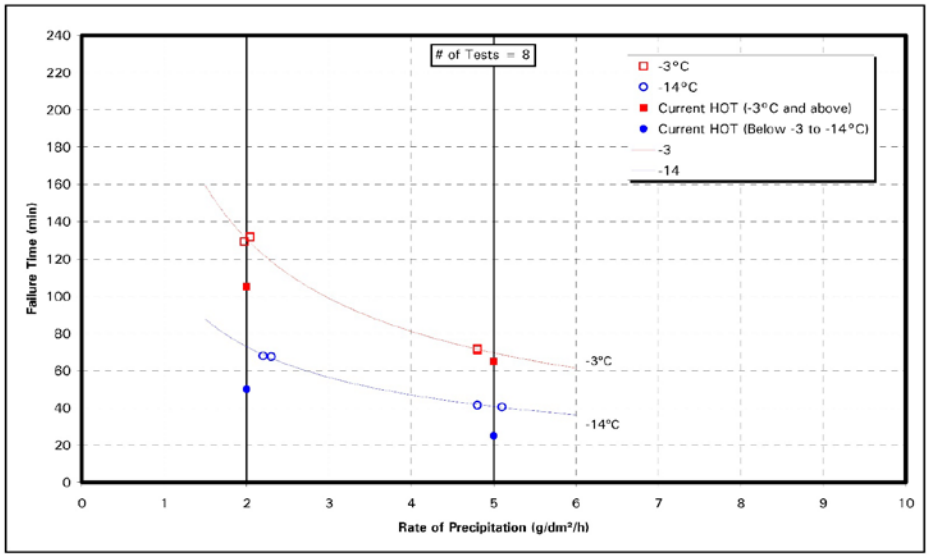

Figure 4.11: Type IV 75/25 – Freezing Fog

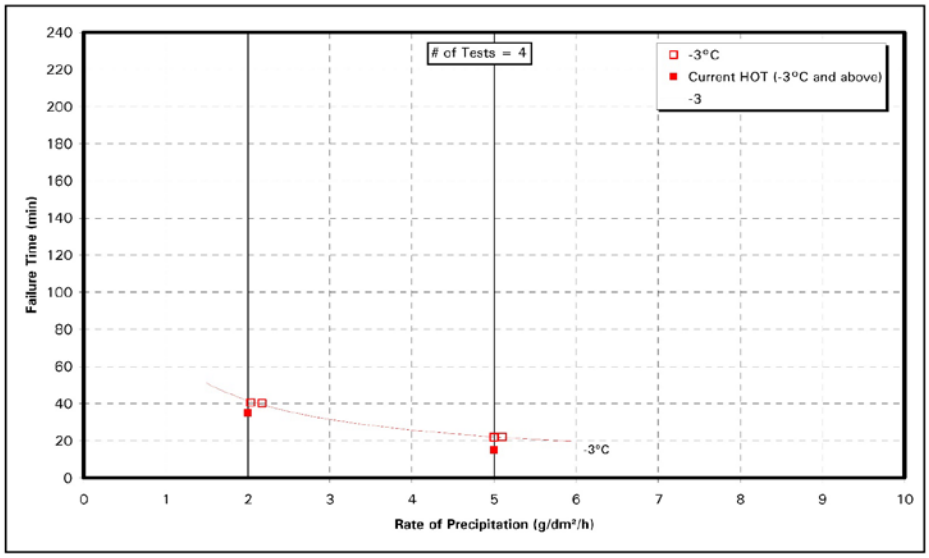

Figure 4.12: Type IV 50/50 – Freezing Fog

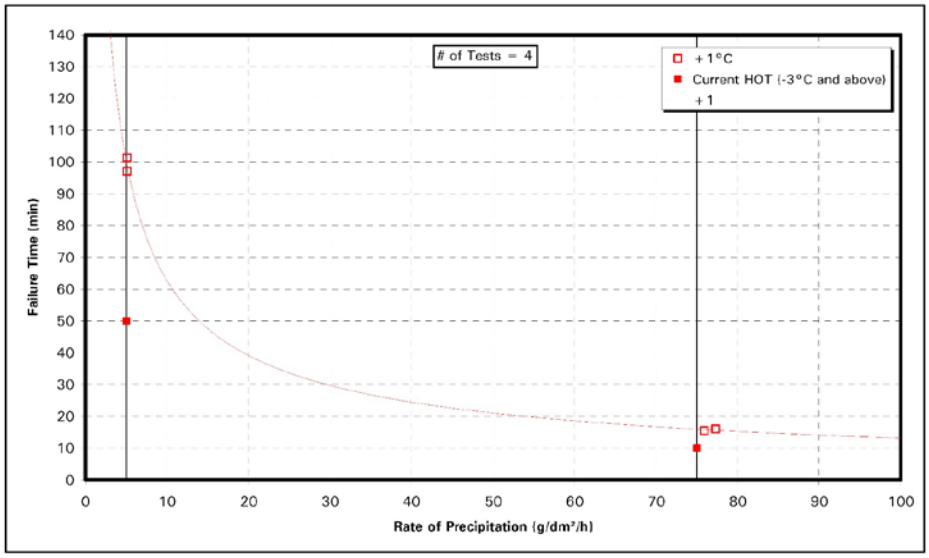

Figure 4.13: Type IV Neat – Rain on Cold-Soaked Surface

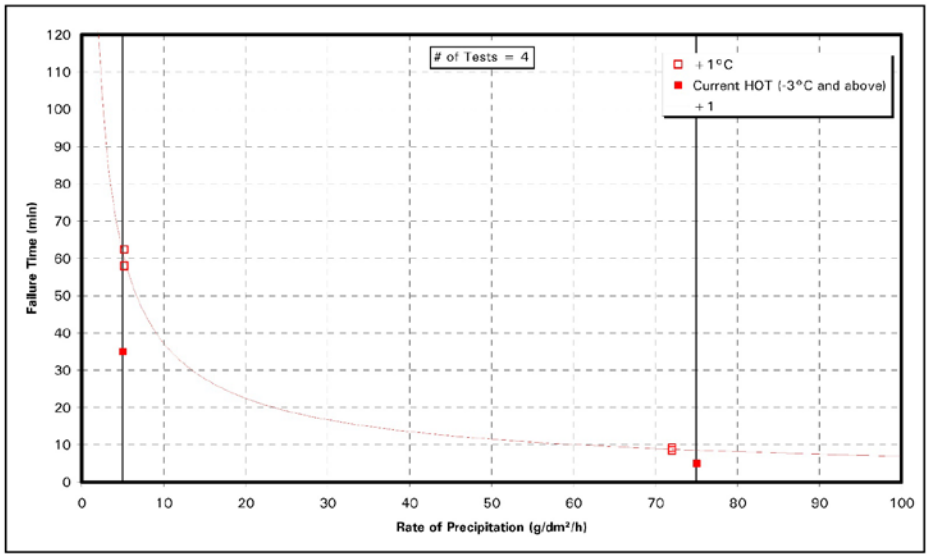

Figure 4.14: Type IV 75/25 – Rain on Cold-Soaked Surface

Table 4.1: Regression Equation Coefficient Summary for Kilfrost ABC-S PLUS

Natural Snow Conditions

Fluid	Dil	R^2	Intercept I	Coeff. Rate (A)	Coeff. Tem (B)	Total Pts.
Kilfrost ABC-S PLUS	Neat	88%	2.8	-0.67	-0.30	11
Kilfrost ABC-S PLUS	75%	97%	2.6	-0.87	-0.04	14
Kilfrost ABC-S PLUS	50%	92%	2.1	-0.90	0.00	10

General Equation $t = 10^{I} R^{A} (2\text{-}T)^{B}$

Simulated Freezing Fog

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-S PLUS	Neat	99%	-3°C	2.6	-0.75	4
Kilfrost ABC-S PLUS	75%	100%	-3°C	2.3	-0.69	4
Kilfrost ABC-S PLUS	50%	100%	-3°C	1.8	-0.70	4
Kilfrost ABC-S PLUS	Neat	98%	-14°C	2.2	-0.85	4
Kilfrost ABC-S PLUS	75%	100%	-14°C	2.1	-0.64	4
Kilfrost ABC-S PLUS	Neat	100%	-25°C	1.9	-0.84	4

General Equation $t = 10^{I} R^{A}$

Simulated Freezing Drizzle

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-S PLUS	Neat	100%	-3°C	2.4	-0.48	4
Kilfrost ABC-S PLUS	75%	91%	-3°C	2.2	-0.44	4
Kilfrost ABC-S PLUS	50%	99%	-3°C	1.9	-0.76	5
Kilfrost ABC-S PLUS	Neat	100%	-10°C	2.8	-1.18	4
Kilfrost ABC-S PLUS	75%	100%	-10°C	2.6	-1.09	4

General Equation $t = 10^{I} R^{A}$

Simulated Light Freezing Rain

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-S PLUS	Neat	98%	-3°C	2.4	-0.47	4
Kilfrost ABC-S PLUS	75%	99%	-3°C	2.2	-0.50	4
Kilfrost ABC-S PLUS	50%	94%	-3°C	1.8	-0.64	4
Kilfrost ABC-S PLUS	Neat	99%	-10°C	2.3	-0.69	4
Kilfrost ABC-S PLUS	75%	99%	-10°C	2.2	-0.55	4

General Equation $t = 10^{I} R^{A}$

Simulated Rain on Cold Soaked Wing

Fluid	Dil	R^2	Temp.	Intercept (I)	Coeff. Rate (A)	Total Pts.
Kilfrost ABC-S PLUS	Neat	100%	+1°C	2.5	-0.68	4
Kilfrost ABC-S PLUS	75%	100%	+1°C	2.3	-0.73	4

General Equation $t = 10^{I} R^{A}$

Table 4.2: Fluid Specific Type IV Fluid Holdover Time Guidelines

KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
ABC-S PLUS

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:50 – 3:40	0:45 – 1:25	1:15 – 1:55	0:50 – 1:10	0:15 – 1:40	
		75/25	5:00	1:10 – 2:10	0:25 – 0:55	0:45 – 1:10	0:30 – 0:45	0:05 – 1:00	
		50/50	3:00	0:20 – 0:40	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	12:00	0:40 – 1:25	0:35 – 1:00	0:30 – 1:35[3]	0:25 – 0:35[3]		
		75/25	5:00	0:40 – 1:15	0:25 – 0:50	0:25 – 1:15[3]	0:30 – 0:40[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:20 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

APPENDIX I

TRANSPORT CANADA AND FEDERAL AVIATION ADMINISTRATION 2006-07 HOLDOVER TIME GUIDELINES

TRANSPORT CANADA
HOLDOVER TIME (HOT) GUIDELINES
WINTER 2006-2007

Transport Canada
Holdover Time (HOT) Guidelines
Winter 2006-2007

Original Issue, July 2006

CHANGE CONTROL RECORDS

This page indicates the changes made to individual pages within the document and those changed pages have the appropriate date in the footer. Sidebars are shown to assist in identifying the changes from the previous version.

It is the responsibility of the end user to periodically check the following website for any Holdover Time Guideline updates: http://www.tc.gc.ca/CivilAviation/commerce/HoldoverTime/menu.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.

General

Ground Icing Operations and Holdover Time (HOT) Guideline information is provided in two documents. The two documents complement each other and should be used together for a more thorough understanding of the subject matter. The first document (TP 14052E) includes reference material related to Ground Icing Operations. The most recent version of TP 14052E is Edition 2, published April 2005. The second document consists of the HOT Guidelines, provided in this dedicated Transport Canada website.

Type I Fluid

The Type I holdover guideline values are unchanged.

Type II Fluid

Fluid-specific tables have been created for two new Type II fluids, Clariant Safewing MP II Flight and Kilfrost ABC-TF2. However, the Kilfrost ABC-TF2 fluid is currently in the qualification process.

The Type II generic holdover guideline values are unchanged.

Type III Fluid

The Type III holdover guideline values are unchanged.

Type IV Fluid

Fluid-specific tables have been created for three new Type IV fluids, Clariant Safewing MP IV Launch, Dow Chemical UCAR™ Endurance EG106 and Kilfrost ABC-S PLUS. However, the Kilfrost ABC-S PLUS is currently in the qualification process.

The Type IV generic holdover guideline values are unchanged.

Note on Operations During Ice Pellet Conditions

Transport Canada is conducting research to provide additional guidance for aircraft operations during ice pellet conditions. Because further research is necessary, no changes to the operational and HOT guidelines with respect to ice pellet conditions have been made at this time.

CHANGES TO TP 14052 SECOND EDITION, APRIL 2005

The following changes will be incorporated into TP 14052 at its next revision. For the time being they are recorded here in advance due to the longer life cycle time associated with the updating and publication of TP 14052 and are for immediate use.

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 and SAE Type II, III and IV fluids described in tables 6 & 7 of the Transport Canada HOT Guidelines document.

Delete Sub-Paragraph 10.13.3.1 Item g) only.

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) have been considered and deemed not to affect the HOT.

If there is doubt surrounding the conditions associated with using the lowest time as decision making criteria, 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.

HOLDOVER TIME (HOT) GUIDELINES FOR WINTER 2006-2007

Table 1	SAE Type I Fluid Holdover Guidelines
Table 2-Generic	SAE Type II Fluid Holdover Guidelines
Table 2-C-2025	Clariant Type II Fluid Holdover Guidelines Safewing MP II 2025 ECO
Table 2-C-Flight	Clariant Type II Fluid Holdover Guidelines Safewing MP II Flight
Table 2-K-ABC-2000	Kilfrost Type II Fluid Holdover Guidelines ABC-2000
Table 2-K-ABC-II+	Kilfrost Type II Fluid Holdover Guidelines ABC-II PLUS
Table 2-K-ABC-TF2	Kilfrost Type II Fluid Holdover Guidelines ABC-TF2
Table 2-O-EM-II	Octagon Type II Fluid Holdover Guidelines E Max II
Table 2-S-E26	SPCA Type II Fluid Holdover Guidelines Ecowing 26
Table 3	SAE Type III Fluid Holdover Guidelines
Table 4-Generic	SAE Type IV Fluid Holdover Guidelines
Table 4-C-2001	Clariant Type IV Fluid Holdover Guidelines Safewing MP IV 2001
Table 4-C-2012	Clariant Type IV Fluid Holdover Guidelines Safewing MP IV 2012 Protect
Table 4-C-2030	Clariant Type IV Fluid Holdover Guidelines Safewing MP IV 2030 ECO
Table 4-C-Launch	Clariant Type IV Fluid Holdover Guidelines Safewing MP IV Launch
Table 4-D-ULTRA+	Dow Chemical Type IV Fluid Holdover Guidelines UCAR™ ADF/AAF ULTRA+
Table 4-D-E106	Dow Chemical Type IV Fluid Holdover Guidelines UCAR™ Endurance EG106
Table 4-K-ABC-S	Kilfrost Type IV Fluid Holdover Guidelines ABC-S
Table 4-K-ABC-S PLUS	Kilfrost Type IV Fluid Holdover Guidelines ABC-S PLUS
Table 4-O-MF	Octagon Type IV Fluid Holdover Guidelines Max-Flight
Table 4-O-MF-04	Octagon Type IV Fluid Holdover Guidelines Max-Flight 04
Table 4-O-MFLO	Octagon Type IV Fluid Holdover Guidelines MaxFlo
Table 4-S-AD-480	SPCA Type IV Fluid Holdover Guidelines AD-480
Table 5	Currently Qualified Fluids
Table 6	SAE Type I Deicing Fluid Application Procedures
Table 7	SAE Type II, Type III and Type IV Anti-Icing Fluid Application Procedures
Table 8	Visibility in Snow vs. Snowfall Intensity Chart
Table 9	Lowest On-Wing Viscosity Values for Anti-Icing Neat Fluids

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 1

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

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

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

NOTES

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

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 2-Generic

SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	0:35 – 1:30	0:20 – 0:45	0:30 – 0:55	0:15 – 0:30	0:05 – 0:40	
		75/25	5:00	0:25 – 1:00	0:15 – 0:30	0:20 – 0:45	0:10 – 0:25	0:05 – 0:25	
		50/50	3:00	0:15 – 0:30	0:05 – 0:15	0:05 – 0:15	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:20 – 1:05	0:15 – 0:35	0:15 – 0:45[3]	0:10 – 0:25[3]		
		75/25	5:00	0:20 – 0:55	0:15 – 0:25	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	8:00[5]	0:15 – 0:20[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES

1 Based on the lowest holdover times of the Type II fluids listed in Table 5-2.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

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

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Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 2-C-2025

CLARIANT TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
SAFEWING MP II 2025 ECO

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	1:30 – 2:05	0:40 – 1:10	0:40 – 1:00	0:25 – 0:35	0:10 – 1:15	
		75/25	5:00	0:55 – 1:45	0:25 – 0:45	0:25 – 0:45	0:20 – 0:25	0:05 – 0:50	
		50/50	3:00	0:20 – 0:35	0:05 – 0:15	0:10 – 0:15	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:45 – 1:50	0:35 – 1:00	0:35 – 1:05[3]	0:20 – 0:35[3]		
		75/25	5:00	0:40 – 1:20	0:25 – 0:45	0:30 – 0:40[3]	0:15 – 0:25[3]		
below -14 to -25	below 7 to -13	100/0	8:00	0:25 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 2-C-Flight

CLARIANT TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
SAFEWING MP II FLIGHT

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	3:30 – 4:00	1:00 – 1:35	1:20 – 2:00	0:45 – 1:25	0:10 – 1:30	
		75/25	5:00	2:30 – 4:00	0:40 – 1:20	1:15 – 2:00	0:30 – 0:55	0:05 – 1:20	
		50/50	3:00	0:55 –1:45	0:10 – 0:25	0:20 – 0:30	0:10 – 0:15		
below -3 to -14	below 27 to 7	100/0	8:00	0:55 – 1:45	0:40 – 1:05	0:35 – 1:30[3]	0:25 – 0:45[3]	CAUTION: No holdover time guidelines exist	
		75/25	5:00	0:40 – 1:10	0:20 – 0:40	0:25 – 1:10[3]	0:30 – 0:40[3]		
below -14 to -25	below 7 to -13	100/0	8:00	0:30 – 0:50	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 2-K-ABC-2000

KILFROST TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
ABC-2000

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	1:30 – 3:05	0:30 – 1:00	0:55 – 1:35	0:40 – 0:50	0:15 – 1:10	
		75/25	5:00	1:40 – 3:30	0:30 – 1:05	0:45 – 1:15	0:40 – 0:50	0:15 – 1:40	
		50/50	3:00	1:00 – 2:10	0:15 – 0:30	0:15 – 0:25	0:05 – 0:15		
below -3 to -14	below 27 to 7	100/0	8:00	0:35 – 1:25	0:25 – 0:45	0:25 – 0:50[3]	0:10 – 0:30[3]	CAUTION: No holdover time guidelines exist	
		75/25	5:00	0:35 – 1:15	0:25 – 0:50	0:25 – 0:55[3]	0:15 – 0:30[3]		
below -14 to -25	below 7 to -13	100/0	8:00	0:20 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 2-K-ABC-II+

KILFROST TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
ABC-II PLUS

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	1:10 – 2:25	0:25 – 0:55	0:35 – 1:10	0:30 – 0:40	0:05 – 1:00	
		75/25	5:00	1:10 – 2:25	0:25 – 0:50	0:30 – 1:00	0:20 – 0:40	0:05 – 0:50	
		50/50	3:00	0:15 – 0:45	0:15 – 0:35	0:05 – 0:25	0:05 – 0:15		
below -3 to -14	below 27 to 7	100/0	8:00	0:30 – 1:05	0:15 – 0:35	0:15 – 0:45[3]	0:10 – 0:30[3]	CAUTION: No holdover time guidelines exist	
		75/25	5:00	0:20 – 0:55	0:15 – 0:35	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	8:00	0:15 – 0:20	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

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

TABLE 2-K-ABC-TF2

KILFROST TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]

ABC-TF2

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	1:10 – 2:25	0:20 – 0:45	0:40 – 1:20	0:30 – 0:45	0:10 – 1:10	
		75/25	5:00	1:20 – 2:25	0:15 – 0:30	0:45 – 1:25	0:30 – 0:45	0:10 – 1:25	
		50/50	3:00	0:45 – 1:25	0:05 – 0:15	0:20 – 0:40	0:15 – 0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:50 – 1:40	0:15 – 0:35	0:35 – 1:15[3]	0:30 – 0:40[3]		
		75/25	5:00	0:35 – 1:25	0:15 – 0:25	0:30 – 1:30[3]	0:30 – 0:40[3]		
below -14 to -25	below 7 to -13	100/0	8:00	0:30 – 1:00	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 2-O-EM-II

OCTAGON TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
E MAX II

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	2:05 – 3:45	0:40 – 1:20	0:45 – 1:35	0:30 – 0:40	0:15 – 1:30	
		75/25	5:00	1:25 – 2:50	0:25 – 0:55	0:40 – 1:10	0:20 – 0:30	0:10 – 1:05	
		50/50	3:00	0:30 – 0:55	0:10 – 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	8:00	0:50 – 1:45	0:35 – 1:10	0:35 – 1:00[3]	0:20 – 0:30[3]		
		75/25	5:00	0:30 – 1:20	0:25 – 0:50	0:35 – 1:05[3]	0:15 – 0:30[3]		
below -14 to -25	below 7 to -13	100/0	8:00	0:20 – 0:35	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 2-S-E26

SPCA TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]

Ecowing 26

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	8:00	1:25 – 2:35	0:40 – 1:00	0:50 – 1:35	0:40 – 0:50	0:20 – 1:25	
		75/25	5:00	1:05 – 1:55	0:25 – 0:45	0:45 – 1:05	0:25 – 0:35	0:10 – 1:00	
		50/50	3:00	0:30 – 0:45	0:10 – 0:20	0:15 – 0:25	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:45 – 2:15	0:35 – 0:55	0:30 – 1:10[3]	0:15 – 0:35[3]		
		75/25	5:00	0:35 – 1:15	0:25 – 0:40	0:20 – 0:50[3]	0:15 – 0:25[3]		
below -14 to -25	below 7 to -13	100/0	8:00	0:25 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007

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

Outside Air Temperature[3]		Approximate Holdover Times Under Various Weather Conditions (minutes)									
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow or Snow Grains			Freezing Drizzle[1]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
					Very Light	Light	Moderate				
-3 and above	27 and above	100/0	120	20 – 40	35	20 – 35	10 – 20	10 – 20	8 – 10	6 – 20	
		75/25	60	15 – 30	25	15 – 25	8 – 15	8 – 15	6 – 10	2 – 10	
		50/50	30	10 – 20	15	8 – 15	4 – 8	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
below -3 to -10	below 27 to 14	100/00	120	20 – 40	30	15 – 30	9 – 15	10 – 20	8 – 10		
		75/25	60	15 – 30	25	10 – 25	7 – 10	9 – 12	6 – 9		
below -10	below 14	100/0	120	20 – 40	30	15 – 30	8 – 15				

NOTES

1 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type III fluid cannot be used.

CAUTIONS

- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground deicing/anti-icing do not provide in-flight icing protection.**

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-Generic

SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:15 – 2:30	0:35 – 1:15	0:40 – 1:10	0:25 – 0:40	0:10 – 0:50	
		75/25	5:00	1:05 – 1:45	0:20 – 0:55	0:35 – 0:50	0:15 – 0:30	0:05 – 0:35	
		50/50	3:00	0:15 – 0:35	0:05 – 0:15	0:10 – 0:20	0:05 – 0:10		
below -3 to -14	below 27 to 7	100/0	12:00	0:20 – 1:20	0:20 – 0:40	0:20 – 0:45[3]	0:10 – 0:25[3]	CAUTION: No holdover time guidelines exist	
		75/25	5:00	0:25 – 0:50	0:15 – 0:35	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	12:00[5]	0:15 – 0:40[5]	0:15 – 0:30[5]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-C-2001

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
SAFEWING MP IV 2001

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:20 – 3:20	1:00 – 1:55	0:55 – 1:55	0:40 – 1:00	0:15 – 2:00	
		75/25	5:00	1:20 – 2:00	0:35 – 1:00	0:35 – 1:10	0:25 – 0:35	0:10 – 1:25	
		50/50	3:00	0:15 – 0:40	0:10 – 0:20	0:10 – 0:20	0:05 – 0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:45 – 1:35	0:30 – 0:50	0:55 – 1:35[3]	0:30 – 0:45[3]		
		75/25	5:00	0:30 – 1:00	0:20 – 0:35	0:40 – 1:10[3]	0:20 – 0:30[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:20 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-C-2012

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
SAFEWING MP IV 2012 PROTECT

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:15 – 2:30	0:40 – 1:15	0:40 – 1:10	0:25 – 0:45	0:10 – 1:05	
		75/25	5:00	1:10 – 2:05	0:25 – 0:55	0:35 – 0:50	0:15 – 0:30	0:05 – 0:40	
		50/50	3:00	0:25 – 0:45	0:15 – 0:25	0:15 – 0:20	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:45 – 1:35	0:20 – 0:40	0:25 – 0:45[3]	0:15 – 0:25[3]		
		75/25	5:00	0:25 — 1:05	0:20 – 0:40	0:15 – 0:30[3]	0:10 – 0:20[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:20 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-C-2030

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
SAFEWING MP IV 2030 ECO

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:55 – 3:20	0:50 – 1:30	0:55 – 2:00	0:40 – 0:50	0:15 – 1:40	
		75/25	5:00	1:15 – 2:05	0:35 – 1:05	0:40 – 1:05	0:25 – 0:35	0:10 – 1:00	
		50/50	3:00	0:30 – 0:45	0:15 – 0:25	0:15 – 0:25	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:50 – 2:00	0:45 – 1:25	0:30 – 1:10[3]	0:20 – 0:35[3]		
		75/25	5:00	0:40 – 1:30	0:35 – 1:05	0:35 – 1:20[3]	0:15 – 0:30[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:25 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-C-Launch

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
SAFEWING MP IV LAUNCH

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	4:00 – 4:00	1:00 – 1:35	1:30 – 2:00	1:00 – 1:40	0:15 – 1:40	
		75/25	5:00	3:40 – 4:00	0:40 – 1:20	1:40 – 2:00	0:45 – 1:15	0:10 – 1:45	
		50/50	3:00	1:25 – 2:45	0:10 – 0:25	0:30 – 0:50	0:20 – 0:25	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	1:00 – 1:55	0:40 – 1:05	0:35 – 1:40[3]	0:25 – 0:45[3]		
		75/25	5:00	0:40 – 1:20	0:20 – 0:40	0:25 – 1:10[3]	0:25 – 0:45[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:30 – 0:50	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

TABLE 4-D-ULTRA+

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
UCAR™ ADF/AAF ULTRA+

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:35 – 3:35	0:35 – 1:15	0:45 – 1:35	0:25 – 0:40	0:10 – 1:20	
		75/25						CAUTION: No holdover time guidelines exist	
		50/50							
below -3 to -14	below 27 to 7	100/0	12:00	1:25 – 3:00	0:25 – 0:55	0:45 – 1:25[3]	0:30 – 0:45[3]		
		75/25							
below -14 to -25	below 7 to -13	100/0	12:00[5]	0:40 – 2:10[5]	0:20 – 0:45[5]				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met.[5] Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 These holdover times only apply to outside air temperatures to -24°C (-11°F).

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-D-E106

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
UCAR™ ENDURANCE EG106

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	2:05 – 3:10	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	12:00	1:50 – 3:20	0:30 – 1:05	0:55 – 1:50[3]	0:45 – 1:10[3]		
		75/25							
below -14 to -25	below 7 to -13	100/0	12:00	0:30 – 1:05	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

TABLE 4-K-ABC-S

KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]

ABC-S

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	2:35 – 4:00	1:00 – 1:40	1:20 – 1:50	1:00 – 1:25	0:20 – 1:15	
		75/25	5:00	1:05 – 1:45	0:30 – 0:55	0:45 – 1:10	0:35 – 0:50	0:10 – 0:50	
		50/50	3:00	0:20 – 0:35	0:05 – 0:15	0:15 – 0:20	0:05 – 0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:45 – 2:05	0:45 – 1:20	0:20 – 1:00[3]	0:10 – 0:30[3]		
		75/25	5:00	0:25 – 1:00	0:25 – 0:50	0:20 – 1:10[3]	0:10 – 0:35[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:20 – 0:40	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-K-ABC-S PLUS

KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
ABC-S PLUS

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	1:50 – 3:40	0:45 – 1:25	1:15 – 1:55	0:50 – 1:10	0:15 – 1:40	
		75/25	5:00	1:10 – 2:10	0:25 – 0:55	0:45 – 1:10	0:30 – 0:45	0:05 – 1:00	
		50/50	3:00	0:20 – 0:40	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	12:00	0:40 – 1:25	0:35 – 1:00	0:30 – 1:35[3]	0:25 – 0:35[3]		
		75/25	5:00	0:40 – 1:15	0:25 – 0:50	0:25 – 1:15[3]	0:30 – 0:40[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:20 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-O-MF

OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
MAX-FLIGHT

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	2:40 – 4:00	0:50 – 1:35	0:55 – 2:00	0:35 – 1:00	0:15 – 1:15	
		75/25	5:00	2:05 – 3:15	0:45 – 1:45	1:15 – 2:00	0:35 – 1:10	0:10 – 0:40	
		50/50	3:00	0:55 – 1:45	0:25 – 1:15	0:35 – 1:00	0:15 – 0:30	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:50 – 2:30	0:25 – 0:50	0:25 – 1:10[3]	0:20 – 0:40[3]		
		75/25	5:00	0:30 – 1:05	0:20 – 0:50	0:20 – 1:00[3]	0:15 – 0:30[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:20 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-O-MF-04

OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
MAX-FLIGHT 04

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	2:40 – 4:00	1:25 – 2:00	2:00 – 2:00	1:10 – 1:30	0:20 – 2:00	
		75/25	5:00	2:05 – 3:15	1:05 – 2:00	1:50 – 2:00	1:00 – 1:20	0:20 – 2:00	
		50/50	3:00	0:55 – 1:45	0:25 – 1:15	0:35 – 1:10	0:25 – 0:35	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:50 – 2:30	0:35 – 1:10	0:25 – 1:30[3]	0:20 – 0:40[3]		
		75/25	5:00	0:30 – 1:05	0:40 – 1:20	0:20 – 1:00[3]	0:15 – 0:30[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:20 – 0:45	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTIONS

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

Transport Canada Holdover Time Guidelines — Winter 2006-2007

TABLE 4-O-MFLO

OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
MAXFLO

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

Outside Air Temperature		Type IV Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
Degrees Celsius	Degrees Fahrenheit	Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	2:20 – 3:35	0:40 – 1:30	1:20 – 2:00	0:30 – 1:00	0:10 – 2:00	
		75/25	5:00	1:25 – 2:00	0:20 – 0:55	0:40 – 1:05	0:20 – 0:35	0:05 – 1:15	
		50/50	3:00	0:20 – 0:40	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	12:00	1:10 – 2:20	0:25 – 1:00	0:35 – 1:45[3]	0:30 – 0:50[3]		
		75/25	5:00	0:40 – 1:25	0:15 – 0:40	0:35 – 1:15[3]	0:15 – 0:30[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:30 – 1:00	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

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

TABLE 4-S-AD-480

SPCA TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
AD-480

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

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		Active Frost	Freezing Fog	Snow or Snow Grains	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[2]
-3 and above	27 and above	100/0	12:00	2:00 – 3:30	0:40 – 1:20	0:50 – 1:30	0:35 – 0:55	0:15 – 1:35	
		75/25	5:00	1:30 – 2:45	0:30 – 1:05	0:50 – 1:15	0:30 – 0:45	0:10 – 1:15	
		50/50	3:00	0:30 – 0:45	0:10 – 0:20	0:15 – 0:25	0:05 – 0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:20 – 1:20	0:30 – 0:55	0:25 – 1:20[3]	0:15 – 0:30[3]		
		75/25	5:00	0:25 – 0:50	0:20 – 0:45	0:25 – 1:05[3]	0:15 – 0:30[3]		
below -14 to -25	below 7 to -13	100/0	12:00	0:15 – 0:40	0:15 – 0:30				
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

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

TABLE 5

CURRENTLY QUALIFIED FLUIDS (2006-2007)

NOTE:
Concentrate fluids have also been qualified at 50/50 (glycol/water) dilution.

Table 5-1: Qualified Type I Anti-icing Fluids†

#	COMPANY NAME	FLUID NAME	EXPIRY (Y-M-D)
1-1	Arcton Ltd.	Arctica DG	08-04-10
1-2	Aviation Xi' an High-tech	KHF-1	07-09-22
1-3	Battelle	D^3: Degradable by Design Deicer™ ADF 1006A	08-01-13
1-4	Beijing Wangye Aviation Chemical Product Co. Ltd.	KLA-1	07-09-07
1-5	Clariant GmbH	Clariant Safewing MP I 1938 TF	06-08-25*
1-6	Clariant GmbH	Clariant Safewing MP I 1938 TF Pre-Mix	07-09-14
1-7	Clariant GmbH	Clariant Safewing MP I 1938 ECO	06-08-30*
1-8	Clariant GmbH	Clariant Safewing EG I 1996	06-08-24*
1-9	Chemical Specialists and Development Inc.	Prist Wing De-Icer	08-05-17
1-10	Dow Chemical Company	Dow UCAR™ Aircraft Deicing Fluid Concentrate	06-10-26
1-11	Dow Chemical Company	Dow UCAR™ ADF XL-54	07-03-10
1-12	Dow Chemical Company	Dow UCAR™ PG Aircraft Deicing Fluid	08-02-02
1-13	Dow Chemical Company	Dow UCAR™ PG ADF Dilute 55/45	08-02-02
1-14	HOC Industries	SafeTemp I ES	07-10-27
1-15	HOC Industries	SafeTemp ES Plus	07-09-15
1-16	*Inland Technologies Inc.*	*Inland Duragly-P ready to use*	*05-09-11*
1-17	*Inland Technologies Inc.*	*Inland Duragly-E ready to use*	*05-10-20*
1-18	Kilfrost Limited	Kilfrost DF PLUS	07-08-26
1-19	Kilfrost Limited	Kilfrost DF PLUS (80)	06-07-05*
1-20	Kilfrost Limited	Kilfrost DF PLUS (88)	07-08-26
1-21	Lyondell Chemical Co.	Lyondell ARCOPlus	08-02-14
1-22	Lyondell Chemical Co.	Lyondell ARCTIC Plus™	08-04-10
1-23	Newave Aerochemical Co. Ltd.	FCY-1A	07-06-15
1-24	Octagon Process Inc.	Octagon Octaflo EF	07-05-12
1-25	Octagon Process Inc.	Octagon Octaflo EG	07-05-12
1-26	SPCA	SPCA DE-950	08-05-30
1-27	Viterbo S.A.	Jarkleer SAE Type I	07-01-20

† Qualified solely with respect to anti-icing performance and aerodynamic acceptance by the Anti-icing Materials International Laboratory, Université du Québec à Chicoutimi. Web site: http://www.uqac.uquebec.ca/amil/
For other specification requirements for Type I fluids, see SAE AMS 1424 (latest version). Fluids that successfully qualify after the issuance of this list will appear in a later update.

Fluids listed in italics have expired and will be removed from this listing four years after expiry.

* Currently in re-qualification process.

TABLE 5 (cont.)

CURRENTLY QUALIFIED FLUIDS (2006-2007)

Table 5-2: Qualified Type II Anti-icing Fluids†			
#	COMPANY NAME	FLUID NAME	EXPIRY (Y-M-D)
2-1	Clariant GmbH	Clariant Safewing MP II 1951	07-06-02
2-2	Clariant GmbH	Clariant Safewing MP II 2025 ECO	06-08-24*
2-3	Clariant GmbH	Clariant Safewing MP II Flight	08-04-27
2-4	*Kilfrost Limited*	*Kilfrost ABC-II PLUS*	*05-10-29*
2-5	Kilfrost Limited	Kilfrost ABC-3	06-08-22*
2-6	Kilfrost Limited	Kilfrost ABC-2000	06-07-05*
2-7	Kilfrost Limited	Kilfrost ABC-TF2	**
2-8	Octagon Process Inc.	Octagon E Max II	06-07-22
2-9	SPCA	SPCA Ecowing 26	07-05-24

Table 5-3: Qualified Type III Anti-icing Fluids†			
#	COMPANY NAME	FLUID NAME	EXPIRY (Y-M-D)
3-1	Clariant GmbH	Clariant Safewing MP III 2031 ECO	07-07-12

CAUTION: The lowest operational use temperature (LOUT) is -16.5°C (2°F) for aircraft with rotation speeds less than 100 knots or -29°C (-20°F) for aircraft with higher rotation speeds.

Table 5-4: Qualified Type IV Anti-icing Fluids†			
#	COMPANY NAME	FLUID NAME	EXPIRY (Y-M-D)
4-1	Clariant GmbH	Clariant Safewing MP IV 2001	06-06-02*
4-2	Clariant GmbH	Clariant Safewing MP IV 2012 Protect	07-07-12
4-3	Clariant GmbH	Clariant Safewing MP IV 2030 ECO	06-07-27
4-4	Clariant GmbH	Clariant Safewing MP IV Launch	08-05-16
4-5	Dow Chemical Company	Dow UCAR ADF/AAF ULTRA+	06-12-20
4-6	Dow Chemical Company	UCAR AAF FlightGuard AD-480 (1)	08-05-31
4-7	Dow Chemical Company	UCAR™ Endurance EG106	08-01-25
4-8	*Ely Chemical Company*	*Octagon Max-Flight*	*06-07-06*
4-9	Kilfrost Limited	Kilfrost ABC-S	07-08-02
4-10	Kilfrost Limited	ABC-S PLUS	**
4-11	*Octagon Process Inc.*	*Octagon Max-Flight*	*06-07-06*
4-12	Octagon Process Inc.	Octagon Max-Flight 04	08-05-30
4-13	Octagon Process Inc.	Octagon MaxFlo	07-03-24
4-14	SPCA	SPCA AD-480	07-07-05

(1) This product is identical to SPCA AD-480; the SPCA AD-480 holdover time table applies.

† Qualified solely with respect to anti-icing performance and aerodynamic acceptance by the Anti-icing Materials International Laboratory, Université du Québec à Chicoutimi. Web site: http://www.uqac.uquebec.ca/amil/
For other specification requirements for Type II, III or IV fluids, see SAE AMS 1428 (latest version). Fluids that successfully qualify after the issuance of this list will appear in a later update.

Fluids listed in italics have expired and will be removed from this listing four years after expiry.

* Currently in re-qualification process.

** Currently in qualification process.

TABLE 6

SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

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

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

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

NOTES

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

CAUTION

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

TABLE 7

SAE TYPE II, Type III and TYPE IV 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 Deicing/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 freezing point of the fluid is at least 7°C (13°F) below OAT and that aerodynamic acceptance criteria (LOUT) are met. Consider the use of Type I when Type II/III/IV fluid cannot be used (see Table 6).		

1 Fluids must only be used at temperatures above their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes.
3 Clean aircraft may be anti-iced with unheated fluid.

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

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 should 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.**

TABLE 8

VISIBILITY IN SNOW VS. SNOWFALL INTENSITY CHART[1]

Lighting	Temperature Range		Visibility in Snow (Statute Miles)			
	°C	°F	Heavy	Moderate	Light	Very Light
Darkness	-1 and above	30 and above	≤1	>1 to 2½	>2½ to 4	>4
	Below -1	Below 30	≤3/4	>3/4 to 1½	>1½ to 3	>3
Daylight	-1 and above	30 and above	≤½	>½ to 1½	>1½ to 3	>3
	Below -1	Below 30	≤3/8	>3/8 to 7/8	>7/8 to 2	>2

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 THE TABLE

Assume that the daytime visibility in snowfall is 1 statute mile and the temperature is -7°C. Based on these conditions, the snowfall intensity is light. This snowfall intensity is used to determine which holdover time guideline value is appropriate for the fluid in use.

TABLE 9

LOWEST ON-WING VISCOSITY VALUES FOR ANTI-ICING NEAT FLUIDS

	Fluid Name	Lowest On-Wing Viscosity [a] (mPa.s)	
		Manufacturer Method	AIR 9968 Revision A Method
Type II	Clariant Safewing MP II 2025 ECO	5,500 [b]	5,750 [g]
	Clariant Safewing MP II Flight	3,340 [g]	3,340 [g]
	Kilfrost ABC-2000	2,350 [c]	2,350 [g]
	Kilfrost ABC-II Plus	3,600 [c]	3,600 [g]
	Kilfrost ABC-TF2	3,550 [c]	3,460 [g]
	Octagon E Max II	13,520 [d]	13,520 [g]
	SPCA Ecowing 26	4,900 [e]	4,600 [g]
Type IV	Clariant Safewing MP IV 2001	18,000 [b]	18,000 [c]
	Clariant Safewing MP IV 2012 Protect	7,800 [b]	7,250 [g]
	Clariant Safewing MP IV 2030 ECO	10,500 [b]	10,500 [c]
	Clariant Safewing MP IV Launch	7,550 [g]	7,550 [g]
	Dow UCAR ADF/AAF ULTRA+	36,000 [f]	28,000 [c]
	Dow UCAR Endurance EG106	24,850 [f]	2,230 [g]
	Kilfrost ABC-S	17,000 [c]	17,000 [c]
	Kilfrost ABC-S PLUS	10,450 [c]	11,040 [g]
	Octagon Max-Flight	5,540 [d]	5,540 [g]
	Octagon Max-Flight 04	5,540 [d]	5,540 [g]
	Octagon MaxFlo	8,670 [g]	8,670 [g]
	SPCA AD-480	15,200 [e]	12,800 [c]

[a] The Aerospace Information Report (AIR) 9968 Revision A (December 2004) 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.

[b] Brookfield Spindle SC4-34/13R, small sample adapter, 10 mL of neat fluid, at 20°C, 0.3 rpm, for 15 minutes 0 seconds.

[c] Brookfield Spindle LV2-disc with guard leg, 150 mL of neat fluid, at 20°C, 0.3 rpm, for 10 minutes 0 seconds.

[d] Brookfield Spindle LV1 with guard leg, 500 mL of neat fluid, at 20°C, 0.3 rpm, for 33 minutes 20 seconds.

[e] Brookfield Spindle SC4-34/13R, small sample adapter, 10 mL of neat fluid, at 20°C, 0.3 rpm, for 30 minutes 0 seconds.

[f] Brookfield Spindle SC4-31/13R, small sample adapter, 10 mL of neat fluid, at 0°C, 0.3 rpm, for 10 minutes 0 seconds.

[g] Brookfield Spindle LV1 with guard leg, 500 mL of neat fluid, at 20°C, 0.3 rpm, for 10 minutes 0 seconds.

SIGNIFICANCE OF THIS TABLE

The viscosity values of the fluids in this table are those of the fluids provided by the manufacturers for holdover time testing. For the holdover time guidelines to be valid, the viscosity of the neat fluid on the wing shall not be lower than that listed in this table. The user should periodically ensure that the viscosity value of a fluid sample taken from the wing is not lower than that listed.

Note: The fluid manufacturer should be consulted for lowest on-wing viscosity associated with dilutions.

FAA
HOLDOVER TIME GUIDELINES
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HOLDOVER TIME TABLES

ICE PELLET ALLOWANCE TIME

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Winter 2006-07 Deicing/Anti-icing Guidance

Background

In October 2005, the FAA issued *Notices 8000.309, Dispatching During Precipitation Conditions of Ice Pellets, Snow Pellets, or Other Icing Events for which No Hold Over Times Exist;* and *8000.313, Parts 121 and 135 Operations Specifications for Deicing/Anti-icing Operations in Ice Pellets Without Deice/Anti-ice Fluids*. As a result of these notices, industry requested the FAA conduct research to obtain data to support relief for some of the current conditions for which no holdover times exist. That research was conducted during the winter season of 2005-06. The following relief is a result of that research and further review of existing data. Although these stated precipitation condition allowances are provided, the general requirement that takeoff not be attempted with any contaminant adhering to the critical surfaces of the aircraft still applies.

Operations in Light Ice Pellets (without any other forms of precipitation present)

A. Tests have shown that ice pellets generally remain in the frozen state imbedded in 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 detectable by the human eye during pre-takeoff contamination check procedures. Therefore, a pre-takeoff contamination check in light ice pellet conditions would not be of value and is not required.

B. These tests have also shown that after proper deicing and anti-icing, the accumulation of light ice pellets in Type IV fluid will still sheer from the aerodynamic surfaces during takeoff. This sheering occurs with rotation speeds consistent with Type IV recommended applications for up to 25 minutes from the start of the Type IV anti-icing fluid application.

C. Operators with a deicing program approved in accordance with Title 14 of the Code of Federal Regulations (14 CFR) part 121, section 121.629, will be allowed, in light ice pellet conditions with no other form of precipitation present, up to 25 minutes after the start of the anti-icing fluid application to commence the takeoff with the following restrictions:

1. The aircraft critical surfaces must be free of contaminants, or the aircraft be properly deiced prior to the application of the anti-icing fluid.

2. This allowance time, of up to 25 minutes, is valid only if the aircraft is anti-iced with undiluted Type IV fluid.

3. Due to the sheer qualities of Type IV fluids with imbedded ice pellets, this allowance is limited to aircraft with a rotation speed of 100 knots or greater.

4. If the takeoff is not accomplished within the 25 minutes allowed, the aircraft must be completely deiced, and if precipitation is still present, anti-iced again prior to a subsequent takeoff.

5. A pre-takeoff contamination check is not required. The allowance time of up to 25 minutes cannot be extended by an internal or external check of the aircraft critical surfaces.

6. If ice pellet precipitation becomes heavier than light or is mixed with any other form of precipitation, the 25-minute allowance time cannot be used.

Operations in Heavy Snow

A. No holdover times exist for heavy snow conditions in the current holdover time tables. Review of existing data from past testing has indicated with proper tactile and/or visual checks, as appropriate for the aircraft, and a determination that the fluid has not failed, takeoffs may be safely conducted. 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 operators pre-takeoff contamination check (when holdover times have been exceeded) for those precipitation conditions for which holdover times exist. Anti-icing fluids dissolve the snow and absorb the resulting moisture into the fluid. When the fluid approaches its moisture saturation point, it starts to change in appearance 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 pre-takeoff contamination check procedures for other precipitation conditions, this check procedure must be verified and approved by the operator's principal operations inspector (POI).

B. Operators with a deicing program approved in accordance with 14 CFR part 121, section 121.629, will be allowed to take off 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 be properly deiced prior to the application of the anti-icing fluid.

3. The operator must accomplish an approved tactile and/or visual check, as appropriate, 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 prior to a subsequent takeoff.

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FAA TYPE I HOLDOVER TIME GUIDELINE

Table 1. FAA Guideline for Holdover Times SAE Type I Fluid Mixtures as a Function of Weather Conditions and OAT.
CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)								
Degrees Celsius	Degrees Fahrenheit	Active Frost	Freezing Fog	Snow/Snow Grains			Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
				Very Light◆◆	Light ◆◆	Moderate◆◆				
-3 and above	27 and above	0:45	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	0:45	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	0:45	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	0:45	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.

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 degrees Celsius (32 degrees Fahrenheit) only
‡ Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, hail
◆◆ **TO USE THESE TIMES, THE FLUID MUST BE HEATED TO A MINIMUM TEMPERATURE OF 60°C (140°F) AT THE NOZZLE AND AT LEAST 1 LITER/M^2 (≈ 2 GALS/100FT^2) MUST BE APPLIED TO DEICED SURFACES**
SAE Type I fluid/water mixture is selected so that the freezing point of the mixture is at least 10 °C (18 °F) below OAT.

CAUTIONS:

- THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY, OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.
- **SAE TYPE I** FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 1A - FAA Guidelines for the Application of SAE Type I Fluid Mixtures.
Minimum Concentrations as a Function of Outside Air Temperature (OAT).
Concentrations in % volume

Outside AirTemperature (OAT)	One-step Procedure Deicing/Anti-icing	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	

Notes:

- Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in snow conditions, at least 1 liter per square meter (2 gal. Per 100 square feet) fluid must be applied to the deiced surfaces.
- This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.

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

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

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TABLE 1B. SNOWFALL INTENSITIES AS A FUNCTION OF PREVAILING VISIBILITY

Time of Day	Temp.		Visibility (Statute Mile)							Snowfall Intensity
	Degrees Celsius	Degrees Fahrenheit	≥2 1/2	2	1 1/2	1	3/4	1/2	≤1/4	
Day	colder/equal -1	colder/equal 30	Very Light	Very Light	Light	Light	Moderate	Moderate	**Heavy**	
	warmer than -1	warmer than 30	Very Light	Light	Light	Moderate	Moderate	**Heavy**	**Heavy**	
Night	colder/equal -1	colder/equal 30	Very Light	Light	Moderate	Moderate	**Heavy**	**Heavy**	**Heavy**	
	warmer than -1	warmer than 30	Very Light	Light	Moderate	**Heavy**	**Heavy**	**Heavy**	**Heavy**	

NOTE: Based upon technical report, "The Estimation of Snowfall Rate Using Visibility," Rasmussen, et al., Journal of Applied Meteorology, October 1999 and additional in situ data.

NOTE: This table is for estimating snow intensities for use with Type I, II, III, and Type IV Fluids Holdover Time Guidelines.

HEAVY = Caution - no holdover time guidelines exist

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FAA TYPE II HOLDOVER TIME GUIDELINE

TABLE 2 - FAA Guideline for Holdover Times SAE Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Type II Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit	Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	8:00	0:35-1:30	0:20-0:45	0:30-0:55	0:15-0:30	0:05-0:40	
		75/25	5:00	0:25-1:00	0:15-0:30	0:20-0:45	0:10-0:25	0:05-0:25	
		50/50	3:00	0:15-0:30	0:05-0:15	0:05-0:15	0:05-0:10		
below -3 to -14	below 27 to 7	100/0	8:00	0:20-1:05	0:15-0:35	***0:15-0:45	***0:10-0:25	CAUTION: No holdover time guidelines exist	
		75/25	5:00	0:20-0:55	0:15-0:25	***0:15-0:30	***0:10-0:20		
below -14 to -25	below 7 to -13	100/0	8:00	0:15-0:20	0:15-0:30				
below -25	below -13	100/0	**SAE Type II** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **SAE Type II** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

** This column is for use at temperatures above 0 °C (32 °F) only

*** No holdover time guidelines exist for this condition below -10 °C (14 °F)

‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- SAE TYPE II FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 2A - FAA Guideline for Holdover Times KILFROST ABC-II PLUS Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other ‡
-3 and above	27 and above	100/0	8:00	1:10-2:25	0:25-0:55	0:35-1:10	0:30-0:40	0:05-1:00	
		75/25	5:00	1:10-2:25	0:25-0:50	0:30-1:00	0:20-0:40	0:05-0:50	
		50/50	3:00	0:15-0:45	0:15-0:35	0:05-0:25	0:05-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:30-1:05	0:15-0:35	***0:15-0:45	***0:10-0:30		
		75/25	5:00	0:20-0:55	0:15-0:35	***0:15-0:30	***0:10-0:20		
below -14 to -25	below 7 to -13	100/0	8:00	0:15-0:20	0:15-0:30				
below -25	below -13	100/0	**KILFROST ABC-II PLUS Type II** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **KILFROST ABC-II PLUS Type II** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

** This column is for use at temperatures above 0 degrees Celsius (32 degrees Fahrenheit) only

*** No holdover time guidelines exist for this condition below -10 °C (14 °F)

‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- KILFROST ABC-II PLUS TYPE II FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 2B - FAA Guideline for Holdover Times KILFROST ABC-2000 Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	8:00	1:30-3:05	0:30-1:00	0:55-1:35	0:40-0:50	0:15-1:10	
		75/25	5:00	1:40-3:30	0:30-1:05	0:45-1:15	0:40-0:50	0:15-1:40	
		50/50	3:00	1:00-2:10	0:15-0:30	0:15-0:25	0:05-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:35-1:25	0:25-0:45	***0:25-0:50	***0:10-0:30		
		75/25	5:00	0:35-1:15	0:25-0:50	***0:25-0:55	***0:15-0:30		
below -14 to -25	below 7 to -13	100/0	8:00	0:20-0:45	0:15-0:30				
below -25	below -13	100/0	**KILFROST ABC-2000 Type II** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **KILFROST ABC-2000 Type II** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 °C (32 °F) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- KILFROST ABC-2000 TYPE II FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 2C - FAA Guideline for Holdover Times KILFROST ABC-TF2 Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold **Soaked** Wing**	Other‡
-3 and above	27 and above	100/0	8:00	1:10-2:25	0:20-0:45	0:40-1:20	0:30-0:45	0:10-1:10	
		75/25	5:00	1:20-2:25	0:15-0:30	0:45-1:25	0:30-0:45	0:10-1:25	
		50/50	3:00	0:45-1:25	0:05-0:15	0:20-0:40	0:15-0:20	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:50-1:40	0:15-0:35	***0:35-1:15	***0:30-0:40		
		75/25	5:00	0:35-1:25	0:15-0:25	***0:30-1:30	***0:30-0:40		
below -14 to -25	below 7 to -13	100/0	8:00	0:30-1:00	0:15-0:30				
below -25	below -13	100/0	**KILFROST ABC-TF2 Type II** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **KILFROST ABC-TF2 Type II** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 °C (32 °F) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- KILFROST ABC-TF2 TYPE II FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 2D - FAA Guideline for Holdover Times OCTAGON E-MAX Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	8:00	2:05-3:45	0:40-1:20	0:45-1:35	0:30-0:40	0:15-1:30	
		75/25	5:00	1:25-2:50	0:25-0:55	0:40-1:10	0:20-0:30	0:10-1:05	
		50/50	3:00	0:30-0:55	0:10-0:25	0:15-0:30	0:10-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:50-1:45	0:35-1:10	***0:35-1:00	***0:20-0:30		
		75/25	5:00	0:30-1:20	0:25-0:50	***0:35-1:05	***0:15-0:30		
below -14 to -25	below 7 to -13	100/0	8:00	0:20-0:35	0:15-0:30				
below -25	below -13	100/0	**OCTAGON E-MAX Type II** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **OCTAGON E-MAX Type II** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 °C (32 °F) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- OCTAGON E-MAX TYPE II FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 2E – FAA Guideline for Holdover Times SPCA ECOWING 26 Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	8:00	1:25-2:35	0:40-1:00	0:50-1:35	0:40-0:50	0:20-1:25	
		75/25	5:00	1:05-1:55	0:25-0:45	0:45-1:05	0:25-0:35	0:10-1:00	
		50/50	3:00	0:30-0:45	0:10-0:20	0:15-0:25	0:05-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:45-2:15	0:35-0:55	***0:30-1:10	***0:15-0:35		
		75/25	5:00	0:35-1:15	0:25-0:40	***0:20-0:50	***0:15-0:25		
below -14 to -25	below 7 to -13	100/0	8:00	0:25-0:45	0:15-0:30				
below -25	below -13	100/0	**SPCA ECOWING 26 Type II** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **SPCA ECOWING 26 Type II** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 °C (32 °F) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- SPCA ECOWING 26 TYPE II FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 2F – FAA Guideline for Holdover Times CLARIANT SAFEWING MP II 2025 ECO Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	8:00	1:30-2:05	0:40-1:10	0:40-1:00	0:25-0:35	0:10-1:15	
		75/25	5:00	0:55-1:45	0:25-0:45	0:25-0:45	0:20-0:25	0:05-0:50	
		50/50	3:00	0:20-0:35	0:05-0:15	0:10-0:15	0:05-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:45-1:50	0:35-1:00	***0:35-1:05	***0:20-0:35		
		75/25	5:00	0:40-1:20	0:25-0:45	***0:30-0:40	***0:15-0:25		
below -14 to -25	below 7 to -13	100/0	8:00	0:25-0:45	0:15-0:30				
below -25	below -13	100/0	**CLARIANT SAFEWING MPII 2025 ECO Type II fluid** may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **CLARIANT SAFEWING MPII 2025 Type II** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 °C (32 °F) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- CLARIANT SAFEWING MP II 2025 ECO TYPE II FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 2G – FAA Guideline for Holdover Times CLARIANT SAFEWING MP II Flight Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type II Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	8:00	3:30-4:00	1:00-1:35	1:20-2:00	0:45-1:25	0:10-1:30	
		75/25	5:00	2:30-4:00	0:40-1:20	1:15-2:00	0:30-0:55	0:05-1:20	
		50/50	3:00	0:55-1:45	0:10-0:25	0:20-0:30	0:10-:015	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	8:00	0:55-1:45	0:40-1:05	***0:35-1:30	***0:25-0:45		
		75/25	5:00	0:40-1:10	0:20-0:40	***0:25-1:10	***0:30-0:40		
below -14 to -25	below 7 to -13	100/0	8:00	0:30-0:50	0:15-0:30				
below -25	below -13	100/0	**CLARIANT SAFEWING MP II FLIGHT Type II** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **CLARIANT SAFEWING MP II FLIGHT Type II** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 °C (32 °F) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- CLARIANT SAFEWING MP II FLIGHT TYPE II FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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FAA TYPE III HOLDOVER TIME GUIDELINE

Table 3. FAA Guideline for Holdover Times SAE Type III Fluid Mixture as a Function of Weather Conditions and OAT.

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

Outside Air Temperature		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)									
Degrees Celsius	Degrees Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Active Frost	Freezing Fog	Snow/Snow Grains			Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
					Very Light	Light	Moderate				
-3 and above	27 and above	100/0	2:00	0:20 - 0:40	0:35 - 0:40	0:20 - 0:35	0:10 - 0:20	0:10 - 0:20	0:08 - 0:10	0:06 - 0:20	
		75/25	1:00	0:15 - 0:30	0:25 - 0:35	0:15 - 0:25	0:08 - 0:15	0:08 - 0:15	0:06 - 0:10	0:02 - 0.10	
		50/50	0:30	0:10 - 0:20	0:15 - 0:20	0:08 - 0:15	0:04 - 0:08	0:05 - 0:09	0:04 - 0:06		
below -3 to -10	below 27 to 21	100/0	2:00	0:20 - 0: 40	0:30 - 0:35	0:15 - 0:30	0:09 - 0:15	0:10 - 0:20	0:08 - 0:10		
		75/25	1:00	0:15 - 0:30	0:25 - 0:30	0:10 - 0:25	0:07 - 0:10	0:09 - 0:12	0:06 - 0:09		
below -10	below 14	100/0	2:00	0:20 - 0:40	0:30 - 0:35	0:15 - 0:30	0:08 - 0:15	CAUTION: No holdover time guidelines exist			

SAE Type III fluid may be used below -10°C (14°F), provided the freezing point of the fluid is at least 7°C (13°F) below OAT and aerodynamic acceptance criteria are met.

Consider the use of **SAE Type I** when **Type III** fluid cannot be used.

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

*Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

**This column is for use at temperatures above 0 °C (32 °F) only

‡Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- SAE TYPE III FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR - AND DOES NOT PROVIDE - PROTECTION DURING FLIGHT.

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FAA TYPE IV HOLDOVER TIME GUIDELINE

TABLE 4 - FAA Guideline for Holdover Times SAE Type IV Fluid Mixtures as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

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		Active Frost	Freezing Fog	Snow/Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	1:15-2:30	0:35-1:15	0:40-1:10	0:25-0:40	0:10-0:50	
		75/25	5:00	1:05-1:45	0:20-0:55	0:35-0:50	0:15-0:30	0:05-0:35	
		50/50	3:00	0:15-0:35	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	12:00	0:20-1:20	0:20-0:40	***0:20-0:45	***0:10-0:25		
		75/25	5:00	0:25-0:50	0:15-0:35	***0:15-0:30	***0:10-0:20		
below -14 to -25	below 7 to -13	100/0	12:00	0:15-0:40	0:15-0:30				
below -25	below -13	100/0	**SAE Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C(13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **SAE Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

** This column is for use at temperatures above 0 °C (32°F) only

*** No holdover time guidelines exist for this condition below -10 °C (14 °F)

‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- SAE TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4A - FAA Guideline for Holdover Times DOW UCAR ULTRA+ Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Contions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	1:35-3:35	0:35-1:15	0:45-1:35	0:25-0:40	0:10-1:20	
		75/25						CAUTION: No holdover time guidelines exist	
		50/50							
below -3 to -14	below 27 to 7	100/0	12:00	1:25-3:00	0:25-0:55	***0:45-1:25	***0:30-0:45		
		75/25							
below -14 to -24	below 7 to -12	100/0	12:00	0:40-2:10	0:20-0:45				
below -24	below -12	100/0	**DOW UCAR ULTRA+ Type IV** fluid may be used below -24 °C (-12 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **DOW UCAR ULTRA+ Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 °C (32 °F) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- DOW UCAR ULTRA+ TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4B - FAA Guideline for Holdover Times DOW UCAR ENDURANCE EG106 Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Contions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	2:05-3:10	0:40-1:20	1:10-2:00	0:50-1:15	0:10-1:20	
		75/25						CAUTION: No holdover time guidelines exist	
		50/50							
below -3 to -14	below 27 to 7	100/0	12:00	1:50-3:20	0:30-1:05	***0:55-1:50	***0:45-1:10		
		75/25							
below -14 to -24	below 7 to -12	100/0	12:00	0:30-1:05	0:15-0:30				
below -24	below -12	100/0	**DOW UCAR ENDURANCE EG 106 Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **DOW UCAR ENDURANCE EG 106 Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 °C (32 °F) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- DOW UCAR ENDURANCE EG 106 TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4C - FAA Guideline for Holdover Times DOW UCAR FLIGHTGUARD AD-480 Type IV Fluid Mixtures as a function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	2:00-3:30	0:40-1:20	0:50-1:30	0:35-0:55	0:15-1:35	
		75/25	5:00	1:30-2:45	0:30-1:05	0:50-1:15	0:30-0:45	0:10-1:15	
		50/50	3:00	0:30-0:45	0:10-0:20	0:15-0:25	0:05-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:20-1:20	0:30-0:55	***0:25-1:20	***0:15-0:30		
		75/25	5:00	0:25-0:50	0:20-0:45	***0:25-1:05	***0:15-0:30		
below -14 to -25	below 7 to -13	100/0	12:00	0:15-0:40	0:15-0:30				
below -25	below -13	100/0	**DOW UCAR FLIGHTGUARD AD-480 Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **DOW UCAR FLIGHTGUARD AD-480 Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

** This column is for use at temperatures above 0 degrees Celsius (32 degrees Fahrenheit) only

*** No holdover time guidelines exist for this condition below -10 °C (14 °F)

‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- DOW UCAR FLIGHTGUARD AD-480 TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4D - FAA Guideline for Holdover Times OCTAGON MAX-FLIGHT Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	2:40-4:00	0:50-1:35	0:55-2:00	0:35-1:00	0:15-1:15	
		75/25	5:00	2:05-3:15	0:45-1:45	1:15-2:00	0:35-1:10	0:10-0:40	
		50/50	3:00	0:55-1:45	0:25-1:15	0:35-1:00	0:15-0:30	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:50-2:30	0:25-0:50	***0:25-1:10	***0:20-0:40		
		75/25	5:00	0:30-1:05	0:20-0:50	***0:20-1:00	***0:15-0:30		
below -14 to -25	below 7 to -13	100/0	12:00	0:20-0:45	0:15-0:30				
below -25	below -13	100/0	**OCTAGON MAX-FLIGHT Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **OCTAGON MAX-FLIGHT Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 °C (32 °F) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- OCTAGON MAX-FLIGHT TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4E - FAA Guideline for Holdover Times OCTAGON MAX-FLIGHT 04 Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	2:40-4:00	1:25-2:00	2:00-2:00	1:10-1:30	0:20-2:00	
		75/25	5:00	2:05-3:15	1:05-2:00	1:50-2:00	1:00-1:20	0:20-2:00	
		50/50	3:00	0:55-1:45	0:25-1:15	0:35-1:10	0:25-0:35	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:50-2:30	0:35-1:10	***0:25-1:30	***0:20-0:40		
		75/25	5:00	0:30-1:05	0:40-1:20	***0:20-1:00	***0:15-0:30		
below -14 to -25	below 7 to -13	100/0	12:00	0:20-0:45	0:15-0:30				
below -25	below -13	100/0	**OCTAGON MAX-FLIGHT 04 Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **OCTAGON MAX-FLIGHT 04 Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

** This column is for use at temperatures above 0 °C (32 °F) only

*** No holdover time guidelines exist for this condition below -10 °C (14 °F)

‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- OCTAGON MAX-FLIGHT 04 TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4F - FAA Guideline for Holdover Times OCTAGON MAXFLO Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Frost	Freezing Fog	Snow /Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	2:20-3:35	0:40-1:30	1:20-2:00	0:30-1:00	0:10-2:00	
		75/25	5:00	1:25-2:00	0:20-0:55	0:40-1:05	0:20-0:35	0:05-1:15	
		50/50	3:00	0:20-0:40	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	12:00	1:10-2:20	0:25-1:00	***0:35-1:45	***0:30-0:50		
		75/25	5:00	0:40-1:25	0:15-0:40	***0:35-1:15	***0:15-0:30		
below -14 to -25	below 7 to -13	100/0	12:00	0:30-1:00	0:15-0:30				
below -25	below -13	100/0	**OCTAGON MAXFLO Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **OCTAGON MAXFLO Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

** This column is for use at temperatures above 0 °C (32 °F) only

*** No holdover time guidelines exist for this condition below -10 °C (14 °F)

‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- OCTAGON MAXFLO TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4G - FAA Guideline for Holdover Times KILFROST ABC-S Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	2:35-4:00	1:00-1:40	1:20-1:50	1:00-1:25	0:20-1:15	
		75/25	5:00	1:05-1:45	0:30-0:55	0:45-1:10	0:35-0:50	0:10-0:50	
		50/50	3:00	0:20-0:35	0:05-0:15	0:15-0:20	0:05-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:45-2:05	0:45-1:20	***0:20-1:00	***0:10-0:30		
		75/25	5:00	0:25-1:00	0:25-0:50	***0:20-1:10	***0:10-0:35		
below -14 to -25	below 7 to -13	100/0	12:00	0:20-0:40	0:15-0:30				
below -25	below -13	100/0	**KILFROST ABC-S Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **KILFROST ABC-S Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 degrees Celsius (32 degrees Fahrenheit) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.

- KILFROST ABC-S TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4H - FAA Guideline for Holdover Times KILFROST ABC-S PLUS Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	1:50-3:40	0:45-1:25	1:15-1:55	0:50-1:10	0:15-1:40	
		75/25	5:00	1:10-2:10	0:25-0:55	0:45-1:10	0:30-0:45	0:05-1:00	
		50/50	3:00	0:20-0:40	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	12:00	0:40-1:25	0:35-1:0 0	***0:30-1:35	***0:25-0:35		
		75/25	5:00	0:40-1:15	0:25-0:50	***0:25-1:15	***0:30-0:40		
below -14 to -25	below 7 to -13	100/0	12:00	0:20-0:45	0:15-0:30				
below -25	below -13	100/0	**KILFROST ABC-S PLUS Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **KILFROST ABC-S PLUS Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 degrees Celsius (32 degrees Fahrenheit) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- KILFROST ABC-S PLUS TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4I – FAA Guideline for Holdover Times CLARIANT SAFEWING MP IV 2001 Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	1:20-3:20	1:00-1:55	0:55-1:55	0:40-1:00	0:15-2:00	
		75/25	5:00	1:20-2:00	0:35-1:00	0:35-1:10	0:25-0:35	0:10-1:25	
		50/50	3:00	0:15-0:40	0:10-0:20	0:10-0:20	0:05-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:45-1:35	0:30-0:50	***0:55-1:35	***0:30-0:45		
		75/25	5:00	0:30-1:00	0:20-0:35	***0:40-1:10	***0:20-0:30		
below -14 to -25	below 7 to -13	100/0	12:00	0:20-0:45	0:15-0:30				
below -25	below -13	100/0	**CLARIANT SAFEWING MP IV 2001 Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **CLARIANT SAFEWING MP IV 2001 Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

** This column is for use at temperatures above 0 °C (32 °F) only

*** No holdover time guidelines exist for this condition below -10 °C (14 °F)

‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- CLARIANT SAFEWING MP IV 2001 TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4J – FAA Guideline for Holdover Times CLARIANT SAFEWING MP IV 2012 PROTECT Type IV Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	1:15-2:30	0:40-1:15	0:40-1:10	0:25-0:45	0:10-1:05	
		75/25	5:00	1:10-2:05	0:25-0:55	0:35-0:50	0:15-0:30	0:05-0:40	
		50/50	3:00	0:25-0:45	0:15-0:25	0:15-0:20	0:05-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:45-1:45	0:20-0:40	***0:25-0:45	***0:15-0:25		
		75/25	5:00	0:25-1:05	0:20-0:40	***0:15-0:30	***0:10-0:20		
below -14 to -25	below 7 to -13	100/0	12:00	0:20-0:45	0:15-0:30				
below -25	below -13	100/0	**CLARIANT SAFEWING MP IV 2012 PROTECT TYPE IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **CLARIANT SAFEWING MP IV 2012 PROTECT TYPE IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

** This column is for use at temperatures above 0 °C (32 °F) only

*** No holdover time guidelines exist for this condition below -10 °C (14 °F)

‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- CLARIANT SAFEWING MP IV 2012 PROTECT TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 4K - FAA Guideline for Holdover Times CLARIANT SAFEWING MP IV 2030 ECO Type IV Fluid Mixtures as a function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	1:55-3:20	0:50-1:30	0:55-2:00	0:40-0:50	0:15-1:40	
		75/25	5:00	1:15-2:05	0:35-1:05	0:40-1:05	0:25-0:35	0:10-1:00	
		50/50	3:00	0:30-0:45	0:15-0:25	0:15-0:25	0:05-0:10	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:50-2:00	0:45-1:25	***0:30-1:10	***0:20-0:35		
		75/25	5:00	0:40-1:30	0:35-1:05	***0:35-1:20	***0:15-0:30		
below -14 to -25	below 7 to -13	100/0	12:00	0:25-0:45	0:15-0:30				
below -25	below -13	100/0	**CLARIANT SAFEWING MPIV 2030 ECO Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **CLARIANT SAFEWING MPIV 2030 ECO Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 degrees Celsius (32 degrees Fahrenheit) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- CLARIANT SAFEWING MP IV 2030 ECO TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT

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TABLE 4L - FAA Guideline for Holdover Times CLARIANT SAFEWING MP IV LAUNCH Type IV Fluid Mixtures as a function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	4:00-4:00	1:00-1:35	1:30-2:00	1:00-1:40	0:15-1:40	
		75/25	5:00	3:40-4:00	0:40-1:20	1:40-2:00	0:45-1:15	0:10-1:45	
		50/50	3:00	1:25-2:45	0:10-0:25	0:30-0:50	0:20-0:25	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	1:00-1:55	0:40-1:05	***0:35-1:40	***0:25-0:45		
		75/25	5:00	0:40-1:20	0:20-0:40	***0:25-1:10	***0:25-0:45		
below -14 to -25	below 7 to -13	100/0	12:00	0:30-0:50	0:15-0:30				
below -25	below -13	100/0	**CLARIANT SAFEWING MPIV LAUNCH Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **CLARIANT SAFEWING MPIV LAUNCH Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
** This column is for use at temperatures above 0 degrees Celsius (32 degrees Fahrenheit) only
*** No holdover time guidelines exist for this condition below -10 °C (14 °F)
‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- CLARIANT SAFEWING MP IV LAUNCH TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT

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TABLE 4M - FAA Guideline for Holdover Times SPCA AD-480 Type IV Fluid Mixtures as a function of Weather Conditions and Outside Air Temperature

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

Outside Air Temperature		Manufacturer Specific Type IV Fluid Concentration Neat-Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours: minutes)						
Degrees Celsius	Degrees Fahrenheit		Active Frost	Freezing Fog	Snow/ Snow Grains	Freezing Drizzle*	Light Freezing Rain	Rain on Cold Soaked Wing**	Other‡
-3 and above	27 and above	100/0	12:00	2:00-3:30	0:40-1:20	0:50-1:30	0:35-0:55	0:15-1:35	
		75/25	5:00	1:30-2:45	0:30-1:05	0:50-1:15	0:30-0:45	0:10-1:15	
		50/50	3:00	0:30-0:45	0:10-0:20	0:15-0:25	0:05-0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	12:00	0:20-1:20	0:30-0:55	***0:25-1:20	***0:15-0:30		
		75/25	5:00	0:25-0:50	0:20-0:45	***0:25-1:05	***0:15-0:30		
below -14 to -25	below 7 to -13	100/0	12:00	0:15-0:40	0:15-0:30				
below -25	below -13	100/0	**SPCA AD-480 Type IV** fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of **SAE Type I** when **SPCA AD-480 Type IV** fluid cannot be used.						

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

* Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

** This column is for use at temperatures above 0 degrees Celsius (32 degrees Fahrenheit) only

*** No holdover time guidelines exist for this condition below -10 °C (14 °F)

‡ Snow pellets, ice pellets, heavy snow, moderate and heavy freezing rain, 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 OAT.
- SPCA AD-480 TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

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TABLE 5 - FAA Guidelines for the Application of SAE Type II, Type III and Type IV Fluid Mixtures. Minimum Concentrations as a Function of Outside Air Temperature (OAT).

Concentrations in % Volume

OAT	One-step Procedure Deicing/Anti-icing	Two-step Procedure	
		First step: Deicing	Second step: Anti-icing[1, 2, 3]
-3 °C (27 °F) and above	50/50 Heated [2] Type 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 [2] Type 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 [2] Type 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 freezing point of the fluid is at least a 7 °C (13 °F) below OAT and that aerodynamic acceptance criteria are met. **SAE Type III** fluid may be used below -10 °C (14 °F) provided that the freezing point of the fluid is at least 7°C (13 °F) below OAT and that aerodynamic acceptance criteria are met. Consider the use of **SAE Type I** when **Type II, III or IV** fluid cannot be used.		

1) Fluids must only be used at temperatures above their lowest operational use temperature.
2) To be applied before first step fluid freezes, typically within 3 minutes.
3) Clean aircraft may be anti-iced with unheated Type II, III, or IV fluid.

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

CAUTIONS:

- Wing skin temperatures may differ and, in some cases, be lower than OAT. A stronger mix (more glycol) can be used under these conditions.
- As fluid freezing may occur, 50/50 **Type 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.

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TABLE 6. LOWEST ON-WING VISCOSITY VALUES FOR NEAT SAE TYPE II AND TYPE IV FLUIDS

	FLUID NAME	LOWEST ON-WING VISCOSITY [a] (mPa.s)	
		MANUFACTURER METHOD	SAE AIR 9968 REVISION A METHOD
TYPE II	Clariant Safewing MP II 2025 ECO	5,500 [b]	5,750 [g]
	Clariant Safewing MP II Flight	3,340 [g]	3,340 [g]
	Kilfrost ABC-2000	2,350 [c]	2,350 [g]
	Kilfrost ABC-II Plus	3,600 [c]	3,600 [g]
	Kilfrost ABC-TF2	3,550 [c]	3,460 [g]
	Octagon E Max	13,520 [d]	13,520 [g]
	SPCA Ecowing 26	4,900 [e]	4,600 [g]
TYPE IV	Clariant Safewing MP IV 2001	18,000 [b]	18,000 [c]
	Clariant Safewing MP IV 2012 Protect	7,800 [b]	7,250 [g]
	Clariant Safewing MP IV 2030 ECO	10,500 [b]	10,500 [c]
	Clariant Safewing MP IV Launch	7,550 [g]	7,550 [g]
	Dow UCAR AAF ULTRA+	36,000 [f]	28,000 [c]
	Dow UCAR Endurance EG 106	24,850 [f]	2,230 [g]
	Dow UCAR AD-480	15,200 [e]	12,800 [c]
	Kilfrost ABC-S	17,000 [c]	17,000 [c]
	Kilfrost ABC-S PLUS	10,450 [c]	11,040 [g]
	Octagon Max-Flight	5,540 [d]	5,540 [g]
	Octagon Max-Flight 04	5,540 [d]	5,540 [g]
	Octagon MaxFlo	8,670 [g]	8,670 [g]
	SPCA AD-480	15,200 [e]	12,800 [c]

[a] The SAE Aerospace Information Report (AIR) 9968 Revision A (December 2004) 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.
[b] Brookfield Spindle SC4-34/13R, small sample adapter, 10 mL of neat fluid, at 20°C, 0.3 rpm, for 15 minutes 0 seconds.
[c] Brookfield Spindle LV2-disc with guard leg, 150 mL of neat fluid, at 20°C, 0.3 rpm, for 10 minutes 0 seconds.
[d] Brookfield Spindle LV1 with guard leg, 500 mL of neat fluid, at 20°C, 0.3 rpm, for 33 minutes 20 seconds.
[e] Brookfield Spindle SC4-34/13R, small sample adapter, 10 mL of neat fluid, at 20°C, 0.3 rpm, for 30 minutes 0 seconds.
[f] Brookfield Spindle SC4-31/13R, small sample adapter, 10 mL of neat fluid, at 0°C, 0.3 rpm, for 10 minutes 0 seconds.
[g] Brookfield Spindle LV1 with guard leg, 500 mL of neat fluid, at 20°C, 0.3 rpm, for 10 minutes 0 seconds.

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SIGNIFICANCE OF TABLE 6

The viscosity values of the fluids in Table 6 are those provided by the fluid manufacturers for holdover time testing. For the holdover time guidelines to be valid, the viscosity of the undiluted fluid on the wing shall not be lower than that listed in this table. The user should periodically ensure that the viscosity of a fluid sample taken from the wing is not lower than the values listed here.

Note: Consult the fluid manufacturer for lowest on-wing viscosity associated with dilutions.

Table 7. List of Qualified [1] Deicing/Anti-Icing Fluids – Winter 2006-2007

Qualified Type I Deicing/Anti-Icing Fluids

Company Name	Fluid Name
Arkton Ltd.	Artica DG
Aviation Xi'an High-Tech	KHF-1
Battelle	D[3]: Degradable by Design Deicer ADF 1006A
Beijing Wangye Aviation Chem. Prod. Co.	KLA-1
Chemical Specialists and Development	Prist Wing Deicer
Clariant	Safewing MPI 1938 TF
Clariant	Safewing MPI 1938 TF Pre-mix
Clariant	Safewing MP I 1938 ECO
Clariant	Safewing EG I 1996
Dow Chemical Company	UCAR ADF Concentrate
Dow Chemical Company	UCAR ADF XL-54
Dow Chemical Company	UCAR PG ADF Concentrate
Dow Chemical Company	UCAR PG ADF Dilute 55/45
HOC Industries	SafeTemp I ES
HOC Industries	SafeTemp I ES Plus
Inland Technologies	Duragly – P ready to use
Inland Technologies	Duragly – E ready to use
Kilfrost	Kilfrost DF PLUS
Kilfrost	Kilfrost DF PLUS (80)
Kilfrost	Kilfrost DF PLUS (88)
Lyondell Chemical Company	ARCOPlus
Lyondell Chemical Company	ARCTIC Plus
Newwave Aerochemical Company	FCY-1A
Octagon Process	Octaflo EF
Octagon Process	Octaflo EG
SPCA	DE-950
Viterbo S.A.	Jarkleer SAE Type I

Table 7. List of Qualified [(1)] Deicing/Anti-Icing Fluids – Winter 2006-2007 (Continued)

Qualified Type II Deicing/Anti-Icing Fluids

Company Name	Fluid Name
Clariant	Safewing MP II 1951
Clariant	Safewing MP II 2025 ECO
Clariant	Safewing MP II Flight
Kilfrost	Kilfrost ABC-II PLUS
Kilfrost	Kilfrost ABC-3
Kilfrost	Kilfrost ABC-2000
Kilfrost	Kilfrost ABC-TF2
Octagon Process	E-Max
SPCA	SPCA Ecowing 26

Qualified Type III Deicing/Anti-Icing Fluids

Company Name	Fluid Name
Clariant	Safewing MP III 2031 ECO

Qualified Type IV Deicing/Anti-Icing Fluids

Company Name	Fluid Name
Clariant	Safewing MP IV 2001
Clariant	Safewing MP IV 2012 Protect
Clariant	Safewing MP IV 2030 ECO
Clariant	Safewing MP IV Launch
Dow Chemical Company	UCAR AAF ULTRA+
Dow Chemical Company	UCAR AAF AD-480
Kilfrost	Kilfrost ABC-S
Kilfrost	Kilfrost ABC-S Plus
Octagon Process	Max Flight
Octagon Process	Max Flight 04
Octagon Process	MaxFlo

Table 7. List of Qualified [1] Deicing/Anti-Icing Fluids – Winter 2006-2007 (Continued)

Qualified Type IV Deicing/Anti-Icing Fluids (Continued)

SPCA	SPCA AD-480

[1] Qualified indicates that the fluid has been qualified solely to the requirements of the applicable SAE anti-icing and aerodynamic performance specifications in effect at the time of certification, as conducted by the Anti-Icing Materials International Laboratory at the University of Quebec at Chicoutimi, Canada, Web site: http://www.uqac.uquebec.ca/amil/. For other specification requirements for Type I fluids, see SAE AMS 1424 (latest version) and for SAE Types II, III, and IV fluids, see SAE AMS 1428 (latest version). Fluids that qualify after the issuance of this list will appear in a later update.

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