TP 14874E

Effect of Heat on Endurance Times of Anti-Icing Fluids

Volume 1 - Final Report

Prepared by

APS Aviation Inc.

Prepared for

Transportation Development Centre

In cooperation with

Civil Aviation

Transport Canada

And

The Federal Aviation Administration
William J. Hughes Technical Center

July 2009
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TP 14874E

Effect of Heat on Endurance Times of Anti-Icing Fluids

Volume 1 - Final Report

by

Peter Dawson

This report contains final conclusions and recommendations. Information collected during initial phases of the study is given in Volume 2 – Preliminary Report.

APS Aviation Inc.

July 2009
Final Version 1.0

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. (APS) has undertaken a research program to advance aircraft ground de/anti-icing technology. The specific objectives of the APS test program are the following:

- To develop holdover time data for all newly-qualified de/anti-icing fluids;
- To examine the effect of heated fluids on Type II, III and IV fluid endurance times;
- To evaluate weather data from previous winters that can have an impact on the holdover time table format;
- 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, III and IV fluids;
- To develop performance specifications for an integrated weather system that measures holdover time;
- To conduct general and exploratory de/anti-icing research;
- To conduct endurance time tests on non-aluminum plates;
- To conduct endurance time tests in frost on various test surfaces;
- To compile historical data for calculation of holdover times based on a small number of inputs; and
- To assist DND Canada in evaluating the standards used at various DND sites.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2007-08 are documented in six reports. The titles of the reports are as follows:

- TP 14869E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2007-08 Winter;
- TP 14870E Winter Weather Impact on Holdover Time Table Format (1995-2008);
- TP 14871E Aircraft Trials to Examine Anti-Icing Fluid Flow-Off Characteristics: Ice Pellet Allowance Time Expansion Research;
- TP 14872E Aircraft Ground Icing General Research Activities During the 2007-08 Winter;
- TP 14873E Regression Coefficients and Equations Used to Develop the Winter 2008-09 Aircraft Ground Deicing Holdover Time Tables; and
- TP 14874E Effect of Heat on Endurance Times of Anti-Icing Fluids.

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

- *Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2007-08 and Other Artificial Snow Projects;*
- *Fluid Endurance Times Using Composite Surfaces; and*

- *Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions.*

In addition, the following report was written for DND as part of this contract; this report does not have a TP number:

- Development of the Canadian Forces Approved Ground Icing Program (AGIP), Evaluation Methods for Current Performance and Recommendations for Improvement Project: Report on Site Visit to 14 Wing Greenwood.

This report, *Effect of Heat on Endurance Times of Anti-Icing Fluids*, has the following objective:

- To compare endurance time tests from heated Type II, III and IV fluids to cold fluid applications, and to recommend specific action needed to reflect the results.

The objective was met by conducting a series of tests under natural and simulated precipitation conditions. Tests were conducted in pairs, with one fluid applied heated and the other fluid applied according to the standard protocol. The report is published in two volumes. *Volume 1 – Final Report* presents data from supplemental testing, and final conclusions and recommendations*. Volume 2 – Preliminary Report* discusses data collected during the initial phases of the study and presents interim conclusions and recommendations.

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 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 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, Stephanie Bendickson, Michael Chaput, John D'Avirro, Peter Dawson, Benjamin Guthrie, Michael Hawdur, Eric Perocchio, Dany Posteraro, Marco Ruggi, Filippo Suriano, Joey Tiano, David Youssef and Victoria Zoitakis.

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.

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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 (TDC). Six reports were produced as part of this winter's research program, along with 3 Interim Reports. Their subject matter is outlined in the preface. The work described in this report was, in part, co-sponsored by the Federal Aviation Administration (FAA).

16. Abstract

APS Aviation Inc. (APS) conducted a series of tests to compare fluid endurance times produced by the application of SAE Types II, III and IV Anti-Icing Fluids heated, to the endurance times produced by fluids applied at ambient temperature.

Tests were conducted in natural snow conditions at the APS test site at Montreal Trudeau airport and in simulated freezing precipitation conditions at the National Research Council Canada (NRC) Climatic Engineering Facility.

In general, endurance times from heated applications of SAE Type II and IV Fluid exceeded those of the application at ambient temperature. The guidance material on heated fluid applications provided in the FAA Approved Deicing Program Updates should be left unchanged for these fluids.

The report recommends that Type III Fluid be tested separately for heated and for OAT fluid applications, according to the fluid manufacturer's advice on its intended method of use, and that holdover guidelines be developed for each of the two test methods. Heated Type III Fluid should be tested in accordance with the existing Type I Fluid test protocol and SAE ARP5485 updated accordingly.

The report further recommends that holdover times for new Type III Fluids be published in fluid specific tables, and that the current Type III Fluid be grandfathered, removing the need to retest it in accordance with the new Type III Fluid test methods.

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Plusieurs rapports de recherche sur les essais de technologies de dégivrage et d'antigivrage ont été produits au cours d'hivers précédents pour le compte de Transports Canada. Ils sont disponibles au Centre de développement des transports (CDT). Six rapports ont été produits dans le cadre du programme de recherche de cet hiver, de même que 3 rapports intérimaires. Leur objet est résumé à la préface. Le travail qui fait l'objet du présent rapport est en partie coparrainé par la Federal Aviation Administration (FAA).

16. Résumé

APS Aviation Inc. (APS) a tenu une série d'essais pour comparer l'endurance résultant de l'application de liquides d'antigivrage chauffés de types II, III et IV de la SAE à l'endurance de liquides appliqués à la température ambiante.

Les essais ont été effectués dans des conditions de neige naturelle au site d'essais d'APS de l'Aéroport Montréal-Trudeau et dans des conditions de précipitations verglaçantes simulées à l'installation d'ingénierie climatique du Conseil national de recherches Canada (CNRC).

En général, l'endurance d'applications chauffées de liquides de types II et IV de la SAE excédait celles des liquides appliqués à la température ambiante. En ce qui concerne ces liquides, les lignes directrices mises à jour du programme de dégivrage approuvé par la FAA sur l'application de liquides chauffés devraient demeurer inchangées.

Le présent rapport recommande que les liquides de type III soient mis à l'essai séparément chauffés et à la température ambiante, en fonction des recommandations du fabricant du liquide sur son utilisation prévue. Il recommande également que des lignes directrices soient élaborées sur les durées d'efficacité, pour chacune des deux méthodes d'essai. Le liquide chauffé de type III devrait être mis à l'essai conformément au protocole d'essai en place pour les liquides de type I et l'ARP5485 de la SAE devrait être actualisée en conséquence.

Le rapport recommande également que les durées d'efficacité des nouveaux liquides de type III soient publiées dans des tableaux spécifiques à chaque liquide et que le liquide de type III existant soit protégé, écartant ainsi le besoin de le remettre à l'essai conformément aux nouvelle méthodes d'essai de liquides de type III.

17. Mots clés Dégivrage, liquides d'antigivrage de la SAE, normes, durée d'efficacité, systèmes de détermination des durées d'efficacité, endurance	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), APS Aviation Inc. (APS) undertook a study to conduct endurance time tests with heated Type II, III and IV fluids and compare these endurance times with endurance times obtained using the standard test protocol.

The objective was met by conducting a series of tests under natural and simulated precipitation conditions. Tests were conducted in pairs, with one fluid applied heated and the other fluid applied according to the standard protocol.

The report is published in two volumes. Volume 1 – Final Report presents data from supplemental testing, and final conclusions and recommendations. Volume 2 – Preliminary Report discusses data collected during the initial phases of the study and presents interim conclusions and recommendations.

Description and Processing of Data

Initial fluid endurance time testing was conducted over the winters of 2001-02, 2004-05 and 2005-06, and in July 2007. Testing was conducted during natural snow conditions at the APS test site at the Montreal-Trudeau Airport and under freezing precipitation conditions at the National Research Council (Canada) (NRC) Climatic Engineering Facility (CEF) in Ottawa using a sprayer assembly to simulate the required freezing precipitation conditions. The data collected from these tests is examined and interim conclusions and recommendations are discussed in Volume 2 – Preliminary Report.

With the exception of one specific Type II fluid brand, the initial data was sufficient to conclude that endurance times from heated applications of Type II and IV fluids was equal to or better than that from cold fluid applications. Additional testing for the brand in question was conducted in natural snow conditions in winter 2007-08.

The initial laboratory test procedure for heated fluid was based on application of fluid heated to 60ºC. This differs from the Type I indoor test protocol, which is based on fluid applied at 20ºC. Later in the test series, after reviewing some indoor test data, it was suspected that the higher temperature fluid might have had too much influence on endurance times for some tests. Investigation led to the recommendation that indoor laboratory testing for Type III fluid should be conducted with fluid applied at 20ºC. For Type II, and IV fluids, the test data collected with fluid at 60ºC was found to be valid for the purpose of the study.

Additional testing on Type III fluid was conducted in natural snow in winter 2007-08.

As well, an experimental low-viscosity, non-Newtonian fluid proposed as a new Type III fluid was subjected to a full range of holdover time (HOT) tests, both in natural snow and in laboratory artificial freezing precipitation. Advantage was taken of these tests to conduct a parallel set of tests using heated fluid (Type I fluid test protocol) for comparison. Although the fluid was subsequently withdrawn from further development, this research provided valuable data on the potential effect of heated fluid on future Type III fluid endurance times, across the full range of precipitation and outside air temperature (OAT) conditions.

Results and Conclusions – Type II/IV Fluids

It was concluded that the guidance material on heated fluid applications provided in the Federal Aviation Administration (FAA) Approved Deicing Program Updates can be left unchanged for Type II and Type IV fluids. One Type II fluid brand, when heated, showed some endurance time deterioration in freezing precipitation, but not in natural snow. That fluid brand is scheduled for removal from service.

Results and Conclusions – Type III Fluids

Based on test results, and on manufacturer advice on how the fluid is actually used in field operations, it was concluded that operational guidelines for the fluid should state that HOT times can be used with this fluid only when it is applied heated. Application tables in the SAE International (SAE) ARP4737 and regulatory authority guidelines would need to be revised to reflect this method of use, mirroring the existing guideline for Type I fluid.

The endurance time test method for Type III fluid in SAE APR5485 would need to be revised to reflect that tests are conducted with heated fluid using the Type I fluid test protocol.

The current SAE AMS1428 should be reviewed and changed to better reflect the unique characteristics of SAE Type III Fluid.

Holdover times for new Type III fluids should be published in fluid specific tables rather than limit them to one generic table. This will enable field operations to take advantage of the longer times that improved fluids may deliver and will provide an incentive to fluid manufacturers to develop improved Type III fluids. This should be reflected in SAE ARP5718.

SOMMAIRE

En vertu d'un contrat avec le Centre de développement des transports (CDT) de Transports Canada (TC), APS Aviation Inc. (APS) a entrepris une étude sur la tenue d'essais d'endurance sur les liquides chauffés de types II, III et IV, pour comparer ces endurances à celles obtenues avec le protocole d'essai standard.

L'objectif a été rencontré par la tenue d'une série d'essais dans des conditions de précipitations naturelles et simulées. Les essais ont été effectués par l'application simultanée d'un liquide chauffé et d'un autre liquide selon le protocole standard.

Le présent rapport est présenté en deux volumes. Le Volume 1 – Rapport final présente les données des essais supplémentaires, les conclusions finales et les recommandations. Le Volume 2 – Rapport préliminaire examine les données recueillies durant les phases initiales de l'étude et présente les conclusions intérimaires et les recommandations.

Description et traitement des données

Les premiers essais d'endurance ont été effectués au cours des hivers 2001-2002, 2004-2005 et 2005-2006, ainsi qu'en juillet 2007. Ils ont été effectués dans des conditions de neige naturelle au site d'essai d'APS à l'Aéroport Montréal-Trudeau et dans des conditions de précipitations verglaçantes à l'installation d'ingénierie climatique (IEC) du Conseil national de recherches (Canada) (CNRC) à Ottawa, à l'aide d'un pulvérisateur pour simuler les conditions requises de précipitations verglaçantes. Les données recueillies lors de ces essais sont étudiées et les conclusions intérimaires et les recommandations sont examinées dans le Volume 2 – Rapport préliminaire.

À l'exception d'une marque de liquide de type II, les données initiales ont suffi à conclure que l'endurance des applications de liquides chauffés de types II et IV est équivalente ou meilleure que celle des applications de liquide froid. Des essais additionnels sur la marque en question ont été effectués dans des conditions de neige naturelle au cours de l'hiver 2007-2008.

La procédure initiale d'essai en laboratoire avec du liquide chauffé était fondée sur l'application de liquide chauffé à 60ºC. Elle diffère du protocole d'essai à l'intérieur pour les liquides de type I, qui est fondé sur l'application de liquide à 20ºC. Plus tard dans la série d'essais, après avoir étudié certaines données des essais à l'intérieur, on a soupçonné que la plus haute température du liquide pouvait avoir eu trop d'influence sur certains essais d'endurance. Une enquête a mené à la recommandation d'effectuer les essais intérieurs en laboratoire sur le liquide de type III en l'appliquant à 20ºC. Pour les liquides de types II et IV, les données recueillies suite aux essais sur les liquides appliqués à 60ºC ont été reconnues valides pour les besoins de l'étude.

Des essais additionnels dans la neige naturelle ont été effectués sur les liquides de type III au cours de l'hiver 2007-2008.

En outre, un liquide expérimental a faible viscosité et non newtonien, proposé comme nouveau liquide de type III, a été soumis à une gamme complète d'essais de durées d'efficacité (HOT), dans la neige naturelle ainsi que dans des précipitations verglaçantes artificielles en laboratoire. Ces essais ont donné l'opportunité d'effectuer une série d'essais parallèles avec du liquide chauffé (protocole d'essai pour liquide de type I), à des fins de comparaison. Bien que le liquide ait été par la suite retiré d'un développement ultérieur, cette recherche a fourni des données utiles à l'avenir sur l'effet potentiel de liquide chauffé sur l'endurance de liquide de type III, à travers toute la gamme de précipitations et de températures ambiantes.

Résultats et conclusions – Liquides de types II et IV

Il a été conclu que les lignes directrices sur l'application de liquides chauffés, données dans les mises à jour du programme de dégivrage de la Federal Aviation Administration (FAA), peuvent demeurer inchangées pour les liquides de types II et IV. Une marque de liquide de type II, lorsque chauffé, a affiché une détérioration d'endurance dans la précipitation verglaçante, mais pas dans la neige naturelle. Le retrait du service est prévu pour cette marque de liquide.

Résultats et conclusions – Liquides de type III

Selon les résultats des essais et sur l'avis du fabricant sur l'utilisation actuelle du liquide sur le terrain, il a été conclu que les lignes directrices opérationnelles sur le liquide devraient spécifier que les durées d'efficacité ne peuvent être appliquées à ce liquide que lorsqu'on l'applique chauffé. Les tableaux d'application de l'ARP4737 de la SAE International (SAE) et les lignes directrices de l'organisme de réglementation devraient être révisés pour représenter cette méthode d'utilisation, reflétant ainsi les lignes directrices en place pour les liquides de type I.

La méthode d'essai d'endurance des liquides de type III de l'APR5485 de la SAE devrait être révisée pour indiquer que les essais sont effectués avec du liquide chauffé, utilisant le protocole d'essai des liquides de type I.

L'AMS1428 actuelle de la SAE devrait être révisée et modifiée pour mieux représenter les caractéristiques uniques du liquide SAE de type III.

Les durées d'efficacité des nouveaux liquides de type III devraient être publiées dans des tableaux spécifiques aux liquides, plutôt que d'être limitées au tableau générique. Cela permettra aux opérations sur le terrain de profiter des durées prolongées que peuvent offrir les liquides améliorés et incitera les fabricants de liquides à développer des liquides de type III améliorés. Ceci devrait être souligné dans l'ARP5718 de la SAE.

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GLOSSARY

APS	APS Aviation Inc.
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
LOWV	Lowest On-Wing Viscosity
MSC	Meteorological Service of Canada
NRC	National Research Council (Canada)
OAT	Outside Air Temperature
SAE	SAE International
TC	Transport Canada
TDC	Transportation Development Centre
ZD	Freezing Drizzle
ZF	Freezing Fog
ZR	Freezing Rain

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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 limited 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.

Over the past several years, the Transportation Development Centre (TDC) of Transport Canada (TC) has managed and conducted de/anti-icing related tests at various sites in Canada; it has also coordinated worldwide testing and evaluation of evolving technologies related to de/anti-icing operations with the co-operation of the US Federal Aviation Administration (FAA), the National Research Council (Canada) (NRC), Meteorological Service of Canada (MSC), TC, 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 Objectives

The overall objective of this project was to investigate the effect of anti-icing fluid application temperature on endurance times for Type II, III and IV fluids, and to make recommendations regarding the impact of the findings on published HOT guidelines, including the guidance material on heated fluid in the *FAA-Approved Deicing Program Updates, Winter 2007-08*, Federal Aviation Administration N 8900.22 (1). The FAA Guidance Material is reported in Volume 2, Section 1.5.

The detailed objectives are presented in an excerpt from the Transport Canada statement of work in Appendix A.

1.2 Report Format

The report is published in two volumes. Volume 1 – Final Report presents data from supplemental testing (subsequent to Summer 2007), and final conclusions and recommendations. Volume 2 – Preliminary Report discusses data collected during the initial phases (up to Summer 2007) of the study and presents interim conclusions and recommendations.

The following list describes the content of subsequent sections of this final report:

- Section 2 describes the methodology used to carry out the comparative endurance time tests;
- Section 3 presents the endurance time data collected during winter 2007-08;
- Section 4 provides analysis of the endurance time test data;
- Section 5 presents conclusions; and
- Section 6 presents recommendations.

2. METHODOLOGY – ENDURANCE TIME TESTING

The overall approach, test parameters and experimental procedures followed in testing up to summer 2007 are described in Volume 2. Those descriptions and procedures continue to apply for the outdoor tests reported in this volume. The procedure for indoor tests was changed to conform to the Type I fluid indoor test protocol, with fluid applied at 20ºC versus 60ºC.

The detailed test procedure is included in Appendix B.

2.1 Description of Test Procedures

Comparative endurance time tests were conducted using standard endurance time test procedures. The heated and standard tests were conducted simultaneously.

2.1.1 Indoor Test Procedures

The objective of these tests was to compare endurance times of an experimental Type III fluid (Fluid J) when applied using the standard Type I test protocol for indoor tests versus the baseline standard test with cold fluid.

Position 1: Baseline Standard Test

- 1.0 L of fluid poured (without spreader) at ambient temperature onto a standard aluminum plate

Position 2: Heated Fluid Test

- 1.0 L of fluid heated to 20ºC and poured with a 12-hole spreader onto a standard aluminum plate

A summary of these application methods is shown in Figure 2.1.

Position 1 (Standard Test)	**Position 2 (Heated Test)**
• Plate • 1 L of fluid • Apply at ambient • Poured	• Plate • 1 L of fluid • Applied at 20 ºC • Poured with a 12-hole spreader

Figure 2.1: Position on Stand – Indoor Tests

2.1.2 Comparison of Test Surfaces to Aircraft Wing

The Type I fluid indoor test protocol produces a test surface temperature cooling profile in laboratory calm conditions that matches the cooling profiles of actual aircraft wing leading edges following treatment with heated deicing fluid. The Type I test protocol for outdoor tests in natural wind conditions produces a similar result, but with use of 0.5 L of fluid heated to 60ºC and poured onto a 7.5 cm test box. The surface temperature cooling profiles for the wing leading edge, and test box outdoors and test plate indoors when treated as described, are shown in Figure 2.2.

Several supplemental tests were included to examine fluid applied at 60°C. During these tests, Brix measurements were taken on a 60°C test plate and also on the equivalent 20°C test plate and ambient air temperature test plate.

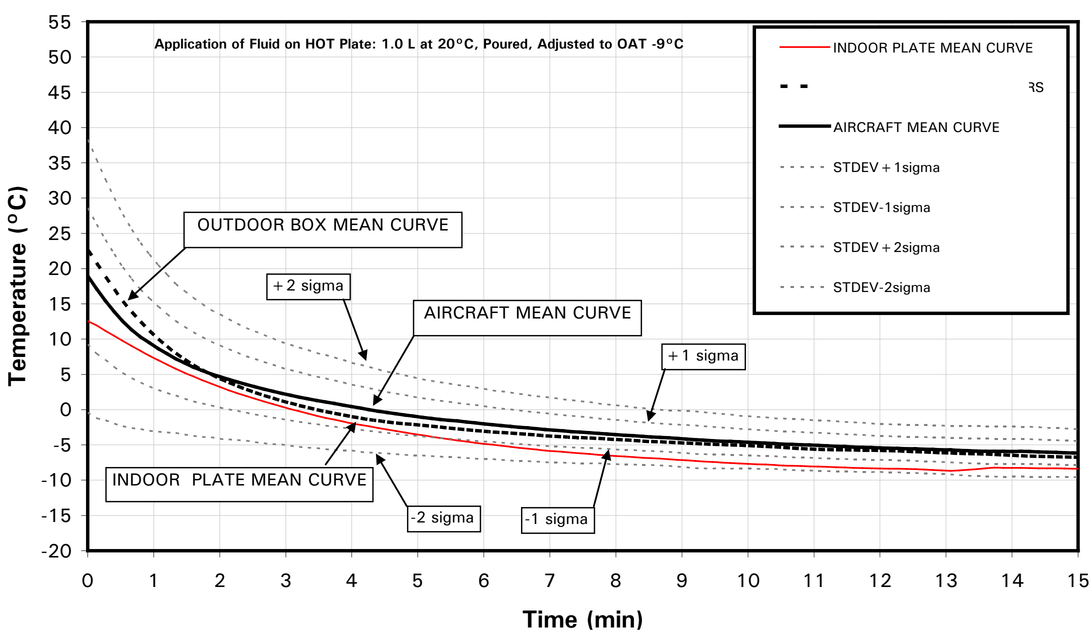

Figure 2.2: Temperature Profiles – Comparison of Average Wing to Outdoor Box and Indoor Plate

2.1.3 Outdoor Test Procedures

The objective of these tests was to compare endurance times in natural snow of Type III fluid (Fluid B and J) and Type II fluid (Fluid A) when applied using the standard Type I test protocol versus the baseline standard test with cold fluid.

During the course of tests described in Volume 2, an examination was conducted to determine if the outdoor test protocol used to measure endurance times for heated Type I fluid was appropriate for evaluating the effect of heated fluid on Type II, III and IV fluid endurance times. Test results showed that heated Type IV on a box produced a temperature profile similar to that of heated Type IV on a wing, and that both temperature profiles (box and wing) fit within the scatter of the Type I data previously collected.

It was concluded that the Type I protocol for outdoor tests is a valid method for testing heated Type II, III and IV fluids outdoors.

The standard endurance time testing procedure and methodology were followed.

Position 1: Baseline Standard Test

- 1 L of fluid poured (without spreader) at outside air temperature (OAT) onto a standard aluminum plate.

Position 2: Heated Fluid Test using Type I fluid outdoor test protocol

- 0.5 L of fluid heated to 60ºC and poured with a 12-hole spreader onto a Type I 7.5 cm test box.

A summary of these application methods is shown in Figure 2.3.

Position 1 (Standard Test)	**Position 2 (Heated Test)**
• Plate • 1 L of fluid • Apply at OAT • Poured	• Box (empty) @ OAT • 0.5 L of fluid • Applied at 60 ºC • Poured with a 12-hole spreader

Figure 2.3: Position on Stand – Outdoor Tests

2.2 Data Forms

Three data forms were required:

- Data form for documenting fluid endurance time (freezing precipitation);
- Data form for documenting fluid endurance time (natural snow); and
- Data form for documenting fluid thickness and Brix.

2.3 Equipment

APS measurement instruments and test equipment are calibrated and verified on an annual basis. This calibration is carried out according to a calibration plan derived from approved ISO 9001:2000 standards, and developed internally by APS.

The test equipment employed, including test surfaces, test stand, thermistor probes, standard twelve-hole spreader, handheld Brixometer and wet film thickness gauges, are described in Volume 2.

2.4 Personnel

Three individuals were required to conduct these tests. The test manager measured endurance times. An assistant prepared the fluids, assisted with fluid application and collected fluid thickness and dilution measurements. A third individual measured precipitation rate.

2.5 Fluids

Three anti-icing fluids were tested over the winter 2007-08.

Table 2.1 lists the details of each fluid tested. The fluids have been coded, as the objective of this project was to generate a generic understanding of the effect of heat, not to evaluate the performance of specific fluids.

Table 2.1: Fluids Tested for Comparative Endurance Time Winter 2007-08

Fluid Brand	Fluid Type	Dilutions Tested	Commercial or Experimental Fluid	Viscosity[1]
Fluid A	II	50%, 75%, 100%	Commercial	LOWV
Fluid B	III	50%, 75%, 100%	Commercial	LOWV
Fluid J	Proposed and tested as a new Type III, but later withdrawn	50%, 75%, 100%	Experimental	LOWV

[1] LOWV: Lowest On-Wing Viscosity

3. DESCRIPTION AND PROCESSING OF DATA

This section describes the endurance time data collected by APS under natural and simulated freezing precipitation conditions in winter 2007-08.

3.1 Total Tests Conducted

A total 277 comparison tests were conducted for this project. Table 3.1 shows the number of comparison tests conducted in snow and freezing precipitation each year.

Table 3.1: Tests Conducted by Year

Precipitation Type	Winter 2001-02	Winter 2004-05	Winter 2005-06	July 2007	Winter 2007-08	Total
Snow	8	19	21	0	82	**130**
Freezing Precip.	12	20	28	11	76	**147**
Total	**20**	**39**	**49**	**11**	**158**	**277**

3.2 Test Logs

Two logs were created for each winter of testing: one for natural snow tests and one for simulated freezing precipitation tests. Logs for tests conducted up to and including July 2007 are given in Volume 2. Logs for winter 2007-08 are given in Table 3.2 and Table 3.3 as follows:

a) Natural Snow Tests 2007-08; and

b) Simulated Freezing Precipitation Tests 2007-08.

Each row in the logs contains data specific to one test. Test numbers are not always sequential, as some tests were conducted in conjunction with testing on other projects; the other project data was removed from the logs as it was not relevant to this report.

A brief description of the column headings used in the test logs is provided below.

Test No.:	Test number given to the test in the given test year. Numbers are unique to the specific test log but may not be unique to the entire dataset. Note: Tests in 2001-02 were not given test numbers.
Date:	Date when the test was conducted.
Fluid Dilution:	Anti-icing fluid glycol concentration.
Fluid Name:	A unique code designating a fluid brand name.
Fluid Type:	Aircraft anti-icing fluid type.
Fluid Application Temp.:	Aircraft anti-icing fluid application temperature.
Test Surface:	Surface used for testing, either plate or box.
Fail Time:	Measured fluid endurance time.
Precipitation Rate:	Average precipitation rate (in $g/dm^2/h$) collected by precipitation pans at set intervals for the duration of the test session.
Test Temp:	The ambient temperature (in degrees Celsius) for the test (simulated freezing precipitation tests only).
OAT:	The average outside air temperature (in degrees Celsius) provided by Meteorological Service of Canada (MSC) (snow tests only).
Precipitation Type:	The type of freezing precipitation simulated in the CEF, either freezing rain (ZR), freezing drizzle (ZD) or freezing fog (ZF) (simulated freezing precipitation tests only).
Wind Speed:	The average hourly wind speed (in km/h), provided by MSC (snow tests only).
Chart:	Designates whether the data collected during the test was plotted and a chart was produced (see Appendix C).

Table 3.2: Natural Snow Tests Winter 2007-08

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid App. Temp. (°C)	Test Surface	Fail Time (min.)	Precip. Rate (g/dm²/h)	OAT (°C)	Wind Speed (km/h)	Chart[1]
HC01	18-Jan-08	50%	Fluid B	III	OAT	Plate	27.0	3.1	-0.9	25	2
HC02	18-Jan-08	50%	Fluid B	III	60	Box	29.2	3.3	-0.9	25	2
HC03	18-Jan-08	75%	Fluid A	II	OAT	Plate	23.7	15.9	-0.4	27	2
HC04	18-Jan-08	75%	Fluid A	II	60	Box	22.3	15.6	-0.4	27	2
HC05	18-Jan-08	50%	Fluid B	III	OAT	Plate	26.2	4.8	-0.3	19	2
HC06	18-Jan-08	50%	Fluid B	III	60	Box	30.7	5.0	-0.3	19	2
HC07	22-Jan-08	100%	Fluid B	III	OAT	Plate	33.3	4.7	-8.0	17	2
HC08	22-Jan-08	100%	Fluid B	III	60	Box	25.8	4.7	-8.0	17	2
HC09	22-Jan-08	75%	Fluid B	III	OAT	Plate	12.3	10.5	-7.8	16	2
HC10	22-Jan-08	75%	Fluid B	III	60	Box	10.4	10.4	-7.8	16	2
HC11	22-Jan-08	100%	Fluid A	II	OAT	Plate	49.1	10.2	-8.1	13	2
HC12	22-Jan-08	100%	Fluid A	II	60	Box	46.3	10.0	-8.1	13	2
HC13	22-Jan-08	75%	Fluid B	III	OAT	Plate	4.7	27.6	-7.9	10	2
HC14	22-Jan-08	75%	Fluid B	III	60	Box	5.3	27.6	-7.9	10	2
HC15	22-Jan-08	75%	Fluid A	II	OAT	Plate	48.9	4.6	-6.9	6	2
HC16	22-Jan-08	75%	Fluid A	II	60	Box	43.8	4.7	-6.9	6	2
HC17	22-Jan-08	100%	Fluid A	II	OAT	Plate	93.5	4.1	-6.7	6	2
HC18	22-Jan-08	100%	Fluid A	II	60	Box	81.3	4.1	-6.7	6	2
HC19	22-Jan-08	100%	Fluid B	III	OAT	Plate	49.3	2.8	-5.8	7	2
HC20	22-Jan-08	100%	Fluid B	III	60	Box	46.0	2.5	-5.8	7	2
HC21	1-Feb-08	100%	Fluid B	III	OAT	Plate	22.7	9.8	-7.6	24	2
HC22	1-Feb-08	100%	Fluid B	III	60	Box	24.1	6.0	-7.6	24	2
HC23	1-Feb-08	75%	Fluid B	III	OAT	Plate	9.8	6.4	-7.6	27	2
HC24	1-Feb-08	75%	Fluid B	III	60	Box	11.8	9.5	-7.6	27	2
HC25	1-Feb-08	100%	Fluid A	II	OAT	Plate	26.5	33.7	-7.1	32	2
HC26	1-Feb-08	100%	Fluid A	II	60	Box	25.7	33.7	-7.1	32	2
HC27	1-Feb-08	75%	Fluid A	II	OAT	Plate	13.0	37.8	-6.1	26	2
HC28	1-Feb-08	75%	Fluid A	II	60	Box	12.2	37.4	-6.1	26	2
HC29	1-Feb-08	100%	Fluid B	III	OAT	Plate	12.8	34.2	-5.4	32	2
HC30	1-Feb-08	100%	Fluid B	III	60	Box	13.4	33.9	-5.4	32	2
HC31	1-Feb-08	75%	Fluid B	III	OAT	Plate	10.5	22.7	-5.2	34	2
HC32	1-Feb-08	75%	Fluid B	III	60	Box	10.2	22.9	-5.2	34	2
HC33	1-Feb-08	100%	Fluid J	III	OAT	Plate	37.7	8.0	-7.6	25	2
HC34	1-Feb-08	100%	Fluid J	III	60	Box	34.1	7.9	-7.6	25	2
HC35	1-Feb-08	75%	Fluid J	III	OAT	Plate	15.8	9.8	-7.6	25	2
HC36	1-Feb-08	100%	Fluid J	III	60	Box	10.6	38.5	-6.4	27	2
HC37	1-Feb-08	100%	Fluid J	III	OAT	Plate	13.6	39.3	-6.4	27	2
HC38	1-Feb-08	75%	Fluid J	III	60	Box	22.3	10.7	-7.6	28	2
HC39	1-Feb-08	75%	Fluid J	III	OAT	Plate	7.2	37.4	-6.4	27	2
HC40	1-Feb-08	75%	Fluid J	III	60	Box	8.2	38.1	-6.4	27	2
HC41	1-Feb-08	100%	Fluid J	III	OAT	Plate	16.3	54.8	-5.9	27	2
HC42	1-Feb-08	100%	Fluid J	III	60	Box	15.3	52.5	-5.9	27	2
HC43	1-Feb-08	75%	Fluid J	III	OAT	Plate	5.8	54.8	-6.0	27	2
HC44	1-Feb-08	75%	Fluid J	III	60	Box	6.9	54.9	-6.0	27	2

Table 3.2: Natural Snow Tests Winter 2007-08 (cont'd)

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid App. Temp. (°C)	Test Surface	Fail Time (min.)	Precip. Rate (g/dm²/h)	OAT (°C)	Wind Speed (km/h)	Chart[1]
HC45	1-Feb-08	100%	Fluid J	III	OAT	Plate	29.8	25.5	-5.4	33	2
HC46	1-Feb-08	100%	Fluid J	III	60	Box	34.8	24.3	-5.4	33	2
HC47	1-Feb-08	75%	Fluid J	III	OAT	Plate	12.3	34.5	-5.4	32	2
HC48	1-Feb-08	75%	Fluid J	III	60	Box	14.3	33.5	-5.4	32	2
HC49	5-Feb-08	100%	Fluid J	III	OAT	Plate	103.8	4.0	-5.6	22	3
HC50	5-Feb-08	100%	Fluid J	III	60	Box	101.8	3.9	-5.6	22	3
HC51	5-Feb-08	75%	Fluid J	III	OAT	Plate	68.2	2.2	-5.6	21	3
HC52	5-Feb-08	75%	Fluid J	III	60	Box	84.2	2.9	-5.6	22	3
HC53	5-Feb-08	100%	Fluid J	III	OAT	Plate	65.0	7.5	-5.5	22	3
HC54	5-Feb-08	100%	Fluid J	III	60	Box	57.0	7.0	-5.5	21	3
HC55	5-Feb-08	75%	Fluid J	III	OAT	Plate	21.7	9.2	-5.6	22	3
HC56	5-Feb-08	75%	Fluid J	III	60	Box	30.2	8.4	-5.5	22	3
HC57	5-Feb-08	100%	Fluid J	III	OAT	Plate	39.7	9.9	-5.4	21	3
HC58	5-Feb-08	100%	Fluid J	III	60	Box	39.7	9.9	-5.4	21	3
HC59	5-Feb-08	75%	Fluid J	III	OAT	Plate	25.0	7.9	-5.5	21	3
HC60	5-Feb-08	75%	Fluid J	III	60	Box	31.0	9.1	-5.4	21	3
HC61	5-Feb-08	100%	Fluid J	III	OAT	Plate	39.5	13.5	-5.1	21	3
HC62	5-Feb-08	100%	Fluid J	III	60	Box	28.5	13.9	-5.1	21	3
HC63	5-Feb-08	75%	Fluid J	III	OAT	Plate	17.0	11.6	-5.2	21	3
HC64	5-Feb-08	75%	Fluid J	III	60	Box	22.0	12.4	-5.1	21	3
HC65	5-Feb-08	100%	Fluid J	III	OAT	Plate	19.0	25.2	-4.9	21	3
HC66	5-Feb-08	100%	Fluid J	III	60	Box	17.0	25.4	-4.9	21	3
HC67	5-Feb-08	75%	Fluid J	III	OAT	Plate	9.6	26.7	-4.9	21	3
HC68	5-Feb-08	75%	Fluid J	III	60	Box	13.6	25.4	-4.9	21	3
HC69	7-Feb-08	75%	Fluid J	III	OAT	Plate	95.4	1.5	-9.9	41	3
HC70	7-Feb-08	75%	Fluid J	III	60	Box	164.4	1.6	-9.9	40	3
HC71	9-Feb-08	100%	Fluid J	III	OAT	Plate	67.5	5.9	-3.8	16	3
HC72	9-Feb-08	100%	Fluid J	III	60	Box	54.5	5.4	-3.0	15	3
HC73	9-Feb-08	75%	Fluid J	III	OAT	Plate	34.7	4.9	-3.9	17	3
HC74	9-Feb-08	75%	Fluid J	III	60	Box	46.7	4.8	-3.8	16	3
HC75	9-Feb-08	100%	Fluid J	III	OAT	Plate	142.2	2.7	-2.7	13	3
HC76	9-Feb-08	100%	Fluid J	III	60	Box	141.2	2.6	-3.0	13	3
HC77	9-Feb-08	50%	Fluid J	III	OAT	Plate	11.2	8.3	-1.2	9	3
HC78	9-Feb-08	50%	Fluid J	III	60	Box	19.7	8.0	-1.1	9	3
HC79	10-Feb-08	100%	Fluid J	III	OAT	Plate	38.3	11.1	-0.2	7	3
HC80	10-Feb-08	100%	Fluid J	III	60	Box	37.3	11.4	-0.5	7	3
HC81	10-Feb-08	75%	Fluid J	III	OAT	Plate	16.4	11.4	-0.6	7	3
HC82	10-Feb-08	75%	Fluid J	III	60	Box	22.4	13.3	-0.6	7	3
HC83	10-Feb-08	50%	Fluid J	III	OAT	Plate	11.8	9.1	-0.6	7	3
HC84	10-Feb-08	50%	Fluid J	III	60	Box	15.8	11.5	-0.6	7	3
HC85	13-Feb-08	100%	Fluid J	III	OAT	Plate	12.5	20.9	-13.5	26	3
HC86	13-Feb-08	100%	Fluid J	III	60	Box	14.0	21.3	-13.5	26	3
HC87	13-Feb-08	100%	Fluid J	III	OAT	Plate	11.5	24.4	-13.5	26	3
HC88	13-Feb-08	100%	Fluid J	III	60	Box	12.5	24.6	-13.5	26	3

Table 3.2: Natural Snow Tests Winter 2007-08 (cont'd)

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid App. Temp. (°C)	Test Surface	Fail Time (min.)	Precip. Rate (g/dm²/h)	OAT (°C)	Wind Speed (km/h)	Chart[1]
HC89	13-Feb-08	100%	Fluid A	II	OAT	Plate	14.0	8.3	-13.4	27	3
HC90	13-Feb-08	100%	Fluid A	II	60	Box	15.7	8.0	-13.4	27	3
HC91	13-Feb-08	100%	Fluid J	III	OAT	Plate	10.5	27.3	-13.3	28	3
HC92	13-Feb-08	100%	Fluid J	III	60	Box	9.2	27.4	-13.3	28	3
HC93	13-Feb-08	100%	Fluid B	III	OAT	Plate	9.8	5.0	-13.3	29	3
HC94	13-Feb-08	100%	Fluid B	III	60	Box	7.6	4.9	-13.3	29	3
HC95	13-Feb-08	100%	Fluid J	III	OAT	Plate	7.3	34.1	-13.1	29	3
HC96	13-Feb-08	100%	Fluid J	III	60	Box	6.3	34.6	-13.1	29	3
HC97	13-Feb-08	100%	Fluid J	III	OAT	Plate	6.2	39.7	-12.1	23	3
HC98	13-Feb-08	100%	Fluid J	III	60	Box	5.7	39.7	-12.1	23	3
HC99	13-Feb-08	100%	Fluid B	III	OAT	Plate	14.5	26.7	-11.6	20	3
HC100	13-Feb-08	100%	Fluid B	III	60	Box	4.0	29.6	-11.6	20	3
HC101	13-Feb-08	100%	Fluid J	III	OAT	Plate	14.0	26.4	-11.6	20	3
HC102	13-Feb-08	100%	Fluid J	III	60	Box	11.5	26.6	-11.6	20	3
HC103	13-Feb-08	100%	Fluid B	III	OAT	Plate	7.7	25.6	-11.0	19	3
HC104	13-Feb-08	100%	Fluid B	III	60	Box	4.7	26.3	-11.0	19	3
HC105	13-Feb-08	100%	Fluid J	III	OAT	Plate	16.7	25.1	-10.9	19	3
HC106	13-Feb-08	100%	Fluid J	III	60	Box	12.7	24.3	-10.9	19	3
HC107	13-Feb-08	100%	Fluid A	II	OAT	Plate	21.7	24.1	-10.7	19	3
HC108	13-Feb-08	100%	Fluid A	II	60	Box	21.7	24.1	-10.7	19	3
HC109	13-Feb-08	100%	Fluid J	III	OAT	Plate	20.0	19.6	-8.8	18	3
HC110	13-Feb-08	100%	Fluid J	III	60	Box	16.2	19.3	-8.6	18	3
HC111	13-Feb-08	75%	Fluid J	III	OAT	Plate	12.8	19.4	-8.9	18	3
HC112	13-Feb-08	75%	Fluid J	III	60	Box	14.3	19.4	-8.7	18	3
HC113	13-Feb-08	100%	Fluid J	III	OAT	Plate	31.8	14.9	-7.1	14	3
HC114	13-Feb-08	100%	Fluid J	III	60	Box	24.8	14.6	-7.3	14	3
HC115	13-Feb-08	75%	Fluid J	III	OAT	Plate	17.1	14.0	-7.1	15	3
HC116	13-Feb-08	75%	Fluid J	III	60	Box	20.1	14.3	-7.3	14	3
HC117	13-Feb-08	100%	Fluid J	III	OAT	Plate	37.0	16.2	-5.9	13	3
HC118	13-Feb-08	100%	Fluid J	III	60	Box	26.0	16.2	-5.9	12	3
HC119	13-Feb-08	75%	Fluid J	III	OAT	Plate	13.0	14.8	-6.2	13	3
HC120	13-Feb-08	75%	Fluid J	III	60	Box	21.0	16.0	-6.3	13	3
HC121	13-Feb-08	100%	Fluid J	III	OAT	Plate	33.3	13.7	-4.6	11	3
HC122	13-Feb-08	100%	Fluid J	III	60	Box	29.3	13.3	-4.6	11	3
HC123	13-Feb-08	75%	Fluid J	III	OAT	Plate	15.8	12.8	-4.8	11	3
HC124	13-Feb-08	75%	Fluid J	III	60	Box	23.8	12.5	-4.6	11	3
HC125	13-Feb-08	75%	Fluid B	III	OAT	Plate	11.3	12.9	-4.3	11	3
HC126	13-Feb-08	75%	Fluid B	III	60	Box	8.3	12.9	-4.3	11	3
HC127	13-Feb-08	100%	Fluid J	III	OAT	Plate	58.3	8.3	-6.8	13	3
HC128	13-Feb-08	100%	Fluid J	III	60	Box	60.3	8.3	-7.7	13	3
HC129	13-Feb-08	75%	Fluid J	III	OAT	Plate	16.0	12.3	-7.1	12	3
HC130	13-Feb-08	75%	Fluid J	III	60	Box	30.0	10.3	-7.4	12	3
HC131	13-Feb-08	100%	Fluid B	III	OAT	Plate	13.0	12.5	-6.5	13	3
HC132	13-Feb-08	100%	Fluid B	III	60	Box	12.0	12.5	-6.5	13	3

Table 3.2: Natural Snow Tests Winter 2007-08 (cont'd)

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid App. Temp. (°C)	Test Surface	Fail Time (min.)	Precip. Rate (g/dm²/h)	OAT (°C)	Wind Speed (km/h)	Chart[1]
HC133	15-Feb-08	100%	Fluid J	III	OAT	Plate	30.0	13.9	-2.8	14	3
HC134	15-Feb-08	100%	Fluid J	III	60	Box	27.0	13.3	-2.8	14	3
HC135	15-Feb-08	75%	Fluid J	III	OAT	Plate	13.2	13.5	-2.8	13	3
HC136	15-Feb-08	75%	Fluid J	III	60	Box	22.3	12.6	-2.8	14	3
HC137	15-Feb-08	50%	Fluid J	III	OAT	Plate	15.5	6.2	-2.8	13	3
HC138	15-Feb-08	50%	Fluid J	III	60	Box	21.5	6.5	-2.8	13	3
HC139	15-Feb-08	50%	Fluid J	III	OAT	Plate	6.2	12.6	-2.9	13	3
HC140	15-Feb-08	50%	Fluid J	III	60	Box	11.7	13.0	-2.9	13	3
HC141	15-Feb-08	50%	Fluid J	III	OAT	Plate	11.3	9.2	-2.9	14	3
HC142	15-Feb-08	50%	Fluid J	III	60	Box	16.8	9.2	-2.9	14	3
HC143	15-Feb-08	100%	Fluid J	III	OAT	Plate	60.2	6.2	-2.8	16	3
HC144	15-Feb-08	100%	Fluid J	III	60	Box	59.2	5.8	-2.8	16	3
HC145	15-Feb-08	75%	Fluid J	III	OAT	Plate	31.7	8.4	-2.9	15	3
HC146	15-Feb-08	75%	Fluid J	III	60	Box	45.7	5.5	-2.8	15	3
HC147	7-Mar-08	75%	Fluid J	III	OAT	Plate	15.0	21.2	0.4	17	3
HC148	7-Mar-08	75%	Fluid J	III	60	Box	27.0	18.5	0.4	17	3
HC149	7-Mar-08	50%	Fluid J	III	OAT	Plate	10.3	22.2	0.4	17	3
HC150	7-Mar-08	50%	Fluid J	III	60	Box	15.8	19.9	0.4	17	3
HC151	8-Mar-08	100%	Fluid J	III	OAT	Plate	69.8	7.9	0.4	17	3
HC152	8-Mar-08	100%	Fluid J	III	60	Box	65.8	7.8	0.4	17	3
HC153	8-Mar-08	75%	Fluid J	III	OAT	Plate	54.3	6.0	0.2	19	3
HC154	8-Mar-08	75%	Fluid J	III	60	Box	65.3	5.8	0.2	19	3
HC155	8-Mar-08	50%	Fluid J	III	OAT	Plate	44.8	6.5	0.2	19	3
HC156	8-Mar-08	50%	Fluid J	III	60	Box	48.8	6.2	0.2	19	3
HC157	8-Mar-08	100%	Fluid J	III	OAT	Plate	84.3	6.2	0.2	20	3
HC158	8-Mar-08	100%	Fluid J	III	60	Box	84.3	6.2	0.2	20	3
HC159	8-Mar-08	100%	Fluid J	III	OAT	Plate	78.7	6.4	-4.6	32	3
HC160	8-Mar-08	100%	Fluid J	III	60	Box	90.3	6.3	-4.6	32	3
HC161	8-Mar-08	75%	Fluid J	III	OAT	Plate	23.8	8.7	-5.0	28	3
HC162	8-Mar-08	75%	Fluid J	III	60	Box	23.8	8.6	-5.0	28	3
HC163	8-Mar-08	75%	Fluid J	III	OAT	Plate	6.5	41.8	-3.9	36	3
HC164	8-Mar-08	75%	Fluid J	III	60	Box	6.5	45.5	-3.9	36	3

[1]Chart Codes: 1. Chart Plotted
2. Chart Not Plotted, Data Available
3. Chart Not Plotted, Data Not Available

Table 3.3: Simulated Freezing Precipitation Tests Winter 2007-08

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid App. Temp. (°C)	Test Surface	Fail Time (min.)	Precip. Rate (g/dm²/h)	Test Temp. (°C)	Precip. Type	Chart[1]
1	31-Mar-08	100%	Fluid J	III	OAT	Plate	24.0	4.9	-25	ZF	3
2	31-Mar-08	100%	Fluid J	III	20	Plate	28.5	4.9	-25	ZF	3
3	31-Mar-08	100%	Fluid J	III	OAT	Plate	22.8	5.1	-25	ZF	3
4	31-Mar-08	100%	Fluid J	III	20	Plate	27.0	5.1	-25	ZF	3
5	31-Mar-08	100%	Fluid J	III	OAT	Plate	42.0	2.0	-25	ZF	3
6	31-Mar-08	100%	Fluid J	III	20	Plate	42.0	2.3	-25	ZF	3
7	31-Mar-08	100%	Fluid J	III	OAT	Plate	41.9	2.2	-25	ZF	3
8	31-Mar-08	100%	Fluid J	III	20	Plate	42.7	2.2	-25	ZF	3
9	2-Apr-08	100%	Fluid J	III	OAT	Plate	69.4	2.2	-14	ZF	3
10	2-Apr-08	100%	Fluid J	III	20	Plate	63.5	2.2	-14	ZF	3
11	2-Apr-08	100%	Fluid J	III	OAT	Plate	69.1	2.3	-14	ZF	3
12	2-Apr-08	100%	Fluid J	III	20	Plate	63.1	2.2	-14	ZF	3
13	2-Apr-08	75%	Fluid J	III	OAT	Plate	46.0	2.1	-14	ZF	3
14	2-Apr-08	75%	Fluid J	III	20	Plate	59.2	2.1	-14	ZF	3
15	2-Apr-08	75%	Fluid J	III	OAT	Plate	46.7	2.2	-14	ZF	3
16	2-Apr-08	75%	Fluid J	III	20	Plate	59.0	2.1	-14	ZF	3
17	2-Apr-08	100%	Fluid J	III	OAT	Plate	32.5	5.5	-14	ZF	3
18	2-Apr-08	100%	Fluid J	III	20	Plate	36.8	5.1	-14	ZF	3
19	2-Apr-08	100%	Fluid J	III	OAT	Plate	32.0	5.4	-14	ZF	3
20	2-Apr-08	100%	Fluid J	III	20	Plate	36.5	5.2	-14	ZF	3
21	2-Apr-08	75%	Fluid J	III	OAT	Plate	27.0	5.4	-14	ZF	3
22	2-Apr-08	75%	Fluid J	III	20	Plate	33.5	5.3	-14	ZF	3
23	2-Apr-08	75%	Fluid J	III	OAT	Plate	25.8	5.4	-14	ZF	3
24	2-Apr-08	75%	Fluid J	III	20	Plate	32.0	5.7	-14	ZF	3
25	2-Apr-08	100%	Fluid J	III	OAT	Plate	47.2	5.3	-3	ZF	3
26	2-Apr-08	100%	Fluid J	III	20	Plate	56.3	5.3	-3	ZF	3
27	2-Apr-08	100%	Fluid J	III	OAT	Plate	53.2	5.5	-3	ZF	3
28	2-Apr-08	100%	Fluid J	III	20	Plate	56.3	5.5	-3	ZF	3
29	2-Apr-08	75%	Fluid J	III	OAT	Plate	28.5	5.1	-3	ZF	3
30	2-Apr-08	75%	Fluid J	III	20	Plate	54.8	4.8	-3	ZF	3
31	2-Apr-08	75%	Fluid J	III	OAT	Plate	33.0	5.1	-3	ZF	3
32	2-Apr-08	75%	Fluid J	III	20	Plate	51.8	4.7	-3	ZF	3
33	2-Apr-08	50%	Fluid J	III	OAT	Plate	12.8	5.3	-3	ZF	3
34	2-Apr-08	50%	Fluid J	III	20	Plate	18.2	4.6	-3	ZF	3
35	2-Apr-08	50%	Fluid J	III	OAT	Plate	13.7	5.1	-3	ZF	3
36	2-Apr-08	50%	Fluid J	III	20	Plate	15.0	5.1	-3	ZF	3
37	3-Apr-08	50%	Fluid J	III	OAT	Plate	28.2	2.0	-3	ZF	3
38	3-Apr-08	50%	Fluid J	III	20	Plate	36.5	1.7	-3	ZF	3
39	3-Apr-08	50%	Fluid J	III	OAT	Plate	25.5	2.0	-3	ZF	3
40	3-Apr-08	50%	Fluid J	III	20	Plate	43.8	1.9	-3	ZF	3
41	3-Apr-08	100%	Fluid J	III	OAT	Plate	114.5	1.9	-3	ZF	3
42	3-Apr-08	100%	Fluid J	III	20	Plate	127.2	2.3	-3	ZF	3
43	3-Apr-08	100%	Fluid J	III	OAT	Plate	110.7	1.9	-3	ZF	3
44	3-Apr-08	100%	Fluid J	III	20	Plate	127.0	2.2	-3	ZF	3

Table 3.3: Simulated Freezing Precipitation Tests Winter 2007-08 (cont'd)

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid App. Temp. (°C)	Test Surface	Fail Time (min.)	Precip. Rate (g/dm²/h)	Test Temp. (°C)	Precip. Type	Chart[1]
45	3-Apr-08	75%	Fluid J	III	OAT	Plate	85.5	2.2	-3	ZF	3
46	3-Apr-08	75%	Fluid J	III	20	Plate	123.5	1.9	-3	ZF	3
47	3-Apr-08	75%	Fluid J	III	OAT	Plate	88.2	2.0	-3	ZF	3
48	3-Apr-08	75%	Fluid J	III	20	Plate	123.3	1.9	-3	ZF	3
49	4-Apr-08	75%	Fluid J	III	OAT	Plate	16.2	13.2	-3	ZD	2
50	4-Apr-08	75%	Fluid J	III	20	Plate	23.3	13.2	-3	ZD	1
51	4-Apr-08	100%	Fluid J	III	OAT	Plate	25.2	12.9	-3	ZD	3
52	4-Apr-08	100%	Fluid J	III	20	Plate	28.2	13.5	-3	ZD	3
53	4-Apr-08	100%	Fluid J	III	OAT	Plate	26.2	13.3	-3	ZD	3
54	4-Apr-08	100%	Fluid J	III	20	Plate	28.2	13.5	-3	ZD	3
55	4-Apr-08	50%	Fluid J	III	OAT	Plate	7.5	12.8	-3	ZD	3
56	4-Apr-08	50%	Fluid J	III	20	Plate	13.7	12.6	-3	ZD	1
57	4-Apr-08	50%	Fluid J	III	OAT	Plate	7.5	12.7	-3	ZD	2
58	4-Apr-08	50%	Fluid J	III	20	Plate	14.5	12.9	-3	ZD	3
59	4-Apr-08	50%	Fluid J	III	60	Plate	18.5	13.4	-3	ZD	1
60	4-Apr-08	75%	Fluid J	III	OAT	Plate	17.0	13.3	-3	ZD	3
61	4-Apr-08	75%	Fluid J	III	20	Plate	24.5	13.6	-3	ZD	3
62	4-Apr-08	75%	Fluid J	III	60	Plate	23.5	12.8	-3	ZD	1
63	4-Apr-08	100%	Fluid J	III	OAT	Plate	94.0	5.4	-3	ZD	3
64	4-Apr-08	100%	Fluid J	III	20	Plate	67.0	4.5	-3	ZD	3
65	4-Apr-08	100%	Fluid J	III	OAT	Plate	48.7	5.2	-3	ZD	3
66	4-Apr-08	100%	Fluid J	III	20	Plate	52.3	5.0	-3	ZD	3
67	4-Apr-08	75%	Fluid J	III	OAT	Plate	38.0	5.4	-3	ZD	3
68	4-Apr-08	75%	Fluid J	III	20	Plate	52.8	5.1	-3	ZD	3
69	4-Apr-08	75%	Fluid J	III	OAT	Plate	36.0	5.2	-3	ZD	3
70	4-Apr-08	75%	Fluid J	III	20	Plate	49.5	5.2	-3	ZD	3
71	4-Apr-08	50%	Fluid J	III	OAT	Plate	15.2	5.1	-3	ZD	3
72	4-Apr-08	50%	Fluid J	III	20	Plate	20.2	4.5	-3	ZD	3
73	4-Apr-08	50%	Fluid J	III	OAT	Plate	15.3	5.1	-3	ZD	3
74	4-Apr-08	50%	Fluid J	III	20	Plate	23.8	4.5	-3	ZD	3
75	7-Apr-08	100%	Fluid J	III	OAT	Plate	38.0	5.0	-10	ZD	3
76	7-Apr-08	100%	Fluid J	III	20	Plate	39.5	5.4	-10	ZD	3
77	7-Apr-08	100%	Fluid J	III	OAT	Plate	38.0	5.4	-10	ZD	3
78	7-Apr-08	100%	Fluid J	III	20	Plate	39.0	5.6	-10	ZD	3
79	7-Apr-08	75%	Fluid J	III	OAT	Plate	27.5	4.6	-10	ZD	3
80	7-Apr-08	75%	Fluid J	III	20	Plate	44.0	4.8	-10	ZD	3
81	7-Apr-08	75%	Fluid J	III	OAT	Plate	24.8	5.3	-10	ZD	3
82	7-Apr-08	75%	Fluid J	III	20	Plate	40.3	4.6	-10	ZD	3
83	7-Apr-08	100%	Fluid J	III	OAT	Plate	12.3	25.7	-10	ZR	3
84	7-Apr-08	100%	Fluid J	III	20	Plate	13.0	25.8	-10	ZR	1
85	7-Apr-08	100%	Fluid J	III	60	Plate	8.7	25.5	-10	ZR	1
86	7-Apr-08	75%	Fluid J	III	OAT	Plate	8.5	25.7	-10	ZR	3
87	7-Apr-08	75%	Fluid J	III	20	Plate	11.7	25.2	-10	ZR	1
88	7-Apr-08	75%	Fluid J	III	OAT	Plate	8.0	25.6	-10	ZR	3

Table 3.3: Simulated Freezing Precipitation Tests Winter 2007-08 (cont'd)

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid App. Temp. (°C)	Test Surface	Fail Time (min.)	Precip. Rate (g/dm²/h)	Test Temp. (°C)	Precip. Type	Chart[1]
89	7-Apr-08	75%	Fluid J	III	20	Plate	12.7	26.1	-10	ZR	3
90	7-Apr-08	75%	Fluid J	III	60	Plate	9.5	24.9	-10	ZR	1
91	7-Apr-08	100%	Fluid J	III	OAT	Plate	12.0	25.8	-10	ZR	3
92	7-Apr-08	100%	Fluid J	III	20.0	Plate	15.5	25.9	-10	ZR	3
93	8-Apr-08	100%	Fluid J	III	OAT	Plate	20.7	12.5	-10	ZD	2
94	8-Apr-08	100%	Fluid J	III	20	Plate	23.7	13.4	-10	ZD	3
95	8-Apr-08	100%	Fluid J	III	OAT	Plate	20.2	12.7	-10	ZD	3
96	8-Apr-08	100%	Fluid J	III	20	Plate	23.2	12.5	-10	ZD	1
97	8-Apr-08	100%	Fluid J	III	60	Plate	18.2	12.5	-10	ZD	1
98	8-Apr-08	75%	Fluid J	III	OAT	Plate	13.3	13.0	-10	ZD	2
99	8-Apr-08	75%	Fluid J	III	20	Plate	26.8	12.6	-10	ZD	1
100	8-Apr-08	75%	Fluid J	III	OAT	Plate	12.0	12.9	-10	ZD	3
101	8-Apr-08	75%	Fluid J	III	60	Plate	14.2	13.3	-10	ZD	1
102	8-Apr-08	75%	Fluid J	III	20	Plate	24.8	13.1	-10	ZD	3
103	8-Apr-08	100%	Fluid J	III	OAT	Plate	19.8	13.0	-10	ZR	3
104	8-Apr-08	100%	Fluid J	III	20	Plate	23.7	13.1	-10	ZR	3
105	8-Apr-08	100%	Fluid J	III	OAT	Plate	20.8	13.1	-10	ZR	3
106	8-Apr-08	100%	Fluid J	III	20	Plate	24.5	13.0	-10	ZR	3
107	8-Apr-08	75%	Fluid J	III	OAT	Plate	14.7	13.0	-10	ZR	3
108	8-Apr-08	75%	Fluid J	III	20	Plate	23.0	12.5	-10	ZR	3
109	8-Apr-08	75%	Fluid J	III	OAT	Plate	14.0	13.1	-10	ZR	3
110	8-Apr-08	75%	Fluid J	III	20	Plate	23.6	13.1	-10	ZR	3
111	8-Apr-08	100%	Fluid J	III	OAT	Plate	24.0	13.5	-3	ZR	3
112	8-Apr-08	100%	Fluid J	III	20	Plate	29.2	12.6	-3	ZR	3
113	8-Apr-08	100%	Fluid J	III	OAT	Plate	23.0	12.9	-3	ZR	3
114	8-Apr-08	100%	Fluid J	III	20	Plate	28.7	12.5	-3	ZR	3
115	8-Apr-08	75%	Fluid J	III	OAT	Plate	22.0	13.1	-3	ZR	3
116	8-Apr-08	75%	Fluid J	III	20	Plate	26.6	12.6	-3	ZR	3
117	8-Apr-08	75%	Fluid J	III	OAT	Plate	17.3	12.9	-3	ZR	3
118	8-Apr-08	75%	Fluid J	III	20	Plate	26.6	12.5	-3	ZR	3
119	8-Apr-08	50%	Fluid J	III	OAT	Plate	10.0	12.5	-3	ZR	3
120	8-Apr-08	50%	Fluid J	III	20	Plate	13.8	13.0	-3	ZR	3
121	8-Apr-08	50%	Fluid J	III	OAT	Plate	9.0	12.5	-3	ZR	3
122	8-Apr-08	50%	Fluid J	III	20	Plate	14.6	13.2	-3	ZR	3
125	9-Apr-08	50%	Fluid J	III	OAT	Plate	5.5	25.0	-3	ZR	3
126	9-Apr-08	50%	Fluid J	III	20	Plate	12.8	25.0	-3	ZR	3
127	9-Apr-08	50%	Fluid J	III	OAT	Plate	5.7	25.2	-3	ZR	3
128	9-Apr-08	50%	Fluid J	III	20	Plate	13.5	25.1	-3	ZR	3
129	9-Apr-08	75%	Fluid J	III	OAT	Plate	8.8	25.1	-3	ZR	3
130	9-Apr-08	75%	Fluid J	III	20	Plate	18.2	25.0	-3	ZR	3
131	9-Apr-08	100%	Fluid J	III	OAT	Plate	13.5	25.1	-3	ZR	3
132	9-Apr-08	100%	Fluid J	III	20	Plate	16.7	25.1	-3	ZR	3
133	9-Apr-08	100%	Fluid J	III	OAT	Plate	13.7	25.4	-3	ZR	3
134	9-Apr-08	100%	Fluid J	III	20	Plate	16.4	25.4	-3	ZR	3

Table 3.3: Simulated Freezing Precipitation Tests Winter 2007-08 (cont'd)

Test No.	Date	Fluid Dilution	Fluid Name	Fluid Type	Fluid App. Temp. (°C)	Test Surface	Fail Time (min.)	Precip. Rate (g/dm²/h)	Test Temp. (°C)	Precip. Type	Chart[1]
135	9-Apr-08	75%	Fluid J	III	OAT	Plate	8.8	25.0	-3	ZR	3
136	9-Apr-08	75%	Fluid J	III	20	Plate	18.5	24.8	-3	ZR	3
137	9-Apr-08	75%	Fluid J	III	OAT	Box	20.5	5.4	1	ROCSW	3
138	9-Apr-08	75%	Fluid J	III	20	Box	53.0	4.7	1	ROCSW	3
139	9-Apr-08	100%	Fluid J	III	OAT	Box	43.8	4.8	1	ROCSW	3
140	9-Apr-08	100%	Fluid J	III	20	Box	52.3	5.5	1	ROCSW	3
141	9-Apr-08	100%	Fluid J	III	OAT	Box	34.0	5.2	1	ROCSW	3
142	9-Apr-08	100%	Fluid J	III	20	Box	56.4	5.3	1	ROCSW	3
143	9-Apr-08	75%	Fluid J	III	OAT	Box	27.2	5.4	1	ROCSW	3
144	9-Apr-08	75%	Fluid J	III	20	Box	44.5	5.2	1	ROCSW	3
145	9-Apr-08	100%	Fluid J	III	OAT	Box	5.9	76.3	1	ROCSW	3
146	9-Apr-08	100%	Fluid J	III	20	Box	7.1	73.1	1	ROCSW	3
147	9-Apr-08	100%	Fluid J	III	OAT	Box	5.5	74.7	1	ROCSW	3
148	9-Apr-08	100%	Fluid J	III	20	Box	7.5	74.6	1	ROCSW	3
149	9-Apr-08	75%	Fluid J	III	OAT	Box	3.8	74.7	1	ROCSW	3
150	9-Apr-08	75%	Fluid J	III	20	Box	5.6	75.2	1	ROCSW	3
151	9-Apr-08	75%	Fluid J	III	OAT	Box	3.9	73.3	1	ROCSW	3
152	9-Apr-08	75%	Fluid J	III	20	Box	5.3	73.6	1	ROCSW	3

[1]Chart Codes: 1. Chart Plotted
2. Chart Not Plotted, Data Available
3. Chart Not Plotted, Data Not Available

4. ANALYSIS AND OBSERVATIONS

In this section, the data collected during winter 2007-08 is analysed and discussed.

4.1 Fluid A (Type II) Examination

The problem conditions had been identified from earlier tests as:

- Freezing rain at high rate and cold temperature;
- Freezing drizzle at high rate and cold temperature; and
- Natural snow at low rate and mild temperature.

Further tests with Fluid A were conducted at these conditions to confirm these results. Further *freezing precipitation* tests conducted in July 2007 were reported in Volume 2. The results were very similar to those recorded from the original tests.

Further endurance tests in *natural snow* were conducted in winter 2007-08. The results are shown in Table 4.1, along with results of previous snow tests for Fluid A.

Table 4.1: Fluid A Snow Test Results

Global Test No.	Year of Test	Fluid Dilution (%)	Precip. Rate ($g/dm^2/h$)	Temp (°C)	Precip. Type	Heated Fail / OAT Fail
60	Previous data	100	7	-3	NS	71%
61	Previous data	75	16	-2	NS	87%
15, 16	2007-08	75	5	-7	NS	90%
3, 4	2007-08	75	16	0	NS	94%
27, 18	2007-08	75	38	-7	NS	94%
11, 12	2007-08	100	10	-9	NS	94%
25, 16	2007-08	100	34	-8	NS	97%
184, 187	2007-08	100	24	-12	NS	100%
33, 34	2007-08	100	8	-14	NS	112%
17, 18	2007-08	100	4	-7	NS	115%

For the winter 2007-08 tests, endurance times for heated fluid ranged from 90 percent to 115 percent of the unheated fluid times. This result indicates that there is not an important difference in performance between the heated and unheated fluid applications, in snow conditions.

In summary, heated applications of Fluid A demonstrated some reduction in endurance time in freezing drizzle and freezing rain at high rates and cold temperatures. Of a total of thirteen tests in freezing precipitation, eight heated fluid endurance times were lower than the cold fluid times by 10 percent or more, and four were lower than the cold fluid times by 20 percent or more. Tests in snow showed no important difference between heated and cold fluid applications. This fluid is being withdrawn from production.

4.2 Fluid B (Type III) Examination

Data collected from the indoor tests on Fluid B conducted at the 60ºC fluid temperature was set aside, based on the recommendation in the interim report that Type III indoor tests should be conducted with 20ºC fluid.

The only Fluid B laboratory test data collected with 20ºC fluid was generated from supplemental comparison tests examining 20ºC versus 60ºC fluid (Volume 2, Table 5.9: Log of Supplemental Type III Tests). This data is repeated here as Table 4.2. Further testing on this fluid was not conducted, as a full range of comparison tests was planned for the new proposed Type III fluid, referred to as Fluid J.

This very limited data for Fluid B indicates that heated applications of the current Type III fluid perform equal to or better than cold fluid applications, in freezing precipitation.

Additional tests in snow were conducted in winter 2007-08. Results of these tests along with those from previous tests in snow are shown in Table 4.3.

A number of tests, for both neat and 75/25 fluid strength, produced endurance times for heated fluid that were shorter than those for cold fluid. This tendency appeared to increase with colder temperatures.

Only two tests were conducted with 50/50 fluid strength, and these produced longer times for heated than for cold fluid.

Table 4.2: Fluid B Freezing Precipitation Test Results (20°C Fluid)

Fluid Application Procedure	Fluid Dilution (%)	Precipitation Type	Precip. Rate ($g/dm^2/h$)	Test Temp (°C)	Fail Time (min)	Heated Fail / OAT Fail
Apply fluid at OAT	100	ZD	13	-3	15.7	
Apply fluid at 20°C, use spreader	100	ZD	13	-3	13.6	86%
Apply fluid at OAT	75	ZD	13	-3	10.6	
Apply fluid at 20°C, use spreader	75	ZD	13	-3	11.2	106%
Apply fluid at OAT	50	ZD	13	-3	6.3	
Apply fluid at 20°C, use spreader	50	ZD	13	-3	12.3	193%
Apply fluid at OAT	100	ZD	13	-10	9.3	
Apply fluid at 20°C, use spreader	100	ZD	13	-10	9.4	101%
Apply fluid at OAT	75	ZD	13	-10	6.7	
Apply fluid at 20°C, use spreader	75	ZD	13	-10	6.8	101%
Apply fluid at OAT	100	ZR	25	-10	6.7	
Apply fluid at 20°C, use spreader	100	ZR	25	-10	7.2	108%
Apply fluid at OAT	75	ZR	25	-10	5.3	
Apply fluid at 20°C, use spreader	75	ZR	25	-10	6.4	120%
					Average of all tests	116%

Table 4.3: Type III Fluid – Total Test Results in Natural Snow

Yearly Test No.	Date	Fluid Dilution (%)	Precip. Rate (g/dm^2/h)	OAT Fail Time (min)	Heated Fail Time (min)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail	Average Fail Ratio by Dilution
3	18-Jan-08	50	4.9	26.2	30.7	-0.3	NS	117%	
1	18-Jan-08	50	3.2	27.0	29.2	-0.9	NS	108%	113%
35	13-Feb-08	75	12.9	11.3	8.3	-4.3	NS	74%	
14/15	10-Feb-05	75	9.7	17.8	18.8	-5.1	NS	106%	
13	1-Feb-08	75	22.8	10.5	10.2	-5.2	NS	97%	
31/33	21-Feb-05	75	13.6	16.0	12.0	-6.3	NS	75%	
11	1-Feb-08	75	7.9	9.8	11.8	-7.6	NS	119%	
5	22-Jan-08	75	10.4	12.3	10.4	-7.8	NS	85%	
7	22-Jan-08	75	27.6	4.7	5.3	-7.9	NS	113%	
57/59	7-Mar-05	75	9.8	17.6	15.9	-10.9	NS	90%	
7/9	6-Jan-05	75	37.2	7	5.5	-12.1	NS	79%	
48/50	7-Mar-05	75	4.9	23.2	20.7	-12.2	NS	89%	
5/6	6-Jan-05	75	31.3	8.0	5.0	-12.3	NS	63%	90%
13	1-Feb-08	100	34.0	12.8	13.4	-5.4	NS	105%	
11/12	10-Feb-05	100	5.7	36.0	36.8	-5.7	NS	102%	
9	22-Jan-08	100	2.7	49.3	46.0	-5.8	NS	93%	
34/36	21-Feb-05	100	13.7	21.3	15.2	-6.3	NS	71%	
36	13-Feb-08	100	12.5	13.0	12.0	-6.5	NS	92%	
10	1-Feb-08	100	7.9	22.7	24.1	-7.6	NS	106%	
4	22-Jan-08	100	4.7	33.3	25.8	-8.0	NS	78%	
31	13-Feb-08	100	25.9	7.7	4.7	-11.0	NS	61%	
54/56	7-Mar-05	100	11.1	26.9	24.5	-11.3	NS	91%	
2/3	6-Jan-05	100	28.0	10.0	7.0	-12.2	NS	70%	
45/47	7-Mar-05	100	7.7	31.1	30.0	-12.8	NS	96%	
14	13-Feb-08	100	4.9	9.8	7.6	-13.3	NS	78%	87%

[1] *Single numbers for tests in 2008 include two runs, fluid at OAT and heated.*

The results of Type III snow tests are summarized in Table 4.4.

Table 4.4: Summary of Type III Fluid Tests in Snow

Fluid Strength	# of Tests	Number and % of Tests where Heated ET / OAT ET < 80%		Number and % of Tests where Heated ET / OAT ET < 100%	
		#	%	#	%
50/50	2	0	0%	0	0%
75/25	11	4	36%	8	73%
100/0	12	5	42%	9	75%
ALL	25	9	36%	17	68%

4.3 Tests on Fluid J

A new low-viscosity non-Newtonian fluid (Fluid J) was tested for endurance times in winter 2007-08. This fluid was proposed as a potential Type III fluid candidate and underwent the full range of testing for HOT guideline construction. While undergoing testing in compliance with the Type II, III and IV test standard, the fluid was subjected to a parallel series of tests wherein the fluid was applied heated according to the Type I test protocol.

Although the fluid was subsequently withdrawn for reasons not related to endurance times, the data collected during this research provided additional information leading to a better understanding of the effect of heated fluid on endurance times, as well as an appreciation of the enhancement to holdover times that future Type III fluids may provide.

4.3.1 Fluid J – Heated versus Cold Fluid Application

The Fluid J data for both heated and cold fluid applications was treated to construct a holdover table (Table 4.5). This table illustrates the effect of heated fluid at all conditions.

Table 4.5: Potential Fluid J HOT Guidelines - Comparison of Heated versus Cold Application

Outside Air Temperature		**Approximate Holdover Times Under Various Weather Conditions (minutes)**									
					Snow or Snow Grains						
Deg. Celsius	**Deg. Fahrenheit**	**Type III Fluid J Concentration Neat Fluid/Water (Volume % / Volume %)**		**Freezing Fog**	**Very Light**	**Light**	**Moderate**	**Freezing Drizzle**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other**
-3 and above	27 and above	100/0	Fluid J Cold Fluid J Heat	53 – 108 61 – 141	92 94	44 43	21 20	26 – 51 29 – 57	14 – 21 17 – 28	6 – 39 7 – 58	
		75/25	Fluid J Cold Fluid J Heat	32 – 90 51 – 117	39 60	20 28	10 13	17 – 39 25 – 52	9 – 20 18 – 26	4 – 25 5 – 48	
		50/50	Fluid J Cold Fluid J Heat	14 – 27 16 – 37	23 32	11 15	5 7	7 – 16 14 – 21	6 – 11 13 – 14	CAUTION: No holdover time guidelines exist	
below -3 to -10	below 27 to 14	100/00	Fluid J Cold Fluid J Heat	35 – 77 37 – 67	70 65	34 30	16 14	20 – 39 23 –41	13 – 20 15 – 24		
		75/25	Fluid J Cold Fluid J Heat	28 – 48 35 – 61	37 62	19 29	10 13	13 – 26 26 – 41	8 – 14 13 – 23		
below -10	below 14	100/0	Fluid J Cold Fluid J Heat	23 – 43 28 – 45	54 46	26 21	12 10				

The table shows that the effect of heat on Fluid J endurance times is not constant for all conditions.

In snow:

- Heated fluid at 75/25 and 50/50 strength delivers significantly longer times than cold fluid; and
- Heated neat fluid delivers times that match cold fluid at mild OAT but are shorter at colder OAT.

In freezing precipitation:

- Heated fluid delivers longer times at both 50/50 and 75/25 strength; and
- Heated neat fluid delivers slightly longer times.

The observed effect of heated fluid for the current Type III fluid (Fluid B) differs from the heated fluid effect on Fluid J.

In snow:

- Heated Fluid B delivers shorter times than cold Fluid B at both 75/25 and neat strength; and
- The gap increases with colder OAT.

In freezing precipitation:

- Heated Fluid B gives longer times than cold fluid, for 50/50 mix and for some 75/25 conditions; and
- Heated neat fluid produces no change.

During this series of tests, a number of investigative tests were conducted with Fluid J applied at 60ºC. Table 4.6 reports the results, comparing endurance times for fluid applied at 60ºC, 20ºC and at ambient temperature. Results for similar tests previously conducted on Fluid B are included for comparison.

The effect of fluid applications at 60ºC was different for the two fluids:

- Overall, for Fluid B, fluid at 60ºC delivered longer endurance times than did fluid at 20ºC; and
- Overall, for Fluid J, fluid at 60ºC delivered shorter endurance times than did fluid at 20ºC.

Although the response to heated fluid was not always the same for the two fluids, this does not detract from the line of reasoning supporting testing with use of the Type I test protocol.

Table 4.6: Comparison of Endurance Times for 60°C, 20°C, and OAT – Indoor Tests

					Fluid B		Fluid J	
Precip. Rate (g/dm²/h)	Test Temp. (°C)	Precip. Type	Fluid Dilution	Type III Fluid Temp	Endurance time (min)	60°C Fail / OAT Fail 20°C Fail / OAT Fail OAT Fail	Endurance time (min)	60°C Fail / OAT Fail 20°C Fail / OAT Fail OAT Fail
13	-3	ZD	50%	60°C	15	238%	18.5	247%
				20°C	12.3	**195%**	13.7	**183%**
				OAT	6.3		7.5	
13	-3	ZD	75%	60°C	16	151%	23.5	138%
				20°C	11.2	**106%**	23.3	**137%**
				OAT	10.6		17	
13	-10	ZD	75%	60°C	9.4	140%	14.2	107%
				20°C	6.8	**101%**	26.8	**202%**
				OAT	6.7		13.3	
25	-10	ZR	75%	60°C	8.5	160%	9.5	112%
				20°C	6.4	**121%**	11.7	**138%**
				OAT	5.3		8.5	
13	-3	ZD	100%	60°C	14.3	91%		
				20°C	13.6	**87%**	25.7	**91%**
				OAT	15.7		28.2	
13	-10	ZD	100%	60°C	9.2	99%	18.2	88%
				20°C	9.4	**101%**	23.7	**114%**
				OAT	9.3		20.7	
25	-10	ZR	100%	60°C	9.1	136%	10.7	84%
				20°C	7.2	**107%**	13	**102%**
				OAT	6.7		12.7	

4.3.2 Potential Enhancements from Future Type III Fluids

Table 4.7 is similar to Table 4.5, but includes the generic Type III HOT times for comparison. The comparison of the two fluids provides an appreciation of the longer endurance times that a new Type III fluid might deliver.

Fluid J times, both for cold and heated fluid applications, are markedly longer than the current Type III times in all precipitation conditions and temperatures. The operational advantage potentially offered by improved future Type III fluids can be exploited only through the publication of fluid specific tables.

Table 4.7: Potential Fluid J HOT Guidelines Compared to Type III HOT

Outside Air Temperature		Approximate Holdover Times Under Various Weather Conditions (minutes)									
Deg. Celsius	Deg. Fahrenheit	Type III Fluid Concentration Neat Fluid/Water (Volume % / Volume %)		Freezing Fog	Snow or Snow Grains: Very Light	Snow or Snow Grains: Light	Snow or Snow Grains: Moderate	Freezing Drizzle	Light Freezing Rain	Rain on Cold Soaked Wing	Other
-3 and above	27 and above	100/0	Type III HOT	20 – 40	35	20	10	10 – 20	8 – 10	6 – 20	
			Fluid J Cold	53 – 108	92	44	21	26 – 51	14 – 21	6 – 39	
			Fluid J Heat	61 – 141	94	43	20	29 – 57	17 – 28	7 – 58	
		75/25	Type III HOT	15 – 30	25	15	8	8 – 15	6 – 10	2 – 10	
			Fluid J Cold	32 – 90	39	20	10	17 – 39	9 – 20	4 – 25	
			Fluid J Heat	51 – 117	60	28	13	25 – 52	18 – 26	5 – 48	
		50/50	Type III HOT	10 – 20	15	8	4	5 – 9	4 – 6	CAUTION: No holdover time guidelines exist	
			Fluid J Cold	14 – 27	23	11	5	7 – 16	6 – 11		
			Fluid J Heat	16 – 37	32	15	7	14 – 21	13 – 14		
below -3 to -10	below 27 to 14	100/00	Type III HOT	20 – 40	30	15	9	10 – 20	8 – 10		
			Fluid J Cold	35 – 77	70	34	16	20 – 39	13 – 20		
			Fluid J Heat	37 – 67	65	30	14	23 –41	15 – 24		
		75/25	Type III HOT	15 – 30	25	10	7	9 – 12	6 – 9		
			Fluid J Cold	28 – 48	37	19	10	13 – 26	8 – 14		
			Fluid J Heat	35 – 61	62	29	13	26 – 41	13 – 23		
below -10	below 14	100/0	Type III OT	20 – 40	30	15	8				
			Fluid J Cold	23 – 43	54	26	12				
			Fluid J Heat	28 – 45	46	21	10				

Note: The Type III HOT values have been reduced by 10 percent and rounded.

4.4 The Future of Type III Fluid Testing and HOT Publication

This examination of the effect on endurance times of heated Type III fluid applications raised some fundamental questions on the Type III Fluid's operational use, method of testing and HOT guideline publication.

These questions include:

1) Should Type III fluid be tested heated or cold, or both?
2) What laboratory test protocol should be used?
3) Should a separate HOT guideline be published for heated and cold times?
4) Should Type III fluids have brand-specific tables along with a generic table?

These questions were discussed with representatives from Transport Canada and FAA, and separately with a representative from the manufacturer of both the current commercially available fluid (Fluid B) and the low-viscosity non-Newtonian fluid tested as a potential new Type III Fluid (Fluid J).

Discussion points that were included are provided below.

- Heated Type III fluid application does produce endurance times that differ from cold fluid applications; some longer and some shorter.
- The tests have shown that the effect of heated fluid is not the same for all conditions, and that at like conditions, it can differ between fluid brands.
- Future Type III fluids may show differences in their response to heated application beyond those observed in this study. These differences can be learned only through testing.
- Type III fluid was originally developed as a replacement for Type I fluid. It was intended to provide an improvement in endurance times in conditions where the Type I Fluid proved to be too short to support the operation. Currently it is used principally at regional airports where it is a drop-in replacement for Type I fluid, using the same unmodified deicing vehicles. In this application, it is usually used heated, at full strength, as a one-step operation. It may also be used as a cold application where holdover times are required. An example of this would be the application of cold fluid on a hangared aircraft, prior to it being exposed to winter precipitation.
- A new Type III fluid is expected to be introduced as a replacement for the current fluid during the next two seasons.

An associated question is whether the current Type III fluid should now be retested for endurance times using the Type I fluid test protocol. Several considerations indicate that this is neither necessary, nor practical.

1) The manufacturer has indicated that the fluid is expected to be replaced in the next two seasons.
2) Testing for all weather conditions would have to be initiated now, for conduct during the approaching winter season. The earliest that changes to holdover times could be introduced would be winter 2009-10.
3) The current generic times have a considerable safety buffer, being based on a 10 percent reduction of measured endurance times, followed by rounding.

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5. CONCLUSIONS

The conclusions to the test program are presented in this section.

5.1 Validity of Test Procedures

The validity of the test procedures followed to study the effect of heated fluid on endurance times was examined and discussed throughout the report.

5.1.1 Outdoor Tests

Outdoor heated fluid testing for all fluid types was conducted throughout the test series according to the Type I fluid test protocol for outdoor tests; *0.5 L fluid at 60ºC applied on the 7.5 cm thermal equivalent leading-edge test box*.

5.1.1.1 Type II and IV Fluids

The results of tests described in Section 2 confirmed that the outdoor Type I Fluid test protocol is a valid method of evaluating endurance times of heated Type II and IV Fluids.

5.1.1.2 Type III Fluids

The only practical use of Type III fluid in conditions where holdover times are required involves the application of heated fluid. Cold Type III Fluid is used only in applications where a HOT is not applicable, such as pre-treating a wing surface to prevent adherence of expected freezing precipitation.

The Type I test protocol reflects the actual operational use of this fluid and has been shown to be representative of actual field applications of heated deicing fluid on wing leading edges.

The Type I test protocol is considered to be the best method of measuring outdoor endurance times for Type III fluids.

5.1.2 Laboratory Tests

The initial heated tests were not conducted according to the Type I Fluid test protocol (*1.0 L fluid at 20ºC applied on the standard HOT test plate*), instead fluid at 60ºC was applied.

5.1.2.1 Type II and IV Fluids

For Type II and IV fluids, the failures for *neat* and *75/25 strength* tests occurred after the test surface temperature had cooled to ambient, and thus were not influenced by this aspect of the warmer fluid application. The application of 60ºC fluid at the *50/50 strength* mix does risk exaggerated endurance times, in some test conditions. However, for those cases, the large spread in endurance times between the 60ºC applications and cold applications indicates that fluid at 20ºC would also have produced times longer than the cold application.

It is concluded that the indoor test procedure for Fluid Types II and IV at 60ºC, generated data that is valid for the purpose of this study.

5.1.2.2 Type III Fluid

Supplemental tests to compare endurance times produced by Type III fluid heated to 20ºC and to 60ºC showed that the warmer fluid extended the endurance times beyond that provided by the 20ºC fluid. This was not limited to 50/50 strength fluid but was observed for neat and 75/25 strength as well.

The conditions where extended times occurred were mainly when the standard test (fluid at ambient) endurance times were short:

- At -3ºC, endurance times of 11 minutes or less; and
- At -10ºC, endurance times of 7 minutes or less.

For Type III fluid tested at 60ºC, there is a risk of exaggerated endurance times that extends to 75/25 and neat concentrations as well as to 50/50 strength, at OAT -3ºC. The exaggerated times are the result of elevated test surface temperatures produced by the 60ºC fluid, which extend the time to failure.

Application of the Type I protocol for indoor tests would avoid this problem and would produce a temperature profile matching that of a typical wing leading edge in natural outdoor windy conditions.

5.2 The Effect of Heat on Fluid Endurance Times

5.2.1 Type II and IV Fluids

During this series of tests, a total of 94 test runs were conducted with nine different SAE Type II and IV Fluids. These all comprised duplicate runs, using heated and cold fluid, for a total of 188 individual tests. Half of these were conducted in natural snow and the remainder in laboratory artificial freezing precipitation conditions. With the exception of Fluid A, heated Type II and IV Fluid endurance times match or exceed those of fluid applied at OAT.

Heated Fluid A demonstrated some reduction in endurance time in freezing drizzle and freezing rain at high rates and cold temperatures. Tests in snow showed no important difference between heated and cold fluid applications. This fluid is being withdrawn from production.

It is concluded that the FAA guidance material related to heated applications of Type II and IV Fluid (Volume 2, Section 1.5) is valid and need not be changed.

5.2.2 Type III Fluid (Fluid B)

The effect of heated Type III fluid on endurance times is summarized in this section. The implications of the findings on the future of this fluid type are presented in Section 5.3.

5.2.2.1 Outdoor Tests in Snow

Twenty-five tests on the current Type III fluid were conducted with use of the Type I fluid test protocol, considered to be the appropriate procedure for these tests. Test results based on heated fluid showed a drop in endurance times, compared to the standard test using cold fluid, on which current HOT times are based.

Of the twenty-five tests conducted, nine (36 percent) produced endurance times that were less than 80 percent of those times generated by standard cold fluid tests. The tendency for heated fluid to produce shorter times increased with colder temperatures.

5.2.2.2 Indoor Tests in Freezing Precipitation

Initial data collected from the indoor tests on Fluid B conducted at the 60ºC fluid temperature was set aside, based on the recommendation that Type III indoor tests should be conducted with 20ºC fluid.

The only Fluid B laboratory test data collected with 20ºC fluid was generated from supplemental comparison tests examining 20ºC versus 60ºC fluid. Further testing on this fluid was not conducted, as a full range of comparison tests was planned for the new proposed Type III fluid, referred to as Fluid J.

This limited data on Fluid B shows a trend that heated applications of the current Type III fluid perform equal to or better than cold fluid applications, in freezing precipitation.

The manufacturer has indicated that the fluid is expected to be replaced over the next two seasons.

5.2.3 Potential Future Type III Fluid (Fluid J)

The effect of heated Fluid J on endurance times is summarized in this section. The implications of the findings are discussed in Section 6.

This fluid was proposed as a potential Type III fluid candidate and underwent the full range of testing for HOT guideline construction. While undergoing testing in compliance with the Type II, III and IV test standard, the fluid was subjected to a parallel series of tests wherein the fluid was applied heated. The Fluid J data for both heated and cold fluid applications was treated to construct a holdover table.

The table shows that the effect of heat on Fluid J endurance times is not constant for all conditions.

In snow:

- Heated fluid at 75/25 and 50/50 strength delivers significantly longer times than cold fluid; and
- Heated neat fluid delivers times that match cold fluid at mild OAT, but are shorter at colder OAT.

In freezing precipitation:

- Heated fluid delivers longer times at both 50/50 and 75/25 strength; and
- Heated neat fluid delivers slightly longer times.

5.2.4 Effect of Residual Heat from First-Step of Two-Step Deicing

Supplemental tests were conducted to examine whether the residual heat from the first-step of a two-step operation enhanced endurance times. Results showed that the two-step method had no influence, as it produced endurance times equivalent to the application of fluid at ambient air temperature.

5.3 The Future of Type III Fluid Testing and HOT Publication

This examination of the effect on endurance times of heated Type III Fluid applications raised some fundamental questions on Type III Fluid's operational use, method of testing and HOT guideline publication. These questions include:

- Should Type III fluid be tested heated or cold, or both?
- What laboratory test protocol should be used?
- Should a separate HOT guideline be published for heated and cold times?
- Fluid specific vs. generic tables?

It was concluded that:

- The test method for Type III Fluid in SAE ARP5485 should be changed to reflect that tests should be conducted separately for heated fluid applications and for OAT fluid applications.
- The fluid manufacturer should select whether the fluid is to be tested heated or at OAT, or both, depending on the intended method of fluid use in field operations.
- The heated fluid should be tested in accordance with the existing Type I test protocol.
- Holdover guidelines should be developed separately for the two test methods.
- Consideration should be given to reflect the new test methods in SAE ARP 5718.
- Review of the test method for Type III Fluid should consider whether it would be feasible and advantageous to test and develop HOTs based on buffered fluid rather than the current 100, 75 and 50 percent mixes.
- Holdover times for new Type III fluids should be published in fluid specific tables to:
    - o Remove limitation of one generic table for all Type III fluids;
    - o Enable field operations to take advantage of the longer times from new fluids; and
    - o Provide an incentive to fluid manufacturers to develop improved Type III fluids.
- The current Type III fluid should be grandfathered, removing the need to retest it in accordance with the new Type III test method.

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6. RECOMMENDATIONS

It is recommended that:

1. The guidance material on heated fluid applications provided in the FAA Approved Deicing Program Updates be left unchanged for Type II and Type IV fluids;
2. The test method for Type III Fluid in SAE ARP5485 be changed to reflect that tests will be conducted separately for heated fluid applications and for OAT fluid applications;
3. The fluid manufacturer should identify whether the fluid is to be tested heated or at OAT, or both, depending on the intended method of use in field operations;
4. The heated fluid be tested in accordance with the existing Type I test protocol;
5. Holdover guidelines be developed separately for the two test methods, heated and OAT;
6. Consideration be given to reflect the new test methods in SAE ARP 5718;
7. Test method for Type III Fluid be reviewed and consideration be given to test and develop HOTs based on buffered fluid rather than the current 100, 75 and 50 percent mixes;
8. Holdover times for new Type III fluids be published in fluid specific tables; and
9. The current Type III fluid be grandfathered, removing the need to retest it in accordance with the new Type III test methods.

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REFERENCES

1. Federal Aviation Administration N 8900.22, *FAA-Approved Deicing Program Updates, Winter 2007-2008,* October 2007.

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2007-08

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2007-08

7.2 FLUID PERFORMANCE RESEARCH

7.2.6 Effect of Heat on Neat/Diluted Type II/III/IV Endurance Times

a) Conduct further tests on Fluid A in natural snow conditions if an opportunity arises in conjunction with another test program;

b) Analyze data and results, compare to previous results;

c) Conduct further tests on Type III fluid in natural snow conditions;

d) Analyze data and results;

e) Examine temperature profiles from previous laboratory tests and compare to profile established for Type I fluid laboratory tests;

f) Based on results from (d) and (e), decide whether it is necessary to test further in a laboratory;

g) Design a test protocol for heated Type III fluid endurance tests in a laboratory setting. This protocol must take into account the effect that heating to 60°C exerts on the fluid's capacity to protect, as well as establishing a test surface temperature profile that corresponds to documented profiles for wing leading edges;

h) Conduct tests in simulated precipitation conditions;

i) Analyze data and results;

j) Prepare a report; and

k) Prepare presentation material.

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APPENDIX B

PROCEDURE:
OVERALL PROGRAM OF TESTS AT NRC, MARCH-APRIL 2008

CM2103.001 (07-08)

OVERALL PROGRAM OF TESTS AT NRC, MARCH-APRIL 2008

Winter 2007-08

Prepared for

Transportation Development Centre
Transport Canada

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Reviewed by: John D'Avirro

March 28, 2008
Final Version 1.0

OVERALL PROGRAM OF TESTS AT NRC, MARCH-APRIL 2008

Winter 2007-08

1. INTRODUCTION

This document was prepared to bring together several projects that require testing at the National Research Council Climactic Engineering Facility (NRC) in Ottawa. Tests will be carried out from March 31 to April 9, 2008.

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

A tentative test schedule is included in Figure 1.

2. PROJECTS, PROCEDURES AND OBJECTIVES

The objectives and procedures for each project are detailed in this section. Each project has been given a shortened name (shown in brackets following full title) which is used throughout this document.

The test procedures for some projects are given in separate documents; these documents are listed in Section 9.

2.1 Endurance Times of New Fluids (Endurance Times)

The objective of this project is to measure endurance times of new fluids in simulated freezing precipitation. The procedure for conducting these tests is given in the document *Test Requirements for Simulated Freezing Precipitation Flat Plate Testing* (1).

Four fluids will be tested:

- Kilfrost P2143-3500 (Type II);
- Kilfrost P2143-5000 (Type II);
- Clariant Flight (Type II) – 75% and 50% dilutions only; and
- Clariant MP III (Type III).

Due to time and financial limitations, the Type III fluid will not be tested in freezing fog at -10°C. Instead, it will be tested at freezing fog at -3 and -14°C and interpolation will be used to ascertain the fluid endurance times in freezing fog at -10°C. All other standard Type III 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.

It should be noted that the lowest operational use temperature (LOUT) of Clariant MP III for low rotation speed aircraft is above -25°C; however, Type III fluids are also certified for use with high rotation speed aircraft, and the LOUT for high rotation speed aircraft is close to -25°C. Therefore, this fluid will be tested in the -25°C conditions.

The test plan for endurance time tests is given in Table 1.

2.2 Endurance Times of Heated Type III Fluid (Heated Type III)

The objective of these tests is to measure endurance times of a Type III fluid (Clariant MP III) when applied using the standard Type I test protocol. The standard endurance time testing procedure and methodology (see Section 2.1) will be followed. The test protocol for Type I fluids differs from the protocol for Type II/III/IV fluids in that fluids are applied heated to 20°C rather than at ambient air temperature. Supplementary tests have been included to examine fluid applied at 60°C as well. During these tests, brix measurements will be taken on 60°C test plate and also on the equivalent 20°C test plate and ambient air temperature test plate.

Tests will be conducted at the standard endurance time testing temperatures, dilutions, precipitation types and precipitation rates. The tests have been included in the endurance time test plan given in Table 1 and are numbered H1 to H78.

2.3 Endurance Times of Type II/IV Fluid at LOUT vs. -25°C (LOUT vs. -25°C)

The objective of these tests is to determine if there is a significant difference in the endurance times of a Type II/IV fluid at -25°C versus at the fluid's lowest operational use temperature (LOUT). The standard endurance time testing procedure and methodology (see Section 2.1) will be followed. To minimize costs, tests will be conducted with only three fluids; if results show large differences, there will be a need to conduct further work. The test plan for these tests is given in Table 2.

2.4 Thickness of New Fluids (Thickness)

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 Table 3.

2.5 Adhesion in Mixed Snow and Rain Conditions (Mixed Snow/Rain)

Transport Canada and the FAA currently do not provide guidelines for operations in mixed snow and rain conditions. However, some aircraft operators have implemented protocols for dealing with such conditions. The purpose of these tests is to identify whether additional work is required in mixed conditions or it the current guidelines can be expanded to include mixed rain and snow conditions.

The objective of this project is to investigate if endurance time testing conducted with neat Type II and Type IV fluids during mixed precipitation conditions (snow/rain) will demonstrate signs of fluid adhesion to aluminum test surfaces. The procedure for conducting these tests is given in the document *Experimental Program: Adhesion of Aircraft De/Anti-Icing Fluids on Aluminum Surfaces During Mixed Precipitation Conditions Snow and Rain* (3) and the test plan for these tests is given in Table 4.

2.6 Ice Pellet Allowance Time Expansion (IP Expansion)

Ice pellet allowance times were issued for neat Type IV fluids within the Transport Canada HOT Guidelines and the Federal Aviation Administration Approved Deicing Program updates for the winter of 2007-08. Allowance times for operations during mixed conditions with ice pellets have been generated based on the results obtained in the Wind Tunnel and with the Falcon 20 aircraft during the winters of 2005-06, 2006-07, and 2007-08. Restrictions for the allowance times were issued based on residual contamination observed on the airfoil, lift characteristics, and limitations of the data collected regarding rotation speeds, test temperatures and fluid types and dilution, and other pertinent parameters. The objective of this project is to conduct a series of preliminary flat plate tests with Type II and Type III fluids to provide support for the ongoing expansion of the current ice pellet guidelines.

The procedure for conducting these tests is given in the document *Experimental Program Adhesion of Aircraft De/Anti-Icing Fluids on Aluminum Surfaces During*

Mixed Precipitation Conditions Snow and Rain (3). The test plan for these tests is given in Table 5.

2.7 Improvement to Snow and Ice Pellet Dispensing Systems (Dispensing System Improvement)

The objective of this project is to conduct work with the ice pellet dispensing system in an attempt to generate a more uniform distribution over the wing surface and improved repeatability for dispensing simulated ice pellets and snow for allowance time testing. This work is being completed in anticipation of further testing in the wind tunnel in the winter of 2008-09.

The procedure for the conduct of these tests is *Procedure: Improvement to Dispensing Systems for Simulated Snow and Ice Pellet Conditions* (4). There is no specific test plan for this work; however, the days on which the work is planned to be conducted are indicated in the test schedule (Figure 1).

3. PERSONNEL REQUIREMENTS/RESPONSIBILITIES

The personnel requirements for each project are as follows:

1. Endurance Times: HOT Team
2. Heated Type III: HOT Team, YOW 1
3. LOUT vs. -25°C: HOT Team
4. Thickness: HOT Team
5. Mixed Snow/Rain: MR, JT, YOW1, Rates Team
6. Ice Pellet Expansion: MR, JT, YOW1
7. Dispensing System Improvement: MR, YOW1

The HOT Team is as follows:

- HOT Manager: JD
- Rate Manager: SB
- Rate Assistant: JT
- Cold-soak Prep: MR, JT, YOW1

In addition, personnel will be designated responsible for:

- Equipment: JT
- Pre-test Setup: JT

- Data Forms: SB
- HOT Data Management: SB

This information is also shown in Table 6.

4. FLUIDS

The required fluids and fluid quantities are shown in Table 7.

5. EQUIPMENT

Table 8 shows the equipment requirements for the following projects:

- Endurance Times
- Heated Type III
- LOUT vs. -25°C
- Thickness

Table 9 shows the equipment requirements for the remaining projects:

- Mixed Snow/Rain
- Ice Pellet Expansion
- Dispensing System Improvement

6. DATA FORMS

1. Endurance Times: The freezing precipitation endurance time data form is required for these tests (Figure 2). The cold-soak wing endurance time data form (Figure 3), is also required.
2. Heated Type III: The freezing precipitation endurance time data form (Figure 2) and the brix and thickness data form () are required for these tests.
3. LOUT vs. -25°C: The freezing precipitation endurance time data form is required for these tests (Figure 2).
4. Thickness: The fluid thickness data form is required (Figure 4).
5. Mixed Snow/Rain: The freezing precipitation endurance time data form (Figure 2), the brix and thickness data form (), the adherence of fluid failure data form (Figure 6) and the position of ice pellet dispenser system data form (Figure 7) are required.

6. Ice Pellet Expansion: The freezing precipitation endurance time data form (Figure 2), the brix and thickness data form (), the adherence of fluid failure data form (Figure 6) and the position of ice pellet dispenser system data form (Figure 7) are required.
7. Dispensing System Improvement: no data forms are required.

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. Rubber mats must be properly placed in and around the test area and cleaned as necessary.
4. Care should be taken when circulating near the test stand due to slipperiness.
5. First aid kit, water and fire extinguisher are available.
6. All NRC safety guidelines must be followed.

8. PRE–TEST SET–UP ACTIVITIES

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

1. Mark plates and boxes.
2. Ensure plates and boxes are equipped with operational and verified thermistors.
3. 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).
4. Determine number of loggers required (loggers are on stands already).
5. Install software on rate PC and on backup laptop.
6. Prepare PC for logging plate temperatures.
7. Ensure fluids are prepared in advance (see Table 7).
8. Prepare labels for pour containers (KB).

9. Empty 1 litre containers must be labelled and cleaned for pouring.
10. Label new rate pans: 4 sets for each #1-12, check for holes, check properly labelled.
11. Rent cube van.
12. Make more 75/25 and 50/50 Clariant MP III fluid based on quantities provided in Table 7.

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

1. Paper towels.
2. White gloves (10 packs of 10).
3. New shelving unit.
4. Scrapers.
5. Floor mats (additional 10) for safety.
6. Large Sharpie markers (2).
7. Printer cartridges (2)

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. Experimental Program: Adhesion of Aircraft De/Anti-Icing Fluids on Aluminum Surfaces During Mixed Precipitation Conditions Snow and Rain, Version 1.0, March 31, 2008.
4. Procedure: Improvement to Dispensing Systems for Simulated Snow and Ice Pellet Conditions, Final Version 1.0, January 30, 2008.

OVERALL PROGRAM OF TESTS AT NRC, MARCH-APRIL 2008

FIGURE 1: TEST SCHEDULE

<table>
<tr><th></th><th>Fri Mar 28</th><th>Mon Mar 31</th><th>Tues Apr 1*</th><th>Wed Apr 2*</th><th>Thurs Apr 3</th><th>Fri Apr 4</th><th>Mon Apr 7</th><th>Tue Apr 8*</th><th>Wed Apr 9</th></tr>
<tr><td>8:00</td><td></td><td rowspan="6">**ZF, -25, 2**</td><td rowspan="10">**ZF, -14, 5**</td><td rowspan="12">**ZF, -3, 2**
TH1-TH28</td><td rowspan="6">**ZR, -10, 25**</td><td rowspan="10">**ZR, -3, 25**
RS4 to RS6</td><td rowspan="8">**ZD, -10, 5**</td><td rowspan="9">**ZD, -3, 5**</td><td rowspan="5">**CSW, 1, 5**</td></tr>
<tr><td>8:30</td><td></td></tr>
<tr><td>9:00</td><td rowspan="16">**Setup**</td></tr>
<tr><td>9:30</td></tr>
<tr><td>10:00</td></tr>
<tr><td>10:30</td><td rowspan="4">**CSW, 1, 75**</td></tr>
<tr><td>11:00</td><td rowspan="9">**ZF, -25, 5**
LOUT4 to
LOUT6</td><td rowspan="5">**ZR, -10, 25**
IP3, IP4,
IP3-1, IP4-1</td></tr>
<tr><td>11:30</td></tr>
<tr><td>12:00</td><td rowspan="7">**ZD, -10, 13**</td></tr>
<tr><td>12:30</td><td rowspan="8">**ZD, -3, 13**</td><td rowspan="4">**Pack up**</td></tr>
<tr><td>13:00</td><td rowspan="8">**ZF, -14, 2**</td><td rowspan="8">**ZR, -3, 13**</td></tr>
<tr><td>13:30</td><td>Warm to -5°C</td></tr>
<tr><td>14:00</td><td rowspan="10">**ZF, -3, 5**</td><td rowspan="5">**ZR, -5, 25 + IP**
IP1, IP2,
IP1-1, IP2-1</td></tr>
<tr><td>14:30</td><td></td></tr>
<tr><td>15:00</td><td></td></tr>
<tr><td>15:30</td><td>Cool to -28.5°C</td><td rowspan="6">**ZR, -10, 13**</td><td></td></tr>
<tr><td>16:00</td><td rowspan="4">**ZF, -28.5, 5**
LOUT1 to
LOUT3</td><td></td></tr>
<tr><td>16:30</td><td></td><td></td><td></td></tr>
<tr><td>17:00</td><td></td><td></td><td></td><td rowspan="4">**ZR, -3, 13 + SN**
RS1 to RS3</td><td></td><td></td></tr>
<tr><td>17:30</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>18:00</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>18:30</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

*IP Calibration will take place all day April 1 and April 2

C:\Documents and Settings\Stephanie Bendickson\My Documents\Work\APS\CM2103.001 (07-08)\HOT\NRC Procedure\NRC Procedure - Final Version 1.0.doc
Final Version 1.0, March 08

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OVERALL PROGRAM OF TESTS AT NRC, MARCH-APRIL 2008

TABLE 1: ENDURANCE TIME TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution	Test Surface	Comments
1	Freezing Fog	-25	5	Clariant MP III	100	Plate	
2	Freezing Fog	-25	5	Clariant MP III	100	Plate	
3	Freezing Fog	-25	5	Kilfrost P2143-3500	100	Plate	Doubles as LOUT 6
4	Freezing Fog	-25	5	Kilfrost P2143-3500	100	Plate	Doubles as LOUT 6A
5	Freezing Fog	-25	5	Kilfrost P2143-5000	100	Plate	
6	Freezing Fog	-25	5	Kilfrost P2143-5000	100	Plate	
7	Freezing Fog	-25	2	Clariant MP III	100	Plate	
8	Freezing Fog	-25	2	Clariant MP III	100	Plate	
9	Freezing Fog	-25	2	Kilfrost P2143-3500	100	Plate	
10	Freezing Fog	-25	2	Kilfrost P2143-3500	100	Plate	
11	Freezing Fog	-25	2	Kilfrost P2143-5000	100	Plate	
12	Freezing Fog	-25	2	Kilfrost P2143-5000	100	Plate	
13	Freezing Fog	-14	5	Clariant MP III	100	Plate	
14	Freezing Fog	-14	5	Clariant MP III	100	Plate	
15	Freezing Fog	-14	5	Kilfrost P2143-3500	100	Plate	
16	Freezing Fog	-14	5	Kilfrost P2143-3500	100	Plate	
17	Freezing Fog	-14	5	Kilfrost P2143-5000	100	Plate	
18	Freezing Fog	-14	5	Kilfrost P2143-5000	100	Plate	
19	Freezing Fog	-14	5	Clariant Flight	75	Plate	
20	Freezing Fog	-14	5	Clariant Flight	75	Plate	
21	Freezing Fog	-14	5	Clariant MP III	75	Plate	
22	Freezing Fog	-14	5	Clariant MP III	75	Plate	
23	Freezing Fog	-14	5	Kilfrost P2143-3500	75	Plate	
24	Freezing Fog	-14	5	Kilfrost P2143-3500	75	Plate	
25	Freezing Fog	-14	5	Kilfrost P2143-5000	75	Plate	
26	Freezing Fog	-14	5	Kilfrost P2143-5000	75	Plate	
27	Freezing Fog	-14	2	Clariant MP III	100	Plate	
28	Freezing Fog	-14	2	Clariant MP III	100	Plate	
29	Freezing Fog	-14	2	Kilfrost P2143-3500	100	Plate	
30	Freezing Fog	-14	2	Kilfrost P2143-3500	100	Plate	
31	Freezing Fog	-14	2	Kilfrost P2143-5000	100	Plate	
32	Freezing Fog	-14	2	Kilfrost P2143-5000	100	Plate	
33	Freezing Fog	-14	2	Clariant Flight	75	Plate	
34	Freezing Fog	-14	2	Clariant Flight	75	Plate	
35	Freezing Fog	-14	2	Clariant MP III	75	Plate	
36	Freezing Fog	-14	2	Clariant MP III	75	Plate	
37	Freezing Fog	-14	2	Kilfrost P2143-3500	75	Plate	
38	Freezing Fog	-14	2	Kilfrost P2143-3500	75	Plate	
39	Freezing Fog	-14	2	Kilfrost P2143-5000	75	Plate	
40	Freezing Fog	-14	2	Kilfrost P2143-5000	75	Plate	
41	Freezing Fog	-3	5	Clariant MP III	100	Plate	
42	Freezing Fog	-3	5	Clariant MP III	100	Plate	
43	Freezing Fog	-3	5	Kilfrost P2143-3500	100	Plate	
44	Freezing Fog	-3	5	Kilfrost P2143-3500	100	Plate	
45	Freezing Fog	-3	5	Kilfrost P2143-5000	100	Plate	
46	Freezing Fog	-3	5	Kilfrost P2143-5000	100	Plate	
47	Freezing Fog	-3	5	Clariant Flight	75	Plate	
48	Freezing Fog	-3	5	Clariant Flight	75	Plate	
49	Freezing Fog	-3	5	Clariant MP III	75	Plate	
50	Freezing Fog	-3	5	Clariant MP III	75	Plate	
51	Freezing Fog	-3	5	Kilfrost P2143-3500	75	Plate	
52	Freezing Fog	-3	5	Kilfrost P2143-3500	75	Plate	
53	Freezing Fog	-3	5	Clariant Flight	50	Plate	
54	Freezing Fog	-3	5	Clariant Flight	50	Plate	

OVERALL PROGRAM OF TESTS AT NRC, MARCH-APRIL 2008

TABLE 1: ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution	Test Surface	Comments
55	Freezing Fog	-3	5	Clariant MP III	50	Plate	
56	Freezing Fog	-3	5	Clariant MP III	50	Plate	
57	Freezing Fog	-3	5	Kilfrost P2143-3500	50	Plate	
58	Freezing Fog	-3	5	Kilfrost P2143-3500	50	Plate	
59	Freezing Fog	-3	5	Kilfrost P2143-5000	75	Plate	
60	Freezing Fog	-3	5	Kilfrost P2143-5000	75	Plate	
61	Freezing Fog	-3	5	Kilfrost P2143-5000	50	Plate	
62	Freezing Fog	-3	5	Kilfrost P2143-5000	50	Plate	
63	Freezing Fog	-3	2	Clariant MP III	100	Plate	
64	Freezing Fog	-3	2	Clariant MP III	100	Plate	
65	Freezing Fog	-3	2	Kilfrost P2143-3500	100	Plate	
66	Freezing Fog	-3	2	Kilfrost P2143-3500	100	Plate	
67	Freezing Fog	-3	2	Kilfrost P2143-5000	100	Plate	
68	Freezing Fog	-3	2	Kilfrost P2143-5000	100	Plate	
69	Freezing Fog	-3	2	Clariant Flight	75	Plate	
70	Freezing Fog	-3	2	Clariant Flight	75	Plate	
71	Freezing Fog	-3	2	Clariant MP III	75	Plate	
72	Freezing Fog	-3	2	Clariant MP III	75	Plate	
73	Freezing Fog	-3	2	Kilfrost P2143-3500	75	Plate	
74	Freezing Fog	-3	2	Kilfrost P2143-3500	75	Plate	
75	Freezing Fog	-3	2	Clariant Flight	50	Plate	
76	Freezing Fog	-3	2	Clariant Flight	50	Plate	
77	Freezing Fog	-3	2	Clariant MP III	50	Plate	
78	Freezing Fog	-3	2	Clariant MP III	50	Plate	
79	Freezing Fog	-3	2	Kilfrost P2143-3500	50	Plate	
80	Freezing Fog	-3	2	Kilfrost P2143-3500	50	Plate	
81	Freezing Fog	-3	2	Kilfrost P2143-5000	75	Plate	
82	Freezing Fog	-3	2	Kilfrost P2143-5000	75	Plate	
83	Freezing Fog	-3	2	Kilfrost P2143-5000	50	Plate	
84	Freezing Fog	-3	2	Kilfrost P2143-5000	50	Plate	
85	Freezing Drizzle	-10	13	Clariant MP III	100	Plate	Measure brix
86	Freezing Drizzle	-10	13	Clariant MP III	100	Plate	
87	Freezing Drizzle	-10	13	Kilfrost P2143-3500	100	Plate	
88	Freezing Drizzle	-10	13	Kilfrost P2143-3500	100	Plate	
89	Freezing Drizzle	-10	13	Kilfrost P2143-5000	100	Plate	
90	Freezing Drizzle	-10	13	Kilfrost P2143-5000	100	Plate	
91	Freezing Drizzle	-10	13	Clariant Flight	75	Plate	
92	Freezing Drizzle	-10	13	Clariant Flight	75	Plate	
93	Freezing Drizzle	-10	13	Clariant MP III	75	Plate	Measure brix
94	Freezing Drizzle	-10	13	Clariant MP III	75	Plate	
95	Freezing Drizzle	-10	13	Kilfrost P2143-3500	75	Plate	
96	Freezing Drizzle	-10	13	Kilfrost P2143-3500	75	Plate	
97	Freezing Drizzle	-10	13	Kilfrost P2143-5000	75	Plate	
98	Freezing Drizzle	-10	13	Kilfrost P2143-5000	75	Plate	
99	Freezing Drizzle	-10	5	Clariant MP III	100	Plate	
100	Freezing Drizzle	-10	5	Clariant MP III	100	Plate	
101	Freezing Drizzle	-10	5	Kilfrost P2143-3500	100	Plate	
102	Freezing Drizzle	-10	5	Kilfrost P2143-3500	100	Plate	
103	Freezing Drizzle	-10	5	Kilfrost P2143-5000	100	Plate	
104	Freezing Drizzle	-10	5	Kilfrost P2143-5000	100	Plate	
105	Freezing Drizzle	-10	5	Clariant Flight	75	Plate	
106	Freezing Drizzle	-10	5	Clariant Flight	75	Plate	
107	Freezing Drizzle	-10	5	Clariant MP III	75	Plate	
108	Freezing Drizzle	-10	5	Clariant MP III	75	Plate	

OVERALL PROGRAM OF TESTS AT NRC, MARCH-APRIL 2008

TABLE 1: ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution	Test Surface	Comments
109	Freezing Drizzle	-10	5	Kilfrost P2143-3500	75	Plate	
110	Freezing Drizzle	-10	5	Kilfrost P2143-3500	75	Plate	
111	Freezing Drizzle	-10	5	Kilfrost P2143-5000	75	Plate	
112	Freezing Drizzle	-10	5	Kilfrost P2143-5000	75	Plate	
113	Freezing Drizzle	-3	13	Clariant MP III	100	Plate	
114	Freezing Drizzle	-3	13	Clariant MP III	100	Plate	
115	Freezing Drizzle	-3	13	Kilfrost P2143-3500	100	Plate	
116	Freezing Drizzle	-3	13	Kilfrost P2143-3500	100	Plate	
117	Freezing Drizzle	-3	13	Kilfrost P2143-5000	100	Plate	
118	Freezing Drizzle	-3	13	Kilfrost P2143-5000	100	Plate	
119	Freezing Drizzle	-3	13	Clariant Flight	75	Plate	
120	Freezing Drizzle	-3	13	Clariant Flight	75	Plate	
121	Freezing Drizzle	-3	13	Clariant MP III	75	Plate	Measure brix
122	Freezing Drizzle	-3	13	Clariant MP III	75	Plate	
123	Freezing Drizzle	-3	13	Kilfrost P2143-3500	75	Plate	
124	Freezing Drizzle	-3	13	Kilfrost P2143-3500	75	Plate	
125	Freezing Drizzle	-3	13	Clariant Flight	50	Plate	
126	Freezing Drizzle	-3	13	Clariant Flight	50	Plate	
127	Freezing Drizzle	-3	13	Clariant MP III	50	Plate	
128	Freezing Drizzle	-3	13	Clariant MP III	50	Plate	Measure brix
129	Freezing Drizzle	-3	13	Kilfrost P2143-3500	50	Plate	
130	Freezing Drizzle	-3	13	Kilfrost P2143-3500	50	Plate	
131	Freezing Drizzle	-3	13	Kilfrost P2143-5000	75	Plate	
132	Freezing Drizzle	-3	13	Kilfrost P2143-5000	75	Plate	
133	Freezing Drizzle	-3	13	Kilfrost P2143-5000	50	Plate	
134	Freezing Drizzle	-3	13	Kilfrost P2143-5000	50	Plate	
135	Freezing Drizzle	-3	5	Clariant MP III	100	Plate	
136	Freezing Drizzle	-3	5	Clariant MP III	100	Plate	
137	Freezing Drizzle	-3	5	Kilfrost P2143-3500	100	Plate	
138	Freezing Drizzle	-3	5	Kilfrost P2143-3500	100	Plate	
139	Freezing Drizzle	-3	5	Kilfrost P2143-5000	100	Plate	
140	Freezing Drizzle	-3	5	Kilfrost P2143-5000	100	Plate	
141	Freezing Drizzle	-3	5	Clariant Flight	75	Plate	
142	Freezing Drizzle	-3	5	Clariant Flight	75	Plate	
143	Freezing Drizzle	-3	5	Clariant MP III	75	Plate	
144	Freezing Drizzle	-3	5	Clariant MP III	75	Plate	
145	Freezing Drizzle	-3	5	Kilfrost P2143-3500	75	Plate	
146	Freezing Drizzle	-3	5	Kilfrost P2143-3500	75	Plate	
147	Freezing Drizzle	-3	5	Clariant Flight	50	Plate	
148	Freezing Drizzle	-3	5	Clariant Flight	50	Plate	
149	Freezing Drizzle	-3	5	Clariant MP III	50	Plate	
150	Freezing Drizzle	-3	5	Clariant MP III	50	Plate	
151	Freezing Drizzle	-3	5	Kilfrost P2143-3500	50	Plate	
152	Freezing Drizzle	-3	5	Kilfrost P2143-3500	50	Plate	
153	Freezing Drizzle	-3	5	Kilfrost P2143-5000	75	Plate	
154	Freezing Drizzle	-3	5	Kilfrost P2143-5000	75	Plate	
155	Freezing Drizzle	-3	5	Kilfrost P2143-5000	50	Plate	
156	Freezing Drizzle	-3	5	Kilfrost P2143-5000	50	Plate	
157	Light Freezing Rain	-10	25	Clariant MP III	100	Plate	Measure brix
158	Light Freezing Rain	-10	25	Clariant MP III	100	Plate	
159	Light Freezing Rain	-10	25	Kilfrost P2143-3500	100	Plate	
160	Light Freezing Rain	-10	25	Kilfrost P2143-3500	100	Plate	
161	Light Freezing Rain	-10	25	Kilfrost P2143-5000	100	Plate	
162	Light Freezing Rain	-10	25	Kilfrost P2143-5000	100	Plate	

TABLE 1: ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution	Test Surface	Comments
163	Light Freezing Rain	-10	25	Clariant Flight	75	Plate	
164	Light Freezing Rain	-10	25	Clariant Flight	75	Plate	
165	Light Freezing Rain	-10	25	Clariant MP III	75	Plate	Measure brix
166	Light Freezing Rain	-10	25	Clariant MP III	75	Plate	
167	Light Freezing Rain	-10	25	Kilfrost P2143-3500	75	Plate	
168	Light Freezing Rain	-10	25	Kilfrost P2143-3500	75	Plate	
169	Light Freezing Rain	-10	25	Kilfrost P2143-5000	75	Plate	
170	Light Freezing Rain	-10	25	Kilfrost P2143-5000	75	Plate	
171	Light Freezing Rain	-10	13	Clariant MP III	100	Plate	
172	Light Freezing Rain	-10	13	Clariant MP III	100	Plate	
173	Light Freezing Rain	-10	13	Kilfrost P2143-3500	100	Plate	
174	Light Freezing Rain	-10	13	Kilfrost P2143-3500	100	Plate	
175	Light Freezing Rain	-10	13	Kilfrost P2143-5000	100	Plate	
176	Light Freezing Rain	-10	13	Kilfrost P2143-5000	100	Plate	
177	Light Freezing Rain	-10	13	Clariant Flight	75	Plate	
178	Light Freezing Rain	-10	13	Clariant Flight	75	Plate	
179	Light Freezing Rain	-10	13	Clariant MP III	75	Plate	
180	Light Freezing Rain	-10	13	Clariant MP III	75	Plate	
181	Light Freezing Rain	-10	13	Kilfrost P2143-3500	75	Plate	
182	Light Freezing Rain	-10	13	Kilfrost P2143-3500	75	Plate	
183	Light Freezing Rain	-10	13	Kilfrost P2143-5000	75	Plate	
184	Light Freezing Rain	-10	13	Kilfrost P2143-5000	75	Plate	
185	Light Freezing Rain	-3	25	Clariant MP III	100	Plate	
186	Light Freezing Rain	-3	25	Clariant MP III	100	Plate	
187	Light Freezing Rain	-3	25	Kilfrost P2143-3500	100	Plate	
188	Light Freezing Rain	-3	25	Kilfrost P2143-3500	100	Plate	
189	Light Freezing Rain	-3	25	Kilfrost P2143-5000	100	Plate	
190	Light Freezing Rain	-3	25	Kilfrost P2143-5000	100	Plate	
191	Light Freezing Rain	-3	25	Clariant Flight	75	Plate	
192	Light Freezing Rain	-3	25	Clariant Flight	75	Plate	
193	Light Freezing Rain	-3	25	Clariant MP III	75	Plate	
194	Light Freezing Rain	-3	25	Clariant MP III	75	Plate	
195	Light Freezing Rain	-3	25	Kilfrost P2143-3500	75	Plate	
196	Light Freezing Rain	-3	25	Kilfrost P2143-3500	75	Plate	
197	Light Freezing Rain	-3	25	Clariant Flight	50	Plate	
198	Light Freezing Rain	-3	25	Clariant Flight	50	Plate	
199	Light Freezing Rain	-3	25	Clariant MP III	50	Plate	
200	Light Freezing Rain	-3	25	Clariant MP III	50	Plate	
201	Light Freezing Rain	-3	25	Kilfrost P2143-3500	50	Plate	
202	Light Freezing Rain	-3	25	Kilfrost P2143-3500	50	Plate	
203	Light Freezing Rain	-3	25	Kilfrost P2143-5000	75	Plate	
204	Light Freezing Rain	-3	25	Kilfrost P2143-5000	75	Plate	
205	Light Freezing Rain	-3	25	Kilfrost P2143-5000	50	Plate	
206	Light Freezing Rain	-3	25	Kilfrost P2143-5000	50	Plate	
207	Light Freezing Rain	-3	13	Clariant MP III	100	Plate	
208	Light Freezing Rain	-3	13	Clariant MP III	100	Plate	
209	Light Freezing Rain	-3	13	Kilfrost P2143-3500	100	Plate	
210	Light Freezing Rain	-3	13	Kilfrost P2143-3500	100	Plate	
211	Light Freezing Rain	-3	13	Kilfrost P2143-5000	100	Plate	
212	Light Freezing Rain	-3	13	Kilfrost P2143-5000	100	Plate	
213	Light Freezing Rain	-3	13	Clariant Flight	75	Plate	
214	Light Freezing Rain	-3	13	Clariant Flight	75	Plate	
215	Light Freezing Rain	-3	13	Clariant MP III	75	Plate	
216	Light Freezing Rain	-3	13	Clariant MP III	75	Plate	

TABLE 1: ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution	Test Surface	Comments
217	Light Freezing Rain	-3	13	Kilfrost P2143-3500	75	Plate	
218	Light Freezing Rain	-3	13	Kilfrost P2143-3500	75	Plate	
219	Light Freezing Rain	-3	13	Clariant Flight	50	Plate	
220	Light Freezing Rain	-3	13	Clariant Flight	50	Plate	
221	Light Freezing Rain	-3	13	Clariant MP III	50	Plate	
222	Light Freezing Rain	-3	13	Clariant MP III	50	Plate	
223	Light Freezing Rain	-3	13	Kilfrost P2143-3500	50	Plate	
224	Light Freezing Rain	-3	13	Kilfrost P2143-3500	50	Plate	
225	Light Freezing Rain	-3	13	Kilfrost P2143-5000	75	Plate	
226	Light Freezing Rain	-3	13	Kilfrost P2143-5000	75	Plate	
227	Light Freezing Rain	-3	13	Kilfrost P2143-5000	50	Plate	
228	Light Freezing Rain	-3	13	Kilfrost P2143-5000	50	Plate	
229	Cold Soak Box	1	75	Clariant MP III	100	Box	
230	Cold Soak Box	1	75	Clariant MP III	100	Box	
231	Cold Soak Box	1	75	Kilfrost P2143-3500	100	Box	
232	Cold Soak Box	1	75	Kilfrost P2143-3500	100	Box	
233	Cold Soak Box	1	75	Kilfrost P2143-5000	100	Box	
234	Cold Soak Box	1	75	Kilfrost P2143-5000	100	Box	
235	Cold Soak Box	1	75	Clariant Flight	75	Box	
236	Cold Soak Box	1	75	Clariant Flight	75	Box	
237	Cold Soak Box	1	75	Clariant MP III	75	Box	
238	Cold Soak Box	1	75	Clariant MP III	75	Box	
239	Cold Soak Box	1	75	Kilfrost P2143-3500	75	Box	
240	Cold Soak Box	1	75	Kilfrost P2143-3500	75	Box	
241	Cold Soak Box	1	75	Kilfrost P2143-5000	75	Box	
242	Cold Soak Box	1	75	Kilfrost P2143-5000	75	Box	
243	Cold Soak Box	1	5	Clariant MP III	100	Box	
244	Cold Soak Box	1	5	Clariant MP III	100	Box	
245	Cold Soak Box	1	5	Kilfrost P2143-3500	100	Box	
246	Cold Soak Box	1	5	Kilfrost P2143-3500	100	Box	
247	Cold Soak Box	1	5	Kilfrost P2143-5000	100	Box	
248	Cold Soak Box	1	5	Kilfrost P2143-5000	100	Box	
249	Cold Soak Box	1	5	Clariant MP III	75	Box	
250	Cold Soak Box	1	5	Clariant MP III	75	Box	
251	Cold Soak Box	1	5	Kilfrost P2143-3500	75	Box	
252	Cold Soak Box	1	5	Kilfrost P2143-3500	75	Box	
253	Cold Soak Box	1	5	Clariant Flight	75	Box	
254	Cold Soak Box	1	5	Clariant Flight	75	Box	
255	Cold Soak Box	1	5	Kilfrost P2143-5000	75	Box	
256	Cold Soak Box	1	5	Kilfrost P2143-5000	75	Box	
H1	Freezing Fog	-25	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H2	Freezing Fog	-25	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H3	Freezing Fog	-25	2	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H4	Freezing Fog	-25	2	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H5	Freezing Fog	-14	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H6	Freezing Fog	-14	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H7	Freezing Fog	-14	5	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H8	Freezing Fog	-14	5	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H9	Freezing Fog	-14	2	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H10	Freezing Fog	-14	2	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H11	Freezing Fog	-14	2	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H12	Freezing Fog	-14	2	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H13	Freezing Fog	-3	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H14	Freezing Fog	-3	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C

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TABLE 1: ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution	Test Surface	Comments
H15	Freezing Fog	-3	5	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H16	Freezing Fog	-3	5	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H17	Freezing Fog	-3	5	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H18	Freezing Fog	-3	5	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H19	Freezing Fog	-3	2	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H20	Freezing Fog	-3	2	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H21	Freezing Fog	-3	2	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H22	Freezing Fog	-3	2	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H23	Freezing Fog	-3	2	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H24	Freezing Fog	-3	2	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H25	Freezing Drizzle	-10	13	Clariant MP III	100	Plate	Apply 1 L @ 20°C, measure brix
H26	Freezing Drizzle	-10	13	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H27	Freezing Drizzle	-10	13	Clariant MP III	100	Plate	Apply 1 L @ 60°C, measure brix
H28	Freezing Drizzle	-10	13	Clariant MP III	75	Plate	Apply 1 L @ 20°C, measure brix
H29	Freezing Drizzle	-10	13	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H30	Freezing Drizzle	-10	13	Clariant MP III	75	Plate	Apply 1 L @ 60°C, measure brix
H31	Freezing Drizzle	-10	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H32	Freezing Drizzle	-10	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H33	Freezing Drizzle	-10	5	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H34	Freezing Drizzle	-10	5	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H35	Freezing Drizzle	-3	13	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H36	Freezing Drizzle	-3	13	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H37	Freezing Drizzle	-3	13	Clariant MP III	75	Plate	Apply 1 L @ 20°C, measure brix
H38	Freezing Drizzle	-3	13	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H39	Freezing Drizzle	-3	13	Clariant MP III	75	Plate	Apply 1 L @ 60°C, measure brix
H40	Freezing Drizzle	-3	13	Clariant MP III	50	Plate	Apply 1 L @ 20°C, measure brix
H41	Freezing Drizzle	-3	13	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H42	Freezing Drizzle	-3	13	Clariant MP III	50	Plate	Apply 1 L @ 60°C, measure brix
H43	Freezing Drizzle	-3	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H44	Freezing Drizzle	-3	5	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H45	Freezing Drizzle	-3	5	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H46	Freezing Drizzle	-3	5	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H47	Freezing Drizzle	-3	5	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H48	Freezing Drizzle	-3	5	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H49	Light Freezing Rain	-10	25	Clariant MP III	100	Plate	Apply 1 L @ 20°C, measure brix
H50	Light Freezing Rain	-10	25	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H51	Light Freezing Rain	-10	25	Clariant MP III	100	Plate	Apply 1 L @ 60°C, measure brix
H52	Light Freezing Rain	-10	25	Clariant MP III	75	Plate	Apply 1 L @ 20°C, measure brix
H53	Light Freezing Rain	-10	25	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H54	Light Freezing Rain	-10	25	Clariant MP III	75	Plate	Apply 1 L @ 60°C, measure brix
H55	Light Freezing Rain	-10	13	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H56	Light Freezing Rain	-10	13	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H57	Light Freezing Rain	-10	13	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H58	Light Freezing Rain	-10	13	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H59	Light Freezing Rain	-3	25	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H60	Light Freezing Rain	-3	25	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H61	Light Freezing Rain	-3	25	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H62	Light Freezing Rain	-3	25	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H63	Light Freezing Rain	-3	25	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H64	Light Freezing Rain	-3	25	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H65	Light Freezing Rain	-3	13	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H66	Light Freezing Rain	-3	13	Clariant MP III	100	Plate	Apply 1 L @ 20°C
H67	Light Freezing Rain	-3	13	Clariant MP III	75	Plate	Apply 1 L @ 20°C
H68	Light Freezing Rain	-3	13	Clariant MP III	75	Plate	Apply 1 L @ 20°C

TABLE 1: ENDURANCE TIME TEST PLAN (cont'd)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Dilution	Test Surface	Comments
H69	Light Freezing Rain	-3	13	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H70	Light Freezing Rain	-3	13	Clariant MP III	50	Plate	Apply 1 L @ 20°C
H71	Cold Soak Box	1	75	Clariant MP III	100	Box	Apply 1 L @ 20°C
H72	Cold Soak Box	1	75	Clariant MP III	100	Box	Apply 1 L @ 20°C
H73	Cold Soak Box	1	75	Clariant MP III	75	Box	Apply 1 L @ 20°C
H74	Cold Soak Box	1	75	Clariant MP III	75	Box	Apply 1 L @ 20°C
H75	Cold Soak Box	1	5	Clariant MP III	100	Box	Apply 1 L @ 20°C
H76	Cold Soak Box	1	5	Clariant MP III	100	Box	Apply 1 L @ 20°C
H77	Cold Soak Box	1	5	Clariant MP III	75	Box	Apply 1 L @ 20°C
H78	Cold Soak Box	1	5	Clariant MP III	75	Box	Apply 1 L @ 20°C

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TABLE 2: TEST PLAN – ENDURANCE TIMES OF TYPE II/IV FLUID AT -25°C VS. LOUT

Test #*	Priority	Fluid Type	Fluid	Dilution	Fluid Temp. [°C]	Test Temp. [°C]	Precip Type	Freezing Fog Precip Rate [g/dm²/h]	-25 / ZF 2 ET [min.]	-25 / ZF 5 ET [min.]	NRC Condition	Timing With HOT Tests	Approx. Testing Time	Objective
LOUT1	2	IV	DOW EG 106	Neat	-28.5	-28.5	ZF	5**	66	32	-28.5 / ZF 5	Invasive (following HOT)	2hrs	LOUT ET Test
LOUT2	1	IV	Kilfrost ABC-S+	Neat	-28.5	-28.5	ZF	5**	60	38	-28.5 / ZF 5	Invasive (following HOT)		LOUT ET Test
LOUT3	1	II	Kilfrost 2143-3500	Neat	-28.5	-28.5	ZF	5**	SEE 2008 DATA	SEE 2008 DATA	-28.5 / ZF 5	Invasive (following HOT)		LOUT ET Test
LOUT4	2	IV	DOW EG 106	Neat	-25	-25	ZF	5**	66	32	-25 / ZF 5	in Conjunction	2hrs	LOUT Baseline Test
LOUT5	1	IV	Kilfrost ABC-S+	Neat	-25	-25	ZF	5**	60	38	-25 / ZF 5	in Conjunction		LOUT Baseline Test
LOUT6***	1	II	Kilfrost 2143-3500	Neat	-25	-25	ZF	5**	SEE 2008 DATA	SEE 2008 DATA	-25 / ZF 5	in Conjunction		LOUT Baseline Test

* Duplicates of each test will be conducted simultaneously. Duplcate tests will be labled "Test #" A. i.e. LOUT1-A
** Can be substituted for a rate of 2 g/dm²/h, however complete set must be done at same rate.
*** Duplicate of ET5 and ET6. Use ET5/ET6 for results.

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TABLE 3: TEST PLAN – FLUID THICKNESS

Test #	Fluid Manufacturer	Fluid Name	Fluid Dilution	Ambient Air Temperature
TH1	Clariant	Flight	75/25	-3°C
TH2	Clariant	Flight	75/25	-3°C
TH3	Clariant	Flight	50/50	-3°C
TH4	Clariant	Flight	50/50	-3°C
TH5	Kilfrost	P2143-5000	100/0	-3°C
TH6	Kilfrost	P2143-5000	100/0	-3°C
TH7	Kilfrost	P2143-5000	75/25	-3°C
TH8	Kilfrost	P2143-5000	75/25	-3°C
TH9	Kilfrost	P2143-5000	50/50	-3°C
TH10	Kilfrost	P2143-5000	50/50	-3°C
TH11	Kilfrost	P2143-3500	100/0	-3°C
TH12	Kilfrost	P2143-3500	100/0	-3°C
TH13	Kilfrost	P2143-3500	75/25	-3°C
TH14	Kilfrost	P2143-3500	75/25	-3°C
TH15	Kilfrost	P2143-3500	50/50	-3°C
TH16	Kilfrost	P2143-3500	50/50	-3°C
TH17	Clariant	MP III (OAT)	100/0	-3°C
TH18	Clariant	MP III (OAT)	100/0	-3°C
TH19	Clariant	MP III (OAT)	75/25	-3°C
TH20	Clariant	MP III (OAT)	75/25	-3°C
TH21	Clariant	MP III (OAT)	50/50	-3°C
TH22	Clariant	MP III (OAT)	50/50	-3°C
TH23	Clariant	MP III (20°C)	100/0	-3°C
TH24	Clariant	MP III (20°C)	100/0	-3°C
TH25	Clariant	MP III (20°C)	75/25	-3°C
TH26	Clariant	MP III (20°C)	75/25	-3°C
TH27	Clariant	MP III (20°C)	50/50	-3°C
TH28	Clariant	MP III (20°C)	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

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TABLE 4: TEST PLAN – ADHERENCE IN MIXED SNOW AND RAIN CONDITIONS

Test #	Priority	Fluid Type	Fluid Brand	Dilution	Fluid Temp. [°C]	Precip Type	Test Temp. [°C]	Water Temp. [°C]	Water Temp Increase	Snow Precip Rate [g/dm²/h]	Freezing Rain Precip Rate [g/dm²/h]	Combined Precip Rate [g/dm²/h]	NRC Condition	Timing With HOT Tests
RS1	1	IV	EG 106	Neat	-3	SN/R	-3	+3	TBD**	12	13	25	R 13, -3	Invasive (following HOT)
RS2	2	IV	ABC-S +	Neat	-3	SN/R	-3	+3	TBD**	12	13	25	R 13, -3	Invasive (following HOT)
RS3	3	II	Kilfrost 2143-3500	Neat	-3	SN/R	-3	+3	TBD**	12	13	25	R 13, -3	Invasive (following HOT)
RS4	1	IV	EG 106	Neat	-3	ZR	-3	-	-	-	25	25	ZR 25, -3	in Conjunction
RS5	2	IV	ABC-S +	Neat	-3	ZR	-3	-	-	-	25	25	ZR 25, -3	in Conjunction
RS6	3	II	Kilfrost 2143-3500	Neat	-3	ZR	-3	-	-	-	25	25	ZR 25, -3	in Conjunction

* Duplicates of each test will be conducted simultaneously. Duplcate tests will be labled "Test #" A. i.e. RS1-A
** Water temperature must be raised incrementally until rain is no longer freezing on cold soaked surfaces.

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TABLE 5: TEST PLAN – ICE PELLET ALLOWANCE TIME EXPANSION

Test #*	Fluid Type	Fluid Brand	Dil.	Fluid Temp. [°C]	Test Temp. [°C]	Precip Type	Ice Pellet Diameter [mm]	Freezing Rain Precip Rate [g/dm²/h]	Ice Pellet Precip Rate [g/dm²/h]	Combined Precip Rate [g/dm²/h]	ZR Generic HOT	Allowance Time Target [min.]	NRC Condition	Timing With HOT Tests	Approx. Testing Time	Comments
IP1	II	Kilfrost 2143-3500	Neat	-5	-5	ZR / IP	1-3.75	25	25	50	-	25	-5 / ZR 25	Invasive (following HOT)	2 hrs	All tests can be run simultaneoulsy.
IP2	III	Clariant MP III	Neat	-5	-5	ZR / IP	1-3.75	25	25	50	-	25	-5 / ZR 25	Invasive (following HOT)		
IP1-1	II	Kilfrost 2143-3500	Neat	-5	-5	ZR	-	25	-	25	15	-	-5 / ZR 25	Invasive (following HOT)		
IP2-1	III	Clariant MP III	Neat	-5	-5	ZR	-	25	-	25	8	-	-5 / ZR 25	Invasive (following HOT)		
IP3	II	Kilfrost 2143-3500	Neat	-10	-10	ZR / IP	1-3.75	25	25	50	-	10	-10 / ZR 25	Invasive (following HOT)	1.5 hrs	All tests can be run simultaneoulsy. If necessary, data from IP3-1 and IP4-1 can be used for the HOT data.
IP4	III	Clariant MP III	Neat	-10	-10	ZR / IP	1-3.75	25	25	50	-	10	-10 / ZR 25	Invasive (following HOT)		
IP3-1	II	Kilfrost 2143-3500	Neat	-10	-10	ZR	-	25	-	25	10	-	-10 / ZR 25	Invasive (following HOT)		
IP4-1	III	Clariant MP III	Neat	-10	-10	ZR	-	25	-	25	8	-	-10 / ZR 25	Invasive (following HOT)		

* Duplicates of each test will be conducted simultaneously. Duplcate tests will be labeled "Test #" A. i.e. IP1-A

TABLE 6: PERSONNEL REQUIREMENTS

	Endurance Times	Heated Type III	LOUT vs. -25°C	Thickness	Mixed Rain/Snow	IP Expansion	Dispensing System Improvement
JD	Mgr	Mgr	Mgr	-	-	-	-
SB	Rate Mgr	Rate Mgr	Rate Mgr	Mgr	-	-	-
JT	Rate Ast	Rate Ast	Rate Ast	-	Ast	Ast	-
MR	-	-	-	-	Mgr	Mgr	Mgr
YOW1	Gen Ast	Gen Ast	Gen Ast	-	Ast	Ast	Ast

TABLE 7: LIST OF FLUIDS

Fluid Name	Fluid Type	Dilution	Litres Required						
			Endurance Times	Heated Type III	LOUT vs. -25°C	Thickness	Mixed Rain/Snow	IP Expansion	Total
Kilfrost P2143-5000	II	100	32	-	-	2	-	-	**34**
Kilfrost P2143-5000	II	75	28	-	-	2	-	-	**30**
Kilfrost P2143-5000	II	50	12	-	-	2	-	-	**14**
Kilfrost P2143-3500	II	100	32	-	4	2	4	8	**50**
Kilfrost P2143-3500	II	75	28	-	-	2	-	-	**30**
Kilfrost P2143-3500	II	50	12	-	-	2	-	-	**14**
Clariant Flight	II	75	28	-	-	2	-	-	**30**
Clariant Flight	II	50	12	-	-	2	-	-	**14**
Clariant MP III	III	100	32	34	-	2	-	8	**76**
Clariant MP III	III	75	28	31	-	2	-	-	**61**
Clariant MP III	III	50	12	13	-	2	-	-	**27**
Dow EG 106 (2006001417-12)	IV	100	-	-	4	-	4	-	**8**
Kilfrost ABC-S+ (0131071797A)	IV	100	-	-	4	-	4	-	**8**
			256	**78**	**12**	**22**	**12**	**16**	**396**

TABLE 8: EQUIPMENT LIST #1

EQUIPMENT	LOCATION	STATUS
2 x 2-plate stand & 2 x 1-plate stand	Site	
1L Pour containers (4 filled/4 empty per fluid/d	Site	
Boards for cold-soak test x 10	Site	
Brixometer x 3	Site	
Clipboards x 6	Site	
Close circuit TV camera for rates	Site	
Cold-Soaked Boxes 7.5 cm x10	Site	
Cotton gloves	Site	
Electrical Extension Cords - Many	Site	
Fluids	Site	
Funnels	Site	
Marker for Waste x3	Site	
Hand-held Temperture Probes (Wahl) x3	Site	
Heating equipment and thermoses x2	Site	
Inclinometer (yellow level) x2	Site	
Isopropyl x4	Site	
Large digital clock x 2	Site	
Metal Rate Pans (for outdoor tests)	Site	
Paper for printer (1 pack)	Site	
Paper Towels (lots)	Site	
Pencils + pens + markers	Site	
Plate covers x 12	Site	
Plates x12 (w/logging capability)	Site	
Precipitation Rate Pans x 100	Site	
Printer	Site	
Protective clothing (6)	Site	
Pump (for waste)	Site	
Rubber Mats	Site	
Rubber squeegees x 4	Site	

EQUIPMENT	LOCATION	STATUS
Scrapers x2	Site	
Shop Vac	Site	
Steel Collection Pans	Site	
Still Digital Camera Rebel (suitcase)	Site	
Storage bins for small equipment	Site	
Surface and immersable temperature probes	Site	
Tape measure	Site	
Test Stands (2 x 6-plate stands)	Site	
Thermistor Kit + Logger	Site	
Thickness Gauges x 3 (both types)	Site	
Walkie Talkies x 4	Site	
Waste containers x MANY (10-15)	Site	
Weigh Scale x 2 (sartorius) + wiring	Site	
White Billboard for water run-off	Site	
Yellow Carrying Cases for Pour Containers x	Site	
Accordian Folder	Office	
ARP 5485 and ARP 5945	Office	
Chamber Layout Diagram	SB	
Data Forms (SB to handle)	Office	
Envelopes (9x12)	Office	
HOT Report + HOT Tables	Office	
NRC Flow Settings (SB)	SB	
Laptop Computers x 3	Office/Site	
Precipitation Rate Data Forms (SB)	Office	
Test Procedures x 2 (1 sided)	Office	
Trend Reader Express Software	Office	
Fluid for cold-soak boxes (barrel)	NRC	
Shelving unit x 1 (to purchase)	NRC	

TABLE 9: EQUIPMENT LIST #2

Test Equipment	
Test Procedure, data forms	
Large clock	
Ice pellets dispensing devices x 6 / stands and adapter	
Desktop/Laptop computer with printer with paper	
Temperature Probe x 2 and spare batteries / immersion and surface probes	
Thickness Gauges (large and small)	
Brixometers x 3	
Adherence Probes	
Weigh scale (NCAR and HOT)	
Large Umbrella x2	
Ice Pellets Fabrication Equipment	
Styrofoam containers x 20	
Ice bags + Freezer (Lake Ontario Ice)	
Blenders (x 6)	
Ice pellets sieves (round and square)	
Folding tables	
Scrapers	
Measuring cups	
Rubber mats	

OVERALL PROGRAM OF TESTS AT NRC, MARCH-APRIL 2008

FIGURE 2: 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: ____________________

C:\Documents and Settings\Stephanie Bendickson\My Documents\Work\APS\CM2103.001 (07-08)\HOT\NRC Procedure\NRC Procedure - Final Version 1.0.doc
Final Version 1.0, March 08

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FIGURE 3: 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: ____________________

FIGURE 4: FLUID BRIX / THICKNESS DATA FORM

DATE: ______________ **PERFORMED BY:** __________________

RUN #: ______________ **WRITTEN BY:** __________________

STAND: ______________ **LOCATION:** __________________

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

FIGURE 5: THICKNESS DATA FORM

DATE: ______________ **TEMPERATURE °C (beg.):** ______________ **PERFORMED BY:** ______________

TEST #: _______ to _______ **WIND SPEED, kph (beg.):** ______________ **WRITTEN BY:** ______________

STAND: ______________ **LOCATION:** CEF (NRC)

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

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

FIGURE 6: ADHERENCE OF FLUID FAILURE DATA FORM

Date: ____________ Time: ______________ Plate Location: _________

Run #: ____________ Fluid Name: ______________ Fluid Dilution: _________

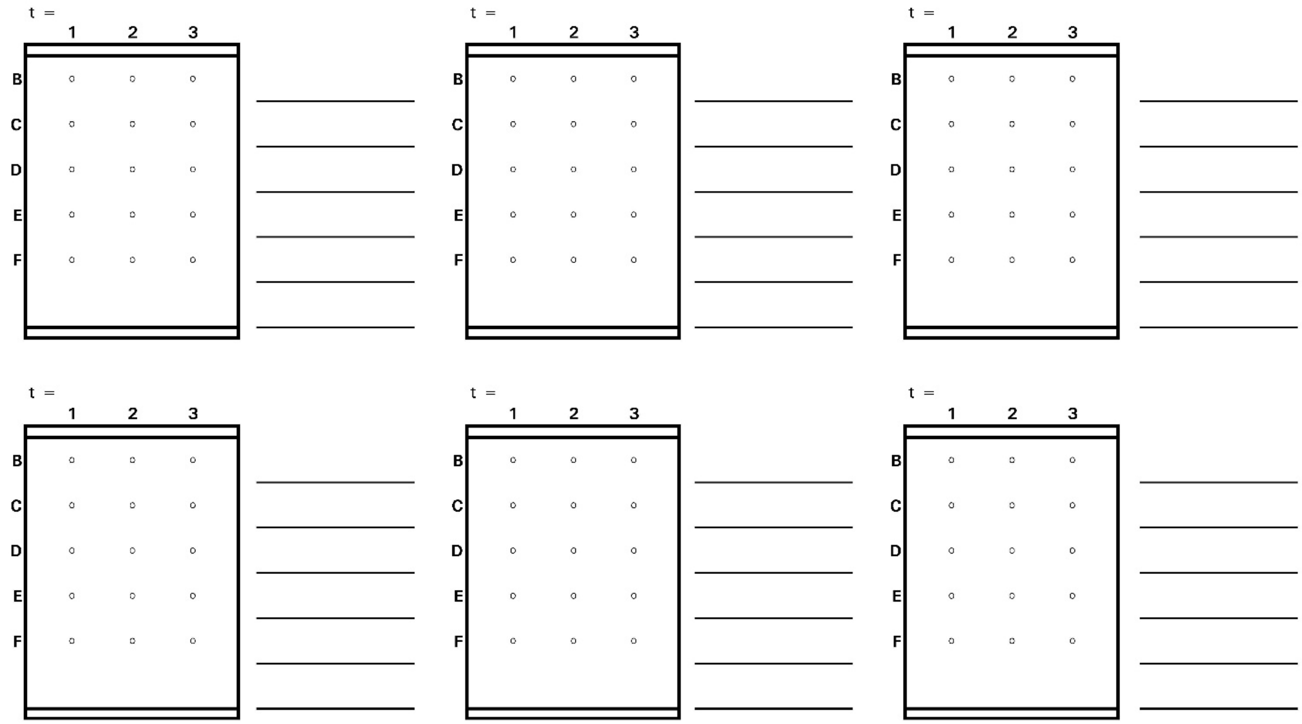


FIGURE 7: POSITION OF ICE PELLET DISPENSER SYSTEM DATA FORM

DATE:______________________ CONDITION:______________________ TIME:______________________

TYPE OF PRECIPITATION ON PLATE (circle precip. type)

Pos. 1	Pos. 2	Pos. 3	Pos. 4	Pos. 5	Pos. 6
ZR IP ZR/ IP	ZR IP ZR/ IP	ZR IP ZR/ IP	ZR IP ZR/ IP	ZR IP ZR/ IP	ZR IP ZR/ IP

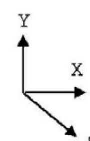
Pos. 7	Pos. 8	Pos. 9	Pos.10	Pos.11	Pos.12
ZR IP ZR/ IP	ZR IP ZR/ IP	ZR IP ZR/ IP	ZR IP ZR/ IP	ZR IP ZR/ IP	ZR IP ZR/ IP

OPERATIONAL TIME LOG OF ICE PELLET DISPENSER

IP DISPENSER ON	IP DISPENSER OFF	IP DISPENSER ON	IP DISPENSER OFF

MARK POSITION OF DISPENSER RELATIVE TO PLATES WITH AN "X" IN SPACE

POSITION[1] OF ICE PELLET DISPENSER



X____________
Y____________
Z____________

(1) Origin is bottom left corner of stand

APPENDIX C

DETAILED TEMPERATURE PROFILE CHARTS

DETAILED TEMPERATURE PROFILE CHARTS

This appendix contains detailed plots of the data collected during the comparison tests described in this report. This includes the surface temperature profile, brix and fluid thickness data measured throughout the test. The test date, test number, test surface, fluid name, fluid dilution, precipitation type, precipitation rate, ambient temperature and failure time are also indicated on each chart.

The charts are presented in the following order:

- 2007-08 Charts.
  - 2007-08 freezing precipitation tests.

Charts have not been created for all tests conducted. The last column in the test logs (see Section 4) indicates whether or not a chart has been created for a given test.

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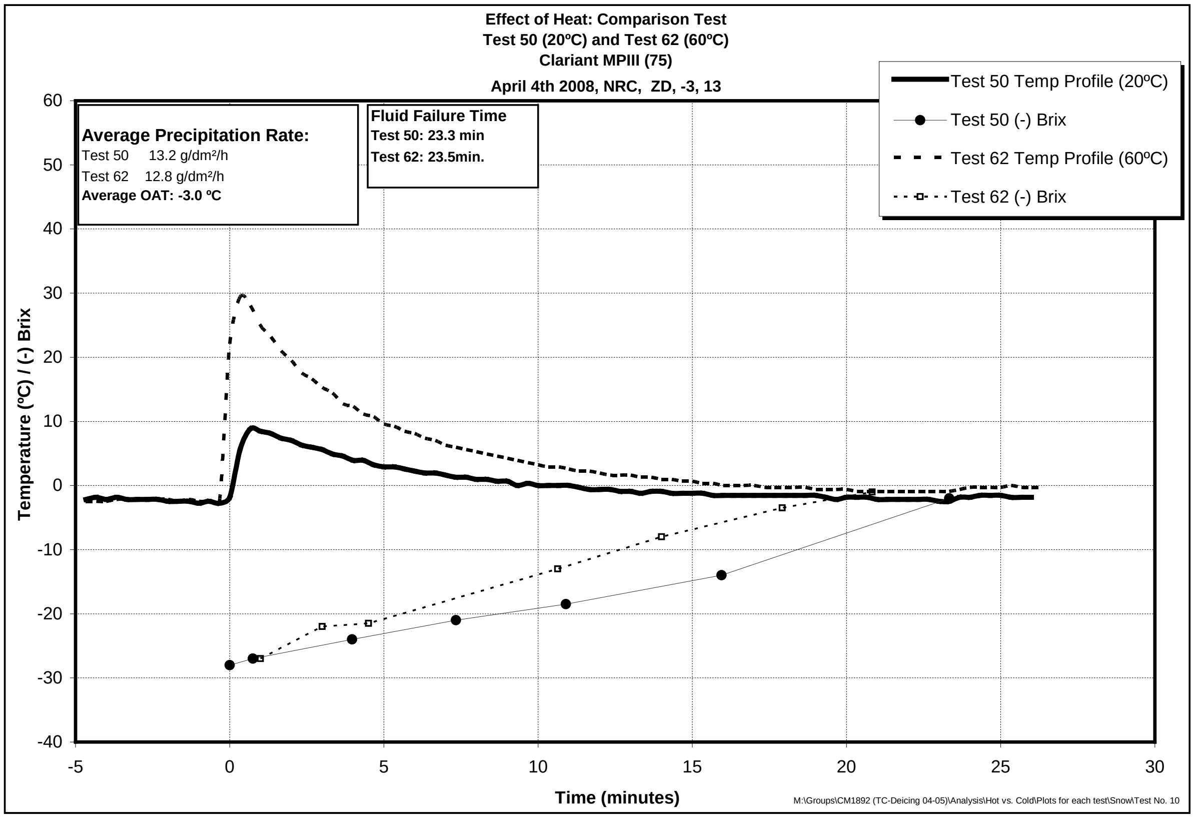
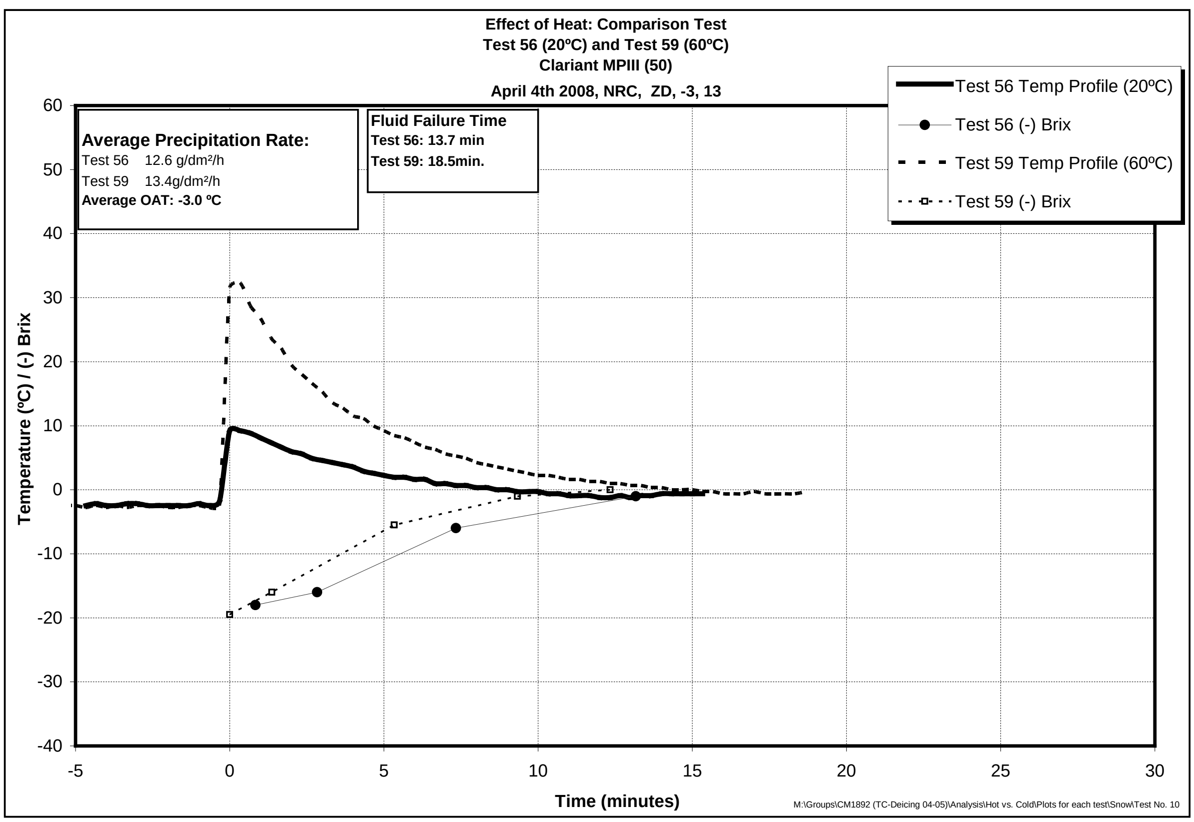
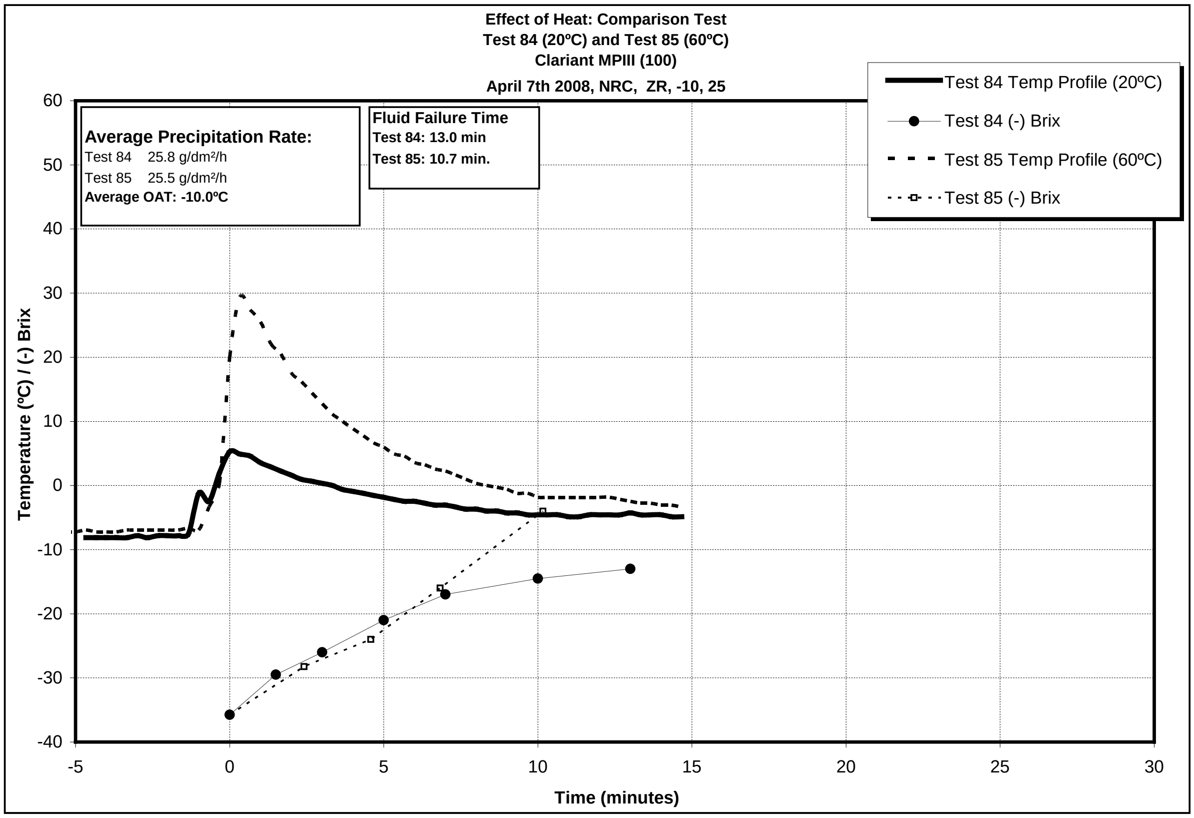
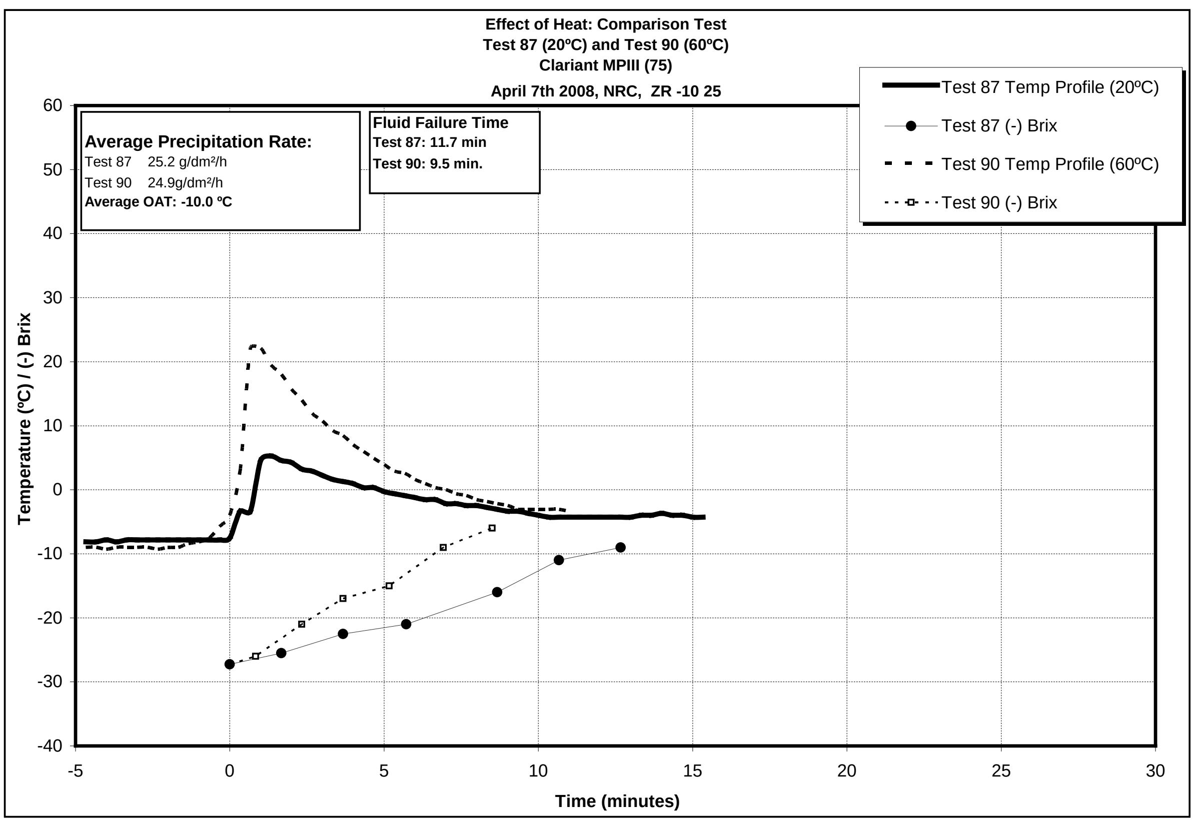
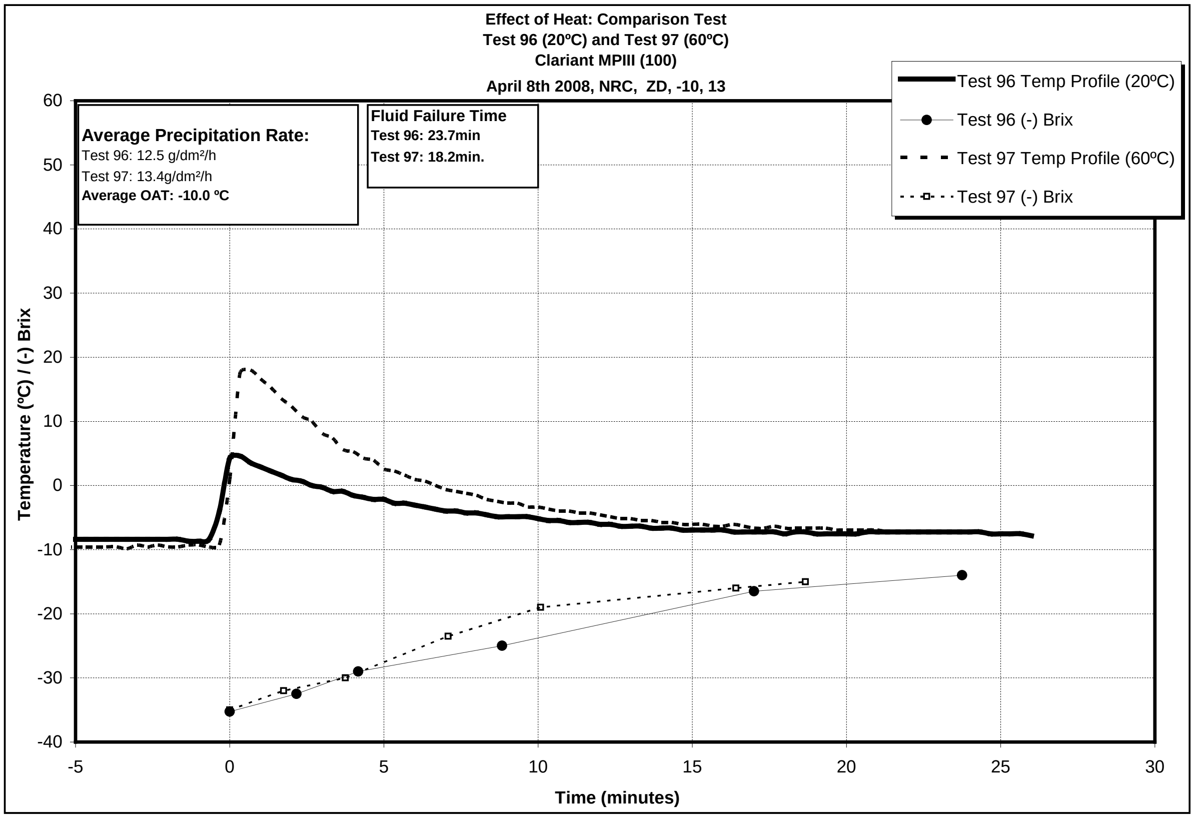
2007-08 CHARTS

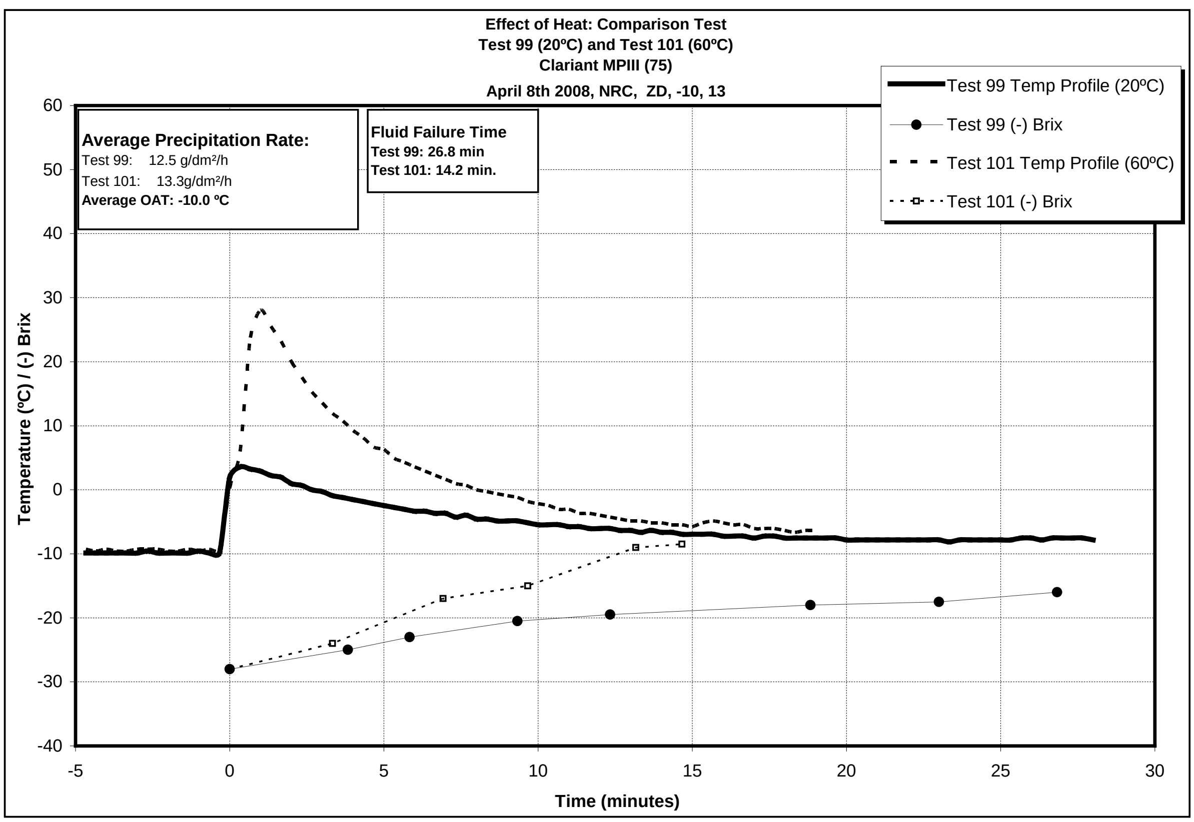

Effect of Heat: Comparison Test
Test 50 (20ºC) and Test 62 (60ºC)
Clariant MPIII (75)
April 4th 2008, NRC, ZD, -3, 13
Average Precipitation Rate:
Test 50 13.2 g/dm²/h
Test 62 12.8 g/dm²/h
Average OAT: -3.0 ºC
Fluid Failure Time
Test 50: 23.3 min
Test 62: 23.5min.
Test 50 Temp Profile (20ºC)
Test 50 (-) Brix
Test 62 Temp Profile (60ºC)
Test 62 (-) Brix
Temperature (ºC) / (-) Brix
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Snow\Test No. 10


Effect of Heat: Comparison Test
Test 56 (20ºC) and Test 59 (60ºC)
Clariant MPIII (50)
April 4th 2008, NRC, ZD, -3, 13
Average Precipitation Rate:
Test 56 12.6 g/dm²/h
Test 59 13.4g/dm²/h
Average OAT: -3.0 ºC
Fluid Failure Time
Test 56: 13.7 min
Test 59: 18.5min.
Test 56 Temp Profile (20ºC)
Test 56 (-) Brix
Test 59 Temp Profile (60ºC)
Test 59 (-) Brix
Temperature (ºC) / (-) Brix
Time (minutes)
M:\Groups\CM1892 (TC-Deicing 04-05)\Analysis\Hot vs. Cold\Plots for each test\Snow\Test No. 10


Effect of Heat: Comparison Test
Test 84 (20ºC) and Test 85 (60ºC)
Clariant MPIII (100)
April 7th 2008, NRC, ZR, -10, 25
Average Precipitation Rate:
Test 84 25.8 g/dm²/h
Test 85 25.5 g/dm²/h
Average OAT: -10.0ºC
Fluid Failure Time
Test 84: 13.0 min
Test 85: 10.7 min.
Test 84 Temp Profile (20ºC)
Test 84 (-) Brix
Test 85 Temp Profile (60ºC)
Test 85 (-) Brix
Temperature (ºC) / (-) Brix
Time (minutes)


Effect of Heat: Comparison Test
Test 87 (20ºC) and Test 90 (60ºC)
Clariant MPIII (75)
April 7th 2008, NRC, ZR -10 25
Average Precipitation Rate:
Test 87 25.2 g/dm²/h
Test 90 24.9g/dm²/h
Average OAT: -10.0 ºC
Fluid Failure Time
Test 87: 11.7 min
Test 90: 9.5 min.
Test 87 Temp Profile (20ºC)
Test 87 (-) Brix
Test 90 Temp Profile (60ºC)
Test 90 (-) Brix
Temperature (ºC) / (-) Brix
Time (minutes)


Effect of Heat: Comparison Test
Test 96 (20ºC) and Test 97 (60ºC)
Clariant MPIII (100)
April 8th 2008, NRC, ZD, -10, 13
Average Precipitation Rate:
Test 96: 12.5 g/dm²/h
Test 97: 13.4g/dm²/h
Average OAT: -10.0 ºC
Fluid Failure Time
Test 96: 23.7min
Test 97: 18.2min.
Test 96 Temp Profile (20ºC)
Test 96 (-) Brix
Test 97 Temp Profile (60ºC)
Test 97 (-) Brix
Temperature (ºC) / (-) Brix
Time (minutes)
60
50
40
30
20
10
0
-10
-20
-30
-40
-5
0
5
10
15
20
25
30


Effect of Heat: Comparison Test
Test 99 (20ºC) and Test 101 (60ºC)
Clariant MPIII (75)
April 8th 2008, NRC, ZD, -10, 13
Average Precipitation Rate:
Test 99: 12.5 g/dm²/h
Test 101: 13.3g/dm²/h
Average OAT: -10.0 ºC
Fluid Failure Time
Test 99: 26.8 min
Test 101: 14.2 min.
Test 99 Temp Profile (20ºC)
Test 99 (-) Brix
Test 101 Temp Profile (60ºC)
Test 101 (-) Brix
Temperature (ºC) / (-) Brix
Time (minutes)
60
50
40
30
20
10
0
-10
-20
-30
-40
-5
0
5
10
15
20
25
30

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