TP 14874E

Effect of Heat on Endurance Times of Anti-Icing Fluids

Volume 2 - Preliminary 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
Final Version 1.0

TP 14874E

Effect of Heat on Endurance Times of Anti-Icing Fluids

Volume 2 - Preliminary Report

by

Peter Dawson

This preliminary report contains information collected during initial phases of the study. Final conclusions and recommendations are given in Volume 1– Final Report.

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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Un sommaire français se trouve avant la table des matières.

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PREFACE

Under contract to the Transportation Development Centre of Transport Canada, 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.

REPORT ACKNOWLEDGEMENTS

The author would like to recognize the significant contributions of Stephanie Bendickson and David Youssef at APS Aviation Inc. for their support in preparing this report.

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 this study and presents interim conclusions and recommendations.

Description and Processing of Data

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. Testing was conducted by APS personnel.

In total, 48 comparison tests (96 individual tests) were conducted in snow and 71 comparison tests (142 individual tests) were conducted in freezing precipitation. These tests were carried out with ten fluid brands and three fluid types.

In addition to endurance times, several parameters were documented during each test conducted. These variables included fluid dilution, fluid thickness and plate surface temperature. These parameters were used to construct charts to better illustrate the test surface temperature, fluid thickness decay and fluid dilution profiles.

Results and Conclusions – Type II/IV Fluids

Analysis of the data showed that, with the exception of one Type II fluid, endurance times of heated Type II and Type IV fluids match or exceed that of fluid applied at ambient temperature as per the standard test protocol.

Three options are presented regarding the guidance material that is currently provided in the related *FAA Approved Deicing Program Updates, Winter 2007-2008* for heated Type II and Type IV fluids:

- Leave the statement as is, with the knowledge that current holdover time values have a large safety factor built in during their development;
- Modify the statement to indicate that generally there is no problem with applying fluid at 60ºC, but users should have the results tested to confirm its adequacy (perhaps by fluid manufacturers); or
- Remove the statement entirely.

The first option is the preferred option.

Results and Conclusions – Type III Fluids

Additional attention needs to be given to measuring endurance times for this fluid type when applied heated, to reflect field deicing operations. Test data indicates that its performance in natural snow, particularly at colder temperatures, may be lower than expected. It is believed that indoor tests of 60ºC fluid at -3ºC ambient produce exaggerated endurance times.

It would be useful to develop more test data in natural snow conditions, as the appropriate test protocol exists for those tests. Sufficient data should be collected to enable construction of a heated-Type III HOT table for snow. If the heated fluid table is significantly different than the currently published table, then a similar activity should be conducted to develop a heated-Type III HOT table for the other types of precipitation. It is recommended that indoor tests for heated Type III fluid follow the indoor test protocol for Type I fluid, until further research proves differently.

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 des 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 essais d'endurance des liquides 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. Ils ont été effectués par du personnel d'APS.

En tout, 48 essais comparatifs (96 essais individuels) ont été effectués dans la neige et 71 essais comparatifs (142 essais individuels) ont été effectués dans la précipitation verglaçante. Ces essais ont été effectués avec dix marques et trois types de liquides.

En plus de l'endurance, plusieurs paramètres ont été documentés au cours de chaque essai. Ces variables comprenaient la dilution du liquide, son épaisseur et la température de la surface de la plaque. Ces paramètres ont servi à construire des tableaux pour mieux illustrer la température de la surface d'essai, la détérioration de l'épaisseur du liquide et les profiles de dilution des liquides.

Résultats et conclusions – Liquides de types II et IV

L'analyse des données a démontré que, à l'exception d'un liquide de type II, l'endurance des liquides chauffés de types II et IV est égale ou supérieure à celle des liquides appliqués à la température ambiante selon le protocole d'essai standard.

Trois options sont offertes en ce qui concerne les lignes directrices actuelles fournies dans les mises à jour du *FAA Approved Deicing Program Updates*, pour l'hiver 2007-2008 et les liquides chauffés de types II et IV :

- Laisser l'énoncé inchangé, en sachant que les valeurs actuelles de durées d'efficacité contiennent un important facteur de sécurité, incorporé lors de leur développement ;
- Modifier l'énoncé pour indiquer qu'en règle générale, l'application de liquide à 60ºC ne pose pas de problème, mais que les utilisateurs devraient faire vérifier les résultats pour confirmer leur pertinence (par le fabricant du liquide, peut-être) ; ou
- Retirer complètement l'énoncé.

La première option est l'option de choix.

Résultats et conclusions – Liquides de type III

Une attention additionnelle doit être portée à mesurer l'endurance de ce type de liquide lorsqu'il est appliqué chauffé, pour représenter les opérations de dégivrage sur le terrain. Les données des essais démontrent que sa performance dans la neige naturelle pourrait être moindre que prévu, en particulier aux températures plus basses. On pense que les essais effectués à l'intérieur avec du liquide chauffé à 60ºC, à une température ambiante de -3ºC, ont donné des endurances exagérées.

L'élaboration de données d'essai dans des conditions de neige naturelle serait utile, puisqu'un protocole d'essai approprié existe pour ces essais. Suffisamment de données devraient être recueillies pour permettre de produire un tableau de durées d'efficacité dans la neige de liquide chauffé de type III. Si le tableau de liquide chauffé est sensiblement différent du tableau actuel en place, alors une activité similaire devrait être menée pour élaborer un tableau de durée d'efficacité dans les autres types de précipitation pour le liquide de type III. Jusqu'à preuve du contraire par d'autres recherches, il est recommandé que les essais à l'intérieur sur le liquide chauffé de type III utilisent le protocole d'essai intérieur pour le liquide de type I.

CONTENTS Page

LIST OF APPENDICES

LIST OF FIGURES Page

LIST OF TABLES Page

LIST OF PHOTOS Page

GLOSSARY

APS	APS Aviation Inc.
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
ISO	International Organization for Standardization
LOWV	Lowest On-Wing Viscosity
MSC	Meteorological Service Canada
NRC	National Research Council Canada
OAT	Outside Air Temperature
SAE	Society of Automotive Engineers
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 (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 Background

At the November 2000 SAE International (SAE) G-12 Holdover Time (HOT) Subcommittee meeting, discussion focused on the need to recognize the contribution of heat in the endurance time test protocol for Type I fluids. Research was subsequently conducted and it was concluded that an empty aluminum box that simulates the wing leading edge was suitable as a thermal equivalent test surface. As a result, the Type I protocol was changed and endurance time tests for fluids tested outdoors are now conducted on boxes.

Because heated Type II and Type IV fluids in 50/50 and 75/25 concentrations are sometimes used heated in one-step de/anti-icing procedures (particularly in Europe), a motion was made at the November 2000 SAE G-12 HOT Subcommittee meeting for changes to be made to the Type II/IV test procedure as well. Specifically, it was put forward that the Type II/IV procedure should require fluids be applied heated to the aluminum box test surface developed for Type I testing.

A field survey conducted in the winter of 2002-03 brought additional attention to this issue. The field survey, documented in the TC report, TP 14154E, *Aircraft Ground Icing Exploratory Research for the 2002-03 Winter* (1), measured temperatures of Type II and Type IV fluids after application and found that the temperature of applied fluids was often well above the outside air temperature (OAT). The warmer fluids may result from the design of older deicers still in field operations, where the fluids may be heated via heat transfer from adjoining heated Type I tanks, or simply from fluid storage tanks being located inside heated buildings. In any case, the field survey brought new significance to the examination of how well heated fluid endurance times correspond to the HOT guideline values, as it showed fluid temperature was also a potential issue with two-step applications.

1.2 Objectives

The primary objective of this project was to investigate the impact of anti-icing fluid application temperature on endurance times. The detailed objectives are as follows:

1. To validate that the Type I protocol test surface can be used as a representative wing test surface for Type II/IV fluids;
2. To determine the effect of heat on Neat and diluted Type II and IV fluid endurance times; and
3. To determine the effect of heat on Neat and diluted Type III fluid endurance times.

The third objective was added to the project in the winter of 2004-05, as operators began to consider using Type III fluid in the same manner as Type I fluid.

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

1.3 History of Endurance Time Testing

Tests on the effect of heat on endurance times have been conducted over three winters and one supplemental test session:

- In 2001-02, exploratory tests were conducted to investigate whether heat significantly influences the endurance times of Type II/IV fluids. The tests showed that the effect of heat did not reduce endurance times. In some cases, a significant improvement was observed. These tests are documented in the TC report, TP 13994E, *Generation of Holdover Times Using the New Type I Fluid Test Protocol* (2).

- Additional tests were conducted in 2004-05. Results were not definitively conclusive. These tests are documented in the TC report, TP 14447E, *Effect of Heat on Endurance Times of Anti-Icing Fluids* (3).
- Further tests were conducted during the winter of 2005-06. These tests have not been previously documented.
- A detailed review of the 2004-05 and 2005-06 test results led to the recommendation that additional specific tests be conducted with two fluids. These tests were conducted in the summer of 2007. These tests have not been previously documented.

To provide a comprehensive analysis of all the endurance time testing that has conducted, the data collected from all of these tests has been consolidated into one data set which is presented and analysed in this report.

1.4 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 of this study and presents interim conclusions and recommendations.

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

a) Section 2 describes the methodology and tests that were conducted to validate that the Type I fluid box can be used as a thermal equivalent of aircraft wings when testing with Type II, III and IV fluids;

b) Section 3 provides a description of the methodology used to carry out the comparative endurance time tests;

c) Section 4 presents the endurance time data collected over the winters of 2001-02, 2004-05 and 2005-06 and July 2007;

d) Section 5 provides analysis of the endurance time test data;

e) Section 6 presents conclusions; and

f) Section 7 presents recommendations.

1.5 Initial Guidance Material

Based on conclusions derived from initial testing, the FAA made the following inclusion in the *FAA-Approved Deicing Program Updates, Winter 2007-2008* (4):

"4 (d) During the application of heated Type II and IV fluids in the one-step procedure, questions have arisen regarding the anticipated HOT performance of these fluids.

1. *In prior advisory information, the FAA indicated that maximum anti-icing effectiveness could be achieved from the application of unheated (cold) Type II fluids to deiced aircraft surfaces. This was based upon observations of the performance of Type II fluids in production at that time. The rationale was that a cold, unheated fluid would produce a thicker protective layer on aircraft surfaces, thus providing longer protection than a heated fluid presumably applied in a thinner layer.*
2. *Some air carriers proposed using the Type I HOT guideline values instead of Type II and IV values when these thickened, heated fluids were applied. Another carrier suggested reducing the Type II and IV HOT values by a factor of 50 percent. During tests conducted by APS Aviation for the FAA using existing test protocol, HOT performance of heated 60°C (140°F) Type II and IV fluids was found to equal or exceed the HOT performance of unheated Type II and IV fluids for the same fluid concentrations, temperature, and precipitation conditions. Therefore, these and other test results indicate that there is no basis for reducing the current HOT guideline values for Types II and IV fluids or for using the Type I fluid HOT guidelines when heated Type II and IV fluids are properly applied.*
3. *In addition, HOT guideline data was obtained for the newly introduced Type III fluids when applied heated and unheated and no significant HOT performance differences were observed. Therefore, anti-icing applications of Type III fluid may be heated or unheated."*

Transport Canada has not included this information in its holdover time guidelines.

2. VALIDATION OF TYPE I PROTOCOL FOR TYPE II, III, AND IV FLUIDS

2.1 Background

At the November 14-15, 2000 meeting of the SAE G-12 Hot Subcommittee, it was resolved that "*the HOT committee will develop Type I testing protocols which consider the heat factor on simulated wing surfaces of various dilutions of Type I fluids for the purpose of developing Type I Holdover Tables that match operational use of the fluid".*

At that meeting, an associated discussion noted that Type II/IV fluids diluted to 75/25 and 50/50 concentrations are sometimes used heated as a one-step de/anti-icing process but the test methodology for evaluating endurance times of these fluids does not account for fluid heat. It was resolved that a test protocol which considers fluid heat should be developed for these fluids.

2.2 Objective

Research conducted in 2000-01 for the current Type I protocol found that an empty 7.5 cm box treated with 0.5 L of fluid at 60°C had a temperature profile representative of the temperature profile of a wing leading edge treated with heated Type I fluid. This was confirmed when the temperature profile of a box treated with Type I fluid was compared to temperature profiles of various aircraft wings treated with Type I fluid and found to be similar.

The objective of this project was to determine if the box developed for Type I testing is also representative of wing leading edges when treated with heated Type IV fluid. If it is, the Type I protocol can be used as the protocol for evaluating endurance times of heated Type II/IV fluids. The objective was accomplished by comparing the temperature profiles of the JetStar test wing and a Type I fluid box both treated with heated Type IV fluid.

2.3 Acceptance Criteria

The JetStar wing was used as a representative aircraft wing in this test. A number of aircraft leading edge temperature profiles were developed in 2000-01 with Type I fluid. When they were compared to the JetStar wing, it was found that the JetStar wing profile was on the lower end of the data set (see Figure 2.1). The JetStar wing was found to be very close to negative one standard deviation of the temperature profile of a box treated with Type I fluid (see Figure 2.2).

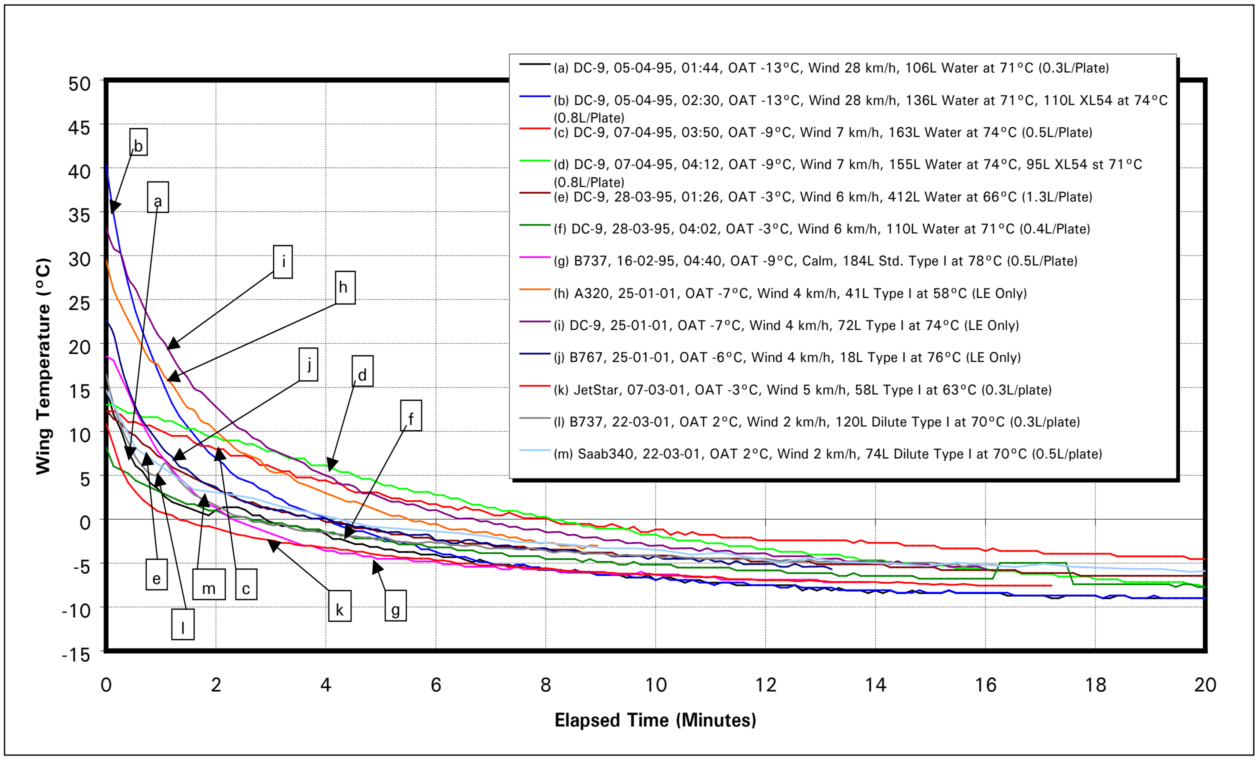

Figure 2.1: Aircraft Leading Edge Temperature Profiles Winter 2000-01

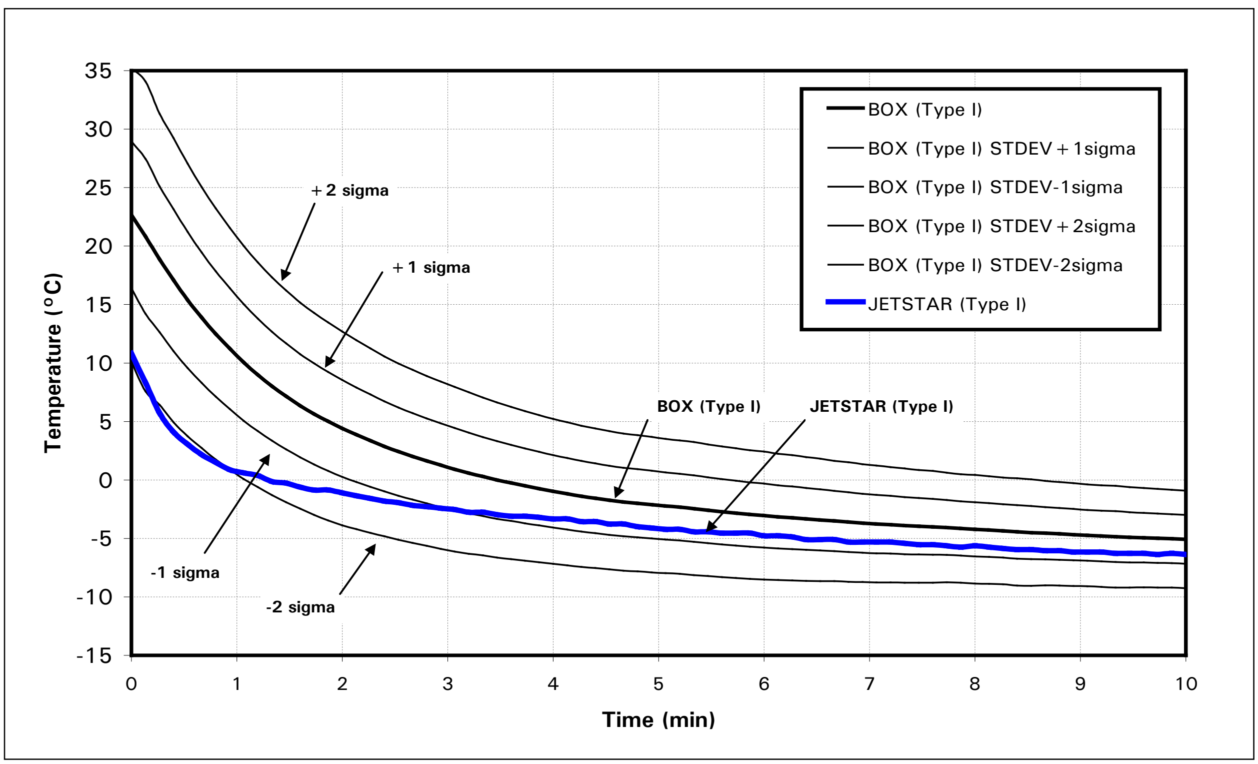

Figure 2.2: JetStar and Box Temperature Profiles – Type I Fluid

It was determined that the Type I box would be considered an acceptable representation of the wing leading edge for heated Type IV fluid testing if:

- The temperature profiles of the JetStar wing and a box following an application of heated Type IV fluid are similar and within a "reasonable scatter" of each other; and
- The temperature profiles of the JetStar wing and a box following an application of heated Type IV fluid are within a "reasonable scatter" of the Type I data shown in Figure 2.2.

2.4 Equipment and Setup

For the purpose of this test, the JetStar wing was moved from its storage location at the AéroMag 2000 deicing facility to the APS test site. Tarpaulins were placed under the wing to facilitate proper waste disposal.

A temporary storage shed was used to house the required equipment for testing which included:

- A dedicated PC to provide a log of the wing skin temperature;
- A conventional residential hot-water tank to heat the fluid to the desired temperature; and
- A portable sprayer.

Power was supplied to the hot water tank using a 3-phase generator, stored directly adjacent to the temporary shed.

APS used various pieces of equipment to conduct the test. The key items employed are described below.

2.4.1 Test Surfaces and Thermistors

Heated fluid was applied to a designated area on the JetStar wing. This test was conducted using the leading edge of the wing, and hence thermistors located only on or around the leading edge were used. The thermistors were located as follows (see Figure 2.3):

- Location 3: Midway on LE, in line between location 1 and 4;
- Location 4: On LE nose, ¼ distance from surface outer end; and
- Location 6: Mid-way on LE chord wise and ½ way laterally.

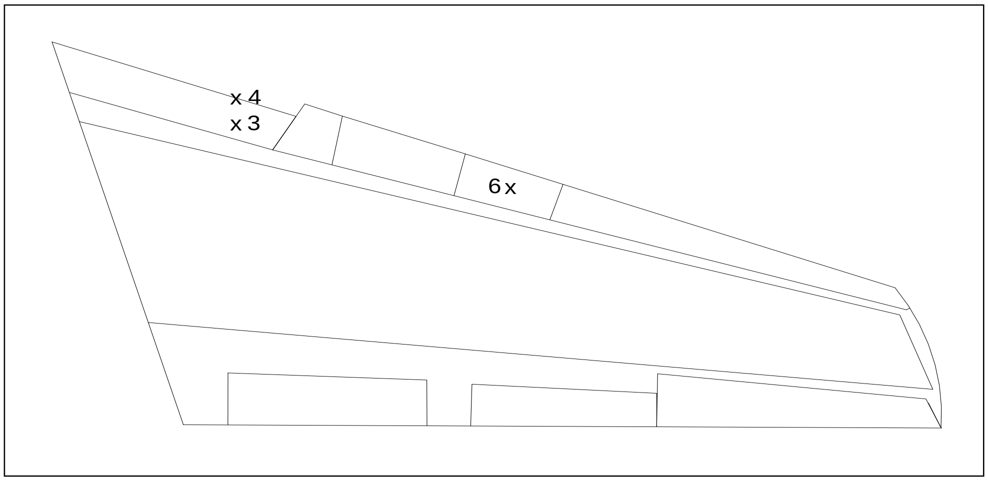

Figure 2.3: Thermistor Probe Mounting Locations

Each box had a thermistor probe installed at the 15 cm line on the underside of the test surface. Surface temperature data collected was constantly monitored during the test event and was stored in a data logger.

2.4.2 Test Stand

The stand used for standard endurance time tests was used to position the test surfaces. The test boxes were placed at a 10º inclination on the test stand and were oriented facing the oncoming wind.

2.4.3 Twelve-Hole Spreader

Fluids were applied to the boxes using a twelve-hole spreader, which distributed the fluid evenly along the top of the test plate.

2.5 Procedure

The detailed test procedure is included in Appendix B.

2.6 Fluid

Dow UCAR Ultra+ was the Type IV fluid used for this test.

2.7 Tests Conducted

On December 29, 2005 three tests were conducted:

- JetStar Wing: Type IV fluid applied at 50ºC;
- Box: 0.5 L of Type IV fluid applied at 50ºC; and
- Box: 0.5 L of Type I fluid applied at 50ºC.

2.8 Analysis and Observations

The temperature profiles for the three thermistors on the JetStar wing and the thermistor on the box treated with Type IV fluid are shown in Figure 2.4, which illustrates that the temperature profile of the box falls within the three wing temperature profiles.

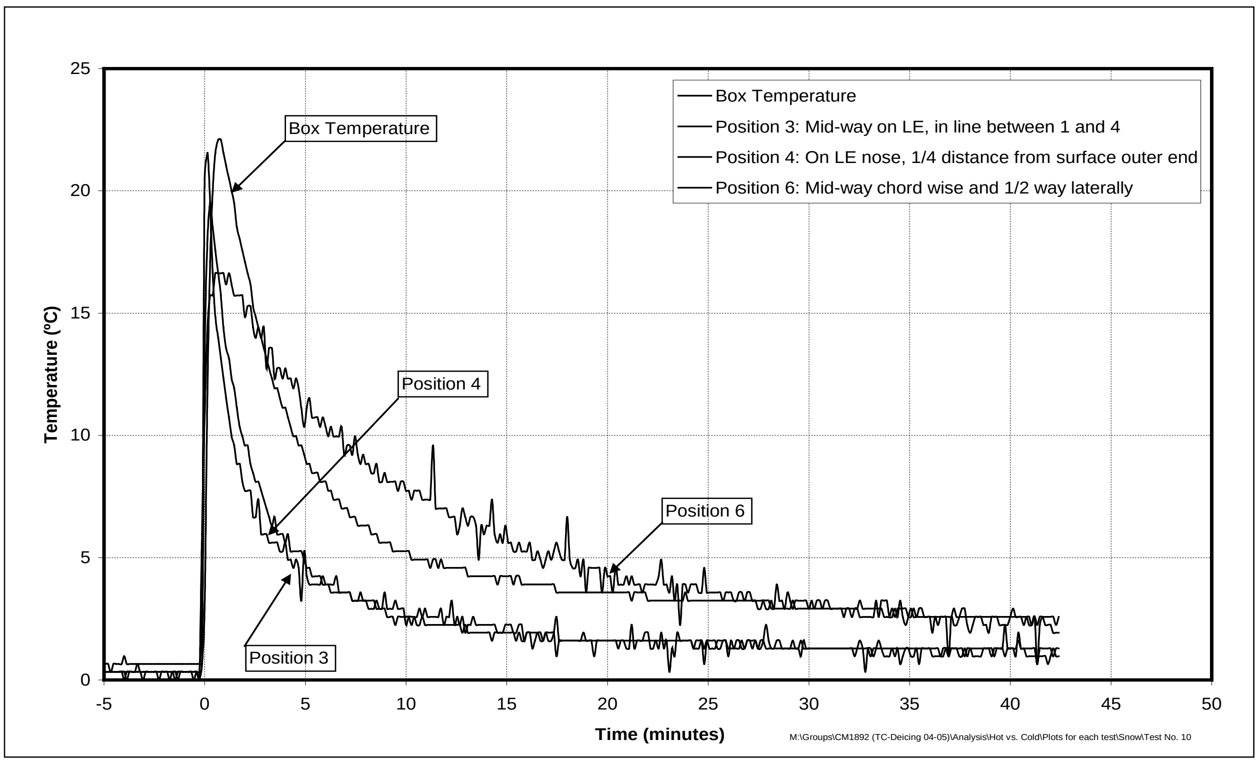

Figure 2.4: Wing Surface Temperature Profile – Ultra+ Applied Heated to 50ºC, December 29, 2005

Figure 2.5 shows the Type I fluid data collected in 2000-01 (see Figure 2.2) plotted with the Type IV fluid data collected in December 2005. The figure shows that the box temperature profiles are similar, as are the wing temperature profiles. Furthermore, all of the Type IV data falls within a “reasonable scatter” of the Type I data.

The Type I fluid box temperature profile that was measured in 2005 is also shown in Figure 2.5. It is virtually identical to the Type I fluid box temperature profile measured in 2000-01, and very similar to the Type IV fluid box temperature profile measured in 2005-06. These results confirm that the Type IV fluid applied to the box is a good representation of Type IV fluid applied to a wing.

2.9 Conclusion

The tests conducted show that the temperature profile of a box after the application of heated Type IV fluid is similar to the temperature profile of a wing following the same application. Both Type IV temperature profiles (box and wing) fit within the scatter of the Type I data previously collected. Therefore, it can be concluded that the box is representative of the leading edge of aircraft wings when treated with heated Type IV fluid, and that the Type I protocol can be used for outdoor tests to evaluate endurance times of heated Type II and Type IV fluids.

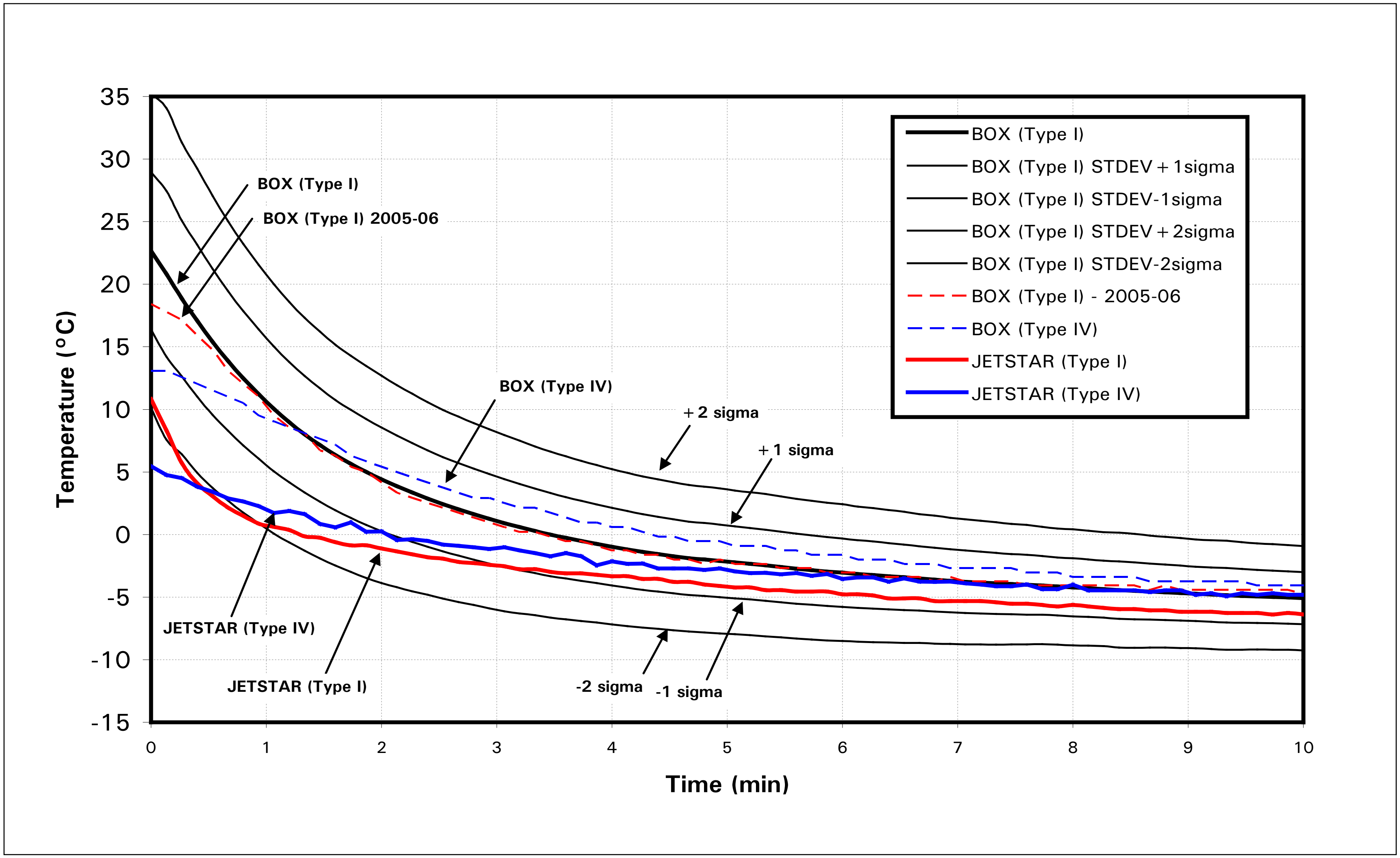

Figure 2.5: JetStar and Box Temperature Profiles of Type I and Type IV Fluids

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3. METHODOLOGY – ENDURANCE TIME TESTING

This section describes the overall approach, test parameters and experimental procedures followed in the endurance time testing conducted for this project.

3.1 Test Site

Fluid endurance time tests in natural snow conditions were conducted at the APS test site at the Montreal-Trudeau Airport. The location of the test site is shown on the plan view of the airport in Figure 3.1. A view of the test site is shown in Photo 3.1.

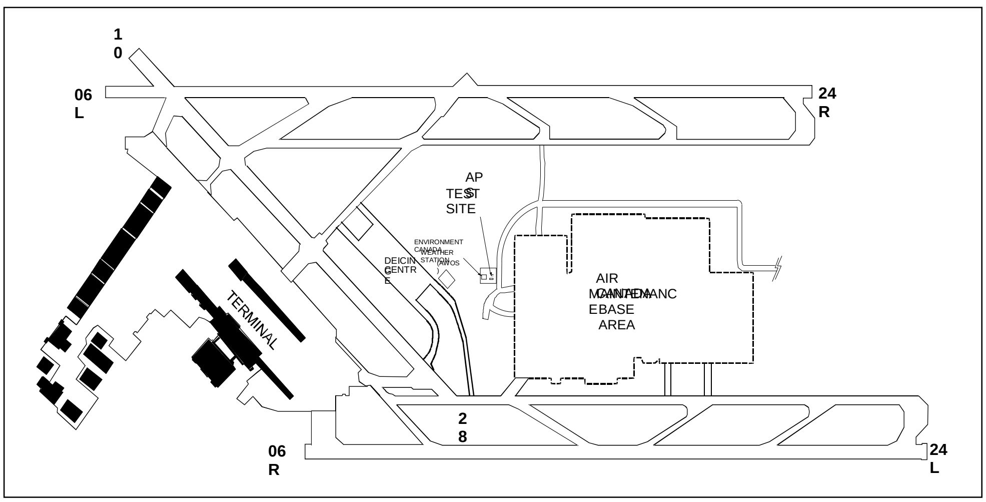

Figure 3.1: Plan View of APS Montreal-Trudeau Airport Test Site

3.2 NRC Climatic Engineering Facility

To obtain the necessary endurance time data in freezing precipitation conditions, testing was carried out at the NRC Climatic Engineering Facility (CEF) (see Photo 3.2) using a sprayer assembly to simulate the required freezing precipitation conditions. Testing was conducted under freezing rain and freezing drizzle conditions.

3.3 Description of Test Procedures

Comparative endurance time tests were conducted using standard endurance time test procedures. The heated and standard tests were conducted simultaneously using the application methods described in Subsections 3.3.1 and 3.3.2.

Separate but similar procedures were developed in each year of testing. The 2005-06 procedure has been included in Appendix C. In an attempt to increase efficiency, testing in the winter of 2004-05 was combined with testing for a project related to endurance time testing of fluids on non-aluminum plates. The 2004-05 test procedure was therefore developed for both heated fluid endurance time tests and non-aluminum plate endurance time tests. Only the portion of the procedure describing heated fluid endurance time testing is of concern to this project.

Photos of the test setup were taken in the winter of 2004-05 when testing was conducted in conjunction with non-aluminum plate testing. The outdoor and indoor setups are shown in Photo 3.3 and Photo 3.4, respectively.

3.3.1 Indoor Tests with Type II/III/IV Fluids

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 60ºC and poured with a 12-hole spreader (if fluid was too viscous, it was hand poured) onto a standard aluminum plate

A summary of these application methods is shown in Figure 3.2.

It must be noted that the indoor test procedure was not conducted in accordance with the *indoor laboratory test protocol* for Type I fluid. Development of that protocol determined the application of one litre of Type I fluid at 20ºC on a standard test plate in the calm environment of an indoor laboratory produced a temperature profile matching that of a typical wing leading edge in natural outdoor windy conditions, as well as that of the outdoor test protocol discussed in Section 2.

However, these tests were meant to examine the impact of applying heated Type II, III and IV fluids. The application of fluid at a temperature of 60ºC represented the field procedure where fluid in the deicer had been heated to that temperature, and thus supports examination of the effect of that heat on the applied fluid. One potential effect that was examined was change in fluid thickness on the test surface. This effect could not be examined by following the Type I protocol using 20ºC fluid.

It is recognized that the higher temperature and its related effect on the plate temperature profile may have influenced the endurance times for some tests. The indoor test protocol and its influence on test results are discussed further in Section 5.

Position 1	Position 2
• Plate • 1 L of fluid • Apply at ambient • Poured	• Plate • 1 L of fluid • Applied at 60 ºC • Poured with a 12-hole spreader

Figure 3.2: Position on Stand – Indoor Tests

3.3.2 Outdoor Tests with Type II/III/IV Fluids

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

- 0.5 L of fluid heated to 60ºC and poured with a 12-hole spreader (if fluid was too viscous, it was hand poured) onto a box.

This procedure reflects the test protocol for Type I fluid HOT measurement outdoors.

A summary of these application methods is shown in Figure 3.3.

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 3.3: Position on Stand – Outdoor Tests

3.4 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.

3.5 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 International Organization for Standardization (ISO) 9001:2000 standards and developed internally by APS.

In order to conduct endurance time comparison testing, APS used various pieces of equipment. The key items employed are described below.

3.5.1 Test Surfaces

Baseline standard fluid endurance time testing, both indoor and outdoor, was conducted using standard aluminum test plates. In the case of outdoor testing, the heated fluid was applied to an empty aluminum box insulated on all sides except the top, as per the Type I fluid application protocol.

3.5.2 Test Stand

The test stand used for standard endurance time tests was used to position the test surfaces. The test plates were placed at a 10º inclination on the test stand and were oriented facing the oncoming wind.

3.5.3 Thermistor Probes

Each test plate had a thermistor probe installed at the 15 cm line, inset 1/3 of the width from the edge, and attached to the underside of the test surface. The box had two thermistors installed at the 15 cm line on the underside of the test surface. Surface temperature data collected was constantly monitored during the test event and was stored in a data logger.

3.5.4 Twelve Hole Fluid Spreader

For the heated tests, fluids were applied to the test surfaces using a standard twelve-hole spreader (see Photo 3.9), which distributed the fluid evenly along the top edge of the surface. For the ambient tests, fluids were applied by freely pouring (without the spreader) the fluid over the flat plate test surface (see Photo 3.10).

3.5.5 Brixometer

Brix measurements provided data relevant to the fluid concentration. Photo 3.5 shows a hand-held Brixometer. Photo 3.6 and Photo 3.7 show an APS employee obtaining a fluid sample from the test plate and using the Brixometer to measure the fluid Brix.

3.5.6 Wet Film Thickness Gauge

Fluid thickness measurements were recorded using wet film thickness gauges. Figure 3.4 shows a schematic of the wet film thickness gauges used to make the measurements. Photo 3.8 shows an APS employee conducting a fluid thickness measurement.

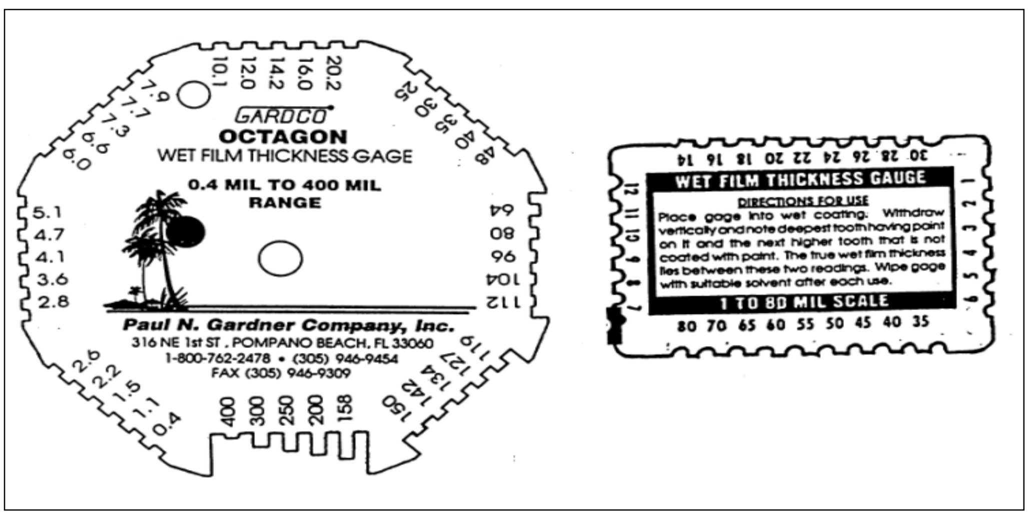

Figure 3.4: Wet Film Thickness Gauges

3.6 Personnel

Three individuals were required to conduct these tests. The test manager measured endurance times. An assistant was required to prepare the fluids, assist with fluid application and collect fluid thickness and dilution measurements. A third individual was required to measure precipitation rates.

3.7 Fluids

Ten anti-icing fluids were tested over the four seasons. Some of the fluids were tested in multiple winters; some were tested in one winter only. The Type II, III and IV fluids were tested in Neat, 75 percent and/or 50 percent dilutions.

Table 3.1 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.

Most of the fluid samples used for testing were lowest on-wing viscosity (LOWV) samples previously submitted to APS for holdover time testing.

Table 3.1: Fluids Used for Comparative Endurance Time Testing

Fluid Brand	Fluid Type	Dilutions Tested	Commercial or Experimental Fluid	Viscosity[1]	When Tested
Fluid A	II	50%, 75%, 100%	Commercial	LOWV	2004-05 2005-06 July 2007
Fluid B	III	50%, 75%, 100%	Commercial	LOWV	2004-05 2005-06 July 2007
Fluid C1	IV	75%, 100%	Experimental	LOWV	2004-05
Fluid C2	II	50%, 75%, 100%	Commercial	LOWV	2005-06
Fluid D	IV	50%, 75%, 100%	Commercial	LOWV	2004-05 2005-06
Fluid E	IV	100%	Commercial	Mid-viscosity	2004-05 2005-06
Fluid F	II	50%, 75%	Commercial	n/a	2001-02
Fluid G	IV	75%	Commercial	n/a	2001-02
Fluid H	IV	50%, 75%	Experimental	LOWV	2001-02
Fluid I	II	50%, 75%	Experimental	Degraded LOWV	2001-02

[1] LOWV: Lowest on-wing viscosity

3.8 Supplemental Tests

A detailed review of the three winters data led to additional tests being conducted with two fluids in indoor laboratory tests in the summer of 2007. The test plan included further tests of the type described previously; these tests examined specific conditions where these two fluids had demonstrated shorter endurance times. In addition, supplemental tests were conducted with the Type III fluid: two additional test plates were added to each test set (see Figure 3.5). The purposes of the additional plates are provided below.

1) **Examine the endurance times of a two-step application:** This test addressed the question as to whether the heat transferred to the surface from the first step (heated deicing fluid) of a two-step deicing process would enhance the endurance times of the second-step anti-icing fluid. If this were found to be the case, then it might be possible to produce a single table for either heated or non-heated Type III fluid. Such a table would reflect the endurance time enhancement from heated fluid at mild OAT, without affecting the shorter times at colder temperatures.

   This test procedure involved application of heated Type I fluid at 60°C, waiting 3 minutes, and then applying Type III at OAT.

2) **Compare endurance times with fluid applied at 20ºC (Type I test protocol for laboratory tests) versus fluid applied at 60ºC:** This test measured endurance times of a Type III fluid applied at 20ºC. The resulting times were compared to times from simultaneous tests conducted with fluid applied at 60ºC and at ambient temperature.

Position 1 (Standard Test)	**Position 2 (Heated Test)**	**Position 3 (Two-Step Test)**	**Position 4 (20°C Test)**
• Plate • 1 L of fluid • Applied at ambient • Poured	• Plate • 1 L of fluid • Applied at 60 ºC • Poured with a 12-hole spreader	• Plate • 1 L Type I applied at 60°C • 1 L Type III applied at ambient • Poured	• Plate • 1 L of fluid • Applied at 20ºC • Poured with a 12-hole spreader

Figure 3.5: Position on Stand – Supplemental Tests

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Photo 3.1: View of APS Test Site

Photo 3.2: Inside View of NRC Climatic Engineering Facility

Photo 3.3: Comparative Endurance Time Testing Setup - Outdoors

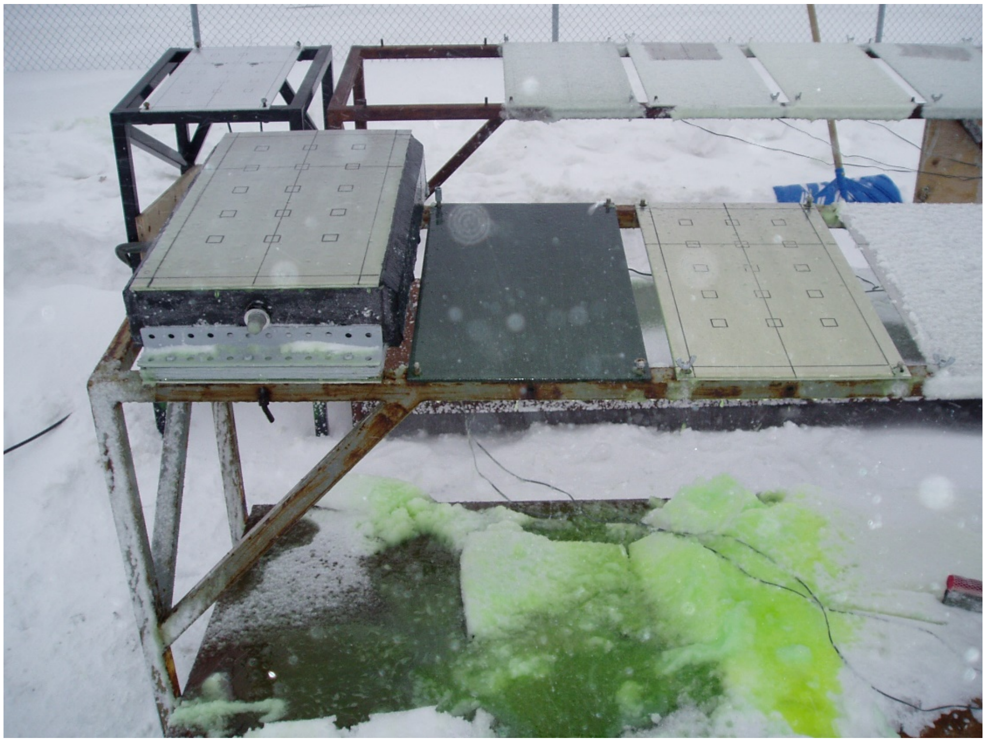


Photo 3.4: Comparative Endurance Time Testing Setup – Indoors

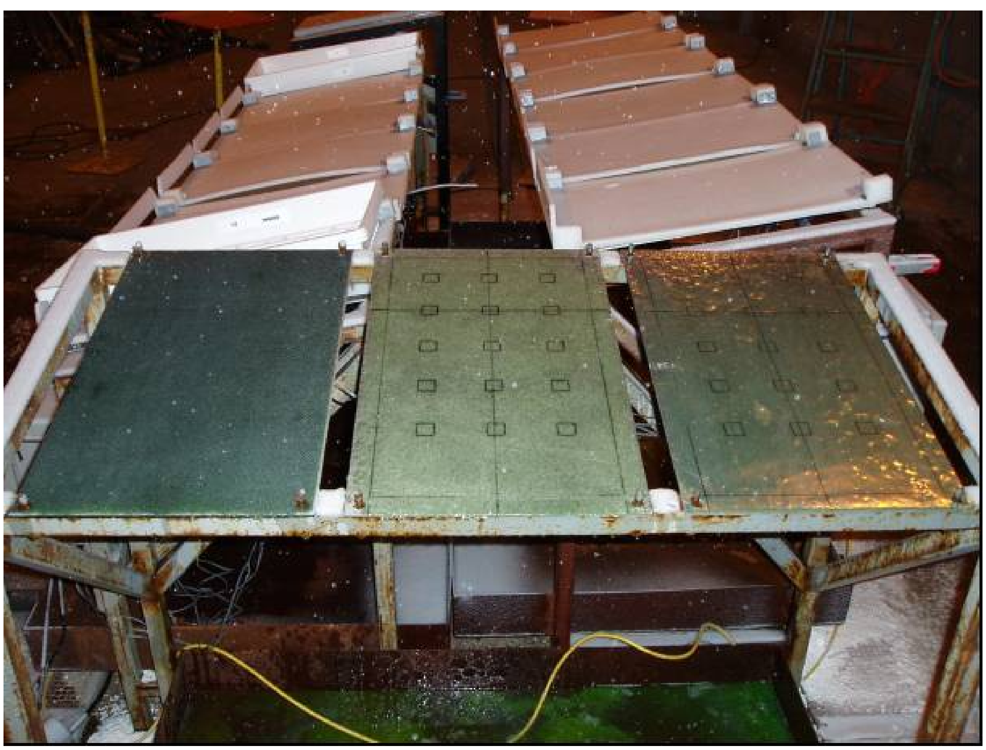


Photo 3.5: Hand-Held Brixometer

Photo 3.6: Obtaining Fluid Sample for Brix Measurement

Photo 3.7: Using Brixometer to Measure Fluid Brix

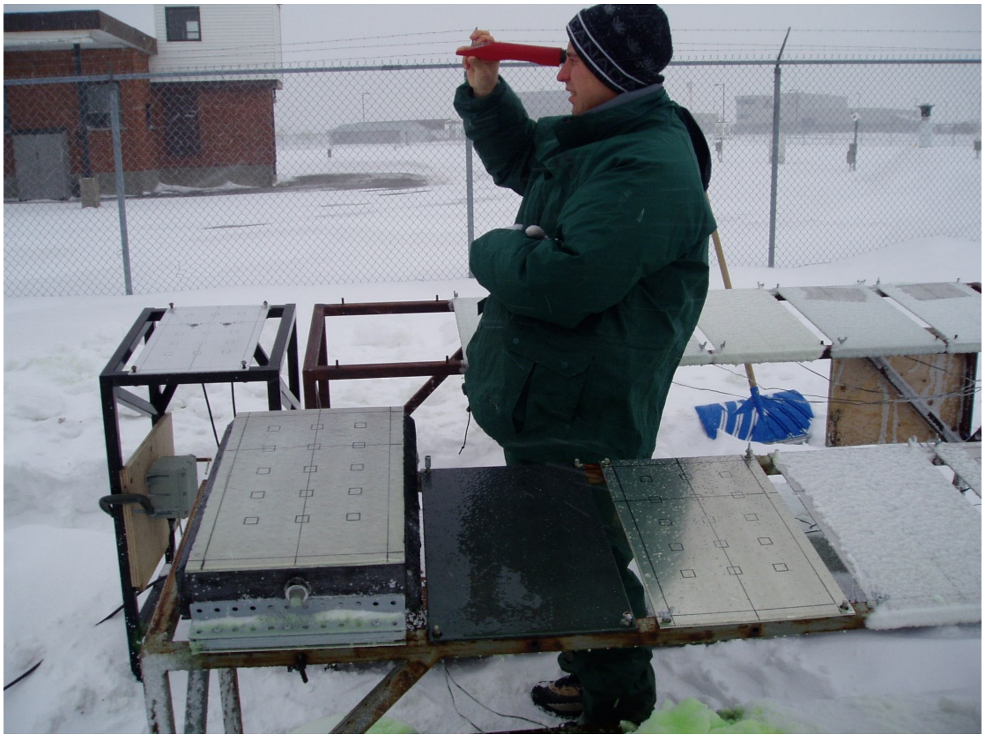


Photo 3.8: Fluid Thickness Measurement Using Wet Film Thickness Gauge

Photo 3.9: Fluid Application Using Twelve Hole Spreader

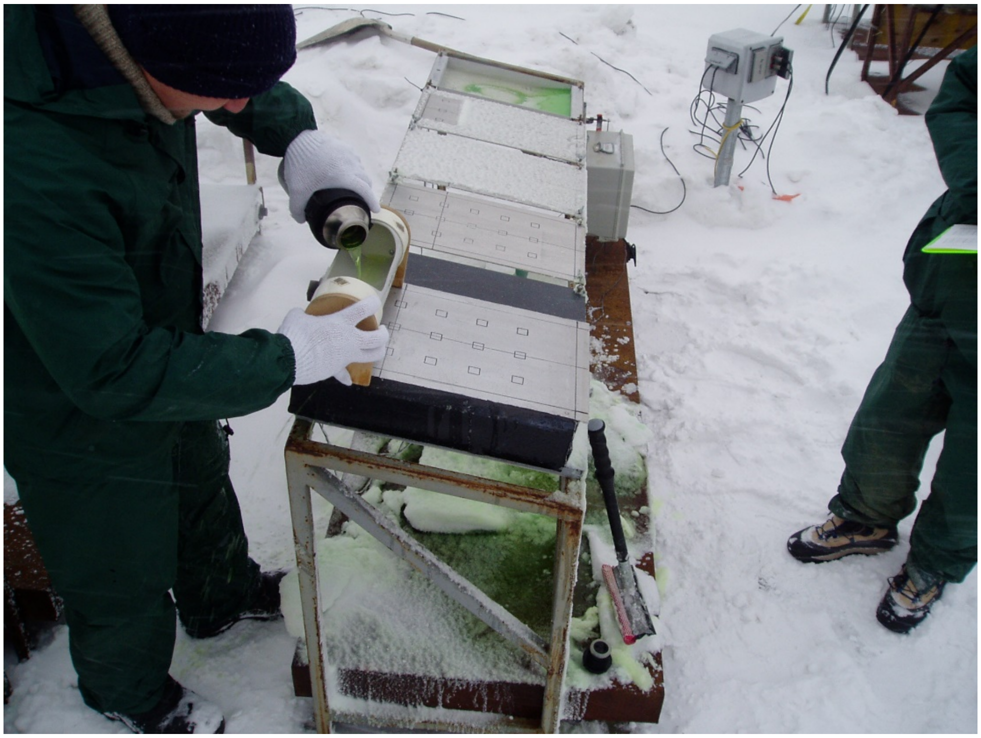
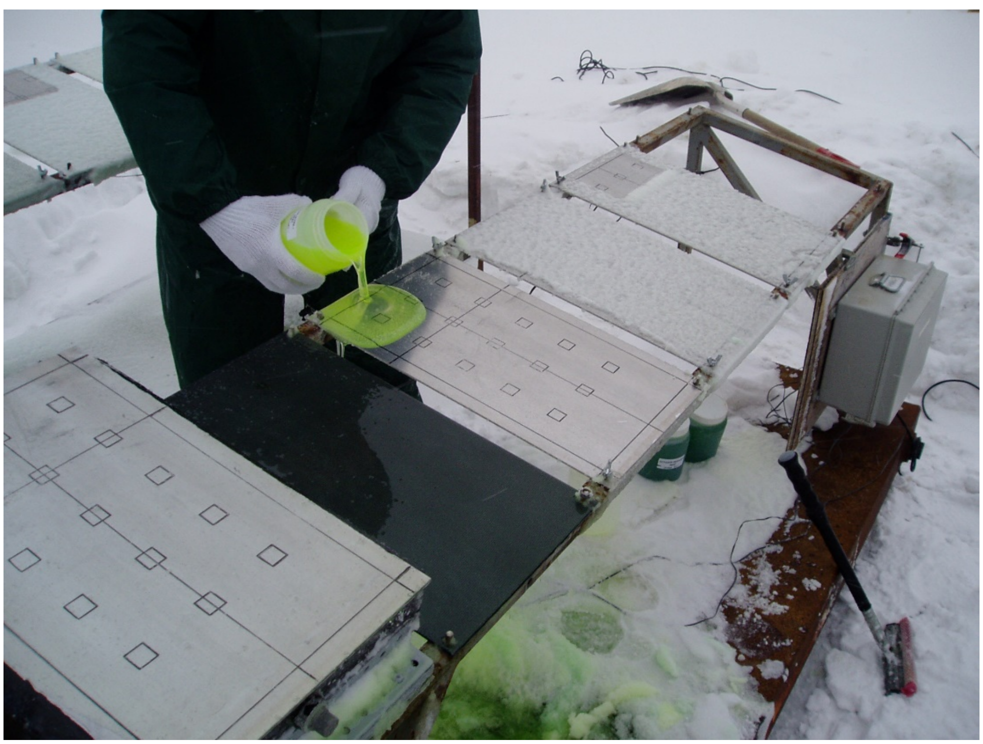


Photo 3.10: Fluid Application by Pouring



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4. DESCRIPTION AND PROCESSING OF DATA

This section describes the endurance time data collected by APS under natural and simulated freezing precipitation conditions over the winters of 2001-02, 2004-05 and 2005-06 and in July 2007.

4.1 Tests Conducted

A total of 119 comparison tests (238 individual tests) were conducted for this project. This included 48 tests in snow and 71 tests in freezing precipitation. Table 4.1 shows the number of comparison tests conducted in snow and freezing precipitation each year.

Table 4.1: Tests Conducted by Year

Precipitation Type	2001-02	2004-05	2005-06	July 2007	Total
Snow	8	19	21	0	**48**
Freezing Precip.	12	20	28	11	**71**
Total	**20**	**39**	**49**	**11**	**119**

4.2 Distribution of Tests in Snow Conditions

During the winter of 2001-02, a total of 8 comparative tests (16 individual tests) were conducted in snow. Most of the tests (88 percent) were conducted during snow conditions with precipitation rates below 10 g/dm²/h. Wind speeds were not measured.

During the winter of 2004-05, a total of 19 comparative tests (38 individual tests) were conducted during 4 natural snow events. The distribution of manually measured precipitation rates shows that 47 percent of the tests were conducted during snow conditions with precipitation rates below 10 g/dm²/h. There was an average wind speed of 28 km/h.

During the winter of 2005-06, a total of 21 comparative tests (42 individual tests) were conducted during 9 natural snow events. The distribution of manually measured precipitation rates shows that 40 percent of the tests were conducted during snow conditions with precipitation rates below 10 g/dm²/h. There was an average wind speed of 25 km/h.

The distribution of manually measured precipitation rates for all years combined shows that 47 percent of the snow tests were conducted at precipitation rates below

10 g/dm²/h (see Figure 4.1). There was an average wind speed of approximately 27 km/h for the snow tests conducted in 2004-05 and 2005-06. Figure 4.2 shows the distribution of tests according to wind speed.

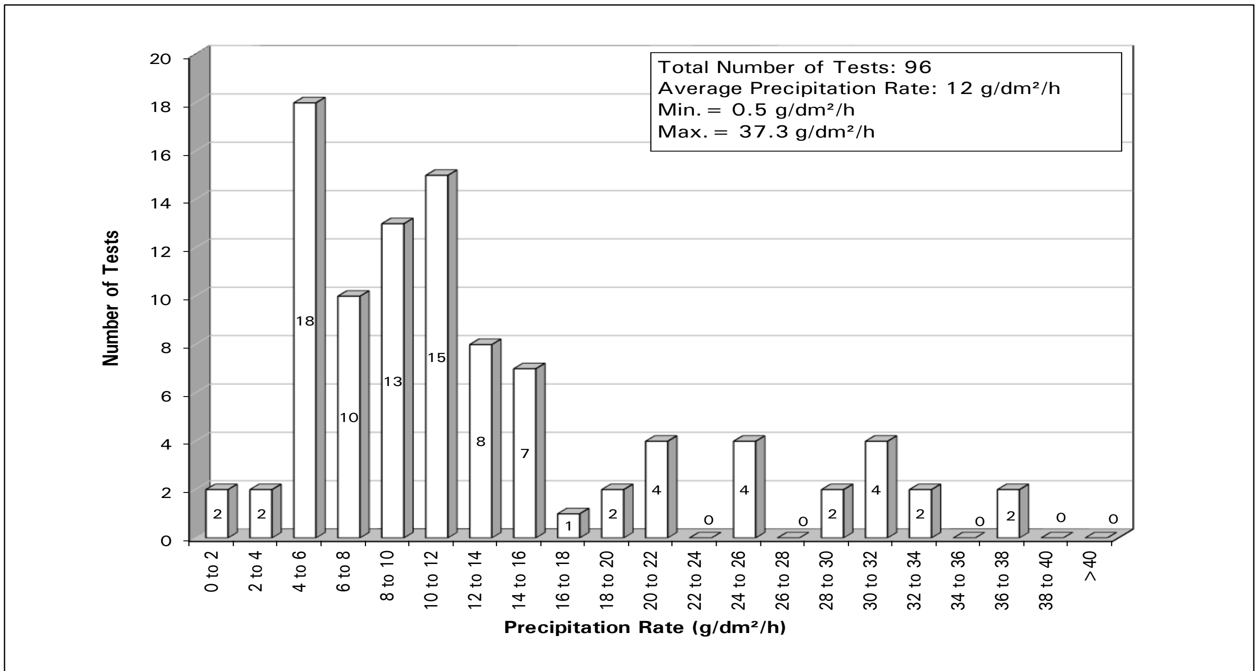

Figure 4.1: Distribution of Precipitation Rate – Natural Snow Tests

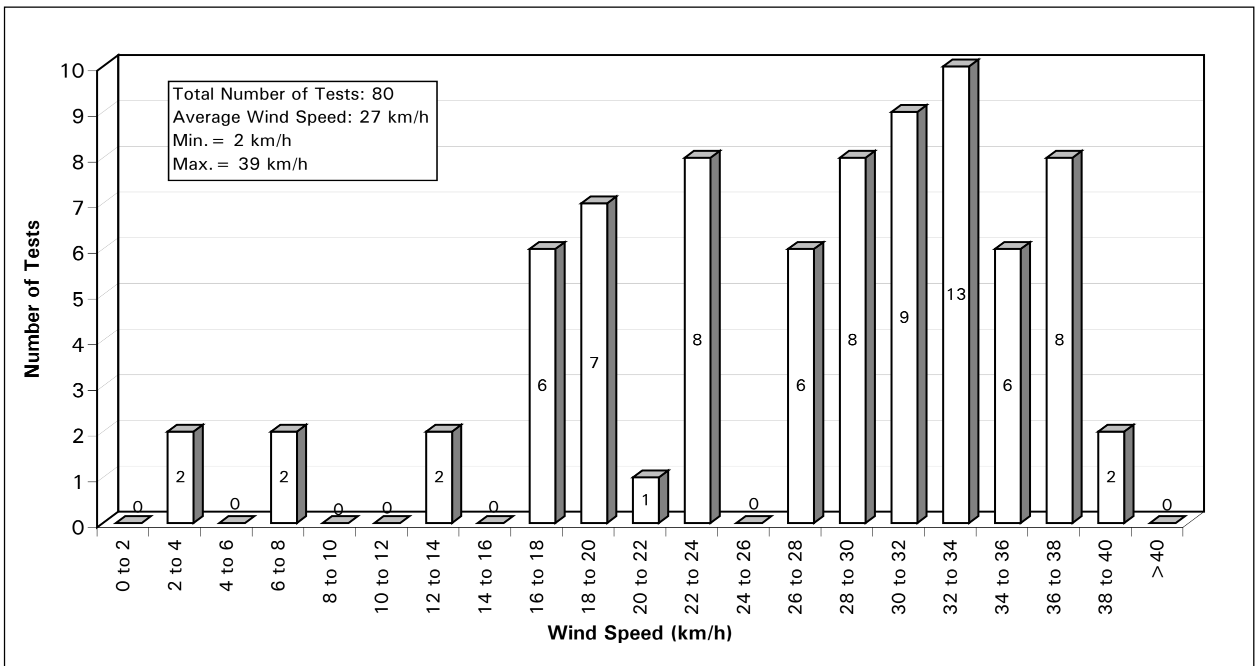

Figure 4.2: Distribution of Wind Speed – Natural Snow Tests

4.3 Distribution of Tests in Simulated Precipitation Conditions

During the 2001-02 season, 12 comparison tests (24 individual tests) were conducted under freezing precipitation conditions. These tests were carried out with two fluid brands and two fluid types, under freezing drizzle, freezing rain and freezing fog. In freezing drizzle and freezing rain, tests were carried out at -3°C and -10°C; in freezing fog they were carried out at -3°C and -14°C. Tests were conducted under the low and high precipitation rate limits specific to each weather condition.

During the 2004-05 season, 20 comparison tests (40 individual tests) were conducted under freezing precipitation conditions. These tests were carried out with four fluid brands and three fluid types, under freezing drizzle and freezing rain. For both conditions, tests were carried out at -3°C and -10°C under the low and high precipitation rate limits specific to each weather condition.

During the 2005-06 season, 28 comparison tests (56 individual tests) were conducted under freezing precipitation conditions. These tests were carried out with four fluid brands and three fluid types, under freezing drizzle and freezing rain. For both conditions, tests were carried out at -3°C and -10°C under the low and high precipitation rate limits specific to each weather condition.

In July 2007, 11 comparison tests (22 individual tests) were conducted under freezing drizzle and freezing rain. These tests were carried out with two fluid brands and two fluid types. Tests were carried out at -3°C and -10°C under the high precipitation rate limits.

A summary of the simulated freezing precipitation comparison tests conducted is given in Table 4.2.

Table 4.2: Comparative Tests Conducted in Simulated Freezing Precipitation

	-3°C		-10°C		-14°C		Total
	Low Rate	High Rate	Low Rate	High Rate	Low Rate	High Rate	
Freezing Drizzle	6	13	6	9	0	0	**34**
Freezing Rain	10	6	7	10	0	0	**33**
Freezing Fog	1	1	0	0	1	1	**4**
Total	**17**	**20**	**13**	**19**	**1**	**1**	**71**

4.4 Detailed Temperature Profiles

Several parameters were documented during each fluid endurance time test. Data collected pertaining to fluid dilution (fluid Brix) and fluid thickness was measured at set intervals for the duration of the test, while plate surface temperature was logged on an ongoing basis. These parameters were used to construct charts to better illustrate the test surface temperature profiles, as well as fluid thickness decay and fluid dilution.

Figure 4.3 and Figure 4.4 demonstrate the detailed temperature profile charts constructed for a comparative natural snow endurance time test conducted using a Type IV fluid applied to a box and to a standard plate, respectively. As seen on the charts, the surface temperature profile and the fluid dilution curve gradually approach an ultimate value, the ambient temperature. The point where the two curves come closest is the expected endurance time. In other words, freezing is expected to occur when the fluid freeze point and the surface temperature match.

For the purpose of this report, similar charts were completed for many of the tests conducted. The last column in the test logs indicates whether or not a chart was created for a given test. The charts are included in Appendix D.

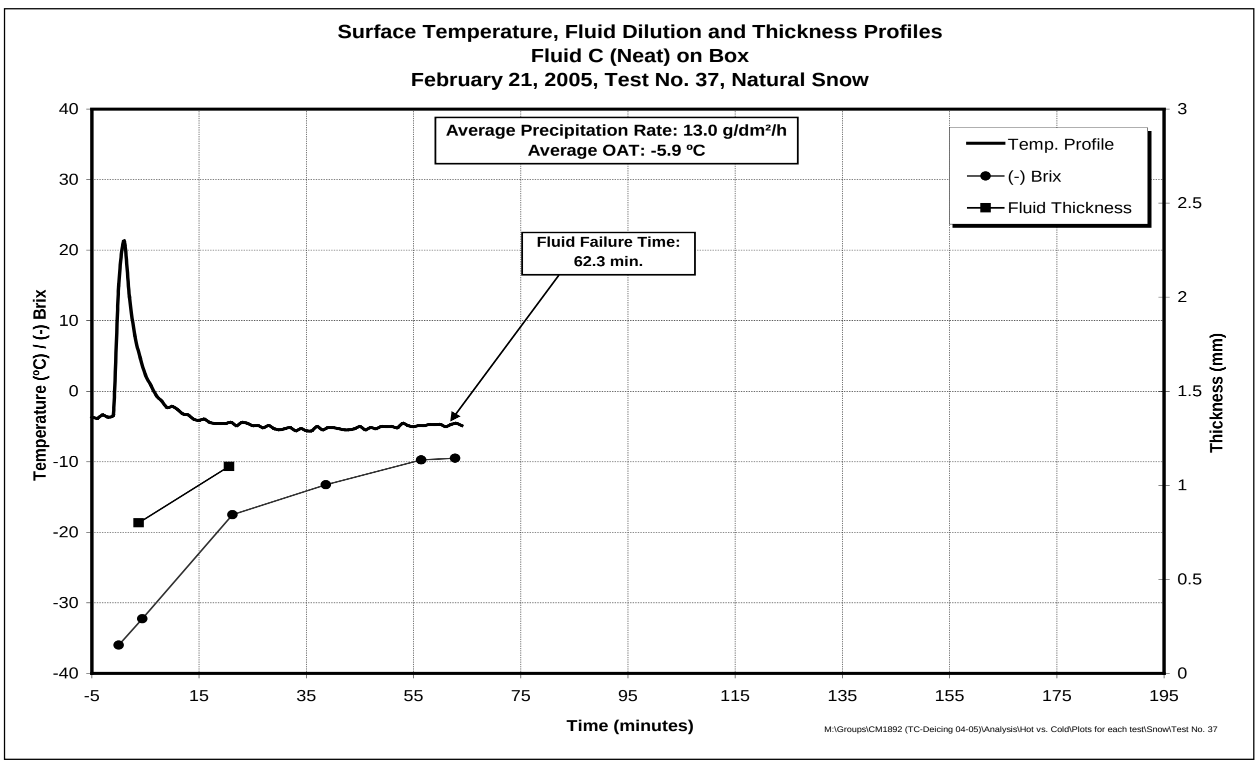

Figure 4.3: Sample Temperature Profiles – Heated Type IV Fluid on Box

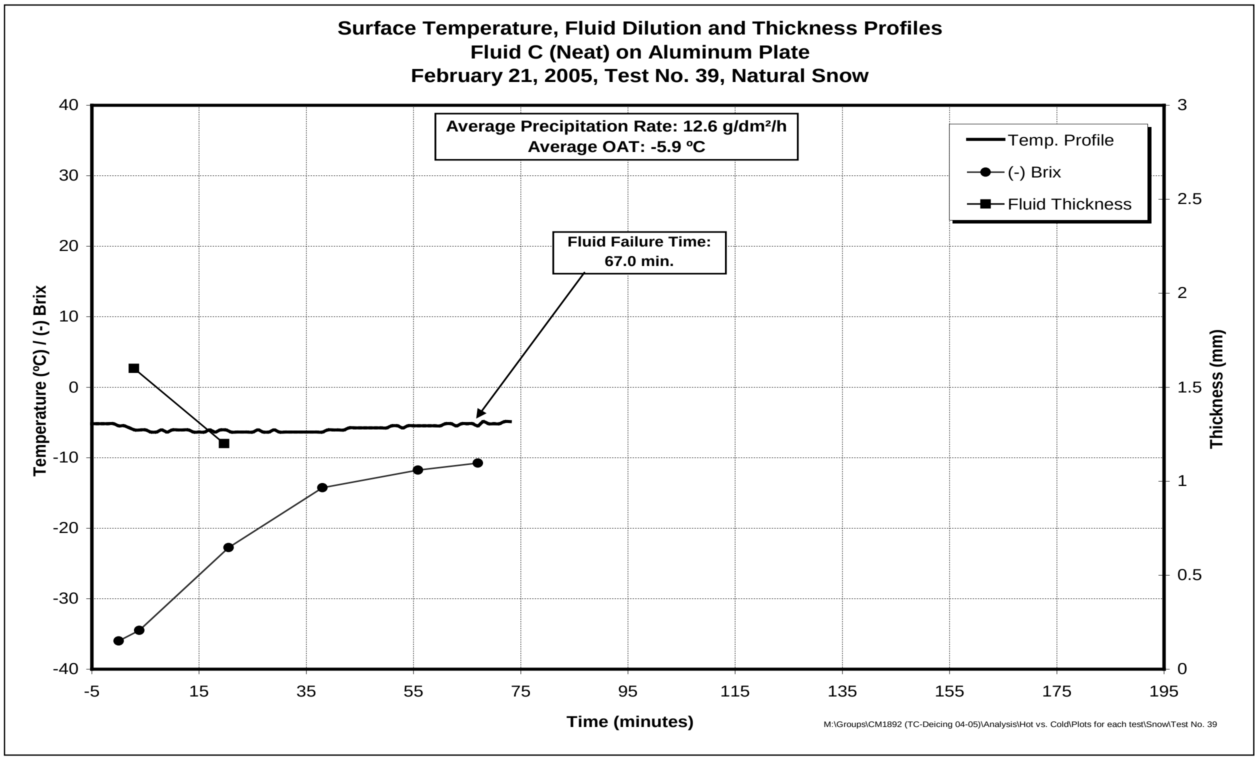

Figure 4.4: Sample Temperature Profiles – OAT Type IV Fluid on Plate

4.5 Test Logs

Two logs were created for each winter of testing: one for natural snow tests and one for simulated freezing precipitation tests. One log was created for the simulated precipitation tests conducted in July 2007. The seven logs are presented in Table 4.3 to Table 4.9 as follows:

a) Table 4.3: Natural Snow Tests 2001-02;
b) Table 4.4: Natural Snow Tests 2004-05;
c) Table 4.5: Natural Snow Tests 2005-06;
d) Table 4.6: Simulated Freezing Precipitation Tests 2001-02;
e) Table 4.7: Simulated Freezing Precipitation Tests 2004-05;
f) Table 4.8: Simulated Freezing Precipitation Tests 2005-06; and
g) Table 4.9: Simulated Freezing Precipitation Tests July 2007.

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 data set. 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 two precipitation pans at set intervals for the duration of the test session.
Test Temp:	The ambient temperature (in degrees Celsius) for the duration of the test (simulated freezing precipitation tests only).
OAT:	The average outside air temperature (in degrees Celsius) provided by 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.

Table 4.3: Natural Snow Tests 2001-02

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]
n/a	01-02	50%	Fluid F	II	OAT	Plate	6.1	31	0	unknown	3
n/a	01-02	50%	Fluid F	II	60	Box	9.2	31	0	unknown	3
n/a	01-02	75%	Fluid F	II	OAT	Plate	24.2	7	-14	unknown	3
n/a	01-02	75%	Fluid F	II	60	Box	32.3	7	-14	unknown	3
n/a	01-02	75%	Fluid F	II	OAT	Plate	29.1	8	-8	unknown	3
n/a	01-02	75%	Fluid F	II	60	Box	38.5	8	-8	unknown	3
n/a	01-02	75%	Fluid F	II	OAT	Plate	37.8	5	-8	unknown	3
n/a	01-02	75%	Fluid F	II	60	Box	46.0	5	-8	unknown	3
n/a	01-02	75%	Fluid F	II	OAT	Plate	56.0	5	-5	unknown	3
n/a	01-02	75%	Fluid F	II	60	Box	73.8	5	-5	unknown	3
n/a	01-02	75%	Fluid G	IV	OAT	Plate	55.9	4	-14	unknown	3
n/a	01-02	75%	Fluid G	IV	60	Box	124.2	4	-14	unknown	3
n/a	01-02	75%	Fluid I	II	OAT	Plate	36.1	5	-5	unknown	3
n/a	01-02	75%	Fluid I	II	60	Box	38.6	5	-5	unknown	3
n/a	01-02	50%	Fluid I	II	OAT	Plate	16.2	4	-4	unknown	3
n/a	01-02	50%	Fluid I	II	60	Box	20.3	4	-4	unknown	3

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

Table 4.4: Natural Snow Tests 2004-05

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]
2	Jan-06-05	100%	Fluid B	III	OAT	Plate	10.0	29	-12	32	3
3	Jan-06-05	100%	Fluid B	III	60	Box	7.0	27	-12	32	3
5	Jan-06-05	75%	Fluid B	III	OAT	Plate	8.0	32	-12	26	3
6	Jan-06-05	75%	Fluid B	III	60	Box	5.0	31	-12	26	3
7	Jan-06-05	75%	Fluid B	III	OAT	Plate	7.0	37	-12	30	3
9	Jan-06-05	75%	Fluid B	III	60	Box	5.5	37	-12	30	3
11	Feb-10-05	100%	Fluid B	III	OAT	Plate	36.0	6	-6	37	1
12	Feb-10-05	100%	Fluid B	III	60	Box	36.8	6	-6	37	1
14	Feb-10-05	75%	Fluid B	III	OAT	Plate	17.8	10	-5	37	1
15	Feb-10-05	75%	Fluid B	III	60	Box	18.8	10	-5	37	1
17	Feb-10-05	75%	Fluid C1	IV	OAT	Plate	57.0	9	-5	33	1
18	Feb-10-05	75%	Fluid C1	IV	60	Box	87.0	7	-5	33	1
19	Feb-21-05	75%	Fluid D	IV	60	Box	43.7	4	-14	28	1
21	Feb-21-05	75%	Fluid D	IV	OAT	Plate	30.5	4	-14	28	1
22	Feb-21-05	100%	Fluid D	IV	60	Box	100.3	6	-14	28	1
24	Feb-21-05	100%	Fluid D	IV	OAT	Plate	58.3	6	-14	28	1
25	Feb-21-05	75%	Fluid C1	IV	60	Box	46.2	4	-14	30	1
27	Feb-21-05	75%	Fluid C1	IV	OAT	Plate	39.3	4	-14	30	1
28	Feb-21-05	100%	Fluid E	IV	60	Box	173.5	4	-12 to -6	22	1
30	Feb-21-05	100%	Fluid E	IV	OAT	Plate	152.3	4	-12 to -8	22	1
31	Feb-21-05	75%	Fluid B	III	60	Box	12.0	13	-6	17	1
33	Feb-21-05	75%	Fluid B	III	OAT	Plate	16.0	14	-6	17	1
34	Feb-21-05	100%	Fluid B	III	60	Box	15.2	13	-6	17	1
36	Feb-21-05	100%	Fluid B	III	OAT	Plate	21.3	14	-6	17	1
37	Feb-21-05	100%	Fluid C1	IV	60	Box	62.3	13	-6	22	1
39	Feb-21-05	100%	Fluid C1	IV	OAT	Plate	67.0	13	-6	23	1
42	Mar-07-05	75%	Fluid C1	IV	60	Box	20.3	12	-13	28	1
44	Mar-07-05	75%	Fluid C1	IV	OAT	Plate	18.2	12	-13	28	1
45	Mar-07-05	100%	Fluid B	III	60	Box	30.0	8	-13	31	1
47	Mar-07-05	100%	Fluid B	III	OAT	Plate	31.1	8	-13	31	1
48	Mar-07-05	75%	Fluid B	III	60	Box	20.7	5	-12	32	1
50	Mar-07-05	75%	Fluid B	III	OAT	Plate	23.2	5	-12	32	1
51	Mar-07-05	100%	Fluid E	IV	60	Box	162.0	7	-11	32	1
53	Mar-07-05	100%	Fluid E	IV	OAT	Plate	111.2	5	-11	32	1
54	Mar-07-05	100%	Fluid B	III	60	Box	24.5	11	-11	28	1
56	Mar-07-05	100%	Fluid B	III	OAT	Plate	26.9	11	-11	28	1
57	Mar-07-05	75%	Fluid B	III	60	Box	15.9	10	-11	27	1
59	Mar-07-05	75%	Fluid B	III	OAT	Plate	17.6	9	-11	27	1

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

Table 4.5: Natural Snow Tests 2005-06

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]
3	Jan-04-06	100%	Fluid A	II	60	Box	61.2	7	-3	13	1
4	Jan-04-06	100%	Fluid A	II	OAT	Plate	86.2	7	-3	12	1
5	Jan-09-06	100%	Fluid D	IV	60	Box	79.0	14	-4	19	1
6	Jan-09-06	100%	Fluid D	IV	OAT	Plate	87.7	15	-4	19	1
7	Jan-09-06	75%	Fluid B	III	60	Box	9.8	18	-2	19	2
10	Jan-09-06	75%	Fluid B	III	OAT	Plate	10.8	18	-2	19	2
12	Jan-09-06	75%	Fluid A	II	60	Box	22.5	14	-2	18	1
13	Jan-09-06	75%	Fluid A	II	OAT	Plate	26.0	16	-2	18	1
15	Jan-21-06	75%	Fluid B	III	60	Box	13.7	20	-1	22	1
14	Jan-21-06	75%	Fluid B	III	OAT	Plate	13.0	20	-1	22	1
17	Jan-24-06	75%	Fluid B	III	60	Box	12.5	12	0	22	1
16	Jan-24-06	75%	Fluid B	III	OAT	Plate	11.5	12	0	22	1
19	Jan-24-06	75%	Fluid B	III	60	Box	16.8	11	-1	17	1
18	Jan-24-06	75%	Fluid B	III	OAT	Plate	12.5	11	-1	17	3
21	Jan-24-06	75%	Fluid D	IV	60	Box	74.8	7	-1	19	1
20	Jan-24-06	75%	Fluid D	IV	OAT	Plate	63.2	6	-1	20	1
24	Jan-29-06	100%	Fluid E	IV	60	Box	131.2	19	-5	37	1
25	Jan-29-06	100%	Fluid E	IV	OAT	Plate	61.8	21	-6	36	1
26	Jan-29-06	100%	Fluid B	III	60	Box	23.5	8	-4	35	1
27	Jan-29-06	100%	Fluid B	III	OAT	Plate	17.0	7	-4	30	1
28	Jan-29-06	100%	Fluid D	IV	60	Box	118.2	10	-4	33	3
29	Jan-29-06	100%	Fluid D	IV	OAT	Plate	88.5	11	-4	34	3
30	Jan-29-06	75%	Fluid D	IV	60	Box	62.8	11	-4	33	1
31	Jan-29-06	75%	Fluid D	IV	OAT	Plate	48.2	10	-4	33	1
32	Jan-29-06	100%	Fluid E	IV	60	Box	194.0	9	-5	35	1
33	Jan-29-06	100%	Fluid E	IV	OAT	Plate	103.3	11	-5	34	1
34	Feb-16-06	75%	Fluid C2	II	60	Box	13.9	31	-9	30	1
35	Feb-16-06	75%	Fluid C2	II	OAT	Plate	14.0	31	-9	30	1
36	Feb-16-06	100%	Fluid C2	II	60	Box	20.6	23	-9	32	1
37	Feb-16-06	100%	Fluid C2	II	OAT	Plate	17.6	23	-9	32	1
38	Feb-16-06	75%	Fluid C2	II	60	Box	15.2	25	-9	27	3
39	Feb-16-06	75%	Fluid C2	II	OAT	Plate	13.4	25	-9	27	3
42	Feb-23-06	50%	Fluid D	IV	60	Box	19.6	9	-1	2	1
43	Feb-23-06	50%	Fluid D	IV	OAT	Plate	12.1	10	-1	2	1
44	Feb-23-06	50%	Fluid C2	II	60	Box	130.2	1	-4	6	1
45	Feb-23-06	50%	Fluid C2	II	OAT	Plate	104.7	1	-3	6	1
46	Feb-25-06	100%	Fluid B	III	60	Box	22.5	8	-14	37	1
47	Feb-25-06	100%	Fluid B	III	OAT	Plate	24.2	8	-14	37	1
48	Feb-25-06	100%	Fluid C2	II	60	Box	24.7	11	-14	39	1
49	Feb-25-06	100%	Fluid C2	II	OAT	Plate	25.9	11	-14	39	1
50	Mar-03-06	100%	Fluid C2	II	60	Box	99.8	2	-9	34	1
51	Mar-03-06	100%	Fluid C2	II	OAT	Plate	100.8	3	-9	34	1

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

Table 4.6: Simulated Freezing Precipitation Tests 2001-02

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]
n/a	01-02	75%	Fluid H	IV	60	Plate	47.3	5	-10	ZD	3
n/a	01-02	75%	Fluid H	IV	OAT	Plate	56.0	5	-10	ZD	3
n/a	01-02	75%	Fluid H	IV	60	Plate	24.6	13	-10	ZD	3
n/a	01-02	75%	Fluid H	IV	OAT	Plate	21.5	13	-10	ZD	3
n/a	01-02	75%	Fluid I	II	60	Plate	21.3	13	-3	ZD	3
n/a	01-02	75%	Fluid I	II	OAT	Plate	20.5	13	-3	ZD	3
n/a	01-02	50%	Fluid I	II	60	Plate	24.2	5	-3	ZD	3
n/a	01-02	50%	Fluid I	II	OAT	Plate	15.1	5	-3	ZD	3
n/a	01-02	75%	Fluid H	IV	60	Plate	72.5	2	-14	ZF	3
n/a	01-02	75%	Fluid H	IV	OAT	Plate	72.0	2	-14	ZF	3
n/a	01-02	75%	Fluid H	IV	60	Plate	38.0	5	-14	ZF	3
n/a	01-02	75%	Fluid H	IV	OAT	Plate	34.5	5	-14	ZF	3
n/a	01-02	50%	Fluid I	II	60	Plate	15.7	5	-3	ZF	3
n/a	01-02	50%	Fluid I	II	OAT	Plate	16.7	5	-3	ZF	3
n/a	01-02	50%	Fluid I	II	60	Plate	28.5	2	-3	ZF	3
n/a	01-02	50%	Fluid I	II	OAT	Plate	26.5	2	-3	ZF	3
n/a	01-02	50%	Fluid H	IV	60	Plate	17.8	25	-3	ZR	3
n/a	01-02	50%	Fluid H	IV	OAT	Plate	10.8	25	-3	ZR	3
n/a	01-02	50%	Fluid H	IV	60	Plate	21.0	13	-3	ZR	3
n/a	01-02	50%	Fluid H	IV	OAT	Plate	14.0	13	-3	ZR	3
n/a	01-02	75%	Fluid I	II	60	Plate	11.2	13	-10	ZR	3
n/a	01-02	75%	Fluid I	II	OAT	Plate	13.7	13	-10	ZR	3
n/a	01-02	75%	Fluid I	II	60	Plate	13.2	25	-10	ZR	3
n/a	01-02	75%	Fluid I	II	OAT	Plate	10.7	25	-10	ZR	3

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

Table 4.7: Simulated Freezing Precipitation Tests 2004-05

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	Apr-05-05	100%	Fluid B	III	OAT	Plate	21.1	5	-10	ZD	1
2	Apr-05-05	100%	Fluid B	III	60	Plate	15.8	5	-10	ZD	1
3	Apr-05-05	75%	Fluid C1	IV	OAT	Plate	14.5	5	-10	ZD	1
4	Apr-05-05	75%	Fluid C1	IV	60	Plate	10.5	5	-10	ZD	1
6	Apr-05-05	75%	Fluid A	II	OAT	Plate	26.3	13	-10	ZD	1
7	Apr-05-05	75%	Fluid A	II	60	Plate	21.6	13	-10	ZD	1
8	Apr-05-05	75%	Fluid B	III	OAT	Plate	8.7	13	-11	ZD	1
9	Apr-05-05	75%	Fluid B	III	60	Plate	8.2	13	-11	ZD	1
10	Apr-05-05	100%	Fluid D	IV	OAT	Plate	29.3	13	-10	ZD	1
11	Apr-05-05	100%	Fluid D	IV	60	Plate	32.0	13	-10	ZD	1
13	Apr-05-05	100%	Fluid A	II	OAT	Plate	24.8	25	-10	ZR	1
14	Apr-05-05	100%	Fluid A	II	60	Plate	19.8	25	-10	ZR	1
15	Apr-05-05	75%	Fluid A	II	OAT	Plate	14.3	25	-10	ZR	1
16	Apr-05-05	75%	Fluid A	II	60	Plate	11.3	25	-10	ZR	1
19	Apr-06-05	100%	Fluid B	III	OAT	Plate	15.5	13	-11	ZR	1
20	Apr-06-05	100%	Fluid B	III	60	Plate	9.5	13	-11	ZR	1
23	Apr-06-05	75%	Fluid B	III	OAT	Plate	10.8	13	-11	ZR	1
24	Apr-06-05	75%	Fluid B	III	60	Plate	9.0	13	-11	ZR	1
26	Apr-06-05	75%	Fluid B	III	OAT	Plate	11.4	13	-3	ZR	1
27	Apr-06-05	75%	Fluid B	III	60	Plate	14.9	13	-3	ZR	1
28	Apr-06-05	50%	Fluid A	II	OAT	Plate	9.7	13	-3	ZR	1
29	Apr-06-05	50%	Fluid A	II	60	Plate	15.1	13	-3	ZR	1
30	Apr-06-05	50%	Fluid B	III	OAT	Plate	7.8	13	-3	ZR	1
31	Apr-06-05	50%	Fluid B	III	60	Plate	16.7	13	-3	ZR	1
32	Apr-06-05	75%	Fluid A	II	OAT	Plate	14.2	25	-3	ZR	1
33	Apr-06-05	75%	Fluid A	II	60	Plate	16.3	25	-3	ZR	1
34	Apr-06-05	100%	Fluid B	III	OAT	Plate	10.5	25	-3	ZR	1
35	Apr-06-05	100%	Fluid B	III	60	Plate	13.8	25	-3	ZR	1
36	Apr-06-05	75%	Fluid C1	IV	OAT	Plate	32.5	25	-3	ZR	1
37	Apr-06-05	75%	Fluid C1	IV	60	Plate	22.0	25	-3	ZR	1
41	Apr-07-05	50%	Fluid A	II	OAT	Plate	11.8	5	-3	ZD	1
42	Apr-07-05	50%	Fluid A	II	60	Plate	16.8	5	-3	ZD	1
43	Apr-07-05	50%	Fluid B	III	OAT	Plate	9.1	5	-3	ZD	1
44	Apr-07-05	50%	Fluid B	III	60	Plate	16.1	5	-3	ZD	1
45	Apr-07-05	75%	Fluid B	III	OAT	Plate	8.8	13	-3	ZD	1
46	Apr-07-05	75%	Fluid B	III	60	Plate	16.6	13	-3	ZD	1
47	Apr-07-05	50%	Fluid A	II	OAT	Plate	6.8	13	-3	ZD	1
48	Apr-07-05	50%	Fluid A	II	60	Plate	16.3	13	-3	ZD	1
49	Apr-07-05	50%	Fluid D	IV	OAT	Plate	9.2	13	-3	ZD	1
50	Apr-07-05	50%	Fluid D	IV	60	Plate	16.2	13	-3	ZD	1

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

Table 4.8: Simulated Freezing Precipitation Tests 2005-06

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]
5	Apr-04-06	100%	Fluid B	III	60	Plate	18.7	14	-3	ZR	1
6	Apr-04-06	100%	Fluid B	III	OAT	Plate	14.8	12	-3	ZR	1
7	Apr-04-06	50%	Fluid B	III	60	Plate	17.7	14	-3	ZR	1
8	Apr-04-06	50%	Fluid B	III	OAT	Plate	8.2	14	-3	ZR	1
9	Apr-04-06	100%	Fluid D	IV	60	Plate	43.0	14	-3	ZR	1
10	Apr-04-06	100%	Fluid D	IV	OAT	Plate	51.9	14	-3	ZR	1
13	Apr-04-06	50%	Fluid D	IV	60	Plate	18.8	13	-3	ZR	1
14	Apr-04-06	50%	Fluid D	IV	OAT	Plate	11.0	13	-3	ZR	1
15	Apr-04-06	50%	Fluid C2	II	60	Plate	20.2	13	-3	ZR	1
16	Apr-04-06	50%	Fluid C2	II	OAT	Plate	12.0	13	-3	ZR	1
17	Apr-05-06	100%	Fluid C2	II	60	Plate	25.0	14	-10	ZR	1
18	Apr-05-06	100%	Fluid C2	II	OAT	Plate	16.8	13	-10	ZR	1
19	Apr-05-06	100%	Fluid B	III	60	Plate	12.8	13	-10	ZR	1
20	Apr-05-06	100%	Fluid B	III	OAT	Plate	13.0	13	-10	ZR	1
21	Apr-05-06	75%	Fluid D	IV	60	Plate	23.2	13	-10	ZR	2
22	Apr-05-06	75%	Fluid D	IV	OAT	Plate	21.8	13	-10	ZR	2
23	Apr-05-06	100%	Fluid C2	II	60	Plate	46.7	5	-10	ZD	2
24	Apr-05-06	100%	Fluid C2	II	OAT	Plate	39.5	5	-10	ZD	2
27	Apr-06-06	75%	Fluid D	IV	60	Plate	40.8	13	-10	ZD	3
28	Apr-06-06	75%	Fluid D	IV	OAT	Plate	48.8	12	-10	ZD	3
29	Apr-05-06	100%	Fluid E	IV	60	Plate	40.8	23	-10	ZR	2
30	Apr-05-06	100%	Fluid E	IV	OAT	Plate	36.5	25	-10	ZR	2
31	Apr-05-06	100%	Fluid B	III	60	Plate	12.0	25	-10	ZR	1
32	Apr-05-06	100%	Fluid B	III	OAT	Plate	10.0	25	-10	ZR	1
33	Apr-05-06	75%	Fluid D	IV	60	Plate	15.7	25	-10	ZR	2
34	Apr-05-06	75%	Fluid D	IV	OAT	Plate	14.2	24	-10	ZR	2
35	Apr-06-06	100%	Fluid E	IV	60	Plate	80.3	13	-3	ZD	2
36	Apr-06-06	100%	Fluid E	IV	OAT	Plate	62.8	13	-3	ZD	2
37	Apr-06-06	50%	Fluid C2	II	60	Plate	24.5	13	-3	ZD	2
38	Apr-06-06	50%	Fluid C2	II	OAT	Plate	14.0	13	-3	ZD	2
39	Apr-06-06	50%	Fluid D	IV	60	Plate	21.4	13	-3	ZD	2
40	Apr-06-06	50%	Fluid D	IV	OAT	Plate	11.0	13	-3	ZD	2
41	Apr-06-06	75%	Fluid B	III	60	Plate	25.3	13	-3	ZD	2
42	Apr-06-06	75%	Fluid B	III	OAT	Plate	11.0	13	-3	ZD	2
43	Apr-06-06	75%	Fluid D	IV	60	Plate	29.5	13	-3	ZD	1
44	Apr-06-06	75%	Fluid D	IV	OAT	Plate	31.0	13	-3	ZD	1
45	Apr-06-06	75%	Fluid B	III	60	Plate	11.5	14	-3	ZD	2
46	Apr-06-06	75%	Fluid B	III	OAT	Plate	9.0	14	-3	ZD	2
49	Apr-07-06	50%	Fluid B	III	60	Plate	21.5	5	-3	ZD	2
50	Apr-07-06	50%	Fluid B	III	OAT	Plate	12.5	5	-3	ZD	2
51	Apr-07-06	100%	Fluid C2	II	60	Plate	82.8	5	-3	ZD	2
52	Apr-07-06	100%	Fluid C2	II	OAT	Plate	72.8	5	-3	ZD	2
55	Apr-07-06	100%	Fluid E	IV	60	Plate	164.0	5	-3	ZD	2

Table 4.8: Simulated Freezing Precipitation Tests 2005-06 (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]
56	Apr-07-06	100%	Fluid E	IV	OAT	Plate	131.0	5	-3	ZD	2
57	Apr-13-06	100%	Fluid D	IV	60	Plate	33.6	23	-3	ZR	2
58	Apr-13-06	100%	Fluid D	IV	OAT	Plate	15.8	24	-3	ZR	2
61	Apr-13-06	50%	Fluid D	IV	60	Plate	19.0	23	-3	ZR	2
62	Apr-13-06	50%	Fluid D	IV	OAT	Plate	7.9	24	-3	ZR	2
63	Apr-25-06	75%	Fluid D	IV	60	Plate	25.3	13	-10	ZR	2
64	Apr-25-06	75%	Fluid D	IV	OAT	Plate	21.2	13	-10	ZR	2
65	Apr-25-06	100%	Fluid B	III	60	Plate	24.4	5	-10	ZD	2
66	Apr-25-06	100%	Fluid B	III	OAT	Plate	11.0	5	-10	ZD	2
67	Apr-25-06	75%	Fluid D	IV	60	Plate	46.8	5	-10	ZD	1
68	Apr-25-06	75%	Fluid D	IV	OAT	Plate	50.7	5	-10	ZD	1
69	Apr-26-06	100%	Fluid D	IV	60	Plate	46.3	13	-3	ZR	1
70	Apr-26-06	100%	Fluid D	IV	OAT	Plate	56.2	13	-3	ZR	1

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

Table 4.9: Simulated Freezing Precipitation Tests July 2007

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]
HC1a	Jul-18-07	100%	Fluid A	II	OAT	Plate	36.3	13	-10	ZD	2
HC1b	Jul-18-07	100%	Fluid A	II	60	Plate	33.8	13	-10	ZD	2
HC2a	Jul-18-07	75%	Fluid A	II	OAT	Plate	18.7	13	-10	ZD	2
HC2b	Jul-18-07	75%	Fluid A	II	60	Plate	14.8	13	-10	ZD	2
HC3a	Jul-18-07	100%	Fluid A	II	OAT	Plate	22.3	25	-10	ZR	2
HC3b	Jul-18-07	100%	Fluid A	II	60	Plate	18.3	25	-10	ZR	2
HC4a	Jul-18-07	75%	Fluid A	II	OAT	Plate	12.3	25	-10	ZR	2
HC4b	Jul-18-07	75%	Fluid A	II	60	Plate	10.5	25	-10	ZR	2
HC5a	Jul-19-07	100%	Fluid B	III	OAT	Plate	15.7	13	-3	ZD	2
HC5b	Jul-19-07	100%	Fluid B	III	60	Plate	14.3	13	-3	ZD	2
HC6a	Jul-19-07	75%	Fluid B	III	OAT	Plate	10.6	13	-3	ZD	2
HC6b	Jul-19-07	75%	Fluid B	III	60	Plate	16.0	13	-3	ZD	2
HC7a	Jul-19-07	50%	Fluid B	III	OAT	Plate	6.3	13	-3	ZD	2
HC7b	Jul-19-07	50%	Fluid B	III	60	Plate	15.0	13	-3	ZD	2
HC8a	Jul-18-07	100%	Fluid B	III	OAT	Plate	9.3	13	-10	ZD	2
HC8b	Jul-18-07	100%	Fluid B	III	60	Plate	9.2	13	-10	ZD	2
HC9a	Jul-18-07	75%	Fluid B	III	OAT	Plate	6.7	13	-10	ZD	2
HC9b	Jul-18-07	75%	Fluid B	III	60	Plate	9.4	13	-10	ZD	2
HC10a	Jul-18-07	100%	Fluid B	III	OAT	Plate	6.7	25	-10	ZR	2
HC10b	Jul-18-07	100%	Fluid B	III	60	Plate	9.1	25	-10	ZR	2
HC11a	Jul-18-07	75%	Fluid B	III	OAT	Plate	5.3	25	-10	ZR	2
HC11b	Jul-18-07	75%	Fluid B	III	60	Plate	8.5	25	-10	ZR	2

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

5. ANALYSIS AND OBSERVATIONS

In this section, the consolidated data set is analysed and discussed.

5.1 General Observations

To compare the performance of fluids applied heated to fluids applied at ambient temperature, the test data was plotted on scatter plots with the heated endurance time on the y-axis and the ambient endurance time on the x-axis. Natural snow test data is plotted in Figure 5.1; freezing precipitation test data is plotted in Figure 5.2.

Data points falling above the 1:1 line indicate tests where the endurance time of fluid applied heated exceeded that of fluid applied at ambient temperature. Data points falling below the 1:1 line indicate tests where the heated endurance time was shorter than the ambient endurance time.

In general, endurance times of heated fluids were longer than fluids applied at ambient temperature. There are exceptions, and an in-depth analysis of the data was conducted to examine which variables caused the variation in the heated fluid performance.

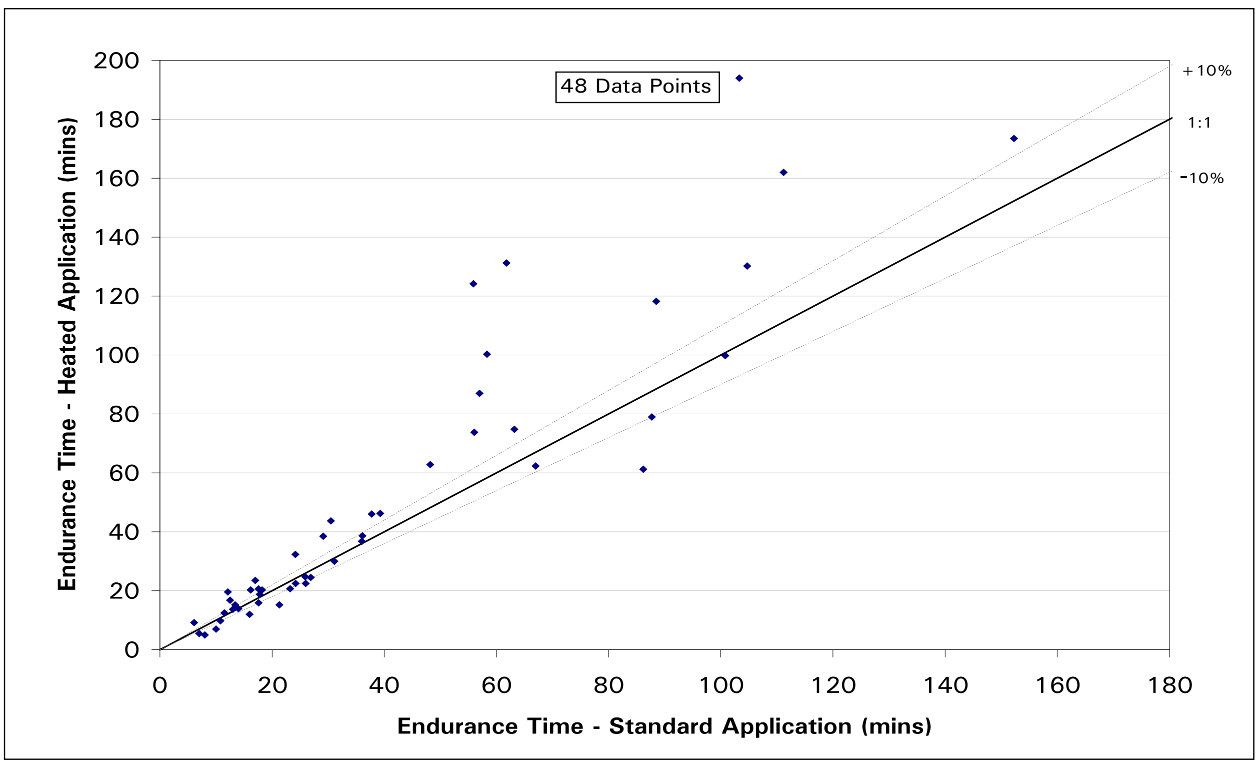

Figure 5.1: Endurance Times in Natural Snow

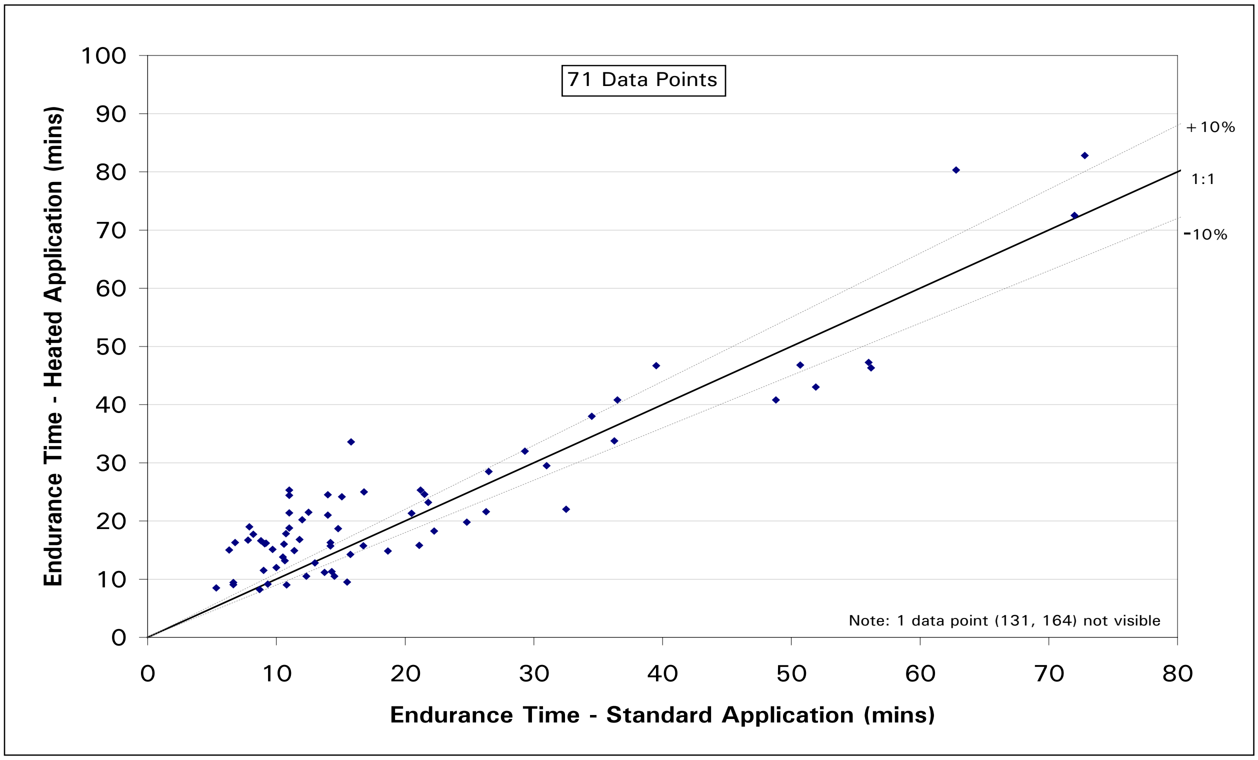

Figure 5.2: Endurance Times in Freezing Precipitation

5.2 Endurance Time Ratio Analysis

The ratio of heated endurance time to ambient endurance time was calculated for each test. A ratio above 100 percent indicates heated endurance times were longer; a ratio below 100 percent indicates ambient endurance times were longer. This data was then grouped by fluid, ambient temperature, precipitation type and precipitation rate, and average ratios were calculated for subgroups within each group. Although the distribution of the data within each group results, in some cases, in small numbers of test points, this analysis gives a useful overview of the influence of heated fluid on endurance times.

5.2.1 Entire Data Set

The average ratios are given in Table 5.1 for the entire data set, as well as for specific groups of data. Generally, it was found that heated endurance times were longer than ambient endurance times (125 percent). However, standard deviations were very high (from 7 to 50 percent) showing that there is a significant amount of variation in the data. As another measure of the relative performance of heated fluids, the numbers of tests with ratios below 90 percent and below 80 percent (shown in red) are also given in Table 5.1. Further details from this analysis are provided in Appendix E.

Table 5.1: Ratio Analysis Summary

All Data	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
All Years	125%	43%	82%	119	24	20%	13	11%

By Fluid	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
Fluid A	107%	48%	59%	13	8	62%	4	**31%**
Fluid B	124%	49%	75%	41	9	22%	7	**17%**
Fluid C1	102%	32%	71%	6	2	33%	2	**33%**
Fluid C2	125%	27%	97%	11	0	0%	0	0%
Fluid D	135%	46%	89%	21	3	14%	0	0%
Fluid E	146%	39%	107%	7	0	0%	0	0%
Fluid F	134%	10%	124%	5	0	0%	0	0%
Fluid G	222%	n/a	n/a	1	0	0%	0	0%
Fluid H	121%	31%	90%	6	1	17%	0	0%
Fluid I	113%	24%	89%	8	1	13%	0	0%

By Precip Type	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
Snow	117%	35%	82%	48	8	17%	6	13%
Freezing Drizzle	135%	50%	85%	34	6	18%	3	9%
Freezing Rain	128%	47%	81%	33	10	30%	4	12%
Freezing Fog	103%	7%	96%	4	0	0%	0	0%

By Temperature	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
Above -3°C	120%	27%	92%	8	1	13%	0	0%
-3°C	151%	50%	101%	38	4	11%	2	5%
-4 to -9°C	121%	33%	88%	22	2	9%	2	9%
-10°C	108%	32%	76%	28	10	36%	5	**18%**
Below -10°C	107%	37%	70%	23	7	30%	4	**17%**

By Rate	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
<10 g/dm^2/h	123%	36%	88%	39	5	13%	3	8%
10 to 24 g/dm^2/h	131%	49%	82%	61	11	18%	4	7%
>24 g/dm^2/h	107%	32%	75%	19	8	42%	6	**32%**

The results below were grouped and examined by several variables.

1. **Fluid Brand:** In this examination, the average ratio for each fluid was above 100 percent. There were no tests conducted with fluids C2, D, E, F, G, H or I where heated endurance times were less than 80 percent of the ambient temperature endurance times. However, there were tests with fluids A, B and C1 where heated endurance time was less than 80 percent of the ambient temperature endurance time. Test results for fluids A and B are examined further in a subsequent section. Fluid C1 was an experimental fluid (see Subsection 3.7) and is not examined further.
2. **Precipitation Type:** The analysis by precipitation type shows, on average, heating fluid causes a lower enhancement in endurance times in snow compared to freezing drizzle and freezing rain.
3. **Ambient Air Temperature:** Analysis by ambient air temperature shows that tests conducted in colder temperatures resulted in fewer cases where heated fluid produced endurance times longer than fluid at ambient temperature.
4. **Precipitation Rate:** In high precipitation rates (above 24 $g/dm^2/h$), 32 percent of the heated fluid endurance times were 20 percent shorter than those of ambient temperature endurance times. At lower precipitation rates, the heated fluid times nearly always exceeded those of the ambient temperature application.

5.2.2 Data Set with Type III Fluid Excluded

The decision on which protocol to use for Type III testing may be made independently from the decision for Type II/IV testing. This is due to the possibility of Type III fluid being used in the same manner as Type I fluid in operations in the future (see Subsection 1.2).

As a result, the Type III fluid results were removed from the data set and the analysis shown in Table 5.1 was repeated. Table 5.2 shows the analysis with the Type III fluid (Fluid B) results excluded.

The average heated versus ambient endurance time ratio remained the same (125 percent), but it was noted that heated applications of Type II and IV fluids were less sensitive to reduction in endurance time than were Type III fluids.

Table 5.2: Ratio Analysis Summary, Type III Data Excluded

All Data	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
All Years	125%	40%	85%	78	15	19%	6	8%

By Fluid	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
Fluid A	107%	48%	59%	13	8	62%	4	**31%**
Fluid C1	102%	32%	71%	6	2	33%	2	**33%**
Fluid C2	125%	27%	97%	11	0	0%	0	0%
Fluid D	135%	46%	89%	21	3	14%	0	0%
Fluid E	146%	39%	107%	7	0	0%	0	0%
Fluid F	134%	10%	124%	5	0	0%	0	0%
Fluid G	222%	n/a	n/a	1	0	0%	0	0%
Fluid H	121%	31%	90%	6	1	17%	0	0%
Fluid I	113%	24%	89%	8	1	13%	0	0%

By Precip Type	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
Snow	130%	35%	95%	31	2	6%	1	3%
Freezing Drizzle	123%	44%	79%	21	5	24%	2	10%
Freezing Rain	125%	47%	78%	22	8	36%	3	14%
Freezing Fog	103%	7%	96%	4	0	0%	0	0%

By Temperature	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
Above -3°C	129%	34%	95%	4	1	25%	0	0%
-3°C	142%	49%	92%	25	4	16%	2	8%
-4 to -9°C	128%	32%	96%	17	0	0%	0	0%
-10°C	99%	20%	79%	20	9	45%	4	**20%**
Below -10°C	129%	38%	91%	12	1	8%	0	0%

By Rate	**Average Heated ET/ OAT ET**	**Standard Deviation**	**minus 1 sigma**	**# Points**	**# Points <90%**	**% Points <90%**	**# Points <80%**	**% Points <80%**
<10 $g/dm^2/h$	123%	31%	92%	29	3	10%	2	7%
10 to 24 $g/dm^2/h$	133%	47%	86%	37	7	19%	1	3%
>24 $g/dm^2/h$	106%	30%	76%	12	5	42%	3	**25%**

5.3 Examination by Fluid Strength and Type

Figure 5.3 and Figure 5.4 examine the influence of fluid strength and fluid type on heated endurance times. In these figures, the percentage of tests where heated endurance time was less than 80 percent of the ambient endurance time (Figure 5.3) and less than 90 percent of the ambient endurance time (Figure 5.4) are presented.

The data is presented in decision trees, with the data first branched by fluid-strength, then by fluid type, and finally by ambient air temperature.

Figure 5.3 shows that at 50/50 fluid strength, a heated fluid application consistently produced longer endurance times than the standard (ambient fluid) application. This is a direct result of elevated temperature of the test surface. As demonstrated in the temperature profile charts, the short endurance times of 50/50 fluids position their normal failure time within the period when the surface temperature is still elevated, which produces a prolonging effect. This is the same mechanism as seen with Type I fluids.

The influence of surface temperature on endurance time does not apply to other fluid dilutions where the time of failure is well beyond the time that the surface temperature has returned to ambient. In cases where these longer endurance times were affected by application of heated fluid, the cause must therefore be related to other factors; possibly altered thickness of the initial fluid layer, faster thinning, change to rate of dilution, delay in onset of failure on the fluid surface, the visual failure call, etc.

For Neat and 75/25 fluid strengths:

- Heated Type III fluid did not perform as well as unheated fluid in some tests at colder ambient air temperatures; and
- Heated Types II and IV fluids performed better at cold ambient air temperatures as compared to milder temperatures.

As Type II and Type IV test data each included several fluids, and as Table 5.1 indicated some variance in performance between different fluids of the same type, an analysis of individual fluids was undertaken.

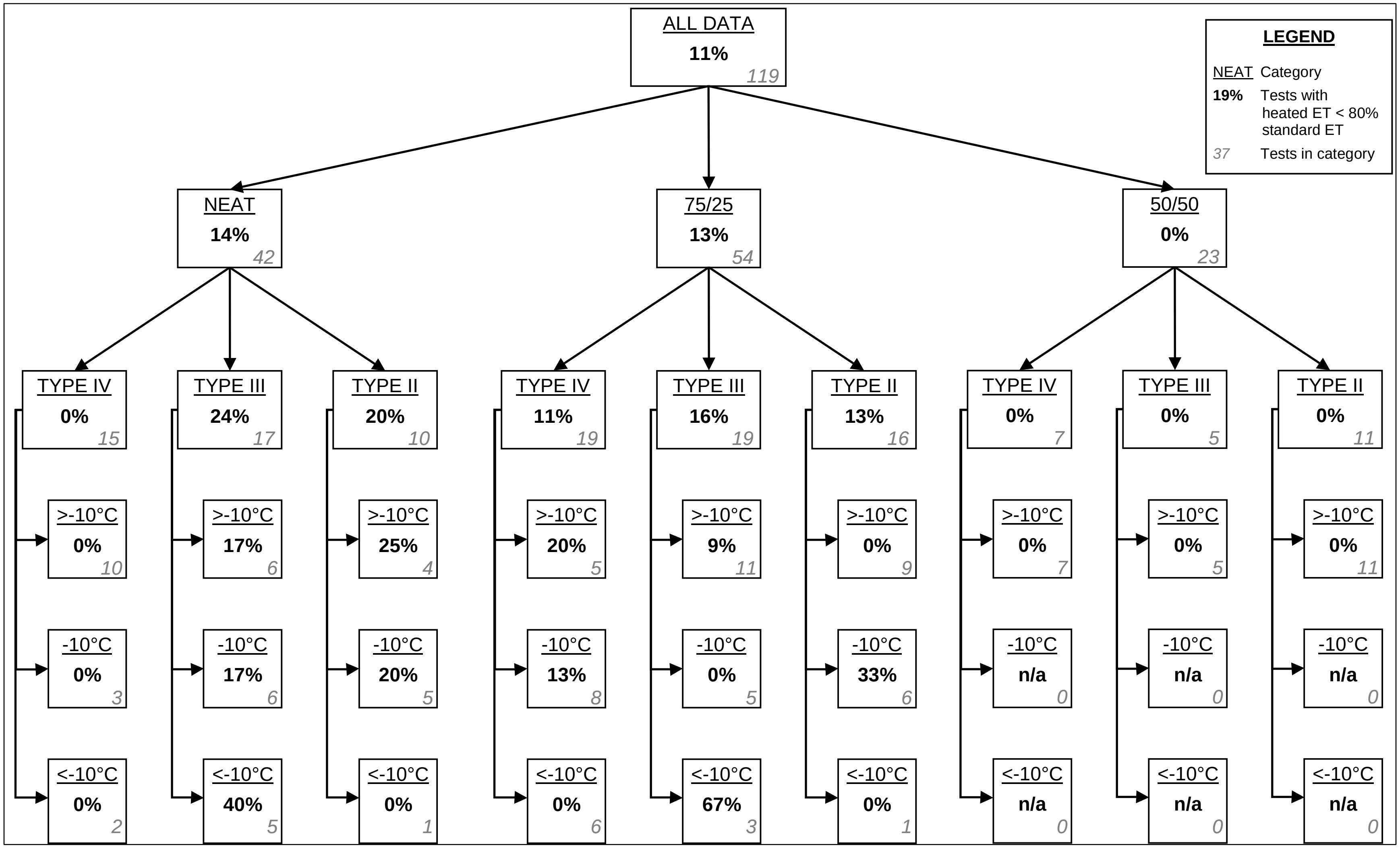

Figure 5.3: Decision Tree for Heated ET < 80 percent of Standard ET

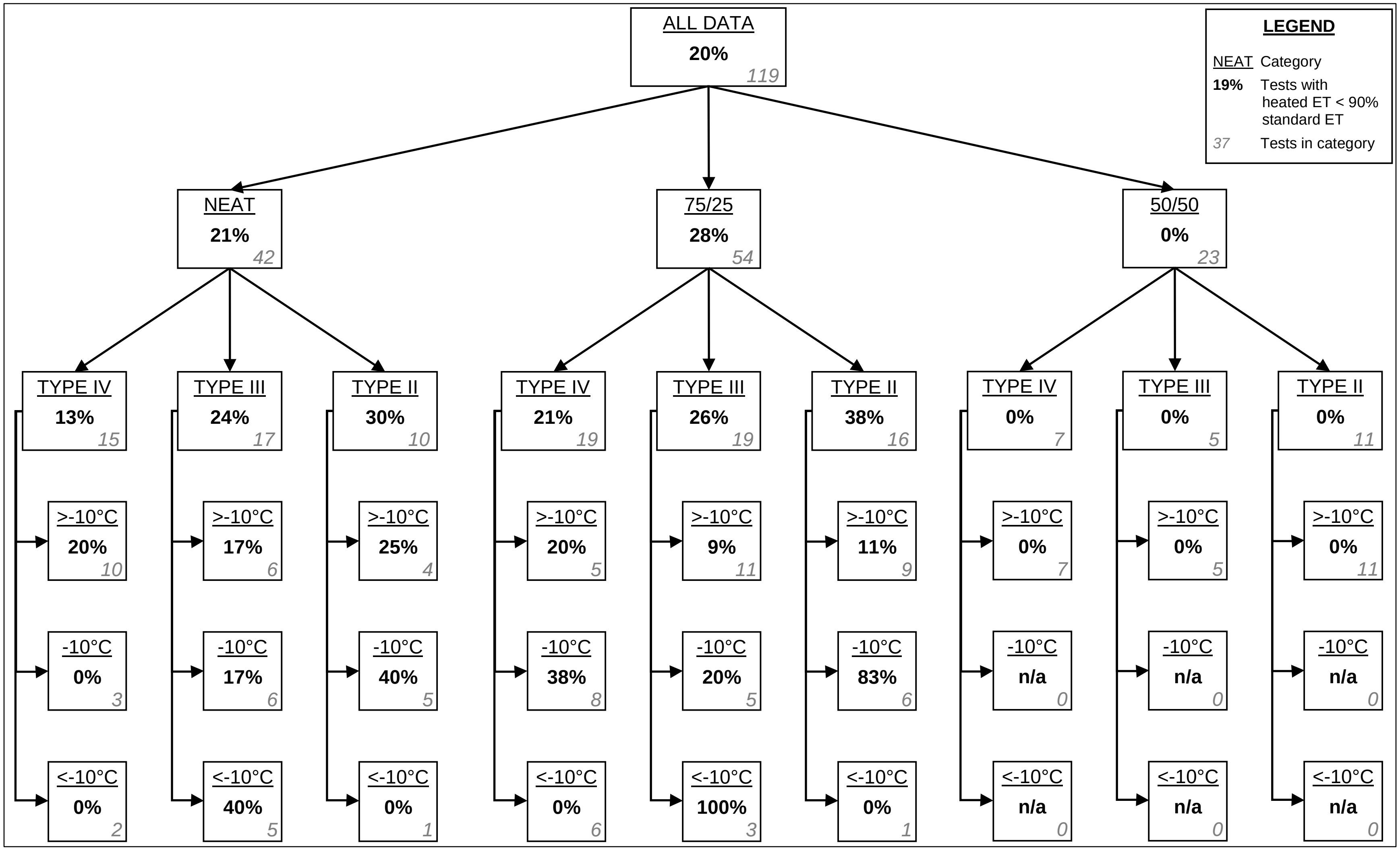

Figure 5.4: Decision Tree for Heated ET < 90 percent of Standard ET

5.4 Individual Fluid Analysis

The individual fluid analysis was conducted using the ratio analysis presented in Table 5.1. Further details from this analysis are provided in Appendix E.

5.4.1 Fluid A Examination

Tests conducted with Fluid A up to and including 2005-06 are shown in Table 5.3, which is an excerpt from the Fluid A spreadsheet given in Appendix E. Of the nine tests, there were five where heated endurance times were shorter than the ambient endurance times. Five of these had heated fail/ambient fail ratios of less than 90 percent; three of these had ratios of 80 percent or lower.

Table 5.3: Fluid A Test Results (excluding July 2007)

Global Test No.	**Fluid Dilution**	**Precip. Rate** (g/dm^2/h)	**Temp.** (°C)	**Precip. Type**	**Heated Fail / OAT Fail**
40	75	13	-11	ZD	82%
45	100	25	-10	ZR	80%
46	75	25	-10	ZR	79%
47	50	13	-3	ZR	156%
48	75	26	-3	ZR	115%
55	50	5	-3	ZD	142%
56	50	13	-3	ZD	240%
60	100	7	-3	NS	71%
61	75	16	-2	NS	87%

The problem conditions were identified 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 to confirm these results. Tests were conducted during a laboratory test session scheduled for an unrelated project in July 2007. Results from the repeat tests were very similar to the original test results (see Table 5.4).

Table 5.4: Fluid A Test Results (July 2007)

Global Test No.	Fluid Dilution	Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated ET / OAT ET	Comparable Test No.	Comparable Test Result
109	75	13	-10	ZD	79%	40	82%
110	100	13	-10	ZD	93%	n/a	n/a
111	75	25	-10	ZR	85%	46	79%
112	100	25	-10	ZR	82%	45	80%

5.4.2 Fluid B (Type III) Examination

Tests where heated Fluid B endurance times were notably shorter than the ambient application endurance times are shown in Table 5.5, which is an excerpt from the Fluid B spreadsheet given in Appendix E. In these seven tests, the ratio of heated endurance time to ambient endurance time was less than 80 percent.

Table 5.5: Type III Problem Tests (excluding July 2007 data)

Global Test No.	Fluid Dilution	Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated ET / OAT ET
21	100	29	-12	NS	70%
22	75	32	-12	NS	63%
23	75	37	-12	NS	79%
27	75	14	-6	NS	75%
28	100	14	-6	NS	71%
41	100	5	-10	ZD	75%
49	100	13	-11	ZR	61%

The problem cases generally occurred at colder temperatures. At milder ambient temperatures, the heated fluid generally performed better than the unheated, as shown in Table 5.6.

Table 5.6: Type III Fluid Performance by Temperature Range

Temperature Range	Heated ET / OAT ET
-3 and above	150%
below -3 to -10	127%
below –10	81%

Advantage was taken of a laboratory test session planned for an unrelated program to repeat tests at cold temperatures in freezing drizzle and freezing rain.

The results of the repeat tests are shown in Table 5.7. Only three cases could be directly compared with previous data, and in all these cases the new data showed a greater enhancement in endurance times for heated fluid than was seen previously. There is no ready explanation for this change.

Table 5.7: Type III Fluid - Test Results 2007

Global Test No.	Fluid Dilution	Precip. Rate (g/dm^2/h)	Temp. (°C)	Precip. Type	Heated ET / OAT ET (July 2007)	Comparable Test No. (previous tests)	Comparable Test Result (previous tests)
113	75	13	-3	ZD	151%	94	128%
114	100	13	-3	ZD	91%	n/a	n/a
115	50	13	-3	ZD	238%	n/a	n/a
116	75	13	-10	ZD	140%	42	94%
117	100	13	-10	ZD	99%	n/a	n/a
118	100	25	-10	ZR	136%	88	120%
119	75	25	-10	ZR	160%	n/a	n/a

5.5 Effect of Heat on Fluid Layer Thickness

The temperature profile charts (given in Appendix D) were examined in an attempt to understand why some fluids perform differently. The charts for Fluid A (Type II) indicate that the heated application is notably thinner than the standard application. Fluid C2, another Type II fluid, does not demonstrate this initial thinning.

Examination of the Type IV fluids (D and E) gives a similar picture. Heated Fluid D is often thinner initially than when it is applied at ambient temperature. Fluid E heated fluid starts off at the same thickness as ambient fluid but never thins, while the ambient application immediately starts to thin.

The relationship between endurance times and fluid thickness then was examined in a series of scatter plots. The data set for the charts includes the majority of the 2004-05 and 2005-06 tests. (Thickness had not been measured for several of the 2004-05 and 2005-06 tests so not all tests could not be included).

Tests with endurance times of less than 15 minutes were excluded from the data set to eliminate the dominant influence of surface temperature on short endurance times. This exclusion caused the elimination of all 50/50 fluid dilution tests. After the exclusions, 45 tests remained in the data set.

The results are shown in full in Appendix F in a series of charts. The charts compare heated and standard initial fluid thickness by dilution, by individual fluids, by fluid type and by fluid type/dilution, and were produced both in the format Δ ET (mins) vs. Δ Thickness (mm) and in the format Δ ET (%) vs. Δ Thickness (%). A sample chart is provided in Figure 5.5.

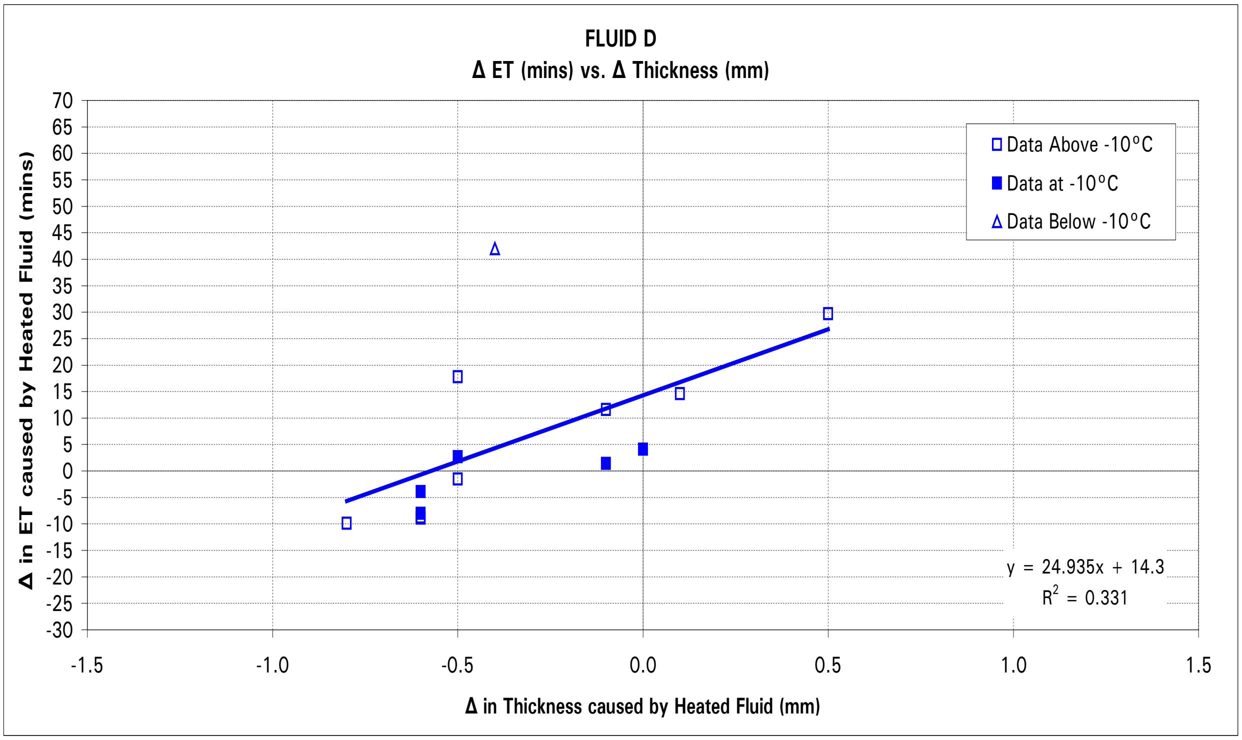

Figure 5.5: Sample Fluid Thickness Chart (Fluid D)

In the individual fluid charts:

- Data points above the horizontal line indicate the endurance time for heated is longer than the ambient application endurance time;
- Data points to the left of the vertical line indicates the thickness of the heated fluid is reduced from that of the ambient fluid;
- A line sloping to the left (like Fluid D) shows endurance time shortens with reduced thickness. However, data points in the upper left quadrant show that even when heating has thinned the fluid, some enhancement in endurance time can be produced;
- Data points grouped in the lower left quadrant (like Fluid A) indicate that reduced endurance times are associated with reduced thickness;

- Data points grouped in the upper right quadrant (like Fluid E) indicate the fluid thickens with heating, leading to enhanced endurance times; and
- Data points grouped about the vertical line (like Fluid C2) indicate that the fluid thickness tends to be unaffected by heating.

The charts show that there is a relationship between fluid thickness and endurance time, but it varies by fluid. The average change in initial thickness caused by heating fluid is shown in Table 5.8. The results in the other charts are blurred by the scatter in the data caused by the different fluids.

Table 5.8: Average Change in Initial Thickness Caused by Fluid Heating

Fluid	Average Change in Thickness
Fluid A	-45%
Fluid B	-20%
Fluid C1	-26%
Fluid C2	-4%
Fluid D	-24%
Fluid E	+24%

The improvement in endurance time when the fluid has been thinned by heating (data points in the upper left quadrant) is unexplained, but indicates that some additional force is at play. This may simply be a delay in the onset of the failure process on the surface of the fluid while the surface temperature is still above 0°C, or a change in the way the precipitation is absorbed into the heated fluid layer.

These thickness charts fail to explain the reduced performance of heated Type III fluid at cold temperatures. Because many of the test endurance times for this fluid were shorter than 15 minutes, only about one-third of the tests are reflected in the thickness analysis. In other words, most of the tests at warm temperatures are excluded. Examination of the fluid thickness in the temperature profile charts (Appendix D) for Type III indicates that thinning of heated fluid is fairly common at all temperatures. It may simply be that the thinner heated fluid would always tend to fail before the standard application, but is prevented from doing so by the higher surface temperature at warmer air temperatures. At colder air temperatures, the surface temperature has cooled quickly to ambient and no longer protects the thinner fluid layer from freezing. Although Type III fluid is grouped with Type II and IV fluids in this study, its endurance characteristics and nature of failure may be more similar to a slightly thicker Type I fluid rather than a thin Type II or IV fluid. If this fluid is used chiefly as a heated one-step fluid, the Type I HOT test protocol may be more appropriate for establishing HOT values.

5.6 Supplemental Type III Tests

This section discusses the results of the supplemental tests conducted with Type III fluid in July 2007. As described in Subsection 3.8, two additional plates were run for each Type III test. The first plate examined fluids applied at 20°C; the second plate examined fluids applied using a two-step application. The results from these tests are shown in Table 5.9. There are four rows for each test: the first two rows show the previously discussed results (ambient application, heated application); the third row shows the 20°C results; and the fourth row shows the two-step application results.

5.6.1 Examination of Endurance Times from a Two-Step Application

This test plate examined whether the heat transferred to the surface from the first step (heated deicing fluid) of a two-step deicing process would enhance the endurance times of a second-step Type III anti-icing fluid applied at ambient temperature. The test procedure involved applying heated Type I fluid at 60°C, waiting 3 minutes, and then applying Type III at ambient temperature.

The two-step process showed an enhanced endurance time only in the one test conducted with a fluid diluted to 50/50. In all other tests, the two-step process produced endurance times equivalent to a one-step application of fluid at ambient temperature.

Table 5.9: Log of Supplemental Type III Tests

Test No.	Date	Precip. Rate (g/dm²/h)	Test Temp. (°C)	Precip. Type	Fluid Dilution	Fluid Application	Endurance Time (min)	Heated Fail/ OAT Fail
HC5	Jul-19-07	13	-3	ZD	100%	Type III at Ambient	15.7	n/a
						Type III at 60°C	14.3	91%
						Type III at 20°C	13.6	87%
						Type I at 20°C, Type III at Ambient	15.0	96%
HC6	Jul-19-07	13	-3	ZD	75%	Type III at Ambient	10.6	n/a
						Type III at 60°C	16.0	151%
						Type III at 20°C	11.2	106%
						Type I at 20°C, Type III at Ambient	10.3	97%
HC7	Jul-19-07	13	-3	ZD	50%	Type III at Ambient	6.3	n/a
						Type III at 60°C	15.0	238%
						Type III at 20°C	12.3	195%
						Type I at 20°C, Type III at Ambient	7.8	124%
HC8	Jul-18-07	13	-10	ZD	100%	Type III at Ambient	9.3	n/a
						Type III at 60°C	9.2	99%
						Type III at 20°C	9.4	101%
						Type I at 20°C, Type III at Ambient	8.8	95%
HC9	Jul-18-07	13	-10	ZD	75%	Type III at Ambient	6.7	n/a
						Type III at 60°C	9.4	140%
						Type III at 20°C	6.8	101%
						Type I at 20°C, Type III at Ambient	6.7	100%
HC10	Jul-18-07	25	-10	ZR	100%	Type III at Ambient	6.7	n/a
						Type III at 60°C	9.1	136%
						Type III at 20°C	7.2	107%
						Type I at 20°C, Type III at Ambient	5.8	87%
HC11	Jul-18-07	25	-10	ZR	75%	Type III at Ambient	5.3	n/a
						Type III at 60°C	8.5	160%
						Type III at 20°C	6.4	121%
						Type I at 20°C, Type III at Ambient	5.3	100%
						Type III at 60°C	Average	145%
						Type III at 20°C	Average	117%
						Type I at 20°C, Type III at Ambient	Average	100%

5.6.2 Examination of Endurance Times of Fluid Applied at 20ºC

This test plate measured endurance times produced by a fluid applied at 20ºC. The results were compared to the test plates where fluid was applied at 60ºC and at ambient temperature.

For all tests:

- When using 60ºC fluid, the average enhancement was 45 percent; and
- When using 20ºC fluid, the average enhancement was 17 percent.

The enhancement due to fluid temperature varied among the different conditions and tended to correspond with short fail times for the standard test with fluid at OAT, and with ambient temperature.

The results provided below are at ambient temperature -3°C, freezing drizzle, and 13 g/dm^2/h.

- Fluid at 100 percent concentration and applied at ambient produced an endurance time over 15 minutes. Both heated fluids had shorter endurance times, indicating that endurance times were not influenced by plate surface temperature. Some other factor associated with heated fluid was in force, perhaps reduced fluid thickness.
- Fluid at 75 percent concentration and applied at ambient produced an endurance time near 10 minutes. The 60°C fluid endurance time was 151 percent of the ambient time, while the 20°C fluid endurance time was only 106 percent. This indicates that the surface temperature for the 60°C fluid did affect the endurance time. The surface temperature for the 20°C fluid apparently had cooled to ambient by the time of failure, and did not affect fluid endurance.
- Fluid at 50 percent concentration and applied at ambient produced an endurance time near 6 minutes. The 60°C fluid endurance time was 237 percent of the ambient time, while the 20°C fluid endurance time was 193 percent. This indicates that the surface temperature for both fluids affected the endurance time, but more so for the hotter fluid.

The results provided below are at ambient temperature -10°C, freezing drizzle, and 13 g/dm^2/h.

- Fluid at 100 percent concentration and applied at ambient produced an endurance time just over 9 minutes. Both heated fluids had fail times equal to that of the ambient fluid. At this colder ambient temperature, the test surfaces cooled more rapidly. That the fluids produced a failure time equal to the ambient fluid application indicates that the surfaces had cooled to ambient some time before failure, and the endurance time was due solely to the fluid anti-icing property.
- Fluid at 75 percent concentration and applied at ambient produced an endurance time near 7 minutes. The 60°C fluid fail time was 141 percent of the ambient time, while the 20°C fluid fail time was equal to the ambient time. This indicates that the surface temperature for the 60°C fluid was still warm enough to extend the endurance time. The surface temperature for the 20°C fluid apparently had cooled to ambient before 7 minutes had passed and did not affect fluid endurance.

The result provided below is at ambient temperature -10ºC, freezing rain at 25 g/dm^2/h.

- Similar results were observed for this condition. Both the neat and the 75/25 dilutions produced short endurance times (6.7 and 5.3 minutes) with fluid at ambient. The 60ºC fluid produced a significantly enhanced endurance time, and the 20ºC fluid produced a small enhancement.

5.7 Test Protocol for Indoor Tests with Heated Fluid

As discussed in Section 2, endurance times for outdoor applications of heated Type II, III and IV Fluids can be effectively measured using the outdoor test protocol for Type I fluids. This involves heating the test fluid to 60ºC before application. For tests with heated Type II, III and IV fluids, this protocol satisfies two requirements:

1) It produces a test surface temperature profile that conforms to measured profiles for aircraft wing leading edges, thus accounting for the endurance enhancement related to warmed test surfaces; and
2) It reflects the field operation of heating the fluid in the deicing vehicle to 60ºC, thus supporting the examination of other effects that heating the fluid may have on endurance times.

The indoor test protocol for Type I fluid involves application of fluid heated to 20ºC. In this study, the indoor tests with Type II, III and IV fluids did not follow this protocol, but were conducted using fluid heated to 60ºC. This test procedure was intended to enable examination of the effect that heating the fluid to that temperature may have on endurance times, through changes to endurance time contributors such as fluid thickness on the test surface. These other effects could not be examined by strictly following the Type I protocol with its use of 20ºC fluid.

These supplemental tests with Type III fluid showed that, in some cases, the 60ºC fluid did enhance the endurance times beyond that provided by the 20ºC fluid. The cases where this occurred were mainly cases where the standard endurance tests (fluid at ambient) were short. At these normally short endurance times, the heated-fluid test-surface temperature profile had not yet cooled to ambient, and this warmer temperature extended the time to fail. The degree of *shortness* for ambient tests where this occurred appeared to be:

- For ambient temperature at -3ºC, endurance times of 11 minutes or less; and
- For ambient temperature at -10ºC, endurance times of 7 minutes or less.

To examine the effect that application of fluid at 60ºC may have had on endurance times measured indoors, the indoor tests that met the criteria in the bullets above were extracted from the data set (see Table 5.10). All of the tests occurred at the milder temperature of -3ºC; there were no cases where tests at ambient temperatures of -10ºC or below produced an ambient fluid fail time of 7 minutes or less.

The following observations were made:

- For Type II/IV fluids, seven tests fit the criteria. All seven involved fluids diluted to 50/50 concentration. Two tests involved Fluid A and four involved Fluid D;
- For Type III fluid (Fluid B), seven of the ten tests conducted at -3ºC met the criteria. All fluid dilutions were represented;
- For all fluids, ten of the sixteen indoor tests conducted with fluid diluted to 50/50. Of these, the 60ºC fluid application potentially influenced ten;
- For Type II/IV fluids, it can be concluded that the indoor test procedure using 60ºC fluid is generally acceptable for dilutions other than 50/50. This does not mean that heated 50/50 fluid does not improve upon the ambient application, but it may not improve it as much as the data indicates; and
- For Type III fluids, the use of 60ºC fluid at -3ºC risks an exaggeration of endurance time enhancement in some conditions with 60ºC fluid.

The fundamental question for these problematical cases is how a fluid application at a colder temperature, such as 20ºC, would perform. Table 5.10 shows that the 20ºC applications produced endurance times equal to or greater than the ambient application in all cases falling within the *endurance time shortness* criteria. However, the results of such tests do not reflect any effect that heating to 60ºC may have on endurance time.

The challenge in defining a protocol for indoor tests on heated Types II, III and IV fluid lies with the conflicting requirements of examining the impact of heat, while still respecting a test surface temperature profile that corresponds to the documented wing leading edge profile.

Table 5.10: Tests with Fail Times Extended by 60°C Fluid

Global Test No.	Fluid	Fluid Dilution	OAT Fail Time (min)	Heated Fail Time (min)	Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
56	A	50	6.8	16.3	13	-3	ZD	240%
47	A	50	9.7	15.1	13	-3	ZR	156%
104	D	50	7.9	19.0	24	-3	ZR	241%
59	D	50	9.2	16.2	13	-3	ZD	176%
97	D	50	11.0	21.4	13	-3	ZD	195%
85	D	50	11.0	18.8	13	-3	ZR	171%
17	H	50	10.8	17.8	25	-3	ZR	166%
52	B	50	7.8	16.7	13	-3	ZR	214%
82	B	50	8.2	17.7	14	-3	ZR	216%
58	B	75	8.8	16.6	13	-3	ZD	189%
94	B	75	9.0	11.5	14	-3	ZD	128%
57	B	50	9.1	16.1	5	-3	ZD	177%
53	B	100	10.5	13.8	25	-3	ZR	131%
93	B	75	11.0	25.3	13	-3	ZD	230%

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6. CONCLUSIONS

The conclusions based on initial testing are presented in this section. Volume 1 – Final Report presents data from supplemental testing, and final conclusions and recommendations.

6.1 Test Protocol for Heated Fluids

6.1.1 Outdoor Tests

The tests described in Section 2 confirm that the Type I test protocol can be used to evaluate endurance times of heated Type II, III and IV fluids.

6.1.2 Laboratory Tests

For fluid types other than Type III, it can be concluded that the indoor test procedure using 60ºC fluid, as followed in this study, is generally acceptable for dilutions other than 50/50.

For all fluid types at 50/50 dilution, fluid application at 60ºC carries a risk of exaggerated endurance time enhancement in some conditions. For Type III fluids at -3ºC, this risk extends to 75/25 and neat concentrations as well.

Applications of Type III fluid at 20ºC produced endurance times equal to or greater than the ambient fluid. The principal contributor to endurance time for these tests was the raised surface temperature, which overrides any other possible diminishing effects on fluid heated to 60ºC.

The ideal protocol for indoor tests of heated Type II, III and IV fluids would examine the effect of heating the fluid to 60ºC, while still producing a test surface temperature profile that corresponds to the documented wing leading edge profile.

6.2 The Effect of Heat on Fluid Endurance Times

6.2.1 Type II and IV Fluids

With the exception of Fluid A, it can be concluded that heated fluid endurance times match or exceed that of fluid applied at OAT. Thus, the FAA statement is suitable for these fluids.

The tests conducted in July 2007 confirmed previous data indicating that in some conditions Fluid A endurance times are shorter when fluid is applied at 60°C rather than at OAT. The problem conditions are:

- 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.

Three options are possible for this fluid relative to the FAA statement:

- Leave the statement as is, with the knowledge that current HOT values have a large safety factor built in during their development. This is the preferred option;
- Modify the statement to indicate that generally applying fluid at 60°C does not cause a problem, but that users should have the results tested to confirm its adequacy (perhaps by fluid manufacturers); and
- Remove the statement entirely.

It may be useful to examine this fluid further in natural snow conditions.

6.2.2 Type III Fluid

It can be accepted that the Type I test protocol is suitable to test Type III fluid outdoors in natural snow. Seventeen tests were conducted in snow, and of these, five produced a heated fail / OAT fail ratio lower than 80 percent. The problem cases generally occurred at colder temperatures. At milder ambient temperatures, the heated fluid generally performed better than the unheated. The overall *heated fail / OAT fail* ratio for all tests in snow was 94 percent.

The indoor test protocol for Type I fluid involves application of fluid heated to 20°C, but in this study, the indoor tests were conducted using fluid heated to 60°C. Under this test methodology, there were only two cases where heated Type III fluid produced an endurance time lower than ambient applications.

Because it was suspected that raised test-surface temperatures enhanced the endurance times, two types of supplemental tests were conducted to examine this aspect (see below).

- Tests were conducted to examine whether the heat transferred to the surface from the first step (heated deicing fluid) of a two-step deicing process would enhance the endurance times of a cold second-step Type III anti-icing fluid.

Results showed that the two-step method produced an enhanced endurance time only in the test conducted with fluid at 50/50 concentration. In all other tests, the two-step method had no impact, producing endurance times equivalent to the application of fluid at ambient air temperature.

- Tests were conducted to compare endurance times produced by fluid heated to 20ºC and to 60ºC. These tests showed that the warmer fluid did extend the endurance times beyond that provided by the 20ºC fluid. The conditions where this 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.

Additional attention needs to be given to measuring endurance times for this fluid type when applied heated, to reflect field deicing operations. Test data indicates that its performance in natural snow, particularly at colder temperatures, may be lower than expected. It is believed that indoor tests of 60ºC fluid at -3ºC produce exaggerated endurance times.

It would be useful to develop more test data in natural snow conditions, as the appropriate test protocol exists for those tests. Sufficient data should be collected to enable construction of a heated-Type III HOT table for snow. If the heated fluid table is significantly different than the currently published table, then a similar activity should be conducted to develop a heated-Type III HOT table for the other types of precipitation. It is recommended that indoor tests for heated Type III fluid follow the indoor test protocol for Type I fluid, until further research proves differently.

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7. RECOMMENDATIONS

The recommendations based on initial testing are presented in this section. Volume 1 – Final Report presents data from supplemental testing, and final conclusions and recommendations.

Recommendations are provided below.

1. The guidance material currently provided in the *FAA Approved Deicing Program Updates, Winter 2007-2008* (4) be left as is for Type II and Type IV fluids other than Fluid A. There are three options possible for providing guidance material for Fluid A:

   a) Leave the statement as is, with the knowledge that current holdover time values have a large safety factor built in during their development. This is the preferred option;

   b) Modify the statement to indicate that generally there is no problem with applying fluid at 60°C, but users should have the results tested to confirm its adequacy (perhaps by fluid manufacturers); and

   c) Remove the statement entirely.

2. Further tests be conducted with Fluid A in natural snow conditions if an opportunity becomes available to conduct such tests in conjunction with another test program.

3. Further tests be conducted with Type III fluid in natural snow conditions, sufficient to enable construction of a heated-Type III HOT table for snow. The following matrix of tests in snow conditions is proposed for this purpose. If the heated fluid table is significantly different than the currently published table, conduct indoor tests to develop a heated-Type III HOT table for the other types of precipitation. It is recommended that indoor tests for heated Type III fluid follow the indoor test protocol for Type I fluid, until further research proves differently. Table 7.1 lists the suggested number of tests that be conducted for each dilution.

Table 7.1: Matrix of Tests

FLUID NAME	DILUTION	HOT	COLD
2031	100	15 runs	
2031	75	10 runs	
2031	50	10 runs	

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2. Alwaid, A., Dawson, P., Moc, N., *Generation of Holdover Times Using the New Type I Fluid Test Protocol,* APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13994E, 106.

3. Moc, N., *Effect of Heat on Endurance Times of Anti-Icing Fluids*, APS Aviation Inc., Transportation Development Centre, Montreal, October 2005, TP 14447E, 34.

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPTS – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2004-05, 2005-06 AND 2006-07

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2004-05, 2005-06 AND 2006-07

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

a) Review previous preliminary research that was completed on selected diluted Type II/III/IV fluids;

b) Design a test protocol with the cooperation of the FAA and TC. A series of tests should be conducted on a wing in outdoor conditions in order to conclude on the validity of the fluid application protocol;

c) Develop a test procedure for testing indoors and also outdoors;

d) Conduct comparative tests in natural and simulated precipitated conditions;

e) Analyse data and results;

f) Prepare a report; and

g) Prepare presentation material.

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

a) Review previous preliminary research that was completed on selected diluted Type II/IV fluids;

b) Design a test protocol with the cooperation of the FAA and TC;

c) Develop a test procedure for testing both outdoors and indoors;

d) Analyse data and results;

e) Prepare a report; and

f) Prepare presentation material.

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

a) Analyse data and results of previously collected data; and

b) Revise previous interim report and prepare a final report.

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APPENDIX B

JETSTAR TEST WING
TYPE II/III/IV LEADING EDGE TEMPERATURE PROFILES

CM (TC-Deicing 05-06)

JETSTAR TEST WING
TYPE II/III/IV LEADING EDGE TEMPERATURE PROFILES

Winter 2005-06

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: David Youssef

Reviewed by: John D'Avirro

APS Aviation Inc.

November 1, 2005
Version 1.0

JETSTAR TEST WING
TYPE II/III/IV LEADING EDGE TEMPERATURE PROFILES

Winter 2005-06

1. BACKGROUND

At an SAE G-12 Holdover Time (HOT) Subcommittee meeting in November 2000, discussion focused on the need to recognize the contribution of heat in the endurance time test procedure for Type I fluids. Research was conducted and it was concluded that an empty box that simulates the wing leading edge was suitable.

The objective was to collect surface temperature decay data for prospective test surfaces following the application of SAE Type I fluid in various quantities and temperatures. These data were then used to develop a series of cooling curves (temperature profiles) for comparison with similar curves developed for actual wings.

Following examination of several test surfaces and various procedures for Type I fluid application, it was concluded that the 7.5 cm cold-soak box, empty, when treated with 0.5 L of fluid at 60°C, produced a reasonable representation of the temperature decay rate demonstrated by wings in natural outdoor conditions.

2. OBJECTIVE

The objective of this procedure is to document temperature profiles for the JetStar test wing, for comparison to the temperature profile produced by the empty box treated with 0.5 L of fluid at 60°C for evaluating HOT when applying SAE Type II/III/IV fluids.

The objective is to validate that a 7.5 cm cold-soak box, empty, treated with 0.5 L of fluid at 60°C, produces a reasonable representation of the temperature decay rate demonstrated by wings for tests concerning heated Type II/III/IV fluids.

These tests will be conducted at the Dorval test site under dry conditions, at night or during overcast conditions.

Note: This procedure is the first of a set of two procedures for the effect of heat on Neat and Diluted Type II/III/IV fluid endurance times. The second procedure, *Experimental Program: Effect of Heat on Endurance Time of Anti-icing Fluids*, is described in a separate document and tests for that will only be carried out after the results for this procedure are known.

3. ANALYSIS AND METHODOLOGY

Several years ago, it was found that the 7.5 cm box, empty, when applying 0.5 L of Type I fluid at 60°C was representative of wing leading edge temperature profiles. This was with some scatter resulting from the different wings used and the ranging environmental conditions.

Figure 1 shows a plot of the mean box curve that was found to be representative of the wing profiles. Also demonstrated, are curves pertaining to plus or minus 1 and 2 sigma from this mean curve. (For a detailed description, see TC Report TP13827E, *SAE Type I Fluid Endurance Time Test Protocol*).

The JetStar wing profile was found to be on the lower end of the scatter plot and close to the −1 sigma curve.

As part of this procedure, tests will be carried out on the JetStar wing and on the same box used for the Type I fluids. However, Type IV Ultra + Neat will be applied on both surfaces. Temperature profiles will be measured.

3.1 Criteria to Determine Acceptability

To determine the acceptability of the box to wings with Type IV fluid, reference will be made to the plot of the mean box curve demonstrated in Figure 1.

This plot demonstrates that the box temperature profile is warmer than the JetStar wing, and that the JetStar wing is very close to the negative 1 standard deviation for the box temperature profile.

When running the Type IV tests, a profile of the box will be developed. The box will be considered an acceptable representation of the wing profile if the wing profile is close to and within a "reasonable scatter" to the proportional minus 1 standard deviation of the box mean from the Type I analysis.

The "reasonable scatter" will be determined from the same scatter that was seen during the Type I analysis.

4. PROCEDURE

These trials will be conducted on the JetStar test wing. Thermistor probes will be installed on the wing according to positions shown in Figure 2.

A standard aluminum test surface and a coldsoak box (7.5 cm, empty) will be placed on the test stand situated near the wing but clear of the fluid spray, and treated with heated fluid according to the test procedure. The wing will be sprayed to simulate a snow removal operation. At the same time, the heated fluid will be applied to the box surface. Wind speed and OAT will be measured at the stand.

The collected data will be the temperature profiles of the wing, and of the test surface, OAT and wind speed.

Testing will be completed on one occasion. There will be two runs, both with an empty wing fuel load. The temperature of the fluids for the test wing will be set at 80°C, whereas the temperature of the 0.5 L fluid for the test box will be set at 60°C.

5. FLUIDS

The wing will be sprayed with SAE Type IV (Ultra+) fluid at a standard strength, heated to 80°C in the tank.

The test surface will be treated with SAE Type IV (Ultra+) fluid at a standard strength, heated to 60°C.

6. EQUIPMENT

See list Attachment 1.

7. PERSONNEL

Two APS personnel are required for these tests following these roles:

- Fluid preparation and application; and
- Data management.

Set up activities and test team tasks are included in Attachments 2 and 3, respectively.

8. DATA FORMS

- Figure 2 Thermistor probe locations for JetStar wing.
- Figure 3 General Form (every test).

The general form will be taken from procedures used for similar tests that were carried out in the past.

9. SAFETY PRECAUTIONS AND MITIGATION

Care and responsibility should be carried out during the following tasks:

- Moving of wing;
- Use of ladder to reach wing;
- Operation of 3 Phase generator; and
- Heating of fluid.

All proper safety equipment should be used or worn during tasks such as:

- Mixing fluids;
- Spraying wing; and
- Operation of 3 Phase generator.

General site safety measures should be followed:

- Pathways, stairs and test areas are to be cleared of snow regularly;
- Appropriate footwear is to be worn by all personnel at the test site to prevent slipping;
- Warm clothing is to be worn by all personnel to prevent frostbite;

- Electrical appliances (including computers) are to be unplugged before any wires or connections are altered. If necessary, the affected breaker is to be turned off;
- If fluid comes into contact with skin, rinse hands under running water;
- If fluid comes into contact with eyes, flush with the portable eye wash station located inside the main trailer; and
- When operating snow blower use ear protection.

JETSTAR TEST WING TYPE II/III/IV LEADING EDGE TEMPERATURE PROFILES

Figure 1

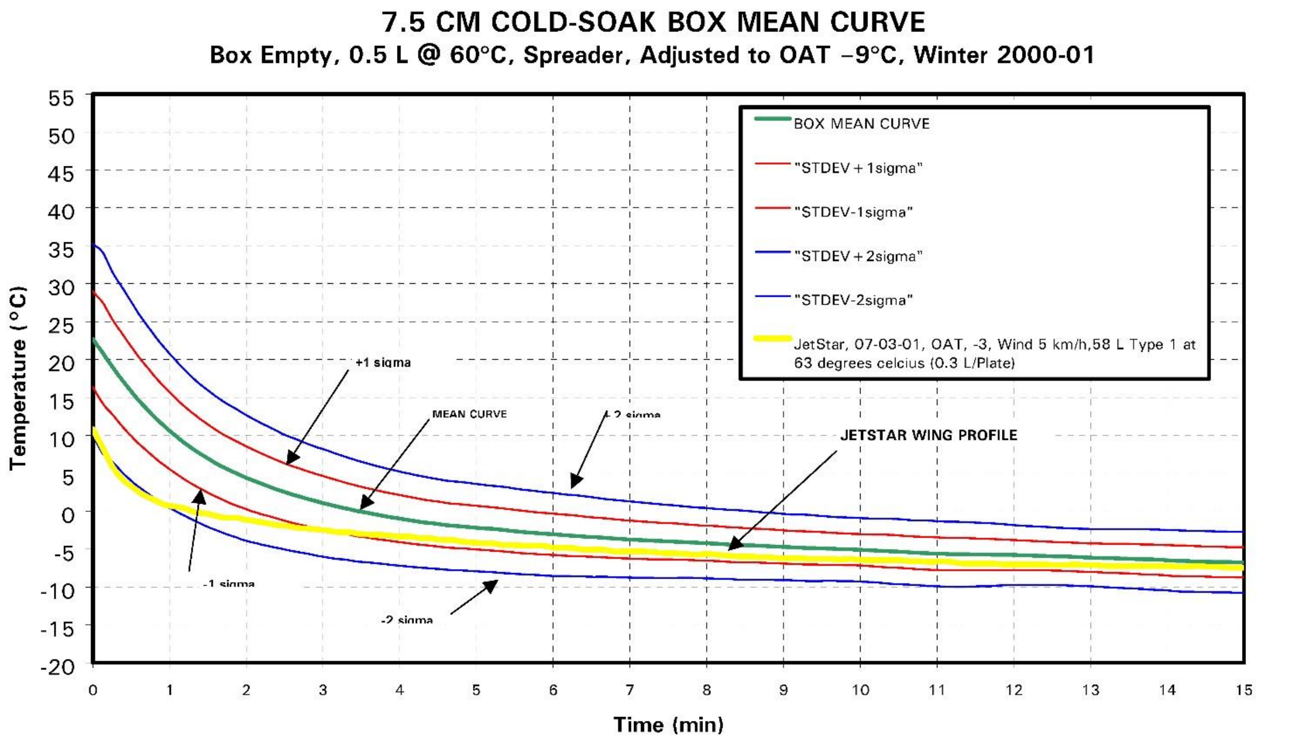
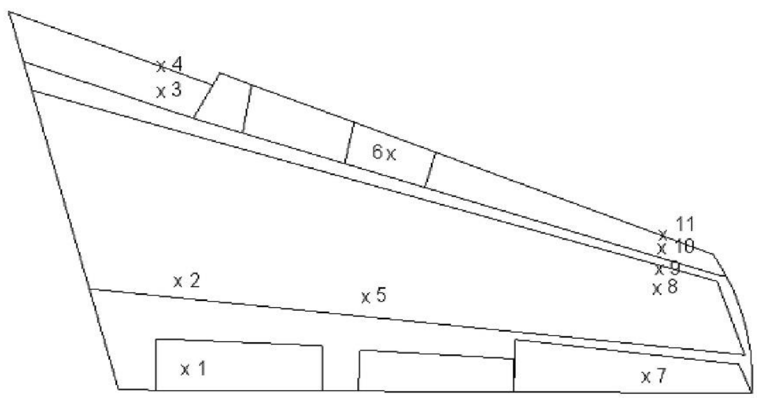


Figure 2

THERMISTOR PROBE LOCATIONS FOR JETSTAR WING
FIELD TRIALS FOR JETSTAR WING TEMPERATURE PROFILES

Thermistor Probes Mounting Locations



3. Mid-way on LE, in line between 1 and 4

4. On LE nose, 1/4 distance from surface outer end

6. Mid-way chord wise and 1/2 way laterally

10. 1/2 way on LE, in line with # 7

11. On LE nose, in line with # 7

Note: Numbers are not sequential. For this test purpose,

we will only be testing on locations 3, 4, 6,10, and 11.

Figure 3

GENERAL FORM (EVERY TEST)

DATE: ____________________

AIRCRAFT TYPE: ATR-42 F-100 B-737 RJ DHC-8

RUN #: ____________________

WING: PORT (A) STARBOARD (B)

AIRLINE ________________

DRAW DIRECTION OF WIND WRT WING:

FIN #: ________________

TRUCK #: __________

TYPE I FLUID NOZZLE TYPE: ____________

FUEL LOAD: ____________ LB / KG

FLUID APPLICATION

Actual Start Time: ____________ am / pm **Actual End Time:** ________________ am / pm

Amount of Fluid Sprayed: ____________ L / gal **Type of Fluid:** ____________

Fluid Temperature: **Tank:** _____ °C **Nozzle:** _____ °C

Fluid Brix: __________

COMMENTS: ____

____

____

____

____

____

____

MEASUREMENTS BY: ____________________

HANDWRITTEN BY: ____________________

ATTACHMENT 1

EQUIPMENT CHECKLIST
LEADING EDGE TEMPERATURE PROFILES

TEST EQUIPMENT	RESPONSIBLE	STATUS
Thermistor kit: loggers, at least 8 probes with extensions, 3M speed tape, PC/logger linking cables		
Isopropyl alcohol and wiping rags		
Paint Dryer		
Wing Forms		
Measuring Tape		
Laptop PC		
Fluid temperature probe with spare batteries		
Fluid Spreaders X 2		
Measuring container for 0.5 L		
Stand for two test surfaces		
7.5 cm cold-soak box, empty, std surface		
Digital Camera		
AA batteries for digital camera		
Surface temperature probes X 2		
Step ladders, X2		
3 phase generator		
Portable sprayer		
Tarp to collect fluid		

Note: Pertinent weather data will be downloaded from the Environment Canada website

ATTACHMENT 2

SET-UP ACTIVITIES

- Make arrangements for spraying the wing during the test. The test will be completed at the APS Test Site location at Trudeau Airport.
- Make arrangements for fluid recovery.
- Make arrangements for towing the wing between the Aeromag facility and the test site.
- Make arrangements for heating of the fluids.

ATTACHMENT 3

TEST TEAM TASKS

- Set up portable stand with thermistor-equipped box.
- Install thermistor probes on test wing in accordance with Figure 3.
- Install thermistor probes on box at 25cm(6") line.
- Set up loggers and confirm that all probes are logging.
- Take fluid from tanks, bring to correct temperature and pour into vacuum containers for treating test plate.
- Record tank fluid temperature at the tank and from the nozzle.
- For each test, record data required on data sheet. Retrieve data on fluid amount sprayed from tank.
- Apply fluid to plate with spreader when spray operation is underway.
- Backup data to PC following the each wing test.
- At end of session ensure all data is saved, by displaying temperature curves on PC.
- At end of test session, dismantle all equipment and return wing to Aeromag facility.

APPENDIX C

EXPERIMENTAL PROGRAM
EFFECT OF HEAT ON ENDURANCE TIME OF ANTI-ICING FLUIDS

CM (TC-Deicing 05-06)

EXPERIMENTAL PROGRAM
EFFECT OF HEAT ON ENDURANCE TIME OF ANTI-ICING FLUIDS

Winter 2005-06

Prepared for

Transportation Development Centre
Transport Canada

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Reviewed by: John D'Avirro

APS Aviation Inc.

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Version 1.0

EXPERIMENTAL PROGRAM
EFFECT OF HEAT ON ENDURANCE TIME OF ANTI-ICING FLUIDS

Winter 2005-06

1. BACKGROUND

At an SAE G-12 HOT Subcommittee meeting in November 2000, discussion focused on the need to recognize the contribution of heat in the endurance time test procedure for Type I fluids. Heated Type II and IV fluids at 50/50 and 75/25 concentrations were currently being used in one-step deicing procedures. A motion was made for the test procedure for these fluids to also recognize the contribution of heat and use the same box that is used in tests with the Type I fluids. This is particularly true in European operations.

In 2001-02, preliminary tests were conducted to investigate whether heat significantly influences the endurance times for Type II and Type IV fluids. Five different fluid brands were used for these exploratory tests.

The tests showed that the effect of heat did not reduce endurance times. In some cases, a significant improvement was observed.

Tests conducted in 2004-05 (TP 14447E), concluded that there is variation between the various fluid types tested, substantiating that perhaps the effect of heat is fluid dependent. However, due to the limited number of tests conducted under both snow and freezing precipitation conditions, and also the slightly contradictory results compared with 2001-02 testing, currently there is not sufficient data to enable a solid conclusion on the effect of heat on different fluid types and even fluid brands. It was recommended that the failure mechanism be further evaluated and analyzed by conducting a new series of comparative tests using different fluid types and dilutions at various temperatures and precipitation rates.

2. OBJECTIVE

The objective of this research program is to investigate the impact of the test procedure (application method) on endurance time performance.

The following are the detailed objectives.

- Effect of heat on Neat and Diluted Type II and Type IV fluid endurance times.

- Effect of heat on Type III fluid (Neat and Diluted) endurance times: currently some operators are considering the use of Type III fluid in the same manner as Type I fluid.

The objective of these tests will be to compare the endurance times using the above methods with the endurance times using the standard protocols.

The matrix of outdoor tests is included in Table 1. In addition, a preliminary plan of indoor tests is also included in Table 2.

Note:

This procedure is the second of a set of 2 procedures for the effect of heat on Neat and Diluted Type II/III/IV fluid endurance times. The first procedure, *JetStar Test Wing: Type II/III/IV Leading Edge Temperature Profiles*, is described in a separate document and results will be evaluated before this procedure for outdoor testing is carried out. The objective of those tests was to ensure that the described cold-soaked box, empty, treated with 0.5 L of fluid at 60 °C, is a suitable representation of wing profiles.

3. PROCEDURE

Endurance time tests will be conducted with the various fluids at the Dorval airport test site. Standard fluid endurance time test procedures will apply. The tests will be conducted simultaneously following the application methods described below.

3.1 Outdoor Tests with Type II/III/IV Fluids

Position 1: Baseline Standard Test:
1 L of fluid poured (with no spreader) at OAT onto an aluminum plate.

Position 2: Heated Test:
0.5 L of fluid warmed at 60 °C and poured with the warm 12-hole spreader (if fluid is too viscous, then hand pour) onto a box.

The summary of these application methods is shown in Figure 1.

Position 1 (Baseline Standard Test)	**Position 2 (Heated Test)**
• Plate • 1 L of fluid • Apply at OAT • Poured	• Plate • 0.5 L of fluid • Applied at 60 °C • Poured with the 12 hole spreader

Figure 1: Position on Stand – Outdoor Tests with Type II/III/IV Fluids

3.2 Indoor Tests Type II/III/IV Fluids

Position 1: Baseline Standard Test:
1 L of fluid poured (with no spreader) at OAT onto an aluminum plate.

Position 2: Heated Test:
1.0 L of fluid warmed at 60 °C and poured with the warm 12-hole spreader (if fluid is too viscous, then hand pour) onto a plate.

The summary of these application methods is shown in Figure 2.

Position 1 (Baseline Standard Test)	**Position 2 (Heated Test)**
• Plate • 1 L of fluid • Apply at OAT • Poured	• Plate • 1 L of fluid • Applied at 60 °C • Poured with the 12 hole spreader

Figure 2: Position on Stand – Indoor Tests with Type II/III/IV Fluids

4. FLUIDS

This section provides information concerning the various fluids utilised for comparative endurance time testing during winter of 2005-06. Type II, III, and IV fluid endurance time testing was conducted using five fluid brands.

Fluids were selected based upon the following criteria:

- Continuation of fluid type for same testing done previously;
- Based upon past tests and recommendations;
- Current inventory levels; and
- Accessibility of fluids.

The following fluids will be used:

FLUID NAME	OUTDOOR TESTS	INDOOR TESTS
Clariant 2031	30 L	10 L
Clariant 2025	30 L	10 L
Octagon Maxflo	30 L	10 L
Ultra+ Type IV	30 L	10 L
ABC 2000	30 L	10 L

5. TEST PLAN

For outdoor testing, it is anticipated that 4 runs of 4 individual tests will be conducted on 10 separate occasions, for a total of 160 tests.

Two plate locations at NRC will be used to conduct these tests. 50 tests will be conducted under various simulated freezing precipitation.

6. EQUIPMENT

- Equipment will be similar to that used during holdover time tests;
- Logging of temperatures will be required for these tests; and
- Brix measurements and thickness measurements will be needed for a small number of tests.

7. PERSONNEL

Three individuals will be required to conduct these tests. The test manager will measure endurance times. An assistant is required to collect rates and assist with fluid application. A third person is required to prepare the fluids, and assist in measuring thickness and Brix measurement.

8. DATA FORM

The standard endurance time test data forms will be used. To measure fluid Brix and thickness on selected tests, use Table 3.

9. SAFETY PRECAUTIONS AND MITIGATION

General site safety measures should be followed:

- Pathways, stairs and test areas are to be cleared of snow regularly;
- Appropriate footwear is to be worn by all personnel at the test site to prevent slipping;
- Warm clothing is to be worn by all personnel to prevent frostbite;
- Electrical appliances (including computers) are to be unplugged before any wires or connections are altered. If necessary, the affected breaker is to be turned off;
- If fluid comes into contact with skin, rinse hands under running water;
- If fluid comes into contact with eyes, flush with the portable eye wash station located inside the main trailer; and
- When operating snow blower use ear protection.

TABLE 1: MATRIX OF OUTDOOR TESTS

Test #	Fluid Type	Fluid Brand*	Dilution	Precip Type	Test Temp. [°C]	Precip Rate [g/dm²/h]	STD Test	Heated Box (outdoor)	Comments
1	III	Clariant 2031	50	Outdoor Snow	>-3	Any	1	1	
2	III	Clariant 2031	50	Outdoor Snow	>-3	Any	1	1	
3	III	Clariant 2031	50	Outdoor Snow	>-3	Any	1	1	
4	III	Clariant 2031	50	Outdoor Snow	>-3	Any	1	1	
5	III	Clariant 2031	50	Outdoor Snow	>-3	Any	1	1	
6	II	Clariant 2025	50	Outdoor Snow	>-3	Any	1	1	
7	II	Clariant 2025	50	Outdoor Snow	>-3	Any	1	1	
8	II	Clariant 2025	50	Outdoor Snow	>-3	Any	1	1	
9	II	Clariant 2025	50	Outdoor Snow	>-3	Any	1	1	
10	II	Clariant 2025	50	Outdoor Snow	>-3	Any	1	1	
11	IV	Octogen Maxflo	50	Outdoor Snow	>-3	Any	1	1	
12	IV	Octogen Maxflo	50	Outdoor Snow	>-3	Any	1	1	
13	IV	Octogen Maxflo	50	Outdoor Snow	>-3	Any	1	1	
14	IV	Octogen Maxflo	50	Outdoor Snow	>-3	Any	1	1	
15	IV	Octogen Maxflo	50	Outdoor Snow	>-3	Any	1	1	
16	III	Clariant 2031	75	Outdoor Snow	>-14	Any	1	1	
17	III	Clariant 2031	75	Outdoor Snow	>-14	Any	1	1	
18	III	Clariant 2031	75	Outdoor Snow	>-14	Any	1	1	
19	III	Clariant 2031	75	Outdoor Snow	>-14	Any	1	1	
20	III	Clariant 2031	75	Outdoor Snow	>-14	Any	1	1	
21	III	Clariant 2031	75	Outdoor Snow	>-14	Any	1	1	
22	III	Clariant 2031	75	Outdoor Snow	>-14	Any	1	1	
23	III	Clariant 2031	75	Outdoor Snow	>-14	Any	1	1	
24	II	Clariant 2025	75	Outdoor Snow	>-14	Any	1	1	
25	II	Clariant 2025	75	Outdoor Snow	>-14	Any	1	1	
26	II	Clariant 2025	75	Outdoor Snow	>-14	Any	1	1	
27	II	Clariant 2025	75	Outdoor Snow	>-14	Any	1	1	
28	II	Clariant 2025	75	Outdoor Snow	>-14	Any	1	1	
29	II	Clariant 2025	75	Outdoor Snow	>-14	Any	1	1	
30	II	Clariant 2025	75	Outdoor Snow	>-14	Any	1	1	
31	II	Clariant 2025	75	Outdoor Snow	>-14	Any	1	1	
32	II	Clariant 2025	75	Outdoor Snow	>-14	Any	1	1	
33	IV	Octogen Maxflo	75	Outdoor Snow	>-14	Any	1	1	
34	IV	Octogen Maxflo	75	Outdoor Snow	>-14	Any	1	1	
35	IV	Octogen Maxflo	75	Outdoor Snow	>-14	Any	1	1	
36	IV	Octogen Maxflo	75	Outdoor Snow	>-14	Any	1	1	
37	IV	Octogen Maxflo	75	Outdoor Snow	>-14	Any	1	1	
38	IV	Octogen Maxflo	75	Outdoor Snow	>-14	Any	1	1	
39	IV	Octogen Maxflo	75	Outdoor Snow	>-14	Any	1	1	
40	IV	Octogen Maxflo	75	Outdoor Snow	>-14	Any	1	1	
41	III	Clariant 2031	100	Outdoor Snow	Any	Any	1	1	
42	III	Clariant 2031	100	Outdoor Snow	Any	Any	1	1	
43	III	Clariant 2031	100	Outdoor Snow	Any	Any	1	1	
44	III	Clariant 2031	100	Outdoor Snow	Any	Any	1	1	
45	III	Clariant 2031	100	Outdoor Snow	Any	Any	1	1	
46	III	Clariant 2031	100	Outdoor Snow	Any	Any	1	1	
47	III	Clariant 2031	100	Outdoor Snow	Any	Any	1	1	
48	II	Clariant 2025	100	Outdoor Snow	Any	Any	1	1	
49	II	Clariant 2025	100	Outdoor Snow	Any	Any	1	1	
50	II	Clariant 2025	100	Outdoor Snow	Any	Any	1	1	
51	II	Clariant 2025	100	Outdoor Snow	Any	Any	1	1	
52	II	Clariant 2025	100	Outdoor Snow	Any	Any	1	1	
53	II	Clariant 2025	100	Outdoor Snow	Any	Any	1	1	
54	IV	Octogen Maxflo	100	Outdoor Snow	Any	Any	1	1	
55	IV	Octogen Maxflo	100	Outdoor Snow	Any	Any	1	1	
56	IV	Octogen Maxflo	100	Outdoor Snow	Any	Any	1	1	
57	IV	Octogen Maxflo	100	Outdoor Snow	Any	Any	1	1	
58	IV	Octogen Maxflo	100	Outdoor Snow	Any	Any	1	1	
59	IV	Octogen Maxflo	100	Outdoor Snow	Any	Any	1	1	
60	IV	Octogen Maxflo	100	Outdoor Snow	Any	Any	1	1	
61	IV	Ultra +	100	Outdoor Snow	Any	Any	1	1	
62	IV	Ultra +	100	Outdoor Snow	Any	Any	1	1	
63	IV	Ultra +	100	Outdoor Snow	Any	Any	1	1	
64	IV	Ultra +	100	Outdoor Snow	Any	Any	1	1	
65	IV	Ultra +	100	Outdoor Snow	Any	Any	1	1	
66	IV	Ultra +	100	Outdoor Snow	Any	Any	1	1	
67	II	ABC2000	100	Outdoor Snow	Any	Any	1	1	
68	II	ABC2000	100	Outdoor Snow	Any	Any	1	1	
69	II	ABC2000	100	Outdoor Snow	Any	Any	1	1	
70	II	ABC2000	100	Outdoor Snow	Any	Any	1	1	
71	II	ABC2000	100	Outdoor Snow	Any	Any	1	1	
72	II	ABC2000	100	Outdoor Snow	Any	Any	1	1	
73	II	ABC2000	75	Outdoor Snow	>-14	Any	1	1	
74	II	ABC2000	75	Outdoor Snow	>-14	Any	1	1	
75	II	ABC2000	75	Outdoor Snow	>-14	Any	1	1	
76	II	ABC2000	75	Outdoor Snow	>-14	Any	1	1	
77	II	ABC2000	50	Outdoor Snow	>-3	Any	1	1	
78	II	ABC2000	50	Outdoor Snow	>-3	Any	1	1	
79	II	ABC2000	50	Outdoor Snow	>-3	Any	1	1	
80	II	ABC2000	50	Outdoor Snow	>-3	Any	1	1	

TABLE 2: MATRIX OF INDOOR TESTS

Test #	Fluid Type	Fluid Brand*	Dilution	Precip Type	Test Temp. [°C]	Precip Rate [g/dm²/h]	STD Test	Heated Plate (indoor)	Comments
H1	II	Clariant 2025	50	ZD	-3	5	1	1	
H2	II	Clariant 2025	75	ZD	-10	13	1	1	
H3	II	Clariant 2025	50	ZR	-3	13	1	1	
H4	II	Clariant 2025	75	ZR	-3	25	1	1	
H5	II	Clariant 2025	100	ZR	-3	25	1	1	
H6	III	Clariant 2031	50	ZD	-3	5	1	1	
H7	III	Clariant 2031	100	ZD	-3	13	1	1	
H8	III	Clariant 2031	75	ZD	-3	13	1	1	
H9	III	Clariant 2031	100	ZD	-10	5	1	1	
H10	III	Clariant 2031	75	ZD	-10	13	1	1	
H11	III	Clariant 2031	75	ZR	-3	13	1	1	
H12	III	Clariant 2031	100	ZR	-10	13	1	1	
H13	III	Clariant 2031	75	ZR	-10	13	1	1	
H14	IV	Octogon Maxflo	50	ZD	-3	13	1	1	
H15	IV	Octogon Maxflo	100	ZD	-10	13	1	1	
H16	IV	Octogon Maxflo	75	ZD	-10	5	1	1	
H17	IV	Octogon Maxflo	100	ZR	-3	25	1	1	
H18	IV	Octogon Maxflo	100	ZR	-10	13	1	1	
H19	IV	Octogon Maxflo	75	ZR	-10	13	1	1	
H20	II	ABC2000	75	ZD	-3	5	1	1	
H21	II	ABC2000	100	ZR	-3	25	1	1	
H22	II	ABC2000	50	ZD	-3	13	1	1	
H23	II	ABC2000	75	ZD	-10	13	1	1	
H24	IV	Ultra +	100	ZD	-3	5	1	1	
H25	IV	Ultra +	100	ZR	-10	25	1	1	

EXPERIMENTAL PROGRAM: EFFECT OF HEAT ON ENDURANCE TIME OF ANTI-ICNG FLUIDS

TABLE 3: FLUID BRIX/THICKNESS DATA FORM

FLUID BRIX / THICKNESS DATA FORM

DATE: ______________ PERFORMED BY: ______________

RUN #: ______________ WRITTEN BY: ______________

STAND: ______________ LOCATION: ______________

Plate / BOX:			Plate / BOX:			Plate / BOX:			Plate / BOX:		
Fluid:			Fluid:			Fluid:			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

M:\Groups\CM (TC-Deicing 05-06)\Procedures\Effect of Heat\Version 1.0
Version 1.0, November 2005

9 of 10

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APPENDIX D

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:

- 2004-05 Charts
  - 2004-05 snow tests; and
  - 2004-05 freezing precipitation tests.
- 2005-06 Charts
  - 2005-06 snow tests; and
  - 2005-06 freezing precipitation tests.

Within these groups, the charts are presented in ascending order by test number. Two charts are shown on each page. The first chart is a heated fluid application test (Type I protocol) and the second chart is the corresponding OAT/ambient temperature test (standard Type II/IV protocol). Depending on the test numbers, the heated chart may appear above or below the OAT/ambient chart.

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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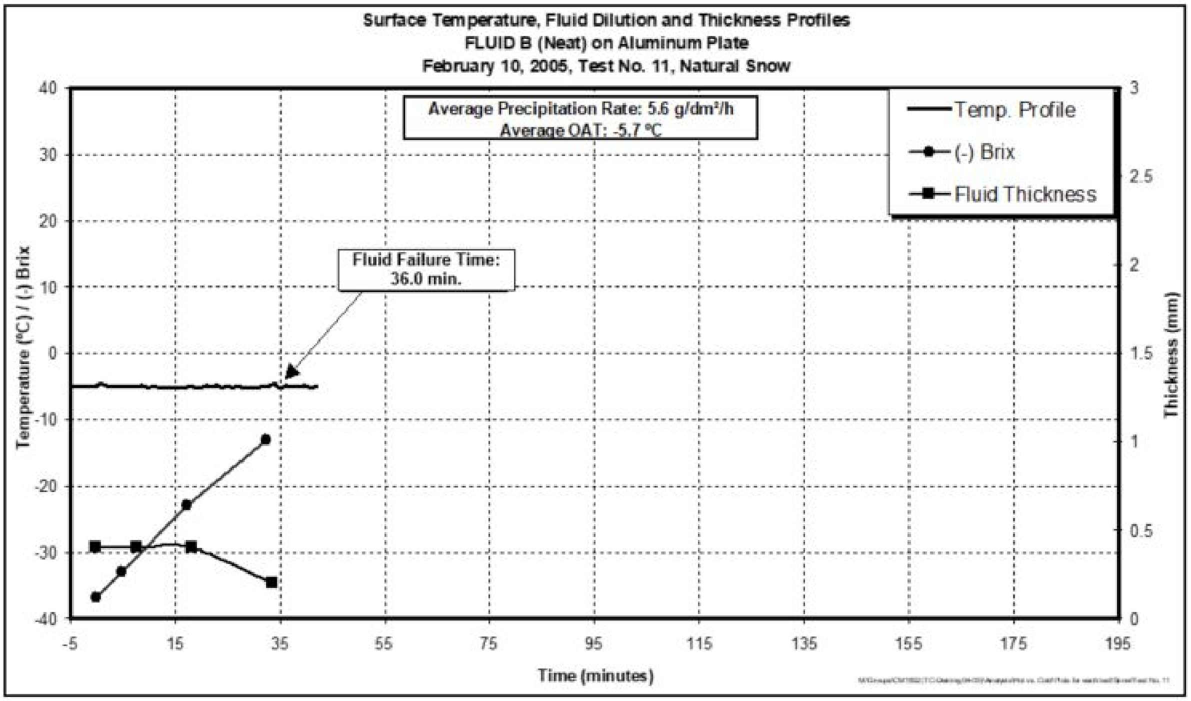
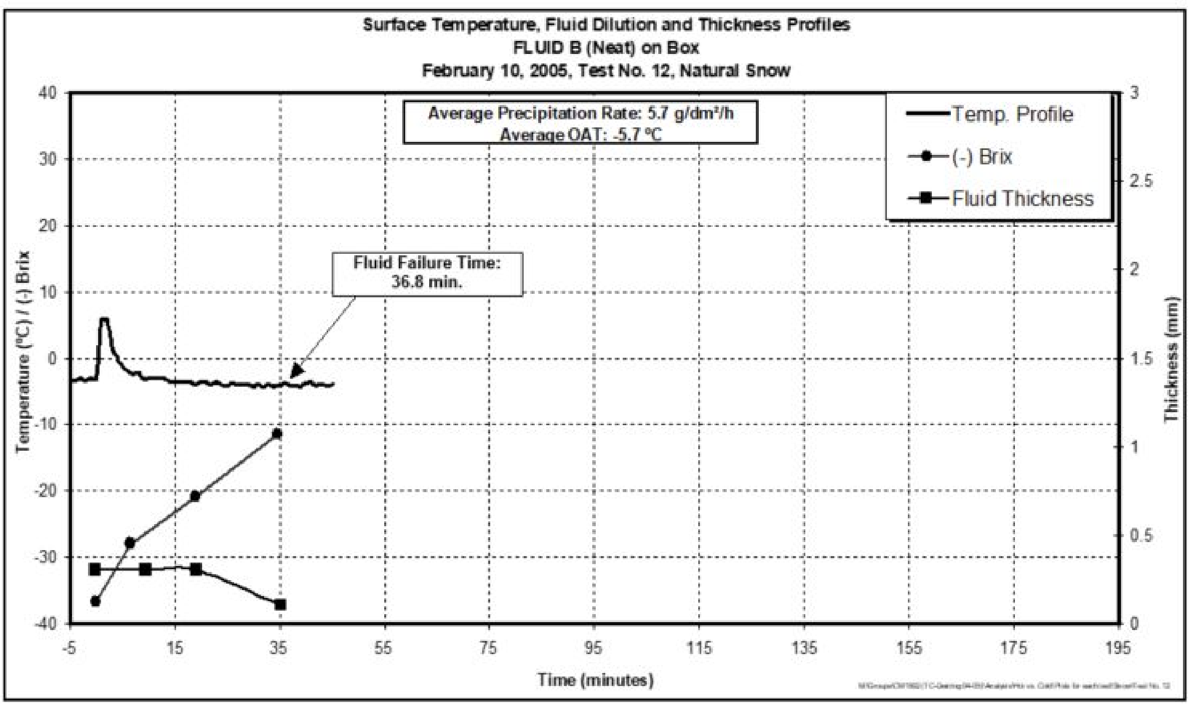
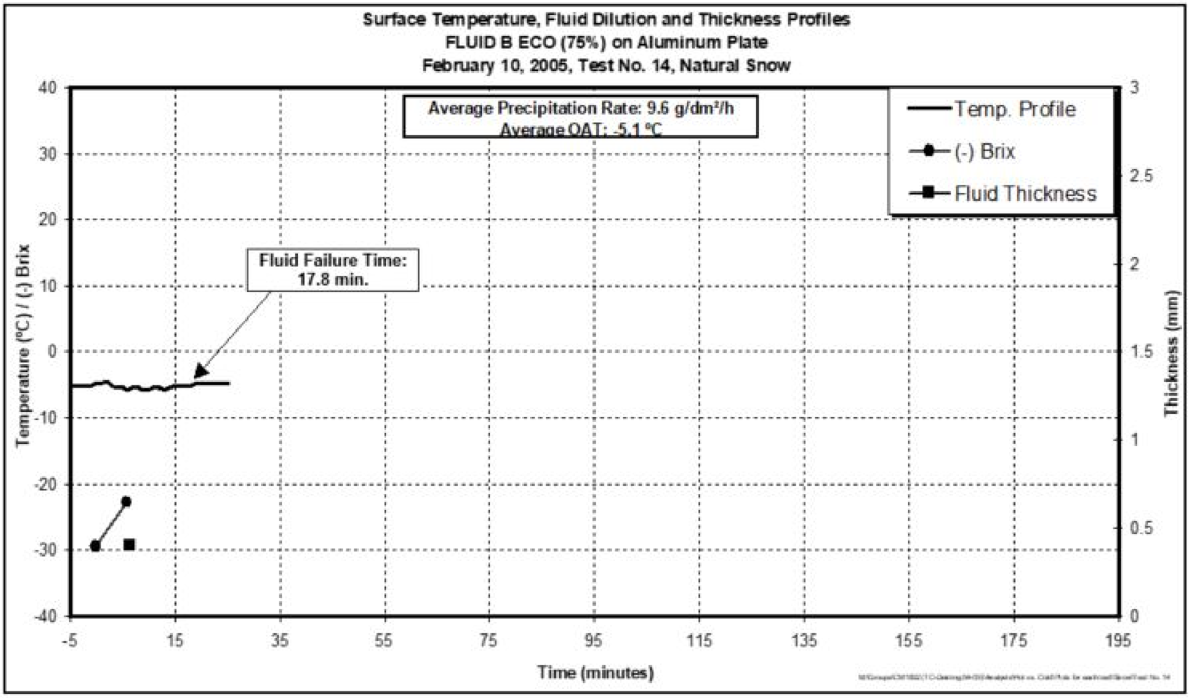
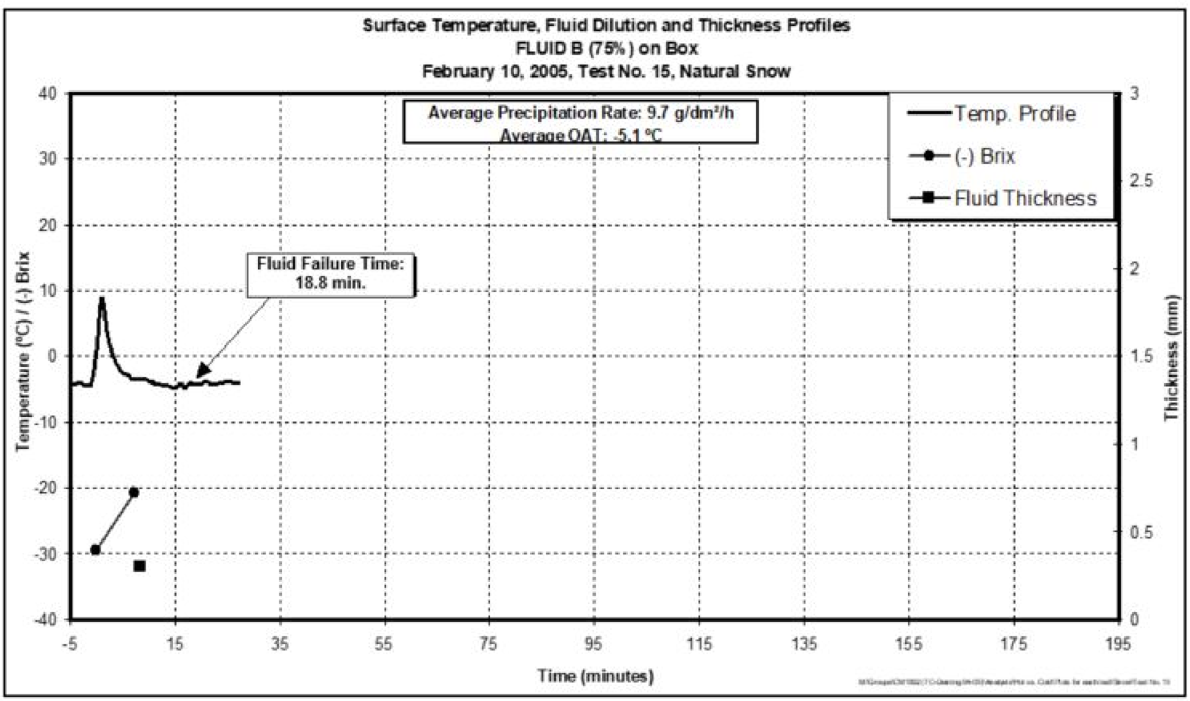
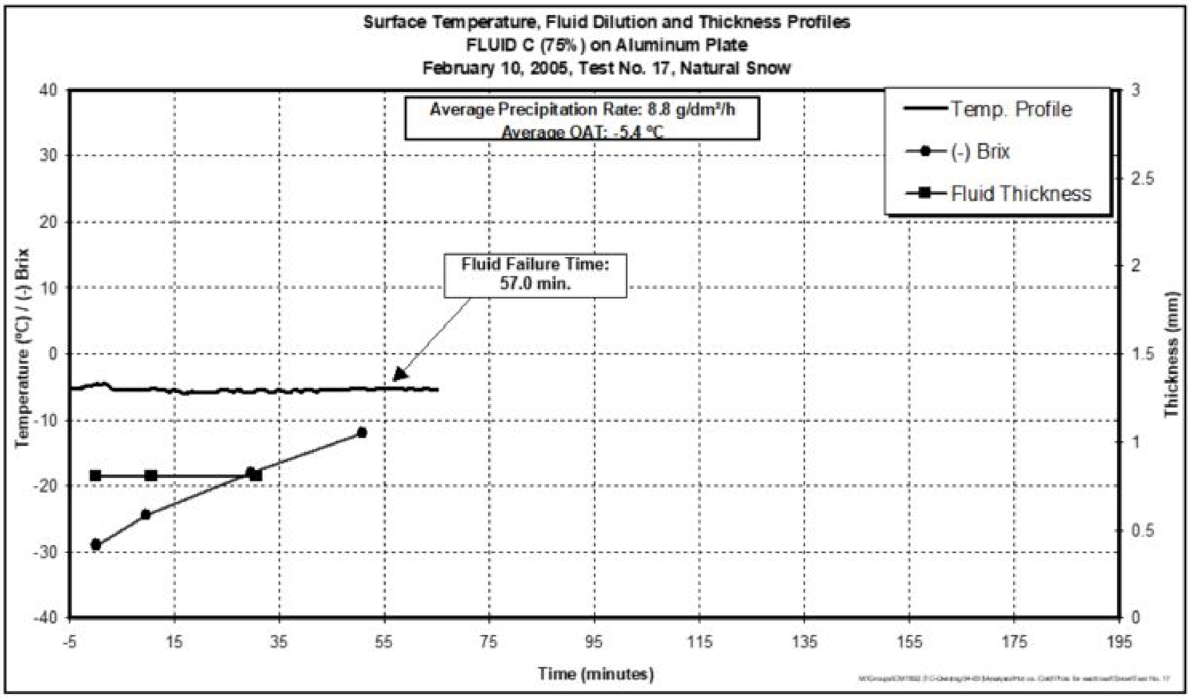
2004-05 CHARTS

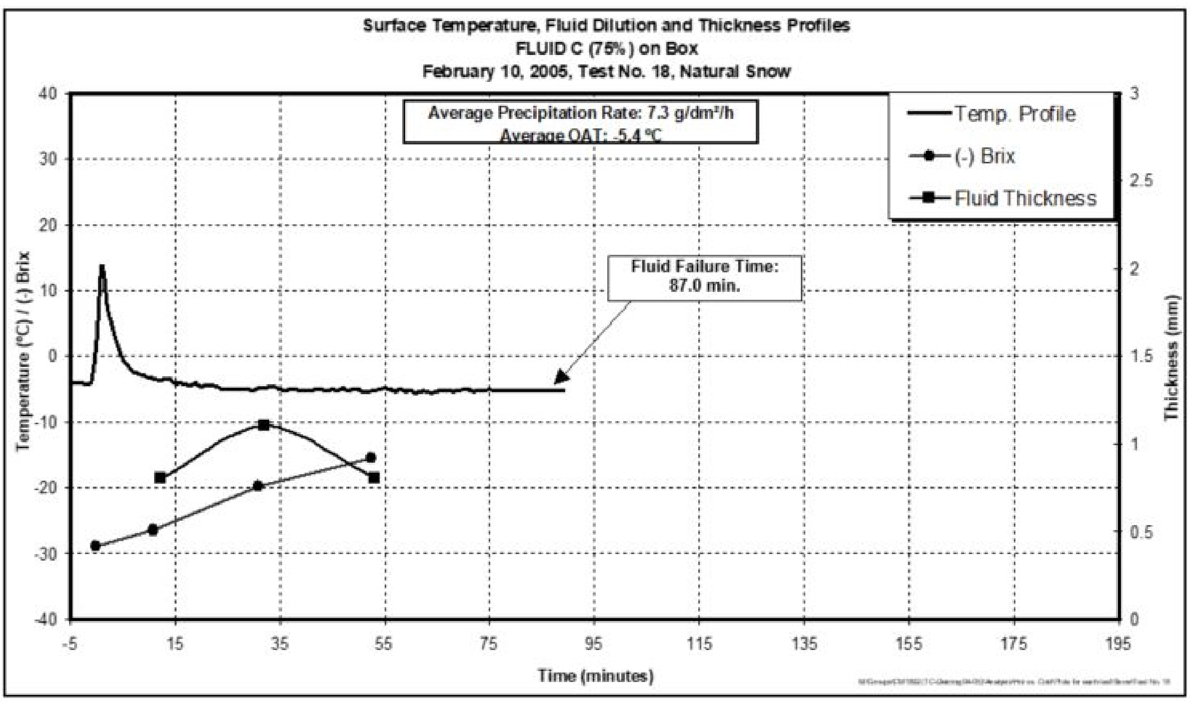

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
February 10, 2005, Test No. 11, Natural Snow
Average Precipitation Rate: 5.6 g/dm²/h
Average OAT: -5.7 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
36.0 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

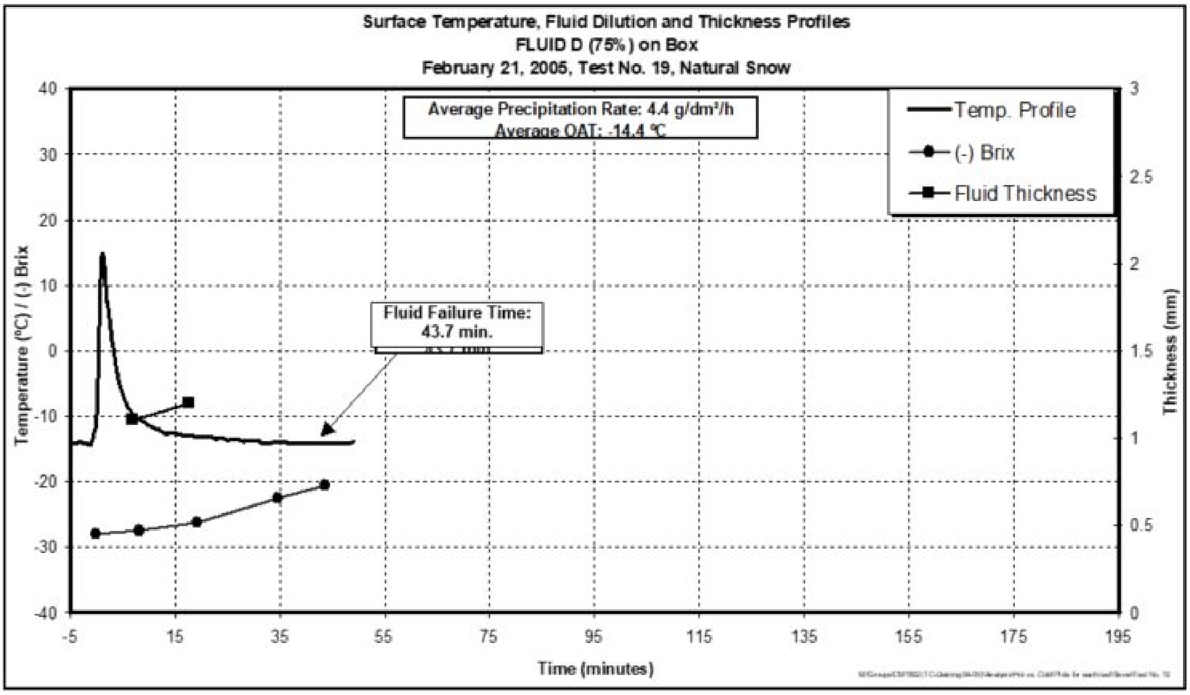

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Box
February 10, 2005, Test No. 12, Natural Snow
Average Precipitation Rate: 5.7 g/dm²/h
Average OAT: -5.7 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
36.8 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B ECO (75%) on Aluminum Plate
February 10, 2005, Test No. 14, Natural Snow
Average Precipitation Rate: 9.6 g/dm²/h
Average OAT: -5.1 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
17.8 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

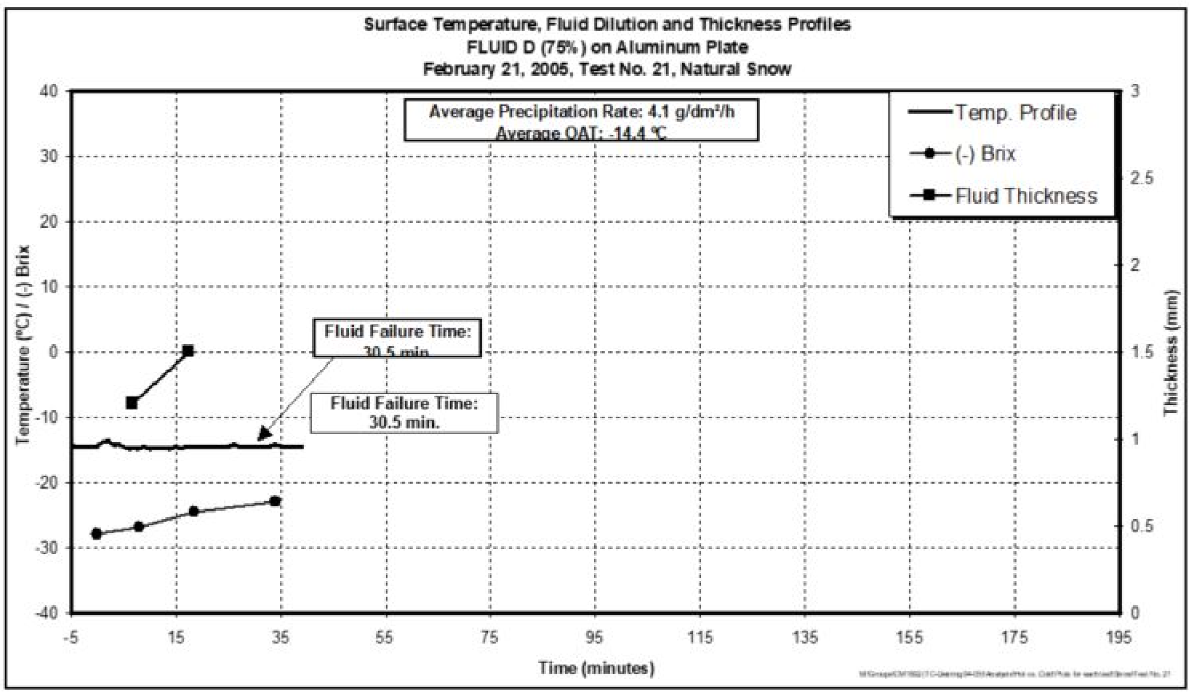

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Box
February 10, 2005, Test No. 15, Natural Snow
Average Precipitation Rate: 9.7 g/dm²/h
Average OAT: -5.1 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
18.8 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
February 10, 2005, Test No. 17, Natural Snow
Average Precipitation Rate: 8.8 g/dm²/h
Average OAT: -5.4 °C
Fluid Failure Time: 57.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

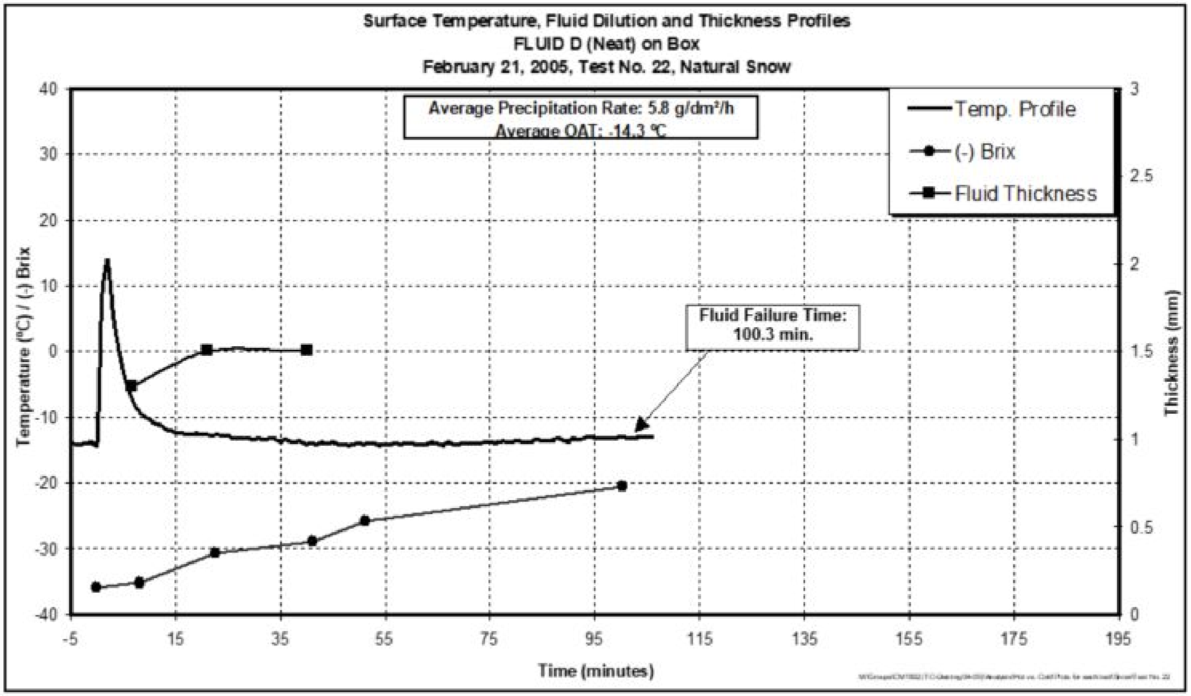

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Box
February 10, 2005, Test No. 18, Natural Snow
Average Precipitation Rate: 7.3 g/dm²/h
Average OAT: -5.4 °C
Fluid Failure Time: 87.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

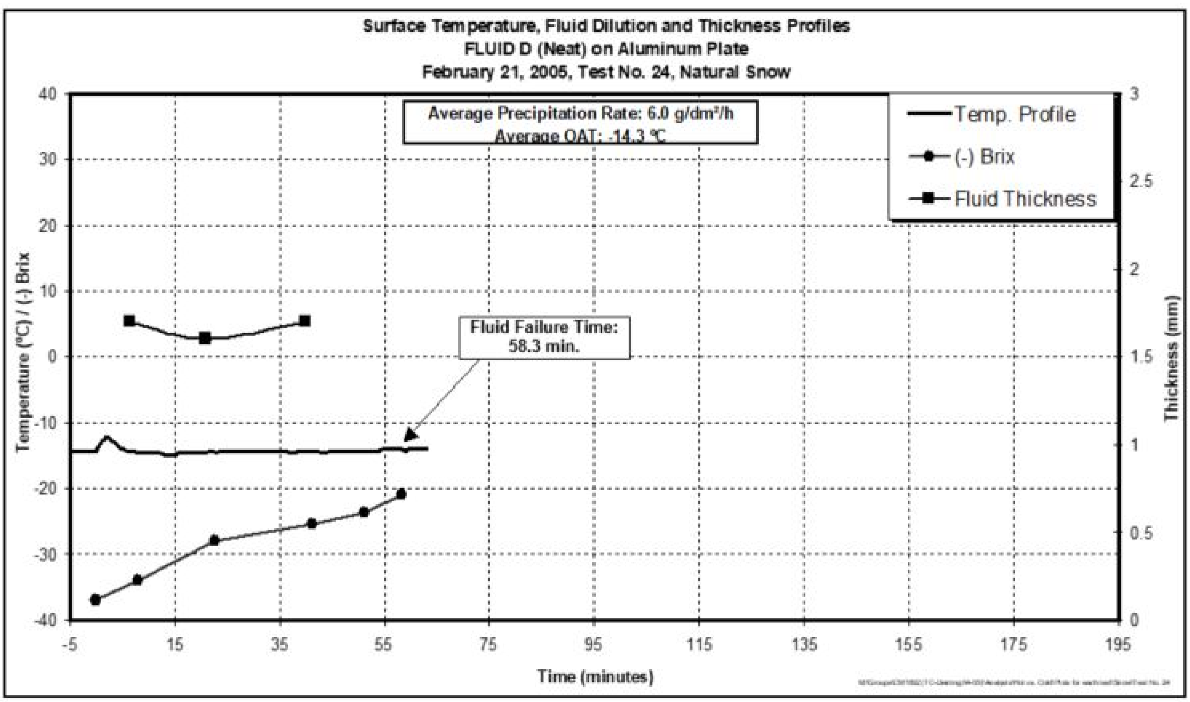


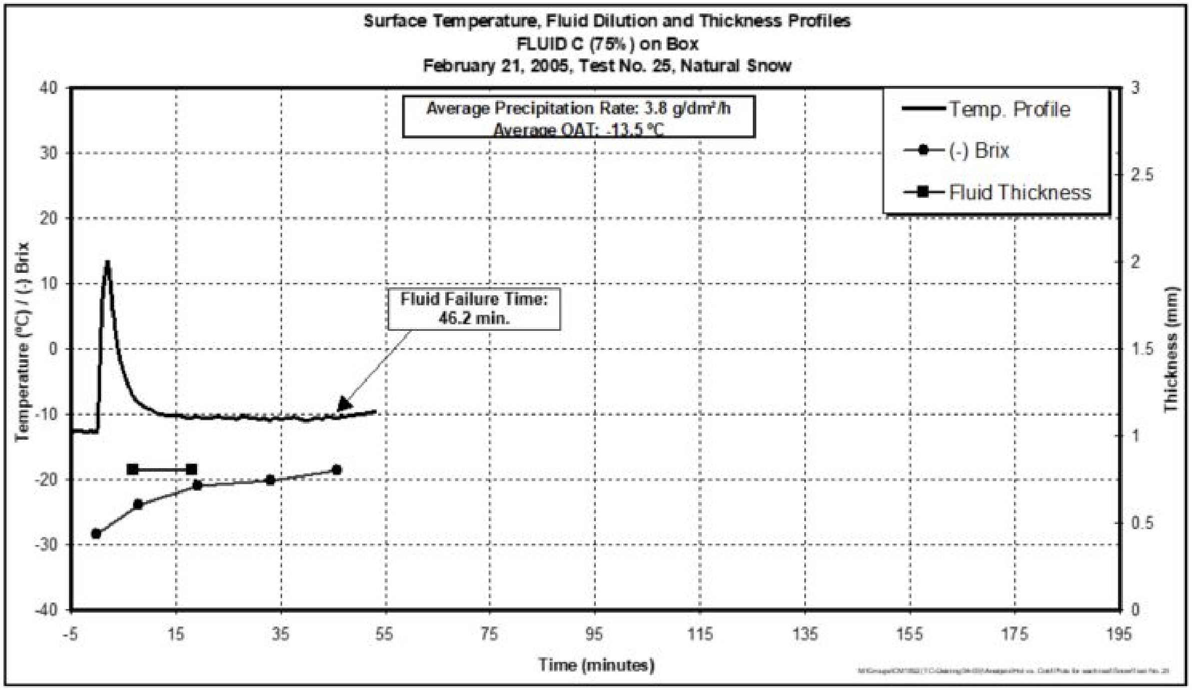
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (75%) on Box
February 21, 2005, Test No. 19, Natural Snow
Average Precipitation Rate: 4.4 g/dm²/h
Average OAT: -14.4 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
43.7 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

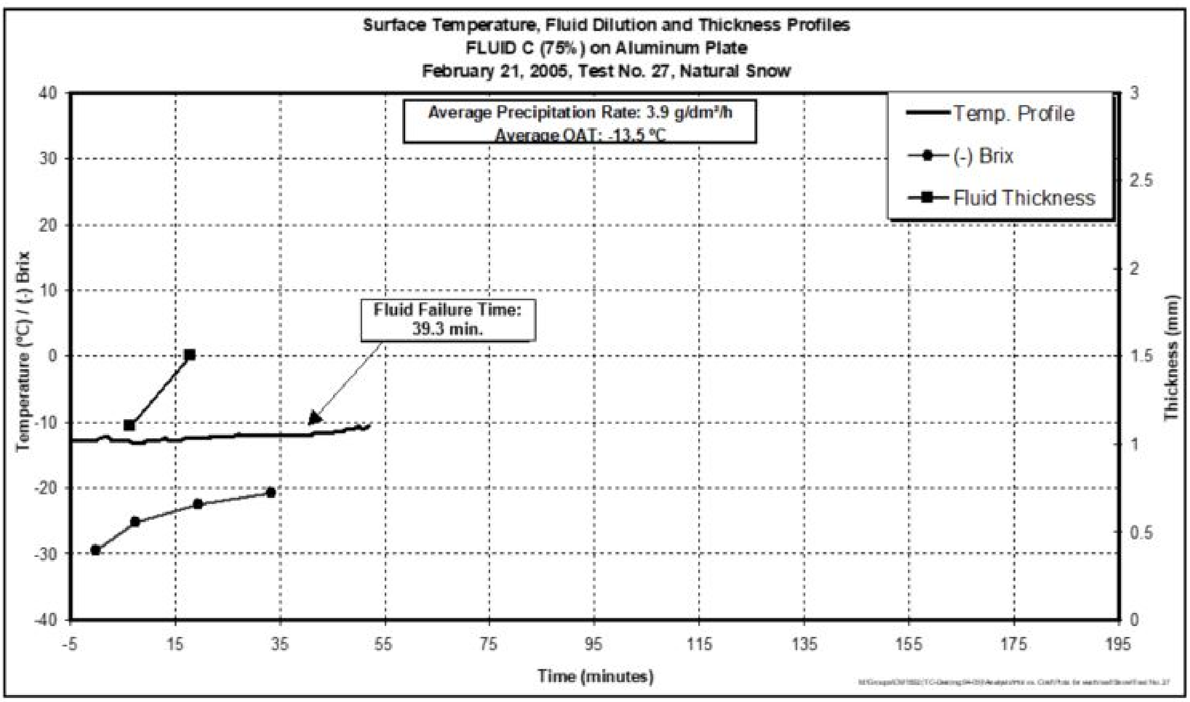


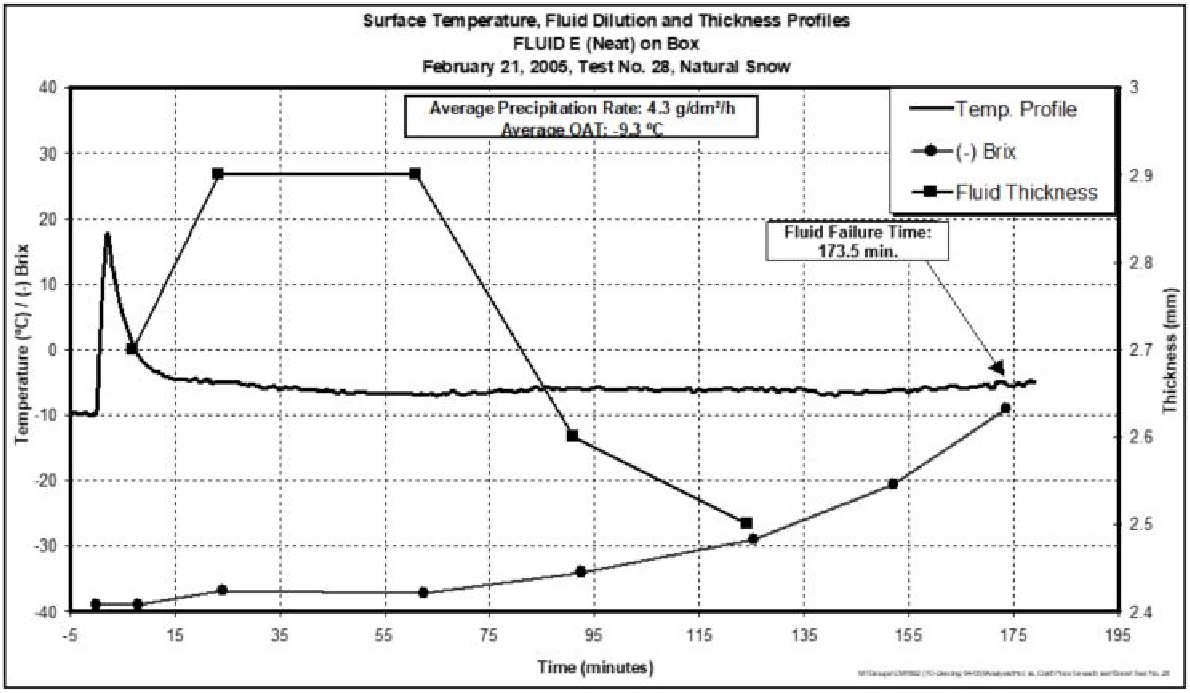
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (75%) on Aluminum Plate
February 21, 2005, Test No. 21, Natural Snow
Average Precipitation Rate: 4.1 g/dm²/h
Average OAT: -14.4 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
30.5 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

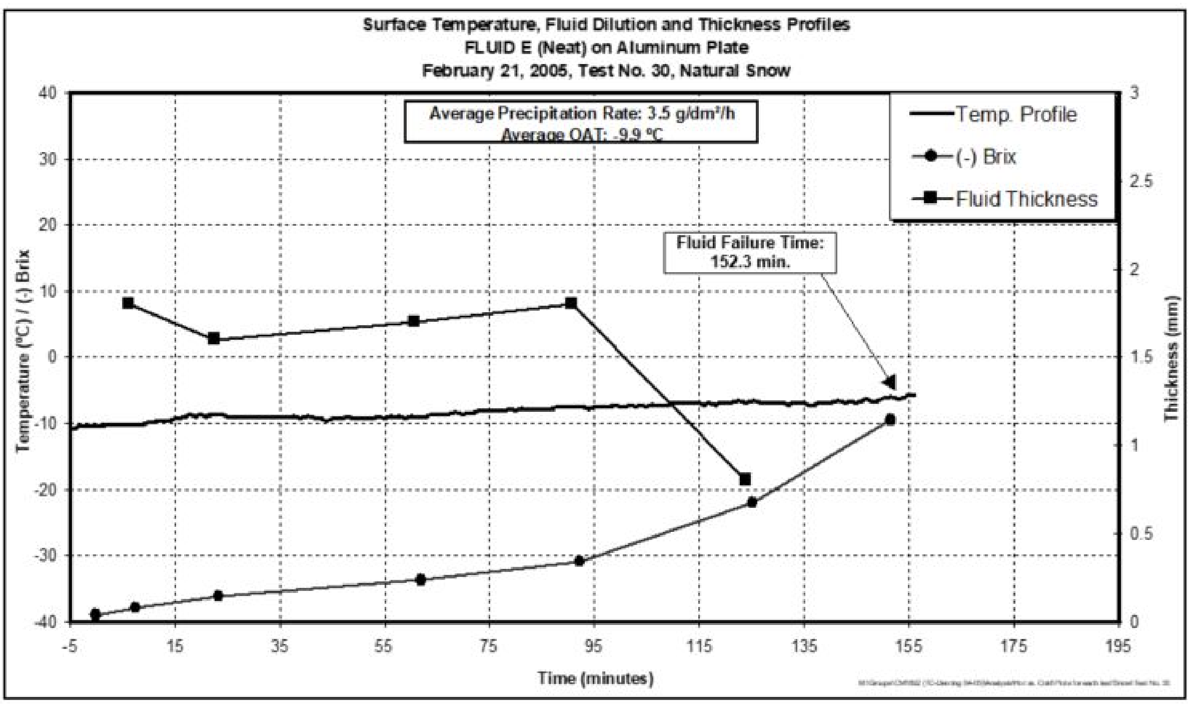

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (Neat) on Box
February 21, 2005, Test No. 22, Natural Snow
Average Precipitation Rate: 5.8 g/dm²/h
Average OAT: -14.3 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
100.3 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

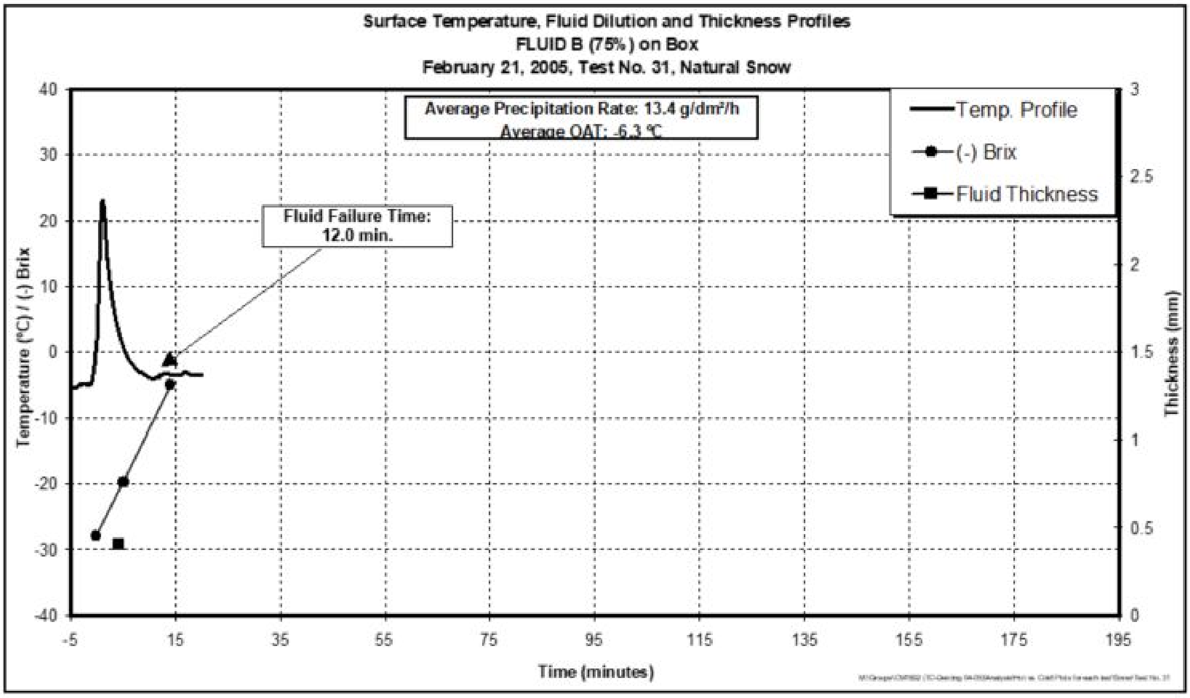

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (Neat) on Aluminum Plate
February 21, 2005, Test No. 24, Natural Snow
Average Precipitation Rate: 6.0 g/dm²/h
Average OAT: -14.3 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
58.3 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

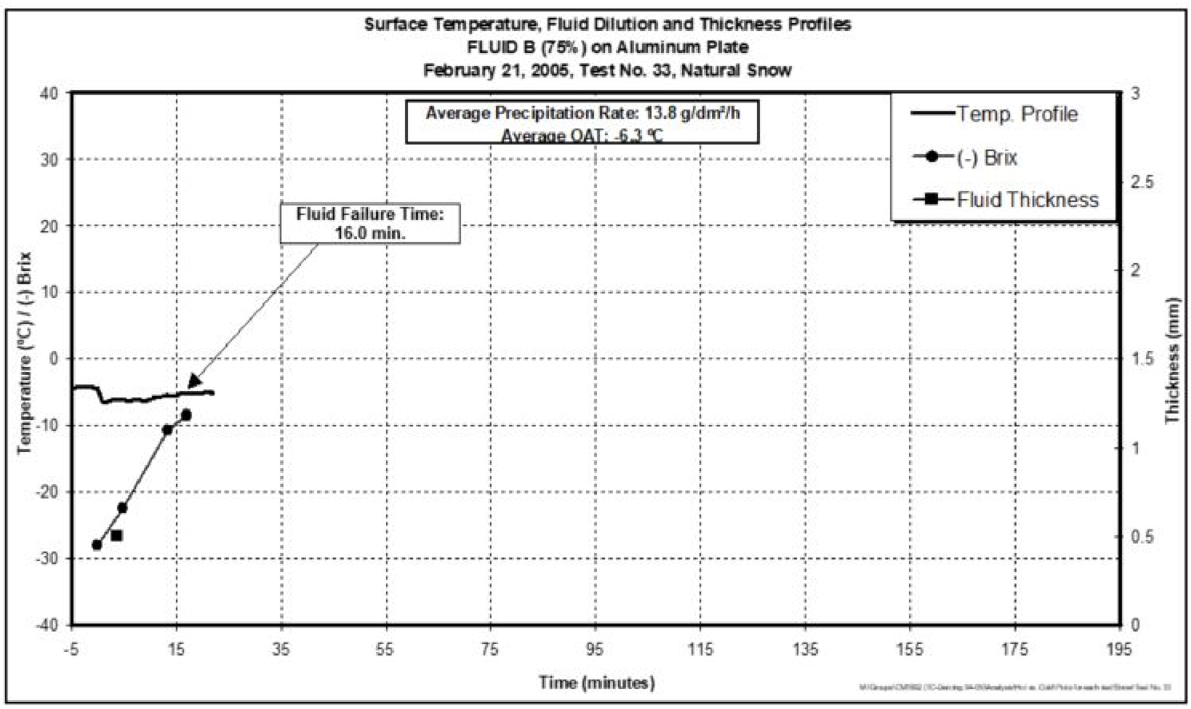

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Box
February 21, 2005, Test No. 25, Natural Snow
Average Precipitation Rate: 3.8 g/dm²/h
Average OAT: -13.5 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
46.2 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

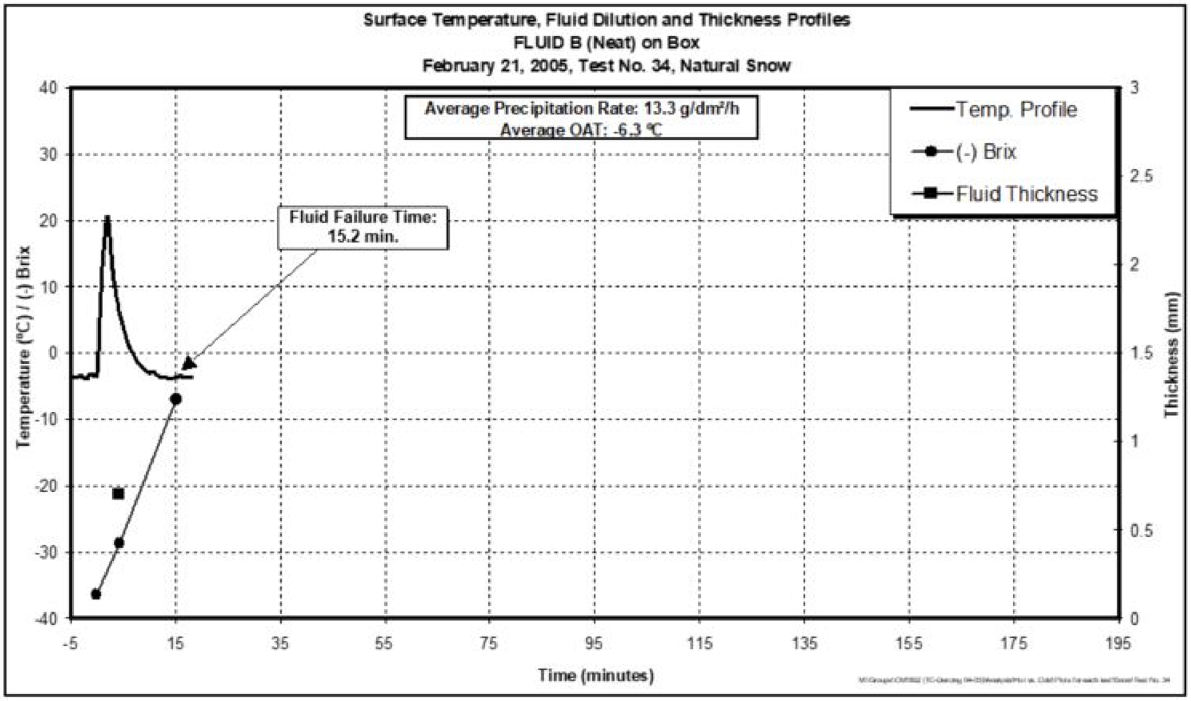

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
February 21, 2005, Test No. 27, Natural Snow
Average Precipitation Rate: 3.9 g/dm²/h
Average OAT: -13.5 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
39.3 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID E (Neat) on Box
February 21, 2005, Test No. 28, Natural Snow
Average Precipitation Rate: 4.3 g/dm²/h
Average OAT: -9.3 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
173.5 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.9
2.8
2.7
2.6
2.5
2.4
-5
15
35
55
75
95
115
135
155
175
195

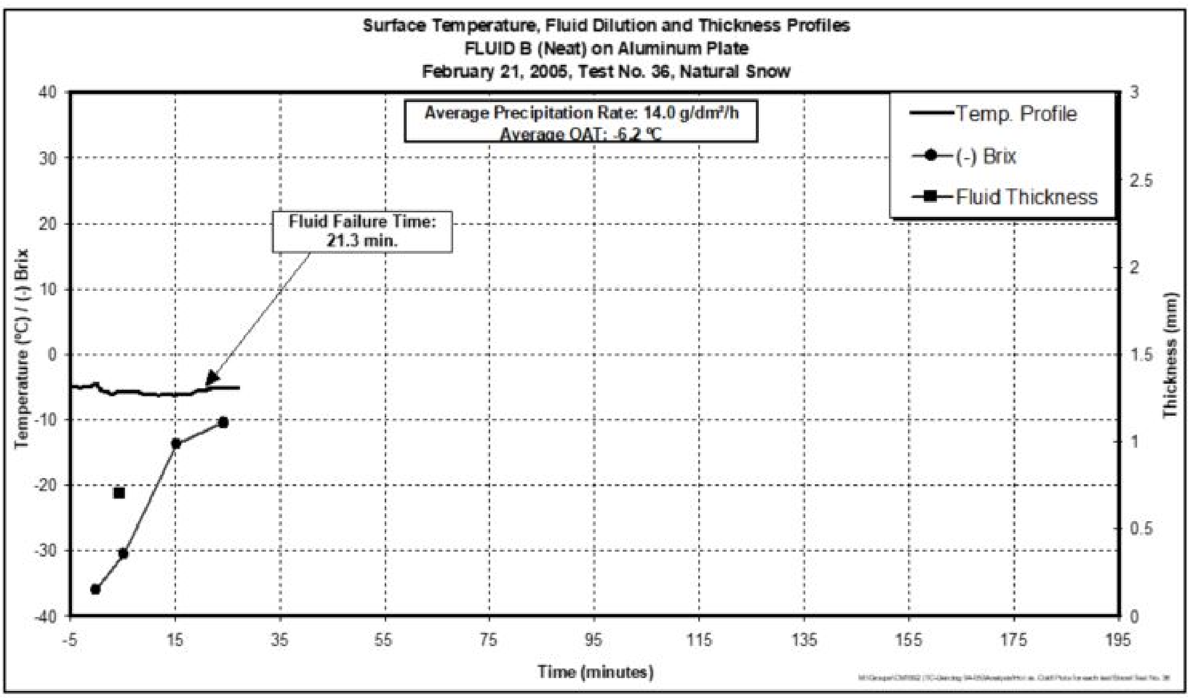

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID E (Neat) on Aluminum Plate
February 21, 2005, Test No. 30, Natural Snow
Average Precipitation Rate: 3.5 g/dm²/h
Average OAT: -9.9 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
152.3 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Box
February 21, 2005, Test No. 31, Natural Snow
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -6.3 °C
Fluid Failure Time:
12.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

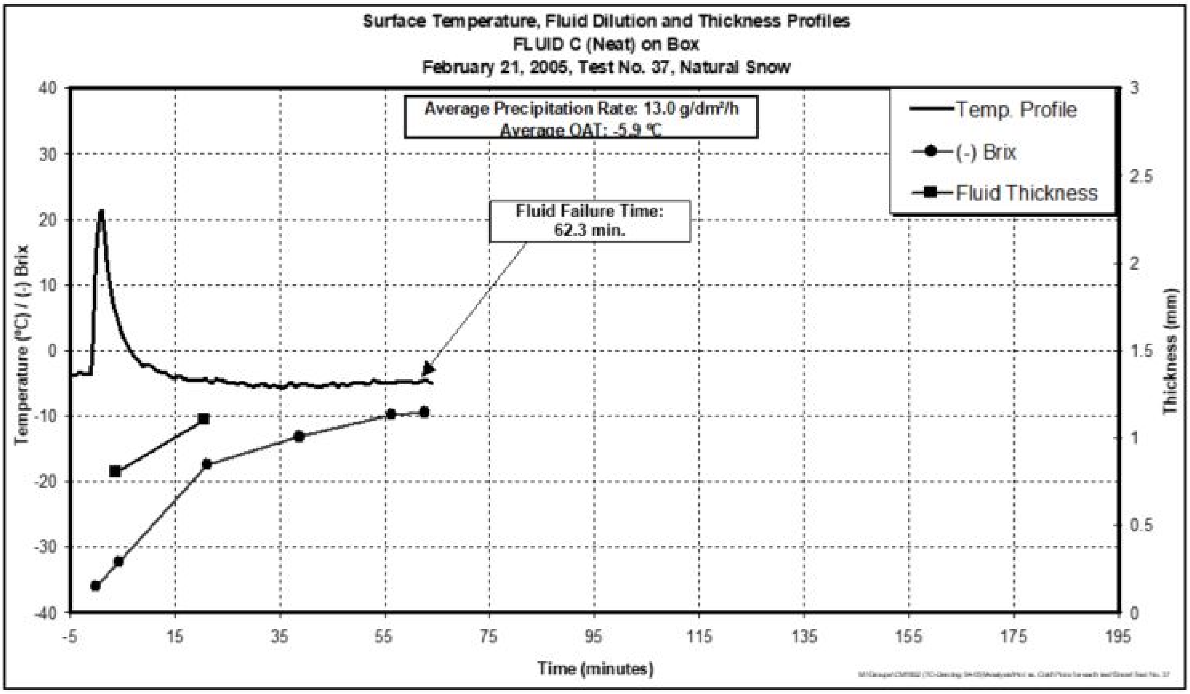

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
February 21, 2005, Test No. 33, Natural Snow
Average Precipitation Rate: 13.8 g/dm²/h
Average OAT: -6.3 °C
Fluid Failure Time:
16.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

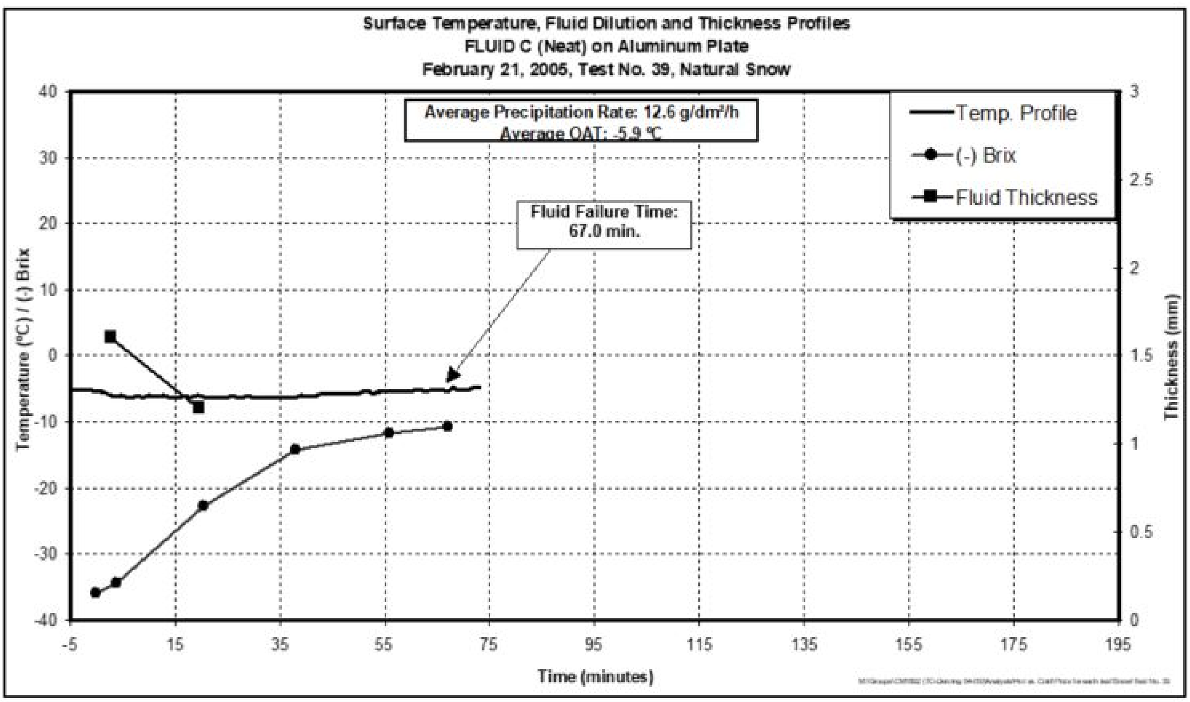


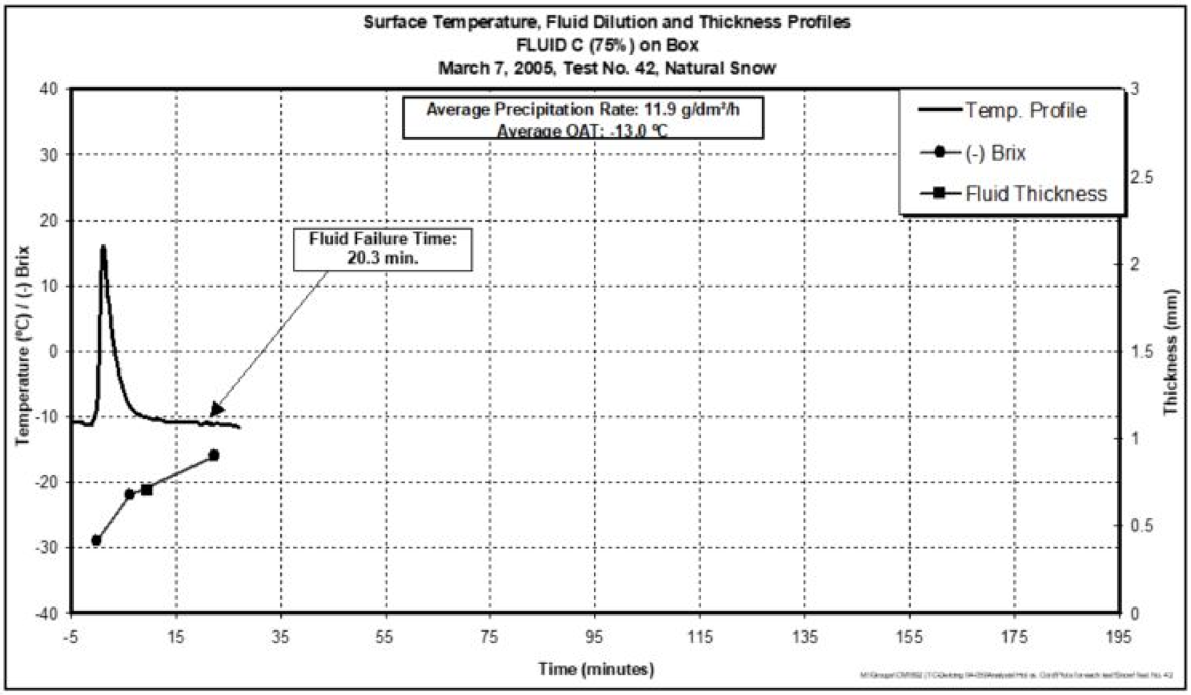
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Box
February 21, 2005, Test No. 34, Natural Snow
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -6.3 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
15.2 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

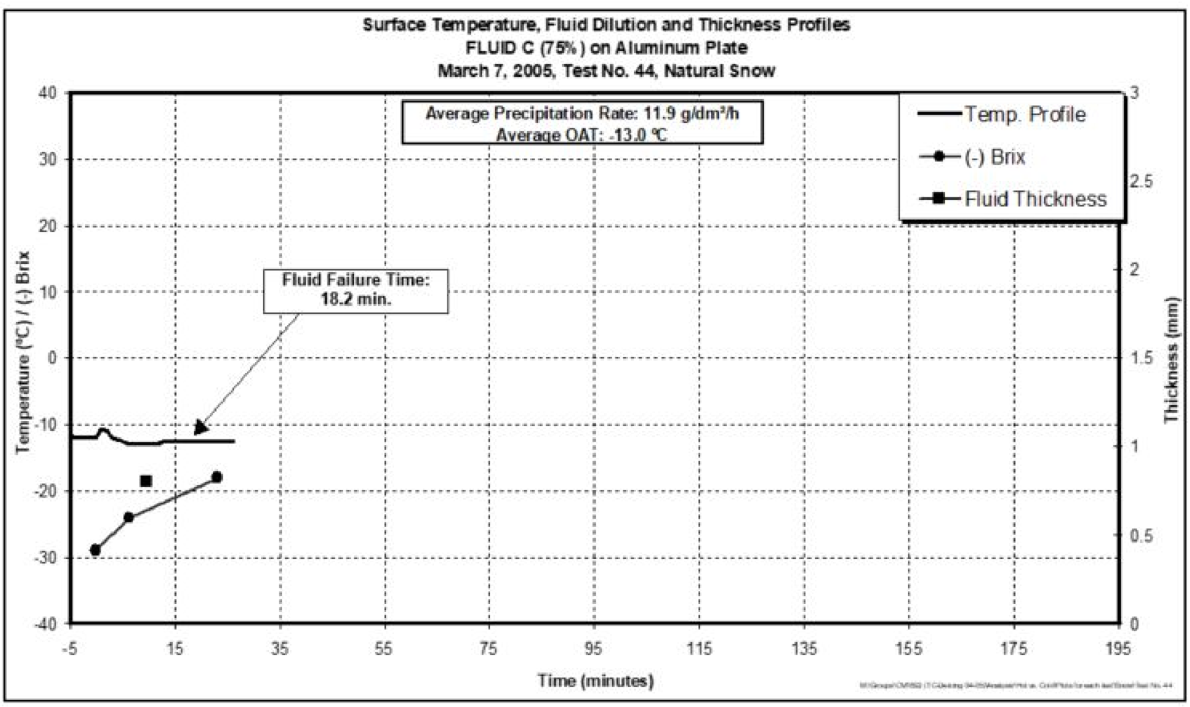


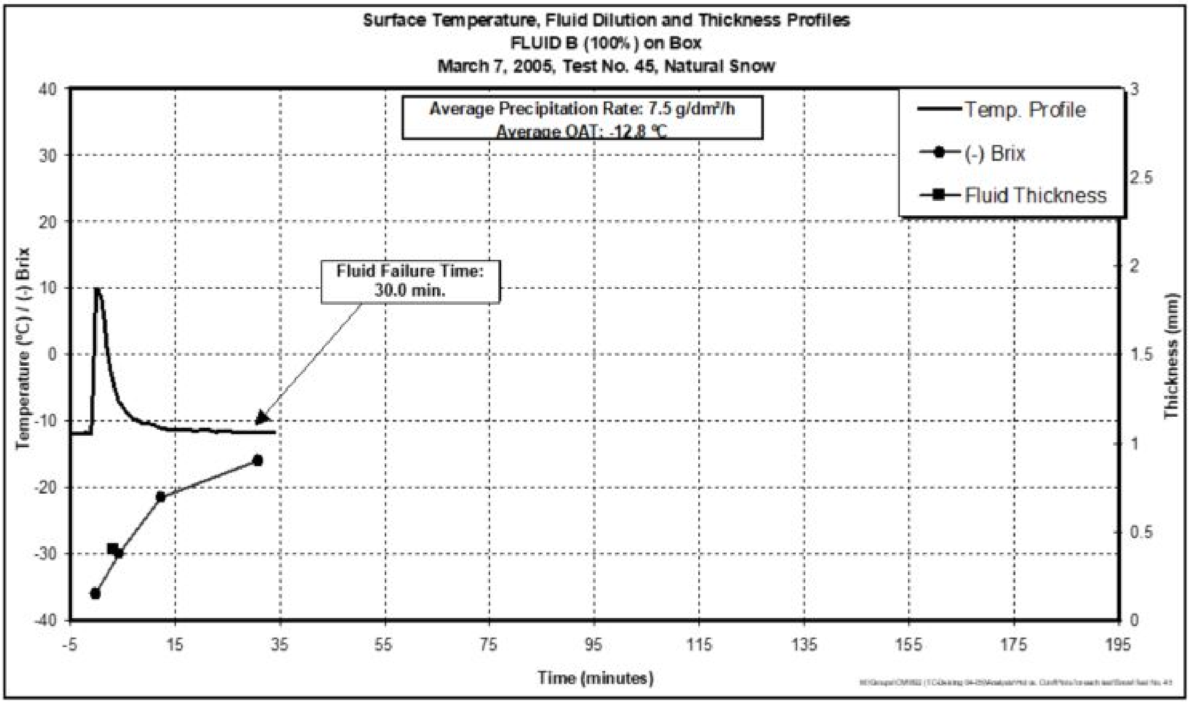
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
February 21, 2005, Test No. 36, Natural Snow
Average Precipitation Rate: 14.0 g/dm²/h
Average OAT: -6.2 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
21.3 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (Neat) on Box
February 21, 2005, Test No. 37, Natural Snow
Average Precipitation Rate: 13.0 g/dm²/h
Average OAT: -5.9 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 62.3 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

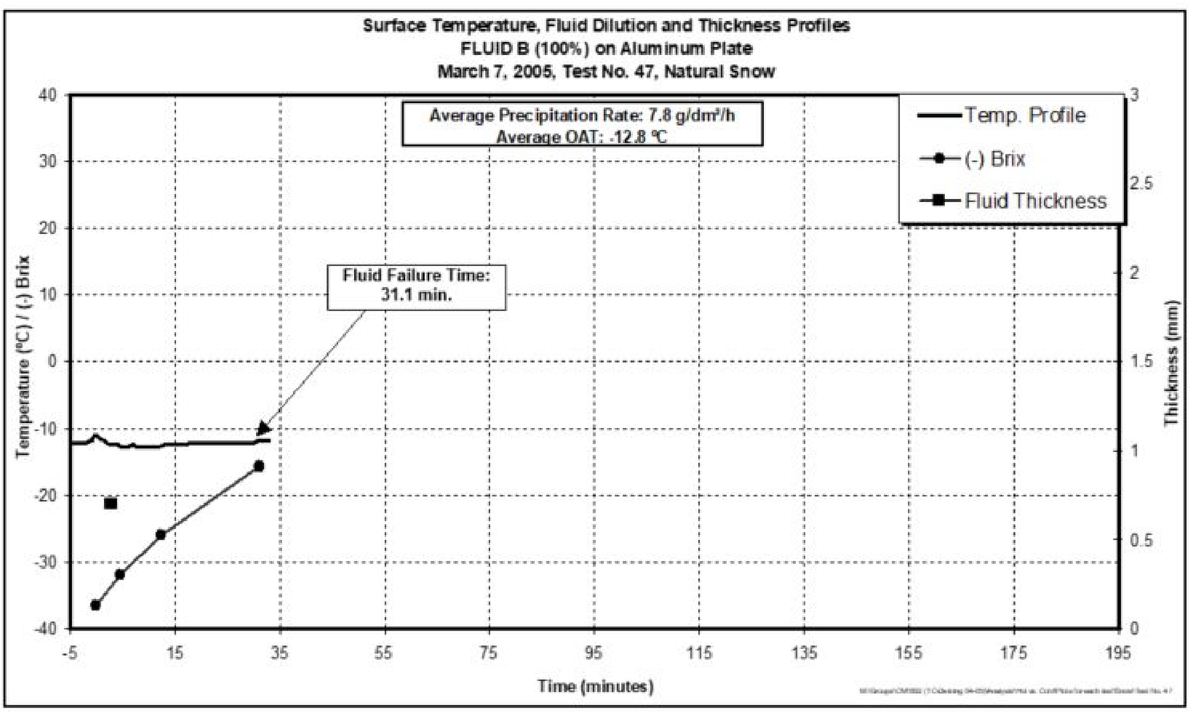

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (Neat) on Aluminum Plate
February 21, 2005, Test No. 39, Natural Snow
Average Precipitation Rate: 12.6 g/dm²/h
Average OAT: -5.9 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 67.0 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Box
March 7, 2005, Test No. 42, Natural Snow
Average Precipitation Rate: 11.9 g/dm²/h
Average OAT: -13.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
20.3 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

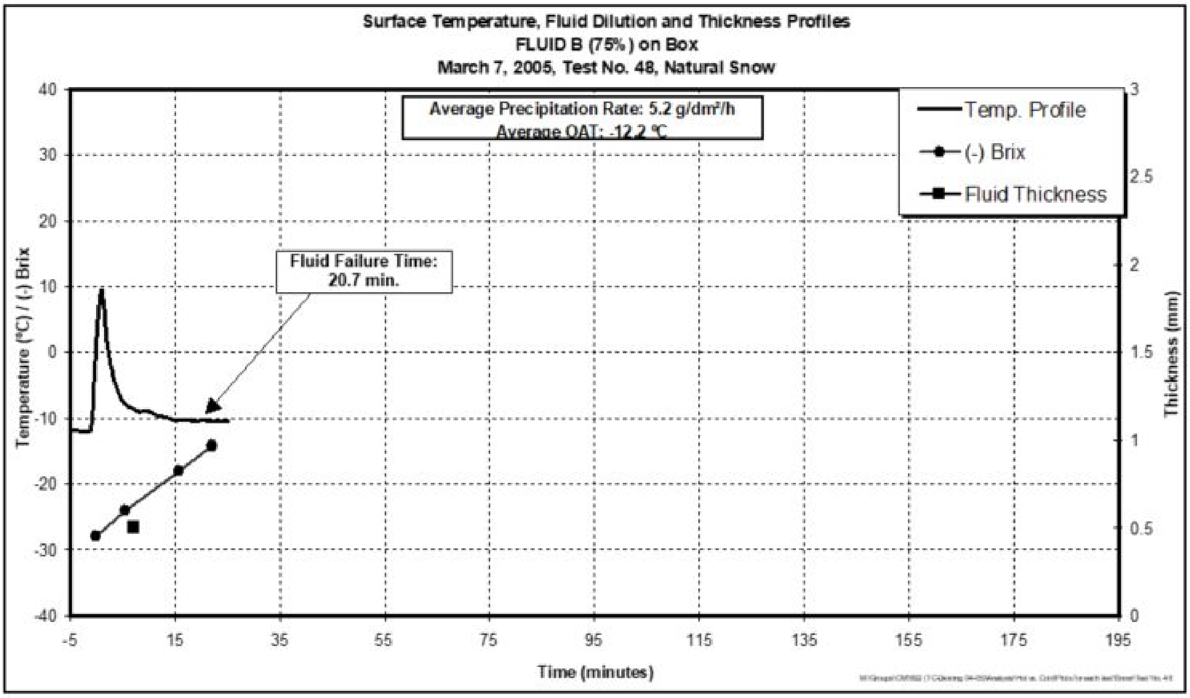

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
March 7, 2005, Test No. 44, Natural Snow
Average Precipitation Rate: 11.9 g/dm²/h
Average OAT: -13.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
18.2 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

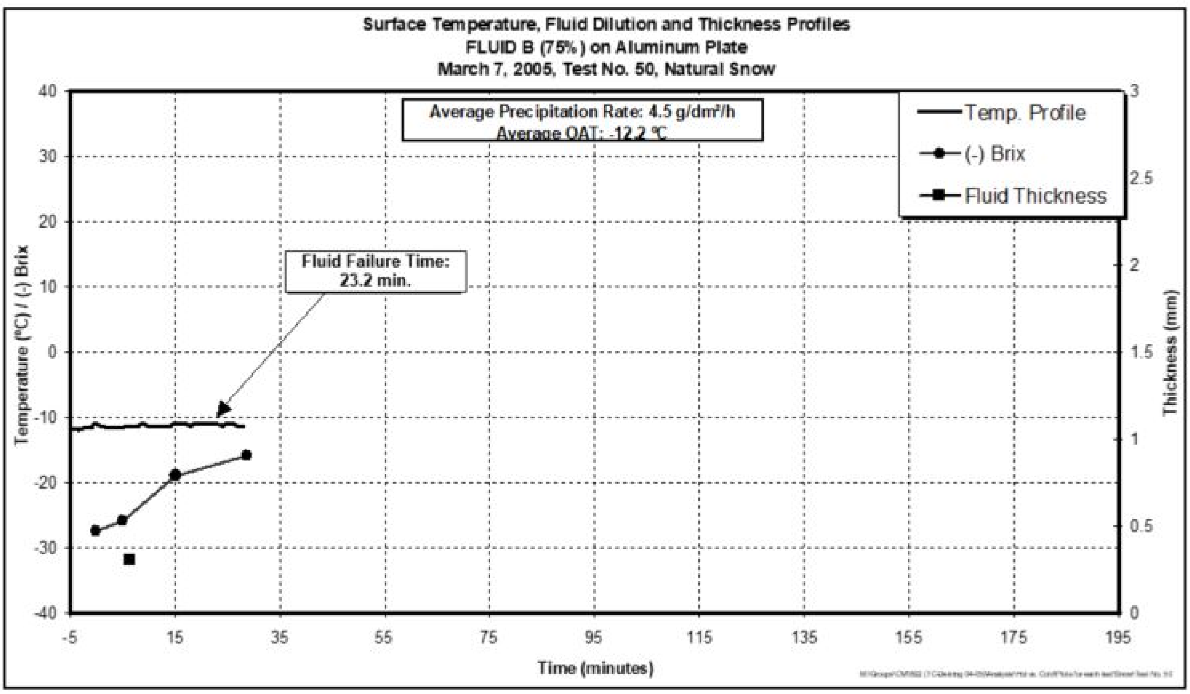


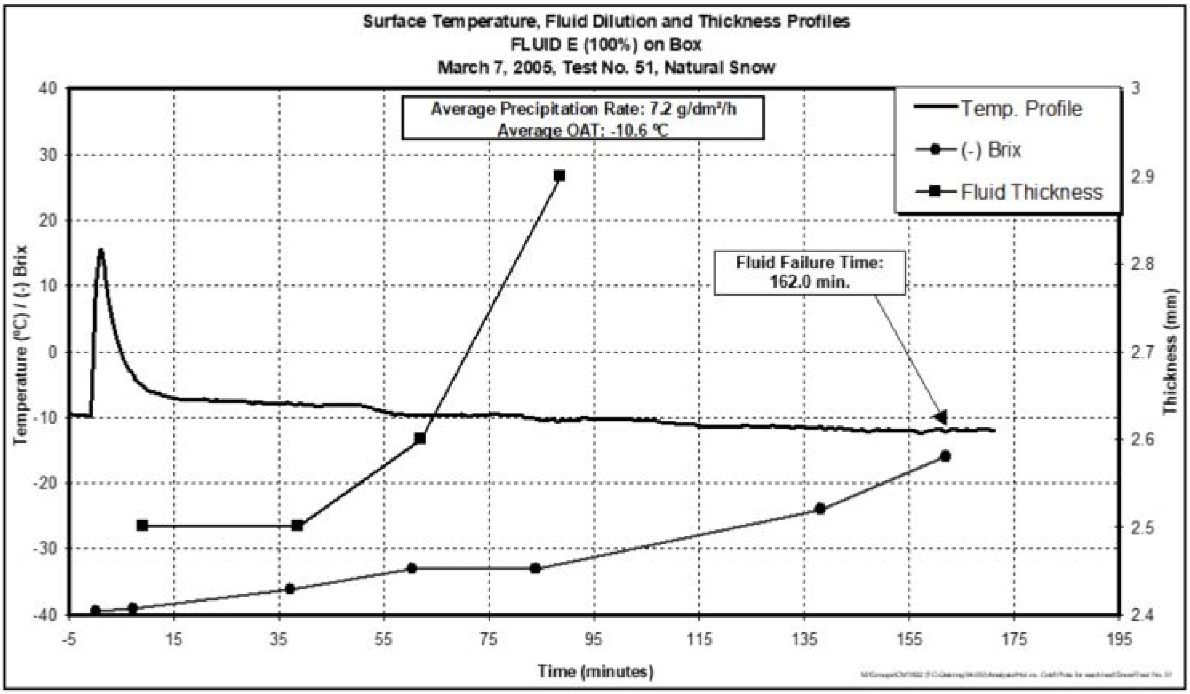
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (100%) on Box
March 7, 2005, Test No. 45, Natural Snow
Average Precipitation Rate: 7.5 g/dm²/h
Average OAT: -12.8 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 30.0 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

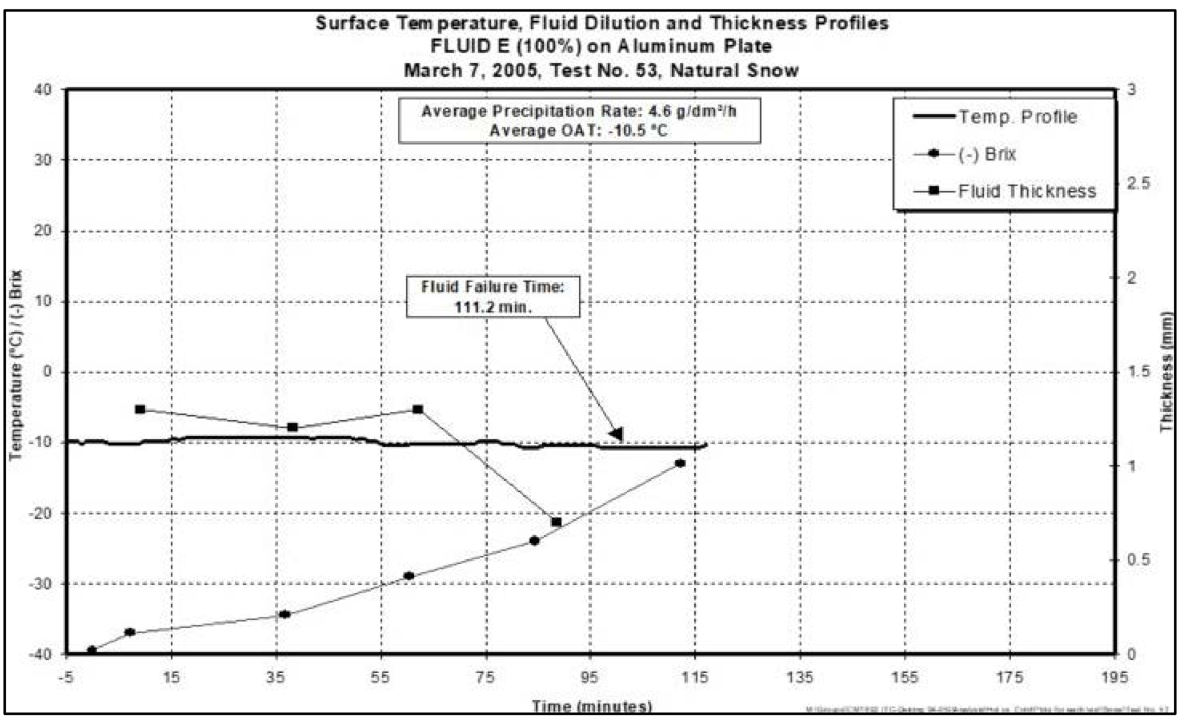


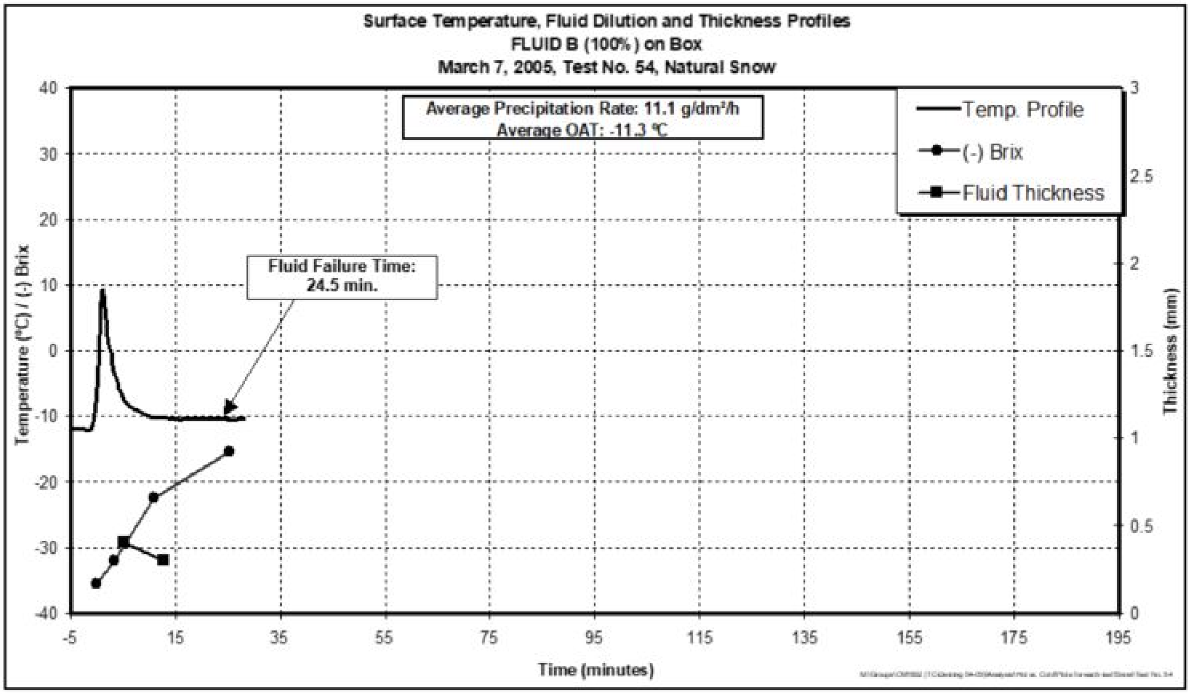
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (100%) on Aluminum Plate
March 7, 2005, Test No. 47, Natural Snow
Average Precipitation Rate: 7.8 g/dm²/h
Average OAT: -12.8 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 31.1 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

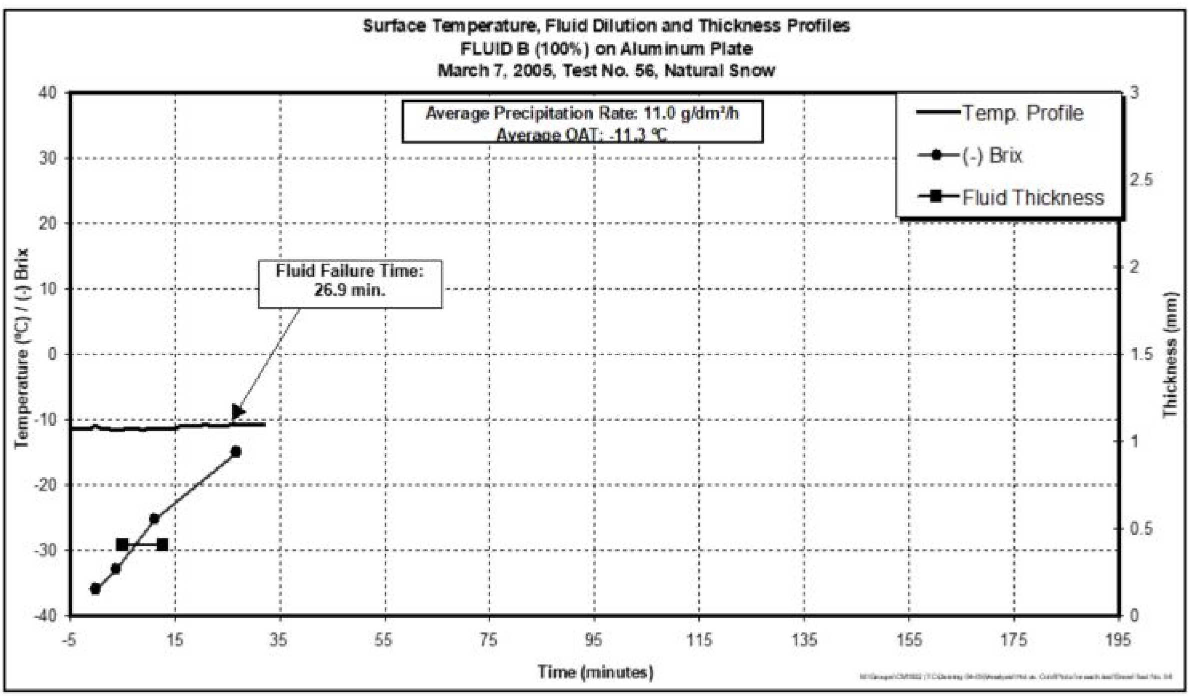

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Box
March 7, 2005, Test No. 48, Natural Snow
Average Precipitation Rate: 5.2 g/dm²/h
Average OAT: -12.2 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
20.7 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

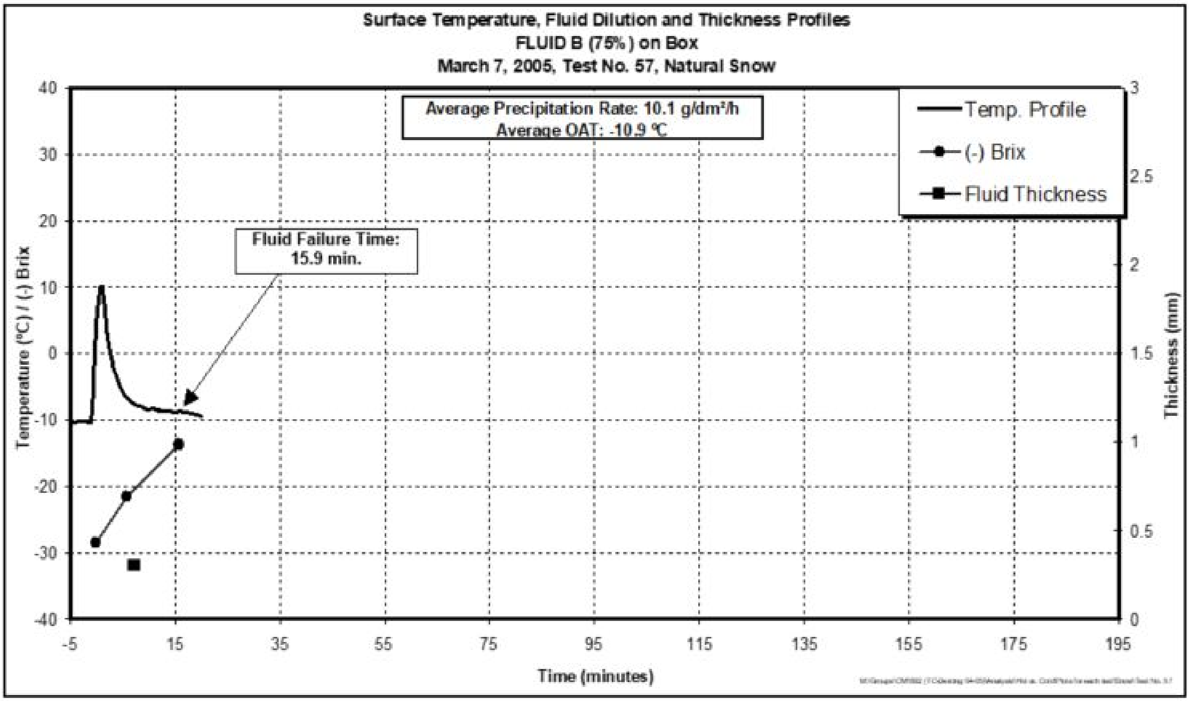

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
March 7, 2005, Test No. 50, Natural Snow
Average Precipitation Rate: 4.5 g/dm²/h
Average OAT: -12.2 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
23.2 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

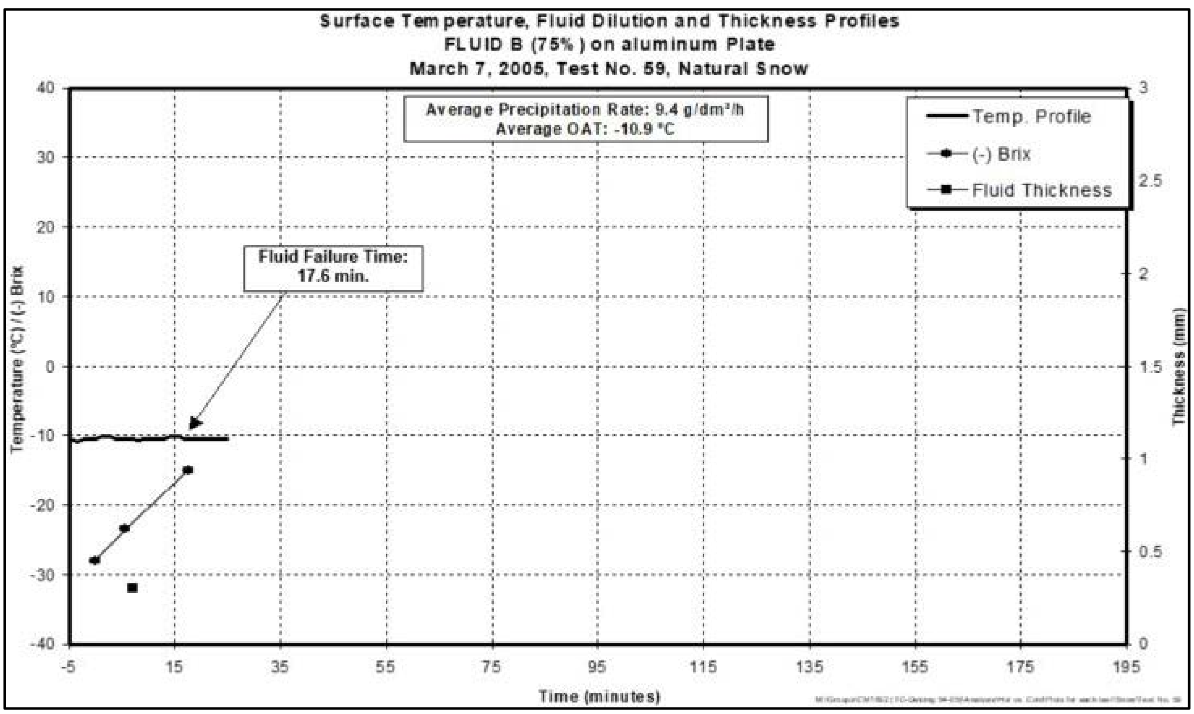

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID E (100%) on Box
March 7, 2005, Test No. 51, Natural Snow
Average Precipitation Rate: 7.2 g/dm²/h
Average OAT: -10.6 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
162.0 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

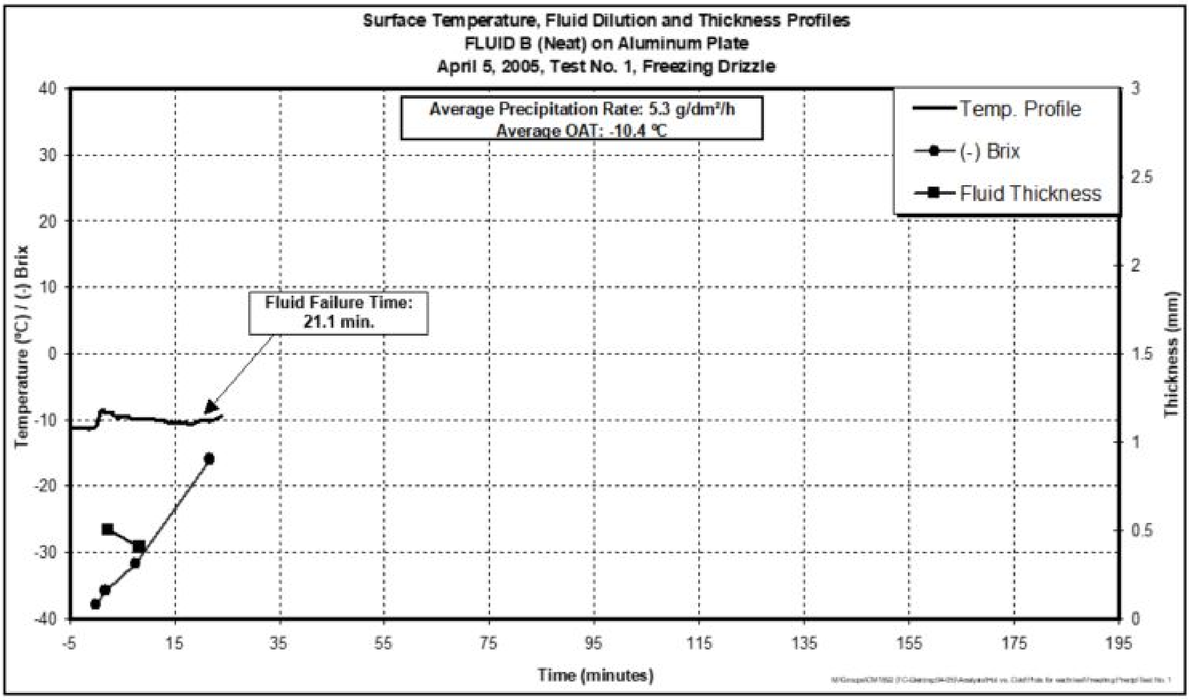

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID E (100%) on Aluminum Plate
March 7, 2005, Test No. 53, Natural Snow
Average Precipitation Rate: 4.6 g/dm²/h
Average OAT: -10.5 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
111.2 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

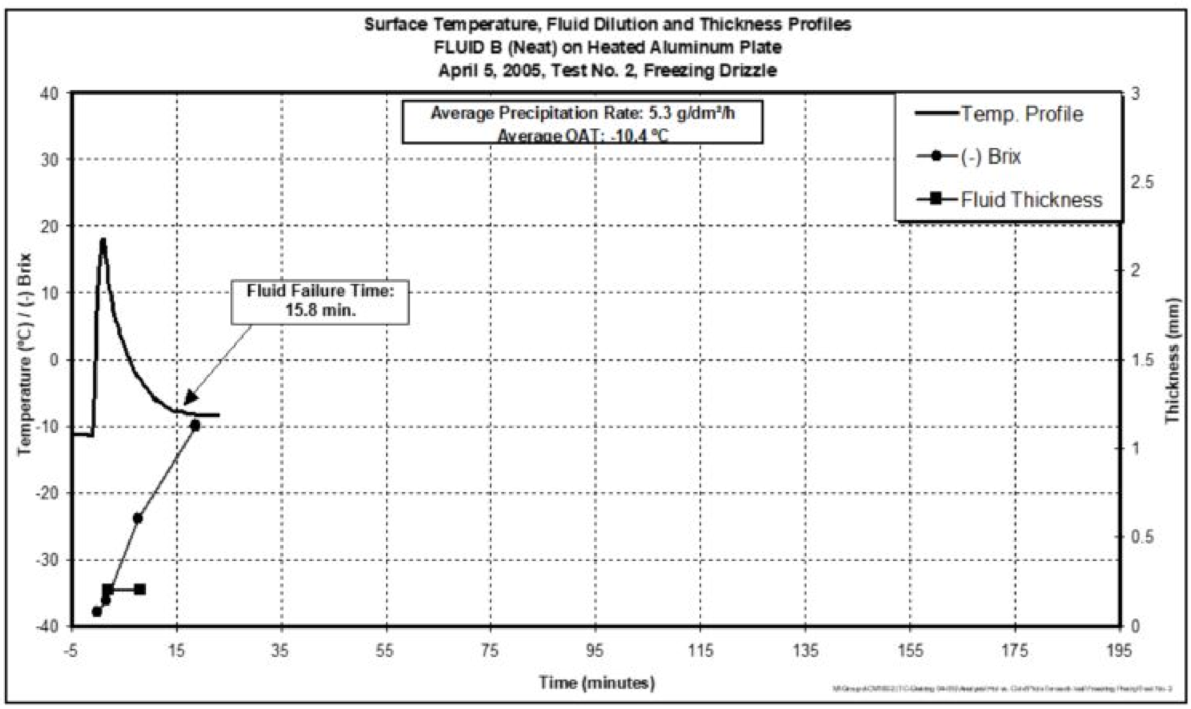

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (100%) on Box
March 7, 2005, Test No. 54, Natural Snow
Average Precipitation Rate: 11.1 g/dm²/h
Average OAT: -11.3 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
24.5 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

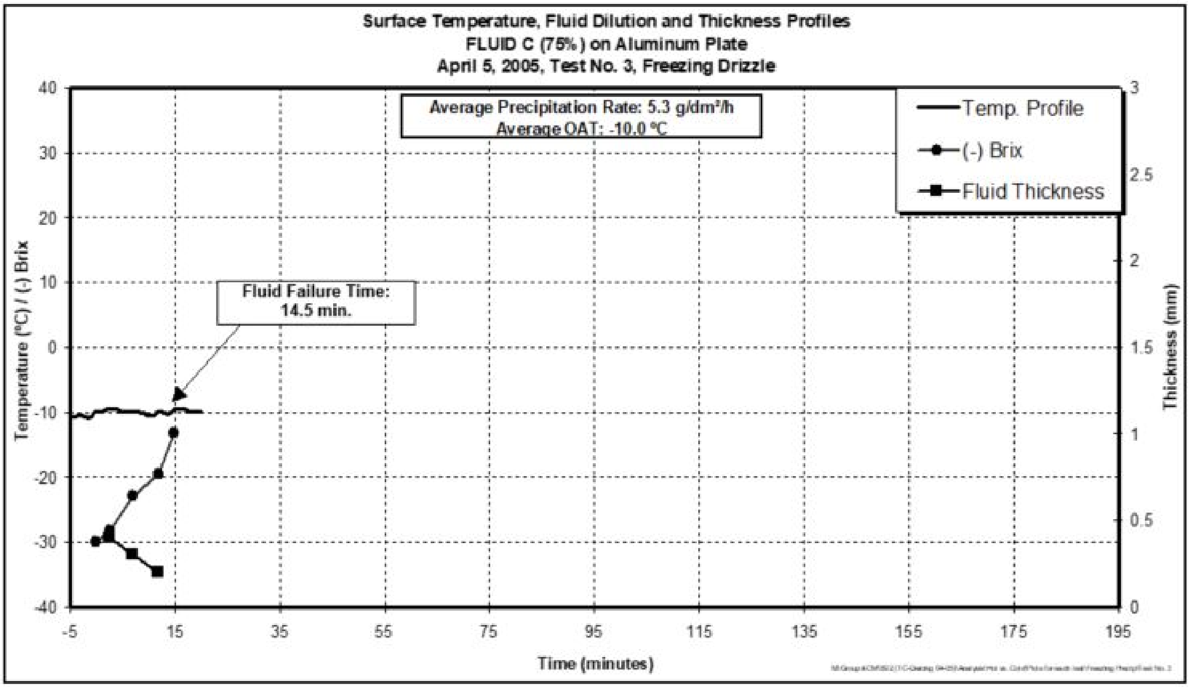

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (100%) on Aluminum Plate
March 7, 2005, Test No. 56, Natural Snow
Average Precipitation Rate: 11.0 g/dm²/h
Average OAT: -11.3 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
26.9 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Box
March 7, 2005, Test No. 57, Natural Snow
Average Precipitation Rate: 10.1 g/dm²/h
Average OAT: -10.9 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
15.9 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

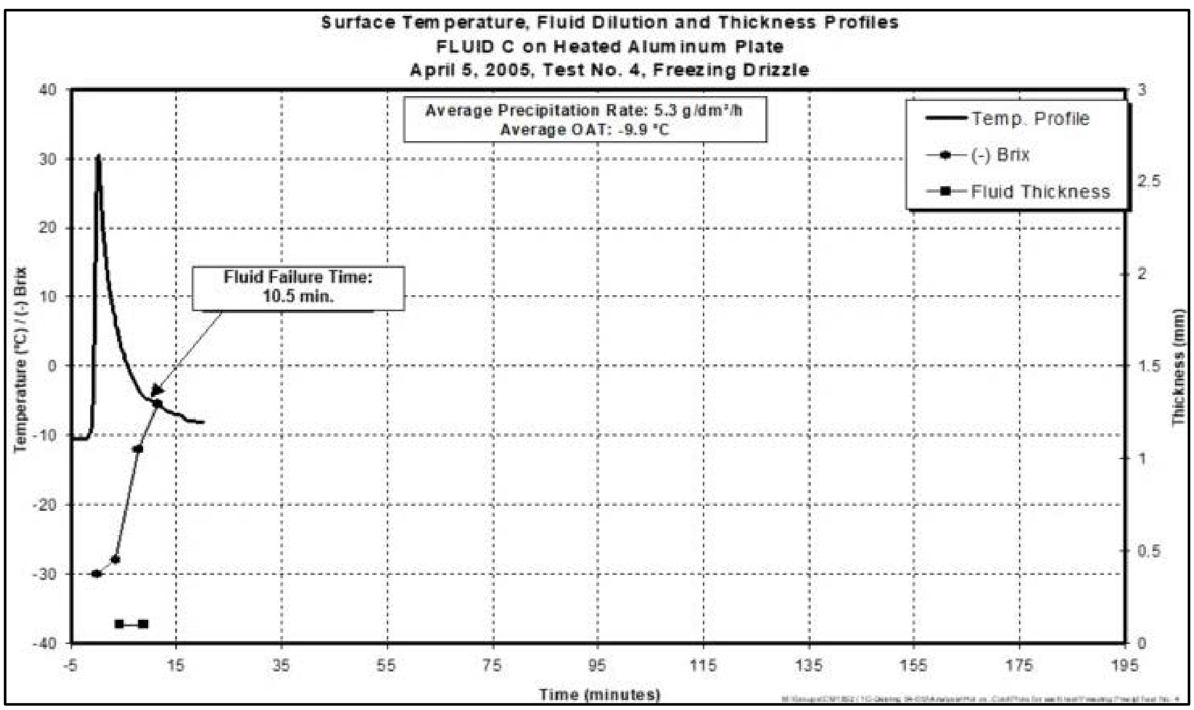

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on aluminum Plate
March 7, 2005, Test No. 59, Natural Snow
Average Precipitation Rate: 9.4 g/dm²/h
Average OAT: -10.9 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
17.6 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
April 5, 2005, Test No. 1, Freezing Drizzle
Average Precipitation Rate: 5.3 g/dm²/h
Average OAT: -10.4 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 21.1 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

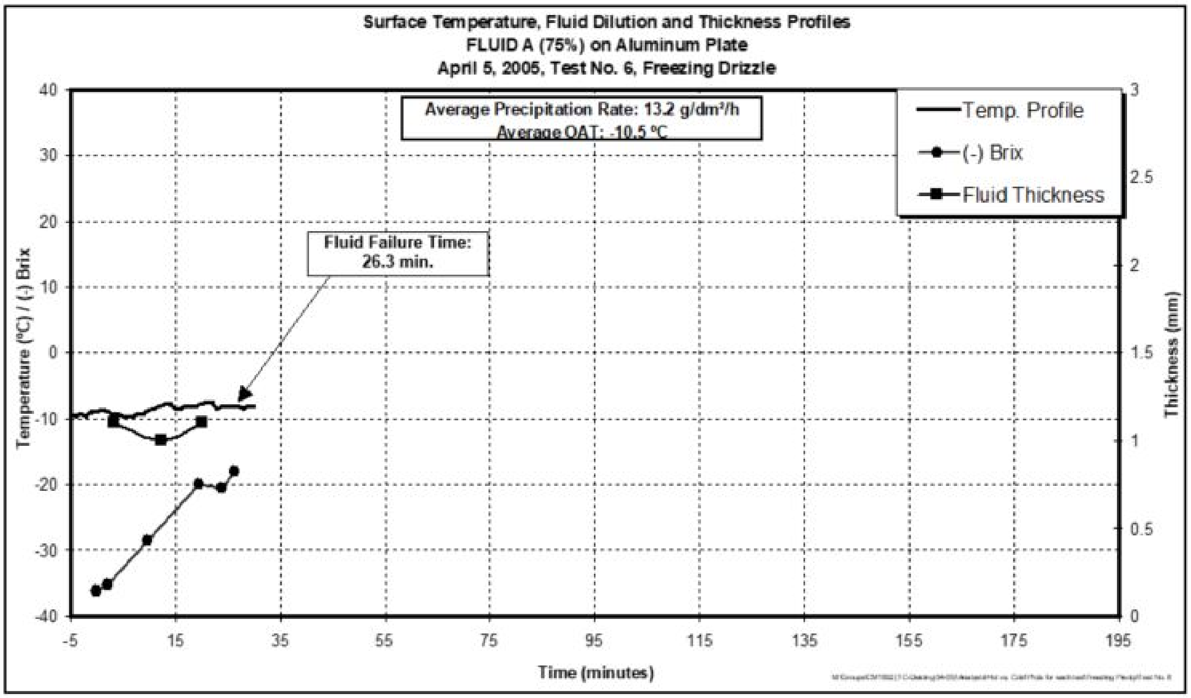

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Heated Aluminum Plate
April 5, 2005, Test No. 2, Freezing Drizzle
Average Precipitation Rate: 5.3 g/dm²/h
Average OAT: -10.4 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 15.8 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)



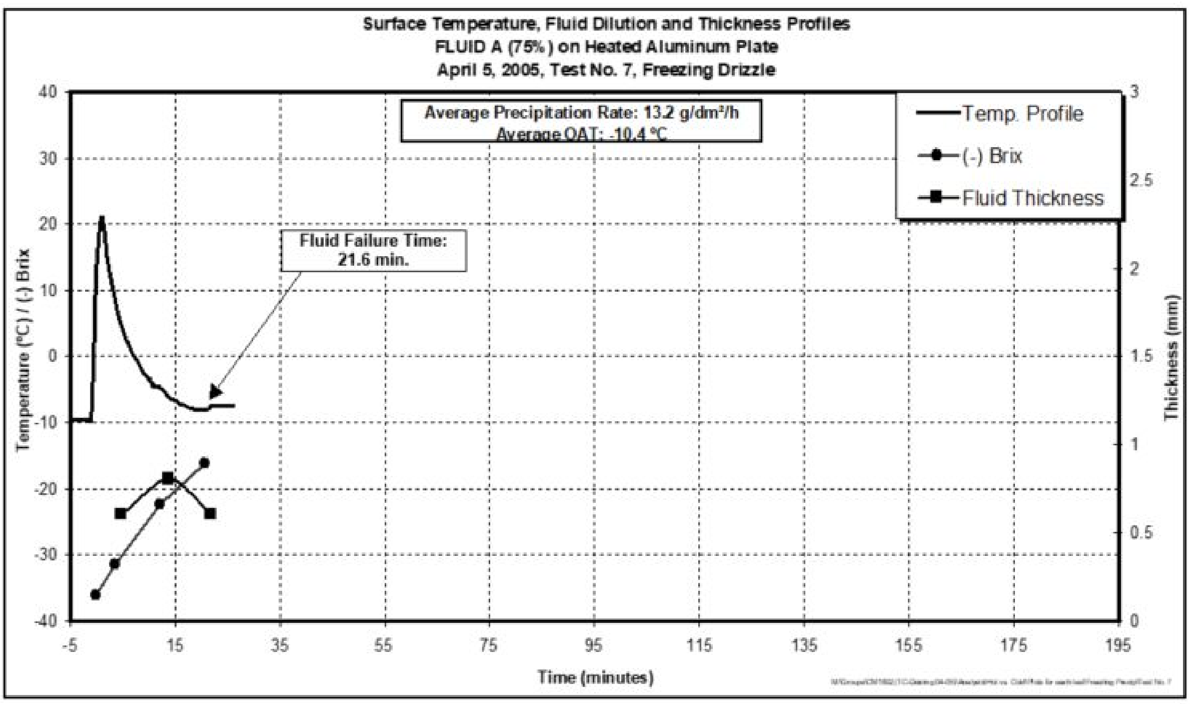
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
April 5, 2005, Test No. 3, Freezing Drizzle
Average Precipitation Rate: 5.3 g/dm²/h
Average OAT: -10.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
14.5 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)



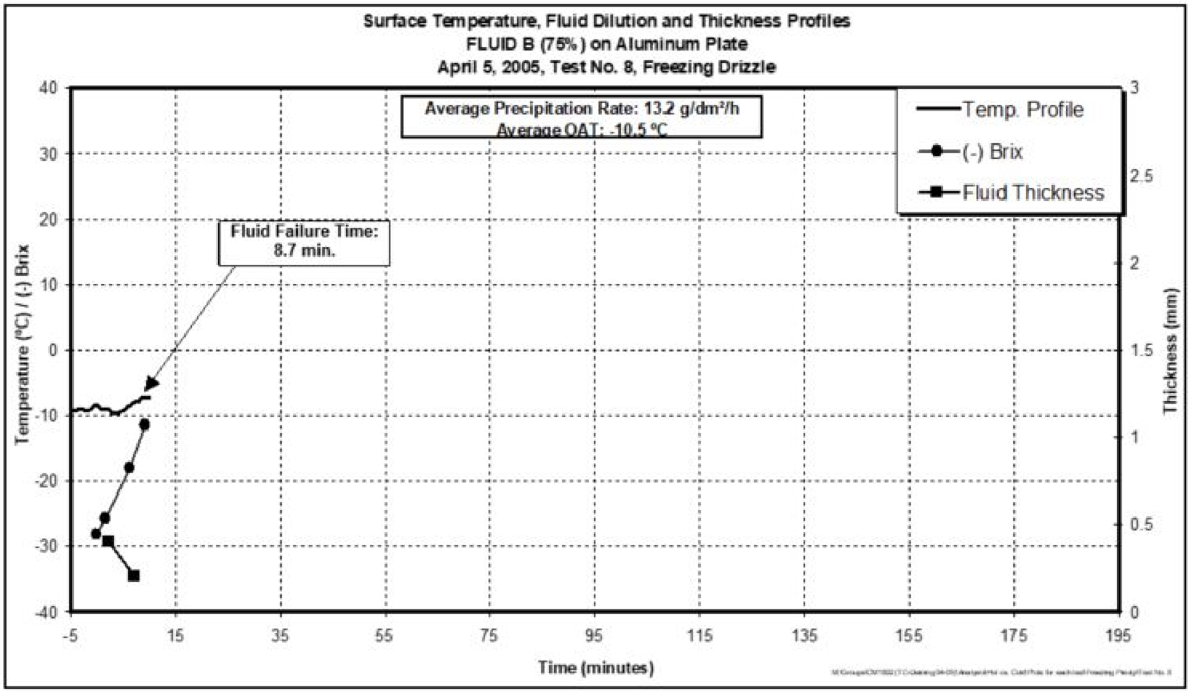
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C on Heated Aluminum Plate
April 5, 2005, Test No. 4, Freezing Drizzle
Average Precipitation Rate: 5.3 g/dm²/h
Average OAT: -9.9 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time:
10.5 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

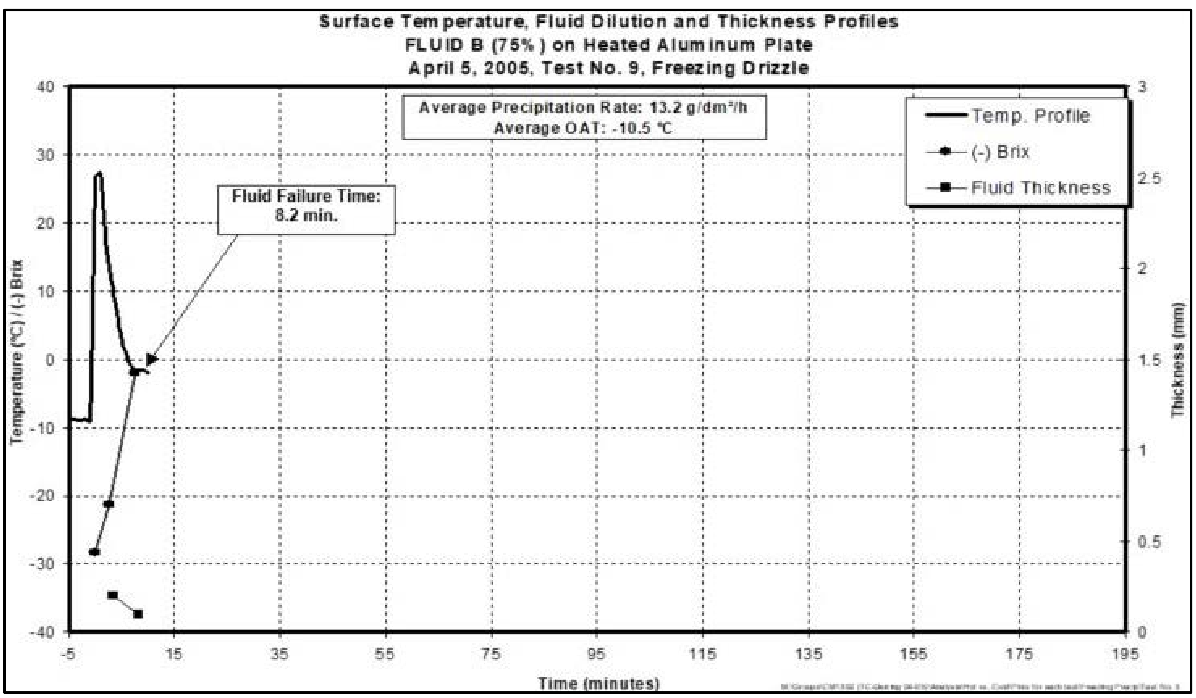


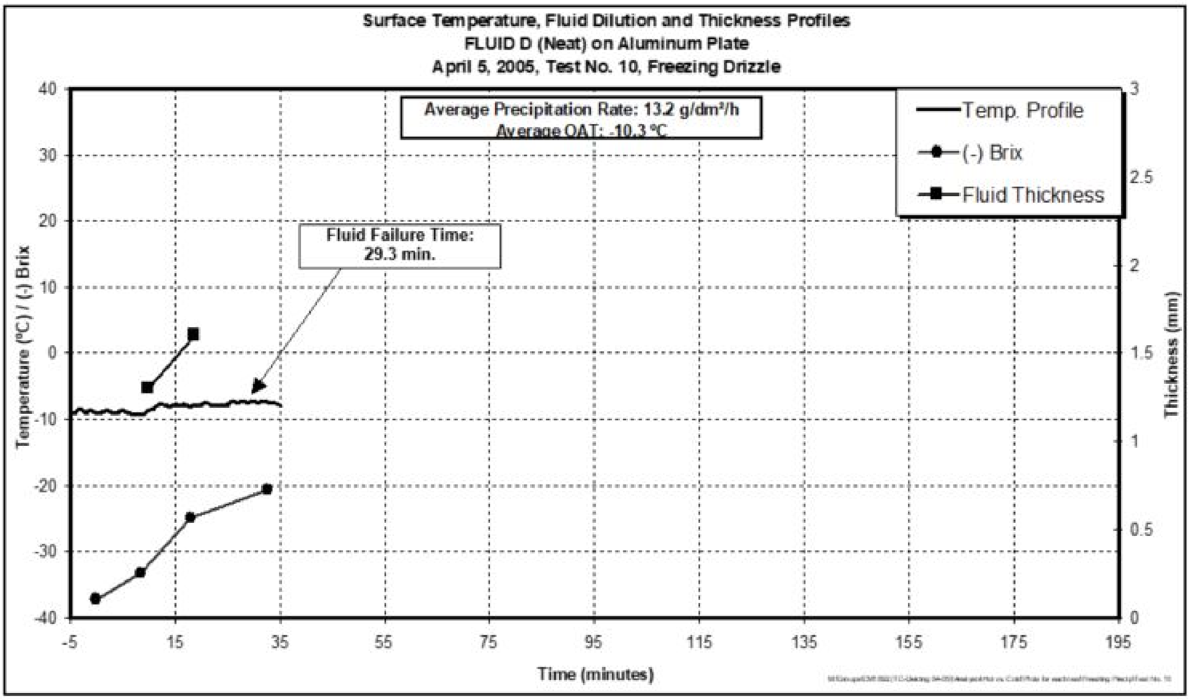
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Aluminum Plate
April 5, 2005, Test No. 6, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.5 °C
Fluid Failure Time: 26.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

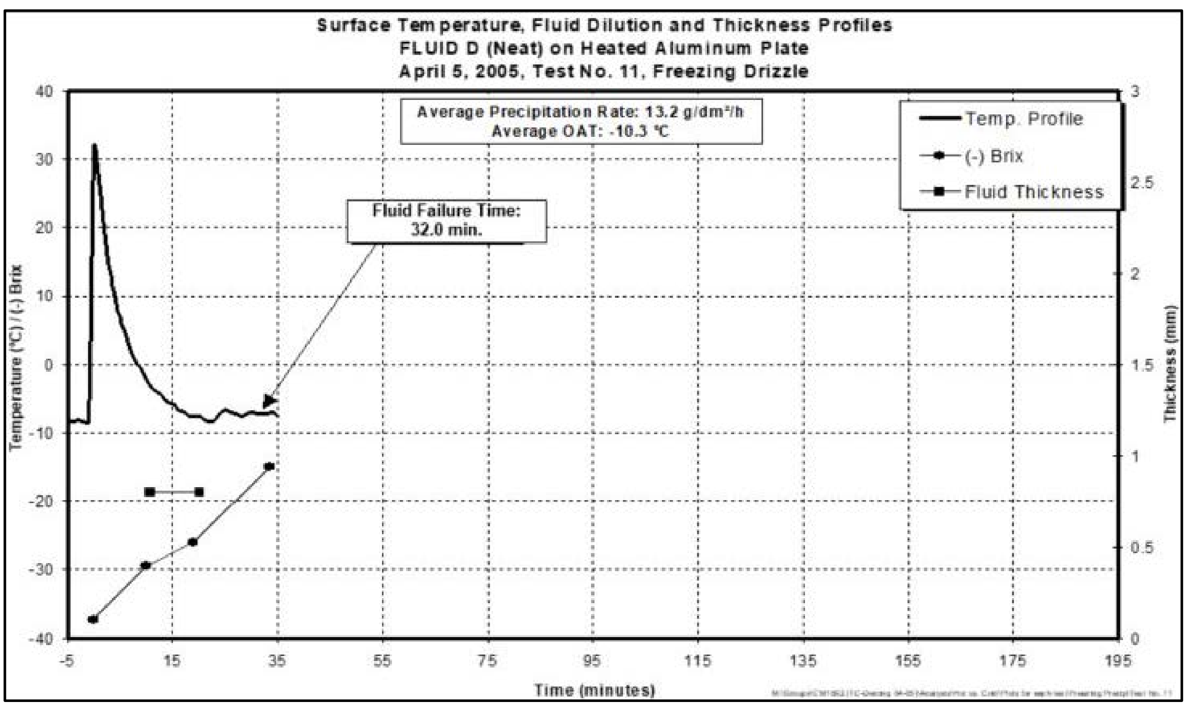


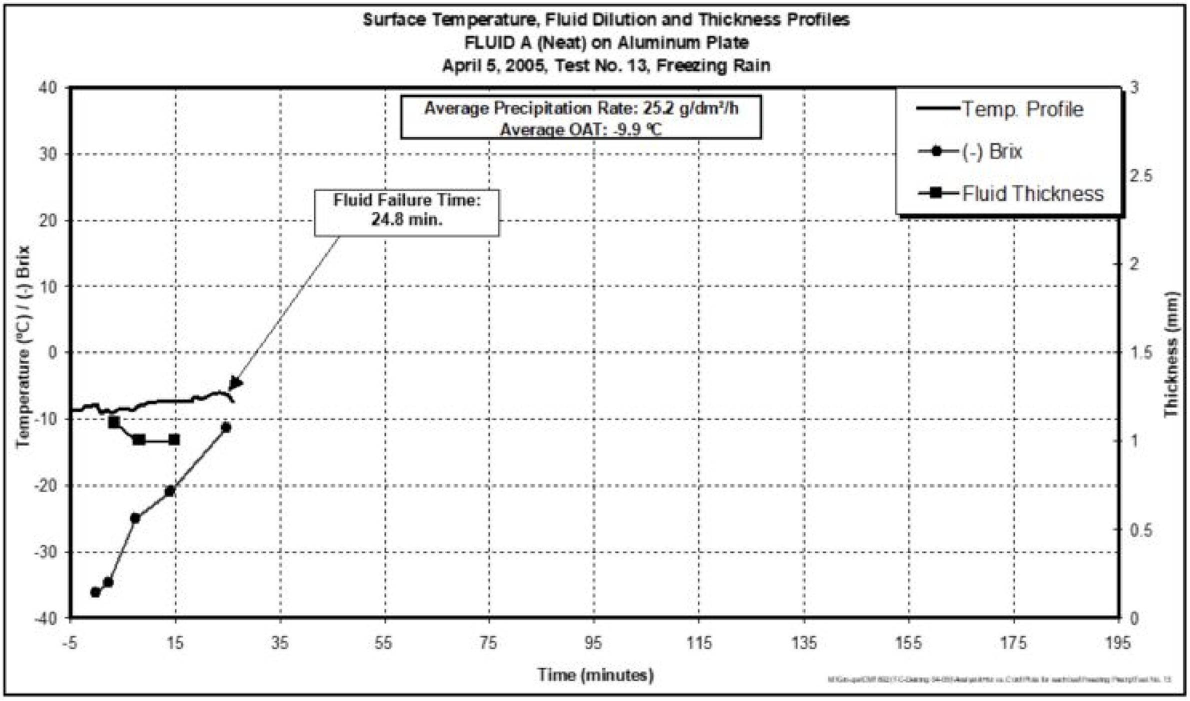
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Heated Aluminum Plate
April 5, 2005, Test No. 7, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.4 °C
Fluid Failure Time: 21.6 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

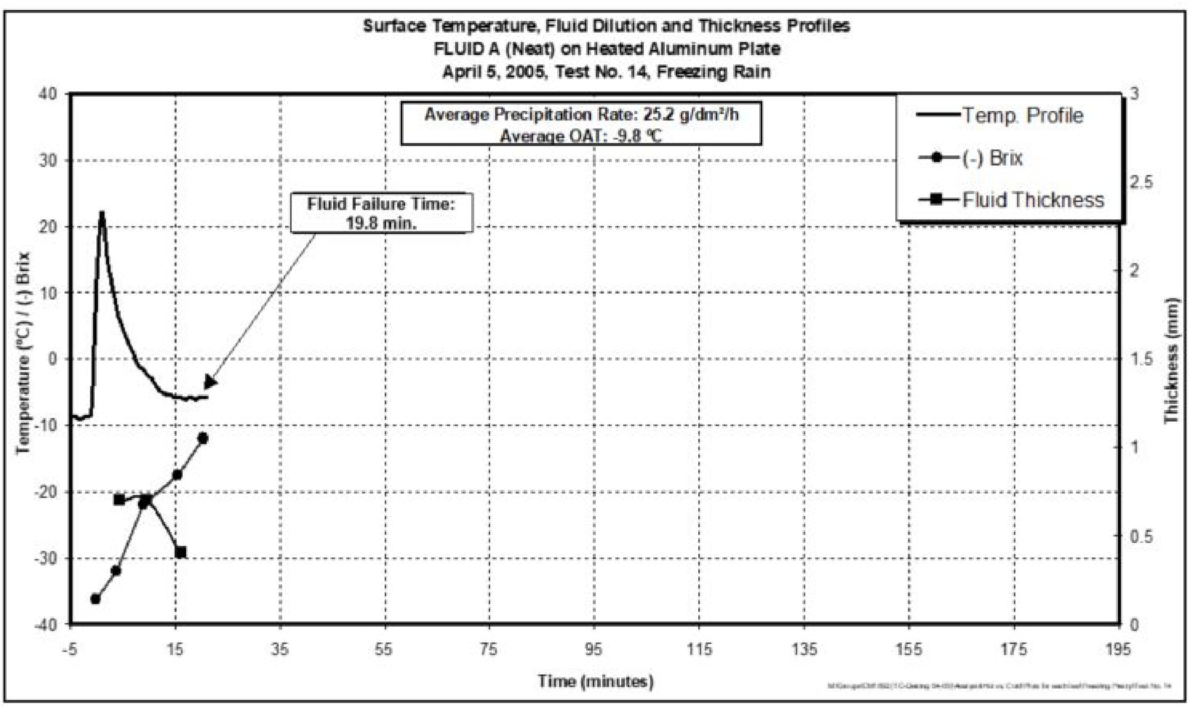

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
April 5, 2005, Test No. 8, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.5 °C
Fluid Failure Time: 8.7 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

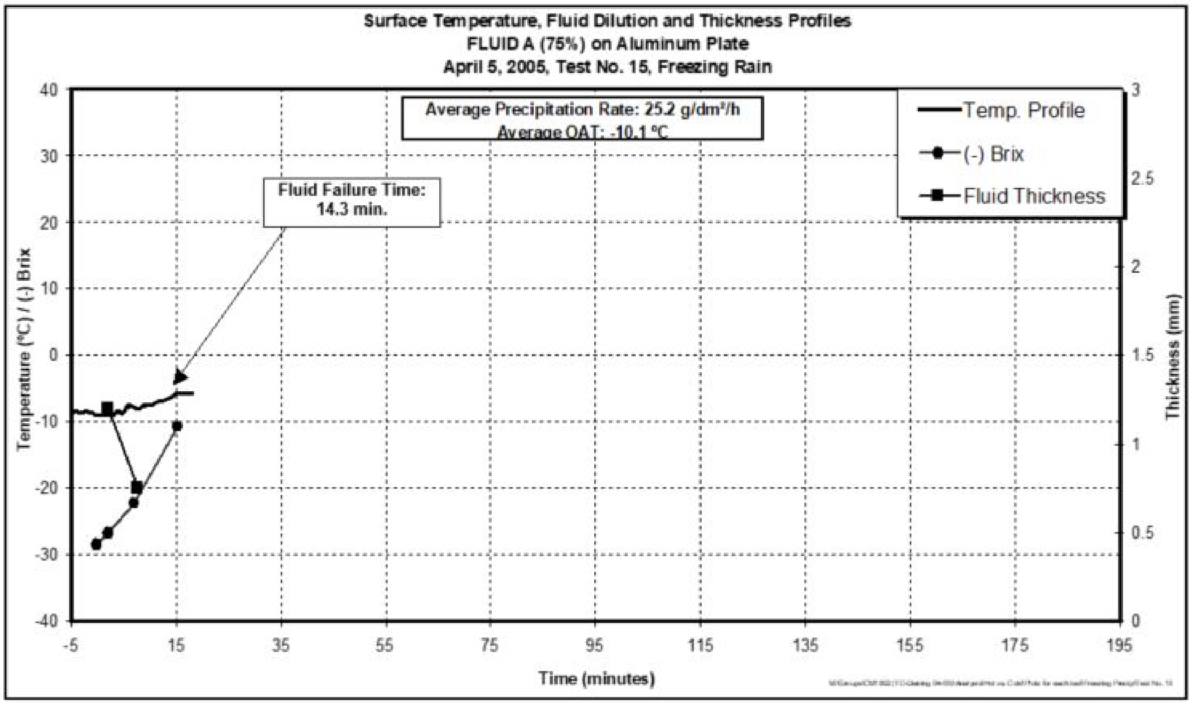

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Heated Aluminum Plate
April 5, 2005, Test No. 9, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.5 °C
Fluid Failure Time: 8.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

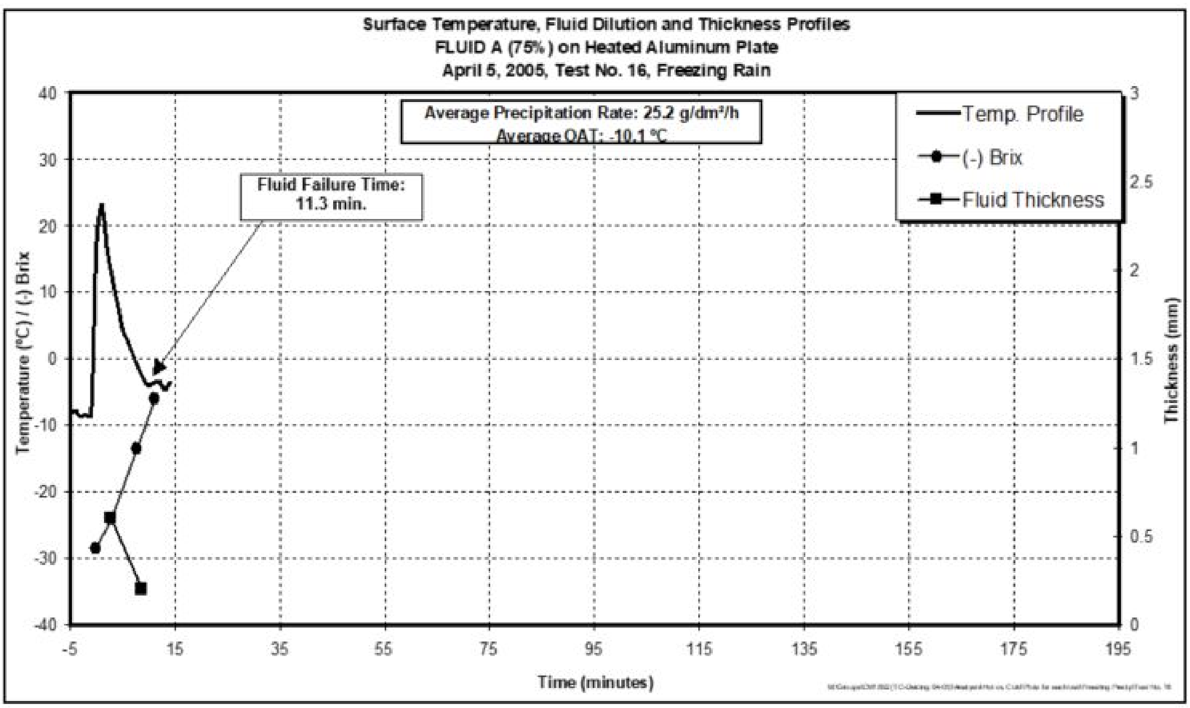

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (Neat) on Aluminum Plate
April 5, 2005, Test No. 10, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.3 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 29.3 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

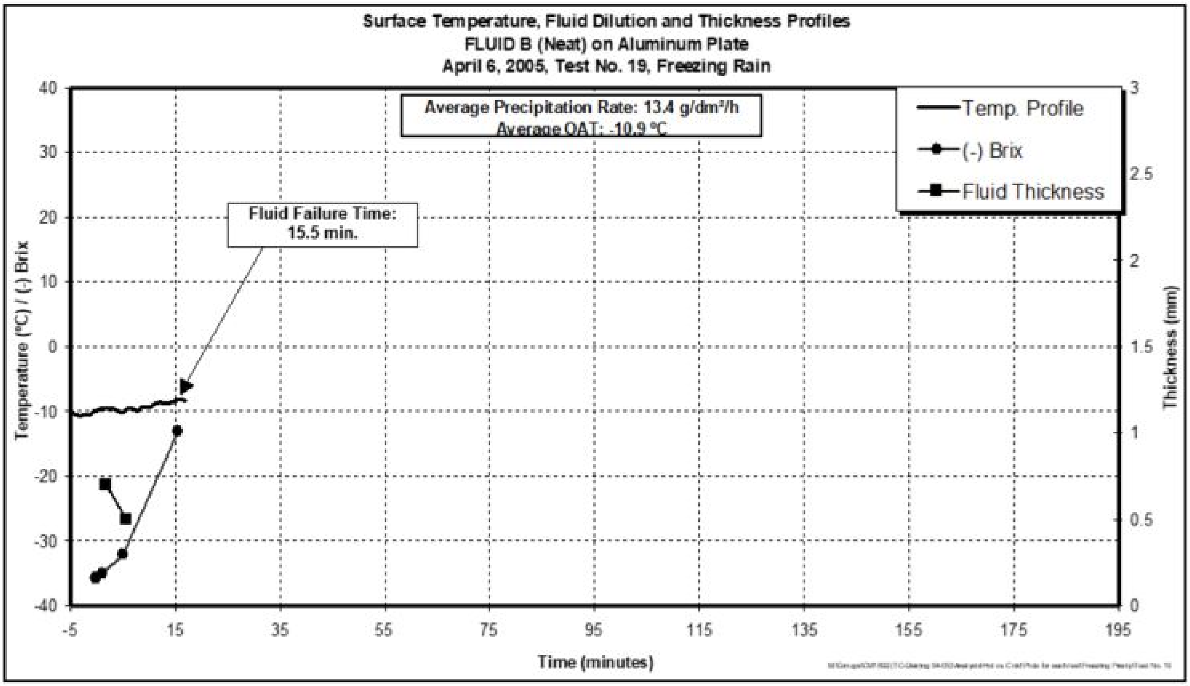

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (Neat) on Heated Aluminum Plate
April 5, 2005, Test No. 11, Freezing Drizzle
Average Precipitation Rate: 13.2 g/dm²/h
Average OAT: -10.3 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 32.0 min.
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

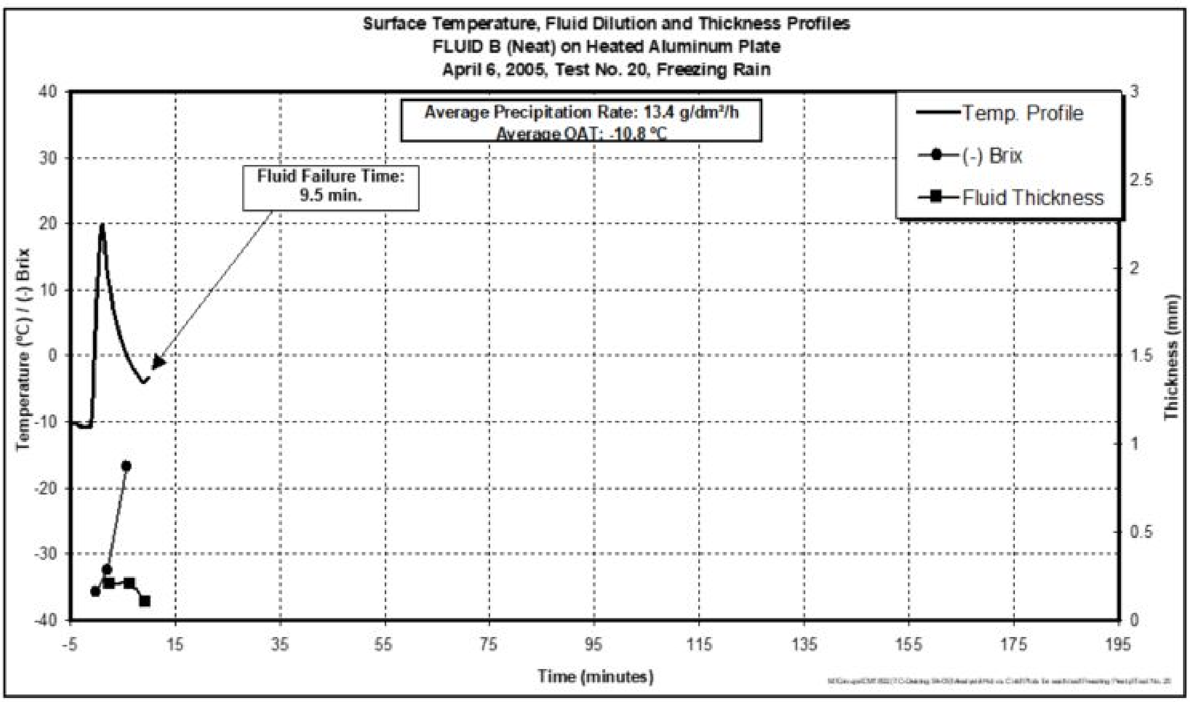

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (Neat) on Aluminum Plate
April 5, 2005, Test No. 13, Freezing Rain
Average Precipitation Rate: 25.2 g/dm²/h
Average OAT: -9.9 °C
Fluid Failure Time:
24.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

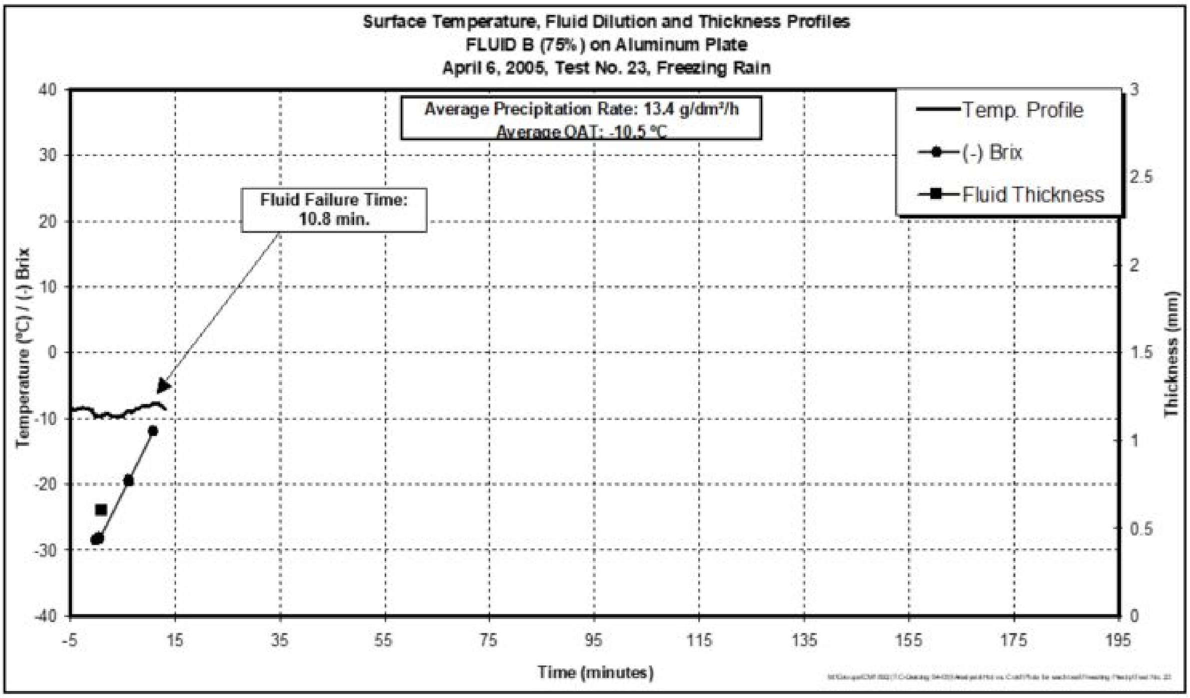

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (Neat) on Heated Aluminum Plate
April 5, 2005, Test No. 14, Freezing Rain
Average Precipitation Rate: 25.2 g/dm²/h
Average OAT: -9.8 °C
Fluid Failure Time:
19.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Aluminum Plate
April 5, 2005, Test No. 15, Freezing Rain
Average Precipitation Rate: 25.2 g/dm²/h
Average OAT: -10.1 °C
Fluid Failure Time: 14.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

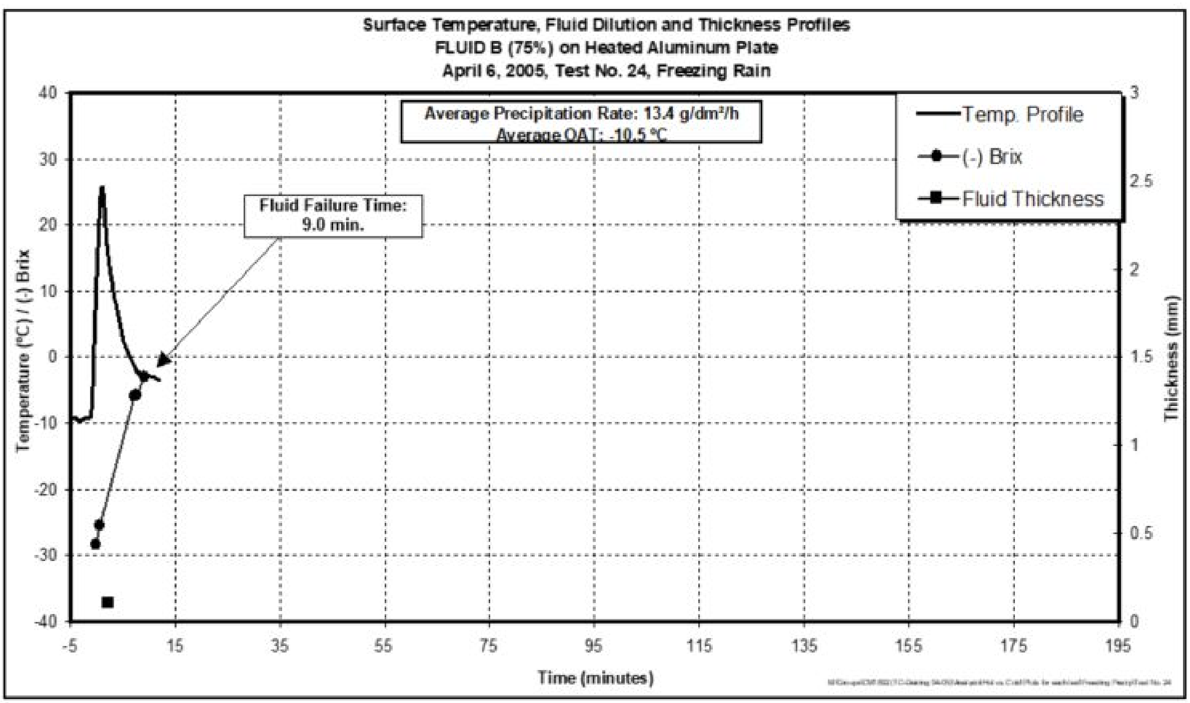

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Heated Aluminum Plate
April 5, 2005, Test No. 16, Freezing Rain
Average Precipitation Rate: 25.2 g/dm²/h
Average OAT: -10.1 °C
Fluid Failure Time: 11.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
April 6, 2005, Test No. 19, Freezing Rain
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -10.9 °C
Fluid Failure Time: 15.5 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

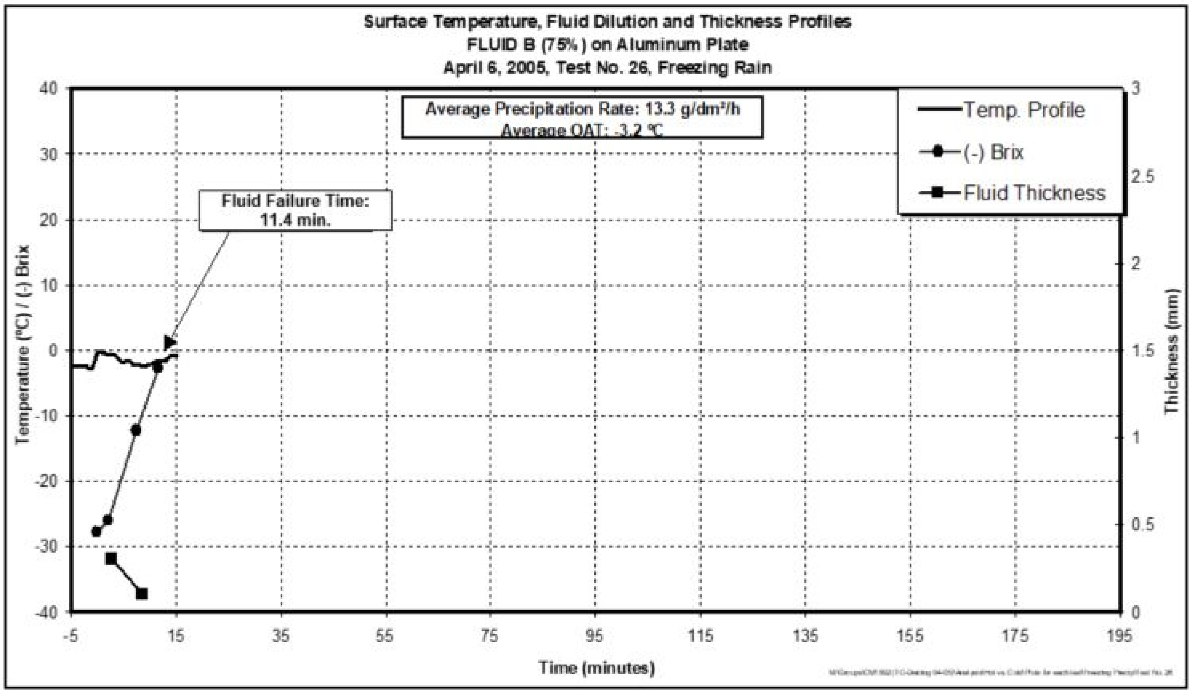

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Heated Aluminum Plate
April 6, 2005, Test No. 20, Freezing Rain
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -10.8 °C
Fluid Failure Time: 9.5 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)



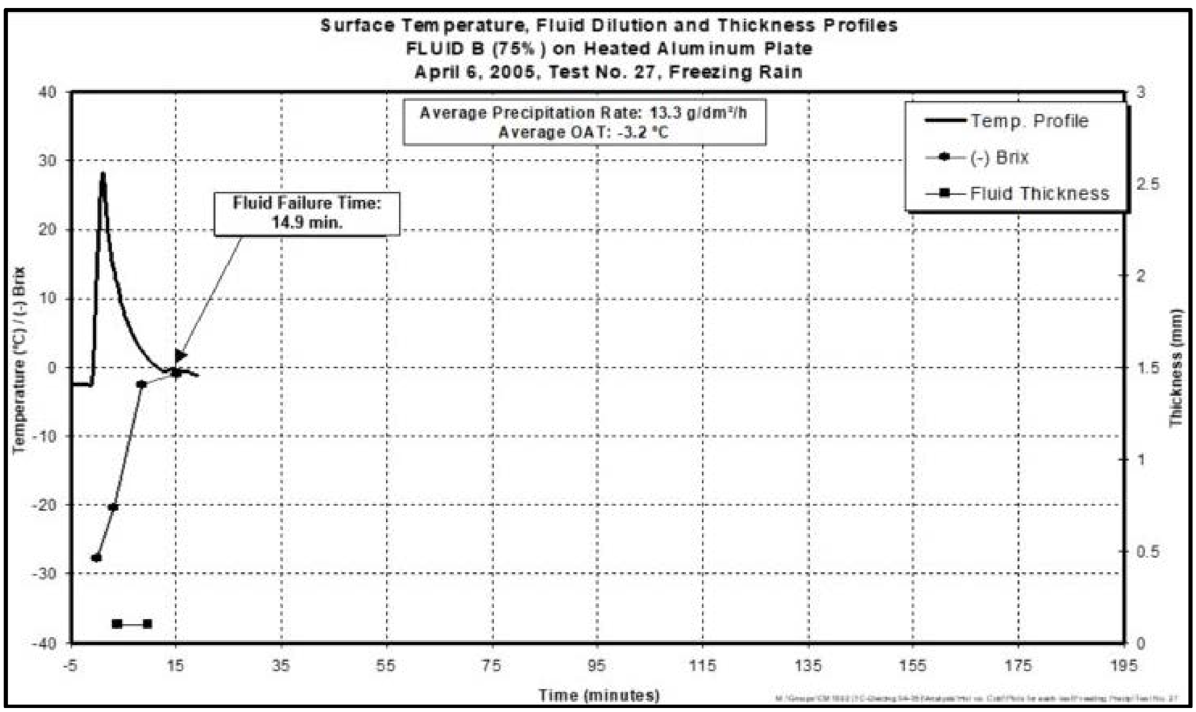
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
April 6, 2005, Test No. 23, Freezing Rain
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -10.5 °C
Fluid Failure Time: 10.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)



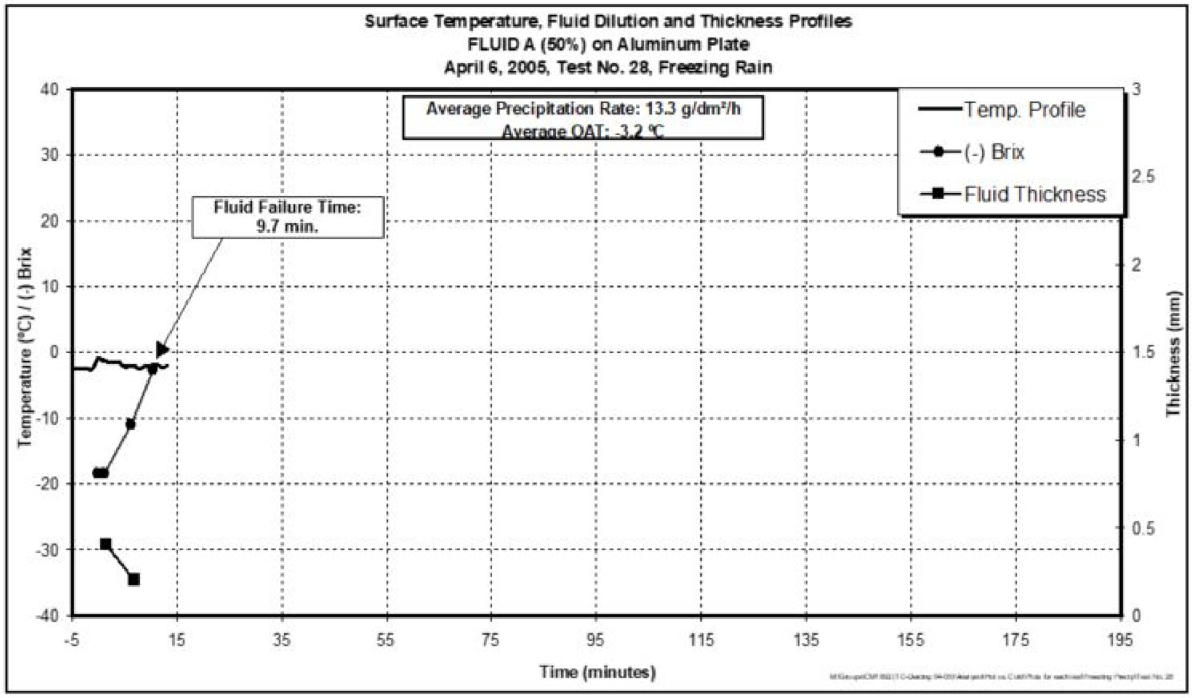
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Heated Aluminum Plate
April 6, 2005, Test No. 24, Freezing Rain
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -10.5 °C
Fluid Failure Time: 9.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

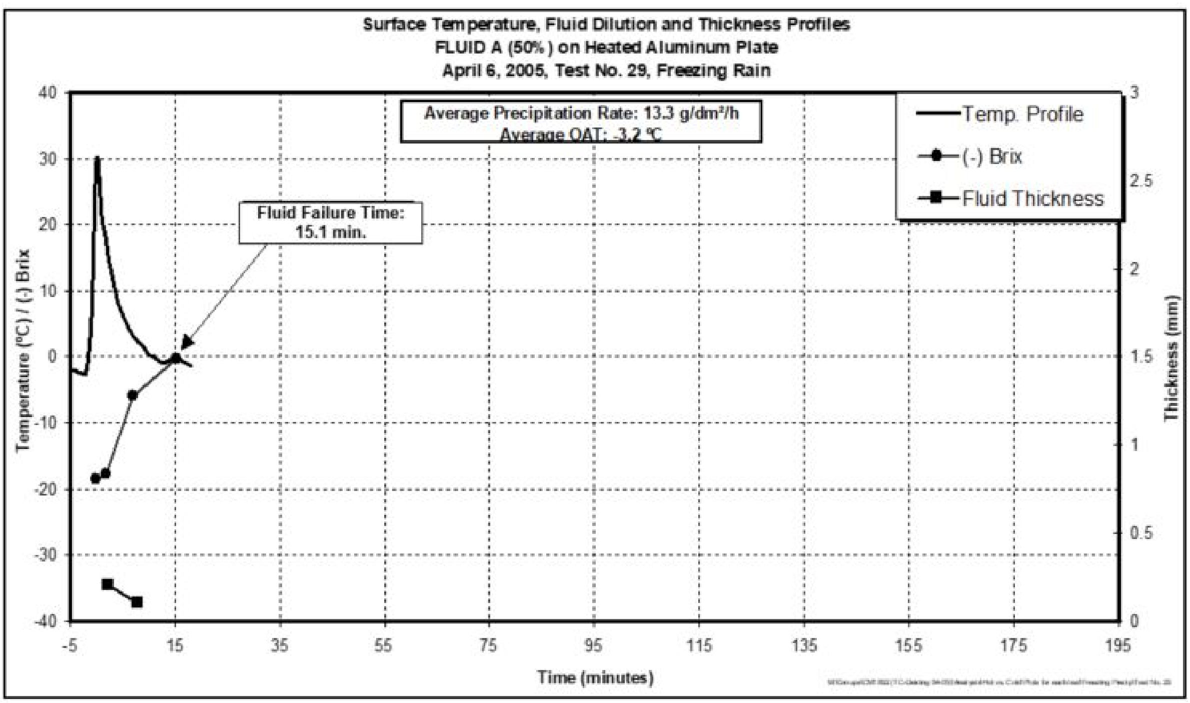


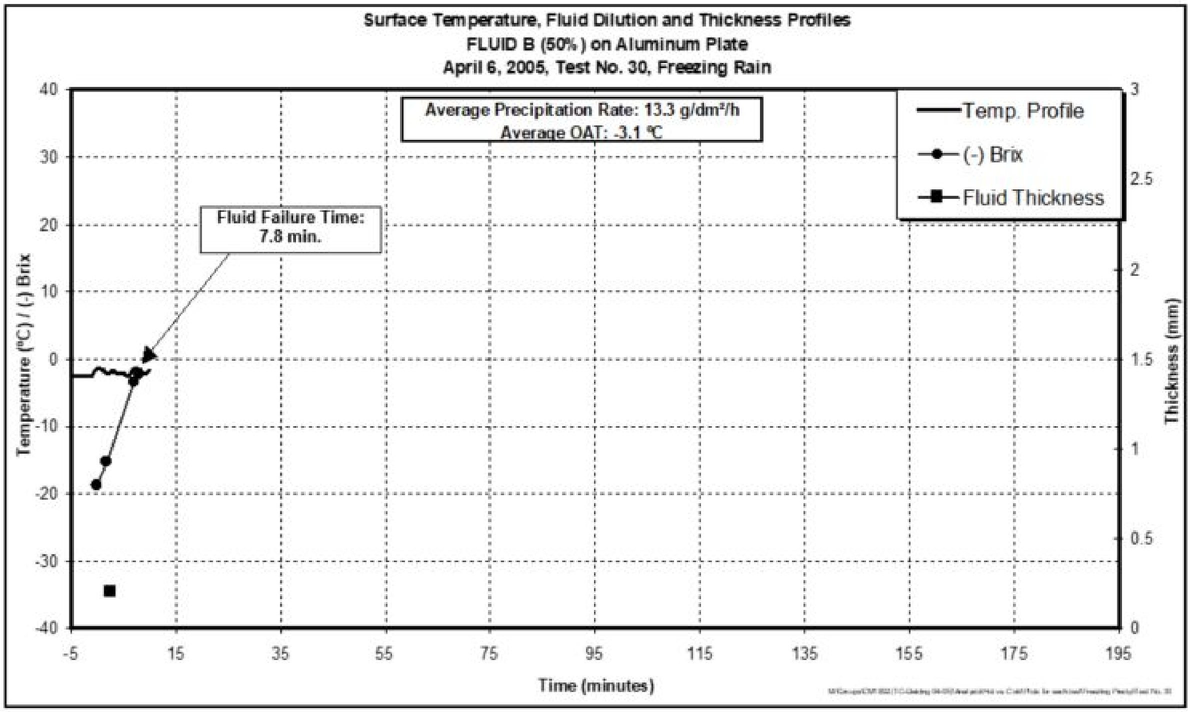
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
April 6, 2005, Test No. 26, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.2 °C
Fluid Failure Time: 11.4 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

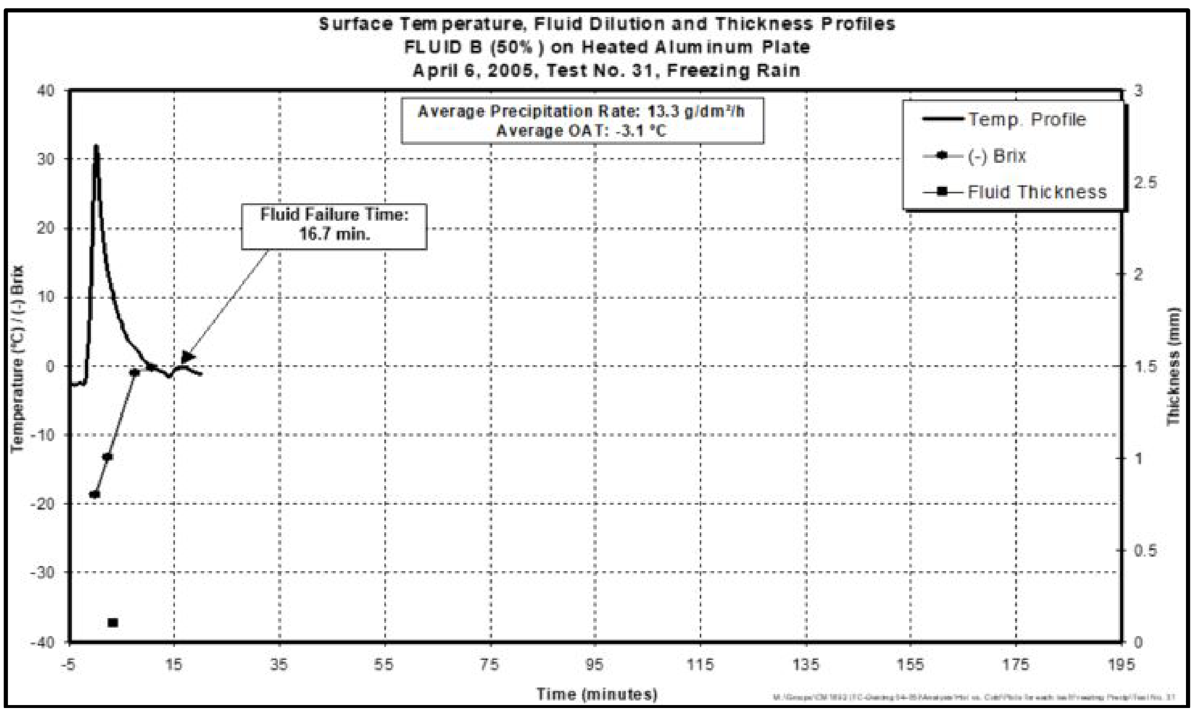


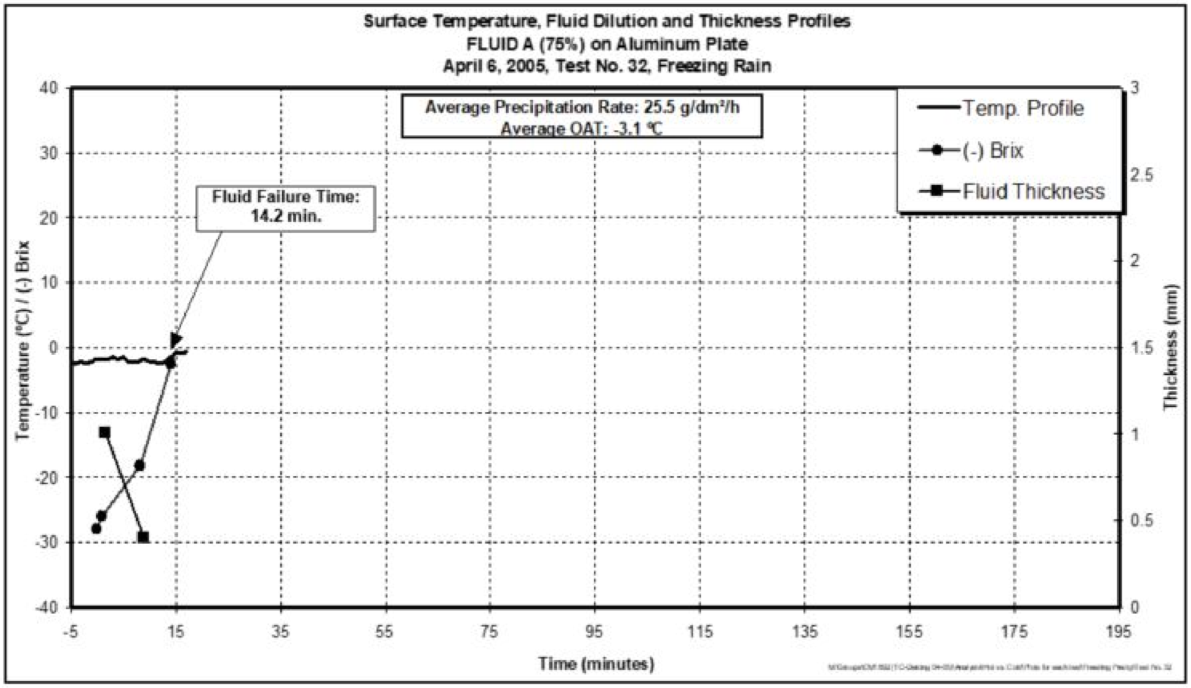
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Heated Aluminum Plate
April 6, 2005, Test No. 27, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.2 °C
Fluid Failure Time: 14.9 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

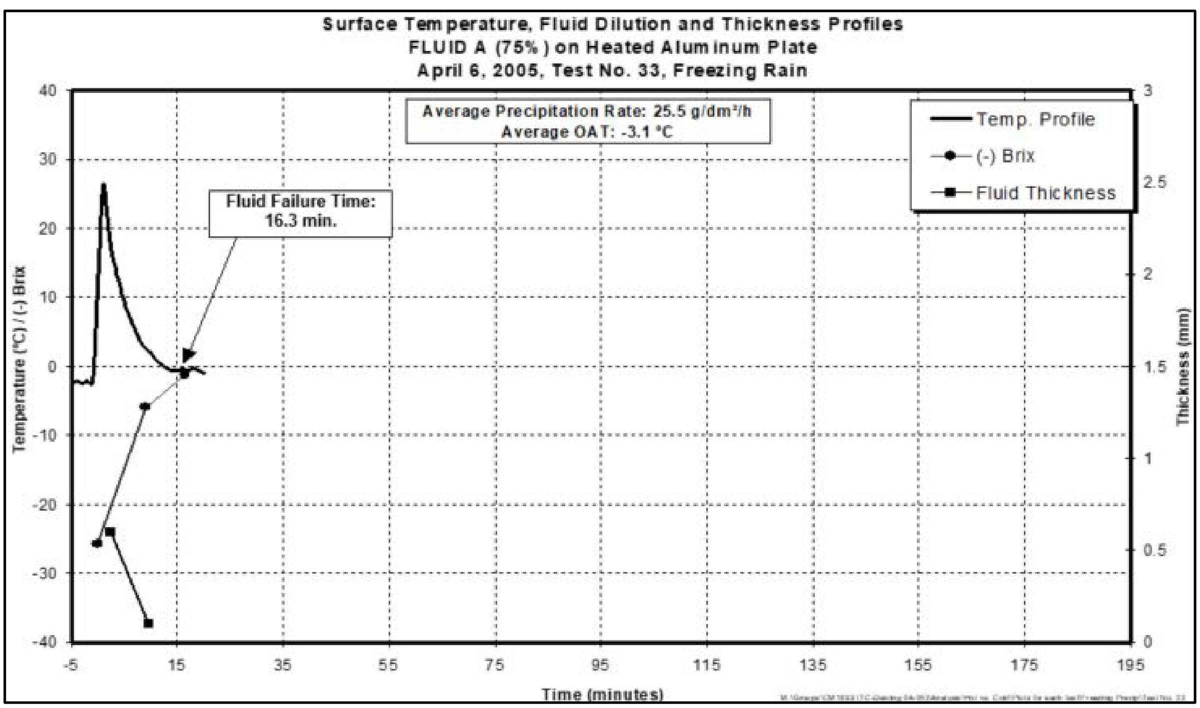

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Aluminum Plate
April 6, 2005, Test No. 28, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.2 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 9.7 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

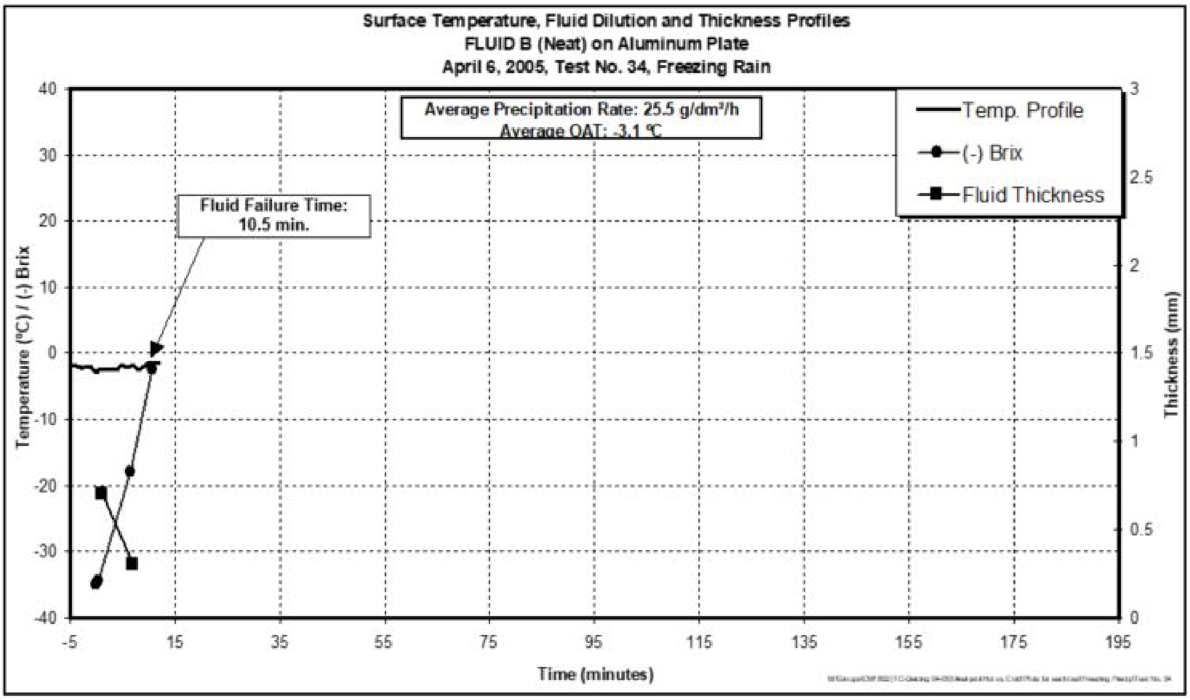

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Heated Aluminum Plate
April 6, 2005, Test No. 29, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.2 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 15.1 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

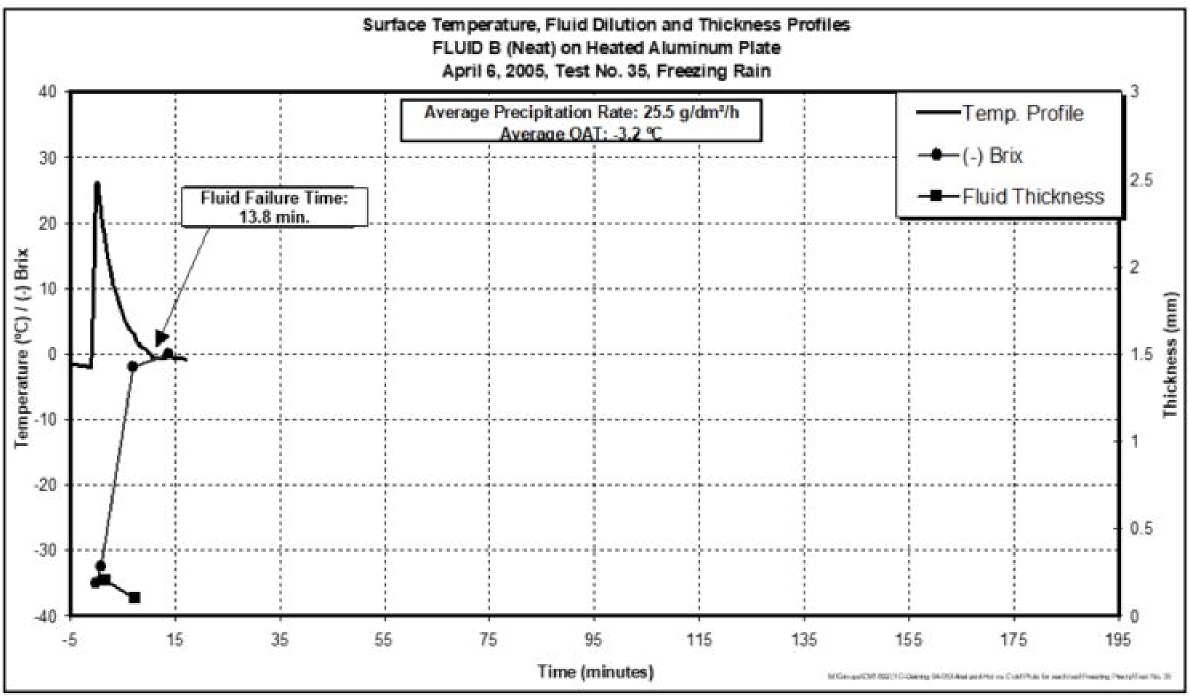

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (50%) on Aluminum Plate
April 6, 2005, Test No. 30, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time:
7.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

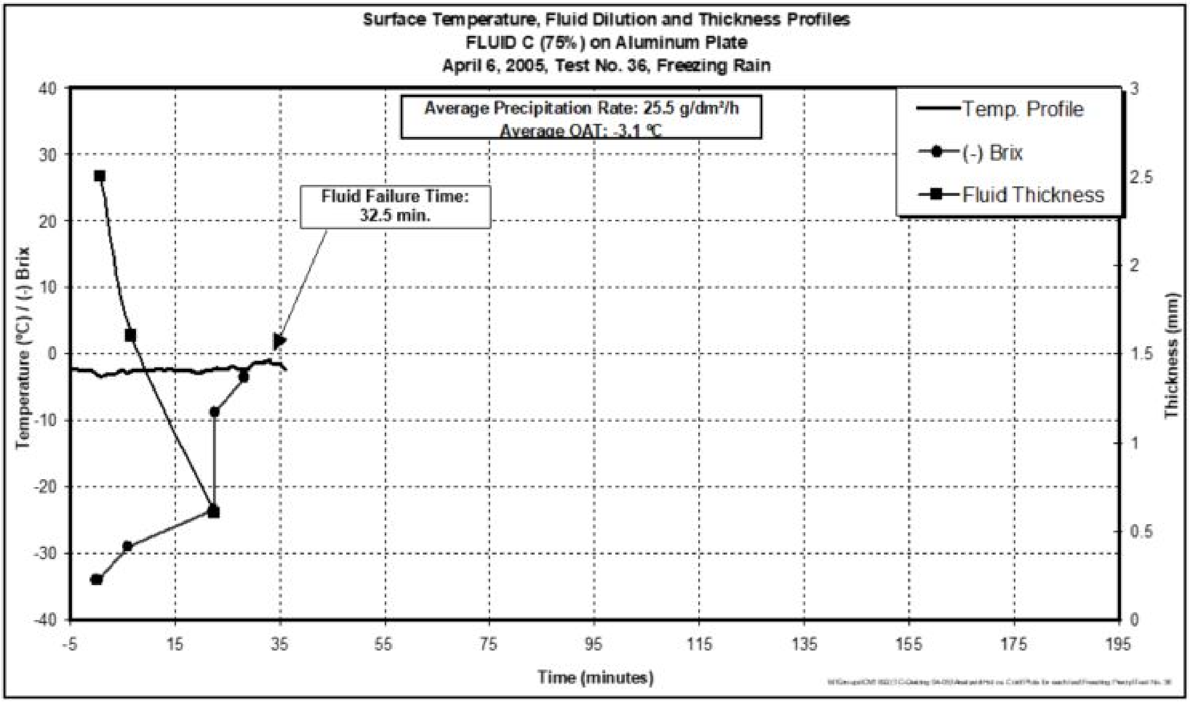

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (50%) on Heated Aluminum Plate
April 6, 2005, Test No. 31, Freezing Rain
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time:
16.7 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

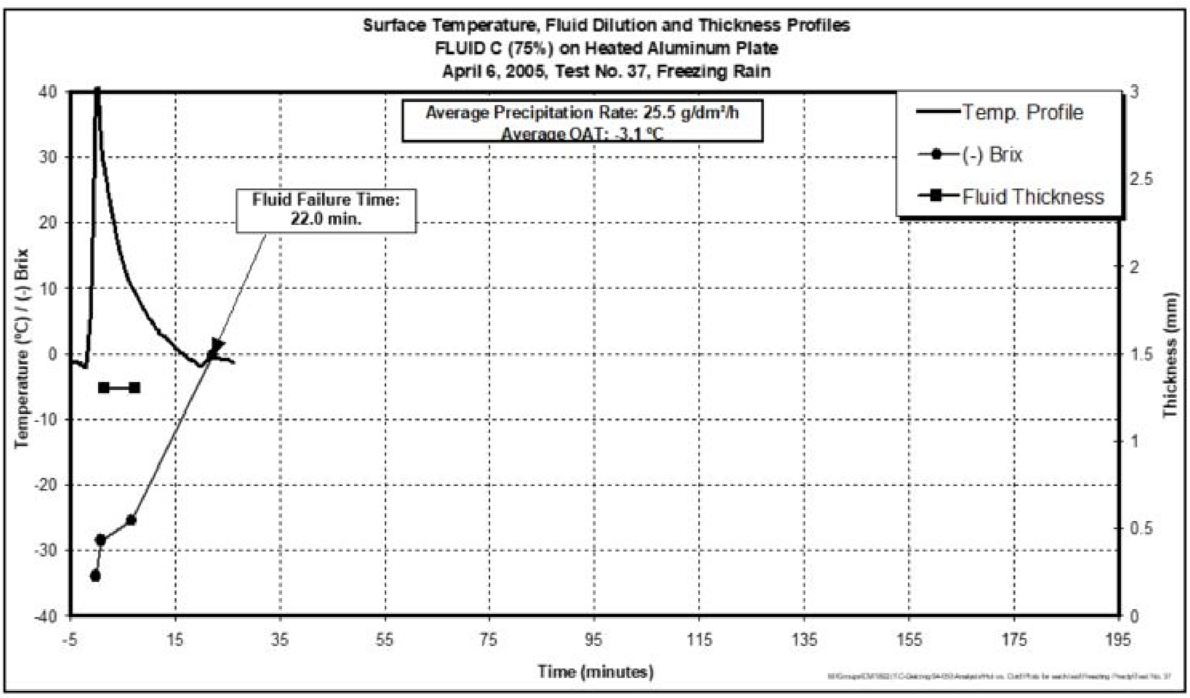

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Aluminum Plate
April 6, 2005, Test No. 32, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time: 14.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

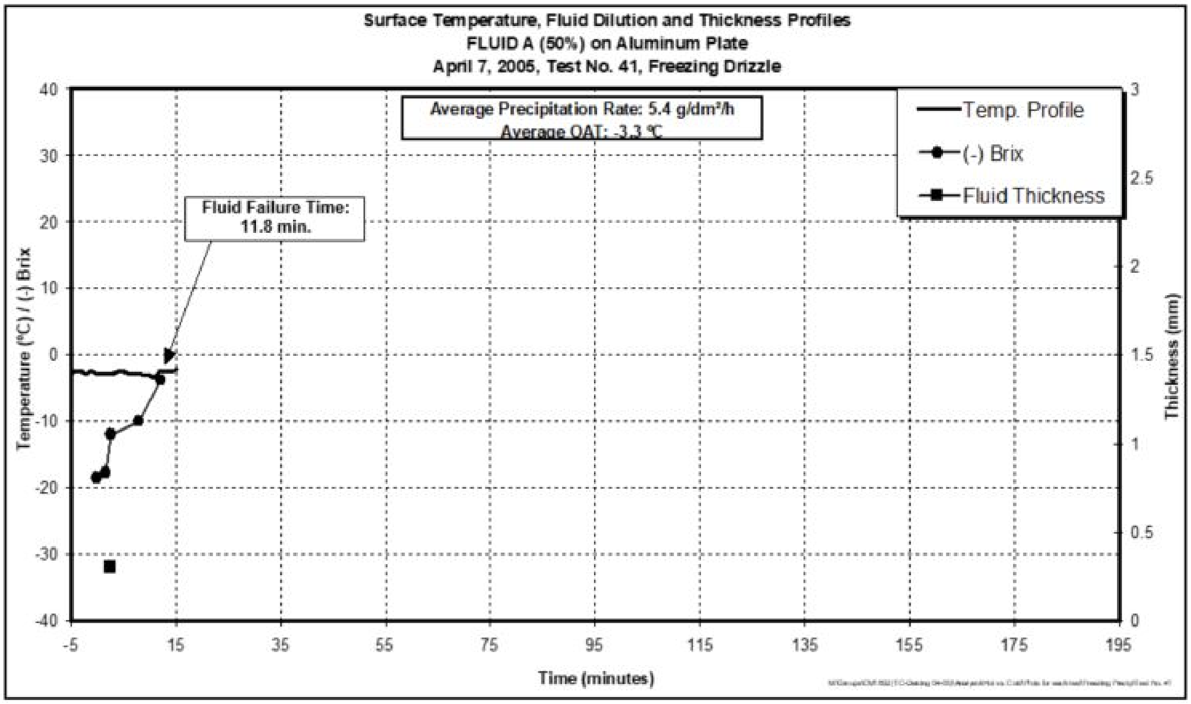

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (75%) on Heated Aluminum Plate
April 6, 2005, Test No. 33, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time: 16.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Aluminum Plate
April 6, 2005, Test No. 34, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time: 10.5 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

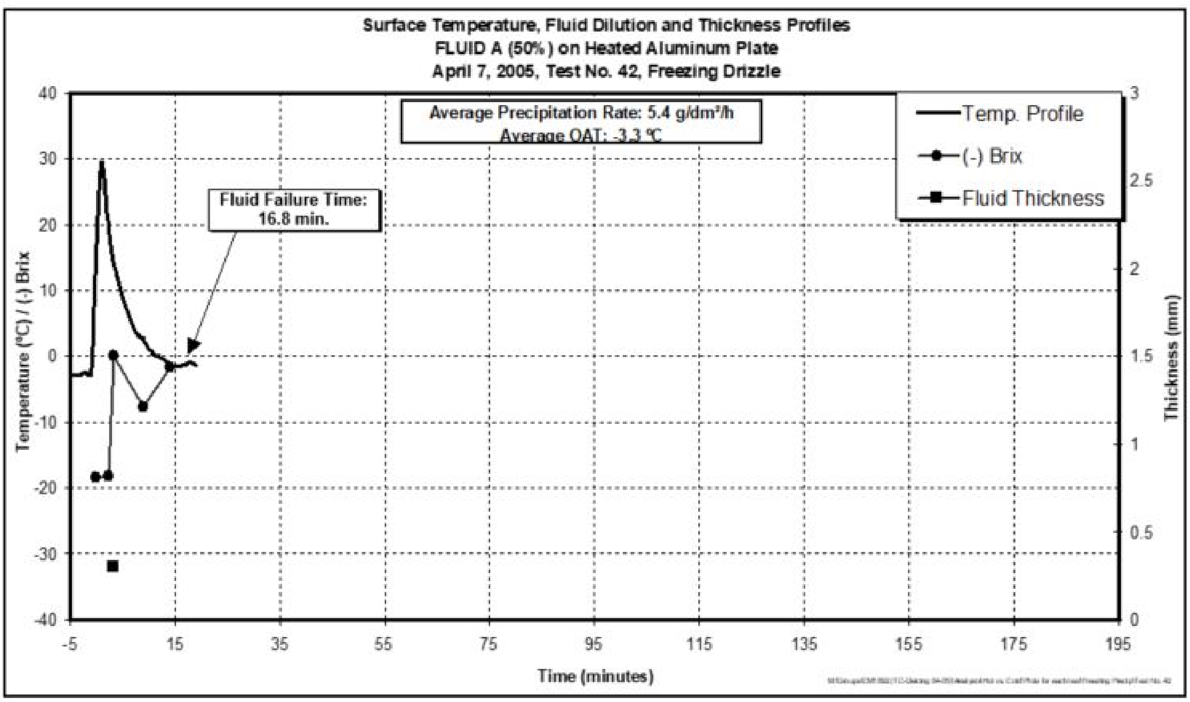

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (Neat) on Heated Aluminum Plate
April 6, 2005, Test No. 35, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.2 °C
Fluid Failure Time: 13.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Aluminum Plate
April 6, 2005, Test No. 36, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time:
32.5 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0

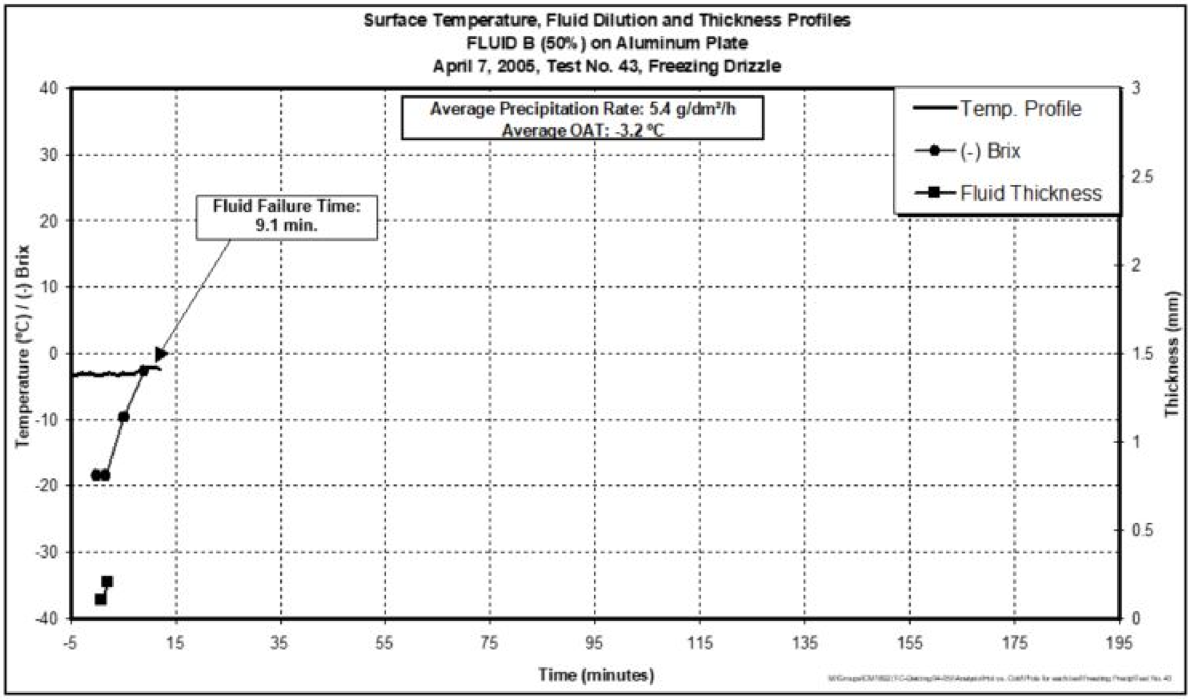

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID C (75%) on Heated Aluminum Plate
April 6, 2005, Test No. 37, Freezing Rain
Average Precipitation Rate: 25.5 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time:
22.0 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
-5
15
35
55
75
95
115
135
155
175
195
3
2.5
2
1.5
1
0.5
0



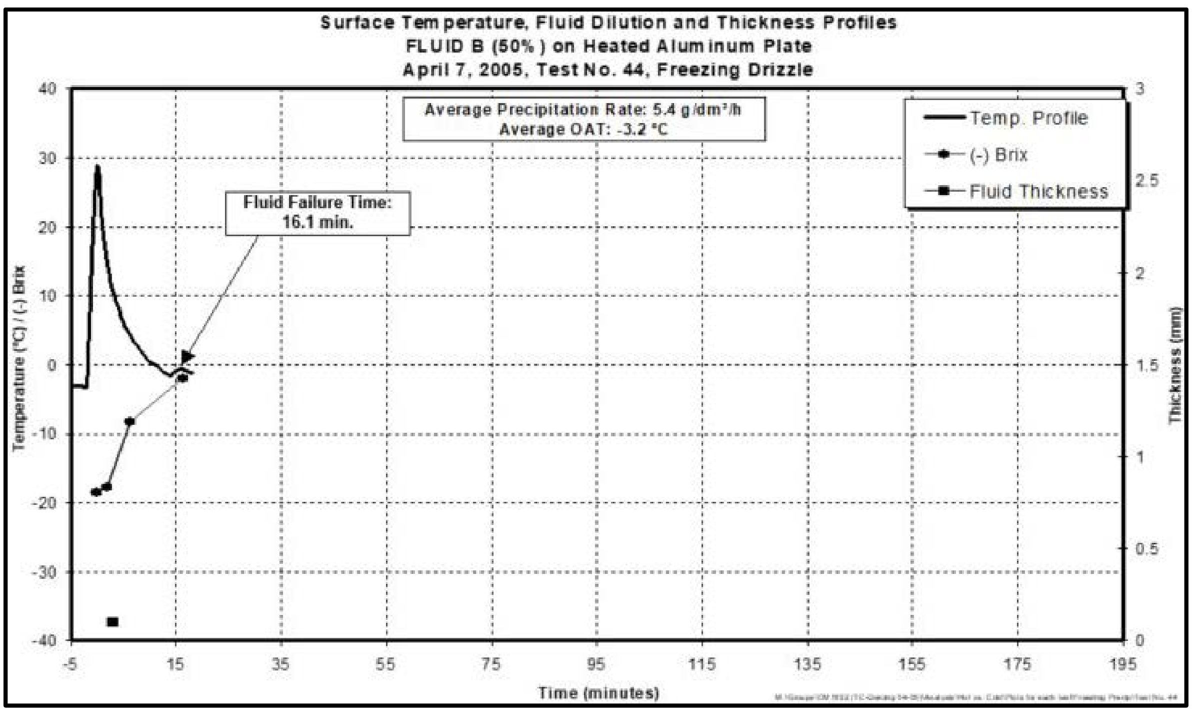
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Aluminum Plate
April 7, 2005, Test No. 41, Freezing Drizzle
Average Precipitation Rate: 5.4 g/dm²/h
Average OAT: -3.3 °C
Fluid Failure Time: 11.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195



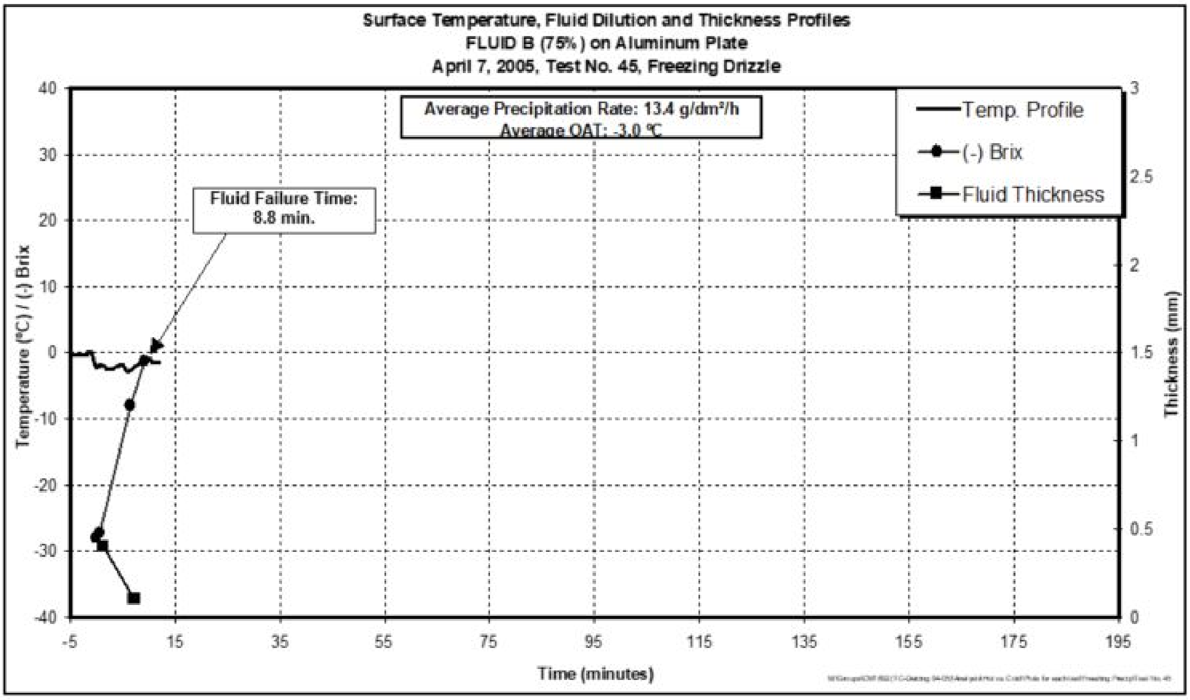
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Heated Aluminum Plate
April 7, 2005, Test No. 42, Freezing Drizzle
Average Precipitation Rate: 5.4 g/dm²/h
Average OAT: -3.3 °C
Fluid Failure Time: 16.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

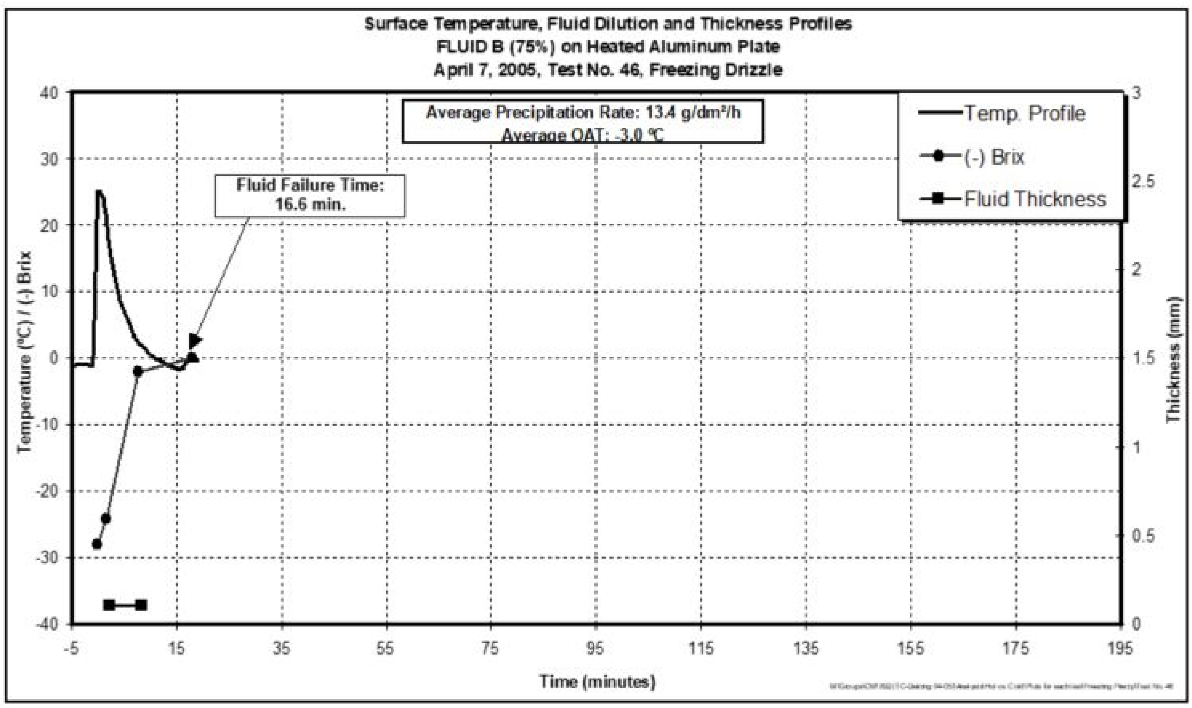


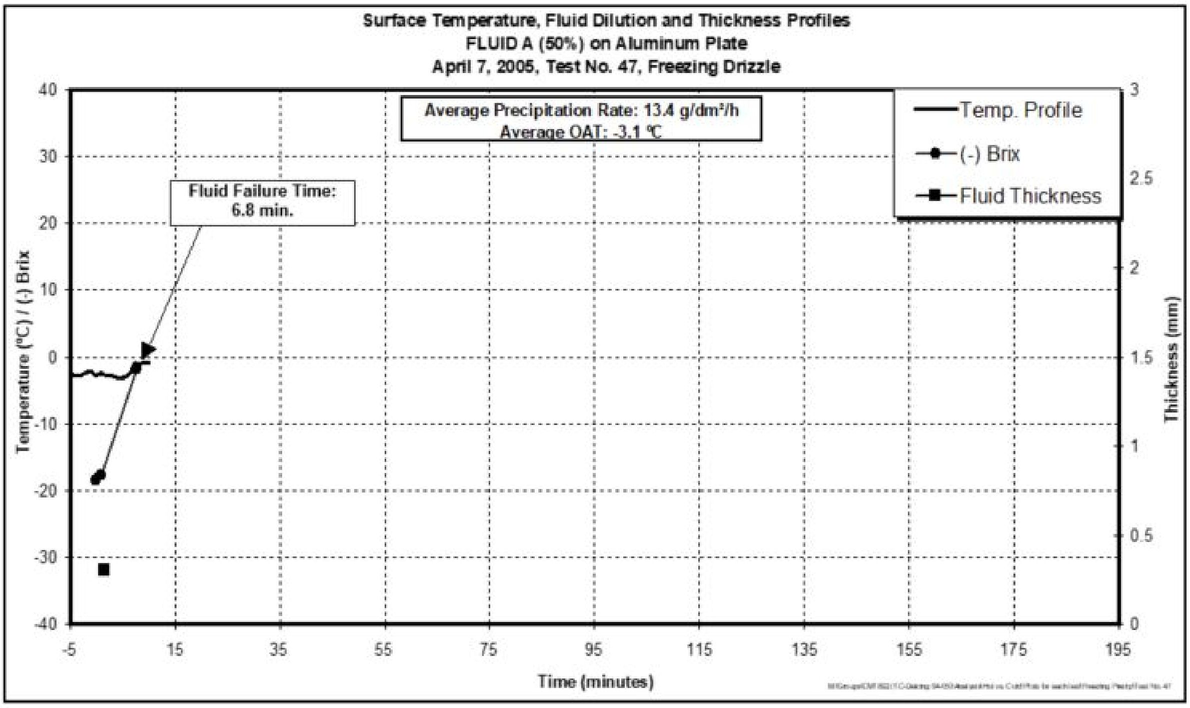
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (50%) on Aluminum Plate
April 7, 2005, Test No. 43, Freezing Drizzle
Average Precipitation Rate: 5.4 g/dm²/h
Average OAT: -3.2 °C
Fluid Failure Time:
9.1 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

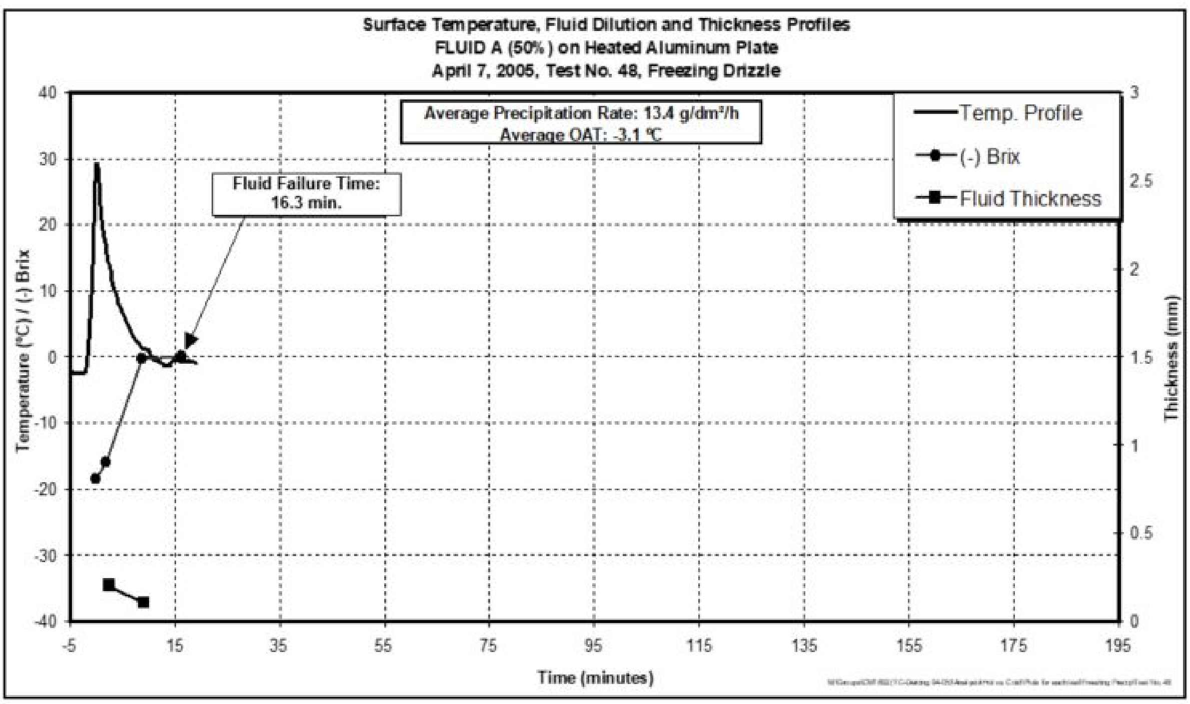


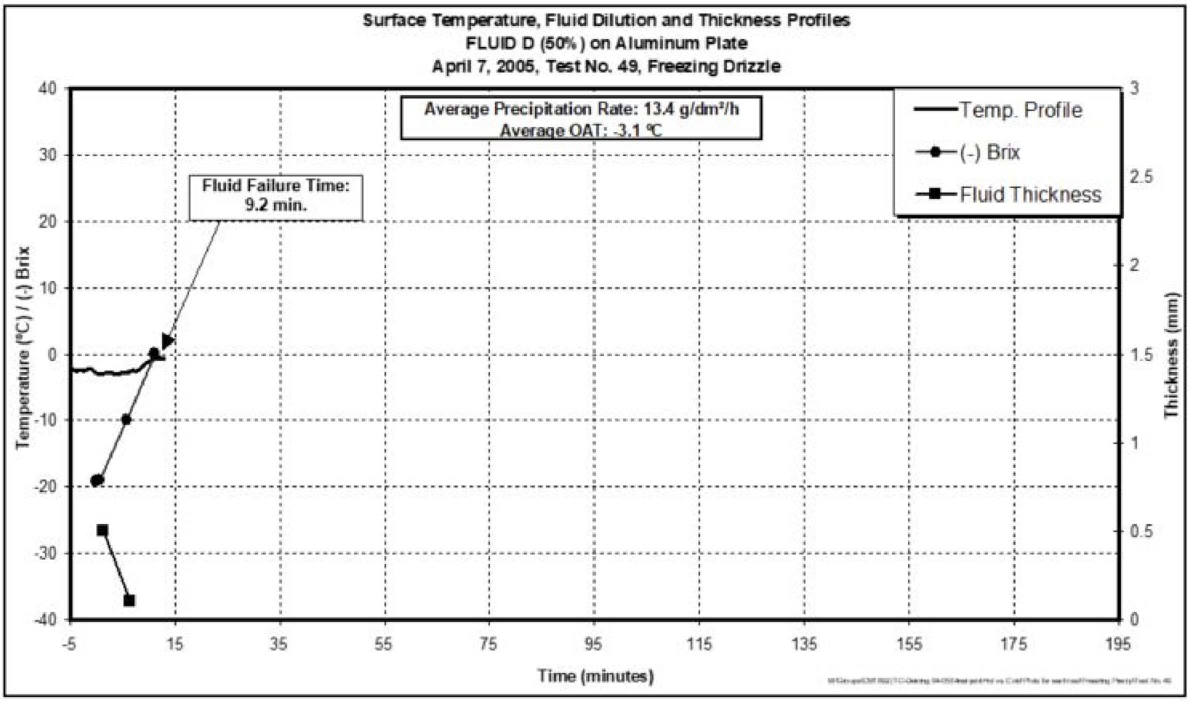
Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (50%) on Heated Aluminum Plate
April 7, 2005, Test No. 44, Freezing Drizzle
Average Precipitation Rate: 5.4 g/dm²/h
Average OAT: -3.2 °C
Fluid Failure Time:
16.1 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

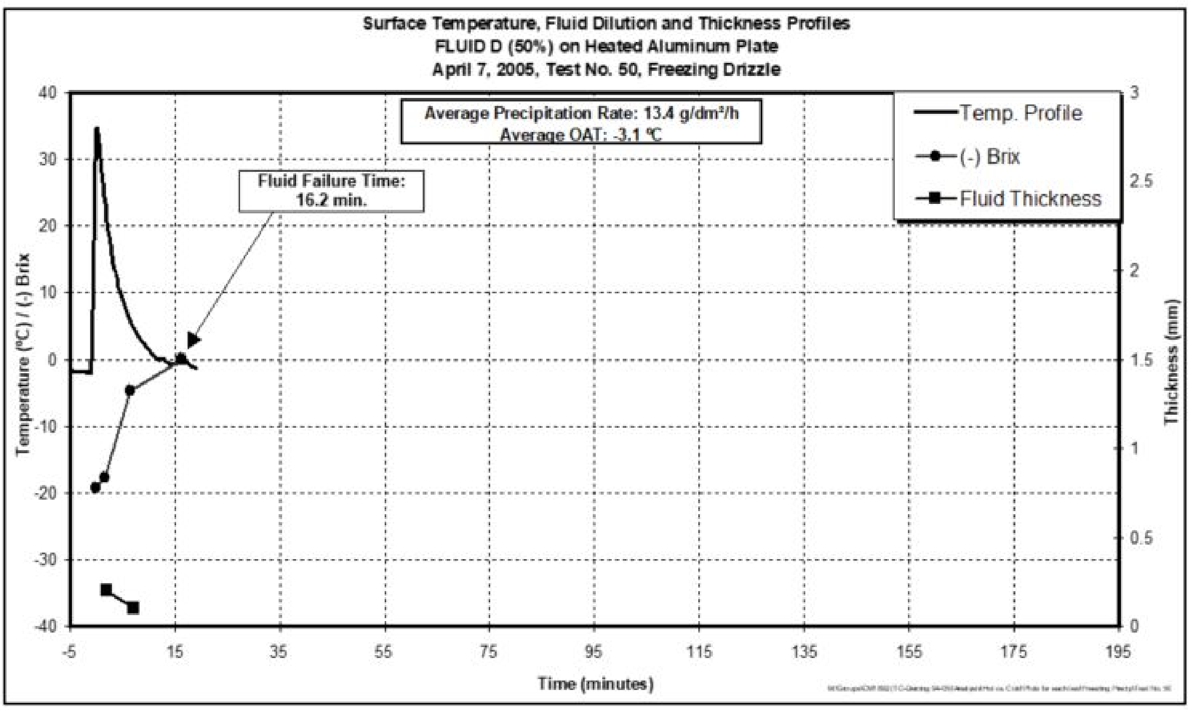

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Aluminum Plate
April 7, 2005, Test No. 45, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.0 °C
Fluid Failure Time: 8.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID B (75%) on Heated Aluminum Plate
April 7, 2005, Test No. 46, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.0 °C
Fluid Failure Time: 16.6 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

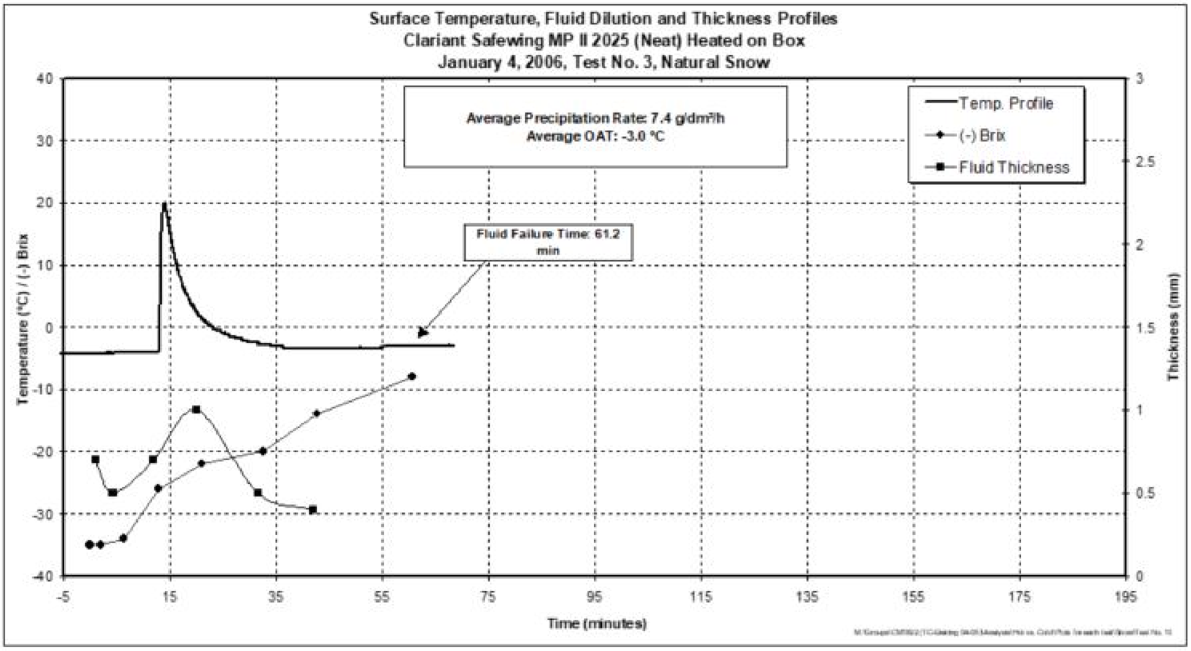

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Aluminum Plate
April 7, 2005, Test No. 47, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time:
6.8 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

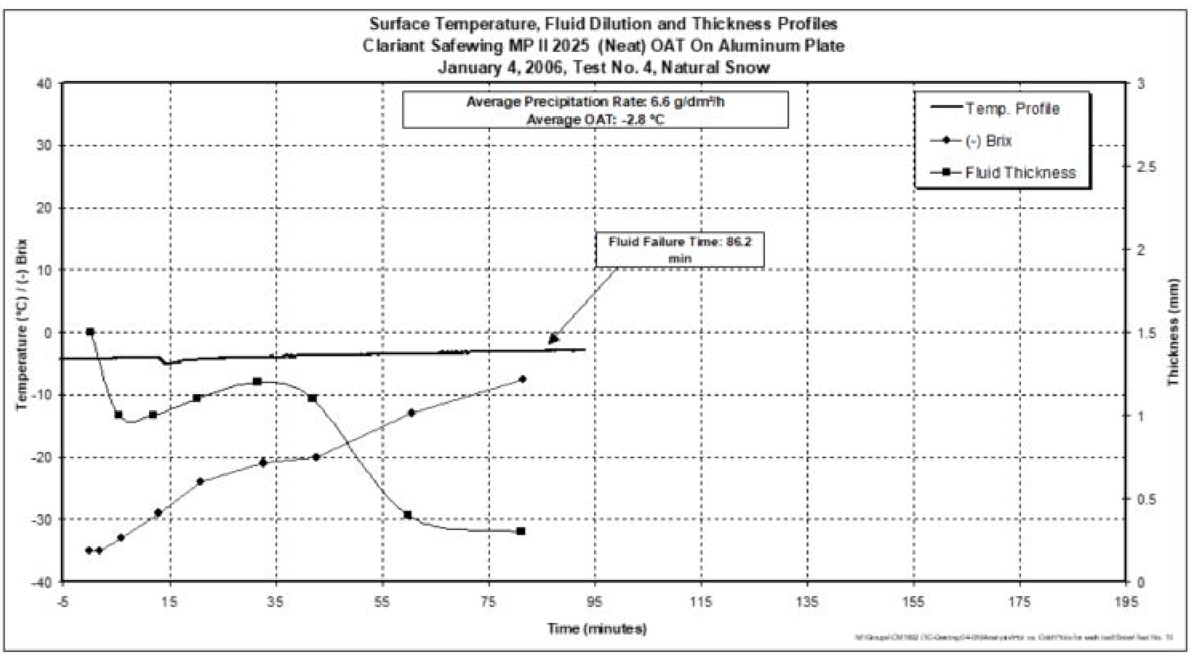

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID A (50%) on Heated Aluminum Plate
April 7, 2005, Test No. 48, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time:
16.3 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)
40
30
20
10
0
-10
-20
-30
-40
3
2.5
2
1.5
1
0.5
0
-5
15
35
55
75
95
115
135
155
175
195

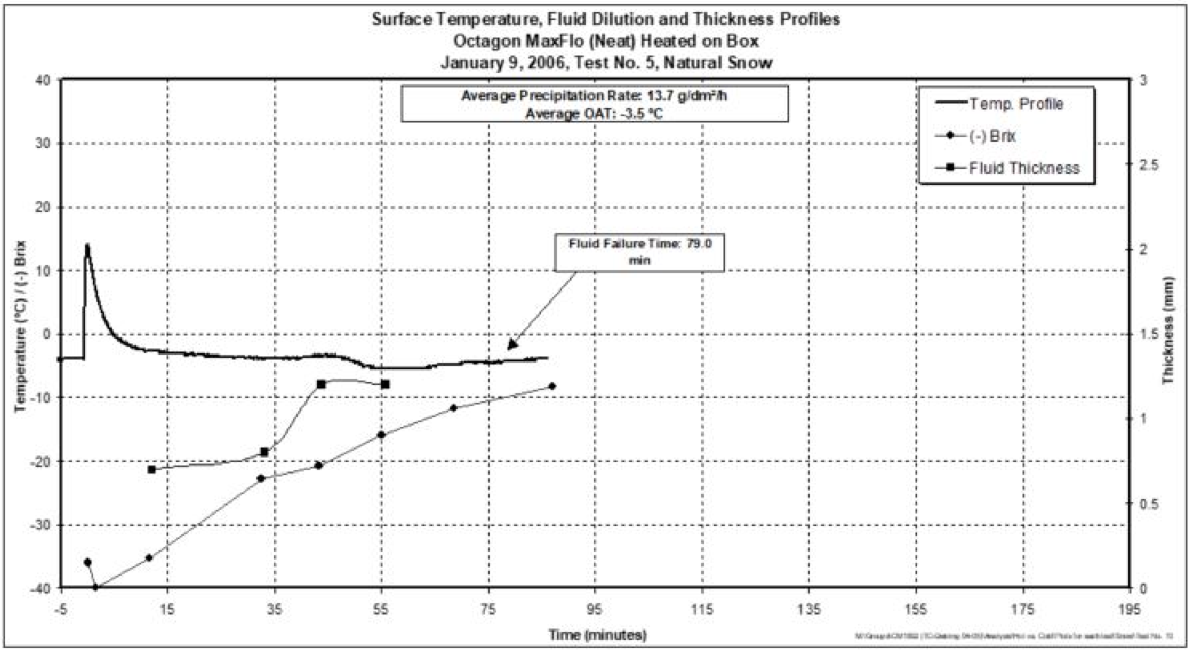

Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (50%) on Aluminum Plate
April 7, 2005, Test No. 49, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time: 9.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
FLUID D (50%) on Heated Aluminum Plate
April 7, 2005, Test No. 50, Freezing Drizzle
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.1 °C
Fluid Failure Time: 16.2 min.
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

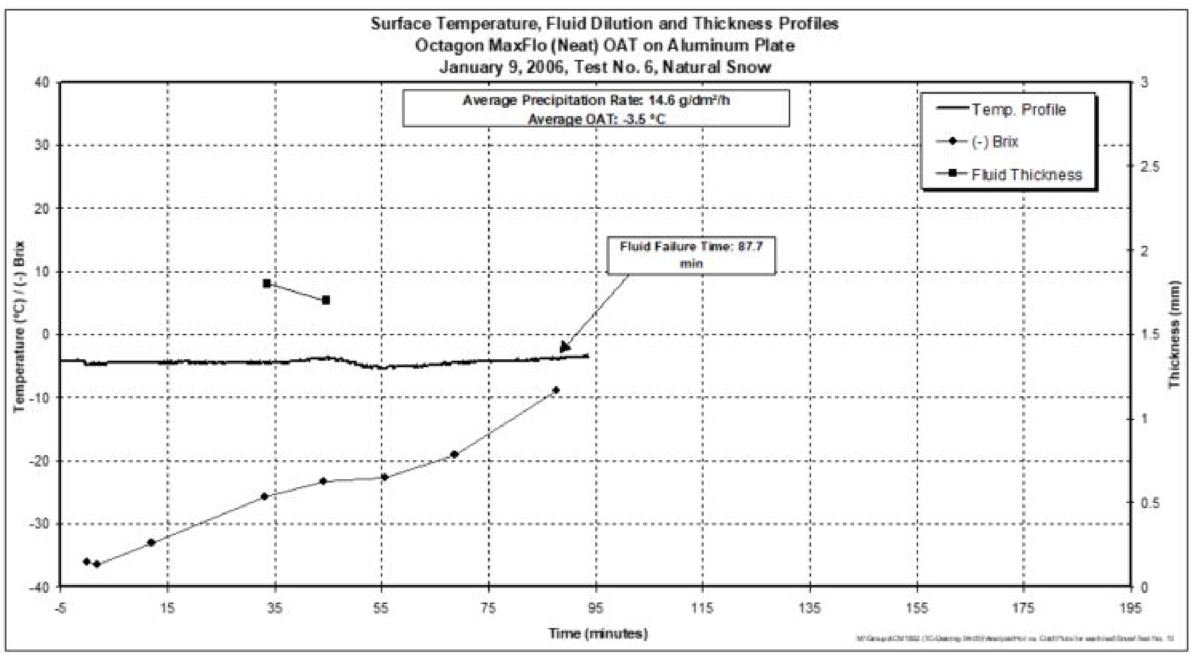
2005-06 CHARTS


Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP II 2025 (Neat) Heated on Box
January 4, 2006, Test No. 3, Natural Snow
Average Precipitation Rate: 7.4 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 61.2 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

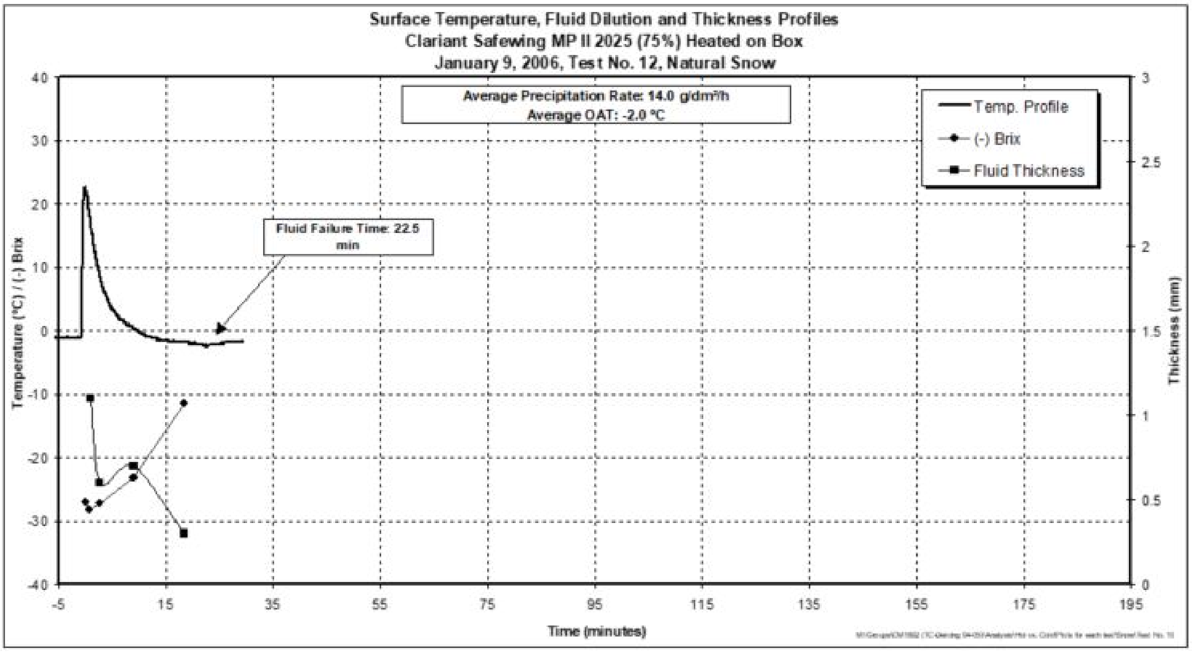

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP II 2025 (Neat) OAT On Aluminum Plate
January 4, 2006, Test No. 4, Natural Snow
Average Precipitation Rate: 6.6 g/dm²/h
Average OAT: -2.8 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 86.2 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

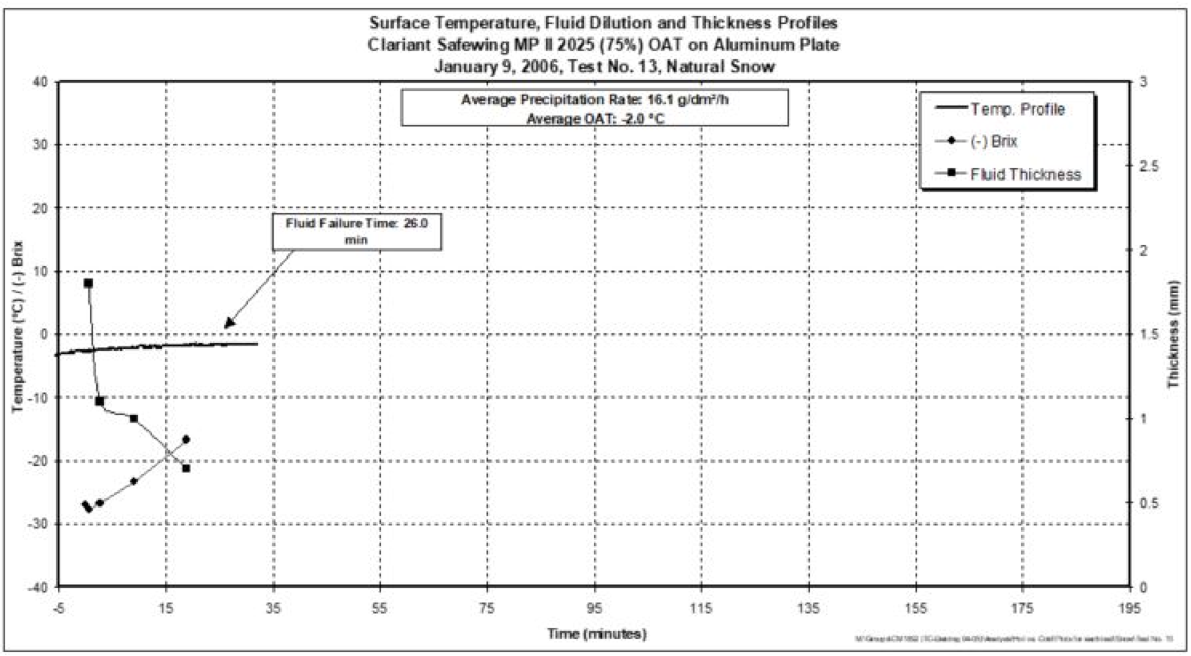


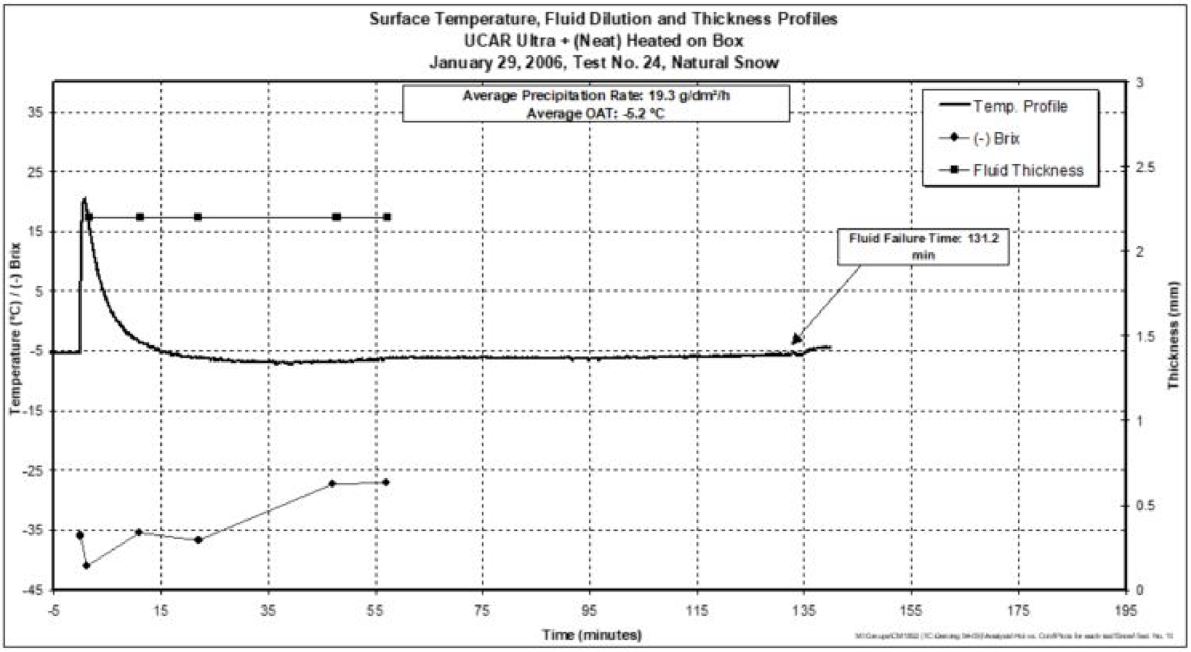
Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (Neat) Heated on Box
January 9, 2006, Test No. 5, Natural Snow
Average Precipitation Rate: 13.7 g/dm²/h
Average OAT: -3.5 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 79.0 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

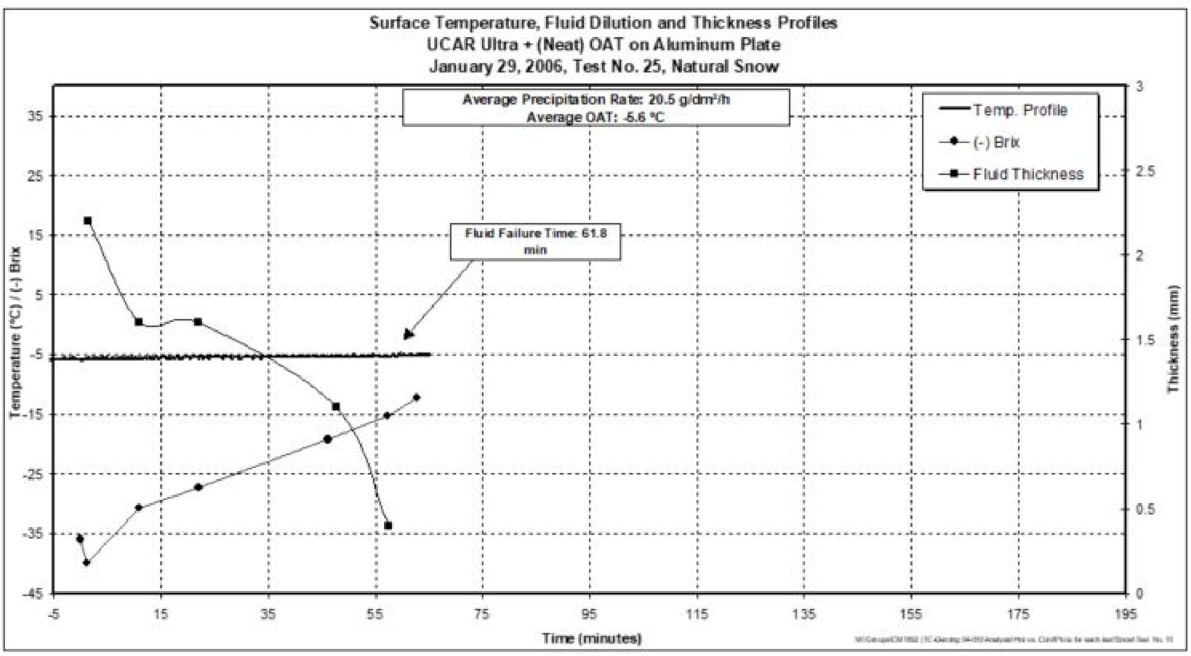


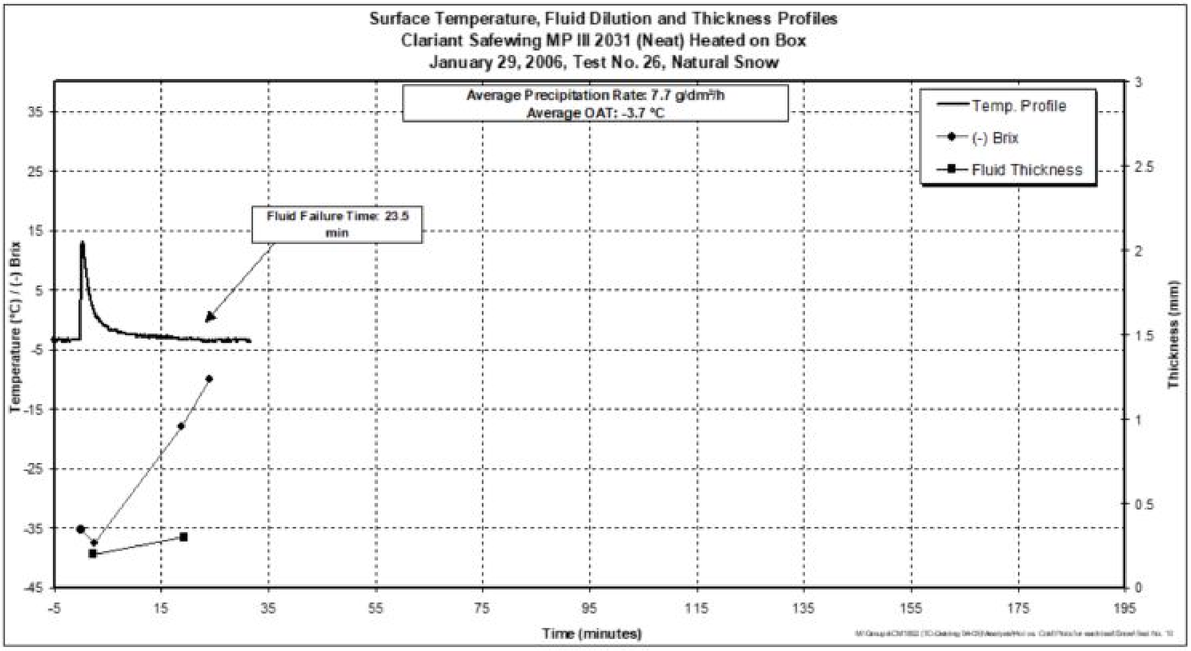
Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (Neat) OAT on Aluminum Plate
January 9, 2006, Test No. 6, Natural Snow
Average Precipitation Rate: 14.6 g/dm²/h
Average OAT: -3.5 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 87.7 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

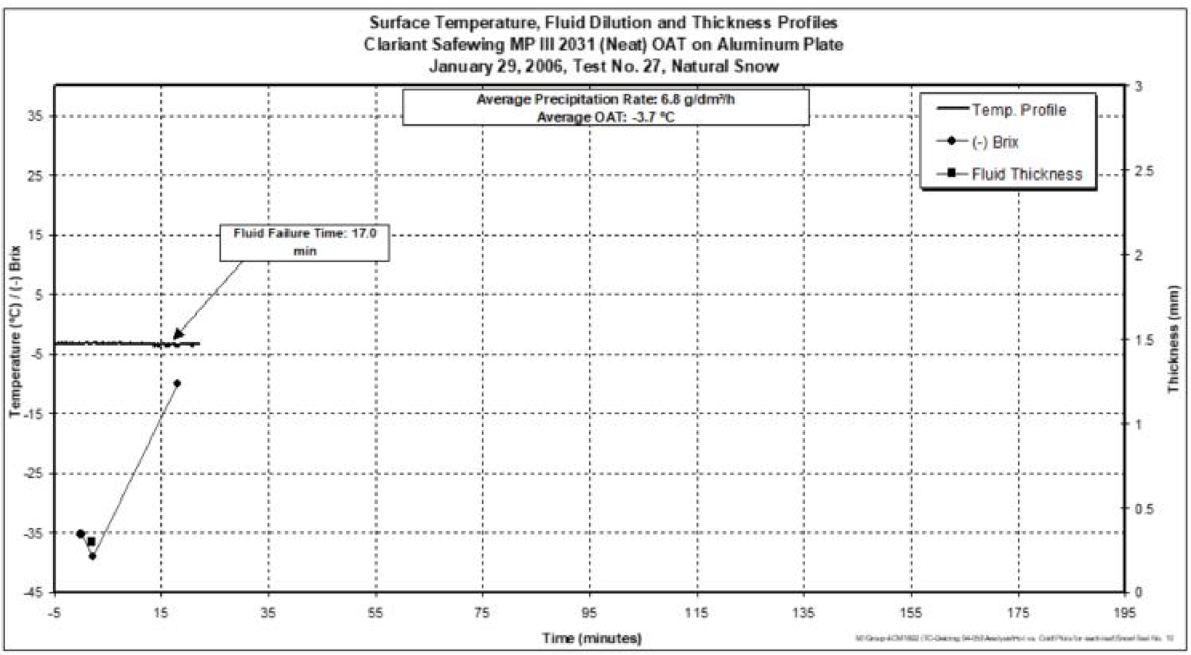

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP II 2025 (75%) Heated on Box
January 9, 2006, Test No. 12, Natural Snow
Average Precipitation Rate: 14.0 g/dm²/h
Average OAT: -2.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 22.5 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

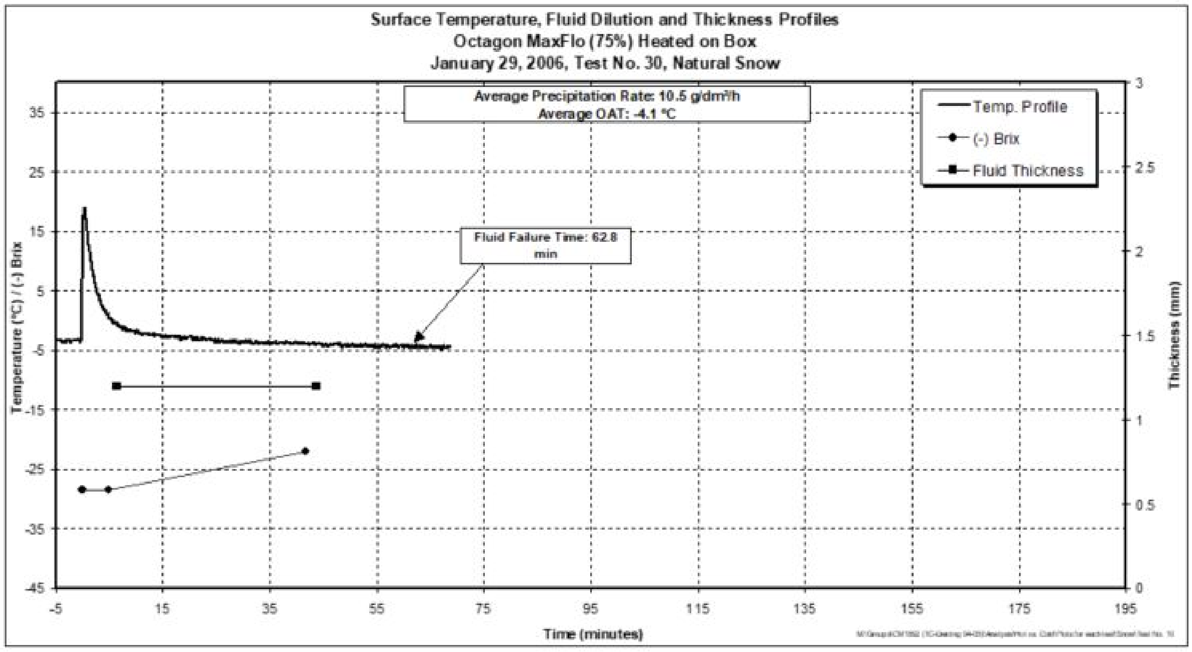

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP II 2025 (75%) OAT on Aluminum Plate
January 9, 2006, Test No. 13, Natural Snow
Average Precipitation Rate: 16.1 g/dm²/h
Average OAT: -2.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 26.0 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

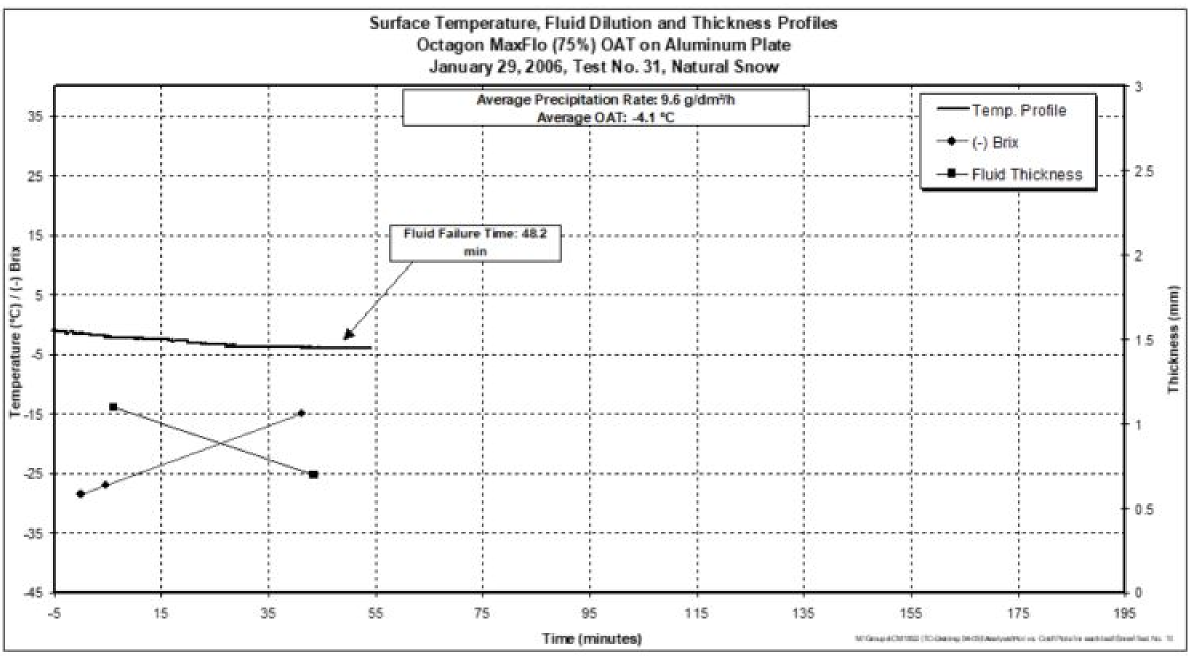

Surface Temperature, Fluid Dilution and Thickness Profiles
UCAR Ultra + (Neat) Heated on Box
January 29, 2006, Test No. 24, Natural Snow
Average Precipitation Rate: 19.3 g/dm²/h
Average OAT: -5.2 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 131.2 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

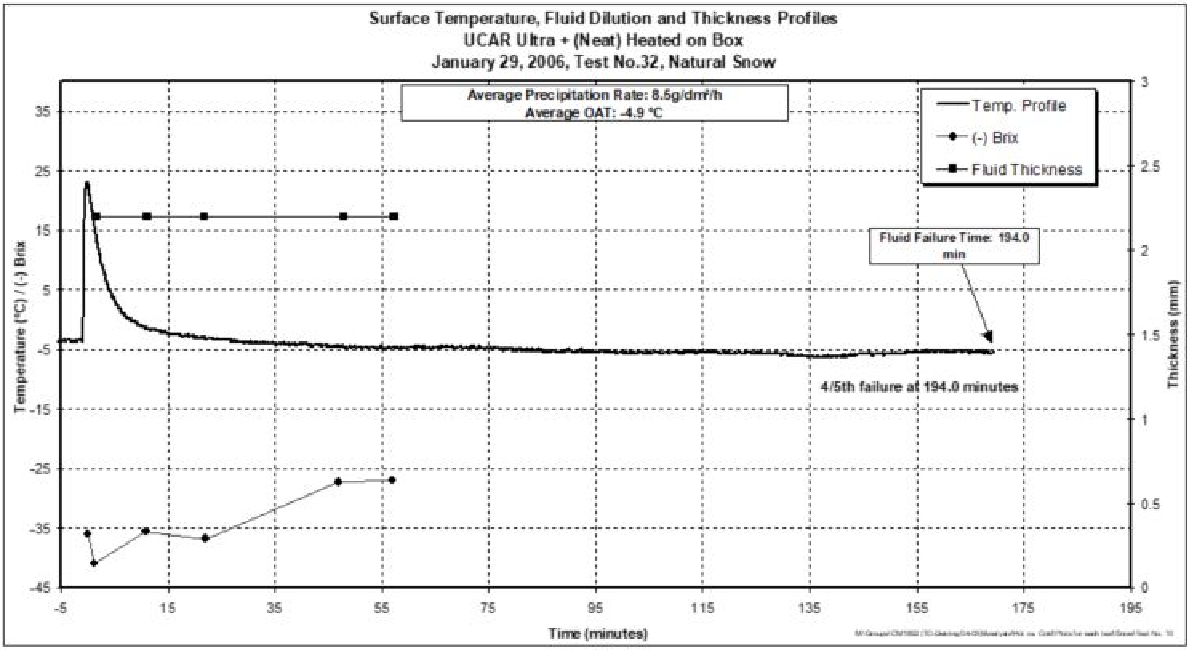

Surface Temperature, Fluid Dilution and Thickness Profiles
UCAR Ultra + (Neat) OAT on Aluminum Plate
January 29, 2006, Test No. 25, Natural Snow
Average Precipitation Rate: 20.5 g/dm²/h
Average OAT: -5.6 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 61.8 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 (Neat) Heated on Box
January 29, 2006, Test No. 26, Natural Snow
Average Precipitation Rate: 7.7 g/dm²/h
Average OAT: -3.7 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 23.5 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

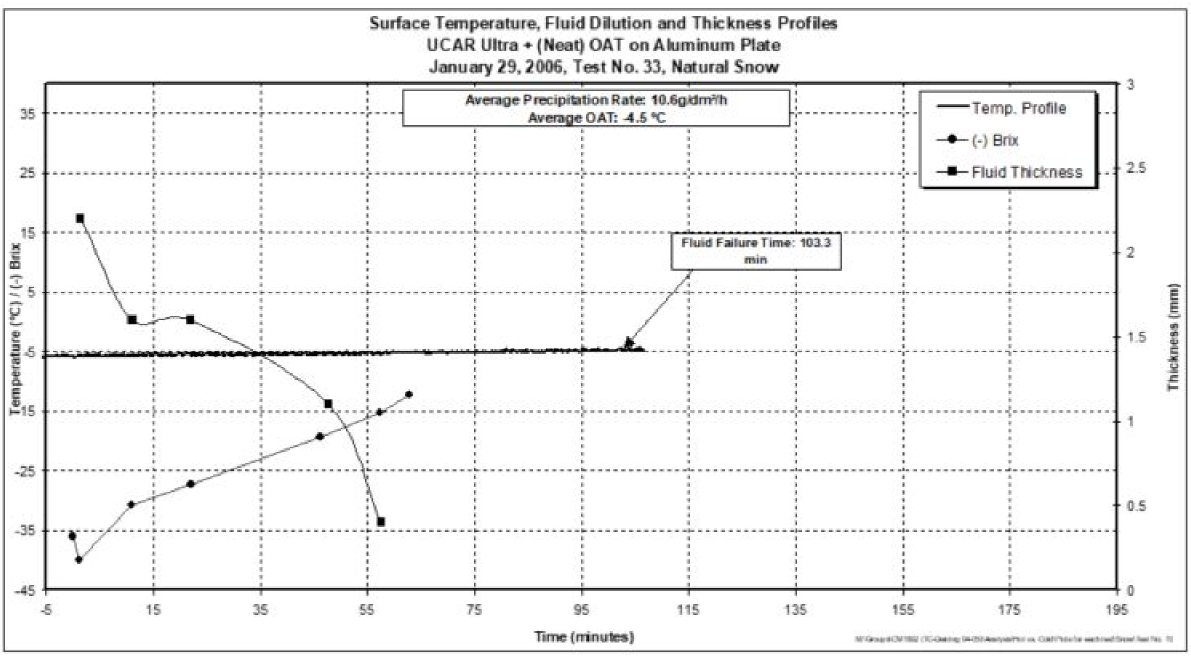

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 (Neat) OAT on Aluminum Plate
January 29, 2006, Test No. 27, Natural Snow
Average Precipitation Rate: 6.8 g/dm²/h
Average OAT: -3.7 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 17.0 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (75%) Heated on Box
January 29, 2006, Test No. 30, Natural Snow
Average Precipitation Rate: 10.5 g/dm²/h
Average OAT: -4.1 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 62.8 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

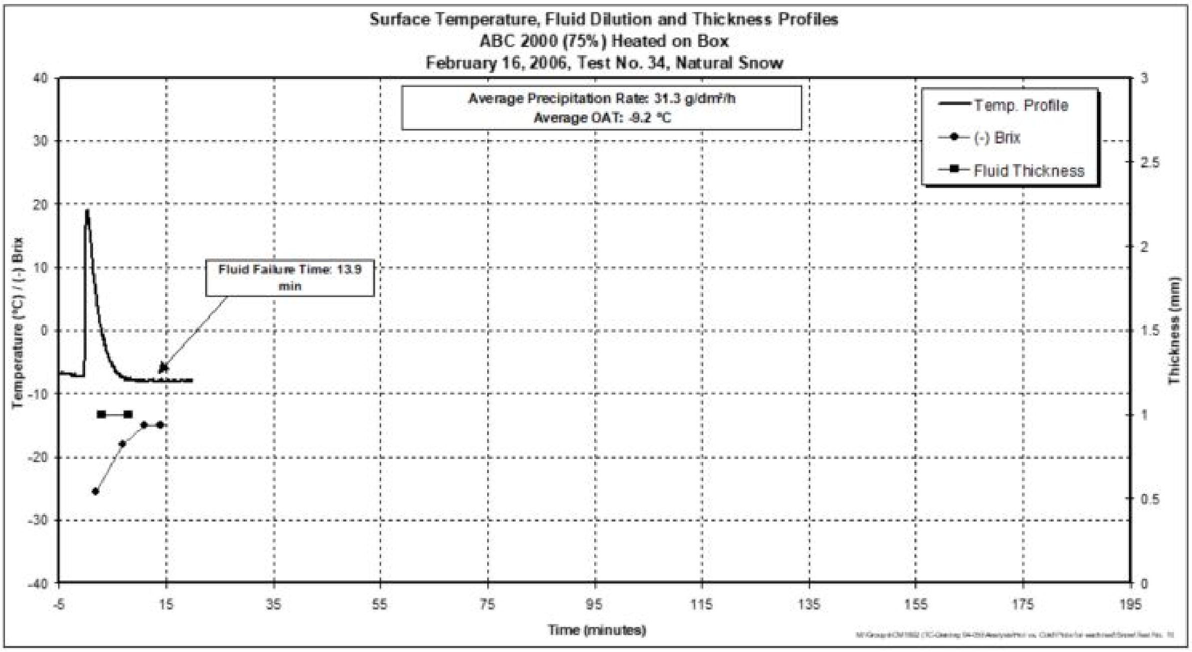

Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (75%) OAT on Aluminum Plate
January 29, 2006, Test No. 31, Natural Snow
Average Precipitation Rate: 9.6 g/dm²/h
Average OAT: -4.1 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 48.2 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

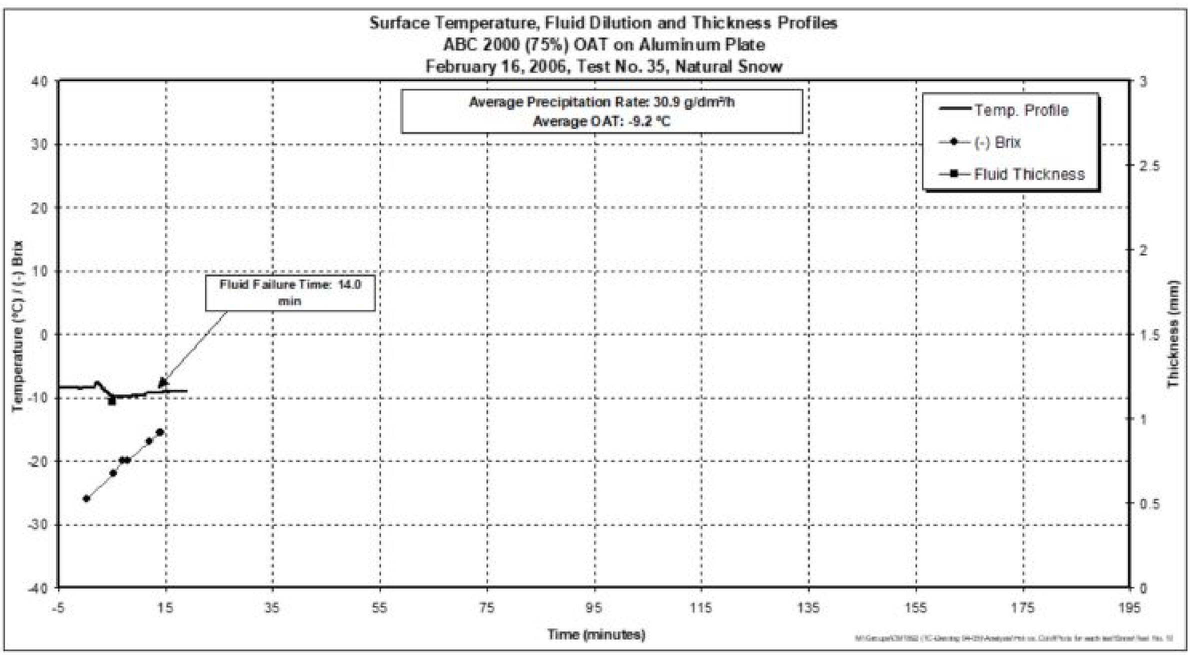


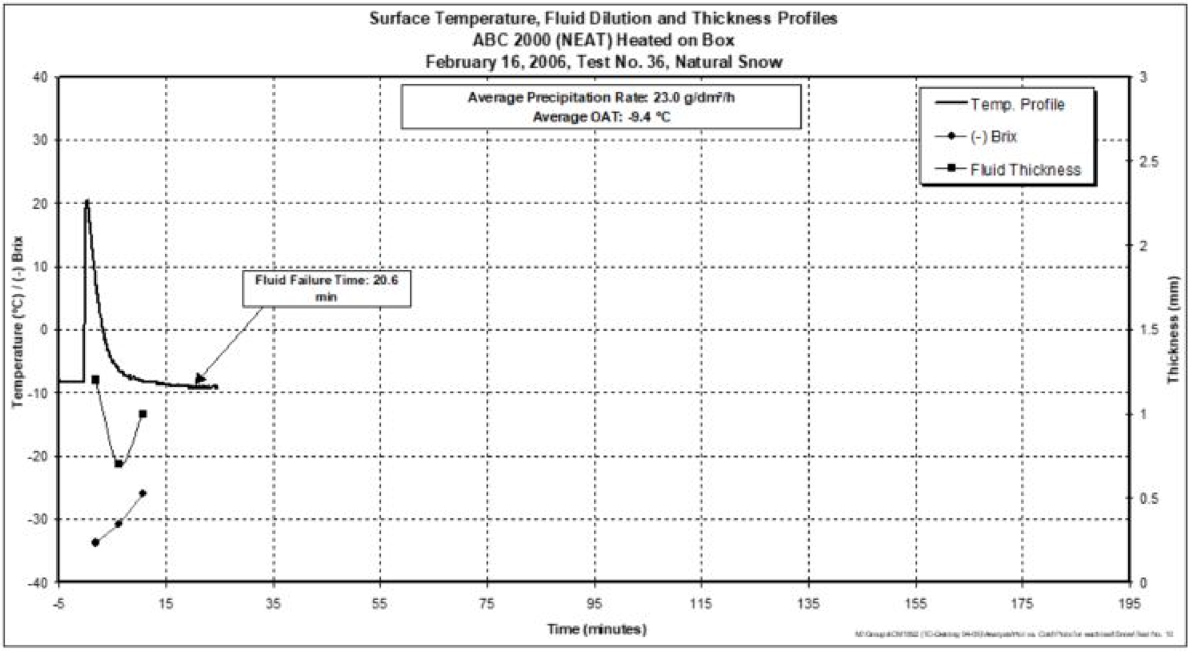
Surface Temperature, Fluid Dilution and Thickness Profiles
UCAR Ultra + (Neat) Heated on Box
January 29, 2006, Test No.32, Natural Snow
Average Precipitation Rate: 8.5g/dm²/h
Average OAT: -4.9 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 194.0 min
4/5th failure at 194.0 minutes
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

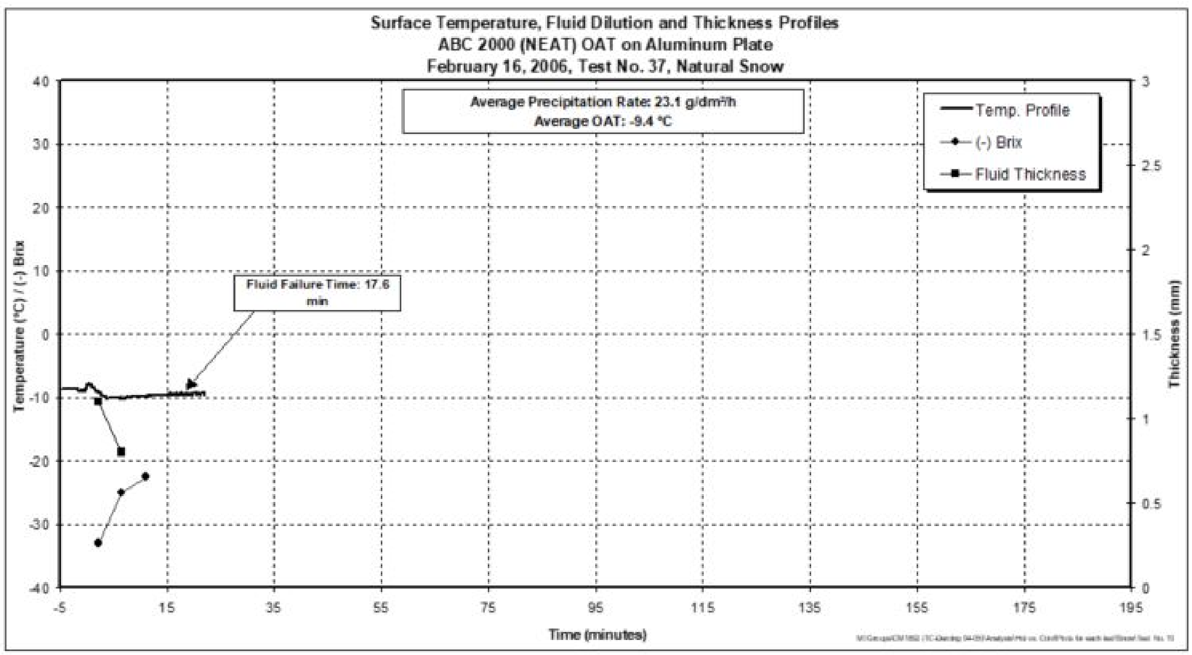


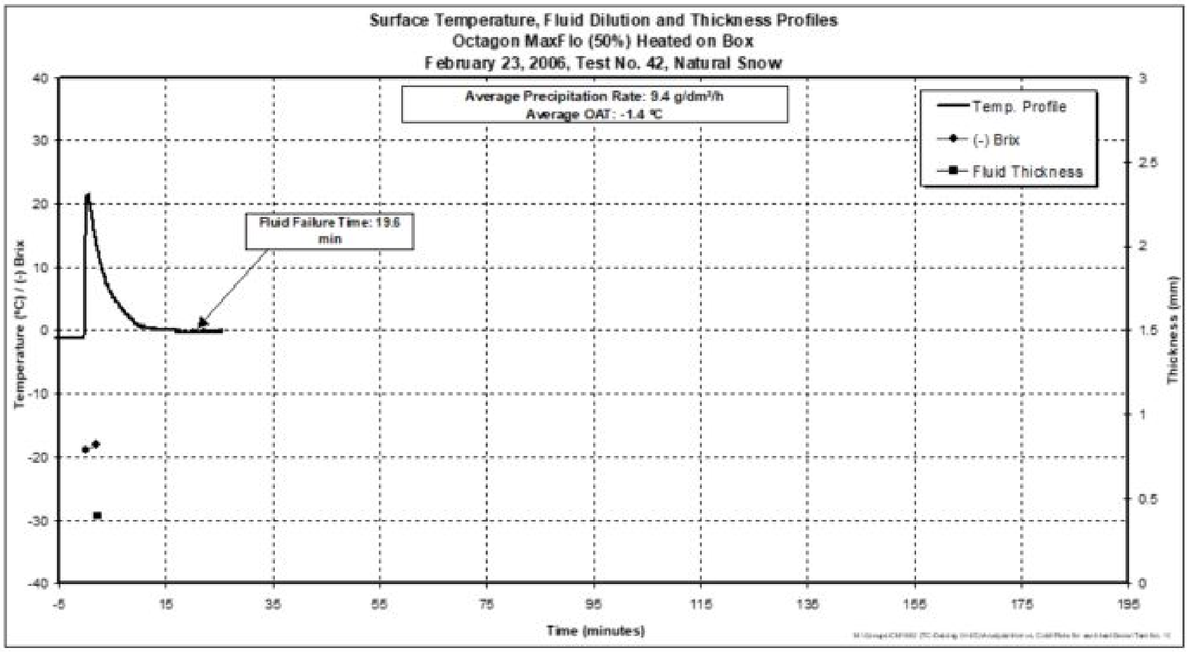
Surface Temperature, Fluid Dilution and Thickness Profiles
UCAR Ultra + (Neat) OAT on Aluminum Plate
January 29, 2006, Test No. 33, Natural Snow
Average Precipitation Rate: 10.6g/dm²/h
Average OAT: -4.5 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 103.3 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

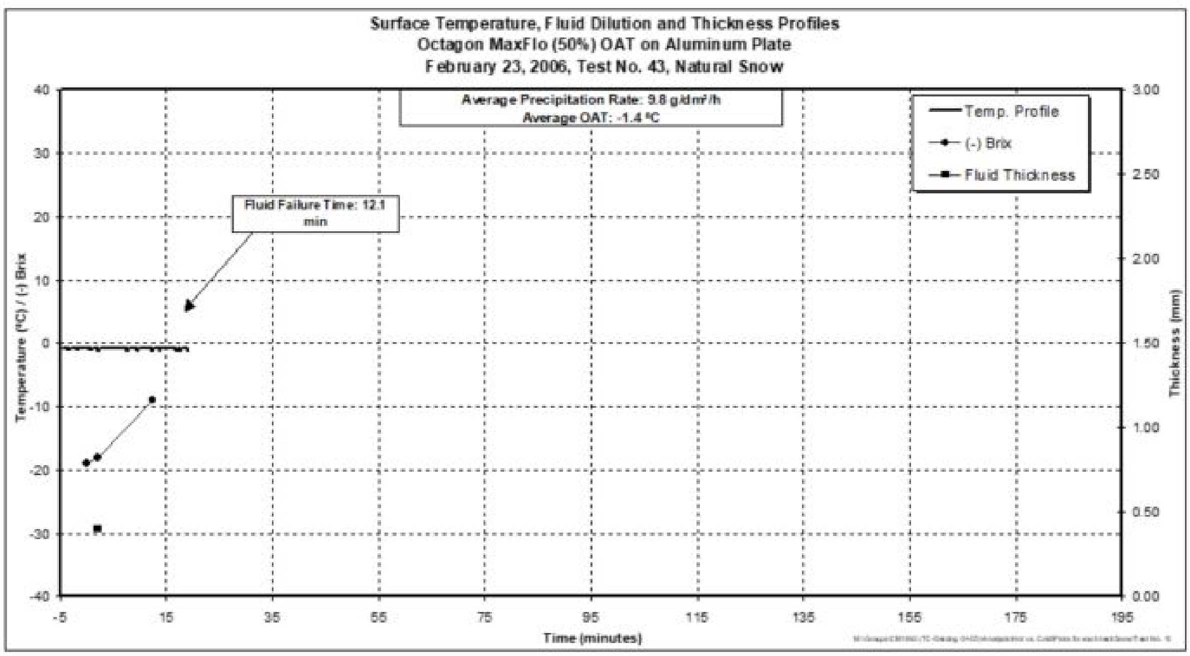

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (75%) Heated on Box
February 16, 2006, Test No. 34, Natural Snow
Average Precipitation Rate: 31.3 g/dm²/h
Average OAT: -9.2 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 13.9 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

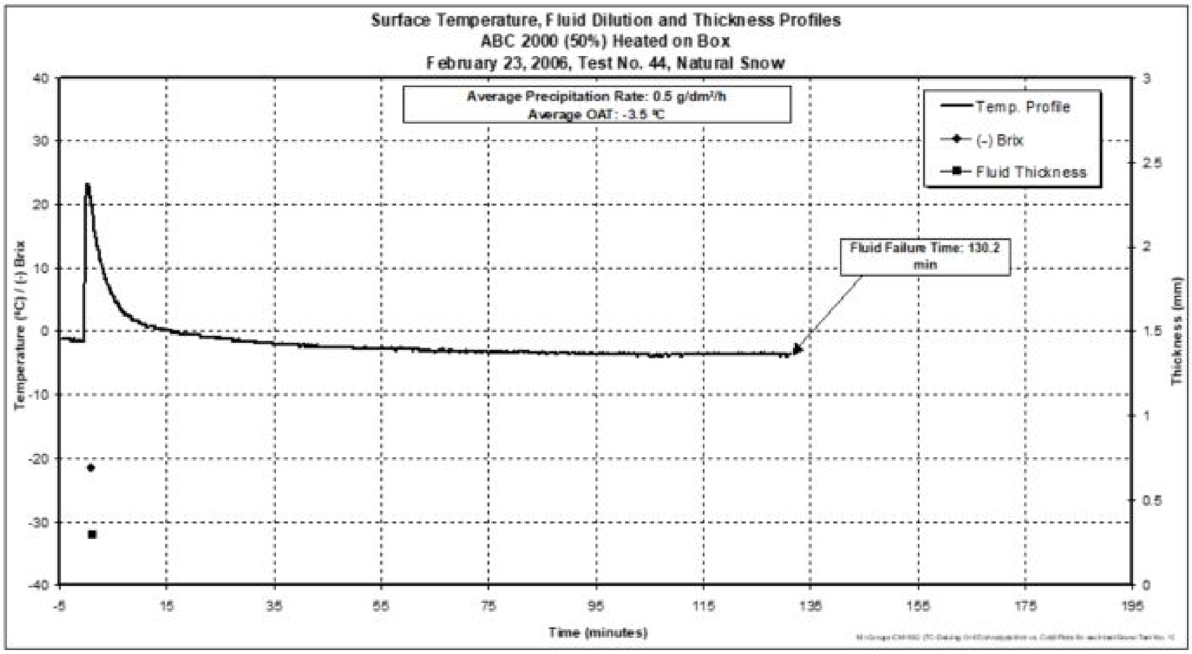

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (75%) OAT on Aluminum Plate
February 16, 2006, Test No. 35, Natural Snow
Average Precipitation Rate: 30.9 g/dm²/h
Average OAT: -9.2 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 14.0 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

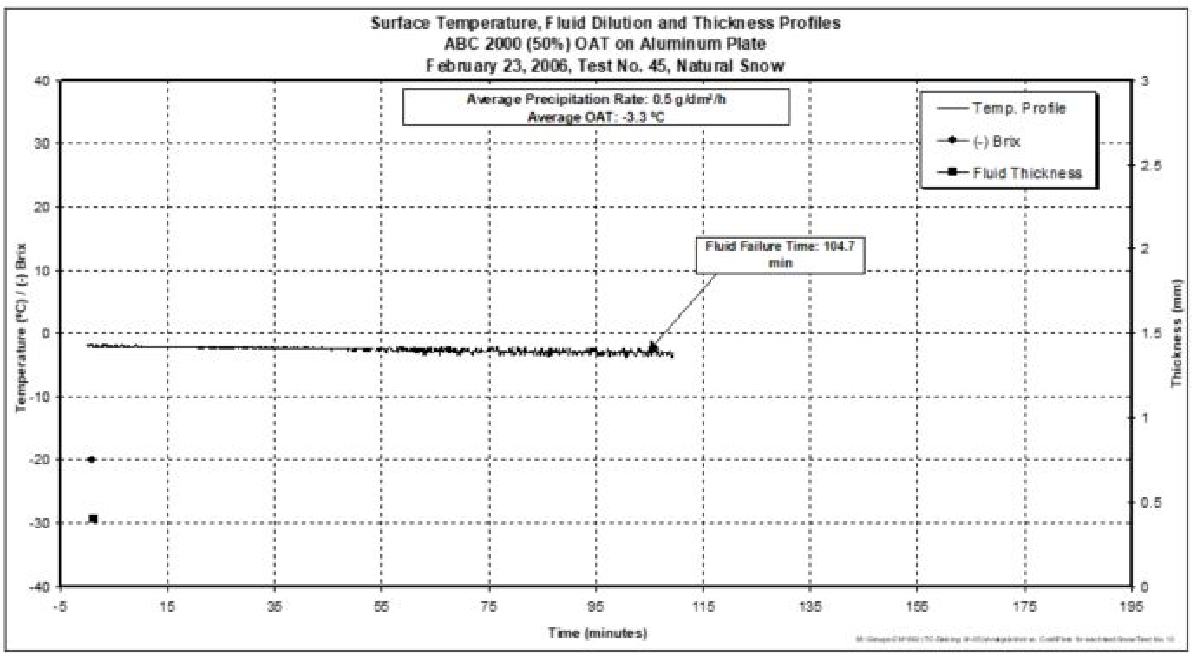

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (NEAT) Heated on Box
February 16, 2006, Test No. 36, Natural Snow
Average Precipitation Rate: 23.0 g/dm²/h
Average OAT: -9.4 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 20.6 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

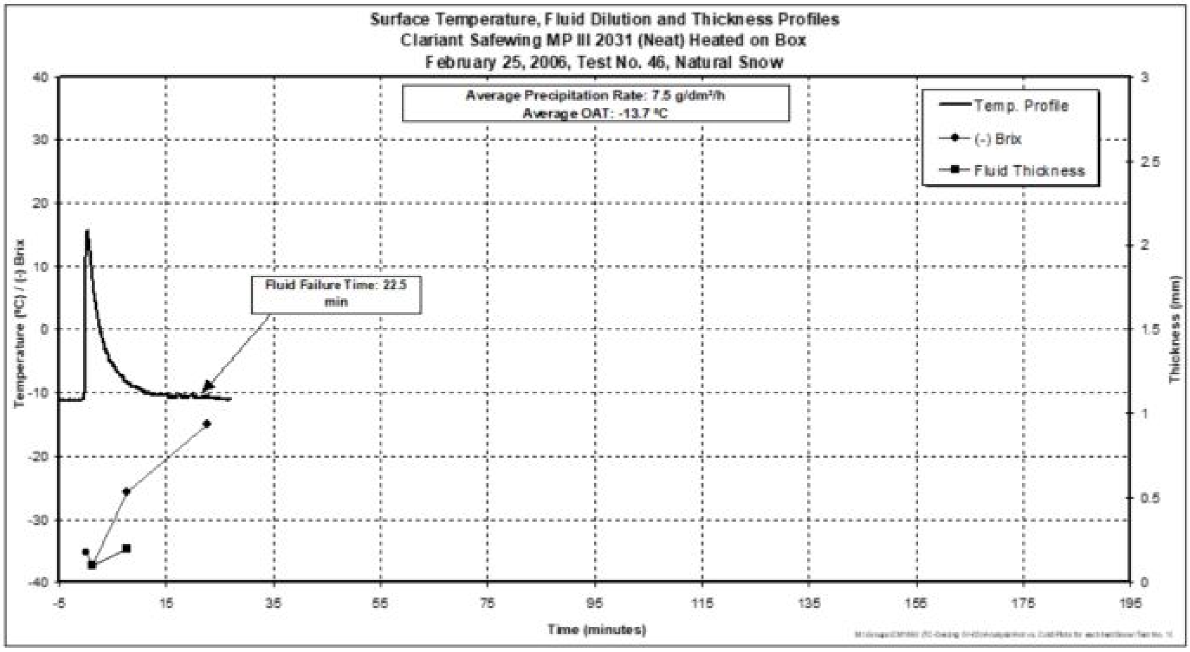

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (NEAT) OAT on Aluminum Plate
February 16, 2006, Test No. 37, Natural Snow
Average Precipitation Rate: 23.1 g/dm²/h
Average OAT: -9.4 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 17.6 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

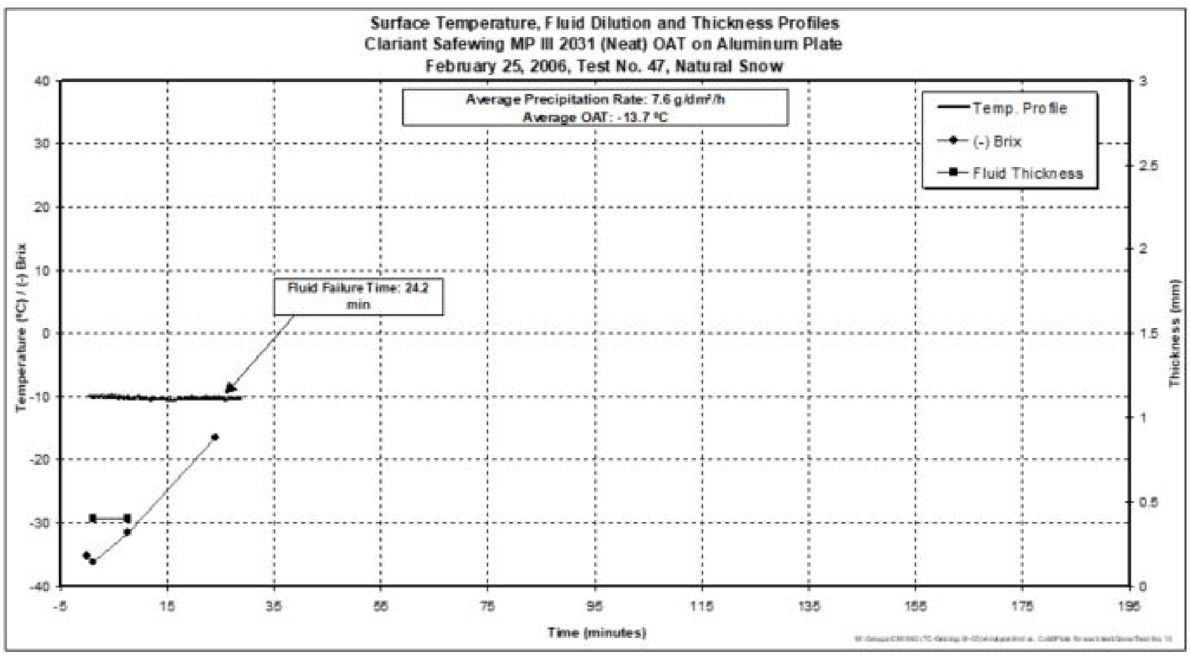

Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (50%) Heated on Box
February 23, 2006, Test No. 42, Natural Snow
Average Precipitation Rate: 9.4 g/dm²/h
Average OAT: -1.4 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 19.6 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

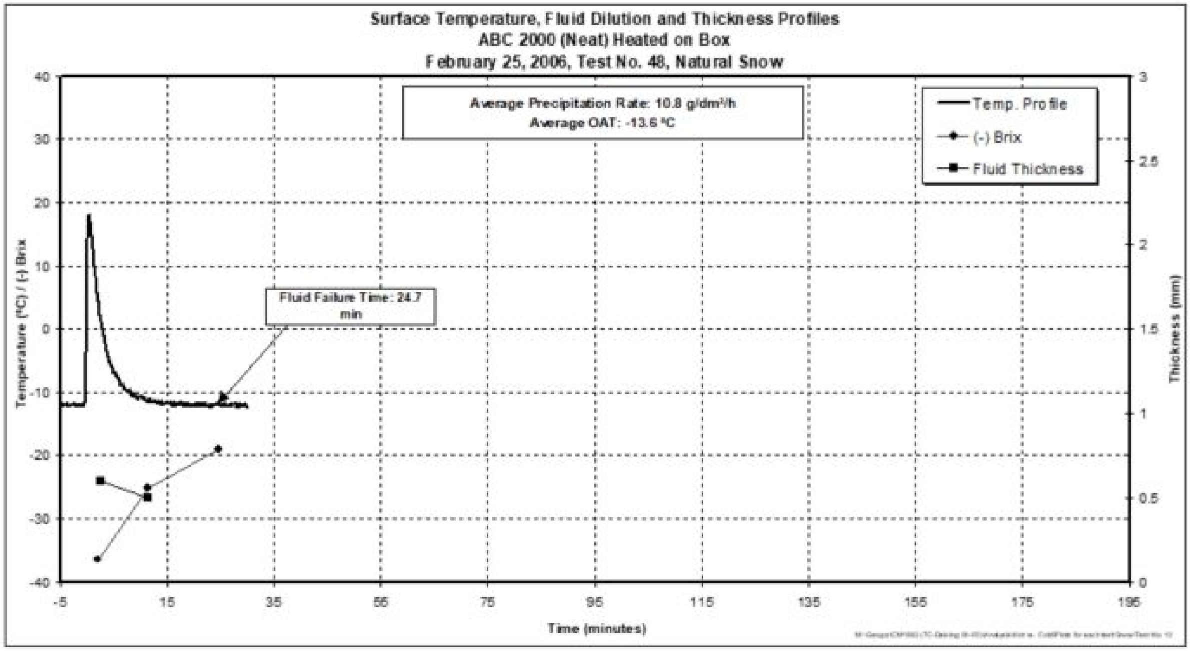

Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (50%) OAT on Aluminum Plate
February 23, 2006, Test No. 43, Natural Snow
Average Precipitation Rate: 9.8 g/dm²/h
Average OAT: -1.4 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 12.1 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

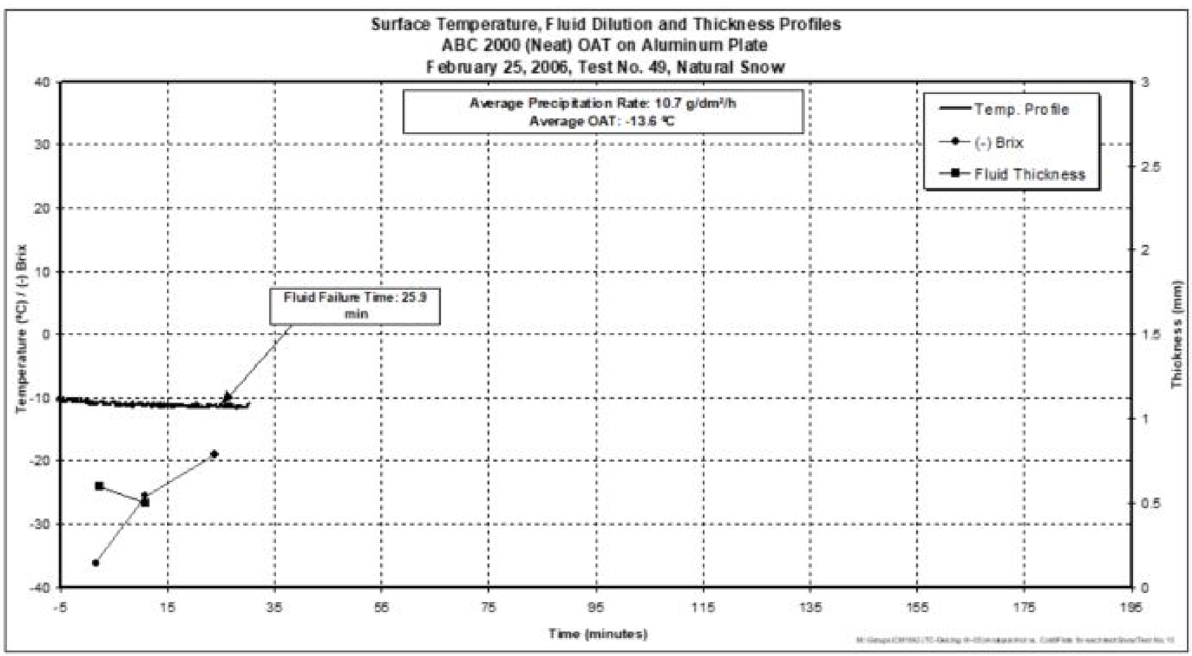

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (50%) Heated on Box
February 23, 2006, Test No. 44, Natural Snow
Average Precipitation Rate: 0.5 g/dm²/h
Average OAT: -3.5 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 130.2 min
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

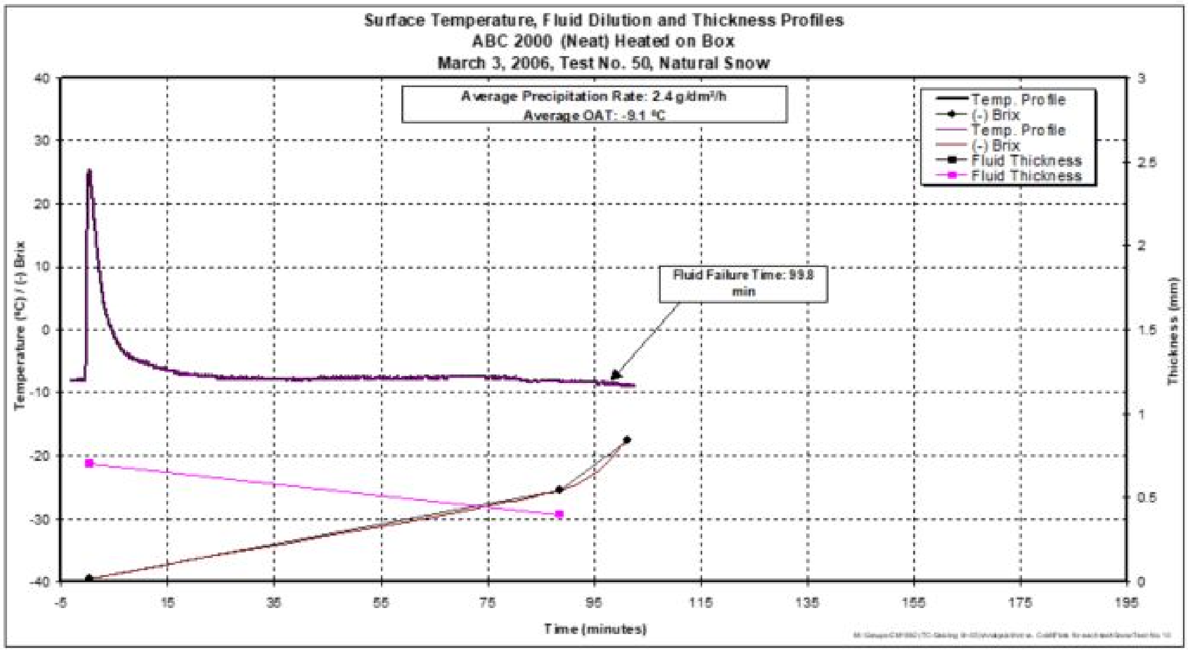

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (50%) OAT on Aluminum Plate
February 23, 2006, Test No. 45, Natural Snow
Average Precipitation Rate: 0.5 g/dm²/h
Average OAT: -3.3 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 104.7 min
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

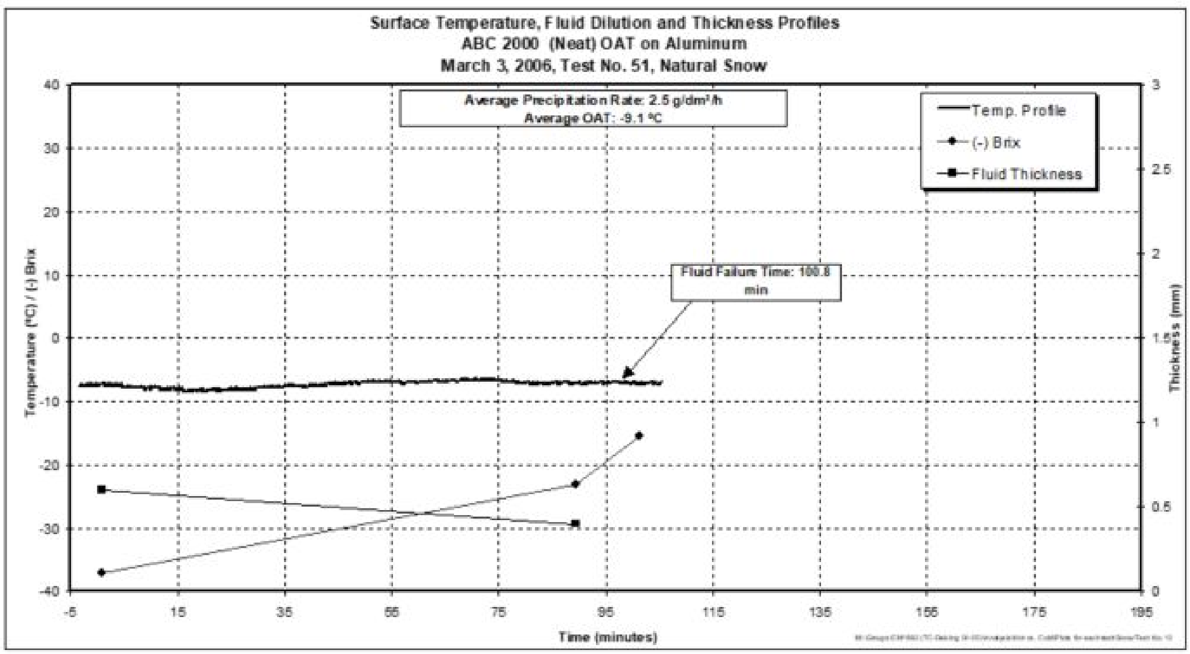

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 (Neat) Heated on Box
February 25, 2006, Test No. 46, Natural Snow
Average Precipitation Rate: 7.5 g/dm²/h
Average OAT: -13.7 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 22.5 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

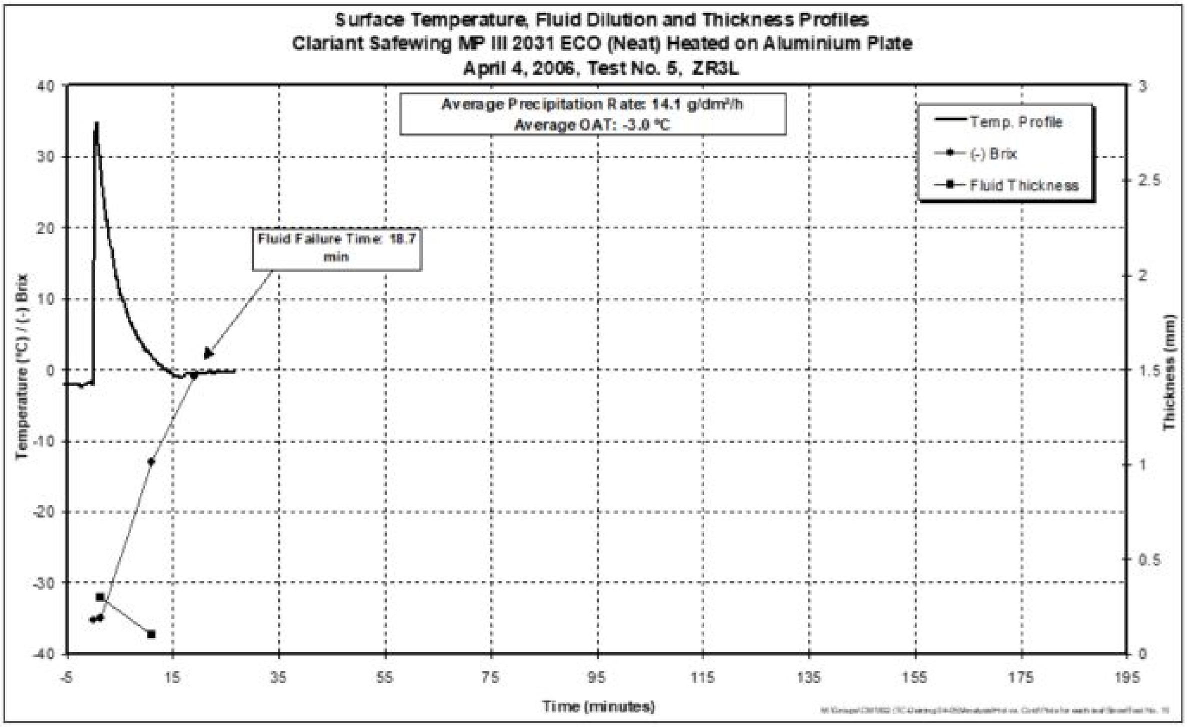

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 (Neat) OAT on Aluminum Plate
February 25, 2006, Test No. 47, Natural Snow
Average Precipitation Rate: 7.6 g/dm²/h
Average OAT: -13.7 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 24.2 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

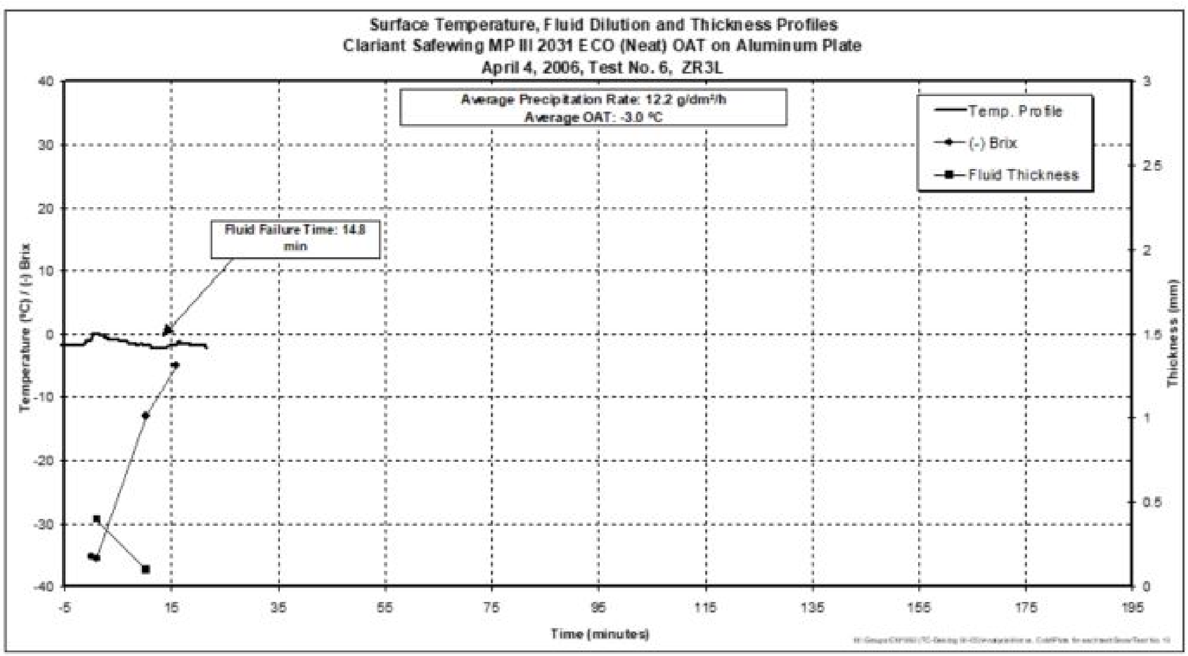

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (Neat) Heated on Box
February 25, 2006, Test No. 48, Natural Snow
Average Precipitation Rate: 10.8 g/dm²/h
Average OAT: -13.6 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 24.7 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

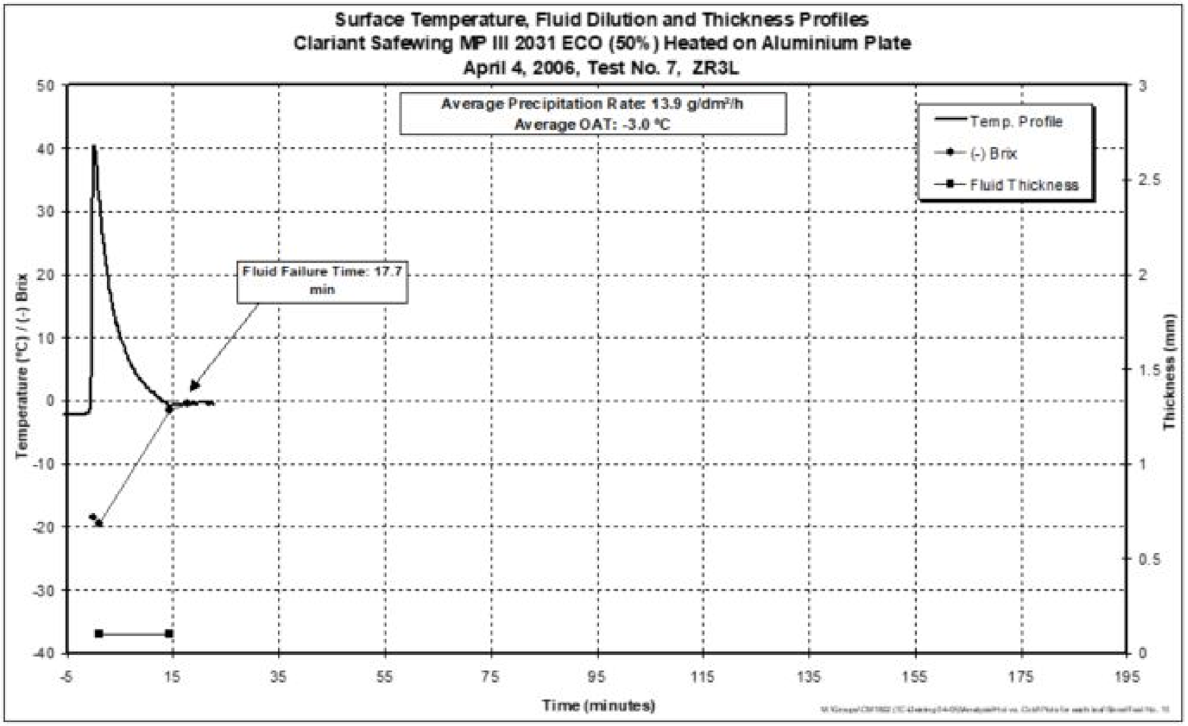

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (Neat) OAT on Aluminum Plate
February 25, 2006, Test No. 49, Natural Snow
Average Precipitation Rate: 10.7 g/dm²/h
Average OAT: -13.6 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 25.9 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

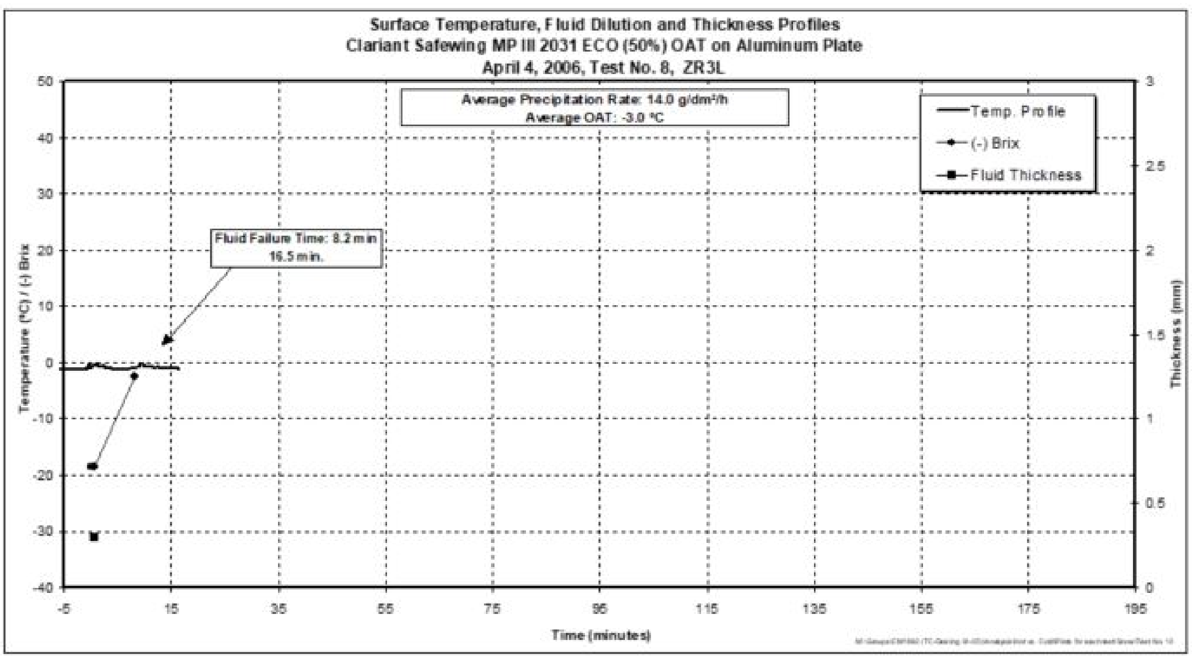

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (Neat) Heated on Box
March 3, 2006, Test No. 50, Natural Snow
Average Precipitation Rate: 2.4 g/dm²/h
Average OAT: -9.1 ºC
Temp. Profile
(-) Brix
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Thickness
Fluid Failure Time: 99.8 min
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

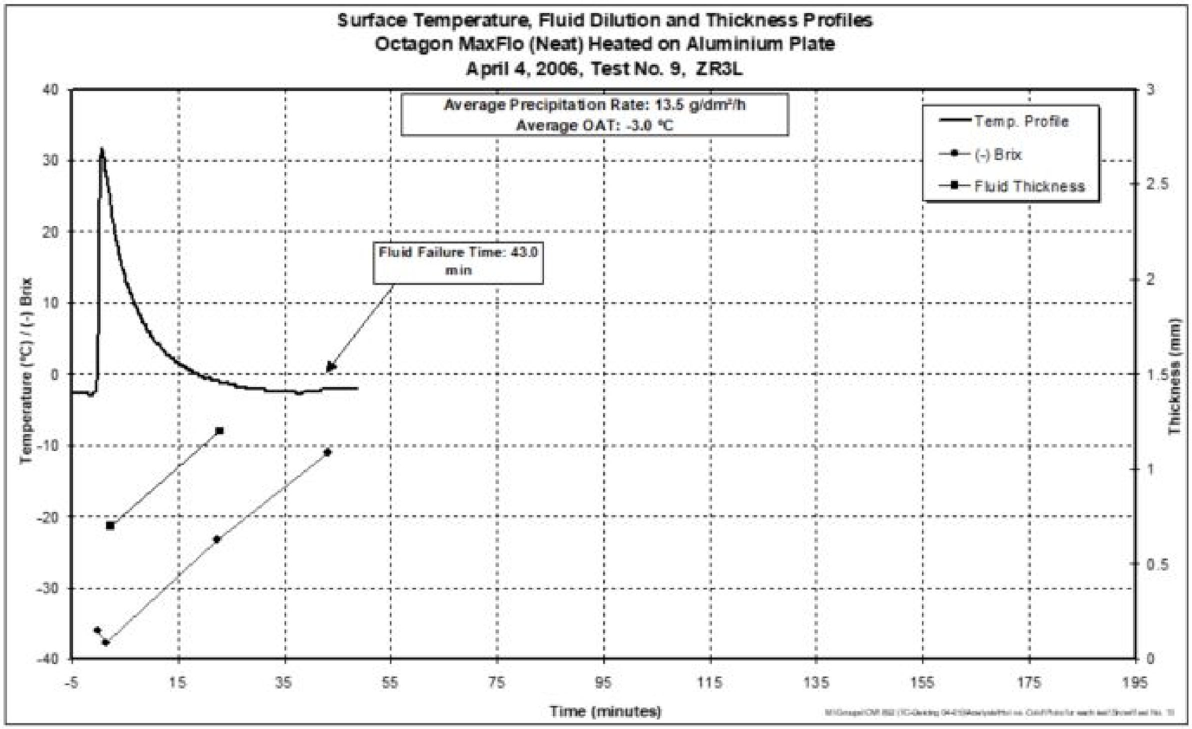

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (Neat) OAT on Aluminum
March 3, 2006, Test No. 51, Natural Snow
Average Precipitation Rate: 2.5 g/dm²/h
Average OAT: -9.1 ºC
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 100.8 min
Temperature (ºC) / (-) Brix
Thickness (mm)
Time (minutes)

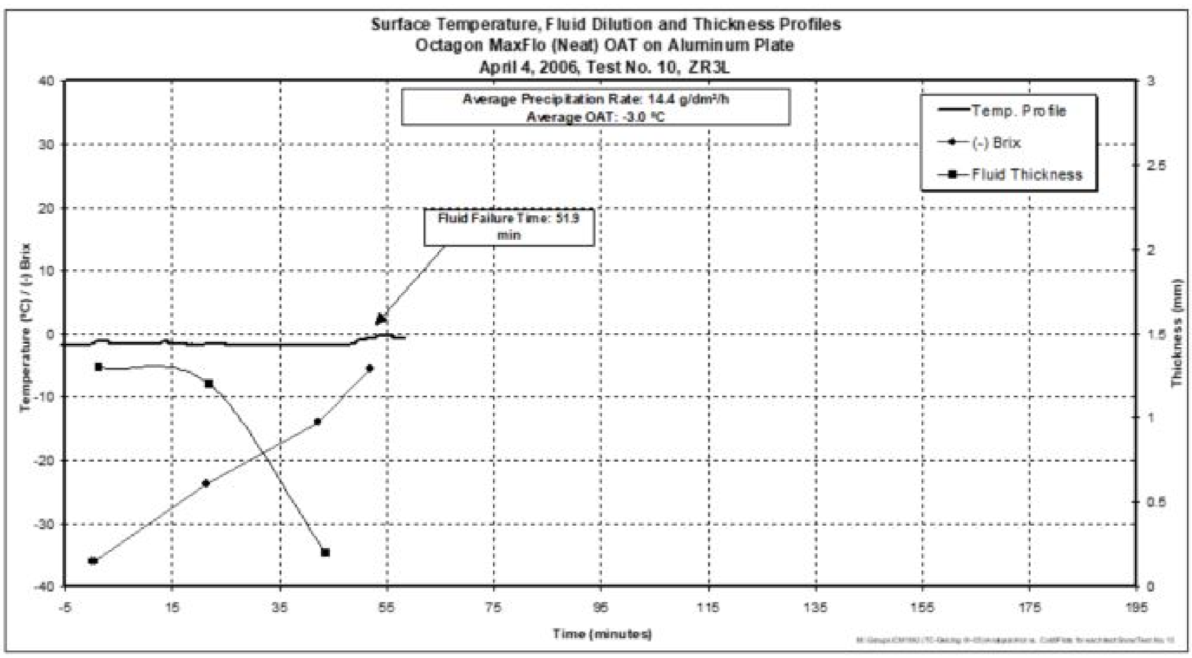

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 ECO (Neat) Heated on Aluminium Plate
April 4, 2006, Test No. 5, ZR3L
Average Precipitation Rate: 14.1 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 18.7 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

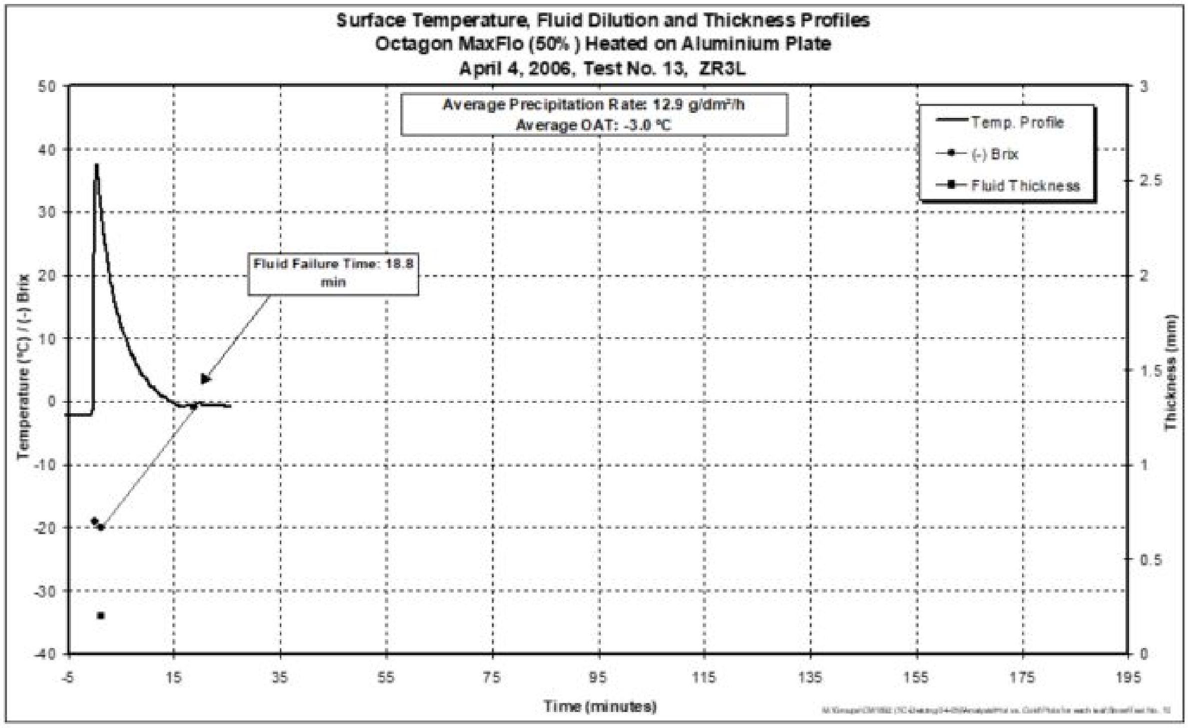

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 ECO (Neat) OAT on Aluminum Plate
April 4, 2006, Test No. 6, ZR3L
Average Precipitation Rate: 12.2 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 14.8 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

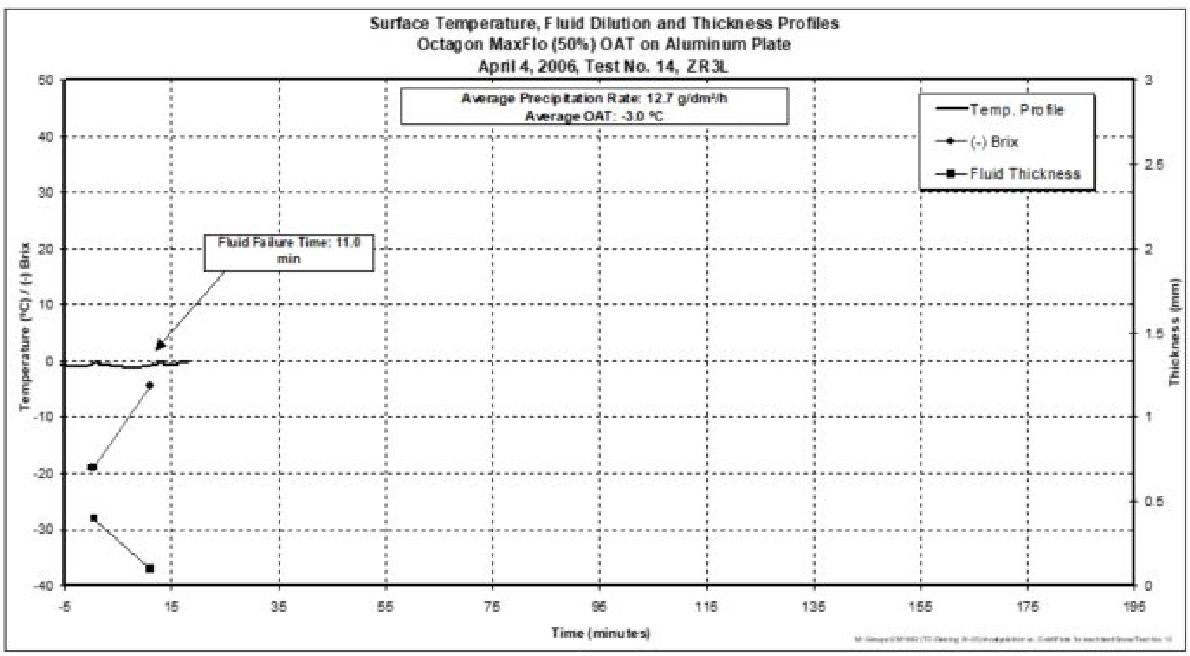

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 ECO (50%) Heated on Aluminium Plate
April 4, 2006, Test No. 7, ZR3L
Average Precipitation Rate: 13.9 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 17.7 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

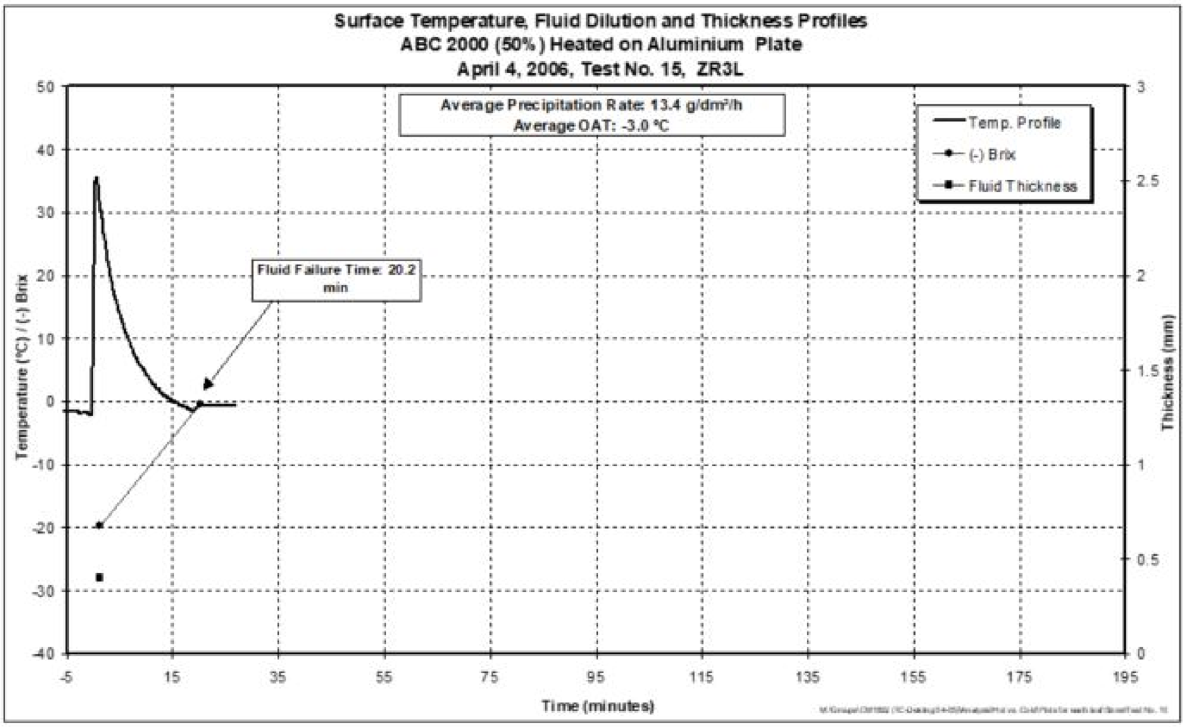

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 ECO (50%) OAT on Aluminum Plate
April 4, 2006, Test No. 8, ZR3L
Average Precipitation Rate: 14.0 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 8.2 min
16.5 min.
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

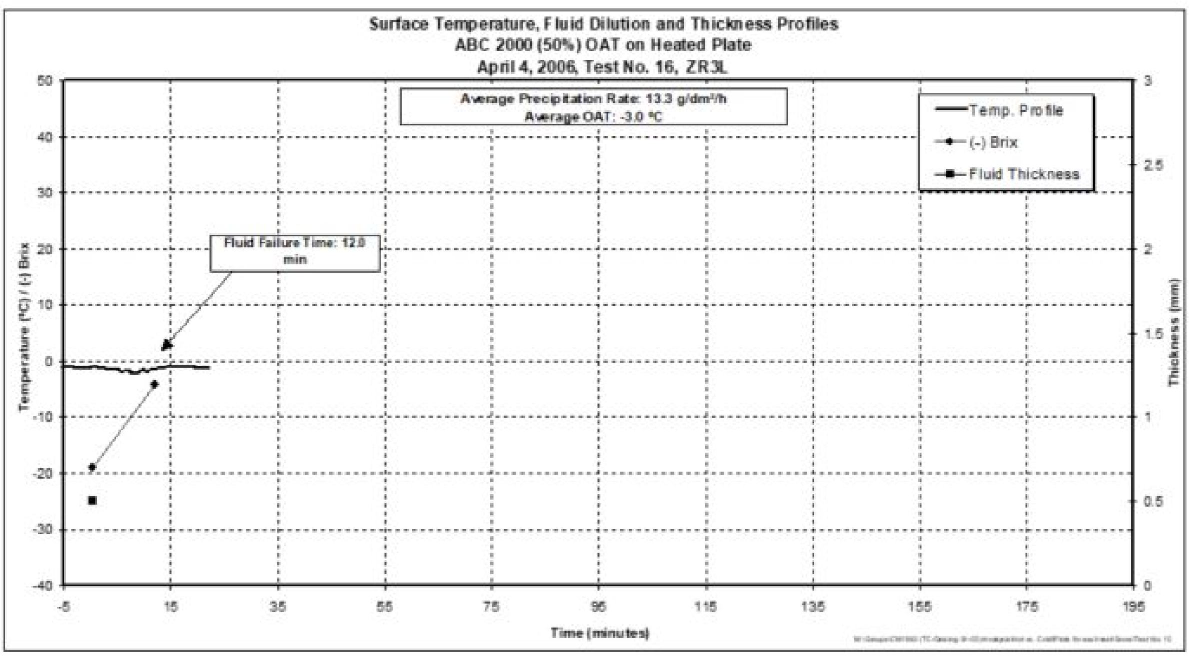

Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (Neat) Heated on Aluminium Plate
April 4, 2006, Test No. 9, ZR3L
Average Precipitation Rate: 13.5 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 43.0 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

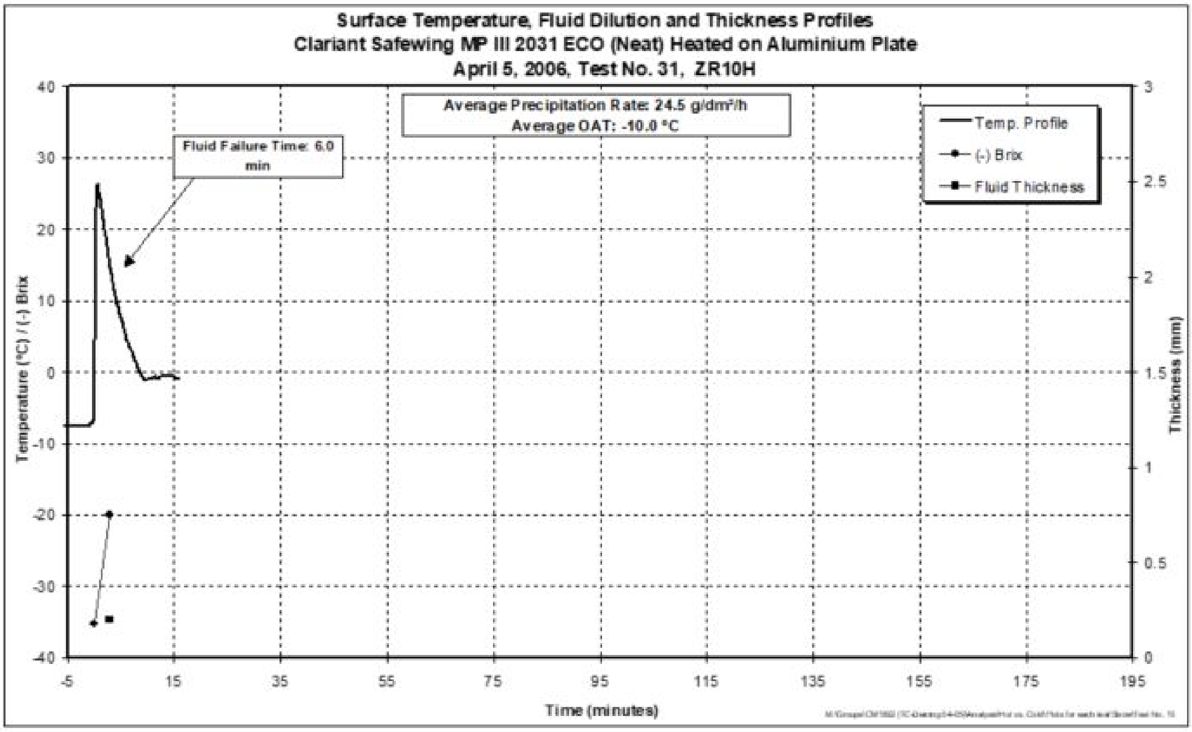

Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (Neat) OAT on Aluminum Plate
April 4, 2006, Test No. 10, ZR3L
Average Precipitation Rate: 14.4 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 51.9 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

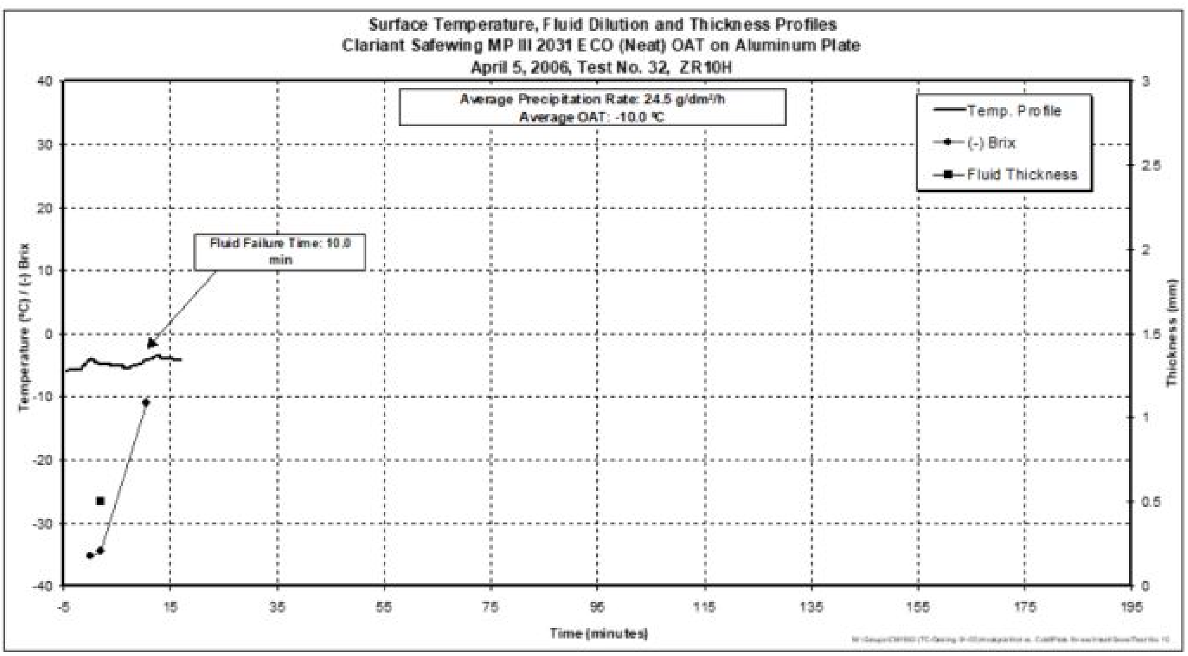

Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (50%) Heated on Aluminium Plate
April 4, 2006, Test No. 13, ZR3L
Average Precipitation Rate: 12.9 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 18.8 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

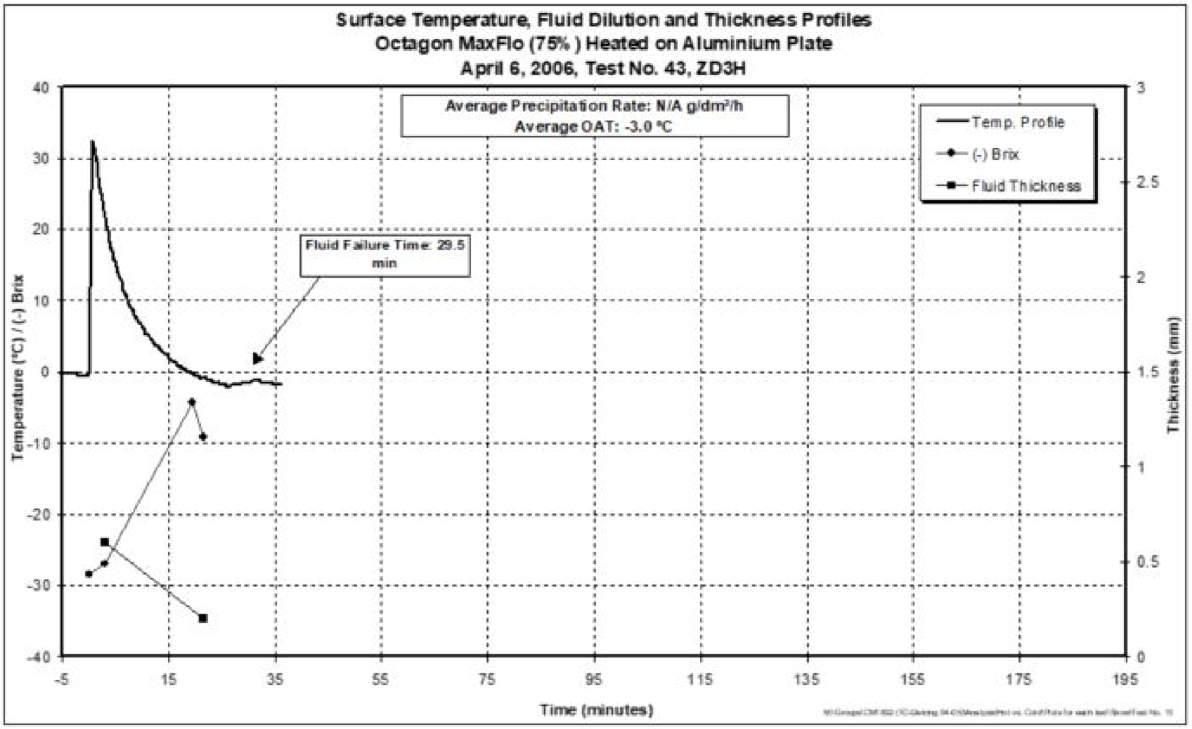

Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (50%) OAT on Aluminum Plate
April 4, 2006, Test No. 14, ZR3L
Average Precipitation Rate: 12.7 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 11.0 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

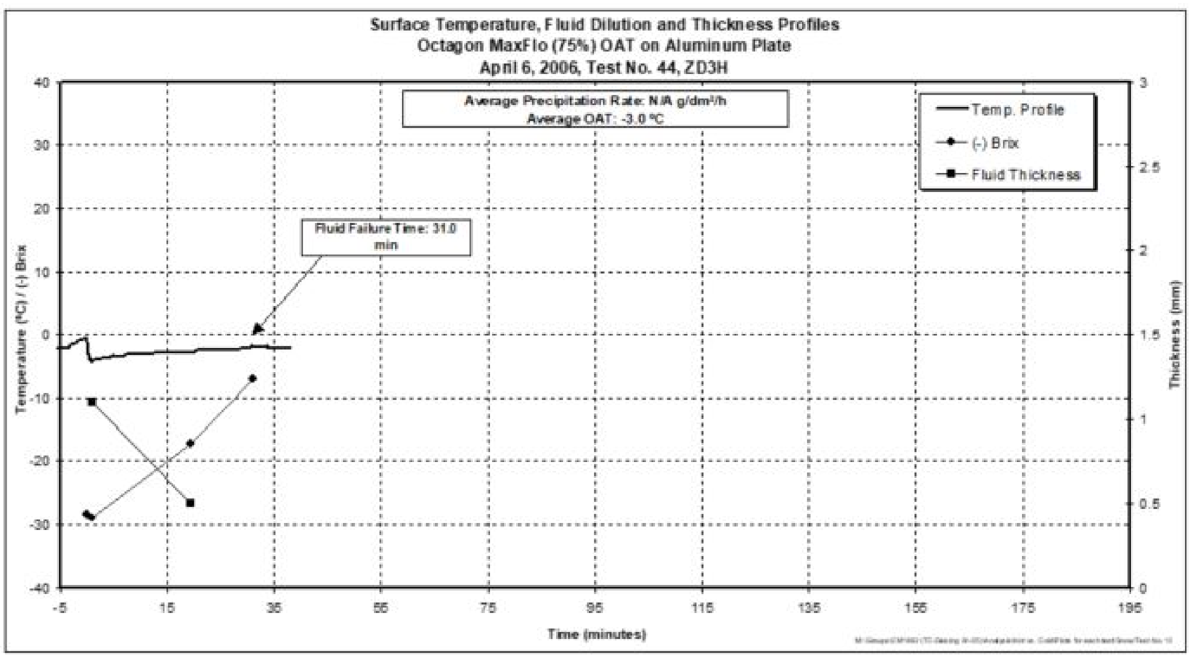

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (50%) Heated on Aluminium Plate
April 4, 2006, Test No. 15, ZR3L
Average Precipitation Rate: 13.4 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 20.2 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

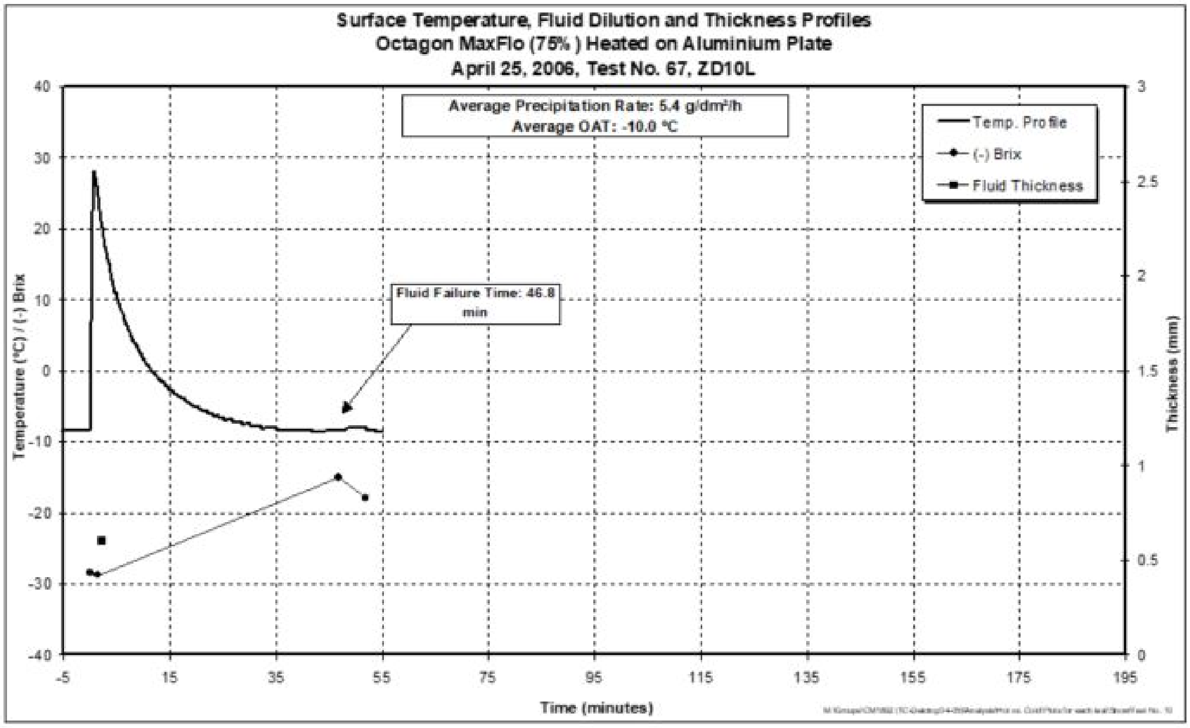

Surface Temperature, Fluid Dilution and Thickness Profiles
ABC 2000 (50%) OAT on Heated Plate
April 4, 2006, Test No. 16, ZR3L
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 12.0 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

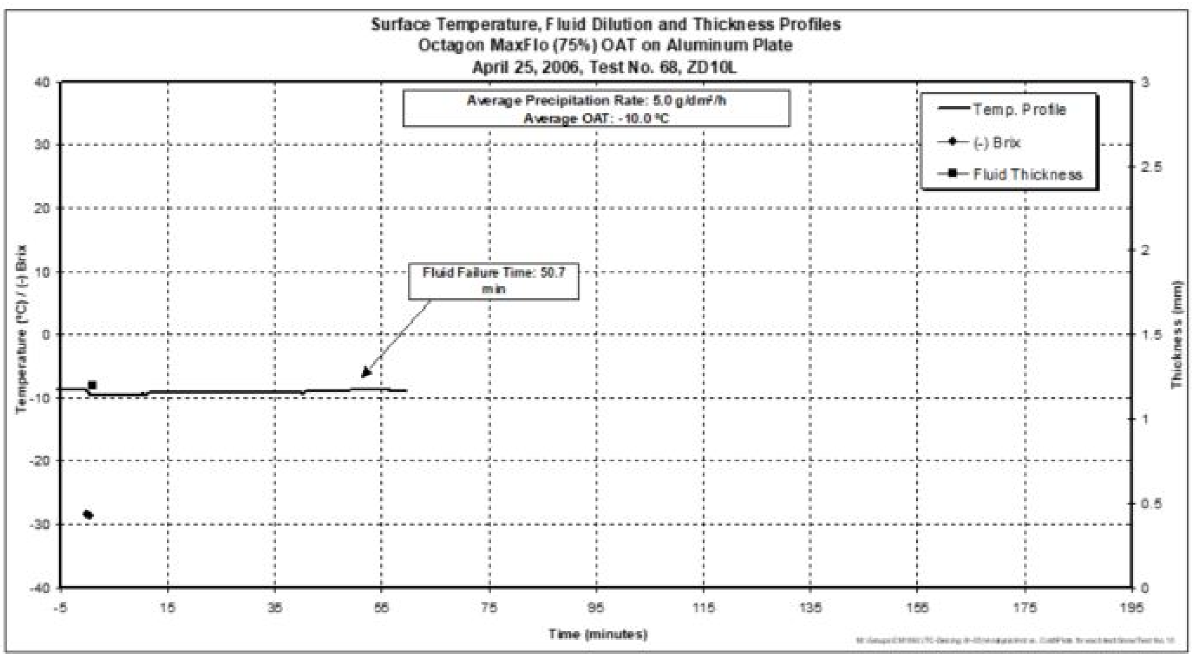

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 ECO (Neat) Heated on Aluminium Plate
April 5, 2006, Test No. 31, ZR10H
Average Precipitation Rate: 24.5 g/dm²/h
Average OAT: -10.0 °C
Fluid Failure Time: 6.0 min
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

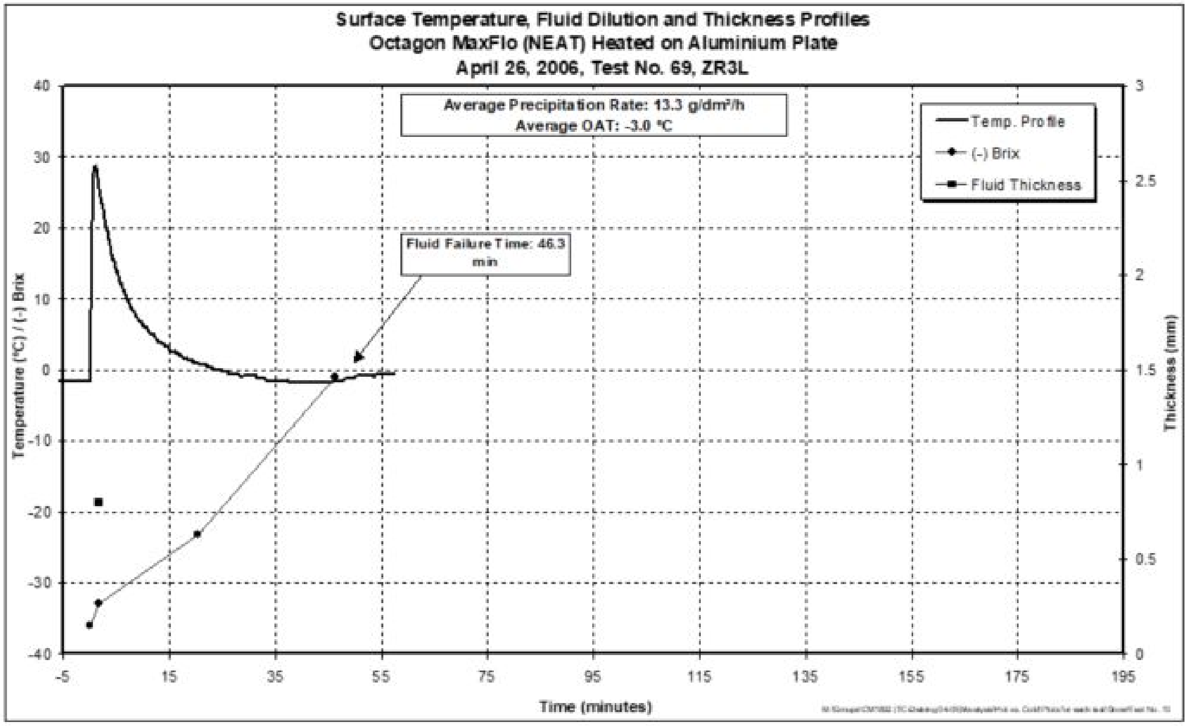

Surface Temperature, Fluid Dilution and Thickness Profiles
Clariant Safewing MP III 2031 ECO (Neat) OAT on Aluminum Plate
April 5, 2006, Test No. 32, ZR10H
Average Precipitation Rate: 24.5 g/dm²/h
Average OAT: -10.0 °C
Fluid Failure Time: 10.0 min
Temp. Profile
(-) Brix
Fluid Thickness
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

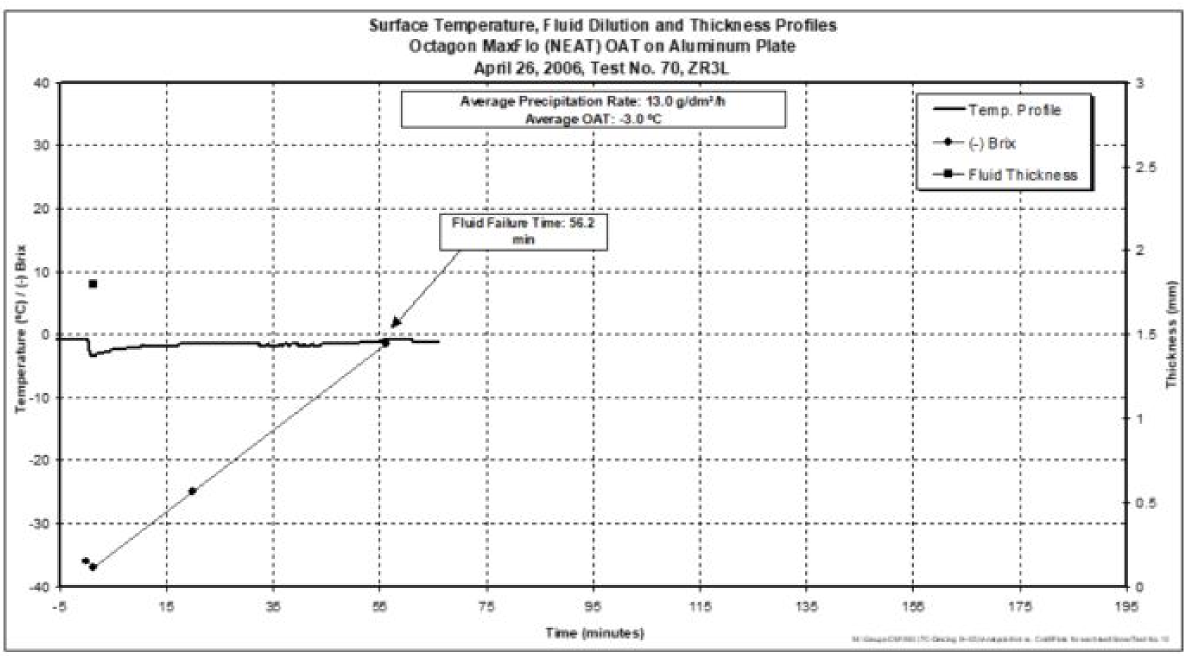

Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (75%) Heated on Aluminium Plate
April 6, 2006, Test No. 43, ZD3H
Average Precipitation Rate: N/A g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 29.5 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (75%) OAT on Aluminum Plate
April 6, 2006, Test No. 44, ZD3H
Average Precipitation Rate: N/A g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 31.0 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (75%) Heated on Aluminium Plate
April 25, 2006, Test No. 67, ZD10L
Average Precipitation Rate: 5.4 g/dm²/h
Average OAT: -10.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 46.8 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (75%) OAT on Aluminum Plate
April 25, 2006, Test No. 68, ZD10L
Average Precipitation Rate: 5.0 g/dm²/h
Average OAT: -10.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 50.7 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (NEAT) Heated on Aluminium Plate
April 26, 2006, Test No. 69, ZR3L
Average Precipitation Rate: 13.3 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 46.3 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)


Surface Temperature, Fluid Dilution and Thickness Profiles
Octagon MaxFlo (NEAT) OAT on Aluminum Plate
April 26, 2006, Test No. 70, ZR3L
Average Precipitation Rate: 13.0 g/dm²/h
Average OAT: -3.0 °C
Temp. Profile
(-) Brix
Fluid Thickness
Fluid Failure Time: 56.2 min
Temperature (°C) / (-) Brix
Thickness (mm)
Time (minutes)

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APPENDIX E

DETAILED RATIO ANALYSIS TABLES

DETAILED RATIO ANALYSISTABLE

This appendix contains a detailed analysis of the comparison tests described in this report. For each comparison test, the endurance time of the heated fluid application test (Type I protocol) was calculated as a percentage of the endurance time of the standard application test (Type II/IV protocol). These values were then analyzed by fluid, precipitation type, temperature and precipitation rate. The data set for this analysis consists of all comparison tests conducted in winter 2001-02, winter 2004-05, winter 2005-06 and July 2007.

A summary table is presented first. Following the summary table, there is a table presented with the data included in each grouping listed in the summary table (i.e. Fluid A, freezing rain, <10 g/dm²/h, etc.). The data is presented in the same order it appears in the summary table, as listed below.

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Table E-1: Ratio Analysis Summary

All Data	Average Heated ET/ OAT ET	Standard Deviation	minus 1 sigma	# Points	# Points <90%	% Points <90%	# Points <80%	% Points <80%
All Years	125%	43%	82%	119	24	20%	13	11%

By Fluid	Average Heated ET/ OAT ET	Standard Deviation	minus 1 sigma	# Points	# Points <90%	% Points <90%	# Points <80%	% Points <80%
Fluid A	107%	48%	59%	13	8	62%	4	**31%**
Fluid B	124%	49%	75%	41	9	22%	7	**17%**
Fluid C1	102%	32%	71%	6	2	33%	2	**33%**
Fluid C2	125%	27%	97%	11	0	0%	0	0%
Fluid D	135%	46%	89%	21	3	14%	0	0%
Fluid E	146%	39%	107%	7	0	0%	0	0%
Fluid F	134%	10%	124%	5	0	0%	0	0%
Fluid G	222%	n/a	n/a	1	0	0%	0	0%
Fluid H	121%	31%	90%	6	1	17%	0	0%
Fluid I	113%	24%	89%	8	1	13%	0	0%

By Precip Type	Average Heated ET/ OAT ET	Standard Deviation	minus 1 sigma	# Points	# Points <90%	% Points <90%	# Points <80%	% Points <80%
Snow	117%	35%	82%	48	8	17%	6	13%
Freezing Drizzle	135%	50%	85%	34	6	18%	3	9%
Freezing Rain	128%	47%	81%	33	10	30%	4	12%
Freezing Fog	103%	7%	96%	4	0	0%	0	0%

By Temperature	Average Heated ET/ OAT ET	Standard Deviation	minus 1 sigma	# Points	# Points <90%	% Points <90%	# Points <80%	% Points <80%
Above -3°C	120%	27%	92%	8	1	13%	0	0%
-3°C	151%	50%	101%	38	4	11%	2	5%
-4 to -9°C	121%	33%	88%	22	2	9%	2	9%
-10°C	108%	32%	76%	28	10	36%	5	**18%**
Below -10°C	107%	37%	70%	23	7	30%	4	**17%**

By Rate	Average Heated ET/ OAT ET	Standard Deviation	minus 1 sigma	# Points	# Points <90%	% Points <90%	# Points <80%	% Points <80%
<10 g/dm^2/h	123%	36%	88%	39	5	13%	3	8%
10 to 24 g/dm^2/h	131%	49%	82%	61	11	18%	4	7%
>24 g/dm^2/h	107%	32%	75%	19	8	42%	6	**32%**

Table E-2: All Data

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
1	01-02	n/a	01-02	50	F	6.1	9.2	31	~31	0	NS	151%
2	01-02	n/a	01-02	75	F	24.2	32.3	7	~7	-14	NS	134%
3	01-02	n/a	01-02	75	F	29.1	38.5	8	~8	-8	NS	132%
4	01-02	n/a	01-02	75	F	37.8	46.0	5	~5	-8	NS	122%
5	01-02	n/a	01-02	75	F	56.0	73.8	5	~5	-5	NS	132%
6	01-02	n/a	01-02	75	G	55.9	124.2	4	~4	-14	NS	222%
7	01-02	n/a	01-02	75	I	36.1	38.6	5	~5	-5	NS	107%
8	01-02	n/a	01-02	50	I	16.2	20.3	4	~4	-4	NS	125%
9	01-02	n/a	01-02	75	H	56.0	47.3	5	5	-10	ZD	84%
10	01-02	n/a	01-02	75	H	21.5	24.6	13	13	-10	ZD	114%
11	01-02	n/a	01-02	75	I	20.5	21.3	13	13	-3	ZD	104%
12	01-02	n/a	01-02	50	I	15.1	24.2	5	5	-3	ZD	160%
13	01-02	n/a	01-02	75	H	72.0	72.5	2	2	-14	ZF	101%
14	01-02	n/a	01-02	75	H	34.5	38.0	5	5	-14	ZF	110%
15	01-02	n/a	01-02	50	I	16.7	15.7	5	5	-3	ZF	94%
16	01-02	n/a	01-02	50	I	26.5	28.5	2	2	-3	ZF	108%
17	01-02	n/a	01-02	50	H	10.8	17.8	25	25	-3	ZR	166%
18	01-02	n/a	01-02	50	H	14.0	21.0	13	13	-3	ZR	150%
19	01-02	n/a	01-02	75	I	13.7	11.2	13	13	-10	ZR	81%
20	01-02	n/a	01-02	75	I	10.7	13.2	25	25	-10	ZR	123%
21	04-05	2/3	6-Jan-05	100	B	10.0	7.0	29	27	-12	NS	70%
22	04-05	5/6	6-Jan-05	75	B	8.0	5.0	32	31	-12	NS	63%
23	04-05	7/9	6-Jan-05	75	B	7.0	5.5	37	37	-12	NS	79%
24	04-05	11/12	10-Feb-05	100	B	36.0	36.8	6	6	-6	NS	102%
25	04-05	14/15	10-Feb-05	75	B	17.8	18.8	10	10	-5	NS	106%
26	04-05	17/18	10-Feb-05	75	C1	57.0	87.0	9	7	-5	NS	153%
27	04-05	31/33	21-Feb-05	75	B	16.0	12.0	14	13	-6	NS	75%
28	04-05	34/36	21-Feb-05	100	B	21.3	15.2	14	13	-6	NS	71%
29	04-05	25/27	21-Feb-05	75	C1	39.3	46.2	4	4	-14	NS	118%
30	04-05	37/39	21-Feb-05	100	C1	67.0	62.3	13	13	-6	NS	93%
31	04-05	19/21	21-Feb-05	75	D	30.5	43.7	4	4	-14	NS	143%
32	04-05	22/24	21-Feb-05	100	D	58.3	100.3	6	6	-14	NS	172%
33	04-05	28/30	21-Feb-05	100	E	152.3	173.5	4	4	-12	NS	114%
34	04-05	45/47	7-Mar-05	100	B	31.1	30.0	8	8	-13	NS	96%

Table E-2 (cont'd): All Data

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
35	04-05	48/50	7-Mar-05	75	B	23.2	20.7	5	5	-12	NS	89%
36	04-05	54/56	7-Mar-05	100	B	26.9	24.5	11	11	-11	NS	91%
37	04-05	57/59	7-Mar-05	75	B	17.6	15.9	9	10	-11	NS	90%
38	04-05	42/44	7-Mar-05	75	C1	18.2	20.3	12	12	-13	NS	112%
39	04-05	51/53	7-Mar-05	100	E	111.2	162.0	5	7	-11	NS	146%
40	04-05	6/7	5-Apr-05	75	A	26.3	21.6	13	13	-11	ZD	82%
41	04-05	1/2	5-Apr-05	100	B	21.1	15.8	5	5	-10	ZD	75%
42	04-05	8/9	5-Apr-05	75	B	8.7	8.2	13	13	-11	ZD	94%
43	04-05	3/4	5-Apr-05	75	C1	14.5	10.5	5	5	-10	ZD	72%
44	04-05	10/11	5-Apr-05	100	D	29.3	32.0	13	13	-10	ZD	109%
45	04-05	13/14	5-Apr-05	100	A	24.8	19.8	25	25	-10	ZR	80%
46	04-05	15/16	5-Apr-05	75	A	14.3	11.3	25	25	-10	ZR	79%
47	04-05	28/29	6-Apr-05	50	A	9.7	15.1	13	13	-3	ZR	156%
48	04-05	32/33	6-Apr-05	75	A	14.2	16.3	26	26	-3	ZR	115%
49	04-05	19/20	6-Apr-05	100	B	15.5	9.5	13	13	-11	ZR	61%
50	04-05	23/24	6-Apr-05	75	B	10.8	9.0	13	13	-11	ZR	83%
51	04-05	26/27	6-Apr-05	75	B	11.4	14.9	13	13	-3	ZR	131%
52	04-05	30/31	6-Apr-05	50	B	7.8	16.7	13	13	-3	ZR	214%
53	04-05	34/35	6-Apr-05	100	B	10.5	13.8	26	26	-3	ZR	131%
54	04-05	36/37	6-Apr-05	75	C1	32.5	22.0	26	26	-3	ZR	68%
55	04-05	41/42	7-Apr-05	50	A	11.8	16.8	5	5	-3	ZD	142%
56	04-05	47/48	7-Apr-05	50	A	6.8	16.3	13	13	-3	ZD	240%
57	04-05	43/44	7-Apr-05	50	B	9.1	16.1	5	5	-3	ZD	177%
58	04-05	45/46	7-Apr-05	75	B	8.8	16.6	13	13	-3	ZD	189%
59	04-05	49/50	7-Apr-05	50	D	9.2	16.2	13	13	-3	ZD	176%
60	05-06	3/4	4-Jan-06	100	A	86.2	61.2	7	7	-3	NS	71%
61	05-06	12/13	9-Jan-06	75	A	26.0	22.5	16	14	-2	NS	87%
62	05-06	7/10	9-Jan-06	75	B	10.8	9.8	18	18	-2	NS	91%
63	05-06	5/6	9-Jan-06	100	D	87.7	79.0	15	14	-4	NS	90%
64	05-06	14/15	21-Jan-06	75	B	13.0	13.7	20	20	-1	NS	105%
65	05-06	16/17	24-Jan-06	75	B	11.5	12.5	12	12	0	NS	109%
66	05-06	18/19	24-Jan-06	75	B	12.5	16.8	11	11	-1	NS	134%
67	05-06	20/21	24-Jan-06	75	D	63.2	74.8	6	7	-1	NS	118%
68	05-06	26/27	29-Jan-06	100	B	17.0	23.5	7	8	-4	NS	138%

Table E-2 (cont'd): All Data

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm^2/h)	Heated Precip. Rate (g/dm^2/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
69	05-06	28/29	29-Jan-06	100	D	88.5	118.2	11	10	-4	NS	134%
70	05-06	30/31	29-Jan-06	75	D	48.2	62.8	10	11	-4	NS	130%
71	05-06	24/25	29-Jan-06	100	E	61.8	131.2	21	19	-5	NS	212%
72	05-06	32/33	29-Jan-06	100	E	103.3	194.0	11	9	-5	NS	188%
73	05-06	34/35	16-Feb-06	75	C2	14.0	13.9	31	31	-9	NS	99%
74	05-06	36/37	16-Feb-06	100	C2	17.6	20.6	23	23	-9	NS	117%
75	05-06	38/39	16-Feb-06	75	C2	13.4	15.2	25	25	-9	NS	113%
76	05-06	44/45	23-Feb-06	50	C2	104.7	130.2	1	1	-4	NS	124%
77	05-06	42/43	23-Feb-06	50	D	12.1	19.6	10	9	-1	NS	162%
78	05-06	46/47	25-Feb-06	100	B	24.2	22.5	8	8	-14	NS	93%
79	05-06	48/49	25-Feb-06	100	C2	25.9	24.7	11	11	-14	NS	95%
80	05-06	50/51	3-Mar-06	100	C2	100.8	99.8	3	2	-9	NS	99%
81	05-06	5/6	4-Apr-06	100	B	14.8	18.7	12	14	-3	ZR	126%
82	05-06	7/8	4-Apr-06	50	B	8.2	17.7	14	14	-3	ZR	216%
83	05-06	15/16	4-Apr-06	50	C2	12.0	20.2	13	13	-3	ZR	168%
84	05-06	9/10	4-Apr-06	100	D	51.9	43.0	14	14	-3	ZR	83%
85	05-06	13/14	4-Apr-06	50	D	11.0	18.8	13	13	-3	ZR	171%
86	05-06	23/24	5-Apr-06	100	C2	39.5	46.7	5	5	-10	ZD	118%
87	05-06	19/20	5-Apr-06	100	B	13.0	12.8	13	14	-10	ZR	98%
88	05-06	31/32	5-Apr-06	100	B	10.0	12.0	25	25	-10	ZR	120%
89	05-06	17/18	5-Apr-06	100	C2	16.8	25.0	13	14	-10	ZR	149%
90	05-06	21/22	5-Apr-06	75	D	21.8	23.2	13	14	-10	ZR	106%
91	05-06	33/34	5-Apr-06	75	D	14.2	15.7	24	25	-10	ZR	111%
92	05-06	29/30	5-Apr-06	100	E	36.5	40.8	25	23	-10	ZR	112%
93	05-06	41/42	6-Apr-06	75	B	11.0	25.3	13	13	-3	ZD	230%
94	05-06	45/46	6-Apr-06	75	B	9.0	11.5	14	14	-3	ZD	128%
95	05-06	37/38	6-Apr-06	50	C2	14.0	24.5	13	13	-3	ZD	175%
96	05-06	27/28	6-Apr-06	75	D	48.8	40.8	12	13	-10	ZD	84%
97	05-06	39/40	6-Apr-06	50	D	11.0	21.4	13	13	-3	ZD	195%
98	05-06	43/44	6-Apr-06	75	D	31.0	29.5	13	13	-3	ZD	95%
99	05-06	35/36	6-Apr-06	100	E	62.8	80.3	13	13	-3	ZD	128%
100	05-06	49/50	7-Apr-06	50	B	12.5	21.5	5	5	-3	ZD	172%
101	05-06	51/52	7-Apr-06	100	C2	72.8	82.8	5	5	-3	ZD	114%
102	05-06	55/56	7-Apr-06	100	E	131.0	164.0	5	5	-3	ZD	125%

Table E-2 (cont'd): All Data

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
103	05-06	57/58	13-Apr-06	100	D	15.8	33.6	24	23	-3	ZR	213%
104	05-06	61/62	13-Apr-06	50	D	7.9	19.0	24	23	-3	ZR	241%
105	05-06	65/66	25-Apr-06	100	B	11.0	24.4	5	5	-10	ZD	222%
106	05-06	67/68	25-Apr-06	75	D	50.7	46.8	6	5	-10	ZD	92%
107	05-06	63/64	25-Apr-06	75	D	21.2	25.3	13	13	-10	ZR	119%
108	05-06	69/70	26-Apr-06	100	D	56.2	46.3	13	13	-3	ZR	82%
109	06-07	HC2	18-Jul-07	75	A	18.7	14.8	13	13	-10	ZD	79%
110	06-07	HC1	18-Jul-07	100	A	36.3	33.8	13	13	-10	ZD	93%
111	06-07	HC4	18-Jul-07	75	A	12.3	10.5	25	25	-10	ZR	85%
112	06-07	HC3	18-Jul-07	100	A	22.3	18.3	25	25	-10	ZR	82%
113	06-07	HC6	19-Jul-07	75	B	10.6	16.0	13	13	-3	ZD	151%
114	06-07	HC5	19-Jul-07	100	B	15.7	14.3	13	13	-3	ZD	90%
115	06-07	HC7	19-Jul-07	50	B	6.3	15.0	13	13	-3	ZD	237%
116	06-07	HC9	18-Jul-07	75	B	6.7	9.4	13	13	-10	ZD	141%
117	06-07	HC8	18-Jul-07	100	B	9.3	9.2	13	13	-10	ZD	98%
118	06-07	HC10	18-Jul-07	100	B	6.7	9.1	25	25	-10	ZR	136%
119	06-07	HC11	18-Jul-07	75	B	5.3	8.5	25	25	-10	ZR	159%

Table E-3: Fluid A

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
40	04-05	6/7	5-Apr-05	75	A	26.3	21.6	13	13	-11	ZD	82%
45	04-05	13/14	5-Apr-05	100	A	24.8	19.8	25	25	-10	ZR	80%
46	04-05	15/16	5-Apr-05	75	A	14.3	11.3	25	25	-10	ZR	79%
47	04-05	28/29	6-Apr-05	50	A	9.7	15.1	13	13	-3	ZR	156%
48	04-05	32/33	6-Apr-05	75	A	14.2	16.3	26	26	-3	ZR	115%
55	04-05	41/42	7-Apr-05	50	A	11.8	16.8	5	5	-3	ZD	142%
56	04-05	47/48	7-Apr-05	50	A	6.8	16.3	13	13	-3	ZD	240%
60	05-06	3/4	4-Jan-06	100	A	86.2	61.2	7	7	-3	NS	71%
61	05-06	12/13	9-Jan-06	75	A	26.0	22.5	16	14	-2	NS	87%
109	06-07	HC2	18-Jul-07	75	A	18.7	14.8	13	13	-10	ZD	79%
110	06-07	HC1	18-Jul-07	100	A	36.3	33.8	13	13	-10	ZD	93%
111	06-07	HC4	18-Jul-07	75	A	12.3	10.5	25	25	-10	ZR	85%
112	06-07	HC3	18-Jul-07	100	A	22.3	18.3	25	25	-10	ZR	82%

Table E-4: Fluid B

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
21	04-05	2/3	6-Jan-05	100	B	10.0	7.0	29	27	-12	NS	70%
22	04-05	5/6	6-Jan-05	75	B	8.0	5.0	32	31	-12	NS	63%
23	04-05	7/9	6-Jan-05	75	B	7.0	5.5	37	37	-12	NS	79%
24	04-05	11/12	10-Feb-05	100	B	36.0	36.8	6	6	-6	NS	102%
25	04-05	14/15	10-Feb-05	75	B	17.8	18.8	10	10	-5	NS	106%
27	04-05	31/33	21-Feb-05	75	B	16.0	12.0	14	13	-6	NS	75%
28	04-05	34/36	21-Feb-05	100	B	21.3	15.2	14	13	-6	NS	71%
34	04-05	45/47	7-Mar-05	100	B	31.1	30.0	8	8	-13	NS	96%
35	04-05	48/50	7-Mar-05	75	B	23.2	20.7	5	5	-12	NS	89%
36	04-05	54/56	7-Mar-05	100	B	26.9	24.5	11	11	-11	NS	91%
37	04-05	57/59	7-Mar-05	75	B	17.6	15.9	9	10	-11	NS	90%
41	04-05	1/2	5-Apr-05	100	B	21.1	15.8	5	5	-10	ZD	75%
42	04-05	8/9	5-Apr-05	75	B	8.7	8.2	13	13	-11	ZD	94%
49	04-05	19/20	6-Apr-05	100	B	15.5	9.5	13	13	-11	ZR	61%
50	04-05	23/24	6-Apr-05	75	B	10.8	9.0	13	13	-11	ZR	83%
51	04-05	26/27	6-Apr-05	75	B	11.4	14.9	13	13	-3	ZR	131%
52	04-05	30/31	6-Apr-05	50	B	7.8	16.7	13	13	-3	ZR	214%
53	04-05	34/35	6-Apr-05	100	B	10.5	13.8	26	26	-3	ZR	131%
57	04-05	43/44	7-Apr-05	50	B	9.1	16.1	5	5	-3	ZD	177%
58	04-05	45/46	7-Apr-05	75	B	8.8	16.6	13	13	-3	ZD	189%
62	05-06	7/10	9-Jan-06	75	B	10.8	9.8	18	18	-2	NS	91%
64	05-06	14/15	21-Jan-06	75	B	13.0	13.7	20	20	-1	NS	105%
65	05-06	16/17	24-Jan-06	75	B	11.5	12.5	12	12	0	NS	109%
66	05-06	18/19	24-Jan-06	75	B	12.5	16.8	11	11	-1	NS	134%
68	05-06	26/27	29-Jan-06	100	B	17.0	23.5	7	8	-4	NS	138%
78	05-06	46/47	25-Feb-06	100	B	24.2	22.5	8	8	-14	NS	93%
81	05-06	5/6	4-Apr-06	100	B	14.8	18.7	12	14	-3	ZR	126%
82	05-06	7/8	4-Apr-06	50	B	8.2	17.7	14	14	-3	ZR	216%
87	05-06	19/20	5-Apr-06	100	B	13.0	12.8	13	14	-10	ZR	98%
88	05-06	31/32	5-Apr-06	100	B	10.0	12.0	25	25	-10	ZR	120%
93	05-06	41/42	6-Apr-06	75	B	11.0	25.3	13	13	-3	ZD	230%
94	05-06	45/46	6-Apr-06	75	B	9.0	11.5	14	14	-3	ZD	128%
100	05-06	49/50	7-Apr-06	50	B	12.5	21.5	5	5	-3	ZD	172%
105	05-06	65/66	25-Apr-06	100	B	11.0	24.4	5	5	-10	ZD	222%

Table E-4 (cont'd): Fluid B

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
113	06-07	HC6	19-Jul-07	75	B	10.6	16.0	13	13	-3	ZD	151%
114	06-07	HC5	19-Jul-07	100	B	15.7	14.3	13	13	-3	ZD	90%
115	06-07	HC7	19-Jul-07	50	B	6.3	15.0	13	13	-3	ZD	237%
116	06-07	HC9	18-Jul-07	75	B	6.7	9.4	13	13	-10	ZD	141%
117	06-07	HC8	18-Jul-07	100	B	9.3	9.2	13	13	-10	ZD	98%
118	06-07	HC10	18-Jul-07	100	B	6.7	9.1	25	25	-10	ZR	136%
119	06-07	HC11	18-Jul-07	75	B	5.3	8.5	25	25	-10	ZR	159%

Table E-5: Fluid C1

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
26	04-05	17/18	10-Feb-05	75	C1	57.0	87.0	9	7	-5	NS	153%
29	04-05	25/27	21-Feb-05	75	C1	39.3	46.2	4	4	-14	NS	118%
30	04-05	37/39	21-Feb-05	100	C1	67.0	62.3	13	13	-6	NS	93%
38	04-05	42/44	7-Mar-05	75	C1	18.2	20.3	12	12	-13	NS	112%
43	04-05	3/4	5-Apr-05	75	C1	14.5	10.5	5	5	-10	ZD	72%
54	04-05	36/37	6-Apr-05	75	C1	32.5	22.0	26	26	-3	ZR	68%

Table E-6: Fluid C2

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
73	05-06	34/35	16-Feb-06	75	C2	14.0	13.9	31	31	-9	NS	99%
74	05-06	36/37	16-Feb-06	100	C2	17.6	20.6	23	23	-9	NS	117%
75	05-06	38/39	16-Feb-06	75	C2	13.4	15.2	25	25	-9	NS	113%
76	05-06	44/45	23-Feb-06	50	C2	104.7	130.2	1	1	-4	NS	124%
79	05-06	48/49	25-Feb-06	100	C2	25.9	24.7	11	11	-14	NS	95%
80	05-06	50/51	3-Mar-06	100	C2	100.8	99.8	3	2	-9	NS	99%
83	05-06	15/16	4-Apr-06	50	C2	12.0	20.2	13	13	-3	ZR	168%
86	05-06	23/24	5-Apr-06	100	C2	39.5	46.7	5	5	-10	ZD	118%
89	05-06	17/18	5-Apr-06	100	C2	16.8	25.0	13	14	-10	ZR	149%
95	05-06	37/38	6-Apr-06	50	C2	14.0	24.5	13	13	-3	ZD	175%
101	05-06	51/52	7-Apr-06	100	C2	72.8	82.8	5	5	-3	ZD	114%

Table E-7: Fluid D

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
31	04-05	19/21	21-Feb-05	75	D	30.5	43.7	4	4	-14	NS	143%
32	04-05	22/24	21-Feb-05	100	D	58.3	100.3	6	6	-14	NS	172%
44	04-05	10/11	5-Apr-05	100	D	29.3	32.0	13	13	-10	ZD	109%
59	04-05	49/50	7-Apr-05	50	D	9.2	16.2	13	13	-3	ZD	176%
63	05-06	5/6	9-Jan-06	100	D	87.7	79.0	15	14	-4	NS	90%
67	05-06	20/21	24-Jan-06	75	D	63.2	74.8	6	7	-1	NS	118%
69	05-06	28/29	29-Jan-06	100	D	88.5	118.2	11	10	-4	NS	134%
70	05-06	30/31	29-Jan-06	75	D	48.2	62.8	10	11	-4	NS	130%
77	05-06	42/43	23-Feb-06	50	D	12.1	19.6	10	9	-1	NS	162%
84	05-06	9/10	4-Apr-06	100	D	51.9	43.0	14	14	-3	ZR	83%
85	05-06	13/14	4-Apr-06	50	D	11.0	18.8	13	13	-3	ZR	171%
90	05-06	21/22	5-Apr-06	75	D	21.8	23.2	13	14	-10	ZR	106%
91	05-06	33/34	5-Apr-06	75	D	14.2	15.7	24	25	-10	ZR	111%
96	05-06	27/28	6-Apr-06	75	D	48.8	40.8	12	13	-10	ZD	84%
97	05-06	39/40	6-Apr-06	50	D	11.0	21.4	13	13	-3	ZD	195%
98	05-06	43/44	6-Apr-06	75	D	31.0	29.5	13	13	-3	ZD	95%
103	05-06	57/58	13-Apr-06	100	D	15.8	33.6	24	23	-3	ZR	213%
104	05-06	61/62	13-Apr-06	50	D	7.9	19.0	24	23	-3	ZR	241%
106	05-06	67/68	25-Apr-06	75	D	50.7	46.8	6	5	-10	ZD	92%
107	05-06	63/64	25-Apr-06	75	D	21.2	25.3	13	13	-10	ZR	119%
108	05-06	69/70	26-Apr-06	100	D	56.2	46.3	13	13	-3	ZR	82%

Table E-8: Fluid E

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
33	04-05	28/30	21-Feb-05	100	E	152.3	173.5	4	4	-12	NS	114%
39	04-05	51/53	7-Mar-05	100	E	111.2	162.0	5	7	-11	NS	146%
71	05-06	24/25	29-Jan-06	100	E	61.8	131.2	21	19	-5	NS	212%
72	05-06	32/33	29-Jan-06	100	E	103.3	194.0	11	9	-5	NS	188%
92	05-06	29/30	5-Apr-06	100	E	36.5	40.8	25	23	-10	ZR	112%
99	05-06	35/36	6-Apr-06	100	E	62.8	80.3	13	13	-3	ZD	128%
102	05-06	55/56	7-Apr-06	100	E	131.0	164.0	5	5	-3	ZD	125%

Table E-9: Fluid F

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
1	01-02	n/a	01-02	50	F	6.1	9.2	31	~31	0	NS	151%
2	01-02	n/a	01-02	75	F	24.2	32.3	7	~7	-14	NS	134%
3	01-02	n/a	01-02	75	F	29.1	38.5	8	~8	-8	NS	132%
4	01-02	n/a	01-02	75	F	37.8	46.0	5	~5	-8	NS	122%
5	01-02	n/a	01-02	75	F	56.0	73.8	5	~5	-5	NS	132%

Table E-10: Fluid G

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
6	01-02	n/a	01-02	75	G	55.9	124.2	4	~4	-14	NS	222%

Table E-11: Fluid H

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
9	01-02	n/a	01-02	75	H	56.0	47.3	5	5	-10	ZD	84%
10	01-02	n/a	01-02	75	H	21.5	24.6	13	13	-10	ZD	114%
13	01-02	n/a	01-02	75	H	72.0	72.5	2	2	-14	ZF	101%
14	01-02	n/a	01-02	75	H	34.5	38.0	5	5	-14	ZF	110%
17	01-02	n/a	01-02	50	H	10.8	17.8	25	25	-3	ZR	166%
18	01-02	n/a	01-02	50	H	14.0	21.0	13	13	-3	ZR	150%

Table E-12: Fluid I

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
7	01-02	n/a	01-02	75	I	36.1	38.6	5	~5	-5	NS	107%
8	01-02	n/a	01-02	50	I	16.2	20.3	4	~4	-4	NS	125%
11	01-02	n/a	01-02	75	I	20.5	21.3	13	13	-3	ZD	104%
12	01-02	n/a	01-02	50	I	15.1	24.2	5	5	-3	ZD	160%
15	01-02	n/a	01-02	50	I	16.7	15.7	5	5	-3	ZF	94%
16	01-02	n/a	01-02	50	I	26.5	28.5	2	2	-3	ZF	108%
19	01-02	n/a	01-02	75	I	13.7	11.2	13	13	-10	ZR	81%
20	01-02	n/a	01-02	75	I	10.7	13.2	25	25	-10	ZR	123%

Table E-13: Natural Snow

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
1	01-02	n/a	01-02	50	F	6.1	9.2	31	~31	0	NS	151%
2	01-02	n/a	01-02	75	F	24.2	32.3	7	~7	-14	NS	134%
3	01-02	n/a	01-02	75	F	29.1	38.5	8	~8	-8	NS	132%
4	01-02	n/a	01-02	75	F	37.8	46.0	5	~5	-8	NS	122%
5	01-02	n/a	01-02	75	F	56.0	73.8	5	~5	-5	NS	132%
6	01-02	n/a	01-02	75	G	55.9	124.2	4	~4	-14	NS	222%
7	01-02	n/a	01-02	75	I	36.1	38.6	5	~5	-5	NS	107%
8	01-02	n/a	01-02	50	I	16.2	20.3	4	~4	-4	NS	125%
21	04-05	2/3	6-Jan-05	100	B	10.0	7.0	29	27	-12	NS	70%
22	04-05	5/6	6-Jan-05	75	B	8.0	5.0	32	31	-12	NS	63%
23	04-05	7/9	6-Jan-05	75	B	7.0	5.5	37	37	-12	NS	79%
24	04-05	11/12	10-Feb-05	100	B	36.0	36.8	6	6	-6	NS	102%
25	04-05	14/15	10-Feb-05	75	B	17.8	18.8	10	10	-5	NS	106%
26	04-05	17/18	10-Feb-05	75	C1	57.0	87.0	9	7	-5	NS	153%
27	04-05	31/33	21-Feb-05	75	B	16.0	12.0	14	13	-6	NS	75%
28	04-05	34/36	21-Feb-05	100	B	21.3	15.2	14	13	-6	NS	71%
29	04-05	25/27	21-Feb-05	75	C1	39.3	46.2	4	4	-14	NS	118%
30	04-05	37/39	21-Feb-05	100	C1	67.0	62.3	13	13	-6	NS	93%
31	04-05	19/21	21-Feb-05	75	D	30.5	43.7	4	4	-14	NS	143%
32	04-05	22/24	21-Feb-05	100	D	58.3	100.3	6	6	-14	NS	172%
33	04-05	28/30	21-Feb-05	100	E	152.3	173.5	4	4	-12	NS	114%
34	04-05	45/47	7-Mar-05	100	B	31.1	30.0	8	8	-13	NS	96%
35	04-05	48/50	7-Mar-05	75	B	23.2	20.7	5	5	-12	NS	89%
36	04-05	54/56	7-Mar-05	100	B	26.9	24.5	11	11	-11	NS	91%
37	04-05	57/59	7-Mar-05	75	B	17.6	15.9	9	10	-11	NS	90%
38	04-05	42/44	7-Mar-05	75	C1	18.2	20.3	12	12	-13	NS	112%
39	04-05	51/53	7-Mar-05	100	E	111.2	162.0	5	7	-11	NS	146%
60	05-06	3/4	4-Jan-06	100	A	86.2	61.2	7	7	-3	NS	71%
61	05-06	12/13	9-Jan-06	75	A	26.0	22.5	16	14	-2	NS	87%
62	05-06	7/10	9-Jan-06	75	B	10.8	9.8	18	18	-2	NS	91%
63	05-06	5/6	9-Jan-06	100	D	87.7	79.0	15	14	-4	NS	90%
64	05-06	14/15	21-Jan-06	75	B	13.0	13.7	20	20	-1	NS	105%
65	05-06	16/17	24-Jan-06	75	B	11.5	12.5	12	12	0	NS	109%
66	05-06	18/19	24-Jan-06	75	B	12.5	16.8	11	11	-1	NS	134%

Table E-13 (cont'd): Natural Snow

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm^2/h)	Heated Precip. Rate (g/dm^2/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
67	05-06	20/21	24-Jan-06	75	D	63.2	74.8	6	7	-1	NS	118%
68	05-06	26/27	29-Jan-06	100	B	17.0	23.5	7	8	-4	NS	138%
69	05-06	28/29	29-Jan-06	100	D	88.5	118.2	11	10	-4	NS	134%
70	05-06	30/31	29-Jan-06	75	D	48.2	62.8	10	11	-4	NS	130%
71	05-06	24/25	29-Jan-06	100	E	61.8	131.2	21	19	-5	NS	212%
72	05-06	32/33	29-Jan-06	100	E	103.3	194.0	11	9	-5	NS	188%
73	05-06	34/35	16-Feb-06	75	C2	14.0	13.9	31	31	-9	NS	99%
74	05-06	36/37	16-Feb-06	100	C2	17.6	20.6	23	23	-9	NS	117%
75	05-06	38/39	16-Feb-06	75	C2	13.4	15.2	25	25	-9	NS	113%
76	05-06	44/45	23-Feb-06	50	C2	104.7	130.2	1	1	-4	NS	124%
77	05-06	42/43	23-Feb-06	50	D	12.1	19.6	10	9	-1	NS	162%
78	05-06	46/47	25-Feb-06	100	B	24.2	22.5	8	8	-14	NS	93%
79	05-06	48/49	25-Feb-06	100	C2	25.9	24.7	11	11	-14	NS	95%
80	05-06	50/51	3-Mar-06	100	C2	100.8	99.8	3	2	-9	NS	99%

Table E-14: Freezing Drizzle

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
9	01-02	n/a	01-02	75	H	56.0	47.3	5	5	-10	ZD	84%
10	01-02	n/a	01-02	75	H	21.5	24.6	13	13	-10	ZD	114%
11	01-02	n/a	01-02	75	I	20.5	21.3	13	13	-3	ZD	104%
12	01-02	n/a	01-02	50	I	15.1	24.2	5	5	-3	ZD	160%
40	04-05	6/7	5-Apr-05	75	A	26.3	21.6	13	13	-11	ZD	82%
41	04-05	1/2	5-Apr-05	100	B	21.1	15.8	5	5	-10	ZD	75%
42	04-05	8/9	5-Apr-05	75	B	8.7	8.2	13	13	-11	ZD	94%
43	04-05	3/4	5-Apr-05	75	C1	14.5	10.5	5	5	-10	ZD	72%
44	04-05	10/11	5-Apr-05	100	D	29.3	32.0	13	13	-10	ZD	109%
55	04-05	41/42	7-Apr-05	50	A	11.8	16.8	5	5	-3	ZD	142%
56	04-05	47/48	7-Apr-05	50	A	6.8	16.3	13	13	-3	ZD	240%
57	04-05	43/44	7-Apr-05	50	B	9.1	16.1	5	5	-3	ZD	177%
58	04-05	45/46	7-Apr-05	75	B	8.8	16.6	13	13	-3	ZD	189%
59	04-05	49/50	7-Apr-05	50	D	9.2	16.2	13	13	-3	ZD	176%
86	05-06	23/24	5-Apr-06	100	C2	39.5	46.7	5	5	-10	ZD	118%
93	05-06	41/42	6-Apr-06	75	B	11.0	25.3	13	13	-3	ZD	230%
94	05-06	45/46	6-Apr-06	75	B	9.0	11.5	14	14	-3	ZD	128%
95	05-06	37/38	6-Apr-06	50	C2	14.0	24.5	13	13	-3	ZD	175%
96	05-06	27/28	6-Apr-06	75	D	48.8	40.8	12	13	-10	ZD	84%
97	05-06	39/40	6-Apr-06	50	D	11.0	21.4	13	13	-3	ZD	195%
98	05-06	43/44	6-Apr-06	75	D	31.0	29.5	13	13	-3	ZD	95%
99	05-06	35/36	6-Apr-06	100	E	62.8	80.3	13	13	-3	ZD	128%
100	05-06	49/50	7-Apr-06	50	B	12.5	21.5	5	5	-3	ZD	172%
101	05-06	51/52	7-Apr-06	100	C2	72.8	82.8	5	5	-3	ZD	114%
102	05-06	55/56	7-Apr-06	100	E	131.0	164.0	5	5	-3	ZD	125%
105	05-06	65/66	25-Apr-06	100	B	11.0	24.4	5	5	-10	ZD	222%
106	05-06	67/68	25-Apr-06	75	D	50.7	46.8	6	5	-10	ZD	92%
109	06-07	HC2	18-Jul-07	75	A	18.7	14.8	13	13	-10	ZD	79%
110	06-07	HC1	18-Jul-07	100	A	36.3	33.8	13	13	-10	ZD	93%
113	06-07	HC6	19-Jul-07	75	B	10.6	16.0	13	13	-3	ZD	151%
114	06-07	HC5	19-Jul-07	100	B	15.7	14.3	13	13	-3	ZD	90%
115	06-07	HC7	19-Jul-07	50	B	6.3	15.0	13	13	-3	ZD	237%
116	06-07	HC9	18-Jul-07	75	B	6.7	9.4	13	13	-10	ZD	141%
117	06-07	HC8	18-Jul-07	100	B	9.3	9.2	13	13	-10	ZD	98%

Table E-15: Freezing Rain

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm^2/h)	Heated Precip. Rate (g/dm^2/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
17	01-02	n/a	01-02	50	H	10.8	17.8	25	25	-3	ZR	166%
18	01-02	n/a	01-02	50	H	14.0	21.0	13	13	-3	ZR	150%
19	01-02	n/a	01-02	75	I	13.7	11.2	13	13	-10	ZR	81%
20	01-02	n/a	01-02	75	I	10.7	13.2	25	25	-10	ZR	123%
45	04-05	13/14	5-Apr-05	100	A	24.8	19.8	25	25	-10	ZR	80%
46	04-05	15/16	5-Apr-05	75	A	14.3	11.3	25	25	-10	ZR	79%
47	04-05	28/29	6-Apr-05	50	A	9.7	15.1	13	13	-3	ZR	156%
48	04-05	32/33	6-Apr-05	75	A	14.2	16.3	26	26	-3	ZR	115%
49	04-05	19/20	6-Apr-05	100	B	15.5	9.5	13	13	-11	ZR	61%
50	04-05	23/24	6-Apr-05	75	B	10.8	9.0	13	13	-11	ZR	83%
51	04-05	26/27	6-Apr-05	75	B	11.4	14.9	13	13	-3	ZR	131%
52	04-05	30/31	6-Apr-05	50	B	7.8	16.7	13	13	-3	ZR	214%
53	04-05	34/35	6-Apr-05	100	B	10.5	13.8	26	26	-3	ZR	131%
54	04-05	36/37	6-Apr-05	75	C1	32.5	22.0	26	26	-3	ZR	68%
81	05-06	5/6	4-Apr-06	100	B	14.8	18.7	12	14	-3	ZR	126%
82	05-06	7/8	4-Apr-06	50	B	8.2	17.7	14	14	-3	ZR	216%
83	05-06	15/16	4-Apr-06	50	C2	12.0	20.2	13	13	-3	ZR	168%
84	05-06	9/10	4-Apr-06	100	D	51.9	43.0	14	14	-3	ZR	83%
85	05-06	13/14	4-Apr-06	50	D	11.0	18.8	13	13	-3	ZR	171%
87	05-06	19/20	5-Apr-06	100	B	13.0	12.8	13	14	-10	ZR	98%
88	05-06	31/32	5-Apr-06	100	B	10.0	12.0	25	25	-10	ZR	120%
89	05-06	17/18	5-Apr-06	100	C2	16.8	25.0	13	14	-10	ZR	149%
90	05-06	21/22	5-Apr-06	75	D	21.8	23.2	13	14	-10	ZR	106%
91	05-06	33/34	5-Apr-06	75	D	14.2	15.7	24	25	-10	ZR	111%
92	05-06	29/30	5-Apr-06	100	E	36.5	40.8	25	23	-10	ZR	112%
103	05-06	57/58	13-Apr-06	100	D	15.8	33.6	24	23	-3	ZR	213%
104	05-06	61/62	13-Apr-06	50	D	7.9	19.0	24	23	-3	ZR	241%
107	05-06	63/64	25-Apr-06	75	D	21.2	25.3	13	13	-10	ZR	119%
108	05-06	69/70	26-Apr-06	100	D	56.2	46.3	13	13	-3	ZR	82%
111	06-07	HC4	18-Jul-07	75	A	12.3	10.5	25	25	-10	ZR	85%
112	06-07	HC3	18-Jul-07	100	A	22.3	18.3	25	25	-10	ZR	82%
118	06-07	HC10	18-Jul-07	100	B	6.7	9.1	25	25	-10	ZR	136%
119	06-07	HC11	18-Jul-07	75	B	5.3	8.5	25	25	-10	ZR	159%

Table E-16: Freezing Fog

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
13	01-02	n/a	01-02	75	H	72.0	72.5	2	2	-14	ZF	101%
14	01-02	n/a	01-02	75	H	34.5	38.0	5	5	-14	ZF	110%
15	01-02	n/a	01-02	50	I	16.7	15.7	5	5	-3	ZF	94%
16	01-02	n/a	01-02	50	I	26.5	28.5	2	2	-3	ZF	108%

Table E-17: >3°C

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
1	01-02	n/a	01-02	50	F	6.1	9.2	31	~31	0	NS	151%
65	05-06	16/17	24-Jan-06	75	B	11.5	12.5	12	12	0	NS	109%
66	05-06	18/19	24-Jan-06	75	B	12.5	16.8	11	11	-1	NS	134%
67	05-06	20/21	24-Jan-06	75	D	63.2	74.8	6	7	-1	NS	118%
64	05-06	14/15	21-Jan-06	75	B	13.0	13.7	20	20	-1	NS	105%
77	05-06	42/43	23-Feb-06	50	D	12.1	19.6	10	9	-1	NS	162%
61	05-06	12/13	9-Jan-06	75	A	26.0	22.5	16	14	-2	NS	87%
62	05-06	7/10	9-Jan-06	75	B	10.8	9.8	18	18	-2	NS	91%

Table E-18: -3°C

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
11	01-02	n/a	01-02	75	I	20.5	21.3	13	13	-3	ZD	104%
12	01-02	n/a	01-02	50	I	15.1	24.2	5	5	-3	ZD	160%
15	01-02	n/a	01-02	50	I	16.7	15.7	5	5	-3	ZF	94%
16	01-02	n/a	01-02	50	I	26.5	28.5	2	2	-3	ZF	108%
17	01-02	n/a	01-02	50	H	10.8	17.8	25	25	-3	ZR	166%
18	01-02	n/a	01-02	50	H	14.0	21.0	13	13	-3	ZR	150%
58	04-05	45/46	7-Apr-05	75	B	8.8	16.6	13	13	-3	ZD	189%
60	05-06	3/4	4-Jan-06	100	A	86.2	61.2	7	7	-3	NS	71%
81	05-06	5/6	4-Apr-06	100	B	14.8	18.7	12	14	-3	ZR	126%
82	05-06	7/8	4-Apr-06	50	B	8.2	17.7	14	14	-3	ZR	216%
83	05-06	15/16	4-Apr-06	50	C2	12.0	20.2	13	13	-3	ZR	168%
84	05-06	9/10	4-Apr-06	100	D	51.9	43.0	14	14	-3	ZR	83%
85	05-06	13/14	4-Apr-06	50	D	11.0	18.8	13	13	-3	ZR	171%
93	05-06	41/42	6-Apr-06	75	B	11.0	25.3	13	13	-3	ZD	230%
94	05-06	45/46	6-Apr-06	75	B	9.0	11.5	14	14	-3	ZD	128%
95	05-06	37/38	6-Apr-06	50	C2	14.0	24.5	13	13	-3	ZD	175%
97	05-06	39/40	6-Apr-06	50	D	11.0	21.4	13	13	-3	ZD	195%
98	05-06	43/44	6-Apr-06	75	D	31.0	29.5	13	13	-3	ZD	95%
99	05-06	35/36	6-Apr-06	100	E	62.8	80.3	13	13	-3	ZD	128%
100	05-06	49/50	7-Apr-06	50	B	12.5	21.5	5	5	-3	ZD	172%
101	05-06	51/52	7-Apr-06	100	C2	72.8	82.8	5	5	-3	ZD	114%
102	05-06	55/56	7-Apr-06	100	E	131.0	164.0	5	5	-3	ZD	125%
103	05-06	57/58	13-Apr-06	100	D	15.8	33.6	24	23	-3	ZR	213%
104	05-06	61/62	13-Apr-06	50	D	7.9	19.0	24	23	-3	ZR	241%
108	05-06	69/70	26-Apr-06	100	D	56.2	46.3	13	13	-3	ZR	82%
113	06-07	HC6	19-Jul-07	75	B	10.6	16.0	13	13	-3	ZD	151%
114	06-07	HC5	19-Jul-07	100	B	15.7	14.3	13	13	-3	ZD	90%
115	06-07	HC7	19-Jul-07	50	B	6.3	15.0	13	13	-3	ZD	237%
48	04-05	32/33	6-Apr-05	75	A	14.2	16.3	26	26	-3	ZR	115%
52	04-05	30/31	6-Apr-05	50	B	7.8	16.7	13	13	-3	ZR	214%
53	04-05	34/35	6-Apr-05	100	B	10.5	13.8	26	26	-3	ZR	131%
54	04-05	36/37	6-Apr-05	75	C1	32.5	22.0	26	26	-3	ZR	68%
56	04-05	47/48	7-Apr-05	50	A	6.8	16.3	13	13	-3	ZD	240%
59	04-05	49/50	7-Apr-05	50	D	9.2	16.2	13	13	-3	ZD	176%

Table E-18 (cont'd): -3°C

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm^2/h)	Heated Precip. Rate (g/dm^2/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
47	04-05	28/29	6-Apr-05	50	A	9.7	15.1	13	13	-3	ZR	156%
51	04-05	26/27	6-Apr-05	75	B	11.4	14.9	13	13	-3	ZR	131%
57	04-05	43/44	7-Apr-05	50	B	9.1	16.1	5	5	-3	ZD	177%
55	04-05	41/42	7-Apr-05	50	A	11.8	16.8	5	5	-3	ZD	142%

Table E-19: -4 to -9°C

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
8	01-02	n/a	01-02	50	I	16.2	20.3	4	~4	-4	NS	125%
63	05-06	5/6	9-Jan-06	100	D	87.7	79.0	15	14	-4	NS	90%
76	05-06	44/45	23-Feb-06	50	C2	104.7	130.2	1	1	-4	NS	124%
68	05-06	26/27	29-Jan-06	100	B	17.0	23.5	7	8	-4	NS	138%
70	05-06	30/31	29-Jan-06	75	D	48.2	62.8	10	11	-4	NS	130%
69	05-06	28/29	29-Jan-06	100	D	88.5	118.2	11	10	-4	NS	134%
72	05-06	32/33	29-Jan-06	100	E	103.3	194.0	11	9	-5	NS	188%
5	01-02	n/a	01-02	75	F	56.0	73.8	5	~5	-5	NS	132%
7	01-02	n/a	01-02	75	I	36.1	38.6	5	~5	-5	NS	107%
25	04-05	14/15	10-Feb-05	75	B	17.8	18.8	10	10	-5	NS	106%
26	04-05	17/18	10-Feb-05	75	C1	57.0	87.0	9	7	-5	NS	153%
71	05-06	24/25	29-Jan-06	100	E	61.8	131.2	21	19	-5	NS	212%
24	04-05	11/12	10-Feb-05	100	B	36.0	36.8	6	6	-6	NS	102%
30	04-05	37/39	21-Feb-05	100	C1	67.0	62.3	13	13	-6	NS	93%
27	04-05	31/33	21-Feb-05	75	B	16.0	12.0	14	13	-6	NS	75%
28	04-05	34/36	21-Feb-05	100	B	21.3	15.2	14	13	-6	NS	71%
3	01-02	n/a	01-02	75	F	29.1	38.5	8	~8	-8	NS	132%
4	01-02	n/a	01-02	75	F	37.8	46.0	5	~5	-8	NS	122%
80	05-06	50/51	3-Mar-06	100	C2	100.8	99.8	3	2	-9	NS	99%
73	05-06	34/35	16-Feb-06	75	C2	14.0	13.9	31	31	-9	NS	99%
75	05-06	38/39	16-Feb-06	75	C2	13.4	15.2	25	25	-9	NS	113%
74	05-06	36/37	16-Feb-06	100	C2	17.6	20.6	23	23	-9	NS	117%

Table E-20: -10°C

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
45	04-05	13/14	5-Apr-05	100	A	24.8	19.8	25	25	-10	ZR	80%
9	01-02	n/a	01-02	75	H	56.0	47.3	5	5	-10	ZD	84%
10	01-02	n/a	01-02	75	H	21.5	24.6	13	13	-10	ZD	114%
19	01-02	n/a	01-02	75	I	13.7	11.2	13	13	-10	ZR	81%
20	01-02	n/a	01-02	75	I	10.7	13.2	25	25	-10	ZR	123%
43	04-05	3/4	5-Apr-05	75	C1	14.5	10.5	5	5	-10	ZD	72%
86	05-06	23/24	5-Apr-06	100	C2	39.5	46.7	5	5	-10	ZD	118%
87	05-06	19/20	5-Apr-06	100	B	13.0	12.8	13	14	-10	ZR	98%
88	05-06	31/32	5-Apr-06	100	B	10.0	12.0	25	25	-10	ZR	120%
89	05-06	17/18	5-Apr-06	100	C2	16.8	25.0	13	14	-10	ZR	149%
90	05-06	21/22	5-Apr-06	75	D	21.8	23.2	13	14	-10	ZR	106%
91	05-06	33/34	5-Apr-06	75	D	14.2	15.7	24	25	-10	ZR	111%
92	05-06	29/30	5-Apr-06	100	E	36.5	40.8	25	23	-10	ZR	112%
96	05-06	27/28	6-Apr-06	75	D	48.8	40.8	12	13	-10	ZD	84%
105	05-06	65/66	25-Apr-06	100	B	11.0	24.4	5	5	-10	ZD	222%
106	05-06	67/68	25-Apr-06	75	D	50.7	46.8	6	5	-10	ZD	92%
107	05-06	63/64	25-Apr-06	75	D	21.2	25.3	13	13	-10	ZR	119%
109	06-07	HC2	18-Jul-07	75	A	18.7	14.8	13	13	-10	ZD	79%
110	06-07	HC1	18-Jul-07	100	A	36.3	33.8	13	13	-10	ZD	93%
111	06-07	HC4	18-Jul-07	75	A	12.3	10.5	25	25	-10	ZR	85%
112	06-07	HC3	18-Jul-07	100	A	22.3	18.3	25	25	-10	ZR	82%
116	06-07	HC9	18-Jul-07	75	B	6.7	9.4	13	13	-10	ZD	141%
117	06-07	HC8	18-Jul-07	100	B	9.3	9.2	13	13	-10	ZD	98%
118	06-07	HC10	18-Jul-07	100	B	6.7	9.1	25	25	-10	ZR	136%
119	06-07	HC11	18-Jul-07	75	B	5.3	8.5	25	25	-10	ZR	159%
46	04-05	15/16	5-Apr-05	75	A	14.3	11.3	25	25	-10	ZR	79%
44	04-05	10/11	5-Apr-05	100	D	29.3	32.0	13	13	-10	ZD	109%
41	04-05	1/2	5-Apr-05	100	B	21.1	15.8	5	5	-10	ZD	75%

Table E-21: <-10°C

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
40	04-05	6/7	5-Apr-05	75	A	26.3	21.6	13	13	-11	ZD	82%
42	04-05	8/9	5-Apr-05	75	B	8.7	8.2	13	13	-11	ZD	94%
50	04-05	23/24	6-Apr-05	75	B	10.8	9.0	13	13	-11	ZR	83%
39	04-05	51/53	7-Mar-05	100	E	111.2	162.0	5	7	-11	NS	146%
37	04-05	57/59	7-Mar-05	75	B	17.6	15.9	9	10	-11	NS	90%
49	04-05	19/20	6-Apr-05	100	B	15.5	9.5	13	13	-11	ZR	61%
36	04-05	54/56	7-Mar-05	100	B	26.9	24.5	11	11	-11	NS	91%
23	04-05	7/9	6-Jan-05	75	B	7.0	5.5	37	37	-12	NS	79%
21	04-05	2/3	6-Jan-05	100	B	10.0	7.0	29	27	-12	NS	70%
33	04-05	28/30	21-Feb-05	100	E	152.3	173.5	4	4	-12	NS	114%
35	04-05	48/50	7-Mar-05	75	B	23.2	20.7	5	5	-12	NS	89%
22	04-05	5/6	6-Jan-05	75	B	8.0	5.0	32	31	-12	NS	63%
34	04-05	45/47	7-Mar-05	100	B	31.1	30.0	8	8	-13	NS	96%
38	04-05	42/44	7-Mar-05	75	C1	18.2	20.3	12	12	-13	NS	112%
29	04-05	25/27	21-Feb-05	75	C1	39.3	46.2	4	4	-14	NS	118%
6	01-02	n/a	01-02	75	G	55.9	124.2	4	~4	-14	NS	222%
79	05-06	48/49	25-Feb-06	100	C2	25.9	24.7	11	11	-14	NS	95%
78	05-06	46/47	25-Feb-06	100	B	24.2	22.5	8	8	-14	NS	93%
2	01-02	n/a	01-02	75	F	24.2	32.3	7	~7	-14	NS	134%
13	01-02	n/a	01-02	75	H	72.0	72.5	2	2	-14	ZF	101%
14	01-02	n/a	01-02	75	H	34.5	38.0	5	5	-14	ZF	110%
32	04-05	22/24	21-Feb-05	100	D	58.3	100.3	6	6	-14	NS	172%
31	04-05	19/21	21-Feb-05	75	D	30.5	43.7	4	4	-14	NS	143%

Table E-22: <10 g/dm²/h

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
2	01-02	n/a	01-02	75	F	24.2	32.3	7	~7	-14	NS	134%
3	01-02	n/a	01-02	75	F	29.1	38.5	8	~8	-8	NS	132%
4	01-02	n/a	01-02	75	F	37.8	46.0	5	~5	-8	NS	122%
5	01-02	n/a	01-02	75	F	56.0	73.8	5	~5	-5	NS	132%
6	01-02	n/a	01-02	75	G	55.9	124.2	4	~4	-14	NS	222%
7	01-02	n/a	01-02	75	I	36.1	38.6	5	~5	-5	NS	107%
8	01-02	n/a	01-02	50	I	16.2	20.3	4	~4	-4	NS	125%
9	01-02	n/a	01-02	75	H	56.0	47.3	5	5	-10	ZD	84%
12	01-02	n/a	01-02	50	I	15.1	24.2	5	5	-3	ZD	160%
13	01-02	n/a	01-02	75	H	72.0	72.5	2	2	-14	ZF	101%
14	01-02	n/a	01-02	75	H	34.5	38.0	5	5	-14	ZF	110%
15	01-02	n/a	01-02	50	I	16.7	15.7	5	5	-3	ZF	94%
16	01-02	n/a	01-02	50	I	26.5	28.5	2	2	-3	ZF	108%
24	04-05	11/12	10-Feb-05	100	B	36.0	36.8	6	6	-6	NS	102%
26	04-05	17/18	10-Feb-05	75	C1	57.0	87.0	9	7	-5	NS	153%
29	04-05	25/27	21-Feb-05	75	C1	39.3	46.2	4	4	-14	NS	118%
31	04-05	19/21	21-Feb-05	75	D	30.5	43.7	4	4	-14	NS	143%
32	04-05	22/24	21-Feb-05	100	D	58.3	100.3	6	6	-14	NS	172%
33	04-05	28/30	21-Feb-05	100	E	152.3	173.5	4	4	-12	NS	114%
34	04-05	45/47	7-Mar-05	100	B	31.1	30.0	8	8	-13	NS	96%
35	04-05	48/50	7-Mar-05	75	B	23.2	20.7	5	5	-12	NS	89%
37	04-05	57/59	7-Mar-05	75	B	17.6	15.9	9	10	-11	NS	90%
39	04-05	51/53	7-Mar-05	100	E	111.2	162.0	5	7	-11	NS	146%
41	04-05	1/2	5-Apr-05	100	B	21.1	15.8	5	5	-10	ZD	75%
43	04-05	3/4	5-Apr-05	75	C1	14.5	10.5	5	5	-10	ZD	72%
55	04-05	41/42	7-Apr-05	50	A	11.8	16.8	5	5	-3	ZD	142%
57	04-05	43/44	7-Apr-05	50	B	9.1	16.1	5	5	-3	ZD	177%
60	05-06	3/4	4-Jan-06	100	A	86.2	61.2	7	7	-3	NS	71%
67	05-06	20/21	24-Jan-06	75	D	63.2	74.8	6	7	-1	NS	118%
68	05-06	26/27	29-Jan-06	100	B	17.0	23.5	7	8	-4	NS	138%
76	05-06	44/45	23-Feb-06	50	C2	104.7	130.2	1	1	-4	NS	124%
78	05-06	46/47	25-Feb-06	100	B	24.2	22.5	8	8	-14	NS	93%
80	05-06	50/51	3-Mar-06	100	C2	100.8	99.8	3	2	-9	NS	99%
86	05-06	23/24	5-Apr-06	100	C2	39.5	46.7	5	5	-10	ZD	118%

Table E-22 (cont'd): <10 g/dm²/h

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate ($g/dm^2/h$)	Heated Precip. Rate ($g/dm^2/h$)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
100	05-06	49/50	7-Apr-06	50	B	12.5	21.5	5	5	-3	ZD	172%
101	05-06	51/52	7-Apr-06	100	C2	72.8	82.8	5	5	-3	ZD	114%
102	05-06	55/56	7-Apr-06	100	E	131.0	164.0	5	5	-3	ZD	125%
105	05-06	65/66	25-Apr-06	100	B	11.0	24.4	5	5	-10	ZD	222%
106	05-06	67/68	25-Apr-06	75	D	50.7	46.8	6	5	-10	ZD	92%

Table E-23: 10-24 g/dm²/h

Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
10	01-02	n/a	01-02	75	H	21.5	24.6	13	13	-10	ZD	114%
11	01-02	n/a	01-02	75	I	20.5	21.3	13	13	-3	ZD	104%
18	01-02	n/a	01-02	50	H	14.0	21.0	13	13	-3	ZR	150%
19	01-02	n/a	01-02	75	I	13.7	11.2	13	13	-10	ZR	81%
25	04-05	14/15	10-Feb-05	75	B	17.8	18.8	10	10	-5	NS	106%
27	04-05	31/33	21-Feb-05	75	B	16.0	12.0	14	13	-6	NS	75%
28	04-05	34/36	21-Feb-05	100	B	21.3	15.2	14	13	-6	NS	71%
30	04-05	37/39	21-Feb-05	100	C1	67.0	62.3	13	13	-6	NS	93%
36	04-05	54/56	7-Mar-05	100	B	26.9	24.5	11	11	-11	NS	91%
38	04-05	42/44	7-Mar-05	75	C1	18.2	20.3	12	12	-13	NS	112%
40	04-05	6/7	5-Apr-05	75	A	26.3	21.6	13	13	-11	ZD	82%
42	04-05	8/9	5-Apr-05	75	B	8.7	8.2	13	13	-11	ZD	94%
44	04-05	10/11	5-Apr-05	100	D	29.3	32.0	13	13	-10	ZD	109%
47	04-05	28/29	6-Apr-05	50	A	9.7	15.1	13	13	-3	ZR	156%
49	04-05	19/20	6-Apr-05	100	B	15.5	9.5	13	13	-11	ZR	61%
50	04-05	23/24	6-Apr-05	75	B	10.8	9.0	13	13	-11	ZR	83%
51	04-05	26/27	6-Apr-05	75	B	11.4	14.9	13	13	-3	ZR	131%
52	04-05	30/31	6-Apr-05	50	B	7.8	16.7	13	13	-3	ZR	214%
56	04-05	47/48	7-Apr-05	50	A	6.8	16.3	13	13	-3	ZD	240%
58	04-05	45/46	7-Apr-05	75	B	8.8	16.6	13	13	-3	ZD	189%
59	04-05	49/50	7-Apr-05	50	D	9.2	16.2	13	13	-3	ZD	176%
61	05-06	12/13	9-Jan-06	75	A	26.0	22.5	16	14	-2	NS	87%
62	05-06	7/10	9-Jan-06	75	B	10.8	9.8	18	18	-2	NS	91%
63	05-06	5/6	9-Jan-06	100	D	87.7	79.0	15	14	-4	NS	90%
64	05-06	14/15	21-Jan-06	75	B	13.0	13.7	20	20	-1	NS	105%
65	05-06	16/17	24-Jan-06	75	B	11.5	12.5	12	12	0	NS	109%
66	05-06	18/19	24-Jan-06	75	B	12.5	16.8	11	11	-1	NS	134%
69	05-06	28/29	29-Jan-06	100	D	88.5	118.2	11	10	-4	NS	134%
70	05-06	30/31	29-Jan-06	75	D	48.2	62.8	10	11	-4	NS	130%
71	05-06	24/25	29-Jan-06	100	E	61.8	131.2	21	19	-5	NS	212%
72	05-06	32/33	29-Jan-06	100	E	103.3	194.0	11	9	-5	NS	188%
74	05-06	36/37	16-Feb-06	100	C2	17.6	20.6	23	23	-9	NS	117%
77	05-06	42/43	23-Feb-06	50	D	12.1	19.6	10	9	-1	NS	162%
79	05-06	48/49	25-Feb-06	100	C2	25.9	24.7	11	11	-14	NS	95%

Table E-23 (cont'd): 10-24 g/dm^2/h

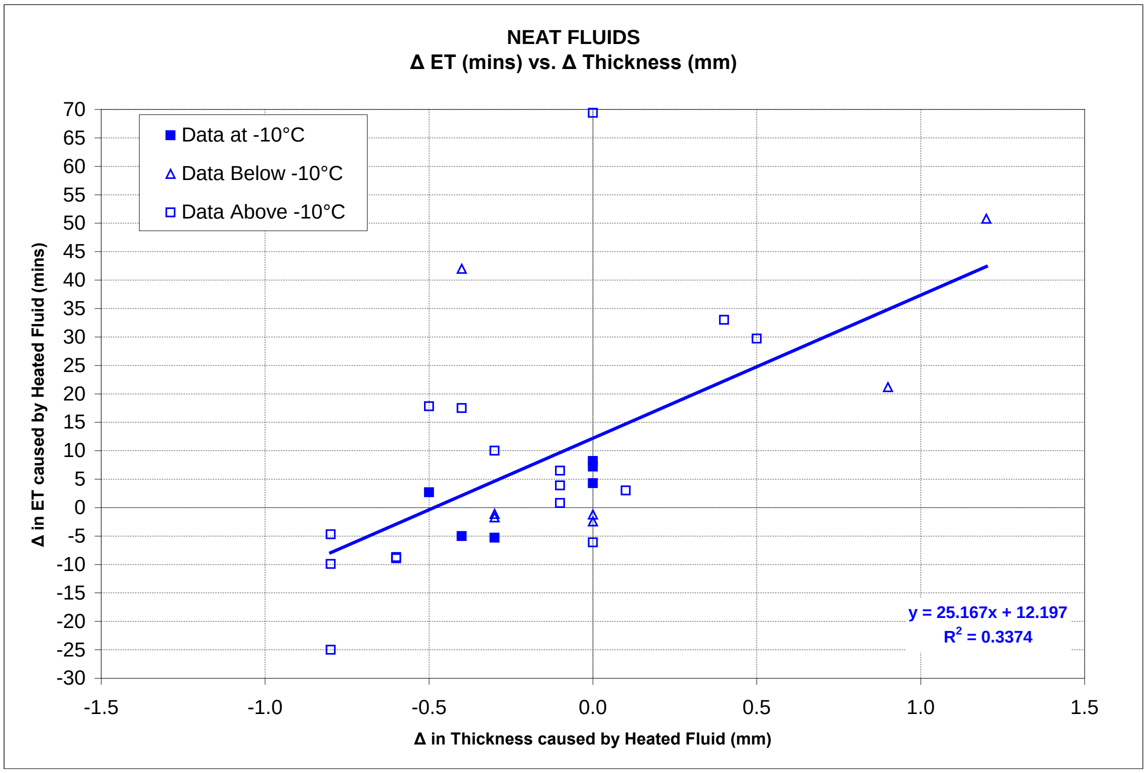
Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm^2/h)	Heated Precip. Rate (g/dm^2/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
81	05-06	5/6	4-Apr-06	100	B	14.8	18.7	12	14	-3	ZR	126%
82	05-06	7/8	4-Apr-06	50	B	8.2	17.7	14	14	-3	ZR	216%
83	05-06	15/16	4-Apr-06	50	C2	12.0	20.2	13	13	-3	ZR	168%
84	05-06	9/10	4-Apr-06	100	D	51.9	43.0	14	14	-3	ZR	83%
85	05-06	13/14	4-Apr-06	50	D	11.0	18.8	13	13	-3	ZR	171%
87	05-06	19/20	5-Apr-06	100	B	13.0	12.8	13	14	-10	ZR	98%
89	05-06	17/18	5-Apr-06	100	C2	16.8	25.0	13	14	-10	ZR	149%
90	05-06	21/22	5-Apr-06	75	D	21.8	23.2	13	14	-10	ZR	106%
91	05-06	33/34	5-Apr-06	75	D	14.2	15.7	24	25	-10	ZR	111%
93	05-06	41/42	6-Apr-06	75	B	11.0	25.3	13	13	-3	ZD	230%
94	05-06	45/46	6-Apr-06	75	B	9.0	11.5	14	14	-3	ZD	128%
95	05-06	37/38	6-Apr-06	50	C2	14.0	24.5	13	13	-3	ZD	175%
96	05-06	27/28	6-Apr-06	75	D	48.8	40.8	12	13	-10	ZD	84%
97	05-06	39/40	6-Apr-06	50	D	11.0	21.4	13	13	-3	ZD	195%
98	05-06	43/44	6-Apr-06	75	D	31.0	29.5	13	13	-3	ZD	95%
99	05-06	35/36	6-Apr-06	100	E	62.8	80.3	13	13	-3	ZD	128%
103	05-06	57/58	13-Apr-06	100	D	15.8	33.6	24	23	-3	ZR	213%
104	05-06	61/62	13-Apr-06	50	D	7.9	19.0	24	23	-3	ZR	241%
107	05-06	63/64	25-Apr-06	75	D	21.2	25.3	13	13	-10	ZR	119%
108	05-06	69/70	26-Apr-06	100	D	56.2	46.3	13	13	-3	ZR	82%
109	06-07	HC2	18-Jul-07	75	A	18.7	14.8	13	13	-10	ZD	79%
110	06-07	HC1	18-Jul-07	100	A	36.3	33.8	13	13	-10	ZD	93%
113	06-07	HC6	19-Jul-07	75	B	10.6	16.0	13	13	-3	ZD	151%
114	06-07	HC5	19-Jul-07	100	B	15.7	14.3	13	13	-3	ZD	90%
115	06-07	HC7	19-Jul-07	50	B	6.3	15.0	13	13	-3	ZD	237%
116	06-07	HC9	18-Jul-07	75	B	6.7	9.4	13	13	-10	ZD	141%
117	06-07	HC8	18-Jul-07	100	B	9.3	9.2	13	13	-10	ZD	98%

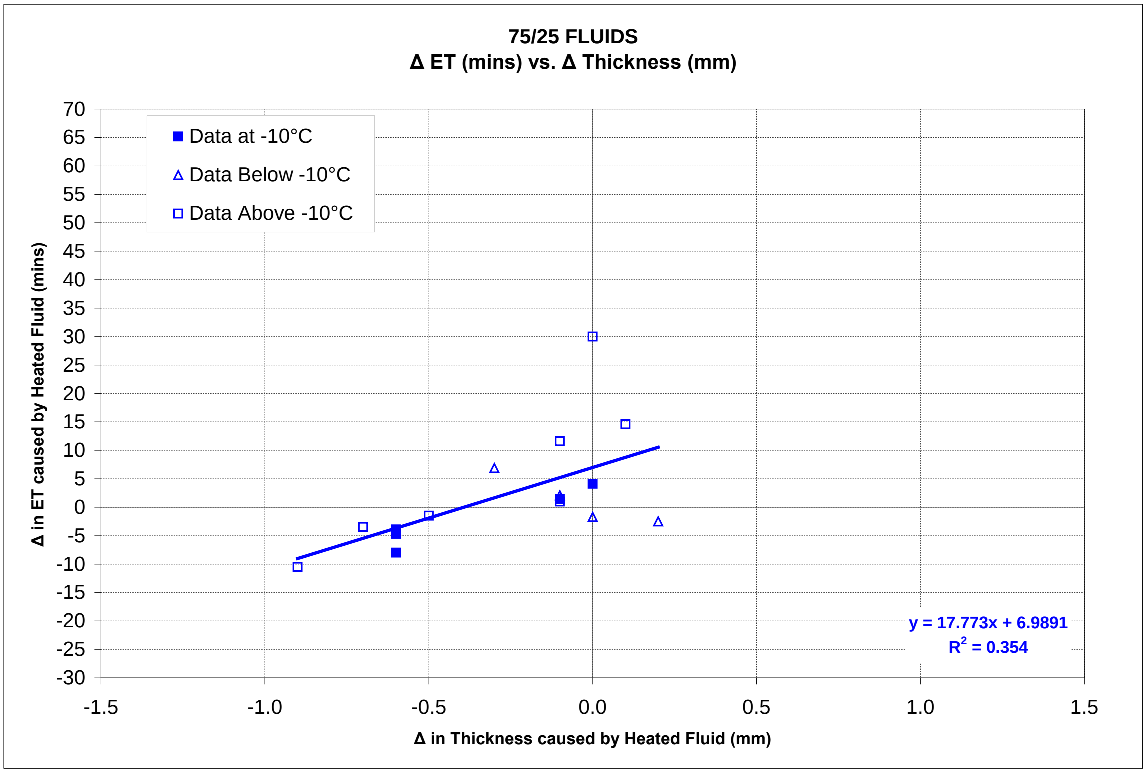
Table E-24: >24 g/dm²/h

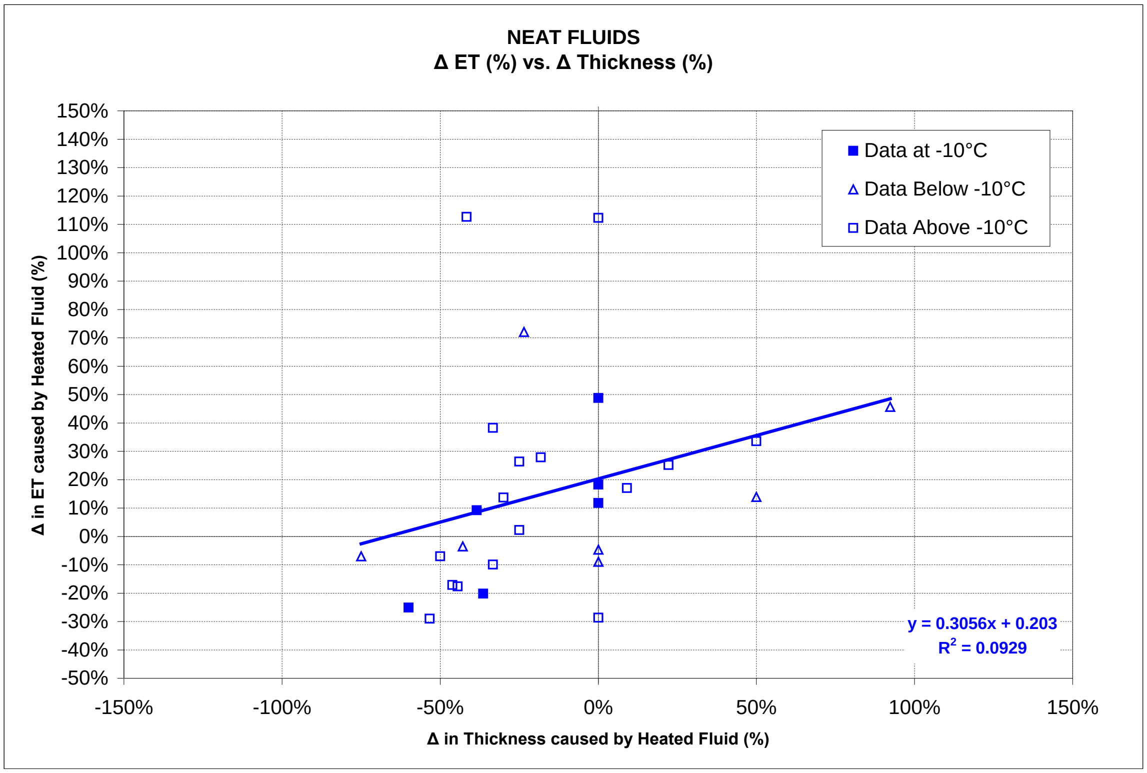
Global Test No.	Test Year	Yearly Test No.	Date	Dil.	Fluid	OAT Fail Time (min)	Heated Fail Time (min)	OAT Precip. Rate (g/dm²/h)	Heated Precip. Rate (g/dm²/h)	Temp. (°C)	Precip. Type	Heated Fail / OAT Fail
1	01-02	n/a	01-02	50	F	6.1	9.2	31	~31	0	NS	151%
17	01-02	n/a	01-02	50	H	10.8	17.8	25	25	-3	ZR	166%
20	01-02	n/a	01-02	75	I	10.7	13.2	25	25	-10	ZR	123%
21	04-05	2/3	6-Jan-05	100	B	10.0	7.0	29	27	-12	NS	70%
22	04-05	5/6	6-Jan-05	75	B	8.0	5.0	32	31	-12	NS	63%
23	04-05	7/9	6-Jan-05	75	B	7.0	5.5	37	37	-12	NS	79%
45	04-05	13/14	5-Apr-05	100	A	24.8	19.8	25	25	-10	ZR	80%
46	04-05	15/16	5-Apr-05	75	A	14.3	11.3	25	25	-10	ZR	79%
48	04-05	32/33	6-Apr-05	75	A	14.2	16.3	26	26	-3	ZR	115%
53	04-05	34/35	6-Apr-05	100	B	10.5	13.8	26	26	-3	ZR	131%
54	04-05	36/37	6-Apr-05	75	C1	32.5	22.0	26	26	-3	ZR	68%
73	05-06	34/35	16-Feb-06	75	C2	14.0	13.9	31	31	-9	NS	99%
75	05-06	38/39	16-Feb-06	75	C2	13.4	15.2	25	25	-9	NS	113%
88	05-06	31/32	5-Apr-06	100	B	10.0	12.0	25	25	-10	ZR	120%
92	05-06	29/30	5-Apr-06	100	E	36.5	40.8	25	23	-10	ZR	112%
111	06-07	HC4	18-Jul-07	75	A	12.3	10.5	25	25	-10	ZR	85%
112	06-07	HC3	18-Jul-07	100	A	22.3	18.3	25	25	-10	ZR	82%
118	06-07	HC10	18-Jul-07	100	B	6.7	9.1	25	25	-10	ZR	136%
119	06-07	HC11	18-Jul-07	75	B	5.3	8.5	25	25	-10	ZR	159%

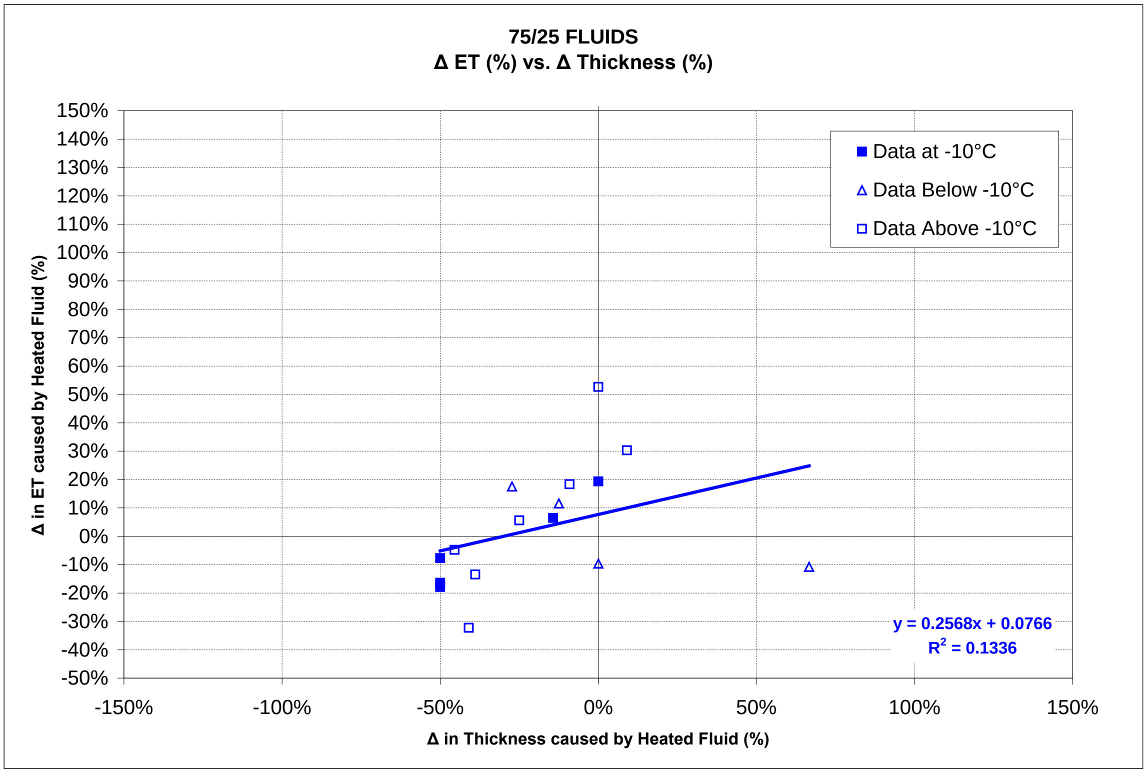
APPENDIX F

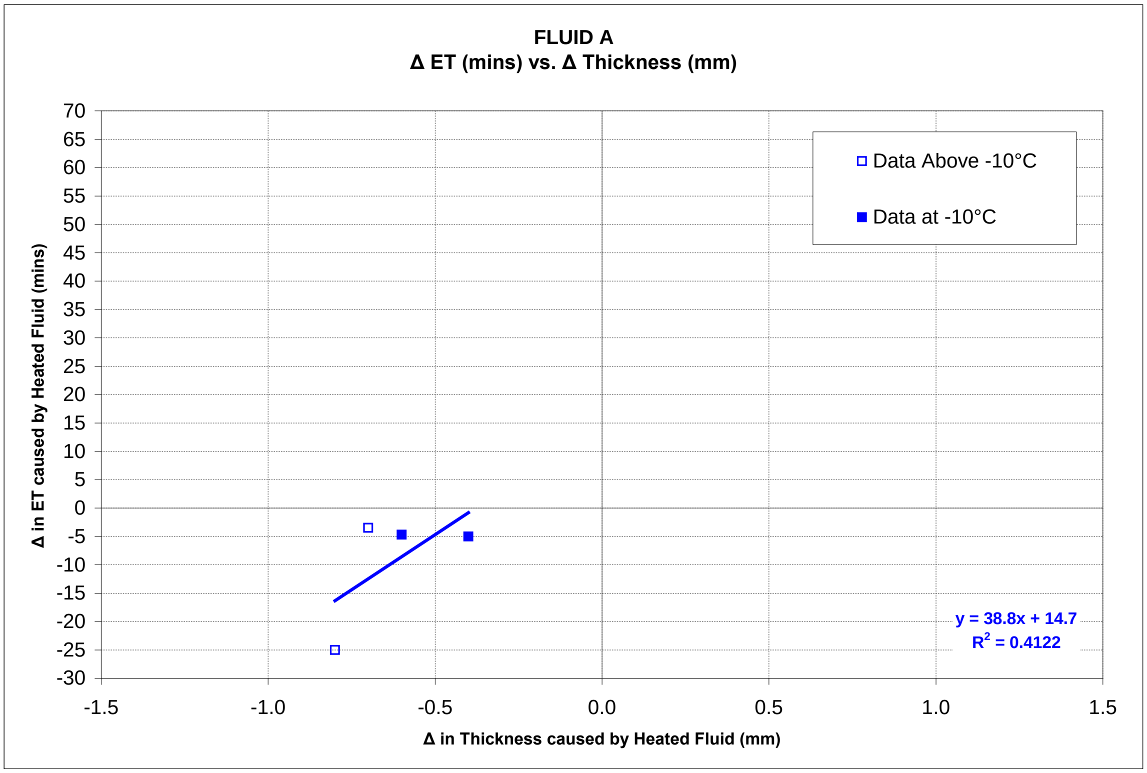
FLUID THICKNESS CHARTS

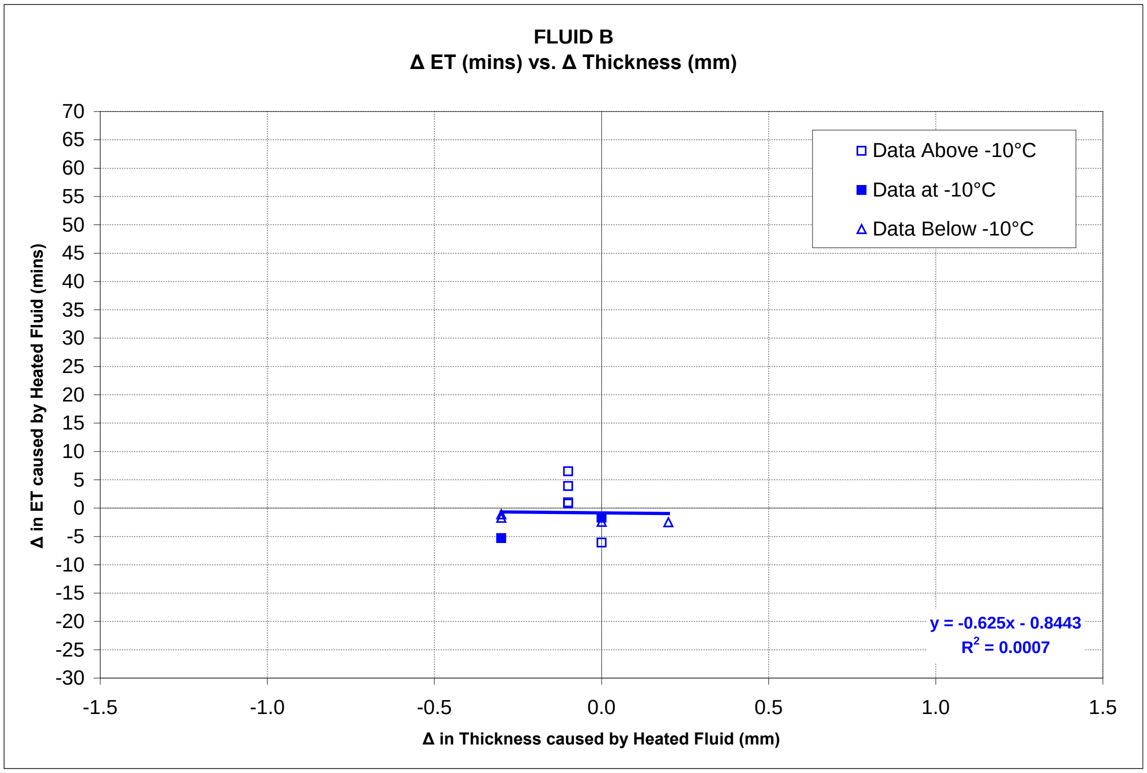

NEAT FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Data at -10°C
Data Below -10°C
Data Above -10°C
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
y = 25.167x + 12.197
R2 = 0.3374
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

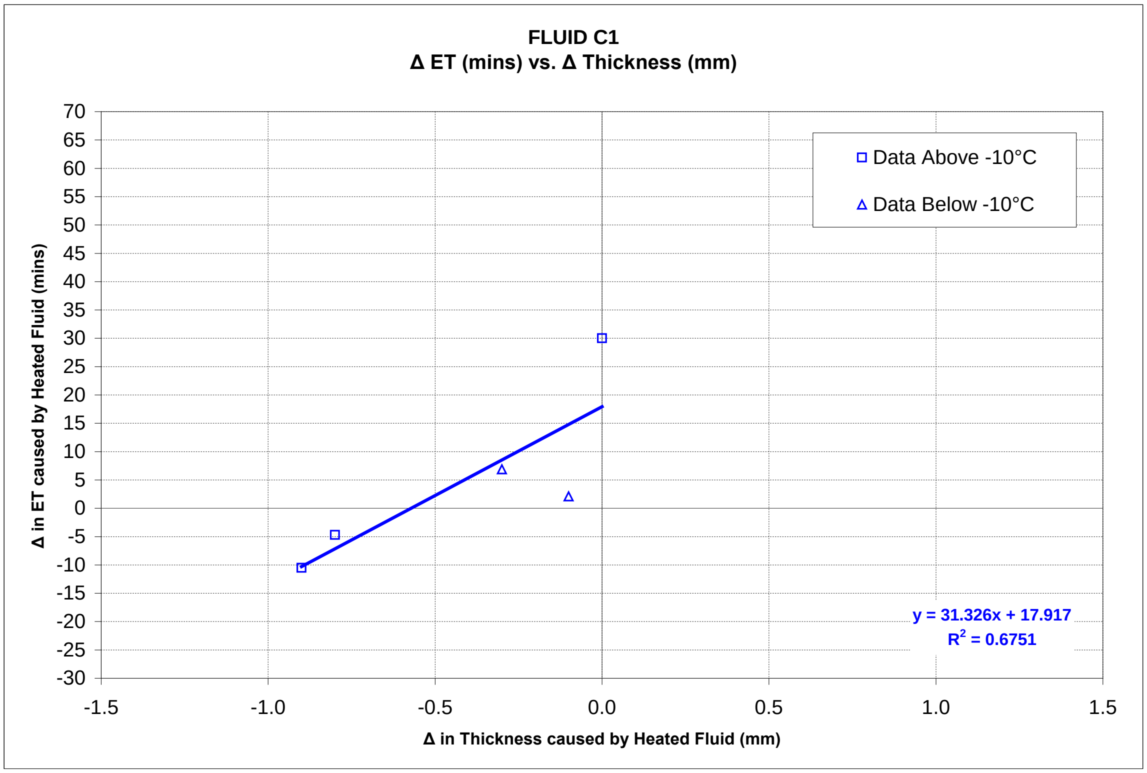

75/25 FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Data at -10°C
Data Below -10°C
Data Above -10°C
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
y = 17.773x + 6.9891
R2 = 0.354
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

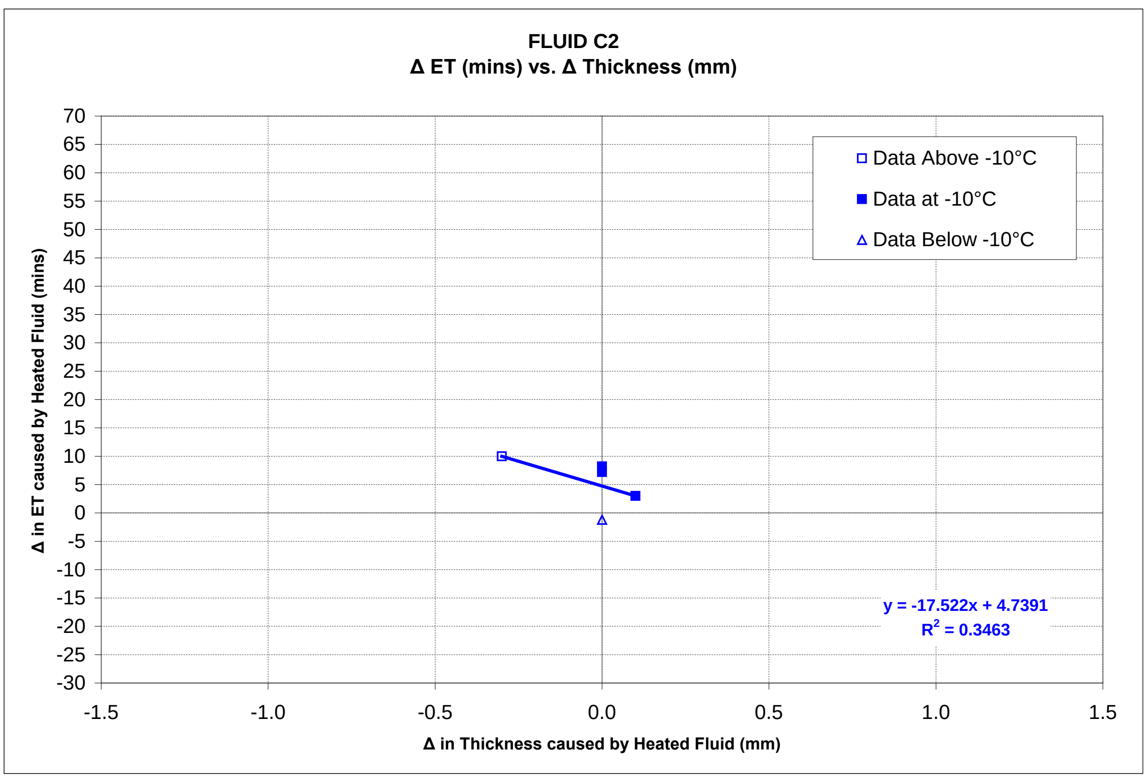

NEAT FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
Data at -10°C
Data Below -10°C
Data Above -10°C
y = 0.3056x + 0.203
R² = 0.0929
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%

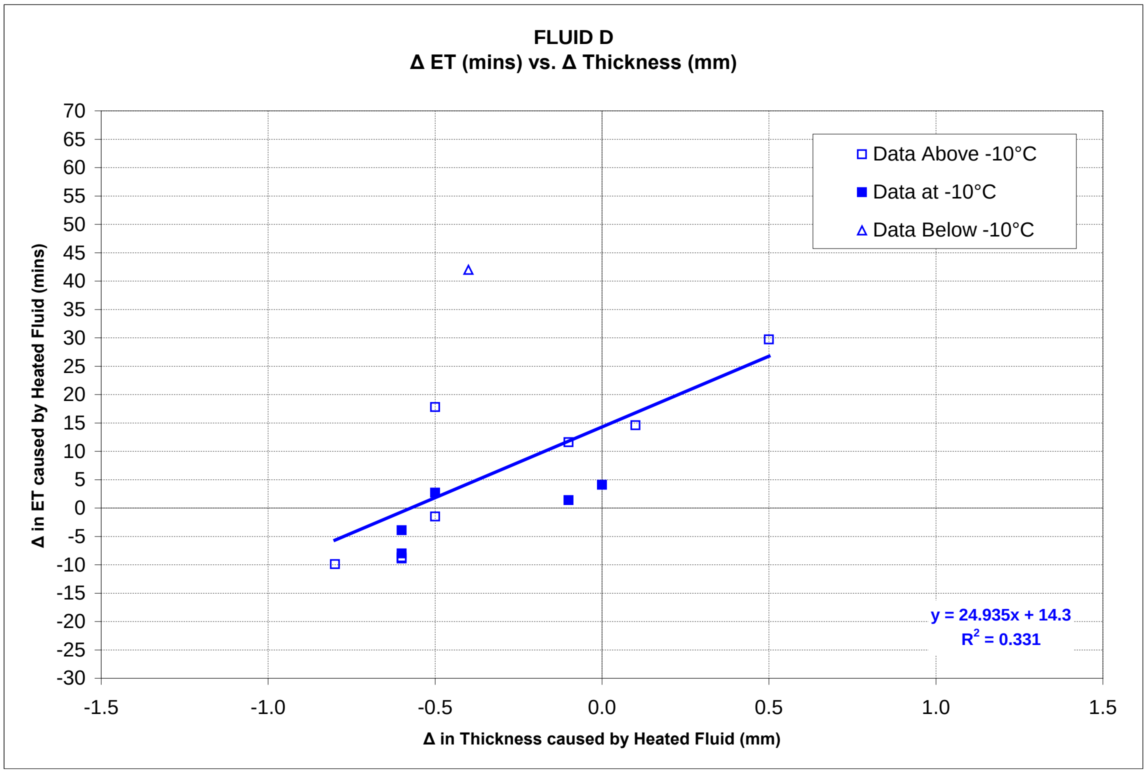

75/25 FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
Data at -10°C
Data Below -10°C
Data Above -10°C
y = 0.2568x + 0.0766
R² = 0.1336
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%

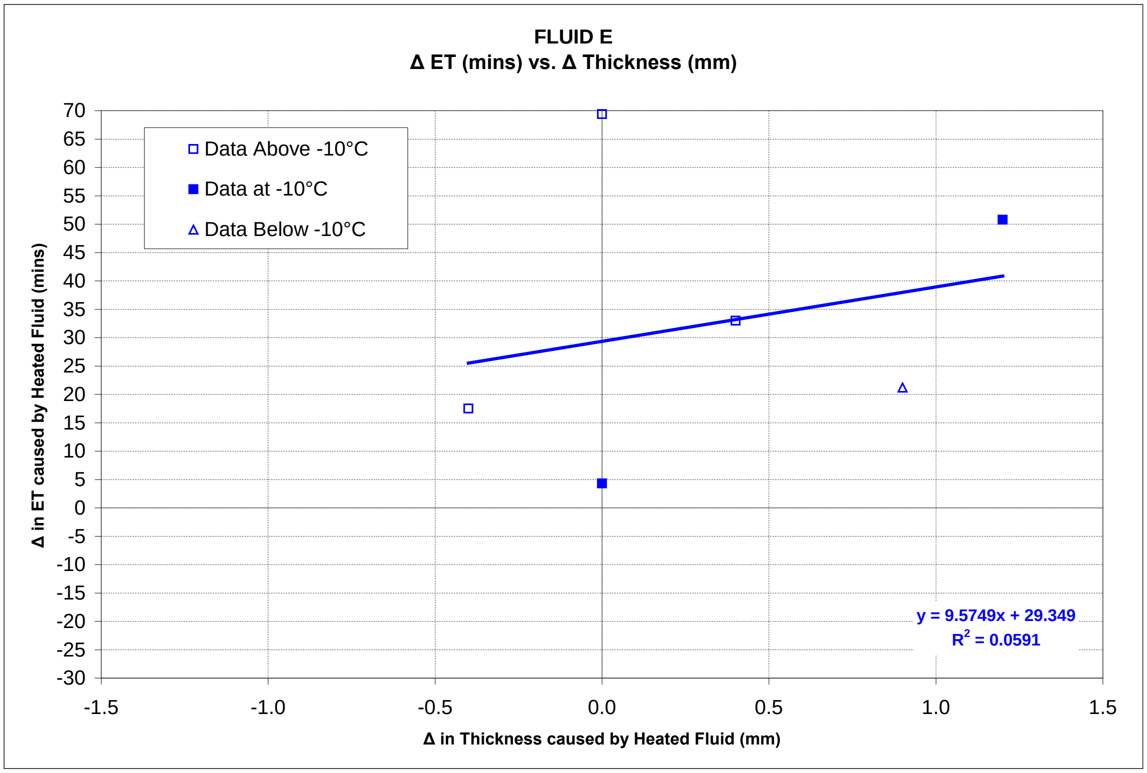

FLUID A
Δ ET (mins) vs. Δ Thickness (mm)
Δ in ET caused by Heated Fluid (mins)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Δ in Thickness caused by Heated Fluid (mm)
Data Above -10°C
Data at -10°C
y = 38.8x + 14.7
R2 = 0.4122

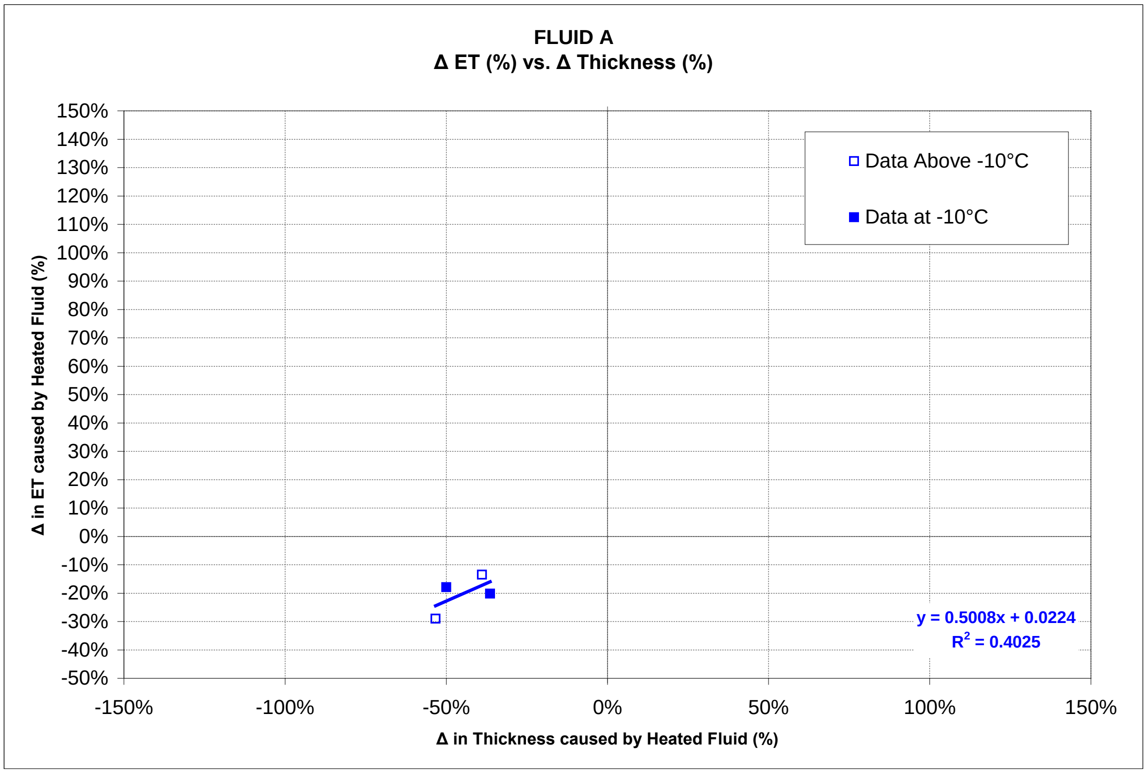

FLUID B
Δ ET (mins) vs. Δ Thickness (mm)
Δ in ET caused by Heated Fluid (mins)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Δ in Thickness caused by Heated Fluid (mm)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = -0.625x - 0.8443
R2 = 0.0007

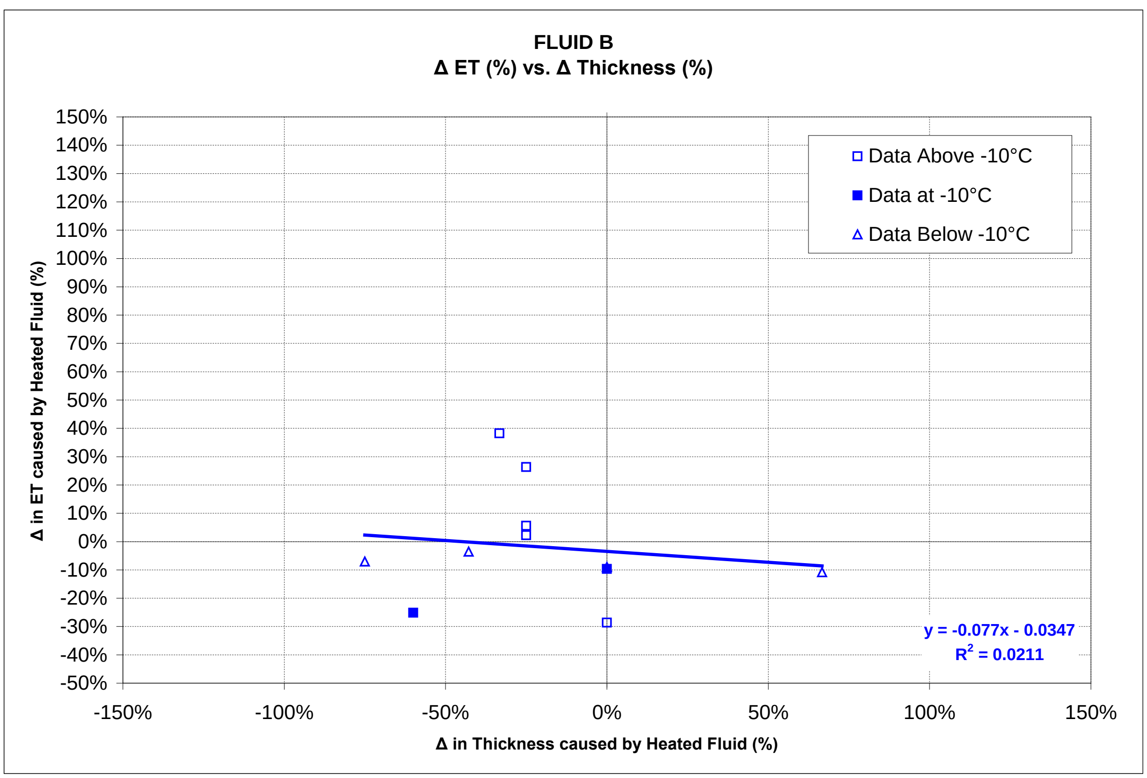

FLUID C1
Δ ET (mins) vs. Δ Thickness (mm)
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
Data Above -10°C
Data Below -10°C
y = 31.326x + 17.917
R² = 0.6751
70 65 60 55 50 45 40 35 30 25 20 15 10 5 0 -5 -10 -15 -20 -25 -30
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

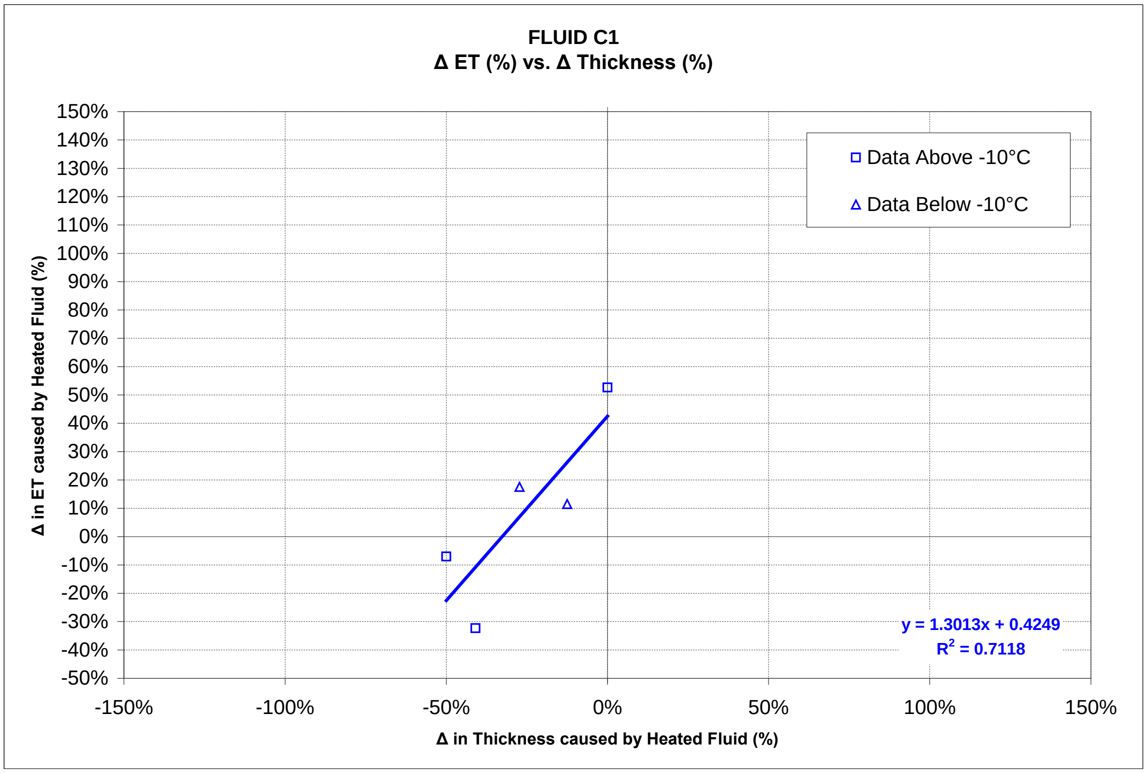

FLUID C2
Δ ET (mins) vs. Δ Thickness (mm)
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = -17.522x + 4.7391
R² = 0.3463
70 65 60 55 50 45 40 35 30 25 20 15 10 5 0 -5 -10 -15 -20 -25 -30
-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

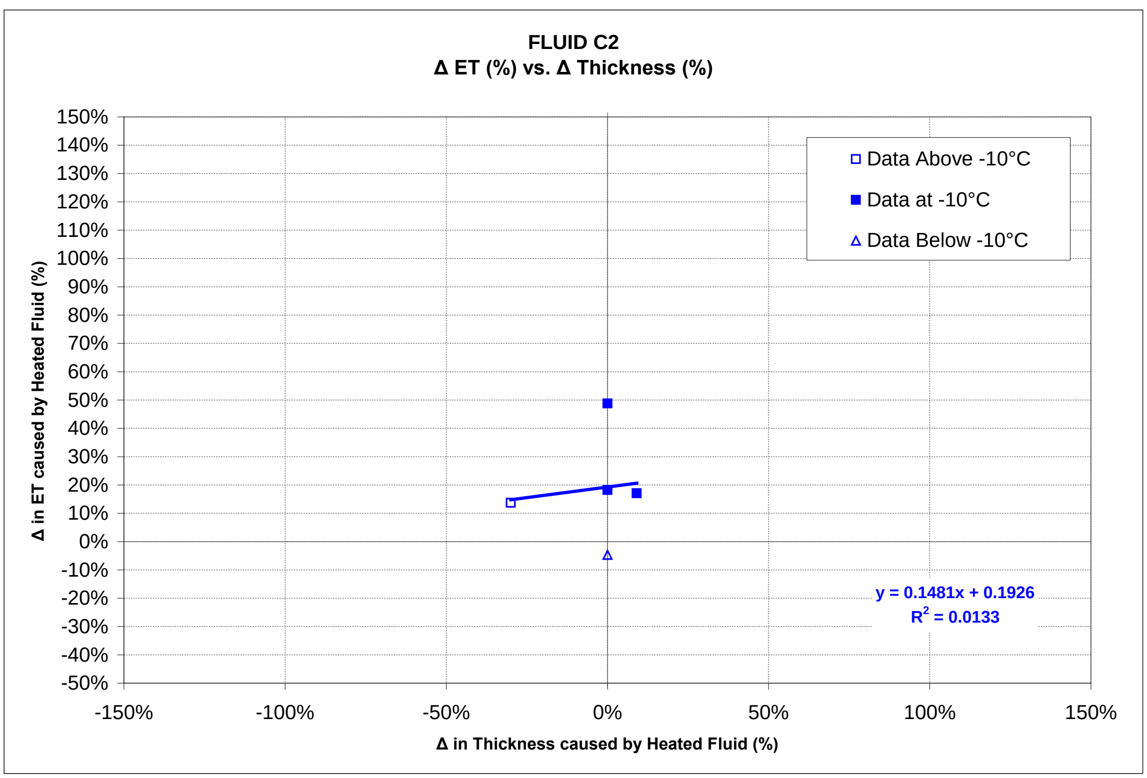

FLUID D
Δ ET (mins) vs. Δ Thickness (mm)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 24.935x + 14.3
R² = 0.331
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

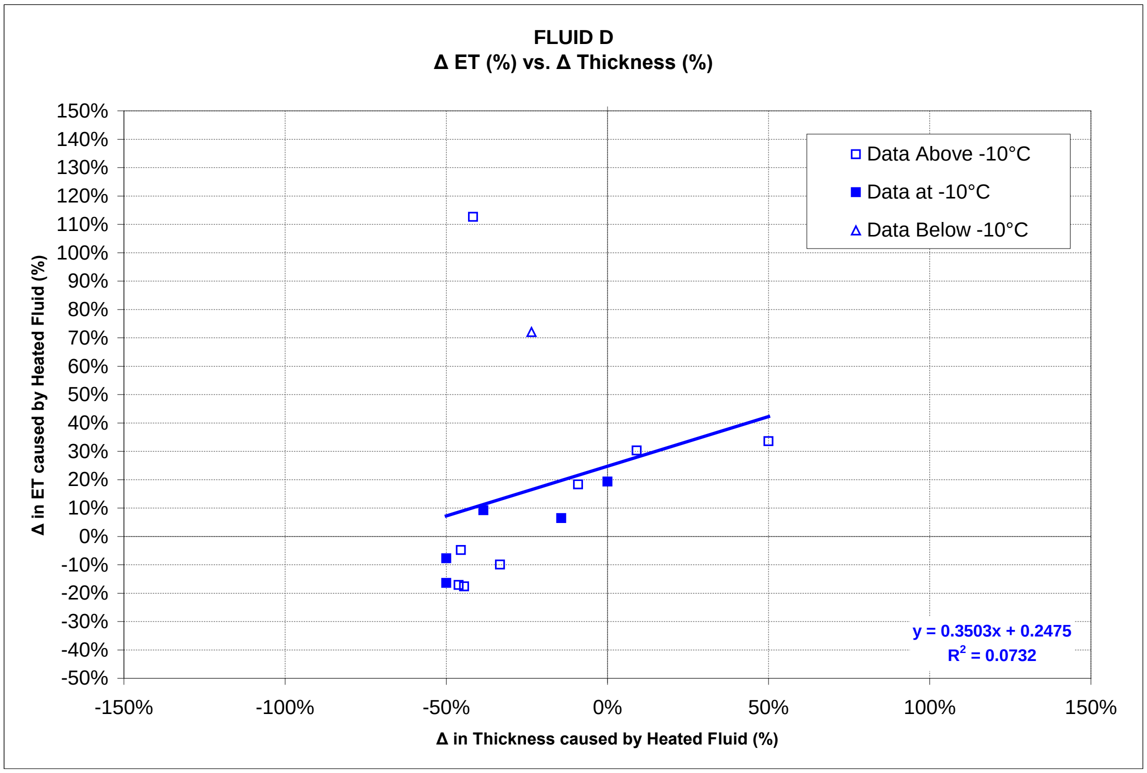

FLUID E
Δ ET (mins) vs. Δ Thickness (mm)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 9.5749x + 29.349
R² = 0.0591
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

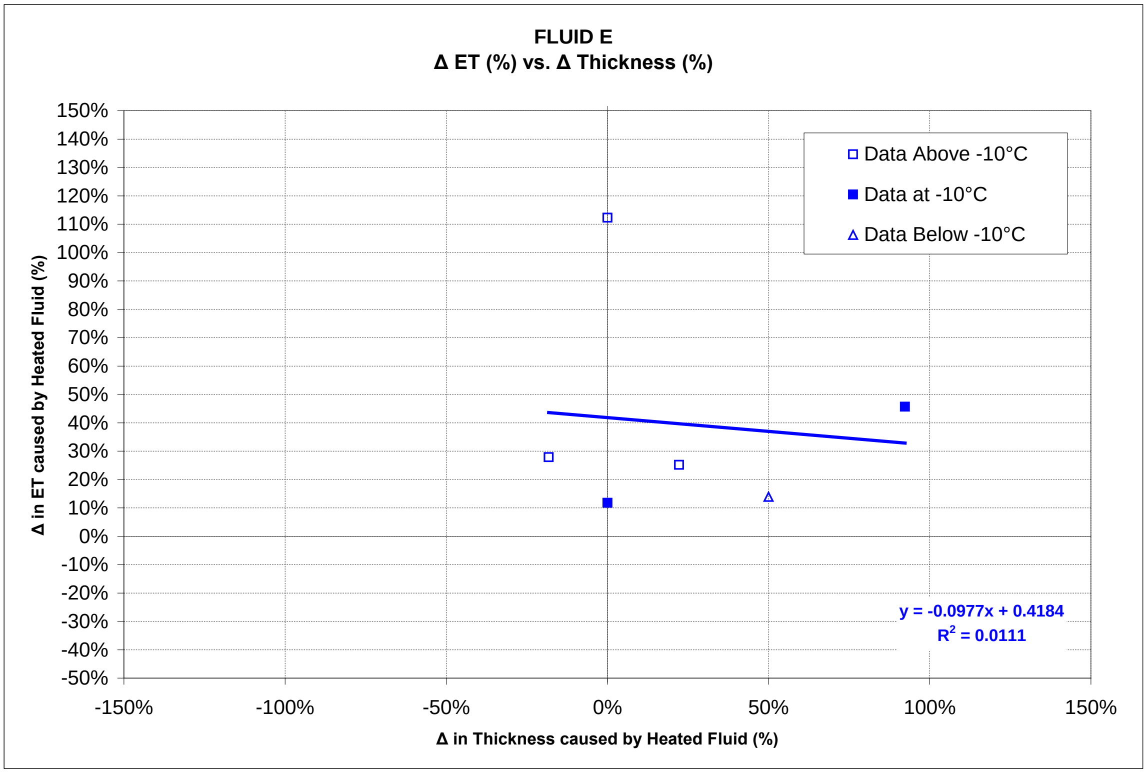

FLUID A
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data at -10°C
y = 0.5008x + 0.0224
R² = 0.4025
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%

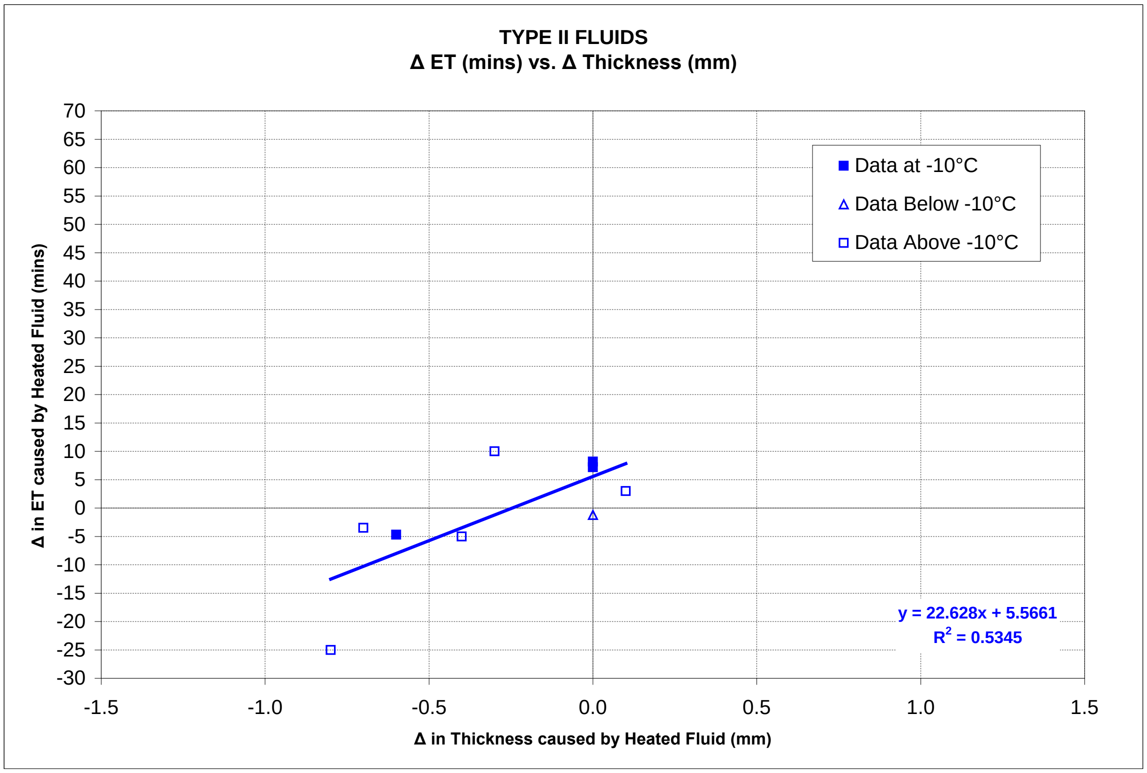

FLUID B
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = -0.077x - 0.0347
R² = 0.0211
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%

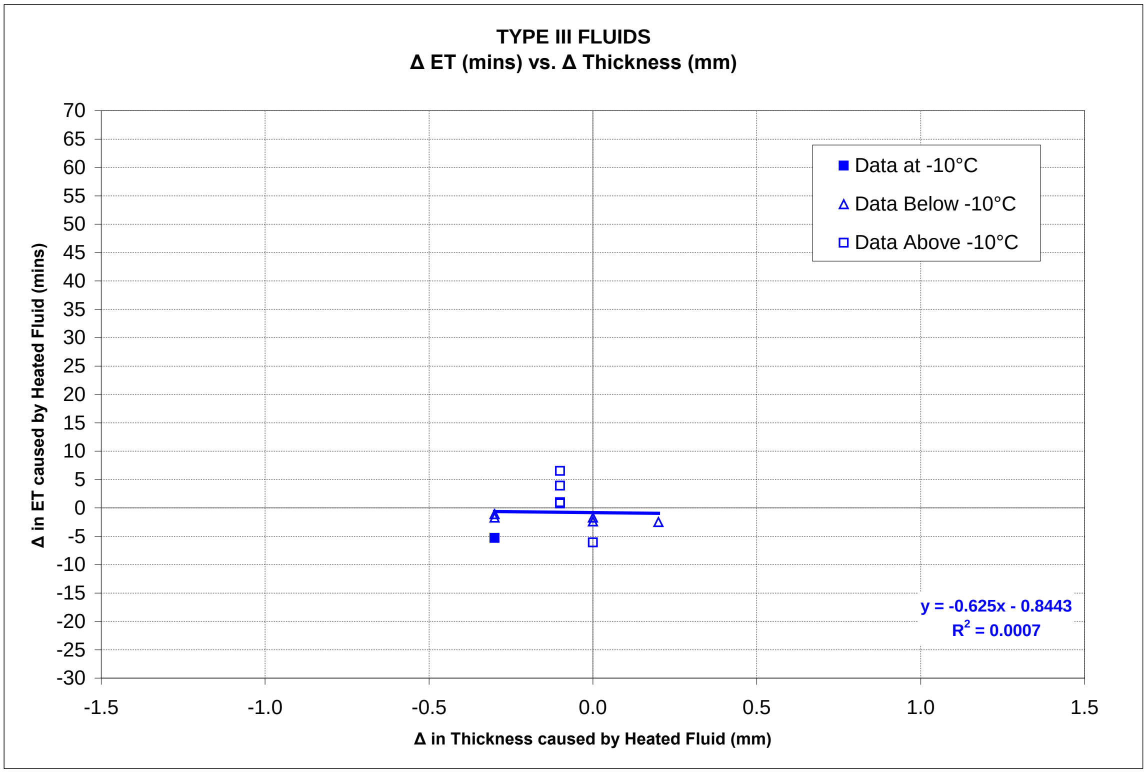

FLUID C1
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data Below -10°C
y = 1.3013x + 0.4249
R2 = 0.7118
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%

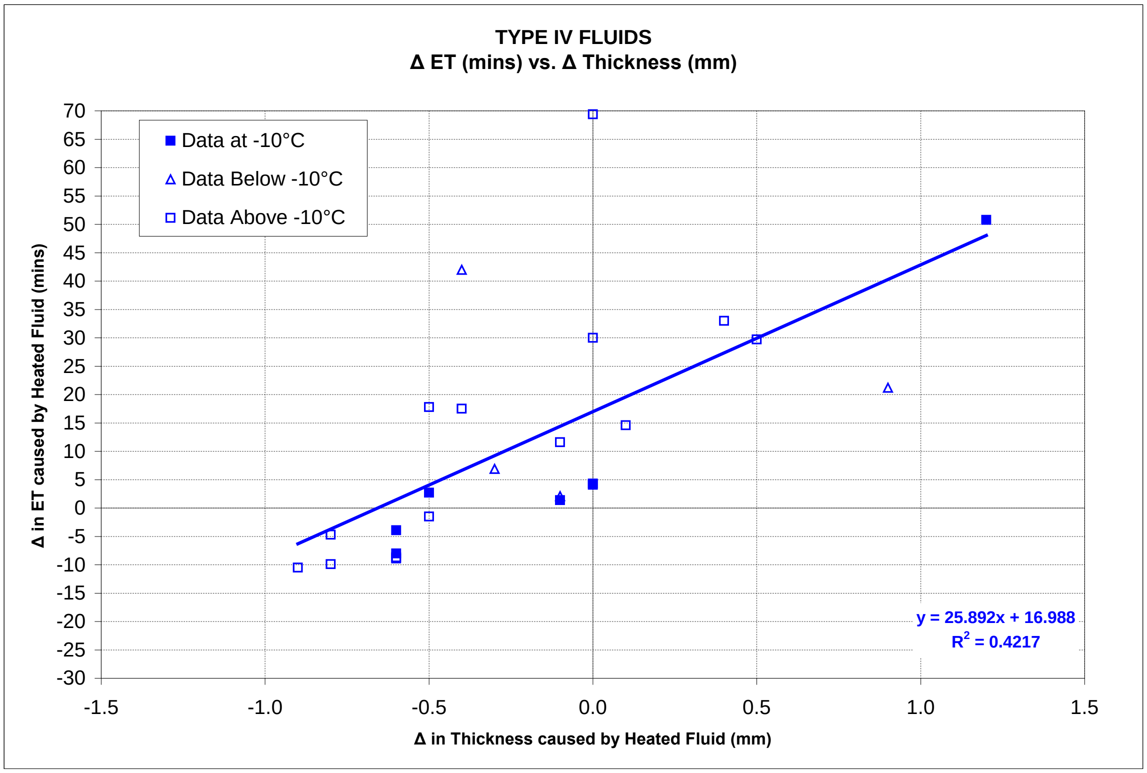

FLUID C2
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 0.1481x + 0.1926
R2 = 0.0133
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%

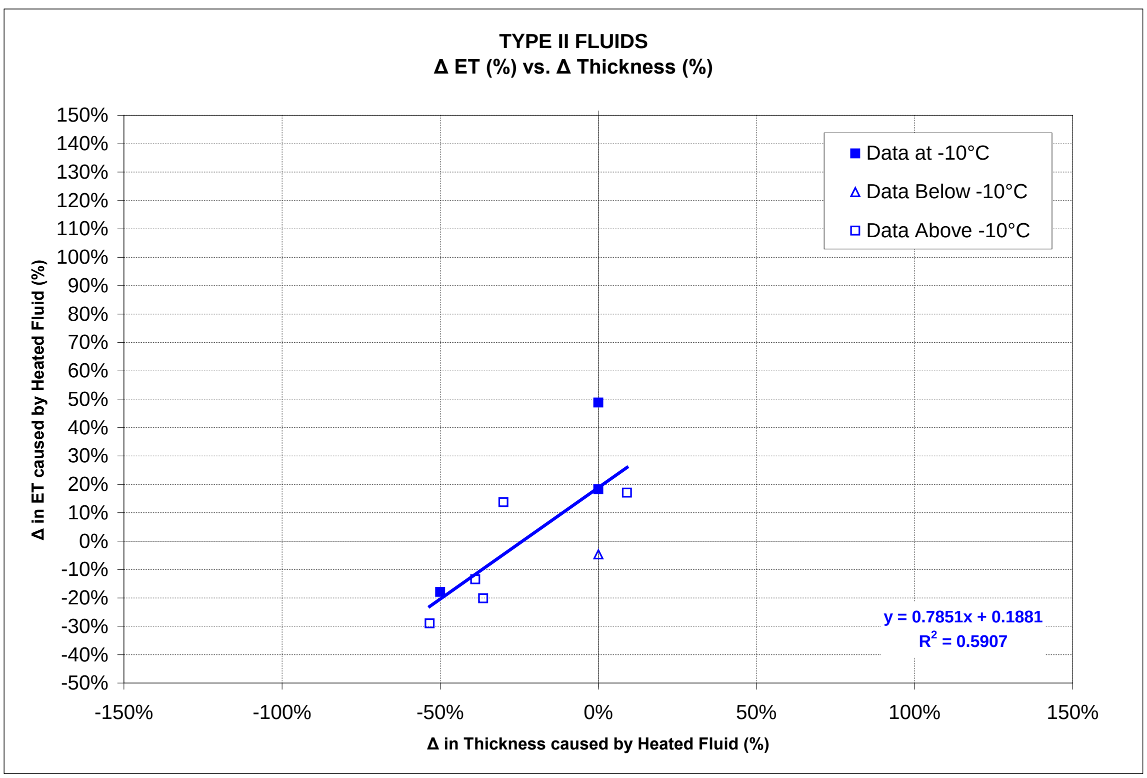

FLUID D
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 0.3503x + 0.2475
R^2 = 0.0732
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)

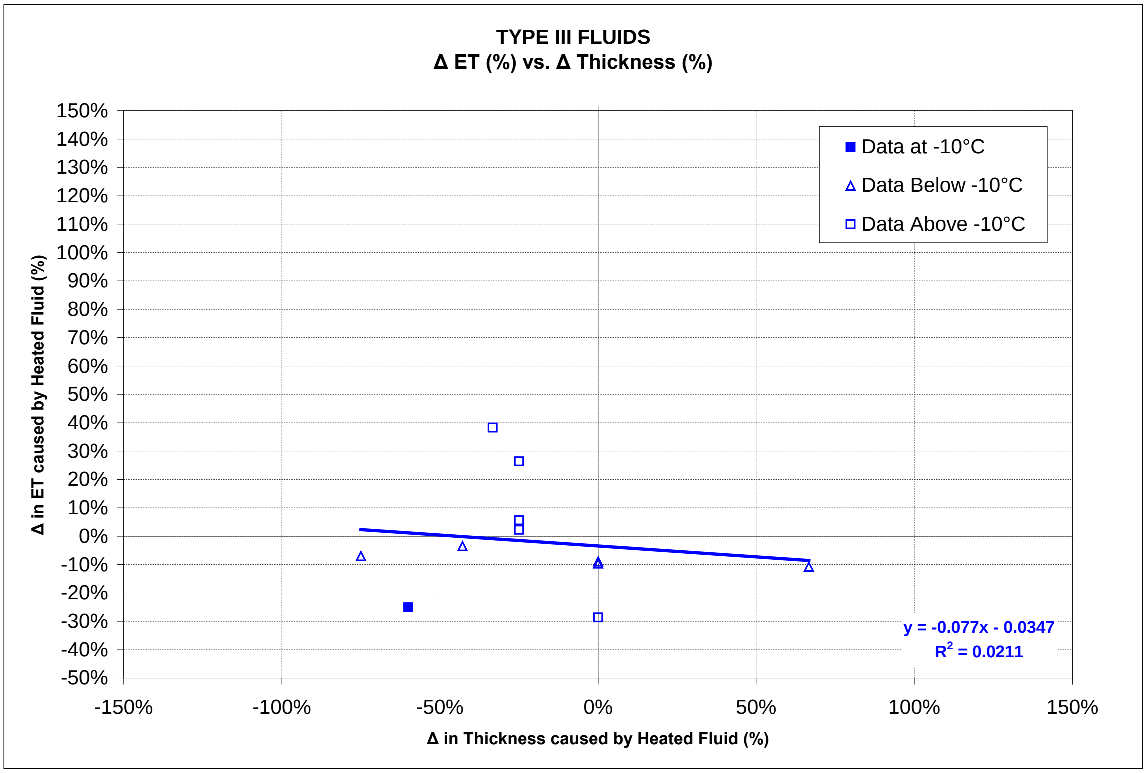

FLUID E
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = -0.0977x + 0.4184
R^2 = 0.0111
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)

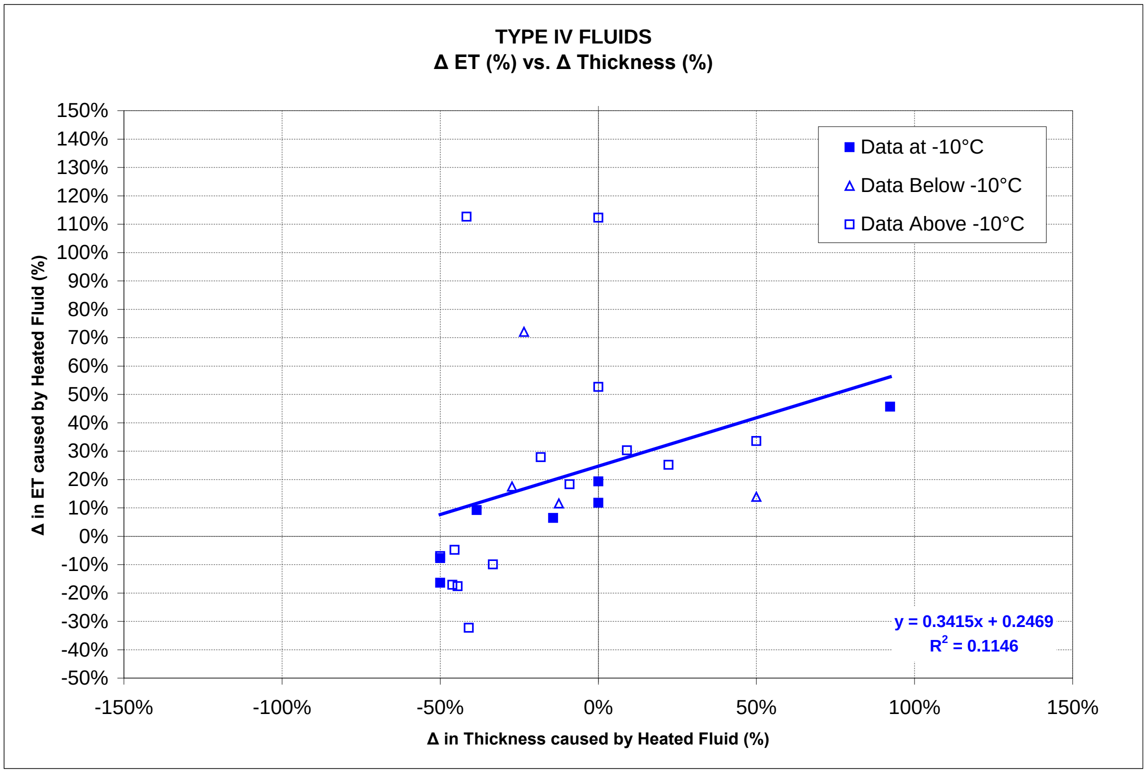

TYPE II FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Δ in ET caused by Heated Fluid (mins)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Δ in Thickness caused by Heated Fluid (mm)
Data at -10°C
Data Below -10°C
Data Above -10°C
y = 22.628x + 5.5661
R² = 0.5345

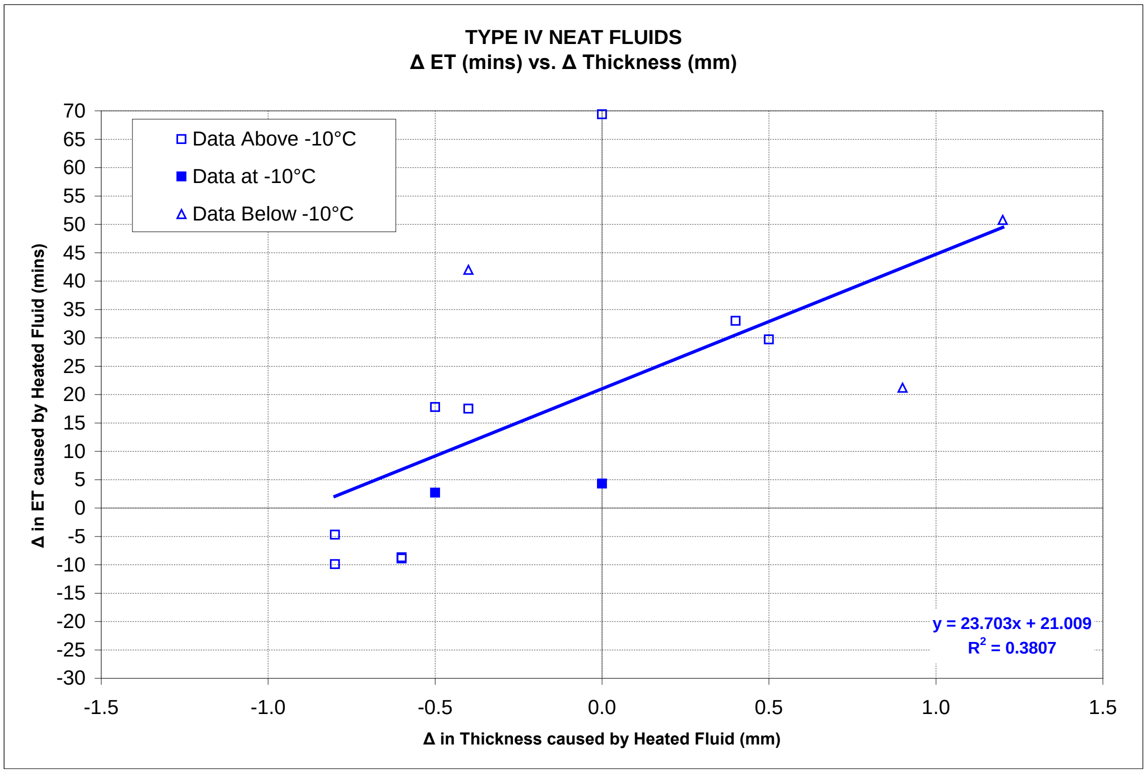

TYPE III FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Δ in ET caused by Heated Fluid (mins)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Δ in Thickness caused by Heated Fluid (mm)
Data at -10°C
Data Below -10°C
Data Above -10°C
y = -0.625x - 0.8443
R² = 0.0007


TYPE IV FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Data at -10°C
Data Below -10°C
Data Above -10°C
Δ in ET caused by Heated Fluid (mins)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
y = 25.892x + 16.988
R2 = 0.4217
Δ in Thickness caused by Heated Fluid (mm)

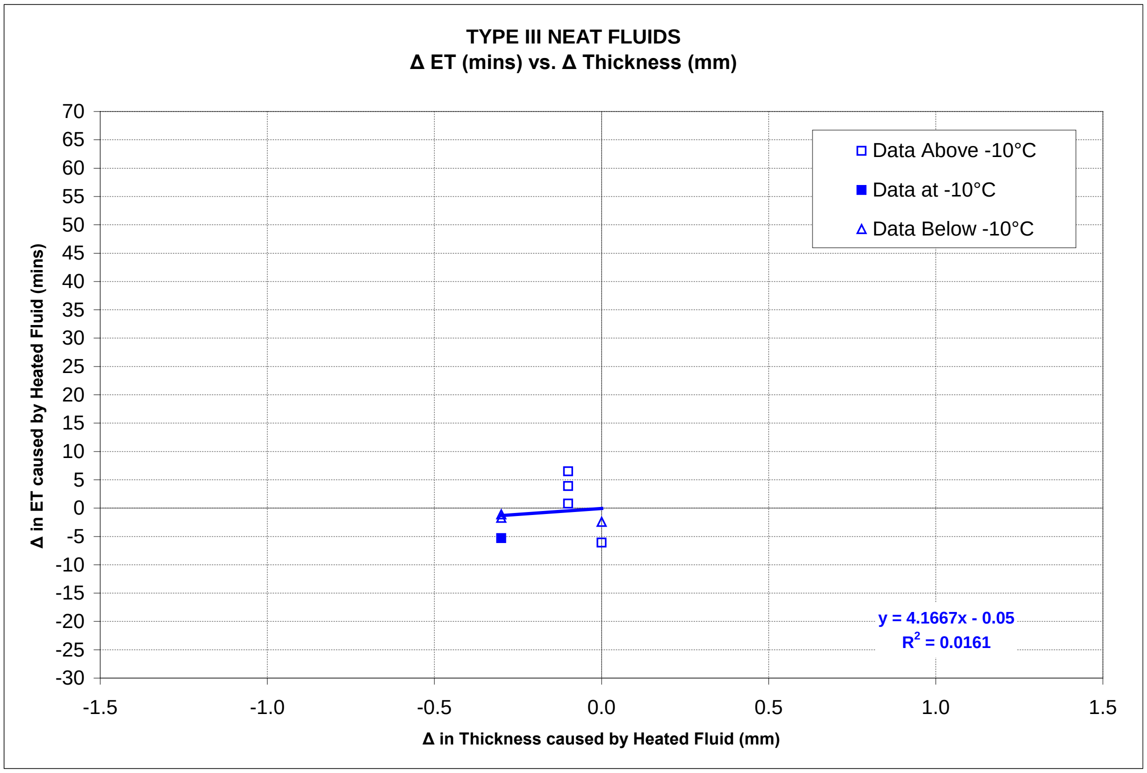

TYPE II FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Data at -10°C
Data Below -10°C
Data Above -10°C
Δ in ET caused by Heated Fluid (%)
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%
y = 0.7851x + 0.1881
R2 = 0.5907
Δ in Thickness caused by Heated Fluid (%)


TYPE III FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Data at -10°C
Data Below -10°C
Data Above -10°C
y = -0.077x - 0.0347
R^2 = 0.0211
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%

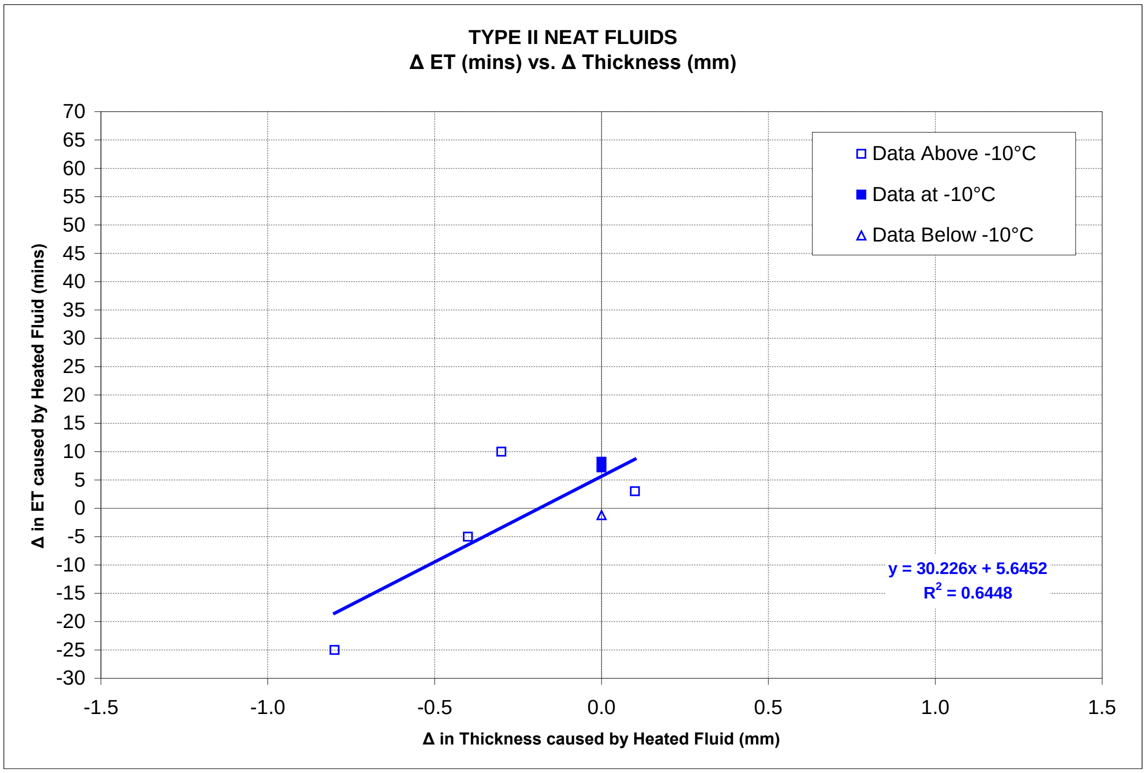

TYPE IV FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Data at -10°C
Data Below -10°C
Data Above -10°C
y = 0.3415x + 0.2469
R^2 = 0.1146
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%

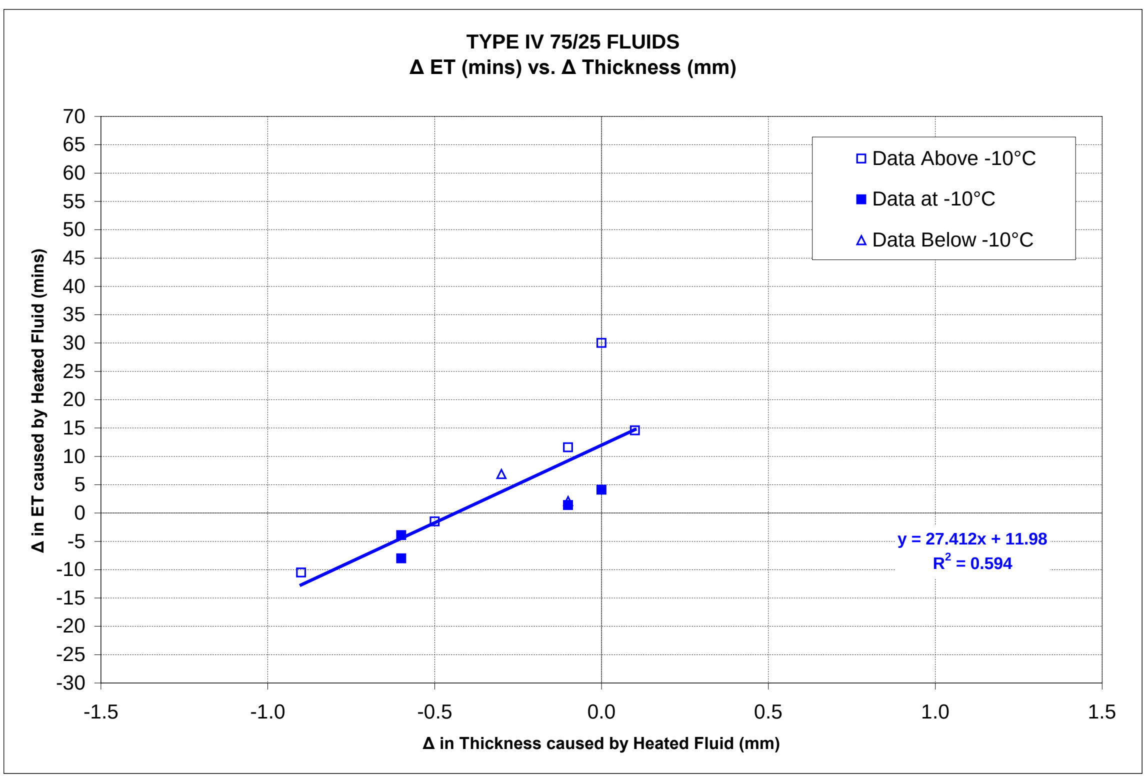


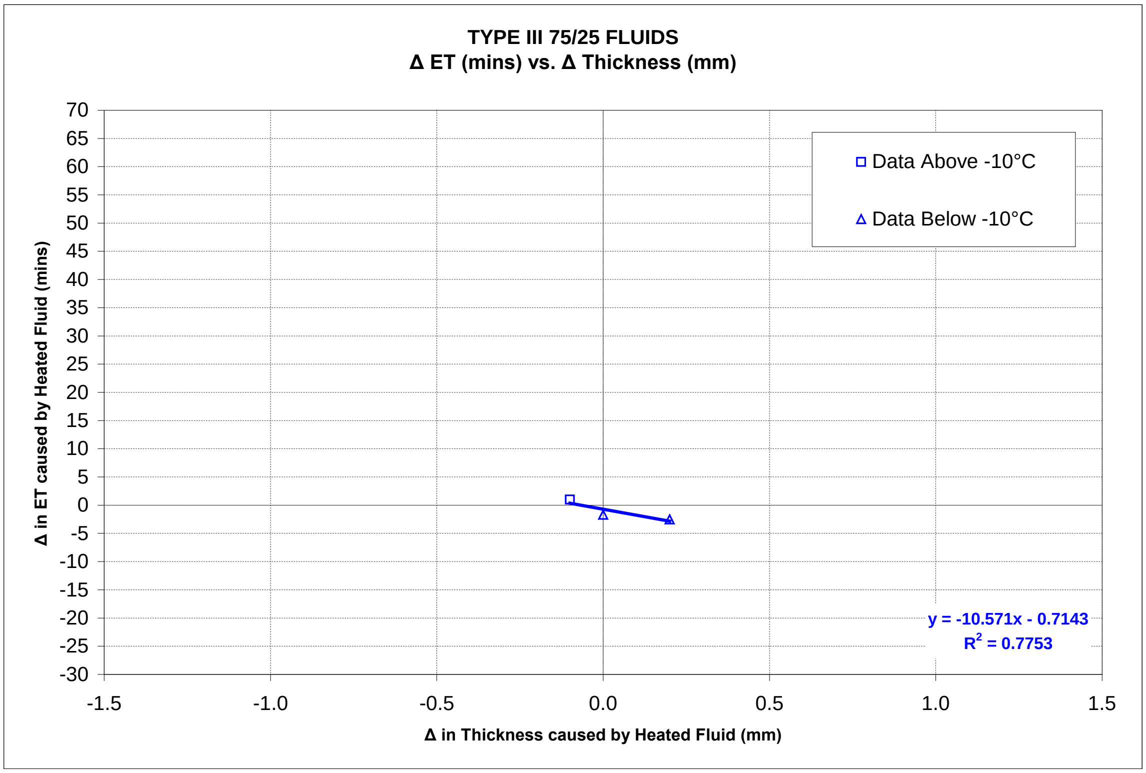
TYPE IV NEAT FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 23.703x + 21.009
R² = 0.3807
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)

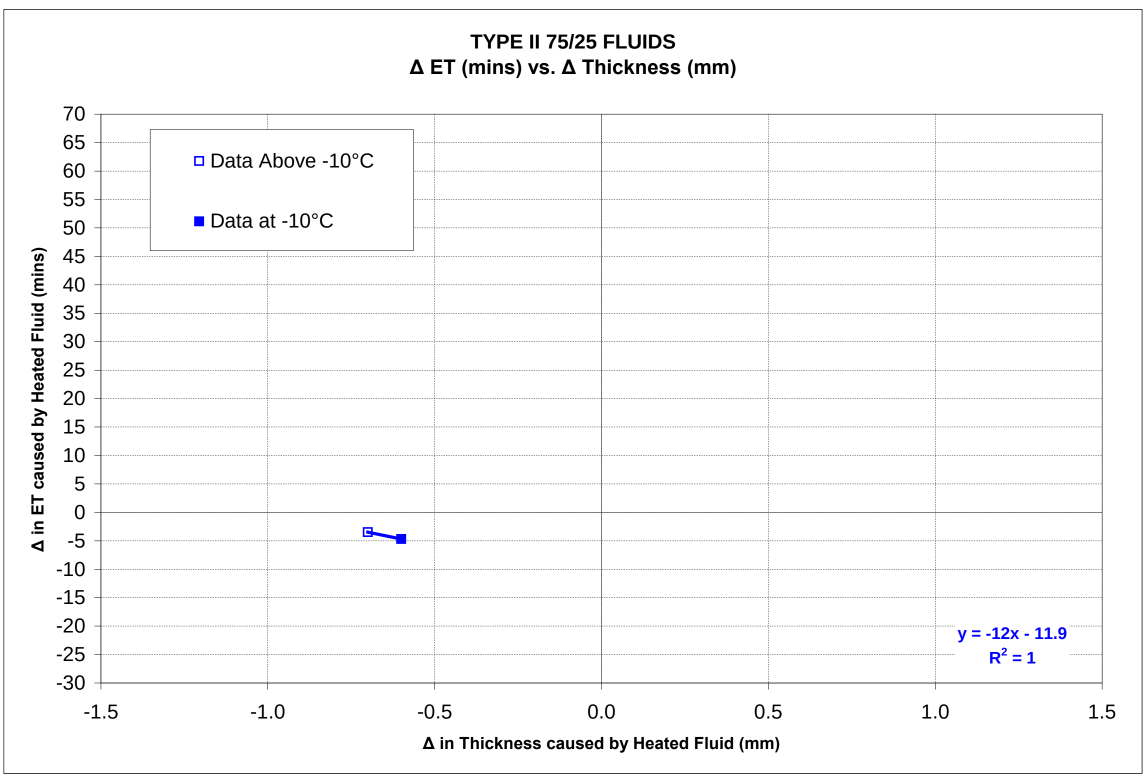


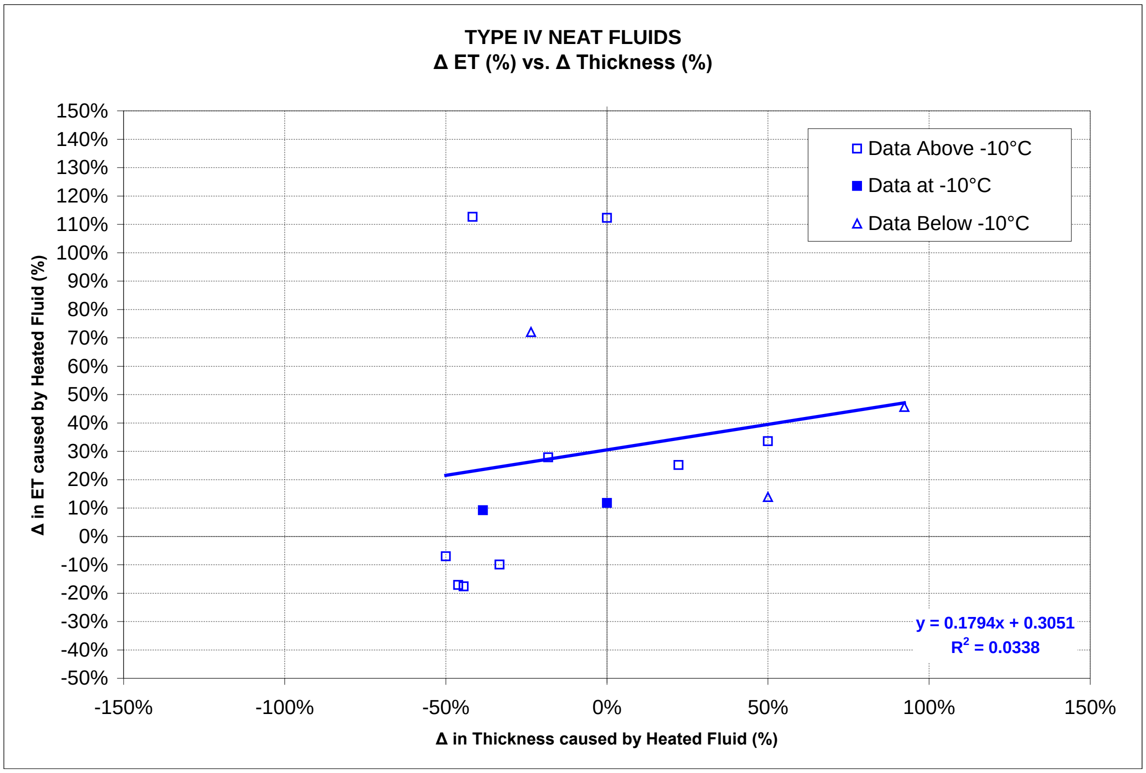
TYPE III NEAT FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 4.1667x - 0.05
R² = 0.0161
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)

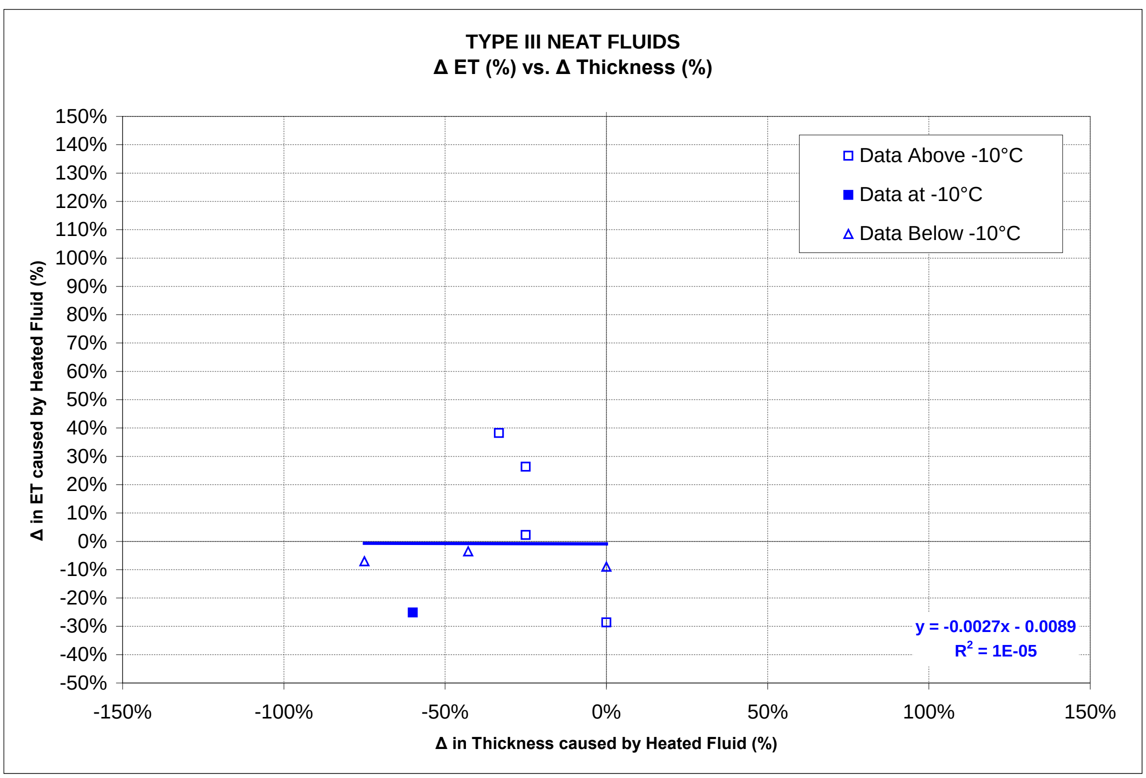

TYPE II NEAT FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 30.226x + 5.6452
R2 = 0.6448
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

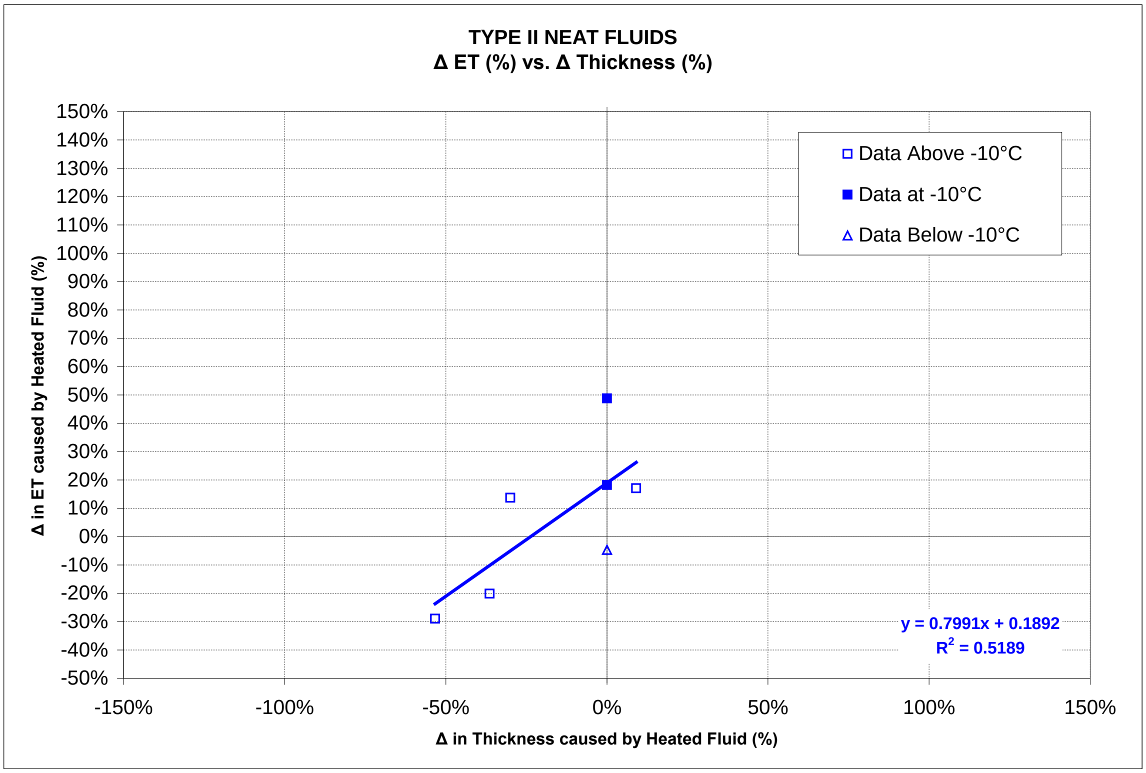

TYPE IV 75/25 FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 27.412x + 11.98
R2 = 0.594
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

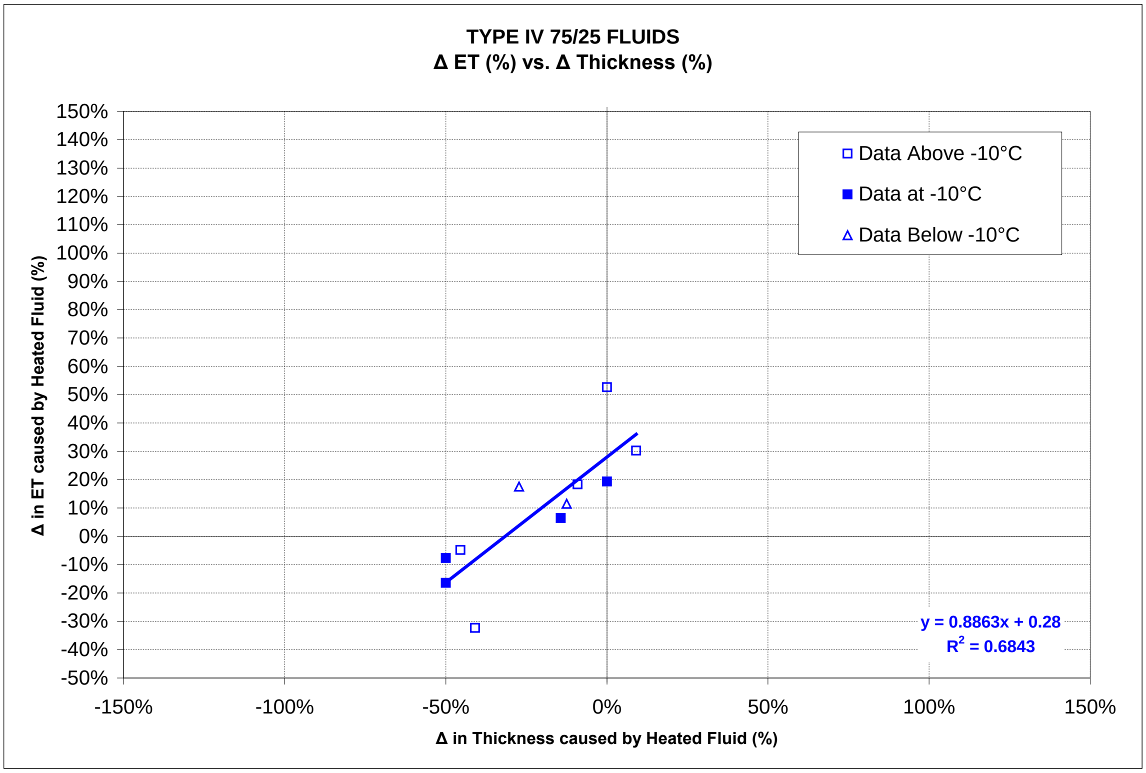

TYPE III 75/25 FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Data Above -10°C
Data Below -10°C
y = -10.571x - 0.7143
R2 = 0.7753
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

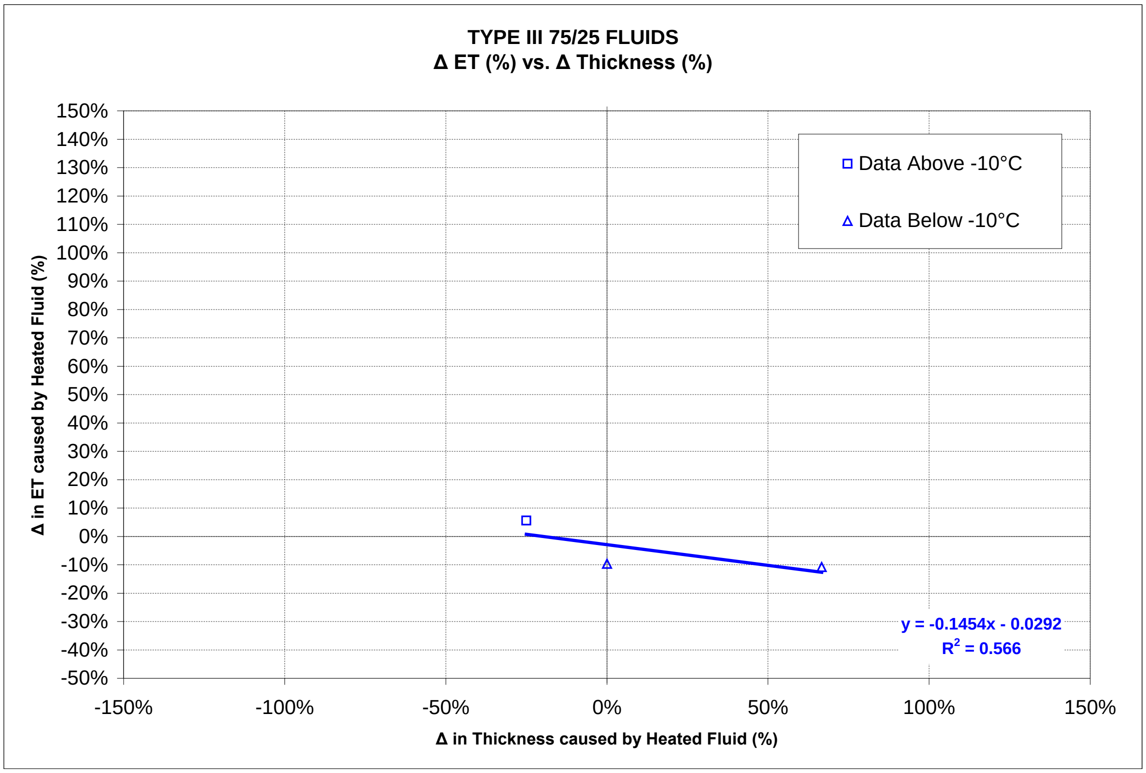

TYPE II 75/25 FLUIDS
Δ ET (mins) vs. Δ Thickness (mm)
Data Above -10°C
Data at -10°C
y = -12x - 11.9
R2 = 1
Δ in ET caused by Heated Fluid (mins)
Δ in Thickness caused by Heated Fluid (mm)
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5

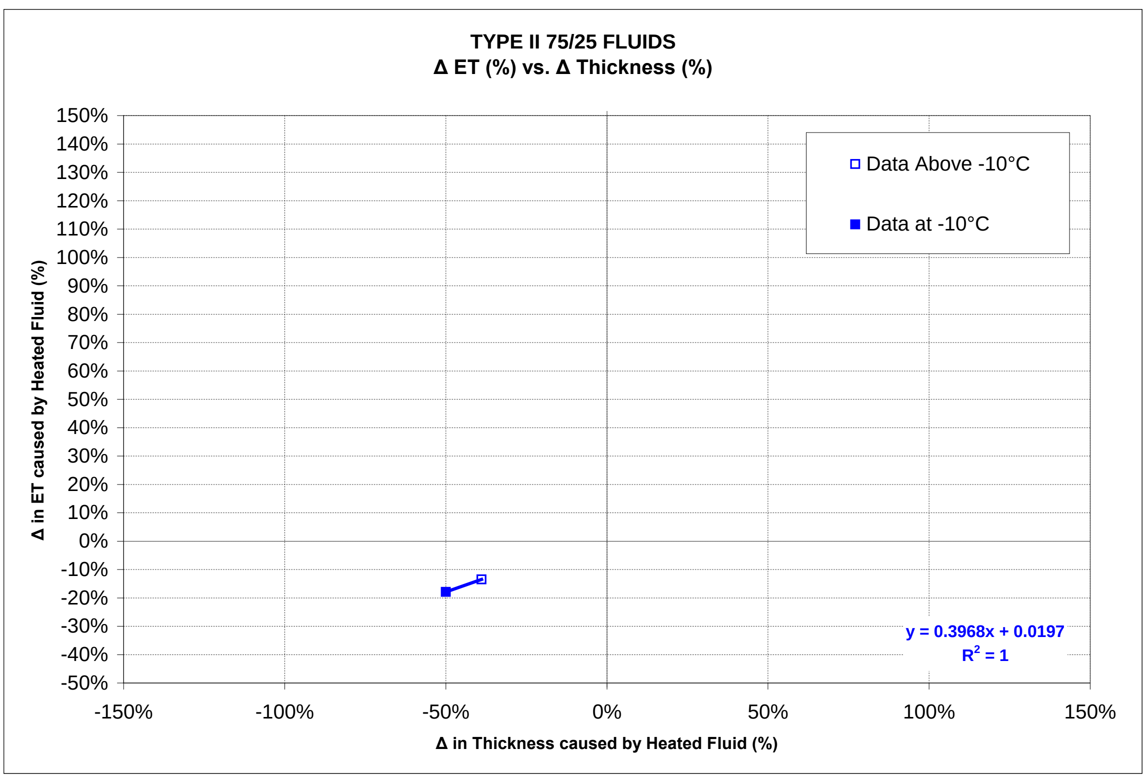

TYPE IV NEAT FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 0.1794x + 0.3051
R2 = 0.0338
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%


TYPE III NEAT FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = -0.0027x - 0.0089
R2 = 1E-05
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%


TYPE II NEAT FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 0.7991x + 0.1892
R2 = 0.5189


TYPE IV 75/25 FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)
Data Above -10°C
Data at -10°C
Data Below -10°C
y = 0.8863x + 0.28
R2 = 0.6843


TYPE III 75/25 FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data Below -10°C
y = -0.1454x - 0.0292
R^2 = 0.566
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)


TYPE II 75/25 FLUIDS
Δ ET (%) vs. Δ Thickness (%)
Data Above -10°C
Data at -10°C
y = 0.3968x + 0.0197
R^2 = 1
150%
140%
130%
120%
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-150%
-100%
-50%
0%
50%
100%
150%
Δ in ET caused by Heated Fluid (%)
Δ in Thickness caused by Heated Fluid (%)

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