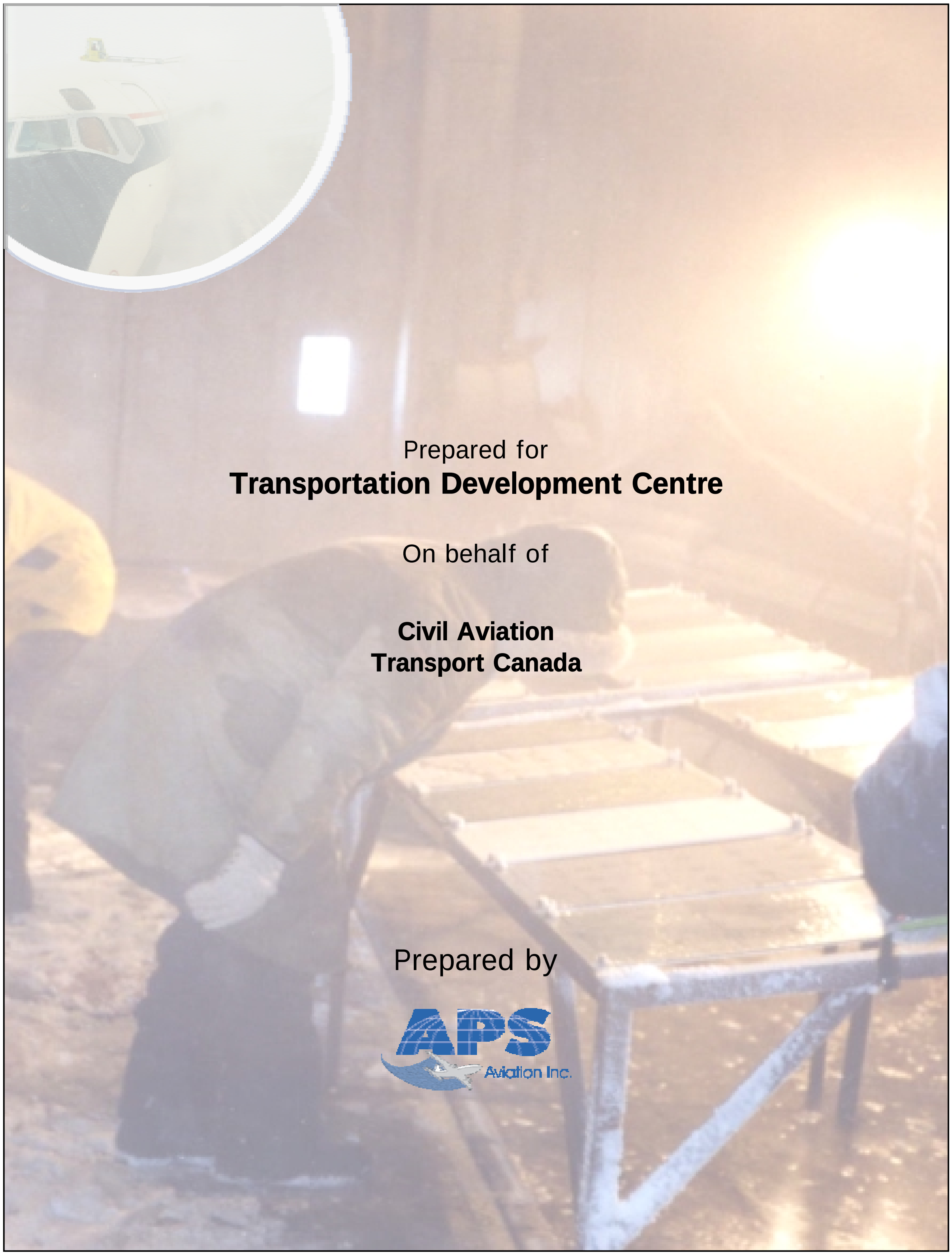
TP 14156E

Variance in Endurance Times of De/Anti-Icing Fluids



Prepared for
Transportation Development Centre

On behalf of

Civil Aviation
Transport Canada

Prepared by

APS Aviation Inc.

December 2003
Final Version 1.0

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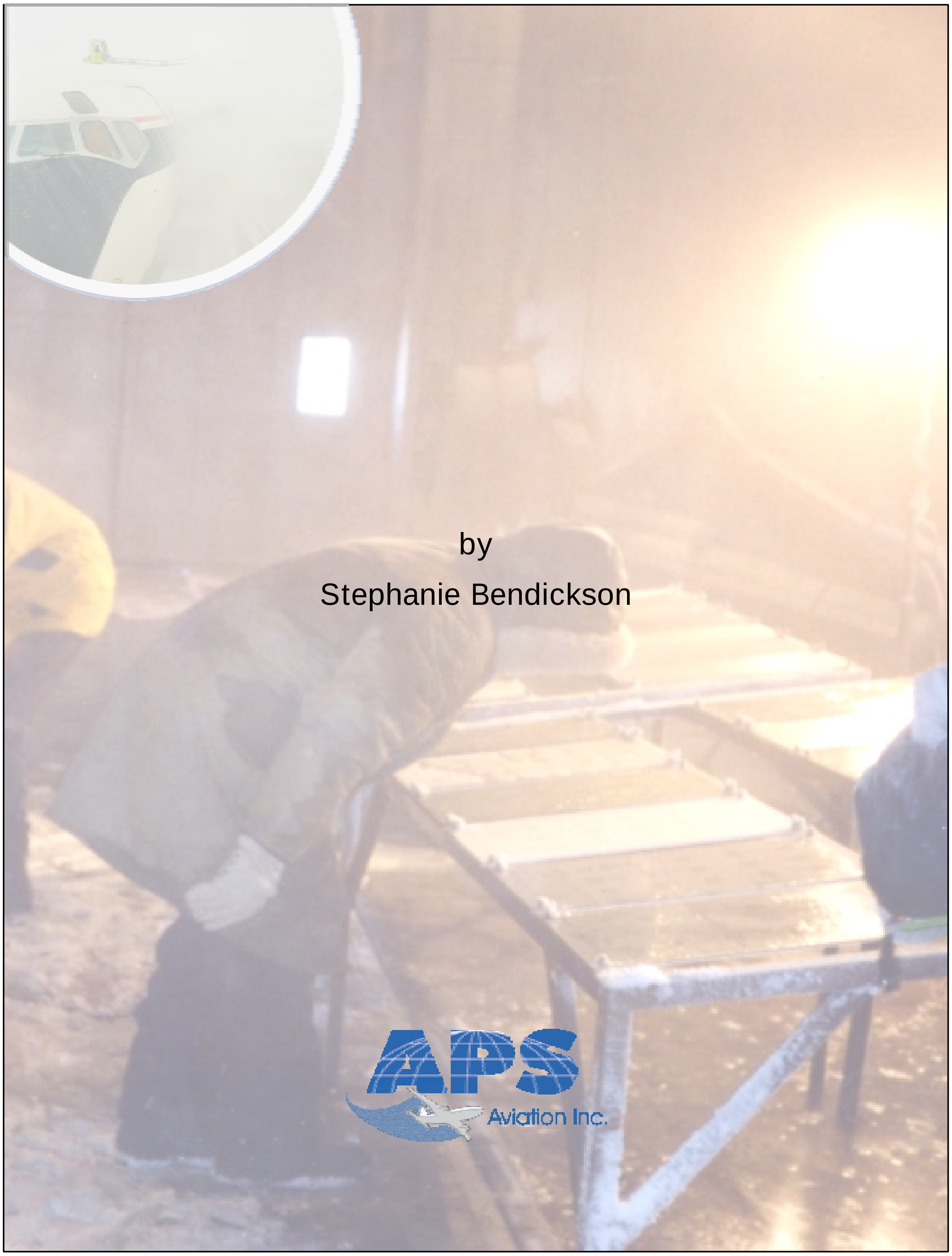

by

Stephanie Bendickson

APS Aviation Inc.

December 2003
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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 evaluate the parameters specified in Proposed Aerospace Standard 5485 for frost endurance time tests in a laboratory;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To further evaluate the flow of contaminated fluid from the wing of an aircraft during simulated takeoff runs;
- To compare endurance times in natural snow with those in laboratory snow;
- To compare fluid endurance time, holdover time and protection time;
- To compare snowfall rates obtained using the National Center for Atmospheric Research hotplate with rates obtained using rate pans;
- To further analyse the relationship between snowfall rate and visibility;
- To stimulate the development of Type III fluids;
- To measure endurance times of fluids applied using forced air-assisted systems;
- To conduct exploratory research, including measuring temperatures of applied Type IV fluids, measuring the effect of lag time on holdover time, evaluating the effectiveness of fluid coverage, and assessing the impact of taxi time on deicing holdover time; and
- To provide support services to Transport Canada.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2002-03 are documented in thirteen reports. The titles of the reports are as follows:

- TP 14144E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2002-03 Winter;
- TP 14145E Laboratory Test Parameters for Frost Endurance Time Tests;
- TP 14146E Winter Weather Impact on Holdover Time Table Format (1995-2003);
- TP 14147E Aircraft Takeoff Test Program for Winter 2002-03: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid;
- TP 14148E Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2002-03;
- TP 14149E Adhesion of Aircraft Anti-Icing Fluids on Aluminum Surfaces;

- TP 14150E Evaluation of a Real-Time Snow Precipitation Gauge for Aircraft Deicing Operations;
- TP 14151E Relationship Between Visibility and Snowfall Intensity;
- TP 14152E A Potential Solution for De/Anti-Icing of Commuter Aircraft;
- TP 14153E Endurance Times of Fluids Applied with Forced Air Systems;
- TP 14154E Aircraft Ground Icing Exploratory Research for the 2002-03 Winter;
- TP 14155E Aircraft Ground Icing Research Support Activities for the 2002-03 Winter; and
- TP 14156E Variance in Endurance Times of De/Anti-Icing Fluids.

This report, TP 14156E has the following objective:

- To quantify variance in endurance times caused by different individuals determining fluid failure.

This objective was met by conducting endurance time tests with individuals of varying levels of knowledge and expertise. Tests were conducted in natural snow at the APS test site and in simulated precipitation conditions at National Research Council Canada's Climatic Engineering Facility.

ACKNOWLEDGEMENTS

This overall multi-year research program has been funded by the Civil Aviation Group and Transport Canada with support from the Federal Aviation Administration, William J. Hughes Technical Center. 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. Special thanks are extended to US Airways Inc., Federal Express, American Eagle Airlines Inc., the National Center for Atmospheric Research, AéroMag 2000, Aéroports de Montreal, Ottawa International Airport Authority, GlobeGround North America, Cryotech, and Dow Chemical Company for provision of personnel and facilities and for their co-operation with the test program.

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: Alia Alwaid, Stephanie Bendickson, Nicolas Blais, Richard Campbell, Mike Chaput, Sami Chebil, John D'Avirro, Peter Dawson, Caroline Duclos, Miljana Horvat, Luis Lopez, Bob MacCallum, Mark Mayodon, Chris McCormack, Nicoara Moc, Marco Ruggi, Sherry Silliker, Ben Slater, and Kim Vepsa.

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

Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No. TP 14156E	2. Project No. 5241-45	3. Recipient's Catalogue No.
4. Title and Subtitle Variance in Endurance Times of De/Anti-Icing Fluids		5. Publication Date December 2003
		6. Performing Organization Document No. CM1747
7. Author(s) Stephanie Bendickson		8. Transport Canada File No. 2450-BP-14
9. Performing Organization Name and Address APS Aviation Inc. 1100 René Lévesque Blvd. West Suite 1340 Montreal, Quebec Canada H3B 4N4		10. PWGSC File No. MTB-2-00015
		11. PWGSC or Transport Canada Contract No. T8200-011557/001/MTB
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 800 René Lévesque Blvd. West Suite 600 Montreal, Quebec H3B 1X9		13. Type of Publication and Period Covered Final
		14. Project Officer Barry B. Myers

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

Research reports produced on behalf of Transport Canada for testing during previous winters are available from the Transportation Development Centre (TDC). Thirteen reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface.

16. Abstract

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. (APS) undertook a research program to analyse variance in endurance times caused by different individuals determining fluid failure. Due to limited funding, only a limited number of tests were conducted. These tests were conducted in conjunction with other projects that were part of the 2002-03 winter research program.

The key difference between the tests conducted for this project and standard endurance time tests was that several individuals with various levels of knowledge, training and experience recorded fluid failures for the tests. Tests were conducted in natural snow at the APS test site at Montreal International Airport, Dorval, and under simulated precipitation conditions at National Research Council Canada's Climatic Engineering Facility in Ottawa. Tests were conducted at various temperatures and rates of precipitation, and with different dilutions of Type I, II and IV fluids.

As a result of modifications made to the procedure and the limited number of tests conducted, precise values for the variance in endurance times in specific conditions could not be confirmed. However, one important conclusion drawn was that knowledge, training and experience do have an effect on variance in endurance times. It was concluded that if a novice or intermediate individual determined fluid failures during holdover time testing, the values in the generic holdover time guidelines could decrease significantly over time.

In the short term it is recommended that the individual who has determined fluid failures in endurance time testing over the past several winters continue to do so. Other individuals should be provided with a training manual and should begin to record fluid failures under supervision. One long-term solution that could minimize variance in endurance times is to develop fluid failure sensor technology.

17. Key Words Deicing, anti-icing, endurance time, fluid failure, fluids, holdover time, variance, snow	18. Distribution Statement Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication) Unclassified	20. Security Classification (of this page) Unclassified	21. Declassification (date) —	22. No. of Pages xvi, 38, apps	23. Price Shipping/ Handling

CDT/TDC 79-005
Rev. 96

Canada

Transports Canada | Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada TP 14156E	2. N° de l'étude 5241-45	3. N° de catalogue du destinataire
4. Titre et sous-titre Variance in Endurance Times of De/Anti-Icing Fluids		5. Date de la publication Décembre 2003 6. N° de document de l'organisme exécutant CM1747
7. Auteur(s) Stephanie Bendickson		8. N° de dossier - Transports Canada 2450-BP-14
9. Nom et adresse de l'organisme exécutant APS Aviation Inc. 1100, boul. René-Lévesque Ouest Bureau 1340 Montréal (Québec) Canada H3B 4N4		10. N° de dossier - TPSGC MTB-2-00015 11. N° de contrat - TPSGC ou Transports Canada T8200-011557/001/MTB
12. Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) 800, boul. René-Lévesque Ouest Bureau 600 Montréal (Québec) H3B 1X9		13. Genre de publication et période visée Final 14. Agent de projet Barry B. Myers

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

Les rapports de recherche produits au nom de Transports Canada sur les essais réalisés au cours des hivers antérieurs peuvent être obtenus auprès du Centre de développement des transports (CDT). Le programme de la saison hivernale a donné lieu à treize rapports (dont celui-ci). On trouvera dans la préface l'objet de ces rapports.

16. Résumé

Dans le cadre d'un contrat passé avec le Centre de développement des transports de Transports Canada, APS Aviation Inc. (APS) a entrepris un programme de recherche visant à analyser les variations du temps d'endurance attribuables au fait que la perte d'efficacité est déterminée par différentes personnes. En raison de fonds limités, seulement un nombre restreint d'essais ont été effectués. Ceux-ci ont été menés conjointement avec d'autres projets du programme de recherche de l'hiver 2002-2003.

Le principal point qui distingue les essais effectués au cours du présent projet et les essais d'endurance standard est que la perte d'efficacité était enregistrée par plusieurs personnes, qui possédaient divers degrés de connaissance, de formation et d'expérience. Les essais ont été effectués avec de la neige naturelle au site d'essai d'APS, à l'Aéroport international de Montréal, Dorval, et sous des précipitations artificielles à l'Installation de génie climatique (IGC) du Conseil national de recherches du Canada (CNRC), à Ottawa. Ils ont été menés à différentes températures, sous différentes intensités de précipitations, et avec des liquides de types I, II et IV affichant différents taux de dilution.

En conséquence de modifications apportées à la procédure d'essai et du nombre restreint d'essais, il a été impossible de confirmer les valeurs précises de variation du temps d'endurance obtenues dans diverses conditions. Toutefois, une conclusion importante a été tirée : les connaissances, la formation et l'expérience ont effectivement une incidence sur les variations du temps d'endurance. De fait, si une personne de niveau débutant ou intermédiaire déterminait la perte d'efficacité lors des essais visant à déterminer la durée d'efficacité des liquides, les valeurs des tableaux des durées d'efficacité pourraient diminuer de façon importante avec le temps.

À court terme, il est recommandé que la personne qui a déterminé les pertes d'efficacité lors des essais d'endurance des derniers hivers continue de le faire. Mais d'autres personnes devraient recevoir un guide de formation et commencer à prendre note des pertes d'efficacité sous supervision. Une solution à long terme, qui permettrait d'atténuer les variations du temps d'endurance, serait de développer une technologie de détection de la perte d'efficacité.

17. Mots clés Dégivrage, antigivrage, temps d'endurance, perte d'efficacité, liquides, durée d'efficacité, variations, neige	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	—	xvi, 38, ann.	Port et manutention

EXECUTIVE SUMMARY

Over the past decade the procedure for holdover time testing of de/anti-icing fluids has been refined. However, the determination of fluid failure, which is a critical aspect in the testing, remains subjective. Over the past several winters, the same experienced individual has determined fluid failure during all de/anti-icing holdover time tests in order to ensure the test results are consistent.

The possibility that a fluid failure sensor may never be developed successfully, coupled with an increased awareness of the dependency of the test program on the same individual and the possibility that the testing process may be commercialized in the future, necessitated a research project be carried out to investigate the variance in endurance times caused by different individuals determining fluid failure.

Due to the limited funding available for this project, tests were conducted in conjunction with testing for other projects. As a result, some procedural modifications were necessary. Nevertheless, tests were carried out with individuals with various levels of knowledge, training and experience determining fluid failures.

The precise variance values calculated under specific conditions may need to be confirmed by a large-scale test program due to the limited number of tests conducted. However, results indicated that variables that cause endurance times to be shorter – including high precipitation rates, Type I fluid, highly diluted fluid, and low ambient temperatures – increase variance in endurance times. One exception to this generalization was tests conducted in warmer temperatures in natural snow. It is possible that part of the variance observed in the shorter tests was a result of the test design.

Despite the limitations imposed on the precise calculations and conclusions described above, one conclusion that is confirmed by the test program is that endurance times vary depending on the individual who determines fluid failure. This variance can be considerable even when an individual with an intermediate level of knowledge, experience and training conducts endurance time tests. Allowing one of these individuals to conduct endurance time tests could have a significant effect on the test results and on the generic holdover time guidelines.

In the short term it is recommended that the individual who has determined fluid failure in endurance time testing over the past several winters continue to do so. Other individuals should be provided with a training manual and should begin determining fluid failures under the supervision of the above individual. One long-term solution that could minimize variance in endurance times is to develop fluid failure sensor technology.

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SOMMAIRE

Au cours des dix dernières années, la procédure des essais visant à déterminer la durée d'efficacité des liquides de dégivrage/antigivrage a été peaufinée. Toutefois, la détermination de la perte d'efficacité, un aspect crucial des essais, demeure subjective. Durant les derniers hivers, pour assurer la constance des résultats, c'est le même expert qui a déterminé la perte d'efficacité pour tous les essais.

Étant donné l'incertitude quant à la faisabilité d'un détecteur de perte d'efficacité, conjuguée à la conscience de plus en plus aiguë que le programme d'essai dépend d'une seule et même personne et que le processus d'essai pourrait être commercialisé dans l'avenir, il est apparu nécessaire de mener un projet de recherche pour examiner les variations du temps d'endurance attribuables au fait que différentes personnes déterminent la perte d'efficacité.

En raison des fonds limités accordés au présent projet, les essais ont été effectués conjointement avec les essais d'autres projets. En conséquence, il a fallu modifier la procédure. Cela étant, les essais ont fait appel à des personnes qui possédaient divers degrés de connaissance, de formation et d'expérience pour déterminer la perte d'efficacité des liquides.

Compte tenu du nombre limité d'essais effectués, il pourrait s'avérer nécessaire de confirmer les valeurs de variation précises obtenues dans des conditions spécifiques, au cours d'un programme d'essais en vraie grandeur. Cela dit, les résultats ont révélé que les variables qui entraînent une diminution du temps d'endurance – intensité de précipitation élevée, liquide de type I, taux de dilution élevé, températures ambiantes faibles – accentuent les variations du temps d'endurance. Mais les essais effectués aux températures supérieures, avec de la neige naturelle, échappent à cette généralisation. Par ailleurs, il est possible que les variations observées dans les temps d'endurance les plus courts soient dues en partie au plan d'essai.

Malgré les restrictions décrites ci-dessus touchant la validité des calculs et des conclusions, le programme d'essais permet de confirmer que le temps d'endurance varie en fonction de la personne qui détermine la perte d'efficacité. Cette variation peut être considérable même quand la personne possède un niveau intermédiaire de connaissance, d'expérience et de formation. Le fait de permettre à une telle personne d'effectuer les essais d'endurance pourrait avoir une incidence de taille sur les résultats des essais et sur les tableaux des durées d'efficacité.

À court terme, il est recommandé que la personne qui a déterminé la perte d'efficacité dans le cadre des essais d'endurance menés au cours des derniers

hivers continue de le faire. Mais d'autres personnes devraient recevoir un guide de formation et commencer à noter les pertes d'efficacité sous la supervision de l'expert. Une solution à long terme, qui permettrait d'atténuer les variations du temps d'endurance, serait de développer une technologie de détection de la perte d'efficacité.

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GLOSSARY

APS	APS Aviation Inc.
AS	Aerospace Standard
ET Score	Endurance Time Score
FAA	Federal Aviation Administration
NRC	National Research Council Canada
OAT	Outside Air Temperature
TC	Transport Canada

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1. INTRODUCTION

1.1 Background

The procedure for endurance time testing of de/anti-icing fluids has been refined over many years. The level of accuracy demanded in Proposed Aerospace Standard (AS) 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids: SAE Type I, II, III, and IV* (1), related to this testing is very high. However, the determination of fluid failure, which is a critical aspect in the testing, remains subjective. Over the past several winters, the same experienced individual has determined fluid failures during all de/anti-icing holdover time tests. Using the same individual has led to consistent results and for this reason, the individual has become an invaluable part of the holdover time testing program.

Efforts have been made to calibrate fluid failure determination using sensor technology. Several fluid failure sensors have been tested over the last decade but to date, none have been developed to the level required by the industry. Previously, the primary purpose of testing and developing these sensors was to create a tool that could be used in real-world settings: for example, to check for contaminated fluid on aircraft wings. Calibrating fluid failure determination in a test setting was considered a secondary objective.

The possibility that a fluid failure sensor that can monitor and identify contamination in all conditions may never be developed, coupled with an increased awareness of the dependency of the test program on the same individual and the possibility that the testing process may be commercialized in the future, necessitated a research project be carried out to investigate the variance in endurance times caused by different individuals determining fluid failures.

1.2 Objectives

The scope of work for this project is outlined in an excerpt from the Transportation Development Centre work statement provided in Appendix A.

In the winter of 2001-02, APS briefly examined variance in endurance times of selected fluids in selected conditions. During this preliminary series of tests, the same individual determined fluid failures in order to remove variance caused by different individuals determining fluid failure from the results. The conclusion drawn from these preliminary tests was that endurance times are typically within 10 percent of the mean average when the same individual determines fluid failures. Refer to Section 8 of the Transport Canada (TC) report, TP 13991E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Testing Program for the 2001-02 Winter,* (2), for a detailed description of these tests.

In the winter of 2002-03, tests were conducted in order to examine variance in endurance times caused by different individuals determining fluid failure. The intent was to determine whether expertise and experience influence individuals' ability to determine fluid failures accurately and reliably. The specific objectives of the test program were as follows:

a) To quantify variance in endurance times caused by different individuals determining fluid failure;

b) To evaluate the influence of training and experience on ability to determine fluid failure; and

c) To evaluate the influence of precipitation condition, precipitation rate, ambient temperature, fluid type, fluid dilution, and fluid chemistry on variance in endurance times.

Due to the limited funding available for this project, testing was completed in conjunction with testing for other projects and the number of tests conducted was limited.

2. METHODOLOGY

This section provides a description of the test methodology. Tests were conducted primarily following the test methodology for holdover time testing. This methodology is documented in detail in the TC report, TP 14144E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2002-03 Winter* (3). While the most important details pertaining to the variance tests have been included here, further information is available on weather conditions, test sites, equipment and holdover time test procedures in that report.

2.1 Weather Conditions

Tests were conducted in most precipitation conditions in which endurance times of new fluids are tested. These conditions included natural snow, freezing fog, freezing drizzle and freezing rain. Tests were performed at the upper and lower limits for precipitation rates for most of the precipitation types.

2.2 Test Sites

Tests conducted in natural snow were performed at the APS test site located at Dorval Airport in Montreal (see Photo 2.3). Tests conducted in simulated freezing fog, freezing rain and freezing drizzle were conducted indoors at the National Research Council Canada (NRC) Climatic Engineering Facility in Ottawa (see Photos 2.1 and 2.2).

2.3 Test Procedures

Two procedures were developed for this project. The initial procedure, included in Appendix B, was developed for testing in natural snow conditions. Following initial testing in natural snow, the procedure was revised and a new procedure, included in Appendix C, was issued for indoor testing.

Standard endurance time test and rate collection protocols were followed. The standard endurance time test procedure requires one individual to determine fluid failures. However, for these tests several individuals with various levels of expertise and training were required to record fluid failure for each test. Subsection 2.6 gives a detailed description of the personnel determining fluid failures.

2.4 Fluids

A variety of Type I, Type II and Type IV fluids were tested. Fluids tested are presented in Table 2.1. For the purposes of this test program, fluids were analysed by fluid characteristics but not by individual fluid.

Table 2.1 Fluids Tested

Fluid Name	Fluid Type	EG/PG
UCAR EG ADF	Type I	EG
Clariant MP I 1938	Type I	PG
Kilfrost ABC 2000	Type II	PG
Clariant Safewing MPII 1951	Type II	PG
Clariant Safewing MP II 2025	Type II	PG
Dow/UCAR Ultra+	Type IV	EG
Clariant Safewing MP IV 2001	Type IV	PG
Clariant Safewing MP IV 2030	Type IV	PG

2.5 Data Forms

A project-specific endurance time data form was developed in order to conduct blind tests and to eliminate the possibility of "cheating". The initial version, published in the outdoor procedure (see Appendix B), had the participants check plates sequentially at set time intervals. The time interval was 30 seconds for Type I fluids and 60 seconds for Type II and Type IV fluids. At each time interval participants indicated "failed" or "not failed" on their data forms.

After initial testing was conducted, the data form was revised due to logistical difficulties. The revised data form, published in the indoor procedure (see Appendix C), required all participants to check the plates at approximately the same time and offered more flexibility as specific times were not indicated. For Type I tests, participants remained in the test stand area and filled in the data form every 30 seconds until the plate was well past failed. For Type II and Type IV tests, participants checked the plates approximately once every 60 seconds.

2.6 Personnel

This project required personnel with various levels of expertise and experience to record the fluid failure for each test. In order to facilitate data processing, all personnel involved in the project were categorized as novice, intermediate or expert. Following is a description of each category:

a) Novice: These individuals had limited or no knowledge of fluid failure and had never determined fluid failures. For natural snow tests they were instructed to read the definition of fluid failure described and photographed in the procedure *Experimental Program for Natural Precipitation Flat Plate Testing,* which is included in TC report, TP 14144E (3). For indoor precipitation tests, novices were instructed to read the definition of fluid failure as stated in Proposed SAE Aerospace Standard (AS) 5485 (1):

   Failure is called when 30 percent of the plate is covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

   - *Ice front;*
   - *Ice sheet;*
   - *Slush, in clusters or as a front;*
   - *Disseminated fine ice crystals;*
   - *Frost on surface; and*
   - *Clear ice pieces partially or totally imbedded in fluid.*

   Novices were not given feedback during the test program.

b) Intermediate: These individuals had previously received informal training and had some experience determining fluid failures. For the purposes of this test program, they were not given additional training nor were they required to read AS 5485 (1). Intermediates were not given feedback during the test program.

c) Expert: These individuals had comprehensive knowledge of fluid failure and extensive experience determining fluid failures.

The following are brief descriptions of the individuals who recorded fluid failures:

a) Expert 1: This is the individual, described in the introduction, who has been responsible for determining fluid failure in endurance time testing over the past several winters;

b) Expert 2: This individual has been involved in endurance time testing for over 10 years, is knowledgeable about all aspects of fluid failure and supervised Expert 1 for many years;

c) Intermediate 1: This individual was closely trained by Expert 1 just prior to the conduct of these tests and has been involved in the testing of de/anti-icing fluids for three years;

d) Intermediate 2: This individual has limited knowledge and experience determining fluid failure and has been involved in the testing of de/anti-icing fluids for two years;

e) Intermediate 3: This individual also has limited knowledge and experience determining fluid failure and has been involved in the testing of de/anti-icing fluids for three years;

f) Intermediate 4: This individual has extensive knowledge of endurance time testing, but no experience determining fluid failures. This individual has been involved in de/anti-icing research for approximately 15 years; and

g) Novices 1 to 7: None of these individuals had ever seen fluids fail and none had previous knowledge of the definition of fluid failure prior to the test program. Although they were given no feedback throughout the test season, the individuals who conducted a large number of tests did improve over time (see Subsection 4.1.2).

2.7 Procedural Alterations

Although the data forms outlined strict procedures pertaining to when plates were checked for fluid failure, in practice, parts of the procedure were difficult to follow and therefore several minor procedural changes had to be made. The main difficulty was the “piggybacking” (conducting variance tests in conjunction with tests for other projects) of these tests, which resulted in complications. For example, many tests were conducted with adherence tests and during these tests the novice variance testers were required to measure Brix and thickness for the adherence tests. At these times it was not always possible for the novices to fill out their data form every 30 or 60 seconds as required. However, the novices continued to monitor the plates when possible and recorded the actual failure times on their data form. During some snow tests, the novices were also required to conduct rate pan measurements.

In addition, when the intermediate and/or expert individuals were involved in other projects at the same time they were determining fluid failures for the variance project, they often recorded failure times on the data forms pertaining to their own tests. This meant that they often did not check the fluid every 30 or 60 seconds as required by the procedure.

The second difficulty with the procedure was the requirement of an expert’s participation. Only two individuals were classified as expert for the purposes of these tests. One of these individuals was very busy with other projects and was only used when variance tests were conducted in conjunction with these projects. The remaining person was not always available, and when available, was often involved simultaneously with one or two other projects. As a result, there were no expert failures recorded during several tests.

Photo 2.1: Outdoor View of National Research Council Canada Facility

Photo 2.2: Inside View of National Research Council Canada Facility

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Photo 2.3: APS Test Site

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3. DESCRIPTION AND PROCESSING OF DATA

This section presents the data and describes the data analysis methodology.

3.1 Test Definition

Each entry in the test log represents one individual's recorded fluid failure for one test. For the purpose of this test program, a test is defined as one fluid poured on one test plate at a given time. As anywhere from two to five people recorded fluid failures for each test, an additional number was given to each fluid failure recorded in order to uniquely identify each log entry. As an example, if three individuals recorded fluid failures for the first test, there would be three entries in the log. The first entry would be Test 1, Observation 1; the second entry would be Test 1, Observation 2; and the third entry would be Test 1, Observation 3.

3.2 Tests Conducted

A complete log of tests showing details from each of the 116 tests conducted is included in Appendix D. Following is a brief description of the column headings in the test log:

Test No.:	A unique number identifying each test – numerous observations were made for each test;
Observation:	Number identifying each fluid failure recorded for a test;
Fluid:	Fluid name;
Dilution:	Glycol/water ratio of the fluid;
PG/EG:	Propylene glycol-based or ethylene glycol-based fluid;
Fluid Type:	Type I, II or IV;
Precipitation:	Type of precipitation in which the test was conducted;
Rate:	Rate of precipitation at which the test was conducted;
Temperature:	Temperature at which the test was conducted;
Start Time:	Time the fluid was poured on the plate;
End Time:	Time the individual recorded fluid failure;
Endurance Time:	End time minus start time, in minutes;
Endurance Time Score:	Endurance time calculated as a percentage of the expert's endurance time; and
Level:	Category the individual was placed in as described in Subsection 2.6.

Some tests were not used in the main analysis because no expert individual was available to record fluid failure during these tests. Refer to Subsection 3.3.2 for a further explanation of removed tests. Table 3.1 shows the total number of tests conducted by precipitation condition. As indicated in this table, an expert was present during 98 of the 116 tests. These 98 tests formed the main analysis. Because the majority of removed tests were conducted in natural snow, the number of tests conducted in natural snow is shown separated by test session in Table 3.2.

Table 3.1: Number of Tests Included in Main Analysis

Precipitation Condition	Tests Conducted	Tests Conducted when Expert Present	Failures Recorded when Expert Present
Natural Snow	70	56	183
Freezing Fog	14	14	47
Freezing Drizzle	12	8	30
Freezing Rain	20	20	77
Total	116	98	337

Table 3.2: Number of Natural Snow Tests Included in Main Analysis

Date	Number of Tests	Tests Conducted when Expert Present	Observations made when Expert Present
March 2, 2003	9	9	27
March 4, 2003	15	15	46
March 8, 2003	15	15	45
April 5, 2003	31	17	65
Total	70	56	183

Tables 3.3 to 3.8 show the number of tests conducted by each of the variables investigated: precipitation type, precipitation rate, fluid type, fluid chemistry, fluid dilution and ambient temperature. The tables include only the tests conducted when an expert recorded failures.

Table 3.3: Number of Tests Conducted by Precipitation Type

Precipitation Type	Number of Tests
Natural Snow	56
Freezing Fog	14
Freezing Drizzle	8
Freezing Rain	20
Total	98

Table 3.4: Number of Tests Conducted by Precipitation Rate

Precipitation Rate	Number of Tests
Low (NRC)	19
High (NRC)	23
Light Snow	19
Moderate Snow	31
Heavy Snow	6
Total	98

Table 3.5: Number of Tests Conducted by Fluid Type

Fluid Type	Number of Tests
Type I	20
Type II	21
Type IV	57
Total	98

Table 3.6: Number of Tests Conducted by Fluid Chemistry

Fluid Chemistry	Number of Tests
PG	67
EG	31
Total	98

Table 3.7: Number of Tests Conducted by Fluid Dilution

Fluid Dilution	Number of Tests
Neat	47
75/25	16
50/50	15
10º Buffer	20
Total	98

Table 3.8: Number of Tests Conducted by Ambient Temperature

Ambient Temperature (ºC)	Number of Tests
-3 (NRC)	20
-10 (NRC)	13
-14 (NRC)	4
-25 (NRC)	5
-3 to -4 (Dorval)	21
-5 to -6 (Dorval)	20
-10 to -12 (Dorval)	15
Total	98

3.3 Analysis Methodology

3.3.1 Expert's Endurance Times as Reference Points

In order to compare endurance times calculated by different individuals, it is necessary to have a point of reference. There is currently no technology available that can accurately determine fluid failure; therefore, human measurements must be used. In other situations, the average test result would be used as the point of comparison and individual measurements would be compared to this average. However, in this situation an assumption has been made that the endurance time observed by the expert will be closest to the actual value. For the purposes of data analysis, the expert's endurance time has been assumed to be the actual endurance time (AET).

Novice and intermediate endurance times are presented in this report as a percentage of the expert's endurance time. This statistic is referred to as the endurance time score (ET score). The formula used to calculate the ET score is:

$$ET\ Score = \frac{Individual\ Endurance\ Time}{Expert\ Endurance\ Time}\ x\ 100 \qquad (1)$$

The example shown in Table 3.9 illustrates this calculation. The value for Novice 1 is calculated by dividing the Novice 1 endurance time by the Expert 1 endurance time (7 minutes/10 minutes = 0.7). Values are multiplied by 100 to obtain a percentage (70%).

Table 3.9: Example of ET Score Calculation

Individual	Endurance Time	ET Score
Expert 1	10 minutes	100%
Intermediate 1	12 minutes	120%
Novice 1	7 minutes	70%
Novice 2	13 minutes	130%

3.3.2 Removed Tests

As noted in Subsection 3.2, fluid failure was not recorded by an expert for every test. Because the expert's endurance time is required to analyze the novice and intermediate endurance time for each test, tests where no expert recorded fluid failure were removed from the analysis. Eighteen tests, including eighteen novice observations and thirty-one intermediate observations, were removed for this reason. At the time of test design the importance of the expert's observation was not known and therefore the tests were conducted despite the unavailability of the experts.

In addition, when two experts recorded fluid failure for the same test, one of the resulting endurance times was removed because only one could be used as the reference point. Five expert observations were removed from the analysis for this reason.

3.3.3 Average and Standard Deviation Measurements

Two statistics were calculated to analyse the data. The first was the average ET score, which shows whether the individual's judgments of endurance times were close to the endurance times established by the expert. The nearer the average ET score is to 100 percent, the closer it is to the expert's evaluation. If the number is greater than 100 percent, then the individual has tended to overestimate endurance times; if it is below 100 percent, the individual has tended to underestimate endurance times.

The second statistic calculated was the standard deviation of the ET score. A standard deviation is a measure of variance calculated in the same units as the data set (percentages in this data). In this data set, the standard deviation measures the variance in endurance times. For example, if the standard deviation is 14 percent, it indicates that 68 percent of the endurance times in the sample were within 14 percent above or below the average endurance time. It should be noted that one standard deviation includes 68 percent of the data points in a sample. The formula used to calculate the standard deviation (σ) is:

$$\sigma = \sqrt{\frac{\sum \left(x_i - \bar{x}\right)^2}{n-1}} \tag{2}$$

The four situations that can occur when comparing these statistics are illustrated in Table 3.10.

Ideally, the average ET score should be near the AET value and the standard deviation should be small. If the standard deviation is small but the average ET score differs from the AET value, it indicates that fluid failure is determined consistently, but the individual judges that failure occurs at a different time than the expert's (AET value). For example, the individual may consistently measure endurance times five percent longer than that judged by the expert (AET value). While this scenario indicates a problem, the problem should be easily corrected by providing the individual with training on the definition of fluid failure. Once this individual has an understanding of the true definition, he or she should consistently measure fluid failures accurately.

However, if the standard deviation is high, it indicates the individual does not understand how to identify fluid failure. In this scenario, the average is not relevant because even if the average is near the AET value, most of the measurements will be significantly lower or higher than the AET value and it is just a coincidence that they have balanced out. This individual will require much more training than the previous individual. It is for this reason that this report examines variance in endurance times.

Table 3.10: Implications of Average and Variance Measurements

Variance / Average	Small	Large
Near True Value	Ideal	Problematic
Far From True Value	Correctable	Problematic

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4. ANALYSIS AND OBSERVATIONS

In this section the data is analysed by expertise level, precipitation type, precipitation rate, fluid type, fluid chemistry, fluid dilution and ambient temperature. In each analysis, the average ET score and the standard deviation of the ET scores of intermediates and novices are calculated. The number of observations included in the calculation is also shown in order to indicate cases where very limited numbers of observations may have rendered the statistics unreliable.

4.1 Expertise Level

Data was sorted by expertise level and it was found that the majority of intermediate ET scores were between 88 and 116 percent. In contrast, the majority of novice ET scores were between 75 and 119 percent. These statistics are presented in Table 4.1 and are also shown graphically in Figure 4.1. Three light grey lines on each data series in Figure 4.1, and on the remaining figures in this section, indicate the average, the average less one standard deviation, and the average plus one standard deviation.

Table 4.1: Endurance Time Comparison by Expertise Level

		Intermediate	Novice
All Conditions	Average	102%	97%
	Std. Dev. (σ)	14%	22%
	Observations	98	133

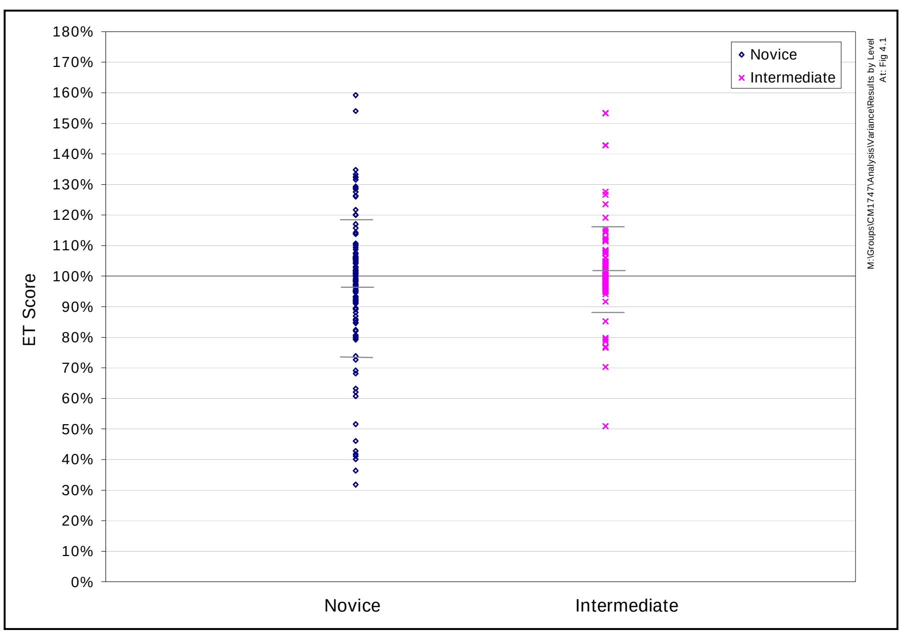

Figure 4.1: Endurance Time Variance by Expertise Level – All Conditions

4.1.1 Individual Results

Results were examined on an individual basis. As can be seen in Table 4.2 and Figure 4.2, there is a difference between individuals at the same level. This indicates that the ability to determine fluid failure does not depend solely on expertise and level of training. Some individuals (Intermediate 4, Novice 3, Novice 5 and Novice 7) recorded fluid failures significantly prematurely.

Table 4.2: Endurance Time Comparison by Individual

Intermediate 1	Average	106%
	Std. Dev. (σ)	7%
	Observations	17
Intermediate 2	Average	99%
	Std. Dev. (σ)	3%
	Observations	27
Intermediate 3	Average	103%
	Std. Dev. (σ)	19%
	Observations	49
Intermediate 4	Average	89%
	Std. Dev. (σ)	9%
	Observations	5
All Intermediates	Average	102%
	Std. Dev. (σ)	14%
	Observations	98

Novice 1	Average	101%
	Std. Dev. (σ)	17%
	Observations	72
Novice 2	Average	103%
	Std. Dev. (σ)	24%
	Observations	15
Novice 3	Average	85%
	Std. Dev. (σ)	37%
	Observations	23
Novice 4	Average	102%
	Std. Dev. (σ)	8%
	Observations	7
Novice 5	Average	89%
	Std. Dev. (σ)	9%
	Observations	8
Novice 6	Average	99%
	Std. Dev. (σ)	2%
	Observations	3
Novice 7	Average	75%
	Std. Dev. (σ)	36%
	Observations	5
All Novices	Average	97%
	Std. Dev. (σ)	22%
	Observations	133

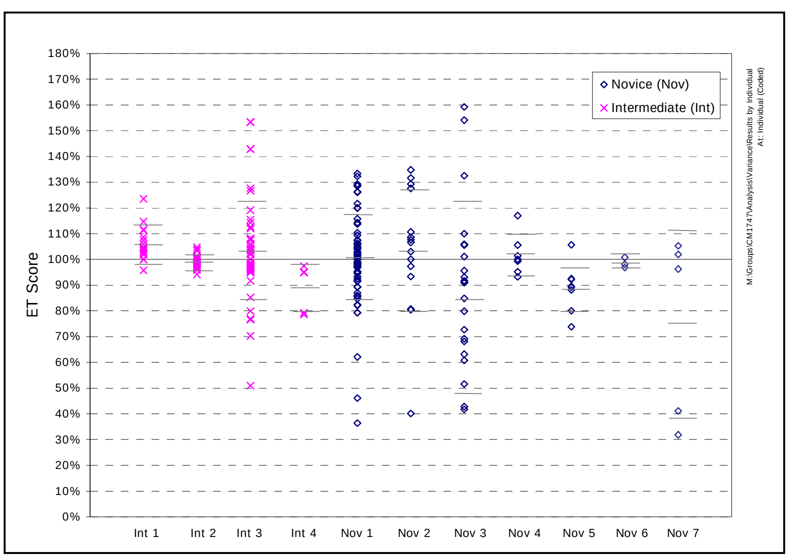

Figure 4.2: Endurance Time Variance by Individual – All Conditions

4.1.2 Novice Learning Curve

Figure 4.3 shows the difference between the Novice 1 endurance time and the expert endurance time for snow tests where Novice 1 recorded fluid failures. The difference between the novice and expert endurance times (NE) is expressed as an absolute percentage. The values were calculated using the formula:

$$NE = \left| ET\ Score - 100\% \right| \quad (3)$$

The data is presented this way so that changes over time can be examined.

As can be seen in Figure 4.3, Novice 1 showed an improvement over time. This improvement occurred despite there being no feedback given to the individual during the test program. These limited results suggest there is a learning curve involved in determining fluid failure.

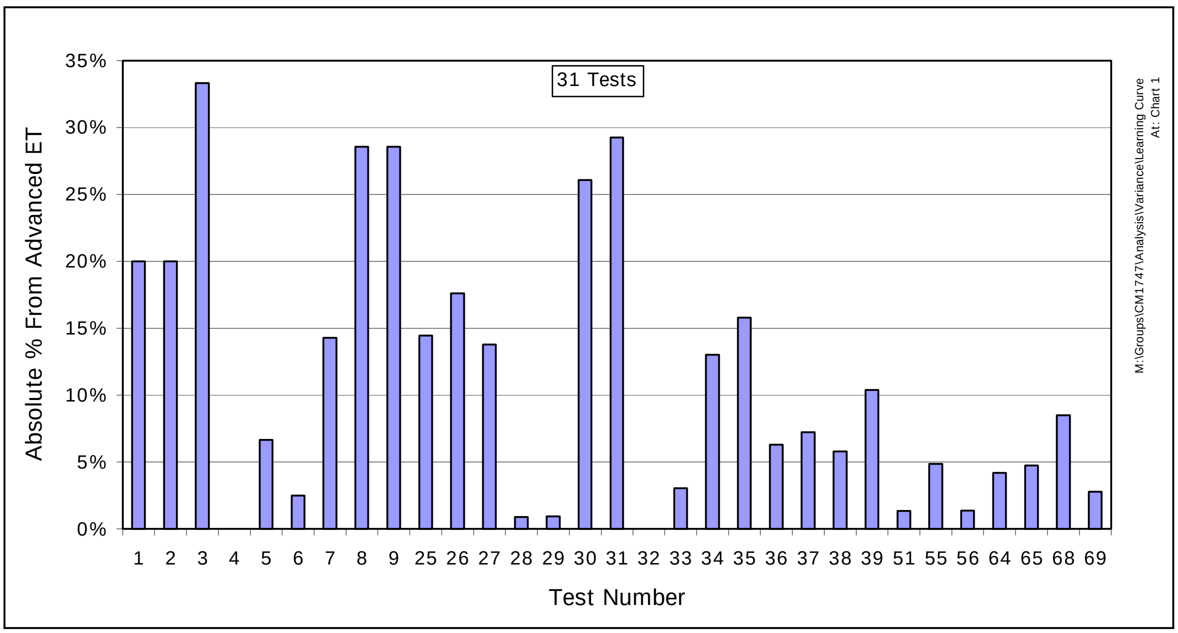

Figure 4.3: Novice Learning Curve in Natural Snow

4.1.3 Comparison of Individuals at the Same Level

Two intermediate individuals and two experts are compared in Figures 4.4 and 4.5, respectively. The limited results show that the two intermediate individuals recorded fluid failures consistently the same, as did the two experts.

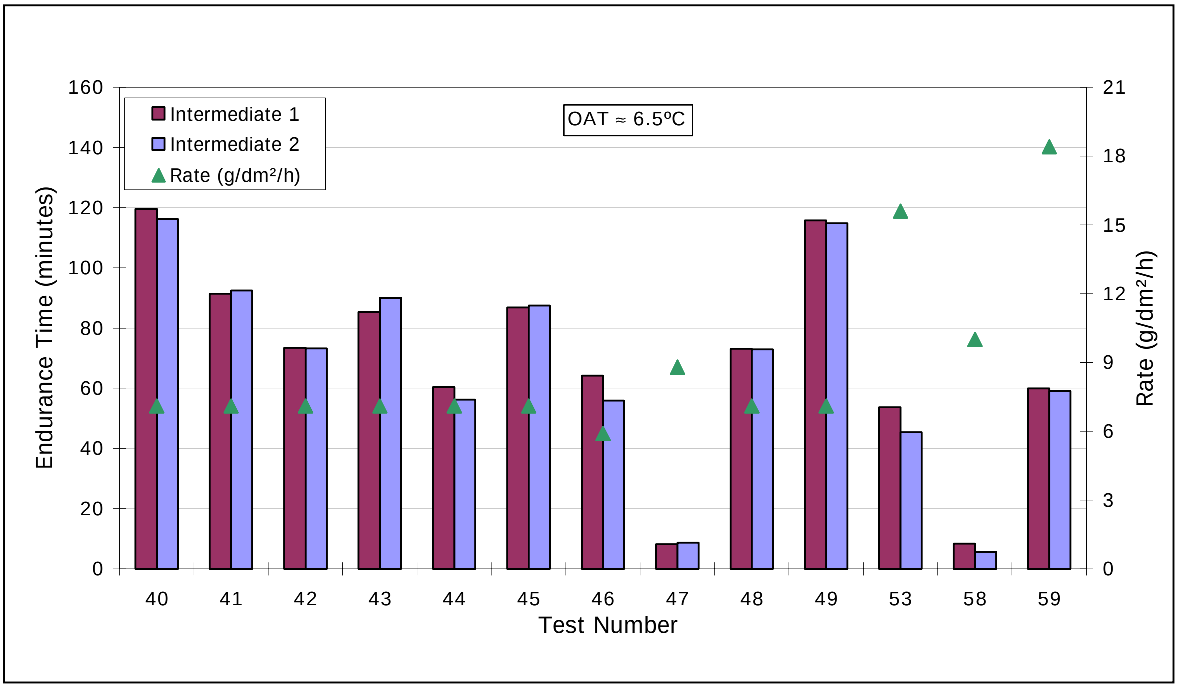

Figure 4.4: Comparison of Two Intermediate Individuals in Natural Snow

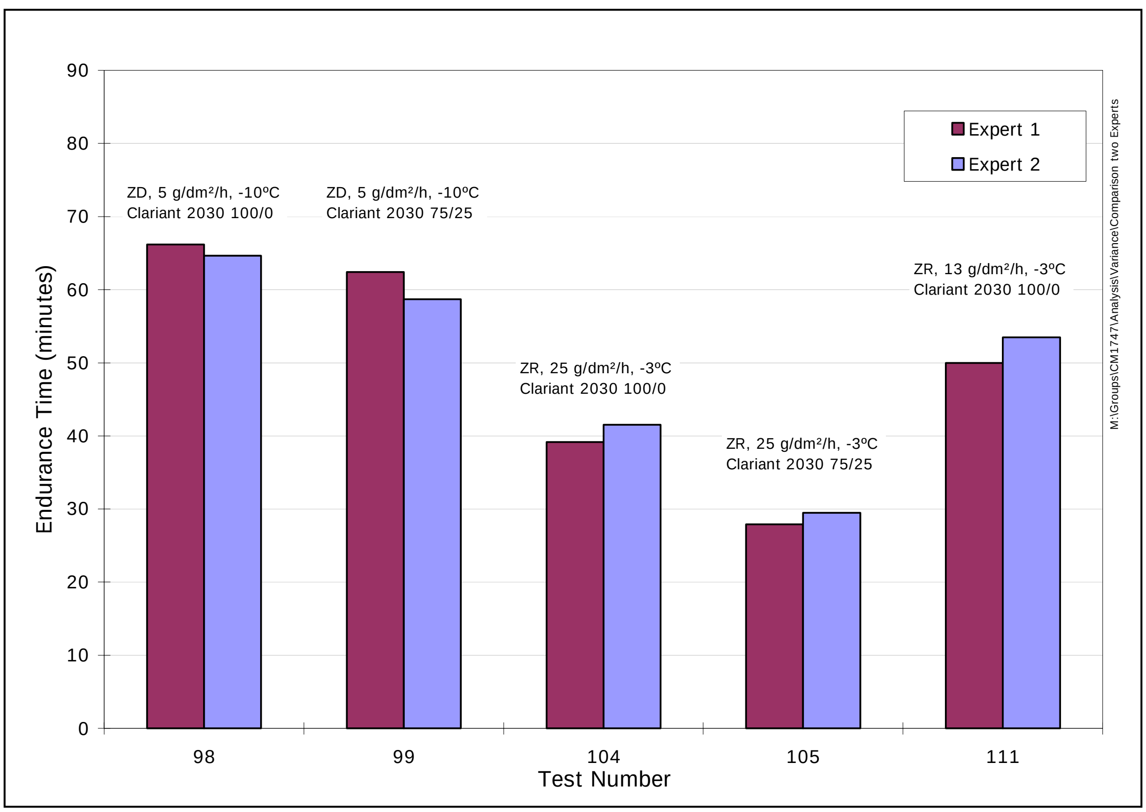

Figure 4.5: Comparison of Two Experts in Simulated Precipitation

4.2 Precipitation Type

When the data was analyzed by precipitation type, no definite conclusions could be made. There was more variance in novice ET scores in freezing rain and freezing fog. There was also more variance in intermediate ET scores in freezing fog. These results are shown in Table 4.3 and Figure 4.6. It should be noted that novices had an average ET score of 86 percent in freezing drizzle; this indicates they consistently recorded fluid failure prematurely.

Table 4.3: Endurance Time Comparison by Precipitation Type

		Intermediate	Novice
Natural Snow	Average	106%	102%
	Std. Dev. (σ)	13%	16%
	Observations	56	64
Freezing Rain	Average	95%	90%
	Std. Dev. (σ)	13%	25%
	Observations	22	34
Freezing Drizzle	Average	98%	86%
	Std. Dev. (σ)	5%	20%
	Observations	6	16
Freezing Fog	Average	100%	103%
	Std. Dev. (σ)	17%	26%
	Observations	14	19

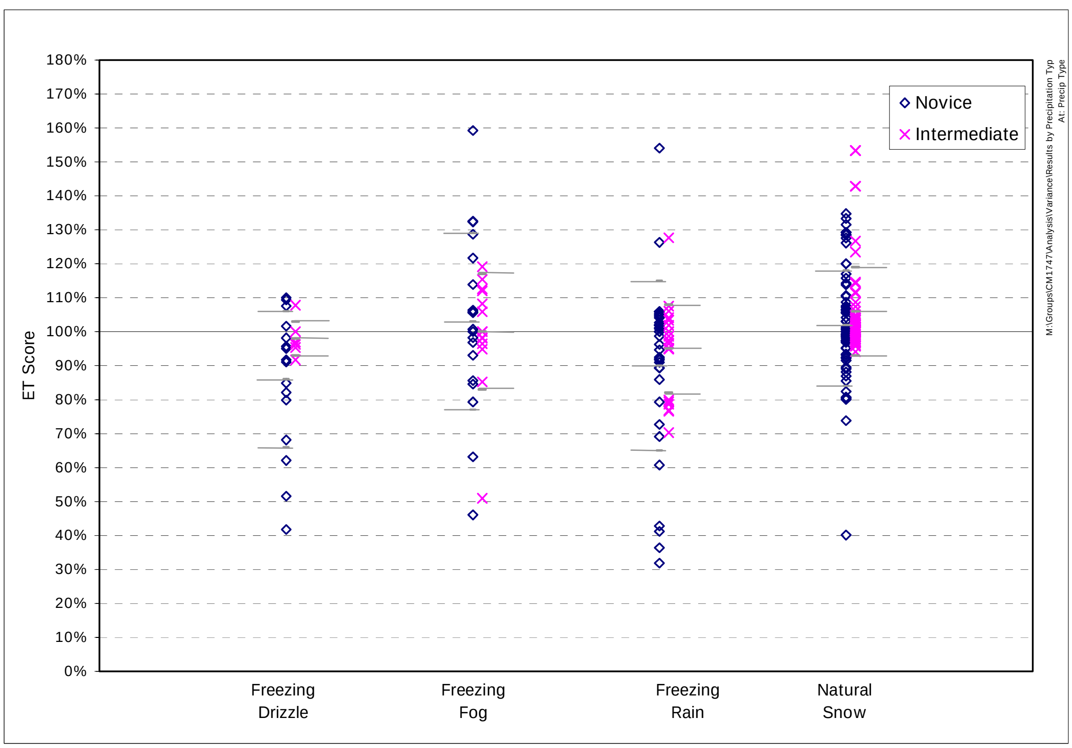

Figure 4.6: Endurance Time Variance by Precipitation Type

4.3 Precipitation Rate

In natural snow, variance increased as precipitation rate increased. In simulated precipitation conditions, the variance was similar in tests at high and low rates. These results are presented in Table 4.4 and Figure 4.7. Although the average intermediate ET score in heavy snow was 133 percent, it should be noted that there were only a limited number of observations from which to calculate this statistic.

Table 4.4: Endurance Time Comparison by Precipitation Rate

		Intermediate	Novice
Low Rate (NRC)	Average	99%	95%
	Std. Dev. (σ)	12%	28%
	Observations	16	38
High Rate (NRC)	Average	96%	91%
	Std. Dev. (σ)	15%	20%
	Observations	26	31
Light Snow (Dorval)	Average	100%	98%
	Std. Dev. (σ)	3%	11%
	Observations	13	19
Moderate Snow (Dorval)	Average	106%	105%
	Std. Dev. (σ)	13%	14%
	Observations	40	36
Heavy Snow (Dorval)	Average	133%	100%
	Std. Dev. (σ)	16%	30%
	Observations	3	9

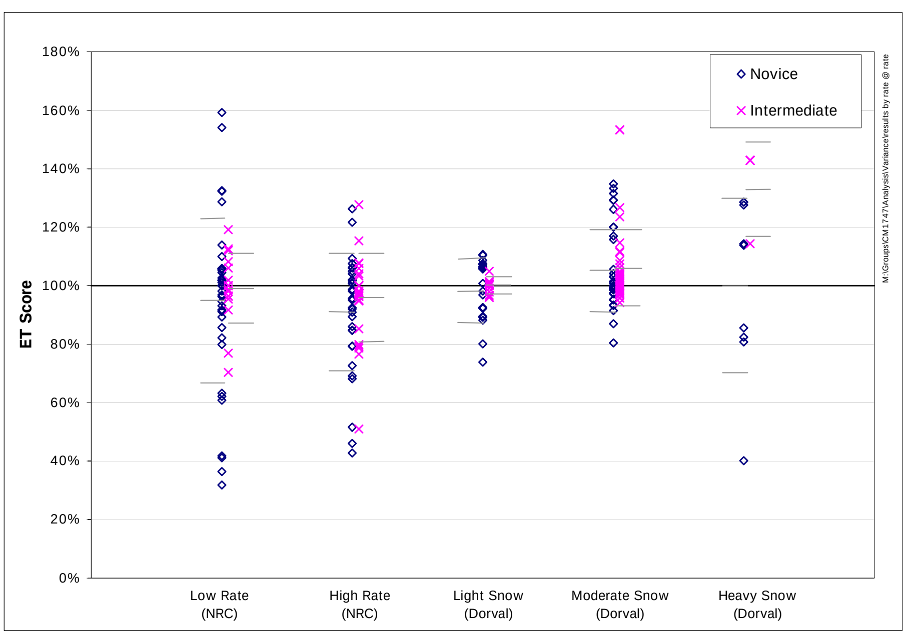

Figure 4.7: Endurance Time Variance by Precipitation Rate

4.4 Fluid Type

When data was analyzed by fluid type, the most variance was observed in tests with Type I fluid. This may be a result of the nature of the test; that is, Type I fluids have very short holdover times and therefore fluid failure occurs quickly. This idea is discussed in more detail in Subsection 4.8. Results are shown in Table 4.5 and Figure 4.8.

Table 4.5: Endurance Time Comparison by Fluid Type

		Intermediate	Novice
Type I	Average	102%	100%
	Std. Dev. (σ)	18%	25%
	Observations	21	31
Type II	Average	108%	102%
	Std. Dev. (σ)	17%	21%
	Observations	24	27
Type IV	Average	99%	95%
	Std. Dev. (σ)	13%	20%
	Observations	53	75

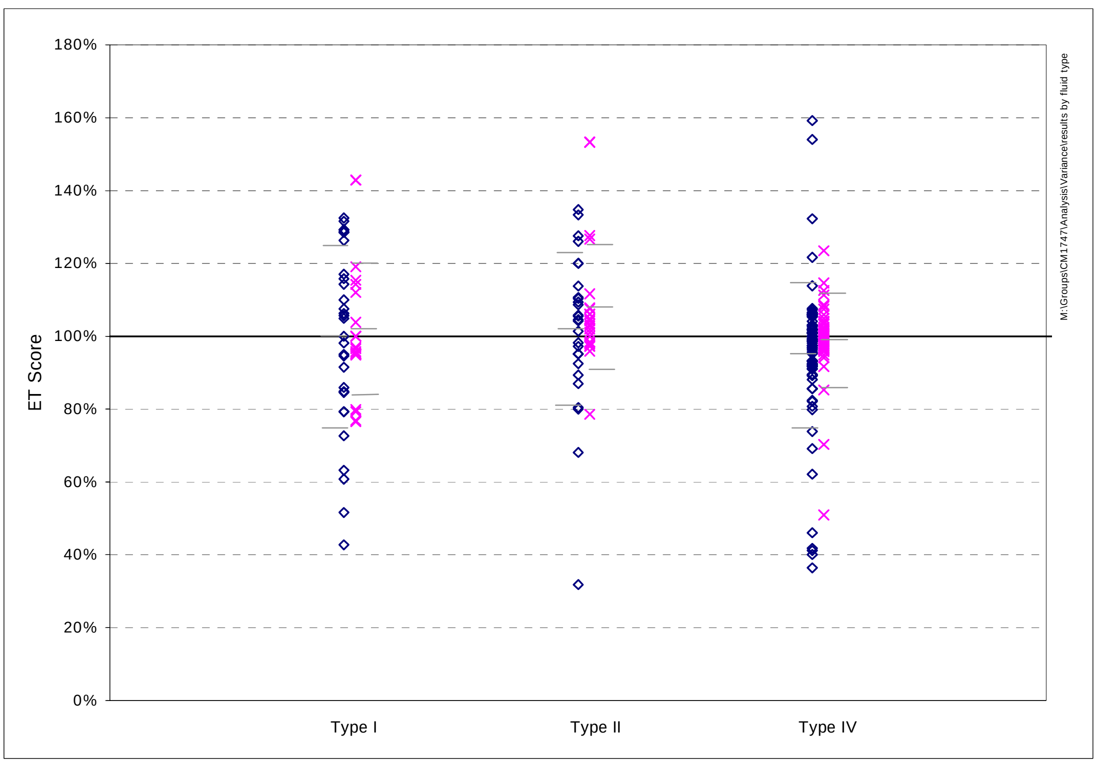

Figure 4.8: Endurance Time Variance by Fluid Type

4.5 Fluid Chemistry

When results were compared by fluid chemistry, either propylene glycol-based or ethylene glycol-based, no difference in variance in endurance times determined by intermediate individuals was found. Slightly more variance was observed in novices with propylene glycol-based fluids compared to ethylene glycol-based fluids. Complete results are shown in Table 4.6 and Figure 4.9.

Table 4.6: Endurance Time Comparison by Fluid Chemistry

		Intermediate	Novice
EG	Average	101%	97%
	Std. Dev. (σ)	14%	19%
	Observations	29	50
PG	Average	102%	98%
	Std. Dev. (σ)	14%	23%
	Observations	69	83

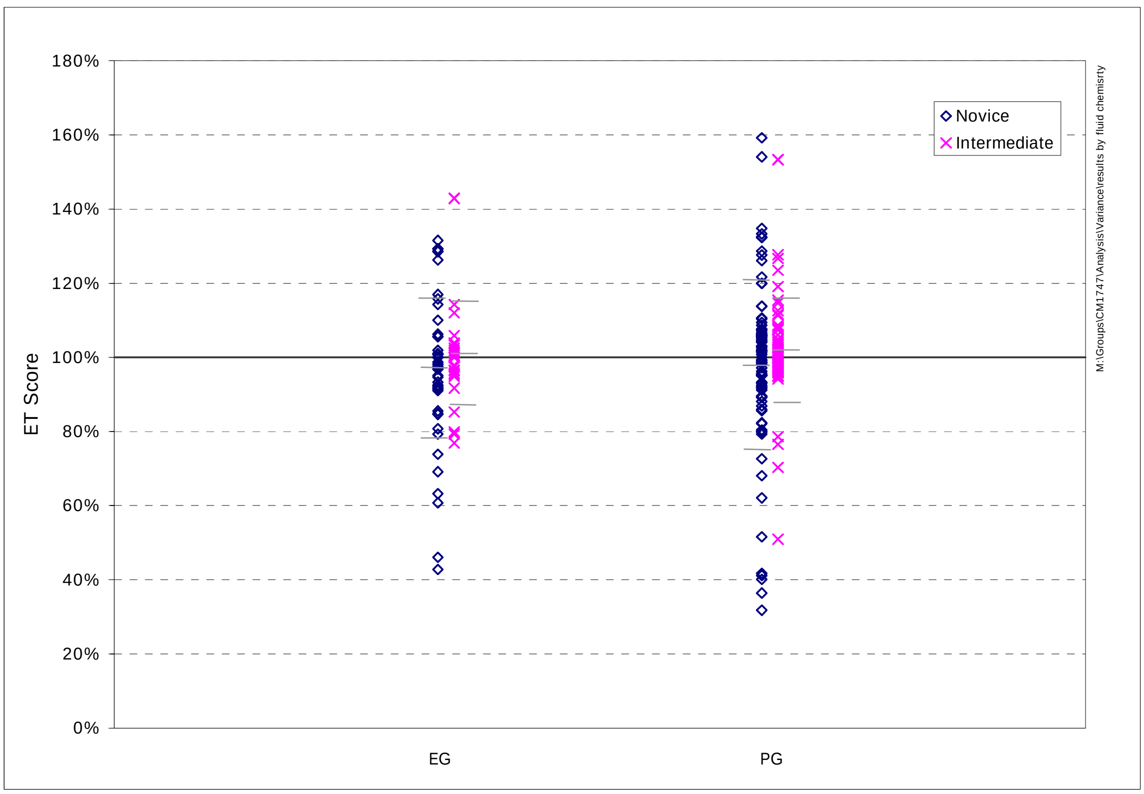

Figure 4.9: Endurance Time Variance by Fluid Chemistry

4.6 Fluid Dilution

Results were also analyzed by fluid dilution. Both novices and intermediate individuals had higher levels of variance for fluids mixed 50/50, and for fluids mixed to a 10º buffer. All Type I fluids are mixed to a 10º buffer. Both of these dilutions are associated with shorter endurance times. Variance in tests with short endurance times is discussed in more detail in Subsection 4.8. Results are presented in Table 4.7 and Figure 4.10.

Table 4.7: Endurance Time Comparison by Fluid Dilution

		Intermediate	Novice
100/0 (Type II/IV)	Average	99%	94%
	Std. Dev. (σ)	10%	21%
	Observations	47	56
75/25 (Type II/IV)	Average	102%	96%
	Std. Dev. (σ)	9%	9%
	Observations	22	21
50/50 (Type II/IV)	Average	122%	102%
	Std. Dev. (σ)	22%	25%
	Observations	8	25
10º Buffer (Type I)	Average	102%	100%
	Std. Dev. (σ)	18%	25%
	Observations	21	31

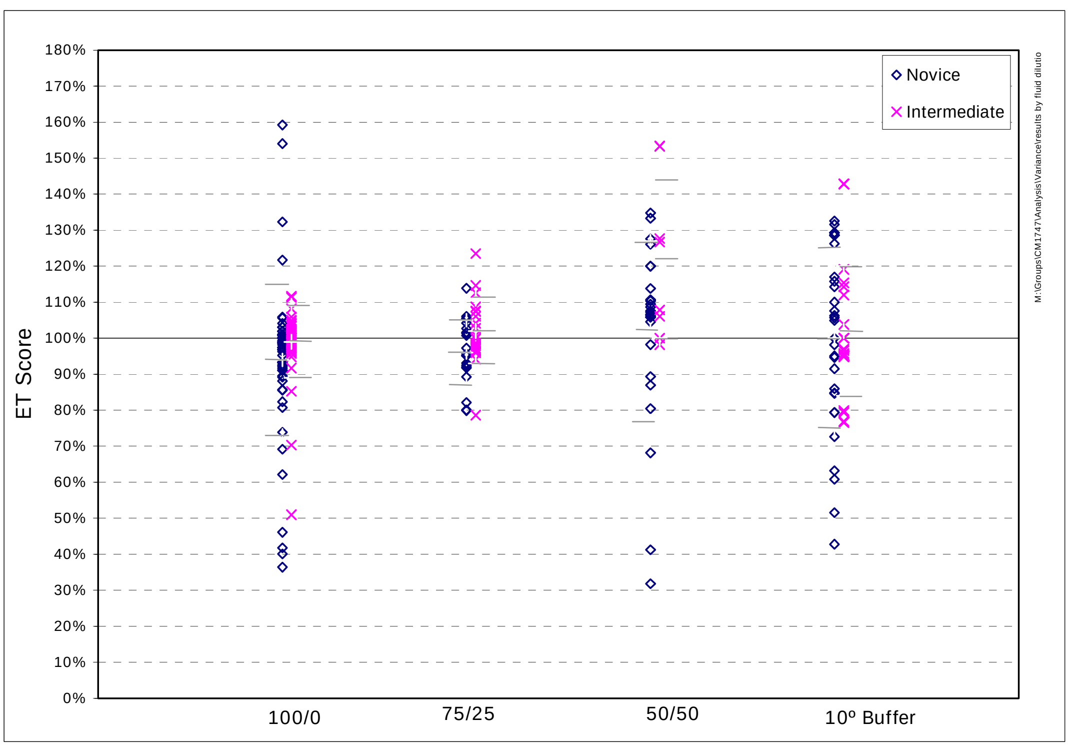

Figure 4.10: Endurance Time Variance by Fluid Dilution

4.7 Ambient Temperature

Data was also analyzed to see whether ambient temperature influenced variance in endurance times. The data was separated into outdoor and indoor tests and is presented in Table 4.8 and Figure 4.11. The most variance occurred during tests conducted at NRC at -25ºC. This was the coldest temperature tested indoors. Variance in the ET scores of novices in this condition was 38 percent; for intermediate individuals it was 27 percent. These statistics may not be accurate as only a limited number of tests were performed at -25ºC; however, experienced APS personnel have confirmed that determining fluid failure at this temperature has traditionally been more difficult. Outdoors, the trend appears to be the opposite; variance increased as temperature increased.

Table 4.8: Endurance Time Comparison by Ambient Temperature

		Intermediate	**Novice**
-25ºC (NRC)	Average	98%	94%
	Std. Dev. (σ)	27%	38%
	Observations	5	7
-14ºC (NRC)	Average	107%	114%
	Std. Dev. (σ)	11%	16%
	Observations	4	8
-10ºC (NRC)	Average	92%	89%
	Std. Dev. (σ)	10%	25%
	Observations	16	21
-3ºC (NRC)	Average	98%	90%
	Std. Dev. (σ)	11%	22%
	Observations	17	33
-10 to -12ºC (Dorval)	Average	100%	92%
	Std. Dev. (σ)	3%	9%
	Observations	13	11
-5 to -6ºC (Dorval)	Average	106%	104%
	Std. Dev. (σ)	13%	12%
	Observations	37	17
-3 to -4ºC (Dorval)	Average	117%	105%
	Std. Dev. (σ)	20%	19%
	Observations	6	36

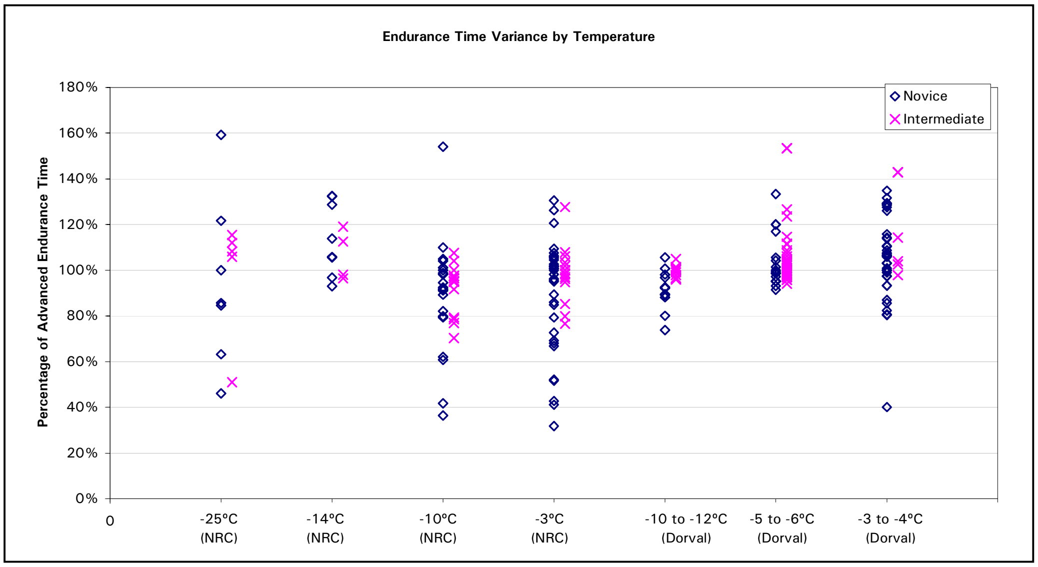

Figure 4.11: Endurance Time Variance by Ambient Temperature

4.8 Error Analysis

As the test procedure allowed individuals to indicate fluid failure every 30 or 60 seconds only (depending on the fluid type), it is possible that this may have influenced the results. Consider a five-minute test with Type I fluid and a thirty-minute test with Type IV fluid. This example is illustrated in Table 4.9. If failure for the first test occurred at 5 minutes, and assuming the expert recorded the fluid failure when it happened, the expert's endurance time would be 5 minutes. If an individual missed the fluid failure, the next possible time the fluid failure could be recorded would be at 5.5 minutes. This would result in an ET score of 110 percent. According to Table 4.8, the possible ET scores for an individual in this test would be 90 percent, 100 percent, 110 percent or 120 percent (or more or less outside this range). However, in a 30-minute test with Type IV fluid, the possible scores would be 97 percent, 100 percent, 103 percent or 107 percent, thereby giving the individual more opportunities to calculate a more accurate endurance time. It is possible that this caused more variance to be present in the shorter tests – predominantly those that occur with Type I fluids and fluids in 50/50 dilutions.

Table 4.9: Example for Error Analysis

	Expert ET (mins)	One interval before Failure		One interval after Failure		Two intervals after Failure	
		ET (min)	ET Score	ET (min)	ET Score	ET (min)	ET Score
Type I Test*	5	4.5	90%	5.5	110%	6.0	120%
Type IV Test**	30	29	97%	31	103%	32	107%

* Checked every 30 seconds
** Checked every 60 seconds

4.9 Summary of Results

The results are summarized by the different variables examined in Table 4.10. The average ET score and the ET score variance are taken from the tables presented previously. The rank of the ET score variance from smallest to largest is indicated in the fourth column for intermediate individuals and the eighth column for novices. The five highest variances for each level are indicated in bold type.

As a general rule, conditions that make endurance times shorter, including high precipitation rates, Type I fluid, highly diluted fluid, and low ambient temperatures, increased the variance in endurance times. One exception was natural snow, where more variance was observed in colder temperatures compared to warmer temperatures. It is possible that some of this variance can be attributed to the test procedure, as discussed in Subsection 4.9. The most variance was observed in tests at temperatures of -25ºC. Experienced APS personnel have confirmed that it has traditionally been difficult to determine fluid failure in this condition.

One finding that occurs throughout the results is that novices had more difficulty determining fluid failure than intermediate individuals. Overall, the variance in novice ET scores was 22 percent, compared to 14 percent for intermediate ET scores.

4.10 Implications for Holdover Time Guidelines

To obtain values for the Type IV generic holdover time guidelines, the endurance times of all certified Type IV fluids with fluid-specific holdover time tables are compared. For each cell in the holdover time table, the lowest value of all tested Type IV fluids is applied. For example, in the *freezing drizzle, 75/25 fluid, -3 to -10ºC* cell, the endurance times of Type IV fluids range from 15 minutes to 30 minutes for the worst performing fluids to 40 minutes to 80 minutes for the best performing fluids. Therefore, in the 2003-04 generic table, this cell contains 15 to 30 minutes.

Assuming that all new fluids tested have endurance times equivalent to the values in the current generic table, if a novice were to conduct endurance time tests with these new fluids, the values in the generic table would decrease over time. This is because the lowest endurance time measured from all fluids tested determines the value in each cell of the holdover time table. Approximately two thirds of novice ET scores fell between 75 and 119 percent; therefore, after many tests were conducted, the values in the generic table would likely fall to 75 percent of their original values. For example, if the value in a cell were currently 15 minutes, it would become 10 minutes. If an intermediate individual conducted the tests, the holdover time values would fall to 88 percent of their original values.

Table 4.10: Summary of Results

		Intermediate				Novice			
		Failure Calls	Average ET Score	ET Score Variance	Variance Rank*	Failure Calls	Average ET Score	ET Score Variance*	Variance Rank
All	**All**	98	102%	14%	n/a	133	97%	22%	n/a
Fluid Chem.	**EG**	29	101%	14%	10	50	97%	19%	17
	PG	69	102%	14%	11	83	98%	23%	10
Fluid Dilution	**100/0 (Type II/IV)**	47	99%	10%	21	56	94%	21%	13
	75/25 (Type II/IV)	22	102%	9%	22	21	96%	9%	25
	50/50 (Type II/IV)	8	122%	**22%**	**2**	25	102%	**25%**	**5**
	10° Buffer (Type I)	21	102%	**18%**	**5**	31	100%	25%	6
Fluid Type	**Type I**	21	102%	**18%**	**4**	31	100%	25%	7
	Type II	24	108%	17%	6	27	102%	21%	12
	Type IV	53	99%	13%	16	75	95%	20%	16
Precipitation Type	**Natural Snow**	56	106%	13%	12	64	102%	16%	19
	Freezing Rain	22	95%	13%	14	34	90%	25%	8
	Freezing Drizzle	6	98%	5%	23	16	86%	20%	14
	Freezing Fog	14	100%	17%	7	19	103%	**26%**	**4**
Precipitation Rate	**Low Rate (NRC)**	16	99%	12%	17	38	95%	**28%**	**3**
	High Rate (NRC)	26	96%	15%	9	31	91%	20%	15
	Light Snow	13	100%	3%	24	19	98%	11%	23
	Moderate Snow	40	106%	13%	15	36	105%	14%	21
	Heavy Snow	3	133%	16%	8	9	100%	**30%**	**2**
Ambient Temperature	**-25ºC (NRC)**	5	98%	**27%**	**1**	7	94%	**38%**	**1**
	-14ºC (NRC)	4	107%	11%	19	8	114%	16%	20
	-10ºC (NRC)	16	92%	10%	20	21	89%	25%	9
	-3ºC (NRC)	17	98%	11%	18	33	90%	22%	11
	-10 to -12ºC (Dorval)	13	100%	3%	25	11	92%	9%	24
	-5 to -6ºC (Dorval)	37	106%	13%	13	17	104%	12%	22
	-3 to -4ºC (Dorval)	6	117%	**20%**	**3**	36	105%	19%	18

* Ranked from highest variance (1) to lowest variance (25). For easy reference the five highest variances for each level are indicated in bold type.

M:\Groups\CM1747\Analysis\Variance\Table 4.10

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5. CONCLUSIONS

Funding for this project was limited and therefore a full test program could not be carried out independently of other projects. Several alterations were made to the test procedure so that it could be used in conjunction with the procedures for other projects. These alterations, and the limited number of tests that were conducted, have made the extrapolation of the results to all endurance time testing not advisable. However, conclusions can be drawn about the data set examined. These conclusions provide an indication of the results that would be returned by a large-scale project:

a) There was a difference between novice, intermediate and expert individuals determining fluid failure. There was more variance in novice ET scores (22 percent) as compared to intermediate ET scores (14 percent).

b) There were differences in individuals at the same level. This is illustrated by the wide range of results reported by the seven novice testers.

c) Novices improved over time in natural snow tests. The average difference in endurance times measured by one of the novices and by the expert was 16 percent in the first five tests. In the last five tests the difference had decreased to 4 percent. This improvement was shown over thirty-one tests.

d) In regards to test parameters:

- Precipitation type and fluid chemistry did not significantly affect variance in endurance times;
- More variance was observed in tests conducted under higher rates of precipitation;
- More variance was observed in tests conducted with Type I fluid tests relative to other fluid types;
- More variance was observed in tests conducted with fluids with lower glycol/water ratios;
- When testing in simulated precipitation conditions, more variance occurred in colder ambient temperatures; and
- When testing in natural snow, more variance occurred in warmer ambient temperatures.

In general, more variance was observed in tests where conditions existed that cause endurance times to be shorter, such as higher precipitation rates, Type I fluids, more diluted fluids and colder ambient temperatures.

One exception to this trend was warmer temperatures in natural snow. However, it is possible that the test procedure, which restricted the times that testers could record fluid failure, may have contributed to the increased variance in shorter tests; and

e) If a novice were to determine fluid failures during endurance time testing, the values in the generic holdover time guidelines could decrease to 75 percent of the original values over time. If an intermediate individual determined fluid failure, the values could decrease to 88 percent.

Despite the limitations imposed on the precision of the statistics, one conclusion that was confirmed by the test program is that endurance times vary depending on the individual who measures fluid failure. This variance can be considerable when individuals with even an intermediate level of knowledge, experience and training are recording fluid failures. The variance will have a significant effect on the outcome of endurance time tests and on holdover time guidelines.

Alterations made to the procedure may have allowed individuals to be influenced by their peers, thereby influencing the test results. However, individual "cheating" would only cause the results to show less variance. This is because the influenced endurance times will have been closer to the actual endurance times than they would have been had no cheating occurred. In other words, the variance would be greater than that which is presented in this report.

6. RECOMMENDATIONS

This section provides recommendations for calibrating the determination of fluid failure.

6.1 Short Term

There is no short-term solution to eliminate variance in endurance times resulting from individual differences in determining fluid failure. In the short term it is recommended that the same individual continue to record fluid failures during holdover time testing. However, other individuals should be trained so that in future, when the current individual is not available for holdover time testing, others will have a good level of expertise, training and experience and be ready to assume this responsibility.

One way of ensuring that individuals are properly trained is to create a fluid failure training manual that includes photos. This document should be brief, user-friendly and no longer than 10 pages.

The importance of photos in the description of fluid failure is paramount. It is recommended that Proposed Aerospace Standard AS 5485 include photos of fluid failure, not only in natural snow, but in all precipitation conditions under which endurance time testing takes place.

A large-scale test program dedicated to investigating variance is probably not required. It has been established that variance in human fluid failure determination is a problem and that even individuals with an intermediate level of knowledge, training and experience do not provide results that are acceptable. Although a large-scale test program would provide more accurate variance in endurance time numbers, it would provide the same general conclusion that has been presented in this report: a significant level of training and experience is required in order to reduce variance in endurance times.

An error analysis illustrated that during short tests an interval of thirty seconds away from the test plate can significantly influence the outcome of the test. Although in standard endurance time testing testers are not constricted by this requirement, it has been observed that some testers will return to the test trailer to warm up during tests. This is equivalent to the 30- or 60-second constriction placed on the testers in this test program. This may not have an effect on longer tests; however, a 30- or 60-second trip to the test trailer could cause the endurance time of a shorter test to be overestimated by 10 percent. Testers should be required to stay in the test stand area for the duration of the test for tests that are 10 minutes or less. Furthermore, testing conditions should be of an adequate comfort level for testers so that they are not constantly motivated to return to the test trailer. Providing testers with appropriate clothing to protect them from uncomfortable test conditions may be one solution.

6.2 Long Term

The only way to standardize the determination of fluid failure and remove subjectivity from endurance time testing is to develop a technology that can measure the contamination of de/anti-icing fluids.

Several fluid failure sensors have been developed in the past decade; however, none have been developed to the level required by the industry. Regulatory bodies need to encourage development of these technologies. Any sensor that may accurately detect contaminated fluid should be tested.

REFERENCES

1. Society of Automotive Engineers (SAE) Aerospace Standard AS 5485, *Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids: SAE Type I, II, III, and IV,* October 2000 (unpublished).

2. Chaput, M., Campbell, R, *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Test Program for the 2001-02 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13991E (to be published).

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

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING
2002-03

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING
2002-03

5.18 Examination of Variance in Endurance Times

5.18.1 Design a test and prepare a test procedure for outdoor tests to examine the variance in endurance time of Type I, II, IV for various people under various weather conditions;

5.18.2 Conduct outdoor tests during several snowstorms;

5.18.3 Design a test and prepare a test procedure for indoor tests;

5.18.4 Conduct indoor tests in various freezing precipitation conditions at the NRC facility;

5.18.5 Analyze results; and

5.18.6 Prepare a report.

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APPENDIX B

EXPERIMENTAL PROGRAM
VARIANCE IN ENDURANCE TIMES

CM1747.001

EXPERIMENTAL PROGRAM
VARIANCE IN ENDURANCE TIMES

Winter 2002-03

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Stephanie Bendickson

Reviewed by: John D'Avirro

February 28, 2003
Version 1.0

Editorial Revision
September 10, 2004
Version 1.1

EXPERIMENTAL PROGRAM
VARIANCE IN FLUID ENDURANCE TIMES
Winter 2002-03

1. OBJECTIVES

Tests conducted during the winter of 2001-02 examined intrapersonal variance in endurance times. The tests concluded that there is a 10% variance in endurance times called by the same person in the same condition. This led to the question of how endurance times vary when different people perform the same tests. The test program for the winter of 2002-03 will examine interpersonal variance in endurance times. A much larger variance in endurance times is expected.

The primary objective of this test program is to measure variance of endurance times when called by people of different levels of knowledge and training. Secondary objectives are to measure other variables that affect the variance of endurance times, including outside air temperature, precipitation type, fluid type, fluid dilution, and fluid chemistry.

This document describes the procedure for outdoor tests required for the test program. A separate procedure for indoor tests will be developed following the completion of outdoor testing.

2. PROCEDURE

Standard endurance time test and rate collection protocol will be followed; however, three people, instead of only one person, will call failure times. Each person will call fluid failures on each plate during every test. Refer to Section 5 for a description of personnel. Two new endurance time data forms and specific protocol for checking tests for fluid failure will be used in order to conduct blind tests and eliminate the possibility of “cheating”.

The protocol for Type I tests is as follows:

1. Fluids are poured. All three personnel mark the starting time on their data forms.
2. Personnel remain in the test stand area and continuously check plates for failure.
3. After thirty seconds, the overall test manager calls out “time”. Each person indicates failed or not failed on his/her data form. This process is repeated every 30 seconds for fifteen minutes.

The protocol for Type II and Type IV tests is as follows:

1. Fluids are poured. All three personnel mark the starting time on their data forms and leave the test stand area.
2. After twenty seconds, the novice person returns to the test stand area and checks the plates. He/she indicates failed or not failed on his/her data form and leaves the test stand area. He/she repeats every minute for twenty minutes. After twenty minutes the procedure is repeated once every three minutes.
3. After forty seconds, the intermediate person returns to the test stand area and checks the plates. He/she indicates failed or not failed on his/her data form and leaves the test stand area. He/she repeats every minute for twenty minutes. After twenty minutes the procedure is repeated once every three minutes.
4. After sixty seconds, the expert person returns to the test stand area and checks the plates. He/she indicates failed or not failed on his/her data form and leaves the test stand area. He/she repeats every minute for twenty minutes. After twenty minutes the procedure is repeated once every three minutes.

3. FLUIDS

Four fluids will be used including a Type I EG, Type II PG, Type IV EG and Type IV PG. Fluids are detailed in Table B-1.

Table B-1: Required Fluids

Fluid Manufacturer	Fluid Name	Batch Number	Fluid Type	Dilution	Quantity Required
Dow UCAR	EG ADF	634626	Type I EG	10º buffer	12 L
Dow UCAR	Dow UCAR Ultra+	10353	Type IV EG	100	6 L
Kilfrost	P1064	P1064	Type IV PG	100	6 L
Ely or Kilfrost	Octagon E Max II or ABC 2000	Unknown P1063	Type II PG	75/25 or 50/50 if >-3ºC	6 L

4. TEST PLAN

Refer to Attachment I for detailed test plan for outdoor tests.

5. PERSONNEL

Three personnel, one in each of the following categories, will be required to call failures:

Expert: This person has comprehensive knowledge of fluid failure and has extensive experience calling failures (MC or JD).

Intermediate: This person has had informal training in calling fluid failures and has limited experience calling failures (RC, NM or MM).

Novice: This person has gained knowledge of fluid failures only through reading written procedures and has never called fluid failures (SB or other).

In addition, an *Overall Test Manager* will be required to instruct fluid failure personnel when to go to the test stand and when to record results.

Rates will be measured by members of the team conducting holdover time tests.

6. EQUIPMENT

Equipment identical to equipment used for standard endurance time tests will be used.

7. DATA FORMS

Two special endurance time data forms have been designed for this test. The data form for Type I tests is presented in Attachment II and the data form for Type II and for Type IV tests is presented in Attachment III. There are three versions of the Type II and IV form; one version each for novice, intermediate, and expert personnel.

The standard rate measurement form will be used. Refer to Attachment IV.

ATTACHMENT I: DETAILED TEST PLAN

Session #	Test #	Plate	Precipitation Type	Fluid Name	Fluid Type	Dilution
1	1	A	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
		B	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
		C	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
	2	A	Natural Snow	Dow UCAR Ultra+	Type IV EG	100
		B	Natural Snow	Dow UCAR Ultra+	Type IV EG	100
		C	Natural Snow	Dow UCAR Ultra+	Type IV EG	100
	3	A	Natural Snow	Kilfrost P1064	Type IV PG	100
		B	Natural Snow	Kilfrost P1064	Type IV PG	100
		C	Natural Snow	Kilfrost P1064	Type IV PG	100
	4	A	Natural Snow	Ely Octagon E Max II or Kilfrost ABC 2000	Type II PG	75/25 (50/50 if >-3ºC)
		B	Natural Snow	Ely Octagon E Max II or Kilfrost ABC 2000	Type II PG	75/25 (50/50 if >-3ºC)
		C	Natural Snow	Ely Octagon E Max II or Kilfrost ABC 2000	Type II PG	75/25 (50/50 if >-3ºC)
2	5	A	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
		B	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
		C	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
	6	A	Natural Snow	Dow UCAR Ultra+	Type IV EG	100
		B	Natural Snow	Kilfrost P1064	Type IV PG	100
		C	Natural Snow	Ely Octagon E Max II or Kilfrost ABC 2000	Type II PG	75/25 (50/50 if >-3ºC)
3*	7	A	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
		B	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
		C	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
	8	A	Natural Snow	Dow UCAR Ultra+	Type IV EG	100
		B	Natural Snow	Kilfrost P1064	Type IV PG	100
		C	Natural Snow	Ely Octagon E Max II or Kilfrost ABC 2000	Type II PG	75/25 (50/50 if >-3ºC)
4*	9	A	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
		B	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
		C	Natural Snow	Dow UCAR EG ADF	Type I EG	10º buffer
	10	A	Natural Snow	Dow UCAR Ultra+	Type IV EG	100
		B	Natural Snow	Kilfrost P1064	Type IV PG	100
		C	Natural Snow	Ely Octagon E Max II or Kilfrost ABC 2000	Type II PG	75/25 (50/50 if >-3ºC)

* Time and Budget Permitting

Note: Plates A, B, and C must be run simultaneously for each run

M:\Groups\CM1747\Procedures\Variance\test plan

ATTACHMENT II: ENDURANCE TIME DATA FORM – TYPE I FLUIDS

DATE: ____________________

LOCATION: Dorval Test Site

	TIME OF INSPECTION	PLATE: _____ TEST: _____	PLATE: _____ TEST: _____	PLATE: _____ TEST: _____
START TIME				
START TIME + 0:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 1:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 1:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 2:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 2:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 3:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 3:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 4:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 4:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 5:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 5:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 6:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 6:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 7:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 7:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 8:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 8:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 9:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 9:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 10:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 10:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 11:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 11:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 12:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 12:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 13:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 13:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 14:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 14:30		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 15:00		Failed Not Failed	Failed Not Failed	Failed Not Failed

FAILURES CALLED BY: LEVEL: Novice Intermediate Expert

COMMENTS: ____

ATTACHMENT III: ENDURANCE TIME DATA FORM – TYPE II AND IV FLUIDS
Version A – Novice

DATE: ____________

LOCATION: Dorval Test Site

	TIME OF INSPECTION	PLATE: _____ TEST: _____	PLATE: _____ TEST: _____	PLATE: _____ TEST: _____
START TIME:				
START TIME + 1:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 2:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 3:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 4:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 5:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 6:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 7:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 8:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 9:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 10:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 11:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 12:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 13:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 14:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 15:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 16:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 17:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 18:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 19:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 20:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 21:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 24:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 27:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 30:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 33:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 36:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 39:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 42:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 45:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 48:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 51:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 54:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 57:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 60:00		Failed Not Failed	Failed Not Failed	Failed Not Failed

FAILURES CALLED BY: LEVEL: Novice

COMMENTS: ____

____

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ATTACHMENT III: ENDURANCE TIME DATA FORM – TYPE II AND IV FLUIDS
Version B – Intermediate

DATE: ____________________

LOCATION: Dorval Test Site

	TIME OF INSPECTION	PLATE: _____ TEST: _____	PLATE: _____ TEST: _____	PLATE: _____ TEST: _____
START TIME:				
START TIME + 1:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 2:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 3:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 4:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 5:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 6:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 7:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 8:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 9:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 10:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 11:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 12:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 13:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 14:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 15:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 16:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 17:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 18:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 19:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 20:20		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 22:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 25:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 28:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 31:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 34:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 37:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 40:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 43:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 46:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 49:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 52:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 55:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 58:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 61:00		Failed Not Failed	Failed Not Failed	Failed Not Failed

FAILURES CALLED BY: LEVEL: Intermediate

COMMENTS: ____________________

ATTACHMENT III: ENDURANCE TIME DATA FORM – TYPE II AND IV FLUIDS
Version C – Expert

DATE: ____________________

LOCATION: Dorval Test Site

	TIME OF INSPECTION	PLATE: _____ TEST: _____	PLATE: _____ TEST: _____	PLATE: _____ TEST: _____
START TIME:				
START TIME + 1:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 2:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 3:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 4:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 5:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 6:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 7:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 8:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 9:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 10:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 11:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 12:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 13:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 14:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 15:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 16:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 17:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 18:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 19:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 20:40		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 23:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 26:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 29:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 32:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 35:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 38:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 41:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 44:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 47:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 50:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 53:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 56:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 59:00		Failed Not Failed	Failed Not Failed	Failed Not Failed
START TIME + 62:00		Failed Not Failed	Failed Not Failed	Failed Not Failed

FAILURES CALLED BY: LEVEL: Expert

COMMENTS: ____________________

ATTACHMENT IV: METEOROLOGICAL AND PRECIPITATION RATE DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

VERSION 1.0 Winter 2002-03

LOCATION: **DATE:** **RUN # :** **STAND # :**

HAND HELD VIDEO CASSETTE #:

PLATE PAN WEIGHT MEASUREMENTS *

PAN #	t TIME BEFORE (h:min:s)	BUFFER TIME (s)	t TIME AFTER (h:min:s)	BUFFER TIME (s)	w WEIGHT BEFORE (g)	w WEIGHT AFTER (g)	COMPUTE RATE (Δ w*4.7/ Δt) (g/dm²/h)

*measurements every 15 min. and at failure time of each test panel

METEO OBSERVATIONS **

TIME (h:min)	TYPE (Table 1) ZR, ZL, S, SG IP, IC, BS, SP	CLASSIF. (See snow classification diagram.)	If SNOW, WET or DRY

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

TEMPERATURE AT START OF TEST ________ °C

WIND SPEED AT START OF TEST ________ km/h

WIND DIRECTION AT START OF TEST ________ °

COMMENTS : ________________

	PRINT	SIGN
WRITTEN & PERFORMED BY :		
VIDEO BY :		
TEST SITE LEADER :		

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APPENDIX C

EXPERIMENTAL PROGRAM
VARIANCE IN ENDURANCE TIMES, INDOOR TESTS

CM1747.001

EXPERIMENTAL PROGRAM
VARIANCE IN ENDURANCE TIMES
INDOOR TESTS

Winter 2002-03

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Stephanie Bendickson

Reviewed by: John D'Avirro

March 21, 2003
Version 1.0

Editorial Revision
September 10, 2004
Version 1.1

EXPERIMENTAL PROGRAM
VARIANCE IN FLUID ENDURANCE TIMES
INDOOR TESTS

Winter 2002-03

1. OBJECTIVES

Tests conducted during the winter of 2001-02 examined intrapersonal variance in endurance times. The tests concluded that there is a 10% variance in endurance times called by the same person in the same condition. This led to the question of how endurance times vary when different people perform the same tests. The test program for the winter of 2002-03 will examine interpersonal variance in endurance times. A much larger variance in endurance times is expected.

The primary objective of this test program is to measure variance of endurance times when called by people of different levels of knowledge and training. Secondary objectives are to measure other variables that affect the variance of endurance times, including outside air temperature, precipitation type, fluid type, fluid dilution, and fluid chemistry.

A procedure for the outdoor testing required for the test program has been published, and preliminary testing has been conducted. This document describes the procedure for indoor testing required for the test program. Tests will be conducted at the NRC Facility in Ottawa during the overall program of tests conducted by APS from April 2nd to April 10th. For more information refer to the procedure *Overall Program of Tests at NRC, April 2003*.

2. PROCEDURE

Standard endurance time test and rate collection protocol will be followed; however, three people, instead of only one person, will call failure times. Each person will call fluid failures on each plate during every test. Refer to Section 5 for a description of personnel. Novices will be instructed to read the definition of fluid failure from proposed Aerospace Standard 5485 dated March 1st 2003, and base their failure calls on their understanding of the definition. Intermediate and expert personnel will not be given additional training, nor will they be required to read the Aerospace Standard.

A project-specific endurance time data form, shown in Attachment I, and specific protocol for checking tests for fluid failure will be used in order to conduct blind tests and eliminate the possibility of “cheating”.

The protocol for Type I tests is as follows:

1. Fluids are poured. Personnel mark the starting time on their data forms.
2. Personnel remain in the test stand area and continuously check plates for failure.
3. After thirty seconds, the overall test manager calls "time". Each person indicates failed or not failed on his/her data form. This process is repeated every 30 seconds until the overall manager ascertains all three personnel have called failure on the plate.

The protocol for Type II and Type IV tests is as follows:

1. Fluids are poured. Personnel mark the starting time on their data forms and leave the test stand area.
2. After three minutes, personnel return to the test stand area and check the plates. Each person indicates failed or not failed on his/her data form and leaves the test stand area. This process is repeated every 3 minutes until the overall manager ascertains all three people have called failure on the plate.

Due to time and budget constraints, it will not be possible, nor is it necessary, to conduct tests in all winter weather conditions simulated during the overall program of tests. However, additional data will be collected during adherence tests conducted during the test session. The protocol described above will be followed by novice and expert personnel, who will use the data form developed for this procedure (Attachment I). The person calling failure times for the adherence tests, who has been designated as the intermediate person for variance tests, will use the standard endurance time data form in order to limit interruption to adherence tests.

It should be noted that only two expert personnel exist. Because both are heavily involved in other testing during the test session, it may not be possible for the expert person to follow the protocol set out above at all times. In these situations, the expert person will use the standard endurance time data form; however, this person will be instructed to use discretion when calling failures.

3. FLUIDS

The fluids that will be used are detailed in Table C-1.

Table C-1: Required Fluids

Fluid Manufacturer	Fluid Name	Fluid Type	Dilution	Quantity Required
UCAR	EG ADF	Type I EG	10º buffer	5 L
UCAR	Ultra+	Type IV EG	100	8 L
Clariant	Safewing MPIV 2030 ECO	Type IV PG	100	8 L
Clariant	Safewing MPIV 2030 ECO	Type IV PG	75/25	8 L

4. TEST PLAN

The detailed test plan for indoor tests is included in the *Overall Test Program at NRC* procedure. An excerpt of the test plan, showing tests for this procedure, is included as Attachment II. Additional tests will be conducted if time permits.

5. PERSONNEL

Three personnel, one in each of the following categories, will be required to call failures:

Expert: This person has comprehensive knowledge of fluid failure and has extensive experience calling failures (MC or JD).

Intermediate: This person has had informal training in calling fluid failures and has limited experience calling failures (NM).

Novice: This person has gained knowledge of fluid failures by reading proposed Aerospace Standard 5485 and has never called fluid failures indoors (SB and/or other).

In addition, an *Overall Test Manager* will be required to instruct fluid failure personnel when to go to the test stand and when to record results.

Rates will be measured by the holdover time team.

6. EQUIPMENT

Equipment identical to equipment used for standard endurance time tests will be used.

7. DATA FORMS

A project-specific endurance time data form has been designed for this test and is presented in Attachment I.

ATTACHMENT I: ENDURANCE TIME DATA FORM – ALL FLUIDS

DATE: ______________________ LOCATION: NRC CONDITION: ________________

TIME OF INSPECTION:	PLATE: ____ RUN: ____ START TIME: ________	PLATE: ____ RUN: ____ START TIME: ________	PLATE: ____ RUN: ____ START TIME: ________	PLATE: ____ RUN: ____ START TIME: ________
	Failed Not Failed	Failed Not Failed	Failed Not Failed	Failed Not Failed
	Failed Not Failed	Failed Not Failed	Failed Not Failed	Failed Not Failed
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	Failed Not Failed	Failed Not Failed	Failed Not Failed	Failed Not Failed
	Failed Not Failed	Failed Not Failed	Failed Not Failed	Failed Not Failed
	Failed Not Failed	Failed Not Failed	Failed Not Failed	Failed Not Failed

FAILURES CALLED BY: LEVEL: Novice Intermediate Expert

COMMENTS:

ATTACHMENT II: DETAILED TEST PLAN

Test #	Precipitation Type	Temp (ºC)	Precipitation Rate (g/dm²/h)	Fluid Name	Fluid Type	Dilution/Brix
V - 20	Light Freezing Rain	-10	13	UCAR Ultra +	Type IV EG	100
V - 21	Light Freezing Rain	-10	13	Clariant Safewing MPIV 2030 ECO	Type IV PG	100
V - 22	Light Freezing Rain	-10	13	Clariant Safewing MPIV 2030 ECO	Type IV PG	75/25
V - 23	Light Freezing Rain	-10	13	UCAR EG ADF	Type I	22.5
V - 16	Light Freezing Rain	-3	25	UCAR Ultra +	Type IV EG	100
V - 17	Light Freezing Rain	-3	25	Clariant Safewing MPIV 2030 ECO	Type IV PG	100
V - 18	Light Freezing Rain	-3	25	Clariant Safewing MPIV 2030 ECO	Type IV PG	75/25
V - 19	Light Freezing Rain	-3	25	UCAR EG ADF	Type I	17
V - 5	Light Freezing Rain	-3	13	UCAR Ultra +	Type IV EG	100
V - 6	Light Freezing Rain	-3	13	Clariant Safewing MPIV 2030 ECO	Type IV PG	100
V - 7	Light Freezing Rain	-3	13	Clariant Safewing MPIV 2030 ECO	Type IV PG	75/25
V - 8	Light Freezing Rain	-3	13	UCAR EG ADF	Type I	17
V - 13	Freezing Fog	-25	2	UCAR Ultra +	Type IV EG	100
V - 14	Freezing Fog	-25	2	Clariant Safewing MPIV 2030 ECO	Type IV PG	100
V - 15	Freezing Fog	-25	2	Clariant Safewing MPIV 2030 ECO	Type IV PG	75/25
V - 24	Freezing Fog	-14	2	UCAR Ultra +	Type IV EG	100
V - 25	Freezing Fog	-14	2	Clariant Safewing MPIV 2030 ECO	Type IV PG	100
V - 26	Freezing Fog	-14	2	Clariant Safewing MPIV 2030 ECO	Type IV PG	75/25
V - 27	Freezing Fog	-14	5	UCAR Ultra +	Type IV EG	100
V - 28	Freezing Fog	-14	5	Clariant Safewing MPIV 2030 ECO	Type IV PG	100
V - 29	Freezing Fog	-14	5	Clariant Safewing MPIV 2030 ECO	Type IV PG	75/25
V - 9	Freezing Fog	-3	5	UCAR Ultra +	Type IV EG	100
V - 10	Freezing Fog	-3	5	Clariant Safewing MPIV 2030 ECO	Type IV PG	100
V - 11	Freezing Fog	-3	5	Clariant Safewing MPIV 2030 ECO	Type IV PG	75/25
V - 12	Freezing Fog	-3	5	UCAR EG ADF	Type I	17
V - 1	Freezing Drizzle	-10	5	UCAR Ultra +	Type IV EG	100
V - 2	Freezing Drizzle	-10	5	Clariant Safewing MPIV 2030 ECO	Type IV PG	100
V - 3	Freezing Drizzle	-10	5	Clariant Safewing MPIV 2030 ECO	Type IV PG	75/25
V - 4	Freezing Drizzle	-10	5	UCAR EG ADF	Type I	22.5

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APPENDIX D

LOG OF VARIANCE TESTS

Table D-1: Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
1	1	Kilfrost ABC 2000	50%	PG	Type II	Natural Snow	23	-5.3	02-Mar-03	8	100%	Exp 2
1	2	Kilfrost ABC 2000	50%	PG	Type II	Natural Snow	23	-5.3	02-Mar-03	12	153%	Int 3
1	3	Kilfrost ABC 2000	50%	PG	Type II	Natural Snow	23	-5.3	02-Mar-03	9	120%	Nov 1
2	1	Kilfrost ABC 2000	50%	PG	Type II	Natural Snow	23	-5.3	02-Mar-03	8	100%	Exp 2
2	2	Kilfrost ABC 2000	50%	PG	Type II	Natural Snow	23	-5.3	02-Mar-03	12	153%	Int 3
2	3	Kilfrost ABC 2000	50%	PG	Type II	Natural Snow	23	-5.3	02-Mar-03	9	120%	Nov 1
3	1	Kilfrost ABC 2000	50%	PG	Type II	Natural Snow	23	-5.3	02-Mar-03	8	100%	Exp 2
3	2	Kilfrost ABC 2000	50%	PG	Type II	Natural Snow	23	-5.3	02-Mar-03	10	127%	Int 3
3	3	Kilfrost ABC 2000	50%	PG	Type II	Natural Snow	23	-5.3	02-Mar-03	10	133%	Nov 1
4	1	UCAR Ultra+	100%	EG	Type IV	Natural Snow	19	-4.1	02-Mar-03	51	100%	Exp 2
4	2	UCAR Ultra+	100%	EG	Type IV	Natural Snow	19	-4.1	02-Mar-03	53	104%	Int 3
4	3	UCAR Ultra+	100%	EG	Type IV	Natural Snow	19	-4.1	02-Mar-03	51	100%	Nov 1
5	1	UCAR Ultra+	100%	EG	Type IV	Natural Snow	19	-4.1	02-Mar-03	45	100%	Exp 2
5	2	UCAR Ultra+	100%	EG	Type IV	Natural Snow	19	-4.1	02-Mar-03	44	98%	Int 3
5	3	UCAR Ultra+	100%	EG	Type IV	Natural Snow	19	-4.1	02-Mar-03	42	93%	Nov 1
6	1	UCAR Ultra+	100%	EG	Type IV	Natural Snow	19	-4.1	02-Mar-03	40	100%	Exp 2
6	2	UCAR Ultra+	100%	EG	Type IV	Natural Snow	19	-4.1	02-Mar-03	41	103%	Int 3
6	3	UCAR Ultra+	100%	EG	Type IV	Natural Snow	19	-4.1	02-Mar-03	39	98%	Nov 1
7	1	Type I	10º buffer	EG	Type I	Natural Snow	34	-4.1	02-Mar-03	4	100%	Exp 2
7	2	Type I	10º buffer	EG	Type I	Natural Snow	34	-4.1	02-Mar-03	4	114%	Int 3
7	3	Type I	10º buffer	EG	Type I	Natural Snow	34	-4.1	02-Mar-03	4	114%	Nov 1
8	1	Type I	10º buffer	EG	Type I	Natural Snow	34	-4.1	02-Mar-03	4	100%	Exp 2
8	2	Type I	10º buffer	EG	Type I	Natural Snow	34	-4.1	02-Mar-03	5	143%	Int 3
8	3	Type I	10º buffer	EG	Type I	Natural Snow	34	-4.1	02-Mar-03	5	129%	Nov 1
9	1	Type I	10º buffer	EG	Type I	Natural Snow	34	-4.1	02-Mar-03	4	100%	Exp 2
9	2	Type I	10º buffer	EG	Type I	Natural Snow	34	-4.1	02-Mar-03	5	143%	Int 3
9	3	Type I	10º buffer	EG	Type I	Natural Snow	34	-4.1	02-Mar-03	5	129%	Nov 1
10	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	8	-10.5	05-Mar-03	81	100%	Exp 2
10	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	8	-10.5	05-Mar-03	85	105%	Int 3
10	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	8	-10.5	05-Mar-03	71	88%	Nov 5
11	1	Clariant Safewing MPII 1951	75%	PG	Type II	Natural Snow	8	-10.5	05-Mar-03	49	100%	Exp 2
11	2	Clariant Safewing MPII 1951	75%	PG	Type II	Natural Snow	8	-10.5	05-Mar-03	47	96%	Int 3
11	3	Clariant Safewing MPII 1951	75%	PG	Type II	Natural Snow	8	-10.5	05-Mar-03	39	80%	Nov 5

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
12	1	Type I	10º buffer	EG	Type I	Natural Snow	8	-10.5	05-Mar-03	12	100%	Exp 2
12	2	Type I	10º buffer	EG	Type I	Natural Snow	8	-10.5	05-Mar-03	12	100%	Int 3
12	3	Type I	10º buffer	EG	Type I	Natural Snow	8	-10.5	05-Mar-03	12	106%	Nov 5
13	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	5	-10.5	05-Mar-03	113	100%	Exp 2
13	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	5	-10.5	05-Mar-03	101	89%	Nov 5
14	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	5	-10.5	05-Mar-03	96	100%	Exp 2
14	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	5	-10.5	05-Mar-03	86	90%	Nov 5
15	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	116	100%	Exp 2
15	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	115	99%	Exp 1
15	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	117	101%	Int 2
16	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	115	100%	Exp 2
16	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	109	95%	Exp 1
16	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	115	100%	Int 2
17	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	75	100%	Exp 2
17	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	71	94%	Exp 1
17	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	75	99%	Int 2
18	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	110	100%	Exp 2
18	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	107	97%	Exp 1
18	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	106	97%	Int 2
19	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	71	100%	Exp 2
19	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	68	95%	Exp 1
19	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	68	96%	Int 2
20	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	116	100%	Exp 2
20	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	115	99%	Exp 1
20	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	116	101%	Int 2
21	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	114	100%	Exp 2
21	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	111	97%	Exp 1
21	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	6	-12	04-Mar-03	115	101%	Int 2
22	1	UCAR Ultra+/UCAR EG	100%	EG	Type IV	Natural Snow	5	-11.3	04-Mar-03	126	100%	Exp 2
22	2	UCAR Ultra+/UCAR EG	100%	EG	Type IV	Natural Snow	5	-11.3	04-Mar-03	127	101%	Int 2
22	3	UCAR Ultra+/UCAR EG	100%	EG	Type IV	Natural Snow	5	-11.3	04-Mar-03	116	92%	Nov 5
22	4	UCAR Ultra+/UCAR EG	100%	EG	Type IV	Natural Snow	5	-11.3	04-Mar-03	122	97%	Nov 6
23	1	UCAR Ultra+/UCAR EG	100%	EG	Type IV	Natural Snow	5	-11	04-Mar-03	136	100%	Exp 2

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
23	2	UCAR Ultra+/UCAR EG	100%	EG	Type IV	Natural Snow	5	-11	04-Mar-03	137	101%	Int 2
23	3	UCAR Ultra+/UCAR EG	100%	EG	Type IV	Natural Snow	5	-11.3	04-Mar-03	125	93%	Nov 5
23	4	UCAR Ultra+/UCAR EG	100%	EG	Type IV	Natural Snow	5	-11	04-Mar-03	137	101%	Nov 6
24	1	UCAR Ultra+	100%	EG	Type IV	Natural Snow	5	-11	04-Mar-03	107	100%	Exp 2
24	2	UCAR Ultra+	100%	EG	Type IV	Natural Snow	5	-11	04-Mar-03	104	98%	Int 2
24	3	UCAR Ultra+	100%	EG	Type IV	Natural Snow	5	-11	04-Mar-03	79	74%	Nov 5
24	4	UCAR Ultra+	100%	EG	Type IV	Natural Snow	5	-11	04-Mar-03	105	98%	Nov 6
25	1	UCAR Ultra+	100%	EG	Type IV	Natural Snow	26	-3	08-Mar-03	83	100%	Exp 2
25	2	UCAR Ultra+	100%	EG	Type IV	Natural Snow	26	-3	08-Mar-03	71	86%	Nov 1
25	3	UCAR Ultra+	100%	EG	Type IV	Natural Snow	26	-3	08-Mar-03	67	81%	Nov 2
26	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	26	-3	08-Mar-03	57	100%	Exp 2
26	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	26	-3	08-Mar-03	47	82%	Nov 1
26	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	26	-3	08-Mar-03	23	40%	Nov 2
27	1	Clariant Safewing MPII 1951	50%	PG	Type II	Natural Snow	26	-3	08-Mar-03	7	100%	Exp 2
27	2	Clariant Safewing MPII 1951	50%	PG	Type II	Natural Snow	26	-3	08-Mar-03	8	114%	Nov 1
27	3	Clariant Safewing MPII 1951	50%	PG	Type II	Natural Snow	26	-3	08-Mar-03	9	128%	Nov 2
28	1	UCAR Ultra+	100%	EG	Type IV	Natural Snow	23	-3	08-Mar-03	112	100%	Exp 2
28	2	UCAR Ultra+	100%	EG	Type IV	Natural Snow	23	-3	08-Mar-03	113	101%	Nov 1
28	3	UCAR Ultra+	100%	EG	Type IV	Natural Snow	23	-3	08-Mar-03	109	97%	Nov 2
29	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	23	-3	08-Mar-03	105	100%	Exp 2
29	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	23	-3	08-Mar-03	104	99%	Nov 1
29	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	23	-3	08-Mar-03	98	93%	Nov 2
30	1	Clariant Safewing MPII 1951	50%	PG	Type II	Natural Snow	23	-3.1	08-Mar-03	6	100%	Exp 2
30	2	Clariant Safewing MPII 1951	50%	PG	Type II	Natural Snow	23	-3.1	08-Mar-03	7	126%	Nov 1
30	3	Clariant Safewing MPII 1951	50%	PG	Type II	Natural Snow	23	-3.1	08-Mar-03	8	135%	Nov 2
31	1	UCAR EG ADF	10° buffer	EG	Type I	Natural Snow	23	-3.1	08-Mar-03	3	100%	Exp 2
31	2	UCAR EG ADF	10° buffer	EG	Type I	Natural Snow	23	-3.1	08-Mar-03	4	129%	Nov 1
31	3	UCAR EG ADF	10° buffer	EG	Type I	Natural Snow	23	-3.1	08-Mar-03	4	129%	Nov 2
32	1	UCAR Ultra+	100%	EG	Type IV	Natural Snow	17	-3.1	08-Mar-03	84	100%	Exp 2
32	2	UCAR Ultra+	100%	EG	Type IV	Natural Snow	17	-3.1	08-Mar-03	84	100%	Nov 1
32	3	UCAR Ultra+	100%	EG	Type IV	Natural Snow	17	-3.1	08-Mar-03	84	100%	Nov 2
33	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	17	-3.1	08-Mar-03	66	100%	Exp 2
33	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	17	-3.1	08-Mar-03	68	103%	Nov 1

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
33	3	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	17	-3.1	08-Mar-03	68	103%	Nov 2
34	1	Clariant Safewing MPII 1951	50%	PG	Type II	Natural Snow	17	-3.1	08-Mar-03	8	100%	Exp 2
34	2	Clariant Safewing MPII 1951	50%	PG	Type II	Natural Snow	17	-3.1	08-Mar-03	7	87%	Nov 1
34	3	Clariant Safewing MPII 1951	50%	PG	Type II	Natural Snow	17	-3.1	08-Mar-03	6	80%	Nov 2
35	1	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	17	-3.1	08-Mar-03	3	100%	Exp 2
35	2	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	17	-3.1	08-Mar-03	4	116%	Nov 1
35	3	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	17	-3.1	08-Mar-03	4	132%	Nov 2
36	1	Clariant Safewing MP IV 2030	50%	PG	Type IV	Natural Snow	10	-3.1	08-Mar-03	23	100%	Exp 2
36	2	Clariant Safewing MP IV 2030	50%	PG	Type IV	Natural Snow	10	-3.1	08-Mar-03	24	106%	Nov 1
36	3	Clariant Safewing MP IV 2030	50%	PG	Type IV	Natural Snow	10	-3.1	08-Mar-03	24	107%	Nov 2
37	1	Clariant Safewing MP IV 2030	50%	PG	Type IV	Natural Snow	10	-3.1	08-Mar-03	22	100%	Exp 2
37	2	Clariant Safewing MP IV 2030	50%	PG	Type IV	Natural Snow	10	-3.1	08-Mar-03	23	107%	Nov 1
37	3	Clariant Safewing MP IV 2030	50%	PG	Type IV	Natural Snow	10	-3.1	08-Mar-03	23	108%	Nov 2
38	1	Clariant Safewing MP II 2025	50%	PG	Type II	Natural Snow	10	-3.1	08-Mar-03	18	100%	Exp 2
38	2	Clariant Safewing MP II 2025	50%	PG	Type II	Natural Snow	10	-3.1	08-Mar-03	19	106%	Nov 1
38	3	Clariant Safewing MP II 2025	50%	PG	Type II	Natural Snow	10	-3.1	08-Mar-03	19	109%	Nov 2
39	1	Clariant Safewing MP II 2025	50%	PG	Type II	Natural Snow	10	-3.1	08-Mar-03	17	100%	Exp 2
39	2	Clariant Safewing MP II 2025	50%	PG	Type II	Natural Snow	10	-3.1	08-Mar-03	19	110%	Nov 1
39	3	Clariant Safewing MP II 2025	50%	PG	Type II	Natural Snow	10	-3.1	08-Mar-03	19	111%	Nov 2
40	1	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	116	n/a	Int 2
40	2	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	120	n/a	Int 1
40	3	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	118	n/a	Nov 4
40	4	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	114	n/a	Nov 1
41	1	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	92	n/a	Int 2
41	2	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	91	n/a	Int 1
42	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	73	n/a	Int 2
42	2	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	73	n/a	Int 1
43	1	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	7	-7	05-Apr-03	90	n/a	Int 2
43	2	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	7	-7	05-Apr-03	85	n/a	Int 1
44	1	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	7	-7	05-Apr-03	56	n/a	Int 2
44	2	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	7	-7	05-Apr-03	60	n/a	Int 1
45	1	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	7	-7	05-Apr-03	87	n/a	Int 2
45	2	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	7	-7	05-Apr-03	87	n/a	Int 1

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
46	1	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	6	-7	05-Apr-03	56	n/a	Int 2
46	2	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	6	-7	05-Apr-03	64	n/a	Int 1
46	3	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	6	-7	05-Apr-03	43	n/a	Nov 4
46	4	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	6	-7	05-Apr-03	63	n/a	Nov 1
47	1	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	9	-7	05-Apr-03	9	n/a	Int 2
47	2	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	9	-7	05-Apr-03	8	n/a	Int 1
47	3	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	9	-7	05-Apr-03	6	n/a	Nov 4
47	4	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	9	-7	05-Apr-03	6	n/a	Nov 1
48	1	Kilfrost ABC-S	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	73	n/a	Int 2
48	2	Kilfrost ABC-S	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	73	n/a	Int 1
49	1	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	115	n/a	Int 2
49	2	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	7	-7	05-Apr-03	116	n/a	Int 1
50	1	UCAR Ultra+	100%	EG	Type IV	Natural Snow	9	-6.8	05-Apr-03	127	n/a	Int 3
50	2	UCAR Ultra+	100%	EG	Type IV	Natural Snow	9	-6.8	05-Apr-03	127	n/a	Nov 4
50	3	UCAR Ultra+	100%	EG	Type IV	Natural Snow	9	-6.8	05-Apr-03	127	n/a	Nov 1
51	1	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	74	100%	Exp 2
51	2	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	74	100%	Int 2
51	3	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	77	103%	Int 1
51	4	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	74	100%	Nov 4
51	5	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	73	99%	Nov 1
52	1	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	57	100%	Exp 2
52	2	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	56	97%	Int 2
52	3	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	71	124%	Int 1
53	1	Clariant Safewing MPIV 2001	100%	PG	Type IV	Natural Snow	16	-6.2	05-Apr-03	45	n/a	Int 2
53	2	Clariant Safewing MPIV 2002	100%	PG	Type IV	Natural Snow	16	-6.2	05-Apr-03	54	n/a	Int 1
54	1	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	18	-6.2	05-Apr-03	64	100%	Exp 2
54	2	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	18	-6.2	05-Apr-03	63	97%	Int 2
54	3	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	18	-6.2	05-Apr-03	64	100%	Int 1
55	1	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	16	-6.2	05-Apr-03	41	100%	Exp 2
55	2	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	16	-6.2	05-Apr-03	41	98%	Int 2
55	3	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	16	-6.2	05-Apr-03	44	106%	Int 1
55	4	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	16	-6.2	05-Apr-03	39	95%	Nov 4
55	5	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	16	-6.2	05-Apr-03	39	95%	Nov 1

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
56	1	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	73	100%	Exp 2
56	2	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	70	96%	Int 2
56	3	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	73	100%	Int 1
56	4	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	68	93%	Nov 4
56	5	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	72	99%	Nov 1
57	1	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	61	100%	Exp 2
57	2	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	57	94%	Int 2
57	3	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	65	107%	Int 1
58	1	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	10	-6.2	05-Apr-03	6	n/a	Int 2
58	2	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	10	-6.2	05-Apr-03	8	n/a	Int 1
58	3	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	10	-6.2	05-Apr-03	8	n/a	Nov 4
58	4	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	10	-6.2	05-Apr-03	8	n/a	Nov 1
59	1	Kilfrost ABC-S	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	59	n/a	Int 2
59	2	Kilfrost ABC-S	100%	PG	Type IV	Natural Snow	18	-6.2	05-Apr-03	60	n/a	Int 1
60	1	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	16	-6.2	05-Apr-03	51	100%	Exp 2
60	2	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	16	-6.2	05-Apr-03	54	105%	Int 2
60	3	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	18	-6.2	05-Apr-03	57	112%	Int 1
61	1	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	14	-6.2	05-Apr-03	76	100%	Exp 2
61	2	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	14	-6.2	05-Apr-03	75	99%	Int 2
61	3	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	14	-6.2	05-Apr-03	77	102%	Int 1
62	1	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	13	-6.2	05-Apr-03	58	100%	Exp 2
62	2	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	13	-6.2	05-Apr-03	58	100%	Int 2
62	3	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	13	-6.2	05-Apr-03	67	115%	Int 1
63	1	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	52	100%	Exp 2
63	2	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	54	103%	Int 2
63	3	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	55	105%	Int 1
64	1	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	36	100%	Exp 2
64	2	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	35	98%	Int 2
64	3	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	37	103%	Int 1
64	4	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	36	101%	Nov 4
64	5	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	37	104%	Nov 1
65	1	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	14	-6.2	05-Apr-03	74	100%	Exp 2
65	2	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	14	-6.2	05-Apr-03	72	97%	Int 2

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
65	3	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	14	-6.2	05-Apr-03	77	104%	Int 1
65	4	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	14	-6.2	05-Apr-03	70	95%	Nov 1
65	5	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	14	-6.2	05-Apr-03	73	99%	Nov 4
66	1	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	13	-6.2	05-Apr-03	52	100%	Exp 2
66	2	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	13	-6.2	05-Apr-03	52	101%	Int 2
66	3	Clariant Safewing MP IV 2030	75%	PG	Type IV	Natural Snow	13	-6.2	05-Apr-03	57	109%	Int 1
67	1	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	51	100%	Exp 2
67	2	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	52	101%	Int 2
67	3	Clariant Safewing MP II 2025	100%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	52	102%	Int 1
68	1	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	16	-6.2	05-Apr-03	12	100%	Exp 2
68	2	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	16	-6.2	05-Apr-03	12	104%	Int 2
68	3	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	16	-6.2	05-Apr-03	11	96%	Int 1
68	4	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	16	-6.2	05-Apr-03	14	117%	Nov 4
68	5	UCAR EG ADF	10º buffer	EG	Type I	Natural Snow	16	-6.2	05-Apr-03	11	92%	Nov 1
69	1	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	36	100%	Exp 2
69	2	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	35	97%	Int 2
69	3	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	37	104%	Int 1
69	4	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	38	106%	Nov 4
69	5	Clariant Safewing MP II 2025	75%	PG	Type II	Natural Snow	13	-6.2	05-Apr-03	35	97%	Nov 1
70	1	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	13	-6.2	05-Apr-03	66	100%	Exp 2
70	2	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	13	-6.2	05-Apr-03	65	99%	Int 2
70	3	Clariant Safewing MP IV 2030	100%	PG	Type IV	Natural Snow	14	-6.2	05-Apr-03	74	111%	Int 1
71	1	Clariant MP IV 2030	75%	PG	Type IV	Freezing Fog	5	-3	02-Apr-03	89	100%	Exp 2
71	2	Clariant MP IV 2030	75%	PG	Type IV	Freezing Fog	5	-3	02-Apr-03	89	100%	Int 3
71	3	Clariant MP IV 2030	75%	PG	Type IV	Freezing Fog	5	-3	02-Apr-03	88	101%	Nov 1
72	1	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Fog	5	-3	02-Apr-03	19	100%	Exp 2
72	2	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Fog	5	-3	02-Apr-03	20	95%	Int 3
72	3	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Fog	5	-3	02-Apr-03	23	79%	Nov 1
73	1	UCAR EG ADF	10° buffer	EG	Type I	Freezing Fog	5	-3	02-Apr-03	13	100%	Exp 2
73	2	UCAR EG ADF	10° buffer	EG	Type I	Freezing Fog	5	-3	02-Apr-03	13	100%	Int 3
73	3	UCAR EG ADF	10° buffer	EG	Type I	Freezing Fog	5	-3	02-Apr-03	12	106%	Nov 1
74	1	Clariant MP II 2025	50%	PG	Type II	Freezing Fog	5	-3	02-Apr-03	28	100%	Exp 2
74	2	Clariant MP II 2025	50%	PG	Type II	Freezing Fog	5	-3	02-Apr-03	29	98%	Int 3

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
74	3	Clariant MP II 2025	50%	PG	Type II	Freezing Fog	5	-3	02-Apr-03	29	98%	Nov 1
75	1	UCAR Ultra+	100%	EG	Type IV	Freezing Fog	5	-3	02-Apr-03	217	100%	Exp 2
75	2	UCAR Ultra+	100%	EG	Type IV	Freezing Fog	5	-3	02-Apr-03	249	85%	Int 3
76	1	UCAR Ultra+	100%	EG	Type IV	Freezing Fog	5	-25	07-Apr-03	51	100%	Exp 2
76	2	UCAR Ultra+	100%	EG	Type IV	Freezing Fog	5	-25	07-Apr-03	48	106%	Int 3
76	3	UCAR Ultra+	100%	EG	Type IV	Freezing Fog	5	-25	07-Apr-03	79	46%	Nov 1
77	1	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	5	-25	07-Apr-03	27	100%	Exp 2
77	2	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	5	-25	07-Apr-03	40	51%	Int 3
77	3	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	5	-25	07-Apr-03	21	122%	Nov 1
78	1	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Fog	5	-25	07-Apr-03	7	100%	Exp 2
78	2	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Fog	5	-25	07-Apr-03	6	115%	Int 3
78	3	Clariant MP I 1938	10° buffer	EG	Type I	Freezing Fog	5	-25	07-Apr-03	8	85%	Nov 1
79	1	UCAR EG ADF	10° buffer	EG	Type I	Freezing Fog	2	-25	07-Apr-03	8	100%	Exp 2
79	2	UCAR EG ADF	10° buffer	EG	Type I	Freezing Fog	2	-25	07-Apr-03	7	112%	Int 3
79	3	UCAR EG ADF	10° buffer	EG	Type I	Freezing Fog	2	-25	07-Apr-03	8	100%	Nov 1
79	4	UCAR EG ADF	10° buffer	EG	Type I	Freezing Fog	2	-25	07-Apr-03	11	63%	Nov 3
80	1	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	2	-25	07-Apr-03	49	100%	Exp 2
80	2	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	2	-25	07-Apr-03	45	108%	Int 3
80	3	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	2	-25	07-Apr-03	56	86%	Nov 1
80	4	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	2	-25	07-Apr-03	20	159%	Nov 3
81	1	UCAR Ultra+	100%	EG	Type IV	Freezing Fog	2	-14	07-Apr-03	251	100%	Exp 2
81	2	UCAR Ultra+	100%	EG	Type IV	Freezing Fog	2	-14	07-Apr-03	260	96%	Int 3
81	3	UCAR Ultra+	100%	EG	Type IV	Freezing Fog	2	-14	07-Apr-03	259	97%	Nov 1
81	4	UCAR Ultra+	100%	EG	Type IV	Freezing Fog	2	-14	07-Apr-03	237	106%	Nov 3
82	1	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Fog	2	-14	10-Apr-03	9	100%	Exp 2
82	2	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Fog	2	-14	10-Apr-03	7	119%	Int 3
82	3	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Fog	2	-14	10-Apr-03	6	129%	Nov 1
82	4	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Fog	2	-14	10-Apr-03	6	133%	Nov 3
83	1	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	2	-14	10-Apr-03	102	100%	Exp 2
83	2	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	2	-14	10-Apr-03	104	98%	Int 3
83	3	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	2	-14	10-Apr-03	69	132%	Nov 1
83	4	Clariant MP IV 2030	100%	PG	Type IV	Freezing Fog	2	-14	10-Apr-03	96	106%	Nov 3
84	1	Clariant MP IV 2030	75%	PG	Type IV	Freezing Fog	2	-14	10-Apr-03	79	100%	Exp 2

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
84	2	Clariant MP IV 2030	75%	PG	Type IV	Freezing Fog	2	-14	10-Apr-03	69	113%	Int 3
84	3	Clariant MP IV 2030	75%	PG	Type IV	Freezing Fog	2	-14	10-Apr-03	68	114%	Nov 1
84	4	Clariant MP IV 2030	75%	PG	Type IV	Freezing Fog	2	-14	10-Apr-03	85	93%	Nov 3
85	1	UCAR Ultra+	100%	EG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	57	100%	Exp 2
85	2	UCAR Ultra+	100%	EG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	57	100%	Int 3
85	3	UCAR Ultra+	100%	EG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	57	100%	Nov 1
85	4	UCAR Ultra+	100%	EG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	56	101%	Nov 3
86	1	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	24	100%	Exp 2
86	2	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	31	70%	Int 3
86	3	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	39	36%	Nov 1
86	4	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	11	154%	Nov 3
87	1	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	28	100%	Exp 2
87	2	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	29	96%	Int 3
87	3	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	31	89%	Nov 1
87	4	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	13	-10	08-Apr-03	30	92%	Nov 3
88	1	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	13	-10	08-Apr-03	4	100%	Exp 2
88	2	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	13	-10	08-Apr-03	5	77%	Int 3
88	3	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	13	-10	08-Apr-03	5	95%	Nov 1
88	4	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	13	-10	08-Apr-03	6	61%	Nov 3
89	1	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	25	-10	08-Apr-03	5	100%	Exp 2
89	2	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	25	-10	08-Apr-03	6	79%	Int 4
89	3	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	25	-10	08-Apr-03	5	97%	Int 3
89	4	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	25	-10	08-Apr-03	6	79%	Nov 1
90	1	Clariant MP I 1938	10° buffer	PG	Type I	Light Freezing Rain	25	-10	08-Apr-03	5	100%	Exp 2
90	2	Clariant MP I 1938	10° buffer	PG	Type I	Light Freezing Rain	25	-10	08-Apr-03	5	95%	Int 4
90	3	Clariant MP I 1938	10° buffer	PG	Type I	Light Freezing Rain	25	-10	08-Apr-03	5	95%	Int 3
90	4	Clariant MP I 1938	10° buffer	PG	Type I	Light Freezing Rain	25	-10	08-Apr-03	5	105%	Nov 1
91	1	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	25	-10	08-Apr-03	24	100%	Exp 2
91	2	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	25	-10	08-Apr-03	25	97%	Int 4
91	3	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	25	-10	08-Apr-03	23	104%	Int 3
91	4	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	25	-10	08-Apr-03	23	104%	Nov 1
92	1	Clariant MP II 2025	75%	PG	Type II	Light Freezing Rain	25	-10	08-Apr-03	13	100%	Exp 2
92	2	Clariant MP II 2025	75%	PG	Type II	Light Freezing Rain	25	-10	08-Apr-03	16	79%	Int 4

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
92	3	Clariant MP II 2025	75%	PG	Type II	Light Freezing Rain	25	-10	08-Apr-03	12	108%	Int 3
92	4	Clariant MP II 2025	75%	PG	Type II	Light Freezing Rain	25	-10	08-Apr-03	14	92%	Nov 1
93	1	UCAR Ultra+	100%	EG	Type IV	Light Freezing Rain	25	-10	08-Apr-03	39	100%	Exp 2
93	2	UCAR Ultra+	100%	EG	Type IV	Light Freezing Rain	25	-10	08-Apr-03	41	95%	Int 4
93	3	UCAR Ultra+	100%	EG	Type IV	Light Freezing Rain	25	-10	08-Apr-03	40	97%	Int 3
93	4	UCAR Ultra+	100%	EG	Type IV	Light Freezing Rain	25	-10	08-Apr-03	39	99%	Nov 1
94	1	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	13	-10	08-Apr-03	6	n/a	Int 3
94	2	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	13	-10	08-Apr-03	6	n/a	Nov 1
94	3	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	13	-10	08-Apr-03	10	n/a	Nov 3
95	1	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Drizzle	13	-10	08-Apr-03	5	n/a	Int 3
95	2	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Drizzle	13	-10	08-Apr-03	7	n/a	Nov 1
95	3	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Drizzle	13	-10	08-Apr-03	7	n/a	Nov 3
96	1	Clariant MP IV 2030	100%	PG	Type IV	Freezing Drizzle	13	-10	08-Apr-03	46	n/a	Int 3
96	2	Clariant MP IV 2030	100%	PG	Type IV	Freezing Drizzle	13	-10	08-Apr-03	42	n/a	Nov 1
96	3	Clariant MP IV 2030	100%	PG	Type IV	Freezing Drizzle	13	-10	08-Apr-03	64	n/a	Nov 3
97	1	Clariant MP II 2025	75%	PG	Type II	Freezing Drizzle	13	-10	08-Apr-03	24	n/a	Int 3
97	2	Clariant MP II 2025	75%	PG	Type II	Freezing Drizzle	13	-10	08-Apr-03	19	n/a	Nov 1
97	3	Clariant MP II 2025	75%	PG	Type II	Freezing Drizzle	13	-10	08-Apr-03	26	n/a	Nov 3
98	1	Clariant MP IV 2030	100%	PG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	65	100%	Exp 2
98	2	Clariant MP IV 2030	100%	PG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	66	98%	Int 1
98	3	Clariant MP IV 2030	100%	PG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	89	62%	Nov 1
98	4	Clariant MP IV 2030	100%	PG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	102	42%	Nov 3
99	1	Clariant MP IV 2030	75%	PG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	59	100%	Exp 2
99	2	Clariant MP IV 2030	75%	PG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	62	94%	Int 1
99	3	Clariant MP IV 2030	75%	PG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	69	82%	Nov 1
99	4	Clariant MP IV 2030	75%	PG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	70	80%	Nov 3
100	1	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	5	-10	08-Apr-03	9	100%	Exp 2
100	2	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	5	-10	08-Apr-03	9	95%	Int 3
100	3	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	5	-10	08-Apr-03	9	98%	Nov 1
100	4	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	5	-10	08-Apr-03	8	110%	Nov 3
101	1	UCAR Ultra+	100%	EG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	121	100%	Exp 2
101	2	UCAR Ultra+	100%	EG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	131	92%	Int 3
101	3	UCAR Ultra+	100%	EG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	131	92%	Nov 1

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
101	4	UCAR Ultra +	100%	EG	Type IV	Freezing Drizzle	5	-10	08-Apr-03	131	91%	Nov 3
102	1	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	25	-3	09-Apr-03	16	100%	Exp 2
102	2	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	25	-3	09-Apr-03	19	80%	Int 3
102	3	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	25	-3	09-Apr-03	12	126%	Nov 1
102	4	UCAR EG ADF	10° buffer	EG	Type I	Light Freezing Rain	25	-3	09-Apr-03	25	43%	Nov 3
103	1	UCAR Ultra +	100%	EG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	40	100%	Exp 2
103	2	UCAR Ultra +	100%	EG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	39	103%	Int 3
103	3	UCAR Ultra +	100%	EG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	40	101%	Nov 1
103	4	UCAR Ultra +	100%	EG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	52	69%	Nov 3
104	1	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	42	98%	Exp 2
104	2	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	39	104%	Int 1
104	3	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	40	102%	Nov 1
104	4	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	45	91%	Nov 3
105	1	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	30	102%	Exp 2
105	2	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	28	107%	Int 1
105	3	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	29	106%	Nov 1
105	4	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	25	-3	09-Apr-03	33	92%	Nov 3
106	1	Clariant MP II 2025	50%	PG	Type II	Light Freezing Rain	25	-3	09-Apr-03	8	100%	Exp 2
106	2	Clariant MP II 2025	50%	PG	Type II	Light Freezing Rain	25	-3	09-Apr-03	6	128%	Int 3
106	3	Clariant MP II 2025	50%	PG	Type II	Light Freezing Rain	25	-3	09-Apr-03	9	89%	Nov 1
107	1	Clariant MP I 1938	10° buffer	PG	Type I	Light Freezing Rain	25	-3	09-Apr-03	11	100%	Exp 2
107	2	Clariant MP I 1938	10° buffer	PG	Type I	Light Freezing Rain	25	-3	09-Apr-03	13	77%	Int 3
107	3	Clariant MP I 1938	10° buffer	PG	Type I	Light Freezing Rain	25	-3	09-Apr-03	12	86%	Nov 1
107	4	Clariant MP I 1938	10° buffer	PG	Type I	Light Freezing Rain	25	-3	09-Apr-03	14	73%	Nov 3
108	1	UCAR Ultra +	100%	EG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	53	100%	Exp 2
108	2	UCAR Ultra +	100%	EG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	52	102%	Int 3
108	3	UCAR Ultra +	100%	EG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	53	100%	Nov 1
108	4	UCAR Ultra +	100%	EG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	52	102%	Nov 7
109	1	Clariant MP IV 2030	50%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	17	100%	Exp 2
109	2	Clariant MP IV 2030	50%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	17	100%	Int 3
109	3	Clariant MP IV 2030	50%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	16	106%	Nov 1
109	4	Clariant MP IV 2030	50%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	27	41%	Nov 7
110	1	Clariant MP II 2025	50%	PG	Type II	Light Freezing Rain	13	-3	09-Apr-03	11	100%	Exp 2

Table D-1 (cont'd): Log of Variance Tests

Test #	Obs.	Fluid	Fluid Dilution	PG/EG	Fluid Type	Precipitation Type	Approx. Rate (g/dm²/h)	Approx. Temp. (°C)	Date	HOT (minutes)	ET Score	Tester
110	2	Clariant MP II 2025	50%	PG	Type II	Light Freezing Rain	13	-3	09-Apr-03	10	106%	Int 3
110	3	Clariant MP II 2025	50%	PG	Type II	Light Freezing Rain	13	-3	09-Apr-03	11	105%	Nov 1
110	4	Clariant MP II 2025	50%	PG	Type II	Light Freezing Rain	13	-3	09-Apr-03	19	32%	Nov 7
111	1	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	54	100%	Exp 2
111	2	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	50	107%	Int 1
111	3	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	53	102%	Nov 1
111	4	Clariant MP IV 2030	100%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	56	96%	Nov 7
112	1	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	38	100%	Exp 2
112	2	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	38	99%	Int 3
112	3	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	37	103%	Nov 1
112	4	Clariant MP IV 2030	75%	PG	Type IV	Light Freezing Rain	13	-3	09-Apr-03	36	105%	Nov 7
113	1	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Drizzle	13	-3	09-Apr-03	11	100%	Exp 2
113	2	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Drizzle	13	-3	09-Apr-03	11	97%	Int 3
113	3	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Drizzle	13	-3	09-Apr-03	10	108%	Nov 1
113	4	Clariant MP I 1938	10° buffer	PG	Type I	Freezing Drizzle	13	-3	09-Apr-03	16	52%	Nov 3
114	1	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	13	-3	09-Apr-03	10	100%	Exp 2
114	2	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	13	-3	09-Apr-03	10	100%	Int 3
114	3	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	13	-3	09-Apr-03	11	95%	Nov 1
114	4	UCAR EG ADF	10° buffer	EG	Type I	Freezing Drizzle	13	-3	09-Apr-03	12	85%	Nov 3
115	1	Clariant MP IV 2030	75%	PG	Type IV	Freezing Drizzle	13	-3	09-Apr-03	31	100%	Exp 2
115	2	Clariant MP IV 2030	75%	PG	Type IV	Freezing Drizzle	13	-3	09-Apr-03	32	96%	Int 3
115	3	Clariant MP IV 2030	75%	PG	Type IV	Freezing Drizzle	13	-3	09-Apr-03	31	102%	Nov 1
115	4	Clariant MP IV 2030	75%	PG	Type IV	Freezing Drizzle	13	-3	09-Apr-03	32	96%	Nov 3
116	1	Clariant MP II 2025	50%	PG	Type II	Freezing Drizzle	13	-3	09-Apr-03	11	100%	Exp 2
116	2	Clariant MP II 2025	50%	PG	Type II	Freezing Drizzle	13	-3	09-Apr-03	10	108%	Int 3
116	3	Clariant MP II 2025	50%	PG	Type II	Freezing Drizzle	13	-3	09-Apr-03	10	109%	Nov 1
116	4	Clariant MP II 2025	50%	PG	Type II	Freezing Drizzle	13	-3	09-Apr-03	14	68%	Nov 3