TP 13661E

A Second-Generation Snowmaking System: Prototype Testing

Prepared for

Transportation Development Centre
On behalf of
Civil Aviation
Transport Canada

and

The Federal Aviation Administration
William J. Hughes Technical Centre

APS AVIATION INC.

August 2000

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by

Marc Hunt and
Medhat Hanna

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PREFACE

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. has undertaken a research program to advance aircraft ground de/anti-icing technology. The specific objectives of the APS test program are the following:

- To develop holdover time data for Type IV fluids using lowest-qualifying viscosity samples, and to develop holdover time data for all newly-qualified de/anti-icing fluids;
- To conduct flat plate holdover time tests under conditions of frost;
- To further evaluate the flow of contaminated fluid from the wing of a Falcon 20D aircraft during simulated takeoff runs;
- To determine the patterns of frost formation and of fluid failure initiation and progression on the wings of commercial aircraft;
- To evaluate whether the proposed locations of Allied Signal's wing-mounted ice sensors on an Air Canada CL65 are optimally positioned;
- To evaluate the second generation of the NCAR snowmaking system;
- To evaluate the capabilities of ice detection camera systems;
- To examine the feasibility of and procedures for performing wing inspections with a remote ice detection camera system at the entrance to the departure runway (end-of-runway);
- To reassemble and prepare the JetStar aircraft wing for mounting, to modify it to obtain cold-soak capabilities, and to conduct fluid failure tests in natural precipitation using the wing;
- To extend hot water deicing tests to aircraft in natural outdoor precipitation conditions, and to correlate outdoor data with 1998-99 laboratory results;
- To examine safety issues and concerns of forced air deicing systems; and
- To evaluate snow weather data from previous winters to establish a range of snow precipitation suitable for the evaluation of holdover time limits.

The research activities of the program conducted on behalf of Transport Canada during the 1999-2000 winter season are documented in nine reports. The titles of these reports are as follows:

- TP 13659E Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 1999-2000 Winter;
- TP 13660E Aircraft Full-Scale Test Program for the 1999-2000 Winter: Evaluation of the Positioning of Surface-Mounted Ice Detection Sensors on the Bombardier CL-65 Aircraft;
- TP 13661E A Second-Generation Snowmaking System: Prototype Testing;

- TP 13662E Ice Detection Sensor Capabilities for End-of-Runway Wing Checks: Phase 2 Evaluation;
- TP 13663E Hot Water Deicing of Aircraft: Phase 2;
- TP 13664E Safety Issues and Concerns of Forced Air Deicing Systems;
- TP 13665E Snow Weather Data Evaluation (1995-2000);
- TP 13666E Contaminated Aircraft Simulated Takeoff Tests for the 1999-2000 Winter: Preparation and Procedures; and
- TP 13667E Preparation of JetStar Wing for Use in Deicing Research.

This report, TP 13661E, has the following objective:

- To evaluate the second generation of the NCAR snowmaking system.

This objective was met by conducting a series of artificial snow tests in a cold-chamber laboratory. Test parameters included ambient temperature, precipitation rate, and test fluid. The following test results were recorded: fluid failure times, snow appearance, and snowmaking-system functionality.

ACKNOWLEDGEMENTS

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

16. Abstract

A research program was conducted to compare holdover times for natural and artificial snow, and to evaluate the general functionality of a second-generation snowmaking system developed by National Council for Atmospheric Research (NCAR) under contract with the Federal Aviation Administration (FAA).

Prior to fluid testing, multiple fan position calibration and artificial snow distribution tests were performed by APS Aviation Inc. A total of 62 Type IV tests and 17 Type I artificial snow tests were conducted on two separate occasions at National Research Council Canada's Climatic Engineering Facility in Ottawa. The fluid failure calls were made according to holdover time flat plate failure call standards.

Type IV fluids were tested at neat, 75/25 and 50/50 concentration, and Type I fluids were diluted with hard water to obtain fluids with a freeze point 10ºC below ambient air temperature. Tests were conducted at -3ºC, -14ºC, and -25ºC. The NCAR snowmaking machine was operated according to the guidelines set forth by NCAR in the operation manual supplied with the system.

The artificial snow exhibited significant differences from natural snow. The failure times observed for most Type I and Type IV fluids were shorter than the holdover times published. The snow distribution produced by the snowmaker does not satisfy the requirement of fluid endurance time in the SAE Proposed Aerospace Standard 5485.

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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 neuf rapports (dont celui-ci). On trouvera dans la préface l'objet de ces rapports.

16. Résumé

Un programme de recherche a été entrepris afin de comparer les durées d'efficacité des fluides antigivrage sous neige naturelle et neige artificielle, et d'évaluer les fonctionnalités générales d'une machine à fabriquer de la neige de deuxième génération mise au point par le National Council for Atmospheric Research (NCAR) pour le compte de la Federal Aviation Administration (FAA).

Avant les essais avec les fluides, APS Aviation Inc. a procédé à plusieurs essais d'étalonnage de la position des ventilateurs et de répartition de la neige artificielle. Les essais de durée d'efficacité ont été menés en deux temps, à l'Installation de génie climatique du Conseil national de recherches du Canada, à Ottawa. Ils comportaient au total 62 essais de fluides de type IV et 17 essais de fluides de type I, sous précipitations de neige artificielle. Les critères de perte d'efficacité sur plaques planes étaient appliqués pour déterminer la durée d'efficacité des fluides testés.

Les fluides de type IV ont été essayés à l'état pur et à des concentrations de 75/25 et de 50/50, et les fluides de type I étaient dilués avec de l'eau dure, de façon à obtenir des fluides dont le point de congélation était de 10 ºC inférieur à la température de l'air ambiant. Les essais ont été réalisés à des températures de -3 ºC, -14 ºC et -25 ºC. La machine à fabriquer de la neige du NCAR était exploitée conformément aux instructions du NCAR figurant dans le manuel fourni avec la machine.

Des différences marquées ont été observées entre la neige artificielle et la neige naturelle. Ainsi, les durées d'efficacité de la plupart des fluides de type I et de type IV étaient plus courtes que celles indiquées par les tables. De plus, la répartition de la neige produite par la machine ne satisfait pas aux exigences du projet de norme Aerospace Standard 5485 de la SAE.

17. Mots clés Neige simulée, machine à fabriquer de la neige de deuxième génération, dégivrage, antigivrage	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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EXECUTIVE SUMMARY

Introduction

Under contract to the Transportation Development Centre (TDC) of Transport Canada, APS Aviation (APS) undertook a research program, co-sponsored by the U.S. Federal Aviation Administration (FAA), to compare holdover times for natural and artificial snow, and to evaluate the general functionality of the second-generation snowmaking system, which was developed by the National Council for Atmospheric Research (NCAR) under contract with the FAA.

Procedures and Data Processing

All testing was conducted at the National Research Council Climatic Engineering Facility in Ottawa.

The snowmaker is equipped with four small fans. The position of the fans changes the distribution of the snow impinging on the test plate. Ten collection pans were used to establish the distribution. Multiple calibration tests were performed in an attempt to obtain a distribution range of 15 percent, as indicated in the SAE Proposed Aerospace Standard AS 5485.

Following calibration, a total of 62 tests with Type IV fluids and 17 tests with Type I fluids were conducted in artificial snow. Type IV fluids were tested at neat, 75/25, and 50/50 concentration, and Type I fluids were diluted with hard water to obtain fluids with a freeze point 10ºC below ambient air temperature. Type IV fluids included an ethylene glycol-based fluid, three propylene glycol-based fluids, and the reference fluid (Fluid X). Tests were conducted at ambient temperatures of -3°C, -14°C, and -25°C. The NCAR snowmaking machine was operated according to the guidelines set forth by NCAR in the operation manual supplied with the system.

Conclusions

The results of the calibration tests indicated that the snow distribution was not uniform. The top and bottom of the test plate received significantly more precipitation due to the tendency of the flakes to follow the walls of the snowmaker booth. In the final configuration of the placement of the fans, the range in snowfall rate distribution from the highest to the lowest was large, up to 92 percent of the average rate of snowfall. Hence, the distribution rate of the second-generation snowmaking machine did not conform to the 15 percent distribution range indicated in the SAE Proposed Aerospace Standard AS 5485.

The artificial snow exhibited significant differences from natural snow. The failure times observed in tests with several Type IV fluids were up to 50 percent shorter than the holdover times published. The failure patterns observed in artificial snow were noticeably different from those seen in natural snow. Snow bridging was detected earlier in the failure progressions during artificial snow conditions.

The differences between natural and artificial snow should be further evaluated, and the modified snowmaking systems require further testing.

SOMMAIRE

Introduction

Le Centre de développement des transports (CDT) de Transports Canada a conclu un marché avec APS Aviation Inc. (APS) visant la réalisation d'une recherche, coparrainée par la Federal Aviation Administration (FAA) des États-Unis, qui consistait à comparer les durées d'efficacité des liquides antigivrage sous neige naturelle et neige artificielle, et à évaluer les fonctionnalités générales de la machine à fabriquer de la neige de deuxième génération mise au point par le National Council for Atmospheric Research (NCAR) pour le compte de la FAA.

Description des essais et traitement des données

Tous les essais ont eu lieu à l'Installation de génie climatique du Conseil national de recherches du Canada à Ottawa.

La machine à fabriquer de la neige comprend quatre petits ventilateurs. La position de ces ventilateurs influe sur la manière dont la neige se répartit sur la plaque d'essai. Dix plateaux de collecte ont donc été utilisés pour établir cette répartition. Puis, plusieurs essais d'étalonnage des ventilateurs ont eu lieu, de façon à obtenir un écart d'au plus 15 p. 100 entre les quantités de neige dans les plateaux, comme le prescrit le projet de norme Aerospace Standard 5485 de la SAE.

Une fois la machine réglée, un total de 62 essais de fluides de type IV et de 17 essais de fluides de type I ont été menés, sous précipitations de neige artificielle. Les fluides de type IV ont été essayés à l'état pur et à des concentrations de 75/25 et de 50/50, et les fluides de type I étaient dilués avec de l'eau dure, de façon à obtenir des fluides dont le point de congélation était de 10 ºC inférieur à la température de l'air ambiant. Les fluides de type IV comprenaient un fluide à base d'éthylèneglycol, trois fluides à base de propylèneglycol et le fluide de référence (fluide X). Les essais ont été réalisés à des températures ambiantes de -3 ºC, -14 ºC et -25 ºC. La machine à fabriquer de la neige du NCAR était exploitée conformément aux instructions du NCAR figurant dans le manuel fourni avec la machine.

Conclusions

Les essais d'étalonnage ont révélé que la neige ne se répartissait pas uniformément sur la plaque d'essai. Celle-ci recevait plus de neige à ses deux extrémités en raison de la tendance des flocons à suivre les parois de la cabine. Dans la configuration finalement retenue pour la position des ventilateurs, l'écart entre la chute de neige la plus forte et la plus faible était considérable, atteignant 92 p. 100 de la quantité moyenne de neige recueillie. La répartition de la neige obtenue avec la machine de deuxième génération ne respectait donc pas l'exigence des 15 p. 100 prescrite par le projet de norme Aerospace Standard 5485 de la SAE.

Des différences marquées ont été observées entre la neige artificielle et la neige naturelle. Ainsi, dans le cas de plusieurs fluides de type IV, la durée d'efficacité observée était jusqu'à 50 p. 100 inférieure à celle indiquée par les tables. Le comportement des liquides jusqu'à la perte d'efficacité était passablement différent de celui observé avec de la neige naturelle. Le pontage de neige était détecté plus tôt dans le cas de la neige artificielle.

D'autres études s'imposent sur les différences entre la neige naturelle et la neige artificielle, et la machine à fabriquer de la neige modifiée doit être soumise à d'autres essais.

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GLOSSARY

APS	APS Aviation Inc.
FAA	Federal Aviation Administration
NCAR	National Council for Atmospheric Research
NRC	National Research Council Canada
SAE	Society of Automotive Engineers
TDC	Transportation Development Centre
UCAR	Union Carbide

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1. INTRODUCTION

At the request of the Transportation Development Centre of Transport Canada and the Federal Aviation Administration (FAA), APS Aviation Inc. undertook a research program to compare holdover times for natural and artificial snow, and to evaluate the general functionality of a second-generation snowmaking system, developed by the National Council for Atmospheric Research (NCAR) under contract with the FAA. This follow-up study formed part of the winter 1999-2000 research program on deicing. An excerpt from the detailed work statement is provided in Appendix A.

During the 1998-99 test season, APS Aviation undertook a research program to evaluate a prototype snowmaking system developed by NCAR. The results of this study and several recommendations proposed by APS were published in the Transport Canada report, *A Snow Generation System – Prototype Testing*, TP 13488E (1).

APS identified the need to increase the weight capacity of the scale, to upgrade various components to enable the system to function at very cold temperatures, and to perform extensive software changes to increase the functionality of the system. The delivery model of the snowmaking system was modified to address the recommendations provided by APS.

The artificial snowmaking system was developed to conduct holdover time testing in laboratory conditions. Other laboratory snowmakers are also in development. The addition of this system would allow a testing agency to evaluate the endurance time of a de/anti-icing fluid at any time of year. Specifications regarding the artificial snow system can be found in the SAE Proposed Aerospace Standard AS 5485, dated March 18, 2000 (2).

Tests were conducted with the new snowmaking machine at National Research Council Canada's Climatic Engineering Facility in Ottawa. Type I and Type IV fluids were tested in artificial snow conditions at various ambient air temperatures and precipitation rates. The tests were performed to obtain fluid failure times for the artificial snow conditions created by the NCAR snowmaking machine.

In addition to determining the fluid failure times and failure patterns resulting from indoor snow precipitation, this body of tests was designed to investigate snowmaker functionality, and to evaluate the second-generation system improvements over the first-generation prototype. Specific fluid failure times and mechanisms were compared to holdover time tables generated from natural precipitation tests.

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2. METHODOLOGY

This section describes the methodology used to perform indoor tests with the NCAR snowmaking system and the outdoor tests in natural snow.

2.1 Test Site

The Type I and Type IV indoor snow tests were conducted on two occasions at National Research Council Canada's Climatic Engineering Facility in Ottawa. The Type I and Type IV tests were performed in April 2000 and another series of Type IV tests was performed in May 2000. The location and set-up are shown in Photos 2.1 and 2.2.

2.2 Description of Test Procedures

The test procedure established by APS for the snowmaker tests is included in Appendix B. All tests, including Type I and Type IV tests, were conducted according to the guidelines in the procedure described below. All failure calls were made according to flat plate failure call standards for snow precipitation.

The tests were performed on a standard aluminum plate attached to the fluid collection bucket of the snowmaker assembly. The snowmaker assembly was levelled to maintain the test plate surface at a 10° incline in the long direction of the plate.

The procedure used for artificial snow tests was similar to the standard holdover time procedure used by APS for natural snow tests. Rate measurements were not required because the snowmaking system records and corrects the snow rate in near real time.

The major steps in the artificial snow flat plate test procedure were as follows:

1. Empty fluid collection bucket, if required;
2. Prepare and secure ice core;
3. Clean upper surfaces of snow machine to remove snow clumps;
4. Begin precipitation and data observation;
5. Clean test plate surface;
6. Apply (pour) fluids to test panels. Type I fluids are at room temperature. Type II and Type IV fluids are at the test air temperature. Fluids are poured using a single-step fluid application;
7. Record the start of the holdover time after fluid is applied;

8. Press the software-based experiment start button to begin data logging;
9. Record crosshair end condition times;
10. Continue testing until at least five crosshairs, or 1/3 of the plate, have failed (standard plate failure); and
11. Press the software-based end of experiment button to stop data logging and to add test run comments to the data file.

The Type IV fluids were tested at neat, 75/25 and 50/50 concentration. The Type I fluids were diluted with hard water to obtain fluids with a freeze point 10°C below ambient air temperature. For example, a fluid with a freeze point of -20°C was used for the tests at -10°C air temperature.

The snowmaking machine was operated according to the guidelines set forth in the updated operation manual supplied by NCAR with the delivery model system. This manual is included in Appendix F.

2.3 Data Forms

The data form employed during the indoor snow test is shown in Figure 2.1. A single data form was required for each test due to the automatic rate logging capability of the system.

2.4 Equipment

The snowmaking machine is a complex assembly of components. It operates by feeding a 7 cm diameter ice core of distilled water into a carbide-tipped spur bit at a controlled rate. The feed rate is determined by a series of high-frequency pulses generated with a notebook PC and outputted to a stepper motor control circuit and to the stepper motor. The ice flakes are then redistributed semi-randomly by a series of fans. They fall 2.5 m onto a standard aluminum plate supported by a fluid trap. The plate and fluid trap assembly, with a dead weight of 4 300 g, rests on a 0.1 g resolution, 12 kg capacity, analytical balance. In this configuration, total mass and snowfall rate can be measured in real time. A high-resolution (Analog Devices) temperature transmitter monitors a temperature channel. The temperature sensor uses a 1.5 mm o.d., 100 ohm platinum resistance temperature detectors (RTD).

A complete list of equipment is included in the test procedure shown in Appendix B.

FIGURE 2.1

END CONDITION DATA FORM

NCAR SNOWMAKER

Winter 1999/2000

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

OAT: ________ °C

PRECIPITATION RATE: ________ g/dm²/h

FLUID TEMPERATURE: ________ °C

FLUID QUANTITY APPLIED: ________ Liters

PLATE WASHING METHOD: ______________

OTHER COMMENTS (Fluid Batch, etc):

____

____

____

____

____

____

____

____

	PRINT	SIGN
FAILURES CALLED BY :		
HANDWRITTTEN BY :		
LEADER :		

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

Time of Fluid Application: ________ h:min

FLUID NAME			
B1 B2 B3			
C1 C2 C3			
D1 D2 D3			
E1 E2 E3			
F1 F2 F3			

CALCULATED FAILURE TIME (MINUTES)

File:h:\cm1589\reports\NCAR\Snow Maker Data Sheet Version 1.0
At: Data Form

2.5 Fluids

The Type I fluids tested in artificial snow precipitation included:

- Octagon Octaflo EG and
- Union Carbide 55A.

The Type IV fluids tested in artificial snow precipitation and their associated concentration and viscosity are listed below:

- UCAR Ultra+ neat, viscosity 41 500 cp;
- SPCA AD-480 neat, viscosity 15 200 cp;
- SPCA AD-480 75/25 fluid/water concentration, viscosity 16 200 cp;
- SPCA AD-480 50/50 fluid/water concentration, viscosity 7 000 cp;
- An unmarketed fluid, Type IV Product A neat, viscosity 18 400 cp;
- An unmarketed fluid, Type IV Product A 75/25 fluid/water concentration, viscosity 38 000 cp;
- An unmarketed fluid, Type IV Product A 50/50 fluid/water concentration, viscosity 15 000 cp;
- Kilfrost ABC-S degraded neat fluid, viscosity 3 900 cp; and
- A reference fluid at standard concentration, Fluid X, viscosity 45,000 cp.

All viscosity values were obtained by APS using the manufacturer-specified method as described in the upcoming 1999-2000 Transport Canada report, *Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 1999-2000 Winter*, TP 13659E (3). Most of the fluids tested with the artificial snowmaker were from the same batch as the fluids used during 1999-2000 natural snow tests. The Ultra+ fluid was obtained from the Central Deicing Facility at Dorval Airport.

The reference fluid was prepared according to the following specifications:

Formula for Standard Fluid X

650 g	Ethylene Glycol
350 g	Deionized Water
6.0 g	Food Grade Xanthan Gum

The procedure for preparing the reference fluid was as follows:

1. Pour ethylene glycol into a container;
2. Slowly add the Food Grade Xanthan Gum while mixing;
3. Slowly add water while mixing; and
4. Agitate for at least 20 minutes, until a homogeneous mixture is obtained.

2.6 Personnel

One person from APS was required to conduct the indoor snow tests; this person poured the fluid, observed plate failures, and ran the snowmaking system. A second person assisted with the assembly of the snowmaking machine, replacement of the ice cores, and various other tasks.

2.7 Standard Natural Snow Holdover Time Tests

Current holdover time tests for snow conditions are conducted at the APS test site near Dorval airport during natural snow precipitation.

The procedure for natural snow flat plate tests was developed by the SAE G-12 Holdover Time Subcommittee. The major steps in the natural snow flat plate test procedure are as follows:

1. Synchronize all timepieces;
2. Clean panels and start;
3. Apply (pour) fluids to test panels. Type I fluids are at room temperature (20ºC ± 3ºC). Type II and Type IV fluid are applied at the outdoor ambient temperature. Fluids are poured using a single-step fluid application;
4. Record crosshair end condition times;
5. Continue testing until at least five crosshairs, or 1/3 of the plate, have failed (standard flat plate failure);
6. Record weather conditions; and
7. Clean panels and restart.

Complete details of the actual test procedures in natural snow conditions are provided in Appendix C.

2.8 Artificial Snow versus Natural Snow Testing Procedure

A procedure was prepared by APS to further evaluate the differences between natural and artificial snow. Due to the late delivery of the snowmaker and a lack of required weather conditions, these tests were not performed. The outdoor versus indoor snow procedure is included in Appendix D.

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Photo 2.1
Outside View of NRC Climatic Engineering Facility

Photo 2.2
Snowmaking Machine Set-up

3. DESCRIPTION AND PROCESSING OF DATA

APS Aviation received the second-generation snowmaking system in March 2000. This system replaced the prototype system received in April 1999.

3.1 Calibration and Snow Distribution Tests

Once the snowmaking machine was assembled, snow pattern distribution tests were conducted to identify and improve the snow distribution range. The snowmaker is equipped with four small fans. The position of the fans changes the distribution of the snow impinging on the test plate below.

Distribution tests were conducted by placing ten individually pre-weighed pans on the test plate. The snow machine produced precipitation for a predetermined period of time. The pans were then weighed and the amount of snow in each pan was calculated by subtracting the initial weight from the final weight for each pan. Since all the pans were the same size, the distribution was found by comparing the change in weight of each pan.

Multiple calibration tests were conducted to determine acceptable fan positions and weigh scale and plate assembly location within the snowmaker. The tests were performed in an attempt to obtain a distribution range of 15 percent, as indicated in the SAE Proposed Aerospace Standard AS 5485. All data from these tests are included in Appendix E.

3.2 Artificial Snow Tests for Type IV Fluids

Type IV fluid holdover time tests in artificial snow conditions were performed using the laboratory snowmaking system, which created the precipitation and collected rate and temperature data. The snowmaking system was used to test nine fluid concentration combinations (see Section 2.5).

Table 3.1 provides a log of all 62 Type IV tests with associated test conditions and failure times. Some tests were repeated to ensure reproducibility, or because of equipment malfunction, such as the ice core breaking.

The failure times recorded from the artificial snow flat plate tests were compared to the natural snow regression curve for each fluid tested. The natural snow curves are power law regression curves based on all available data for each fluid. Artificial snow tests were performed at precipitation rates of 10 and 25 g/dm^2/h to match the holdover times calculated from the regression curves.

TABLE 3.1
TYPE IV FLUIDS HOLDOVER TIME TEST
ARTIFICIAL SNOW TEST

ID	Date	Fluid Type	Fluid Name	Fluid Dilution	Fail Time (min)	Rate of Precip ($g/dm^2/h$)	Ambient Temp. (°C)
2	Mar-29-00	4	SPCA AD-480	Neat	25.4	25.0	-3.8
3	Mar-29-00	4b	SPCA AD-480	75%	53.5	10.0	-4.0
4	Mar-29-00	4b	SPCA AD-480	75%	20.3	25.0	-4.0
5	Mar-29-00	4a	SPCA AD-480	50%	15.3	10.0	-4.0
6	Mar-29-00	4a	SPCA AD-480	50%	7.3	25.0	-4.0
7	Mar-29-00	4b	TYPE IV PRODUCT A	75%	29.0	25.0	-4.0
8	Mar-29-00	4a	TYPE IV PRODUCT A	50%	16.8	10.0	-4.0
9	Mar-29-00	4a	TYPE IV PRODUCT A	50%	10.2	25.0	-4.0
18	Mar-30-00	4	UCAR ULTRA +	Neat	68.0	10.0	-11.0
19	Mar-30-00	4	UCAR ULTRA +	Neat	30.3	25.0	-11.0
20	Mar-30-00	4	UCAR ULTRA +	Neat	60.3	10.0	-11.0
21	Mar-30-00	4	UCAR ULTRA +	Neat	29.7	25.0	-11.0
22	Mar-31-00	4	SPCA AD-480	Neat	44.5	10.0	-11.0
23	Mar-31-00	4	SPCA AD-480	Neat	17.0	25.0	-11.0
24	Mar-31-00	4	SPCA AD-480	Neat	35.3	10.0	-11.0
25	Mar-31-00	4	SPCA AD-480	Neat	18.3	25.0	-11.0
26	Mar-31-00	4b	SPCA AD-480	75%	29.4	10.0	-11.0
27	Mar-31-00	4b	SPCA AD-480	75%	16.5	25.0	-11.0
28	Mar-31-00	4b	SPCA AD-480	75%	30.4	10.0	-11.0
29	Mar-31-00	4b	SPCA AD-480	75%	14.0	25.0	-11.0
30	Mar-31-00	4	TYPE IV PRODUCT A	Neat	28.0	10.0	-11.0
31	Mar-31-00	4	TYPE IV PRODUCT A	Neat	15.5	25.0	-11.0
32	Apr-03-00	N/A	FLUID X	Neat	68.0	10.0	-26.5
33	Apr-03-00	N/A	FLUID X	Neat	15.4	25.0	-26.5
34	Apr-03-00	4	UCAR ULTRA +	Neat	53.7	10.0	-26.5
35	Apr-03-00	4	UCAR ULTRA +	Neat	19.8	25.0	-26.5
41	Apr-04-00	4	TYPE IV PRODUCT A	Neat	26.0	10.0	-26.5
42	Apr-04-00	4	TYPE IV PRODUCT A	Neat	8.6	25.0	-26.5
44	Apr-04-00	N/A	FLUID X	Neat	28.5	25.0	-14.5
45	Apr-05-00	N/A	FLUID X	Neat	64.5	10.0	-3.9
46	Apr-05-00	N/A	FLUID X	Neat	31.4	25.0	-3.5
47	Apr-05-00	4	UCAR ULTRA +	Neat	67.4	10.0	-3.5
48	Apr-05-00	4	UCAR ULTRA +	Neat	29.9	25.0	-3.5
49	Apr-05-00	4	TYPE IV PRODUCT A	Neat	65.9	10.0	-3.5
50	Apr-06-00	4	TYPE IV PRODUCT A	Neat	29.3	25.0	-3.5
51	Apr-06-00	4b	TYPE IV PRODUCT A	75%	64.2	10.0	-3.5
52	Apr-06-00	4a	SPCA AD-480	50%	9.8	25.0	-3.5
57	Apr-07-00	4b	TYPE IV PRODUCT A	75%	34.7	10.0	-15.1
58	Apr-07-00	4b	TYPE IV PRODUCT A	75%	18.0	25.0	-14.1
59	Apr-07-00	4b	TYPE IV PRODUCT A	75%	28.6	10.0	-14.1
60	Apr-07-00	4b	TYPE IV PRODUCT A	75%	9.6	25.0	-14.1
61	Apr-07-00	N/A	FLUID X	Neat	63.1	10.0	-14.1
62	Apr-10-00	N/A	FLUID X	Neat	26.3	25.0	-14.3
63	Apr-10-00	4b	TYPE IV PRODUCT A	75%	33.4	10.0	-14.3
64	Apr-10-00	4b	TYPE IV PRODUCT A	75%	14.4	25.0	-14.3
65	Apr-10-00	4b	TYPE IV PRODUCT A	75%	29.4	10.0	-14.3
66	Apr-10-00	4b	TYPE IV PRODUCT A	75%	13.4	25.0	-14.3
67	Apr-11-00	4b	TYPE IV PRODUCT A	75%	20.0	25.0	-4.5
68	Apr-11-00	4	UCAR ULTRA +	Neat	94.3	10.0	-4.5
69	Apr-11-00	4	UCAR ULTRA +	Neat	32.3	25.0	-4.5
71	Apr-11-00	4	SPCA AD-480	Neat	47.7	10.0	-4.5
72	May-24-00	N/A	KILFROST ABC-S Degraded	Neat	69.0	10.0	-3.0
73	May-24-00	N/A	KILFROST ABC-S Degraded	Neat	32.0	25.0	-3.0
74	May-24-00	N/A	KILFROST ABC-S Degraded	Neat	29.0	25.0	-3.0
75	May-24-00	N/A	KILFROST ABC-S Degraded	Neat	63.0	10.0	-3.0
77	Jun-07-00	N/A	KILFROST ABC-S Degraded	Neat	22.0	25.0	-14.0
78	Jun-07-00	N/A	KILFROST ABC-S Degraded	Neat	23.0	25.0	-14.0
79	Jun-07-00	N/A	KILFROST ABC-S Degraded	Neat	48.0	10.0	-14.0
80	Jun-07-00	N/A	KILFROST ABC-S Degraded	Neat	47.0	10.0	-14.0
139	Jul-27-00	N/A	KILFROST ABC-S Degraded	Neat	26.5	10.0	-23.8
141	Jul-27-00	N/A	KILFROST ABC-S Degraded	Neat	12.0	25.0	-23.3
140	Jul-27-00	N/A	KILFROST ABC-S Degraded	Neat	22.2	10.0	-23.9

3.3 Artificial Snow Test for Type I Fluids

Type I fluid holdover time tests in artificial snow conditions were performed using the laboratory snowmaking system, which created the precipitation and collected rate and temperature data. The snowmaking system was used to test two fluids diluted to a 10ºC buffer below ambient temperature. These fluids included:

- Octagon Octaflo EG; and
- Union Carbide 55A.

Table 3.2 provides a log of all Type I tests with associated test conditions and failure times. A total of 17 tests were conducted in artificial snow with Type I fluid. The precipitation rate and the total snow accumulation during each test were recorded by the weigh scale and logged to a data file.

3.4 Artificial Snow Data

The data shown in Tables 3.1 and 3.2 were collected from the snowmaker as well as by the test observer.

The artificial snowmaking system collects data from various sensors. These data are displayed to the user and logged to a data file. The average precipitation rate during a test can be found in the data file. The precipitation rate is calculated from the total snow mass during a test divided by the total elapsed time. The fluid failure time is calculated from the difference between the moment the observer pours the fluid and the instant standard plate failure is visually called. The ambient temperature was recorded from the NRC thermocouples located near the snowmaker.

TABLE 3.2
TYPE I HOLDOVER TIME TEST
ARTIFICIAL SNOW TEST

ID	Date	Fluid Type	Fluid Name	Fluid Dilution	Fail Time (min)	Rate of Precip (g/dm²/h)	Ambient Temp. (°C)
10	Mar-30-00	1	UCAR 55A	10°	5.3	10.0	-11.0
11	Mar-30-00	1	UCAR 55A	10°	3.6	25.0	-11.0
12	Mar-30-00	1	UCAR 55A	10°	5.7	10.0	-11.0
13	Mar-30-00	1	UCAR 55A	10°	4.2	25.0	-11.0
14	Mar-30-00	1	OCTAFLO EG	10°	7.0	10.0	-11.0
15	Mar-30-00	1	OCTAFLO EG	10°	3.5	25.0	-11.0
16	Mar-30-00	1	OCTAFLO EG	10° Buffer	6.0	10.0	-11.0
17	Mar-30-00	1	OCTAFLO EG	10° Buffer	3.6	25.0	-11.0
36	Apr-03-00	1	UCAR 55A	10° Buffer	2.9	10.0	-26.5
37	Apr-03-00	1	UCAR 55A	10° Buffer	2.4	25.0	-26.5
38	Apr-04-00	1	OCTAFLO EG	10° Buffer	2.9	10.0	-26.5
39	Apr-04-00	1	OCTAFLO EG	10° Buffer	2.2	25.0	-26.5
40	Apr-04-00	1	OCTAFLO EG	10° Buffer	3.0	10.0	-26.5
53	Apr-06-00	1	UCAR 55A	10° Buffer	6.0	10.0	-3.5
54	Apr-06-00	1	UCAR 55A	10° Buffer	6.0	10.0	-3.5
55	Apr-06-00	1	UCAR 55A	10° Buffer	6.0	10.0	-3.5
56	Apr-06-00	1	UCAR 55A	10° Buffer	6.0	10.0	-3.5

4. ANALYSIS AND OBSERVATIONS

This section presents discussions of the observations made during the tests, and compares the experimental data collected with data from natural snow tests.

4.1 Calibration and Snow Distribution Tests

The initial comments recorded by the test observers during the snow distribution tests include the following:

- The snowflake size is larger than that observed in natural precipitation, but smaller than the flakes produced by the previous version of the snowmaking system;
- The distribution of precipitation is not always consistent; some sections of the test plate receive significantly more snow;
- Snow clumping occurs on the redirection shield at the top of the snowmaker; these clumps then fall on the test plate below; and
- The ice cores are less prone to cracks or breaks with the new ice core tubes.

The flakes produced by the snowmaker are ice shavings cut from a long ice core. Based on visual observation, the flakes are, on average, larger than those found in nature at temperatures of -14ºC and -25ºC. At colder temperatures, natural snow typically forms smaller crystals. Large flakes could have an increased tendency to dilute the fluid at localized points, while suspending other flakes above the fluid surface. The flat, non-dendritic shape of the artificial snow may require additional time to be absorbed by the fluid.

The main focus of the snow distribution tests was to determine the variation in precipitation intensity. The results of these tests indicated that the distribution was not uniform. The top and bottom of the test plate received more precipitation due to the tendency of the flakes to descend along the enclosure walls of the snowmaker booth. The snowmaker fans were repositioned on multiple occasions in an attempt to improve the snow distribution. In the final configuration of the placement of the fans, the range in snowfall rate distribution from the highest to the lowest was large, up to 92 percent of the average rate of snowfall. For example, if the average precipitation rate was 10 $g/dm^2/h$, the variation between the lowest and highest rate would be 9.2 $g/dm^2/h$. The distribution ranges indicated by the SAE Proposed Aerospace Standard AS 5485 for each temperature range and precipitation rate are included in Table 4.1.

TABLE 4.1

SAE PROPOSED SNOW TEST CONDITIONS

Test Condition	SNW-A	SNW-B	SNW-C	SNW-D	SNW-E	SNW-F	SNW-G	SNW-H	SNW-I
Type I	No	No	Yes	Yes	No	No	Yes	Yes	No
Types II III, and IV, neat	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes*
Types II and IV, 75/25 (neat fluid/water)	Yes	Yes	No	No	Yes	Yes	No	No	No
Types II and IV, 50/50 (neat fluid/water)	Yes	Yes	No	No	No	No	No	No	No
Air temperature, °C	-3 ± 0.5	-3 ± 0.5	-10 ± 0.5	-10 ±0.5	-14 ± 0.5	-14 ± 0.5	-25 ± 0.5	-25 ± 0.5	< -25 ±0.5
Air temperature standard deviation	± 0.3	± 0.3	± 0.3	± 0.3	± 0.3	± 0.3	± 0.5	± 0.5	± 0.5
Icing intensity, $g/dm^2/h$	10 ± 0.5	25 ± 1.0	10 ± 0.5	25 ± 1.0	10 ± 0.5	25 ± 1.0	10 ± 0.5	25 ± 1.0	5 ± 0.2
Icing intensity range across a test plate, $g/dm^2/h$	≤ 1.5	≤ 4.0	≤ 1.5	≤ 4.0	≤ 1.5	≤ 4.0	≤ 1.5	≤ 4.0	≤ 0.8

*This test will be performed at the Lowest Operational Use Temperature (LOUT) if it is below -25°C

A Plexiglas shield around the upper surface of the snowmaker serves to redirect the precipitation. This shield is positioned above the drill press to prevent snow from accumulating in the top corners of the snowmaker booth. During tests conducted at warmer temperatures and during long tests, snow clumps formed on this shield, as shown in Photo 4.1. Clumping was attributed to the high speeds at which the flakes hit the shield. Sometimes clumps of snow fell into one or more of the distribution pans, and led to distortion of the precipitation distribution. Large clumps of snow result in unexpected fluid failure patterns if these clumps fall on the test surface during a test.

The PVC ice core tubes supplied with the 1999 snowmaking system were replaced with custom made aluminum tubes, as shown in Photo 4.2. These aluminum tubes are much more solid and contribute to the production of ice cores with a reduced tendency to crack and shatter. Insulation pieces were supplied with the new ice core tubes. When the ice cores are frozen in insulated tubes, the water freezes from the bottom up and less air is trapped in the ice.

4.2 Artificial Snow Tests for Type IV Fluids

Snow bridging occurred frequently during tests with propylene fluids. This type of failure pattern could be partially attributed to the larger flakes produced by the snowmaker. Because of the larger snowflake dimensions, a reduced percentage of the snowflake is in contact with the fluid film on the plate surface. The remainder of the precipitation that falls on the plate surface is suspended above the fluid. The fluid film must absorb the lower levels of precipitation before the rest of the flakes can be absorbed. The snow has a greater tendency to accumulate more quickly than the quantity of precipitation being absorbed. The localized fluid dilution due to larger flakes reduces the effectiveness of anti-icing fluid at these points. A combination of these two effects reduces the time to fluid failure.

Analysis of the data collected indicates that the Type IV failure times were generally shorter for the tests performed with the snowmaking system when compared to the natural snow failure times. The fluids can be separated into three categories: ethylene glycol-based fluids, propylene glycol-based fluids and Fluid X.

The number of artificial snow tests conducted for each fluid is displayed in Table 4.2. The natural snow fluid specific holdover times used for comparison will be published in the Transport Canada report, *Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 1999-2000 Winter*, TP 13659E (3).

TABLE 4.2

NUMBER OF NCAR ARTIFICIAL SNOW TESTS AT NRC

Fluid Name	Neat	75/25	50/50	Total
Type IV Product A	6	11	2	19
Degraded Kilfrost ABC-S	11			11
Fluid X	7			7
SPCA AD-480	6	6	3	15
UCAR Ultra+	10			10
Type I	17			17
Total	57	17	5	**79**

4.2.1 Ethylene Glycol-Based Type IV Fluids

Tests were conducted on one ethylene glycol-based Type IV fluid, UCAR Ultra+. The results of indoor snow tests were compared to the holdover time graphs, which are based on natural snow tests. The results are shown in Figure 4.1.

The ethylene glycol-based fluid Ultra+ did not exhibit large variations between the artificial snow tests and the natural snow tests. The fluid did, however, fail slightly more rapidly during the artificial snow test. The difference between the natural snow regression curves and the artificial snow failure times is in the order of 5 to 10 percent. A significant difference between this fluid and all other fluids tested is the flake acceptance demonstrated by Ultra+. In all temperatures and precipitation conditions tested, Ultra+ easily accepted contamination within the fluid matrix.

The results from the tests conducted in 1999 with the first-generation prototype snowmaking machine are similar to the results obtained with the new system. The variations between the natural snow failure times and the artificial snow failure times were similar to those obtained with the first-generation system.

4.2.2 Propylene Glycol-Based Type IV Fluids

Tests were conducted with three different propylene glycol-based fluids. Two fluids, Type IV Product A and SPCA AD-480, were tested in all standard dilutions. A degraded Kilfrost ABC-S fluid was tested in neat concentration. Figures 4.2 to 4.8 show the holdover time graphs for these fluids.

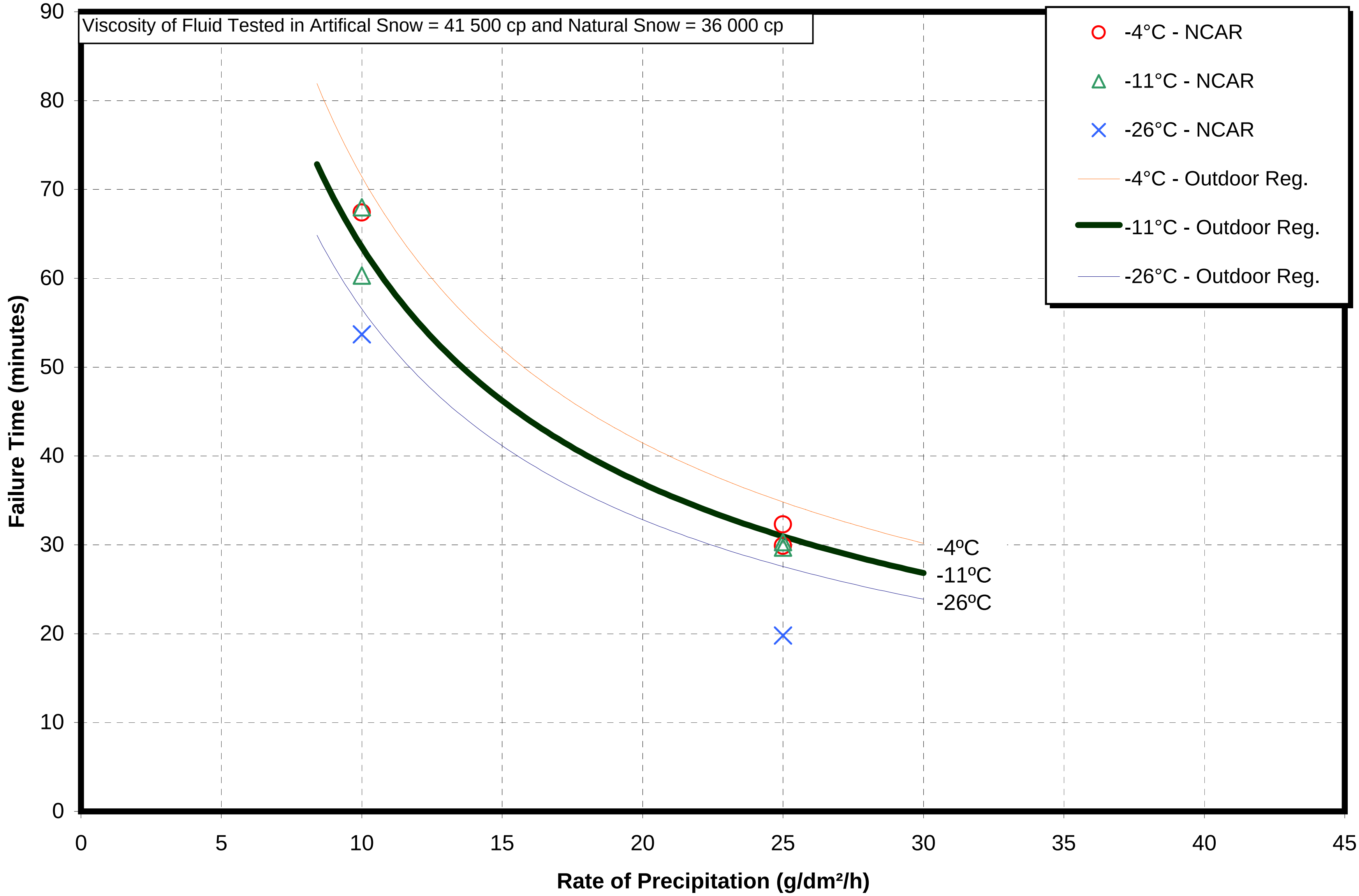
The holdover time graphs for Type IV Product A fluid, presented in Figures 4.2 to 4.4, show significant differences between the failure times recorded during natural versus artificial snow. Artificial snow failure patterns produced failure times up to 50 percent shorter in some tests. The largest variations are found during cold tests and during tests conducted with higher precipitation rates.

The second fluid that was tested in all dilutions was SPCA AD-480. The graphs shown in Figures 4.5 to 4.7 indicate less variation between the artificial snow and natural snow failure times for this fluid. In the neat concentration, SPCA AD-480 failed up to 40 percent more quickly during artificial snow tests. In diluted forms, this fluid demonstrated failure times significantly closer to the natural precipitation holdover times. In 50/50 concentration, the artificial snow failure times were within 10 to 20 percent of the natural snow failure times.

FIGURE 4.1

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

UCAR ULTRA+ TYPE IV NEAT



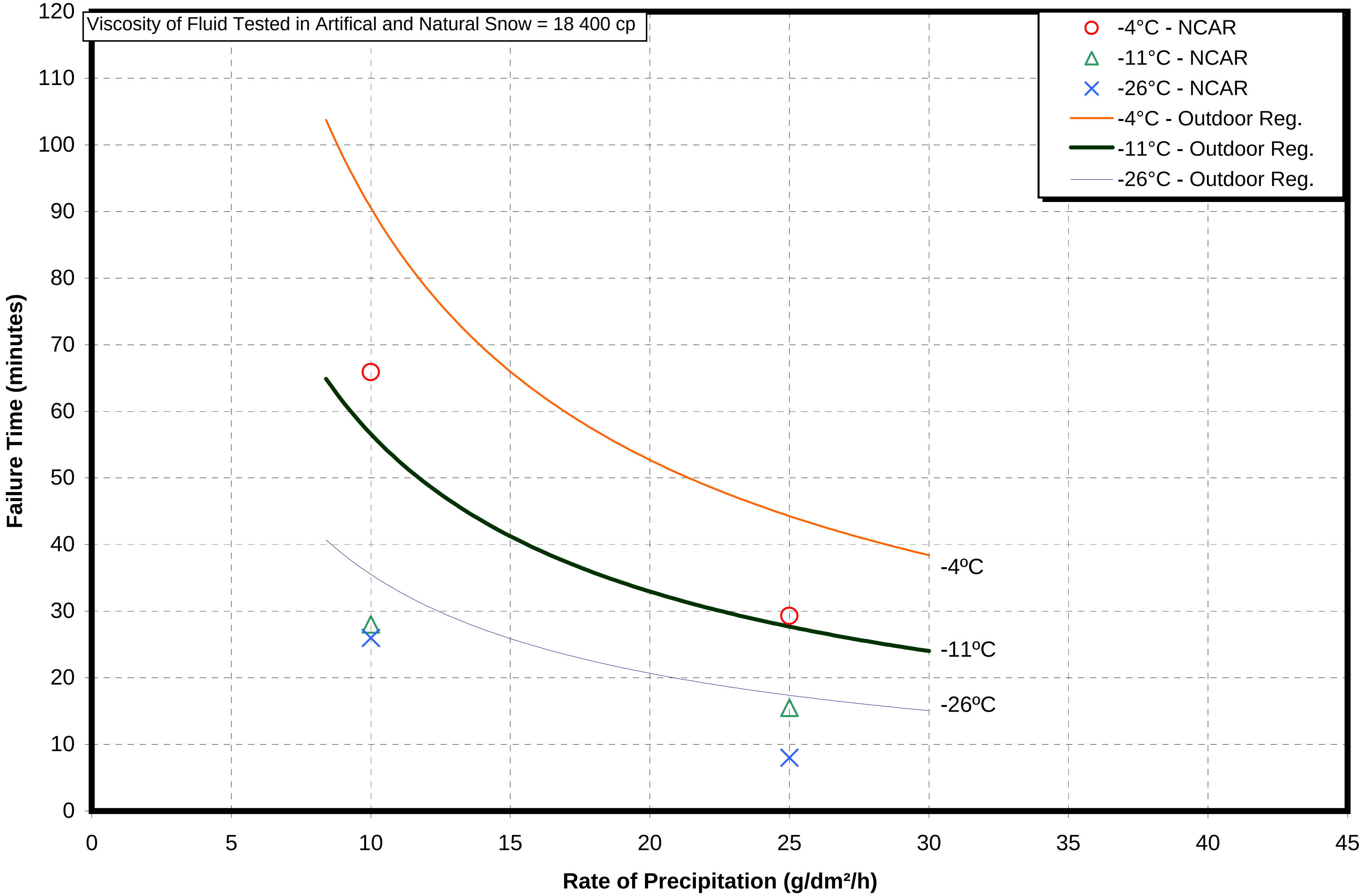
cm1589/reports/ncar/NCAR Regression Analysis

At: Ultra +

FIGURE 4.2

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

TYPE IV PRODUCT A NEAT

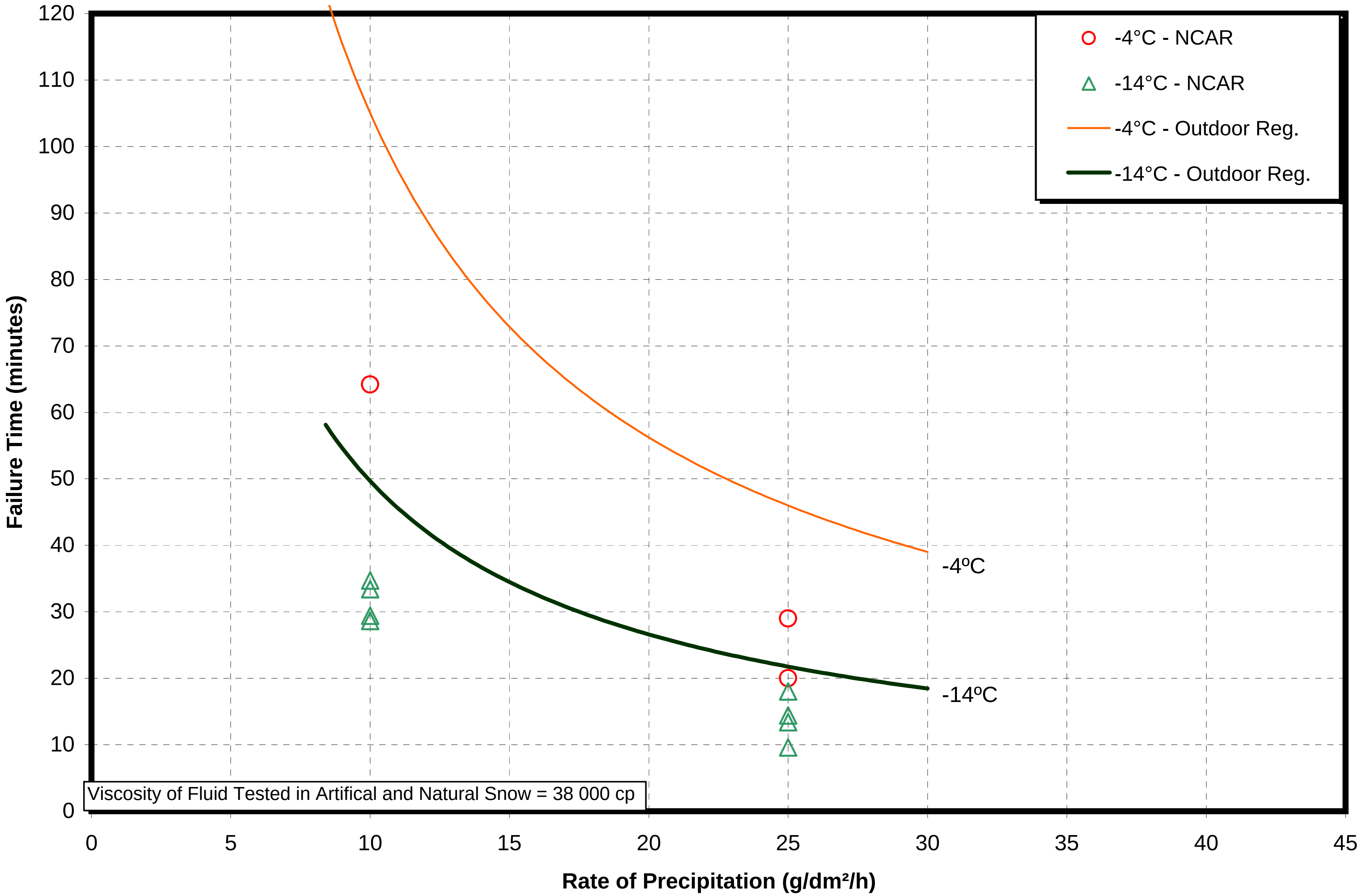


cm1589/reports/ncar/NCAR Regression Analysis
At: CS4 100

FIGURE 4.3

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

TYPE IV PRODUCT A 75/25

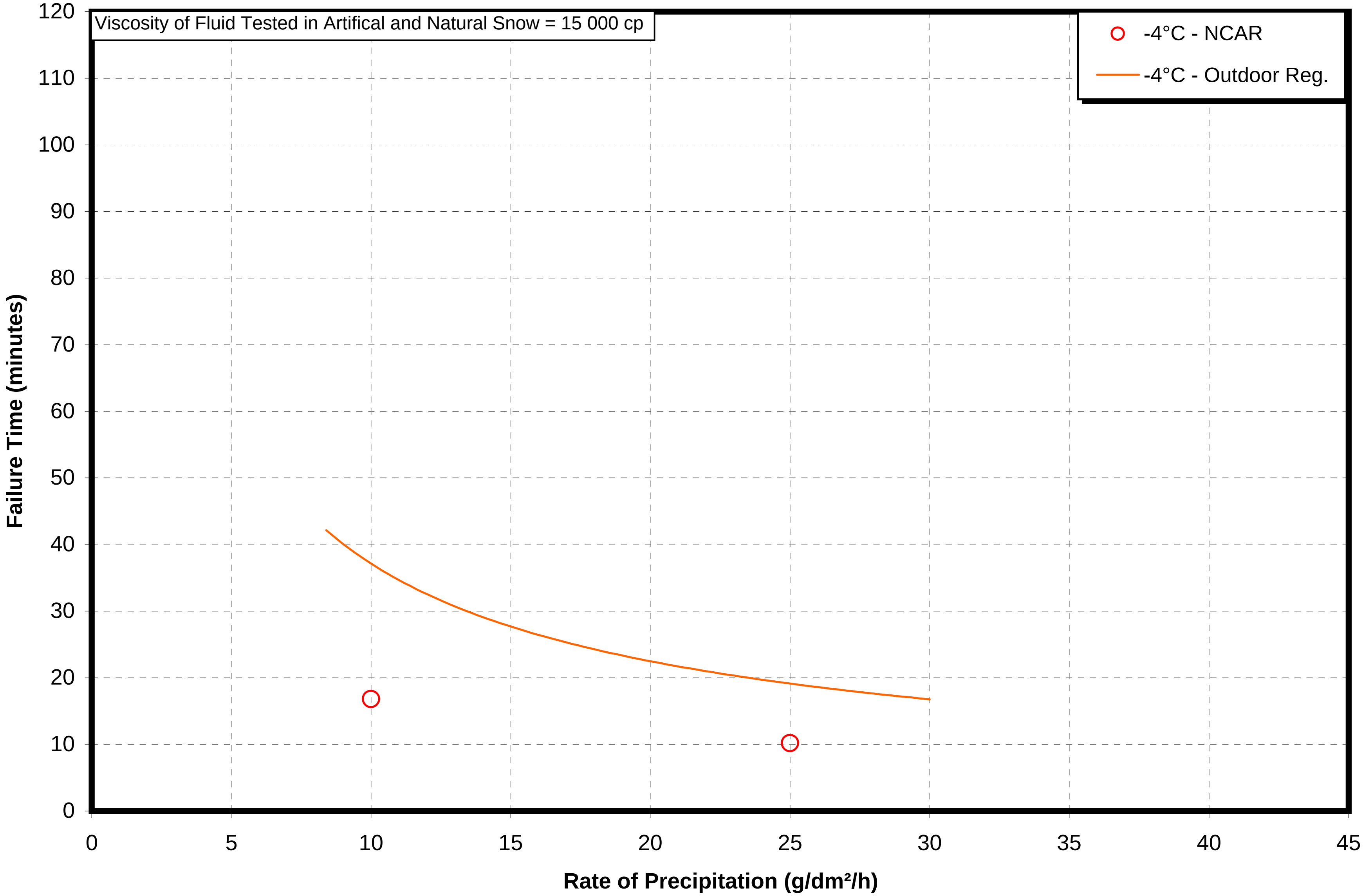


cm1589/reports/ncar/NCAR Regression Analysis
At: CS4 75

FIGURE 4.4

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

TYPE IV PRODUCT A 50/50

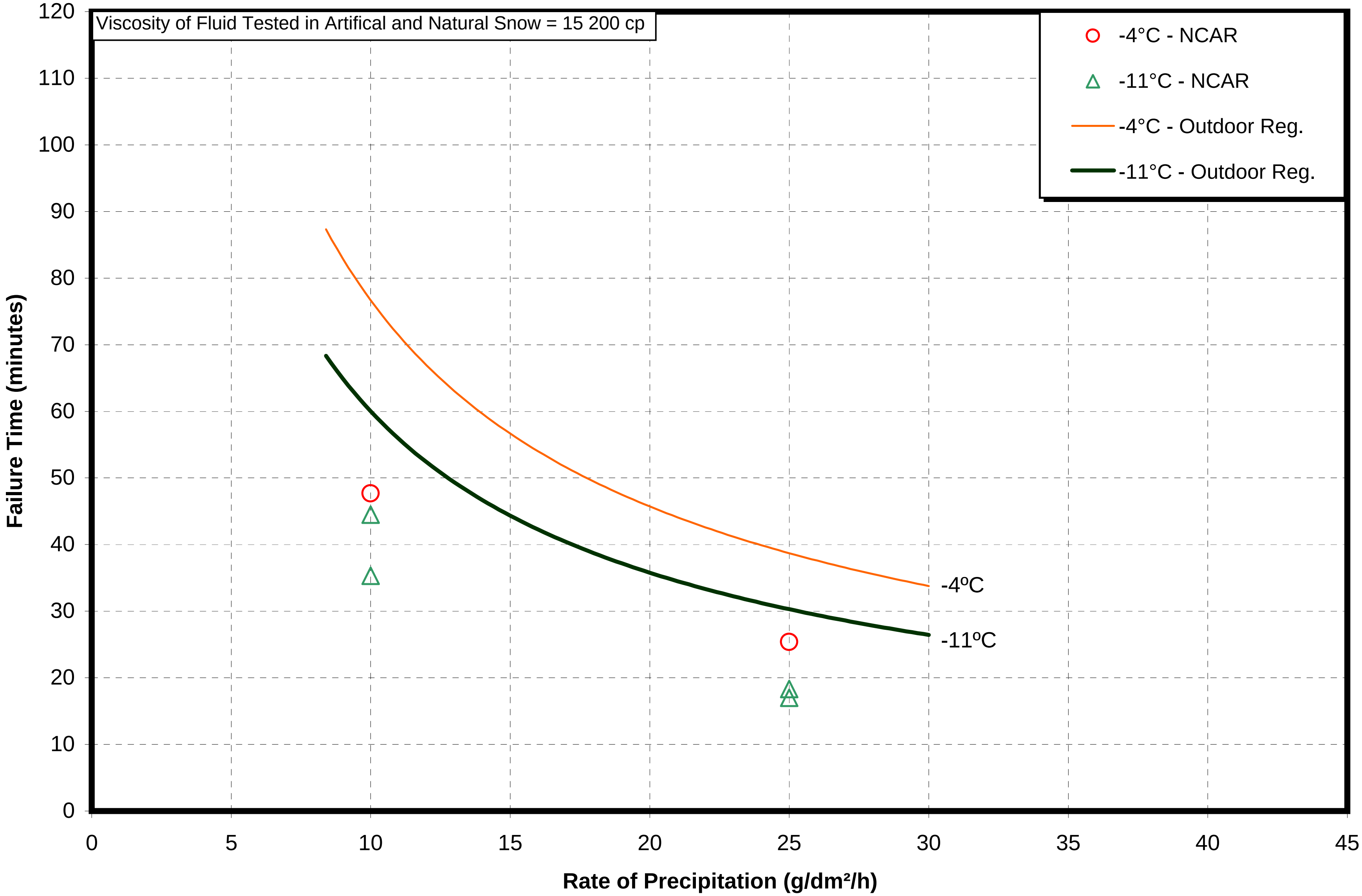


cm1589/reports/ncar/NCAR Regression Analysis
At: CS4 50

FIGURE 4.5

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

SPCA 480 TYPE IV NEAT

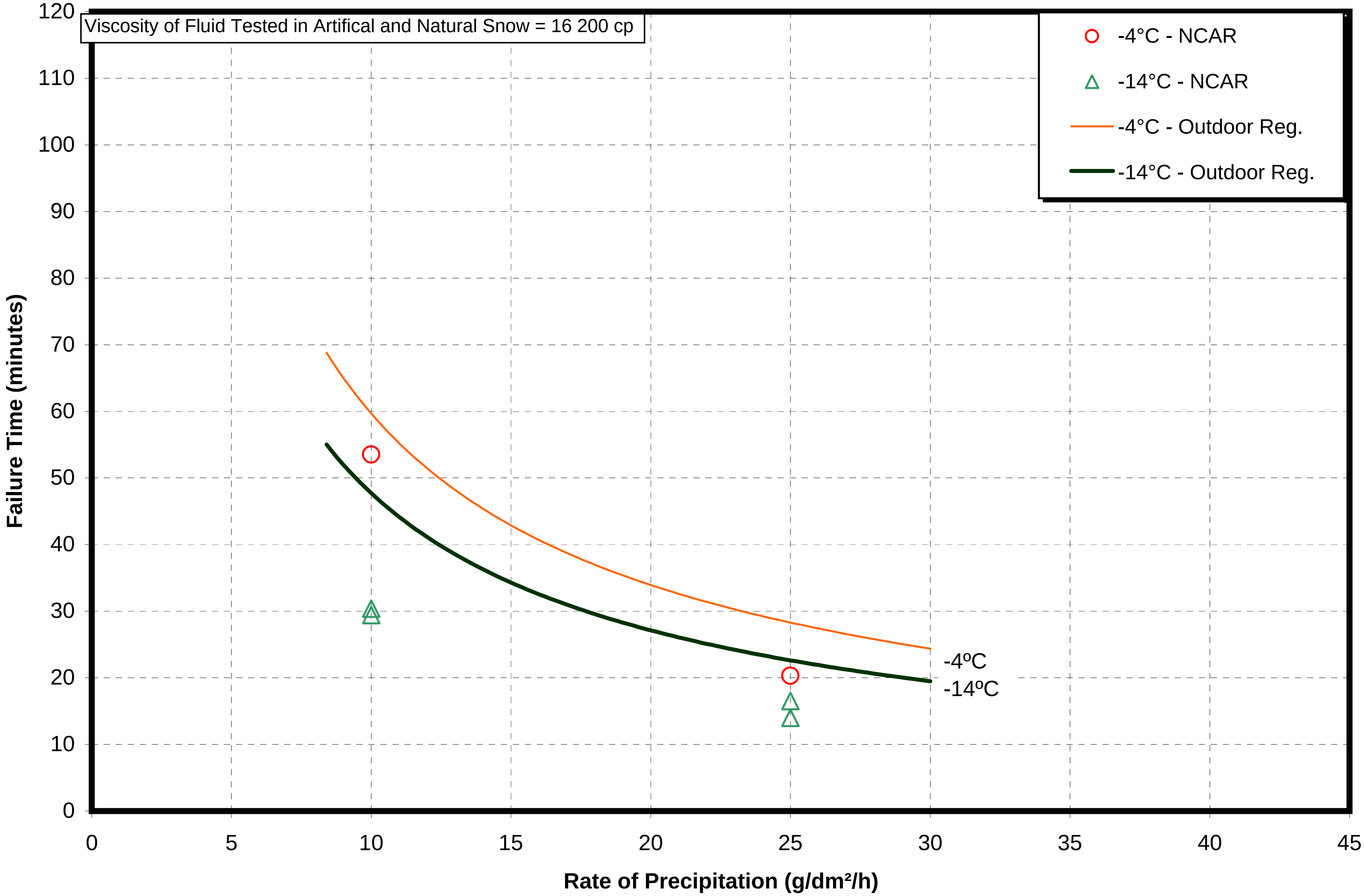


cm1589/reports/ncar/NCAR Regression Analysis
At: S480 100

FIGURE 4.6

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

SPCA 480 TYPE IV 75/25

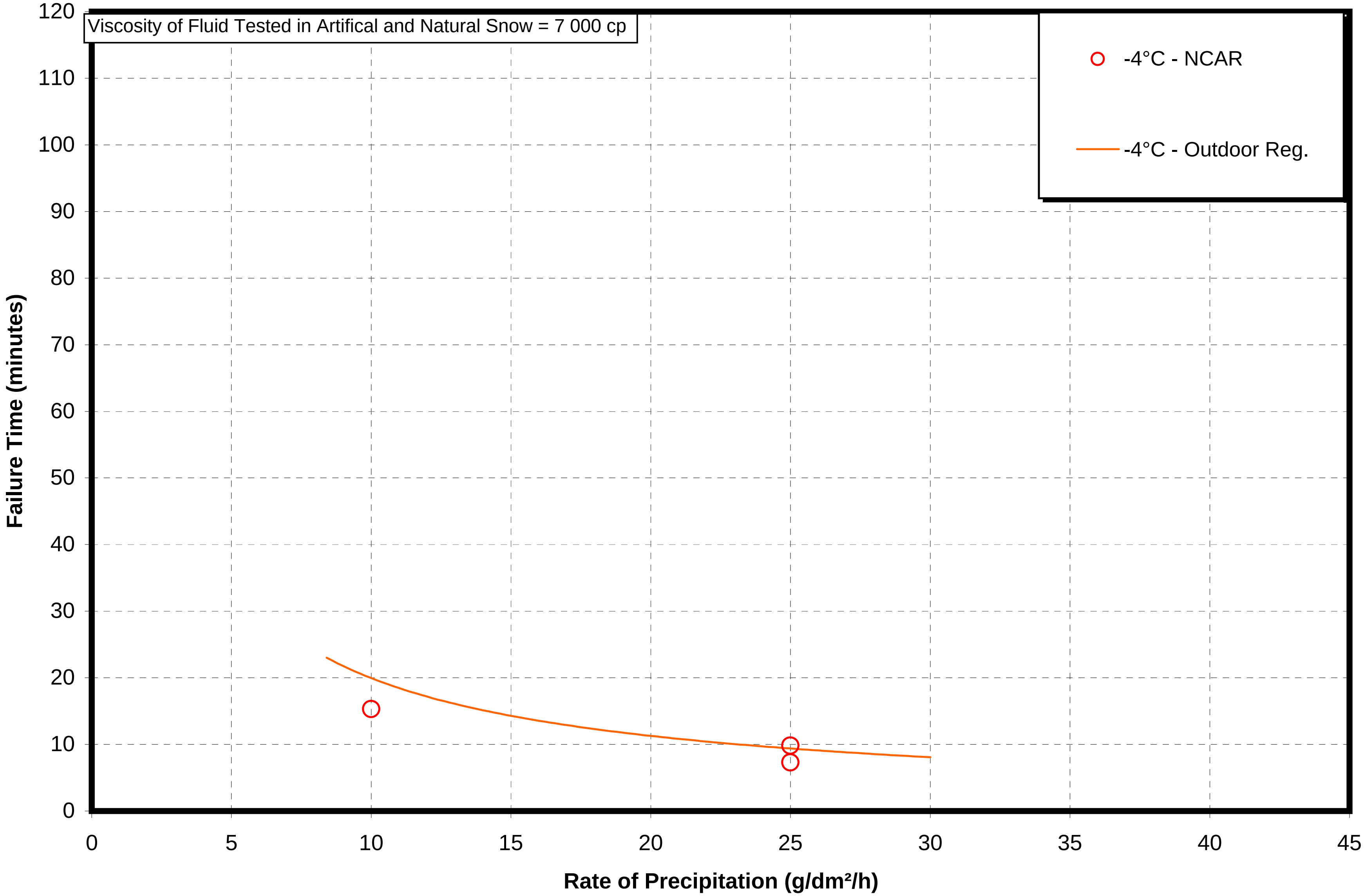


cm1589/reports/ncar/NCAR Regression Analysis
At: S480 75

FIGURE 4.7

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

SPCA 480 TYPE IV 50/50



cm1589/reports/ncar/NCAR Regression Analysis
At: S480 50

In a later series of tests, an undiluted degraded Kilfrost ABC-S fluid was tested. The results of these tests are presented in Figure 4.8. Due to a lack of natural snow precipitation data, the outdoor regression curve is not available for the -14 or -25°C temperature. The warmer temperature data are in the same range as the natural snow data for this fluid.

4.2.3 Fluid X

Figure 4.9 shows the holdover time graph for the reference fluid, Fluid X. The curves represent regression curves generated from outdoor data collected during the 1998-99 test season. The points represent failure times recorded during the tests at the NRC test facility conducted in 2000.

4.2.4 General Type IV Observations

The failure calls for the ethylene glycol-based Fluid X and most propylene glycol-based fluids occurred much more quickly during the artificial snow tests than during the natural snow tests. In many cases, the artificial snow caused failure times in the order of half the time observed during natural snow precipitation. This is, however, an improvement over the 1999 result, where the failure times for artificial snow were less than half those of natural snow. The nature of artificial snow creates large safety factors and would reduce the holdover times. The differences between natural and artificial snow need to be studied further and their differences reconciled. Table 4.3 shows the percent difference observed between artificial snow and natural snow endurance times.

The failure times recorded during tests conducted with Ultra+ and lower viscosity fluids were frequently closer to the natural snow precipitation tests. Due to the high precipitation acceptance of Ultra+ and the lower tendency for snow bridging in lower viscosity fluids, the failure patterns were more similar to natural snow for those fluids.

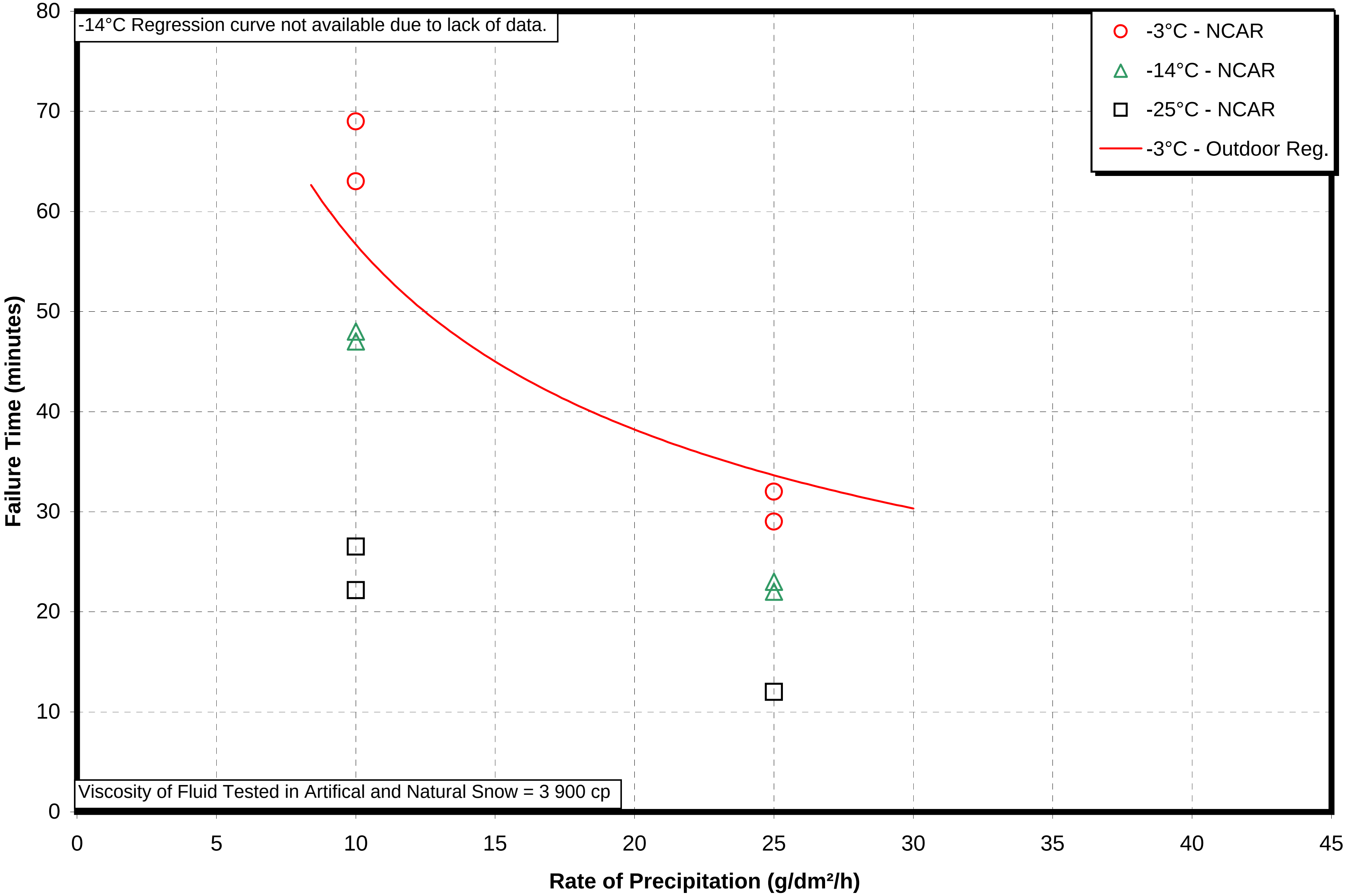
The plate temperature progression, recorded during indoor snow tests, exhibited large drops in temperature during some tests. Further analysis is necessary to compare temperature traces from natural and artificial snow tests. The impact of lower plate temperatures on holdover times would also require investigation.

Another factor that may be the cause of the discrepancies between artificial and natural snow failure times is the effect of wind. During natural snow tests, the fluids covering the test plates were usually subjected to significant winds, as opposed to artificial snow tests where the air surrounding the test plate was completely calm. The results of air currents on fluid holdover times are not known.

FIGURE 4.8

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

DEGRADED KILFROST ABC-S TYPE IV NEAT

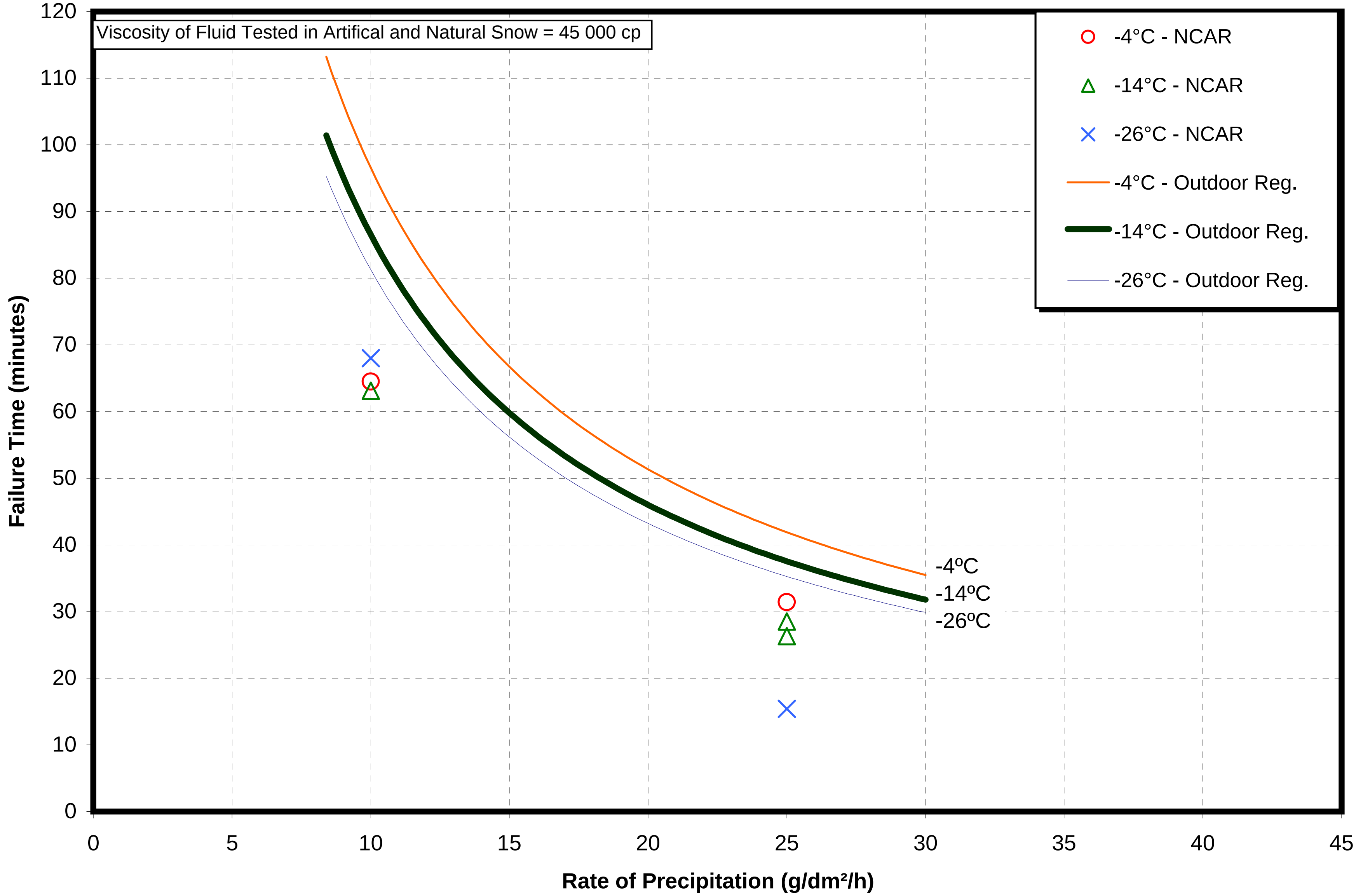


cm1589/reports/ncar/NCAR Regression Analysis
At: kILFROST

FIGURE 4.9

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

FLUID X



cm1589/reports/ncar/NCAR Regression Analysis
At: Fluid X

TABLE 4.3

ENDURANCE TIME DIFFERENCE NCAR ARTIFICIAL SNOW TESTS AT NRC

Fluid Name		Neat	75/25	50/50	Average Difference by Fluid
Type IV Product A	(passed certification but not manufactured)	71%	67%	110%	83%
Degraded Kilfrost ABC-S		-2%			-2%
Fluid X		45%			45%
SPCA AD-480		55%	41%	15%	37%
UCAR Ultra+		14%			14%
Average by Fluid Dilution		37%	54%	63%	**35%**

* Value designated % (percent) by which the average outdoor results are higher than the average indoor results.

The precipitation rate affecting the top third of the test plate was higher than the average rate across the plate. Since most fluids first fail on the top section of the plate, the average rate may not be a good measure of the rate which caused the fluid to fail.

4.3 Artificial Snow Test for Type I Fluids

Figures 4.10 and 4.11 show the holdover time graphs for the Type I tests performed with the snowmaking system during the 2000 season. When comparing the indoor snow data to the holdover time values, certain discrepancies are noticed. At -25°C, the natural and artificial precipitation failure times correlate strongly. As the ambient temperature increases, the correlation degrades. At -10°C and -3°C, the failure times in tests with artificial snow are up to two minutes longer than failure times in natural snow.

The properties of the artificial precipitation create difficulties in making failure calls that are consistent with natural snow failure calls. At lower temperatures, the larger flakes created from ice-core shavings have a tendency to dissolve more slowly than natural snow and cause the thin fluid film to dry near the flakes. Shorter failure times can result from the artificial snowflakes bridging above the thin fluid layer. Due to this behaviour, failure calls may occur when uncontaminated fluid remains on the plate surface.

4.4 *Autorate* Function

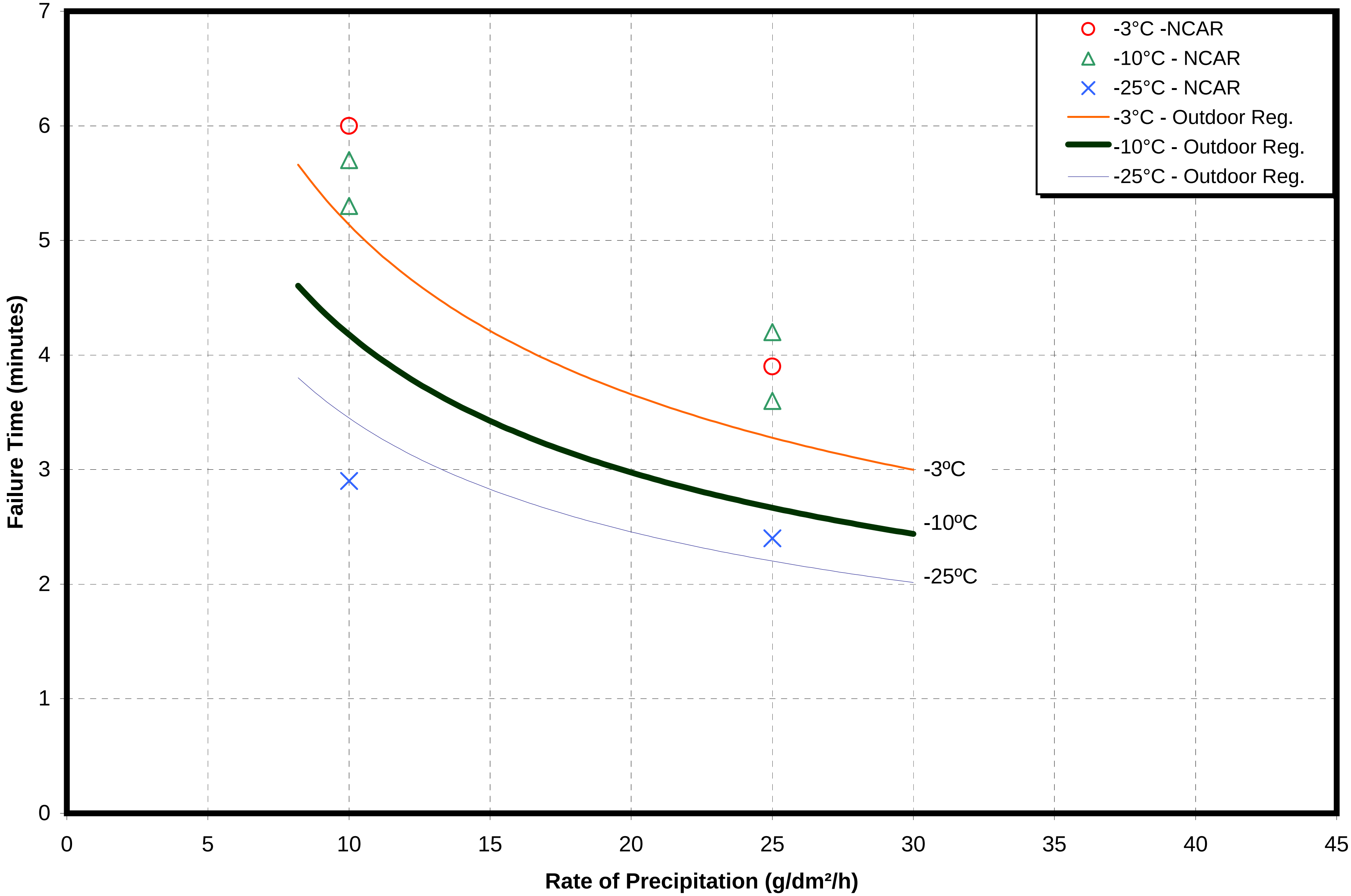
The precipitation rate and the total snow mass accumulated on the plate are displayed in near real time by the system software and logged to the data file. The scale under the plate and collection bucket assembly records the weight and transmits the data to the system software. Based on the returned weight and the elapsed time from the start of the test, the software calculates the average precipitation rate. The recorded precipitation rate is continually recalculated based on the weight of snow that has fallen on the test area during the elapsed time.

A new feature of the delivery model snowmaker is the *autorate* function. This software modification enables the control system to increase or decrease the ice core feeding speed to obtain the desired average rate. If the detected precipitation rate is below the desired rate, the ice core feeding speed can be increased.

FIGURE 4.10

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

UCAR 55A TYPE I FLUID



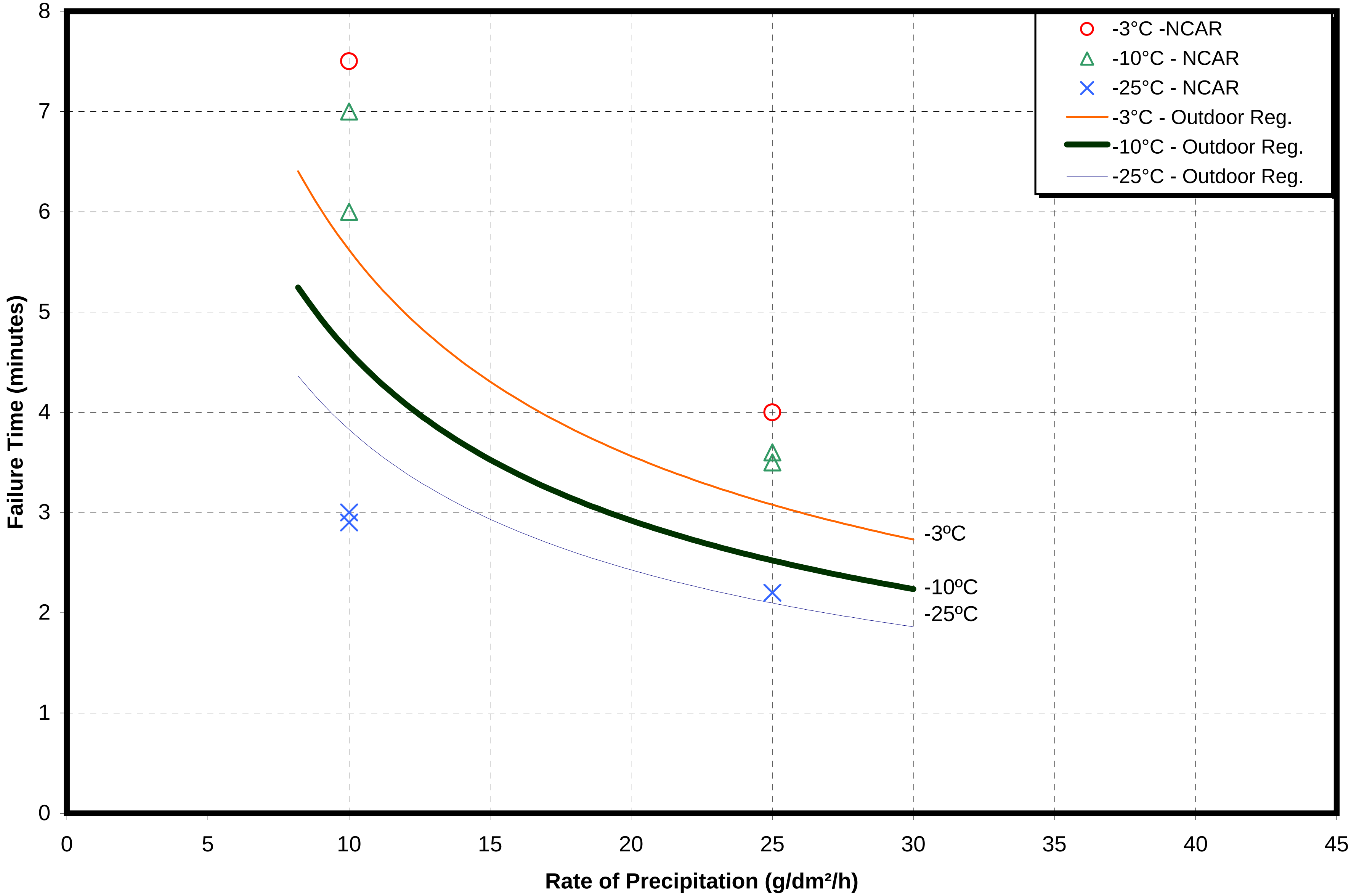
cm1589/reports/ncar/NCAR Regression Analysis

At: 55A

FIGURE 4.11

ARTIFICIAL SNOW DATA vs. NATURAL SNOW DATA

OCTAFLO EG TYPE I FLUID



cm1589/reports/ncar/NCAR Regression Analysis
At: EG

The previous prototype snowmaker did not accurately obtain the desired precipitation rate. The actual precipitation rate would regularly drift away from the selected rate. The *autorate* function now compensates for variation in ice core dimensions and other inconsistencies. This feature greatly increases the functionality of the system.

4.5 General System Functionality and Improvements

The observations made during the holdover time tests performed using the snowmaking system during the 1998-99 season led to a list of functionality issues that required attention. Many suggestions were made to improve the old system. A list of recommendations was compiled and sent to both NCAR and the FAA. The list is included in Appendix E of the 1998-99 Transport Canada report, *A Snow Generation System – Prototype Testing*, TP 13488E (1). This section outlines the issues, discusses actions taken to address them, and presents outcomes and further suggestions.

The first-generation prototype was not capable of operating in the temperature range required to test fluids at their lowest operating temperature. A high torque output motor was installed to replace the drill press motor. The new system is capable of operating at -25°C, although it did experience some difficulties starting.

Snow distribution was not always consistent; some areas of the plate received more snow than others. It was possible to change the pattern by rotating the fans but this did not always produce even snow distribution. The fan positions are fixed in the new snowmaker. This produces repeatable snow distributions. The distribution pattern must now be optimized.

Some modifications to the rate logging and start time triggering software were required. In the previous design, the NCAR snowmaker software began logging the temperatures, scale readings, and precipitation rates when the translator started moving toward the drill. Significant software modifications were performed and a test start and test stop function was incorporated in the design.

The rate logging was modified to include an average rate for the entire test period. The previous system logged the precipitation rate for a given time interval. In the previous configuration, data manipulation was required to obtain an average rate for a test.

The weigh scale was replaced with a higher maximum capacity scale. The previous scale required the fluid collection bucket to be emptied after most tests. With the new scale, multiple tests can be conducted before the bucket weight approaches the maximum capacity of the scale.

4.6 Snowmaker Maintenance and Operation

The snowmaking system requires a knowledgeable operator to set up the system. Various electronic connections must be made during the assembly of the snowmaker. The following list of connections must be made to ensure correct operation of the snowmaker without the risk of serious equipment damage.

- The large grey power supply cable must be connected from the electronics box to the drill;
- The scale must be connected directly to the controlling computer;
- The electronics box must be connected to:
    - the translator;
    - the limit switch;
    - the fans;
    - the temperature probe at the middle of the test plate;
    - the temperature probe at the top of the test plate; and
    - the plate heater.
- The electronics box must be connected to the controlling computer.

Certain hardware components critical to the correct operation of the snow maker could be subject to equipment malfunction. Due to the high cost of cold chamber rentals it would be desirable to have backups for the more critical items. Extra components should be available for the following list of items:

- The translator motor;
- The weigh scale;
- The system computer and software; and,
- The fans.

Regular maintenance is required to ensure the snowmaker will function correctly. The drill bit used to create the snowflakes should be sharpened after every 30 hours of operation. Details on this and other required maintenance are included in the NCAR Operation manual in Appendix F.

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Photo 4.1
Snow Clumping on Upper Shield

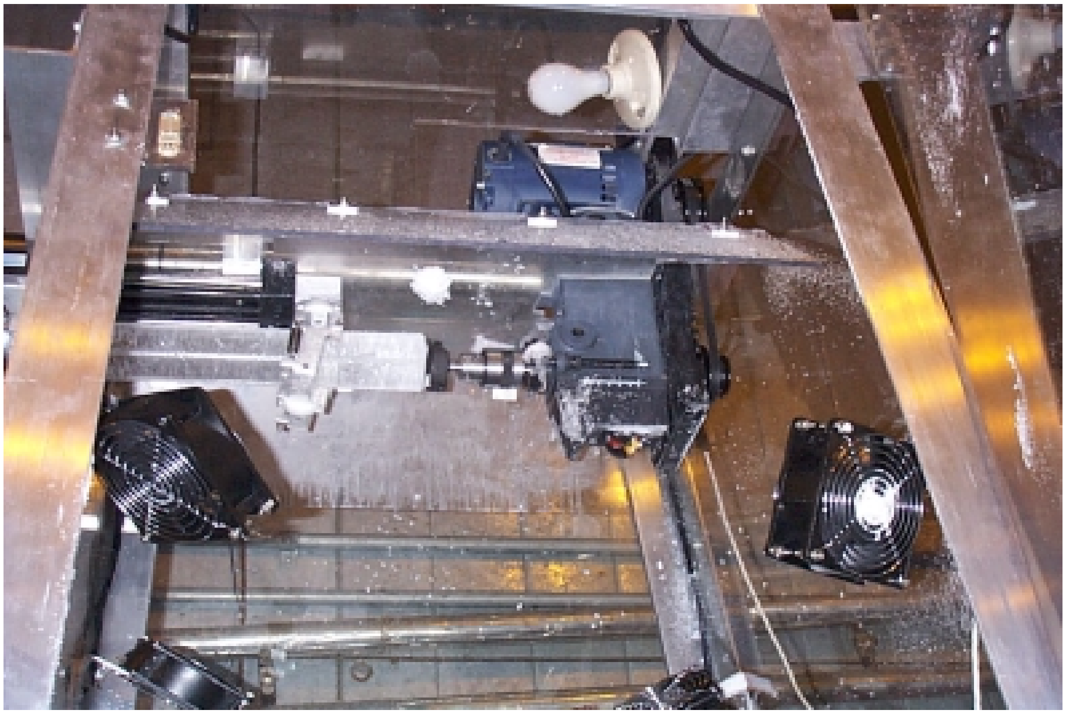

Photo 4.2
Aluminum Ice Core Tubes

5. CONCLUSIONS

The system updates incorporated into the new delivery model snowmaker are a vast improvement over the previous prototype snowmaker. The system reliability and software functionality reflect a large evolution from the first – to the second-generation system. The *autorate* function, the higher capacity weigh scale, and the stronger ice cores help reduce the number of unusable tests.

The artificial snow fluid failure times and flake characteristics observed during this study exhibited significant differences from natural snow. The failure times observed for Type IV fluids were generally shorter than the holdover times published in the SAE tables. The appearance of the fluid failures and the precipitation dimensions also deviated from those of natural snow.

The differences between natural and artificial snow precipitation failure times remain problematic. The fluid failure patterns and the failure times observed with the new snowmaker are better than the previous snowmaker model, although significant variations remain.

The snow distribution on the test surface is relatively consistent from one test to the other but is not uniform over the entire test surface. In the final configuration of the placement of the fans, the range in snowfall rate distribution from the highest to the lowest was large, up to 92 percent of the average rate of snowfall. The snow distribution range indicated in the draft SAE Proposed Aerospace Standard AS 5485 (2) is 15 percent of the average snow rate for each condition. The distribution will require correction to obtain a nearly constant precipitation rate over the entire test plate.

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6. RECOMMENDATIONS

Precipitation rates over the test surface must be uniform. More distribution tests should be performed, and the fan positions and locations should be optimized to obtain the rate distribution range required by the SAE Proposed Aerospace Standard AS 5485.

Rate distribution tests should also be performed in natural snow. The data from the tests could be used to evaluate the performance of the NCAR snowmaker and to re-examine the tolerances specified in the SAE Proposed Aerospace Standard AS 5485.

New fluids should be tested with the updated system to compare holdover times at several ambient temperatures, with several fluid dilutions. Both propylene glycol- and ethylene glycol-based fluids should be tested.

It is recommended that further testing be performed to reconcile fluid failure times of artificial snow versus natural snow. All test variables (such as ambient temperature, plate temperature, relative humidity, and precipitation rates) should be recorded in natural snow tests and duplicated during indoor snow tests.

The effects of snowflake size should be studied to determine the impact of the artificial snowflake size on the holdover time. The correct flake size, as a function of temperature, required to reconcile natural and artificial should be identified.

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REFERENCES

1. Hunt, M., Hanna, M., Chaput, M., Ruggi, E., *A Snow Generation System – Prototype Testing,* APS Aviation Inc., Montreal, October 1999, Transport Canada Report, TP 13488E, 34.

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

3. Chaput, M., D'Avirro, J., Hanna, *Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 1999-2000 Winter*, APS Aviation Inc., Montreal, August 2000, Transport Canada report, TP 13659E (to be published).

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APPENDIX A

EXCERPT FROM TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT

PROJECT DESCRIPTION

PROJECT DESCRIPTION EXCERPT FROM TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT

AIRCRAFT AND FLUID HOLDOVER TIME TESTS FOR WINTER 1999-2000 (December 1999)

5.6 Simulated Snow Validation

A research program was undertaken in 1998/1999 to evaluate the precipitation conditions produced, as well as the general functionality of the snow generation system developed by the National Centre for Atmospheric Research (NCAR).

Type I and Type IV fluids were tested in simulated snow conditions at various ambient temperatures and precipitation rates. The failure times observed during these trials were significantly shorter than the times published in the holdover time tables. The findings of these tests resulted in a list of requirements that should be incorporated into the hardware and software components of the snowmaking machine.

The simulated snowmaker software modifications will be performed by NCAR under contract from the FAA. It is anticipated that additional hardware components to improve the snowmaking system performance will be recommended by NCAR.

The contractor shall re-evaluate the NCAR system for the future conduct of holdover time testing in simulated snow conditions. Tests will be conducted in a small climatic chamber at PMG Technologies, Institut de Recherche d'Hydro-Québec, or at NRC. Tests will be conducted with three Type IV fluids (one ethylene – and two propylene-based fluids) and one Type I fluid over a range of temperature and snowfall rates to compare with the SAE holdover times for these fluids.

A further series of tests will be performed with the system in order to assess the holdover time performance of the reference fluid, Fluid X (as described in the proposed SAE test procedures).

A total of 10 days of climatic chamber use will be planned for the conduct of the proposed tests. The tests will be performed in conjunction with the holdover time tests and the climatic chamber rental will be covered under the holdover time proposal.

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APPENDIX B

EXPERIMENTAL PROGRAM

TRIALS TO ASSESS THE PERFORMANCE OF THE NCAR SNOWMAKING SYSTEM

CM1589.001

EXPERIMENTAL PROGRAM

TRIALS TO ASSESS THE PERFORMANCE OF THE NCAR SNOW GENERATION SYSTEM

Winter 1999/2000

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marc Hunt

Reviewed by: John D'Avirro

APS AVIATION INC.

February 28, 2000
Version 2.0

Editorial Revision
August 11, 2003
Version 2.1

EXPERIMENTAL PROGRAM
TRIALS TO ASSESS THE PERFORMANCE OF THE NCAR SNOW GENERATION SYSTEM

Winter 1999/2000

This set of tests will produce the data required for further evaluating the snow precipitation produced by the NCAR snow generation system. The failure times from natural snow trials and artificial snow trials will be compared and the differences will be analyzed.

1. OBJECTIVES

The purpose of these tests is to evaluate the NCAR system for the future conduct of holdover time testing.

The tests required to create holdover time tables for artificial snow will be performed for two Type I fluids (one ethylene glycol – and one propylene glycol-based fluid) and three Type IV fluids (one ethylene glycol – and two propylene glycol-based fluids). A further series of tests will be performed in artificial precipitation in order to assess the holdover time performance of the reference fluid, Fluid X.

The snowmaking system functionality will be evaluated during the conduct of holdover time trials in artificial precipitation. Snow types will be observed during the tests.

2. TEST REQUIREMENTS

Trials will be conducted at PMG Technologies, Institut de Recherche d'Hydro-Québec, or at NRC in Ottawa.

All Type IV fluids must be tested at outside air temperature. If the cold chamber is not maintained at low temperatures over night, the fluids must be refrigerated to ensure temperature is according to requirements.

Type I fluids must be at room temperature until the test is performed. They must not be stored in the cold chamber.

Temperatures of -3°C, -14°C, -25°C and 7°C above fluid freezing point are required for the holdover time tests. Attachment I presents a test matrix for these tests.

3. EQUIPMENT

Attachment II presents a list of required equipment for the holdover time tests.

All additional equipment required for the operation of the snowmaking system is included in the snowmaking machine operators' manual, supplied by NCAR (Attachment III).

4. PERSONNEL

The personnel requirements for the holdover time tests are as follows:

- One person to pour the fluids and to call the failure on the plate.
- One person part-time to assist in preparing the snow generation system (particularly for Type I trials) and to verify its correct operation.

5. SUMMARY OF PROCEDURES

The ice core tubes must be filled with de-mineralized water and cooled to below 0ºC, a minimum of twelve hours before testing begins.

The procedures for the holdover time tests are as indicated in the *Experimental Program for Dorval Natural Precipitation Flat Plate Testing* (Appendix C) with the exception that the plate rate pans are not required since the rates are collected by the NCAR system.

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

1. Empty fluid collection bucket;
2. Prepare and secure ice core;
3. Begin precipitation and data logging;
4. Clean panels and start;
5. Apply (pour fluids to test panels). Type I fluids are at room temperature. Type II and Type IV fluids are at the test air temperature. Fluids are poured using a single-step fluid application;
6. Record the start of the holdover time after fluid is applied;
7. Record crosshair end condition times; and

8. Continue testing until at least five crosshairs or 1/3 of the plate have failed.

The operation of the snowmaking system is detailed in the snowmaking machine operators' manual supplied by NCAR (Attachment III).

6. DATA FORM

The holdover time tests will only require the end condition data form modified for simulated snow trials. This form is included as Figure 1.

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ATTACHMENT I

ARTIFICIAL SNOW TEST MATRIX

1999/2000

	Run #	Fluid Type	Dilution	OAT	Precipitation Rate	Estimated Duration *	Priority
Type IV fluids	1	Fluid X	100/0	-3	10	75	1
	2	Fluid X	100/0	-3	10	75	2
	3	Fluid X	100/0	-3	25	45	1
	4	Fluid X	100/0	-3	25	45	2
	5	Fluid X	100/0	-14	10	55	1
	6	Fluid X	100/0	-14	10	55	2
	7	Fluid X	100/0	-14	25	30	1
	8	Fluid X	100/0	-14	25	30	2
	9	Fluid X	100/0	-25	10	40	1
	10	Fluid X	100/0	-25	10	40	2
	11	Fluid X	100/0	-25	25	25	1
	12	Fluid X	100/0	-25	25	25	2
	13	Fluid X	100/0	LOUT+7	10	30	1
	14	Fluid X	100/0	LOUT+7	10	30	2
	15	Fluid X	100/0	LOUT+7	25	25	1
	16	Fluid X	100/0	LOUT+7	25	25	2
	17	Ultra +	100/0	-3	10	75	1
	18	Ultra +	100/0	-3	10	75	2
	19	Ultra +	100/0	-3	25	45	1
	20	Ultra +	100/0	-3	25	45	2
	21	Ultra +	100/0	-14	10	55	1
	22	Ultra +	100/0	-14	10	55	2
	23	Ultra +	100/0	-14	25	30	1
	24	Ultra +	100/0	-14	25	30	2
	25	Ultra +	100/0	-25	10	50	1
	26	Ultra +	100/0	-25	10	50	2
	27	Ultra +	100/0	-25	25	30	1
	28	Ultra +	100/0	-25	25	30	2
	29	Ultra +	100/0	LOUT+7	10	35	1
	30	Ultra +	100/0	LOUT+7	10	35	2
	31	Ultra +	100/0	LOUT+7	25	30	1
	32	Ultra +	100/0	LOUT+7	25	30	2
	33	CS4 HV	100/0	-3	10	100	1
	34	CS4 HV	100/0	-3	10	100	2
	35	CS4 HV	100/0	-3	25	70	1
	36	CS4 HV	100/0	-3	25	70	2
	37	CS4 HV	75/25	-3	10	65	1
	38	CS4 HV	75/25	-3	10	65	2
	39	CS4 HV	75/25	-3	25	40	1
	40	CS4 HV	75/25	-3	25	40	2
	41	CS4 HV	50/50	-3	10	15	1
	42	CS4 HV	50/50	-3	10	15	2
	43	CS4 HV	50/50	-3	25	15	1
	44	CS4 HV	50/50	-3	25	15	2
	45	CS4 HV	100/0	-14	10	80	1
	46	CS4 HV	100/0	-14	10	80	2
	47	CS4 HV	100/0	-14	25	50	1
	48	CS4 HV	100/0	-14	25	50	2
	49	CS4 HV	75/25	-14	10	60	1
	50	CS4 HV	75/25	-14	10	60	2
	51	CS4 HV	75/25	-14	25	30	1
	52	CS4 HV	75/25	-14	25	30	2
	53	CS4 HV	100/0	-25	10	70	1
	54	CS4 HV	100/0	-25	10	70	2
	55	CS4 HV	100/0	-25	25	45	1
	56	CS4 HV	100/0	-25	25	45	2
	57	CS4 HV	100/0	LOUT+7	10	65	1
	58	CS4 HV	100/0	LOUT+7	10	65	2
	59	CS4 HV	100/0	LOUT+7	25	45	1
	60	CS4 HV	100/0	LOUT+7	25	45	2
	61	SPCA 480	100/0	-3	10	100	1

Run #	Fluid Type	Dilution	OAT	Precipitation Rate	Estimated Duration *	Priority
62	SPCA 480	100/0	-3	10	100	2
63	SPCA 480	100/0	-3	25	70	1
64	SPCA 480	100/0	-3	25	70	2
65	SPCA 480	75/25	-3	10	65	1
66	SPCA 480	75/25	-3	10	65	2
67	SPCA 480	75/25	-3	25	40	1
68	SPCA 480	75/25	-3	25	40	2
69	SPCA 480	50/50	-3	10	15	1
70	SPCA 480	50/50	-3	10	15	2
71	SPCA 480	50/50	-3	25	15	1
72	SPCA 480	50/50	-3	25	15	2
73	SPCA 480	100/0	-14	10	80	1
74	SPCA 480	100/0	-14	10	80	2
75	SPCA 480	100/0	-14	25	50	1
76	SPCA 480	100/0	-14	25	50	2
77	SPCA 480	75/25	-14	10	60	1
78	SPCA 480	75/25	-14	10	60	2
79	SPCA 480	75/25	-14	25	30	1
80	SPCA 480	75/25	-14	25	30	2
81	SPCA 480	100/0	-25	10	70	1
82	SPCA 480	100/0	-25	10	70	2
83	SPCA 480	100/0	-25	25	45	1
84	SPCA 480	100/0	-25	25	45	2
85	SPCA 480	100/0	LOUT+7	10	65	1
86	SPCA 480	100/0	LOUT+7	10	65	2
87	SPCA 480	100/0	LOUT+7	25	45	1
88	SPCA 480	100/0	LOUT+7	25	45	2
Type I fluid 89	UCAR I	10° Buffer	-3	10	15	1
90	UCAR I	10° Buffer	-3	10	15	2
91	UCAR I	10° Buffer	-3	25	15	1
92	UCAR I	10° Buffer	-3	25	15	2
93	UCAR I	10° Buffer	-10	10	15	1
94	UCAR I	10° Buffer	-10	10	15	2
95	UCAR I	10° Buffer	-10	25	15	1
96	UCAR I	10° Buffer	-10	25	15	2
97	UCAR I	10° Buffer	-25	10	15	1
98	UCAR I	10° Buffer	-25	10	15	2
99	UCAR I	10° Buffer	-25	25	15	1
100	UCAR I	10° Buffer	-25	25	15	2
101	UCAR I	10° Buffer	LOUT+10	10	15	1
102	UCAR I	10° Buffer	LOUT+10	10	15	2
103	UCAR I	10° Buffer	LOUT+10	25	15	1
104	UCAR I	10° Buffer	LOUT+10	25	15	2
105	Octaflo	10° Buffer	-3	10	15	1
106	Octaflo	10° Buffer	-3	10	15	2
107	Octaflo	10° Buffer	-3	25	15	1
108	Octaflo	10° Buffer	-3	25	15	2
109	Octaflo	10° Buffer	-10	10	15	1
110	Octaflo	10° Buffer	-10	10	15	2
111	Octaflo	10° Buffer	-10	25	15	1
112	Octaflo	10° Buffer	-10	25	15	2
113	Octaflo	10° Buffer	-25	10	15	1
114	Octaflo	10° Buffer	-25	10	15	2
115	Octaflo	10° Buffer	-25	25	15	1
116	Octaflo	10° Buffer	-25	25	15	2
117	Octaflo	10° Buffer	LOUT+10	10	15	1
118	Octaflo	10° Buffer	LOUT+10	10	15	2
119	Octaflo	10° Buffer	LOUT+10	25	15	1
120	Octaflo	10° Buffer	LOUT+10	25	15	2

Note: The estimated duration of each test includes a nominal amount of time required to change ice cores, empty the collection bucket and restart the snowmaking machine.

Estimated Duration	Totals
Minutes	4830
Hours	80.5
Days	10.0625

ATTACHMENT II
TEST EQUIPEMENT CHECKLIST

- Snowmaking machine and related equipment;
- Aluminum plate;
- Fluid thickness gauge;
- Squeegee/scraper;
- Extension cord;
- Paper towels;
- Rags;
- Flood lights;
- Stopwatch;
- Wet vacuum;
- Brixometer;
- Data forms;
- Clipboard;
- Video camera;
- Photo camera; and
- RH meter.

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NCAR Snow Machine Operation Manual

Provided to: *APS Aviation Inc.*

Montreal, Quebec

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revision: 27 September 1999

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Foreword

This manual should allow easy set up, and operation of the snow machine with a short learning curve. The instrument has been designed to allow easy access to power supplies, electronics, signal cables, A/D system, and essential subassemblies.

Be sure to read through this manual to learn the proper operation protocol for accurate and safe use of the snow machine. For further information, please contact Alan Hills at hills@ucar.edu.

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A. Theory of operation

The NCAR Snow Machine produces extremely fine ice shavings which mimic natural snow in; density, size distribution, fall velocity, and mass accumulation rates. In anti/de-icing studies, the snow has been demonstrated to be functionally equivalent to natural snow with a density of 0.1 g/ml.

The instrument operates by feeding a deionized-water ice core, 7 cm diameter x 1 m long, into a carbide-tipped spur bit at a controlled rate. The feed rate is determined by a series of high frequency pulses generated with a notebook PC and output to a stepper motor control circuit and to a stepper motor. The ice flakes are then redistributed in semi-random fashion by a series of fans, and then fall 2.2 m to a 30x50 cm^2 aluminum plate. The plate is part of a fluid containment unit that collects and weighs all the snow falling on the plate and also retains any de-icing fluid applied on the plate. The plate and fluid trap rest on an 0.1 g resolution/6100g capacity, analytical balance, so that total mass and snowfall rate may be measured in real time. The plate may be temperature controlled with a PID controller to 0.1 C. A high resolution (Analog Devices) temperature transmitter monitors a second temperature channel. Both temperature sensors use 1.5 mm o.d., 100 ohm platinum RTD sensing elements. The system may be used in anti/de-icing studies or other experiments.

B. Initial setup

1. Select an 8-foot high flat 30”x 45” area in a coldroom for placement of the machine. Leave an extra 24” of clearance to allow opening of the Lucite doors. 120 VAC power outlets should be available within 1 m.

2. Place upper stage onto lower stage and bolt together using ¼”x20 tpi bolts and nuts through the holes labeled “transport”.

3. Place the electronic control box and notebook PC, outside the coldroom. Auxiliary monitor, keyboard and mouse are to reside inside the coldroom.

4. Place digital balance feet in the holes of the Lucite index board on bottom of snowmachine. Install containment tray on top of balance. Carefully do a visual check to be certain that the tray sits flat on the balance.

5. Check angle of snow plate to ensure lateral flatness and 10.0 degrees along the axis of the snow plate. Fine tune the angle using adjustable feet on balance.

6. Plug in all cabling. Ensure that cables going to the snow plate are loose (hanging freely). Tension in these cables will prohibit accurate mass readings. Ensure also that the cables do not block the freefall path of snow onto the plate.

C. Operation-experimental setup

1. Prepare ice core. Fill the aluminum ice core tubes with deionized water to a level 10 cm from the top edge. This allows for expansion of the mixture during cooling. Install the special insulation piece over the upper part of the tube. Install Let freeze for at least 12 hours.

2. Thaw PVC tube for 20-30 min. until the ice core will slip out of the tube via gravity. DO NOT HEAT THE TUBE using water or some other method, such heating will fracture the ice core.

3. Place the bare ice core back in the cold room for at least 10 minutes to refreeze the melted surface layer.

4. The electronic balance should *always* be left on. If the balance is currently off, turn on the balance and momentarily hold the tray away from the balance. Press "zero" on the balance and wait for 00.0g to appear, then place tray assembly back on balance. Be quite careful to position the tray on the top of the balance. It’s easy to misplace the tray assembly.

5. Turn on the Electronic Control box.

6. Power-up PC and double-click on "APSsnow46.vi" (or current version). To allow both the notebook display and the external monitor (in the cold room) both to be active, press function key + F2 about 10 seconds after turning the PC on.

7. Start program execution by clicking once on the program start arrow (top left of control panel display, see Figure 1.). Temperature traces and other functions should now be operating.

8. Back the translator up sufficiently to load the ice core. This is done by flipping the ice translator toggle switch to the "on" position. The value stored in the "Snow rate" digital control may be altered to speed up translation speed. If the translator doesn't move either you forgot step 6 or one of the contact switches has been tripped. These switches reside at either end of the translator and prevent the translator from driving to far left or right.

To force translator movement, momentarily depress the red "limit switch" (~3 sec.) override on the front of the electronic control box.

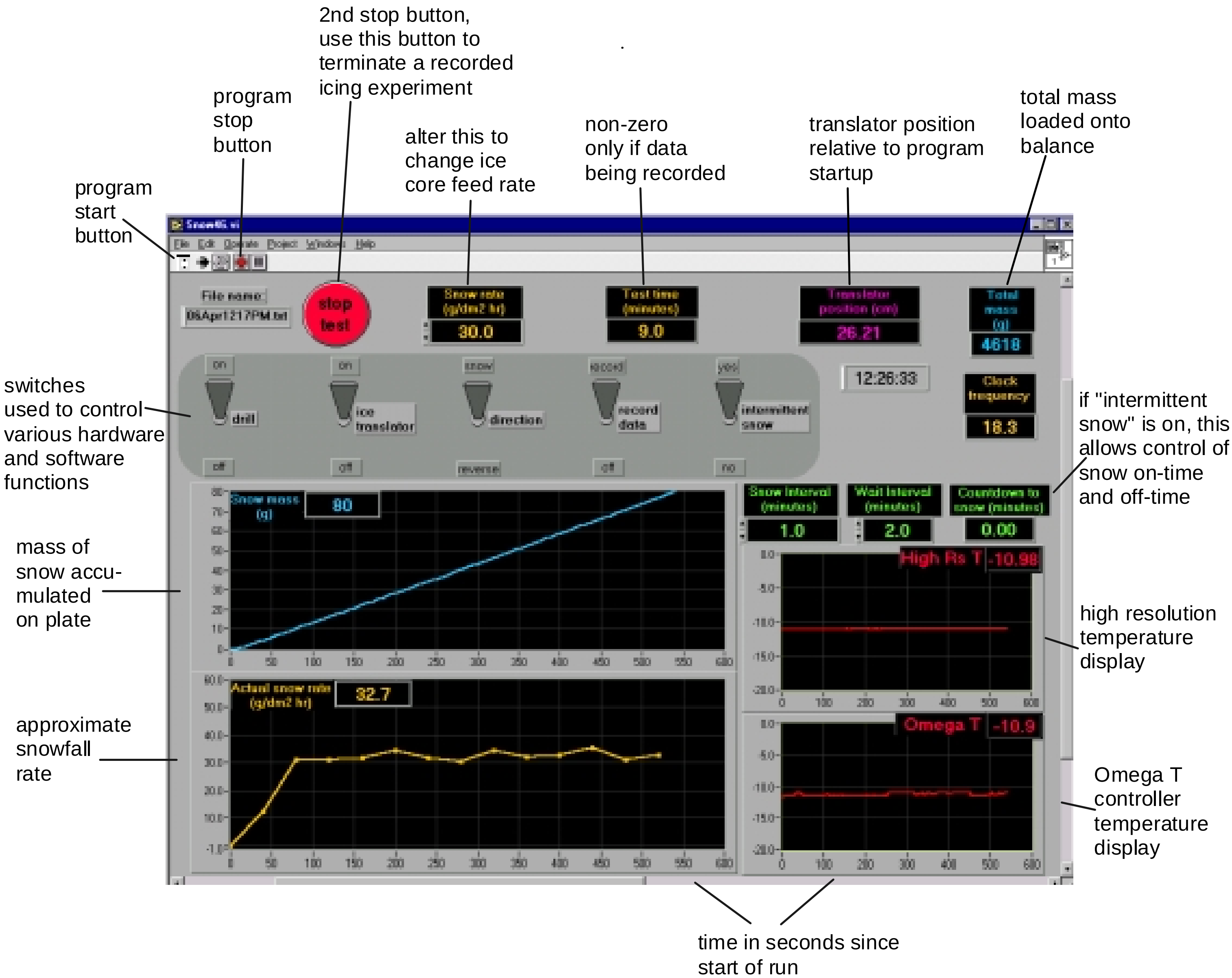
****** CAUTION: Depressing the "limit switch" override while the computer is commanding the translator to move in the wrong direction, <u>will</u> result in major damage!!! *** The wrong direction would be "reverse" if the translator is at the left limit position and "snow" if the translator were at the right limit position. ******

9. Slide the ice core into the translator. Replace the #10-32 bolt in the translator (screw the bolt in finger tight). Slide the ice core to the left so that it rests against the bolt. Tighten the hose clamps snugly. (The #10-32 bolt pushes on the ice core during operation.)

10. Turn on "drill" and drive translator to the right (towards the drill bit) by clicking the "ice translator" to "on" and the "direction" toggle switch to "snow".

11. When snow shavings start to fall, stop translator. The system is now ready to perform a snow experiment. Note: The balance capacity is 6100g. If the indicated mass + what you are about to add (deicing fluid + snow loading) will exceed this, you should empty the tray by carefully lifting and tipping it to one side into a suitable reservoir. Be certain tray is properly seated when finished (see step 4.).

Figure 1. APSsnow46.vi code control panel



D. Conducting a snow experiment

1. Turn drill on, set translator direction to "snow", and enter desired snow rate.

2. Start translator. Advance ice core to point of contact with cutter.

3. Stop translator

4. Pour fluid on snow plate.

5. Hit "record data" and acknowledge the date/time stamp on output file, or rename the file. Note or redirect where the file will reside.

6. Start translator again.

7. Observe experiment and fluid failure.

8. When fluid has failed hit the large red "stop test" button. Enter comments and experimental details which will be written to the bottom of the data file.

9. If another experiment is to be performed, completely close out of "APSsnow46.vi" file using the "X" button on the top right of the window. This is necessary for proper reset of the code.

E. LabView code details

The LabView source code resides in drive D, in the NCAR folder.

Questions? Contact Alan Hills or LabView directly at 800 433-3488 or, 512 795-8248.

The address to their web site is: http://www.natinst

If the code is not working properly, close out of LabView and relaunch. If you still have problems, shut down and restart computer and cycle power on electronic control box.

If you accidentally move components on the PC "panel", hit control + z, for each step of undo. If it has really been screwed up, close the file *WITHOUT* saving changes.

F. Calibrations

Recalibration of measured/controlled snow machine parameters is occasionally needed. The calibration procedure is to carefully monitor the parameter against a fundamental measurement method, calculate and input a new calibration parameter into the APSsnow46.vi code.

Electronic balance

I recalibrated the balance parameters in April of 1999.

1. Warm up balance and data system for 1 hr. (its OK to leave them on continuously).
2. Monitoring the “total mass” readout (upper right display), add a calibrated mass to the balance.
3. If there is >2% discrepancy, calculate a correction factor.
4. At the APSsnow46.vi control panel, go to “windows”and “show diagram”. Go to frame 9 of the code. There are four boxes in each quadrant of the screen. Go to frame 5 of the lower left box. Within box 5, go to frame 1 of the true case. Replace the “1.031” multiplier with a new factor *(Note: to replace text in a LabView diagram you have to enter text mode by clicking on windows and "show tools" and clicking once on the large "A").* Go to “File” and “Save”, to make the change permanent.

Omega temperature controller

1. Warm up controller and data system for 30 minutes.

2. Monitor "Omega T" readout on the PC. (*Note: The display on the actual Omega controller may have an offset error of ~1 ^{o}C.)* Compare the PC readout to a high accuracy (0.1 C or better) mercury thermometer or other suitable precision reference thermometer placed on top of the snow plate at 6" from top edge. If the difference between the two is large (> 0.6 ^{o}C), follow the recalibration procedure shown below.

3. Record reference temperature from the calibration standard of step 2. Also record "mean omega" voltage on the panel display (PC screen). This digital display is normally way off to the right of the normal display, but can be viewed by using the slider control at the bottom of the screen.

4. Use temperature controller to boost plate temperature say 40 ^{o}C higher than the coldroom value of previous step. Wait 30 min for thorough equilibration. Record values as in step 3.

5. Perform linear regression on the two points and compute appropriate values for "a" and "m" for an equation of the form: $T = a + mV$ where T= temperature ^{o}C, a is intercept, m is slope and V is "mean omega" voltage.

6. At the APSsnow46.vi control panel, go to "windows"and "show diagram". Go to frame 9 of the code. There are four boxes in each quadrant of the screen. Go to frame 5 of the upper right box. Replace the slope and intercept values with those of the linear regression. Go to "File" and "Save", to make the change permanent. Calibration is complete.

High resolution temperature sensor

Calibration of the high resolution temperature sensor is identical to steps presented for the Omega calibration, *except* the parameters are held in frame 6 of the same code segment.

Snow rate calibration factor

The snow rate calibration factor is the parameter in APSsnow46.vi that ensures the desired snow rate will in fact be produced, during operation. To evaluate the accuracy of this factor, perform a snow experiment at a given rate, say 30 g $dm^{-2}hr^{-1}$, saving the data to a file. Then go to the ".txt" file created during the test and view the total mass of snow to collect on the plate and the test time in minutes. Calculate the actual rate via the equation:

$$\text{rate} = \text{snow mass} / (16.84\ dm^2)\ (\text{test time}/60).$$

Rate is the actual snow fall rate in g $dm^{-2}hr^{-1}$, 16.84 dm^2 is the area of the APS Aviation snow plate + that measured to the very edge of the collection tray (30x50cm + edges), test time is in minutes. If the measured rate differs from the mean command rate by more than 4 g $dm^{-2}hr^{-1}$. The code needs to be altered.

At the APSsnow46.vi control panel, go to "windows"and "show diagram". Go to frame 9 of the code. There are four boxes in each quadrant of the screen. Go to frame 4 of the upper left box. The new "constant" will be given by:

$$\text{constant}_{(new)} = \text{constant}_{(old)} \times (\text{command rate}/\text{actual rate})$$

G. Operational hints

- Don't leave ice cores in cold room for >12 hrs unless contained in PVC core. Sublimation will reshape core rendering it with incorrect shape.
- Leave balance on at all times. Memories and settings require power to hold values.
- Don't overfill PVC tubes.
- Check alignment guide and adjust if necessary. Ice core and guide friction can lead to unsteady snow rates.
- Plot range values may be reset during execution by clicking on the value and entering a new value. Then hit "enter" (top left) or moving cursor to another area and clicking once. The snow mass plot is set to autorange.
- To check snowfall pattern, place a dark plasticboard in the bottom of the snow machine. The board should cover most of the bottom area. Run the snow machine for 5-10 minutes and evaluate the pattern. Does the pattern produce uniform snow over the snow plate? If necessary redirect dispersion fans.

H. Parts ordering

Listed below are some of the components in the snow machine and their suppliers.

Component	Manufacturer & Part number	Distributor	Approximate cost
platinum RTD temperature sensor	Omega, RTD-2-1PT100K2515-36-T	Omega 800 826-6342	$80
Temperature controller	Omega, 76120-PV	Omega 800 826-6342	$270
Silicone heater for underside of snow plate	Omega, SRFG-101/10-P	Omega 800 826-6342	$62
Translator	Thomson Industries, 2DB08OUBAA x44.00”		$1700
Stepper motor electronic drive board and motor	CSK243-ATA, with 245 series, high torque motor	MSI, 303 792-5518	$300

I. Troubleshooting

Listed below are some symptoms and their possible causes and remedies. I've tried to think of several potential problems.

Symptom	Possible Cause	Remedy
Translator won't move, when commanded by computer.	Program not in run mode	Hit top left "run" arrow
	Limit switch activated	Reset limit switch as discussed in Section C step 8. Carefully observe the cautions presented!
	Ice core guide badly catching	Realign ice core guide.
	Stepper motor not getting 12 V	Turn on Electronic Control box.
Snow mass is way out of range	Code is "confused"	Restart code, or LabView, or PC
	Balance has not be tared properly	Reset balance zero as discussed in Section C step 4. Cycle balance power if needed. Balance power is cycled only by yanking the power jack out of the balance for >30s and then reinserting it.
Snow rate is very unsteady	ice core feed rate is varying	ice-core *guide* (the PVC collar near the drill bit) may be misaligned, realign it-carefully
	ice core might be slipping backward in translator as translator moves forward	thrust bolt behind ice core not installed or is damaged
Snow rate suddenly falls	ice core might be slipping backward in translator as translator moves forward	thrust bolt behind ice core not installed or is damaged

FIGURE 1

END CONDITION DATA FORM

NCAR SNOWMAKER

Winter 1999/2000

LOCATION:	DATE:	RUN # :	STAND # :

OAT: ________ °C

PRECIPITATION RATE: ________ g/dm²/h

FLUID TEMPERATURE: ________ °C

FLUID QUANTITY APPLIED: ________ Liters

PLATE WASHING METHOD: ______________

<u>OTHER COMMENTS</u> (Fluid Batch, etc):

	PRINT	SIGN
FAILURES CALLED BY :		
HANDWRITTTEN BY :		
LEADER :		

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

Time of Fluid Application: ________ h:min

FLUID NAME			
B1 B2 B3			
C1 C2 C3			
D1 D2 D3			
E1 E2 E3			
F1 F2 F3			

CALCULATED FAILURE TIME (MINUTES)

File:h:\cm1589\reports\NCAR\Snow Maker Data Sheet Version 1.0
At: Data Form

APPENDIX C

EXPERIMENTAL PROGRAM

FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING

CM1589.001

EXPERIMENTAL PROGRAM FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING

Winter 1999/2000

Prepared for

Transportation Development Centre
Transport Canada

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Reviewed by: John D’Avirro

APS AVIATION INC.

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ATTACHMENT I
EXPERIMENTAL PROGRAM
FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING
1999/2000

This document provides the detailed procedures and equipment required for the conduct of natural precipitation flat plate tests at Dorval for the 1999/2000 winter season.

1. OBJECTIVE

To conduct tests on standard flat plates to validate the current holdover time tables and develop holdover time tables for new fluids.

2. TEST REQUIREMENTS (PLAN)

Attachment IA provides the test plan for fluid types to be tested at the Dorval test site located adjacent to the Atmospheric Environment Services. These tests shall be conducted during natural snow conditions.

3. EQUIPMENT

Test equipment required for the flat plate tests was determined from previous winters in association with the Society of Automotive Engineers (SAE) working group. This equipment is listed in Attachment II.

4. PERSONNEL (see Attachment III)

The following personnel are required for the conduct of tests. The responsibility for each tester is provided in Attachment III.

For one stand	For two stands
1 x Test site Leader/video	1 x Test site leader/video
1 x End condition tester	2 x End condition tester
1 x Meteo tester	2 x Meteo tester

5. PROCEDURE

The modified test procedure is included in Attachment II. This procedure was developed more than six years ago and was modified over the years to incorporate discussions at the SAE working group meetings. Attachment V contains a brief summary of the steps required to conduct a test.

6. DATA FORM

The data forms are included at the end of this document. One data form was developed for the end-condition tester (Table 1) and one data form for the Meteo/Video tester (Table 2).

ATTACHMENT IA

NATURAL SNOW PRECIPITATION TEST PLAN

NEW FLUIDS

Temperature Range	Type IV/II Neat	Type IV/II 75/25	Type IV/II 50/50	Type III	Type I Diluted
> 0ºC	YES	YES	YES	YES	YES
0 to -3ºC	YES	YES	YES	YES	YES
-3 to -14ºC	YES	YES	NO	YES	YES
-14 to -25ºC	YES	NO	NO	NO	YES
below -25ºC	YES	NO	NO	NO	YES

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ATTACHMENT II

FLAT PLATE FIELD TEST EQUIPMENT AND PROCEDURE

1999/2000

This field test procedure has been developed by the SAE G-12 Holdover Time Subcommittee working group on aircraft ground de/anti-icing as part of an overall testing program that includes laboratory tests, field tests and full-scale aircraft tests, which is aimed at substantiating the holdover time table entries for freezing point depressant fluids known as de/anti-icing fluids.

1. SCOPE

This procedure describes the equipment and generalized steps to follow in order to standardize the method to be used to establish the time period for which freezing point depressant fluids provide protection to test panels during inclement weather such as freezing rain or snow.

2. EQUIPMENT

Environment Canada's READAC (Automated Weather Station) is located within 50 metres of the Dorval test stands. Data from this station will be acquired on a one minute basis. Temperature, total precipitation, visibility, wind speed and direction are among a few of the parameters measured.

2.1 Precipitation Rate Measurement

The following equipment or equivalent are recommended:

2.1.1 Plate Pan (see Figure 1)

A plate pan, placed at a 10º inclination on the test stand will be used to collect and weigh snow. The procedure for the collection of precipitation rates using this method is described in Attachment VI. A schematic of the plate pan is provided in Figure 1.

Note: When this method is used the bottom and sides of the pan MUST BE WETTED (before each pre-test weighing) with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The plate pans should be carefully rotated every 5 minutes to prevent accumulating snow from blowing away. The time of rotation should be reduced to 2 minutes during heavy precipitation or high wind conditions.

2.2 Plate Temperature Monitoring

Type T Kapton insulated thermocouple probes have been embedded within the test plates to monitor plate temperatures during a test. The accuracy of the thermocouples is 1.0ºC over the range +404ºC to -250ºC. Data from the thermocouples will be recorded with a logger.

2.3 Test Stand

A typical test stand is illustrated in Figure 2; it may be altered to suit the location and facilities, but the angle for the panels, their arrangement and markings must all conform to Figures 2 and 3. There shall be no flanges or obstructions close to the edges of the panels that could interfere with the airflow over the panels.

2.4 Test Panels

2.4.1 Material and Dimensions

Alclad Aluminum 2024-T6 or 5052-H32 polished standard roll mill finish 30x50x0.32 cm (12x20x1/8"), for a working area of 25x40 cm (10x18"). Thicker aluminum stock may be needed when an instrument is mounted on the plate.

2.4.2 Markings

Each panel shall be marked as shown in Figure 2 with lines at 2.5 and 15 cm (1 and 6") from the panel top edge, with 15 crosshair points and with vertical lines 2.5 cm (1") from each side; this marks off a working area of 25x40 cm (10x18") on each panel. All marks shall be made using a 0.3 cm (1/8") thick black marker or silk screen process, which does not come off with application of the test fluids or any of the cleaning agents. Re-marking of the plates will be required as the markings fade because of the cleaning actions.

2.4.3 Attachment

For attachment to the test stand, at least four holes shall be made, spaced along the two sides of each panel; the holes shall be within 2 cm (0.8") from the panel edge.

2.5 Fluid Application

The fluid should be poured onto the plates from a manageable container, until the entire test section surface is saturated and a consistent fluid thickness over the entire plate surface is obtained. Up to two litres of fluid may be applied to each panel for tests using anti-icing fluids. For Type I tests, 1 litre of fluid is sufficient.

Anti-icing fluids are applied to test surfaces at ambient outside air temperature. Type I fluids are applied at 20ºC +/- 3ºC, and diluted to a 10ºC buffer. The mixing procedure for Type I fluids has been included in Attachment VIII.

2.6 Film Thickness Gauge

Film thickness at the 15 cm (6") line can be evaluated (this is optional). Painter's wet paint film thickness gauge, 1-08 mil gauge or equivalent, is available from Paul N. Gardner Company Inc., Pompano Beach, Florida.

2.7 Video Recording (Optional)

Tests may also be recorded with a hand-held video camera, in particular at the start of the test and when failures are being called. Care must be taken that the camera and any lighting do not interfere with the airflow or ambient temperatures.

2.8 Anemometer

Wind Minder Anemometer Model 2615 or equivalent. Available from Qualimetrics Inc., Princeton, New Jersey. To be mounted at 3 metres (10'). (For wind data and calibration sources, see TP 12896E[1] and TP 12654E[2]). Additional meteorological information is obtained from READAC.

[1] D'Avirro, J., *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1995-1996 Winter*, APS Aviation Inc., Montreal, November 1996, Transportation Development Centre report, TP 12896E, 172.

[2] Boutanios, Z., D'Avirro, J., *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1994-1995 Winter*, APS Aviation Inc., Montreal, December 1995, Transportation Development Centre report, TP 12654E, 180.

2.9 Wind Vane

Model 2020 Qualimetrics or equivalent. To be mounted at 3 metres (10'). (For wind data and calibration sources, see TP12896E and TP12654E)

2.10 Relative Humidity Meter

Relative humidity will be provided by READAC on a minute-by-minute basis.

2.11 Ice Detection Sensors

Where feasible, surface or remotely mounted ice detection sensors should be used during the tests.

2.12 Additional Equipment

- Squeegee/scraper
- Extension power cords
- Flood lights
- Watches/stopwatches

3. DE/ANTI-ICING FLUIDS

3.1 Certification

Only fluids that have been certified will be included in tests. Fluid suppliers shall submit to the test coordinating organization proof of certification for the fluids they provide.

3.2 Test Fluids

Samples of deicing and anti-icing fluids for holdover time testing shall be prepared and delivered according to the sample selection procedures, intended for inclusion in AMS 1424 and 1428.

3.3 Dye

Fluids should be supplied for certification and for testing in the form to be used on aircraft.

4. PROCEDURE

Attachment IV contains a summary of the major steps required for the conduct of flat plate tests. This should be mounted on the wall in the trailer at the site.

4.1 Start-up and Close-up

Attachment IV provides a reference to enable testers to start the equipment at the beginning of a test session, and also provides reference on what should be closed at the end of a session.

4.2 Set-up

4.2.1 Panel Test Stand

If there is any wind, orient the test stand so that the test panels are facing into the wind direction at the beginning of the test and the wind is blowing up the panels,

i.e. ----> /
wind panel

If the wind shifts during the test do not move the stand; simply note it on the data sheet.

4.2.2 Plate Pan Method

Coat the bottom of the plate pan, as well as the inner sides of the pan, with about 0.6 cm (¼") of anti-icing fluid (Type IV). Weigh the wetted pan prior to testing to the nearest gram. Weigh the pan at 10-minute intervals over the course of the test (see Table 2). Replace the pans on the test stand after each weighing. Do not remove the contents of the pan until the test is complete. Weigh again after test completion of each panel to determine the true water content reading of the precipitation.

When using plate pans to measure precipitation rate, two plate pans shall be used. Care must be taken to ensure that snow or ice does not fall into the pans when transporting them into the trailer. The complete description of this method is included in Attachment VI.

4.3 Test Panel Preparation

4.3.1 Before the start of each day's testing, ensure the panels are clean.

4.3.2 Place the panels on the fixture and attach to the frame screws with flat bolts (wing nuts will make attaching and removal easier in poor weather).

4.3.3 Allow the panels to cool to outside air temperature.

4.4 Fluid Preparation and Application

4.4.1 Fluid Temperature

Anti-icing fluids should be placed outside (cold-soaked to ambient temperature conditions) prior to the start of the test session. Deicing fluids should be applied to test surfaces at 20ºC +/- 5ºC. Deicing fluids should be stored in the trailer at all times.

4.4.2 Cleaning Panels

Before applying test fluid to a panel, squeegee the surface to remove any precipitation or moisture. Fluid being used for the test could be used to help remove snow or ice from the test panel.

4.4.3 Order of Application

Apply the fluid to the panels, commencing at the upper edge of the test panel and working downwards to the lower edge. Ensure complete coverage by applying the fluid in a flooding manner. Start with the top left panel U, then cover panel X in the second row with the same fluid, then flood the second test fluid on panel V followed by panel Y, etc. (see Figure 1).

4.5 Holdover Time Testing

- Commence recording the test until the test reaches the END CONDITION. See Section 5 for definition of end condition.
- Record the elapsed time (holdover time) required for the fluid to achieve the test END CONDITION.

4.6 Video Recording (not performed routinely)

Video record test (if required) with a hand-held camera in the following sequences:

1. General outdoor condition prior to test (get good view of snow falling).
2. Video record the data forms.
3. Video record pouring. Ensure that name of fluids are captured, testers', faces, your voice, name and stand # (ensure date and time are available and synchronized).
4. Record pans being weighed and brought out.
5. Record establishing shot of test stand (all the plates).
6. Record establishing shot of each plate, followed by a close-up of the plate (scan the plate slowly), then returning to wide shot of the plate. Repeat this with each plate in sequence, beginning from left to right, top to bottom. Always follow the same sequence. Ensure that each plate has a tag marked with the type of fluid used on the plate and that the plate itself is marked with its corresponding letter (X, Y, Z...). Record the clock/timer often.
7. For each failure, record an overview of the plates, followed by a wide shot of the plate, zooming in into a close-up of the failure. Return to the establishing shot at the end of the procedure. Repeat this procedure for each failure.
8. Ensure that the lighting is appropriate for video purposes.
9. Ensure that the video camera is in fact recording. At the end of a test,

rewind a few seconds and check that the test was recorded.

4.7 Plate Pan Measurements

Measure the quantity (rate) of precipitation using at least two plate pans mounted on the test stand. Record these measurements on the Form (Table 2) at the following times:

- At the start of the test;
- Every 10 minutes;
- When there is a significant change in the rate (intensity) for more than one minute;
- After failure of each panel (measure only once if two panels fail at almost the same time); and
- At the end of the test.

4.8 Meteorological Observations

Meteorological observations must be recorded at the same times as in Subsection 4.7, and when there are changes in the type and category of precipitation. Significant changes in wind speed and direction should also be noted.

4.8.1 Type of Precipitation

Note the type of precipitation (refer to Figure 5 for the codes). This is a subjective determination. If two or three forms of precipitation co-exist, then note all of these.

4.8.2 Classification of Precipitation

While many different classifications are available, a simple classification of ten forms of solid precipitation is shown in Figure 4. Use of black velvet to collect the snow and inspect it, will facilitate the identification.

4.8.3 Determination of Wet or Dry Snow

While this is usually temperature and humidity level dependant, determination of wet or dry snow could be determined by collecting snow in a dry plate pan on a stand not being used. If in the course of a test, the snow in the pan can be combined and formed into a *snowball*, then this will be identified as wet snow. If the snow does not form into a *snowball* or if the snow does not even accumulate, then this is considered dry snow. Note that the time to form a *snowball*, when collecting with gloves, should be less then five seconds. One other method to determine whether the snow is wet or dry would be to measure the depth of the snow in the pan and compare it to the liquid equivalent depth. If the ratio is >10, then it would be dry snow.

4.8.4 Temperature and Wind Measurements

These are to be recorded from the computer monitor at the site at the start of the test. READAC information will also be used for data analysis.

4.9 Video Organization

The video equipment cassettes should be marked sequentially for the panning camera and the Hi 8 cameras. These numbers should be recorded on the data form at the time of testing. When these are full, then they should be marked as full.

5. END CONDITION

The plate failure time is that time required for the end conditions to be achieved. This occurs when the accumulating precipitation fails to be absorbed at any five of the crosshair marks on the panels or when 1/3 of the test panel is covered with accumulating precipitation.

A crosshair is considered failed if:

- There is a visible accumulation of snow (not slush, but white snow) on the fluid at the crosshair when viewed from the front (i.e. perpendicular to the plate). You are looking for an indication that the fluid can no longer accommodate or absorb the precipitation at this point.

OR

- When precipitation or frosting produces a *loss of gloss* (i.e. a dulling of the surface reflectivity) or a change in colour (dye) to grey or greyish appearance at any five crosshairs, or ice (or crusty snow) has formed on the crosshair (look for ice crystals). This condition is only applicable during freezing rain/drizzle, ice pellets, freezing fog or during a mixture of snow and freezing rain/drizzle and ice pellets.

As these determinations are subjective in nature, the following is **very important**:

- Whenever possible, have the same individual make the determination that a crosshair has failed.

- When making such a determination, ensure consistency in the criteria used to call the end of a test.

- Under light snow conditions or when the precipitation rate decreases, snow may sometimes build up on the fluid and then be absorbed later as the fluid accommodates (absorbs) it. If this occurs, record the first time snow builds up and note (in the comments sections) that there was an *un-failure* at a specific crosshair.

Updated definitions of fluid failure in natural snow conditions, along with photographs of the various failure conditions, have been included in Attachment VII.

6. REPORTING AND OBSERVATIONS

Calculate and record test data, observations and comments in the format of Tables 1 and 2. Each test must be conducted in duplicate. Detailed definitions and descriptions of meteorological phenomena are available in the Manual of Surface Weather Observation (MANOBS) - a copy is available at APS offices.

ATTACHMENT III
PERSONNEL RESPONSIBILITY

Test Site Leader

- Call personnel to conduct tests;
- Ensure test site is safe, functional and operational at all times;
- Supervise site personnel during the conduct of tests;
- Ensure site is opened and closed properly;
- Monitor weather forecasts on a daily basis and during test period;
- Report to project manager on site activities on daily basis;
- Review data forms upon completion of test for completeness and correctness;
- Decide what fluids should be tested;
- Ensure results are reasonable;
- Ensure all clocks are synchronized at all times;
- Ensure fluids are available and verify fluids being used for test are correct;
- Ensure computers are all operational;
- Ensure electronic data is being collected for all tests;
- Ensure proper documentation of tapes, diskettes, cassettes;
- Verify test procedure is correct (e.g. stand into wind);
- Ensure all materials are available (pens, paper, batteries, etc.); and
- Fill in end of testing checklist for every session (see Attachment VI).

End Condition Tester

- Monitor the progression of failures on the plates;
- Record end condition times for each crosshair;
- Communicate to video operator the end condition times;
- Apply fluids onto test panels;
- Complete and sign Data Form (Table 1); and
- Prepare fluids for each test.

Meteo Tester

- Record meteo for both stands;
- Rotate and measure plate pan weights;
- Squeegee plates prior the fluid application;
- Complete and sign Data Form (Table 2);
- Assist end condition tester when failure times occur quickly; and
- Place stopwatch and start stopwatch on test stand.

Video Tester

- Sign and fill in cassette #'s, etc. in Data Form (Table 2);
- Video all tests (see procedure);
- Verify all equipment is on;
- Document and mark all cassettes used for all electronic equipment;
- Ensure camera batteries are recharged and available;
- Ensure lighting is appropriate; and
- Video fluid application (capture fluid name on container).

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ATTACHMENT IV
SUMMARY OF STEPS TO CONDUCT TESTS

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

Upon Entering Trailer

1. Turn on lights (outside and inside) and sign in.
2. Determine tests to be conducted and fluids (Type II, III, IV to be placed outdoors).
3. Remove snow and clear access to stands.
4. Turn on C/FIMS computers.
5. Synchronize all clocks on all equipment in 4) and stopwatches.

For Each Test

1. Fill in general material on Tables 1 and 2, and prepare plate pans for start of test.
2. Place fluids by stand.
3. Ensure stand is into wind.
4. Start logging C/FIMS computers.
5. Record end condition times of all panels **(care to be taken for the 5th crosshair of each panel)**.
6. Measure plate pan weights over the course of the test.
7. Video record start of test, progression of failures, and when the end condition (5 of 15 crosshairs) is being called on each panel.
8. Ensure forms are properly completed and signed.
9. Save C/FIMS data.
10. Start a new test.

To Close Trailer

1. Replenish fluids.
2. Log and document date, times, test #'s, etc. on all media
3. After major events (more than 10 tests), start new tapes for next occasion.
4. Place all media and test forms in large envelope for delivery to office.
5. Shut off the C/FIMS.
6. Clean trailer and all garbage.
7. Ensure outdoor is left clean and presentable.
8. Turn off lights and sign out.

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ATTACHMENT V

CHECKLIST FOR SITE LEADER FOR END OF TESTING

	ENTER DATE														
ITEM															
ALL FLUIDS BROUGHT IN															
ALL FLUIDS REPLENISHED															
WASTE FLUIDS BROUGHT IN															
HANDHELD CAMERAS BROUGHT IN															
OUTDOOR AND STAND LIGHTS TURNED OFF															
WRIST WATCHES HANDED IN															
ALL TEST MEDIA PROPERLY LABELED (HI 8, RVSI, C/FIMS)															
DATA FORMS CHECKED AND SIGNED															
ALL PERSONNEL SIGNED OUT															
TRAILER CLEANED UP															
TRAILER HEATER KEPT AT 20ºC															
SITE LEADER INITIALS															

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ATTACHMENT VI
PROCEDURE FOR THE COLLECTION OF PRECIPITATION

GENERAL

1. Two large timepieces should be installed in the trailer (one above the rate station, the other in the window adjacent to the door) to ensure that accurate collection times are recorded. Both timepieces should be synchronized.

2. Rates should be collected every 10 minutes in normal conditions and every 5 minutes in periods of high precipitation rates and high winds.

3. In the event of error (dropped pan, lost fluid…), the error and time should be recorded on the data form. When fluid has been lost from the plate pans, pans should be re-weighed prior to being placed on the test stand.

4. The start time of the rate collection period is recorded from the timepiece above the rate station prior to exiting the trailer. The time required to get from the rate station to outside the trailer door should also be recorded. This value (in sec.) should be included in the buffer column in Table 2, and eventually deducted from the rate collection time. When entering the trailer following a rate collection period, record the time from the timepiece in the window near the door.

PROCEDURE

1. Ensure that both plate pans are marked (*upper* and *lower*).

2. The bottom and sides of the pan must be wetted with Type IV anti-icing fluid to prevent blowing snow from escaping the pan.

3. Tare the scale, then weigh the wetted pan to the nearest gram.

4. Record the start time (hr/min/sec) from the timepiece located near the rate station before leaving the trailer to place the pans on the test stand, taking into consideration the time delay necessary to proceed outside from the rate station.

5. Ensure that the pans are placed in the proper location (upper and lower locations).

6. Prior to removing the plate pans from the test stand for re-weighing, carefully wipe away any accumulated precipitation from the lips of the plate pans (ensure that the precipitation does not fall into the plate pan). Carefully remove the plate pans from the stand and proceed **immediately** to the trailer to re-weigh the pans. Do not rest the pans on top of one another while transporting. Once inside the trailer, rest the pans on a clean dry table surface.

7. Upon entering the trailer, record the end time (hr/min/sec) from the timepiece in the window near the door.

8. Carefully wipe the bottom, sides and lips of the pans prior to weighing.

9. Weigh the plate pan. Plate pans should be re-weighed until consistent measurements are obtained.

10. Record the new weight (do not tare scale again), and bring the pans back outside.

11. Start time from the timepiece near the rate station.

12. Continue this procedure until the final plate on the test stand has failed.

ATTACHMENT VII
UPDATED DEFINITIONS OF PLATE FAILURE IN NATURAL SNOW CONDITIONS

In all natural snow tests, regardless of the method of fluid failure, an accumulation of snow is apparent in the failed areas. Type IV fluid failures in natural snow tests normally occur when:

- The fluid has eroded due to dilution and snow begins to accumulate on the plate surface (dilution failure); and

- The fluid no longer absorbs the snow which begins to rest on top of the fluid (snow-bridging failure).

A typical dilution-style failure is shown in Photo 1. In this case, the fluid has been diluted due to ongoing precipitation and the fluid film has eroded substantially. Failures have reached just beyond the 7.5 cm (3") line on the plate (white snow is visible in the failed area). Dilution failures normally occur from top-to-bottom on the test surface, and are common at warm temperatures and low rates of precipitation. Ethylene glycol-based Type IV fluids usually fail in this manner.

A snow-bridging failure is shown in Photo 2. In this case, the fluid resists dilution and a thick film of fluid remains on the entire plate surface. Plate failure has occurred in this test because snow, resting on top of the fluid, covers more than 1/3 of the plate surface. Snow-bridging failures do not always occur in top-to-bottom fashion, and are common at cold temperatures and high rates of precipitation. Propylene glycol-based Type IV fluids usually fail in this manner.

Photo 1
Dilution Failure

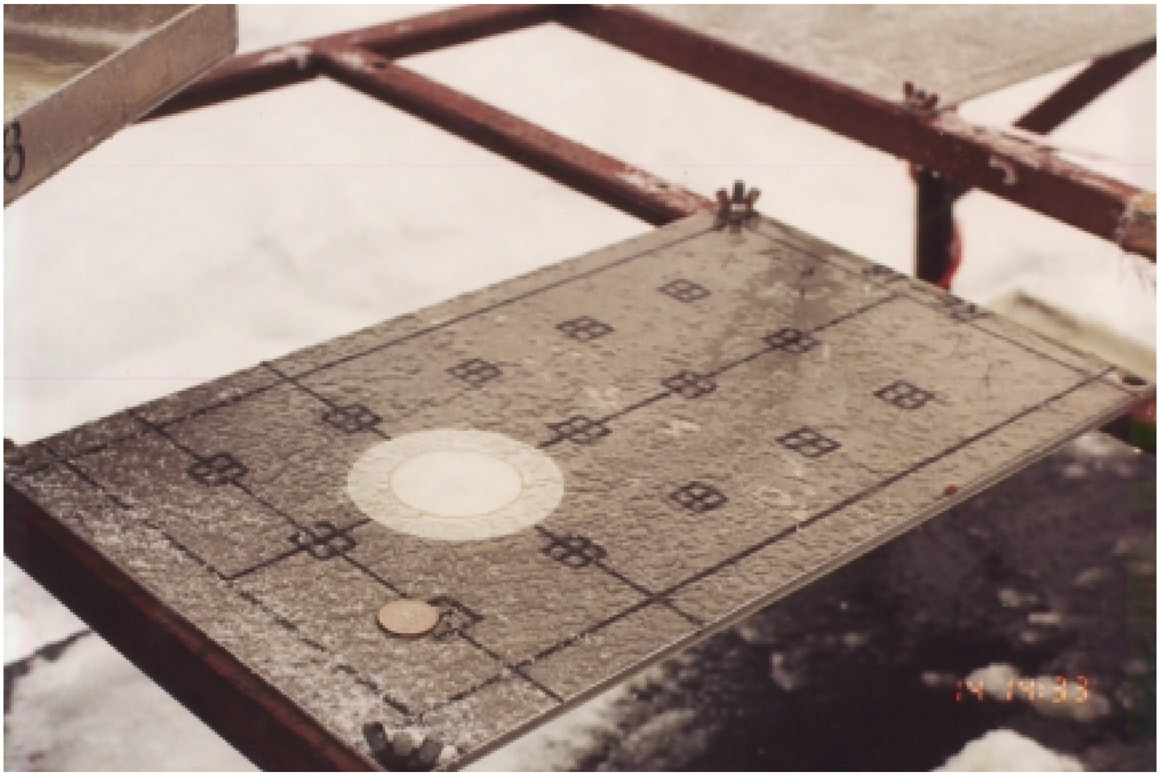

Photo 2
Snow-bridging Failure

ATTACHMENT VIII
TYPE I FLUID HOLDOVER TIME TEST MIXING PROCEDURE FOR NATURAL SNOW TESTS
Winter 1999/2000

In order to conduct Type I fluid holdover time tests, fluids must be pre-mixed to a 10ºC buffer. This signifies that the fluid freeze point must be 10ºC below the ambient air temperature. For example, if tests are conducted at an outside air temperature of -12ºC, the fluid freeze point must be -22ºC.

All Type I fluids must be diluted from their concentrated forms with HARD WATER. The procedure for the preparation of hard water is included in Attachment VIIIA. Plastic containers (20-litre) of hard water will be pre-mixed and placed on the large shelf near the fluid mixing station.

The fluid dilutions and fluid freeze point measurements (ºBrix) for each Type I fluid at various temperatures are shown in Table A. Using the information in this table, Type I fluids should be prepared prior to the start of each test period. Fluid concentrations should also be adjusted using this information during any given test period if the ambient air temperature fluctuates by more than 1ºC.

The following is an example of Type I fluid preparation for holdover time testing:

The ambient air temperature is -7ºC. Type I fluids will be mixed to a freeze point of -17ºC. In the case of Home Oil Safetemp Type I, the required glycol concentration of the -17ºC freeze point fluid is 40%. Using a graduated cylinder, measure out the required amount of the Home Oil Safetemp concentrate. If mixing into an 8-litre container, the required amount of Safetemp concentrate would be 3.2 litres. Add this amount to the container. The remainder of the 8-litre container will be filled with hard water (4.8 litres). The mixture should be shaken prior to measuring the refractive index (ºBrix). The Brix of the diluted fluid should be 26, based on the information in Table A. If the Brix is below 26, additional concentrate should be added to the container. If the Brix is above 26, hard water should be added. The mixture is deemed acceptable for testing when the refractive index of the fluid (ºBrix) is within 0.25 of the value stated in Table A. A summary for the testers is provided as Attachment VIIIB.

Fluids for Type I testing should be applied to the test plates at 20ºC +/-5ºC. One litre of fluid is required for each individual test plate, and will be poured from 1-litre containers. Prior to the start of each test run, the Brix and temperature of each test fluid should be indicated on the End Condition Data Form.

In order to ensure that Type I fluids are sufficiently warm for holdover time testing, the containers of concentrated fluids should be replenished and stored in the trailer following each test period.

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ATTACHMENT VIIIA
PROCEDURE FOR PREPARING HARD WATER

Hard water is required to dilute Type I fluids for holdover time testing. The following procedure outlines the steps required to produce 1 litre of hard water.

Hard Water =	Distilled (deionized) water	+	calcium acetate monohydrate or anhydrous calcium acetate	+	magnesium sulfate heptahydrate

In order to produce 1 liter of hard water:

1. Take 1 liter of Distilled Water.
2. Dissolve 400 mg of the calcium acetate monohydrate or anhydrous calcium acetate.
3. Dissolve 280 mg of the magnesium sulfate heptahydrate.

Requirements:

The distilled water must conform to specifications of Type IV water outlined in D 1193-91.

Electrical conductivity at 25ºC = 5
Electrical resistance = 0.2
pH = 5.0 - 8.0
Total organic carbon = no limit
Sodium = 50 ug
Chlorides = 50 ug
Total silica = no limit

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ATTACHMENT VIIIB
SUMMARY PROCEDURE FOR MIXING OF TYPE I FLUIDS FOR 10ºC BUFFER

An example is included below in brackets using Home Oil Safetemp:

1. Determine the outside air temperature (for example, -7ºC).

2. Find the volume of the fluid and hard water (see below) to be mixed in Table A. (Mix 3.2 L glycol and 4.8 L hard water for Safetemp).

3. Shake the container and measure the refractive index in Brix and compare the value with that in Table A (for Safetemp, it should be 26).

4. If the Brix value is off by more than 0.25, adjust mixture by adding hard water to decrease Brix, or fluid to increase Brix. Redo Step 3.

As a general rule of thumb, add 150 ml of water or fluid for every 1 Brix value that the mixture is off (in the example, if the Brix was 28, then add 300 ml of water to reduce the Brix to about 26).

To produce 1 litre of hard water:

5. Take 1 litre of Distilled Water.

6. Dissolve 400 mg of the calcium acetate monohydrate or anhydrous calcium acetate.

7. Dissolve 280 mg of the magnesium sulfate heptahydrate.

TABLE A

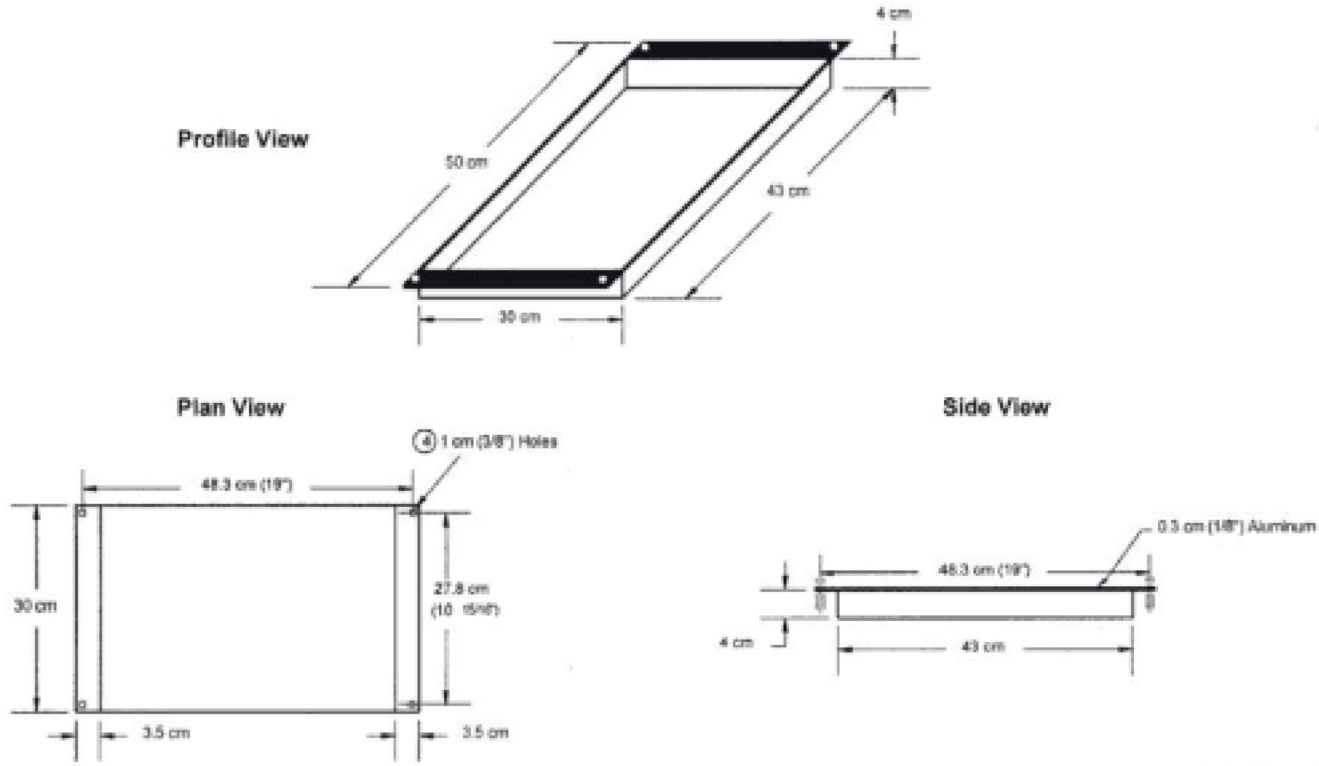
FLUID DILUTION FOR TYPE I TESTING

OAT (°C)	FFP (°C)	Clariant EG I 1996				Home Oil Safetemp				Inland Duragly-P				Jarchem Jarkleer				Kilfrost DF Plus				Octagon Octaflo / EF				Octagon EG				UCAR ADF				1DPL55A ADF (NEW)			
		% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres	% Glycol	Brix	Glycol for 8 Litres	Water for 8 Litres
5	-5																					15	9.75	12.0	6.8												
1	-9	28	14	2.2	5.8	27.5	18.5	2.2	5.8	30	21.25	2.4	5.6	26.5	17.25	2.1	5.9	28.5	17.5	2.3	5.7	27.5	18.5	2.2	5.8	23.45	14.75	1.9	6.1	21.5	13.5	1.7	6.3	32.5	19.5	2.6	5.4
0	-10	29.5	14.75	2.4	5.6	29	19.25	2.3	5.7	31	21.5	2.5	5.5	28	18.25	2.2	5.8	31	19	2.5	5.5	29	19	2.3	5.7	25.76	16	2.1	5.9	22	14	1.8	6.2	33.5	20.25	2.7	5.3
-1	-11	31	15.5	2.5	5.5	30.5	20.5	2.4	5.6	32	22	2.6	5.4	29	19	2.3	5.7	33	20	2.6	5.4	30	20	2.4	5.6	27.61	17	2.2	5.8	23	15	1.8	6.2	34.8	21.25	2.8	5.2
-2	-12	33	16.5	2.6	5.4	32	21.5	2.6	5.4	33	22.5	2.6	5.4	31	20.25	2.5	5.5	35	21.25	2.8	5.2	31	20.5	2.5	5.5	29	17.75	2.3	5.7	24.5	16	2.0	6.0	35.8	22	2.9	5.1
-3	-13	35	17.5	2.8	5.2	34	22.5	2.7	5.3	33	22.5	2.6	5.4	32	21	2.6	5.4	37	22.5	3.0	5.0	32	21.25	2.6	5.4	30.38	18.5	2.4	5.6	26	17	2.1	5.9	37.1	23	3.0	5.0
-4	-14	36.5	18.25	2.9	5.1	36	23.5	2.9	5.1	34	22.5	2.7	5.3	33.5	22	2.7	5.3	39	23	3.1	4.9	34	22.5	2.7	5.3	32.23	19.5	2.6	5.4	28	18	2.2	5.8	38.5	24	3.1	4.9
-5	-15	38	19	3.0	5.0	37	24	3.0	5.0	35	23	2.8	5.2	35	23	2.8	5.2	40	23.5	3.2	4.8	35	23	2.8	5.2	33.16	20	2.7	5.3	30	19	2.4	5.6	39.9	25	3.2	4.8
-6	-16	39.5	19.75	3.2	4.8	39	25	3.1	4.9	36	23.5	2.9	5.1	36	23.5	2.9	5.1	42	24.75	3.4	4.6	36	23.5	2.9	5.1	34.55	20.75	2.8	5.2	31	19.75	2.5	5.5	40.9	25.75	3.3	4.7
-7	-17	41	20.5	3.3	4.7	40	26	3.2	4.8	37	24	3.0	5.0	37	24	3.0	5.0	44	26	3.5	4.5	37	24	3.0	5.0	35.93	21.5	2.9	5.1	32	20.5	2.6	5.4	42.3	26.75	3.4	4.6
-8	-18	42.5	21.25	3.4	4.6	41	26.5	3.3	4.7	38.5	25	3.1	4.9	38.5	25	3.1	4.9	45	26.5	3.6	4.4	38.5	25	3.1	4.9	36.86	22	2.9	5.1	33.5	21.25	2.7	5.3	43.4	27.5	3.5	4.5
-9	-19	44	22	3.5	4.5	42	27	3.4	4.6	40	26	3.2	4.8	40	26	3.2	4.8	47	27.75	3.8	4.2	40	26	3.2	4.8	38.25	22.75	3.1	4.9	34.5	21.75	2.8	5.2	44.8	28.5	3.6	4.4
-10	-20	45	22.5	3.6	4.4	43	27.25	3.4	4.6	41.5	27	3.3	4.7	41	26.5	3.3	4.7	48	28.25	3.8	4.2	42	27	3.4	4.6	39.17	23.25	3.1	4.9	36	22.5	2.9	5.1	45.9	29.25	3.7	4.3
-11	-21	46	23	3.7	4.3	44	28	3.5	4.5	43.5	28	3.5	4.5	42	27	3.4	4.6	49.5	29.5	4.0	4.0	44	28	3.5	4.5	40.1	23.75	3.2	4.8	37	23	3.0	5.0	47.0	30	3.8	4.2
-12	-22	47.5	23.75	3.8	4.2	45	28	3.6	4.4	45	29	3.6	4.4	43	27.75	3.4	4.6	51	30	4.1	3.9	45	28.5	3.6	4.4	41.02	24.25	3.3	4.7	38	23.75	3.0	5.0	48.1	30.75	3.8	4.2
-13	-23	48.5	24.25	3.9	4.1	46	28.5	3.7	4.3	46	29.5	3.7	4.3	44.5	28.5	3.6	4.4	52	30	4.2	3.8	46	29	3.7	4.3	41.95	24.75	3.4	4.6	39	24.5	3.1	4.9	49.6	31.75	4.0	4.0
-14	-24	50	25	4.0	4.0	46.5	29	3.7	4.3	47	30	3.8	4.2	46	29	3.7	4.3	53.5	31	4.3	3.7	47	29.5	3.8	4.2	42.87	25.25	3.4	4.6	40	25	3.2	4.8	50.7	32.5	4.1	3.9
-15	-25	50.5	25.25	4.0	4.0	47.5	29.5	3.8	4.2	47.5	30.5	3.8	4.2	47	29.5	3.8	4.2	55	31.5	4.4	3.6	47.5	30	3.8	4.2	43.8	25.75	3.5	4.5	41	25.5	3.3	4.7	51.9	33.25	4.1	3.9
-16	-26	52	26	4.2	3.8	48.5	30	3.9	4.1	48.5	31	3.9	4.1	48	30	3.8	4.2	56	32	4.5	3.5	48.5	30.5	3.9	4.1	44.72	26.25	3.6	4.4	42	26	3.4	4.6	52.6	33.75	4.2	3.8
-17	-27	53	26.5	4.2	3.8	49.5	30	4.0	4.0	49	31.5	3.9	4.1	49	30.75	3.9	4.1	57	32.75	4.6	3.4	49	31	3.9	4.1	45.65	26.75	3.7	4.3	43	26.5	3.4	4.6	53.8	34.5	4.3	3.7
-18	-28	54	27	4.3	3.7	50	30.5	4.0	4.0	50	32	4.0	4.0	50.5	31.5	4.0	4.0	58	33.25	4.6	3.4	50	31.5	4.0	4.0	46.57	27.25	3.7	4.3	44	27	3.5	4.5	54.9	35.25	4.4	3.6
-19	-29	55	27.5	4.4	3.6	51	31.5	4.1	3.9	51	32.5	4.1	3.9	51.5	32	4.1	3.9	59	33.75	4.7	3.3	51	32	4.1	3.9	47.5	27.75	3.8	4.2	45	27.5	3.6	4.4	56.1	36	4.5	3.5
-20	-30	56	28	4.5	3.5	52	32.5	4.2	3.8	51.75	33	4.1	3.9	53	32.75	4.2	3.8	60	34.25	4.8	3.2	52	32.5	4.2	3.8	48.42	28.25	3.9	4.1	45.75	28	3.7	4.3	56.9	36.5	4.6	3.4
-22	-32	58	29	4.6	3.4	54	34	4.3	3.7	53	34	4.2	3.8	55	34	4.4	3.6	62	35.25	5.0	3.0	53.5	33.5	4.3	3.7	49.81	29	4.0	4.0	47	28.75	3.8	4.2	58.5	37.5	4.7	3.3
-25	-35	61.5	30.75	4.9	3.1	56	35.5	4.5	3.5	56	35.5	4.5	3.5	58	35.5	4.6	3.4	64	36	5.1	2.9	56	34.5	4.5	3.5	52.12	30.25	4.2	3.8	49	30	3.9	4.1	61.3	39.25	4.9	3.1
-30	-40	66.5	33.25	5.3	2.7	60	37	4.8	3.2	60	37	4.8	3.2	64	38.25	5.1	2.9	68	38	5.4	2.6	60	37	4.8	3.2	56.28	32.5	4.5	3.5	53	32	4.2	3.8	65.4	41.75	5.2	2.8
Standard Mix																						63	38.25	5	3.0					57	34	4.6	3.4				

FIGURE 1

SCHEMATICS OF PLATE PAN AND TEST STAND

PLATE PAN



TEST STAND

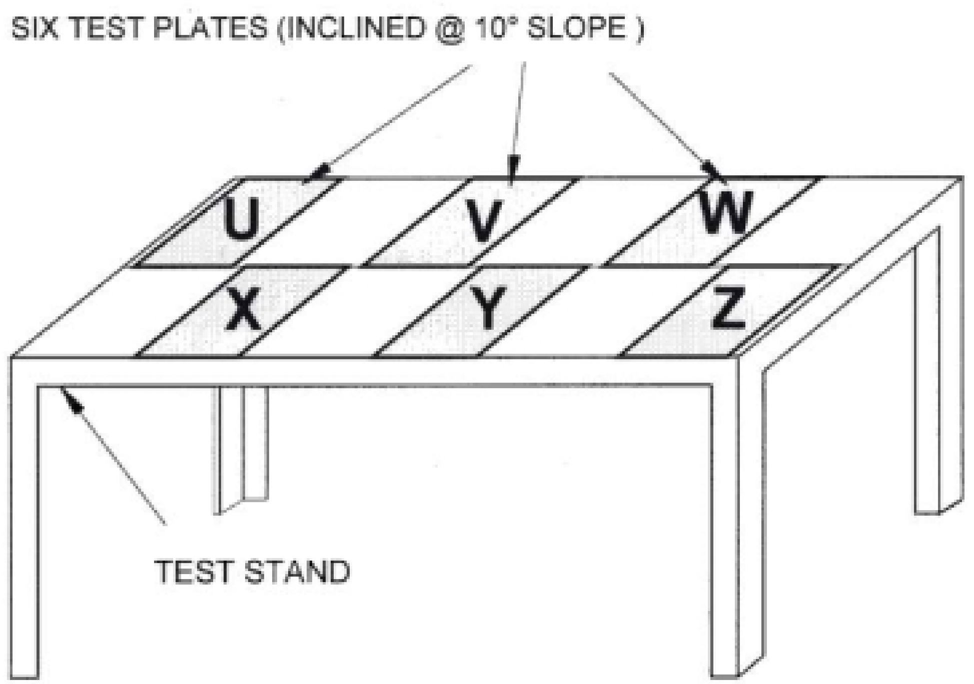
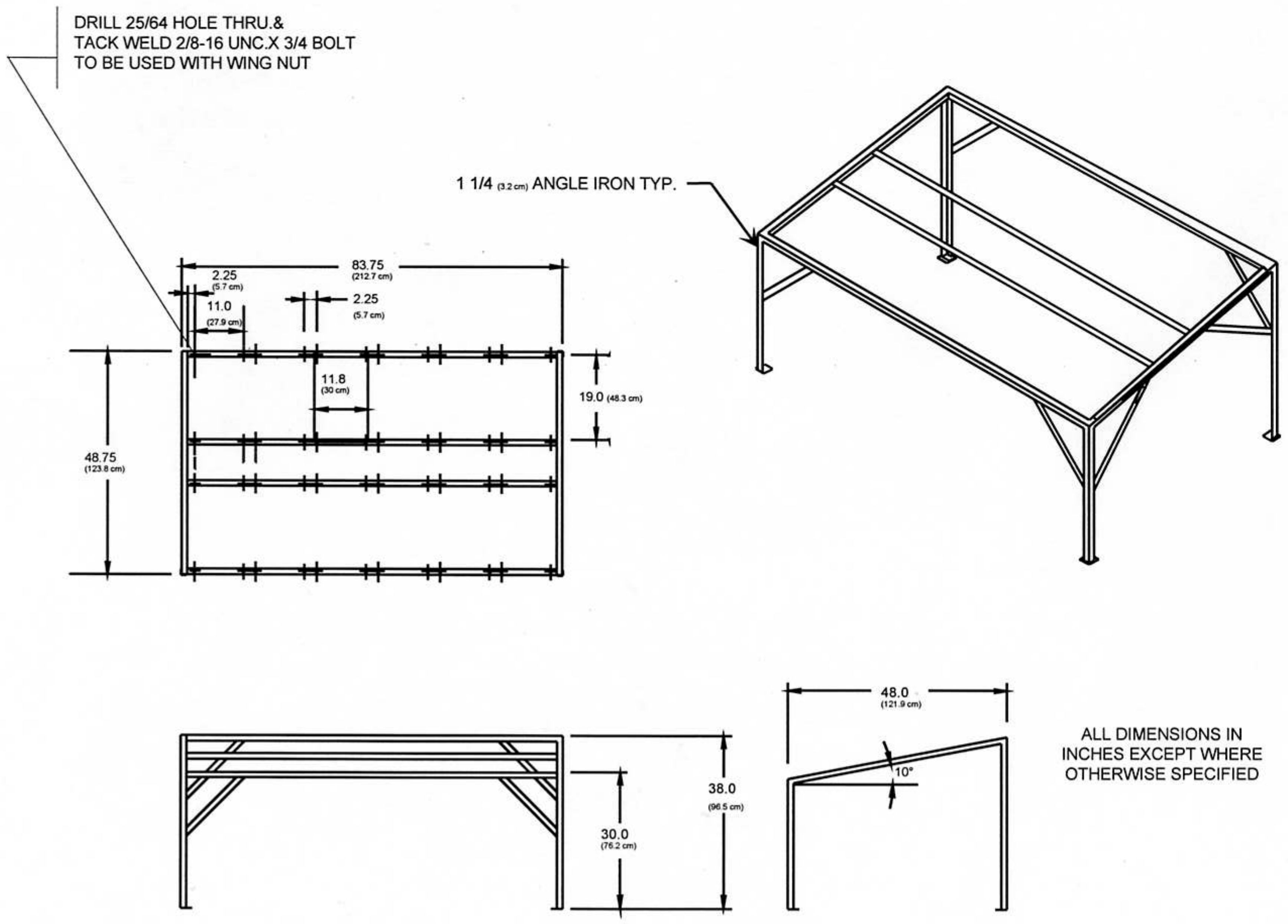
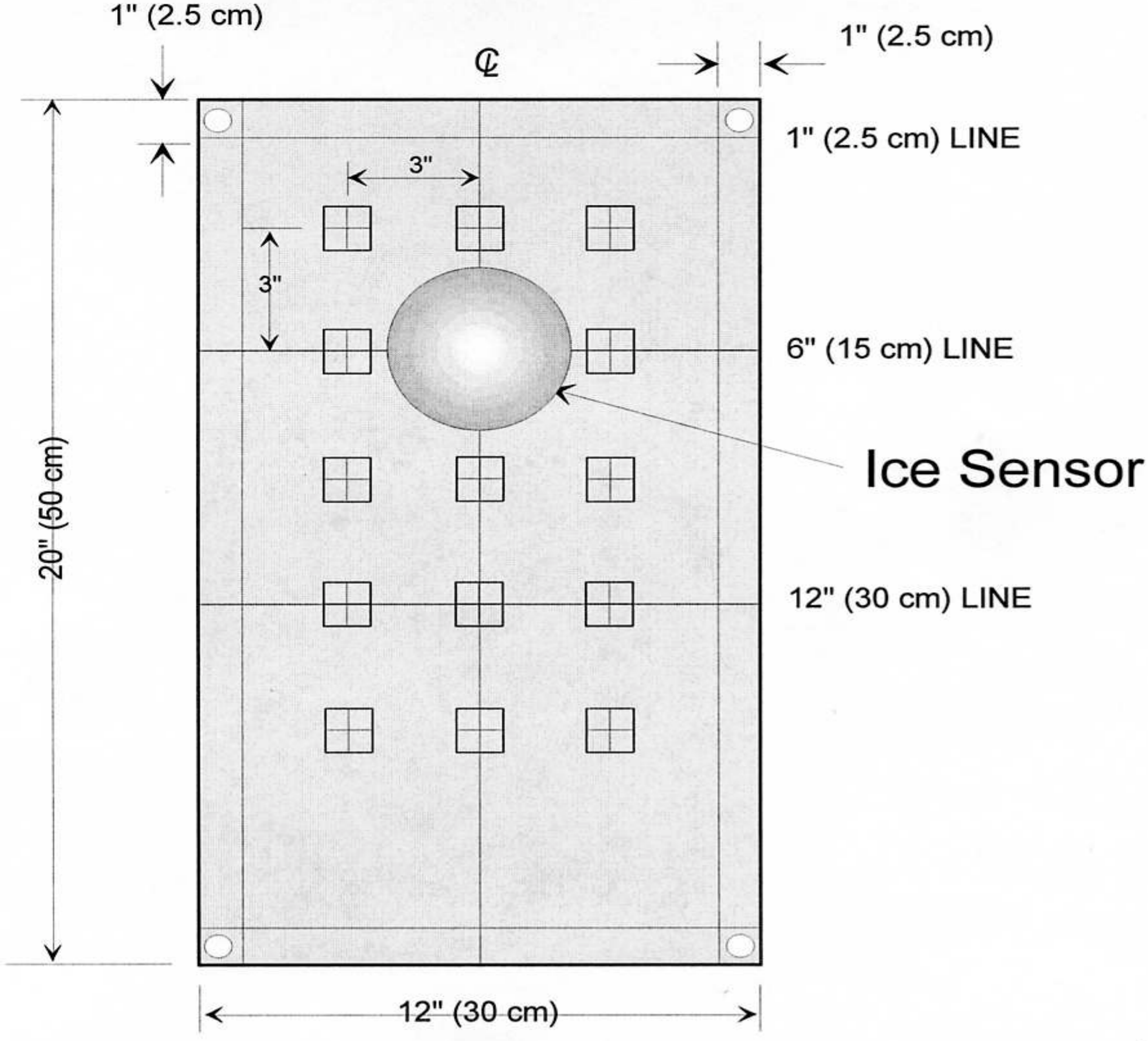


FIGURE 2
TEST STAND



cm1589\procel\nat_snow\rack_r2.ch4

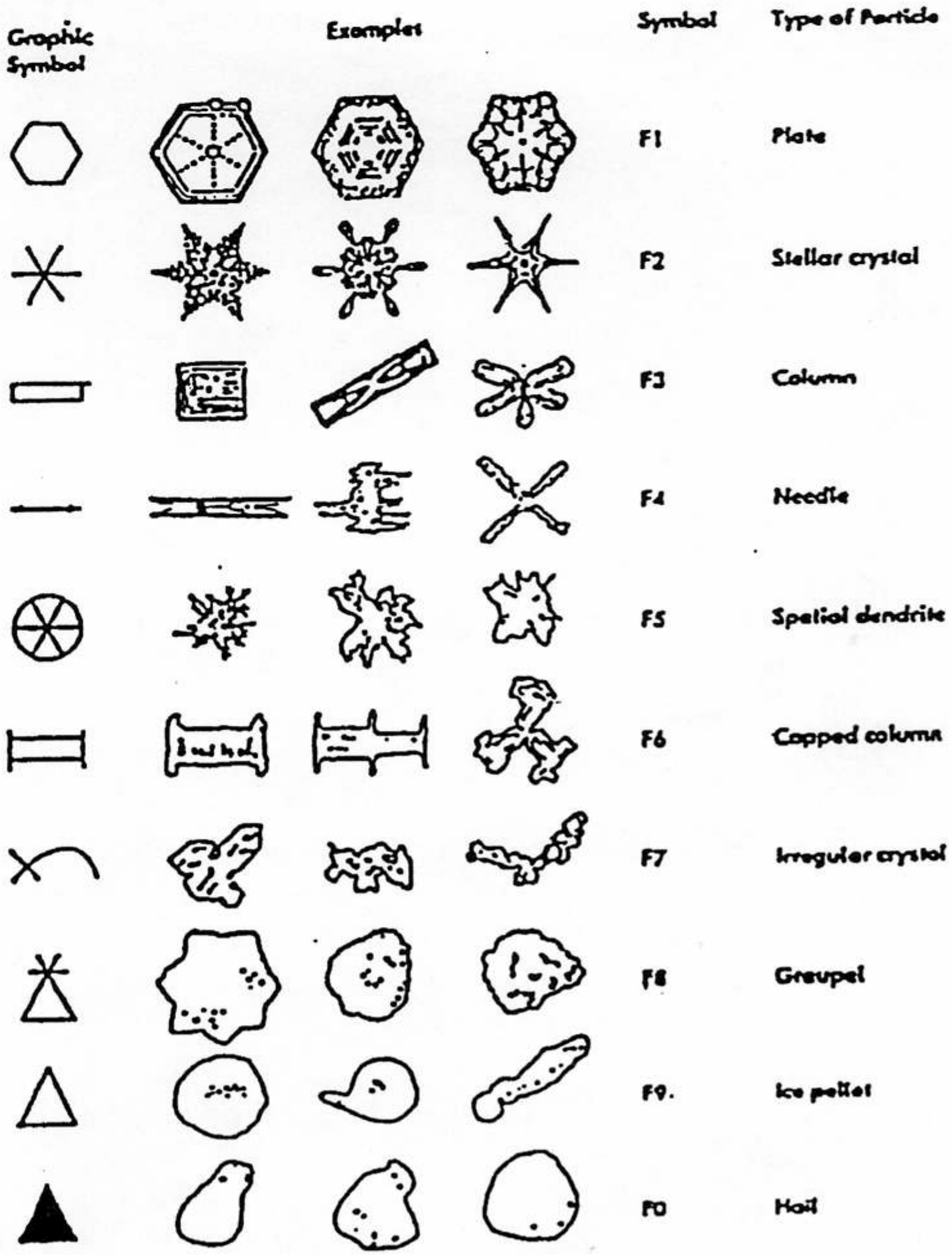
FIGURE 3
TYPICAL ICE SENSOR FLAT PLATE MARKINGS



cm1589\procedur\nat_snow\plate.ch4

FIGURE 4

INTERNATIONAL CLASSIFICATION FOR SOLID PRECIPITATION



4. A pictorial summary of the International Snow Classification for solid precipitation. This classification applies to falling snow.

Source: *International Commission on Snow and Ice, 1951*

FIGURE 5

WEATHER PHENOMENA AND SYMBOLS

General Category	Specific Phenomena	Symbol
Tornadoes and Thunderstorms	Tornado	Tornado
	Waterspout	Waterspout
	Funnel Cloud	Funnel Cloud
	Thunderstorm	T, T+
Precipitation	Rain	R--, R-, R, R+
	Rain Showers	RW--, RW-, RW, RW+
	Drizzle	L--, L-, L, L+
	Freezing Rain	ZR--, ZR-, ZR, ZR+
	Freezing Drizzle	ZL--, ZL-, ZL, ZL+
	Snow	S--, S-, S, S+
	Snow Grains	SG--, SG-, SG, SG+
	Ice Crystals	IC
	Ice Pellets	IP--, IP-, IP, IP+
	Ice Pellet Showers	IPW--, IPW-, IPW, IPW+
	Snow Showers	SW--, SW-, SW, SW+
	Snow Pellets	SP--, SP-, SP, SP+
	Hail	A--, A-, A, A+
Obstructions to Vision (visibility 6 miles or less)	Fog	F
	Ice Fog	IF
	Haze	H
	Smoke	K
	Blowing Snow	BS
	Blowing Sand	BN
	Blowing Dust	BD
	Dust Haze	D

TABLE 1

END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

VERSION 6.0 Winter 1999/2000

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

CIRCLE SENSOR PLATE: u v w x y z

SENSOR NUMBER: ____ ____ ____ ____ ____ ____

DIRECTION OF STAND: ________ o

OTHER COMMENTS (Fluid Batch, etc):

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

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

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

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

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

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

TABLE 2

METEO/PLATE PAN DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

VERSION 6.0 Winter 1999/2000

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

HAND HELD VIDEO CASSETTE #:

PLATE PAN WEIGHT MEASUREMENTS *

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

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

METEO OBSERVATIONS **

TIME (hr:min)	TYPE (Fig. 4) ZR, ZL,S, SG IP, IC, BS, SP	CLASSIF. (See Fig. 3)	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 ________ ºC

WIND SPEED AT START OF TEST ________ km/h

WIND DIRECTION AT START OF TEST ________ º

COMMENTS : ________________________________

____

____

____

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

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APPENDIX D

EXPERIMENTAL PROGRAM

TRIALS TO DETERMINE THE DIFFERENCES
BETWEEN NATURAL SNOW AND THE
NCAR SNOWMAKING SYSTEM

CM1589.001

EXPERIMENTAL PROGRAM

TRIALS TO DETERMINE THE DIFFERENCES BETWEEN NATURAL SNOW AND THE NCAR SNOW GENERATION SYSTEM

Winter 1999/2000

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marc Hunt

Reviewed by: John D'Avirro

APS AVIATION INC.

January 5, 2000
Version 1.0

Editorial Revision
August 12, 2003
Version 1.1

TRIALS TO DETERMINE THE DIFFERENCES BETWEEN NATURAL SNOW AND THE NCAR SNOW GENERATION SYSTEM

Winter 1999/2000

This set of tests will produce the data required for further evaluation of the snow precipitation produced by the NCAR snow generation system. The failure times and failure patterns from natural snow trials and artificial snow trials will be compared in similar environmental conditions.

1. OBJECTIVES

The purpose of these tests is to analyze the artificial precipitation to reconcile fluid failure times in natural and artificial snow.

Holdover time trials will be performed with the NCAR artificial snow generation system located in a cold chamber and at the APS test site. In the outdoor trials, the precipitation will be natural snow. In the laboratory trials, the precipitation will be created by the snow generation system.

2. TEST REQUIREMENTS

Indoor trials will be conducted at PMG Technologies, Institut de Recherche d'Hydro-Québec, or at NRC in Ottawa.

Outdoor trials will be conducted at the APS test site located at Dorval airport or at other suitable outdoor locations. The NCAR snow generation system will initially be set up at an outdoor location where vertically falling snow is expected. The system will remain at this location until all outdoor trials are performed. Sensitive equipment (such as the scale, etc.) will be removed from the assembly after each test session.

All Type IV fluids must be tested at the ambient air temperature. During indoor trials, if the cold chamber is not maintained at low temperatures overnight, the fluids must be refrigerated to ensure temperature is according to requirements.

Temperatures, precipitation rates, relative humidity and other ambient conditions will be recorded during the natural snow trials and duplicated during the indoor trials. Environmental conditions will be monitored by automated sensors.

Outdoor trial conditions will be selected based on the ambient temperature and the wind velocity. Ideal conditions will match the indoor holdover time evaluation limits of -3, -10 or -14°C with zero wind.

Trials will be performed with a propylene glycol-based Type IV fluid and the reference fluid, Fluid X. Approximately 5 outdoor trials and 5 indoor trials are anticipated for each fluid.

3. EQUIPMENT

Attachment I presents a list of required equipment for the holdover time tests.

All additional equipment required for the operation of the snowmaking system is included in the snowmaking machine operators' manual, supplied by NCAR (Attachment III of Appendix B).

4. PERSONNEL

The personnel requirements for the indoor and outdoor trials are as follows:

- One person to pour the fluids and to call the failure on the plate; and
- One person to assist in preparing the snow generation system and to record environmental conditions, photograph failures and record other test data.

5. SUMMARY OF PROCEDURES

5.1 Outdoor Snow Trials

The NCAR snow generation system will be set up outside, at the test site or at another suitable location. The top portion of the snowmaker will be opened to allow snow precipitation to enter the snowmaker booth.

The procedures for the holdover time tests are as indicated in Appendix C with the exception that the plate rate pans are not required since the rates are collected by the NCAR system. Trials will be conducted until the entire flat plate is covered in fluid failures.

Still photographs will be taken immediately after standard plate failure and complete plate failure calls. Photographs will be taken during both indoor and outdoor trials.

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

1. Empty fluid collection bucket;
2. Clean panels;
3. Apply (pour fluids to test panels). Type IV fluids are at the test air temperature. Fluids are poured using a single-step fluid application;
4. Begin data logging of rates precipitation and ambient conditions;
5. Record the start of the holdover time after fluid is applied;
6. Record failure patterns throughout the trials;
7. Record crosshair end condition times; and
8. Continue testing beyond fifth crosshair plate failure, until complete plate failure.

5.2 Laboratory Trials

The ambient conditions for these trials will be based on the conditions recorded during natural snow trials. The precipitation rates will also match the rates recorded during natural snow trials.

The ice core tubes must be filled with de-mineralized water and cooled to below 0ºC, a minimum of 12 hours before testing begins.

The procedures for the holdover time tests are as indicated in Appendix C with the exception that the plate rate pans are not required since the rates are collected by the NCAR system.

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

1. Empty fluid collection bucket;
2. Prepare and secure ice core;
3. Begin precipitation and data logging;
4. Clean panels and start;
5. Apply (pour fluids to test panels). Type IV fluids are at the test air temperature. Fluids are poured using a single-step fluid application;
6. Record the start of the holdover time after fluid is applied;
7. Record failure patterns throughout the trials;

8. Record crosshair end condition times; and
9. Continue testing beyond fifth crosshair plate failure, until complete plate failure.

The operation of the snowmaking system is detailed in Appendix B.

6. DATA FORM

The tests will require the end condition data form modified for simulated snow trials (Figure 1).

A separate form is required for documentation of failure appearances (Figure 2).

A third data sheet will be used to record environmental conditions and precipitation observations (Figure 3).

ATTACHMENT I
TEST EQUIPEMENT CHECKLIST

- Snowmaking machine and related equipment;
- Aluminum plate;
- Fluid thickness gauge;
- Squeegee/scraper;
- Extension cord;
- Paper towels;
- Rags;
- Flood lights;
- Stopwatch;
- Wet vacuum;
- Brixometer;
- Hand held anemometer;
- Air temperature gauge;
- Data forms;
- Clipboard;
- Video camera;
- Photo camera; and
- RH meter.

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FIGURE 1

END CONDITION DATA FORM

NCAR SNOW MAKER

Winter 1999/2000

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

OAT: ________ °C

PRECIPITATION RATE: ________ g/dm²/hr

FLUID TEMPERATURE: ________ °C

FLUID QUANTITY APPLIED: ________ Liters

PLATE WASHING METHOD: ________________

OTHER COMMENTS (Fluid Batch, etc):

____

____

____

____

____

____

____

____

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

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

Time of Fluid Application: ________ hr:min

FLUID NAME			
B1 B2 B3			
C1 C2 C3			
D1 D2 D3			
E1 E2 E3			
F1 F2 F3			

CALCULATED FAILURE TIME (MINUTES)

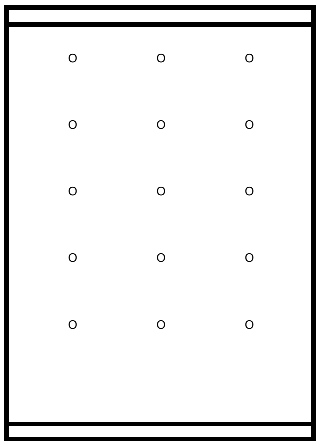
FIGURE 2

APPEARANCE OF FLUID FAILURE

Date: ____________ Time: ____________ Plate Location: __________

Run #: ____________ Fluid Name: ____________ Fluid Dilution: __________

t =



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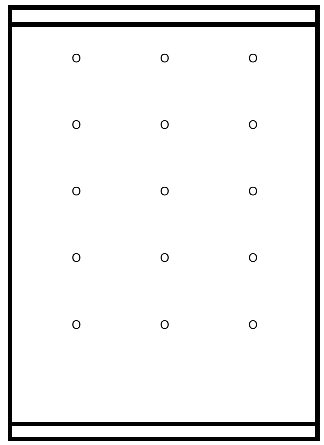

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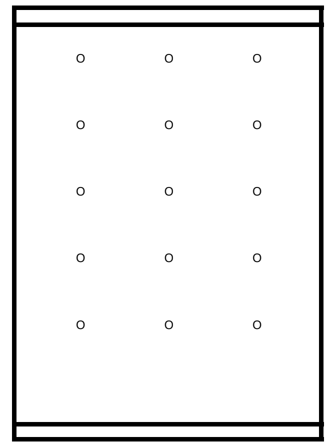

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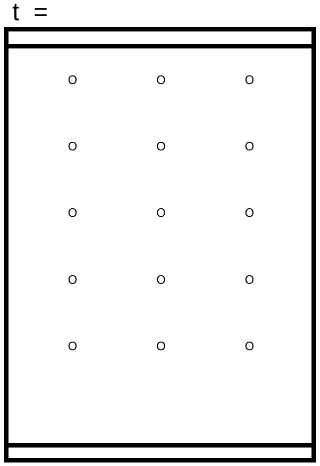

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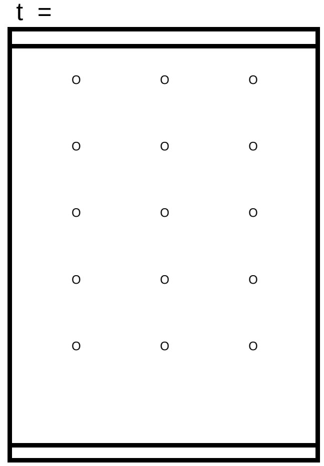

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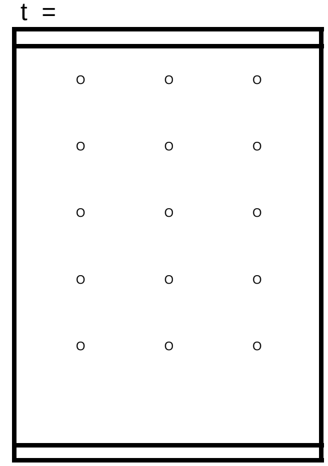

Note: Ensure observations are made at the 5th crosshair, and for the whole plate

Figure 3

ENVIRONMENT COMMENT FORM

Winter 1999/2000

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

TIME (hh:min:ss)	AIR TEMPERATURE (°C)	RELATIVE HUMIDITY (%)	COMMENTS

COMMENTS : ______________________

____

____

____

	PRINT	SIGN
WRITTEN & PERFORMED BY :	________	________
VIDEO BY :	________	________

File h:\cm1589\procedures\Outdoor vs Indoor Snow \Comment Form

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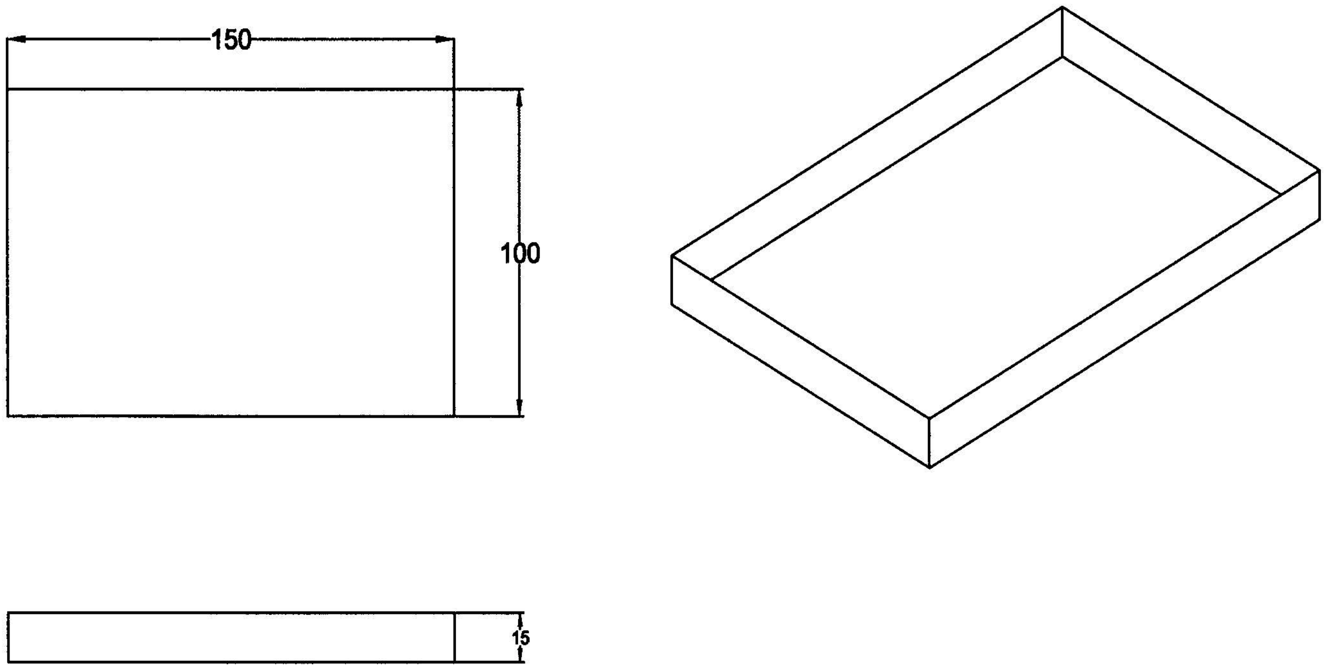
APPENDIX E

DATA FROM RATE DISTRIBUTION TESTS



All dimensions are in mm
Aluminum 0.8mm Thickness

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

APS AVIATION INC.

Rate Pans (100mm x 150mm)

SIZE	FSCM NO.	DWG NO. Pan (100x150)	REV 1.0
SCALE	MAT'L Aluminum	SHEET 1/1	

cm1589/report/ncar/Pan (100x150)

NCAR SNOWMAKER DETAILED RATES
March 27 and 28, 2000, OAT = -4°C

Precipitation Rate **25 g/dm²/h**

10 **117%**	9 **103%**
8 **126%**	7 **116%**
6 **129%**	5 **106%**
4 **92%**	3 **84%**
2 **65%**	1 **62%**

Average Weight of snow catch pans (g) = **18.66**

Rate Range* = (This is the maximum minus the minimum value above) **66%**

Precipitation Rate **25 g/dm²/h**

10 **147%**	9 **134%**
8 **99%**	7 **96%**
6 **90%**	5 **85%**
4 **87%**	3 **87%**
2 **96%**	1 **79%**

Average pan weight = **7.09**

Rate Range = **68%**

Precipitation Rate **10 g/dm²/h**

10 **145%**	9 **106%**
8 **91%**	7 **60%**
6 **85%**	5 **48%**
4 **106%**	3 **57%**
2 **184%**	1 **118%**

Average pan weight = **6.62**

Rate Range = **136%**

Note: All values are a percentage of the average rate.

*Range shows the difference between the heaviest pan and the lightest pan

NCAR SNOWMAKER DETAILED RATES
March 29, 2000, OAT = -10°C

Precipitation Rate **10 g/dm²/h**

10 **152%**	9 **117%**
8 **96%**	7 **61%**
6 **84%**	5 **46%**
4 **96%**	3 **58%**
2 **155%**	1 **135%**

Average Weight of snow catch pans (g) = **7.88**

Rate Range* = **109%**
(This is the maximum minus the minimum value above)

Precipitation Rate **25 g/dm²/h**

10 **136%**	9 **107%**
8 **103%**	7 **86%**
6 **95%**	5 **74%**
4 **103%**	3 **74%**
2 **123%**	1 **99%**

Average pan weight = **4.86**

Rate Range = **62%**

Precipitation Rate **10 g/dm²/h**

10 **143%**	9 **125%**
8 **103%**	7 **83%**
6 **94%**	5 **71%**
4 **96%**	3 **65%**
2 **121%**	1 **100%**

Average pan weight = **8.96**

Rate Range = **78%**

Note: All values are a percentage of the average rate.
*Range shows the difference between the heaviest pan and the lightest pan

NCAR SNOWMAKER DETAILED RATES
March 30, 2000, OAT = -15°C, 10 g/dm²/h

10 **152%**	9 **147%**
8 **100%**	7 **85%**
6 **80%**	5 **60%**
4 **85%**	3 **62%**
2 **109%**	1 **122%**

Average Weight of snow catch pans (g) = **8.04**

Rate Range * = **92%**
(This is the maximum minus the minimum value above)

Note: All values are a percentage of the average rate.

*Range shows the difference between the heaviest pan and the lightest pan

APPENDIX F

NCAR SNOW MACHINE
OPERATION MANUAL

NCAR Snow Machine Operation Manual

Provided to: *APS Aviation Inc.*
Montreal, Quebec

Alan Hills, hills@ucar.edu, (303) 497-8970
Research Applications Program
National Center for Atmospheric Research
1850 Table Mesa Dr.
Boulder, Colorado 80303 USA

revision: 3 August 2000

Foreword

This manual should enable set up and operation of the snow machine with a short learning curve. Be sure to read through this manual to learn the proper operation protocol for accurate and safe use of the snow machine. For further information, please contact Alan Hills at hills@ucar.edu (303) 497-8970, Roy Rasmussen at rasmus@ucar.edu (303) 497-8430 or Scott Landolt at landolt@ucar.edu (303) 497-2048.

Contents

A. Theory of operation

The NCAR Snow Machine produces fine ice shavings which mimic natural snow in; density, size distribution, fall velocity, and mass accumulation rates. In anti/de-icing studies, the snow has been demonstrated to be functionally equivalent to natural snow with a density between 0.05 and 0.12 g cm^{-3} depending on the feed rate and drill speed. The instrument operates by feeding a purified-water ice core, 7 cm diameter x 100 cm long, into a carbide-tipped spur bit at a controlled rate. The feed rate is determined by a series of high frequency pulses generated with a notebook PC and output to a stepper motor control circuit and to a stepper motor. The ice flakes are then redistributed in semi-random fashion by a series of fans, and then fall 2.5 m onto a 30 x 50 cm aluminum frosticator plate. The plate is a component of a fluid containment unit that collects and weighs all the snow falling on the plate and also retains any de-icing fluid applied on the plate. The plate and fluid trap rest on an 0.1 g resolution/12 kg capacity, analytical balance, so that total mass and snowfall rate may be measured in real time. If the user chooses to, the plate temperature may be controlled using an Omega temperature controller. A high resolution (Analog Devices) temperature transmitter monitors a second temperature channel. The accuracy of the high resolution temperature channel is ±0.1 ^{o}C. Both temperature sensors use 1.5 mm o.d., 100 ohm platinum RTD sensing elements. The system may be used in anti/de-icing studies or other experiments.

B. Initial setup

1. Select a flat 1.5 m x 1.5 m area in a 3 m tall coldroom for placement of the machine. Leave an extra 0.5 m of clearance to allow opening of the polycarbonate doors. 120 VAC power outlets should be available within 1 m.

2. Place lower stage in coldroom with the doors to open the same direction as the upper stage doors.

3. Place upper stage onto lower stage and bolt together using ¼”x20 tpi bolts and Nylock nuts.

4. Place the electronic control box and notebook PC, outside the coldroom. Auxiliary monitor, keyboard and mouse are to reside inside the coldroom.

5. Place digital balance on the Bakelite index board on bottom of snowmachine. Plug in the balance and leave it continually powered up if possible (power consumption is 1.5 W).

6. Place tray assembly on top of balance. Carefully do a visual check to be certain that the tray sits flat on the balance. Be certain the tray drain fittings are in place to prevent fluid leakage and experimental mass loss.

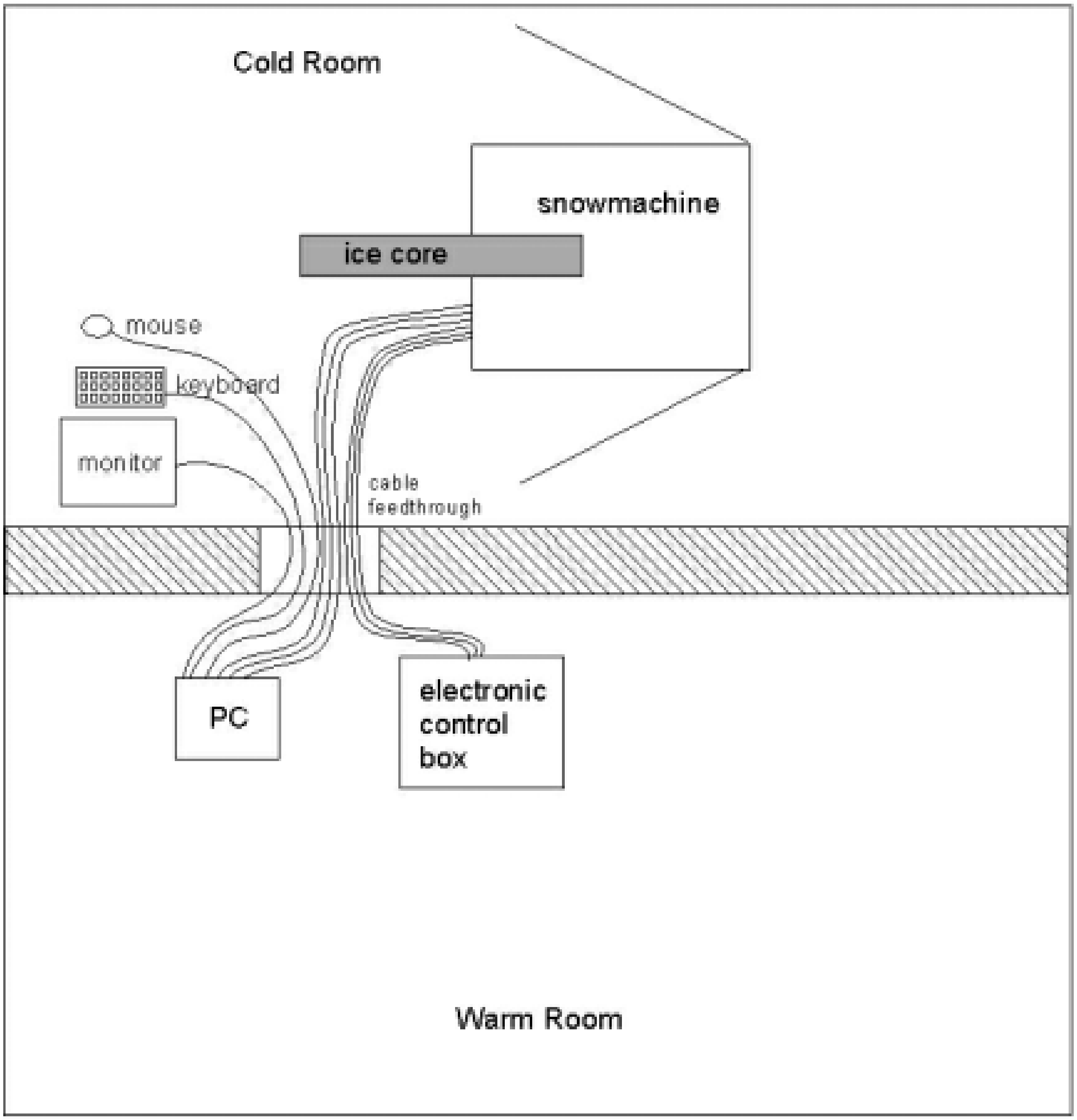
7. Check angle of snow plate to ensure lateral flatness and 10.0 degrees along the axis of the snow plate. Fine tune the angle using adjustable feet on balance.

8. Place PC and electronic control box in warm room within 10 m of the snow machine.

9. Place CRT, keyboard and mouse in the cold room for auxiliary control and viewing.

10. Connect all cabling. Ensure that cables going to the snow plate are loose (hanging freely). Tension in these cables will prevent accurate mass readings.

Snowmachine Configuration



C. Ice core generation

1. Fill the aluminum ice core tube with deionized water to a level 10 cm from the top edge of the metal tube. This allows for expansion of the mixture during freezing. Install the special insulation piece over the upper part of the tube. Place additional insulation over the top of the ice core tube. The function of the gradient pipe insulation and the insulation over the top is to ensure that the water freezes from the bottom up. Such freezing is necessary to ensure that trapped air in the water escapes without fracturing the ice core.

2. Let freeze for about 48 hours.

3. Bring ice core tube to room temperature area. Remove pipe insulation

4. Place ice core tube on an insulated surface.

5. Thaw ice core (~25 min.) at room temperature until core can be rotated with finger. Do not apply external heat to the tube, heating will fracture the ice core.

6. Dump ice core carefully out of the aluminum tube.

7. Place the bare ice core back in the cold room for at least 10 minutes to refreeze the melted surface layer. If the core is not to be used for several days, place it in one of the PVC storage tubes (provided by NCAR) to prevent sublimation or breakage.

D. Operation-experimental setup

1. Turn on the Electronic Control box (leave it continually on if doing daily experiments).

2. The electronic balance should *always* be left on. If the balance is currently off, turn on the balance (let it power up and stabilize for a few seconds) then lift the tray off the balance. Press "zero" on the balance and wait for 00.0g to appear, then place tray assembly back on balance. Be careful to position the tray on the top of the balance. It’s easy to misplace the tray assembly. The balance should now read in the neighborhood of 5000 g (Canadian setup, 3300 g NCAR setup).

3. Power-up PC and double-click on the appropriate “vi" file. To allow both the notebook display and the external monitor (in the cold room) both to be active, press function key + F2 about 10 seconds after turning the PC on.

4. The program automatically comes up in run mode. If it is not running, start program execution by clicking once on the program start arrow (top left of control panel display, see Figure 2.). The data traces and other functions should now be operating.

5. Turn on the “fans” toggle switch. Check that all 4 fans are on and up to speed. During the night sometimes snow/ice jams the fans.

6. Back the translator up sufficiently to load the ice core. This is done by flipping the ice translator toggle switch to the "on" position and direction to “reverse”

7. The ice core feed rate is changed via the “Command snow rate” control panel. Type a large number in for “Command snow rate” so that the machine will back up the translator rapidly (eg “200 g/dm2 hr”). The machine will stop automatically at either end of its travel.

8. Slide the ice core into the translator. Replace the bolt (5/16”x24 tpi) in the translator (screw the bolt in finger tight). Slide the ice core to the left so that it rests against the bolt. Tighten the hose clamps snugly. (The bolt drives the ice core during operation.)

9. With program running, fans on, drill on, and command rate set to an appropriate value, turn on the “ice translator” toggle switch. At this point the code will tell you that the translator has hit a left or right limit switch and how to reset the electronic control box. The limit switch reset is overcome by: (1) Changing the “direction” toggle switch to opposite of what it was when the limit switch was triggered and (2) momentarily depressing the red "limit switch" (~3 sec.) override on the front of the electronic control box. <u>Be sure that direction is set to opposite of the direction that caused the reset</u> (i.e. if the translator was backed up for an ice core reload--the correct direction would be “forward”).

****** CAUTION: Depressing the "limit switch" override with the computer commanding the translator to move in an incorrect direction, <u>will</u> result in major damage!!! (I know I’ve done it) *** The <u>wrong</u> direction would be "reverse" if the translator is at the left limit position and "snow" if the translator were at the right limit position. ******

10. When snow shavings start to fall the system is ready to perform a snow experiment. Note: The balance capacity is 12,000g (APS machine, 6,000g NCAR machine). If the indicated mass + what you are about to add (deicing fluid plus snow loading) will exceed this, you should empty the tray by attaching a shop vacuum cleaner with at least 5 L of fluid capacity. After the fluid is drained, reattach the drain plug fitting.

Figure 2. LabView graphical user interface (GUI).

E. Conducting a de-icing fluid test (APS Aviation procedure)

1. Ensure that the “rate parameter” of the graphical user interface (GUI) is correct for the particular setup. Rarely does it need to be altered, but the rate parameter must be adjusted each time: the fans are altered (number of fans on, location and angle) or anytime the balance/snow tray assembly is repositioned, or any modifications made which will alter the snow distribution pattern, such as modifications to the snow shield or components near the ice core/drill bit interface. For instructions on resetting the “rate parameter” refer to *K. Calibrations/Rate parameter* or contact NCAR.

2. Turn on fans and drill.

3. Set translator direction to "snow", and enter desired command snow rate.

4. Start translator. Observe snowfall for about a minute.

5. Pour “some” fluid on the plate.

6. Squeegy the plate.

7. Pour the rest of the fluid on snow plate.

8. Hit the green "start experiment”. The three traces reinitialize and test time resets to 0.0 seconds. Data is being written to the file indicated on the display.

9. Text may be added to the data file at any time after the “start experiment” button has been clicked. To enter text move the cursor into the black box residing underneath the “Add text here, enter with F8” label. Next left click within the black box and type in the text. Hit the F8 key to send the text to the ASCII data file. The text will reside in a cell of the text file corresponding to the time that the F8 key was pressed. The program can take any length of comment and the procedure may be repeated every six seconds.

10. When the fluid has failed press the red button: “press to end experiment”.

11. Enter any additional comments in the pop-up window. Like: fluid type, snowflake diameter in mm, and pertinent observations.

F. Auto-rate function

Questions? Contact NCAR. In general if the code is not working normally, shut it down and restart computer and cycle power on electronic control box. If you accidentally move components on the PC "panel", hit control + z, for each step of undo. Always close the vi file *WITHOUT* saving changes (unless you have specifically made changes to the code—and <u>in that case save the code under another name</u>).

Auto-rate function. The Auto-rate function was added to actively control the snow rate, forcing the actual rate to match the desired "command rate". A few details of the algorithm are given below.

$$\text{Corrected snow rate} = \text{Command snow rate} - (\text{rate error})(\text{DF}) \qquad (1)$$

Where DF is the "damping factor"
Command snow rate is the desired snow rate entered by the user.

$$\text{Rate error} = \text{Overall snow rate} - \text{Command snow rate} \qquad (2)$$

$$\text{Overall snow rate} = (3600/16.84)\ (\text{accumulated mass}) / \text{time} \qquad (3)$$

DF is itself a function of the rate error:

$$\text{DF} = (4/\text{rate error}) + 5 \qquad (4)$$

The first term, 4/rate error, ensures that DF grows as error decreases. Without this term unresolved rate errors remain after the majority of the error has been removed and the remaining error would permanently persist. The second term, 5, ensures that at large error values (often at the beginning of a run), DF is large enough so that equation (1) can effectively adjust the snow rate to force convergence of the overall snow rate to the command rate.

During auto-rate operation, the following sequence occurs,

Time period (after "Begin Experiment" button pressed)	Auto-rate control
0 to 30 seconds	Auto-rate is off

30 to 80 seconds	Auto-rate is on, but DF=2.5
>80 seconds	Auto-rate is on, and DF = (4/rate error) + 5
>80 seconds	If eqn. 4 calculates DF > 15, DF set equal to 15
All times	If corrected snow rate < 0, corrected snow rate is set equal to a function of command rate

Auto-rate is not allowed to operate for the first 30 seconds because very little mass has been deposited on the plate and the potential for large error and erroneous correction exists. 30-80 seconds, auto-rate engages and begins to force convergence between overall snow rate (the measured integrated rate) and the command rate (desired rate). During this time DF is set = 2.5, to minimize potential rate correction since error rate may still be considerable. At >80 seconds, full rate control is allowed with DF growing as error decreases. Auto-rate effectively forces the overall snow rate to match the chosen command rate.

G. Operational hints

- Don't leave ice cores in cold room for >1 day unless contained in PVC storage jacket. Sublimation will reshape core rendering it with incorrect shape.
- Leave balance on at all times. Memories and settings require power to hold values.
- Don't overfill aluminum tubes. Fill the ice core tubes to no more than 10 cm from the top.
- To check snowfall pattern, place a dark plasticboard in the bottom of the snow machine. The board should cover most of the bottom area. Run the snow machine for 5-10 minutes and evaluate the pattern. Does the pattern produce uniform snow over the snow plate? If necessary redirect dispersion fans. When the pattern looks acceptable it must be remeasured quantitatively using weighing plates put onto the snow plate, and weighed before and after a significant amount of snow has been deposited. The (numbered) plates should be weighed on a 0.01g digital scale before and after snow deposition. The plates should have deicing fluid in them to assist in quantitative deposition of the snow and elimination of pileup which can spill over the plate edge resulting in mass loss.

- When powering the machine on at the start of a new day, check carefully to see that the fans and drill actually come on when turned on with the software.
- Always check to see that drill is spinning before driving the ice core into it. Driving an ice core into a non-spinning drill will break the coupler and possibly the stepper motor.

H. Maintenance Schedule

Interval (operational hours)	Procedure
Every 20 hours	Spray down containment region with Fluorospray to lessen snow adhesion. Spray containment region, drill press and components directly above the snow place area. Avoid spraying the chamber walls—*it's permanent!*
Every 30 hours	Replace cutting bit with a new or sharpened one. Tighten bit very tightly with a small wrench on top of the chuck key. Using the chuck key by itself will not keep the bit tight at speed 4 and above.
Every 200 hours	Check drill press belt for shredding, replace as necessary.
Every time that the balance/tray assembly is reset to a new position, or if fans or upper shrouds are altered in any way	Reset the "rate parameter" on the GUI refer to *K. Calibrations/Rate parameter* or contact NCAR.

I. Motor or coupler replacement

1. Turn off electronic control box and shut down code.
2. Unplug stepper motor and contact switch cables.

3. Unscrew the bolt holding the limit switch in place.
4. Loosen the two ¼”x20 tpi bolts on either side of the translator end block, all the way.
5. Pull the translator assembly out of the snow machine, to the left.
6. Replace coupler or motor as needed.
7. Reassemble.

Note: The small coupler allen set screws (0.050” allen wrench size) must be very tight AND you must be certain the set screws are tightening onto the flat part of the motor shaft and the lead screw.

J. Troubleshooting

Listed below are some symptoms and their possible causes and remedies.

Symptom	Possible Cause	Remedy
Translator won't move, when commanded by computer.	Program not in run mode	Hit top left "run" arrow
	Limit switch activated	Reset limit switch as discussed in Section C step 8. Carefully observe the cautions presented!
	Stepper motor not getting 12 V	Turn on Electronic Control box Check that the control cable is plugged in on both ends, and check 12 V fuse.
	Code is confused	Stop the run and restart code and/or the LabView application
	Coupler is loose Coupler is broken Stepper motor is ruined	Command motor to run and see if it is running by shining a flashlight into the set screw hole, view rotation. If motor is fine but lead screw is not rotating, the coupler is either loose or broken. Go to section I. for coupler/motor replacement and tightening procedures.

Snow mass is way out of range or reads zero	Code is "confused"	Restart code, or LabView, or PC
	Balance has not been tared properly	Reset balance zero as discussed in Section C step 4. Cycle balance power if needed. Balance power is cycled only by yanking the power jack out of the balance for >30s and then reinserting it.
Snow rate suddenly falls	ice core might be slipping backward in translator as translator moves forward	Thrust bolt behind ice core not in place. Reinstall it.
Ice cores fracture	Probably there is trapped air in the ice/water as it freezes.	Apply gradient insulation to the metal ice core tube during freezing, and be sure to cover and insulate the top. This ensures that freezing occurs from the bottom up (normal ice freezes from the top down). The bottom up freezing progressively forces air out of the water and out of the aluminum tube.
Drill won't turn on	Be sure drill press is plugged in and that the power strip is powered up	
	The drill toggle on the GUI is not on, or the code is not actually running.	
Drill won't turn on or barely turns	The belt is too cold and is holding a set	Power up the drill press at $-10\ ^{o}C$ or above
		Power up the drill press at a lower speed, i.e. move the belt to a different position (lower geared). A lower ratio is when the pulley on the motor is small and the pulley on the cutter spindle is big.
		Heat the spindle and drill (gently) with a heat gun

Fans won't turn on or turn slowly	The fan(s) is jammed with ice or snow.	Poke the snow/ice out of the fan blade with a screwdriver, then restart the fan. POWERING UP A FAN WHILE IT IS JAMMED WITH ICE WILL PERMANENTLY DAMAGE THE FAN MOTOR. Power up the fans at –10 ^{o}C or above and leave them on all the time if operating the cold room below -15 ^{o}C. Heat the fan (gently) with a heat gun
	Fans may not be plugged in and/or the power strip is powered up The fans toggle on the LabView panel is not on, or the code is not in run mode. The fan(s) is too cold.	Power them up properly
Balance not transmitting to the code	Serial cable not plugged to both PC and balance Balance not powered up	Plug cables in Be sure power strip is on, power supply is plugged into strip and that the output of the power supply is plugged into the back of the balance
Raw mass data is going into the PC but the data is gibberish (strange characters and lots of them)	Balance is "confused"	Restart code, LabView or the PC, cycle the balance power. Bringing the balance to room temperature for a while can also fix this problem.

K. Calibrations

Calibration procedures for the Pt-100 temperature measurement, digital balance, and snow rate are given below. It is extremely unusual that a recalibration of temperature or of the balance would be needed. The rate parameter is likely to need adjusting if the machine has been altered in some way.

Electronic balance

The balance will normally not need calibration. Go to the *Denver Instruments* operation manual for calibration procedures. When in doubt about the balance, place a reference mass on the measurement tray to assess its accuracy. If out of calibration (>0.5% error) refer to the Denver Instruments operation manual for calibration procedures. The balance may also be calibrated in LabView software, contact NCAR for details.

High Resolution Platinum RTD Temperature Sensor

1. Turn on data system and control electronics box.
2. Place a suitable precision reference thermometer (glass) placed on top of the snow plate at 6” from top edge.
3. Wait one hour or more for equilibration.
4. Monitor temperature readout on the PC. Compare the PC readout to the reference mercury thermometer. If the difference between the two is large (> 0.5 ^{o}C) recalibration is needed. <u>*(*** It is expected that drift of the temperature sensor will never occur ***)*</u>
5. If calibration is necessary, record the reference temperature from the reference thermometer. Also record “mean high Rs T volts” on the panel display (PC screen). This digital display is normally way off to the right of the normal display, but can be viewed by using the slider control at the bottom of the screen.
6. Warm the room up to room to 25 ^{o}C or so. Wait 1 hour for thorough equilibration. Record values as in step 3.
7. Perform linear regression on the two points and compute appropriate values for “a” and “m” for an equation of the form: $T = a + mV$ where T= temperature ^{o}C, a is intercept, m is slope and V is “mean omega” voltage.
8. At the vi control panel, go to “windows”and “show diagram”. Go to frame 8 of the code. There are four boxes in each quadrant of the screen. Go to frame 7 of the upper right box. Replace the slope and intercept values with those of the linear regression. Go to “File” and “Save”, to make the change permanent. Calibration is complete.

Rate parameter

The rate parameter is a variable in the vi program that *roughly* forces the "Overall snow rate" (measured integrated snow rate, displayed as the yellow trace and digital display on the lower left GUI) to match the "Command rate". If the rate parameter is way off (>35%), the autorate may not function.

To evaluate the accuracy of this factor, perform a snow experiment (<u>with the autorate function switched off)</u> at a given rate, say 25 g $dm^{-2}hr^{-1}$, saving the data to a file. Then go to the ".txt" file created during the test and view the total mass of snow to collect on the plate and the test time in minutes. Calculate the actual rate via the equation:

$$\text{Actual rate} = \text{snow mass} / (16.84\ dm^2)\ (\text{test time in seconds}/3600).$$

Actual rate is the snow fall in g $dm^{-2}hr^{-1}$, 16.84 dm^2 is the area of the snow plate + that measured to the very edge of the collection tray (30x50 cm + edges), test time is in seconds. The integrated rate calculated in this way should match the "Overall snow rate" calculation made and displayed on the GUI.

If the measured rate differs from the mean command rate by more than 20% the rate parameter needs to be altered. The new "rate parameter" will be given by:

$$\text{Rate parameter}_{(new)} = \text{Rate parameter}_{(old)} \times (\text{command snow rate}/\text{overall snow rate})$$

The new rate parameter is entered onto the GUI. At the vi control panel, drag the sliding bar on the bottom of the GUI to the right, this will allow you to see the "rate parameter" digital control (it is in red letters). Enter the new rate parameter as calculated above. Next, right click on the value and drag down to "Data Operations" and "Make Current Value Default". Next, drag the bottom slider back to the left so that the GUI display is as before. Go to "File" and "Save". The new rate parameter is saved. You can test the parameter with a new snow experiment with Autorate again toggled off. If you feel lucky, skip the retest.

L. Specifications

1. Height: 2.8 m
2. Weight: ~150 kg
3. Power consumption: 150W nominal
4. Cutter speeds: 620, 1100, 1720, 2340 and 3100 RPM. Speed #4 (2340 RPM) is the speed used normally. The speed of the electric motor is 1720 RPM.
5. Electronic balance, Denver Instruments model TR-12000

   capacity: 12,000 g (APS, NCAR's is 6,000g)

   accuracy: ±2 g absolute

   resolution: 0.1 g

   temperature coefficient: 0.25 g/^{o}C

6. Temperature measurement. Omega PT-100 RTD and Analog Devices transmitter.

   accuracy: ±0.10 C

7. Raw Omega temperature measurement. Omega PT-100 RTD and Omega 76000 LED display. accuracy: ±0.25 C

M. Replacement parts

Listed below are some of the components in the snow machine and their suppliers.

Component	Manufacturer & Part number	Distributor	Approximate cost
Platinum RTD temperature sensor	Omega, RTD-2-1PT100K2515-36-T	Omega 800 826-6342	$80
Temperature controller	Omega, 76120-PV	Omega	$270

Silicone heater for underside of snow plate	Omega, SRFG-101/10-P	Omega 800 826-6342	$62
Translator	Thomson Industries, 2DB08OUBAA x44.00”	800 554-8466	$1700
Stepper motor	PK245M-01AA (stepper motor and driver must be matched carefully)	Oriental Motor, Calif. Ordering: 310 784-8200 Tech support: 800 468-3982	$65
Stepper motor drive electronics	CSD2112-T (goes with PK245 series stepper motor)	Oriental Motor, Calif. See above	$200
Coupler	part#: S9901Z-G404-03 The coupler must be enlarged to 5.0 mm (0.197”) to fit onto either the stepper motor shaft or the end of the translator lead screw, one of which is metric	Sterling Instrument NY 516 328-3300	$18
Carbide drill bit	part#: 802-112, carbide tipped spur bits, the bits must then be shortened on a lathe to match the length of current bits	Woodworkers Supply 800 645-9292	$70

Heavy duty drill press electric motor	Leeson motor, 10015.00 Model A4D17DB1D The APS snowmachine uses a 28” long outside diameter by 3/8” wide belt A more flexible belt would be (maybe) a 27”x1/4” belt. Easy flexing belts are required at low T’s. (belts are generally measured to outside diameter)	Boulder Electric Motor #032096 (their stock number)	$62