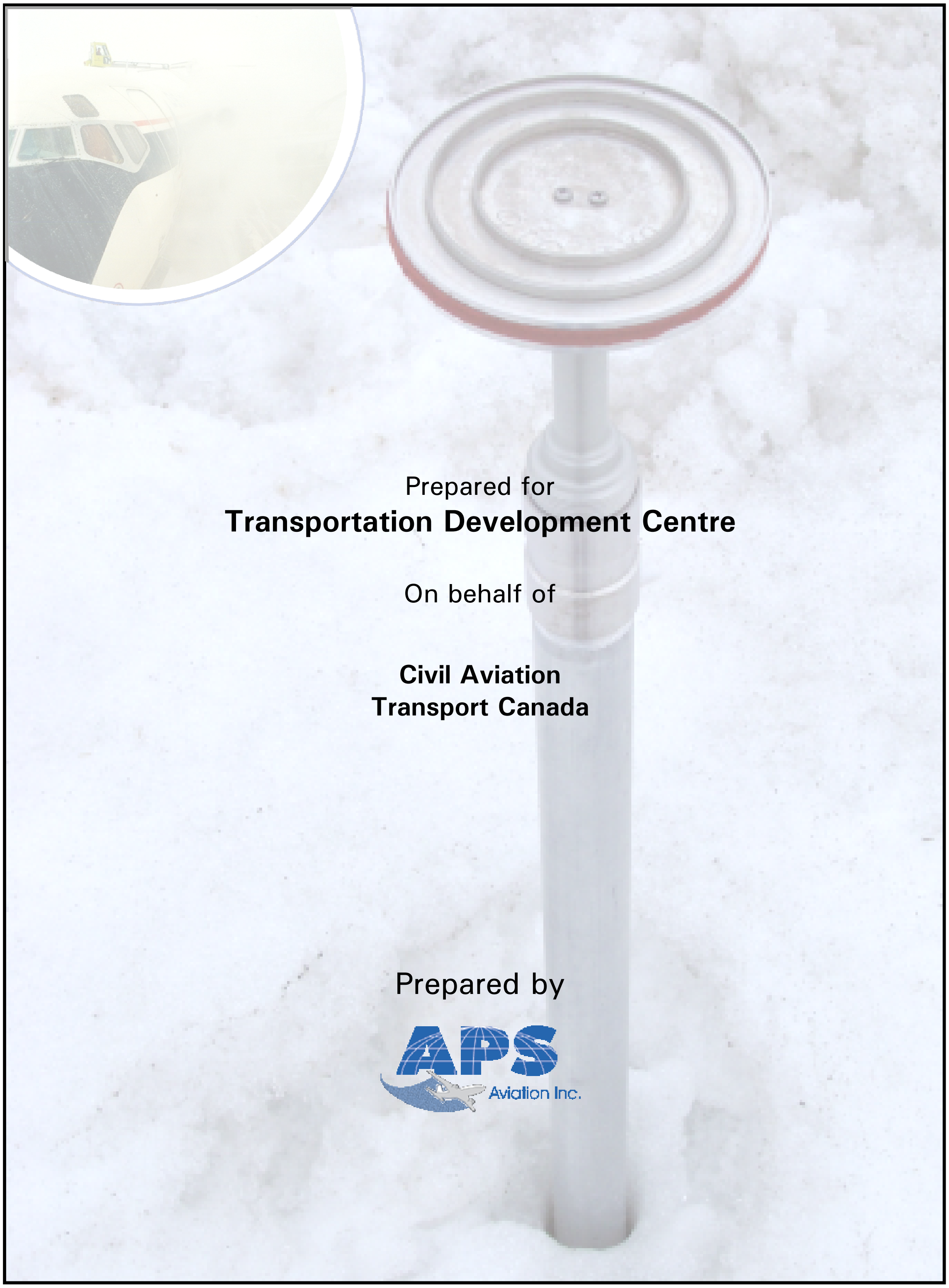
TP 14150E

Evaluation of a Real-Time Snow Precipitation Gauge for Aircraft Deicing Operations



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On behalf of

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Prepared by

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October 2003
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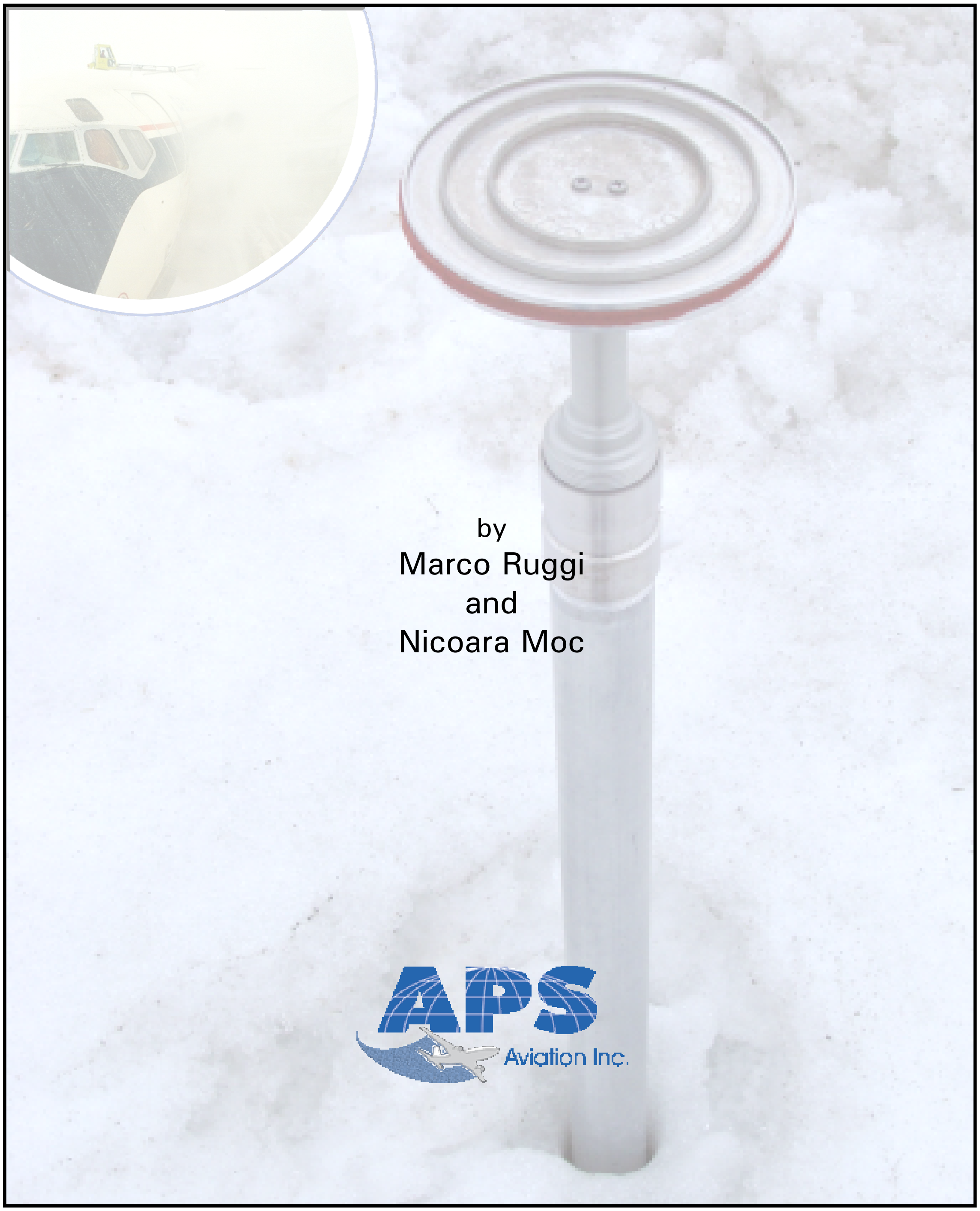

by
Marco Ruggi
and
Nicoara Moc

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Since some of the accepted measures in the industry are imperial, metric measures are not always used in this report.

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Un sommaire français se trouve avant la table des matières.

PREFACE

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

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

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

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

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

This report, TP 14150E, has the following objective:

- To compare snowfall rates obtained by the National Center for Atmospheric Research (NCAR) hotplate snow gauge with rates obtained using rate pans.

This objective was met by performing a series of comparative tests at the APS Dorval Airport test site during the winter of 2002-03.

ACKNOWLEDGEMENTS

This research has been funded by Transport Canada. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Civil Aviation Group and the Transportation Development Centre of Transport Canada, the U.S. Federal Aviation Administration, National Research Council Canada, the Meteorological Service of Canada, and several fluid manufacturers. Special thanks are extended to US Airways Inc., Federal Express, American Eagle Airlines Inc., the National Center for Atmospheric Research, the Desert Research Institute, AéroMag 2000, Aéroports de Montreal, Ottawa International Airport Authority, GlobeGround North America, and Dow Chemical Company for provision of personnel and facilities and for their co-operation with the test program. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Alia Alwaid, Stephanie Bendickson, Nicolas Blais, Richard Campbell, Mike Chaput, Sami Chebil, John D'Avirro, Peter Dawson, Caroline Duclos, Miljana Horvat, Luis Lopez, Bob MacCallum, Mark Mayodon, Chris McCormack, Nicoara Moc, Marco Ruggi, Sherry Silliker, Ben Slater, and Kim Vepsa.

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

APS especially wishes to recognize the contribution of Roy Rasmussen, of the National Center for Atmospheric Research, who designed and developed the hot plate snow gauge under contract to the Federal Aviation Administration, William J. Hughes Technical Center.

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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). Thirteen reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface.

16. Abstract

The objective of this study was to ascertain the validity and measuring accuracy of a real-time hot plate snow precipitation gauge jointly developed by the U.S. National Center for Atmospheric Research and the Desert Research Institute. To satisfy this objective, the precipitation rates produced by the hot plate snow gauge were compared to the precipitation rates collected manually using the same type of pans employed for endurance time tests. A total of 296 tests were conducted during 11 snow events. The differences in the data collected were analyzed.

Results showed that high wind conditions and low precipitation rates significantly reduced the accuracy of the snow gauge. In several tests conducted during snow events, no precipitation was measured with the snow gauge. The snow gauge precipitation rate accuracy was best during conditions with low winds and moderate-to-high precipitation. The current method for predicting snowfall intensities uses visibility measurements together with a visibility versus snowfall intensity table. In comparison, the hot plate snow gauge produced a greater number of accurate observations, but also a significant number of underestimated observations. The underestimation of snowfall intensity can subsequently cause the selection of an erroneous holdover time, creating a negative impact on aircraft safety. Therefore, it will be important to bias the output of the snow gauge to reduce the underestimation to a level equivalent to that chosen for the visibility table; this will increase the percentage of overestimates and reduce the apparent accuracy, but provide a level of safety equivalent to that of the visibility table.

An improved version of the hot plate snow gauge is currently being developed. It is recommended that testing continue in the upcoming year using the upgraded snow gauge.

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Snow gauge, hot plate, precipitation pan, precipitation rate, visibility, snow type categorization

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

16. Résumé

Le but de l'étude était de confirmer la validité et la précision de mesure d'un nivomètre à plaque chauffante fonctionnant en temps réel, développé conjointement par le National Center for Atmospheric Research des États-Unis et le Desert Research Institute. Les taux de précipitation mesurés par le nivomètre à plaque chauffante ont été comparés à ceux déterminés par la méthode manuelle, à l'aide du même type de bacs à précipitations utilisés pour les essais de durée d'efficacité des liquides de dégivrage/antigivrage. Un total de 296 essais ont été menés au cours de 11 épisodes de chute de neige. Les écarts entre les deux ensembles de données ont été analysés.

L'étude a révélé que de forts vents et de faibles taux de précipitation diminuent de beaucoup la précision du nivomètre. En effet, à plusieurs des essais sous précipitations neigeuses, le nivomètre a enregistré un niveau de précipitations nul. La précision du nivomètre était optimale par vent faible et lorsque le taux de précipitation était de modéré à élevé. Actuellement, pour établir l'intensité des chutes de neige, on utilise des mesures de la visibilité, reportées à des tableaux de visibilité en fonction de l'intensité des précipitations. Comparativement à cette méthode, le nivomètre à plaque chauffante a produit un plus grand nombre d'observations exactes, mais aussi un nombre important d'observations sous-estimées. Or, la sous-estimation de l'intensité des chutes de neige peut conduire à surestimer la durée d'efficacité des liquides antigivre, ce qui peut compromettre la sécurité aérienne. Il importera donc de «biaiser» les résultats du nivomètre afin que la sous-estimation ne dépasse pas la marge d'erreur établie pour le tableau de visibilité; on se trouvera ainsi à augmenter le pourcentage des valeurs surestimées et à réduire la précision apparente de l'instrument, mais le niveau de sécurité obtenu sera équivalent à celui du tableau de visibilité.

Une version améliorée du nivomètre à plaque chauffante est en cours de développement. Il est recommandé de procéder à d'autres essais, au cours de l'année qui vient, à l'aide du nivomètre amélioré.

17. Mots clés
Nivomètre, plaque chauffante, bac à précipitations, taux de précipitation, visibilité, classification des types de neige

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EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre of Transport Canada, APS Aviation Inc. has undertaken a research program, co-sponsored by the U.S. Federal Aviation Administration, that among other objectives, will support the evolution of an improved format for holdover time (HOT) tables for all fluid types, providing simplicity and ease of reference together with optimum operational advantage.

Recently, the deicing Type I HOT tables were revised and new divisions for the snow conditions were introduced: moderate, light, and very light. Under appropriate conditions, these changes safely and advantageously extend the HOT of Type I fluids; however, these revisions have evoked discussion on the proper guidelines a pilot should apply to interpret and distinguish between a “very light snowfall” and a “light snowfall”. The detail provided by existing weather advisories fails to accommodate the new “very light snow” column. The “light” advisory indicates that the snowfall rate is 10 g/dm²/h or less without specifying how much less. The requirement for more detail at rates of snowfall of less than 10 g/dm²/h suggests the need to accelerate the development of a snow gauge, a device that records the real-time rate of snowfall by measuring the liquid equivalent collected on the surface of the heated plate.

During the winter of 2002-03, testing was conducted by APS to determine the validity and measuring accuracy of a new snow gauge. The instrument, jointly developed by the U.S. National Center for Atmospheric Research and the Desert Research Institute, was tested during natural snow conditions. This instrument is referred to as the “hot plate snow gauge” in this report. The precipitation rates recorded by the hot plate snow gauge were compared to the precipitation rates collected manually using the same stand and pans employed for endurance time tests. The differences in the data collected were analyzed to determine whether the hot plate snow gauge is a suitable device for accurately measuring rates of precipitation.

CONCLUSIONS

Results from a total of 296 tests performed during the winter of 2002-03 comparing the readings from the hot plate snow gauge and those of the precipitation pans were analyzed. A few conclusions were drawn.

First, high winds significantly reduced the accuracy of the hot plate snow gauge. During several high wind condition tests, no precipitation was recorded.

Also, the hot plate snow gauge did not record any precipitation below a rate of 3 g/dm²/h.

To determine the validity of the hot plate snow gauge, the accuracy of the device was measured against the current method for measuring snowfall intensity, which uses visibility measurements together with a visibility versus snowfall intensity table. In comparison, the hot plate snow gauge produced a greater number of accurate observations, but also a significant amount of underestimated observations. The underestimation of snowfall intensity can subsequently cause the selection of an erroneous HOT, creating a negative impact on aircraft safety. Therefore, it will be important to bias the output of the snow gauge to reduce the underestimation to a level equivalent to that chosen for the visibility table; this will increase the percentage of overestimates and reduce the apparent accuracy, but provide a level of safety equivalent to that of the table.

An improved version of the snow gauge is currently being developed. It is recommended that testing continue in the upcoming year using the upgraded snow gauge.

SOMMAIRE

À la demande du Centre de développement des transports de Transports Canada (TC), APS Aviation Inc. (APS) a entrepris un programme de recherche, coparrainé par la Federal Aviation Administration (FAA) des États-Unis, qui vise entre autres à améliorer les tableaux de durées d'efficacité relatifs à tous les types de liquides antigivre, afin de rendre ces tableaux plus simples et plus faciles à consulter, pour des avantages opérationnels optimaux.

Lors d'une révision récente des tableaux de durées d'efficacité relatifs aux liquides de dégivrage de type I, de nouvelles catégories ont été introduites concernant la neige : modérée, légère et très légère. Dans des conditions appropriées, ces changements prolongent la durée d'efficacité des liquides de type I, sans que la sécurité soit compromise; mais en l'occurrence, on s'est demandé à quels critères un pilote doit se fier pour distinguer entre «neige très légère» et «neige légère». Les avis météorologiques actuels ne sont pas assez détaillés pour tenir compte de la nouvelle colonne «neige très légère». L'avis de «neige légère» indique que le taux de précipitation de la neige est de 10 g/dm²/h ou moins, sans préciser de combien il est inférieur à cette valeur. Le besoin de connaître avec plus de détail le taux de précipitation de neige lorsqu'il est inférieur à 10 g/dm²/h met en relief la nécessité d'accélérer le développement d'un nivomètre, un instrument qui enregistre en temps réel le taux de précipitation de neige en mesurant l'équivalent liquide recueilli sur la surface de la plaque chauffée.

Pendant l'hiver 2002-2003, APS a mené des essais pour déterminer la validité et la précision de mesure d'un nouveau nivomètre. L'instrument, développé conjointement par le National Center for Atmospheric Research des États-Unis et le Desert Research Institute, a été essayé dans des conditions de chute de neige naturelle. Cet instrument est désigné ci-après «nivomètre à plaque chauffante». Les taux de précipitation mesurés par le nivomètre à plaque chauffante ont été comparés à ceux déterminés par la méthode manuelle, à l'aide du même type de bacs à précipitations utilisés pour les essais de durée d'efficacité des liquides de dégivrage/antigivrage. Les différences entre les deux ensembles de données ont été analysées, afin de déterminer si le nivomètre à plaque chauffante permet de mesurer avec précision les taux de précipitation.

CONCLUSIONS

Les résultats d'un total de 296 essais réalisés pendant l'hiver 2002-2003, qui consistaient à comparer les lectures du nivomètre à plaque chauffante et celles des bacs à précipitations, ont été analysés. Quelques conclusions ont été tirées de cette analyse.

Premièrement, le nivomètre à plaque chauffante était beaucoup moins précis par vent fort. Souvent, lors d'essais par vents forts, aucune précipitation n'était enregistrée. De plus, le nivomètre à plaque chauffante n'a enregistré aucune précipitation en deçà d'un taux de 3 g/dm²/h.

Pour déterminer la validité du nivomètre à plaque chauffante, on a comparé les résultats obtenus à l'aide de cette méthode avec ceux obtenus par la méthode actuelle de mesure de l'intensité des précipitations neigeuses, qui consiste à reporter des mesures de la visibilité à des tableaux de visibilité en fonction de l'intensité des chutes de neige. En comparaison, le nivomètre à plaque chauffante a produit un plus grand nombre d'observations exactes, mais aussi un nombre important d'observations sous-estimées. Or, la sous-estimation de l'intensité des chutes de neige peut mener à choisir une valeur erronée dans le tableau des durées d'efficacité, ce qui peut compromettre la sécurité du vol. Il importera donc de «biaiser» les résultats du nivomètre afin que la sous-estimation ne dépasse pas la marge d'erreur établie pour le tableau de visibilité; on se trouvera ainsi à augmenter le pourcentage des valeurs surestimées et à réduire la précision apparente de l'instrument, mais le niveau de sécurité obtenu sera équivalent à celui assuré par le tableau de visibilité.

Une version améliorée du nivomètre est en cours de développement. Il est recommandé, pour l'année qui vient, de procéder à d'autres essais, à l'aide du nivomètre amélioré.

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GLOSSARY

APS	APS Aviation Inc.
DRI	Desert Research Institute
HOT	Holdover Time
NCAR	National Center for Atmospheric Research
OAT	Outside Air Temperature
TC	Transport Canada
TDC	Transportation Development Centre
UTC	Coordinated Universal Time

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1. INTRODUCTION

1.1 Background

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), APS Aviation Inc. (APS) has undertaken a research program, co-sponsored by the U.S. Federal Aviation Administration (FAA), that among other objectives, will support the evolution of an improved format for holdover time (HOT) tables for all fluid types, providing simplicity and ease of reference together with optimum operational advantage.

One of the recent changes has been the division of the snow condition in the Type I table into two conditions: moderate snow and light snow. More recently, an additional “very light snow” condition was added.

Introduction of the new snow conditions requires that the precipitation rate limits be defined. The upper precipitation rate limit for light snow is less than 10 g/dm^2/h. As a result of recent discussions with TDC, the upper precipitation limit for very light snow was defined as less than 4 g/dm^2/h.

Under appropriate conditions, these changes safely and advantageously extend the HOT of the Type I fluid; however, these revisions have evoked discussion on the proper guidelines a pilot should apply to interpret and distinguish between a “very light snowfall” and a “light snowfall”. The detail provided by existing weather advisories fails to accommodate the new “very light snow” column. The “light” advisory indicates that the snowfall rate is 10 g/dm^2/h or less without specifying how much less. The requirement for more detail at rates of snowfall less than 10 g/dm^2/h suggests the need to accelerate the development of a snow gauge, a device that records the real-time rate of snowfall by measuring the liquid equivalent collected on the surface of the heated plate.

This device, jointly developed by the National Center for Atmospheric Research (NCAR) and the Desert Research Institute (DRI), will be referred to in this report as the “hot plate snow gauge”. Testing the hot plate snow gauge under natural snowfall requires a comparison of its output with the precipitation rates measured with precipitation pans. Providing assistance for testing of the device should facilitate development of the hot plate snow gauge offering a possible long-term solution.

The following is an abstract from the AMS 11th Conference on Cloud Physics presented by Roy M. Rasmussen from NCAR and describes the hot plate snow gauge:

> *A hotplate snowgauge has been jointly developed by the National Center for Atmospheric Research (NCAR) and Desert Research Institute (DRI) that provides a method to measure liquid equivalent snowfall rates every minute. One of the main motivations for this work is the need for improved methods to measure liquid equivalent snowfall rates in support of aircraft deicing operations at airports. The hotplate snow gauge does not require glycol or oil or a windshield, typical requirements of current weighing snow gauges. The principle of operation is to measure the amount of heat necessary to melt and evaporate all the snow or rain striking the top surface of the hotplate. The system has an upper and lower plate heated to nearly identical constant temperatures (near 75°C). The lower plate is placed directly underneath the upper plate with an insulator in between. The plates are maintained at constant temperature during wind and precipitation conditions by increasing or decreasing the current to the plate heaters. During normal windy conditions without precipitation, the plates cool nearly identically due to their identical size and shape. During precipitation conditions, the top plate has an additional cooling effect due to the melting and evaporation of precipitation. The difference between the power required to cool the top plate compared to the bottom plate is proportional to the precipitation rate. The initial design of the plates had a smooth upper and lower surface. It was determined that snow would "skate" off the upper surface during high wind conditions leading to the underestimation of the snowfall rate during these periods. In order to overcome this problem, three concentric walls were added to both the top and bottom plates. These concentric walls help prevent snow or rain impacting the plate at an angle from sliding off during high wind conditions. This modification greatly increased the catch efficiency of the gauge. The snow gauge has undergone two years of testing at Marshall (a site near Boulder) and at Mt. Washington, NH (1).*

1.2 Objective

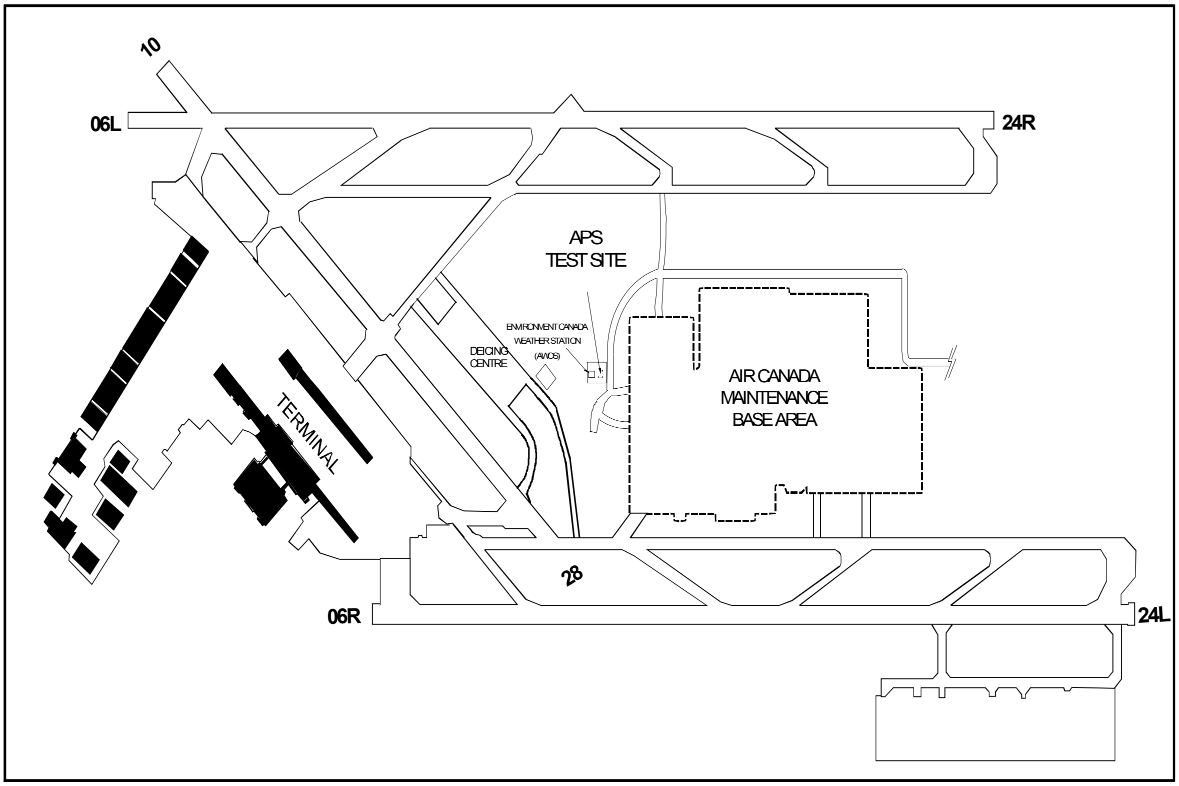
During the winter of 2002-03, testing was conducted to determine the validity and measuring accuracy of the hot plate snow gauge during natural snow conditions. The precipitation rates recorded by the hot plate snow gauge were compared to the precipitation rates collected manually using pans. The difference between the data collected was analyzed to determine whether the hot plate snow gauge is a suitable device for accurately measuring rates of precipitation in real time. Throughout testing, feedback was provided to DRI to contribute to the development of the hot plate snow gauge software program. The original work statement for testing with the hot plate snow gauge under natural precipitation is provided in Appendix A.

2. METHODOLOGY

This section describes the test conditions and experimental methodologies followed in the 2002-03 testing of the hot plate snow gauge, as well as the equipment and personnel requirements.

2.1 Test Site

Natural snow testing of the hot plate snow gauge during the winter of 2002-03 was conducted at the APS Dorval Airport test site. The location of the test site is shown on the plan view of the airport in Figure 2.1. The APS test site is located near the Meteorological Service of Canada's automated weather observation station.



cm1680\reports\HOTWorking DSocuments\Test Site.CH4

Figure 2.1: Plan View of APS Dorval Airport Test Site

A layout of the APS Dorval test site is shown in Figure 2.2. The hot plate snow gauge was located approximately 15 m away from the trailers, and 3 m away from the precipitation pans. The equipment shown in the layout is described is Section 2.4.

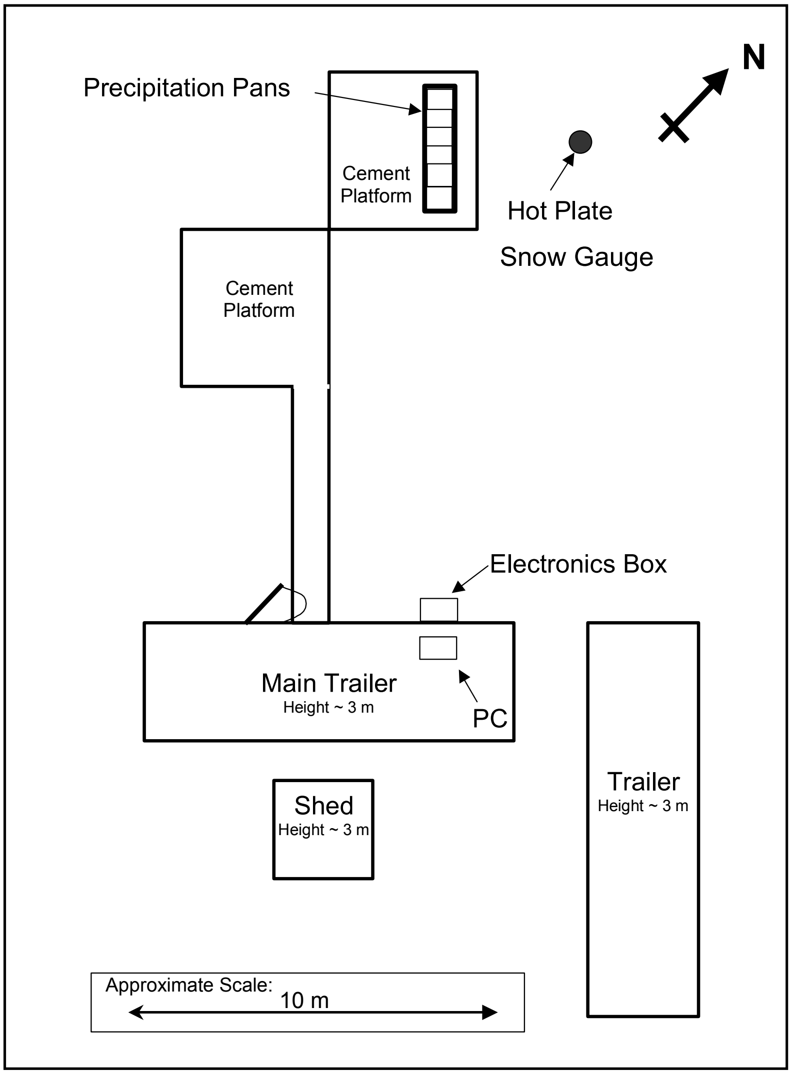


Figure 2.2: Layout of APS Dorval Airport Test Site

2.2 Description of Test Procedures

Analysis of the validity and measuring accuracy of the hot plate snow gauge required the gathering of snowfall information by manually collecting precipitation and comparing the data obtained to the snow gauge's output. Additional test data was obtained by Environment Canada. The data collected and the method used to process the results of the 296 tests conducted during the winter of 2002-03 are provided in Section 3. A complete description of the procedure used for testing the hot plate snow gauge is provided in Appendix B. The procedure for the collection of precipitation required that two precipitation pans be measured during staggered time intervals. Several modifications were made to the procedure:

a) For tests 1 to 63, precipitation was collected using one pan;

b) For tests 64 to 136, precipitation was collected using two pans. The precipitation rates were measured during staggered time intervals;

c) For tests 137 to 188, precipitation was collected using four pans. Two precipitation rate measurements were conducted simultaneously;

d) For tests 188 to 296, precipitation was collected using two pans. Two precipitation rates were measured simultaneously;

e) Typically, precipitation rates were collected every 20 minutes during light precipitation, every 10 minutes during moderate precipitation, and every 5 minutes during heavy precipitation; and

f) For tests 64 to 296, precipitation rates were measured every minute.

2.3 Data Forms

One data form was required for the manual precipitation rate measurement. The data form is provided in the procedure given in Appendix B.

2.4 Equipment

2.4.1 Hot Plate Snow Gauge

2.4.1.1 Gauge

The post and sensing heads (Photo 2.1) were mounted on a square base plate. The sensing heads were positioned horizontally 1 m above the ground. The gauge was positioned approximately 15 m away from the APS test site trailer, and approximately 3 m away from the precipitation pans (Photo 2.2).

2.4.1.2 Hardware

The electronics box was mounted on the side of the APS test site trailer and connected to both the gauge and the PC located inside the trailer.

2.4.1.3 Firmware

The software installed in the electronics box was referred to as “firmware”. Feedback on the results obtained using different versions of the firmware was provided to DRI. The firmware was modified accordingly and resubmitted to APS for further testing. Versions 1.12, 1.13, and 1.14 of the firmware were installed and tested.

2.4.1.4 Software

The “precip” program provided by DRI was used to establish communication with the gauge. The “precip” graphing program sampled data from the gauge every minute. Version 1.12 of the software was used throughout testing.

The “precip” program provided access to a parameter controlling the hot plate snow gauge’s bottom plate set point. The bottom plate set point was used to increase or decrease the sensitivity of the device. Decreasing the bottom plate set point increased the sensitivity of the gauge; the snow gauge was able to detect lower rates of precipitation.

2.4.1.5 PC computer

A Micron laptop remained connected to the gauge throughout testing. The laptop was used to set up, monitor, and retrieve data from the gauge using the “precip” program.

2.4.2 Manual Collection of Precipitation Rates

2.4.2.1 Precipitation pans

A maximum of four aluminum precipitation pans were used for the manual collection of precipitation. The collection area of each pan measured 12.9 dm^2 (Figure 2.3). This area was wetted with a Type IV fluid prior to exposure to precipitation to prevent snow from blowing off the pan. At the beginning of each test run, the precipitation pans were placed on the test stand at a 10° inclination facing the oncoming wind (Photo 2.3). Detailed specifications for the precipitation pans used are provided in the procedure given in Appendix B.

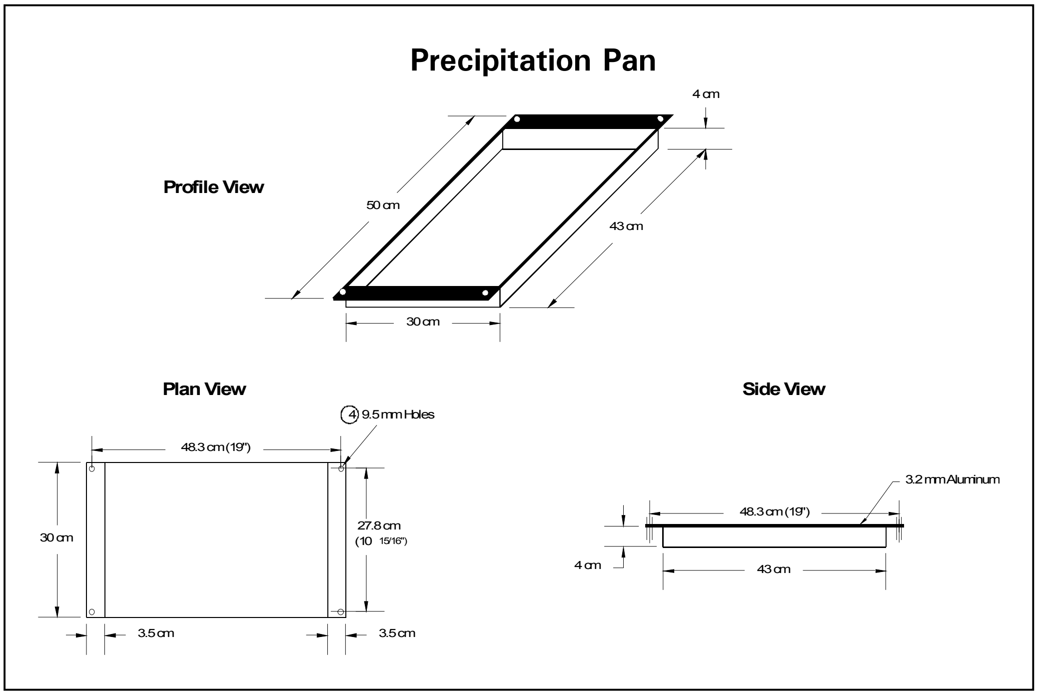


Figure 2.3: Schematic of Precipitation Pan

2.4.2.2 Test stand

The stand used for standard endurance time tests was used to position the precipitation pans. The precipitation pans were placed at a 10º inclination on the test stand located approximately 3 m away from the hot plate snow gauge.

2.4.2.3 Weigh scale

A Sartorius weigh scale, with a precision of 0.2 g, was used to measure the rate of precipitation. The scale was zeroed prior to the weighing of each precipitation pan.

2.5 Personnel

One member of the APS staff was involved during testing. This technician was assigned the following tasks:

a) Manage the hot plate snow gauge; and
b) Manually collect precipitation rates.

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Photo 2.1: Hot Plate Snow Gauge

Photo 2.2: Hot Plate Snow Gauge and Test Stand with Precipitation Pans

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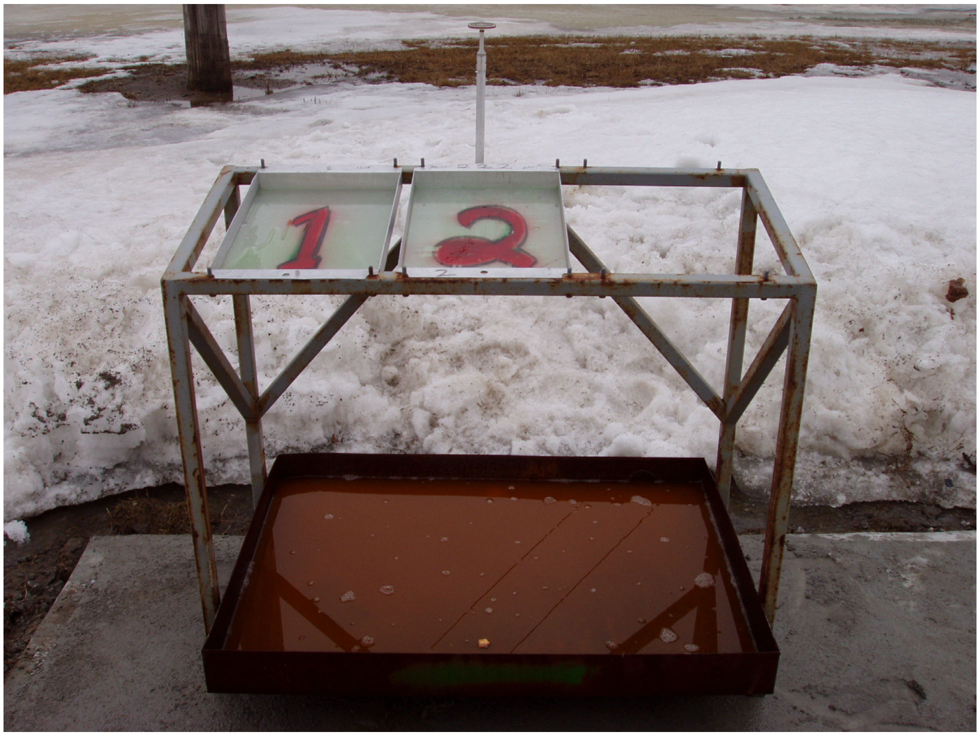
Photo 2.3: Test Stand and Precipitation Pans



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3. DESCRIPTION OF DATA COLLECTION AND ANALYSIS METHODOLOGY

In this section, the data collected is presented and the method used for processing the results is described.

3.1 Test Information

During the winter of 2002-03, tests were conducted by APS at the Dorval Airport test site. The hot plate snow gauge was tested during this period in natural snow conditions. Each test was represented by the start and end time of the pan exposure to precipitation. Trials were conducted alone or in conjunction with standard endurance tests. Lengthy test sessions were divided into multiple series to facilitate analysis. A detailed summary of the pertinent information for each test session is presented in Subsections 3.1.1 to 3.1.17.

3.1.1 January 7-8, 2003, Series #1

- Start Time: 20:54:00
- End Time: 4:30:00
- Ambient Temperature: -5.3°C to -7.1°C
- Wind Speed: 12.0 km/h to 19.5 km/h
- Software Version: 1.12
- Firmware Version: 1.12
- Bottom Plate Set Point: 6.36
- Number of Precipitation Pans: 1
- Total Number of Tests: 31

3.1.2 January 26, 2003, Series #1

- Start Time: 10:05:10
- End Time: 12:31:35
- Ambient Temperature: -4.9°C to -5.6°C
- Wind Speed: 8.8 km/h to 21.5 km/h
- Software Version: 1.12
- Firmware Version: 1.13
- Bottom Plate Set Point: 6.36
- Number of Precipitation Pans: 2 (staggered)
- Total Number of Tests: 32

3.1.3 February 4, 2003, Series #1

- Start Time: 3:46:00
- End Time: 7:01:00
- Ambient Temperature: 0.4ºC to -2.6ºC
- Wind Speed: 17.6 km/h to 27.9 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.36
- Number of Precipitation Pans: 2 (staggered)
- Total Number of Tests: 28

3.1.4 February 10, 2003, Series #1

- Start Time: 21:33:30
- End Time: 23:20:45
- Ambient Temperature: -4.8ºC to -10.1ºC
- Wind Speed: 5.6 km/h to 34.8 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.36
- Number of Precipitation Pans: 2 (staggered)
- Total Number of Tests: 11

3.1.5 February 19, 2003, Series #1

- Start Time: 0:18:40
- End Time: 3:28:00
- Ambient Temperature: -6.4ºC to -11ºC
- Wind Speed: 3.2 km/h to 13.0 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.33
- Number of Precipitation Pans: 2 (staggered)
- Total Number of Tests: 20

3.1.6 February 19, 2003, Series #2

- Start Time: 4:00:30
- End Time: 5:13:30
- Ambient Temperature: -5.7ºC to -6.2ºC

- Wind Speed: 9.1 km/h to 14.3 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.36
- Number of Precipitation Pans: 2 (staggered)
- Total Number of Tests: 14

3.1.7 February 22-23, 2003, Series #1

- Start time: 16:28:00
- End Time: 18:48:00
- Ambient Temperature: -4.9ºC to -6.5ºC
- Wind Speed: 39.4 km/h to 46.6 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.33
- Number of Precipitation Pans: 4 (2 on the stand at a time)
- Total Number of Tests: 14

3.1.8 February 22-23, 2003, Series #2

- Start Time: 21:38:00
- End Time: 23:38:00
- Ambient Temperature: -6.2ºC to -6.4ºC
- Wind Speed: 44.4 km/h to 52.0 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.33
- Number of Precipitation Pans: 4 (2 on the stand at a time)
- Total number of Tests: 11

3.1.9 February 22-23, 2003, Series #3

- Start Time: 0:08:00
- End Time: 2:18:00
- Ambient Temperature: -6.0ºC to -6.3ºC
- Wind Speed: 40.2 km/h to 50.5 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.36
- Number of Precipitation Pans: 4 (2 on the stand at a time)
- Total Number of Tests: 13

3.1.10 February 23, 2003, Series #1

- Start Time: 13:41:00
- End Time: 17:20:00
- Ambient Temperature: -3.6°C to -5.0°C
- Wind Speed: 9.8 km/h to 23.4 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.33
- Number of Precipitation Pans: 4 (2 on the stand at a time)
- Total Number of Tests: 14

3.1.11 March 2, 2003, Series #1

- Start Time: 8:03:28
- End Time: 11:08:20
- Ambient Temperature: 0.5°C to 0.2°C
- Wind Speed: 10.1 km/h to 17.8 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.33
- Number of Precipitation Pans: 2 (simultaneously)
- Total Number of Tests: 10

3.1.12 March 4-5, 2003, Series #1

- Start Time: 19:17:00
- End Time: 0:03:00
- Ambient Temperature: -6.0°C to -8.4°C
- Wind Speed: 0.0 km/h to 8.2 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.33
- Number of Precipitation Pans: 2 (simultaneously)
- Total Number of Tests: 20

3.1.13 March 4-5, 2003, Series #2

- Start Time: 0:07:00
- End Time: 4:32:00
- Ambient Temperature: -6.3°C to -9.3°C

- Wind Speed: 3.9 km/h to 22.8 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.33
- Number of Precipitation Pans: 2 (simultaneously)
- Total Number of Tests: 19

3.1.14 March 8-9, 2003, Series #1

- Start Time: 21:42:00
- End Time: 0:01:00
- Ambient Temperature: -1.5ºC to -2.0ºC
- Wind Speed: 6.4 km/h to 13.9 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.33
- Number of Precipitation Pans: 2 (simultaneously)
- Total Number of Tests: 15

3.1.15 March 8-9, 2003, Series #2

- Start Time: 0:02:00
- End Time: 2:39:00
- Ambient Temperature: -2.0ºC to -2.5ºC
- Wind Speed: 10.9 km/h to 20.2 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.33
- Number of Precipitation Pans: 2 (simultaneously)
- Total Number of Tests: 18

3.1.16 April 5, 2003, Series #1

- Start Time: 4:44:00
- End Time: 7:42:00
- Ambient Temperature: -3.0ºC to -4.4ºC
- Wind Speed: 24 km/h to 31 km/h
- Software Version: 1.12
- Firmware Version: 1.14
- Bottom Plate Set Point: 6.30
- Number of Precipitation Pans: 2 (simultaneously)
- Total Number of Tests: 11

3.1.17 April 5, 2003 Series #2

• Start Time:	8:02:00
• End Time:	10:25:00
• Ambient Temperature:	-3.4°C to -4.4°C
• Wind Speed:	26 km/h to 33 km/h
• Software Version:	1.12
• Firmware Version:	1.14
• Bottom Plate Set Point:	6.27
• Number of Precipitation Pans:	2 (simultaneously)
• Total Number of Tests:	16

3.2 Test Log

To facilitate the accessibility of the data collected, a log was created for the series of tests conducted by APS at the Dorval test site. The log presented in Table 3.1 provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. The following is a brief description of the column headings for the test log:

Test No.:	Exclusive number identifying each test.
Series No.:	Series number in which the test was performed.
Date:	Date when the test was conducted.
Start Time:	Start time for the test recorded in local time.
End Time:	End time for the test recorded in local time.
Midpoint:	The halfway mark for the duration of a test, determined from the start and end times.
Test Duration:	The duration of the test, calculated in minutes and determined by the difference between the start time and the end time.
Average Pan Rate:	Average precipitation rate, measured in g/dm²/h, collected from the precipitation pans for the duration of the test.
Average Snow Gauge Rate:	Average precipitation rate, measured in g/dm²/h and provided by the hot plate snow gauge data logger for the duration of the test.
OAT:	The average outside ambient temperature for the duration of the test, measured in °C and provided by Environment Canada.
Wind:	The average wind speed for the duration of the test, measured in km/h, at a height of 10 m and provided by Environment Canada.
Set Point:	Bottom plate set point used to increase or decrease sensitivity of the hot plate snow gauge.

No. of Pans: The number of precipitation pans used to calculate the rate of precipitation, measured independently or simultaneously.

Table 3.1: Log of Tests Conducted During the 2002-03 Winter

Test Log

Test No.	**Series No.**	**Date**	**Start Time**	**End Time**	**Midpoint**	**Test Duration (min)**	**Average Pan Rate (g/dm²/h)**	**Average Snow Gauge Rate (g/dm²/h)**	**OAT (ºC)**	**Wind Speed (km/h)**	**Set Point**	**No. of Pans**
1	1	7-Jan-03	20:54:00	21:04:30	20:59:15	10.5	3.6	9.2	-7.0	15.3	6.36	1
2	1	7-Jan-03	21:05:45	21:15:56	21:10:51	10.2	3.3	9.2	-7.1	15.5	6.36	1
3	1	7-Jan-03	21:16:50	21:36:55	21:26:52	20.1	1.0	0.7	-7.0	15.9	6.36	1
4	1	7-Jan-03	21:38:10	21:58:02	21:48:06	19.9	1.7	1.2	-6.8	14.5	6.36	1
5	1	7-Jan-03	21:59:05	22:19:00	22:09:02	19.9	1.8	5.2	-6.6	16.3	6.36	1
6	1	7-Jan-03	22:20:00	22:30:00	22:25:00	10.0	3.5	7.1	-6.6	17.1	6.36	1
7	1	7-Jan-03	22:30:50	22:41:00	22:35:55	10.2	0.2	0.0	-6.5	17.4	6.36	1
8	1	7-Jan-03	22:42:00	23:02:00	22:52:00	20.0	1.1	0.9	-6.3	17.2	6.36	1
9	1	7-Jan-03	23:02:50	23:21:17	23:12:03	18.5	1.9	5.8	-6.1	15.2	6.36	1
10	1	7-Jan-03	23:22:00	23:42:40	23:32:20	20.7	2.4	7.0	-6.0	13.5	6.36	1
11	1	7-Jan-03	23:43:25	0:03:20	23:53:23	19.9	3.1	7.1	-5.7	14.6	6.36	1
12	1	8-Jan-03	0:03:50	0:23:10	0:13:30	19.3	6.8	10.9	-5.7	14.8	6.36	1
13	1	8-Jan-03	0:23:55	0:34:15	0:29:05	10.3	13.2	27.4	-5.8	16.1	6.36	1
14	1	8-Jan-03	0:34:50	0:44:00	0:39:25	9.2	12.9	25.4	-5.9	17.2	6.36	1
15	1	8-Jan-03	0:44:40	0:54:45	0:49:42	10.1	20.9	39.3	-6.0	16.8	6.36	1
16	1	8-Jan-03	0:55:25	1:05:10	1:00:18	9.7	14.2	57.5	-6.0	16.7	6.36	1
17	1	8-Jan-03	1:06:00	1:16:00	1:11:00	10.0	36.4	30.9	-5.9	16.7	6.36	1
18	1	8-Jan-03	1:17:00	1:26:50	1:21:55	9.8	9.6	16.7	-5.8	15.2	6.36	1
19	1	8-Jan-03	1:31:10	1:40:55	1:36:02	9.7	15.1	27.6	-5.7	17.4	6.36	1
20	1	8-Jan-03	1:41:45	1:52:00	1:46:52	10.2	10.3	18.3	-5.7	15.7	6.36	1
21	1	8-Jan-03	1:52:45	2:03:10	1:57:57	10.4	8.7	16.3	-5.7	15.6	6.36	1
22	1	8-Jan-03	2:03:55	2:14:00	2:08:57	10.1	9.1	13.8	-5.7	14.8	6.36	1
23	1	8-Jan-03	2:14:45	2:24:40	2:19:43	9.9	3.9	2.7	-5.7	16.0	6.36	1
24	1	8-Jan-03	2:25:30	2:35:15	2:30:23	9.7	1.6	0.0	-5.7	18.4	6.36	1
25	1	8-Jan-03	2:36:15	2:57:15	2:46:45	21.0	0.3	0.0	-5.6	19.5	6.36	1
26	1	8-Jan-03	2:58:00	3:17:45	3:07:53	19.7	2.1	3.0	-5.5	17.0	6.36	1
27	1	8-Jan-03	3:18:20	3:38:05	3:28:12	19.7	3.8	11.3	-5.4	14.7	6.36	1
28	1	8-Jan-03	3:38:50	3:58:50	3:48:50	20.0	11.7	30.6	-5.4	13.7	6.36	1
29	1	8-Jan-03	3:59:50	4:09:50	4:04:50	10.0	5.5	15.7	-5.3	12.6	6.36	1
30	1	8-Jan-03	4:10:30	4:20:20	4:15:25	9.8	4.8	17.3	-5.3	12.0	6.36	1
31	1	8-Jan-03	4:21:00	4:30:00	4:25:30	9.0	9.8	29.9	-5.3	12.2	6.36	1
32	1	26-Jan-03	10:05:10	10:10:10	10:07:40	5.0	3.8	0.0	-5.4	14.2	6.36	1
33	1	26-Jan-03	10:06:50	10:13:35	10:10:12	6.7	3.9	0.0	-5.4	14.1	6.36	1
34	1	26-Jan-03	10:11:00	10:15:50	10:13:25	4.8	4.9	0.0	-5.3	13.7	6.36	1

Table 3.1: Log of Tests Conducted During the 2002-03 Winter *(continued)*

Test Log												
Test No.	Series No.	Date	Start Time	End Time	Midpoint	Test Duration (min)	Average Pan Rate (g/dm²/h)	Average Snow Gauge Rate (g/dm²/h)	OAT (ºC)	Wind Speed (km/h)	Set Point	No. of Pans
35	1	26-Jan-03	10:14:00	10:18:50	10:16:25	4.8	4.9	0.0	-5.3	13.3	6.36	1
36	1	26-Jan-03	10:16:20	10:21:15	10:18:47	4.9	5.5	0.0	-5.3	13.0	6.36	1
37	1	26-Jan-03	10:19:15	10:24:15	10:21:45	5.0	5.5	0.0	-5.4	13.0	6.36	1
38	1	26-Jan-03	10:21:45	10:26:45	10:24:15	5.0	3.8	1.8	-5.4	13.9	6.36	1
39	1	26-Jan-03	10:24:45	10:34:45	10:29:45	10.0	3.2	1.0	-5.3	13.6	6.36	1
40	1	26-Jan-03	10:28:35	10:38:35	10:33:35	10.0	1.9	0.0	-5.2	12.8	6.36	1
41	1	26-Jan-03	10:35:20	10:45:20	10:40:20	10.0	0.9	0.0	-5.2	12.1	6.36	1
42	1	26-Jan-03	10:39:00	10:49:00	10:44:00	10.0	0.5	0.0	-5.2	12.6	6.36	1
43	1	26-Jan-03	10:45:55	11:05:55	10:55:55	20.0	2.2	0.0	-5.1	13.1	6.36	1
44	1	26-Jan-03	10:49:50	11:08:30	10:59:10	18.7	2.9	0.5	-5.1	12.6	6.36	1
45	1	26-Jan-03	11:06:25	11:11:25	11:08:55	5.0	3.9	1.8	-5.1	10.2	6.36	1
46	1	26-Jan-03	11:09:10	11:14:10	11:11:40	5.0	3.6	0.0	-5.1	11.4	6.36	1
47	1	26-Jan-03	11:11:50	11:16:50	11:14:20	5.0	3.2	0.0	-5.1	13.0	6.36	1
48	1	26-Jan-03	11:14:40	11:20:05	11:17:22	5.4	1.9	0.0	-5.2	14.3	6.36	1
49	1	26-Jan-03	11:17:20	11:22:20	11:19:50	5.0	1.7	0.0	-5.2	14.2	6.36	1
50	1	26-Jan-03	11:20:05	11:25:30	11:22:48	5.4	1.9	0.0	-5.1	13.3	6.36	1
51	1	26-Jan-03	11:22:50	11:28:50	11:25:50	6.0	1.6	0.0	-5.1	11.9	6.36	1
52	1	26-Jan-03	11:25:30	11:35:55	11:30:42	10.4	0.9	0.0	-5.1	11.6	6.36	1
53	1	26-Jan-03	11:29:10	11:39:20	11:34:15	10.2	1.4	0.0	-5.0	11.4	6.36	1
54	1	26-Jan-03	11:35:55	11:46:25	11:41:10	10.5	1.0	0.0	-5.0	11.7	6.36	1
55	1	26-Jan-03	11:39:45	11:49:40	11:44:43	9.9	1.0	0.0	-5.0	12.0	6.36	1
56	1	26-Jan-03	11:46:25	11:57:00	11:51:43	10.6	0.8	0.0	-4.9	10.3	6.36	1
57	1	26-Jan-03	11:50:15	12:00:15	11:55:15	10.0	0.5	0.0	-4.9	9.3	6.36	1
58	1	26-Jan-03	11:57:00	12:08:00	12:02:30	11.0	0.6	0.0	-4.9	8.8	6.36	1
59	1	26-Jan-03	12:00:40	12:10:45	12:05:42	10.1	0.8	0.0	-4.9	9.1	6.36	1
60	1	26-Jan-03	12:08:00	12:19:10	12:13:35	11.2	0.6	0.0	-5.1	14.1	6.36	1
61	1	26-Jan-03	12:11:15	12:21:15	12:16:15	10.0	0.6	0.0	-5.1	16.0	6.36	1
62	1	26-Jan-03	12:19:10	12:29:50	12:24:30	10.7	0.6	0.0	-5.5	21.5	6.36	1
63	1	26-Jan-03	12:21:35	12:31:35	12:26:35	10.0	0.7	0.0	-5.6	20.9	6.36	1
64	1	4-Feb-03	3:46:00	3:51:00	3:48:30	5.0	22.9	13.3	-2.3	23.8	6.36	2
65	1	4-Feb-03	3:46:00	3:57:00	3:51:30	11.0	15.8	10.9	-2.5	23.2	6.36	2
66	1	4-Feb-03	3:52:00	4:03:00	3:57:30	11.0	9.5	4.0	-2.6	22.6	6.36	2
67	1	4-Feb-03	4:04:00	4:15:00	4:09:30	11.0	6.4	4.1	-2.6	25.9	6.36	2
68	1	4-Feb-03	4:10:00	4:21:00	4:15:30	11.0	8.0	9.7	-2.5	27.2	6.36	2
69	1	4-Feb-03	4:16:00	4:27:00	4:21:30	11.0	20.3	15.6	-2.4	27.9	6.36	2
70	1	4-Feb-03	4:22:00	4:33:00	4:27:30	11.0	15.2	12.3	-2.3	27.6	6.36	2
71	1	4-Feb-03	4:28:00	4:39:00	4:33:30	11.0	0.0	4.7	-2.1	26.7	6.36	2
72	1	4-Feb-03	4:34:00	4:50:00	4:42:00	16.0	7.9	7.6	-1.9	26.0	6.36	2
73	1	4-Feb-03	4:40:00	4:56:00	4:48:00	16.0	10.0	11.9	-1.8	24.7	6.36	2

Table 3.1: Log of Tests Conducted During the 2002-03 Winter *(continued)*

Test Log												
Test No.	Series No.	Date	Start Time	End Time	Midpoint	Test Duration (min)	Average Pan Rate (g/dm²/h)	Average Snow Gauge Rate (g/dm²/h)	OAT (ºC)	Wind Speed (km/h)	Set Point	No. of Pans
74	1	4-Feb-03	4:51:00	5:07:00	4:59:00	16.0	14.4	19.9	-1.4	23.6	6.36	2
75	1	4-Feb-03	4:57:00	5:18:00	5:07:30	21.0	23.6	23.9	-1.1	24.2	6.36	2
76	1	4-Feb-03	5:08:00	5:25:00	5:16:30	17.0	39.4	28.1	-0.9	24.9	6.36	2
77	1	4-Feb-03	5:20:00	5:31:00	5:25:30	11.0	52.0	33.8	-0.7	27.1	6.36	2
78	1	4-Feb-03	5:26:00	5:37:00	5:31:30	11.0	36.9	21.4	-0.5	27.2	6.36	2
79	1	4-Feb-03	5:32:00	5:45:00	5:38:30	13.0	30.3	20.8	-0.4	25.8	6.36	2
80	1	4-Feb-03	5:40:00	5:52:00	5:46:00	12.0	29.2	24.6	-0.3	24.1	6.36	2
81	1	4-Feb-03	5:47:00	5:58:00	5:52:30	11.0	33.7	23.1	-0.2	21.6	6.36	2
82	1	4-Feb-03	5:53:00	6:01:00	5:57:00	8.0	40.0	26.2	-0.2	21.6	6.36	2
83	1	4-Feb-03	6:00:00	6:08:00	6:04:00	8.0	40.3	27.3	-0.2	21.4	6.36	2
84	1	4-Feb-03	6:03:00	6:15:00	6:09:00	12.0	39.8	28.6	-0.1	20.4	6.36	2
85	1	4-Feb-03	6:10:00	6:23:00	6:16:30	13.0	48.3	33.6	0.1	20.1	6.36	2
86	1	4-Feb-03	6:18:00	6:30:00	6:24:00	12.0	52.9	40.9	0.2	19.9	6.36	2
87	1	4-Feb-03	6:25:00	6:36:00	6:30:30	11.0	54.5	44.3	0.2	17.9	6.36	2
88	1	4-Feb-03	6:31:00	6:43:00	6:37:00	12.0	52.3	38.9	0.3	17.6	6.36	2
89	1	4-Feb-03	6:38:00	6:50:00	6:44:00	12.0	58.8	36.2	0.3	18.8	6.36	2
90	1	4-Feb-03	6:45:00	7:00:00	6:52:30	15.0	51.8	31.5	0.4	19.7	6.36	2
91	1	4-Feb-03	6:52:00	7:01:00	6:56:30	9.0	50.5	22.2	0.4	19.8	6.36	2
92	1	10-Feb-03	21:33:30	21:43:30	21:38:30	10.0	3.7	0.0	-4.8	25.3	6.36	2
93	1	10-Feb-03	21:33:31	21:51:15	21:42:23	17.7	3.0	0.0	-5.6	29.0	6.36	2
94	1	10-Feb-03	21:56:00	22:06:00	22:01:00	10.0	0.9	0.0	-7.7	34.8	6.36	2
95	1	10-Feb-03	21:58:15	22:18:15	22:08:15	20.0	1.1	0.0	-7.9	32.2	6.36	2
96	1	10-Feb-03	22:06:15	22:26:15	22:16:15	20.0	0.8	0.0	-8.1	29.7	6.36	2
97	1	10-Feb-03	22:18:30	22:38:50	22:28:40	20.3	1.1	0.0	-8.5	30.3	6.36	2
98	1	10-Feb-03	22:26:30	22:46:30	22:36:30	20.0	1.8	0.0	-9.0	30.8	6.36	2
99	1	10-Feb-03	22:39:10	22:59:10	22:49:10	20.0	0.9	0.0	-9.6	30.2	6.36	2
100	1	10-Feb-03	22:46:50	23:06:50	22:56:50	20.0	0.2	0.0	-9.8	28.8	6.36	2
101	1	10-Feb-03	22:59:30	23:19:30	23:09:30	20.0	0.0	0.0	-10.0	31.0	6.36	2
102	1	10-Feb-03	23:07:15	23:20:45	23:14:00	13.5	0.0	0.0	-10.1	31.0	6.36	2
103	1	19-Feb-03	0:18:40	0:28:30	0:23:35	9.8	0.7	0.0	-11.0	13.0	6.33	2
104	1	19-Feb-03	0:21:50	0:31:45	0:26:48	9.9	0.5	0.0	-7.0	10.1	6.33	2
105	1	19-Feb-03	0:29:00	0:48:50	0:38:55	19.8	0.4	0.0	-7.1	7.2	6.33	2
106	1	19-Feb-03	0:32:05	0:51:45	0:41:55	19.7	0.3	0.0	-7.2	6.8	6.33	2
107	1	19-Feb-03	0:49:10	1:09:10	0:59:10	20.0	0.5	0.0	-7.2	6.0	6.33	2
108	1	19-Feb-03	0:52:10	1:12:10	1:02:10	20.0	0.6	0.0	-7.2	6.3	6.33	2
109	1	19-Feb-03	1:09:40	1:29:30	1:19:35	19.8	0.2	0.0	-7.3	7.7	6.33	2
110	1	19-Feb-03	1:12:30	1:32:30	1:22:30	20.0	0.2	0.0	-7.3	8.2	6.33	2
111	1	19-Feb-03	1:30:00	1:50:00	1:40:00	20.0	0.3	0.0	-7.0	5.6	6.33	2
112	1	19-Feb-03	1:33:10	1:53:30	1:43:20	20.3	0.2	0.0	-7.0	5.6	6.33	2

Table 3.1: Log of Tests Conducted During the 2002-03 Winter *(continued)*

Test Log												
Test No.	Series No.	Date	Start Time	End Time	Midpoint	Test Duration (min)	Average Pan Rate (g/dm²/h)	Average Snow Gauge Rate (g/dm²/h)	OAT (ºC)	Wind Speed (km/h)	Set Point	No. of Pans
113	1	19-Feb-03	1:50:30	2:10:40	2:00:35	20.2	0.3	0.4	-7.0	3.4	6.33	2
114	1	19-Feb-03	1:54:00	2:14:00	2:04:00	20.0	0.3	0.4	-7.0	3.2	6.33	2
115	1	19-Feb-03	2:11:00	2:31:00	2:21:00	20.0	0.1	0.0	-6.8	5.6	6.33	2
116	1	19-Feb-03	2:14:30	2:34:30	2:24:30	20.0	0.0	0.0	-6.8	5.6	6.33	2
117	1	19-Feb-03	2:31:30	2:52:30	2:42:00	21.0	0.1	0.3	-6.6	6.6	6.33	2
118	1	19-Feb-03	2:35:00	2:55:00	2:45:00	20.0	0.1	0.8	-6.6	7.0	6.33	2
119	1	19-Feb-03	2:53:00	3:13:00	3:03:00	20.0	0.4	0.8	-6.4	11.3	6.33	2
120	1	19-Feb-03	2:55:30	3:15:30	3:05:30	20.0	0.5	0.6	-6.4	12.0	6.33	2
121	1	19-Feb-03	3:13:30	3:27:00	3:20:15	13.5	1.5	1.6	-6.5	12.3	6.33	2
122	1	19-Feb-03	3:16:00	3:28:00	3:22:00	12.0	1.8	2.2	-6.5	12.3	6.33	2
123	2	19-Feb-03	4:00:30	4:10:30	4:05:30	10.0	0.7	0.0	-6.2	9.1	6.36	2
124	2	19-Feb-03	4:01:30	4:11:30	4:06:30	10.0	0.8	0.0	-6.2	9.3	6.36	2
125	2	19-Feb-03	4:11:00	4:20:00	4:15:30	9.0	3.0	1.2	-6.1	10.7	6.36	2
126	2	19-Feb-03	4:12:00	4:21:00	4:16:30	9.0	3.4	1.8	-6.1	10.7	6.36	2
127	2	19-Feb-03	4:20:30	4:30:30	4:25:30	10.0	3.4	1.9	-6.1	11.3	6.36	2
128	2	19-Feb-03	4:21:30	4:31:30	4:26:30	10.0	2.9	1.4	-6.0	11.4	6.36	2
129	2	19-Feb-03	4:31:00	4:41:00	4:36:00	10.0	0.4	0.0	-5.9	13.1	6.36	2
130	2	19-Feb-03	4:32:00	4:42:00	4:37:00	10.0	0.4	0.0	-5.9	13.1	6.36	2
131	2	19-Feb-03	4:41:30	4:51:30	4:46:30	10.0	0.3	0.0	-5.8	12.8	6.36	2
132	2	19-Feb-03	4:42:30	4:52:30	4:47:30	10.0	0.2	0.0	-5.8	12.8	6.36	2
133	2	19-Feb-03	4:52:00	5:02:00	4:57:00	10.0	1.0	0.0	-5.8	14.1	6.36	2
134	2	19-Feb-03	4:53:00	5:03:00	4:58:00	10.0	1.0	0.0	-5.8	14.1	6.36	2
135	2	19-Feb-03	5:02:30	5:12:30	5:07:30	10.0	0.0	0.0	-5.7	14.1	6.36	2
136	2	19-Feb-03	5:03:30	5:13:30	5:08:30	10.0	0.0	0.0	-5.7	14.3	6.36	2
137	1	22-Feb-03	16:28:00	16:38:00	16:33:00	10.0	15.8	0.0	-4.9	42.1	6.33	4
138	1	22-Feb-03	16:38:00	16:48:00	16:43:00	10.0	11.3	0.0	-5.0	43.9	6.33	4
139	1	22-Feb-03	16:48:00	16:58:00	16:53:00	10.0	15.4	0.0	-5.2	44.6	6.33	4
140	1	22-Feb-03	16:58:00	17:08:00	17:03:00	10.0	15.7	0.0	-5.5	46.5	6.33	4
141	1	22-Feb-03	17:08:00	17:18:00	17:13:00	10.0	12.6	0.0	-5.5	41.9	6.33	4
142	1	22-Feb-03	17:18:00	17:28:00	17:23:00	10.0	13.0	0.0	-5.6	39.4	6.33	4
143	1	22-Feb-03	17:28:00	17:38:00	17:33:00	10.0	7.7	0.0	-5.6	40.6	6.33	4
144	1	22-Feb-03	17:38:00	17:48:00	17:43:00	10.0	12.5	0.0	-5.8	45.6	6.33	4
145	1	22-Feb-03	17:48:00	17:58:00	17:53:00	10.0	15.9	0.0	-5.8	44.6	6.33	4
146	1	22-Feb-03	17:58:00	18:08:00	18:03:00	10.0	18.8	0.0	-6.0	46.6	6.33	4
147	1	22-Feb-03	18:08:00	18:18:00	18:13:00	10.0	18.6	9.1	-6.1	43.6	6.33	4
148	1	22-Feb-03	18:18:00	18:28:00	18:23:00	10.0	16.6	3.1	-6.3	46.3	6.33	4
149	1	22-Feb-03	18:28:00	18:38:00	18:33:00	10.0	16.1	0.0	-6.5	44.6	6.33	4
150	1	22-Feb-03	18:38:00	18:48:00	18:43:00	10.0	16.0	0.0	-6.5	43.4	6.33	4
151	2	22-Feb-03	21:38:00	21:48:00	21:43:00	10.0	11.7	0.0	-6.4	48.2	6.33	4

Table 3.1: Log of Tests Conducted During the 2002-03 Winter *(continued)*

Test Log

Test No.	Series No.	Date	Start Time	End Time	Midpoint	Test Duration (min)	Average Pan Rate (g/dm²/h)	Average Snow Gauge Rate (g/dm²/h)	OAT (ºC)	Wind Speed (km/h)	Set Point	No. of Pans
152	2	22-Feb-03	21:48:00	21:58:00	21:53:00	10.0	17.5	0.0	-6.4	48.3	6.33	4
153	2	22-Feb-03	21:58:00	22:08:00	22:03:00	10.0	19.9	0.0	-6.4	47.6	6.33	4
154	2	22-Feb-03	22:08:00	22:18:00	22:13:00	10.0	12.8	0.0	-6.3	47.8	6.33	4
155	2	22-Feb-03	22:18:00	22:28:00	22:23:00	10.0	24.2	16.9	-6.2	47.6	6.33	4
156	2	22-Feb-03	22:28:00	22:38:00	22:33:00	10.0	24.9	17.9	-6.3	47.1	6.33	4
157	2	22-Feb-03	22:38:00	22:48:00	22:43:00	10.0	23.1	0.0	-6.3	44.4	6.33	4
158	2	22-Feb-03	22:58:00	23:08:00	23:03:00	10.0	21.9	0.0	-6.4	47.7	6.33	4
159	2	22-Feb-03	23:08:00	23:18:00	23:13:00	10.0	17.5	0.0	-6.3	50.3	6.33	4
160	2	22-Feb-03	23:18:00	23:28:00	23:23:00	10.0	20.2	0.0	-6.2	52.0	6.33	4
161	2	22-Feb-03	23:28:00	23:38:00	23:33:00	10.0	12.5	0.0	-6.2	51.5	6.33	4
162	3	23-Feb-03	0:08:00	0:18:00	0:13:00	10.0	11.6	0.0	-6.1	48.2	6.36	4
163	3	23-Feb-03	0:18:00	0:28:00	0:23:00	10.0	34.8	0.0	-6.0	40.2	6.36	4
164	3	23-Feb-03	0:28:00	0:38:00	0:33:00	10.0	75.3	39.6	-6.1	45.3	6.36	4
165	3	23-Feb-03	0:38:00	0:48:00	0:43:00	10.0	63.4	44.8	-6.2	45.8	6.36	4
166	3	23-Feb-03	0:48:00	0:58:00	0:53:00	10.0	22.5	0.0	-6.2	47.1	6.36	4
167	3	23-Feb-03	0:58:00	1:08:00	1:03:00	10.0	10.6	0.0	-6.3	49.8	6.36	4
168	3	23-Feb-03	1:08:00	1:18:00	1:13:00	10.0	9.8	0.0	-6.3	48.0	6.36	4
169	3	23-Feb-03	1:18:00	1:28:00	1:23:00	10.0	15.5	0.0	-6.3	49.2	6.36	4
170	3	23-Feb-03	1:28:00	1:38:00	1:33:00	10.0	8.6	0.0	-6.3	48.5	6.36	4
171	3	23-Feb-03	1:38:00	1:48:00	1:43:00	10.0	8.3	0.0	-6.2	50.5	6.36	4
172	3	23-Feb-03	1:48:00	1:58:00	1:53:00	10.0	15.9	0.0	-6.3	49.3	6.36	4
173	3	23-Feb-03	1:58:00	2:08:00	2:03:00	10.0	34.4	0.0	-6.2	47.5	6.36	4
174	3	23-Feb-03	2:08:00	2:18:00	2:13:00	10.0	55.7	16.5	-6.2	49.3	6.36	4
175	1	23-Feb-03	13:41:00	13:51:01	13:46:01	10.0	2.1	0.0	-5.0	22.1	6.33	4
176	1	23-Feb-03	14:01:08	14:11:03	14:06:05	9.9	5.1	0.0	-4.8	22.1	6.33	4
177	1	23-Feb-03	14:11:05	14:21:02	14:16:03	9.9	8.3	0.0	-4.7	17.7	6.33	4
178	1	23-Feb-03	14:21:08	14:31:00	14:26:04	9.9	8.1	6.7	-4.7	16.2	6.33	4
179	1	23-Feb-03	14:42:01	15:00:00	14:51:00	18.0	3.7	0.0	-4.7	18.5	6.33	4
180	1	23-Feb-03	15:30:10	15:40:01	15:35:05	9.8	11.5	8.4	-4.1	11.3	6.33	4
181	1	23-Feb-03	15:40:01	15:50:01	15:45:01	10.0	10.7	11.3	-3.9	9.8	6.33	4
182	1	23-Feb-03	15:50:01	16:00:01	15:55:01	10.0	13.4	16.7	-3.8	11.3	6.33	4
183	1	23-Feb-03	16:00:01	16:10:01	16:05:01	10.0	16.0	16.9	-3.6	14.1	6.33	4
184	1	23-Feb-03	16:10:01	16:20:01	16:15:01	10.0	6.0	6.2	-3.6	13.8	6.33	4
185	1	23-Feb-03	16:20:01	16:30:02	16:25:02	10.0	0.0	0.0	-3.6	12.8	6.33	4
186	1	23-Feb-03	16:40:01	16:50:01	16:45:01	10.0	2.3	0.0	-3.8	23.9	6.33	4
187	1	23-Feb-03	17:00:00	17:10:00	17:05:00	10.0	8.7	5.4	-4.1	18.5	6.33	4
188	1	23-Feb-03	17:10:00	17:20:00	17:15:00	10.0	3.4	1.6	-4.3	19.9	6.33	4
189	1	2-Mar-03	8:03:28	8:26:00	8:14:44	22.5	25.6	33.8	0.2	17.8	6.33	2
190	1	2-Mar-03	8:27:10	8:45:20	8:36:15	18.2	20.2	26.9	0.3	14.9	6.33	2

Table 3.1: Log of Tests Conducted During the 2002-03 Winter *(continued)*

Test Log												
Test No.	**Series No.**	**Date**	**Start Time**	**End Time**	**Midpoint**	**Test Duration (min)**	**Average Pan Rate (g/dm²/h)**	**Average Snow Gauge Rate (g/dm²/h)**	**OAT (ºC)**	**Wind Speed (km/h)**	**Set Point**	**No. of Pans**
191	1	2-Mar-03	8:46:18	9:00:50	8:53:34	14.5	15.1	20.3	0.3	12.7	6.33	2
192	1	2-Mar-03	9:01:36	9:21:40	9:11:38	20.1	22.0	26.6	0.3	10.9	6.33	2
193	1	2-Mar-03	9:22:24	9:36:58	9:29:41	14.6	22.7	26.9	0.3	10.1	6.33	2
194	1	2-Mar-03	9:39:45	9:55:35	9:47:40	15.8	38.3	43.9	0.3	10.8	6.33	2
195	1	2-Mar-03	9:56:20	10:10:30	10:03:25	14.2	33.2	40.4	0.3	13.5	6.33	2
196	1	2-Mar-03	10:11:15	10:26:05	10:18:40	14.8	20.4	26.3	0.3	14.4	6.33	2
197	1	2-Mar-03	10:28:17	10:48:45	10:38:31	20.5	12.1	16.7	0.4	13.7	6.33	2
198	1	2-Mar-03	10:49:45	11:08:20	10:59:02	18.6	11.2	14.8	0.5	16.5	6.33	2
199	1	4-Mar-03	19:17:00	19:37:00	19:27:00	20.0	0.3	0.0	-8.4	8.2	6.33	2
200	1	4-Mar-03	20:27:00	20:44:00	20:35:30	17.0	2.9	2.1	-7.9	6.3	6.33	2
201	1	4-Mar-03	20:44:00	20:55:00	20:49:30	11.0	3.7	3.8	-7.8	4.8	6.33	2
202	1	4-Mar-03	20:55:00	21:05:00	21:00:00	10.0	5.6	6.5	-7.4	0.7	6.33	2
203	1	4-Mar-03	21:05:00	21:15:00	21:10:00	10.0	6.9	10.4	-7.3	0.0	6.33	2
204	1	4-Mar-03	21:16:00	21:26:00	21:21:00	10.0	5.8	8.8	-7.5	1.7	6.33	2
205	1	4-Mar-03	21:27:00	21:37:00	21:32:00	10.0	8.9	10.0	-7.5	5.2	6.33	2
206	1	4-Mar-03	21:38:00	21:48:00	21:43:00	10.0	4.2	4.4	-7.3	5.6	6.33	2
207	1	4-Mar-03	21:49:00	21:59:00	21:54:00	10.0	4.0	2.8	-7.1	3.5	6.33	2
208	1	4-Mar-03	22:00:00	22:10:00	22:05:00	10.0	7.9	8.8	-7.2	2.0	6.33	2
209	1	4-Mar-03	22:11:00	22:21:00	22:16:00	10.0	5.6	7.3	-7.4	0.7	6.33	2
210	1	4-Mar-03	22:22:00	22:32:00	22:27:00	10.0	9.8	11.9	-7.5	0.0	6.33	2
211	1	4-Mar-03	22:33:00	22:46:00	22:39:30	13.0	5.5	8.6	-7.3	0.0	6.33	2
212	1	4-Mar-03	22:47:00	22:57:00	22:52:00	10.0	5.2	7.9	-6.8	0.3	6.33	2
213	1	4-Mar-03	22:58:00	23:08:00	23:03:00	10.0	2.6	3.6	-6.6	0.9	6.33	2
214	1	4-Mar-03	23:09:00	23:19:00	23:14:00	10.0	6.1	6.3	-6.4	3.4	6.33	2
215	1	4-Mar-03	23:20:00	23:30:00	23:25:00	10.0	8.9	11.5	-6.2	0.7	6.33	2
216	1	4-Mar-03	23:31:00	23:41:00	23:36:00	10.0	7.5	9.8	-6.0	2.5	6.33	2
217	1	4-Mar-03	23:42:00	23:52:00	23:47:00	10.0	8.6	10.2	-6.3	2.4	6.33	2
218	1	4-Mar-03	23:53:00	0:03:00	23:58:00	10.0	6.8	7.3	-6.4	4.1	6.33	2
219	2	5-Mar-03	0:07:00	0:17:00	0:12:00	10.0	5.8	2.2	-6.4	4.5	6.33	2
220	2	5-Mar-03	0:18:00	0:28:00	0:23:00	10.0	6.8	4.5	-6.3	3.9	6.33	2
221	2	5-Mar-03	0:29:00	0:39:00	0:34:00	10.0	3.7	0.0	-6.3	5.4	6.33	2
222	2	5-Mar-03	0:40:00	0:50:00	0:45:00	10.0	3.0	0.0	-6.3	6.5	6.33	2
223	2	5-Mar-03	0:51:00	1:01:00	0:56:00	10.0	3.1	0.0	-6.5	9.6	6.33	2
224	2	5-Mar-03	1:02:00	1:12:00	1:07:00	10.0	4.4	0.0	-7.9	19.0	6.33	2
225	2	5-Mar-03	1:13:00	1:23:00	1:18:00	10.0	5.1	0.0	-8.9	20.2	6.33	2
226	2	5-Mar-03	1:24:00	1:34:00	1:29:00	10.0	3.6	0.0	-9.3	17.3	6.33	2
227	2	5-Mar-03	1:35:00	1:45:00	1:40:00	10.0	4.6	0.0	-9.2	15.3	6.33	2
228	2	5-Mar-03	1:46:00	1:55:00	1:50:30	9.0	6.1	0.0	-8.8	14.4	6.33	2
229	2	5-Mar-03	1:56:00	2:06:00	2:01:00	10.0	7.4	6.2	-7.8	13.8	6.33	2

Table 3.1: Log of Tests Conducted During the 2002-03 Winter *(continued)*

Test Log												
Test No.	Series No.	Date	Start Time	End Time	Midpoint	Test Duration (min)	Average Pan Rate (g/dm²/h)	Average Snow Gauge Rate (g/dm²/h)	OAT (ºC)	Wind Speed (km/h)	Set Point	No. of Pans
230	2	5-Mar-03	2:18:00	2:30:00	2:24:00	12.0	7.0	6.1	-8.0	12.1	6.33	2
231	2	5-Mar-03	2:31:00	2:53:00	2:42:00	22.0	4.4	0.2	-8.2	12.6	6.33	2
232	2	5-Mar-03	2:55:00	3:05:00	3:00:00	10.0	7.6	2.6	-8.2	14.8	6.33	2
233	2	5-Mar-03	3:06:00	3:24:00	3:15:00	18.0	6.1	0.3	-7.9	13.8	6.33	2
234	2	5-Mar-03	3:26:00	3:38:00	3:32:00	12.0	4.1	0.9	-7.5	10.8	6.33	2
235	2	5-Mar-03	3:39:00	3:53:00	3:46:00	14.0	2.8	0.0	-7.1	9.5	6.33	2
236	2	5-Mar-03	3:54:00	4:08:00	4:01:00	14.0	14.8	3.6	-8.2	22.8	6.33	2
237	2	5-Mar-03	4:09:00	4:32:00	4:20:30	23.0	8.4	0.0	-8.9	25.5	6.33	2
238	1	8-Mar-03	21:42:00	21:55:00	21:48:30	13.0	28.1	26.0	-1.7	11.6	6.33	2
239	1	8-Mar-03	21:57:00	22:07:00	22:02:00	10.0	20.6	24.7	-1.7	9.1	6.33	2
240	1	8-Mar-03	22:08:00	22:18:00	22:13:00	10.0	30.1	33.4	-1.6	8.3	6.33	2
241	1	8-Mar-03	22:19:00	22:29:00	22:24:00	10.0	29.8	30.4	-1.5	8.8	6.33	2
242	1	8-Mar-03	22:30:00	22:40:00	22:35:00	10.0	25.3	26.3	-1.5	6.4	6.33	2
243	1	8-Mar-03	22:41:00	22:52:00	22:46:30	11.0	21.5	22.4	-1.5	9.7	6.33	2
244	1	8-Mar-03	22:53:00	23:02:00	22:57:30	9.0	21.0	20.7	-1.5	12.0	6.33	2
245	1	8-Mar-03	23:05:00	23:15:00	23:10:00	10.0	9.6	8.7	-1.5	12.3	6.33	2
246	1	8-Mar-03	23:16:00	23:25:00	23:20:30	9.0	8.8	9.0	-1.6	13.1	6.33	2
247	1	8-Mar-03	23:26:00	23:31:00	23:28:30	5.0	14.4	15.0	-1.7	12.7	6.33	2
248	1	8-Mar-03	23:32:00	23:37:00	23:34:30	5.0	31.2	30.6	-1.7	11.1	6.33	2
249	1	8-Mar-03	23:38:00	23:43:00	23:40:30	5.0	32.7	31.8	-1.7	10.4	6.33	2
250	1	8-Mar-03	23:44:00	23:49:00	23:46:30	5.0	35.8	28.6	-1.9	12.0	6.33	2
251	1	8-Mar-03	23:50:00	23:55:00	23:52:30	5.0	35.2	28.2	-1.9	12.4	6.33	2
252	1	8-Mar-03	23:56:00	0:01:00	11:58:30	5.0	37.4	30.6	-2.0	13.9	6.33	2
253	2	9-Mar-03	0:02:00	0:10:00	0:06:00	8.0	31.7	19.6	-2.0	16.5	6.33	2
254	2	9-Mar-03	0:11:00	0:17:00	0:14:00	6.0	31.3	22.5	-2.1	16.4	6.33	2
255	2	9-Mar-03	0:18:00	0:26:00	0:22:00	8.0	26.7	18.1	-2.1	17.3	6.33	2
256	2	9-Mar-03	0:27:00	0:33:00	0:30:00	6.0	24.1	11.8	-2.4	17.7	6.33	2
257	2	9-Mar-03	0:39:00	0:46:00	0:42:30	7.0	22.0	10.0	-2.4	19.5	6.33	2
258	2	9-Mar-03	0:47:00	0:55:00	0:51:00	8.0	28.1	13.8	-2.5	18.5	6.33	2
259	2	9-Mar-03	0:56:00	1:02:00	0:59:00	6.0	31.3	16.7	-2.5	18.5	6.33	2
260	2	9-Mar-03	1:03:00	1:13:00	1:08:00	10.0	22.8	11.3	-2.5	20.2	6.33	2
261	2	9-Mar-03	1:14:00	1:20:00	1:17:00	6.0	20.7	12.5	-2.5	18.5	6.33	2
262	2	9-Mar-03	1:21:00	1:28:00	1:24:30	7.0	15.7	7.9	-2.4	17.8	6.33	2
263	2	9-Mar-03	1:29:00	1:37:00	1:33:00	8.0	13.0	8.0	-2.4	15.8	6.33	2
264	2	9-Mar-03	1:38:00	1:46:00	1:42:00	8.0	10.8	3.4	-2.4	15.4	6.33	2
265	2	9-Mar-03	1:47:00	1:58:00	1:52:30	11.0	9.6	8.0	-2.3	14.5	6.33	2
266	2	9-Mar-03	1:54:00	2:07:00	2:00:30	13.0	5.7	6.8	-2.3	13.3	6.33	2
267	2	9-Mar-03	2:08:00	2:15:00	2:11:30	7.0	9.5	5.9	-2.2	10.9	6.33	2
268	2	9-Mar-03	2:17:00	2:22:00	2:19:30	5.0	8.8	8.2	-2.3	11.7	6.33	2

Table 3.1: Log of Tests Conducted During the 2002-03 Winter *(continued)*

Test Log												
Test No.	**Series No.**	**Date**	**Start Time**	**End Time**	**Midpoint**	**Test Duration (min)**	**Average Pan Rate (g/dm^2/h)**	**Average Snow Gauge Rate (g/dm^2/h)**	**OAT (ºC)**	**Wind Speed (km/h)**	**Set Point**	**No. of Pans**
269	2	9-Mar-03	2:23:00	2:31:00	2:27:00	8.0	6.1	3.6	-2.4	11.9	6.33	2
270	2	9-Mar-03	2:32:00	2:39:00	2:35:30	7.0	2.9	0.0	-2.3	11.4	6.33	2
271	1	5-Apr-03	4:44:00	4:54:00	4:49:00	10.0	7.8	1.8	-3.0	24.0	6.30	2
272	1	5-Apr-03	4:55:00	5:07:00	5:01:00	12.0	8.1	2.4	-4.4	24.0	6.30	2
273	1	5-Apr-03	5:08:00	5:18:00	5:13:00	10.0	7.3	1.4	-4.4	24.0	6.30	2
274	1	5-Apr-03	5:19:00	5:29:00	5:24:00	10.0	5.5	0.0	-4.4	24.0	6.30	2
275	1	5-Apr-03	5:30:00	5:40:00	5:35:00	10.0	4.1	0.0	-4.4	24.0	6.30	2
276	1	5-Apr-03	5:41:00	6:01:00	5:51:00	20.0	4.0	0.0	-4.4	24.0	6.30	2
277	1	5-Apr-03	6:02:00	6:21:00	6:11:30	19.0	5.4	0.0	-4.3	26.0	6.30	2
278	1	5-Apr-03	6:22:00	6:42:00	6:32:00	20.0	6.8	0.0	-4.3	26.0	6.30	2
279	1	5-Apr-03	6:43:00	7:03:00	6:53:00	20.0	9.5	0.0	-4.3	26.0	6.30	2
280	1	5-Apr-03	7:04:00	7:20:00	7:12:00	16.0	9.4	0.0	-4.4	31.0	6.30	2
281	1	5-Apr-03	7:21:00	7:42:00	7:31:30	21.0	9.7	2.1	-4.4	31.0	6.30	2
282	2	5-Apr-03	8:02:00	8:11:00	8:06:30	9.0	15.7	7.8	-4.4	33.0	6.27	2
283	2	5-Apr-03	8:12:00	8:18:00	8:15:00	6.0	22.9	19.0	-4.4	33.0	6.27	2
284	2	5-Apr-03	8:19:00	8:23:00	8:21:00	4.0	24.4	18.6	-4.4	33.0	6.27	2
285	2	5-Apr-03	8:24:00	8:31:00	8:27:30	7.0	22.6	17.1	-4.4	33.0	6.27	2
286	2	5-Apr-03	8:32:00	8:39:00	8:35:30	7.0	20.4	6.0	-4.4	33.0	6.27	2
287	2	5-Apr-03	8:40:00	8:46:00	8:43:00	6.0	14.9	4.6	-4.4	33.0	6.27	2
288	2	5-Apr-03	8:47:00	8:54:00	8:50:30	7.0	14.4	6.8	-4.4	33.0	6.27	2
289	2	5-Apr-03	8:55:00	9:05:00	9:00:00	10.0	7.7	0.0	-3.7	28.0	6.27	2
290	2	5-Apr-03	9:06:00	9:16:00	9:11:00	10.0	6.4	0.0	-3.7	28.0	6.27	2
291	2	5-Apr-03	9:30:00	9:40:00	9:35:00	10.0	14.9	12.0	-3.7	28.0	6.27	2
292	2	5-Apr-03	9:41:00	9:49:00	9:45:00	8.0	16.0	17.6	-3.7	28.0	6.27	2
293	2	5-Apr-03	9:50:00	9:55:00	9:52:30	5.0	14.5	9.3	-3.7	28.0	6.27	2
294	2	5-Apr-03	9:56:00	10:06:00	10:01:00	10.0	15.3	9.5	-3.4	26.0	6.27	2
295	2	5-Apr-03	10:07:00	10:18:00	10:12:30	11.0	10.6	2.7	-3.4	26.0	6.27	2
296	2	5-Apr-03	10:19:00	10:25:00	10:22:00	6.0	16.8	4.6	-3.4	26.0	6.27	2

3.2.1 Session Log

During the winter of 2002-03, 296 tests were conducted during 11 snow events. A summary of the data collected for each snowfall is presented in Table 3.2.

Table 3.2: Log of Data Collected During Each Snow Event

Session Log							
Date	**No. of Tests**	**No. of Series**	**Set Point**	**OAT (°C)**	**Wind Speed (km/h)**	**Average Pan Rate ($g/dm^2/h$)**	**Average Snow Gauge Rate ($g/dm^2/h$)**
January 7-8, 2003	31	1	6.36	-5.3 to -7.1	12.0 to 19.5	0.2 to 36.4	0 to 30.9
January 26, 2003	32	1	6.36	-4.9 to -5.6	8.8 to 21.5	0.5 to 5.5	0 to 1.8
February 4, 2003	28	1	6.36	0.4 to -2.6	17.6 to 27.9	4.0 to 44.3	0 to 58.8
February 10, 2003	11	1	6.36	-4.8 to -10.1	5.6 to 34.8	0 to 3.7	0
February 19, 2003	34	2	6.33	-5.7 to -11.0	3.2 to 14.3	0 to 3.4	0 to 2.2
February 22-23, 2003	38	3	6.33 (Run #1, #2) 6.36 (Run #3)	-4.9 to -6.5	39.4 to 52.0	7.7 to 75.3	0 to 44.8
February 23, 2003	14	1	6.33	-3.6 to -5.0	9.8 to 23.4	0 to 16	0 to 16.9
March 2, 2003	10	1	6.33	0.5 to 0.2	10.1 to 17.8	11.2 to 38.3	14.8 to 43.9
March 4-5, 2003	39	2	6.33	-6.0 to -9.3	0 to 22.8	0.3 to 14.8	0 to 11.9
March 8-9, 2003	33	2	6.33	-1.5 to -2.5	6.4 to 20.2	2.9 to 37.4	0 to 33.4
April 5, 2003	27	2	6.30 (Run #1) 6.27 (Run #2)	-3.0 to -4.4	24 to 33	4.0 to 24.4	0 to 19.0

3.3 Description of Data Collected and Analysis Methodology

Testing of the hot plate snow gauge was conducted under conditions of natural snow precipitation at the APS Dorval Airport test site. During the 11 snow events, precipitation rates were collected using precipitation rate pans, and then compared to the hot plate snow gauge output to assess the differences. The data collected is discussed below.

3.3.1 Determination of Hot Plate Snow Gauge Rate

The hot plate snow gauge produces an instantaneous time stamped record every 60 seconds. The output maintains the following format:

```
T,SSSSSSSSSS,VVVVV,RR.R,AAA.A,PPP.P,bBB.B,dDD.D,CCC,NN.NN,FF.FF,tTT,mMM,WW.W<CR>
```

Each upper case letter is a character or digit, and each lower case letter is either a digit or a minus, '-', sign. Complete specifications are provided in Appendix C.

Two output parameters were analyzed.

One, the time stamp, denoted by SSSSSSSSSS, was recorded in Coordinated Universal Time (UTC) every 60 seconds and converted to local time. The local time was corrected to obtain the midpoint reading at the 30th second.

The second output parameter analyzed was the rate of precipitation. This rate was denoted by the letters RR.R and was measured in units of mm/h. When imperial units were used, the precipitation rate was denoted by R.RR and measured in units of in./h. The recorded value was an instantaneous average of the last 60 seconds of sampling. The value recorded was manually converted to g/dm²/h.

3.3.2 Calculation of Precipitation Pan Rate

The precipitation rates obtained from the precipitation pans were measured over varying intervals of time. The surface area of the pan exposed to precipitation was calculated to be 12.9 dm². The increase in weight of the precipitation pan (measured in grams) and the time interval (measured in minutes) were used to calculate the rate of precipitation (calculated in g/dm²/h) with Equation 1:

$$\text{Rate of Precipitation} = (\Delta\text{weight} * 60) / (12.9 * \Delta\text{time}) \qquad (1)$$

During trials where two simultaneous pan rates were measured (tests 137 to 296), the average of the two measured rates was calculated. The midpoint of the time interval was determined by halving the total time the precipitation pan was exposed.

3.3.3 Method of Calculation

To evaluate the strength of the correlation between the hot plate snow gauge data and the data collected from the precipitation pans, the calculated average rates were compared. An example of the method for calculation is demonstrated in Table 3.3, which contains a set of minute-by-minute data points also shown in Figure 3.1 as triangles. The precipitation pan was exposed for 17 minutes; therefore, the average of 17 hot plate snow gauge readings was calculated. An average was taken of the hot plate snow gauge rates recorded during the designated time interval, these are shown as solid triangles in Figure 3.1. The snow gauge average rate was compared to the average precipitation pan rate to assess deviations.

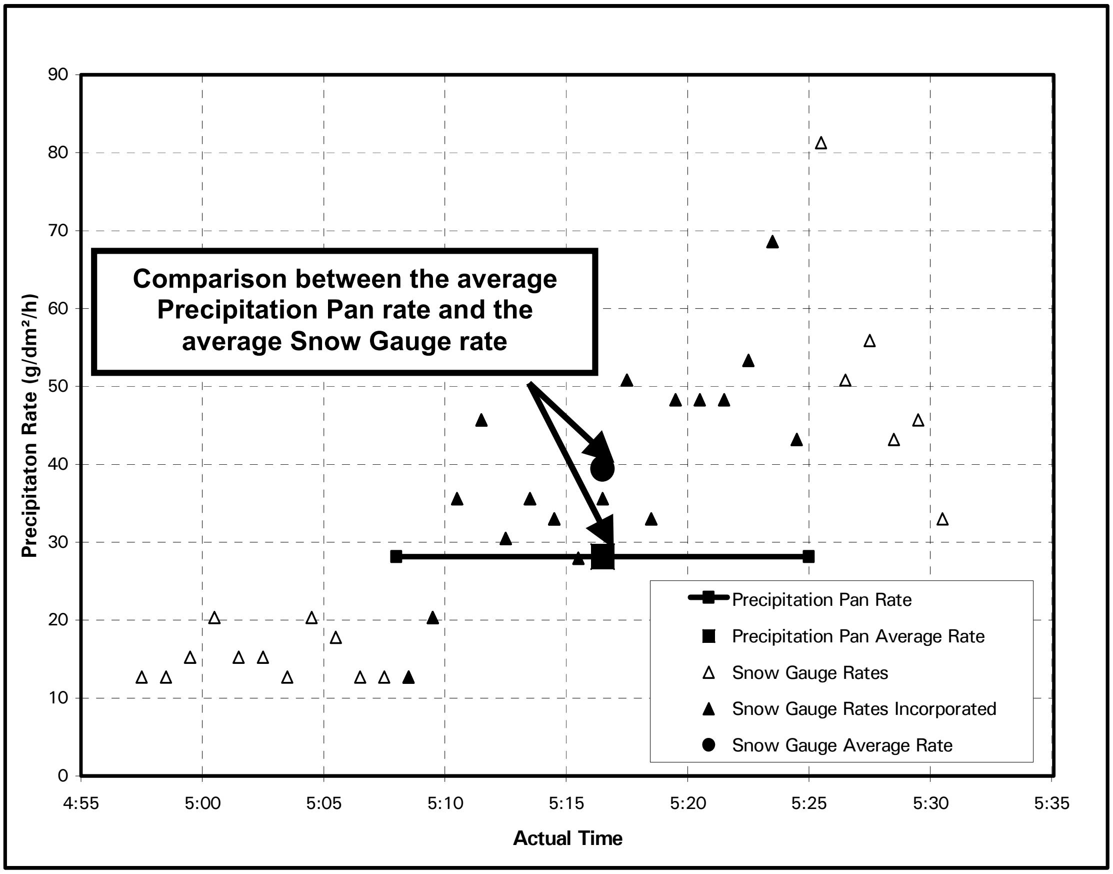

Figure 3.1: Graphical Example of the Method for Calculation (February 4, 2003)

Table 3.3: Tabular Example of the Method for Calculation (February 4, 2003)

Precipitation Pan				Snow Gauge		
Plotted Time (Midpoint)	Start Time	End Time	Average Pan Rate (g/dm²/h)	Snow Gauge Corrected Time	Snow Gauge Instantaneous Rate (g/dm²/h)	Snow Gauge Average Rate (g/dm²/h)
5:07:30	4:57:00	5:18:00	24.0	4:57:30	12.7	23.6
				4:58:30	12.7	
				4:59:30	15.2	
				5:00:30	20.3	
				5:01:30	15.2	
				5:02:30	15.2	
				5:03:30	12.7	
				5:04:30	20.3	
				5:05:30	17.8	
				5:06:30	12.7	
				5:07:30	12.7	
				5:08:30	12.7	
				5:09:30	20.3	
				5:10:30	35.6	
				5:11:30	45.7	
				5:12:30	30.5	
				5:13:30	35.6	
				5:14:30	33.0	
				5:15:30	27.9	
				5:16:30	35.6	
				5:17:30	50.8	
5:16:30	5:08:00	5:25:00	**28.1**	5:08:30	12.7	**39.4**
				5:09:30	20.3	
				5:10:30	35.6	
				5:11:30	45.7	
				5:12:30	30.5	
				5:13:30	35.6	
				5:14:30	33.0	
				5:15:30	27.9	
				5:16:30	35.6	
				5:17:30	50.8	
				5:18:30	33.0	
				5:19:30	48.3	
				5:20:30	48.3	
				5:21:30	48.3	
				5:22:30	53.3	
				5:23:30	68.6	
				5:24:30	43.2	
5:25:30	5:20:00	5:31:00	33.8	5:20:30	48.3	52.0
				5:21:30	48.3	
				5:22:30	53.3	
				5:23:30	68.6	
				5:24:30	43.2	

Comparison between the average Precipitation Pan rate and the average Snow Gauge rate.

3.4 Omitted Data

Some of the data collected during the test sessions were omitted due to at least one of the following reasons:

a) The hot plate snow gauge was recording during a period when manual precipitation rates were not being measured;

b) The hot plate snow gauge stopped logging during a run, which resulted in a lack of data; and

c) While using two simultaneous precipitation pans, the difference between the rates calculated was greater than 25 percent. This occurred on less than 10 percent of the total data set.

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4. DATA ANALYSIS AND OBSERVATIONS

In this section, the data collected for each trial is analysed and discussed. For each test, the average rate produced by the hot plate snow gauge is compared to the average rate measured by the precipitation pan. The following criteria are considered:

Precipitation Rate

a) Very Light Snow	<4 g/dm²/h
b) Light	4 to 10 g/dm²/h
c) Moderate	10 to 25 g/dm²/h
d) Heavy	>25 g/dm²/h

Wind Speed

a) Low	<9 km/h
b) Moderate	9 to 28 km/h
c) High	>28 km/h

4.1 General Observations

Comparative analyses of the measured precipitation rates were performed for each series of tests and are demonstrated in Figures 4.1 to 4.17. Adjacent pairs of bars represent the precipitation rate (measured in g/dm²/h) recorded by the hot plate snow gauge and by the precipitation pans. Each circle corresponding to a pair of bars represents the wind speed (measured in km/h) during that test. The results obtained for each series of tests performed are described in Sections 4.1.1 to 4.1.17.

4.1.1 January 7-8, 2003, Series #1 (Figure 4.1)

In conditions of light-to-moderate precipitation and moderate winds, the hot plate snow gauge recorded a rate higher than the measured precipitation pan rate for 23 of the 31 tests preformed. During three tests, the hot plate snow gauge failed to detect any precipitation.

4.1.2 January 26, 2003, Series #1 (Figure 4.2)

In conditions of light precipitation and moderate winds, the hot plate snow gauge failed to detect any precipitation during 28 of the 32 tests performed. During the four cases where the hot plate snow gauge did record precipitation, the rate registered was lower than the rate measured by the precipitation pan.

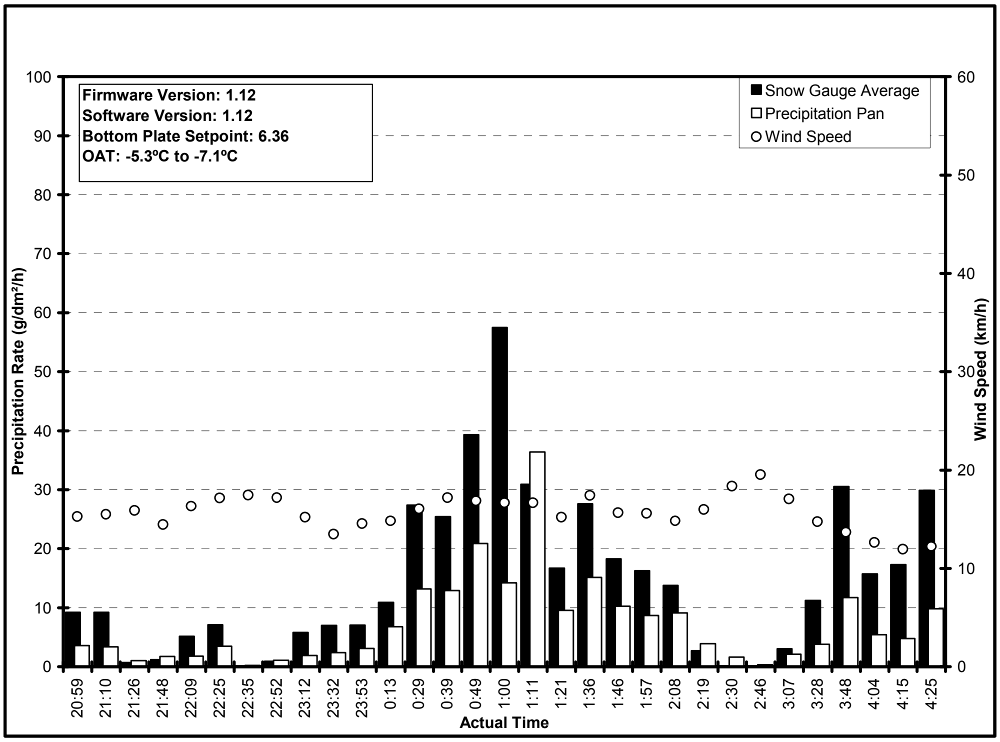


Figure 4.1: Comparison of Hot Plate Snow Gauge and Precipitation Pan, January 7-8, 2003, Series #1

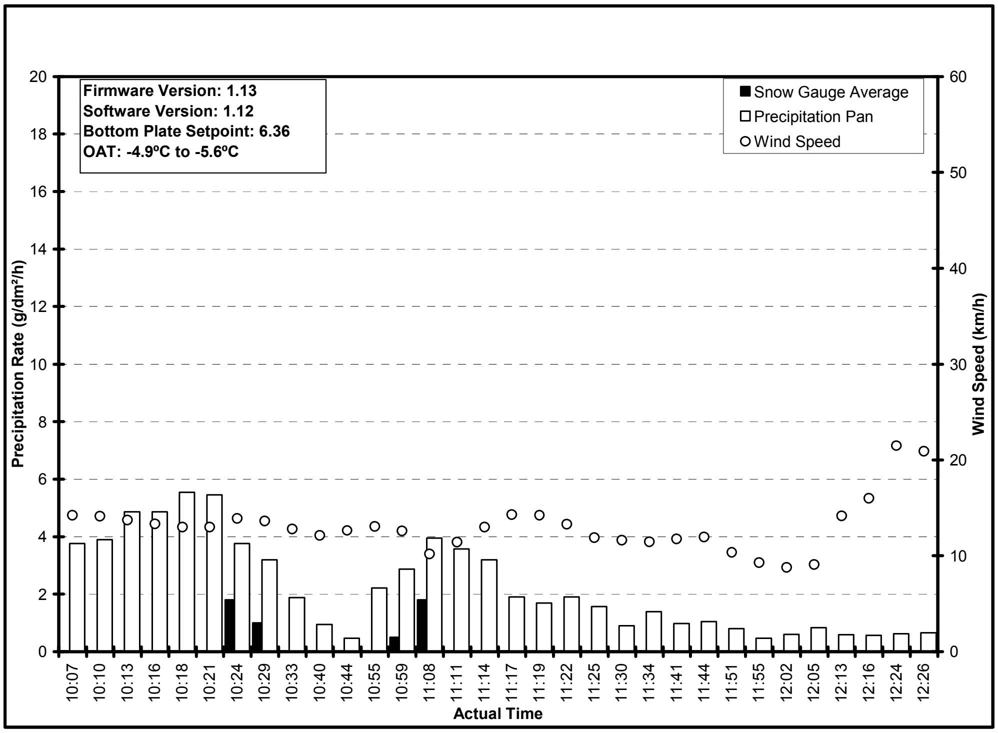


Figure 4.2: Comparison of Hot Plate Snow Gauge and Precipitation Pan, January 26, 2003, Series #1

4.1.3 February 4, 2003, Series #1 (Figure 4.3)

In conditions of light-to-heavy precipitation and moderate winds, the hot plate snow gauge recorded a rate higher than the measured precipitation rate for 23 of the 28 tests performed. During one test, the hot plate snow gauge failed to detect any precipitation.

4.1.4 February 10, 2003, Series #1 (Figure 4.4)

In conditions of light precipitation, and moderate-to-high winds, the hot plate snow gauge failed to detect any precipitation for the duration of the tests.

4.1.5 February 19, 2003, Series #1 (Figure 4.5)

In conditions of light precipitation and low-to-moderate winds, the hot plate snow gauge failed to detect any precipitation for 12 of the 20 tests. During the tests where the hot plate snow gauge did record precipitation, the rate registered was higher than that measured by the precipitation pan.

4.1.6 February 19, 2003, Series #2 (Figure 4.6)

In conditions of light precipitation and moderate winds, the hot plate snow gauge failed to detect any precipitation for 10 of the 14 tests. When the hot plate snow gauge did record precipitation, the rate registered was lower than the rate measured by the precipitation pan.

4.1.7 February 22-23, 2003, Series #1 (Figure 4.7)

In conditions of light-to-moderate precipitation and high winds, the hot plate snow gauge failed to detect any precipitation for 12 of the 14 tests. During the two tests where the hot plate snow gauge did record precipitation, the rate registered was lower than that measured by the precipitation pan.

4.1.8 February 22-23, 2003, Series #2 (Figure 4.8)

In conditions of moderate precipitation and high winds, the hot plate snow gauge failed to detect any precipitation for 9 of the 11 tests. During the two tests where the hot plate snow gauge did record precipitation, the rate registered was lower than that measured by the precipitation pan.

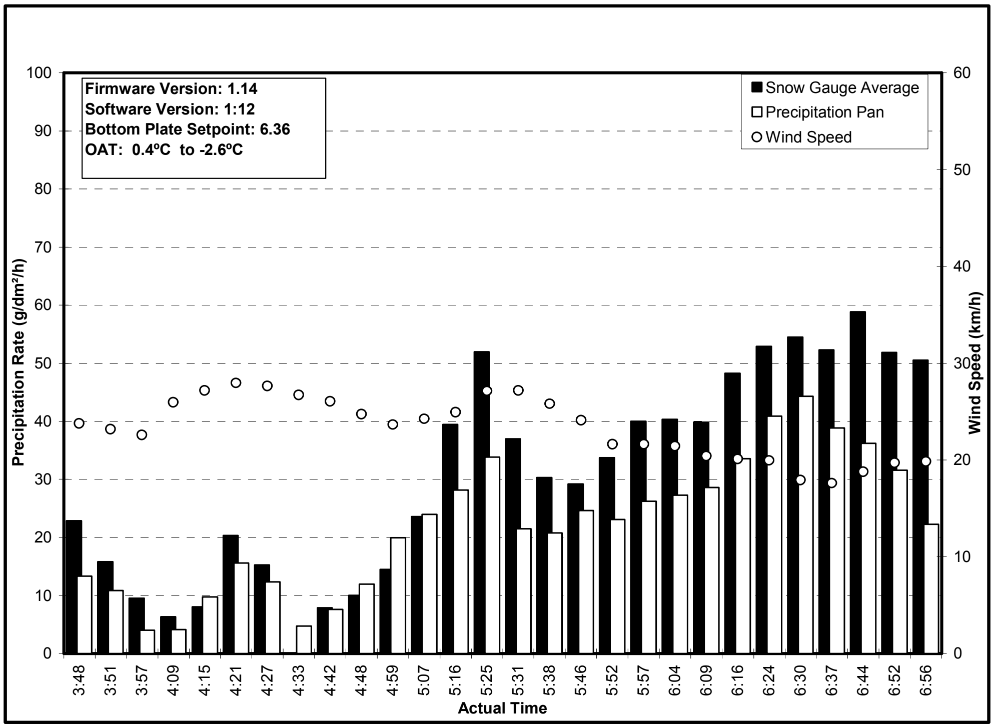


Figure 4.3: Comparison of Hot Plate Snow Gauge and Precipitation Pan, February 4, 2003, Series #1

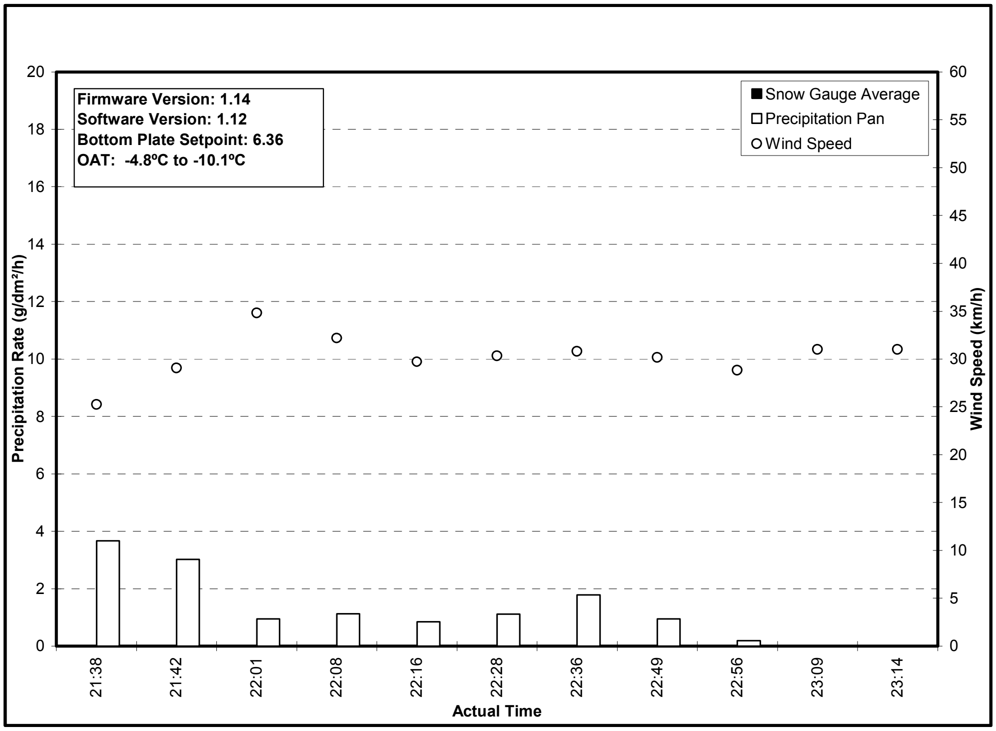


Figure 4.4: Comparison of Hot Plate Snow Gauge and Precipitation Pan, February 10, 2003, Series #1

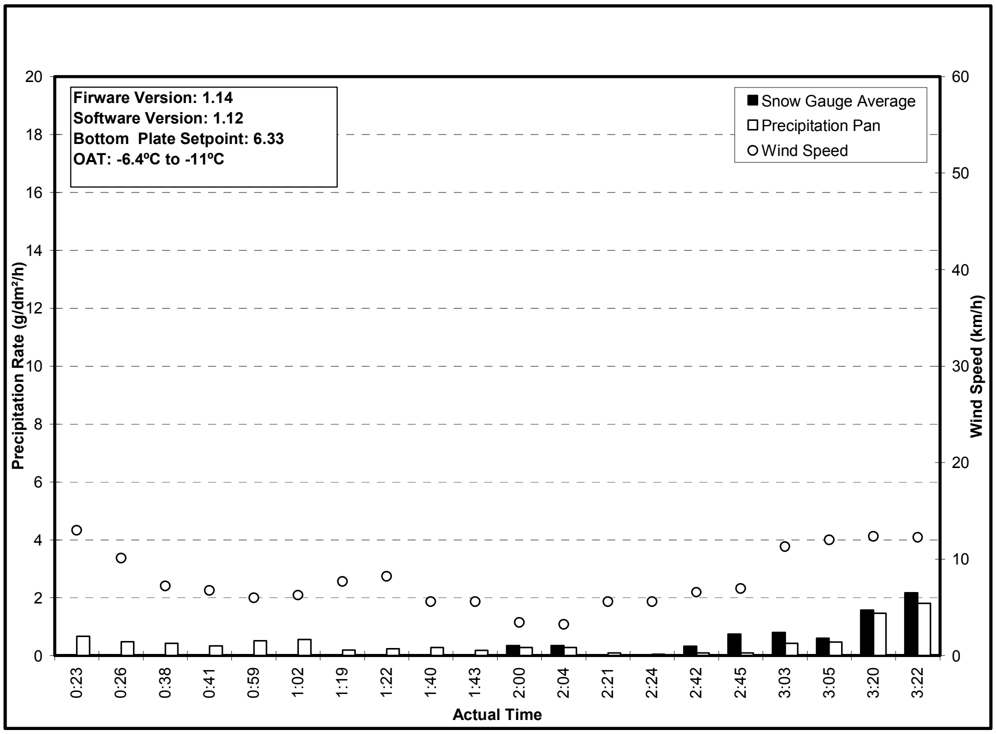


Figure 4.5: Comparison of Hot Plate Snow Gauge and Precipitation Pan, February 19, 2003, Series #1

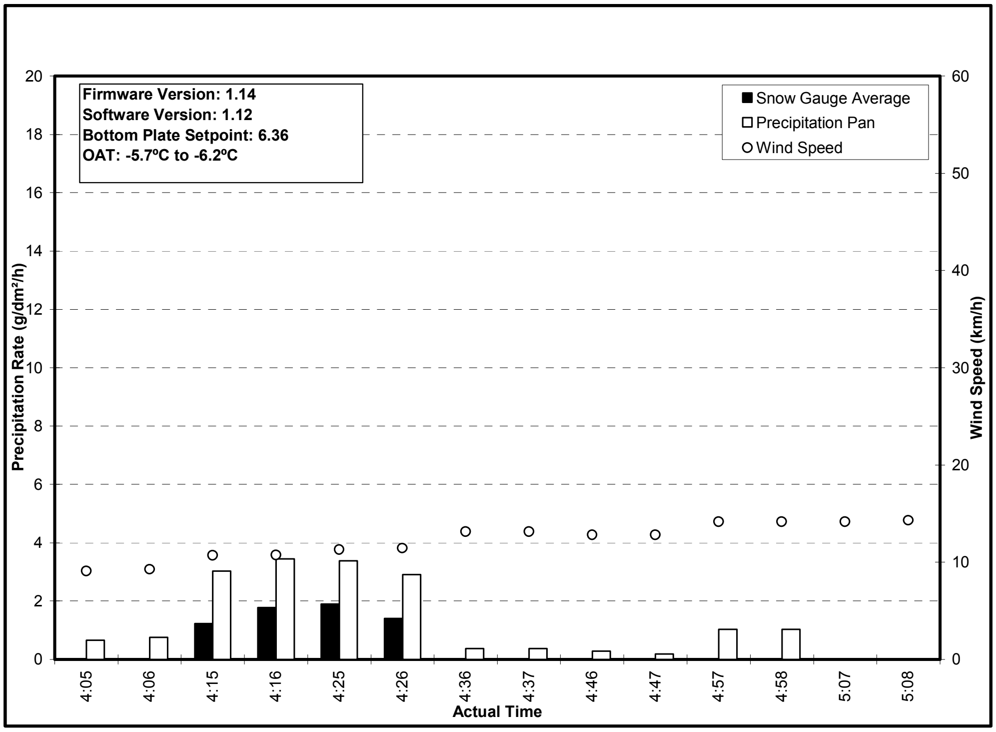


Figure 4.6: Comparison of Hot Plate Snow Gauge and Precipitation Pan, February 19, 2003, Series #2

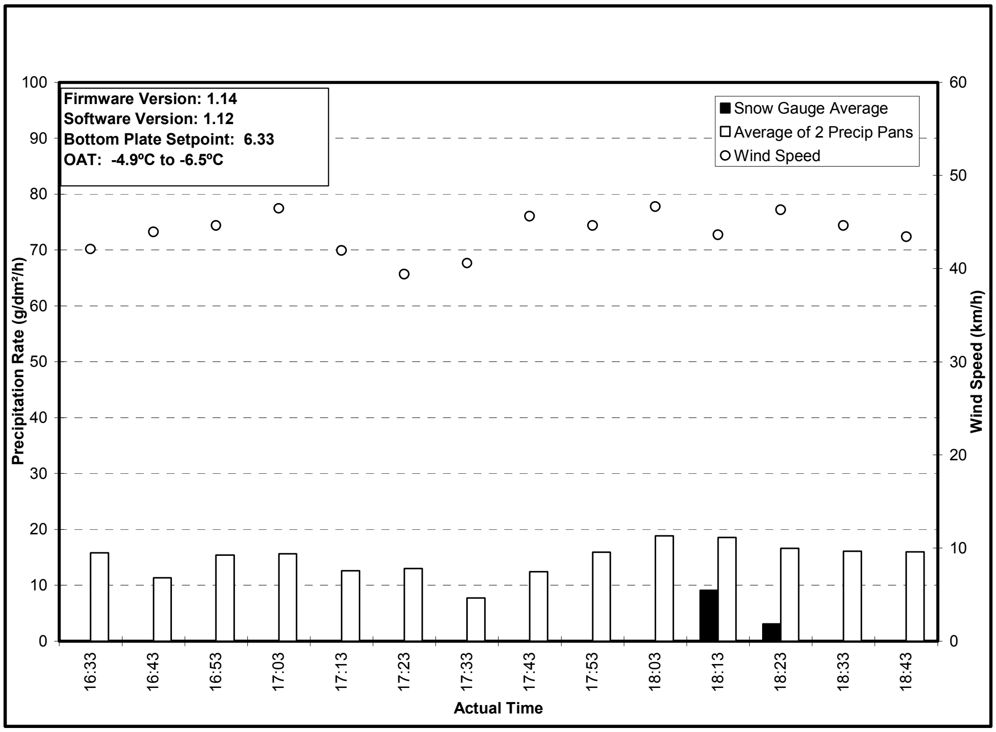


Figure 4.7: Comparison of Hot Plate Snow Gauge and Precipitation Pan, February 22-23, 2003, Series #1

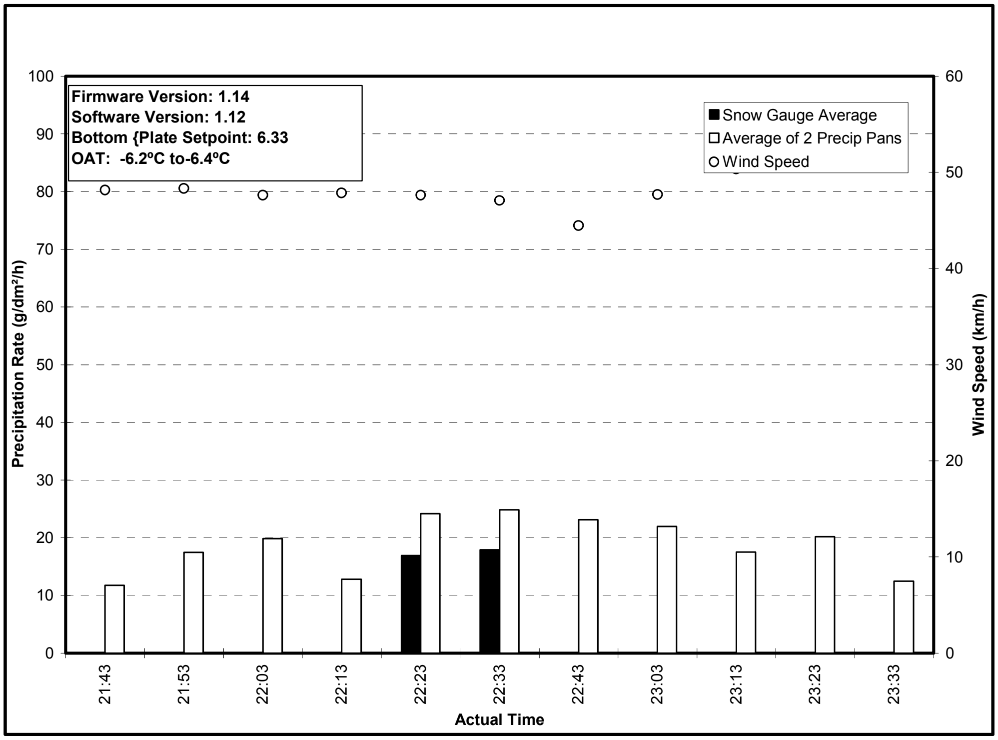


Figure 4.8: Comparison of Hot Plate Snow Gauge and Precipitation Pan, February 22-23, 2003, Series #2

4.1.9 February 22-23, 2003, Series #3 (Figure 4.9)

At 00:00 on February 23, the precipitation changed from snow to snow pellets and therefore the rate of precipitation increased. In these conditions of light-to-heavy precipitation and high winds, the hot plate snow gauge failed to detect any precipitation for 11 of the 14 tests. During the three tests where the hot plate snow gauge did record precipitation, the rate registered was lower than that measured by the precipitation pan.

4.1.10 February 23, 2003, Series #1 (Figure 4.10)

In conditions of light-to-moderate precipitation and moderate winds, the hot plate snow gauge failed to detect any precipitation for 5 of the 13 tests. During the tests where the hot plate snow gauge did record precipitation, the rates registered were inconsistently higher or lower than those measured by the precipitation pan.

4.1.11 March 2, 2003, Series #1 (Figure 4.11)

In conditions of moderate-to-heavy precipitation and moderate winds, the hot plate snow gauge recorded a rate that was consistently higher than the rate measured by the precipitation pan.

4.1.12 March 4-5, 2003, Series #1 (Figure 4.12)

In conditions of light precipitation and low winds, the hot plate snow gauge recorded a rate higher than the rate measured by the precipitation pan for 17 of the 20 tests. During one test, the hot plate snow gauge failed to detect any precipitation.

4.1.13 March 4-5, 2003, Series #2 (Figure 4.13)

In conditions of light precipitation and low-to-moderate winds, the hot plate snow gauge failed to detect any precipitation for 10 of the 19 tests. During the tests where the hot plate snow gauge did record precipitation, the rate registered was lower than that measured by the precipitation pan.

4.1.14 March 8-9, Series #1 (Figure 4.14)

In conditions of light-to-moderate precipitation and low-to-moderate winds, the hot plate snow gauge recorded a rate lower than that obtained from the precipitation pan rate for 9 of the 15 tests.

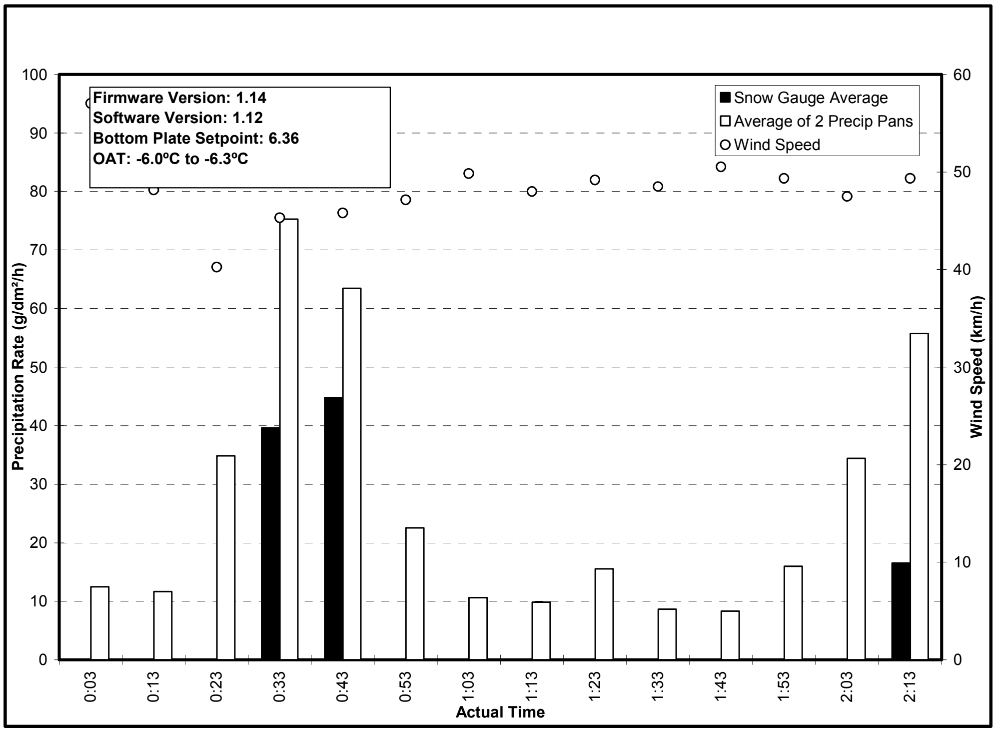


Figure 4.9: Comparison of Hot Plate Snow Gauge and Precipitation Pan, February 22-23, 2003, Series #3

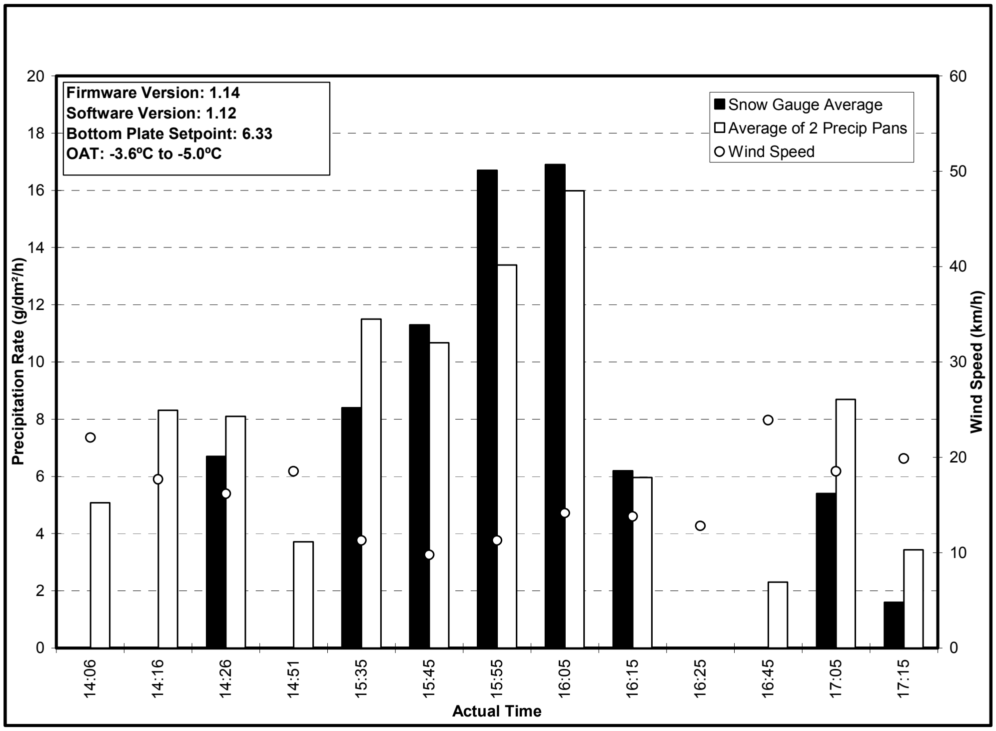


Figure 4.10: Comparison of Hot Plate Snow Gauge and Precipitation Pan, February 23, 2003, Series #1

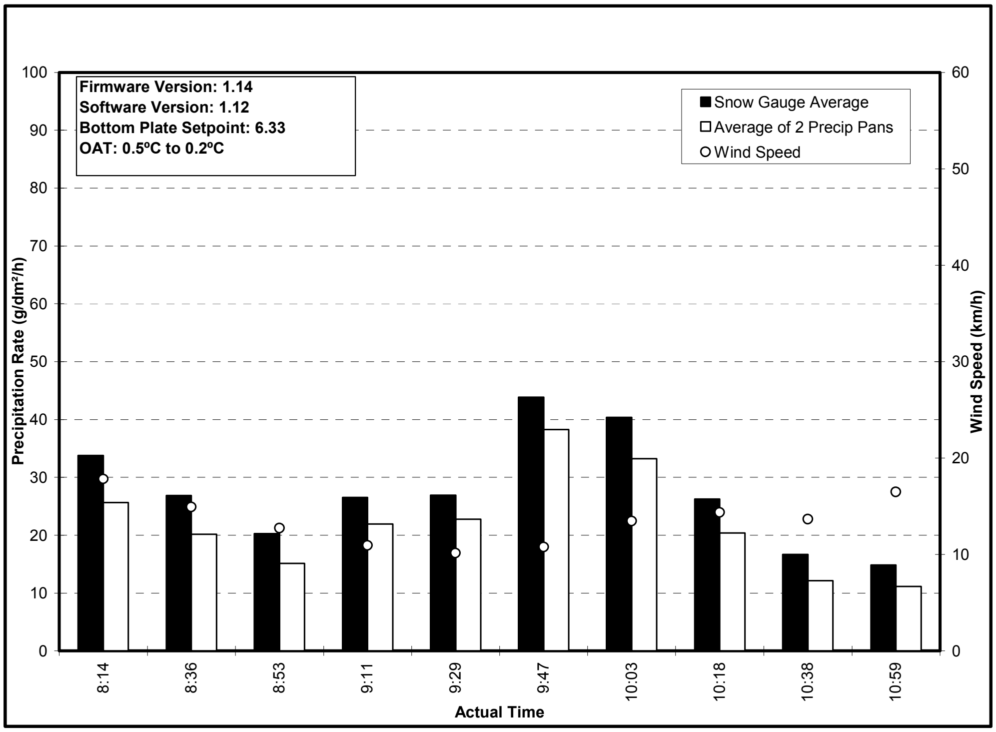


Figure 4.11: Comparison of Hot Plate Snow Gauge and Precipitation Pan, March 2, 2003, Series #1

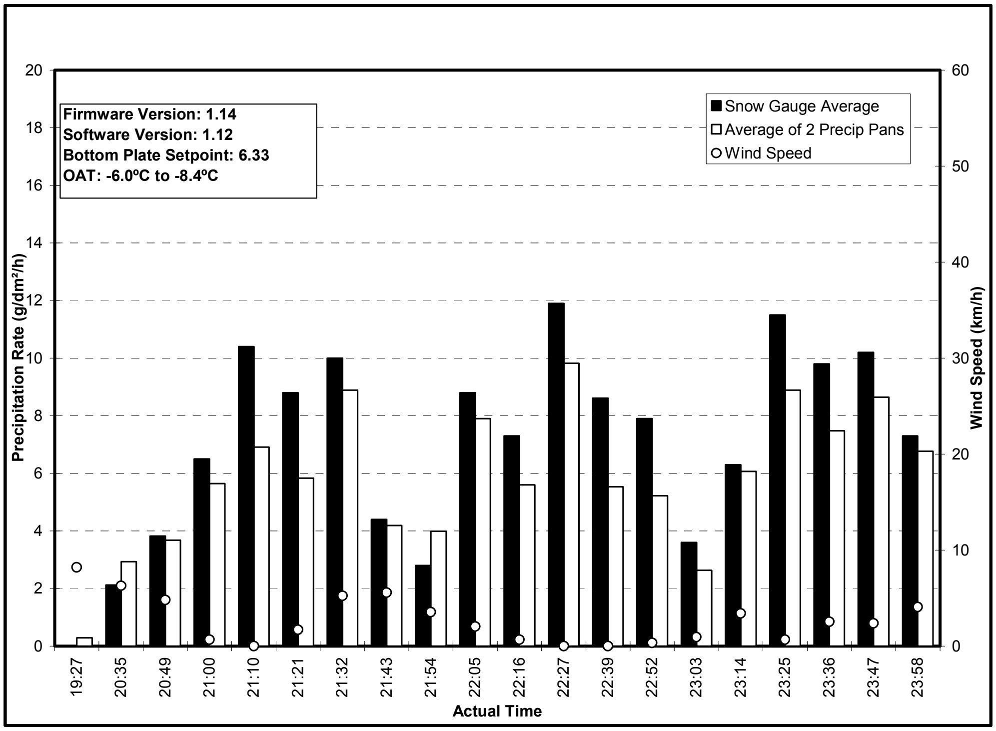


Figure 4.12: Comparison of Hot Plate Snow Gauge and Precipitation Pan, March 4-5, 2003, Series #1

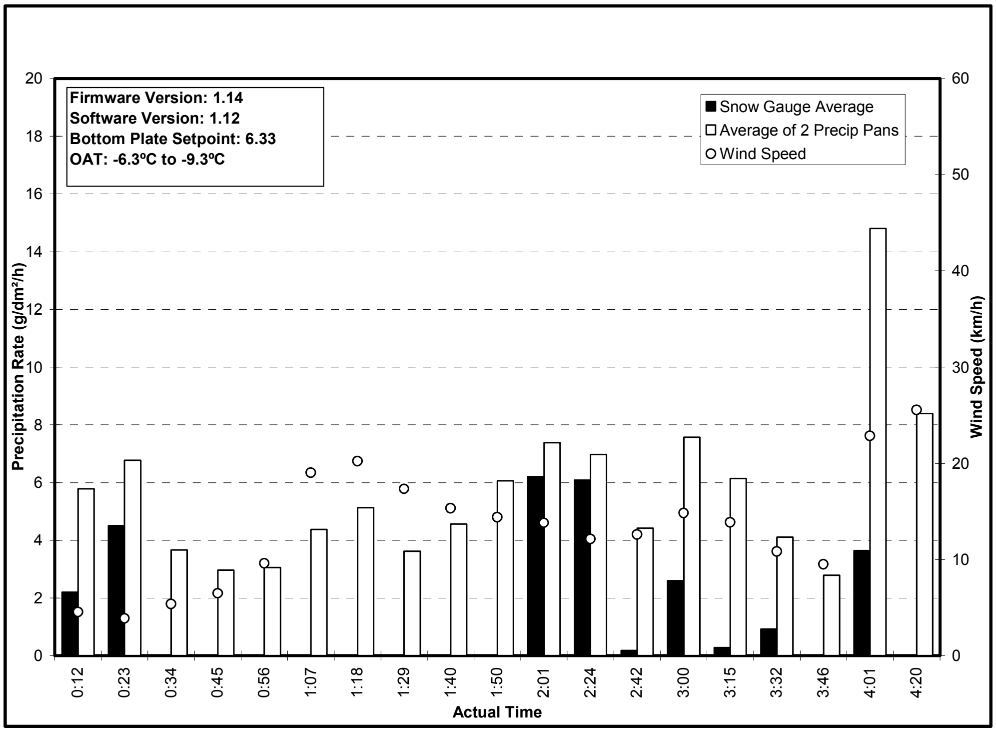


Figure 4.13: Comparison of Hot Plate Snow Gauge and Precipitation Pan, March 4-5, 2003, Series #2

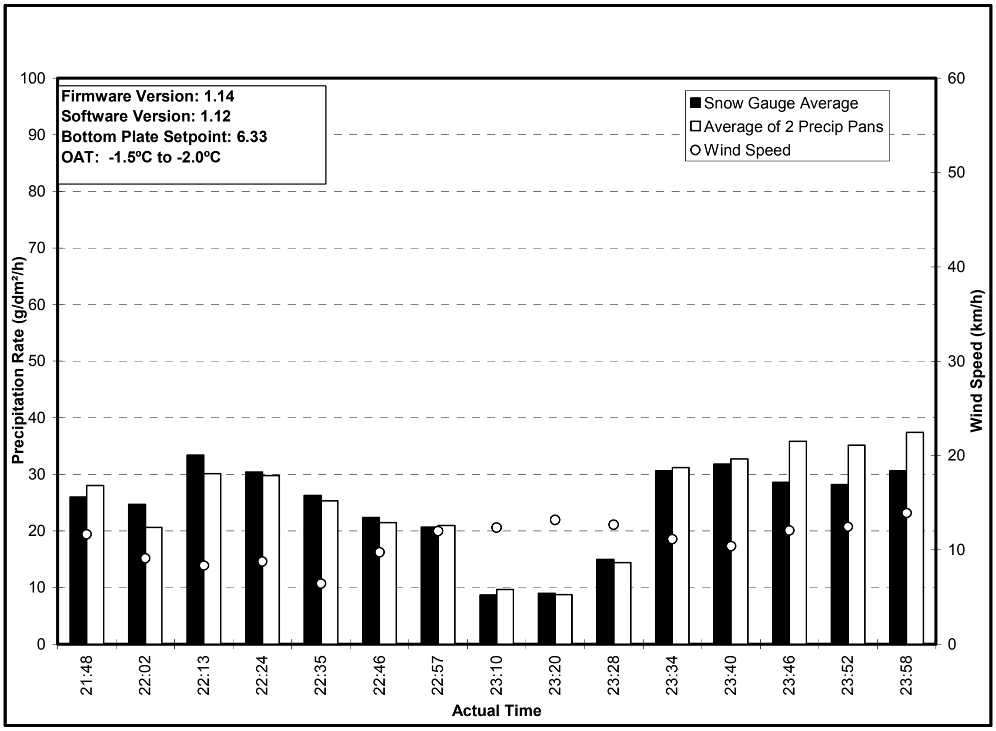


Figure 4.14: Comparison of Hot Plate Snow Gauge and Precipitation Pan, March 8-9, 2003, Series #1

4.1.15 March 8-9, 2003, Series #2 (Figure 4.15)

In conditions of light-to-heavy precipitation and moderate winds, the hot plate snow gauge recorded a rate lower than the rate measured by the precipitation pan for 16 of the 18 tests. During one test, the hot plate snow gauge failed to detect any precipitation.

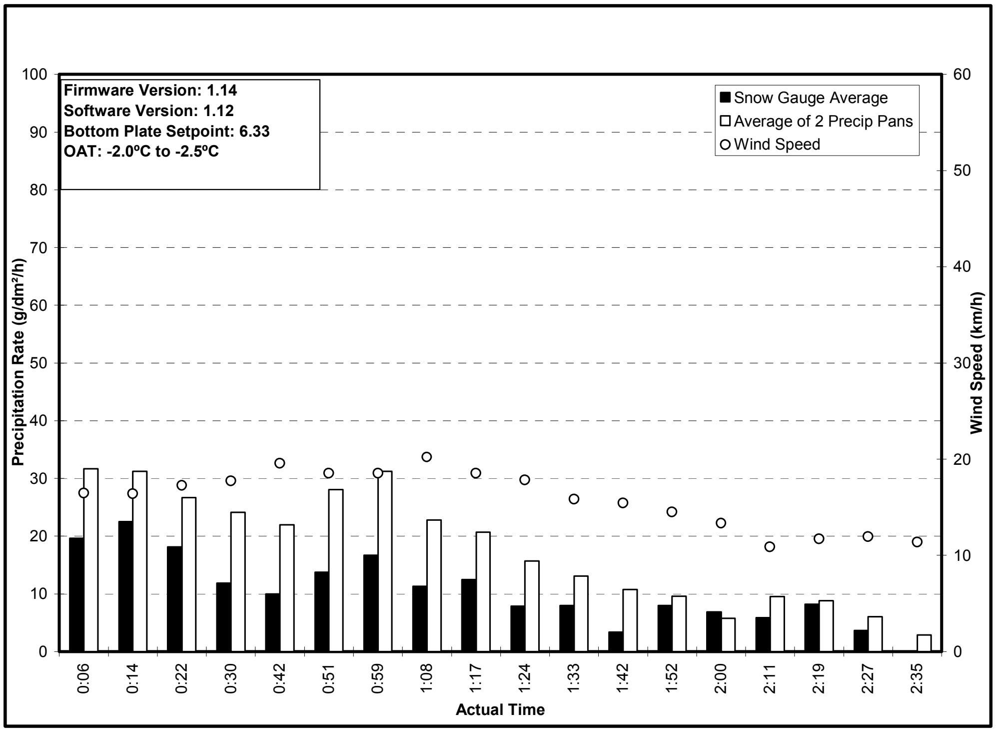


Figure 4.15: Comparison of Hot Plate Snow Gauge and Precipitation Pan, March 8-9, 2003, Run #2

4.1.16 April 5, 2003, Series #1 (Figure 4.16)

In conditions of light precipitation and moderate-to-high winds, the hot plate snow gauge failed to detect any precipitation for 7 of the 11 tests. During the tests where the hot plate snow gauge did record precipitation, the rate registered was lower than that measured by the precipitation pan.

4.1.17 April 5, 2003, Series #2 (Figure 4.17)

In conditions of light-to-moderate precipitation and moderate-to-heavy winds, the hot plate snow gauge recorded a rate lower than that measured by the precipitation pan for 12 of the 15 tests. During two tests, the hot plate snow gauge failed to detect any precipitation.

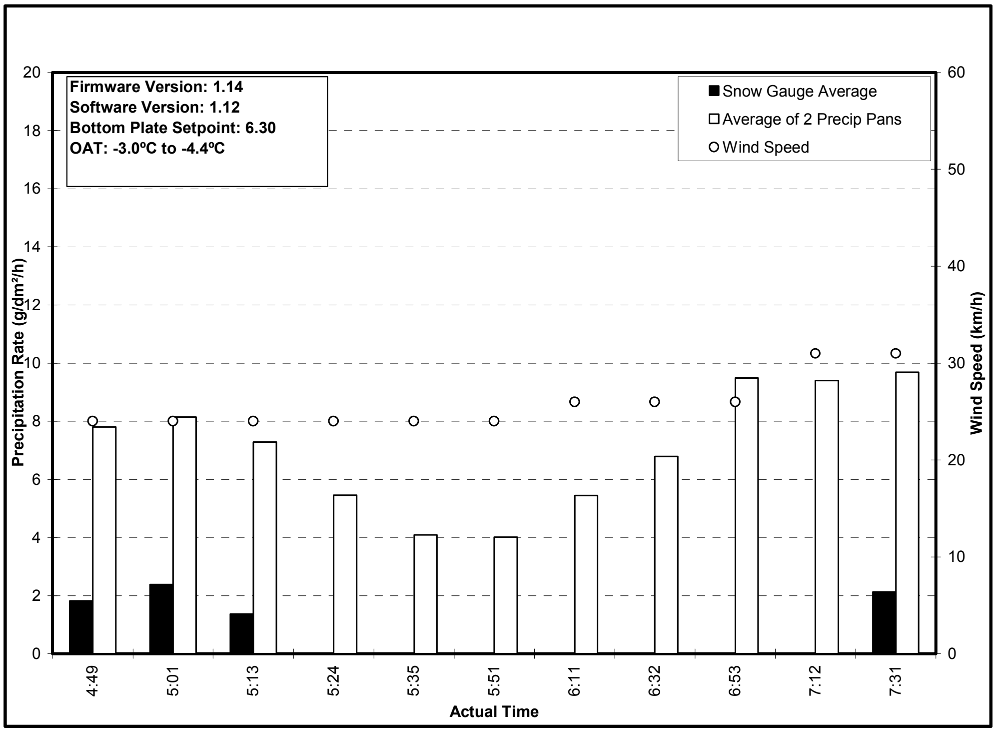


Figure 4.16: Comparison of Hot Plate Snow Gauge and Precipitation Pan, April 5, 2003, Run #1

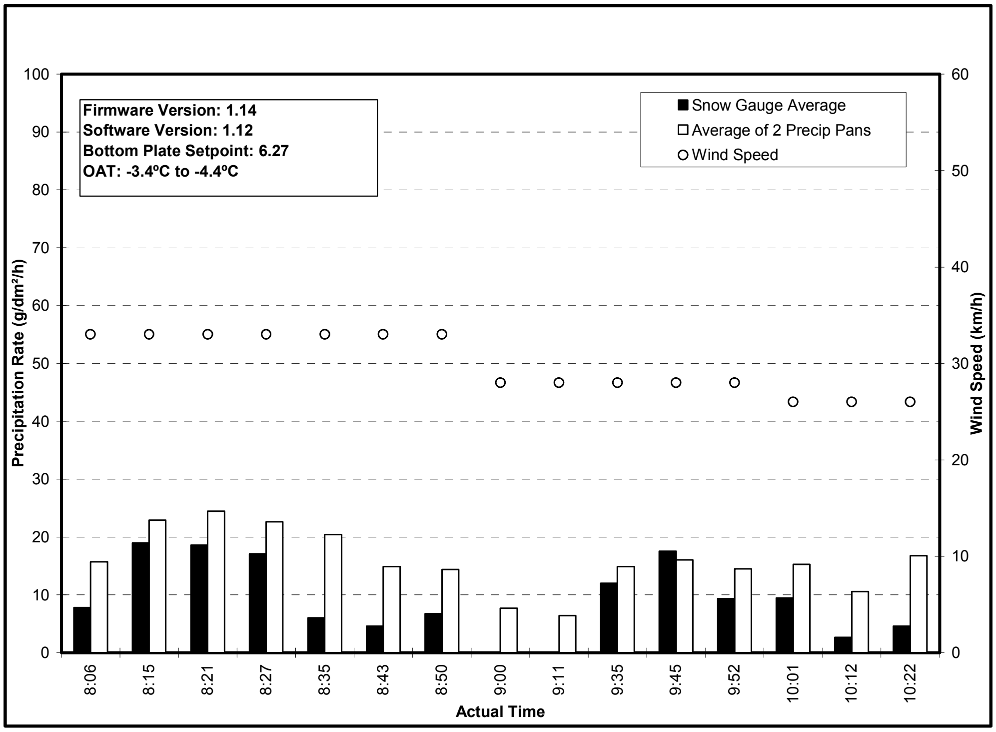


Figure 4.17: Comparison of Hot Plate Snow Gauge and Precipitation Pan, April 5, 2003, Run #2

4.2 Test Summary

To evaluate the hot plate snow gauge, 296 tests were conducted during the winter of 2002-03. A one-to-one comparison was made between each calculated average hot plate snow gauge rate and the related precipitation pan rate. The tests were sorted according to wind speed and rate of precipitation.

The data points in Figure 4.18 represent values of the calculated average hot plate snow gauge rates and the measured precipitation pan rates during moderate wind and moderate-to-heavy precipitation. The diagonal line indicates the imaginary correlation between the two parameters. Data points above the diagonal line represent tests where the hot plate snow gauge produced a rate lower than the measured precipitation pan rate. Data points below the diagonal line represent tests where the hot plate snow gauge produced a rate higher than the rate measured by the precipitation pan.

A distinction was made between the different bottom plate set points used. The hot plate snow gauge, with the bottom plate set point at 6.36, produced rates that were generally higher than those measured by the precipitation pans. Tests in which the bottom plate set point was 6.33 produced rates that were generally lower than those measured by the precipitation pans. For tests conducted with bottom plate set point at 6.33, results gave rise to a closer correlation to the rates recorded by the precipitation pans. Tests were also conducted with bottom plate set points 6.30 and 6.27; however, due to insufficient data for these bottom plate set points, no conclusions were drawn.

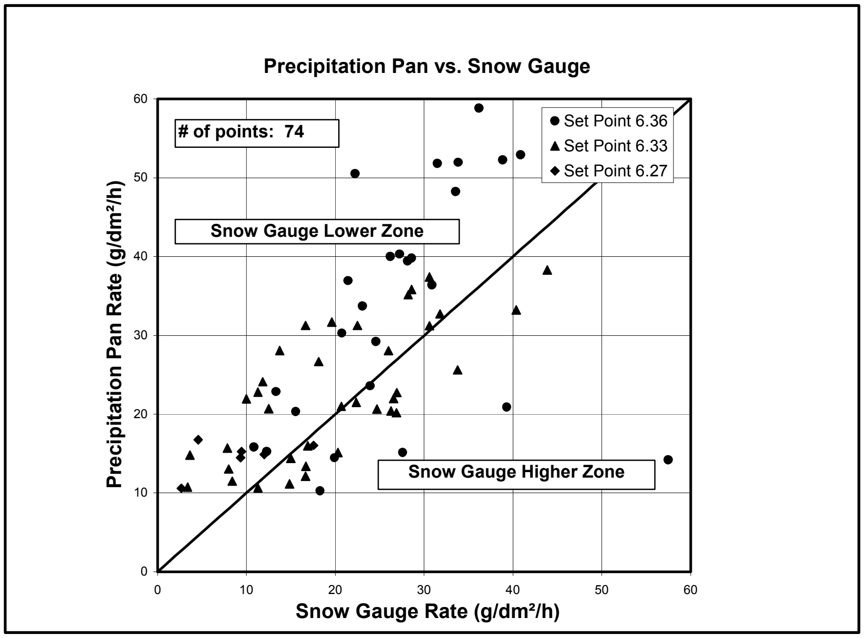


Figure 4.18: One-to-One Comparison Diagram for Moderate Wind and Moderate-to-Heavy Precipitation

The four categories of precipitation, as defined at the beginning of this section, are represented in Figure 4.19 by squares labeled VLS (Very Light Snow), LS (Light Snow), MS (Moderate Snow), and HS (Heavy Snow). Any data point above the diagonal line and outside these areas represents a hot plate snow gauge rate of precipitation that categorized the snow type as less severe than it actually was, i.e., deductions from this data could lead to the categorization of the snow type as moderate when it is actually heavy. Similarly, any data point below the diagonal line and outside these areas represents a hot plate snow gauge rate of precipitation that categorized the snow type as more severe than it actually was, i.e., deductions from this data could lead to the categorization of the snow type as heavy when it is actually moderate. Readings from the hot plate snow gauge and precipitation pans categorized the same precipitation type in 58 percent of the tests conducted during moderate winds and moderate-to-heavy precipitation. Compared with the results obtained from the precipitation pans, the hot plate snow gauge underestimated the precipitation rate (and thus the category of precipitation) in 22 percent of the tests, and overestimated the precipitation rate (and thus the category of precipitation) in 20 percent of the tests.

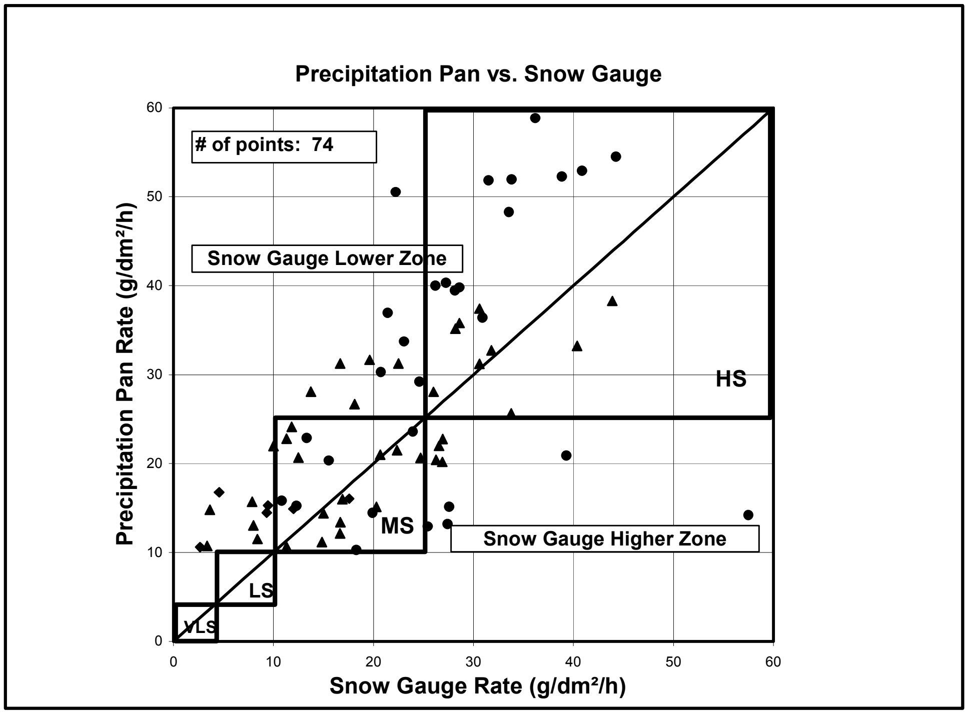
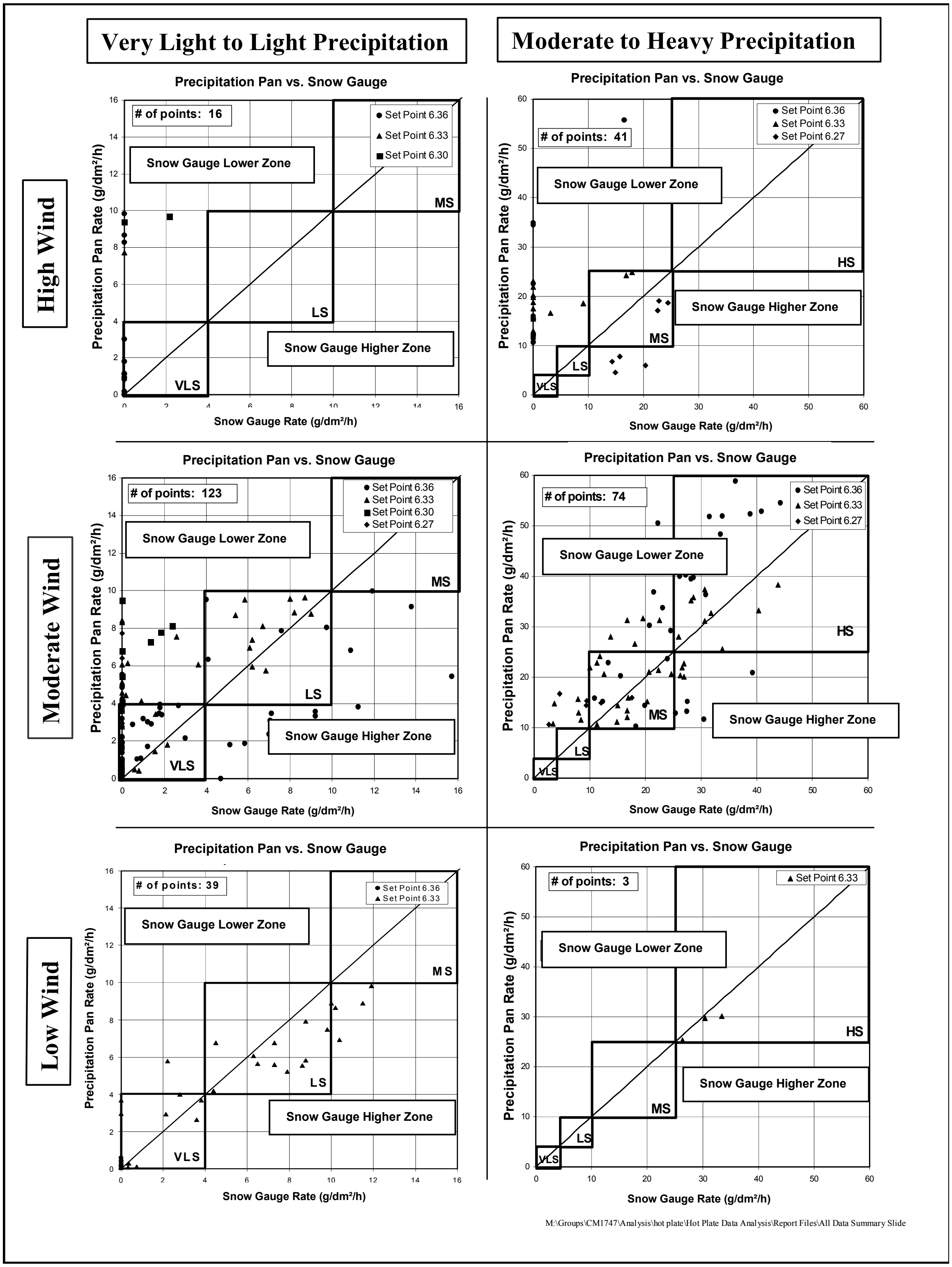


Figure 4.19: Snow Categorization Diagram for Moderate Wind and Moderate-to-Heavy Precipitation

Figure 4.20 presents a summary of all the tests conducted for the evaluation of the hot plate snow gauge. The tests were divided into six categories according to rate of precipitation and wind speed.



M:\Groups\CM1747\Analysis\hot plate\Hot Plate Data Analysis\Report Files\All Data Summary Slide

Figure 4.20: Summary of All Tests

Tables 4.1, 4.2, and 4.3 demonstrate the correlation between the snowfall intensity categorized by the precipitation pan and by the hot plate snow gauge. The shaded squares represent the tests correctly categorized by the hot plate snow gauge. The results are separated by wind condition: low, moderate, and high. Table 4.4 demonstrates the degree of inaccuracy created by overestimating or underestimating the snowfall intensity. Consequences associated with errors made by overestimating snowfall intensities are considered to be less severe than for errors made by underestimating snowfall intensities.

Table 4.1: Snowfall Intensity Categorization During Low Wind Conditions

		Hot Plate Snow Gauge				
		Very Light	Light	Moderate	Heavy	Total Tests
Precipitation Pan	Heavy				3	3
	Moderate			▨		0
	Light	1	12	4		17
	Very Light	22				22
	Total Tests	23	12	4	3	42

Table 4.2: Snowfall Intensity Categorization During Moderate Wind Conditions

		Hot Plate Snow Gauge				
		Very Light	Light	Moderate	Heavy	Total Tests
Precipitation Pan	Heavy			5	21	26
	Moderate	3	8	22	15	48
	Light	28	15	6	1	50
	Very Light	65	7	1		73
	Total Tests	96	30	34	37	197

Table 4.3: Snowfall Intensity Categorization During High Wind Conditions

		Hot Plate Snow Gauge				
		Very Light	**Light**	**Moderate**	**Heavy**	**Total Tests**
Precipitation Pan	**Heavy**	2		1	2	5
	Moderate	26	5	5		36
	Light	6				6
	Very Light	10				10
	Total Tests	44	5	6	2	**57**

Table 4.4: Snowfall Intensity Categorization

		Hot Plate Snow Gauge				
		Very Light	**Light**	**Moderate**	**Heavy**	**Total Tests**
Precipitation Pan	**Heavy**	Very Very Poor	Very Poor	Poor	Excellent	0
	Moderate	Very Poor	Poor	Excellent	Fair	0
	Light	Poor	Excellent	Fair	Acceptable	0
	Very Light	Excellent	Fair	Acceptable	Unacceptable	0
	Total Tests	0	0	0	0	**0**

The accuracy of the hot plate snow gauge was significantly affected by wind speed. The hot plate snow gauge was 88 percent accurate during low wind conditions, 63 percent accurate during moderate wind conditions, and 30 percent accurate during high wind conditions. The hot plate snow gauge correctly categorized the snow type for 60 percent of all the tests conducted. Twenty-nine percent of the tests were underestimated (this would potentially create aircraft safety concerns) and 11 percent of the tests were overestimated (considered to be conservative). The results obtained are demonstrated in Table 4.5.

The analysis of discrepancy between the baseline precipitation pan rate measurement and the reading obtained from the hot plate snow gauge leads to the conclusion that the hot plate snow gauge is not sufficiently accurate to be used as a reference instrument for measuring snowfall intensity.

Table 4.5: Accuracy of the Hot Plate Snow Gauge

	Low Wind	Moderate Wind	High Wind	TOTAL	
	Percentage	Percentage	Percentage	Percentage	# of Tests
Accurate	88%	63%	30%	60%	177
Undersetimated (Safety Concern)	2%	22%	70%	29%	85
Overestimated (Conservative)	10%	15%	0%	11%	34
Total	100%	100%	100%	100%	296

4.3 Comparison of Snowfall Intensity Categorization – Hot Plate Snow Gauge vs. Visibility Table

4.3.1 Background

To determine the validity of the hot plate snow gauge, the accuracy of the device must be measured against the current method for measuring snowfall intensity. Currently, snowfall intensity levels are predicted using visibility measurements together with a visibility versus snowfall intensity table.

During the winter of 2002-03, research was conducted to further analyze the relationship between visibility and snowfall rate. The Visibility in Snow vs. Snowfall Intensity Chart (Table 4.6) was proposed in TC report TP 14151E, *Relationship Between Visibility and Snowfall Intensity* (2), and will be used by Canadian pilots during the winter of 2003-04. A detailed analysis of the use of visibility to measure snowfall intensity can be found in TP 14151E (2).

4.3.2 Comparison of Hot Plate Snow Gauge and Visibility Measurements

To evaluate the measuring accuracy of the hot plate snow gauge as compared to the accuracy of the visibility table, the recorded snowfall intensities measured using both methods were compared to the rates calculated using precipitation pans. Visibility measurements were obtained from the Meteorological Service of Canada's automated weather observation station located adjacent to the APS test site.

Data collected for each precipitation pan measurement, hot plate snow gauge measurement and visibility measurement were classified as one of the following four types of snowfall: very light, light, moderate or heavy. The snowfall intensities are defined in Table 4.7.

Table 4.6: Visibility in Snow vs. Snowfall Intensity Chart[1]

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

[1] Based on (2,3):

Table 4.7: Snowfall Intensity Categorization

Rate ($g/dm^2/h$)	Snowfall Intensity
< 4	Very Light
4 to 10	Light
10 to 25	Moderate
> 25	Heavy

During nine of the eleven snow events measured during the winter of 2002-03, 242 observations were performed and compared. (Visibility data was unavailable for tests conducted on February 4, 2003, and April 5, 2003.) Each observation consisted of a precipitation pan rate, hot plate snow gauge rate, OAT, and visibility measurement. These parameters were used to categorize snowfall intensities. Data relevant to each of these observations are found in Appendix D.

The snowfall intensity, deduced using the visibility table and the hot plate snow gauge, was compared to the snowfall intensity determined using precipitation pans. Based on these results, it was found that the hot plate snow gauge inaccurately categorized the snowfall intensity 38 percent of the time: 26 percent of the observations were underestimated and 12 percent were overestimated. The visibility table inaccurately categorized the snowfall intensity 44 percent of the time: 6 percent of the observations were underestimated and 38 percent were overestimated. These findings are summarized in Table 4.8.

Table 4.8: Accuracy of Hot Plate Snow Gauge and Visibility Snowfall Intensity Measurements

	Hot Plate Snow Gauge	Visibility Table
Accurate	62%	56%
Underestimated	26%	6%
Overestimated	12%	38%

It is important to note that a pilot's interpretation of snowfall intensity is one of the parameters that drives the decision to select a HOT from the HOT table. However, the underestimation of snowfall intensity can subsequently cause the selection of an erroneous HOT, creating a negative impact on aircraft safety. Therefore, it will be important to bias the output of the hot plate snow gauge to reduce the underestimation to a level equivalent to that chosen for the visibility table; this will increase the percentage of overestimates and reduce the apparent accuracy, but provide a level of safety equivalent to that of the visibility table.

4.3.3 Summary

Due to the conservative design of the visibility table, most errors occur by overestimating snowfall intensity. Although inefficient, overestimating snowfall intensity is not a safety concern. However, data obtained from the hot plate snow gauge gave rise to underestimates of snowfall intensity in one quarter of all recorded observations, which is a safety concern.

Although the hot plate snow gauge produced a greater number of accurate observations, the significant number of underestimated observations creates a greater aircraft safety concern. At this time, the hot plate snow gauge is not a suitable replacement for the visibility table. However, snowfall intensity and visibility are imperfectly correlated; therefore, the accuracy of the visibility table cannot be improved. With further development, the hot plate snow gauge may become a suitable replacement for the reliance on visibility for measuring snowfall intensity.

4.4 Effect of Trailers on the Hot Plate Snow Gauge

To evaluate the effect the APS trailers have on the airflow surrounding the hot plate snow gauge, the recorded test results were sorted according to wind direction and assessed for inconsistencies. The location of the trailer (Figure 2.2) was determined to be an obstruction for tests with winds prevailing from the east-southeast direction to the south direction. The correlation between the snowfall intensity categorized using the precipitation pans and the hot plate snow gauge was analysed. The results were grouped by wind direction: winds prevailing from the obstructed zone versus winds prevailing from the un-obstructed zone. The data set in Section 4.3 was used for this analysis. The results obtained are demonstrated in Figure 4.21.

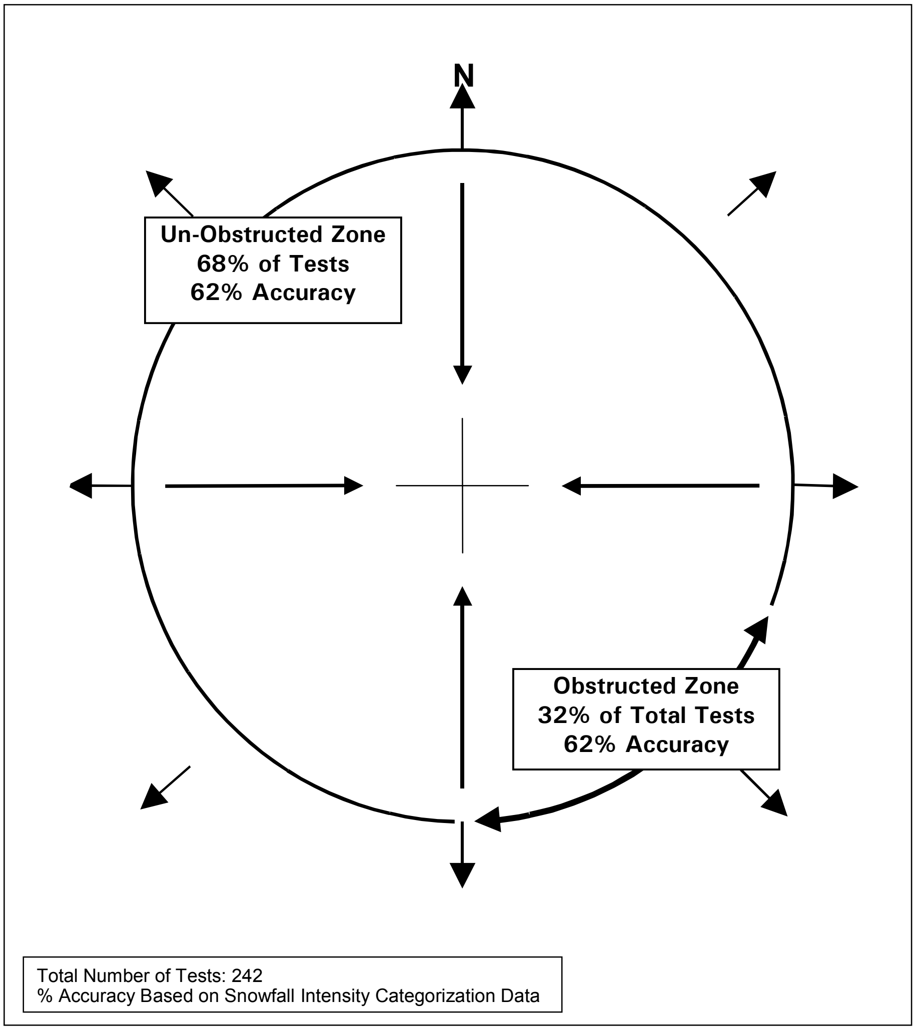


Figure 4.21: Wind Direction During Testing of the Hot Plate Snow Gauge

The APS trailers did not have a significant effect on the airflow surrounding the hot plate snow gauge; the hot plate accurately categorized the snow type 62 percent of the time during tests with winds from the obstructed zone and 62 percent of the time during tests with winds from the un-obstructed zone. Thirty-five percent of the tests conducted with wind directions from the un-obstructed zones were underestimated, compared to 5 percent of the tests conducted with wind directions from the obstructed zone. This discrepancy can be attributed to the average wind speed during the tests: approximately 21 km/h greater than the tests with wind directions from the un-obstructed zones. The high wind speeds during these tests significantly reduced the accuracy of the hot plate snow gauge. These findings are summarized in Tables 4.9, 4.10, and 4.11.

Table 4.9: Accuracy of the Hot Plate Snow Gauge Snowfall Intensity Measurements

	Total Tests
Accurate	62%
Underestimated	26%
Overestimated	12%

Table 4.10: Accuracy of the Hot Plate Snow Gauge Snowfall Intensity Measurements with Respect to Wind Direction

	Wind from Obstructed Zone	Wind from Un-Obstruced Zone
Accurate	62%	62%
Underestimated	5%	35%
Overestimated	33%	3%

Table 4.11: Wind Speed During Hot Plate Snow Gauge Snowfall Intensity Measurements

	Average Wind Speed from Obstructed Zone	Average Wind Speed from Un-Obstruced Zone
Accurate	12.6 km/h	12.9 km/h
Underestimated	13.2 km/h	34.0 km/h
Overestimated	14.7 km/h	0.8 km/h

5. CONCLUSIONS

The conclusions drawn from the tests preformed during the winter of 2002-03 are described in this section.

5.1 Hot Plate Snow Gauge vs. Visibility Table

The number of accurately categorized snowfall intensity observations recorded with the hot plate snow gauge was greater than those measured using the visibility table. Unfortunately, the inaccuracies produced created a significant number of underestimated observations, which gives rise to aircraft safety concerns. Therefore, it will be important to bias the output of the snow gauge to reduce the underestimation to a level equivalent to that chosen for the visibility table; this will increase the percentage of overestimates and reduce the apparent accuracy, but provide a level of safety equivalent to that of the visibility table.

5.2 Low Wind vs. High Wind

High winds significantly reduced the accuracy of the hot plate snow gauge. During several tests under high wind conditions, the hot plate snow gauge did not record any precipitation. Under low wind conditions, the readings produced by the hot plate snow gauge were much closer to those recorded by the precipitation pans.

5.3 Light Precipitation vs. Moderate-to-High Precipitation

The hot plate snow gauge did not record any precipitation below the rate of 3 g/dm^2/h; consequently, the accuracy was reduced in conditions of light precipitation. However, the precipitation rates recorded by the hot plate snow gauge during moderate-to-high precipitation were better correlated to those measured by the precipitation pans.

The accurate measurement of low levels of precipitation is important to help identify light and very light snow conditions; high levels of precipitation do not require accuracy, because once 25 g/dm^2/h is exceeded, no HOTs exist.

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6. RECOMMENDATIONS

Based on tests conducted by APS during the winter of 2002-03, the following recommendations were made.

6.1 Further Testing

An improved version of the hot plate snow gauge is necessary and currently under development. It is recommended that testing continue in the upcoming year using an improved hot plate snow gauge.

6.2 System Improvements

The significant number of underestimated snowfall intensity observations must be reduced in order to consider the hot plate snow gauge as a suitable replacement for the use of the visibility table.

6.2.1 Software

Improvements to the “precip” program should be made to more accurately record precipitation rates during conditions of high winds and light precipitation events. The algorithm used by the program should be modified to better compensate for the reduced catch ability and sensitivity of the snow gauge sensing heads under these conditions.

6.2.2 Logging Capabilities

The hot plate snow gauge’s logging capabilities should be further developed to continuously and consistently record data over several days. During testing, the hot plate snow gauge had a tendency to stop logging during test sessions, thus requiring constant observation. A system that entails little or no monitoring should be developed.

6.2.3 Screen Ergonomics

Developments should be made to the “precip” program’s visual display of information. An average rate of precipitation of the last 10 minutes of sampling should be displayed to the user. The rate of precipitation should be displayed in units of g/dm²/h and mm/h, or provide a choice between the two for the default setting.

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3. Rasmussen, R., Vivekanandan, J., Cole, J., Karplus, E., *Theoretical Considerations in the Estimation of Snowfall Rate Using Visibility* Transportation Development Centre, Transport Canada, Montreal, November 1998, TP 12893E.

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APPENDIX A

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

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

5.17 Testing with the NCAR Hotplate Under Natural Precipitation

5.17.1 Develop procedure for the conduct of tests with the NCAR Hotplate outdoors under natural snow precipitation;

5.17.2 Install the snow gauge at the test site;

5.17.3 Conduct tests with the NCAR Hotplate at Dorval Airport, comparing outputs from the NCAR Hotplate with snowfall rates measured in rate pans;

5.17.4 Provide feedback to DRI in order to support development of the software;

5.17.5 Analyze the data collected testing with the NCAR Hotplate during the winter of 2002-03;

5.17.6 Report the findings and prepare final report.

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APPENDIX B

EXPERIMENTAL PROGRAM
EVALUATION OF THE NCAR HOT PLATE SNOW GAUGE

CM1747.001

EXPERIMENTAL PROGRAM
EVALUATION OF THE NCAR HOT PLATE SNOW GAUGE

Winter 2002-03

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Alia Alwaid

Reviewed by: John D'Avirro

December 17, 2002
Version 1.0

Editorial Revision
June 27, 2005
Version 1.1

EXPERIMENTAL PROGRAM
EVALUATION OF THE NCAR HOT PLATE SNOW GAUGE
Winter 2002-03

1. BACKGROUND

APS Aviation has undertaken a research program that, among other objectives, will support the evolution of an improved format for HOT Tables for all fluid types that will provide simplicity and ease of reference together with optimum operational advantage.

One of the recent changes has been the snow column in the Type I table which was divided into two columns: light and moderate.

Introduction of a new column for light snow requires that the precipitation rate limits of light snow be defined. The upper precipitation limit as stated in *Definition of Weather Phenomena* (compiled by the National Center for Atmospheric Research and included in TP 14144E) is < 10 g/dm^2/h. However, a lower limit is also needed and for this and no definition of the lower precipitation limit currently exists.

Introduction of the light snow column provokes the question of how the pilot will recognize that the lower precipitation limit conditions are being experienced during his departure. Currently, the pilot may be advised that the snowfall is *heavy, moderate or light.* The "light" advisory indicates that the snowfall rate is 10 g/dm^2/h or less, however the pilot is not told how much less. At an actual rate of 3 g/dm^2/h, the advisory would still only indicate "light". Some development is needed to assist in the pilot's decision to use the longer holdover times available in the new "light snow" column.

One option is to accelerate the development of the National Center for Atmospheric Research (NCAR) hot plate snow intensity measuring device. This device is intended to measure water content of snowfall over the entire range of snow intensity, which would then provide the pilot with the needed information. This development should be facilitated through providing assistance in the form of testing the device in natural snowfall and comparing it's reading to snowfall rates measured on rate pans. This device offers a possible solution for the longer term.

The following is an Abstract describing the hot plate snow gauge from the 11th Conference on Cloud Physics, in 2002, from Roy M Rasmussen of NCAR:

> *"A hotplate snowgauge has been jointly developed by the National Center for Atmospheric Research (NCAR) and Desert Research Institute (DRI) that provides a method to measure liquid equivalent*

> *snowfall rates every minute. One of the main motivations for this work is the need for improved methods to measure liquid equivalent snowfall rates in support of aircraft deicing operations at airports. The hotplate snowgauge does not require glycol or oil or a windshield, typical requirements of current weighing snowgauges. The principle of operation is to measure the amount of heat necessary to melt and evaporate all the snow or rain striking the top surface of the hotplate. The system has an upper and lower plate heated to nearly identical constant temperatures (near 75°C). The lower plate is place directly underneath the upper plate with an insulator in between. The plates are maintained at constant temperature during wind and precipitation conditions by increasing or decreasing the current to the plate heaters. During normal windy conditions without precipitation, the plates cool nearly identically due to their identical size and shape. During precipitation conditions, the top plate has an additional cooling effect due to the melting and evaporation of precipitation. The difference between the power required to cool the top plate compared to the bottom plate is proportional to the precipitation rate. The initial design of the plates had a smooth upper and lower surface. It was determined that snow would "skate" off the upper surface during high wind conditions leading to the underestimation of the snowfall rate during these periods. In order to overcome this problem, three concentric walls were added to both the top and bottom plates. These concentric walls help prevent snow or rain impacting the plate at an angle from sliding off during high wind conditions. This modification greatly increased the catch efficiency of the gauge. The snow gauge has undergone two years of testing at Marshall (a site near Boulder) and at Mt. Washington, NH."*

2. OBJECTIVE

This procedure will provide a guideline to test the device in natural snow and compare its data output to precipitation rates measured using the conventional endurance time testing procedure. Other sources for collecting the precipitation rate may also be used.

3. TEST REQUIREMENTS (PLAN)

Test will be conducted at the Dorval test site in natural snow precipitation conditions. Tests may be conducted in conjunction with standard endurance tests. At least 30 hours of data collection is planned.

Testing of this device will require gathering snow fall information from various sources along with the snow gauge's output and analysing the deviations, if any, in the measurements that are produced.

Data will be collected from the following sources simultaneously:

a) Hot plate snow gauge;

b) Environment Canada's Automated Weather Station;

c) Precipitation Rate Measurement method used in endurance time testing; and

d) Campbell Scientific weight measuring device (using the Denver Instruments balance) – availability depending on the progress of the Frost Project.

4. PROCEDURE

The procedure required to operate and collect data from the hot plate snow gauge is contained in Appendix B-1.

Environment Canada's READAC (Automated Weather Station) is located within 50 m 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.

Refer to *Experimental Program for Natural Precipitation Flat Plate Testing procedure, December 2002* (TP 14144E, Appendix C), for a detailed account of the equipment required and the procedures followed to conduct manual precipitation rate measurements.

When conducting these tests, ensure that all time pieces are synchronized with the official time. Following is a brief description of the major setup items.

Two plate pans, placed at a 10º inclination on the test stand will be used to collect and weigh snow. Rate measurements must be conducted every five minutes. A schematic of the plate pan is provided in Figure B-1.

It is important to note that 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 2 to 3 minutes to prevent accumulating snow from blowing away. The time of rotation should be reduced during heavy precipitation or high wind conditions.

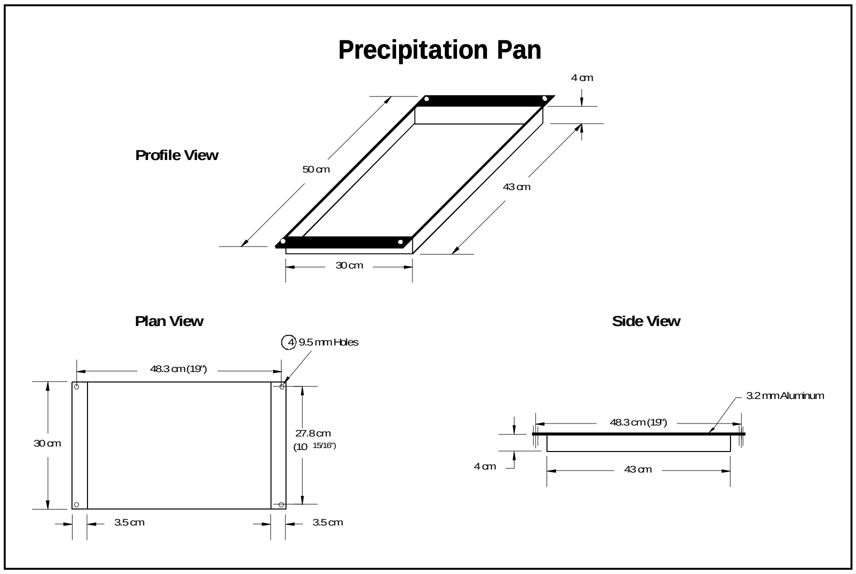

Figure B-1: Schematic of Precipitation Plate Pan

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. If the wind shifts during the test do not move the stand: simply note it on the data sheet. Refer to Figure B-2.

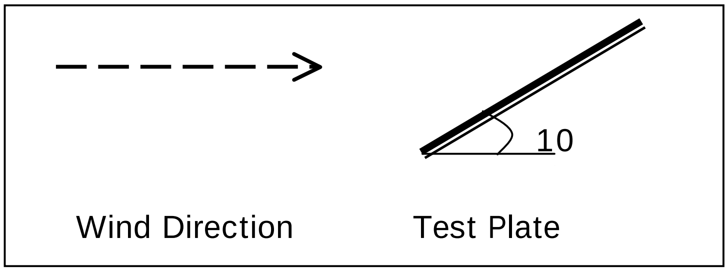

Figure B-2: Test Plate Orientation

The hot plate must be located within close proximity of the test stand; a maximum distance of 3 m away from test stands and at the same level of the test stand. Refer to Figure B-3 for a general guideline of the setup.

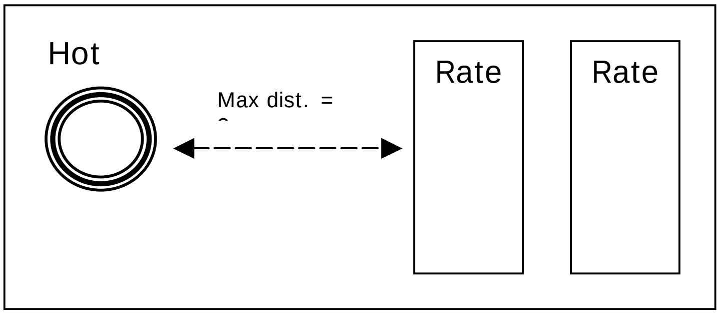

Figure B-3: General Guideline for Setup

5. PERSONNEL

One person is required to conduct these tests.

6. DATA FORMS

One data form (Table B-1) will be required for the manual precipitation rate measurement. Data must be collected as per the data form.

Table B-1: Meteorological and Precipitation Rate Data Form

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

VERSION 1.0 Winter 2002-03

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

HAND HELD VIDEO CASSETTE #:

PLATE PAN WEIGHT MEASUREMENTS *

	t		t		w	w	COMPUTE
PAN #	**TIME BEFORE (h:min:s)**	**BUFFER TIME (s)**	**TIME AFTER (h:min:s)**	**BUFFER TIME (s)**	**WEIGHT BEFORE (g)**	**WEIGHT AFTER (g)**	**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 (h:min)	**TYPE (Fig. 4)** ZR, ZL,S, SG IP, IC, BS, SP	**CLASSIF.** (See snow classification diagram.)	**If SNOW, WET or DRY**

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

TEMPERATURE AT START OF TEST ________ ºC

WIND SPEED AT START OF TEST ________ kph

WIND DIRECTION AT START OF TEST ________ º

COMMENTS : ________

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

M:\Groups\CM1747\Procedures\HOT\data forms

APPENDIX B-1

HOTPLATE SNOW GAUGE SET-UP TIPS

1. The sensing head is shipped on its mounting post; the 20 cm (8 in.) square base plate has been removed. If required, it may be reattached using the four screws provided. Keep the cable strain relieved to one of the four stand-offs.

2. Mount the sensing head using the base plate or clamp/the post to a suitable upright or both. The hotplates should be horizontal and mounted approximately 1 m above the ground. It should be located similar to any rain gauge – away from buildings or structures that can interfere with its catch. Try to avoid shadows (less important in morning and evening).

3. The short white plastic tube near the top of the mounting post contains a thermistor for monitoring air temperature. It should be oriented to the north to minimize radiation effects.

4. The tan electronics box should be mounted in shade. If located indoors or tested indoors, release the latch on the box so the door is slightly ajar. This will keep the electronics from overheating.

5. The first connection should be the white serial cable from the electronics box to your PC. Any available com port will work, although COM1 is preferred. Then connect the blue power cord to 120 VAC, 60 Hz. A software installation diskette is included.

6. After communications have been established and the 'precip' program is running, attach the black cable from the sensing head to the electronics box. It will take about five minutes for the gauge to stabilize. The graphing program updates once a minute, so it will take at least that long for the first data points to appear.

7. The hotplates will run at about 85°C.

8. The PC is not required to run the gauge; only for set-up, data retrieval, and monitoring. The internal single board computer provides control and data logging. It will retain data for over a week in the event of a power failure. The data should be retrieved once per week via a PC.

9. It is highly desirable to leave the PC connected to the gauge since it will log more parameters than internal gauge storage. These can be used to determine the health and proper operation of the gauge. You will also find the graphs useful in monitoring operation.

10. If the gauge is to be intentionally disconnected from power for several days, or is being shipped, the positive battery wire inside the electronics box should be disconnected using the quick connect terminal and moved aside.

11. Software and set-up questions should be addressed to:
    Morien Roberts
    775.673.7330
    morien@dri.edu

12. Other questions should be addressed to:
    Rick Purcell
    775.674.7025
    rickp@dri.edu

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APPENDIX C

SPECIFICATIONS OF THE SERIAL DATA STREAM FROM THE D.R.I. PRECIPITATION GAUGES

Specifications of the serial data stream from the D.R.I precipitation gauges

V1.12 - 12/01/2002

Gauges using this specification report version V1.12.
Reference power modify to display power with a resolution of 0.1W, field modified from 3 characters to 5 characters (extra digit and a decimal point).

Delta Power modified to display power difference between the two plates with a resolution of 0.1W, field modified from 3 characters to 5 characters (extra digit and a decimal point).

If the data stream is outputted using imperial units (default units are metric) the format of the precipitation rate and the accumulated precipitation are modified to display one less significant digit and one extra decimal digit.

V1.1 - 05/25/2002
Gauges using this specification report version V1.11 or below.
Original specification

The electronic enclosure uses a serial data stream, RS232, to transmit data from the precipitation gauge to a computer. The RS232 interface is configured for 9600 baud, 8 data bits, no parity and 1 stop bit. The data appears as a series of time stamped records. A new time stamped record is sent every 60 seconds. Each data record is on a single line, terminated with a carriage return. The time stamped data records are in a fixed width format and commas are used to separate the various fields. The data can easily be imported into another application, such as Excel or Access, for additional processing and analysis. Each data field is right justified and padded with leading zeros. Positive numbers are unsigned while negative numbers have a leading '-'. Four of the data fields could hold negative values.

Each time stamped record has the following format:
T,SSSSSSSSSS,VVVVV,RR.R,AAA.A,PPP.P,bBB.B,dDD.D,CCC,NN.NN,FF.FF,tTT,mMM,WW.W<CR>
{each lower case letter is either a digit or a minus, '-', sign}

The first character in a data record is the ASCII 'T' character – indicating that a time stamped data record follows. In addition to the above time stamped data records, the apparatus occasionally sends out other of types of data; e.g. after the gauge's clock is set from a controlling PC, a confirmation record is transmitted back to the PC. Any records not starting with a 'T' should be ignored by your computer. The maximum length of any non time stamped data record is 512 characters. All records are terminated with a carriage return.

SSSSSSSSSS – Time, 10 digit integer, represents the number of seconds since 00:00 1/1/1970. The gauge always reports time in UTC. When a command is issued to set the gauge's time, allowance is made for the local time zone of the controlling PC.

VVVVV – Version, 5 characters, denotes the version of the firmware in the precipitation gauge. The last character of the firmware version is either 'M' or 'I'. When this character is an 'M' the gauge is reporting data using Metric units. When it is an 'I' Imperial units are being used.

RR.R – Rain rate, 2 digits plus a decimal point followed by a single digit, rain rate averaged over the last minute, units = mm/hour. When imperial units are used this field has the format R.RR, units = inches/hour

AAA.A – Accumulation, 3 digits plus a decimal point followed by a single digit, precipitation accumulated since midnight local standard time, units = mm. When imperial units are used this field has the format AA.AA, units = inches..

PPP.P – Reference plate power, 3 digits plus a decimal point followed by a single digit, units = Watts.

bBB.B – Base line average power, 4 digits plus a decimal point, average of delta power (see next item) between precipitation events, by design will always be a negative number, units = Watts.

dDD.D – Delta power, 3 digits plus a decimal point followed by a single digit, difference between sensor (top) plate power and the reference (bottom) plate power, negative between precipitation events, units = Watts.

CCC – Sensor plate duty cycle, 3 digit integer, units = percentage.

NN.NN – Sensor plate resistance, 4 digits plus a decimal point, units = Ohms.

FF.FF – Reference plate resistance, 4 digits plus a decimal point, units = Ohms.

tTT – Sense plate temperature, 3 digit integer, positive during normal operation, negative during a cold startup or a possible malfunction, units = Celsius. Even if imperial units are selected the temperature is always display in Celsius.

mMM – Ambient air temperature – 3 digit integer, may be negative, units = Celsius. Even if imperial units are selected the temperature is always display in Celsius.

WW.W – Wind Speed - 3 digits plus a decimal point, units = Meters/Second.

All values are instantaneous values unless otherwise noted.

Summary of the fields in the time stamped data record

Field Name	Position	Length	Format	Description
Record Type	1	1	C	T = time stamped data record
Time	3	10	D*10	Time stamp in seconds
Version	14	5	C*5	Version of the software
Rain Rate	20	4	DD.D	Mm/hour, ave. over last min.
Accumulation	25	5	DDD.D	Mm of precipitation since 00:00
Ref. Power	31	5	DDD.D	Reference plate power in Watts
Base Line	37	5	dDD.D	Ave power diff with no precip
Delta Power	43	5	dDD.D	Power diff, between plates
Duty Cycle	49	3	DDD	Percentage sensor plate duty cycle
Sense Resistance	53	5	DD.DD	Sensor plate resistance, Ohms
Ref. Resistance	59	5	DD.DD	Reference plate resistance, Ohms
Sense Temp.	65	3	dDD	Sensor plate temp. in Celsius
Ambient Temp.	69	3	dDD	Ambient temp. in Celsius
Wind Speed	73	4	DD.D	Wind speed in M/Second

C = ASCII character
D = decimal digit
d = decimal digit or ‘-‘

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APPENDIX D

SNOW TYPE CATEGORIZATION DATA

Test No.	Date	Plate Pan Rate	Average Hot Plate Rate	Temp (ºC)	Visibility (stat miles)	Snow Type determined by Hot Plate	Snow Type determined by Plate Pan	Snow Type determined by Visibility
1	7-Jan	3.58	9.20	-7.0	1.5	light	very light	light
2	7-Jan	3.32	9.20	-7.1	1.4	light	very light	light
3	7-Jan	1.03	0.70	-7.0	2.8	very light	very light	very light
4	7-Jan	1.70	1.20	-6.8	3.0	very light	very light	very light
5	7-Jan	1.79	5.15	-6.6	4.3	light	very light	very light
6	7-Jan	3.48	7.10	-6.6	2.6	light	very light	very light
7	7-Jan	0.18	0.00	-6.5	9.0	very light	very light	very light
8	7-Jan	1.08	0.90	-6.3	7.7	very light	very light	very light
9	7-Jan	1.89	5.83	-6.1	5.7	light	very light	very light
10	7-Jan	2.37	7.00	-5.9	5.0	light	very light	very light
11	7-Jan	3.07	7.05	-5.7	4.4	light	very light	very light
12	8-Jan	6.81	10.89	-5.7	2.9	moderate	light	very light
13	8-Jan	13.19	27.40	-5.8	1.0	heavy	moderate	light
14	8-Jan	12.92	25.44	-5.9	0.7	heavy	moderate	moderate
15	8-Jan	20.88	39.30	-6.0	0.5	heavy	moderate	moderate
16	8-Jan	14.17	57.50	-6.0	0.3	heavy	moderate	heavy
17	8-Jan	36.38	30.90	-5.9	0.4	heavy	heavy	moderate
18	8-Jan	9.56	16.70	-5.8	0.6	moderate	light	moderate
19	8-Jan	15.14	27.60	-5.7	0.5	heavy	moderate	moderate
20	8-Jan	10.27	18.30	-5.7	0.7	moderate	moderate	moderate
21	8-Jan	8.66	16.30	-5.7	0.7	moderate	light	moderate
22	8-Jan	9.14	13.80	-5.7	0.8	moderate	light	moderate
23	8-Jan	3.89	2.70	-5.7	1.2	very light	very light	light
24	8-Jan	1.64	0.00	-5.7	2.0	very light	very light	light
25	8-Jan	0.31	0.00	-5.6	7.9	very light	very light	very light
26	8-Jan	2.14	3.00	-5.5	3.8	very light	very light	very light
27	8-Jan	3.81	11.25	-5.4	2.6	moderate	very light	very light
28	8-Jan	11.70	30.55	-5.4	0.7	heavy	moderate	moderate
29	8-Jan	5.45	15.70	-5.3	1.0	moderate	light	light
30	8-Jan	4.78	17.30	-5.3	1.3	moderate	light	light
31	8-Jan	9.82	29.89	-5.3	0.9	heavy	light	light
32	26-Jan	3.76	0.00	-5.3	1.2	very light	very light	light
33	26-Jan	3.90	0.00	-5.3	1.2	very light	very light	light
34	26-Jan	4.86	0.00	-5.3	1.2	very light	light	light
35	26-Jan	4.86	0.00	-5.4	1.1	very light	light	light
36	26-Jan	5.54	0.00	-5.4	1.1	very light	light	light
37	26-Jan	5.45	0.00	-5.3	1.1	very light	light	light
38	26-Jan	3.76	1.80	-5.3	1.1	very light	very light	light
39	26-Jan	3.20	1.00	-5.2	1.3	very light	very light	light
40	26-Jan	1.88	0.00	-5.2	1.4	very light	very light	light
41	26-Jan	0.94	0.00	-5.2	2.1	very light	very light	very light
42	26-Jan	0.47	0.00	-5.2	2.5	very light	very light	very light
43	26-Jan	2.21	0.00	-5.1	1.8	very light	very light	light
44	26-Jan	2.87	0.50	-5.1	1.5	very light	very light	light
45	26-Jan	3.95	1.80	-5.1	1.0	very light	very light	light
46	26-Jan	3.57	0.00	-5.2	1.1	very light	very light	light

Test No.	Date	Plate Pan Rate	Average Hot Plate Rate	Temp (ºC)	Visibility (stat miles)	Snow Type determined by Hot Plate	Snow Type determined by Plate Pan	Snow Type determined by Visibility
47	26-Jan	3.20	0.00	-5.2	1.2	very light	very light	light
48	26-Jan	1.91	0.00	-5.1	1.3	very light	very light	light
49	26-Jan	1.69	0.00	-5.1	1.4	very light	very light	light
50	26-Jan	1.91	0.00	-5.1	1.4	very light	very light	light
51	26-Jan	1.57	0.00	-5.1	1.4	very light	very light	light
52	26-Jan	0.90	0.00	-5.0	1.6	very light	very light	light
53	26-Jan	1.39	0.00	-5.0	1.8	very light	very light	light
54	26-Jan	0.98	0.00	-5.0	1.9	very light	very light	light
55	26-Jan	1.04	0.00	-5.0	2.0	very light	very light	very light
56	26-Jan	0.80	0.00	-4.9	2.1	very light	very light	very light
57	26-Jan	0.47	0.00	-4.9	2.1	very light	very light	very light
58	26-Jan	0.60	0.00	-5.0	2.0	very light	very light	light
59	26-Jan	0.84	0.00	-5.0	1.9	very light	very light	light
60	26-Jan	0.59	0.00	-5.2	2.0	very light	very light	light
61	26-Jan	0.56	0.00	-5.3	2.0	very light	very light	very light
62	26-Jan	0.62	0.00	-5.7	2.1	very light	very light	very light
63	26-Jan	0.66	0.00	-5.8	2.1	very light	very light	very light
92	10-Feb	3.67	0.00	-5.7	1.4	very light	very light	light
93	10-Feb	3.02	0.00	-6.4	1.1	very light	very light	light
94	10-Feb	0.94	0.00	-7.9	2.0	very light	very light	light
95	10-Feb	1.13	0.00	-8.0	2.2	very light	very light	very light
96	10-Feb	0.85	0.00	-8.2	2.3	very light	very light	very light
97	10-Feb	1.11	0.00	-8.8	2.0	very light	very light	very light
98	10-Feb	1.79	0.00	-9.3	1.6	very light	very light	light
99	10-Feb	0.94	0.00	-9.7	3.7	very light	very light	very light
100	10-Feb	0.19	0.00	-9.9	6.4	very light	very light	very light
101	10-Feb	0.00	0.00	-10.1	9.0	very light	very light	very light
102	10-Feb	0.00	0.00	-10.2	9.0	very light	very light	very light
103	19-Feb	0.67	0.00	-7.1	3.9	very light	very light	very light
104	19-Feb	0.47	0.00	-7.1	3.6	very light	very light	very light
105	19-Feb	0.43	0.00	-7.2	4.0	very light	very light	very light
106	19-Feb	0.33	0.00	-7.2	4.3	very light	very light	very light
107	19-Feb	0.52	0.00	-7.2	3.6	very light	very light	very light
108	19-Feb	0.56	0.00	-7.2	3.3	very light	very light	very light
109	19-Feb	0.19	0.00	-7.2	3.4	very light	very light	very light
110	19-Feb	0.23	0.00	-7.2	3.5	very light	very light	very light
111	19-Feb	0.28	0.00	-7.0	4.0	very light	very light	very light
112	19-Feb	0.18	0.00	-7.0	4.0	very light	very light	very light
113	19-Feb	0.28	0.35	-6.9	4.0	very light	very light	very light
114	19-Feb	0.28	0.35	-6.9	4.0	very light	very light	very light
115	19-Feb	0.09	0.00	-6.8	3.0	very light	very light	very light
116	19-Feb	0.05	0.00	-6.7	3.2	very light	very light	very light
117	19-Feb	0.09	0.33	-6.6	4.0	very light	very light	very light
118	19-Feb	0.09	0.75	-6.5	4.0	very light	very light	very light
119	19-Feb	0.42	0.80	-6.4	4.0	very light	very light	very light
120	19-Feb	0.47	0.60	-6.4	4.0	very light	very light	very light

Test No.	Date	Plate Pan Rate	Average Hot Plate Rate	Temp (ºC)	Visibility (stat miles)	Snow Type determined by Hot Plate	Snow Type determined by Plate Pan	Snow Type determined by Visibility
121	19-Feb	1.46	1.57	-6.5	3.1	very light	very light	very light
122	19-Feb	1.80	2.17	-6.5	3.0	very light	very light	very light
123	19-Feb	0.66	0.00	-6.2	2.1	very light	very light	very light
124	19-Feb	0.75	0.00	-6.2	2.1	very light	very light	very light
125	19-Feb	3.03	1.22	-6.1	1.5	very light	very light	light
126	19-Feb	3.45	1.78	-6.1	1.3	very light	very light	light
127	19-Feb	3.38	1.90	-6.0	1.2	very light	very light	light
128	19-Feb	2.91	1.40	-6.0	1.3	very light	very light	light
129	19-Feb	0.38	0.00	-5.9	1.9	very light	very light	light
130	19-Feb	0.38	0.00	-5.9	1.9	very light	very light	light
131	19-Feb	0.28	0.00	-5.8	2.5	very light	very light	very light
132	19-Feb	0.19	0.00	-5.8	2.5	very light	very light	very light
133	19-Feb	1.03	0.00	-5.8	2.4	very light	very light	very light
134	19-Feb	1.03	0.00	-5.8	2.4	very light	very light	very light
135	19-Feb	0.00	0.00	-5.7	2.5	very light	very light	very light
136	19-Feb	0.00	0.00	-5.7	2.5	very light	very light	very light
137	22-Feb	15.79	0.00	-5.0	0.8	very light	moderate	moderate
138	22-Feb	11.33	0.00	-5.1	0.9	very light	moderate	moderate
139	22-Feb	15.42	0.00	-5.3	0.7	very light	moderate	moderate
140	22-Feb	15.65	0.00	-5.5	0.7	very light	moderate	moderate
141	22-Feb	12.64	0.00	-5.5	0.7	very light	moderate	moderate
142	22-Feb	13.02	0.00	-5.6	0.7	very light	moderate	moderate
143	22-Feb	7.71	0.00	-5.7	0.7	very light	light	moderate
144	22-Feb	12.45	0.00	-5.8	0.8	very light	moderate	moderate
145	22-Feb	15.93	0.00	-5.9	0.7	very light	moderate	moderate
146	22-Feb	18.85	0.00	-6.1	0.5	very light	moderate	moderate
147	22-Feb	18.57	9.10	-6.2	0.5	light	moderate	moderate
148	22-Feb	16.59	3.10	-6.4	0.5	very light	moderate	moderate
149	22-Feb	16.12	0.00	-6.5	0.5	very light	moderate	moderate
150	22-Feb	15.98	0.00	-6.6	0.5	very light	moderate	moderate
151	22-Feb	11.75	0.00	-6.4	0.5	very light	moderate	moderate
152	22-Feb	17.48	0.00	-6.4	0.5	very light	moderate	moderate
153	22-Feb	19.88	0.00	-6.4	0.5	very light	moderate	moderate
154	22-Feb	12.83	0.00	-6.3	0.6	very light	moderate	moderate
155	22-Feb	24.20	16.90	-6.2	0.3	moderate	moderate	heavy
156	22-Feb	24.86	17.90	-6.3	0.4	moderate	moderate	heavy
157	22-Feb	23.12	0.00	-6.3	0.4	very light	moderate	moderate
158	22-Feb	21.95	0.00	-6.4	0.4	very light	moderate	moderate
159	22-Feb	17.53	0.00	-6.3	0.5	very light	moderate	moderate
160	22-Feb	20.16	0.00	-6.2	0.6	very light	moderate	moderate
161	22-Feb	12.45	0.00	-6.2	1.0	very light	moderate	light
162	22-Feb	11.62	0.00	-6.1	0.9	very light	moderate	light
163	22-Feb	34.81	0.00	-6.0	1.3	very light	heavy	light
164	22-Feb	75.29	39.60	-6.1	0.9	heavy	heavy	moderate
165	22-Feb	63.45	44.80	-6.2	0.5	heavy	heavy	moderate
166	22-Feb	22.53	0.00	-6.2	0.4	very light	moderate	moderate

Test No.	Date	Plate Pan Rate	Average Hot Plate Rate	Temp (ºC)	Visibility (stat miles)	Snow Type determined by Hot Plate	Snow Type determined by Plate Pan	Snow Type determined by Visibility
167	22-Feb	10.59	0.00	-6.3	0.6	very light	moderate	moderate
168	22-Feb	9.84	0.00	-6.3	0.7	very light	light	moderate
169	22-Feb	15.51	0.00	-6.3	0.7	very light	moderate	moderate
170	22-Feb	8.65	0.00	-6.3	0.6	very light	light	moderate
171	22-Feb	8.27	0.00	-6.2	0.7	very light	light	moderate
172	22-Feb	15.95	0.00	-6.3	0.8	very light	moderate	moderate
173	22-Feb	34.44	0.00	-6.2	0.9	very light	heavy	light
174	22-Feb	55.74	16.50	-6.2	0.9	moderate	heavy	moderate
175	23-Feb	2.06	0.00	-5.0	1.4	very light	very light	light
176	23-Feb	5.07	0.00	-4.7	1.0	very light	light	light
177	23-Feb	8.31	0.00	-4.7	0.7	very light	light	moderate
178	23-Feb	8.10	6.70	-4.6	0.7	light	light	moderate
179	23-Feb	3.71	0.00	-4.6	0.8	very light	very light	moderate
180	23-Feb	11.50	8.40	-4.0	0.8	light	moderate	moderate
181	23-Feb	10.67	11.30	-3.8	0.8	moderate	moderate	moderate
182	23-Feb	13.39	16.70	-3.7	0.6	moderate	moderate	moderate
183	23-Feb	15.98	16.90	-3.6	0.6	moderate	moderate	moderate
184	23-Feb	5.97	6.20	-3.6	1.0	light	light	light
185	23-Feb	0.00	0.00	-3.6	2.9	very light	very light	very light
186	23-Feb	2.30	0.00	-4.0	3.7	very light	very light	very light
187	23-Feb	8.69	5.40	-4.2	2.6	light	light	very light
188	23-Feb	3.43	1.60	-4.3	2.4	very light	very light	very light
189	2-Mar	25.61	33.78	0.2	0.4	heavy	heavy	heavy
190	2-Mar	20.18	26.89	0.3	0.5	heavy	moderate	heavy
191	2-Mar	15.13	20.29	0.3	0.5	moderate	moderate	heavy
192	2-Mar	21.97	26.55	0.4	0.4	heavy	moderate	heavy
193	2-Mar	22.74	26.93	0.3	0.4	heavy	moderate	heavy
194	2-Mar	38.29	43.88	0.3	0.4	heavy	heavy	heavy
195	2-Mar	33.21	40.36	0.4	0.4	heavy	heavy	heavy
196	2-Mar	20.41	26.27	0.4	0.4	heavy	moderate	heavy
197	2-Mar	12.13	16.65	0.4	0.7	moderate	moderate	moderate
198	2-Mar	11.15	14.84	0.6	1.2	moderate	moderate	moderate
199	5-Mar	0.28	0.00	-8.5	2.2	very light	very light	very light
200	5-Mar	2.93	2.12	-7.9	1.3	very light	very light	light
201	5-Mar	3.67	3.82	-7.7	1.0	very light	very light	light
202	5-Mar	5.64	6.50	-7.4	0.8	light	light	moderate
203	5-Mar	6.91	10.40	-7.4	0.7	moderate	light	moderate
204	5-Mar	5.83	8.80	-7.5	0.7	light	light	moderate
205	5-Mar	8.88	10.00	-7.4	0.6	light	light	moderate
206	5-Mar	4.18	4.40	-7.1	0.7	light	light	moderate
207	5-Mar	3.99	2.80	-7.1	0.9	very light	very light	moderate
208	5-Mar	7.90	8.80	-7.2	0.7	light	light	moderate
209	5-Mar	5.59	7.30	-7.4	0.7	light	light	moderate
210	5-Mar	9.82	11.90	-7.5	0.6	moderate	light	moderate
211	5-Mar	5.53	8.62	-7.1	0.7	light	light	moderate
212	5-Mar	5.22	7.90	-6.7	0.7	light	light	moderate

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213	5-Mar	2.63	3.60	-6.5	0.8	very light	very light	moderate
214	5-Mar	6.06	6.30	-6.3	0.8	light	light	moderate
215	5-Mar	8.88	11.50	-6.1	0.6	moderate	light	moderate
216	5-Mar	7.47	9.80	-6.1	0.6	light	light	moderate
217	5-Mar	8.65	10.20	-6.4	0.6	moderate	light	moderate
218	5-Mar	6.77	7.30	-6.3	0.6	light	light	moderate
219	5-Mar	5.78	2.20	-6.4	0.7	very light	light	moderate
220	5-Mar	6.77	4.50	-6.3	0.7	light	light	moderate
221	5-Mar	3.67	0.00	-6.3	0.7	very light	very light	moderate
222	5-Mar	2.96	0.00	-6.3	0.9	very light	very light	moderate
223	5-Mar	3.05	0.00	-6.5	1.0	very light	very light	light
224	5-Mar	4.37	0.00	-7.9	1.0	very light	light	light
225	5-Mar	5.12	0.00	-8.9	1.1	very light	light	light
226	5-Mar	3.62	0.00	-9.3	1.2	very light	very light	light
227	5-Mar	4.56	0.00	-9.2	1.1	very light	light	light
228	5-Mar	6.06	0.00	-8.8	1.0	very light	light	light
229	5-Mar	7.38	6.20	-7.8	0.8	light	light	moderate
230	5-Mar	6.97	6.08	-8.0	0.9	light	light	light
231	5-Mar	4.42	0.18	-8.2	1.1	very light	light	light
232	5-Mar	7.57	2.60	-8.2	0.9	very light	light	light
233	5-Mar	6.14	0.28	-7.9	0.9	very light	light	light
234	5-Mar	4.11	0.92	-7.5	1.3	very light	light	light
235	5-Mar	2.79	0.00	-7.1	1.7	very light	very light	light
236	5-Mar	14.80	3.64	-8.2	0.7	very light	moderate	moderate
237	5-Mar	8.40	0.00	-8.9	0.9	very light	light	light
238	9-Mar	28.1	26.0	-11.6	0.0	heavy	heavy	heavy
239	9-Mar	20.6	24.7	-11.6	0.0	moderate	moderate	heavy
240	9-Mar	30.1	33.4	-11.6	0.0	heavy	heavy	heavy
241	9-Mar	29.8	30.4	-11.6	0.0	heavy	heavy	heavy
242	9-Mar	25.3	26.3	-11.6	0.0	heavy	heavy	heavy
243	9-Mar	21.5	22.4	-11.6	0.0	moderate	moderate	heavy
244	9-Mar	21.0	20.7	-11.6	0.0	moderate	moderate	heavy
245	9-Mar	9.6	8.7	-11.6	0.0	light	light	heavy
246	9-Mar	8.8	9.0	-11.6	0.0	light	light	heavy
247	9-Mar	14.4	15.0	-11.6	0.0	moderate	moderate	heavy
248	9-Mar	31.2	30.6	-11.6	0.0	heavy	heavy	heavy
249	9-Mar	32.7	31.8	-11.6	0.0	heavy	heavy	heavy
250	9-Mar	35.8	28.6	-11.6	0.0	heavy	heavy	heavy
251	9-Mar	35.2	28.2	-11.6	0.0	heavy	heavy	heavy
252	9-Mar	37.4	30.6	-2.6	3.0	heavy	heavy	very light
253	9-Mar	31.7	19.6	-2.0	0.3	moderate	heavy	heavy
254	9-Mar	31.3	22.5	-2.1	0.3	moderate	heavy	heavy
255	9-Mar	26.7	18.1	-2.3	0.3	moderate	heavy	heavy
256	9-Mar	24.1	11.8	-2.4	0.3	moderate	moderate	heavy
257	9-Mar	22.0	10.0	-2.5	0.4	light	moderate	moderate
258	9-Mar	28.1	13.8	-2.5	0.4	moderate	heavy	moderate

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259	9-Mar	31.3	16.7	-2.5	0.4	moderate	heavy	moderate
260	9-Mar	22.8	11.3	-2.5	0.4	moderate	moderate	moderate
261	9-Mar	20.7	12.5	-2.4	0.4	moderate	moderate	moderate
262	9-Mar	15.7	7.9	-2.4	0.4	light	moderate	moderate
263	9-Mar	13.0	8.0	-2.4	0.4	light	moderate	moderate
264	9-Mar	10.8	3.4	-2.3	0.5	very light	moderate	moderate
265	9-Mar	9.6	8.0	-2.3	0.6	light	light	moderate
266	9-Mar	5.7	6.8	-2.3	0.6	light	light	moderate
267	9-Mar	9.5	5.9	-2.2	0.7	light	light	moderate
268	9-Mar	8.8	8.2	-2.3	0.7	light	light	moderate
269	9-Mar	6.1	3.6	-2.3	0.9	very light	light	light
270	9-Mar	2.9	0.0	-2.4	1.1	very light	very light	light