TP 14146E

Winter Weather Impact on Holdover Time Table Format (1995-2003)

Prepared for

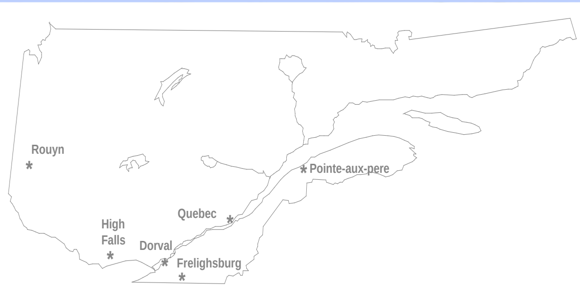
Transportation Development Centre

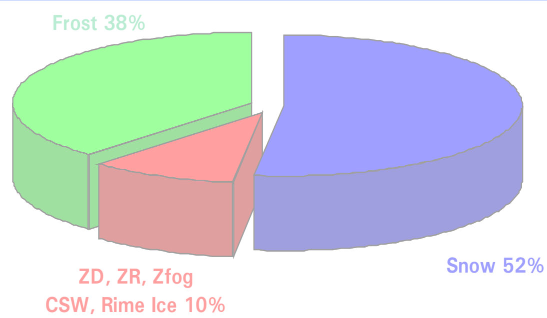
On behalf of

Civil Aviation
Transport Canada

Prepared by

APS Aviation Inc.

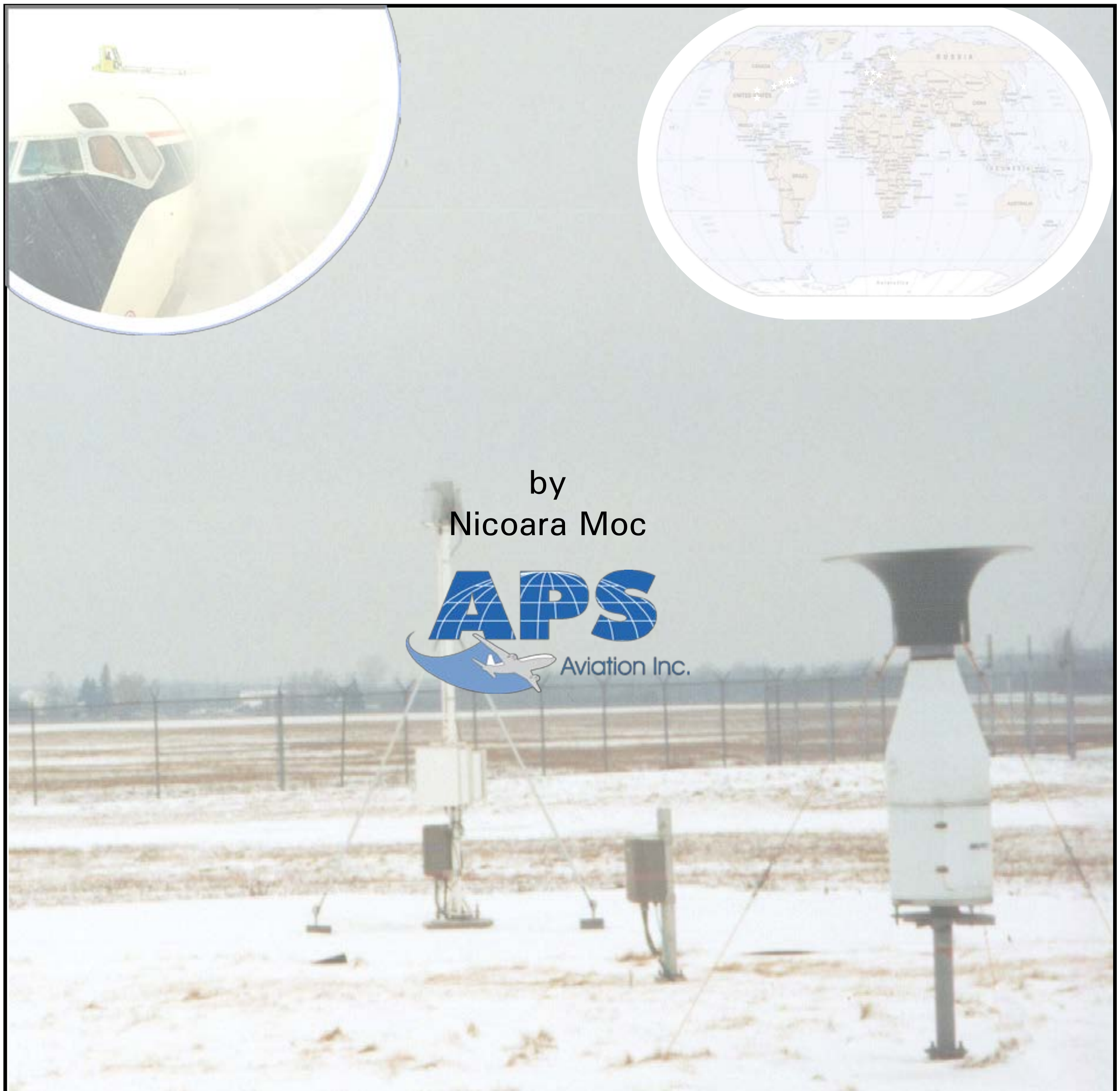




October 2003
Final Version 1.0

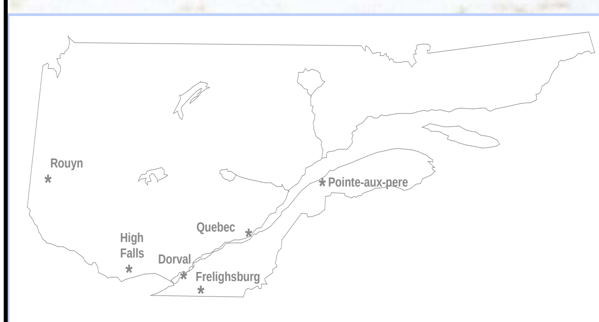
TP 14146E

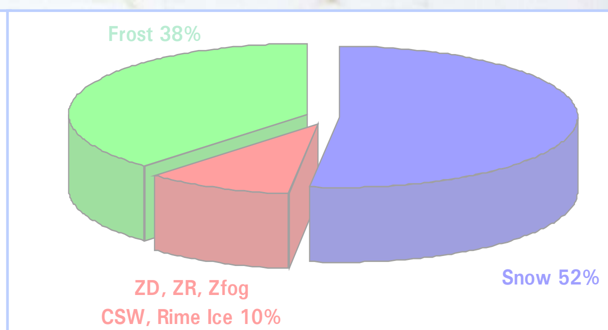
Winter Weather Impact on Holdover Time Table Format (1995-2003)



by
Nicoara Moc

APS Aviation Inc.





October 2003
Final Version 1.0

The contents of this report reflect the views of APS Aviation Inc. and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

DOCUMENT ORIGIN AND APPROVAL RECORD

Prepared by:	Nicoara Moc (Project Analyst)
Reviewed by:	Gilles Nappert, P. Eng. (Director, Quality Assurance)

This report was prepared and signed by Nicoara Moc, reviewed and signed by Gilles Nappert and approved and signed by John D'Avirro in October 2003 as part of the first submission to Transport Canada (Final Draft 1.0). A final Transport Canada technical and editorial review was completed in September 2017; Nicoara Moc and Gilles Nappert were not available to participate in the final review or to sign the current version of this report.

Approved by:

John D'Avirro, Eng.
Program Manager

November 17, 2017
Date

Un sommaire français se trouve avant la table des matières.

PREFACE

Under contract to the Transportation Development Centre of Transport Canada and in conjunction with the Federal Aviation Administration, 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 14146E, has the following objective:

To review of Holdover Time Table Format using Winter Weather Data.

This objective was met by acquiring and analysing winter weather data from six meteorological stations in Quebec, Canada, along with the findings from a survey of deicing operations from several major airports across the world. This information was used to review and assess the format of the holdover time tables.

ACKNOWLEDGEMENTS

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

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

Transport Canada | Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.
TP 14146E

2. Project No.
B14W

3. Recipient's Catalogue No.

4. Title and Subtitle
Winter Weather Impact on Holdover Time Table Format (1995-2003)

5. Publication Date
October 2003

6. Performing Organization Document No.
CM1747.001

7. Author(s)
Nicoara Moc

8. Transport Canada File No.
2450-BP-14

9. Performing Organization Name and Address
APS Aviation Inc.
6700 Cote-de-Liesse, Suite 102
Montreal, Quebec H4T 2B5
Canada

10. PWGSC File No.
TOR-4-37170

11. PWGSC or Transport Canada Contract No.
T8156-140243/001/TOR

12. Sponsoring Agency Name and Address
Transportation Development Centre (TDC)
Transport Canada
330 Sparks St., 25th Floor
Ottawa, Ontario K1A 0N5
Canada

13. Type of Publication and Period Covered
Final

14. Project Officer
Antoine Lacroix

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

16. Abstract

This study examines the frequency of occurrence of the various winter weather conditions experienced during ground deicing of aircraft with a view to recommending and supporting immediate and future changes to the format of the holdover time tables for SAE Type I, II and IV anti-icing fluids.

Data were acquired from Meteorological Service of Canada (MSC) for six automated weather stations in the province of Quebec, Canada. A total of 4 839 hours of snowstorm data recorded between 1995 and 2003 and 391 hours of freezing rain data were analysed. The data set included 957 hours of snowstorm data from the 2002-03 winter.

In addition, data from surveys of winter operations conducted at several international airports over a two-year period was used to report the frequency of snow, frost, freezing fog, freezing rain/drizzle and cold–soak wing de/anti–icing occurrences during actual deicing operations.

Based on the analysis of the data, the Type I fluid holdover time table format was modified through incorporation of new temperature ranges and the addition of a new winter condition column for very light snow. Further changes to the holdover time table format for other fluid types are discussed.

This report contains recommendations to continue the surveys and to further advance the development of the snowmaker and the snow precipitation gauge.

17. Key Words
Natural snow, precipitation rates, weather data, holdover time table format, frequency and distribution of deicing operations

18. Distribution Statement
Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
Unclassified	Unclassified	—	xviii, 68 apps	—

CDT/TDC 79-005
Rev. 96

Canada

Transports Canada | Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada TP 14146E	2. N° de l'étude B14W	3. N° de catalogue du destinataire
4. Titre et sous-titre Winter Weather Impact on Holdover Time Table Format (1995-2003)		5. Date de la publication Octobre 2003 6. N° de document de l'organisme exécutant CM1747.001
7. Auteur(s) Nicoara Moc		8. N° de dossier - Transports Canada 2450-BP-14
9. Nom et adresse de l'organisme exécutant APS Aviation Inc. 6700 Côte-de-Liesse, Suite 102 Montréal, Québec H4T 2B5 Canada		10. N° de dossier - TPSGC TOR-4-37170 11. N° de contrat - TPSGC ou Transports Canada T8156-140243/001/TOR
12. Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) Transport Canada 330 Sparks St., 25th Floor Ottawa, Ontario K1A 0N5 Canada		13. Genre de publication et période visée Final 14. Agent de projet Antoine Lacroix

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

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

16. Résumé

La présente étude examine la fréquence des différents événements météorologiques hivernaux qui se produisent durant le dégivrage d'aéronefs au sol, dans le but de recommander et d'appuyer des changements immédiats et futurs au format des tableaux d'efficacité des liquides d'antigivrage de types I, II et IV de la SAE.

Les données, obtenues auprès du Service météorologique du Canada (SMC), provenaient de six stations météorologiques automatisées situées au Québec, Canada. Un total de 4 839 heures de données de précipitations neigeuses, enregistrées entre 1995 et 2003, et plus de 391 heures de données de pluie verglaçante, ont été analysées. Sont comprises dans l'ensemble de données plus de 957 heures de données de précipitations neigeuses recueillies au cours de l'hiver 2002-2003.

De plus, les données des études sur les opérations hivernales menées à plusieurs aéroports internationaux sur une période de deux ans ont servi à signaler la fréquence d'événements de dégivrage ou d'antigivrage dans la neige, le givre, le brouillard verglaçant, la pluie ou la bruine verglaçantes et dans le cas d'aile imprégnée de froid.

En fonction des données, le format du tableau des durées d'efficacité des liquides de type I a été modifié par l'incorporation de nouvelles plages de températures et l'ajout d'une nouvelle colonne pour la neige légère. D'autres changements au format du tableau pour d'autres types de liquides font l'objet de discussions.

Ce rapport contient des recommandations afin de poursuivre la récolte des données et de favoriser le développement de l'appareil de mesure des précipitations de neige et du canon à neige.

17. Mots clés Neige naturelle, taux de précipitation, données météorologiques, tableau de durées d'efficacité, fréquence et répartition des opérations de dégivrage.	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	—	xviii, 68 ann.	—

CDT/TDC 79-005
Rev. 96

Canada

EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), APS Aviation Inc. (APS) undertook a study to evaluate precipitation data (precipitation rate/temperature data) from several winters to confirm the suitability of precipitation rate ranges used for holdover time evaluation.

In addition, information collected from other research that relates to winter weather data has been compiled and is included in this report.

The information contained in this report can be used to further evaluate potential refinements to the format of the holdover time (HOT) tables.

Description and Processing of Data

A total of 4 839 hours of storm data points was developed from precipitation gauge logs for natural snow, including 957 hours from the 2002-03 data. Freezing rain/drizzle data were used to develop 391 hours of storm data. Data were acquired from Meteorological Service of Canada (MSC) from instruments located at Montreal's Dorval Airport and five other stations in the province of Quebec, Canada. The Dorval Airport data were collected over several winters; data from other stations were collected from the winters of 1997-98 to 2002-03. Similar data were collected for two winters and analysed by MSC at Toronto's Pearson Airport.

In addition, the results from a survey of deicing operations at worldwide airports were analysed and used to recommend improvements to the HOT tables.

Results and Conclusions

The weather data base gathered over eight years from six sites in Quebec showed that current snow precipitation rate limits of 10 and 25 g/dm^2/h are valid for moderate snow. The data analysis concluded that the current HOT table snow column representing moderate snow encompasses only 23.7 percent of all snow events. This supports earlier data that led to the introduction of a light snow column for snow events occurring at precipitation rates of 4 to 10 g/dm^2/h. This column was used during the 2002-03 winter season.

Most snowfall events occur at rates less than 4 g/dm^2/h and are not acknowledged in the current HOT table. In order to use the longer holdover times in the light snow column, and because snow comprises 52 percent of all deicing operations, further introduction of a very light snow column in the HOT table was recommended and accepted at the 2003 SAE G–12 meeting.

It was concluded for the Type I HOT table that the temperature row of *-3 to -10 ºC* should be replaced by two new temperature bands, *below -3 to -6 ºC* and *below -6 to -10 °C*. Selection of -6 °C as the temperature break was found to be the most operationally advantageous. This value is also the same as the temperature break used by the FAA. Further changes to the holdover time table format for other fluid types are discussed. The format of the Type II/IV HOT tables should be examined to integrate the Type I table changes, including removal of the above 0 ºC row and introduction of additional snow columns for precipitation rates lower than 10 g/dm²/h.

The survey of actual winter operations showed that the HOT table for snow is given the most frequent use, and thus deserves a corresponding degree of attention. Development of the National Center For Atmospheric Research (NCAR) snowmaker to allow snow endurance time testing in controlled laboratory conditions is an important part of this effort.

Frost is the second most frequent type of deicing condition, and sufficient attention should be given to investigating and substantiating frost holdover times for Type I fluids.

The limited data base for freezing rain and drizzle indicates that the current temperature and rate limits for those conditions are valid. However, the data base for these conditions is small and additional data would be useful.

HOT tables for freezing fog are used only 1.4 percent of the time. Modifying the HOT table column for freezing fog to a single value rather than a range would be justified, based on lengthy endurance times and infrequency of use.

Recommendations

It is recommended that high priority and support be given to development of the NCAR hotplate snow gauge to an operational state and to the NCAR snowmaker for use in snow endurance time testing. The weather data survey and the winter operations survey have provided useful information and should be continued to generate more data, and expanded to include more cities worldwide. A workgroup should be assembled to examine and formulate the optimum format for HOT tables and to document a generic HOT table format in an Aerospace Standard as discussed at the SAE G–12 HOT Committee.

SOMMAIRE

En vertu d'un contrat avec le Centre de développement des transports (TDC) de Transports Canada (TC), APS Aviation Inc. (APS) a entrepris une étude pour évaluer les données de précipitation (données sur les taux et températures des précipitations) de plusieurs hivers, afin de confirmer la pertinence des plages de taux de précipitation utilisées pour l'évaluation des durées d'efficacité.

De plus, le présent rapport englobe aussi des données colligées à l'occasion d'autres recherches connexes.

L'information contenue dans ce rapport peut servir à évaluer la pertinence d'améliorations possibles à la présentation des tableaux des durées d'efficacité.

Description et traitement des données

Des points de données de précipitations neigeuses ont été établis à partir de relevés nivométriques couvrant un total de 4 839 heures, dont 957 heures pendant l'hiver 2002-2003. Des données de pluie/bruine verglaçante ont servi à générer des points de données couvrant plus de 391 heures. Ces données, obtenues auprès du Service météorologique du Canada (SMC), provenaient d'instruments situés à l'Aéroport de Dorval, Montréal et de cinq autres stations du Québec, Canada. Les données de l'Aéroport de Dorval couvraient plusieurs hivers, tandis que celles des autres stations ne couvraient que les hivers 1997-98 à 2002-03. Des données analogues ont été recueillies et analysées par SMC à l'Aéroport international Pearson de Toronto pour deux hivers.

De plus, les résultats d'une enquête sur les opérations de dégivrage à des aéroports à travers le monde ont été analysés et ont servi à recommander des améliorations aux tableaux de durées d'efficacité.

Résultats et conclusions

La base de données météorologiques recueillie au cours de huit ans sur six emplacements du Québec a démontré que les limites actuelles de taux de précipitation de neige de 10 et 25 g/dm^2/h sont valides dans le cas de neige modérée. L'analyse des données a conclu que la colonne du tableau actuel de durées d'efficacité qui illustre la neige modérée ne couvre que 23,7 pourcent de tous les événements de neige. Cela concorde avec les données antérieures qui ont mené à l'introduction d'une colonne de neige légère pour les chutes de neige ayant des taux de précipitation de 4 à 10 g/dm^2/h. Cette colonne a servi durant l'hiver 2002-03.

La plupart des chutes de neige se produisent à un taux inférieur à 4 g/dm^2/h et ne sont pas identifiées dans le tableau actuel de durées d'efficacité. Afin d'utiliser des durées d'efficacité plus longues dans la colonne de neige légère et parce que la neige compte pour 52 pourcent de toutes les opérations de dégivrage, l'introduction additionnelle d'une colonne de neige très légère au tableau des durées d'efficacité a été recommandée et acceptée à la réunion de 2003 du G–12 de la SAE.

L'analyse a conclu que, pour le tableau de durées d'efficacité des liquides de type I, la rangée des températures de *-3 à -10°C* devrait être retirée et remplacée par une nouvelle rangée, *au-dessous de -3 à -6°C*. Le choix de -6°C comme température limite produit le mélange de durées d'efficacité le plus avantageux du point de vue opérationnel. Cette valeur est la même que la température limite utilisée par la FAA. D'autres changements au format du tableau de durées d'efficacité pour les autres types de liquide font l'objet de discussions. Le format des tableaux de durées d'efficacité des liquides de types II et IV devrait être examiné en vue d'y intégrer les changements au tableau de type I, y compris le retrait de la rangée de températures au-dessus de 0°C et l'introduction de colonnes de neige additionnelles pour les taux de précipitation inférieurs à 10 g/dm^2/h.

L'enquête sur les opérations hivernales réelles a démontré que le tableau de durées d'efficacité applicable à la neige est le plus utilisé et, en conséquence, mérite une attention équivalente. Le développement canon à neige du National Center For Atmospheric Research (NCAR), qui permet des essais de durée d'efficacité dans la neige dans des conditions contrôlées en laboratoire, représente une partie importante de cet effort.

Le givre est deuxième en importance parmi les conditions de dégivrage et suffisamment d'attention devrait être portée à l'étude et à la justification des durées d'efficacité dans le givre pour les liquides de type I.

La base de données limitée sur la pluie et la bruine verglaçantes démontre que les limites actuelles de température et de taux sont valides dans ces conditions. Cependant, cette base de données est petite et des données additionnelles seraient utiles.

Les tableaux de durées d'efficacité applicables au brouillard verglaçant ne sont utilisés que 1,4 pourcent du temps. La modification pour une seule valeur plutôt que pour plusieurs de la colonne du tableau de durées d'efficacité applicable au brouillard verglaçant serait justifiée, étant donné les longues durées d'efficacité et l'usage peu fréquent.

Recommandations

Il est recommandé qu'une priorité et un soutien élevés soient accordés au développement opérationnel de l'appareil de mesure de la neige à plaque chauffante et du canon à neige du NCAR pour les essais des durées d'efficacité dans la neige. L'étude sur les données météorologiques et l'étude sur les opérations hivernales ont produit de l'information utile et devraient être poursuivies pour générer davantage de données. Elles devraient aussi être étendues à plus de villes à l'international. Un groupe de travail devrait être créé pour examiner et élaborer le format optimal des tableaux de durées d'efficacités, ainsi que pour documenter un format de tableau générique de durées d'efficacité sous forme de Standard aéronautique, tel que discuté au comité G–12 de la SAE sur les durées d'efficacité.

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

Page

LIST OF TABLES

Page

GLOSSARY

ADM	Aéroports de Montréal
AIR	Aerospace Information Report
AMIL	Anti–Icing Materials International Laboratory
APS	APS Aviation Inc.
FAA	Federal Aviation Administration
HOT	Holdover Time
IREQ	Institut de Recherche d'Hydro–Québec
MSC	Meteorological Service of Canada
NCAR	National Center for Atmospheric Research
OAT	Outside Air Temperature
READAC	Remote Environmental Automatic Data Acquisition Concept
SAE	SAE International
TC	Transport Canada
TDC	Transportation Development Centre

This page intentionally left blank.

1. INTRODUCTION

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), APS Aviation Inc. (APS) undertook a study to advance de/anti–icing technology. This report contains the results of an analysis conducted by APS between 1995-96 and 2002-03 on the evaluation of snow precipitation rate data. It also encompasses all the data presented in the 2001-02 TC report, *Impact of Winter Weather on Holdover Time Table Format*, TP 13993E (1). This study formed part of the 2002-03 winter research program on deicing, as described in the work statement presented as Appendix A.

Holdover time (HOT) tables are developed as guidelines to be used by pilots in aircraft departure planning under different winter weather conditions. Each Holdover Time (HOT) table is composed of cells, with each cell containing a holdover time range for a specific temperature range and category of precipitation. The time range in each cell is defined by a “lower” time and an “upper” time; these values represent the failure time of the fluid at the upper and lower precipitation rate range, respectively.

There are three standard types of fluid: Type I, Type II, and Type IV. Aircraft are deiced using heated Type I fluids. Type II and Type IV fluids are anti–icing fluids that are applied following aircraft deicing, with Type II fluids being thicker and more viscous than Type I fluids. Type IV fluids are the latest generation of anti-icing fluids and are designed to provide the utmost in holdover time protection.

The Type I and Type II/IV HOT table formats have undergone significant change since the early 1990s. While the changes have been made primarily to improve and address safety concerns of many individuals and organizations involved in the deicing industry, a structured approach has not been taken for implementing changes. In fact, many of the changes have been made on a year–by–year basis at industry meetings. These changes were typically minor in nature, but after nearly ten years, the impact on the HOTs is more significant. More recently, several changes have been made to improve and simplify the tables, while simultaneously ensuring that a high level of safety is maintained when the tables are put to use. Proposals for changes to the HOT tables have been made by TC, and these include new temperature breakdowns to better reflect winter precipitation conditions, expansion of the snow column to reflect its high usage, and removal of unnecessary HOT ranges in certain columns to result in a single value. To substantiate these changes, a survey of airlines at several international airports was conducted. The survey provided information relating to the frequency of deicing operations as a function of weather condition and temperature.

Several years ago, holdover times for snow were evaluated or developed using lower and upper precipitation rates of 10 and 25 $g/dm^2/h$ for all air temperatures (0, -3, -14 and -25°C). In 1997, at a workshop meeting in Montreal, these rates were considered extreme at temperatures of -14 and -25°C because such high precipitation rates, although they do exist, were thought to be less frequent at these lower temperatures. The 2001-02 report, *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, TP 13993E (1) concluded that the holdover time rate limits of 10 and 25 g/dm²/h are indeed representative of natural snow conditions.

The main purposes of this study were to:

a) Further evaluate weather precipitation data (precipitation rate/temperature data) over several recent winters and substantiate the suitability of proposed data ranges for the evaluation of upper and lower holdover time limits;

b) Review the survey of winter weather data and apply it to evaluate the format of the HOT tables; and

c) Conduct an analysis of the HOT table format and recommend changes.

The following section of this report (Section 2) analyses the natural snow and freezing rain/drizzle data collected in 2002-03 from six stations in Quebec and provides, in conjunction with data from seven previous winter seasons, a distribution of precipitation events by temperature and precipitation rate. Section 3 reviews the survey data collected in 2000-01 and 2001-02, and presents an allocation of deicing operations worldwide based on 2 years of observation. Section 4 analyses the findings in Sections 2 and 3 with the goal of substantiating the current and proposed changes to the format of the HOT tables. Section 5 presents a brief summary of the frost deposition rates measured in natural conditions. The conclusions and recommendations are presented in Sections 6 and 7 of this report.

2. DESCRIPTION AND ANALYSIS OF NATURAL SNOW AND FREEZING RAIN/DRIZZLE DATA

2.1 Methodology

This section describes the methods used to evaluate weather data that were collected to study the occurrence of high precipitation rates at low temperatures for natural snow and freezing rain/drizzle.

2.1.1 Sources of Data and Test Sites

The precipitation rates analysed in this report were extracted from the following:

a) The Dorval Remote Environmental Automatic Data Acquisition Concept (READAC) log for the years 1995 to 1999;

b) The data logs from 1998 to 2003 for the three CR21X stations at Rouyn, Pointe-au-Père (Mont-Joli), and Ancienne Lorette (Quebec City);

c) The data log from the Dorval Airport CR21X station from 1998 to 2003; and

d) The data logs for 2000 to 2003 from two additional stations located in High Falls (near Ottawa, Ontario) and Frelighsburg (in Quebec's Eastern Townships).

Moreover, results from the survey of several international airports were used as a source of data for the evaluation of the HOT table format.

The data collected by APS from various sources extending back to the 1991-92 winter season, using different precipitation gauges, are shown in Table 2.1. Each site is identified on a map of Quebec, shown in Figure 2.1. The data, starting with the 1995-96 winter season, analysed and sorted by temperature ranges, are included in Appendix B.

Two similar studies were conducted. One study was conducted by APS in the 1993-94 to 1994-95 winters using data collected from three weather stations located around Montreal. Meteorological Service of Canada (MSC) carried out a similar study in 1995 using data collected at the Lester B. Pearson International Airport in Toronto. Overall, the data sets from MSC and APS were found to be similar enough to merit a comparison for temperature ranges above -7°C. Below that temperature, the MSC data contains no high rate precipitation points. These two studies can be found in Appendices C and D of TC report, *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, TP 13993E (1).

Table 2.1: Summary of Winter Weather Data

PROJECT #	YEAR	PLATE PAN	READAC YUL	CR21X						CITY OF MONTREAL (Fisher/Porter)
				WUY (Rouyn)	WTQ (Dorval)	WQB (Québec)	WYQ (Pointe-au-Père)	WFQ (Frelighsburg)	XHF (High Falls)	
	1990/91	Test period								
	1991/92	Test period								X(6)
	1992/93	Test period								X(6)
C1171	1993/94	Test period								X(1) (Three stations)
CM1222	1994/95	Test period	X(1)							
CM1283	1995/96	15 min	X(2)							
CM1338	1996/97	15 min	X(2)		X(5)					
CM1380	1997/98	5-15 min	X(2)	X(2)	X(2)	X(2)	X(2)			
CM1514	1998/99	5-15 min	X(2)	X(2)	X(2)	X(2)	X(2)			
CM1589	1999/00	5-15 min		X(2)	X(5)	X(2)	X(2)	X(2)	X(2)	
CM1680	2000/01	5-15 min		X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	
CM1680(01-02)	2001/02	5-15 min		X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	
CM1747	2002/03	5-15 min		X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	

(1) Data analysed for Transport Canada in 1996.

(2) Data used for this report.

(3) Unusable data - precipitation rate determined by this gauge was always lower than other instruments.

(4) Analysis completed by AES at YYZ.

(5) Unusable data - scattered data (gauge was not shielded).

(6) Data archived.

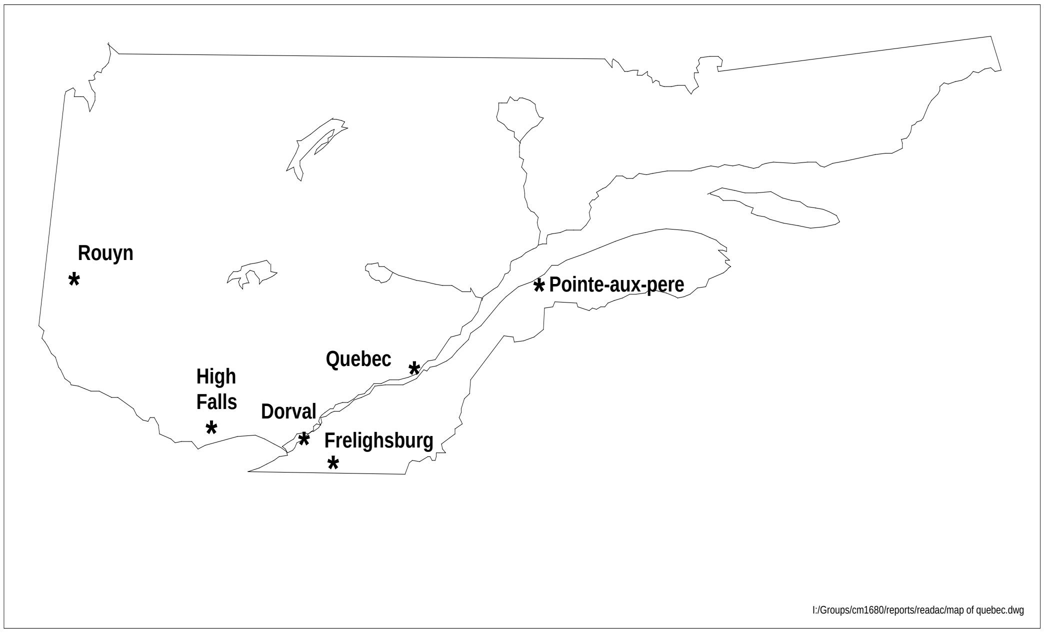


Figure 2.1: Map of Precipitation Gauge Locations

2.1.2 Equipment

Both the READAC and CR21X stations were used to measure precipitation rates. The READAC precipitation gauge consists of a bucket partially filled with an antifreeze compound so that it effectively captures snow. A weighing transducer shaft provides instantaneous displacement values of the bucket in terms of millimetres of precipitation. This shaft displacement is transmitted every 2.5 seconds and averaged every minute in an attempt to eliminate spurious data caused by gusts of wind and temperature-induced contraction and expansion of the sensor. The READAC instrument has a resolution of 0.5 mm (5 g/dm^2).

The CR21X station operates on the same principle as the READAC station and has an accuracy of 0.1 mm (1 g/dm^2). The station measures precipitation with a Fisher Porter precipitation gauge and the readings are logged with a CR21X data logger. A more detailed description of the CR21X equipment can be found in Appendix C.

Precipitation rates tend to fluctuate rapidly during snowstorms. The weight resolution of the READAC stations is less accurate in measuring rapid changes compared to the CR21X station. The data from the CR21X station therefore required less smoothing before it could be interpreted. The increased resolution of the CR21X weighing transducer allows better observation of short periods with heavy precipitation.

For this project, the measuring instruments used to record weather precipitation data were owned and operated by MSC, and these instruments were calibrated according to their standards. The data were acquired for the purpose of this project.

2.1.3 Description of Analytical Methods

Precipitation rate data were averaged at intervals that correspond to three specified periods typically used in the HOT tables: 6 minutes for Type I fluids, 20 minutes for Type II fluids, and 35 minutes for Type IV fluids. For natural snow, data were classified into four temperature ranges: *above 0°C*, *0 to -3°C*, *-3 to -14°C* and *-14 to 25°C*. For freezing rain/drizzle, data were classified into two ranges: *0 to -3°C* and *-3 to -10°C*.

Snowfalls at Dorval were tracked from 1995 to 2003 using the Monthly Meteorological Data Summary provided by Environment Canada. This summary includes meteorological data such as temperature, wind speed and direction, dew point temperature, and humidity on an hourly basis, and precipitation type and total accumulation on a daily basis. An example of the Monthly Meteorological Summary for Montreal is included in Appendix D. The last page of the summary (D–6) states whether it snowed on a particular day and the first page (D–1) provides the total snow accumulation for each day. Based on this information, the precipitation and temperature data were extracted from READAC logs on a minute-by-minute basis and added to a data base. The CR21X data were treated in a similar way.

Periods of snowfall were identified using Environment Canada summaries and snow accumulation data were added to the data base along with ambient air temperatures. The six CR21X data loggers (at Rouyn, Pointe–au–Père, Ancienne Lorette, Dorval, High Falls, and Frelighsburg) provided temperatures on an hourly basis. The temperatures were then linearly interpolated throughout the hour on a minute-by-minute basis.

2.1.4 Linearization of Cumulative Snow Weight Data

Precipitation rates were calculated in a two-step procedure. First, using an algorithm developed by APS, the total precipitation for each snowfall was linearized to produce a smooth curve. Table 2.2 shows an example of linearized values for total snow accumulation.

Secondly, precipitation rates were calculated according to the linearized total snow accumulation values and the time between readings. This procedure is described in Section 2.3.

Figure 2.2 shows an output from the CR21X data logger recording the output from the precipitation gauges and the linearized data for a typical snowfall. The precipitation gauge output, sensitive to 1 g/dm², is plotted versus time to establish the periods of snowfalls.

Table 2.2: Sample of Linearized READAC Data

Location	Date	UTC Time	Temp (°C)	Type of Precip.	Total Snow Accumulation (g/dm²)	Linearized Total Snow Accumulation (g/dm²)
YUL	14/12/1995	21:16	-11.8	S-	**40**	**40**
YUL	14/12/1995	21:17	-11.7	S-	**40**	**40.16**
YUL	14/12/1995	21:18	-11.6	S-	**40**	**40.31**
YUL	14/12/1995	21:19	-11.6	S-	**40**	**40.47**
YUL	14/12/1995	21:20	-11.6	S-	**40**	**40.63**
YUL	14/12/1995	21:21	-11.6	S-	**40**	**40.78**
YUL	14/12/1995	21:22	-11.6	S-	**40**	**40.94**
YUL	14/12/1995	21:23	-11.5	S-	**40**	**41.09**
YUL	14/12/1995	21:24	-11.6	S-	**40**	**41.25**
YUL	14/12/1995	21:25	-11.6	S-	**40**	**41.41**
YUL	14/12/1995	21:26	-11.4	S-	**40**	**41.56**
YUL	14/12/1995	21:27	-11.4	S-	**40**	**41.72**
YUL	14/12/1995	21:28	-11.5	S-	**40**	**41.88**
YUL	14/12/1995	21:29	-11.5	S-	**40**	**42.03**
YUL	14/12/1995	21:30	-11.4	S-	**40**	**42.19**
YUL	14/12/1995	21:31	-11.4	S-	**40**	**42.34**
YUL	14/12/1995	21:32	-11.4	S-	**40**	**42.50**
YUL	14/12/1995	21:33	-11.4	S-	**40**	**42.66**
YUL	14/12/1995	21:34	-11.4	S-	**40**	**42.81**
YUL	14/12/1995	21:35	-11.4	S-	**40**	**42.97**
YUL	14/12/1995	21:36	-11.3	S-	**40**	**43.13**
YUL	14/12/1995	21:37	-11.3	S-	**40**	**43.28**
YUL	14/12/1995	21:38	-11.4	S-	**40**	**43.44**
YUL	14/12/1995	21:39	-11.4	S-	**40**	**43.59**
YUL	14/12/1995	21:40	-11.3	S-	**40**	**43.75**
YUL	14/12/1995	21:41	-11.3	S-	**40**	**43.91**
YUL	14/12/1995	21:42	-11.3	S-	**40**	**44.06**
YUL	14/12/1995	21:43	-11.3	S-	**40**	**44.22**
YUL	14/12/1995	21:44	-11.2	S-	**40**	**44.38**
YUL	14/12/1995	21:45	-11.2	S-	**40**	**44.53**
YUL	14/12/1995	21:46	-11.2	S-	**40**	**44.69**
YUL	14/12/1995	21:47	-11.2	S-	**40**	**44.84**
YUL	14/12/1995	21:48	-11.2	S-	**45**	**45.00**
YUL	14/12/1995	21:49	-11.2	S-	**45**	**45.29**
YUL	14/12/1995	21:50	-11.2	S-	**45**	**45.59**
YUL	14/12/1995	21:51	-11.2	S-	**45**	**45.88**
YUL	14/12/1995	21:52	-11.1	S-	**45**	**46.18**
YUL	14/12/1995	21:53	-11.1	S-	**45**	**46.47**
YUL	14/12/1995	21:54	-11.1	S-	**45**	**46.76**
YUL	14/12/1995	21:55	-11.1	S-	**45**	**47.06**
YUL	14/12/1995	21:56	-11.1	S-	**45**	**47.35**
YUL	14/12/1995	21:57	-11.1	S-	**45**	**47.65**
YUL	14/12/1995	21:58	-11.1	S-	**45**	**47.94**
YUL	14/12/1995	21:59	-11.0	S-	**45**	**48.24**
YUL	14/12/1995	22:00	-11.0	S-	**45**	**48.53**
YUL	14/12/1995	22:01	-11.0	S-	**45**	**48.82**
YUL	14/12/1995	22:02	-11.0	S-	**45**	**49.12**
YUL	14/12/1995	22:03	-11.0	S-	**45**	**49.41**
YUL	14/12/1995	22:04	-10.9	S-	**45**	**49.71**
YUL	14/12/1995	22:05	-10.8	S-	**50**	**50.00**

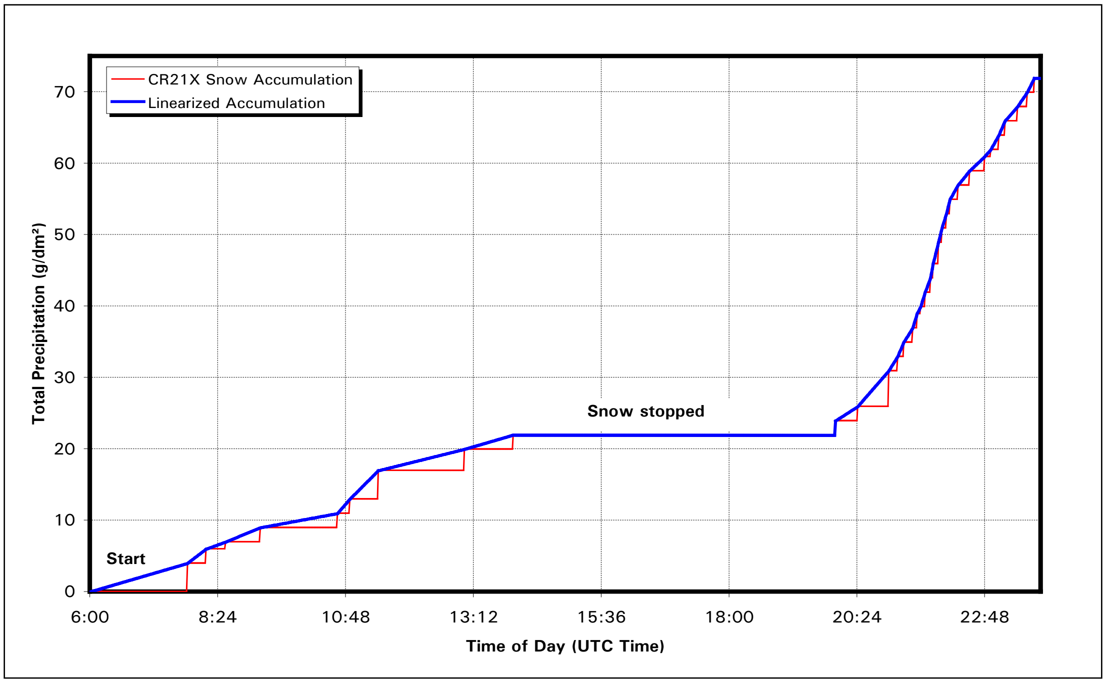


Figure 2.2: CR21X Precipitation Gauge Cumulative and Linearized Precipitation

As seen in Figure 2.2, intervals when snowfalls were interrupted for long periods of time were excluded from the analysis. Subsequent snowfalls were treated in a similar manner. The first and last indications of snowfall (first and last 1 g/dm²) were excluded due to uncertainty about the precise start and end time of the snowfall.

Periods of low–rate snow precipitation might have been overlooked due to long interruptions in bucket weight changes. It is difficult to establish whether these weight changes were due to constant low rate precipitation or long periods with no precipitation and short intervals of higher precipitation. The start and end of a snowstorm are difficult to establish because snow may start and end gradually at slow rates or abruptly at high rates. For several recent winters, light snowfalls over long periods of time were excluded. Starting with the 2000-01 winter season, it was established as a guideline that snowfalls with total precipitation of 2 cm over 6 hours be excluded; this analytical pattern was used for subsequent years.

2.2 Description and Processing of Natural Snow and Freezing Rain/Drizzle Data

2.2.1 Natural Snow

Using the information provided in the monthly meteorological summaries by MSC for each of the six weather stations across Quebec, the amount of snow during the

2002-03 winter was compared with Quebec's accumulation over the last 30 years. The period of time used to evaluate the quantity of snow precipitation was from November 2002 to April 2003. It was concluded that the 2002-03 winter had, on average, snow accumulation similar to Quebec's average over the last 30 years. For the six monitored meteorological stations in Quebec, the quantity of snow in cm/year is shown in Table 2.3.

Table 2.3: Snow Accumulation

	STATION					
	Frelighsburg	Quebec City	Montreal	Rouyn Noranda	Mont–Joli	High Falls
Average Snow Accumulation (cm/year)	–	333	190	–	362	232
2002-03 Winter Snow Accumulation (cm)	–	264	199	212	376	254

During the 2002-03 winter season, 57,441 data points were collected for natural snow conditions at the six stations in Quebec. These represent 957 hours of snowfall and an average of approximately 160 hours of snowfall at each station. Due to improvements in the CR21X stations, much more of the data collected during the past winter was usable in this analysis.

The distribution of the 2002-03 data points across the six meteorological stations is summarized in Table 2.4.

The distribution of new data points from all stations, sorted by temperature, is listed in Table 2.5.

Table 2.4: Distribution of 2002-03 Snow Data Points by Station

Station	# of Data Points	%
Frelighsburg	7205	13
Quebec	10517	18
Montreal	7722	13
Rouyn Noranda	10152	18
Mont–Joli	11435	20
High Falls	10410	18
Total	**57441**	**100**

Table 2.5: Distribution of 2002-03 Snow Data Points by Temperature

Temperature Range	# of Data Points
Above 0°C	4272
Between 0 and -3°C	20176
Between -3 and -6°C	17595
Between -6 and -10°C	10095
Between -10 and -14°C	3658
Between -14 and -25°C	1645
Total	**57441**

The distribution of data points for 2002-03, by temperature and in histogram format is shown in Figure 2.3. The following observations should be noted:

a) 7.4 percent of the snowfalls occurred at temperatures above 0°C;

b) 35.1 percent of the snowfalls occurred within the range of 0 to -3°C;

c) 30.6 percent occurred between -3 and -6°C;

d) 17.6 percent occurred between -6 and -10°C;

e) 6.4 percent occurred between -10 and -14°C; and

f) 2.9 percent occurred between -14 and -25°C.

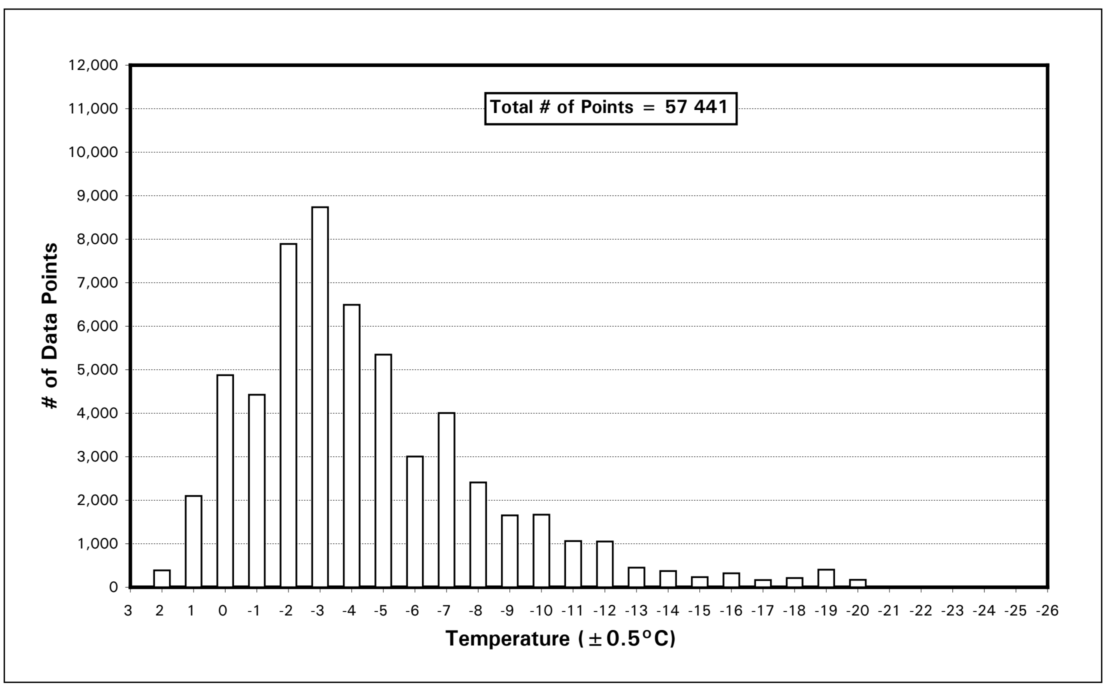


Figure 2.3: Temperature Distribution for 2002-03 Winter – Natural Snow

This is a consolidated report, encompassing all the data presented in TC report, *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, TP 13993E (1). A total of 290 372 data points were collected for natural snow conditions from 1995-96 to 2002-03. On average, this represented over 100 hours of snowfall per year for each of the six stations in Quebec.

The distribution of snow data points over the eight years of observation is illustrated in Table 2.6.

The distribution of data points by temperature range is listed in Table 2.7.

Table 2.6: Distribution of Snow Data Points (1995-96 to 2002-03)

Year	# of Data Points	%
1995-98	39426	13.6
1998-99	37272	12.8
1999-00	43927	15.1
2000-01	57280	19.7
2001-02	55026	19.0
2002-03	57441	19.8
Total	**290372**	**100**

Table 2.7: Temperature Distribution (1995-96 to 2002-03)

Temperature Range	# of Data Points
Above 0°C	31194
Between 0 and -3°C	79684
Between -3 and -6°C	71348
Between -6 and -10°C	62220
Between -10 and -14°C	30494
Between -14 and -25°C	15432
Total	**290372**

Figure 2.4 shows the temperature breakdown of all data points collected from the winters of 1995-96 to 2002-03 for natural snow. The following observations should be noted:

a) 10.7 percent of the snowfalls occurred at temperatures above 0°C;

b) 27.4 percent of the snowfalls occurred within the range of 0 to -3°C;

c) 24.6 percent occurred between -3 and -6°C;

d) 21.4 percent occurred between -6 and -10°C;

e) 10.5 percent occurred between -10 and -14°C; and

f) 5.3 percent occurred between -14 and -25°C.

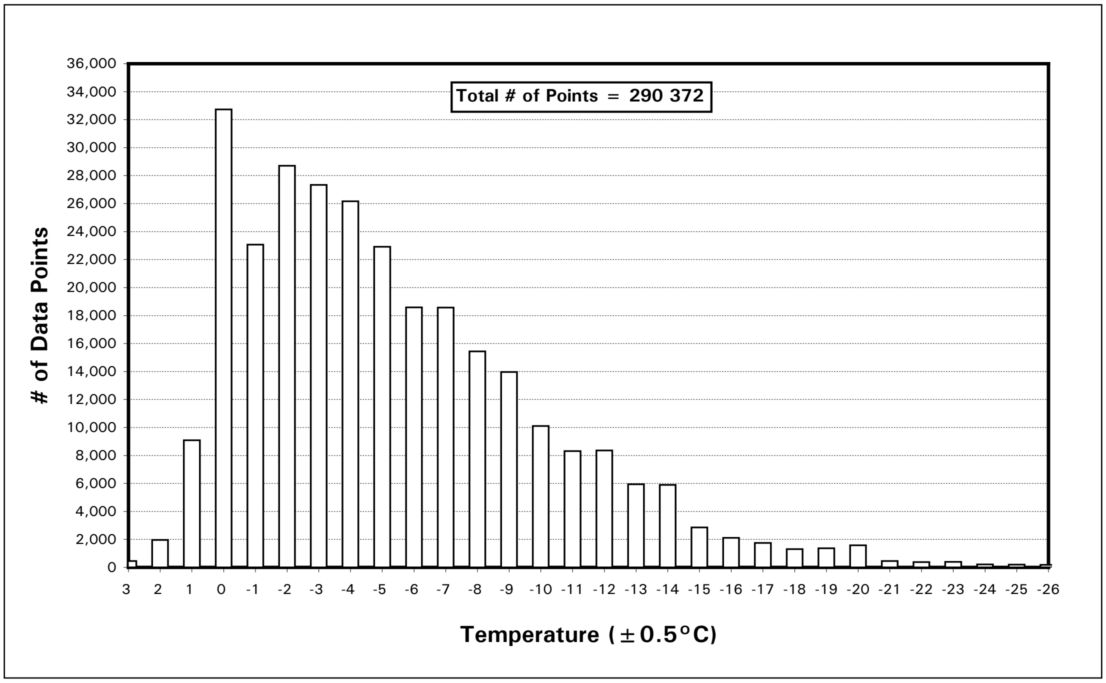


Figure 2.4: Temperature Distribution for the 1995-96 to 2002-03 Winters – Natural Snow

2.2.2 Freezing Rain/Drizzle

For Montreal and five other Quebec stations during the 2002-03 winter, 3,859 data points were collected. These represent approximately 64 hours of freezing rain/drizzle data. The distribution of the data by temperature range is shown in Figure 2.5.

The distribution of the 2002-03 data points by temperature range is listed in Table 2.8.

The following observation should be noted:

- Freezing rain/drizzle did not occur at temperatures below -6.3°C.

A total of 23,490 data points were collected for freezing rain/drizzle conditions from 1995-96 to 2002-03. These represent approximately 391 hours of light freezing rain/drizzle data. Freezing rain/drizzle data were developed from CR21X and READAC logs and were based largely on the 1998 ice storm.

The distribution of these data points over the eight years of observation is illustrated in Table 2.9.

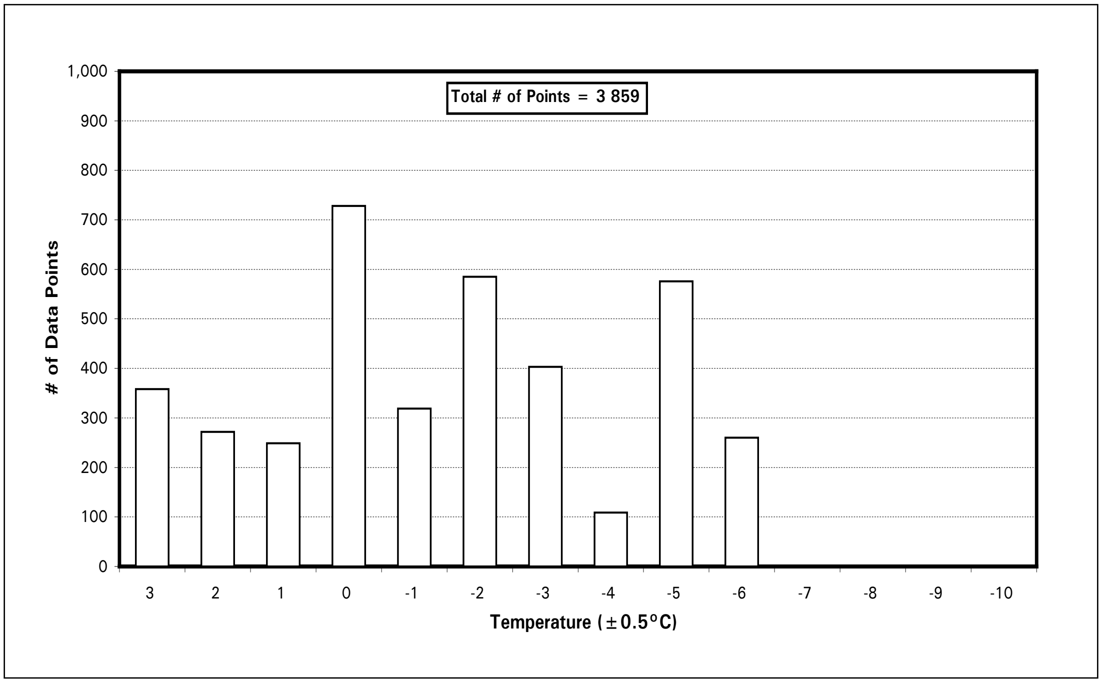


Figure 2.5: Temperature Distribution for 2002-03 – Freezing Rain/Drizzle

Table 2.8: Distribution of 2002-03 Freezing Rain/Drizzle Data Points by Temperature

Temperature Range	# of Data Points
Above 0ºC	1352
Between 0 and -3°C	1411
Between -3 and -6°C	889
Between -6 and -10°C	207
Total	**3859**

The distribution of data points by temperature range is listed in the Table 2.10.

Table 2.9: Distribution of Freezing Rain/Drizzle Data Points over the Last Eight Winters (1995-96 to 2002-03)

Year	# of Data Points	%
1995–00	13381	57
2000–01	785	3
2001–02	5465	23
2002–03	3859	17
Total	**23490**	**100**

Table 2.10: Distribution of 1995-96 to 2002-03 Freezing Rain/Drizzle Data Points by Temperature

Temperature Range	# of Data Points
Above 0ºC	5348
Between 0 and -3°C	8599
Between -3 and -6°C	7731
Between -6 and -10°C	1812
Total	**23490**

The following observation should be noted:

- Freezing rain/drizzle did not occur at temperatures below -9°C.

These observations should not be used as a generalization of freezing rain/drizzle occurrences because a significant amount of the data were derived from the 1998 ice storm.

The distribution of these data points by temperature range is shown in Figure 2.6.

2.2.3 Temperature and Precipitation Relationship for Canadian Stations

Several reports have been published on temperature relationships and the occurrence of precipitation. These reports are listed in the Reference Section as points (2), (3), (4), (5), (6) and (7).

Temperature and precipitation are two of the most important variables used to describe our climate. The dependence of daily precipitation on average daily temperature has been examined for all seasons using climatological data from 56 stations across Canada. The study was published in The Journal of Climate by the MSC in August 1992 (4).

According to the above study, the relation between these two factors is important for several reasons. First, precipitation–forming processes could be identified from any of the relationships observed. Second, if they are closely linked, an effective weather forecasting aid could be developed. Third, predictions of climate temperature changes may be used to predict precipitation changes.

The 56 stations were chosen because they contained long records (over 30 years) and were distributed across the area of interest. For every month, for each degree to the mean daily temperature, the distribution of precipitation amounts was calculated for the entire station record. These data were then processed and the appropriate graphs compiled. For example, Figure 2.7 shows the 1953 to 1988 frequency distributions of mean daily air temperature for Halifax for the month of January. Superimposed is the distribution of total precipitation as a function of mean daily temperature. As is evidenced by this graph, precipitation is observed on relatively warm days during the winter. The fraction of total precipitation occurring at temperatures below median daily temperature is only 20 percent.

The study shows that this is a consistent pattern across the country, with a few exceptions when this dependence is influenced by geography, as seen in the coastal areas and near the Rocky Mountains.

Using the same procedure, APS analysed the dataset from the 2000-01 to 2002-03 winters for six stations in Quebec (Quebec, Montreal, Rouyn Noranda, Pointe-aux-Peres, High Falls and Frelighsburg). The period taken into consideration was from December to March. Because the duration of measurements was very short in comparison with that of the MSC study, a mean daily temperature for the whole season was calculated by averaging the mean daily temperatures for each day of this period. The results are graphed in Figure 2.8.

As can be seen, the Quebec stations closely follow the pattern presented by Halifax. For these six measuring stations, 84 percent of the precipitation occurred at a temperature above the median.

The dataset from the MSC study shows that 20 percent of precipitation occurs below the median temperature; in the case of the Quebec stations, 16 percent occurs below the median.

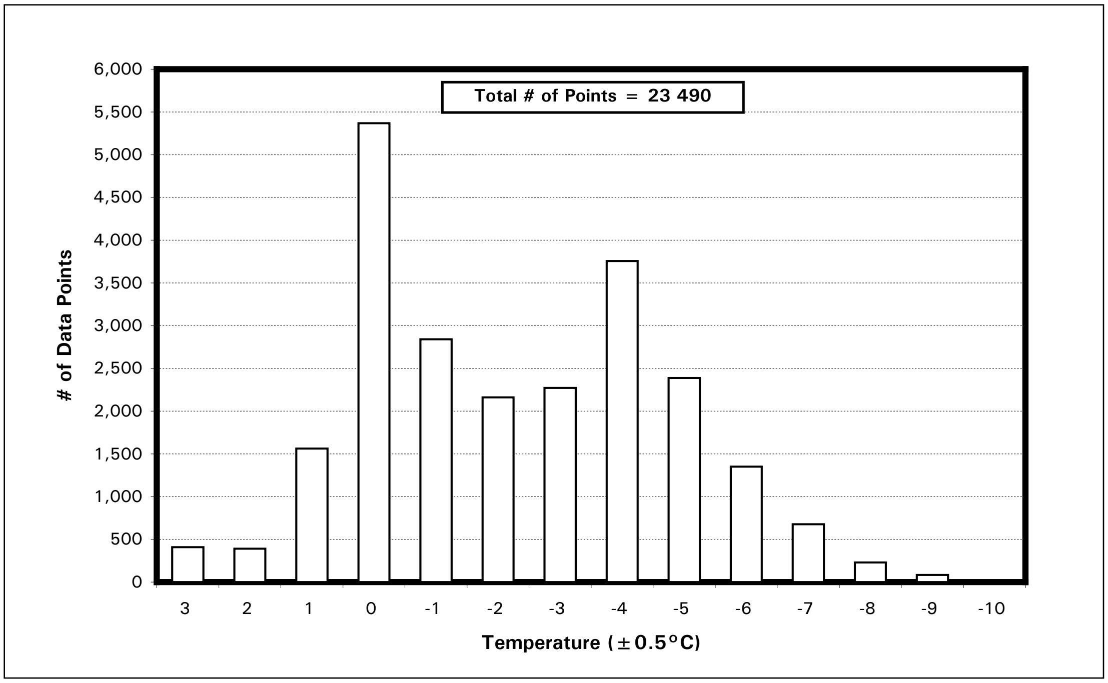


Figure 2.6: Temperature Distribution for Freezing Rain/Drizzle 1995-96 to 2002-03

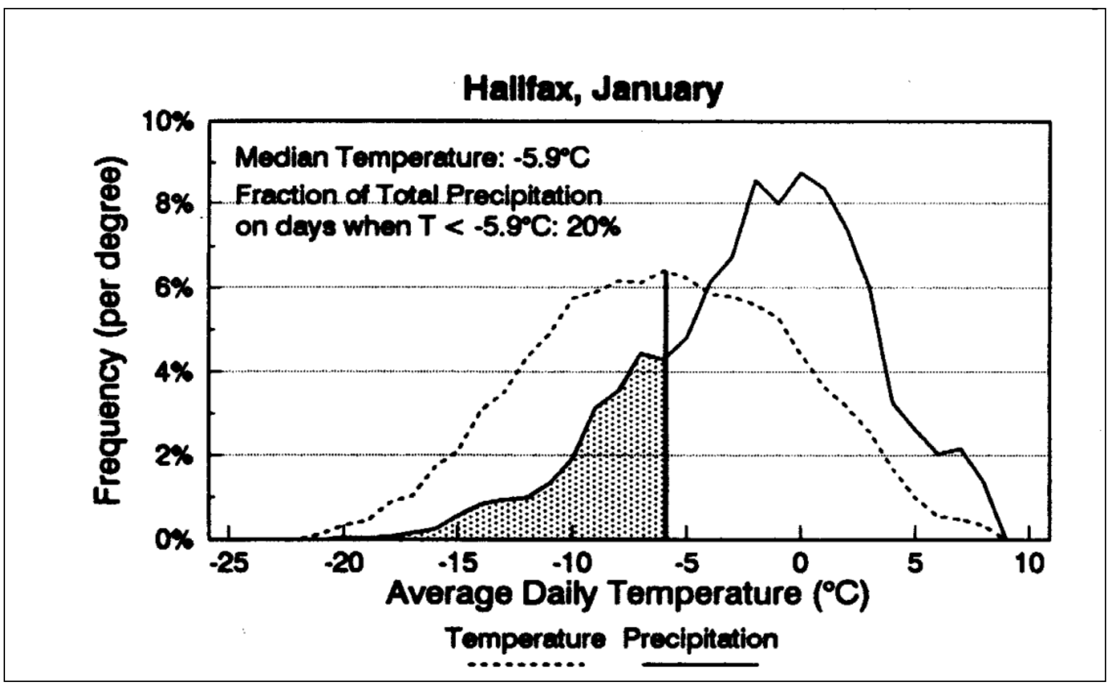


Figure 2.7: Frequency Distributions of Mean Daily Temperature, Halifax, January 1953-88

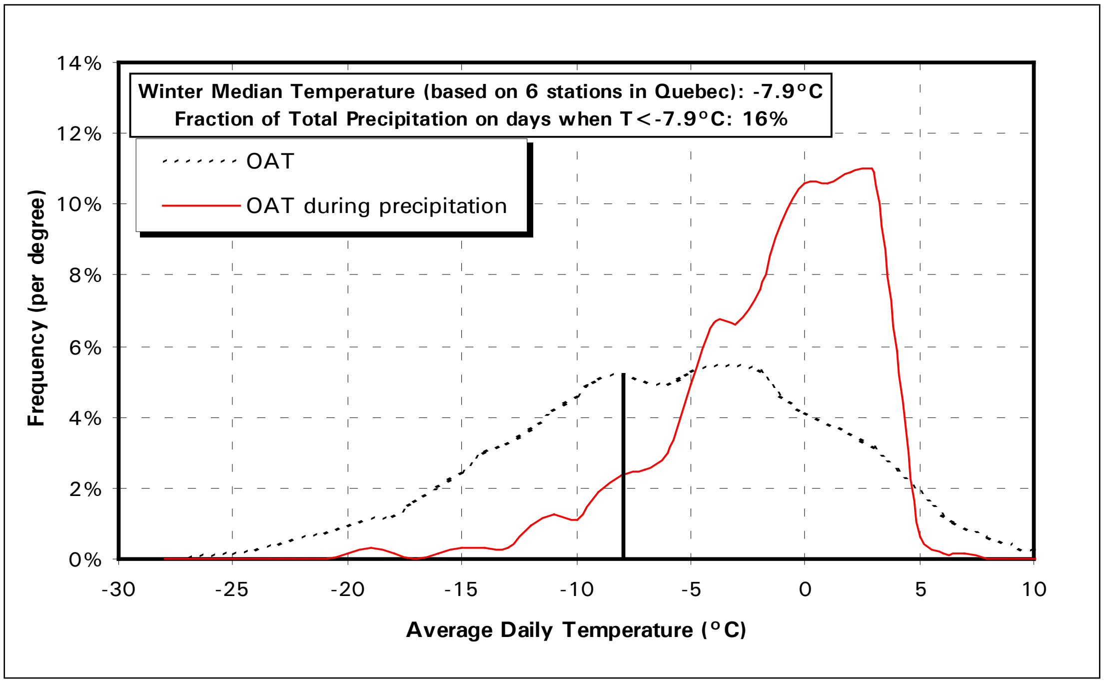


Figure 2.8: Frequency Distributions of Mean Daily Temperature, Quebec, 2000-03 Winters

2.3 Analysis and Observations for Natural Snow and Freezing Rain/Drizzle

Precipitation rates were calculated from the weather data on a minute-by-minute basis using a moving average based on 6-, 20-, and 35-minute intervals.

Table 2.11 shows minute–by–minute READAC data at Dorval Airport for a 49-minute period on December 14, 1995. Also shown are the 6-minute, 20-minute, and 35-minute averages computed using the linearized accumulation. The average snow rates, used as data points, were calculated by taking the snow accumulation during a specific time interval and dividing it by the interval. The three intervals used for this analysis are represented by brackets in the column next to “Linearized Total Snow Accumulation” in Table 2.11. The average snow rate was recalculated every minute by moving the brackets down at one minute intervals.

For each interval, the rate was calculated every minute using the following method:

$$Rate_i = \frac{W_i - W_{i-1}}{\Delta time}$$

Where:

$Rate_i$	is the rate at a given time;
W_i	is the linearized bucket weight at that time;
W_{i-1}	is the linearized bucket weight at a one-time interval before the given time; and
$\Delta time$	is the length of the time interval (6, 20, or 35 minutes).

A temperature was associated with the rate, based on the time and day at which the rate was measured. All rate and temperature data were added to a data base that contained calculated precipitation rates classified by ambient temperature for all sites included in the study. The data base was then sorted by temperature range (above 0°C, 0 to -3°C, -3 to -7°C, -7 to -14°C and -14 to -25°C) and the probability for each precipitation rate at each temperature range was calculated using histograms and cumulative percentages.

The snow weather data were graphed in two formats. In one format, the number of snow precipitation events was plotted against the precipitation rates (Figure 2.9). The other format (Figure 2.10) plots the cumulative probability of snow over all possible precipitation rates. The figures shown correspond to the temperature range of -3 to -7ºC for 20-minute rate calculations. Both plots used the corresponding period to calculate average precipitation rates.

The histogram in Figure 2.9 indicates that snow events with low precipitation rates occurred much more frequently than those with high precipitation rates for the temperature range shown.

The cumulative probability in Figure 2.10 indicates that over 97 percent of all the natural snow events in the data had precipitation rates below 25 g/dm^2/h for 20-minute rate intervals.

A complete set of plots for all temperature ranges and rate durations for natural snow and freezing rain/drizzle is included in Appendix B. As mentioned earlier, this report encompasses all the data presented in TC report, *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, TP 13993E (1). For consistency purposes, the data in Appendix B is presented using the same temperature ranges used in the previous versions of this report. Moreover, changing the temperature breakdowns to reflect the values in the TC HOT table for Type I fluids (i.e. change -7°C to -6°C), does not produce a major change in the charts. These temperature ranges will also be used in the remainder of this section.

Table 2.11: Sample READAC Data and Analysis

Location	Date	UTC Time	Temp (°C)	Type of Precip.	Total Snow Accumulation (g/dm²)	Linearized Total Snow Accumulation (g/dm²)		Precipitation Rate (g/dm²/h) Moving Average Intervals		
								6 min	20 min	35 min
YUL	14/12/1995	21:16	-11.8	S-	40	40.00		(a)	(b)	(c)
YUL	14/12/1995	21:17	-11.7	S-	40	40.16		9.38	[illegible]	[illegible]
YUL	14/12/1995	21:18	-11.6	S-	40	40.31		9.38	[illegible]	[illegible]
YUL	14/12/1995	21:19	-11.6	S-	40	40.47		9.38	[illegible]	[illegible]
YUL	14/12/1995	21:20	-11.6	S-	40	40.63		9.38	[illegible]	[illegible]
YUL	14/12/1995	21:21	-11.6	S-	40	40.78		9.38	[illegible]	[illegible]
YUL	14/12/1995	21:22	-11.6	S-	40	40.94		9.38	[illegible]	[illegible]
YUL	14/12/1995	21:23	-11.5	S-	40	41.09		9.38	[illegible]	[illegible]
YUL	14/12/1995	21:24	-11.6	S-	40	41.25		9.38	[illegible]	[illegible]
YUL	14/12/1995	21:25	-11.6	S-	40	41.41		9.38	9.38	[illegible]
YUL	14/12/1995	21:26	-11.4	S-	40	41.56		9.38	9.38	[illegible]
YUL	14/12/1995	21:27	-11.4	S-	40	41.72		[illegible]	9.38	[illegible]
YUL	14/12/1995	21:28	-11.5	S-	40	41.88		9.38	9.38	[illegible]
YUL	14/12/1995	21:29	-11.5	S-	40	42.03		9.38	9.79	13.16
YUL	14/12/1995	21:30	-11.4	S-	40	42.19		9.38	10.20	13.39
YUL	14/12/1995	21:31	-11.4	S-	40	42.34		9.38	10.62	13.48
YUL	14/12/1995	21:32	-11.4	S-	40	42.50		9.38	11.03	13.57
YUL	14/12/1995	21:33	-11.4	S-	40	42.66		9.38	[illegible]	13.66
YUL	14/12/1995	21:34	-11.4	S-	40	42.81		9.38	[illegible]	13.75
YUL	14/12/1995	21:35	-11.4	S-	40	42.97		[illegible]	12.27	13.84
YUL	14/12/1995	21:36	-11.3	S-	40	43.13		9.38	12.68	13.93
YUL	14/12/1995	21:37	-11.3	S-	40	43.28		9.38	13.10	14.02
YUL	14/12/1995	21:38	-11.4	S-	40	43.44		9.38	13.51	14.11
YUL	14/12/1995	21:39	-11.4	S-	40	43.59		9.38	13.92	14.20
YUL	14/12/1995	21:40	-11.3	S-	40	43.75		9.38	14.34	14.29
YUL	14/12/1995	21:41	-11.3	S-	40	43.91		9.38	14.75	14.38
YUL	14/12/1995	21:42	-11.3	S-	40	44.06		9.38	15.17	14.46
YUL	14/12/1995	21:43	-11.3	S-	40	44.22		10.75	15.58	14.55
YUL	14/12/1995	21:44	-11.2	S-	40	44.38		12.13	15.99	14.64
YUL	14/12/1995	21:45	-11.2	S-	40	44.53		13.51	16.41	14.73
YUL	14/12/1995	21:46	-11.2	S-	40	44.69		14.89	16.56	14.82
YUL	14/12/1995	21:47	-11.2	S-	40	44.84		16.27	16.72	14.91
YUL	14/12/1995	21:48	-11.2	S-	45	45.00		17.65	16.88	15.00
YUL	14/12/1995	21:49	-11.2	S-	45	45.29		17.65	16.62	14.85
YUL	14/12/1995	21:50	-11.2	S-	45	45.59		17.65	16.36	14.71
YUL	14/12/1995	21:51	-11.2	S-	45	45.88		17.65	16.10	14.56
YUL	14/12/1995	21:52	-11.1	S-	45	46.18		17.65	15.85	14.41
YUL	14/12/1995	21:53	-11.1	S-	45	46.47		17.65	15.59	14.26
YUL	14/12/1995	21:54	-11.1	S-	45	46.76		17.65	15.33	14.12
YUL	14/12/1995	21:55	-11.1	S-	45	47.06		17.65	15.07	14.18
YUL	14/12/1995	21:56	-11.1	S-	45	47.35		17.65	14.82	14.25
YUL	14/12/1995	21:57	-11.1	S-	45	47.65		17.65	14.56	14.32
YUL	14/12/1995	21:58	-11.1	S-	45	47.94		17.65	14.30	14.39
YUL	14/12/1995	21:59	-11.0	S-	45	48.24		17.65	14.04	14.45
YUL	14/12/1995	22:00	-11.0	S-	45	48.53		16.79	13.79	14.52
YUL	14/12/1995	22:01	-11.0	S-	45	48.82		15.93	13.53	14.59
YUL	14/12/1995	22:02	-11.0	S-	45	49.12		15.07	13.27	14.66
YUL	14/12/1995	22:03	-11.0	S-	45	49.41		14.22	13.01	14.72
YUL	14/12/1995	22:04	-10.9	S-	45	49.71		13.36	12.76	14.79
YUL	14/12/1995	22:05	-10.8	S-	50	50.00		12.50	12.50	14.86

(a) = (40.94 - 40.00)*60 / 6
(b) = (43.13 - 40.00)*60 / 20
(a) = (45.88 - 40.00)*60 / 35

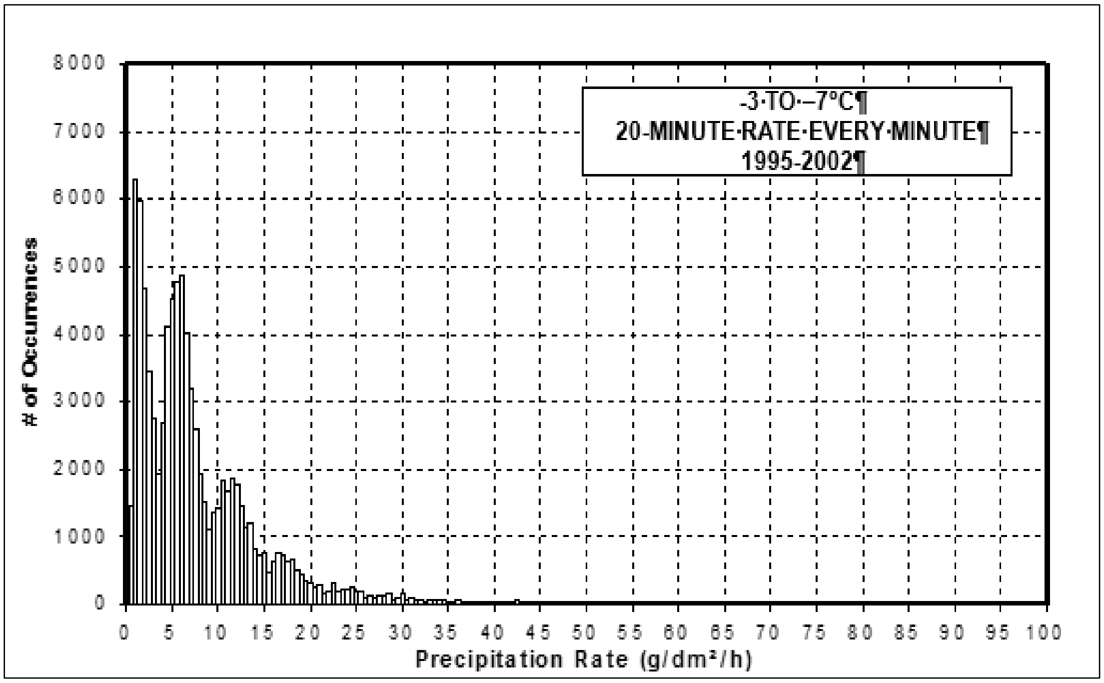


Figure 2.9: READAC and CR21X Analysis – Natural Snow Histogram

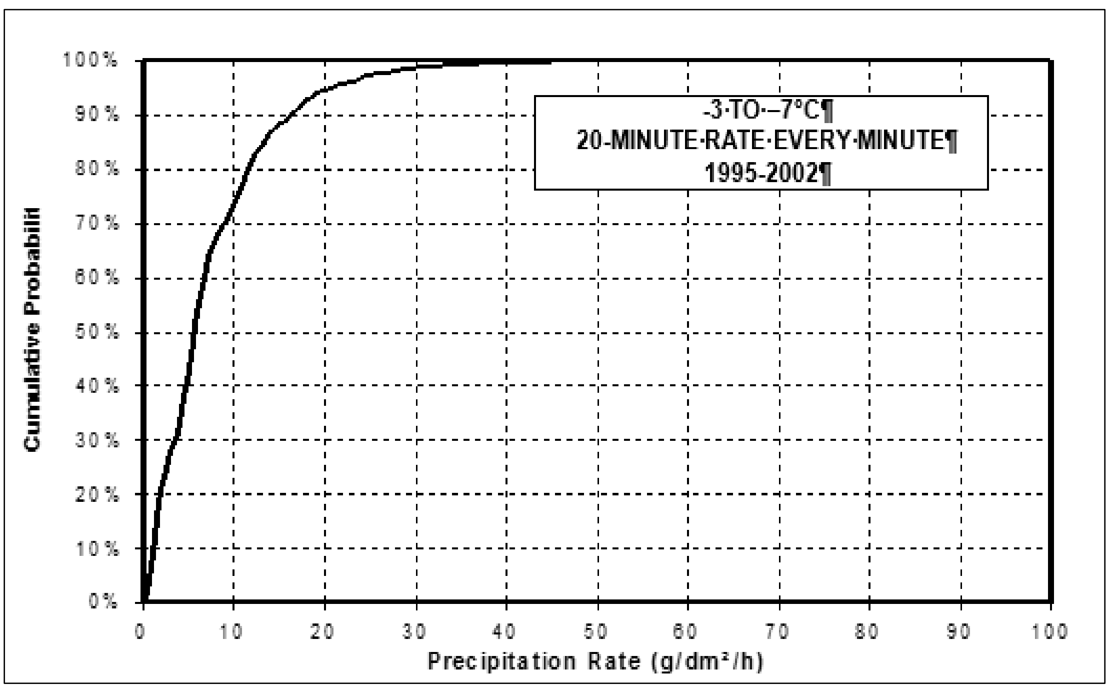


Figure 2.10: READAC and CR21X Analysis – Natural Snow Cumulative Probability

2.3.1 Validity of Gauges for Recording Precipitation Data

The objective of this section is to evaluate and compare precipitation rates measured with the automated gauge used for this study to rates from the plate pans used for measuring rates for endurance times.

Figure 2.11 shows a comparison of precipitation rates of the READAC gauge and the plate pans (described below) for a storm on January 15, 1999. Figure 2.12 illustrates another comparison during the same storm, this time using the CR21X gauge.

Figure 2.11 and Figure 2.4 show the precipitation rate over a 24-hour period. The 6-minute moving average rates calculated from the CR21X data show much more detail than the READAC. Higher rates were detected from this station because the smoothed data from the lower–resolution READAC station does not allow detection of rapid increases and decreases in rates.

Plate pan data collected from the APS test site located at Dorval Airport are included in Figure 2.11 and Figure 2.12. The pans were placed at a 10º angle on test stands approximately 30 m away from the precipitation gauge. The rates from the pans are based on the weight of snow that collected in the pans during 10-minute periods. The rates were recorded at the end of each time interval, and each value is based on the average of the two simultaneous pan measurements.

Furthermore, because of questions raised by MSC concerning the accuracy of precipitation gauges, a new analysis has been performed on the 2000-01 winter data. Following the same methodology, the CR21X gauge data were plotted against the plate pan data collected by APS at Dorval Airport on January 11, 2001. The results are presented in Figure 2.13. At least one verification should be made annually by comparing the rates obtained from the precipitation gauges and the plate pans.

For the 2002-03 winter, the recorded snow event took place on February 22, 2003. The results are presented in Figure 2.14. As can be seen, the data points from the plate pans correlate well with the traces shown in Figure 2.14. More precipitation collects in the rate pans during high winds because the stands are placed facing the wind. The differences between the precipitation gauge trace and the plate pan points could be due to the 10º angle of the test stand. Even so, the CR21X and READAC results are close enough to those of the plate pan collection that they can be used to analyse precipitation data.

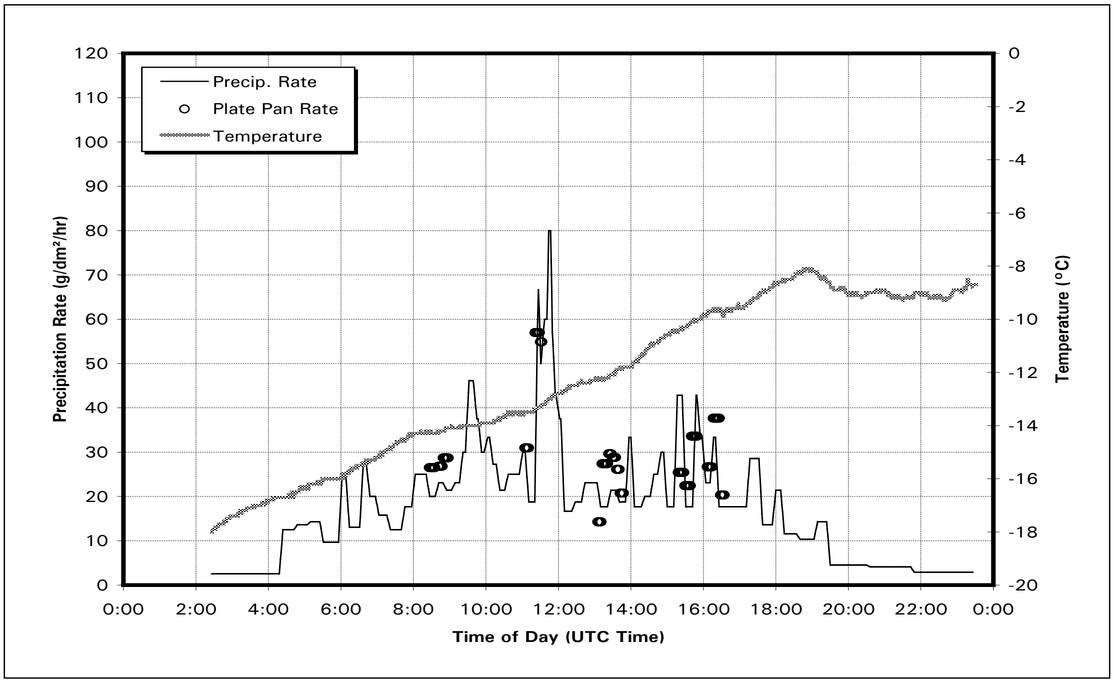


Figure 2.11: READAC Precipitation Rate, January 15, 1999

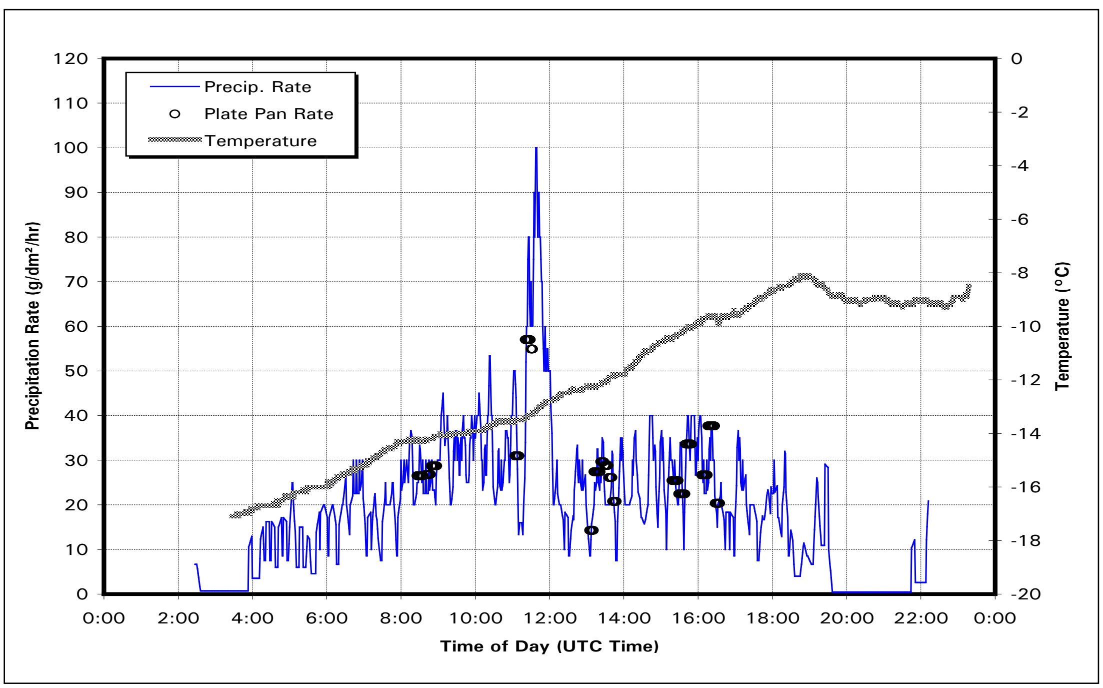


Figure 2.12: CR21X Precipitation Rate, January 15, 1999

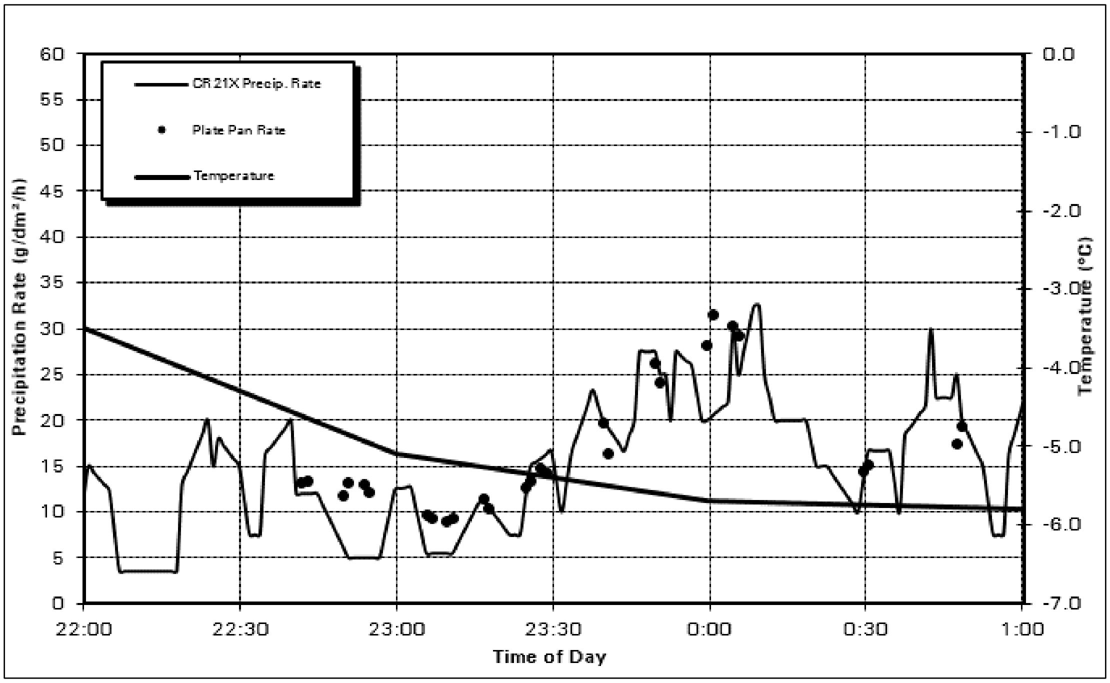


Figure 2.13: CR21X Precipitation Rate, January 11, 2001

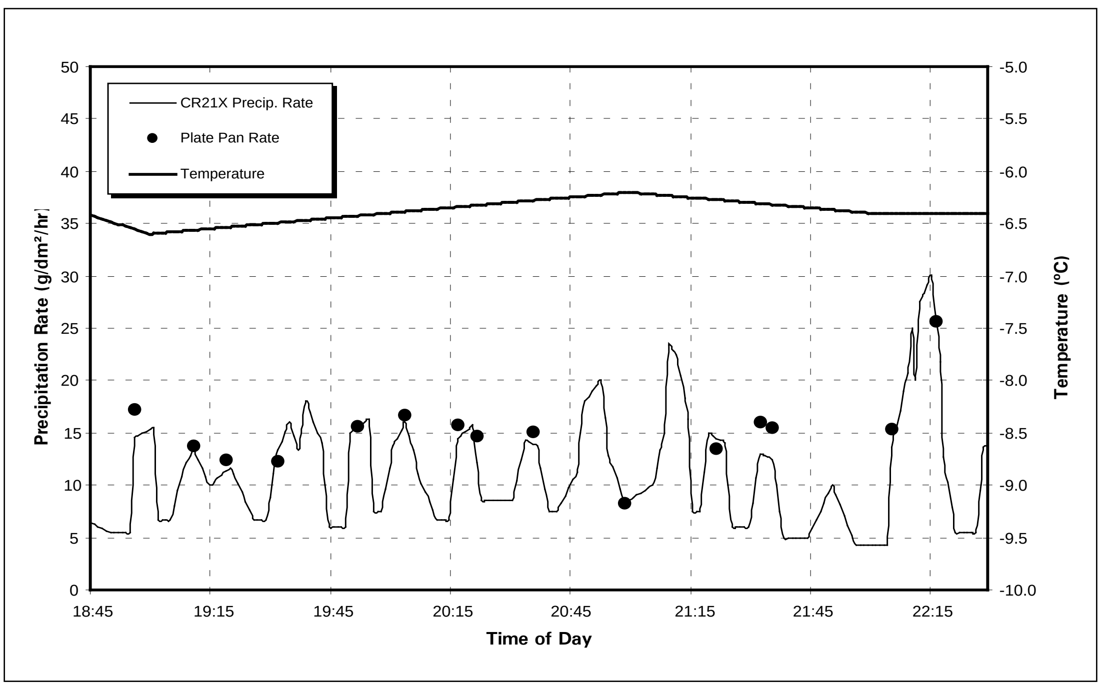


Figure 2.14: CR21X Precipitation Rate, February 22, 2003

2.3.2 Natural Snow

This analysis takes into account the snow data set from the last eight winters – the 1995-96 winter to the 2002-03 winter.

The 95th percentiles for several temperature ranges for natural snow conditions are shown in Table 2.12 below.

Table 2.12: 95th Percentile in Each Temperature Range – Natural Snow

Temperature Range	95th Percentile Precipitation Rate (g/dm²/h)		
	6 min	**20 min**	**35 min**
Above 0°C	20	19	20
0°C to -3°C	21	21	21
-3°C to -7°C	21	21	20
-7°C to -14°C	21	21	21
-14°C to -25°C	20	19	20

Each of the rates in this table represents the rate below which 95 percent of all snowfalls occurred in a specific temperature range for a given rate duration. For example, in the temperature range of *-3 to -7ºC* for a duration of 20 minutes, the 95th percentile is 21 g/dm^2/h. This indicates that 95 percent of the 20-minute rates recorded between *-3ºC to -7ºC* were equal to or below 21 g/dm^2/h. Table 2.13 shows the percent of occurrences for precipitation rates above 25 g/dm^2/h for all temperature ranges.

Table 2.13: Percentage of Heavy Snow Occurrences In Each Temperature Range, Natural Snow

Temperature Range	Percent of Occurrences when Rate is above 25 g/dm^2/h		
	6 min	**20 min**	**35 min**
Above 0°C	2.6%	2.5%	2.4%
0°C to -3°C	3.1%	2.9%	2.7%
-3°C to -7°C	3.1%	2.9%	2.6%
-7°C to -14°C	2.9%	2.9%	2.9%
-14°C to -25°C	2.0%	1.8%	2.1%

2.3.3 Snow at Cold Temperatures

The general shape of the curve for the cumulative probability of occurrence at colder temperatures is similar to that of the curves drawn for other temperatures, as shown in Figure 2.15. The chart shows that high precipitation rates occur equally at all temperature breakdowns.

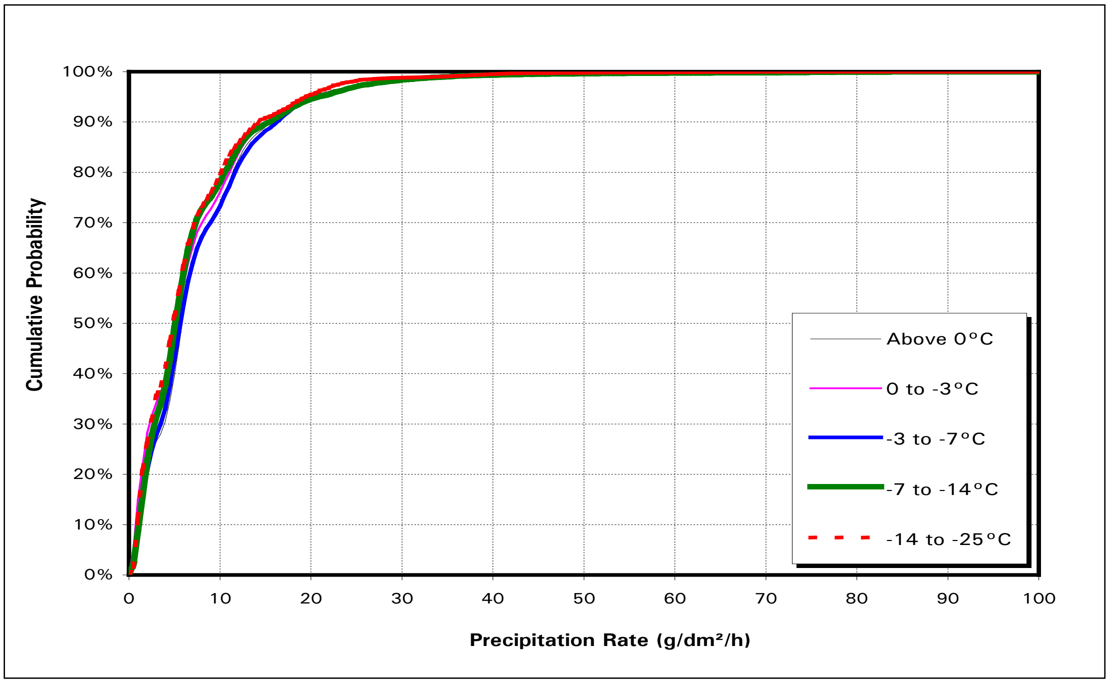


Figure 2.15: 20–Minute Rate Every Minute, All Temperature Ranges

The coldest temperature interval was divided into three smaller intervals (the data is shown in Appendix B):

a) -14 to -18°C;
b) -18 to -22°C; and
c) -22 to -25°C.

High precipitation rates were more common in the *-14 to -18°C* range, but a few high-rate snowfalls were recorded in the other two ranges, as seen in Figure 2.16.

For each cold temperature interval the percentage of occurrences when the precipitation rates were above 25 g/dm^2/h is shown in Table 2.14.

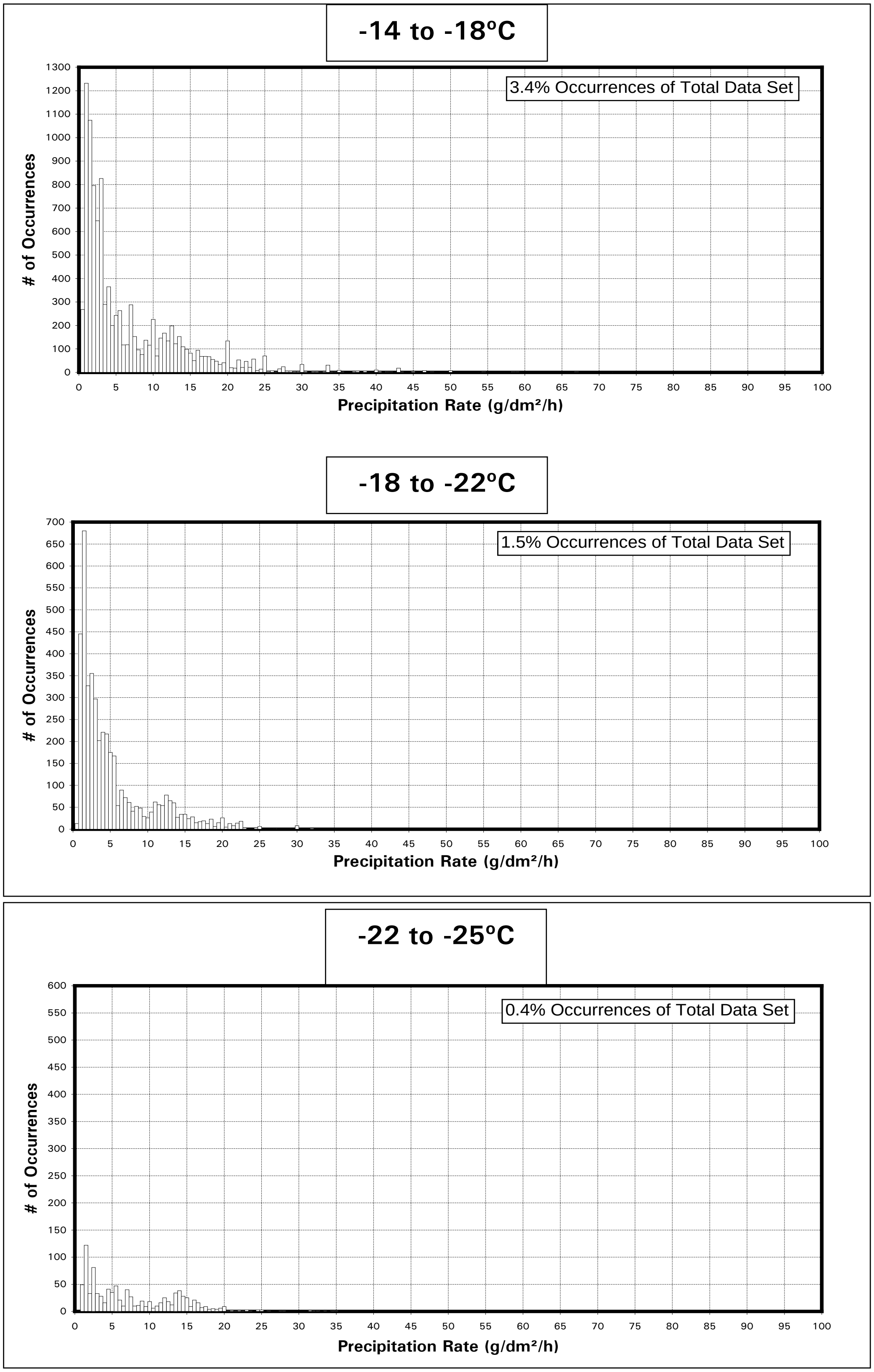


Figure 2.16: Subdivision of -14 to -25ºC – Snow Data

Table 2.14: Percentage of Heavy Snow Occurrences In Cold Temperatures – Natural Snow

Temperature Range	Percent of Occurrences when Rate is above 25 $g/dm^2/h$			Percent of -14 to -25°C Data Points in Each Temperature Range	Percent of Total Data Points in Each Temperature Range
	6 min	20 min	35 min		
-14 to -18°C	2.8%	2.7%	2.2%	64.2%	3.4%
-18 to -22°C	0.2%	0%	0%	27.9%	1.5%
-22 to -25°C	1.0%	0.4%	0%	7.9%	0.4%
			Total	**100%**	**5.3%**

Based on these results, consideration should be given to reformatting the HOT tables by dividing the *-14 to -25°C* interval, as precipitation rates were significantly lower at temperatures below -18°C and occurrences less frequent. However, the number of potential deicing operations at these lower temperatures needs to be considered.

2.3.4 Freezing Rain/Drizzle

The 95th percentile for two temperature ranges is shown below (Table 2.15) for freezing rain/drizzle.

Table 2.15: 95th Percentile in Each Temperature Range – Freezing Rain/Drizzle

Temperature Range	95th Percentile Precipitation Rate ($g/dm^2/h$)		
	6 min	20 min	35 min
0 to -3°C	32	29	27
-3 to -10°C	26	25	24

In freezing rain/drizzle, the 6–minute 95th percentile was 26 $g/dm^2/h$ for the *-3 to -10°C* range and somewhat higher, near 32 $g/dm^2/h$, for the *0 to -3°C* range.

2.3.5 Probability of Snow Events for Holdover Time Table Temperature Ranges

In an attempt to find the optimum temperature breakdowns for the HOT tables, the snow dataset (290,372 data points) was divided into 1°C intervals. In addition, each temperature range was split into precipitation rate ranges using 1 g/dm²/h increments. The results were translated into percentages to determine the probability of snow occurrence in each cell of the new table. The outcome is shown in Table 2.16.

The probability of snow event occurrences in each of the holdover time temperature ranges of the HOT tables is shown in Table 2.17 and Table 2.18. Table 2.17 corresponds to the temperature ranges of Type I fluid and Table 2.18 to the ranges of Type II and Type IV fluids. These two tables are determined based on Table 2.16. There were no data available for natural snow conditions below -25°C. In addition, each of the tables provides probability data for snowfall as a function of very light, light, moderate, and heavy snow.

For Type I fluids, over 84 percent of snow events occurred above -10°C, justifying the current temperature break at -6°C. Over 53 percent of the rates were classified as very light snow according to the newly introduced column in the Type I table. The probability of snow events for the Type IV table are 27.4 percent in the range of 0 to *-3°C* and nearly 57 percent for the range of *-3 to -14°C*.

The analysis presented in this report is based on data collected over eight years of observation from six meteorological stations across Quebec. A similar weather information data base, comprising of hourly measurements over a 12-year period for two stations (Montreal and La Grande), was used for different projects and is discussed in the following subsection. It has been included in this report for documentation purposes.

2.3.6 Weather Information Data base – La Grande and Montreal

The extensive dataset was acquired by APS from MSC. The hourly data contains weather observations for two meteorological stations in Quebec, located in Montreal and La Grande. The observation period is from January 1, 1990 to December 31, 2001. The data contains observations of the following parameters: visibility, wind speed, wind direction, dew point, relative humidity, atmospheric pressure, cloud opacity, cloud amount and weather condition.

As mentioned earlier, this dataset of weather information was used for different projects. Initially, it was used to evaluate historical relative humidity values during conditions typical of frost, and is therefore presented in Section 4 of TC report, *Laboratory Test Parameters for Frost Endurance Time Tests*, TP 14145E (8). The objective of this study was to examine the range of relative humidity that exists in the natural environment during periods of frost formation. The dataset was filtered by APS by eliminating conditions that were not conducive to frost formation. The resulting data base was examined for two ranges of wind – below 15 km/h and below 10 km/h.

Table 2.16: Probability (%) of Natural Snow Occurrence – 1995-96 to 2002-03 (Quebec)

TEMP (ºC)	RATE OF PRECIPITATION (g/dm²/h)																											
	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	13 to 14	14 to 15	15 to 16	16 to 17	17 to 18	18 to 19	19 to 20	20 to 21	21 to 22	22 to 23	23 to 24	24 to 25	>25	Total	Cumulative
above 0	1.45	1.90	1.41	0.88	0.55	0.45	0.37	0.26	0.21	0.16	0.20	0.33	0.44	0.36	0.30	0.26	0.18	0.17	0.15	0.17	0.06	0.06	0.06	0.04	0.05	0.27	10.7	10.7
0 to -1	1.15	1.75	1.02	0.77	0.46	0.32	0.31	0.19	0.17	0.13	0.16	0.26	0.34	0.28	0.24	0.18	0.13	0.13	0.10	0.09	0.04	0.04	0.03	0.02	0.03	0.17	8.5	19.3
-1 to -2	1.79	1.41	0.91	0.57	0.51	0.32	0.36	0.23	0.21	0.14	0.14	0.22	0.22	0.23	0.21	0.19	0.15	0.13	0.09	0.12	0.06	0.05	0.05	0.03	0.05	0.27	8.7	27.9
-2 to -3	1.31	1.91	1.04	0.95	0.61	0.37	0.46	0.29	0.23	0.16	0.17	0.27	0.36	0.36	0.25	0.22	0.17	0.15	0.16	0.13	0.06	0.08	0.06	0.03	0.06	0.42	10.3	38.2
-3 to -4	1.28	1.54	1.13	0.77	0.55	0.31	0.43	0.31	0.19	0.20	0.15	0.28	0.32	0.28	0.22	0.17	0.13	0.11	0.09	0.11	0.05	0.05	0.04	0.03	0.05	0.29	9.1	47.3
-4 to -5	1.05	1.28	1.01	0.60	0.41	0.32	0.36	0.24	0.17	0.13	0.16	0.27	0.29	0.29	0.26	0.23	0.16	0.14	0.14	0.16	0.06	0.07	0.04	0.03	0.06	0.33	8.2	55.5
-5 to -6	1.09	1.21	0.87	0.59	0.42	0.30	0.33	0.19	0.16	0.13	0.16	0.22	0.24	0.18	0.17	0.13	0.11	0.11	0.10	0.12	0.06	0.05	0.03	0.02	0.04	0.20	7.2	62.8
-6 to -7	0.77	1.33	0.76	0.58	0.35	0.28	0.21	0.15	0.12	0.11	0.12	0.21	0.21	0.18	0.18	0.11	0.10	0.11	0.08	0.09	0.04	0.02	0.03	0.01	0.02	0.13	6.3	69.1
-7 to -8	0.87	1.32	0.96	0.49	0.37	0.27	0.18	0.10	0.10	0.10	0.10	0.20	0.19	0.16	0.13	0.11	0.06	0.04	0.04	0.05	0.01	0.01	0.01	0.01	0.03	0.10	6.0	75.1
-8 to -9	0.72	0.84	0.71	0.44	0.30	0.21	0.18	0.12	0.08	0.10	0.11	0.19	0.19	0.15	0.13	0.07	0.07	0.05	0.04	0.03	0.01	0.03	0.01	0.01	0.01	0.07	4.9	80.0
-9 to -10	0.54	0.71	0.56	0.37	0.25	0.16	0.16	0.09	0.10	0.11	0.08	0.15	0.16	0.14	0.09	0.09	0.07	0.07	0.05	0.06	0.02	0.03	0.02	0.03	0.03	0.11	4.2	84.2
-10 to -11	0.41	0.69	0.42	0.30	0.15	0.11	0.07	0.06	0.05	0.03	0.04	0.09	0.09	0.06	0.06	0.04	0.06	0.05	0.04	0.06	0.02	0.03	0.01	0.01	0.02	0.09	3.0	87.2
-11 to -12	0.31	0.62	0.40	0.24	0.15	0.10	0.12	0.05	0.04	0.05	0.04	0.09	0.08	0.06	0.05	0.05	0.04	0.04	0.04	0.05	0.02	0.02	0.02	0.01	0.04	0.09	2.8	90.0
-12 to -13	0.51	0.48	0.31	0.24	0.14	0.09	0.07	0.03	0.05	0.04	0.03	0.07	0.07	0.08	0.05	0.04	0.03	0.04	0.03	0.03	0.01	0.02	0.01	0.02	0.01	0.10	2.6	92.7
-13 to -14	0.24	0.43	0.26	0.14	0.11	0.07	0.07	0.06	0.04	0.04	0.03	0.08	0.06	0.05	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.15	2.0	94.7
-14 to -15	0.22	0.27	0.17	0.08	0.07	0.05	0.05	0.03	0.02	0.04	0.03	0.04	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.04	0.01	0.02	0.02	0.02	0.02	0.07	1.4	96.1
-15 to -16	0.17	0.24	0.07	0.04	0.02	0.02	0.04	0.02	0.01	0.05	0.02	0.02	0.01	0.02	0.01	0.01	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.02	0.8	97.0
-16 to -17	0.21	0.08	0.08	0.03	0.03	0.02	0.02	0.01	0.01	0.05	0.01	0.02	0.03	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.7	97.6
-17 to -18	0.10	0.07	0.12	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.5	98.1
-18 to -19	0.07	0.09	0.08	0.05	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.5	98.6
-19 to -20	0.06	0.12	0.10	0.05	0.05	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.5	99.1
-20 to -21	0.08	0.09	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.3	99.5
-21 to -22	0.04	0.03	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	99.6
-22 to -23	0.03	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	99.7
-23 to -24	0.03	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	99.8
-24 to -25	0.05	0.04	0.02	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.2	100.0
Total	14.5	18.6	12.5	8.3	5.6	3.9	3.9	2.5	2.0	1.8	1.8	3.1	3.4	3.0	2.5	2.0	1.6	1.4	1.2	1.4	0.5	0.6	0.5	0.3	0.5	2.9		
Cumulative	14.5	33.1	45.6	53.8	59.4	63.3	67.2	69.6	71.6	73.4	75.2	78.3	81.7	84.7	87.1	89.1	90.7	92.1	93.3	94.7	95.2	95.8	96.2	96.6	97.1	100.0		

Table 2.17: Probability of Snow in Each HOT Table Temperature Range – Type I Fluids

Temperature (°C)	Very Light Snow	Light Snow	Moderate Snow	Heavy Snow	Total
-3 and above	20.2%	7.5%	9.4%	1.1%	**38.2%**
below -3 to -6	12.4%	5.2%	6.2%	0.8%	**24.6%**
below -6 to -10	12.0%	4.2%	4.8%	0.4%	**21.4%**
below -10	9.2%	2.8%	3.3%	0.5%	**15.8%**
Total	**53.8%**	**19.6%**	**23.7%**	**2.9%**	**100.0%**

Table 2.18: Probability of Snow in Each HOT Table Temperature Range – Type II and Type IV Fluids

Temperature (°C)	Very Light Snow	Light Snow	Moderate Snow	Heavy Snow	Total
above 0	5.7%	2.0%	2.8%	0.3%	**10.7%**
0 to -3	14.6%	5.5%	6.5%	0.9%	**27.4%**
below -3 to -14	30.4%	11.2%	13.3%	1.7%	**56.5%**
below -14 to -25	3.2%	1.0%	1.0%	0.1%	**5.3%**
below -25	0.0%	0.0%	0.0%	0.0%	**0.0%**
Total	**53.8%**	**19.6%**	**23.7%**	**2.9%**	**100.0%**

A second application of this dataset was to assess the wind and ambient temperature distributions during natural freezing precipitation conditions, and is presented in Section 7 of TC report, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2002-03 Winter,* TP 14144E (9). The absence of wind appears to have a large influence on Type I fluid endurance times in freezing rain at mild ambient temperatures such as -3ºC. It appears that convective heat transfer in calm conditions is unable to remove the heat derived from latent heat of freezing quickly enough to prevent the surface temperature from rising above the ambient temperature. To ascertain typical wind conditions during periods of freezing rain, weather data collected at Montreal and La Grande, Quebec were examined. It was found that about 75 percent of the freezing rain events occurred at -3ºC and above*,* and winds of 11 km/h or above were experienced 90 percent of the time. It was concluded that such wind speeds would be expected to enhance convective heat transfer and counteract the effect of latent heat by rapidly cooling the wing to ambient temperature.

Finally, a study was conducted to identify the worst–case scenario for fluid evaporation (dry-out) following application in expected frost conditions. Among other parameters, the relative humidity was found to play an important role in the process. Subsequently, the historical data were filtered to include only weather conditions facilitating the occurrence of frost, but under all wind speed conditions. The analysis concluded that a relative humidity of 55 to 60 percent adequately represents worst-case real world dry-out conditions, and that this range is valid for wind speeds from 0 to 20 km/h and for temperatures from +2 to -25°C. The outcome from this analysis was presented to the industry at the SAE G–12 Fluids Time Subcommittee meeting, held in Vancouver in May 2003. The presentation can be found in Appendix E of TC report, *Aircraft Ground Icing Research Support Activities for the 2002-03 Winter*, TP 14155E (10).

This page intentionally left blank.

3. WINTER OPERATIONS SURVEY

A survey was conducted by APS on behalf of TC in an attempt to collect data on actual deicing operations at several worldwide stations.

TC was seeking this information in support of a review of the HOT table temperature and weather condition breakdowns such that the research and development emphasis is aimed at conditions where an important number of operations occur worldwide. In addition, the intent was to identify where improvements could be made to the HOT table format.

This section consists of an introduction, methodology, description and processing of data, analysis, and future survey requirements.

3.1 Introduction

Several years ago, an estimate of the number of deicing operations as a function of precipitation condition for Dorval Airport was carried out and is presented in Figure 3.1.

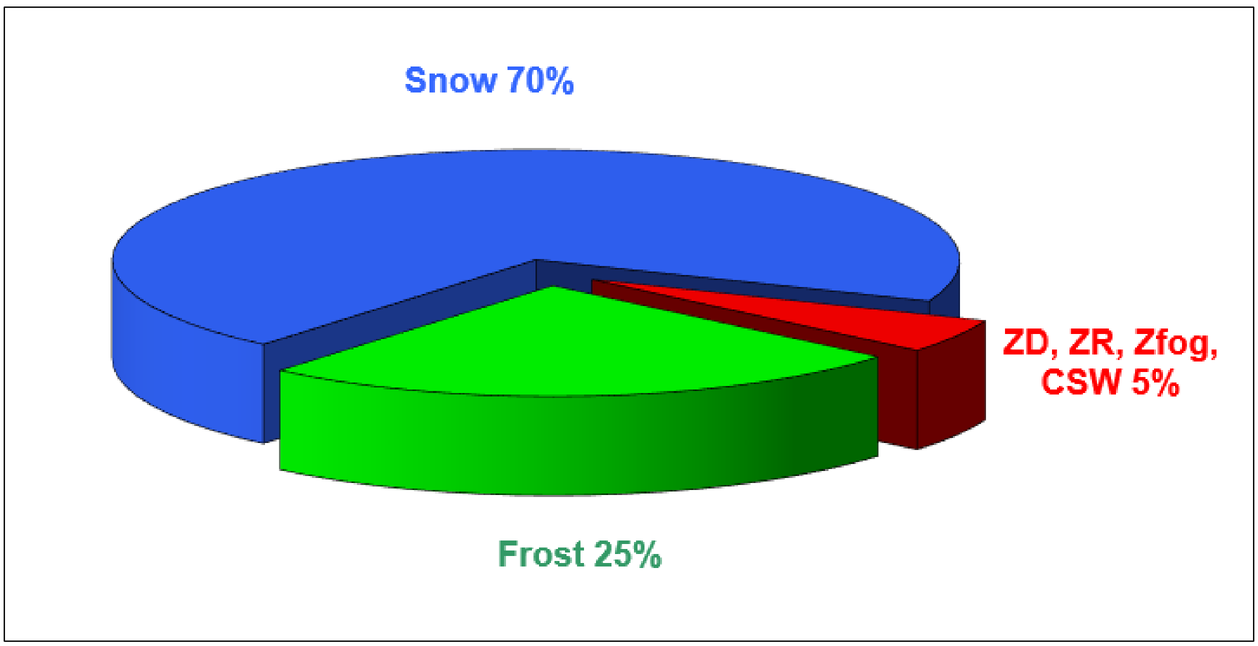


Figure 3.1: Previous Estimate of Frequency of Deicing Operations as a Function of Weather Condition at Dorval Airport

This study was based on data from hourly weather observations over 30 years at Dorval Airport and on data relating to aircraft deicing events taken from airport deicing logs.

The distribution in Figure 3.1 was obtained according to the following steps:

Step I) Aéroports de Montréal (ADM) authorities provided the deicing operation log from a year prior to when Aeromag began operating the deicing centre. The deicing operations were separated into two categories: frost-related deicing and precipitation–related deicing.

Step II) Data from the 1999-00 winter season was averaged with the data collected over the previous 30 years. It was estimated that frost accounted for 25 percent of the deicing operations.

Step III) 75 percent of the deicing operations were due to freezing precipitation, of which 94 percent was in the form of snow, and 6 percent in the form of freezing drizzle, freezing rain, freezing fog and cold-soak wing.

Step IV) It was established that 70 percent of all deicing operations were due to snow, 25 percent were due to frost, and 5 percent were due to freezing precipitation.

These estimates were reported in the TC report, *Winter Weather Data Evaluation (1995-2001),* TP 13830E (11), and also in the TC report, *Snow Weather Data Evaluation (1995-2000),* TP 13665E (12).

To substantiate these findings and to evaluate the consistency of the results with other worldwide stations, TC initiated a survey (Appendix E) of airlines from several international airports. The findings from this survey are described and analysed later in this section.

3.2 Methodology

To acquire a worldwide representation of deicing operations, TC distributed the survey to several airlines. The information obtained is important in supporting a review of the HOT table temperature and weather condition breakdowns so that the fluid research can be aimed at conditions where an important number of operations occur worldwide. It also helps in identifying where improvements can be made to the format.

For this purpose, the survey (see Appendix E) included four tables. The first two tables were for participants to complete: Table 1 for Type I operations and Table 2 for Type II and/or Type IV operations. The last two tables (Tables 3 and 4) served as examples; these tables show the totalled results from the 2000-01 survey of information on deicing operations gathered from seven international airports. The surveyed airlines were given the option to provide data in the form of either percentages or numerical values. If separate data for Type I operations was not available, information for all fluids was provided in Table 2.

To receive the maximum number of responses, the survey was distributed to the SAE G–12 Committee participants. A summary of who was polled and who replied in 2000-01 and 2001-02 is presented in Subsection 3.3.

3.3 Description and Processing of Data

The feedback from the 2000-01 survey resulted in four tables for Type I fluids and seven tables for Type II/IV fluids. The feedback from the 2001-02 survey produced twelve tables for Type I fluids and fifteen tables of Type II/IV fluids. These tables are included in Appendix E. Some responses provided actual numbers of operations in each cell of the HOT while some provided percentages. In order to obtain the actual number of deicing operations surveyed, all of the data were converted to the same units. The responses from the two years gave a total number of 62 891 deicing operations (Type I Table) and 53 710 anti–icing operations (Type II/IV Table).

A summary of the deicing operators polled is presented in Table 3.1. In 2000-01, seven of the twenty-one deicing operators replied to the survey, a response rate of 33 percent. In 2001-02, fifteen of the twenty–five deicing operators replied to the survey, a response rate of 60 percent, which is almost twice that of the previous year.

The worldwide distribution of the seven airports that answered the survey is presented in Figure 3.2.

Table 3.1: Summary of Deicing Operators Surveyed

DEICING OPERATOR	CITY	RESPONSE 2000-01	RESPONSE 2001-02
Air Canada/ GlobeGround	Toronto	X	X
Aero–Mag	Montreal	X	X
American Eagle Airlines	Chicago		X
United Airlines	Denver, Chicago		X
Aéroports de Paris	Paris (CDG)	N/A	X
Continental	Newark	N/A	X
Japan Airlines	Sapporo	X	
Air France	Paris (Orly)	X	X
All Nippon Airways	Tokyo		
Finnair	Helsinki		X
KLM	Amsterdam	X	X
Northwest	Detroit		
Delta	Boston		
British Airways	Heathrow	X	X
SAS	Stockholm, Oslo		
FedEx	Memphis		
UPS	Louisville		X
Swissair	Zurich		
US Airways	Pittsburgh	X	X
American Airlines	Chicago		
JAS	Tokyo	N/A	
Lufthansa	Munich, Frankfurt	N/A	X

N/A – Survey responses not received.

Figure 3.2: Worldwide Distribution of Responses to the 2000-02 Survey

The distributions of deicing operations (from 2000-02) of Type I fluids and Type II/IV fluids are illustrated in Table 3.2 and Table 3.3 respectively.

Table 3.4 shows the total number of Type I and Type II/IV deicing operations as a function of location and by precipitation condition.

Table 3.2: Type I Operations

City	Number of Operations
Montreal	12616
Chicago (AE)	2500
Chicago (United)	3510
Paris CDG	1300
Pittsburgh	11067
Sapporo	690
Toronto	16200
Newark	342
Helsinki	10063
Louisville	1000
Munich	2788
Paris ORLY	654
Denver	161
Total	**62891**

Table 3.3: Type II/IV Operations

City	Number of Operations
Montreal	4599
Chicago (AE)	2500
Chicago (United)	2425
Paris CDG	150
Pittsburgh	3107
Sapporo	485
Toronto	5259
Newark	342
Helsinki	7741
Louisville	5031
Munich	2438
Frankfurt	4474
Paris ORLY	1225
London	5474
Amsterdam	8460
Total	**53710**

Table 3.4: Type I and Type II/IV Combined Deicing Data 2000 to 2002

	FROST	FRZ. FOG	SNOW	FRZ. DRIZZLE	LIGHT FRZ. RAIN	RAIN ON COLD SOAKED WING	RIME ICE	Total
MONTREAL	4791	0	11013	400	789	123	99	17215
PITTSBURGH	360	0	11101	484	1704	0	525	14174
SAPPORO	327	0	848	0	0	0	0	1175
CHICAGO	3560	300	6280	245	550	0	0	10935
DENVER	104	3	50	4	0	0	0	161
TORONTO	5170	0	14030	244	204	273	1538	21459
PARIS (CDG)	985	0	415	50	0	0	0	1450
NEWARK	88	0	454	0	134	8	0	684
HELSINKI	7902	208	8951	596	110	37	0	17804
LOUISVILLE	4031	0	1200	500	300	0	0	6031
MUNICH	2675	517	2002	12	3	17	0	5226
FRANKFURT	2059	0	1967	46	123	279	0	4474
LONDON	5274	100	100	0	0	0	0	5474
AMSTERDAM	5280	520	2422	150	38	50	0	8460
PARIS	1399	0	477	0	3	0	0	1879
Total	44005	1648	61310	2731	3958	787	2162	**116601**

3.4 Validation of Data

3.4.1 Montreal, Quebec – Dorval Airport

a) Winter 2000-01: Dorval Airport reported 7,531 deicing operations and 2,927 anti-icing operations. With the exception of freezing fog, deicing and anti-icing operations took place under all weather conditions. Snow precipitation accounted for the largest number of deicing operations; and

b) Winter 2001-02: Dorval Airport reported results consistent with the previous year. A total number of 5,085 deicing operations and 1,672 anti-icing operations took place. Deicing procedures were most frequent under frost and natural snow conditions. Anti–icing operations were mostly conducted during snow precipitation.

3.4.2 Pittsburgh, Pennsylvania

c) Winter 2000-01: Pittsburgh Airport reported 7,825 deicing operations and 2,345 anti-icing operations. Approximately 80 percent of these operations were during snow precipitation. Freezing rain and freezing drizzle accounted for 19 percent of operations while frost accounted for the remaining 1 percent. In comparison to Montreal, the number of deicing operations performed was greater during snow and freezing rain/drizzle and much lower during frost. The warmer average temperature in Pittsburgh can justify these differences; and

d) Winter 2001-02: In comparison to the previous year, there was a 60 percent decline in the total number of operations performed during the winter of 2001-02. The Pittsburgh area received less precipitation during the 2001-02 winter. Most operations were performed during snow precipitation.

3.4.3 Sapporo, Japan

Winter 2000-01: Sapporo Airport performed 690 deicing operations, of which 53 percent were during snow precipitation and 47 percent during frost. 485 anti-icing operations were performed during snow precipitation.

3.4.4 Chicago, Illinois

Winter 2001-02: American Eagle Airlines and United Airlines provided data for the Chicago Airport. The results obtained were in the same magnitude with one exception. United Airlines reported that all of their Type I operations (3 510) were due to frost precipitation. American Eagle Airlines reported that only 2 percent of their Type I operations were due to frost precipitation. United Airlines did not distinguish between Type I and Type II/IV operations on the returned survey, which may have led to the difference in results. The proper distribution of operations performed by United Airlines was not available.

3.4.5 Denver, Colorado

Winter 2001-02: United Airlines provided data for the Denver Airport. A total of 161 Type I procedures were reported, of which 64 percent were during frost precipitation. No data were obtained for anti–icing operations.

3.4.6 Toronto, Ontario – Pearson Airport

a) Winter 2000-01: Pearson Airport presents a particularity in that two different companies manage the airport's deicing operations. GlobeGround is responsible for the majority of deicing operations under all weather conditions. During frost conditions, Air Canada does most of its deicing operations independently at the gates. Both firms replied to the survey. Air Canada provided their data for frost together with the GlobeGround deicing operations of Air Canada aircrafts. GlobeGround's electronic data base collects data in a somewhat different manner than the format requested. They categorize the weather conditions as rime ice, light snow, medium snow, or clear ice, among others. In addition, their data base does not make a distinction between Type I operations and Type II/IV operations. To facilitate a global analysis, all tables were to be in the same format, so the total number of operations from GlobeGround were compiled with Air Canada's distribution of deicing operations. The final table shows that anti-icing operations as a result of snow account for almost 93 percent of the cases (just 56 percent for deicing operations). With the exception of freezing fog, deicing operations took place under all weather conditions, including a substantial amount (10 percent) for rime ice. Air Canada reported that rime ice occurs primarily from landing aircraft that accrete ice on the leading edge; and

b) Winter 2001-02: The values provided for Toronto were a combination of GlobeGround's data along with Air Canada's data. GlobeGround data were incorporated into Air Canada's results by distributing the data based on Air Canada's operation ratios. Toronto reported a large amount of rime ice, (about 7 percent), but the majority of the precipitation was snow. It should be noted that the values for snow operations include procedures done for "Layover Ice" and "Pre-treating".

3.4.7 Paris, France – Charles de Gaulle Airport

Winter 2001-02: Aéroports de Paris reported having only three snow-days, with a minimum temperature of -5.9°C. They received just over half the amount of rain received the previous year. It should also be noted that no deicing operations took place after January 17, 2002.

3.4.8 Newark, New Jersey

Winter 2001-02: Continental Airlines provided data for the Newark International Airport, but did not record precise data during the winter of 2001-02. However, they estimated that roughly 70 percent of all their deicing and anti–icing operations were due to snow precipitation.

3.4.9 Helsinki, Finland

Winter 2001-02: A total of 10,063 deicing and anti-icing operations were reported. Type I followed by Type IV fluid operations were performed 7,741 times, leaving 2,322 deicing operations that were not accompanied by anti-icing operations. Frost and snow were the predominant types of precipitation.

3.4.10 Louisville, Kentucky

Winter 2001-02: The original data sent from Louisville Airport was given in number of days of de/anti–icing activity. These figures were converted into a number of operations with the help of a Louisville representative via telephone. It was estimated that roughly 80 percent of the Type II/IV operations were due to frost. All Type I operations were followed by Type II/IV operations. The number of deicing operations due to snow, ZD and ZR were the same for both tables. For the Type II/IV table, the numbers were split between the 0°C to -3°C and -3°C to -14°C using Federal Aviation Administration (FAA) worldwide data (1982-97).

3.4.11 Munich, Germany

Winter 2001-02: Lufthansa reported 2,788 Type I operations for Munich. Over 85 percent of the Type I operations were followed by Type IV anti-icing operations. Approximately 92 percent of the Type I operations were performed during frost precipitation, while 75 percent of the Type IV operations were performed under natural snow conditions.

3.4.12 Frankfurt, Germany

Winter 2001-02: Lufthansa supplied data collected from Frankfurt, but only Type II/IV data were returned. The concentration of fluid dilution used was neat, 75/25, or 50/50. All the data collected was taken above -14°C. Snow and frost accounted for most of the precipitation.

3.4.13 London, England

a) Winter 2000-01: At Heathrow International Airport the de/anti-icing operations were conducted using exclusively Type II fluid at a dilution of 75/25. 2,000 deicing operations were performed during the winter of 2001-02. The deicing log showed that frost contamination occurred in 90 percent of the situations. This could be explained by the high relative humidity of the region combined with moderately low temperatures over the winter; and

b) Winter 2001-02: Data were collected from London Heathrow Airport and London Gatwick Airport. Only Type II/IV results were provided in their reply. At both airports, anti–icing operations were performed solely during frost precipitation. Approximately 75 percent of these procedures took place in the temperature range of *0°C to -3°C*.

3.4.14 Amsterdam, Netherlands – Schiphol Airport

a) Winter 2000-01: Deicing operations at Schiphol Airport were reported during all weather conditions in the HOT table. The largest volume is represented by snow precipitation conditions (60 percent). Of the 5,500 deicing operations, approximately 30 percent were classified as "preventive anti–icing operations;" and

b) Winter 2001-02: Only anti–icing data were provided. The state of the fluid dilution varied from neat to 75/25 to 50/50, depending on the specific step in the procedure. Frost precipitation accounted for about 66 percent of anti-icing procedures.

3.4.15 Paris, France – Orly Airport

a) Winter 2000-01: Of the 550 deicing operations, 95 percent took place during frost precipitation and only 4.5 percent were performed during snow precipitation. Only Type II/IV fluids were used for the deicing operations; and

b) Winter 2001-02: The data provided by Air France was not divided into temperature ranges. Only the total number of operations for each precipitation condition was provided. In order to make these data compatible with the rest of the survey, actual numbers had to be allocated to each temperature range. Using the ratios from the 2000-01 survey for this airport, the maximum number of operations was divided appropriately to assign a number to each cell of the table.

3.5 Analysis and Observations

3.5.1 2000 to 2002 Survey Results

Based on the total number of operations reported, a weighted average was calculated. The results from the survey are provided in both actual number of operations and percentages in Table 3.5 to Table 3.8.

To allow a global analysis, the responses for Type I (16 tables) were compiled with the responses for Type II/IV (22 tables), for a total of 116 601 de/anti–icing operations worldwide. As previously shown in Table 3.4, the total number of Type I and Type II/IV deicing operations are illustrated as a function of location and precipitation condition.

Figure 3.3 graphically shows the distribution of weather conditions grouped in three major categories: snow, frost and freezing precipitation.

The results from the 2000-02 surveys describe the following distribution of precipitation conditions:

a) 52 percent of the de/anti–icing operations occurred under snow precipitation, substantiating that snow represents the most significant weather condition for deicing operations worldwide;

b) Frost accounted for 38 percent of the deicing operations; and

c) The remaining 10 percent of the deicing operations were due to freezing fog, freezing drizzle, light freezing rain, rain on cold–soak wing and rime ice combined. Of the latter, light freezing rain was the most significant weather condition, representing 3.5 percent of the total operations.

Table 3.5: 2000-02 Winter Deicing Operations Survey Results for Type I Fluids(Operations)

62891 Deicing Operations

OAT °C	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	Total
above 0	6538	62	6442	272	502	363	110	14289
0 to -10	13568	77	25886	894	1860		1858	44143
below -10	3218	0	1200				41	4459
Total	23324	139	33528	1166	2362	363	2009	

62891 of Operations

Table 3.6: 2000-02 Winter Deicing Operations Survey Results for Type I Fluids (Percentages)

62891 Deicing Operations

OAT °C	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	Total
above 0	10.4%	0.1%	10.3%	0.4%	0.8%	0.6%	0.2%	23%
0 to -10	21.6%	0.1%	41.3%	1.4%	3.0%		3.0%	70%
below -10	5.3%	0.0%	1.9%				0.1%	7%
Total	37.2%	0.2%	53.4%	1.8%	3.7%	0.6%	3.2%	

100% of Operations

Table 3.7: 2000-02 Winter Deicing Operations Survey Results for Type II/IV Fluids (Operations)

53710 Deicing Operations

OAT	Weather Conditions							Total
°C	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0	4787	415	7506	458	560	414	53	14193
0 to -3	11806	610	12558	562	594		85	26215
below -3 to -14	3990	487	7468	578	426		12	12961
below -14 to -25	97	2	242					341
below -25	0	0	0					0
	20680	1514	27774	1598	1580	414	150	

53710 of Operations

Table 3.8: 2000-02 Winter Deicing Operations Survey Results for Type II/IV Fluids (Percentages)

53710 Deicing Operations

OAT	Weather Conditions							Total
°C	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0	8.9%	0.7%	14.0%	0.8%	1.1%	0.8%	0.1%	26%
0 to -3	22.0%	1.2%	23.4%	1.1%	1.1%		0.1%	49%
below -3 to -14	7.4%	0.9%	13.9%	1.1%	0.8%		0.0%	24%
below -14 to -25	0.2%	0.0%	0.5%					1%
below -25	0.0%	0.0%	0.0%					0%
	38.4%	2.8%	51.7%	3.0%	2.9%	0.8%	0.2%	

100% of Operations

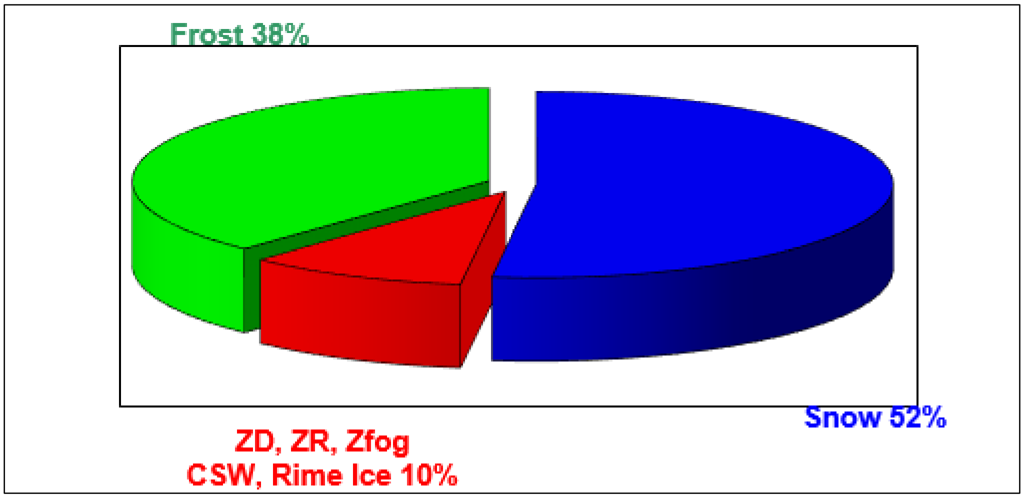


Figure 3.3: Frequency of Deicing Operations (All Airports) – Survey 2000-02

The results of the 2001-02 survey differed from that of the previous year. According to the combined dataset from the 2000-01 and 2001-02 surveys, the frequency of de/anti-icing operations due to frost increased from 27 percent to 38 percent, while the number of operations due to snow precipitation decreased from 62 percent to 52 percent. The deicing operations due to freezing precipitation remained relatively the same.

3.5.2 Previous Estimates of Deicing Operations at Dorval Airport

Table 3.9 shows a complete summary of the data provided by AeroMag and MSC prior to 2001, and also the distribution of deicing operations at Dorval, derived from the last two years of observation.

Table 3.9: Summary of All Results

	FROST [%]	FRZ. FOG [%]	SNOW [%]	FRZ. DRIZZLE [%]	LIGHT FRZ. RAIN [%]	RAIN ON CSW [%]	RIME ICE [%]
Estimate for Dorval based on MSC and AeroMag Data (Prior to 2001)	25	1	70	1	2	1	0
Estimate for Dorval based on 2000-02 Survey	28	0	64	2	5	0.5	0.5
Estimate of all airports 2000-01	27	1	62	2	5	1	2
Estimate of all airports 2000-02	38	2	52	2	3	1	2

The distribution illustrated in Figure 3.3 is different from the Dorval allocation over the last two years. At Dorval, snow accounted for 64 percent of the deicing operations whereas in the worldwide results from 2000-02, snow accounted for 52 percent of the deicing operations. The variation could be explained by the difference in the average winter temperature between Quebec and the surveyed regions.

3.6 Future Survey Requirements

Though the culmination of 2000-01 and 2001-02 data were more representative of different climate conditions, the survey would further benefit if more regions were added, such as Northern Alberta and North-Eastern Europe.

Also, even if the additional data from the areas suggested above were present, it is impossible to state that the 2000-01 and 2001-02 weather conditions were typical of those for the past 10 years or the next 10 years. In fact, the analysis should be extended over the next several years, and ideally over 11 years to include the solar cycle, since this seems to have a significant effect on weather cycles.

In summary, it is recommended that this study continue for the next several winters and that the number of surveyed airports be increased.

4. CURRENT AND PROPOSED CHANGES TO THE FORMAT OF THE HOLDOVER TIME TABLES

In 2001-02, the Type I fluid HOT table format underwent a thorough examination. Research in previous years had indicated a need to make changes to the format. Some of the changes have been presented and accepted by the community, while others have yet to be formally accepted. The two major changes to the format of the Type I fluid HOT table were:

a) Modifying the split point between the two warmest temperature ranges from 0°C to -3°C (temperature ranges change from *above 0°C* and *0°C* to *-10°C* to *above -3°C* and *-3°C* to *-10°C*); and
b) Addition of a column for light snow.

A detailed study providing the reasoning and justification behind those changes was conducted and could be found in Section 6 of TC report, *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, TP 13993E (1).

In 2002-03 the format of the Type I tables was further reviewed and two new significant changes were implemented:

a) A new temperature breakdown was introduced by splitting the *-3 to -10°C* interval into *below -3 to -6°C* and *below -6 to -10°C* temperature ranges; and
b) Apart from the existing light snow and moderate snow columns, a new column for very light snow was introduced.

This section will document the two major changes to the format of the Type I table format and, in addition, will provide a brief overview of the possible changes that may be anticipated for the Type II and Type IV fluid HOT table format.

4.1 Modifying the Temperature Range

4.1.1 Establishing a Temperature Range Division for *-3 to -10°C* Range

As described in Section 3 of this report, a deicing operation survey was conducted over a number of airports worldwide that yielded a temperature distribution of deicing operations. Within the snow column for Type I fluids (see Table 3.6), 70 percent of Type I fluid deicing operations occur within the *0 to -10ºC* temperature band. Examined further, the data indicates that snow in the *0 to -10ºC* temperature band accounts for over 41 percent of all deicing. In other words, a single cell in the Type I HOT table (Snow, 0 to -10ºC) is referred to 41 percent of the time.

A separate weather survey based on eight winters of observation across Quebec showed similar results. 46 percent of all snow events fell within the -3 to -10 ºC temperature band. This supports the previous comment on the high rate of referral to the single cell in the HOT table.

Since a high number of snow events occur within this temperature range, and because those operations conducted at warmer temperatures are being penalised with a holdover time that is related to -10°C, a break should be placed to split the *-3°C to -10°C* temperature range. Since the fluid in question is Type I, the holdover times tend to be shorter and therefore each additional minute of holdover time is valuable.

Following the SAE G–12 meetings in Frankfurt (June 2002), the Federal Aviation Administration (FAA) published a HOT Guideline for 2002-03 (Table 4.1) using an additional split at -6°C.

Table 4.1: FAA Type I HOT Guideline for 2002–2003

OAT		Approximate Holdover Times Under Various Weather Conditions (hours: minutes)							
°C	**°F**	**Frost**	**Freezing Fog**	**Light Snow**	**Moderate Snow**	**Freezing Drizzle**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**	**Other**
-3 and above	27 and above	0:45	0:11 - 0:17	0:11 - 0:16	0:06 - 0:11	0:09 - 0:13	0:02 - 0:05	0:02 - 0:05	CAUTION: No holdover time guidelines exist
Below -3 to -6	Below 27 to 21	0:45	0:08 - 0:14	0:08 - 0:13	0:05 - 0:08	0:07 - 0:10	0:02 - 0:05	CAUTION: Clear ice may require touch for confirmation	
-7 to -10	20 to 14	0:45	0:06 - 0:10	0:06 - 0:10	0:04 - 0:06	0:05 - 0:08	0:02 - 0:05		
Below -10	Below 14	0:45	0:05 - 0:09	0:04 - 0:06	0:02 - 0:04				

In moderate snow, this format provides a HOT of 5 to 8 minutes in the range *-3°C to -6ºC*, versus 4 to 6 minutes when the range is *-3°C to -10ºC*.

A narrower range, with -6ºC suggested as the temperature breakpoint, would ensure longer times at the milder temperatures. An analysis was conducted to validate the overall effectiveness of the temperature ranges.

4.1.2 Why at -6ºC?

Selecting -6ºC as the temperature breakpoint presents the optimum solution, as this provides the most beneficial use of the holdover times at warmer temperatures.

An optimisation analysis was conducted to evaluate the effectiveness of a split at -6ºC, as opposed to any other temperature. This analysis:

a) Considered each temperature interval above -10ºC as being a potential lower limit for the new temperature range;

b) Linked the holdover time that would apply to each new potential lower limit with the frequency of use over its entire range;

c) Linked the holdover time that applies at the -10ºC lower limit with the frequency of use over its now–diminished range; and

d) Summed the products of *frequency of use* times *holdover time* for the two ranges, compared the numerical results for the various potential split points, and concluded that the split point giving the highest numerical value provides the optimum solution.

The detailed calculation proceeded as follows (refer to Table 4.2). The snowfall events were derived from Table 2.16, which is a distribution of the frequency of occurrence of snow by temperature and precipitation rate. The data were taken from hourly-based historical weather records over a period of eight years from six airports in Quebec.

Table 4.2: Optimisation of Temperature Ranges for Type I Fluids

Temp. Interval (°C)	Number of Snow Fall Events	Snow Fall Events			Precipitation Rate (g/dm²/h)					
					4		10		25	
		% at Temperature Interval	Cumulative % from -3°C to the Potential Split	Cumulative % from -10°C to the Potential Split	Holdover Time (min)	Optimization Value (min)	Holdover Time (min)	Optimization Value (min)	Holdover Time (min)	Optimization Value (min)
-3 to -4	26,379	19.7%	19.7%	80.3%	16.8	12.50	9.9	7.38	5.9	4.36
-4 to -5	23,947	17.9%	37.7%	62.3%	15.5	12.95	9.1	7.64	5.4	4.51
-5 to -6	21,022	15.7%	53.4%	46.6%	14.3	**12.99**	8.5	**7.67**	5.0	**4.53**
-6 to -7	18,305	13.7%	67.1%	32.9%	13.4	12.77	7.9	7.54	4.7	4.45
-7 to -8	17,548	13.1%	80.3%	19.7%	12.7	12.42	7.5	7.33	4.4	4.33
-8 to -9	14,085	10.5%	90.8%	9.2%	12.0	11.95	7.1	7.06	4.2	4.17
-9 to -10	12,282	9.2%	100.0%	0.0%	11.4	11.44	6.8	6.75	4.0	3.99
Total	133,568	100.0%								

The number of snowfall events at each temperature interval was calculated as a percentage of the total number of snowfall events within the *-3ºC* and *-10ºC* range. These percentages were then accumulated in ascending and descending order between -3 and -10°C.

Analysis was conducted for three precipitation rates. A rate of 10 g/dm²/h represents the upper limit and a rate of 25 g/dm²/h represents the lower limit of holdover time in the current moderate snow column. The rate of 4 g/dm²/h represents the lower precipitation limit in the current light snow column.

For each precipitation rate, a holdover time at the lower limit for each of the two temperature ranges (*below -3ºC to -xºC* and *-xºC to -10ºC*) was used to calculate the optimisation value. These holdover times are calculated values from a regression analysis of the holdover time test data produced by both APS and Anti-Icing Materials International Laboratory (AMIL) during 2001-02. Refer to TC report, *Generation of Holdover Times Using the New Type I Fluid Test Protocol,* TP 13994E (13).

An optimisation value was then calculated treating each temperature interval as a potential division point of the two ranges, as explained in the following example.

Example for ranges *-3ºC to -6ºC* and *below -6 to -10ºC* for a precipitation rate of 10 g/dm²/h

a) Range *-3ºC to -6ºC*
   - lower limit is -6ºC;
   - holdover time = 8.5 minutes; and
   - percent of operations affected = 53.4%.

b) Range *below -6 to -10ºC*
   - lower limit is -10ºC;
   - holdover time = 6.8 minutes; and
   - percent of operations affected = 46.6%.

c) Optimization value for split at *-6ºC*
   - (53.4% of 8.5 minutes) + (46.6% of 6.8 minutes) = 7.67 minutes.

The optimisation value of 7.67 minutes for a split at -6°C provides an increase of around one minute compared to the value of 6.75 minutes for the single range *-3 to -10ºC.*

The same routine was followed for other potential split points and for the other precipitation rates. The results were entered in Table 4.2 and compared. It was found that the optimisation value is also highest at -6°C for precipitation rates of 4 and 25 g/dm²/h.

Therefore, when dividing the temperature interval from *-3ºC to -10ºC* into two ranges, a split at -6°C produces the most beneficial utilization of endurance time for deicing operations.

For harmonization purposes with the format presented by the FAA, and in conjunction with the findings from the aforementioned optimisation analysis, TC agreed to open a new temperature row at -6°C in their Type I guideline table.

4.1.3 Revised Format for TC Type I HOT Table

Table 4.3 presents the new Type I fluid HOT table format that includes the temperature ranges *below -3ºC to -6* and *below -6 to -10ºC.*

Table 4.3: New Temperature Range Format for Type I Fluid HOT Table

<table>
<tr><th colspan="2">OAT</th><th colspan="8">Approximate Holdover Times Under Various Weather Conditions (minutes)</th></tr>
<tr><th>°C</th><th>°F</th><th>Frost</th><th>Freezing Fog</th><th>Light Snow</th><th>Moderate Snow</th><th>Freezing Drizzle</th><th>Light Freezing Rain</th><th>Rain on Cold Soaked Wing</th><th>Other</th></tr>
<tr><td>-3 and above</td><td>27 and above</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2" rowspan="3"></td></tr>
<tr><td>**below -3 to -6**</td><td>**below 27 to 21**</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>**below -6 to -10**</td><td>**below 21 to 14**</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>below -10</td><td>below 14</td><td></td><td></td><td></td><td></td><td colspan="4">CAUTION:
No holdover time guidelines exist</td></tr>
</table>

As this discussion deals only with the format of the HOT table, holdover values have not been reported for the various cells. The holdover time values are reported in the TC report, *Aircraft Ground De/Anti–Icing Fluid Holdover Time Development Program for the 2002-03 Winter*, TP 14144E (9).

Apart from introducing a new temperature breakpoint, this new format of the TC HOT table includes the -3°C temperature in the first row of the table. The TC Type I table presented in 2001-02 categorized this temperature range as *above -3°C.* As a result, the TC holdover value for the first row would apply only over the range of *-2 ºC and above*, while the FAA value would apply over the range of *-3ºC and above*. The TC and FAA Type I HOT tables were harmonized to read *-3ºC and above.*

This format change, as well as the effect on the subsequent temperature ranges, is presented in more detail in Section 7 of TC report, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2002-03 Winter*, TP 14144E (9).

4.2 Adding the Very Light Snow Column

4.2.1 The Probability of Very Light Snow versus Light and Moderate Snow Events

The Type I fluid HOT table format used for 2002-03 operations contained two columns for snow. Snow is defined as "light" and "moderate" in the HOT table, which means it has a liquid equivalent of 4 to 10 and 10 to 25 g/dm^2/h.

As presented in Section 3, the results from the 2000-02 surveys have shown that 52 percent of the de/anti-icing operations occurred under snow precipitation, substantiating that snow represents the most significant weather condition for deicing operations worldwide.

In Section 2.3.5 of this report, the frequency of snow occurrences is subdivided into four major snow conditions: *very light snow, light snow*, *moderate snow* and *heavy snow*. The frequency of *very light snow* events, at over 53 percent, is significantly higher than *light, moderate* and *heavy snow* events, which occur at frequencies of 19.6 percent, 23.7 percent and 2.9 percent, respectively (refer to Table 2.17). This indicates that using *light snow* with its shorter holdover time as the basis for the snow column imposes a penalty on operations taking place during the 53 percent of snowfall events represented by *very light snow*.

4.2.2 Changes to the HOT Table Format Proposed at SAE G-12 Meeting

To rectify the penalty imposed on operations by using the light snow column for any precipitation rate less than 10 g/dm^2/h, it was proposed that a new column for very light snow be introduced in the HOT table.

Moreover, the TC Type I HOT table contains a note stating that the only acceptable decision criteria time is the shortest time within the applicable HOT table cell. This caution penalizes the operators, preventing them from taking advantage of the longer holdover value within the applicable holdover time cell.

The 2002-03 TC Type I HOT table used 3 g/dm^2/h as the lower precipitation rate limit for *light snow*. However, FAA preferred a lower limit of 5 g/dm^2/h for the same column. The FAA position, which resulted in shorter endurance times at the lower limit, was balanced by the FAA rule that adds 5 minutes to a pre-takeoff contamination check. For harmonization purposes, at the SAE G-12 HOT Subcommittee meeting held in Vancouver in May 2003, the two regulatory authorities agreed upon using 4 g/dm^2/h as the lower limit for the *light snow* column.

The proposed split in the temperature ranges and the addition of the *very light snow* column were proposed at the SAE G–12 HOT Subcommittee meeting in May 2003. In a presentation entitled, "Changes To The Transport Canada / FAA Type I Fluid Holdover Time Guidelines", APS presented the modified temperature ranges and the introduction of the *very light snow* column in the Type I HOT table to the SAE G-12 Holdover Time Subcommittee. The committee agreed in principle to the changed format.

For 2003-04 winter season, each agency will publish its own table with different formats for *very light snow*. The TC table will have single values in the *very light snow* column, while the FAA table will have a range. The holdover time values for both TC and FAA are calculated using the dataset of Type I tests conducted by APS and by AMIL during the 2001-02 winter season.

The revised Table 4.4 reflects the changes agreed upon at the industry meetings and represents the current format of the Type I table format.

Table 4.4: New Type I Fluid Holdover Time Table Format for 2002–03 Operations

<table>
<tr><th colspan="2">OAT</th><th colspan="9">Approximate Holdover Times Under Various Weather Conditions (minutes)</th></tr>
<tr><th>°C</th><th>°F</th><th>Frost</th><th>Freezing Fog</th><th>Very Light Snow</th><th>Light Snow</th><th>Moderate Snow</th><th>Freezing Drizzle</th><th>Light Freezing Rain</th><th>Rain on Cold Soaked Wing</th><th>Other</th></tr>
<tr><td>-3 and above</td><td>27 and above</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="3" colspan="2"></td></tr>
<tr><td>below -3 to -6</td><td>below 27 to 21</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>below -6 to -10</td><td>below 21 to 14</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>below -10</td><td>below 14</td><td></td><td></td><td></td><td></td><td></td><td colspan="4">CAUTION:
No holdover time guidelines exist</td></tr>
</table>

4.3 Motion to Create an SAE Standard for Type I, Type II and Type IV Fluid Holdover Time Tables

During the SAE G–12 Holdover Time Subcommittee meetings in Frankfurt, it was decided that there was a need for the SAE to develop and publish a standard format for all HOT tables. This is of particular importance because the SAE will no longer be publishing HOT tables.

The major reason for the initiation of an SAE standard concerning the format of the tables was to set the format to be used for all future HOT tables. This standard would grant the SAE control over any future modifications to the tables and therefore would not leave the responsibility solely up to the regulatory authorities.

The template would contain the weather conditions, the precipitation rates and the temperature ranges that are required when formulating fluid HOT tables. The templates would not contain any holdover times.

A first draft of such a standard is currently being developed by APS, and is included in Appendix F.

At this time, the Aerospace Standard is preliminary. Because the guidelines have existed for some years, it is probable that operators have evolved their own internal procedures for interpretation and application, and that these may differ significantly between operators. It is important therefore that the variety of application procedures existing within the industry be investigated and documented before deciding upon and issuing industry–wide procedures. Its contents were not reviewed, corrected or approved by the SAE G–12 Holdover Time Subcommittee. The standard will also have to undergo a balloting process before it becomes effective.

4.4 Impact of Type I Format Changes on Type II and Type IV Tables

The changes that have been made to the Type I fluid HOT table format warrant a look at the impact that this may have on Type II and Type IV fluid HOT table formats. It is expected that in the near future, a change to the Type II and Type IV table formats will be implemented to provide more consistent HOT tables for all fluid types. Section 4.4.1 presents the most prominent inconsistencies.

4.4.1 Evaluation of the Type II/IV HOT Table Temperature Ranges

4.4.1.1 Temperature ranges of above 0°C and 0 to -3°C

The Type II and Type IV fluid HOT tables continue to have two temperature ranges for temperatures above -3°C:

a) *Above 0°C*; and

b) *0 to -3°C*.

These two subdivisions could be combined in a single range, *above -3°C*, to conform to the Type I table. In the Type II and IV tables, frost is the only condition for which there is a notable difference in HOT values between the two ranges *above 0°C* and *0 °C to -3°C*. However, the current values are not substantiated, and preliminary frost endurance tests indicated there may be no difference between the two ranges. The Type II/IV fluid times for frost are very long and the cost of testing is very high, so there is justification for merging the two ranges.

4.4.1.2 Temperature range -3 to -14°C

Using the present format of the Type II/IV HOT tables, any anti-icing operation done at a temperature just below -3°C would have the same holdover times as an operation at -14°C.

The following example using existing HOTs for a particular Type IV fluid illustrates this effect.

Suppose the following:

a) Temperature: -2ºC;

b) Precipitation condition: Snow;

c) Weather Advisory: Moderate snow; and

d) Fluid Type: Clariant Safewing MPIV 2001 100%.

The HOT guideline range for *0ºC to -3ºC* would then be 1:00 to 1:55 and the HOT guideline used by a pilot would be 1:00 because the snow is moderate.

However, if the temperature was -4ºC rather than -2ºC, then the HOT guideline range for *-3ºC to -14ºC* would be 0:30 to 0:50 and the HOT guideline used by a pilot would be 0:30.

A temperature difference of only 2ºC results in a time difference of 30 minutes based on the current HOT chart. This situation occurs frequently because the likelihood of snow between -3ºC and, for example, -7ºC is high. Table 2.16 shows that over 58 percent of the snow precipitation was recorded between 0°C and -7°C, and over 73 percent between 0°C and -10°C.

The above example clearly demonstrates that consideration should be given to changing the temperature ranges in the Type II/IV HOT tables.

When considering temperature break changes in the Type II/IV HOT tables, consideration should be given to the natural freeze point limits of the fluids and their dilutions to ensure that the required 7°C buffer is maintained.

An optimisation analysis was conducted that tested for the optimal break. This analysis was conducted using a methodology that is similar to the methodology described in Section 4.1.2, and can be found in Section 6.5 of TC report, *Impact of Winter Weather on Holdover Time Table Format (1995-2002)*, TP 13993E (1).

The analysis showed that the following temperature breaks would provide the highest weighted holdover time values:

a) *-3°C to -8°C*; and
b) *-8°C to -14°C*.

The optimisation analysis was updated by adding the 2002-03 weather data. The analysis showed consistent results with previous year's findings. It was concluded that a split at -8°C for the *-3°C to -14°C* temperature ranges produces the most beneficial utilization of endurance time for deicing operations.

4.4.1.3 Temperature range -14°C to -25°C

Section 2.3.3 of this report suggests that a break at -18°C would be appropriate.

4.4.2 Introduction of Light Snow Column

The current SAE Type II and Type IV fluid HOT tables have only one snow column based on endurance times measured for moderate snow. Introduction of a *very light snow* and a *light snow* column would conform to the new Type I table format.

4.5 Changes to the HOT Tables Proposed by Workgroup

At the SAE G–12 Workgroup meeting held in Montreal in September 2003, the participants agreed in principle to the following changes:

a) Remove the viscosity information from the brand specific Type II and Type IV fluid HOT guideline tables. Develop a table of viscosities for the HOT tables, including the viscosities measured using the fluid manufacturer method and the Aerospace Information Report (AIR) method. The table will include viscosities of the 100, 75/25 and 50/50 dilutions;

b) Remove the *Above 0°C* row for the Type II/III/IV HOT table guidelines; and

c) Editorial changes (i.e. removal of abbreviations).

Before implementing these changes to the 2004-05 HOT guideline tables, they will have to be presented and proposed to the SAE G–12 HOT Subcommittee meeting in the spring of 2004.

4.6 Other Potential Future Changes

Consideration should be given to the use of a single digit HOT value in the HOT table cells. The grounds for this change are explained below, for several weather conditions.

4.6.1 Natural Snow

The format of the HOT tables has been the subject of considerable discussion at industry meetings. The ultimate aim of issuing such a table is to provide pilots with a guideline containing endurance times for anti–icing fluids in different weather conditions. To suit the busy environment in the flight deck, the table should be easy to understand and simple to use. There should be no chance of misunderstanding how to use the HOT values, and little need for the pilot to interpret what the values mean in the particular situation.

The current tables for all fluid types are quite busy, with many HOT values, notes and cautions. Over the years that the HOT tables have been published, the information conveyed on the tables has grown to satisfy various issues and interests.

By replacing the holdover time range with a value in each cell of the HOT table, the interpretation of the table would be significantly simplified and the confusion that occurs when dealing with HOT tables would be eliminated.

4.6.2 Freezing Fog

Since the use of this column is not extensive and because the times are generally higher than is required for operations, consideration should be given to removing the range and replacing it with a value. This would result in a reduced cost of testing.

4.6.3 Freezing Drizzle

Consideration should be given to the use of one value rather than a range, particularly because this condition has a low utilization. This would result in a reduction of the cost of testing.

4.6.4 Light Freezing Rain

Consideration should be given to the use of one value rather than a range, because this condition has a low occurrence and also because it has already been specified as “light” freezing rain. It would reduce the cost of testing.

5. EVALUATION OF FOG AND FROST DEPOSITION RATES IN NATURAL CONDITIONS

This chapter contains an account of the tests conducted over the 2002-03 winter season to collect frost deposition rates in natural conditions. In addition, an account of the freezing fog tests conducted in the previous seasons is also described.

5.1 Study to Quantify Freezing Fog Deposition Rates

Natural freezing fog deposition rate measurements were conducted during previous test seasons. It was concluded that current HOT table precipitation rate limits of 2 and 5 $g/dm^2/h$ are conservative, with rates measured during actual fog conditions being closer to 1 $g/dm^2/h$. For an account of testing from previous years, refer to TC report, *Impact of Winter Weather on Holdover Time Table Format (1995-2002),* TP 13993E (1).

5.2 Measurement of Frost Deposition Rates in Natural Conditions

Frost testing was conducted over two winter seasons, 2001-02 and 2002-03. The objective of the winter 2001-02 research was to document rates of frost accretion representative of that on aircraft surfaces, and to document the corresponding environmental conditions, for the purpose of defining laboratory test conditions for fluid endurance tests in active frost.

A new recommended table of frost parameters for fluid endurance tests was formulated. The test conditions included new values for both frost intensity and test surface temperature at the various ambient test temperatures. Values for frost intensity were derived from recorded frost intensity data together with typical values for relative humidity during frost conditions taken from a 12-year winter-weather survey at Montreal and La Grande, Quebec.

The newly recommended table of frost test parameters was tested for validity in the Institut de Recherche d'Hydro-Québec (IREQ) test facility, in October 2002. The test examined whether the desired frost rates could be generated, and measured fluid enrichment during some Type I fluid endurance tests. The recommended frost rates could not be produced at the specified test conditions.

After it was determined that the desired frost rates could not be generated, it was decided that it was necessary to ensure that the frost rate targets were realistic by collecting further data on natural frost rates. As well, fluid enrichment on wings during real deicing operations and endurance time for Type I fluids in natural frost were documented.

These tests documented frost rates at mild temperatures considerably higher than those recorded in the previous season. As well, surface temperature differentials were different from previous data, and led to the recommendation to use a 6 ºC differential at all test temperatures. These new values for rates and temperature differentials were used to define new test parameters.

A detailed analysis of the results and conclusions from indoor and outdoor frost testing over the two–year period are summarized in TC report, *Laboratory Test Parameters for Frost Endurance Time Tests*, TP 14145E (8).

6. CONCLUSIONS

A number of conclusions can be drawn from the various data collected for this report.

6.1 Precipitation Rate Limits for the Moderate Snow Range

Data gathered over eight years from six sites in Quebec form the basis for the winter weather analysis discussed in this report. The data confirms that the long-established HOT table snow precipitation rates of 10 and 25 g/dm^2/h are valid limits at all temperature ranges for the *moderate snow* range. However, the data analysis also emphasizes that this range encompasses only 23.7 percent of all snow events, and snowfall at rates less than 10 g/dm^2/h accounts for over 73 percent of all snow events. This stimulated the addition of new snow columns for Type I fluids.

6.2 Addition of a Very Light Snow Range to the Type I HOT Table

Because the majority of all snowfall events occur at rates less than 10 g/dm^2/h, and because snow comprises 52 percent of all deicing operations worldwide, introduction of an additional column in the Type I fluid HOT table, in conjunction with the *light snow* and *moderate snow* columns, is justified. Such a recommendation was accepted at the 2003 SAE G–12 Vancouver meeting, resulting in the need to define a new *very light snow* column. TC and FAA agreed upon using 0 to 4 g/dm^2/h as the precipitation rate range. The resulting *very light snow* column accounts for over 53 percent of all snow operations.

In order to use the longer holdover times in the Type I table, operators need more comprehensive information on snowfall rates lower than 10 g/dm^2/h. This need was addressed by opening a new column in the visibility table. Development of the National Center for Atmospheric Research (NCAR) hot plate snow gauge to an operational state would further satisfy this need, and should therefore be given high priority.

6.3 Modifications to HOT Tables

It was concluded that two new rows, *below -3 to -6°C* and *below -6 to -10°C,* should be introduced to split the *below -3 to -10°C* row in the Type I HOT table. These temperature breakdowns were chosen for harmonization purposes with the format of the Type I table presented by the FAA. The selection of -6ºC as the temperature break was also based on results of an optimization analysis that showed that this temperature break produced the most operationally advantageous mix of holdover times.

It was also concluded that the format of the Type II/IV HOT tables should be examined to integrate the same changes as in the Type I table, including removal of the *above 0ºC* row and introduction of snow divisions for precipitation rates lower than 10 g/dm²/h.

6.4 Frequency Distribution of Types of Deicing Operations

The survey of actual winter operations concluded that, for the reporting centres, the distribution of types of deicing operations was:

a) Snow 52%;
b) Frost 38%; and
c) Other 10%.

The *other* category consisted of freezing rain, freezing drizzle, freezing fog, cold-soaked wing and rime ice.

6.4.1 Snow

This distribution confirms that snow is the most frequently used condition in the HOT table and, therefore, a corresponding degree of attention should be given to further refining it. Development of the NCAR snowmaker to allow snow endurance time testing in controlled laboratory conditions is an important part of this effort and should be given high priority.

6.4.2 Frost

Similarly, this distribution confirms that frost is the second most frequent type of deicing condition, and it is also important that a sufficient degree of attention be given to investigating and substantiating Type I fluid frost holdover times.

6.4.3 Freezing Rain/Freezing Drizzle

Analysis of the winter weather data and survey data concluded that:

a) Freezing rain and drizzle occur in a band with -10ºC as a lower limit; and

b) 91 percent of the time, precipitation rates are less than 25 g/dm^2/h.

6.4.4 Freezing Fog

Based on the tests conducted in previous years, it was concluded that:

a) Deicing operations due to freezing fog comprise only 1.4 percent of all precipitation conditions requiring use of HOT tables;

b) Current HOT table precipitation rate limits of 2 and 5 g/dm^2/h are conservative, with rates measured during actual fog conditions closer to 1 g/dm^2/h; and

c) Modifying the HOT table column for freezing fog to provide a single value rather than a range is justified, based on long endurance times and infrequent use.

This page intentionally left blank.

7. RECOMMENDATIONS

Recommendations related to specific subjects are offered.

7.1 HOT Table format

It is recommended that:

a) A workgroup be assembled to examine and formulate the optimum format of the Type II and Type IV fluid HOT guideline tables. An Aerospace Standard that regulates the format and provides instructions as to how the HOT tables are to be interpreted should also be developed. This standard grants the SAE control over future modifications required to the tables and would not leave the responsibility solely up to the regulatory authorities. It is important that the variety of HOT table application procedures existing within the industry be investigated and documented before deciding upon and issuing industry-wide interpretations;

b) A presentation be prepared of changes to the HOT guideline table format agreed upon at the SAE G–12 Workgroup meeting, held in Montreal in September 2003; and

c) Development of the NCAR hot plate snow gauge to an operational state be given high priority.

7.2 Weather Data Survey

It is recommended that:

a) This survey be continued in order to generate more data, which is particularly needed for relatively infrequent precipitation conditions such as freezing drizzle and rain.

7.3 Winter Operations Survey

It is recommended that:

a) The survey be continued and expanded to include more cities worldwide;

b) Development of the NCAR snowmaker for use in snow endurance time testing be given high priority and continued support. The needed research is reflected in an associated report; and

c) More emphasis be placed on investigating and substantiating endurance times for frost conditions.

This page intentionally left blank.

REFERENCES

1. Moc, N., Alwaid A., *Impact of Winter Weather on Holdover Time Table Format (1995–2002)*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13993E, XX (to be published).

2. Stuart, R.A. and G.A. Isaac, 1999: *Freezing Precipitation in Canada. Atmosphere Ocean*, 37–1, 87–102.

3. Isaac, G.A., and R.A. Stuart, 1996: *Relationships between cloud type and amount, precipitation and surface temperature in the Mackenzie River valley-Beaufort Sea area*. J. of Climate, 9, 1921–1941.

4. Isaac, G.A. and R.A. Stuart, 1992: *Temperature–precipitation relationships for Canadian stations*. J. Climate, 5, 822–830.

5. Strapp, J.W., R.A. Stuart and G.A. Isaac, 1996: *Canadian climatology of freezing precipitation, and a detailed study using data from St. John's, Newfoundland. FAA International Conference on Aircraft Inflight Icing*, Springfield, Virginia, Volume II, DOT/FAA/AR–96/81, 45–55.

6. Stuart, R.A., and G.A. Isaac, 1994: *Archived weather data is providing new insights into ground–based icing*. ICAO Journal, 49, #8, 5–7.

7. Stuart, R.A., 1994: *A comparison of the potential for ice accumulation on ground-based aircraft at airports in Canada, Western Europe and the United States*. Report of Weather Research House to AES.

8. Dawson, P., *Laboratory Test Parameters for Frost Endurance Time Tests,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2003, TP 14145E, XX (to be published).

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

10. Moc, N., *Aircraft Ground Icing Research Support Activities for the 2002-03 Winter,* APS Aviation Inc., Transportation Development Centre, Montreal, September 2003, TP 14155E, XX (to be published).

11. Moc, N., *Winter Weather Data Evaluation (1995-2001)*, APS Aviation Inc., Transportation Development Centre, Montreal, October 2001, TP 13830E, 56.

12. Hanna, M., Hunt, M., Chaput, M., *Snow Weather Data Evaluation (1995-2000)*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2000, TP 13665E, 48.

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

APPENDIX A

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

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

5.4 Evaluation of Winter Weather Data

5.4.1 Collect more data from the six weather stations in Quebec, with emphasis on freezing drizzle and freezing rain;

5.4.2 Collect more natural fog deposition rates to correlate with the 2 g/dm²/h to 5 g/dm²/h range being used in environmental chambers fog deposition measurements, on at least two occasions;

5.4.3 Continue and expand the operations survey to include more cities worldwide;

5.4.4 Analyze historical weather data to evaluate the levels of extremes as well as the range and rate of change of precipitation rates;

5.4.5 Review available worldwide data and undertake preliminary analysis; and

5.4.6 Analyze all data collected to prepare presentation material and a final report to TC.

This page intentionally left blank.

APPENDIX B

WINTER WEATHER DATA 1995-96 TO 2002-03

WINTER WEATHER DATA 1995-96 TO 2002-03

The following charts include the complete rate data analysis, subdivided by temperature ranges for both snow and freezing rain. A histogram of points and a cumulative probability chart are included for each rate calculation interval in all temperature ranges.

The lowest holdover time temperature range for snow conditions (-14ºC to -25ºC) was subdivided into three ranges. The charts for this analysis are also included.

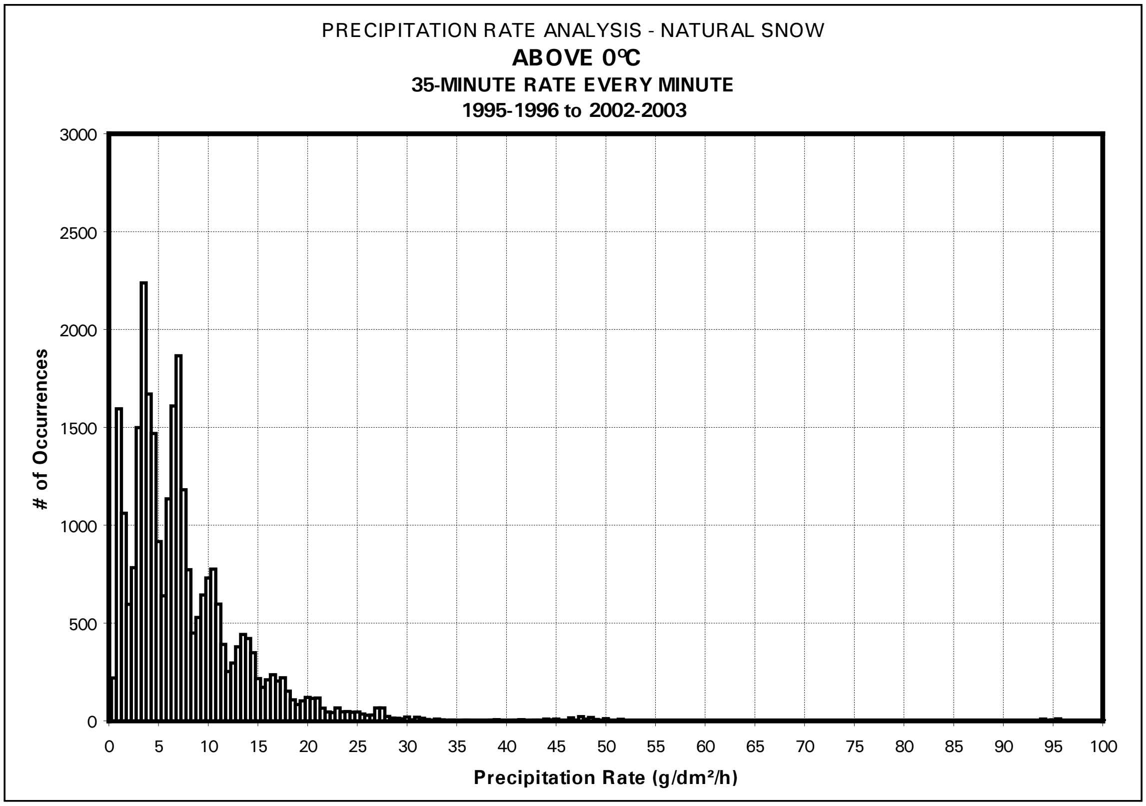
INDEX

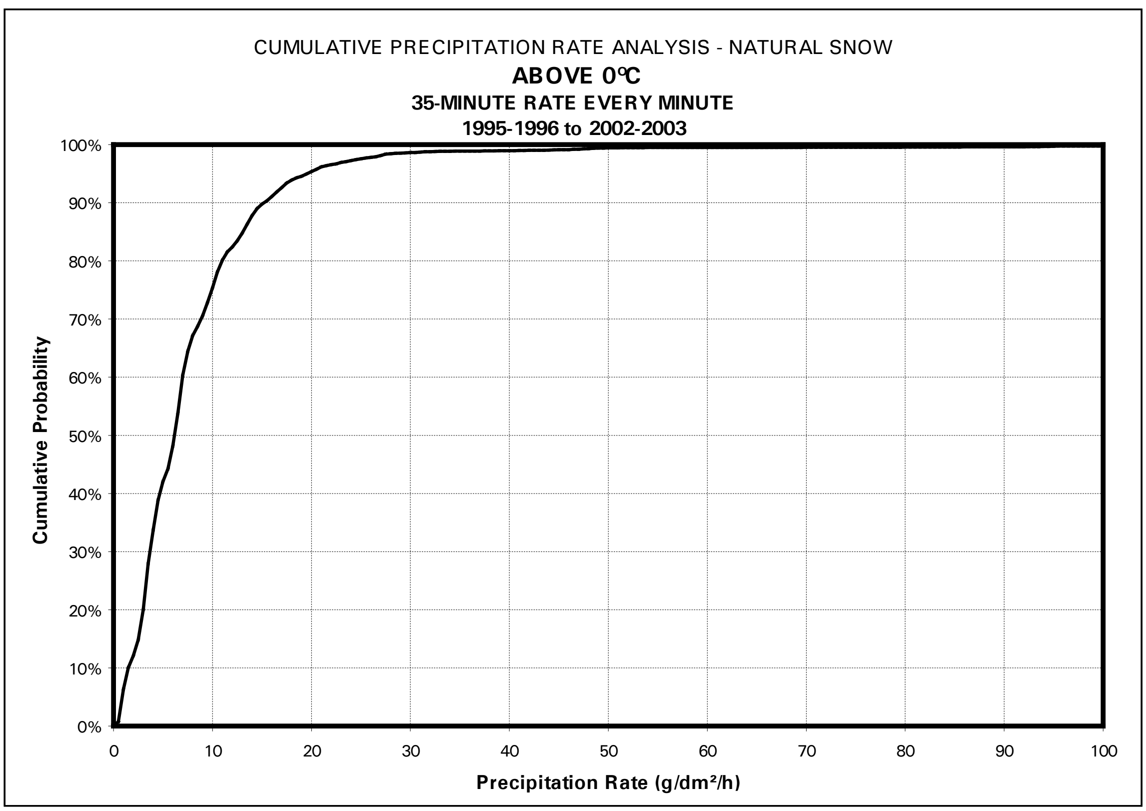
SNOW

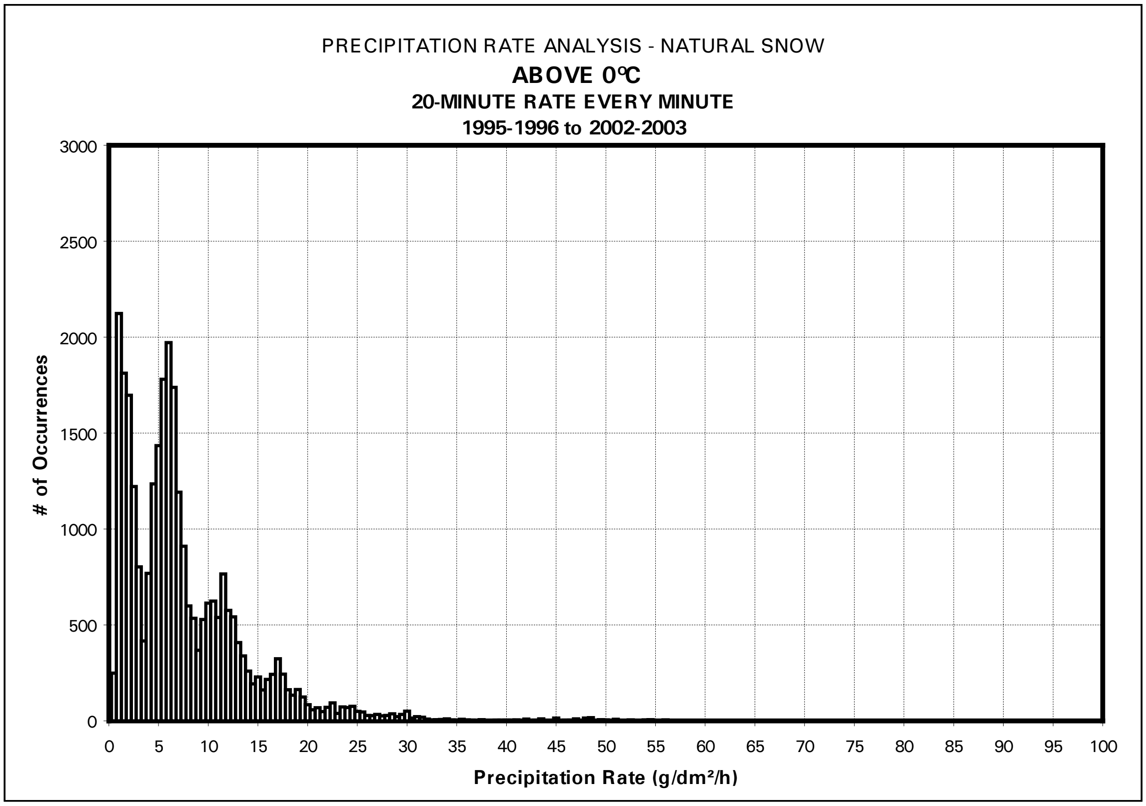
LIGHT FREEZING RAIN / DRIZZLE

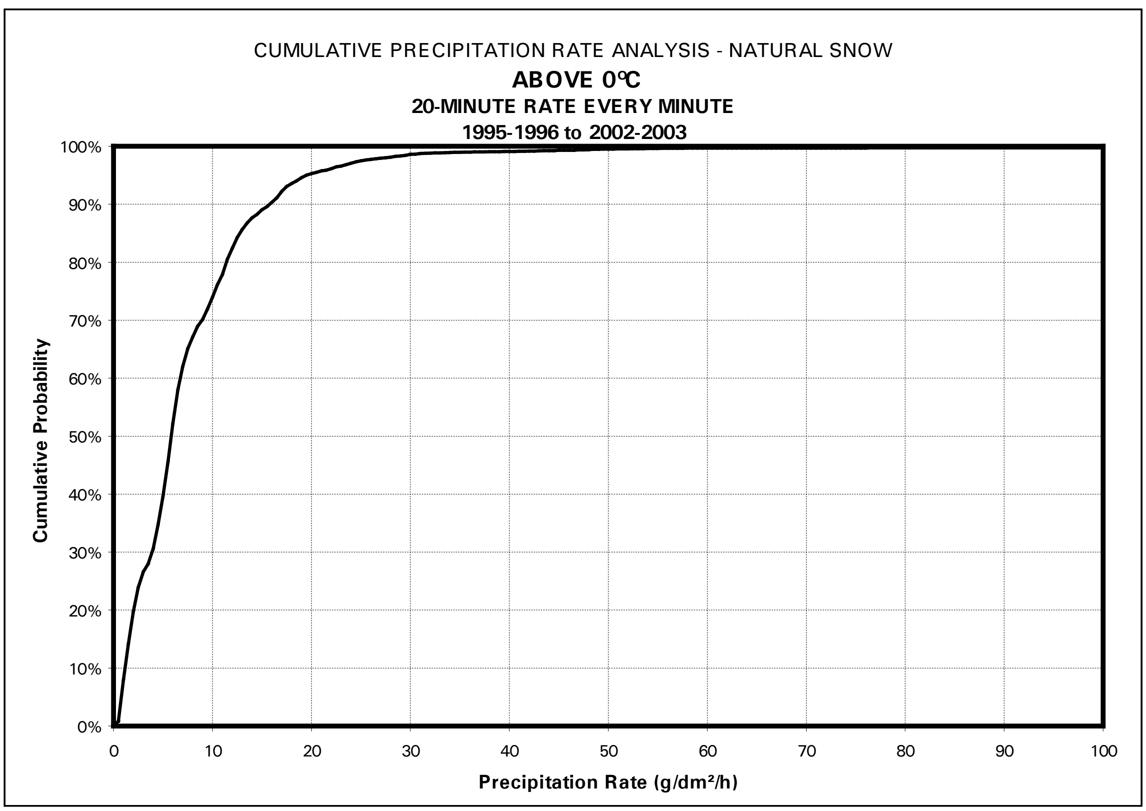
COLD SNOW SUBDIVISION

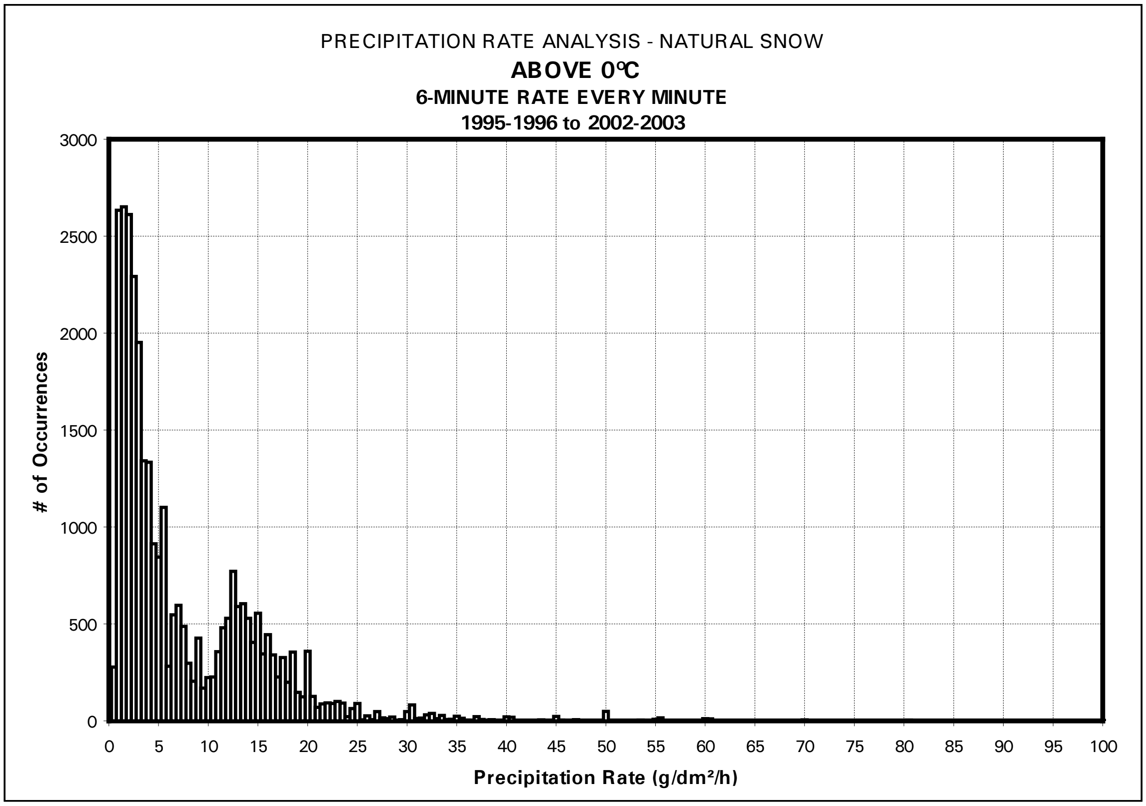
This page intentionally left blank.

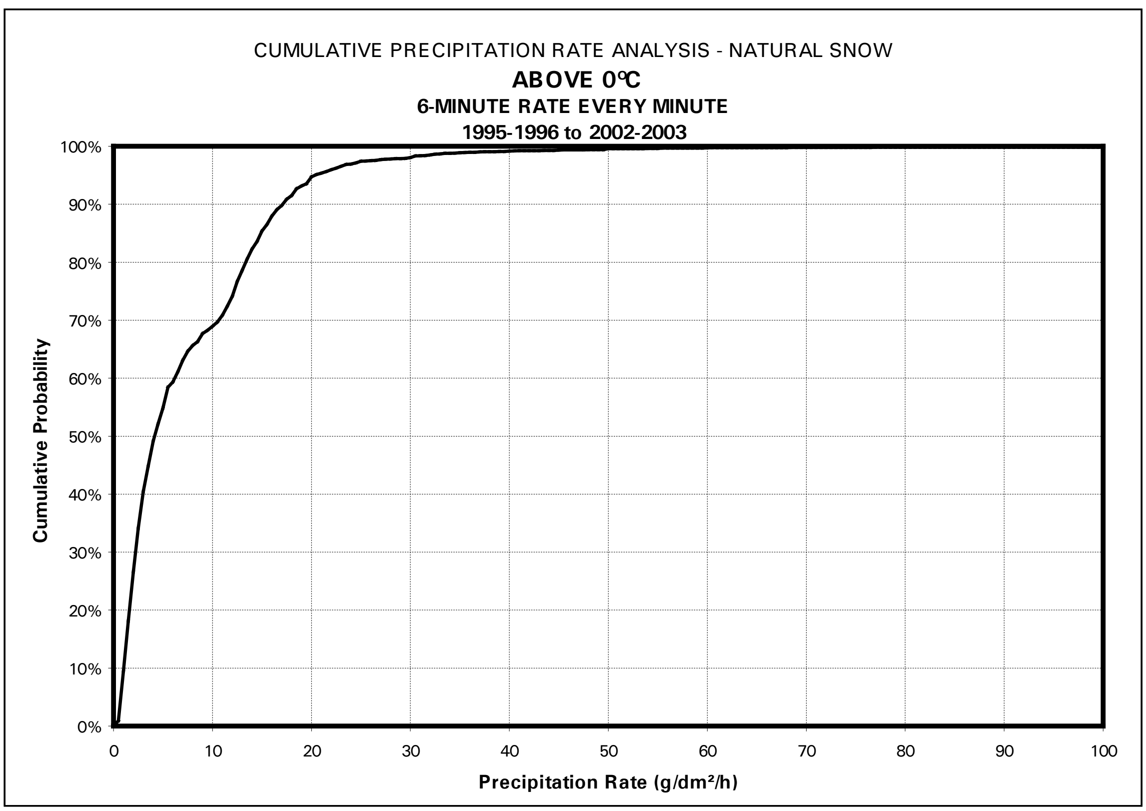

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
ABOVE 0°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
500
1000
1500
2000
2500
3000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

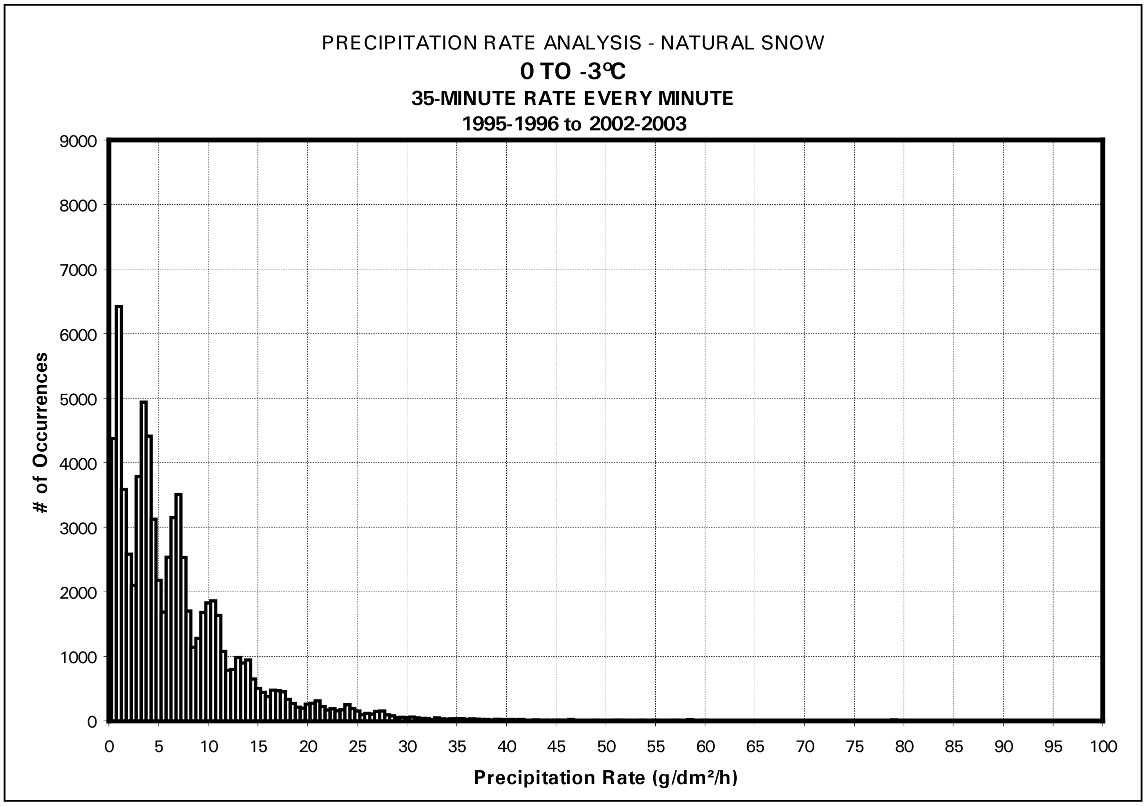

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
ABOVE 0°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

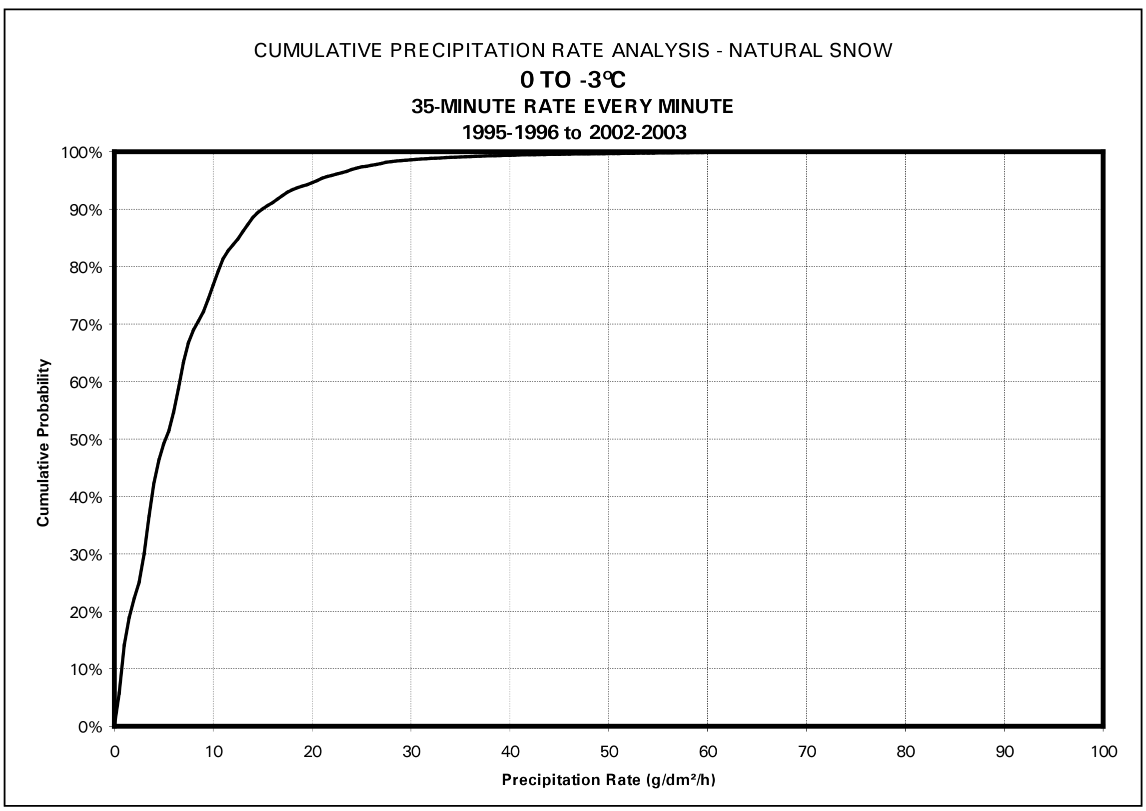

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
ABOVE 0°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
500
1000
1500
2000
2500
3000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

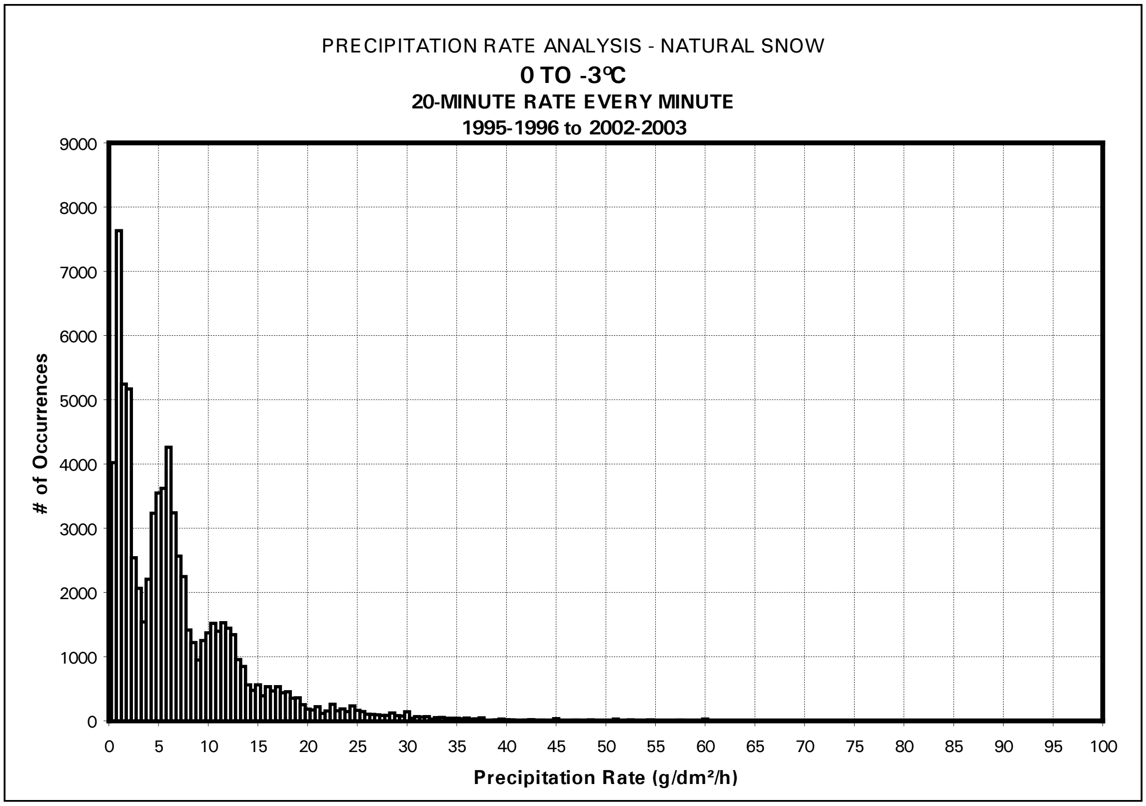

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
ABOVE 0°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

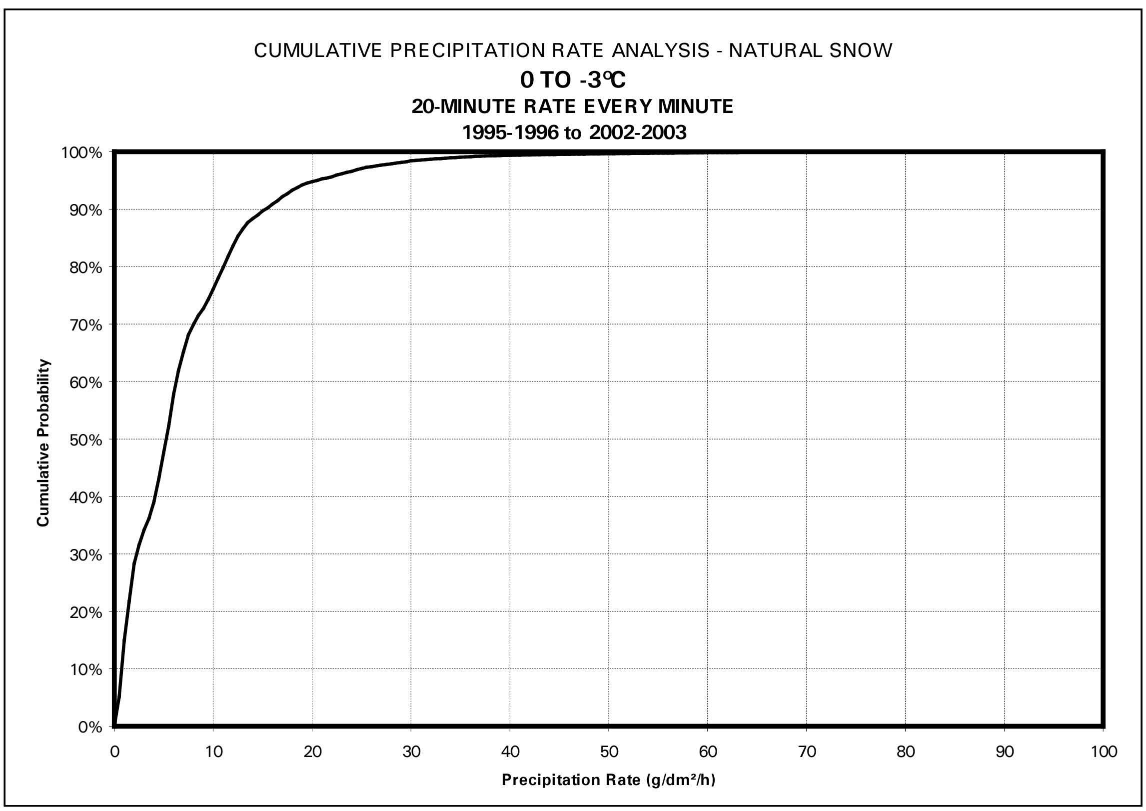

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
ABOVE 0°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
3000
2500
2000
1500
1000
500
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

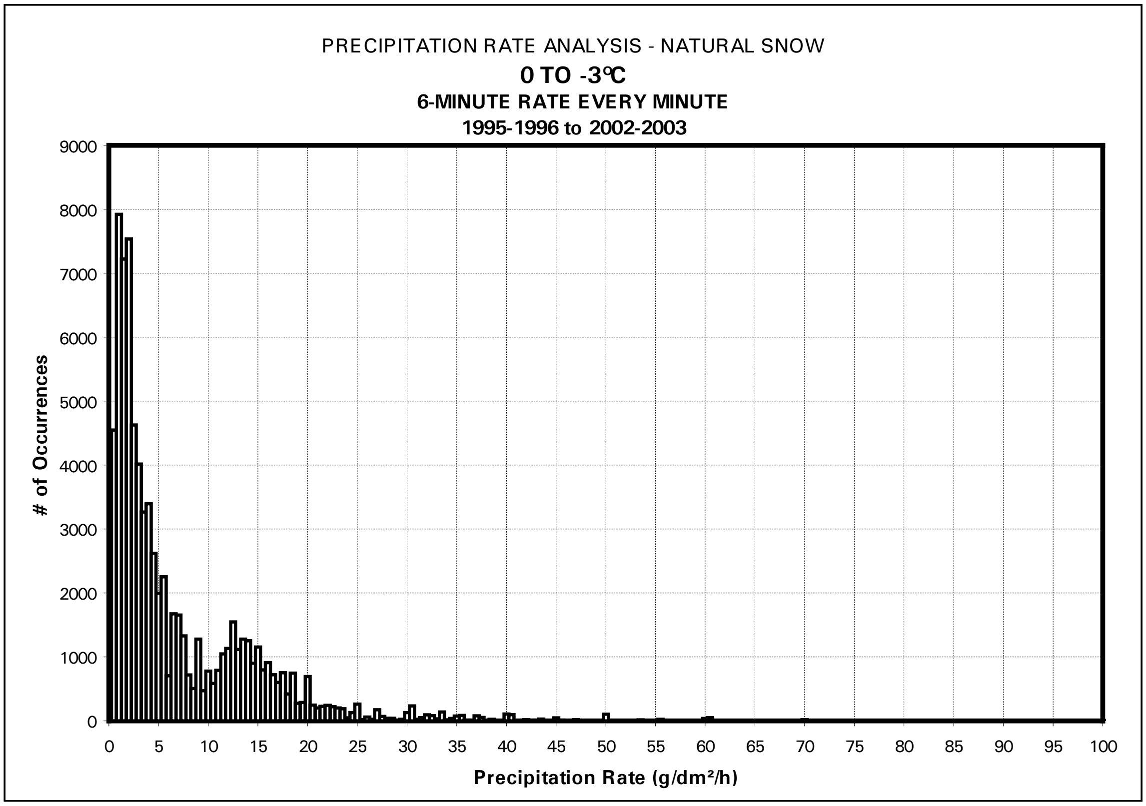

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
ABOVE 0°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

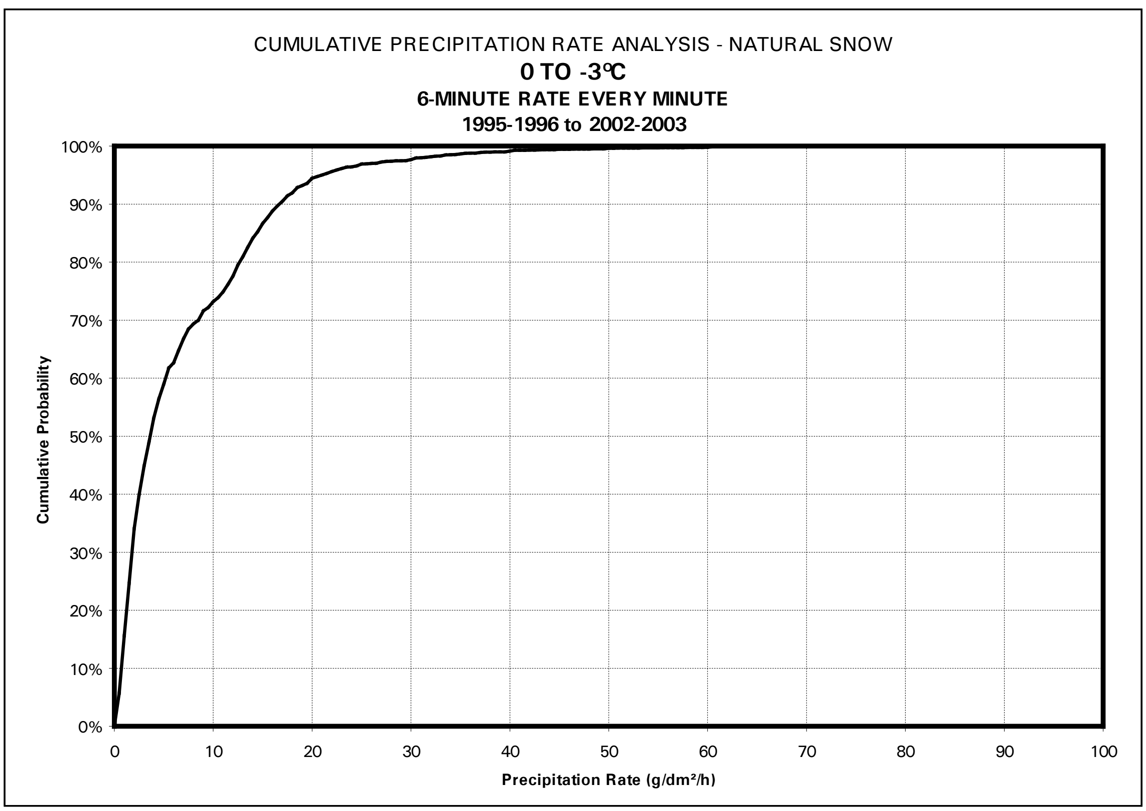

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
0 TO -3°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

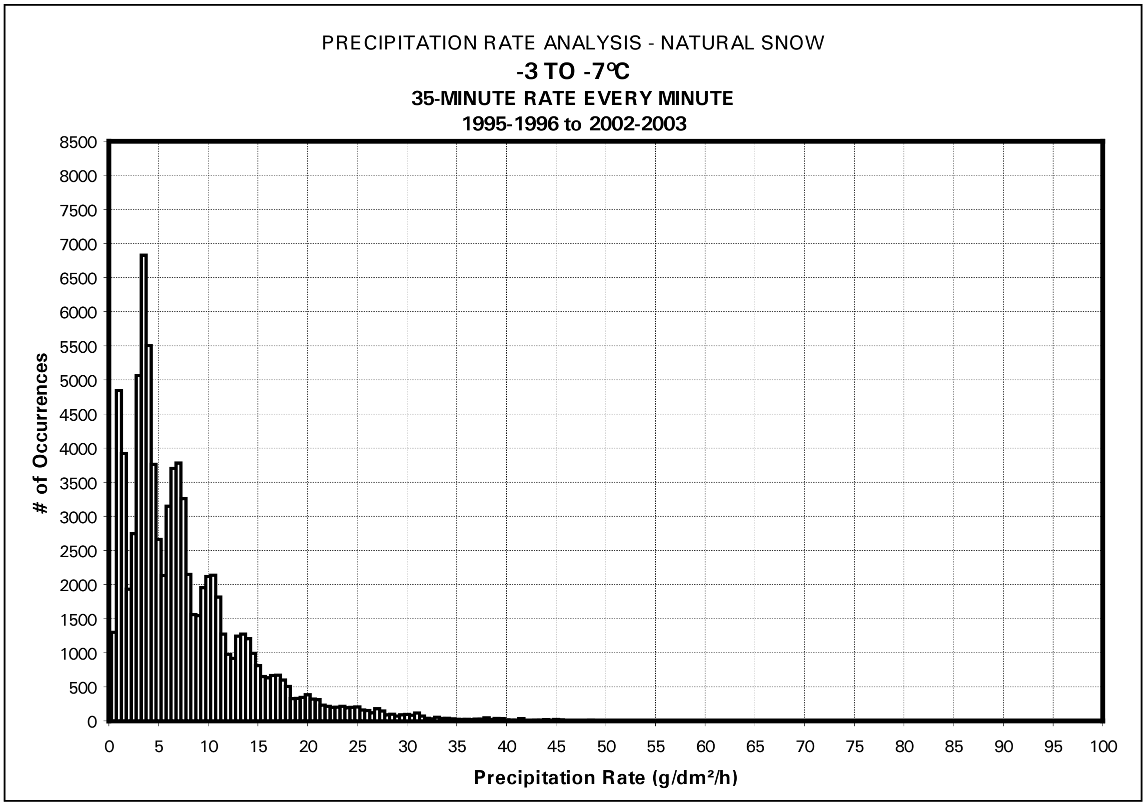

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
0 TO -3°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

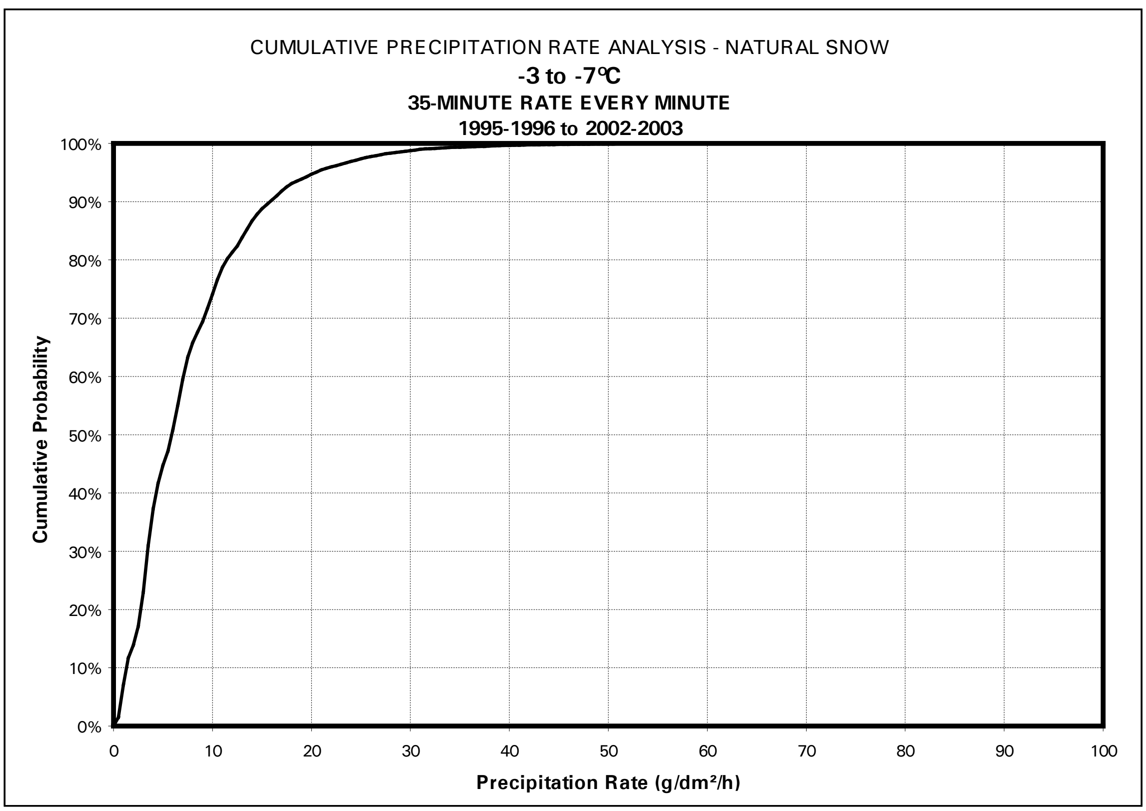

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
0 TO -3°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

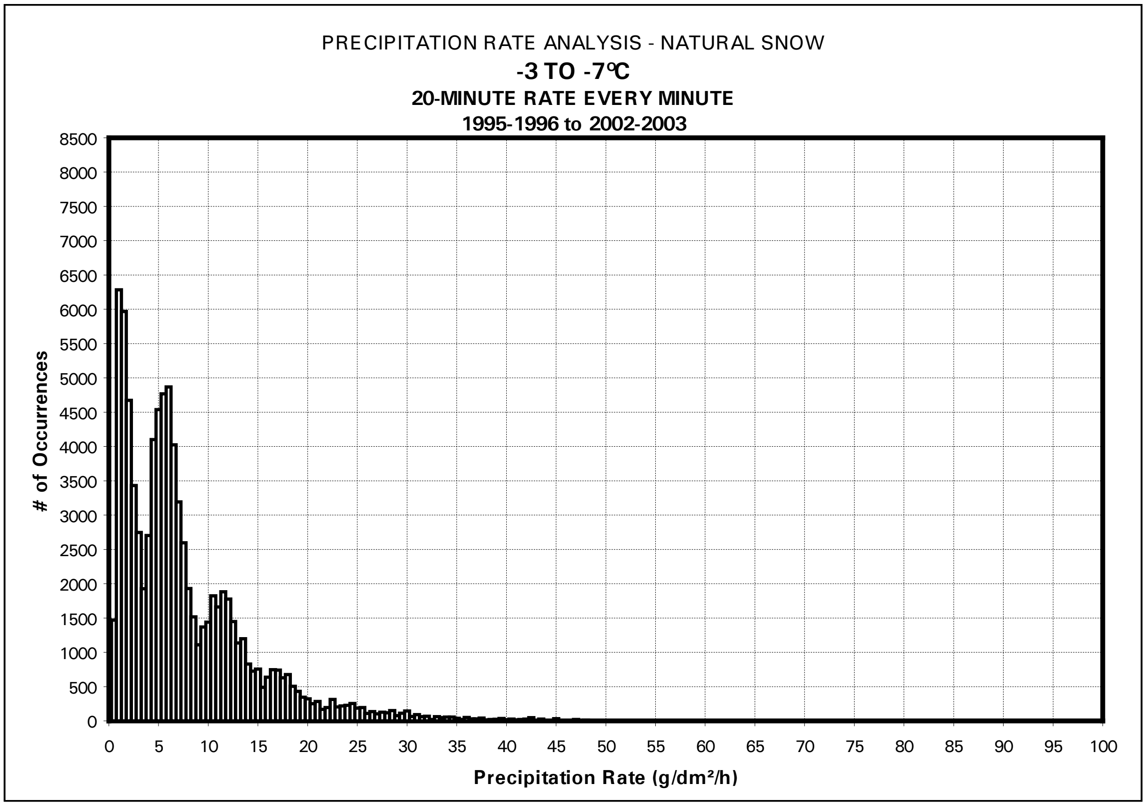

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
0 TO -3°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

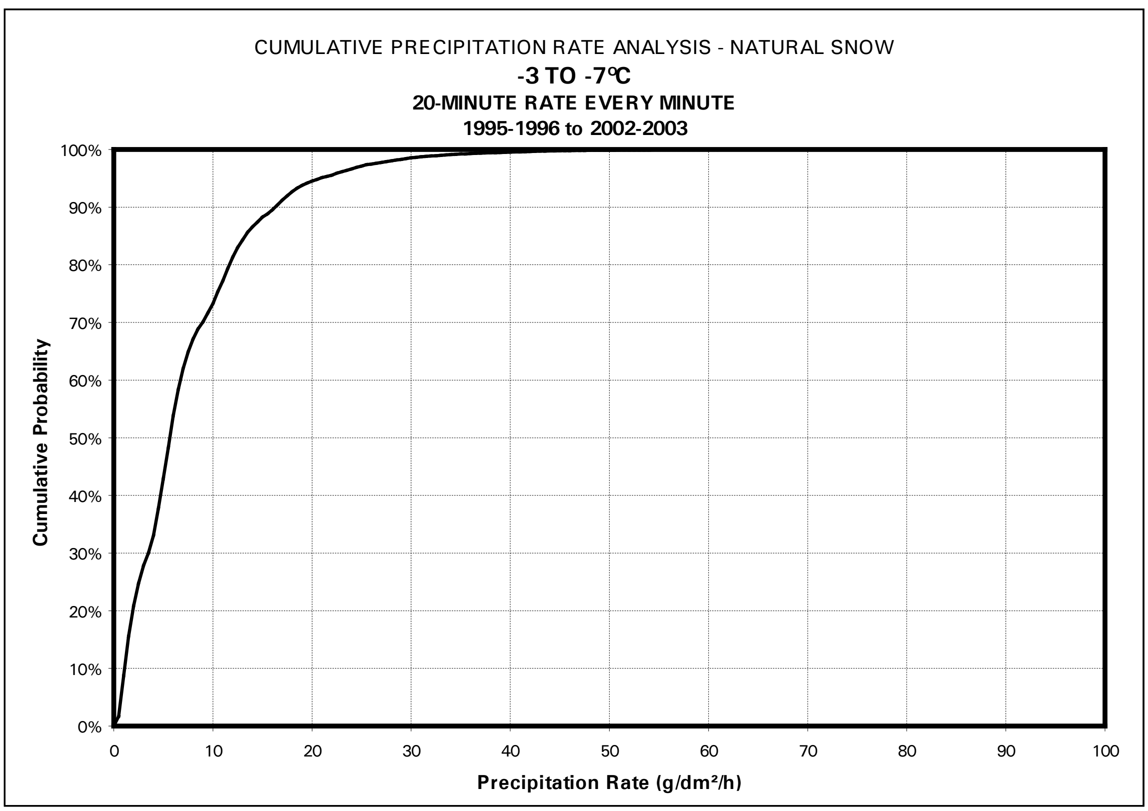

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
0 TO -3°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100

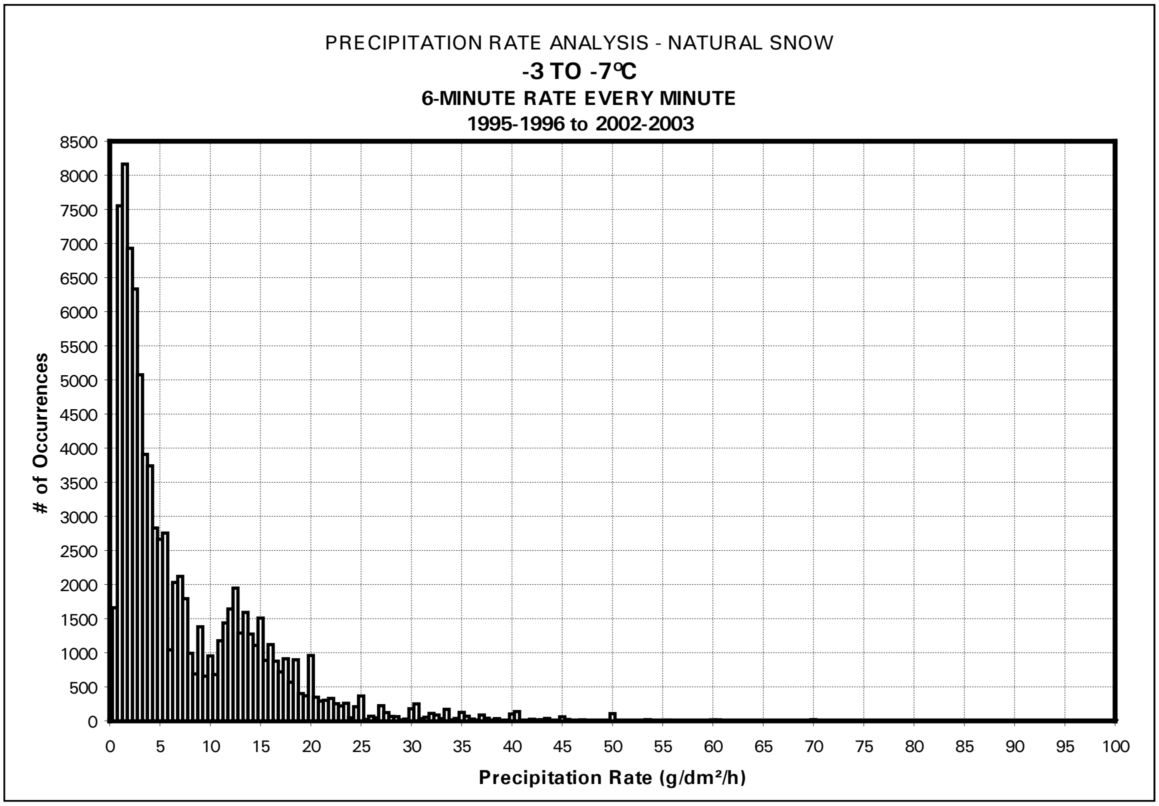

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
0 TO -3°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0
10
20
30
40
50
60
70
80
90
100


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-3 TO -7°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

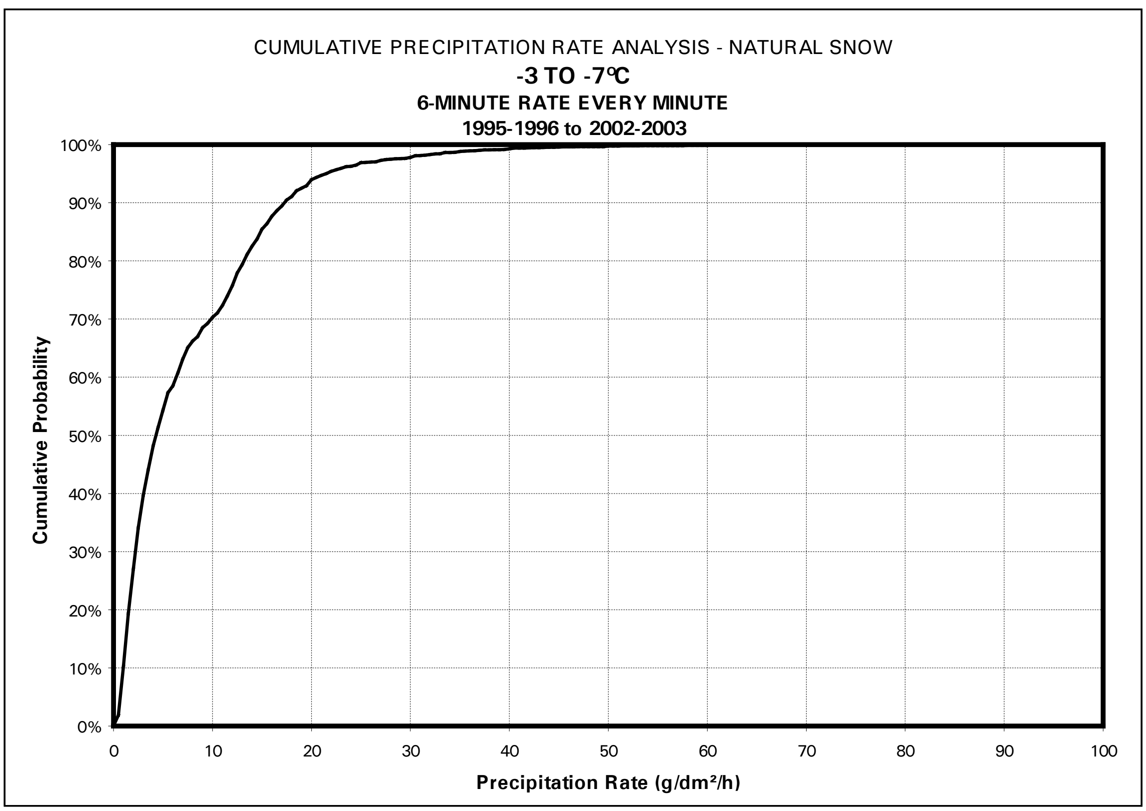

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-3 to -7°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-3 TO -7°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

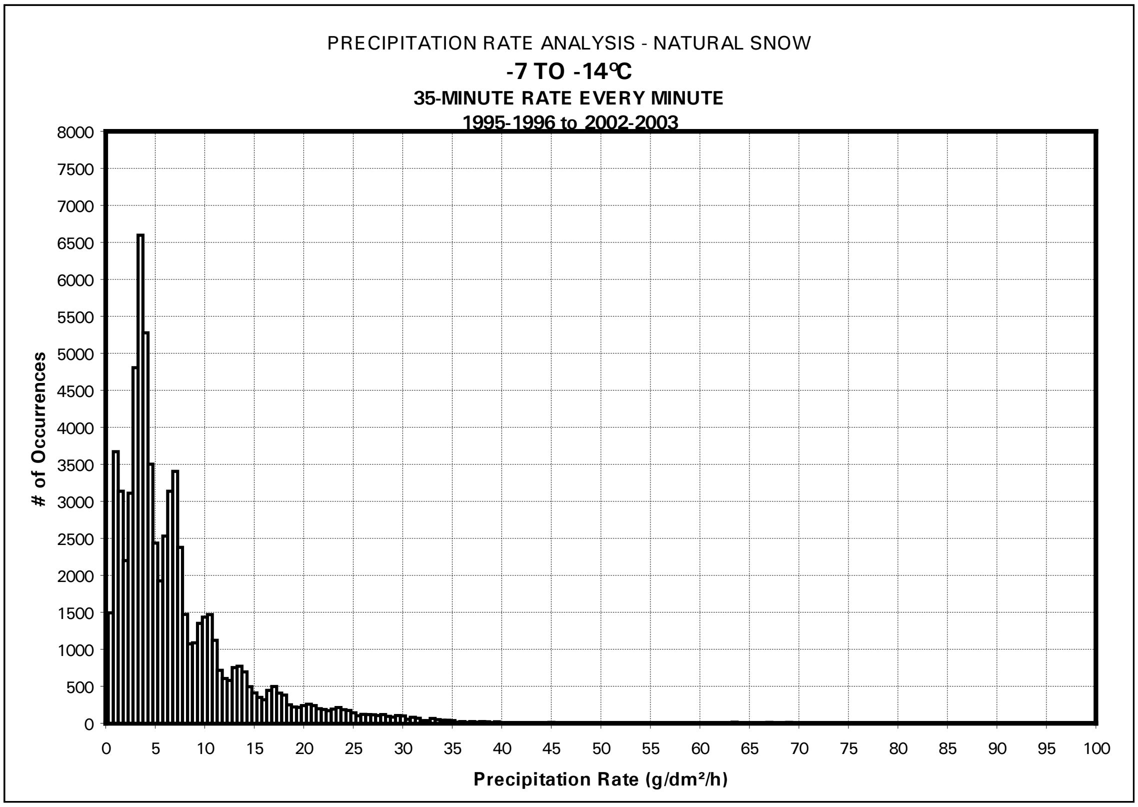

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-3 TO -7°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

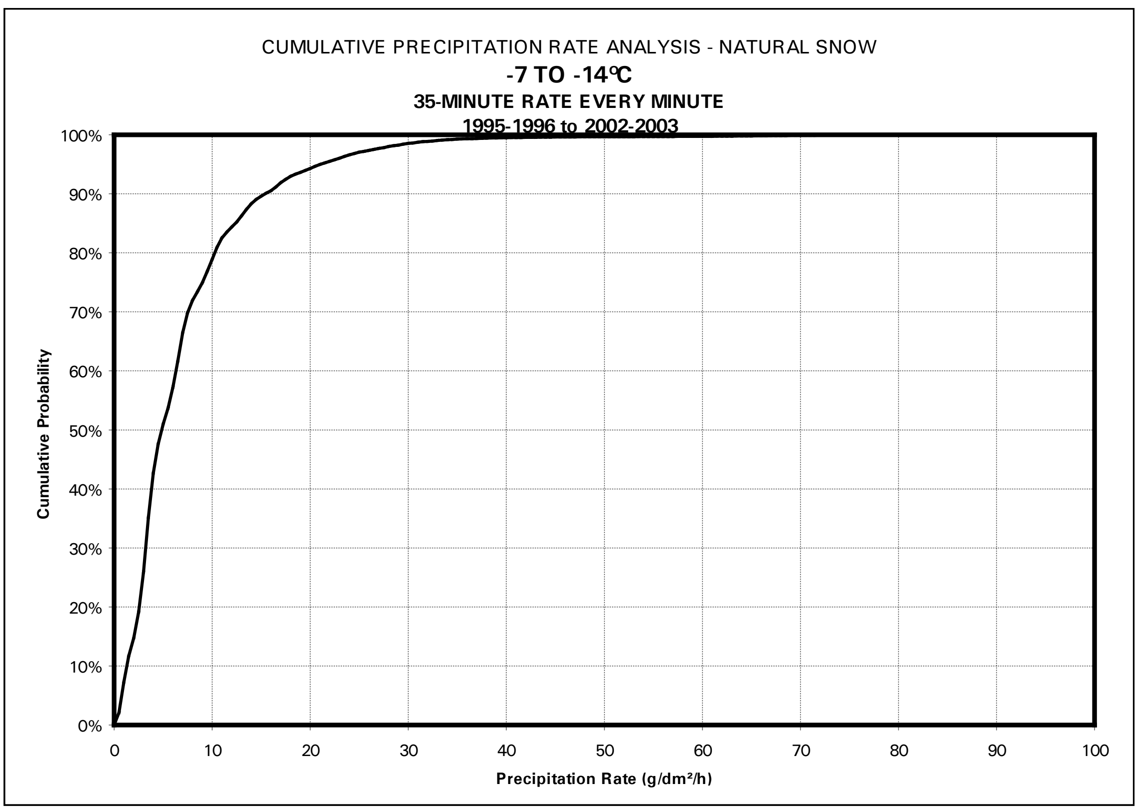


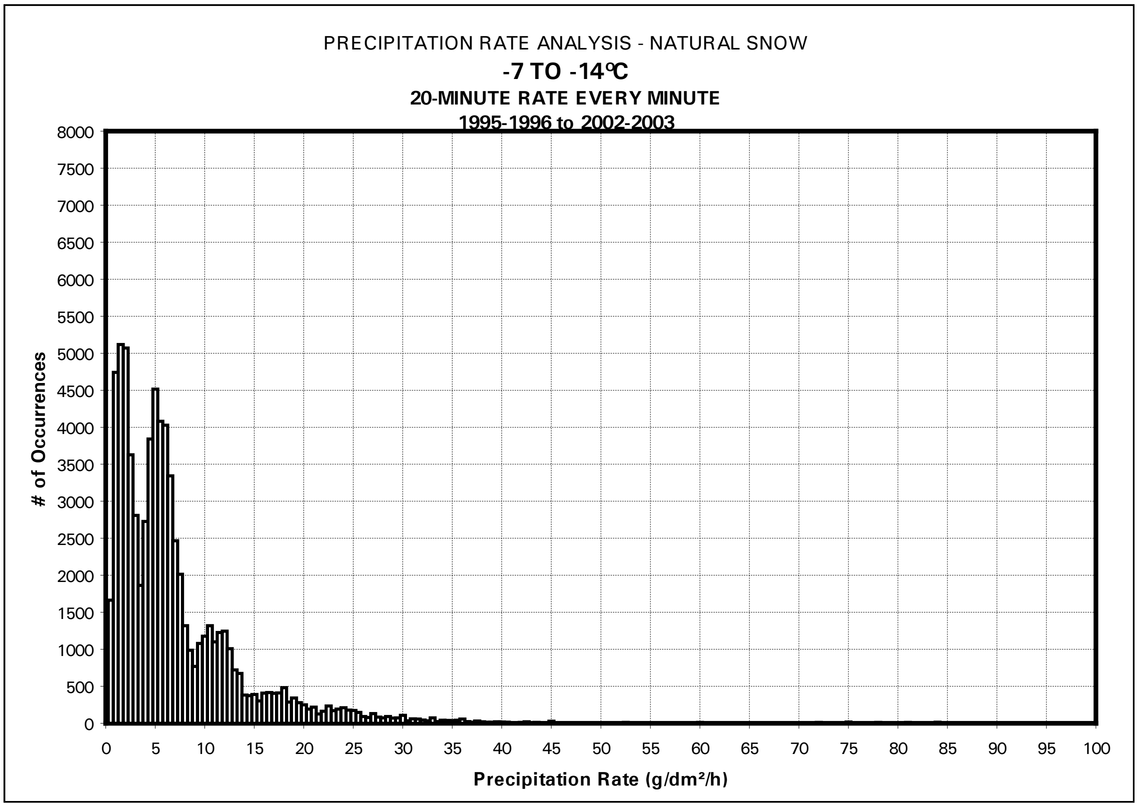
PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-3 TO -7°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Precipitation Rate (g/dm²/h)

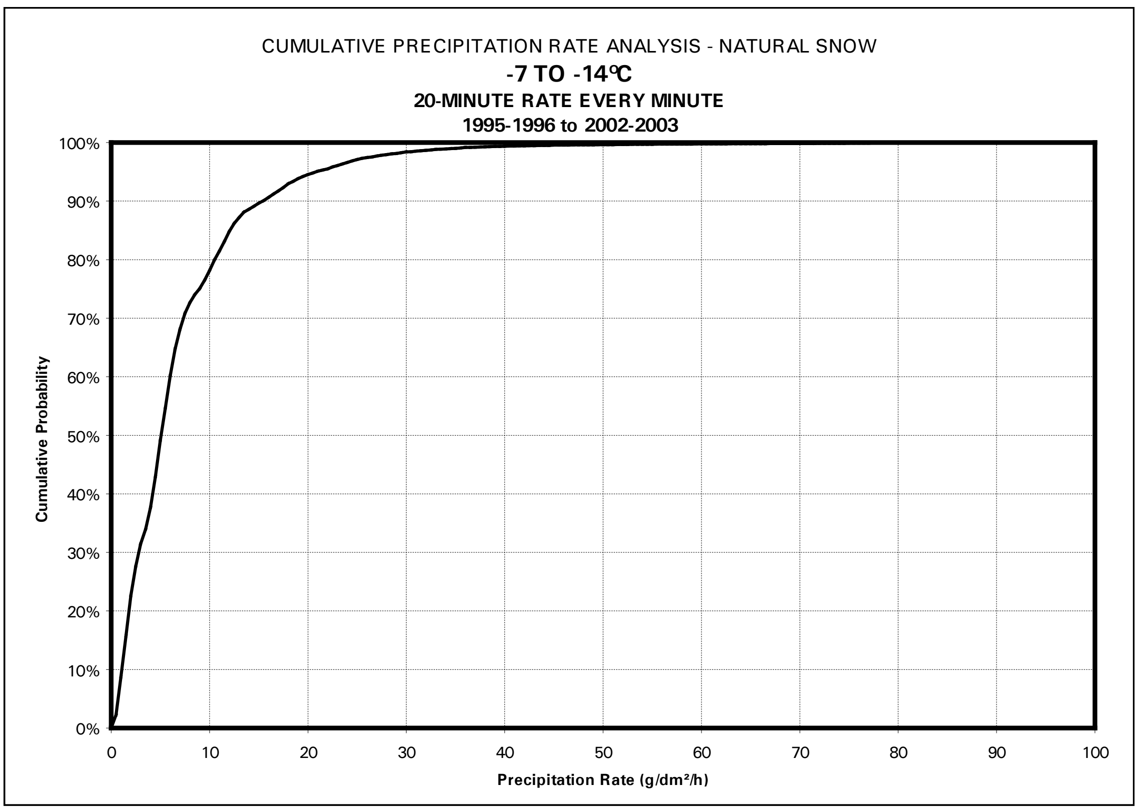


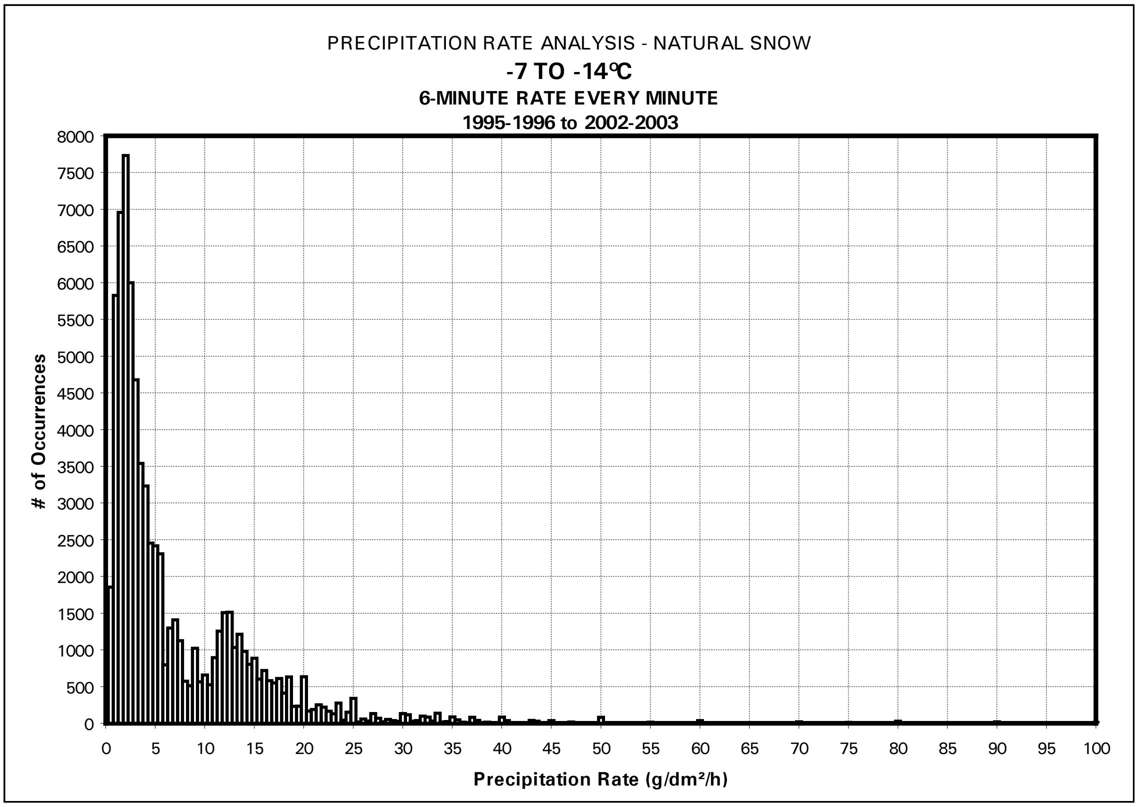
CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-3 TO -7°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
70
80
90
100
Precipitation Rate (g/dm²/h)

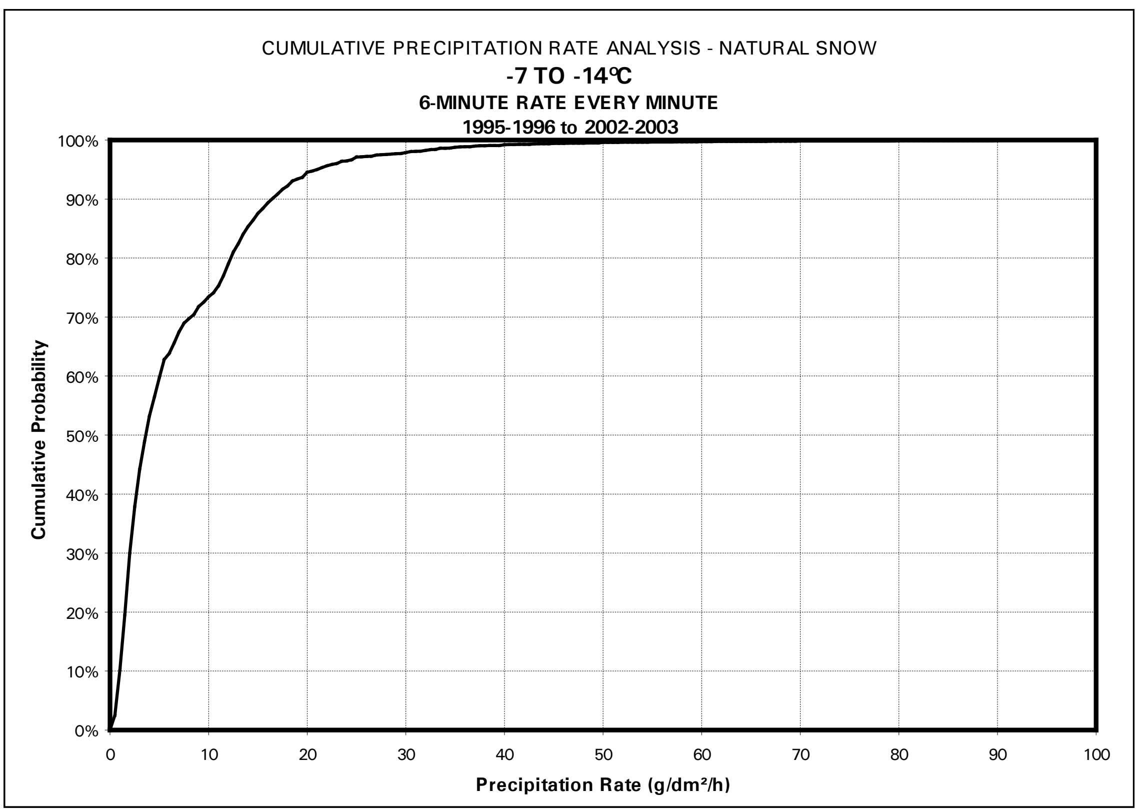

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)

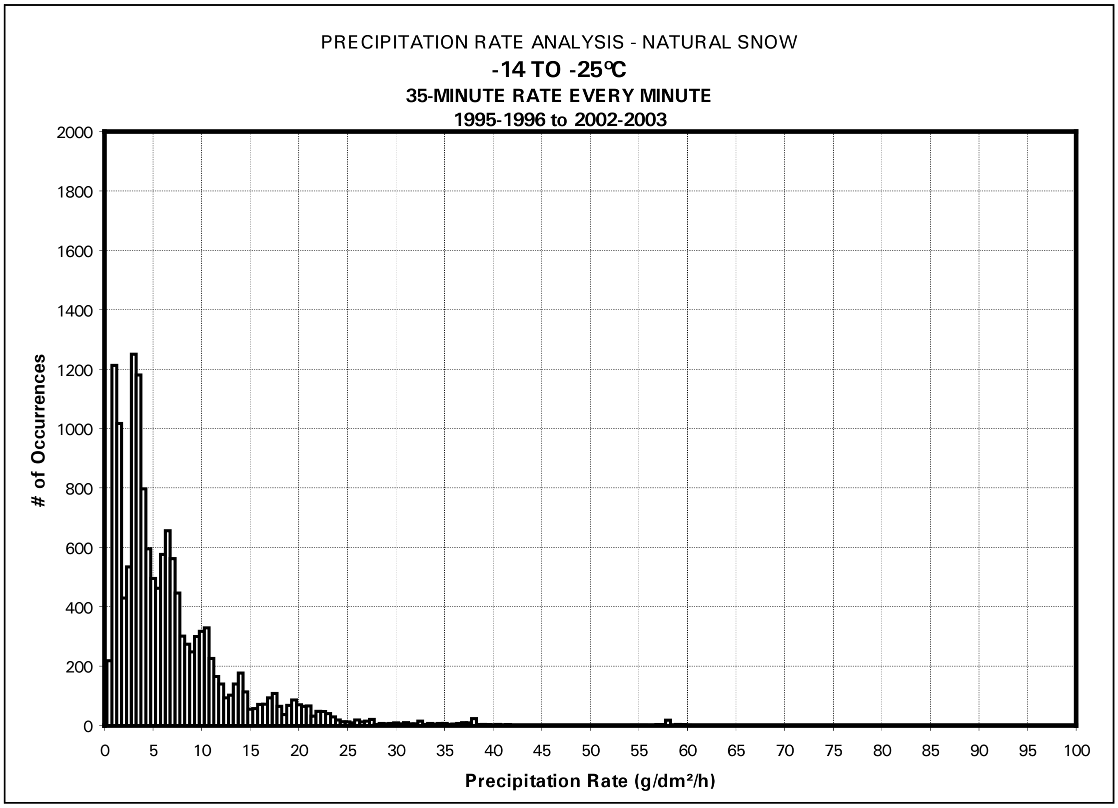

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)

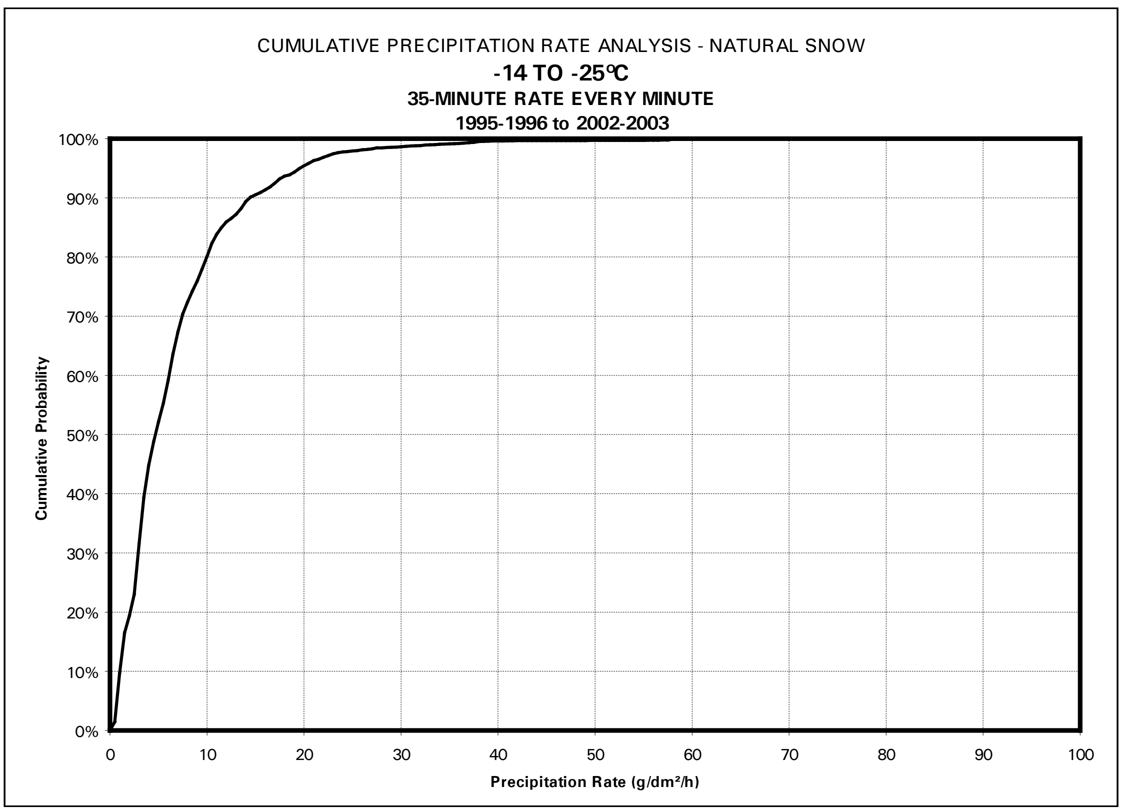

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Precipitation Rate (g/dm²/h)

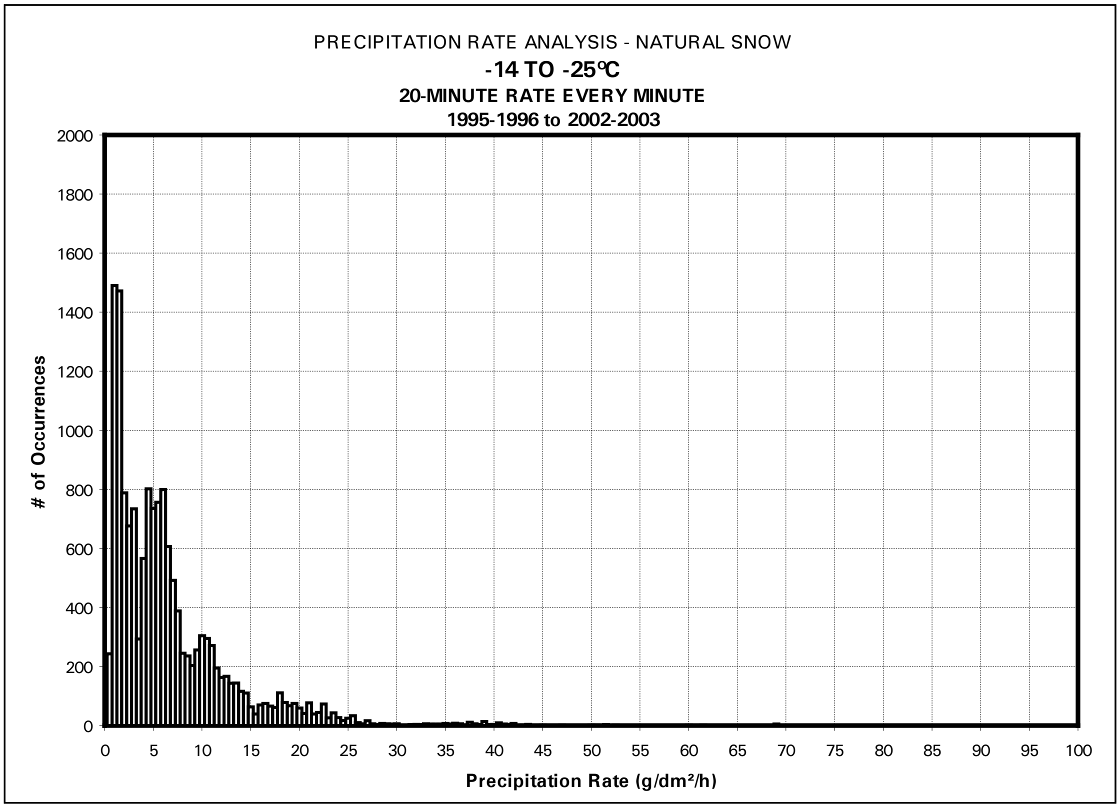

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
10
20
30
40
50
60
70
80
90
100
Precipitation Rate (g/dm²/h)

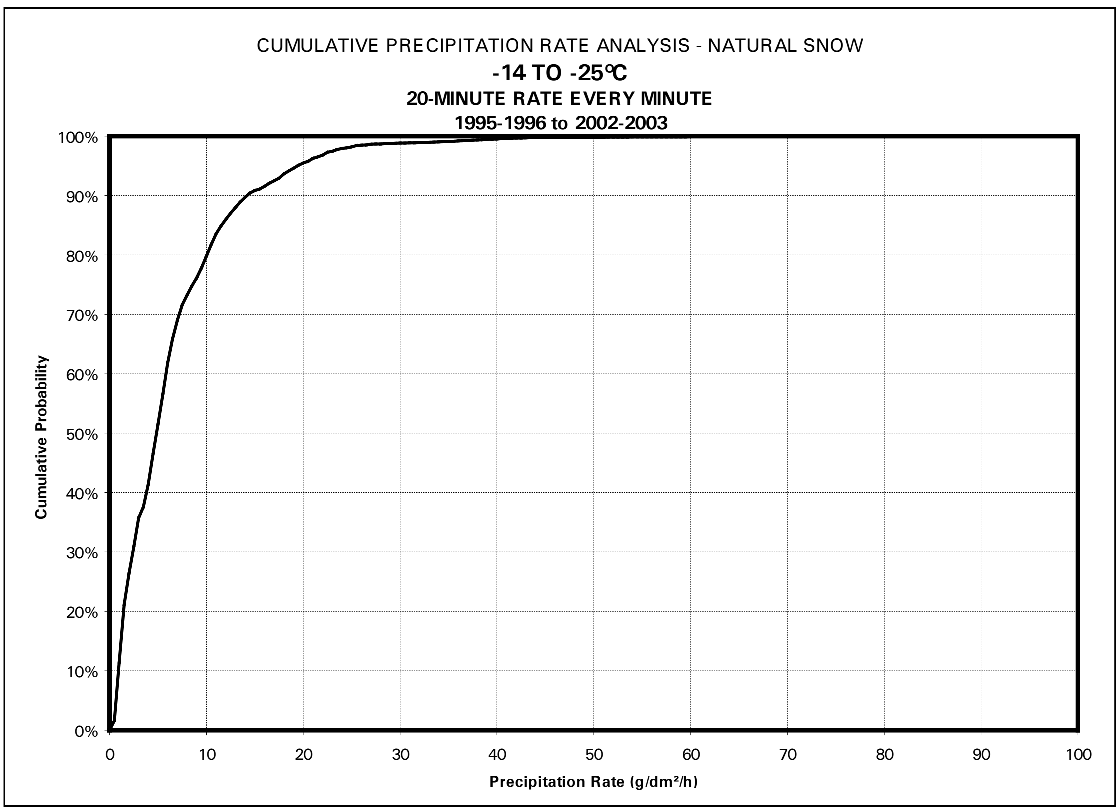

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)

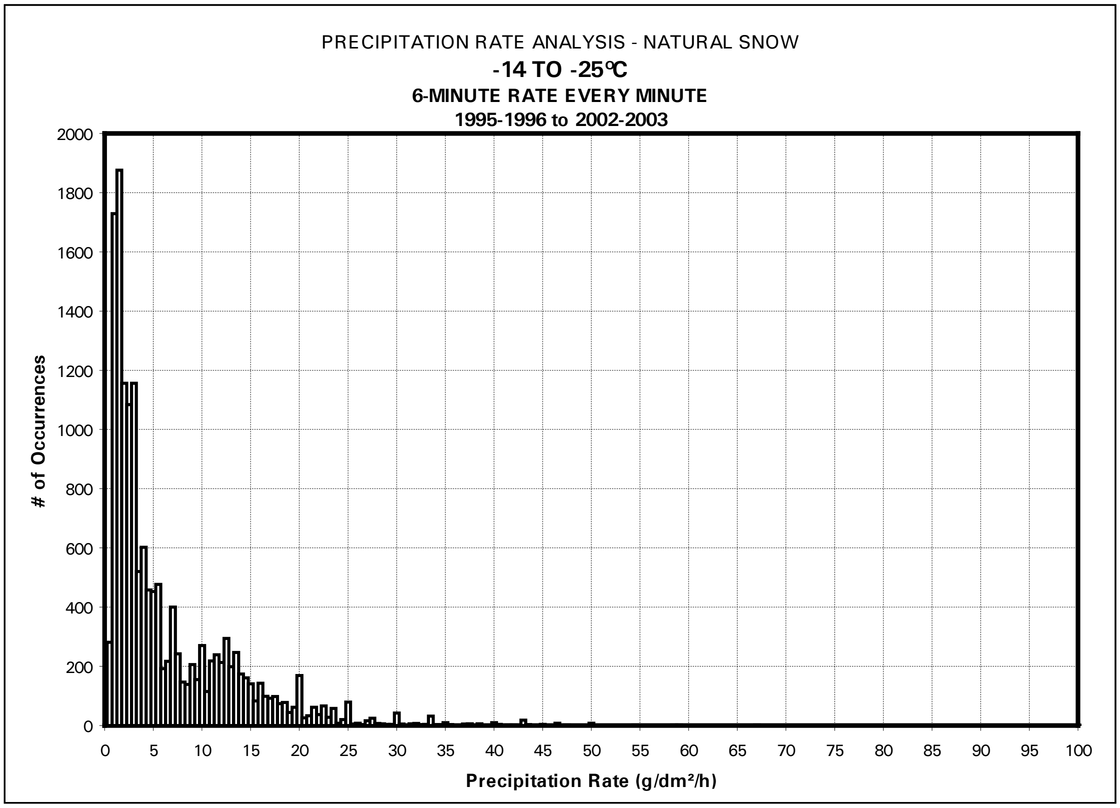

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)

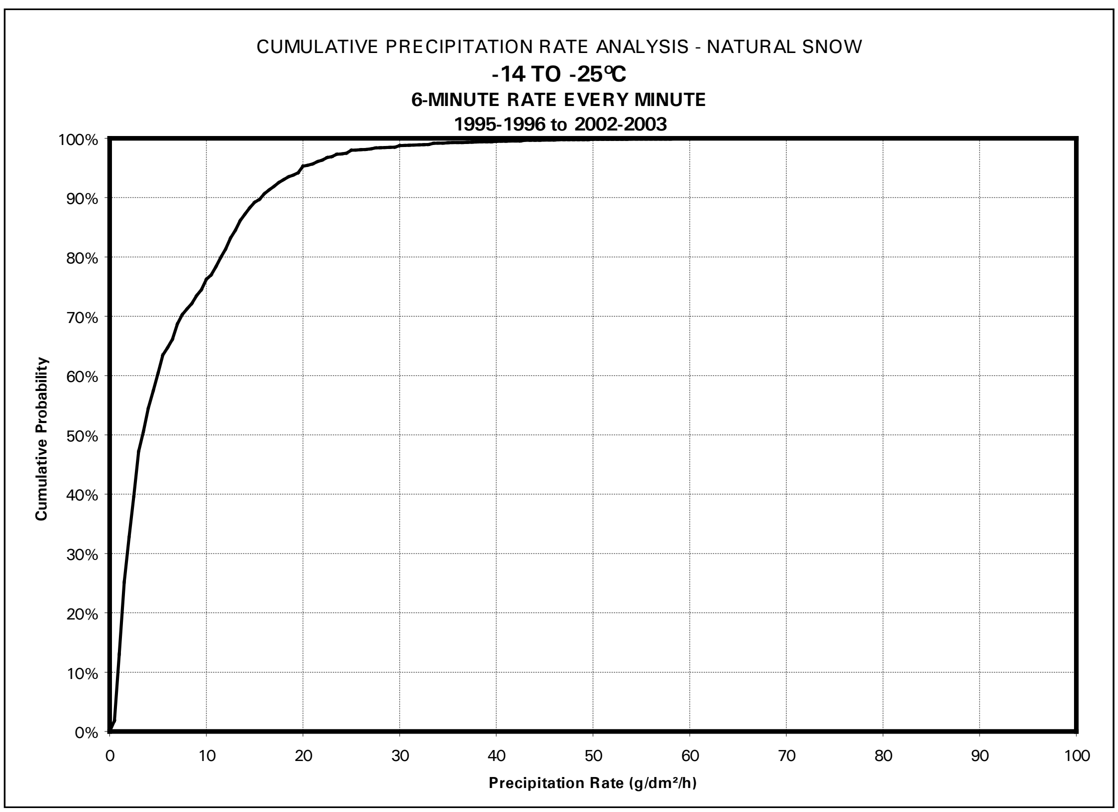

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)

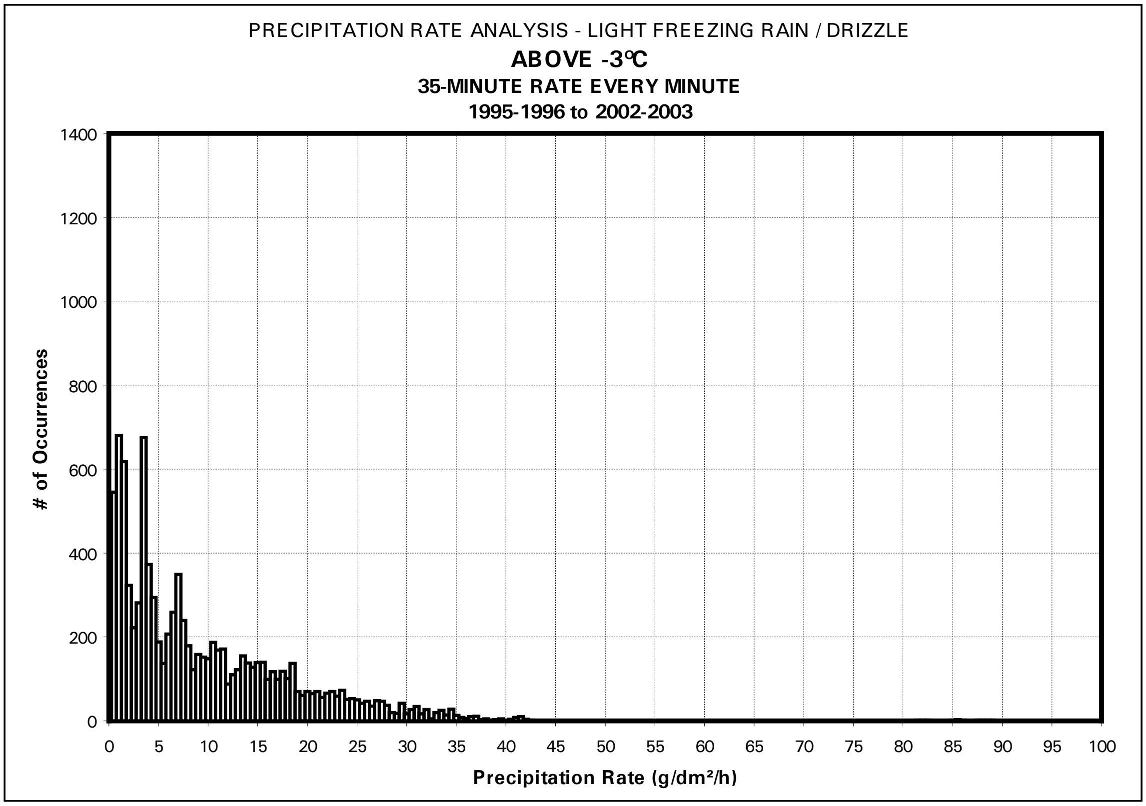

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)

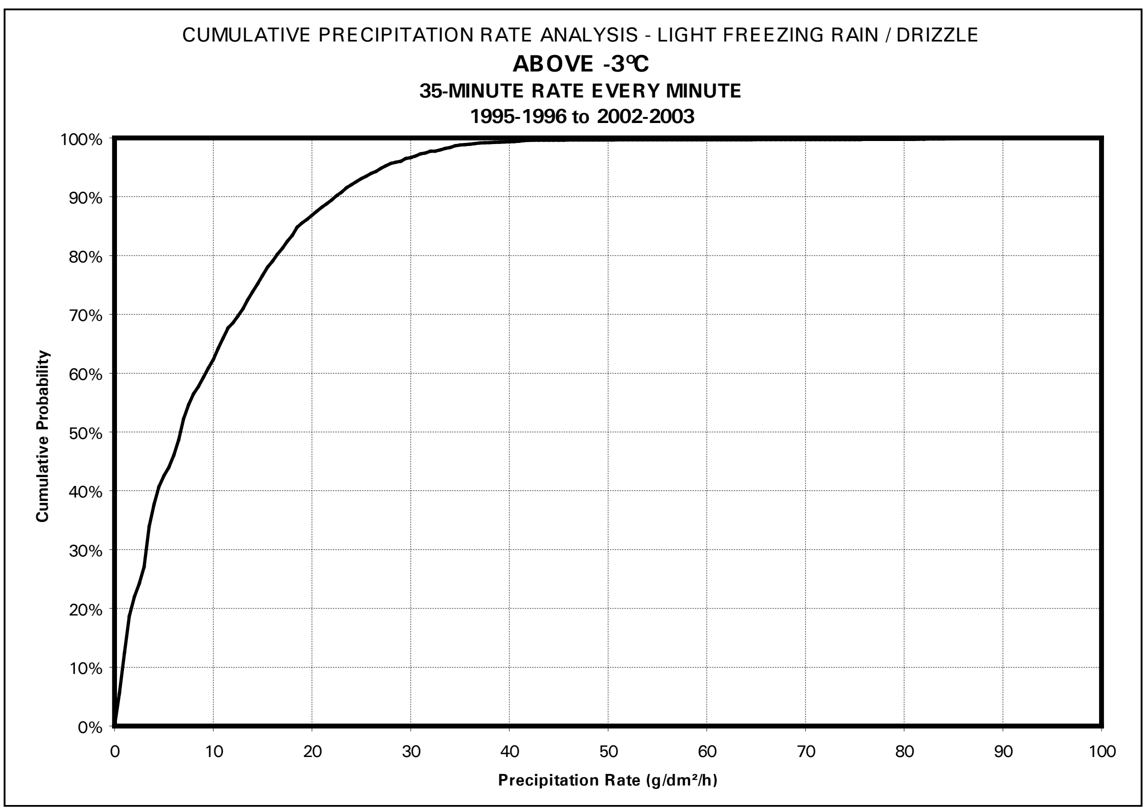

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

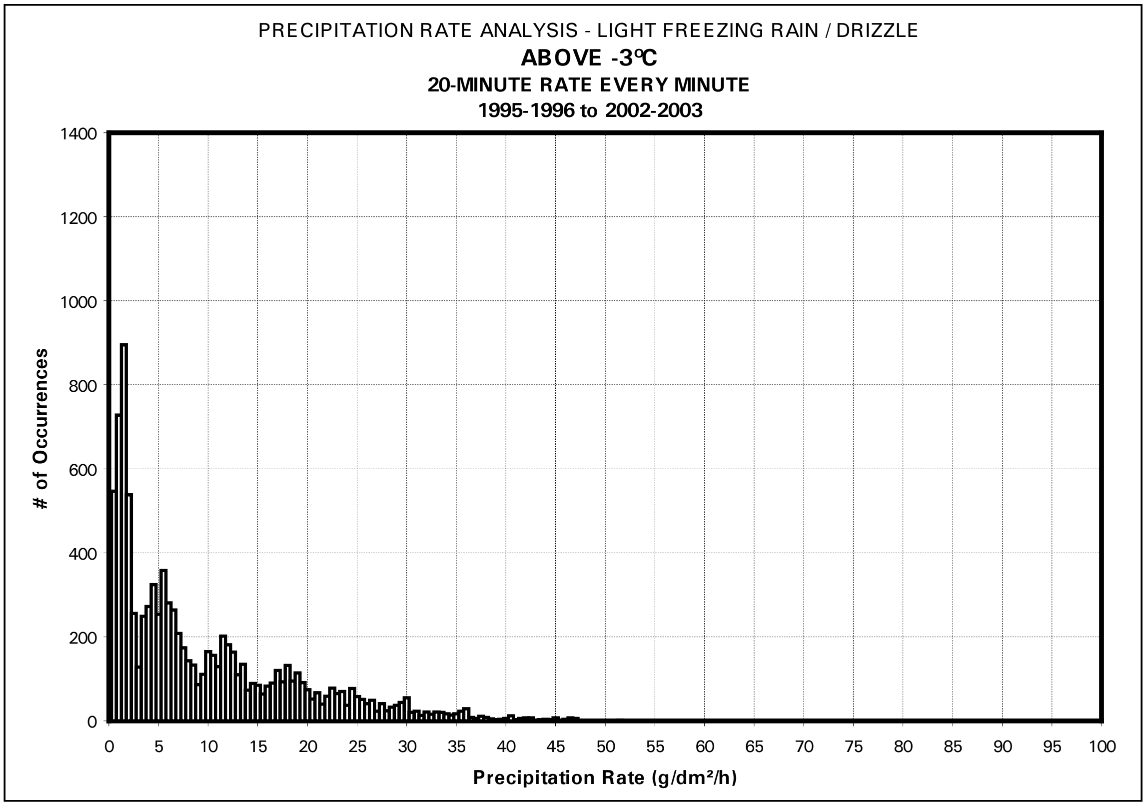

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

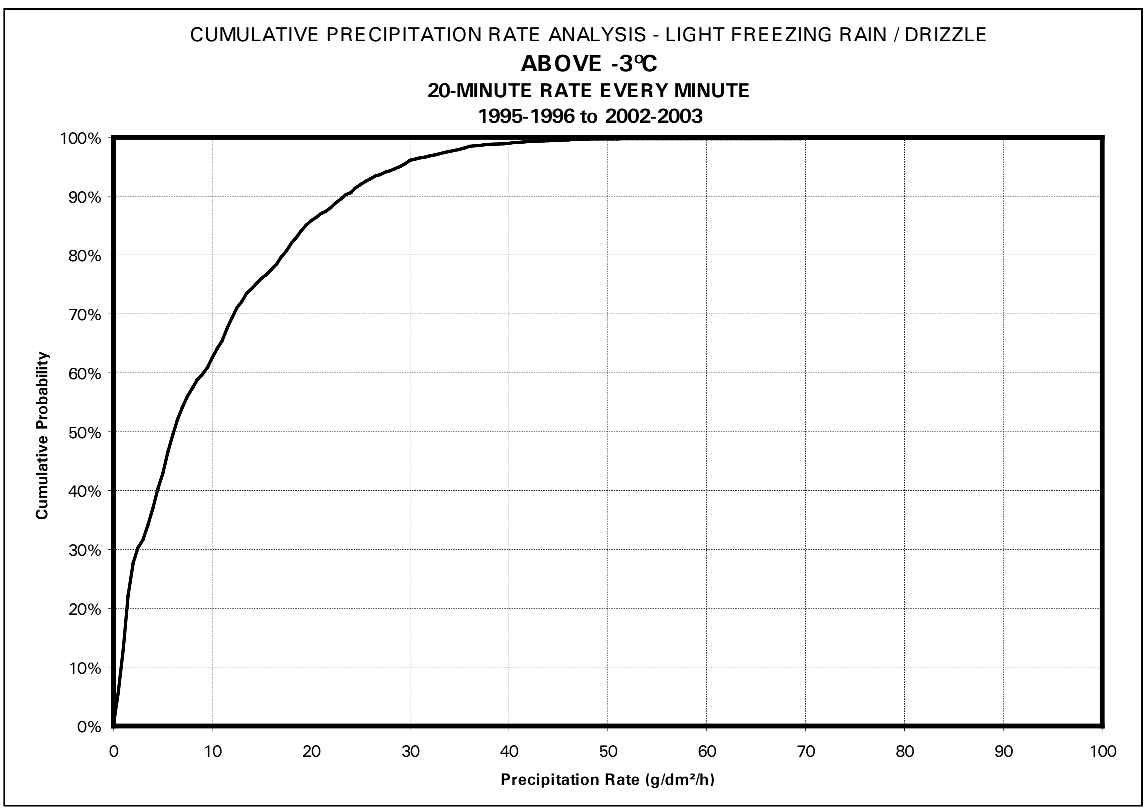

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)

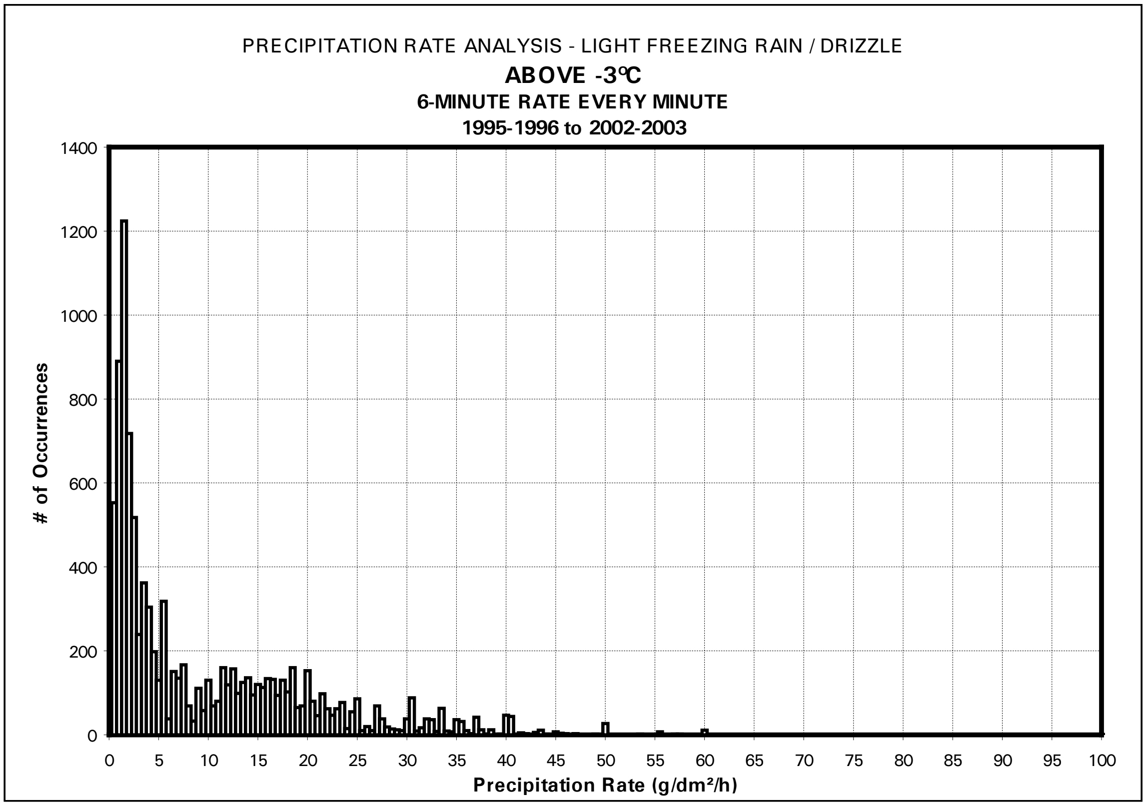

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)

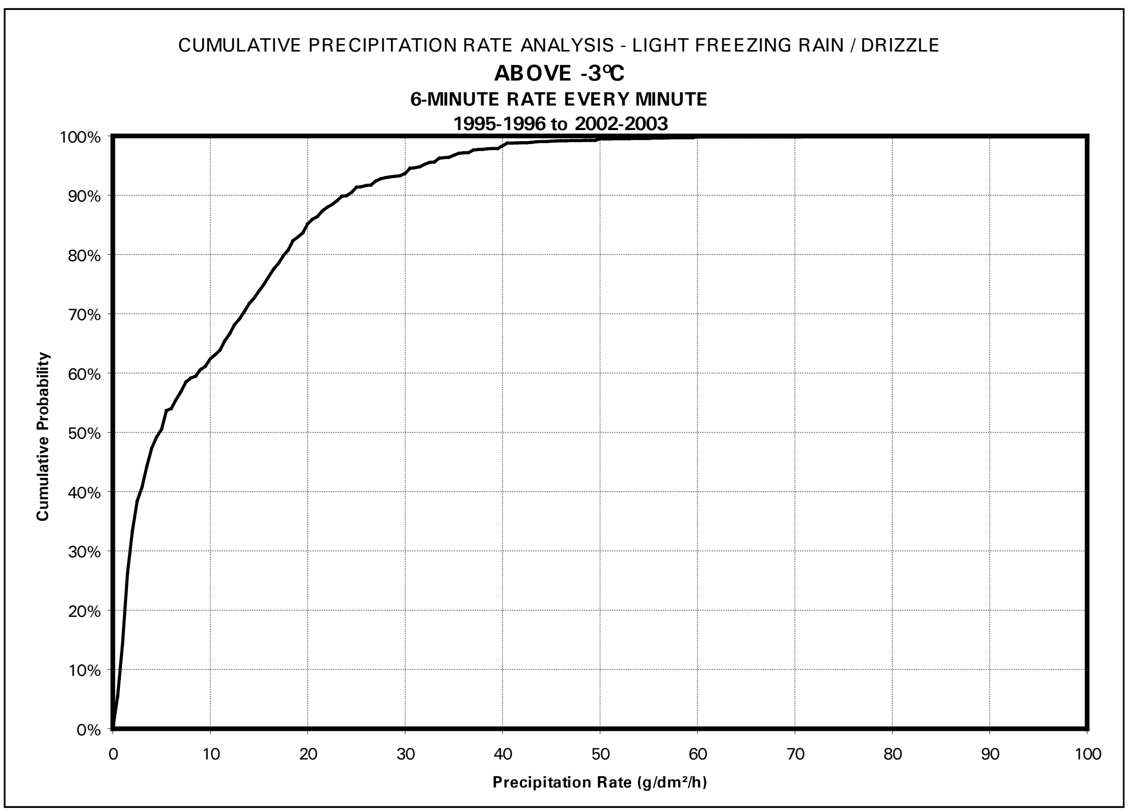

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
200
400
600
800
1000
1200
1400
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

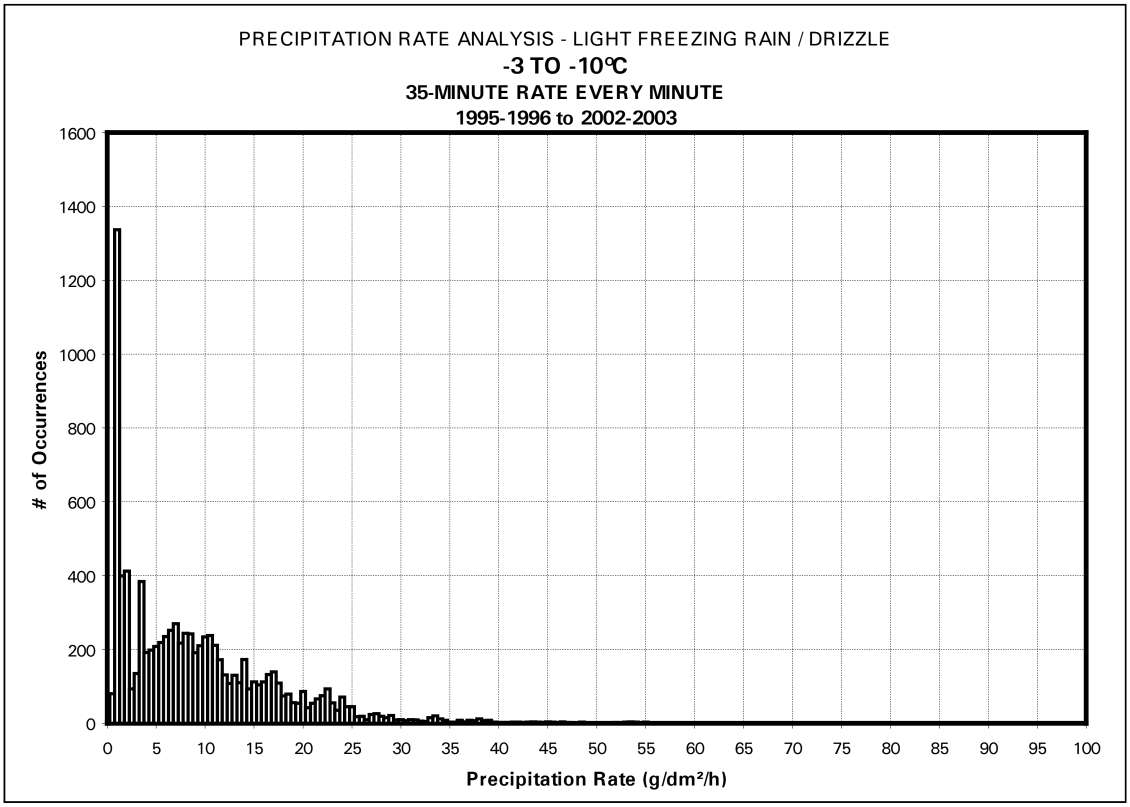

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

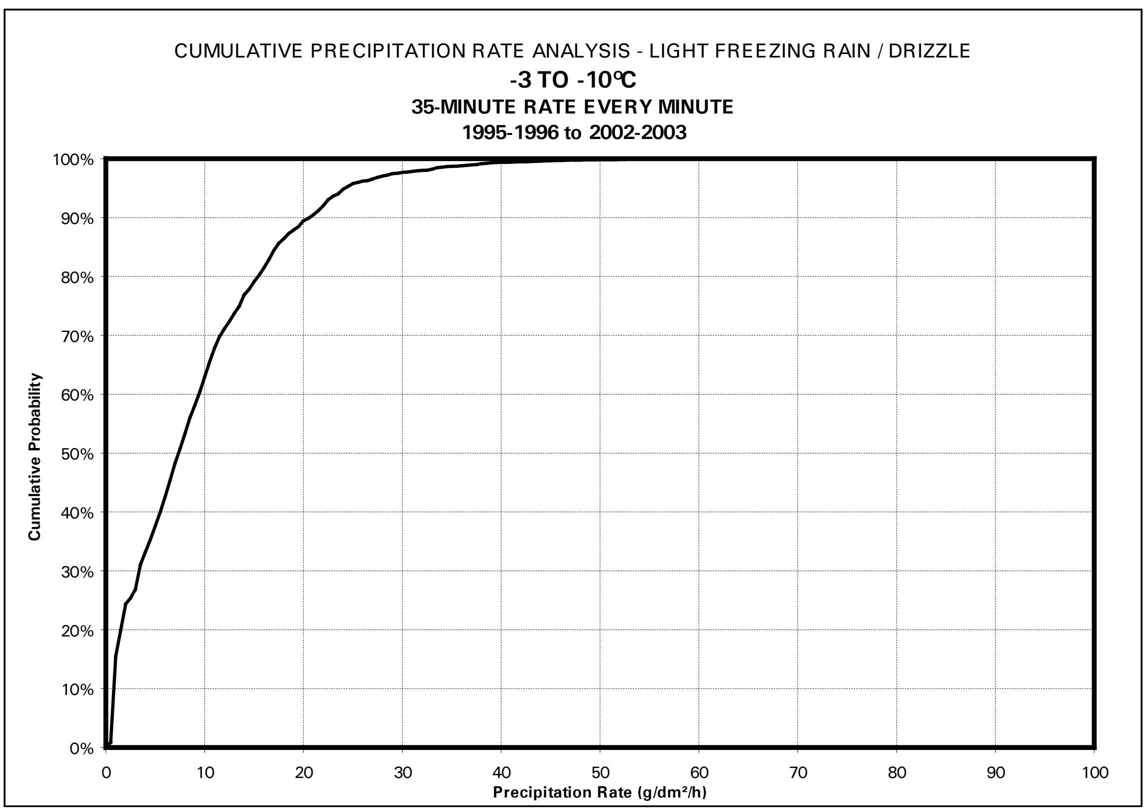

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
200
400
600
800
1000
1200
1400
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

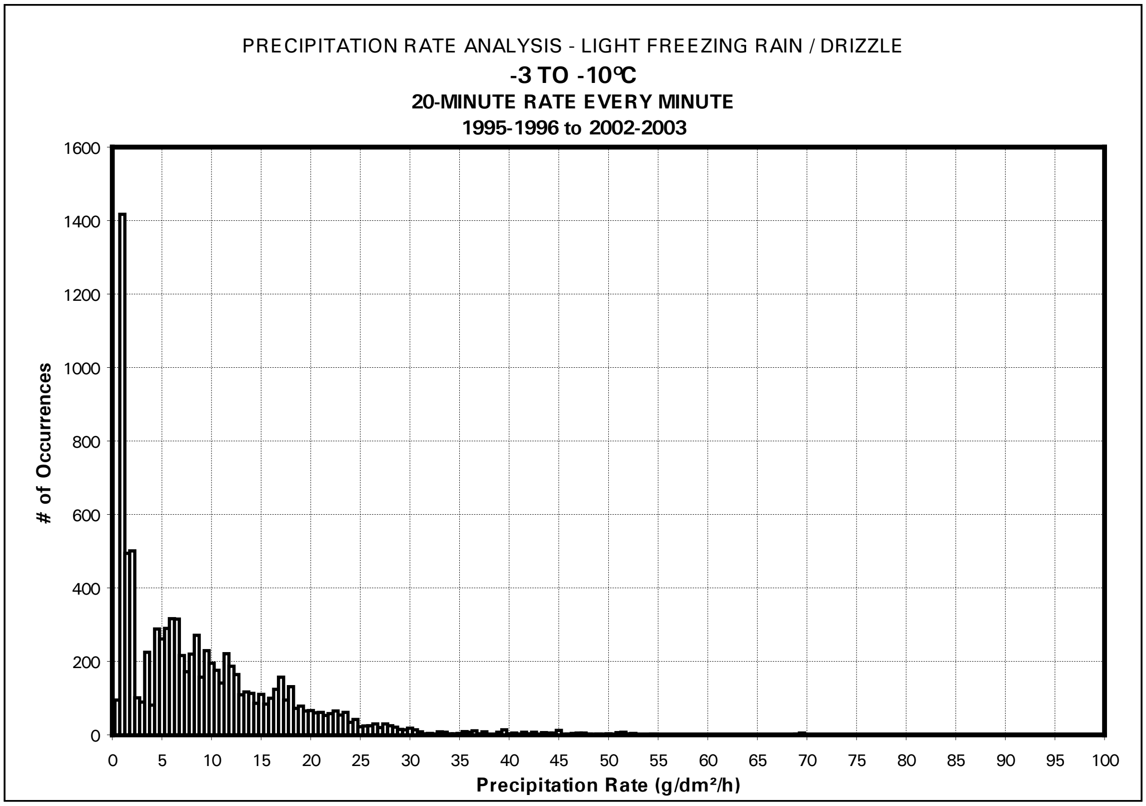

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

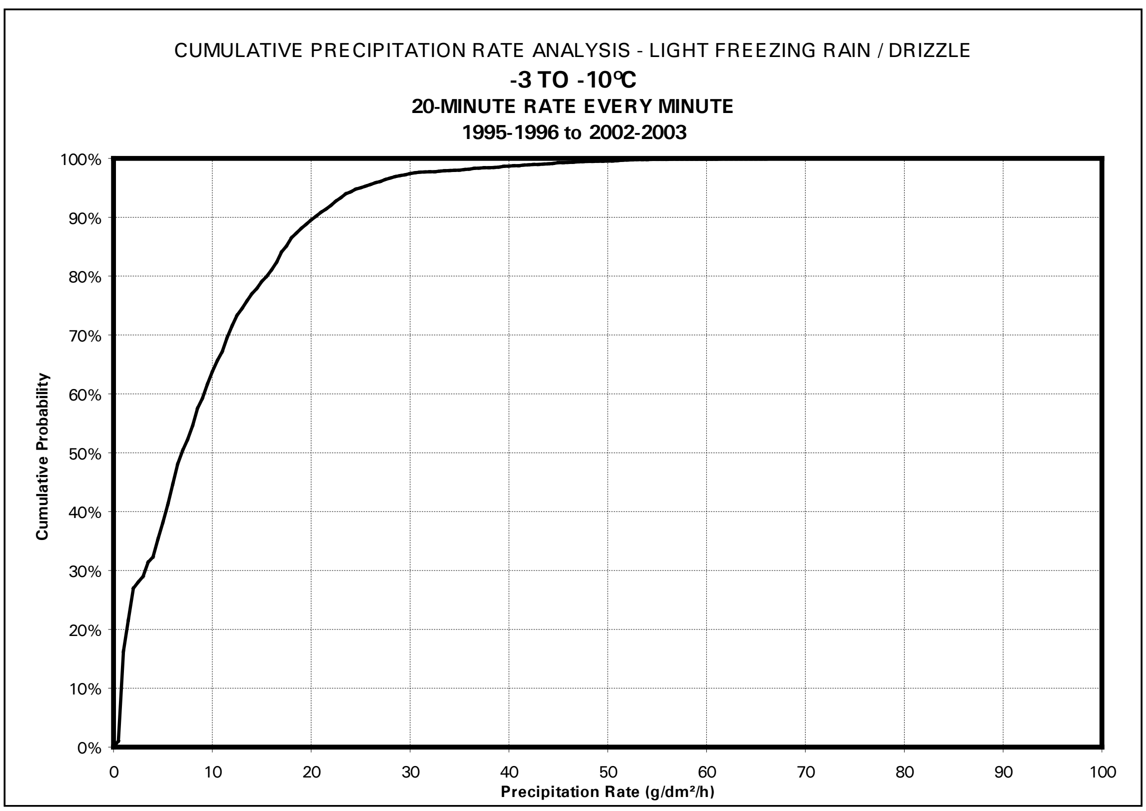

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
200
400
600
800
1000
1200
1400
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Precipitation Rate (g/dm²/h)

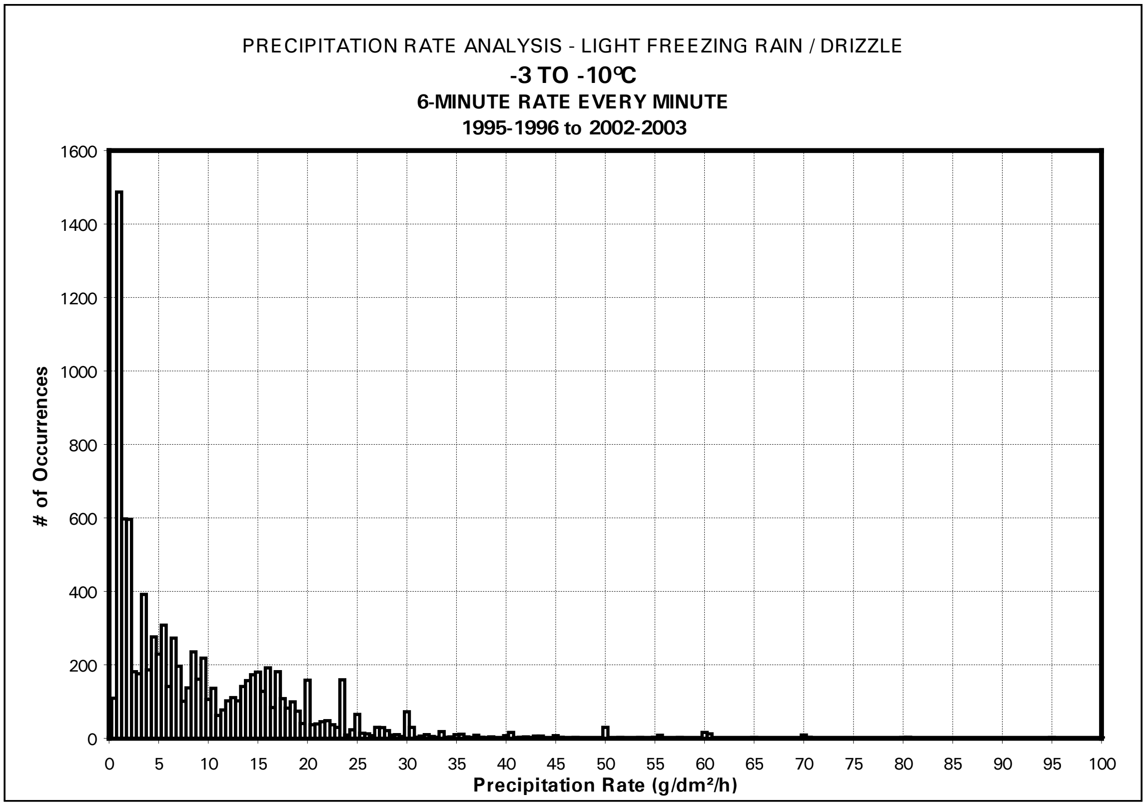

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
ABOVE -3°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0
10
20
30
40
50
60
70
80
90
100
Precipitation Rate (g/dm²/h)

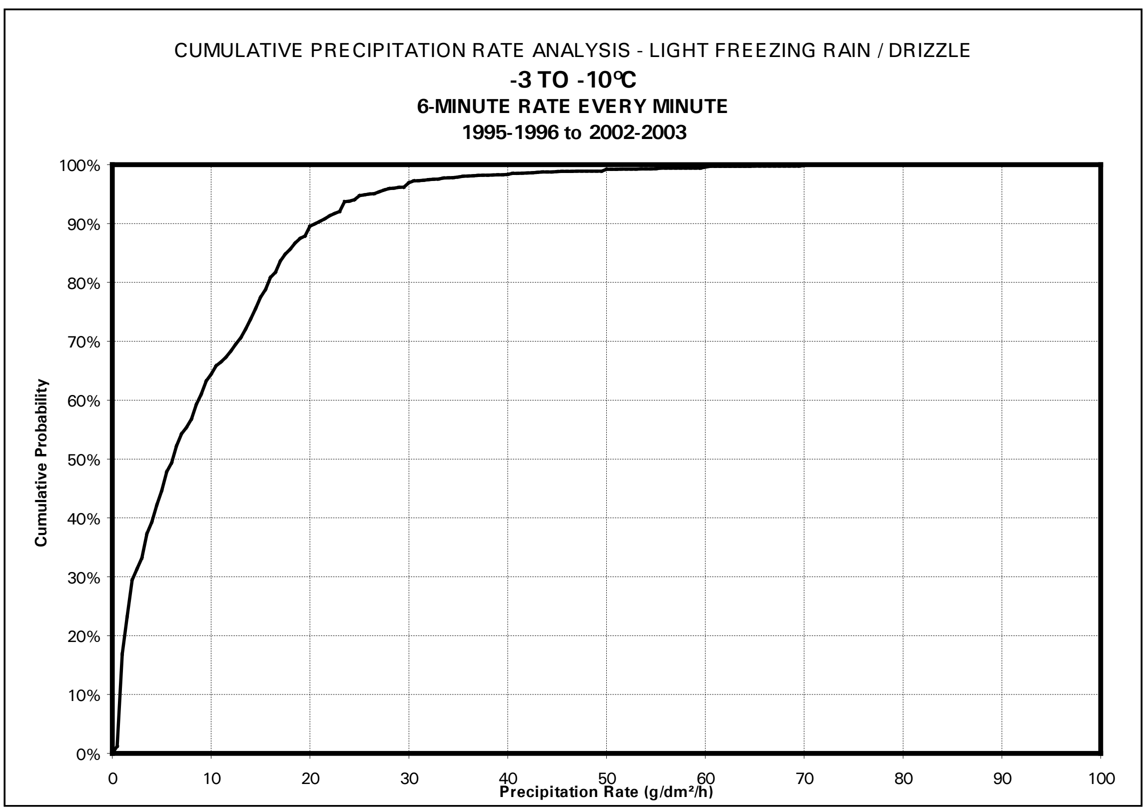

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)

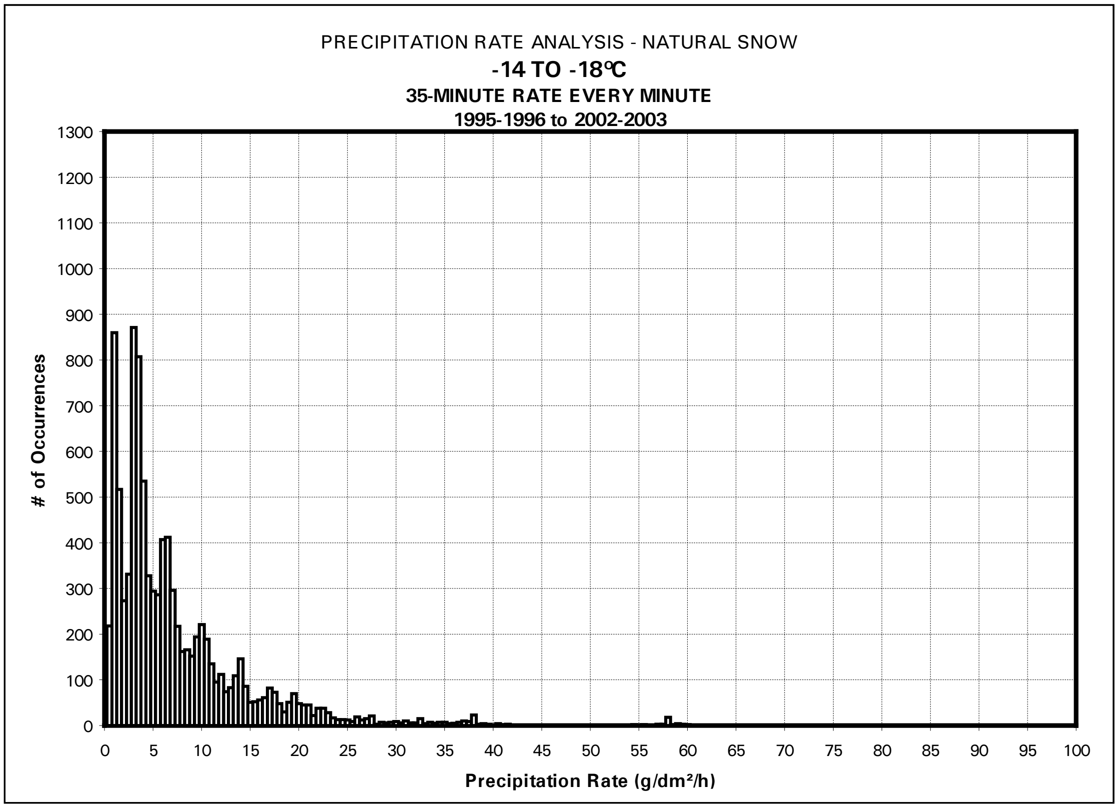

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

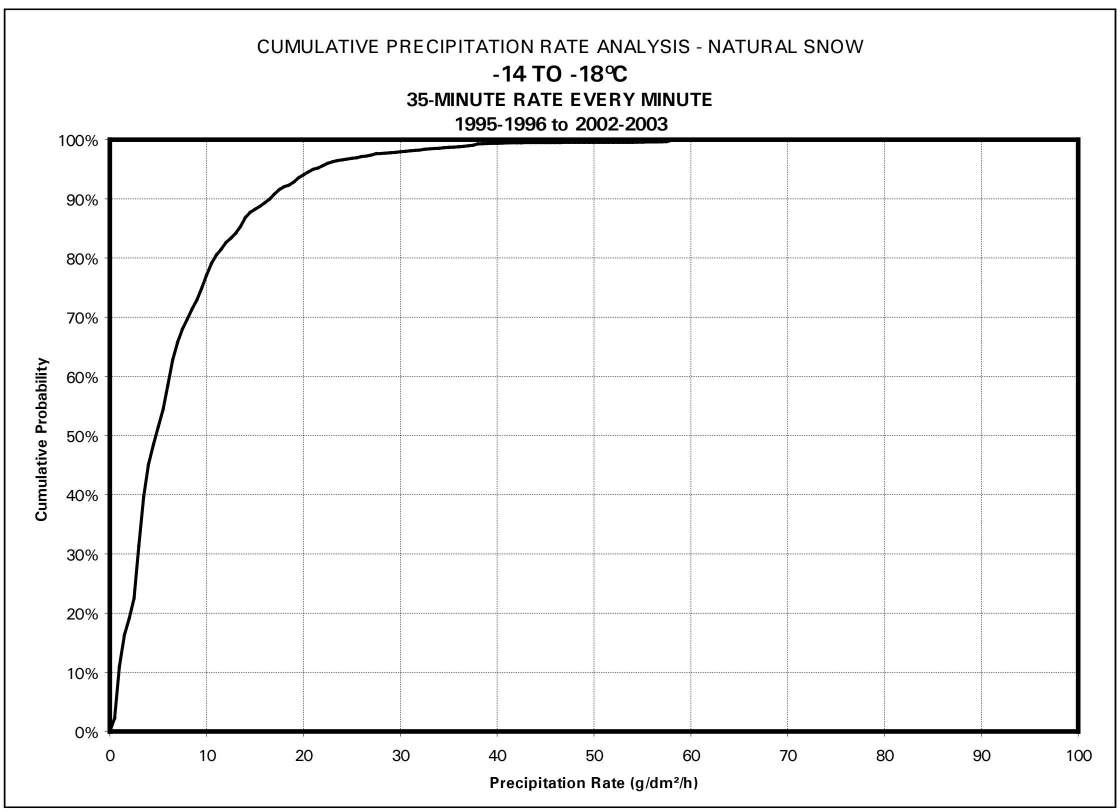

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)

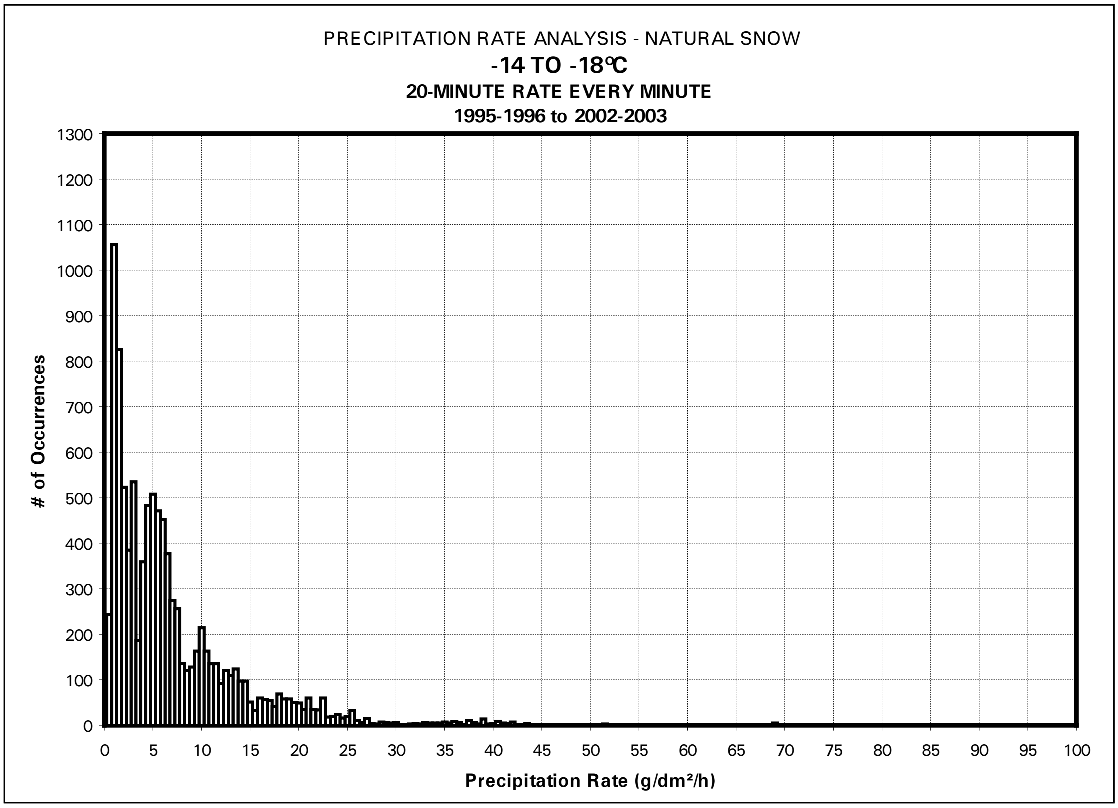

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)

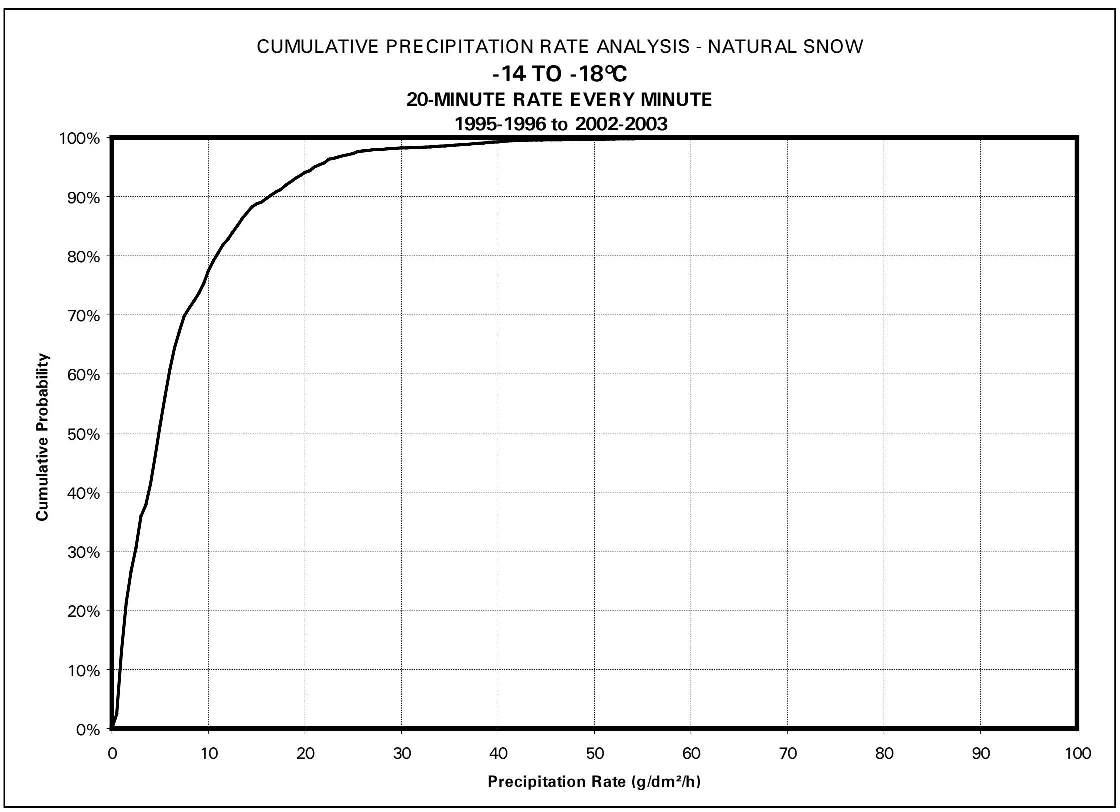


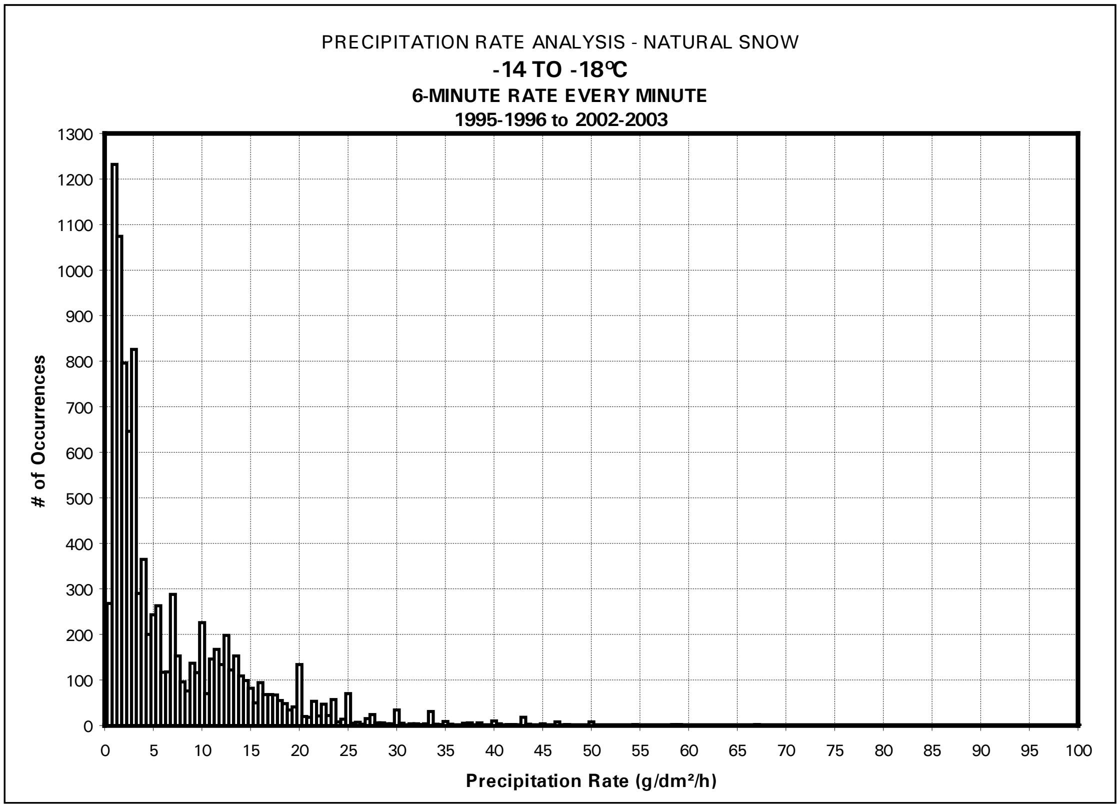
PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)

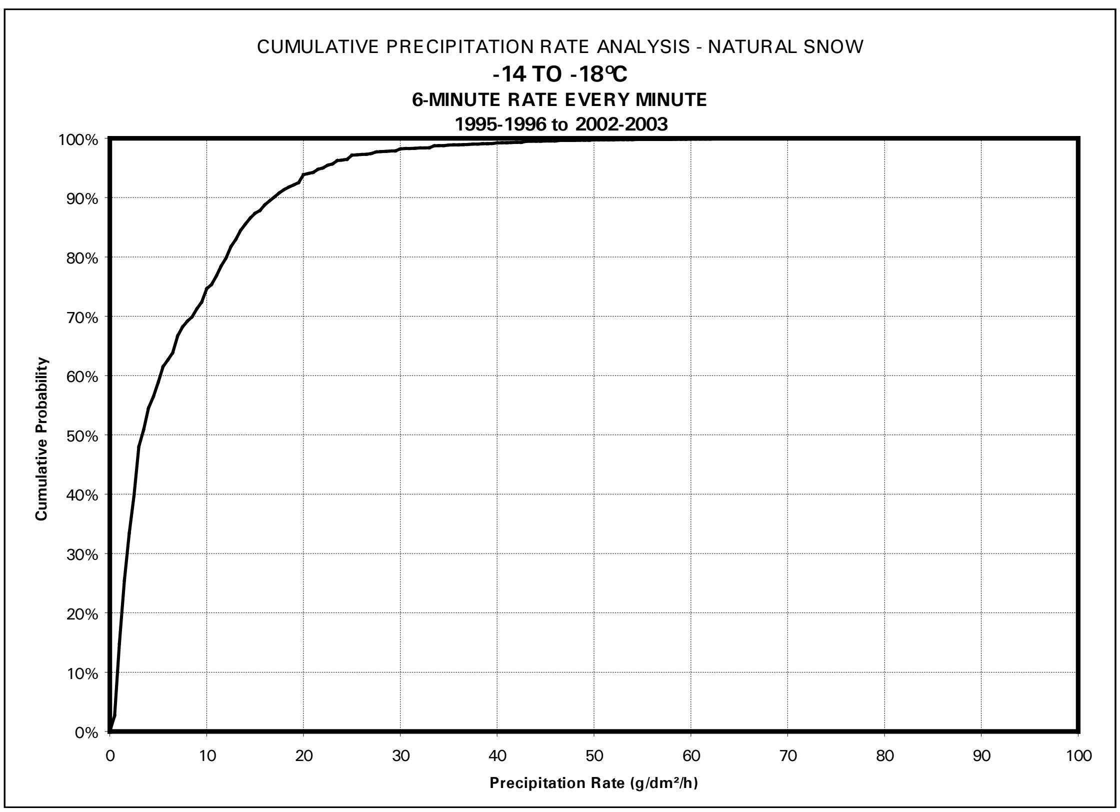


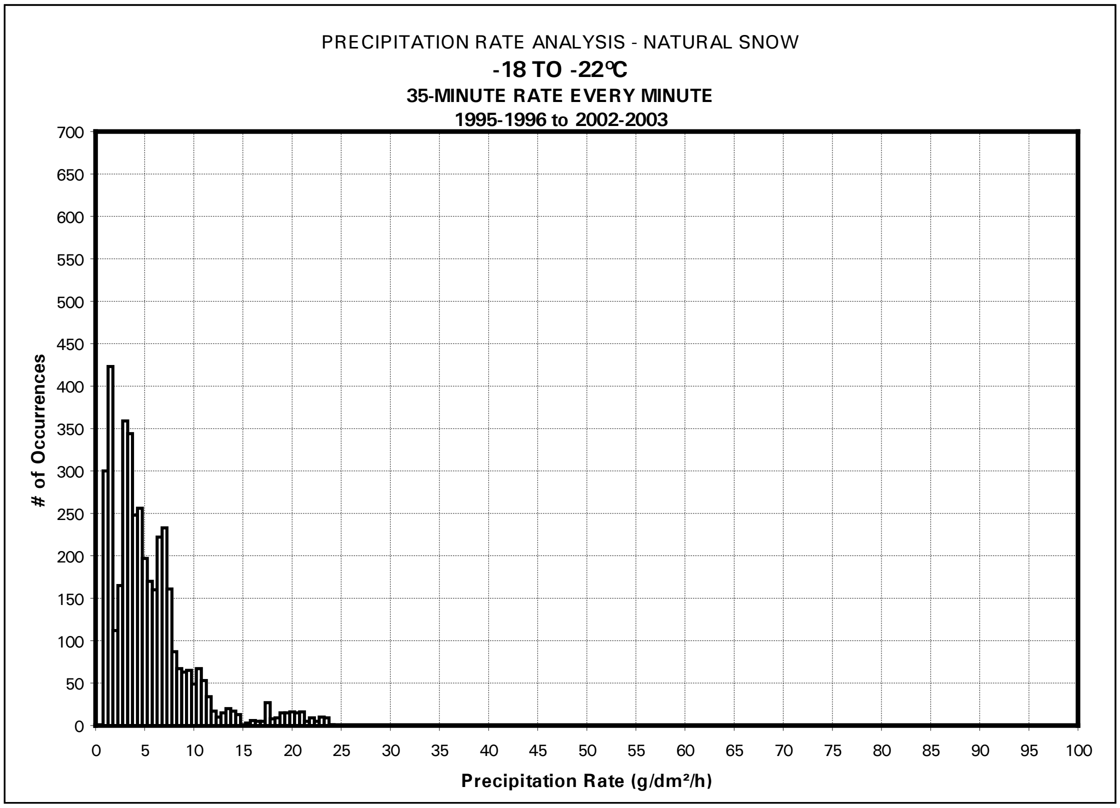
CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)

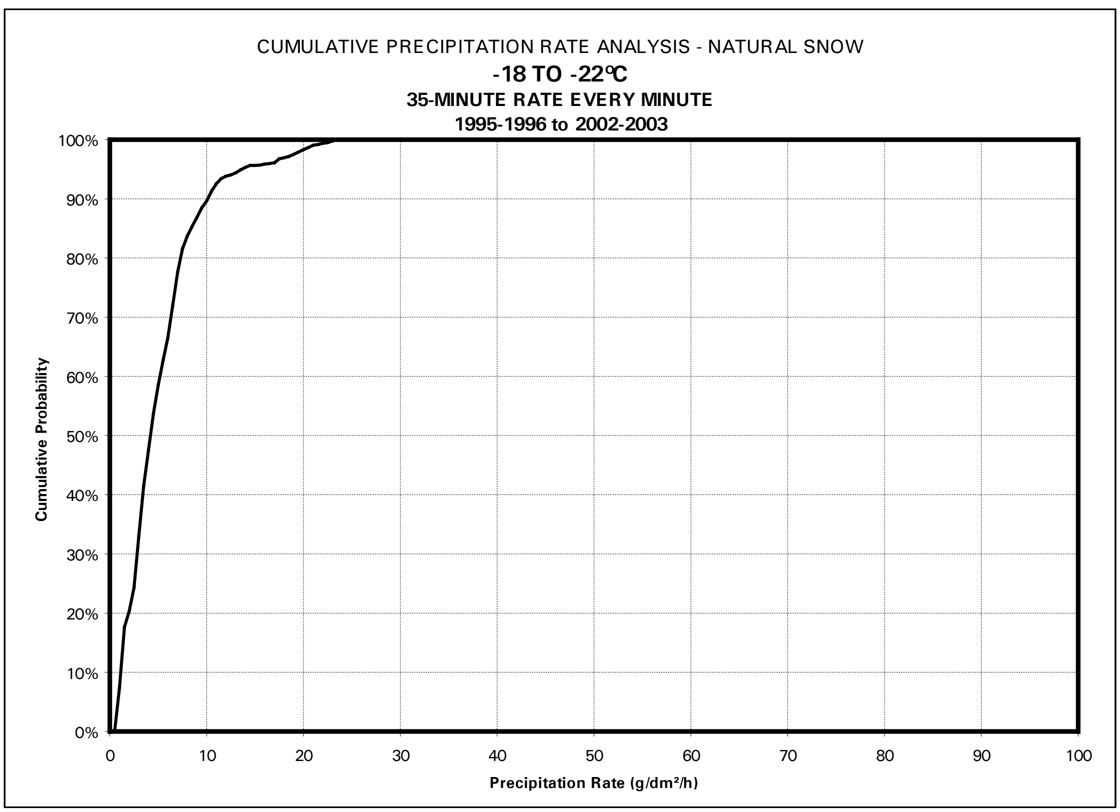

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100

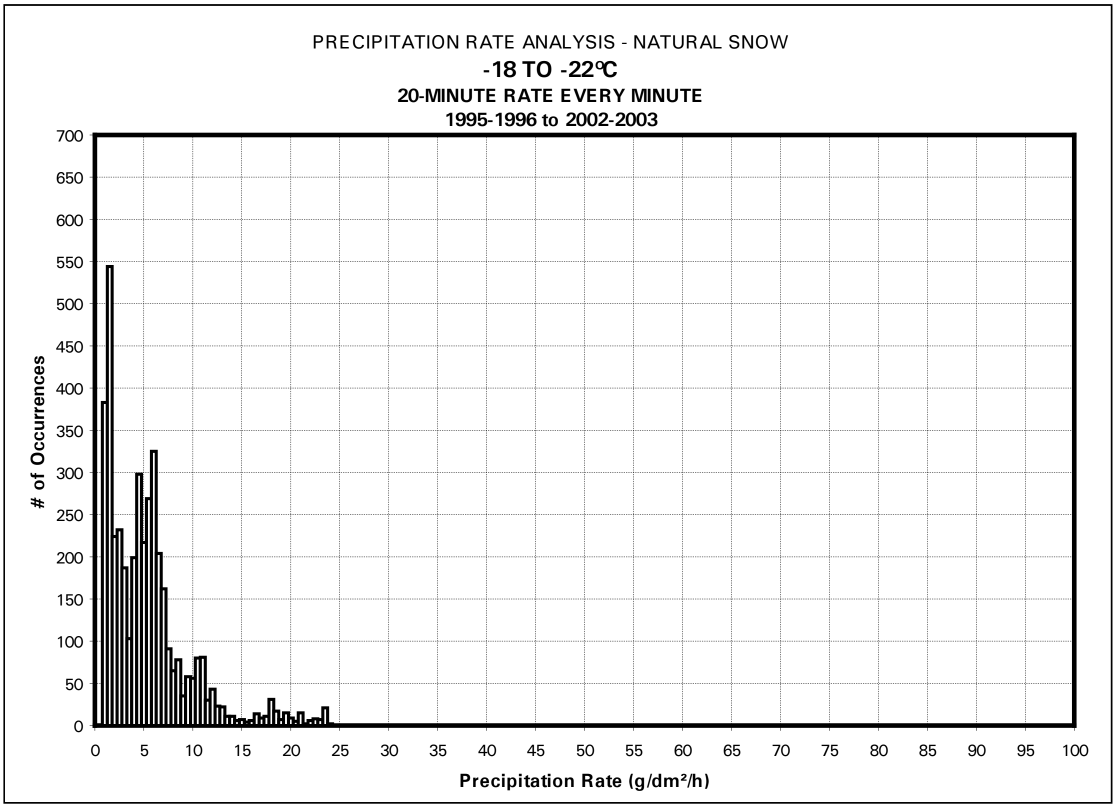

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0
10
20
30
40
50
60
70
80
90
100

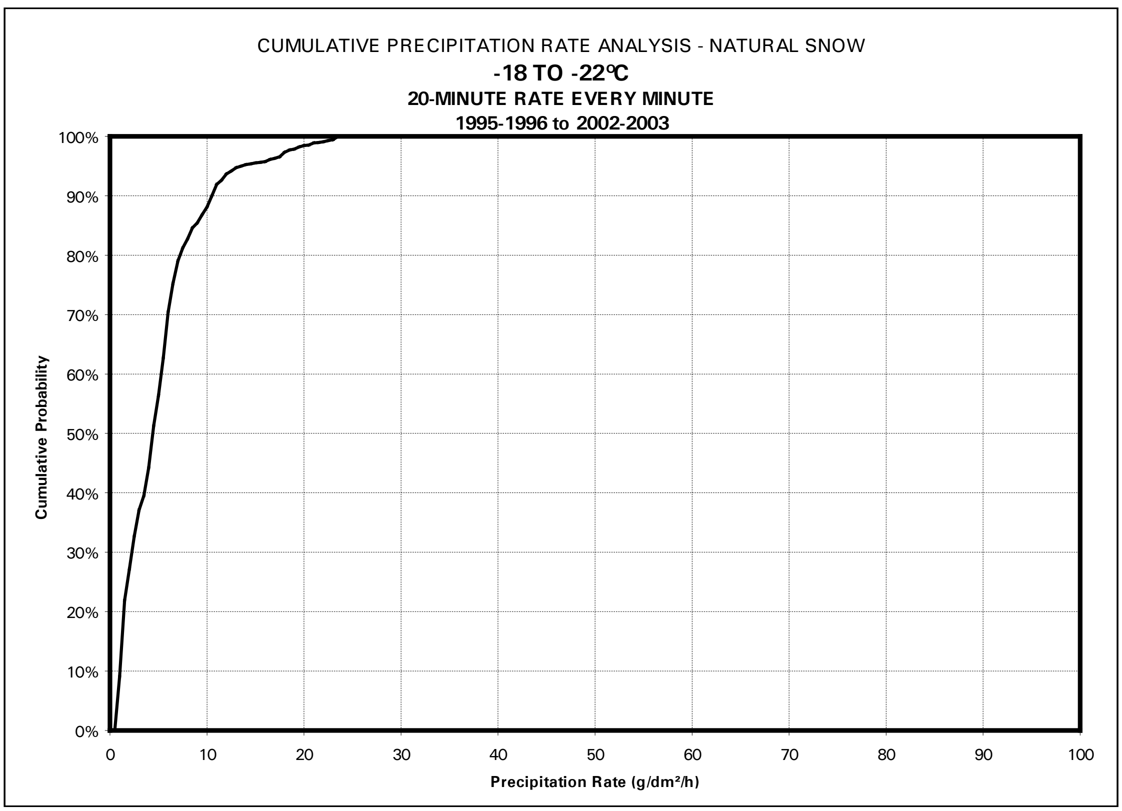

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)

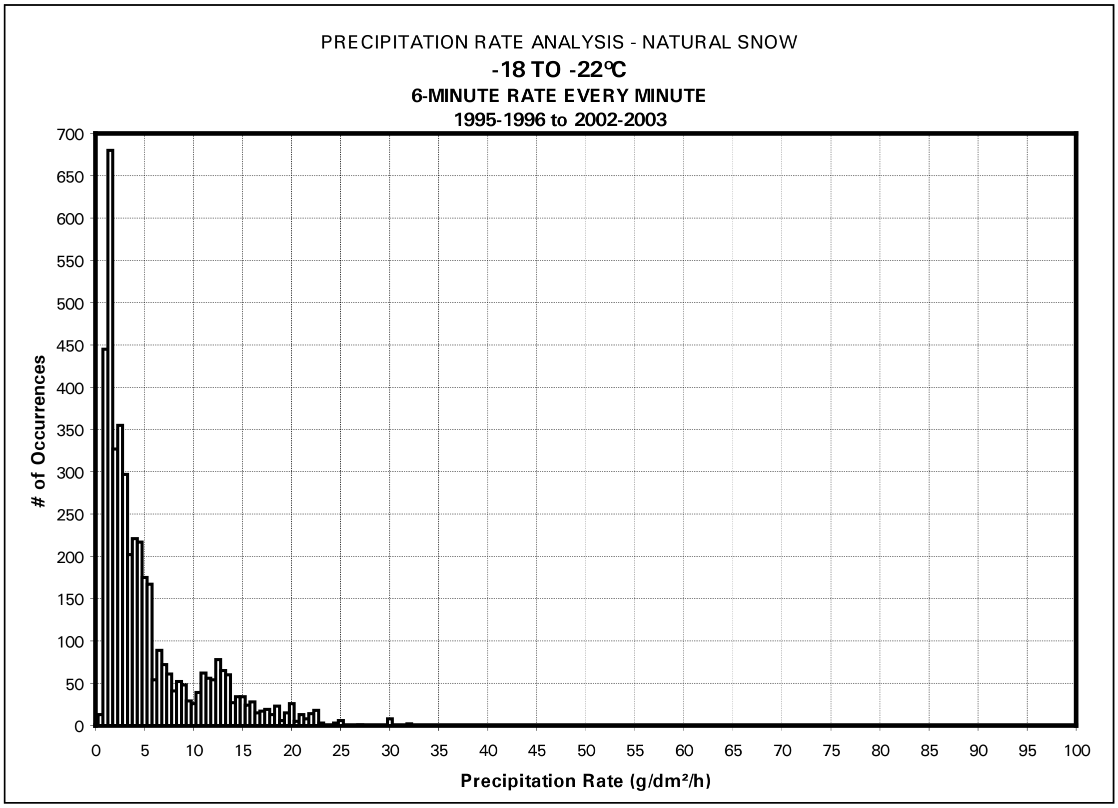

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)

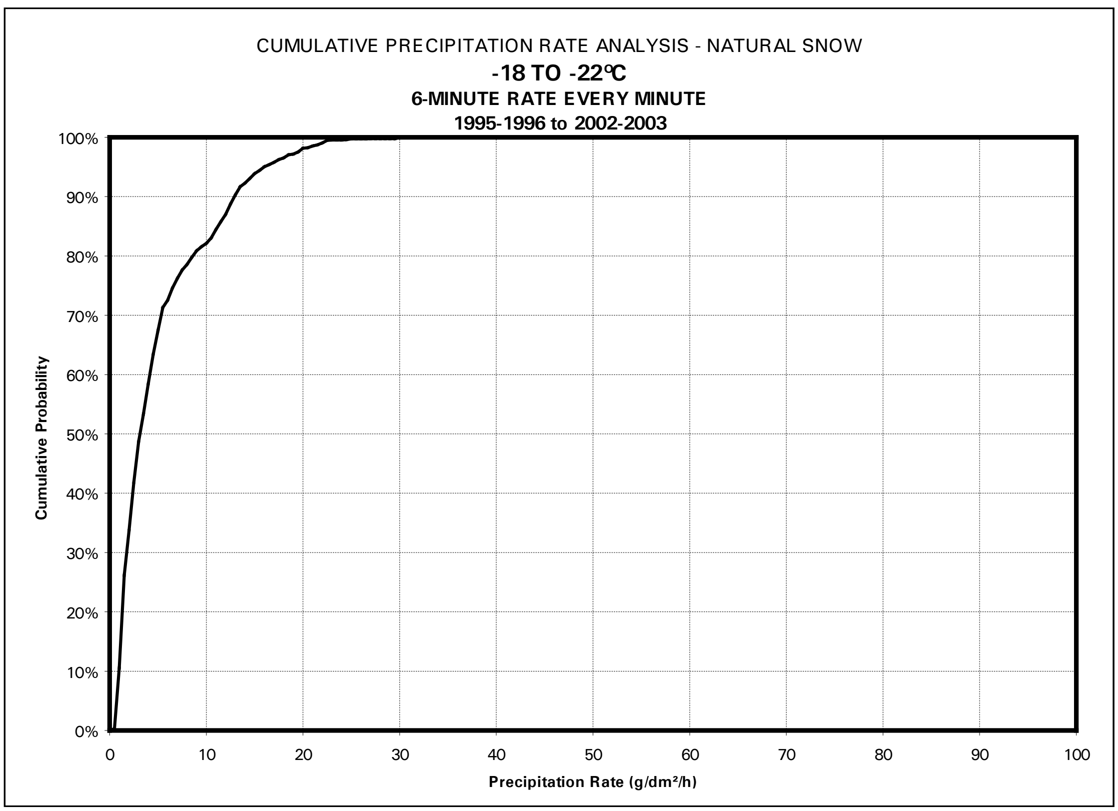

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)

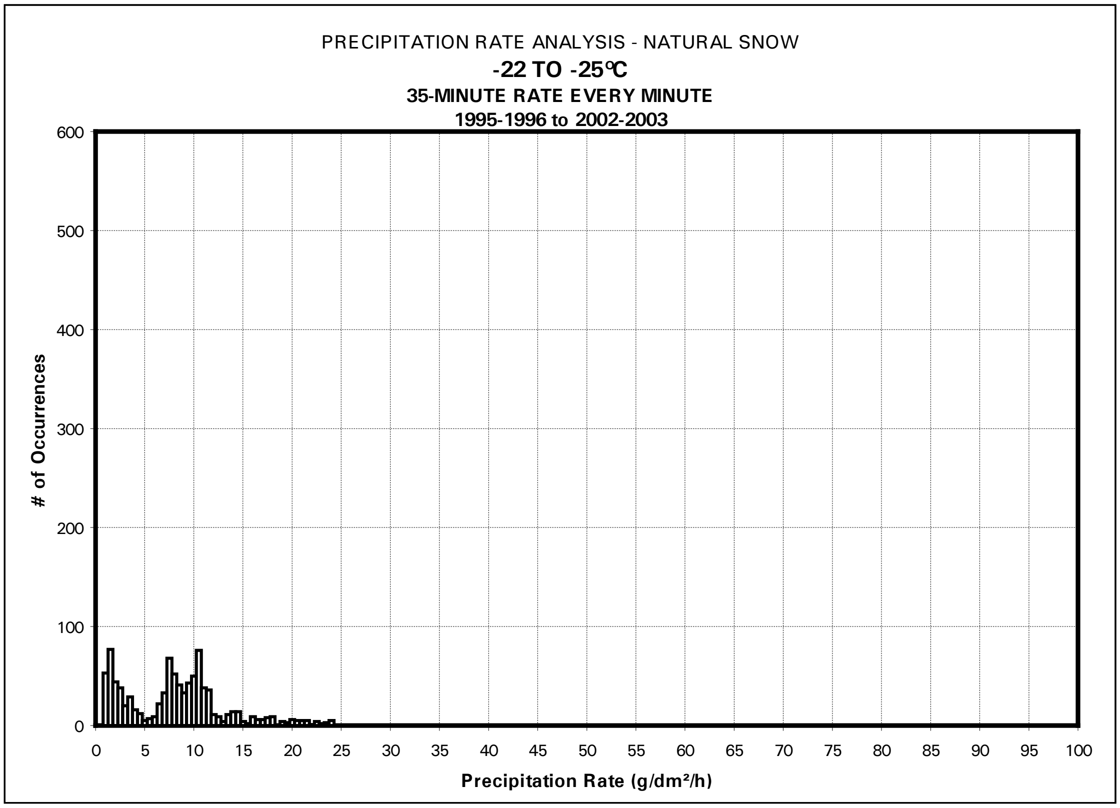

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)

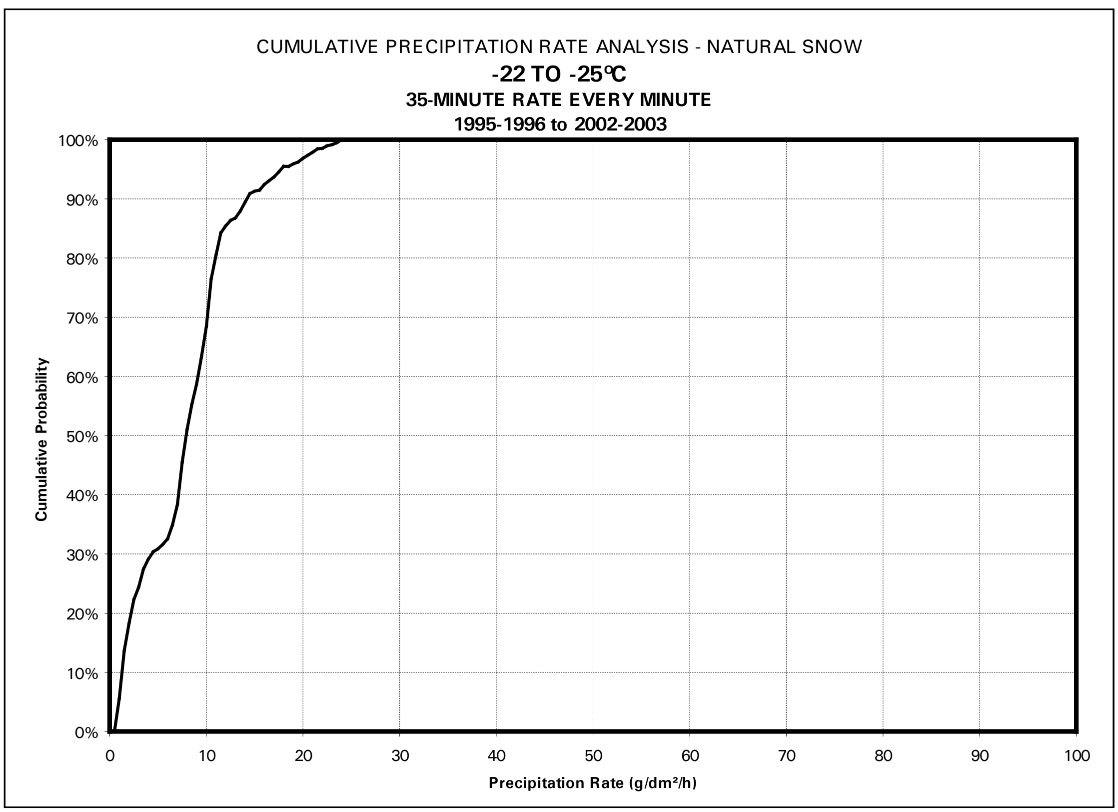

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Precipitation Rate (g/dm²/h)

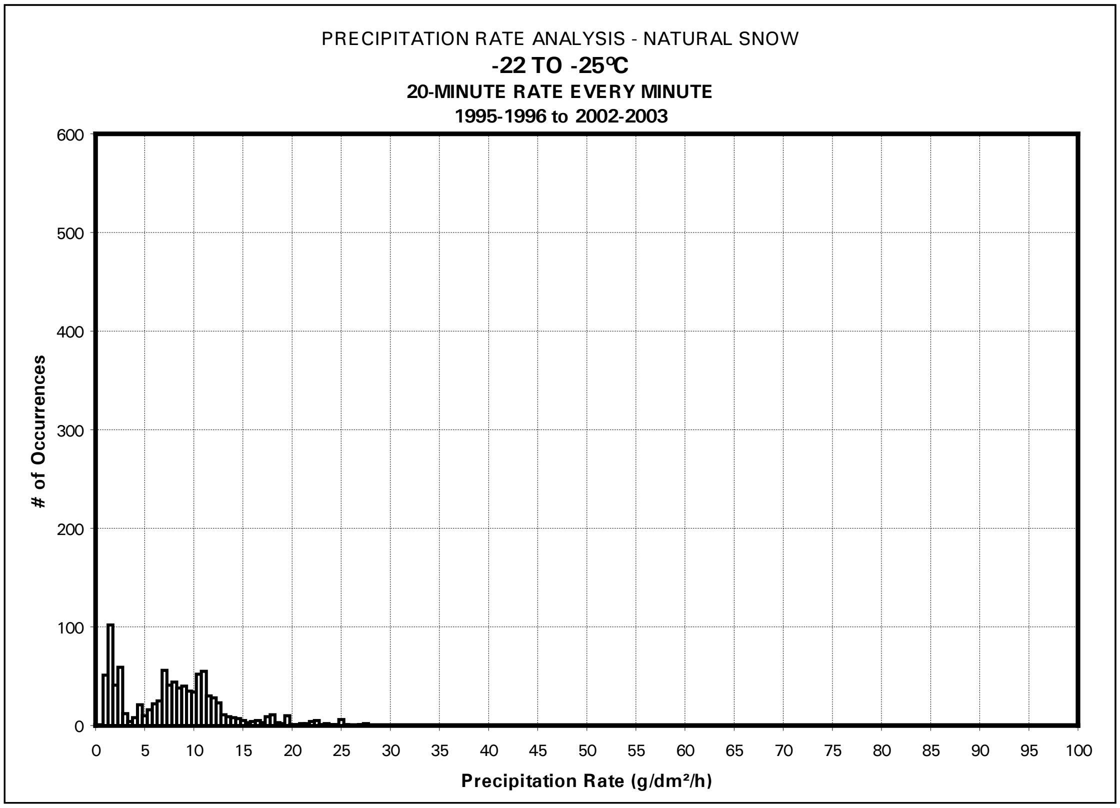

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0
10
20
30
40
50
60
70
80
90
100
Precipitation Rate (g/dm²/h)

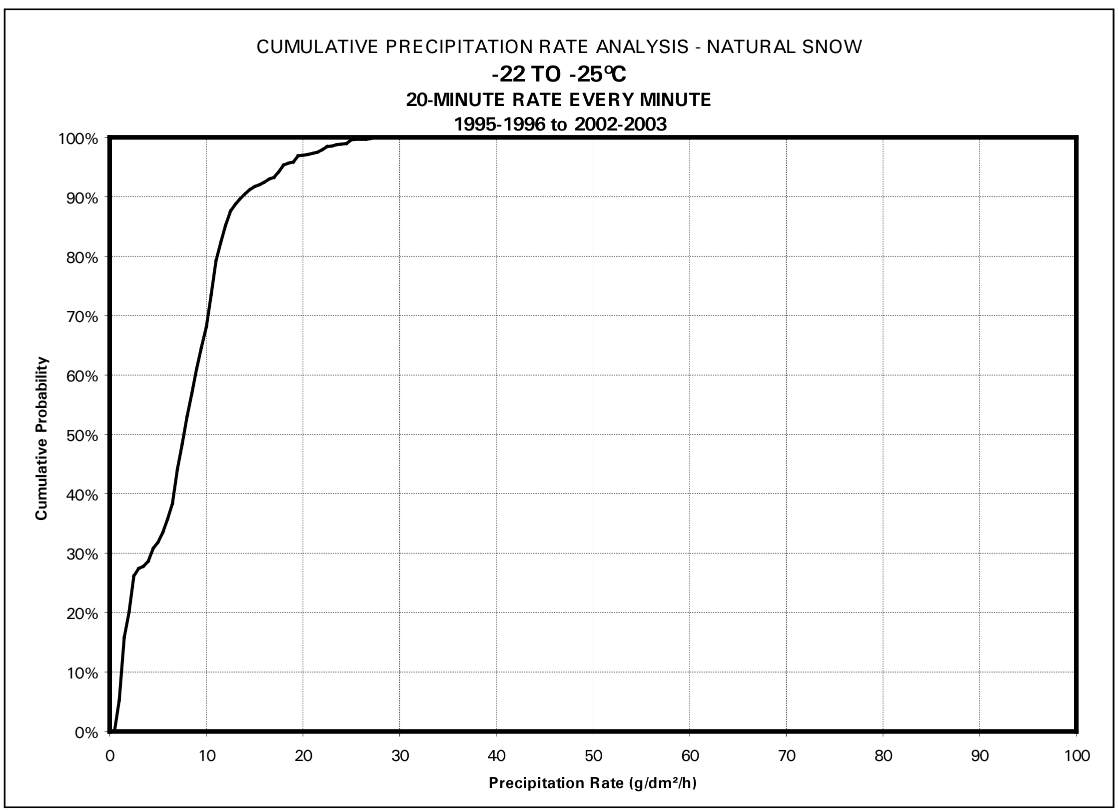

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
Precipitation Rate (g/dm²/h)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

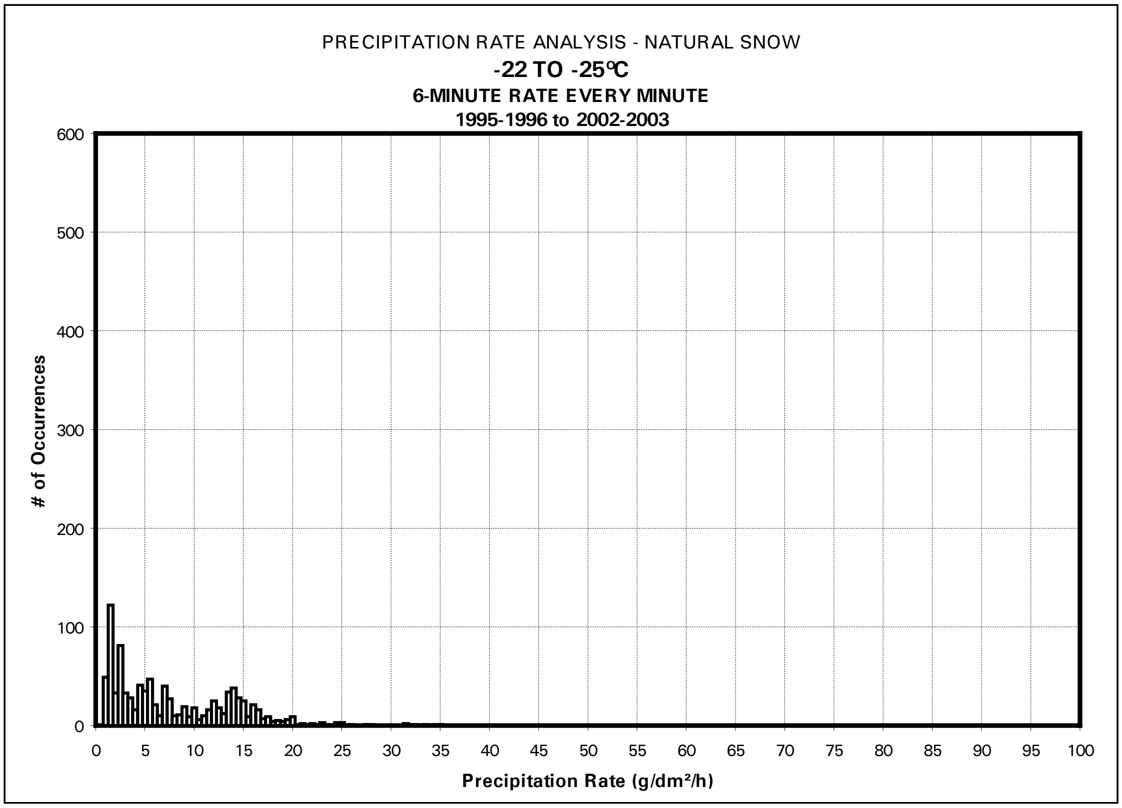

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
Precipitation Rate (g/dm²/h)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100

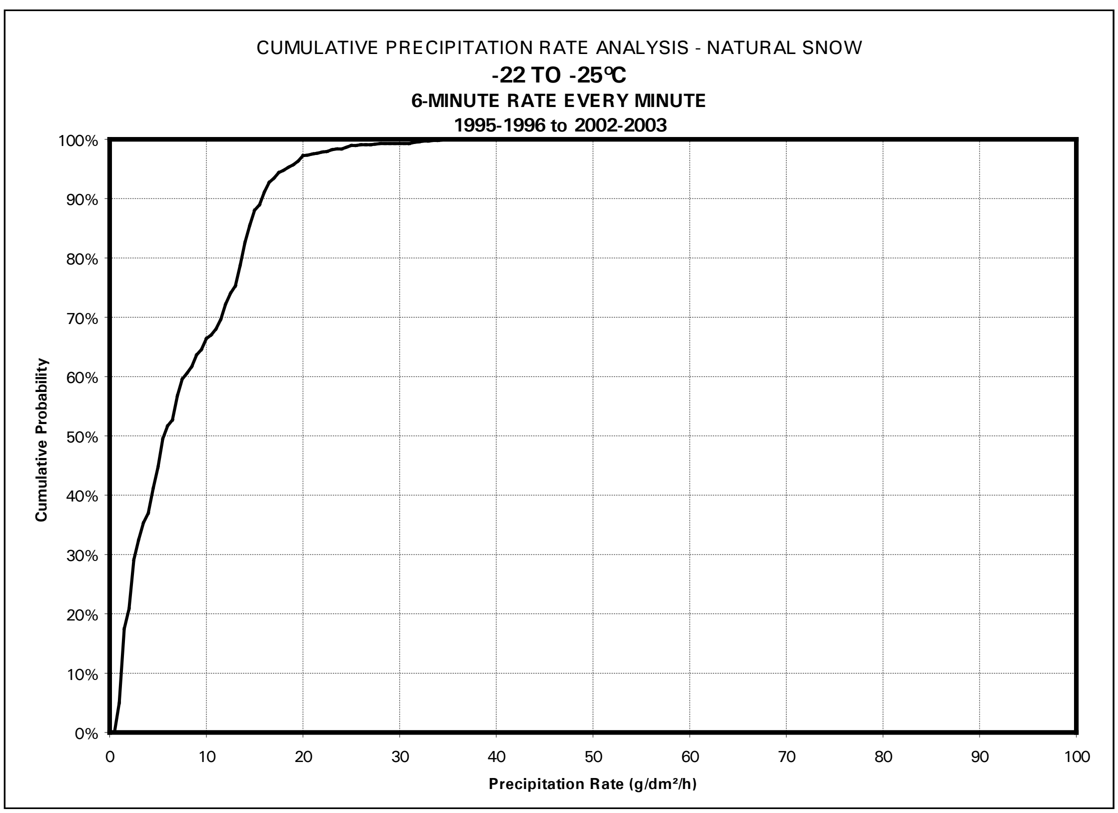

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
100
200
300
400
500
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)


CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
100
200
300
400
500
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)


CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
# of Occurrences
0
100
200
300
400
500
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)


CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2002-2003
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

APPENDIX C

CR21X AUTOMATIC DATA ACQUISITION STATION

CR21X Automatic Data Acquisition Station

Source: Most of the info was researched and obtained from various web sites.

Observations of hourly precipitation amount are extremely useful tools for diagnostic and research purposes. In Canada, such observations are made at a number of sites, the most common being from Meteorological Service of Canada stations around the country.

The meteorological station at Dorval Airport (Photo 1) uses a Fisher/Porter (500 mm) precipitation gauge as a precipitation gauge and also a tipping bucket rain gauge.

Photo 1

The Fisher/Porter (F&P) precipitation gauge, developed by the Belfort instrument Company (Photo 2), is designed to work for many years in remote and harsh environments. The F&P gauge weighs the precipitation it collects in a large metal bucket. This bucket sits atop a mechanism that records the amount of precipitation (Photo 3). The recording & transmitting precipitation gauge converts the weight of collected precipitation into the equivalent depth of accumulated water in conventional units of inches or millimeters. An 8-inch (20.3cm) diameter, knife-edge orifice collects all forms of precipitation. Rain travels through a funnel into the galvanized weighing bucket. The funnel is removed during the winter season to collect snow. When sub-freezing temperatures are expected, the bucket is partially filled with an antifreeze compound, which allows snow and ice to melt and be accurately measured. A weighing transducer provides instantaneous displacement values of the bucket in terms of millimeters of precipitation. This shaft displacement is transmitted every 5 seconds and averaged every minute in an attempt to eliminate spurious data caused by gusts of wind and temperature-induced contraction and expansion of the sensor. The readings are automatically logged with a CR21X data logger. The CR21X station has an accuracy of 0.1 mm (1 g/dm²).

Photo 2

Photo 3

Precipitation rates tend to fluctuate rapidly during snowstorms. The data from the CR21X station required less smoothing before it could be interpreted. The increased resolution of the CR21X weighing transducer allows better observation of short periods with heavy precipitation.

APPENDIX D

EXAMPLE OF MONTHLY METEOROLOGICAL SUMMARY
MONTREAL – DORVAL

ENVIRONNEMENT CANADA
SERVICE MÉTÉOROLOGIQUE DU CANADA

ENVIRONMENT CANADA
METEOROLOGICAL SERVICE OF CANADA

SOMMAIRE MÉTÉOROLOGIQUE MENSUEL
MONTHLY METEOROLOGICAL SUMMARY

Montreal - Dorval (AUTO)

MARS 2003
MARCH 2003

LAT : 45'28 N ALTITUDE : 35.7 MÈTRES (NMM) HEURE NORMALE UTILISÉE : DE L'EST
LONG : 73'45 W ÉLÉVATION : 35.7 MÈTRES (ASL) STANDARD TIME USED : EASTERN

DATE	TEMPÉRATURE / TEMPERATURE: MAXIMALE / MAXIMUM °C	MINIMALE / MINIMUM °C	MOYENNE / MEAN °C	DEGRÉS-JOURS / DEGREE-DAYS: DE CHAUFFE / HEATING Base 18°C	DE CROISSANCE / GROWING Base 5°C	DE RÉFRIGÉRATION / COOLING Base 18°C	HUMIDITÉ REL / REL. HUMIDITY: MAXIMALE / MAXIMUM %	MINIMALE / MINIMUM %	ORAGE / THUNDERSTORM	PRÉCIPITATIONS / PRECIPITATION: PLUIE (HAUTEUR) / RAINFALL mm	NEIGE (HAUTEUR) / SNOWFALL cm	PRÉCIP TOTAL / TOTAL PRECIP mm	NEIGE AU SOL / SNOW ON GROUND mm	VENTS / WINDS: VITESSE MOYENNE / AVERAGE SPEED Km/h	DIRECTION DOMINANTE / PREVAILING DIRECTION	VITESSE MOYENNE MAX SUR 2 MIN ET DIRECTION / MAX 2 MIN MEAN SPEED AND DIRECTION	Km/h	INSOLATION EFFECTIVE / BRIGHT SUNSHINE HEURES / HOURS
1	2.3	-14.5	-6.1	24.1			87	55					8	4.8	SW*	ESE*	9	7.8
2	2.4	-19.7	-8.7	26.7			90	70		1.0	5.0	6.8	8	21.8	W	W*	46	
3	-18.8	-26.8	-22.8	40.8			62	42					12	30.6	W	W*	43	10.3
4	-5.1	-22.0	-13.6	31.6			86	51			4.6	3.2	12	8.3	SE	SE	20	2.0
5	-4.9	-10.2	-7.6	25.6			85	78			13.2	12.2	19	22.5	NE*	NE	37	
6	-8.0	-19.9	-14.0	32.0			88	43					20	9.8	SSW	NNE	24	8.5
7	-4.3	-21.0	-12.7	30.7			73	41			0.4	0.2	20	7.5	SSW	SE*	13	8.3
8	0.6	-6.8	-3.1	21.1			86	61			8.4	9.0	18	13.0	SW	WSW	26	0.7
9	-2.2	-16.1	-9.2	27.2			87	49			3.0	3.2	30	25.1	W	WNW*	39	9.1
10	-11.8	-15.5	-13.7	31.7			74	40			TR	TR	20	31.8	SW	W*	44	10.4
11	-2.9	-14.2	-8.6	26.6			68	56			TR	TR	18	24.8	SW	SW	44	4.4
12	2.5	-10.0	-3.8	21.8			87	44			0.4	0.6	17	24.2	SW	WSW	41	2.3
13	-7.5	-15.5	-11.5	29.5			58	37					16	13.3	NE	NE	22	9.7
14	-6.0	-18.3	-12.2	30.2			62	35					16	11.3	SSW*	SW	28	5.2
15	1.3	-8.9	-3.8	21.8			83	61			4.4	2.8	20	5.8	SSE	SSW	15	1.6
16	6.6	-10.0	-1.7	19.7			82	45					17	6.6	NNE	NNE	19	8.7
17	5.7	0.1	2.9	15.1			90	61					15	10.8	NNE	NE*	15	3.7
18	4.2	-4.5	-0.2	18.2			83	31					9	14.5	NE	NE	31	11.1
19	0.4	-7.4	-3.5	21.5			57	38					8	18.9	NE	ENE	30	11.3
20	3.1	-6.9	-1.9	19.9			89	52		23.8		23.8	8	11.7	NNE*	NNE	17	0.6
21	7.1	0.9	4.0	14.0			91	77		11.4		11.4	6	10.1	W	WSW*	24	
22	4.8	1.8	3.3	14.7			91	85		2.4		2.4	5	10.0	SW	SSW	28	
23	4.5	0.9	2.7	15.3			88	72		1.2	TR	1.2	2	9.6	SW	SW*	19	
24	8.4	-0.3	4.1	13.9			87	62					1	9.8	SW	WSW	26	3.4
25	10.8	2.6	6.7	11.3	1.7		91	64		1.6		1.6	TR	8.9	SE	SE*	20	0.1
26	8.4	1.6	5.0	13.0			92	63		1.2		1.2	TR	14.4	SW	WSW*	19	1.1
27	8.1	-1.1	3.5	14.5			82	48					TR	14.9	WSW	W*	28	8.8
28	11.6	-0.8	5.4	12.6	0.4		69	47					TR	20.0	NE	SSE*	31	3.3
29	13.7	2.9	8.3	9.7	3.3		89	55		6.2		6.2	TR	25.8	SSE	SSE*	37	
30	3.2	-2.7	0.3	17.7			82	60			2.5	2.5	TR	15.5	W*	WSW*	24	
31	-1.3	-7.4	-4.4	22.4			64	38					2	20.8	WNW	WNW	35	11.1
	MOY 1.2 MEAN	MOY -8.7 MEAN	MOY -3.8 MEAN	TOTAL 674.9	TOTAL 5.4	TOTAL	MOY 81 MEAN	MOY 54 MEAN	TOTAL	TOTAL 48.8	TOTAL 41.9	TOTAL 88.3		MOY 15.4 MEAN	DOMINANTE SW PREVAILING	MAXIMALE W MAXIMUM	46	TOTAL 143.5
NORMALE NORMAL	2.0	-6.9	-2.4	633.7	6.4					34.1	31.3	67.6		16.0	W			158.7

SOMMAIRE DE DEGRÉS-JOURS
DEGREE-DAY SUMMARY

AU-DESSOUS DE 18 °C / BELOW 18°C	ANNÉE EN COURS / THIS YEAR	NORMALE / NORMAL	AU-DESSUS DE 5°C / ABOVE 5°C	ANNÉE EN COURS / THIS YEAR	NORMALE / NORMAL
TOTAL DU MOIS / TOTAL FOR MONTH	674.9	633.7	TOTAL DU MOIS / TOTAL FOR MONTH	5.4	6.4
ACCUMULÉS DEPUIS LE 1er JUILLET / ACCUMULATED SINCE JULY 1st	4048.1	3993.9	ACCUMULÉS DEPUIS LE 1er AVRIL / ACCUMULATED SINCE APRIL 1st	2244.2	2078.8

JOURS AVEC PRÉCIPITATIONS TOTALES / DAYS WITH TOTAL PRECIPITATION mm					JOURS AVEC CHÛTES DE NEIGE / DAYS WITH SNOWFALL cm				
0,5 ou plus / or more	1,0 ou plus / or more	2,0 ou plus / or more	10,0 ou plus / or more	50,0 ou plus / or more	0,2 ou plus / or more	1,0 ou plus / or more	2,0 ou plus / or more	10,0 ou plus / or more	50,0 ou plus / or more
15	14	11	3		9	7	7	1	

Canada

1. Normale/Normal 1961-1990
2. Journée climatologique/Climatological Day (01h00HNE à/to 01h00HNE)
3. (AUTO) : mesures d'une station automatique/data from automatic station
4. TR = Trace M = Manquant/Missing E = Estimé/Estimated C = Calme/Calm
5. Pas de valeur/No entry = Pas d'événement/No occurence
6. * = indique la première de plusieurs valeurs valides/indicates first of many valid values
7. c = correction

Données horaires non controlées
Hourly data not validated
Les précipitations ont un seuil mesurable de 1,0 mm
Measurable threshold of precipitation is 1,0 mm

Creation : 3 AVRIL 2003
Created : APRIL 3 2003

RELEVÉS COMPARATIFS À / COMPARATIVE RECORDS AT : Montreal - Dorval (AUTO) — MARS 2003 / MARCH 2003

	UNITÉS / UNITS	CE MOIS-CI / THIS MONTH		ANNÉE PRÉCÉDENTE / PREVIOUS YEAR		NORMALE / NORMAL	RECORD POUR LE MOIS / RECORD FOR THE MONTH — MAXIMUM ABSOLU / HIGHEST EVER			MINIMUM ABSOLU / LOWEST EVER			DEPUIS / SINCE
		RELEVÉ / VALUE	JOUR / DAY	RELEVÉ / VALUE	JOUR / DAY		RELEVÉ / VALUE	JOUR / DAY	ANNÉE / YEAR	RELEVÉ / VALUE	JOUR / DAY	ANNÉE / YEAR	
TEMPÉRATURE MAXIMALE / HIGHEST TEMPERATURE (MAXIMUM)	°CELSIUS	13.7	29	16.8	9		25.6	28	1945				1941
TEMPÉRATURE MINIMALE / LOWEST TEMPERATURE (MINIMUM)	°CELSIUS	-26.8	3	-15.7	25					-29.4	4	1950	1941
TEMPÉRATURE MENSUELLE MOYENNE / MEAN MONTHLY TEMPERATURE	°CELSIUS	-3.8		-1.9		-2.4	3.6		1946	-6.5		1950	1941
HAUTEUR TOTALE MENSUELLE DE PLUIE / TOTAL MONTHLY RAINFALL	mm	48.8		24.2		34.1	93.0		1948	0.3		1965	1941
HAUTEUR TOTALE MENSUELLE DE NEIGE / TOTAL MONTHLY SNOWFALL	cm	41.9		58.5		31.3	108.9		1955	3.3		1946	1941
PRÉCIPITATION TOTALE MENSUELLE / TOTAL MONTHLY PRECIPITATION	mm	88.3		80.8		67.6	165.3		1955	7.5		1984	1941
NOMBRE DE JOURS AVEC PRECIPITATION MESURABLE / NO OF DAYS WITH MEASURABLE PRECIPITATION		16		14		13	20		1981	0.2		1984	1941
HAUTEUR DE PLUIE MAXIMALE EN UNE JOURNÉE / GREATEST RAINFALL IN ONE DAY	mm	23.8	20	14.8	3		32.0	17	1973				1941
HAUTEUR DE NEIGE MAXIMALE EN UNE JOURNÉE / GREATEST SNOWFALL IN ONE DAY	cm	13.2	5	18.8	18		43.2	4	1971				1941
PRÉCIPITATION MAXIMALE EN UNE JOURNÉE / GREATEST PRECIPITATION IN ONE DAY	mm	23.8	20	15.6	26		37.6	22	1955				1941
HAUTEUR DE PLUIE ENREGISTRÉE EN : / MAXIMUM RAINFALL RECORDED IN :													
5 MINUTES	mm						2.8	5	1966				de/from
10 MINUTES	mm						4.1	5	1966				1943
15 MINUTES	mm						5.0	10	1983				à/to
30 MINUTES	mm						5.3	5	1966				1990
60 MINUTES	mm						7.6	4	1977				
24 HEURES CONSÉCUTIVE / CONSECUTIVE HOURS	mm												
VITESSE MOYENNE DU VENT / MEAN WIND SPEED	KM/H	15.4		20.6		16.0	23.2		1955	11.4		1987	1953
VITESSE MAXIMALE (MOYENNE SUR 2 MIN.) / MAXIMUM SPEED (2 MIN. MEAN)	KM/H	W46	2	WSW 78	10		WSW 78	10	2002				1953
POINTE DE VENT MAXIMALE / MAXIMUM GUST SPEED	KM/H	W61	3	W 104	10		S 161	5	1964				1955
TOTAL DES HEURES INSOLATION / TOTAL HOURS OF SUNSHINE	HEURES	143.5		152.5		158.7	205.4		1988	108.6		1973	1969
PRESSION MOYENNE À LA STATION / MEAN STATION PRESSURE	kPa	101.07		101.44		101.12	101.75		1967	100.43		1981	1953
PRESSION MAXIMALE À LA STATION / GREATEST STATION PRESSURE	kPa	102.81	19	103.41	2		104.48	7	1990				1953
PRESSION MINIMALE À LA STATION / LEAST STATION PRESSURE	kPa	99.16	2	98.79	3					96.99	17	1973	1953

DONNÉES CLIMATOLOGIQUES CE MOIS-CI POUR LES 10 DERNIÈRES ANNÉES
CLIMATOLOGICAL DATA THIS MOUNTH FOR THE PAST 10 YEARS

ANNÉE / YEAR	TEMPÉRATURE MAXIMALE / MAXIMUM TEMP.	TEMPÉRATURE MINIMALE / MINIMUM TEMPERATURE	TEMPÉRATURE MOYENNE / MEAN TEMPERATURE	HAUTEUR DE PLUIE / RAINFALL	HAUTEUR DE NEIGE / SNOWFALL	PRÉCIPITATION TOTALE / TOTAL PRECIPITATION	VITESSE MOYENNE DES VENTS / MEAN WIND SPEED	VITESSE MAXIMALE DES VENTS / MAXIMUM WIND SPEED	HEURES D'ENSOLEILLEMENT / SUNSHINE HOURS	DEGRÉS-JOURS DE CHAUFFE / HEATING DEGREE-DAYS	DEGRÉS-JOURS DE CROISSANCE / GROWING DEGREE-DAYS	DEGRÉS-JOURS DE RÉFRIGÉRATION / COOLING DEGREE-DAYS	A.S.N / S.A.S
1994	8.7	-20.6	-3.0	17.4	47.2	64.4	13.8	SW 44	141.8	651.4			250.2
1995	12.0	-22.9	-0.4	20.3	24.8	45.9	11.6	SSE 33	148.0	570.3	5.5		185.7
1996	16.7	-16.2	-2.5	2.8	13.2	19.4	16.6	WSW 48	202.3	636.0	6.2		189.3
1997	10.0	-17.2	-4.4	29.4	72.5	100.3	16.9	WSW 50	154.9	695.9	1.3		278.8
1998	20.3	-16.8	-0.8	69.2	56.0	128.7	14.0	W 41	118.3	582.0	17.9		246.4
1999	13.9	-15.5	-1.3	34.6	38.5	84.1	16.3	SSW 44	170.5	597.4	3.9		161.3
2000	17.4	-13.5	1.6	43.6	24.2	69.8	17.4	NE 48	155.7	507.2	11.9		178.7
2001	8.2	-20.3	-3.3	1.6	89.5	109.8	19.4	ENE 59	170.4	661.6			278.1
2002	16.8	-15.7	-1.9	24.2	58.5	80.8	20.6	WSW 78	152.5	616.2	4.4		153.3
2003	13.7	-26.8	-3.8	48.8	41.9	88.3	15.4	W 46	143.5	674.9	5.4		173.8

Avis / Note :
- * : Nouveau record / New record
- # : Station manuelle / Manual station
- A.S.N : Accumulation Saisonnière de Neige / S.A.S = Season Accumulation Snowfall

TEMPÉRATURE / TEMPERATURE

TEMPÉRATURE HORAIRE
HOURLY TEMPERATURE

Montreal - Dorval (AUTO)

MARS 2003
MARCH 2003

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	-95	-108	-121	-120	-121	-131	-136	-144	-121	-85	-56	-34	-20	-5	14	13	13	11	3	5	-20	-14	-25	-26
2	-32	-42	-40	-44	-42	-39	3	5	2	4	2	6	11	11	20	21	22	17	14	12	9	-26	-85	-137
3	-177	-197	-215	-232	-243	-254	-263	-266	-265	-262	-253	-242	-228	-218	-212	-203	-194	-190	-194	-194	-195	-193	-195	-199
4	-201	-205	-215	-215	-199	-188	-192	-179	-163	-151	-134	-118	-107	-94	-79	-66	-64	-60	-54	-73	-86	-74	-72	-66
5	-63	-64	-82	-83	-76	-79	-80	-81	-81	-79	-77	-75	-73	-68	-66	-59	-54	-52	-55	-53	-53	-51	-52	-58
6	-65	-102	-121	-129	-142	-141	-160	-142	-125	-125	-117	-114	-105	-102	-85	-86	-92	-102	-110	-119	-120	-160	-162	-183
7	-182	-184	-197	-198	-203	-188	-187	-193	-163	-143	-127	-96	-72	-63	-54	-55	-51	-51	-51	-47	-48	-51	-52	-54
8	-51	-54	-55	-53	-55	-61	-48	-42	-32	-26	-14	-8	-6	-9	-9	2	4	2	-3	-5	-2	-2	-17	-15
9	-20	-25	-23	-25	-28	-24	-58	-75	-80	-99	-107	-109	-112	-114	-118	-117	-116	-118	-128	-134	-140	-143	-154	-150
10	-146	-151	-144	-146	-148	-151	-146	-146	-143	-142	-146	-142	-138	-138	-136	-131	-125	-119	-121	-128	-125	-121	-118	-124
11	-125	-129	-133	-124	-128	-135	-139	-135	-122	-102	-85	-73	-58	-47	-36	-32	-33	-34	-41	-44	-57	-48	-44	-38
12	-35	-35	-26	-11	4	6	4	11	14	24	16	6	-5	-7	-3	-7	-9	-10	-18	-26	-39	-52	-60	-73
13	-85	-100	-112	-124	-126	-133	-143	-143	-140	-136	-130	-127	-121	-116	-107	-94	-95	-100	-105	-114	-127	-133	-138	-152
14	-132	-131	-143	-139	-168	-174	-167	-167	-150	-127	-111	-109	-101	-91	-80	-74	-70	-62	-61	-64	-64	-60	-61	-62
15	-65	-64	-68	-71	-73	-72	-71	-66	-59	-55	-48	-35	-27	-20	-11	-6	-10	-11	-19	-36	-61	-59	-58	-55
16	-58	-67	-80	-69	-72	-73	-76	-75	-52	-38	-30	-10	11	35	40	58	51	48	42	24	20	18	26	18
17	9	14	21	31	42	17	11	11	13	14	24	28	35	42	55	46	46	37	33	27	26	24	23	17
18	16	11	4	-5	-13	-24	-26	-25	-5	13	21	26	30	34	34	38	38	37	32	18	9	-5	-18	-19
19	-29	-45	-50	-58	-63	-68	-72	-71	-66	-58	-48	-37	-23	-14	-6	0	2	-1	-8	-13	-16	-21	-26	-35
20	-50	-53	-57	-58	-57	-58	-66	-67	-48	-29	-21	-18	-12	8	9	11	10	11	13	15	16	19	23	25
21	27	31	34	24	17	17	13	11	13	21	34	45	51	56	58	61	69	53	56	36	35	28	39	26
22	19	24	30	29	32	28	26	30	35	34	40	45	36	41	34	39	39	36	35	36	32	22	27	27
23	24	20	18	18	14	11	11	13	18	19	22	27	34	35	42	44	41	44	38	31	27	25	25	27
24	28	27	14	14	9	5	9	7	24	26	43	47	52	57	66	76	81	79	55	58	53	41	25	25
25	30	26	39	35	32	44	46	43	50	58	63	79	92	104	107	84	76	66	65	58	49	55	51	57
26	58	55	44	42	39	34	32	36	37	47	49	67	73	74	72	76	77	81	73	66	50	44	28	33
27	25	16	13	12	8	2	1	11	19	25	41	55	65	68	69	74	72	69	51	34	37	30	32	5
28	2	1	13	20	23	15	11	13	17	21	32	43	62	72	102	110	108	97	81	70	108	101	103	100
29	96	96	99	98	98	97	100	109	117	127	135	124	116	105	101	100	90	85	73	61	58	57	54	43
30	41	30	26	22	18	15	13	12	10	5	8	9	16	10	4	3	-2	-8	-13	-16	-18	-21	-23	-23
31	-23	-27	-35	-59	-50	-51	-65	-57	-54	-50	-40	-35	-33	-22	-20	-20	-20	-24	-33	-36	-41	-43	-47	-55

Avis / Note : Unités / Units: 0.1 °C M = Manquant / Missing

Lire / Read -123 = -12.3 °C -1 = -0.1 °C 0 = 0.0 °C 12 = +1.2 °C 123 = 12.3 °C

Heure normale locale : Est
Local standard time: Eastern

Si vous avez des questions, commentaires ou désirez recevoir de l'information sur les produits offerts pas Environnement Canada :
If you have questions, comments or wish information on products offered by Environment Canada:

Écrivez-nous à : *Write to us at :*

ENVIRONNEMENT CANADA / ENVIRONMENT CANADA
Services climatologiques et de qualité de l'air / Climate and Air Quality Services
100 Alexis Nihon, 3e
Ville St-Laurent, QC - H4M 2N8 Télécopieur / Fax : (514) 283-2264
Courrier éléctronique / Email : *Climat.Quebec@ec.gc.ca*
Renseignements climatologiques / Climate Information : 1-900-565-1111 (2,99 $ / minute)

VENTS / WINDS

VENTS HORAIRES (KM/H)
HOURLY WINDS (KM/H)

Montreal - Dorval (AUTO)

MARS 2003
MARCH 2003

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	RAFALE MAX PEAK GUST	Heure Time	Jour Day
1	C 0	SSW 6	SW 4	SW 7	SW 6	SSW 4	C 0	C 0	C 0	NE 4	C 0	N 4	C 0	C 0	C 0	ESE 6	ESE 9	ESE 9	ENE 6	ENE 9	NNE 9	NE 6	NE 9	NNW 6			
2	N 7	NNE 9	N 6	NNE 7	NNE 7	NNE 4	SSE 11	SE 19	SSE 22	SSE 13	SSE 13	S 17	S 17	S 19	SSW 17	WSW 15	WSW 24	WSW 22	W 26	WSW 22	WSW 30	W 44	W 39	W 46	W 57	22	2
3	W 46	W 37	W 35	WNW 33	W 41	W 37	W 35	W 22	W 24	W 43	W 41	W 33	W 43	WSW 35	WSW 39	WSW 43	WSW 39	W 37	WSW 30	W 28	WSW 22	WSW 26	WSW 19	SW 13	W 61	2	3
4	SW 9	SW 7	SSW 6	SSW 4	SSW 6	C 0	SE 11	SE 9	SE 11	SE 20	SE 13	ESE 13	ESE 13	ESE 11	SE 9	SSW 11	S 11	SSE 9	S 7	N 9	NNE 7	C 0	NNW 4	WNW 4			
5	N 4	N 7	NE 15	NNE 13	NNE 15	NE 30	NE 31	NE 37	NE 33	NE 35	NE 35	NNE 28	NNE 33	NNE 31	NNE 35	NNE 22	N 30	NNW 17	NNW 15	WNW 9	W 9	W 15	WNW 9	WNW 13	NE 56	8	5
6	WNW 15	NW 15	NW 9	NW 7	NW 7	WNW 6	N 4	N 15	N 19	NNE 24	NE 19	NE 19	NE 9	E 7	SE 6	SSW 4	WSW 6	SW 17	SSW 15	SSW 11	WSW 6	SSW 6	C 0	S 9	NNE 33	9	6
7	SW 4	SSW 6	SW 4	SSW 9	SSW 6	SSW 6	SSW 6	SSW 9	SSW 6	SSW 4	S 6	SE 13	ESE 6	SE 13	SE 6	SSE 6	ESE 6	SE 11	SE 9	SSE 9	SSW 9	NW 11	N 9	C 0			
8	SSW 9	SSW 6	SSW 13	SW 9	SW 6	S 6	SW 7	WSW 11	SW 9	WSW 13	WSW 19	SW 22	SW 24	WSW 26	SW 17	SW 19	W 15	WSW 7	C 0	N 7	ENE 13	E 15	ENE 9	NNE 13	WSW 37	13	8
9	N 13	NNE 19	N 13	NW 15	W 13	W 22	WNW 39	WNW 26	W 35	W 33	W 31	W 35	WNW 35	W 30	W 39	W 31	W 39	W 33	W 22	W 17	SSW 15	SW 19	SW 13	SW 17	WNW 54	12	9
10	SW 17	SSW 13	SW 22	SW 22	SW 15	SW 20	SW 26	WSW 24	W 28	W 33	W 43	W 41	W 39	W 44	W 44	W 39	W 37	WSW 24	SW 22	SW 26	SW 35	SW 39	WSW 30	WSW 43	W 61	11	10
11	WSW 37	SW 30	SW 28	SW 33	SW 20	SW 24	SW 22	SW 20	SSW 20	SW 20	SW 28	SW 24	SW 31	SW 33	SW 35	WSW 39	SW 37	SW 44	SW 24	SW 24	SSW 15	S 19	S 20	S 20	SW 57	16	11
12	S 9	SSE 7	SSW 11	SW 28	SW 31	SW 30	SW 31	SW 35	SW 31	WSW 41	WSW 30	WNW 26	WNW 24	WNW 20	W 24	W 30	W 26	W 30	WNW 17	NW 13	NNW 13	NNW 15	NNW 20	NNW 13	SW 57	8	12
13	N 19	NNE 22	NNE 20	NNE 17	NE 22	NE 20	NNE 19	NE 17	NE 20	NE 17	ENE 13	NE 13	NNE 6	N 6	E 4	C 0	SSW 9	SW 13	SW 15	SW 15	W 17	WNW 11	NW 13	NW 13			
14	NNW 11	N 9	NNW 6	C 0	NNW 4	NNW 6	C 0	NW 6	C 0	SSW 6	SW 6	SSW 11	SSW 17	S 20	SSW 22	SW 28	WSW 26	SW 19	WSW 20	W 15	W 7	WSW 9	SW 11	S 11	WSW 35	16	14
15	S 11	SSE 11	SSW 15	SSE 9	SSE 7	ESE 7	SE 9	ESE 9	ESE 9	ESE 7	E 7	E 6	E 7	ENE 6	E 4	C 0	SSE 7	S 6	SSE 6	WSW 4	WNW 4	N 4	C 0	C 0			
16	SSE 6	C 0	NNE 6	N 6	NNE 7	NNE 9	NE 6	NNE 9	NNE 6	NNE 13	NNE 19	NNE 17	NNE 9	E 4	ESE 4	C 0	SE 6	WNW 6	C 0	SW 4	WSW 6	C 0	N 6	C 0			
17	S 9	SSW 7	WSW 11	SW 7	NE 7	ENE 7	NE 6	NE 9	N 7	NNE 11	NE 11	NNE 11	N 11	NNE 11	NE 15	NNE 15	NNE 13	NNE 13	NNE 15	NNE 15	NNE 7	NNE 7	NNE 13	NNE 13			
18	NE 15	N 9	NNE 9	NNE 9	N 7	NNW 6	N 6	N 7	N 4	NE 15	NE 17	NE 11	NE 17	NNE 19	NNE 13	NE 15	NE 9	NE 11	NE 13	ENE 13	NE 15	NNE 22	NNE 22	NE 31	ENE 41	0	18
19	ENE 28	ENE 28	ENE 30	ENE 22	NE 20	NE 22	NE 19	ENE 28	NE 28	ENE 19	NE 19	NE 13	NE 17	ENE 15	NE 19	NE 15	NE 19	NE 17	NE 24	NE 19	NE 19	NE 19	NE 15	NNE 11	NE 37	2	19
20	NNE 15	NNE 9	NNE 11	NNE 13	NNE 15	NNE 15	NNE 13	NNE 15	NNE 13	N 13	NNE 17	NNE 11	N 9	E 7	E 7	E 9	ESE 11	ESE 13	ESE 13	ESE 7	ESE 9	ESE 11	ESE 9	ESE 15			
21	ESE 13	E 11	E 11	NNE 19	NNE 15	NNE 7	NNW 7	NW 7	W 7	WSW 6	WSW 19	WSW 24	W 24	W 22	W 13	W 9	WSW 7	NW 9	W 4	C 0	NNW 4	NW 6	N 6	N 4			
22	W 7	N 6	N 6	N 7	N 6	N 7	NNW 9	N 9	NNE 11	C 0	C 0	C 0	SW 13	SW 7	SSW 11	SW 11	SW 9	SSW 11	SW 7	SW 7	SSW 11	SSE 15	SSW 13	SSW 19	SSW 33	0	22
23	SSW 28	SW 22	SW 19	SW 19	SW 19	SW 13	SW 11	WSW 11	W 17	W 9	NW 13	N 9	N 6	WNW 7	WNW 4	SSW 7	W 6	SW 6	SW 7	SSW 11	SSE 9	S 11	S 7	C 0			
24	SSE 6	S 4	S 6	C 0	SE 6	SSE 9	SSE 4	S 7	SW 11	WSW 19	WSW 26	SW 24	SW 19	SW 17	SW 15	SSW 15	SW 11	SW 9	SSE 7	SE 9	C 0	SE 6	S 4	SE 4	WSW 33	11	24
25	SSE 4	SE 4	ESE 7	SE 9	SE 13	C 0	ESE 7	SE 20	SE 13	SSE 19	SSE 9	S 4	SE 6	SSE 4	C 0	WNW 11	W 9	SSW 13	SSW 13	SW 9	WSW 4	C 0	WNW 4	W 9			
26	WSW 11	WSW 20	WSW 19	WSW 17	W 11	W 13	SSW 13	W 11	W 9	WSW 17	SW 11	W 15	W 13	WSW 19	SSW 15	SW 11	SW 15	SW 17	SSW 11	SW 17	SW 13	SW 19	SSW 17	SW 15			
27	SW 15	SSW 13	WSW 15	SW 15	WSW 22	WSW 15	WSW 15	WSW 19	SW 19	WSW 20	SW 13	SW 20	SW 26	WSW 22	W 28	W 24	W 20	W 28	W 13	W 9	WNW 7	C 0	C 0	C 0	W 39	14	27
28	E 4	ESE 4	NE 9	NE 13	ENE 13	NE 17	NE 15	NE 24	NE 20	NE 24	NE 22	NE 24	NE 22	NE 20	ENE 19	NNE 24	NE 15	N 11	NE 11	N 7	SE 24	SE 26	SSE 31	SSE 31	SSE 44	23	28
29	SSE 28	SE 31	SSE 30	SSE 30	S 24	SSE 33	SSE 30	SSE 24	SSE 30	SSE 31	SSE 37	WSW 26	SW 17	WSW 22	SW 15	WSW 37	W 37	WSW 30	SW 22	SW 11	SW 24	WSW 15	W 28	W 22	WSW 56	16	29
30	W 24	W 20	W 22	WSW 19	WSW 24	WSW 19	WSW 19	WSW 19	W 24	W 20	W 13	W 9	W 11	W 20	WNW 13	NW 4	NE 11	N 4	N 20	NNW 15	NNW 15	N 22	N 9	N 9	W 35	2	30
31	N 19	N 11	NNW 15	NW 9	NNW 13	NNW 11	NW 19	NNW 15	NW 20	NW 22	NW 19	W 26	WNW 33	WNW 26	NW 28	WNW 30	WNW 31	WNW 35	WNW 28	WNW 17	WNW 19	WNW 22	WNW 17	WNW 17	W 46	13	31

Avis / Note: C = Calme / Calm M = Manquant / Missing

Heure normale locale : Est
Local standard time : Eastern

HUMIDITÉ / HUMIDITY

POINTS DE ROSÉE HORAIRES
HOURLY DEW POINTS

Montreal - Dorval (AUTO)

MARS 2003
MARCH 2003

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	-129	-139	-150	-145	-142	-156	-155	-164	-138	-111	-93	-84	-71	-65	-66	-68	-59	-59	-64	-66	-75	-67	-70	-74
2	-79	-85	-87	-89	-83	-71	-22	-21	-22	-13	-12	-8	-5	-3	5	4	4	-1	-3	-15	-20	-47	-124	-176
3	-217	-238	-268	-289	-328	-336	-353	-353	-356	-344	-331	-320	-305	-300	-290	-280	-275	-276	-283	-284	-286	-283	-279	-276
4	-274	-275	-281	-280	-257	-251	-237	-229	-225	-224	-213	-192	-168	-147	-132	-118	-99	-91	-84	-98	-112	-99	-93	-87
5	-84	-84	-109	-105	-96	-105	-107	-109	-110	-109	-108	-105	-103	-97	-93	-86	-85	-81	-86	-83	-81	-78	-78	-85
6	-96	-126	-156	-165	-161	-157	-187	-164	-173	-187	-191	-198	-192	-196	-189	-188	-187	-192	-196	-198	-202	-220	-212	-222
7	-234	-231	-242	-247	-248	-232	-232	-238	-210	-196	-198	-169	-169	-158	-164	-165	-163	-150	-132	-126	-124	-120	-125	-131
8	-117	-94	-89	-83	-83	-91	-82	-79	-73	-70	-61	-66	-64	-60	-53	-53	-54	-65	-60	-62	-61	-58	-41	-37
9	-40	-46	-42	-45	-46	-43	-82	-101	-109	-140	-155	-160	-189	-183	-187	-191	-195	-195	-207	-212	-214	-216	-236	-216
10	-212	-219	-209	-204	-194	-191	-182	-189	-196	-203	-206	-205	-209	-219	-225	-219	-216	-228	-212	-203	-205	-201	-200	-201
11	-201	-203	-201	-191	-194	-197	-198	-192	-181	-164	-150	-130	-118	-104	-103	-107	-103	-98	-107	-117	-121	-114	-109	-111
12	-102	-86	-72	-46	-51	-47	-30	-23	-19	-26	-21	-13	-42	-63	-82	-109	-105	-118	-115	-123	-134	-139	-150	-150
13	-161	-172	-185	-189	-199	-202	-209	-214	-215	-207	-217	-215	-212	-204	-208	-214	-210	-215	-206	-200	-207	-212	-220	-228
14	-217	-217	-220	-214	-228	-234	-225	-226	-206	-198	-202	-214	-212	-189	-189	-201	-194	-188	-179	-164	-170	-164	-162	-144
15	-141	-135	-123	-100	-98	-96	-95	-91	-88	-87	-82	-80	-77	-75	-71	-70	-75	-74	-72	-82	-93	-98	-98	-93
16	-84	-93	-109	-98	-100	-99	-102	-102	-81	-83	-77	-70	-59	-57	-52	-51	-44	-38	-38	-41	-44	-45	-41	-44
17	-41	-32	-17	-1	13	-12	-4	-16	-23	-29	-24	-21	-21	-18	-14	-16	-15	-18	-22	-24	-22	-22	-23	-26
18	-24	-27	-30	-37	-43	-51	-51	-53	-30	-55	-63	-81	-88	-98	-100	-110	-111	-118	-119	-118	-117	-131	-135	-145
19	-154	-163	-164	-166	-165	-167	-169	-167	-167	-158	-146	-137	-139	-133	-124	-124	-121	-126	-127	-128	-135	-127	-128	-123
20	-122	-126	-135	-140	-137	-135	-134	-132	-114	-95	-82	-67	-51	-18	-15	-12	-12	-8	-6	-4	-2	0	4	7
21	11	14	18	7	0	2	-4	-6	-2	7	20	30	33	28	27	29	31	21	24	12	14	11	20	3
22	-1	5	12	10	13	10	9	12	15	19	26	29	18	24	16	24	24	21	19	18	14	6	11	6
23	2	-2	-3	-2	-5	-9	-7	-5	1	-1	2	4	5	-1	-3	-1	3	5	4	0	0	0	2	3
24	3	-1	-13	-13	-13	-14	-12	-13	0	-1	8	3	5	5	7	12	14	11	6	3	8	-1	-1	-4
25	6	1	-2	-10	-10	-4	8	8	8	12	19	27	32	42	41	40	44	42	43	42	35	39	33	42
26	42	40	29	30	26	21	21	22	24	29	27	39	32	29	29	25	21	23	20	0	-9	-11	-22	-23
27	-25	-29	-27	-26	-28	-30	-27	-17	-15	-12	-6	-4	0	-18	-21	-19	-26	-34	-37	-41	-43	-39	-37	-46
28	-42	-43	-38	-34	-41	-47	-50	-54	-50	-47	-39	-32	-21	-12	3	14	17	9	5	-3	11	4	-5	-7
29	-5	2	13	26	35	45	53	62	71	79	85	85	94	85	84	81	71	50	42	32	28	29	9	-19
30	-17	-31	-33	-47	-52	-53	-55	-56	-53	-48	-40	-37	-41	-56	-47	-46	-40	-35	-41	-46	-52	-54	-55	-57
31	-80	-84	-97	-116	-119	-122	-132	-136	-137	-136	-130	-115	-116	-120	-127	-128	-138	-141	-150	-157	-152	-154	-153	-149

Avis / Note: Unités / Units : 0,1 °C M = Manquant / Missing

HUMIDITÉS RELATIVES HORAIRES RELEVÉE À :
HOURLY RELATIVE HUMIDITIES AT :

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	76	78	79	82	84	81	85	85	87	81	75	68	68	64	55	55	59	59	61	59	66	67	71	69
2	70	72	70	71	73	78	83	83	84	88	90	90	89	90	90	88	88	88	88	82	81	85	73	72
3	71	70	62	59	45	46	42	43	42	46	48	48	49	47	49	50	48	46	45	44	44	45	47	50
4	52	53	55	55	60	57	67	65	59	53	51	54	61	65	66	66	76	79	79	82	81	82	85	85
5	85	86	81	84	85	81	81	80	80	79	78	79	79	80	81	81	79	80	79	79	81	81	82	81
6	79	82	75	74	85	88	80	83	67	60	54	50	49	46	43	43	46	47	49	52	50	60	65	71
7	63	66	67	65	67	68	67	67	67	64	55	55	46	47	41	41	41	46	53	54	55	58	56	55
8	60	73	77	79	81	79	77	75	73	72	70	65	65	68	72	66	65	61	65	65	64	66	84	85
9	86	85	87	86	87	87	83	82	80	72	68	66	53	56	56	54	52	53	51	52	53	54	49	57
10	57	56	58	61	68	71	74	70	64	60	60	59	55	50	47	47	46	40	46	53	51	51	50	52
11	53	54	56	57	58	59	61	62	61	60	59	64	62	64	60	56	58	61	60	57	60	60	60	57
12	60	68	71	77	66	68	78	78	79	69	76	87	76	66	55	46	48	44	47	47	47	50	49	54
13	54	55	55	58	54	56	57	55	53	55	48	48	46	48	43	37	38	38	43	49	51	51	50	52
14	49	48	52	53	59	59	61	60	62	55	47	41	40	45	41	35	36	36	39	45	43	43	44	52
15	55	57	65	80	82	83	83	82	80	78	77	71	68	66	64	62	61	62	67	70	78	74	73	74
16	82	82	80	80	80	82	82	81	80	71	70	64	59	51	51	45	50	54	56	62	62	63	61	63
17	69	71	76	79	81	81	90	82	77	73	71	70	67	65	61	64	65	67	67	69	71	72	72	73
18	75	76	78	79	80	82	83	81	83	60	54	45	41	37	37	33	33	31	32	36	38	38	40	37
19	37	39	40	42	44	45	46	46	44	45	46	46	40	40	40	39	39	38	40	41	40	44	45	50
20	57	56	54	52	53	54	58	60	60	60	63	69	75	83	84	85	85	87	87	87	88	87	87	88
21	89	89	89	89	88	90	88	88	90	90	91	90	88	82	80	80	77	80	80	84	86	89	87	85
22	87	87	88	87	87	88	89	88	87	90	91	89	88	89	88	90	90	90	89	88	88	89	89	86
23	85	85	86	87	87	86	88	88	88	87	87	85	81	77	72	72	76	76	78	80	82	84	85	84
24	84	82	82	82	85	87	86	86	84	82	78	73	72	69	66	64	63	62	71	68	73	74	83	81
25	84	84	75	72	74	71	76	78	74	72	73	70	66	65	64	74	80	85	86	89	91	89	88	90
26	89	90	90	92	91	91	92	91	91	88	86	82	75	73	74	70	68	67	69	63	66	67	70	67
27	69	72	75	76	77	79	81	82	78	77	71	66	63	54	53	52	50	48	53	58	56	60	60	69
28	72	72	69	67	63	63	64	61	61	61	60	58	55	55	50	51	53	54	59	60	51	51	47	47
29	49	52	55	61	65	70	73	73	73	73	72	77	86	87	89	88	88	79	81	82	81	82	73	64
30	66	64	65	60	60	60	60	60	63	68	70	71	66	61	69	70	75	82	81	80	77	78	79	77
31	65	65	62	64	58	57	59	54	52	51	49	54	53	47	44	43	40	40	40	38	42	41	43	47

Avis / Note: Unités / Units : pourcent /percent (%) M = Manquant / Missing

- Résumé / Summary -

Sommaire quotidien de mars 2003 **Aéroport International de Montréal/Dorval**	**Daily summary for March 2003** **Montreal/Dorval International Airport**
Date	Date
1 - Généralement ensoleillé.	1 - Mostly sunny.
2 - Neige le matin se changeant en pluie vers midi redevenant de la faible neige en soirée. Venteux.	2 - Morning snow changing to rain around noon becoming light snow in the evening. Windy.
3 - Ensoleillé. Très froid. Venteux.	3 - Sunny. Very cold. Windy.
4 - Neige commençant vers midi. Très froid.	4 - Snow beginning around noon. Very cold.
5 - Neige. Poudrerie par moments. Venteux. Moins froid.	5 - Snow. Blowing snow at times. Windy. Less cold.
6 - Généralement ensoleillé. Très froid.	6 - Mostly sunny. Very cold.
7 - Généralement ensoleillé. Faible neige en fin de soirée. Très froid	7 - Mostly sunny. Light snow by late evening. Very cold.
8 - Averses de neige éparses. Neige en soirée parfois modérée.	8 - Scattered snowshowers. Evening snow at times moderate.
9 - Neige cessant le matin. Soleil par la suite. Refroidissement marqué. Très venteux.	9 - Snow ending in the morning. Sunny thereafter. Sharp cooling. Very windy.
10 - Flocons la nuit. Ensoleillé. Très froid et venteux.	10 - Overnight flurries. Sunny. Very cold and windy.
11 - Soleil le matin. Flocons vers minuit. Froid. Venteux.	11 - Morning sunshine. Flurries around midnight. Cold. Windy.
12 - Faible neige intermittente avant midi. Percées de soleil par la suite. Venteux.	12 - Intermittent light snow before noon. Sunny breaks thereafter. Windy.
13 - Généralement ensoleillé. Très froid.	13 - Mostly sunny. Very cold.
14 - Ciel variable. Très froid.	14 - Variable skies. Very cold.
15 - Neige la nuit suivi d'un dégagement graduel.	15 - Snow at night then gradual clearing.
16 - Généralement ensoleillé. Doux.	16 - Mostly sunny. Mild.
17 - Plutôt nuageux. Doux.	17 - Mainly cloudy. Mild.
18 - Ensoleillé. Doux.	18 - Sunny. Mild.
19 - Ensoleillé.	19 - Sunny.
20 - Pluie verglaçante débutant en matinée se changeant en pluie vers midi.	20 - Freezing rain beginning in mid-morning changing to rain around noon.
21 - Pluie devenant de la bruine vers l'aube cessant le matin. Nuageux par la suite. Doux.	21 - Rain changing to drizzle around dawn ending in the morning. Cloudy thereafter. Mild
22 - Faible pluie ou bruine intermittente. Doux.	22 - Intermittent light rain or drizzle. Mild.
23 - Faible pluie ou faible neige durant la nuit. Doux.	23 - Light rain or light snow overnight. Mild.
24 - Nuageux avec éclaircies. Doux.	24 - Cloud with breaks. Mild.
25 - Averses de pluie surtout en après-midi. Très doux.	25 - Rainshowers mainly in the afternoon. Very mild.
26 - Averses de pluie le matin. Dégagement en après-midi. Doux.	26 - Rainshowers in the morning. Clearing in the afternoon. Mild.
27 - Ensoleillé avec passages nuageux. Doux.	27 - Sunny with cloudy periods. Mild.
28 - Nuageux avec éclaircies. Très doux. Venteux.	28 - Cloudy with breaks. Very mild. Windy.
29 - Pluie débutant avant midi et cessant en après-midi. Très doux. Venteux.	29 - Rain beginning before noon and ending in the afternoon. Very mild. Windy.
30 - Flocons le matin. Neige débutant vers midi et cessant en fin de soirée.	30 - Morning flurries. Snow beginning around noon and ending by late evening.
31- Ensoleillé. Froid. Venteux.	31 - Sunny. Cold. Windy.

APPENDIX E

WINTER OPERATIONS SURVEY QUESTIONNAIRE AND RESPONSES OF WORLDWIDE AIRLINES

Transports Canada

Centre de développement des transports

800, bd René-Lévesque O.
6e étage
Montréal (Québec)
H3B 1X9
Tél. : (514) 283-0000
Télécopieur : (514) 283-7158
Site Web :
Www.tc.gc.ca/tdc/index_f.htm

Transport Canada

Transportation Development Centre

800 René-Lévesque Blvd. W.
6th Floor
Montreal, Quebec
H3B 1X9
Tel.: (514) 283-0000
Fax: (514) 283-7158
Web Site:
www.tc.gc.ca/tdc/index.htm

Votre référence *Your file*

Notre référence *Our file*

SUBJECT: Winter Operations Survey

Dear Sir or Madam:

Transport Canada is attempting to collect additional data on actual deicing operations at several worldwide stations. Last year a similar survey was conducted and the dataset from this study of seven stations (Montreal, Toronto, Sapporo, Amsterdam, Pittsburgh, Paris and London) was analyzed. It was found that approximately 65% of de/anti-icing operations occur in snow, that over 25% occur in frost and that less than 10% of all operations occur in freezing fog, light freezing rain, freezing drizzle, and rain on a cold-soaked wing combined. Data from another winter and also from other regions such as Denver, Helsinki, Stockholm, Calgary, Anchorage, Boston, Buffalo and Chicago would put more confidence in the data set as a representation of worldwide deicing operations. If you do not have precise data, we encourage you to provide us with estimates made using your best judgment.

The importance and significance of this survey is to better evaluate and determine where to place the resources and funding of de/anti-icing research. Presently, we are seeking this information in support of a review of the Holdover time table temperature and weather condition breakdowns such that we can ensure that our R&D emphasis is aimed at conditions where an important number of operations occur worldwide. It will also assist us in identifying where improvements can be made to the format of the HOT tables. Your input and data will ensure that your operational conditions are included in the review process. We shall provide you with feedback of our findings from this survey.

Attached is one Microsoft Excel file containing four "tabs". The first two tabs are the tables for you to complete: Table 1 for Type I operations and Table 2 for Type II and/or Type IV operations. Enter your data directly into these tables. If your data are in the form of percentages, please provide the total number of deicing operations as a numerical value as well. If you cannot separate out Type I operations, please provide the information for all fluids on Table 2 and check the appropriate box. The last two tabs - Tables 3 and 4 - serve as examples; these tables show the totaled results from last year's survey (2000-2001) of information on deicing operations gathered from the seven international airports.

The following are our general guidelines for completing the tables:

1. First identify one deicing station for which you have data, or are willing to estimate operations, and provide information for this station. If possible, it should be the busiest winter station in your country. If you cannot isolate one station in your data, provide the names of the stations included. If you have large operations at many stations, data from these other stations would be appreciated. Please make copies of Tables 1 or 2 for this additional data.

2. Establish your level of operations by stating the number of deicing operations performed last winter at the station you have identified.

3. Assess how many or what proportion of your operations were for frost and how many were for snow at the bottom of the table.

4. Assess how many or what proportion of your operations were for freezing rain, freezing drizzle or freezing fog.

5. Assess how many or what proportion of your operations were for rain on a cold soaked wing.

6. State (or estimate) how many of the operations were in each temperature range in the table and do this for each weather class if possible in the body of the table.

7. Identify or estimate how operations were distributed by temperature on the right of the table.

When you make estimates, please identify that the figure is an estimate with the letter "E" alongside the value. If all entries are estimates, you need only indicate this in the space labeled "All values are estimates."

If you need assistance in processing your data into a format for the forms provided, please feel free to call John D'Avirro of APS at 514 878 4388.

Please fill out the Tables as completely as you can and return them to my attention by August 15, 2002.

Yours Sincerely,

Barry Myers

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS

Enter Station's Name: ____________________

Enter # of Deicing Operations: ____________________ **Specify if values are estimates (YES or NO):** _________

OAT °C	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ. RAIN	RAIN ON COLD SOAKED WING	OTHER Specify:	Total
above 0								0
0 to -10								0
below -10								0
Total	0	0	0	0	0	0	0	0

COMMENTS:

____

____

____

TABLE 2 (FOR TYPE II & IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

Enter Station's Name: ____________________ **Specify if Type I is included (YES or NO):** ____________

Enter # of Deicing Operations: ____________________ **Specify if values are estimates (YES or NO):** ____________

State fluid dilution used (100 or 75/25 or 50/50 or all): ____________________

OAT °C	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER Specify:	Total
above 0º								0
0 to -3								0
-3 to -14								0
-14 to -25								0
below -25								0
Total	0	0	0	0	0	0	0	0

COMMENTS:

____

____

____

TABLE 3 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

SUMMARY OF ALL AIRPORTS

Total # of Deicing Operations: *25800* **All values are estimates:**

OAT °C	OAT °F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	Total
above 0°	above 32°	800	0	1625	52	232	284	26	3019
0 to -10	32 to 14	3406	0	14216	361	1290		903	20176
below -10	below 14	1600	0	980				25	2605
	Total	5806	0	16821	413	1522	284	954	

25800 of Operations

TABLE 4 (FOR TYPE II & IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

SUMMARY OF ALL AIRPORTS

Total # of Deicing Operations: *17517* **Type I included** NO **All values are estimates:**

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	Total
above 0°	above 32°	100/0 75/25 50/50	972	0	1055	53	35	88	0	2203
0 to -3	32 to 27	100/0 75/25 50/50	3878	193	4660	180	324		35	9270
below -3 to -14	below 27 to 7	100/0 75/25	841	105	4362	350	175		0	5833
below -14 to -25	below 7 to -13	100/0	18	0	193				0	211
below -25	below -13	100/0	0	0	0				0	0
		Total	5709	298	10270	583	534	88	35	

17517 of Operations

RESPONSES

Table 1 (for Type I Fluid) – Distribution of Deicing Operations in the Following Station (s)

Table 2 (for Type IV Fluid) – Distribution of Deicing Operations in the Following Station (s)

This page intentionally left blank.

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

CHICAGO - ORD (AMERICAN EAGLE)

Total # of Deicing Operations: 2500

All values are estimates: X

OAT °C	OAT °F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	Total
above 0°	above 32°	2.0%	0.0%	72.0%	2.0%	8.0%	0.0%		84.0%
0 to -10	32 to 14	0.0%	0.0%	16.0%	0.0%	0.0%			16.0%
below -10	below 14	0.0%	0.0%	0.0%					0.0%
	Total	2.0%	0.0%	88.0%	2.0%	8.0%	0.0%	0.0%	

100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Chicago AE

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

CHICAGO - ORD (UNITED)

Total # of Deicing Operations: *3510*

All values are estimates:

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	76.6%	0.0%	0.0%	0.0%	0.0%	0.0%		76.6%
0 to -10	32 to 14	23.4%	0.0%	0.0%	0.0%	0.0%			23.4%
below -10	below 14	0.0%	0.0%	0.0%					0.0%
	Total	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	

100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Chicago UN

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

DENVER - DEN

Total # of Deicing Operations: *161*

All values are estimates:

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	14.3%	0.0%	1.9%	2.5%	0.0%	0.0%		18.6%
0 to -10	32 to 14	44.7%	1.9%	24.8%	0.0%	0.0%			71.4%
below -10	below 14	5.6%	0.0%	4.3%					9.9%
	Total	64.6%	1.9%	31.1%	2.5%	0.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Denver

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

HELSINKI - HEL

Total # of Deicing Operations: *10063*

All values are estimates: X

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	15%	1%	19%	2%	0.4%	0.3%		37.0%
0 to -10	32 to 14	25.5%	0.5%	25.1%	1.4%	0.1%			52.6%
below -10	below 14	10%	0%	0.2%					10.3%
Total		51.0%	1.0%	44.1%	3.0%	0.5%	0.3%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Helsinki

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

LOUISVILLE - SDF

Total # of Deicing Operations: *1000*

All values are estimates: X

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		0.0%
0 to -10	32 to 14	0.0%	0.0%	60.0%	25.0%	15.0%			100.0%
below -10	below 14	0.0%	0.0%	0.0%					0.0%
	Total	0.0%	0.0%	60.0%	25.0%	15.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Louisville

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

MONTREAL DORVAL - YUL

Total # of Deicing Operations: *5085*

All values are estimates:

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	4.2%	0.0%	4.9%	0.2%	0.2%	0.4%	0.1%	10.0%
0 to -10	32 to 14	31.0%	0.0%	42.6%	2.0%	5.3%		1.2%	82.1%
below -10	below 14	6.5%	0.0%	1.2%				0.0%	7.7%
	Total	41.7%	0.0%	48.7%	2.2%	5.5%	0.4%	1.3%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Montreal

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

MUNICH - MUC

Total # of Deicing Operations: ***2788***

All values are estimates:

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	13.8%	0.2%	1.7%	0.0%	0.0%	0.0%		15.7%
0 to -10	32 to 14	69.4%	1.0%	5.2%	0.0%	0.0%			75.6%
below -10	below 14	8.7%	0.0%	0.0%					8.7%
	Total	91.9%	1.2%	6.9%	0.0%	0.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Munich

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

NEWARK - EWR (CONTINENTAL)

Total # of Deicing Operations: **343**

All values are estimates: **X**

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	5.8%	0.0%	0.0%	0.0%	0.0%	2.3%		8.2%
0 to -10	32 to 14	7.0%	0.0%	52.5%	0.0%	19.5%			79.0%
below -10	below 14	0.0%	0.0%	12.8%					12.8%
Total		12.8%	0.0%	65.3%	0.0%	19.5%	2.3%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Newark

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

PARIS CHARLES DE GAULLE - CDG

Total # of Deicing Operations: 1300

All values are estimates:

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	17%	0%	0%	0%	0%	0%		17.4%
0 to -10	32 to 14	58%	0%	24%	0%	0%			82.6%
below -10	below 14	0%	0%	0%					0.0%
	Total	75.8%	0.0%	24.2%	0.0%	0.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Paris CDG

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

PARIS ORLY - ORY

Total # of Deicing Operations: *654*

All values are estimates:

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	15.1%	0.0%	8.4%	0.0%	0.0%	0.0%		23.5%
0 to -10	32 to 14	50.3%	0.0%	26.1%	0.0%	0.0%			76.5%
below -10	below 14	0.0	0.0	0.0					0.0%
	Total	65.4%	0.0%	34.6%	0.0%	0.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Paris ORL

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

PITTSBURGH - PIT

Total # of Deicing Operations: 3242

All values are estimates:

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	0.0%	0.0%	0.6%	0.1%	0.4%	0.0%	0.3%	1.4%
0 to -10	32 to 14	8.7%	0.0%	70.7%	1.1%	2.2%		15.5%	98.2%
below -10	below 14	0.0%	0.0%	0.0%				0.4%	0.4%

Total	8.7%	0.0%	71.3%	1.2%	2.6%	0.0%	16.2%

100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Pittsburgh

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

TORONTO - YYZ

Total # of Deicing Operations: **6446**

All values are estimates:

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	7.5%	0.0%	11.8%	0.0%	0.0%	0.2%	1.1%	20.6%
0 to -10	32 to 14	27.8%	0.0%	43.7%	0.0%	0.0%		6.0%	77.6%
below -10	below 14	0.2%	0.0%	1.3%				0.0%	1.6%
Total		35.6%	0.0%	56.8%	0.0%	0.0%	0.2%	7.2%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Toronto

TABLE 1 (FOR TYPE I FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

SUMMARY OF ALL AIRPORTS

Total # of Deicing Operations: *37091*

All values are estimates:

OAT		Weather Conditions							Total
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
above 0°	above 32°	15.5%	0.17%	13.0%	0.6%	0.7%	0.2%	0.2%	30.4%
0 to -10	32 to 14	27.4%	0.21%	31.42%	1.43%	1.53%		2.6%	64.5%
below -10	below 14	4.4%	0.0%	0.59%				0.0%	5.0%
	Total	47.7%	0.4%	45.0%	2.0%	2.3%	0.2%	2.8%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TI 01-02
At: T1-Final

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

AMSTERDAM - AMS

Total # of Deicing Operations: **2960** | Type I included: **NO** | All values are estimates: **X**

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Weather Conditions: FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0 75/25 50/50	6.5%	1.8%	3.3%	1.5%	0.0%	0.7%	0.0%	13.9%
0 to -3	32 to 27	100/0 75/25 50/50	50.7%	9.3%	15.4%	1.1%	0.0%		0.0%	76.5%
below -3 to -14	below 27 to 7	100/0 75/25	9.7%	0.0%	0.0%	0.0%	0.0%		0.0%	9.7%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	66.9%	11.1%	18.7%	2.6%	0.0%	0.7%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Amsterdam

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

CHICAGO - ORD (AMERICAN EAGLE)

Total # of Deicing Operations: *2500* **Type I included** NO **All values are estimates:** X

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0 75/25 50/50	0.0%	0.0%	72.0%	4.0%	8.0%	0.0%	0.0%	84.0%
0 to -3	32 to 27	100/0 75/25 50/50	0.0%	0.0%	16.0%	0.0%	0.0%		0.0%	16.0%
below -3 to -14	below 27 to 7	100/0 75/25	0.0%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	0.0%	0.0%	88.0%	4.0%	8.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Chicago A.E.

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

CHICAGO - ORD (UNITED)

Total # of Deicing Operations: **2425** Type I included **YES** All values are estimates:

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0 75/25 50/50	0.0%	12.4%	66.0%	3.9%	6.2%	0.0%	0.0%	88.5%
0 to -3	32 to 27	100/0 75/25 50/50	0.0%	0.0%	11.5%	0.0%	0.0%		0.0%	11.5%
below -3 to -14	below 27 to 7	100/0 75/25	0.0%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
Total			0.0%	12.4%	77.5%	3.9%	6.2%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Chicago UN

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

FRANKFURT - FRA

Total # of Deicing Operations: **4474** | Type I included **NO** | All values are estimates:

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Weather Conditions: FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0 75/25 50/50	16.4%	0.0%	18.0%	0.0%	2.7%	6.2%	0.0%	43.4%
0 to -3	32 to 27	100/0 75/25 50/50	12.9%	0.0%	16.7%	1.0%	0.0%		0.0%	30.6%
below -3 to -14	below 27 to 7	100/0 75/25	16.8%	0.0%	9.3%	0.0%	0.0%		0.0%	26.0%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	46.0%	0.0%	44.0%	1.0%	2.7%	6.2%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Frankfurt 4

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

HELSINKI - HEL

Total # of Deicing Operations: *7741* **Type I included** NO **All values are estimates:** X

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0 75/25 50/50	9.7%	0.7%	12.7%	2.0%	0.4%	0.0%	0.0%	25.5%
0 to -3	32 to 27	100/0 75/25 50/50	10.9%	0.0%	37.1%	1.3%	0.2%		0.0%	49.5%
below -3 to -14	below 27 to 7	100/0 75/25	14.2%	0.6%	8.3%	0.6%	0.1%		0.0%	23.8%
below -14 to -25	below 7 to -13	100/0	1.0%	0.0%	0.1%					1.1%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	35.8%	1.4%	58.2%	3.8%	0.7%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: t2-Helsinki

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

LONDON HEATHROW - LHR

Total # of Deicing Operations: *2053* **Type I included** NO **All values are estimates:** X

OAT		Type IV Fluid Concentration	Weather Conditions							Total
°C	°F	Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	
above 0º	above 32º	100/0 75/25 50/50	15.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.0%
0 to -3	32 to 27	100/0 75/25 50/50	75.0%	0.0%	0.0%	0.0%	0.0%		0.0%	75.0%
below -3 to -14	below 27 to 7	100/0 75/25	10.0%	0.0%	0.0%	0.0%	0.0%		0.0%	10.0%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-London HR

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

LONDON GATWICK - LGW

Total # of Deicing Operations: **1421** | Type I included: **NO** | All values are estimates: **X**

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0 75/25 50/50	15.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.0%
0 to -3	32 to 27	100/0 75/25 50/50	70.0%	0.0%	0.0%	0.0%	0.0%		0.0%	70.0%
below -3 to -14	below 27 to 7	100/0 75/25	15.0%	0.0%	0.0%	0.0%	0.0%		0.0%	15.0%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	

100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-London GW

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

LOUISVILLE - SDF

Total # of Deicing Operations: 5031 **Type I included** NO **All values are estimates:** X

OAT		Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Weather Conditions							Total
°C	°F		FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	
above 0º	above 32º	100/0 75/25 50/50	30.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	30.1%
0 to -3	32 to 27	100/0 75/25 50/50	40.1%	0.0%	5.2%	2.2%	1.3%		0.0%	48.8%
below -3 to -14	below 27 to 7	100/0 75/25	10.0%	0.0%	6.7%	2.8%	1.7%		0.0%	21.1%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	80.1%	0.0%	11.9%	5.0%	3.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Louisville

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

MONTREAL DORVAL - YUL

Total # of Deicing Operations: 1672 **Type I included** NO **All values are estimates:**

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0 75/25 50/50	0.1%	0.0%	5.3%	0.1%	0.5%	0.2%	0.0%	6.2%
0 to -3	32 to 27	100/0 75/25 50/50	0.7%	0.0%	37.3%	0.8%	6.5%		1.5%	46.8%
below -3 to -14	below 27 to 7	100/0 75/25	1.9%	0.0%	36.2%	1.9%	5.7%		0.4%	46.1%
below -14 to -25	below 7 to -13	100/0	0.1%	0.0%	0.8%					0.9%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	2.7%	0.0%	79.5%	2.9%	12.7%	0.2%	1.9%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Montreal

1672

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

MUNICH - MUC

Total # of Deicing Operations: 2439 **Type I included** NO **All values are estimates:**

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0º	above 32º	100/0 75/25 50/50	0.3%	0.2%	24.6%	0.2%	0.0%	0.7%	0.0%	26.0%
0 to -3	32 to 27	100/0 75/25 50/50	2.3%	5.8%	40.9%	0.3%	0.1%		0.0%	49.4%
below -3 to -14	below 27 to 7	100/0 75/25	2.1%	13.7%	8.7%	0.0%	0.0%		0.0%	24.5%
below -14 to -25	below 7 to -13	100/0	0.0%	0.1%	0.0%					0.1%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	4.7%	19.8%	74.2%	0.5%	0.1%	0.7%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Munich

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

NEWARK - EWR (CONTINENTAL)

Total # of Deicing Operations: **343** Type I included **YES** All values are estimates: **X**

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0 75/25 50/50	5.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.8%
0 to -3	32 to 27	100/0 75/25 50/50	7.0%	0.0%	23.3%	0.0%	7.9%		0.0%	38.2%
below -3 to -14	below 27 to 7	100/0 75/25	0.0%	0.0%	37.0%	0.0%	11.7%		0.0%	48.7%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	7.3%					7.3%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
Total			12.8%	0.0%	67.6%	0.0%	19.5%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Newark

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

PARIS CHARLES DE GAULLE - CDG

Total # of Deicing Operations: *150* **Type I included** YES **All values are estimates:**

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0, 75/25, 50/50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0 to -3	32 to 27	100/0, 75/25, 50/50	0.0%	0.0%	0.0%	33.3%	0.0%		0.0%	33.3%
below -3 to -14	below 27 to 7	100/0, 75/25	0.0%	0.0%	66.7%	0.0%	0.0%		0.0%	66.7%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	0.0%	0.0%	66.7%	33.3%	0.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Paris CDG

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

PARIS ORLY - ORY

Total # of Deicing Operations: **675** | Type I included: **NO** | All values are estimates:

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Weather Conditions: FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0, 75/25, 50/50	11.9%	0.0%	5.9%	0.0%	0.0%	0.0%	0.0%	17.8%
0 to -3	32 to 27	100/0, 75/25, 50/50	53.5%	0.0%	26.7%	0.0%	0.0%		0.0%	80.1%
below -3 to -14	below 27 to 7	100/0, 75/25	1.2%	0.0%	0.6%	0.0%	0.0%		0.0%	1.8%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
Total			66.5%	0.0%	33.2%	0.0%	0.0%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Paris ORLY

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

TORONTO - YYZ

Total # of Deicing Operations: 1549 **Type I included:** NO **All values are estimates:**

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	Total
above 0°	above 32°	100/0 75/25 50/50	0.0%	0.0%	28.0%	0.0%	0.0%	0.1%	3.4%	31.6%
0 to -3	32 to 27	100/0 75/25 50/50	0.1%	0.0%	42.3%	0.0%	0.0%		1.6%	44.0%
below -3 to -14	below 27 to 7	100/0 75/25	0.0%	0.0%	23.8%	0.0%	0.0%		0.3%	24.1%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	0.1%	0.0%	94.1%	0.0%	0.0%	0.1%	5.4%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

PITTSBURGH - PIT

Total # of Deicing Operations: 762 **Type I included** YES **All values are estimates:**

OAT		Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Weather Conditions							Total
°C	°F		FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	
above 0°	above 32°	100/0	0.0%	0.0%	0.0%	0.4%	1.7%	0.0%	0.0%	2.1%
		75/25								
		50/50								
0 to -3	32 to 27	100/0	0.0%	0.0%	44.8%	3.0%	6.7%		0.0%	54.5%
		75/25								
		50/50								
below -3 to -14	below 27 to 7	100/0	0.0%	0.0%	39.0%	1.7%	2.8%		0.0%	43.4%
		75/25								
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%					0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	0.0%	0.0%	83.7%	5.1%	11.2%	0.0%	0.0%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-PIT

TABLE 2 (FOR TYPE IV FLUID)
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

SUMMARY OF ALL AIRPORTS 2001-2002

Total # of Deicing Operations: **36193** Type I included **YES** All values are estimates:

OAT		Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Weather Conditions							Total
°C	°F		FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER	
above 0º	above 32º	100/0 75/25 50/50	10.5%	1.1%	17.8%	1.1%	1.5%	0.9%	0.1%	33.1%
0 to -3	32 to 27	100/0 75/25 50/50	21.9%	1.2%	21.8%	1.1%	0.7%		0.1%	46.8%
below -3 to -14	below 27 to 7	100/0 75/25	8.7%	1.1%	8.6%	0.6%	0.7%		0.0%	19.7%
below -14 to -25	below 7 to -13	100/0	0.2%	0.0%	0.1%					0.4%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	41.4%	3.4%	48.3%	2.8%	2.9%	0.9%	0.3%	100% of Operations

M:\Groups\CM1747\Survey\Survey Results\Percent Tables TII TIV 01-02
At: T2-Final

This page intentionally left blank.

APPENDIX F

PROPOSED STANDARD FOR HOLDOVER TIME TABLE FORMAT

PROPOSED STANDARD FOR HOLDOVER TIME TABLE FORMAT

Foreword

The purpose of this Aerospace Standard (AS) would be to set the format used for the future Holdover Time Tables. This standard would encompass formats for tables used for all fluid types.

The current table format was developed a decade ago, and has been retained for the sake of continuity. In June 2002, it was decided by the SAE G–12 Holdover Time Subcommittee, that there was a need for the SAE to develop and publish a standard format for all Holdover Time Tables, as the SAE had decided to discontinue their role in publishing HOT tables. The consequence of this decision was that guidelines (or tables) would now be published by different regulatory authorities. An SAE standard table format would allow the holdover time subcommittee a degree of control over the form of tables. This common framework would also provide uniformity in the future.

The structure of the tables is based on categories of precipitation and, with these categories, cell representing temperature ranges. Each cell contains a holdover time range for a specific fluid type and dilution. The holdover time range is the endurance time in hours: minutes for the icing intensity limits. Freezing the format of the present Type II, Type IV, Type III and Type I tables would provide a standard format for regulatory authorities and industry to follow. It would also grant the SAE control over any future modifications required to the tables and would not leave the responsibility solely up to the regulatory authorities.

Providing pilots with HOT guidelines in a constant format is an important enhancement, making the tables easier to use during operations, as well as potentially reducing errors where incorrect holdover time values are selected. However, it is equally important that pilots be provided with instruction as to how the tables are to be interpreted and applied in winter operations.

The process for developing values for the various cells in the HOT tables is founded on very refined and precise test procedures that have evolved over a number of years. On the other hand, the field application of those same values is somewhat open to user interpretation. It is believed that there is a large gap between the level of refinement and sophistication typical of the HOT guideline development process, and the precision with which the HOT guidelines are applied in the field. Providing pilots with common information on applying the HOT guidelines might assist in closing that gap.

The potential for differing interpretations of HOT guidelines may be illustrated by exploring their application in a frost and a snowfall condition, with an application of SAE Type I fluid.

Applying HOT Guideline Values for SAE Type I Fluid in Frost

The selection of HOT values used with Type I fluid application is not open to interpretation as only a single value is used in each cell, and for Type I Fluid, the same values applies regardless of temperature.

Here the only real question is whether the HOT guideline is used at all, and this decision is based on whether *active* frost exists. If the frosting condition that produced frost on the aircraft surfaces has terminated, then holdover times are not needed. Because there is no external advice on the existence or non-existence of active frost, the pilot makes his own decision.

The conditions that generate frost are:

- Temperatures below or slightly warmer than 0ºC;
- Calm or low wind;
- Darkness; and
- Clear sky.

These are generally known to pilots, however some advice may assist in making the right decision. Some examples are listed below.

OAT
As an example, the pilot may believe that an outside temperature above 0ºC may terminate frost generation. In fact, this may be the condition in which frost intensity is heaviest, and shortest fluid endurance times may occur. Providing pilots with some information on the relationship of frost intensity to OAT may be useful.

Darkness
Although the sun may have risen and the sky has lightened, some part of the wings may still be in shadow, and may be experiencing frost growth. Non-symmetrical frost growth may occur because of the shadowing effect of terminal structures such as loading bridges.

Fuel temperature on aircraft parked overnight
Typically, flight fuel is boarded in the morning and thus overnight temperatures do not influence fuel temperature. Some operations, however, use tankered fuel where sufficient fuel is boarded for the return trip, and the fuel resides in the wing tanks overnight. Because in frost conditions the wing surface temperature may drop as much as 6ºC below OAT, at time of morning departure the wing tank fuel may be considerably colder than OAT, and may support ongoing frost on wing surfaces over the fuel tanks. Although similar to the cold-soaked fuel condition that can be experienced at arrival after long flight legs with tankered fuel, it may not be recognized by the pilot as a special condition that needs to be considered.

Applying HOT Guideline Values for SAE Type I Fluid in Snowfall (Temperature in the range *below -3 to -6ºC*)

Moderate snow is defined as being a snowfall rate greater than 10 $g/dm^2/h$ but less than 25 $g/dm^2/h$. Because weather information provided to the pilot does not reflect these measures, nor does it necessarily reflect the real condition existing during the actual flight departure, the pilot uses visual clues to assess the intensity of snowfall. HOT guidelines provided by Transport Canada include a table for the pilot's use to convert visibility distance in snow to snowfall intensity. The resulting snowfall intensity value, along with ambient temperature, is then used to select a HOT value from the guideline.

In the conversion table, moderate snow is associated with visibility distance greater than 1 mile and up to 2 ½ miles. If the pilot can see a reference point at 2 miles distant, then moderate snowfall is indicated.

When the pilot has made this identification, he may refer to the table, select the moderate snow column and the appropriate temperature band, and simply choose to use the lower of the two values shown in the selected cell of the HOT table.

Alternatively, because the reference point is closer to the light end of the moderate snowfall range, the pilot may believe that a *light-moderate* condition exists, as opposed to a *heavy-moderate* if visibility had been more restricted, and may choose a different value within the indicated HOT range.

In the holdover guideline, the holdover time range for moderate snow in the temperature range *below -3 to -6ºC* is 5 to 8 minutes. The pilot, having identified a *light-moderate* snowfall, then may select 8 minutes as being the appropriate holdover time.

A similar interpolative process can occur with the temperature band, where the pilot may choose to select a value somewhere within the range of holdover time values (5 to 8 minutes) based on where the temperature falls within the temperature band (below -3 to -6ºC).

To improve the commonality of guideline interpretation and to ensure its safe application, it is recommended that a common industry set of application instructions be developed.

Before doing this, it would be useful to review what is currently happening in the field. Because the guidelines have existed for some years, it is probable that operators have evolved their own internal procedures for interpretation and application, and that these may differ significantly between operators. It is important therefore that the variety of application procedures existing within the industry be investigated and documented before deciding upon and issuing industry-wide procedures. In addition to avoiding unpleasant surprises, the review process may also be helpful in identifying operationally viable and realistic ways of applying the HOT guidelines for incorporation in the common set of instructions.

At this time, the aerospace standard is at the project phase of development; its contents have not been reviewed, corrected or approved by the SAE G-12 Holdover Time Subcommittee. The standard will need to be subjected to a detailed review before it becomes effective.

CONTENTS

1. SCOPE

1.1 Purpose

The purpose of this Aerospace Standard (AS) would be to set the format used for the Holdover Time Tables. This standard would encompass formats for the tables used for all fluid types. An SAE standard table format would allow the holdover time subcommittee a degree of control over the tables. The regulatory authorities want the Holdover Time Subcommittee role to be advisory to the HOT development process. SAE considers that there is value in providing a medium for the aerospace industry to discuss testing methods and the latest data.

1.2 Role of SAE in Table Format

The SAE Aerospace council made the decision in June 2001 to no longer publish holdover timetables. For that reason ARP4737 was modified and these tables were removed. The generic and fluid-specific guidelines have been published by Transport Canada and the FAA since this time.

1.3 Role of the G-12 HOT Subcommittee

The Holdover Time Subcommittee will now make recommendations to the regulatory authorities. However, the regulatory authorities do not have to act on recommendations made by the Holdover Time Subcommittee.

2. EXAMINATION OF HOLDOVER TABLE FORMAT

2.1 Explanation of Holdover Times

All holdover timetables are composed of cells. Each cell, with the exception of frost, contains a holdover time range for a specific fluid type and dilution, temperature range, and category of precipitation. The time range in each cell is defined by a "lower" time and an "upper" time; these values represent the average failure time of the fluid at upper and lower precipitation rate limits, respectively. The upper and lower precipitation limits for each condition is shown in Figure 2.1.

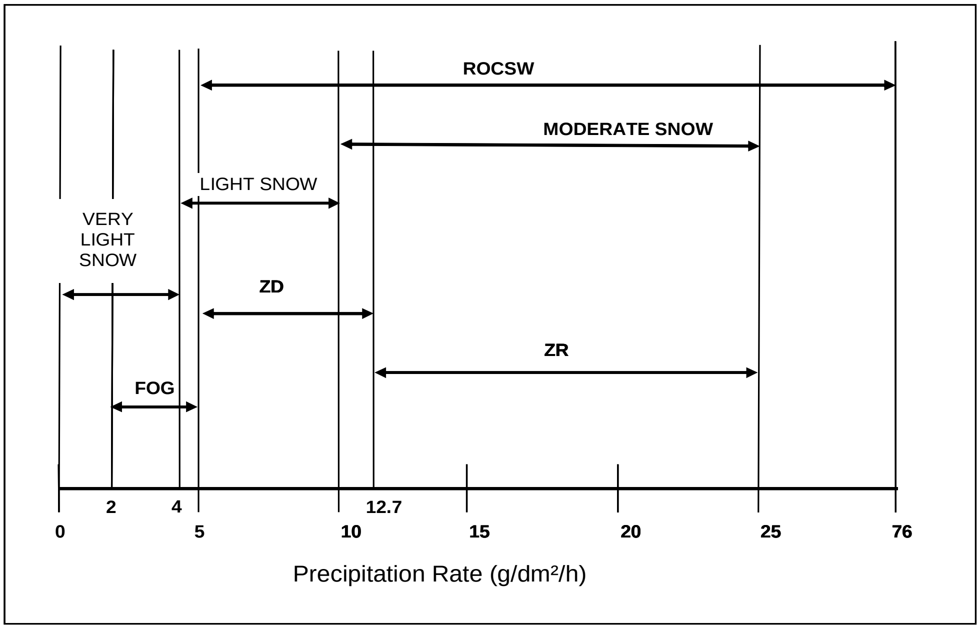


Figure 2.1: Precipitation Rate Ranges Used For Evaluation of Holdover Time Limits

2.2 Definition of Winter Weather Conditions

Holdover time guidelines are provided as a function of *weather condition*, fluid mixture, and outside air temperature (OAT). Table 2.1 provides definitions of most weather conditions experienced in winter operations and includes the criteria used to determine precipitation intensity (light, moderate, and heavy). This table was compiled by the National Centre for Atmospheric Research (NCAR) from the World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983), and from the American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS) (3/94).

Table 2.1 includes definitions for the weather conditions noted in the holdover timetables: frost, freezing fog, snow, freezing drizzle, light freezing rain, and rain). Definitions for hail and ice pellets are also presented; however, no holdover time guidelines exist for these conditions.

Table 2.1: Definition of Winter Weather Data

Weather Phenomenon*	Definition*
FROST (No METAR code) Note: No Intensity is assigned to FROST.	Ice crystals that form from ice-saturated air at temperatures below 0°C (32°F) by direct sublimation on the ground or other exposed objects.
FREEZING FOG (FZFG) Note: No Intensity is assigned to FRZ FOG.	A suspension of numerous minute water droplets which freezes upon impact with ground or other exposed objects, generally reducing the horizontal visibility at the earth's surface to less than 1 km (5/8 mile).
SNOW (SN)	Precipitation of ice crystals, most of which are branched, star-shaped, or mixed with unbranched crystals. At temperatures higher than about -5°C (23°F), the crystals are generally agglomerated into snowflakes.
FRZING DRIZZLE (FZDZ)	Fairly uniform precipitation composed exclusively of fine drops [diameter less than 0.5 mm (0.02 in.)] very close together which freezes upon impact with the ground or other exposed objects.
FREEZING RAIN (FZRA)	Precipitation of liquid water particles which freezes upon impact with the ground or other exposed objects, either in the form of drops of more than 0.5 mm (0.02 in.) or smaller drops which, in contrast to drizzle, are widely separated.
RAIN (RA)	Precipitation of liquid water particles either in the form of drops of more than 0.5 mm (0.02 in.) diameter or of smaller widely scattered drops.
SNOW PELLETS (GS)	Precipitation of white and opaque grains of ice. These grains are spherical or sometimes conical; their diameter is about 2-5 mm (0.1-0.2 in.). Grains are brittle, easily crushed; they bounce and break on hard ground.
SNOW GRAINS (SG)	Precipitation of very small white and opaque grains of ice. These grains are fairly flat or elongated; their diameter is less than 1 mm (0.04 in.). When the grains hit hard ground, they do not bounce or shatter.
HAIL (GR)	Precipitation of small balls or pieces of ice with a diameter ranging from 5 to > 50 mm (0.2 to 2.0 in.) falling either separately or agglomerated.
ICE PELLETS (PE) Note: Includes Sleet and Small Hail	Precipitation of transparent (sleet or grains of ice), or translucent (small hail) pellets of ice, which are spherical or irregular, and which have a diameter of 5 mm (0.2 in.) or less. The pellets of ice usually bounce when hitting hard ground.

Intensity Criteria**

	Snow(SN),Pellets(GS),Grains(SG),Frz Drizzle(FZDZ)		Ice Pellets (PE)
Estimated Intensity	Horizontal Visibility (statute mile)	Liquid Equivalent Snow (S) Intensity***	Definition and Horizontal Visibility
Light (-)	If visibility is: ≥ 5/8 mi (≥ 1.0 km)	Trace to 0.05 in/hr (≤ 1.0 mm or 10.0 gr/dm²/hr)	Scattered pellets on the ground. Visibility <u>not</u> affected.
Moderate	If visibility is: < 5/8 to 5/16 mi (< 1.0 to 0.5 km)	> 0.05 to 0.10 in/hr (> 1.0 to 2.5 mm/hr) (> 10.0 to 25.0 gr/dm²/hr)	Slow accumulation on the ground. Visibility reduced to less than 7 mi.
Heavy (+)	If visibility is: < 5/16 mi (< 0.5 km)	More than 0.10 in/hr (> 2.5 mm or 25.0 gr/dm²/hr)	Rapid accumulation on the ground. Visibility reduced to less than 3 mi.

Note: Horizontal visibility is only an estimation of snow and freezing drizzle intensity. Measurements and observations have shown that visibility and precipitation intensity are not always directly correlated.

	Drizzle Intensity (FZDZ)
Light(-)	Trace to 0.01 in/hr (0.254 mm or 2.54 gr/dm²/hr)
Moderate	From 0.01 to 0.02 in/hr (2.54 to 5.08 gr/dm²/hr)
Heavy(+)	More than 0.02 in/hr (> 5.08 gr/dm²/hr) Note: Drizzle > 0.04 in/hr is usually in the form of rain.

		Rain (RA), Freezing Rain (FZRA), Ice Pellets (PE)
Light (-)	Measured Intensity	Up to 0.10 in/hr (2.5 mm or 25 gr/dm²/hr); Maximum 0.01 inch in 6 minutes
	Estimated Intensity	From scattered drops that, regardless of duration, do not completely wet an exposed surface up to a condition where individual drops are easily seen.
Moderate	Measured Intensity	0.11 in to 0.30 in/hr (7.6 mm or 76 gr/dm²/hr); More than 0.01 to 0.03 inch in 6 minutes
	Estimated Intensity	Individual drops are not clearly identifiable; spray is observable just above pavement and other hard surfaces.
Heavy (+)	Measured Intensity	More than 0.30 in/hr (7.6 mm or 76 gr/dm²/hr); More than 0.03 inch in 6 minutes
	Estimated Intensity	Rain seemingly falls in sheets; individual drops are not identifiable; heavy spray to height of several inches is observed over hard surfaces.

* From World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983)
** From American Meteorological Society, Glossary of Meteorology WSOH #7 MANOBS (3/94)
*** NCAR Proposed Definition for Liquid Equivalent Snowfall Intensity

1) gm/dm² = 0.01 cm = 0.1 mm = 0.0039 in
2) in = 2.54 cm = 25.4 mm = 254 gm/dm²

Compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP June 17, 1997 (Updated for METAR codes)

2.2.1 Frost

The numbers set forth in the SAE Holdover Time (HOT) Guidelines relating to frost have never been substantiated but merely produced based on High Humidity Endurance Tests (HHET). Since HHET are conducted under one test condition, the frost endurance numbers indicated in the SAE HOT Guidelines as well as those in all fluid-specific tables, except for a few, are the same for the five frost conditions that exist in the current HOT tables. These numbers are more appropriate for the warmer conditions, but some SAE G-12 members have expressed concern that the numbers may be too high at the colder temperatures.

Frost is a uniform thin white deposit of fine crystalline texture that forms on exposed surfaces during below-freezing, calm, cloudless nights with the air at the surface close to saturation but with no precipitation. The deposit is thin enough for surface features underneath, such as paint lines, markings and lettering, to be distinguished (TC Web Site).

2.2.2 Snow

Table 2.1 contains the criteria generally used to estimate the intensity of snow. These criteria are based upon horizontal visibility. Three intensity levels are defined as follows:

a) Light snow Visibility is greater than or equal to 1.0 km;
b) Moderate snow Visibility is 0.5 km to less than1.0 km; and
c) Heavy snow Visibility is less than 0.5 km.

As stated in a cautionary note in Table 2.1, visibility is only an indicator of snow intensity, and the two parameters are not always correlated.

Table 2.2 provides more detail about snow visibility than outlined in Table 2.1. Devised by APS and Transport Canada, this table was revised this year for operations in the winter of 2003-04. Changes from the table used in the winter of 2002-03 include the addition of a very light snow category and changes to the visibility ranges for snowfall intensities. The changes are documented in detail in a separate TC report entitled *Examination off the Relationship between Visibility and Snowfall Intensity based on Historical Data*, TP 14145E.

The visibility table is based on NCAR field data, theoretical work on classes of snow and additional field data compiled by APS. The table gives visibility in distance for four snowfall intensities in both daylight and in darkness. The Snow Visibility versus Snowfall Intensity Chart, shown in Table 2.2, is published annually by TC for use in winter operations. The FAA visibility table differs somewhat from the TC visibility table (see Appendix D).

Table 2.2: TC Snow Visibility Chart

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	≤ ½	> ½ 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: *Relationship between Visibility and Snowfall Intensity* (TP 14151E), Transportation Development Centre, Transport Canada, to be published in November 2003; and *Theoretical Considerations in the Estimation of Snowfall Rate Using Visibility* (TP 12893E), Transportation Development Centre, Transport Canada, November 1998.

2.2.3 Freezing Drizzle

Freezing drizzle is composed of closely-spaced fine water droplets with a diameter of less than 0.5 mm (see Table 2.1). Like snow, the intensity of freezing drizzle is estimated through the measurement of horizontal visibility. The holdover timetable has one column for freezing drizzle, but Table 2.1 shows three intensity levels (light, moderate, and heavy). For example, under moderate freezing drizzle, the rate of precipitation should range between 2.5 and 5.1 $g/dm^2/h$. For heavy freezing drizzle, the definition indicates that the intensity is greater than 5 $g/dm^2/h$. The upper limit value of 12.7 $g/dm^2/h$ for freezing drizzle was discussed and set by United Airlines, National Centre for Atmospheric Research, and the National Research Council Canada (NRC). This value was also used as the lower limit for light freezing rain.

2.2.4 Freezing Rain

Freezing rain exists in the form of drops; droplets are distinguished by a diameter size of greater or less than 0.5 mm. In contrast to drizzle, freezing rain droplets are widely separated. For each of the three intensities of freezing rain given in Table 2.1, a visual description is supplied to provide a subjective guideline for estimating rain intensity. However, when an instrument is available to measure the intensity of precipitation, the following definitions apply:

a) Light — Precipitation rate is $\leq$ 25 $g/dm^2/h$;
b) Moderate — Precipitation rate is $>$25 $g/dm^2/h$ but $\leq$76 $g/dm^2/h$; and
c) Heavy — Precipitation rate is $>$76 $g/dm^2/h$.

2.2.5 Freezing Fog

Freezing fog is defined as suspended minute water droplets that freeze upon impact with the ground or exposed objects (see Table 2.1). Horizontal visibility is reduced to less than 1 km in freezing fog, there is however no indication of the intensity or the liquid water content of the fog.

It was concluded that current HOT table precipitation rate limits of 2 and 5 $g/dm^2/h$ are conservative, with rates measured during actual fog conditions closer to 1 $g/dm^2/h$. For an account of testing from previous years, refer to Transport Canada report, TP 13993E (1), *Impact of Winter Weather on Holdover Time Table Format (1995-2002),* December 2002.

2.2.6 Rain on Cold Soaked Wing

Cold soaking derives largely from tankering fuel in a wet wing for an extended period of time at high altitude, which often results in the aircraft arriving at an airport with the wings at a below freezing temperature. When rain or warm humid conditions are present at the destination airport, ice tends to form on the wing's upper surface. There may also be an accumulation of ice at the wing's cold corner. In addition, there may also be substantial frost or ice forming under the wing. Under such conditions careful checks should be made because the ice thusly formed is often difficult to identify; the wing may merely appear to be wet. The icing intensity range shown in Figure 2.1, of 5 to 76 g/dm²/h is considered moderate.

2.3 Type II, Type III, and Type IV Tables

The HOT table format for Type II, Type III, and Type IV fluids remain essentially the same as those published in 2003-04. The Type IV table used here as an example (see Figure 2.2) is comprised of seven columns, which describe the precipitation and five rows that indicate temperature ranges. The applicable fluid dilutions by temperature are also listed here. This table format would be essentially the one used for all three fluid types.

SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2003-2004[1]

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Type IV Fluid Concentration	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
°C	°F	Neat Fluid/Water (Vol% / Vol%)	Frost[2]	Freezing Fog	Snow	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[5]
above 0	above 32	100/0							
		75/25							
		50/50							
0 to -3	32 to 27	100/0						CAUTION:	
		75/25						No holdover	
		50/50						time	
below -3 to -14	below 27 to 7	100/0						guidelines	
		75/25						exist	
below -14 to -25	below 7 to -13	100/0							
below -25	below -13	100/0	Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.						

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature Vol = Volume

NOTES

1 Based on tests of neat fluids with the lowest viscosity deliverable on the aircraft, yet meeting Type IV WSET and HHET.
2 During conditions that apply to aircraft protection for ACTIVE FROST.
3 The lowest use temperature is limited to -10°C (14°F).
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.

CAUTIONS

- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.**
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**
- **Fluids used during ground deicing do not provide ice protection during flight.**

Figure 2.2: Example of Type IV Table Format

2.3.1 Precipitation Conditions

The precipitation conditions covered in the columns across the table are Frost, Freezing Fog, Snow, Freezing Drizzle, and Light Freezing Rain, Rain on Cold Soaked Wing, and Other. Figure 2.1 shows the icing intensities values for the above conditions.

2.3.2 Temperature Ranges

The temperature ranges are indicated in rows along the side of the table, these are: Above 0ºC, 0 to -3ºC, below -3 to -14ºC, below -14ºC to -25ºC, and below -25ºC

2.3.3 Interpretation of HOT Values

This section is to be established, and is beyond the scope of this document at the present time.

2.3.4 Type I Tables

The Type I table is comprised of nine columns, which describe the precipitation and four rows that indicate temperature ranges (see Figure 2.3).

SAE TYPE I[5] FLUID HOLDOVER GUIDELINES FOR WINTER 2003-2004

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

OAT		Approximate Holdover Times Under Various Weather Conditions (minutes)								
°C	°F	Frost[2]	Freezing Fog	Very Light Snow[1]	Light Snow[1]	Moderate Snow[1]	Freezing Drizzle[3]	Light Freezing Rain	Rain on Cold Soaked Wing	Other[4]
-3 and above	27 and above									
below –3 to –6	below 27 to 21									
below –6 to –10	below 21 to 14								CAUTION: No holdover time guidelines exist	
below –10	below 14									

°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature FP = Freezing Point

NOTES

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 L/m^2 (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 During conditions that apply to aircraft protection for ACTIVE FROST.
3 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
5 Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10°C (18°F) below OAT.

CAUTIONS

- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content. High wind velocity or jet blast may reduce holdover time below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.**
- **The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.**

Fluids used during ground deicing do not provide ice protection during flight.

Figure 2.3: Type I Table Format

2.3.5 Precipitation Conditions

The Type I table includes the following precipitation conditions: Frost, Freezing Fog, Very Light Snow, Light Snow, Moderate Snow, Freezing Drizzle, Light Freezing Rain, Rain on Cold Soaked Wing, and Other. Figure 2.1 shows the icing intensities values for the above conditions.

2.3.6 Temperature Ranges

Within the Type I table the temperature ranges are used: -3ºC and above, below -3ºC to -6ºC, below -6ºC to -10ºC, and below -10ºC.

2.3.7 Interpretation of HOT Values

This section is to be established, and is beyond the scope of this document at the present time.

3. GUIDANCE FOR PILOT APPLICATION OF HOLDOVER TABLES

(This section is to be established in cooperation with regulatory authorities and industry.)

Providing pilots with HOT guidelines in a constant format is an important enhancement, making the tables easier to use during operations, and as well, potentially reducing errors where incorrect holdover time values are selected. However, it is equally important that pilots be provided with instruction as to how the tables are to be interpreted and applied in winter operations.

The process for developing values for the various cells in the HOT tables is founded on very refined and precise test procedures that have evolved over a number of years. On the other hand, the field application of those same values is somewhat open to user interpretation. It is believed that there is a large gap between the level of refinement and sophistication typical of the HOT guideline development process, and the precision with which the HOT guidelines are applied in the field. Providing pilots with common information on applying the HOT guidelines might assist in closing that gap.

4. REVISION OF HOT TABLE FORMAT

4.1 Role of G-12 HOT Subcommittee

The role of the HOT Subcommittee will be advisory to the HOT development process. They will provide recommendations on future modifications to the table format.

4.2 Role of Regulatory Authorities

The regulatory authorities will follow the proposals made by the HOT subcommittee as much as possible. The regulatory authorities will publish the generic and fluid-specific holdover timetables.