TP 13993E

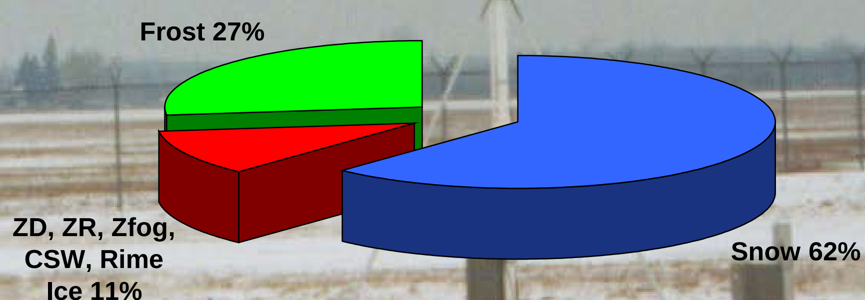
Impact of Winter Weather on Holdover Time Table Format

(1995-2002)

Prepared for
Transportation Development Centre

On behalf of

Civil Aviation
Transport Canada



APS Aviation Inc.

December 2002
Final Version 1.0

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by

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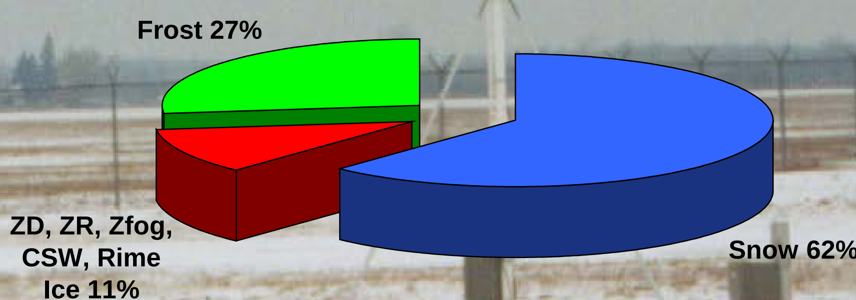
and

Alia Alwaid



APS Aviation Inc.

December 2002

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DOCUMENT ORIGIN AND APPROVAL RECORD

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Notarius

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Program Manager

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Date

Un sommaire français se trouve avant la table des matières

PREFACE

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

- To develop holdover time data for all newly qualified de/anti-icing fluids;
- To evaluate the parameters that are specified in the Proposed Aerospace Standard AS5485 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 develop holdover times in snow using a more realistic protocol for Type I fluid endurance time testing;
- To further evaluate the flow of contaminated fluid from the wing of an aircraft during simulated takeoff runs;
- To examine the change in viscosity with the application process of Type IV fluids;
- To further evaluate hot water deicing;
- To compare endurance times from natural snow with those generated from artificial snow;
- To provide support for the conduct of tactile tests at the Toronto Airport Central Deicing Facility;
- To apply ice sensors to the pre–takeoff contamination check;
- To prepare the JetStar and Canadair RJ wings for thermodynamic tests; and
- To provide support services to Transport Canada.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2001-02 are documented in nine reports. The titles of the reports are as follows:

- TP 13991E Aircraft Ground De/Anti–Icing Fluid Holdover Time and Endurance Time Test Program for the 2001-02 Winter;
- TP 13993E Impact of Winter Weather on Holdover Time Table Format (1995-2002);
- TP 13994E Generation of Holdover Times Using the New Type I Fluid Test Protocol;
- TP 13995E Aircraft Takeoff Test Program for Winter 2001-02: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti–Icing Fluid;
- TP 13996E Influence of Application Procedure on Anti-icing Fluid Viscosity;
- TP 13997E Endurance Time Tests in Snow: Reconciliation of Indoor and Outdoor Data 2000-02;
- TP 13998E Exploratory Deicing Research for the 2001-02 Winter; and
- TP 13999E Support Activities Related to Deicing Research for the 2001-02 Winter.

In addition, the following interim report is being prepared:

- Evaluation of Laboratory Test Parameters for Frost Endurance Time Tests.

This report, TP 13993E, has the following objective:

- To review the 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 the Civil Aviation Group and Transport Canada, with support from the Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City, NJ. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, the National Research Council Canada, Atmospheric Environment Services Canada, and several fluid manufacturers. Special thanks are extended to US Airways Inc., Air Canada, American Eagle Airlines Inc., National Centre for Atmospheric Research, AéroMag 2000, Aéroports de Montreal, Ottawa International Airport Authority, ATCO Airports, Aviation Boréale, 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: Nicolas Blais, Yagusha Bodnar, Alison Cairns, Robert Paris, Parimal Patel, Harvinder Rajwans, Ruth Tikkanen, Bob MacCallum, Trevor Leslie, Chris McCormack, and David Belisle.

Special thanks are extended to Frank Eyre and Barry Myers of the Transportation Development Centre for their participation, contribution, and guidance in the preparation of these documents.

APS especially wishes to recognize the contribution of Charles Ryerson, a cold weather physical specialist, for taking the time to review the report examining parameters for frost endurance time tests while in its draft stage. His technical comments and advice were most helpful in finalizing the report.

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

16. Abstract

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 Environment Canada for six automated weather stations in the province of Quebec, Canada. A total of 3882 hours of snowstorm data recorded between 1995 and 2002 and over 327 hours of freezing rain data were analysed. Included in the data set was over 917 hours of snow data from the 2001-02 winter.

Data from a winter operations survey conducted at a number of international airports was used to report the frequency of snow, frost, freezing fog, freezing rain/drizzle and cold-soak wing occurrences during actual deicing operations. Freezing fog rates measured during natural conditions are also reported.

Based on the data, the Type I fluid holdover time table format was modified through incorporation of new temperature ranges and the addition of a new column for light snow. Further changes to holdover time table format for Type I and other fluid types are discussed. Activities are recommended towards developing a format that offers ease of use while providing optimum operational advantages.

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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 neuf 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 d'Environnement Canada, provenaient de six stations météorologiques automatisées situées au Québec, Canada. Un total de 3 882 heures de données de précipitations neigeuses, enregistrées entre 1995 et 2002, et plus de 327 heures de données de pluie verglaçante, ont été analysées. Sont comprises dans l'ensemble de données plus de 917 heures de données de précipitations neigeuses recueillies au cours de l'hiver 2001-02.

Les données issues d'un sondage sur les opérations hivernales à un certain nombre d'aéroports internationaux ont servi à signaler la fréquence d'événements de neige, de givre, de brouillard verglaçant, de pluie ou bruine verglaçantes et d'aile imprégnée de froid au cours du dégivrage. Les taux de brouillard verglaçant mesurés dans des conditions naturelles sont également signalés.

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 de durées d'efficacité des liquides de type I et d'autres types font l'objet de discussions. Il est recommandé de développer un format facile à utiliser et qui offre des avantages opérationnels optimaux.

17. Mots clés Neige naturelle, taux de précipitation, données météorologiques, tableau de durées d'efficacité, fréquence et répartition des opérations de dégivrage, taux de brouillard, givre.	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
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EXECUTIVE SUMMARY

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. 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 3 882 hours of storm data points was developed from precipitation gauge logs for natural snow, including 917 hours from the 2001-2002 data. Freezing rain/drizzle data, based largely on the 1998 ice storm, were used to develop over 327 hours of storm data. Data were acquired from Environment Canada 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 2001-2002. Similar data were collected for two winters and analysed by Environment Canada, at Toronto's Pearson Airport. Frost and freezing fog deposition rates that were measured during natural conditions are also reported.

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

Results and Conclusions

The weather data base gathered over seven 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 24 percent of all snow events.

Most snowfall events occur at rates less than 10 g/dm^2/h and are not acknowledged in the current HOT table. Because snow comprises 62 percent of all deicing operations, introduction of a light snow column in the HOT table was recommended and accepted at the 2002 SAE G-12 meeting. This led to the need to define a lower rate limit for the new light snow column.

In order to use the longer holdover times in the light snow column, operators need more comprehensive information on snowfall rates lower than 10 g/dm^2/h. This need could be satisfied by the development of the National Center for Atmospheric Research (NCAR) hot plate snow intensity measuring device.

It was concluded for the Type I HOT table that the temperature row *above 0ºC* should be removed and replaced by a new row, *above -3ºC*. The selection of -3ºC as the temperature break produced the most operationally advantageous mix of holdover times, and conformed to the current Type II and IV HOT tables. The format of the Type II/IV HOT tables should be examined with a view to integrating the Type I table changes, including removal of the above 0ºC row and introduction of a light snow column. The HOT table formats should be reviewed to determine the optimum format for ongoing use. This review should consider concepts in Transport Canada's vision of future table format, and finer temperature breaks such as those included in the FAA Type I table.

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 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 formulating frost holdover times for Type I fluid.

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

HOT tables for freezing fog are used only 1 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 development of the NCAR hot plate snow intensity measuring device and the NCAR snowmaker for use in snow endurance time testing be given high priority and support. 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 requested by the SAE G-12 HOT Committee.

SOMMAIRE

À la demande du Centre de développement des transports de Transports Canada, APS Aviation Inc. a entrepris une étude rétrospective des données de précipitation (taux de précipitation, température) de plusieurs hivers pour confirmer la pertinence des intensités de précipitations utilisées pour l'évaluation des durées d'efficacité.

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 3 882 heures, dont 917 heures pendant l'hiver 2001-2002. Des données de pluie/bruine verglaçante, en grande partie fondées sur la tempête de verglas de 1998, ont servi à générer des points de données couvrant plus de 327 heures. Ces données, obtenues auprès d'Environnement Canada, 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 1997-1998 à 2001-2002. Des données analogues ont été recueillies et analysées par Environnement Canada à l'Aéroport international Pearson de Toronto pour deux hivers. Ce rapport comprend les taux de dépôt de givre et de brouillard verglaçant, mesurés en conditions naturelles.

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 sept 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 24 pourcent de tous les événements de neige.

La plupart des chutes de neige se produisent à un taux inférieur à 10 g/dm^2/h et ne sont pas identifiées dans le tableau actuel de durées d'efficacité. Puisque la neige compte pour 62 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 2002 du G–12 de la SAE. Il en a résulté un besoin de définir un taux plancher plus bas pour la nouvelle colonne de neige légère.

Pour utiliser des durées d'efficacité plus basses dans la colonne de neige légère, les exploitants ont besoin de plus amples renseignements sur les taux de chute de neige inférieurs à 10 g/dm^2/h. Ce besoin pourrait être comblé par le développement d'un appareil de mesure de l'intensité de la neige à plaque chauffante du National Center for Atmospheric Research (NCAR).

L'analyse a conclu que, pour le tableau de durées d'efficacité des liquides de type I, la rangée des températures au-dessus de *0ºC* devrait être retirée et remplacée par une nouvelle rangée, *au-dessus de -3ºC*. Le choix de -3ºC comme température limite produit le mélange de durées d'efficacité le plus avantageux du point de vue opérationnel et est conforme aux tableaux actuels des durées d'efficacité des liquides de types II et IV. 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 0ºC et l'introduction d'une colonne de neige légère. Les formats des tableaux de durées d'efficacité devraient être révisés afin d'établir le format optimal pour un usage courant. Cette révision devrait prendre en considération les concepts de futurs formats de tableaux envisagés par Transports Canada, de même que des limites de température plus précises, comme celles du tableau de type I de la FAA.

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 pourcent du temps. La modification de la colonne du tableau de durées d'efficacité applicable au brouillard verglaçant serait justifiée pour une seule valeur plutôt que pour plusieurs, 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 requis par le comité G–12 de la SAE sur les durées d'efficacité.

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GLOSSARY

ADM	Aéroports de Montréal
AES	Atmospheric Environment Services, name changed to MSC as of 2000
AMIL	Anti-Icing Materials International Laboratory
APS	APS Aviation Inc.
ET	Endurance Time
FAA	Federal Aviation Administration
HOT	Holdover Time
NCAR	National Center for Atmospheric Research
NRC	Nation Research Council Canada
OAT	Outside Air Temperature
READAC	Remote Environmental Automatic Data Acquisition Concept
TC	Transport Canada
TDC	Transportation Development Centre

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1. INTRODUCTION

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC), 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 2001-2002 on the evaluation of snow precipitation rate data. It also encompasses all the data presented in the 2000-01 Transport Canada Report, *Evaluation of Winter Weather Data*, TP 13830E (1). This study formed part of the 2001-02 winter research program on deicing, as described in Sections 5.4 and 5.6 of the work statement presented as Appendix A.

Holdover time (HOT) tables are developed as guidelines to be used by the pilots in aircraft departure planning under different winter weather conditions. Each holdover time 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. A general format of these tables is shown later in Section 4.

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 – 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 when implementing the 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, a number of industry members have questioned the suitability of the HOT table format. Several proposed suggestions for change have been made to improve and simplify the tables, while at the same time ensuring that a high level of safety is maintained when the tables are put to use. Proposed changes could 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 resulting 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 conditions and temperatures.

Several years ago, holdover times for snow were evaluated or developed using lower and upper precipitation rates of 10 and 25 g/dm²/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 2000-01 report, *Evaluation of Winter Weather Data*, TP 13830E (1) concluded that the holdover time rate limits of 10 and 25 g/dm²/h are 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 winter weather data and apply it to evaluate the format of the HOT tables; and

c) conduct a more detailed analysis of the HOT table format to evaluate changes and their impact on HOTs.

Secondary objectives included conducting fog deposition measurements outdoors, using a procedure devised during the past year and thus establish the range of fog deposition rates that occur in natural conditions. Also, frost deposition rates were conducted in natural conditions at both warm and cold temperatures to establish deposition rates.

2. METHODOLOGY

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

2.1 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 2002 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 2002; and

d) The data logs for 2000 to 2002 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.

In addition, data has been collected by APS from various sources extending back to the 1990-91 winter season, using different precipitation gauges, as shown in Table 2.1. Each site is identified on a map of Quebec, shown in Figure 2.1. The data 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 (included in Appendix C). Atmospheric Environment Services (AES) carried out a similar study in 1995 using data collected at Lester B. Pearson International Airport in Toronto (included in Appendix D).

2.2 Equipment

The Remote Environmental Automatic Data Acquisition Concept (READAC) precipitation gauge consists of a bucket partially filled with an antifreeze compound so that it effectively captures snow. A weighing transducer 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/dm²).

Table 2.1: Summary of Winter Weather Data

PROJECT #	YEAR	PLATE PAN	READAC YUL	CR21X WUY (Rouyn)	CR21X WTQ (Dorval)	CR21X WQB (Québec)	CR21X WYQ (Pointe-au-Père)	CR21X WFQ (Frelighsburg)	CR21X XHF (High Falls)	CITY OF MONTREAL (Fisher/Porter)
	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]	

[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.

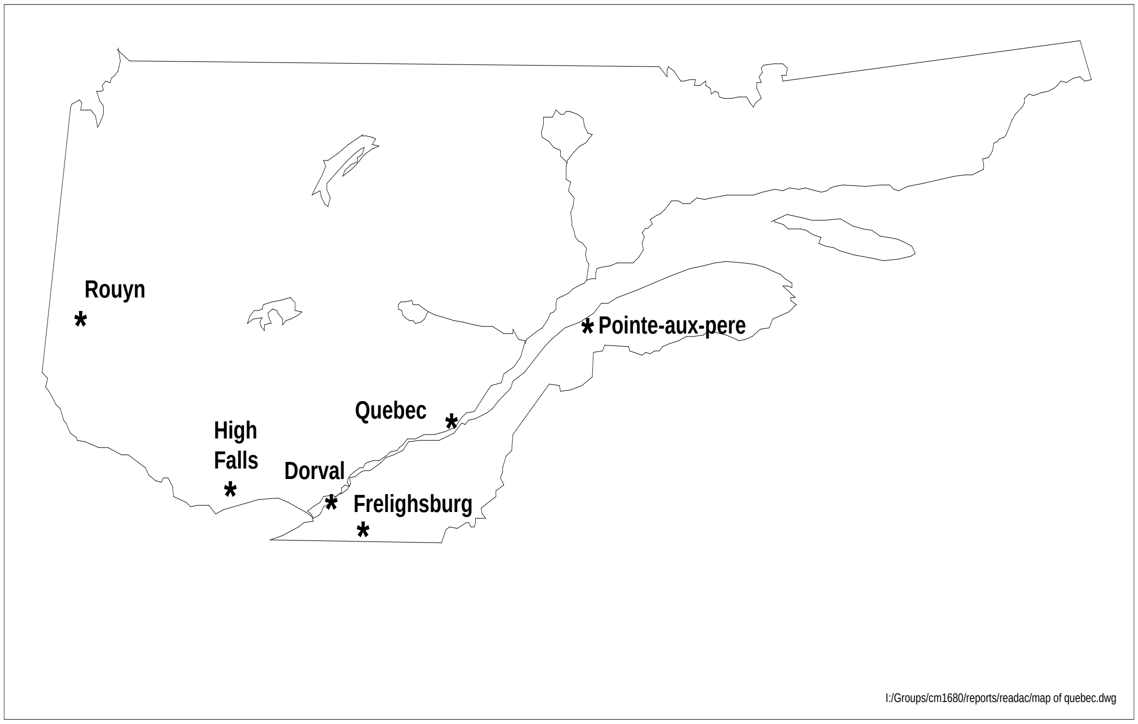

Figure 2.1: Map of Precipitation Gauge Locations

The CR21X station operates on the same principle as the READAC station and has an accuracy of 0.1 mm (1 g/dm²). 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 H.

Precipitation rates tend to fluctuate rapidly during snowstorms. The weight resolution of the READAC stations is less accurate in measuring rapid changes. 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.

For this project, the measuring instruments used to record weather precipitation data were provided by Environment Canada, and these instruments were calibrated according to their standards.

2.3 Description of Analytical Methods

Precipitation rate data were averaged at intervals that correspond to three specified periods typically used in the holdover time tables: 6 minutes for Type I fluids; 20 for

Type II, and 35 for Type IV. 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 2002 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 E. The last page of the summary (E-6) states whether it snowed on a particular day and the first page (E-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.

2.4 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 4. 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. As seen in Figure 2.2, the period when snowfalls were interrupted for a long period of time was 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 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 near the time of weight changes. The start and end of a snowstorm are difficult to establish because the snow might have started and ended gradually at slow rates or abruptly at high rates. For several recent winters, light snowfalls over long periods of time were excluded. For the 2000-01 winter, it was established as a guideline, that snowfalls with total precipitation of 2 cm over 6 hours be excluded; this will be the analytical pattern for successive years.

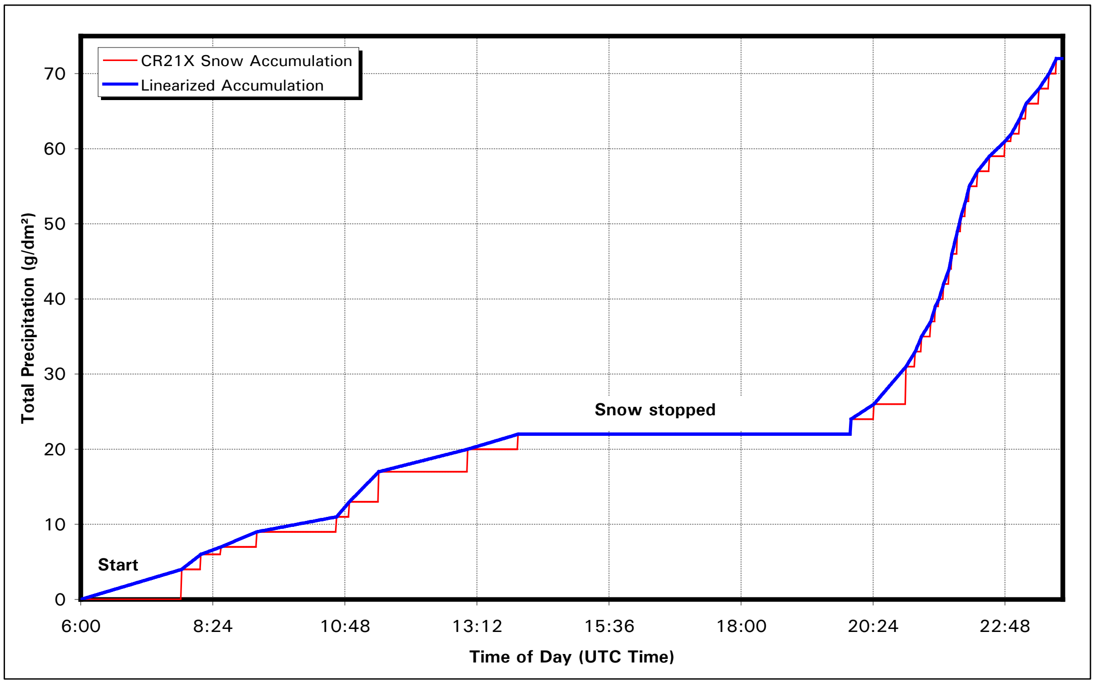

Figure 2.2: CR21X Precipitation Gauge Cumulative and Linearized Precipitation

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**

3. DESCRIPTION AND PROCESSING OF NATURAL SNOW AND FREEZING RAIN/DRIZZLE DATA

3.1 Natural Snow

The 2001-02 winter had less snow accumulation than Quebec's average over the last 30 years. The period of time taken into account to evaluate the quantity of snow precipitation was from November 2001 to April 2002. For the six monitored meteorological stations in Quebec, the quantity of snow in cm/year is shown in Table 3.1.

Table 3.1: Snow Accumulations

	STATION					
	Frelighsburg	Quebec City	Montreal	Rouyn Noranda	Mont-Joli	High Falls
Average Snow Accumulation (cm/year)	-	332	210	-	362	216
2001-02 Winter Snow Accumulation (cm/year)	-	254	173	318	252	213

During the 2001-02 winter season, 55 026 data points were collected for natural snow conditions at the six stations in Quebec. These represent 917 hours of snowfall and an average of approximately 150 hours of snowfall at each station. Due to improvements in the CR21X stations, much more data collected during the past winter were usable in this analysis. The Dorval and Quebec data for 2001-02 were not available for the whole winter due to some technical problems. Approximately 50 percent of the Montreal data were unusable due to abrupt fluctuation in the recorded precipitation mass. Data from Quebec stations collected between November 27, 2001 and February 8, 2002 was also unavailable.

The distribution of the 2001-02 data points across the six meteorological stations is summarized in Table 3.2.

Table 3.2: Distribution of 2001–02 Snow Data Points by Station

Station	# of data points	%
Frelighsburg	6 572	12
Quebec	7 340	13
Montreal	4 379	8
Rouyn Noranda	16 755	30
Mont-Joli	12 345	22
High Falls	7 635	14
Total	**55 026**	**100**

The distribution of new data points from all stations, sorted by temperature, is listed in Table 3.3.

Table 3.3: Distribution of 2001–02 Snow Data Points by Temperature

Temperature Range	# of Data Points (2001-02)
Above 0°C	9 399
Between 0 and -3°C	17 676
Between -3 and -7°C	12 180
Between -7 and -14°C	12 830
Between -14 and -25°C	2 941
Total	**55 026**

The distribution of data points for 2001-02, by temperature and in histogram format is shown in Figure 3.1. The following observations should be noted:

a) 17.1 percent of the snowfalls occurred at temperatures above 0°C;

b) 32.1 percent of the snowfalls occurred within the range of 0 to -3°C;

c) 22.1 percent occurred between -3 and -7°C;

d) 23.3 percent occurred between -7 and -14°C; and

e) 5.4 percent occurred between -14 and -25°C.

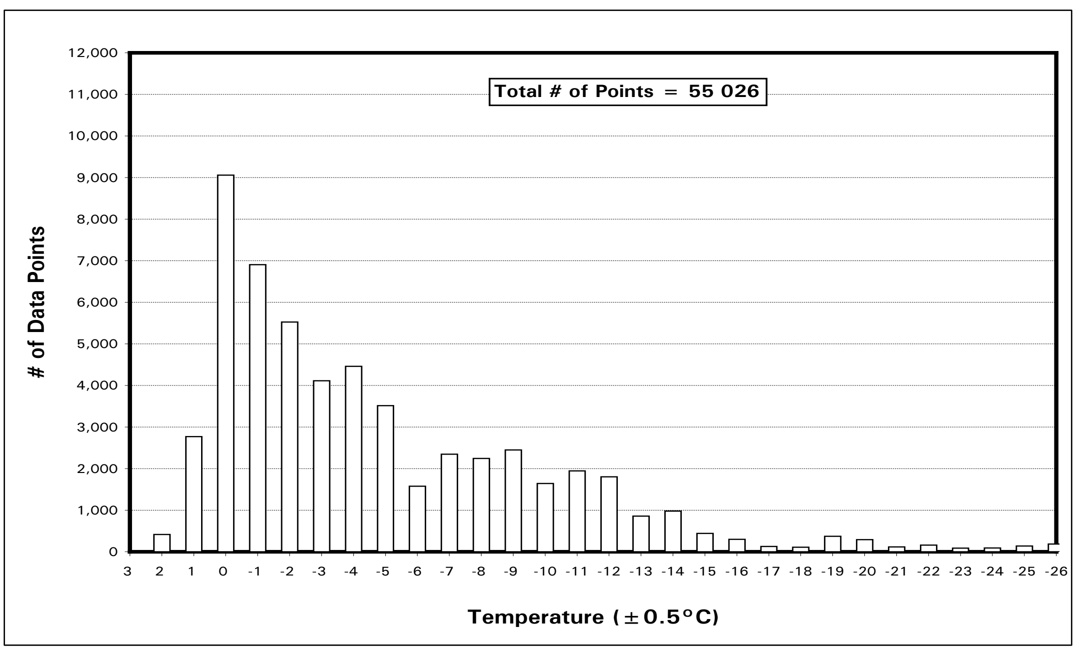

Figure 3.1: Temperature Distribution for 2001–02 Winter – Natural Snow

A total of 232 931 data points were collected for natural snow conditions from 1995-96 to 2001-02. On average, this represented approximately 92 hours of snowfall per year for each of the 6 stations in Quebec.

The distribution of snow data points over the seven years of observation is illustrated in Table 3.4.

The distribution of snow data points by temperature range is listed in Table 3.5.

Table 3.4: Distribution of Snow Data Points over the Last Seven Winters (1995-96 to 2001-02)

Year	# of data points	%
1995–98	39 426	17
1998–99	37 272	16
1999–00	43 927	19
2000–01	57 280	25
2001–02	550 26	24
Total	**232 931**	**100**

Table 3.5: Temperature Distributions Over the Last Seven Winters (1995–96 to 2001-02)

Temperature Range	# of Data Points (1996 to 2002)
Above 0°C	26 922
Between 0 and -3°C	59 508
Between -3 and -7°C	68 856
Between -7 and -14°C	63 858
Between -14 and -25°C	13 787
Total	**232 931**

Figure 3.2 shows the breakdown of total data points collected from 1995-96 to 2001-02 and sorted by temperature for natural snow. The following observations should be noted:

a) 11.6 percent of the snowfalls occurred at temperatures above 0°C;

b) 25.5 percent of the snowfalls occurred within the range of 0 to -3°C;

c) 29.6 percent occurred between -3 and -7°C;

d) 27.4 percent occurred between -7 and -14°C; and

e) 5.9 percent occurred between -14 and -25°C.

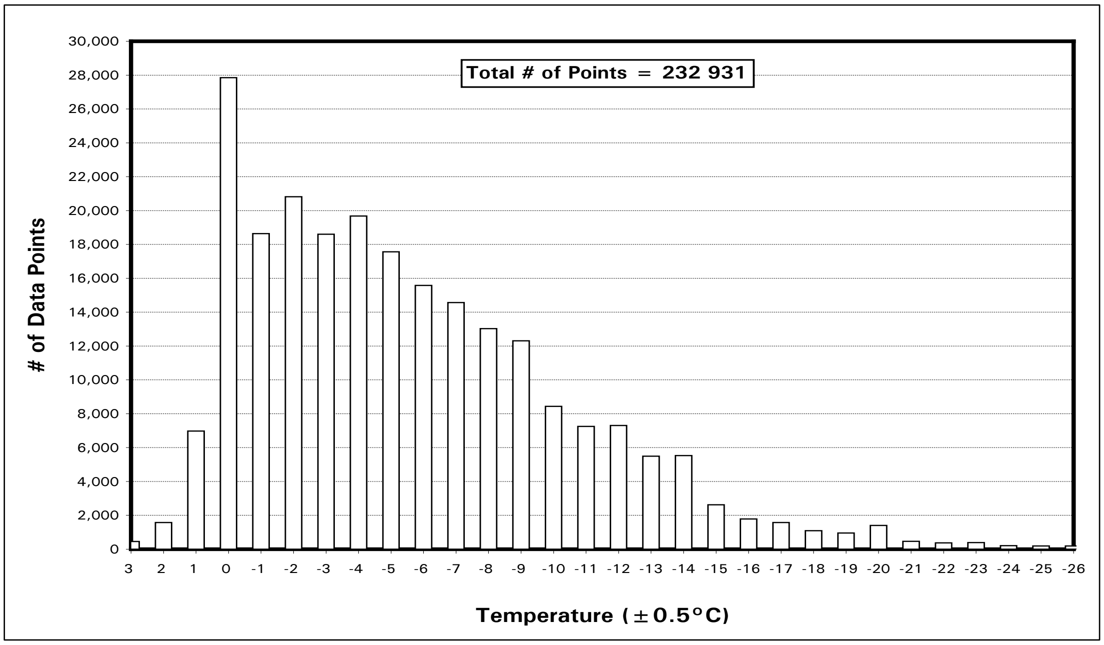

Figure 3.2: Temperature Distribution for the 1995-96 to 2001-02 Winters - Natural Snow

3.2 Freezing Rain/Drizzle

For Montreal and five other Quebec stations during the 2001-02 winter, 5 465 data points were collected. These represent approximately 91 hours of freezing rain/drizzle data. The distribution of these data by temperature range is shown in Figure 3.3.

The distribution of the 2001-02 data points across the six meteorological stations is summarized in Table 3.6.

The distribution of data points by temperature range is listed in Table 3.7.

The following observation should be noted:

- Freezing rain/drizzle did not occur at temperatures below -8°C.

A total of 19 631 data points were collected for freezing rain/drizzle conditions from 1995-96 to 2001-02. These represent approximately 327 hours of light freezing rain/drizzle data. Freezing rain/drizzle data were developed from CR21X and READAC logs, based largely on the 1998 ice storm.

The distribution of these data points over the seven years of observation is illustrated in Table 3.8.

The distribution of data points by temperature range is listed in Table 3.9.

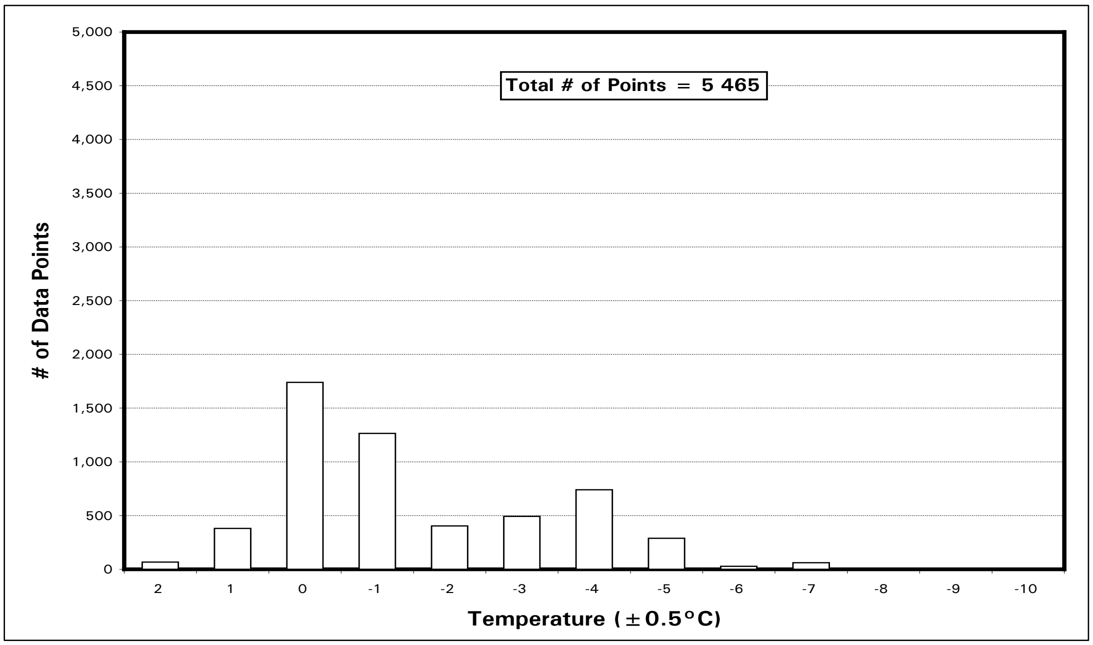

Figure 3.3: Temperature Distribution for 2001-02 – Freezing Rain/Drizzle

Table 3.6: Distribution of 2001–02 Freezing Rain/Drizzle Data Points by Station

Station	# of data points	%
Frelighsburg	530	10
Quebec	230	4
Montreal	844	15
Rouyn Noranda	516	9
Mont-Joli	474	9
High Falls	2 871	53
Total	**5 465**	**100**

Table 3.7: Distribution of 2001–02 Freezing Rain/Drizzle Data Points by Temperature

Temperature Range	# of Data Points
Above 0ºC	1 105
Between 0 and -3°C	3 070
Between -3 to -10°C	1 290
Total	**5 465**

Table 3.8: Distribution of Freezing Rain/Drizzle Data Points Over the Last Seven Winters 1995–96 to 2001–02

Year	# of data points	%
1996–00	13 381	68
2000–01	785	4
2001–02	5 465	28
Total	**19 631**	**100**

Table 3.9: Distribution of 1995–96 to 2001–02 Freezing Rain/Drizzle Data Points by Temperature

Temperature Range	# of Data Points
Above 0ºC	3 996
Between 0 and -3°C	7 188
Between -3 to -10°C	8 447
Total	**19 631**

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 limited to the 1998 ice storm.

The distribution of these data by temperature range is shown in Figure 3.4.

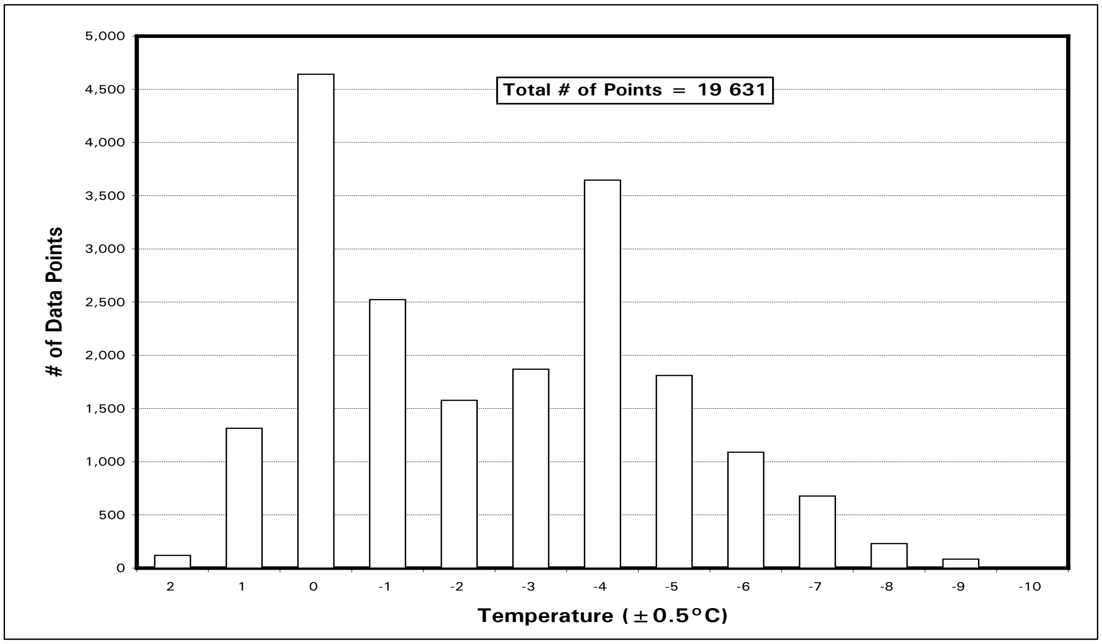

Figure 3.4: Temperature Distribution for Freezing Rain/Drizzle 1995-96 to 2001-02

3.3 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 References 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 in a study published in The Journal of Climate by the Atmospheric Environment Service on November 20, 1991 (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 relations observed. Second, if they are closely linked, an effective weather forecasting aid could be developed. Third, predictions of climate temperature changes might be used to predict precipitation changes.

The 56 stations were chosen because they contained long records (over 40 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. The data were then processed and the appropriate graphs compiled.

For example, Figure 3.5 shows the 1953-88 frequency distributions of mean daily air temperature for Halifax for January. Superimposed is the distribution of total precipitation as a function of mean daily temperature. As is evident from 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 the geography, as seen in coastal areas and near the Rocky Mountains).

Using the same procedure, APS analysed the dataset from the 2000-01 and 2001-02 winters for six stations in Quebec (Quebec, Montreal, Rouyn Noranda, Pointe-aux-Pères, 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 the AES 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 3.6.

As can be seen, the Quebec stations closely follow the pattern presented for Halifax. For these six measuring stations, 82 percent of the precipitation occurred at a temperature above the median.

The dataset from the AES study shows that 20 percent of precipitation occurs below the median temperature; in the case of Quebec, 18 percent occurs below it. The Quebec estimate includes data from the 2001-02 winter, which had an above-average median daily temperature.

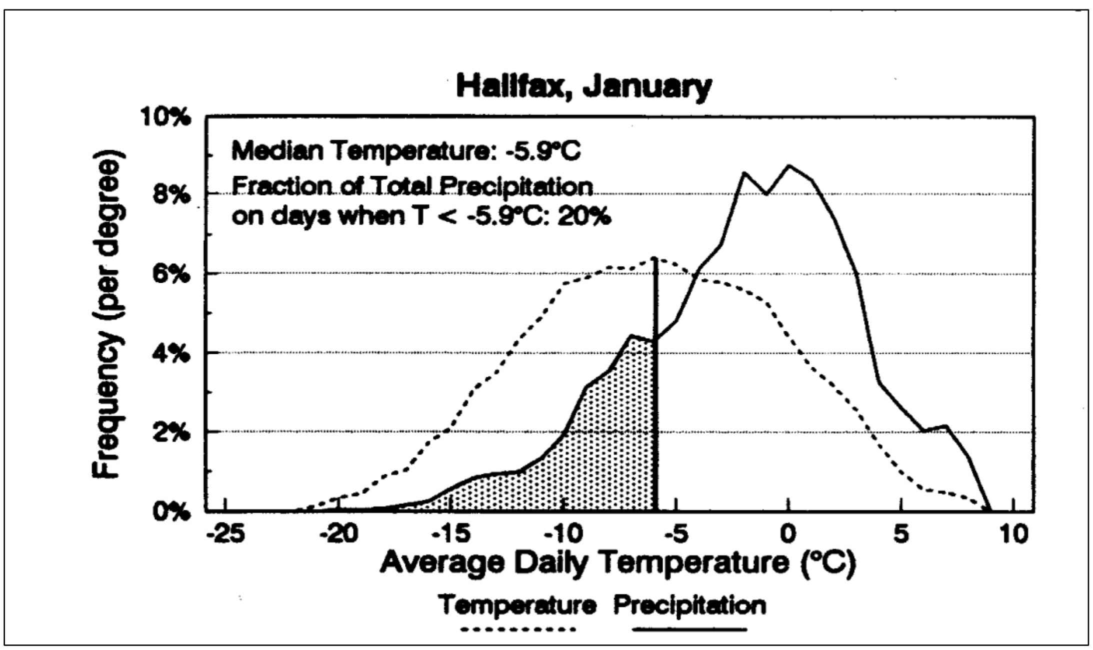

Figure 3.5: Frequency Distributions of Mean Daily Temperature for Halifax for January 1953-88

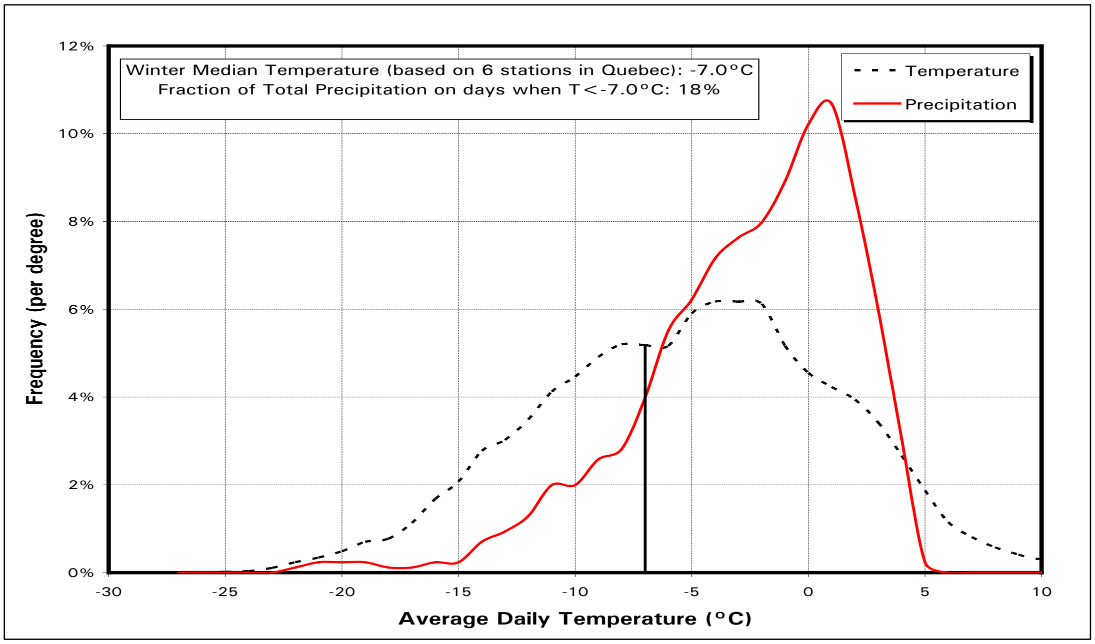

Figure 3.6: Frequency Distributions of Mean Daily Temperature for Quebec for the 2000–01 and 2001–02 Winters

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4. 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 4.1 shows minute-by-minute READAC data at Dorval Airport for a 37 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 point data, were calculated by taking the snow accumulation during a specific time interval and dividing this value 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 4.1. The average snow rate was re-calculated 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, the number of snow precipitation events was plotted against the precipitation rates (Figure 4.1). The other (Figure 4.2) 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.

A complete set of plots for all temperature ranges and rate durations for natural snow and freezing rain/drizzle is included in Appendix B.

The histogram in Figure 4.1 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 4.2 indicates that over 96 percent of all the natural snow events in the data had precipitation rates below 25 $g/dm^2/h$ for 20 minute rate intervals.

The 95th percentile criterion was used in the analysis conducted by AES in 1995 to establish the frequency of precipitation rates. The same criterion was used by APS. Results are described in the following subsections.

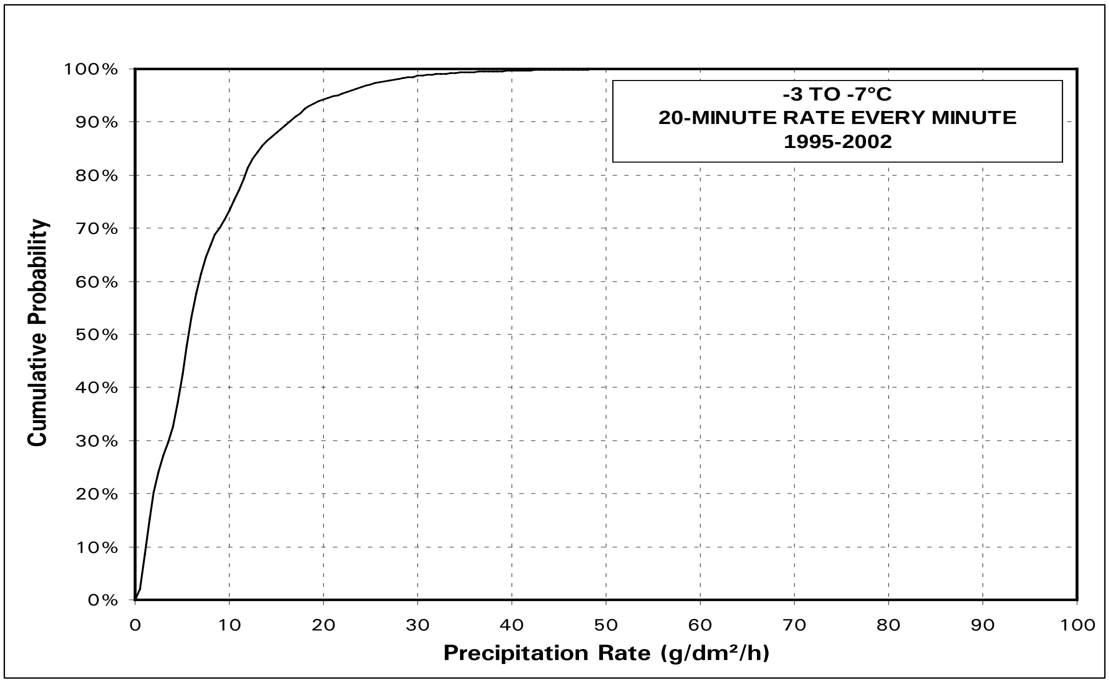

Figure 4.1: READAC and CR21X Analysis – Natural Snow Histogram

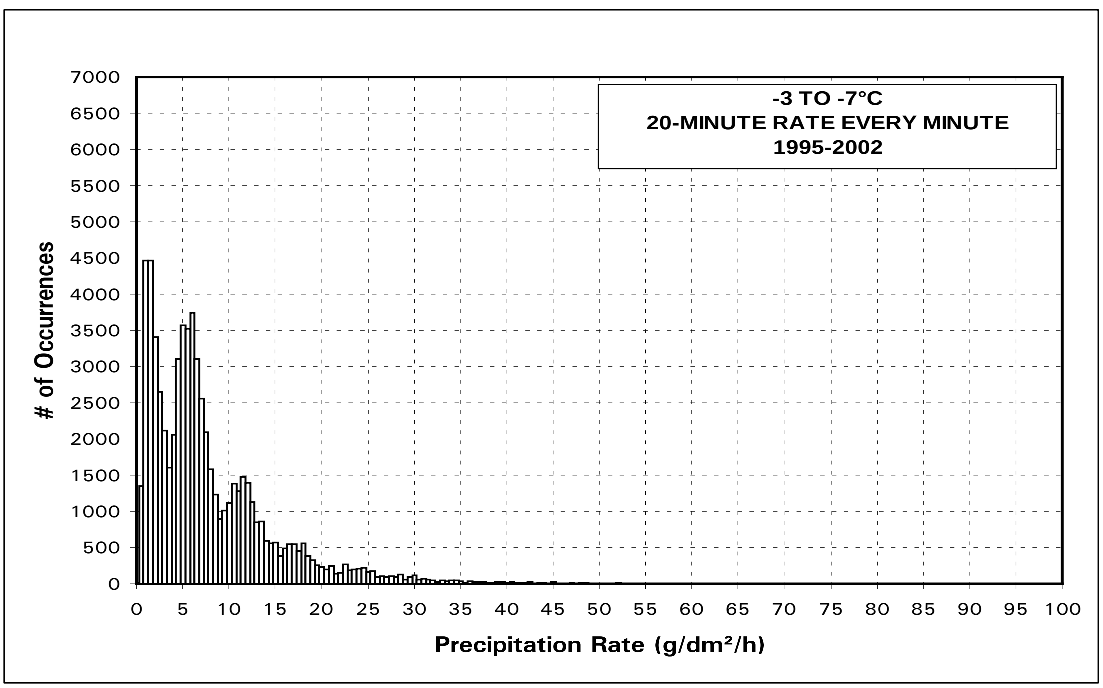

Figure 4.2: READAC and CR21X Analysis – Natural Snow Cumulative Probability

Table 4.1: 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

4.1 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 4.3 shows a comparison of precipitation rates of the READAC gauge and the plate pans (described below) for a storm on January 15, 1999. Figure 4.4 illustrates another comparison during the same storm, this time for the CR21X gauge.

Figure 4.3 and Figure 4.4 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 4.4. 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 a 10 minute period. The rates are recorded at the end of this time interval. Both the upper and lower rate pans are included in the figures.

Furthermore, because of questions raised by AES concerning the accuracy of precipitation gauges, a new analysis has been done 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 on January 11, 2001. The results are presented in Figure 4.5.

As can be seen, the data points from the plate pans correlate well with the traces shown in Figure 4.4 and Figure 4.5. More precipitation collects in the rate pans during high winds because the stands are always 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 could be used to analyse precipitation data.

At least one verification should be made annually by comparing the rates obtained from the precipitation gauges and the plate pans. For the 2001-02 winter, the snow event charted took place on March 20th. The results are presented in Figure 4.6.

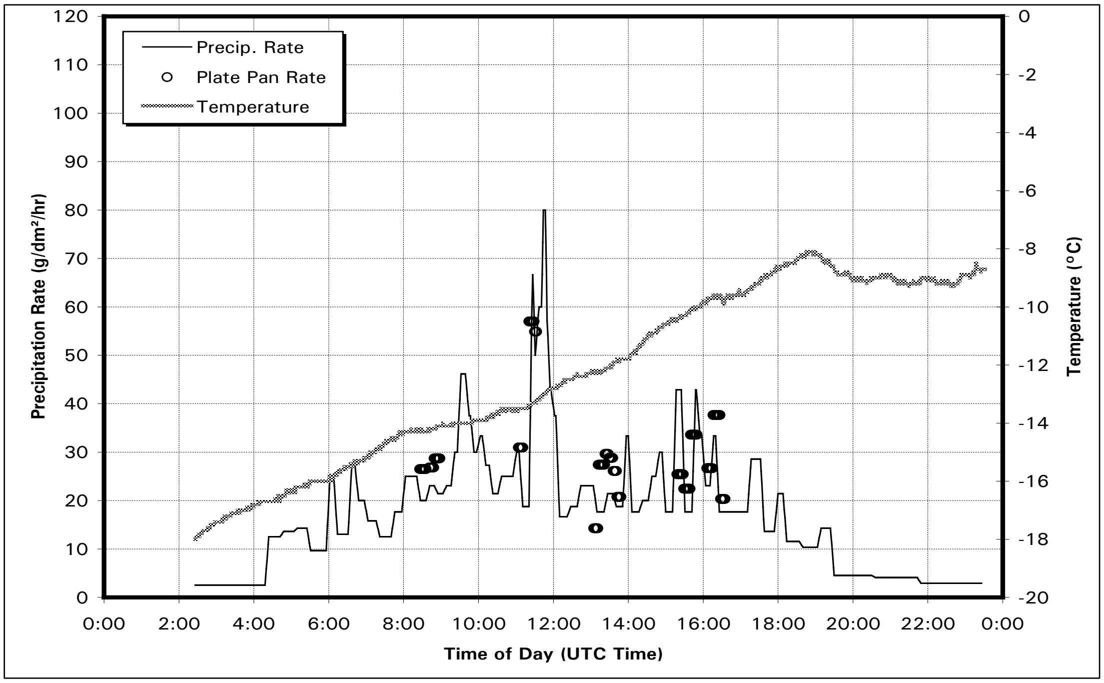

Figure 4.3: READAC Precipitation Rate, January 15, 1999

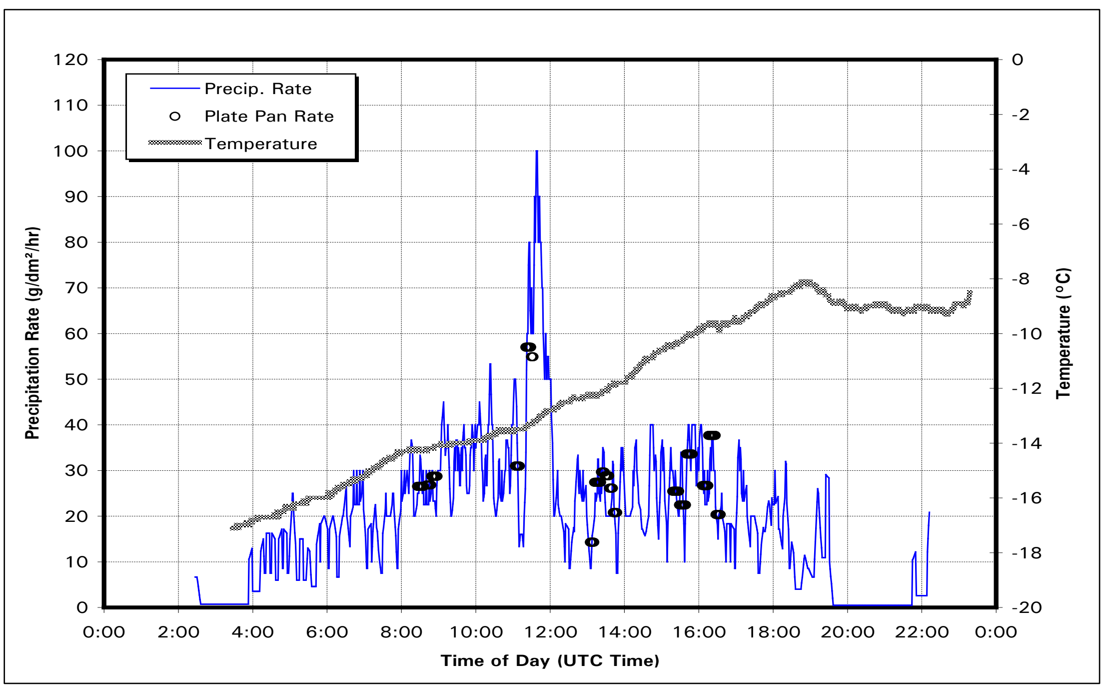

Figure 4.4: CR21X Precipitation Rate, January 15, 1999

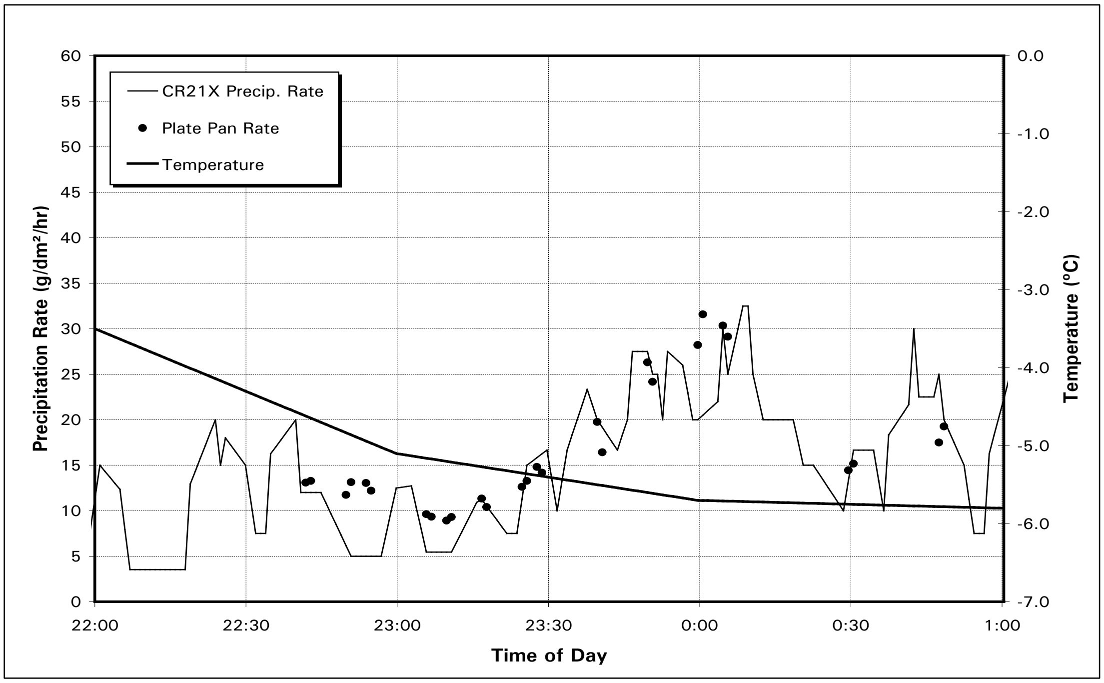

Figure 4.5: CR21X Precipitation Rate, January 11, 2001

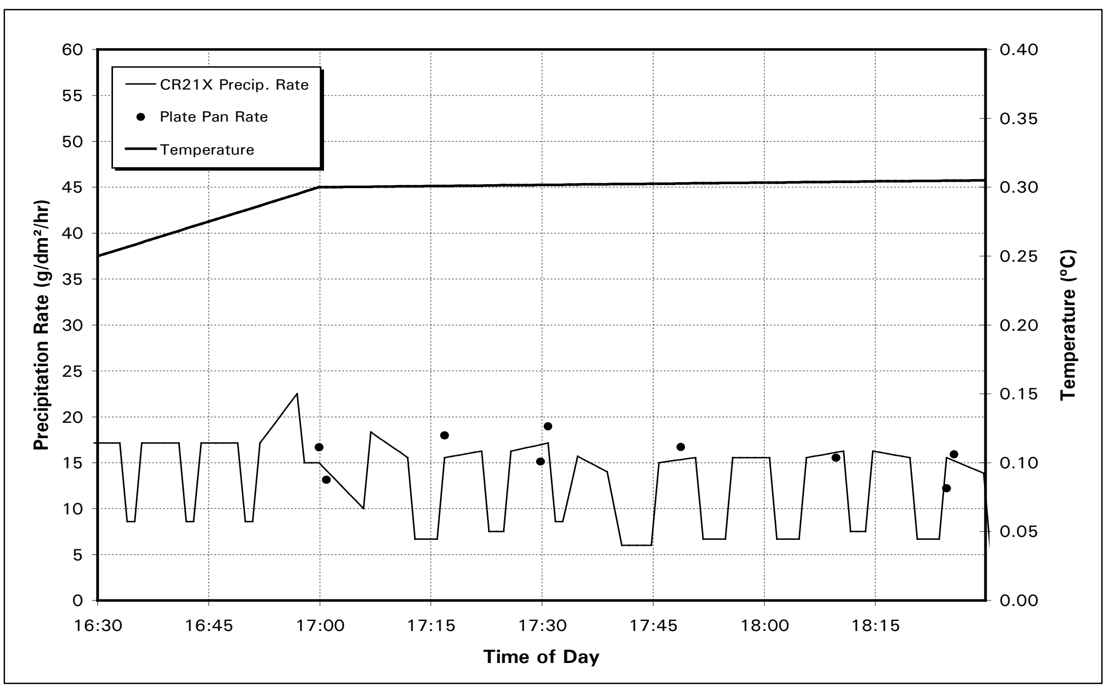

Figure 4.6: CR21X Precipitation Rate, March 20, 2002

4.2 Natural Snow

This analysis takes into account the snow data set from the last seven winters - the 1995-96 winter to the 2001-02 winter.

The 95th percentiles for several temperature ranges for natural snow conditions are shown in Table 4.2 below:

Table 4.2: 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	20	20
0°C to -3°C	20	19	20
-3°C to -7°C	22	21	21
-7°C to -14°C	22	22	22
-14°C to -25°C	21	20	20

The rates shown in this table are explained in the following 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 4.3 shows the percent of occurrences when the precipitation rates were above 25 g/dm^2/h for all temperature ranges.

Table 4.3: 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	2.8 %	2.8 %	2.6 %
0°C to -3°C	2.8 %	2.7 %	2.3 %
-3°C to -7°C	3.0 %	2.9 %	2.6 %
-7°C to -14°C	3.1 %	3.2 %	3.2 %
-14°C to -25°C	2.2 %	2.0 %	2.3 %

4.3 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 4.7. The 95th percentile precipitation rate for the -7 to -14°C and the -14 to -25°C temperature intervals were very similar to rates at warmer temperatures. This indicates that high rates do occur at cold temperatures.

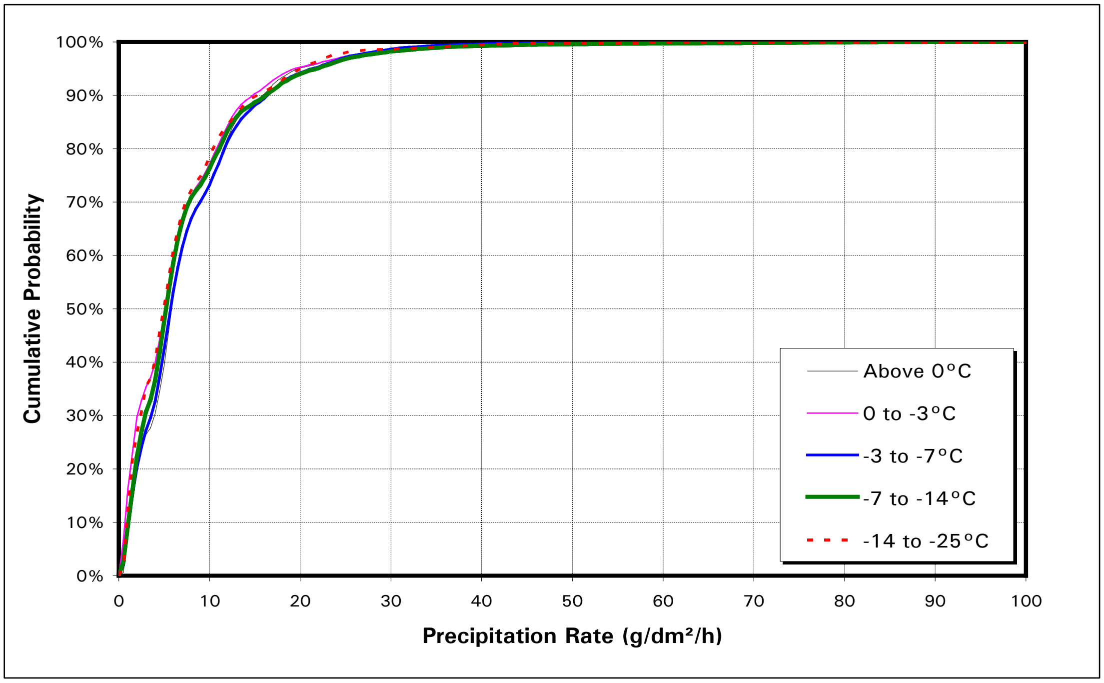

Figure 4.7: 20 Minute Rate Every Minute - All Temperature Ranges

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 4.8.

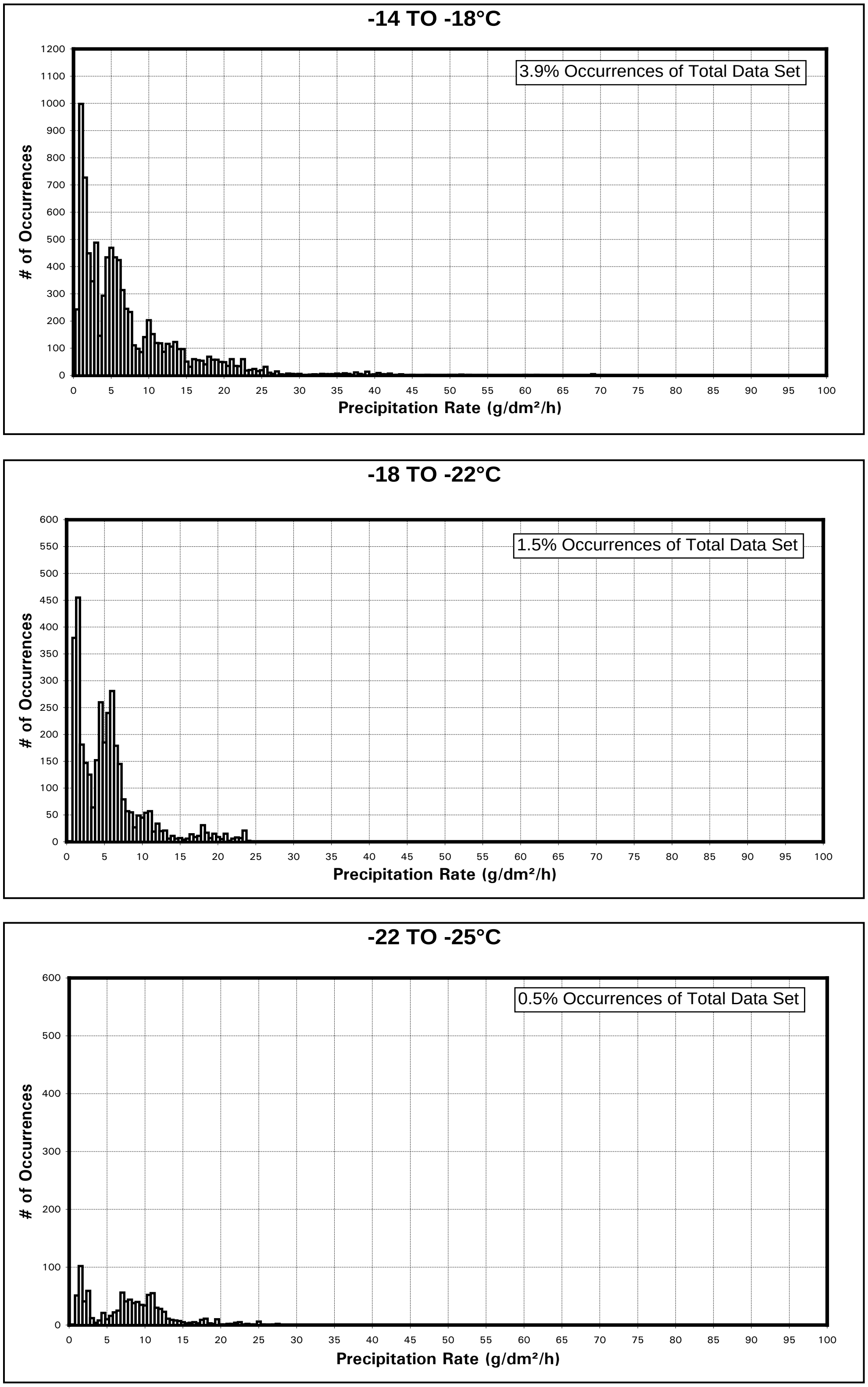

Figure 4.8: Subdivision of -14 to -25°C – Snow Data

It should be noted, however, that the 95th percentile had an upper limit of 16 g/dm²/h for all subdivided intervals. The percentage of occurrences when the precipitation rates were above 25 g/dm²/h are shown below (Table 4.4) for the subdivided intervals.

Table 4.4: Percentage of Heavy Snow Occurrences In Cold Temperatures – Natural Snow

Temperature Range	Percent of Occurrences when Rate is above 25 g/dm²/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	3.1%	3.0%	3.6%	66.0%	3.9%
-18 to -22°C	0.3%	0%	0%	25.0%	1.5%
-22 to -25°C	1.1%	0.4%	0%	9.0%	0.5%
			Total	**100%**	**5.9%**

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

4.4 Freezing Rain/Drizzle

The 95th percentile for two temperature ranges is shown below (Table 4.5) for freezing rain/drizzle:

Table 4.5: 95th Percentile in Each Temperature Range – Freezing Rain/Drizzle

Temperature Range	95th Percentile Precipitation Rate (g/dm²/h)		
	6 min	20 min	35 min
0 to -3°C	30	26	24
-3 to -10°C	25	24	24

In freezing rain/drizzle, the 95th percentile was near 25 g/dm²/h for the -3 to -10ºC range and somewhat higher, near 30 g/dm²/h, for the 0 to -3ºC range.

4.5 Comparing AES with APS 1995–2002 Snow Weather Data

In 1995, AES prepared a study of the precipitation rate in each holdover time temperature interval. This study, based on data collected at an experimental site at Pearson Airport, is included as Appendix D. The graphs (Cumulative Probability versus Precipitation Rate) were reasonably similar in overall curve shape but not necessarily in exact values.

For the temperature range of 0 to -3°C, the results of the AES study are very similar to those in this report. The 6, 20, and 35 minute rates are nearly identical in both studies. The 95th percentile was 16 g/dm^2/h in the AES report and 20 g/dm^2/h as reported in this one.

In the -3 to -7°C temperature range, the general shape of the curves is not as similar as the 0 to -3°C curves. The findings of this study show that only 70.4 percent of precipitation is expected to be below 10 g/dm^2/h. The findings of the AES study suggest that 87 percent of precipitation will be at a rate lower than 10 g/dm^2/h. The curves from the APS and the AES studies show very little change in precipitation rate for the various time intervals, although a slight tendency toward higher rates is shown for shorter time intervals in the AES study.

The 95th percentile rates, based on data collected from the READAC and CR21X stations, are 22 g/dm^2/h for the -7 to -14°C range. The 95th percentile precipitation rates for this temperature range are significantly higher than those of the AES study, primarily due to very high rates recorded during at least two specific snowfalls during the 1998-99 winter.

The -14 to -25°C range presents the largest variation in results between the two studies. The AES graphs indicate that snow precipitation rates in that temperature range are much lower than in the other ranges. The AES study shows that 98 percent of precipitation is expected to be below 10 g/dm^2/h. It is only 74.6 percent according to the APS study. The data from the READAC and CR21X stations show very little difference in the probability-versus-precipitation rate curves for various temperature ranges.

Overall, these two data sets (AES and Snow Weather Data for 1995-2002) are similar enough to merit a comparison for temperature ranges above -7°C. Below that temperature, the AES data contains no high rate precipitation points. The data collected by AES was recorded in Toronto. The average temperature is warmer in that region than in the regions where the APS data were collected. This resulted in comparatively colder ambient temperatures in the data analysed for this study.

4.6 Comparison of APS 1993–95 with 1995–02 Snow Weather Data

Analysis of these two sets of data revealed that numerous data conversions are needed to help make substantial conclusions. Variations in scales between the two data sets can present other difficulties. The data presented in the 1993-95 analysis were not separated into temperature ranges. The 95^{th} percentiles, shown in Table 4.6, were approximated from the graphs presented in Appendix C.

From the data, it can be observed that very high snowfall rates were recorded during the 1993-94 winter. The 95^{th} percentile for the 1994-95 winter was 21 g/dm^2/h, which is identical to the 95^{th} percentile for the dataset from 1995-02. The 95^{th} percentile for the entire temperature range from 1993-95 was 26 g/dm^2/h.

Table 4.6: Summary of 1993–95 Snow Weather Data

Date	Ambient Temperatures (°C)	95^{th} Percentile Snowfall Rate (g/dm^2/h)
1993-95	N/A	26
1993-94	N/A	37
21-Dec-93	0.5	37
1-Apr-94	-13	61
8-Jan-94	-18	11
14-Jan-94	-10	5
23-Jan-94	-16	13
27-Jan-94	-9	27
12-Feb-94	-8	17
23-Feb-94	-9	31
10-Mar-94	-5	19
27-Mar-94	0.2	31
7-Apr-94	-1.3	16
1994-95	N/A	21
7-Jan-95	-3	17
12-Jan-95	-14	20
4-Feb-95	-8	9
11-Feb-95	-9	14
16-Feb-95	-1	28
24-Feb-95	-0.2	11
27-Feb-95	-12	13
6-Mar-95	-7	25
8-Mar-95	-5	17

4.7 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 (232 931 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 4.7.

The probability of snow event occurrences in each of the holdover time temperature ranges of the Holdover Time tables is shown in Table 4.8 and Table 4.9. Table 4.8 corresponds to the temperature ranges of Type I fluid and Table 4.9 to the ranges of Type II and Type IV fluids. These two tables are determined based on Table 4.7. There was 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 light, moderate, and heavy snow.

For Type I fluid, over 82 percent of the probability of snow events occurred in the range of 0 to -10°C. Over 73 percent of the rates were classified as light snow (<10 g/dm²/h). The probability of snow events for the Type IV table are 37.1 percent in the range of 0 to -3°C and 57 percent in the range of -3 to -14°C.

Table 4.7: Probability (%) of Natural Snow Occurrence – 1995-96 to 2001–02 (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	1.59	2.06	1.55	0.88	0.58	0.49	0.41	0.29	0.23	0.18	0.20	0.36	0.46	0.36	0.34	0.29	0.19	0.18	0.15	0.19	0.06	0.06	0.05	0.04	0.05	0.32	11.6	11.6
0 to -1	1.21	1.70	0.93	0.74	0.45	0.31	0.28	0.16	0.16	0.14	0.16	0.25	0.33	0.29	0.25	0.18	0.13	0.12	0.11	0.09	0.03	0.03	0.03	0.02	0.03	0.19	8.3	19.9
-1 to -2	1.86	1.45	0.86	0.50	0.49	0.28	0.32	0.21	0.19	0.12	0.12	0.20	0.21	0.19	0.19	0.16	0.14	0.12	0.08	0.11	0.05	0.04	0.05	0.02	0.04	0.25	8.2	28.1
-2 to -3	1.11	1.72	0.93	0.84	0.56	0.34	0.40	0.24	0.20	0.14	0.14	0.24	0.31	0.32	0.23	0.20	0.16	0.13	0.15	0.12	0.05	0.06	0.04	0.02	0.04	0.31	9.0	37.1
-3 to -4	1.29	1.42	1.06	0.77	0.54	0.30	0.39	0.29	0.15	0.17	0.10	0.23	0.26	0.26	0.20	0.15	0.11	0.07	0.06	0.10	0.04	0.04	0.04	0.02	0.04	0.20	8.3	45.4
-4 to -5	0.96	1.10	0.87	0.58	0.40	0.31	0.35	0.26	0.17	0.13	0.15	0.24	0.26	0.28	0.27	0.24	0.16	0.13	0.13	0.17	0.06	0.07	0.04	0.03	0.07	0.34	7.8	53.2
-5 to -6	1.08	1.12	0.81	0.56	0.39	0.30	0.35	0.19	0.17	0.14	0.15	0.24	0.25	0.17	0.16	0.13	0.11	0.10	0.10	0.11	0.06	0.05	0.03	0.02	0.04	0.19	7.0	60.2
-6 to -7	0.87	1.36	0.78	0.63	0.38	0.29	0.21	0.15	0.11	0.11	0.11	0.20	0.21	0.18	0.18	0.11	0.09	0.09	0.07	0.09	0.03	0.02	0.03	0.01	0.02	0.13	6.5	66.7
-7 to -8	1.02	1.21	0.99	0.48	0.39	0.27	0.20	0.10	0.10	0.12	0.11	0.20	0.19	0.18	0.14	0.11	0.07	0.04	0.03	0.05	0.01	0.01	0.01	0.01	0.02	0.07	6.1	72.8
-8 to -9	0.80	0.79	0.76	0.45	0.28	0.21	0.20	0.14	0.07	0.11	0.12	0.21	0.20	0.17	0.14	0.08	0.08	0.05	0.05	0.04	0.01	0.03	0.01	0.01	0.01	0.08	5.1	77.9
-9 to -10	0.62	0.73	0.54	0.39	0.29	0.17	0.18	0.10	0.11	0.12	0.08	0.17	0.19	0.17	0.11	0.11	0.09	0.08	0.06	0.07	0.03	0.03	0.02	0.03	0.04	0.14	4.6	82.6
-10 to -11	0.51	0.69	0.40	0.31	0.15	0.08	0.06	0.05	0.04	0.03	0.03	0.10	0.10	0.07	0.06	0.04	0.07	0.06	0.05	0.07	0.03	0.03	0.02	0.01	0.02	0.11	3.2	85.8
-11 to -12	0.38	0.72	0.45	0.25	0.12	0.07	0.08	0.04	0.03	0.03	0.04	0.10	0.09	0.06	0.06	0.06	0.05	0.05	0.05	0.07	0.02	0.03	0.02	0.02	0.04	0.11	3.0	88.8
-12 to -13	0.61	0.54	0.35	0.26	0.15	0.10	0.07	0.04	0.06	0.05	0.03	0.07	0.08	0.09	0.06	0.05	0.04	0.05	0.04	0.04	0.02	0.02	0.01	0.02	0.01	0.12	3.0	91.8
-13 to -14	0.27	0.51	0.26	0.16	0.13	0.08	0.08	0.06	0.04	0.04	0.03	0.09	0.07	0.06	0.04	0.04	0.04	0.02	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0.19	2.3	94.1
-14 to -15	0.27	0.30	0.19	0.09	0.06	0.05	0.06	0.03	0.03	0.05	0.03	0.05	0.06	0.04	0.02	0.03	0.03	0.03	0.02	0.05	0.01	0.02	0.02	0.02	0.02	0.09	1.7	95.7
-15 to -16	0.18	0.26	0.07	0.04	0.02	0.01	0.02	0.01	0.01	0.06	0.02	0.02	0.01	0.03	0.01	0.01	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.01	0.01	0.03	0.9	96.6
-16 to -17	0.26	0.08	0.08	0.03	0.02	0.02	0.02	0.02	0.01	0.06	0.01	0.02	0.03	0.03	0.02	0.01	0.01	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.8	97.4
-17 to -18	0.13	0.06	0.15	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.5	97.9
-18 to -19	0.08	0.08	0.06	0.05	0.02	0.03	0.00	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.5	98.4
-19 to -20	0.06	0.11	0.09	0.04	0.04	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	98.9
-20 to -21	0.10	0.12	0.02	0.03	0.04	0.02	0.01	0.01	0.01	0.00	0.02	0.01	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	0.4	99.3
-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	99.5
-22 to -23	0.04	0.08	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	0.2	99.7
-23 to -24	0.03	0.06	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	0.10	0.05	0.01	0.01	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	0.00	0.00	0.00	0.00	0.00	0.2	100.0
Total	15.5	18.3	12.3	8.1	5.5	3.8	3.7	2.4	1.9	1.8	1.7	3.0	3.4	3.0	2.5	2.0	1.6	1.4	1.2	1.5	0.5	0.6	0.4	0.3	0.5	2.9		
Cumulative	15.5	33.8	46.1	54.2	59.8	63.5	67.3	69.7	71.6	73.4	75.1	78.2	81.5	84.5	87.1	89.1	90.6	92.0	93.2	94.7	95.2	95.8	96.2	96.6	97.1	100.0		

Table 4.8: Probability of Snow Event in Each Holdover Time Table Temperature Range – Type I Fluids

Temperature (°C)	Light Snow (<10 g/dm²/h)	Moderate Snow (10 to 25 g/dm²/h)	Heavy Snow (>25 g/dm²/h)	Total
Above 0 to -3	27.1%	9.0%	1.1%	**37.1%**
-3 to -10	33.4%	10.9%	1.2%	**45.5%**
Below -10	12.9%	3.9%	0.7%	**17.4%**
Total	**73.4%**	**23.7%**	**2.9%**	**100.0%**

Table 4.9: Probability of Snow Event in Each Holdover Time Table Temperature Range – Type II and Type IV Fluids

Temperature (°C)	Light Snow (<10 g/dm²/h)	Moderate Snow (10 to 25 g/dm²/h)	Heavy Snow (>25 g/dm²/h)	Total
Above 0	8.3%	3.0%	0.3%	**11.6%**
0 to -3	18.8%	6.0%	0.7%	**25.5%**
-3 to -14	41.8%	13.5%	1.7%	**57.0%**
-14 to -25	4.6%	1.2%	0.1%	**5.9%**
Total	**73.4%**	**23.7%**	**2.9%**	**100.0%**

5. WINTER OPERATIONS SURVEY

A survey was conducted by Transport Canada 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 Holdover time 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 can be made to the format.

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

5.1 Introduction

Several years ago, an estimate of the number of deicing operations as a function of precipitation condition for Dorval Airport had been carried out and is presented in Figure 5.1.

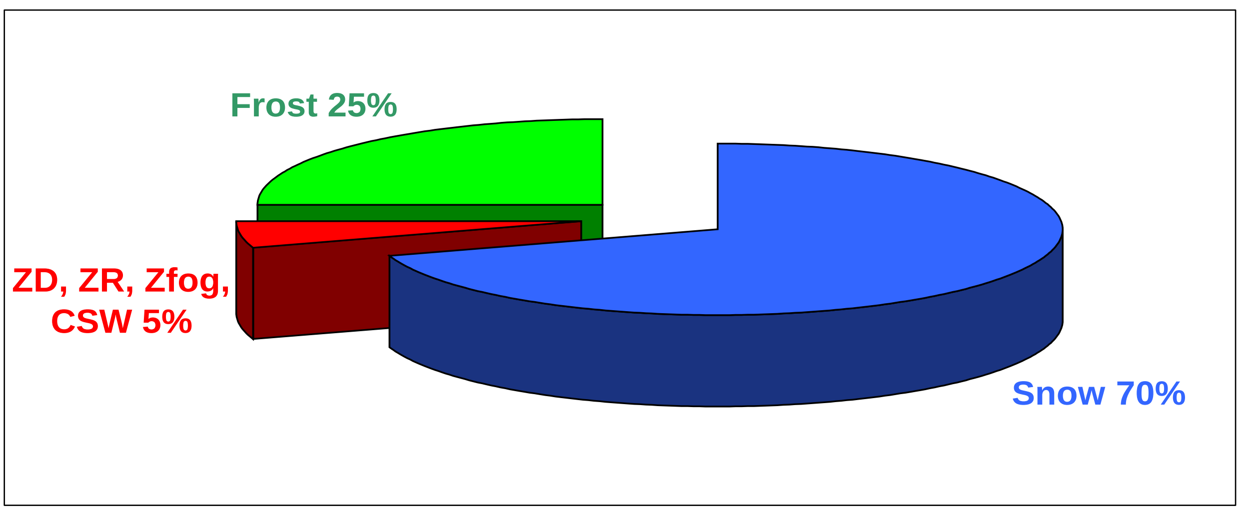

Figure 5.1: Previous Estimate of Frequency of Deicing Operations as a Function of Weather Condition at Dorval

The study was based on the summary of hourly weather observations for 30 years of data at Dorval Airport and on data relating to aircraft deicing events derived from the airport deicing logs.

The distribution in Figure 5.1 was obtained according to the following steps:

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

Step II) Additional data on frost, obtained from deicing operations during the 1999-00 winter season at Dorval, were averaged with the prior findings and frost deicing operations at Dorval were estimated to be 25 percent.

Step III) Using the summary of hourly weather observations for 30 years of data at Dorval, freezing drizzle, freezing rain, freezing fog and cold-soak wing make up about 6 percent of freezing precipitation occurrences (i.e., when there is freezing precipitation, it falls as snow 94 percent of the time).

Step IV) By calculating these percentages from the 75 percent of non-frost deicing operations, and after rounding the numbers, it was established that freezing precipitation amounts to 5 percent of deicing of all conditions, and snow represents 70 percent.

These estimates were made several years ago and were reported in the Transport Canada Report, *Winter Weather Data Evaluation (1995-2001), TP 13830E*, October 2001 (1), and also in Transport Canada Report, *Snow Weather Data Evaluation (1995-2000), TP 13665E*, November 2000 (8).

To substantiate these findings and have a better understanding of how consistent these results are at other worldwide stations, Transport Canada initiated a survey (Appendix G) of airlines at several international airports. The findings from this survey are described and analysed in this section.

The most important winter weather condition encountered in terms of de/anti-icing at Dorval was estimated as snow (approximately 70 percent). This percentage was reflected in the Type I and Type II/IV de/anti-icing operations tables from Dorval, which were sent with the survey. Tables depicting the percent of de/anti-icing operations at Dorval have been updated since the survey was distributed; therefore, the current tables are not identical to those released to the airlines.

5.2 Methodology

Attempting to collect data on actual deicing operations at several worldwide stations, Transport Canada distributed the survey to airlines at several international airports. This information is important in supporting a review of the Holdover time table temperature and weather condition breakdowns in that the research is 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 G) 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 showed the estimates from Dorval airport for Type I and Type II/IV deicing operations. The surveyed airlines were given the possibility to provide data in the form of percentages or as numerical values. If the separation of Type I operations was impossible, they were also given the option to provide the information for all fluids on Table 2.

In an attempt to obtain as many responses as possible, the questionnaire was disseminated to the SAE G-12 Committee participants. A summary table of who was asked and who responded is presented in Section 5.3.

5.3 Description and Processing of Data

The feedback from the survey resulted in four tables for Type I fluids and seven tables for Type II/IV fluids worldwide. All these tables are included in Appendix G. Some of those who responded provided actual numbers in each cell of the holdover time table and others provided percentages of operations in each cell. In order to obtain the actual number of deicing operations surveyed, they were all converted to the same units. There was a total number of 25 800 deicing operations (Type I table) and 17 517 anti-icing operations (Type II/IV table).

A summary of the airports/airlines that received the survey is presented in Table 5.1. Out of 19 airlines that received the survey, seven responded, resulting in a response rate of 37 percent.

The worldwide distribution of the seven airports that answered the survey is presented in Figure 5.2.

The distribution of deicing operations for Type I fluids and Type II/IV fluids is illustrated in Table 5.2 and Table 5.3, respectively.

Table 5.4 shows the total number of Type I and Type II/IV deicing operations as a function of location and by precipitation condition.

Table 5.1: Summary of Airlines Surveyed

AIRLINE	AIRPORT	RESPONSE RECEIVED
Air France	Paris	X
Lufthansa	Frankfurt	
Japan Airlines	Sapporo	X
All Nippon Airways	Tokyo	
Finnair	Helsinki	
KLM	Amsterdam	X
United Airlines	Denver, Chicago	
American Eagle	Dallas, TX	
Northwest	St. Paul, MN	
Delta	Atlanta, Boston	
British Airways	London	X
SAS	Stockholm, Oslo	
FedEx	Memphis, TN	
UPS	Louisville, KY	
Swissair	Zurich	
GlobeGround / Air Canada	Toronto	X
All airlines - AeroMag	Montreal	X
US Airways	Pittsburgh	X
American Airlines	Chicago	

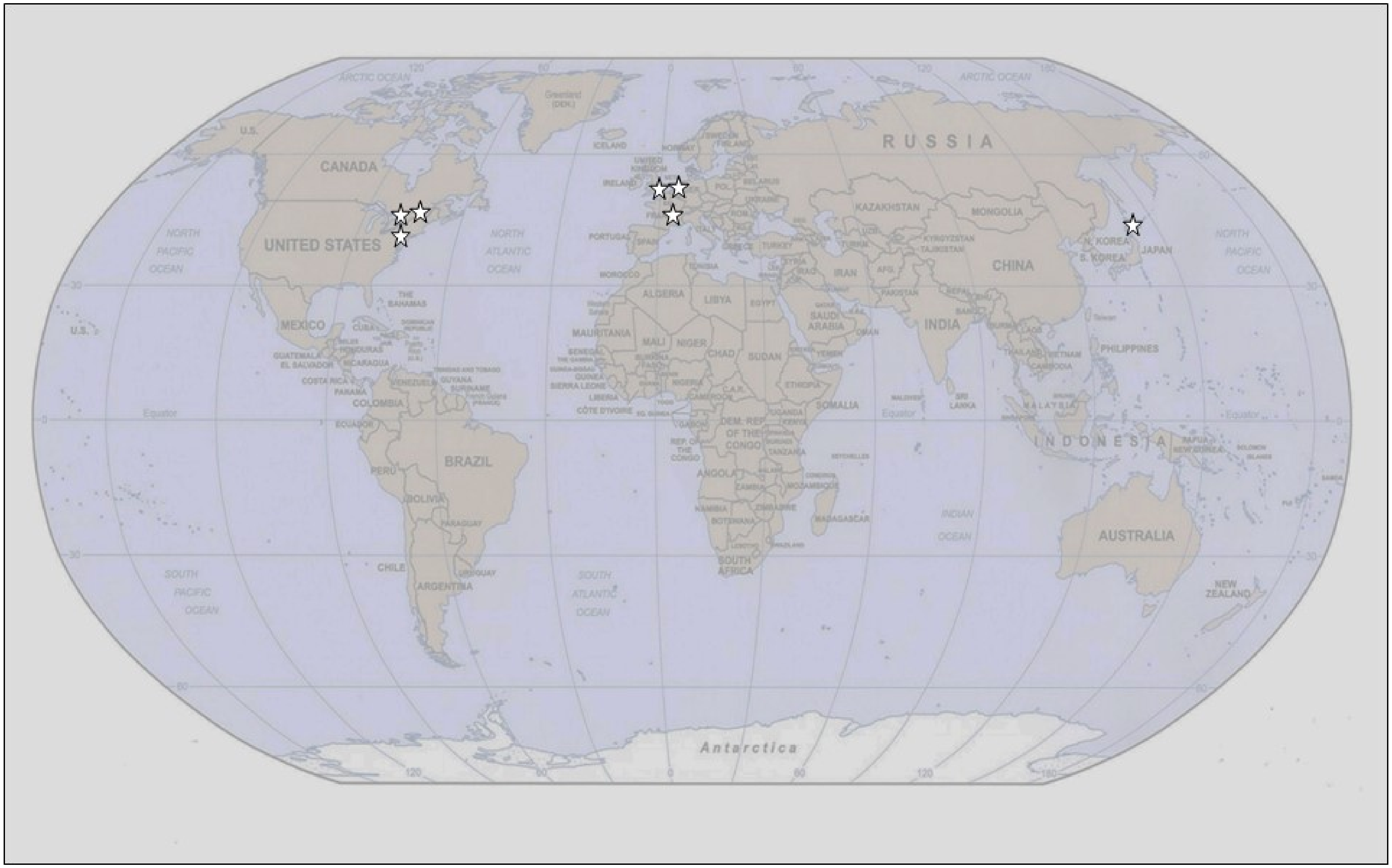

Figure 5.2: Worldwide Distribution of Responses to the 2000–01 Survey

Table 5.2: Type I Operations

City	Number of Operations
Montreal	7 531
Pittsburgh	7 825
Sapporo	690
Toronto	9 754
Total	**25 800**

Table 5.3: Type II/IV Operations

City	Number of Operations
Montreal	2 927
Pittsburgh	2 345
Sapporo	485
Toronto	3 710
London	2 000
Amsterdam	5 500
Paris	550
Total	**17 517**

Table 5.4: Type I and Type II/IV Combined Deicings 2000–01

	FROST	FRZ. FOG	SNOW	FRZ. DRIZZLE	LIGHT FRZ. RAIN	RAIN ON COLD-SOAKED WING	RIME ICE	Total
DORVAL	2622	0	7206	240	293	97	0	10458
PITTSBURGH	78	0	8152	406	1534	0	0	10170
SAPPORO	327	0	848	0	0	0	0	1175
TORONTO	2868	0	8899	244	204	257	992	13464
LONDON	1800	100	100	0	0	0	0	2000
AMSTERDAM	3300	192	1869	73	38	28	0	5500
PARIS	522	0	25	0	3	0	0	550
Total	11517	292	27099	963	2072	382	992	**43317**

5.3.1 Validation of Data

5.3.1.1 Montreal – Dorval Airport

The deicer at 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.

5.3.1.2 Pittsburgh

For the 2000-2001 winter, Pittsburgh Airport recorded 7 825 deicing operations and 2 345 anti-icing operations. Approximately 80 percent of the time, these operations took place under snow conditions. Freezing rain, freezing drizzle and frost accounted for the rest of the operations, with frost accounting for only 1 percent of deicing operations. In comparison with Montreal, the percentages are generally greater in the snow and freezing drizzle/rain columns and much lower in the frost column. These numbers could be justified by the fact that the average temperature is warmer in the Pittsburgh area than in the Montreal area.

5.3.1.3 Sapporo – Japan

For the 2000-01 winter, Type I deicing operations (690) at Sapporo Airport were due to snow precipitation and frost accumulation in a ratio of 53/47. The anti-icing operations (485) occurred exclusively under snow precipitation conditions.

5.3.1.4 Toronto – Pearson Airport

Pearson Airport presents a peculiarity, in that two different companies manage the airport's deicing operations. GlobeGround does the vast majority of deicing operations under all weather conditions. Independently, Air Canada does most of its deicing for frost conditions at the gates. Both deicers replied to the survey. Air Canada provided their data for frost together with the GlobeGround deicing operations of Air Canada aircraft. 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, and 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 was compiled with Air Canada's distribution of deicing operations. The final table shows that anti-icing operations caused by 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.

5.3.1.5 Heathrow Airport – London

At Heathrow International Airport, the de/anti-icing operations are conducted using exclusively Type II fluid at a dilution of 75/25. 2000 deicing operations were carried out in the 2000-01 winter. The deicing log shows that frost contamination occurs 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.

5.3.1.6 Schiphol Airport – Amsterdam

Deicing operations at Schiphol Airport were performed under all weather conditions in the holdover time table. The larger volume is represented by snow precipitation conditions (60 percent). Of the total number (5 500 deicing operations), almost 30 percent were classified as “preventive anti-icing operations”.

5.3.1.7 Paris Orly

Of the total number of deicing operations (550), 95 percent took place under frost contamination conditions and only 4.5 percent were caused by snow precipitation. Only Type II/IV fluids were used for the deicing operations.

5.4 Analysis and Observations

5.4.1 2000-01 Survey Results

The survey results were tallied for all the airports based on a weighted average using the total number of operations. The outcome from these calculations is illustrated in Table 5.5 to Table 5.8, with actual numbers of operations and percentages for Type I and Type IV fluids.

Table 5.5: 2000–01 Winter Deicing Operations Survey Results for Type I Fluid (Operations)

25800 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	800	0	1625	52	232	284	26	3019
0 to -10	3406	0	14216	361	1290		903	20176
below -10	1600	0	980				25 0	2605
Total	5806	0	16821	413	1522	284	954	

25800 of Operations

Table 5.6: 2000–01 Winter Deicing Operations Survey Results for Type I Fluid (Percentages)

25800 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	3.1%	0.0%	6.3%	0.2%	0.9%	1.1%	0.1%	11.7%
0 to -10	13.2%	0.0%	55.1%	1.3%	5.0%		3.5%	78.2%
below -10	6.2%	0.0%	3.8%				0.1%	10.1%
Total	22.5%	0.0%	65.3%	1.5%	5.9%	1.1%	3.7%	

100.0% of Operations

Table 5.7: 2000–01 Winter Deicing Operations Survey Results for Type IV Fluid (Operations)

17517 Deicing Operations

OAT °C	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
	Weather Conditions							
above 0	972	0	1055	53	35	88	0	2203
0 to -3	3878	193	4660	180	324		35	9270
below -3 to -14	841	105	4362	350	175		0	5833
below -14 to -25	18	0	193				0	211
below -25	0	0	0				0	0
Total	5709	298	10270	583	534	88	35	

17517 of Operations

Table 5.8: 2000–01 Winter Deicing Operations Survey Results for Type IV Fluid (Percentages)

17517 Deicing Operations

OAT °C	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER RIME ICE	
	Weather Conditions							
above 0	5.5%	0.0%	6.0%	0.3%	0.2%	0.5%	0.0%	12.6%
0 to -3	22.1%	1.1%	26.6%	1.0%	1.8%		0.2%	52.9%
below -3 to -14	4.8%	0.6%	24.9%	2.0%	1.0%		0.0%	33.3%
below -14 to -25	0.1%	0.0%	1.1%				0.0%	1.2%
below -25	0.0%	0.0%	0.0%				0.0%	0.0%
Total	32.6%	1.7%	58.5%	3.3%	3.1%	0.5%	0.3%	

100.0% of Operations

To allow a global analysis, the responses for Type I (4 tables) were compiled with the responses for Type II/IV (7 tables), for a total of 43 317 de/anti-icing operations worldwide. As previously shown in Table 5.4, the total number of Type I and Type II/IV deicing operations are illustrated as a function of location and by precipitation condition.

Figure 5.3 graphically shows the distribution of weather conditions, provided that they are grouped in three major categories: snow, frost and freezing precipitations.

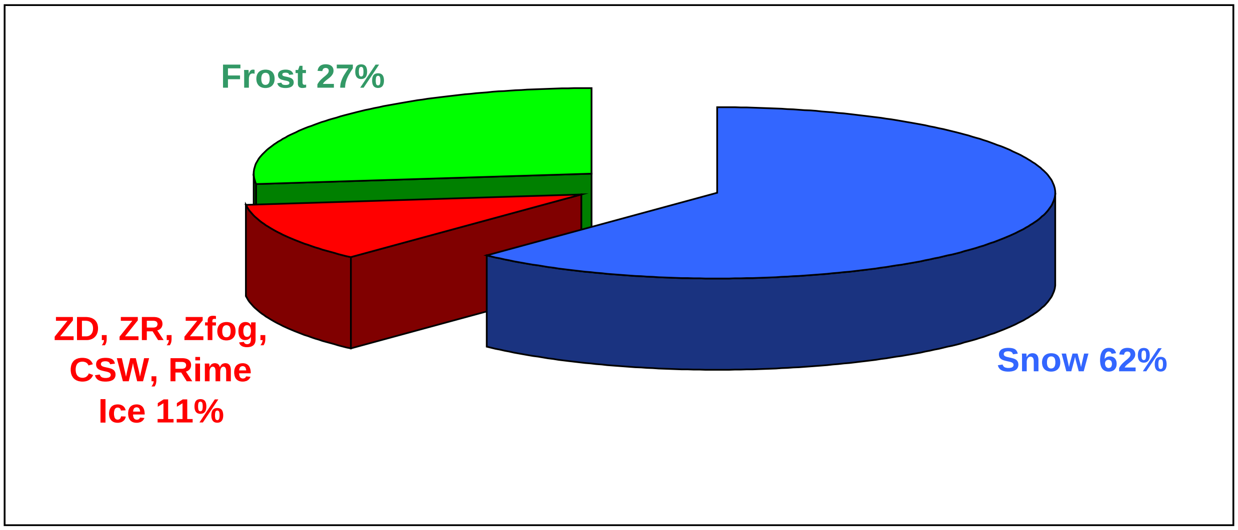

Figure 5.3: Estimate of Frequency of Deicing Operations (All Airports) – Survey 2000–01

The output from the 2000-01 survey of airlines at several international airports shows the following distribution of precipitation conditions:

a) 62 percent of the de/anti-icing operations occurred under snow precipitation, substantiating that snow represents by far the most important weather condition in terms of deicing operations worldwide;

b) Frost accounted for 27 percent of deicing operations; in other words one out of four deicing operations worldwide was caused by frost accretion. The survey has shown that frost has an even greater significance in areas with mild temperatures and above-average humidity levels (i.e. London, Amsterdam); and

c) The balance of 11 percent was distributed between freezing fog, freezing drizzle, light freezing rain, rain on cold-soak wing and rime ice. Within this group, light freezing rain is the most important weather condition, accounting for 4.8 percent of the operations.

The analysis shows that Toronto's weather phenomena distribution is closest and most representative of the worldwide distribution. The distribution for Montreal comes in second, with more precipitation towards lower temperatures. To a certain extent this is the expected result, since the survey is largely based (55 percent) on the numbers provided by these two airports.

5.4.2 Previous Estimates of Deicing Operations at Dorval Airport

Table 5.9 shows a complete summary of results from estimates made prior to 2001 and the recent survey results.

Table 5.9: Summary of All Results

	FROST [%]	FRZ. FOG [%]	SNOW [%]	FRZ. DRIZZLE [%]	LIGHT FRZ. RAIN [%]	RAIN ON CSW [%]	RIME ICE [%]
Estimate for Dorval based on AES And AeroMag Data (Prior to 2001)	25	1	70	1	2	1	0
Estimate for Dorval based on 2000-01 Survey	25	0	69	2	3	1	0
Estimate of all airports	27	1	62	2	5	1	2

The distribution illustrated in Figure 5.3 is very similar to the Dorval allocation (Figure 5.1) that was estimated a few years ago. In the survey, the snow division accounts for 62 percent of the total number of operations whereas in Figure 5.1 snow was estimated at 70 percent. The variation could be explained by the difference in the average winter temperature between Quebec and the surveyed regions.

5.5 Future Survey Requirements

This data represents a year of observation from several international airports. While the data were found to provide important information, they do not represent a true random sample of climate conditions where deicing is taking place. Airports in more northern latitudes are missing from this sample. To increase the confidence level of this analysis, more airports, such as Helsinki, Oslo or Stockholm should be added. Data from one airport from the western part of the continent, say Denver or Edmonton, along with information from Boston, New York or Washington would also have a significant input.

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

The recommendation for the future is to continue this study for the next several winters and also to increase the number of surveyed airports.

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

In 2001-02, the Type I fluid holdover time table format underwent a thorough examination. Research in previous years has indicated a need to make changes to the format. Some of the changes have been presented and accepted by the community, others have yet to be formally accepted. This section will document the two major changes to the format of the Type I fluid holdover time table and provide the reasoning and justification behind those changes. The two changes that will be discussed are:

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.

In addition, a brief overview of the possible changes that may be anticipated for the Type II and Type IV fluid holdover time table format is outlined. Other general changes to the format of the holdover time tables will also be presented.

6.1 Modifying the Temperature Ranges

During previous winter research programs, concerns relating to testing at temperatures above freezing, as well as conclusions from several studies, have indicated the need to modify the temperature ranges in the Type I fluid holdover time table format. These modifications affect the current temperature ranges of *above 0°C* and from *0 to -10°C*.

The following subsections are derived from the studies in question.

6.1.1 Testing for the Temperature Range Above 0°C

Determining fluid endurance time values at temperatures above freezing has always been a concern. Laboratory testing for conditions above 0ºC would require that the artificial precipitation be at a temperature below freezing, which leads to premature freezing of the feed water in supply pipes and spray nozzles. Thus, testing above 0ºC in controlled conditions has not been possible. As a result, the endurance times measured at the next lowest temperature range for freezing precipitation (which is always tested in a laboratory), have been applied to the above 0ºC range.

For snow conditions, testing has continued in the natural outdoor environment due to the lack of a proven system to produce artificial snow indoors. The natural snow tests have generated fluid endurance time data at temperatures above 0°C, which has resulted in specific endurance time values for Type II and IV fluids in snow in the above 0°C cell of the holdover table.

While the historic snow endurance time value (6 to 15 minutes) for Type I Fluid was applied at all temperature ranges, the new test protocol could conceivably generate values specific to *above 0ºC.* Unfortunately, the data for Type I endurance times at temperatures above freezing has been very scattered. Values collected during the daytime differed from those taken at night, due to the differences in radiative heat exchange in daylight and darkness. Additionally, tests at mild temperatures near 0ºC sometimes exhibited adherence of the failed fluid layer to the substrate test surface. The lack of confidence in data at temperatures above freezing and the risk of adherence at these temperatures together cast doubt on the usefulness of the above 0ºC row.

Because conditions other than snow use the same values for the *above 0°C* range are used for the *0 to -3ºC* range and because the data collected for snow tests at temperatures above freezing are unreliable, it has been recommended that the *above 0°C* row be eliminated from the Type I Holdover Table format. The upper temperature limit for the next lowest temperature range would then extend to above 0°C. This recommendation was accepted at the annual SAE G-12 Meeting in Frankfurt in June 2002.

6.1.2 Establishing a Temperature Range Division for -10°C and Above

6.1.2.1 Distribution of Deicing Operations (Survey)

As described in Section 5 of this report, a deicing survey was conducted over a number of airports worldwide that yielded a temperature distribution of deicing operations. Within the snow column for Type I fluid (see Table 5.5), over 84 percent of Type I fluid deicing operations occur within the 0 to -10ºC temperature band. Examined further, the data indicates that snow in the temperature band 0 to -10ºC accounts for 55 percent of all deicing. In other words, a single cell in the Type I holdover time table (Snow, 0 to -10ºC) is referred to 55 percent of the time.

A separate weather survey based on seven winters of observation across Quebec showed that 71 percent of all snow events fall within that same temperature band (0 to -10ºC). This supports the previous comment on the high rate of referral to the single cell in the holdover time table.

This suggests a need to institute a new temperature range with its lower limit somewhere above -10°C. This new temperature range's upper limit, would be above -0°C, eliminating the need for the single range above -0°C.

6.1.3 Effect of Temperature Range Limits on Holdover Time

In conjunction with research pertaining to the formulation of a new Type I test protocol, analysis was conducted to study the effect of the temperature range limits on holdover time. This analysis was documented in *SAE Type I Fluid Endurance Time Test Protocol,* TP 13827E (9).

Because current holdover times in the above 0 to -10ºC temperature range are determined at -10ºC, it was concluded that the current wide temperature range in the holdover time guidelines penalizes operations at milder temperatures in the range. A narrower range, with -3ºC suggested as its lower limit, would ensure much longer times at the milder temperatures.

The following subsections are excerpts from the afore-mentioned report and provide the reasoning behind the conclusion.

6.1.3.1 Temperature range 0 to -10ºC

Figure 6.1 illustrates the surface temperature and fluid freeze point mechanisms that influence fluid failure at Outside Air Temperature (OAT) -10ºC, the range's lower limit in the current guidelines. The average wing leading edge temperature profile curve is shown adjusted to an OAT (Outside Air Temperature) of -10ºC. The curve gradually approaches its ultimate value and ambient temperature.

The fluid freeze point temperature curve is derived from an amalgamation of fluid concentration (Brix) values measured continually during several actual tests in precipitation conditions. This curve represents the fluid freeze point temperature as the fluid gradually dilutes, rising from its initial value of -20ºC (10ºC buffer) and approaching its ultimate value of 0ºC.

Freezing is expected to occur when the two curves intersect and the surface temperature matches the fluid freeze point temperature, in this case at about 5.5 minutes after fluid application.

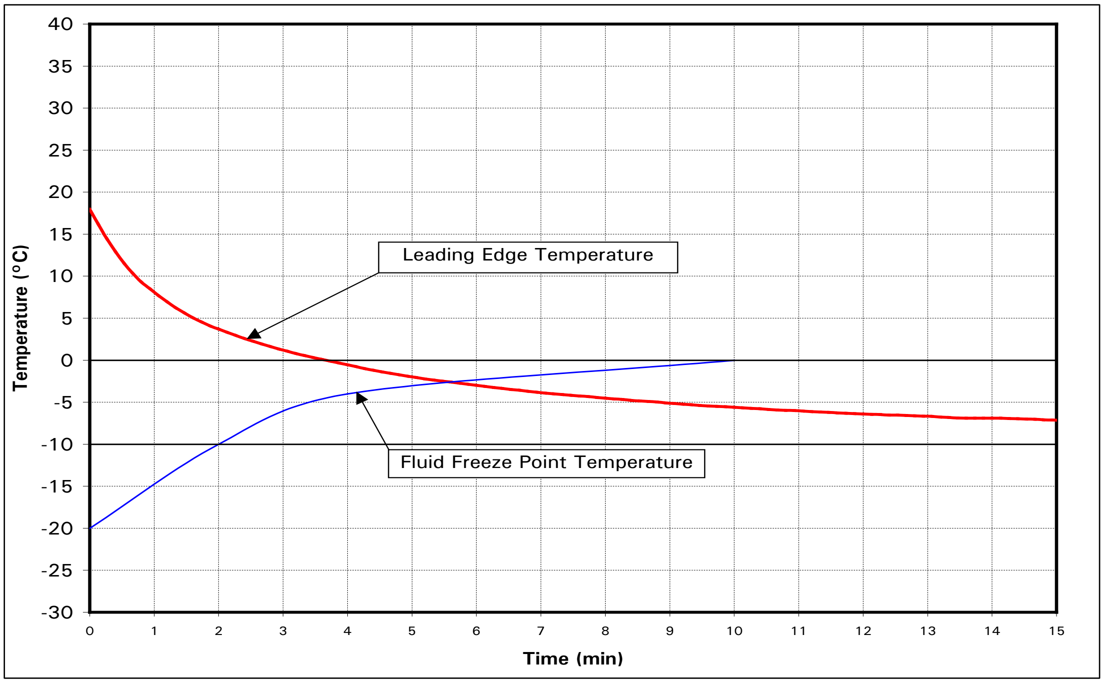

Figure 6.1: Intersection of Wing Temperature and FFP Profiles at OAT -10°C

6.1.3.2 Temperature range 0 to -3°C

Figure 6.2 represents the surface temperature and fluid freeze point mechanisms that influence fluid failure at a different lower limit for the range, in this case -3°C.

The average wing leading edge temperature profile curve is shown adjusted to an OAT of -3°C. The curve gradually approaches its ultimate value, ambient temperature. Because it started at a higher temperature, the leading edge temperature reaches a higher peak temperature than in the previous case. In this instance, it is assumed that the leading edge temperature progressively approaches its ultimate value (OAT -3°C) at the same rate as it approached OAT -10°C in the previous case. Any errors in this assumption do not change the nature of the argument.

The fluid freeze point temperature curve shown here is also derived from fluid concentration values measured periodically throughout actual tests. The fluid freeze point temperature gradually rises from its initial value of -13°C (10° fluid freeze point buffer) and approaches 0°C as a result of ongoing dilution under precipitation.

In this case, the point of intersection at 13 minutes or more is much later than in the previous case. This later intersection is influenced by the increasing flatness of the two curves as they near their ultimate values, which in this case are very close to each other (-3°C and 0°C).

The benefit of using smaller ranges in the guideline is demonstrated in the comparison of these two cases. Adoption of a range that has -3°C as its lower limit offers much longer holdover times than would a range with a lower limit of -10°C.

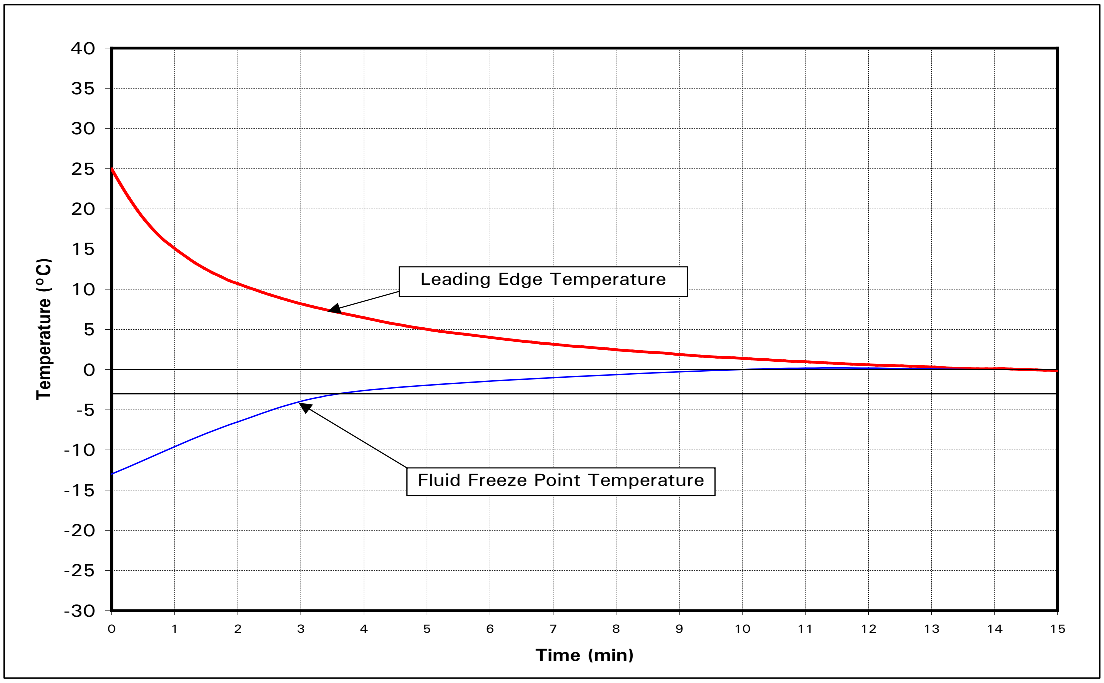

Figure 6.2: Intersection of Wing Temperature and FFP Profiles at OAT -3°C

6.1.3.3 Conclusions of the study

It was concluded in the Report *SAE Type I Fluid Endurance Time Test Protocol*, TP 13827E (9), that the current wide temperature range in the holdover time guidelines from 0 to -10°C incurs significant operational penalties, as short holdover times are imposed by the lower limit (-10°C) over the entire range. A range with -3°C as its lower limit would have much longer holdover times than one with -10°C as the lower limit.

6.1.4 Why at -3°C?

Several factors support the selection of -3°C as the division point for new temperature ranges above -10°C in the Type I holdover time table.

6.1.4.1 Current Type II and Type IV holdover time table format

A temperature range of 0 to -3°C currently exists in both Type II and Type IV holdover time tables. Creating a similar range in the Type I holdover time table will provide for a more consistent table format for all fluid types.

6.1.4.2 Holdover time optimisation analysis

Selecting -3ºC as the lower limit for the new temperature range presents the optimum solution, as it 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 -3ºC, as opposed to any other temperature; this analysis did as follows:

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* X *holdover time* for the two ranges and 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 6.1 – Temperature Range column, Number of Snowfall Events column and Snowfall Events columns). The snowfall events are derived from Table 4.7, 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 7 years from six airports in Quebec.

The number of snowfall events at each temperature interval was calculated as a percentage of the total number of snowfall events between the *above 0ºC* and *-10ºC* range. These percentages were then accumulated in ascending and descending order between above 0ºC and -10 ºC.

Analysis was conducted for three precipitation rates. A rate of 10 g/dm^2/h represents the upper limit and a rate of 25 g/dm^2/h represents the lower limit of holdover time in the current snow column. A rate of 3 g/dm^2/h will be introduced and discussed in the following sections.

For each precipitation rate, a holdover time at the lower limit for each of the two temperature ranges (*above 0ºC to -xºC* and *-xºC to -10ºC*) was used to calculate the optimisation value. These holdover times are rounded, calculated values from a regression analysis of the new Type I protocol holdover time test data produced by both APS and Anti-Icing Materials International Laboratory (AMIL) during 2001-02. Refer to *Generation of Holdover Times using Representative Type I Fluid Endurance Time Test Protocol* report.

Table 6.1: Optimisation of Temperature Ranges for Type I Fluid

Temperature Interval (ºC)	Number of Snow Fall Events	Snow Fall Events			Precipitation Rate in g/dm²/h					
					3		10		25	
		% at Temperature Interval	Cum % from above 0ºC to the Potential Split	Cum % from 10ºC to the Potential Split	Holdover Time (min)	Optimization Value	Holdover Time (min)	Optimization Value	Holdover Time (min)	Optimization Value
above 0	26,922	14.0%	14.0%	86.0%	36	16.2	18	7.7	10	4.8
0 to -1	19,390	10.1%	24.1%	75.9%	29	16.9	14	7.9	8	5.0
-1 to -2	19,213	10.0%	34.1%	65.9%	24	16.7	12	8.0	7	**5.0**
-2 to -3	20,905	10.9%	44.9%	55.1%	22	**17.0**	11	**8.2**	6	4.9
-3 to -4	19,308	10.0%	55.0%	45.0%	19	16.3	9	7.6	5	4.5
-4 to -5	18,121	9.4%	64.4%	35.6%	18	16.2	9	7.9	5	4.6
-5 to -6	16,324	8.5%	72.9%	27.1%	16	15.2	8	7.5	5	4.7
-6 to -7	15,103	7.9%	80.7%	19.3%	15	14.6	7	6.8	4	4.0
-7 to -8	14,254	7.4%	88.2%	11.8%	14	13.9	7	6.9	4	4.0
-8 to -9	11,949	6.2%	94.4%	5.6%	14	13.9	7	6.9	4	4.0
-9 to -10	10,819	5.6%	100.0%	0.0%	13	13.0	6	6.0	4	4.0
Total (0 to -10)	192,308	100.0%								

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 *above 0ºC to -6ºC* and *-7 to -10ºC for a precipitation rate of 10 g/dm²/h*

a) Range *above 0ºC to -6ºC*
- lower limit is -6ºC
- holdover time = 8 minutes
- percent of operations affected = 72.9 percent

b) Range *-7 to -10ºC*
- lower limit is -10ºC
- holdover time = 6 minutes
- percent of operations affected = 27.1 percent

c) Optimization value for split at *-6ºC*
- (72.9 percent of 8 minutes) + (27.1 percent of 6 minutes) = 7.5 minutes

The optimisation value of 7.5 minutes for a split at -6°C provides an increase of 1.5 minutes compared to the value of 6 minutes for the single range *above 0 to -10ºC.*

The same routine was followed for other potential split points and for the other precipitation rates. The results were then entered in Table 6.1 and compared:

a) the optimisation value is highest at -3°C for precipitation rates of 3 and 10 g/dm²/h; and

b) for the precipitation rate of 25 g/dm²/h, the split at -3ºC gives the second highest value.

Therefore, when dividing the temperature interval from *above 0ºC* to *-10ºC* into two ranges, a split at -3°C produces the most beneficial utilisation of endurance time for deicing operations.

Dividing the temperature interval from *above 0ºC* to *-10ºC* into three ranges is also an option, and this is discussed in Section 6.5.2.

6.1.5 Revised Format for Type I HOT Table

Table 6.2 presents the proposed new Type I fluid holdover time table format that includes temperature ranges *above -3ºC* and *-3 to -10ºC.*

As this discussion deals only with the format of the holdover time table, values have not been reported for the various cells, holdover time values are reported in the Holdover Time report.

Table 6.2: New Temperature Range Format for Type I Fluid Holdover Time Table

OAT		**Approximate Holdover Times Under Various Weather Conditions (hours:minutes)**						
°C	**°F**	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER
above	**above**							
-3	**27**							
-3	**27**						**CAUTION**	
to	**to**						**No holdover**	
-10	**14**						**Time**	
below	**below**						**guidelines**	
-10	**14**						**exist**	

6.2 Adding the Light Snow Column

6.2.1 The Probability of Light Snow versus Moderate Snow Events

The current Type I fluid holdover time table format contains only one column for snow. Snow is defined as "moderate" in the holdover time table, which means it has a liquid equivalent of 10 to 25 g/dm²/h. This definition is proposed by the National Center for Atmospheric Research (NCAR) in the *Definition of Weather Phenomena* compiled by Jeff Cole and Roy Rasmussen of NCAR/RAP.

In Section 4 of this report, the frequency of snow occurrences is subdivided into three major snow conditions: light snow, moderate snow and heavy snow Figure 6.3 illustrates the boundaries. The frequency of light snow events at 73 percent is significantly higher than moderate and heavy snow; 24 percent and 3 percent, respectively (refer to Table 4.8). This indicates that using moderate snow with its shorter holdover time as the basis for the snow column imposes a penalty on operations taking place during the 73 percent of snowfall events that occur in light snow.

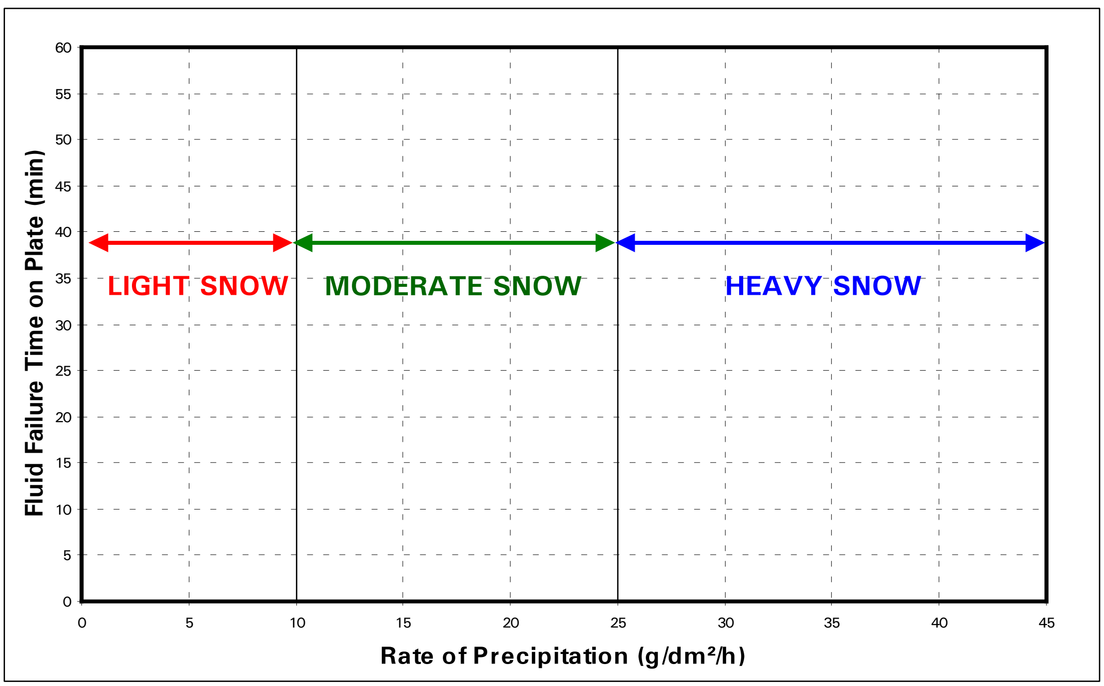

Figure 6.3: Snow Rate Definition

6.2.2 Light Snow Column Proposed at SAE G–12 Meeting

To rectify the penalty imposed on operations by using moderate snow as the basis for holdover times, it was proposed that a new column for light snow be introduced in the holdover time table and that the current snow column be renamed *"moderate snow".* This was accepted at the SAE G-12 meeting in June 2002.

The new Table 6.3 reflects this change as well as the modification to temperature ranges.

Table 6.3: New Type I Fluid Holdover Time Table Format for 2002–03 Operations

		Approximate Holdover Times Under							
OAT		**Various Weather Conditions**							
		(hours:minutes)							
°C	**°F**	FROST	FREEZING FOG	LIGHT SNOW	MODERATE SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER
above	**above**								
-3	**27**								
-3	**27**							**CAUTION**	
to	**to**							**No holdover**	
-10	**14**							**Time**	
below	**below**							**guidelines**	
-10	**14**							**exist**	

6.2.3 Implications of a Light Snow Column

Introduction of a new column for light snow requires that the precipitation rate limits of light snow be defined. The upper precipitation limit as stated in *Definition of Weather Phenomena* is <10 g/dm^2/h. However, a lower limit is also needed and for this no definition of the lower precipitation limit currently exists.

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

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

The following is an Abstract from the 11th Conference on Cloud Physics, Roy M Rasmussen, NCAR:

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

In the shorter term, an option is to extend the existing visibility charts (that relate visibility limits to snowfall rates) to the snowfall rates in lighter snow. A way to do this is to review existing data on snowfall rates gathered during snow endurance tests and in turn relate that data to concurrent visibility restrictions reported by Environment Canada.

6.2.4 Differences between TC and FAA Type I HOT Tables

TDC has proposed that a lower limit of 3 g/dm^2/h be used for the "light snow" column; however, the Federal Aviation Administration (FAA) prefers a lower limit of 5 g/dm^2/h. The TDC position has taken into consideration the very low rates that are experienced in Northern Canada at low temperatures. The FAA position, which results in shorter endurance times at the lower limit, is balanced by the FAA rule that adds 5 minutes to a pre-takeoff contamination check.

At this time, it appears that each agency will publish its own table, with different times for *light snow*.

The differences in Holdover times resulting from the different precipitation rates selected as the upper limit for "light snow" are discussed in the report *Generation of Holdover Times Using the New Type I Fluid Test Protocol*, TP 13994E (10).

In addition, there is a difference between the TC and FAA labels for the Type I HOT table rows:

a) FAA uses row labels	1st row	-3ºC and above
	2nd row	below -3ºC to
b) TC uses row labels	1st row	above -3ºC
	2nd row	-3ºC to

The same HOT values are used by TC and FAA for the 1st and 2nd rows. However, the TC value for the 1st row would apply only over the range -2ºC and above, while the FAA value would apply over the range -3ºC and above. A similar discrepancy in application range exists for the 2nd row.

6.3 Acceptance by the Industry

6.3.1 Presentation of the Findings to SAE G–12 HOT Subcommittee, November 2001

The proposed split in the temperature ranges and the addition of the light snow column was first proposed by APS at the SAE G-12 HOT Subcommittee meeting in November 2000, and again by TDC to the SAE G-12 Holdover Time Subcommittee Meeting, Montreal, November 2001. Most Subcommittee members were in general agreement with the concept of reformatting the HOT tables.

6.3.2 Presentation of the Findings to SAE G–12 Holdover Time Subcommittee, June 2002

In a presentation entitled, 'Type I Fluid Endurance Time Tests Using the New Protocol' in Frankfurt in June 2002, APS presented the modified temperature ranges and the introduction of a light snow column in the Type I holdover time table to the SAE G-12 Holdover Time Subcommittee. The new format contained the existing holdover times except for the *Light Snow* column where times could not be established until the upper precipitation rate for that column was settled upon.

The committee agreed in principle to the changed format.

6.3.3 Motion to Create Templates for Type I, Type II and Type IV Fluid Holdover Time Tables

During the meetings in Frankfurt, a motion was put forward to develop a fluid holdover time table template. This template will be a document published by the SAE. The template would contain the weather conditions, the precipitation rates and the temperature ranges that are required when formulating fluid holdover time tables. The templates would not contain any holdover times.

The major reason behind the initiation of the process was to provide a formal discussion forum for the committee members. The members would validate and accept any changes to the holdover time tables' format that may be proposed by individuals and organizations in the future.

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

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

6.4.1 Temperature Ranges

The split point of -3°C for the new temperature range in the Type I fluid holdover time table had the effect of making the temperature ranges of the three tables more consistent. However, the Type II and Type IV fluid HOT tables continue to have two temperature ranges for temperatures above -3°C:

a) *above 0℃*; and

b) *0 to -3℃*.

These two subdivisions could be combined into a single range, *above -3℃*, 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℃* and *0℃ to -3℃*. In any case, the current values are not substantiated, and preliminary frost endurance tests in winter 2000-2001 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.

6.4.2 Introduction of Light Snow Column

The current Type I Fluid Holdover Time Table currently has the following weather conditions:

a) Frost;

b) Freezing Fog;

c) Light Snow;

d) Moderate Snow;

e) Freezing Drizzle;

f) Light Freezing Rain; and

g) Rain on Cold-Soaked Wing.

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

6.5 Other Potential Future Changes

6.5.1 Evaluation of the Type II/IV HOT Table Temperature Breakdowns

6.5.1.1 Temperature range -3°C 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 HOT's for a particular Type IV fluid illustrates this effect.

Suppose that:

a) Temperature: -2ºC

b) Precipitation condition: snow

c) Weather Advisory: Moderate snow

d) Fluid Type: Clariant MPIV 2001 100 percent

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, say -7ºC, is high. Figure 3.2 (Section 3) shows that over 55 percent of the snow precipitation was recorded between 0°C and -7°C, and over 71 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, thought needs to be given to the natural freeze point limits of the fluid and their dilutions, to ensure that the required 7ºC buffer is maintained.

6.5.1.2 Break at -6°C and -10ºC for temperature range -3ºC to -14ºC

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 6.1.4.2.

The optimisation analysis was carried out twice:

a) Snow, range -3°C to -14ºC, Neat Cell of the Type IV Holdover Time Table; and

b) Snow, range -3°C to -14ºC, 75/25 Dilution Cell of the same table.

Two scenarios were considered:

a) one break, thus creating two ranges in lieu of the -3ºC to -14ºC range; and
b) two breaks and therefore three ranges in lieu of the -3ºC to -14ºC range.

The optimisation analysis then revealed which of the two scenarios would yield the highest weighted average holdover time for the range in question, and identified the values at which the break must occur (see Table 6.4).

It can be seen from the analysis that the following temperature breaks would provide the highest weighted holdover time value:

a) -3°C to -6ºC;
b) -6°C to -10ºC; and
c) -10°C to -14ºC.

The highest weighted holdover time value was 46.6 minutes for the first analysis - Snow Neat Cell (current HOT is 40 minutes) and 19.4 minutes for the second - Snow 75/25 Dilution Cell (current HOT is 15 minutes).

6.5.1.3 Temperature range -14°C to -25ºC

Section 4.3 of this report suggests that a break at -18ºC would be appropriate. This may be further examined by conducting an optimisation analysis similar to the one carried out in Section 6.1.4.2.

Table 6.4: Optimisation of Temperature Ranges for Type II/IV Fluid

Tamperature Range (ºC)	Number of Snow Fall Data Points*	At Temperature Range	Suggested Split	Number of Snow Fall Events: Between -3 and the Temperature X1	Number of Snow Fall Events: Between X1 and the Temperature X2	Number of Snow Fall Events: Between X2 and the Temperature -14	Percentage of Snow Fall Events: Between -3 and the Temperature X1	Percentage of Snow Fall Events: Between X1 and the Temperature X2	Percentage of Snow Fall Events: Between X2 and the Temperature -14	Percentage of Snow Fall Events: Total	Governing Temperature for Holdover Time: X1	Governing Temperature for Holdover Time: X2	Governing Temperature for Holdover Time: -14
	132714	100%											
-3 to -4	19308	15%	-3 to -4 to -14	19,308	0	113,406	15%	0%	85%	100%	-4	0	-14
-4 to -5	18121	14%	-3 to -4 to -5 to -14	19,308	18,121	95,285	15%	14%	72%	100%	-4	-5	-14
-5 to -6	16324	12%	-3 to -4 to -6 to -14	19,308	34,445	78,961	15%	26%	59%	100%	-4	-6	-14
-6 to -7	15103	11%	-3 to -4 to -7 to -14	19,308	49,548	63,858	15%	37%	48%	100%	-4	-7	-14
-7 to -8	14254	11%	-3 to -4 to -8 to -14	19,308	63,802	49,604	15%	48%	37%	100%	-4	-8	-14
-8 to -9	11949	9%	-3 to -4 to -9 to -14	19,308	75,751	37,655	15%	57%	28%	100%	-4	-9	-14
-9 to -10	10819	8%	-3 to -4 to -10 to -14	19,308	86,570	26,836	15%	65%	20%	100%	-4	-10	-14
-10 to -11	7453	6%	-3 to -4 to -11 to -14	19,308	94,023	19,383	15%	71%	15%	100%	-4	-11	-14
-11 to -12	7049	5%	-3 to -4 to -12 to -14	19,308	101,072	12,334	15%	76%	9%	100%	-4	-12	-14
-12 to -13	6933	5%	-3 to -4 to -13 to -14	19,308	108,005	5,401	15%	81%	4%	100%	-4	-13	-14
-13 to -14	5401	4%	-3 to -5 to -14	37,429	0	95,285	28%	0%	72%	100%	-5	0	-14
			-3 to -5 to -6 to -14	37,429	16,324	78,961	28%	12%	59%	100%	-5	-6	-14
			-3 to -5 to -7 to -14	37,429	31,427	63,858	28%	24%	48%	100%	-5	-7	-14
			-3 to -5 to -8 to -14	37,429	45,681	49,604	28%	34%	37%	100%	-5	-8	-14
			-3 to -5 to -9 to -14	37,429	57,630	37,655	28%	43%	28%	100%	-5	-9	-14
			-3 to -5 to -10 to -14	37,429	68,449	26,836	28%	52%	20%	100%	-5	-10	-14
			-3 to -5 to -11 to -14	37,429	75,902	19,383	28%	57%	15%	100%	-5	-11	-14
			-3 to -5 to -12 to -14	37,429	82,951	12,334	28%	63%	9%	100%	-5	-12	-14
			-3 to -5 to -13 to -14	37,429	89,884	5,401	28%	68%	4%	100%	-5	-13	-14
			-3 to -6 to -14	53,753	0	78,961	41%	0%	59%	100%	-6	0	-14
			-3 to -6 to -7 to -14	53,753	15,103	63,858	41%	11%	48%	100%	-6	-7	-14
			-3 to -6 to -8 to -14	53,753	29,357	49,604	41%	22%	37%	100%	-6	-8	-14
			-3 to -6 to -9 to -14	53,753	41,306	37,655	41%	31%	28%	100%	-6	-9	-14
		→	-3 to -6 to -10 to -14	53,753	52,125	26,836	41%	39%	20%	100%	-6	-10	-14
			-3 to -6 to -11 to -14	53,753	59,578	19,383	41%	45%	15%	100%	-6	-11	-14
			-3 to -6 to -12 to -14	53,753	66,627	12,334	41%	50%	9%	100%	-6	-12	-14
			-3 to -6 to -13 to -14	53,753	73,560	5,401	41%	55%	4%	100%	-6	-13	-14
			-3 to -7 to -14	68,856	0	63,858	52%	0%	48%	100%	-7	0	-14
			-3 to -7 to -8 to -14	68,856	14,254	49,604	52%	11%	37%	100%	-7	-8	-14
			-3 to -7 to -9 to -14	68,856	26,203	37,655	52%	20%	28%	100%	-7	-9	-14
			-3 to -7 to -10 to -14	68,856	37,022	26,836	52%	28%	20%	100%	-7	-10	-14
			-3 to -7 to -11 to -14	68,856	44,475	19,383	52%	34%	15%	100%	-7	-11	-14
			-3 to -7 to -12 to -14	68,856	51,524	12,334	52%	39%	9%	100%	-7	-12	-14
			-3 to -7 to -13 to -14	68,856	58,457	5,401	52%	44%	4%	100%	-7	-13	-14
			-3 to -8 to -14	83,110	0	49,604	63%	0%	37%	100%	-8	0	-14
			-3 to -8 to -9 to -14	83,110	11,949	37,655	63%	9%	28%	100%	-8	-9	-14
			-3 to -8 to -10 to -14	83,110	22,768	26,836	63%	17%	20%	100%	-8	-10	-14
			-3 to -8 to -11 to -14	83,110	30,221	19,383	63%	23%	15%	100%	-8	-11	-14
			-3 to -8 to -12 to -14	83,110	37,270	12,334	63%	28%	9%	100%	-8	-12	-14
			-3 to -8 to -13 to -14	83,110	44,203	5,401	63%	33%	4%	100%	-8	-13	-14
			-3 to -9 to -14	95,059	0	37,655	72%	0%	28%	100%	-9	0	-14
			-3 to -9 to -10 to -14	95,059	10,819	26,836	72%	8%	20%	100%	-9	-10	-14
			-3 to -9 to -11 to -14	95,059	18,272	19,383	72%	14%	15%	100%	-9	-11	-14
			-3 to -9 to -12 to -14	95,059	25,321	12,334	72%	19%	9%	100%	-9	-12	-14
			-3 to -9 to -13 to -14	95,059	32,254	5,401	72%	24%	4%	100%	-9	-13	-14
			-3 to -10 to -14	105,878	0	26,836	80%	0%	20%	100%	-10	0	-14
			-3 to -10 to -11 to -14	105,878	7,453	19,383	80%	6%	15%	100%	-10	-11	-14
			-3 to -10 to -12 to -14	105,878	14,502	12,334	80%	11%	9%	100%	-10	-12	-14
			-3 to -10 to -13 to -14	105,878	21,435	5,401	80%	16%	4%	100%	-10	-13	-14
			-3 to -11 to -14	113,331	0	19,383	85%	0%	15%	100%	-11	0	-14
			-3 to -11 to -12 to -14	113,331	7,049	12,334	85%	5%	9%	100%	-11	-12	-14
			-3 to -11 to -13 to -14	113,331	13,982	5,401	85%	11%	4%	100%	-11	-13	-14
			-3 to -12 to -14	120,380	0	12,334	91%	0%	9%	100%	-12	0	-14
			-3 to -12 to -13 to -14	120,380	6,933	5,401	91%	5%	4%	100%	-12	-13	-14
			-3 to -13 to -14	127,313	0	5,401	96%	0%	4%	100%	-13	0	-14

Suggested Split	Precipitation Rate in g/dm²/h 10: Temperature	Precipitation Rate in g/dm²/h 10: Holdover Time (based on straight line interpolation of the rounded generic values)	Precipitation Rate in g/dm²/h 10: HOT at X1	Precipitation Rate in g/dm²/h 10: HOT at X2	Precipitation Rate in g/dm²/h 10: HOT AT -14	Precipitation Rate in g/dm²/h 10: Optimization Value	Precipitation Rate in g/dm²/h 25: Temperature	Precipitation Rate in g/dm²/h 25: Holdover Time (based on straight line interpolation of the rounded generic values)	Precipitation Rate in g/dm²/h 25: HOT at X1	Precipitation Rate in g/dm²/h 25: HOT at X2	Precipitation Rate in g/dm²/h 25: HOT AT -14	Precipitation Rate in g/dm²/h 25: Optimization Value
			55		40				25		15	
-3 to -4 to -14	-3	55	54	0	40	41.98	-3	25	24	0	15	16.32
-3 to -4 to -5 to -14	-4	54	54	52	40	43.66	-4	24	24	23	15	17.44
-3 to -4 to -6 to -14	-5	52	54	51	40	44.82	-5	23	24	22	15	18.21
-3 to -4 to -7 to -14	-6	51	54	50	40	45.55	-6	22	24	21	15	18.70
-3 to -4 to -8 to -14	-7	50	54	48	40	45.92	-7	21	24	20	15	18.94
-3 to -4 to -9 to -14	-8	48	54	47	40	45.88	-8	20	24	20	15	18.92
-3 to -4 to -10 to -14	-9	47	54	45	40	45.54	-9	20	24	19	15	18.69
-3 to -4 to -11 to -14	-10	45	54	44	40	44.88	-10	19	24	18	15	18.25
-3 to -4 to -12 to -14	-11	44	54	43	40	44.06	-11	18	24	17	15	17.71
-3 to -4 to -13 to -14	-12	43	54	41	40	43.09	-12	17	24	16	15	17.06
-3 to -5 to -14	-13	41	52	0	40	43.46	-13	16	23	0	15	17.31
-3 to -5 to -6 to -14	-14	40	52	51	40	44.80	-14	15	23	22	15	18.20
-3 to -5 to -7 to -14	0	0	52	50	40	45.72	0	0	23	21	15	18.81
-3 to -5 to -8 to -14			52	48	40	46.28			23	20	15	19.18
-3 to -5 to -9 to -14			52	47	40	46.42			23	20	15	19.28
-3 to -5 to -10 to -14			52	45	40	46.27			23	19	15	19.18
-3 to -5 to -11 to -14			52	44	40	45.80			23	18	15	18.87
-3 to -5 to -12 to -14			52	43	40	45.17			23	17	15	18.44
-3 to -5 to -13 to -14			52	41	40	44.38			23	16	15	17.92
-3 to -6 to -14			51	0	40	44.42			22	0	15	17.95
-3 to -6 to -7 to -14			51	50	40	45.50			22	21	15	18.67
-3 to -6 to -8 to -14			51	48	40	46.23			22	20	15	19.15
-3 to -6 to -9 to -14			51	47	40	46.54			22	20	15	19.36
-3 to -6 to -10 to -14			51	45	40	46.56			22	19	15	19.37
-3 to -6 to -11 to -14			51	44	40	46.25			22	18	15	19.17
-3 to -6 to -12 to -14			51	43	40	45.79			22	17	15	18.86
-3 to -6 to -13 to -14			51	41	40	45.17			22	16	15	18.45
-3 to -7 to -14			50	0	40	44.95			21	0	15	18.30
-3 to -7 to -8 to -14			50	48	40	45.83			21	20	15	18.89
-3 to -7 to -9 to -14			50	47	40	46.30			21	20	15	19.20
-3 to -7 to -10 to -14			50	45	40	46.47			21	19	15	19.32
-3 to -7 to -11 to -14			50	44	40	46.32			21	18	15	19.22
-3 to -7 to -12 to -14			50	43	40	46.01			21	17	15	19.01
-3 to -7 to -13 to -14			50	41	40	45.55			21	16	15	18.70
-3 to -8 to -14			48	0	40	45.12			20	0	15	18.42
-3 to -8 to -9 to -14			48	47	40	45.74			20	20	15	18.83
-3 to -8 to -10 to -14			48	45	40	46.06			20	19	15	19.04
-3 to -8 to -11 to -14			48	44	40	46.06			20	18	15	19.04
-3 to -8 to -12 to -14			48	43	40	45.89			20	17	15	18.93
-3 to -8 to -13 to -14			48	41	40	45.58			20	16	15	18.72
-3 to -9 to -14			47	0	40	44.88			20	0	15	18.26
-3 to -9 to -10 to -14			47	45	40	45.33			20	19	15	18.55
-3 to -9 to -11 to -14			47	44	40	45.45			20	18	15	18.63
-3 to -9 to -12 to -14			47	43	40	45.40			20	17	15	18.60
-3 to -9 to -13 to -14			47	41	40	45.22			20	16	15	18.48
-3 to -10 to -14			45	0	40	44.35			19	0	15	17.90
-3 to -10 to -11 to -14			45	44	40	44.58			19	18	15	18.05
-3 to -10 to -12 to -14			45	43	40	44.65			19	17	15	18.10
-3 to -10 to -13 to -14			45	41	40	44.57			19	16	15	18.05
-3 to -11 to -14			44	0	40	43.49			18	0	15	17.33
-3 to -11 to -12 to -14			44	43	40	43.64			18	17	15	17.43
-3 to -11 to -13 to -14			44	41	40	43.64			18	16	15	17.42
-3 to -12 to -14			43	0	40	42.47			17	0	15	16.65
-3 to -12 to -13 to -14			43	41	40	42.55			17	16	15	16.70
-3 to -13 to -14			41	0	40	41.31			16	0	15	15.87
					Optimum Value	46.56					Optimum Value	19.37

6.5.2 Additional Temperature Ranges in the Type I HOT Table

The earlier discussion was based on a format where two ranges were utilised down to -10°C:

a) Above -3°C;

b) -3°C to -10°C; and

c) Below -10°C.

Some members in the industry have raised the question of whether the temperature range from -3°C to -10°C should be further divided.

The following argument is being put forward. Since a high number of snow events occur within this temperature range and for the same reasons stated above, namely, 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 every additional minute of holdover time is valuable.

Following the SAE G-12 meetings, FAA published a HOT Guideline for 2002-2003 (Table 6.5) using an additional split at -6°C.

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

An analysis following the methodology described in Section 6.1.4.2 was conducted to validate the overall effectiveness of the temperature ranges and limit for light snow intensity as used in the FAA HOT table, versus those used in the Transport Canada HOT table. The results are shown in Table 6.6. The results show that the Transport Canada table is more advantageous at the lighter end of the light snow range but the reverse is true at the heavy end of the light snow range and in the moderate snow range.

Table 6.5: FAA Type I HOT Guideline for 2002–2003

<table>
<tr><th colspan="2">OAT</th><th colspan="8">Approximate Holdover Times Under Various Weather Conditions
(hours: 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>0:45</td><td>0:11 - 0:17</td><td>0:11 - 0:16</td><td>0:06 - 0:11</td><td>0:09 - 0:13</td><td>0:02 - 0:05</td><td>0:02 - 0:05</td><td rowspan="4">CAUTION: No holdover time guidelines exist</td></tr>
<tr><td>below -3 to -6</td><td>below 27 to 21</td><td>0:45</td><td>0:08 - 0:14</td><td>0:08 - 0:13</td><td>0:05 - 0:08</td><td>0:07 - 0:10</td><td>0:02 - 0:05</td><td rowspan="2">CAUTION: Clear ice may require touch for confirmation</td></tr>
<tr><td>-7 to -10</td><td>20 to 14</td><td>0:45</td><td>0:06 - 0:10</td><td>0:06 - 0:10</td><td>0:04 - 0:06</td><td>0:05 - 0:08</td><td>0:02 - 0:05</td></tr>
<tr><td>Below -10</td><td>below 14</td><td>0:45</td><td>0:05 - 0:09</td><td>0:04 - 0:06</td><td>0:02 - 0:04</td><td colspan="3"></td></tr>
</table>

Table 6.6: Comparison of Transport Canada and FAA 2002–2003 Type I HOT Tables for Snow

Transport Canada Table			**FAA Table**		
Precipitation Rate 3 g/dm²/h			**Precipitation Rate 5 g/dm²/h**		
Temperature Range	HOT	% Snow Events Applicable	Temperature Range	HOT	% Snow Events Applicable
Above -3°C	22	44.9	-3°C and above	16	44.9
			Below -3 to -6	12	28.0
-3 to -10	13	55.1	Below -6 to -10	10	27.1
Weighted HOT Value Above 0 to -10°C	17.0	100	Weighted HOT Value Above 0 to -10°C	13.3	100
Precipitation Rate 10 g/dm²/h			Precipitation Rate 10 g/dm²/h		
Temperature Range	HOT	% Snow Events Applicable	Temperature Range	HOT	% Snow Events Applicable
Above -3°C	11	44.9	-3°C and above	11	44.9
			Below -3 to -6	8	28.0
Below -3 to -10	6	55.1	Below -6 to -10	6	27.1
Weighted HOT Value Above 0 to -10°C	8.2	100	Weighted HOT Value Above 0 to -10°C	8.8	100
Precipitation Rate 25 g/dm²/h			Precipitation Rate 25 g/dm²/h		
Temperature Range	HOT	% Snow Events Applicable	Temperature Range	HOT	% Snow Events Applicable
Above -3°C	6	44.9	-3°C and above	6	44.9
			Below -3 to -6	5	28.0
Below -3 to -10	4	55.1	Below -6 to -10	4	27.1
Weighted HOT Value Above 0 to -10°C	4.9	100	Weighted HOT Value Above 0 to -10°C	5.2	100

6.5.3 Further Potential Changes to the Format of the HOT Tables

Modifications to the Type II and IV tables to correspond to the Type I table (removal of the row *above 0°C* and the addition of the light snow column) have already been discussed in Section 6.4.

Other changes to the HOT table format are possible and are discussed as follows.

6.5.3.1 Use of minutes for holdover time

The current holdover time tables report holdover time in the following manner:

- HH:MM

SAS uses a different format in their tables and has suggested that the holdover time tables be modified to report holdover time in the following manner:

a) MM when HOT ≤ 65 minutes; and
b) HH:MM when HOT > 65 minutes.

6.5.3.2 Order of Snow Columns

Following the addition of the Light Snow column and change of the existing snow column to "Moderate Snow", there has been a discussion as to the best order of the two columns. Historically, the order of the weather conditions in the HOT tables has been from left to right, the least severe to the most severe. Hence, the current order of the two snow columns. Ergonomically, this is more difficult when reading the holdover times within the temperature ranges since both weather conditions share a common holdover time; the upper limit of Light Snow is identical to the lower limit of Moderate snow, and those two numbers, based on the current layout, are not next to each other (see Table 6.7).

It is recommended that this suggestion be further evaluated. As well, the order of all columns should be examined for best format.

6.5.3.3 Use of a single digit HOT value

6.5.3.3.1 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 using one value. This would reduce the cost of testing.

Table 6.7: Current Light Snow-Moderate Snow Layout versus Suggested Layout

Current Layout (Light Snow - Moderate Snow)									
°C	°F	Frost	Freezing Fog	Light Snow	Moderate Snow	Freezing Drizzle	Light Freezing Rain	Rain On Cold Soaked Wing	Other
above -3	above 27			11 - 22	6 - 11				

Suggested Layout (Moderate Snow - Light Snow)									
°C	°F	Frost	Freezing Fog	Moderate Snow	Light Snow	Freezing Drizzle	Light Freezing Rain	Rain On Cold Soaked Wing	Other
above -3	above 27			6 - 11	11 - 22				

6.5.3.3.2 Freezing drizzle

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

6.5.3.4 Light freezing rain

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

6.6 Possible Future Format of HOT Table

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 easily understood 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 HOT tables have been published, the information conveyed on the tables has grown to satisfy various issues and interests.

Transport Canada has examined the format with a view to providing a version that is easier to use, without negatively impacting the operation. That examination has led to a vision of a very simple chart. An example of the current format, and the Transport Canada vision for a HOT table, are shown in Table 6.8 and Table 6.9 respectively. The comparative simplicity of the envisioned table is evident.

Achieving this vision will require considerable consultation and education, and it is recommended that the effort needed to bring this about be given early priority and ongoing attention.

Table 6.8: Current Format of Holdover Time Table

OAT		Type xx Fluid Concentration Neat-Fluid/Water (% by volume)	Various Weather Conditions (hours:minutes)						
°C	°F		*FROST	FREEZING FOG	SNOW □	***FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING	OTHER****
above 0º	above 32º	**100/0**	18:00	1:05-2:15	0:35-1:05	0:40-1:10	0:25-0:45	0:10-0:50	
		75/25	6:00	1:05-1:45	0:30-1:05	0:35-0:50	0:15-0:30	0:05-0:35	
		50/50	4:00	0:15-0:35	0:05-0:20	0:10-0:20	0:05-0:10		
0 to -3	32 to 27	**100/0**	12:00	1:05-2:15	0:30-0:55	0:40-1:10	0:25-0:45	**CAUTION No holdover time guidelines exist**	
		75/25	5:00	1:05-1:45	0:25-0:50	0:35-0:50	0:15-0:30		
		50/50	3:00	0:15-0:35	0:05-0:15	0:10-0:20	0:05-0:10		
below -3 to -14	below 27 to 7	**100/0**	12:00	0:20-1:20	0:20-0:40	**0:20-0:45	**0:10-0:25		
		75/25	5:00	0:25-0:50	0:15-0:25	0:15-0:30	**0:10-0:20		
below -14 to -25	below 7 to -13	**100/0**	12:00	0:15-0:40	0:15-0:30				
below -25	below -13	**100/0**	SAE TYPE xx fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.						

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Table 6.9: Transport Canada Vision of Holdover Time Table Format

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) FREEZING FOG	Light Snow	Moderate Snow	***FREEZING DRIZZLE	LIGHT FRZ RAIN	OTHER****
above -3	above 27	100/0	1:05	0:55	0:30	0:40	0:25	CAUTION No holdover time guidelines exist
		75/25	1:05	0:50	0:25	0:35	0:15	
		50/50	0:15	0:15	0:05	0:10	0:05	
below -3 to -10	below 27 to 14	100/0	0:30	0:45	0:20	0:20	0:10	
		75/25	0:30	0:30	0:15	0:15	0:10	
below -10 to -25	below 14 to -13	100/0	0:15	0:30	0:15			
below -25	below -13	100/0	SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used.					

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

This chapter contains a description of tests conducted over the 2001-02 winter to collect fog and frost deposition rates in natural conditions.

7.1 Study to Quantify Freezing Fog Deposition Rates

7.1.1 Background and Objective

The objective of this study was to measure the range of deposition rates that occur naturally in fog and to correlate the measurements with the 2 to 5 g/dm^2/h range that is used in environmental chambers. The history of how the two limits of 2 and 5 g/dm^2/h were obtained can be found in the Transport Canada Report, *Aircraft Ground De/Anti-icing Fluid Holdover Time Development Program for the 2000/2001 Winter*, TP 13826E (11), Section 2.9. The values were obtained with input on liquid water content from meteorologists at the National Research Council Canada (NRC) and NCAR and based on estimates of expected aircraft taxi speeds and the collection efficiencies of wings.

7.1.2 Data Collection and Procedure

Fog deposition rates were collected on several occasions in periods of natural fog. The procedure for the fog deposition tests appears as Appendix F.

The test assembly included a precipitation collection pan inclined forward at 10° from the horizontal, wetted with Type IV fluid and mounted on the top of an automobile travelling at a speed of 30 to 40 km/h for a 10-30 minute time interval. The weight of the precipitation collection pan was to be measured after each interval so that the fog deposition rate could be calculated. One APS team member conducted the tests. Photo 7.1 shows the test assembly.

Five tests were conducted during 2001-02 at various times of the day and night. Another test was carried out two years earlier and has been included with this report. Two of these six tests included a “static” test in order to gain a better understanding of the effect travel speed had on the deposition rate. The tests are listed in Table 7.1.

Often, the occurrence of intense fog conditions was preceded by precipitation of rain, freezing rain or snow. A summary chart (Figure 7.1) of the tests conducted shows the OAT, the average travel speed and rate in relation to visibility for each test. Figure 7.2 shows the same results normalized to a travel speed of 30 km/h.

The curve drawn on Figure 7.2 is a power law best-fit curve for the complete data set but excluding the static data.

Table 7.1: Fog Deposition Measurement Summary

Date	Visibility (m)	Rate ($g/dm^2/h$)	OAT (°C)	Travel Speed (km/h)
2000	152	1.29	14.0	27
1–Nov–01	201	0.36	3.0	31
5–Nov–01	137	1.80	5.5	39
6–Dec–01	46	2.50	11.1	34
24–Dec–01	457	0.16	-3.9	23
31–Mar–02	274	0.68	0.1	39
6–Dec–01	46	0.22	11.1	Static
24–Dec–01	457	0.11	-3.9	Static

7.1.3 Observations and Results

The tests indicate that there is a relationship between visibility and deposition rates. As visibility dropped, a significant increase in deposition rate was observed. The rates measured ranged from 0.1 $g/dm^2/h$ for 457 m (1500 ft.) to 2.5 $g/dm^2/h$ for 46 m (150 ft.).

These results indicate that the selected rates for the laboratory tests of 2 $g/dm^2/h$ (lower rate used to measure Endurance Time (ET)) and 5 $g/dm^2/h$ (higher rate used to measure ET) do not match the natural rates, which are lower.

Using 2 and 5 $g/dm^2/h$ as ET parameters appears to be conservative. The Canadian Air Regulations (CARS 624.14 and 725.34) indicate that the lowest actual visibility limit for departures under instrument meteorological conditions is 183 m (600 ft.). This visibility in Figure 7.2 gives a rate of 0.7 $g/dm^2/h$. One other issue related to freezing fog endurance times is that the holdover times for Type II and IV fluids are typically greater than one hour. It is rare for aircraft to taxi for periods longer than one hour. The data from the two static tests (see Figure 7.1) show that the rates are much lower in a static condition suggesting that the rates of 2 and 5 $g/dm^2/h$ are conservative.

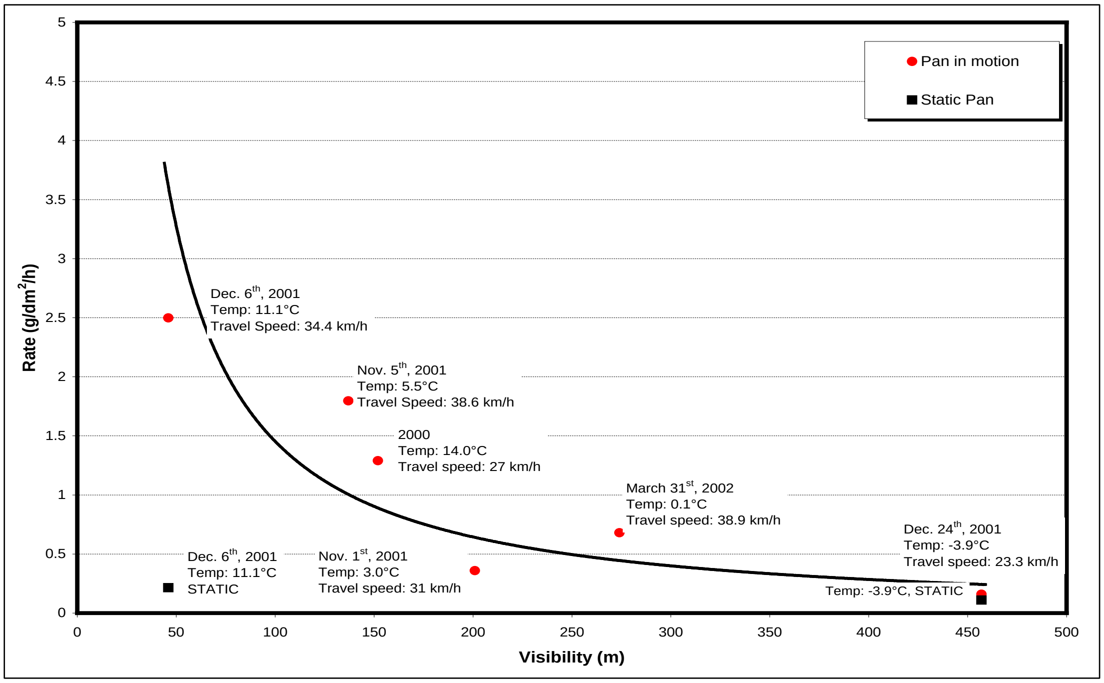

Figure 7.1: Fog Tests – Original Deposition Data

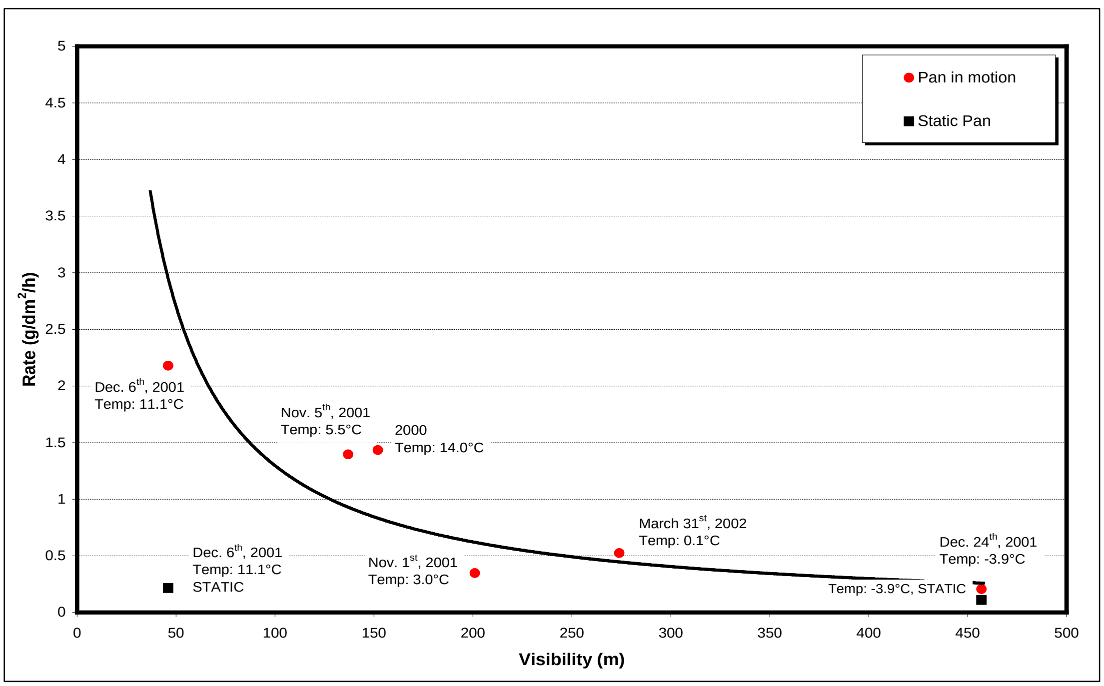

Figure 7.2: Fog Tests – Deposition Data Adjusted to 30 km/h Travel Speed

7.2 Measurement of Frost Deposition Rates in Natural Conditions

7.2.1 Background

During the 2000-01 winter, tests were conducted to substantiate values as published in current holdover time tables, for fluid endurance in active frost conditions, and to evaluate the proposed Aerospace Standard (AS) 5485 procedure for measuring fluid endurance times.

Because the test results and a subsequent theoretical analysis concluded that the specified test conditions were not appropriate for producing the required frost rates, it was concluded that further research was necessary (see Transport Canada Report *Endurance Time Tests in Simulated Frost Conditions*, TP 13831E (12)).

7.2.2 Objective

The objective of this research was to document rates of frost accretion representative of those on aircraft surfaces, and the corresponding environmental conditions, for the purpose of refining the laboratory test conditions in AS5485 for fluid endurance tests in active frost.

To achieve this objective, the research was organized into three phases:

- Phase I) Evaluation of Frost Accretion Rates in Natural Conditions;
- Phase II) Evaluation of Wing-To-Air Temperature Differential; and
- Phase III) Validation Frost Tests in Conjunction with Aircraft Wings.

7.2.3 Observation and Results

The results and conclusions from this year's tests are summarized in Transport Canada Report TP 13992E, *Evaluation of Laboratory Test Parameters for Frost Endurance Time Tests* (13). New frost rates and wing-to-air temperature differentials have been proposed in this associated report.

Photo 7.1: Test Assembly for Fog Deposition Rates

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8. CONCLUSIONS

8.1 Precipitation Rate Limits for the Moderate Snow Range

Data gathered over seven 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 24 percent of all snow events and snowfall at rates less than 10 $g/dm^2/h$ accounts for 73 percent of all snow events.

8.2 Addition of a 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 62 percent of all deicing operations, introduction of an additional column in the HOT table representing *light snow* is justified. Such a recommendation was accepted at the 2002 SAE G-12 meeting, resulting in the need to define a lower rate limit for the new *light snow* column. Transport Canada subsequently decided to use 3 $g/dm^2/h$, and the FAA to use 5 $g/dm^2/h$, for the lower limit. The resulting *light snow* ranges account for 27 percent and 13 percent of all snow operations respectively. The *light* and *moderate* snow ranges together account for 51 percent of all snow events in the Transport Canada Type I HOT table, and 37 percent in the FAA table.

In order to use the longer holdover times in the *light snow* column, operators need more comprehensive information on snowfall rates lower than 10 $g/dm^2/h$. Development of the NCAR hot plate snow intensity measuring device to an operational state would satisfy this need, and should therefore be given high priority.

8.3 Modifications to HOT Tables

It was concluded that the temperature row *above 0°C* should be removed from the Type I HOT table. This conclusion was based on the inability to test for the non-snow columns above 0°C, which resulted in the cells simply repeating values from the next lower temperature row, and, in the case of snow, on the lack of confidence in endurance times measured above 0°C, where radiation heat exchange with the sky leads to highly variable times. Furthermore, fluid failures at mild temperatures were found to frequently adhere to the test surface.

It was concluded that a new row, *above -3ºC,* should be introduced to replace the *above 0ºC* row in the Type I HOT table. The selection of -3ºC as the temperature break was based on:

a) An examination of the surface temperature and fluid freeze point profiles that demonstrated that longer endurance times are generated with warmer temperature breaks;
b) The current Type II and IV HOT tables that include a row at -3ºC; and
c) 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 with a view to integrating the same changes as in the Type I table including:

a) Removal of the *above 0ºC* row; and
b) Introduction of a light snow column.

It was further concluded that the HOT table formats should be subjected to an overall review to determine the best format for ongoing use. In addition to other issues, such a review should examine:

a) Concepts addressed in Transport Canada's vision of future table format;
b) Implementation of finer temperature breaks, as included in the FAA Type I table; and
c) The relative benefits of various alternatives through the application of an optimization analysis.

8.4 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 62 percent;
b) Frost 27 percent; and
c) Other 11 percent.

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

8.4.1 Snow

This distribution confirms that the HOT table for snow is the most frequently used 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.

8.4.2 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 formulating Type I fluid frost holdover times.

8.4.3 Freezing Rain / Freezing Drizzle

Analysis of the weather survey data concluded that:

a) Freezing rain and drizzle occur in a band with -10ºC as a lower limit; and
b) 93 percent of the time precipitation rates are less than 25 g/dm^2/h.

8.4.4 Freezing Fog

It was concluded that:

a) Deicing operations due to freezing fog comprise only 1 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, that is envisioned in the Transport Canada future HOT table format and is justified based on long endurance times and infrequent use.

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9. RECOMMENDATIONS

Recommendations related to specific subjects are offered.

9.1 HOT Table format

It is recommended that:

a) A workgroup 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 requested by the SAE G-12 HOT Committee; and

b) Development of the NCAR hot plate snow intensity measuring device be given high priority.

9.2 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.

9.3 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 formulating endurance times for frost conditions. The needed research is reflected in an associated report.

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APPENDIX A

WORK STATEMENT (EXCERPT)
PROJECT DESCRIPTION

PROJECT DESCRIPTON EXCERPT FROM TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT DC 202 AIRCRAFT & ANTI-ICING FLUID WINTER TESTING WINTER OPERATIONS CONTAMINATED AIRCRAFT – GROUND 2001 -2003 (March 2002)

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; and

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

5.6 HOT Guideline Format Review

5.6.1 Review the survey data collected and the Dorval weather data;

5.6.2 Gather more weather and operational de-icing data to consolidate the analysis;

5.6.3 Conduct a more detailed analysis of the HOT table format to evaluate potential changes and their impact on HOTs;

5.6.4 Analyze all the data collected; and

5.6.5 Report the findings in order to support any proposed changes.

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APPENDIX B

WINTER WEATHER DATA 1995-96 TO 2001-02

WINTER WEATHER DATA
1995-96 TO 2001-02

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

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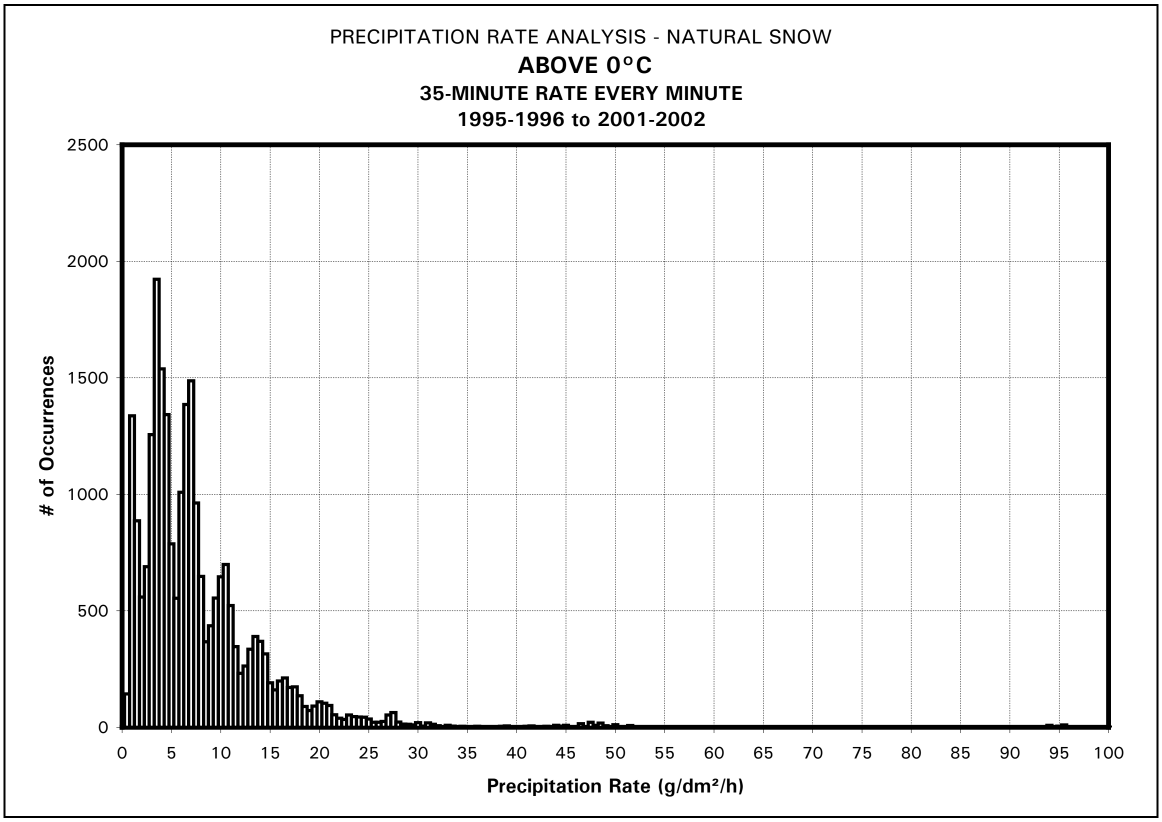
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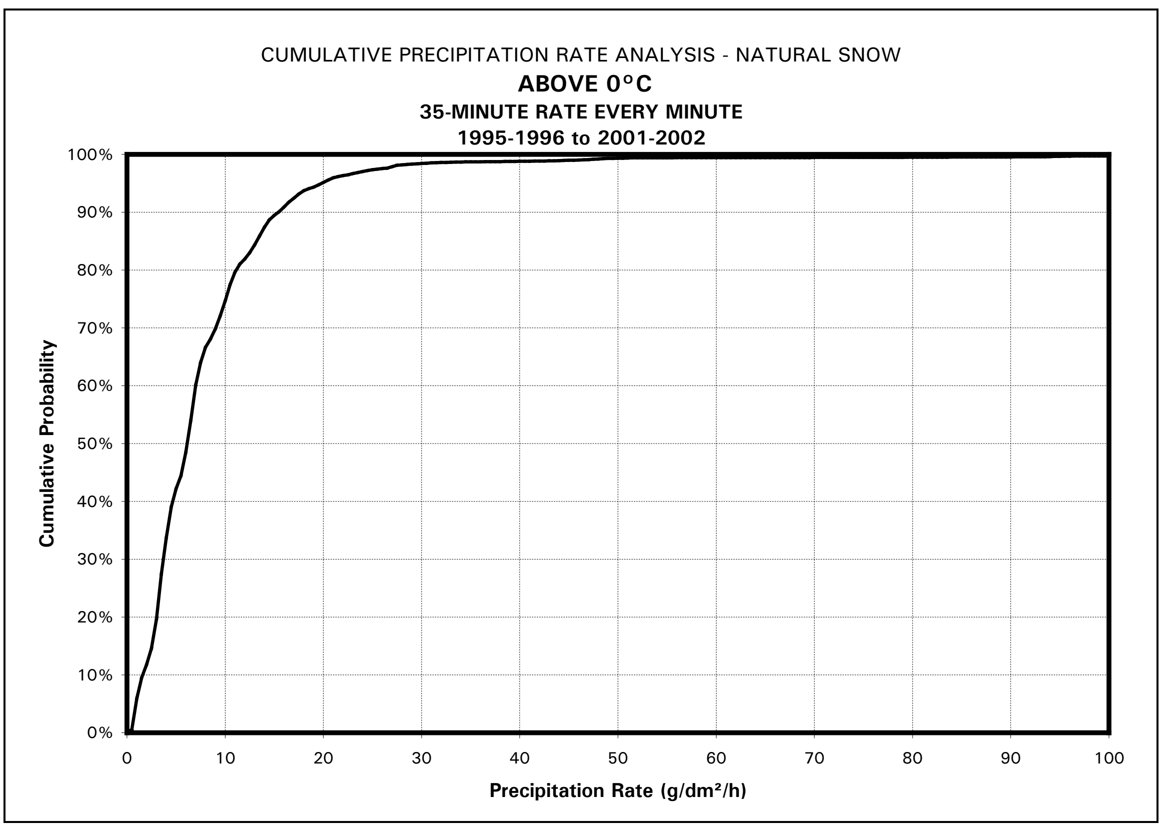
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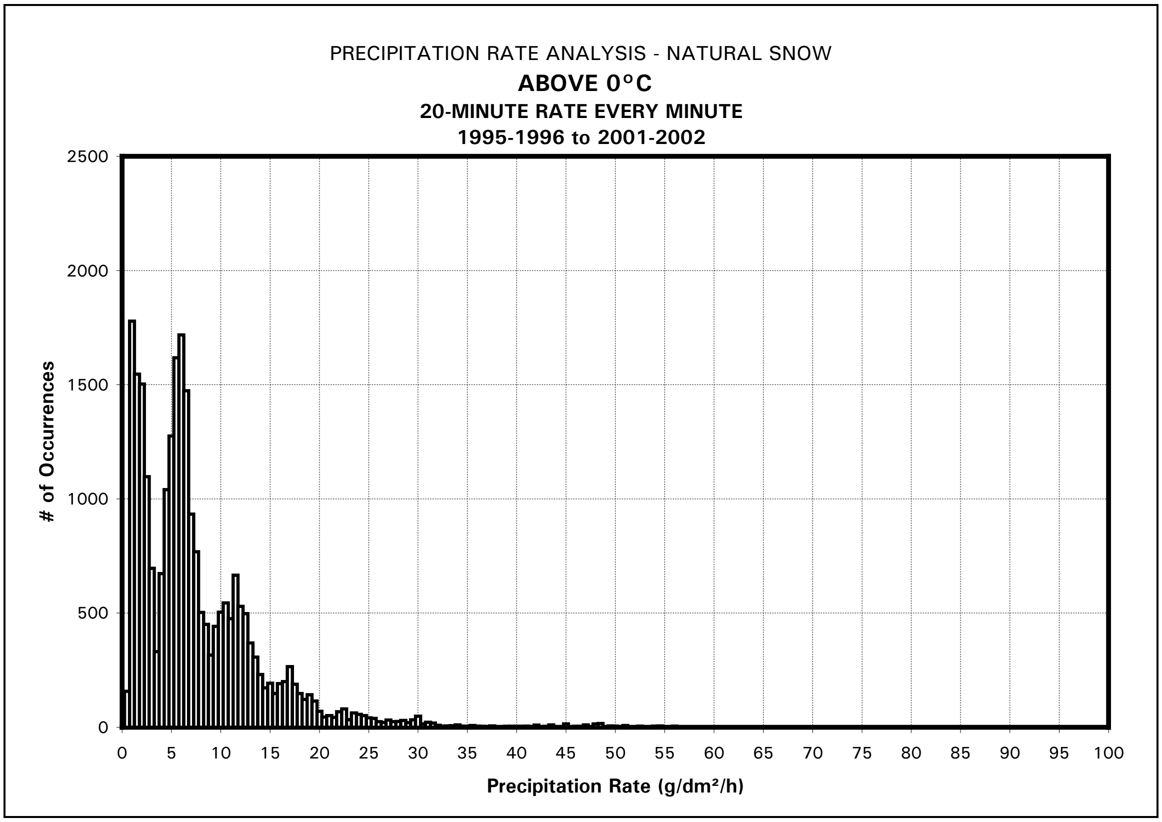
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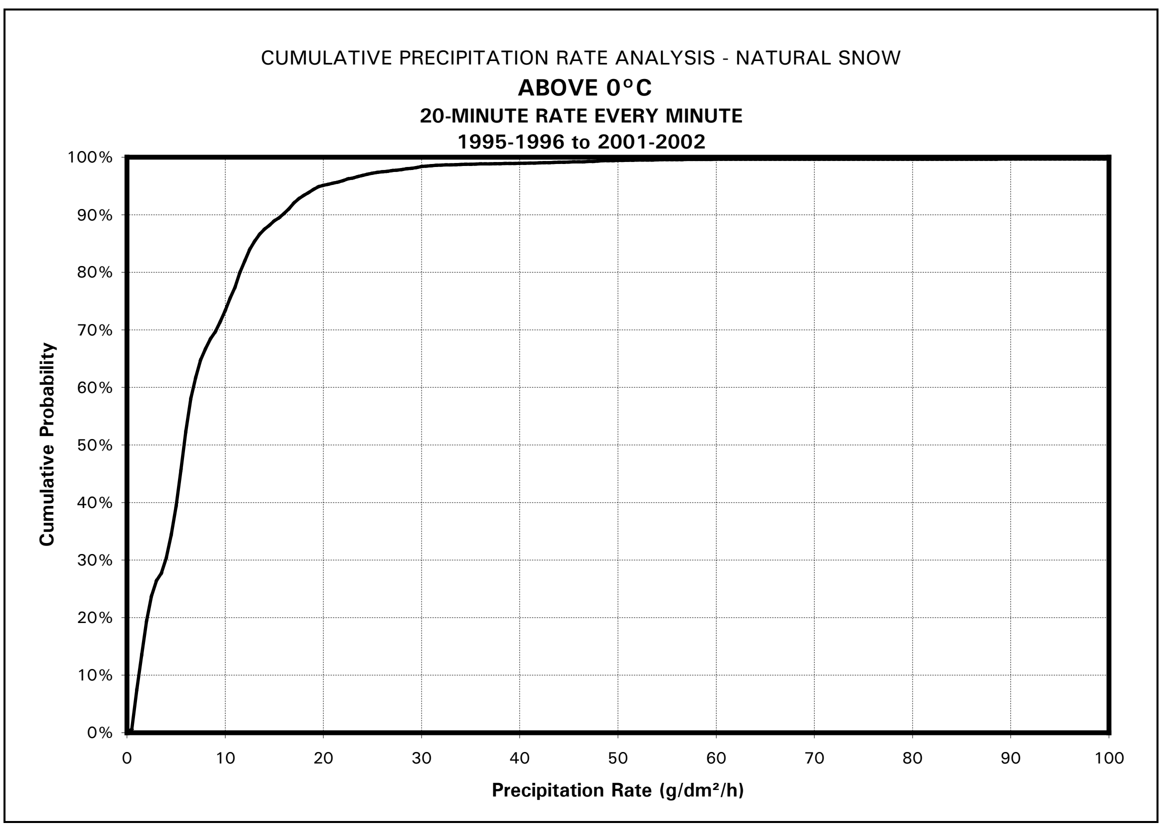
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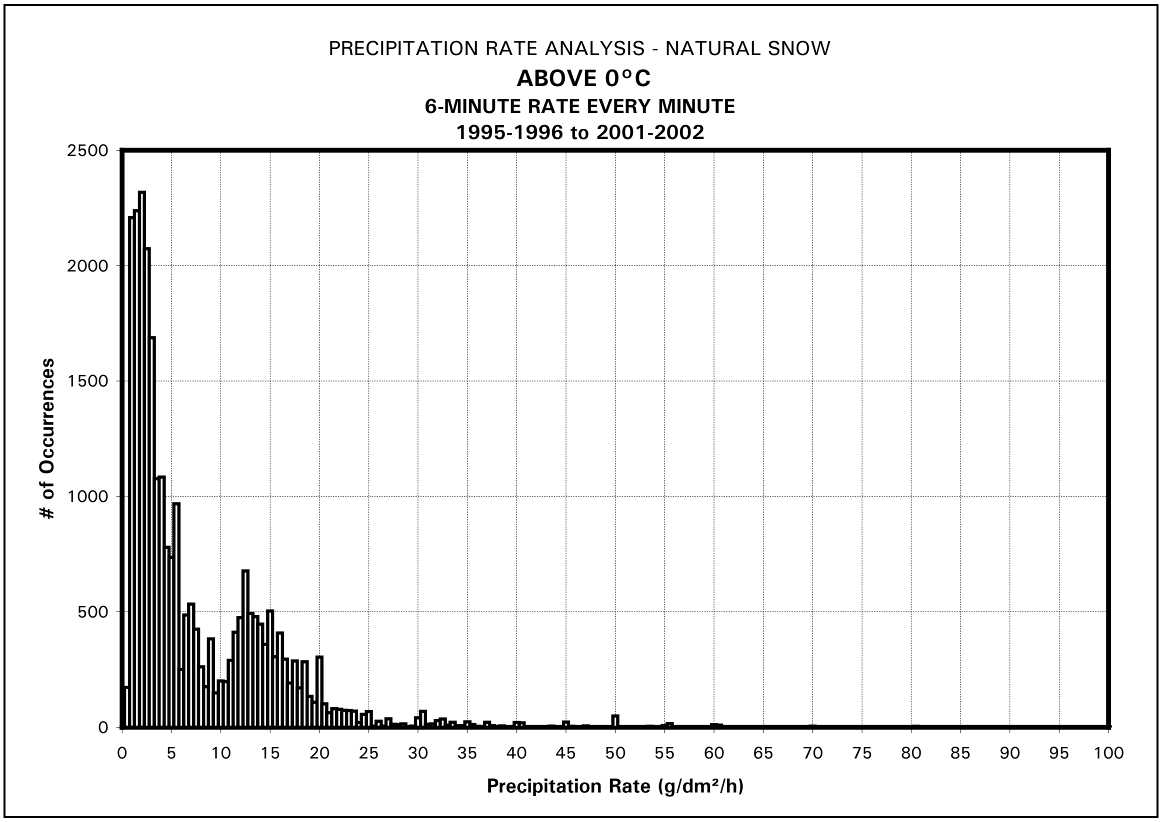
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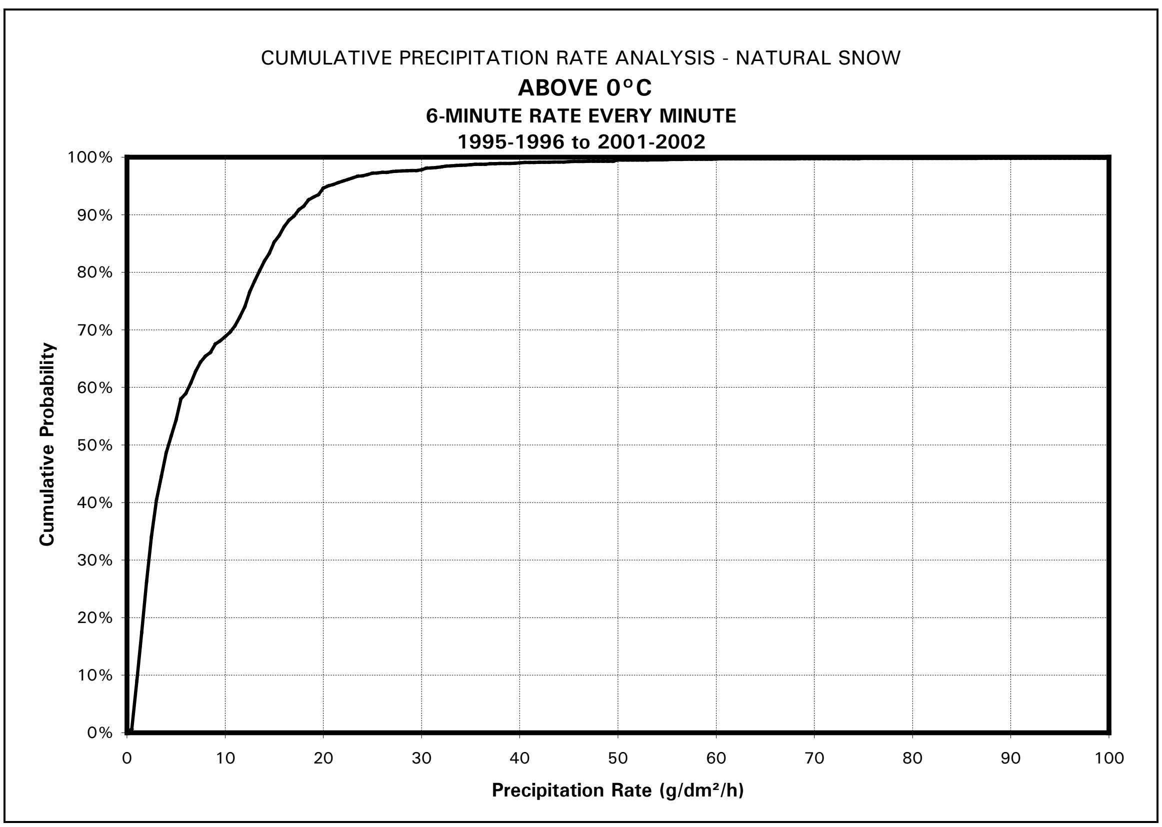
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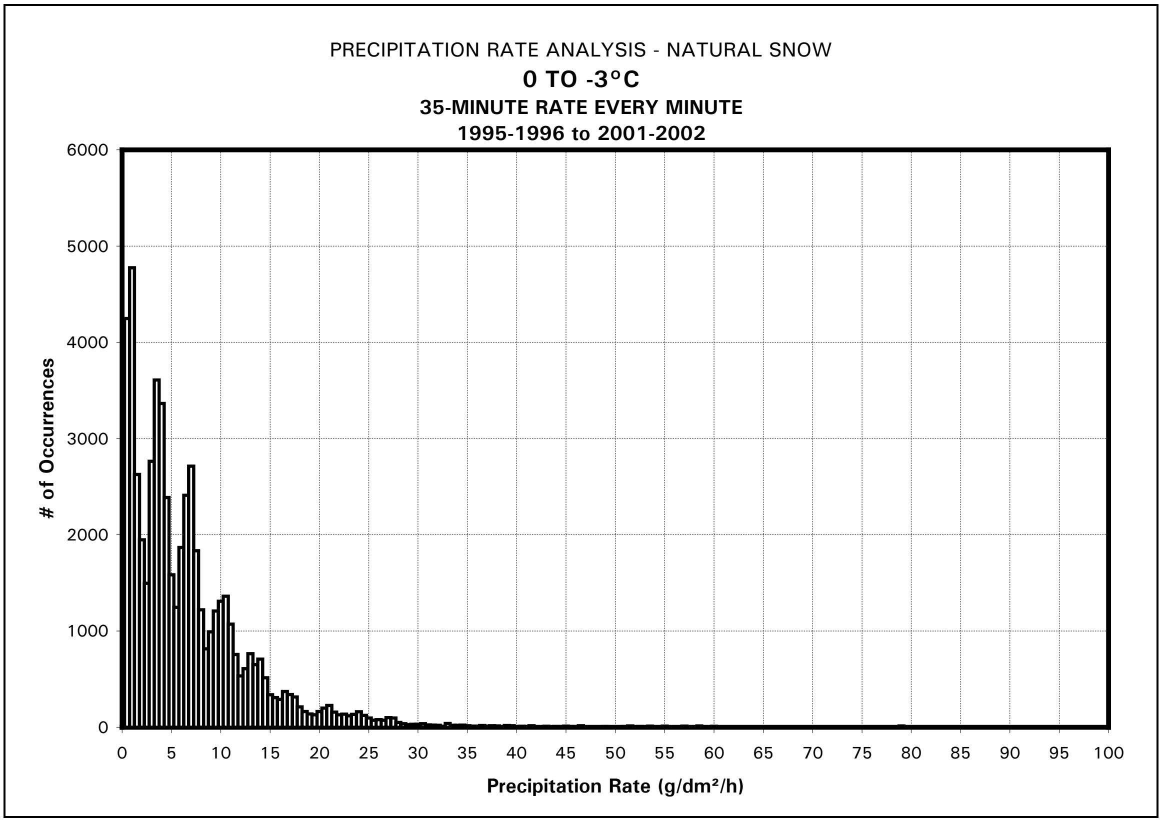
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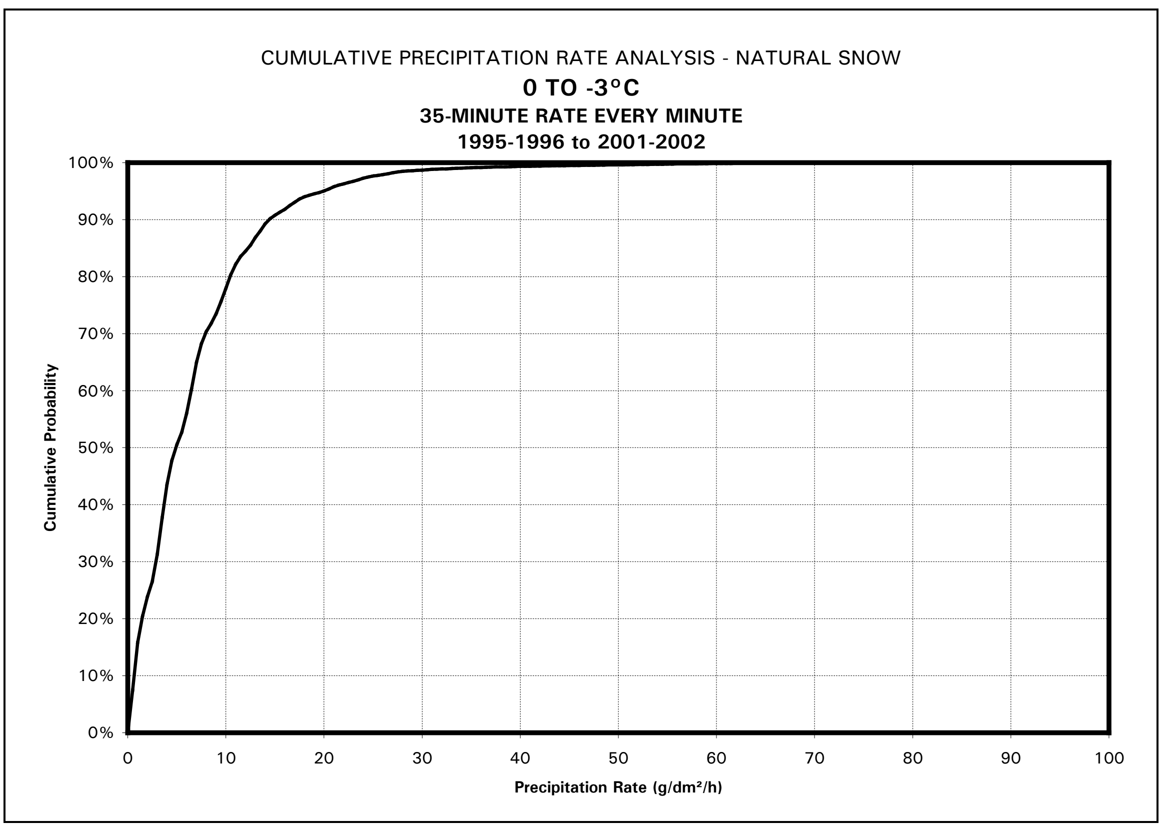
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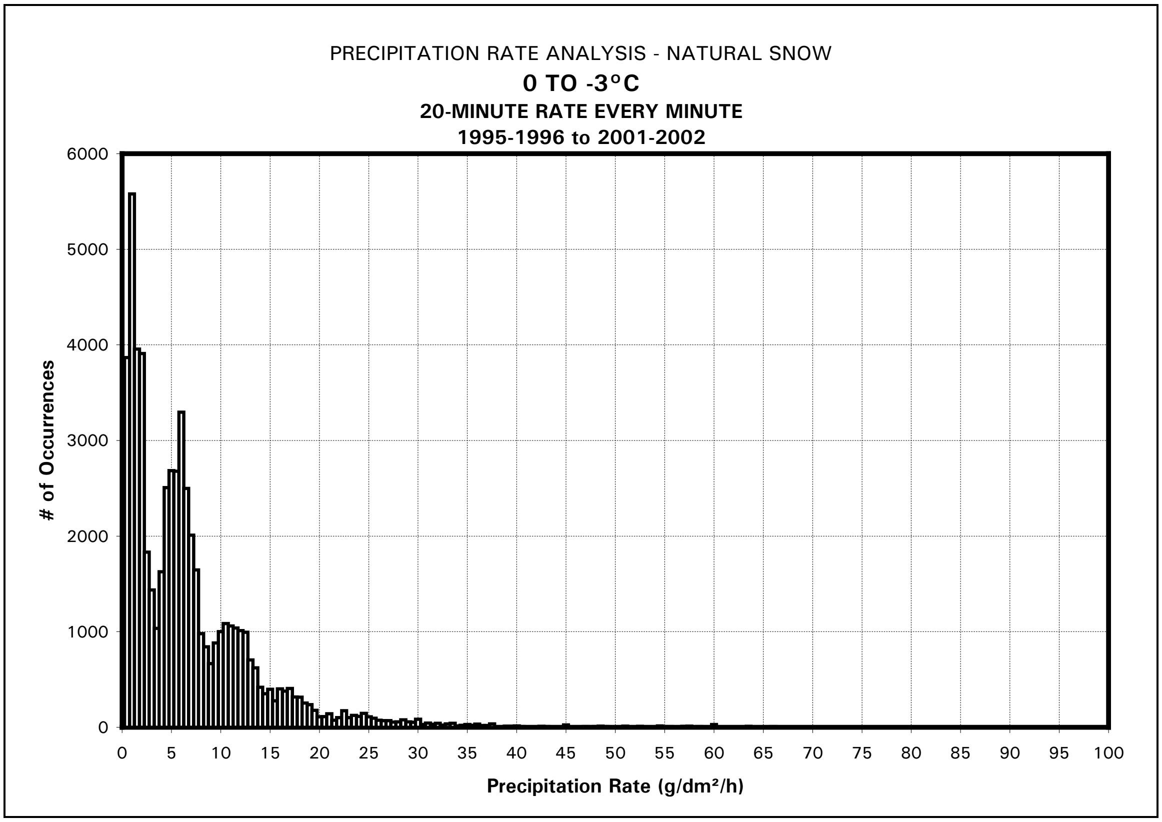
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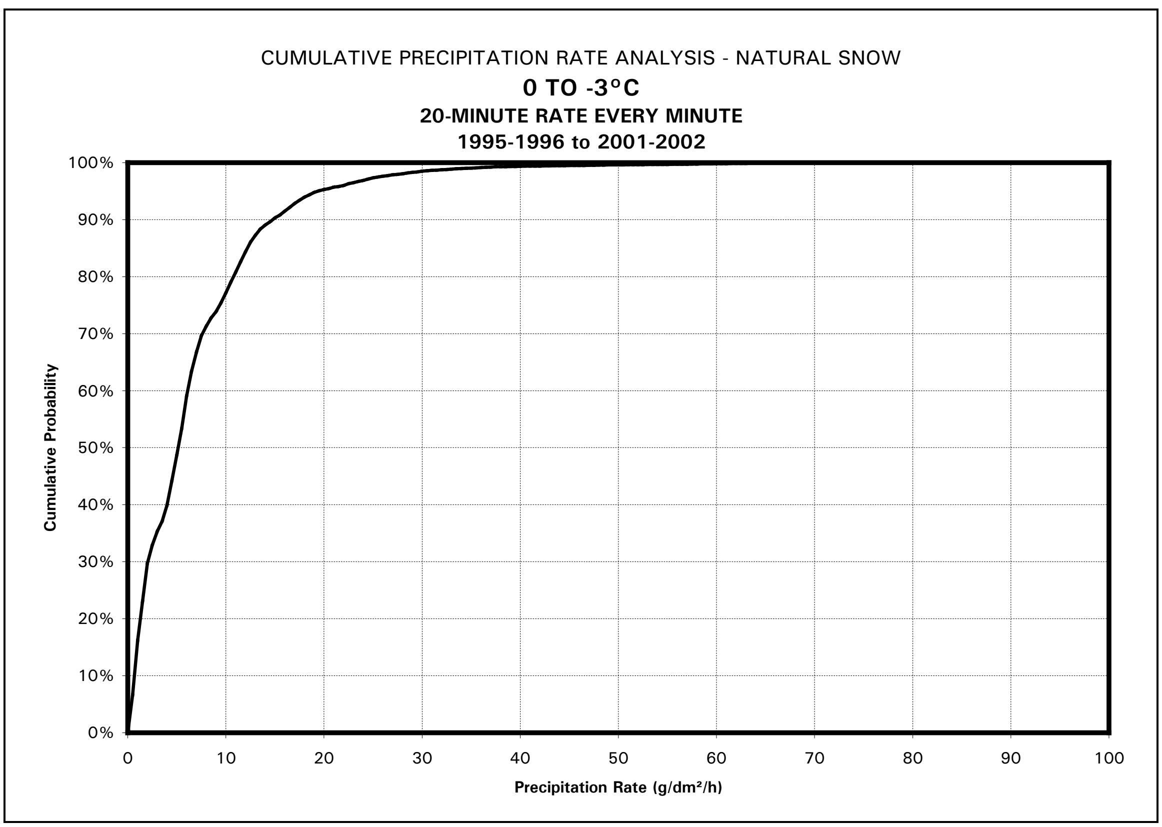
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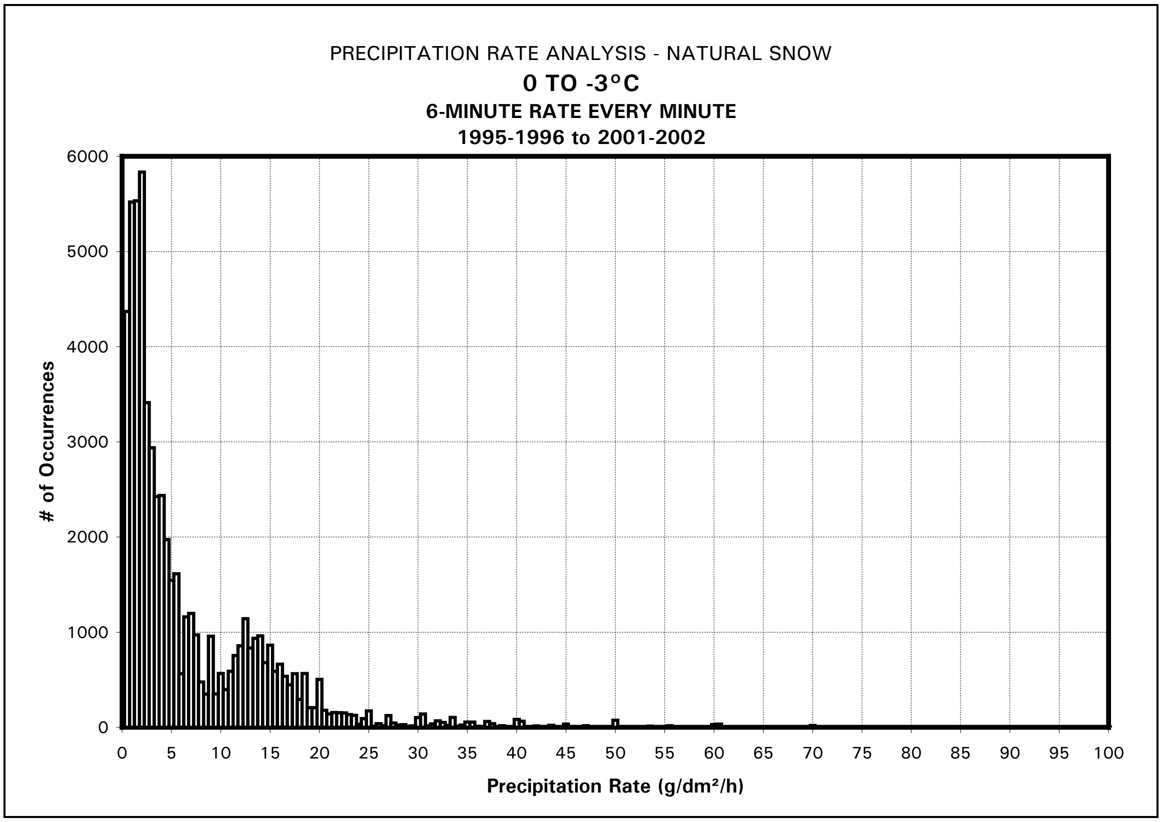
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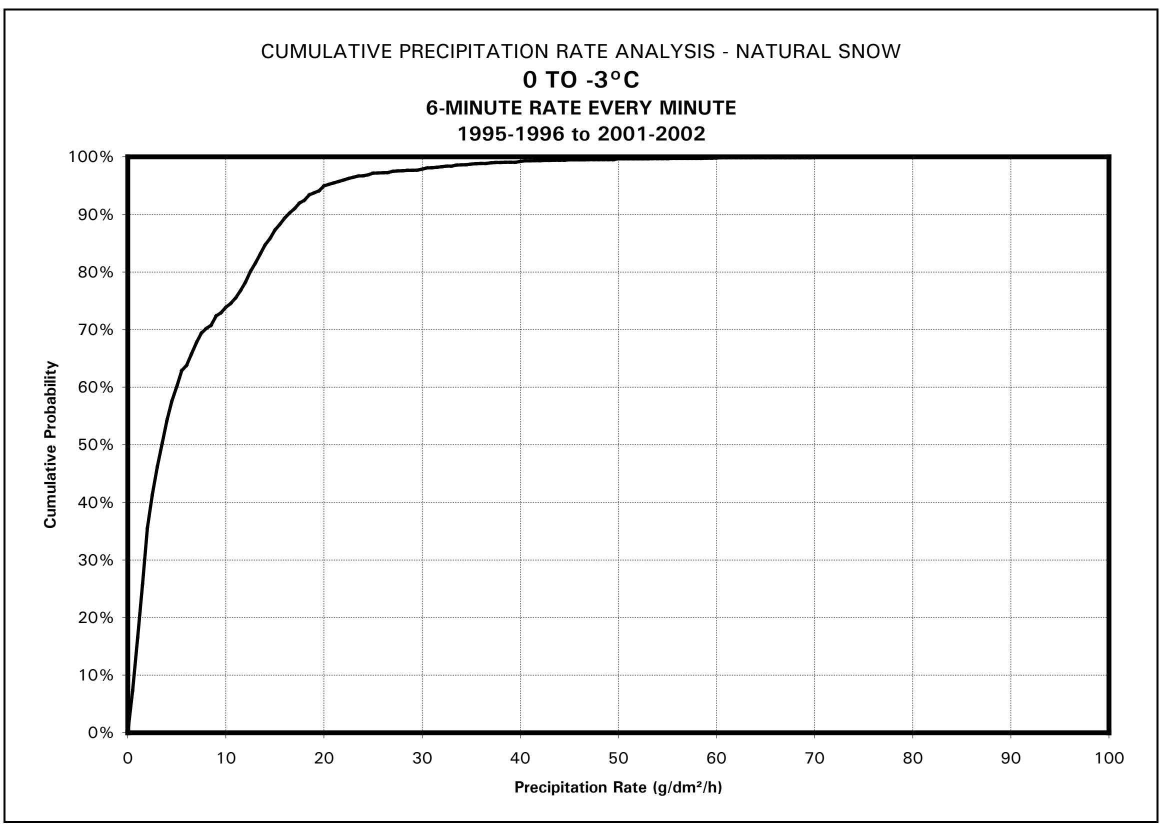
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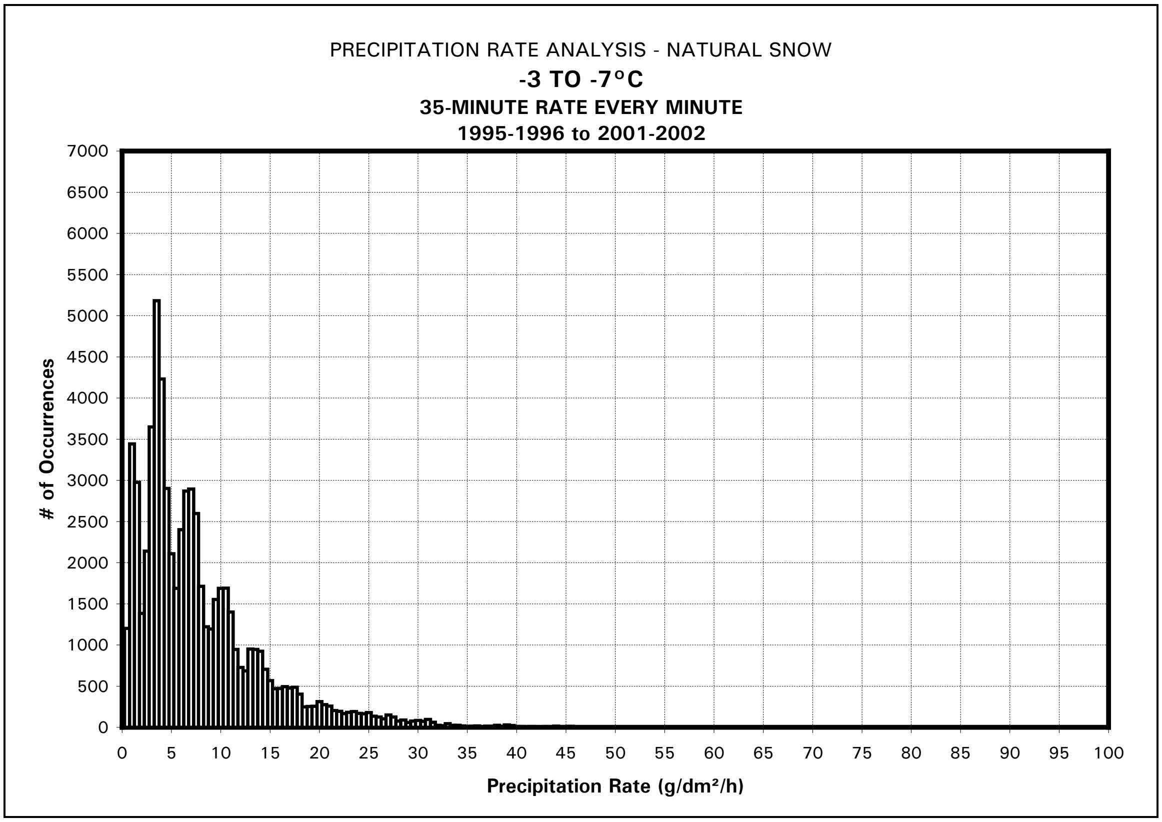
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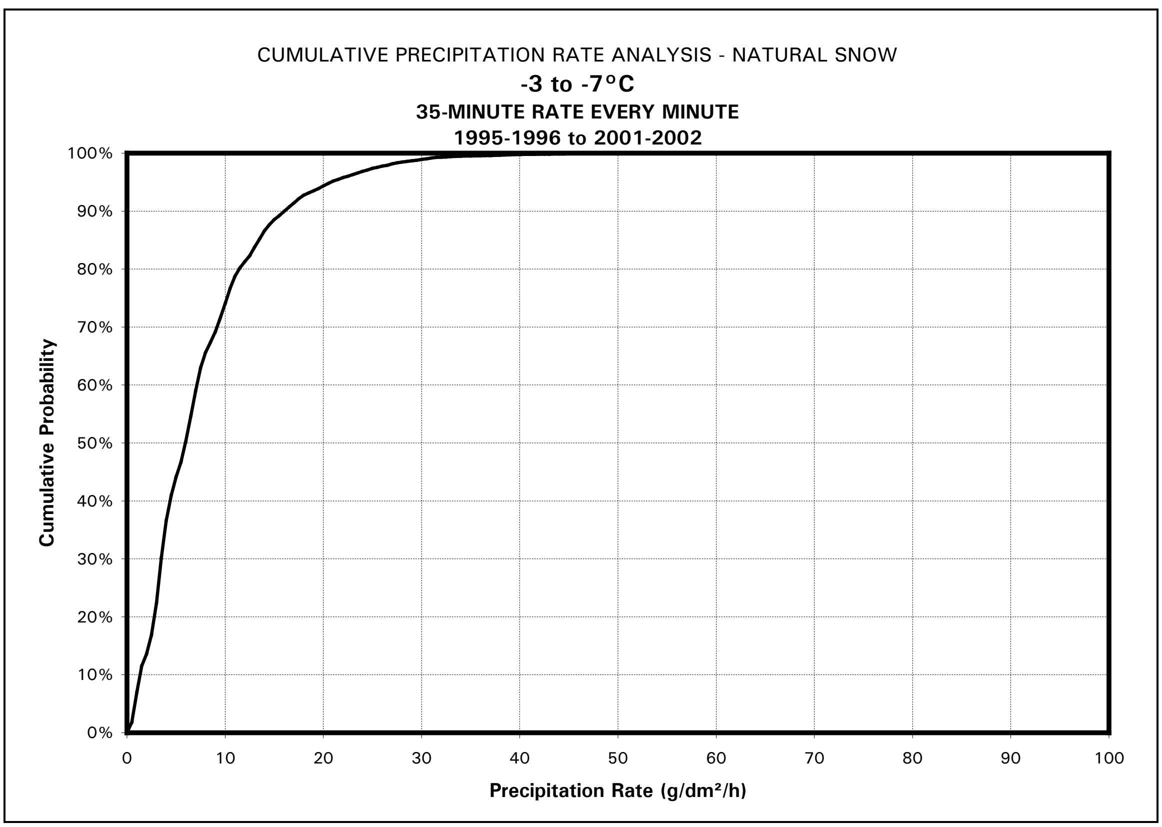
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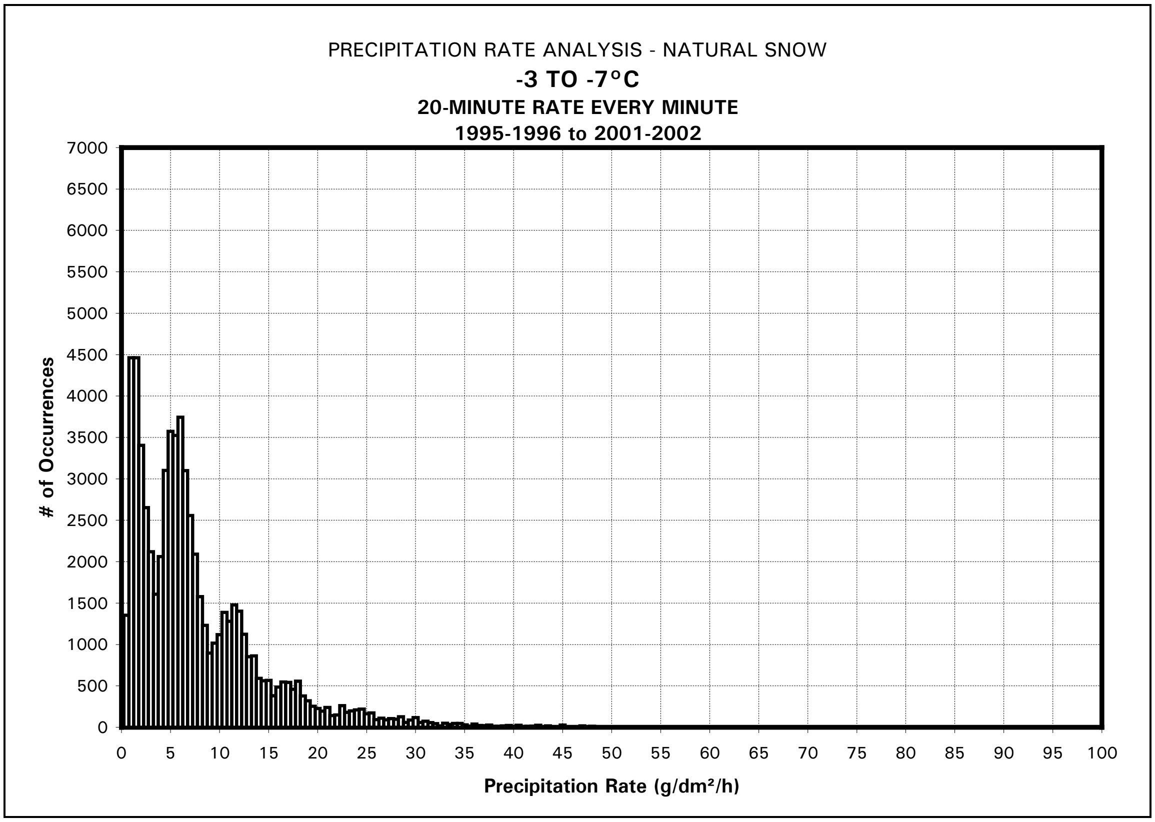
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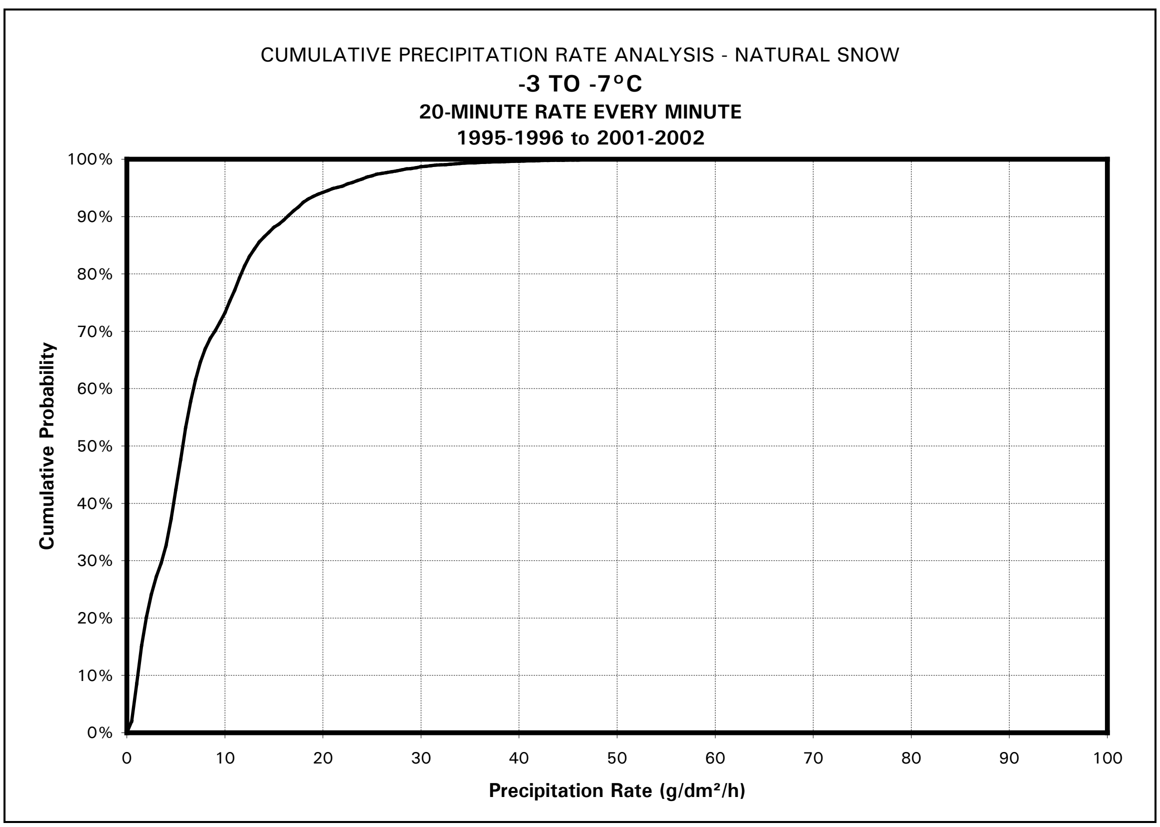
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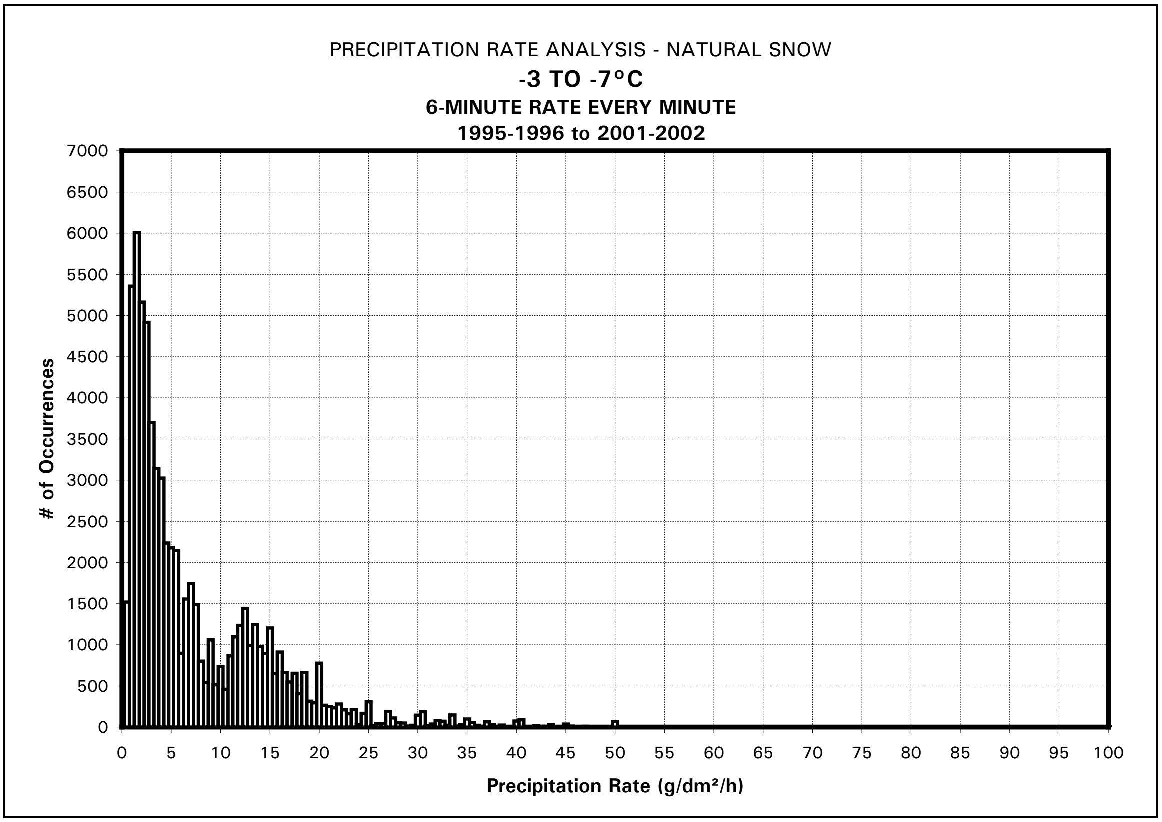
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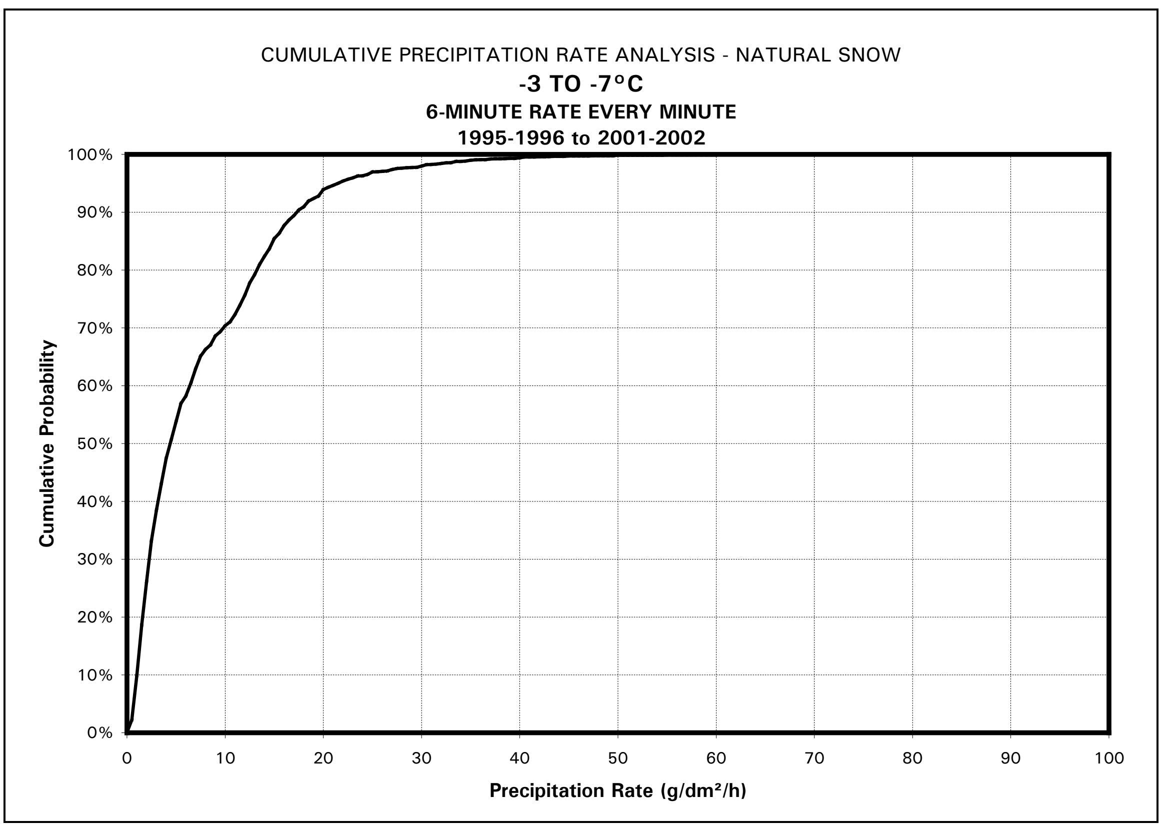
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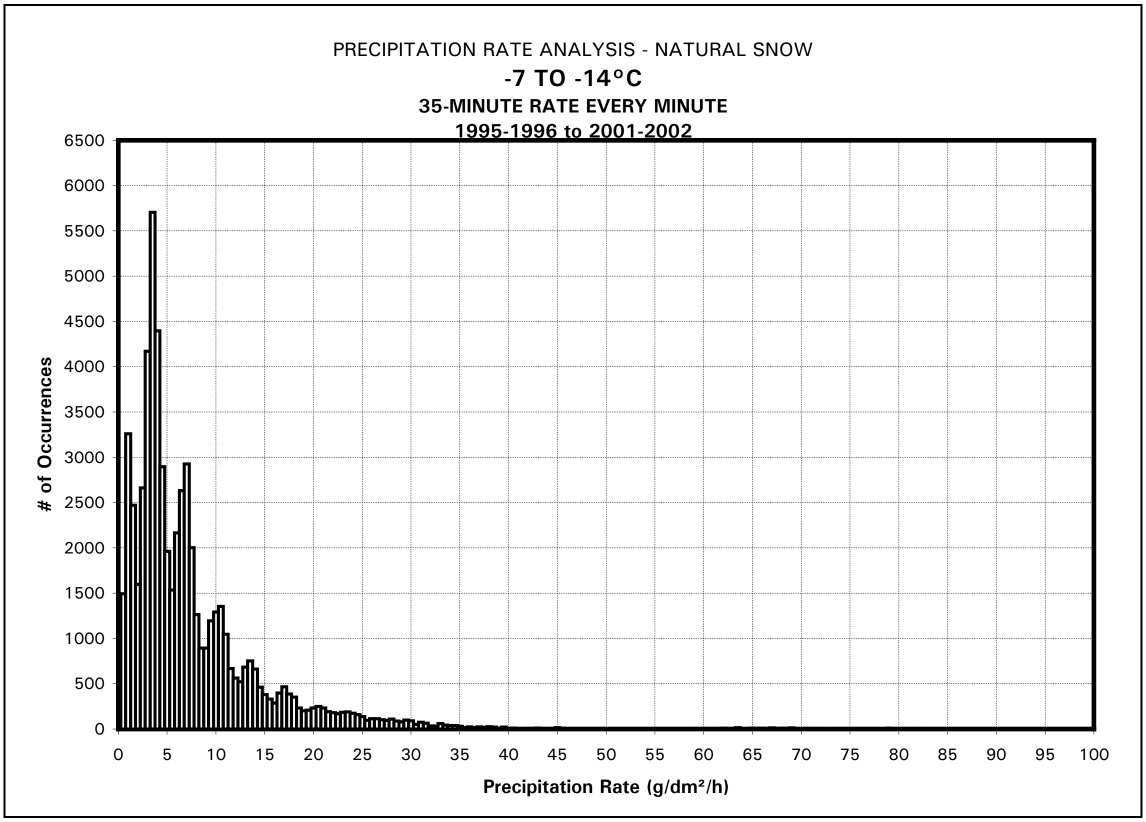
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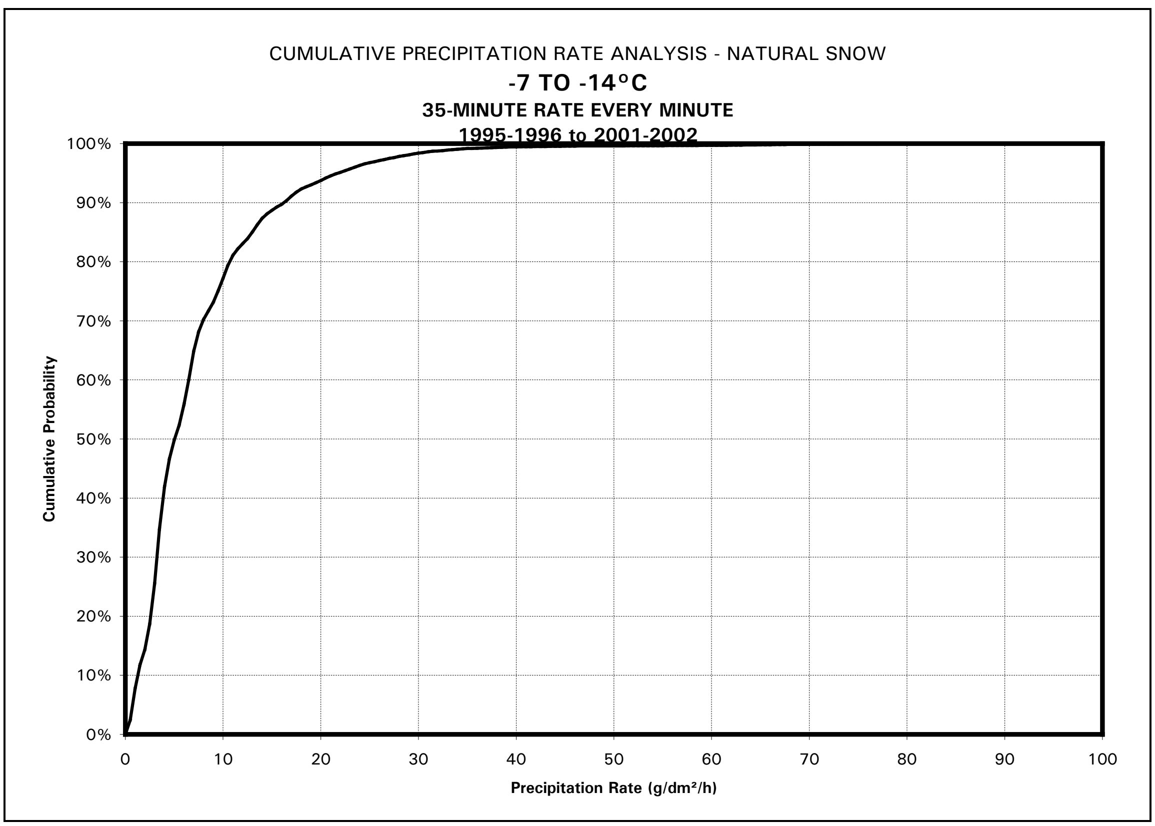
# of Occurrences
Precipitation Rate (g/dm²/h)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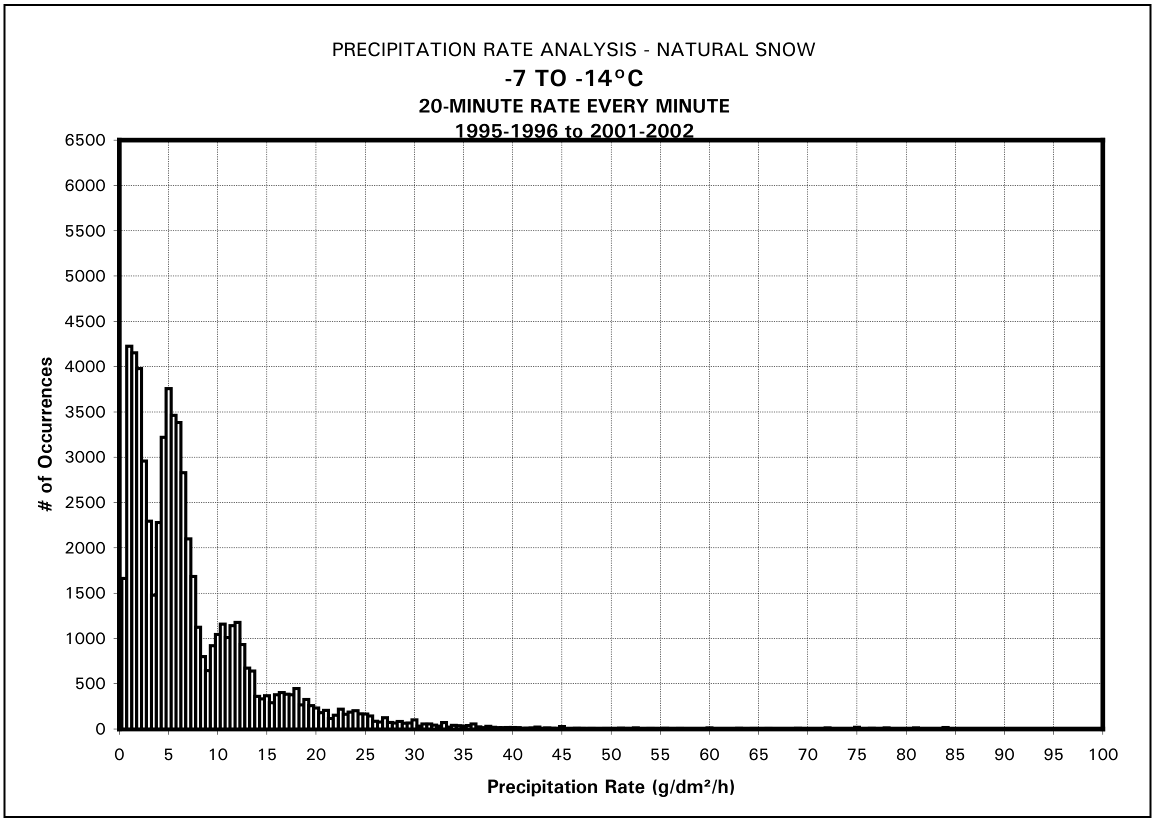
Precipitation Rate (g/dm²/h)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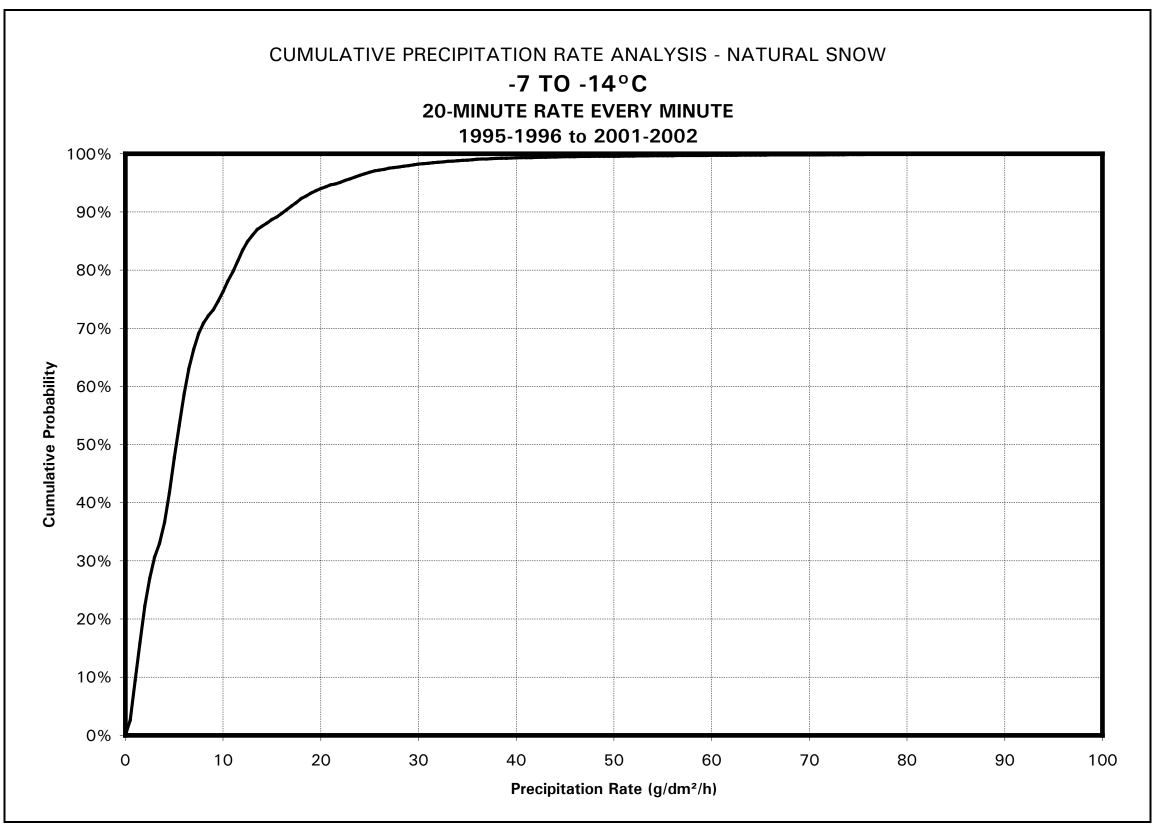
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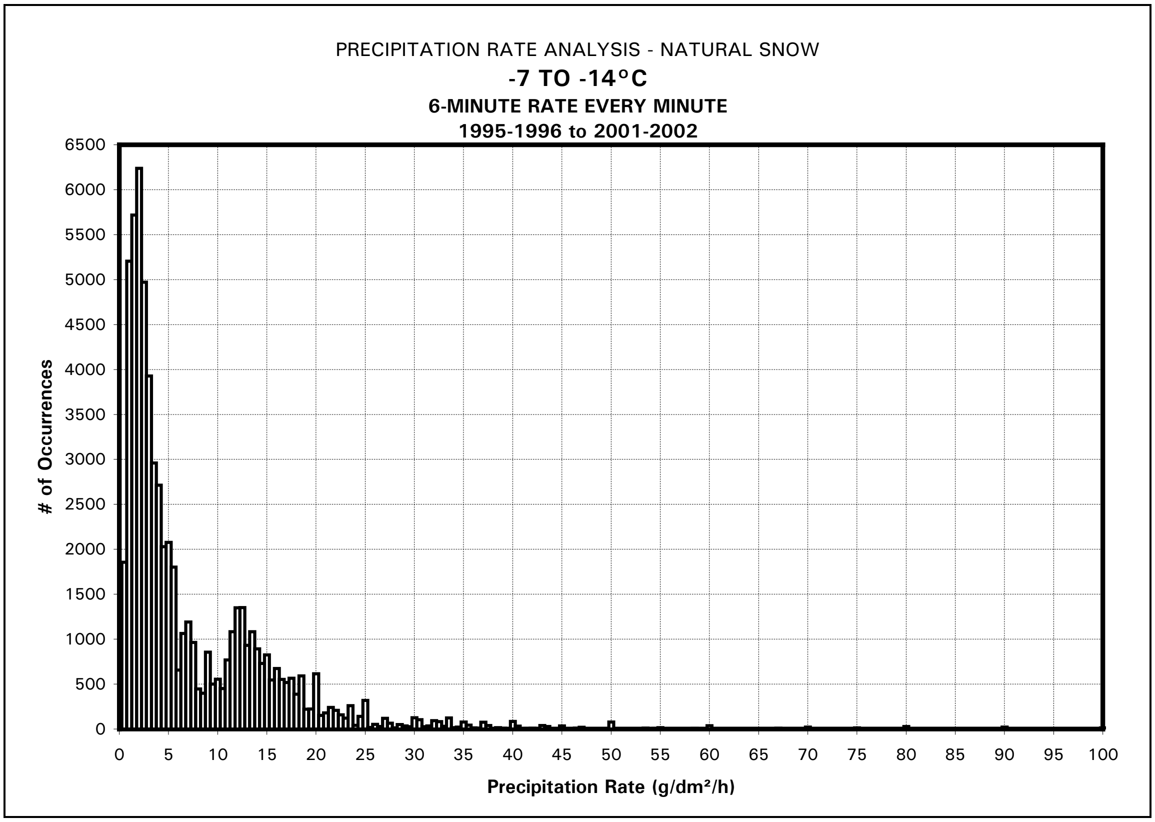
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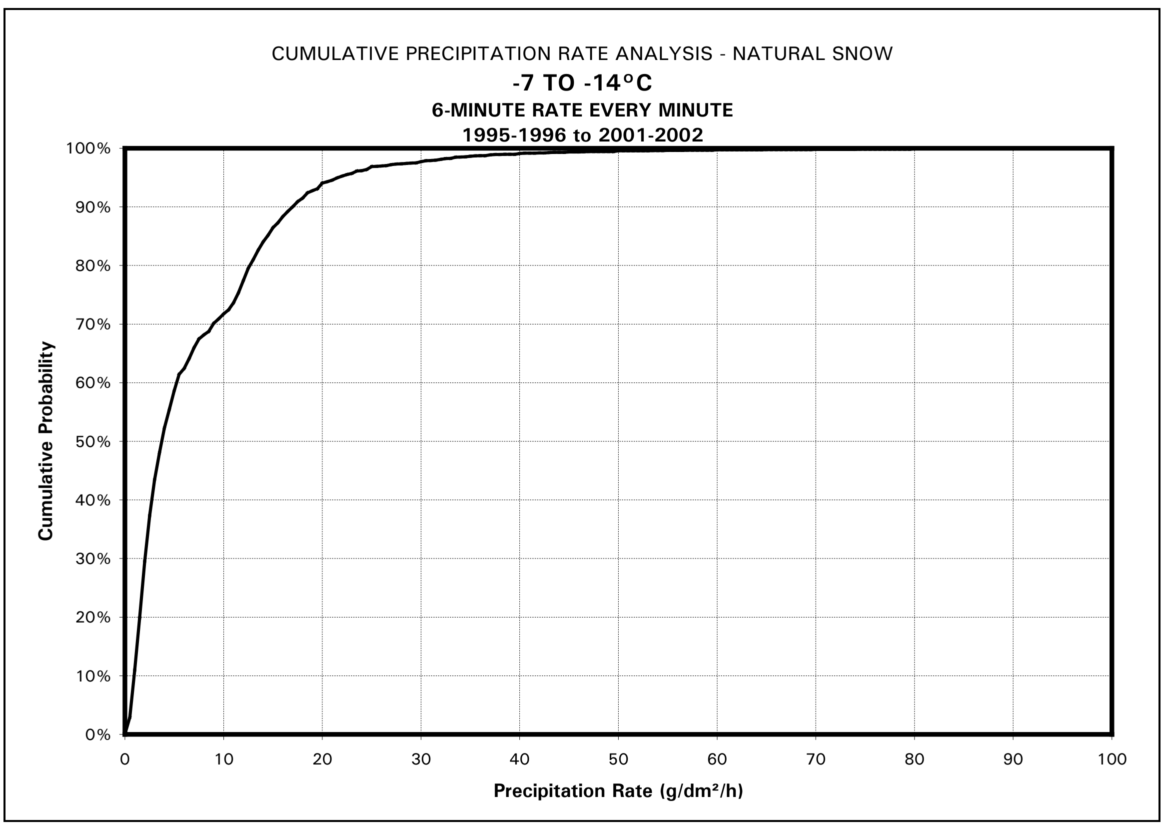
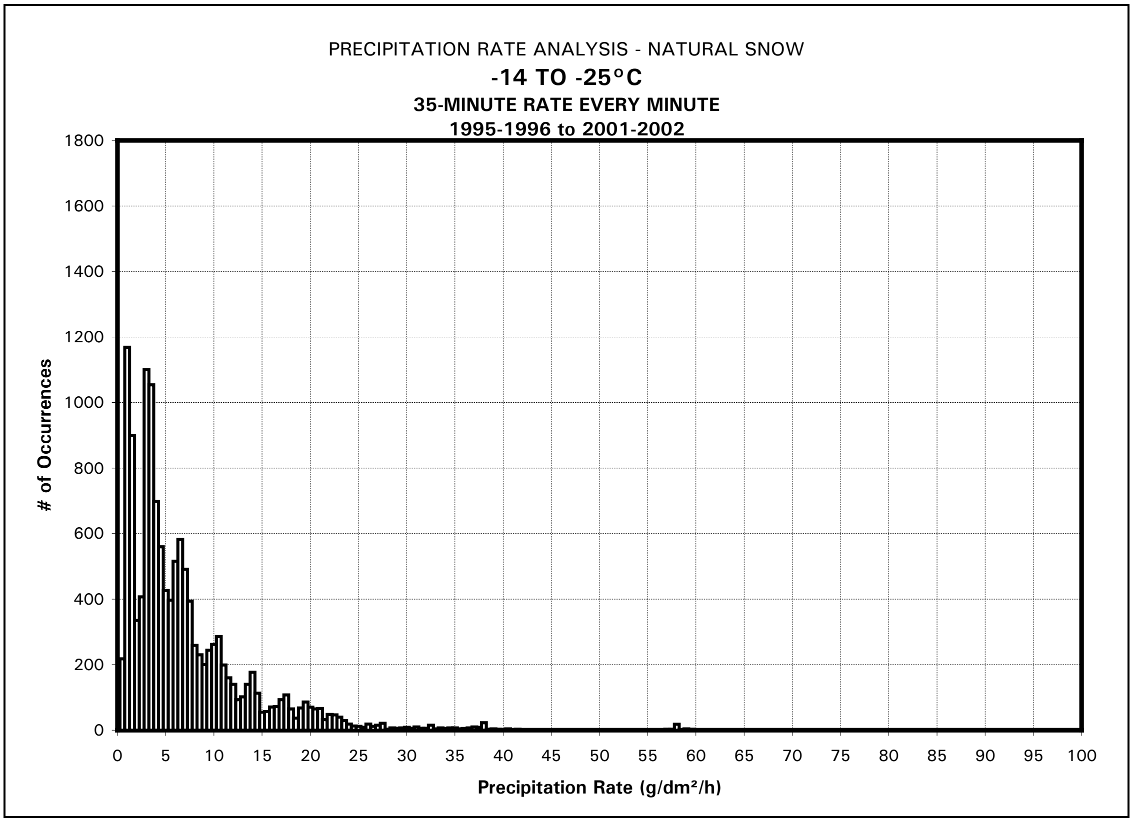
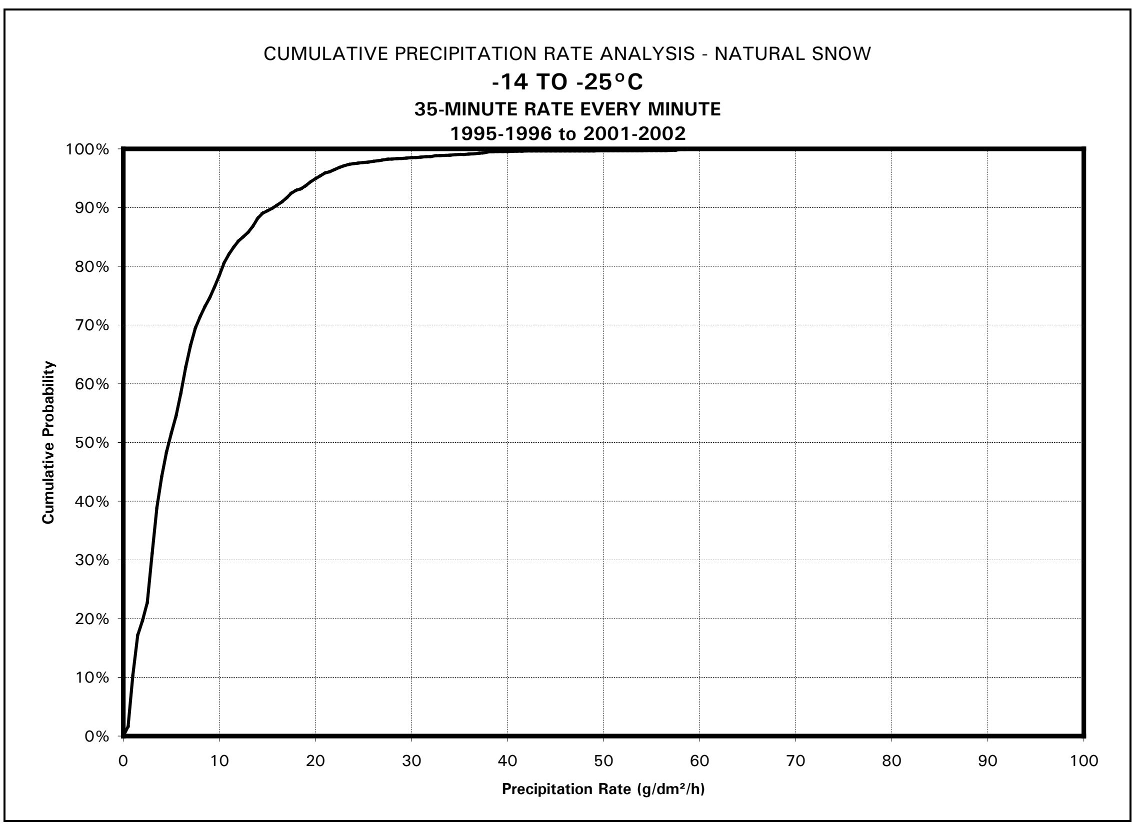
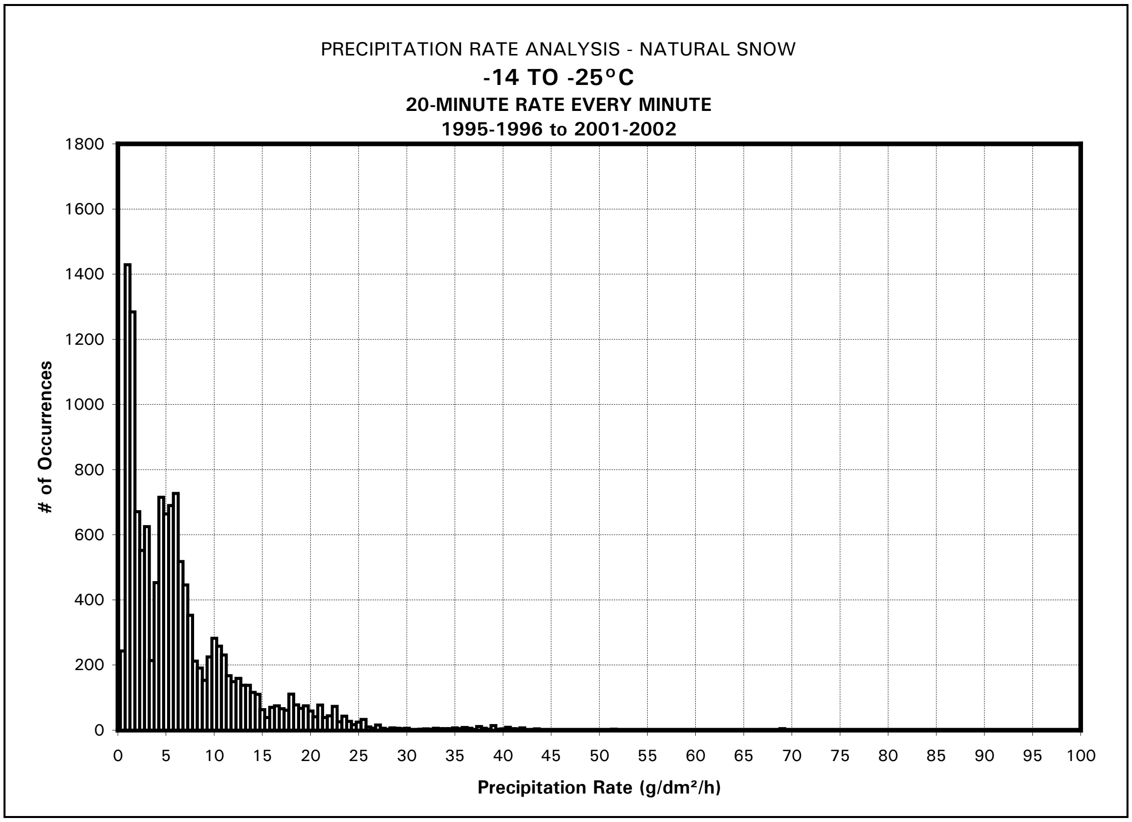
Precipitation Rate (g/dm²/h)

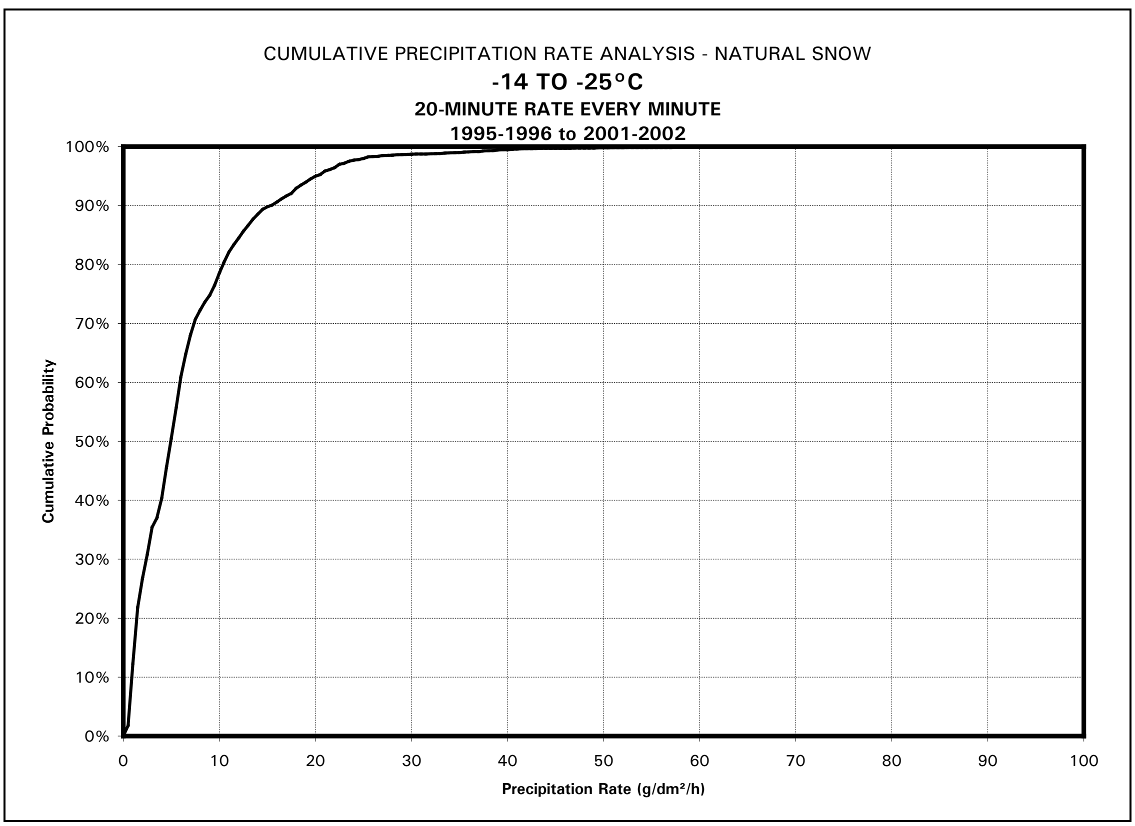

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-7 TO -14°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
Precipitation Rate (g/dm²/h)

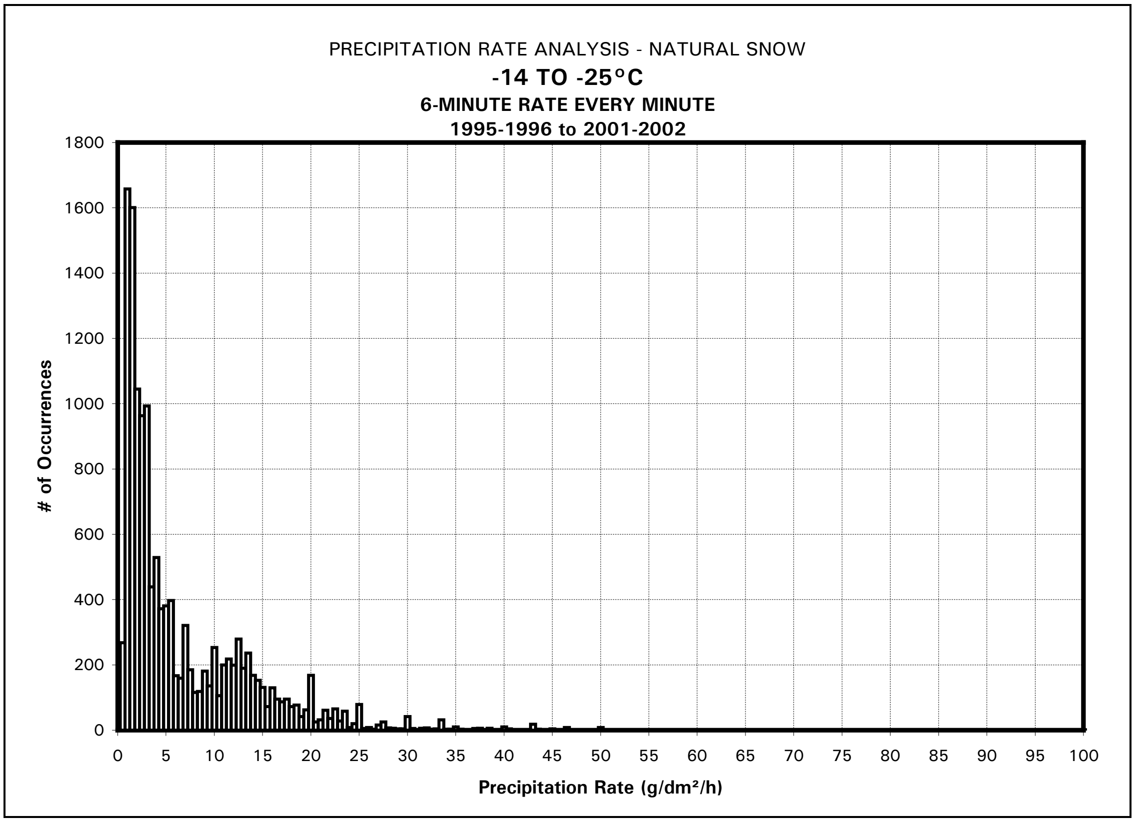

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
Precipitation Rate (g/dm²/h)

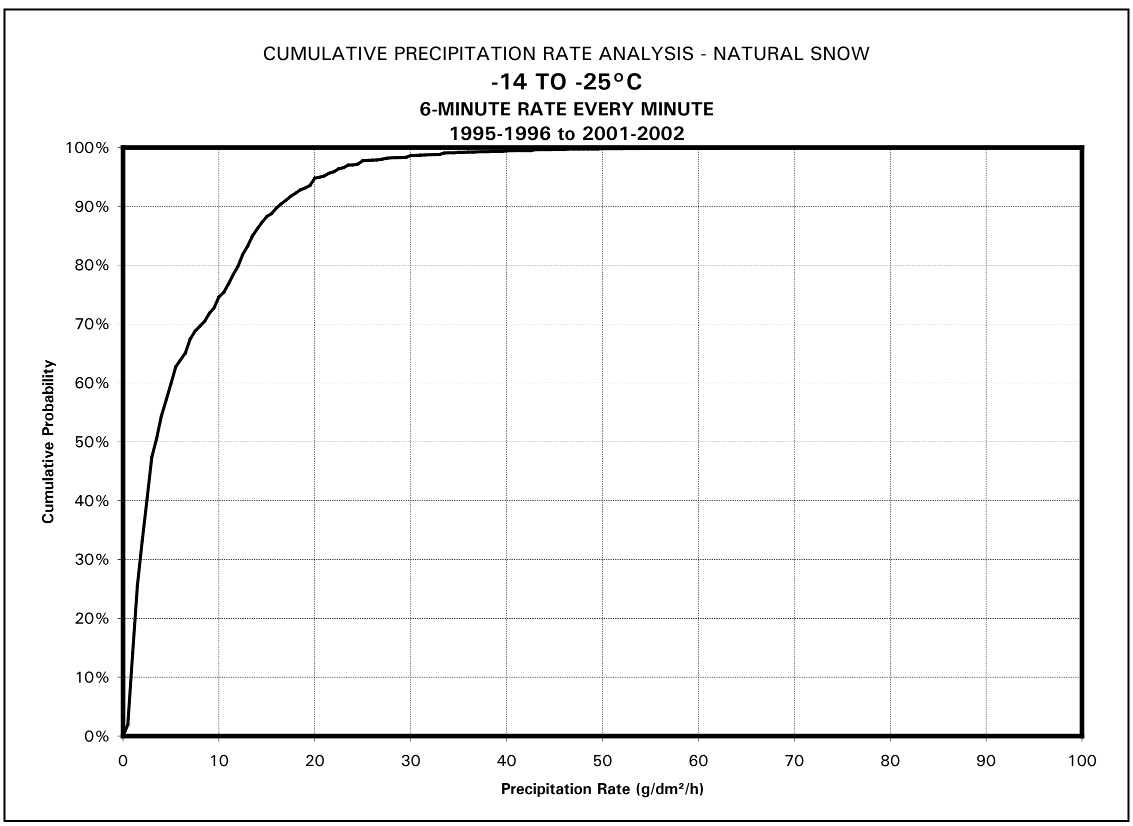


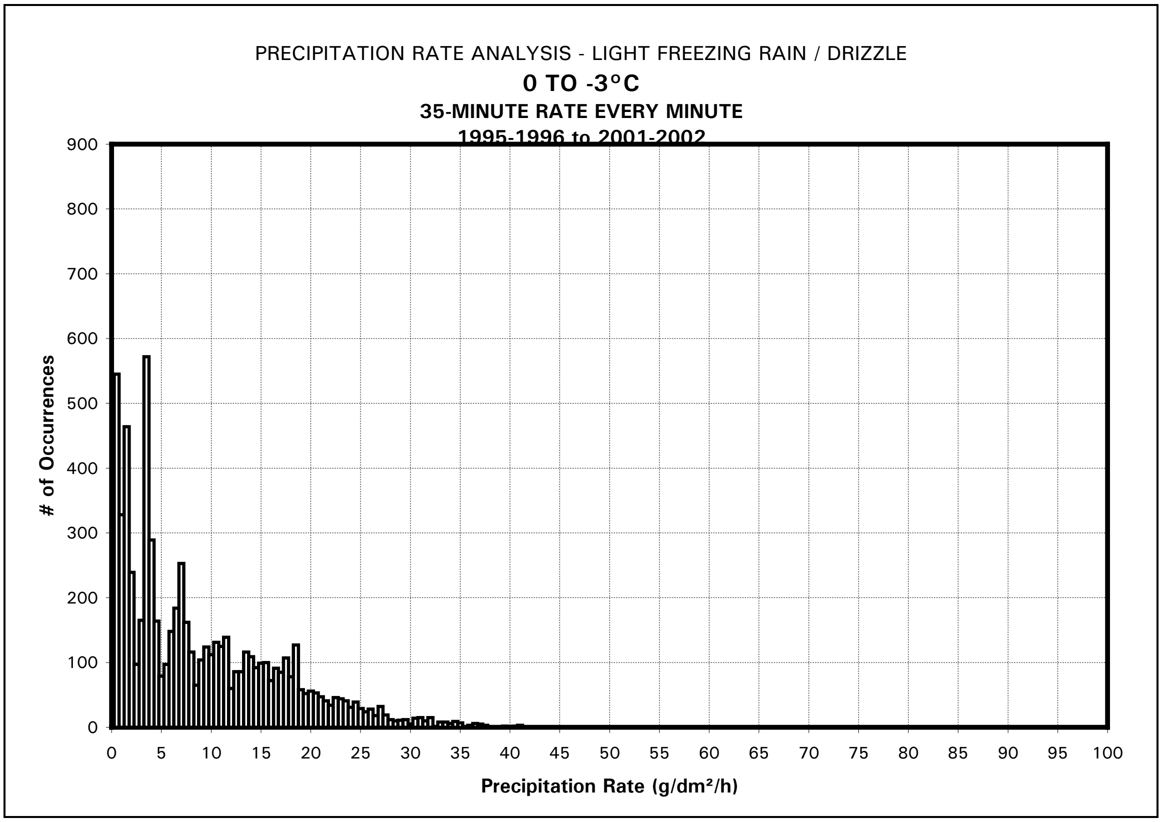
PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
1800
1600
1400
1200
1000
800
600
400
200
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

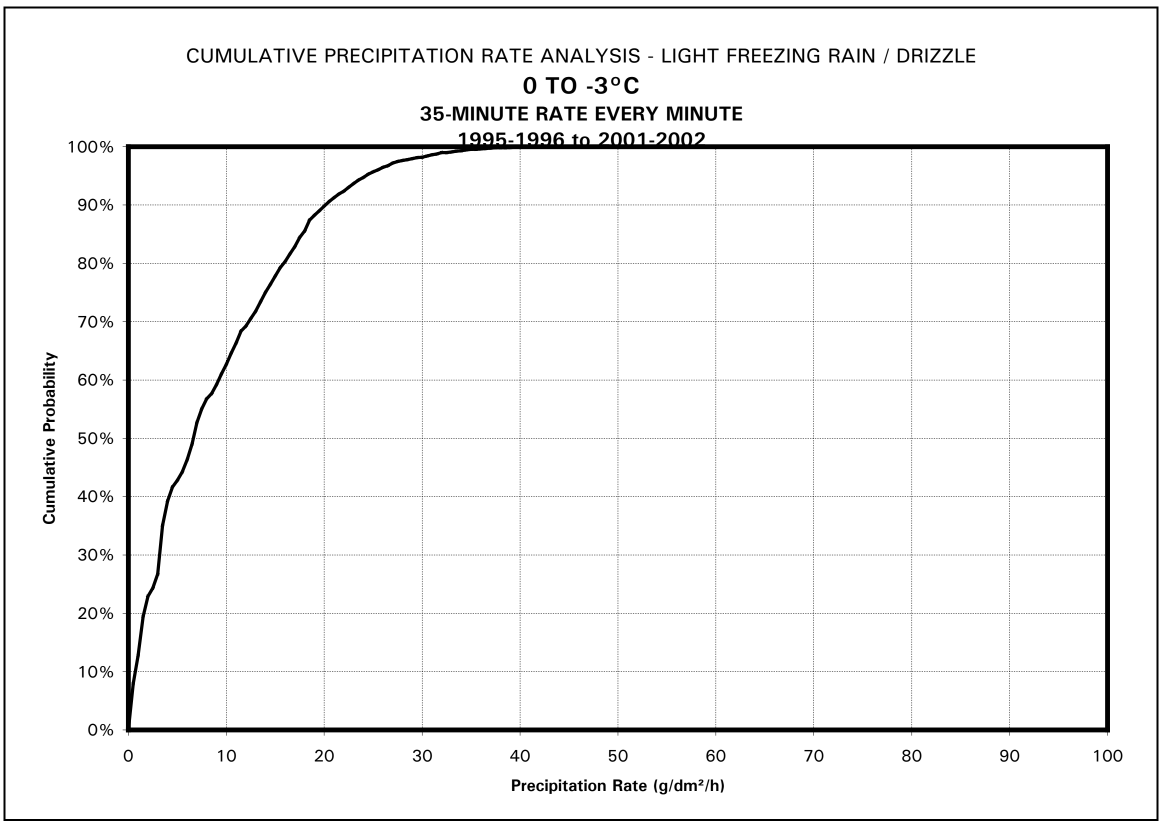


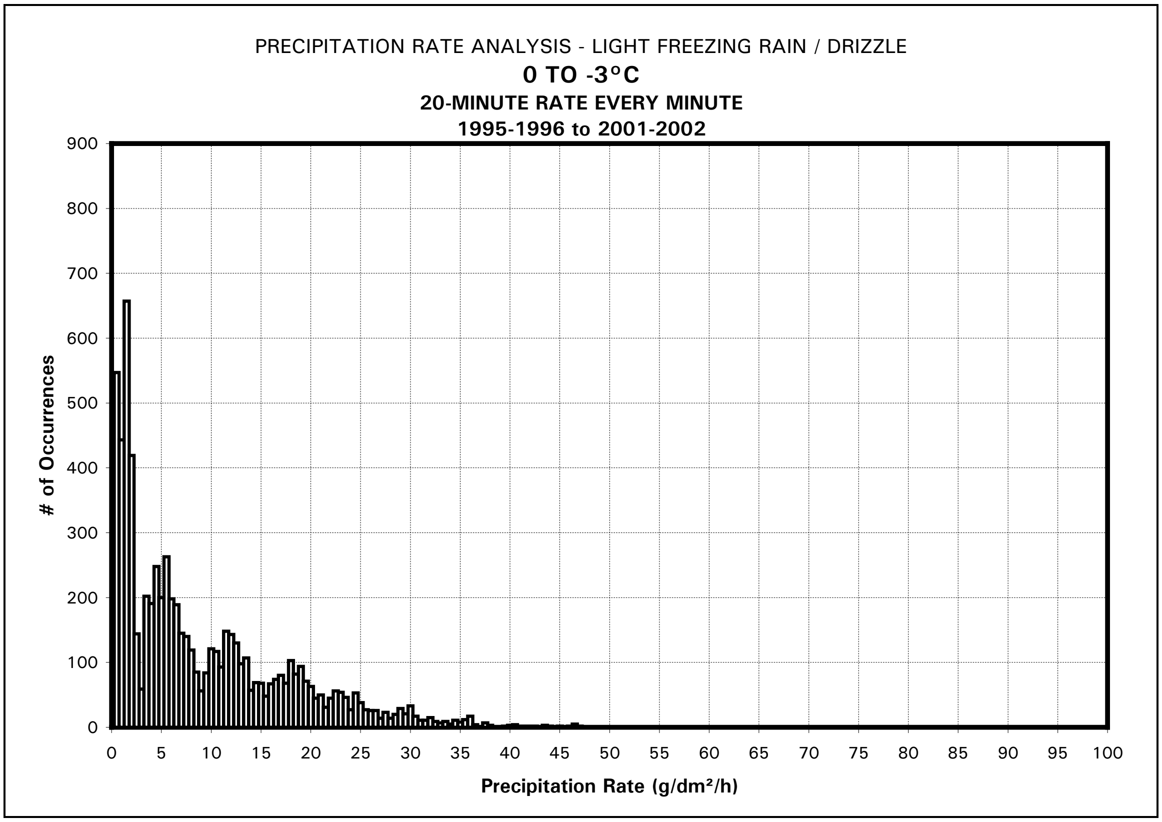
CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

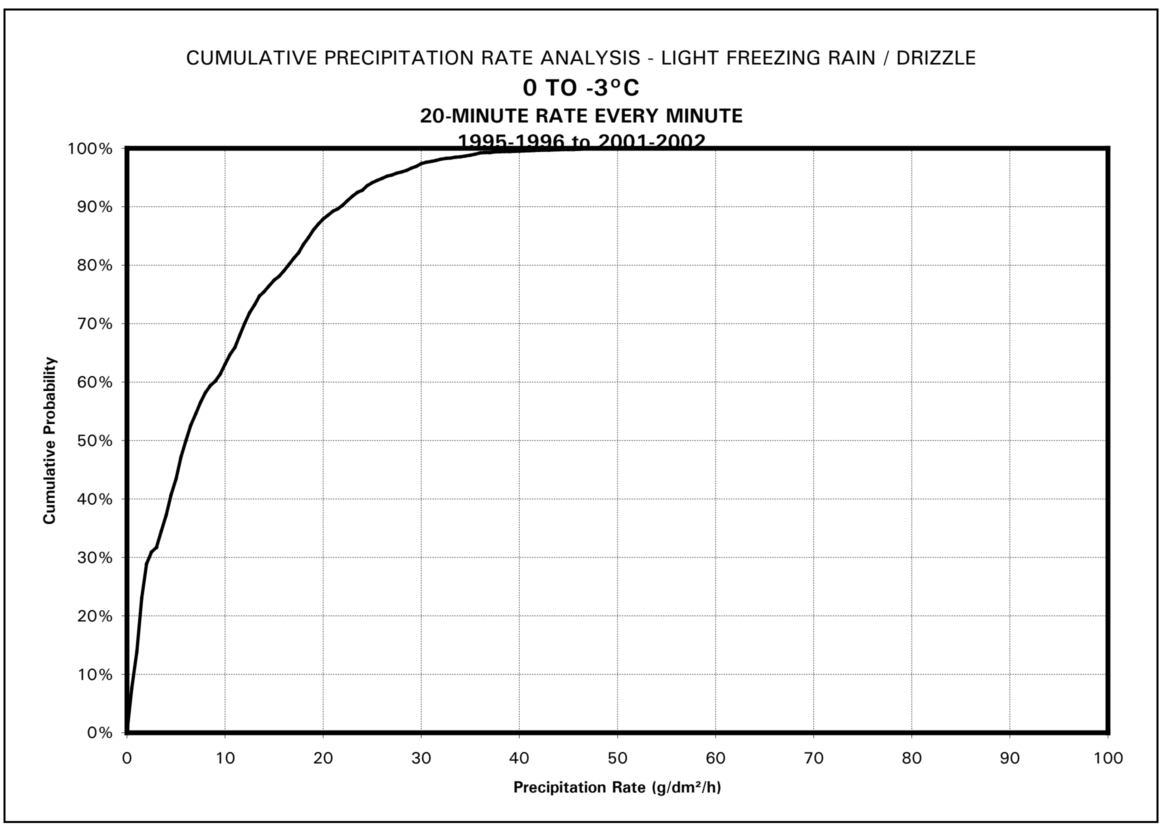

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
Precipitation Rate (g/dm²/h)
0
200
400
600
800
1000
1200
1400
1600
1800
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

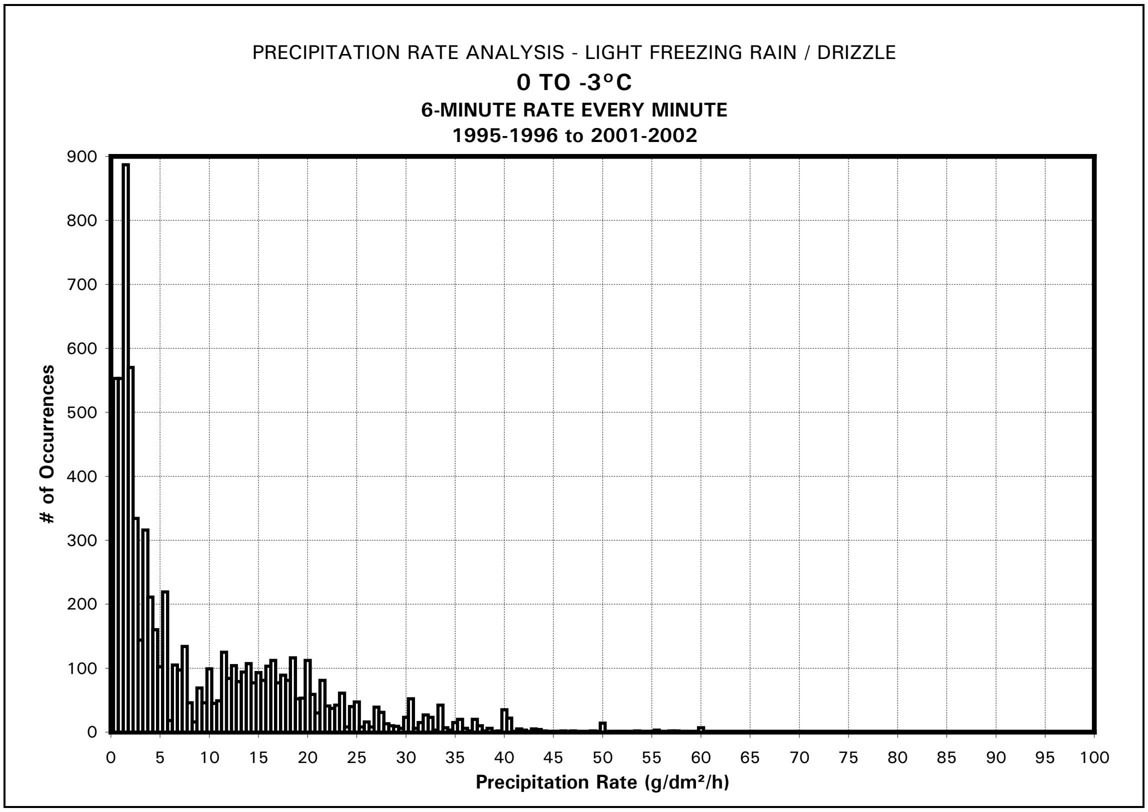

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
Precipitation Rate (g/dm²/h)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100

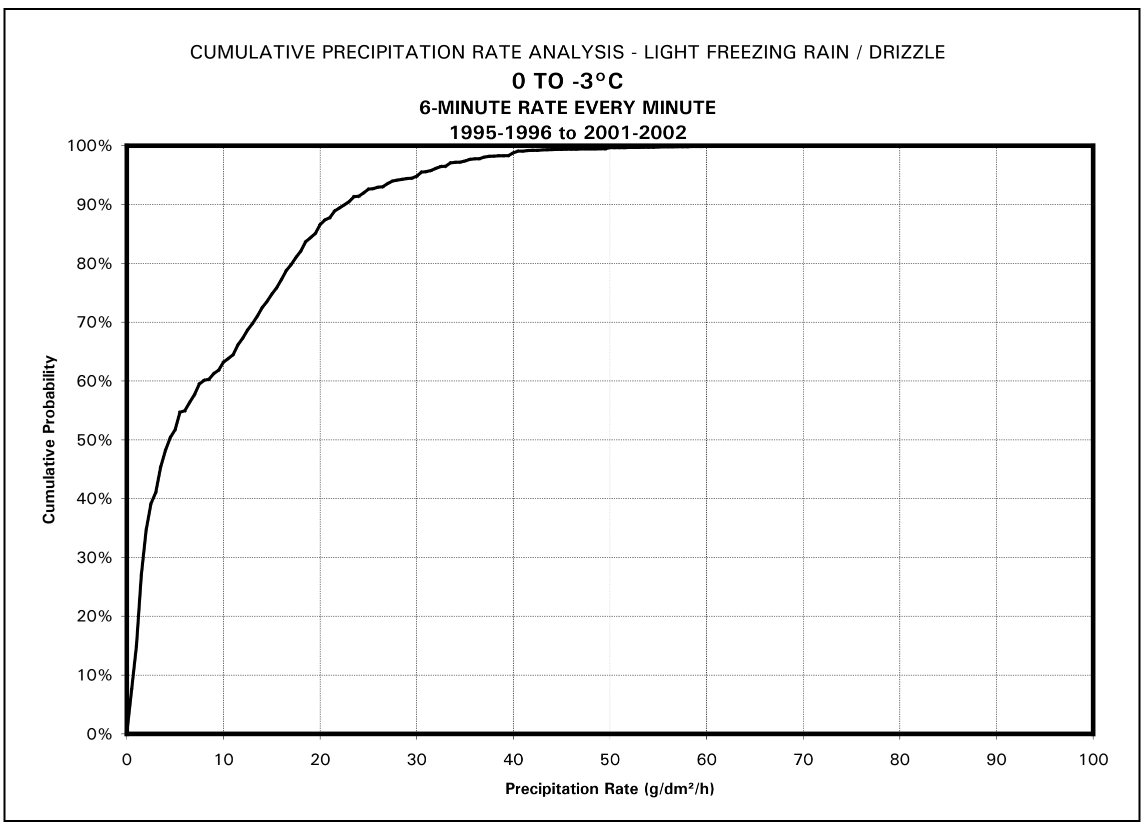

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
0 TO -3°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
0
100
200
300
400
500
600
700
800
900
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

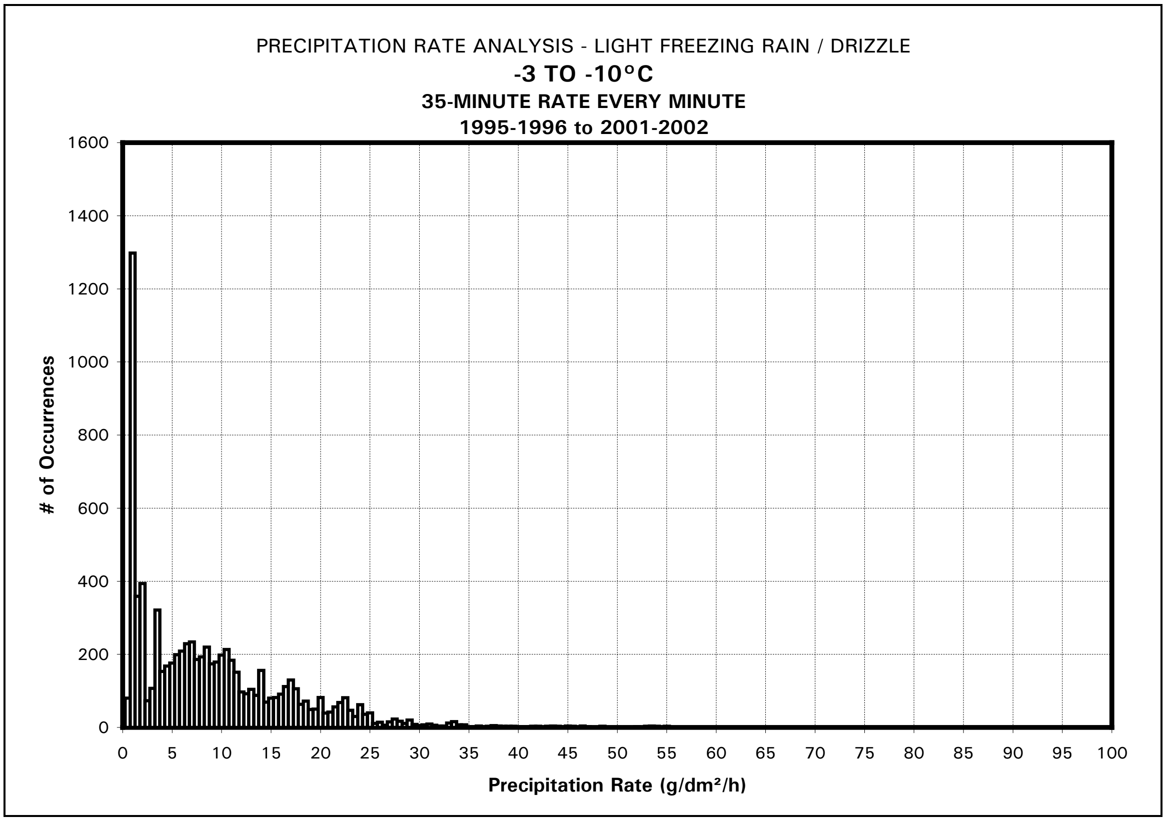

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
0 TO -3°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

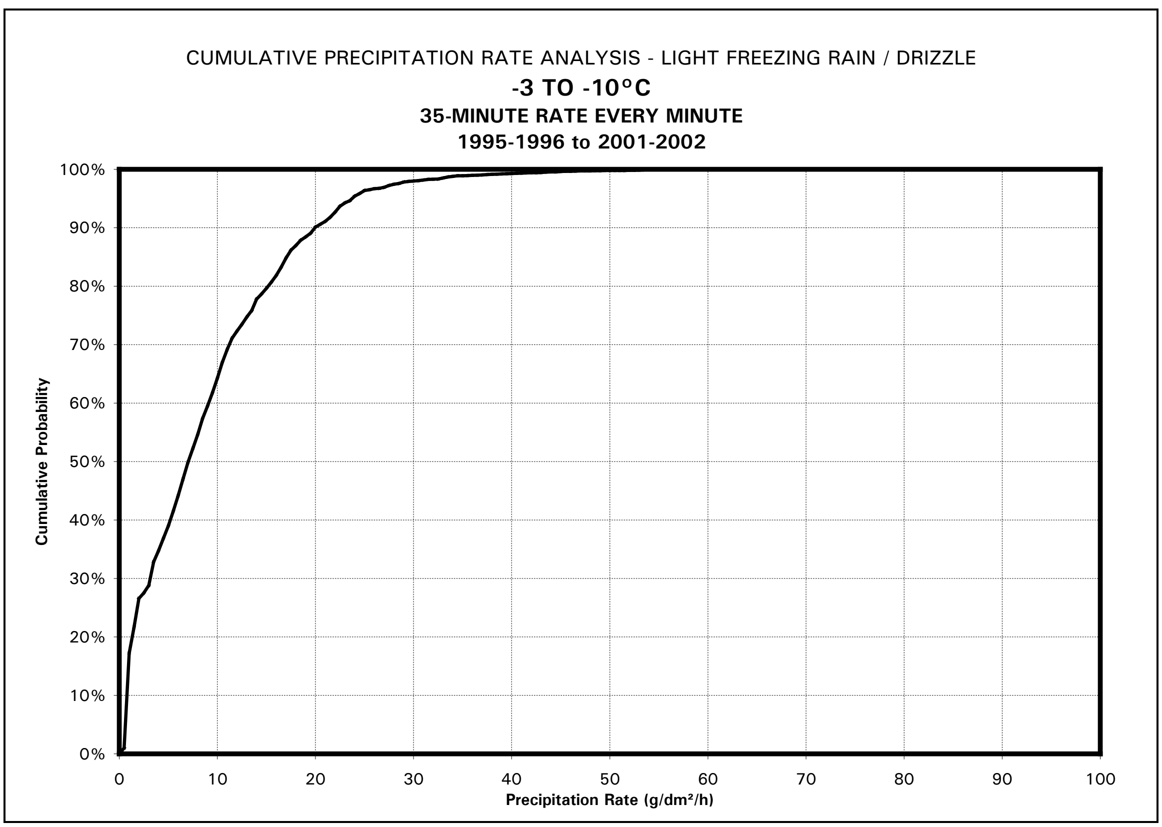

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
0 TO -3°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
0
100
200
300
400
500
600
700
800
900
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

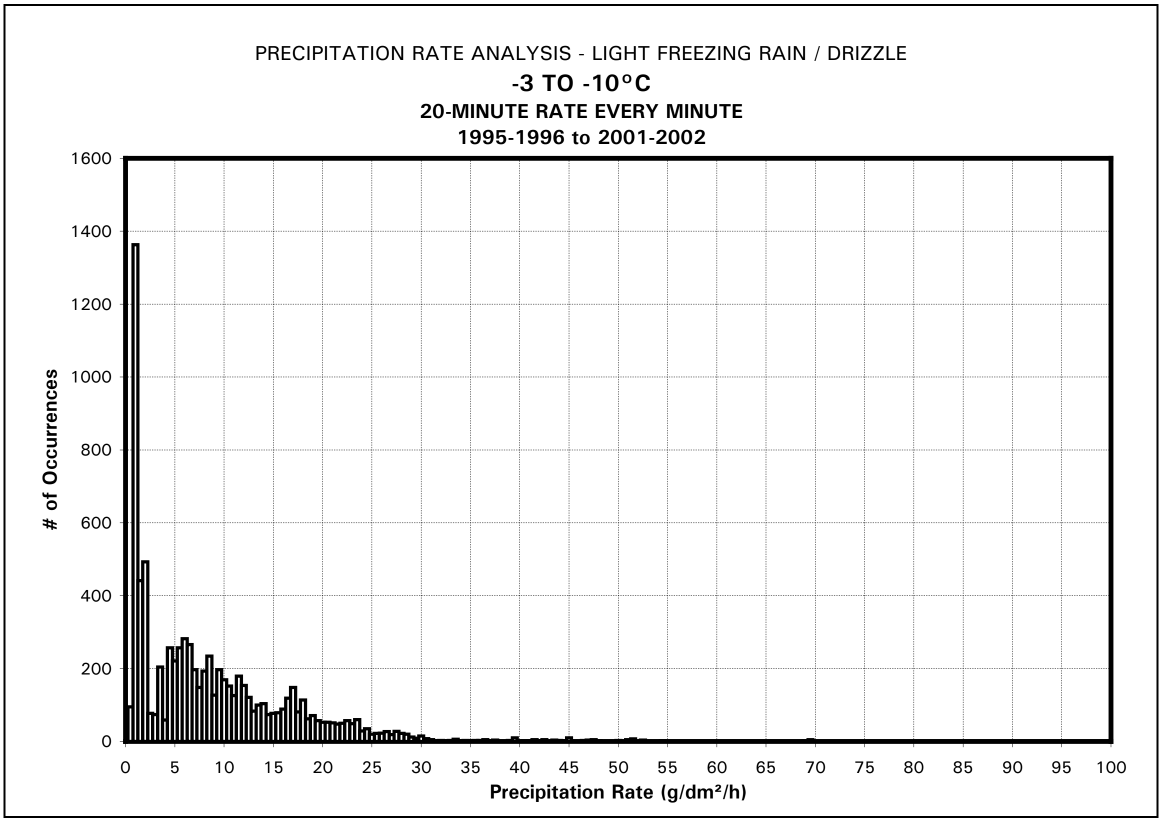

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
0 TO -3°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

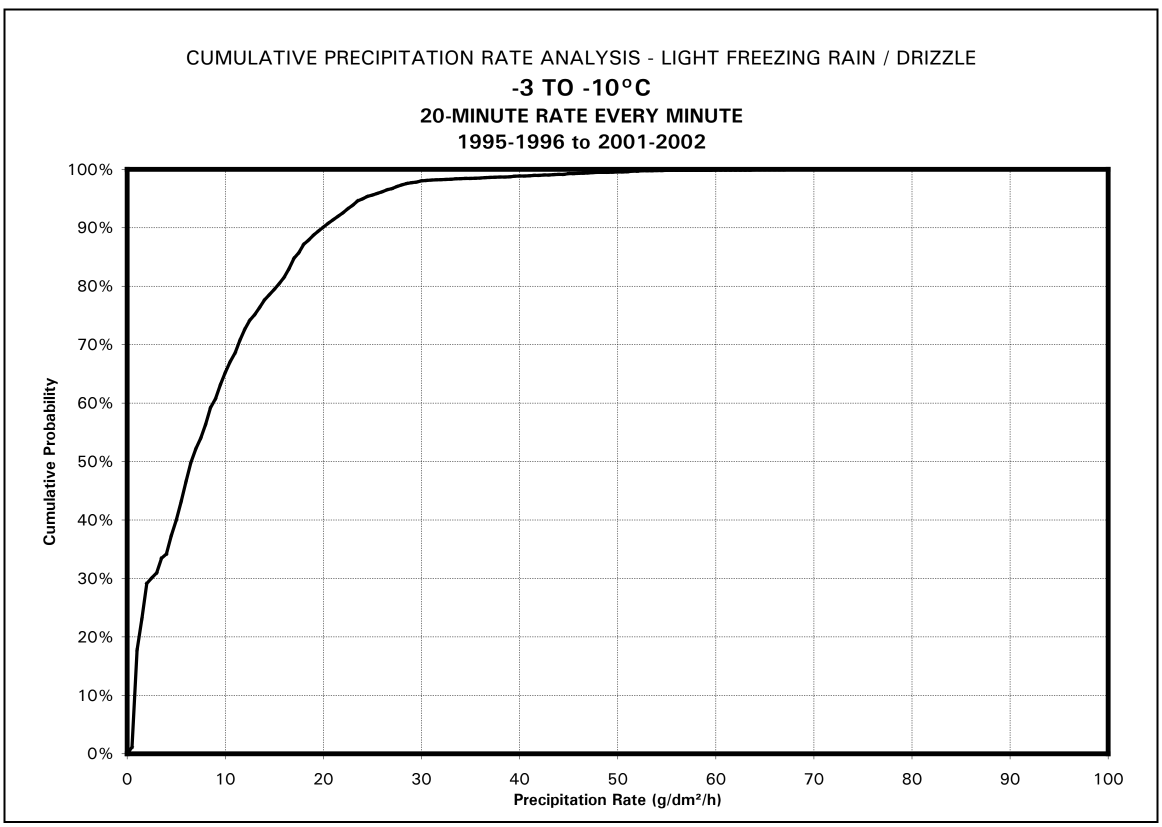

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
0 TO -3°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
Precipitation Rate (g/dm²/h)
0
100
200
300
400
500
600
700
800
900
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

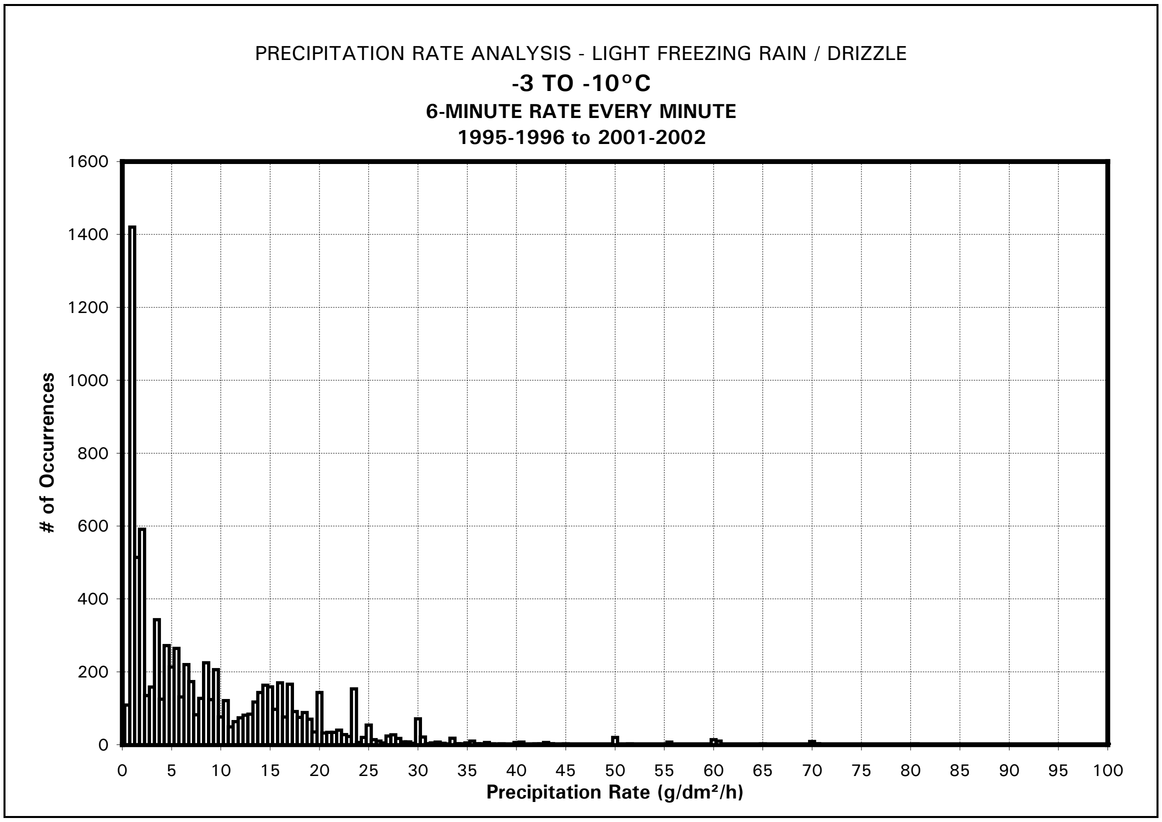

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
0 TO -3°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
Precipitation Rate (g/dm²/h)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100

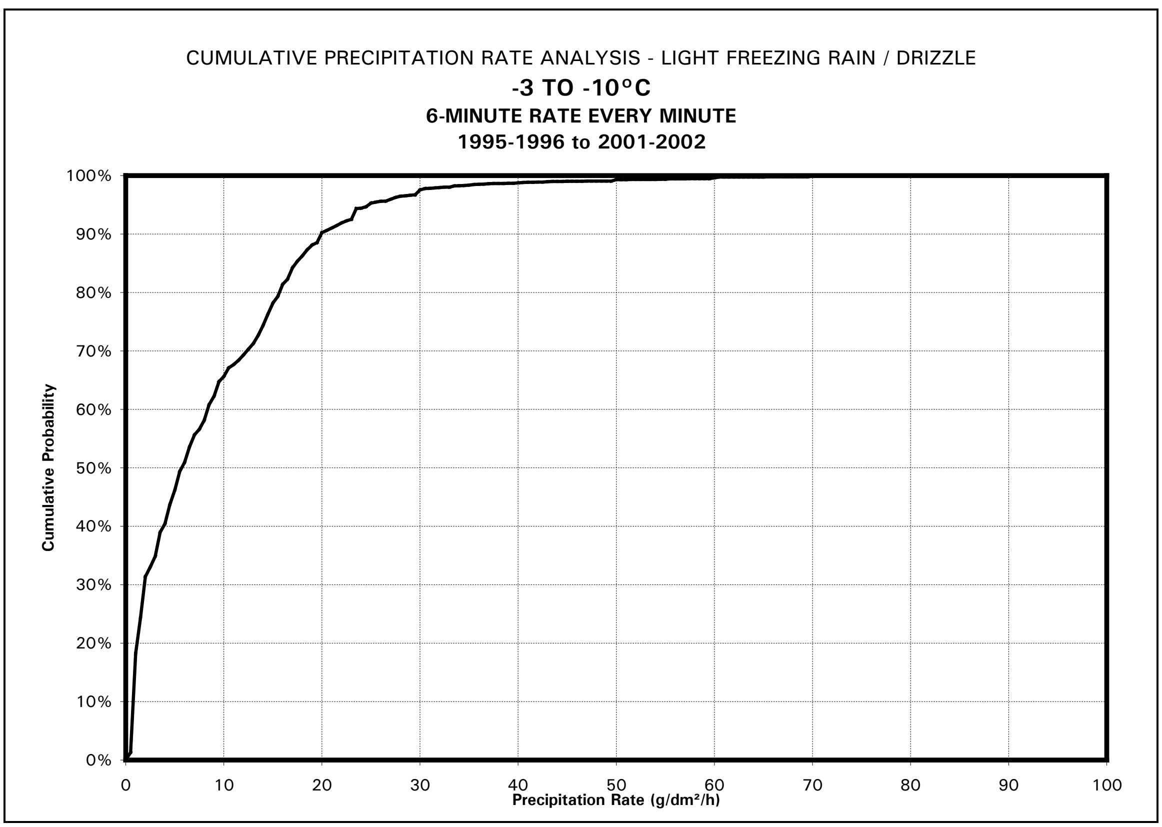

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
Precipitation Rate (g/dm²/h)

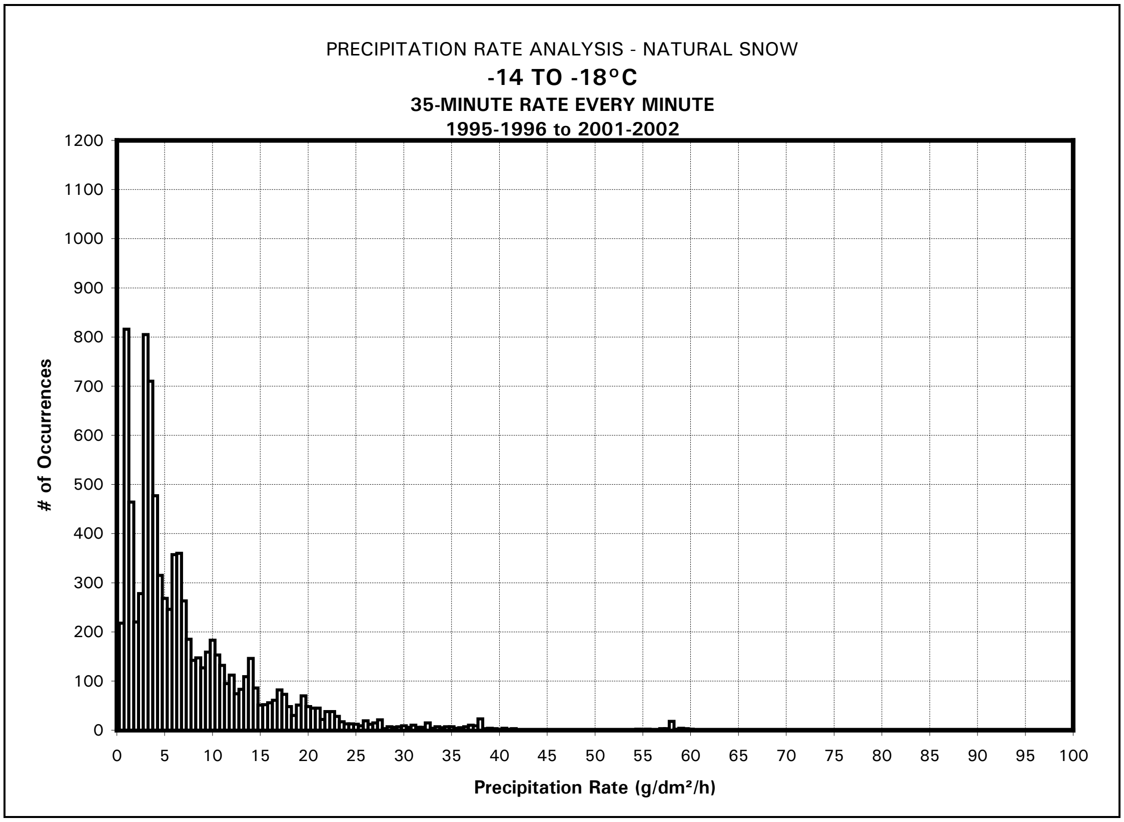

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
Precipitation Rate (g/dm²/h)

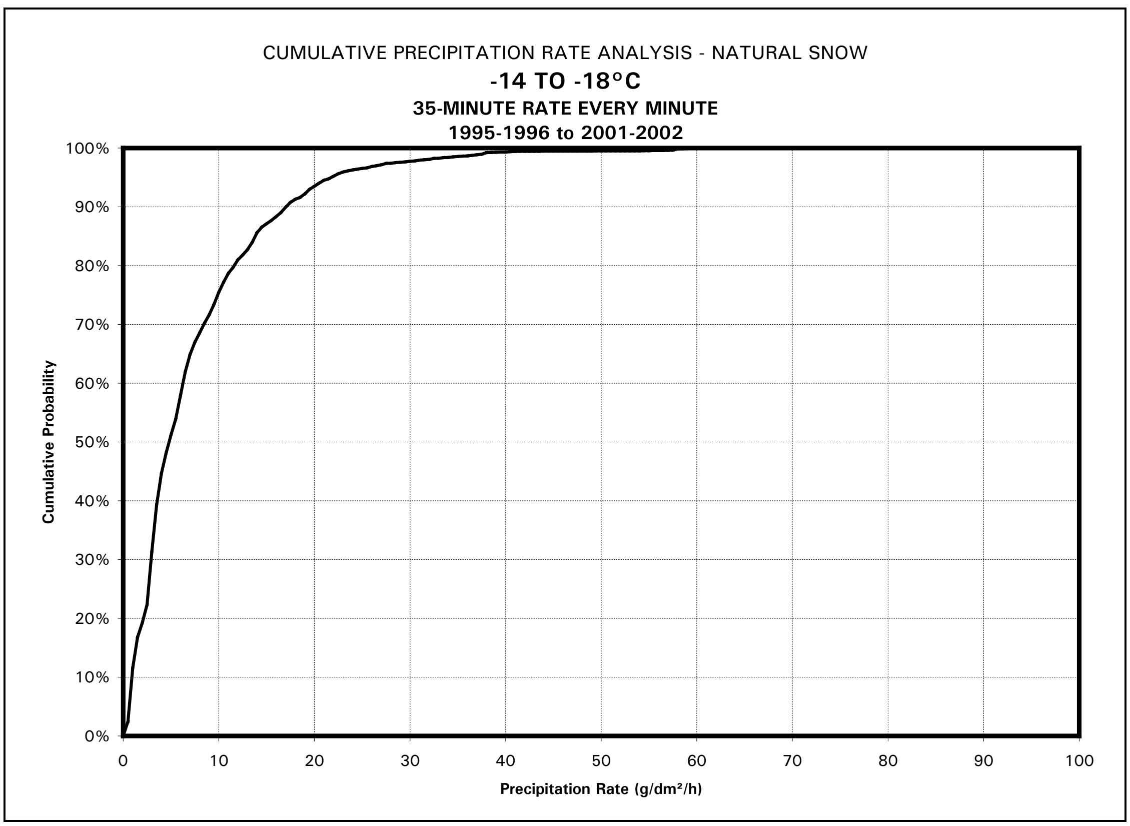

PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
0
200
400
600
800
1000
1200
1400
1600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

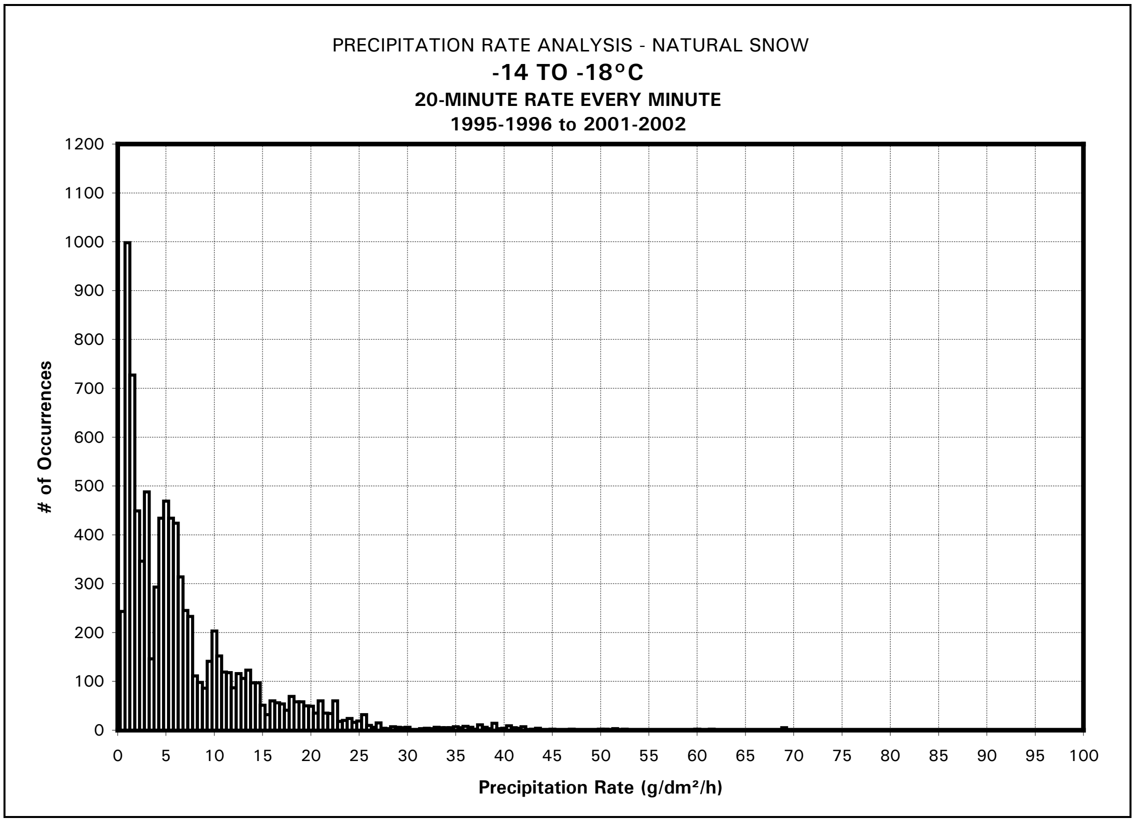

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
1600
1400
1200
1000
800
600
400
200
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)

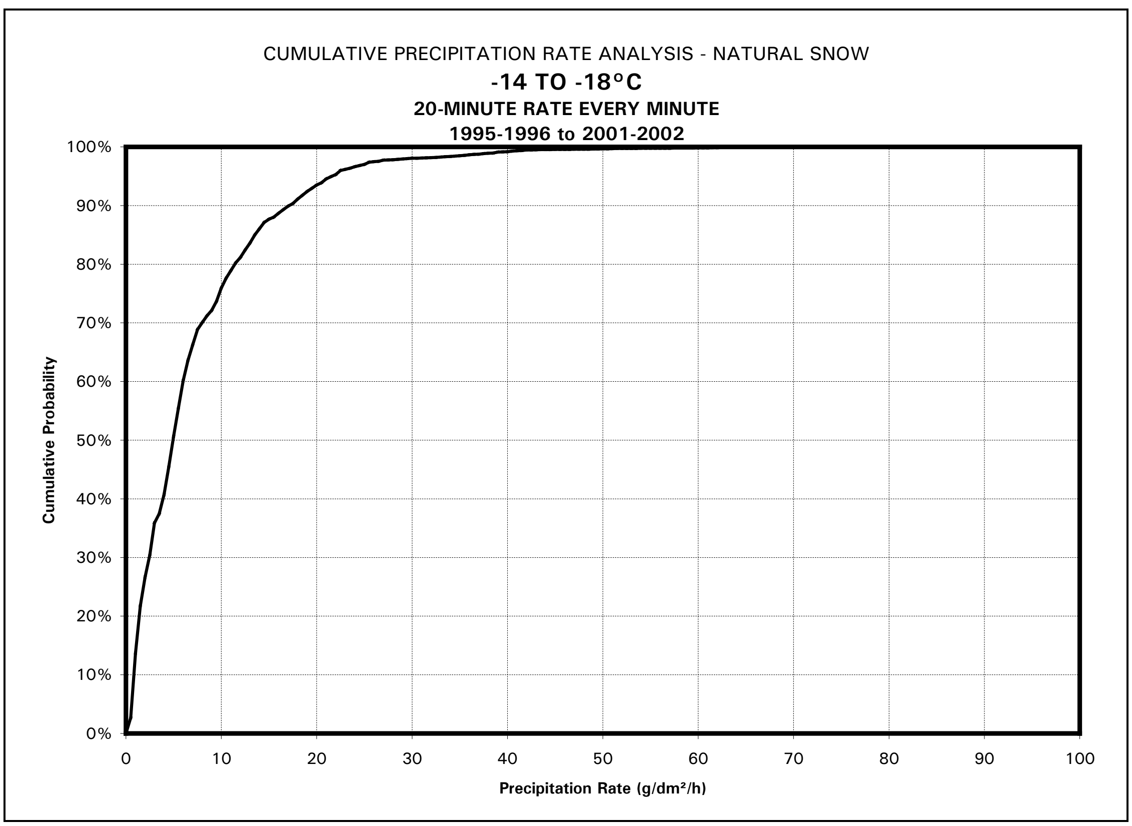

CUMULATIVE PRECIPITATION RATE ANALYSIS - LIGHT FREEZING RAIN / DRIZZLE
-3 TO -10°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)


PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
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)

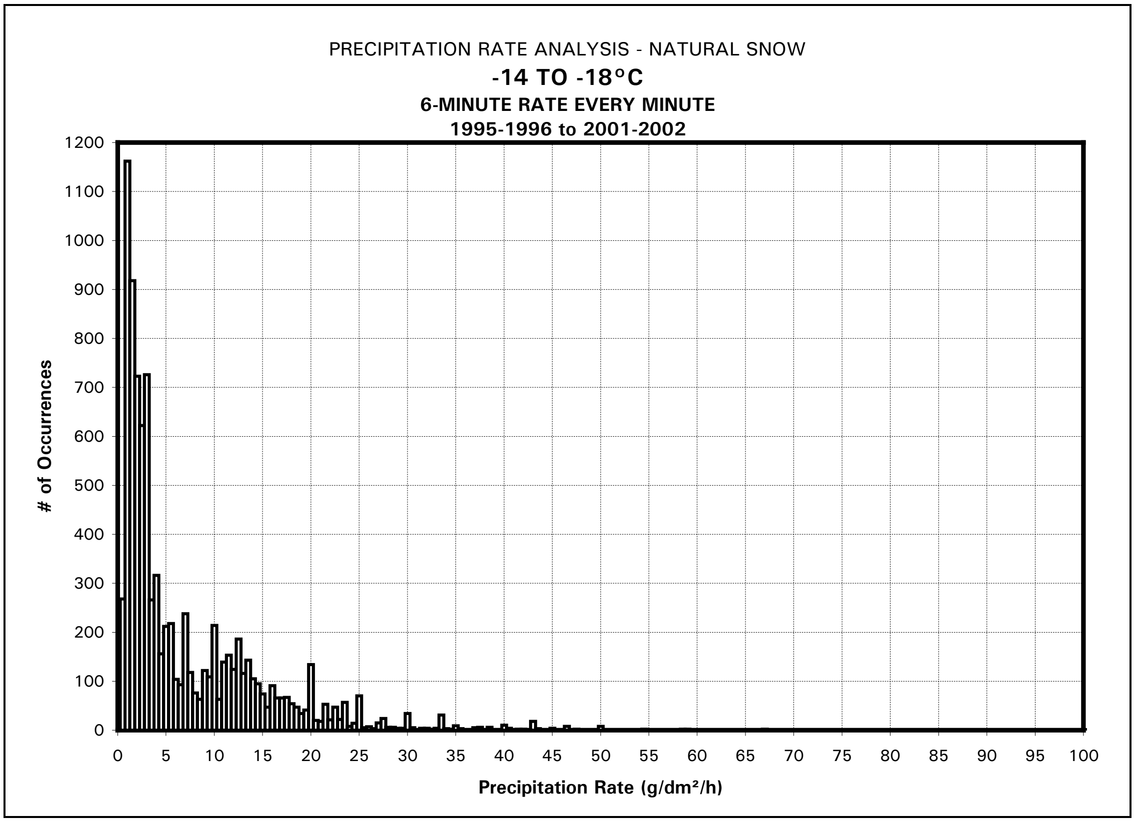

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

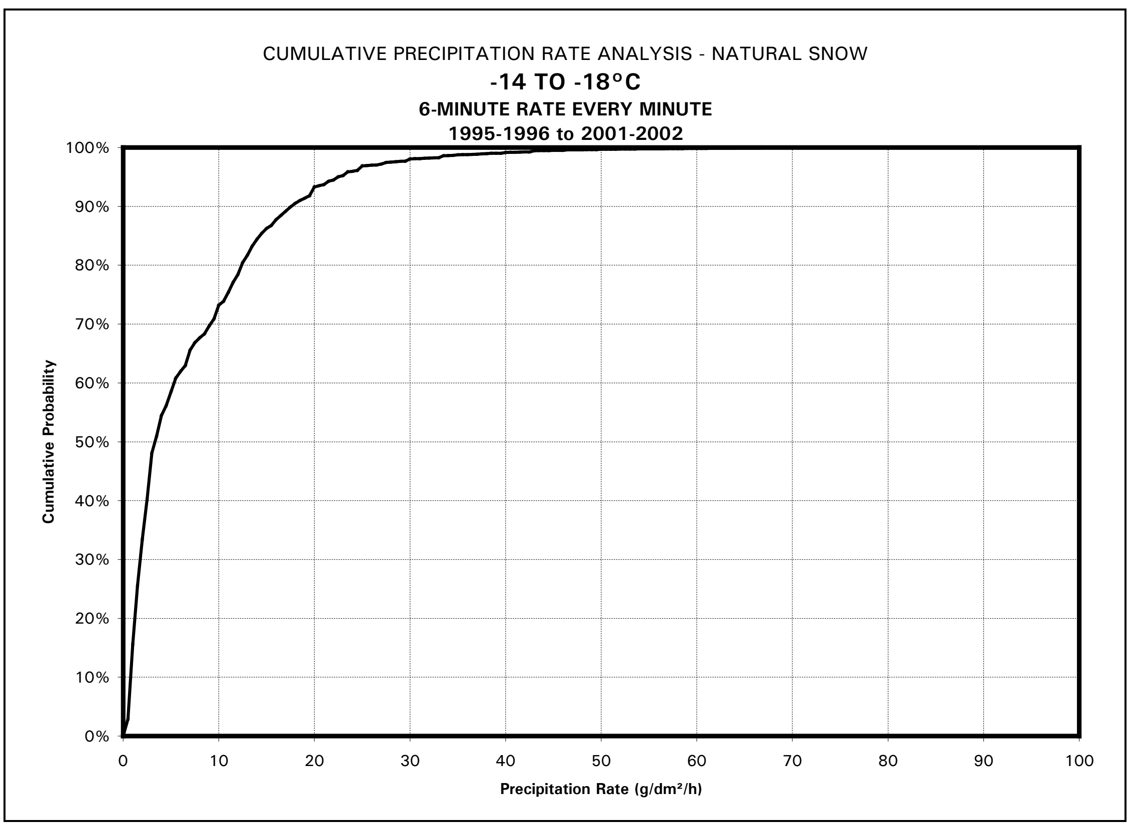


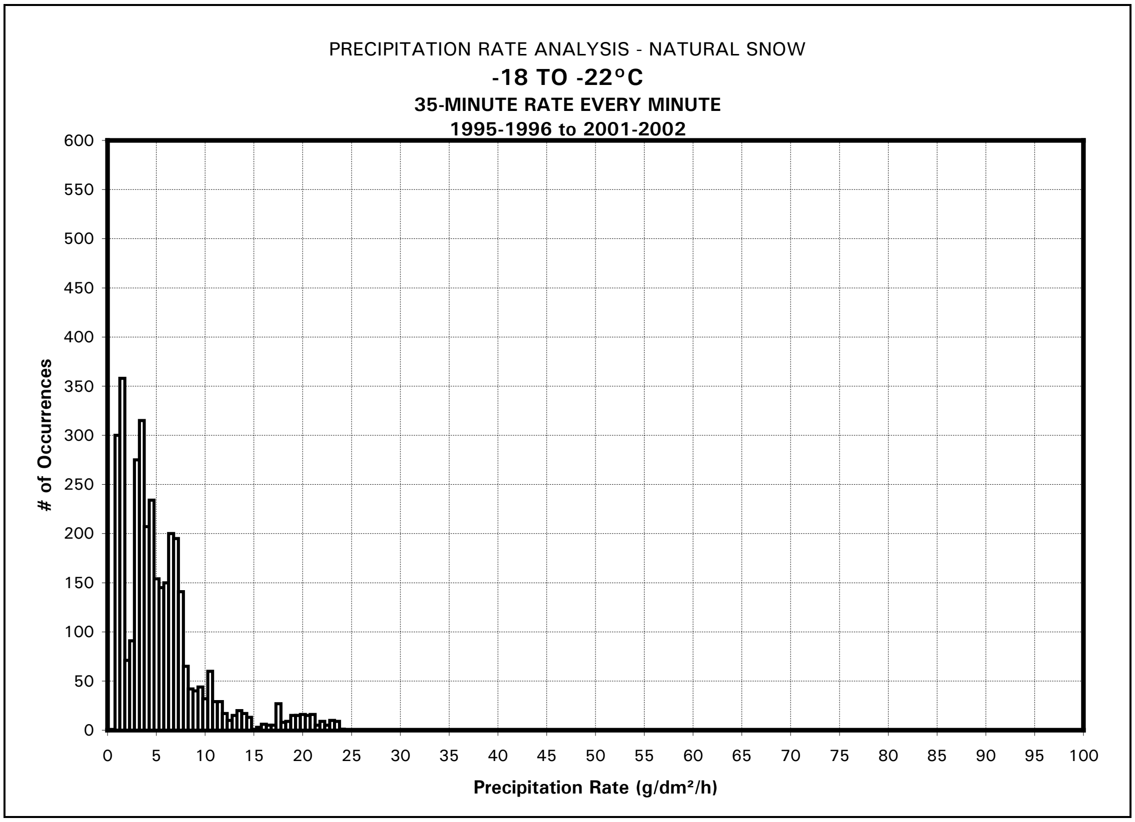
PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
Precipitation Rate (g/dm²/h)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100

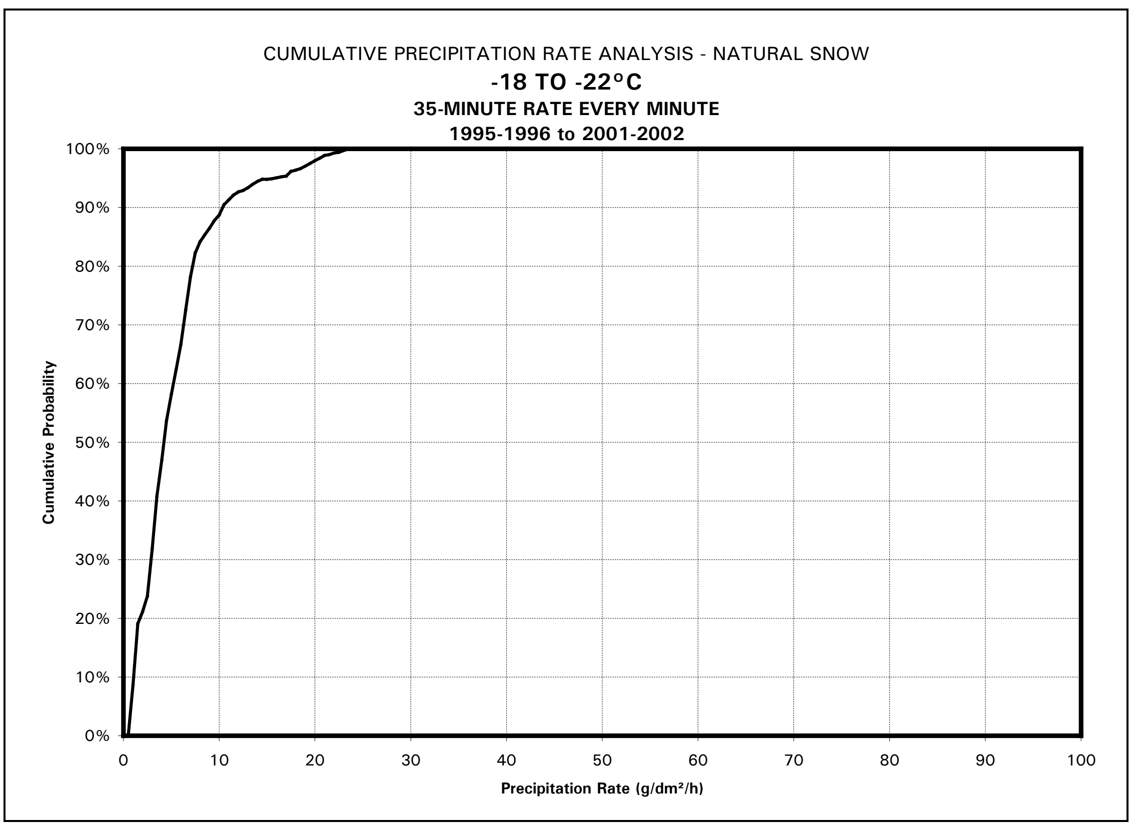


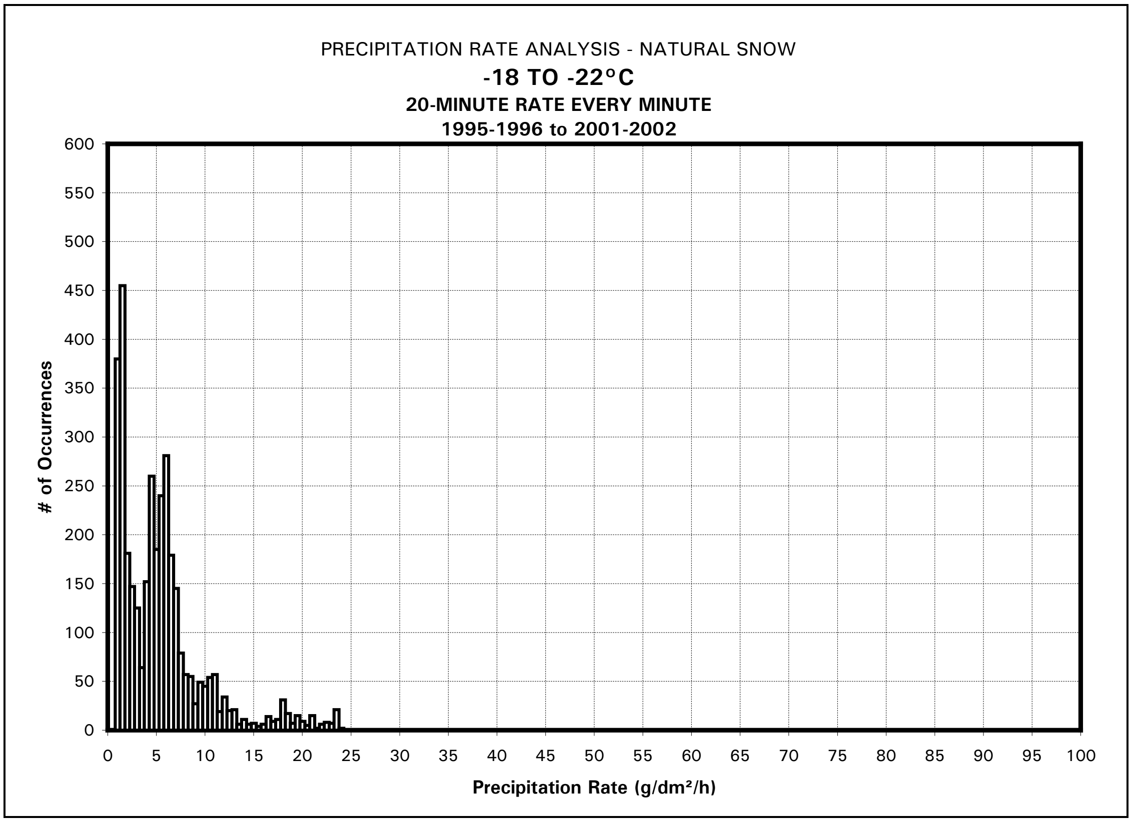
CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
Precipitation Rate (g/dm²/h)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0
10
20
30
40
50
60
70
80
90
100

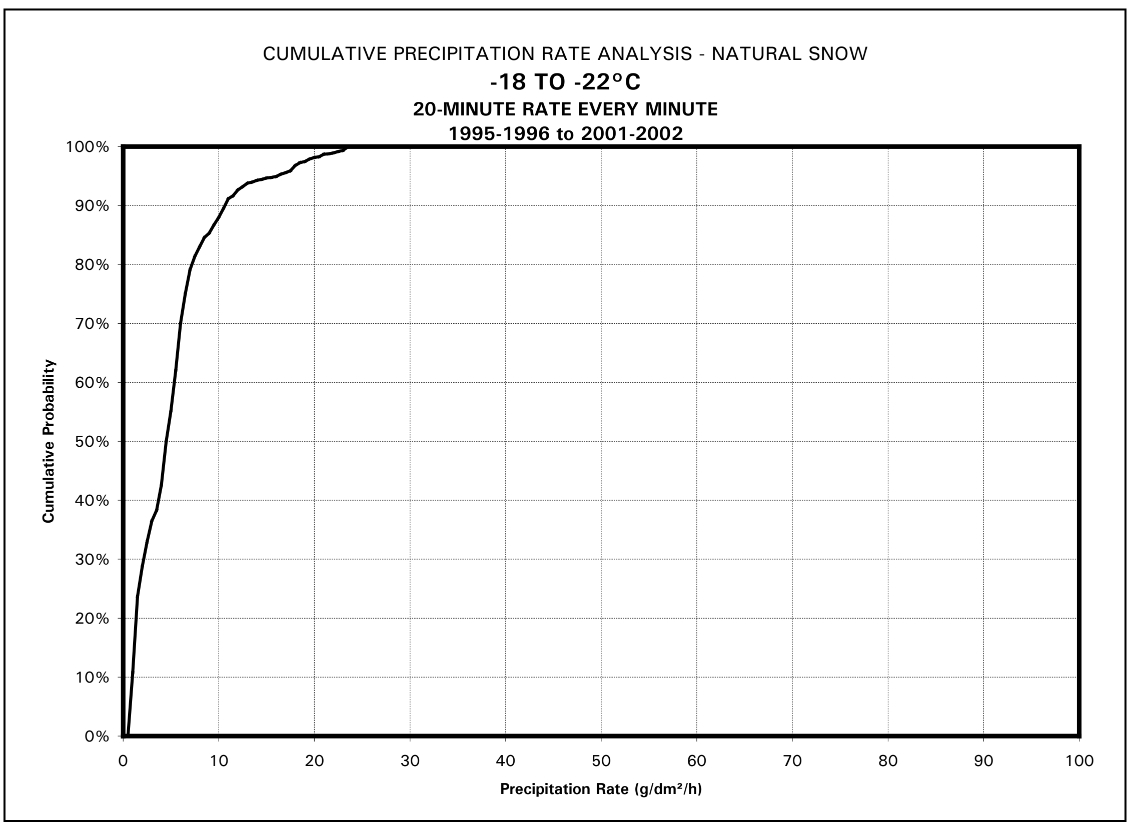

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

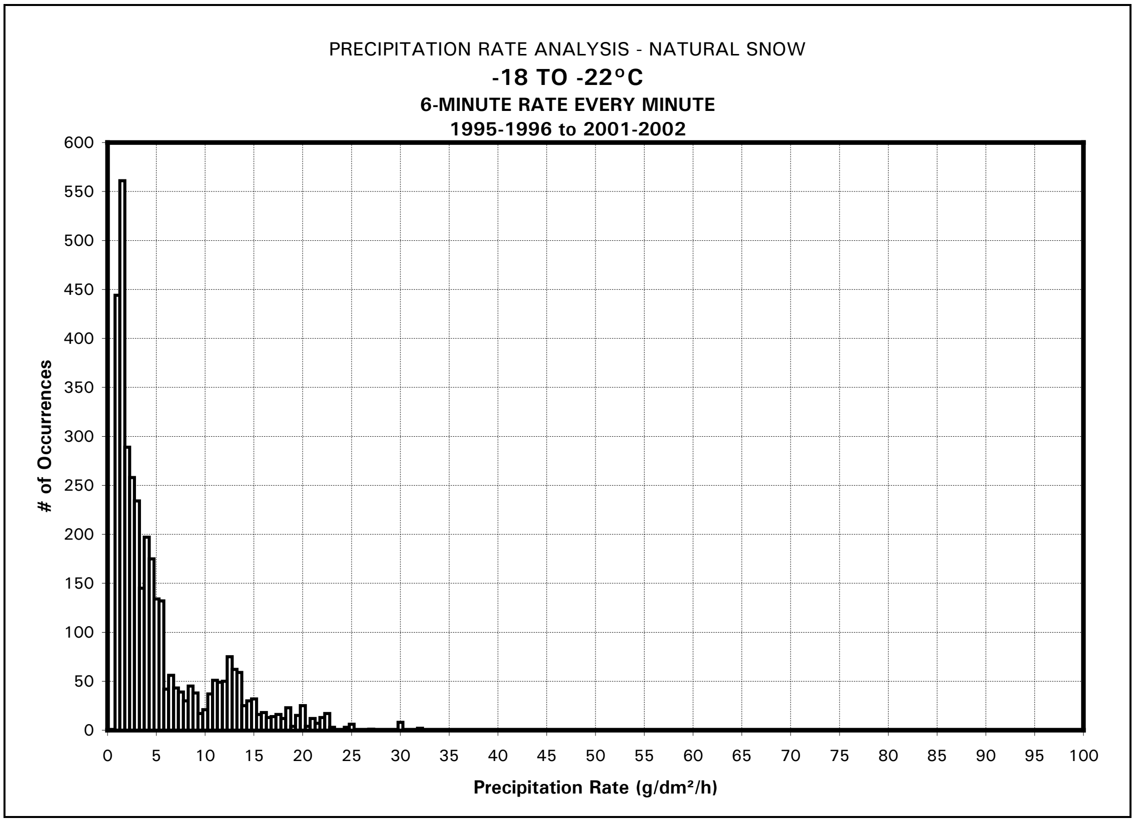

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-14 TO -18°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

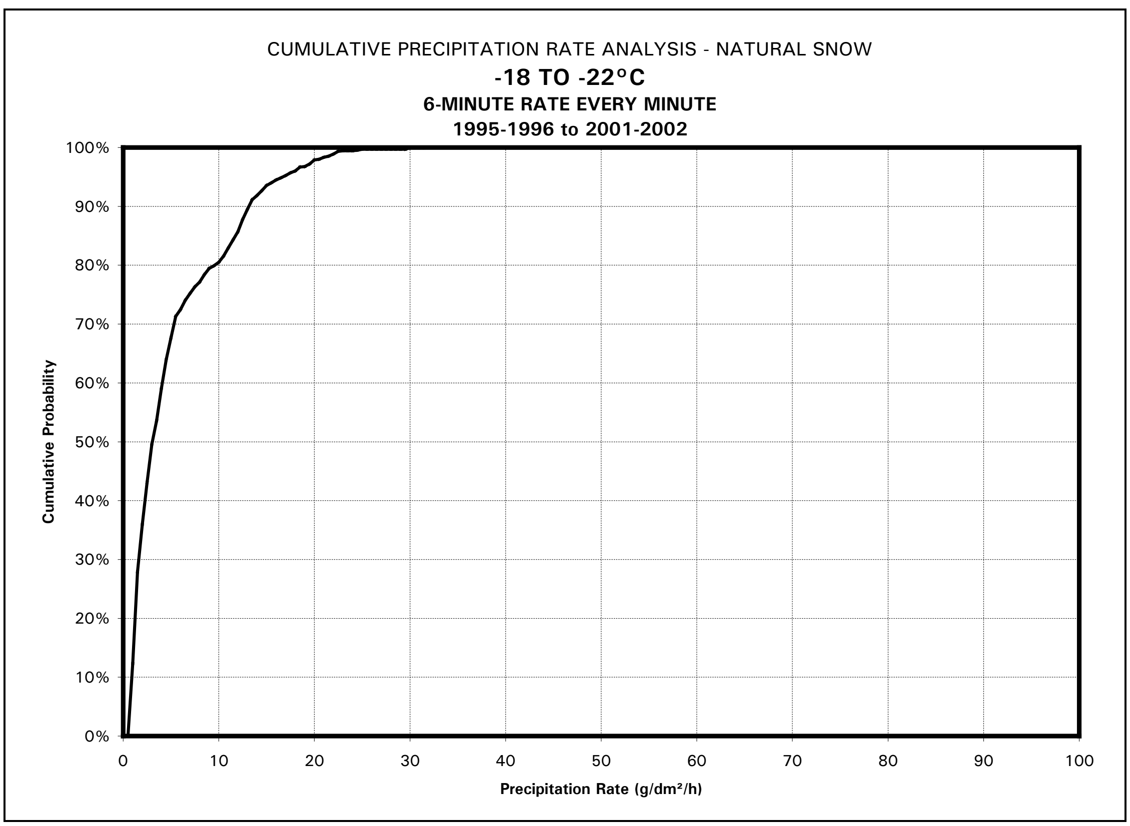

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
0
50
100
150
200
250
300
350
400
450
500
550
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

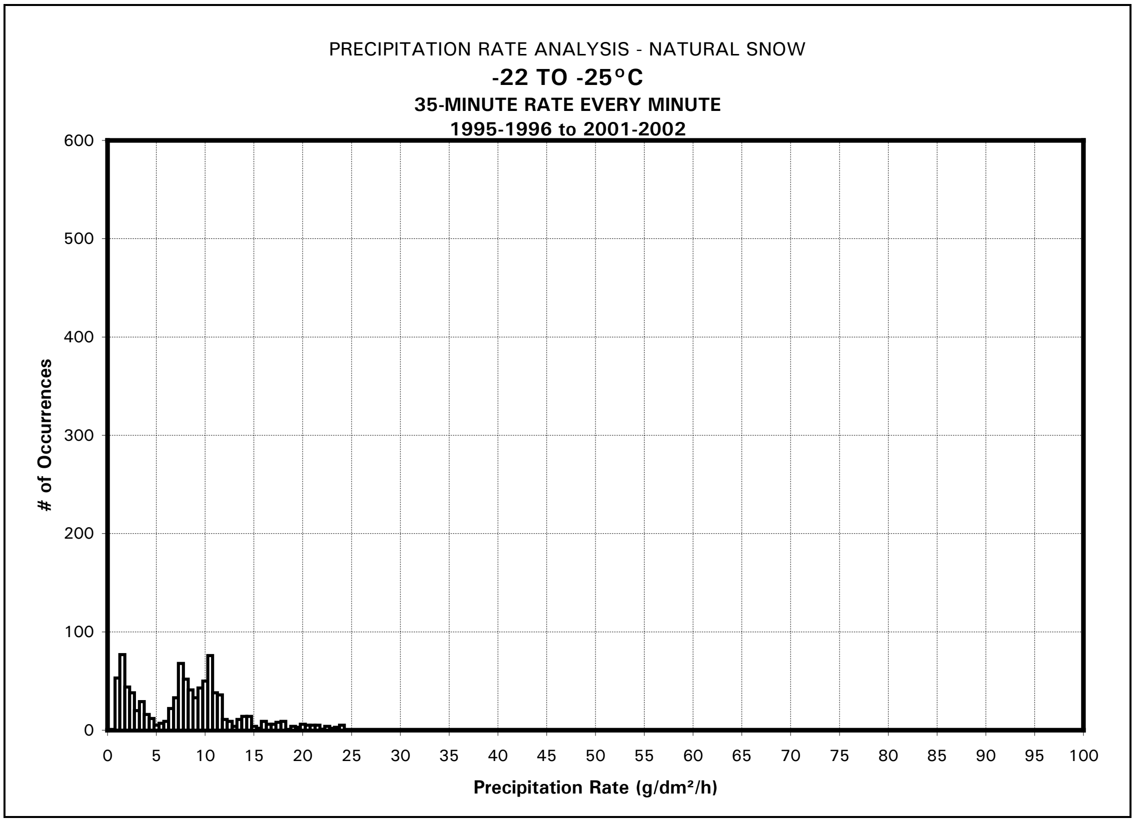

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

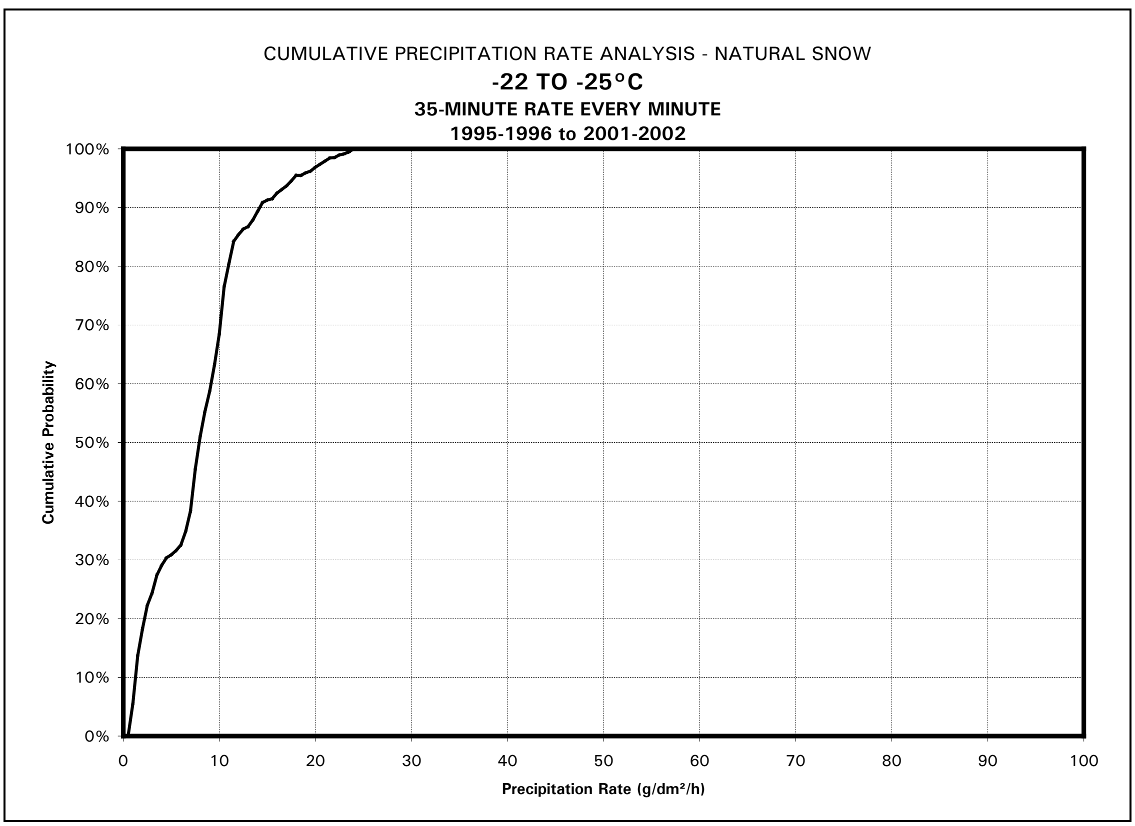

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
0
50
100
150
200
250
300
350
400
450
500
550
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

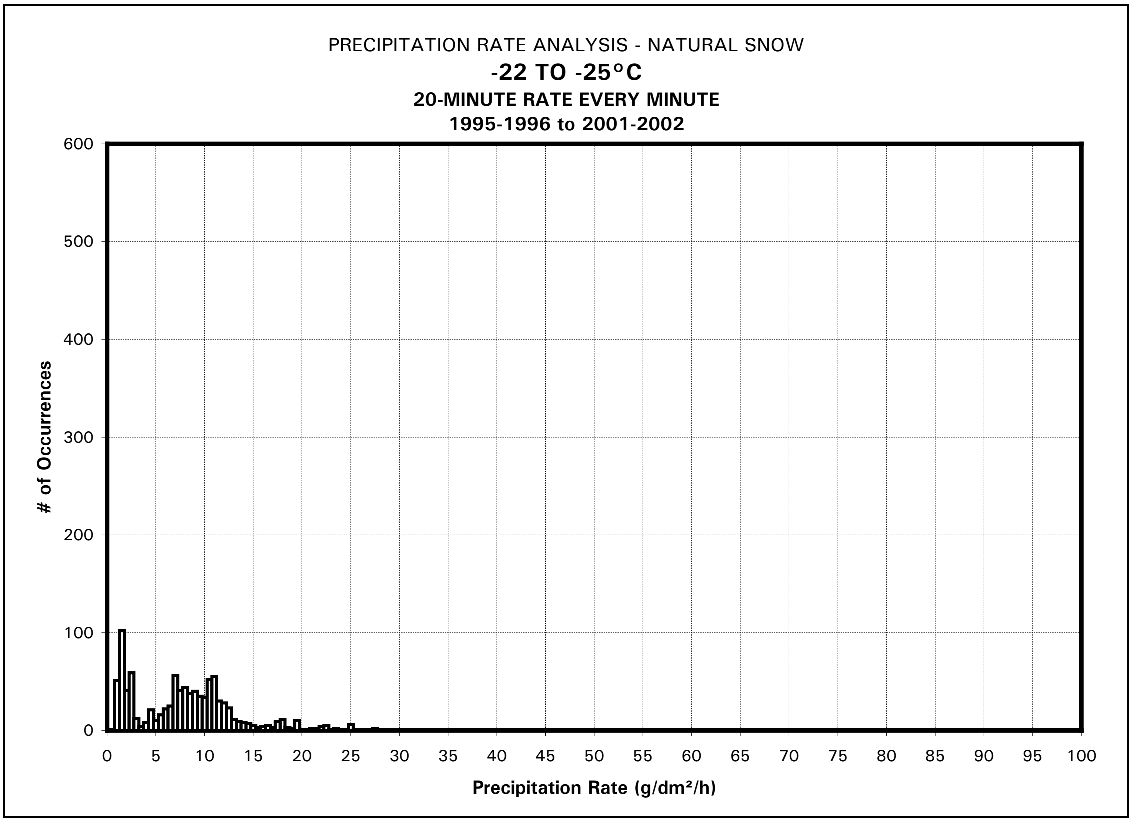

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

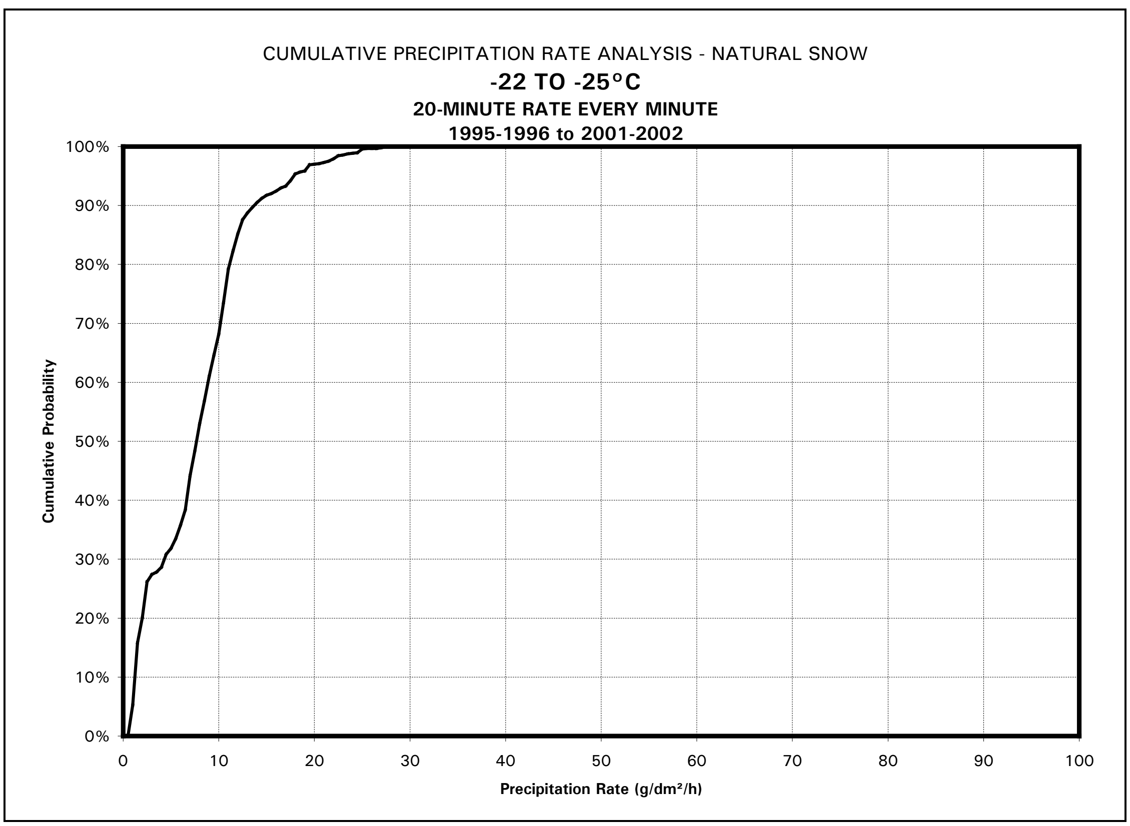

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
0
50
100
150
200
250
300
350
400
450
500
550
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)

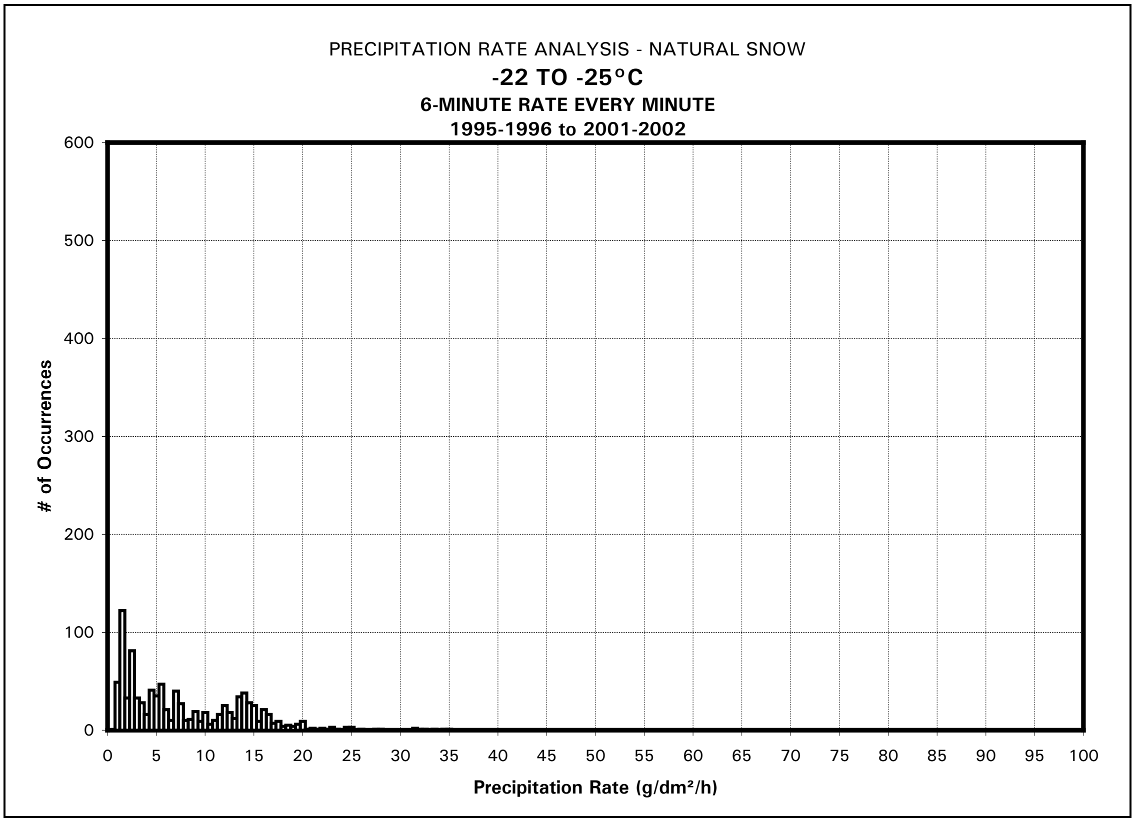

CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-18 TO -22°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
Cumulative Probability
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0 10 20 30 40 50 60 70 80 90 100
Precipitation Rate (g/dm²/h)

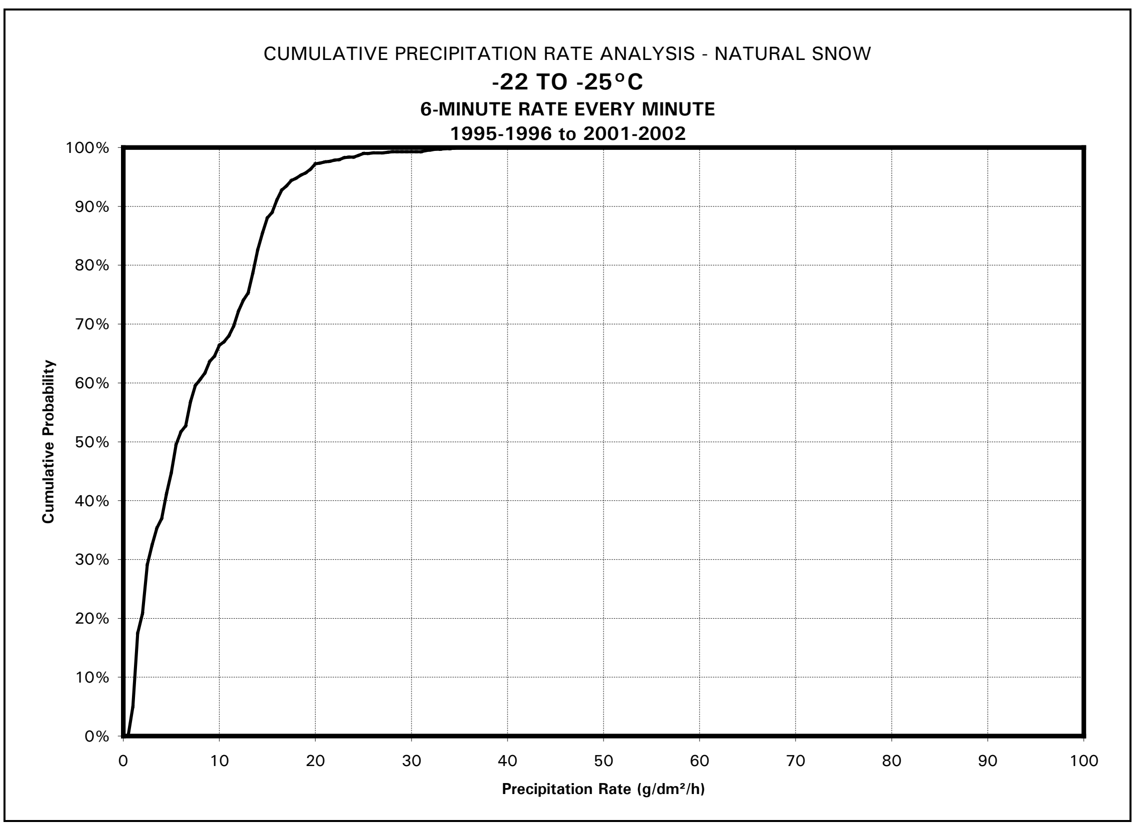

PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# of Occurrences
0
100
200
300
400
500
600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Precipitation Rate (g/dm²/h)


CUMULATIVE PRECIPITATION RATE ANALYSIS - NATURAL SNOW
-22 TO -25°C
35-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
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 2001-2002
# of Occurrences
600
500
400
300
200
100
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
-22 TO -25°C
20-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
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
-22 TO -25°C
6-MINUTE RATE EVERY MINUTE
1995-1996 to 2001-2002
# 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 2001-2002
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

SNOW WEATHER DATA 1993-94 AND 1994-95

SNOW WEATHER DATA
1993-94 AND 1994-95

INDEX

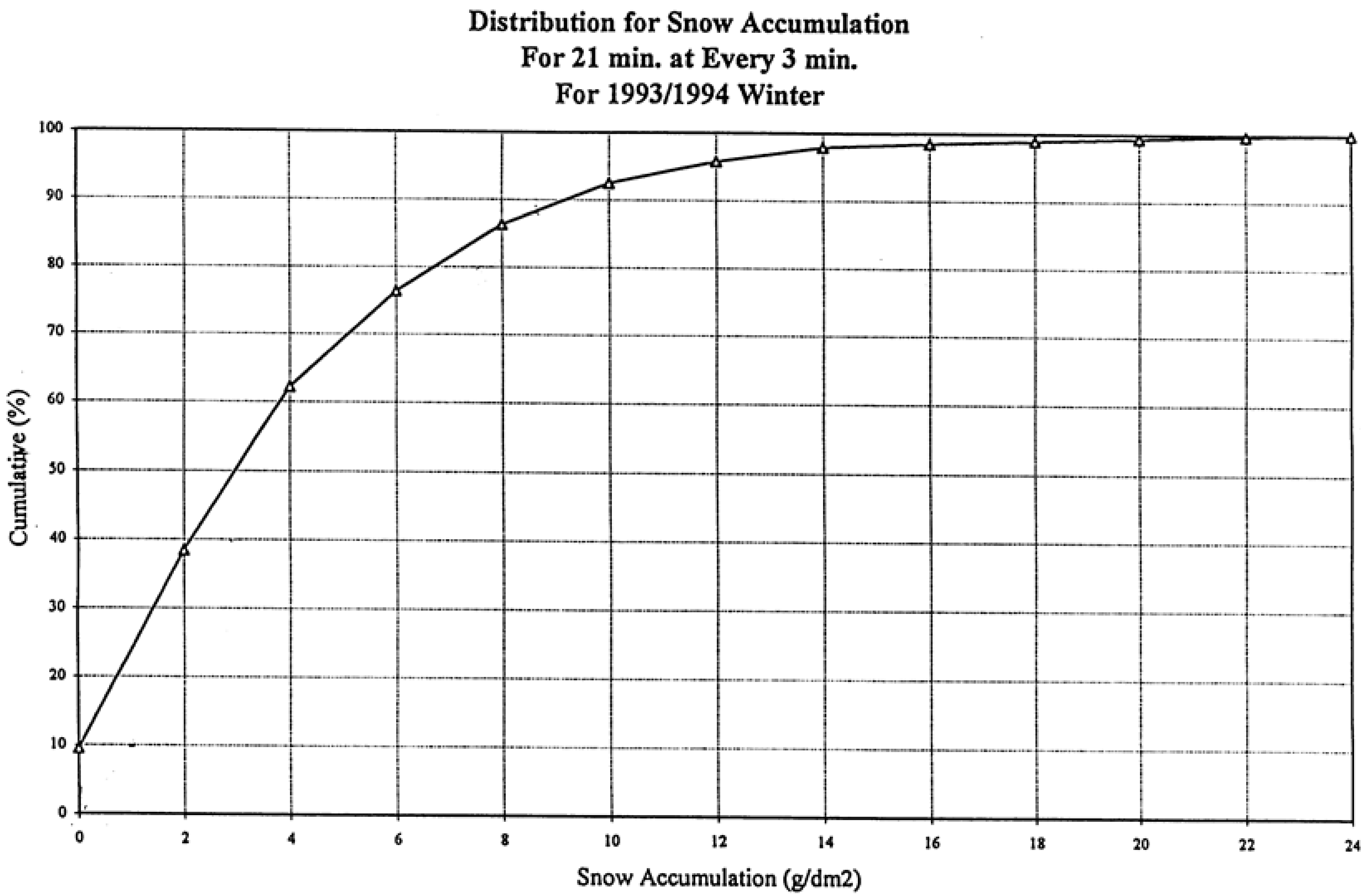
DISTRIBUTION FOR SNOW ACCUMULATION **Page**

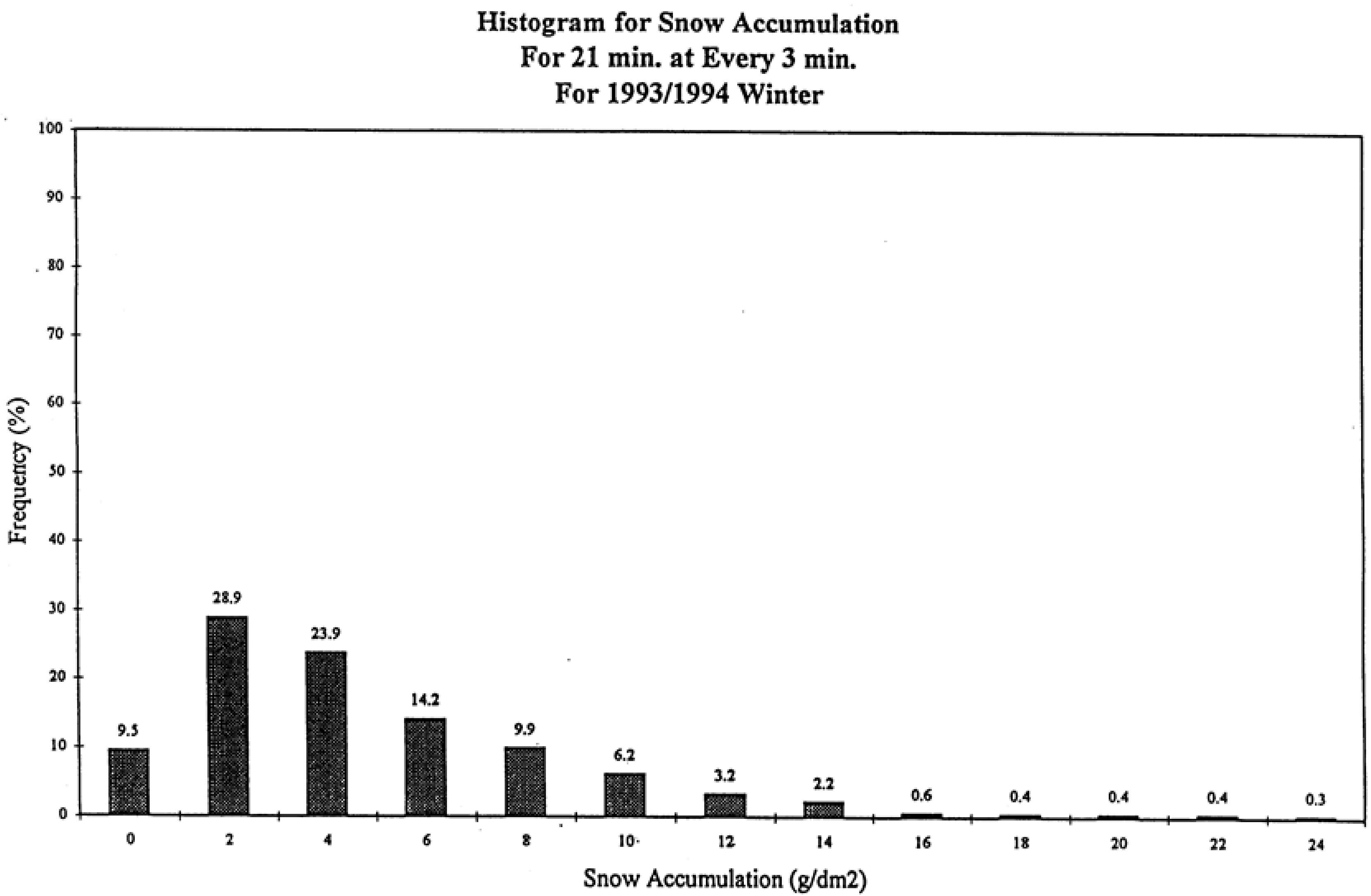
HISTOGRAM FOR SNOW ACCUMULATION

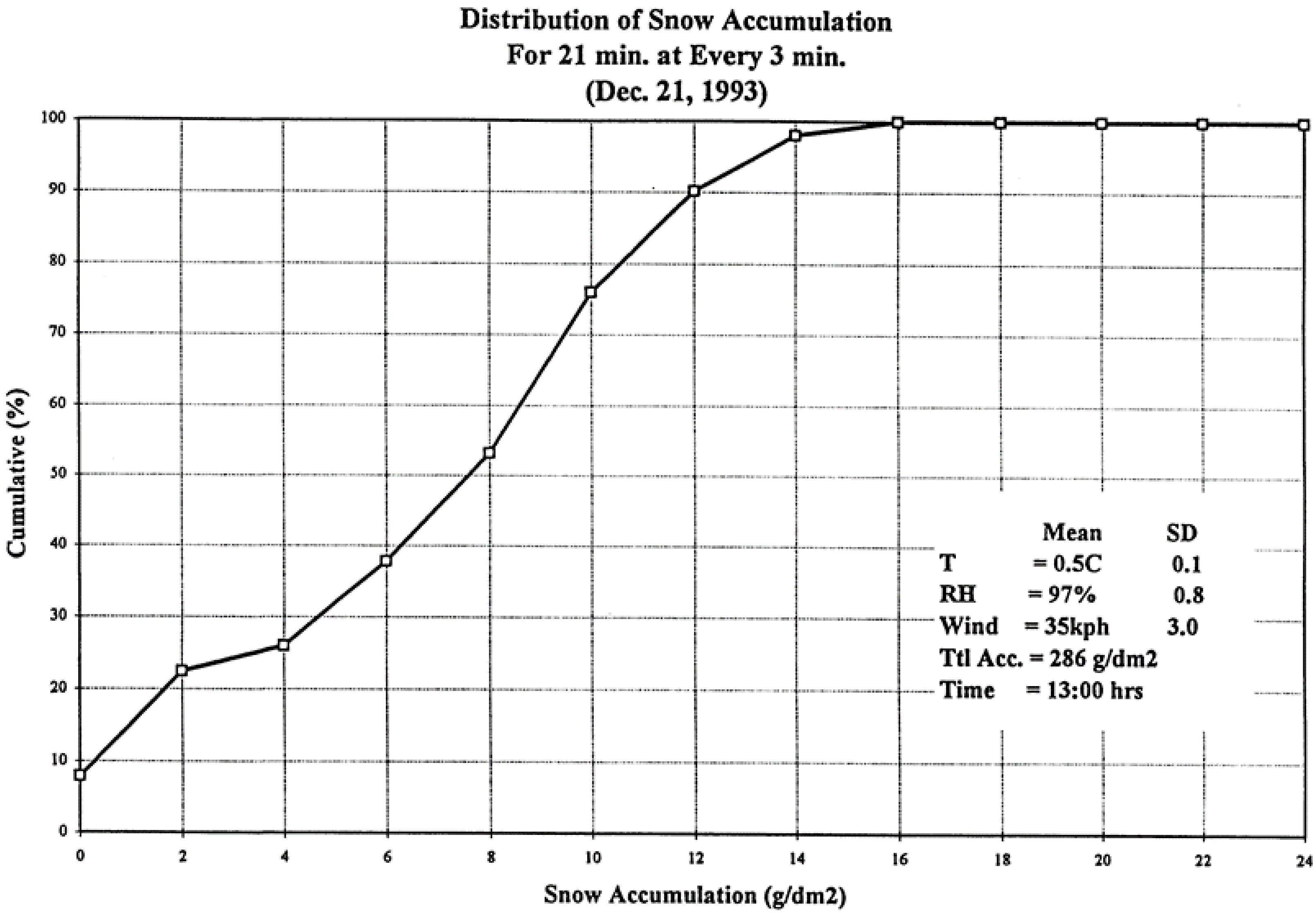
TOTAL SNOW ACCUMULATION

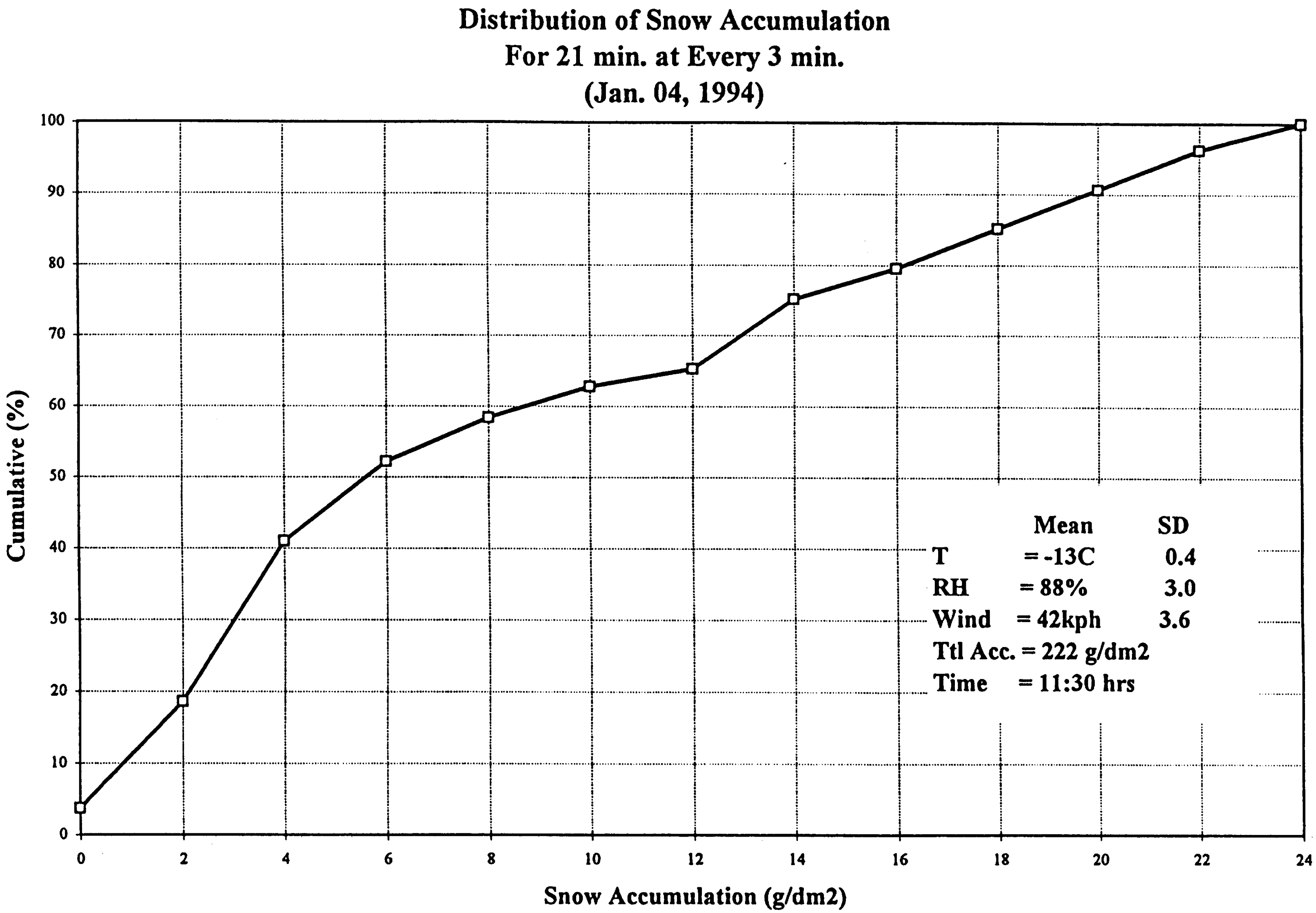
COMPARISON BETWEEN MOVING & REG. AVERAGES FOR DISTRIBUTION FOR SNOW ACCUMULATION

MOVING AVERAGE

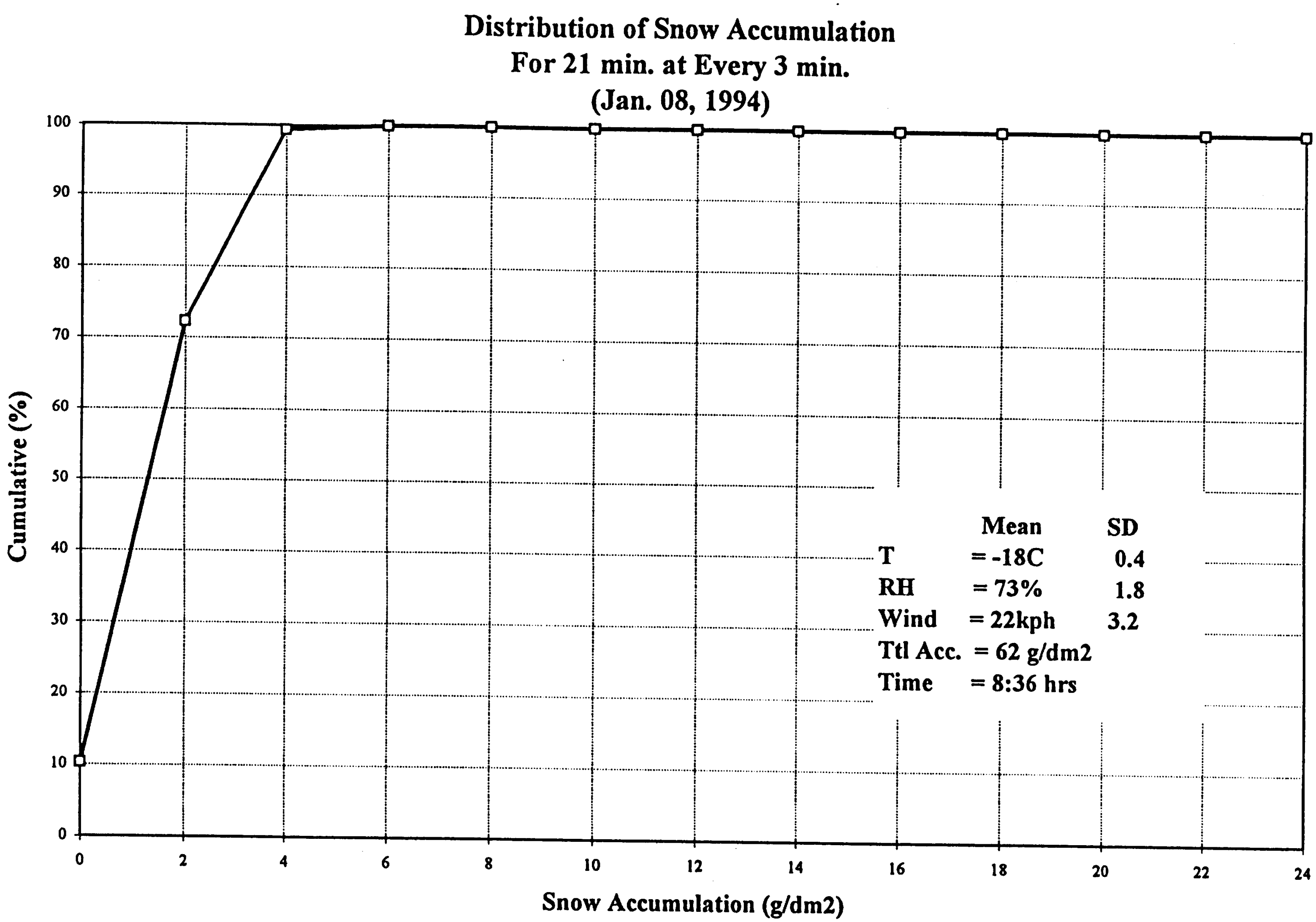

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/1994 Winter
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)

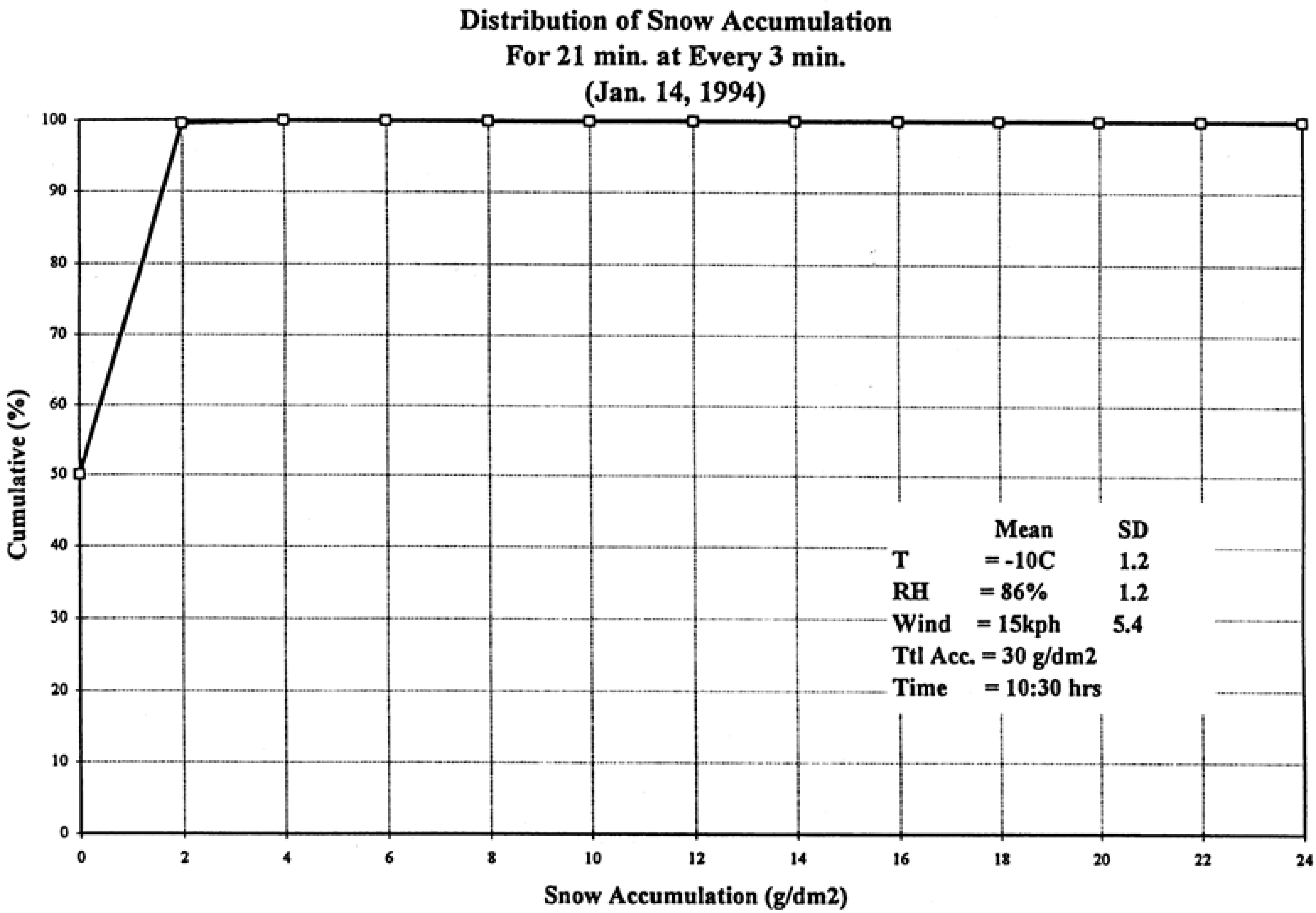

Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/1994 Winter
Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
9.5
28.9
23.9
14.2
9.9
6.2
3.2
2.2
0.6
0.4
0.4
0.4
0.3
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)

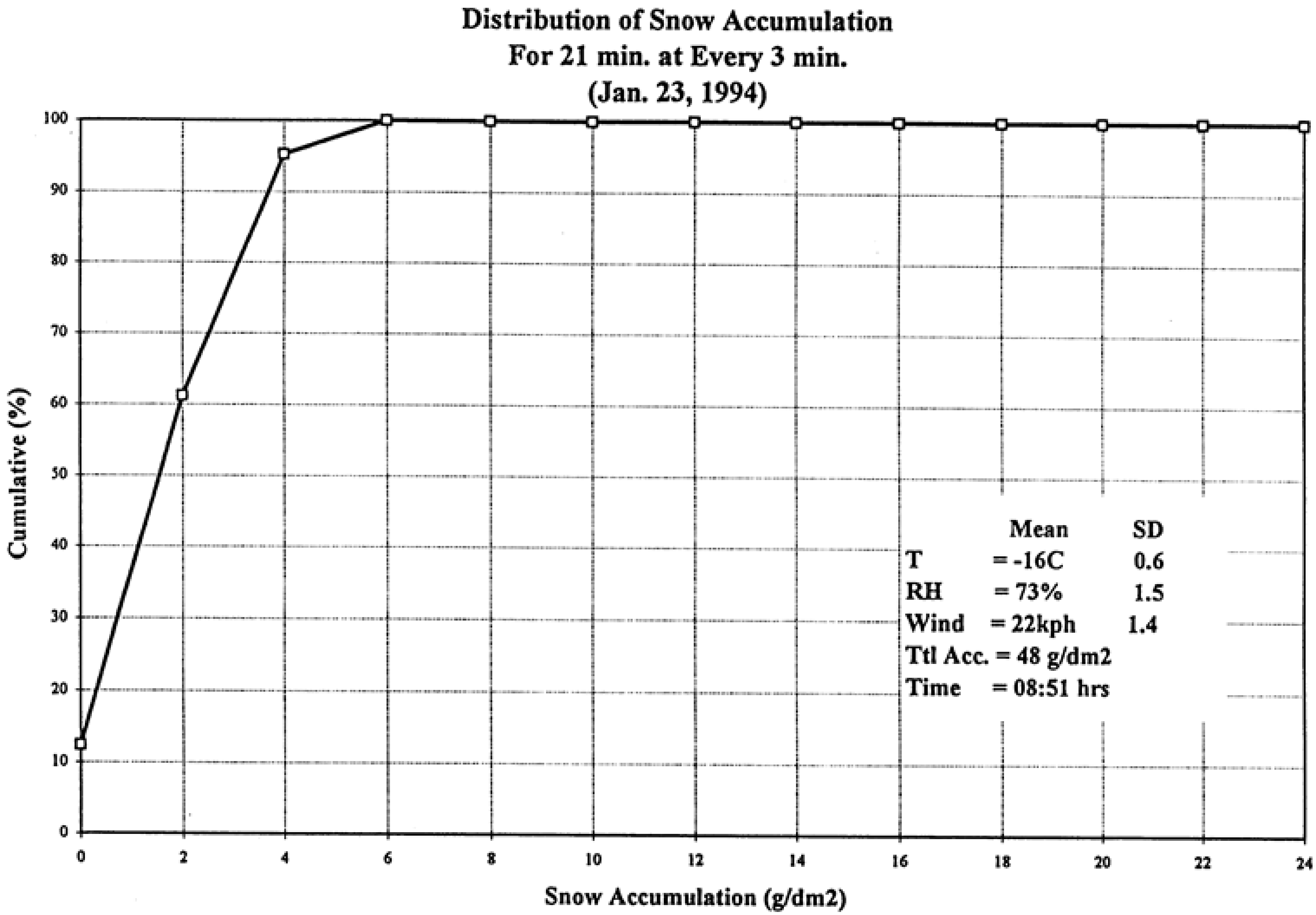

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Dec. 21, 1993)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean
SD
T = 0.5C 0.1
RH = 97% 0.8
Wind = 35kph 3.0
Ttl Acc. = 286 g/dm2
Time = 13:00 hrs

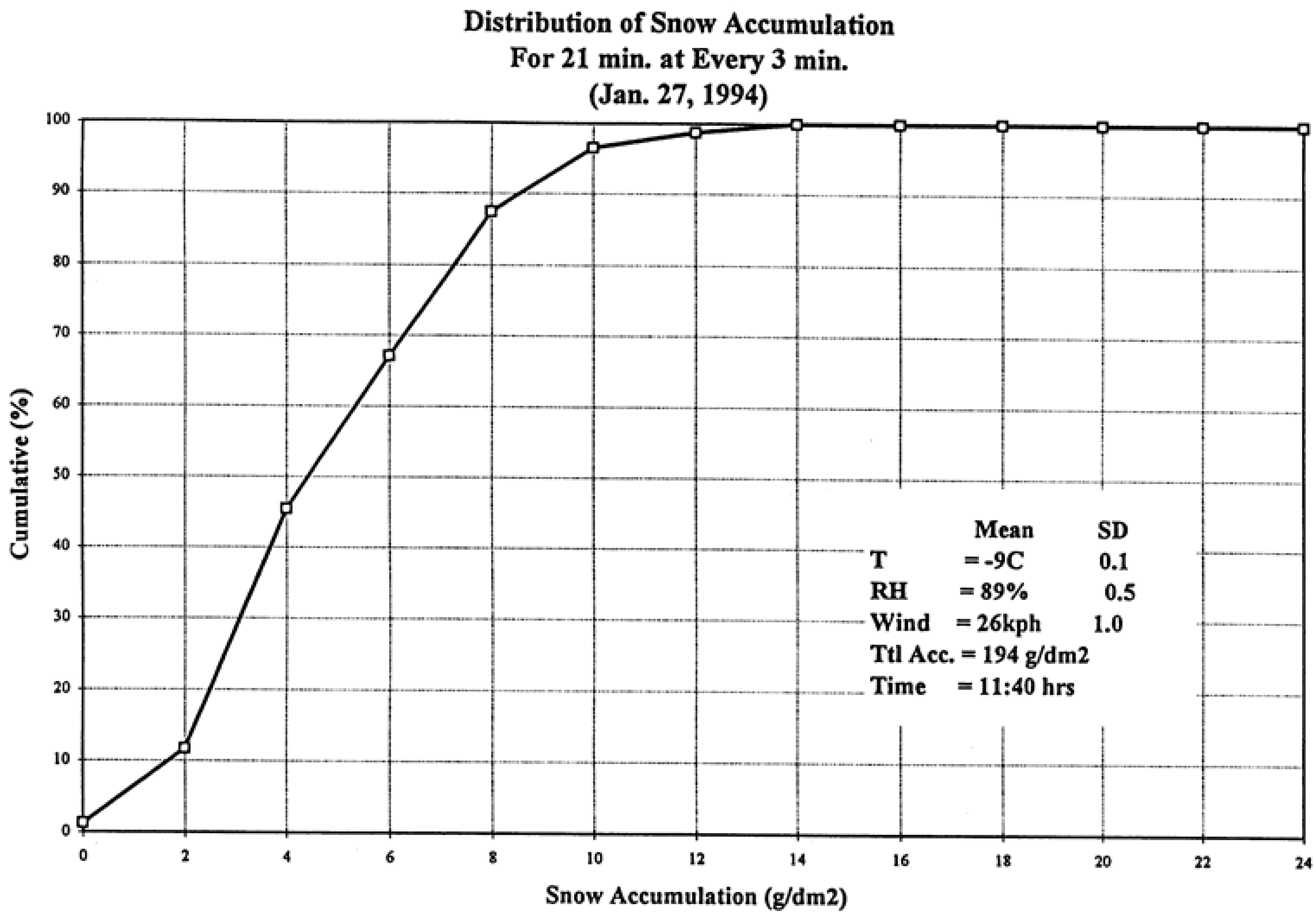


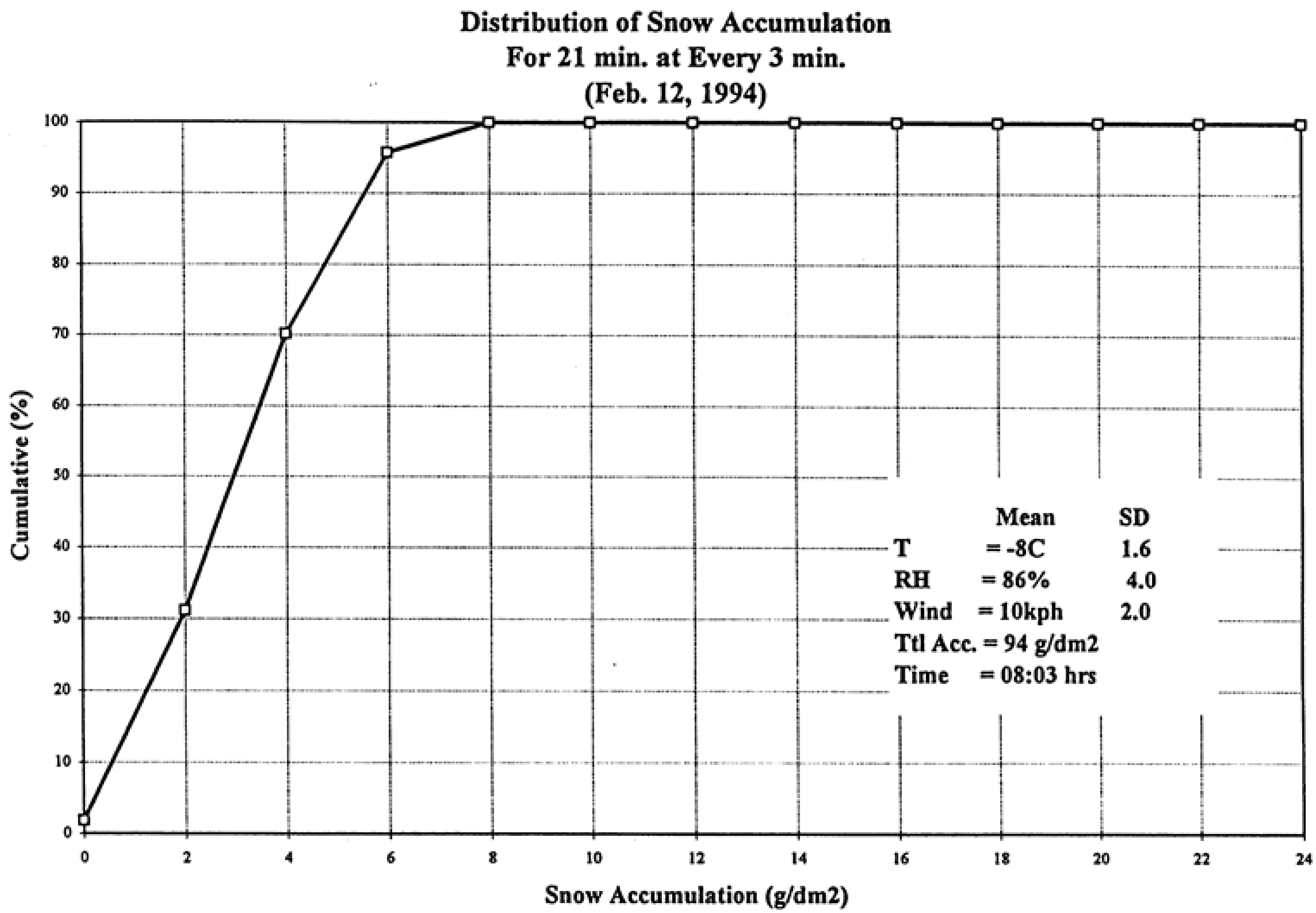
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 04, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -13C 0.4
RH = 88% 3.0
Wind = 42kph 3.6
Ttl Acc. = 222 g/dm2
Time = 11:30 hrs

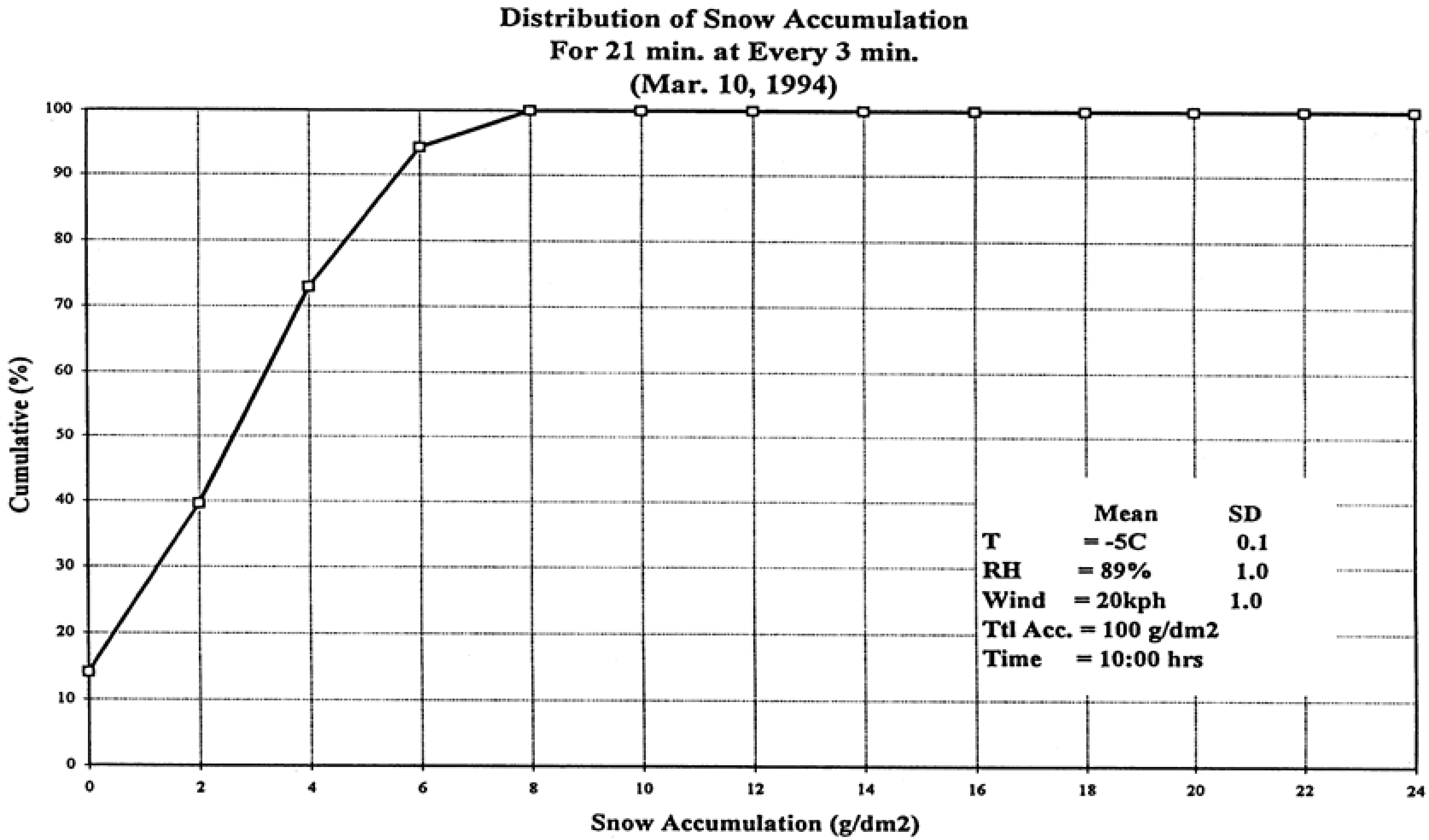

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 08, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -18C 0.4
RH = 73% 1.8
Wind = 22kph 3.2
Ttl Acc. = 62 g/dm2
Time = 8:36 hrs


Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 14, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean
SD
T = -10C 1.2
RH = 86% 1.2
Wind = 15kph 5.4
Ttl Acc. = 30 g/dm2
Time = 10:30 hrs

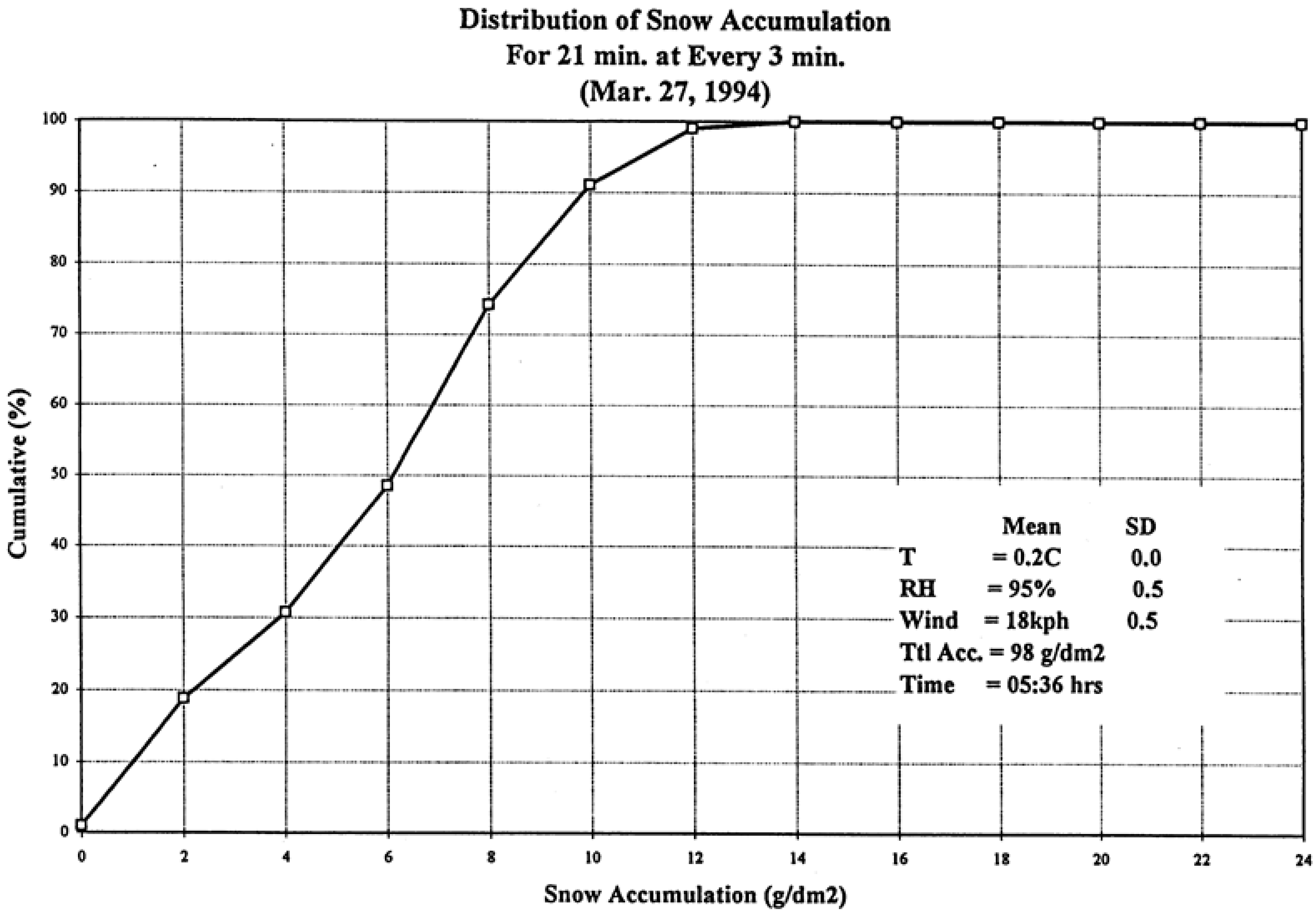

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 23, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -16C 0.6
RH = 73% 1.5
Wind = 22kph 1.4
Ttl Acc. = 48 g/dm2
Time = 08:51 hrs

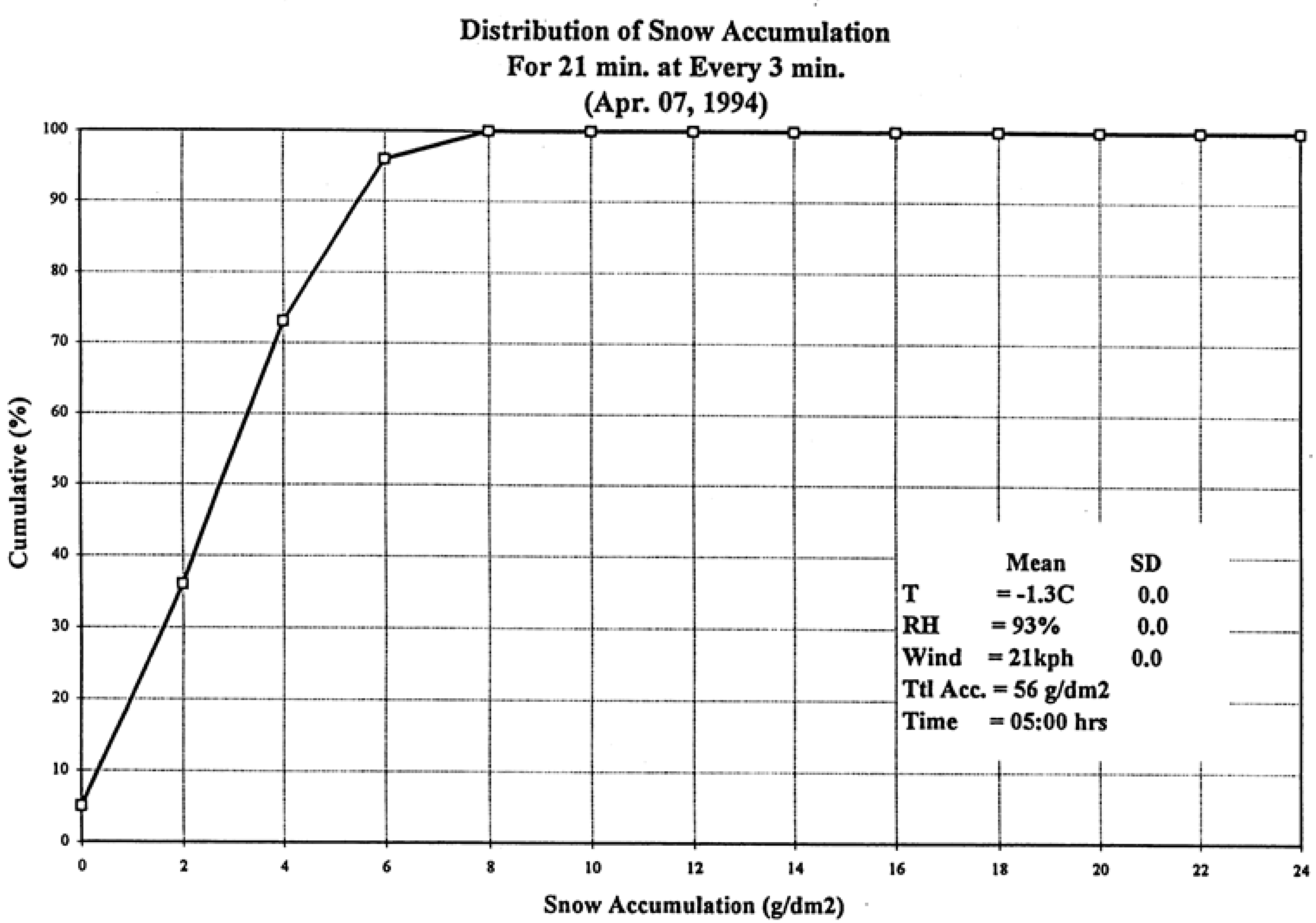

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 27, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -9C 0.1
RH = 89% 0.5
Wind = 26kph 1.0
Ttl Acc. = 194 g/dm2
Time = 11:40 hrs

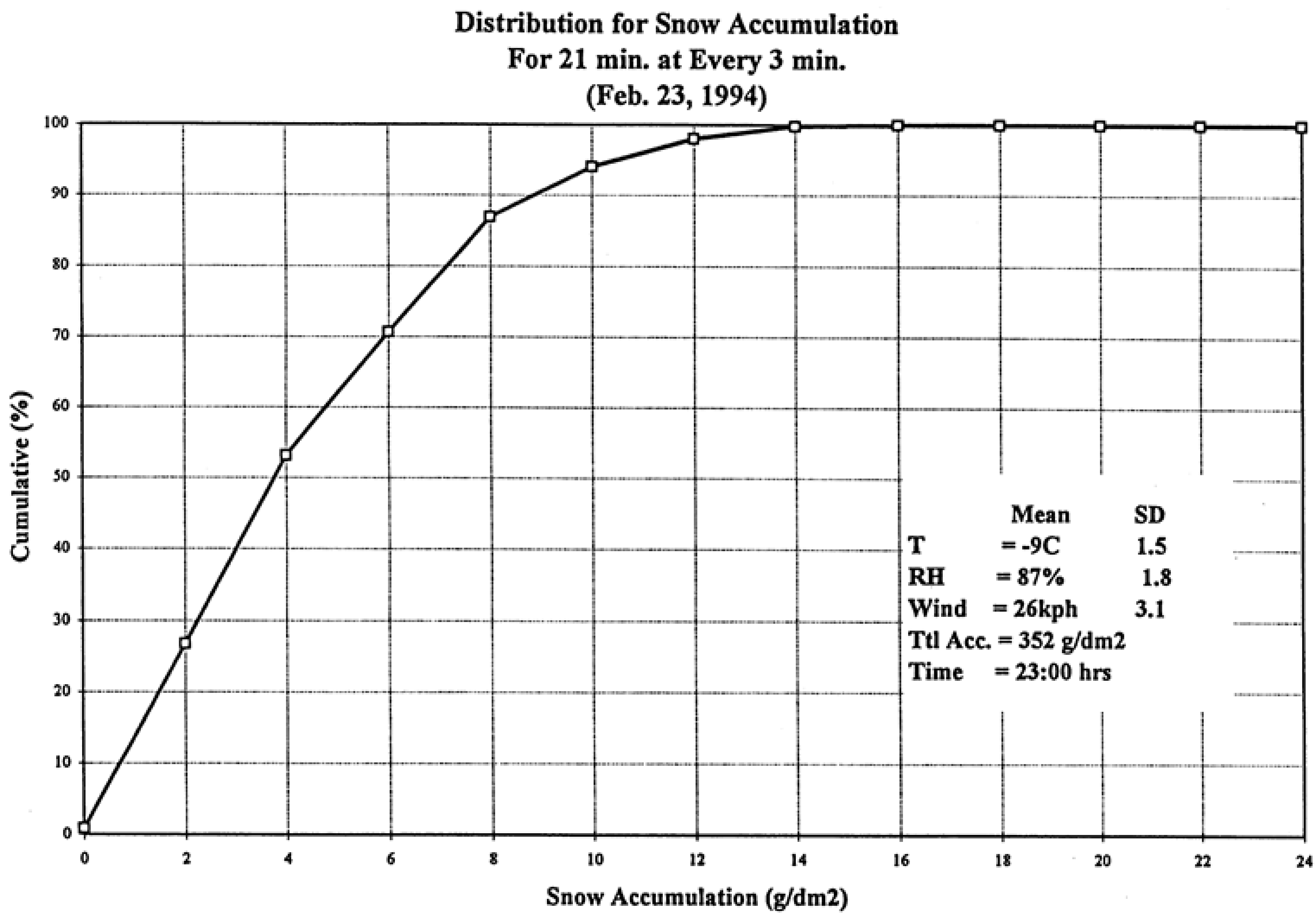

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 12, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -8C 1.6
RH = 86% 4.0
Wind = 10kph 2.0
Ttl Acc. = 94 g/dm2
Time = 08:03 hrs

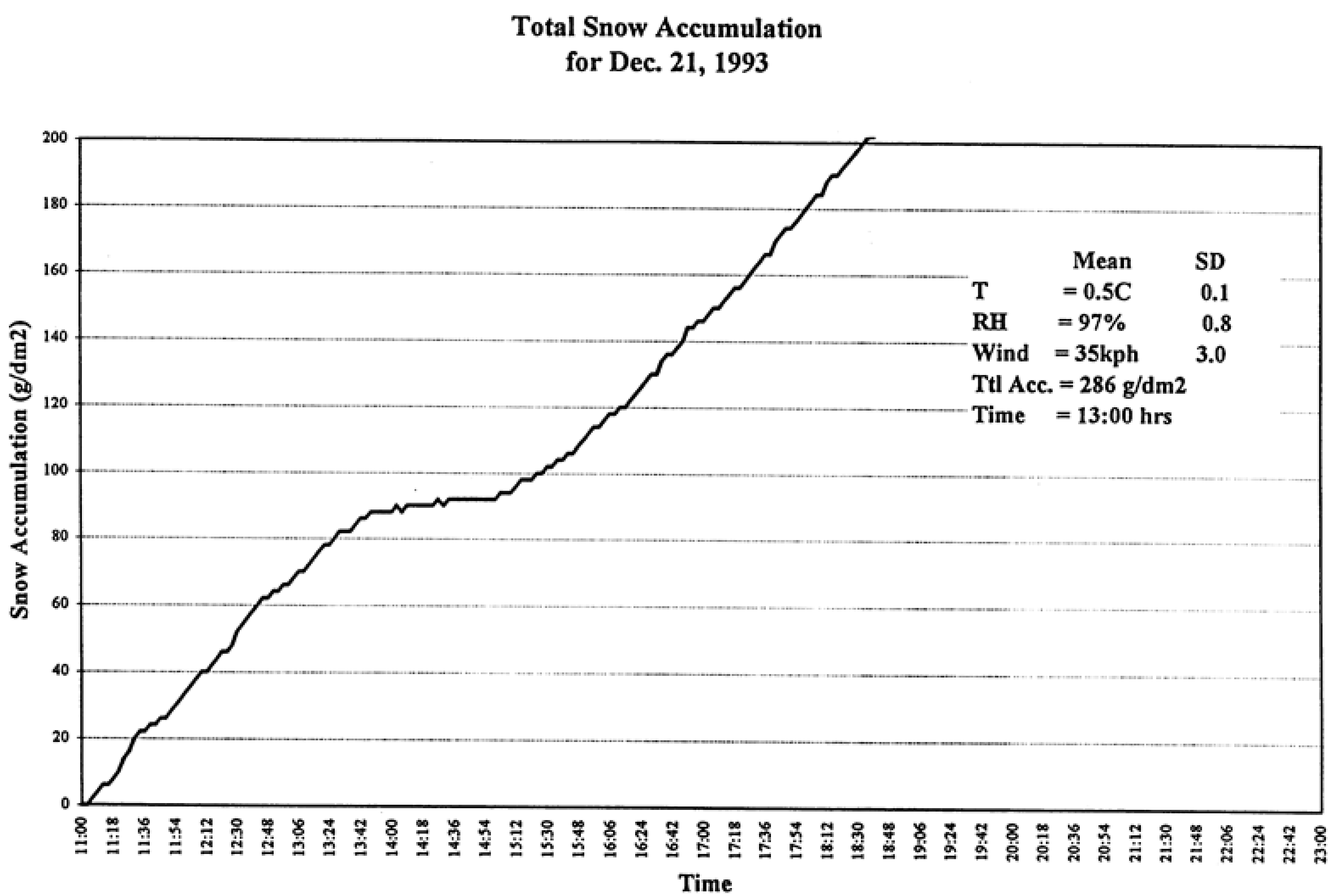


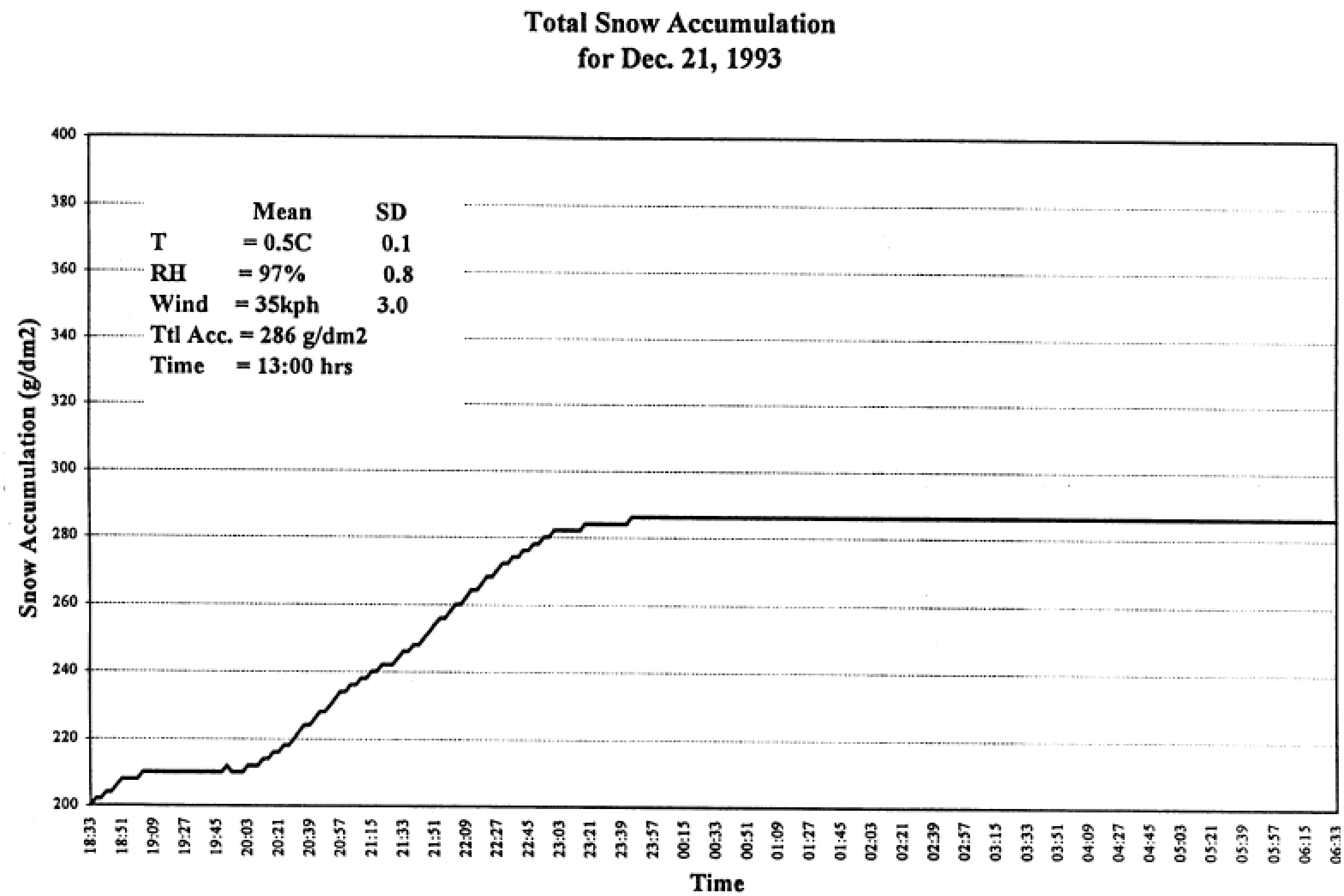
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Mar. 10, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -5C 0.1
RH = 89% 1.0
Wind = 20kph 1.0
Ttl Acc. = 100 g/dm2
Time = 10:00 hrs


Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Mar. 27, 1994)
Cumulative (%)
Snow Accumulation (g/dm2)
0
10
20
30
40
50
60
70
80
90
100
2
4
6
8
10
12
14
16
18
20
22
24
Mean SD
T = 0.2C 0.0
RH = 95% 0.5
Wind = 18kph 0.5
Ttl Acc. = 98 g/dm2
Time = 05:36 hrs

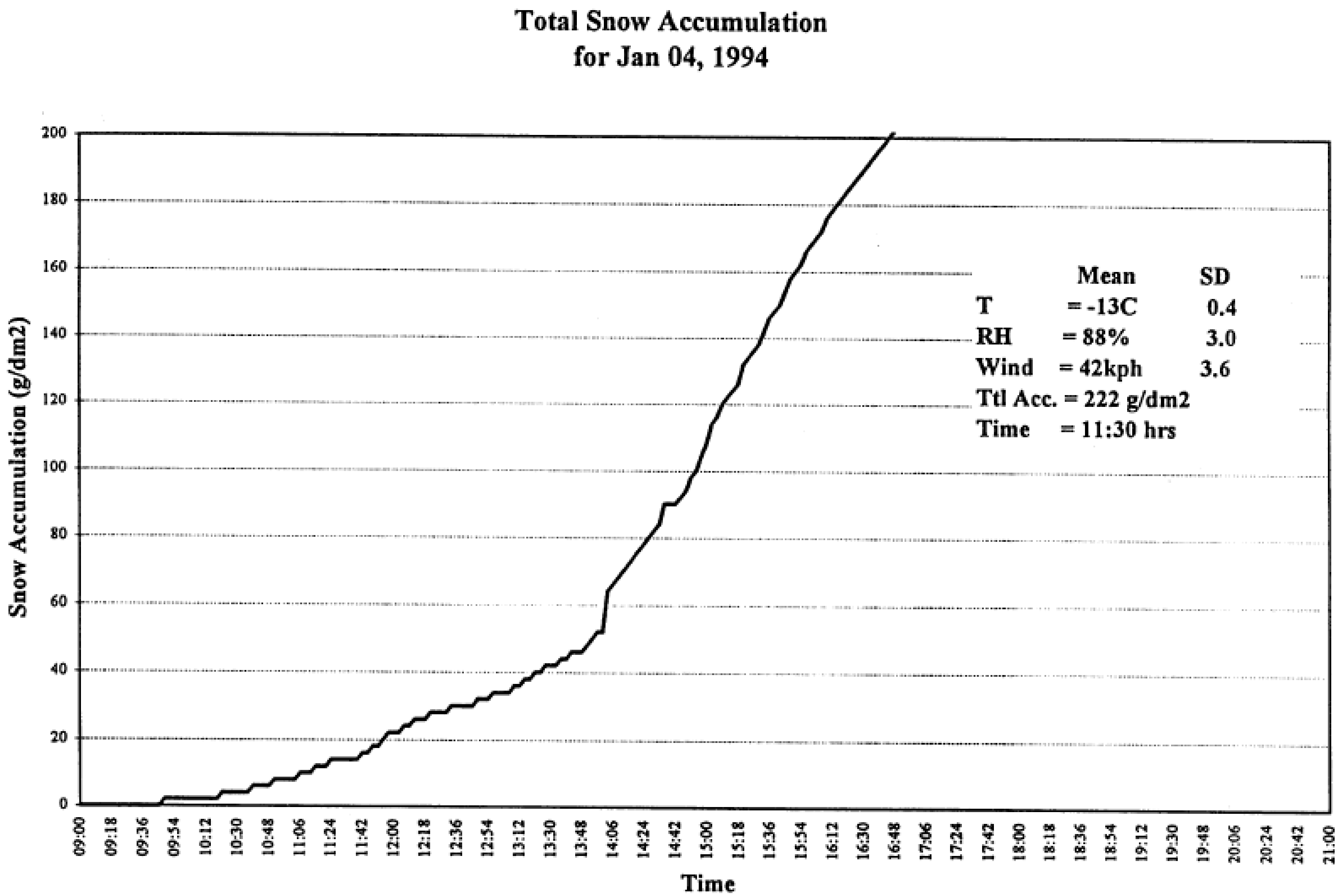

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Apr. 07, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean
SD
T = -1.3C 0.0
RH = 93% 0.0
Wind = 21kph 0.0
Ttl Acc. = 56 g/dm2
Time = 05:00 hrs

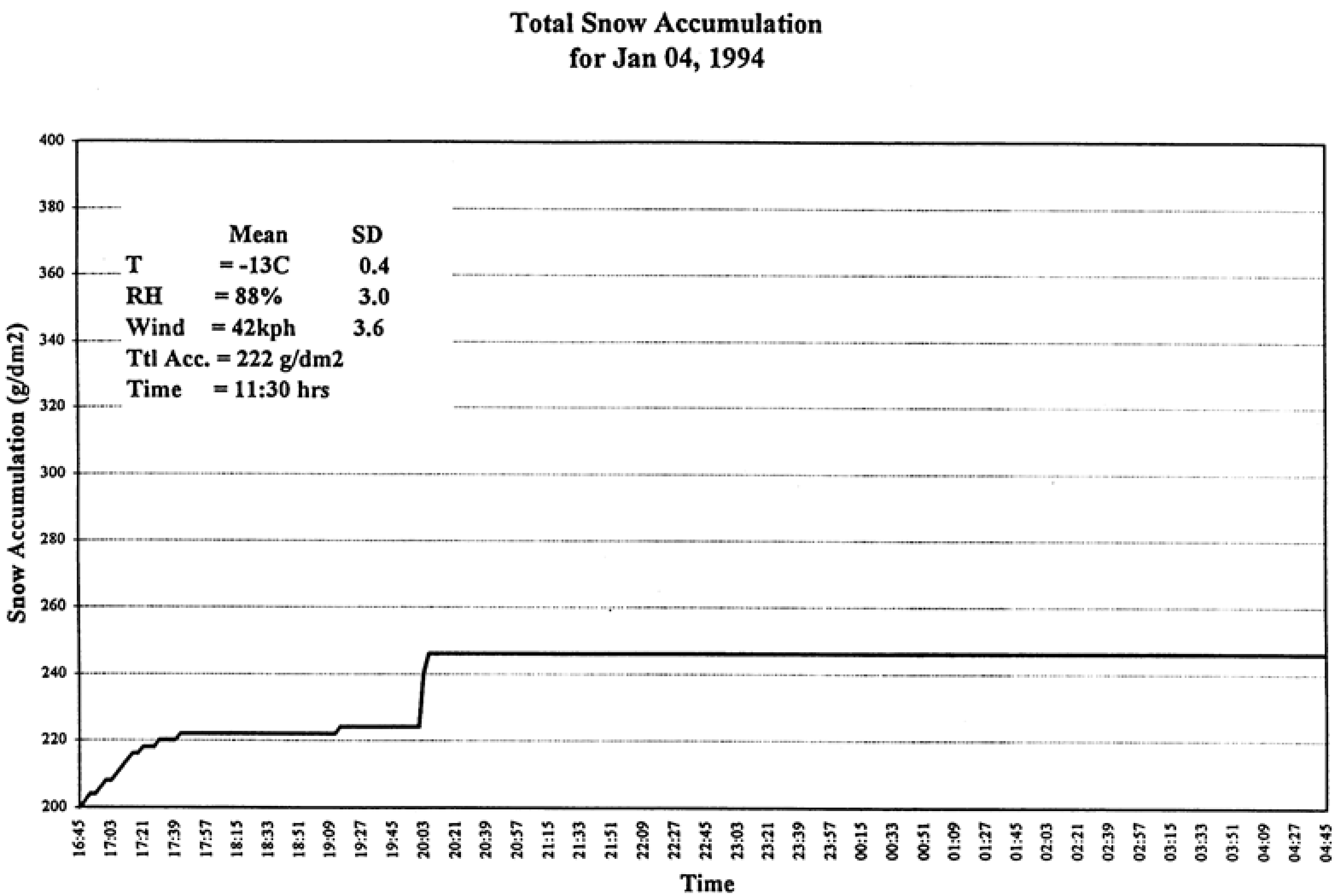

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 23, 1994)
Cumulative (%)
Snow Accumulation (g/dm2)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
Mean
SD
T = -9C
1.5
RH = 87%
1.8
Wind = 26kph
3.1
Ttl Acc. = 352 g/dm2
Time = 23:00 hrs


Total Snow Accumulation
for Dec. 21, 1993
Snow Accumulation (g/dm2)
200
180
160
140
120
100
80
60
40
20
0
Mean SD
T = 0.5C 0.1
RH = 97% 0.8
Wind = 35kph 3.0
Ttl Acc. = 286 g/dm2
Time = 13:00 hrs
11:00
11:18
11:36
11:54
12:12
12:30
12:48
13:06
13:24
13:42
14:00
14:18
14:36
14:54
15:12
15:30
15:48
16:06
16:24
16:42
17:00
17:18
17:36
17:54
18:12
18:30
18:48
19:06
19:24
19:42
20:00
20:18
20:36
20:54
21:12
21:30
21:48
22:06
22:24
22:42
23:00
Time

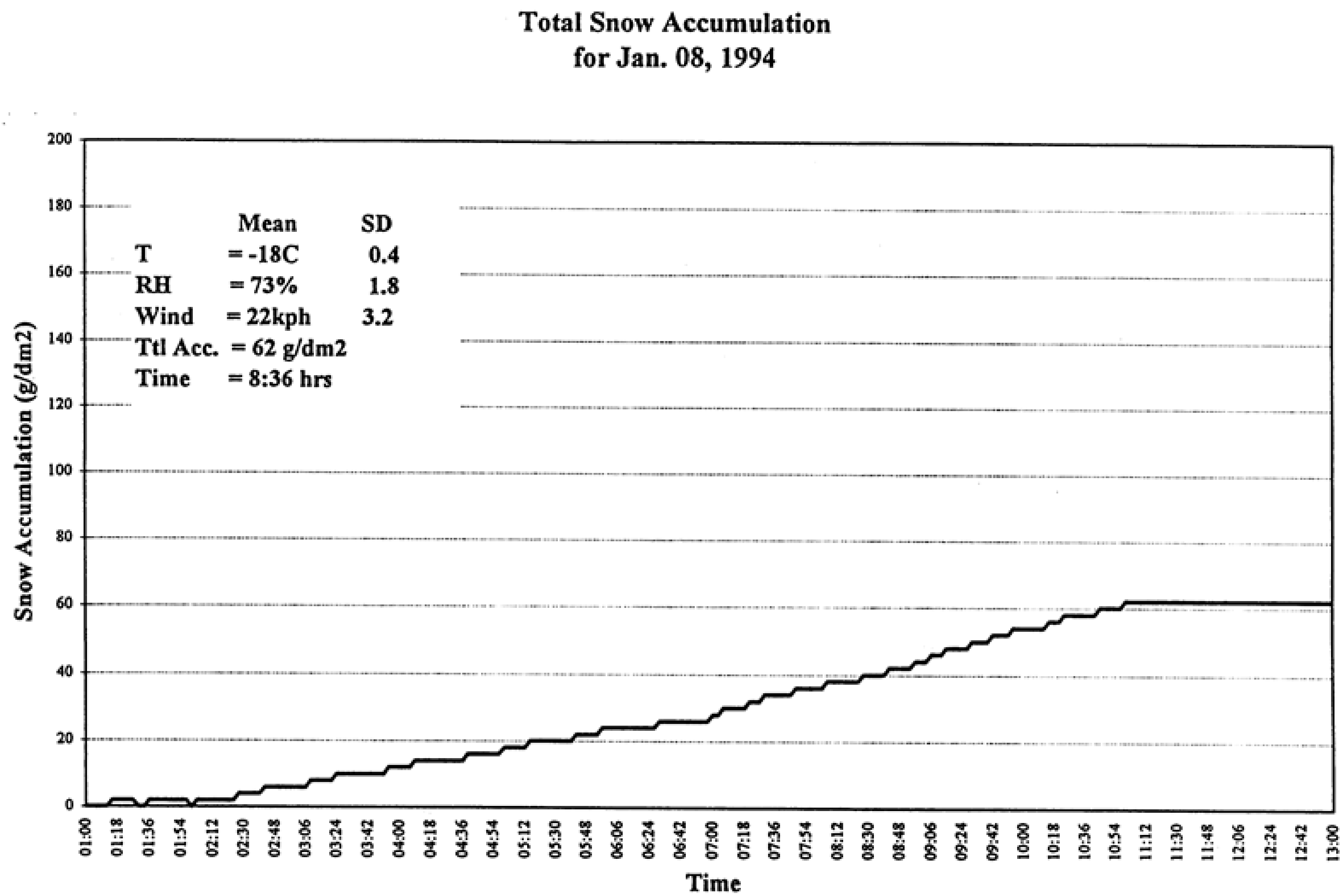


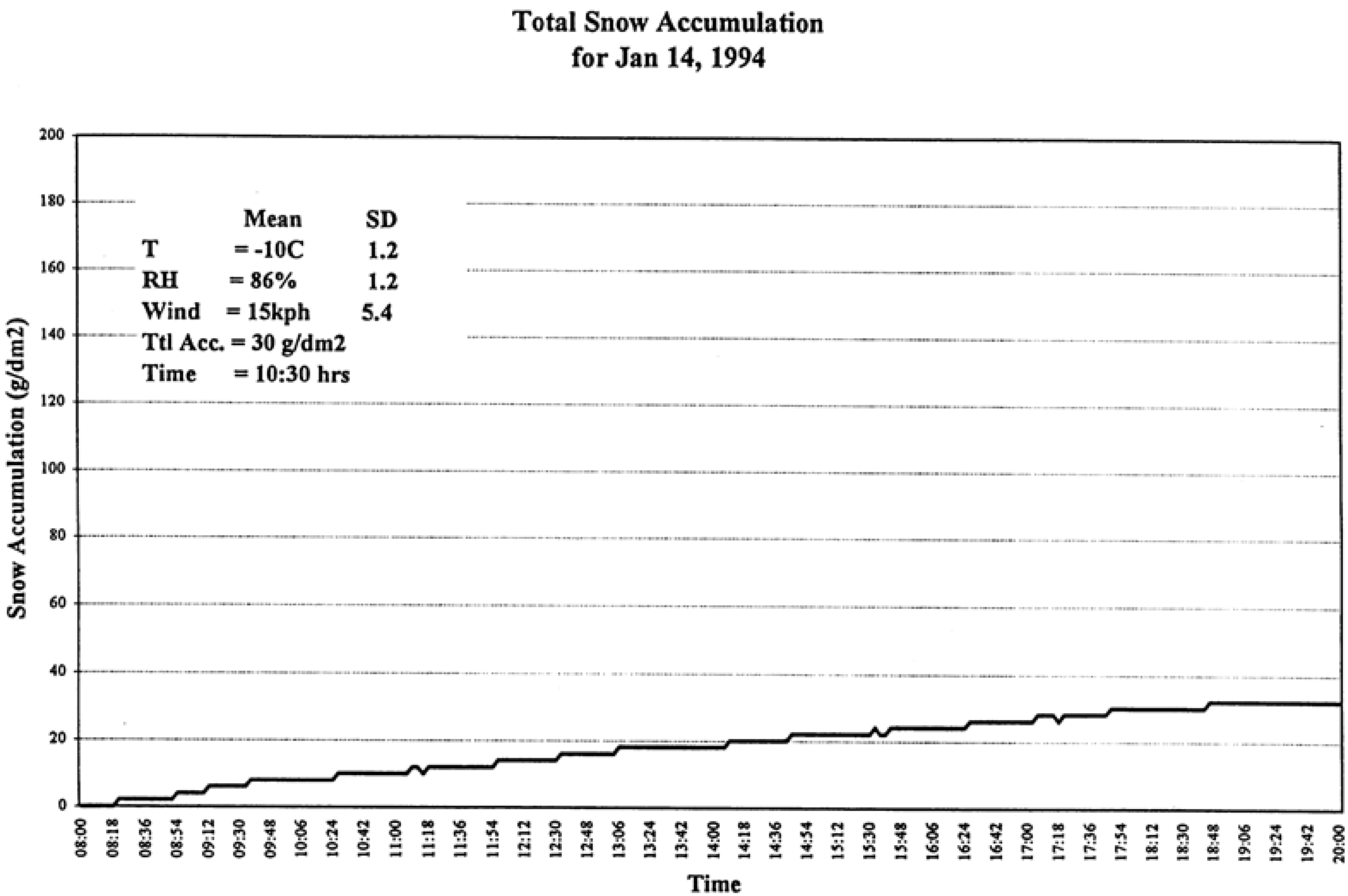
Total Snow Accumulation
for Dec. 21, 1993
Mean SD
T = 0.5C 0.1
RH = 97% 0.8
Wind = 35kph 3.0
Ttl Acc. = 286 g/dm2
Time = 13:00 hrs
Snow Accumulation (g/dm2)
400
380
360
340
320
300
280
260
240
220
200
18:33
18:51
19:09
19:27
19:45
20:03
20:21
20:39
20:57
21:15
21:33
21:51
22:09
22:27
22:45
23:03
23:21
23:39
23:57
00:15
00:33
00:51
01:09
01:27
01:45
02:03
02:21
02:39
02:57
03:15
03:33
03:51
04:09
04:27
04:45
05:03
05:21
05:39
05:57
06:15
06:33
Time

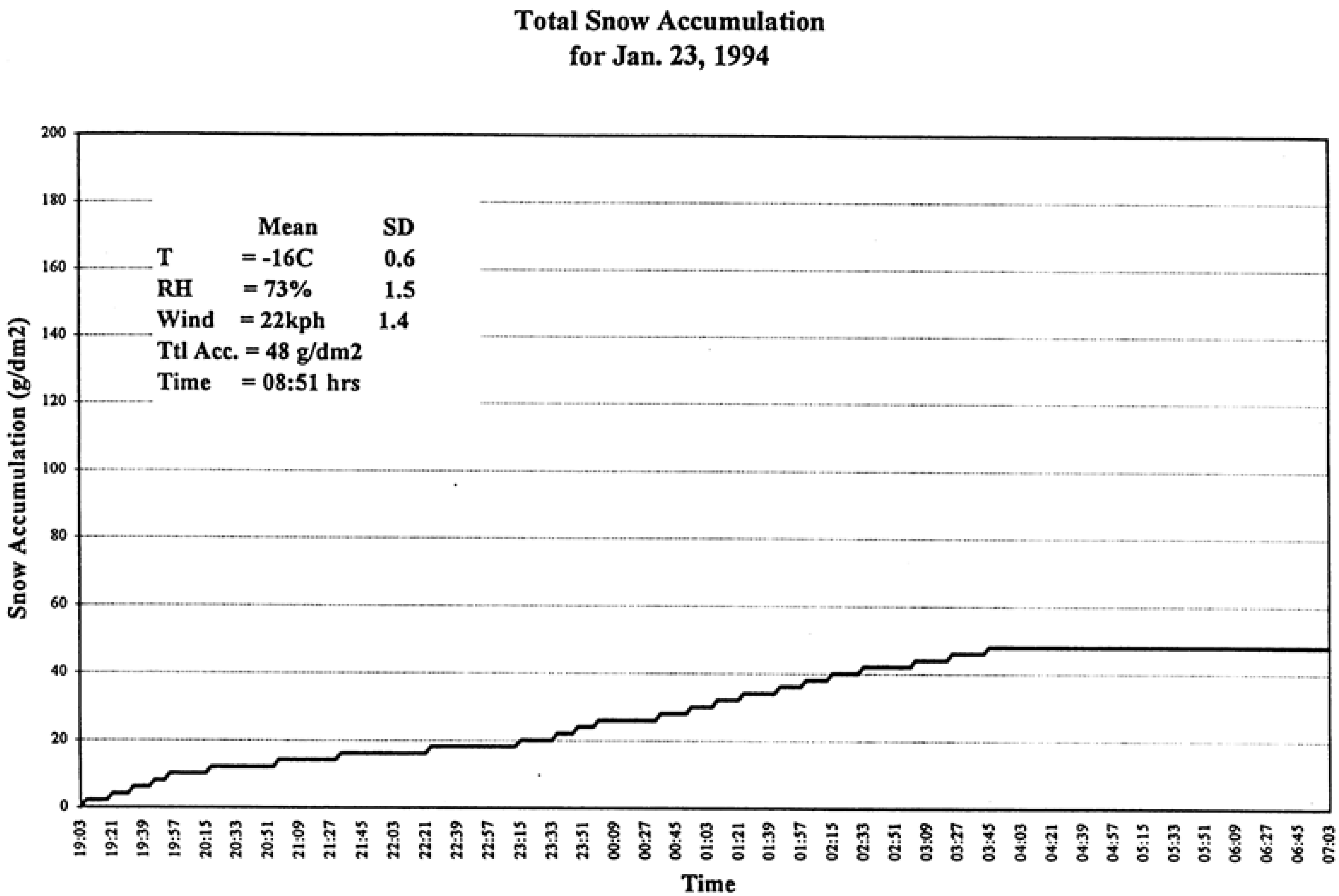

Total Snow Accumulation
for Jan 04, 1994
Snow Accumulation (g/dm2)
200
180
160
140
120
100
80
60
40
20
0
Mean SD
T = -13C 0.4
RH = 88% 3.0
Wind = 42kph 3.6
Ttl Acc. = 222 g/dm2
Time = 11:30 hrs
09:00 09:18 09:36 09:54 10:12 10:30 10:48 11:06 11:24 11:42 12:00 12:18 12:36 12:54 13:12 13:30 13:48 14:06 14:24 14:42 15:00 15:18 15:36 15:54 16:12 16:30 16:48 17:06 17:24 17:42 18:00 18:18 18:36 18:54 19:12 19:30 19:48 20:06 20:24 20:42 21:00
Time

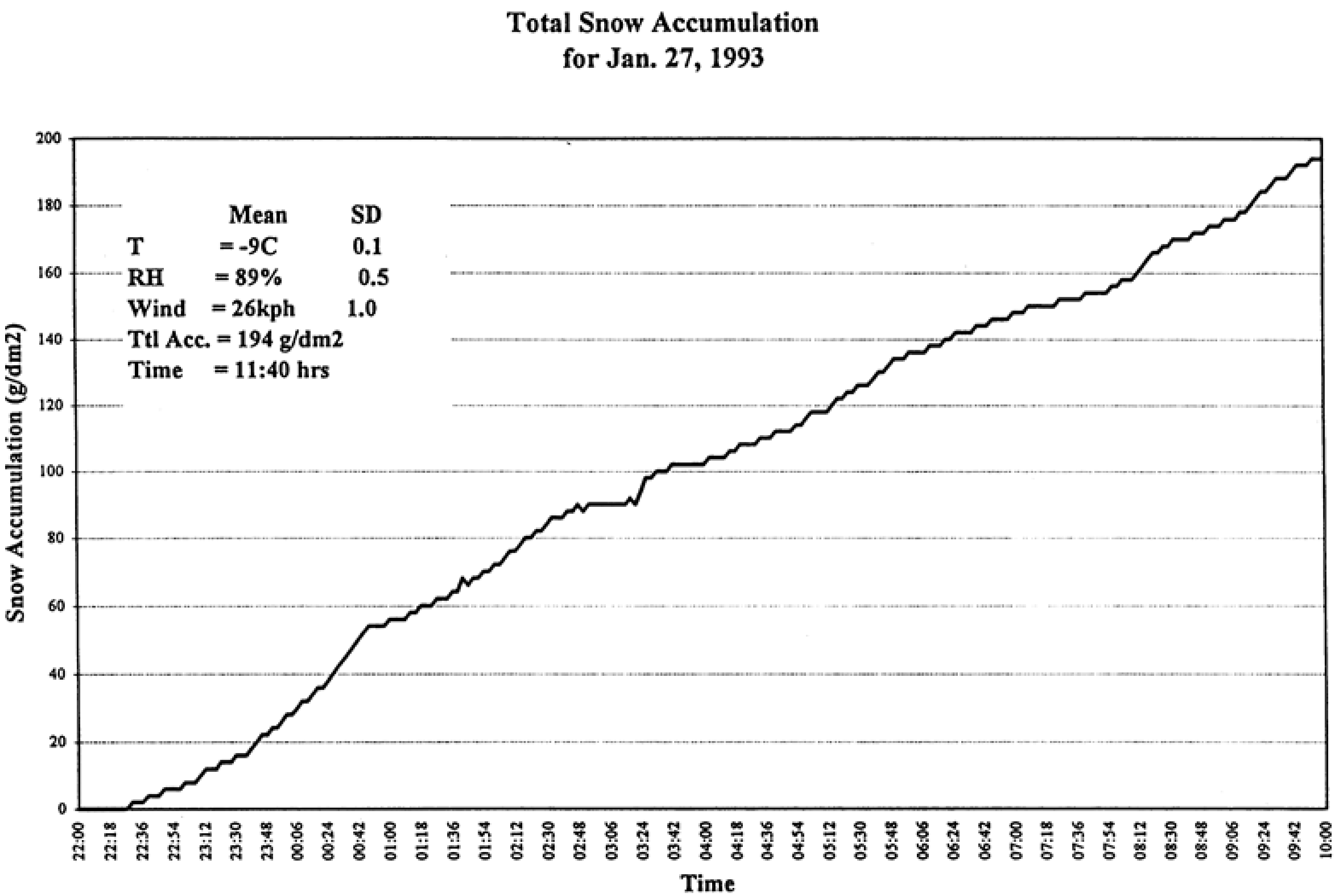


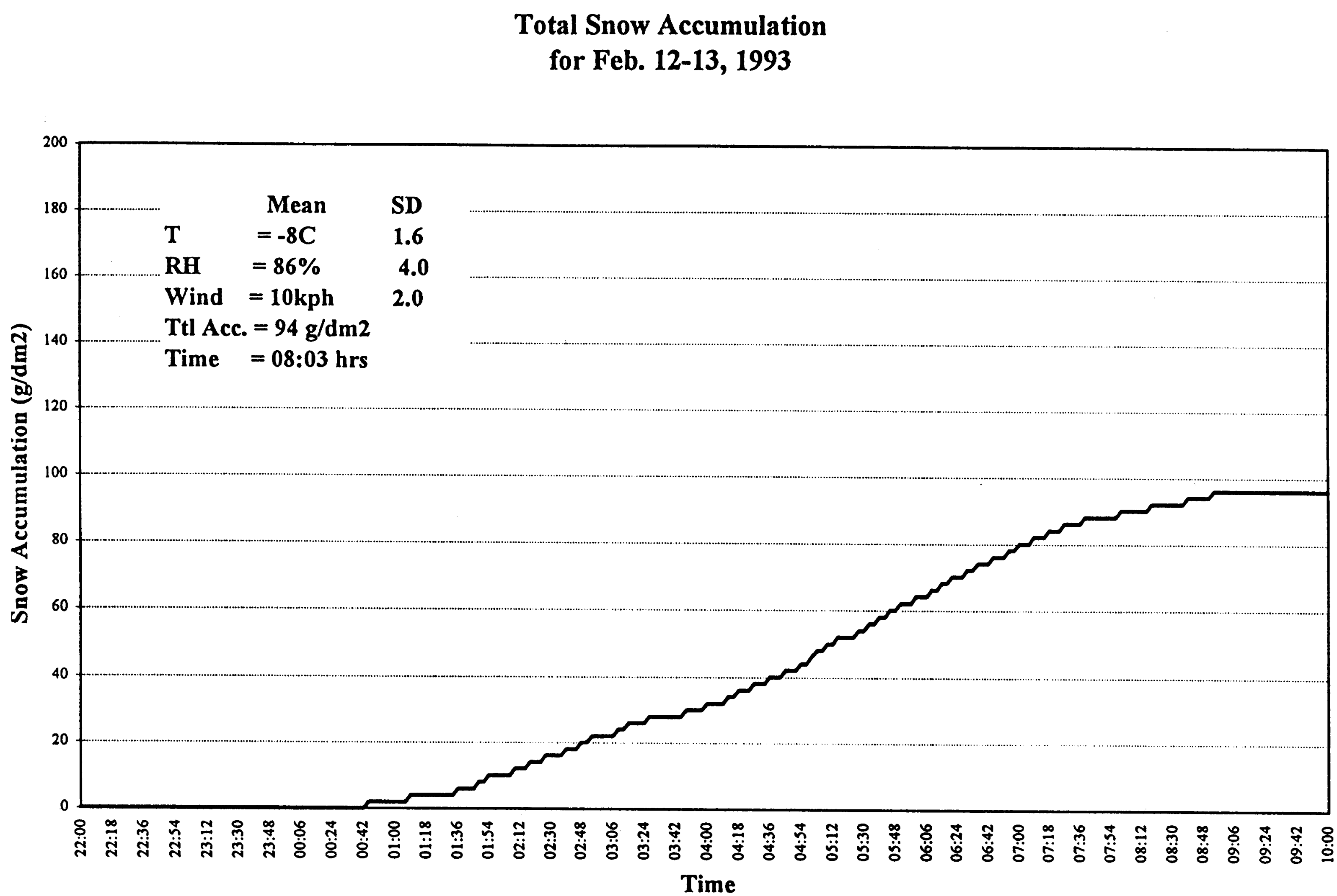
Total Snow Accumulation
for Jan 04, 1994
Mean SD
T = -13C 0.4
RH = 88% 3.0
Wind = 42kph 3.6
Ttl Acc. = 222 g/dm2
Time = 11:30 hrs
Snow Accumulation (g/dm2)
400
380
360
340
320
300
280
260
240
220
200
16:45
17:03
17:21
17:39
17:57
18:15
18:33
18:51
19:09
19:27
19:45
20:03
20:21
20:39
20:57
21:15
21:33
21:51
22:09
22:27
22:45
23:03
23:21
23:39
23:57
00:15
00:33
00:51
01:09
01:27
01:45
02:03
02:21
02:39
02:57
03:15
03:33
03:51
04:09
04:27
04:45
Time

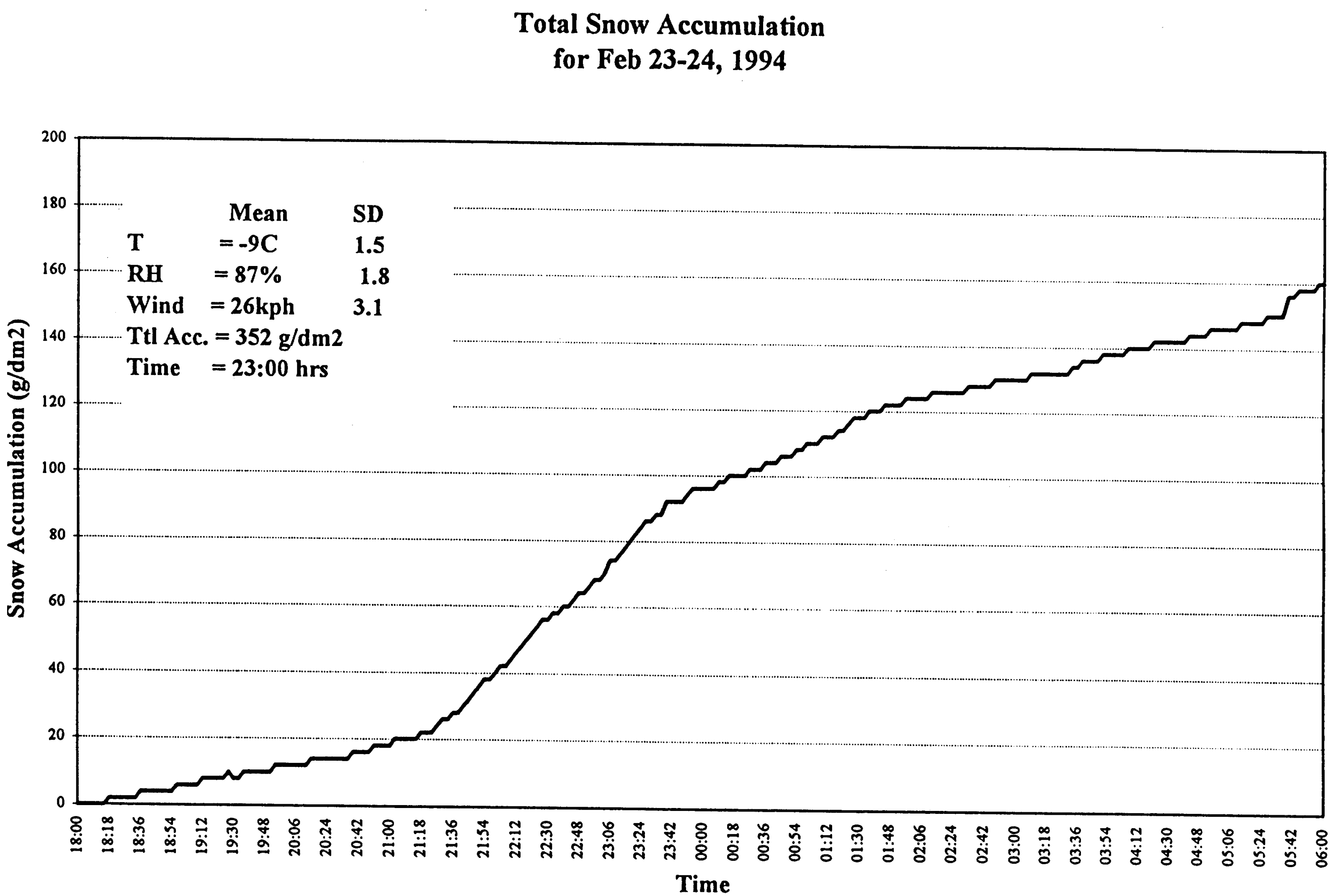

Total Snow Accumulation
for Jan. 08, 1994
Mean SD
T = -18C 0.4
RH = 73% 1.8
Wind = 22kph 3.2
Ttl Acc. = 62 g/dm2
Time = 8:36 hrs
Snow Accumulation (g/dm2)
0
20
40
60
80
100
120
140
160
180
200
01:00
01:18
01:36
01:54
02:12
02:30
02:48
03:06
03:24
03:42
04:00
04:18
04:36
04:54
05:12
05:30
05:48
06:06
06:24
06:42
07:00
07:18
07:36
07:54
08:12
08:30
08:48
09:06
09:24
09:42
10:00
10:18
10:36
10:54
11:12
11:30
11:48
12:06
12:24
12:42
13:00
Time

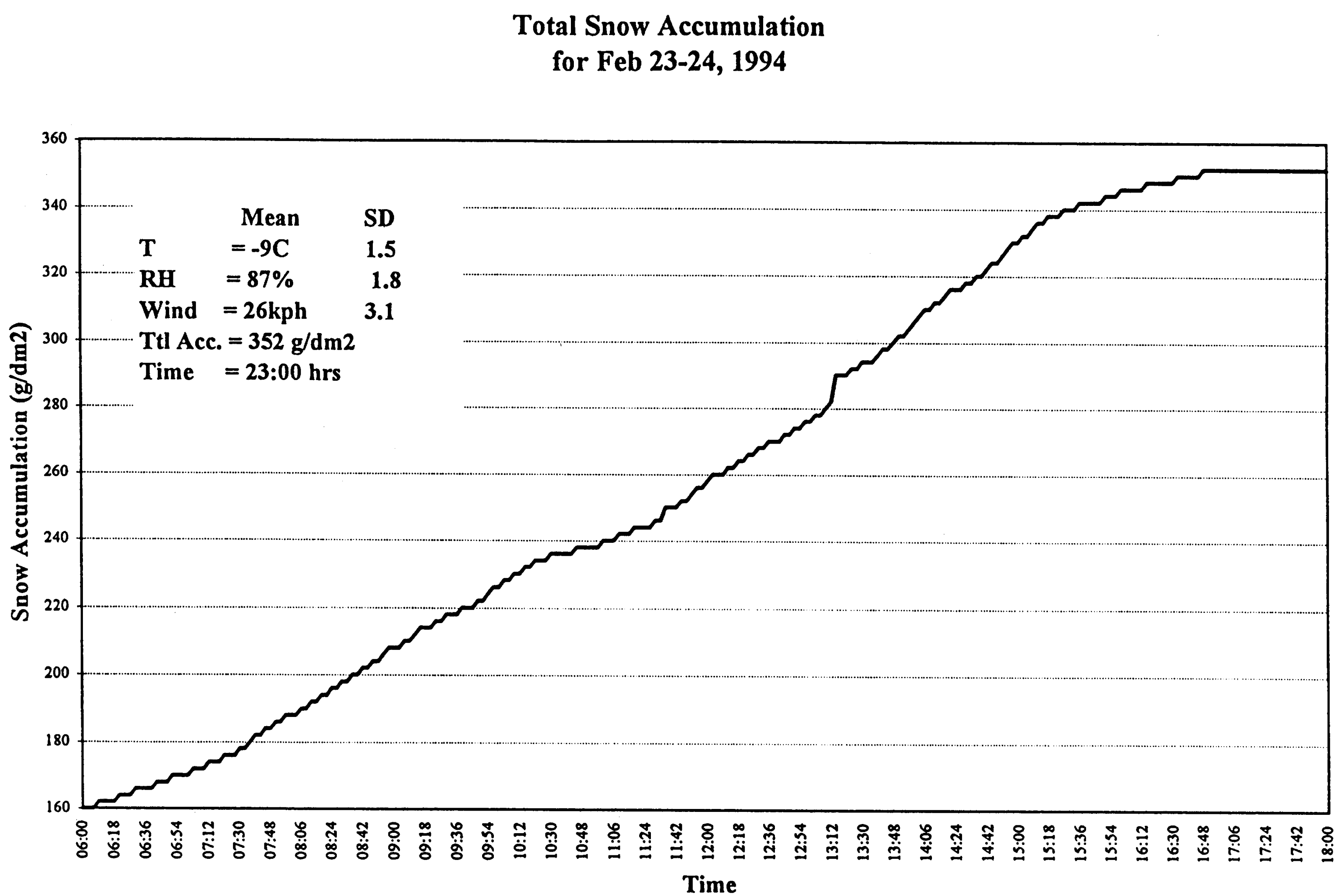

Total Snow Accumulation
for Jan 14, 1994
Mean SD
T = -10C 1.2
RH = 86% 1.2
Wind = 15kph 5.4
Ttl Acc. = 30 g/dm2
Time = 10:30 hrs
Snow Accumulation (g/dm2)
Time
200
180
160
140
120
100
80
60
40
20
0
08:00
08:18
08:36
08:54
09:12
09:30
09:48
10:06
10:24
10:42
11:00
11:18
11:36
11:54
12:12
12:30
12:48
13:06
13:24
13:42
14:00
14:18
14:36
14:54
15:12
15:30
15:48
16:06
16:24
16:42
17:00
17:18
17:36
17:54
18:12
18:30
18:48
19:06
19:24
19:42
20:00

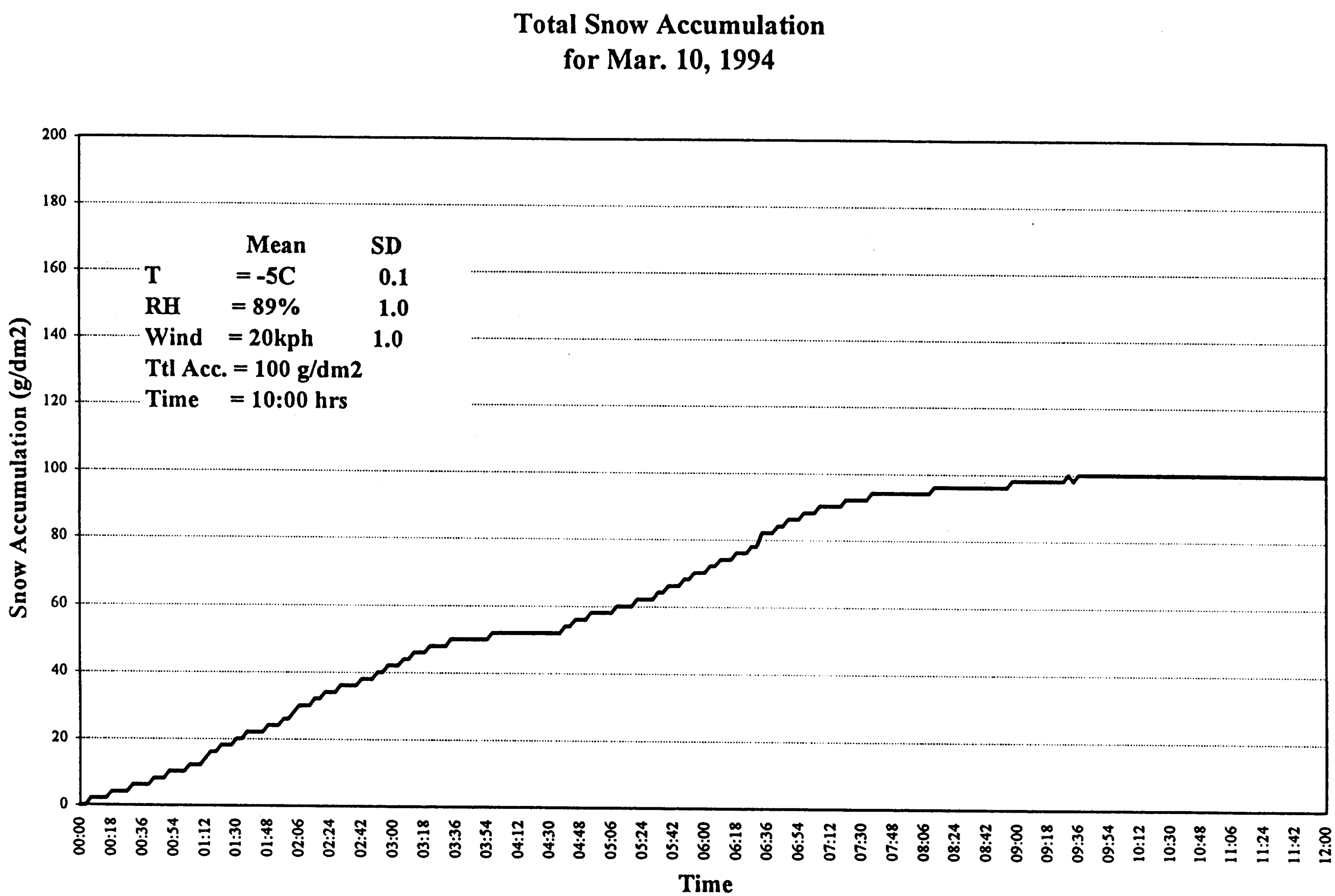

Total Snow Accumulation
for Jan. 23, 1994
Mean SD
T = -16C 0.6
RH = 73% 1.5
Wind = 22kph 1.4
Ttl Acc. = 48 g/dm2
Time = 08:51 hrs
Snow Accumulation (g/dm2)
0
20
40
60
80
100
120
140
160
180
200
19:03
19:21
19:39
19:57
20:15
20:33
20:51
21:09
21:27
21:45
22:03
22:21
22:39
22:57
23:15
23:33
23:51
00:09
00:27
00:45
01:03
01:21
01:39
01:57
02:15
02:33
02:51
03:09
03:27
03:45
04:03
04:21
04:39
04:57
05:15
05:33
05:51
06:09
06:27
06:45
07:03
Time

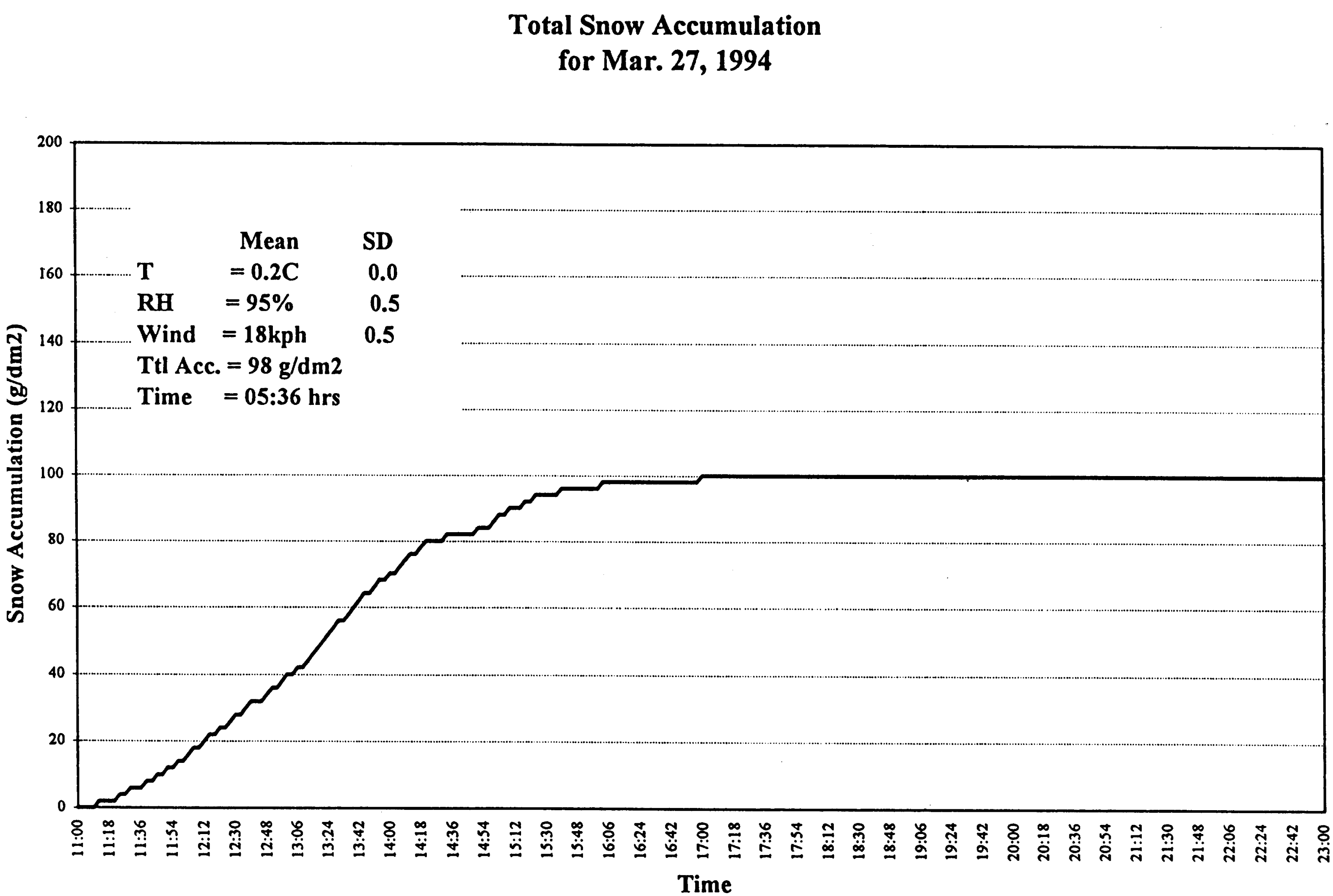

Total Snow Accumulation
for Jan. 27, 1993
Mean SD
T = -9C 0.1
RH = 89% 0.5
Wind = 26kph 1.0
Ttl Acc. = 194 g/dm2
Time = 11:40 hrs
Snow Accumulation (g/dm2)
0
20
40
60
80
100
120
140
160
180
200
22:00
22:18
22:36
22:54
23:12
23:30
23:48
00:06
00:24
00:42
01:00
01:18
01:36
01:54
02:12
02:30
02:48
03:06
03:24
03:42
04:00
04:18
04:36
04:54
05:12
05:30
05:48
06:06
06:24
06:42
07:00
07:18
07:36
07:54
08:12
08:30
08:48
09:06
09:24
09:42
10:00
Time

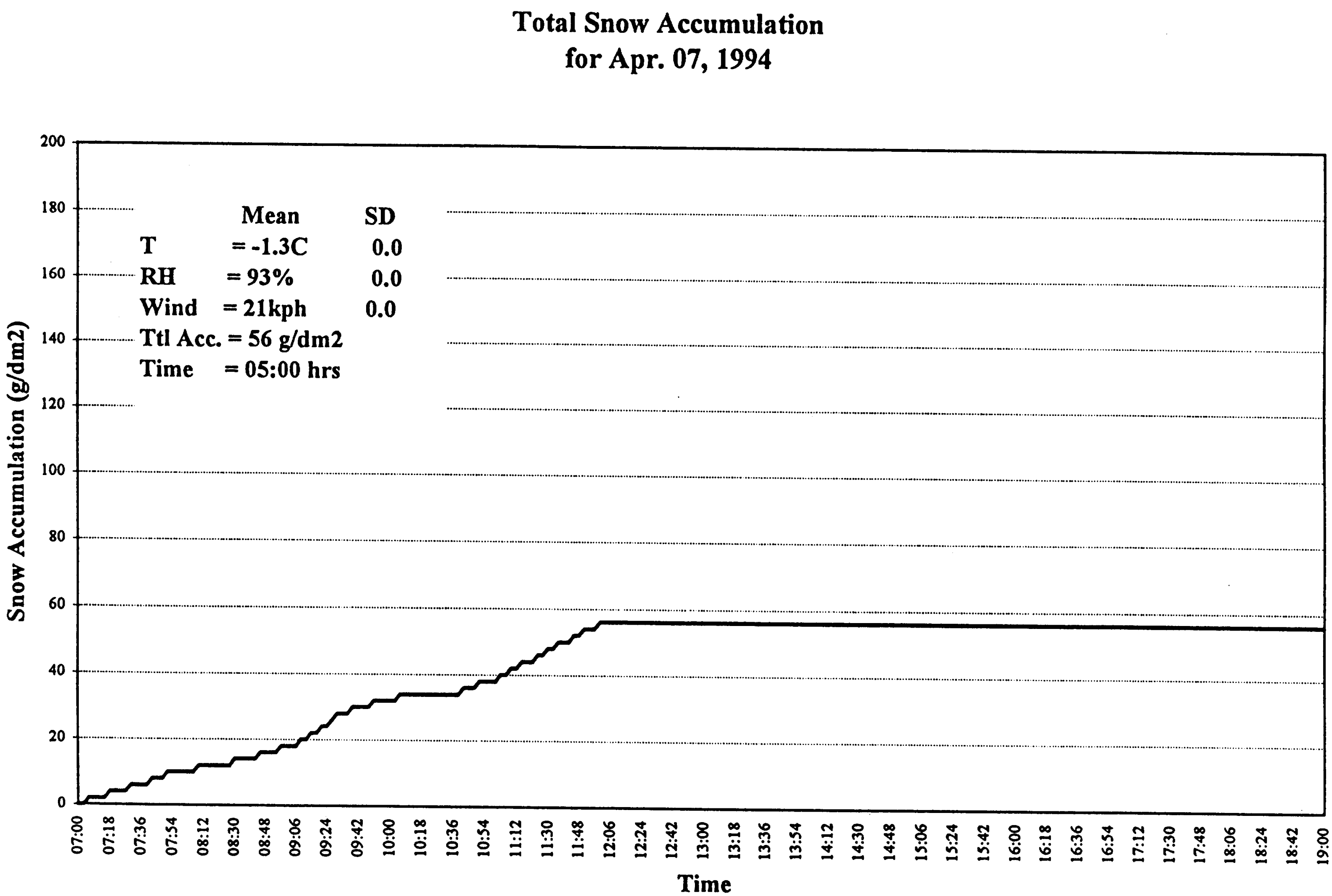

Total Snow Accumulation
for Feb. 12-13, 1993
Mean SD
T = -8C 1.6
RH = 86% 4.0
Wind = 10kph 2.0
Ttl Acc. = 94 g/dm2
Time = 08:03 hrs
Snow Accumulation (g/dm2)
Time
0
20
40
60
80
100
120
140
160
180
200
22:00
22:18
22:36
22:54
23:12
23:30
23:48
00:06
00:24
00:42
01:00
01:18
01:36
01:54
02:12
02:30
02:48
03:06
03:24
03:42
04:00
04:18
04:36
04:54
05:12
05:30
05:48
06:06
06:24
06:42
07:00
07:18
07:36
07:54
08:12
08:30
08:48
09:06
09:24
09:42
10:00


Total Snow Accumulation
for Feb 23-24, 1994
Mean SD
T = -9C 1.5
RH = 87% 1.8
Wind = 26kph 3.1
Ttl Acc. = 352 g/dm2
Time = 23:00 hrs
Snow Accumulation (g/dm2)
0
20
40
60
80
100
120
140
160
180
200
Time
18:00
18:18
18:36
18:54
19:12
19:30
19:48
20:06
20:24
20:42
21:00
21:18
21:36
21:54
22:12
22:30
22:48
23:06
23:24
23:42
00:00
00:18
00:36
00:54
01:12
01:30
01:48
02:06
02:24
02:42
03:00
03:18
03:36
03:54
04:12
04:30
04:48
05:06
05:24
05:42
06:00

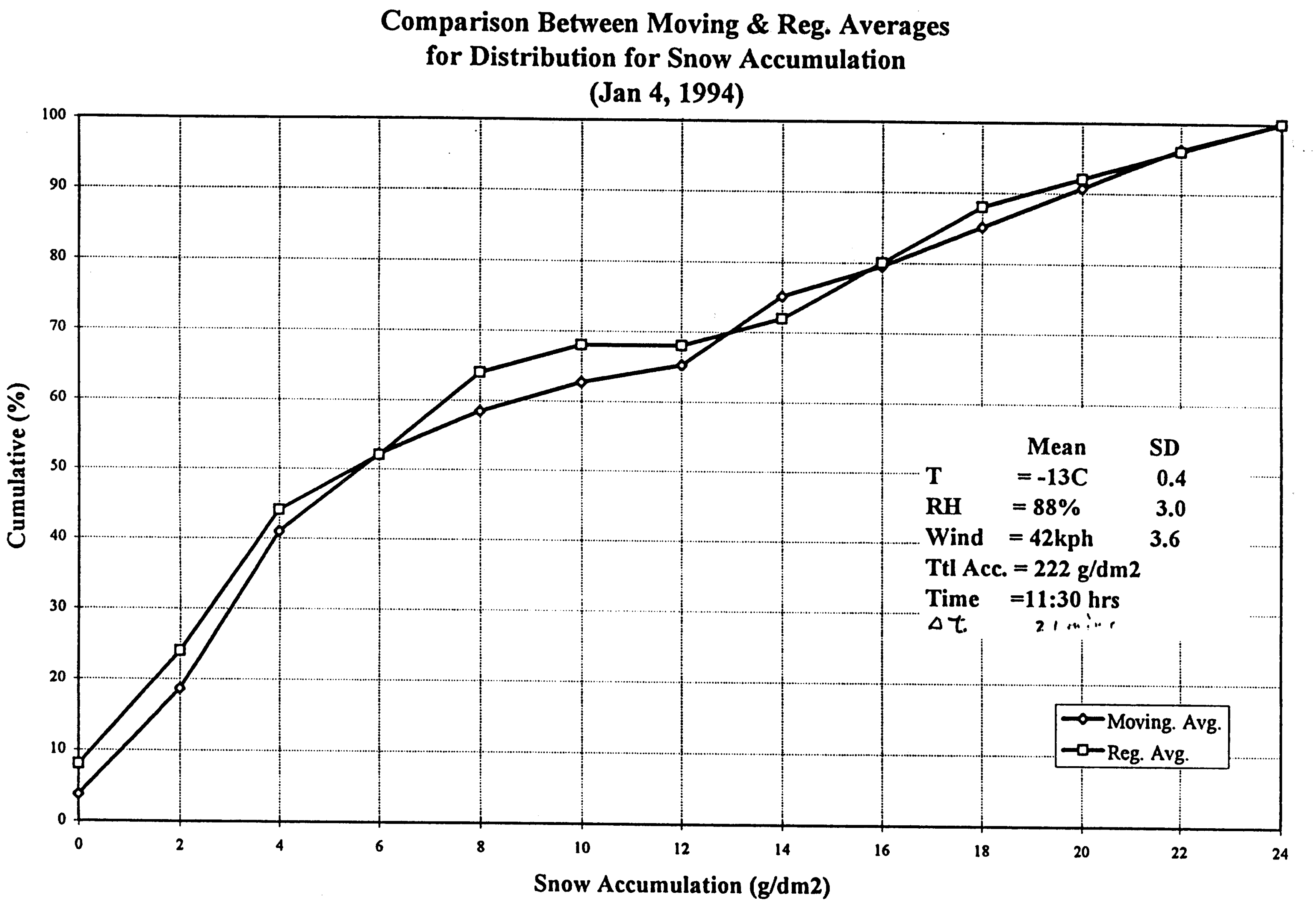

Total Snow Accumulation
for Feb 23-24, 1994
Mean SD
T = -9C 1.5
RH = 87% 1.8
Wind = 26kph 3.1
Ttl Acc. = 352 g/dm2
Time = 23:00 hrs
Snow Accumulation (g/dm2)
360
340
320
300
280
260
240
220
200
180
160
06:00
06:18
06:36
06:54
07:12
07:30
07:48
08:06
08:24
08:42
09:00
09:18
09:36
09:54
10:12
10:30
10:48
11:06
11:24
11:42
12:00
12:18
12:36
12:54
13:12
13:30
13:48
14:06
14:24
14:42
15:00
15:18
15:36
15:54
16:12
16:30
16:48
17:06
17:24
17:42
18:00
Time

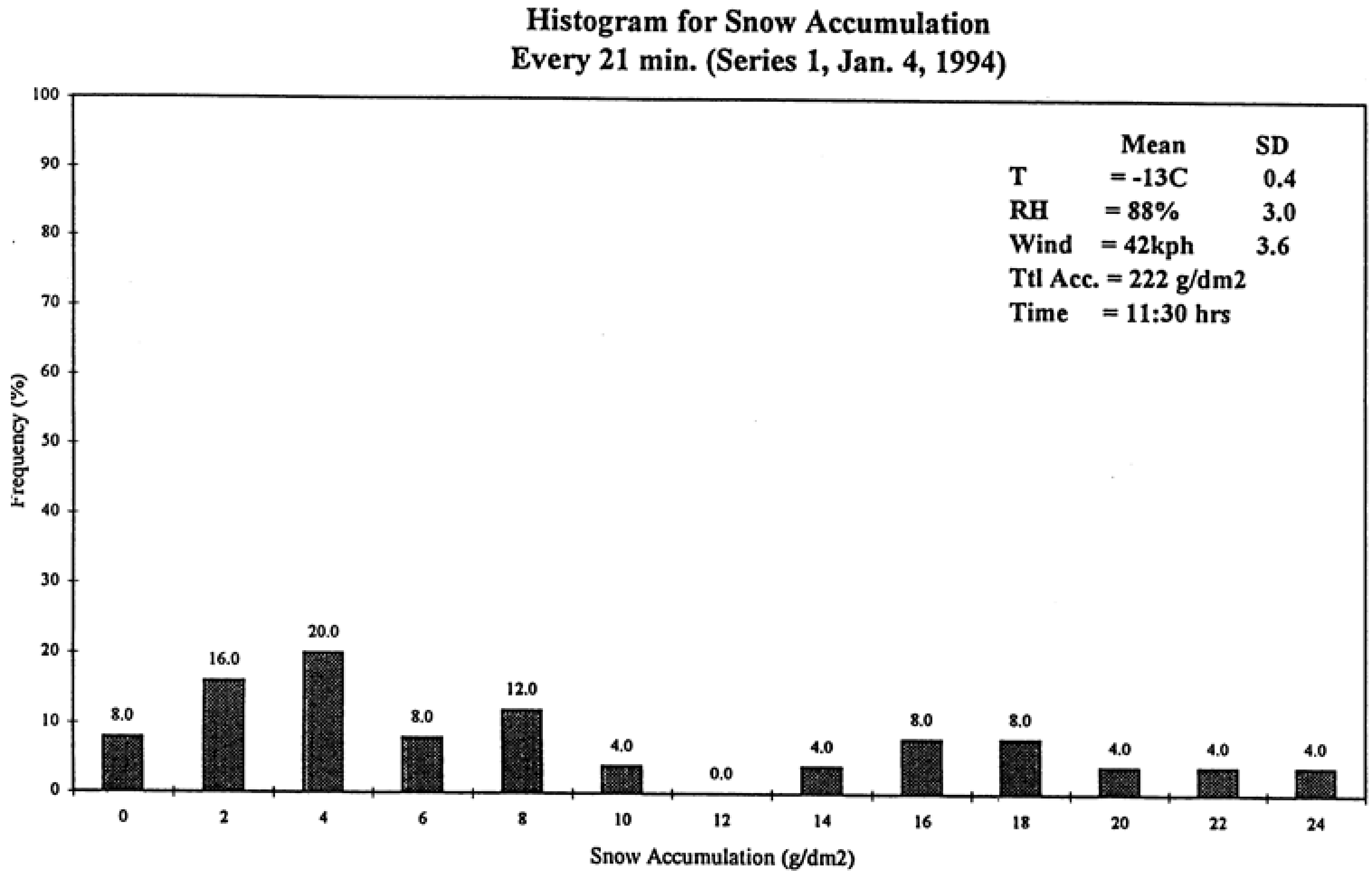

Total Snow Accumulation
for Mar. 10, 1994
Mean SD
T = -5C 0.1
RH = 89% 1.0
Wind = 20kph 1.0
Ttl Acc. = 100 g/dm2
Time = 10:00 hrs
Snow Accumulation (g/dm2)
0
20
40
60
80
100
120
140
160
180
200
Time
00:00
00:18
00:36
00:54
01:12
01:30
01:48
02:06
02:24
02:42
03:00
03:18
03:36
03:54
04:12
04:30
04:48
05:06
05:24
05:42
06:00
06:18
06:36
06:54
07:12
07:30
07:48
08:06
08:24
08:42
09:00
09:18
09:36
09:54
10:12
10:30
10:48
11:06
11:24
11:42
12:00

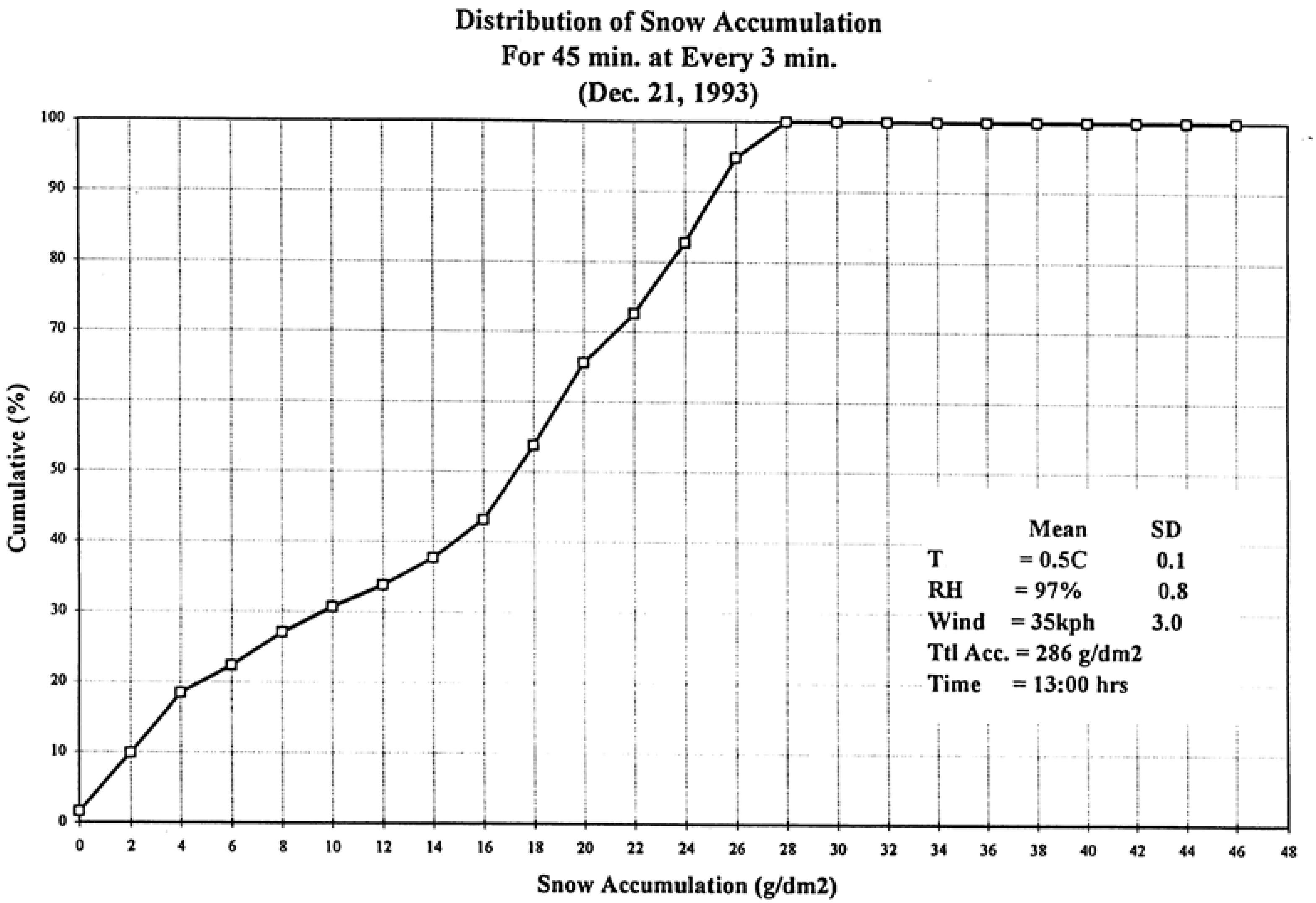

Total Snow Accumulation
for Mar. 27, 1994
Mean SD
T = 0.2C 0.0
RH = 95% 0.5
Wind = 18kph 0.5
Ttl Acc. = 98 g/dm2
Time = 05:36 hrs
Snow Accumulation (g/dm2)
0
20
40
60
80
100
120
140
160
180
200
11:00
11:18
11:36
11:54
12:12
12:30
12:48
13:06
13:24
13:42
14:00
14:18
14:36
14:54
15:12
15:30
15:48
16:06
16:24
16:42
17:00
17:18
17:36
17:54
18:12
18:30
18:48
19:06
19:24
19:42
20:00
20:18
20:36
20:54
21:12
21:30
21:48
22:06
22:24
22:42
23:00
Time

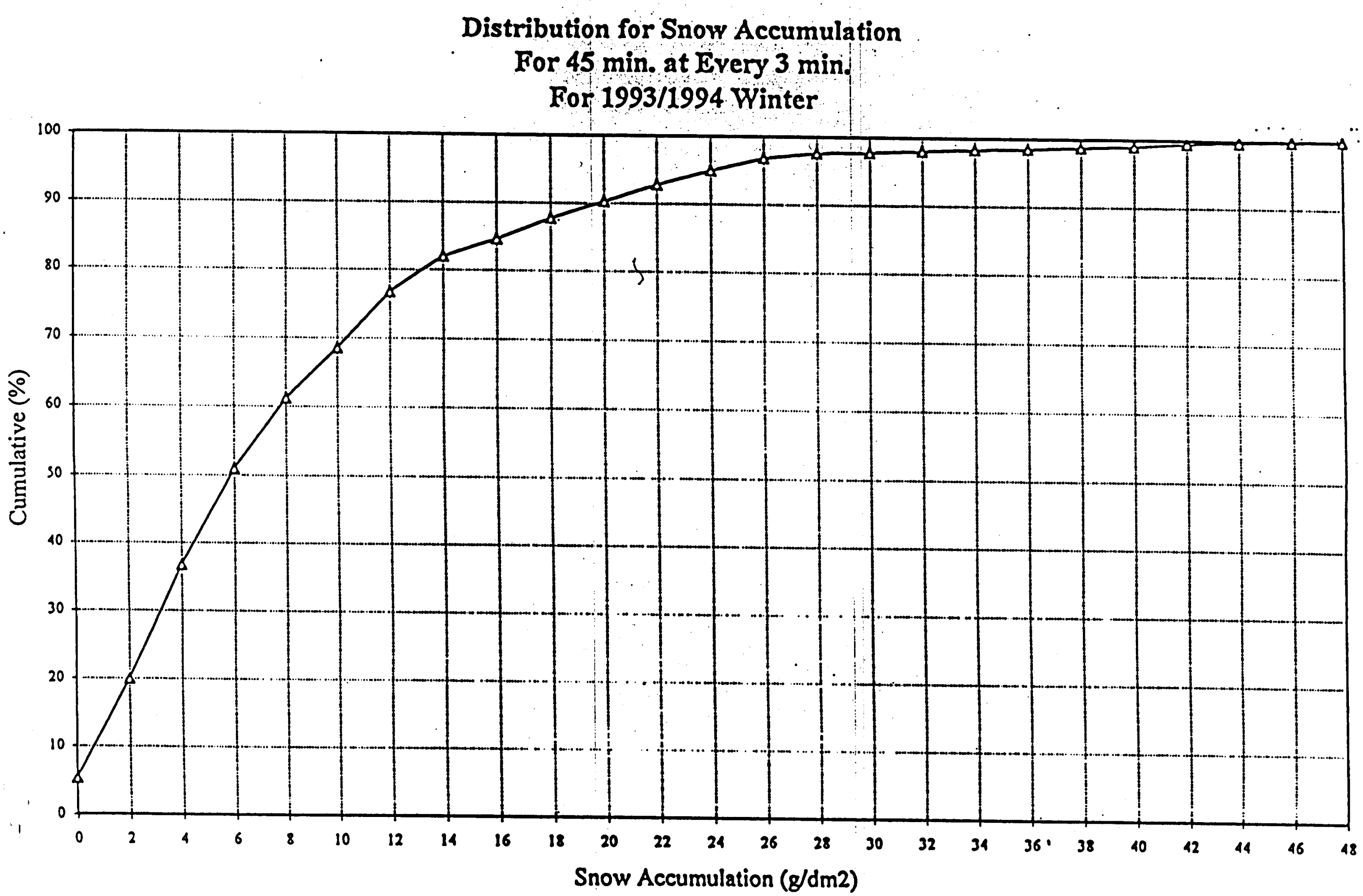


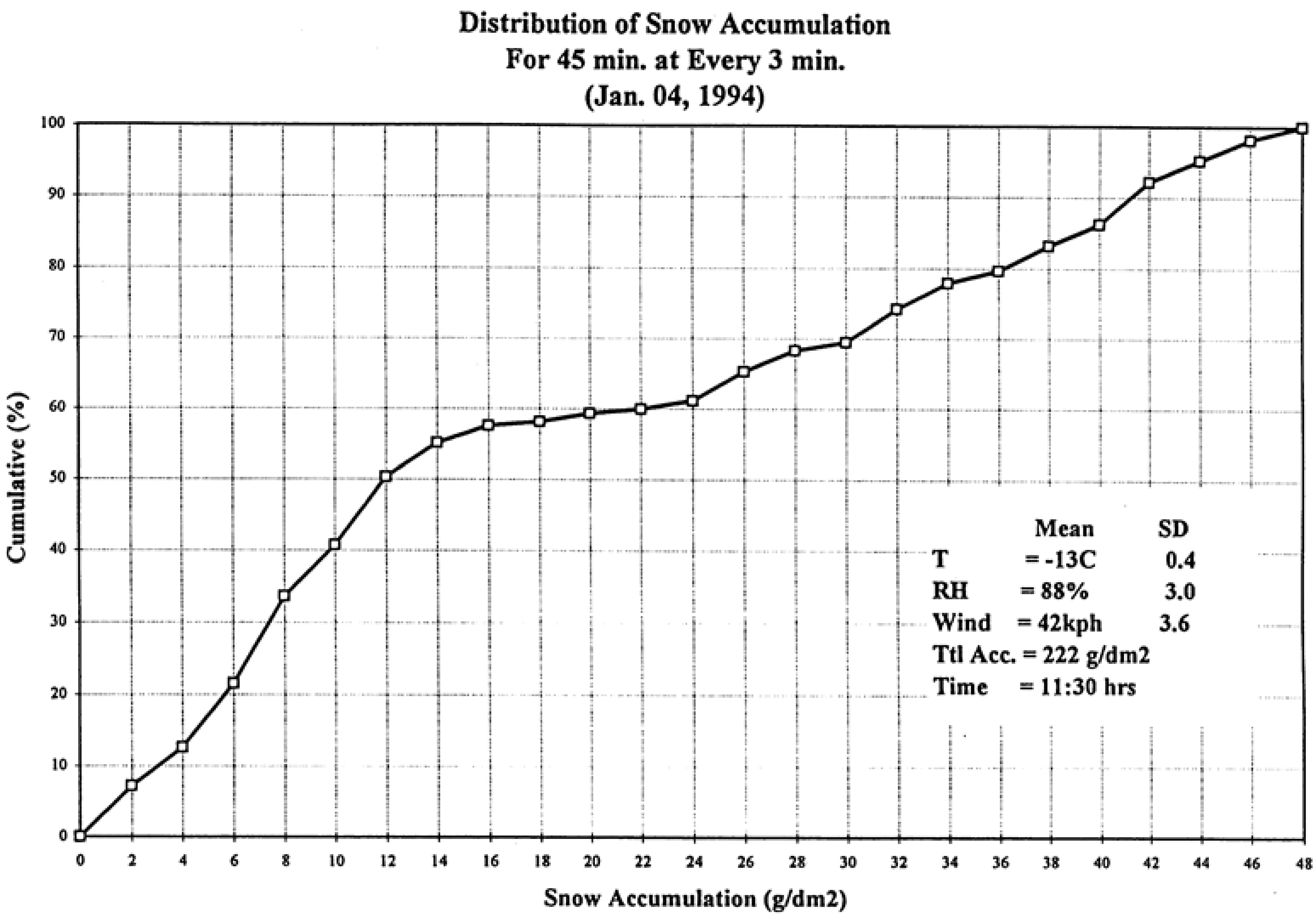
Total Snow Accumulation
for Apr. 07, 1994
Mean SD
T = -1.3C 0.0
RH = 93% 0.0
Wind = 21kph 0.0
Ttl Acc. = 56 g/dm2
Time = 05:00 hrs
Snow Accumulation (g/dm2)
200
180
160
140
120
100
80
60
40
20
0
07:00
07:18
07:36
07:54
08:12
08:30
08:48
09:06
09:24
09:42
10:00
10:18
10:36
10:54
11:12
11:30
11:48
12:06
12:24
12:42
13:00
13:18
13:36
13:54
14:12
14:30
14:48
15:06
15:24
15:42
16:00
16:18
16:36
16:54
17:12
17:30
17:48
18:06
18:24
18:42
19:00
Time


Comparison Between Moving & Reg. Averages
for Distribution for Snow Accumulation
(Jan 4, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean
SD
T = -13C 0.4
RH = 88% 3.0
Wind = 42kph 3.6
Ttl Acc. = 222 g/dm2
Time =11:30 hrs
Δt
Moving. Avg.
Reg. Avg.

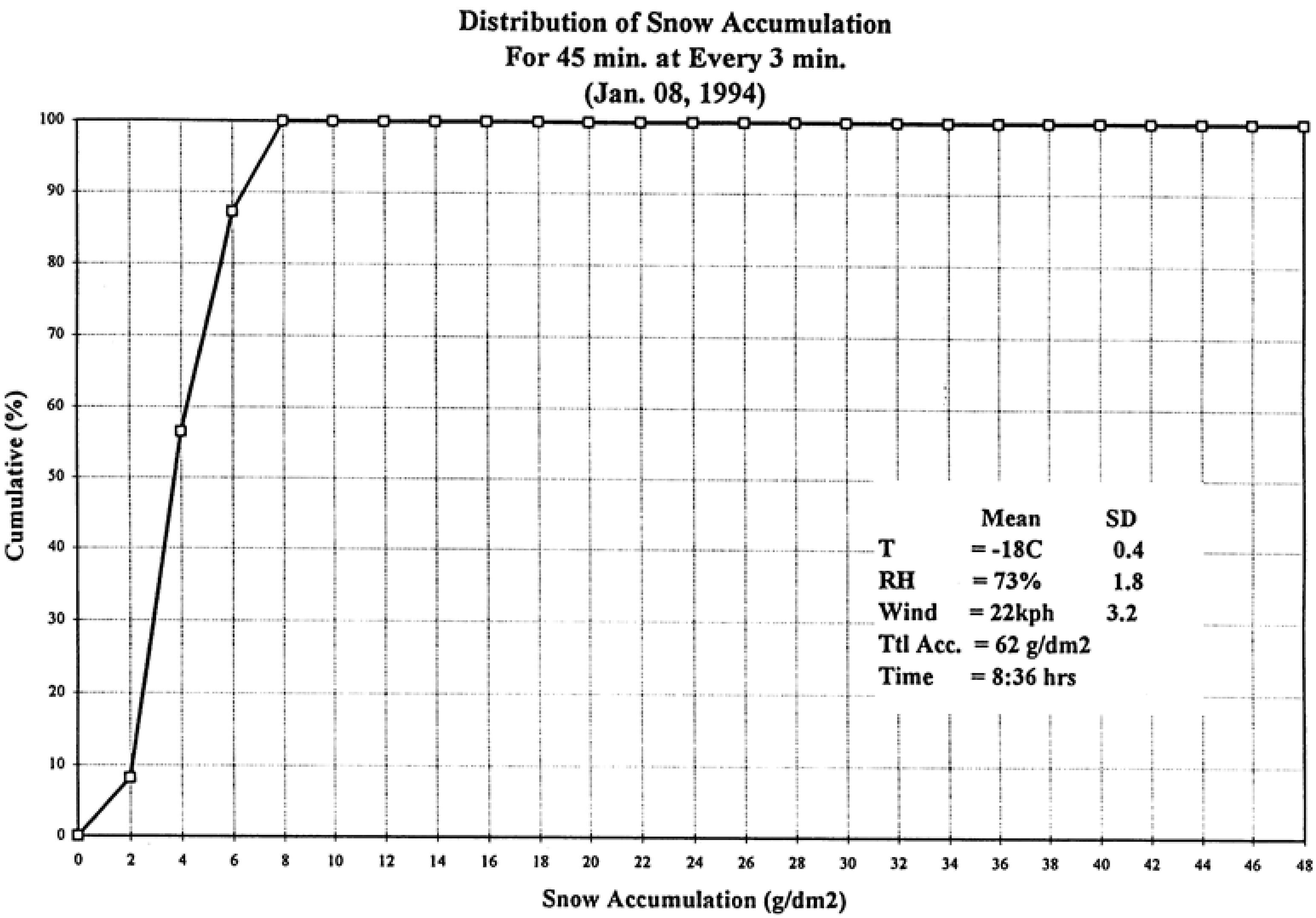

Histogram for Snow Accumulation
Every 21 min. (Series 1, Jan. 4, 1994)
Mean SD
T = -13C 0.4
RH = 88% 3.0
Wind = 42kph 3.6
Ttl Acc. = 222 g/dm2
Time = 11:30 hrs
Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
8.0
16.0
20.0
8.0
12.0
4.0
0.0
4.0
8.0
8.0
4.0
4.0
4.0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)

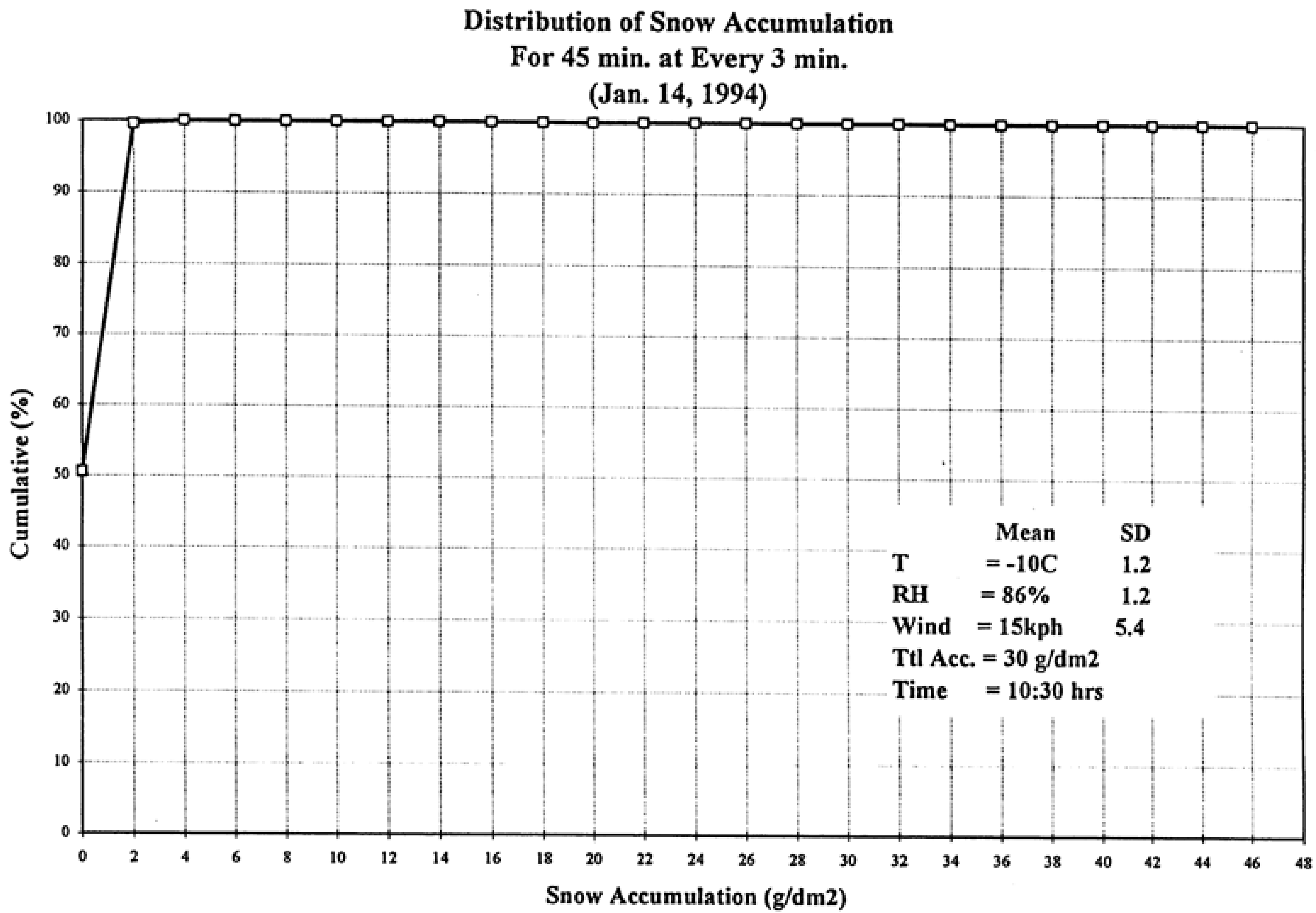

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Dec. 21, 1993)
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
Snow Accumulation (g/dm2)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Mean SD
T = 0.5C 0.1
RH = 97% 0.8
Wind = 35kph 3.0
Ttl Acc. = 286 g/dm2
Time = 13:00 hrs

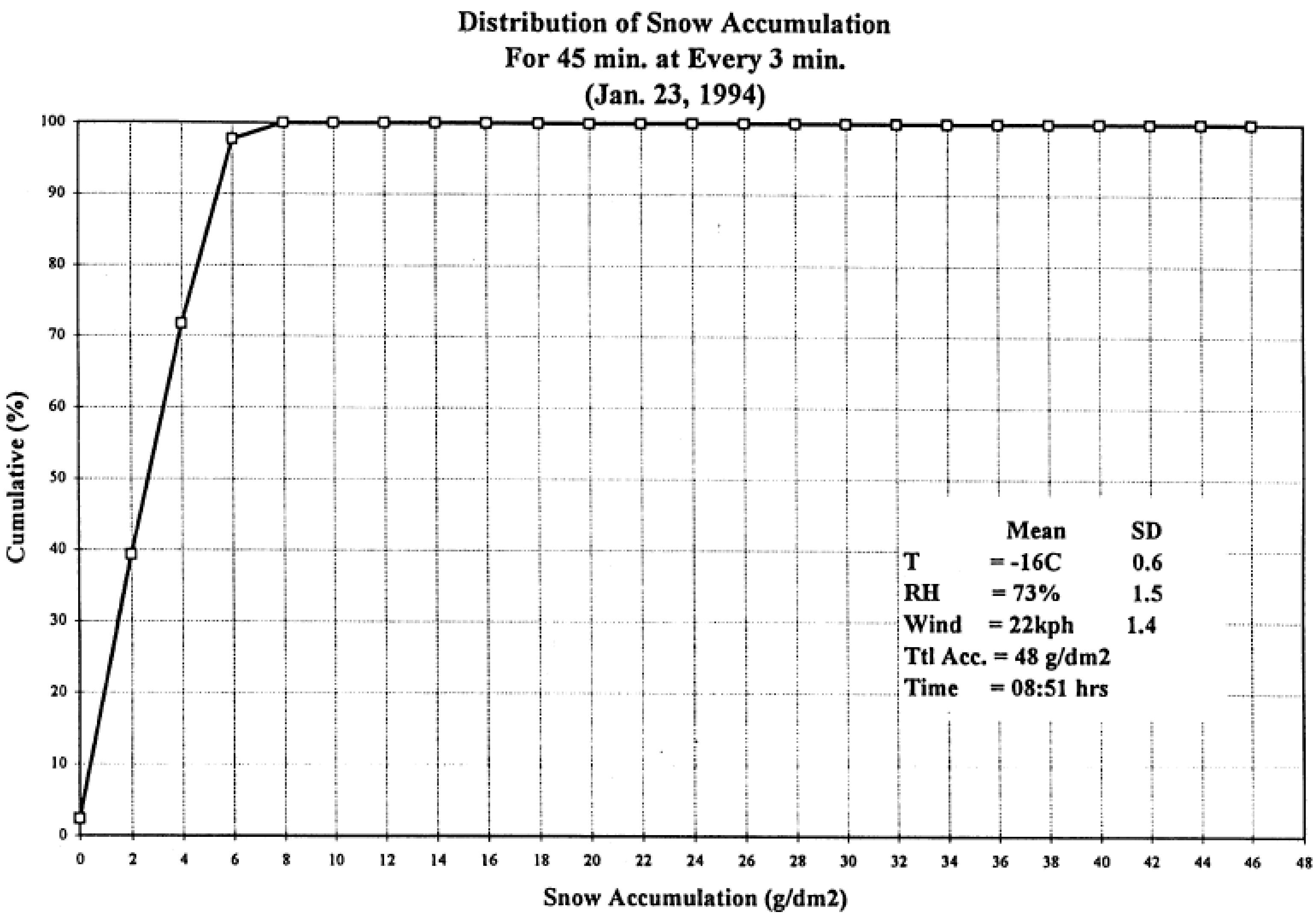

Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/1994 Winter
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)

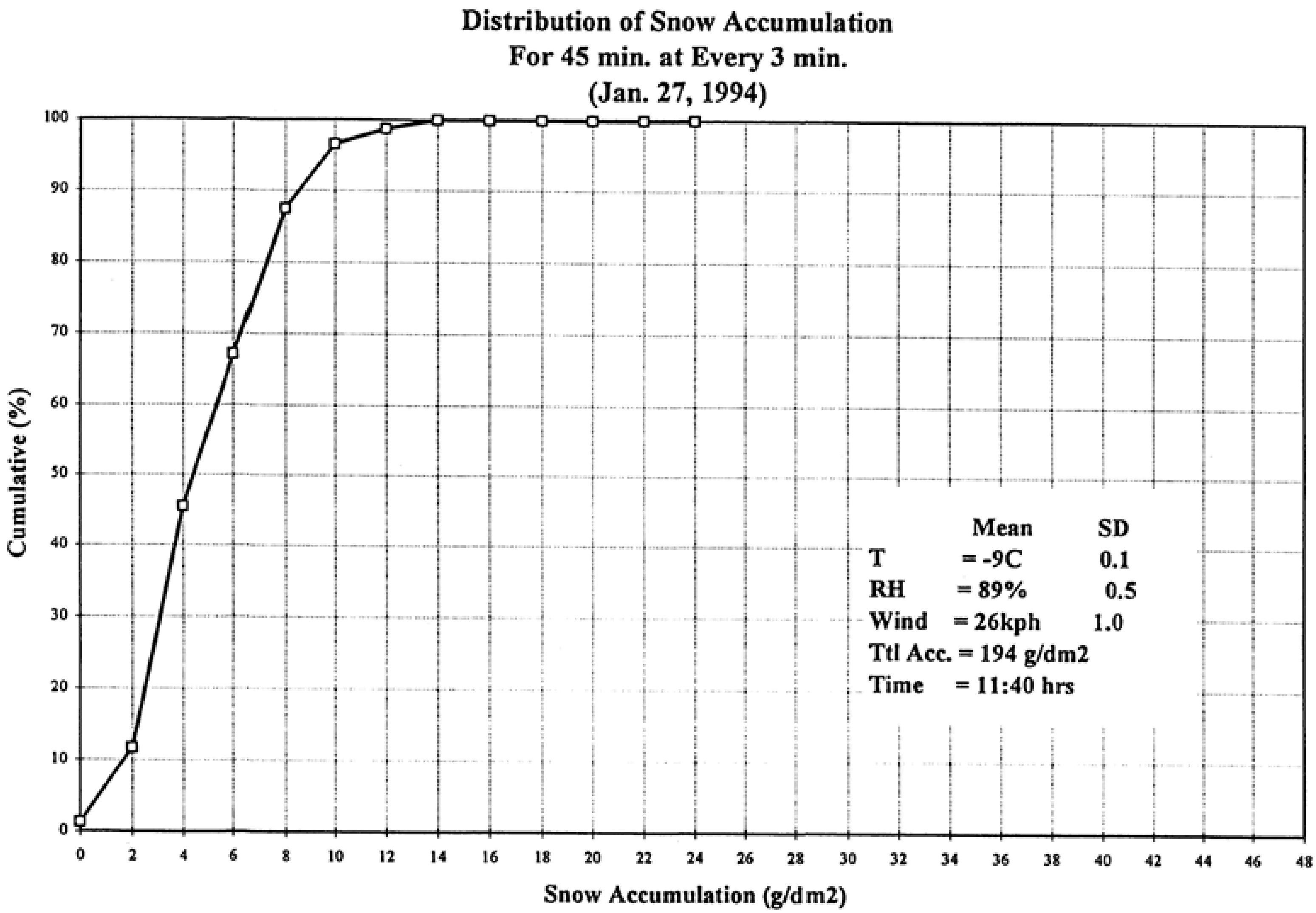


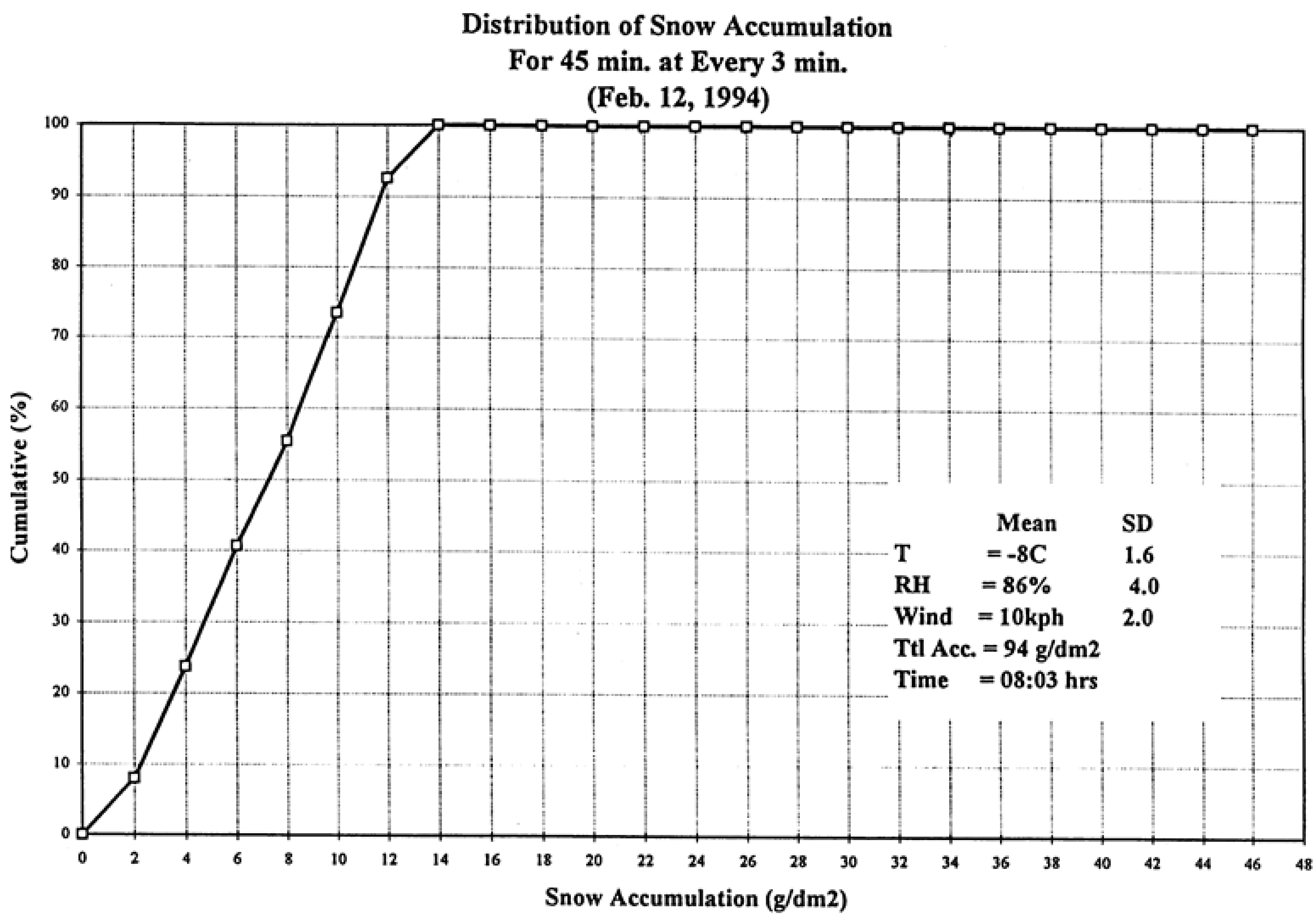
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 04, 1994)
Cumulative (%)
Snow Accumulation (g/dm2)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Mean
SD
T = -13C 0.4
RH = 88% 3.0
Wind = 42kph 3.6
Ttl Acc. = 222 g/dm2
Time = 11:30 hrs

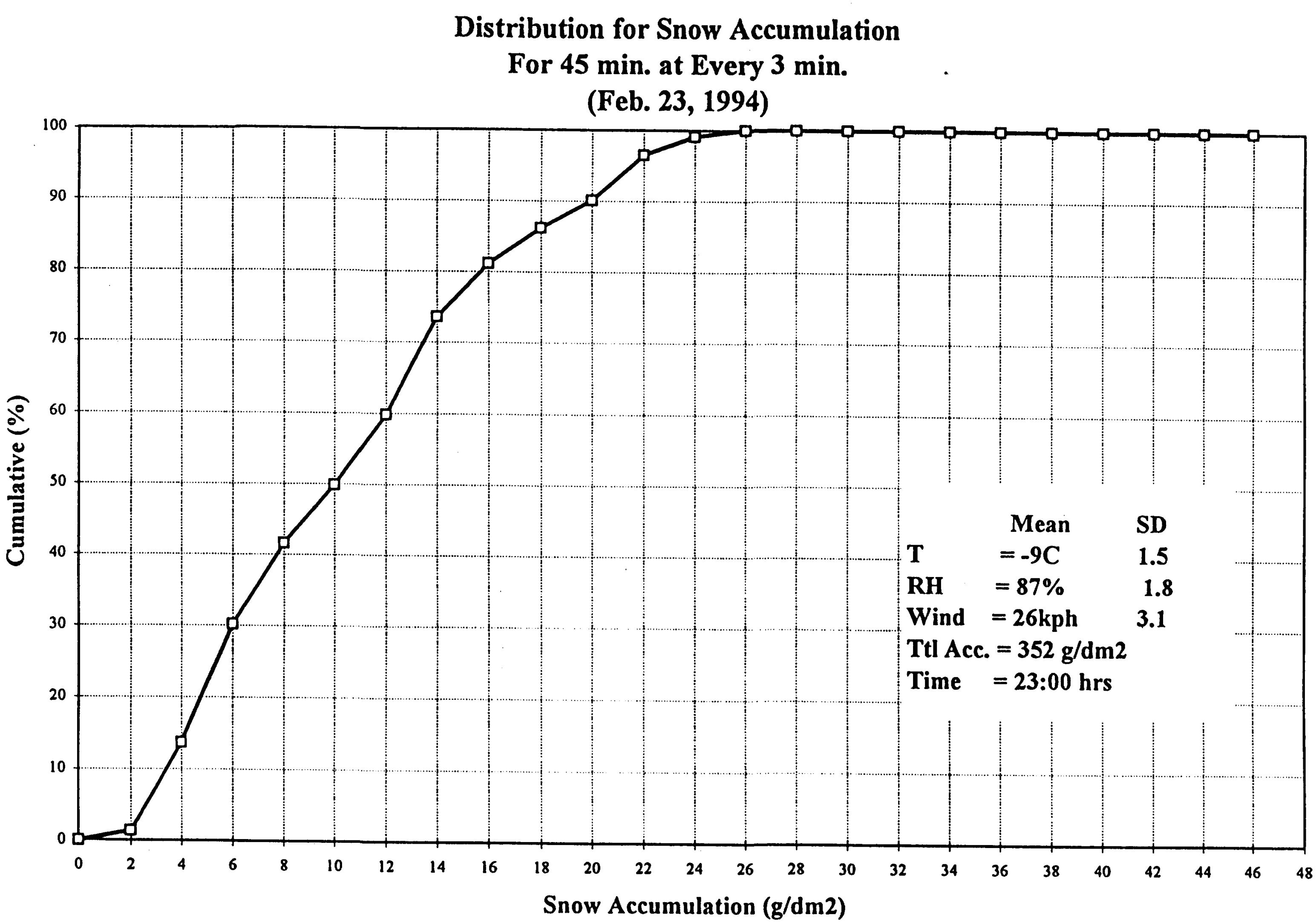

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 08, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)
Mean SD
T = -18C 0.4
RH = 73% 1.8
Wind = 22kph 3.2
Ttl Acc. = 62 g/dm2
Time = 8:36 hrs

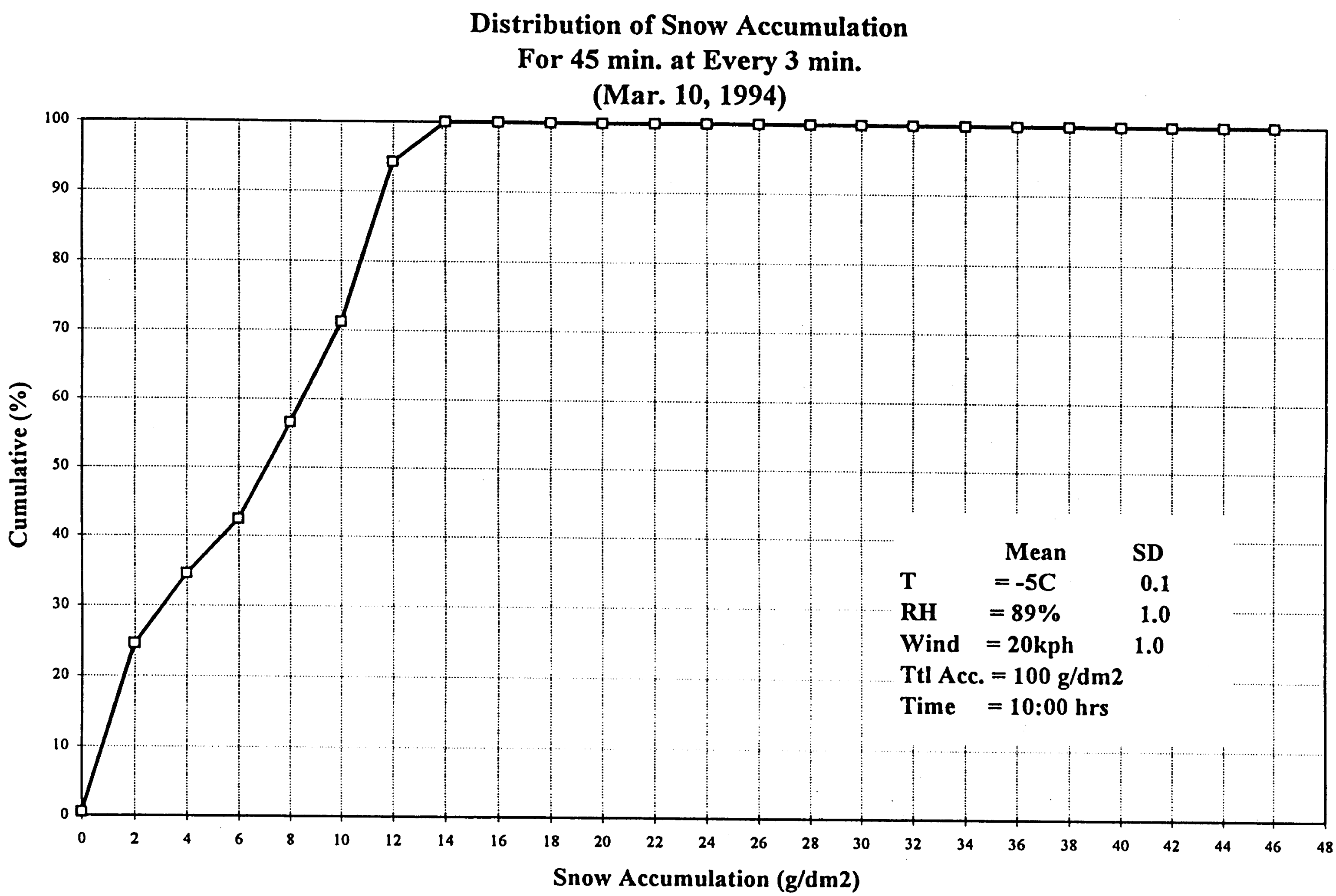

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 14, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)
Mean
SD
T = -10C 1.2
RH = 86% 1.2
Wind = 15kph 5.4
Ttl Acc. = 30 g/dm2
Time = 10:30 hrs

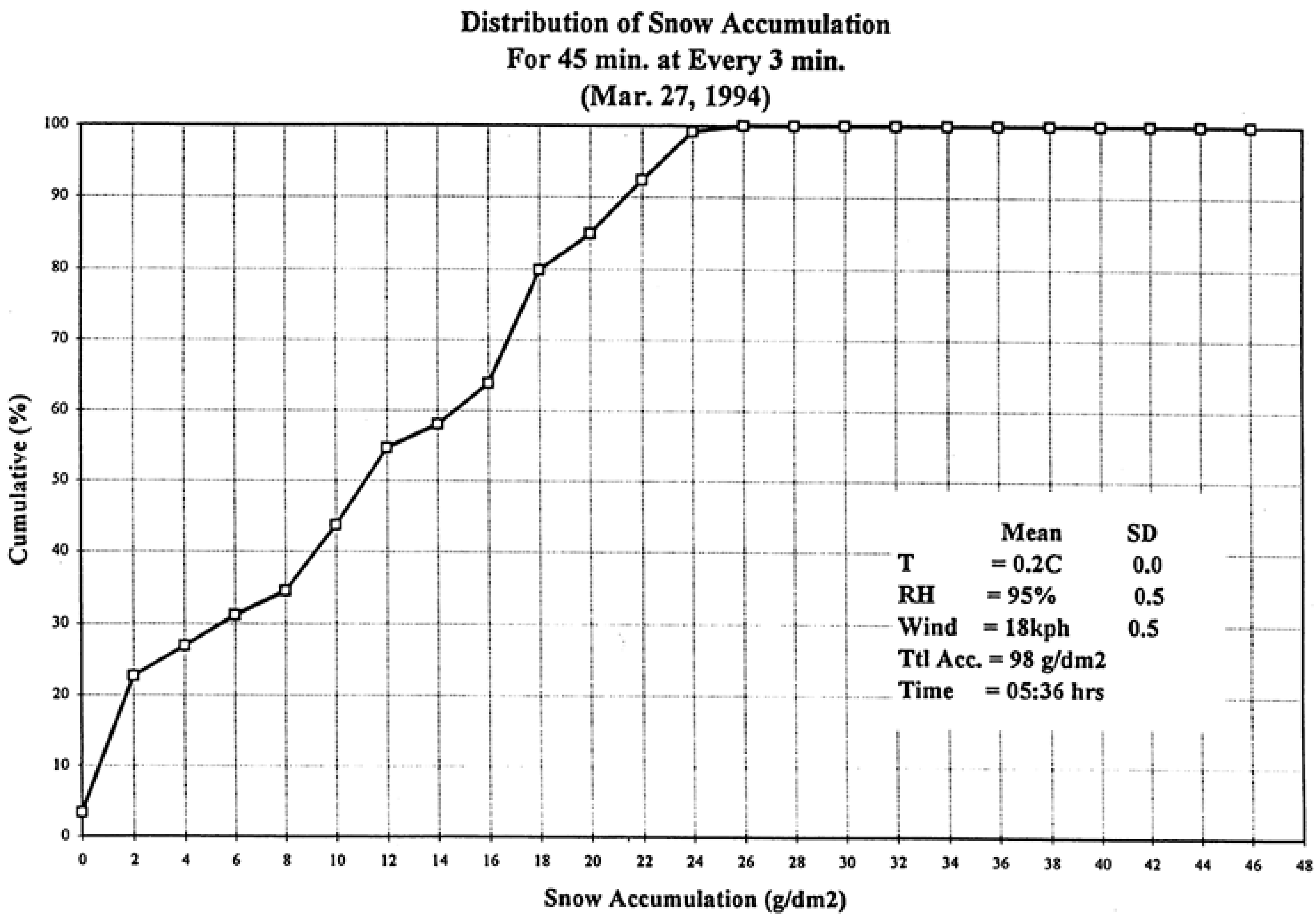

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 23, 1994)
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
Snow Accumulation (g/dm2)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Mean SD
T = -16C 0.6
RH = 73% 1.5
Wind = 22kph 1.4
Ttl Acc. = 48 g/dm2
Time = 08:51 hrs


Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 27, 1994)
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
Snow Accumulation (g/dm2)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Mean SD
T = -9C 0.1
RH = 89% 0.5
Wind = 26kph 1.0
Ttl Acc. = 194 g/dm2
Time = 11:40 hrs

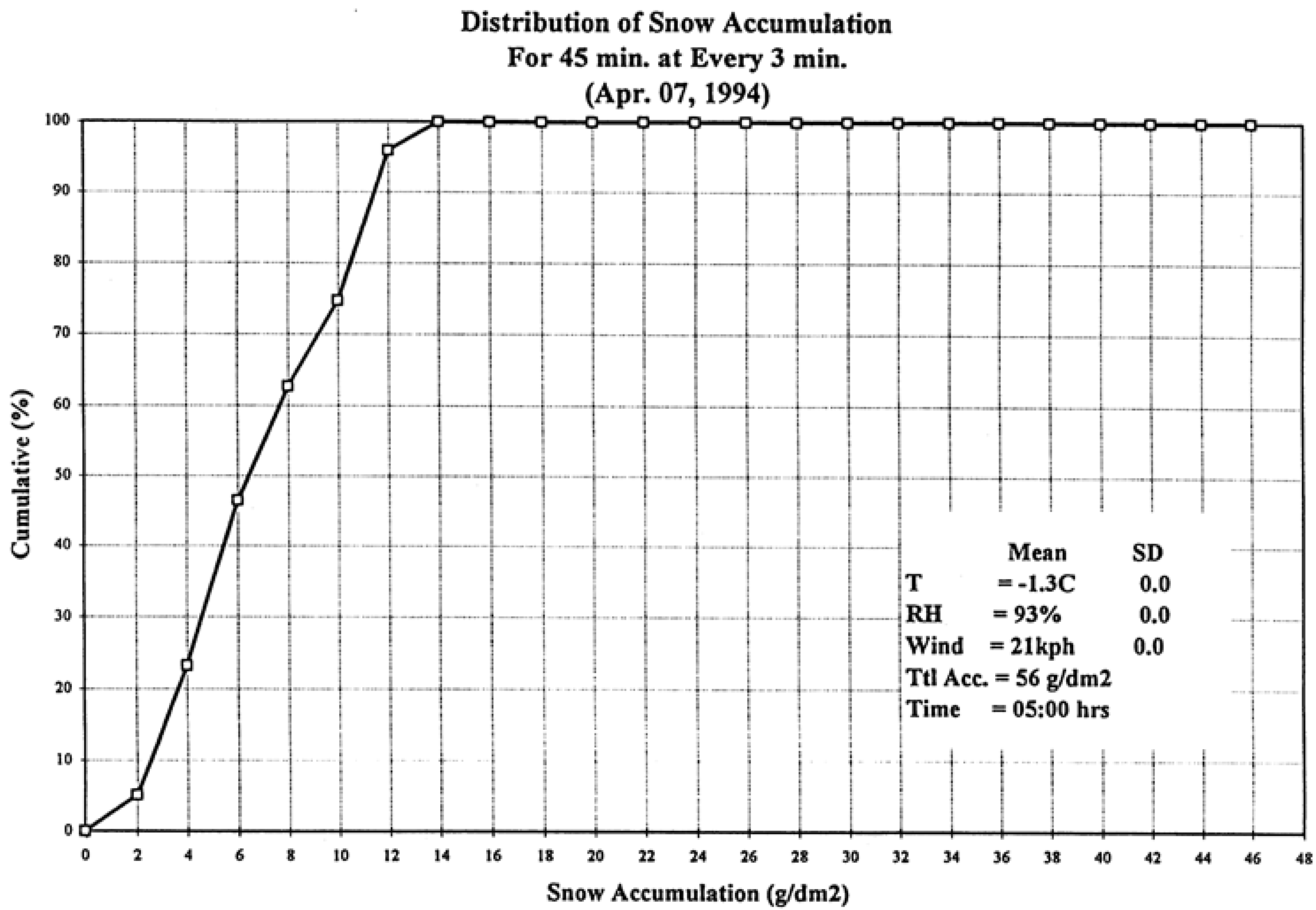

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 12, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)
Mean SD
T = -8C 1.6
RH = 86% 4.0
Wind = 10kph 2.0
Ttl Acc. = 94 g/dm2
Time = 08:03 hrs


Distribution for Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 23, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)
Mean SD
T = -9C 1.5
RH = 87% 1.8
Wind = 26kph 3.1
Ttl Acc. = 352 g/dm2
Time = 23:00 hrs

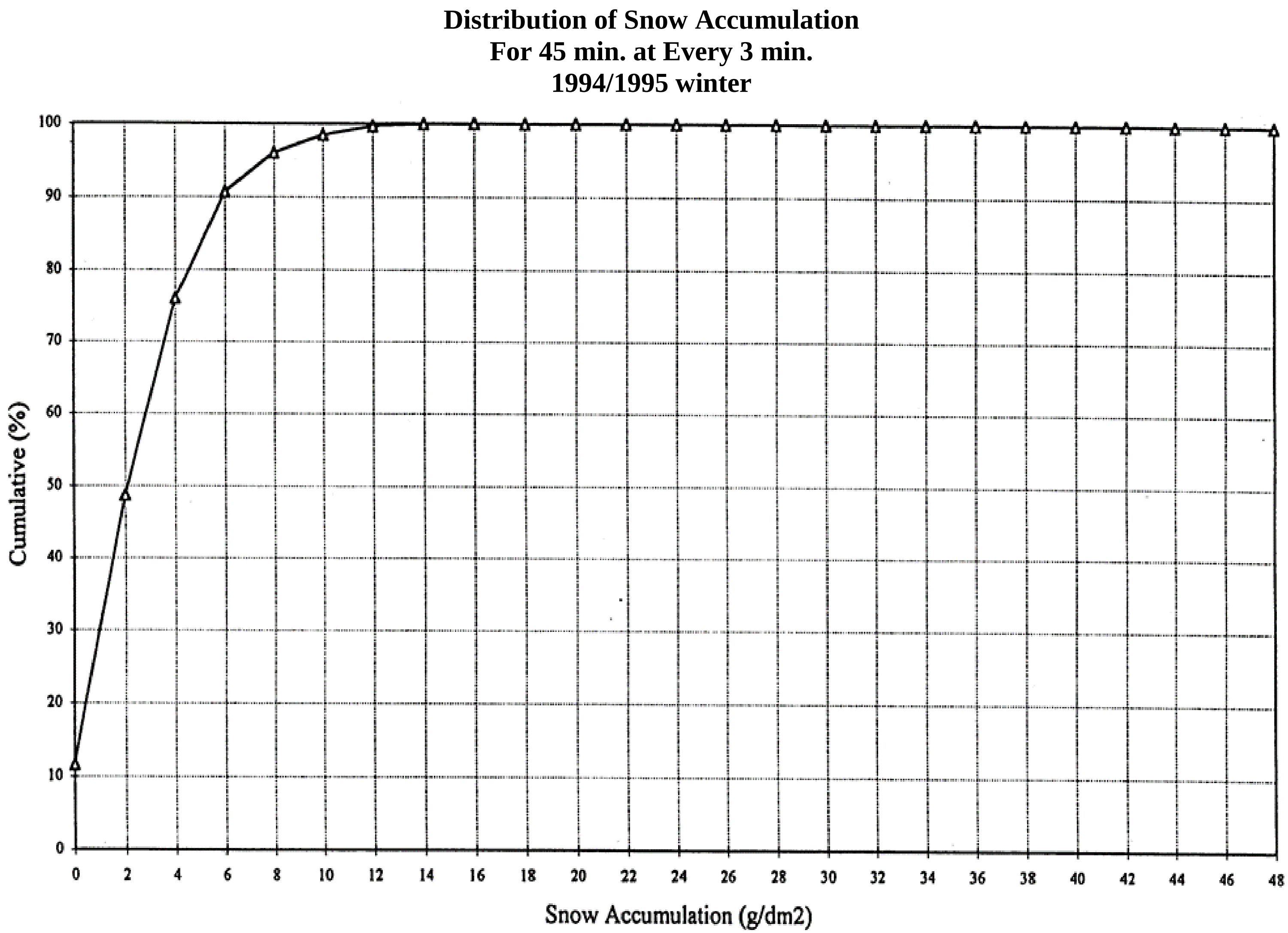

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 10, 1994)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)
Mean SD
T = -5C 0.1
RH = 89% 1.0
Wind = 20kph 1.0
Ttl Acc. = 100 g/dm2
Time = 10:00 hrs

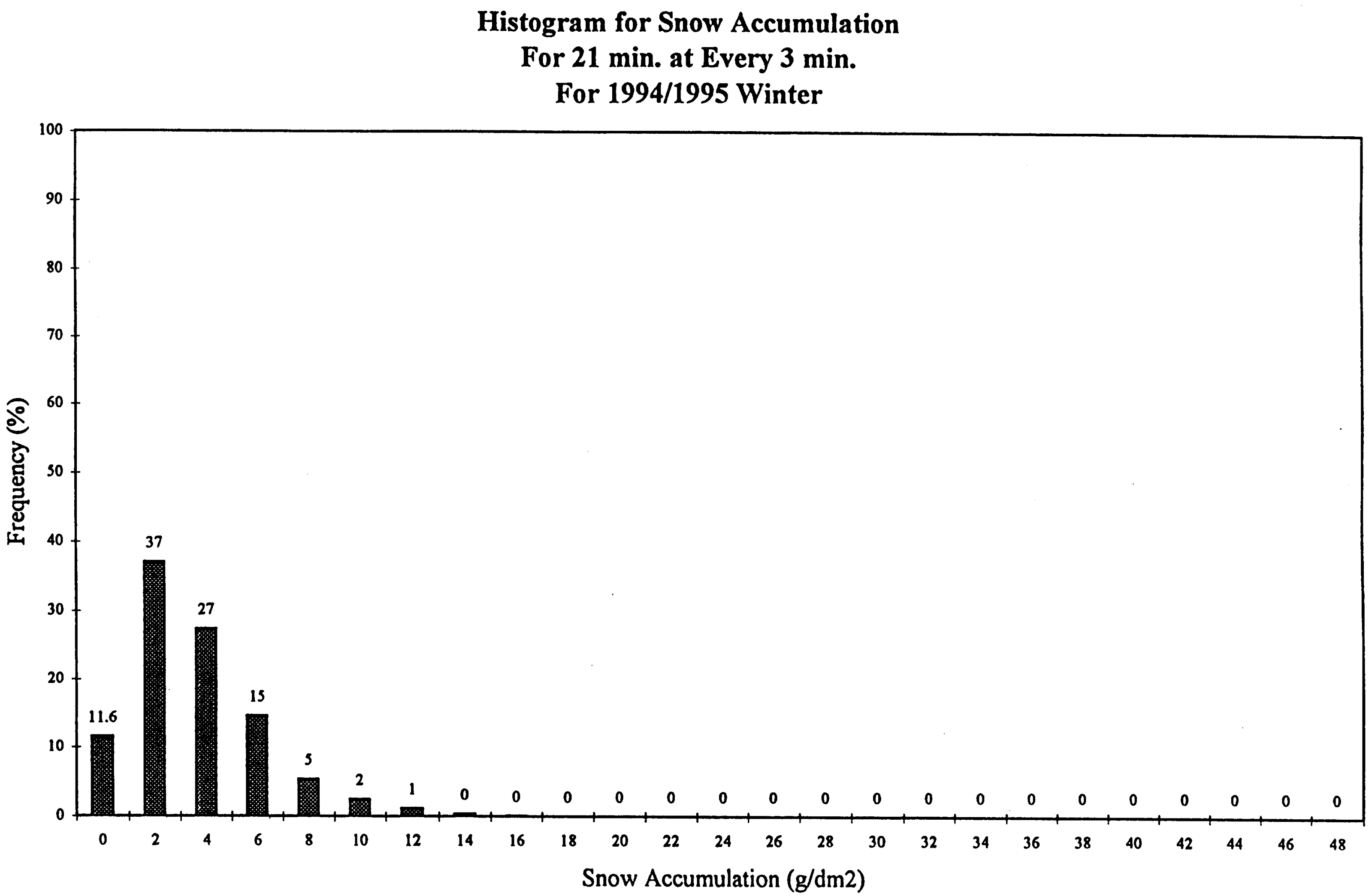


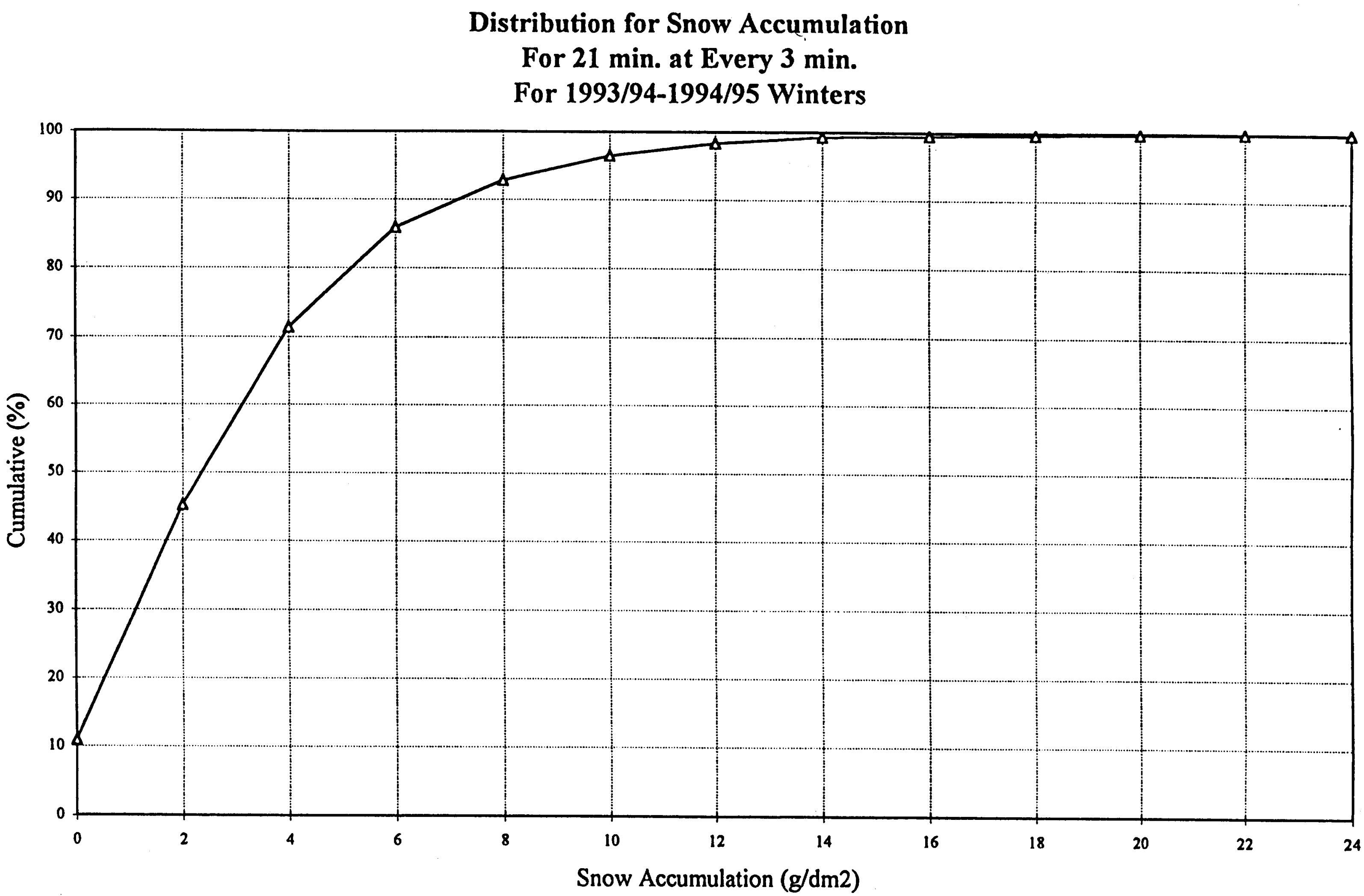
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 27, 1994)
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)
Mean SD
T = 0.2C 0.0
RH = 95% 0.5
Wind = 18kph 0.5
Ttl Acc. = 98 g/dm2
Time = 05:36 hrs



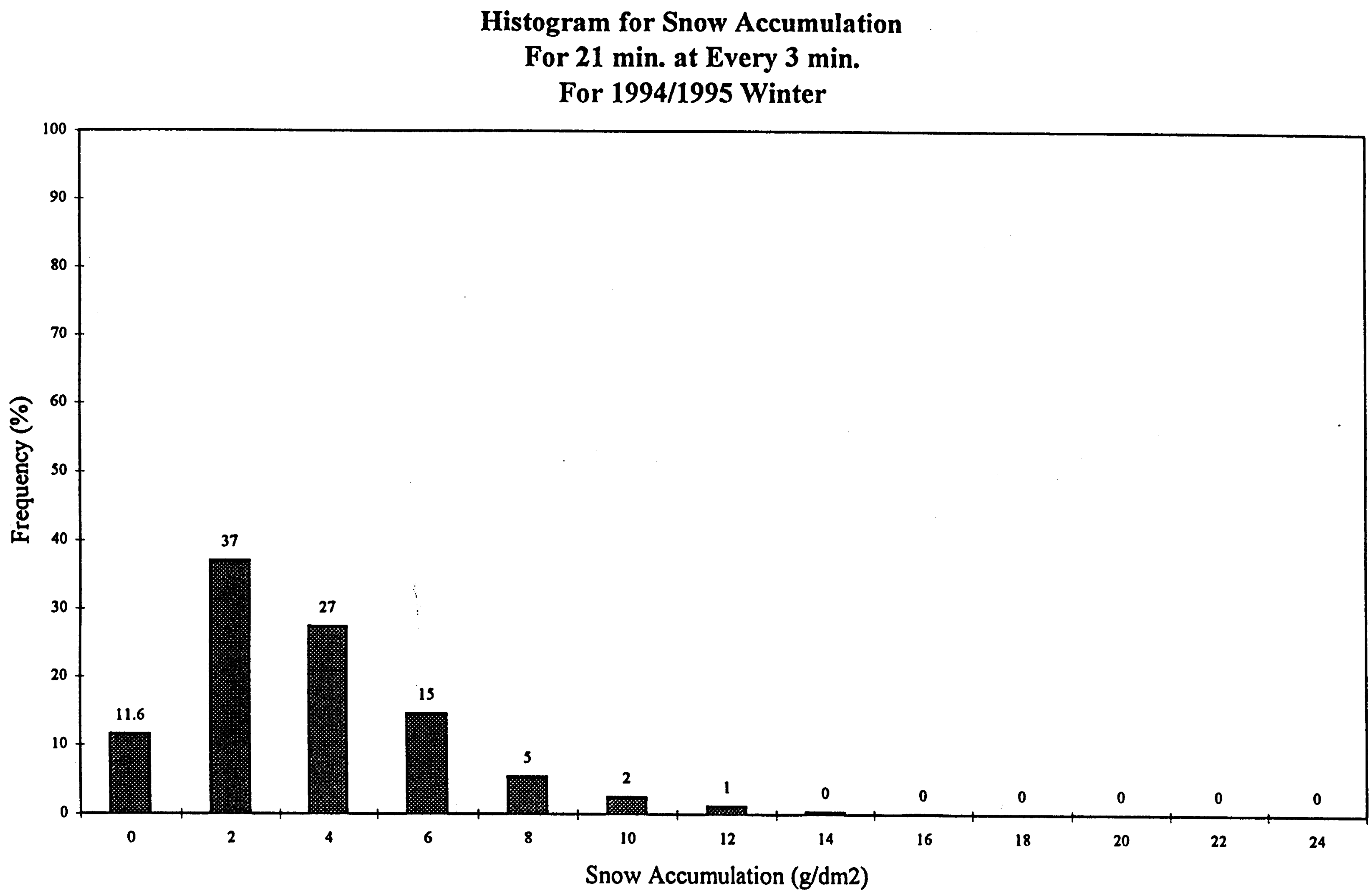
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Apr. 07, 1994)
Cumulative (%)
Snow Accumulation (g/dm2)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Mean
SD
T = -1.3C 0.0
RH = 93% 0.0
Wind = 21kph 0.0
Ttl Acc. = 56 g/dm2
Time = 05:00 hrs

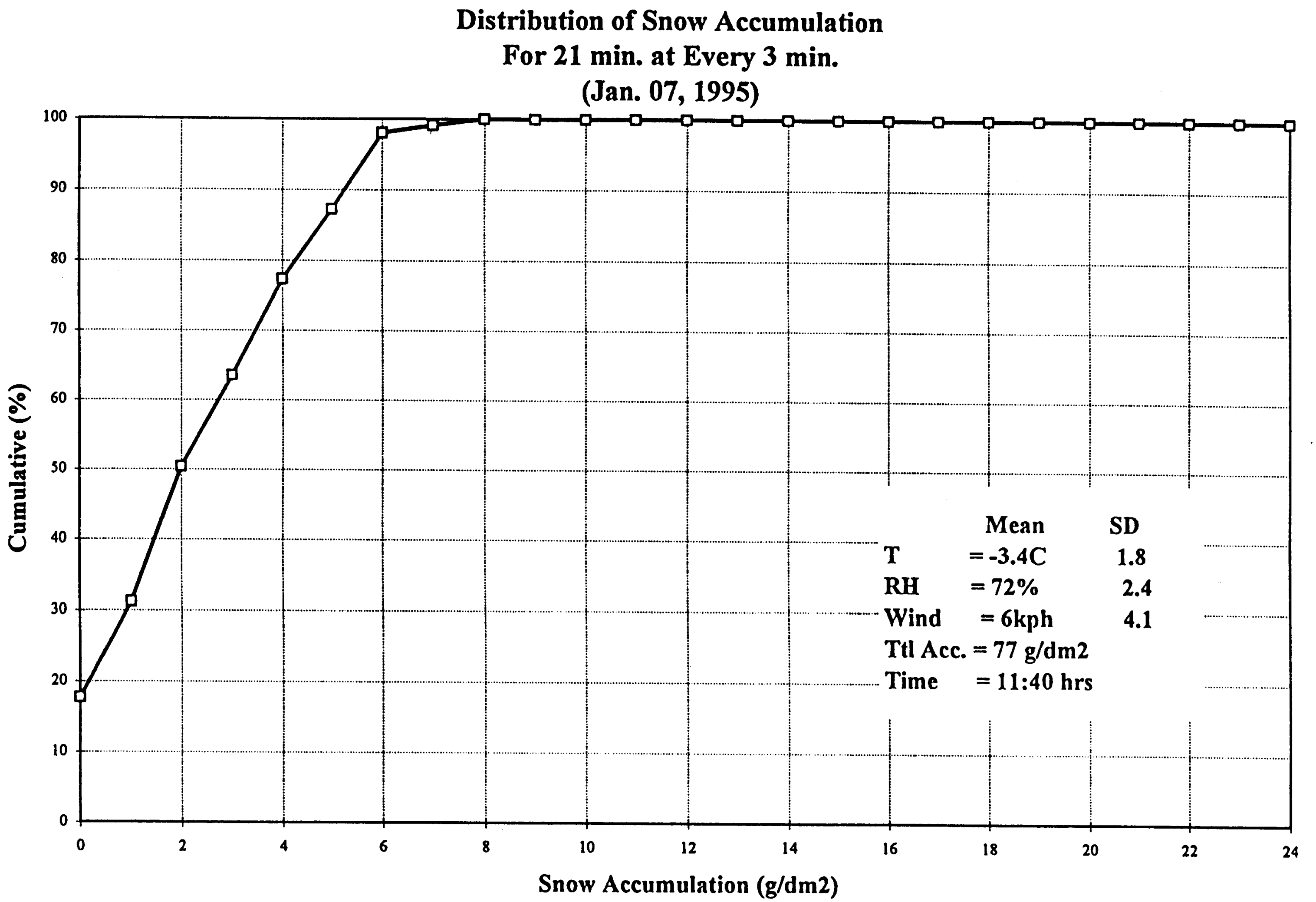

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
1994/1995 winter
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)

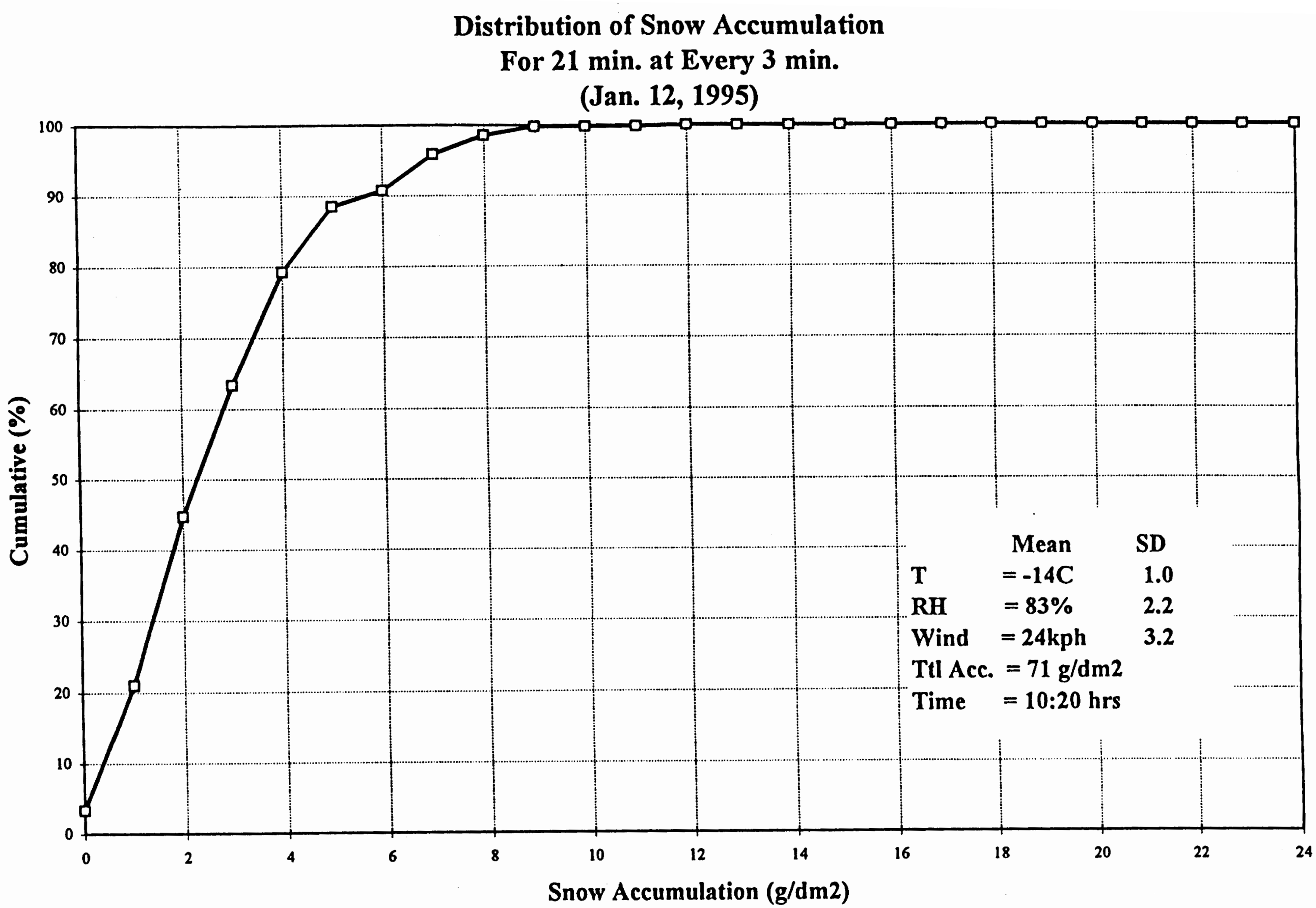

Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1994/1995 Winter
Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
11.6
37
27
15
5
2
1
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)

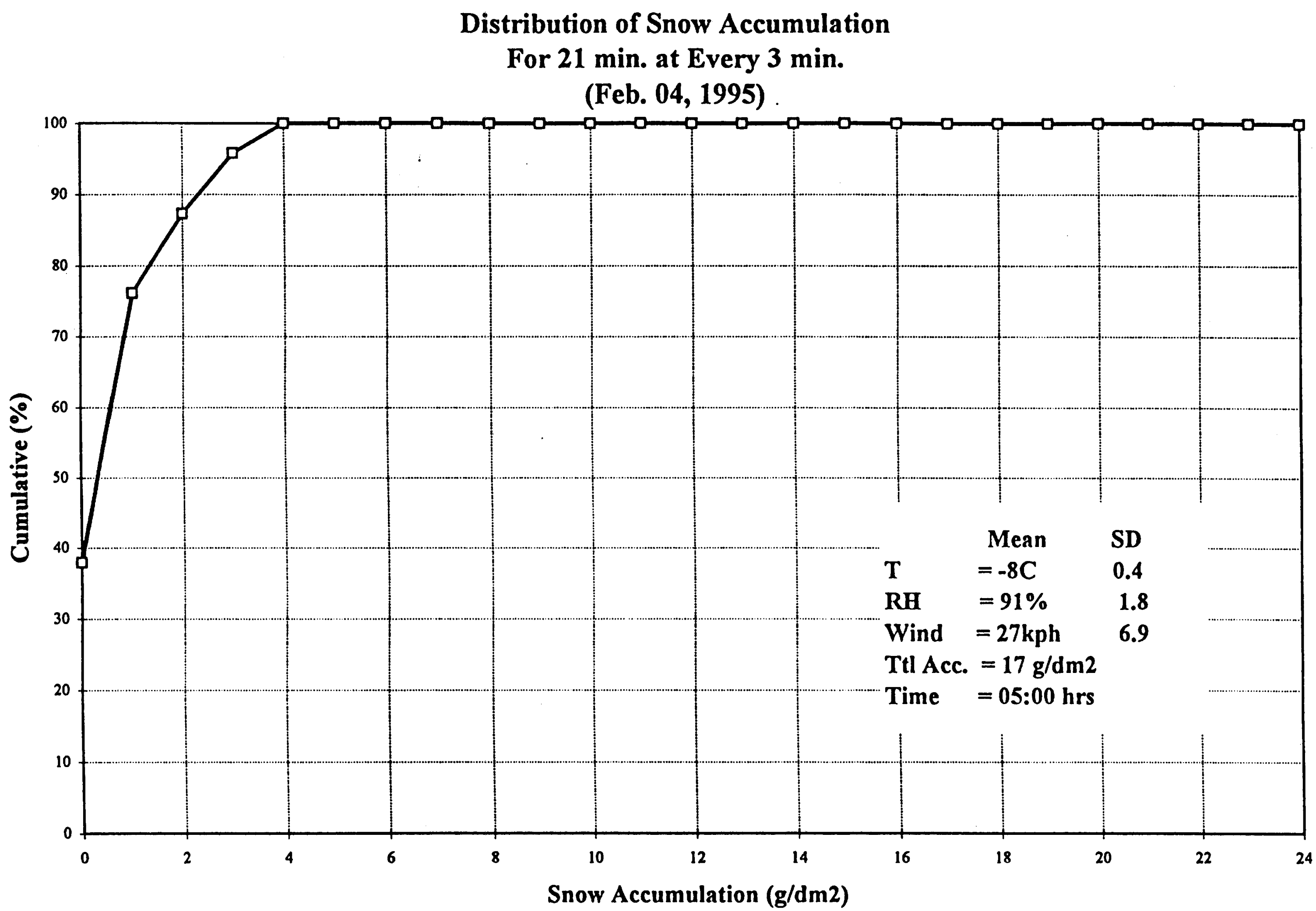

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/94-1994/95 Winters
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)

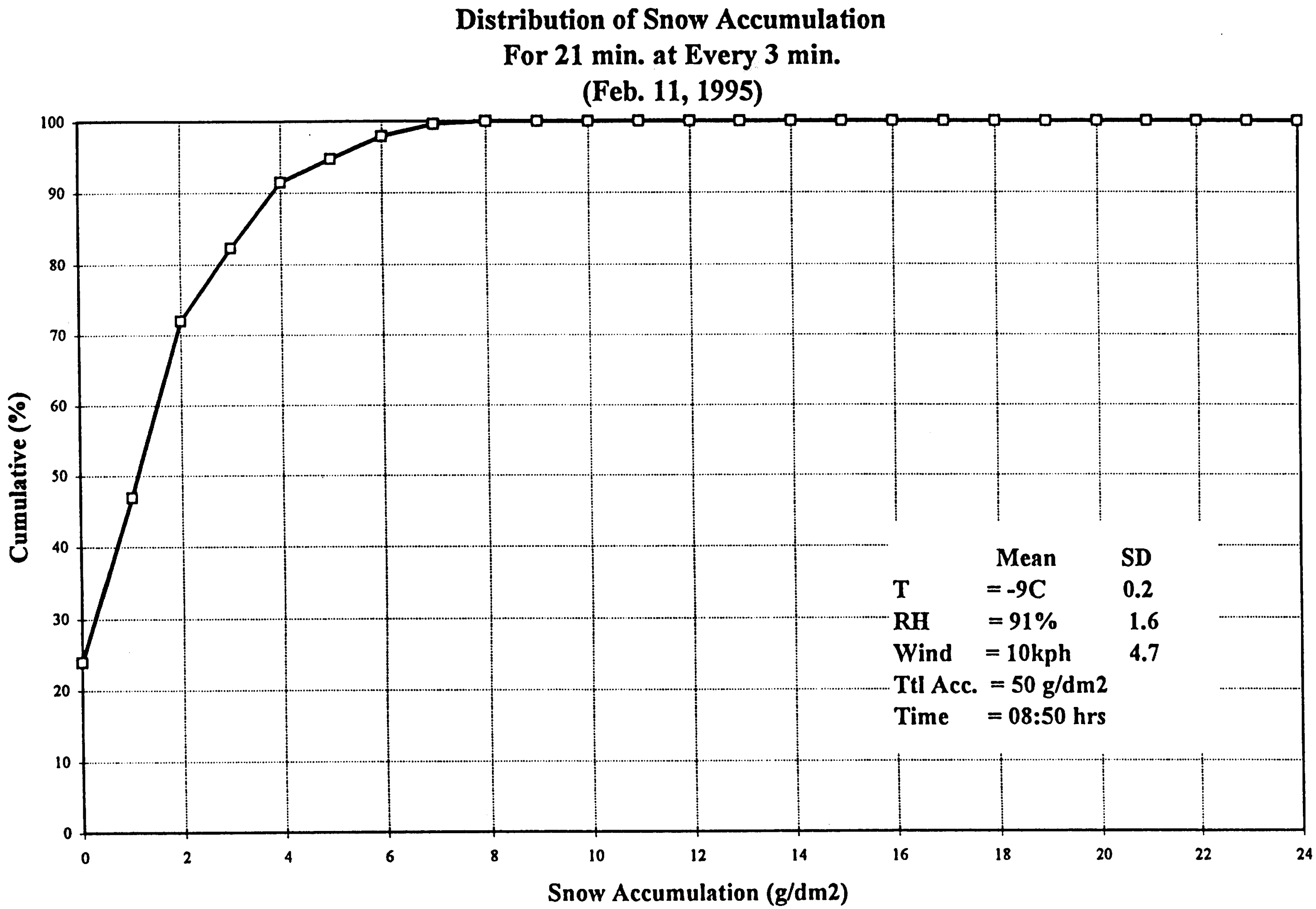
				MOVING AVERAGE									
				1994/1995									
RANGE	**950107**	**950112**	**950204**	**950211**	**950216**	**950224**	**950227**	**950306**	**950308A**	**950308B**	**950308C**	**SUM**	**%**	**CUMUL.**
0	100	16	116	123	0	85	44	23	0	0	3	510	11.6	11.6
1	76	86	117	118	7	41	101	93	3	40	58	740	16.8	28.4
2	108	115	34	129	14	151	121	14	12	26	164	888	20.2	48.6
3	74	91	26	53	53	36	152	13	22	31	83	634	14.4	63.1
4	78	77	13	47	67	29	121	17	6	6	109	570	13.0	76.0
5	56	45	0	17	43	6	48	32	1	17	129	394	9.0	85.0
6	61	11	0	16	46	9	4	26	8	18	51	250	5.7	90.7
7	6	25	0	9	34	0	1	36	3	17	28	159	3.6	94.3
8	5	13	0	2	24	0	0	13	6	11	1	75	1.7	96.0
9	0	6	0	0	11	0	0	20	13	15	0	65	1.5	97.5
10	0	0	0	0	18	0	0	10	5	10	0	43	1.0	98.5
11	0	0	0	0	7	0	0	7	15	4	0	33	0.8	99.2
12	0	1	0	0	6	0	0	2	8	1	0	18	0.4	99.6
13	0	0	0	0	1	0	0	0	4	4	0	9	0.2	99.8
14	0	0	0	0	0	0	0	0	5	1	0	6	0.1	100.0
15	0	0	0	0	0	0	0	0	2	0	0	2	0.0	100.0
16	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
17	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
18	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
19	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
20	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
21	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
22	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
23	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
24	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
												4396		

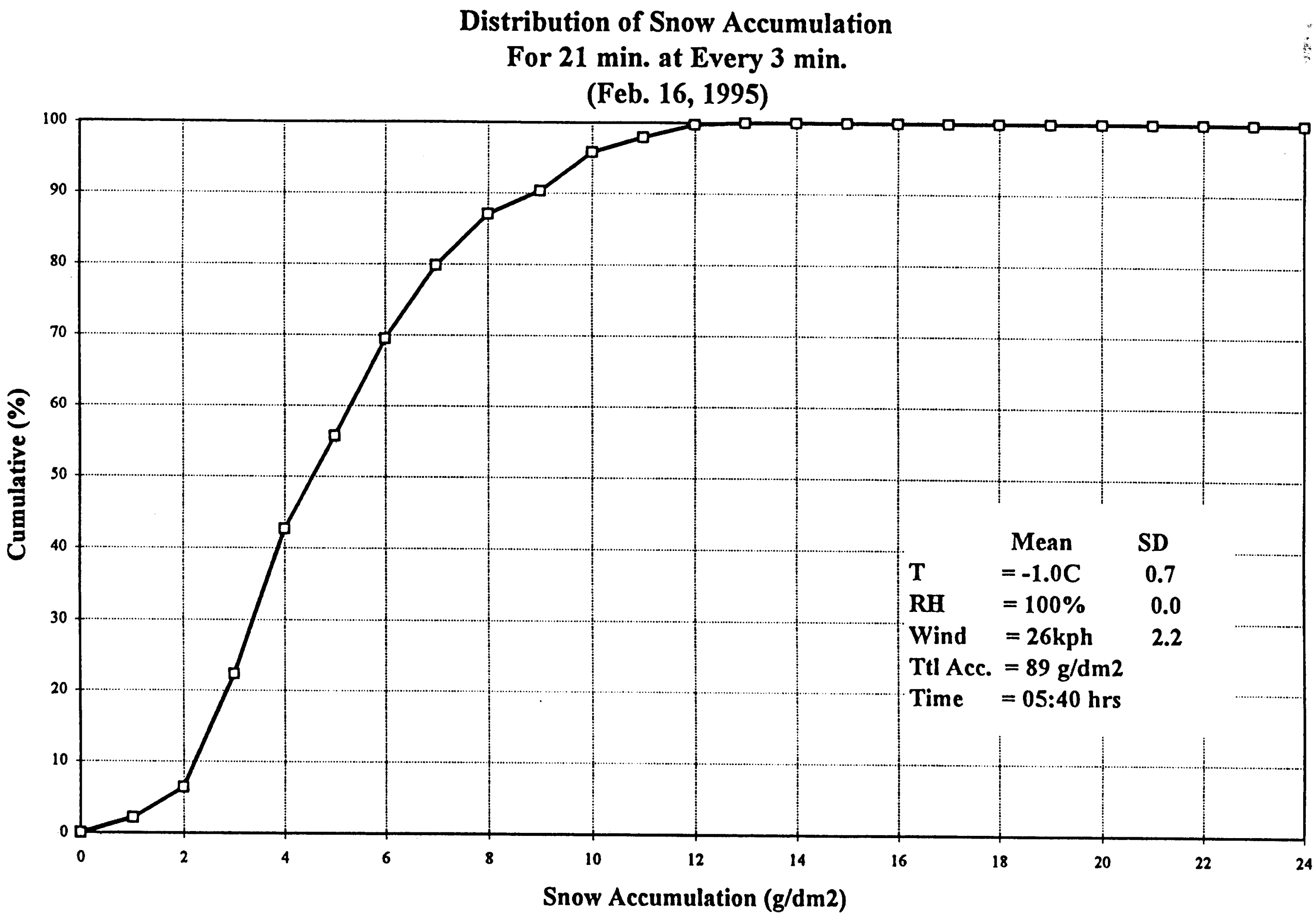

Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1994/1995 Winter
Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
11.6
37
27
15
5
2
1
0
0
0
0
0
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)


Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 07, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -3.4C 1.8
RH = 72% 2.4
Wind = 6kph 4.1
Ttl Acc. = 77 g/dm2
Time = 11:40 hrs

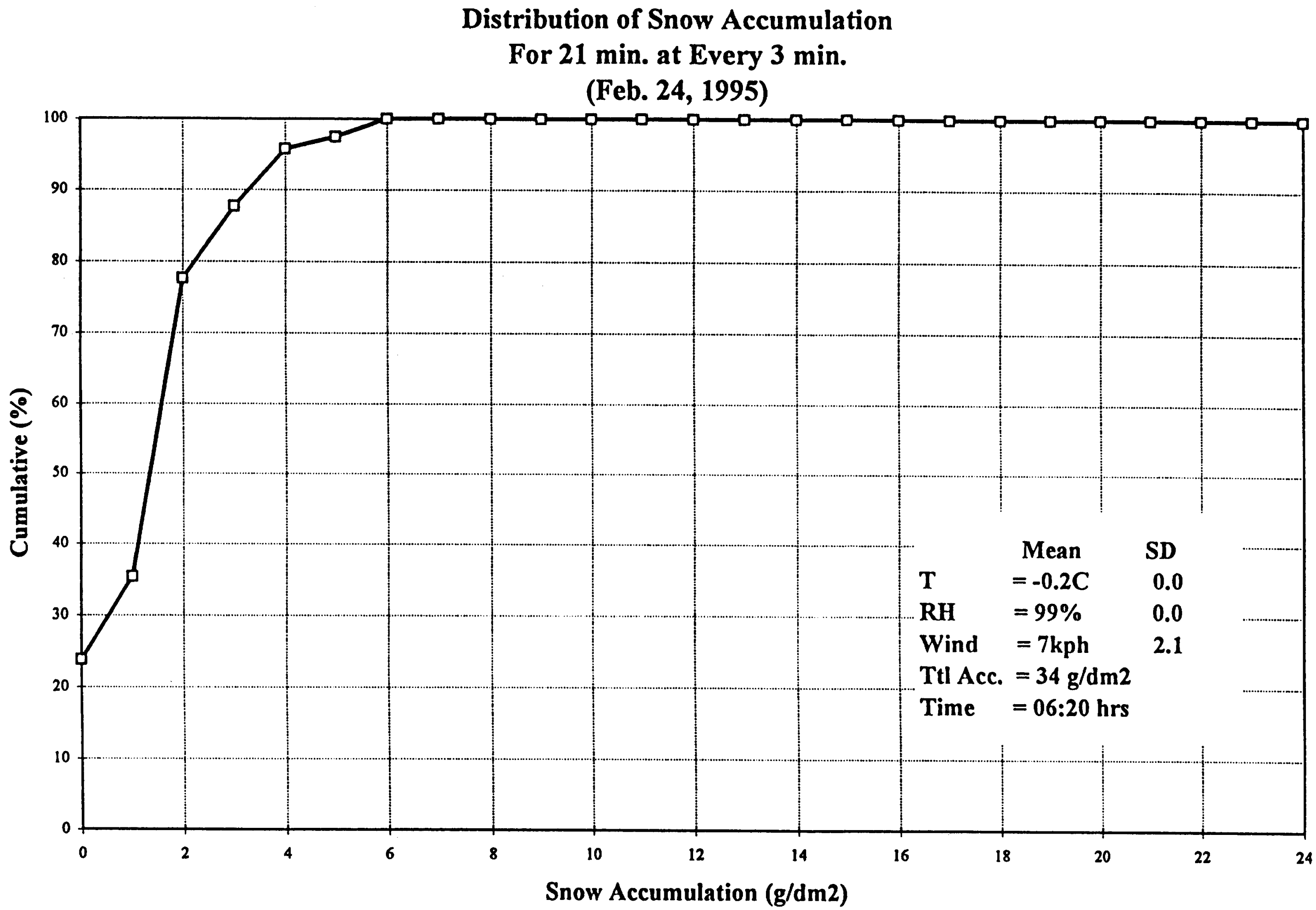

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 12, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -14C 1.0
RH = 83% 2.2
Wind = 24kph 3.2
Ttl Acc. = 71 g/dm2
Time = 10:20 hrs

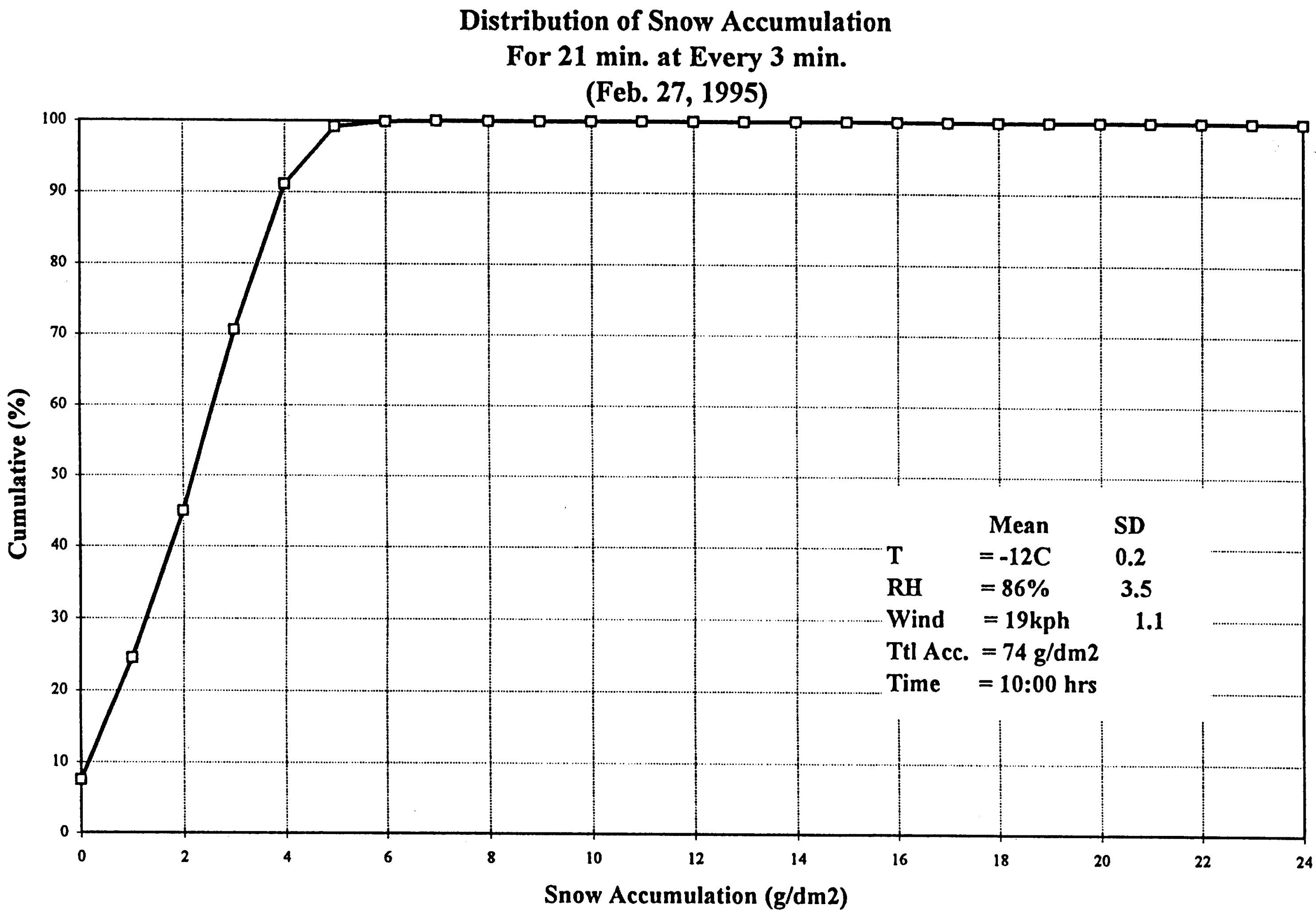

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 04, 1995)
Cumulative (%)
Snow Accumulation (g/dm2)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
Mean
SD
T = -8C 0.4
RH = 91% 1.8
Wind = 27kph 6.9
Ttl Acc. = 17 g/dm2
Time = 05:00 hrs


Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 11, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -9C 0.2
RH = 91% 1.6
Wind = 10kph 4.7
Ttl Acc. = 50 g/dm2
Time = 08:50 hrs

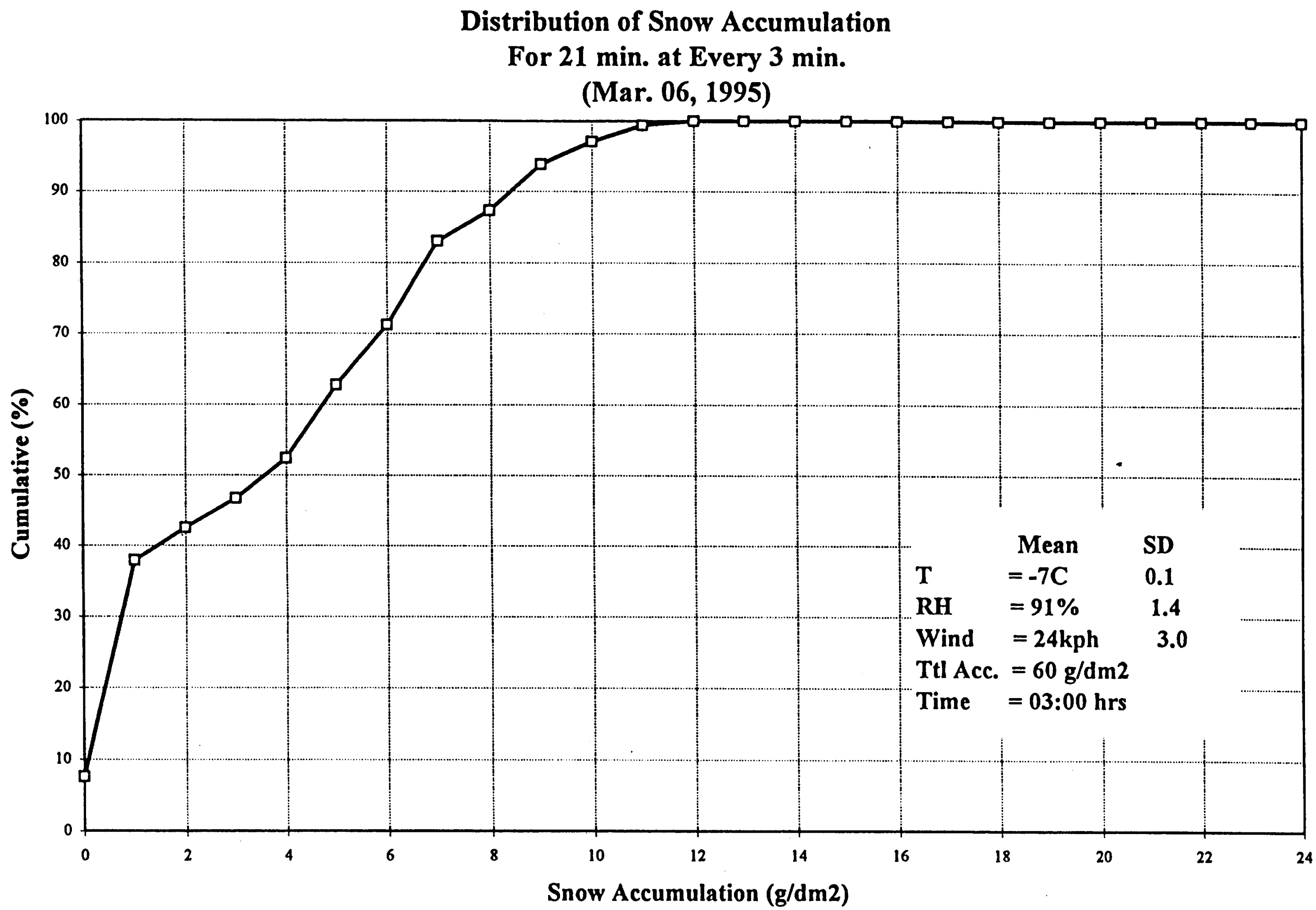


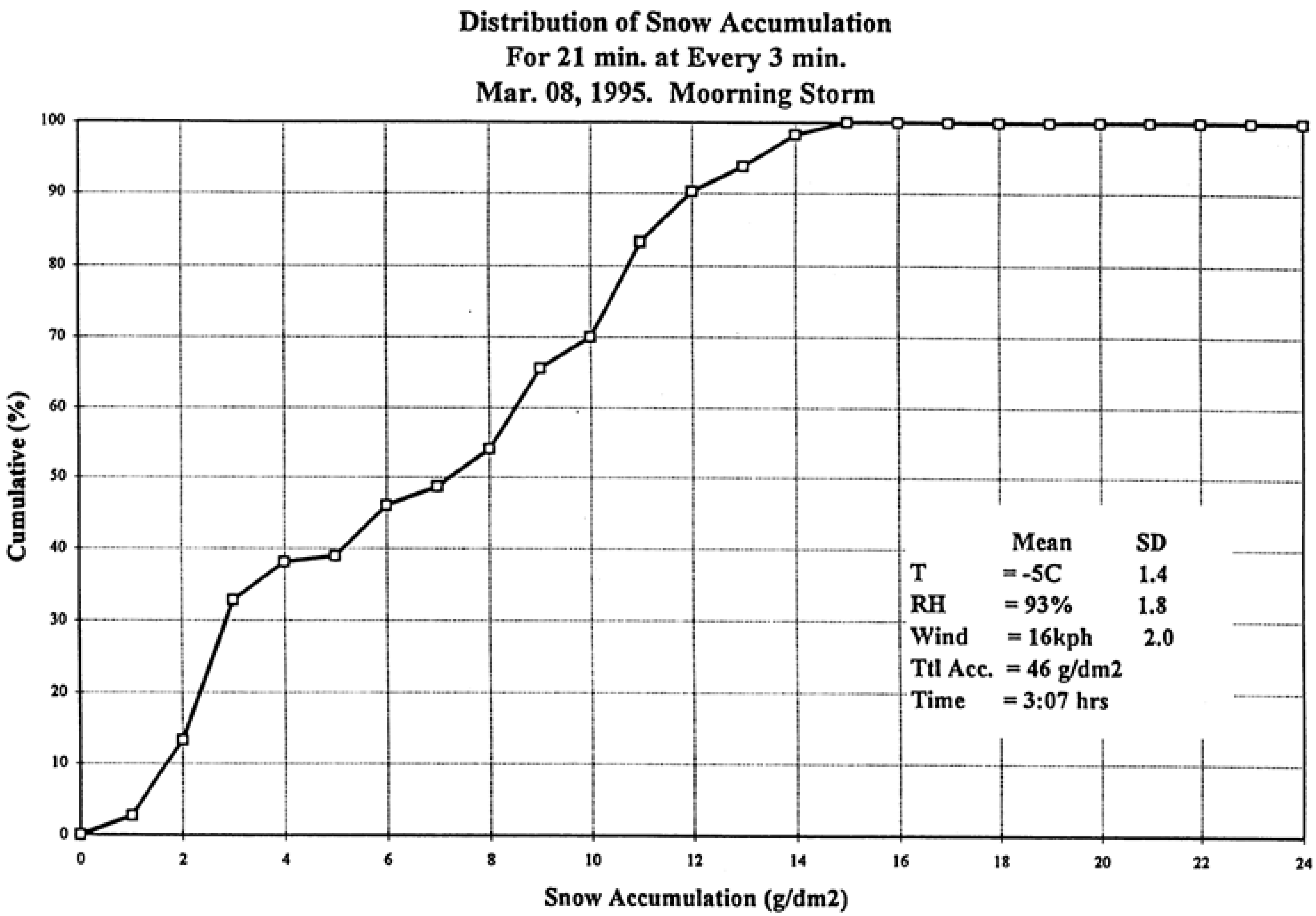
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 16, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -1.0C 0.7
RH = 100% 0.0
Wind = 26kph 2.2
Ttl Acc. = 89 g/dm2
Time = 05:40 hrs

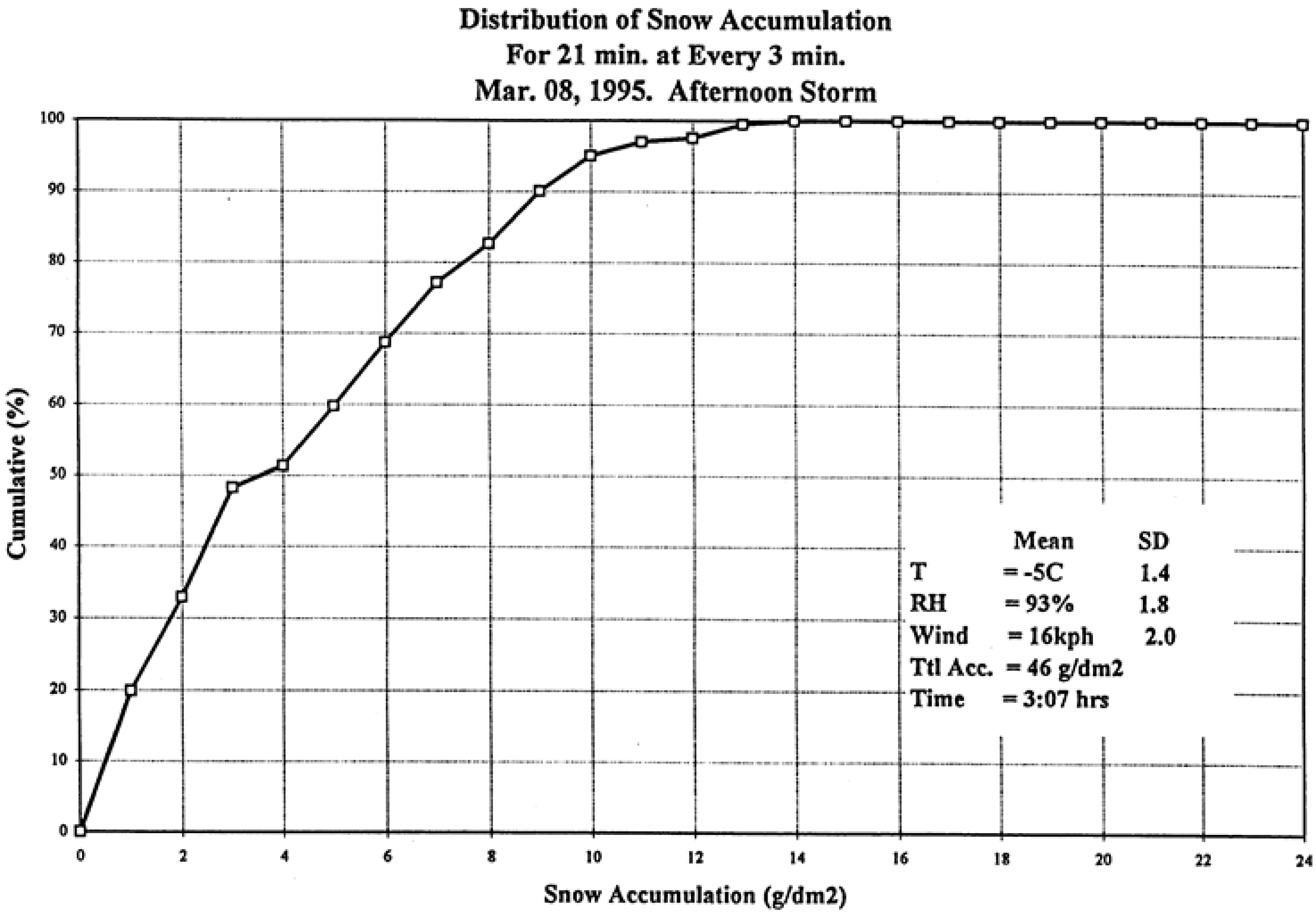

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 24, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -0.2C 0.0
RH = 99% 0.0
Wind = 7kph 2.1
Ttl Acc. = 34 g/dm2
Time = 06:20 hrs

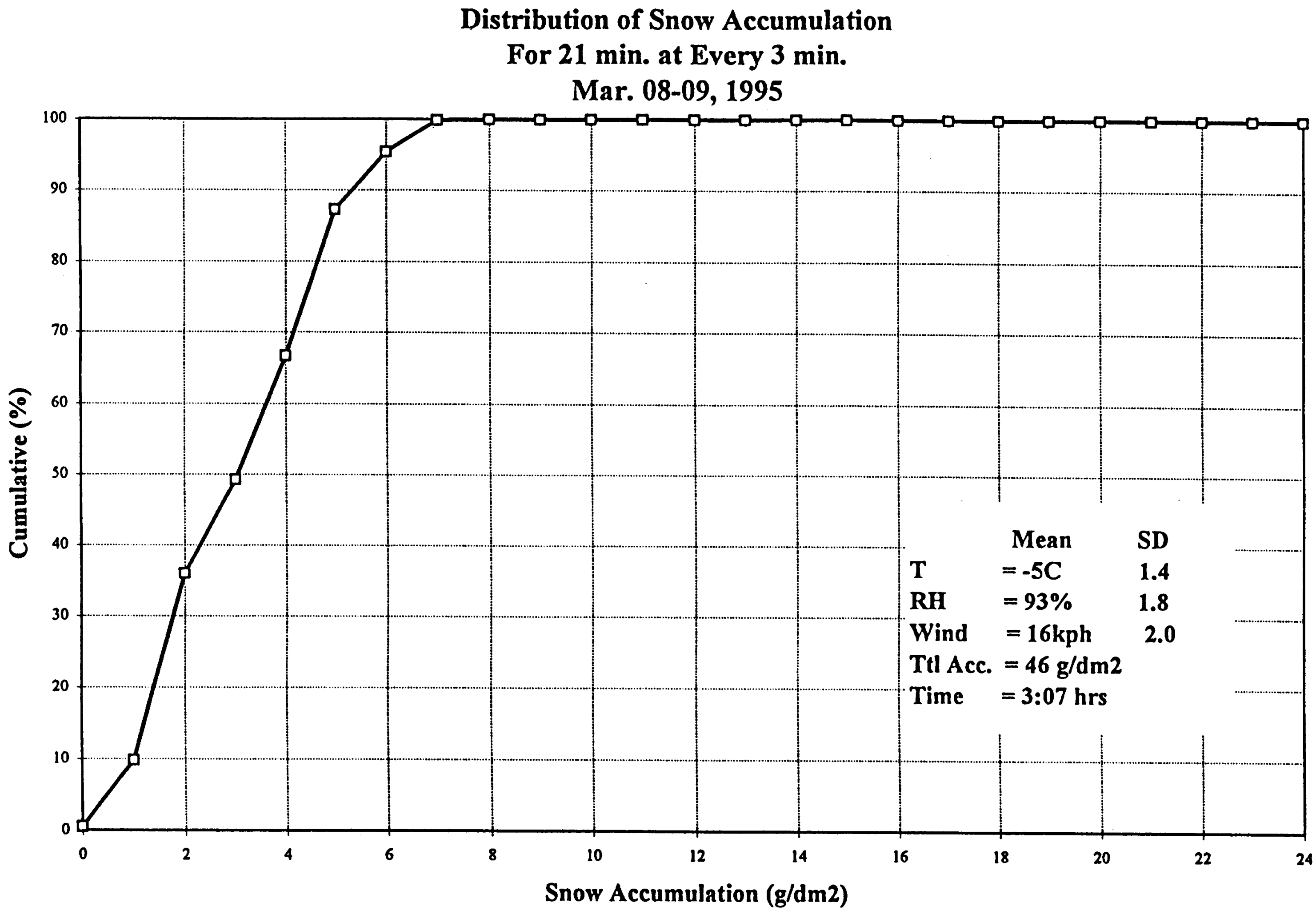


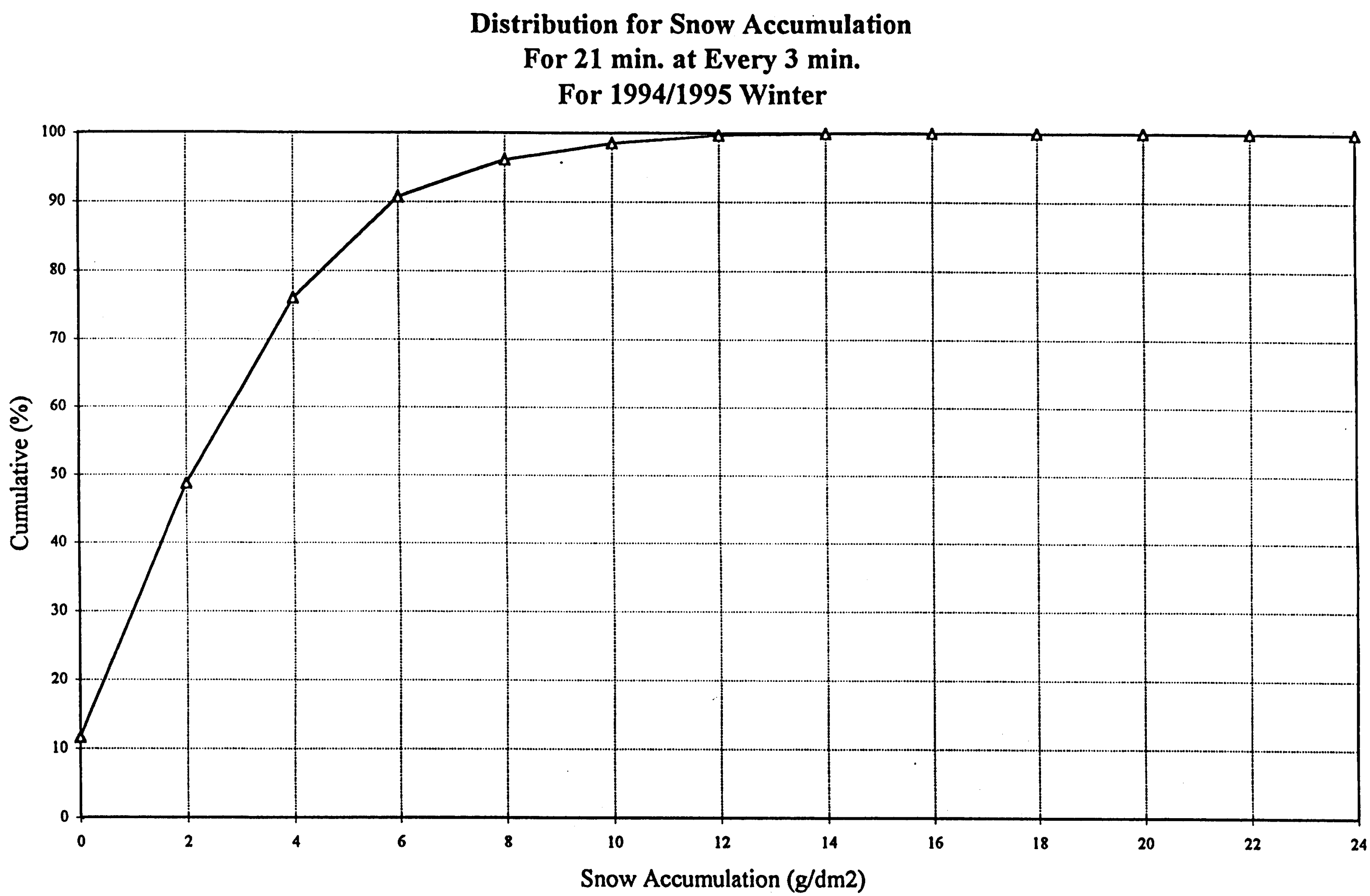
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 27, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -12C 0.2
RH = 86% 3.5
Wind = 19kph 1.1
Ttl Acc. = 74 g/dm2
Time = 10:00 hrs

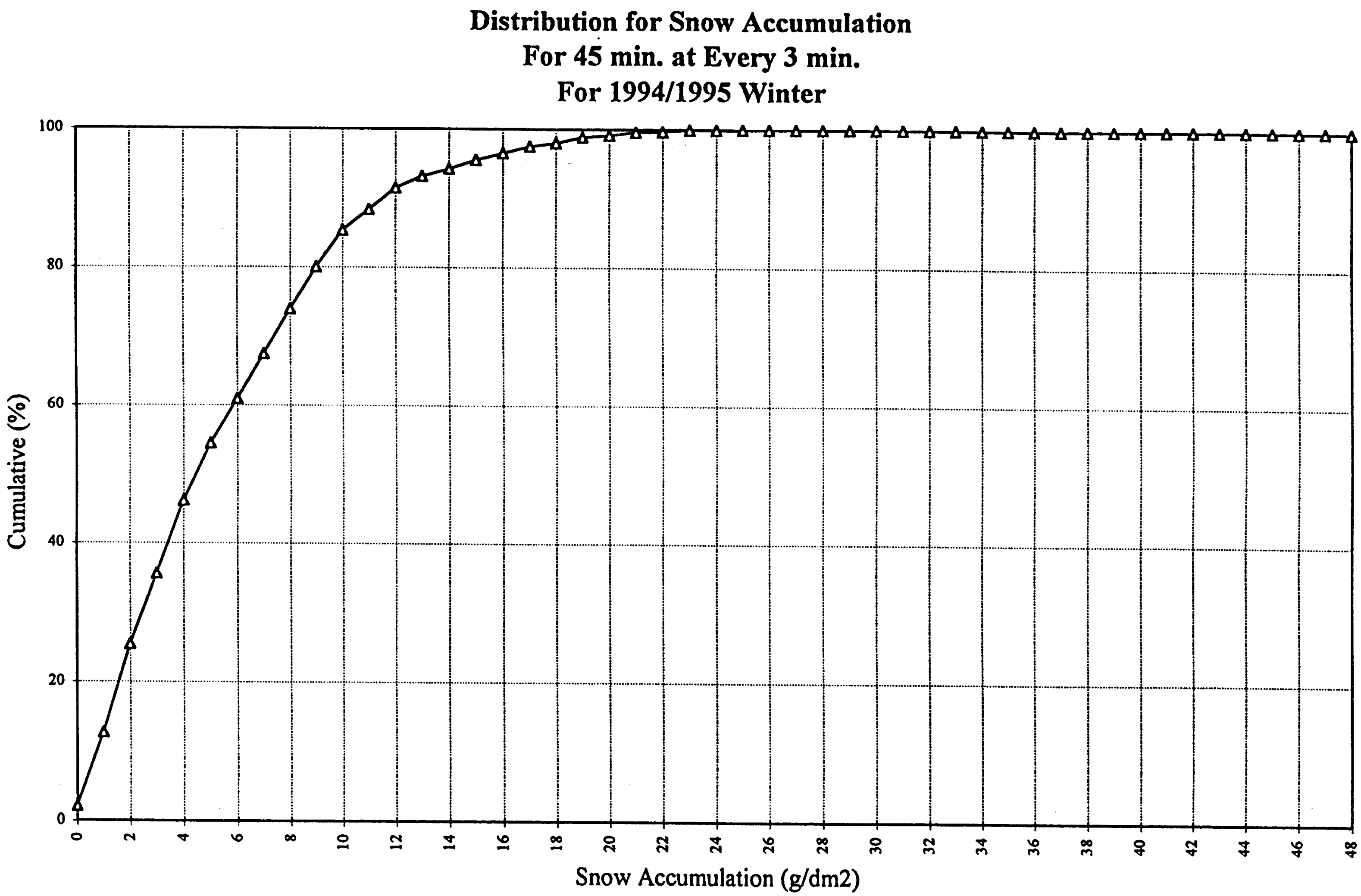

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Mar. 06, 1995)
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -7C 0.1
RH = 91% 1.4
Wind = 24kph 3.0
Ttl Acc. = 60 g/dm2
Time = 03:00 hrs

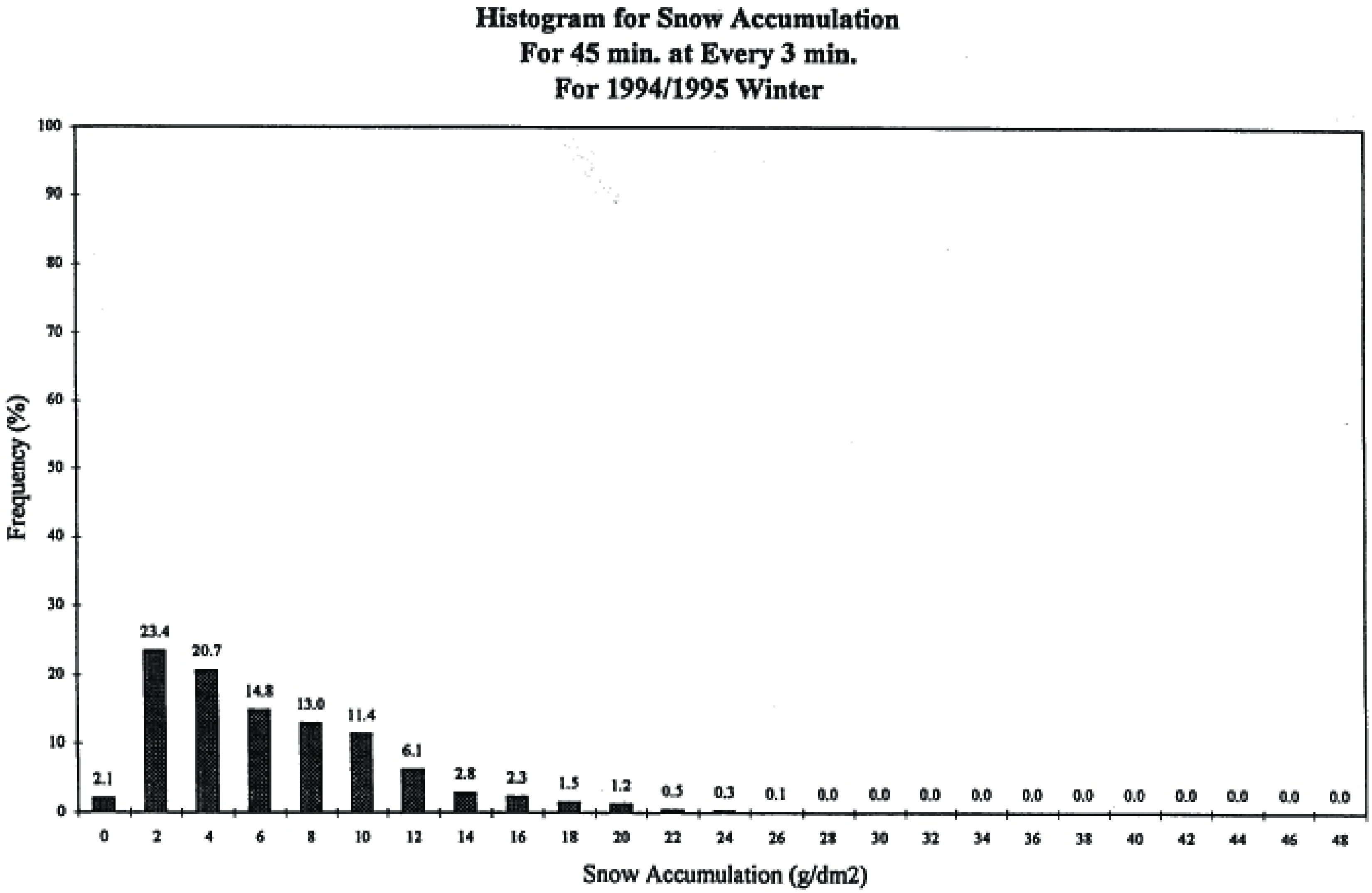

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
Mar. 08, 1995. Moorning Storm
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -5C 1.4
RH = 93% 1.8
Wind = 16kph 2.0
Ttl Acc. = 46 g/dm2
Time = 3:07 hrs

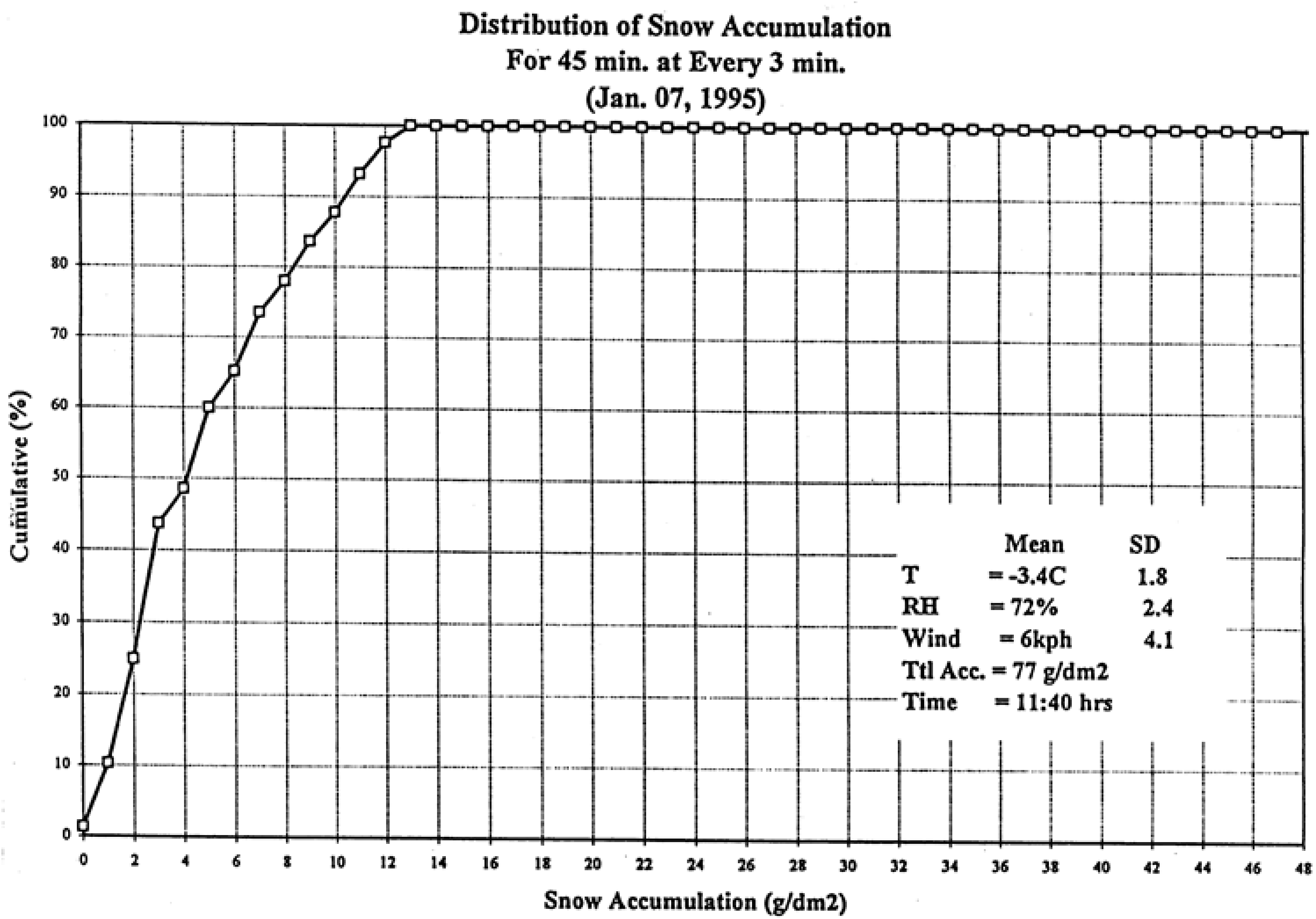

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
Mar. 08, 1995. Afternoon Storm
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean
SD
T = -5C 1.4
RH = 93% 1.8
Wind = 16kph 2.0
Ttl Acc. = 46 g/dm2
Time = 3:07 hrs

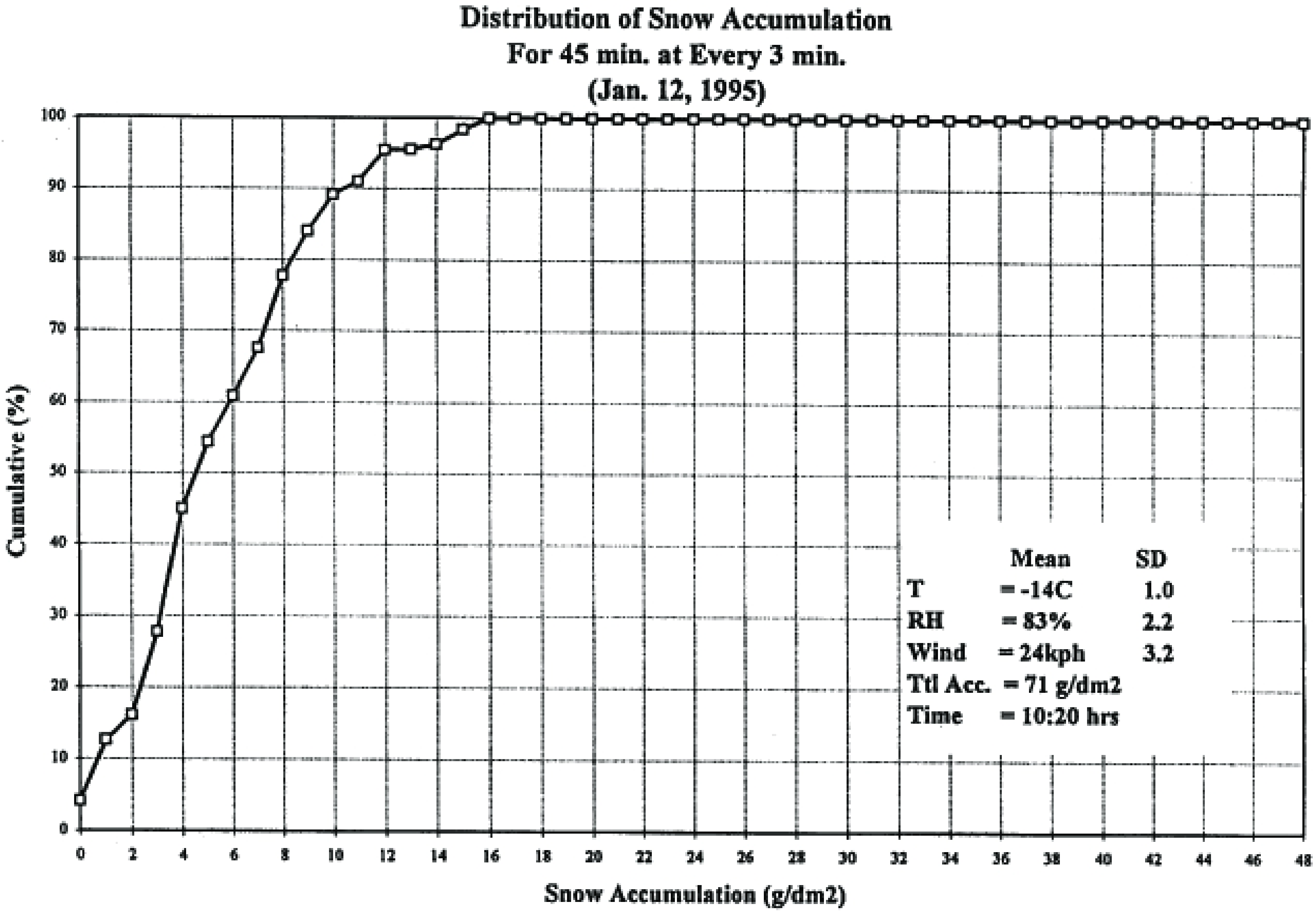

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
Mar. 08-09, 1995
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)
Mean SD
T = -5C 1.4
RH = 93% 1.8
Wind = 16kph 2.0
Ttl Acc. = 46 g/dm2
Time = 3:07 hrs

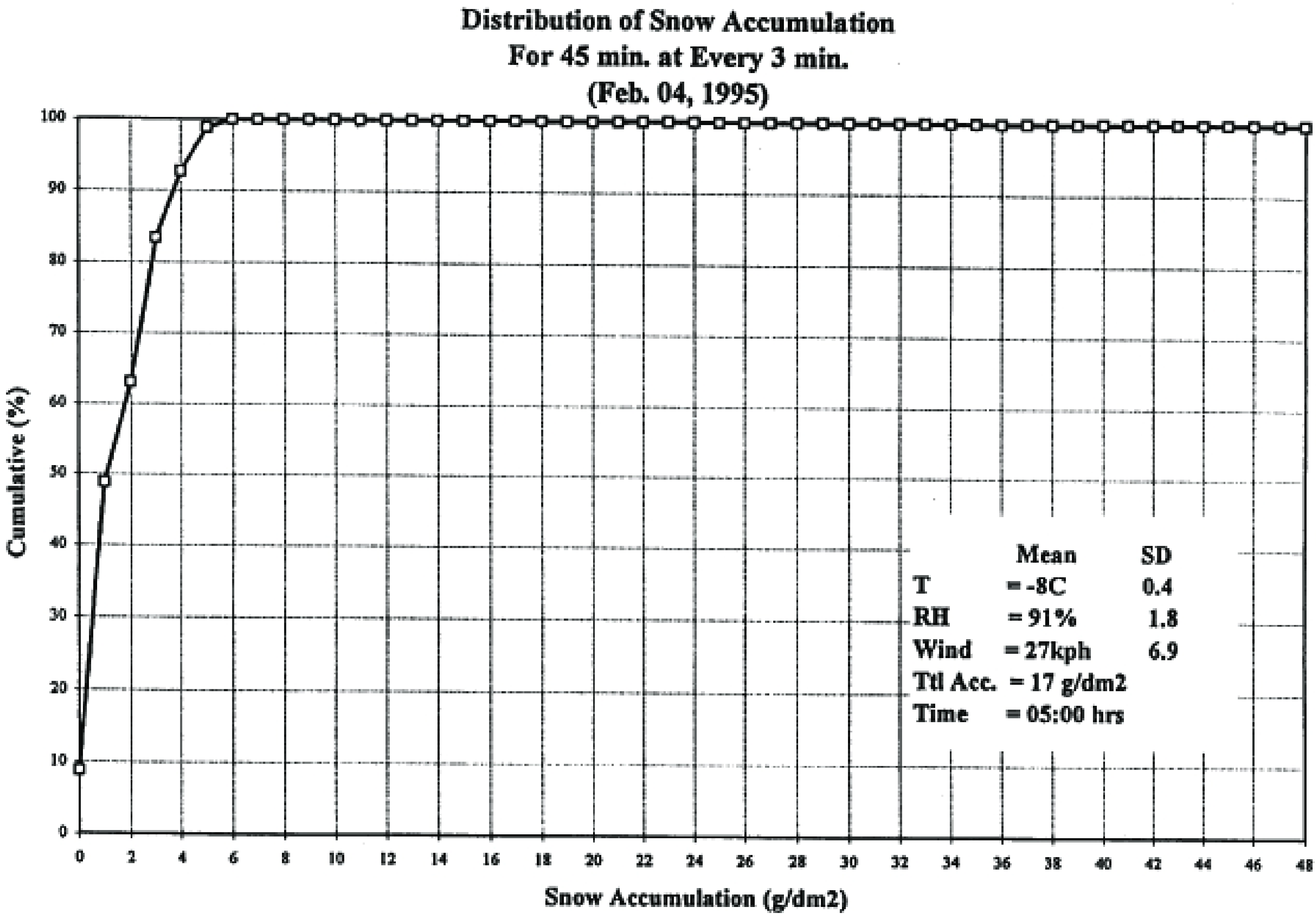

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1994/1995 Winter
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)


Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1994/1995 Winter
Cumulative (%)
0
20
40
60
80
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)

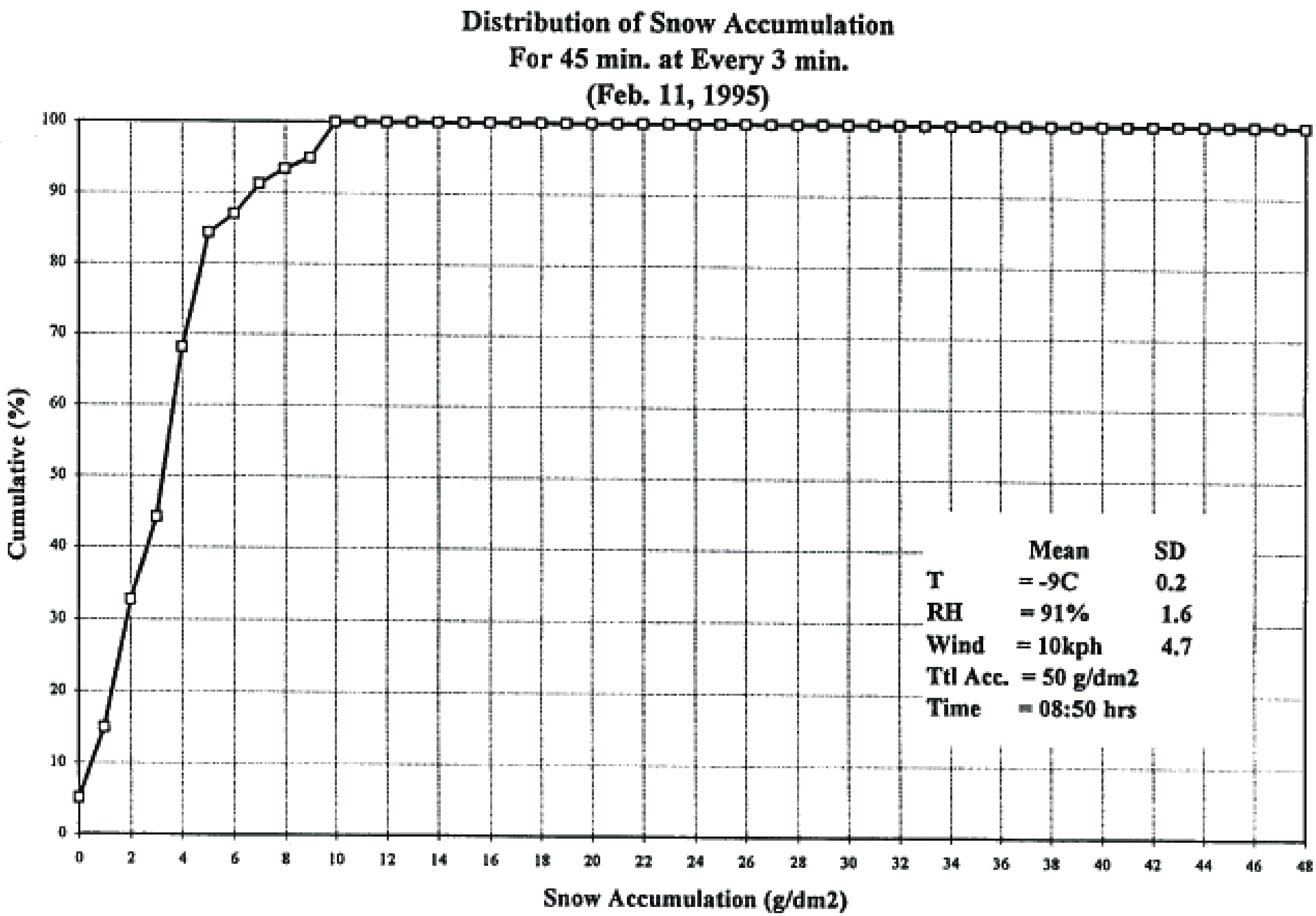

Histogram for Snow Accumulation
For 45 min. at Every 3 min.
For 1994/1995 Winter
Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
2.1
23.4
20.7
14.8
13.0
11.4
6.1
2.8
2.3
1.5
1.2
0.5
0.3
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)

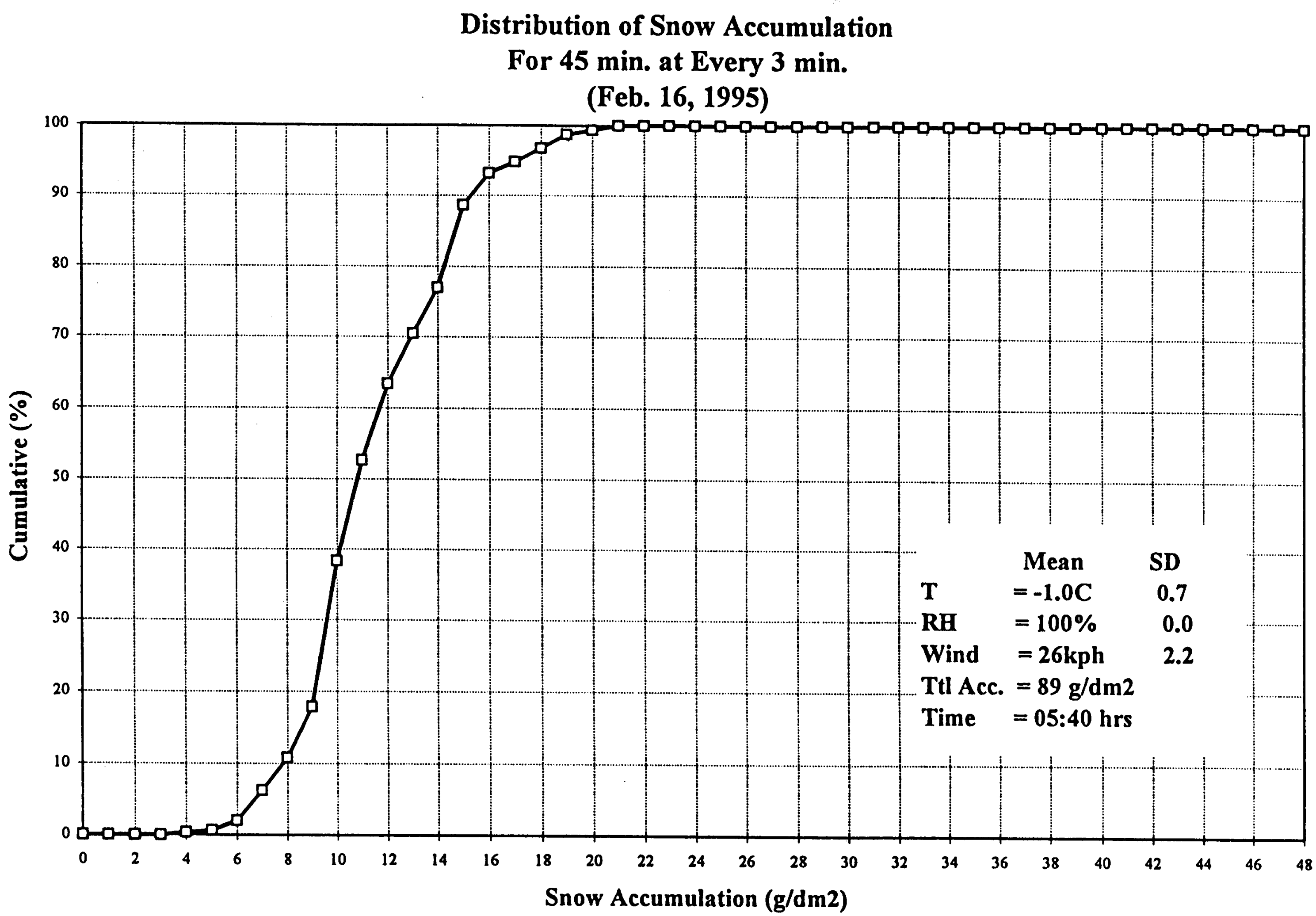

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 07, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)
Mean SD
T = -3.4C 1.8
RH = 72% 2.4
Wind = 6kph 4.1
Ttl Acc. = 77 g/dm2
Time = 11:40 hrs

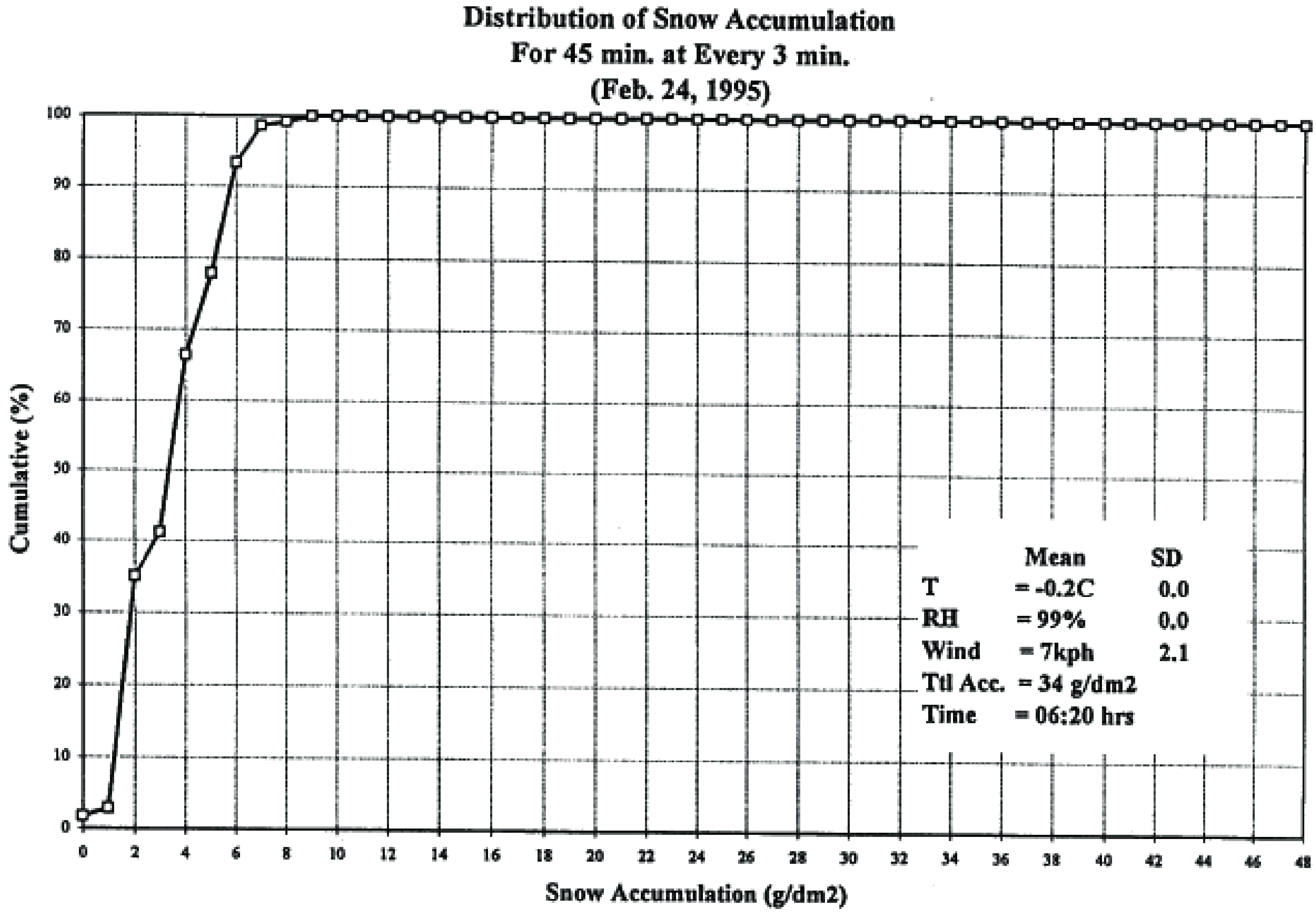

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 12, 1995)
Cumulative (%)
Snow Accumulation (g/dm2)
Mean
SD
T
= -14C
1.0
RH
= 83%
2.2
Wind
= 24kph
3.2
Ttl Acc.
= 71 g/dm2
Time
= 10:20 hrs

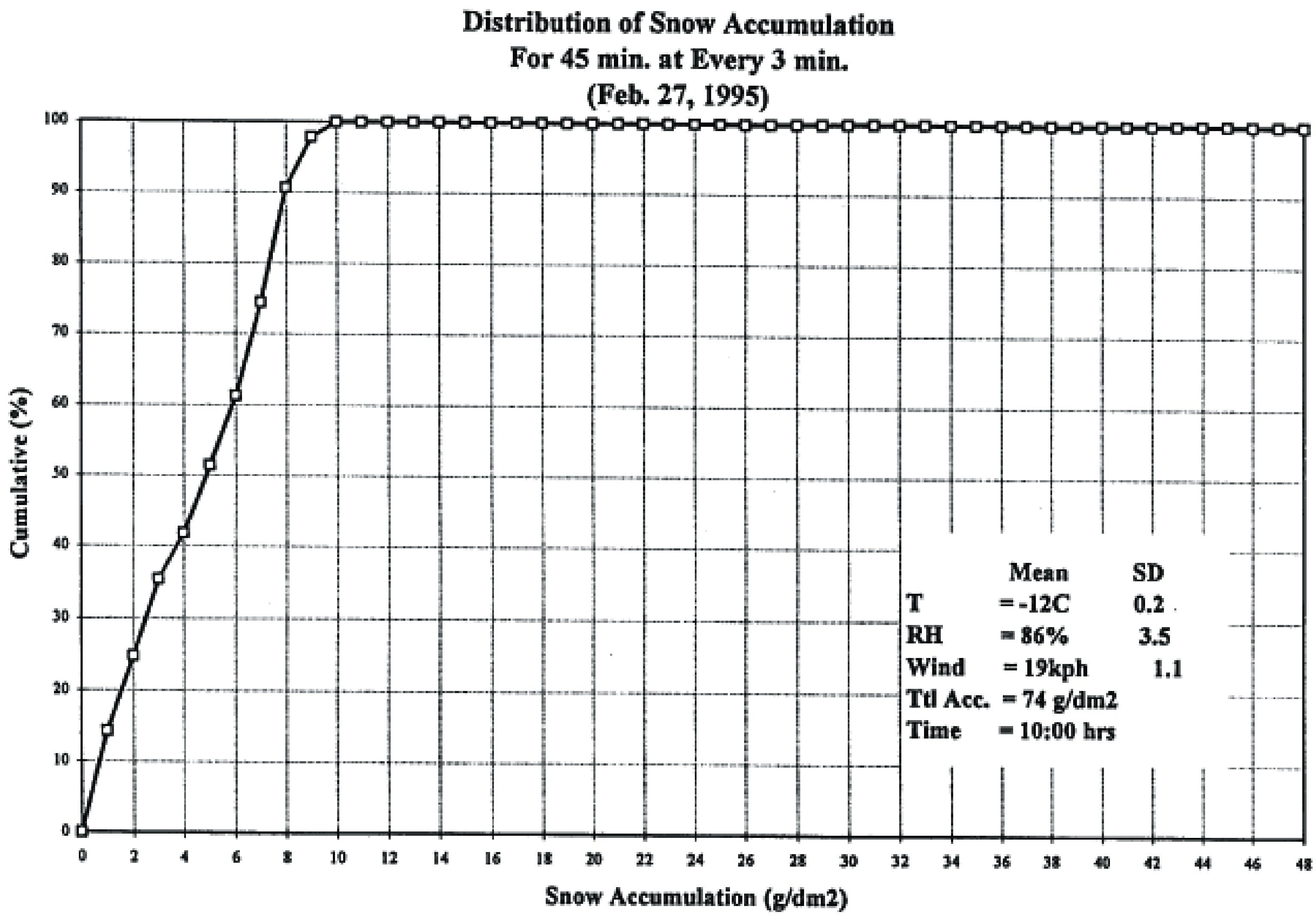


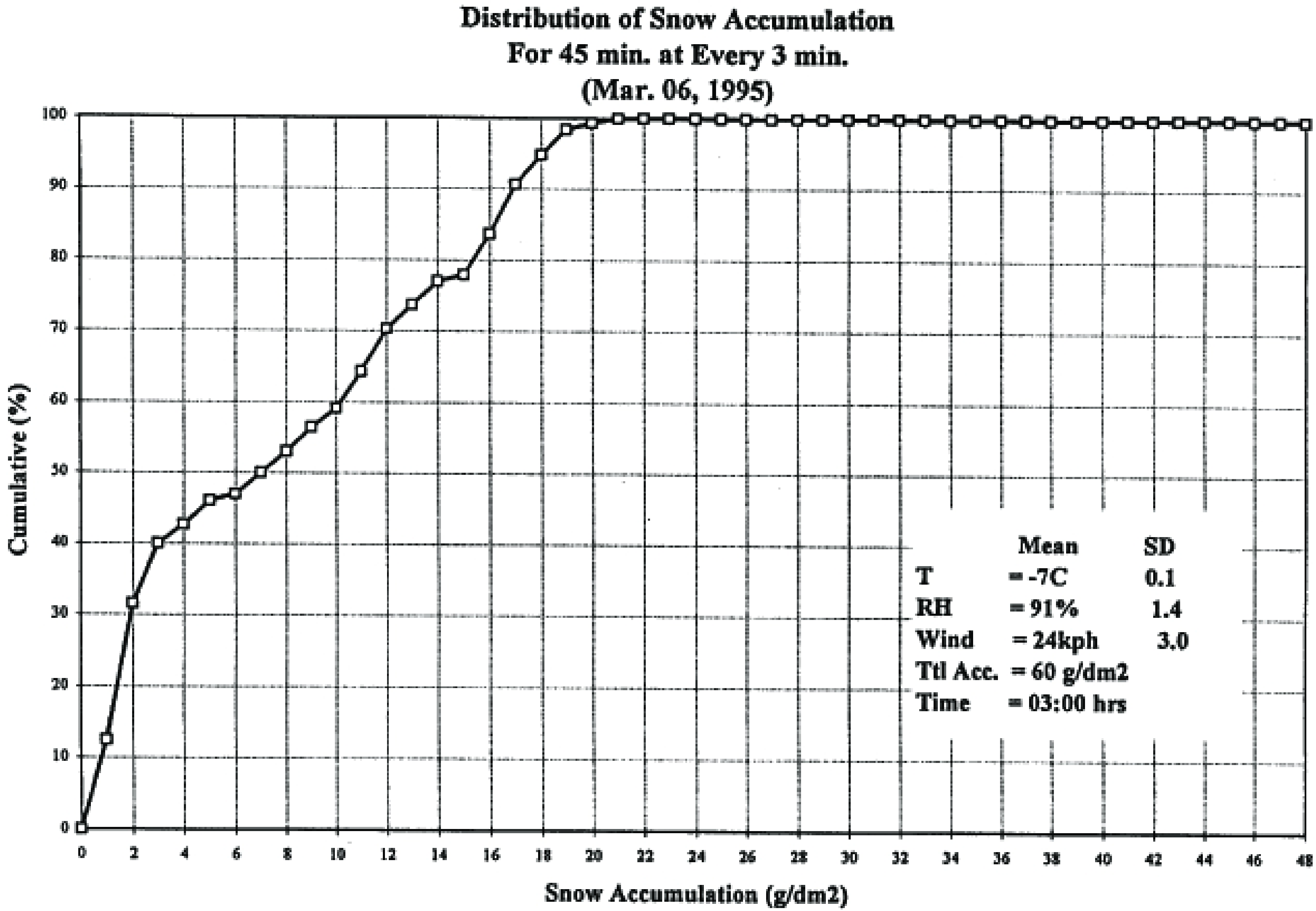
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 04, 1995)
Cumulative (%)
Snow Accumulation (g/dm2)
Mean SD
T = -8C 0.4
RH = 91% 1.8
Wind = 27kph 6.9
Ttl Acc. = 17 g/dm2
Time = 05:00 hrs


Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 11, 1995)
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)
Mean SD
T = -9C 0.2
RH = 91% 1.6
Wind = 10kph 4.7
Ttl Acc. = 50 g/dm2
Time = 08:50 hrs

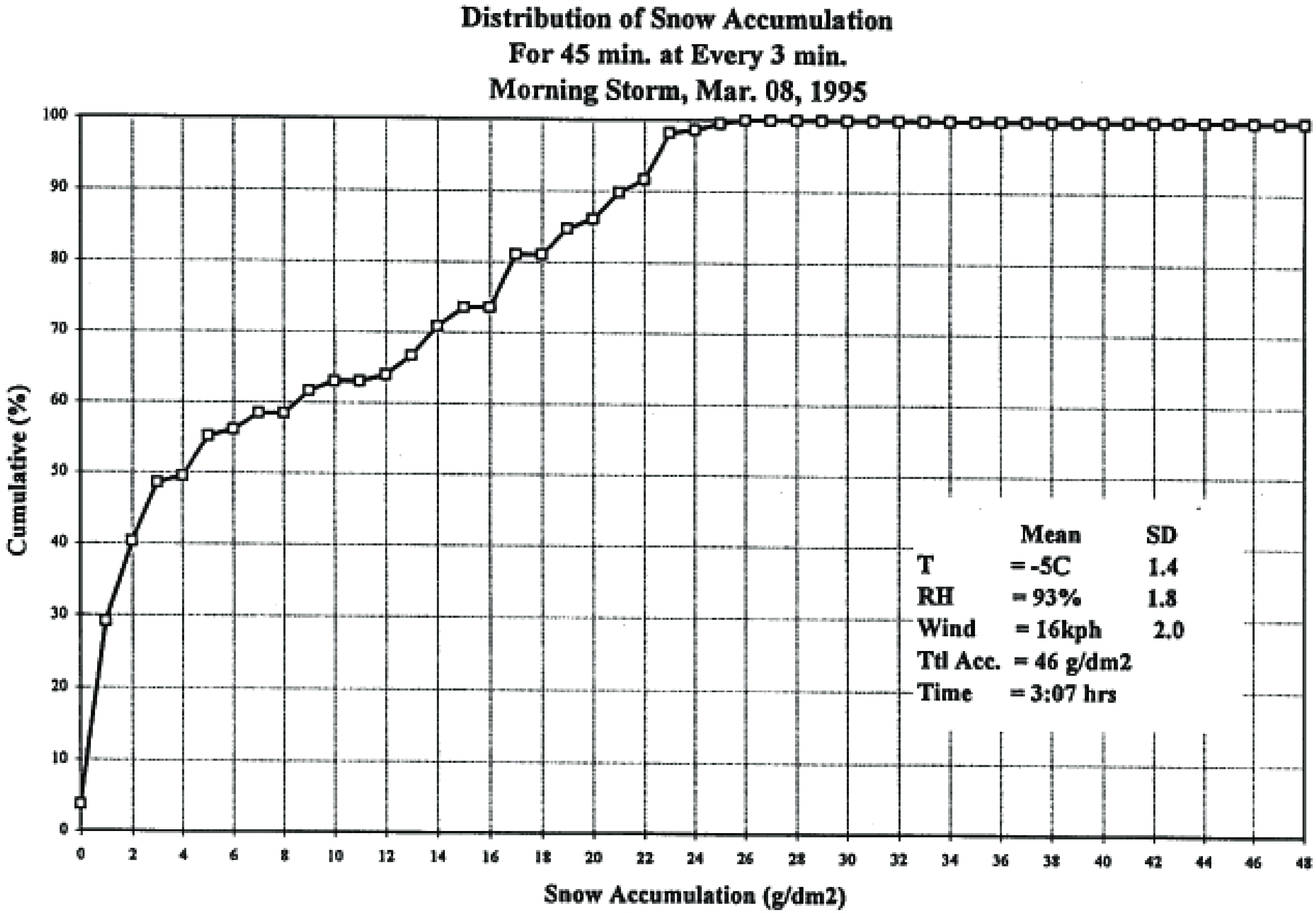

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 16, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)
Mean SD
T = -1.0C 0.7
RH = 100% 0.0
Wind = 26kph 2.2
Ttl Acc. = 89 g/dm2
Time = 05:40 hrs


Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 24, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)
Mean SD
T = -0.2C 0.0
RH = 99% 0.0
Wind = 7kph 2.1
Ttl Acc. = 34 g/dm2
Time = 06:20 hrs

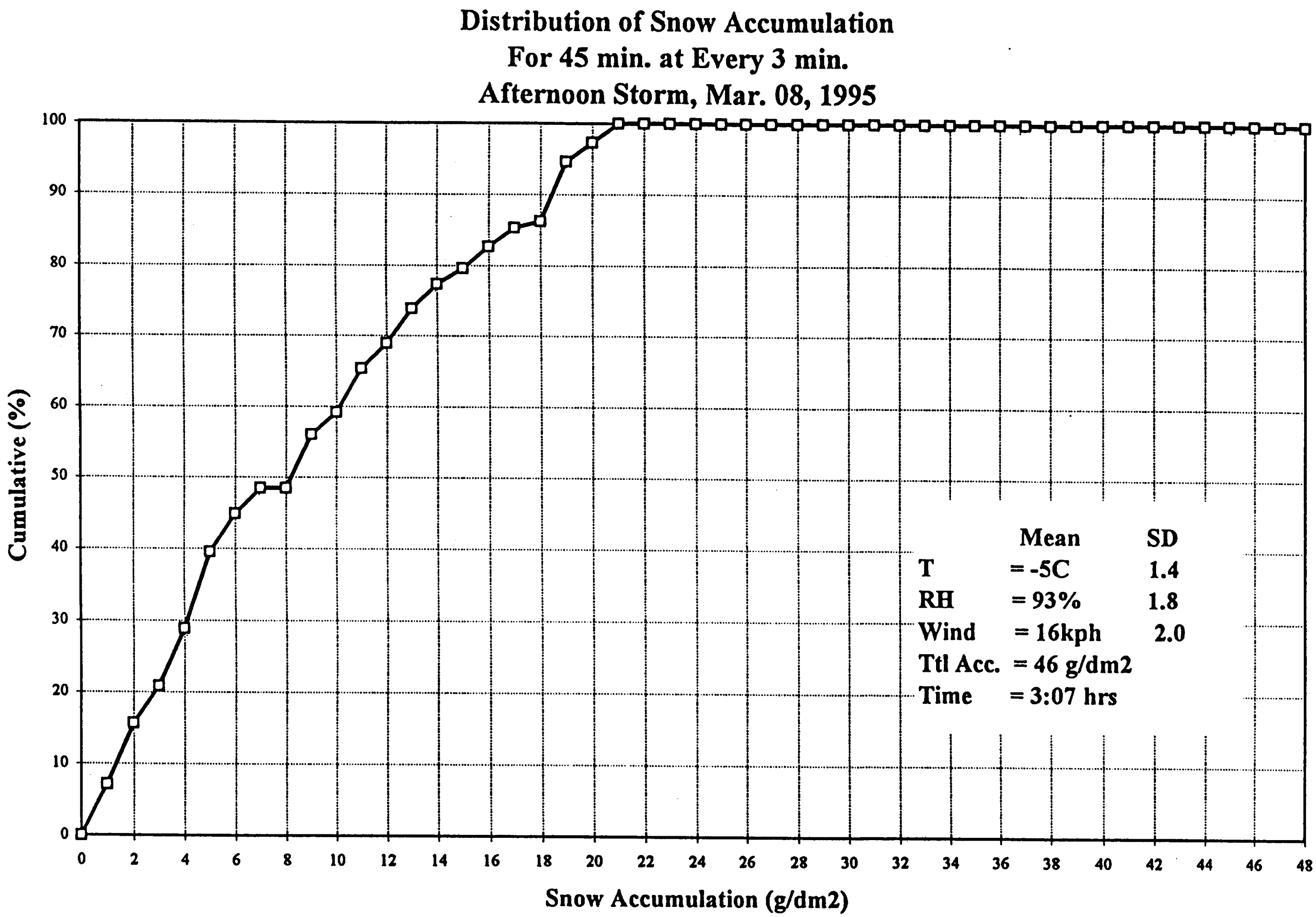

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 27, 1995)
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)
Mean SD
T = -12C 0.2
RH = 86% 3.5
Wind = 19kph 1.1
Ttl Acc. = 74 g/dm2
Time = 10:00 hrs

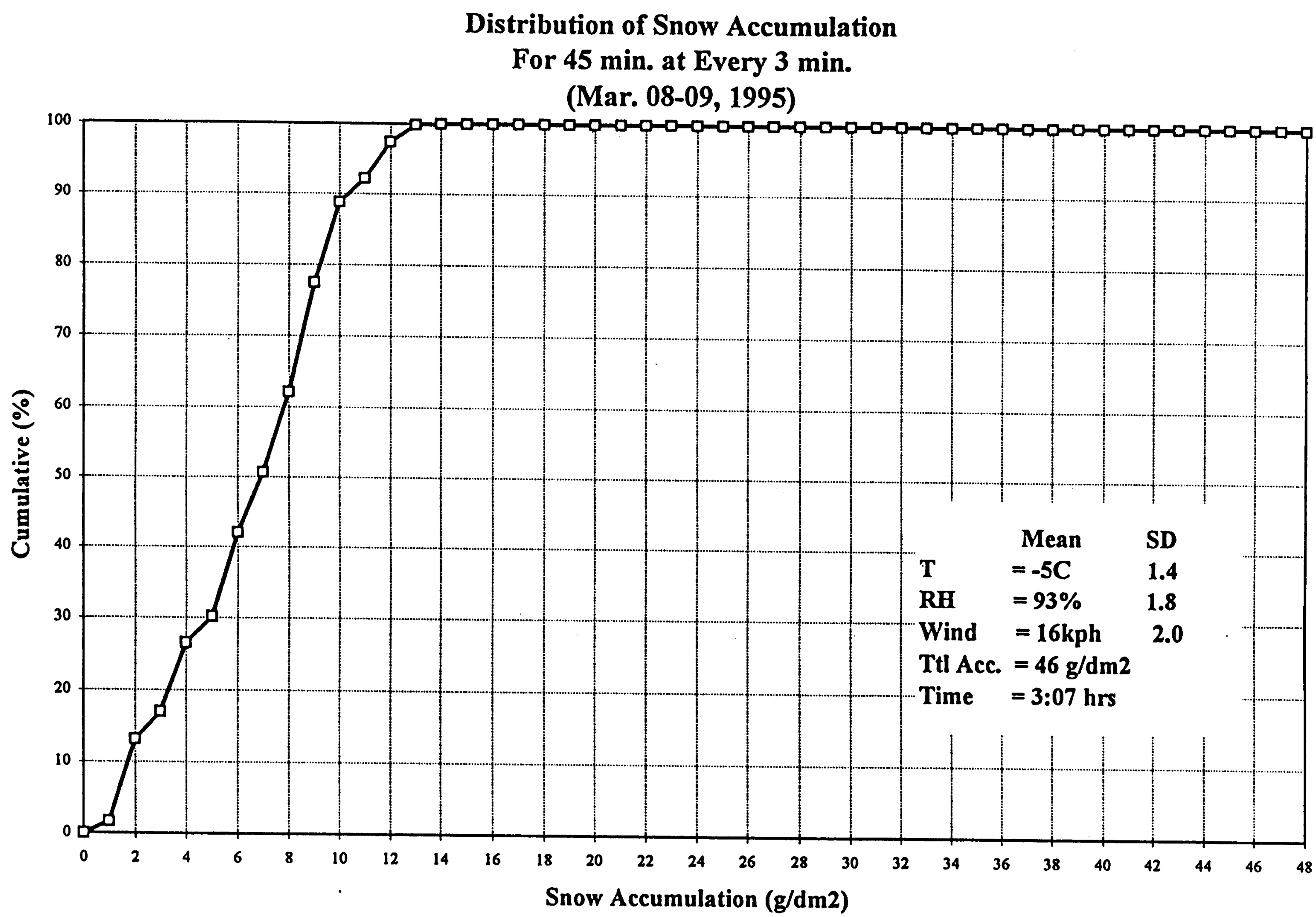


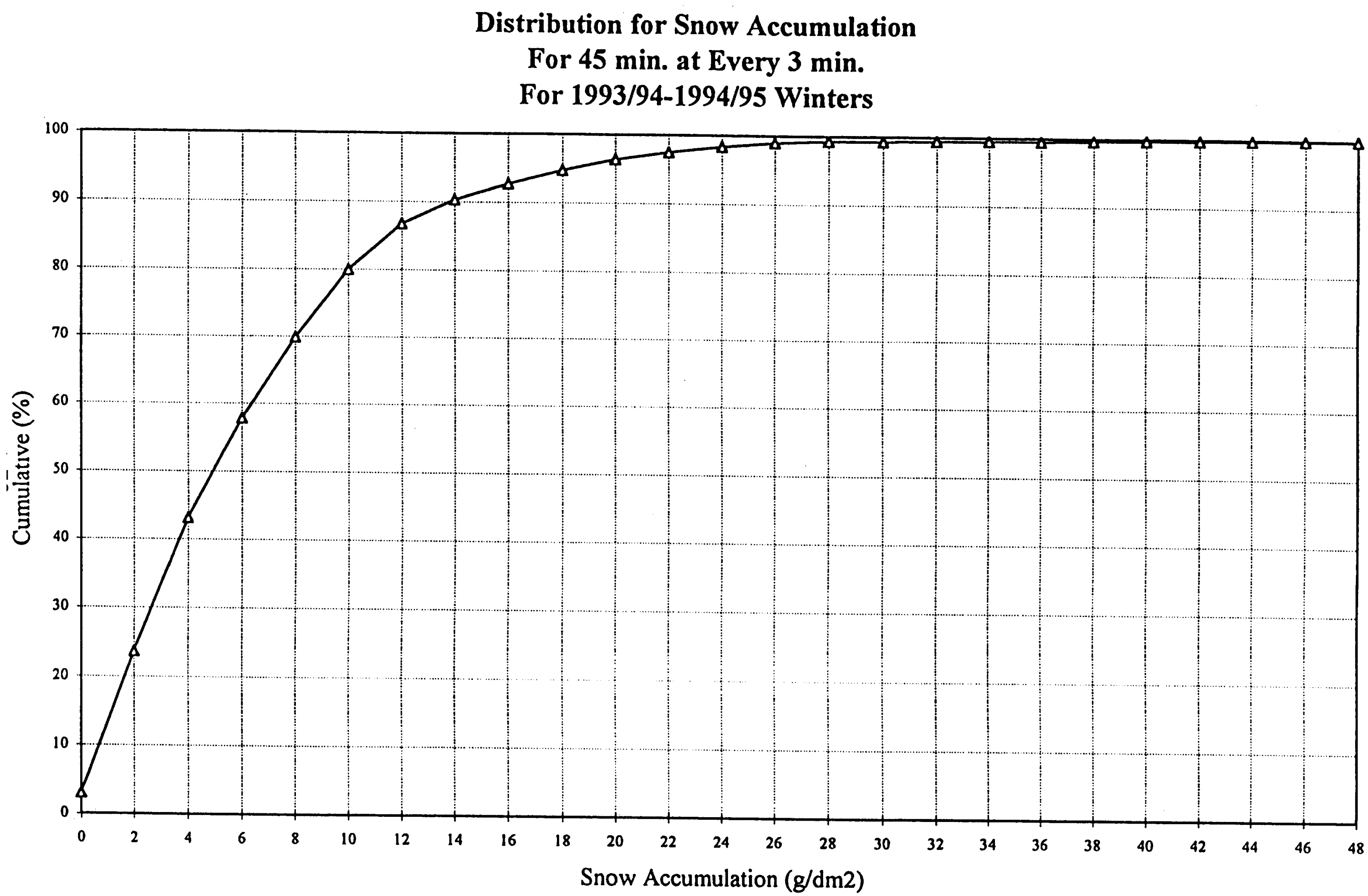
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 06, 1995)
Cumulative (%)
Snow Accumulation (g/dm2)
0
10
20
30
40
50
60
70
80
90
100
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Mean SD
T = -7C 0.1
RH = 91% 1.4
Wind = 24kph 3.0
Ttl Acc. = 60 g/dm2
Time = 03:00 hrs



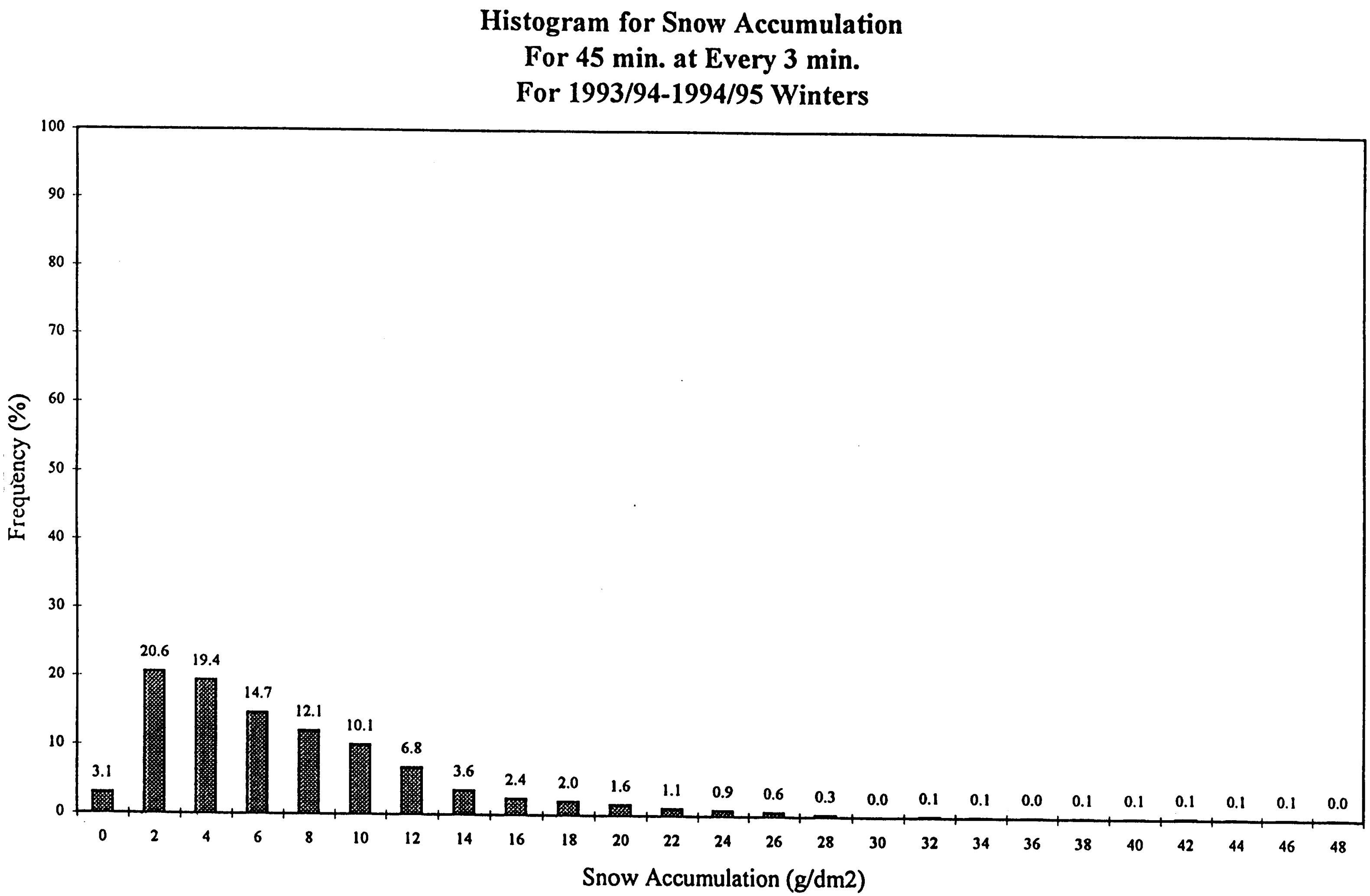
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
Morning Storm, Mar. 08, 1995
Cumulative (%)
Snow Accumulation (g/dm2)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Mean
SD
T = -5C 1.4
RH = 93% 1.8
Wind = 16kph 2.0
Ttl Acc. = 46 g/dm2
Time = 3:07 hrs


Distribution of Snow Accumulation
For 45 min. at Every 3 min.
Afternoon Storm, Mar. 08, 1995
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)
Mean SD
T = -5C 1.4
RH = 93% 1.8
Wind = 16kph 2.0
Ttl Acc. = 46 g/dm2
Time = 3:07 hrs

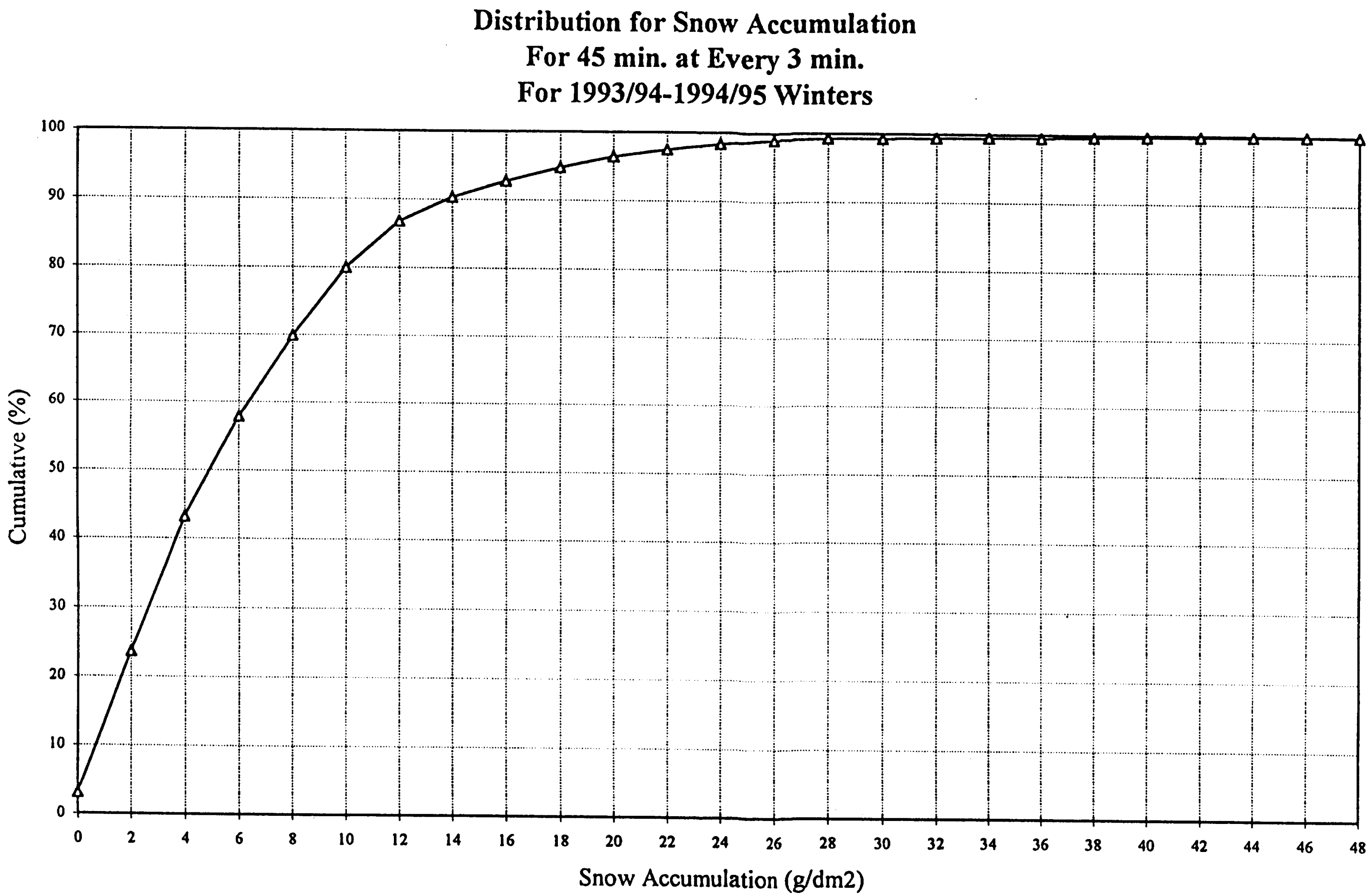

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 08-09, 1995)
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)
Mean SD
T = -5C 1.4
RH = 93% 1.8
Wind = 16kph 2.0
Ttl Acc. = 46 g/dm2
Time = 3:07 hrs

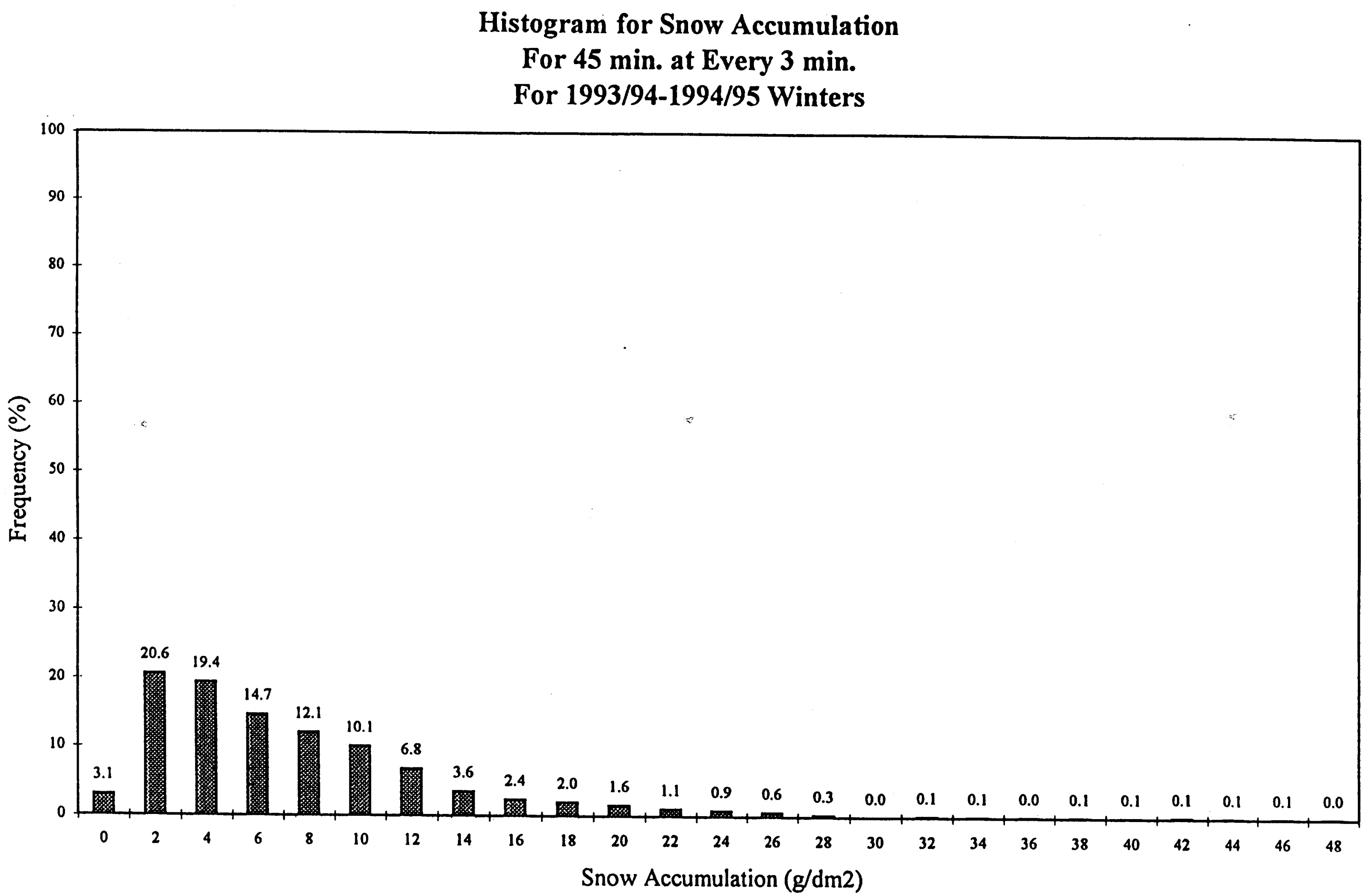


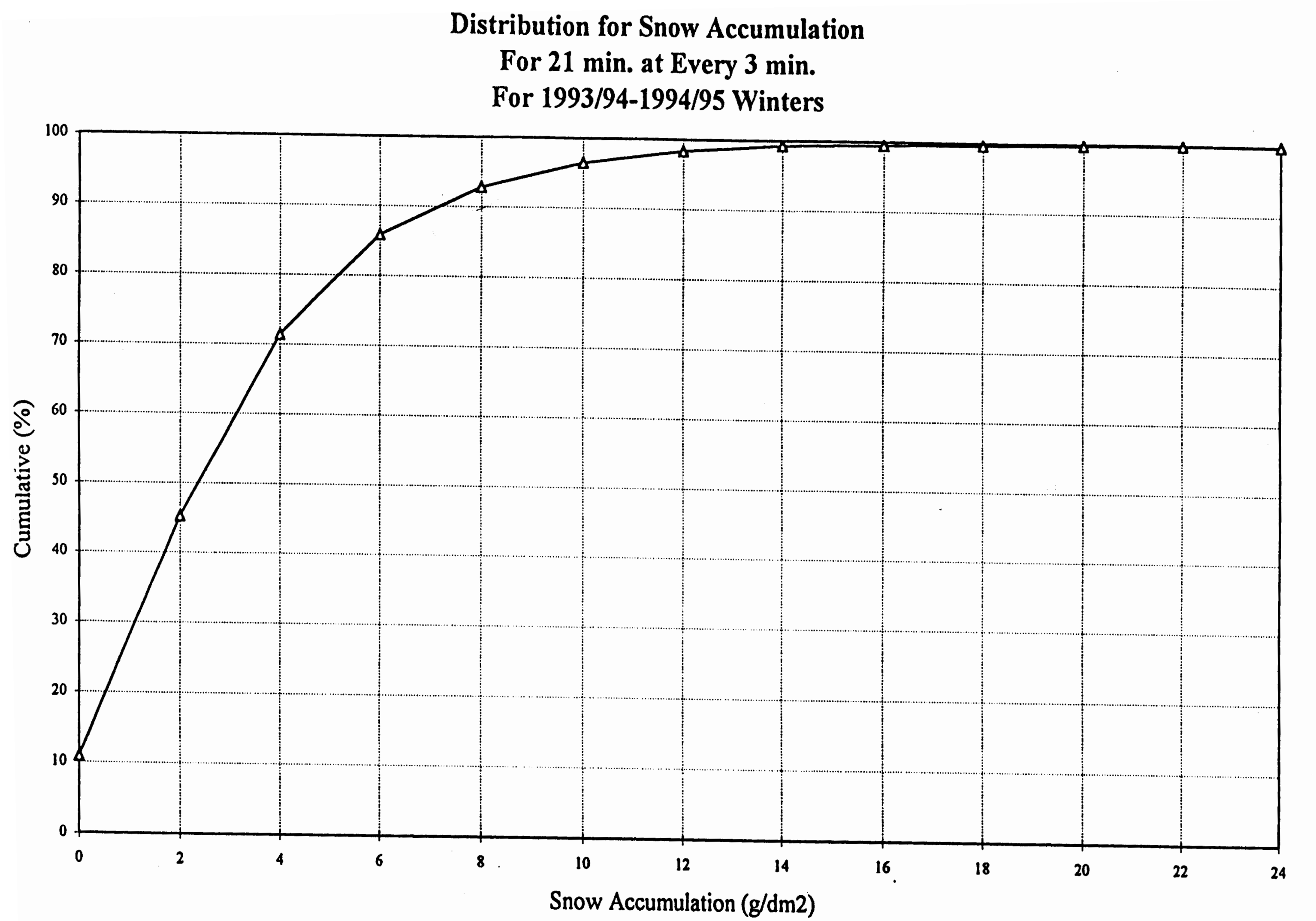
Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/94-1994/95 Winters
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)

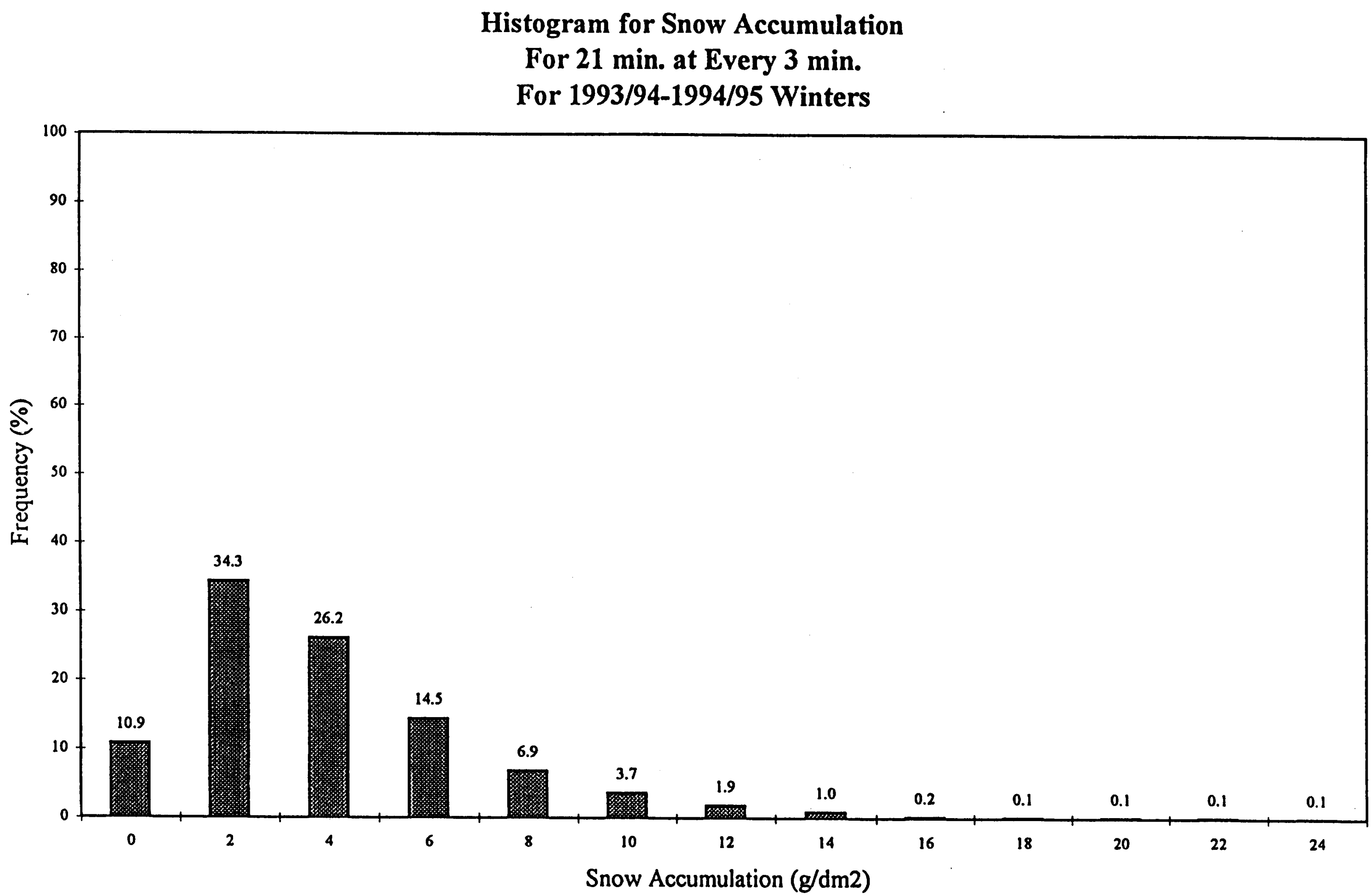


Histogram for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/94-1994/95 Winters
Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
3.1
20.6
19.4
14.7
12.1
10.1
6.8
3.6
2.4
2.0
1.6
1.1
0.9
0.6
0.3
0.0
0.1
0.1
0.0
0.1
0.1
0.1
0.1
0.1
0.0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Snow Accumulation (g/dm2)


Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/94-1994/95 Winters
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)


Histogram for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/94-1994/95 Winters
Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
3.1
20.6
19.4
14.7
12.1
10.1
6.8
3.6
2.4
2.0
1.6
1.1
0.9
0.6
0.3
0.0
0.1
0.1
0.0
0.1
0.1
0.1
0.1
0.1
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Snow Accumulation (g/dm2)


Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/94-1994/95 Winters
Cumulative (%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)


Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/94-1994/95 Winters
Frequency (%)
100
90
80
70
60
50
40
30
20
10
0
10.9
34.3
26.2
14.5
6.9
3.7
1.9
1.0
0.2
0.1
0.1
0.1
0.1
0
2
4
6
8
10
12
14
16
18
20
22
24
Snow Accumulation (g/dm2)

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APPENDIX D

AES STUDY

FREQUENCY OF OCCURRENCE OF WATER EQUIVALENT PRECIPITATION RATES AS A FUNCTION OF AVERAGING TIME, TEMPERATURE AND TYPE

Draft
Frequency Of Occurrence Of
Water Equivalent Precipitation Rates
as a function of
AVERAGING TIME, TEMPERATURE AND TYPE

1.0 Introduction

The proposed Holdover Time Tables give the failure time of various types of anti-icing fluids for different precipitation types, temperatures and water equivalent precipitation rates. In order to specify realistic precipitation rates in these tables, the cumulative probability distribution of rates averaged over the different holdover times must be determined. This report presents these distributions using data collected from an experimental site situated at Pearson International Airport established in 1995 with Dryden Commission Implementation Project funding to study now casting of on-ground aircraft icing.

2.0 Precipitation rate measurement

There is no internationally recognized “reference” instrumentation for measuring precipitation rate. Standard automated weighing gauges do not have sufficient resolution to report rate with the minutely time resolution required. Meteorological observers report an “intensity” of precipitation in four categories: very light, light, moderate and heavy. This is based on a broad classification of rate which is inadequate for the now casting of the holdover times. The observer also makes climatological measurements of accumulated amounts of precipitation every six hours. In the case of frozen precipitation the amount reported is the “water equivalent” of the melted precipitation.

One of the objectives of the experiment at Pearson International Airport (YYZ) was to evaluate the performance of new technologies designed to measure precipitation rates in both liquid and frozen phases with minutely reporting resolution. Several sensors were evaluated and it was determined that a small Doppler radar called the Precipitation Occurrence Sensor System (POSS) agreed the best with the observed 6-hourly accumulated precipitation amounts. This study will be reported on elsewhere.

2.1 POSS

The Precipitation Occurrence Sensor System is a small Doppler X-band radar designed by the Atmospheric Environment Service as a present weather sensor for its automatic weather observing stations. It is commercially manufactured under license by Andrew Antenna, Canada. The sensor reports every minute the occurrence, type, intensity, rate and accumulation of precipitation.

The precipitation rate is estimated using the same method as is done with large-scale precipitation radars. The method, referred to as the "Z-R" method, measures the radar reflectivity factor (Z) to estimate the precipitation rate (R).

3.0 Analysis

The water equivalent precipitation rate is reported by the POSS every minute. These rates are averaged using a "sliding box car " for the three specified periods used in the holdover time tables: 6, 20 and 35 minutes. The data is then classified into three precipitation types as reported by the meteorological observer at the site: snow, freezing rain of light intensity and freezing drizzle. In the case of mixed precipitation types the data is included in a class if that type is reported as one of the mixed types. The data is further classified into the four temperature ranges proposed in the Holdover time tables: 0 to -3°C, -3 to -7°C, -7 to -14°C and -14 to -25°C.

The frequency of occurrence with respect to the average water equivalent precipitation rate is determined. The average is included in these statistics only if at least half the minutes have non-zero precipitation rates. In addition, if there is missing data, then at least have the averaging time must have valid measurements. This approach deliberately excludes intermittent precipitation from biasing the percentile statistics.

4.0 Results

The results are presented graphically in plots of cumulative probability versus precipitation rate averaged over a specified period. The cumulative probability at a specific precipitation rate is the percentage of the dataset with precipitation rates less than that rate. There is one graph for each combination of averaging time and temperature (see Figures below).

Each graph displays a curve for each of the three precipitation classes.

In snow, the 95% percentile of the water equivalent precipitation rate averaged over 6 minutes decreases with temperature from about 1.6 mm/h at 0 to -3°C to 0.8 mm/h at -14 to -25°C. Similar results were found for the other averaging times.

The 95% percentile for light freezing rain is 4.3 mm/h for a 6-minute averaging time in the temperature range 0 to -3°C. Light freezing rain did not occur below -3°C.

There were few occurrences of freezing drizzle from this location during the experimental period.

A second set of graphs compares the effect of changing the averaging time for calculating the precipitation rate for snow and freezing rain of light intensity.

The cumulative probability curves in snow for the temperature range 0 to -3°C are very similar, with the 95% percentile constant at 1.6 mm/h.

In light freezing rain the 95% percentile is also quite constant although other percentiles are more strongly affected.

The averaging time will have the greatest influence when the precipitation rate is variable. This preliminary analysis indicates that the rates in snow are less variable than in light freezing rain.

B.E. Sheppard
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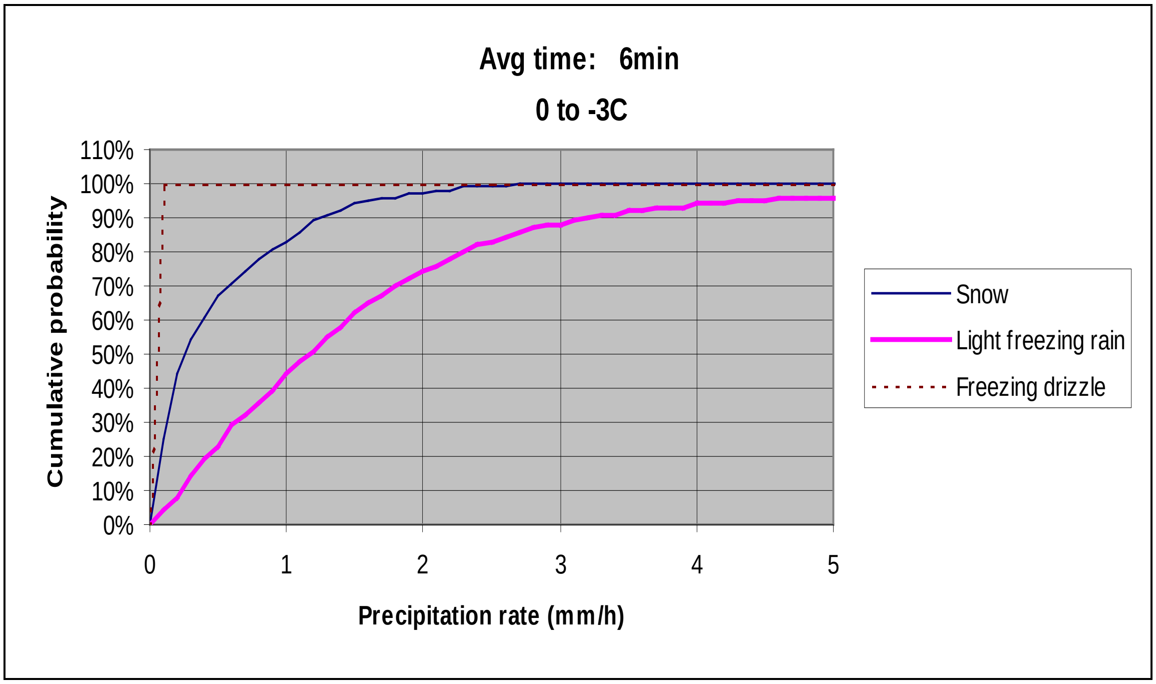
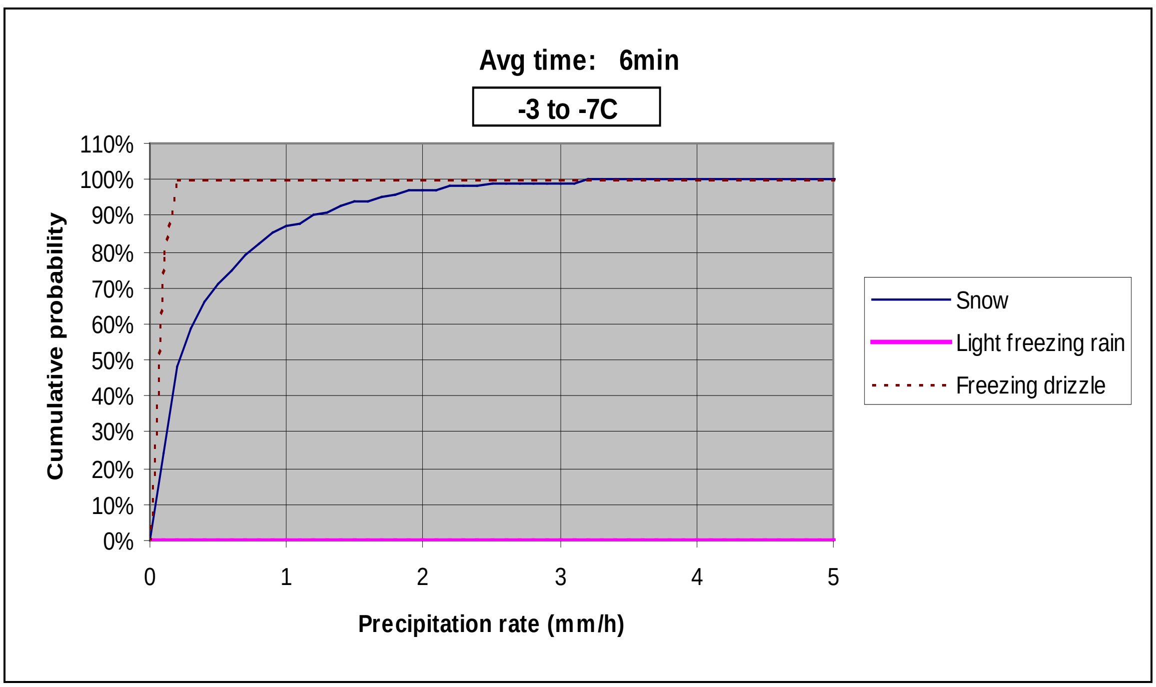
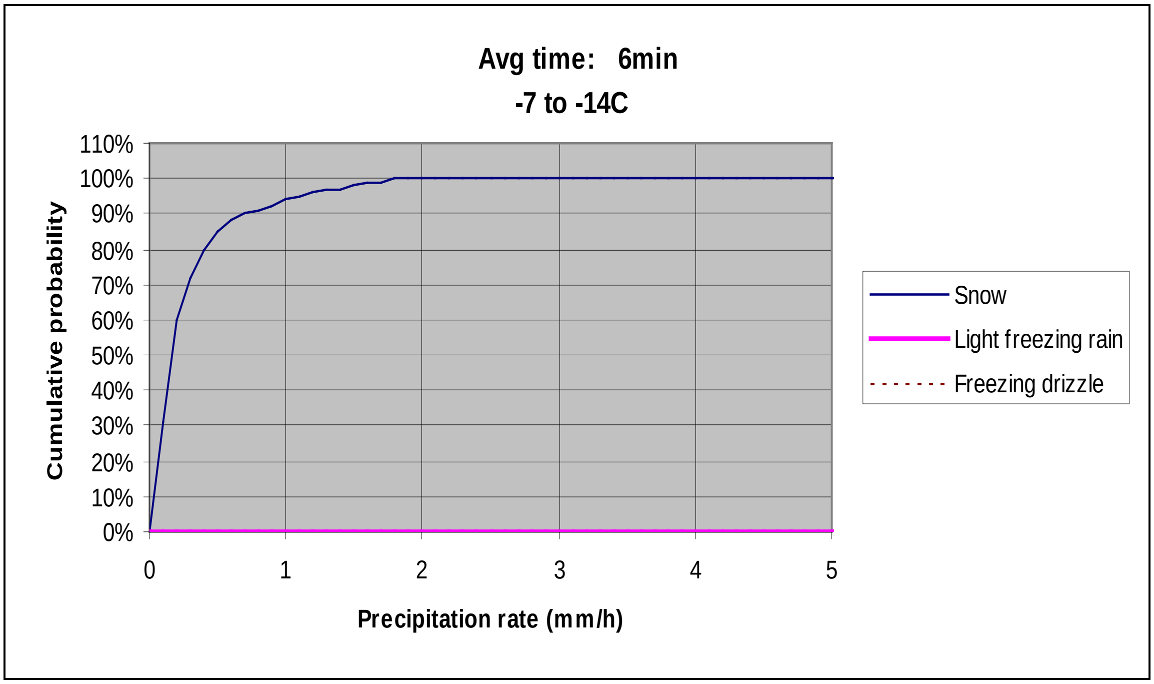
17 Nov. 97

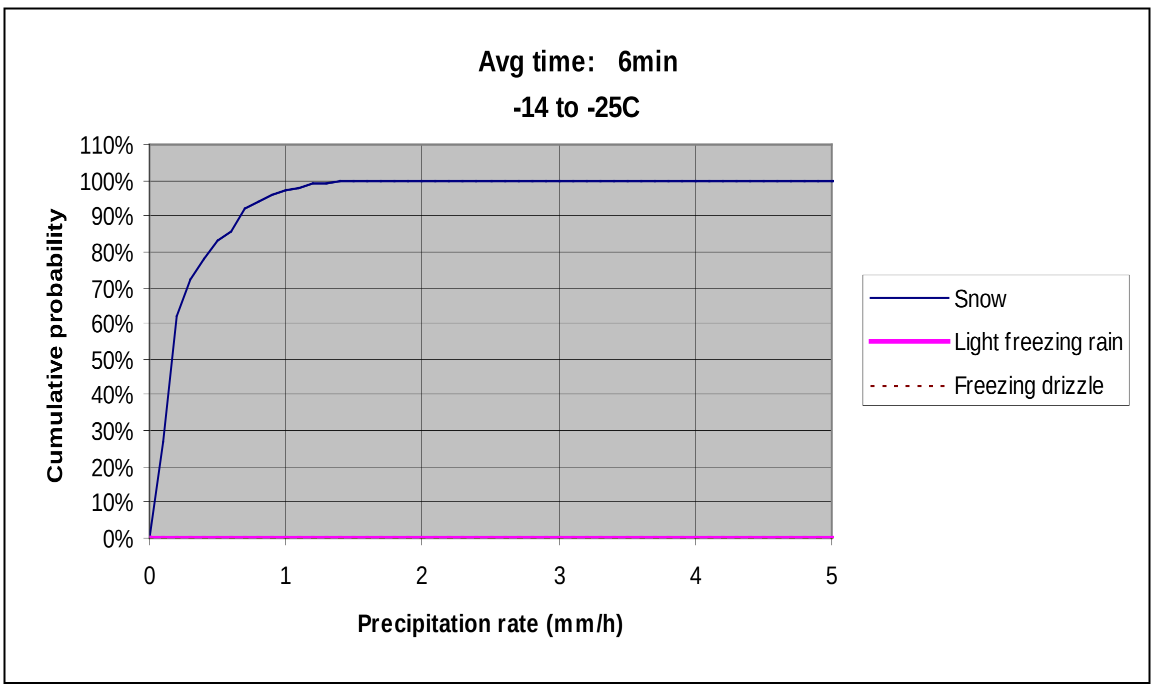


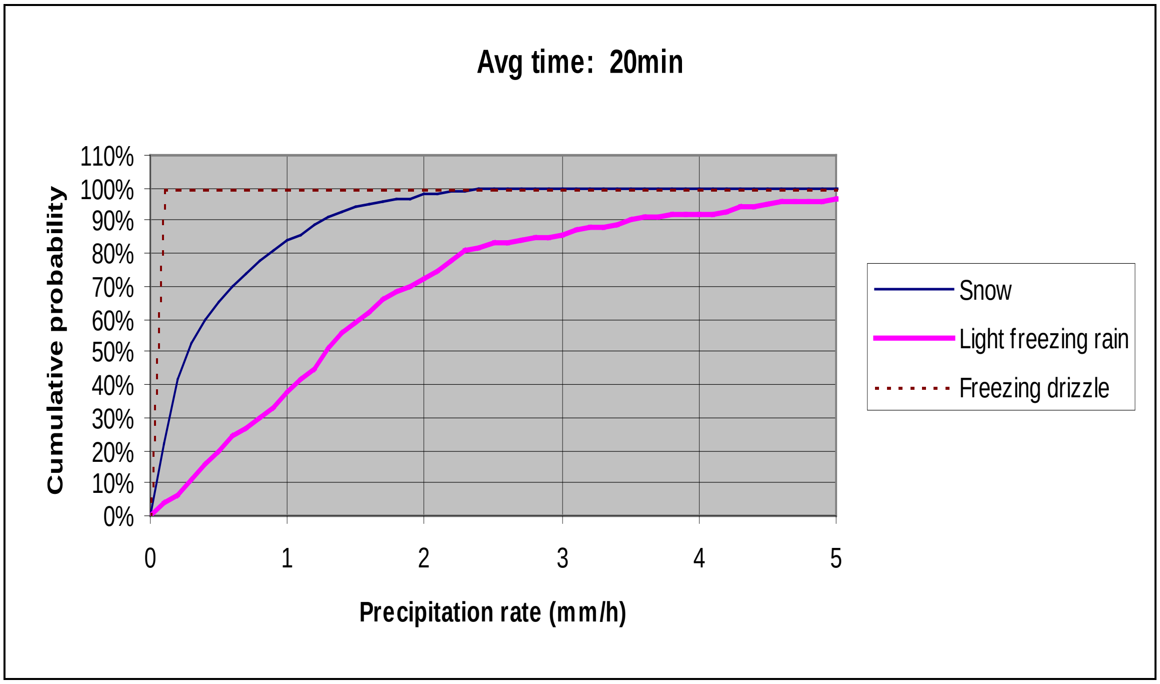
Avg time: 6min
0 to -3C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

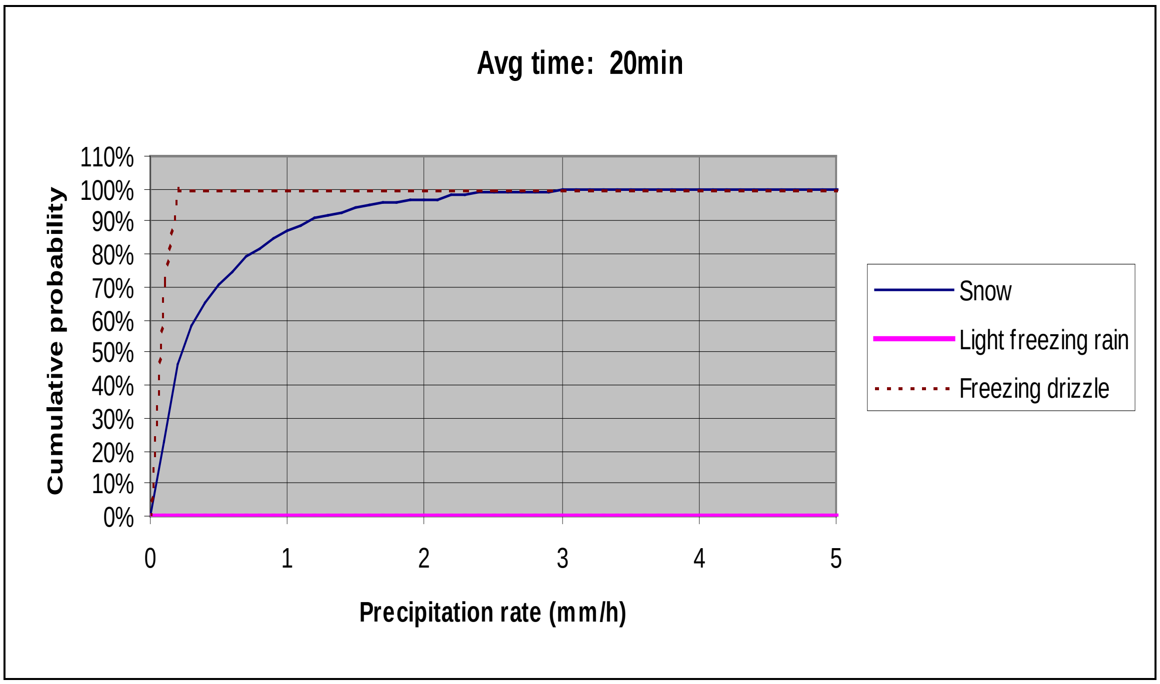


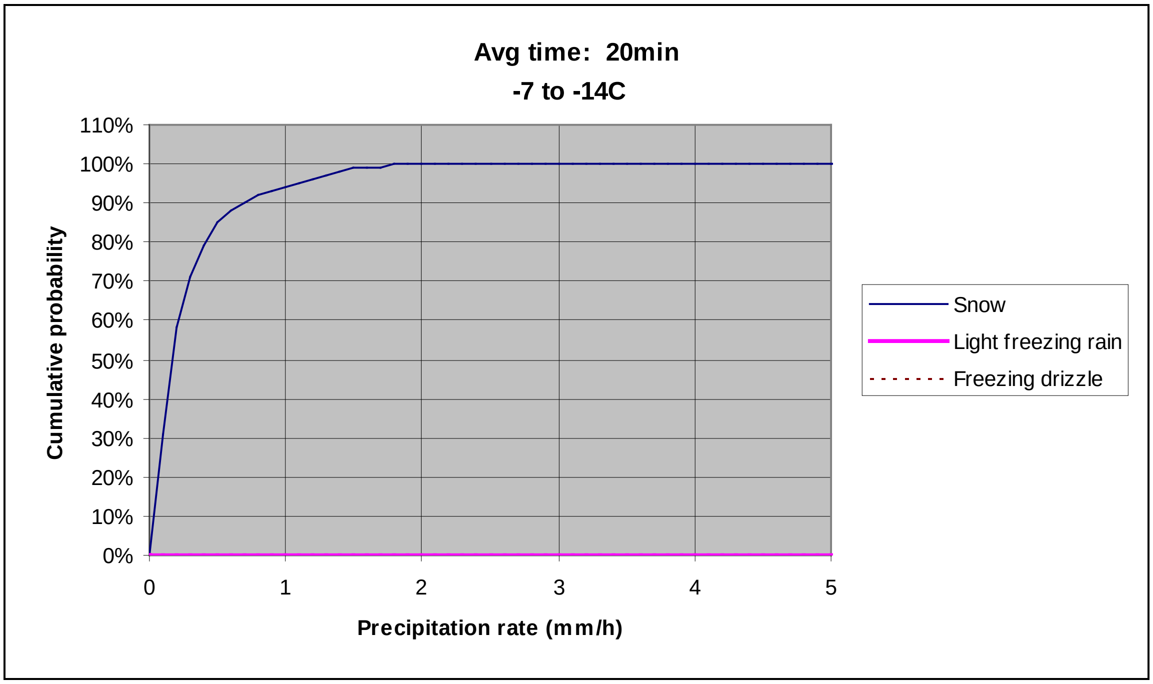
Avg time: 6min
-3 to -7C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

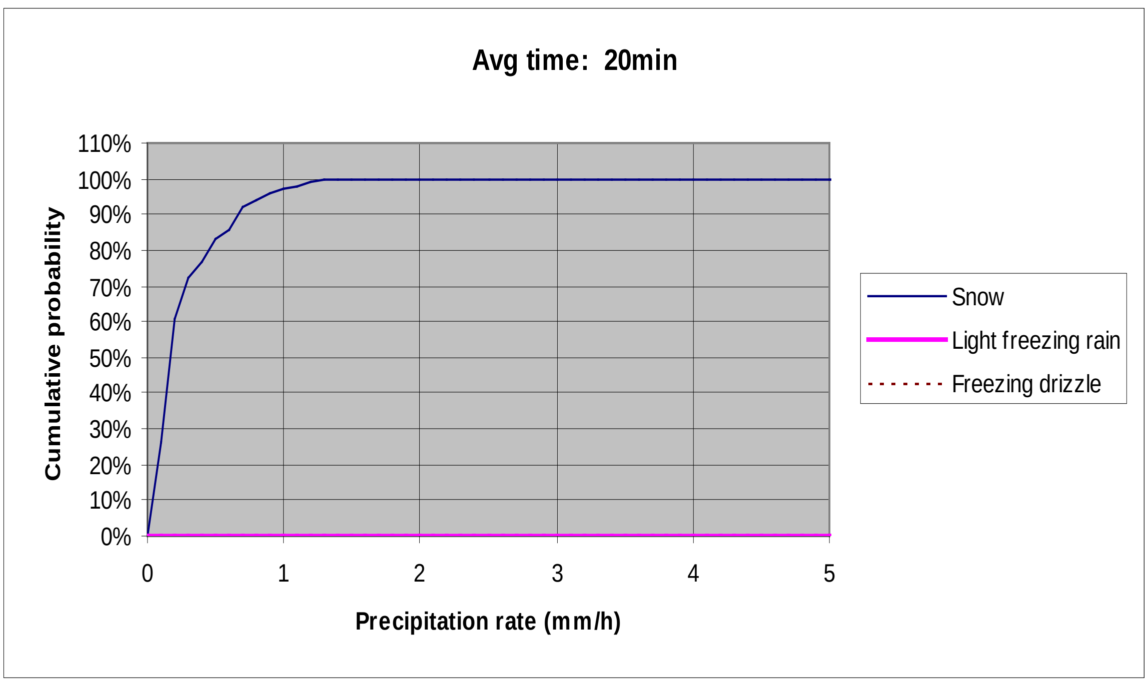

Avg time: 6min
-7 to -14C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

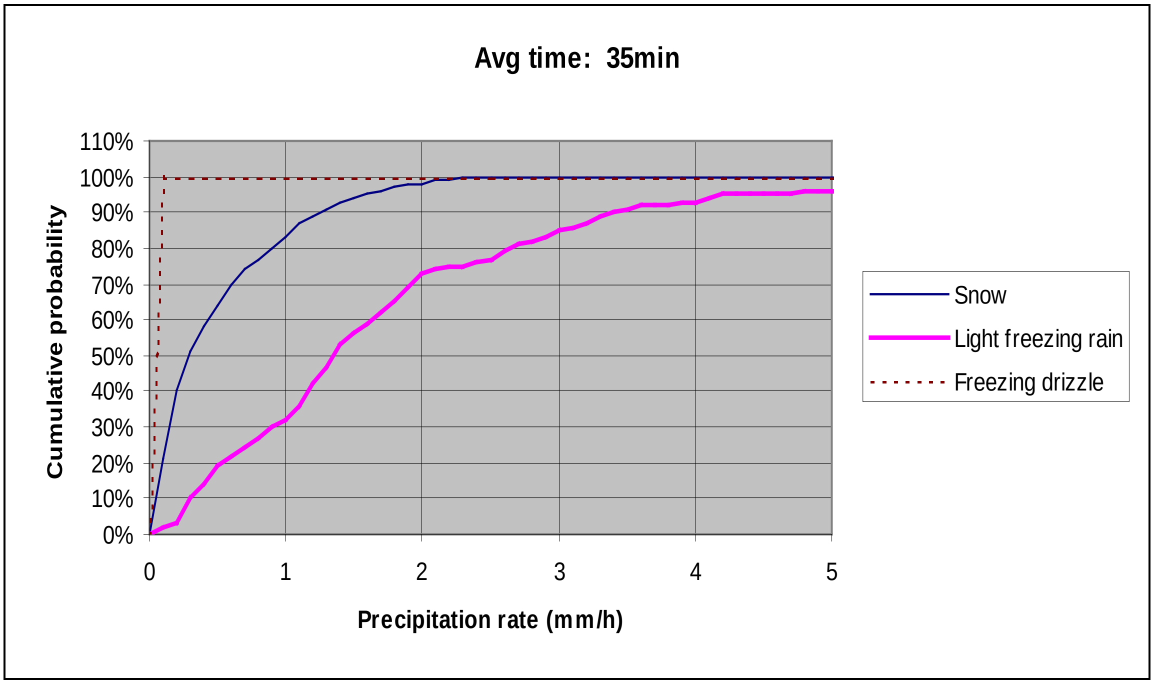

Avg time: 6min
-14 to -25C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

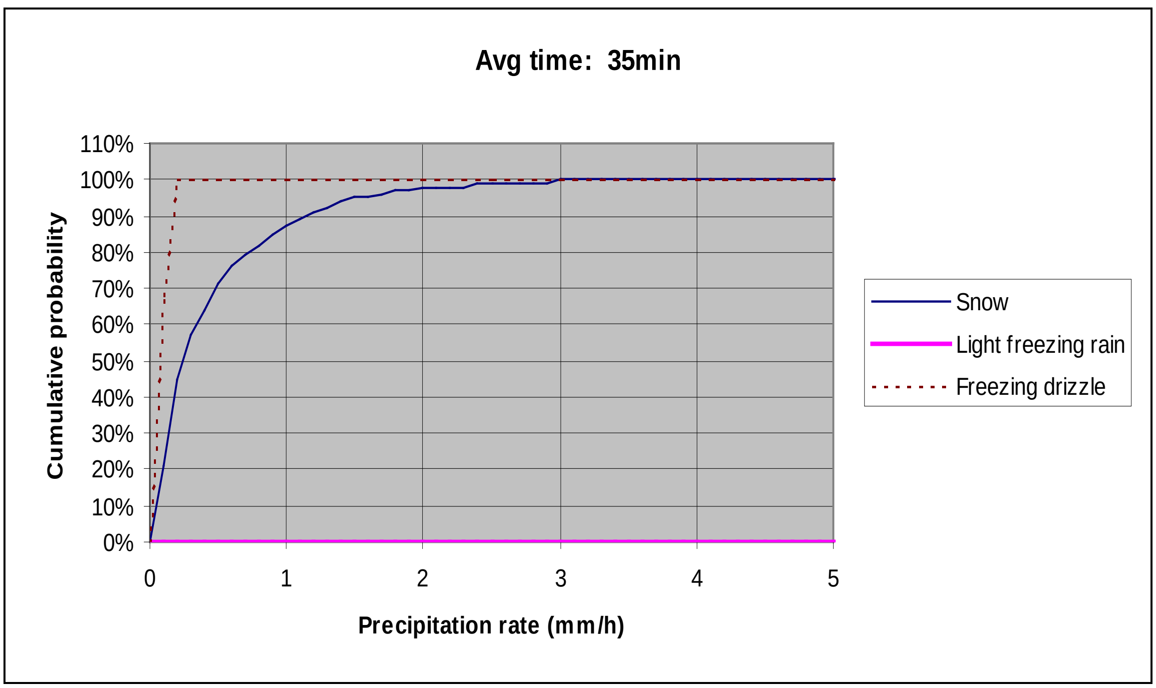

Avg time: 20min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

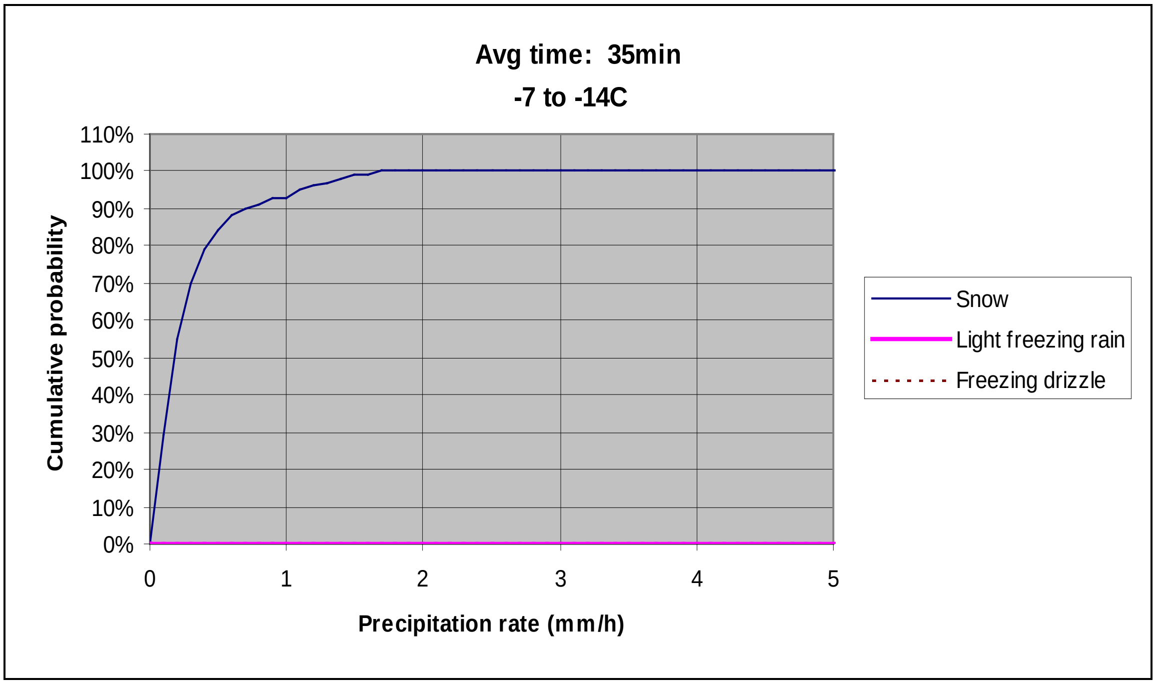

Avg time: 20min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

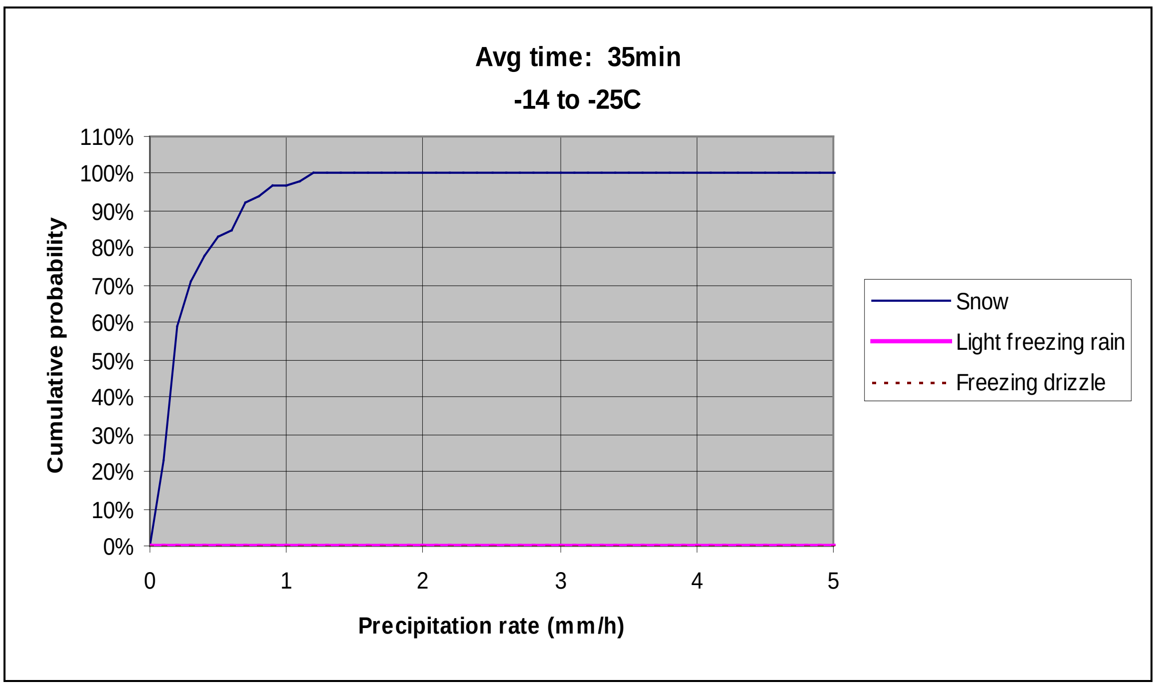

Avg time: 20min
-7 to -14C
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

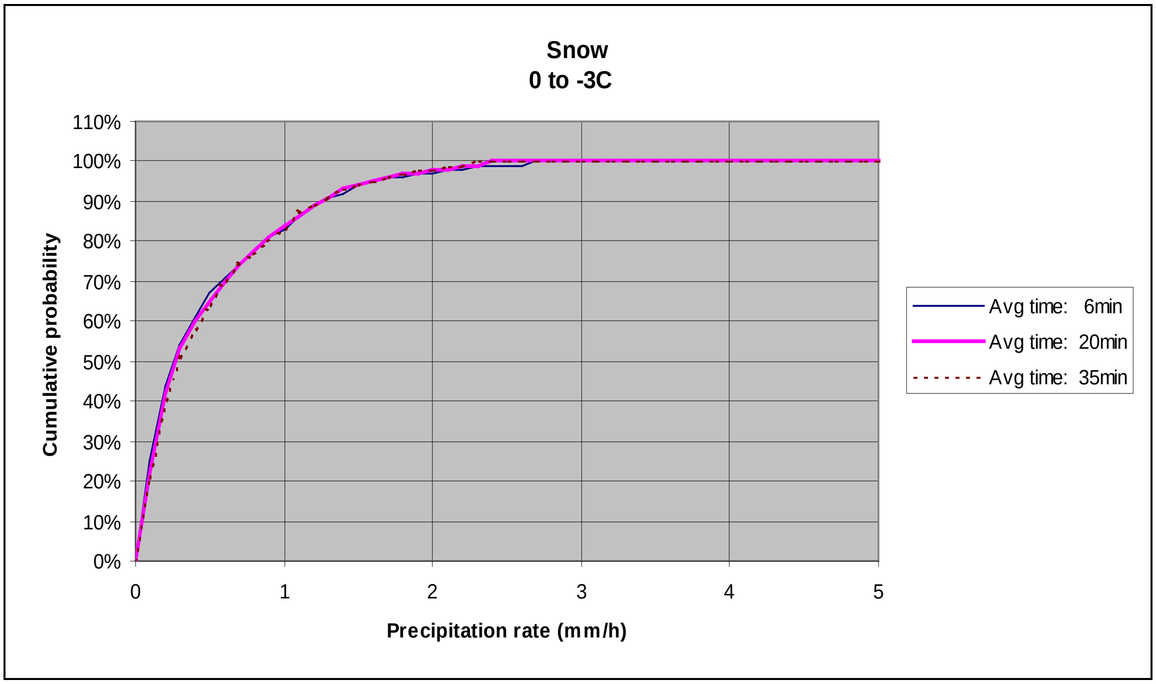

Avg time: 20min
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

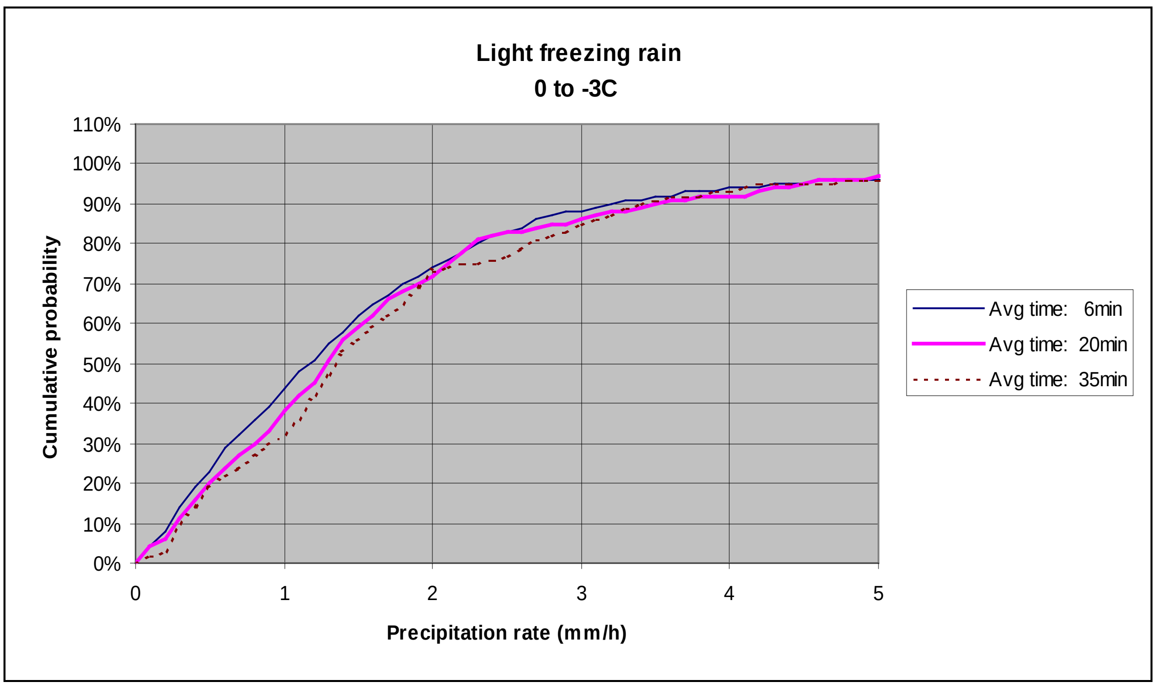

Avg time: 35min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Avg time: 35min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Avg time: 35min
-7 to -14C
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Cumulative probability
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Avg time: 35min
-14 to -25C
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Cumulative probability
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Snow
0 to -3C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Avg time: 6min
Avg time: 20min
Avg time: 35min


Light freezing rain
0 to -3C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Avg time: 6min
Avg time: 20min
Avg time: 35min

APPENDIX E

EXAMPLE OF MONTHLY METEOROLOGICAL SUMMARY
MONTREAL - DORVAL

Environnement Canada Service météorologique du Canada
Environment Canada Meteorological Service of Canada

SOMMAIRE MÉTÉOROLOGIQUE MENSUEL (c)
MONTHLY METEOROLOGICAL SUMMARY (c)

Mars 2002

Montreal - Dorval (AUTO)

March 2002

LAT 45' 28N LONG 73' 45W ALTITUDE 36 MÈTRES (NMM) / ÉLÉVATION 36 METRES (ASL) HEURE NORMALE UTILISÉE DE L'EST / 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 REFRIGERATION / 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 cm	VENTS / WINDS: VITESSE MOYENNE / AVERAGE SPEED km/h	DIRECTION DOMINANTE / PREVAILING DIRECTION	VITESSE MOYENNE MAX SUR 2 MIN & DIRECTION / MAX 2 MIN MEAN SPEED & DIRECTION	km/h	INSOLATION EFFECTIVE / BRIGHT SUNSHINE HEURES / HOURS
1	1.1	-5.1	-2.0	20.0			96	60			1.8	1.6	TR	21.8	SW	SW	39	0.3
2	4.1	-9.8	-2.9	20.9			93	60		0.4		0.4	1.0	20.7	NE	SE	39	1.6
3	11.2	-4.5	3.4	14.6			97	60		14.8		14.8	TR	35.9	SE	WSW	63	1.4
4	-4.5	-13.3	-8.9	26.9			69	43			TR	TR	TR	28.1	W	W*	43	10.2
5	-3.0	-11.4	-7.2	25.2			84	47			TR	TR		20.7	SW	SW	37	7.8
6	0.3	-7.3	-3.5	21.5			94	55			0.4	0.4		15.0	WSW	WSW	30	5.4
7	-0.2	-4.5	-2.4	20.4			91	37			TR	TR	TR	12.1	SW	SW	20	6.3
8	0.2	-4.1	-2.0	20.0			85	39		TR	TR	TR	TR	23.3	NE	NNE	31	0.7
9	16.8	-2.0	7.4	10.6	2.4		93	60		3.6		3.6		22.5	NNE	WSW	54	6.6
10	5.8	-7.7	-1.0	19.0			92	43		1.4	2.4	4.8	TR	48.8	WSW	WSW	78	5.4
11	-1.0	-9.0	-5.0	23.0			72	40					TR	30.1	W	W*	44	10.4
12	5.8	-2.7	1.6	16.4			96	49					TR	11.0	SSW	W	33	2.8
13	7.9	-2.6	2.7	15.3			97	67		TR		TR	TR	15.5	SSE	SSE*	26	0.8
14	5.3	-2.0	1.7	16.3			89	37						20.0	W	NW*	33	10.6
15	-2.0	-6.5	-4.3	22.3			91	45		1.2	TR	1.6	TR	31.5	NE	NE	50	
16	0.5	-6.6	-3.1	21.1			89	56			TR	TR		9.8	N*	NNE*	22	4.4
17	2.5	-6.7	-2.1	20.1			70	36						13.5	E	ENE	26	9.9
18	1.8	-2.1	-0.2	18.2			100	51			18.8	13.8		24.0	NE	ESE	31	
19	0.8	-2.7	-1.0	19.0			99	77			TR	TR	15.0	9.8	N	N	20	
20	2.6	-2.7	-0.1	18.1			100	76		TR	12.1	12.2	13.0	18.3	SSE	SSE	35	
21	1.0	-12.8	-5.9	23.9			99	70			4.8	4.8	18.0	20.5	W	WSW	48	1.7
22	-7.8	-15.3	-11.6	29.6			75	53					20.0	25.5	W	W	46	11.2
23	-0.1	-9.7	-4.9	22.9			96	57			2.8	2.6	19.0	27.0	WSW	SW*	37	3.7
24	-3.3	-12.2	-7.8	25.8			92	41					19.0	12.5	WSW	WSW	28	10.3
25	-5.3	-15.7	-10.5	28.5			65	44					18.0	9.3	N	N	24	9.8
26	0.4	-9.7	-4.7	22.7			100	53		0.2	14.2	15.6	18.0	22.7	NE	NE	33	
27	1.3	-0.8	0.3	17.7			99	77			1.2	2.0	28.0	18.6	W	W	31	0.1
28	5.7	-2.8	1.5	16.5			89	52					26.0	12.7	W	W	30	8.0
29	8.1	-3.6	2.3	15.7			76	48		TR		TR	21.0	9.6	E	SE	37	3.2
30	8.7	2.8	5.8	12.2	0.8		87	60		2.6		2.6	10.0	32.5	WSW	WSW	56	9.2
31	11.1	1.3	6.2	11.8	1.2		88	51					TR	12.8	SW	WSW	28	10.7
	MOY. 2.4 MEAN	MOY. -6.2 MEAN	MOY. -1.9 MEAN	TOTAL 616.2	TOTAL 4.4	TOTAL	MOY. 89 MEAN	MOY. 53 MEAN	TOTAL	TOTAL 24.2	TOTAL 58.5	TOTAL 80.8		MOY. 20.5 MEAN	DOMINANTE W PREVAILING	MAXIMALE WSW MAXIMUM	78	TOTAL 152.5
NORMALE / NORMAL	2.0	-6.9	-2.4	633.7	6.4	0.0				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	616.2	633.7	TOTAL DU MOIS / TOTAL FOR MONTH	4.4	6.4
ACCUMULÉS DEPUIS LE 1ER JUILLET / ACCUMULATED SINCE JULY 1st	3247.8	3993.9	ACCUMULÉS DEPUIS LE 1ER AVRIL / ACCUMULATED SINCE APRIL 1st	2456.1	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
ACCUMULATED	12	12	10	4		9	8	6	3	

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 occurrence
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

RELEVÉS COMPARATIFS A:
COMPARATIVE RECORDS AT:

Montreal - Dorval (AUTO)

Mars 2002
March 2002

		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			No. D'ANNÉES NO OF YEARS
		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	16.8	9	8.2	21		25.6	28	1945				61
TEMPÉRATURE MINIMALE / LOWEST TEMPERATURE (MINIMUM)	°CELSIUS	-15.7	25	-20.3	1					-29.4	4	1950	61
TEMPÉRATURE MENSUELLE MOYENNE / MEAN MONTHLY TEMPERATURE	°CELSIUS	-1.9		-3.3		-2.4	3.6		1946	-6.5		1950	61
HAUTEUR TOTALE MENSUELLE DE PLUIE / TOTAL MONTHLY RAINFALL	Millimètres (mm) / Millimetres (mm)	24.2		1.6		34.1	93.0	0	1948	0.3		1965	61
HAUTEUR TOTALE MENSUELLE DE NEIGE / TOTAL MONTHLY SNOWFALL	Centimètres (cm) / Centimetres (cm)	58.5		89.5		31.3	108.9	0	1955	3.3		1946	61
PRÉCIPITATION TOTALE MENSUELLE / TOTAL MONTHLY PRECIPITATION	Millimètres (mm) / Millimetres (mm)	80.8		109.8		67.6	165.3	0	1955	7.5		1984	61
NOMBRE DE JOURS AVEC PRÉCIPITATION MESURABLE / NO OF DAYS WITH MESURABLE PRECIPITATION		14		13		13	20	0	1981	2		1984	61
HAUTEUR DE PLUIE MAXIMALE EN UNE JOURNÉE / GREATEST RAINFALL IN ONE DAY	Millimètres (mm) / Millimetres (mm)	14.8	3	1.6	22		32.0	17	1973				61
HAUTEUR DE NEIGE MAXIMALE EN UNE JOURNÉE / GREATEST SNOWFALL IN ONE DAY	Centimètres (cm) / Centimetres (cm)	18.8	18	31.0	22		43.2	4	1971				61
PRÉCIPITATION MAXIMALE EN UNE JOURNÉE / GREATEST PRECIPITATION IN ONE DAY	Millimètres (mm) / Millimetres (mm)	15.6	26	42.8	22		37.6	22	1955				61
HAUTEUR DE PLUIE ENREGISTRÉE EN: / MAXIMUM RAINFALL RECORDED IN:													
5 MINUTES	Millimètres (mm) / Millimetres (mm)						2.8	5	1966				47
10 MINUTES	Millimètres (mm) / Millimetres (mm)						4.1	5	1966				47
15 MINUTES	Millimètres (mm) / Millimetres (mm)						5.0	10	1983				47
30 MINUTES	Millimètres (mm) / Millimetres (mm)						5.3	5	1966				47
60 MINUTES	Millimètres (mm) / Millimetres (mm)						7.6	4	1977				47
24 HEURES CONSÉCUTIVES / CONSECUTIVE HOURS	Millimètres (mm) / Millimetres (mm)												
VITESSE MOYENNE DU VENTS (KM/H) / MEAN WIND SPEED (KM/H)		20.5		19.4		16.0	23.2		1955	11.4		1987	49
VITESSE MAXIMALE (MOYENNE SUR 2 MIN.) (KM/H) / MAXIMUM SPEED (2 MIN. MEAN) (KM/H)		* WSW 78	10	ENE 59	22		NE 74	4	1971				49
POINTE DU VENT MAXIMALE (KM/H) / MAXIMUM GUST SPEED (KM/H)		W 104	10	NE 80	22		S 161	5	1964				49
TOTAL DES HEURES INSOLATION / TOTAL HOURS OF SUNSHINE		152.5		170.4		158.7	205.4		1988	108.6		1973	33
PRESSION MOYENNE À LA STATION (kPa) / MEAN STATION PRESSURE (kPa)		101.45		100.96		101.12	101.75		1967	100.43		1981	47
PRESSION MAXIMAL À LA STATION (kPa) / GREATEST STATION PRESSURE (kPa)		103.41	2	102.94	20		104.48	7	1990				47
PRESSION MINIMALE À LA STATION (kPa) / LEAST STATION PRESSURE (kPa)		98.95	3	98.72	14					96.99	17	1973	47

DONNEES CLIMATOLOGIQUES CE MOIS-CI POUR LES 10 DERNIERES ANNEES
CLIMATOLOGICAL DATA THIS MONTH FOR THE PAST 10 YEARS

ANNEE YEAR	TEMP. MAXIMALE MAXIMUM TEMP.	TEMP. MINIMALE MINIMUM TEMP.	TEMP MOYENNE MEAN TEMP.	HAUTEUR DE PLUIE RAINFALL	HAUTEUR DE NEIGE SNOWFALL	PRECIP. TOTALE TOTAL PRECIP	VITESSE MOYENNE DES VENTS MEAN WIND SPEED	VITESSE MAXIMALE DES VENTS MEAN WIND SPEED	HEURES INSOLATION SUNSHINE HOURS	DEGRES-JOURS DE CHAUFFE HEATING DEGREE-DAYS	DEGRES-JOURS DE CROISSANCE GROWING DEGREE-DAYS	DEGRES-JOURS DE RÉFRIGÉRATION COOLING DEGREE-DAYS	A.S.N. S.A.S.
1993	14.0	-23.9	-4.0	1.4	69.2	70.0	14.7	NNE 54	163.7	682.9	5.2		200.4
1994	8.7	-20.6	-3.0	17.4	47.2	64.4	13.8	SW 44	141.8	651.4			250.6
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	20.5	WSW 78	152.5	616.2	4.4		153.3

Note: * Nouveau record / New record   # Station manuelle   A.S.N. = Accumulation Saisonnière de Neige / S.A.S. = Seasonal Accumulation Snowfall

Température/Temperature

Température horaire / Hourly temperature — **Montreal - Dorval (AUTO)** — **Mars 2002 / March 2002**

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	-28	-23	-22	-24	-27	-30	-32	-28	-26	-21	-13	-5	7	9	11	-12	-2	-14	-15	-20	-31	-27	-28	-28
2	-48	-50	-57	-69	-70	-79	-85	-96	-90	-83	-76	-60	-51	-46	-42	-32	-24	-20	-20	-10	15	32	36	37
3	28	28	30	29	29	28	31	32	46	57	63	66	90	103	102	73	41	29	28	24	18	9	-3	-18
4	-29	-45	-57	-75	-91	-101	-116	-129	-129	-123	-114	-108	-99	-86	-82	-78	-79	-79	-87	-87	-86	-90	-94	-94
5	-93	-96	-106	-109	-105	-105	-112	-105	-90	-87	-70	-67	-50	-39	-39	-40	-33	-42	-46	-43	-46	-45	-48	-47
6	-49	-51	-49	-54	-55	-57	-64	-65	-45	-40	-32	-21	-16	-5	-7	-2	-5	-6	-8	-6	-17	-17	-21	-21
7	-21	-22	-22	-20	-22	-24	-28	-36	-43	-43	-40	-38	-28	-19	-14	-5	-10	-12	-18	-22	-25	-38	-29	-25
8	-21	-20	-21	-22	-26	-30	-32	-35	-39	-38	-37	-34	-26	-21	-9	-2	-4	-3	-14	-14	-14	-27	-26	-25
9	-19	-20	-17	-18	-16	-15	-11	-1	16	39	64	87	137	145	153	166	103	145	140	138	140	130	131	140
10	146	58	12	13	8	6	3	-7	-3	-2	-5	-5	-11	-6	-11	-12	-20	-37	-56	-63	-66	-73	-75	-76
11	-74	-71	-83	-83	-86	-85	-89	-85	-78	-70	-63	-54	-41	-38	-31	-21	-12	-16	-15	-20	-16	-16	-17	-17
12	-27	-27	-23	-19	-18	-16	-21	-13	-1	16	27	48	52	46	46	43	28	25	17	16	13	9	2	4
13	6	6	-1	-13	-19	-18	-10	-6	4	24	43	67	72	63	59	58	64	69	63	58	66	64	48	37
14	36	41	47	41	32	27	24	19	24	25	32	34	35	37	44	41	36	27	11	1	5	2	1	3
15	-6	-20	-23	-34	-42	-48	-51	-55	-57	-60	-62	-59	-54	-39	-47	-46	-50	-49	-49	-56	-52	-50	-48	-47
16	-46	-42	-38	-37	-37	-38	-40	-43	-60	-65	-59	-51	-30	-20	-12	-4	1	0	-7	-20	-28	-25	-21	-33
17	-46	-43	-41	-47	-59	-62	-67	-57	-39	-28	-16	-13	-1	8	11	20	19	15	11	4	0	-1	-1	-2
18	-2	0	-9	-16	-20	-20	-20	-20	-17	-8	1	16	7	-6	-4	-5	-5	-4	-7	-9	-12	-10	-9	-4
19	3	4	-5	-20	-25	-25	-25	-23	-20	-19	-17	-14	-11	-8	-5	-2	-2	-2	-2	-6	-3	-11	-18	-14
20	-13	-14	-20	-20	-22	-17	-16	-12	-2	11	23	23	24	4	3	3	2	3	3	3	3	5	9	7
21	10	9	7	2	-1	-1	-5	-10	-16	-8	-2	-12	-9	-10	-2	1	2	-2	2	-2	-69	-88	-108	-115
22	-122	-125	-132	-141	-142	-145	-152	-148	-142	-130	-121	-111	-103	-95	-94	-89	-82	-80	-83	-86	-100	-113	-113	-111
23	-112	-97	-88	-79	-67	-60	-61	-59	-51	-43	-32	-21	-20	-10	-8	-12	-8	-9	-12	-1	-21	-20	-23	-28
24	-33	-33	-63	-66	-69	-100	-90	-95	-93	-94	-85	-74	-70	-62	-60	-50	-48	-45	-51	-56	-78	-82	-110	-118
25	-100	-89	-88	-91	-107	-122	-150	-120	-121	-104	-97	-91	-83	-77	-71	-64	-57	-55	-55	-55	-69	-68	-75	-75
26	-83	-70	-78	-84	-95	-95	-75	-88	-65	-59	-54	-44	-37	-36	-45	-40	-34	-24	-8	-4	-4	-4	-5	-2
27	4	-2	-2	-2	-2	-3	-7	-6	-2	5	6	2	5	6	8	11	12	12	11	11	10	9	5	6
28	3	2	-13	-17	-15	-20	-22	-26	-13	1	14	23	32	41	42	41	47	51	52	34	25	17	21	14
29	1	-9	-8	-14	-15	-21	-17	-12	6	39	48	50	48	58	67	67	73	73	68	72	76	58	39	71
30	77	59	58	49	43	53	65	56	46	51	61	66	72	78	81	83	85	82	72	69	66	64	35	33
31	33	37	20	27	25	20	23	37	45	56	70	87	96	100	109	105	106	102	98	76	71	79	79	79

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

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Renseignements climatologiques / Climate Informations :**1-900-565-1111**

Vents/Winds

Vents horaires (km/h)
Hourly winds (km/h)

Montreal - Dorval (AUTO)

Mars 2002
March 2002

Heure normale locale: Est
Local standard time : Eastern

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	SW	SW	SW	SW	SW	SSW	SW	SW	SW	SW	SW	SW	SW	SW	WSW	W	SW	W	WSW	W	WSW	WSW	WSW	WSW	SW		
	26	26	22	24	22	26	24	24	28	35	30	22	33	39	28	33	22	17	20	17	11	11	11	9	54	13	1
2	WNW	N	NE	NNE	NE	ENE	NE	NNE	NE	NE	NE	NE	NE	NNE	NE	NE	NE	NE	NE	NE	SE	SE	SE	SSE	SE		
	6	9	11	19	15	17	20	19	19	24	22	17	30	24	26	24	31	19	13	13	15	13	17	20	52	1	3
3	SE	SE	SE	SE	SE	SE	E	ESE	ESE	SSE	SSE	SSE	SE	SE	SSE	W	WSW	SW	WSW	WSW	WSW	W	WSW	W	WSW		
	39	30	31	31	30	22	19	17	20	26	22	19	15	22	20	54	41	56	63	61	56	61	59	41	89	19	3
4	W	W	W	W	W	W	WNW	WNW	WNW	W	W	WSW	W	W	W	W	W	W	W	W	WSW	WSW	WSW	W	W		
	37	39	43	35	35	33	24	31	24	28	20	30	30	39	39	43	35	41	28	15	17	17	13	19	59	2	4
5	W	WNW	WNW	W	WSW	W	W	W	W	WSW	WSW	SW	W	WSW	WSW	SW	SW	WSW	WSW	SW	SW	SW	SW	SW	WSW		
	20	15	11	7	11	13	11	15	19	20	26	26	31	28	28	37	28	31	19	22	19	15	20	19	46	14	5
6	SW	SW	SW	WSW	WSW	WSW	WSW	W	W	SSW	SW	SW	SSW	SSW	SSW	S	SW	W	WSW	WSW	SW	WSW	W	W	WSW		
	19	22	20	13	13	11	11	9	13	19	19	19	15	13	20	17	17	17	30	15	13	13	13	9	41	18	6
7	WNW	W	W	WSW	W	W	NNW	NNW	NNW	NNW	WNW	W	SSW	SSW	SW	SW	SW	SW	SW	SW	SW	W	WNW	NNW			
	7	15	11	13	9	9	13	19	15	11	6	9	9	15	15	11	20	19	15	13	9	6	6	7			
8	NE	NE	NE	ENE	ENE	ENE	NE	ENE	NE	NNE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NNE	NNE	NNE	NNE	ENE		
	11	19	15	19	17	22	20	24	28	30	26	28	28	26	28	30	28	26	24	22	31	24	19	19	41	12	8
9	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NE	NNE	NNE	NNE	ESE	ESE	ESE	SSE	N	SSE	SE	SSE	SE	SSE	SE	SSE	W		
	13	13	9	13	15	13	19	13	13	11	13	17	13	19	24	11	17	22	31	35	37	31	30	37	104	1	10
10	S	WSW	WSW	WSW	SW	WSW	SW	WSW	SW	SW	WSW	WSW	WSW	WSW	SW	WSW	WSW	WSW	W	WNW	W	WNW	W	W	SW		
	44	54	69	78	63	54	61	50	41	46	56	59	59	56	57	54	52	46	44	33	35	30	28	35	98	2	10
11	W	WNW	W	W	W	W	W	W	W	W	W	WSW	W	WSW	W	W	W	W	WSW	WSW	SW	SW	SW	SW	WNW		
	31	33	37	31	30	33	30	30	31	43	44	44	37	39	37	39	28	20	24	22	20	28	26	22	65	2	11
12	S	SSE	ESE	SE	SE	C	SSE	C	SSW	SSW	SSW	W	W	WNW	NW	NW	W	W	S	SSW	SW	SSW	SSW	C	W		
	17	11	11	15	13	0	4	0	7	11	13	33	24	15	19	19	11	7	11	11	9	9	7	0	41	12	12
13	ENE	E	E	NNE	N	NE	NE	NE	NE	ESE	SE	SE	SE	SSE	SSE	SSE	SSE	SSE	S	S	SSW	S	S	SSE	SSE		
	9	7	6	9	6	7	13	9	6	11	20	24	24	26	26	24	20	15	24	19	22	22	11	11	33	12	13
14	WSW	SSW	W	W	W	W	NW	WNW	WNW	NW	NW	NW	WNW	WSW	WNW	W	W	W	W	WNW	NW	N	N	ENE	NW		
	7	9	17	20	19	19	33	19	24	20	13	17	7	19	22	28	22	24	19	15	17	17	11	20	46	6	14
15	ENE	ENE	NE	ENE	ENE	NE	ENE	NE	NE	NE	NE	NE	NE	NNE	NE	NNE	NNE	NNE	ENE	NE	NNE	ENE	NNW	N	NE		
	24	33	39	31	41	37	35	31	39	43	43	50	44	46	41	31	33	28	26	26	24	15	17	19	65	12	15
16	N	NNW	N	N	NE	NE	NNE	NE	NNE	NNE	N	NNE	N	N	NNW	NNE	NNE	W	SW	SSE	S	S	C	N	NNE		
	7	9	7	6	7	11	13	20	20	22	22	13	11	9	9	13	7	6	11	4	7	4	0	4	33	9	16
17	NNW	NE	NNE	NNE	N	NNE	NNE	NNE	NE	NE	NE	E	NE	E	ENE	E	ENE	ENE	E	ESE	E	E	E	E	E		
	6	4	11	9	13	6	9	11	17	13	17	9	15	19	7	6	17	15	15	11	7	9	19	24	35	0	17
18	E	ENE	ENE	NE	NE	NE	NE	NE	ENE	NE	NE	E	ESE	E	ESE	E	E	E	E	ESE	ESE	ESE	ESE	SE	ESE		
	20	26	22	20	24	22	24	30	20	22	26	17	30	24	26	20	26	26	26	30	30	31	26	17	46	19	18
19	SSE	S	N	NW	NW	NW	NNW	NNW	N	N	N	N	NNW	N	NE	C	C	NW	N	NNW	NE	SE	SSE	SSE			
	22	15	20	17	15	13	13	15	15	13	15	9	7	9	6	0	0	6	6	6	6	9	11	9			
20	ESE	E	E	E	E	NE	E	NE	ESE	ESE	SE	SE	SSE	SSE	SSE	SE	SE	SSE	SSE	SSE	S	S	SW	WSW	S		
	6	9	11	9	15	11	7	9	15	15	24	31	31	24	35	17	19	20	22	15	15	17	19	17	52	13	20
21	WSW	WSW	W	W	W	W	W	W	WNW	C	C	S	S	SE	E	E	SE	SE	SSE	WSW	W	W	W	WNW	W		
	24	17	17	17	17	20	13	19	15	0	0	15	11	7	15	15	20	19	26	48	43	39	37	30	63	22	21
22	WNW	W	W	W	W	WNW	W	W	WNW	WNW	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W		
	26	22	22	24	26	22	19	30	30	26	28	33	33	41	35	37	46	35	26	22	15	11	17	11	57	17	22
23	W	SW	W	WSW	WSW	WSW	WSW	W	W	WSW	WSW	SW	WSW	SW	SW	SW	SW	WSW	SW	SSW	W	WSW	W	W	SW		
	13	11	19	28	33	28	31	26	24	33	28	37	37	37	37	35	26	22	20	26	28	35	30	9	54	11	23
24	WSW	W	W	WNW	NNW	NW	NW	NNW	NW	WNW	WNW	C	SW	SW	WSW	WSW	WSW	WSW	WSW	SW	WSW	WNW	NNW	W	WSW		
	7	13	11	11	13	9	17	20	17	17	6	0	13	20	17	28	26	20	13	9	6	6	6	7	39	16	24
25	C	NNW	N	N	N	N	NNW	N	NNW	W	NW	W	SW	W	SW	SSW	SW	SSW	SW	W	W	C	N	C	N		
	0	7	17	24	13	13	9	11	6	6	4	9	15	6	13	15	11	9	9	9	6	0	4	0	33	4	25
26	NE	NE	NNE	NE	NNE	NNE	NE	NNE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	E	E	E	E	ENE	ENE	ENE		
	4	9	7	7	13	11	20	15	28	33	28	30	24	26	24	26	30	24	31	28	24	24	28	26	44	19	26
27	ENE	NE	NE	NE	NE	N	NW	WNW	W	WSW	WSW	WSW	WSW	W	W	W	W	W	W	WSW	WSW	W	W	WSW	W		
	15	22	22	20	13	9	9	13	17	11	28	30	28	31	22	24	24	19	22	17	22	17	11	11	48	13	27
28	W	W	W	W	SW	WSW	SW	WSW	WSW	SW	WSW	W	W	W	W	W	W	WSW	SW	SSW	S	SSW	SSW	SW	WSW		
	11	15	7	9	7	9	13	9	11	15	11	19	20	22	30	20	17	20	13	13	7	7	7	6	35	14	28
29	W	W	W	SSE	SE	SSE	ESE	SSE	SE	C	E	ESE	E	E	E	SE	E	NE	E	E	ENE	NNE	NNE	E	SE		
	6	6	4	6	9	6	6	7	4	0	9	11	11	9	7	9	7	7	11	15	11	9	7	13	48	1	30
30	SE	SSE	SSE	SSE	SSE	S	SSW	W	WSW	WSW	WSW	WSW	W	WSW	WSW	WSW	WSW	SW	WSW	WSW	WSW	WSW	W	W	SW		
	37	15	46	37	30	39	31	50	56	35	46	37	41	37	43	46	31	31	28	22	24	26	15	13	83	7	30
31	WSW	WSW	SSW	SW	SSW	SSW	SSW	SW	SW	SW	SW	WSW	W	WSW	W	NW	NNW	NNW	NE	N	N	E	E	NE	W		
	9	7	9	11	11	11	9	13	15	15	20	22	22	28	20	15	9	7	7	11	4	7	9	9	35	14	31

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

Humidité/Humidity

Points de rosée horaires — Montreal - Dorval (AUTO) — Mars 2002
Hourly dew points — March 2002

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	-73	-61	-59	-60	-59	-54	-46	-59	-77	-70	-68	-66	-61	-53	-46	-21	-9	-19	-24	-41	-53	-52	-56	-58
2	-65	-85	-120	-116	-124	-142	-144	-138	-128	-130	-123	-111	-99	-94	-85	-75	-72	-68	-66	-54	-48	-33	-17	-7
3	15	18	18	19	21	22	26	27	41	51	55	60	78	83	85	68	30	14	1	-15	-34	-56	-70	-82
4	-96	-109	-110	-132	-152	-164	-161	-187	-194	-181	-176	-171	-164	-154	-157	-161	-183	-180	-182	-168	-166	-159	-155	-156
5	-163	-162	-164	-160	-159	-147	-141	-137	-135	-141	-149	-149	-140	-130	-135	-127	-128	-105	-101	-95	-74	-73	-76	-71
6	-74	-73	-74	-78	-80	-85	-89	-94	-87	-77	-79	-82	-85	-84	-82	-78	-80	-72	-65	-65	-34	-33	-35	-36
7	-34	-31	-37	-37	-35	-38	-61	-80	-109	-118	-120	-138	-113	-129	-113	-133	-105	-109	-119	-105	-107	-96	-91	-101
8	-119	-130	-143	-139	-133	-133	-132	-137	-129	-128	-129	-117	-106	-99	-93	-89	-85	-77	-75	-69	-59	-66	-56	-49
9	-42	-41	-37	-37	-34	-29	-24	-17	-3	7	20	36	79	89	89	88	42	87	88	92	92	78	79	86
10	103	48	1	-37	-55	-58	-61	-55	-84	-76	-75	-91	-87	-116	-96	-113	-110	-74	-112	-157	-156	-159	-160	-171
11	-157	-146	-154	-160	-160	-162	-162	-156	-153	-145	-139	-145	-138	-141	-144	-139	-115	-122	-116	-105	-85	-86	-72	-72
12	-75	-71	-77	-76	-73	-75	-66	-70	-61	-48	-39	-47	-46	-38	-37	-26	-17	-13	-8	-6	-4	-1	-5	-2
13	-7	-5	-9	-25	-34	-22	-17	-13	-4	-1	4	19	18	7	3	4	13	16	13	14	36	36	29	20
14	20	26	31	25	14	6	-37	-46	-60	-65	-67	-68	-82	-72	-79	-93	-94	-96	-105	-106	-109	-114	-123	-125
15	-130	-132	-121	-133	-143	-138	-129	-101	-95	-92	-99	-96	-92	-79	-82	-80	-74	-62	-67	-72	-72	-70	-64	-66
16	-61	-59	-54	-53	-54	-56	-60	-66	-93	-101	-100	-97	-83	-80	-77	-77	-76	-77	-74	-58	-56	-55	-50	-52
17	-65	-64	-88	-105	-113	-119	-121	-112	-117	-119	-113	-117	-109	-123	-118	-115	-108	-110	-108	-104	-99	-104	-107	-117
18	-116	-117	-97	-95	-91	-93	-94	-93	-92	-87	-81	-74	-25	-15	-7	-5	-6	-6	-9	-11	-15	-11	-10	-4
19	3	4	-7	-21	-32	-35	-37	-39	-40	-44	-40	-42	-41	-40	-38	-38	-35	-38	-33	-33	-32	-30	-33	-30
20	-31	-32	-35	-42	-48	-47	-39	-36	-25	-18	-10	-15	-14	1	3	3	2	3	3	3	3	5	9	5
21	5	3	-1	-13	-24	-37	-33	-38	-47	-46	-44	-45	-36	-20	-11	-8	-8	-3	0	-3	-92	-105	-143	-154
22	-162	-168	-171	-178	-182	-184	-186	-182	-180	-178	-163	-165	-163	-168	-164	-167	-157	-152	-154	-146	-151	-151	-161	-156
23	-159	-149	-121	-106	-97	-101	-103	-98	-94	-84	-82	-85	-82	-85	-70	-59	-56	-52	-40	-30	-32	-31	-28	-43
24	-53	-52	-74	-80	-102	-121	-131	-148	-161	-164	-162	-171	-155	-163	-164	-150	-155	-156	-154	-155	-159	-158	-163	-156
25	-140	-138	-148	-176	-197	-206	-223	-213	-206	-200	-197	-191	-175	-167	-152	-154	-142	-141	-138	-135	-141	-147	-150	-142
26	-136	-129	-131	-118	-124	-126	-147	-131	-143	-138	-128	-120	-112	-102	-62	-51	-42	-29	-12	-6	-4	-4	-8	-6
27	-2	-4	-7	-7	-6	-7	-9	-9	-9	-7	-6	-11	-13	-20	-25	-24	-23	-21	-21	-19	-19	-19	-20	-21
28	-21	-23	-35	-38	-32	-37	-38	-41	-36	-32	-29	-30	-26	-26	-26	-28	-25	-34	-38	-30	-38	-40	-46	-50
29	-63	-65	-61	-51	-61	-67	-71	-64	-60	-50	-28	-19	-22	-20	-17	-25	-19	-15	-15	-20	-28	-19	-16	-15
30	-4	10	10	14	19	19	45	31	15	9	14	12	8	15	9	18	19	21	18	16	13	5	6	12
31	11	8	2	8	7	3	4	6	7	15	21	20	30	19	33	13	15	17	1	0	-1	1	3	0

Unités / Units: 0.1 °C — M = Manquant / Missing

Humidités relatives horaires — Mars 2002
Hourly relative humidities — March 2002

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	71	75	76	76	79	83	90	79	68	69	66	63	60	63	66	94	95	96	94	85	85	83	81	80
2	88	76	61	69	65	60	62	71	74	69	69	67	69	69	72	72	69	70	71	72	63	62	68	73
3	91	93	92	93	94	96	97	97	97	96	95	96	92	87	89	97	93	90	82	75	68	62	60	62
4	60	61	66	64	61	60	69	62	58	62	60	60	59	58	55	51	43	44	46	52	52	57	61	60
5	57	58	62	66	64	71	79	77	70	65	53	52	49	49	47	51	48	61	65	67	81	81	81	83
6	83	84	83	83	82	81	82	80	72	75	70	63	59	55	57	56	57	61	65	64	88	89	90	89
7	91	94	89	88	91	90	78	71	60	56	54	46	52	43	47	37	48	48	46	53	53	64	62	56
8	47	43	39	40	43	45	46	45	49	49	49	52	54	55	53	52	54	57	63	66	71	74	80	84
9	84	85	86	87	87	90	91	89	87	80	73	70	68	69	66	60	66	68	71	74	73	71	71	70
10	75	93	92	69	63	62	62	70	54	57	59	52	56	43	52	46	50	75	65	47	49	50	50	46
11	51	55	56	54	55	54	55	56	55	55	55	49	47	44	41	40	45	44	46	52	59	59	66	66
12	69	72	66	65	66	64	71	65	64	62	62	50	49	54	55	61	72	76	83	85	88	93	95	96
13	91	92	94	92	89	97	95	95	94	84	76	71	68	67	67	68	70	69	70	73	81	82	87	89
14	89	90	89	89	88	86	64	62	54	51	48	47	42	45	40	37	38	40	42	44	42	41	39	37
15	38	42	47	46	45	49	54	70	74	78	75	75	74	74	76	77	83	91	87	88	86	86	89	86
16	89	88	89	89	88	87	86	84	77	75	73	70	67	63	61	58	56	56	60	75	81	80	80	87
17	87	85	70	64	65	64	65	65	54	49	47	45	44	37	37	36	38	39	41	44	47	46	45	41
18	42	41	51	55	58	57	57	57	56	55	54	51	79	94	98	100	99	99	99	99	98	99	99	100
19	100	100	99	99	95	93	91	89	86	83	84	81	80	79	78	77	78	77	80	82	81	87	89	89
20	88	87	89	85	82	80	84	84	84	81	79	76	76	98	100	100	100	100	100	100	100	100	100	99
21	96	96	94	90	84	77	81	81	79	75	73	78	82	93	94	94	93	99	99	99	84	87	75	73
22	72	70	72	73	72	72	75	75	73	67	71	64	61	55	57	53	55	56	56	62	66	73	67	69
23	68	66	77	81	79	73	72	74	72	73	68	61	62	57	63	70	70	73	81	81	92	92	96	89
24	86	87	92	90	77	85	72	65	58	57	54	46	51	44	43	45	43	41	44	45	52	54	65	73
25	72	67	62	50	47	49	53	46	49	45	44	44	47	48	52	49	51	51	52	53	56	53	55	59
26	65	63	66	76	79	78	56	71	54	53	56	55	56	60	88	92	94	96	97	99	100	100	98	97
27	96	99	96	96	97	97	99	98	95	92	92	91	88	83	79	77	77	79	79	80	81	81	83	82
28	84	83	85	86	88	88	89	89	84	78	73	68	66	62	61	61	59	54	52	63	63	66	61	62
29	62	66	67	76	71	71	66	68	61	52	58	61	60	57	55	52	52	54	55	52	48	58	67	54
30	56	71	71	78	84	79	87	84	80	74	72	68	64	64	60	64	63	65	68	69	69	66	81	86
31	85	81	88	87	88	88	87	80	76	75	71	63	63	57	59	53	53	55	51	59	60	58	59	57

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

- Résumé / Summary -

Sommaire quotidien de Mars 2002
Aéroport International de Montréal/Dorval

Date
1 - Nuageux avec quelques averses de neige. Venteux.
2 - Généralement nuageux. Un peu de pluie tard en soirée. Venteux et doux.
3 - Nuageux avec éclaircies. Pluie intermittente parfois modérée. Très venteux et très doux.
4 - Plutôt ensoleillé. Quelques flocons tôt la nuit et l'après-midi. Froid. Venteux.
5 - Plutôt ensoleillé. Quelques flocons. Venteux.
6 - Ciel variable. Un peu de neige en soirée.
7 - Flocons cessant tôt la nuit. Ciel variable.
8 - Nuageux. Un peu de neige et de pluie verglaçante en soirée. Venteux.
9 - Ciel variable. Quelques averses en soirée. Très doux. Très venteux.
10 - Ciel variable. Quelques averses tôt la nuit se changeant en averses de neige parfois mêlées de grésil. Averses de neige parfois fortes. Refroidissement marqué. Vents violents la nuit.
11 - Ensoleillé avec passages nuageux. Très venteux.
12 - Plutôt nuageux. Doux
13 - Quelques éclaircies. Faibles averses de pluie en après-midi. Doux.
14 - Généralement ensoleillé. Doux. Venteux.
15 - Faible neige la nuit. Pluie verglaçante intermittente débutant en après-midi mêlée parfois de grésil devenant de la bruine verglaçante intermittente en mi-soirée. Très venteux.
16 - Flocons le matin. Dégagement en après-midi.
17 - Ensoleillé.
18 - Neige débutant vers midi. Venteux.
19 - Faible neige cessant la nuit.
20 - Neige débutant vers midi devenant de la faible bruine en soirée.
21 - Neige débutant vers midi et cessant en soirée. Devenant très venteux en soirée.
22 - Ensoleillé. Très froid. Très venteux.
23 - Quelques éclaircies. Faible neige débutant en soirée. Venteux.
24 - Ensoleillé. Froid.
25 - Généralement ensoleillé. Très froid.
26 - Neige parfois forte débutant en après-midi devenant mêlée de grésil en soirée et parfois de pluie verglaçante. Venteux.
27 - Faible neige cessant le matin.
28 - Ensoleillé avec passages nuageux.
29 - Ennuagement en matinée. Faibles averses de pluie en soirée.
30 - Pluie cessant vers l'aube. Ensoleillé par la suite. Doux. Très venteux.
31- Ensoleillé. Doux.

Daily summary for March 2002
Montreal/Dorval International Airport

Date
1 - Cloudy with some snowshowers. Windy.
2 - Mainly cloudy. Some rain late in the evening. Windy and mild.
3 - Cloudy with breaks. Intermittent rain moderate at times. Very windy and very mild.
4 - Mainly sunny. Few flurries early in the night and in the afternoon. Cold. Windy.
5 - Mainly sunny. A few flurries. Windy.
6 - Variable cloudiness. Light snow in the evening.
7 - Flurries ending early at night. Variable clouds.
8 - Cloudy. Some flurries and some freezing rain in the evening. Windy.
9 - Variable clouds. A few showers in the evening. Very mild. Very Windy.
10 - Variable cloudiness. Few showers early in the night changing into snowshowers mixed at times with ice pellets. Snowshowers heavy at times. Sharp cooling. Severe winds at night.
11 - Sunny with cloudy periods. Very windy.
12 - Mainly cloudy. Mild.
13 - Sunny breaks. Light afternoon rainshowers. Mild.
14 - Mainly sunny. Mild. Windy.
15 - Light snow at night. Intermittent freezing rain beginning in the afternoon mixed at times with ice pellets becoming intermittent freezing drizzle by mid-evening. Very windy.
16 - Morning flurries. Clearing in the afternoon.
17 - Sunny.
18 - Snow beginning around noon. Windy.
19 - Light snow ending at night.
20 - Snow beginning around noon becoming light drizzle by evening.
21 - Snow beginning around noon and ending in the evening. Becoming very windy in the evening.
22 - Sunny. Very cold. Very windy.
23 - Sunny breaks. Light snow beginning in the evening. Windy.
24 - Sunny. Cold.
25 - Mainly sunny. Very cold.
26 - Snow at times heavy beginning in the afternoon becoming mixed with ice pellets in the evening et at times with freezing rain. Windy.
27 - Light snow ending in the morning.
28 - Sunny with cloudy periods.
29 - Increasing clouds in the morning. Light evening rainshowers.
30 - Rain ending around dawn. Sunny thereafter. Mild. Very windy.
31 - Sunny. Mild.

APPENDIX F

EXPERIMENTAL PROCEDURE FOR THE COLLECTION OF FOG RATES OF DEPOSITION IN NATURAL CONDITIONS

BM3833

EXPERIMENTAL PROCEDURE FOR THE COLLECTION OF FOG RATES OF DEPOSITION IN NATURAL CONDITIONS

Winter 2000/2001

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: John D'Avirro

APS AVIATION INC.

November 09, 2000
Version 1.0

Experimental Procedure for the Collection of Fog Rates of Deposition in Natural Conditions

WINTER 2000/2001

1. OBJECTIVE

The objective of this study is to determine the range of deposition rates that occur naturally in fog.

2. PLAN

Collect fog deposition rates on several occasions in periods of natural fog or freezing fog.

3. PROCEDURE

A precipitation collection pan will be used to measure fog deposition rates in natural conditions. Prior to the start of the test, a collection pan will be coated with Ultra+ Type IV fluid (see flat plate test procedure) and weighed. The pan weight (in grams) and the test start time (hh:mm:ss) will then be recorded on a meteo/plate pan data form. In order to simulate the taxi of an aircraft in fog conditions, the collection pan will be mounted on a stand positioned on the hood of a car. In preliminary trials, the mounted pan will be inclined forward at 10°. Prior to the start of the test, zero the car odometer. The vehicle with the mounted plate pan should then be accelerated to a speed not exceeding 30 km/h for a period of 10 minutes to 30 minutes in order to collect precipitation. Following the test, the distance traveled during the test will be recorded along with the test end time in order to calculate the average velocity during the test. Finally, the precipitation pan will be re-weighed in order to evaluate the fog catch.

An estimate of visibility will be made based on markers on the road (such as lamp poles).

Tests shall be repeated if conditions are still appropriate.

4. PERSONNEL

One research assistant is required for these tests.

5. DATA FORMS

A Meteo / Plate Pan data form (see Table 1) is required for these tests.

6. EQUIPMENT

- Weigh scale;
- Precipitation plate pan;
- Test plate mount for vehicle;
- Inclinometer; and
- Type IV Ultra+ fluid.

TABLE 1: METEO/PLATE PAN DATA FORM (FOG DEPOSTION TRIALS)

Winter 2000/2001

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

PLATE PAN WEIGHT MEASUREMENTS

PAN #	t TIME BEFORE (hr:min:ss)	t TIME AFTER (hr:min)	w WEIGHT BEFORE (grams)	w WEIGHT AFTER (grams)	COMPUTE RATE (Δ w*4.7/ Δt) (g/dm^2/h)

COLLECTION PERIOD INFORMATION

TIME BEFORE (hr:min:ss)	TIME AFTER (hr:min:ss)	TOTAL DISTANCE TRAVELED

TEMPERATURE AT START OF TEST ______________ °C

ESTIMATED VISIBILITY ______________ Miles

DAY OR NIGHT ______________

COMMENTS : ______________________________

____

____

____

____

PRINT SIGN

WRITTEN & PERFORMED BY : ______________ ______________

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APPENDIX G

WINTER OPERATIONS SURVEY QUESTIONNAIRE AND RESPONSES OF WORLDWIDE AIRLINES

Transports Canada | Transport Canada

Centre de développement des transports | **Transportation Development Centre**

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

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*

June 22, 2001

SUBJECT: Winter Operations Survey

Dear Sir or Madam:

Transport Canada is attempting to collect data on actual deicing operations at several worldwide stations.

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. Your inputs and data will ensure that your operational conditions are included in the review process. We shall feed back to you our findings from this survey.

I have attached two tables for this purpose: Table 1 for Type I operations and Table 2 for Type II/IV operations. As examples, I also show estimates from information we have for Dorval in Tables 3 and 4.

Recognizing that you may not have data in this exact format, there are several ways you can provide data. You can provide numbers of deicing operations or percentages and you may need to change temperature breakdowns. If you cannot separate out Type I operations, please provide the information for all fluids on Table 2 and check the appropriate box.

The following are our guidelines for completing the tables:

1. First identify ONE deicing station for which you have data and provide information only for this station. If possible, it should be your busiest winter station in your country. If you cannot separate out one station provide the names of the stations included.

2. Establish your level of operations by stating the number of deicing operations performed in an average winter at the station you have identified.
3. Assess how many or what proportion of your operations are for frost and how many are for snow at the bottom of the table.
4. Assess how many or what proportion of your operations are for freezing rain, freezing drizzle or freezing fog.
5. Assess how many or what proportion of your operations treat for rain on a cold soaked wing.
6. State (or estimate) how many of the operations are 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 are 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, please check the box labelled “Type I included”.

For your convenience the tables were saved as Microsoft Excel Workbook (recommended format), Quattro Pro and Word Perfect (both Novell Perfect Office format).

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 complete the Tables as best as you can and return them to my attention by July 20, 2001.

Yours Sincerely,

Barry Myers

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

Total # of Deicing Operations: 　　　　**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	
above 0°	above 32°								
0 to -10	32 to 14								
below -10	below 14								
	Total								

of Operations

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

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

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 0°	above 32°	100/0								
		75/25								
		50/50								
0 to -3	32 to 27	100/0								
		75/25								
		50/50								
below -3 to -14	below 27 to 7	100/0								
		75/25								
below -14 to -25	below 7 to -13	100/0								
below -25	below -13	100/0								
		Total								

of Operations

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RESPONSES

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

MONTREAL DORVAL - YUL

Total # of Deicing Operations: *7531*

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°	4.7%	0.0%	11.9%	0.0%	0.0%	0.9%		17.4%
0 to -10	32 to 14	15.8%	0.0%	41.9%	2.0%	2.1%			61.8%
below -10	below 14	13.3%	0.0%	7.5%					20.7%

Total	33.7%	0.0%	61.2%	2.0%	2.1%	0.9%

100.0% of Operations

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

PITTSBURGH - PIT

Total # of Deicing Operations: *7825*

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°	0.5%	0.0%	3.0%	0.5%	3.0%	0.0%		7.0%
0 to -10	32 to 14	0.5%	0.0%	75.0%	0.5%	13.0%			89.0%
below -10	below 14	0.0%	0.0%	4.0%					4.0%

Total	1.0%	0.0%	82.0%	1.0%	16.0%	0.0%

100.0% **of Operations**

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

SAPPORO

Total # of Deicing Operations: ***690***

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°	13.9%	0.0%	18.6%	0.0%	0.0%	0.0%		32.5%
0 to -10	32 to 14	21.7%	0.0%	23.3%	0.0%	0.0%			45.1%
below -10	below 14	11.7%	0.0%	10.7%					22.5%

Total	47.4%	0.0%	52.6%	0.0%	0.0%	0.0%

100.0% of Operations

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

MODIFIED TORONTO - YYZ

Total # of Deicing Operations: *9754*

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°	3.3%	0.0%	3.9%	0.0%	0.0%	2.3%	0.2%	9.7%
0 to -10	32 to 14	20.9%	0.0%	51.6%	1.5%	1.2%		9.3%	84.5%
below -10	below 14	5.2%	0.0%	0.4%				0.2%	5.8%
	Total	29.4%	0.0%	55.9%	1.5%	1.2%	2.3%	10%	

100.0% of Operations

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TABLE 1 (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		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°	3.1%	0.0%	6.3%	0.2%	0.9%	1.1%	0.1%	11.7%
0 to -10	32 to 14	13.2%	0.0%	55.1%	1.3%	5.0%		3.5%	78.2%
below -10	below 14	6.2%	0.0%	3.8%				0.1%	10.1%

Total	22.5%	0.0%	65.3%	1.5%	5.9%	1.1%	3.7%

100.0% of Operations

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

MONTREAL DORVAL - YUL

Total # of Deicing Operations: *2927* **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	0.7%	0.0%	8.9%	0.0%	0.0%	1.1%		10.7%
0 to -3	32 to 27	100/0 75/25 50/50	0.6%	0.0%	24.0%	0.3%	2.5%			27.4%
below -3 to -14	below 27 to 7	100/0 75/25	1.1%	0.0%	49.7%	2.7%	2.0%			55.6%
below -14 to -25	below 7 to -13	100/0	0.4%	0.0%	6.0%					6.4%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
Total			2.8%	0.0%	88.6%	3.0%	4.5%	1.1%		100.0% of Operations

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TABLE 2 (FOR TYPE II FLUID) - ONLY 75/25
DISTRIBUTION OF DEICING OPERATIONS IN THE FOLLOWING STATION (S):

LHR - GB

Total # of Deicing Operations: 2000 **Type I included** N/A **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	20.0%	0.0%	3.0%	0.0%	0.0%	0.0%		23.0%
0 to -3	32 to 27	100/0 75/25 50/50	65.0%	4.0%	2.0%	0.0%	0.0%			71.0%
below -3 to -14	below 27 to 7	100/0 75/25	5.0%	1.0%	0.0%	0.0%	0.0%			6.0%
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			90.0%	5.0%	5.0%	0.0%	0.0%	0.0%		

100% **of Operations**

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

KLM at Schiphol - SPL

Total # of Deicing Operations: **5500** * 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 0º	above 32º	100/0 75/25 50/50	10.0%	0.1%	6.0%	0.5%	0.3%	0.5%		17.4%
0 to -3	32 to 27	100/0 75/25 50/50	40.0%	2.0%	24.0%	0.5%	0.3%			66.8%
below -3 to -14	below 27 to 7	100/0 75/25	10.0%	1.4%	4.0%	0.3%	0.1%			15.8%
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			60.0%	3.5%	34.0%	1.3%	0.7%	0.5%		100% of Operations

* - operations include 1500 preventive anti-icing operations

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

PITTSBURGH - PIT

Total # of Deicing Operations: *2345* **Type I included** 2345 **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	0.0%	0.0%	2.0%	1.0%	1.0%	0.0%		4.0%
		75/25								
		50/50								
0 to -3	32 to 27	100/0	0.0%	0.0%	40.0%	2.0%	6.0%			48.0%
		75/25								
		50/50								
below -3 to -14	below 27 to 7	100/0	0.0%	0.0%	32.0%	11.0%	5.0%			48.0%
		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%	74.0%	14.0%	12.0%	0.0%		

100% **of Operations**

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

PARIS ORLY - ORY (AF Facilities)

Total # of Deicing Operations: *550* **Type I included** **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	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		0.0%
		75/25								
		50/50								
0 to -3	32 to 27	100/0	66.0%	0.0%	4.0%	0.0%	0.5%			70.5%
		75/25								
		50/50								
below -3 to -14	below 27 to 7	100/0	29.0%	0.0%	0.5%	0.0%	0.0%			29.5%
		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			95.0%	0.0%	4.5%	0.0%	0.5%	0.0%		

100% **of Operations**

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

SAPPORO

Total # of Deicing Operations: *485* 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%	24.1%	0.0%	0.0%	0.0%		24.1%
0 to -3	32 to 27	100/0 75/25 50/50	0.0%	0.0%	41.9%	0.0%	0.0%			41.9%
below -3 to -14	below 27 to 7	100/0 75/25	0.0%	0.0%	28.9%	0.0%	0.0%			28.9%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	5.2%					5.2%
below -25	below -13	100/0	0.0%	0.0%	0.0%					0.0%
		Total	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%		

100.0% **of Operations**

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

MODIFIED TORONTO - YYZ

Total # of Deicing Operations: *3710* **Type I included** **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 RIME ICE	Total
above 0º	above 32º	100/0 75/25 50/50	0.0%	0.0%	6.2%	0.0%	0.0%	0.9%	0.1%	7.2%
0 to -3	32 to 27	100/0 75/25 50/50	0.0%	0.0%	38.5%	2.7%	2.4%		1.0%	44.5%
below -3 to -14	below 27 to 7	100/0 75/25	0.0%	0.0%	48.2%	0.0%	0.0%		0.1%	48.3%
below -14 to -25	below 7 to -13	100/0	0.0%	0.0%	0.0%				0.0%	0.0%
below -25	below -13	100/0	0.0%	0.0%	0.0%				0.0%	0.0%
Total			0.0%	0.0%	92.9%	2.7%	2.4%	0.9%	1.2%	

100.0% of Operations

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TABLE 2 (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		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 RIME ICE	
above 0°	above 32°	100/0 75/25 50/50	5.5%	0.0%	6.0%	0.3%	0.2%	0.5%	0.0%	12.6%
0 to -3	32 to 27	100/0 75/25 50/50	22.1%	1.1%	26.6%	1.0%	1.8%		0.2%	52.9%
below -3 to -14	below 27 to 7	100/0 75/25	4.8%	0.6%	24.9%	2.0%	1.0%		0.0%	33.3%
below -14 to -25	below 7 to -13	100/0	0.1%	0.0%	1.1%				0.0%	1.2%
below -25	below -13	100/0	0.0%	0.0%	0.0%				0.0%	0.0%
Total			32.6%	1.7%	58.5%	3.3%	3.1%	0.5%	0.3%	

100.0% **of Operations**

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APPENDIX H

CR21X AUTOMATIC DATA ACQUISTION 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 Environment 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 (20.3 cm) 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.