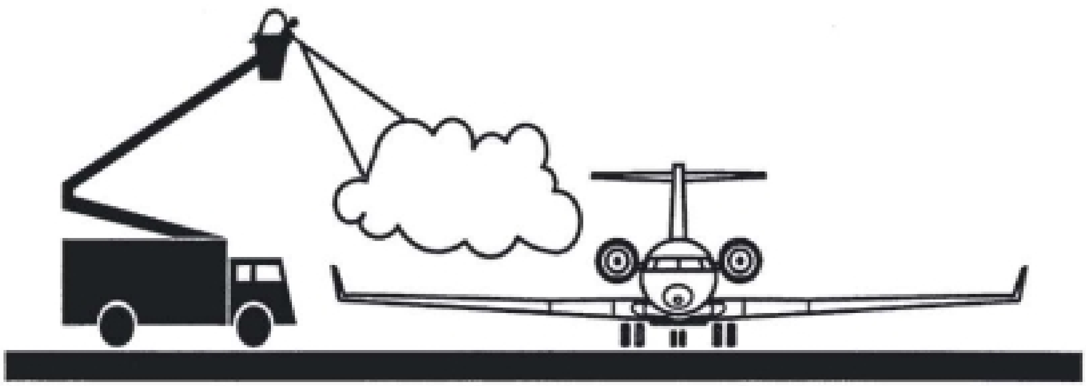
TP 13314E

Research on Aircraft Deicing Operations for the 1997/98 Winter



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APS AVIATION INC.

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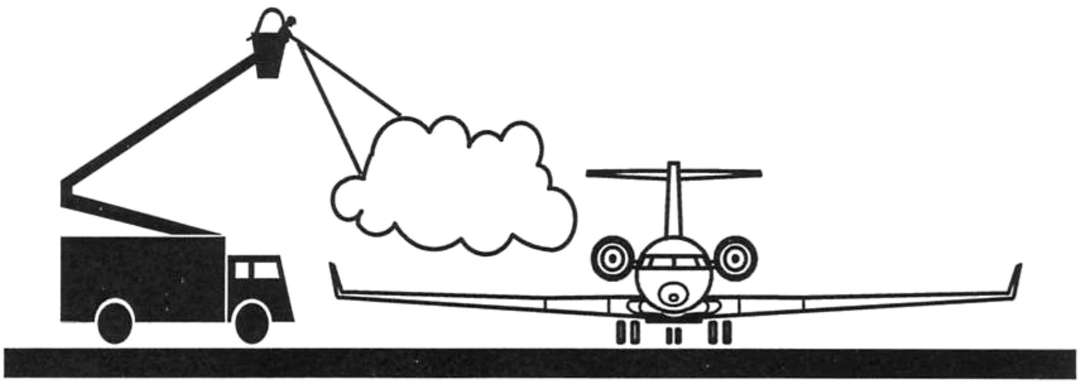

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Un sommaire français se trouve avant la table des matières.

PREFACE

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. has undertaken a research program to further advance aircraft ground deicing/anti-icing technology. Specific objectives of the APS test program were:

- To develop holdover time tables for new Type IV fluids and to validate *fluid-specific* tables and SAE tables;

- To determine the influence of fluid type, precipitation, and wind on location and time to fluid failure initiation, and also failure progression on the Canadair Regional Jet and on high-wing turboprop commuter aircraft;

- To establish experimental data sufficient to support development of a *deicing only* table to serve as an industry guideline, and to evaluate freeze point temperature limits for fluids used as the first step of a two-step deicing operation;

- To establish conditions for which contamination due to anti-icing fluid failure in freezing precipitation fails to flow from the wing of a jet transport aircraft when subjected to rotation speeds;

- To document the appearance of fluid failure and the characteristics of the fluid at time of failure, through conduct of a series of trials on standard flat plates; and

- To determine the feasibility of examining the condition of aircraft wings prior to takeoff through use of ice contamination sensor systems.

The research activities of the program conducted on behalf of Transport Canada during the 1997/98 winter season are documented in separate reports. The titles of these reports are as follows:

- TP 13318E Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1997/98 Winter;

- TP 13314E Research on Aircraft Deicing Operations for the 1997/98 Winter;

- TP 13315E Aircraft Deicing Fluid Freeze Point Buffer Requirements: *Deicing only* and First Step of Two-Step Deicing;

- TP 13316E Contaminated Aircraft Takeoff Test for the 1997/98 Winter;

- TP 13317E Characteristics of Aircraft Anti-Icing Fluids Subjected to Precipitation; and

- TP 13489E Deicing with a Mobile Infrared System.

This report, TP 13314E, addresses the following objectives:

- To evaluate precipitation data (precipitation rate/temperature data) from previous winters to ascertain the suitability of the data ranges used to date for evaluation of holdover time limits;
- To determine the influence of fluid type, precipitation, and wind on the location and time to fluid failure initiation, and on failure progression on service aircraft;
- To conduct frost formation tests on flat plates and service aircraft;
- To measure the film thickness and examine the flow characteristics of new Type IV fluids applied to aircraft wings, using a mobile Type IV fluid sprayer;
- To document, through a series of photographs, non-glycol or reduced-glycol deicing methods;
- To provide further photographic documentation of the area of the wing that is visible to the flight crew from the inside of several aircraft;
- To identify problems and solutions with respect to the operation of remote sensors in order to supplement the pilot-in-command's visual pre-takeoff contamination inspection; and
- To record and report taxi times from the start of holdover time to start of takeoff roll under conditions of winter precipitation in order to assess actual taxi times experienced as well as to assess the impact of conditions of precipitation on ground operations.

These objectives were met primarily by conducting field trials at Dorval Airport and laboratory trials at the National Research Council Climatic Engineering Facility in Ottawa.

Research has been funded by the Civil Aviation Group, Transport Canada. This program of research could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre, the Federal Aviation Administration, US Airways Inc., the National Research Council Canada, Atmospheric Environment Services, Transport Canada, and the fluid manufacturers for their contributions to, and assistance with the program. Special thanks are extended to US Airways Inc., Air Canada, the National Research Council Canada, Canadian Airlines International, Inter-Canadien, AéroMag 2000, Aéroport de Montreal, RVSI, Cox and Company Inc., KnightHawk, and Shell Aviation for provision of personnel and facilities, and for their co-operation on the test program. Union Carbide, Octagon, SPCA, Kilfrost, Clariant, and Inland Technologies Inc. are thanked for provision of fluids for testing. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data leading to the preparation of this document.

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16. Abstract

The primary objectives of the research project were to:

- Evaluate precipitation weather data;
- Determine the influence of several variables on the progression of fluid failure on aircraft wings in freezing precipitation;
- Conduct frost deposition trials on flat plates and service aircraft;
- Explore the effectiveness of a mobile infrared deicing system;
- Evaluate the use of remote sensors to supplement the pilot-in-command's visual pre-takeoff contamination inspection;
- Assess actual taxi times experienced subsequent to deicing; and
- Assess the impact of precipitation on ground operations.

Winter weather precipitation data for several winters from four sites in Quebec, Canada, were acquired and analysed. A preliminary evaluation indicated that current precipitation rate criteria used for holdover time evaluation should not be reduced at very cold temperatures.

Aircraft full-scale tests were planned for Bombardier Canadair RJ and ATR 42 aircraft, but were not conducted because of unsuitable weather and aircraft availability problems.

Frost deposition trials on flat plates were performed on three occasions. Deposition rates were found to be surface dependent and ranged from 0 to 0.16 g/dm^2/hr. The lack of frost conditions late in the season meant that frost tests could not be undertaken.

Field and laboratory trials to evaluate the use of remote sensors were performed. The field demonstration confirmed that the unit tested is capable of identifying contamination on moving aircraft. Laboratory trials reached a number of preliminary conclusions on sensor limitations with respect to aircraft surface effects.

Taxi times from the deicing centre to the runways at Montreal's Dorval Airport were assessed by recording aircraft/airport transmissions, which indicated that the average time was 15 minutes and virtually all aircraft had taxi times within or below the suggested fluid holdover times.

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Les rapports sur les recherches effectuées au cours des hivers précédents pour le compte de Transports Canada sont disponibles au Centre de développement des transports (CDT). Six rapports, dont le présent, ont été produits dans le cadre des recherches menées pendant l'hiver 1997-1998. Leur objet est précisé dans l'avant-propos.

16. Résumé

Le programme 1997-1998 visait les objectifs suivants :

- évaluer les données météorologiques concernant les précipitations;
- déterminer l'influence de diverses variables sur la progression de la perte d'efficacité des fluides antigivrage sur des ailes d'avions, sous précipitations givrantes;
- réaliser des essais de formation de givre sur des plaques planes et un avion en service;
- étudier l'efficacité d'un système de dégivrage mobile utilisant l'infrarouge;
- étudier l'opportunité de recourir à des capteurs à distance comme compléments à l'inspection visuelle de l'état de contamination des ailes, effectuée par le pilote avant le décollage;
- mesurer les temps réels de roulage au sol d'avions venant d'être déglacés;
- évaluer les répercussions des précipitations sur les manoeuvres au sol.

Les données concernant les précipitations enregistrées par quatre stations météorologiques du Québec, au Canada, pendant plusieurs hivers, ont été colligées et analysées. Une première évaluation de ces données révèle qu'il n'y a pas lieu d'abaisser les valeurs de taux de précipitation actuellement utilisées dans l'évaluation des durées d'efficacité par temps très froid.

Les essais en vraie grandeur qui devaient utiliser un RJ de Bombardier Canadair et un ATR 42 ont été contremandés en raison de conditions météorologiques défavorables et de la non-disponibilité des appareils aux moments propices.

Les essais de formation de givre, menés en trois occasions, ont révélé que les taux d'accrétion de givre sur les plaques planes dépendent de la surface et varient de 0 à 0,16 g/dm²/h. L'absence de conditions givrantes tard dans la saison d'essai ont empêché la tenue d'essais en vraie grandeur.

Des essais en laboratoire et *in situ* ont eu lieu pour évaluer l'utilité de capteurs à distance dans l'inspection des surfaces portantes d'un avion. La démonstration en vraie grandeur a confirmé la capacité du système mis à l'essai de détecter la présence de contamination sur un avion en mouvement. Les premières conclusions tirées des essais en laboratoire font ressortir les limites des capteurs quand vient le temps de prendre en compte le facteur «surface».

Les temps de roulage entre le poste de dégivrage et les pistes, à l'aéroport de Montréal, Dorval, ont été déduits des enregistrements des communications entre l'avion et la tour de contrôle. Il a été constaté que le délai moyen entre le dégivrage et le décollage est de 15 minutes et que dans la grande majorité des cas, les temps de roulage étaient conformes aux limites de durée d'efficacité figurant dans les tables, ou en-deçà de celles-ci.

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EXECUTIVE SUMMARY

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. undertook a research program to further advance aircraft ground deicing/anti-icing technology, and to enhance safety. The primary objectives of the project were to:

- Evaluate precipitation weather data (precipitation rate/temperature data) from previous winters to ascertain the suitability of the data ranges used to date for evaluation of holdover times;
- Determine the influence of fluid type, precipitation, and wind on the location and time to fluid failure initiation, and on failure progression on service aircraft;
- Conduct frost formation tests on flat plates and service aircraft;
- Measure film thickness and examine the flow characteristics of new Type IV fluids applied to aircraft wings using a mobile Type IV fluid sprayer;
- Document, through a series of photographs, non-glycol or reduced-glycol deicing methods;
- Provide further photographic documentation of the wing area that is visible to the flight crew from the inside of several aircraft;
- Identify problems and solutions with respect to using remote sensors to supplement the pilot-in-command's visual pre-takeoff contamination inspection;
- Record and report taxi times from the start of holdover time to the start of takeoff roll in winter precipitation; and
- Assess the impact of precipitation on ground operations.

Description and Processing of Data

In the evaluation of winter weather precipitation data, a total of 38 256 data points were developed for natural snow and 5 791 data points for light freezing rain. Data were acquired from Environment Canada for instruments located at Montreal's Dorval Airport and three other stations in Quebec, Canada. The Dorval Airport data were collected over several winters. Similar data were collected and analysed by Environment Canada at Toronto's Pearson Airport for two winters.

Full-scale aircraft trials were designed involving simultaneous application of Type I and Type IV fluids on standard flat plates and aircraft wings in natural precipitation conditions. Standard flat plate test procedures, as used in holdover time trials, were to be followed, and the aircraft were to be tested in a static position. Tests were planned on Bombardier Canadair Regional Jet, de Havilland Dash 8, and ATR 42 aircraft.

Frost deposition tests on flat plates were conducted on three occasions. Deposition rates on each of the different test surfaces during periods of active frost were calculated. Frost trials for operational aircraft could not be carried out because of unsuitable conditions late in the test season.

A mobile Type IV fluid sprayer was developed, built, and tested by APS in 1997-98. A series of tests were conducted at Dorval Airport to validate the new sprayer and to examine the thickness profiles and flow characteristics of Type IV fluids when sprayed on the wing of a Bombardier Canadair Regional Jet aircraft. Three Type IV fluids, including two new formulations, were used in the trials.

Photo documentation of alternative deicing methods and practices within the aviation industry was recorded.

The wing area visible to flight crews from inside the cabin was documented, using both still photography and video. Viewing positions from the flight deck, as well as several suitable windows in the passenger cabin, were included. Documentation was recorded for McDonnell Douglas DC-9, Boeing 767, Airbus A340, de Havilland Dash 8, and BAe 146 aircraft.

Field and laboratory trials using remote sensors to conduct pre-takeoff contamination inspections were performed. The field demonstration was conducted on one occasion, using a sensor-equipped vehicle during an actual deicing operation. The vehicle was positioned near a taxi route from the deicing centre to a runway. From this position, departing aircraft were scanned. Laboratory trials were conducted on two occasions. The camera's performance was examined under several conditions, such as periods of reduced visibility.

Taxi times subsequent to deicing at Dorval Airport, in winter precipitation, were assessed. A VHF radio was used to monitor and record airport/aircraft transmissions. When an aircraft entered the deicing facility, information such as the time, flight number, type of aircraft, and fluid holdover start times were noted. Takeoff times of the same aircraft were later retrieved from the Aeroport de Montréal (ADM). Heldover time (taxi time), which is defined as the difference between the start time of the final fluid application and the time of takeoff, was calculated for each flight and compared to the holdover time ranges.

Results and Conclusions

Preliminary evaluation of precipitation weather data indicated that the present precipitation rate limits used in the evaluation of fluid holdover times should not be changed until the data from the 1998-99 winter are evaluated.

No fluid failure trials were conducted on operational aircraft during the past year, because of weather considerations and problems in obtaining aircraft in suitable weather conditions.

Frost deposition rates, collected on flat plates, were found to be surface dependent. Standard aluminum surfaces collected no frost whatsoever. Deposition rates on painted aluminum surfaces ranged from 0.04 to 0.07 g/dm^2/hr, depending on colour. A kevlar composite surface collected frost at rates ranging from 0.07 to 0.11 g/dm^2/hr, while an aluminum honeycomb core plate collected frost at 0.06 g/dm^2/hr. The heaviest deposition rates were observed in the plate pan coated with Type IV fluid, and ranged from 0.12 to 0.16 g/dm^2/hr.

The field demonstration of the remote sensor confirmed that it is capable of identifying contamination on a moving aircraft, at some distance. Laboratory trials resulted in a number of preliminary conclusions on sensor limitations with respect to aircraft surface effects.

The study of taxi times at Dorval Airport indicated that the average time from the deicing centre to departure was 15 minutes, with a standard deviation of about three minutes. Use of the newer Type IV fluids appears adequate for Dorval Airport; the times were mostly within or below the suggested holdover time limits.

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SOMMAIRE

À la demande du Centre de développement des transports de Transports Canada, APS Aviation Inc. a lancé un programme de recherche visant à développer la technologie de dégivrage/antigivrage des avions au sol, et à accroître la sécurité du transport aérien. Le programme visait les objectifs suivants :

- Évaluer les données météorologiques des hivers antérieurs (taux de précipitation et température) afin de garantir le bien-fondé des gammes de données utilisées jusqu'à maintenant pour évaluer les durées d'efficacité.

- Déterminer l'influence du type de fluide utilisé, du type de précipitation et du vent sur l'endroit où s'amorce la perte d'efficacité, le délai d'apparition de la perte d'efficacité initiale et la progression de la perte d'efficacité sur un avion en service.

- Réaliser des essais de formation de givre sur des plaques planes et sur un avion en service.

- Mesurer l'épaisseur et caractériser l'écoulement de la couche de fluide appliquée sur les ailes d'un avion au moyen d'un système mobile de vaporisation conçu exprès pour les nouveaux fluides de type IV.

- Documenter, par une série de photographies, des méthodes de dégivrage utilisant des liquides à teneur nulle ou réduite en glycol.

- Étoffer la documentation photographique existante sur la zone de l'aile visible depuis l'intérieur de divers types d'avions.

- Cerner les problèmes (et solutions) relatifs au recours à des capteurs à distance comme compléments à l'inspection visuelle de l'état de contamination des ailes, effectuée par le pilote avant le décollage.

- Enregistrer le temps de roulage au sol pendant des précipitations hivernales, c'est-à-dire le temps qui s'écoule entre le début de la durée d'efficacité des fluides antigivrage et la course au décollage.

- Évaluer les effets des précipitations sur les manoeuvres au sol.

Description des essais et traitement des données

L'évaluation des données de précipitations hivernales a conduit à un total de 38 256 points de données pour la neige naturelle et de 5 791 points de données pour la pluie légère verglaçante. Les données, recueillies auprès d'Environnement Canada, provenaient de mesures prises à l'Aéroport de Montréal, Dorval et à trois autres stations météorologiques du Québec, au Canada. Les données concernant l'aéroport de Dorval couvraient plusieurs hivers. Des données semblables, concernant deux hivers, ont été colligées et analysées par Environnement Canada à l'aéroport Pearson de Toronto.

Des essais en vraie grandeur prévoyaient l'application parallèle de fluides de type I et de type IV sur des plaques planes et sur des ailes d'avions, en conditions de précipitations naturelles. La méthode d'essai sur plaques planes, éprouvée lors des essais de durée d'efficacité, devait être reprise ici. Pour ce qui est des essais sur avions, ils devaient porter sur un Regional Jet de Bombardier Canadair, un Dash 8 de de Havilland et un ATR 42, lesquels devaient demeurer à l'arrêt.

Trois essais de formation de givre sur plaques planes ont eu lieu. Les chercheurs ont calculé le taux d'accrétion du givre sur chacune des surfaces d'essai, sous précipitations givrantes. Les essais de formation de givre sur des avions en service ont dû être annulés en raison de conditions météorologiques qui n'étaient plus propices, tard au cours de la saison d'essai.

Un système mobile de vaporisation des fluides de type IV a été conçu, construit et mis à l'essai par APS en 1997-1998. Une série d'essais ont été menés à l'aéroport de Dorval, pour valider le nouveau pulvérisateur et étudier les profils d'épaisseur et les caractéristiques d'écoulement des fluides de type IV appliqués sur l'aile d'un Regional Jet de Bombardier Canadair. Trois fluides de type IV, y compris deux nouveaux mélanges, ont été essayés.

Une documentation photographique se rapportant à de nouvelles méthodes de dégivrage utilisées par l'industrie aérienne a été constituée.

Des documents photo et vidéo ont également été produits, montrant la zone des ailes à portée de vue de l'équipage de conduite depuis l'intérieur de l'avion. Ceux-ci représentent la vue depuis les fenêtres du poste de pilotage et certaines fenêtres de la cabine passagers. Les avions étudiés comprenaient un DC-9 de McDonnell Douglas, un Boeing 767, un Airbus A340, un Dash 8 de de Havilland et un BAe 146.

Des essais en laboratoire et in situ utilisant des capteurs à distance pour l'inspection de la contamination des surfaces portantes avant le décollage ont été réalisés. Une seule démonstration in situ a eu lieu. Elle faisait appel à un véhicule équipé de capteurs, pendant une opération réelle de dégivrage. Le véhicule était placé en bordure d'une voie de circulation menant du poste de dégivrage à une piste. De cet endroit, l'avion en partance était balayé par les capteurs. Ce type d'essais a été repris deux fois en laboratoire. Les performances de la caméra ont été étudiées dans diverses conditions, y compris par visibilité réduite.

Les chercheurs ont mesuré les temps de roulage au sol d'avions venant d'être déglacés, lors de précipitations hivernales à l'aéroport de Dorval. Ils utilisaient une radio VHF pour surveiller et enregistrer les communications entre l'avion et la tour de contrôle. Lorsqu'un avion se présentait au poste de dégivrage, ils notaient diverses données, comme l'heure, le numéro de vol, le type d'avion et l'heure du début du chronométrage de la durée d'efficacité. L'heure du décollage de l'avion en question était par la suite communiquée par un représentant des Aéroports de Montréal (ADM). Le temps de roulage et d'attente au sol, c'est-à-dire le temps écoulé entre le début du chronométrage et la course au décollage a été calculé pour chaque vol et comparé avec les tables de durée d'efficacité.

Résultats et conclusions

Selon une première évaluation des données de précipitations hivernales, il n'y a pas lieu de modifier la plage des taux de précipitation utilisée dans l'évaluation des durées d'efficacité des fluides antigivrage, du moins pas avant que les données du programme d'essais 1998-1999 aient été évaluées.

Aucun essai de perte d'efficacité n'a été réalisé sur un avion en service, en raison de conditions météorologiques défavorables et de la non-disponibilité des appareils lorsque les conditions étaient propices.

Les taux d'accrétion de givre sur les plaques planes se sont révélés dépendants des surfaces. Ainsi, aucun givre ne s'est accumulé sur les surfaces en aluminium standard. Les taux d'accrétion sur les surfaces en aluminium peint variaient de 0,04 à 0,07 g/dm²/h, selon la couleur de la peinture. Une surface en Kevlar accumulait le givre à des taux variant de 0,07 à 0,11 g/dm²/h, et celui-ci s'accumulait à un taux de 0,06 g/dm²/h sur une plaque à âme alvéolaire d'aluminium. Les taux d'accrétion les plus élevés ont été mesurés sur une plaque recouverte d'un fluide de type IV. Ceux-ci variaient de 0,12 à 0,16 g/dm²/h.

La démonstration in situ du capteur de givre a confirmé la capacité de celui-ci de détecter la contamination sur un avion en mouvement, à une distance appréciable. Des essais en laboratoire ont débouché sur des conclusions préliminaires qui font ressortir les limites de ces capteurs quand vient le temps de prendre en compte le facteur «surface».

L'étude sur les temps de roulage au sol, à l'aéroport de Dorval, a révélé que le délai moyen entre le dégivrage et le décollage est de 15 minutes, avec un écart-type d'environ trois minutes. Les nouveaux liquides de type IV semblent appropriés pour l'aéroport de Dorval; en effet, les temps de roulage au sol étaient la plupart du temps conformes aux limites de durée d'efficacité figurant dans les tables, ou en-deçà de celles-ci.

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GLOSSARY

ADM	Aéroports de Montréal
AES	Atmospheric Environment Services
APS	APS Aviation Inc.
HOT	Holdover Time
OAT	Outside Air Temperature
READAC	Remote Environmental Automatic Data Acquisition Concept
RVSI	Robotic Vision System Inc.
TDC	Transportation Development Centre
UCAR	Union Carbide Corporation

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1. INTRODUCTION

At the request of the Transportation Development Centre (TDC), Transport Canada, APS undertook a research program to further advance aircraft ground deicing/anti-icing technology.

Aircraft ground deicing/anti-icing has been the subject of concentrated industry attention over the past decade due to a number of fatal aircraft accidents. Recent attention has been placed upon the enhancement of anti-icing fluids, in order to provide an extended duration of protection against further contamination following initial deicing. This has led to the development of fluid holdover time tables, for use by aircraft operators, and accepted by regulatory authorities. New fluids continue to be developed with the specific objective to prolong fluid holdover times without compromise to the airfoil aerodynamics.

This report contains the results of work conducted by APS Aviation in 1997/98 on support activities related to aircraft deicing operations. The studies included in this report are:

- An evaluation of precipitation weather data;
- Fluid failure tests on operational aircraft;
- Frost formation tests on flat plates;
- Frost formation observations on service aircraft;
- Fluid thickness tests conducted with a mobile Type IV sprayer;
- Documentation of the wing areas visible to flight crew;
- A preliminary evaluation of the use of remote sensors for end-of-runway inspections;
- A limited evaluation of the demand for holdover time during actual deicing operations; and
- An evaluation of the cost of deicing.

1.1 Study Objectives

This subsection provides an outline of the research on aircraft deicing operations that was undertaken by APS Aviation on behalf of TDC, including the objectives of each study.

1.1.1 Evaluation of Snow Weather Data

The existing holdover times for snow were developed using lower and upper precipitation rates of 10 and 25 g/dm²/hr, for all temperatures (0, -3, -14, and -25°C). These rates have been considered extreme at temperatures of –14°C and –25°C, since such high precipitation rates, although they do exist, are perhaps less frequent at these lower temperatures. Similarly, for the other holdover time table precipitation conditions, it is believed that the precipitation rates diminish and are less frequent at the colder temperatures.

The purpose of this study was to evaluate precipitation weather data (precipitation rate/temperature data) from previous winters in order to ascertain the suitability of the data ranges currently in use for the evaluation of upper and lower holdover time limits.

1.1.2 Fluid Failure Tests on Operational Aircraft

The primary objective of this project was to determine the influence of fluid type, precipitation (type and rate), and wind (speed and direction) has on the location and time of fluid failure initiation, and to document the failure progression on service aircraft. The detailed work statement is contained in Appendix A.

To support the primary objective, several detailed objectives were subsequently defined and are listed below:

- To generate data which can be used to assist pilots with visual identification of fluid failure;

- To assess whether representative surfaces can be used to provide a reliable first indication of anti-icing fluid failure; observations related to the validity of the visual inspection of representative surfaces, as a method to determine early failures, were obtained during fluid failure tests on aircraft wings;

- To explore the potential application of point detection sensors to warn the pilot-in-command of an unsafe to take-off condition;

- To obtain failed fluid contamination distributions and profiles, which can serve as inputs to a theoretical program designed to assess the effects of such contamination on aircraft take-off performance; and

- To compare the performance of de/anti-icing fluids on aircraft surfaces with the performance of de/anti-icing fluids on flat plates.

1.1.3 Frost Formation on Aircraft

The purpose of this activity was to determine the roughness of frost formation on the wings on a Canadair Regional Jet.

1.1.4 Frost Tests on Flat Plates

The objectives of this study were to determine:

- Frost deposition rates in natural conditions; and
- Whether frost deposition rates were dependent on the surface characteristics of the material.

1.1.5 Fluid Thickness Tests with Mobile Type IV Spray Unit

A mobile Type IV fluid sprayer was developed, built, and tested by APS in 1997/98 to be able to apply different qualified Type IV fluids as required by test plans. A series of tests were conducted to:

- Validate the APS Type IV sprayer; and
- Evaluate the film uniformity of new Type IV fluids when sprayed on aircraft wings.

1.1.6 Alternative Deicing Methods

The traditional approach to aircraft deicing focussed on removal of contamination from aircraft surfaces through application of heated glycol mixtures. The deicing fluid approach has some inherent drawbacks, including high economic cost, disruptions to flight departure schedules, and the release of contaminants into the environment. This is especially so when only small quantities of ice are present on wing/flight surfaces.

The purpose of this activity was to support the Transportation Development Centre by providing photographic documentation of deicing methods and practices within the aviation industry that do not use glycol-based fluids.

1.1.7 Documentation of Wing Area Visible to Flight Crew

Industry regulations for operating in conditions involving ground deicing require the flight crew to perform pre-takeoff checks to ensure that the wings are still clean. Performance of those checks from inside the aircraft is hampered by certain inherent physical limitations associated with viewing geometries and which, for some aircraft types, includes a restricted view of the wing surface. During the winter season 1996/97, an activity was conducted which documented the area of the wing that is visible to the flight crew, for four aircraft types. Results were reported in the TDC report, TP 13130E[3] *Aircraft Full-Scale Test Program for the 1996/97 Winter*.

The purpose of this activity was to provide further photographic documentation of the area of the wing that is visible to the flight crew, for other commercial aircraft types. Advantage was to be taken of any fluid failure tests conducted on aircraft to document the visibility of wing surfaces from the cabin and flight deck during actual precipitation conditions.

1.1.8 Use of Remote Sensors for End-of-Runway Inspections

Considerable research efforts have resulted in the development of remote ice sensing cameras. These devices are operated in a fashion similar to video cameras. They are able to scan wing surfaces from some distance for evidence of ice contamination. An important potential application for these sensor cameras is to provide additional information to pilots when they perform visual pre-takeoff contamination inspections of aircraft wings during snow or freezing precipitation conditions. These inspections are sometimes carried out just prior to entering the departure runway for takeoff.

The objective of this study was to conduct a preliminary examination of the potential use of a remote ice contamination sensor to assess ice contamination on wings of operating aircraft immediately before aircraft enter the departure runway. The principal elements of such an examination were identified to be:

- Technical performance of the system;
- Regulatory limitations on positioning the sensors; and
- Standard operating procedures (pilot, tower, ground).

In examining this potential, a single demonstration trial was conducted with a Spar/Cox camera mounted on the bucket of a van equipped with a cherry picker. Laboratory trials were also conducted in the National Research Council Climatic Engineering Facility to explore the operating capabilities of the Spar/Cox camera.

1.1.9 Evaluation of the Demand for Holdover Time during Actual Deicing Operations

Over the past few years, considerable effort has been successfully directed toward the development of new anti-icing fluids to provide lengthened holdover times following deicing. A related research effort has quantified holdover times that can be expected from these various fluids when exposed to different environmental conditions. The objective of this task was to assess actual taxi times experienced and their compatibility with existing fluid holdover times, consequently exploring the possible need for improved holdover times. For the purpose of this report, these taxi times will be referred to as **heldover times**. Data were collected at Dorval Airport to determine taxi times, from the start of the holdover time to the start of the takeoff roll, of various aircraft under conditions of winter precipitation. These conditions included frost. Attempts to collect similar data from other airports were unsuccessful.

1.1.10 Cost of Deicing

As new and more effective means of addressing the problem of ground icing are developed, costs to the operation continue to be an ongoing concern for airlines. A brief review of typical costs associated with deicing operations was developed and is included in Appendix G and entitled *Cost of Deicing*.

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2. METHODOLOGY

This section of the report details the complete environment surrounding testing, including information about test facilities, equipment, procedures, and personnel.

2.1 Evaluation of Snow Weather Data

This section describes the weather data collected to study the occurrences of high precipitation rates at low temperatures, for natural snow and light freezing rain.

Holdover timetables generated from data collected during the 1997/98 winter test season, and all descriptions of precipitation types, precipitation rates, rate limits, and the methods used to calculate holdover times, are presented in the TDC report, TP 13318E[1].

At the Montreal 1997 SAE Workshop on Laboratory Methods, the holdover time table guidelines were proposed for revision. It was proposed that the upper and lower precipitation rate limits for the snow category be reduced. This was suggested because there is a natural tendency toward reduced precipitation rates as outside air temperature drops. As well, it is generally contended that precipitation rate limits should reflect natural conditions as closely as possible.

The option to maintain the currently accepted precipitation rate limits for snow of 10 and 25 $g/dm^2/hr$ was considered. After much debate, it was determined that the following precipitation rate limits would be adopted for the lowest temperature ranges in the snow category.

Temperature range	**Holdover Time calculation temperature**	**Precipitation rate ($g/dm^2/hr$) upper limit**	**lower limit**
-3 to –14ºC	-14ºC	20	10
-14 to –25ºC	-25ºC	10	5
Below –25ºC	(TBD by event)	5	2

The complete set of guidelines for all categories of precipitation that appear in the holdover times is presented in Table 2.1. The remainder of this section describes the test sites, equipment, and test procedures used to collect the data.

2.1.1 Sources of Data and Test Sites

APS collected data from various sources extending back to the 1990/91 winter season. A summary of these sources is shown in Table 2.2. The precipitation rates analysed in this report were extracted from:

TABLE 2.1
PRECIPITATION RATES FOR HOLDOVER TIMES

OAT		Precipitation Rates Under Various Weather Conditions, g/dm^2/h					
°C	**°F**	**Frost**	**Freezing Fog**	**Snow**	**Freezing Drizzle**	**Light Freezing Rain**	**Rain on Cold Soaked Wing**
0	32	**.2**		**25 -10**	**13 - 5**	**25 - 13**	**75 - 5**
-3	27	**.2**	**2 - 5**	**25 -10**	**13 - 5**	**25 - 13**	
-7	19	**.2**	**2 - 5**	**25 -10**	10 - 5	25	
-10	14	**.2**	**2 - 5**	25 -10	10 - 5	25	
-14	7	.2	**2 - 5**	20 - 10			
-25	-13	.1	**2 - 5**	10 - 5			
< -25	< -13	.1	2 - 5	5 - 2			

TABLE 2.2

SUMMARY OF WEATHER DATA

PROJECT #	YEAR	PLATE PANS	READAC YUL	CR21X				CITY OF MONTREAL (Fisher/Porter)	OMBROMETER THIES	ETI	TIPPING BUCKET	YYZ
				WUY (Rouyn)	WTQ (Dorval)	WQB (Quebec)	WYQ (Pointe-au-Père)					
	1990/91	Test period									X[3]	
	1991/92	Test period						X[6]	X[3]			
	1992/93	Test period						X[6]	X[3]			
C1171	1993/94	Test period						X[1] (Three stations)	X[3] (Shielded)			
CM1222	1994/95	Test period	X[1]									
CM1283	1995/96	15 min	X[2]							X		X[4]
CM1338	1996/97	15 min	X[2]		X[5]							X[4]
CM1380	1997/98	5-15 min	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.

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- The Dorval READAC log for the years 1995 to 1998;
- The data logs for three CR21X stations 1998 at these locations: Rouyn, Pointe-au-Père (Mont Joli), and Ancienne Lorette (Quebec City); and
- The data log from the Dorval Airport CR21X station.

The data are included in Appendix K. Furthermore, two similar studies were conducted in 1995/96, one by APS using data collected from three weather stations located around the city of Montreal (included in Appendix L), the other by AES (Atmospheric Environment Services) using data collected at Lester B. Pearson International Airport in Toronto.

2.1.2 Equipment

The READAC precipitation gauge consists of a bucket partially filled with an antifreeze compound so that snow is also effectively captured by the device. 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 *wind pumping* and temperature-induced contraction and expansion of the sensor. The READAC instrument has a resolution of 0.5 mm (5 g/dm²).

The CR21X gauge operates on the same principle with an accuracy of 0.1 mm (1 g/dm²).

2.1.3 Description of Test Procedures

Precipitation rate data were averaged at time intervals that correspond to three specified periods typically used in the holdover time tables: 6 minutes for Type I fluids, 20 minutes for Type II, and 35 minutes for Type IV. The data were classified into the five temperature ranges: above 0°C, 0 to –3°C, -3 to –7°C, -7 to –14°C and -14 to –25°C for natural snow. For light freezing rain, data were classified into 2 ranges: 0 to -3°C and –3 to –10°C.

Snowfalls at Dorval were tracked from 1995 to 1998 using the Monthly Meteorological Data provided by Environment Canada. The precipitation and temperature data were then extracted from READAC on a minute-by-minute basis and added to a data base. The CR21X data were treated in a similar manner: The periods of snowfall were identified using Environment Canada summaries and snow accumulation data were added to the data base along with the temperatures. For the three CR21X gauges positioned at Rouyn, Pointe-au-Père, and Ancienne Lorette, the temperatures were provided on an hourly basis and interpolated throughout the hour on a minute-by-minute basis.

The total precipitation for each individual snowfall was averaged over time, to produce a smooth curve, using an algorithm developed by APS. Figure 2.1 shows an output from the READAC precipitation gauge and the linearized data for a typical snowfall. The precipitation gauge output, sensitive to 5 g/dm^2 is plotted versus time to determine the periods of snowfalls. For the example shown in Figure 2.1, the period when the snowfalls were interrupted for a long period of time was not included in the analysis. Subsequent snowfalls were treated similarly. The first and last indications of snowfall (1^{st} 5 g/dm^2) were excluded due to the uncertainty of exact timing of start and end of snowfall.

Periods of low rate snow precipitation may have been overlooked due to long interruptions in bucket weight charges. It is difficult to determine whether these weight changes are due to constant low rate precipitation or long periods with no precipitation and short intervals of higher precipitation near the time of the weight change. The beginnings and ends of snowstorms are also difficult to predict since the snow may have started and finished gradually, at slow rates, or abruptly, at high rates.

The READAC and the CRT21X precipitation gauges record the bucket weight at each minute. The precipitation rates are calculated based on the bucket weight and the time between weight readings. For each time interval the rate is calculated every minute using the following method of calculation.

$$Rate_i = (W_i - W_{i-1})/(\ time)$$

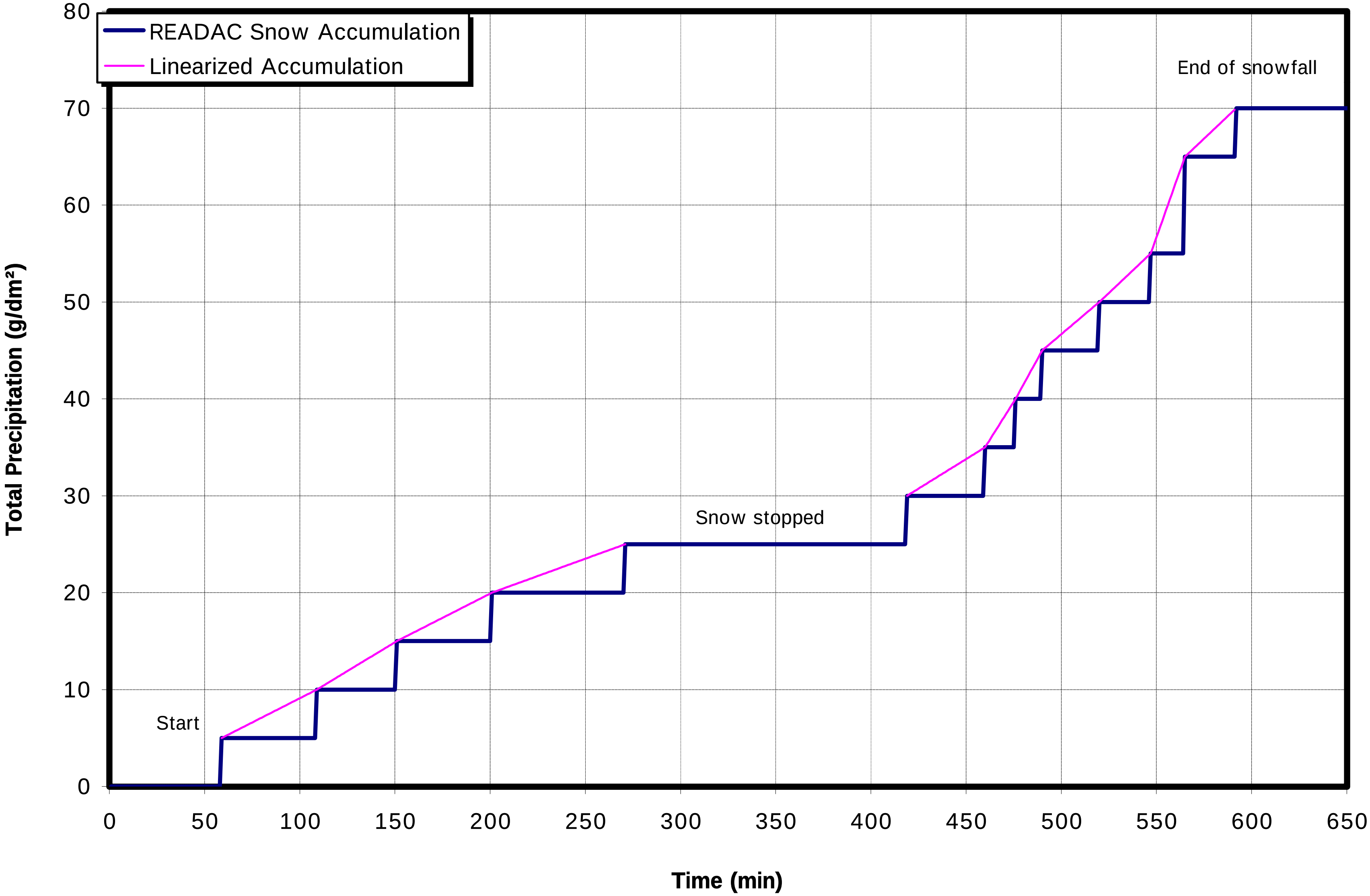
Where:

$Rate_i$	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 one time interval prior to the given time
time	is the length of the time interval (6, 20, or 35 minutes)

Once each rate is calculated a temperature is associated with the precipitation rate based on the time and day at which the rate is measured. All the rate and temperature data were added to a database. The database contains all the calculated precipitation rates, classified by ambient temperature for all the sites included in the study. Through statistical analysis the probability for each precipitation rate at each temperature was calculated.

FIGURE 2.1

READAC PRECIPITATION GAUGE
CUMULATIVE AND LINEARIZED PRECIPITATION AT DORVAL



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2.2 Fluid Failure Tests on Operational Aircraft

This subsection describes tests that were focussed on the identification and the evaluation of characteristics associated with fluid failure.

Failure time is defined as the time required for the end condition to be achieved. This occurs when the accumulating precipitation fails to be absorbed by the fluid.

A surface is failed if:

- There is a visible accumulation of snow on the fluid or on the wing surface; or
- Ice is visible on the surface.

2.2.1 Test Sites

Aircraft fluid failure tests were planned at Dorval International Airport, Montreal, during the 1997/98 test season. Consideration was also given to conducting tests at Pearson International Airport, Toronto, Ottawa International Airport (Uplands), and Ancienne Lorette Airport, Quebec City, depending on aircraft availability.

These tests were to be conducted at Dorval Airport's new central deicing facility, operated by Aéromag 2000 Inc. (see Figure 2.1). The APS test site (where flat plate tests to determine holdover times are conducted) is also indicated in Figure 2.1, as is Environment Canada's automated weather station.

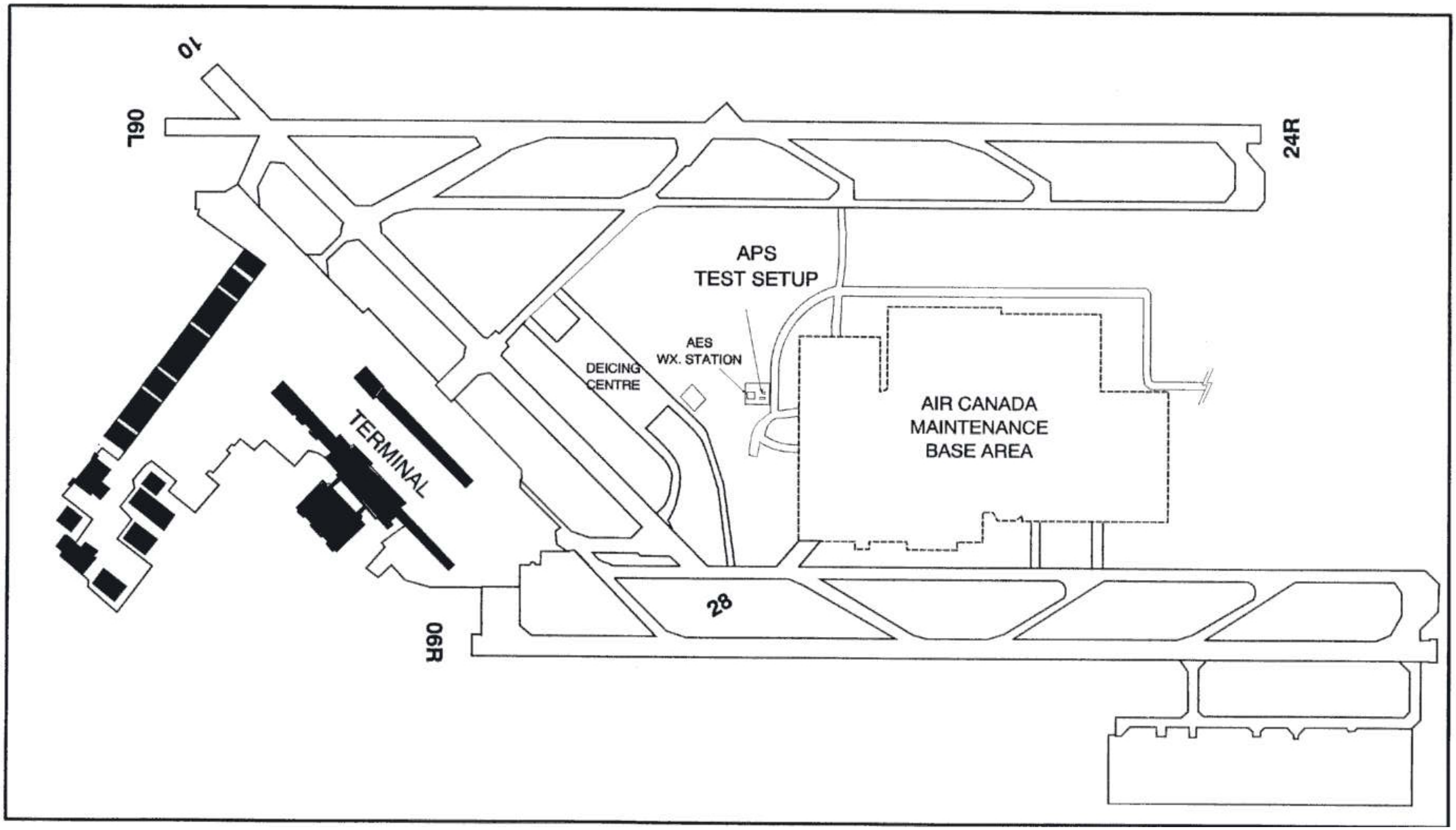
One full-scale fluid failure test was also performed in Ottawa at the Shell Aerospace deicing pad on a KnightHawk Falcon 20. This test was planned to support aerodynamic tests on the Falcon 20 (see related TDC report, TP 13316E[2]).

2.2.2 Test Plan

A dry run and up to a total of five one-night test sessions were planned for winter 1997/98. Planning of the tests was based on the following aircraft and operators:

Aircraft	**Airline**
Canadair Regional Jet	Air Canada
ATR 42	Inter-Canadian
de Havilland Dash 8	Air Alliance, Canadian Regional

FIGURE 2.2
DEICING PAD LOCATION AT DORVAL AIRPORT



Test sessions on Canadair Regional Jet aircraft were planned after normal daily operating times, between 23:00 and 06:00. The ATR 42 aircraft was available for several hours during the middle of the day. de Havilland Dash 8 aircraft were made available to APS; however, no flight crews were available to operate the engines.

Tests were planned under the following conditions:

Aircraft orientation:	headwind, tailwind, crosswind
Precipitation type:	snow, freezing rain, freezing drizzle
Fluids:	Type I, Type IV
Engines:	operating for turboprop tests

Tests were scheduled based on a reasonable forecast of precipitation for the evening/overnight, provided that the airline was available to support and participate in the tests.

Forecasts were monitored daily using radio, television, and Internet sources. A forecast was obtained from the Environment Canada Web site for Montreal. This forecast prompted an alert that was issued to all tests and airline personnel related to the execution of fluid tests. The weather system was closely monitored as the storm approached. This was done via direct one-to-one telephone communication with a trained Environment Canada professional using their 1-900 service.

For each session, up to ten tests were planned (see Table 2.3) using both Type I and Type IV fluids. Aircraft were positioned at a pre-determined orientation prior to the start of the first test. The test plan included the re-orientation of the aircraft relative to wind direction between individual tests during the course of the session.

2.2.3 Equipment

Five full-scale test sessions were scheduled for Dorval Airport during the winter 1997/98 test season. Test aircraft were provided by Air Canada (Canadair Regional Jet), and Inter-Canadian (ATR 42). Aéromag 2000 Inc., operators of the deicing facility at Dorval, supplied specially equipped vehicles and personnel for the application of fluids. Fluids were provided by Union Carbide.

Photo 2.1 shows the equipment used to measure precipitation rate. Two collection pans were used for the collection of precipitation, and a scale, shielded with plexiglass to prevent wind effects, was used to weigh the precipitation. The rate station was positioned on a table in a rented cube van, which was positioned adjacent to the test stand. Photo 2.2 shows

TABLE 2.3

TEST PLAN FOR TURBOFAN FULL-SCALE FLUID FAILURE TESTS

TURBOFAN

OCCASION	RUN #	FLUID[(1)] TYPE	A/C ORIENTATION
1	1	I / IV	Tail
1	2	I	Tail
1	3	I	Tail
1	4	I / IV	Cross
1	5	I / IV	Cross
1	6	I	Cross
1	7	I	Cross
1	8	I / IV	Head
1	9	I	Head
1	10	I	Head

[(1)] Selection of fluid is dependent upon precipitation rate.

TURBOPROP

RUN #	FLUID TYPE	AIRCRAFT ORIENTATION	WING
1	I	Tail	Starboard
2	I	Tail	Port
3	I	Cross*	Starboard
4	I	Cross*	Port
5	I	Cross**	Starboard
6	I	Cross**	Port
7	I	Head	Starboard
8	I	Head	Port

* Wind direction such that starboard wing is on upwind side and port wing is on downwind side.

** Wind direction such that port wing is on upwind side and starboard wing is on downwind side.

the truck used during the full-scale tests. The space in the van was also used for debriefing of test personnel between tests.

Six rolling staircases and several stepladders (see Photo 2.3) were positioned around each aircraft wing. Each wing was adequately illuminated by a mobile mast-lighting system. Each mast-light unit consisted of four 1 000W lights. A 6 kW diesel generator (a component of each unit) was also used to supply current for the lights and other electrical requirements. The new lights were a significant improvement over those used in previous years, with respect to light set-up time, which was reduced substantially. Photo 2.4 shows the mast-lights ready for testing.

During full-scale aircraft trials, standard flat plate tests were conducted simultaneously on a 10º inclined stand. The plates were marked with three parallel lines, 2.5 cm (1"), 15 cm (6") and 30 cm (12") from the top of the plates. The plates were also marked with 15 cross hairs, which served as criteria for the calling of fluid failure on flat plate test surface. Figure 2.3 shows a schematic of a test stand and one of the test plates used. Figure 2.4 provides a schematic of the positioning of major equipment and key personnel about the aircraft.

A list of the mobile equipment used by each of the test team members is shown on Pages B-29 and B-30 of Appendix B. A list of the mobile equipment required for the truck is shown on Page B-31 of Appendix B.

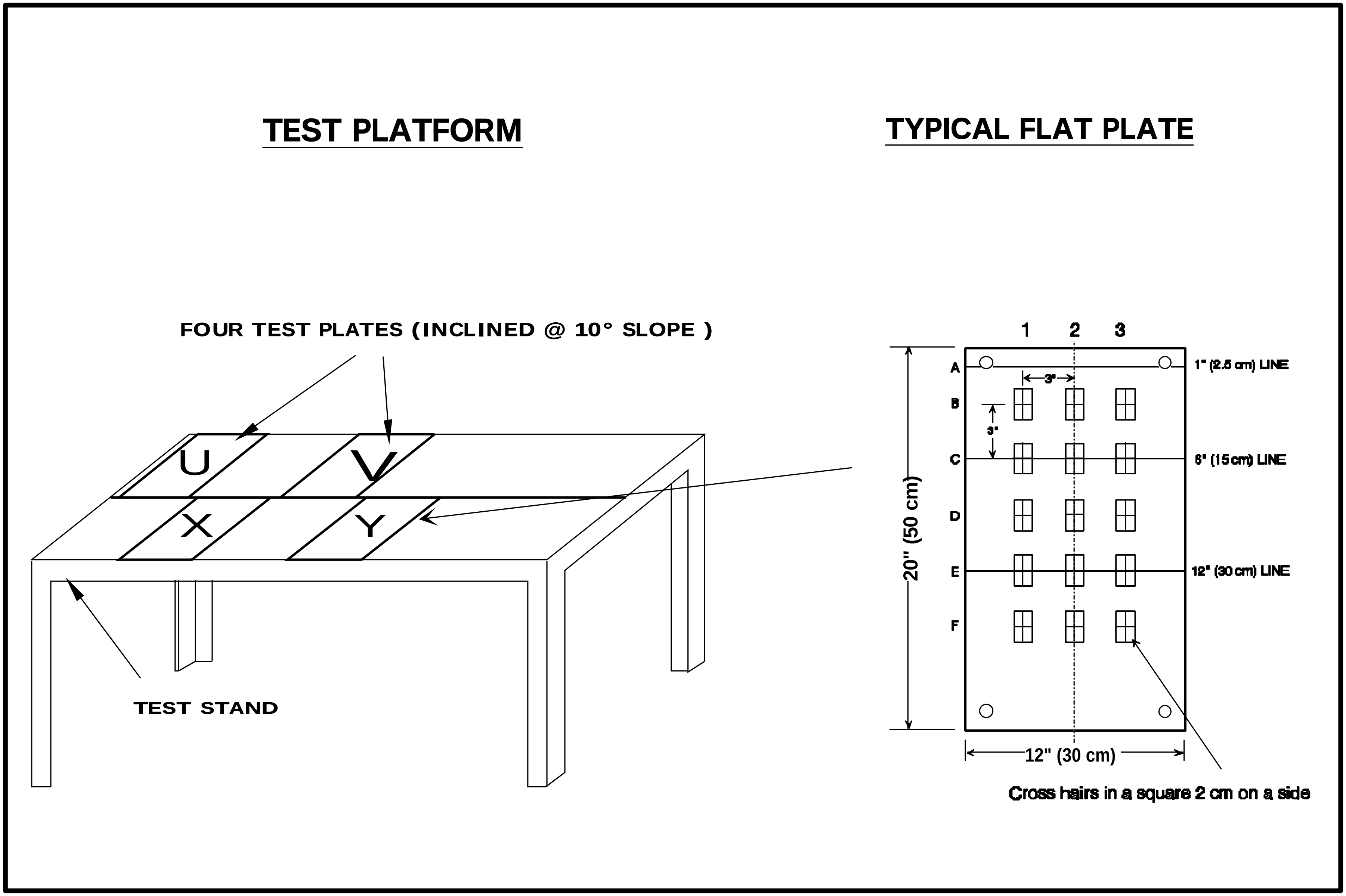
Sampling kits that consisted of spatulas and small collection and storage containers were distributed to personnel responsible for the collection of fluid samples at failure locations on the wing. The freeze points of the fluid samples collected were to be measured immediately with a hand-held Brix-scale refractometer. Photo 2.5 shows the Misco refractometer used by APS and most of the industry.

Photo 2.6 shows the hand-held ID 1H ice contamination sensor unit provided by Robotic Vision Systems Inc. (RVSI). The unit consists of a hand-held camera type sensor used to scan the wing surface and measure the response to ice, a main power supply, and an image storage unit. The entire system is portable.

Photo 2.7 shows the Spar/Cox sensor. The unit uses infrared technology developed by Spar (and manufactured by Cox and Co.) to detect ice accumulation on aircraft surfaces from remote positions. The unit is not yet portable and was mounted on a mechanical lift or the basket of a cherry picker equipped vehicle for test purposes.

FIGURE 2.3

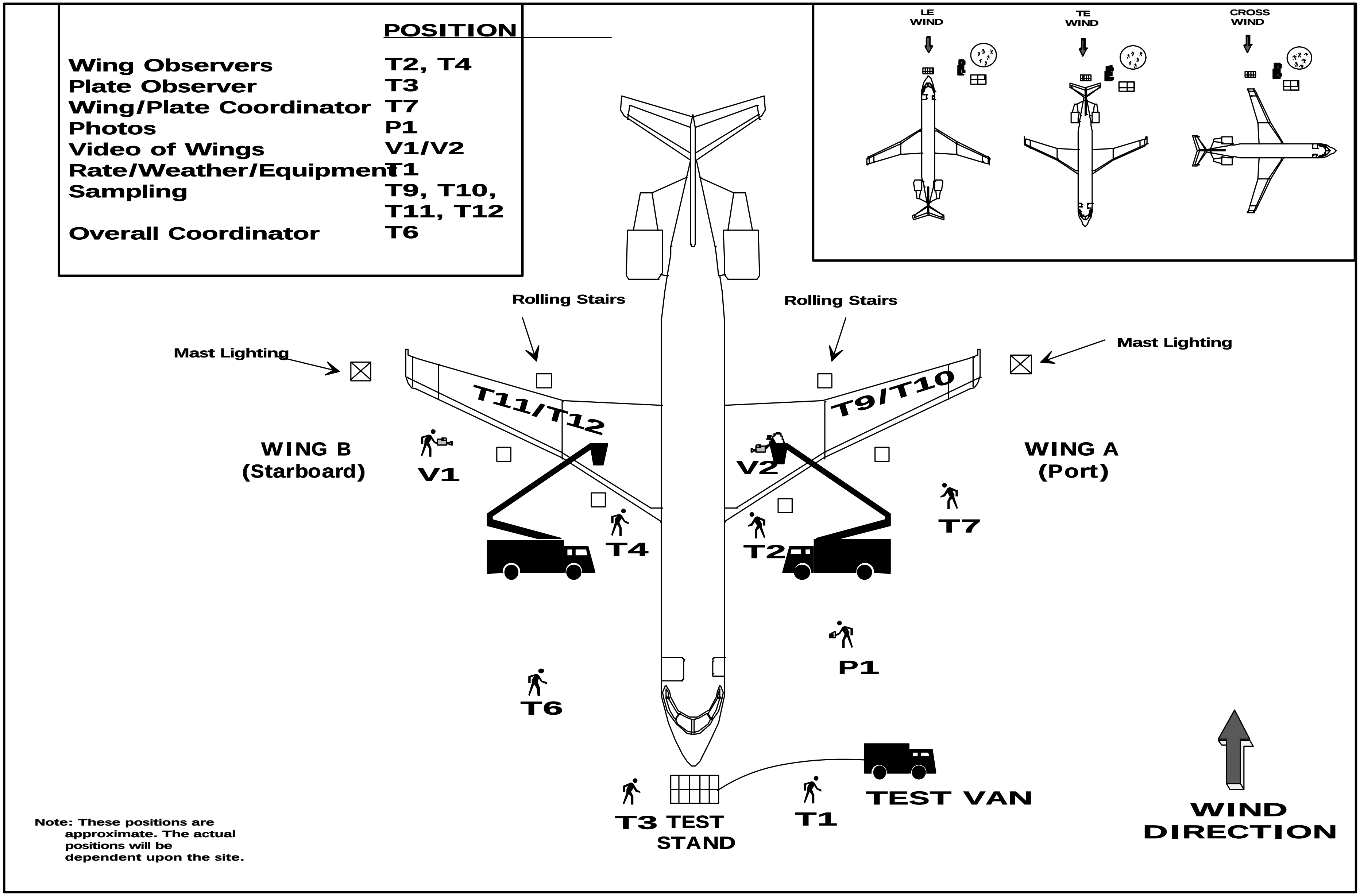
FLAT PLATE TEST SET-UP



11380\report\opnsl\INS_SNW.DRW

FIGURE 2.4

POSITION OF EQUIPMENT AND PERSONNEL



cm1380\report\opns\YULSETUP.DRW

used to record fluid failures on wings and plates. Preparations were also in place to rent a digital video camera, as needed, for the documentation of selected tests.

Four VHF radios were rented to allow communication between co-ordinators and video personnel. Meteorological data, such as temperature, wind speed, and wind direction, were provided by the Remote Environmental Automatic Data Acquisition Concept (READAC), which is located within a 2 km radius of the aircraft test locations. (Refer to Transport Canada holdover time reports for complete descriptions of the READAC instruments).

Wing skin temperatures were recorded using temperature probes mounted on telescopic extension poles. Preliminary tests were also conducted this year into the use of remote infrared temperature sensors, as a means to replace the temperature probes. An infrared thermometer was used briefly during the 1997/98 test season and will be evaluated further in experimental conditions. A hand-held anemometer was used to measure local wind speed. A complete list of test equipment used for the Dorval aircraft full-scale test program is given in Appendix B, Attachment III, *Test Equipment Checklist*.

2.2.4 Description of Test Procedures

The APS document *Experimental Program for Simultaneous Aircraft versus Plate Testing* is provided in Appendix B. It describes the detailed procedures employed during the course of full-scale testing.

APS monitored weather forecasts on an ongoing basis throughout the test season to anticipate conditions that would require aircraft deicing. If these conditions were forecast, the test team was alerted 48 hours prior to the predicted event. Confirmation of the freezing precipitation event was proceeded by contacting airlines to secure a test aircraft. Arrangements were then made with Aéromag for use of the deicing facility and for spray equipment and personnel. An airport security company was then contacted for security escorts. Test equipment, including trucks, mast-lights, and generators were rented. Transport Canada and other companies working in conjunction with APS Aviation, were then notified.

Fluids for full-scale flat plate tests were prepared and stocked in pre-marked red polyethylene fuel containers at the APS test site. The Type IV fluids were stored outdoors at ambient temperature, while the Type I fluids were stored inside the APS trailer. All prepared test fluids were transported to the full-scale test site with the rest of the equipment necessary for testing. The fluids were applied directly from these containers to flat plates by pouring. The standard flat plate test one-step fluid application procedure was used.

Fluid samples were to be collected by the APS fluid sampling team on an ongoing basis during tests at the location of first wing failure and at various points of failure on the wing thereafter (as indicated by the wing observer). The fluid sample concentrations were measured directly using a hand-held Brix-scale refractometer and both the fluid sample time and the location in which the sample was taken were recorded immediately. The sampling procedure is contained in Appendix B, Attachment VI.

Several modifications were made to the plate pan precipitation rate data collection procedure. The start and end times of the rate collection period were to be recorded in hours, minutes, and seconds rather than rounded off to the nearest whole minute. Also, a few seconds were added or subtracted from the rate collection start and end times for time delays created by entering and exiting the truck. Finally, any precipitation that accumulated on the lips, sides, and bottoms of the plate pans was to be removed prior to the weighing of the pans.

A new procedure was developed to collect precipitation rate data in aircraft tests conducted in crosswind conditions. In this case, rates were to be measured on aircraft wings as well as on the test stand. One plate pan mounted on suction cups was to be placed on each wing (mid-section). Plate pans were to be weighed following complete wing failure for Type I fluid tests. For two-step (Type IV over Type I) fluid tests, rates were measured every 15 minutes following application, and directly following complete wing failure. The complete rate collection procedure appears on Pages B-39 and B-40 in Appendix B.

In past years, the time and precise location of first failure was sometimes missed by the wing observer. This is due to the rapid propagation of failures, especially in the case of Type I fluid tests. In certain tests, failure progressed so rapidly that they reached the 25% level at the time of documenting the first failure contour. Procedures were altered to emphasise the requirement to identify the precise location of first wing failure. In tests where rapid progression of failure is to be expected, additional observers would be assigned from the test team to assist the wing observer in failure detection.

Pilots were to be present during full-scale test sessions to record their observations of fluid failure and failure progression observations from inside the cabin and cockpit. This data would later be correlated with the data recorded by the external observers. The pilot observation procedures appear on Pages B-41 and B-42 in Appendix B. Also included in

Appendix B are the two data forms to be filled out by the pilot (Page B-43 and Page B-44).

The video and photo recording procedures are also described in Appendix B. In the past, there was one video recorder for the aircraft wings and one for the flat plates. The flat plate video recorder was also responsible for taking still photographs of the plates and wings. This procedure has since been modified, such that one video recorder was assigned to each wing of the aircraft, and one still camera photographer was dedicated entirely to taking photographs of important events during tests.

A photo procedure was developed for documenting roughness of the failed fluid and is included on Pages B-33 and B-34 (Appendix B). Each aircraft wing was divided into seven sections. Each section was assigned a different colour (see Page B-34). Several coins were painted the colours of the different wing sections (see Photo 2.8). When the point of initial contamination was determined by the wing observer, an unpainted coin was to be placed at this location and photographed plan, profile and overall. When failures occurred elsewhere on the wing (as designated by the wing observer), the colour-designated coins were to be placed in the appropriate sections and photographed in the same fashion. A final set of photographs was planned for the end of the test (at complete wing failure).

Ice detection sensors were to be provided by RVSI and Spar/Cox. The procedure for use of the RVSI unit is provided in Appendix B. At the time of initial fluid application, the instrument operator was instructed to scan and capture an image of the tail identification number of the aircraft in order to mark the start of the holdover time period. The grid structure on Page B-37 of Appendix B was used to determine the order of images taken by the operator. An entire series of images covering the wing was to be performed every 15 minutes. At the end of the test, the instrument operator was instructed to scan and capture the tail identification number again, to signify the end of the record for that test.

2.2.5 Data Forms

Several different data forms were produced for full-scale testing in 1997/98.

The General Form – used for every test – (see Appendix B, Figure 3, Page B-47) was completed by the plate/wing co-ordinator and was used to record information such as the type, temperature and quantity of fluid sprayed, as well as the start and end times of the fluid applications.

A second General Form – filled in once per session – (see Appendix B, Figure 3a, Page B-48) was completed by the overall co-ordinator and was used to record information relating to the aircraft, fluids and initial aircraft skin temperatures.

The third data form is the Aircraft Wing Form. Appendix B (Page B-50) shows the form used for fluid failure tests on the Canadair Regional Jet. Similar forms were also produced for the ATR 42 and the de Havilland Dash 8, and these forms appear in Appendix B. Wing observers were assigned to identify fluid failures and draw failure contours on the wing diagrams.

The fourth data form is the Fluid Thickness on Aircraft Form and is shown on Page B-55 of Appendix B. This form was to be filled out by the individuals assigned to perform thickness measurements during test events when snow or freezing precipitation had ceased, or during dry runs.

The fifth data form is the End Condition Data Form (see Appendix B, Table 1, Page B-57) and was completed by the end condition tester. This form was used to record information related to fluid failure times on the flat plates. The Meteo/Plate Pan Data Form (see Appendix B, Table 2, Page B-57) was completed by the meteo/equipment tester and was used to record information on weather conditions and rates of precipitation.

2.2.6 Fluids

The Type I and Type IV fluids required for full-scale testing were provided by Union Carbide and Octagon. Union Carbide Type I ADF was to be applied in standard concentration (XL54), and Type IV Ultra+ was to be applied in its neat concentration. Type IV Octagon Maxflight was also to be applied in its neat concentration. Prior to the start of the test season, Octagon was contacted by APS to determine whether propylene Octagon Maxflight would be compatible with ethylene XL54 in two-step fluid applications. Octagon replied that the fluids were fully compatible and, therefore, no propylene Octagon Type I fluid was required for test purposes.

2.2.7 Personnel

A minimum of thirteen personnel is required to conduct full-scale aircraft tests. Figure 2.4 provides a schematic description of the general test set-up, as well as the standby location of each member of the full-scale test team. All personnel were involved in setting up equipment prior to tests.

The primary roles and responsibilities of each personnel member are listed below:

- **Rate/Weather/Equipment (T1)**: Responsible for monitoring meteorological equipment and for recording all weather and precipitation rate data;
- **Wing Observers (T2, T4)**: Responsible for drawing failure contours as they occur on wing surfaces;
- **Plate Observer (T3)**: Responsible for the execution of flat plate holdover time tests during full-scale aircraft tests;
- **Wing/Plate Co-ordinator (T7)**: Responsible for ensuring consistency between wing and plate failure calls;
- **Photographer (P1)**: Responsible for taking photographs of important events during each test;
- **Video Recorder (V1, V2)**: Responsible for taking video recordings of aircraft wings, with particular attention on fluid contamination, failure initiation and progression;
- **RVSI and Spar/Cox (R1, S1)**: Responsible for taking sensor images of fluids undergoing failure on aircraft wings;
- **Overall Co-ordinator (T6)**: Responsible for co-ordinating all aspects of the full-scale tests. The overall co-ordinator was also responsible for safety awareness training (based on guidelines that appear in Attachment VI of Appendix B) and ensuring that safety measures were being respected during the course of full-scale testing;
- **Cabin Observer (T7)**: Responsible for observations of fluid treated surfaces and the recording of failures from inside the aircraft; and
- **Sampler (T9, T11)**: Responsible for the collection of fluid samples at selected points of failure on the wings.

Attachment IV of Appendix B, *The Responsibilities/Duties of Test Personnel* contains full descriptions of test personnel responsibilities, individual duties, and positions.

Ground support personnel from the airlines were made available to tow aircraft to and from the deicing facility, and to orient the aircraft between tests. Deicing crews and fluid application equipment were provided by Aéromag 2000 Inc.

2.3 Frost Formation on Aircraft

This subsection describes the methodology related to frost formation tests on service aircraft.

2.3.1 Test Sites

Tests were planned either at the central deicing facility of Dorval Airport or directly at the gate.

2.3.2 Description of Test Procedures

The procedure for frost deposition tests on aircraft resulted from a request for data by Transport Canada late in the test season. Procedures for the conduct of these tests, shown in Appendix E, were not in place until the end of February.

Frost formation tests were also planned on aircraft prior to the start of aircraft full-scale fluid failure tests. Operational aircraft were to be towed to the central deicing facility and examined for frost accumulation on the wings prior to fluid tests. If frost was present, plan, profile, and overall perspective photographs of any frost-laden surfaces detected on the wings were to be recorded. Painted coins described in Subsection 2.2.4 and shown in Photo 2.8 were to be used to identify the location and extent (area and thickness) of frost formations on the wing surface.

2.3.3 Data Forms

No data forms were required for these tests.

2.3.4 Equipment

A 35 mm camera was required for documentation purposes.

2.3.5 Fluids

No fluids were required for these tests.

2.3.6 Personnel

A wing observer and a photographer were required for this documentation.

2.4 Frost Tests on Flat Plates

This subsection describes the methods used to determine frost deposition rates in natural conditions.

2.4.1 Test Sites

Frost deposition trials were conducted at two test sites: the APS Dorval Airport test facility, and a private facility in Montreal. These tests were conducted on three separate occasions in February and March, 1998.

2.4.2 Description of Test Procedures

The experimental procedure for frost tests on flat plates is shown in Appendix D.

Several bare test surfaces with various compositions and/or finishes were prepared for the frost deposition trials. Each surface was pre-weighed to the nearest gram prior to being placed on a 10º inclined test stand in active frost conditions and the start time was recorded. Following exposure to frost, the test surfaces were re-weighed. The final weights were calculated by difference and were recorded along with the end time of the test.

In addition to the bare surfaces tested, two separate plates were coated with fluid; one with Type I fluid, and the other with Type IV fluid, prior to exposure to frost. Fluid failure tests were carried out on these two plates using standard holdover time procedures.

Photo documentation of frost deposition trials was recorded using a 35 mm camera. Before and after photographs of each test surface were recorded.

2.4.3 Data Forms

Two data forms were used during frost deposition trials:

- The End Condition Data Form (Appendix B, Table 1, Page B-57) was used to record fluid failure results; and
- The Meteo/Plate Pan Data Form (Appendix B, Table 2, Page B-58) contains information on the weather conditions and was used to record deposition rates.

2.4.4 Equipment

The following equipment was required for the conduct of frost deposition tests:

- 1.6 mm aluminum plates;
- 3.2 mm aluminum plates;
- Kevlar composite plate;
- 0.5 mm aluminum honeycomb core plate;
- Precipitation rate pans;
- Test stand;
- Weigh scale; and
- 35 mm camera.

In the last session, one red-, one white-, and one blue-pointed 1.6 mm aluminum plate were also included among the surfaces tested.

2.4.5 Fluids

Union Carbide Type I XL54 and Type IV Ultra+ fluids were used to coat certain test surfaces.

2.4.6 Personnel

Two APS personnel, a photographer and a plate observer, were required to conduct frost deposition tests.

2.5 Fluid Thickness Tests with Mobile Type IV Fluid Sprayer Unit

A mobile Type IV fluid spray unit was developed, built, and tested by APS in 1997/98. A series of tests were conducted at Dorval in order to validate the new APS Type IV sprayer and to evaluate the film uniformity of new Type IV fluids when sprayed on aircraft wings. The unit was assembled so APS could apply Type IV fluids other than Union Carbide Ultra+ as required by test plans.

2.5.1 Test Sites

Fluid thickness trials on operational aircraft were conducted on one occasion at the central deicing facility at Dorval Airport during a period of no precipitation. To minimise costs, thickness tests were performed on the starboard wing of a US Airways McDonnell Douglas DC-9 aircraft while a different series of trials were in progress on the port wing.

The trials were conducted overnight, with an ambient air temperature of -8°C, calm winds, and no precipitation. Meteorological data were made available from Environment Canada's automated weather station situated in close proximity to the deicing facility.

2.5.2 Description of Test Procedures

Thickness measurement locations were marked on the USAirways McDonnell Douglas DC-9 aircraft wing in chord-wise fashion from the leading edge to the trailing edge, as shown in Figure 2.5.

In each trial using the APS sprayer, one Type IV fluid was applied on the wing by an Aéromag operator. All Type IV fluid applications were preceded by Type I fluid applications, also performed by an Aéromag spray vehicle. Fluid thickness was measured immediately after Type IV fluid application and then at pre-determined intervals thereafter in order to determine the stabilized thickness. Test duration was 30 minutes.

2.5.3 Data Forms

The general form for recording fluid thickness measurements on jet aircraft is shown in Figure 2.5. Figure 2.5 is a representation of the general form for recording fluid thickness measurements on jet aircraft wings. On the actual form, a plan-view of the wing that show the chord location is also included, but has been omitted in Figure 2.5 to show the

FIGURE 2.5

FLUID THICKNESS ON AIRCRAFT

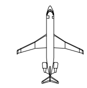
AIRPORT: YUL YYZ YOW

AIRCRAFT TYPE: DC-9

DATE: ____________________

WING: PORT (A) STARBOARD (B)

DRAW DIRECTION OF WIND WRT WING:



RUN #: ____________________

DIRECTION OF AIRCRAFT: __________ DEGREES

1st FLUID APPLICATION

Actual Start Time: ____________________ **am / pm** **Actual End Time:** ____________________ **am / pm**

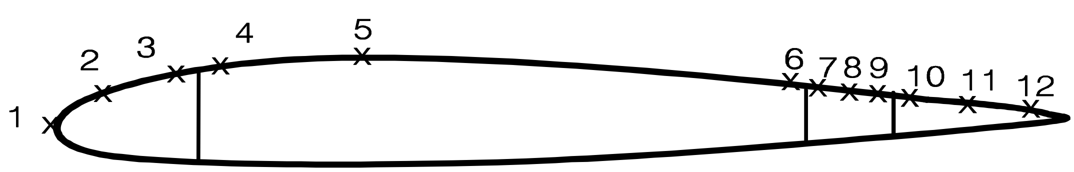
Amount of Fluid Sprayed: ____________________ **L / gal** **Type of Fluid:** ____________________

2nd FLUID APPLICATION

Actual Start Time: ____________________ **am / pm** **Actual End Time:** ____________________ **am / pm**

Amount of Fluid Sprayed: ____________________ **L / gal** **Type of Fluid:** ____________________

Location	Time	Gauge	Time	Gauge	Time	Gauge	Time	Gauge	Time	Gauge
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										



<u>Location</u>

1 - LE Nose

2,8,11 - Half-way

3,4,6,7,9,10 - 1" from joint

5 - High Point

12 - 1" from TE

COMMENTS: ____________________

MEASUREMENTS BY: ____________________

HAND WRITTEN BY: ____________________

profile details more clearly. The actual form used in tests is given in Appendix B, Figure 5, Page B-55.

2.5.4 Equipment

The Type IV fluid spray unit developed by APS is shown Photo 2.9. The mobile sprayer was designed to enable outdoor and indoor testing in all conditions using different Type IV fluids as required. It comprises three interrelated components: a fluid reservoir, a fluid pump, and a fluid application nozzle. The components of the mobile sprayer are described below:

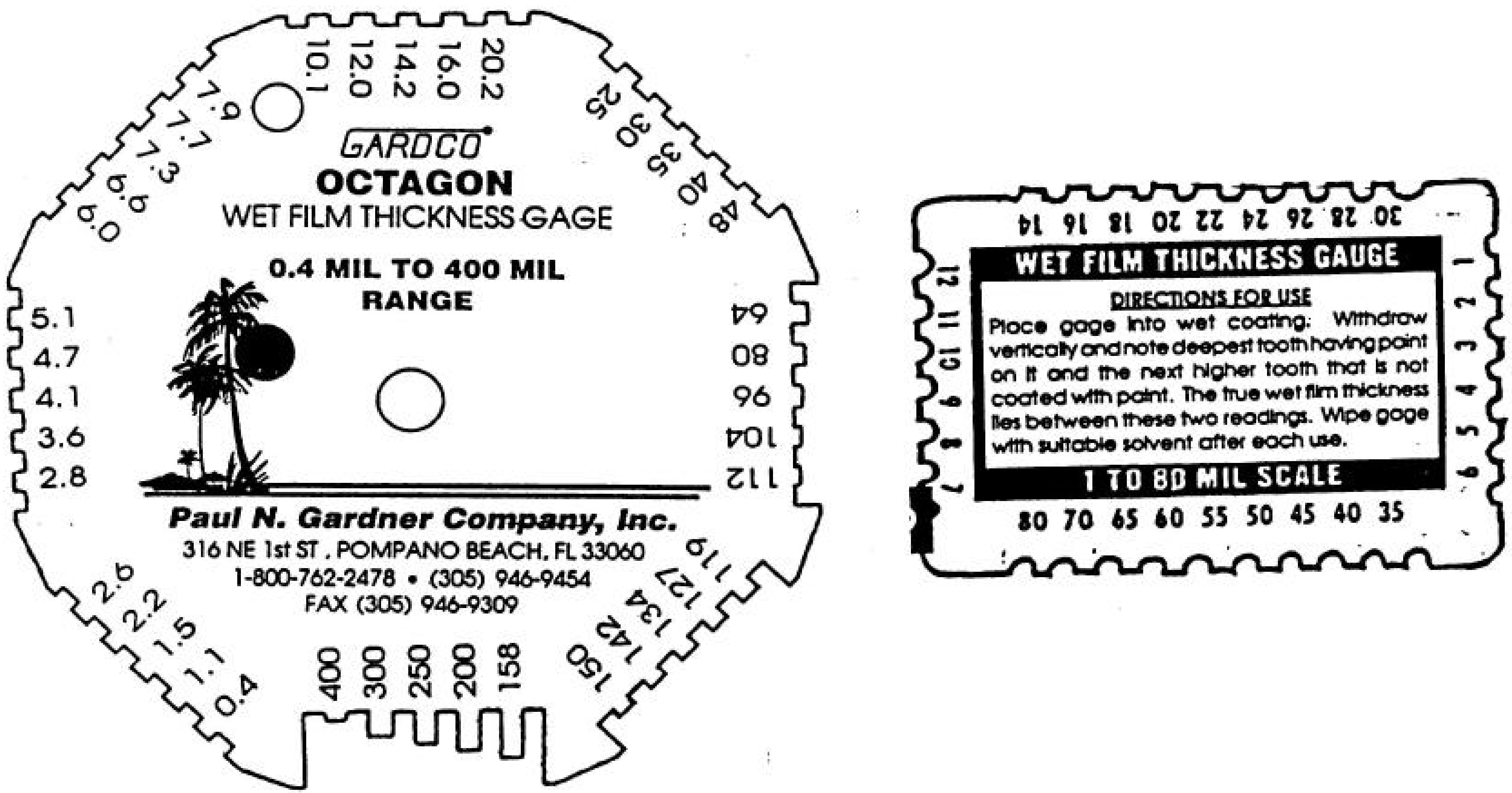
- The fluid is pumped from the reservoir by a fluid pump designed to be non-shearing and identical to those installed in deicing vehicles. The fluid reservoir is a 200-litre drum, adapted with the appropriate fittings and hoses to supply the pump and to receive fluid when the application nozzle is closed;
- A pressure gauge is used to monitor system pressure. The system pressure is controlled by an adjustable relief valve. A check valve mounted at the root of the fluid supply hose prevents any fluid from draining back to the reservoir when the pump is turned off;
- The pump is turned by an electric motor, which requires a generator capable of producing a minimum of 550 V, 30 kW, and three-phase current;
- A Task Force Tips nozzle, shown in Photo 2.10, is connected to the pump with pressure resistant rubber hose fitted with lacking couplings; and
- The total weight of the sprayer system is approximately 315Kg (not including the generator) and can be easily transported with a pick-up truck. The generator used was a large portable unit and is shown in Photo 2.11. It was pulled on its own trailer.

Octagonal wet film thickness gauges, shown in Figure 2.6, were used to measure fluid film thickness. These gauges were selected because they provide an adequate range of thickness (0.01 mm to 10.2 mm) for Type IV fluids. The rectangular gauge shown in the figure has a finer scale and was used in some cases when the fluid film was less thick (toward the end of a test).

The Type I fluid applications for these trials, as mentioned earlier, were performed by Aéromag 2000 personnel using their own spray vehicle.

FIGURE 2.6

WET FILM THICKNESS GAUGES



Equipment necessary for the documentation of these tests included video and still cameras. Mast-lights for aircraft wing illumination were rented prior to test sessions.

2.5.5 Fluids

Tests were planned using Type IV fluids provided by Union Carbide and Octagon. Type I fluid-XL54 (standard concentration ADF) was applied prior to Type IV fluids. Type IV fluids were applied in neat form. All Type IV fluids used in APS sprayer tests were shipped by the fluid manufacturers in 200 litre drums.

2.5.6 Personnel

Up to five people were required for aircraft thickness tests using the mobile sprayer. All personnel were involved in setting up equipment prior to tests.

2.6 Alternative Deicing Methods

2.6.1 Test Sites

The bulk of the photo documentation of alternative deicing methods was taken at Dorval and St. Hubert airports in the Montreal area using operational aircraft. Additional photographs were retrieved from APS photo archives.

2.6.2 Description of Test Procedures

APS was asked to document several alternative methods of aircraft deicing. Aircraft operators were contacted in order to obtain access to aircraft. The aircraft deicing equipment and/or deicing technique were then demonstrated and photographed.

2.6.3 Equipment

A 35 mm camera was used for documentation.

2.6.4 Data Forms

No data forms were required for these tests.

2.6.5 Fluids

No fluids were required for these tests.

2.6.6 Personnel

A test co-ordinator and a photographer were required for this documentation.

2.7 Documentation of Wing Area Visible to Flight Crew

2.7.1 Test Sites

This activity was to be conducted at Montreal International Airport (Dorval) making use of operational aircraft parked on gates during normal ground time when no passengers were on board. Gaining airline approval was necessary to enable access to the aircraft.

The documentation of wing and contamination visibility during the fluid failure tests was to be carried out on aircraft test at Dorval Airport.

2.7.2 Equipment

Both a 35 mm camera and a video camera were used for documentation.

2.7.3 Description of Trial Procedures

Target aircraft were: McDonnell Douglas DC-9, Boeing 767, Canadair RJ, de Havilland Dash 8, and British Aerospace BAe 146.

A record was maintained of the aircraft type, airline, aircraft fin number, and date.

Photo and video images of the wing were taken from several vantage points in the aircraft, including:

- The flight deck with and without window open, if possible;
- The seat row ahead of the leading edge that gives the best view of the wing;
- The overwing exit seat row;
- The seat row close to the trailing edge of the wing; and
- The seat row further back in the cabin that gives the best view of the wing.

At each location, as many images as necessary to capture the entire visible area of the wing were taken. In the passenger cabin, photos were taken both at the window and from the aisle, leaning over the first (aisle) seat, simulating a situation where all seats are occupied.

For high wing aircraft, photos were taken from any window and passenger door that afforded a view of some part of the wing top surface.

For documentation activities conducted at night in conjunction with any fluid failure tests on aircraft, photos were to be taken both with and without external lighting.

The procedures for these activities are included in Appendix F.

2.7.4 Data Forms

A single data form was used for the documentation activity to record aircraft specific information, and the locations from where photos were taken.

2.7.5 Participants

Two APS personnel, a photographer, and a co-ordinator, were required.

2.8 Use of Remote Sensors for End-of-Runway Inspections

2.8.1 Test Sites

The single field demonstration with the Spar/Cox Camera was conducted at Montreal International Airport (Dorval). To avoid conflict with the operation and possible infringements on normal obstacle clearances for runways, the vehicle was positioned at the east deicing bay which was vacant following relocation of all deicing activities to the new deicing centre. This position was in close proximity to aircraft taxi lines from terminal gates to the new deicing centre and from the deicing centre to Runway 06R following deicing.

2.8.2 Description of Test Procedures

The procedure for operational field trials was developed based on discussions with Aéroports de Montréal (ADM) management. This procedure is included as Appendix C.

2.8.2.1 Field Demonstration

A Spar/Cox contamination sensor was installed in the bucket of a leased van equipped with a bucket. During the demonstration, the van was positioned at the unused east deicing bay, close to the taxi route from the deicing centre to Runway 06R. As aircraft taxied past the sensor position, the sensor scanned the wing on the near side. Observers in the van were able to watch live images of the aircraft, with contaminated areas indicated on the sensor system monitor as the aircraft taxied past the observation post. Aircraft en route to the deicing centre were also scanned, but at a further distance.

Following this demonstration, it was decided that fundamental information on sensor limitations, such as: the distance to the subject; the viewing angle; the ambient light level; the colours of airline lettering and logos; and the types of surface materials were needed. It was determined that this information could be more rapidly documented in a laboratory environment. No further field trials were conducted during the 1997/98 winter season.

2.8.2.2 Laboratory Trials

Laboratory trials were conducted in the large end of the National

Research Council Climatic Engineering Facility (19 m long by 8 m high) at Ottawa.

Parameters investigated included:

- Distance from subject; operational range required is 7.5 to 45 m;
- Angle of incidence of the surface being viewed to the system line of sight; operational range varies from a very shallow angle to 90°. The wing dihedral must be factored in;
- Size of area contaminated;
- Impact of different coloured surfaces and different surface types; and
- Levels of system lighting required (intended application would be located in unlighted area on the airfield).

A series of tests were defined to record the camera performance in various geometries (distances, elevations, angles) relative to a set of test surfaces, and to assess the camera performance under conditions of reduced visibility using artificial snow generated in the chamber.

2.8.3 Data Sheets

The principal data sheet for field trials was formatted to record aircraft information as each aircraft taxied past the sensor equipped vehicle. A copy of this data form is included in Appendix E.

For the laboratory trials, forms to record time, elevation (of sensor camera), distance, surface type and observations were employed.

2.8.4 Equipment

For field trials, a van equipped with a cherry picker bucket capable of 7.5 m height was leased. The Spar/Cox camera was installed in the bucket, and equipped with remote pan/tip controls. The sensor system monitor was installed in the van, where up to three personnel could be accommodated as observers.

For laboratory trials, a test stand (Photo 2.12) holding three standard (30 cm by 50 cm) aluminum flat plates, one kevlar plate, one honeycomb-section plate, and three different-coloured aluminum plates (red, white, and blue) were assembled in the chamber. Two plate pans to collect rate data and two inverted plate pans to supply clean aluminum surfaces for calibration if needed were also mounted. A carbon fibre composite plate was later substituted for one of the inverted plate pans, as one clean test surface was deemed sufficient. Figure 2.7 shows the positioning of the various test surfaces on the test stand.

Other test surfaces included a 0.9 m x 1.8 m long (leading to trailing edge) airfoil section possessing most of the contours and compound angles of a simpler aircraft wing, and two 2.1 m x 0.6 m flexible aluminum plates. These long plates were inserted into a railroad track slot (two of which run through the chamber) in order to simulate long (front-to-back), narrow airfoil sections. When the tip of each sheet was wedged into the track recess, it bowed under its own weight. Additional mass to make the arc more pronounced was applied using “vice grips” or locking pliers attached to the free end of the sheet. These surfaces are shown in Photo 2.13, which affords a view of the test surfaces from the sensor position. The airfoil is in the foreground. The long plates are shown in front of the test stand, with the words “Cox” and “ICE” carved in the snow on their surfaces.

The sensor camera was mounted on a scissor lift (Photo 2.14) to enable variation of the height of the sensor camera to produce various angles of incidence typical of an installation observing live operations. The camera was set up with two narrow beam light sources to optimise ice detection under conditions of reduced secondary illumination at distances greater than 15 m. The test distances were reduced during precipitation simulation due to visibility considerations. Sensor monitors (Photo 2.15) were set-up in an adjoining office. The sensor image in this photo is displaying the word “ICE” which has been outlined in the snow covering one of the foil test surfaces in Photo 2.13.

2.8.5 Personnel

Three APS staff participated in the field demonstration, along with Cox staff. Staffs from TDC and from airport ADM were present as observers.

Laboratory trials involved two APS personnel as well as Cox personnel. Several external observers (from Transport Canada, the Federal Aviation Administration, Hudson General, and US Airways) were also in attendance at various stages of the laboratory trials.

FIGURE 2.7

POSITION OF TEST SURFACES ON TEST STAND

Kevlar	White Painted Aluminum	Blue Painted Aluminum	Bare Aluminum	Red Painted Aluminum	Bare Aluminum

Inverted Plate Pan (Aluminum)	Plate Pan # 1	Honeycomb Core Aluminum Surfaces	Bare Aluminum	Plate Pan # 2	Inverted Plate Pan (Aluminum)

2.9 Evaluation of the Demand for Holdover Time during Actual Deicing Operations

2.9.1 Test Sites

The APS test site, located 200 m from the Aéromag 2000 deicing bay between the Runways 06L/24R and 06R/24L of the Dorval airport, was used as a base for all operations involved in observing and recording data (see Figure 2.1). Collection of data from Denver airport through United Airlines was explored but the data could not be released due to company policies of confidentiality. Toronto airport agreed to provide data from the new deicing centre; however, it only became functional in late winter and no pertinent data could be collected.

2.9.2 Description of Data Collection Procedures

During conditions of snow or frost, one person stationed at the APS test site was equipped with a set of binoculars and a VHF radio to monitor and record airport/aircraft transmissions. When an aircraft entered the deicing bay to start deicing, the time, flight number, type of aircraft, general weather condition, Iceman Holdover Time call and deicing fluid Type I or IV/I were noted (see Figure 2.8). Takeoff times (the start of the take-off roll) of the same aircraft were later retrieved from departure data provided by ADM. The flight numbers from the two sources were then matched using a custom Microsoft Excel subroutine. The heldover time (taxi time), defined as the interval from the beginning of the second step of a two-step de/anti-icing (or the beginning of the first and only step for a one-step deicing) and the time of takeoff. This procedure was developed in view of the fact that heldover time data could not be made available by Aéromag.

2.9.3 Data Forms

A data form including the flight number, the type of aircraft, the general weather condition, the Iceman's start of holdover time, and the deicing fluid type was completed on each occasion (see Figure 2.8). Each row represents a different aircraft and the information associated with that departure.

2.9.4 Equipment

A VHF radio linked to an audiocassette recorder was used to monitor and

FIGURE 2.8

SAMPLE OF DATA REQUIREMENTS

Date	Flight ID	Aircraft Type or Code	Fluid Type	Start of HOT	Reason for Deicing	Amount of Precip. On ground
March 15, 1998	Northwest 623	BAe 146	Type I/IV	8:11	Light Snow	Negligable
March 15, 1998	Delta 2087	DC-9	Type I	8:09	Light Snow	Negligable
March 15, 1998	Air Canada 974	A320	Type I	8:10	Light Snow	Negligable
March 15, 1998	Air Canada 922	DC-9	Type I/IV	8:15	Light Snow	Negligable
March 15, 1998	Mexicana 881	A320	Type I	8:11	Light Snow	Negligable
March 15, 1998	Air Canada 403	A320	Type I	8:19	Light Snow	Negligable
March 15, 1998	Royal 572	A330	Type I	8:30	Light Snow	Negligable
March 15, 1998	Air Canada 988	A320	Type I	9:11	Light Snow	Negligable
March 15, 1998	Canadian 911	A320	Type I	9:12	Light Snow	Negligable
March 15, 1998	Canadian Regional 1947	F28	Type I/IV	9:14	Light Snow	Negligable
March 15, 1998	Air Canada 405	A320	Type I	9:14	Light Snow	Negligable
March 15, 1998	American 1041	DC-9	Type I	9:20	Light Snow	Negligable
March 15, 1998	Air Canada 111	A330	Type I	9:31	Light Snow	Negligable

cm1380/report/opns/Smp_data.xls
7/22/02

record airport/aircraft transmissions (see Photo 2.16). Binoculars were also provided to the APS personnel monitoring the departure times.

2.9.5 Fluids

Union Carbide products, namely XL54 (Type I fluid) and Ultra+ (Type IV fluid), were used exclusively by the deicing centre operator (Aéromag 2000) for deicing and anti-icing operations. Operations involved either a one-step (Type I) fluid application or a two-step (Type IV over Type I) fluid application.

2.9.6 Personnel

A pilot with VHF radio experience monitored deicing operations and recorded data.

2.9.7 Data Analysis Methodology

A histogram was produced from the total data showing heldover time versus frequency of occurrences. Separate histograms were produced to evaluate four other relationships; aircraft size, runway used, climate condition (snow or frost) and type of fluid mixture used (Type I or Type IV over Type I). These results are provided in Section 4.

An evaluation of heldover times versus precipitation rates was also completed using data from APS environmental measurements associated with holdover time tests. This material is also presented in Section 4.

Photo 2.1
Precipitation Rate Measurement Equipment

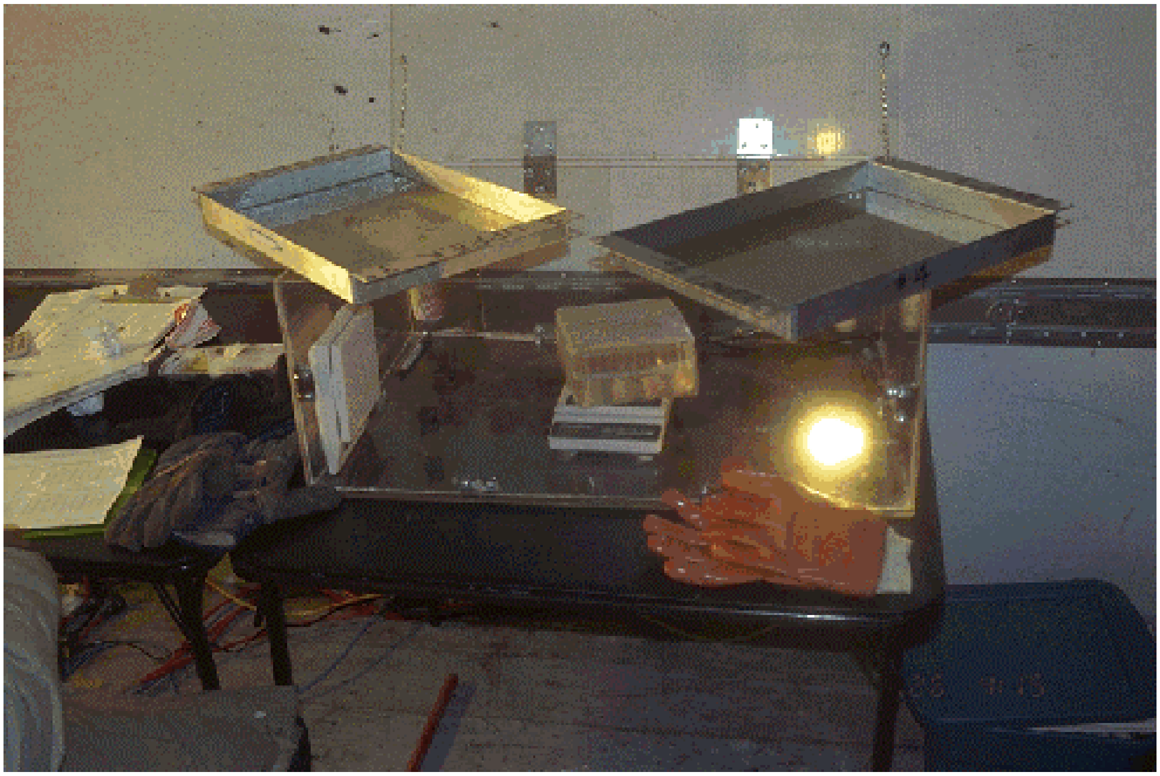


Photo 2.2
Field Lab for Full-Scale Tests

Photo 2.3
Rolling Stairs and Step Ladders Positioned Around Aircraft

Photo 2.4
Mast Lighting Used for Aircraft Illumination

Photo 2.5
Misco Refractometer

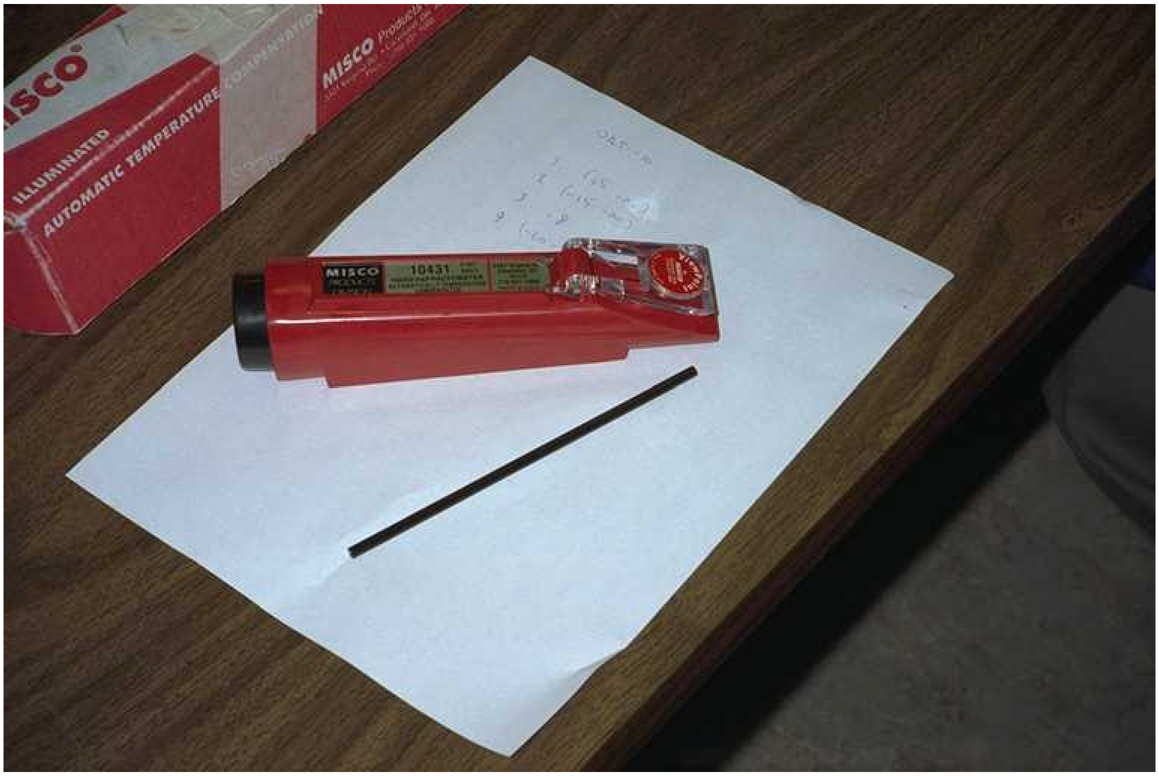


Photo 2.6
Hand-Held Ice Detection Sensor by RVSI ID-1H

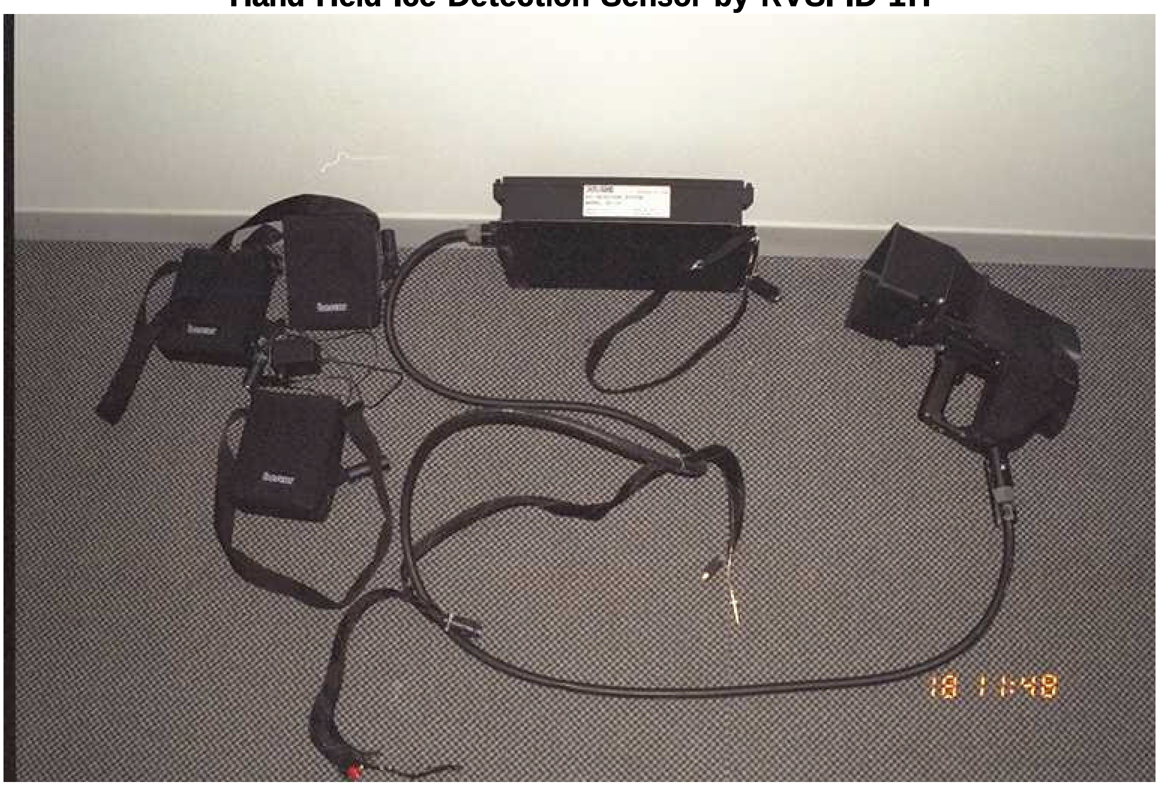


Photo 2.7
Spar/Cox Sensor

Photo 2.8
Painted Coins Used in Documentation of Roughness of a Failed Fluid

Photo 2.9
Mobile Type IV Fluid Sprayer Unit

Photo 2.10
Task Force Tip Nozzle

Photo 2.11
Type IV Mobile Sprayer Setup

Photo 2.12
Plate Test Surfaces

Photo 2.13
Test Surfaces Viewed from Sensor Position

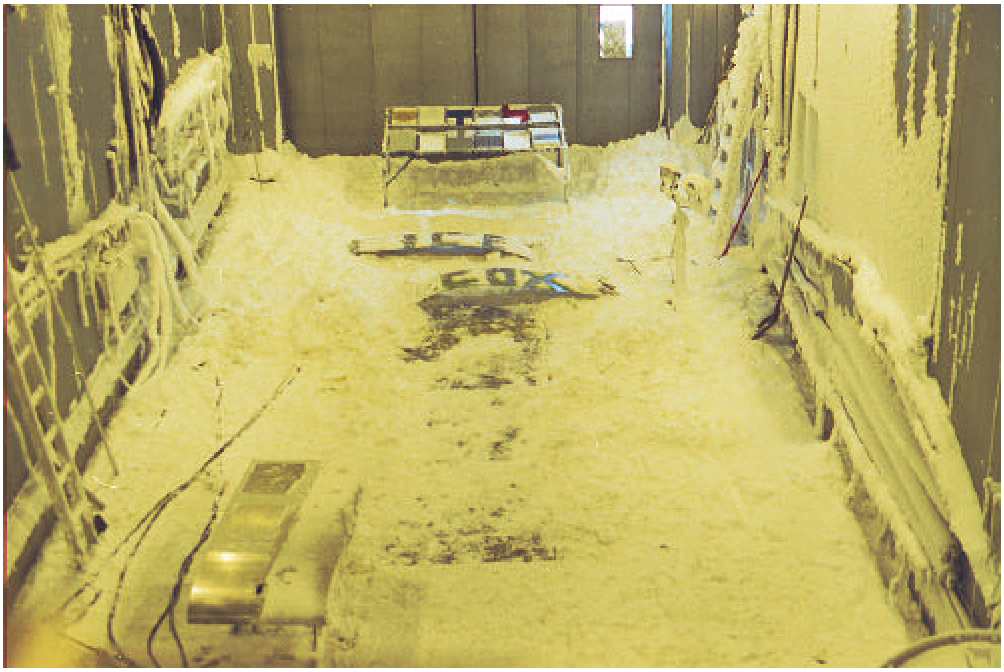


Photo 2.14
Sensor Installation on Scissor Lift

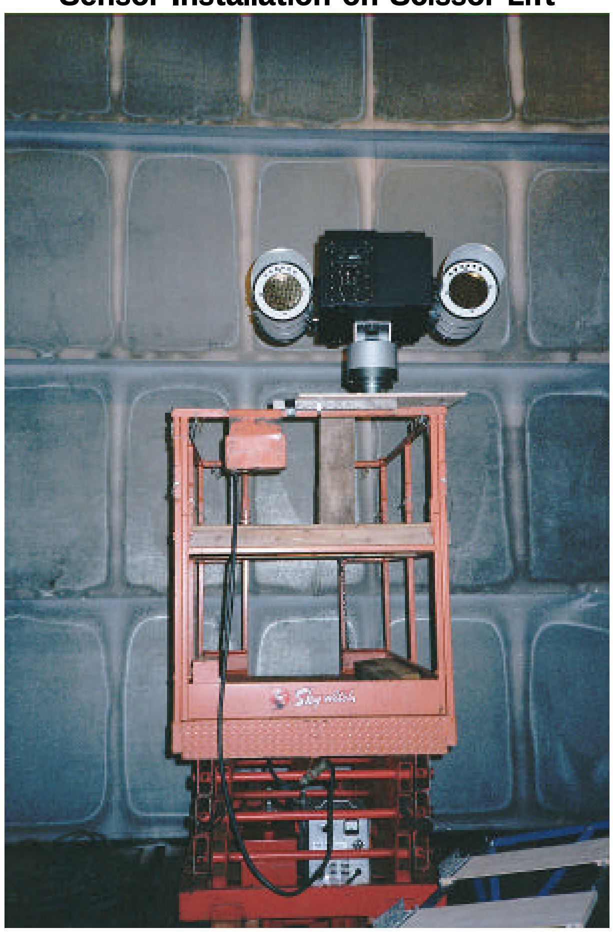


Photo 2.15
Ice Sensor Monitors

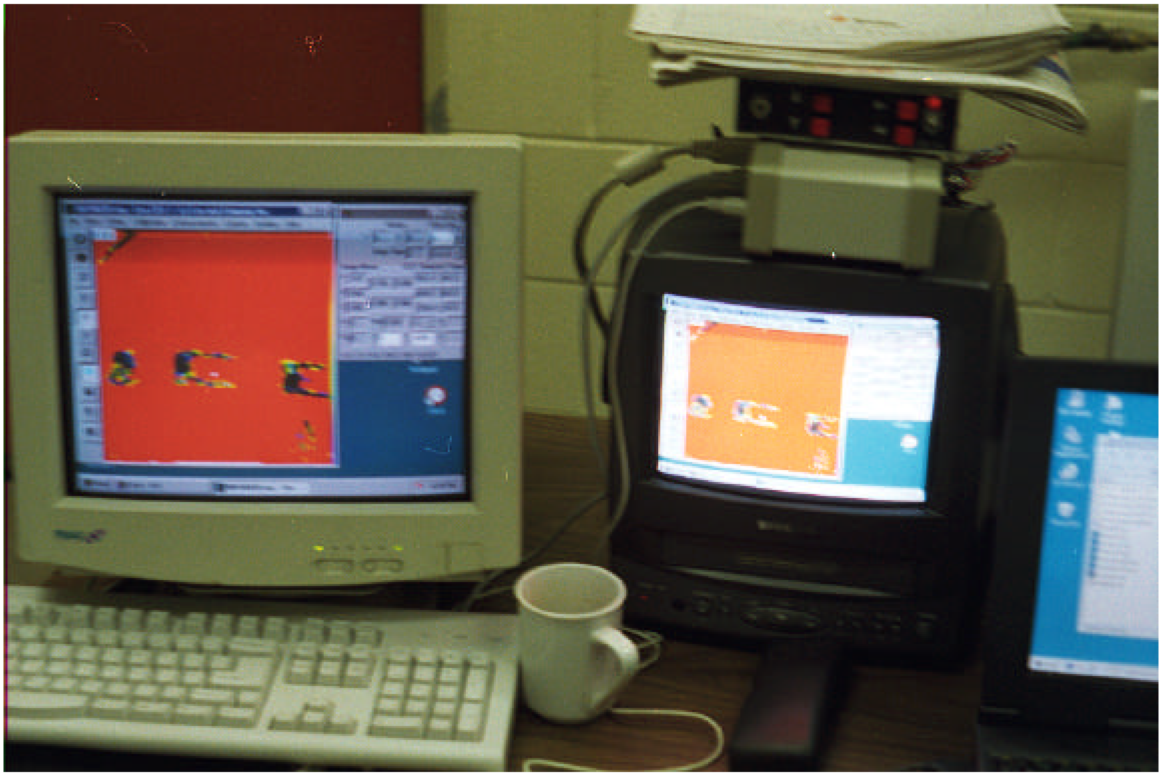


Photo 2.16
VHF Radio Used to Monitor Deicing Operations

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3. DESCRIPTION AND PROCESSING OF DATA

3.1 Evaluation of Snow Weather Data

3.1.1 Natural Snow

A total of 41 029 data points were developed analytically for natural snow conditions. This represents, on average, about 100 hours of snowfall per year per station or 15 snowfalls of 6.5 hours each. The distribution of data points collected, by temperature range, is listed below:

	# of Data Points
Above 0°C	2 664
Between 0 and –3°C	10 860
Between –3 to –7°C	12 793
Between –7 to –14°C	11 767
Between –14 to –25°C	2 945

The distribution of data points, by temperature range, in histogram format is shown in Figure 3.1.

Figure 3.1 shows the breakdown of data points collected by temperature for natural snow. The following observations should be noted:

- Over 1/3 of the snowfalls occurred within the range of 0 to –3°C;
- Only 5% of the snowfalls occurred between –14 and –25°C; and
- Only 4% of the snowfalls occurred at above 0°C temperature.

3.1.2 Light Freezing Rain

Light freezing rain data were developed from READAC on five occasions, mostly during the January 1998 ice storm, for a total of 5 791 data points. (Approximately 96 hours of light freezing rain). Other light freezing rain occurrences were not used due to a malfunction in READAC instruments. The distribution of these data, by temperature range, is shown in Figure 3.2, and summarized by the temperature ranges below:

	# of Data Points
Above 0ºC	82
Between 0 and –3°C	1 390
Between –3 to –10°C	4 319

FIGURE 3.1

TEMPERATURE DISTRIBUTION

Natural Snow

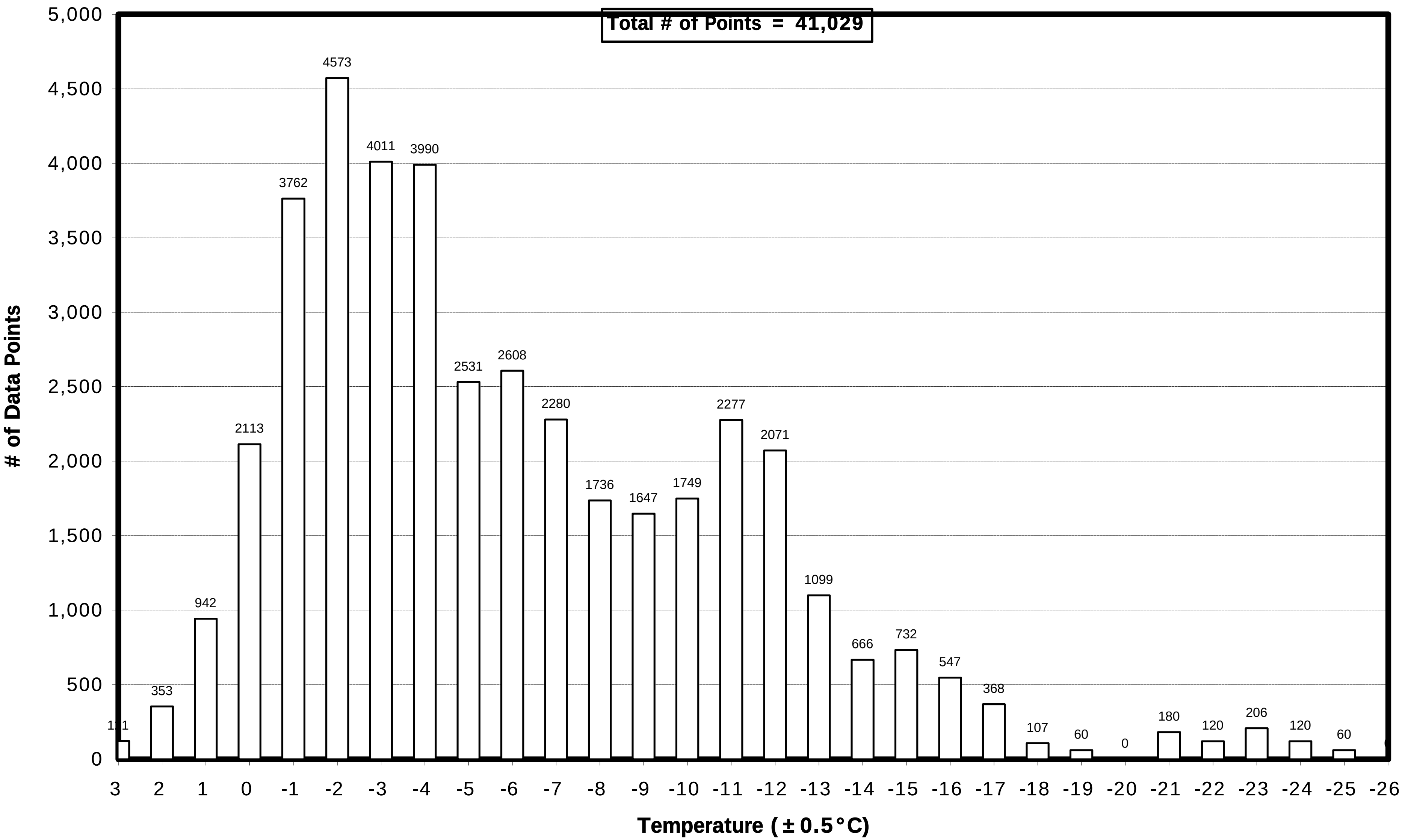

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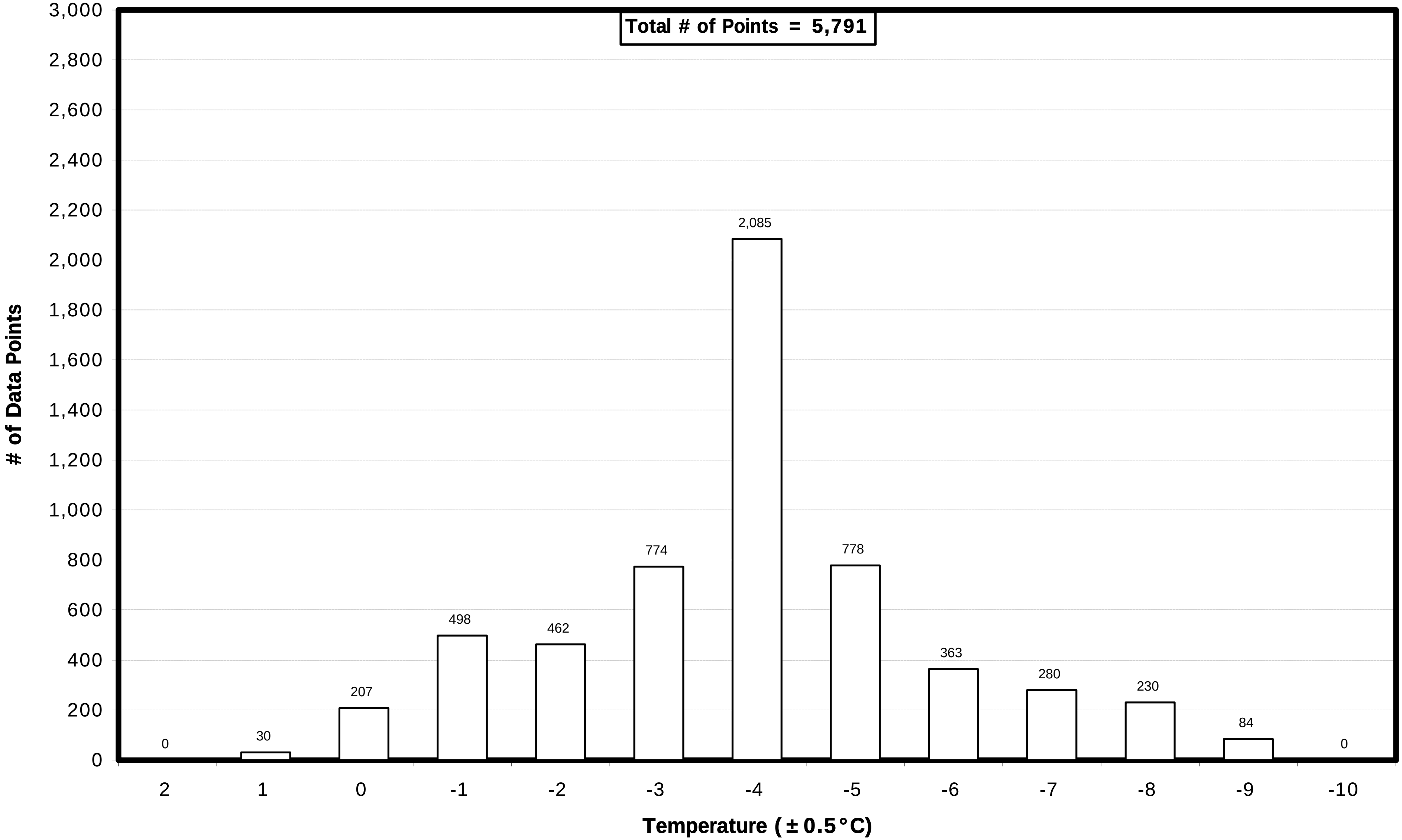
FIGURE 3.2

TEMPERATURE DISTRIBUTION

Light Freezing Rain



cm1380/readac/Tem_dist.xls
7/22/02, 1:35 PM

The breakdown of freezing rain occurrences by temperature is shown in Figure 3.2. The following observations should be noted:

- Freezing rain did not occur at temperatures below –9°C; and
- Most of the freezing rain (60%) occurred at temperatures between –3 and –5°C.

These observations should not be used as a generalization of freezing rain occurrences since most of the data were limited to the January 1998 ice storm.

3.2 Fluid Failure Tests on Operational Aircraft

3.2.1 Overview of Test Sessions

A dry run was scheduled for the night of January 7/8, 1998, to train personnel and evaluate test procedures. However, the session was cancelled due to severe freezing rain conditions which overloaded the deicing facility.

The dry run was rescheduled for January 13, 1998, but was again cancelled due to the ice storm. A dry run and training session was held on January 14, 1998, at the Dorval APS test facility. (Aircraft surfaces were to be simulated using flat plates because no precipitation was present, and no aircraft were used in simulations, no useable data were gathered.)

A full-scale test session was planned for the night of January 23/24, 1998, but was cancelled when the snowfall was forecasted to end around 1:00 am.

A Regional Jet fluid failure test session was initiated on February 12, 1998, but the forecasted freezing rain did not occur. As a result, only fluid thickness tests were conducted. The test session was called off at 2:30.

An ATR 42 turboprop test was scheduled for February 18, 1998. The weather forecast predicted snow for an extended time interval, however, the test had to be cancelled as the snowfall ended earlier then predicted.

ATR 42 and Canadair Regional Jet full-scale trials were planned for February 24, 1998. The ATR 42 test was cancelled because the forecast snow never started. The Regional Jet test was cancelled because Air Canada was unable to provide an aircraft.

Substantial preparation had been undertaken to organise full-scale test sessions. On several occasions, costs were incurred for truck rental, equipment rental and airport security escorts.

Fluid failure tests were performed on a KnightHawk Falcon 20 aircraft in Ottawa on March 14, 1998. Two runs were conducted, one with Type I fluid, the other with a Type I fluid oversprayed with a Type IV fluid. The results of these trials are presented in a related TDC report, TP 13316E[2], *Contaminated Aircraft Takeoff Test for the 1997/98 Winter*.

A series of exploratory tests were performed at the Dorval test facility on March 27, 1998, to evaluate the lifting of spoilers on high wing aircraft as a means to conduct pre-takeoff checks. These results are presented in Section 4.2.

3.3 Frost Formation on Aircraft

3.3.1 Overview of Test Sessions

As no full-scale tests were conducted in 1997/98, no frost formations on aircraft tests were performed. Attempts were made on a few occasions in late April to conduct tests on Regional Jet aircraft directly at the gate. Weather forecasts were monitored daily on the Internet and through one-on-one conversations with Environment Canada meteorologists; however, no suitable conditions happened to occur.

Plans were made to perform frost trials on a leading edge wing section from a Canadair Regional Jet. Although Canadair had indicated that a wing section was available to APS for testing, all attempts to obtain the wing section were not successful and no tests were performed.

Although no frost tests were performed on operational aircraft, tests were conducted on flat plates, and the data will be presented in Section 3.4.

3.4 Frost Tests on Flat Plates

This subsection will discuss the processing of data as it relates to frost tests on flat plates.

3.4.1 Overview of Test Sessions

Frost deposition trials were conducted on three occasions at two sites.

Run #1 was a preliminary test, performed in the early morning hours of February 21, 1998, at a private facility in Montreal. Three bare test surfaces, a standard 3.2 mm (1/8") aluminum plate, a kevlar composite plate, and a 0.5 mm (0.020") aluminum honeycomb core plate were weighed and placed on portable test stands inclined at 10°. One plate pan with its bottom inside surface coated with a thin film of Type IV fluid was also placed outside. Test surfaces remained outdoors for a 3.5 hour period. Frost depositions of up to 6 grams were measured on the surfaces when they were re-weighed following the exposure period.

Run #2 was another preliminary test, performed during the night of February 21/22, 1998, at the same facility. The same four surfaces tested in Run #1 were placed outside on portable test stands for more than six hours. Test surfaces were re-weighed after three and six hours of exposure to frost conditions. Frost depositions of up to 5 grams per 3-hour period were measured on the surfaces when re-weighed.

The final test, Run #3, was conducted at the Dorval Airport test facility during the night of March 17/18, 1998. Six bare surfaces, a 1.6 mm (1/16") aluminum plate, a 1.6 mm (1/16") aluminum plate (painted blue), a 1.6 mm (1/16") aluminum plate (painted red), a 1.6 mm (1/16") aluminum plate (painted white), a kevlar composite plate, and a 3.2 mm (1/8") aluminum plate were weighed and placed on a test stand. A plate pan with its inside bottom surface coated with a film of Type IV fluid, was also weighed, and placed on the stand. Finally, two 3.2 mm (1/8") aluminum plates were placed on the stand and coated with fluid, one was coated with Type I fluid, and the other was coated with Type IV fluid. The surfaces remained outdoors for over five hours. The measured frost depositions varied depending on the test surface and were as high as 7 grams.

3.4.2 Description of Data Collected and Analysis

The frost deposits were measured by weighing each test surface prior to and subsequent to exposure to active frost conditions. Deposition rates were calculated by dividing the difference between the start and end weights of the test surfaces (in grams) by the number of hours that the surfaces were exposed to frost conditions. The result was then divided by the area of the test surface (in dm^2). The frost deposition is expressed in $g/dm^2/hr$.

3.5 Fluid Thickness Tests with the Mobile Type IV Fluid Spray Unit

This section presents the data from fluid thickness trials conducted with the APS mobile spray unit. Comparison was made between surfaces coated with Union Carbide Ultra+ Type IV fluid from both the APS mobile spray unit and Aéromag vehicles.

3.5.1 Overview of Test Sessions

A total of four fluid thickness tests were conducted on March 18, 1998, using a McDonnell Douglas DC-9 provided by US Airways. APS had planned to perform trials using Octagon Maxflight fluid. Despite efforts to obtain this fluid prior to the test, it was not received on time. As a result, tests were performed using three Type IV fluids provided by Union Carbide; Ultra+, and two new formulations, one designated as PG AAF, and the other designated as Ultra IV.

The breakdown of the tests conducted is as follows:

- Run 1 Type IV UCAR Ultra+ applied using APS mobile sprayer;
- Run 2 Type IV UCAR Ultra+ applied using Aeromag truck sprayer;
- Run 3 Type IV UCAR Ultra IV applied using APS mobile sprayer; and
- Run 4 Type IV UCAR PG AAF applied using APS mobile sprayer.

The results of the four tests are presented in Figure 3.3. They are arranged in four charts that show the stabilized thickness values 30 minutes after Type IV fluid application. Note that all tests were carried out using heated Union Carbide XL54 (Type I) as the first-step fluid of a two-step fluid application.

3.6 Alternative Deicing Methods

APS was asked by TDC to provide photo documentation of deicing methods and practices within the airline industry in which no glycol-based fluids are used.

The photo documentation of alternative deicing methods is shown in Subsection 4.6.

3.7 Documentation of Wing Area Visible to Flight Crew

Documentation activities were conducted on five aircraft types, including

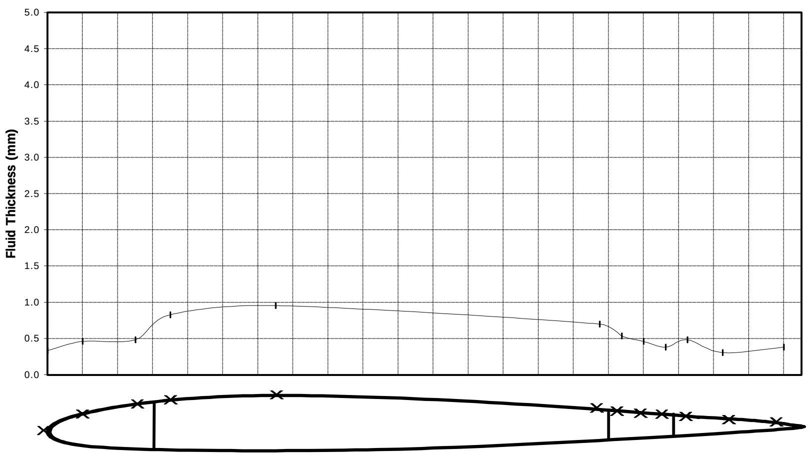
FIGURE 3.3

TYPE IV FLUID THICKNESS (STABILIZED) PROFILE

March 18, 1998, DC-9

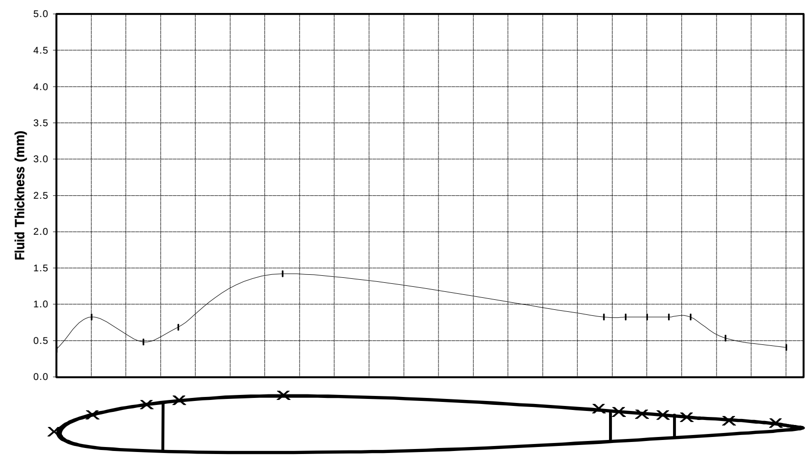
APS MOBILE SPRAYER

RUN 1 - UCAR ULTRA +



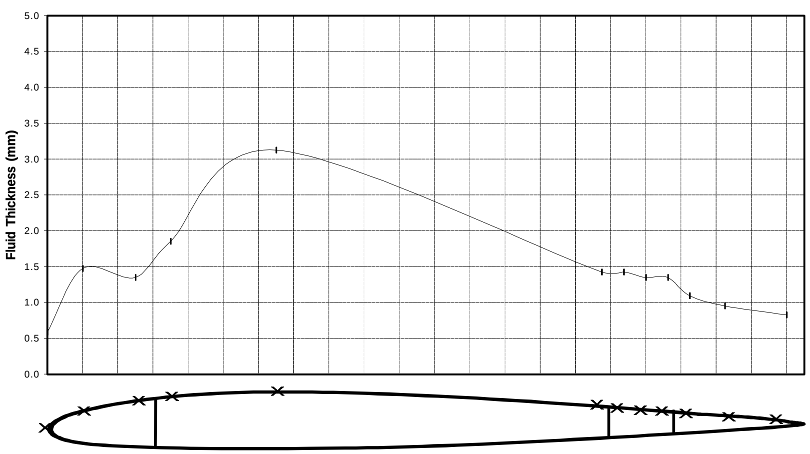
AEROMAG TRUCK SPRAYER

RUN 2 - UCAR ULTRA +



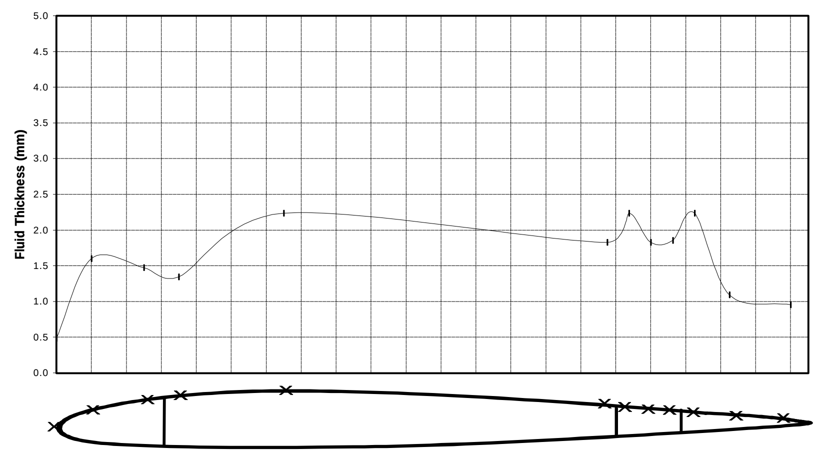
APS MOBILE SPRAYER

RUN 3 - UCAR ULTRA IV



APS MOBILE SPRAYER

RUN 4 - UCAR PG AAF



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McDonnell Douglas DC-9, Boeing 767, Airbus A340, de Havilland Dash 8, and BAE146. Appendix H provides a series of photographs for each aircraft, documented by observer location.

In addition to the photographs, APS was asked to provide three view illustrations of several aircraft in commercial operation in Canada in order to identify the critical surface inspection areas on these aircraft. The complete catalogue of aircraft illustrations is included in Appendix I.

Because the planned full-scale fluid failure aircraft tests were not performed (due to lack of suitable weather conditions), the documentation of wing visibility from the aircraft interior during actual precipitation was pre-empted.

This activity did, however, provide supplementary photographic documentation to the photo catalogue assembled during the winter 1996/97 program and contained in the TDC report, TP 13130E[3]. That series included photos for the Boeing 737, Airbus A320, ATR 42, and Fokker F28 aircraft.

3.8 Use of Remote Sensors for End-of-Runway Inspections

The field demonstration of the Spar/Cox ice detection unit served the purpose of examining the use of a sensor-equipped vehicle during actual deicing operations. It demonstrated how an observation post could be equipped with a contamination sensor suitable to the task, and how it might be positioned at a site suitable to scanning aircraft while they taxi to a departure runway. Real-time sensor images of aircraft taxiing past the sensor position were observed on the system monitor. Some aircraft en route to the deicing centre had areas of snow coverage. As this was an initial demonstration, only observer notes were recorded.

During the laboratory trials, observer notes on the test set-up and the sensor unit's capabilities were recorded.

Placement of the sensor (distance from subject, height and angle of incidence), subject type (plate type, wing section) and lighting levels were noted for each test. Cox staff also maintained a log of test conditions and camera positions and a time stamped electronic record of sensor images. A videotape copy of the sensor log with captured still images was made available by Cox Inc. for later analysis by APS staff.

3.8.1 Overview of Test Sessions

3.8.1.1 Field demonstration

The field demonstration utilising the sensor mounted in the van took place on the morning of March 19, 1998. A snowfall was underway, with departing aircraft proceeding through the deicing centre. The van was positioned at the decommissioned east deicing centre nearby the taxi route from the deicing centre to Runway 06R. From that position, departing aircraft could be scanned as well as some aircraft en route to the deicing centre. The remote controls on the sensor allowed it to be turned to scan aircraft from different perspectives: as they approached the site and as they taxied past.

The nature of the demonstration was to gain experience using the sensor camera in this environment, and to understand the kind of images of contamination on aircraft surfaces that would result. Observers included representatives from the TDC, NAVCAN, and airport management (ADM).

3.8.1.2 Laboratory trials

Laboratory trials were conducted on April 8 and 9, 1998, at the National Research Council Climatic Engineering Facility in Ottawa. Trials on the first day of tests were conducted in simulated snow which allowed examination of the camera's performance under conditions of reduced visibility (Photo 3.1). The snow produced at the facility resembled a thick freezing fog in the air but resulted in the deposition of a fine dry snow. Upon close inspection, this snow was seen to be composed of a distribution of microcrystalline agglomerates ranging in size from approximately 0.01 mm to 1.0 mm in diameter. The snow making nozzles are shown in Photo 3.2. The temperature of the chamber was maintained at -12 to -15°C during snowmaking (on April 8th).

During the second day of trials, there was no active snowfall but the accumulation of snow from the previous day was used to simulate a snowfall by pulverizing and then sprinkling snow that had accumulated throughout the chamber onto test surfaces with a flour sifter. The temperature of the chamber was held at -18°C for the day.

As snow was produced on the first day of tests, the visibility inside the chamber was reduced. The centre of the test stand was repositioned to 3.2 m from the camera (reduced from 17.4) while the airfoil leading edge was positioned 9.9 m from the camera. When visibility was further reduced to 6 m, distances to test surfaces were further reduced. Eventually, conditions inside the chamber could be considered equivalent to a total whiteout. Data collection was continued and a number of failures were recorded.

In one such test, half the leading-to-trailing edge section of the airfoil was cleaned off and a Type IV fluid (SPCA AD-404) was applied in neat form to the cleaned section. The failure was monitored on the sensor monitor from a remote location and could be seen to progress in a manner relatively consistent with observations made at close range (less than 1 m) by an experienced observer. It is important to note that the visibility reductions associated with natural precipitation events (with equivalent precipitation rates) would not be expected to be as severe as those encountered in the chamber. Test details are described in the test log that follows (see Tables 3.1 and 3.2).

3.9 Evaluation of the Demand for Holdover Time during Actual Deicing Operations

3.9.1 Overview of Recording Sessions

Recording sessions (VHF recordings) were conducted throughout the month of March. A log of events was completed which shows the number of operations observed on each test day and the corresponding type of precipitation that prevailed during each test session (see Table 3.3). Because heldover time data would not be made available by the deicing centre, the data are limited and only corresponds to the end of the winter season. A total of 289 aircraft were monitored and logged for about forty hours over a period of ten days. The procedure involved collecting data, namely on the start of the holdover time through the monitoring of radio communications regarding deicing. Takeoff time was obtained from an ADM database. The latter time was subtracted from the start time of final fluid application to yield the heldover time (see Appendix J). It should be noted that throughout the duration of these sessions, the greatest precipitation accumulation was measured to be 10 cm during one particular session. There were no opportunities to collect data under conditions of heavier accumulation.

3.9.2 Discussion of Test Variables

During each recording session, when an aircraft entered the deicing bay to start deicing, the time, flight number, type of aircraft, runway, general weather condition, Iceman Holdover Time call, and deicing fluid type were noted. Takeoff times (the time the aircraft begins its acceleration from

TABLE 3.1
TEST LOG - APRIL 8, 1998

Temperature: -12ºC
Precipitation rate: 10-15 g/dm²/hr

TIME (hh:mm)	ACTIVITY
8:00	Center of test stand positioned 17.4 m from the camera Leading edge of airfoil positioned 14.1 m from camera (in front of the test stand).
8:15	Snow production commenced. Camera elevation was varied from 2.7 m to 5.7 m. Better viewing at angles closer to normal - as expected.
9:30	Reduction in visibility serious after 15 min. Stand and foil positioned 13.2 m and 9.9 m from camera, respectively.
9:45	Application of Type I (Kilfrost 50/50) fluid to plates 1,2,3,4, and 5. Application of Type IV (SPCA AD404) fluid to plate 6; 1/2 airfoil edge - edge. Application of Type IV (SPCA AD480) fluid to plate 10. Observations of failures were continued until 11:30 hrs.
11:30	1/2 of airfoil section was cleaned and SPCA AD480 fluid was applied.
11:45	Change in plate 7: inverted pan replaced with a composite plate.
11:47	SPCA AD480 applied to new plate 7 material as per FTPT procedure.
12:30	Rectangular sections cleared on airfoil to provide contrast and create new failure zones to monitor. This was also done to plates on test stand, which was retained for the next day's observations.
15:00	"I-C-E" pattern cut into snow accumulated on one long plate. "C-O-X" pattern cut into snow accumulated on the second long plate.
15:30	Snow production stopped. Observations monitored until 16:00 hrs.
16:00	Shut down; computer hardware and software modifications, general preparations for tests to be conducted the following day.

TABLE 3.2

TEST LOG - APRIL 9, 1998

Temperature: -18ºC
Precipitation rate: 0 g/dm²/hr

TIME (hh:mm)	ACTIVITY
8:00	Re-ran dark current to determine the instruments baseline response to no light. Camera response was not optimum so the dark current from the previous day's experiment was used and gave a satisfactory response. Completed at 08:15.
8:15	Dynamic range and non-uniformity tests conducted. Test stand positioned with plate failures from the previous day's snow accumulation. Selected areas were strategically cleaned of to test the resolution of ice detection.
9:20	With camera at 18.6 m from stand and elevation of 5.7 m, a sequence of responses using either one or two ice camera light sources was commenced. Plates 6 and 10 were cleaned. Two images were taken at each 0.6 m decrement in height until a final height of 2.7 m was reached.
11:15	Type IV (SPCA AD480) fluid was applied to plate 6.
11:18	Type I (Kilfrost ADF 50/50) fluid was applied to plate 10.
11:20	Several image sequences were captures at different heights with both camera light sources on to see if there was a difference in response with fluid as opposed to the bare plates (5.7 m to 2.7 m in 0.6 m decrements).
11:40	Carbon fiber composite (plate 1) was exchanged in position with the Kevlar (plate 7) due to thickness of the carbon fiber plate which threw a shadow onto plate 1 at low angle views.
11:48	Series of sequences captured from 5.7 m to 2.7 m elevation at 18.6m distance. Began to lose ability to see failures at 4.5 m elevation (about 13 degree angle).
12:15	Tape #2. (04 09 98) Camera adjusted to view plate failures (simulated). Distance to stand is 14.7 m.
12:28	Point contamination on plate 6. Seems minimum resolution to capture failure is 4 pixels at this distance.
12:32	Top 1/3 of plate 6 is artificially failed. Visible on camera.
12:33	Top 2/3 of plate 6 is artificially failed. Difference is again visible.
12:36	Good images captured with invalid pixels and "no ice" displayed.
12:40	Airfoil is positioned and prepared for tests. Leading edge toward camera. Camera adjustments made to optimize response from foil surface.
12:42	Airfoil partially cleaned. Image sequence captured.
12:59	90º rotation. Starboard side toward camera. Image sequence captured.
13:00	180º rotation. Trailing edge toward camera. Image sequence captured.
13:01	270º rotation. Port side toward camera. Image sequence captured.
13:10	Begin height variation sequence on foil. Difficulty seeing top surface contamination at 3.0m elevation.
13:34	180º rotation. Trailing edge toward camera. Airfoil surface cleaned off. At 13:38, Type I (Kilfrost ADF 50/50) fluid applied to the whole surface. Simulated failure on the center strip of airfoil (front-to-back) by dusting on loose snow with a flour sieve. Also failed top area on the port side of center using the dusting method to allow the failed region to taper off toward the portside edge of the airfoil. Saved sequence 13:37. Also saved sequence at 13:39 hrs.
13:41	225º rotation. Trailing edge and portside view. Saved sequence at 14:01.
13:58	315º rotation. Leading edge and portside view. Saved sequence ar 14:01.
14:02	Reduced height of camera to 2.7 m. Last sequence saved before taking test surface outdoors.
14:42	Outdoor shots. Distance approximately 45 m. Failures simulated on Type I fluid-coated surface using dusting method. Failures observed and recorded at this distance. Unfailure of wing monitored as the snow melted in the warm sunlight. Failure was evident from camera imaging at this distance. Invited spectators looked on appreciatively.

TABLE 3.3
LOG OF EVENTS

Occasion	# of Departures Evaluated	Type of Precipitation
March 04, 1998	19	Wet Snow
March 08, 1998	16	Frost
March 10, 1998	21	Snow
March 11, 1998	6	Frost
March 12, 1998	26	Frost
March 13, 1998	8	Frost
March 14, 1998	58	Snow
March 15, 1998	23	Snow
March 19, 1998	108	Snow
March 21, 1998	37	Snow

TABLE 3.4
SAMPLE OF ADM DATA BASE

Date	Flight #	Time	A/C Type	Runway	Operation Type
March 04, 1998	ACA433	8:00:00 AM	A320	U	D
March 04, 1998	AMO550	7:59:15 AM	C550	24L	D
March 04, 1998	ICN1641	7:58:12 AM	ATR	24L	A
March 04, 1998	COA563	7:55:39 AM	B737	24R	D
March 04, 1998	CDN856	7:55:28 AM	A320	24L	A
March 04, 1998	ACA741	7:55:19 AM	DC-9	24R	A
March 04, 1998	AAQ170	7:53:33 AM	DHC-8	24R	A
March 04, 1998	ICN1678	7:51:18 AM	ATR	28	D
March 04, 1998	ARN832	7:48:38 AM	DHC-8	28	D
March 04, 1998	ACA401	7:47:35 AM	A340	24R	D
March 04, 1998	AAQ179	7:46:27 AM	DHC-8	28	D

rest on the runway) of the same aircraft were later retrieved from data provided by ADM (see Table 3.4). The total data set collected and the distribution of occurrence by category of different variables is shown below:

Occurrences as a Function of Precipitation Type	
Frost	55
Snow	234
Total	289

Occurrences as a Function of Fluid Type and Precipitation		
	Type I	**Type IV/Type I**
Frost	50	5
Snow	109	126
Total	159	130

Occurrences as a Function of Runway	
Runway 28	33
Runway 06L	52
Runway 06R	133
Runway 24L	32
Runway 24R	20
Runway Undetermined	19
Total	289

Occurrences by Aircraft Size	
Large	30
Medium	177
Small	82
Total	289

3.9.3 Description of Data Collected and Analysis

A special study of heldover times versus precipitation rates was performed. The study involved a total of 30 samples. Of the total, 19 samples involved a one-step Type I fluid application, and 11 samples involved two-step operation (Type IV over Type I) (see Appendix J). The analysis assumes that the data is a random sample taken from an infinite set of data, (i.e. the taxi times taken are representative of all aircraft). This assumption is not always correct and taxi times can be seen to fluctuate as a function of several variables including weather patterns, traffic congestion aircraft size, and inherent limitations to data collection of this nature.

Several sources of data were considered in the calculation of any particular heldover time. During conditions of snow or frost, personnel stationed at the APS test site were equipped with a set of binoculars and a VHF radio to monitor and record airport/aircraft transmissions. Heldover time (taxi time) was designated to be the difference between takeoff time and the beginning of the second step of a two-step de/anti-icing, or the beginning of the first and only step for a one-step deicing. The rate of precipitation, in g/dm^2/hr, recorded during the heldover time of any particular sample was determined using APS environmental measurements collected during holdover time tests (see TDC report, TP 13318E[1], 1997/98). The heldover time and the corresponding precipitation rate were then plotted against each other to develop a profile of the traffic behaviour observed.

3.9.4 Validation of Source Data

An auxiliary form, containing a schematic diagram of an aircraft where path times of the deicing trucks could be noted, was also completed by the observer for six aircraft operations. This was later used to validate the Iceman's call of holdover start time. The number of deicing trucks and the respective areas they were deicing were also recorded (see Figure 3.4). Figure 3.4 shows the operational times of the three trucks involved in the deicing of an Airbus A320. The lowest time recorded on the schematic coincided with the iceman call for start of holdover time (the lowest corresponding second step application time should be used for two-step operations).

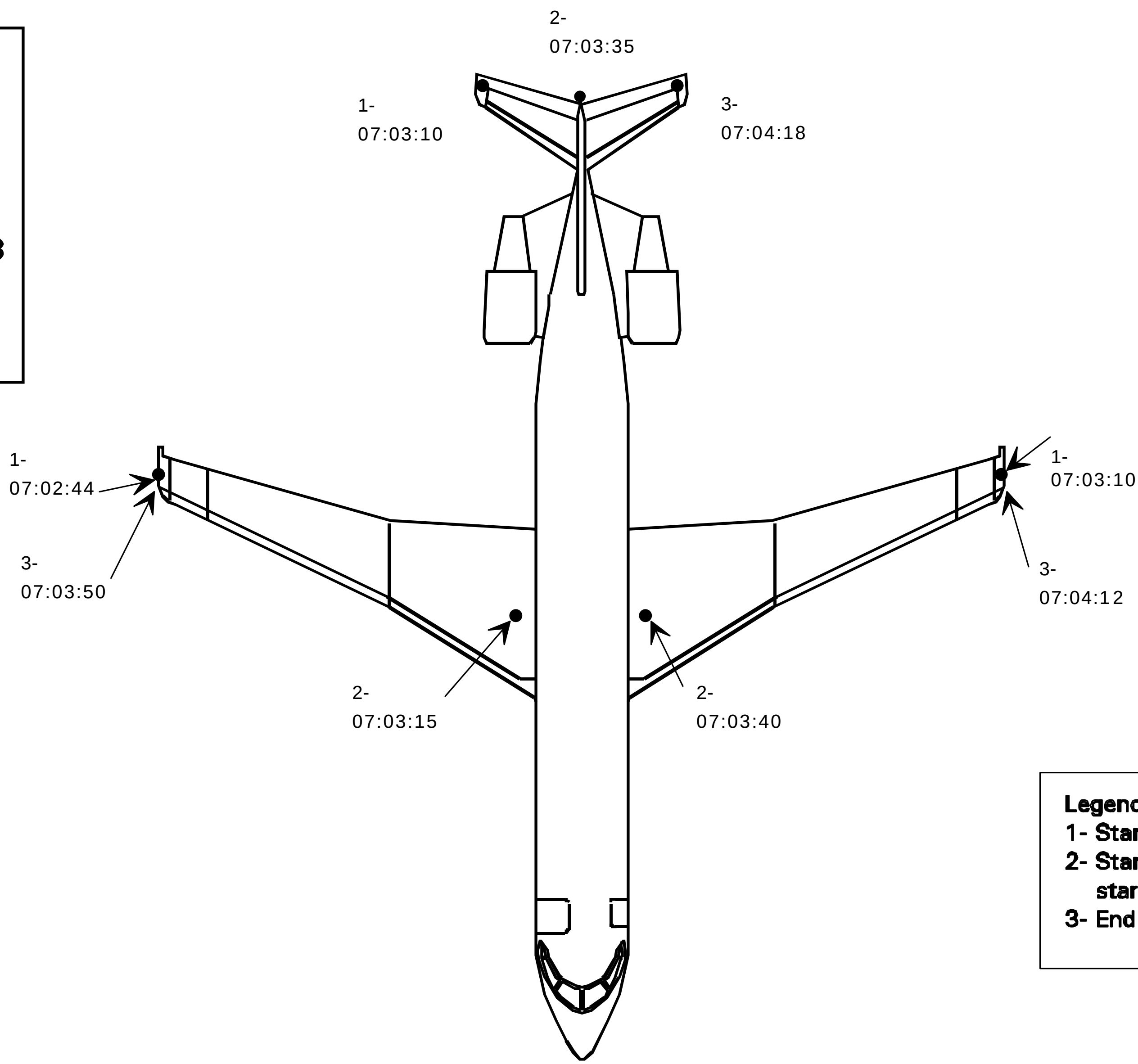
Visual takeoff was also noted and used to validate the takeoff time recorded by the airport.

FIGURE 3.4

ICEMAN VALIDATION FORM

TYPICAL DEICING OPERATION

March 08, 1998
Air Canada 781
3 deicing trucks:
1 on each wing
1 on the tail
Iceman HOT - 07:03
Type 1 (Frost)
Take-off: 07:14



Legend:
1- Start of first step deicing
2- Start of second step and start of heldover time.
3- End of deicing.

cm1380/report/opns/ICEMAN.CH4

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Photo 3.1
Reduced Visibility during Simulated Snowfall

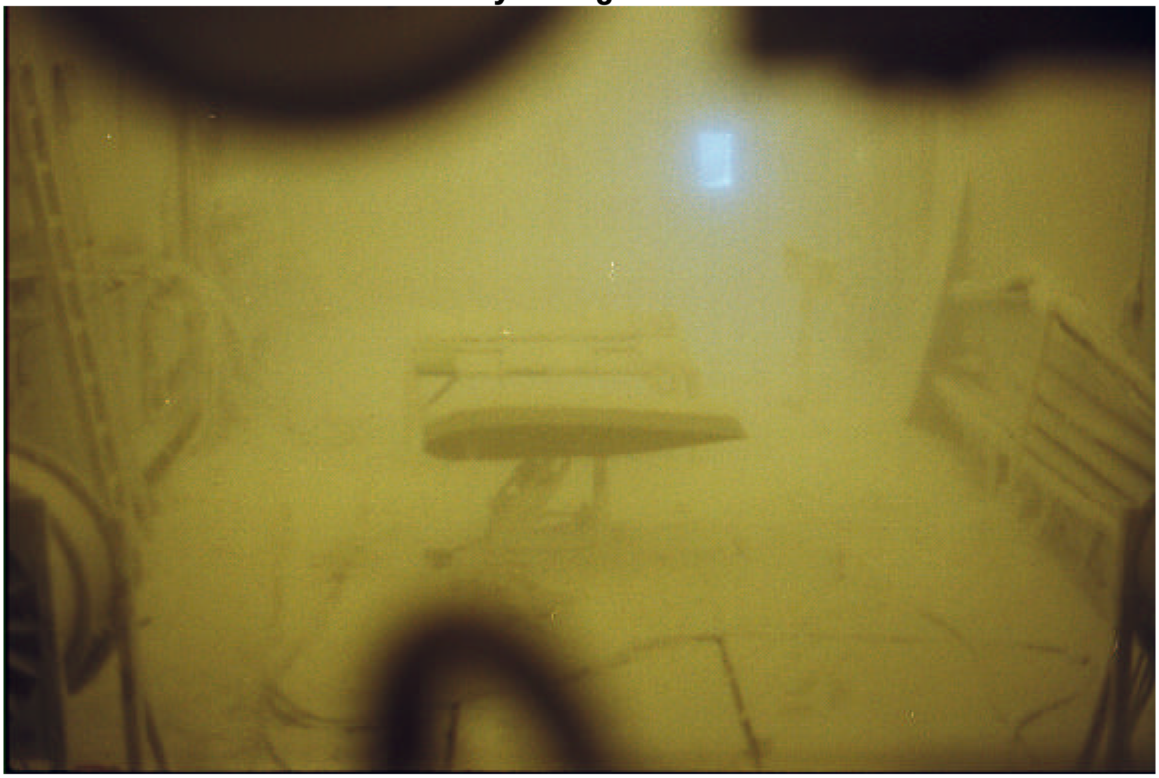


Photo 3.2
Snow-making Nozzles

4. DISCUSSION AND OBSERVATIONS

4.1 Evaluation of Snow Weather Data

The snow weather data were graphed in two formats: one in which the number of occurrences of snow precipitation events was plotted versus the precipitation rates for these events (Figure 4.1), and the other (Figure 4.2), which is a plot of the cumulative probability of snow over all possible precipitation rates. Both plots used the corresponding period to calculate average precipitation rates.

The histogram in Figure 4.1 indicates that low precipitation rate snow events occur much more frequently than high precipitation rate snow events.

The cumulative probability in Figure 4.2 indicates that essentially all the natural snow events in the data records used had precipitation rates below 30 g/dm^2/hr.

A complete set of plots of all temperature ranges for natural snow and freezing rain conditions is included in Appendix K.

Table 4.1 shows minute-by-minute READAC data for Dorval on December 14, 1995, for a 30-minute period. Also shown are the 1-minute, 6-minute, 20-minute, and 35-minute averages computed using the linearized accumulation.

The 95th percentile was used in the analysis conducted by AES in 1995 to determine the frequency of occurrence of precipitation rates. The same methodology was used by APS and the results are described in the following subsections.

4.1.1 Natural Snow

The 95th percentile for several temperature ranges is shown below for natural snow conditions:

Temperature Range	*Average Precipitation Rate (g/dm² /hr)*			
	1 min	6 min	20 min	35 min
Above 0°C	15	20	18	17
0 to –3°C	13	14	13	13
-3 to –7°C	20	22	22	22
-7 to –14°C	20	24	24	25
-14 to –25°C	17	19	19	19

TABLE 4.1

SAMPLE OF READAC DATA AND ANALYSIS

Location	Date	Zulu Time	Temp (°C)	Type of Precip.	Total Snow Accumula	Linearized Total Snow	Average Every Minute 1 min	6 min	20 min	35 min
YUL	14/12/1995	21:16	-11.8	S-	40	40.00	9.38	9.38	9.38	10.08
YUL	14/12/1995	21:17	-11.7	S-	40	40.16	9.38	9.38	9.38	10.32
YUL	14/12/1995	21:18	-11.6	S-	40	40.31	9.38	9.38	9.38	10.56
YUL	14/12/1995	21:19	-11.6	S-	40	40.47	9.38	9.38	9.38	10.79
YUL	14/12/1995	21:20	-11.6	S-	40	40.63	9.38	9.38	9.38	11.03
YUL	14/12/1995	21:21	-11.6	S-	40	40.78	9.38	9.38	9.38	11.27
YUL	14/12/1995	21:22	-11.6	S-	40	40.94	9.38	9.38	9.38	11.50
YUL	14/12/1995	21:22	-11.5	S-	40	41.09	9.38	9.38	9.38	11.74
YUL	14/12/1995	21:23	-11.6	S-	40	41.25	9.38	9.38	9.38	11.97
YUL	14/12/1995	21:24	-11.6	S-	40	41.41	9.38	9.38	9.38	12.21
YUL	14/12/1995	21:24	-11.4	S-	40	41.56	9.38	9.38	9.38	12.45
YUL	14/12/1995	21:25	-11.4	S-	40	41.72	9.38	9.38	9.38	12.68
YUL	14/12/1995	21:25	-11.5	S-	40	41.88	9.38	9.38	9.38	12.92
YUL	14/12/1995	21:26	-11.5	S-	40	42.03	9.38	9.38	9.79	13.16
YUL	14/12/1995	21:26	-11.4	S-	40	42.19	9.38	9.38	10.20	13.39
YUL	14/12/1995	21:27	-11.4	S-	40	42.34	9.38	9.38	10.62	13.48
YUL	14/12/1995	21:28	-11.4	S-	40	42.50	9.38	9.38	11.03	13.57
YUL	14/12/1995	21:29	-11.4	S-	40	42.66	9.38	9.38	11.44	13.66
YUL	14/12/1995	21:30	-11.4	S-	40	42.81	9.38	9.38	11.86	13.75
YUL	14/12/1995	21:31	-11.4	S-	40	42.97	9.38	9.38	12.27	13.84
YUL	14/12/1995	21:31	-11.3	S-	40	43.13	9.38	9.38	12.68	13.93
YUL	14/12/1995	21:32	-11.3	S-	40	43.28	9.38	9.38	13.10	14.02
YUL	14/12/1995	21:32	-11.4	S-	40	43.44	9.38	9.38	13.51	14.11
YUL	14/12/1995	21:33	-11.4	S-	40	43.59	9.38	9.38	13.92	14.20
YUL	14/12/1995	21:33	-11.3	S-	40	43.75	9.38	9.38	14.34	14.29
YUL	14/12/1995	21:34	-11.3	S-	40	43.91	9.38	9.38	14.75	14.38
YUL	14/12/1995	21:34	-11.3	S-	40	44.06	9.38	9.38	15.17	14.46
YUL	14/12/1995	21:35	-11.3	S-	40	44.22	9.38	10.75	15.58	14.55
YUL	14/12/1995	21:35	-11.2	S-	40	44.38	9.38	12.13	15.99	14.64
YUL	14/12/1995	21:36	-11.2	S-	40	44.53	9.38	13.51	16.41	14.73
YUL	14/12/1995	21:36	-11.2	S-	40	44.69	9.38	14.89	16.56	14.82
YUL	14/12/1995	21:37	-11.2	S-	40	44.84	9.38	16.27	16.72	14.91
YUL	14/12/1995	21:37	-11.2	S-	45	45.00	17.65	17.65	16.88	15.00
YUL	14/12/1995	21:38	-11.2	S-	45	45.29	17.65	17.65	16.62	14.85
YUL	14/12/1995	21:39	-11.2	S-	45	45.59	17.65	17.65	16.36	14.71
YUL	14/12/1995	21:40	-11.2	S-	45	45.88	17.65	17.65	16.10	14.56
YUL	14/12/1995	21:41	-11.1	S-	45	46.18	17.65	17.65	15.85	14.41
YUL	14/12/1995	21:42	-11.1	S-	45	46.47	17.65	17.65	15.59	14.26
YUL	14/12/1995	21:43	-11.1	S-	45	46.76	17.65	17.65	15.33	14.12
YUL	14/12/1995	21:44	-11.1	S-	45	47.06	17.65	17.65	15.07	14.18
YUL	14/12/1995	21:45	-11.1	S-	45	47.35	17.65	17.65	14.82	14.25
YUL	14/12/1995	21:46	-11.1	S-	45	47.65	17.65	17.65	14.56	14.32
YUL	14/12/1995	21:47	-11.1	S-	45	47.94	17.65	17.65	14.30	14.39
YUL	14/12/1995	21:47	-11.0	S-	45	48.24	17.65	17.65	14.04	14.45
YUL	14/12/1995	21:48	-11.0	S-	45	48.53	17.65	16.79	13.79	14.52
YUL	14/12/1995	21:49	-11.0	S-	45	48.82	17.65	15.93	13.53	14.59
YUL	14/12/1995	21:50	-11.0	S-	45	49.12	17.65	15.07	13.27	14.66
YUL	14/12/1995	21:51	-11.0	S-	45	49.41	17.65	14.22	13.01	14.72
YUL	14/12/1995	21:52	-10.9	S-	45	49.71	17.65	13.36	12.76	14.79
YUL	14/12/1995	21:53	-10.8	S-	50	50.00	12.50	12.50	12.50	14.86

FIGURE 4.1

READAC AND CR21X ANALYSIS - NATURAL SNOW
-3 to -7°C
20 MINUTES RATE EVERY MINUTE
1995-98

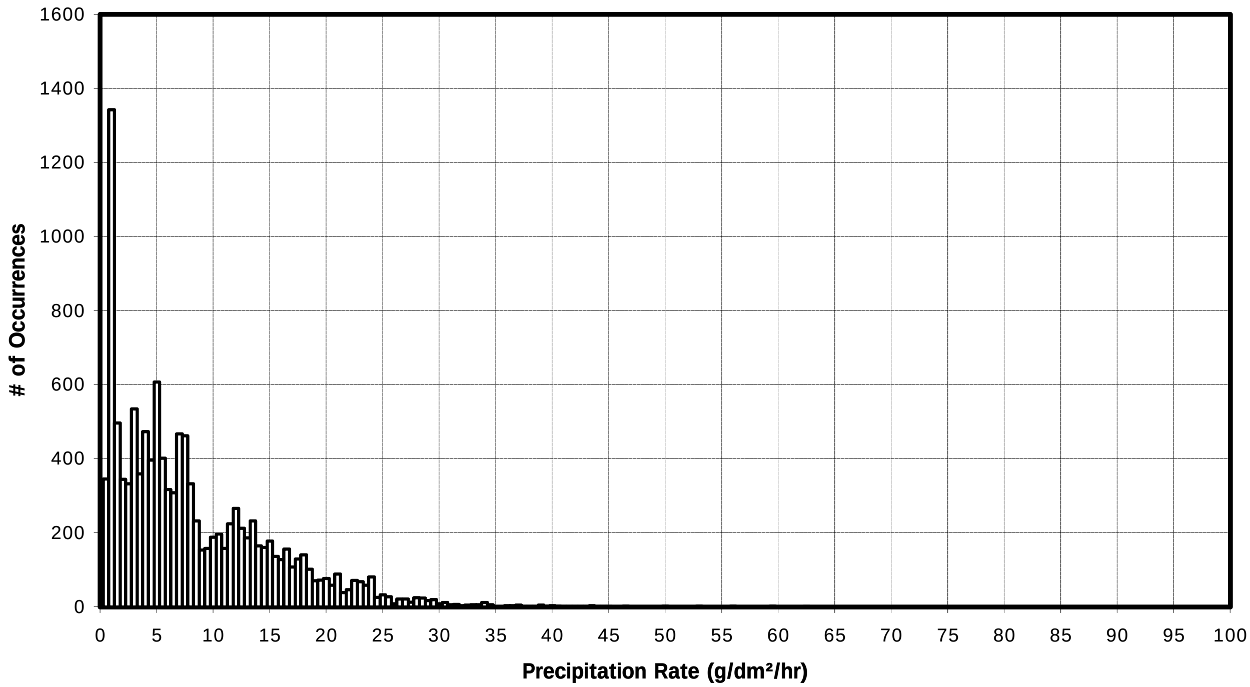
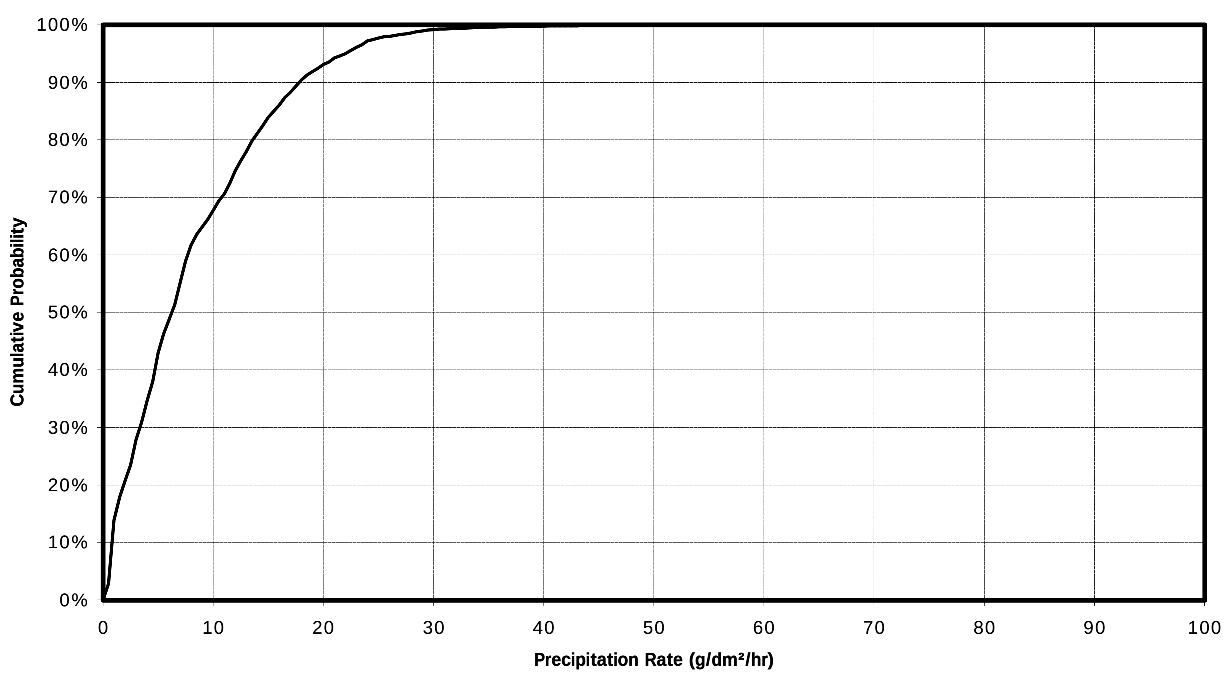


FIGURE 4.2

READAC AND CR21X ANALYSIS - NATURAL SNOW
-3 to -7°C
20 MINUTES RATE EVERY MINUTE
1995-98



cm1380/report/opns/Anal_-7d.xls
At: 20 min
7/22/02, 1:41 PM

There were no data available for natural snow conditions below –25°C.

4.1.2 Freezing Rain

The 95th percentile for two temperature ranges is shown below for freezing rain conditions:

Temperature Range	*Average Precipitation Rate (g/dm² /hr)*			
	1 min	6 min	20 min	35 min
0 to –3°C	30	27	24	22
-3to –10°C	25	25	24	24

In freezing rain, the 95th percentile was constant for the range of –3 to -10°C at 25 g/dm²/hr.

4.1.3 Comparison of AES and APS 1995/98 Snow Weather Data

The graphs (Cumulative Probability vs Precipitation rate) were found to be reasonably similar - not necessarily in exact values, but in overall curve shape. Most exact values, and overall curve shape similarities were found on the 0 to –3ºC and –3 to –7ºC graphs with 6-minute time averages. At 95% cumulative probability, the precipitation rates were 17 $g/dm^2/hr$ for both. Values along the graphs were compared (for example at 70% and 80%) and were found to be similar.

Overall, these two data sets (AES and Snow Weather Data for 1995/98) are similar enough to compare with each other.

4.1.4 Comparison of 1993/95 and 1995/98 Snow Weather Data

Preliminary analysis of the two data sets revealed that numerous data conversions are needed to help make substantial conclusions. Variations in scales between the two data sets may also present difficulties. Further investigations are needed, in order to determine similarities and possible differences in the data sets.

4.2 Fluid Failure Tests on Operational Aircraft

No full-scale tests were performed during the past year and therefore no data were collected.

A series of exploratory tests were performed at the Dorval test facility to evaluate the lifting of spoilers on high wing aircraft as a means to conduct pre-takeoff checks. Type I and Type IV fluids were poured on flat plates. Using a sieve (see Photo 4.1), snow was sprinkled on the plates until failure (5 cross hairs) was achieved. The plates were then rotated upwards 100º from their 10º declination on the test stand to a vertical position (to simulate the lifting of the spoiler). The plates remained at this position for 10 minutes.

The tests showed that failed Type I fluid did not immediately slide off the plate. In fact, a large percentage of the failure remained on the plate for several minutes, and only gradually slid off the plate. Snow failures were still present on the plate following the 10-minute test period (See Photo 4.2A and Photo 4.2B).

In contrast, the results showed that the bulk of the failed Type IV fluid slid off the plate soon after being rotated. A thin layer of fluid was all that remained on the plate after ten minutes (See Photo 4.3A and Photo 4.3B).

4.3 Frost Formation on Aircraft

No frost tests were conducted on operational aircraft in 1997/98 and, as a result, no data were gathered

4.4 Frost Tests on Flat Plates

Three frost deposition trials were conducted on three different occasions.

Results from preliminary Run #1 indicate that frost deposition rates were in the range of 0 to 0.12 $g/dm^2/hr$, depending on the test surface. The highest deposition rate was experienced by the plate pan coated with Type IV fluid. Six grams of frost accumulated in this pan in the 3.5 hour duration of the test, which is equivalent to a rate of 0.12 $g/dm^2/hr$. Rates observed on the kevlar composite plate and the 0.5 mm (0.020") aluminum plate backed with honeycomb were 0.10 $g/dm^2/hr$ and 0.06 $g/dm^2/hr$, respectively. No accumulation of frost was observed on the 3.2 mm (1/8") standard aluminum plate.

Results from preliminary Run #2 showed similar frost deposition rates as Run #1. All test surfaces were exposed to frost conditions for two 3-hour periods. The highest deposition rates were again experienced by the plate pan, which saw an average deposition rate of 0.12 g/dm^2/hr. The kevlar composite plate had an average deposition rate of 0.11 g/dm^2/hr, while the 0.5 mm (0.020") aluminum plate backed with honeycomb had an average rate of 0.6 g/dm^2/hr. Again, no accumulation of frost was detected on the standard 3.2 mm (1/8") aluminum plate.

The results of Run #3 are shown in Table 4.2. The Before row shows all the different test surfaces prior to exposure to frost conditions. The After row shows the result of frost exposure on the test surfaces. The rate of frost deposition for each surface has also been included. Before and after photographs were recorded for each test surface (with the exception of the plate pan), and are displayed in Photos 4.3 to 4.18.

Although the test surfaces in Run #3 were outdoors for more than five hours, the period of active frost for these tests was estimated at three hours. The highest rate of deposition is once again achieved by the plate pan (Column 7, Table 4.2), 7 grams of accumulation in three hours, which is equivalent to a rate of 0.16 g/dm^2/hr.

Four 1.6 mm (1/16") aluminum plates were used for testing, one bare, the other three painted different colours. The uncoated 1.6 mm (1/16") aluminum plate (Column 1) displayed no trace of frost accumulation following testing (Photos 4.4 and 4.5). The red and blue 1.6 mm (1/16") aluminum plates (Columns 2 and 3) had frost accumulations of 2 grams over the test period, or a rate of 0.04 g/dm^2/hr (Photos 4.6 and 4.7, and Photos 4.8 and 4.9). The white 1.6 mm (1/16") plate (Column 4) accumulated three grams of frost, which is equal to a rate of 0.07 g/dm^2/hr (Photos 4.10 and 4.11).

The kevlar composite plate (Column 5), collected three grams of frost, equivalent to a deposition rate of 0.07 g/dm^2/hr (Photos 4.12 and 4.13). The standard 3.2 mm (1/8") aluminum plate (Column 6) had no frost deposition at all (Photos 4.14 and 4.15).

Two 3.2 mm (1/8") aluminum plates were coated with fluids, one with Type I, the other with Type IV. The plate coated with Type I (Column 8), was found to be failed at the end of the test period (Photos 4.16 and 4.17). The exact time of failure was not noted. The plate coated with Type IV (Column 9), did not show any signs of impending failure at the end of the test period (Photos 4.18 and 4.19).

Conclusions as to why unpainted aluminum surfaces remained frost–free are not easy to come by. Three parameters that might be mitigating factors in

TABLE 4.2

RESULTS OF TESTS

	1	2	3	4	5	6	7	8	9
Before	Standard Aluminum Plate 1/16" (1.6 mm) (Bare)	Standard Aluminum Plate 1/16" (1.6 mm) *Painted Red* (Bare)	Standard Aluminum Plate 1/16" (1.6 mm) *Painted Blue* (Bare)	Standard Aluminum Plate 1/16" (1.6 mm) *Painted White* (Bare)	Kevlar Composite Plate (Bare)	Standard Aluminum Plate 1/8" (3.2 mm) (Bare)	Plate Pan (Coated with Type 4 fluid)	Standard Aluminum Plate 1/8" (3.2 mm) (Coated with Type 1 fluid)	Standard Aluminum Plate 1/8" (3.2 mm) (Coated with Type 4 fluid)
After	No frost has accumulated 0 g/dm^2/hr	2g of frost has accumulated 0.04 g/dm^2/hr	2g of frost has accumulated 0.04 g/dm^2/hr	3g of frost has accumulated 0.07 g/dm^2/hr	3g of frost has accumulated 0.07 g/dm^2/hr	No frost has accumulated 0 g/dm^2/hr	7g of frost has accumulated 0.16 g/dm^2/hr	Plate has failed	No failures on the plate have occurred

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7/22/02, 1:42 PM

these results are related to radiation or surface effects, as all temperatures of the test surfaces were equilibrated with the outside air temperature. The three parameters are:

- The surface material's emissivity;
- The surface roughness; and
- The photoelectric effect.

4.5 Fluid Thickness Tests with the Mobile Type IV Fluid Spray Unit

This section provides a detailed analysis of observations that relate to fluid thickness trials using the APS mobile spray unit.

The overall performance of the device was satisfactory, despite an undetermined problem that caused oscillations in fluid pressure. The sprayer design needs to be refined in order to eliminate this problem before extended future use.

It has long been stated that Octagon Maxflight flows more freely on aircraft wings than other propylene glycol-based anti-icing fluids, and as such, should provide better fluid uniformity over the entire wing surface. For this reason, fluid thickness tests using Octagon fluid were planned. Due to the unfortunate late arrival of the required Octagon fluid, the sample tests were conducted with only three fluids from Union Carbide, including two new formulations.

From the stabilized thickness profile charts in Figure 3.1, certain observations can been made:

- The stabilized thickness profiles of the Ultra+ fluid applied using the mobile sprayer were slightly inferior to those obtained using the Aéromag deicing vehicle; and
- The stabilized thickness profiles of the new fluids tested, Union Carbide PG AAF and Ultra IV, were significantly greater than those of the Ultra+.

The stabilized thickness profiles of Union Carbide Ultra+, Ultra IV, and PG AAF, obtained in flat plate tests, are similar to those obtained with the mobile sprayer, indicating that the mobile sprayer did provide an adequate supply of fluid to the wing surface.

The two new fluids from Union Carbide also appeared to behave similar to Ultra+ when applied over the wing surface in an improper manner. Attempts were purposely made to obtain inconsistent coverage over the wing surface with patches of thick fluid interspersed with patches of thin film in order to view the flow and levelling characteristics of the fluid. The results of improper applications with Ultra+ and PG AAF are shown in Photos 4.20 and 4.21.

4.6 Alternative Deicing Methods

APS was asked to provide photo documentation of deicing methods and practices within the airline industry in which no glycol-based fluids are used.

Photo documentation of the following deicing methods were provided:

- Hot water deicing (Photo 4.22);
- Truck-mounted hot air blower (Photo 4.23);
- Portable hot air blower (Photo 4.24);
- Hangar deicing (Photo 4.25);
- Portable sprayers (Photo 4.26);
- Mobile infrared heating device, not yet in service (Photo 4.27);
- Brooms (Photo 4.28);
- Scrapers and squeegees (Photo 4.29);
- Ropes (Photo 4.30); and
- Wing, cockpit, and engine covers (Photos 4.31 and 4.32).

4.7 Documentation of Wing Area Visible to Flight Crew

The photo documentation of the wing areas visible from the cabin show that, for low wing aircraft, good views of the entire wing surface can be gained from window positions. Viewing from more than one window is usually necessary in order to have a consolidated view of the complete wing.

Although the entire wing can be viewed, distances to the outer wing on some of the larger aircraft are considerable, and would limit the pilot's ability to identify failed fluid or wing contamination with the naked eye. A report related to this activity indicated that use of common field binoculars provided a much-improved view of small details on the wing surface.

Observations and photos from aisle positions have a very restricted field of view and show only small areas of the wing surface. In high load factor cases where passengers are seated at all those window locations giving best views, overwing emergency exit rows generally offer the best alternative. The larger pitch at emergency exit rows allows the viewer to lean ahead of seated passengers and get closer to the window.

For high wing aircraft, window views of the wing surface are very restricted, and are basically limited to the leading edge. The designated critical surface on the BAe 146 (top of the engine nacelle) is easily visible from a cabin window. Standing at open passenger or galley doors offers a view of some additional wing surface area.

Wing documentation activities were previously conducted in 1996/97 on four aircraft types, and those photographs appear in the TDC report, TP 13130E[3]. Using these photographs, illustrations depicting the critical surface inspection areas were prepared for two aircraft, the Fokker F28 and the Boeing 737, and are presented in Figures 4.3 and 4.4.

4.8 Use of Remote Sensors for End-of-Runway Inspections

4.8.1 Field Demonstration

The installed system provided real-time images of moving aircraft as they taxied past the sensor location. Aircraft passing by the sensor camera en route to Runway 06R were about 50 m distant (to fuselage), typical of distances that would be encountered in a real installation.

The camera's tilt and pan mount performed satisfactorily, allowing taxiing aircraft to be scanned from different perspectives, affording views of aircraft approaching and passing in front of the sensor site. This perspective allowed scanning of the wing leading edge from some distance, and as the aircraft moved closer.

Aircraft en route to the deicing centre were scanned at a further distance, estimated to be 150 m to the aircraft fuselage. The system was able to identify snow on the fuselage of some of these aircraft, which was visibly identifiable on the display monitor

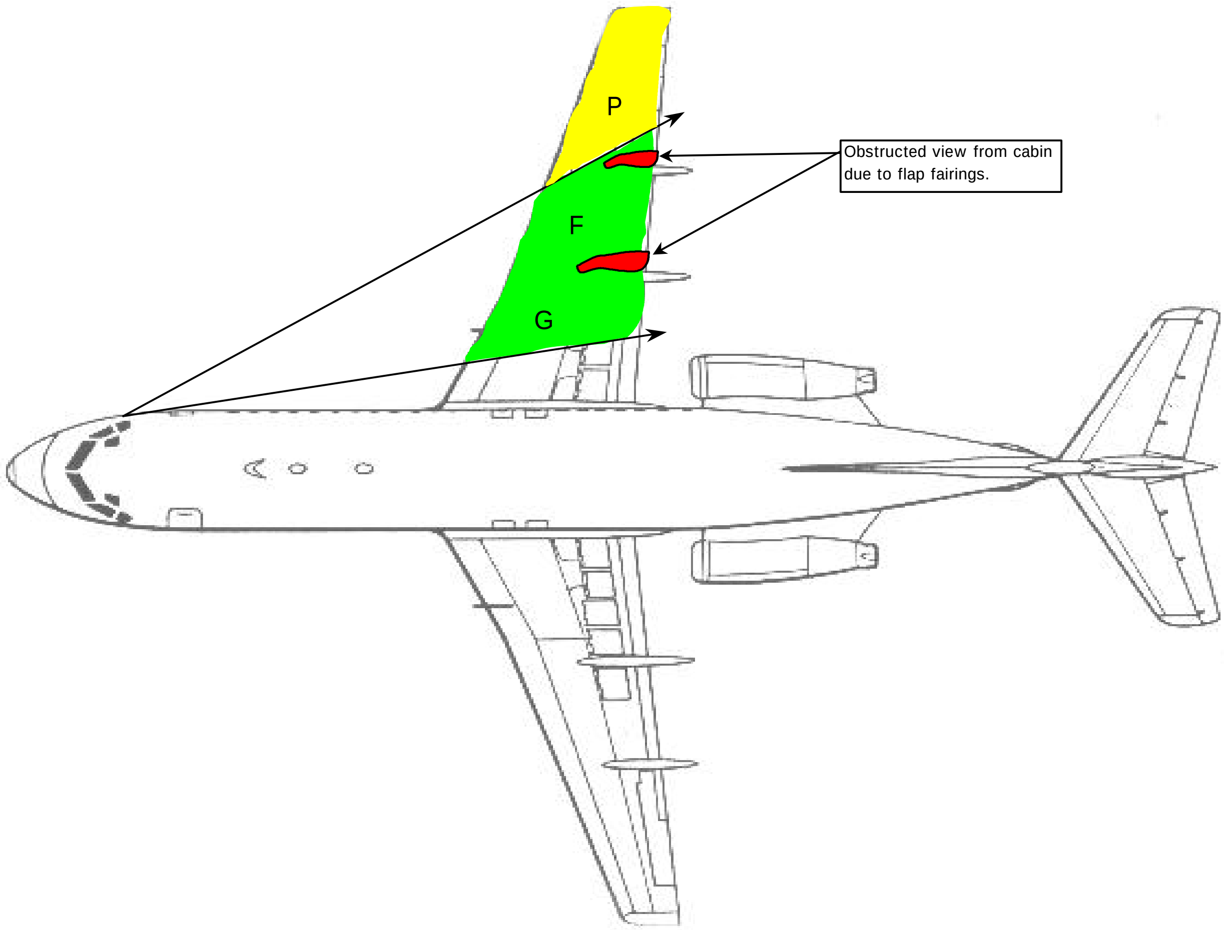
The system experienced problems interpreting aircraft movement especially in the situation when aircraft were passing close by the sensor site (where relative motion was greatest), resulting in invalid indications of contamination. As well, it was noted that some problem was caused by aircraft paint colours. The blue colour of Air Canada aircraft tail sections appeared as a contaminated area on the display monitor.

The height of the sensor camera on the cherry picker bucket (about 7 m) did not allow the wing top-surface to be scanned, but was suitable for scanning the wing leading edge as aircraft approached the sensor site.

FIGURE 4.3

PRIORITY CRITICAL SURFACE INSPECTION AREAS

FOKKER F28



- (yellow) Wing section visible with cockpit window closed.
- (green) Wing section visible with cockpit window open.

Visibility from inside the cabin:

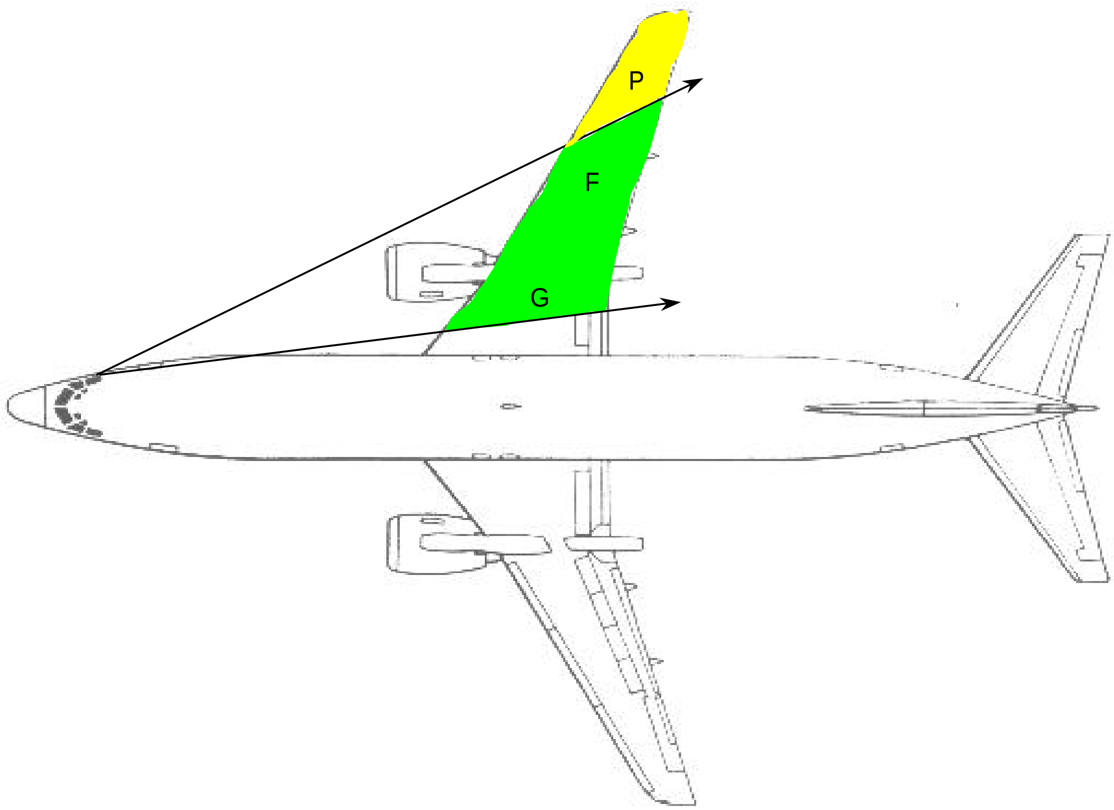
- P - Poor
- F - Fair
- G - Good

The trailing edge of the F28 wing is not visible from the flight deck.

FIGURE 4.4

PRIORITY CRITICAL SURFACE INSPECTION AREAS

BOEING 737



Wing section visible with cockpit window closed.

Wing section visible with cockpit window open.

Visibility from inside the cabin:

P - Poor
F - Fair
G - Good

The trailing edge of the B737 wing is not visible from the flight deck.

4.8.2 Laboratory Trials

The Cox Ice Detection Unit functioned well in conditions of good to fair visibility. In conditions of poorer visibility, the camera could see no better than the naked eye.

The camera worked well at longer distances. A test surface (wing section) was positioned about 45 m from the camera in full sunlight. Snow from the accumulation remaining from the artificial snowfall of the previous day (Photo 4.33) was used as a source of contamination. This snow was spread over the surface using a flour sifter. The area of contamination was identified and displayed accurately by the sensor system. The angle of incidence for that test was about 7° to the horizontal. Photo 4.34 shows the wing foil as viewed from the sensor position.

Tests to determine minimum viewing angle were conducted on flat plates. Plates were first treated with anti-icing fluid and subjected to precipitation to cause different levels of fluid contamination. The sensor camera height was progressively varied to produce different angles of incidence. It was determined that the minimum angle at which contaminated areas could be identified was about 23° (composed of an angle of view of 13° to horizontal and the plate angle of 10°).

Through observation and discussion with Cox technical staff, it was determined that the resolution of ice detection was about a four-pixel square on the display screen. This is roughly equivalent to an area of 5 cm x 5 cm (in plan view) when viewed from a distance of 45 m. This infers that a contaminated area smaller than these dimensions would not be identified by the sensor.

The influence of various coloured substrates on sensor effectiveness was examined. Test surfaces of various colours were prepared such that small squares or rectangular areas remained clear of contamination, while the remainder was allowed to become contaminated. The shapes were evident from camera images, displayed as non-contaminated areas. The positive result may have been enhanced by the distinctiveness of the straight edges of the test areas.

Influence of lighting levels was examined. Experiments were conducted in which one or both camera sources of illumination were used to observe the same surface from the same position. With both camera lights on, the number of invalid pixels from metal or other more reflective surfaces was significantly increased. This effect may arise from a degree of polarisation of the light reflected back to the camera from these surfaces, in which case a rotational polarizing filter could be mounted onto the camera lens. Testing with test chamber lights turned off did not result in a noticeable influence on sensor effectiveness. The sensor camera lighting was sufficient to provide adequate illumination within the test chamber. Further tests at longer viewing distances at night would be useful to fully assess this unit's capabilities.

4.9 Evaluation of the Demand for Holdover Time during Actual Deicing Operations

4.9.1 Total Data

A total of 290 data samples were analysed. This data is shown on a bar chart, with the bar height representing the percentage of occurrence of different heldover times. The total percentage of the bars on the chart is equal to 100% (see Figure 4.5). Approximately 80% of the samples had heldover times no longer than 20 (±1) minutes. Less than 2% of the samples were longer than 30 (±1) minutes. The two longest times were 67 minutes and 52 minutes and were found to be the only samples having times above 40 minutes. The shortest time was found to be 6.2 minutes, which occurred in snow conditions using only Type I fluid.

The mean heldover time for all the samples was found to be 15 (±1) minutes, and the standard deviation was determined to be approximately 3 minutes. An analysis of the data showed that there is a 95% confidence level that the 15-minute mean would not vary by more than one minute in subsequent winters. This assumes that storms in subsequent winter seasons would be similar and that no significant changes would occur in the design or operation of the deicing centre or airport. It is believed that these two conditions will not hold; in particular, the storms experienced during the data collection were not severe, and a modification to a taxiway will provide improved access to Runway O6R from the deicing centre

4.9.2 Heldover Time Variations with Weather

A total of 235 data points were collected in conditions of snow, 55 in conditions of frost. No points were collected in conditions of freezing rain or freezing drizzle. In frost conditions (See Figure 4.6), 96% of the aircraft had heldover times of less than 20 (±1) minutes.

In snow conditions, 86% of the aircraft had heldover times under 20 (±1) minutes and 98% under 30 (±1) minutes. Heldover times for snow conditions show more scatter than frost. The mean heldover time was 14 minutes for frost and 16 minutes for snow. The standard

FIGURE 4.5

VARIATION OF HELDOVER TIME (Percentages)

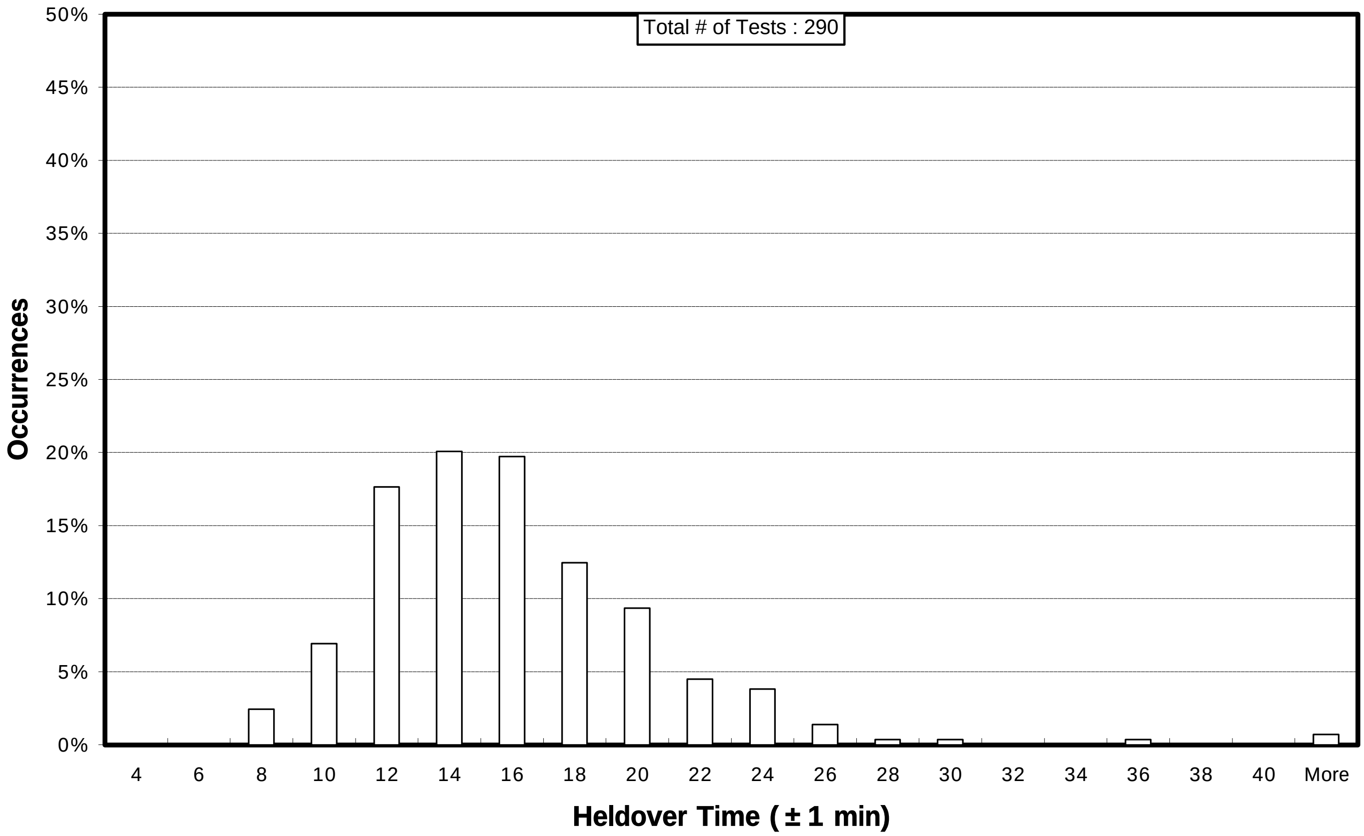
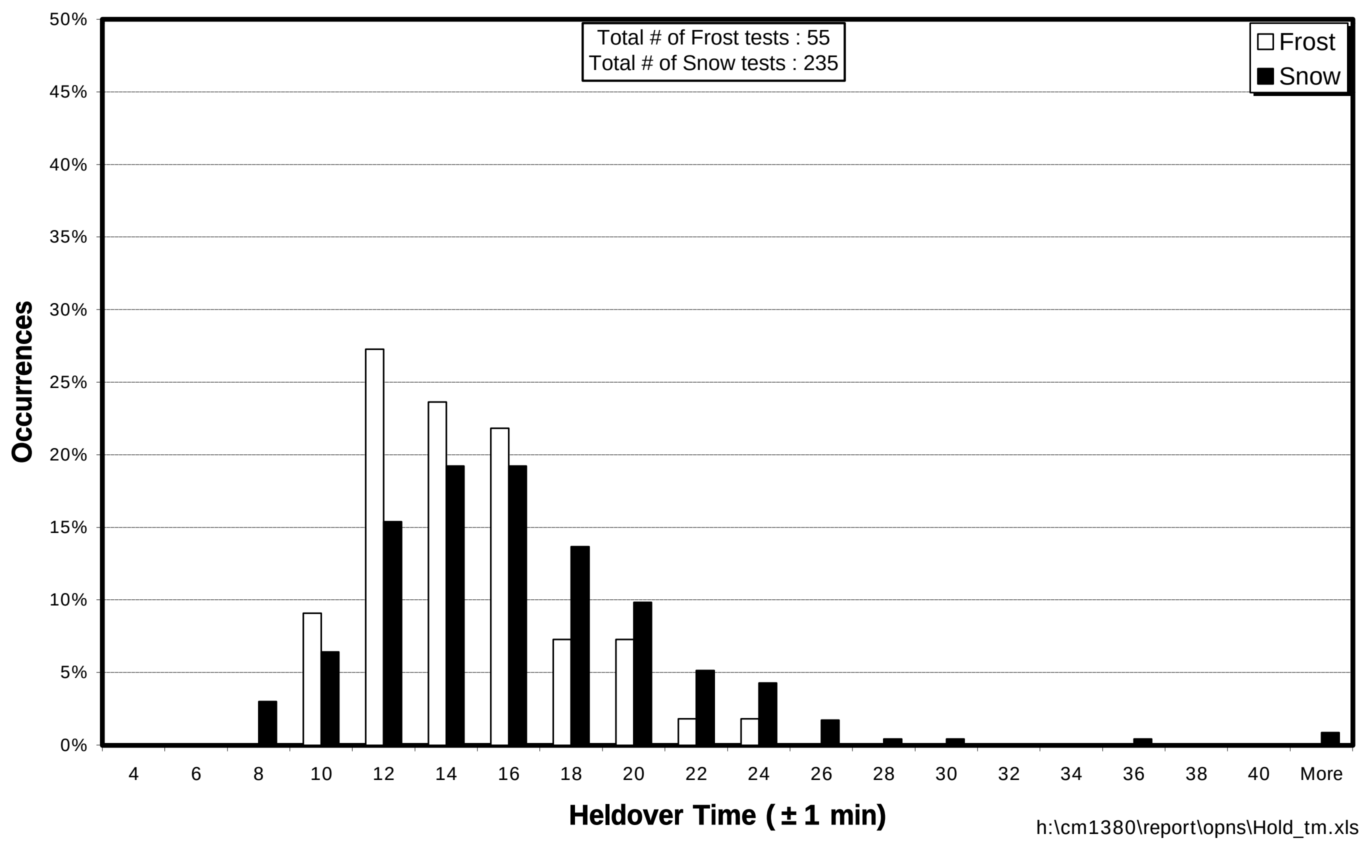


FIGURE 4.6

VARIATION OF HELDOVER TIME WITH WEATHER (Percentages)



deviation for snow was found to be 5 minutes compared to 3 minutes for frost.

4.9.3 Heldover Time Variation with Type of Fluid Used

Union Carbide products are used exclusively at Dorval airport. Of the total data recorded, (Figures 4.7 and 4.8), 159 involved one-step Type I fluid application, and 131 involved the combined Type IV over Type I fluid
application. Of the 159 one-step Type I data points, 109 occasions involved Type I applications in snow conditions. Of these points, only 54% of the aircraft had heldover times of less than 15 minutes (15 minutes is the required holdover time for SAE Type I between 0°C and -10°C for precipitation rates less than 10 g/dm^2/hr).

A more detailed study (see Section 4.10.6) was done using 20 samples of one-step Type I fluid applications in snow conditions having heldover times greater than 15 minutes. This study showed that in most cases, when the heldover time exceeded 15 minutes the precipitation rate was under 10 g/dm^2/hr. In one case, the precipitation rate was greater than 25 g/dm^2/hr.

In conditions of snow with one-step Type I application, 89% of aircraft heldover times were under 20 (±1) minutes, 2% were over 30 minutes. When one-step Type I fluid applications were performed in frost conditions, 98% of the heldover times were under 20 (±1) minutes (see Figure 4.7).

In conditions of snow with two-step Type IV over Type I fluid applications, 99% of aircraft heldover times were under 30 minutes, 85% were under 20 (±1) minutes (see Figure 4.8). On five occasions, Type IV over Type I applications were used in conditions of frost. The average heldover time during snow conditions was slightly longer (one minute) when Type IV fluid was used, probably due to more severe ground conditions and the heavier precipitation conditions associated with the use of Type IV.

4.9.4 Heldover Time Variation with Aircraft Size

Smaller aircraft tend to have shorter heldover times than larger aircraft (See Figure 4.9). A comparison of aircraft size and heldover time showed that small aircraft were on average three minutes faster than medium and large aircraft.

FIGURE 4.7

VARIATION OF HELDOVER TIME FOR TYPE I FLUID WITH WEATHER (Percentages)

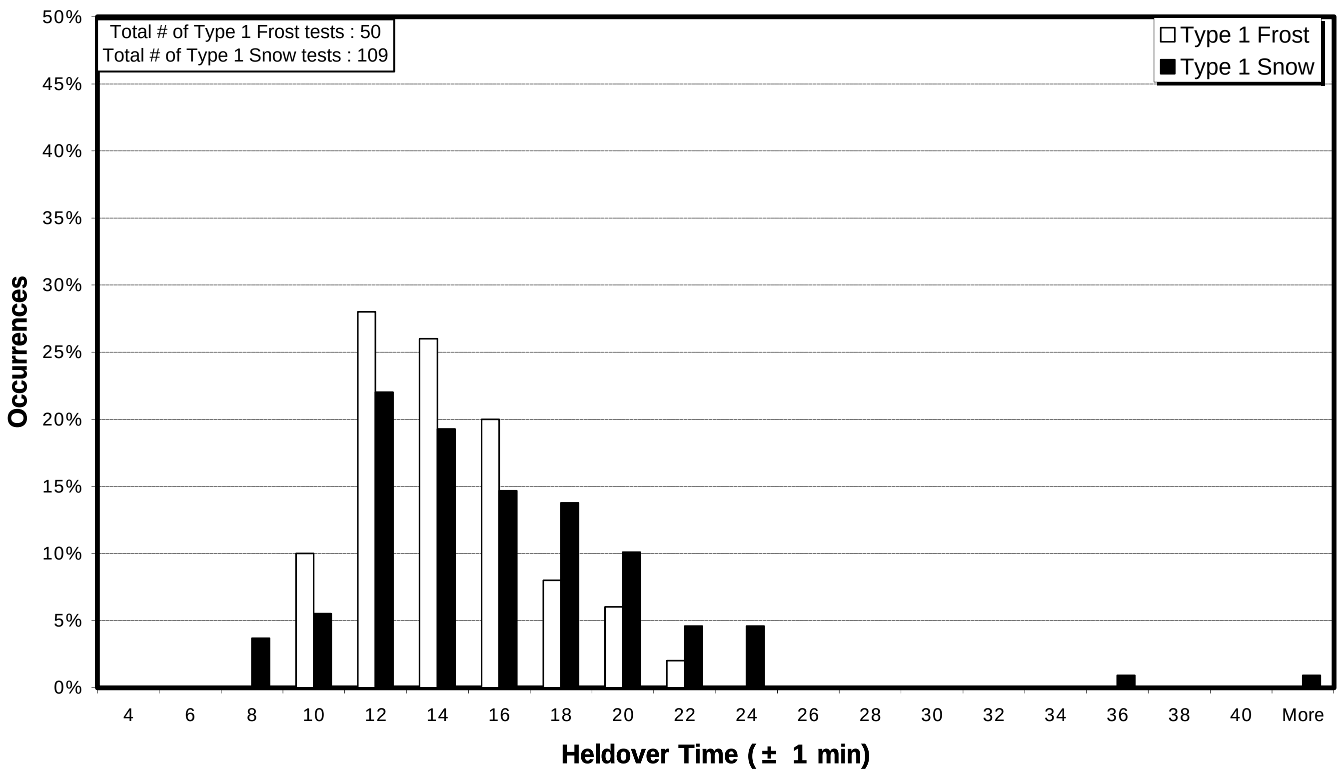
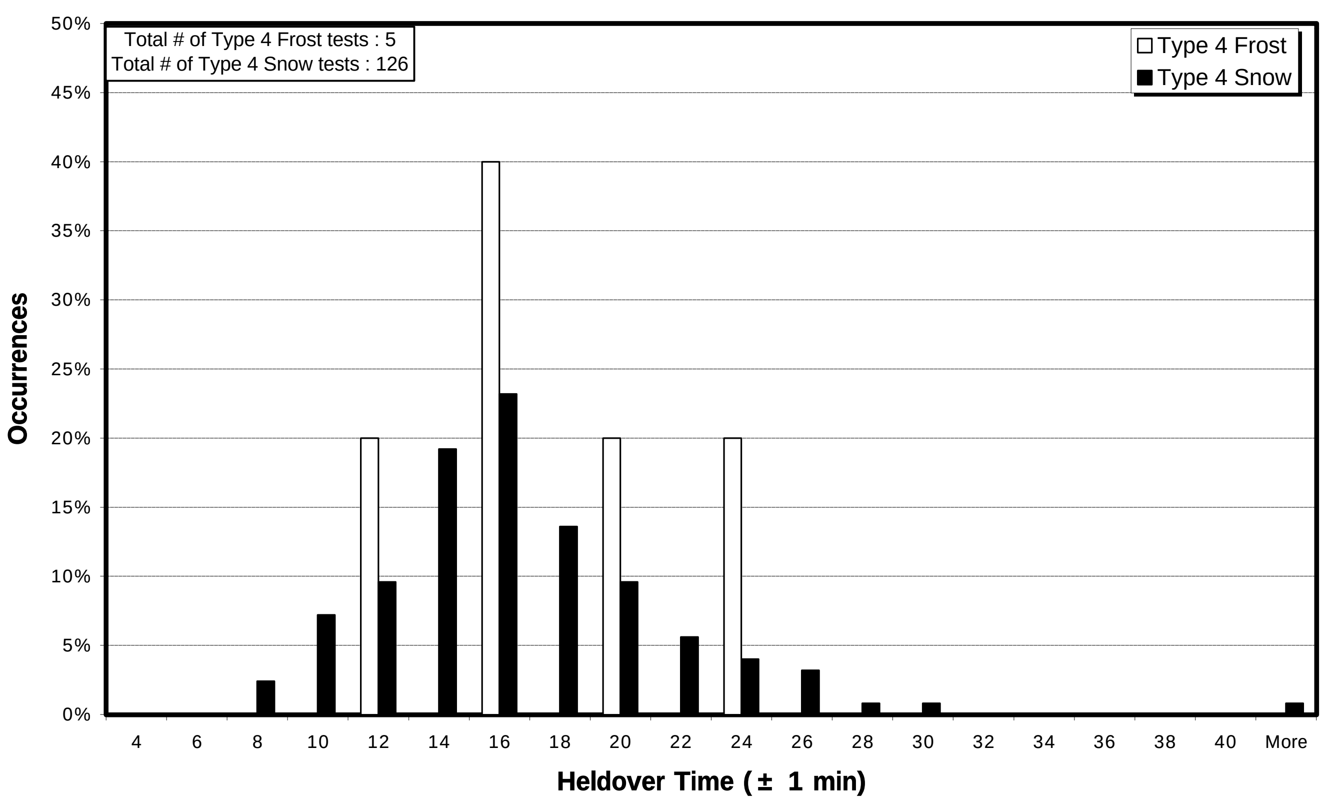


FIGURE 4.8

VARIATION OF HELDOVER TIME FOR TYPE IV FLUID WITH WEATHER (Percentages)



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Printed on 7/22/02

FIGURE 4.9

VARIATION OF HELDOVER TIME WITH AIRCRAFT TYPE (Percentages)

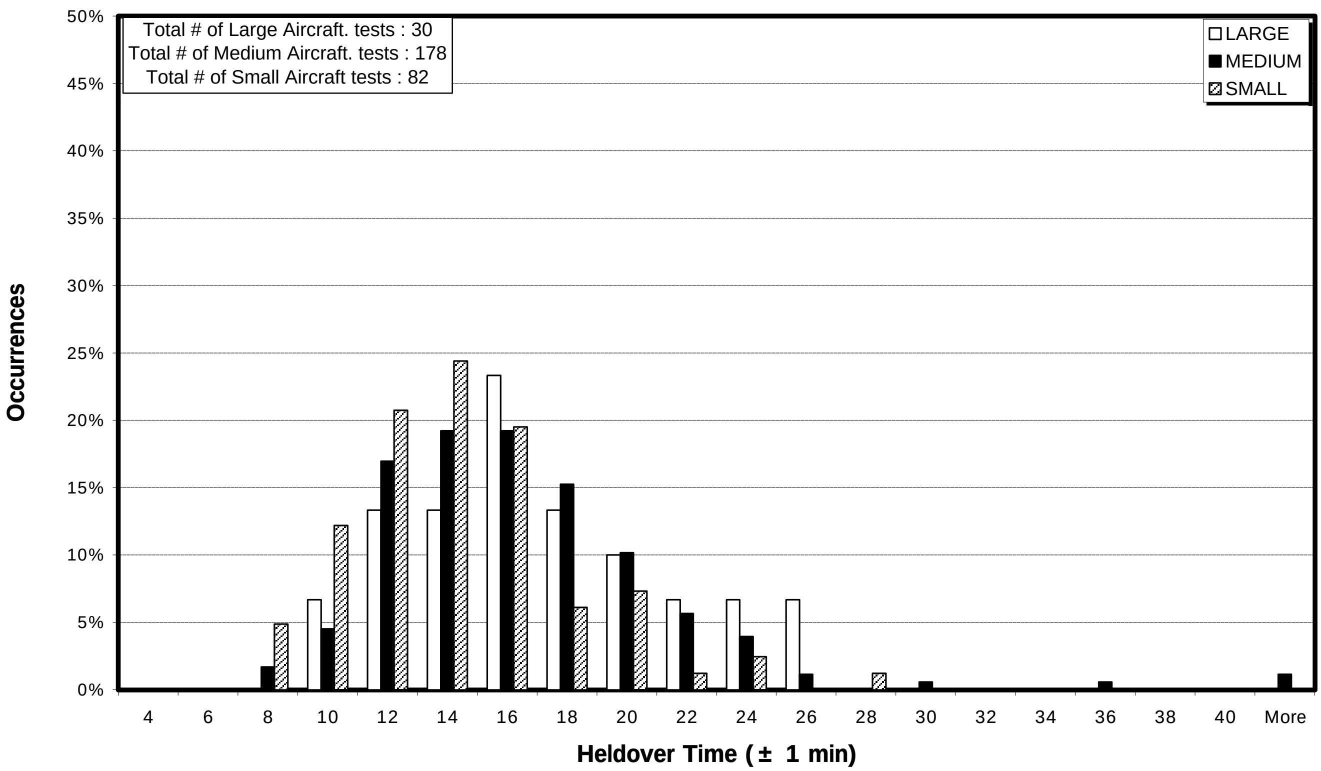
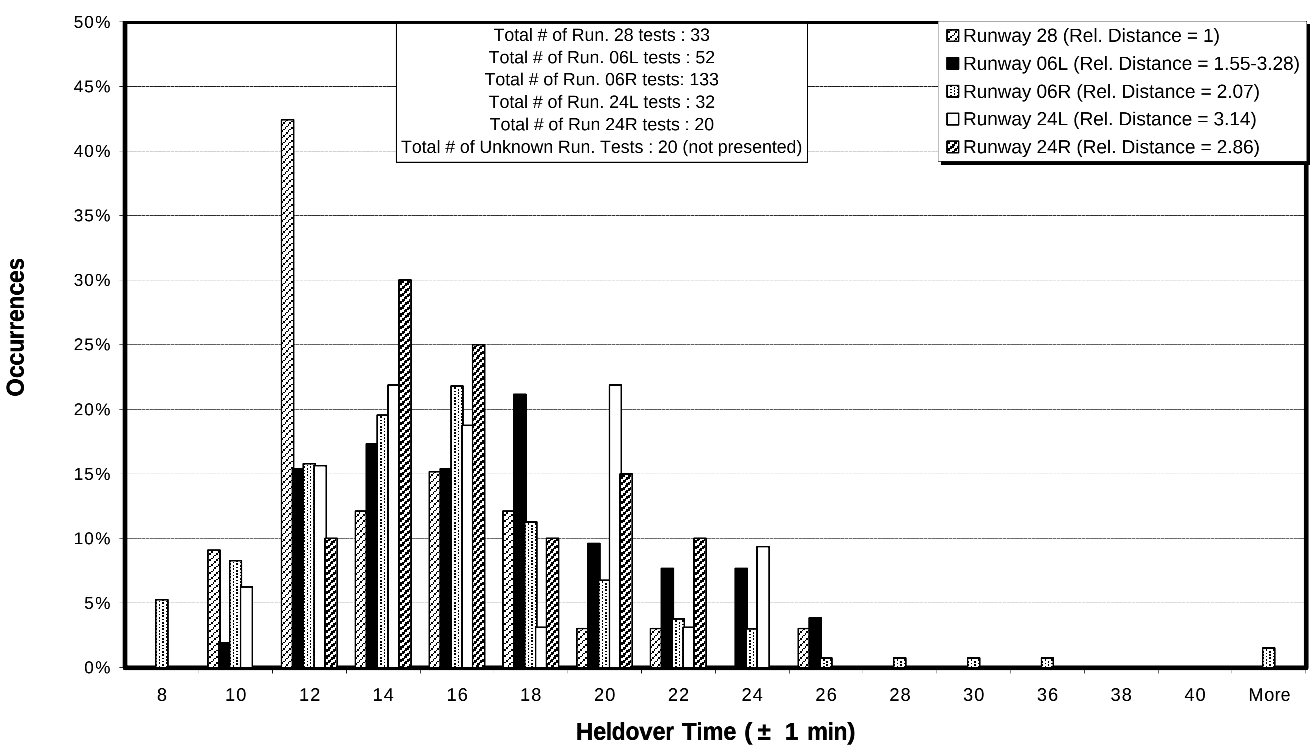


FIGURE 4.10

VARIATION OF HELDOVER TIME WITH RUNWAY LOCATION (Percentages)



4.9.5 Heldover Time Variation with Runway Location

Forty-two percent of aircraft directed to Runway 28 had heldover times of 12 (±1) minutes (See Figure 4.10). Figure 4.10 also provides relative distances to each of the runways and shows that Runway 28 is the closest runway to the deicing centre. This is the highest percentage frequency of occurrence when compared to other runways. The second highest frequency was on Runway 24R. Thirty percent of the aircraft directed to Runway 24R had heldover times of 14 (±1) minutes (see Figure 4.10).

4.9.6 Evaluation of Heldover Time versus Precipitation Rate

An evaluation of heldover times versus precipitation rates was completed using data from APS environmental measurements used for holdover time tests (See Figures 4.11 and 4.12). The study involved a total of 30 points. Of the total, 19 points were taken from the original sample of one-step Type I fluid applications, 11 points using two-step Type IV over Type I fluid applications. The selection of the points was random with the exception that the heldover times had to be in excess of 15 minutes. Heldover times and the corresponding precipitation rates were then plotted against each other to develop a profile of the traffic behaviour experienced. Two charts were developed, one for Type I fluid applications and another for two-step Type IV/Type I fluid applications. The charts were then fitted with three curves, developed from holdover time charts for the respective fluids.

The three curves in each figure represent the lower, middle and upper range of the heldover time variation. This variation is primarily caused by the different fluid brands (for Type I), wind, outside air temperature, and perhaps precipitation type. For Type IV, the curve in the centre represents the recommended heldover time.

This evaluation found that 77% of departures that needed one-step Type I fluid deicing, and 64% of aircraft departures that used two-step Type IV/Type I de/anti-icing, had heldover times less than the holdover times represented by the curve in the middle. 23% of departures involved in one-step Type I deicing and 27% of aircraft involved in two-step Type IV/Type I de/anti-icing had holdover times immediately above or below the middle curve. No departures involved in one-step Type I deicing and 9% of aircraft involved in two-step Type IV over Type I de/anti-icing had holdover times above the upper bound.

FIGURE 4.11

HELDOVER TIME vs PRECIPITATION RATE (XL54 Type I)

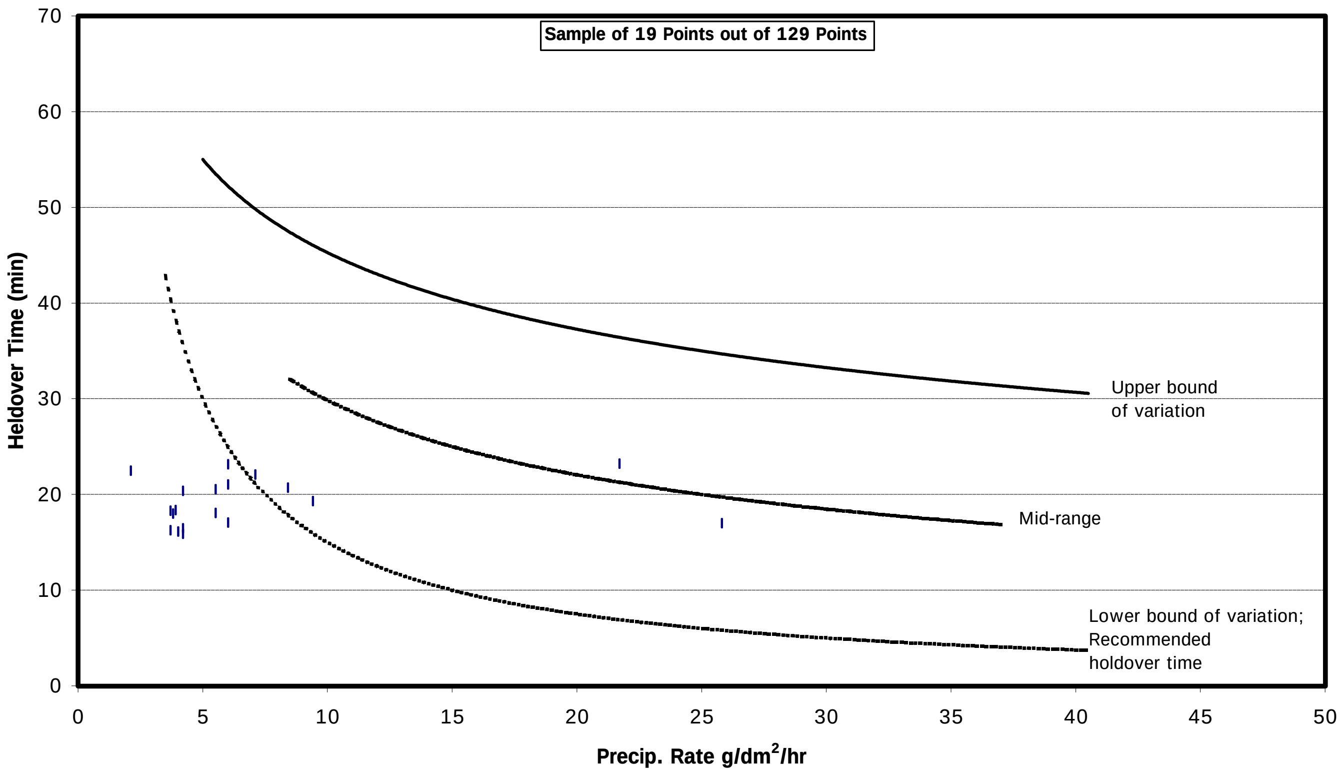
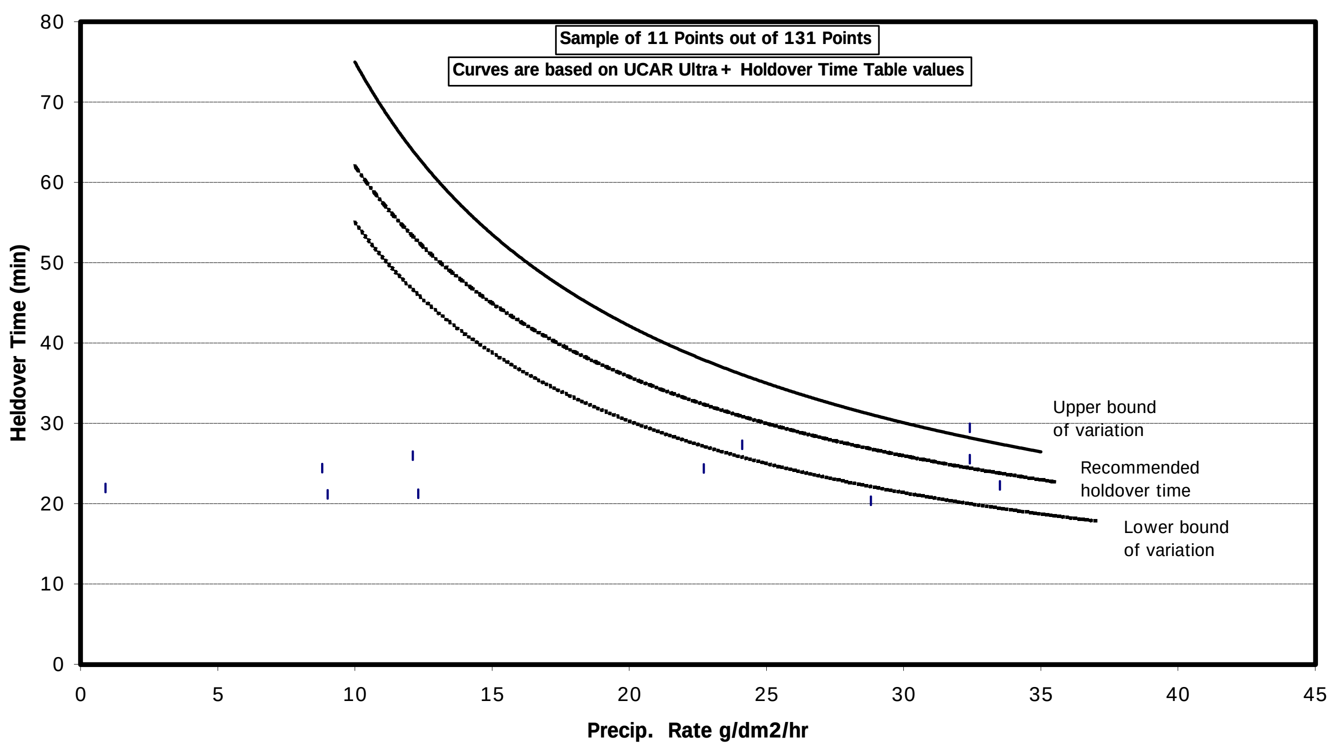


FIGURE 4.12

HELDOVER TIME vs PRECIPITATION RATE (Type IV)



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Printed on 7/22/02

Photo 4.1
Sieve Used to Contaminate Plates

Photo 4.2

Type I Failure (at Plate Rotation)

Type I Failure (7 minutes after Plate Rotation)

Photo 4.3

Type IV Failure (at Plate Rotation)

Type IV Failure (3 minutes after Plate Rotation)

Photo 4.4

1.6 mm (1/16") Aluminium Plate Prior to Frost Deposition Test

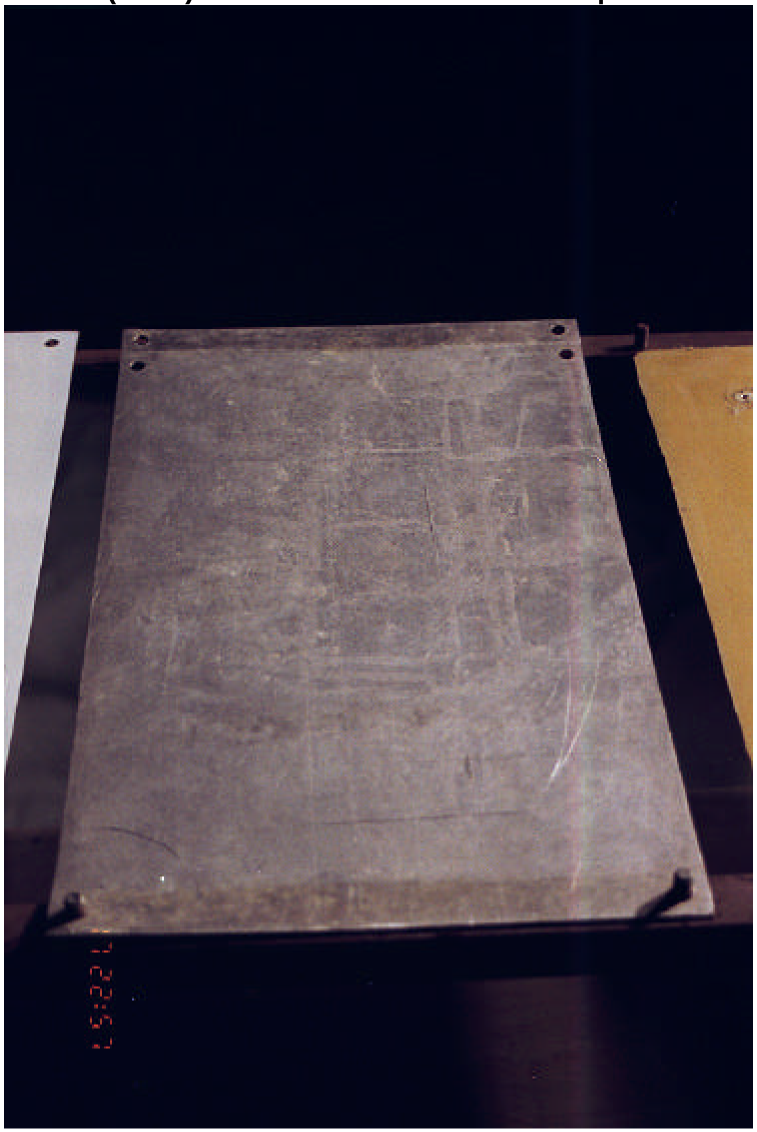

Photo 4.5

1.6 mm (1/16") Aluminium Plate Following Frost Deposition Test

Photo 4.6
Red 1.6 mm (1/16") Aluminium Plate Prior to Frost Deposition Test

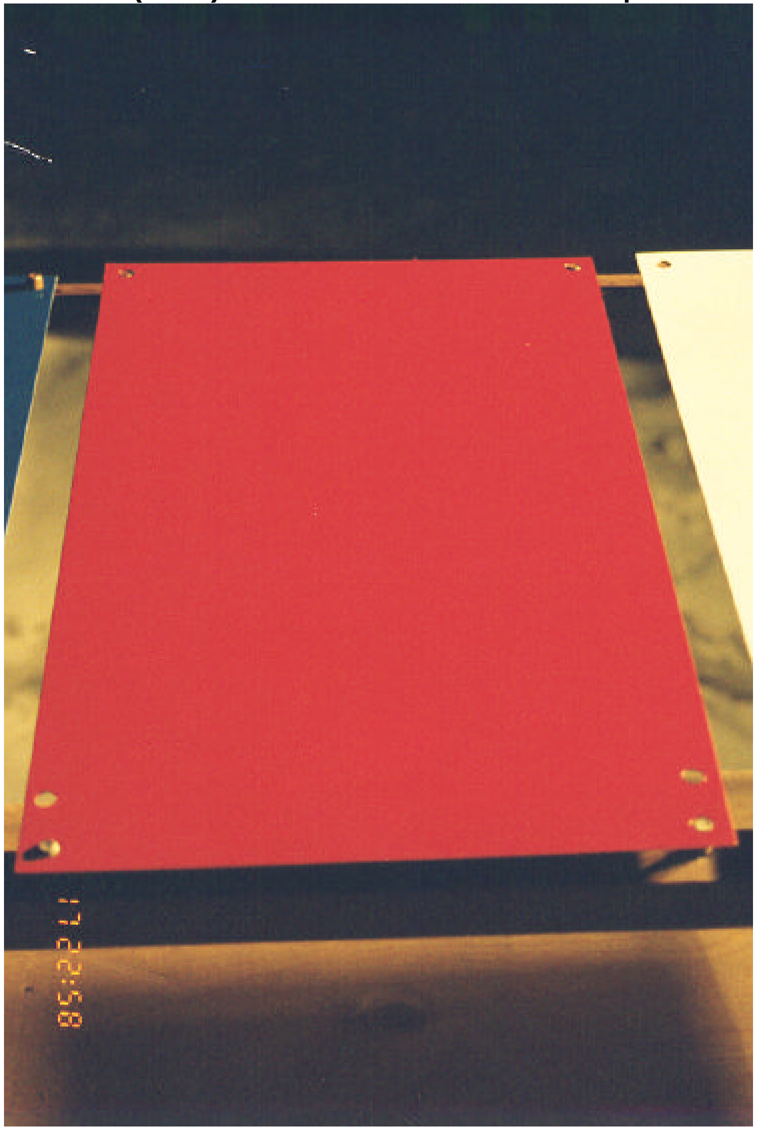

Photo 4.7
Red 1.6 mm (1/16") Aluminium Plate Following Frost Deposition Test

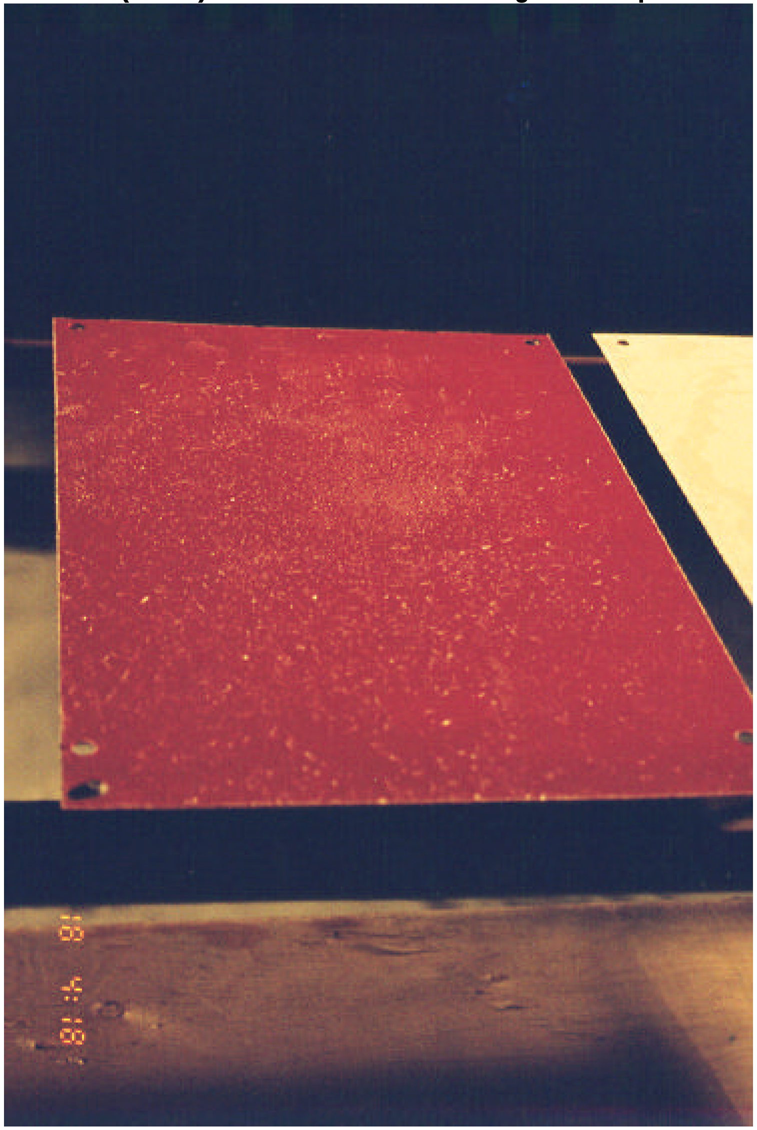

Photo 4.8

Blue 1.6 mm (1/16") Aluminium Plate Prior to Frost Deposition Test

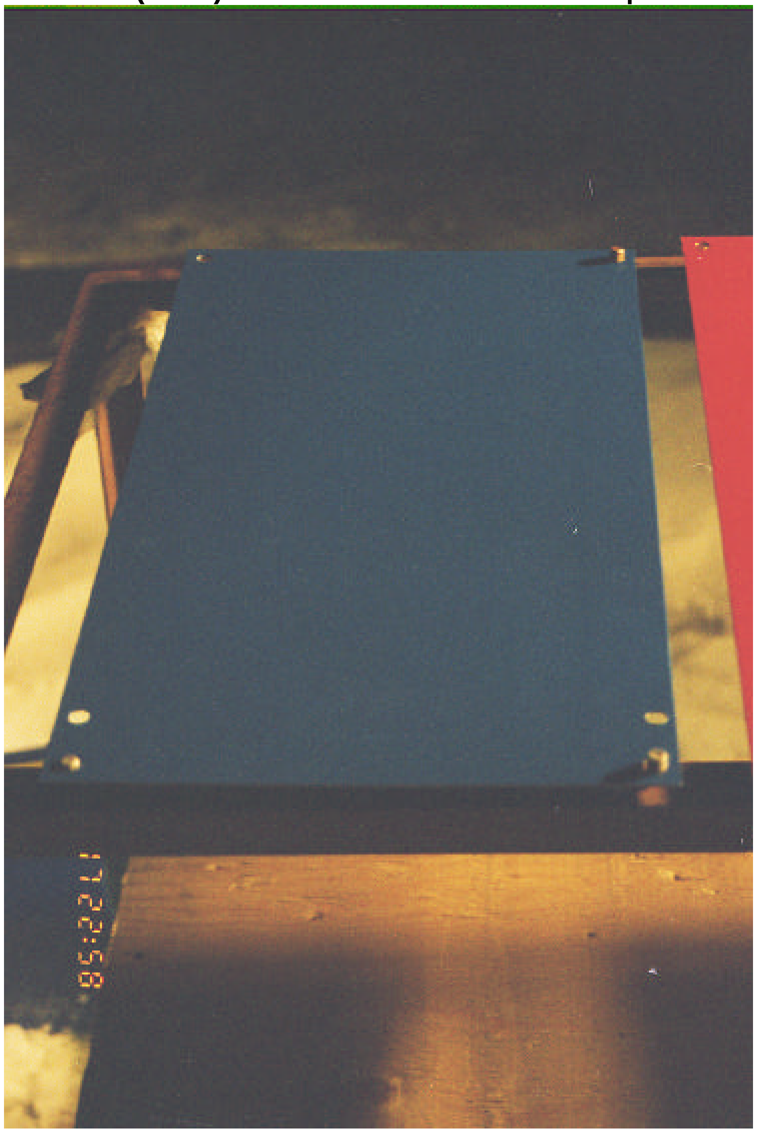

Photo 4.9

Blue 1.6 mm (1/16") Aluminium Plate Following Frost Deposition Test

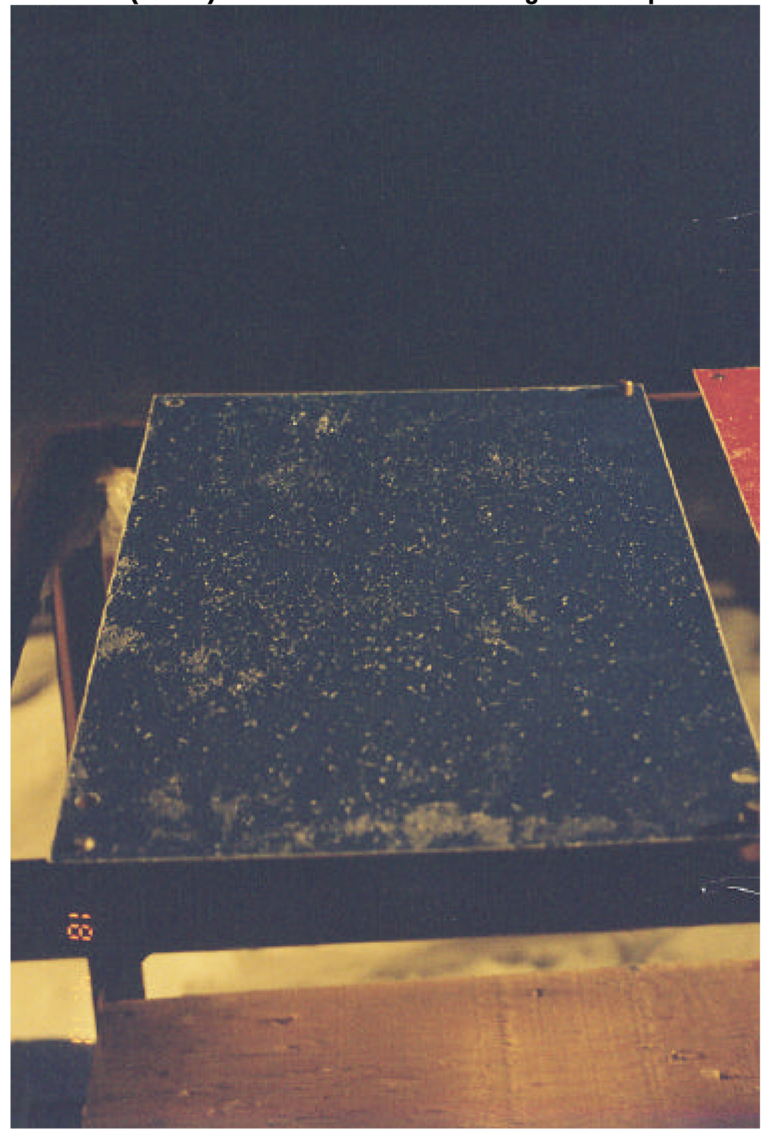

Photo 4.10
White 1.6 mm (1/16”) Aluminium Plate Prior to Frost Deposition Test

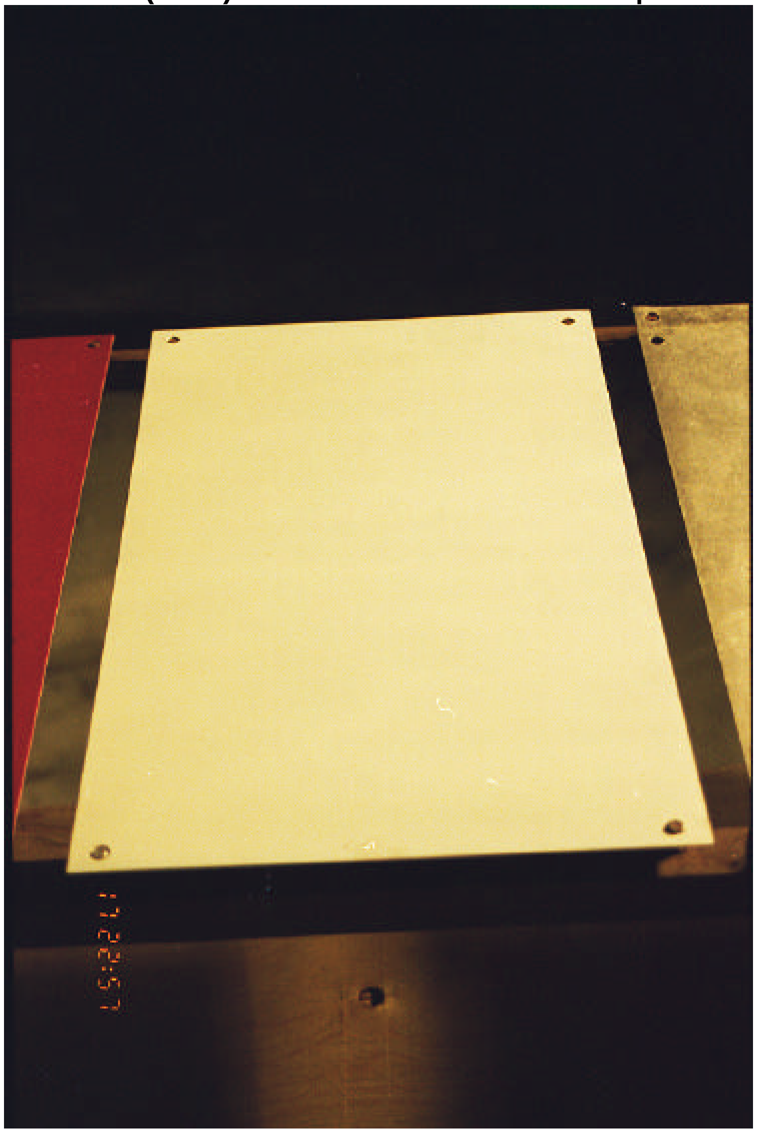

Photo 4.11
White 1.6 mm (1/16”) Aluminium Plate Following Frost Deposition Test

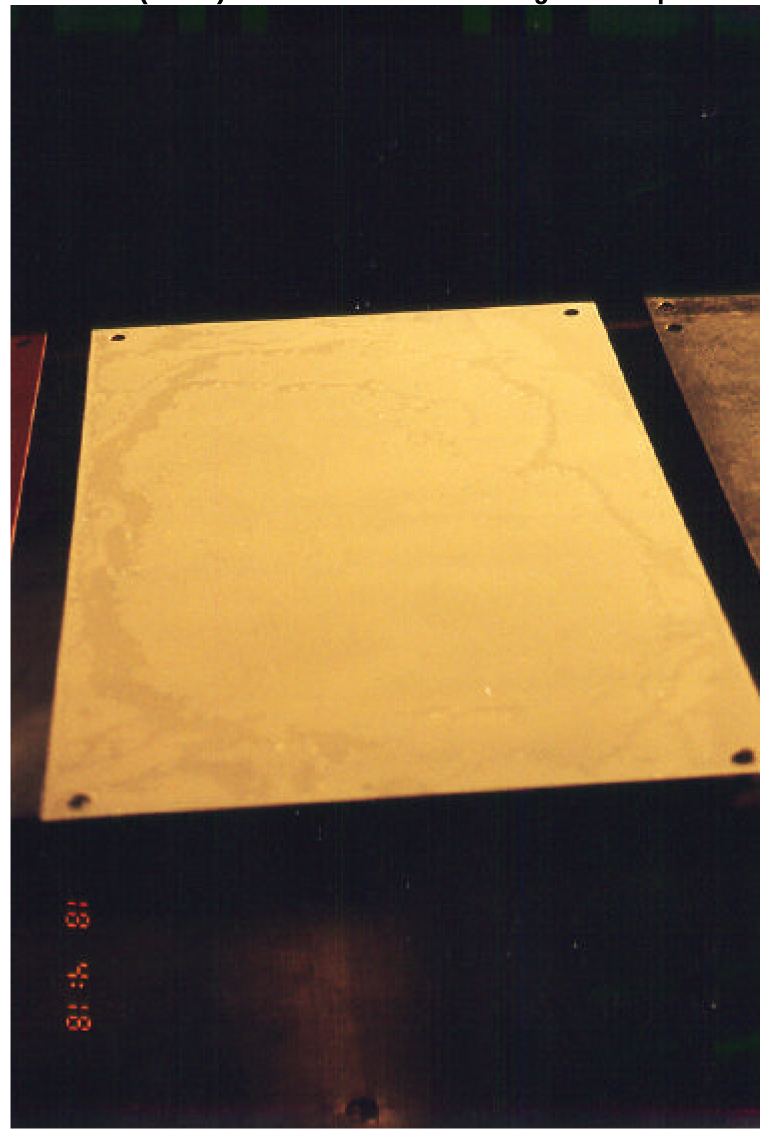

Photo 4.12
Kevlar Composite Plate Prior to Frost Deposition Test

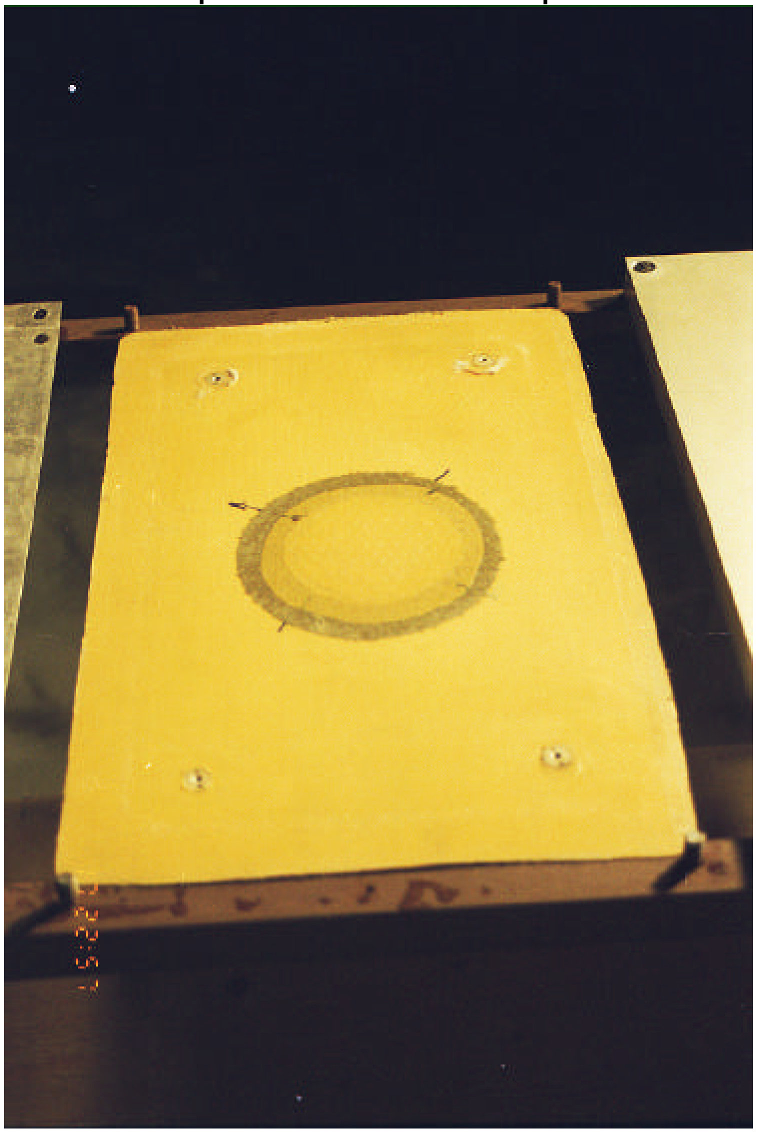

Photo 4.13
Kevlar Composite Plate Following Frost Deposition Test

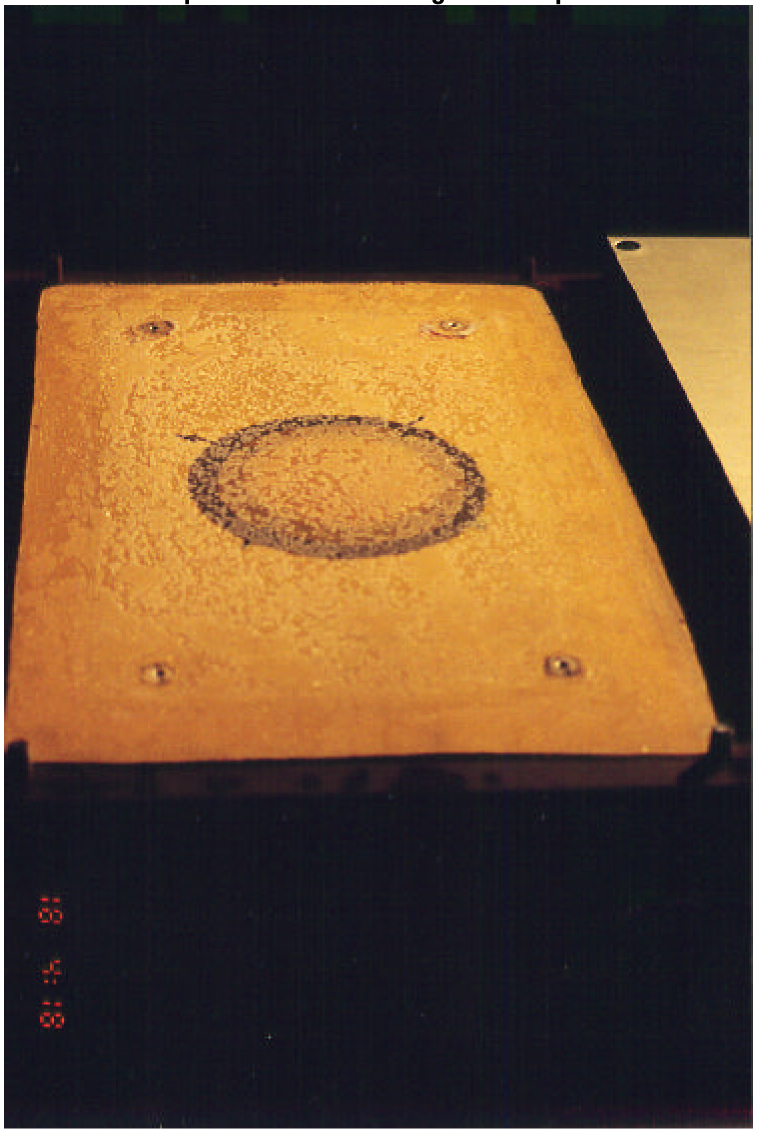

Photo 4.14
3.2 mm (1/8") Aluminium Plate Prior to Frost Deposition Test

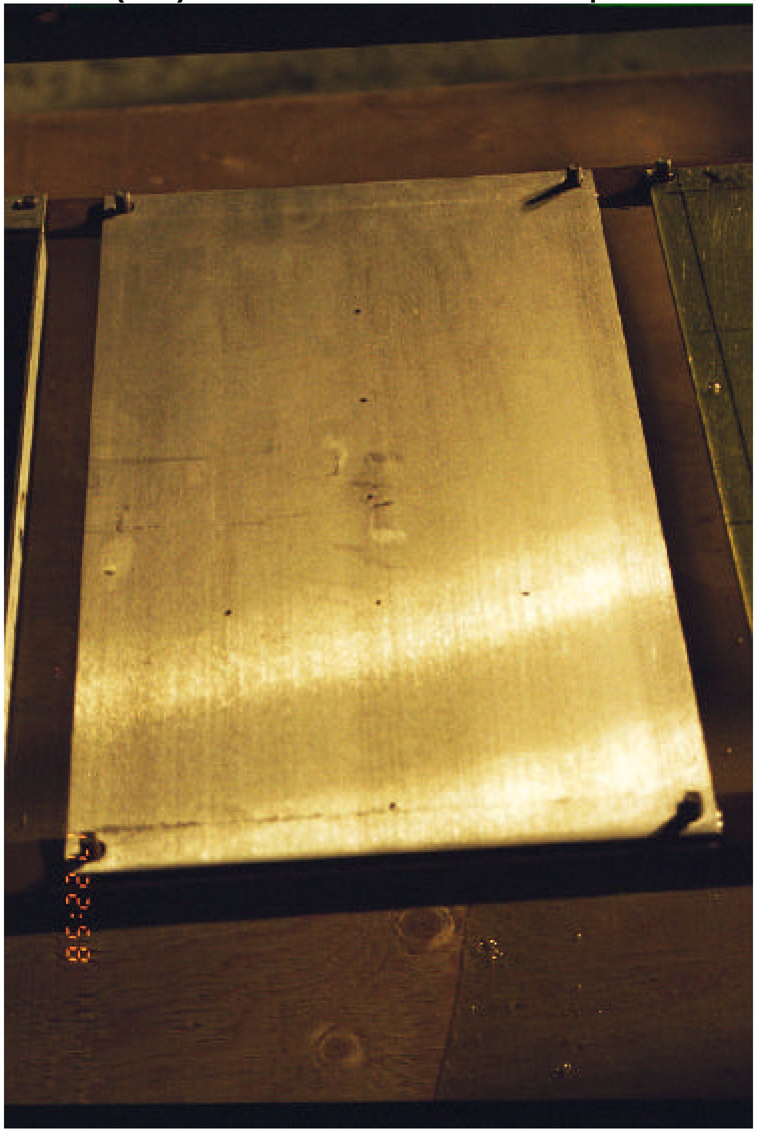

Photo 4.15
3.2 mm (1/8") Aluminium Plate Following Frost Deposition Test

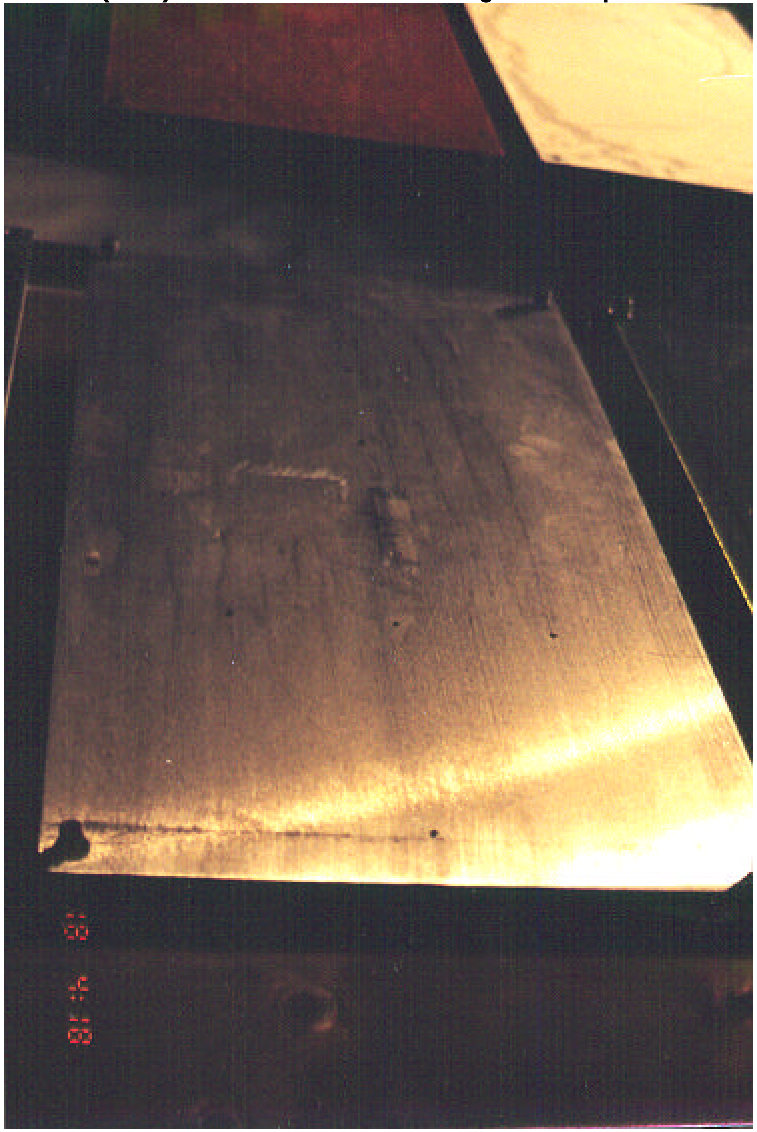

Photo 4.16
3.2 mm (1/8") Aluminium Plate Coated with Type I Fluid Prior to Frost Deposition Test

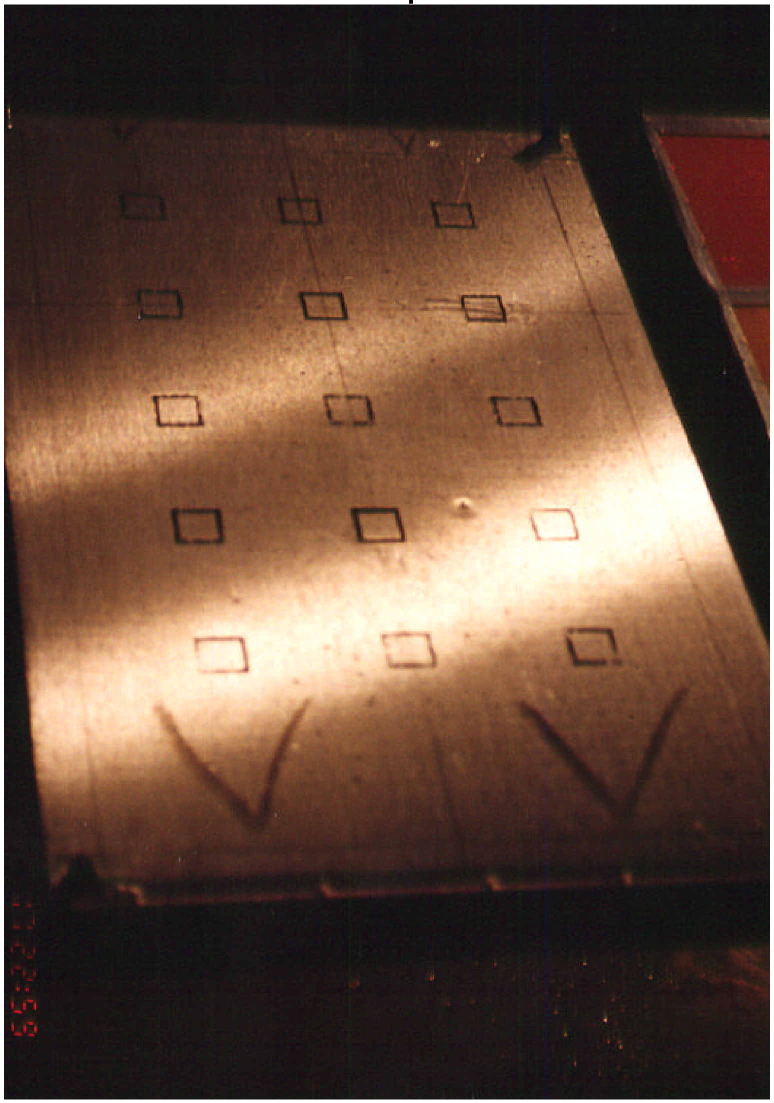

Photo 4.17
3.2 mm (1/8") Aluminium Plate Coated with Type I Fluid Following Frost Deposition Test

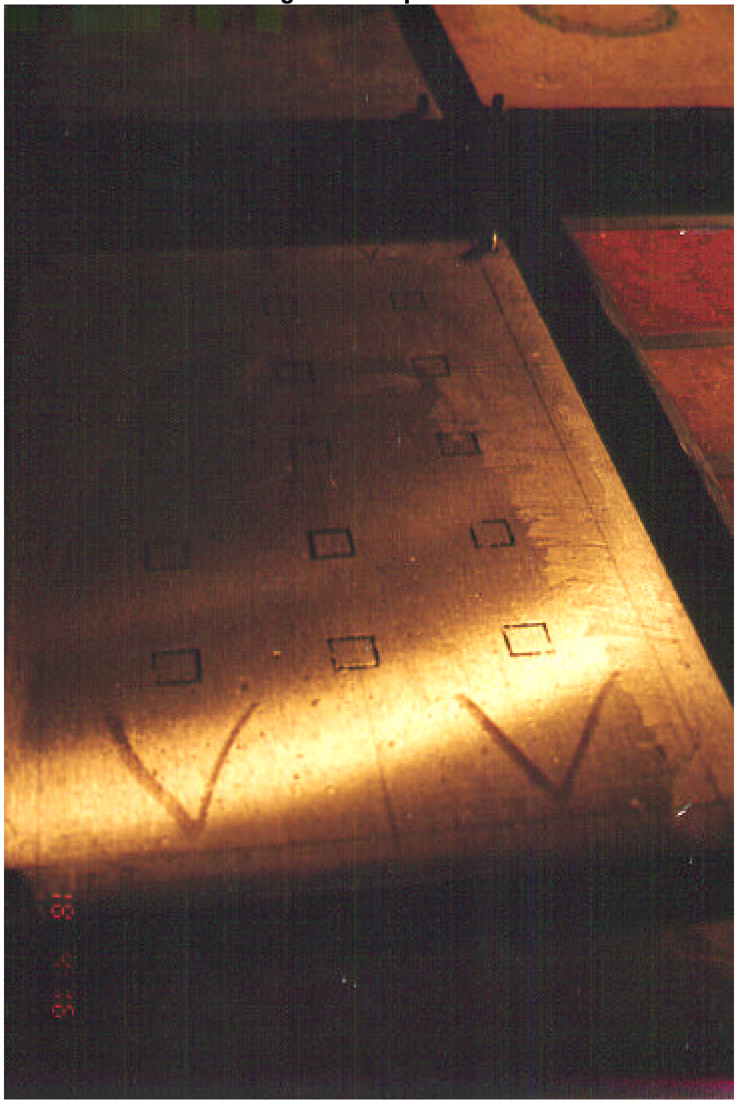

Photo 4.18
3.2 mm (1/8") Aluminium Plate Coated with Type IV Fluid
Prior to Frost Deposition Test

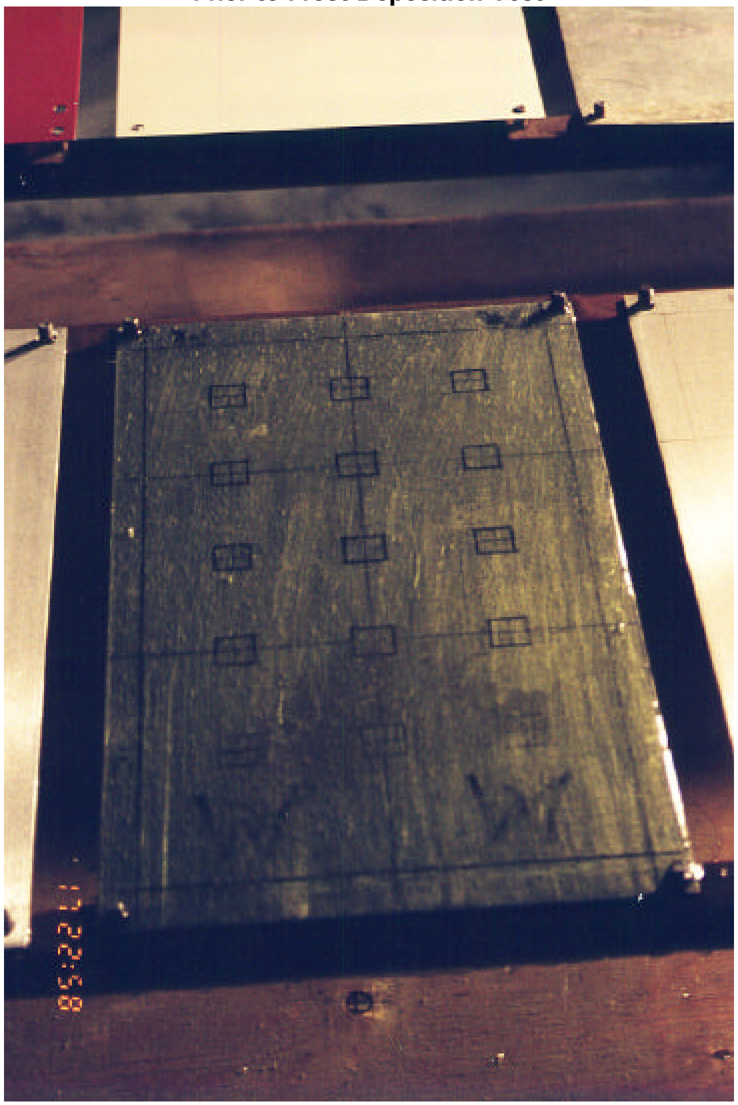

Photo 4.19
3.2 mm (1/8") Aluminium Plate Coated with Type IV Fluid
Following Frost Deposition Test

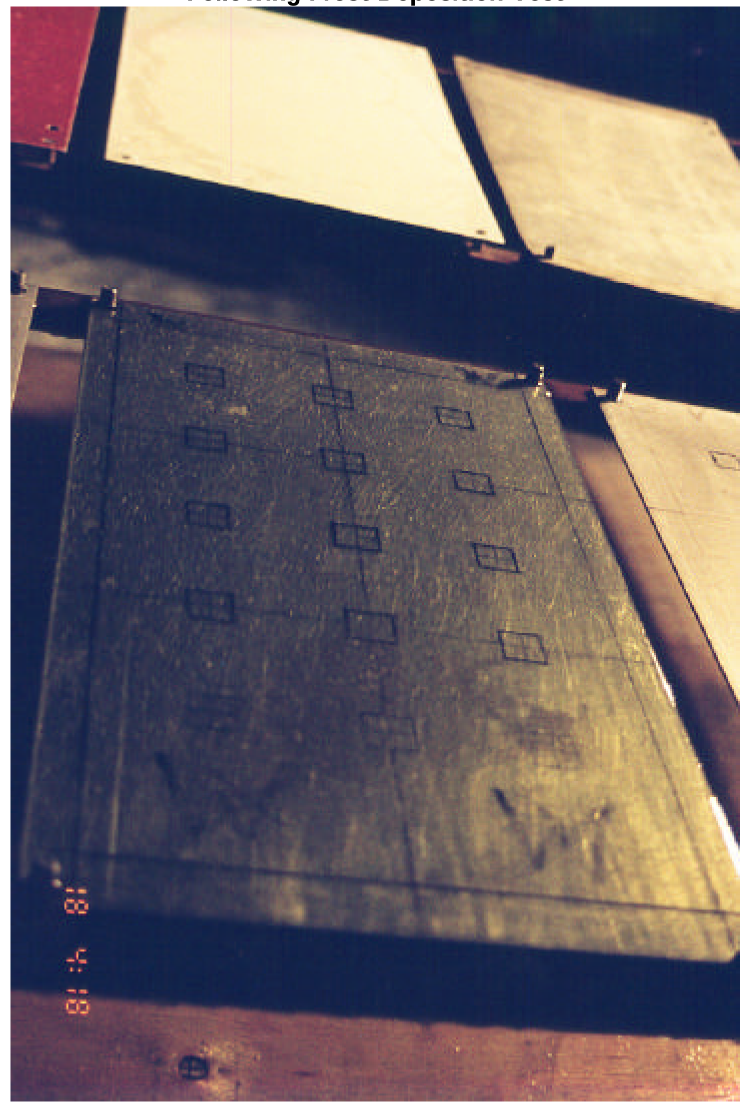

Photo 4.20
Type IV Ultra+ Applied Improperly with Mobile Sprayer

Photo 4.21
Type IV Union Carbide PG AAF Applied Improperly with Mobile Sprayer

Photo 4.22
Hot Water Deicing

Photo 4.23
Truck-Mounted Hot Air-Blowing Device

Photo 4.24
Portable Hot Air-Blowing Device

Photo 4.25
Hangar Deicing

Photo 4.26
Portable Sprayers

Photo 4.27
Mobile Infrared Heating Device

Photo 4.28
Brooms

Photo 4.29
Scrapers and Squeegees

Photo 4.30
Ropes

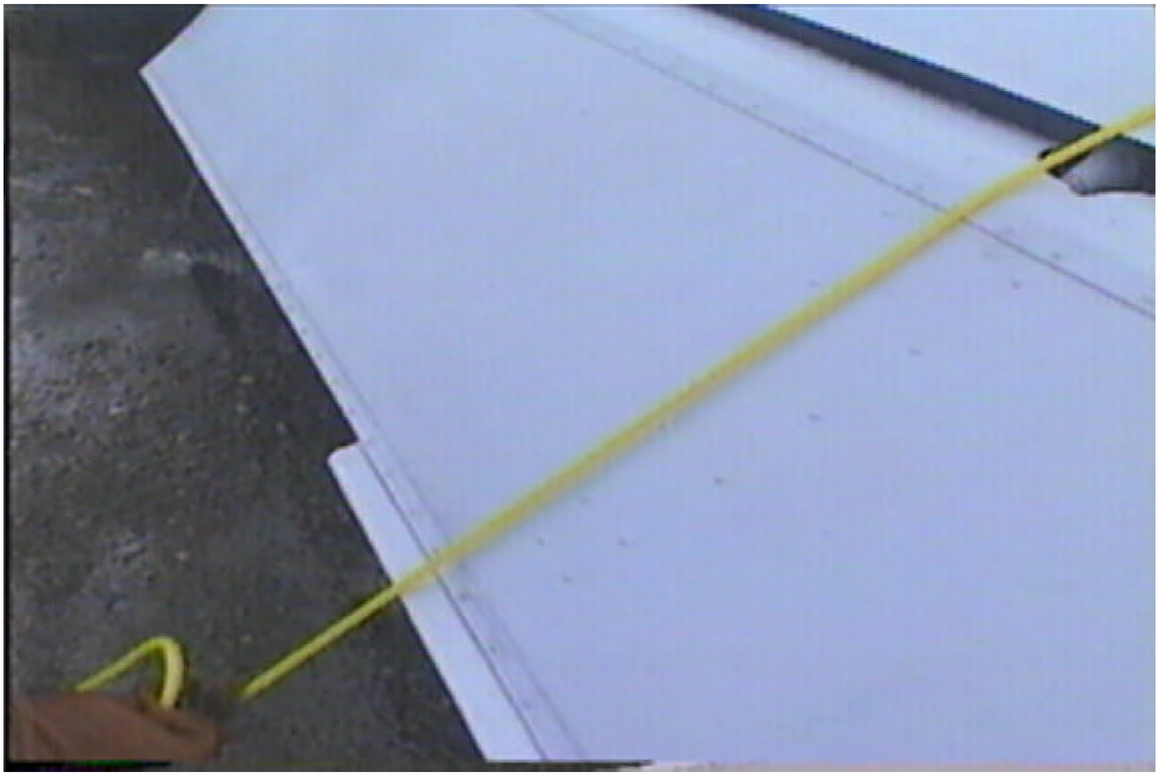

Photo 4.31

Cockpit Covers

Wing Covers

Photo 4.32
Engine Covers

Photo 4.33
Wing Foil at 4.5 m from Sensor

Photo 4.34
Wing Foil Viewed from Sensor

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5. CONCLUSIONS

5.1 Evaluation of Snow Weather Data

Preliminary analysis of data indicates that the current holdover time data evaluation limits are satisfactory. Further analysis needs to be conducted and shall include the additional data collected in the 1998/99 winter season.

5.2 Fluid Failure Tests on Operational Aircraft

No fluid failure tests were conducted on operational aircraft during the past test season, and as such, no conclusions can be made.

The results of tests performed to evaluate the use of lifting spoilers on high wing aircraft as a means to conduct pre-takeoff checks showed that the Type I contamination only gradually slid off the plate. In contrast, the Type IV contamination slid off the plate soon after being rotated. These preliminary results indicate that the lifting of spoilers may be effective for detecting Type I failures but not Type IV failures. It should be noted, however, that only one test was conducted per fluid type using fluid from one manufacturer.

5.3 Frost Tests on Flat Plates

From the results of these tests, it is possible to conclude that:

- The rate of frost deposition is surface-dependent;
- Frost does not readily accumulate on bare aluminum surfaces;
- Frost does accumulate on painted aluminum surfaces; and
- Composite surfaces and honeycomb-backed surfaces (similar to aircraft flight controls) are prone to frost accumulation.

The rate of frost deposition varies from 0.4 to 0.7 g/dm^2/hr on painted surfaces to 0 g/dm^2/hr on unpainted aluminum surfaces.

5.4 Frost Formation on Aircraft

Frost formation tests were not conducted on aircraft in 1997/98.

5.5 Fluid Thickness Tests with the Mobile Type IV Fluid Spray Unit

The two new Type IV formulations from Union Carbide, PG AAF and Ultra IV, behaved similar to Ultra+ when applied over the wing surface with the mobile sprayer; the uniformity of the fluid coverage was inconsistent with all three fluids, when the application was purposely made using non-standard high pressure settings. Inappropriate spray equipment or poor spray techniques can adversely affect the application of the fluid.

5.6 Alternative Deicing Methods

A catalogued series of photographs of alternative deicing methods was compiled and presented in Section 4.

5.7 Documentation of Wing Area Visible to Flight Crew

For low wing aircraft, good views of the entire wing surface are possible by locating oneself close to one or more windows of the cabin. A combination of window locations may be necessary in order to have a consolidated view of the entire wing surface.

Even though a clear view of the outer wing may be had, distances on some of the larger aircraft are considerable and would limit the pilot's ability to identify failed fluid or other contamination. Use of an optical instrument such as common binoculars or a simple compact telescope would assist greatly in this activity.

Observations made from aisle positions are constrained by a very restricted field of view. For the pilot, being positioned close to the window is more important than the precise location of the window. However, in situations when the pilot cannot gain access to a window due to passenger loads, positioning at an overwing exit row offers the next best alternative, where the additional legroom may allow the pilot to get closer to the window.

For high wing aircraft, window views of the wing surface are very restricted, and are generally limited to the leading edge. The designated critical surface on the BAe 146 (top of the engine nacelle) is easily visible from a cabin window. Standing at an open passenger or galley door can offer a view of some additional wing surface area.

A method of illustrating critical surface inspection areas was developed based on wing view photo documentation and could be used to generate illustrations for all aircraft in commercial operation in Canada.

5.8 Use of Remote Sensors for End-of-Runway Inspections

The field demonstration of the Spar sensor installed on the basket of a cherry picker confirmed that the sensor system is capable of identifying contamination on moving aircraft, at some distance. The problem of interpreting aircraft movement as contamination needs to be resolved, as well as any remaining conflict caused by aircraft paint colours.

Laboratory trials reached a number of preliminary conclusions on sensor limitations. These are based on a limited number of tests, and should be confirmed through further trials.

- The sensor system can identify contamination at some distance; it was shown to be effective at 45 m.
- The minimum angle of viewing was observed to be about 23 degrees.
- The minimum area of contamination identifiable is about 5 cm x 5 cm at a distance of 45 m. An area of contamination smaller than this risks not being identified by the sensor.
- Illumination provided by the sensor lights was sufficient within the confines of the test chamber. There can be a problem of too much light as well as too little, shown in a test when use of both sensor lights gave less effective results than a single light.
- Tests of surface colours showed no detrimental effect in laboratory trials. Because field trials did indicate that the sensor system had a problem interpreting aircraft colours, further tests are recommended to explore this aspect fully.

5.9 Evaluation of the Demand for Holdover Time During Actual Deicing Operations

A methodology for collecting and analyzing the taxi time from the deicing centre to the runway (heldover) times of aircraft departures, in an attempt to evaluate the demand for Holdover times, was developed and implemented at Dorval airport. The study showed that 98% of the departure heldover times were less than 30 minutes. The average heldover time at Dorval was found to be 15 minutes, with a standard deviation of 3 minutes. The lengthy period involved in frost deicing (also 15 minutes) has prompted operators at Dorval to seek an alternative method for frost removal. A small sample of all data collected showed that virtually all aircraft had heldover times within or below the suggested holdover time limits.

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6. RECOMMENDATIONS

6.1 Evaluation of Snow Weather Data

Further data should be collected and analysed from READAC and the four CR21X stations located in Quebec and Dorval.

6.2 Fluid Failure Tests on Operational Aircraft

Thickness tests, conducted in 1995/96 on Canadair Regional Jet aircraft (see TDC report, TP 12900E[4]), indicated that fluid appeared to thin rapidly on the leading edge of this aircraft, and recommended further tests to investigate this phenomenon. These tests were not conducted during the 1997/98 winter due to a lack of freezing precipitation and to the unavailability of the aircraft during periods of precipitation.

Results from the single test session conducted on an ATR 42 high-wing turboprop aircraft (1996/97) proved to be inconclusive. Attempts were made during the past season to test ATR 42 and de Havilland Dash 8 aircraft in periods of freezing precipitation; however, tests never materialized.

All failure progression tests conducted in the past have employed the same brand of Type IV fluid.

It is recommended that:

- Failure progression tests be conducted on Canadair Regional Jet aircraft, and on either the ATR 42 or de Havilland Dash 8; and
- Failure progression tests be conducted using other brands of Type IV fluid, to identify any differences in fluid performance and behaviour of these fluids on aircraft wings.

6.3 Frost Tests on Flat Plates

Frost deposition should be collected to determine suitable rate limits for holdover time testing in this condition. Consideration should also be given to obtaining frost deposition rates at temperatures below –14ºC (perhaps in Thompson, Manitoba).

6.4 Frost Formation on Aircraft

Frost formation tests were not conducted on aircraft during the 1997/98 test season due to a lack of suitable conditions. The same series of trials should be performed during the upcoming test season.

6.5 Fluid Thickness Tests with the Mobile Type IV Fluid Spray Unit

It is recommended that the fluid thickness profiles and flow characteristics of other Type IV fluids be examined on aircraft wings using the mobile sprayer. The sprayer should be refined prior to tests to reduce negative aspects of the pumping system (pulsations).

6.6 Alternative Deicing Methods

It is recommended that photo documentation of any subsequent non-glycol deicing methods be compiled and added to the current catalogue. Deicing procedures should also be documented for each method.

6.7 Documentation of Wing Area Visible to Flight Crew

For low-wing aircraft, the pilot can gain best view of the wing by positioning himself as close as possible to a window surface. To do this, he should seek out a seat row that is vacant or has low passenger occupancy. The ability to get close to a window is more important than the precise location of the window being used. Carriers might consider blocking specified seat rows during deicing operations unless needed for full passenger loads.

The best alternative location for viewing is the overwing exit where the additional seat spacing may allow closer access to the window.

Providing pilots with a common optical device, such as binoculars or a simple compact telescope, to assist in identification of fluid failure or contamination on the wing, should be considered.

Illustrations of critical surface inspection areas should be generated for all aircraft in commercial use in Canada.

6.8 Use of Remote Sensors for End-of-Runway Inspections

Based on the demonstrated capabilities of the Spar/Cox ice detection sensor, it is recommended that:

- Further field trials be conducted to fully assess the feasibility of examining aircraft wings prior to takeoff.

- Further trials be conducted to fully assess the sensor limitations.

Further trials, both in the field and laboratory, could be enhanced through modifications to the sensor:

- A voice recording function enabling tester comments to be recorded directly onto the video record of monitor images would assist in later analysis of data. Three-voice channels would be optimum.

- Zoom capability would allow more detailed views of small surface areas.

The problem of over illumination may be a result of polarization of reflected light, in which case it may be resolved with use of a polarization filter.

6.9 Evaluation of the Demand for Holdover Time During Actual Deicing Operations

The presented data cannot be used as a reference for all airports around the world; it is recommended that similar studies be conducted at other airports to determine heldover time variances from one airport to another. Any future tests should include a greater number of test sessions and a greater variety of precipitation conditions, including heavier snowfalls, freezing rain, and freezing drizzle at Dorval airport.

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APPENDIX A

TERMS OF REFERENCE – WORK STATEMENT

APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE

WORK STATEMENT

AIRCRAFT AND FLUID HOLDOVER TIME TESTS FOR WINTER 97/98
(Short Title: Winter Tests 97/98)
(December 1997)

1 INTRODUCTION

Following the crash of a F-28 at Dryden in 1989 and the subsequent recommendations of the Commission of Inquiry, the Dryden Commission Implementation Project (DCIP) of Transport Canada was set up. Together with many other regulatory activities an intensive DCIP research program of field testing of deicing and anti-icing fluids was initiated with guidance from the international air transport sector through the SAE G-12 Committee on Aircraft Ground De/Anti-icing. As a result of the work performed to date Transport Canada and the US Federal Aviation Administration (the FAA) have been introducing holdover time regulations and the FAA has requested that the SAE, continue its work on substantiating the existing ISO/AEA/SAE Holdover Time (HOT) tables (DCIP research representing the bulk of the testing).

The times given in HOT Tables were originally established by European Airlines based on assumptions of fluid properties, and anecdotal data. The extensive testing conducted initially by the DCIP R&D Task Group and subsequently by Transport Canada, Transportation Development Centre (TDC), which has taken over the functions of the DCIP, has been to determine the performance of fluids on standard flat plates in order to substantiate the times, or if warranted, to recommend changes.

DCIP has undertaken most of the field research and much other allied research to improve understanding of the fluid HoldOver Times. Most of the HOT table cells been substantiated, however low temperatures have not been adequately explored and further tests are needed.

The development of ULTRA by Union Carbide stimulated all the fluid manufacturers to produce new long lasting anti-icing fluids defined as Type IV. All the Type IV fluids were upgraded in early 1996 and therefore all table conditions need to be re-evaluated and the table revised if necessary. Certain special conditions for which advance planning is particularly difficult such as low temperatures with precipitation, rain or other precipitation on cold soaked surfaces, and precipitation rates as high as 25 $gm/dm^2/hr$ need to be included in the data set. All lead to the need for further research.

Although the Holdover tables are widely used in the industry as guides to operating aircraft in winter precipitation the significance of the range of time values given in each cell of the table is obscure. There is a clear need to improve the understanding of the limiting weather conditions to which these values relate.

An important effort was made in the 94/95 and 95/96 seasons to verify that the flat plate data were representative of aircraft wings. Airlines cooperated with DCIP by making aircraft and ground support staff available at night to facilitate the correlation testing of flat plates with performance of fluids on aircraft. An extension of this testing was to observe patterns of fluid failure on aircraft in order to provide data to assist pilots with visual determination of fluid failure failure, and to provide a data to contamination sensor manufacturers. The few aircraft tests made to validate the flat plate tests were inconclusive and more such tests are needed. Additional tests testing with hot water and with hot air for special deicing conditions were not completed. All these areas are the subjects for the further research that is planned for the 96/97 winter.

2 PROGRAM OBJECTIVE (MCR 16)

Take an active and participatory role to advance aircraft ground de-icing/anti-icing technology. Develop international standards, guidance material for remote and runway-end de-icing facilities, and more reliable methods of predicting de-icing/anti-icing hold-over times.

3 PROGRAM SUB-OBJECTIVES

3.1 Develop reliable holdover time (HOT) guideline material based on test information for a wide range of winter weather operating conditions.

3.2 Substantiate the guideline values in the existing holdover time (HOT) tables for fluids that have been qualified as acceptable on the basis of their impact on aircraft take-off performance.

3.3 Perform tests to establish relationships between laboratory testing and real world experience in protecting aircraft surfaces.

3.4 Support development of improved approaches to protecting aircraft surfaces from winter precipitation.

4 PROJECT OBJECTIVES

4.1 Develop new Holdover Time Tables applicable (a) to anti-icing fluids wiwhich offer extended HoldOver Times within a particular temperature /precipitation regime;and (b) applicable to de-icing operations, only.

4.2 Determine the influence of fluid type, precipitation and wind on location of fluid failure initiation, time to fluid failure initiation, pattern of fluid failure progression, and visibility of failed fluid on a sample high wing tubo-propeller and a low wing turbojet commuter aircraft.

4.3 Collect data on the taxi time from start of de-icing or anti-icing, as applicable, to start of the take-off roll under conditions of winter precipitation at sample airports.

4.4 Assess the practicality of using a vehicle mounted remote area detection contamination sensor for pre-flight (end of runway) checks.

5. DETAILED STATEMENT OF WORK

5.1 Planning and Preparation

5.1.1 Scope of Work

The work Shall be executed as eleven separate sub-projects:

1) Planning and Preparation.
2) Holdover Time Testing and Evaluation of de/anti-icing fluids.
3) 'Negative Buffer' De-icing Fluids
4) Development of a Low Glycol 'De-icing only' Fluid Table.
5) Aircraft Full Scale Tests.
6) Documentation of Pilot field of View, and Wing Visibility
7) Documentation of the Appearance of Failed Fluids.
8) Potential use of Remote Sensors for End-of-Runway inspection.
9) Taxi Times under conditions of Precipitation.
10) Support for Review of Alternative Technologies.
11) Provision of Support Services.

5.1.2 Program management

The work shall be broken down into the distinct areas of activity consistent with the project objectives.

A detailed workplan, activity schedule, cash flow projection, project management control and documentation procedure shall be developed for each of the seven sub-projects, and delivered to the TDC project officer for approval within one week of the pertinent start date.

5.1.3 Coordination

Prepare, plan, and coordinate with personnel from TDC, airlines, airport authorities, fluid manufacturers, Instrumentation suppliers, and the National Research Council of Canada (NRC) with respect to site requirements and test procedures; training of test personnel; conduct of dry-run(s) and tests.

5.1.4 Safety of Personnel and Aircraft

Planning shall include precautions to ensure safety of personnel, and safety (freedom from damage) of aircraft.

A safety officer shall be nominated to prepare an appropriate plan, and monitor its implementation.

Conduct of tests shall respect recognized safety standards and applicable sections of Federal and Provincial labour codes. Where exceptions are taken due to the nature of the work, e.g. emplacement of power and instrumentation cables in the work area, test personnel shall be made aware of potential hazards.

Within the work area, comprising the de-icing pad and access ways, test personnel shall co-ordinate their movements and be made aware of all other operations taking place. Movement of airline equipment - aircraft, tow trucks, de-icing trucks, shall have precedence over test personnel activities.

Care shall be taken to ensure that mobile equipment, such as inspection platforms, lighting stands etc. are not in contact with aircraft surfaces. Potential contact points for such equipment shall be padded.

Movements of visitors and personnel not directly involved in tests at any given time shall be tightly controlled, with safety as the governing criteria.

Obtain 'Airport owners and operators premises and products liability insurance' to indemnify and hold harmless the airport and the operators against any claim arising.

5.1.5 Coordination with the National Research Council, Environmental Test Facility

Arrangements will be made by Transport Canada for use of the National Research Council, Climatic Engineering Facility (NRC, CEF) for conduct of certain tests.

Coordinate with NRC for use of the Test facility, including setting of dates for tests, environmental conditions to be simulated, and equipment and test materials to be supplied by the respective agencies.

5.1.6 Supply and Condition of De/Anti-icing Fluids

Fluids will be made available by TDC at no cost to the contractor.

The contractor shall make arrangements for fluids delivery and on-site storage.

For dedicated flat plate tests, the contractor shall ensure and record that Type IV fluids are pre-sheared prior to delivery, and are representative of the manufacturer's marketed product, i.e. the samples used in the conduct of tests should not be those with the manufacturer's lowest level of viscosity.

Where exceptions are taken to this requirement these shall be noted, and every effort shall be made to obtain samples which comply with the requirements.

Where testing necessitates application of fluids sheared consistent with normal truck application, and such fluids are not available, the contractor shall subject the fluids to appropriate shearing by similar means.

5.2 Holdover Time Testing and Evaluation of de/anti-icing fluids

5.2.1 Site preparation.
Set up experimental sites and install sensors as inspection aids to provide consistent plate failure conditions under field and laboratory conditions.

5.2.2 Flat Plate Tests for New Type IV fluids
Conduct flat plate tests under conditions of natural snow and freezing drizzle precipitation to record the holdover times, and to develop individual Holdover Time Tables based on samples of new and previously qualified Type IV fluids supplied by Fluid Manufacturers under as wide a range of temperature, precipitation rate, precipitation type, and wind conditions as can be experienced. Tests shall be anticipated for at least four different manufacturer's fluids and shall be conducted in the field and the laboratory.

5.2.3 Validation of "Fluid-Specific" and SAE Tables
Conduct flat plate tests to validate "fluid-specific" and SAE tables that currently lack sufficient supporting data. For the "freezing fog" condition the current upper holdover time shall be revised as necessary.

5.2.4 Evaluation of Snow Weather Data
Evaluate snow weather data (precipitation rate/temperature data) from previous winters to ascertain the suitability of the data ranges used to date for evaluation of HOT limits.
Obtain data from Environment Canada for four sites in Quebec: Rouyn, Mingan (Sept Isles), Pointe-au-père (Mont Joli), and Ancienne Lorette (Qebec City), in addition to Dorval (Montreal).

5.2.5 Analysis of Current Type I and Type II Holdover Time Tables
Conduct an analysis of current Type I and II fluid holdover time data to determine their concurrence with values determined from the data ranges established in task 5.2.4 above. This evaluation will be conducted for all fluid dilutions and precipitation conditions. Develop appropriate regression equations.

5.2.6 Evaluation of the SPAR Aerospace Ice Detection Camera
TDC will arrange for provision of a SPAR Aerospace (Also referred to as a "SPAR/Cox") camera, with software modifications appropriate for data collection and evaluation.
Install the Camera at the Dorval "Field" test site for use in standard flat plate tests.
Calibrate camera output to characterize fluid 'failure' consistent with visual and other instrumented failure 'calls'. Compare camera observations during

conduct of flat plate tests with visual observations of fluid behaviour under conditions of precipitation, and similar observations by other sensing devices.

5.2.7 Supplementary Tests

Conduct supplementary tests in the NRC Climatic Engineering Facility to:

- Measure film thickness of 'new' fluids (fluids made available by TDC, but not previously tested) on flat plates.
- Observe the effects of fluids on ice-phobic materials on standard (aluminum) plates.
- Determine the effect on holdover time of spraying versus pouring of Type IV fluids.
- Determine the effect on holdover time of applying heated versus cold Type IV fluids for standard flat plate tests.

5.2.8 Compatibility with De-icing Fluids

Holdover time tests shall in general be conducted with fluid applied directly to clean plates. Additional tests shall be conducted to determine compatibility of the Type IV fluid samples with a proposed new category, "Type 0" fluid, derived from reclaimed spent fluid.

5.2.9 Measurements and instrumentation

In addition to measurements and records of environmental conditions pertinent to the tests, measurements shall be made during the conduct of the tests to obtain histories at selected locations on the plates of fluid thickness, refractive index, and viscosity through to the end of the tests.
SPAR/Cox and RVSI remote sensors shall also be used to record the initiation and progression of fluid failure.

5.2.10 Location of Tests

Planning shall be based on conduct of outdoor (field) tests at Dorval Airport, Montreal, and indoor laboratory tests in the NRC Climatic Engineering Facility, Ottawa. Anticipate 20 days occupancy in the laboratory.
Consideration shall be given to conduct field tests at alternate sites where desirable test conditions may occur more frequently.

5.3 'Negative Buffer' De-icing Fluids

(Note: The guidelines for holdover times given in the SAE Tables call for the freezing points of fluid mixtures to be at least 10^0C (18^0F) for Type I, and 7^0C (13^0F) for Type II below the ambient air temperature).

Conduct tests to determine the limits of the use of hot water, and reduced glycol content de-icing fluids under conditions of precipitation.
Focus of activity shall be conduct of tests in the laboratory (NRC

Environmental Test Facility) under controlled conditions. Availability of aircraft and procurement of laboratory services will be by TDC.
All other services and facilities shall be provided by the contractor.

5.3.1 Aircraft Tests

- Conduct a test with a selected aircraft at Dorval Airport, Montreal to establish a 'reference' case for comparison with laboratory results. Choice of aircraft shall be determined in cooperation with US Airways and TDC. Test records shall include relative humidity at the time of test, and the fuel load of the aircraft to be tested.
- Test shall be conducted under conditions without precipitation, at zero or low wind velocity, and with low level of insolation - i.e. overcast or night-time. Plan for conduct of tests at the lowest temperature possible, based on forecast conditions.
- Tests shall be conducted with hot water heated and applied in accordance with the first step of SAE ARP4737, latest edition, Two-Step de-icing/anti-icing procedure.
- Tests shall be repeated for at least two different glycol concentrations, Type I fluid, only, to be selected in coordination with TDC. Fluids to be tested shall include at least one propylene glycol- and one ethylene glycol-based fluid.
- Condition of fluid as applied, duration of application, and quantity and thickness distribution of fluid applied shall be recorded.
- Temperature histories on the wing surfaces at selected locations shall be recorded starting prior to fluid application and terminating after fluid freezing. Locations shall include 'over fuel tank' and low thermal inertia surfaces such as control surfaces.
- Simultaneous tests shall be conducted adjacent to the aircraft using standard 1/8" (1.2mm) thick 'SAE' flat plates, increased thermal capacity 1/4" (6mm) plates, and 'Cold-Soak' boxes developed for laboratory simulation of cold-soaked wing. Boxes of appropriate depth shall be provided, as necessary, to ensure that the observed range of fluid behaviour on the wing can be adequately simulated in the laboratory.

5.3.2 Laboratory Tests

- Schedule a test session of one-week nominal duration in the NRC Environmental Test Facility in coordination with TDC. Notify TDC of the anticipated start date with minimum of two weeks notice.
- Anticipate tests using Type I ethylene glycol, and Type I propylene glycol de-icing fluids, and at least one Type IV fluid, heated and applied in accordance with the first step of SAE ARP4737, latest edition, Two-Step de-icing/anti-icing procedure.

- Conduct a matrix of tests using standard 1/8" (1.2mm) thick 'SAE' flat plates, increased thermal capacity 1/4" (6mm) plates, and 'Cold-Soak' boxes developed for laboratory simulation of cold-soaked wing, based on:
  - A range of selected temperatures (e.g. -3^{0}C, -7^{0}C, -14C, -25^{0}C,).
  - A range of appropriate precipitation rates, based on simulated light Freezing Rain.
  - A range of selected buffers, i.e. fluid dilutions.

  Relative humidity at time of test shall be recorded.
  Effects of wind are not to be considered.
- Record all test conditions, and time to fluid failure.
- Prepare recommendations for use of 'Negative Buffer' fluids based on ambient temperature, an appropriate, conservative delay (e.g. 3 minutes) before application of Anti-icing fluid, and limitations which might be imposed by wind conditions.

5.4 Development of a Low Glycol 'De-icing only' Fluid Table

Conduct tests to develop a 'De-icing Only' table for removal of ice, slush, snow or frost, in the absence of precipitation when the fluid is applied in accordance with SAE ARP 4737, latest revision. It is anticipated that the table would give values of minimum acceptable de-icing fluid glycol content, with appropriate buffer, as a function of a set of ambient temperature ranges.
Focus of activity shall be conduct of tests in the laboratory (NRC Environmental Test Facility) under controlled conditions. Procurement of laboratory services will be by TDC.

5.4.1 Laboratory Tests

- Schedule a test session of one-week nominal duration in the NRC Environmental Test Facility in coordination with TDC. Notify TDC of the anticipated start date with minimum of two weeks notice.
- Anticipate tests using water; a proposed new category "Type “0” fluid based on recycled spent fluid; and Type I ethylene glycol, and Type I propylene glycol diluted to provide a range of 'low-glycol' heated de-icing fluids.
- Conduct a matrix of tests using standard 1/8" (1.2mm) thick 'SAE' flat plates, increased thermal capacity 1/4" (6mm) plates, and 'Cold-Soak' boxes developed for laboratory simulation of cold-soaked wing, based on:
  - A range of five or more selected temperatures.
  - A range of selected precipitation rates, based on simulated light Freezing Rain.
  - A range of simulated wind velocities, representative of those encountered in operational service.
  - A range of selected buffers, i.e. fluid dilutions.
- Record the relative humidity.
- Record all test conditions including history of test surface temperature, and

time to fluid failure.

- Develop a draft 'De-Icing, only,Table'
- Prepare a presentation to the SAE G-12 HoldOver Time Subcommittee.

5.5 Aircraft Full Scale Tests

5.5.1 Purpose of tests

Conduct full scale aircraft tests:

- to generate data which can be used to assist pilots with visual identification of fluid failure;
- to assess a pilot's field of view during adverse conditions of winter precipitation for selected aircraft;
- to assess whether Representative Surfaces can be used to provide a reliable first indication of anti-icing fluid failure;
- to explore the potential application of point detection sensors to warn the Pilot in Command (P.I.C.) of an 'unsafe to take-off condition';
- to obtain failed fluid contamination distributions and profiles which can serve as inputs to a theoretical program designed to assess the effects of such contamination on possible aircraft take-off performance; and
- to compare the performance of de/anti-icing fluids on aircraft surfaces with the performance of de/anti-icing fluids on flat plates.

5.5.2 Test Locations

Conduct tests at the Central De-icing Facility, Dorval International Airport, Montreal using aircraft made available by airlines.

Contingency plans shall be made to conduct tests at alternative sites: Ottawa, Uplands Airport; Quebec City, Ancienne Lorette Airport.

Tests shall be performed at the new central de-icing facility. Coordinate with the facility operator for application and clean-up of fluids.

5.5.3 Facilities to be Provided

Provide all necessary equipment and facilities for conduct of the tests. Negotiate provision of ancillary equipment and services where possible with the pertinent airlines. Notify TDC of such arrangements. Equipment shall include lighting fixtures as necessary, observation platforms, vehicles, storage facilities, office facilities and personnel rest accommodation. Additional facilities and test equipment, if required, may be requested subject to agreement by all parties involved.

5.5.4 Test Plans

Prepare Test Plans for full-scale aircraft tests to include the following:

a) A detailed statement of work for each of the participants;

b) A specific test plan, for review by all parties, which will include as a minimum:
- Schedule and sequence of activities;
- Detailed list of responsibilities;
- Complete equipment list;
- List of data, measurements and observations to be recorded; and
- Test procedures.

c) A list of test activities including:
- Visual and Instrumented Data Logging;
- Monitoring and recording environmental conditions, including:
  - Air temperature,
  - Wing surface temperature at selected locations,
  - Wind velocity and direction, and
  - Precipitation type and rate;
- Record of aircraft and plate orientation to the wind; and
- Use of instrumentation to determine the condition of the fluid.

d) Data to be acquired from the tests including:
- Identification of fluid failure criteria;
- Location and time of first point of fluid failure on the wing, and of subsequent failure progression;
- Correlation of fluid failure time to environmental conditions;
- Correlation of fluid failure times on flat plates and aircraft; and
- Behaviour of fluid on the "representative" surface.

Plans shall include concurrent comparison tests of fluids on flat plates with the aircraft tests.

Present plans for review and approval by the TDC project officer.

Present the approved program to the airline and de-icing facility operator involved prior to the start of field tests.

5.5.5 Test Scheduling

Schedule tests on the basis of forecast freezing precipitation.

Notify the airline and de-icing facility operator in advance of the desired test set-up, including aircraft orientation with respect to the forecast wind direction, sequence of fluid applications, and any additional services requested.

Confirm that the de-icing equipment used for the tests is equipped with a nozzle suitable for the application of the pertinent fluids. Application of fluids will be by de-icing facility operator personnel.

5.5.6 Personnel and facility preparation

Recruit and train local personnel who will conduct test work.

Secure necessary approvals and passes for personnel and vehicle access for operation on airport airside property.

Provide all equipment and all other instrumentation necessary for conduct of tests and recording of data.

Arrange (with the cooperation of TDC) for deicing equipment and aircraft to be made available for the tests .

Arrange for the provision of fluids for spraying an aircraft.

Arrange for spray application during the initial tests to be observed by the fluid manufacturer's representative for endorsement.

5.5.7 Aircraft, De-Icing Pads and Crews

Planning shall be based on the following aircraft and facilities:

Aircraft	Airline	Test Locn.	De-Icing Pad	De-Icing Crew
Canadair RJ	Air Canada	Dorval	Central	Aeromag 2000
DHC-8	Air alliance	Dorval	Central	Aeromag 2000

5.5.8 Dry Runs

Conduct a 'dry run' for test team personnel to ensure familiarity with their requested roles. Dry runs shall be scheduled as early in the winter season as can reasonably be achieved and shall be scheduled at the participating airline's convenience. Operations shall include Type I and Type IV fluid applications and re-orientation of the aircraft.

5.5.9 Full-Scale Tests

Conduct up to 8 full all-night test sessions.

Note: In general, aircraft will be made available for testing outside regular service hours, i.e. available between 23:00 hrs. and 06:00 hrs. Subject to weather conditions additional test sessions may be requested.

Tests shall be conducted under a selection of the following conditions:

Aircraft orientations: Headwind, Crosswind, Tailwind
Precipitation: Snow, Freezing drizzle (If possible)
Fluids: Type I, Type IV 'Ultra' and Octagon.
Engine Operations: Anticipate dry run & full scale tests with engines running for Turbo-prop aircraft.

The following matrix of tests is anticipated:

Aircraft	No. of Tests	A/C Orient's*	Comments
Canadair RJ	1	T, C, H	Dry Run
Canadair RJ	4	T, C, H	
DHC-8	3	T, C, H	Engines running
Total Tests	7 + 1 dry run		

T = Tail Wind, C = Cross- Wind, H = Head Wind

5.5.10 Priority of Tests

Initial planning for tests shall be based on the matrix of tests covered by

items 5.5.7 and 5.5.9, above.
Plans shall be made such that the number of tests with each aircraft and sequence of tests can be easily revised.

5.5.11 Aircraft Orientation and Fluid Application:
Tests shall be conducted in the following sequence: Tail to wind, Cross wind, Head wind.
Type IV tests shall be conducted with UCAR ULTRA, unless otherwise indicated.
For tests with Tail to wind and Nose to wind, Type I fluid shall be applied to the port wing, and Type I fluid followed by Type IV fluid shall be applied to the starboard wing in a standard 2-step application procedure. Tests with Type I fluid, only, shall be repeated without change in aircraft orientation until failure of the Type IV fluid.
For cross-wind tests both wings shall be treated with Type I only and observations of fluid behaviour shall be to failure of the fluid on both wings.
Under conditions of light precipitation when the expected time to failure of the Type IV fluid is judged to be be 'excessive' the Type IV test shall be aborted, and the aircraft re-orientaion shall proceed for further Type I tests.
Under conditions of heavy precipitation when the expected time to failure of the Type IV fluid is judged to be be 'short', Type IV test(s) shall also be conducted in a cross-wind, with the same fluid application to both wings.
A maximum of three (3) Type I tests and one Type (IV) test are contemplated for each orientation, on a given test night.

5.5.12 Tests with a Canadair RJ
Tests with a Canadair RJ shall include sessions with a local area of the wing having fluid thinly applied. Thickness distribution and history shall be monitored, and observations made to determine whether local fluid failure occurs, and in such an event whether the failure propagates prematurely.
Tests shall also be conducted during a single test session with UCAR ULTRA and with OCTAGON fluids to compare their behaviours.

5.5.13 Tests with Turbo-prop aircraft
True functional tests with Turbo-prop aircraft require that the engines should be running.
Gather available information applicable to the ground operations of these aircraft in regular service. Based on observation and the observations of others, assess the influence of propeller 'wash' on fluid flow-back patterns, and on precipitation behaviour, particularly under cross wind conditions.
Particular consideration shall be given to safety. In the event of conflict between access for data gathering to obtain required test results and safety considerations, safety shall govern.

5.5.14 Test Measurements

Make the following measurements during conduct of each test:

Contaminated thickness histories at points on wings, selected in cooperation with TDC.

Contamination histories at points on wings to be selected in cooperation with TDC.

Location and time of first failure of fluids on wings -

Concurrent measurement of time to failure of fluids on flat plates; plates to be mounted on standard frames and on aircraft wings at agreed locations.

Pattern and history of fluid failure Progression.

Wing temperature distributions.

Amount of fluid applied in each test run, and fluid temperature

Meteorological conditions.

5.5.15 'Clean' Fluid Thickness Measurements

In the event that there is no precipitation at the time of the dry run, or during full scale tests, advantage shall be taken to make measurements of fluid thickness distributions on the wings. These measurements shall be repeated for a number of fluid applications to assess uniformity of fluid application.

5.5.16 Pilot Observations

Contact airlines and arrange for pilots to be present during tests to observe fluid failure and failure progression. Record pilot observations for later correlation with aircraft external observations.

5.5.17 Remote sensor records

Record the progression of fluid failure on the wing using RVSI and/or SPAR remote contamination detection sensors.

5.5.18 Videotape Records

Make videotape records of tests. Provide professional video tape coverage for at least two overnight test sessions.

5.5.19 Return of equipment

Return any equipment obtained from airlines for use during the tests to its original condition at the end of the test program.

5.5.20 Assembly and analysis of results

Assemble and analyze all results.

5.5.21 Flat plate tests
Conduct standard flat plate tests concurrently with the aircraft tests.
One of the flat plates to be used for flat plate measurements of fluid behaviour in all tests shall be fitted with a C/FIMS sensor.

5.6 Documentation of Pilot field of View, and Wing Visibility

5.6.1 Aircraft Types
Document the area of the wing that is visible to the PIC from inside the cockpit and from inside the cabin for as many aircraft types in service in Canada as can reasonably be checked. Aircraft types shall include at least DC-9, B-767, Canadair RJ, DHC-8 and Bae-146.

5.6.2 Lighting Conditions
Area of visibility shall be recorded under conditions of 'normal' daylight, and at night under conditions of precipitation with on-board lighting, only.

5.6.3 Documentation
Provide sketches, illustrations and photographic records of the visible area(s) of the wing.

5.7 Documentation of the Appearance of Failed Fluids

5.7.1 Tests
Conduct flat plate tests in the NRC CEF laboratory, and in the field designed to address the following issues:

What is the appearance of a failed fluid.
How does the appearance of a Type I fluid failure differ from a Type IV fluid failure.
How does the appearance of failure under conditions of freezing drizzle differ from failure under conditions of freezing rain, and under conditions of snow fall.
Under what conditions do de/anti-icing fluids "Flash freeze".
Are there differences in failure appearance between ethylene-, and propylene-glycol fluids when exposed to freezing drizzle.
Do strong winds significantly affect failure appearance.

5.7.2 Records
For each test record the following information with appropriate instrumentation:

Fluid thickness history at selected locations.
Viscosity history at selected locations.
Refractive Index history at selected locations.
Video camera appearance of flat plate at time of fluid failure.

Video camera appearance of ‘cross-hair’ detail at time of fluid failure.
RVSI remote sensor record of fluid failure.
SPAR/COX remote sensor record of fluid failure.
C/FIMS point sensor record of fluid failure.

and record the description of the visual appearance of fluid failure

5.7.3 Documentation

For each test provide the following documentation:

Record of purpose of test, and test conditions.
Photographic record of initiation and progression of failure.
Output ‘traces’ for each of the three sensors as a function of time.
Fluid freeze point temperature history.
Fluid viscosity history.
Fluid thickness history.
A subjective determination of failed fluid adherence, together with criteria used.

5.8 Potential use of Remote Sensors for End-of-Runway inspection

5.8.1 Preparation

Purpose of the task is to determine the problems and possible solutions with respect to operation of remote sensors for to supplement the PIC’s visual pre-takeoff contamination inspection.

Arrange for installation of a SPAR/COX remote sensor to be installed on a mobile vehicle.

Arrange with pertinent agencies having jurisdiction for the sensor and vehicle to be operated on a trial basis suitable for conduct of pre-takoff inspection of aircraft at, or close to, the end of runway immediately prior to start of the take-off roll.

Anticipated duration of the test period will be approximately two weeks and shall encompass at least two periods of freezing precipitation.

5.8.2 Records

Anticipated problems include:

accessibility of the vehicle to the end of runway,
liasion with the tower
communication between vehicle, tower, and aircraft,
responsibility for communication of sensor observations to the PIC,
qualifications required for the vehicle/sensor operator.

Solutions to these problems will be reported.

5.8.3 Sensor Outputs

Sensor electronic outputs shall be recorded for analysis at the end of the winter season. During conduct of the task the sensor operator shall NOT report the sensor observations of the condition of the aircraft critical surfaces.

5.9 Taxi Times under conditions of Precipitation

Record and report taxi times from start of hold-over time to start of take-off roll (Nominal time of conduct of the pre-takeoff inspection) under conditions of winter precipitation to assess actual taxi times experienced and the impact of conditions of precipitation on ground operations.

Record and report taxi times under daylight conditions in the absence of precipitation, for aircraft requiring de-icing only, in order to provide reference times for sample runway use.

5.9.1 Locations

Collect data for operations at Montreal, Dorval Airport, and at Toronto, Lester B. Pearson Airport, and supply any additional relevant data as may be readily available.

5.10 Support for Review of Alternative Technologies

Provide support services for the evaluation of an infra-red heating device to be demonstrated by Infra-Red Technologies Inc. as a low cost and zero environmental impact alternative technology for aircraft de-icing.

5.11 Provision of Support Services

Provide support services to assist with reduction of data and presentation of findings in areas related to the content of this work statement, but not specifically included.

5.12 Presentations of test program results

5.12.1 Preliminary Findings

Prepare and present preliminary findings of test programs involving field tests with aircraft to representatives of Transport Canada and the Airlines involved at end of the test season, but no later than May 30 1997.

5.12.2 Presentation of findings to the SAE

Participate at the SAE meeting to be held in Vienna in May1998, and present the results of the work conducted during the winter season 1997/98.

5.13 Reporting

Reporting shall be in accordance with section 10 "Reporting", below.

Separate final reports shall be issued for each area of activity consistent with the project objectives.

APPENDIX B

PROCEDURES FOR CONDUCTING TESTS

ON AIRCRAFT

CM1380.001

EXPERIMENTAL PROGRAM
FOR FULL-SCALE FLUID FAILURE TESTING

Winter 1997/98

APS AVIATION INC.

March 3, 1998
Version 5.0

EXPERIMENTAL PROGRAM FOR FULL-SCALE FLUID FAILURE TESTING

Winter 1997/98

This document provides the detailed procedures and equipment required for the conduct of full-scale fluid failure testing for the 1997/98 winter season. The document is a revision to the documents used for testing during the previous winters.

1. PURPOSE OF TESTS

Objective:

- To generate data which can be used to assist pilots with visual identification of fluid failure;
- To assess a pilot's field of view during adverse conditions of winter precipitation for selected aircraft;
- To assess whether Representative Surfaces can be used to provide a reliable first indication of anti-icing fluid failure;
- To explore the potential application of point detection sensors to warn the Pilot-in-Command of an "unsafe to take-off condition";
- To obtain failed fluid contamination distributions and profiles which can serve as inputs to a theoretical program designed to assess the effects of such contamination on possible aircraft take-off performance;
- To compare the performance of de/anti-icing fluids on aircraft surfaces with the performance of de/anti-icing fluids on flat plates; and
- For turboprop tests, to observe and record the impact that propeller wash over the top of the wing has on the film of deicing fluid, and on patterns of failure on those wings.

Applications:

- To determine where pilots should concentrate visual inspection at the end of the holdover time, and to determine the extent of fluid failure during the five-minute period following first (leading edge) failure.

- To determine whether an array of point detection fluid integrity sensors, with an appropriate algorithm, can provide a reliable warning of an *unsafe to take-off* condition. A remote camera to detect ice will also be utilized.

2. AIRCRAFT, TEST LOCALE, AND TEST SET-UP

Aircraft: Canadair CL65, ATR 42, DeHavilland Dash 8

Locale: Dorval Airport, Montreal, Central Deicing Facility

Test Set-up:

- Aircraft out-of-service, overnight tests based on predicted precipitation 24 hrs notice;
- Aircraft cabin accessible for simulated pilot inspection of critical surfaces;
- Aircraft parked at pre-determined orientation prior to start of test. Re-orientation required during each one-night test session;
- De/Anti-icing to be performed by Aéromag 2000 Inc; and
- Aircraft to be deiced and returned to *service* condition at completion of tests (prior to first airline use in the morning).

3. TEST PROGRAM

A matrix of tests is anticipated based on:

- Headwind, crosswind, and tailwind orientations;
- Application of Deicing, and Deicing/Anti-icing fluids; and
- Snow, freezing drizzle and light freezing rain precipitation.

Test Period (nominal):

- Early Dec. 1997 - 15 Apr. 1998;
- No tests on Sat/Sun & Sun/Mon overnights, and period Dec. 19 1997 - Jan. 4 1998, inclusive, unless by prior agreement; and
- A total of five one-night test sessions is anticipated, preceded by a *dry* run.

4. EQUIPMENT

Test equipment required for the tests is provided in Attachment III. Details and specifications for some of the equipment is provided in the experimental plan developed for Dorval's standard flat plate testing *Experimental Program for Dorval Natural Precipitation Testing 1997/98*.

5. PERSONNEL

Several personnel are required to conduct tests for each occasion. A description of the responsibilities and duties of each of the personnel is provided in Attachment IV. Depending upon the weather forecast at the site, the number of personnel may be reduced or increased. Figure 1 shows a schematic of the positioning of the test personnel. Ground support personnel from the airlines will be available to apply fluids, position the aircraft and facilitate the inspection of the critical aircraft surfaces.

6. SUMMARY OF PROCEDURE AND MEASUREMENTS

The test procedure is included in Attachment V. The following observations are anticipated: pilot assessment of wing condition from inside the aircraft; and trained observer assessment of wing condition from outside the aircraft.

Fluid thickness histories: advantage will be taken of occasions when precipitation stops during the night to take thickness measurements on uncontaminated fluids.

Comparison of fluid performance on the aircraft with fluid performance on standard test plates.

Video-record coverage of the tests will be made.

7. DATA FORMS

The data forms are listed below:

- Figure 3 — General Data Form (every test) — T5
- Figure 3a — General Data Form (once per session) — T6
- Figure 4 — De/Anti-icing Form for Aircraft Wing — T2/T4/T8
- Figure 5 — Fluid Thickness on Aircraft — -
- Figure 6 — Fluid Thickness on Flat Plates — -
- Table 1 — End Condition Data Form — T3
- Table 2 — Meteo/Plate Pan Data Form — T1

8. ROLES OF PARTICIPATING AGENCIES

APS: To coordinate and conduct tests on behalf of TDC.

TDC: Transport Canada or its contractor/representative will organize the tests. Transport Canada will assume the cost of trained observers, conduct of tests and provision of instrumentation, ancillary lighting, and power supplies. Transport Canada will assume the cost of Air Canada ground crew. Transport Canada will make appropriate arrangements Aéroports De Montréal as necessary, and with Aéromag 2000 Inc. for use of the deicing facility. Findings and reports will be made available to the aviation community.

Airlines: Provide and tow aircraft. Provide access by pilot to the cabin.

Others: Union Carbide and Octagon will provide fluid samples. Aéromag 2000 will provide a deicing vehicle, personnel and access/use of the deicing centre. RVSI and/or Spar/Cox will be requested to provide a remote sensor.

9. PROPOSED NOTICE PROCEDURE

		Notice given
i)	Potential for testing	24 to 48 hrs before
ii)	Day of testing - Monitoring throughout day	By 4:00 pm
iii)	Day of testing - Confirm or cancel (if possible)	By 8:00 pm
iv)	Proceed to Deicing Pad	10:00 pm
v)	Preparation/Briefing	10 to 11:00 pm

10. EQUIPMENT AND SERVICES REQUESTED FROM AIRLINES

Airlines are requested to make available aircraft for Transport Canada to implement the above test program.

Aircraft to be initially positioned, re-positioned following individual tests, and towed away at end of each one-night test session.

Aéromag 2000 Inc. is requested to provide a de/anti-icing truck with crew for fluid application in accordance with the above program.

Direct cost of crew to be borne by contractor. Credits for fluids will be given by the fluid manufacturer.

ATTACHMENT I

PROCEDURE FOR CONDUCTING TESTS ON PROPELLER AIRCRAFT

Winter 1997/98

1. OBJECTIVE

The pertinent objective of these tests is to observe and record the impact that propeller wash over the top of the wing has on the film of deicing fluid, and on patterns of failure on those wings. The ATR 42 and DHC DASH 8 aircraft are planned for these tests. Further reference on procedures for these tests can be found in the related document prepared for full-scale testing.

2. SAFETY CONSIDERATIONS

The objective by definition can only be satisfied by operating the engines and propellers. Turning propeller blades are a well recognized danger in ramp operations, and operators of propeller aircraft in general have strict procedures to ensure personnel are kept well away from danger zones during propeller operation.

Tests involving personnel not trained and experienced in ramp operations must take particular care to ensure safety of personnel.

Additional safety awareness issues are contained in the full-scale fluid failure testing procedure.

The test program examines patterns of failure on the wing of a propeller aircraft. The procedure for these tests is based on the test procedure for full-scale tests and the following sequence of events for turboprops:

i) Apply the test fluids on wing with engine shut down. Simultaneously, initiate a fluid test on flat plates on a stand situated outside the danger zone and clear of influence of the propeller airstream. Move all personnel back away from the aircraft.

ii) Start the engine, advance the throttle to operating speed with propeller blades in normal pitch used for taxiing. The operational expertise and procedures of the operator will be the rule in this phase of the test. Allow the engines to continue running until the plate on the test stand has failed, then shut down the engines. This may be varied to trigger engine shut down upon plate failure at the 2.5 cm (1") line, or other rule as may be determined during actual testing.

iii) Move access ladders to the wing edge to allow examination of the surface for fluid failure, and continue monitoring throughout remaining progress of fluid failure. Collect fluid samples as indicated in Attachment VI.

iv) Simultaneous tests on the opposite wing could be considered, as well as repositioning the aircraft to examine impact of tail into the wind and crosswind.

3. SENSOR CONSIDERATIONS

Use of an area scanning sensor mounted in a location allowing viewing of the wing during engine running would be a possible alternative. The current plan outlooks use of an RVSI or Spar sensor. As this coincides with planned tests on the turboprop aircraft, consideration will be given to the possibility of employing this sensor to monitor the wing condition during engine operation.

4. TEST PLAN

Attachment IIA provides a list of tests to be conducted under conditions with precipitation. The conditions required for the tests are listed.

5. EQUIPMENT/PERSONNEL

Test equipment required for the tests is provided in Attachment III. Attachment IV provides guidance for personnel assigned to the full-scale precipitation tests with turboprops.

6. DATA FORMS

The data forms for the turboprop precipitation tests are included in the full-scale fluid failure test procedure.

ATTACHMENT II

TEST PLAN FOR TURBOFAN FULL-SCALE FLUID FAILURE TESTS

OCCASION	RUN #	FLUID[1] TYPE	A/C ORIENTATION
1	1	I / IV	Tail
1	2	I	Tail
1	3	I	Tail
1	4	I / IV	Cross
1	5	I / IV	Cross
1	6	I	Cross
1	7	I	Cross
1	8	I / IV	Head
1	9	I	Head
1	10	I	Head

(1) Selection of fluid is dependent upon precipitation rate.

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ATTACHMENT IIA

TEST PLAN FOR TURBOPROP FULL-SCALE TESTS

WITH PRECIPITATION

RUN #	FLUID TYPE	AIRCRAFT ORIENTATION	WING
1	I	Tail	Starboard
2	I	Tail	Port
3	I	Cross*	Starboard
4	I	Cross*	Port
5	I	Cross**	Starboard
6	I	Cross**	Port
7	I	Head	Starboard
8	I	Head	Port

* Wind direction such that starboard wing is on upwind side and port wing is on downwind side.

** Wind direction such that port wing is on upwind side and starboard wing is on downwind side.

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ATTACHMENT III

FULL-SCALE FLUID FAILURE TESTS

TEST EQUIPMENT CHECKLIST

Logistics for Every Test
15 Block Passes
Rent two mast lights
Rent Truck
Call Personnel
Advise Airlines (Personnel, A/C Orientation, Equip)
Monitor Forecast
Call potential participants
Book escort if required
Test Equipment
15 Procedures
All data forms required (wing, plates, general)
1 Blue stand with 4 x 1/8" thick plates W,X,Y,Z
2 Mast lights and 1 spare generator
3 x 500 Watts tripod lights
Red pylons
6 Rolling stairs(2 Tall, 2 Med, 2 Small)
7 Step ladders (2 Tall, 2 Med, 2 Small, 1 Short for truck)
Stand fluids: Type I and Type 4 in red containers
Extension chords 4 x extension cords stored in bin.
1 tool kit including socket set, hammer, tie-wraps, duct tape, safety goggles, spare Batteries (AA, D)
1 parabolic heater
2 Suction cup plate pans
2 Standard plate pans
2 Wide plastic shovels, 2 small steel shovels
2 big and 2 small squeegees
2 small plate scrapers
Pens and pencils
Paper Towels, rags
1 First aid kit
4 extended octagon thickness gauges + 4 x ordinary Octagon thickness gauges
1 Rates station with 2 weight scales, 1 table for station
Rain suits
8 Stop watches
2 Two black markers
3 Tape measures (1 long, 2 standard)
1 whistle
3 Flashlights
5 Clipboards
2 Ink solvent bottles
1 anometer
2 Temp gauges (1 extended tip and 1 normal tip)
2 Laser pointers
5 Head set radios and chargers
1 Brixometer
2 Tape recorders
Extra mini cassettes for tape recorders
24 video cameras power batteries, 1 belt power pack, and 1 power regulator
3 Video cam CR2025 spare batteries
9x8 mm film
3 Video cameras batteries chargers
2 Photo cameras 35 mm, 1 Nikkon, 1 Snappy
Plastic glue for video cameras
35 mm film
1 video cam AC cable
3 Photo camera lithium 223 power batteries
1 video cam RCA cable
1 Megaphone
Garbage bags
1 filling pocket for data forms
2 Tripods for video/photo cameras
All individual kit boxes: V1, V2, P1, T3, T2/T4, T5, T6, T7, T8, Sampling, Marking
1 Adherence brush prototype
OTHER TEST EQUIPMENT (1)
Type I fluid for the wing
Type IV fluid for the wing
Sprayer Vehicle (Aeromag)
A/C
Storage Facilities
Fluid Collection Facilities
Airline Personnel

(1) To be provided by others

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ATTACHMENT IV
Full-Scale Fluid Failure
RESPONSIBILITIES/DUTIES OF TEST PERSONNEL

Refer to Figure 1 for position of equipment and personnel relative to the aircraft. Also refer to the test procedure (Attachment V) for more detailed tester requirements.

Video 1 (V1/V2)

- One video operator per wing;
- Located on ground (Refer to the flat plate test procedure);
- Ensure proper plate identification - zoom in and out;
- Knowledge of test procedures and end conditions;
- Video application of all fluids;
- Assist in deployment and return of lighting;
- To video wing before and after fluid application, to concentrate on fluid contamination and failure; and
- Ensure proper identification of wing.

Photographer (P1)

- Photograph aircraft test site;
- Photograph wing during and after fluid application, to concentrate on fluid contamination and failure;
- Overall photography of wing condition is extremely important;
- Photograph fluid roughness on wing (Refer to Attachment XI) and photograph cabin views;
- Picture to be steady and well lit;
- Photography of both wings required; and
- Knowledge of test procedures and end conditions.

Meteo/Equipment Tester (T1)

- Coordinate all equipment (inventory and operation);
- Record meteo for both stands;
- Rotate and measure plate pan weights;
- Complete and sign data form (Table 2);
- Ensure power cables and lighting is in place;
- Prepare plate pans;
- Ensure all clocks are synchronized (including video camera); and
- Record rates on both aircraft wings during crosswind tests.

Wing Observers (T2/T4)

- Located on ground (rolling stairs) or in cherry picker;
- Communicate with V1/V2 and P1, and T5;
- Make observations of failures on starboard or port wing; and
- Knowledgeable in procedures and calling end conditions.

End Condition Tester (T3)

- Apply fluids to Stand;
- Located by Test Stand;
- Make observations and call end conditions on test stand; and
- Knowledge of procedures for test stands.

Wing/Plate Coordinator (T5)

- Ensure failure calls on plates and wings are consistent;
- Communicate initial failure to all involved;
- Assist wing and plate observers as required;
- Assist overall coordinator as required;
- Complete and sign general data form (Figure 3) for each test;
- Manage and direct equipment deployment and return;
- Assist T1 in coordination of equipment;
- Communicate with cabin observer the spraying of wing A and wing B;
- Review data forms upon completion of test for completeness and correctness (sign);
- Ensure proper documentation of tapes, diskettes, cassettes; and
- Call personnel to conduct tests.

Overall Coordinator (T6)

- Team Coordinator;
- Knowledge of test procedures and calling end conditions;
- Responsible for area and people;
- To aid any personnel;
- Coordinate actions of APS team and as required airline personnel;
- Responsible for weather condition observations and forecast, advise tester team;
- Ensure that there are no objects on the ground which may cause foreign object damage at end of session;
- Ensure test site is safe, functional and operational at all times;
- Supervise site personnel during the conduct of tests;
- Ensure aircraft positioned appropriately;
- Monitor weather forecasts during test period;
- Ensure fluids are available and verify fluids being used for test are correct;
- Ensure electronic data are being collected for all tests ;
- Verify test procedure is correct (eg. stand into wind);
- Ensure all materials are available (pens, paper, batteries, etc.);
- Ensure all equipment is on;
- Ensure aircraft is not damaged; and
- Complete general data form (Figure 3a) at beginning of night.

RVSI and Spar/Cox (V1/S1)

- Knowledgeable in procedures and calling end condition; and
- Take images of fluid failure on starboard and port wing.

Cabin Observer (T7)

- Located in aircraft cabin;
- Make observations of failures on starboard or port wing;
- Knowledgeable in procedures and calling end conditions;
- Video and photograph contamination and failure on wing; and
- Ensure proper identification of wing.

Sampler (T8)

- One fluid sampler for both wings;
- Collect fluid samples at first failure location, and at several other points of failure;
- Communicate with T2/T4 for locations of failure;
- Knowledge of test procedures and end conditions;
- Measure wing temperatures at beginning of night; and
- Collect fluid samples from deicing truck at the start of testing.

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ATTACHMENT V
TEST PROCEDURE

1. TRAINING AND SAFETY

Training for this experiment will consist of a dry-run in which team members are assembled and duties are assigned to each member. This will allow the team to conduct an experiment in which team members will coordinate their activities to prepare for a systematic and comprehensive execution of a given experimental run and try to determine the logistics of an actual experiment. The dry run will familiarize all test members with the equipment and provide the participating airline with an understanding of the procedure. This procedure will inevitably be streamlined during field testing. Most team members should be familiar with salient aspects of flat plate testing. They should possess the ability to identify fluid failures, and call end conditions.

Attachment VII refers to Safety Awareness Issues for these tests. Ensure that these are observed and understood.

2. PRE-TEST SET-UP

Figure 1 should be consulted in reference to the responsibilities.

1. Arrange favourable aircraft orientation (**leading edge, crosswind or trailing edge into the wind**) and place pylons below wings to delineate sections.
2. Set-up power cords and generator.
3. Position stairs and lights.
4. Ensure temperature probes and weigh scale are functional.
5. Position flat plate test stand into the wind as per the flat plate test procedure. Note that this orientation may be different than that of the aircraft.
6. Position pre-filled test fluid containers, squeegees, and scrapers accordingly. (Type I fluids are stored inside at 20°C; Type IV fluids are applied at ambient temperature).
7. Check cameras, sensors and recording devices for proper function.
8. Ensure proper illumination of test areas.
9. Position RVSI and/or Spar/Cox sensor on truck.
10. Establish communication between team members and coordinator.
11. Camera and test personnel ensure ability to identify laser light signature.
12. Synchronize all timepieces including video cameras.
13. Ensure airline personnel are aware and knowledgeable of test procedures.
14. Prepare data forms in advance of all tests.

3. INITIALIZATION OF FLUID TEST

1. Ensure all aircraft de/anti-icing systems are off.
2. Measure and record fuel load in wing to be tested.
3. Measure wing skin temperature at predetermined locations before fluid application (see Figure 3a).
4. Record all necessary data from fluid delivery vehicle (cherry picker). (Temperature, nozzle-type, fluid type, dilution of fluid, etc.).
5. Record all general measurements and general information in the data forms.
6. Ensure all fluids are prepared to the appropriate concentrations.
7. Collect a sample of fluid from deicing truck.

4. EXECUTION OF FLUID TEST

a) Turbofan Tests

1. Type I Fluid Application (Figure 2a)
   - 1.1 Apply Type I fluid with deicing vehicle to wing; and
   - 1.2 Simultaneously apply Type I to plates V and Y from containers.

2. Type IV Fluid Application (Figure 2b)
   - 2.1 Apply Type I and then Type IV to wing with deicing vehicle; and
   - 2.2 Apply Type IV to plate W and Z when application of Type IV to the wing begin.

3. Plate/wing coordinator sounds whistle once to confirm the beginning of test (after fluid application).

4. Put two plate pans on test stand and note time and initial weights (see Attachment XIII for rate procedure). Continue measuring every five minutes until end of test. Re-measure when second wing is started.

5. Take RVSI and Spar/Cox sensor images every 15 minutes (see Attachment XII for sensor procedure).

6. Continue testing until the end conditions are called for both flat plates.

7. Collect fluid samples as per the test procedure in Attachment VI.

b) Turboprop Tests

The turboprop test program examines patterns of failure on the wing of a propeller aircraft. The procedure for these tests is based on the test procedure for full-scale turbofan tests and the following sequence of events for turbo-props:

1. Apply the test fluids on wing with engine shut down. Simultaneously, initiate a fluid test on flat plates on a stand situated outside the danger zone and clear of influence of the propeller airstream. Move all personnel back away from the aircraft.

2. Start the engine, advance the throttle to operating speed with propeller blades in normal pitch used for taxiing. The operational expertise and procedures of the operator will be the rule in this phase of the test. Allow the engines to continue running until the plate on the test stand has failed, then shut down the engines. This may be varied to trigger engine shut down upon plate failure at the 2.5 cm (1") line, or other rule as may be determined during actual testing.

3. Move access ladders to the wing edge to allow examination of the surface for fluid failure, and continue monitoring throughout remaining progress of fluid failure. Collect fluid samples as indicated in Attachment VI.

4. Simultaneous tests on the opposite wing could be considered, as well as repositioning the aircraft to examine impact of tail into the wind and crosswind.

5. HOLDOVER TIME (END CONDITION) TESTING

Holdover time testing will consist of: A) Video/photo recording of all procedures and fluid failures; and B) Visual monitoring and manual recording of failure data. Attachment XII contains a typical procedure for recording contamination on the wing with a remote sensor.

A) *Video/Photo Recording (V1/V2, P1)*
Camera recordings are to be systematic so that subsequent viewing of documented tests allow for the visual identification of failing sections of the wing surface with respect to the aircraft itself.

1. Record the complete fluid application on plates and wing from a distance.
2. Record the conditions of the flat plate set-up and the wing at time = 0.

3. i) For Type I fluids, record conditions of wing and flat plates every two minutes.
   ii) For Type IV fluids, record conditions of wing and test plates every five minutes.
4. Once the first failure on the wing or on the one inch line is called, monitor (record) continuously until the end of the test.
5. Record condition of the wing and representative surface continuously from the aircraft cabin.

B) *Visual Recording*
1. For the plates, refer to the flat plate test procedure for determination of the end condition.
2. For the wing, three ways to record visual observations have been devised.
   i) Manual recording of failure contours on preprinted data form (Figure 4). This is to be performed by person making the observations, and/or
   ii) Observer may talk to a voice recorder, and/or
   iii) Observer may talk directly to the video camera microphone.

In any case, the methods would utilize the De/Anti-icing Form for Aircraft Wing (Figure 4), and these are complementary to the video recording.

It was found in previous tests that using generic wing plans, available from the literature test forms, did not always provide accurate detail for the actual wings tested. Accurate wing details must be portrayed on the data form wing plan to support accuracy in drawing failure locations and patterns. Modification of generic wing plans, based on inspection of actual test wings sometime prior to the test session, is necessary;

C) Due to the rapid propagation of failures, especially in the case to Type I tests, the time and precise location of first failure was sometimes missed. In certain tests, rapid failure had progressed to the 25% level at the time of documenting the first failure contour. Procedures and training must emphasize the requirement to identify the precise location of first failure, and additional observers are to be assigned from the test team complement to assist in failure identification when rapid progress of failure is expected. A further discipline can be added by requiring observer comments on wing conditions at defined intervals while awaiting occurrence of first failure;

D) The pattern of failures should be drawn on the data form every **5 minutes for Type I and every 15 minutes for Type IV after first failure on the wing**.

E) When the first flat plate failure is reported at the 5th crosshair (1/3 of plate), the visual data recorder must acquire contours every 2 to 5 minutes, thereafter. Time increment is dependent upon weather. Process is continued until all flat plates have failed according to the end condition defined in the flat plate test procedure.

F) If wing fails before first flat plate fails, continue data collection for wing via contour drawing and/or voice communication until all flat plates fail.

G) Wing/plate coordinator must confirm initial end condition calls on flat plate tests. Once the first flat plate fails at the six inch line (1/3 of plate), the coordinator is notified and makes inspection of the wing contour drawing to confirm the accuracy of the wing data and instructs video camera operator to make a record of the area. The area should be located using a laser pointer. If the wing start to fail first, the coordinator must confirm this and simultaneously note areas of failure on the flat plates using the laser pointer.

H) Measure wing skin temperatures at the start of the evening. If the wing is cold-soaked, then continue monitoring the temperatures.

6. END CONDITION

Refer to the flat plate test procedure for this definition.

7. END OF TEST

Plate/wing coordinator sounds whistle to confirm the full failure of wing (end of run). This occurs when all plates have reached the end condition (under heavy snow conditions, continue testing until nine crosshairs have failed) and when a substantial part of the aircraft wings leading/trailing edge has reached the end condition. Ensure all data collection are completed including plate pan measurements.

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ATTACHMENT VI
TEST PROCEDURE FOR FLUID SAMPLING

1. Prior to the start of testing, the refractive index of the Type I and Type IV fluids in each truck should be taken using a hand-held refractometer and recorded on the sampler's wing data form (Figure 4) for the first test run. As well, a Type IV fluid sample should be collected from each truck and placed in a small sample container. On each container, information such as the date, truck number, airport, operator and sample number should be recorded. The containers should then be stored in a safe location and returned to the test site following each test session.

2. At the beginning of the night, the temperatures at several locations on the wing (shown in Figure 3a) should be taken by the sampler using a temperature probe mounted on an extension pole. Temperatures should be recorded in the box in Figure 3a.

3. After the location of first wing failure has been identified by the wing observer, a fluid sample should be collected at this position. A small sample of fluid (average mixture) from this location should be placed in a hand-held Brixometer and the refractive index and sample time immediately recorded on a wing data form (Figure 4). Also, the skin temperature at this location should be taken. When recording sample times, Brix values and skin temperatures on the data sheet, simply circle the location on the wing plan and write in the information below the circle. Make sure that the written information is clear!

4. Subsequent wing samples should be collected using the same procedure at various points of failure on the wing (as indicated by the wing observer).

5. A new data sheet should be used by the sampler for each run.

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ATTACHMENT VII
SAFETY AWARENESS ISSUES

1) Review MSDS sheets for fluids at site.
2) Protective clothing is available.
3) Care should be taken when climbing rolling stairs due to slipperiness.
4) When moving rolling stairs, ensure they do not touch aircraft.
5) To take fluid samples or measure film thickness on the aircraft, ensure minimum pressure is applied to the wing.
6) Entry into the aircraft cabin is not authorized, except for cabin observer (T7), video (V1), or overall coordinator (T6). For these people, booths are to be removed at entrance.
7) When aircraft is being sprayed with fluid, testers and observers should be positioned away in the hold area (see Figure 1).
8) First aid kit, water and fire extinguisher is available in trailer. Second first aid kit is available in mobile truck.
9) No smoking permitted on the ramp area and in trailer.
10) Care to be taken when moving generators and fuel for the generators.
11) Electrical cabling is needed to power lights - these will be positioned around the wing - do not trip over them. Do not roll stairs or other equipment over cables.
12) Do not walk by yourself in any area away from the pad or trailer - if required to do so, ask the coordinator T6 who will advise the security escort service.
13) Gasoline containers are needed to power the generators - ensure you know where these are.
14) Ensure lights and rolling stairs are stabilized to not damage the wing.
15) Ensure all objects and equipment are removed from deicing pad at end of night.
16) Ensure all markings removed from wing.
17) Personnel with escort required passes must always be accompanied by persons with permanent passes.
18) Rolling stairs should always be positioned such that the stairs are into the wind. Small ladders should be laid down under windy conditions.
19) For turboprop tests, the test objective by definition can only be satisfied by operating the engines and propellers. Turning propeller blades are a well recognized danger in ramp operations, and operators of propeller aircraft in general have strict procedures to ensure personnel are kept well away from danger zones during propeller operation.
20) Tests involving personnel not trained and experienced in ramp operations must take particular care to ensure safety of personnel.

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ATTACHMENT VIII
TEST PROCEDURE FOR MEASURING FLUID THICKNESS

Fluid thickness tests on aircraft and flat plates will be conducted during periods of no precipitation. This may be during test events when snow or rain fall has ceased, or during dry runs.

The following instructions are to be followed when measuring fluid thickness:

- Use the MIL scale on the octagonal thickness gauge;
- Record the gauge of the tooth that is wetted;
- When measuring fluid thickness, follow offset routine to avoid inaccuracies related to depressions in fluid surface caused by previous gauge placement;
- Ensure the thickness gauge is perpendicular to the surface of the wing;
- Record time in seconds during the initial measurements when the rate of fluid thinning is fastest. Time to the nearest minute is acceptable for subsequent recording;
- Wipe gauge following each measure attempt; and
- Proceed as quickly as possible without sacrificing accuracy.

The following individuals are assigned to perform thickness measurements:

<u>On flat plates</u>:	Elio Ruggi and Cassia Pole
<u>On wing:</u>	Nicolas Blais and Bassem Ghobrial (Location 1 to 5)
	Geddes Thurton and Joe Argento (Location 6 to 10)

FLAT PLATES

Thickness tests on flat plates consist of one-step procedure where only Type IV (Union Carbide Ultra+ or Octagon Maxflight) is applied:

- Apply some Type IV fluid on plate and squeegee to clean it;
- Apply Type IV fluid and record start time;
- Immediately proceed to measure and record thickness at 2.5 cm (1") and 15 cm (6") lines; and
- Repeat thickness measurements for 30 minutes, with higher frequency during the initial measurements, untill fluid thickness is stabilized.

AIRCRAFT WING

i) Locations where fluid thickness will be measured are shown in Figure 5. Indicate measurement points using a black marker. (Ensure markings are removed at end of test, using solvent).

ii) Fluid thickness will be measured four times; two initial fluid thickness measures taken immediately following fluid application, and subsequently at 10 minutes and at 30 minutes following fluid application.

iii) Measure each location three times to increase reliability of results; record the thickness measure resulting from these consecutive trials. Ensure that thickness gauge placement for consecutive measures is slightly offset from previous placement to avoid influence of indents remaining in fluid film. Wipe gauge following each measure attempt.

iv) Record data on the Fluid Thickness Data Form, Figure 5, in the format shown; measurement location, time, gauge reading.

ATTACHMENT IX
MOBILE EQUIPMENT FOR EACH TESTER

Video V1/V2	→ batteries → video camera → charger → 8 mm film → pens/pencils
Photographer P1	→ photo camera → batteries (for 35 mm camera) → 35 mm films → pens/pencils → VHF radio
Meteo/Equipment T1	→ pens/pencils → stop watch → clipboard → data form (Table 2) → plate pans, plate pans with suction cups → mobile equipment for truck (see Attach. X)
Wing/Plate Coordinator T5	→ test procedure → stop watch → laser pointer → flash light → data form (Figure 3) → pens/pencils → clipboard → compass → VHF radio
Wing Observer T2/T4	→ data form (Figure 4) → laser pointer → pens/pencils → stop watch → clipboard
End Condition T3	→ data form (Table 1) → pens/pencils → stop watch → compass → clipboard

Cabin Observer T7	→ video camera → batteries → data form (Figure 4) → pens/pencils → stop watch → tape recorder → VHF radio
Overall Coordinator T6	→ test procedures → flash light → pens/pencils → stop watch → clipboard → tape recorder (x1) → data form (Figure 3a) (x1) → small tape measure → VHF radio
Mobile Marking Kit	→ flashlight → tape measure - long → marker → ink remover solvent → degreaser → pencils → tape measure - short → aluminium tape
Sampler T8	→ data form (Figure 4) → clipboard → Brixometer → pens/pencils → stop watch → temperature probe → skin temperature equipment

ATTACHMENT X
MOBILE EQUIPMENT REQUIRED FOR TRUCK (VAN)

Weigh scale x 2 (with battery backup)
Table and chairs
Light and electrical extension cable
Heater dish
Wind protection booth
Step ladder (non-slip)
Plate pans
Skin temperature equipment

Mobile box with extra:

- pens and pencils
- data forms
- clipboard
- batteries
- paper towels
- flash light
- thickness gauge
- test procedure
- first aid kit
- fire extinguisher

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ATTACHMENT XI
PROCEDURE FOR ROUGHNESS ON AIRCRAFT WING

Equipment:
- 35 mm camera with date back and macro sens;
- Film - 35 mm 800 ASA;
- Walkie-Talkie;
- Spray paint - red, yellow, orange, purple, aqua marine, burgundy, blue;
- Markers - black, white; and
- Quarters - 16 (American).

Details:
- Each wing has been broken up into seven sections (see wing diagrams). The seven sections on each wing have a designated colour;
- The coins have been painted according to the sections colours;
- The coins are also indicated by an A (port wing) or B (starboard wing); and
- There should also be several unpainted quarters to indicate point of initial failure on each wing.

Procedure:
- When the point of initial contamination is determined by the wing observer, an unpainted coin (bearing an A or B) is placed at this location and photographed plan, profile and overall (see explanation).

- When failures occur elsewhere on the wing (confirmed by wing observer), the colour designated coins should be placed in the appropriate sections and photographed plan, profile and overall (see explanation); and

- A final set of photographs for each section of wing is to be taken at end of test (wing failure).

Three photos per location:

1. Overall location of coin relative to the rest of wing.

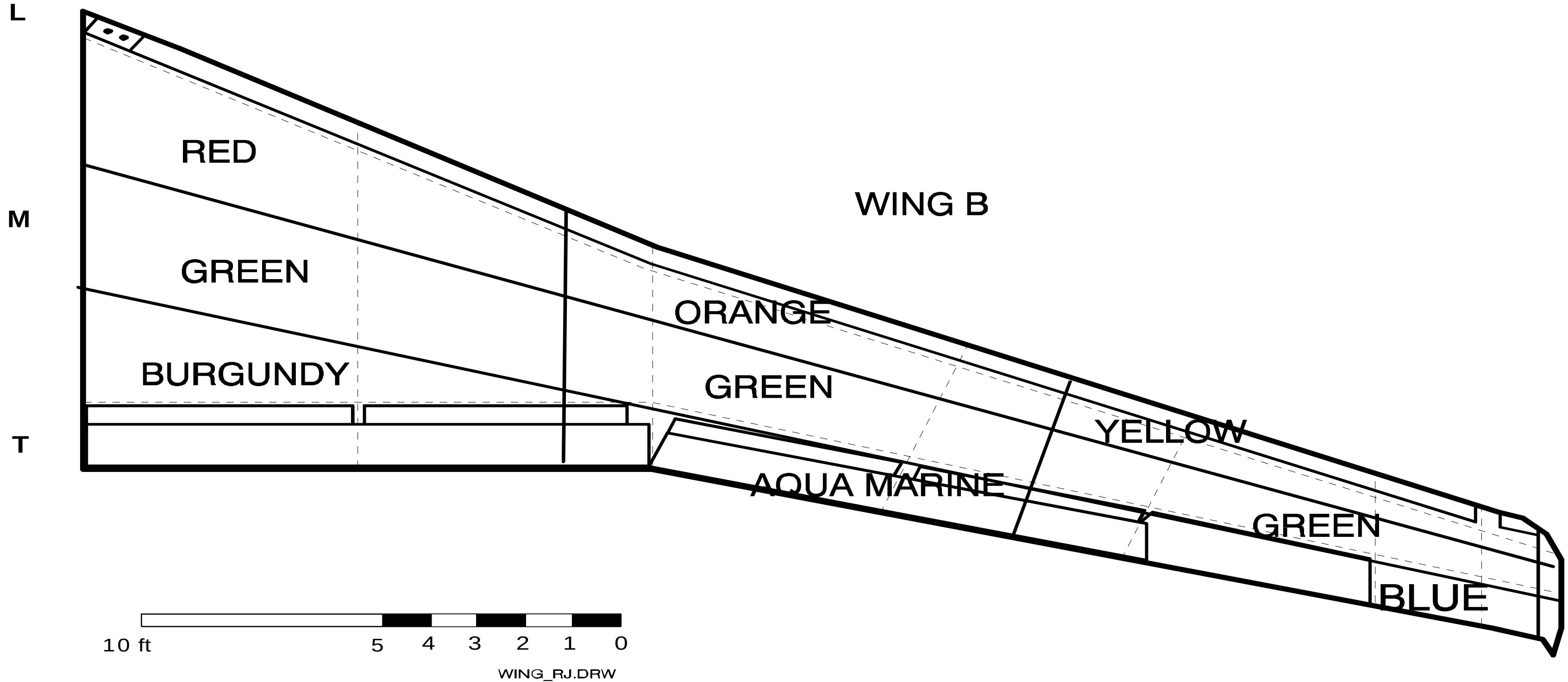
2. Macro profile of coin to determine surrounding crystals height, shape and size.

3. Macro plan of coin to determine the roughness and texture of surrounding crystals relative to the coin.

ATTACHMENT XI

FIGURE 1

INDEX OF COLOURS FOR PHOTOS OF ROUGHNESS ON AIRCRAFT WING



File: cm1380\procedur\full-scl\ROUGH_AC
At: Wing B

ATTACHMENT XII
SENSOR PROCEDURES

Test Procedure and Equipment

- At initial application of Type I fluid the RVSI operator will take an image of the aircraft's tail identification numbers in order to determine fluid holdover time.

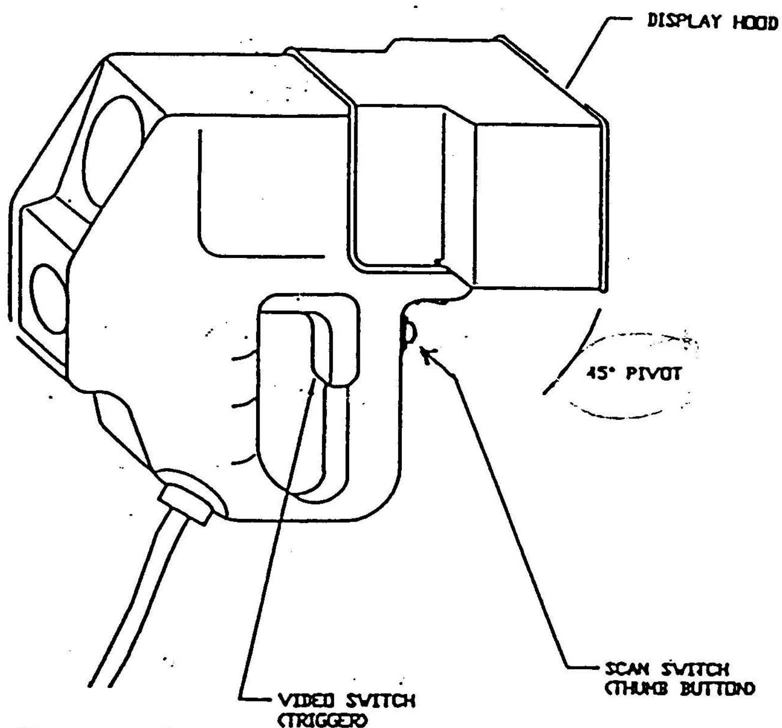
- Use a grid structure such as in the diagram to take images of the failure. Take four images across base of wing overlapping each frame. As you progress towards the wingtip less images are needed across the width of the wing. ** Try to get some identifying object in each frame so as to be able to easily identify location at a later date. **

- Number of images taken are as follows. Every fifteen minutes one entire series of images covering the wing should be performed.

- At end of the test procedure the tail numbers will be image again in order to show that all previous images are associated with that particular aircraft.

- For turboprop tests, use of an area scanning sensor mounted in a location allowing viewing of the wing during engine running would be a possible alternative. The current plan outlooks use of an RVSI or Spar/Cox sensor. As this coincides with planned tests on the turboprop aircraft, consideration will be given to the possibility of employing this sensor to monitor the wing condition during engine operation.

Fig - 2 ID-1H SENSOR MODULE A HAND HELD VIDEO SCANNING UNIT.



Sensor Module Components:

Video Switch (trigger)
Scan Switch
Adjustable Display Screen and Hood

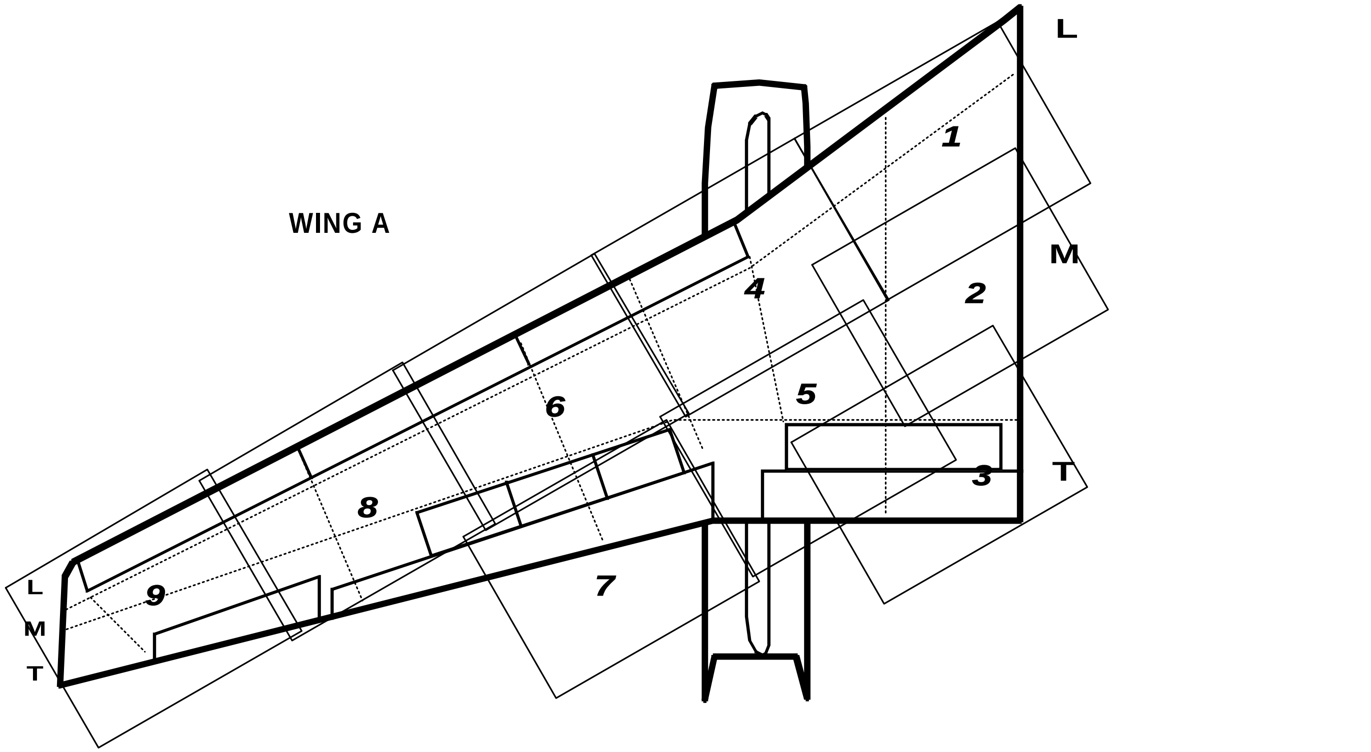
Pulling the video trigger will enable the viewer to see a real time video and record the area of the aircraft being checked. The display screen hood is adjustable for operating at various heights. Pivots for comfortable viewing

When taking a digitally enhanced image, Press and release the scan button. First a black and white still image will appear; then an enhanced image appears. Enhanced images are:

- Green indicates no contamination
- White indicates contamination
- Black means that the scanned object is out of range. This will give a range error message on the monitor.

Reinitiate the next video scan by depressing the scan button.

BREAKDOWN OF BOEING 737-200 FOR RVSI ID-1H IMAGING



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ATTACHMENT XIII
EXPERIMENTAL PROGRAM
AMENDED PROCEDURE FOR THE COLLECTION OF PRECIPITATION
Winter 1997/98

GENERAL

i) A timepiece should be installed near the rate station to insure that accurate collection times are recorded. All watches used in testing should be synchronized;

ii) Rates should be collected every five minutes.

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

iv) When recording start and end times, a few seconds should be added or subtracted for the time delays created by entering and exiting the truck.

PROCEDURE

i) Ensure that both plate pans are marked (*upper* and *lower*);

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

iii) Tare the scale, then weigh the wetted pan to the nearest gram;

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

v) Ensure that the pans are placed in the proper location (upper and lower locations);

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

viii) Upon entering the truck, record the end time (hr/min/sec) from the timepiece near the rate station;

ix) Carefully wipe the bottom, sides and lips of the pans prior to weighing;

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

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

xii) Start time from the timepiece near the rate station; and

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

CROSSWIND PROCEDURE

xiv) During the course of full-scale tests conducted in crosswind conditions, rates of precipitation will be collected on both aircraft wings as well as on the test stand. Plate pans with suction cups will be used for this purpose, and the amended rate collection procedure should be respected. One plate pan should be positioned on the mid-section of each wing (not on the leading or trailing edges). Plate pans should be reweighed following complete wing failure for Type I tests and every 15 minutes for Type IV tests.

ATTACHMENT XIV
EXPERIMENTAL PROGRAM
FULL-SCALE FLUID FAILURE PILOT PROCEDURE

Pilots will be present at full-scale test sessions to record observations from inside the cabin and/or cockpit on fluid failure and failure progression, which will later be correlated with external observations. Refer to the flat plate test procedure for definitions of fluid failure.

- Pilots will be located in the cabin of the aircraft in order to observe and note the progression of fluid failure on the wing. A pilot coordinator will also be present in the cabin;

- Observations of fluid failure patterns and drawings of failure contours will be completed by the pilots and pilot coordinator from the cockpit and cabin for each test run and will be recorded on the appropriate wing data form (Figure 4). A separate data form should be used for recording failure contours at each location (one for the cabin/overwing, one for the cockpit);

- Observations of fluid failure from the cockpit should be recorded with the cockpit window open if possible;

- Cabin observations can be made from any location within the cabin. It is important to record the time of the observation;

- In order to simulate wing observations in operational conditions, the pilot coordinator must insure that the side of the fuselage is deiced and that the windows remain uncleaned following deicing;

- Observations and failure contours should be recorded by the pilot coordinator at first wing failure and at pre-determined time intervals thereafter for Type I and Type IV tests with the exterior lights on. The pilots inside the cabin should not be observing the wing during this period;

- In order to simulate a pre-takeoff inspection at night under conditions of precipitation, all external lighting will be shut down at the request of the pilot coordinator and the on-board lighting turned on. The pilots will record progression of failure observations under these conditions from the same onboard locations (cockpit and cabin). The time of exterior light shutdown should not exceed one minute for Type I and two minutes for Type IV fluid. Two new data forms (one for cabin observations, one for cockpit observations) should be completed by each pilot for each test run;

- A video camera installed on a tripod should be positioned in the window providing the best overwing view of failures and should be running for the duration of testing (ensure proper focus); and

- Opinions and comments on wing visibility from the aisle, as well as comparisons with operational conditions should be recorded at different times during testing by the pilots, and should be recorded on a separate data form.

Full-Scale Fluid Failure Pilot Procedure
Data Form for Comments by Pilots on Each Run

Date: Run Number:
Pilot ID Number:

After each inspection of the wing with lights out, finalize areas where you observed fluid failure, then answer the following two questions (give answer in table below).

Q1. How did the reduction in visibility due to fluid on the windows compare with what you have experienced in actual pre-take-off inspections. Visibility here is:

1. better than what I have previously experienced
2. better than average, but within range of previous experience
3. very typical of previous experience
4. worse than average, but within range of previous experience
5. worse than what I have previously experienced

Q2. If you did not identify any failed fluid (FF) on the wing, answer the following question:

Picture yourself in an actual departure situation where your flight was already late due to deicing, you need to connect with other flights, and you make an inspection of the wing under the same conditions as this test (i.e., the inspection and observation you just made). Taking into account:

- the visibility of wing and the difficulty is determining fluid failure,
- the fluid type and holdover time remaining (or expired), and
- the wind and precipitation type & rate;

would you return to redeice?: Yes / No

Inspection	Q1:Visibility reduction due to fluid on windows					Q2. Return to Deice?
No. 1	1.	2	3	4	5	Observed FF / Yes / No
No. 2	1.	2	3	4	5	Observed FF / Yes / No
No. 3	1.	2	3	4	5	Observed FF / Yes / No

At end of Test Run

Q3. How did the lighting on the wing compare with what you have experienced in actual pre-take-off inspections near the runway apron at night. Visibility of the fluid due to the lighting here is:

1. better than what I have previously experienced
2. better than average, but within range of previous experience
3. very typical of previous experience
4. worse than average, but within range of previous experience
5. worse than what I have previously experienced

Comments:

Full-Scale Fluid Failure Pilot Procedure
Data Form for Information on Pilot

Date:

Pilot ID Number:

Experience:

How many years have you been a commercial pilot operating in areas subject to ground icing?

________ years

During the last 4 years[1] how many times per year:

(a) was your aircraft deiced ___________

(b) did you make a pre-take-off inspection ___________

(c) did you re-deiced your aircraft because you felt the fluid may have failed _________

Training for Recognizing Fluid Failure

During your training for ground icing, have you:

(a)	received verbal instructions for recognizing fluid failure..............................	Yes	No
(b)	been shown black and white pictures of fluid failure	Yes	No
(c)	been shown colour photos of fluid before and soon after fluid failure	Yes	No
(d)	been shown videos of fluid failing..	Yes	No
(e)	been shown (live) fluid in process of failure	Yes	No

How many months ago did you:

(a) receive your last recurrent training for ground icing? _______months

(b) review properties to look for when determining if the fluid has failed? _________ months

Confidence

How confident are you that you can recognize fluid failure accurately at night near the end of the runway with no external lighting during:

	Confidence: Low				High
(a) snowfall	1	2	3	4	5
(b) freezing rain...................	1	2	3	4	5

---

[1] If now retired, answer for the last 4 years you were a commercial pilot

FIGURE 2.3

POSITION OF EQUIPMENT AND PERSONNEL

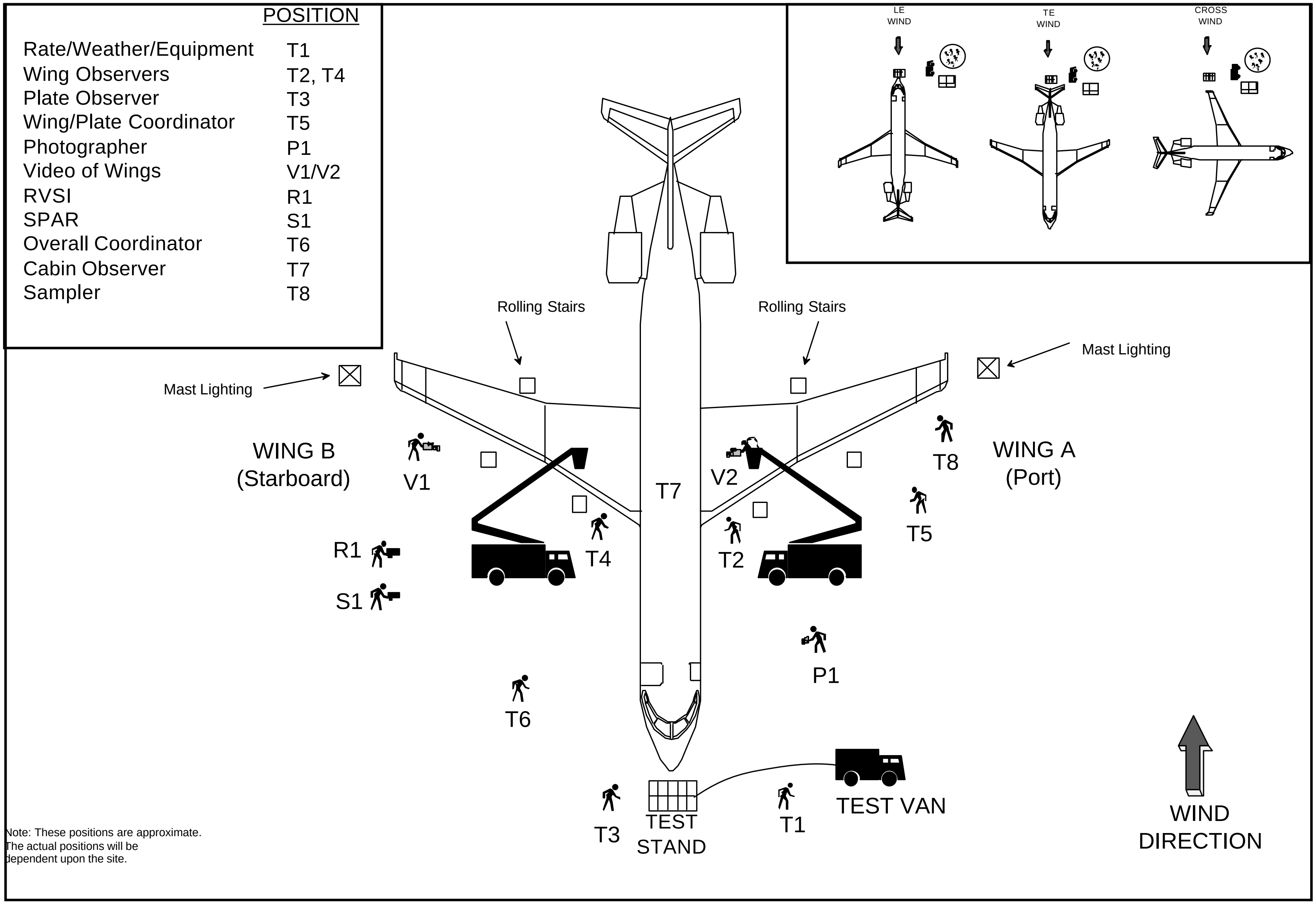

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FIGURE 2a

TYPE I FLUID APPLICATION

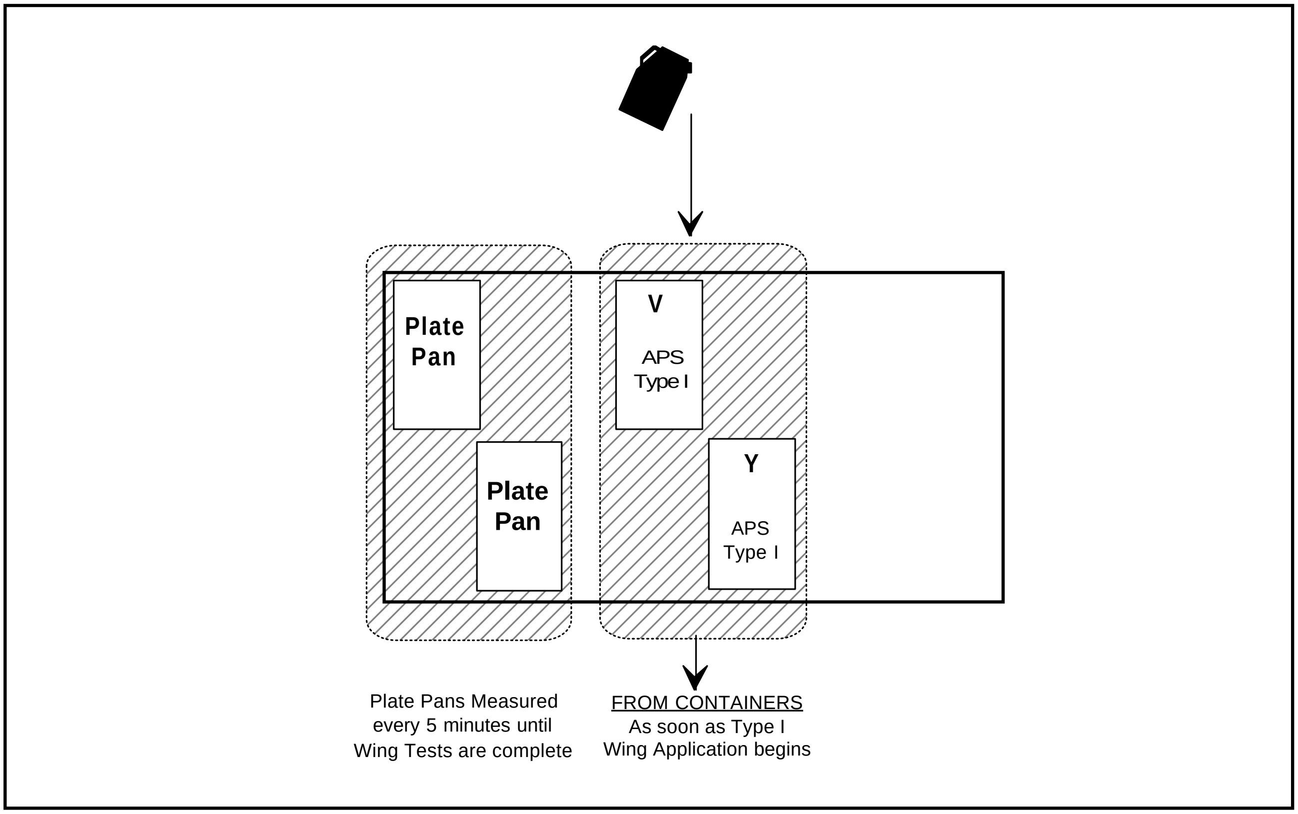

FIGURE 2b

TYPE IV FLUID APPLICATION

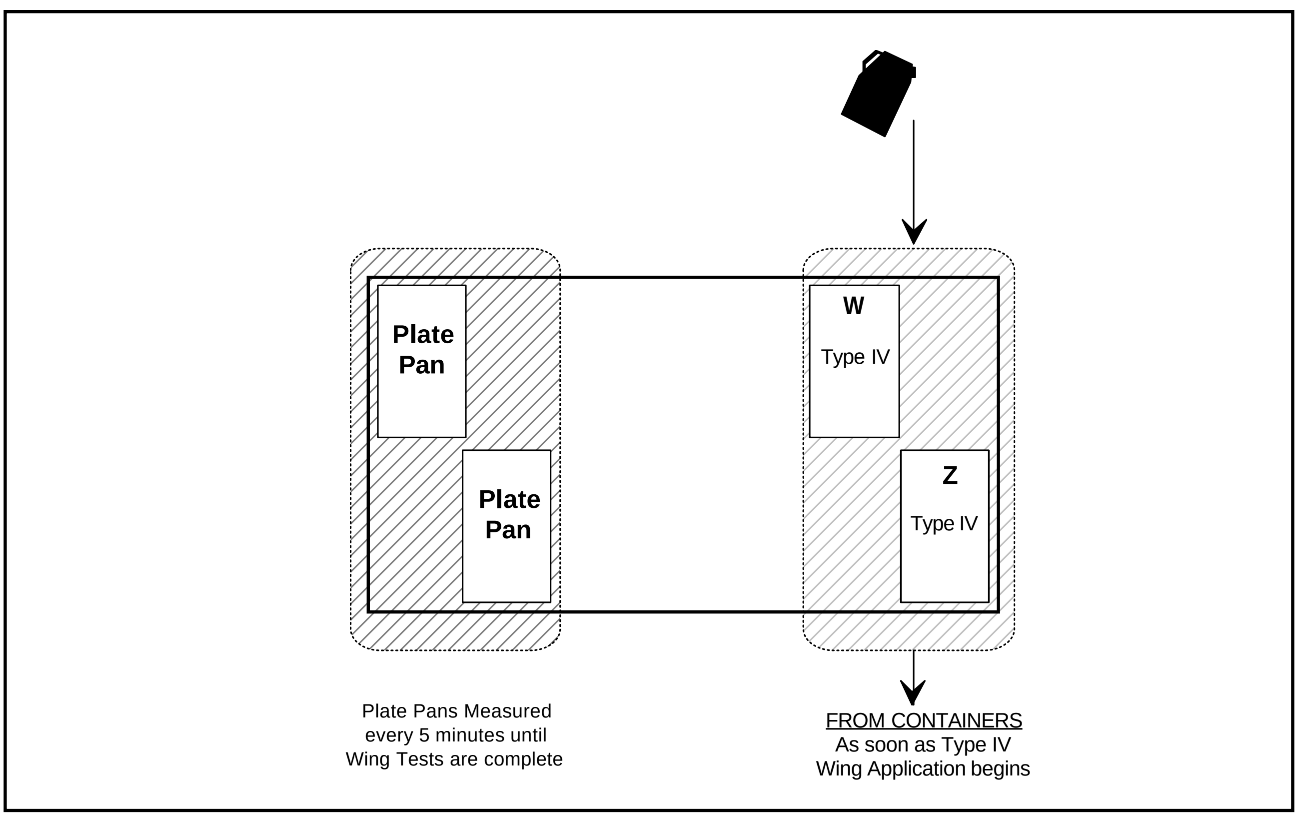

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FIGURE 3

GENERAL FORM (EVERY TEST)

(TO BE FILLED IN BY PLATE/WING COORDINATOR)

DATE: ______________________

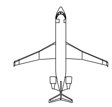
RUN #: ______________________

AIRCRAFT TYPE: ATR-42 F-100 B-737 RJ DHC-8

WING: PORT (A) STARBOARD (B)

DIRECTION OF AIRCRAFT: ________ DEGREES

DRAW DIRECTION OF WIND WRT WING:



1st FLUID APPLICATION

Actual Start Time: ________________ **am / pm** **Actual End Time:** ________________ **am / pm**

Amount of Fluid Sprayed: ________________ **L / gal** **Type of Fluid:** ________________

2nd FLUID APPLICATION

Actual Start Time: ________________ **am / pm** **Actual End Time:** ________________ **am / pm**

Amount of Fluid Sprayed: ________________ **L / gal** **Type of Fluid:** ________________

End of Test Time: ________________ (hr:min:ss) am/pm

COMMENTS: ______________________________________

MEASUREMENTS BY: ______________________

HAND WRITTEN BY: ______________________

FIGURE 3a

GENERAL FORM (ONCE PER SESSION)

(TO BE FILLED IN BY OVERALL COORDINATOR)

AIRPORT: YUL YYZ YOW

AIRCRAFT TYPE: ATR-42 F-100 B-737 RJ DHC-8

EXACT PAD LOCATION OF TEST: ______________________

AIRLINE: ______________________

DATE: ______________________

FIN #: ______________________

APPROX. AIR TEMPERATURE: ________ °C

FUEL LOAD: ______________________ **LB / KG**

TYPE I FLUID APPLICATION	***TYPE IV FLUID APPLICATION***
TYPE I FLUID TEMP: ________ °C	**TYPE IV FLUID TEMP:** ________ °C
Type I Truck #: ________	**Type IV Truck #:** ________
Type I Fluid Nozzle Type: ________	**Type IV Fluid Nozzle Type:** ________
Sample collected: Y / N	**Sample collected: Y / N**

TEMPERATURE MEASUREMENTS

ENTER FLUID TYPE:						
TIME (min)	**TEMPERATURE AT LOCATION (°C)**					
	M6/7	**M5/6**	**L4/5**	**M4/5**	**M3/4**	**M2/3**
Before[1] ( )						

(1) Actual Time Before Fluid Application

COMMENTS: ______________________

MEASUREMENTS BY: ______________________

HAND WRITTEN BY: ______________________

FIGURE 4

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME VERSION 4.0 Winter 97/98

DATE:	RUN NUMBER:

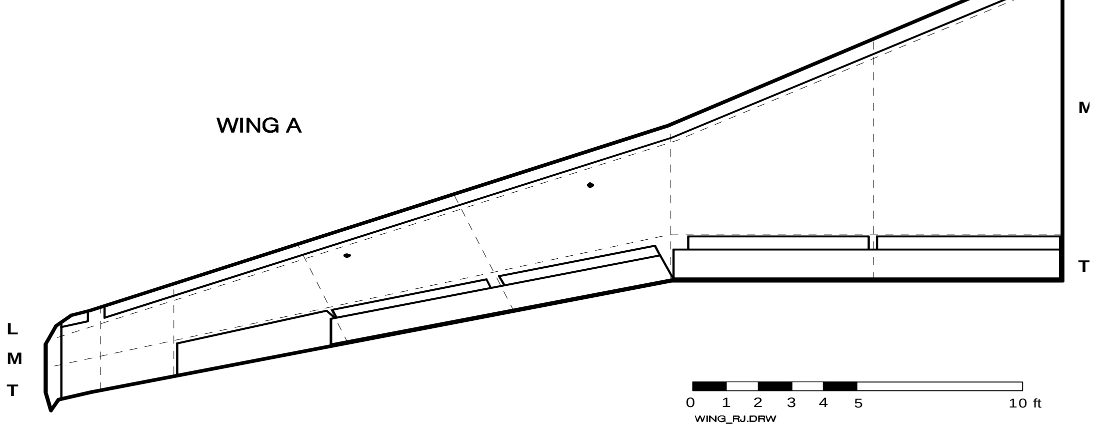
FAILURES CALLED BY: ____________ **COMMENTS:** ____________________

HANDWRITTEN BY: ____________

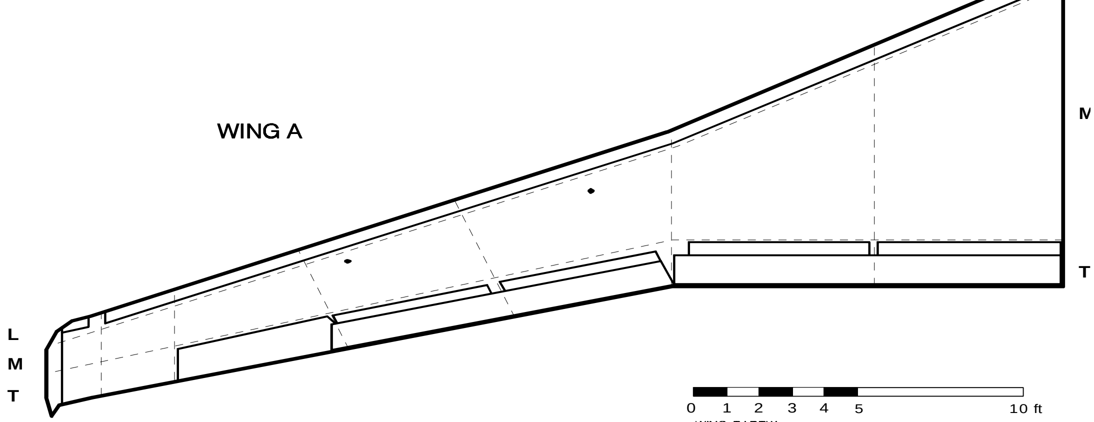
ASSISTED BY: ____________

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

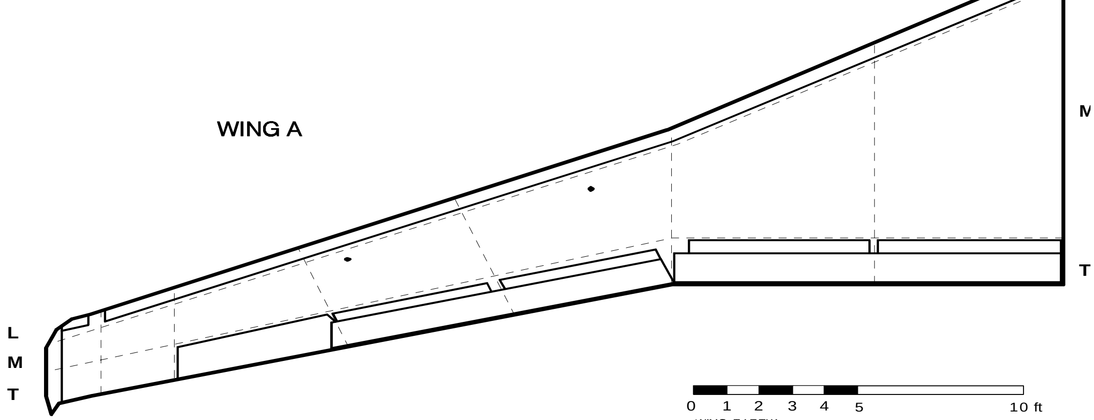
Time = ________ **RJ**



Time = ________ **RJ**



Time = ________ **RJ**



Note: To Compare to Flat Plate testing, subtract "Time of Initial Fluid Apllication".

File: cm1380\procedur\full-scl\V4_RJ_WA
At: Wing A

FIGURE 4

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME | VERSION 4.0 | Winter 97/98

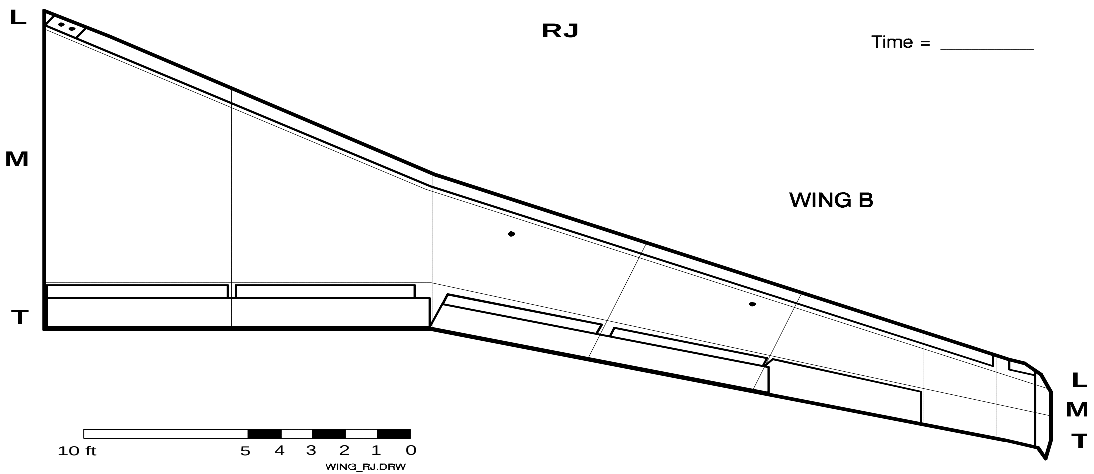
DATE: **RUN NUMBER:**

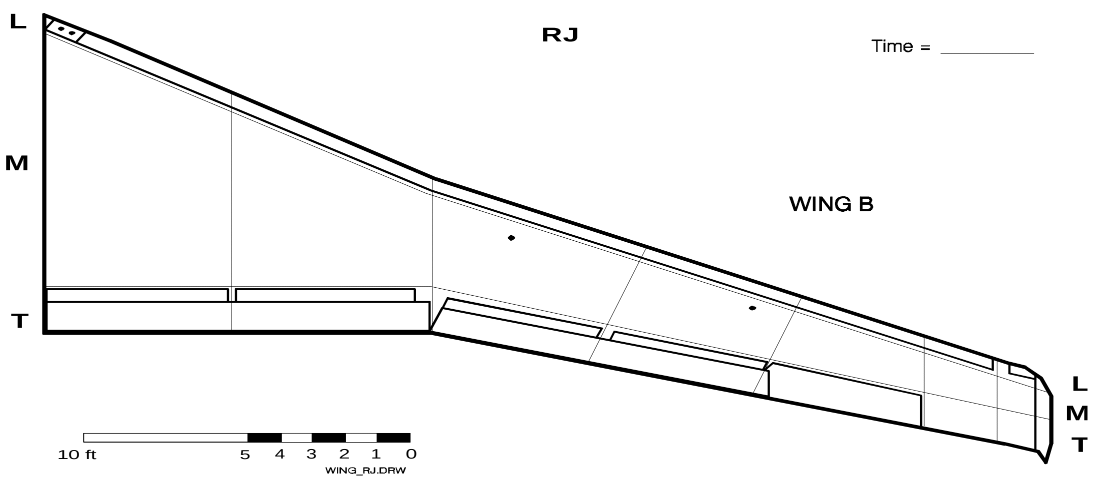
FAILURES CALLED BY: ____________ **COMMENTS:** ____________

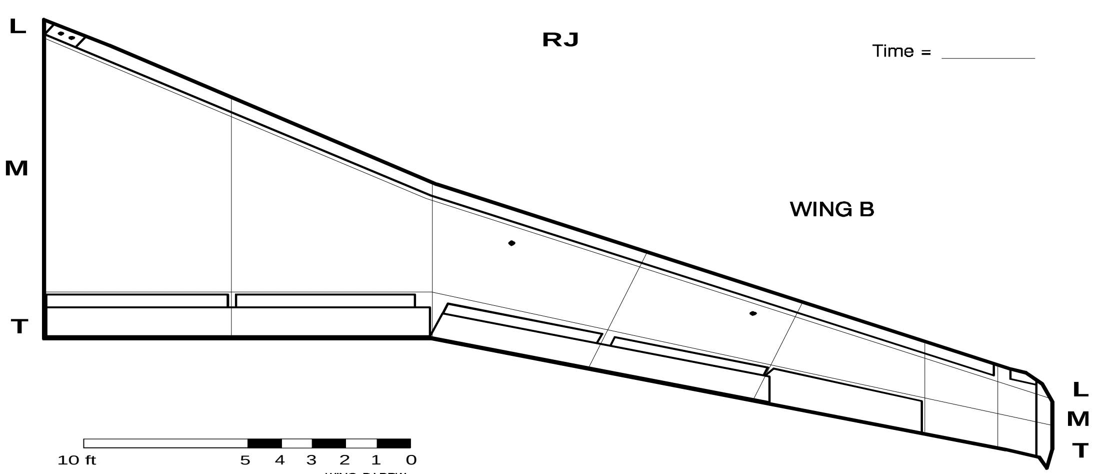
HANDWRITTEN BY: ____________

ASSISTED BY: ____________

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE







Note: To Compare to Flat Plate testing, subtract "Time of Initial Fluid Apllication".

File: cm1514\procedur\full-scl\V4_RJ_WB
At: Wing B Printed: 10/06/2002. 11:21 AM

FIGURE 4

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME | VERSION 4.0 | Winter 97/98

DATE: RUN NUMBER:

FAILURES CALLED BY: ____________ COMMENTS: ____________

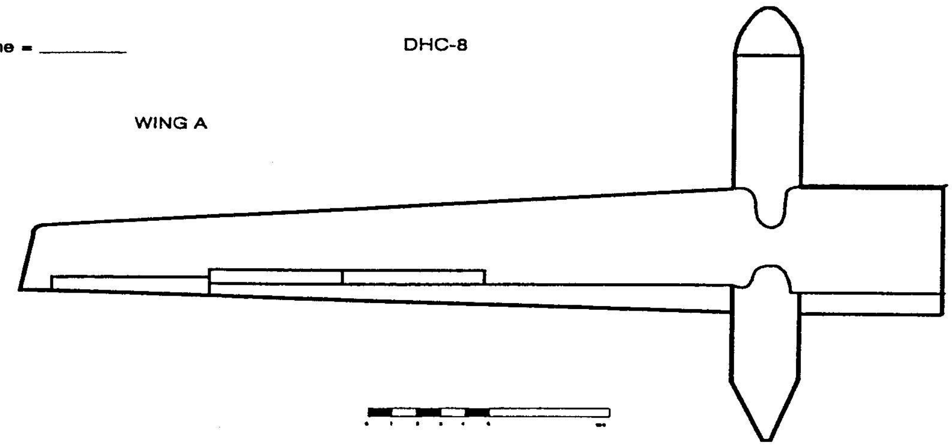
HANDWRITTEN BY: ____________ ____________

ASSISTED BY: ____________ ____________

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

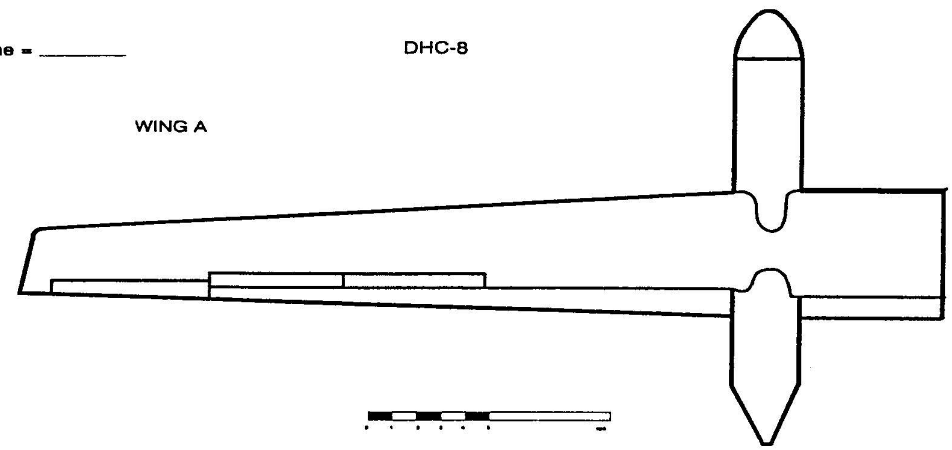
Time = ________ DHC-8

WING A



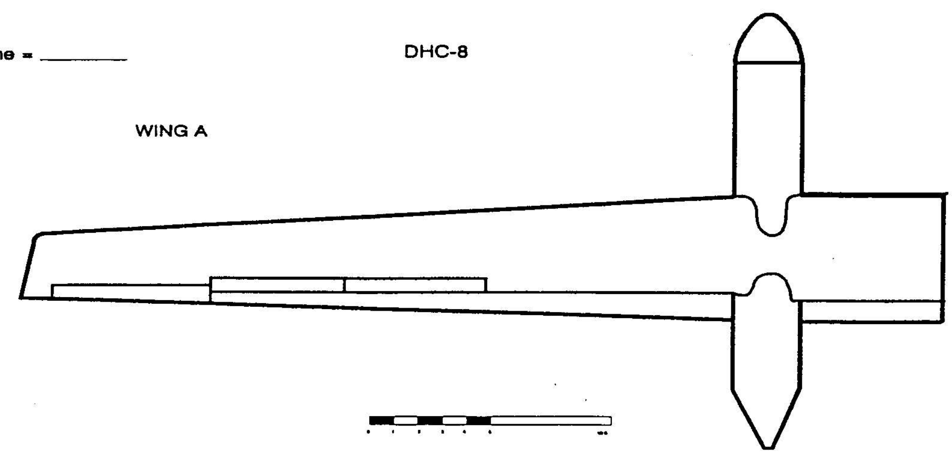
Time = ________ DHC-8

WING A



Time = ________ DHC-8

WING A



Note: To Compare to Flat Plate testing, subtract "Time of Initial Fluid Application".

File: \cm1380\procedur\turbopro\V4_d8_a.xls
At: Wing A Printed: 97-12-19

FIGURE 4

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME | VERSION 4.0 | Winter 97/98

DATE: | RUN NUMBER:

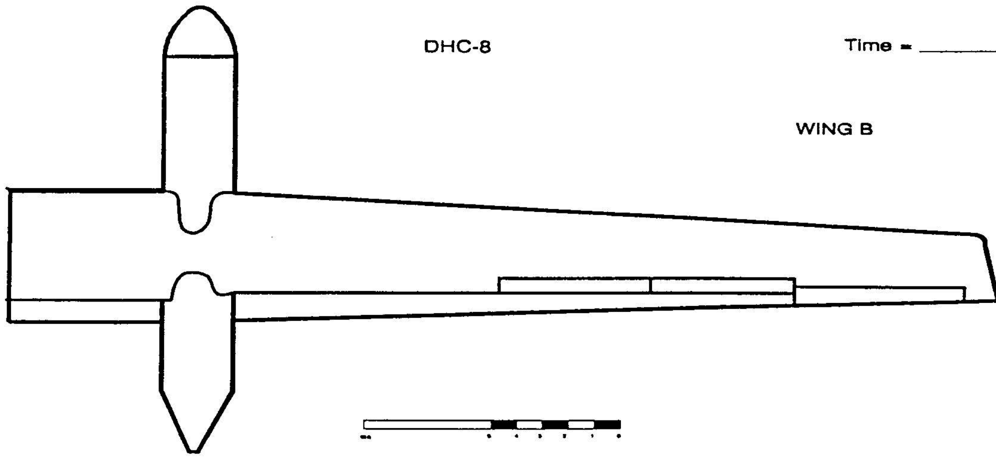
FAILURES CALLED BY: ____________ COMMENTS: ____________

HANDWRITTEN BY: ____________ ____________

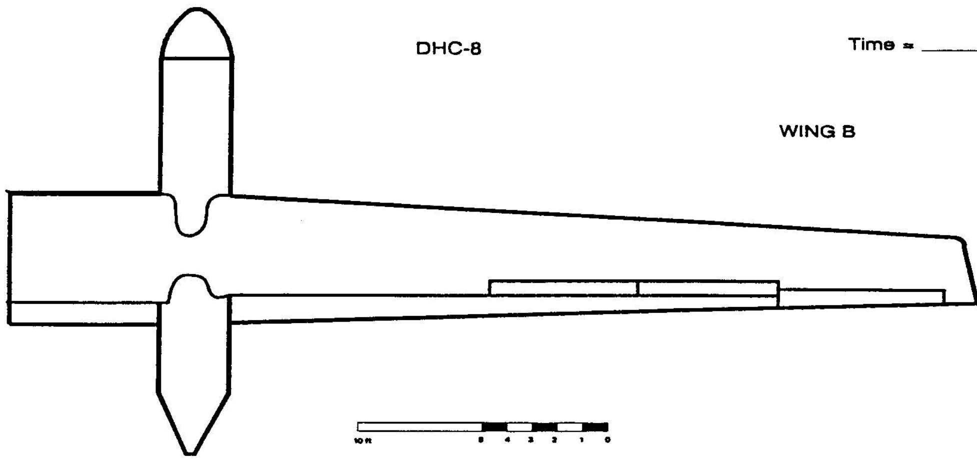
ASSISTED BY: ____________ ____________

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

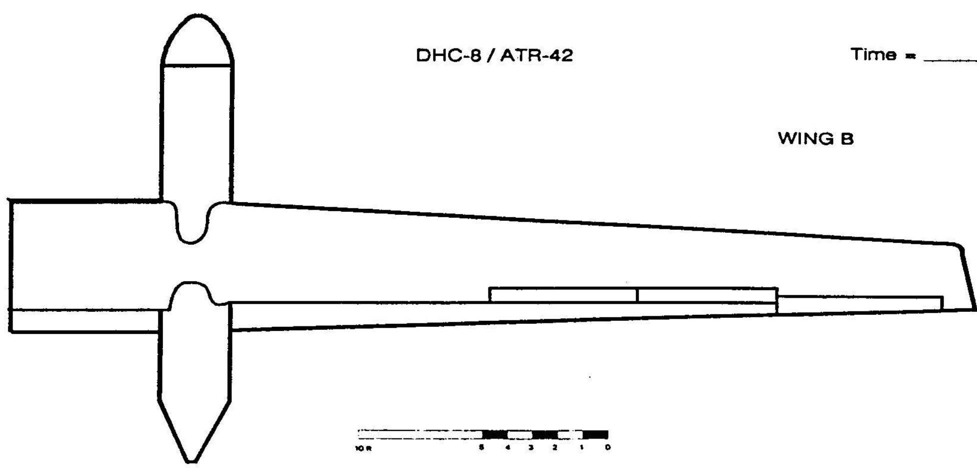
Time = ________



Time = ________



Time = ________



Note: To Compare to Flat Plate testing, subtract "Time of Initial Fluid Aplication".

File: g:\cm1380\procedur\turbopro\V4_dl
At: Wing B Printed: 97

FIGURE 4
DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME | VERSION 4.0 | Winter 97/98

DATE: | **RUN NUMBER:**

FAILURES CALLED BY: ______________ **COMMENTS:** ______________

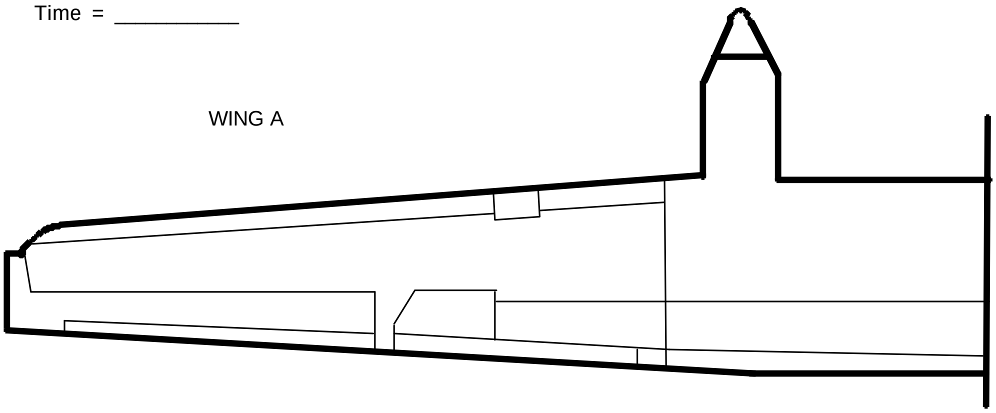
HANDWRITTEN BY: ______________

ASSISTED BY: ______________

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

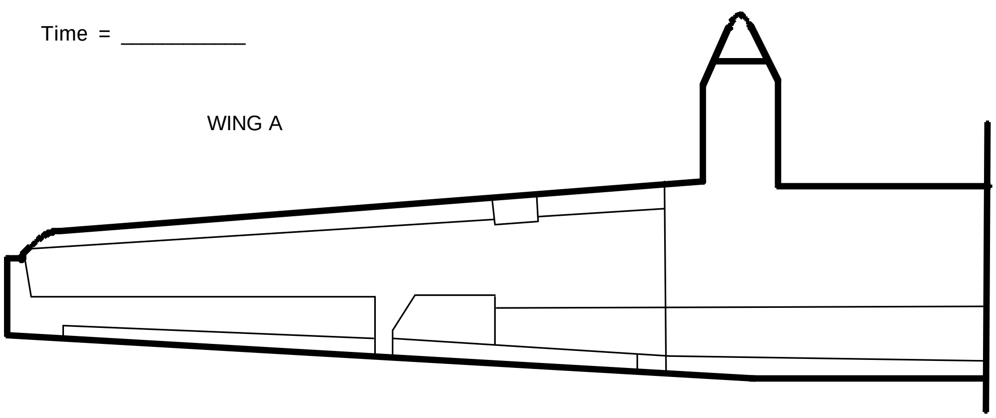
ATR 42

Time = __________



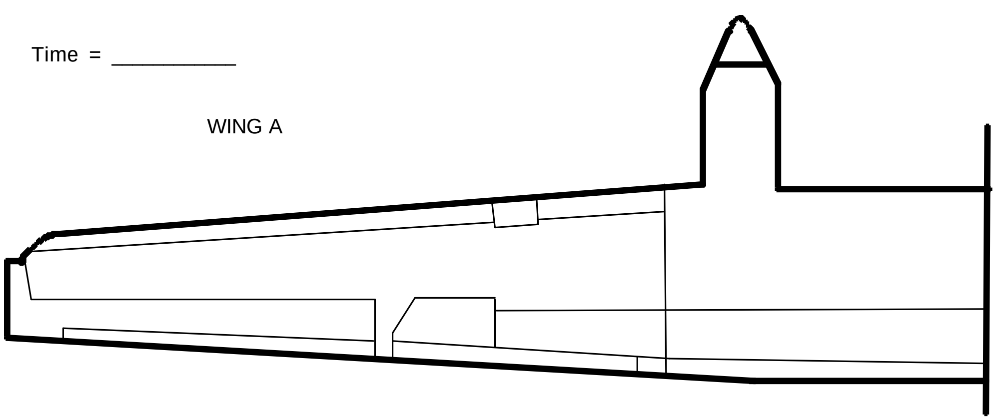
ATR 42

Time = __________



ATR 42

Time = __________



cm1514/procedur/full_scl/ATR_42WA.DRW

FIGURE 4

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME | VERSION 4.0 | Winter 97/98

DATE:	RUN NUMBER:

FAILURES CALLED BY: ____________ COMMENTS: ____________

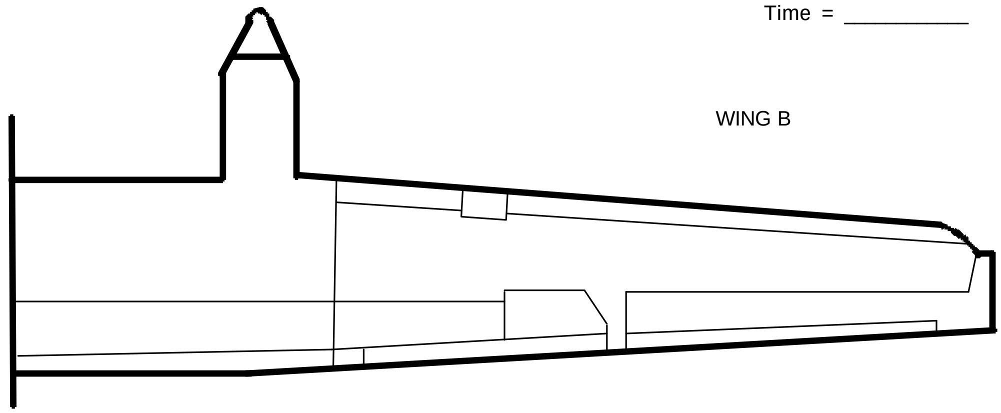
HANDWRITTEN BY: ____________

ASSISTED BY: ____________

DRAW FAILURE CONTOURS (hr:min) ACCORDING TO THE PROCEDURE

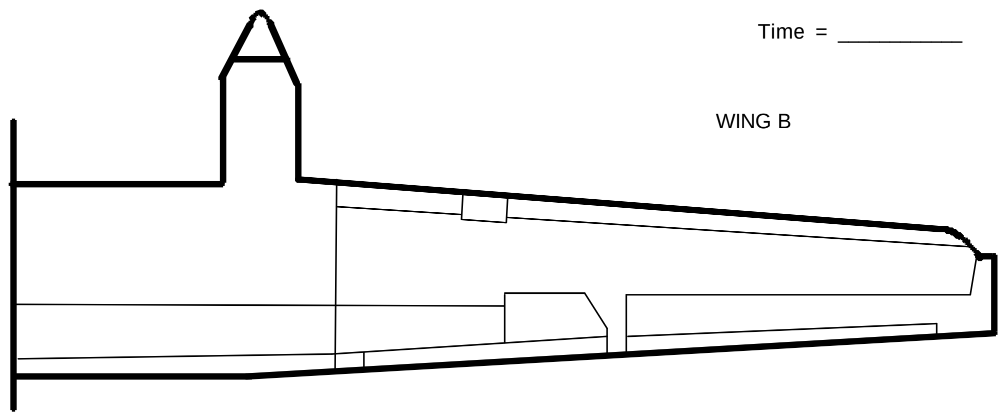
ATR 42

Time = __________



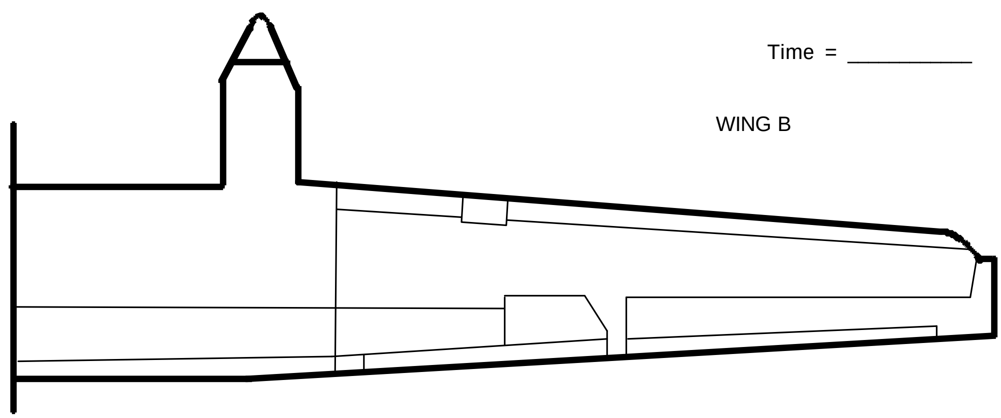
ATR 42

Time = __________



ATR 42

Time = __________



cm1514/procedur/full_scl/ATR_42WB.DRW

FIGURE 5

FLUID THICKNESS ON AIRCRAFT

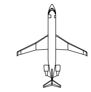
AIRPORT: YUL YYZ YOW

AIRCRAFT TYPE: ATR 42 F100 B-737 RJ DHC-8

DATE: ______________________

WING: PORT (A) STARBOARD (B)

DRAW DIRECTION OF WIND WRT WING:



RUN #: ______________________

DIRECTION OF AIRCRAFT: ____________ DEGREES

1st FLUID APPLICATION

Actual Start Time: ______________________ **am / pm** **Actual End Time:** ______________________ **am / pm**

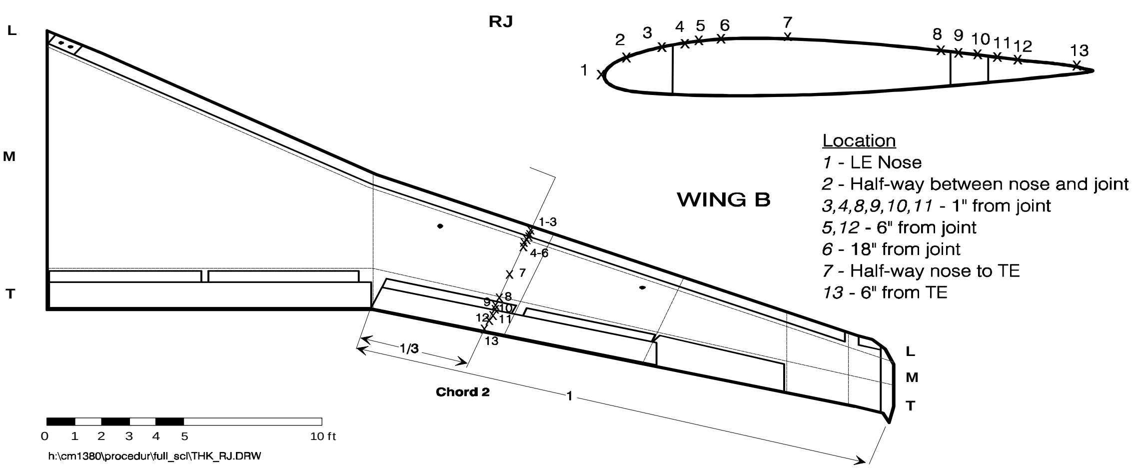
Amount of Fluid Sprayed: ______________________ **L / gal** **Type of Fluid:** ______________________

2nd FLUID APPLICATION

Actual Start Time: ______________________ **am / pm** **Actual End Time:** ______________________ **am / pm**

Amount of Fluid Sprayed: ______________________ **L / gal** **Type of Fluid:** ______________________

Location	Time	Gauge	Time	Gauge	Time	Gauge	Time	Gauge	Time	Gauge
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										



COMMENTS: ______________________

____

MEASUREMENTS BY: ______________________

HAND WRITTEN BY: ______________________

Version 2.0
File:g:\cm1514\procedur\full_scl\:Thck_frm.xls
Printed: 6/3/02

TABLE 1

END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME — VERSION 5.0 — Winter 97/98

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

RVSI Series # : ____________

CIRCLE SENSOR PLATE: u v w x y z

SENSOR NAME: ___ ___ ___ ___ ___ ___

DIRECTION OF STAND: _______ °

OTHER COMMENTS (Fluid Batch, etc):

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

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

Time of Fluid Application: _______ hr:min (U & X) _______ hr:min (V & Y) _______ hr:min (W & Z)

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

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

TABLE 2

METEO/PLATE PAN DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME VERSION 5.0 Winter 97/98

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

HAND HELD VIDEO CASSETTE #:

PLATE PAN WEIGHT MEASUREMENTS *

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

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

METEO OBSERVATIONS **

TIME (hr:min)	TYPE (Fig. 4) **ZR, ZL,S, SG IP, IC, BS, SP**	CLASSIF. **(See Fig. 3)**	If SNOW, WET or DRY

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

TEMPERATURE AT START OF TEST _______ ºC

WIND SPEED AT START OF TEST _______ kph

WIND DIRECTION AT START OF TEST _______ º

COMMENTS : ____

____

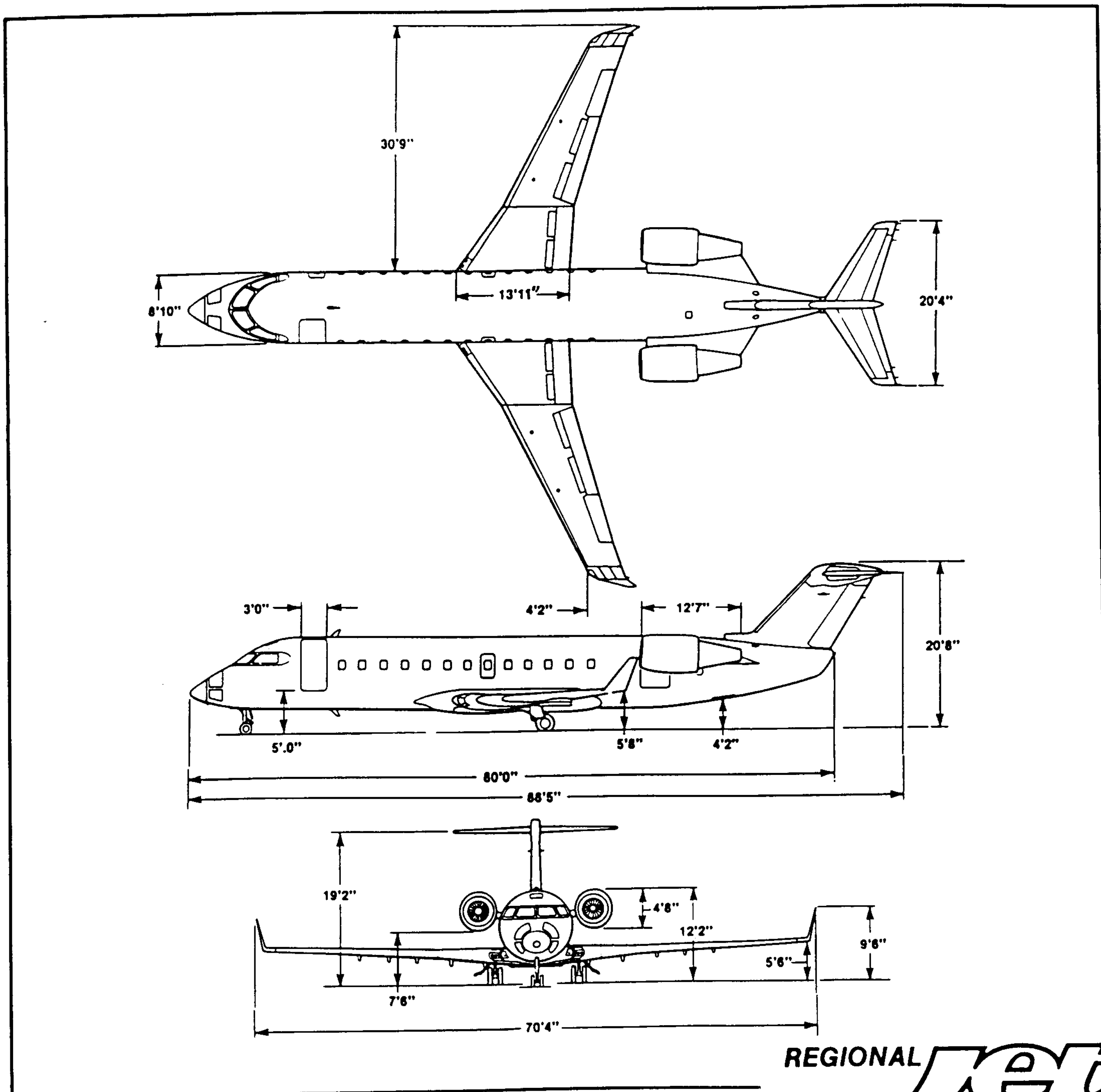
____

____

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

File g:\bm3469\procedur\nat_snow\Pform6.xls At:Meteo & Pan

THREE VIEW DRAWING
Canadair RJ

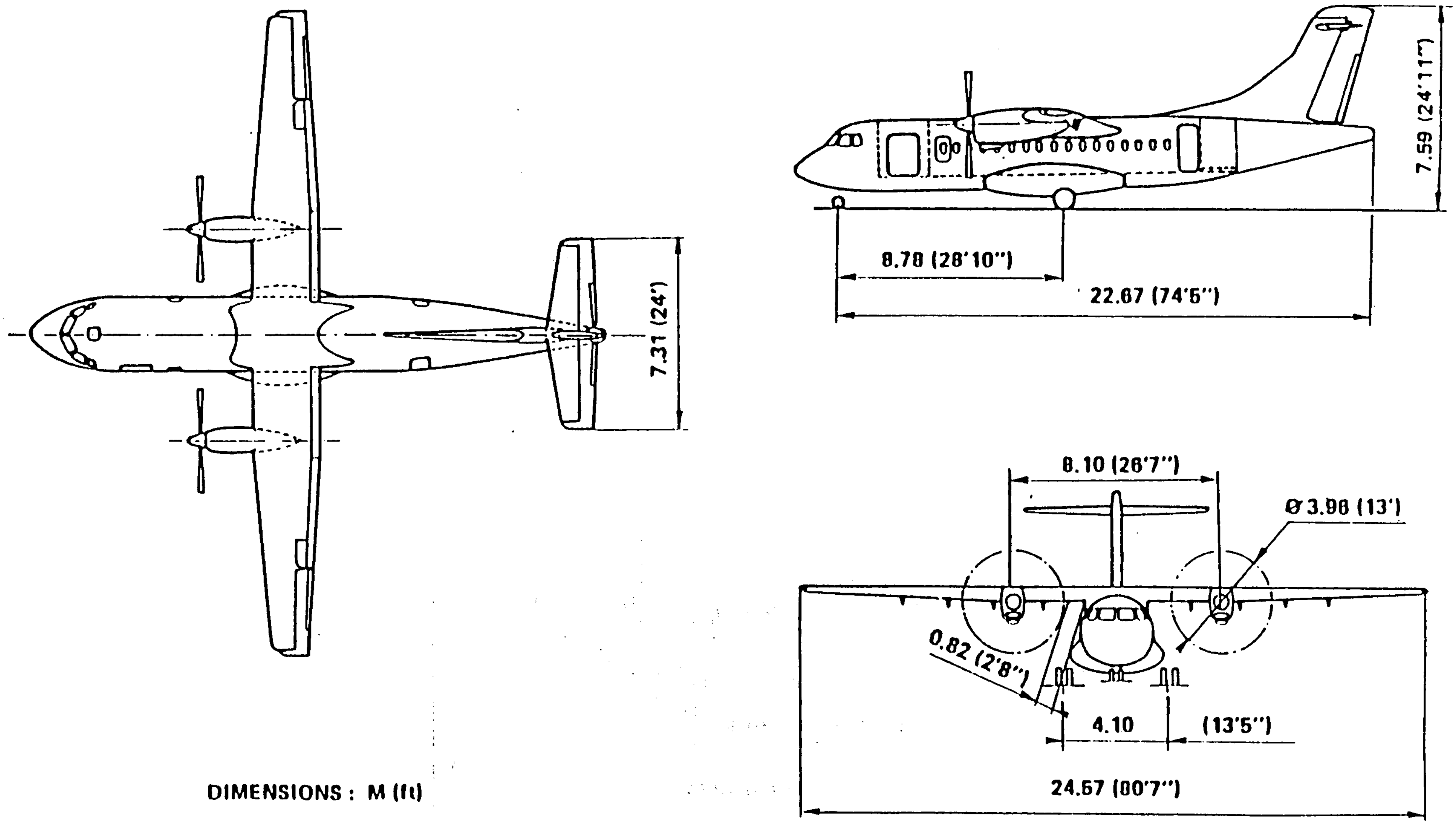


All data presented in this document are strictly based on preliminary estimates
Canadair does not make or intend to make any commitment, representation, or warranties whatsoever.
All data subject to change without prior notice by Canadair

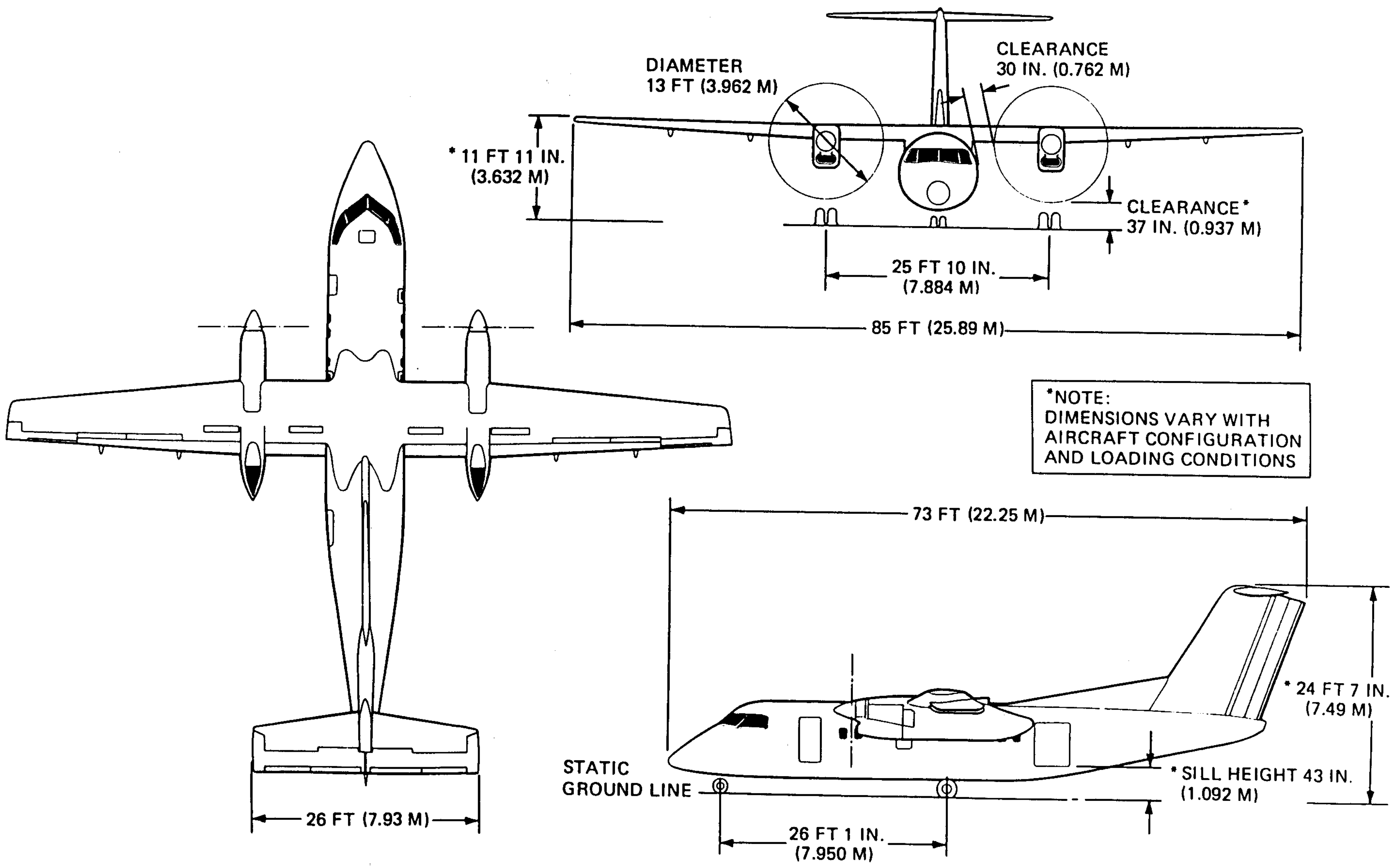
REGIONAL jet

Litho Canada

THREE VIEW DRAWING
ATR 42



THREE VIEW DRAWING
De Havilland Dash 8



APPENDIX C

PLAN OF EVALUATION OF THE USE OF REMOTE SENSOR FOR END-OF-RUNWAY INSPECTION

CM1380.001

EXPERIMENTAL PROGRAM
TRIALS TO EVALUATE THE USE OF REMOTE SENSORS FOR END-OF-RUNWAY INSPECTION

Winter 1997/98

APS AVIATION INC.

October 13, 1998
Version 1.0

EXPERIMENTAL PROGRAM
TRIALS TO EVALUATE THE USE OF REMOTE SENSORS
FOR END-OF-RUNWAY INSPECTION
Winter 1997/98

APS will conduct trials to evaluate the use of a remote ice contamination sensor to assess ice contamination on wings of operating aircraft prior to the aircraft entering the departure runway.

1. OBJECTIVES

The purpose of this series of tests is to determine and evaluate problems, and recommend solutions to those problems, with respect to operation of remote sensors to assist the Pilot-in-Command in the performance of the pretakeoff contamination inspection.

2. TEST REQUIREMENTS

2.1 Preparation

It is proposed to satisfy the objective of this program by conducting sensor trials at Dorval airport during actual operations in periods of snow or freezing precipitation. A Spar/Cox sensor will be used to scan wings of departing aircraft, after having been deiced and just prior to entering the departure runway. Data on any icing contamination on the wings will be collected for subsequent analysis.

Familiarisation with the operation of the sensor, and appreciation of general limitations of its capabilities will be gained during separate trials at the National Research Council cold chamber (Deicing Trials) and while installed at the APS test site.

APS will plan and coordinate the installation of a Spar/Cox contamination sensor in a mobile vehicle, which will be made available for a two week period. A vehicle with a cherry picker bucket is planned for this purpose.

APS will coordinate planning and conduct of operational trials with Transportation Development Centre, Aéroports de Montreal, and NavCan. Test procedures will be developed and approved by all parties prior to trials, to ensure that required runway clearances and communications during operations are respected. The precise location and method of operation of the sensor vehicle for these trials will be agreed with these agencies. Advice will be provided to aircraft operators by a distributed notice (to be prepared by the Transportation Development Centre) as well as a briefing by Aéroports de Montréal and the Transportation Development Centre to the Airport Operating Committee.

2.2 Conduct of Trials

Limitations on the range and angle of view of the sensor will be evaluated based on the truck installation, prior to operational trials. It is planned that an initial dry run trial be conducted during non-icing conditions to support this evaluation, and to check out procedures. Consideration will be given to conducting this dry run having the sensor equipped vehicle located at the previous east deicing pad at Dorval airport, and scanning wings of aircraft as they taxi past en route to Runway 6R. Results of this trial will be useful in defining acceptable locations for subsequent operational trials.

APS personnel will monitor forecasted weather and initiate operational trials based on suitable conditions. Contacts at the Transportation Development Centre, Aéroports de Montréal and NavCan will be advised when tests are planned.

Trials during actual operations will involve situating the sensor vehicle at a location beside the taxiway, as near to the point of entry to the departure runway as possible. If the east pad is seen to be a useful site during the dry run, that location may be used for operational trials.

As aircraft taxi past the parked sensor vehicle, the sensor will scan the wing on the near side and record any evidence of contamination. Aircraft identification will be recorded. At the end of the test session, deicing history of each aircraft will be retrieved from the deicing operator, to be incorporated into the data analysis. There will be no communication of results of sensor readings during the course of the trials. Weather conditions will be recorded on an ongoing basis. Simultaneous testing on flat plates will be conducted (at the nearby APS test site) to assist in documenting actual operating conditions and related fluid holdover times.

At least two trial sessions during periods of snow or freezing precipitation will be attempted.

Complete photo and video records of test setup will be maintained.

3. EQUIPMENT

Test equipment is included in Attachment I.

4. PERSONNEL

It is anticipated that a team of two people will be required to conduct the sensor trials. Descriptions of responsibilities and duties of each team member are given in Attachment II. One team member will be an experienced airport driver, with a background in airport operations.

In addition, staff will be involved in conduct of simultaneous fluid failure trials on flat plates. It is expected that this staff will be in place to conduct scheduled tests on fluid failure, and that no additional staff will be required for this activity.

Support from Spar/Cox will be coordinated for installation of the sensor on the vehicle, and, as required, for actual tests.

5. DATA FORMS

The following data form will be used:

C Figure 1 Record of Scanned Aircraft.

FIGURE 1

RECORD OF SCANNED AIRCRAFT

Montreal International Airport Date: ____________________

Aircraft Type	Fin #	Carrier	Time

ATTACHMENT I

END-OF-RUNWAY INSPECTION

TEST EQUIPMENT CHECKLIST

TASK
Logistics for Every Test
Rent Van
Call Personnel
Advise TDC, ADM, NavCan
Monitor Forecast
Call potential participants
Test Equipment
Cherry picker truck equipped for airport operations (radio, lights)
Communications between driver + bucket operator
Spar/Cox sensor installed in truck
Personnel van
Video camera
Data form

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ATTACHMENT II
RESPONSIBILITIES/DUTIES OF TEST PERSONNEL

Driver

- Safe operation of truck and bucket;
- Maintain communications with sensor operator when postioned in the bucket;
- Establish and maintain radio contact with NavCan; and
- Maintain record of aircraft scanned.

Sensor Operator

- Ongoing operation of sensor; and
- Located in cherry picker bucket as required.

APS Test Site Staff

- Perform fluid holdover trials using same fluids as used for operational deicing, during course of scanning trials.

Coordinator

- Outlook weather forecasts and initiate scanning trials;
- Advise NavCan, Aéroports de Montréal of intention to conduct trials; and
- Ensure deicing records for trial period retrieved from AéroMag.

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APPENDIX D

PLAN FOR FROST TESTS ON FLAT PLATES

EXPERIMENTAL PROGRAM
PLAN FOR FROST TESTS ON FLAT PLATES

December 11, 1998, Version 2.0
Winter 1997/98

- The ideal conditions for the development of frost are:
  i) Less than two knots of wind;
  ii) Clear sky preferred; and
  iii) Dew point and ambient temperatures comparable.

- Frost tests should be planned overnight.

- Surfaces to be tested include standard flat plates, 0.020" aluminium plates backed with honeycomb and 1/8" kevlar plates.

- Prior to being placed on the test stand, test surfaces should be weighed to the nearest gram. Weights should be recorded on a meteo/plate pan data form.

- Once test surface weights have been recorded, the test surfaces should be placed on the test stand. Ensure that the test stand is properly inclined at 10°. Ensure that test start times are recorded.

- Reweigh the test surfaces at 3-hour intervals to determine frost deposition.

- Two additional standard plates should be coated with Type I XL54 and Ultra+ Type IV. Following the pouring of fluids, record the start times.

- If/When frost builds on the plate, record the failure time when five crosshairs on the plate have failed. Record failure times on an End Condition Data Form (Table 1).

- A measure of Brix (at the top and bottom layer of the fluid) and fluid thickness is required at one-hour intervals.

- Test surfaces used to determine frost deposition should be reweighed following plate failure.

APPENDIX E

PLAN FOR OVERNIGHT FROST TESTS ON AIRCRAFT

EXPERIMENTAL PROGRAM
PLAN FOR OVERNIGHT FROST TESTS ON AIRCRAFT

December 11, 1998, Version 1.1
Winter 1997/98

- When aircraft are towed to the deicing pad, it is possible that frost has accumulated on the wing surfaces.

- It frost is present, P1 should take photographs of the accumulations on both wings.

- Overall photographs of each wing are required. As well, photographs of frost formation on each wing section should be recorded. Place a painted quarter in the appropriate wing section when taking photos of wing sections as per Attachment X in the full-scale test procedure. A scale should be utilized for dimensions.

- Three photos should be taken at each location:
  - i) Overall location of the coin relative to the rest of the wing;
  - ii) Macro profile of the coin to determine surrounding crystal height, shape and size; and
  - iii) Macro plan of the coin to determine the roughness and texture of surrounding crystals relative to the coin.

APPENDIX F

PLAN FOR DOCUMENTATION OF PILOT FIELD OF VIEW AND WING VISIBILITY

CM1380.001

EXPERIMENTAL PROGRAM
DOCUMENTATION OF PILOT FIELD OF VIEW, AND WING VISIBILITY

Winter 1997/98

APS AVIATION INC.

October 5, 1998
Version 1.1

EXPERIMENTAL PROGRAM
DOCUMENTATION OF PILOT FIELD OF VIEW, AND WING VISIBILITY
Winter 1997/98

1. OBJECTIVE

To define and demonstrate through still photos and video tape, the actual area of the wing that is visible to an observer from inside the aircraft.

2. REQUIREMENT

This documentation is expected to make use of aircraft available during normal ground time at gates, between flights when no passengers are on board. Arrangements need to be made with operators to gain access to the aircraft. The activity will take place at Dorval airport.

Documentation is required under both dry and precipitation conditions, during daylight and at night.

Target aircraft are; McDonnell Douglas DC-9, Boeing 767, DeHavilland Dash 8, and BAe 146. The Canadair Regional Jet and further views on the ATR 42 will be documented during the Aircraft Full-Scale Fluid Failure Trials.

3. PROCEDURE

i) Maintain a record of the aircraft type, airline, aircraft fin number and date of photography. Photograph the aircraft fin number, or the aircraft placard on the flight deck.

ii) From the flight deck; from the side windows looking back toward the wing, photograph the wing as it appears to the observer. Take as many images as are needed to capture the entire wing area that is visible. Repeat with video camera. Conduct this activity both with window closed and open.

iii) From the passenger cabin; locate the overwing exit seat row. If there is more than one overwing exit, locate the one most adjacent to the representative surface area of the wing. Record the seat row number used on the data form (Table 1). Looking out through the side window of that row, photograph the wing as it appears to the observer. Take as many images as are needed to capture the entire wing area that is visible. Repeat with video camera. Repeat the activity while standing in the aisle to simulate a situation where the pilot conducts an inspection and passengers are seated in that row.

Repeat the foregoing while located at the cabin window, and in the aisle at the seat row approximately at the leading edge of the wing. Record the seat row number used.

Repeat again while located at the cabin window and in the aisle at the seat row approximately at the trailing edge of the wing. Record the seat row number used.

If time permits, and if the lighting on the opposite wing is obviously different, repeat the entire sequence for the opposite wing.

For high wing aircraft, conduct photography from the cabin windows that enable a view of the leading edge and/or trailing edge, and from any passenger door that enables a view of the wing top surface. Record the seat row number or door used.

4. EQUIPMENT

A still photo camera and a video camera are required, along with support equipment.

5. PERSONNEL

Two personnel are required; a coordinator and a photographer.

6. DATA FORMS

Table 1 provides the data form for this activity. A single line on the form can be completed for each photo session per aircraft.

TABLE 1

VISIBILITY OF WING FROM AIRCRAFT INTERIOR

Winter 1997/98

Airport ___________________ **Date** _________________

AIRLINE	AIRCRAFT TYPE	FIN #	CABIN SEAT ROW #S	PRECIPITATION YES/NO	PRECIPITATION TYPE	DAYLIGHT	TIME	OUTSIDE LIGHTING	GATE

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ATTACHMENT II
PHOTOGRAPHER DUTIES DURING TRIALS ON OPERATIONAL AIRCRAFT

Trials to evaluate the effectiveness of the proposed solution to enhance visibility of fluid failure will be conducted in conjunction with fluid failure trials on aircraft. The enhanced visibility project will require a photographer to be located in the aircraft cabin.

PHOTOGRAPHER DUTIES

The activities of the photographer located in the cabin of the aircraft will involve support to three separate projects:

- Enhanced visibility of fluid failure on wing surfaces;
- Documentation of pilot field of view, and wing visibility; and
- Aircraft full scale tests.

The procedures for each of these support activities follows:

1. ENHANCED VISIBILITY OF FLUID FAILURE ON WING SURFACES

Sheets of retroflective tape will be applied to selected areas of the wing surface during the setup phase. During fluid failure trials, these sheets will be viewed from the cabin interior with an optical instrument composed of a set of binoculars (or telescope) together with a light source and light shield. When fluid on the sheet starts to fail, the reflected light from the sheet is expected to deteriorate in brightness, with the appearance of shadows on the sheet surface indicating points of fluid failure.

The duties of the photographer are to:

1.1 Photographic Record of Tape Installation

Provide a photographic record of the installed tape on the aircraft wing. This is to be performed prior to start of fluid failure tests, as soon as the tape has been installed. Photos are to include images of the tape sheets, taken with and without illumination. Areas of the bare wing surface adjacent to the tape should be included in the photos for reference.

1.2 Documentation of Results

During the progress of fluid failure trials, a team member will observe the tapes with use of the viewing instrument. When fluid failure is noted on any sheet, the photographer will be advised to perform photo documentation of the event.

On occasions when external lighting is extinguished (as part of the full-scale program or for any other reason) photos of taped surfaces are to be taken.

All photos are to be date stamped. A photo log is to be maintained, identifying locations and condition of specific sheets being viewed.

2. DOCUMENTATION OF PILOT FIELD OF VIEW, AND WING VISIBILITY

2.1 Objective

Define and demonstrate through still photos and video tape, the actual area of the wing that is visible to an observer from inside the aircraft. This documentation is to include photos taken during lighted conditions, as well as at night under conditions of precipitation with onboard lighting only.

For the Canadair CL65 aircraft, this activity will be completed as much as possible during the dry run, and finalized as necessary during subsequent fluid failure trial sessions. For high wing test aircraft, the activity will be completed during fluid failure trials.

2.2 Procedure under Lighted Conditions:

a) Maintain a record of the aircraft type, airline, aircraft fin number and date of photography using form Attachment I. Photograph the aircraft fin number placard in the aircraft flight deck.

b) From the flight deck: from the side windows looking back toward the wing, photograph the wing as it appears to the observer. Take as many shots as are needed to capture the entire wing area that is visible. Repeat with video camera. Conduct this activity both with window closed and open.

c) From the passenger cabin: locate the overwing exit seat row. If there is more than one overwing exit, locate the one most adjacent to the representative surface area of the wing. Record the seat row number used. Looking out through the side window of that row, photograph the wing as it appears to the observer. Take as many shots as are needed to capture the entire wing area that is visible. Repeat with video camera. Repeat the activity while standing in the aisle to simulate a pilot leaning over passengers seated in that row.

   Repeat the foregoing while located at the cabin window, and in the aisle at the seat row approximately at the leading edge of the wing. Record the seat row number used.

Repeat again while located at the cabin window and in the aisle at the seat row approximately at the trailing edge of the wing. Record the seat row number used.

For high wing aircraft, conduct photography from the cabin windows and passenger doors that enable a view of the leading edge or any part of the wing upper surface. Record the seat row number or passenger door used.

2.2 Procedure Under Non-lighted Conditions

During the dry run or if necessary, following actual test sessions, external lighting will be turned off to allow photography of wing surfaces under lighting conditions typical of actual operations.

The procedure for photographing under these conditions will follow the same routine as for lighted conditions.

3. AIRCRAFT FULL-SCALE TESTS

As part of the Full-Scale Fluid Failure Test Program, a pilot will be located in the aircraft cabin to document the extent that fluid failures are visible from the cabin interior.

The pilot will have a video camera mounted on a tripod to document failures. The photographer will extend any necessary assistance to ensure operation of the video camera.

On those occasions when the pilot identifies fluid failure, or when the pilot is unable to see fluid failure following advice from external observers, the photographer will photograph the wing locations where fluid failure is occurring, to document what the pilot is seeing.

When specific events occur, the pilot will request that external lights be turned off. Advantage is to be taken of these occasions to photograph views of failure in darkened conditions.

ATTACHMENT II

DOCUMENTATION OF PILOT FIELD OF VIEW, AND WING VISIBILITY

Airport ______________________________ **Date** ______________________________

AIRLINE	AIRCRAFT TYPE	FIN #	CABIN SEAT ROW #S	TYPE PRECIPITATION	TIME	OUTSIDE LIGHTING	GATE

APPENDIX G

COST OF DEICING

COST OF DEICING

This document was prepared by Brian Jensen, formerly of Air Canada, in March 1998 at the request of APS. It provides budgetary costs of deicing aircraft typically experienced at Canadian airports.

1. DE-ICING FLUID COST PER LITRE

The cost of fluid in Canada varies from one location to another. The major variables in determining the price are:

a) The Quantity shipped per order. Prices are quoted for orders greater than 19,000 litres, for orders between 14,000 and 19,000 litres and, for orders between 9,000 and 14,000 litres. The larger the order, the chap per the price.
b) The cost of transportation between the manufacturing plant and the user station.
c) The total quantity ordered per season.

Union Carbide - Bulk (50-50 fluid - ethylene)

	Type I	Type 4
Central Canada	1.005	1.84
Western Canada	1.125 to 1.75	1.96 to 2.06

Source: Air Canada Vancouver Operations (G. Cameron).

Union Carbide - 55 Gallon Drums (50-50 fluid - ethylene)

Type I	
2.69	(1 to 3 drums)
1.89	(40 + drums)

Plus taxes and deposit on drums.
Source: Timberline Air Operations (J. Rutledge).

Octagon - Bulk (propylene) - Cost quoted in U.S. gallons and U.S. Dollars

	Type 1 (88% glycol*)		Type 4 (50-50**)
Octoflo	5.30	Maxflight	5.70

* Diluted to 55% glycol, the cost is as follows:
88% - 55%) 33% less strength
33/88*100 = 37.5% reduction in cost
Cost per U.S. gallon: $5.10 - 37.5% = $3.19 or $0.84 per litre.

** $5.60 per U.S. gallon - 1.48 per litre.

Source: Octagon Sales (J. Wakelin)

Typical Application Rates by ground handler
Source: Word of mouth

$3.00 per litre Includes cost of fluid.
Up to $20.00 per gallon for transient customers.

2. DE-ICING FLUID CONSUMPTION - LITRES USED[1] (ONE STEP DEICING)

AIRCRAFT TYPE	SEATS[2]	FROST	LIGHT SNOW	MED SNOW	HVY SNOW	FR RAIN	O/N ACCUM
COMM	60	70	275	600	1020	1120	670
S N/B	120	90	350	770	1310	1440	865
L N/B	175	100	390	860	1460	1605	965
S W/B	225	120	475	1045	1775	1950	1170
L W/B	500	140	545	1225	2045	2270	1360

a) 10 Year average of fluid use reported by Air Canada operations in Canada. Extreme conditions such as ice storms have been excluded.

b) The number of seats include all aircraft types having the capacity of accommodating this number of seats in an all-passenger version. Commuter aircraft (60) includes J31, DHC8, ATR42 & CL65 aircraft. Small narrow-body aircraft (120) includes DC9-30, B737-200 & F100. Large narrow-body aircraft (175) A320, B737-400 & B757. Small wide-body aircraft (225) includes A320 & B767. Large wide-body aircraft (500) includes DC10, L1011, MD11, A340, B747, etc.

3. RECOVERY COST

This cost varies greatly with the airport location and the recovery method.

Where the recovery method is mostly passive (run-off fluid is recovered from the de-icing area without the use of manpower and machinery) provided by the airport, the airlines are not charged directly for the actual recovery even though a capital expense was incurred to construct the recovery system.

Where the recovery involves the use of vacuum trucks, this is charged at a "cost plus" formula, usually involving an accelerated rate of depreciation (3 to 5 years) for the vacuum trucks. Vancouver's rate, as an example, was charged on the fair market value of the trucks assigned to the station (both new and used vehicles were used), depreciated over 3 years. Assuming a fair market value for the vacuum trucks to be $250,000, a yearly depreciation cost of about $95,000 over 3 years and about $60,000 over 5 years per truck can be expected.

Therefore, operating cost will vary depending on the city, the cost and age of the equipment used, the recovery conditions and any additional resources used.

As an example, recovery costs at Vancouver International Airport during the 1996/97 season was $165,000 which included depreciation on 1 new vehicle (transferred in from YYZ), rental of a local vehicle, the use of a rented vehicle during peak spray conditions and labour. However, it excluded any reference to ownership of the existing fleet of vacuum trucks.(1)

In Toronto, a combination of active (Terminals 1, 2 & 3) and passive (Terminal 3) recovery methods are used depending on the location and de-icing condition. A total of 9 vacuum trucks are used in the recovery process.

(1) Hudson General end-of-season presentation (1996/97 season).

The cost for recovery at YVR is about $2.11/litre applied, based on Hudson General.

4. DISPOSAL COST

This also varies greatly from one airport to another depending on the method used.

The highest cost is charged at Vancouver and Halifax at $0.15 per litre of recovered fluid. This is due to the requirement to transport the fluid by truck to a disposal facility (Vancouver transports its fluid to Seattle).[1]

In Calgary the fluid is routed to the sanitary sewer from a holding pond at no charge.[1]

At Toronto, the high concentrate fluid is recycled for other industry uses by Inland Technologies Inc. Dilute fluid is disposed of in the sanitary sever system for about $0.01 per litre. This is a reduction from $0.07 per litre about 2 years ago.[1]

At Montreal, 20 tonnes of glycol per day can be discharged into the MUC sanitary sewer. This has resulted in the elimination of the high concentrate separation which was routed to Inland Technologies Inc. for recycling. Their future in the Montreal operation is, therefore, is question.[2][3]

Similar to the practice at some airports in the U.S., at some airports in Canada (Toronto & Hamilton), fluid discharged to the sanitary sewer is assessed a conveyance and a BOD charge.[4]

(1) Air Canada Environmental Services (D. McLeay).

(2) Aéromag 2000 (W. Randa).

(3) Inland Technologies Inc. (D. Goldbeck).

(4) Zenon Environmental (W. Moran).

5. SUMMARY

Based on average and rounded values the following is an example of the costs.

Cost of fluid (Type I)	=	$1 per litre
Cost to apply	=	$2 per litre
Cost of recovery	=	$2 per litre
		$5 per litre

Therefore for a DC-9 during light snow, the cost for deicing should be about $1,750. Simularly costs for other aircraft under other conditions could be estimated.

Canadian Airlines International indicated cost of Dorval is $5.5/litre for deicing.

Shell in Ottawa is charging $7.50/litre for the service of applying fluids on aircraft.

APPENDIX H

DOCUMENTATION OF WING AREA VISIBLE TO FLIGHT CREW

Documenting Wing Area Visible to Flight Crew

Industry regulations for operating in conditions involving ground deicing require the flight crew to perform pre-takeoff checks to ensure that the wings are still clean. Performance of those checks from inside the aircraft has some physical limitations associated with it, which for some aircraft types includes a restricted view of the wing surface. During the winter season 1996/97, an activity was conducted which photographed the area of the wing that is visible to the flight crew, for four aircraft types (McDonnell Douglas DC-9, Boeing 767, Airbus A340, DeHavilland Dash 8, and BAe 146). Results were reported in TP13130E Aircraft Full-Scale Test Program for the 1996/97 Winter[1].

This appendix provides similar photographic for other commercial aircraft types.

TABLE 5.1
VISIBILITY OF DC-9 WING

PHOTO	NUMBER	TITLE
5.1	DC-9-1	Flight Deck Placard – Tail Number
5.2	DC-9-2	Window at Row 14
5.3	DC-9-3	View of Wing form Aisle – Row 14
5.4	DC-9-4	View of Wing from Window – Row 14
5.5	DC-9-5	View of Wing form Aisle – Row 18
5.6	DC-9-6	View of Wing from Window – Row 18
5.7	DC-9-7	View of Inner Wing Leading Edge – Window at Row 18
5.8	DC-9-8	View of Inner Wing Trailing Edge – Window at Row 18
5.9	DC-9-9	Window at Row 22
5.10	DC-9-10	View form Aisle – Row 22
5.11	DC-9-11	View from Window – Row 22

TABLE 5.2
VISIBILITY OF B767 WING

PHOTO	NUMBER	TITLE
5.12	B767-1	Aircraft Tail Number
5.13	B767-2	View from flight Deck Window (Wing not Visible)
5.14	B767-3	Window at Row 6
5.15	B767-4	View of Wing from Aisle – Row 6
5.16	B767-5	View form Window – Row 6
5.17	B767-6	Overwing Exit – Row 17
5.18	B767-7	View of Wing from Overwing Exit
5.19	B767-8	Leading Edge – inner Wing from Aisle at Overwing
5.20	B767-9	Inner Wing – Trailing Edge – Overwing Exit from Aisle
5.21	B767-10	Window at Row 27
5.22	B767-11	Overview from Aisle – Row 27
5.23	B767-12	View form Window – Row 27
5.24	B767-13	Window at Row 34
5.25	B767-14	View form Aisle – Row 34
5.26	B767-15	View from Window – Row 34

TABLE 5.3
VISIBILITY OF A340 WING

PHOTO	NUMBER	TITLE
5.27	A340-1	A340 Fin 982
5.28	A340-2	Window at Row 14
5.29	A340-3	View form Window – Row 14
5.30	A340-4	View from Aisle – Row 14 – Wing Leading Edge
5.31	A340-5	Window at Row 22
5.32	A340-6	View of Wing from Aisle – Row 22
5.33	A340-7	View of Wing from Window – Row 22
5.34	A340-8	View of Inner Wing from Aisle - Row 32
5.35	A340-9	View of Outer Wing from Aisle - Row 32
5.36	A340-10	View of Wing from Window – Row 32

TABLE 5.4
VISIBILITY OF DHC DASH 8 WING

PHOTO	NUMBER	TITLE
5.37	DHC Dash 8-1	Flight Deck Placard – Tail Number
5.38	DHC Dash 8-2	View of Wing from Flight Deck
5.39	DHC Dash 8-3	View of Leading Edge form Window – Row 1
5.40	DHC Dash 8-4	View from Open Passenger Door
5.41	DHC Dash 8-10	View over Fuselage from Open Passenger Door

TABLE 5.5
VISIBILITY OF BAe 146 WING

PHOTO	NUMBER	TITLE
5.42	BAe 146-1	BAe 146 – Fin 203
5.43	BAe 146-2	View of Wing from Flight Deck
5.44	BAe 146-3	Window at Row 1
5.45	BAe 146-4	View from Window at Row 1
5.46	BAe 146-5	Rear Galley Door – Starboard Side
5.47	BAe 146-6	View from Rear Galley Door

Photo 5.1
Flight Deck Placard – Tail Number (DC-9-1)

Photo 5.2
Window at Row 14 (DC-9-2)

Photo 5.3
View of Wing from Aisle – Row 14 (DC-9-3)

Photo 5.4
View of Wing from Window – Row 14 (DC-9-4)

Photo 5.5
View of Wing from Aisle – Row 18 (DC-9-5)

Photo 5.6
View of Wing from Window – Row 18 (DC-9-6)

Photo 5.7
View of Inner Wing leading Edge - Window at Row 18 (DC-9-7)

Photo 5.8

View of Inner Wing Trailing Edge – Window at Row 18 (DC-9-8)

Photo 5.9
Window at Row 22 (DC-9-9)

Photo 5.10
View from Aisle – Row 22 (DC-9-10)

Photo 5.11
View from Window - Row 22 (DC-9-11)

Photo 5.12
Aircraft Tail Number (B767-1)

Photo 5.13
View from Flight Deck Closed Window (Wing not Visible) (B767-2)

Photo 5.14
Window at Row 6 (B767-3)

Photo 5.15
View of Wing from Aisle – Row 6 (B767-4)

Photo 5.16
View from Window – Row 6 (B767-5)

Photo 5.17
Overwing Exit - Row 17 (B767-6)

Photo 5.18
View of Wing from Overwing Exit (B767-7)

Photo 5.19
Leading Edge – Inner Wing from Aisle at Overwing Exit (B767-8)

Photo 5.20
Inner Wing – Trailing Edge – Overwing Exit from Aisle (B767-9)

Photo 5.21
Window at Row 27 (B767-10)

Photo 5.22
Overview from Aisle – Row 27 (B767-11)

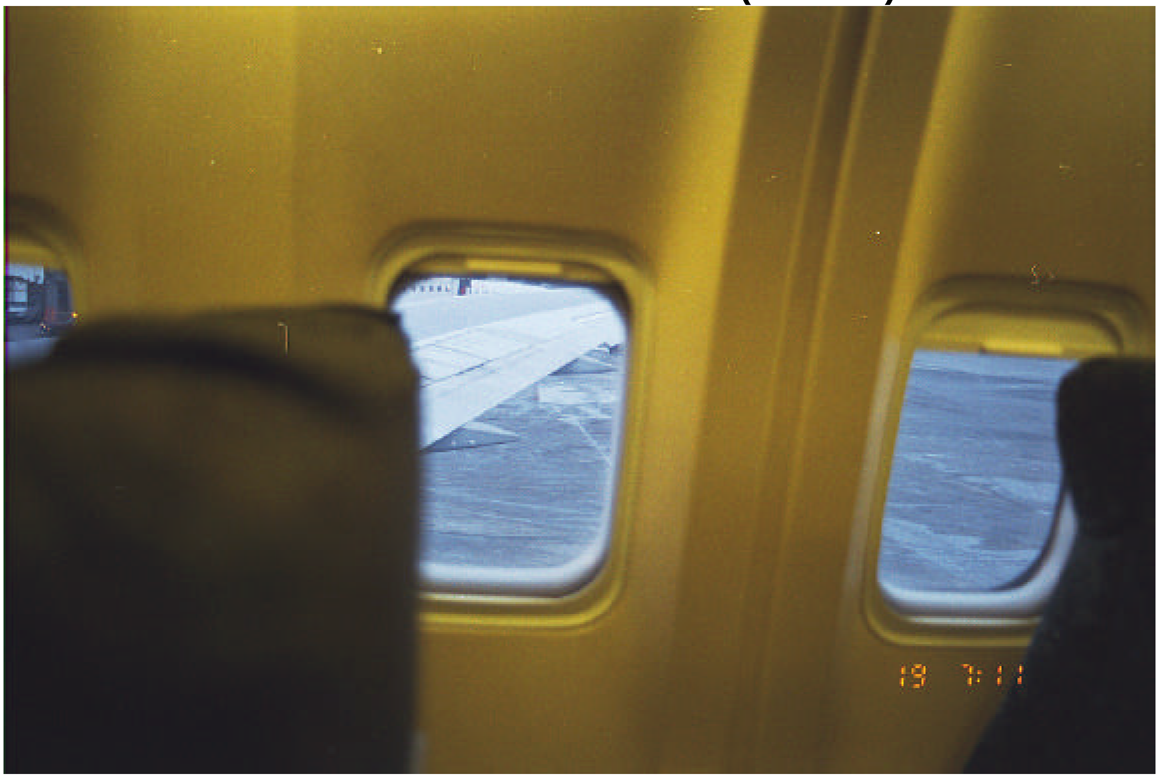


Photo 5.23
View from Window – Row 27 (B767-12)

Photo 5.24
Window at Row 34 (B767-13)

Photo 5.25
View from Aisle – Row 34 (B767-14)

Photo 5.26
View from Window – Row 34 (B767-15)

Photo 5.27
A340 Fin 982 (A340-1)

Photo 5.28
Window at Row 14 (A340-2)

Photo 5.29
View from Window – Row 14 (A340-3)

Photo 5.30
View from Aisle - Row 14 – Wing Leading Edge (A340-4)

Photo 5.31
Window at Row 22 (A340-5)

Photo 5.32
View of Wing from Aisle – Row 22 (A340-6)

Photo 5.33
View of Wing from Window - Row 22 (A340-7)

Photo 5.34

View of Inner Wing from Aisle – Row 32 (A340-8)

Photo 5.35

View of Outer Wing from Aisle - Row 32 (A340-9)

Photo 5.36
View of Wing from Window - Row 32 (A340-10)

Photo 5.37
Flight Deck Placard – Tail Number (DHC Dash 8-1)

Photo 5.38
View of Wing from Flight Deck (DHC Dash 8-2)

Photo 5.39
View of Leading Edge from Window – Row 1 (DHC Dash 8-3)

Photo 5.40

View from Open Passenger Door (DHC Dash 8-4)

Photo 5.41

View over Fuselage from Open Passenger Door (DHC Dash 8-5)

Photo 5.42
BAe 146 – Fin 203 (BAe 146-1)

Photo 5.43
View from Flight Deck (BAe 146-2)

Photo 5.44
Window at Row 1 (BAe 146-3)

Photo 5.45
View from Window at Row 1 (BAe 146-4)

Photo 5.46
Rear Galley Door – Starboard Side (BAe 146-5)

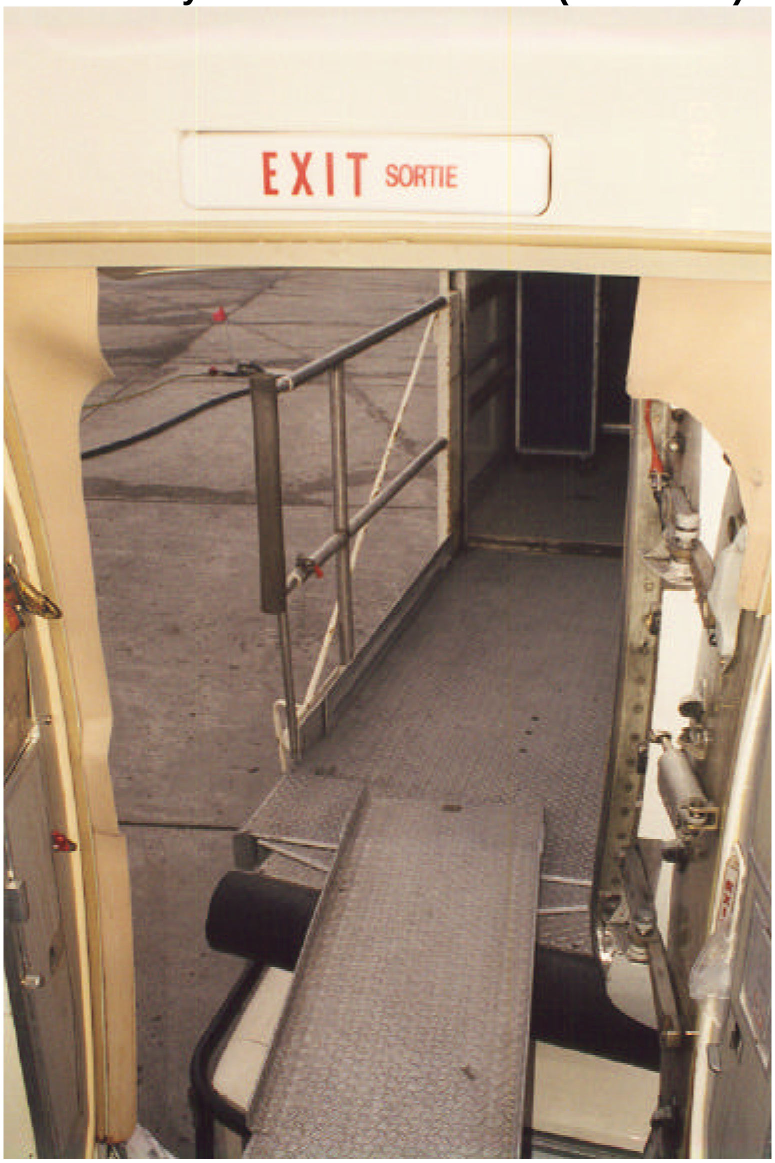


Photo 5.47
View from Rear Galley Door (BAe 146-6)

APPENDIX I

AIRCRAFT THREE VIEWS

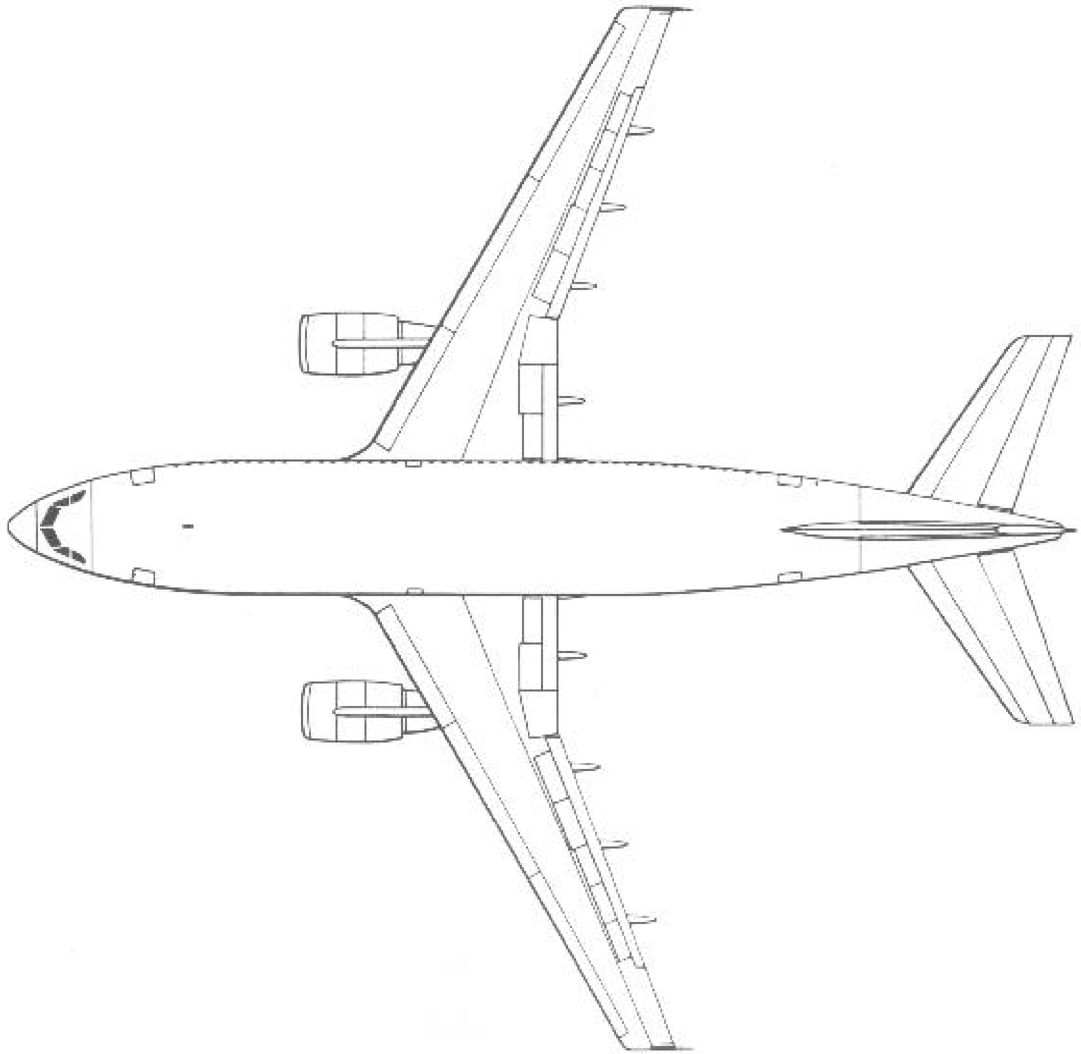
The following aircraft have been scanned and three views are included in this appendix.

List of all the aircraft:

- Airbus A310
- Airbus A320
- ATR 42
- BAe 146
- Beechcraft 90
- Beechcraft KA100
- Beechcraft SKA200
- Beechcraft 1900D
- Boeing 727
- Boeing 737
- Boeing 747
- Boeing 757
- Boeing 767
- Canadair Challenger
- Canadair Regional Jet
- Cessna Citation III
- Convair 580
- DHC Dash7
- DHC Dash8
- DHC Twin Otter
- Douglas DC-3
- McDonnell Douglas DC-9
- McDonnell Douglas DC-10
- Falcon 20
- Fokker F28
- Grumman Gulfstream I
- Jetstream 31
- Jetstream 41
- Lockheed L-1011
- Saab 340
- Swearingen SA226/7
- Shorts SD-330
- Shorts SD-360

Airbus A310

Priority Critical Surface Inspection Areas



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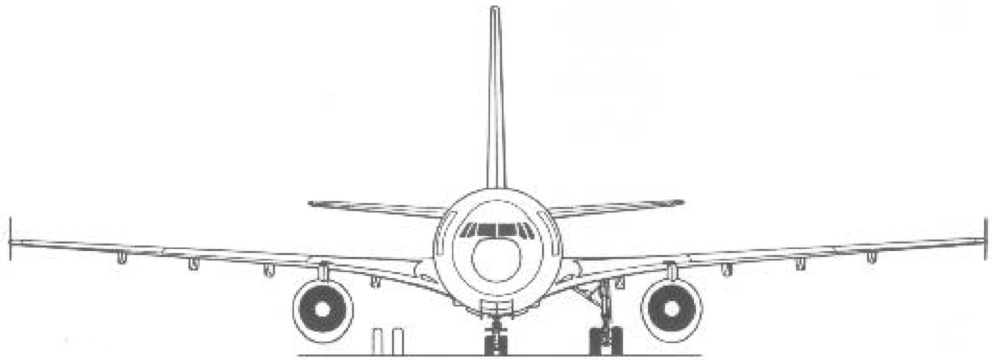
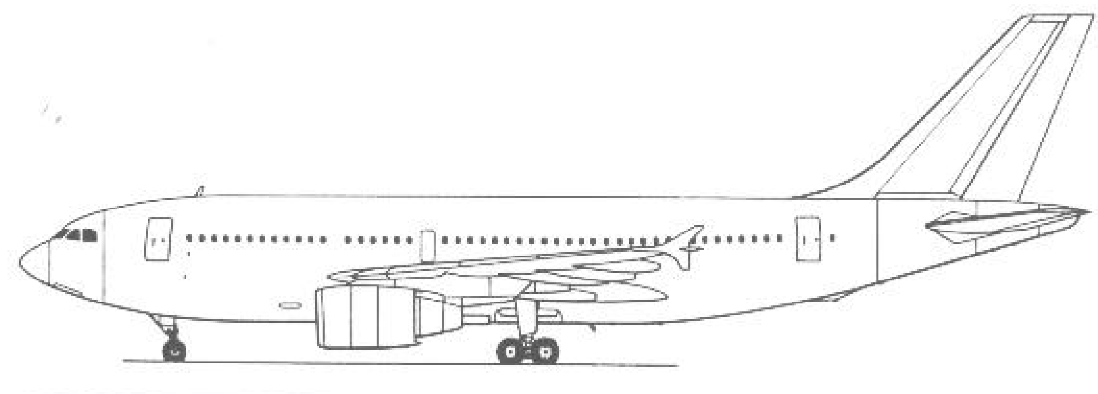
Airbus A310

Priority Critical Surface Inspection Areas





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Airbus A320

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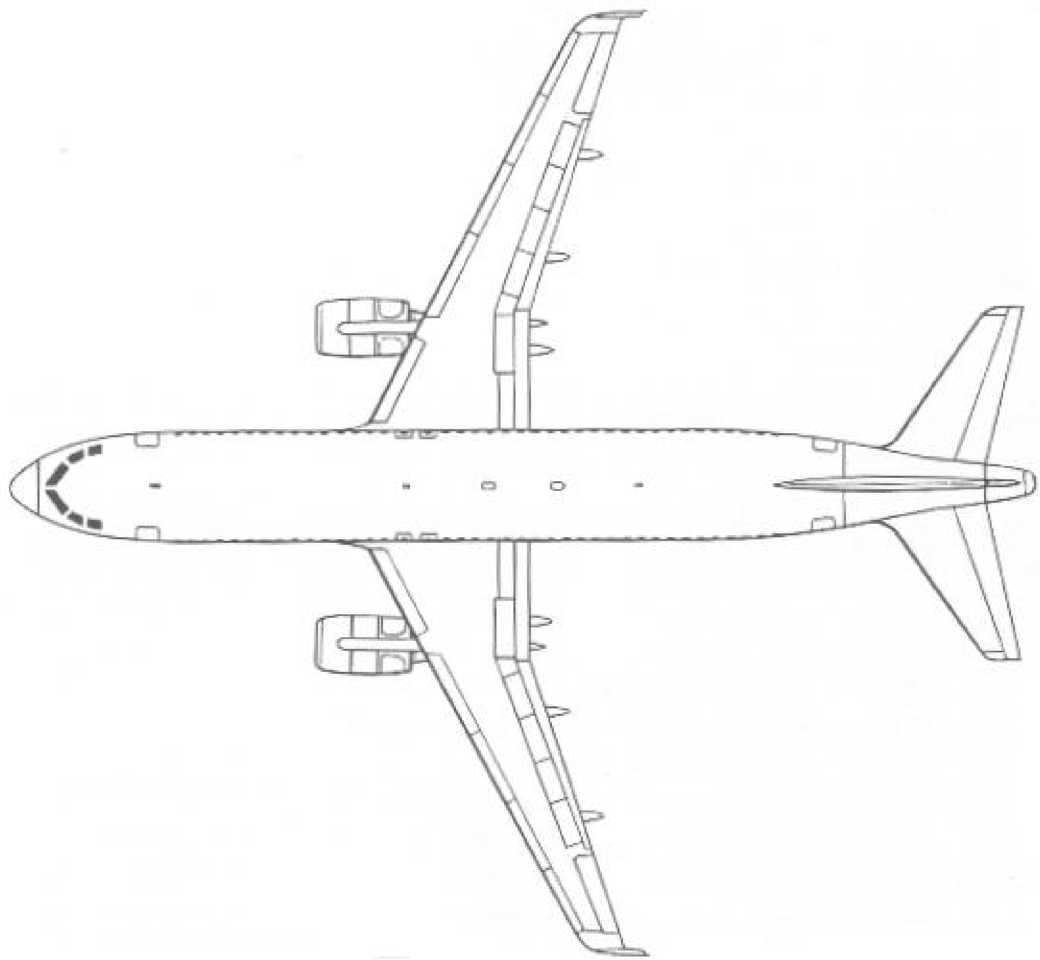

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Airbus A320

Priority Critical Surface Inspection Areas

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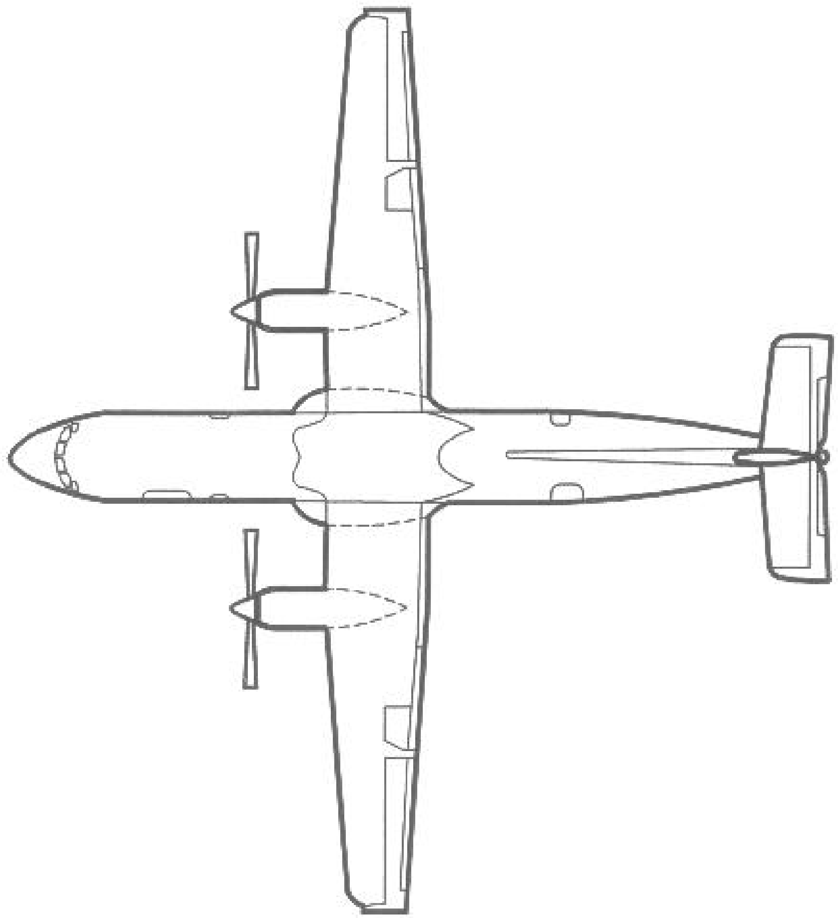
ATR 42

Priority Critical Surface Inspection Areas



ATR 42

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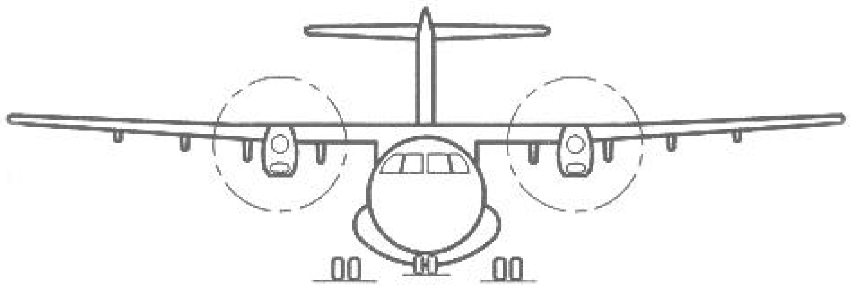

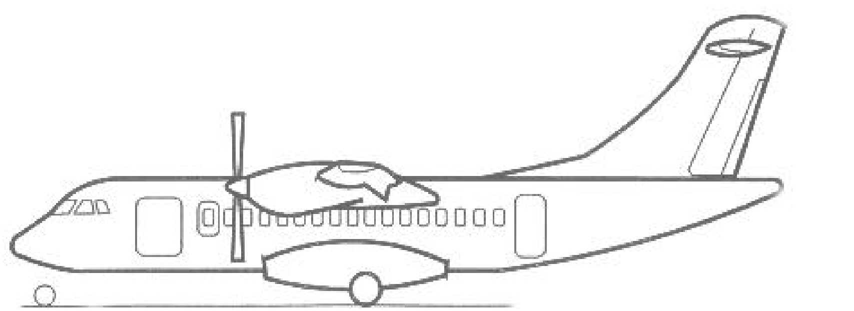

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BAe 146

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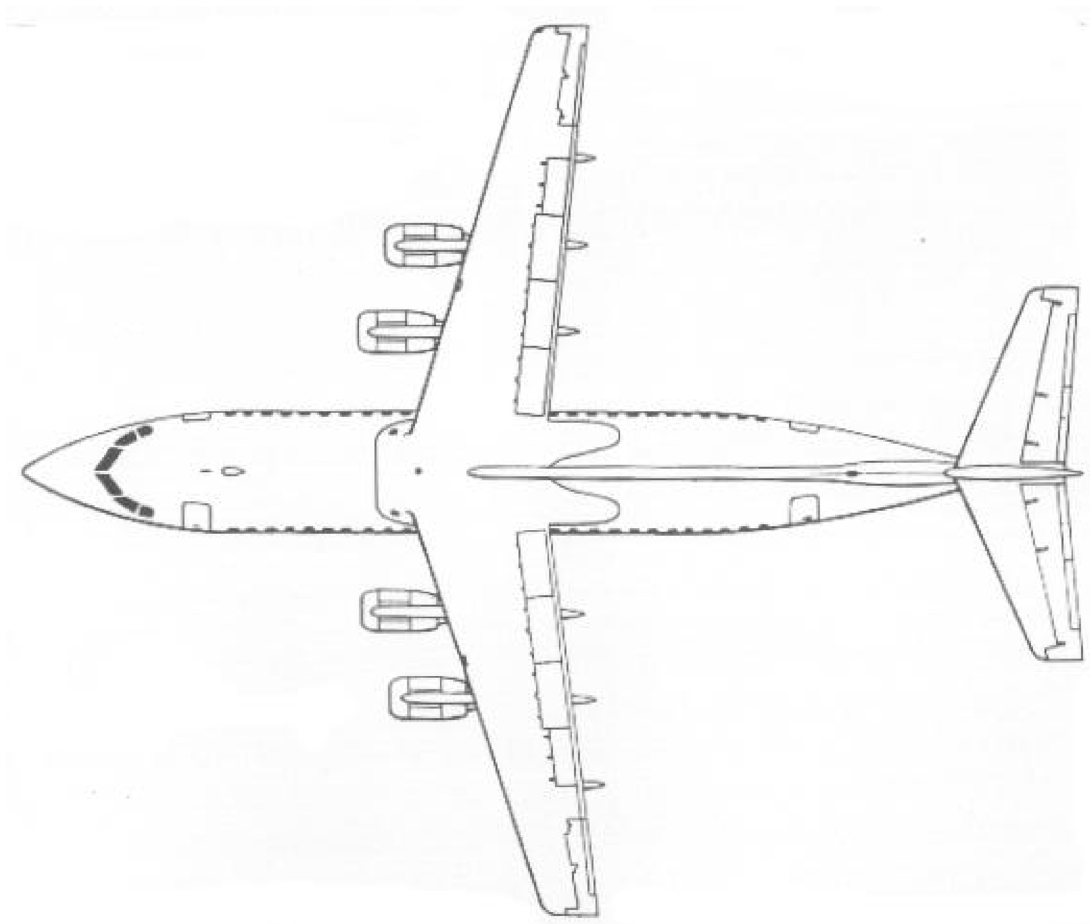

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BAe 146

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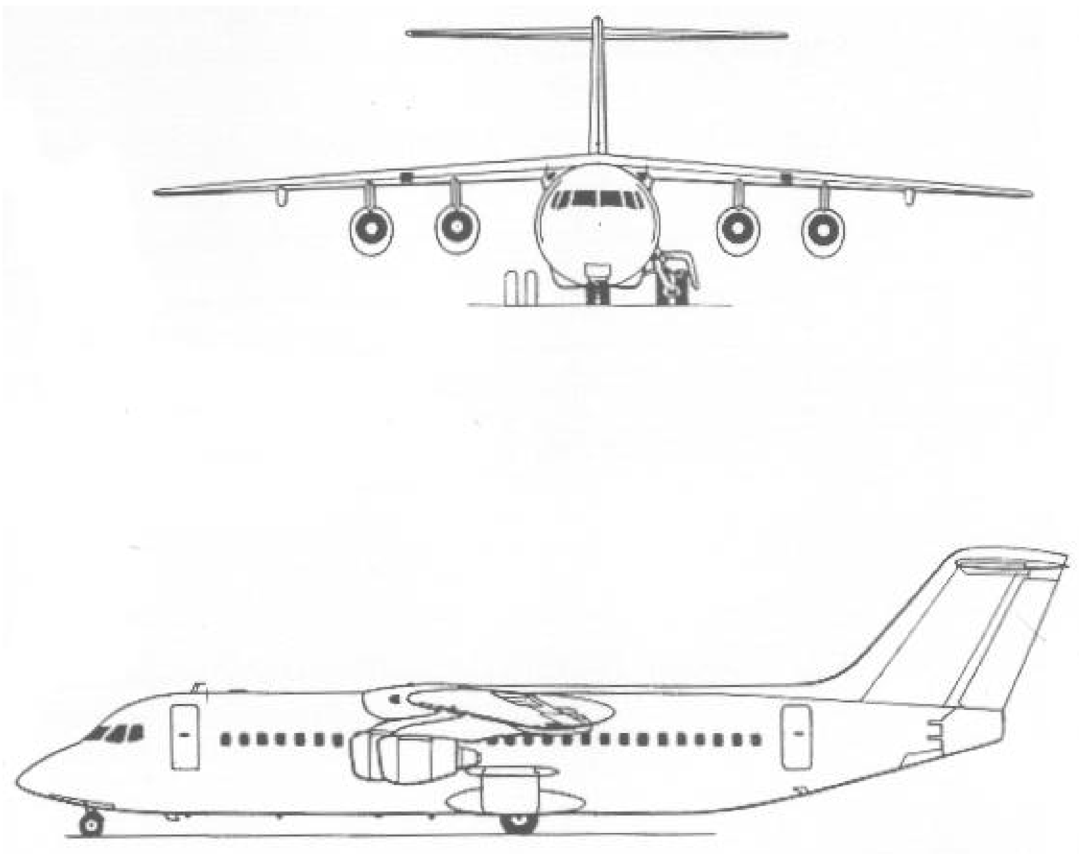

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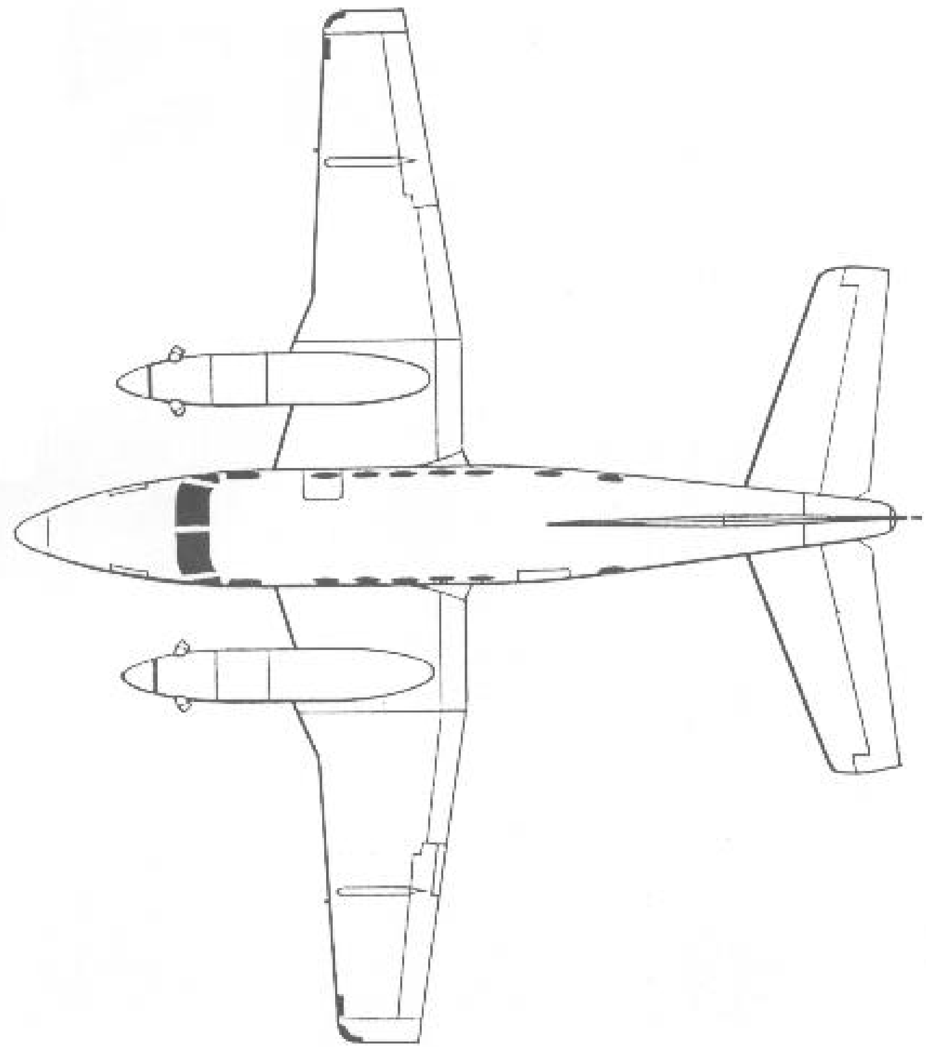
Beechcraft 90

Priority Critical Surface Inspection Areas



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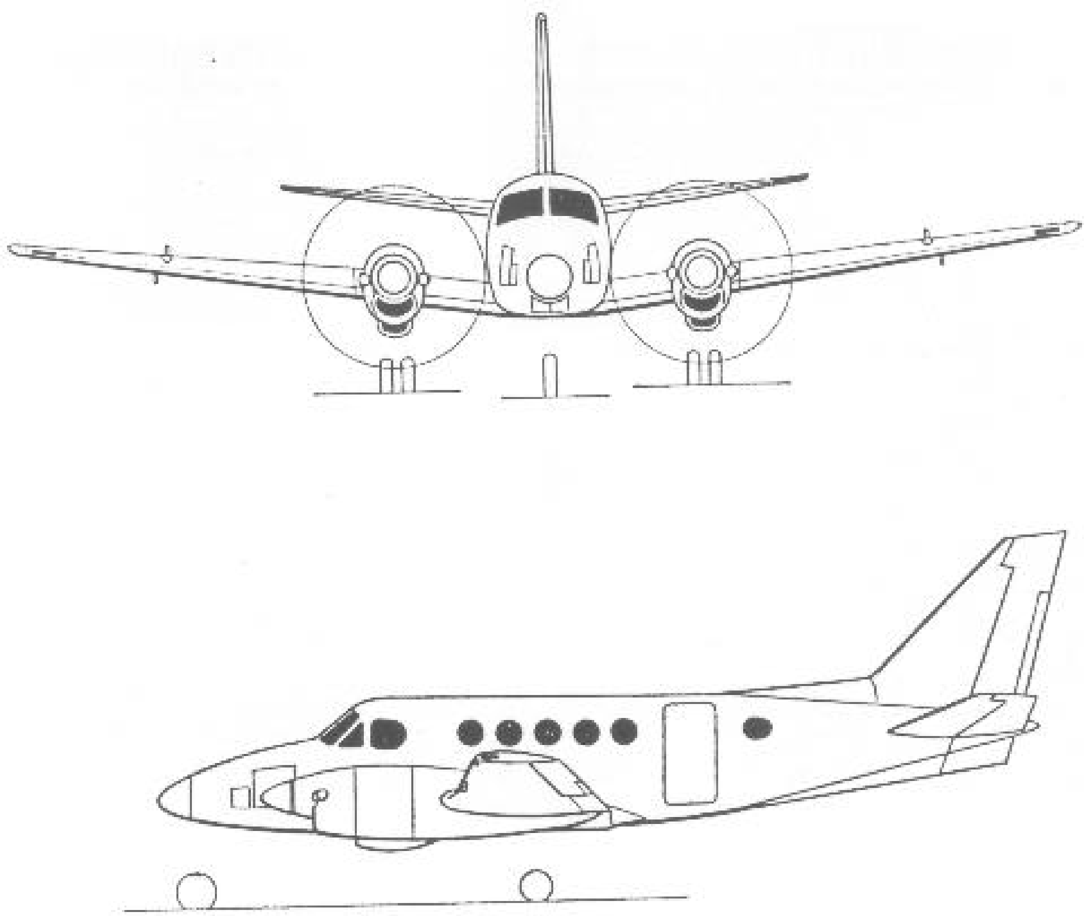
Beechcraft 90

Priority Critical Surface Inspection Areas



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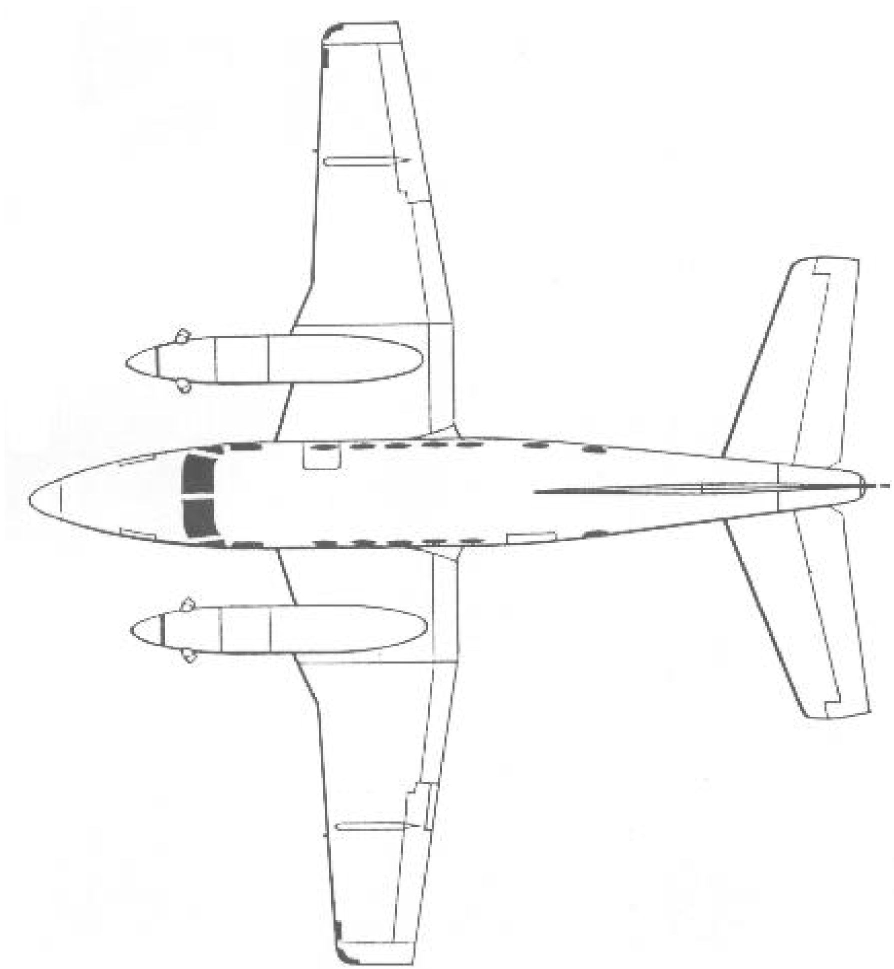
Beechcraft KA100

Priority Critical Surface Inspection Areas



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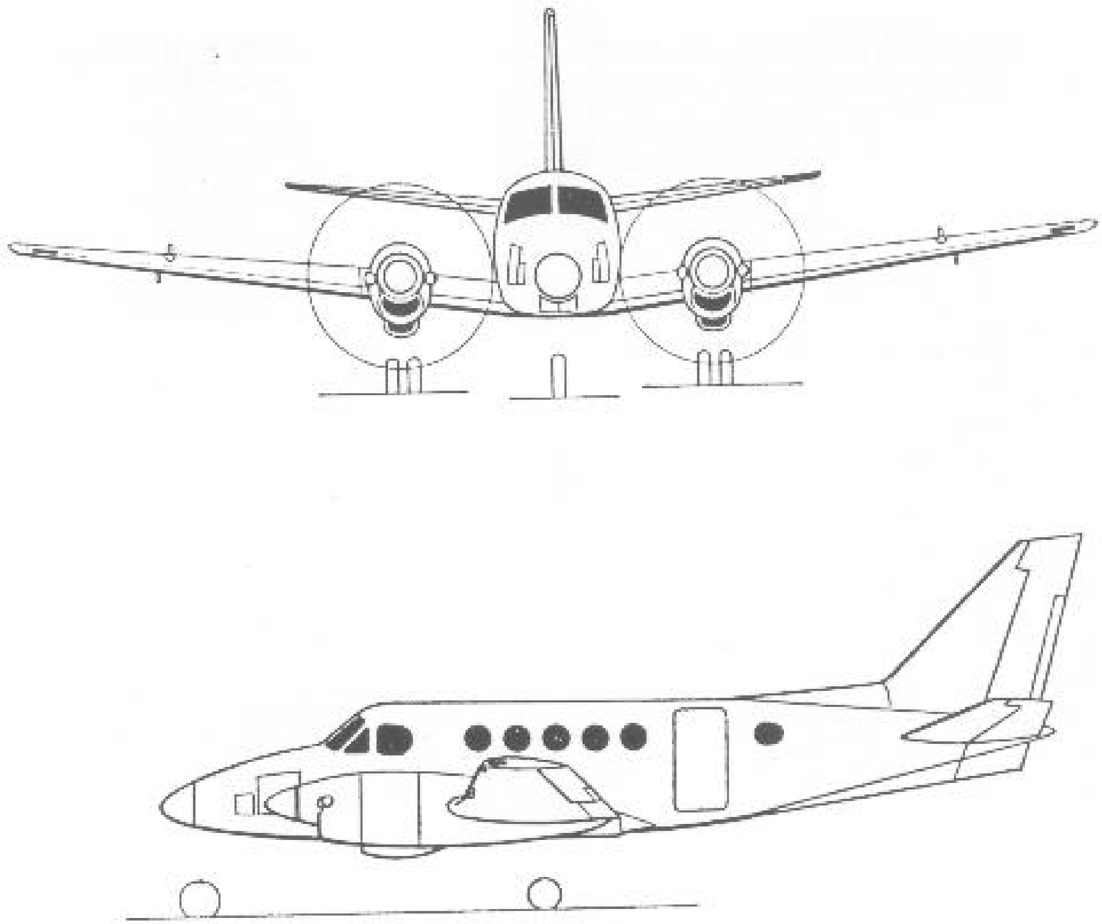
Beechcraft KA100

Priority Critical Surface Inspection Areas



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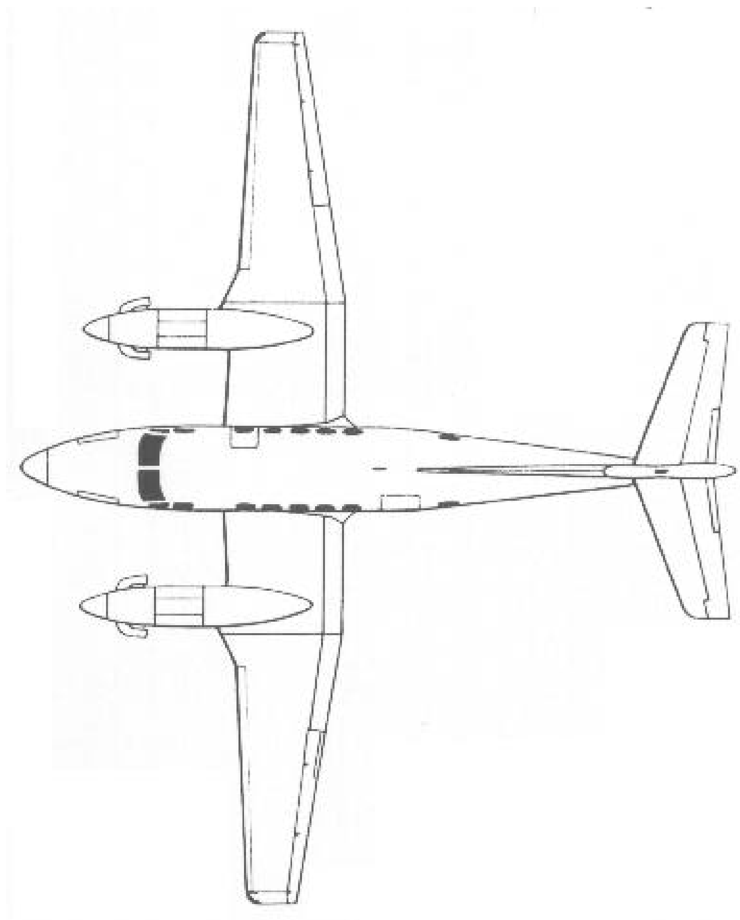
Beechcraft SKA200

Priority Critical Surface Inspection Areas



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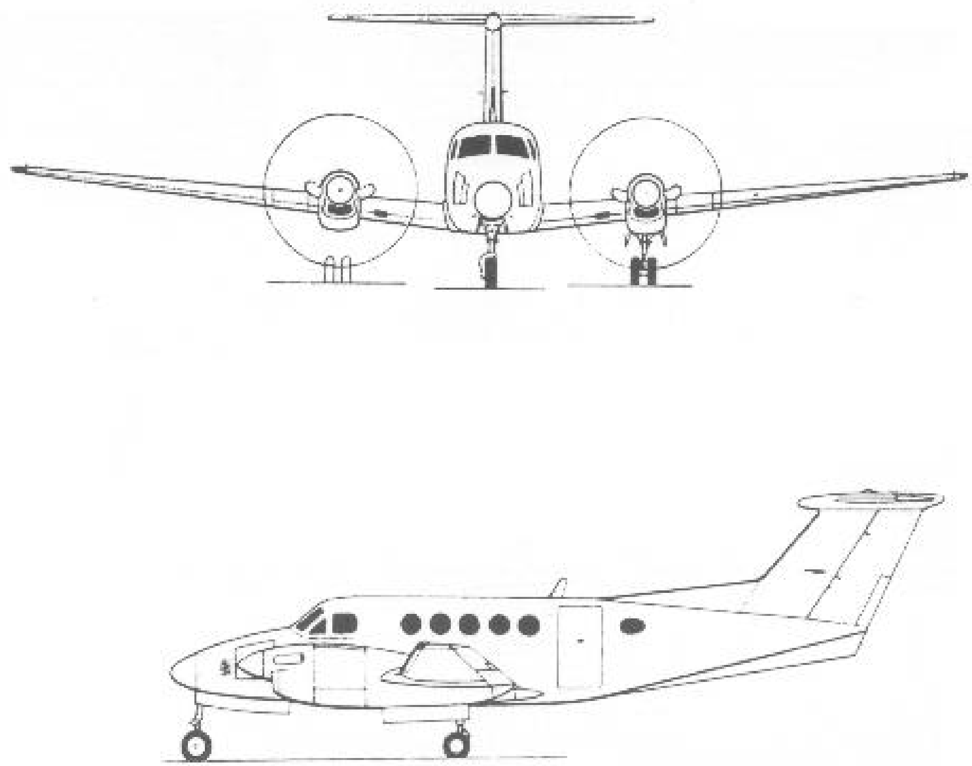
Beechcraft SKA200

Priority Critical Surface Inspection Areas



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Beechcraft 1900D

Priority Critical Surface Inspection Areas

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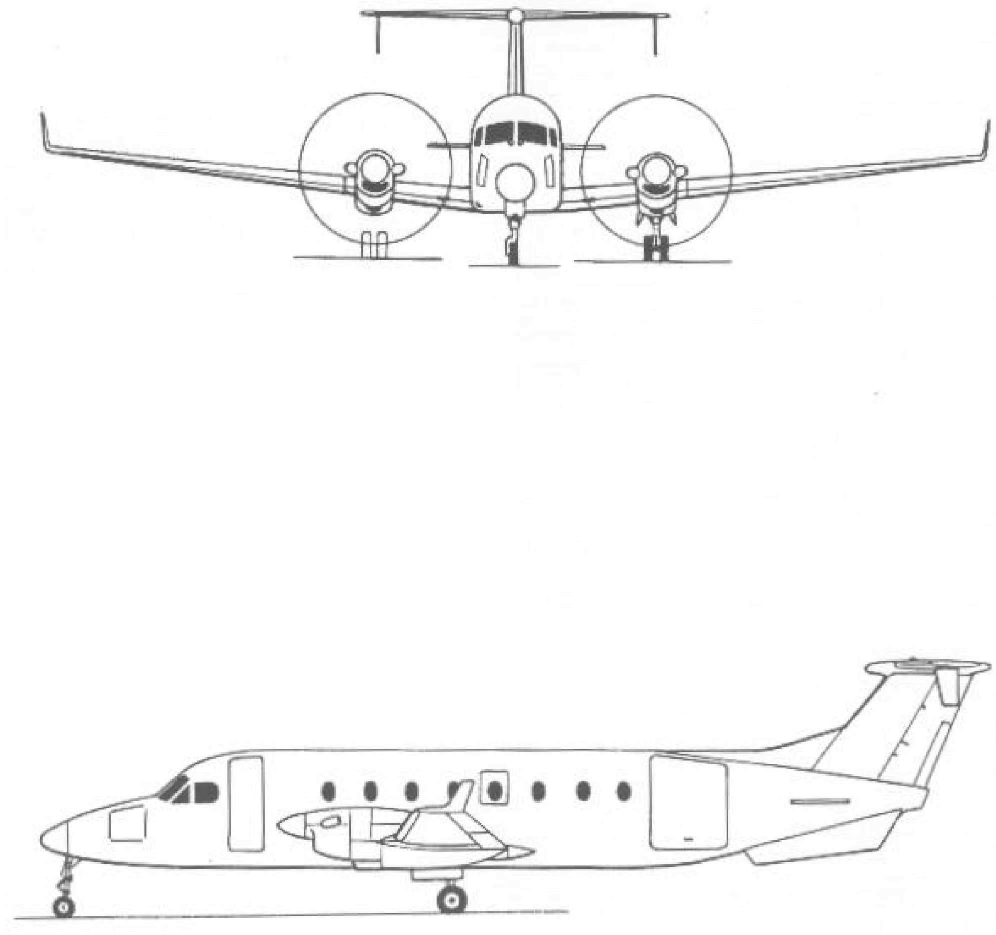
Beechcraft 1900D

Priority Critical Surface Inspection Areas



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Boeing 727

Priority Critical Surface Inspection Areas

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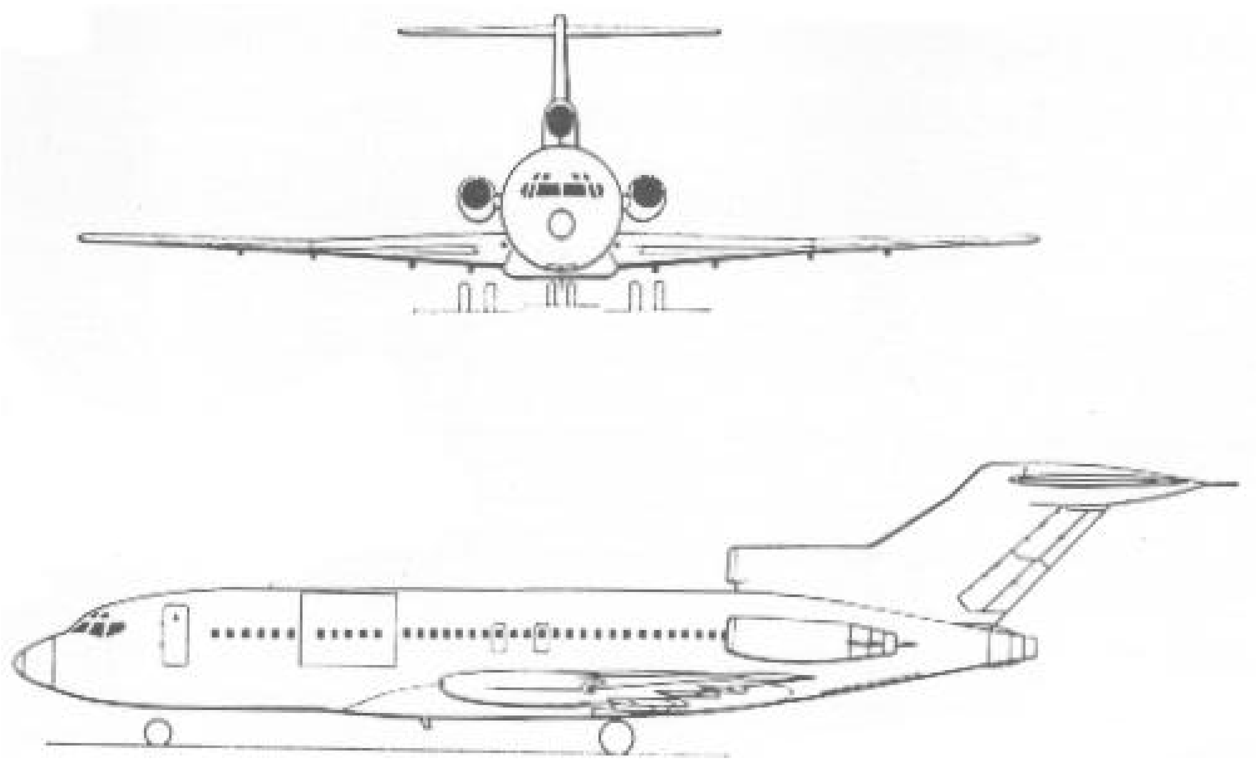
Boeing 727

Priority Critical Surface Inspection Areas



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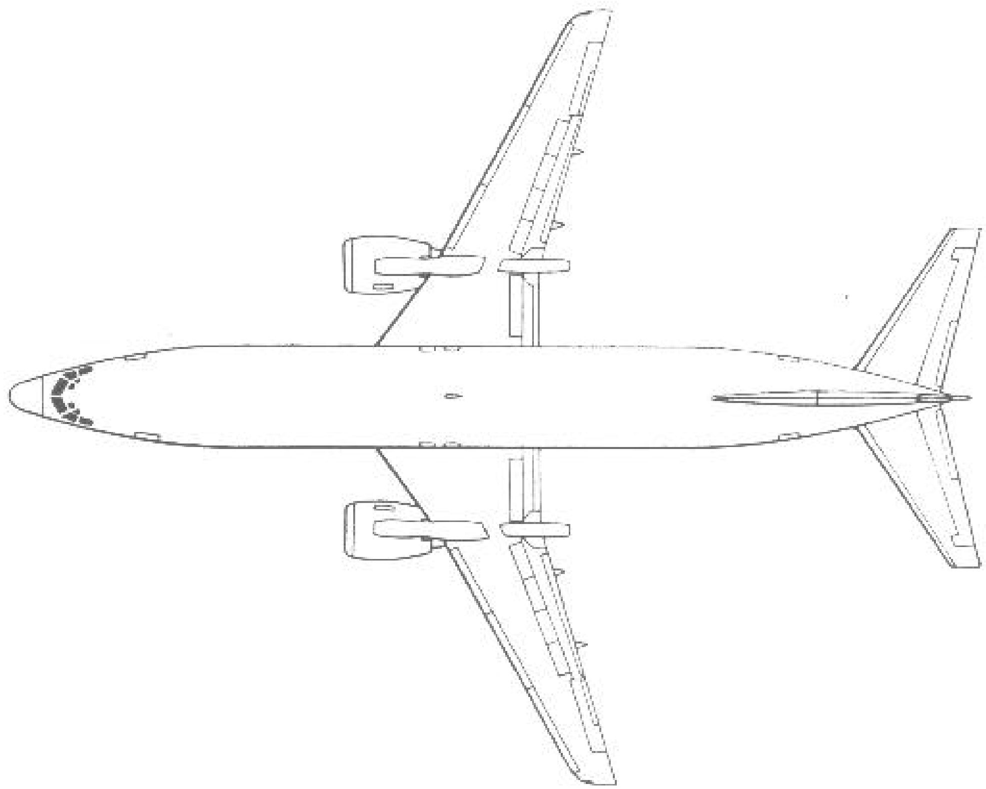
Boeing 737

Priority Critical Surface Inspection Areas



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Boeing 737

Priority Critical Surface Inspection Areas

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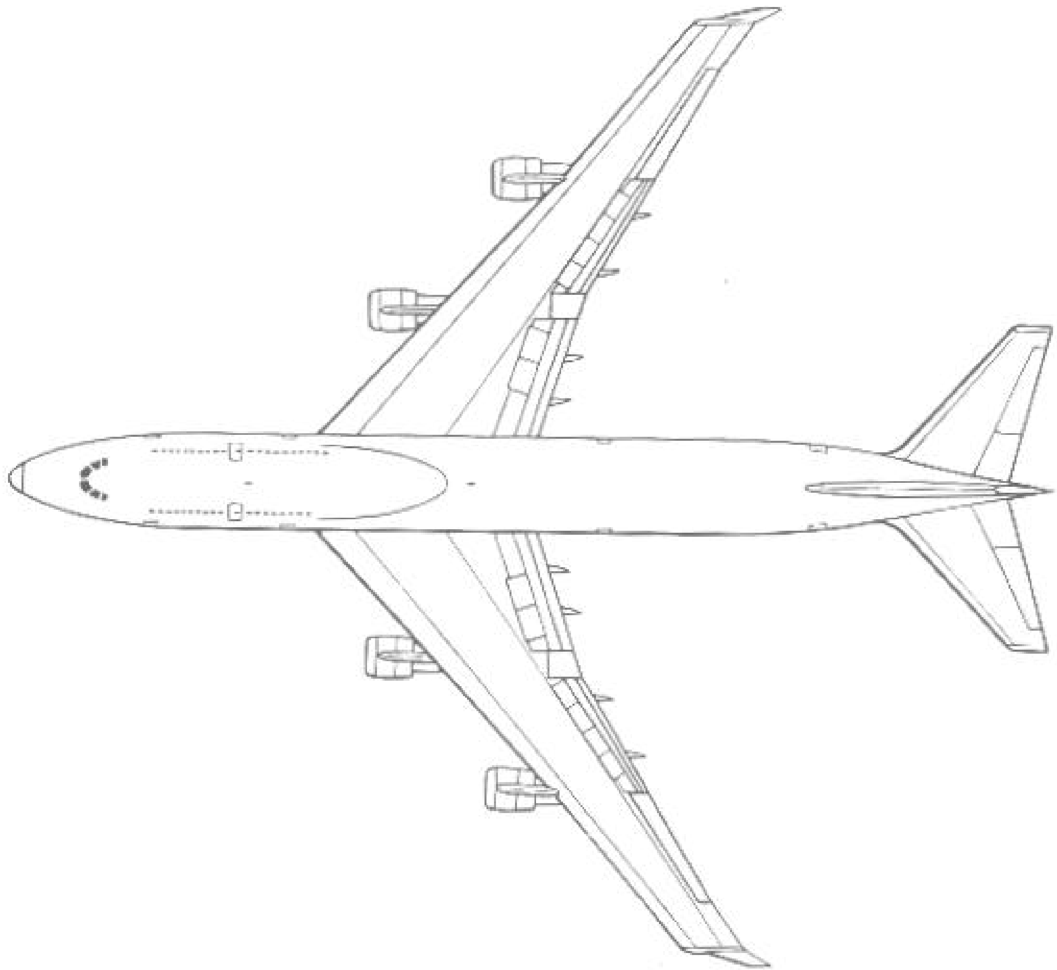
Boeing 747

Priority Critical Surface Inspection Areas



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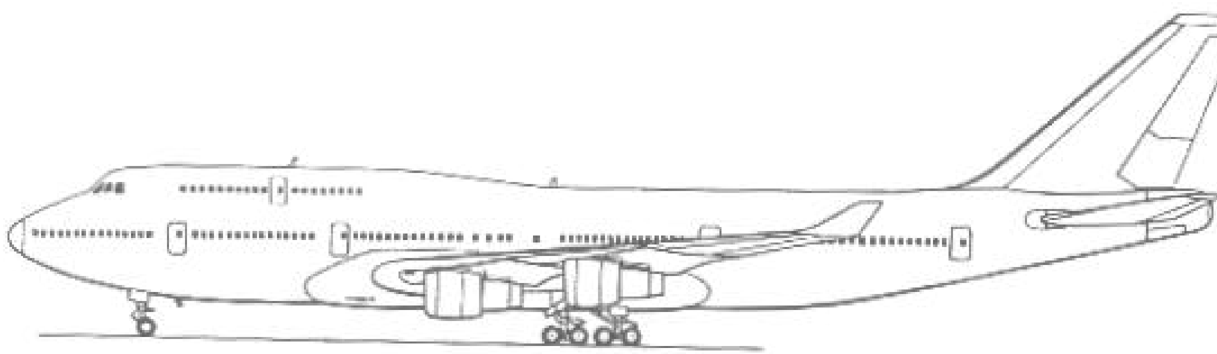
Boeing 747

Priority Critical Surface Inspection Areas



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Boeing 757

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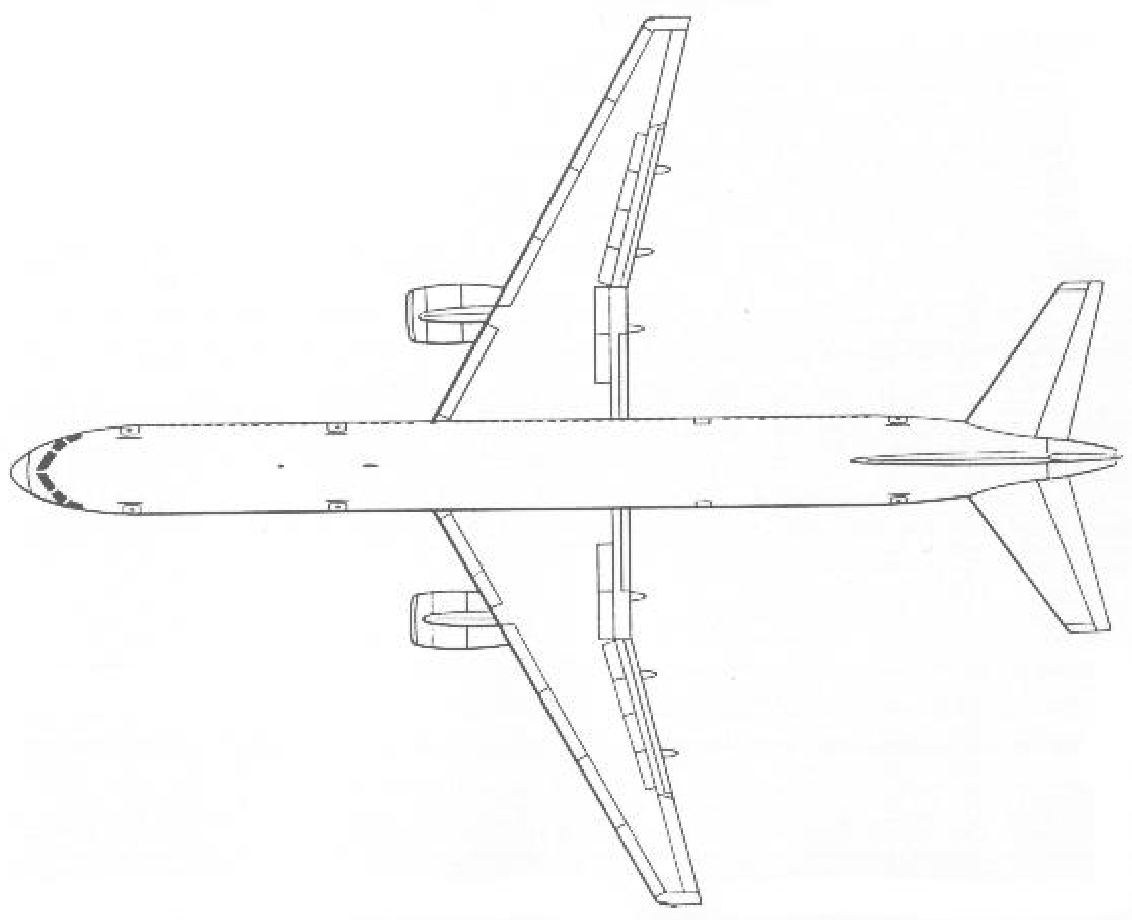

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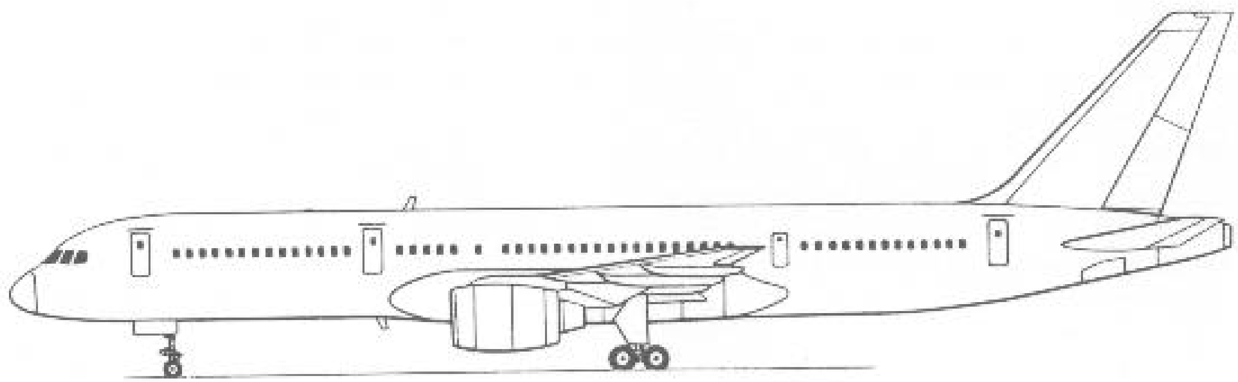
Boeing 757

Priority Critical Surface Inspection Areas



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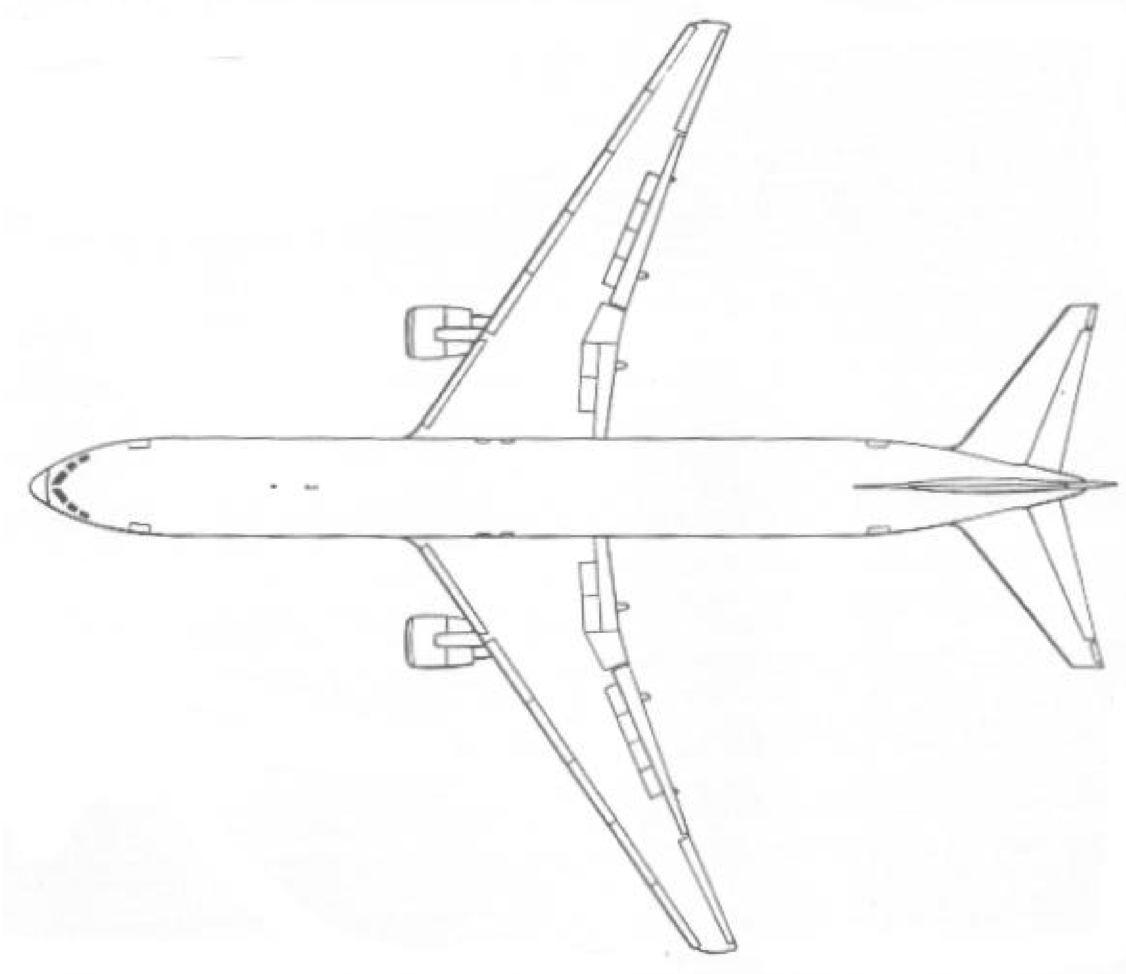
Boeing 767

Priority Critical Surface Inspection Areas



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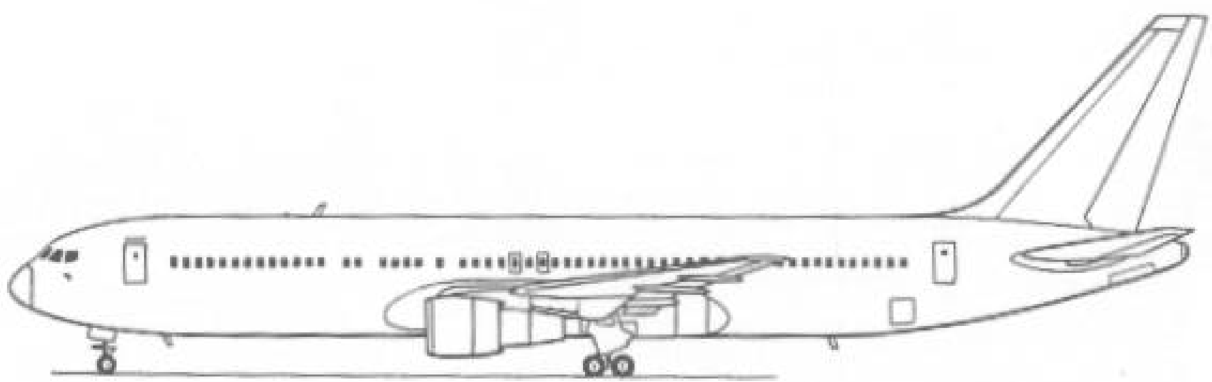
Boeing 767

Priority Critical Surface Inspection Areas



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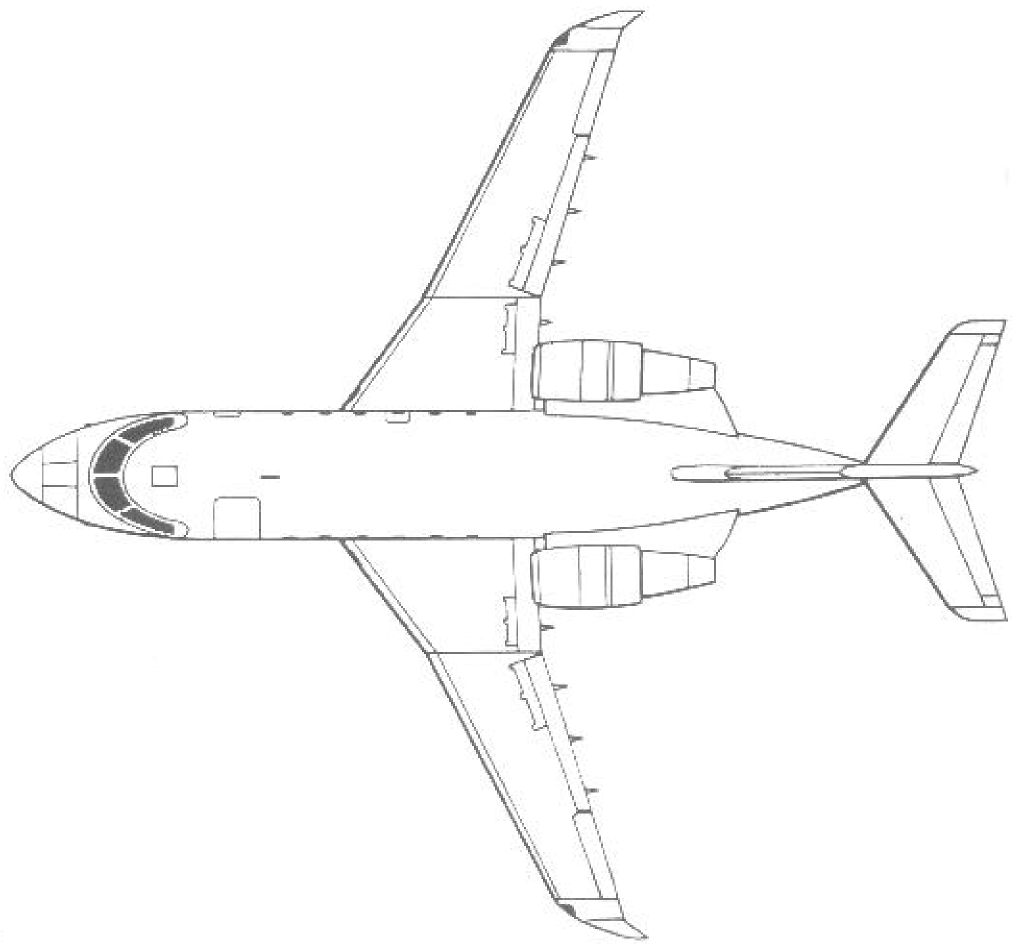
Canadair Challenger

Priority Critical Surface Inspection Areas



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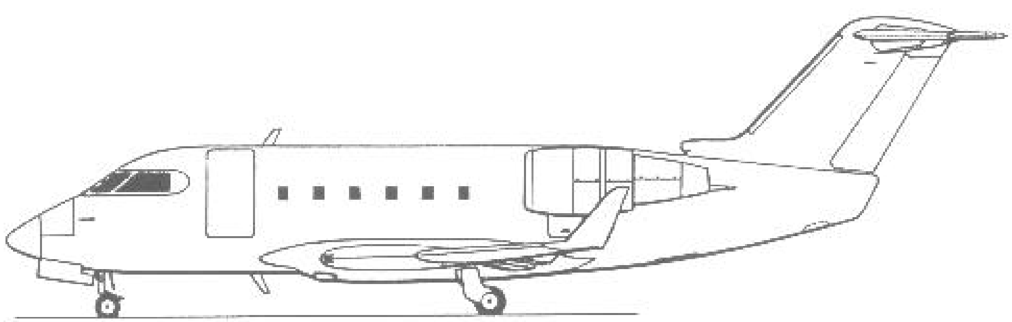
Canadair Challenger

Priority Critical Surface Inspection Areas



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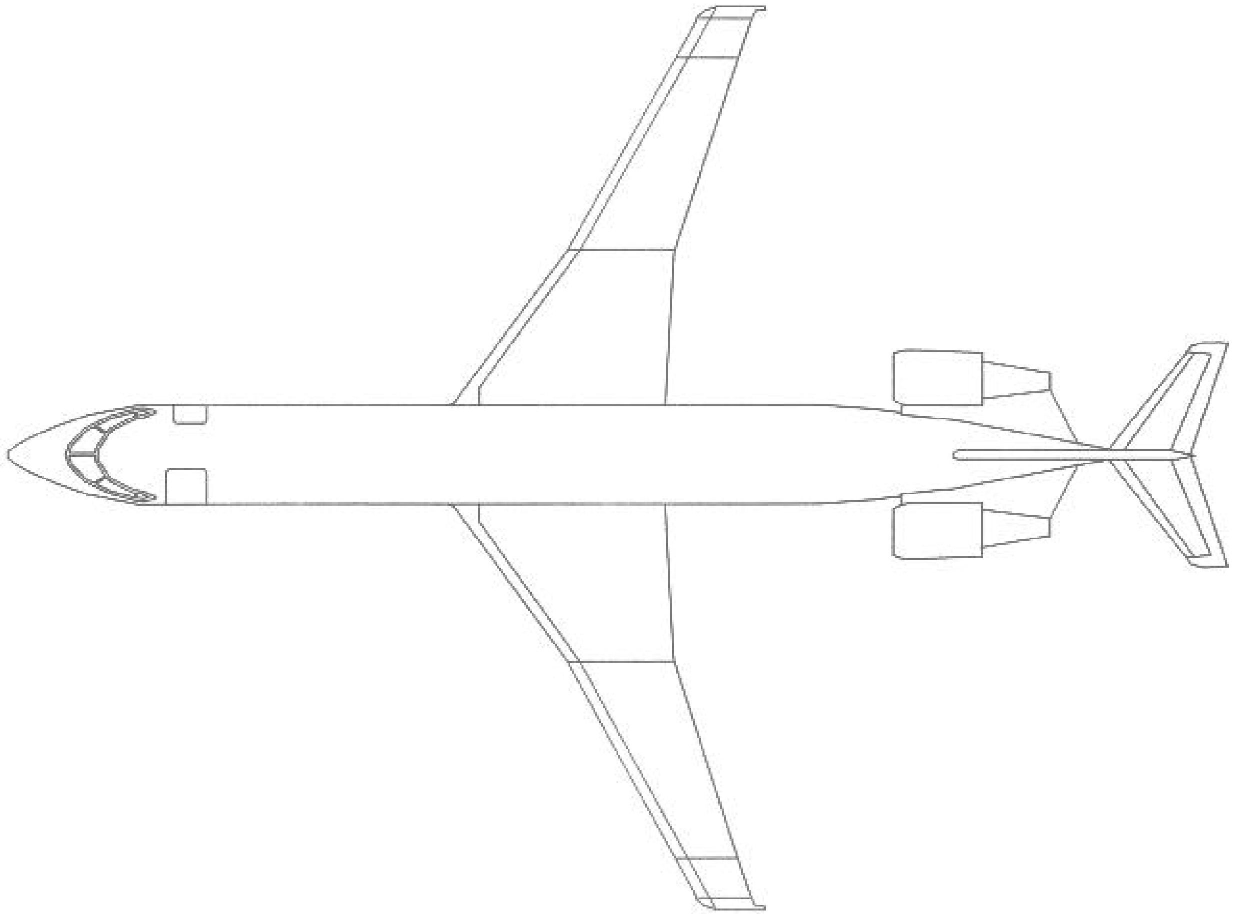
Canadair Regional Jet

Priority Critical Surface Inspection Areas



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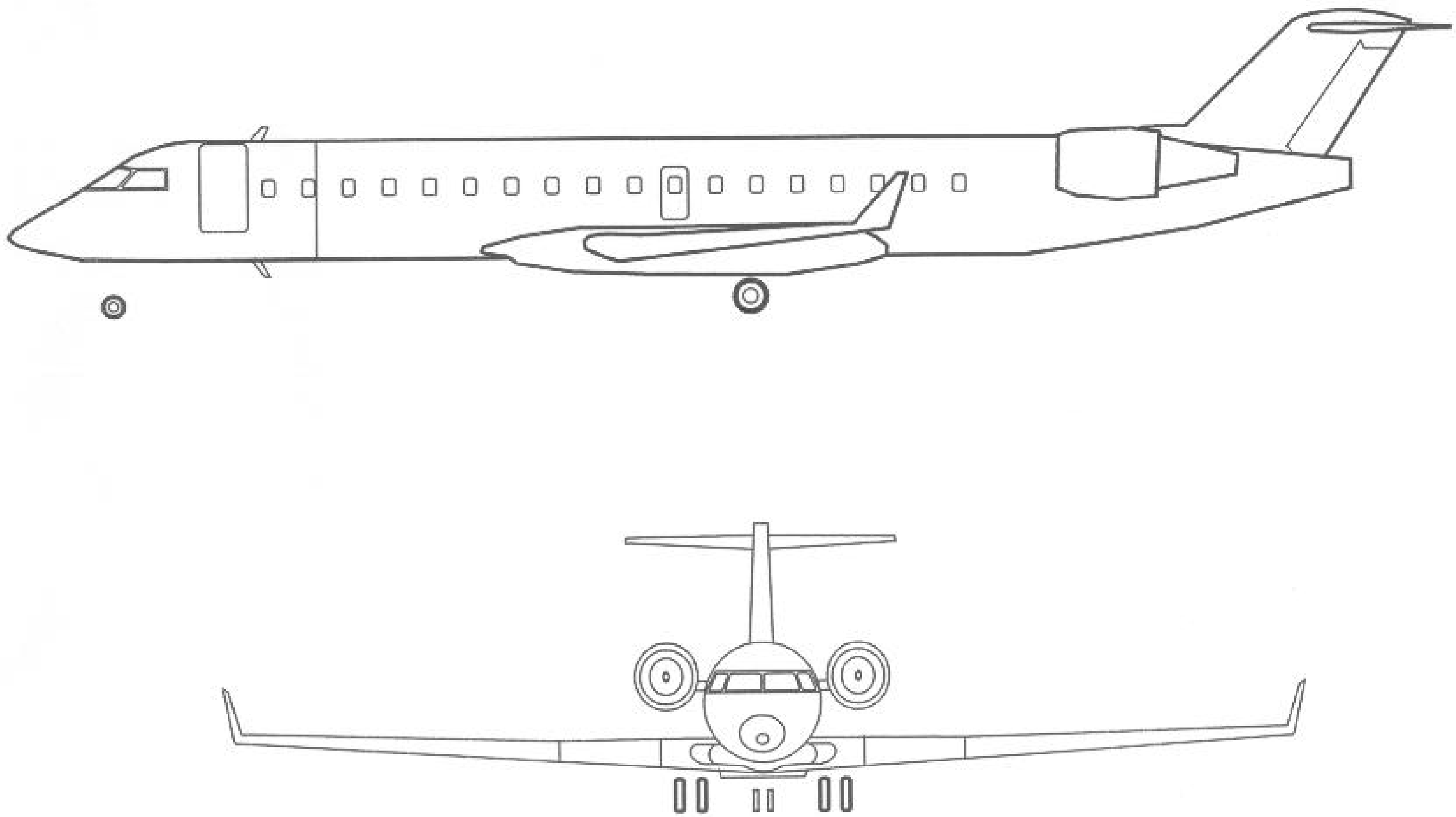
Canadair Regional Jet

Priority Critical Surface Inspection Areas



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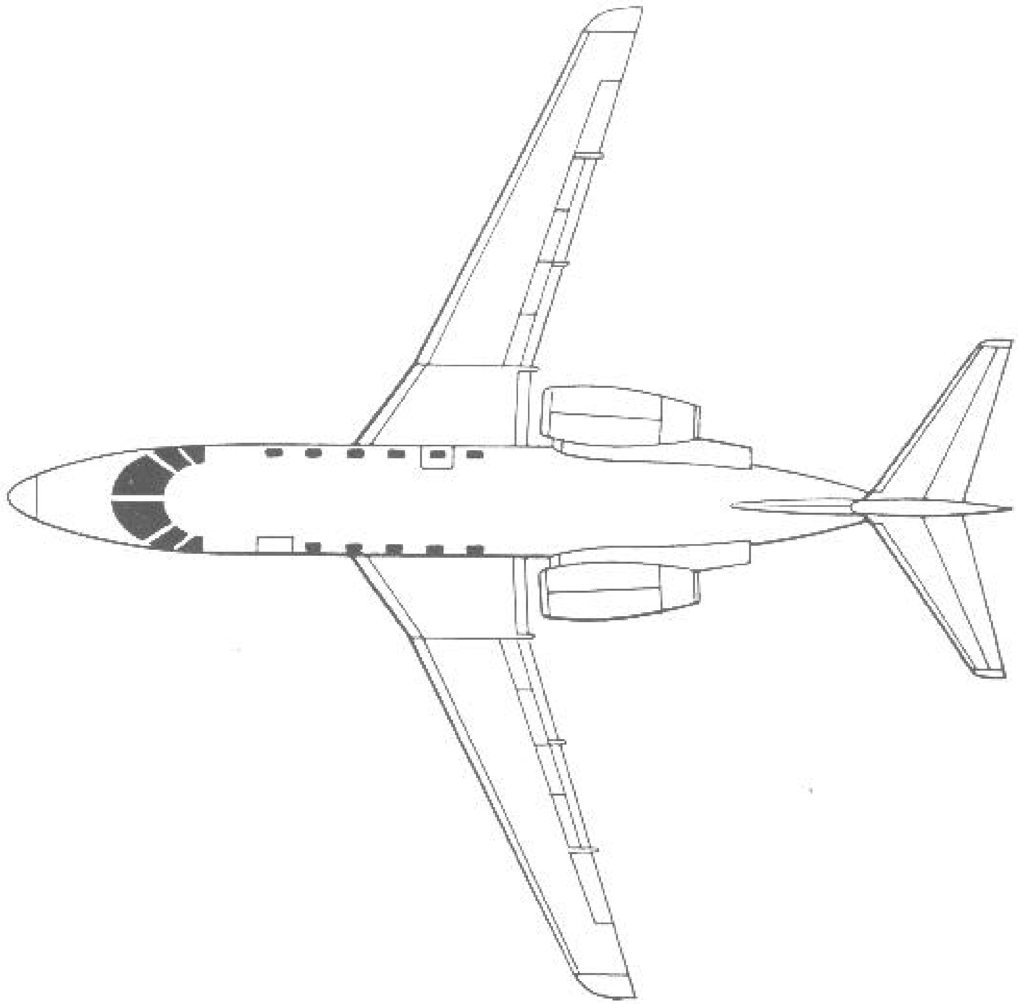
Cessna Citation III

Priority Critical Surface Inspection Areas



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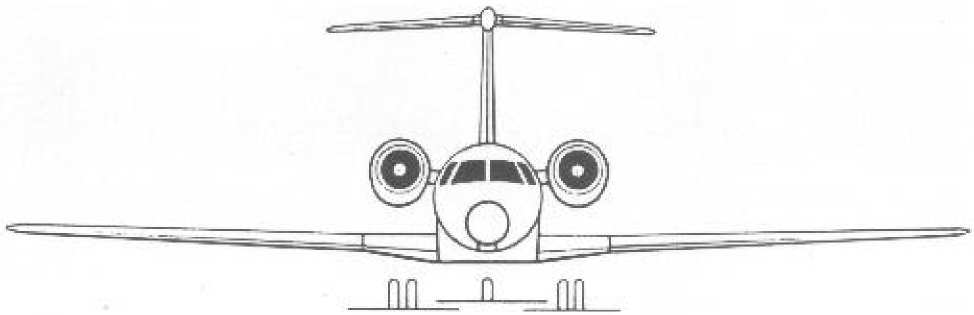
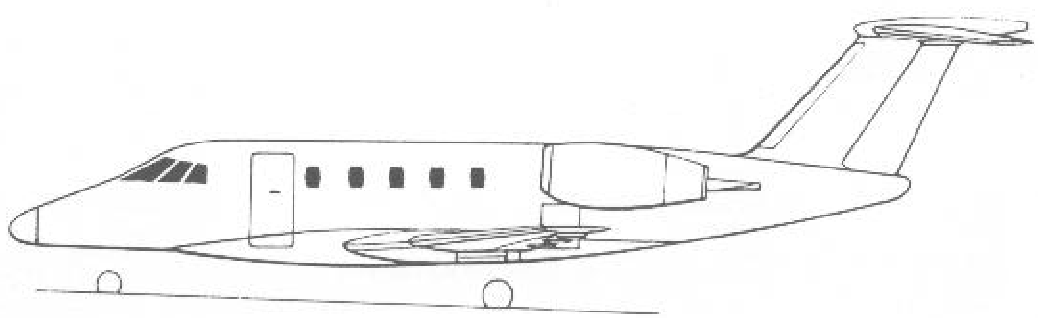
Cessna Citation III

Priority Critical Surface Inspection Areas





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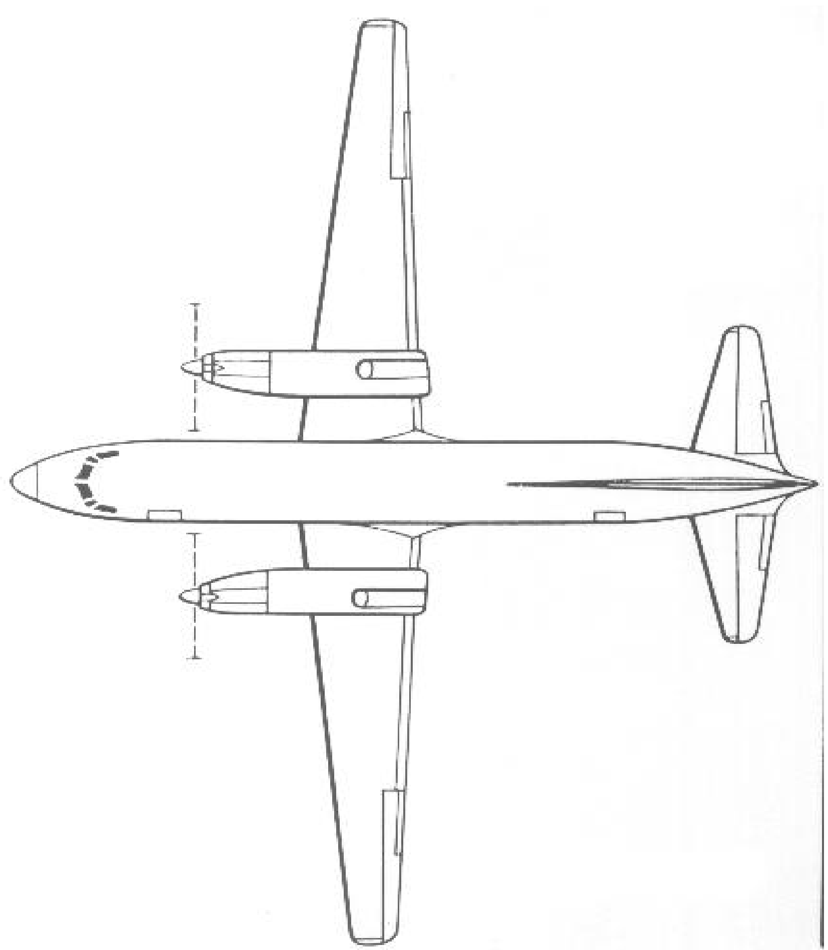
Convair 580

Priority Critical Surface Inspection Areas



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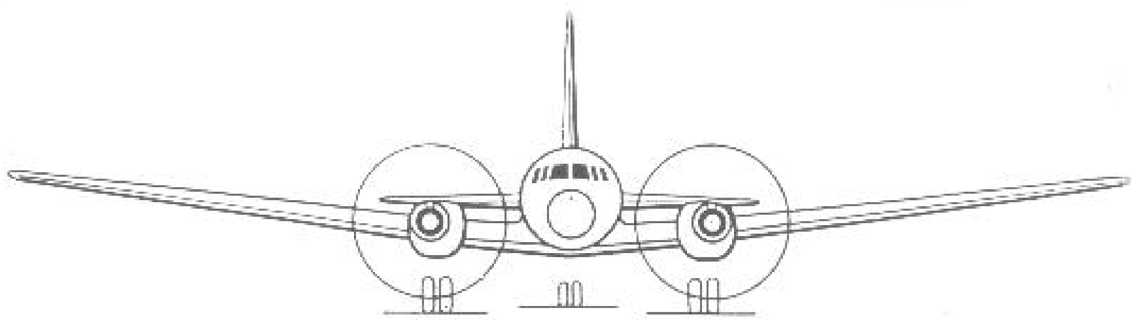
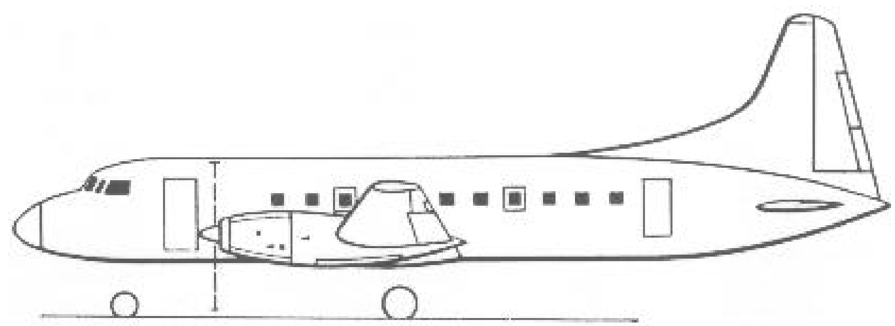
Convair 580

Priority Critical Surface Inspection Areas





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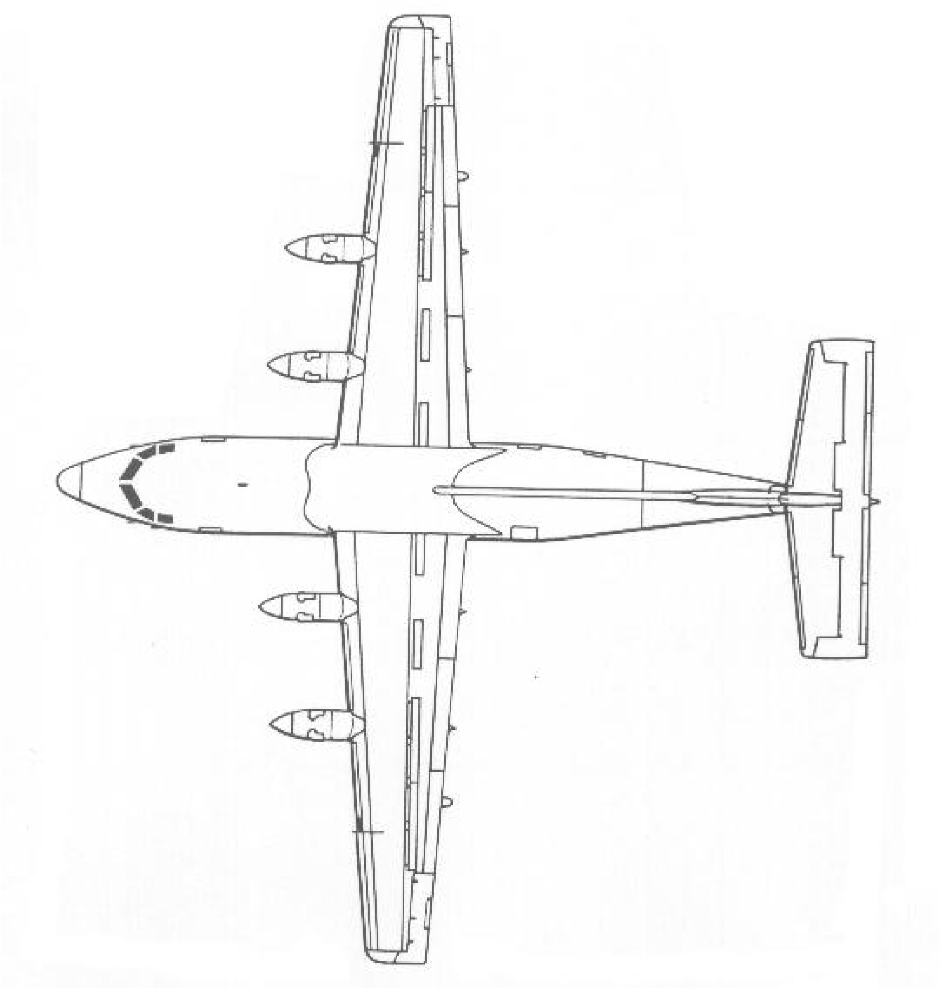
DHC Dash7

Priority Critical Surface Inspection Areas



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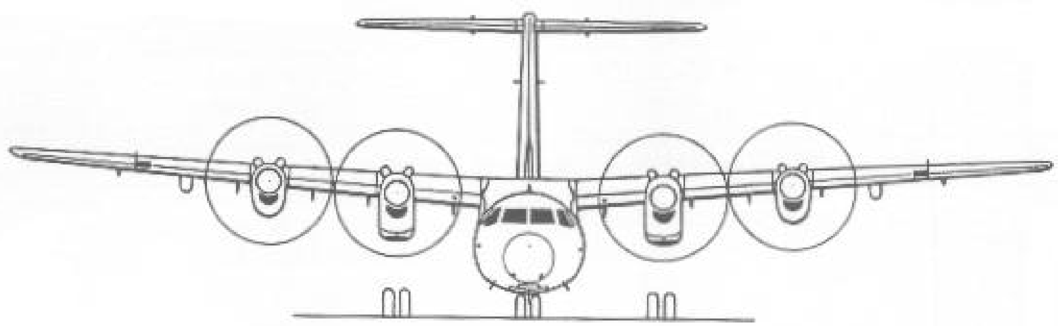
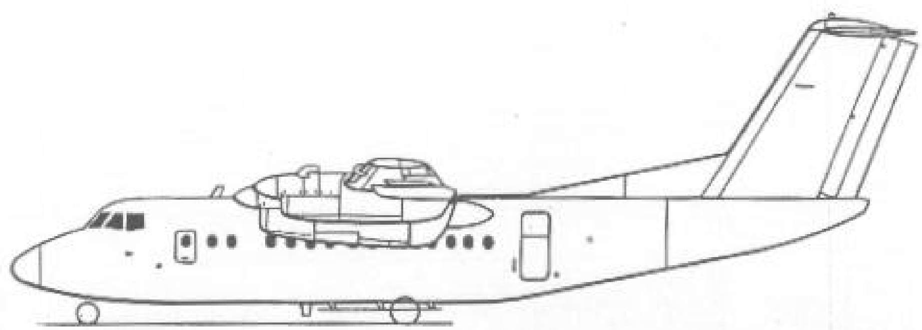
DHC Dash7

Priority Critical Surface Inspection Areas

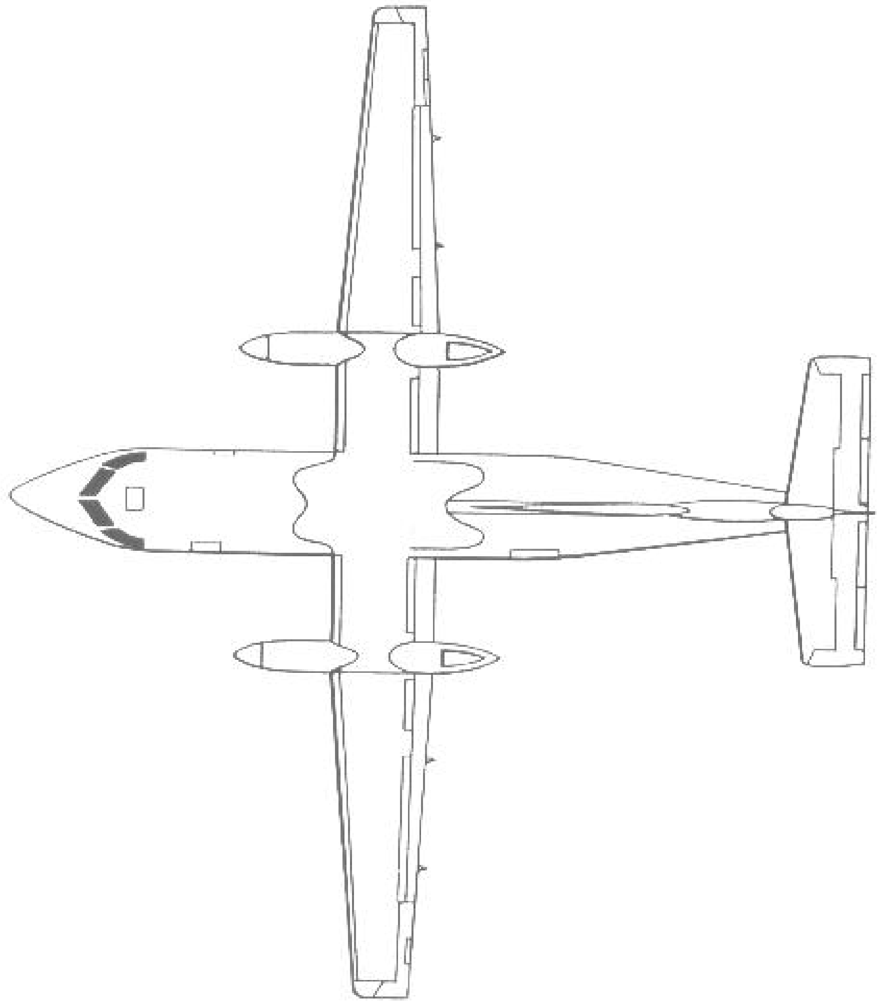




cm1380/3views/DHC7_2.ppt

DHC Dash8

Priority Critical Surface Inspection Areas



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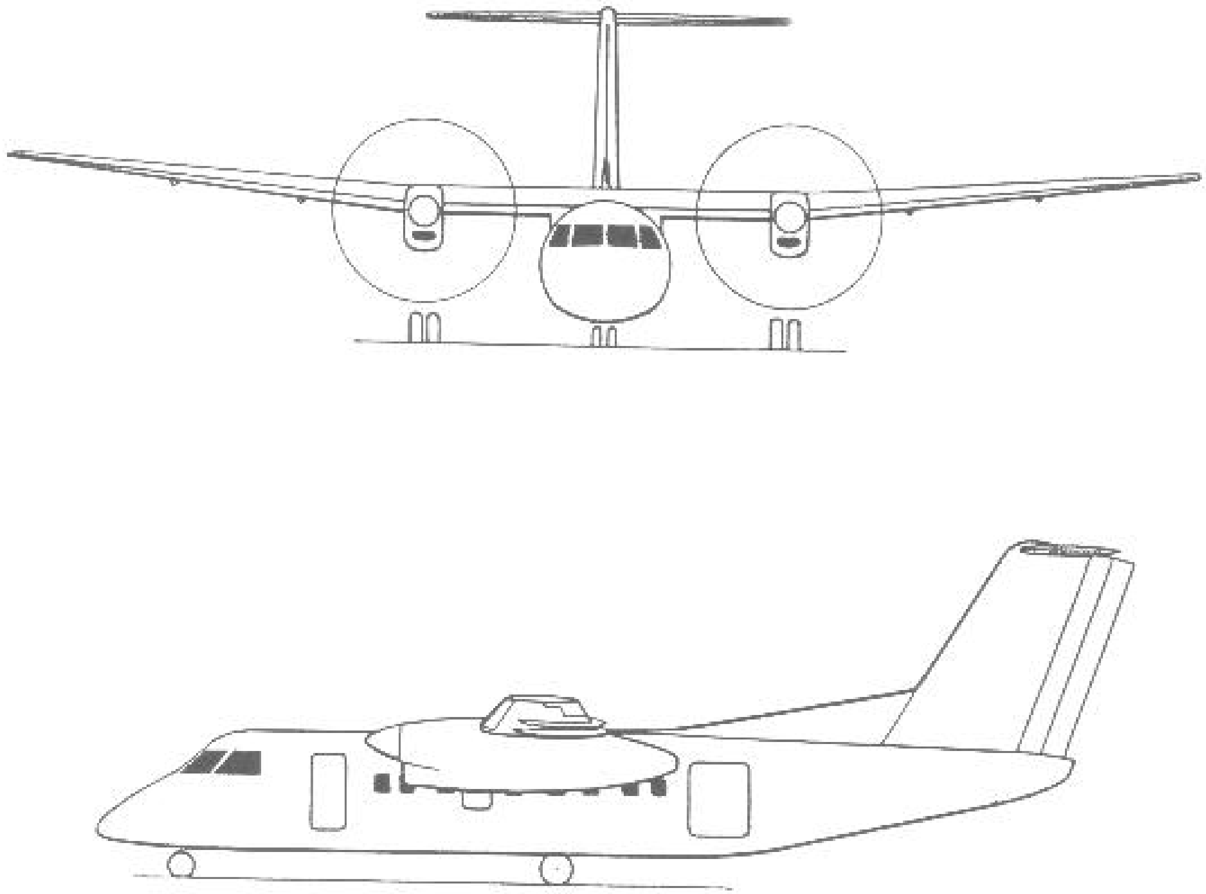
DHC Dash8

Priority Critical Surface Inspection Areas



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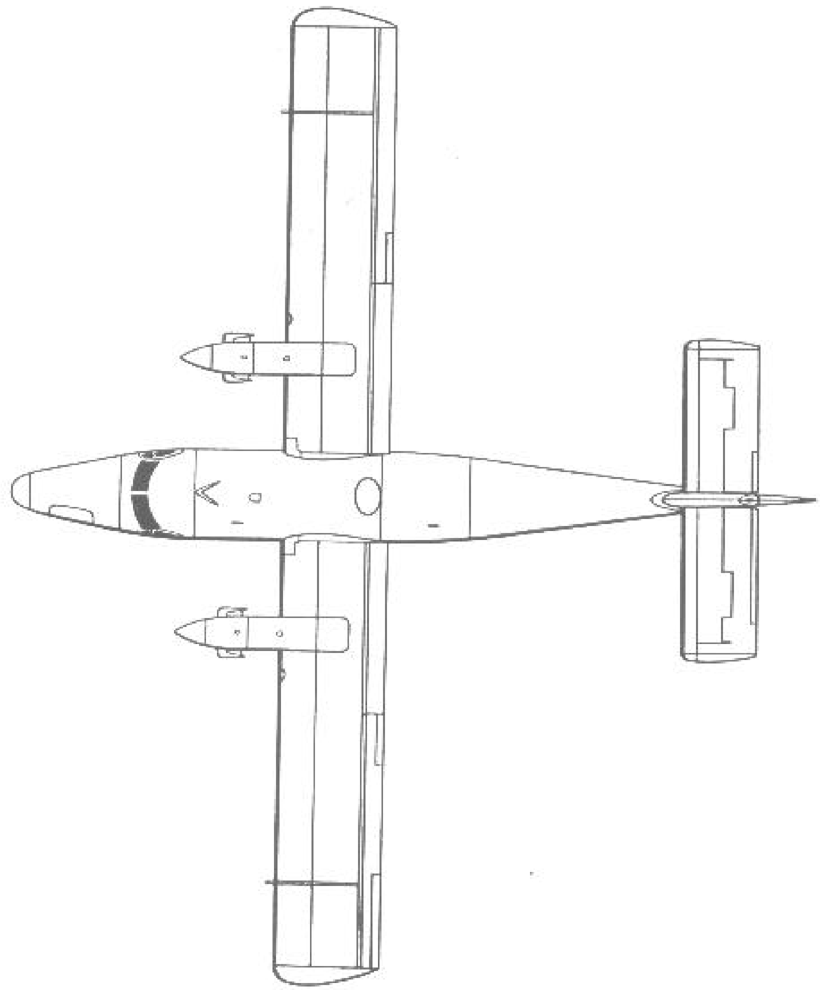
DHC Twin Otter

Priority Critical Surface Inspection Areas



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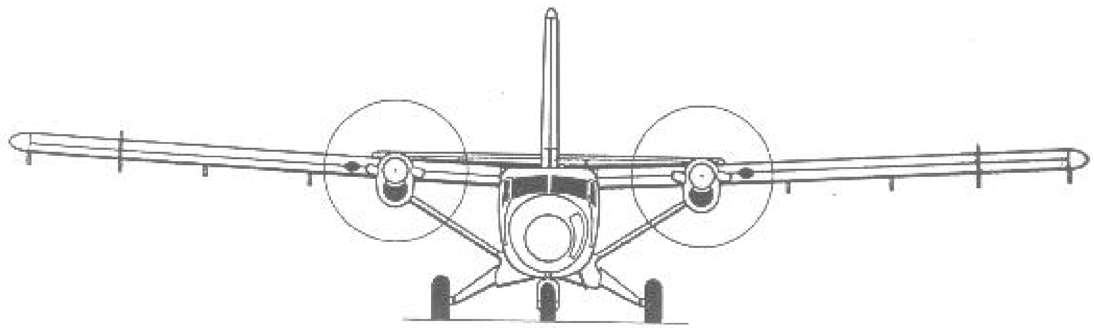
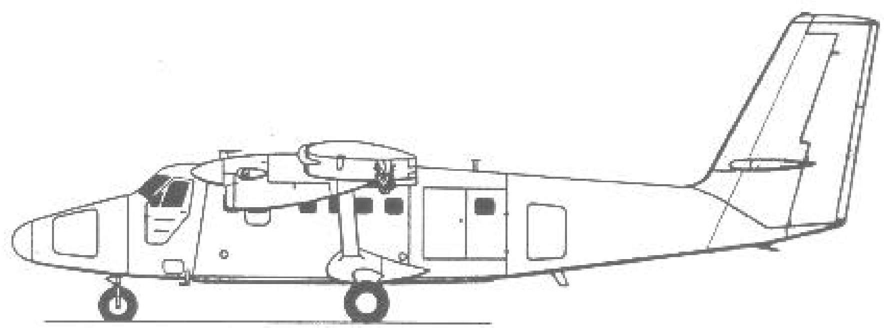
DHC Twin Otter

Priority Critical Surface Inspection Areas





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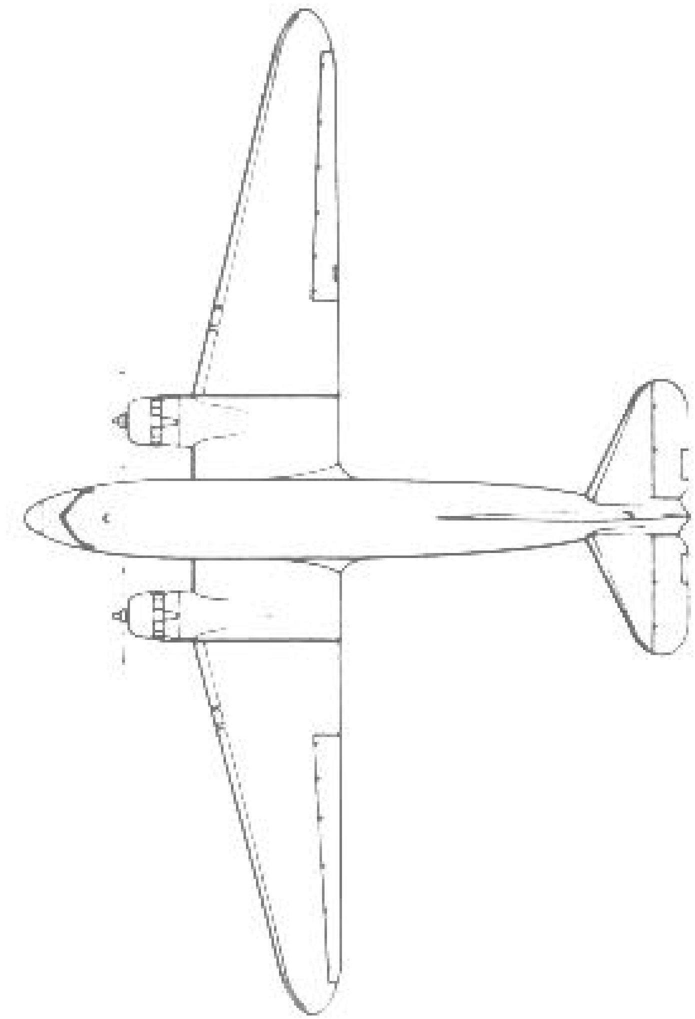
Douglas DC-3

Priority Critical Surface Inspection Areas



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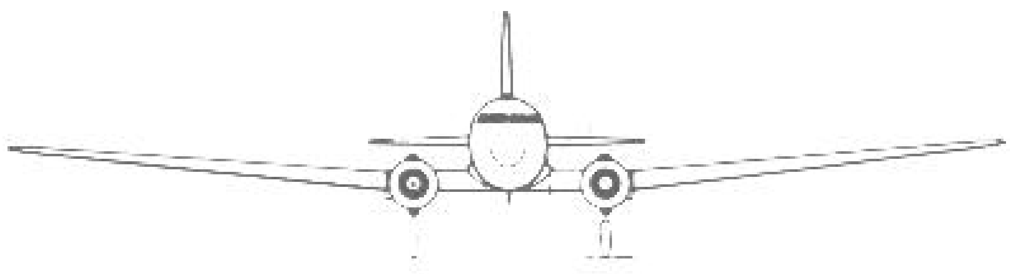
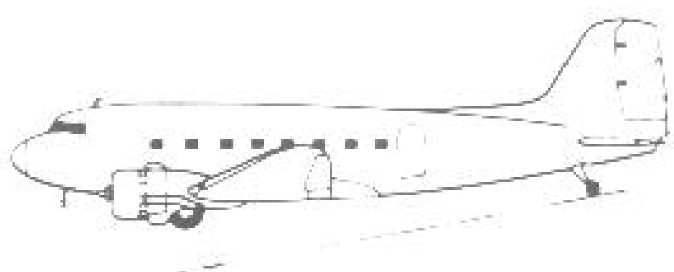
Douglas DC-3

Priority Critical Surface Inspection Areas





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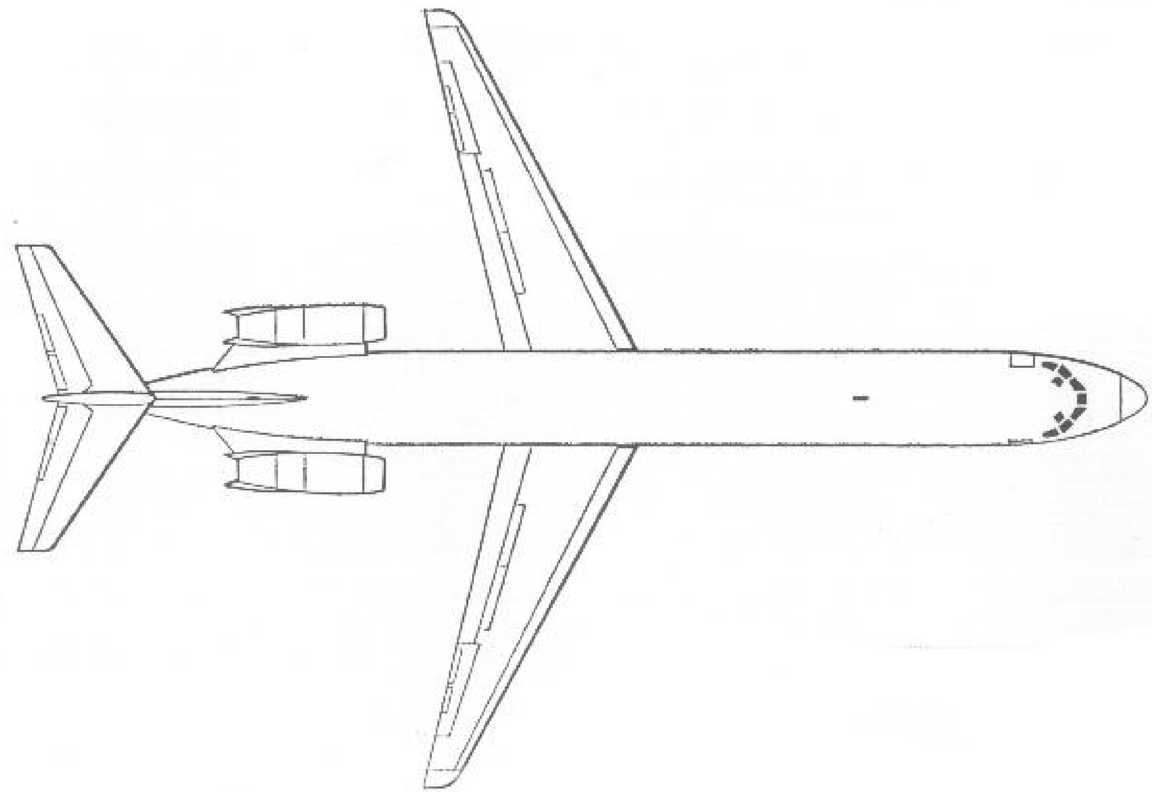
McDonnell Douglas DC-9

Priority Critical Surface Inspection Areas



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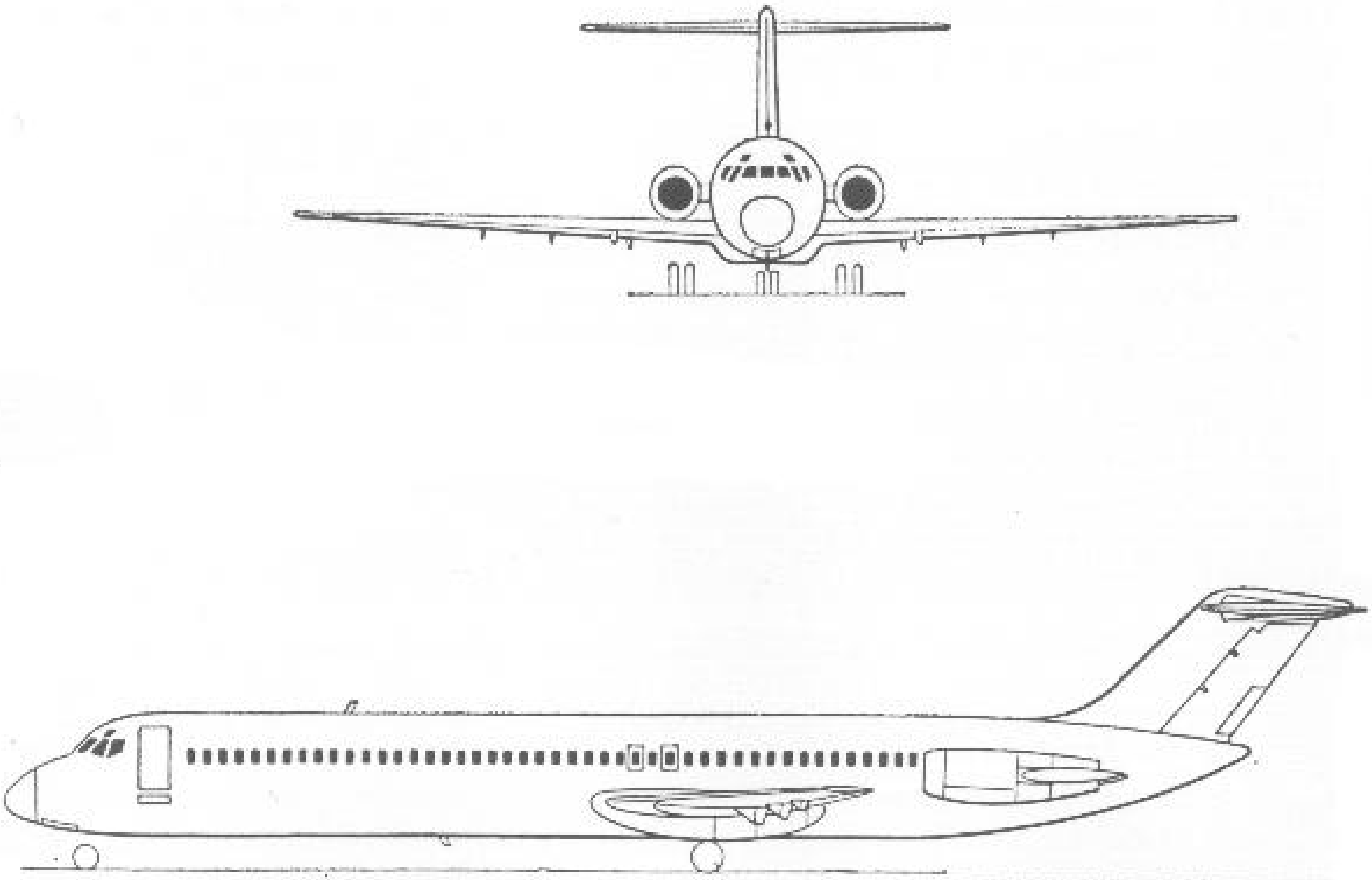
McDonnell Douglas DC-9

Priority Critical Surface Inspection Areas



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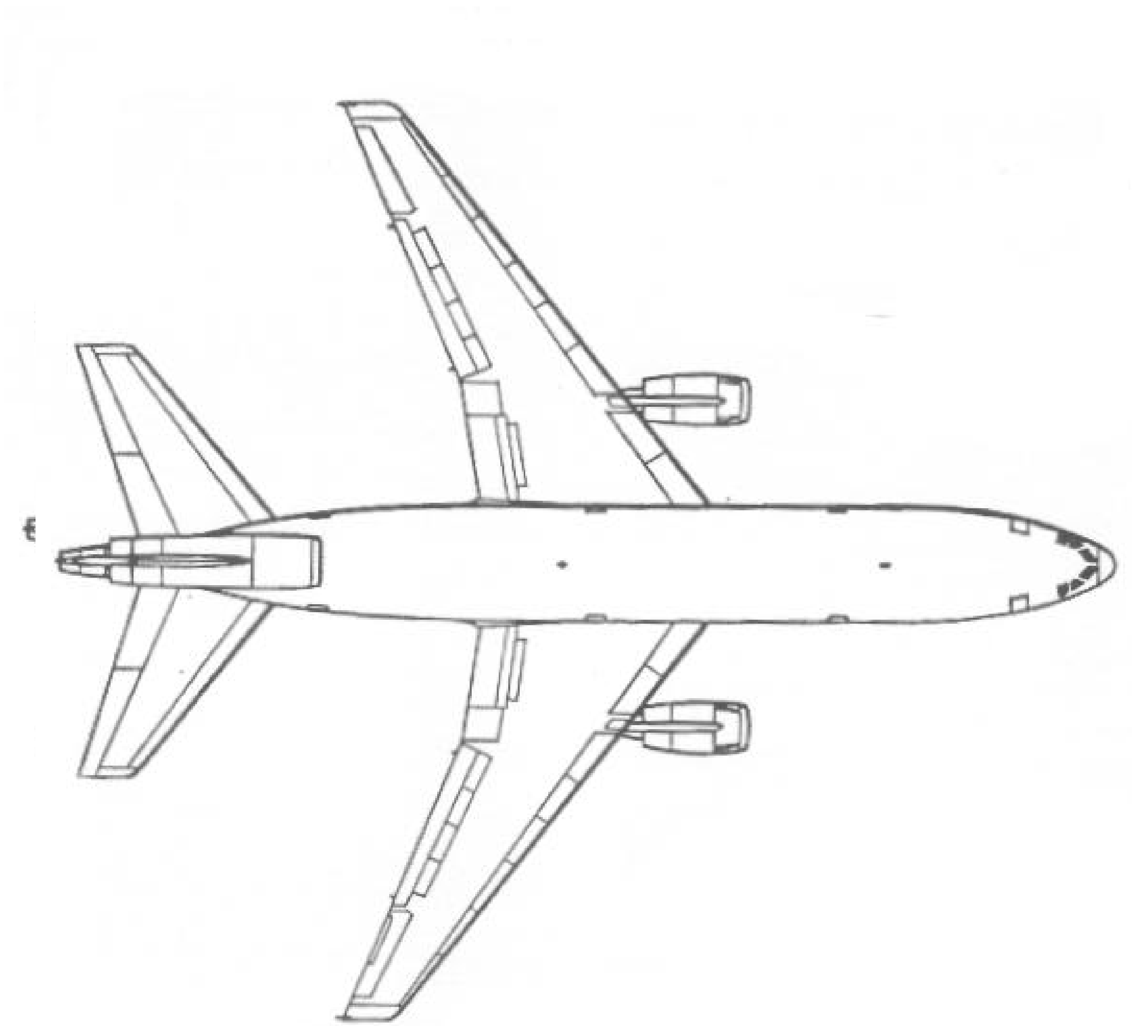
McDonnell Douglas DC-10

Priority Critical Surface Inspection Areas



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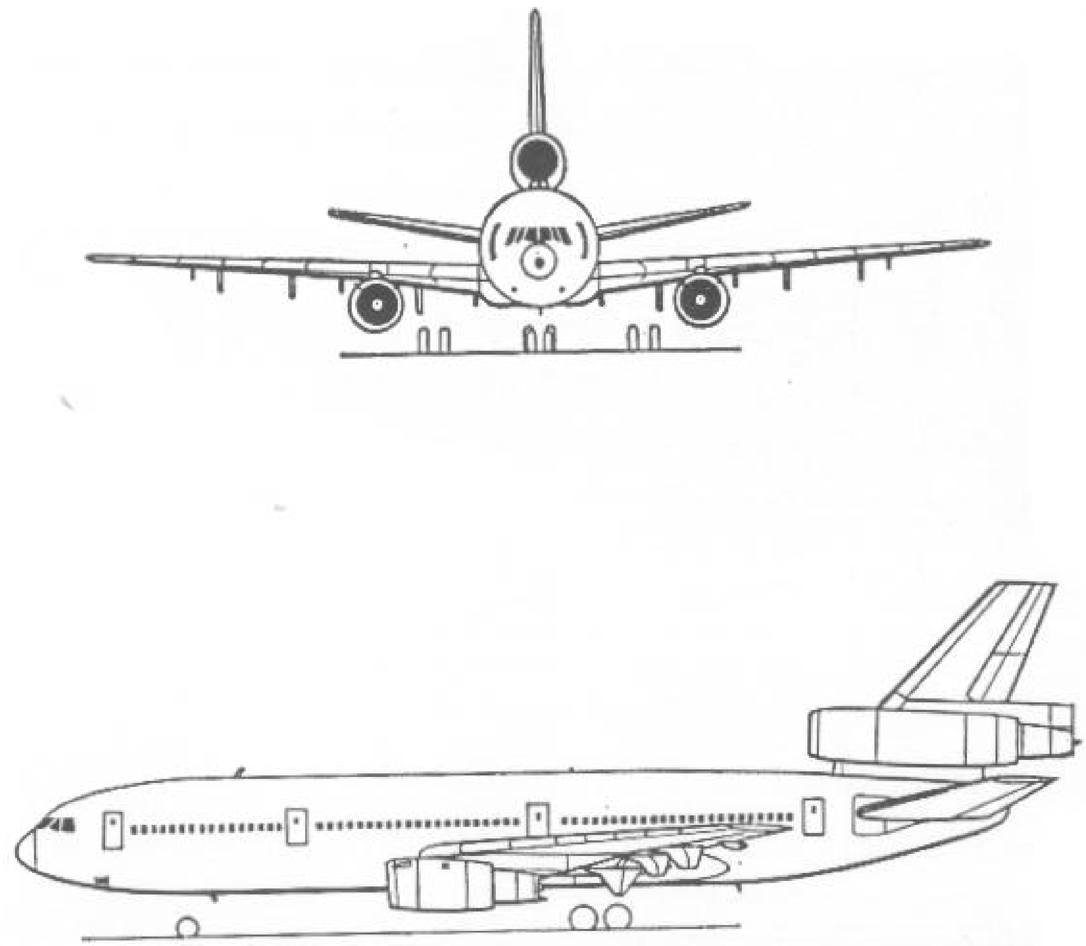
McDonnell Douglas DC-10

Priority Critical Surface Inspection Areas



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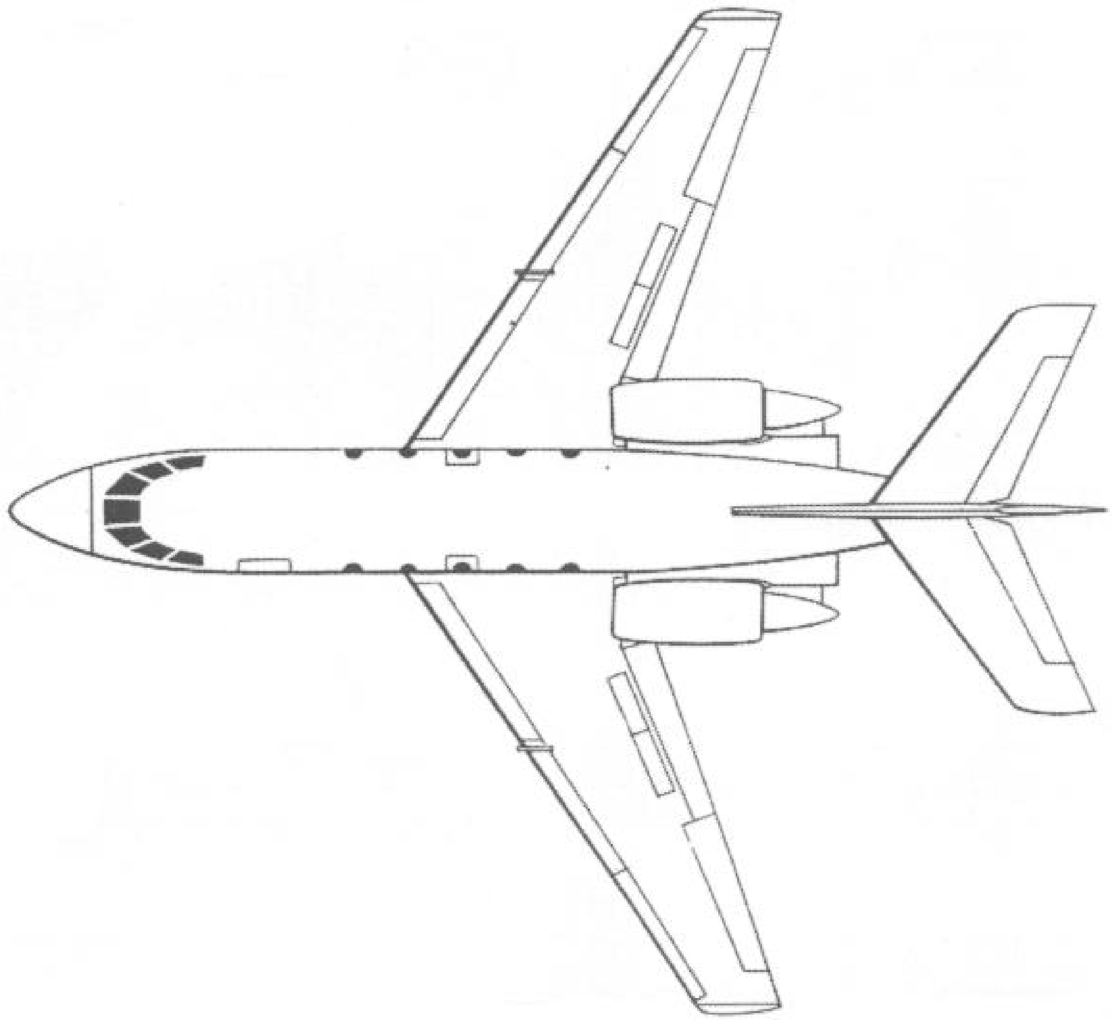
Falcon 20

Priority Critical Surface Inspection Areas



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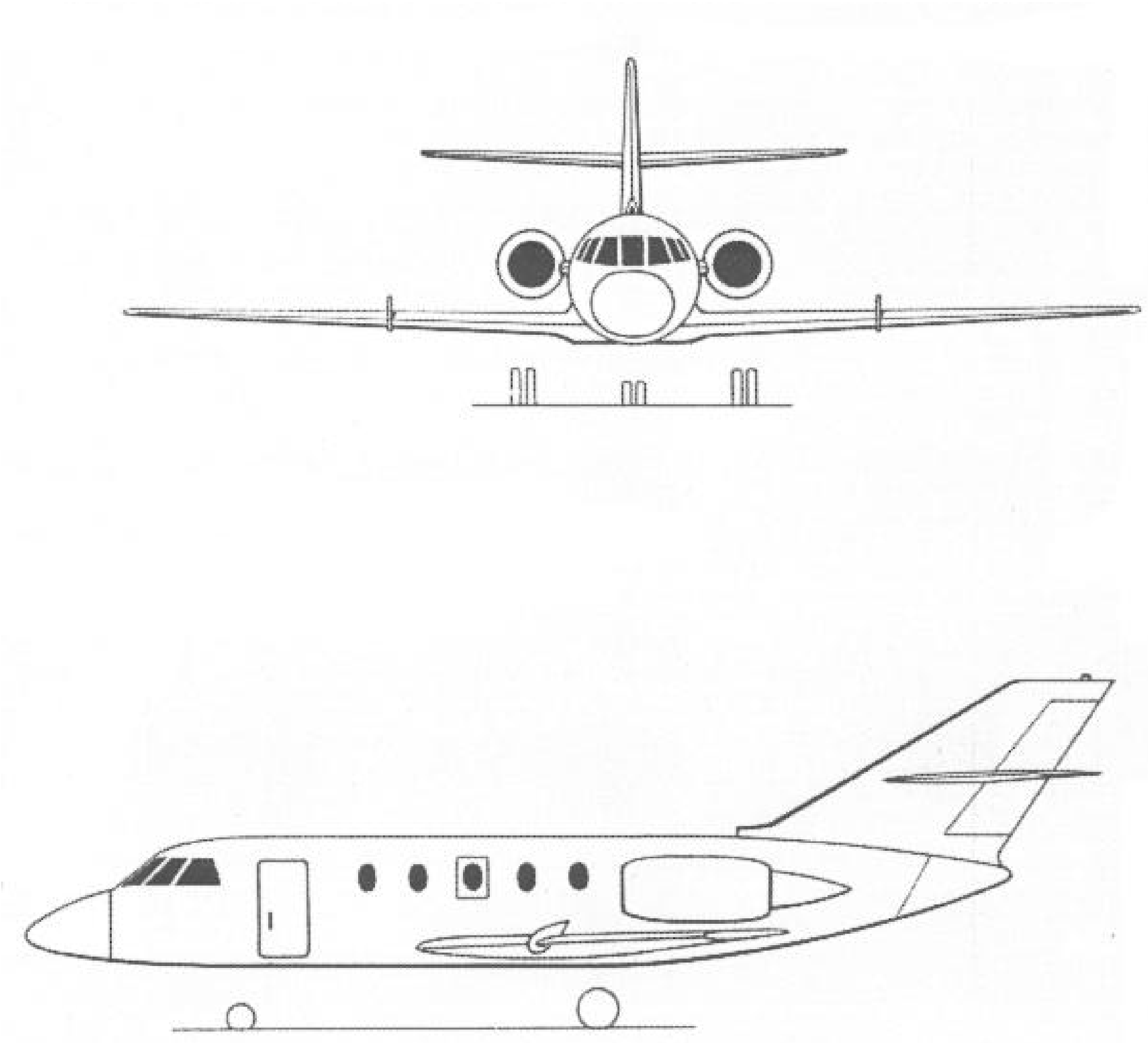
Falcon 20

Priority Critical Surface Inspection Areas



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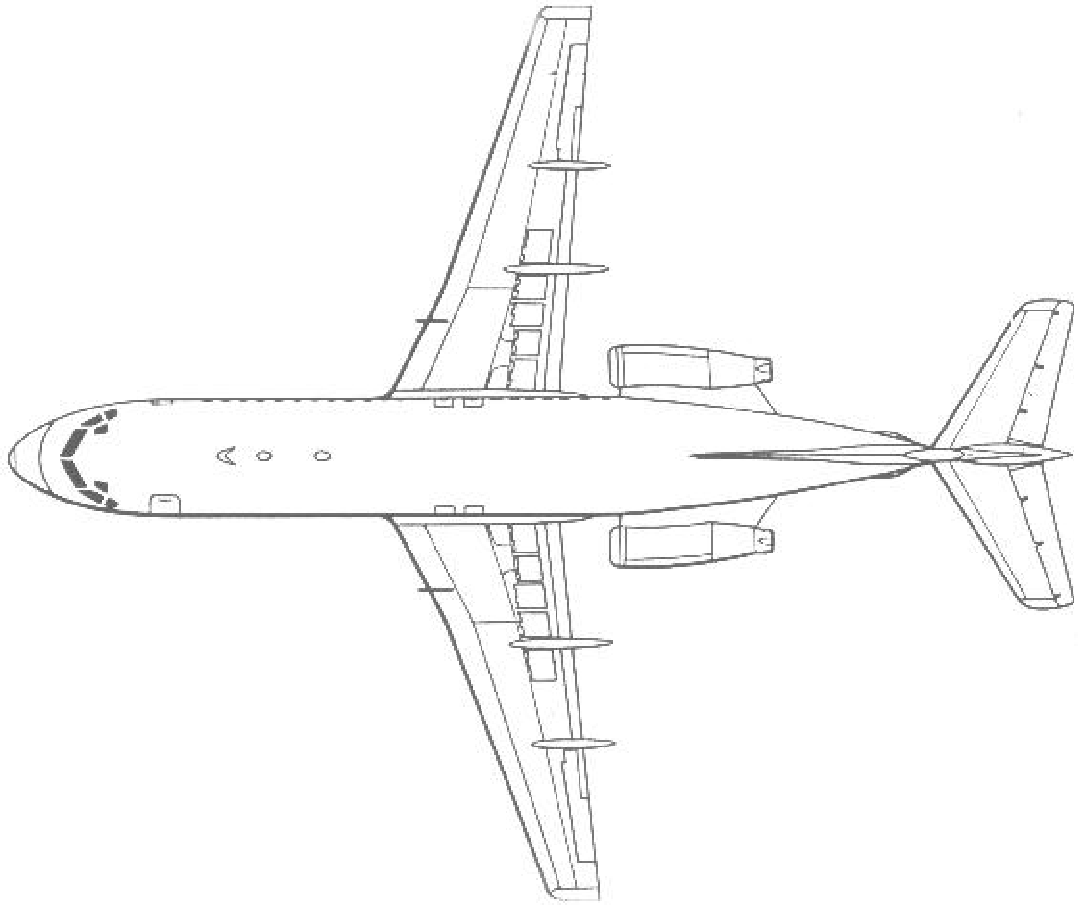
Fokker F28

Priority Critical Surface Inspection Areas



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Fokker F28

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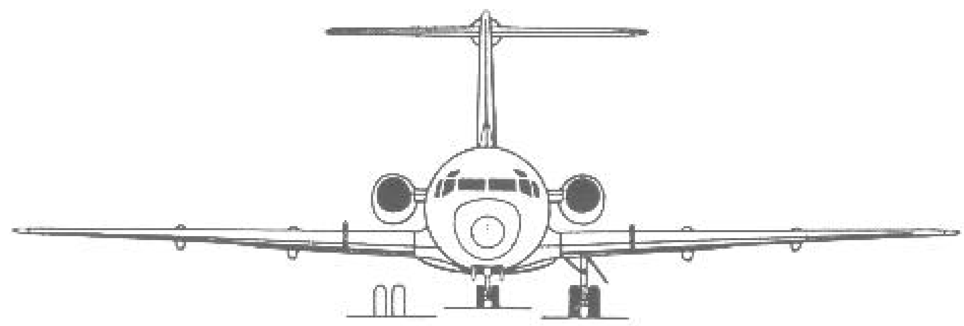

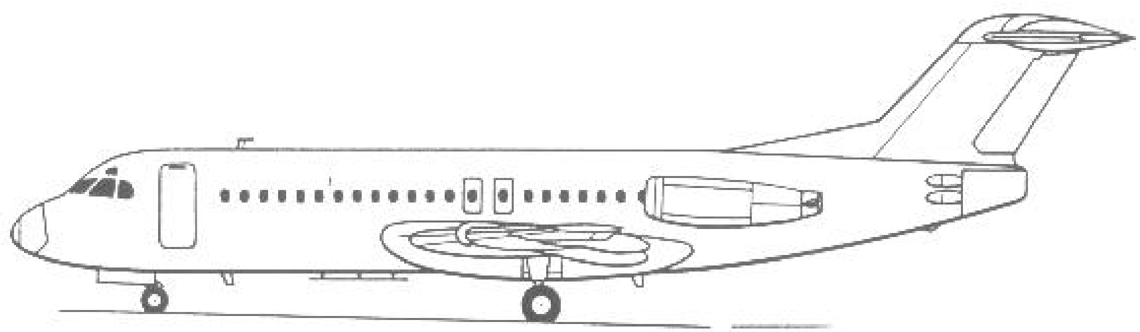

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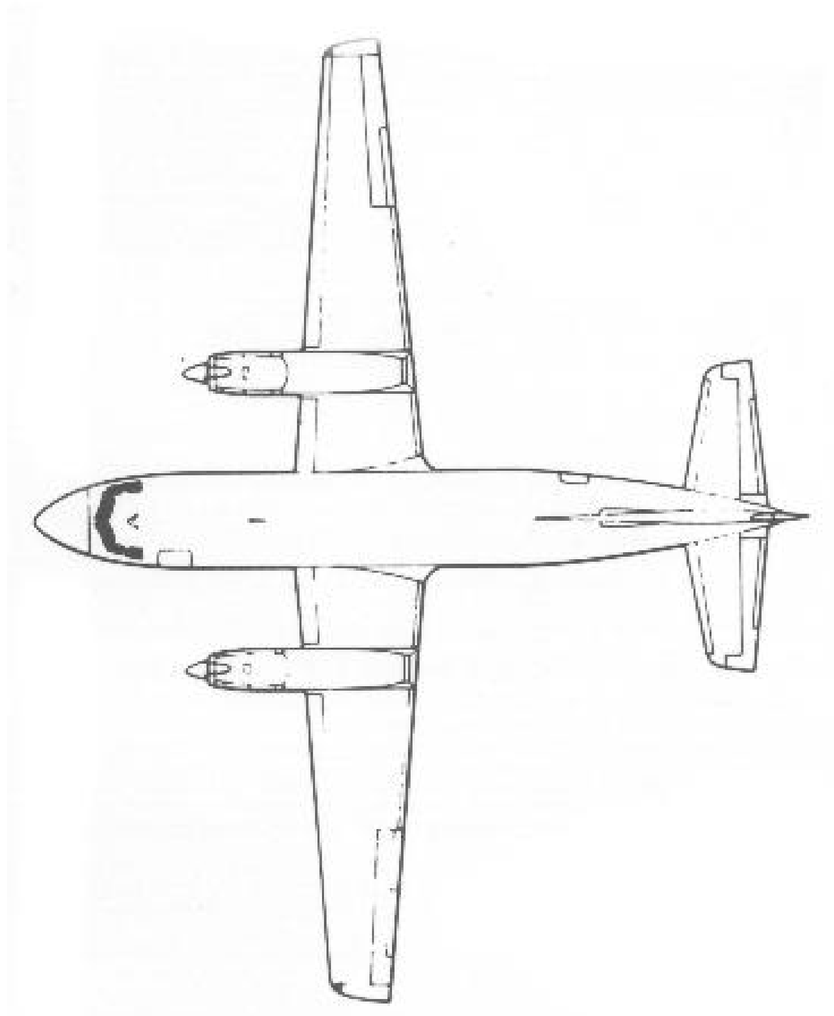
Grumman Gulfstream I

Priority Critical Surface Inspection Areas



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Grumman Gulfstream I

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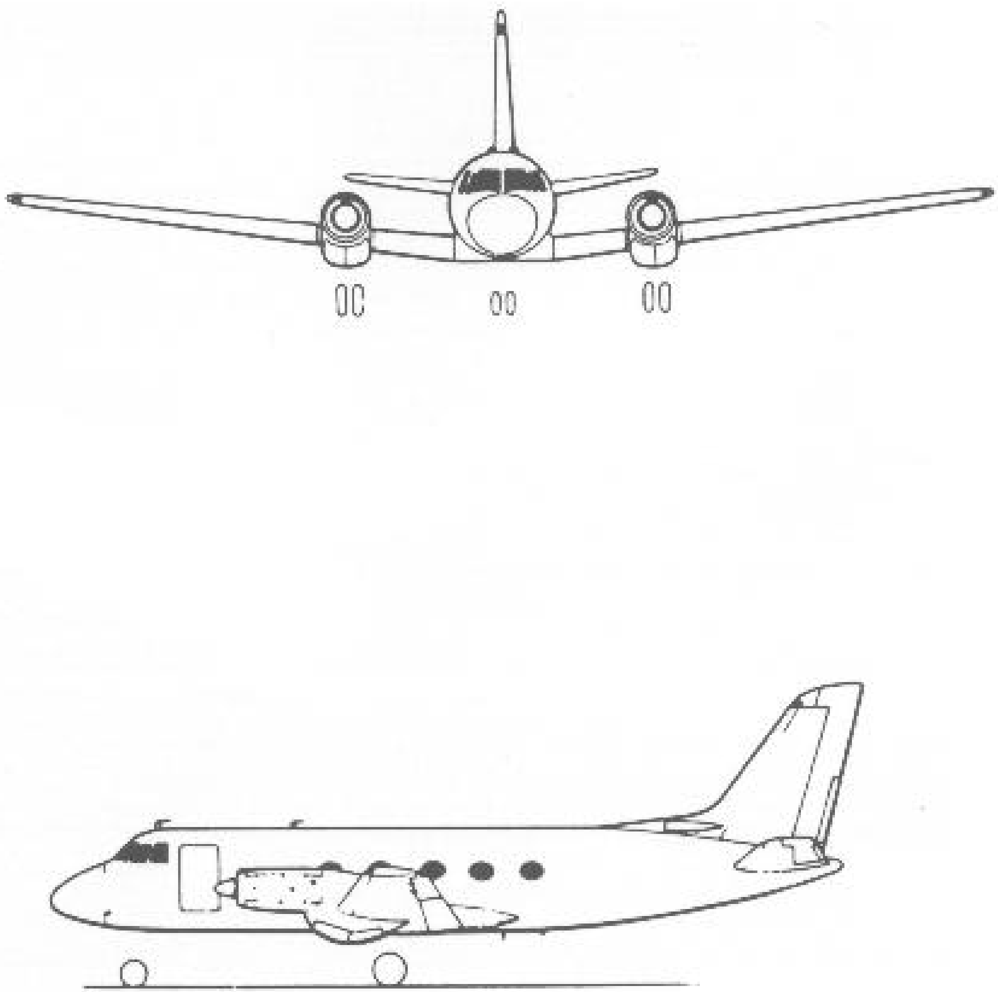

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Jetstream 31

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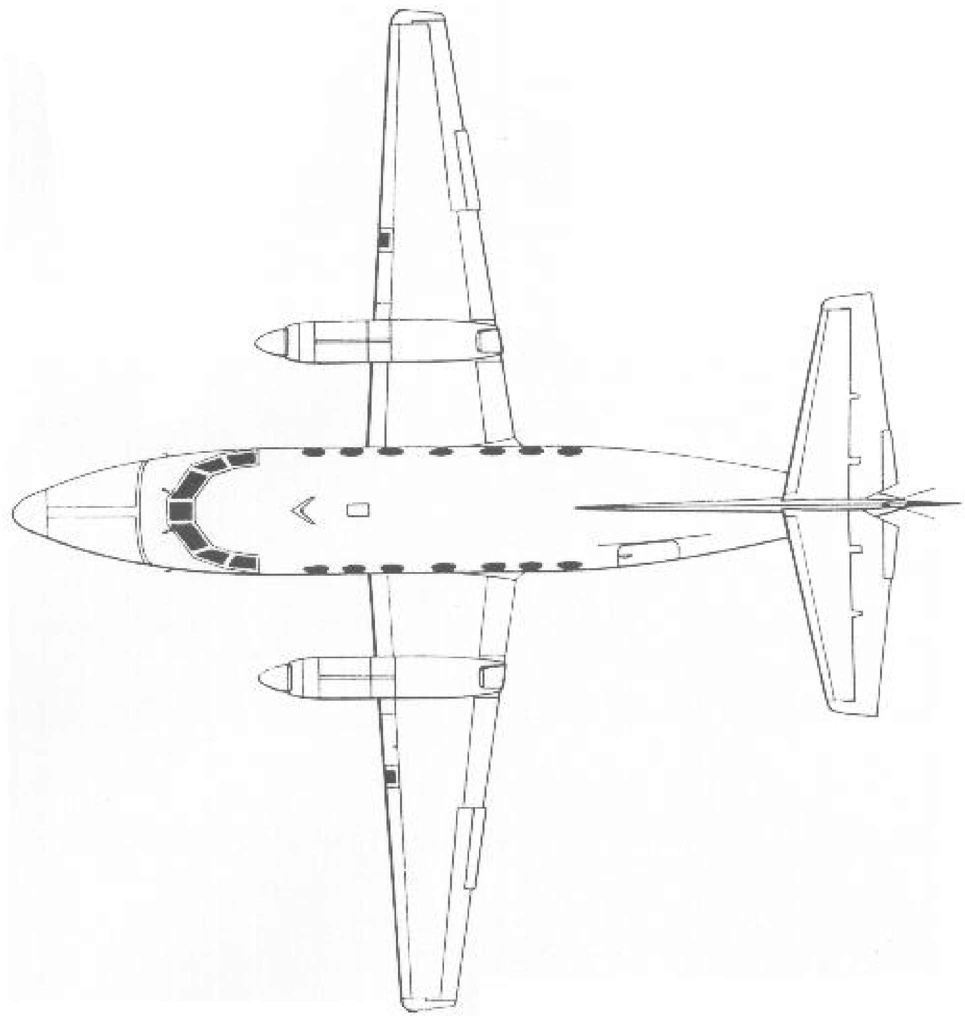

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Jetstream 31

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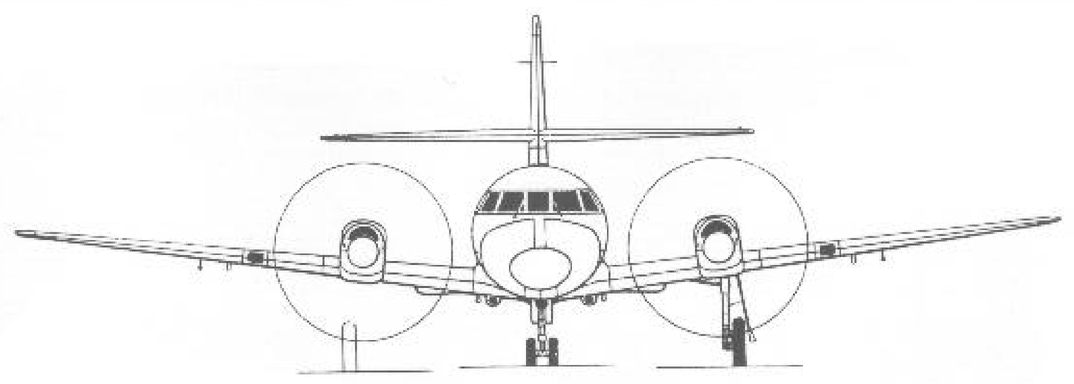

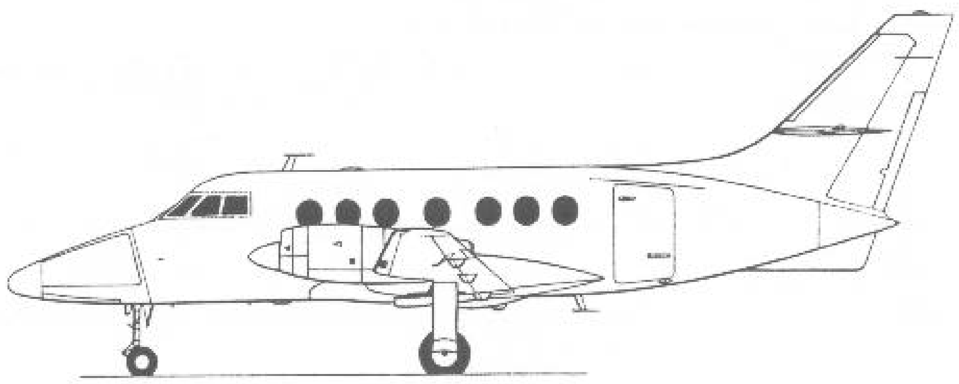

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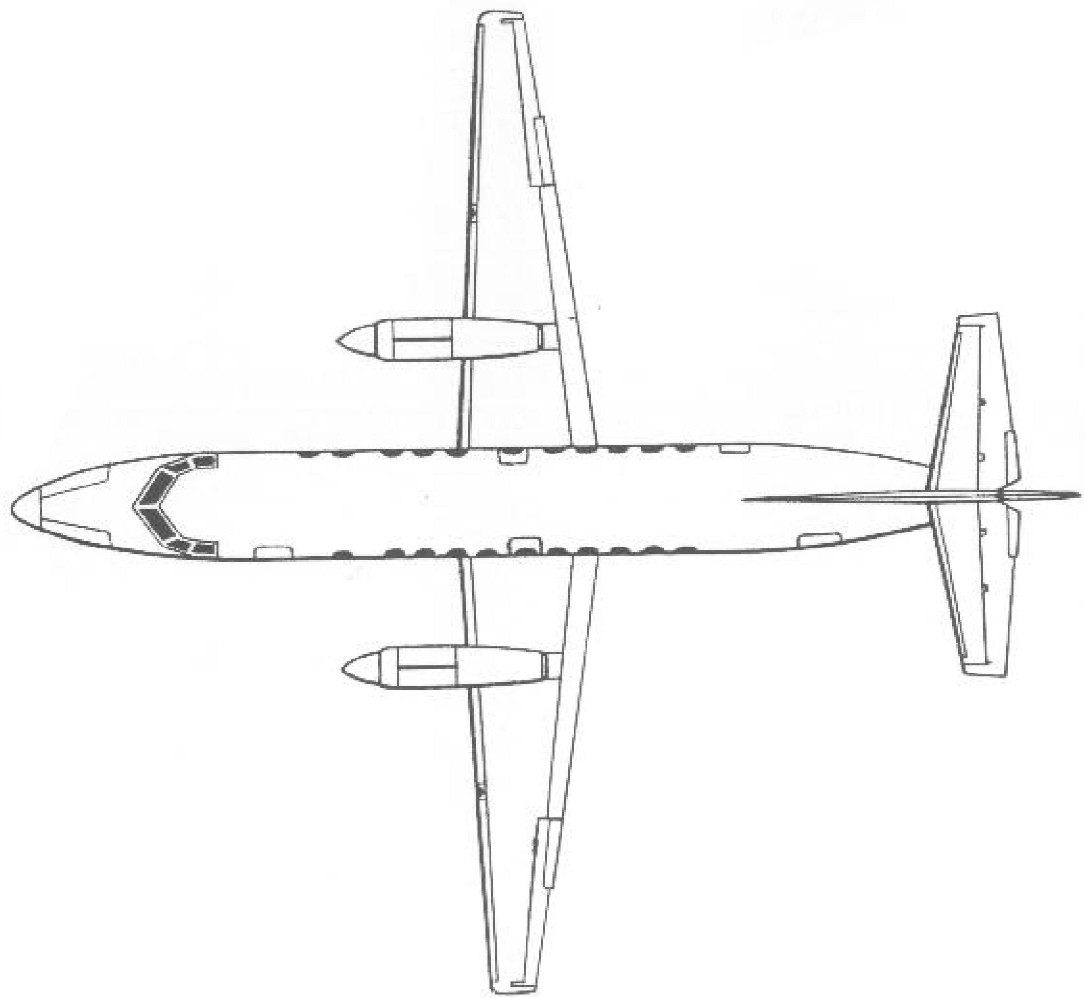
Jetstream 41

Priority Critical Surface Inspection Areas



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Jetstream 41

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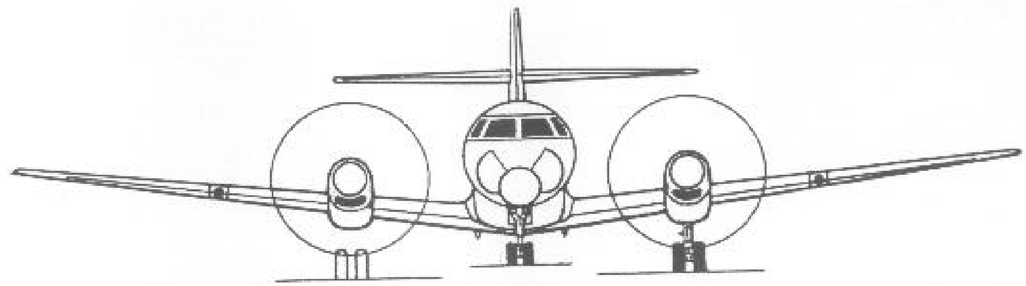

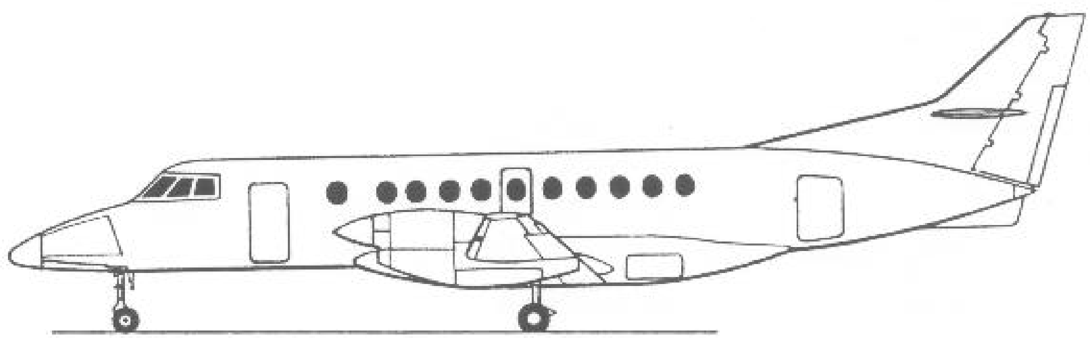

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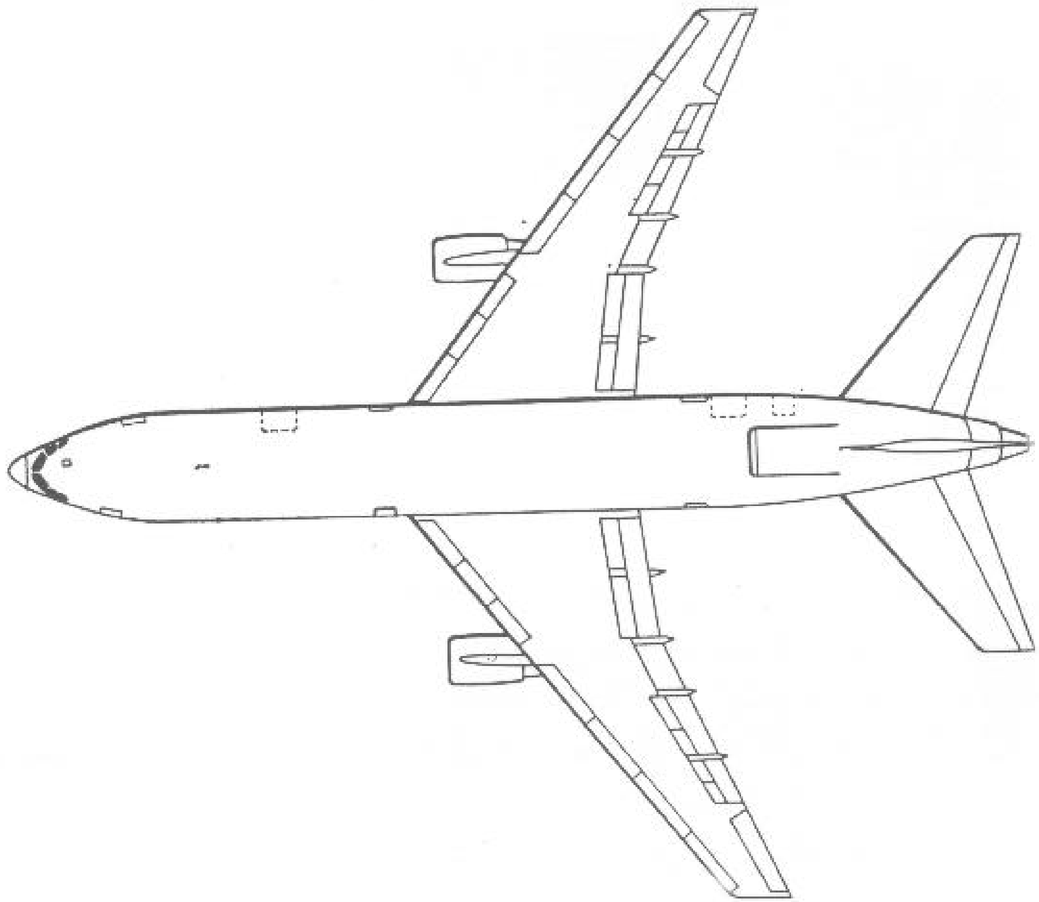
Lockheed L-1011

Priority Critical Surface Inspection Areas



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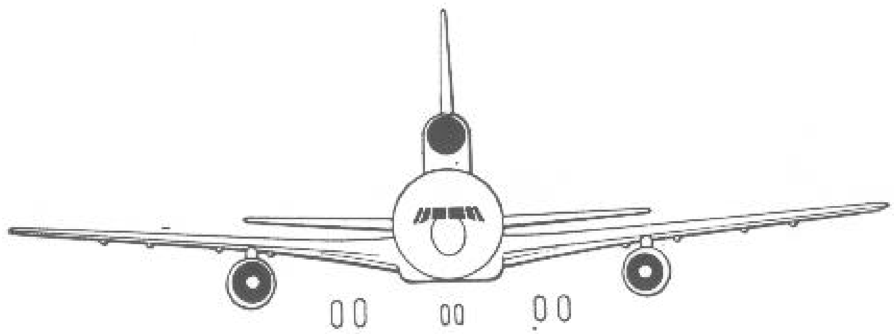
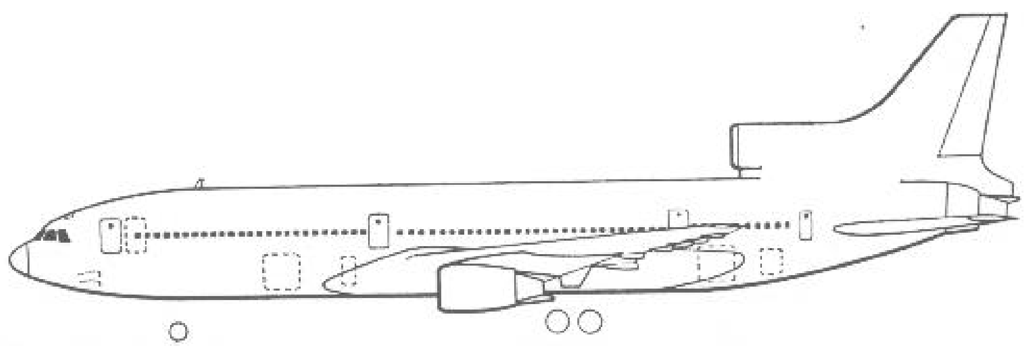
Lockheed L-1011

Priority Critical Surface Inspection Areas





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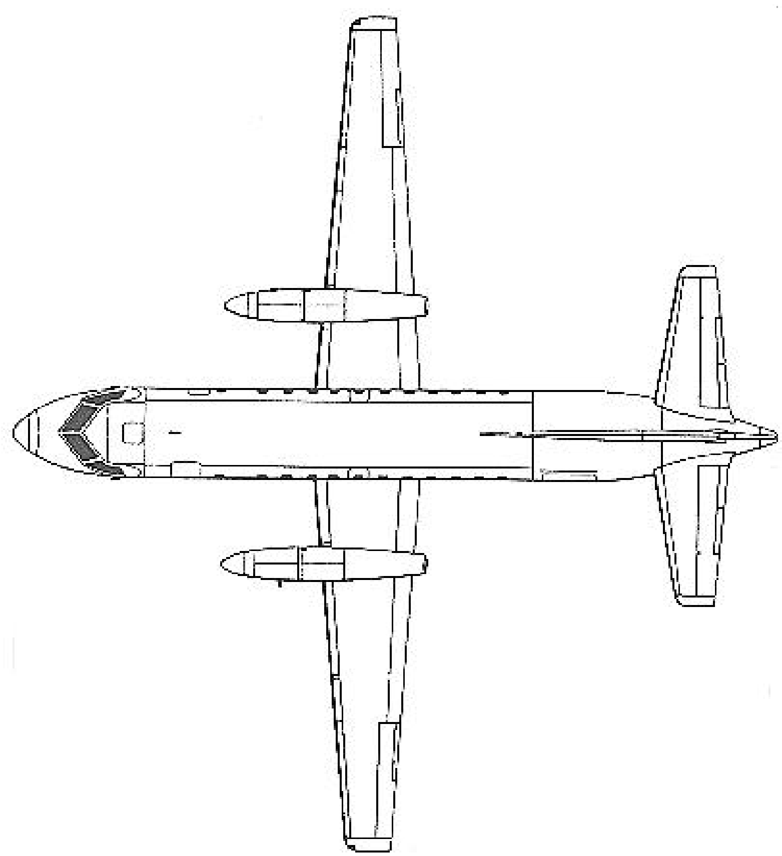
Saab 340

Priority Critical Surface Inspection Areas



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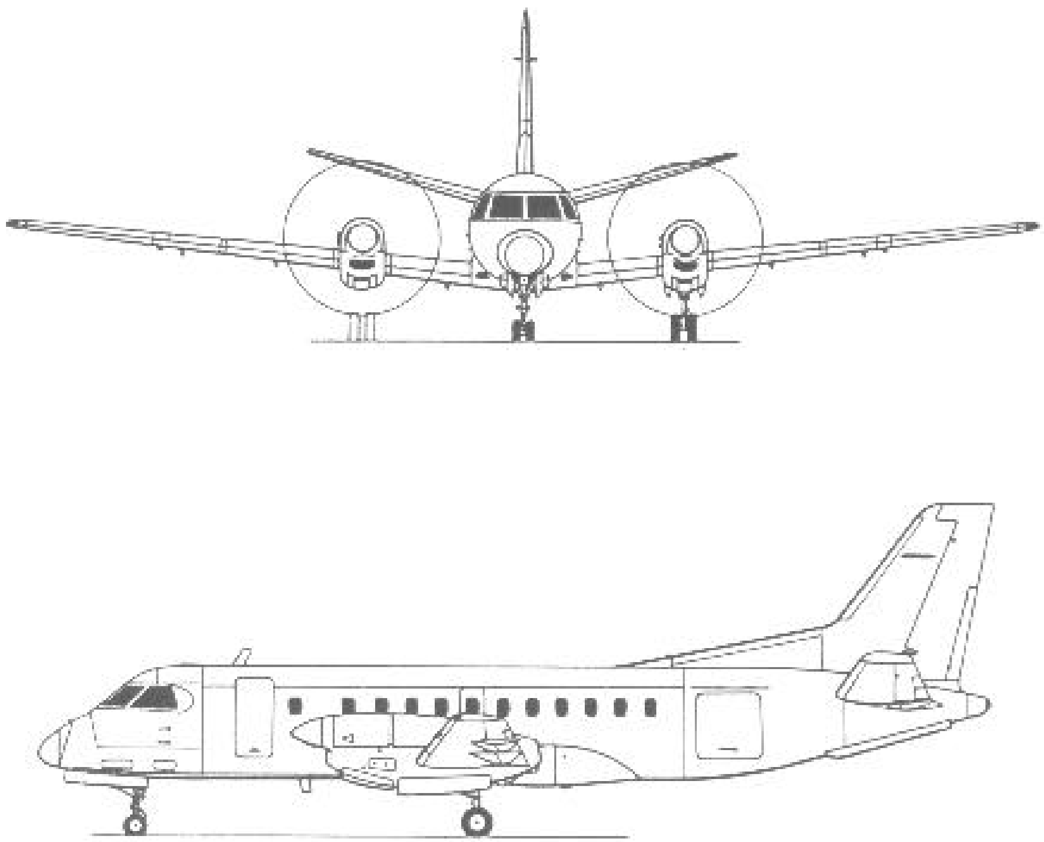
Saab 340

Priority Critical Surface Inspection Areas



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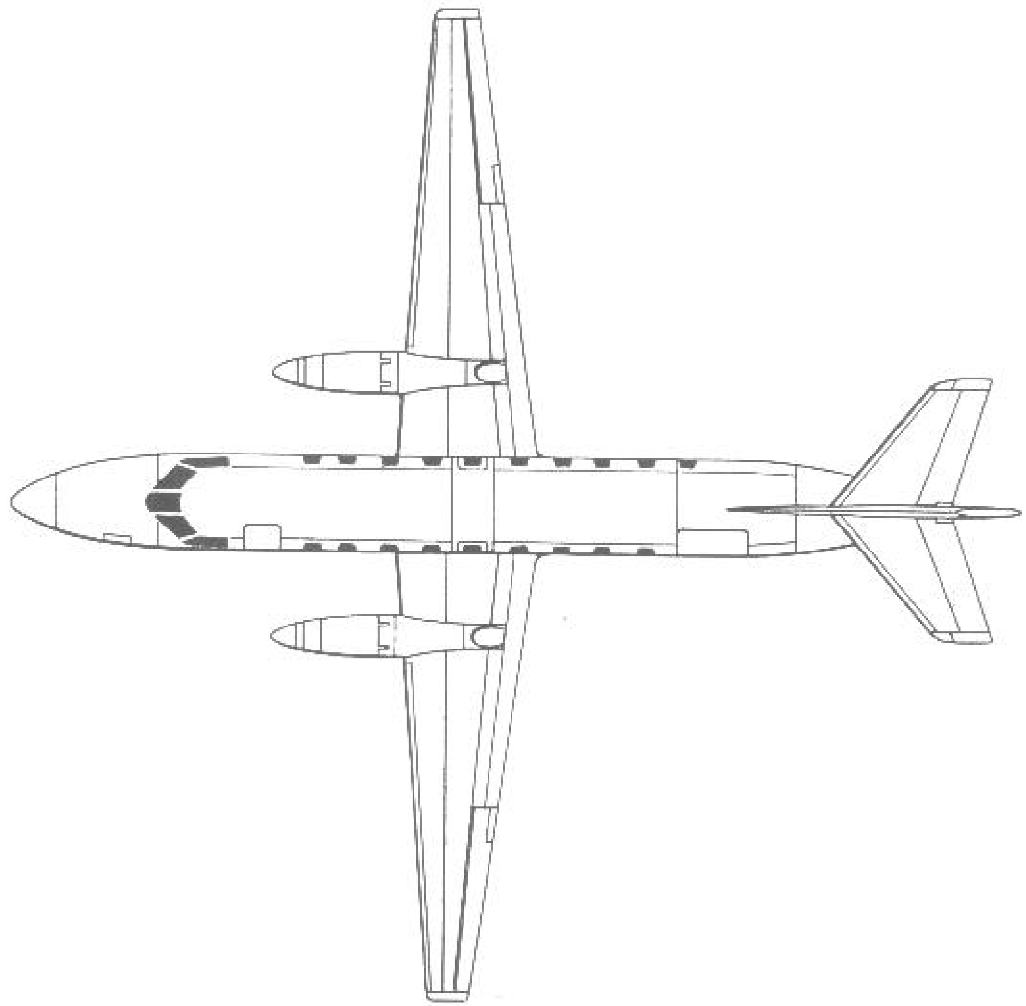
Swearingen SA226/7

Priority Critical Surface Inspection Areas



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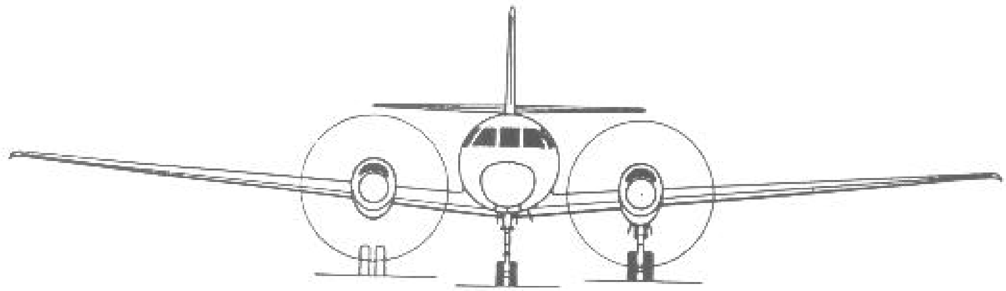
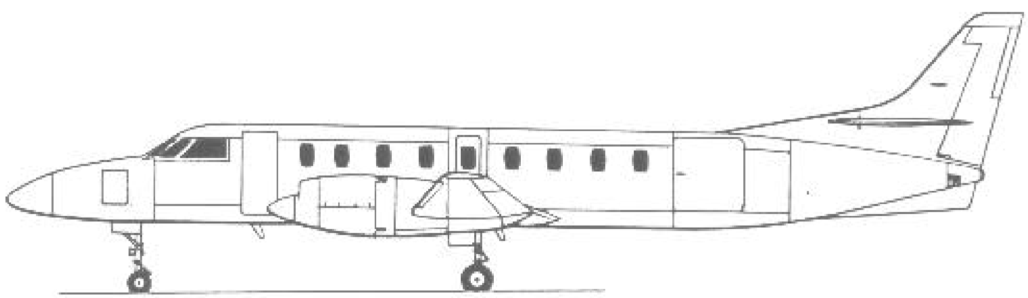
Swearingen SA226/7

Priority Critical Surface Inspection Areas





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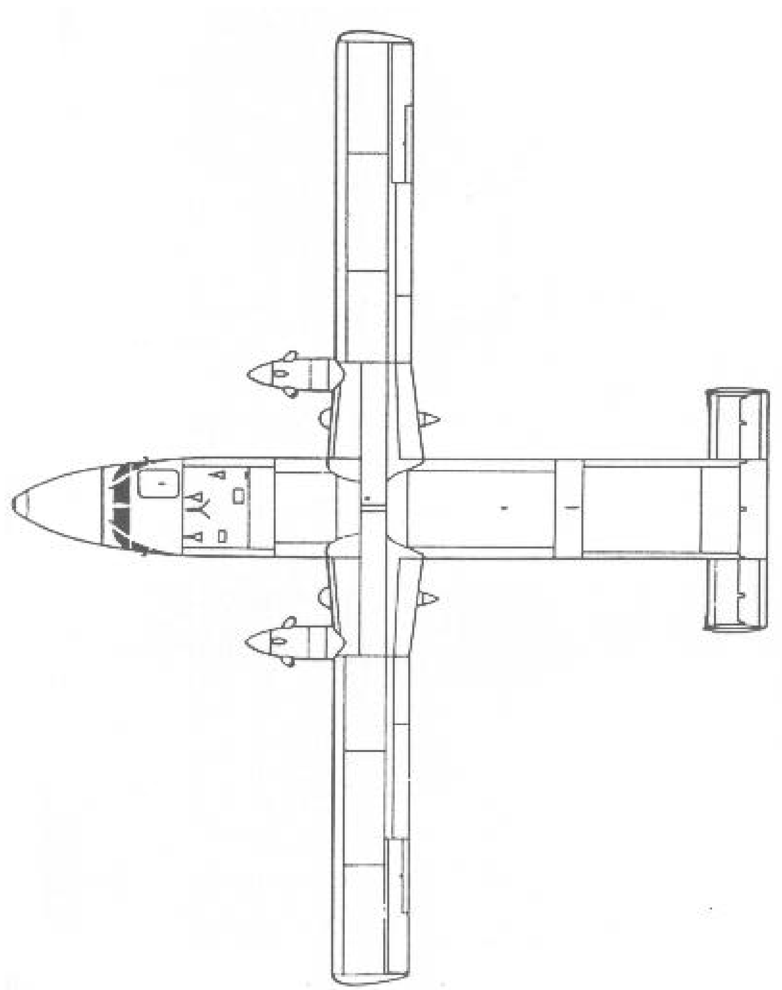
Shorts SD-330

Priority Critical Surface Inspection Areas



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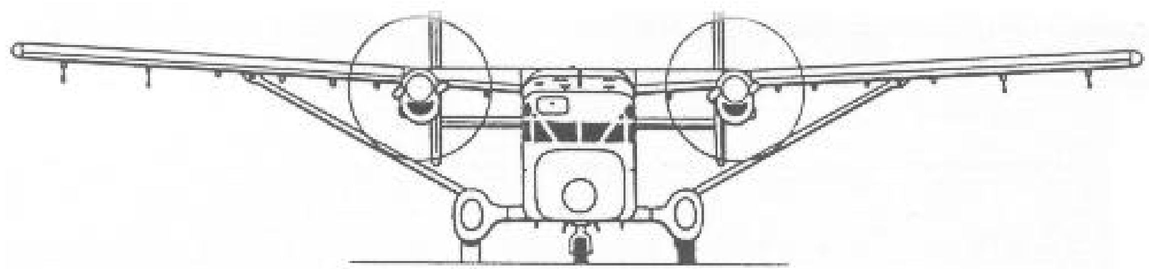
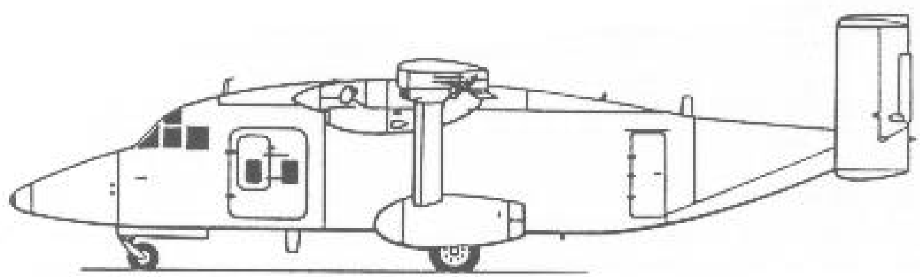
Shorts SD-330

Priority Critical Surface Inspection Areas





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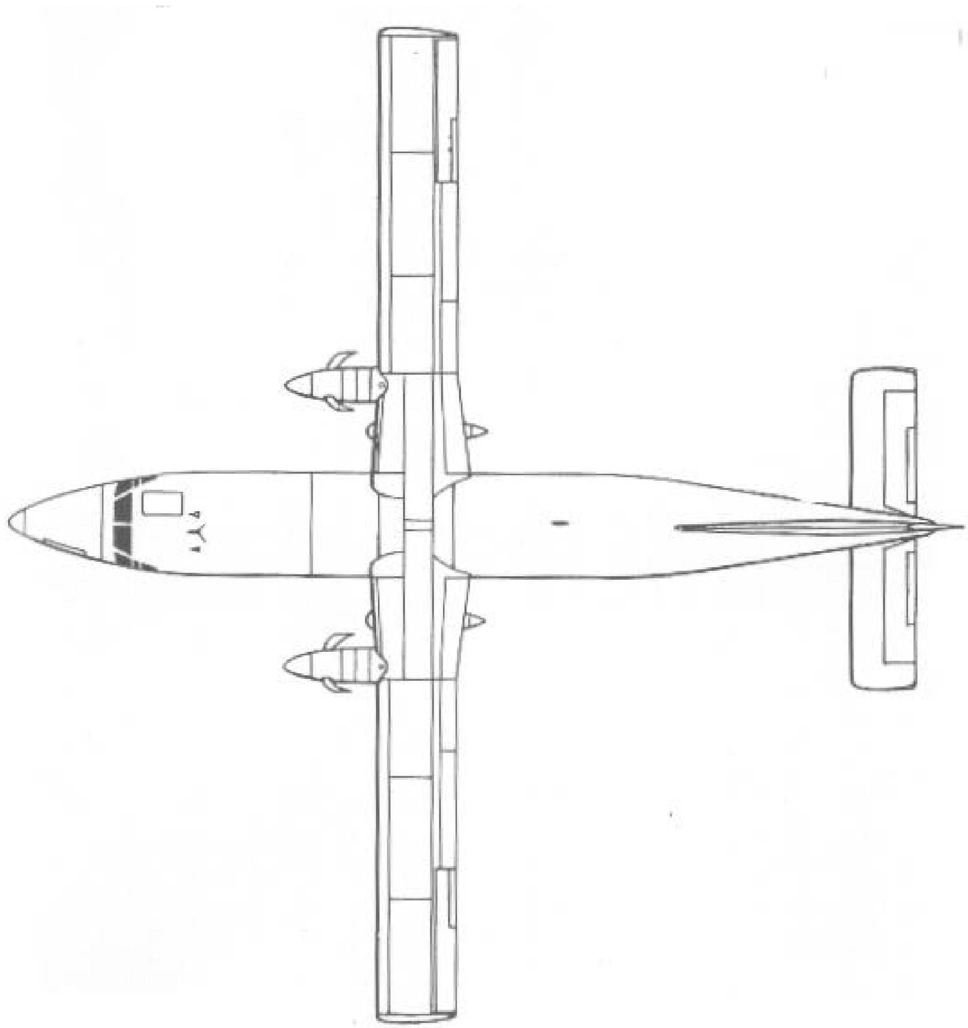
Shorts SD-360

Priority Critical Surface Inspection Areas



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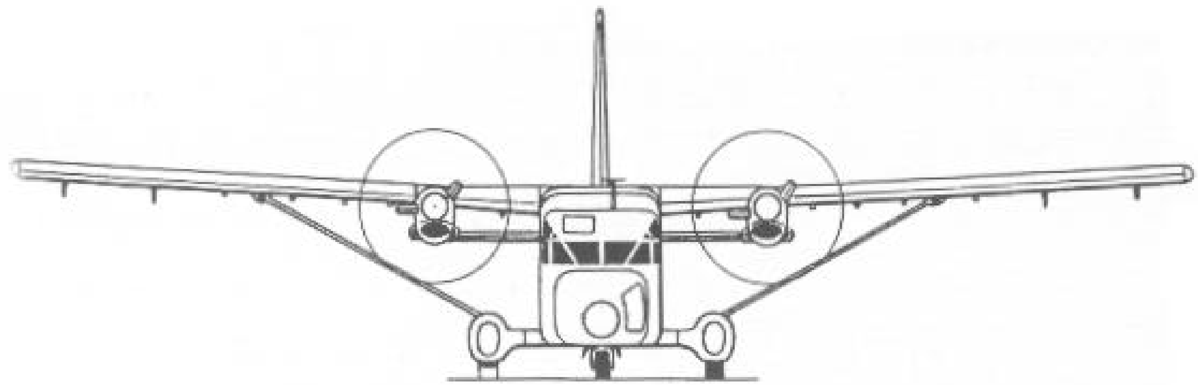
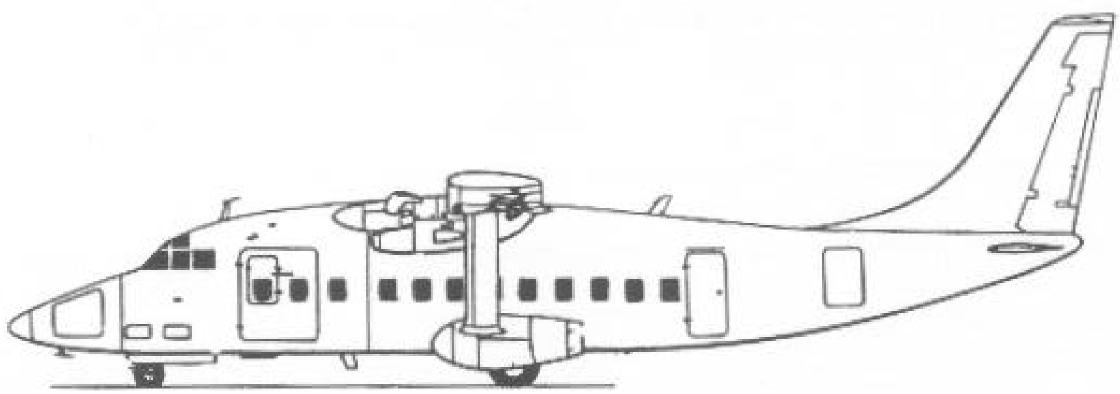
Shorts SD-360

Priority Critical Surface Inspection Areas





cm1380/3views/SD360_2.ppt

APPENDIX J

SUPPORTING DATA FOR TAXI TIME ANALYSIS

ACTUAL NUMBER OF OCCURANCES

BY PRECIPITATION

	289	55	234
Time (min)	*Total*	*Frost*	*Snow*
4	0	0	0
6	0	0	0
8	7	0	7
10	20	5	15
12	51	15	36
14	58	13	45
16	57	12	45
18	36	4	32
20	27	4	23
22	13	1	12
24	11	1	10
26	4	0	4
28	1	0	1
30	1	0	1
32	0	0	0
34	0	0	0
36	1	0	1
38	0	0	0
40	0	0	0
More	2	0	2

BY FLUID TYPE AND PRECIPITATION

	289	50	109	5	125
Time (min)	*Total*	*Type 1 Frost*	*Type 1 Snow*	*Type 4 Frost*	*Type 4 Snow*
4	0	0	0	0	0
6	0	0	0	0	0
8	7	0	4	0	3
10	20	5	6	0	9
12	51	14	24	1	12
14	58	13	21	0	24
16	57	10	16	2	29
18	36	4	15	0	17
20	27	3	11	1	12
22	13	1	5	0	7
24	11	0	5	1	5
26	4	0	0	0	4
28	1	0	0	0	1
30	1	0	0	0	1
32	0	0	0	0	0
34	0	0	0	0	0
36	1	0	1	0	0
38	0	0	0	0	0
40	0	0	0	0	0
More	2	0	1	0	1

ACTUAL NUMBER OF OCCURANCES

BY RUNWAY

	289	33	52	133	32	20	19
Time (min)	*Total*	*Runway 28*	*Runway 06L*	*Runway 06R*	*Runway 24L*	*Runway 24R*	*Runway U*
4	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
8	7	0	0	7	0	0	0
10	20	3	1	11	2	0	3
12	51	14	8	21	5	2	1
14	58	4	9	26	7	6	6
16	57	5	8	29	6	5	4
18	36	4	11	15	1	2	3
20	27	1	5	9	7	3	2
22	13	1	4	5	1	2	0
24	11	0	4	4	3	0	0
26	4	1	2	1	0	0	0
28	1	0	0	1	0	0	0
30	1	0	0	1	0	0	0
32	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0
36	1	0	0	1	0	0	0
38	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0
More	2	0	0	2	0	0	0

BY AIRCRAFT SIZE

	289	30	177	82
Time (min)	*Total*	*LARGE*	*MEDIUM*	*SMALL*
4	0	0	0	0
6	0	0	0	0
8	7	0	3	4
10	20	2	8	10
12	51	4	30	17
14	58	4	34	20
16	57	7	34	16
18	36	4	27	5
20	27	3	18	6
22	13	2	10	1
24	11	2	7	2
26	4	2	2	0
28	1	0	0	1
30	1	0	1	0
32	0	0	0	0
34	0	0	0	0
36	1	0	1	0
38	0	0	0	0
40	0	0	0	0
More	2	0	2	0

PERCENTAGE OF OCCURANCES

BY PRECIPITATION

	289	55	234
Time (min)	*Total*	*Frost*	*Snow*
4	0.00%	0.00%	0.00%
6	0.00%	0.00%	0.00%
8	2.42%	0.00%	2.99%
10	6.92%	9.09%	6.41%
12	17.65%	27.27%	15.38%
14	20.07%	23.64%	19.23%
16	19.72%	21.82%	19.23%
18	12.46%	7.27%	13.68%
20	9.34%	7.27%	9.83%
22	4.50%	1.82%	5.13%
24	3.81%	1.82%	4.27%
26	1.38%	0.00%	1.71%
28	0.35%	0.00%	0.43%
30	0.35%	0.00%	0.43%
32	0.00%	0.00%	0.00%
34	0.00%	0.00%	0.00%
36	0.35%	0.00%	0.43%
38	0.00%	0.00%	0.00%
40	0.00%	0.00%	0.00%
More	0.69%	0.00%	0.85%

BY FLUID TYPE AND PRECIPITATION

	289	50	109	5	125	159	130
Time (min)	*Total*	*Type 1 Frost*	*Type 1 Snow*	*Type 4 Frost*	*ype 4 Snow*	*Type 1*	*Type 4*
4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
8	2.42%	0.00%	3.67%	0.00%	2.40%	2.52%	2.31%
10	6.92%	10.00%	5.50%	0.00%	7.20%	6.92%	6.92%
12	17.65%	28.00%	22.02%	20.00%	9.60%	23.90%	10.00%
14	20.07%	26.00%	19.27%	0.00%	19.20%	21.38%	18.46%
16	19.72%	20.00%	14.68%	40.00%	23.20%	16.35%	23.85%
18	12.46%	8.00%	13.76%	0.00%	13.60%	11.95%	13.08%
20	9.34%	6.00%	10.09%	20.00%	9.60%	8.81%	10.00%
22	4.50%	2.00%	4.59%	0.00%	5.60%	3.77%	5.38%
24	3.81%	0.00%	4.59%	20.00%	4.00%	3.14%	4.62%
26	1.38%	0.00%	0.00%	0.00%	3.20%	0.00%	3.08%
28	0.35%	0.00%	0.00%	0.00%	0.80%	0.00%	0.77%
30	0.35%	0.00%	0.00%	0.00%	0.80%	0.00%	0.77%
32	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
34	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
36	0.35%	0.00%	0.92%	0.00%	0.00%	0.63%	0.00%
38	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
40	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
More	0.69%	0.00%	0.92%	0.00%	0.80%	0.63%	0.77%

PERCENTAGE OF OCCURANCES

BY RUNWAY

Time (min)	*Total*	*Runway 28 (*	*Runway 06L (*	*Runway 06R (*	*Runway 24L*	*(Rel. Distar*	*Runway U*
8	2.42%	0.00%	0.00%	5.26%	0.00%	0.00%	0.00%
10	6.92%	9.09%	1.92%	8.27%	6.25%	0.00%	15.79%
12	17.65%	42.42%	15.38%	15.79%	15.63%	10.00%	5.26%
14	20.07%	12.12%	17.31%	19.55%	21.88%	30.00%	31.58%
16	19.72%	15.15%	15.38%	21.80%	18.75%	25.00%	21.05%
18	12.46%	12.12%	21.15%	11.28%	3.13%	10.00%	15.79%
20	9.34%	3.03%	9.62%	6.77%	21.88%	15.00%	10.53%
22	4.50%	3.03%	7.69%	3.76%	3.13%	10.00%	0.00%
24	3.81%	0.00%	7.69%	3.01%	9.38%	0.00%	0.00%
26	1.38%	3.03%	3.85%	0.75%	0.00%	0.00%	0.00%
28	0.35%	0.00%	0.00%	0.75%	0.00%	0.00%	0.00%
30	0.35%	0.00%	0.00%	0.75%	0.00%	0.00%	0.00%
36	0.35%	0.00%	0.00%	0.75%	0.00%	0.00%	0.00%
38	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
40	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
More	0.69%	0.00%	0.00%	1.50%	0.00%	0.00%	0.00%

BY AIRCRAFT SIZE

Bin	*Total*	*LARGE*	*MEDIUM*	*SMALL*
4	0.00%	0.00%	0.00%	0.00%
6	0.00%	0.00%	0.00%	0.00%
8	2.42%	0.00%	1.69%	4.88%
10	6.92%	6.67%	4.52%	12.20%
12	17.65%	13.33%	16.95%	20.73%
14	20.07%	13.33%	19.21%	24.39%
16	19.72%	23.33%	19.21%	19.51%
18	12.46%	13.33%	15.25%	6.10%
20	9.34%	10.00%	10.17%	7.32%
22	4.50%	6.67%	5.65%	1.22%
24	3.81%	6.67%	3.95%	2.44%
26	1.38%	6.67%	1.13%	0.00%
28	0.35%	0.00%	0.00%	1.22%
30	0.35%	0.00%	0.56%	0.00%
32	0.00%	0.00%	0.00%	0.00%
34	0.00%	0.00%	0.00%	0.00%
36	0.35%	0.00%	0.56%	0.00%
38	0.00%	0.00%	0.00%	0.00%
40	0.00%	0.00%	0.00%	0.00%
More	0.69%	0.00%	1.13%	0.00%

Heldover Time

	Run 28	Run 06L	Run 06R	Run 24L	Run 24R
Average	13.41	16.23	15.08	15.35	15.36
Skewness	1.44	0.48	4.09	0.28	0.47
Number of samples	33	52	134	32	20
Standard Deviation (min)	3.38	3.96	7.19	4.10	2.94
95% Confidence const	0.05	0.05	0.05	0.05	0.05
Confidence Interval (min)	1.15	1.08	1.22	1.42	1.29
Max	24.43	25.98	67.05	23.22	21.25
Min	8.75	10.00	6.22	8.05	11.02

	Frost	Snow
Average	13.61	15.22
Skewness	0.88	2.21
Number of samples	55	233
Standard Deviation (min)	2.97	4.97
95% Confidence const	0.05	0.05
Confidence Interval (min)	0.79	0.64
Max	23.22	51.95
Min	8.75	6.22

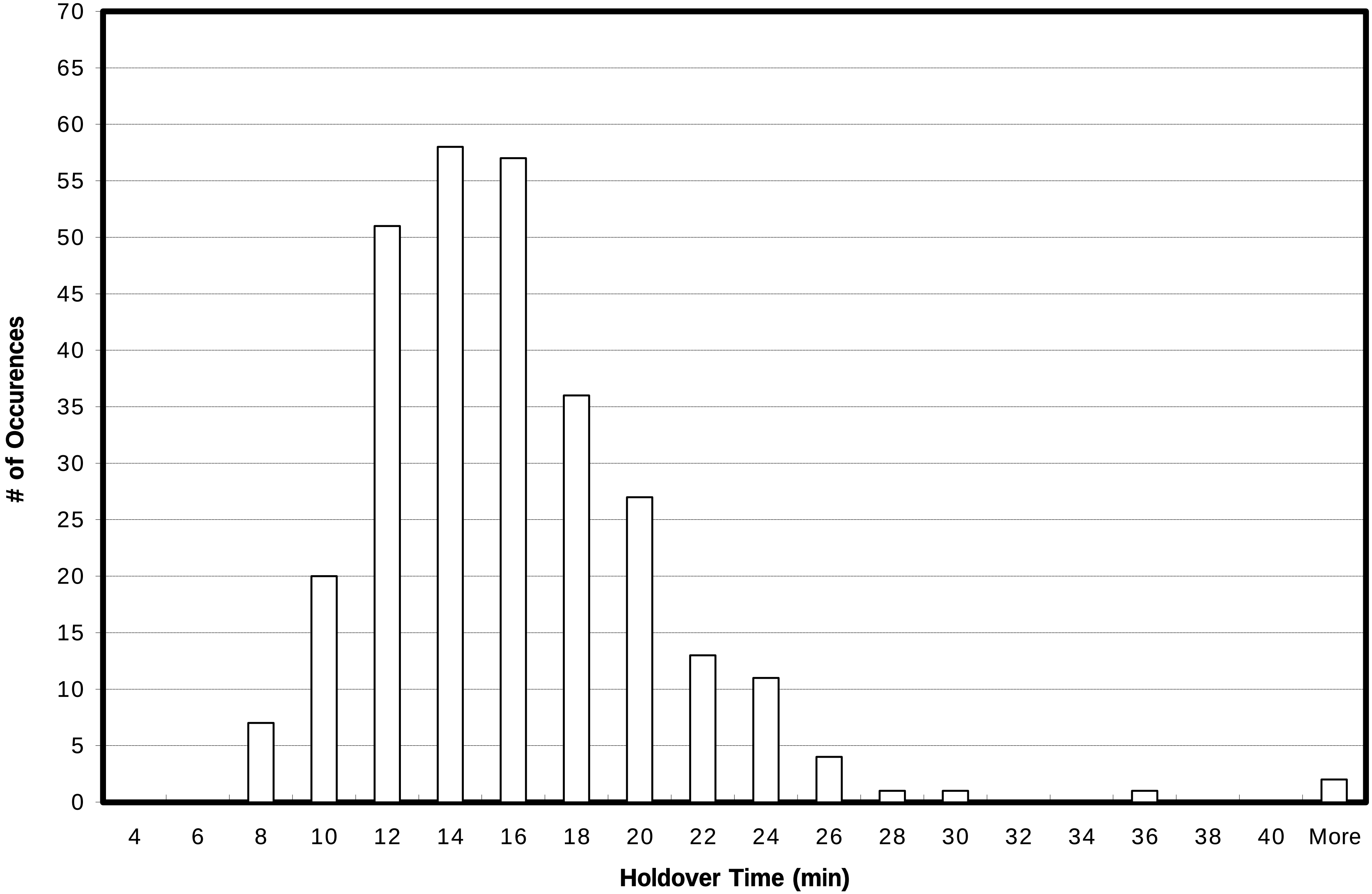
	Type 1 Frost	Type 1 Snow	Type 4 Frost	Type 4 Snow
Average	13.30	14.96	16.72	15.87
Skewness	0.56	3.14	0.64	4.37
Number of samples	50	109	5	125
Standard Deviation	2.65	5.57	4.48	6.36
95% Confidence const	0.05	0.05	0.05	0.05
Confidence Interval (min)	0.73	1.05	3.93	1.11
Max	20.27	51.95	23.22	67.05
Min	8.75	6.22	11.63	6.63

	Type 1	ype 1 / Type 4
Average	14.44	15.90
Skewness	3.39	4.33
Number of samples	159	130
Standard Deviation	4.90	6.28
95% Confidence const	0.05	0.05
Confidence Interval (min)	0.76	1.08
Max	51.95	67.05
Min	6.22	6.63

	Large	Medium	Small
Average	16.11	15.73	13.35
Skewness	0.56	4.36	0.97
Number of samples	30	177	82
Standard Deviation (min)	4.20	6.30	3.81
95% Confidence const	0.05	0.05	0.05
Confidence Interval (min)	1.50	0.93	0.83
Max	25.98	67.05	27.33
Min	9.65	6.63	6.22

FIGURE D.1

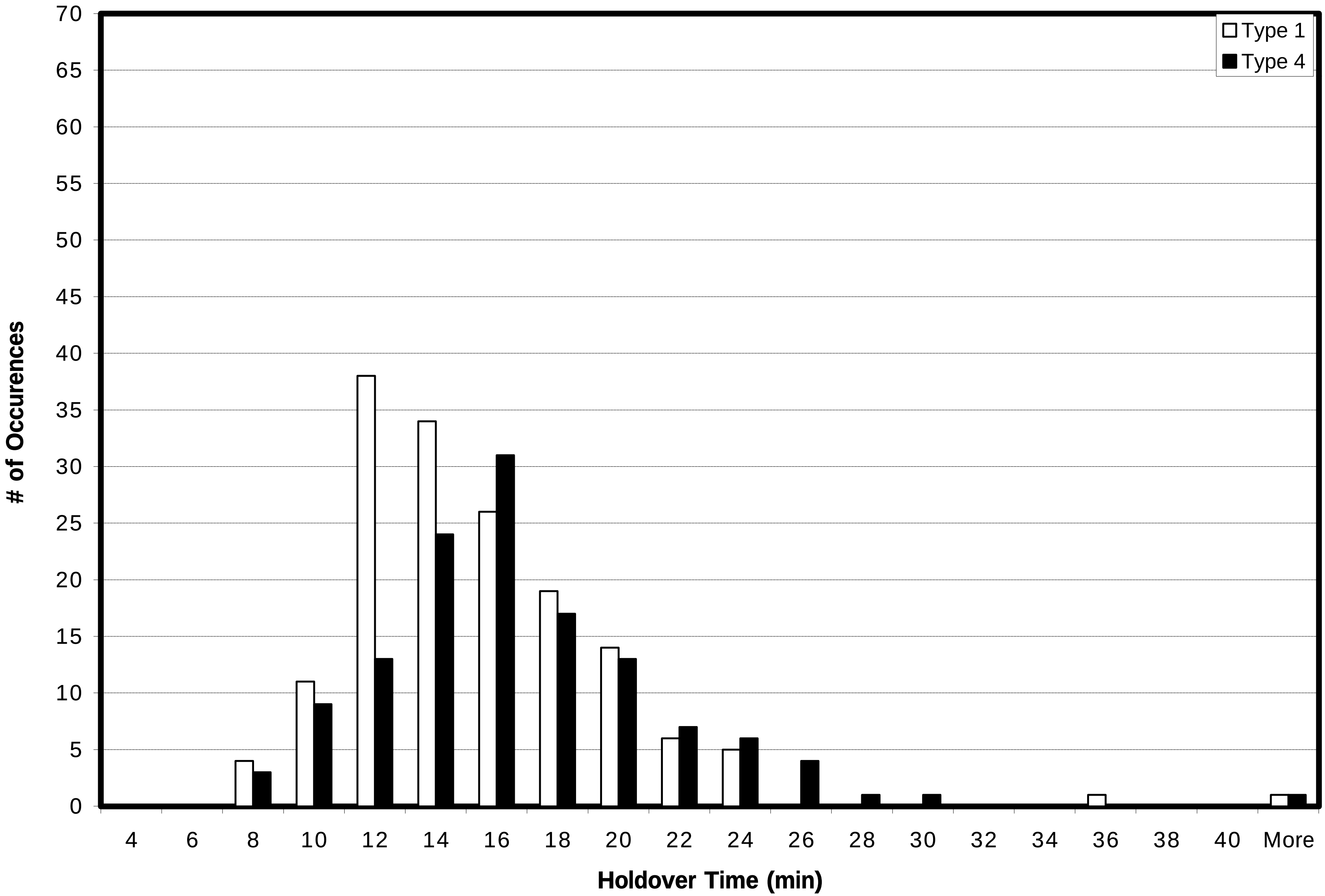
VARIATION OF HOLDOVER TIME



h:\cm1380\report\opns\Hold_tm.xls
At: VAR
Printed on 7/23/02

FIGURE D.2

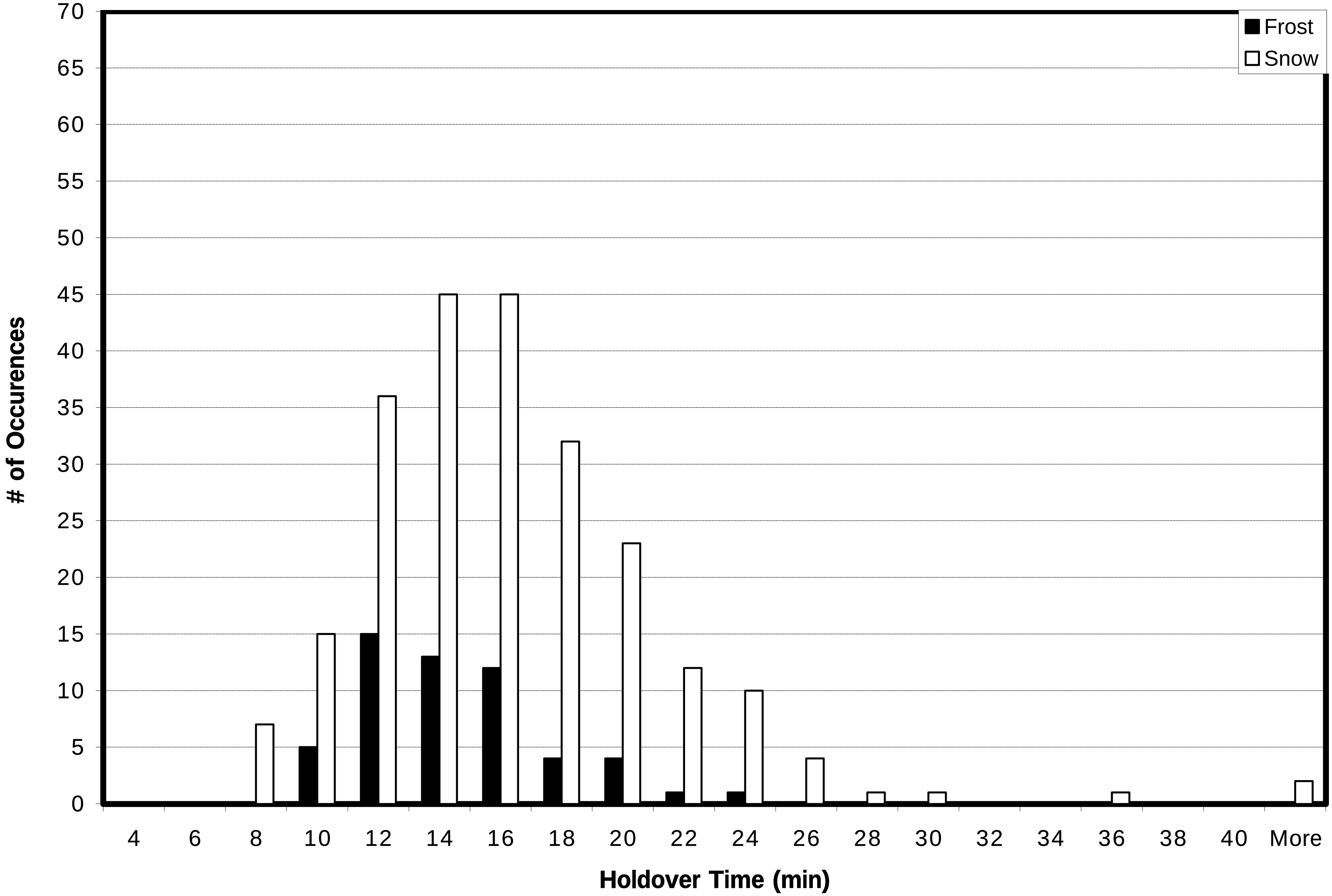
VARIATION OF HOLDOVER TIME WITH FLUID TYPE



h:\cm1380\report\opns\Hold_tm.xls
At: fld_type
Printed on 7/23/02

FIGURE D.3

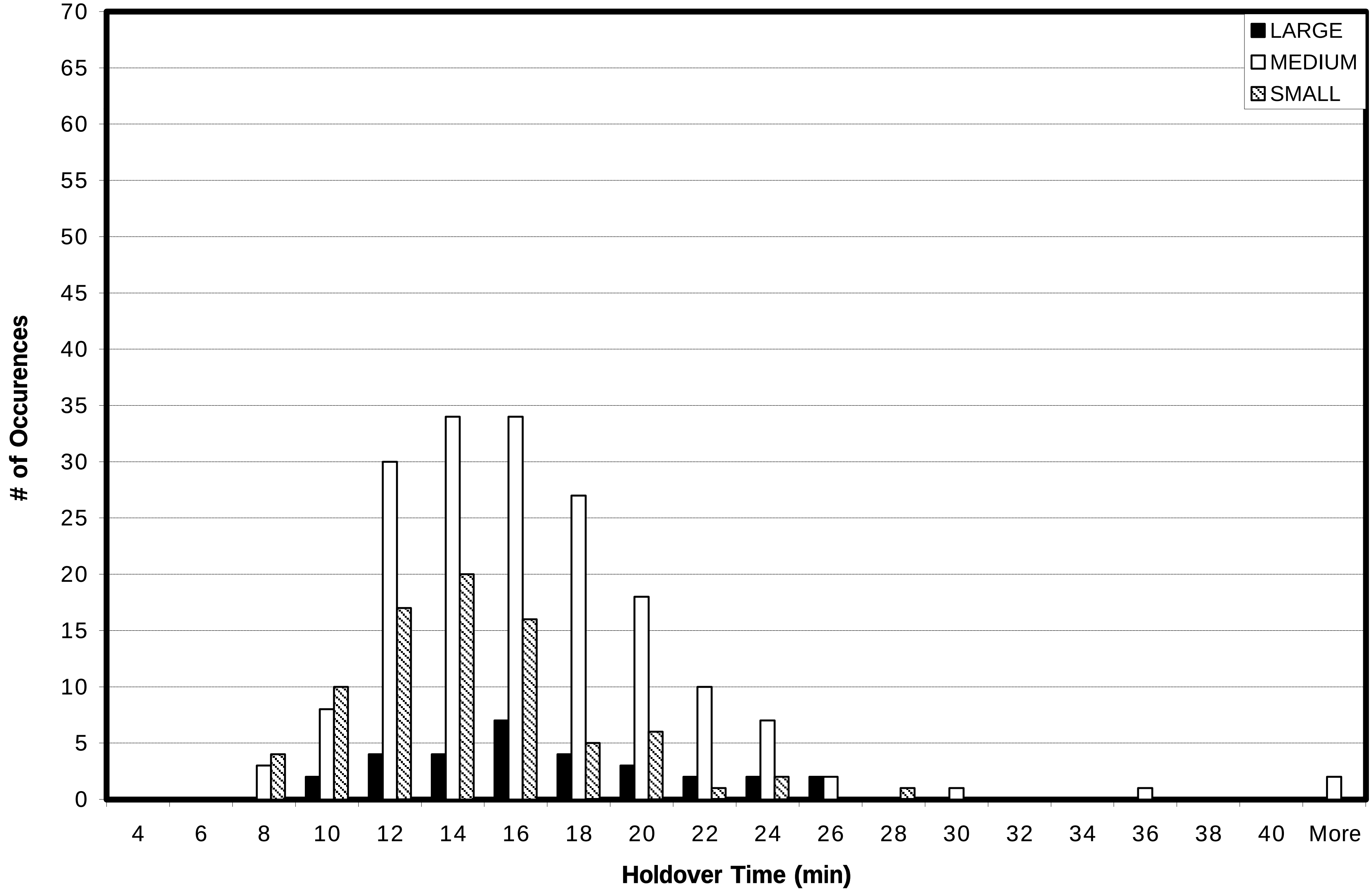
VARIATION OF HOLDOVER TIME WITH WEATHER CONDITIONS



h:\cm1380\report\opns\Hold_tm.xls
At: WX
Printed on 7/23/02

FIGURE D.4

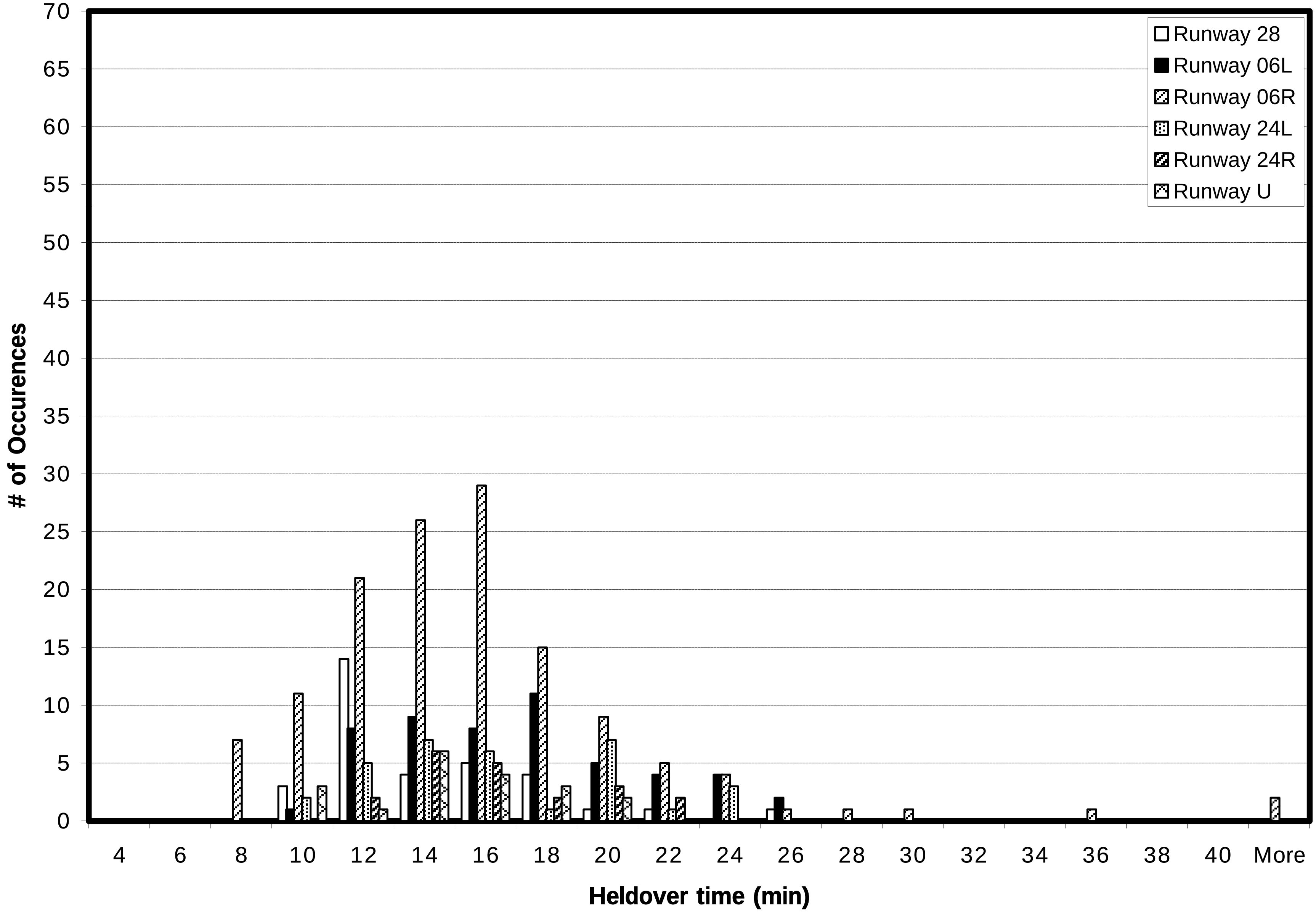
VARIATION OF HOLDOVER TIME WITH AIRCRAFT SIZE



h:\cm1380\report\opns\Hold_tm.xls
At: AC
Printed on 7/23/02

FIGURE D.5

VARIATION OF HOLDOVER TIME WITH RUNWAY LOCATION



h:\cm1380\report\opns\Hold_tm.xls
At: RUNWAY
Printed on 7/23/02

Useable data for analysis

Data #	Date	Flight ID	Fluid type	Reson for Deicing	Precipt. Amt on ground (CM)	Runway	Operation Type	t2-t1	Aircraft Size
1	4-Mar-98	MES3503	TYPE 1/TYPE 4	SNOW	N/A	06R	D	14.05	M
2	4-Mar-98	ACA485	TYPE 1	SNOW	N/A	24L	D	19.17	S
3	4-Mar-98	ONT371	TYPE 1	SNOW	N/A	24L	D	19.20	S
4	4-Mar-98	COM881	TYPE 1	SNOW	N/A	06R	D	12.43	S
5	4-Mar-98	ICN1628	TYPE 1	SNOW	N/A	28	D	11.27	S
6	4-Mar-98	AAL581	TYPE 1/TYPE 4	SNOW	N/A	28	D	11.18	L
7	4-Mar-98	AAQ254	TYPE 1	SNOW	N/A	28	D	14.15	S
8	4-Mar-98	ACA380	TYPE 1	SNOW	N/A	24L	D	19.55	M
10	4-Mar-98	CDN857	TYPE 1	SNOW	N/A	28	D	17.10	M
11	4-Mar-98	ACA117	TYPE 1	SNOW	N/A	28	D	15.20	L
12	4-Mar-98	CDN859	TYPE 1	SNOW	N/A	28	D	11.40	M
13	4-Mar-98	USA506	TYPE 1/TYPE 4	SNOW	N/A	24R	D	16.00	M
14	4-Mar-98	ACA770	TYPE 1	SNOW	N/A	24R	D	18.50	M
15	4-Mar-98	ACA740	TYPE 1	SNOW	N/A	24R	D	16.37	M
17	4-Mar-98	ACA401	TYPE 1/TYPE 4	SNOW	N/A	24R	D	20.58	L
18	4-Mar-98	ACA781	TYPE 1/TYPE 4	SNOW	N/A	28	D	16.12	M
19	4-Mar-98	ICN1630	TYPE 1	SNOW	N/A	28	D	11.67	S
20	8-Mar-98	EGF812	TYPE 1	FROST	-	24L	D	10.78	S
21	8-Mar-98	COM752	TYPE 1	FROST	-	24L	D	12.63	S
22	8-Mar-98	COM900	TYPE 1	FROST	-	24L	D	11.75	S
23	8-Mar-98	AAL581	TYPE 1	FROST	-	24L	D	15.53	M
24	8-Mar-98	MES3503	TYPE 1	FROST	-	24L	D	13.10	M
26	8-Mar-98	CDN857	TYPE 1	FROST	-	U	D	11.13	M
27	8-Mar-98	AAQ102	TYPE 1	FROST	-	28	D	11.60	S
28	8-Mar-98	ACA781	TYPE 1	FROST	-	28	D	11.95	M
29	8-Mar-98	USA506	TYPE 1	FROST	-	24L	D	18.52	M
30	8-Mar-98	ACA602	TYPE 1	FROST	-	28	D	8.75	M
31	8-Mar-98	ACA922	TYPE 1	FROST	-	24R	D	11.02	M
32	8-Mar-98	ACA974	TYPE 1	FROST	-	24R	D	14.88	M
33	8-Mar-98	ACA403	TYPE 1	FROST	-	28	D	9.65	L
34	8-Mar-98	MES3623	TYPE 1	FROST	-	28	D	14.92	M
35	8-Mar-98	ACA988	TYPE 1	FROST	-	24R	D	15.02	M
36	10-Mar-98	ACA392	TYPE 1/TYPE 4	SNOW	5	24R	D	21.25	M

Data #	Date	Flight ID	Fluid type	Reson for Deicing	Precipt. Amt on ground (CM)	Runway	Operation Type	t2-t1	Aircraft Size
37	10-Mar-98	ATL446	TYPE 1	SNOW	5	28	D	11.93	M
38	10-Mar-98	ACA928	TYPE 1/TYPE 4	SNOW	5	24R	D	18.27	M
39	10-Mar-98	ACA742	TYPE 1/TYPE 4	SNOW	5	U	D	18.00	M
40	10-Mar-98	NWA1271	TYPE 1/TYPE 4	SNOW	5	24R	D	13.55	M
41	10-Mar-98	ACA499	TYPE 1	SNOW	6	28	D	11.45	M
42	10-Mar-98	NWA1101	TYPE 1/TYPE 4	SNOW	6	28	D	24.43	M
43	10-Mar-98	ACA382	TYPE 1/TYPE 4	SNOW	6	24R	D	13.60	S
44	10-Mar-98	CDN865	TYPE 1/TYPE 4	SNOW	6	24L	D	22.97	M
45	10-Mar-98	ACA783	TYPE 1/TYPE 4	SNOW	6	28	D	14.10	M
46	10-Mar-98	COM892	TYPE 1/TYPE 4	SNOW	6	24R	D	12.25	M
47	10-Mar-98	COA311	TYPE 1	SNOW	6	28	D	20.70	M
48	10-Mar-98	CMM722	TYPE 1/TYPE 4	SNOW	6	28	D	10.10	M
49	10-Mar-98	COM902	TYPE 1/TYPE 4	SNOW	6	28	D	18.25	S
50	10-Mar-98	ACA407	TYPE 1	SNOW	6	U	D	15.27	L
51	10-Mar-98	ACA797	TYPE 1/TYPE 4	SNOW	7	24L	D	18.15	M
52	10-Mar-98	FAB866	TYPE 1	SNOW	7	24L	D	22.08	L
54	10-Mar-98	ACA109	TYPE 1/TYPE 4	SNOW	7	28	D	15.98	L
55	10-Mar-98	CDN851	TYPE 1	SNOW	7	28	D	12.35	M
56	10-Mar-98	AAL479	TYPE 1	SNOW	7	24L	D	19.93	M
57	11-Mar-98	AAL581	TYPE 1	FROST	-	24L	D	14.13	M
58	11-Mar-98	ACA380	TYPE 1	FROST	-	24L	D	15.20	S
59	11-Mar-98	COM881	TYPE 1	FROST	-	24L	D	12.70	S
60	11-Mar-98	ACA117	TYPE 1	FROST	-	28	D	9.95	L
61	11-Mar-98	ACA781	TYPE 1	FROST	-	24R	D	11.67	L
62	11-Mar-98	ACA401	TYPE 1	FROST	-	U	D	18.12	L
63	12-Mar-98	ACA483	TYPE 1	FROST	-	24L	D	8.85	S
64	12-Mar-98	COM752	TYPE 1	FROST	-	24L	D	12.32	S
65	12-Mar-98	AAL581	TYPE 1/TYPE 4	FROST	-	24L	D	14.38	M
66	12-Mar-98	COM900	TYPE 1/TYPE 4	FROST	-	24L	D	11.63	S
67	12-Mar-98	ACA380	TYPE 1/TYPE 4	FROST	-	24L	D	15.40	S
68	12-Mar-98	ONT371	TYPE 1	FROST	-	24L	D	14.88	S
69	12-Mar-98	ACA485	TYPE 1/TYPE 4	FROST	-	24L	D	18.98	S
70	12-Mar-98	MES3503	TYPE 1/TYPE 4	FROST	-	24L	D	23.22	M
71	12-Mar-98	COM881	TYPE 1	FROST	-	24L	D	20.27	S

Data #	Date	Flight ID	Fluid type	Reson for Deicing	Precipt. Amt on ground (CM)	Runway	Operation Type	t2-t1	Aircraft Size
72	12-Mar-98	AAQ254	TYPE 1	FROST	-	28	D	12.27	S
73	12-Mar-98	ACA117	TYPE 1	FROST	-	28	D	16.75	L
74	12-Mar-98	ACA781	TYPE 1	FROST	-	28	D	13.43	M
75	12-Mar-98	CDN857	TYPE 1	FROST	-	28	D	12.75	M
76	12-Mar-98	ACA740	TYPE 1	FROST	-	24L	D	13.93	M
77	12-Mar-98	CDN859	TYPE 1	FROST	-	28	D	11.20	M
78	12-Mar-98	ACA770	TYPE 1	FROST	-	24R	D	12.87	M
79	12-Mar-98	ACA401	TYPE 1	FROST	-	28	D	11.63	L
80	12-Mar-98	USA506	TYPE 1	FROST	-	24R	D	15.95	M
81	12-Mar-98	COA563	TYPE 1	FROST	-	28	D	16.60	M
82	12-Mar-98	ROY942	TYPE 1	FROST	-	24R	D	18.53	M
83	12-Mar-98	ACA602	TYPE 1	FROST	-	24L	D	13.50	L
84	12-Mar-98	ACA433	TYPE 1	FROST	-	28	D	11.28	M
85	12-Mar-98	USA1670	TYPE 1	FROST	-	24R	D	15.70	M
86	12-Mar-98	CDR1941	TYPE 1	FROST	-	28	D	11.22	S
87	12-Mar-98	DAL2087	TYPE 1	FROST	-	24R	D	16.05	M
88	12-Mar-98	NWA1271	TYPE 1	FROST	-	28	D	11.30	M
89	13-Mar-98	COM752	TYPE 1	FROST	-	24L	D	12.15	S
90	13-Mar-98	ACA481	TYPE 1	FROST	-	U	D	14.05	S
91	13-Mar-98	COM900	TYPE 1	FROST	-	24L	D	10.17	S
92	13-Mar-98	COM881	TYPE 1	FROST	-	24L	D	16.62	S
93	13-Mar-98	MES3503	TYPE 1	FROST	-	24L	D	11.53	M
94	13-Mar-98	AAL581	TYPE 1	FROST	-	U	D	13.98	S
95	13-Mar-98	COA563	TYPE 1	FROST	-	U	D	9.68	M
96	13-Mar-98	ACA740	TYPE 1	FROST	-	U	D	12.47	M
97	14-Mar-98	ONT377	TYPE 1	SNOW	0	06R	D	7.57	S
98	14-Mar-98	CDR1947	TYPE 1/TYPE 4	SNOW	0	06R	D	8.47	S
99	14-Mar-98	ACA405	TYPE 1	SNOW	0	06R	D	11.18	M
100	14-Mar-98	CDN911	TYPE 1	SNOW	0	06L	D	11.40	M
101	14-Mar-98	AAL1041	TYPE 1/TYPE 4	SNOW	0	06R	D	16.87	M
102	14-Mar-98	ACA742	TYPE 1	SNOW	0	U	D	16.30	M
103	14-Mar-98	DAL879	TYPE 1/TYPE 4	SNOW	1	06R	D	13.52	M
104	14-Mar-98	ACA111	TYPE 1	SNOW	1	06R	D	12.25	L
105	14-Mar-98	ACA930	TYPE 1	SNOW	1	06R	D	19.32	M

Data #	Date	Flight ID	Fluid type	Reson for Deicing	Precipt. Amt on ground (CM)	Runway	Operation Type	t2-t1	Aircraft Size
106	14-Mar-98	COM892	TYPE 1	SNOW	1	06R	D	12.72	S
107	14-Mar-98	ACA392	TYPE 1/TYPE 4	SNOW	1	06R	D	11.05	S
108	14-Mar-98	ACA928	TYPE 1/TYPE 4	SNOW	1	06R	D	6.63	M
109	14-Mar-98	ACA920	TYPE 1	SNOW	1	06R	D	11.77	M
110	14-Mar-98	COM902	TYPE 1/TYPE 4	SNOW	1	06R	D	9.42	S
111	14-Mar-98	FAB866	TYPE 1	SNOW	1	06R	D	15.60	L
112	14-Mar-98	CDR1945	TYPE 1/TYPE 4	SNOW	1	06R	D	9.22	S
113	14-Mar-98	ACA407	TYPE 1	SNOW	1	06L	D	13.13	M
114	14-Mar-98	COA1471	TYPE 1	SNOW	1	06L	D	13.73	M
115	14-Mar-98	ACA797	TYPE 1/TYPE 4	SNOW	2	06L	D	15.58	M
117	14-Mar-98	NWA1101	TYPE 1	SNOW	2	06L	D	21.05	M
118	14-Mar-98	ACA956	TYPE 1/TYPE 4	SNOW	2	06L	D	11.25	L
119	14-Mar-98	ACA671	TYPE 1/TYPE 4	SNOW	2	06L	D	12.85	M
120	14-Mar-98	CDR1951	TYPE 1/TYPE 4	SNOW	2	06L	D	12.15	S
132	14-Mar-98	ARN881	TYPE 1/TYPE 4	SNOW	3	06R	D	10.42	M
133	14-Mar-98	AAL1671	TYPE 1/TYPE 4	SNOW	3	06L	D	20.88	M
134	14-Mar-98	ACA384	TYPE 1/TYPE 4	SNOW	3	06L	D	16.70	S
135	14-Mar-98	AAL479	TYPE 1/TYPE 4	SNOW	3	U	F	19.10	M
136	14-Mar-98	CDR1955	TYPE 1/TYPE 4	SNOW	3	06R	D	15.90	S
137	14-Mar-98	COM905	TYPE 1/TYPE 4	SNOW	4	06R	D	11.97	S
138	14-Mar-98	COM849	TYPE 1/TYPE 4	SNOW	4	06L	D	17.25	S
139	14-Mar-98	ACA413	TYPE 1/TYPE 4	SNOW	4	06R	D	12.75	M
140	14-Mar-98	ATL440	TYPE 1	SNOW	4	06L	D	11.77	M
141	14-Mar-98	ACA785	TYPE 1	SNOW	4	06L	D	11.60	M
142	14-Mar-98	COM916	TYPE 1/TYPE 4	SNOW	4	06L	D	12.17	S
143	14-Mar-98	CDR1957	TYPE 1/TYPE 4	SNOW	4	06R	D	8.38	S
144	14-Mar-98	USA261	TYPE 1/TYPE 4	SNOW	4	06L	D	13.52	M
145	14-Mar-98	ARN874	TYPE 1/TYPE 4	SNOW	4	06R	D	6.73	S
146	14-Mar-98	ACA774	TYPE 1/TYPE 4	SNOW	4	06L	D	13.05	S
147	14-Mar-98	ATL486	TYPE 1/TYPE 4	SNOW	4	06R	D	9.33	M
148	14-Mar-98	AAQ296	TYPE 1/TYPE 4	SNOW	4	06L	D	11.20	S
149	14-Mar-98	ONT383	TYPE 1/TYPE 4	SNOW	5	06L	D	14.33	S
150	14-Mar-98	EGF834	TYPE 1/TYPE 4	SNOW	5	06L	D	22.60	S
151	14-Mar-98	ACA2928	TYPE 1/TYPE 4	SNOW	5	06L	D	11.30	M

Data #	Date	Flight ID	Fluid type	Reson for Deicing	Precipt. Amt on ground (CM)	Runway	Operation Type	t2-t1	Aircraft Size
152	14-Mar-98	ACA417	TYPE 1/TYPE 4	SNOW	5	06L	D	17.07	M
153	14-Mar-98	BAW95	TYPE 1/TYPE 4	SNOW	5	06L	D	14.55	L
154	14-Mar-98	DAL2091	TYPE 1	SNOW	5	06L	D	17.05	M
155	15-Mar-98	MES3623	TYPE 1/TYPE 4	SNOW	0	24R	D	12.65	M
156	15-Mar-98	DAL2087	TYPE 1	SNOW	0	06R	D	34.23	M
157	15-Mar-98	ACA974	TYPE 1	SNOW	0	06L	D	19.85	M
159	15-Mar-98	MXA881	TYPE 1	SNOW	0	24R	D	12.40	M
160	15-Mar-98	ACA403	TYPE 1	SNOW	0	06R	D	15.03	M
161	15-Mar-98	ROY572	TYPE 1	SNOW	0	06R	D	17.50	M
162	15-Mar-98	ACA988	TYPE 1	SNOW	0	06L	D	18.48	M
163	15-Mar-98	CDN911	TYPE 1	SNOW	0	06R	D	14.50	M
164	15-Mar-98	CDR1947	TYPE 1/TYPE 4	SNOW	0	06R	D	16.62	S
165	15-Mar-98	ACA405	TYPE 1	SNOW	0	06R	D	13.70	M
166	15-Mar-98	AAL1041	TYPE 1	SNOW	1	06R	D	17.55	M
167	15-Mar-98	ACA111	TYPE 1	SNOW	1	06R	D	13.33	L
168	15-Mar-98	ACA930	TYPE 1	SNOW	1	06R	D	11.23	M
169	15-Mar-98	ACA928	TYPE 1	SNOW	1	06R	D	14.22	M
170	15-Mar-98	DAL879	TYPE 1	SNOW	1	06R	D	17.93	M
171	15-Mar-98	ACA392	TYPE 1	SNOW	1	06R	D	10.05	S
172	15-Mar-98	ACA742	TYPE 1	SNOW	1	06R	D	11.27	M
173	15-Mar-98	NWA1101	TYPE 1	SNOW	1	06R	D	16.93	M
174	15-Mar-98	COM892	TYPE 1	SNOW	1	06R	D	11.60	S
175	15-Mar-98	COA311	TYPE 1	SNOW	1	06R	D	10.73	M
176	15-Mar-98	ACA407	TYPE 1	SNOW	1	06R	D	12.42	M
177	15-Mar-98	ACA920	TYPE 1	SNOW	1	06R	D	11.12	M
178	19-Mar-98	ACA481	TYPE 1	SNOW	2	06R	D	14.15	S
179	19-Mar-98	AAL581	TYPE 1/TYPE 4	SNOW	2	06R	D	14.15	S
180	19-Mar-98	ACA483	TYPE 1/TYPE 4	SNOW	2	U	D	12.48	S
181	19-Mar-98	COM900	TYPE 1/TYPE 4	SNOW	2	06R	D	14.23	S
182	19-Mar-98	MES3503	TYPE 1	SNOW	2	06L	D	22.48	M
183	19-Mar-98	COM881	TYPE 1/TYPE 4	SNOW	2	06L	D	13.30	S
184	19-Mar-98	ACA485	TYPE 1/TYPE 4	SNOW	2	06L	D	15.98	S
185	19-Mar-98	CDN857	TYPE 1/TYPE 4	SNOW	2	06L	D	16.88	M
186	19-Mar-98	CDN859	TYPE 1	SNOW	2	06L	D	18.32	M

Data #	Date	Flight ID	Fluid type	Reson for Deicing	Precipt. Amt on ground (CM)	Runway	Operation Type	t2-t1	Aircraft Size
187	19-Mar-98	ACA781	TYPE 1	SNOW	2	06L	D	16.25	M
188	19-Mar-98	AAQ102	TYPE 1	SNOW	2	06L	D	10.00	S
189	19-Mar-98	ACA401	TYPE 1	SNOW	2	06R	D	20.53	L
190	19-Mar-98	ACA117	TYPE 1/TYPE 4	SNOW	2	06R	D	18.92	L
191	19-Mar-98	ROY942	TYPE 1	SNOW	2	06R	D	23.15	M
193	19-Mar-98	ACA770	TYPE 1	SNOW	2	06R	D	18.08	M
194	19-Mar-98	ATL482	TYPE 1	SNOW	2	06R	D	17.05	M
195	19-Mar-98	USA506	TYPE 1/TYPE 4	SNOW	2	06R	D	15.33	M
196	19-Mar-98	ACA602	TYPE 1	SNOW	2	06R	D	18.38	M
197	19-Mar-98	ACA433	TYPE 1	SNOW	2	06R	D	51.95	M
198	19-Mar-98	USA1670	TYPE 1/TYPE 4	SNOW	2	06R	D	14.53	M
199	19-Mar-98	ROY006	TYPE 1	SNOW	2	06R	D	11.17	M
200	19-Mar-98	AIE434	TYPE 1/TYPE 4	SNOW	2	06R	D	9.58	S
201	19-Mar-98	CDR1941	TYPE 1/TYPE 4	SNOW	2	06R	D	12.43	S
202	19-Mar-98	ACA403	TYPE 1/TYPE 4	SNOW	2	06R	D	18.70	L
203	19-Mar-98	NWA1271	TYPE 1/TYPE 4	SNOW	2	06R	D	14.72	M
204	19-Mar-98	MXA881	TYPE 1/TYPE 4	SNOW	3	06R	D	19.02	M
205	19-Mar-98	DAL2087	TYPE 1/TYPE 4	SNOW	3	06R	D	21.95	M
206	19-Mar-98	DAL879	TYPE 1	SNOW	3	06R	D	17.18	M
207	19-Mar-98	ACA499	TYPE 1	SNOW	3	U	D	13.23	M
208	19-Mar-98	ACA930	TYPE 1	SNOW	3	06R	D	13.42	M
209	19-Mar-98	ACA928	TYPE 1	SNOW	3	06R	D	12.48	M
210	19-Mar-98	NWA1101	TYPE 1	SNOW	3	06R	D	20.38	M
211	19-Mar-98	ACA742	TYPE 1	SNOW	3	06R	D	15.90	M
212	19-Mar-98	ACA797	TYPE 1	SNOW	3	06L	D	16.47	M
213	19-Mar-98	ACA783	TYPE 1	SNOW	3	06L	D	16.13	M
214	19-Mar-98	COM902	TYPE 1	SNOW	3	06L	D	12.83	S
215	19-Mar-98	ACA382	TYPE 1	SNOW	3	06L	D	18.00	M
216	19-Mar-98	AAQ182	TYPE 1	SNOW	3	U	D	9.00	S
217	19-Mar-98	ACA3109	TYPE 1	SNOW	3	06R	D	12.97	L
218	19-Mar-98	ATL484	TYPE 1	SNOW	3	06R	D	11.15	M
219	19-Mar-98	COA311	TYPE 1	SNOW	3	06R	D	15.57	M
220	19-Mar-98	ATL483	TYPE 1	SNOW	3	06R	D	8.12	M
221	19-Mar-98	AAL479	TYPE 1	SNOW	3	06R	D	15.10	M

Data #	Date	Flight ID	Fluid type	Reson for Deicing	Precipt. Amt on ground (CM)	Runway	Operation Type	t2-t1	Aircraft Size
222	19-Mar-98	EGF928	TYPE 1	SNOW	3	06R	D	10.78	S
223	19-Mar-98	USA950	TYPE 1	SNOW	3	06R	D	8.63	M
224	19-Mar-98	CDR1953	TYPE 1	SNOW	3	06R	D	9.95	S
225	19-Mar-98	ACA411	TYPE 1	SNOW	3	06R	D	12.72	M
226	19-Mar-98	AAL1671	TYPE 1	SNOW	3	06R	D	7.07	M
227	19-Mar-98	ACA785	TYPE 1	SNOW	3	06R	D	11.72	M
228	19-Mar-98	ACA384	TYPE 1	SNOW	3	06R	D	14.53	M
229	19-Mar-98	ACA415	TYPE 1	SNOW	3	U	D	12.25	M
230	19-Mar-98	ACA774	TYPE 1	SNOW	3	06R	D	9.70	M
231	19-Mar-98	ACA417	TYPE 1	SNOW	3	06R	D	12.67	M
232	19-Mar-98	ACA748	TYPE 1	SNOW	3	06R	D	12.13	M
233	19-Mar-98	AAL2267	TYPE 1	SNOW	3	06R	D	20.05	M
234	19-Mar-98	EGF825	TYPE 1	SNOW	3	06R	D	11.10	S
236	19-Mar-98	ACA435	TYPE 1	SNOW	3	06R	D	11.13	M
237	19-Mar-98	ACA421	TYPE 1	SNOW	3	06R	D	15.50	M
238	19-Mar-98	ACA776	TYPE 1	SNOW	3	06R	D	23.78	M
239	19-Mar-98	AAQ258	TYPE 1	SNOW	3	06R	D	7.75	S
240	19-Mar-98	ACA388	TYPE 1/TYPE 4	SNOW	3	06R	D	12.15	S
241	19-Mar-98	ACA750	TYPE 1/TYPE 4	SNOW	3	06R	D	15.78	M
242	19-Mar-98	ACA155	TYPE 1/TYPE 4	SNOW	3	06R	D	10.73	M
243	19-Mar-98	USA297	TYPE 1/TYPE 4	SNOW	3	06R	D	21.17	M
244	19-Mar-98	ACA144	TYPE 1	SNOW	3	06R	D	12.80	M
245	19-Mar-98	ACA143	TYPE 1/TYPE 4	SNOW	3	06R	D	11.17	M
246	19-Mar-98	AAQ181	TYPE 1	SNOW	3	06R	D	12.98	S
247	19-Mar-98	ACA439	TYPE 1/TYPE 4	SNOW	3	06R	D	16.00	M
248	19-Mar-98	CDN789	TYPE 1/TYPE 4	SNOW	3	06R	D	15.90	M
249	19-Mar-98	ARN838	TYPE 1	SNOW	3	06R	D	6.22	S
250	19-Mar-98	AAQ266	TYPE 1	SNOW	3	06R	D	15.15	S
251	19-Mar-98	ATL442	TYPE 1	SNOW	3	06R	D	10.78	M
252	19-Mar-98	CDN883	TYPE 1/TYPE 4	SNOW	3	06R	D	13.17	M
253	19-Mar-98	ACA425	TYPE 1	SNOW	3	06R	D	17.00	L
254	19-Mar-98	CDR1967	TYPE 1/TYPE 4	SNOW	3	06R	D	13.33	S
255	19-Mar-98	ARN886	TYPE 1/TYPE 4	SNOW	3	06R	D	15.87	M
256	19-Mar-98	AAQ286	TYPE 1	SNOW	4	06R	D	10.92	S

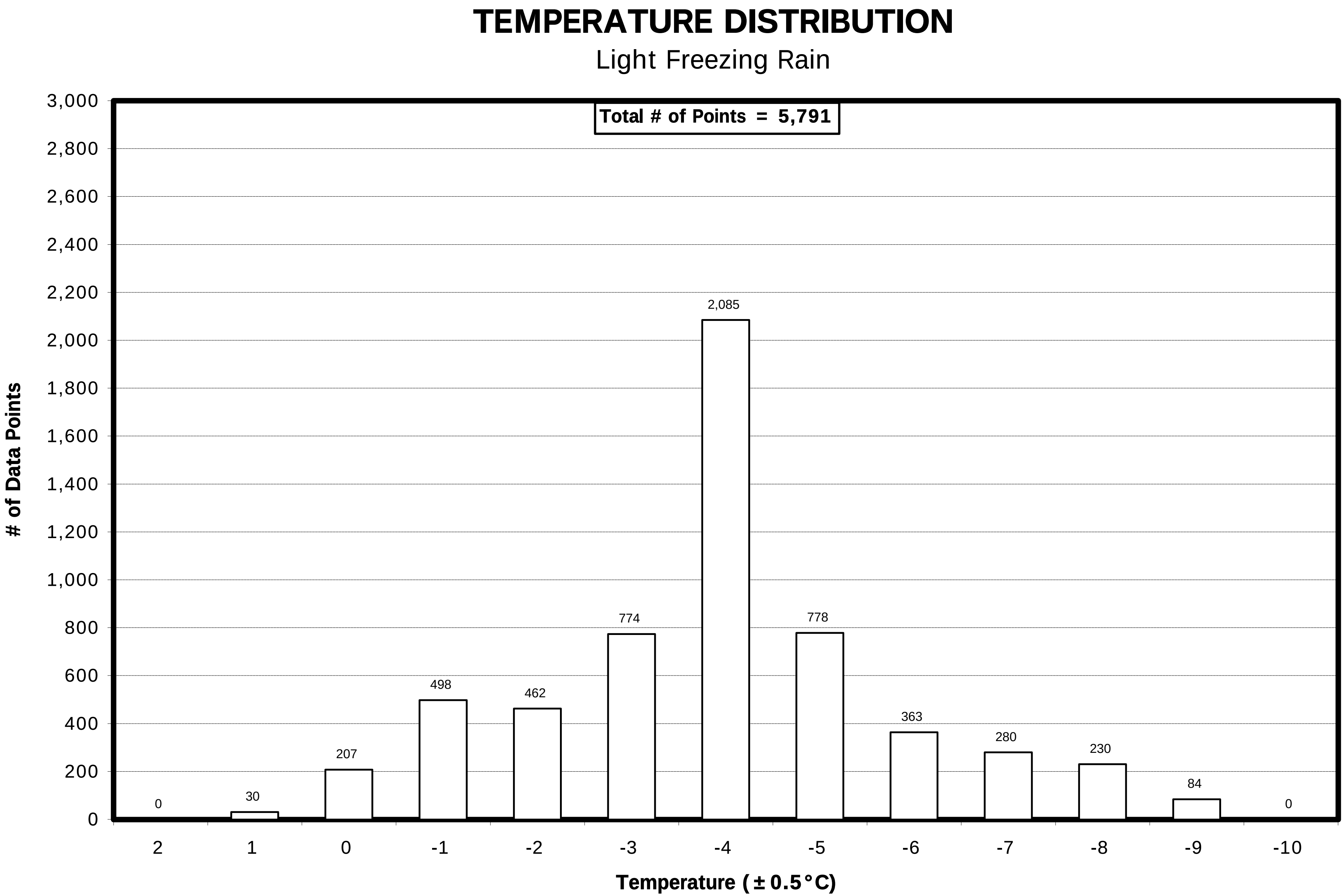
Data #	Date	Flight ID	Fluid type	Reson for Deicing	Precipt. Amt on ground (CM)	Runway	Operation Type	t2-t1	Aircraft Size
257	19-Mar-98	KLM672	TYPE 1/TYPE 4	SNOW	4	06L	D	24.37	L
258	19-Mar-98	NWA1107	TYPE 1/TYPE 4	SNOW	4	06R	D	17.40	M
259	19-Mar-98	AAL1259	TYPE 1/TYPE 4	SNOW	4	06R	D	27.33	S
260	19-Mar-98	ARN882	TYPE 1/TYPE 4	SNOW	4	06R	D	14.97	M
261	19-Mar-98	ACA398	TYPE 1	SNOW	4	06R	D	23.23	S
262	19-Mar-98	AAQ164	TYPE 1	SNOW	4	U	D	15.52	S
263	19-Mar-98	ACA129	TYPE 1/TYPE 4	SNOW	4	06L	D	20.37	M
264	19-Mar-98	ACA752	TYPE 1/TYPE 4	SNOW	4	06R	D	13.23	M
265	19-Mar-98	ACA870	TYPE 1/TYPE 4	SNOW	4	06L	D	17.35	L
266	19-Mar-98	ACA427	TYPE 1/TYPE 4	SNOW	4	06L	D	14.80	L
267	19-Mar-98	CDR1973	TYPE 1/TYPE 4	SNOW	4	06L	D	15.87	S
268	19-Mar-98	COM710	TYPE 1/TYPE 4	SNOW	4	06L	D	11.23	S
269	19-Mar-98	ARN897	TYPE 1/TYPE 4	SNOW	4	06L	D	10.93	M
270	19-Mar-98	ACA866	TYPE 1/TYPE 4	SNOW	4	06L	D	22.07	L
271	19-Mar-98	CSA101	TYPE 1/TYPE 4	SNOW	4	06L	D	19.40	M
272	19-Mar-98	AAQ262	TYPE 1	SNOW	4	06L	D	14.57	S
273	19-Mar-98	ACA041	TYPE 1/TYPE 4	SNOW	4	06L	D	16.27	M
274	19-Mar-98	AFR347	TYPE 1/TYPE 4	SNOW	4	06L	D	25.98	L
275	19-Mar-98	CDN855	TYPE 1/TYPE 4	SNOW	4	06L	D	15.47	M
276	19-Mar-98	ACA429	TYPE 1/TYPE 4	SNOW	4	U	D	9.73	M
277	19-Mar-98	AAQ137	TYPE 1/TYPE 4	SNOW	4	06R	D	19.43	S
278	19-Mar-98	ACA431	TYPE 1/TYPE 4	SNOW	4	06R	D	18.08	M
280	19-Mar-98	KNX9911	TYPE 1/TYPE 4	SNOW	4	24L	D	8.05	S
281	19-Mar-98	ARN899	TYPE 1/TYPE 4	SNOW	4	06R	D	7.28	M
282	21-Mar-98	ACA419	TYPE 1/TYPE 4	SNOW	4	06R	D	16.68	M
283	21-Mar-98	ACA183	TYPE 1/TYPE 4	SNOW	4	06R	D	67.05	M
284	21-Mar-98	ACA417	TYPE 1/TYPE 4	SNOW	4	06R	D	14.60	M
285	21-Mar-98	NWA1105	TYPE 1/TYPE 4	SNOW	4	06R	D	12.23	M
287	21-Mar-98	COM918	TYPE 1/TYPE 4	SNOW	4	06L	D	19.87	S
288	21-Mar-98	ACA940	TYPE 1/TYPE 4	SNOW	4	06R	D	15.73	M
289	21-Mar-98	ACA867	TYPE 1/TYPE 4	SNOW	4	U	D	15.95	L
290	21-Mar-98	ACA396	TYPE 1/TYPE 4	SNOW	4	06R	D	13.13	S
291	21-Mar-98	CDN887	TYPE 1/TYPE 4	SNOW	4	06R	D	12.30	M
292	21-Mar-98	ACA787	TYPE 1/TYPE 4	SNOW	4	06R	D	12.08	M

Data #	Date	Flight ID	Fluid type	Reson for Deicing	Precipt. Amt on ground (CM)	Runway	Operation Type	t2-t1	Aircraft Size
293	21-Mar-98	ATL485	TYPE 1/TYPE 4	SNOW	4	U	D	16.25	M
294	21-Mar-98	ACA183	TYPE 1/TYPE 4	SNOW	4	06R	D	15.05	M
295	21-Mar-98	ACA421	TYPE 1/TYPE 4	SNOW	4	06R	D	15.85	M
296	21-Mar-98	AAL1133	TYPE 1/TYPE 4	SNOW	4	06R	D	17.80	M
297	21-Mar-98	ACA143	TYPE 1/TYPE 4	SNOW	4	06R	D	14.85	M
298	21-Mar-98	ACA155	TYPE 1/TYPE 4	SNOW	4	06R	D	13.55	M
305	22-Mar-98	AAQ102	TYPE 1/TYPE 4	SNOW	10	06R	D	14.67	S
306	22-Mar-98	ACA117	TYPE 1/TYPE 4	SNOW	10	06R	D	16.12	L
307	22-Mar-98	USA506	TYPE 1/TYPE 4	SNOW	10	06L	D	22.28	M
308	22-Mar-98	ATL482	TYPE 1/TYPE 4	SNOW	10	06R	D	9.88	M
309	22-Mar-98	USA1670	TYPE 1/TYPE 4	SNOW	10	U	D	13.87	M
310	22-Mar-98	ACA922	TYPE 1/TYPE 4	SNOW	10	06R	D	18.07	M
312	22-Mar-98	ACA403	TYPE 1/TYPE 4	SNOW	10	06R	D	29.45	M
313	22-Mar-98	ACA602	TYPE 1/TYPE 4	SNOW	10	06R	D	25.55	M
314	22-Mar-98	ACA974	TYPE 1/TYPE 4	SNOW	10	06R	D	17.98	M
315	22-Mar-98	MXA881	TYPE 1/TYPE 4	SNOW	10	06R	D	22.58	M
316	22-Mar-98	AAL581	TYPE 1/TYPE 4	SNOW	10	06R	D	16.95	S
318	22-Mar-98	ACA988	TYPE 1/TYPE 4	SNOW	10	06L	D	21.73	M

Stand. Dev (min.)	5.60
Average	15.09
# of Samples	289
Conf. Const.	0.05
Conf. Interval	0.646
Skewness	4.05

APPENDIX K

SNOW WEATHER DATA 1995/96 TO 1997/98



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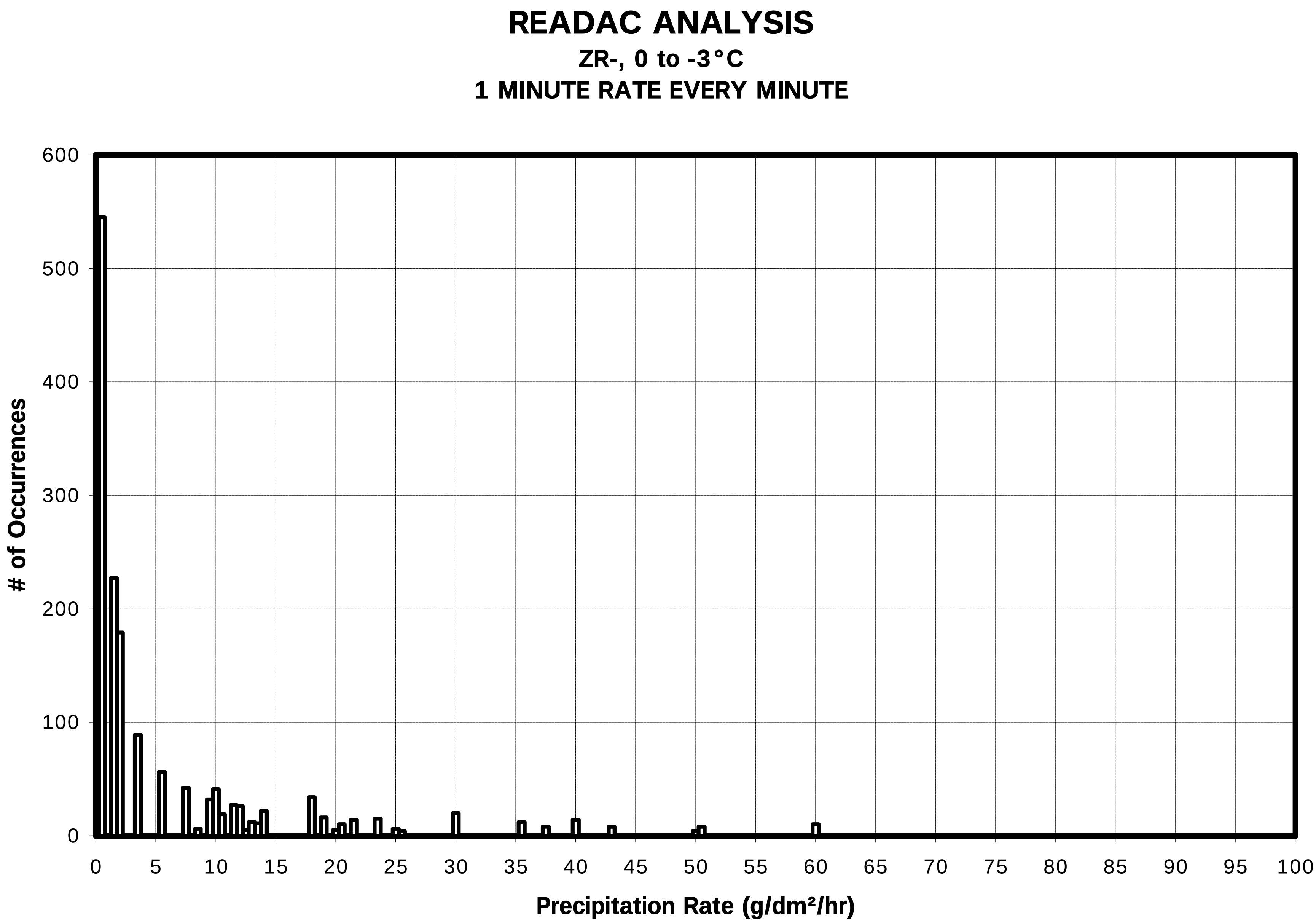

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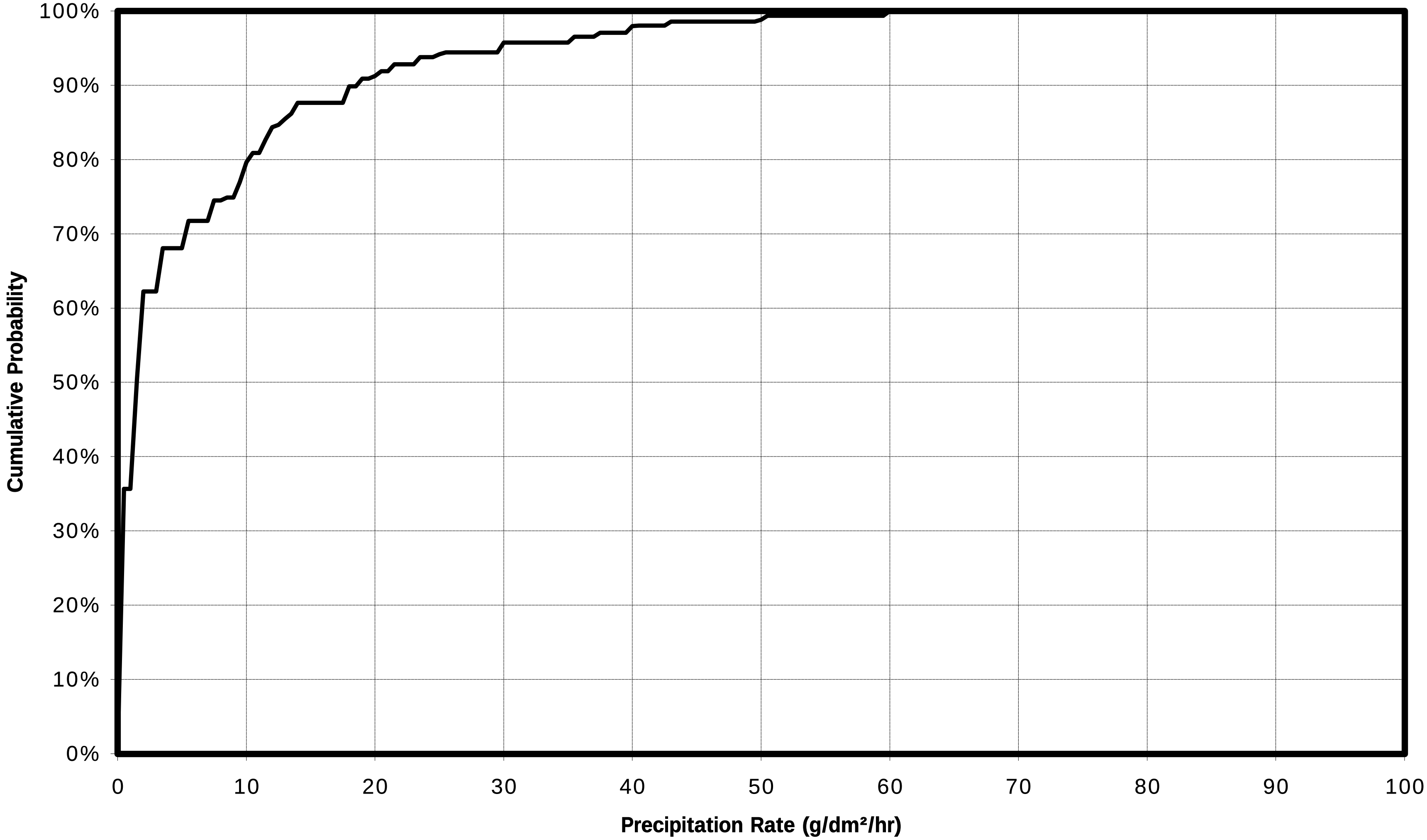
READADAC ANALYSIS

ZR-, 0 to -3°C

1 MINUTE RATE EVERY MINUTE



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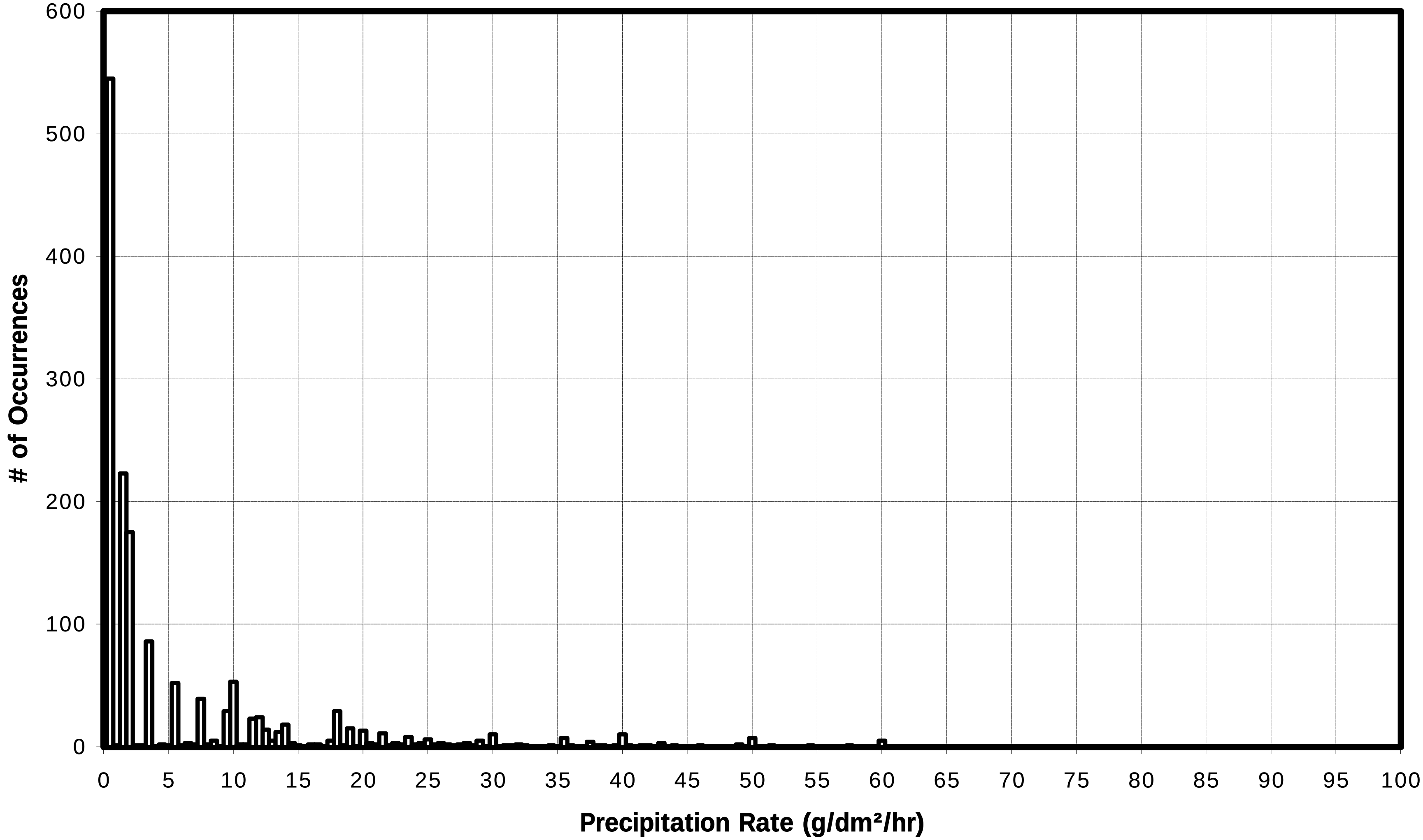
READAC ANALYSIS

ZR-, 0 to -3°C

6 MINUTES RATE EVERY MINUTE



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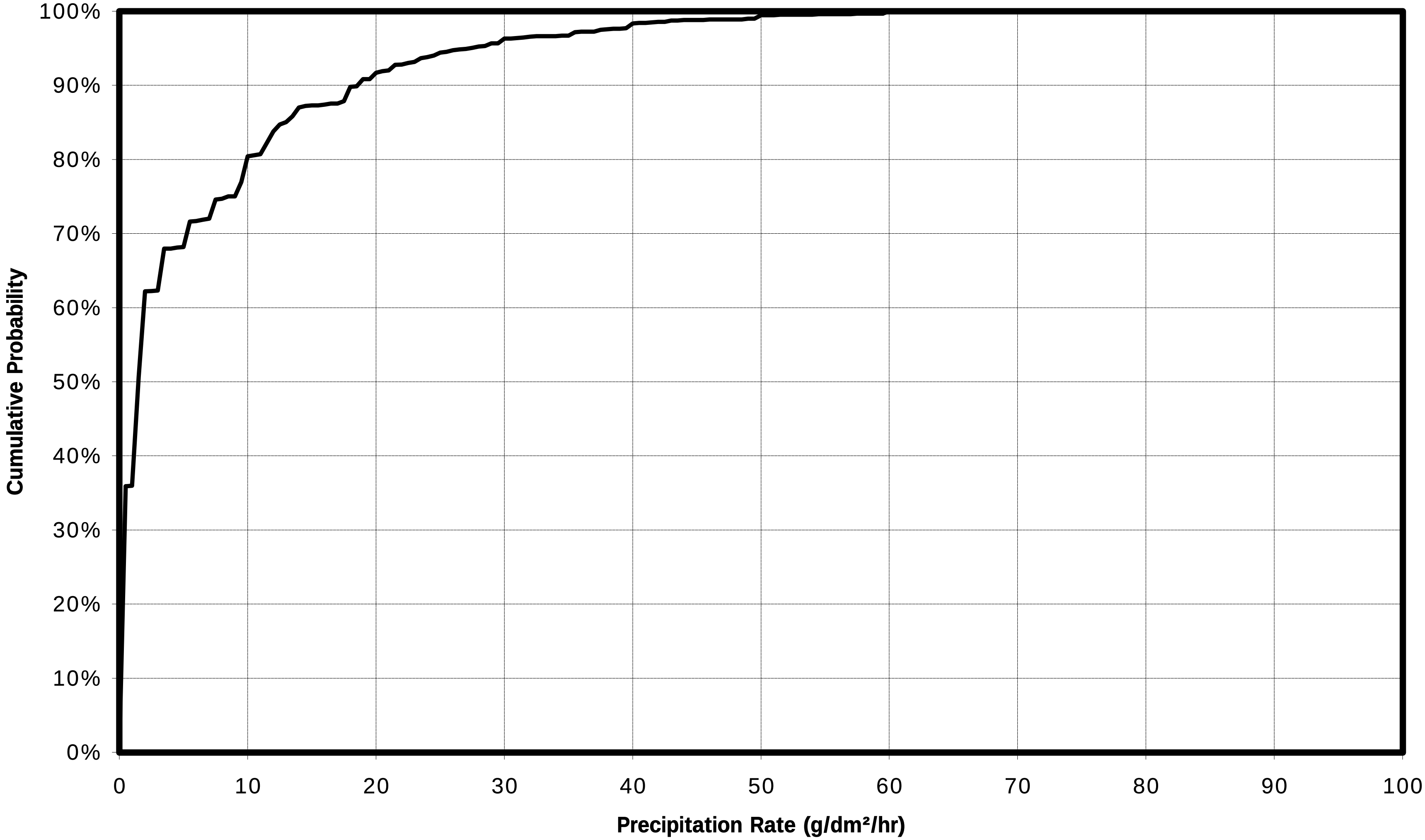
READADAC ANALYSIS

ZR-, 0 to -3°C

6 MINUTES RATE EVERY MINUTE



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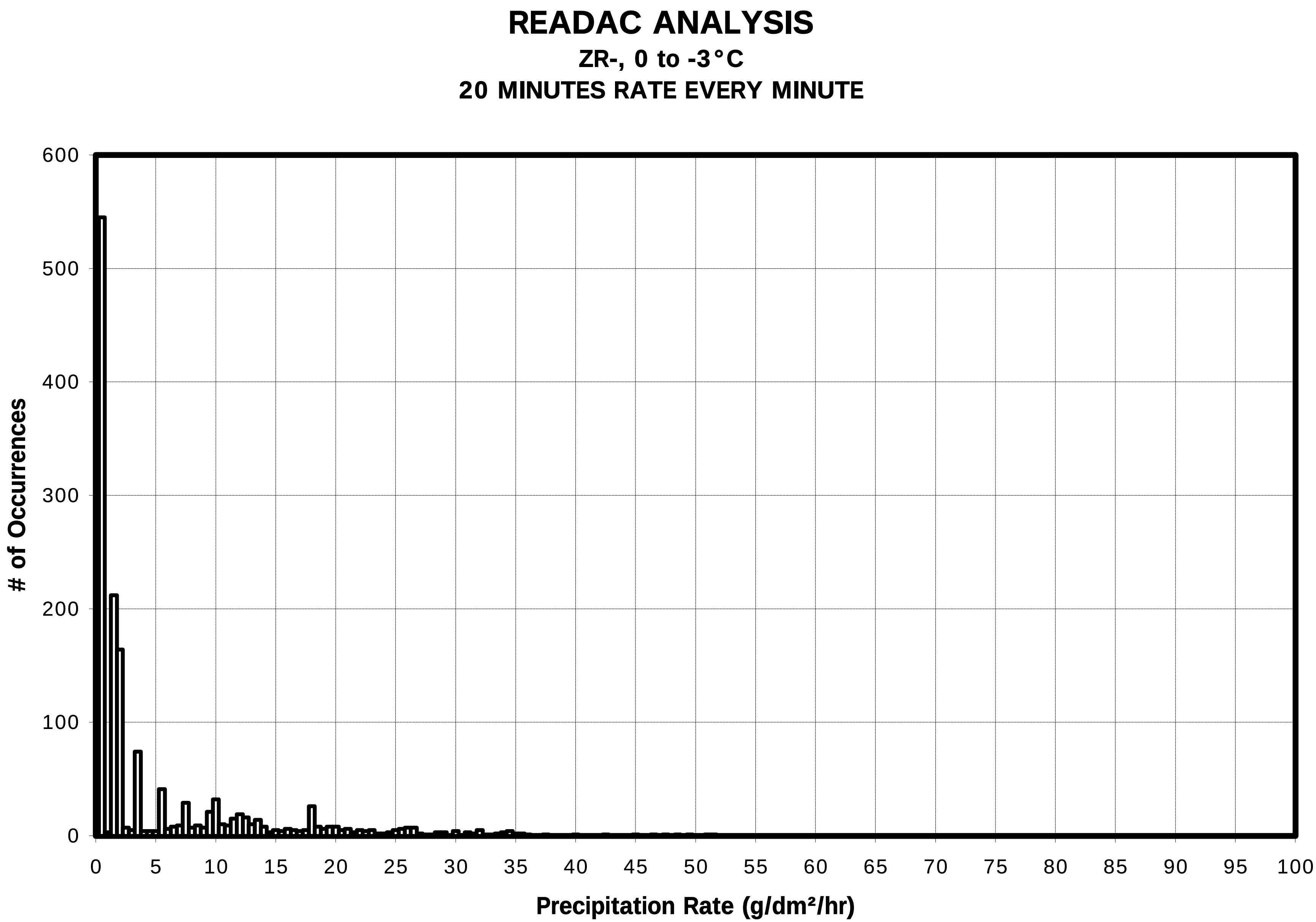

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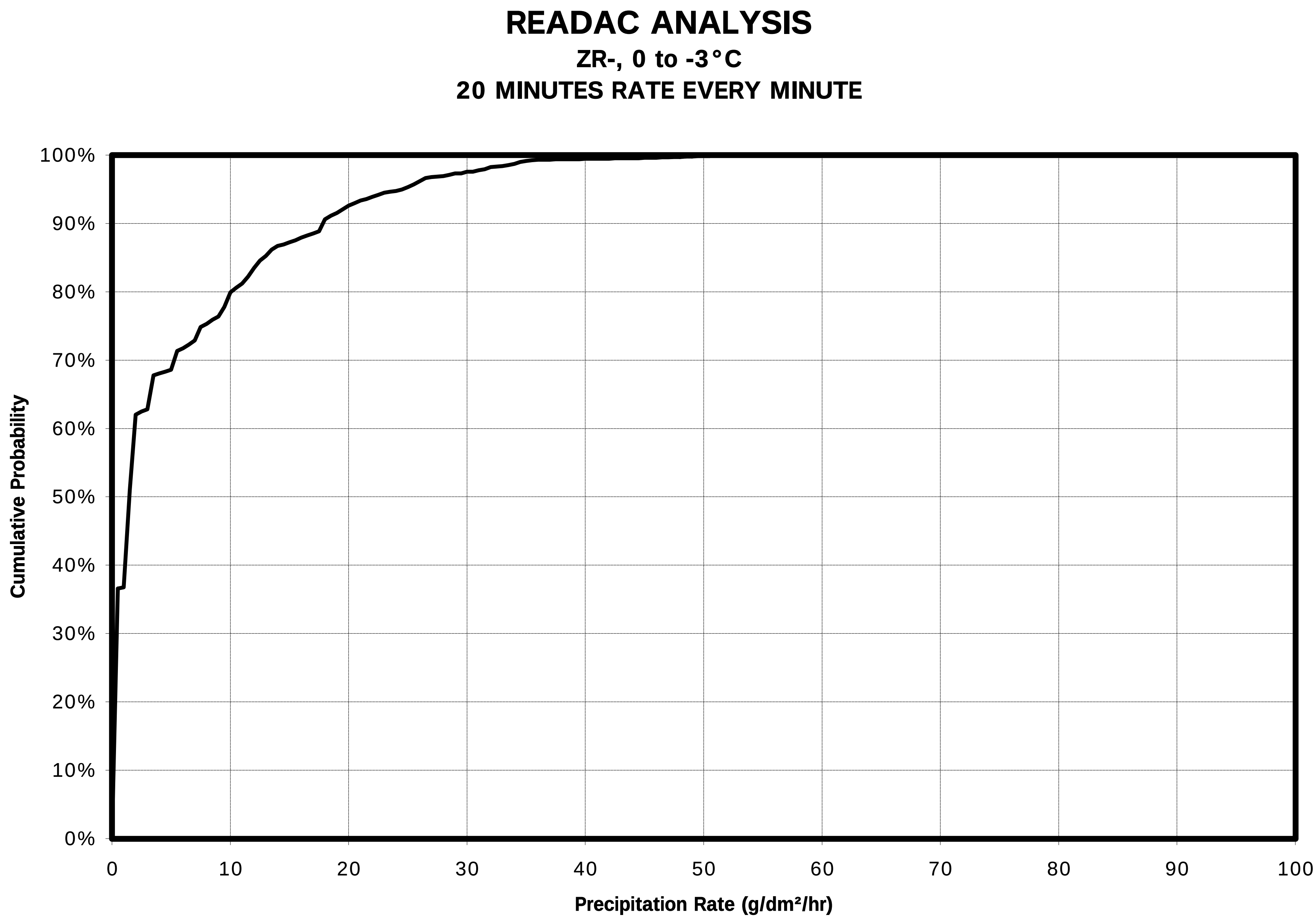

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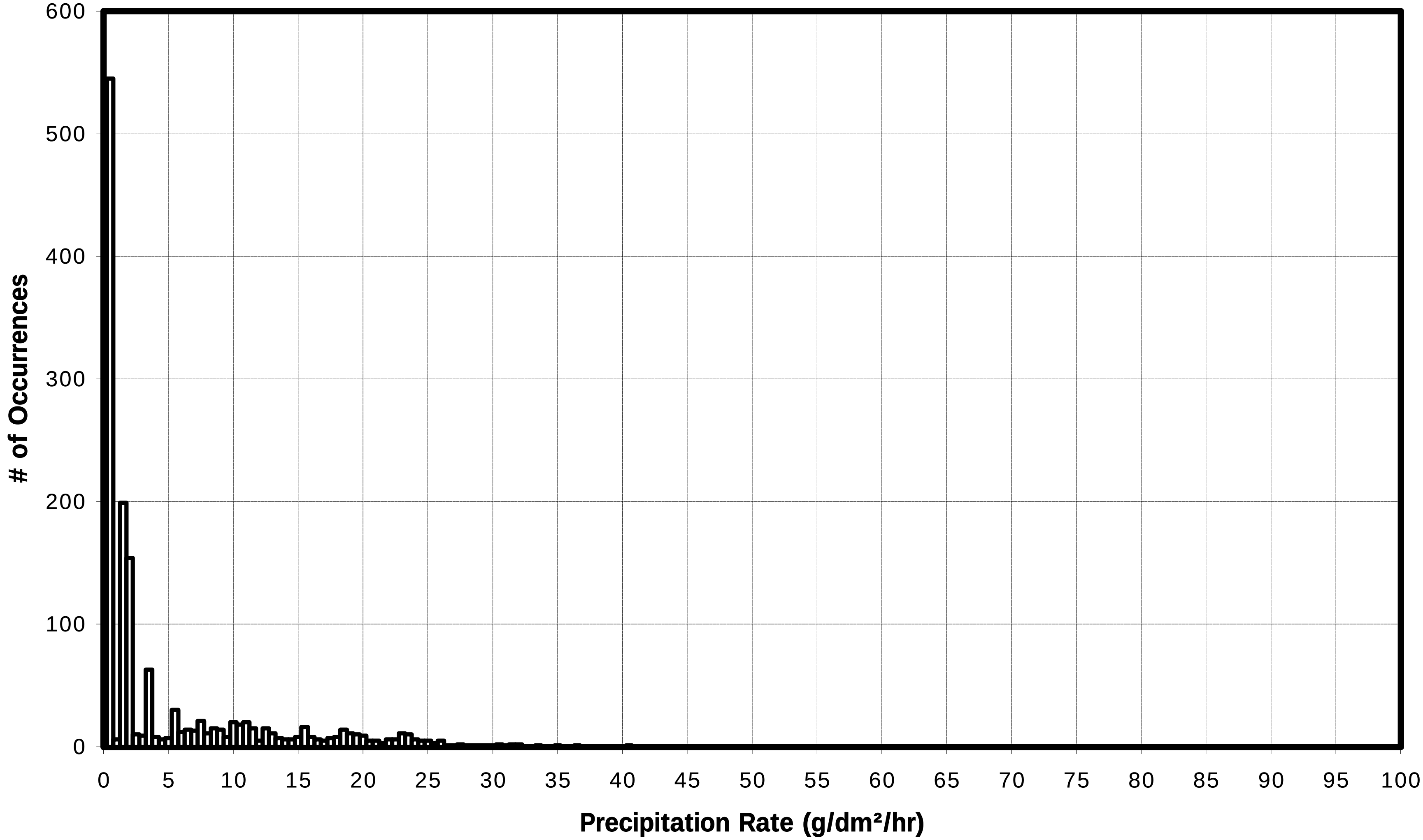
READAC ANALYSIS - FREEZING RAIN

0 to -3°C

35 MINUTES RATE EVERY MINUTE



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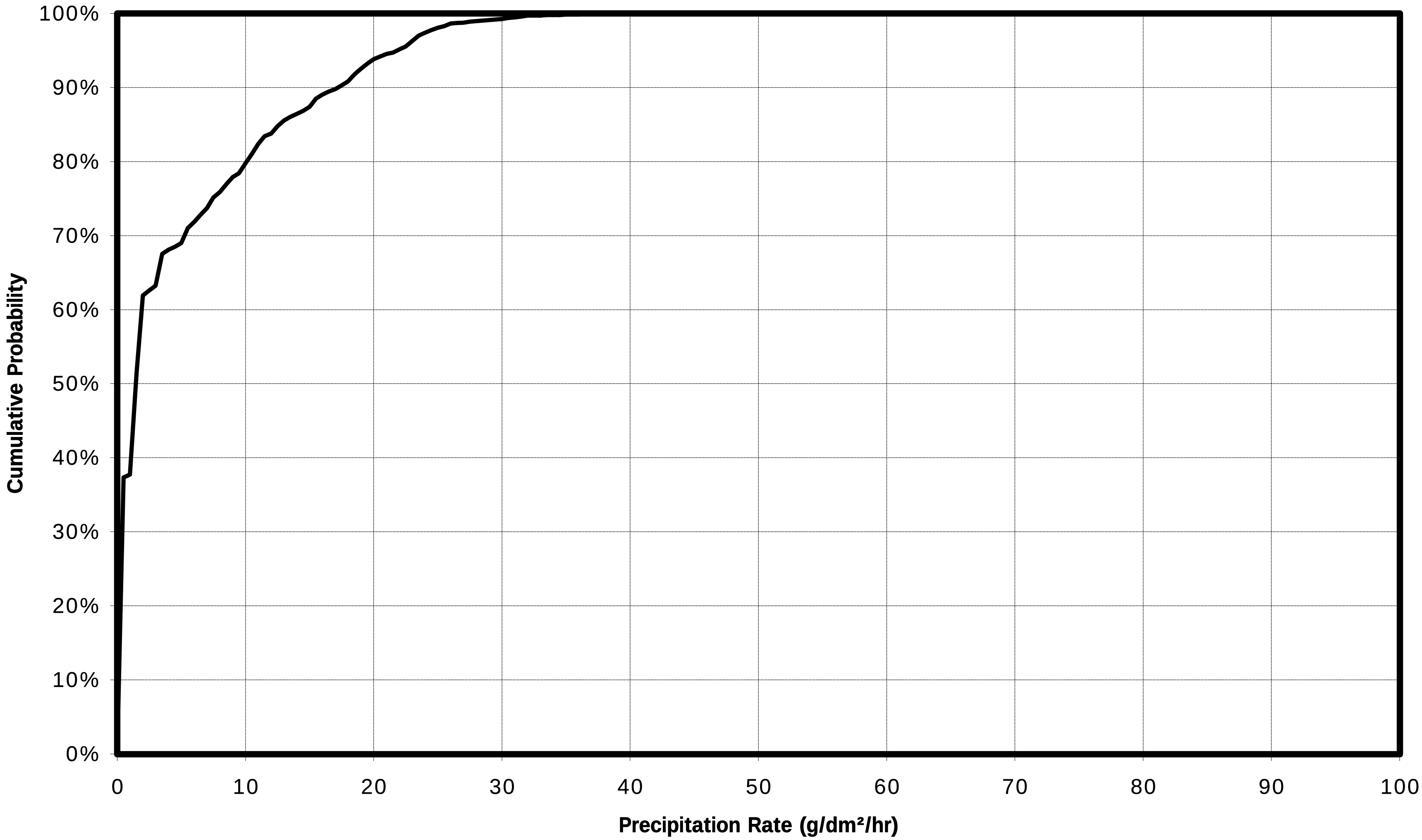
READAC ANALYSIS - FREEZING RAIN

0 to -3°C

35 MINUTES RATE EVERY MINUTE



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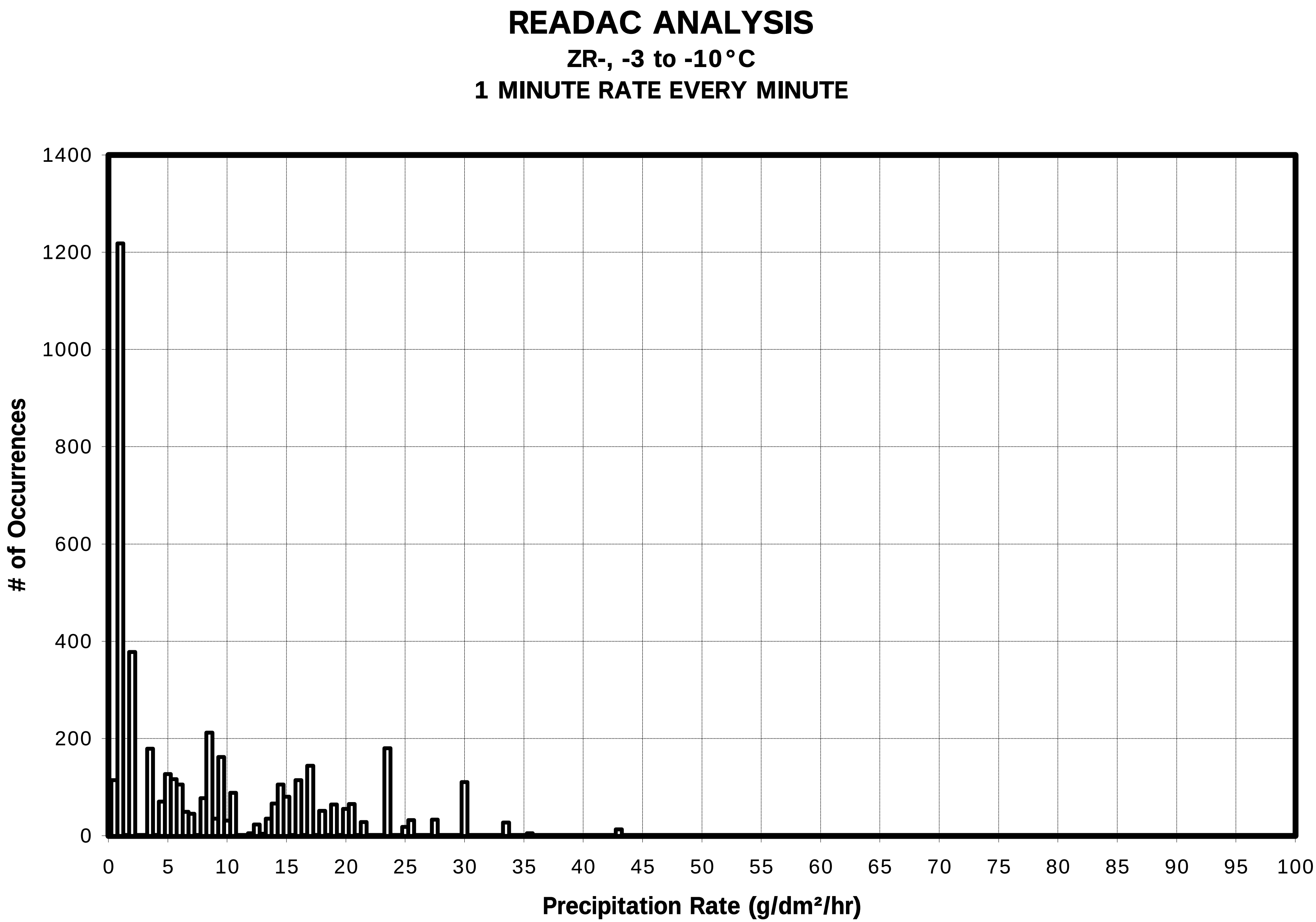

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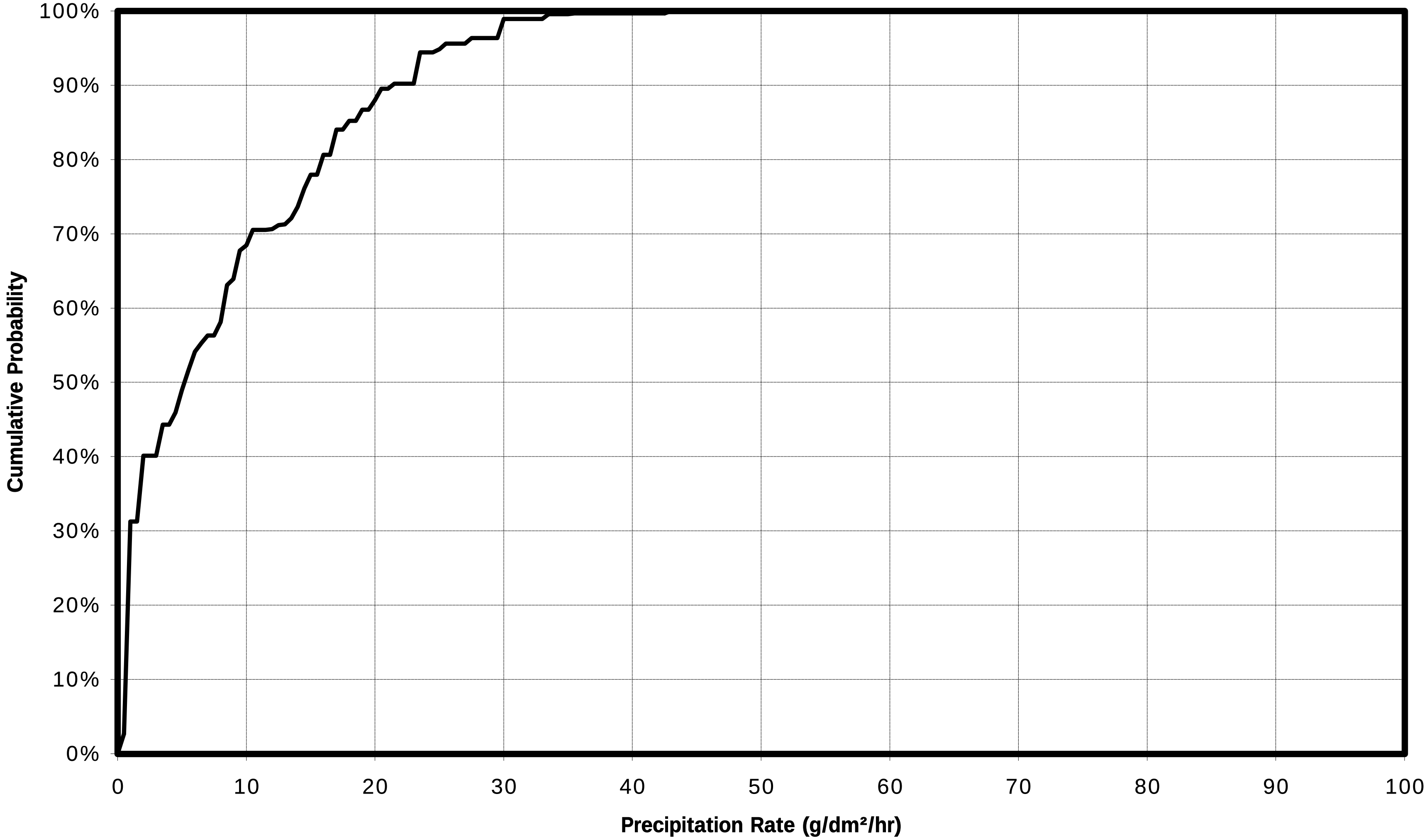
READAC ANALYSIS

ZR-, -3 to -10°C

1 MINUTE RATE EVERY MINUTE



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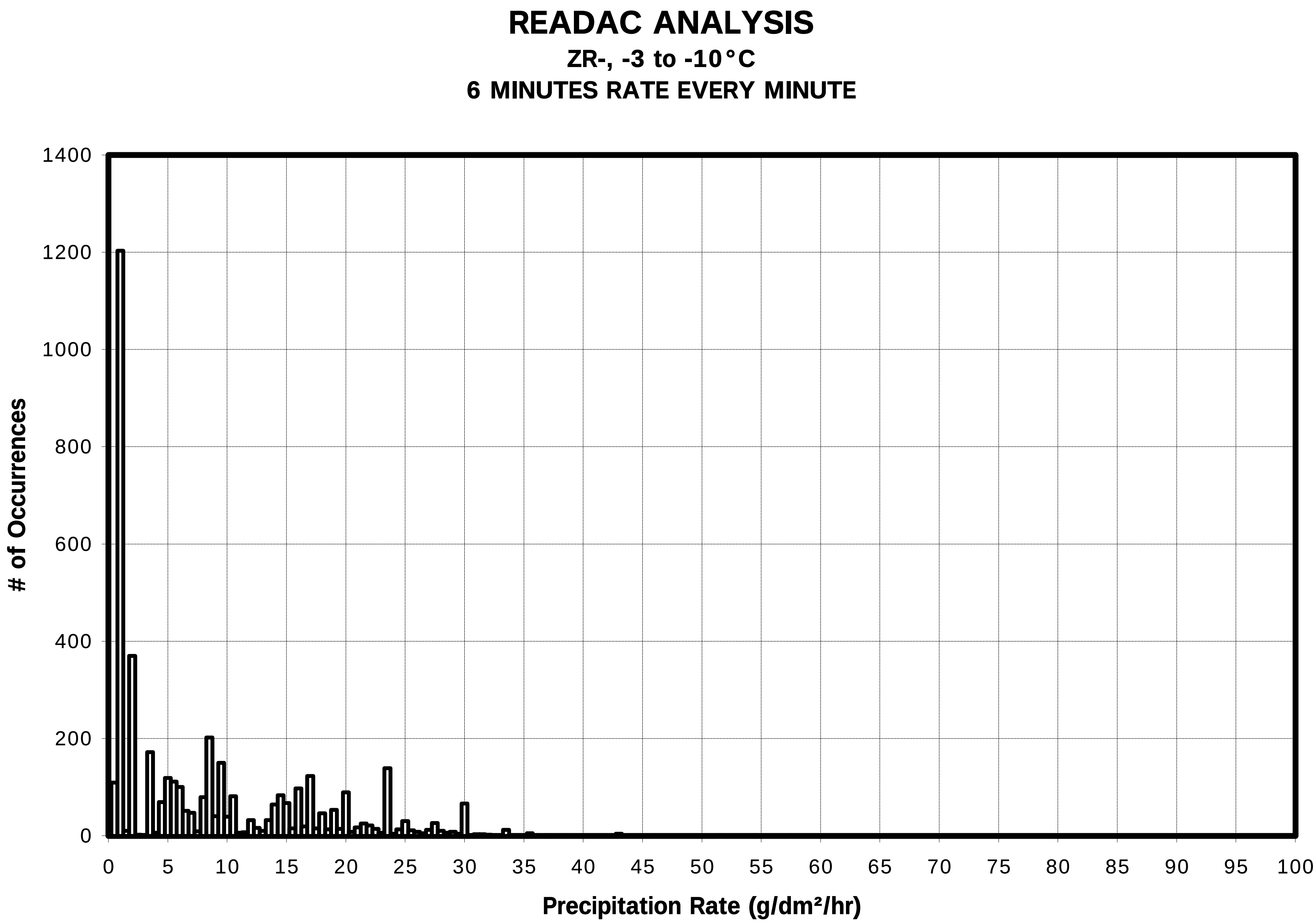

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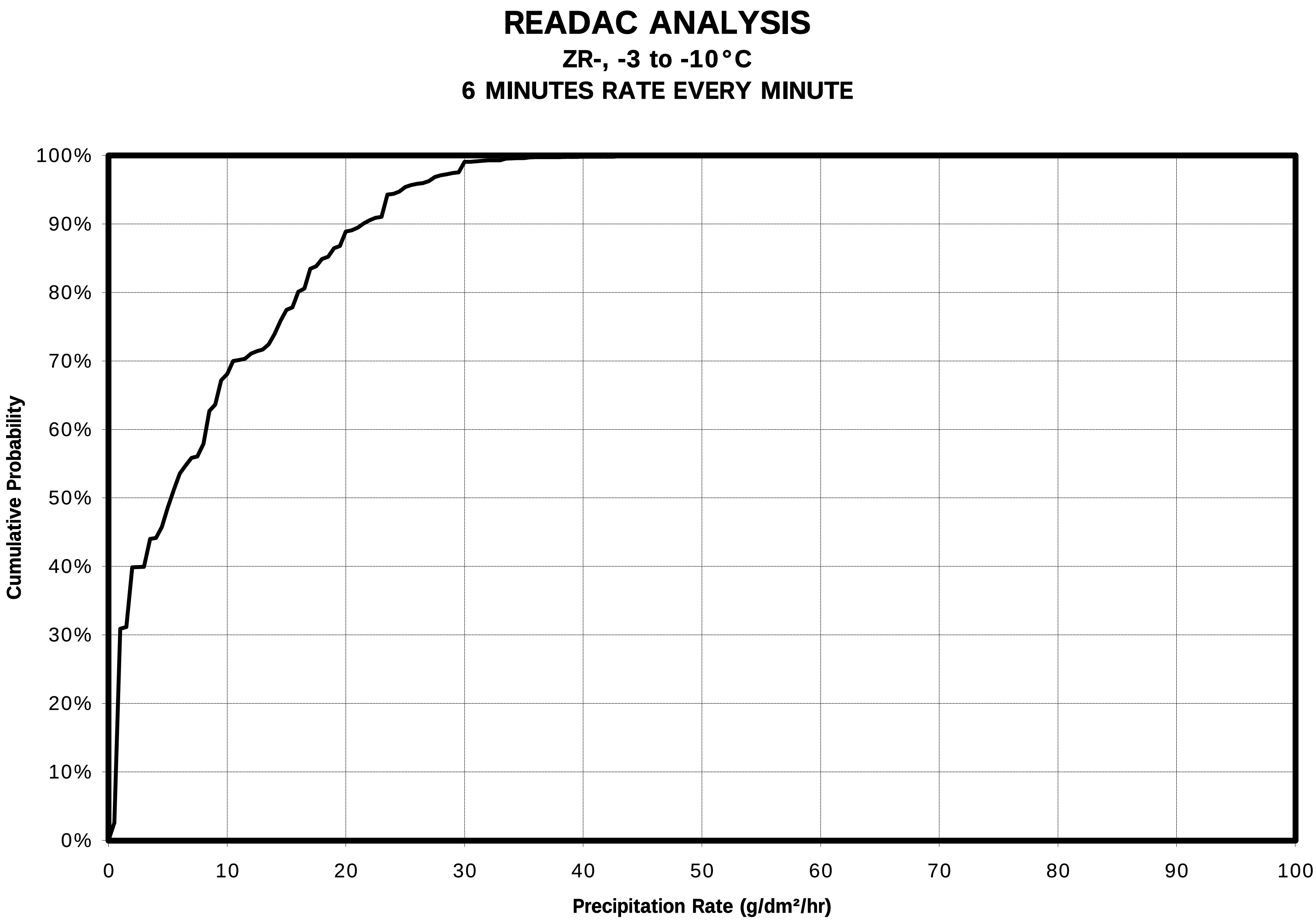
READADC ANALYSIS



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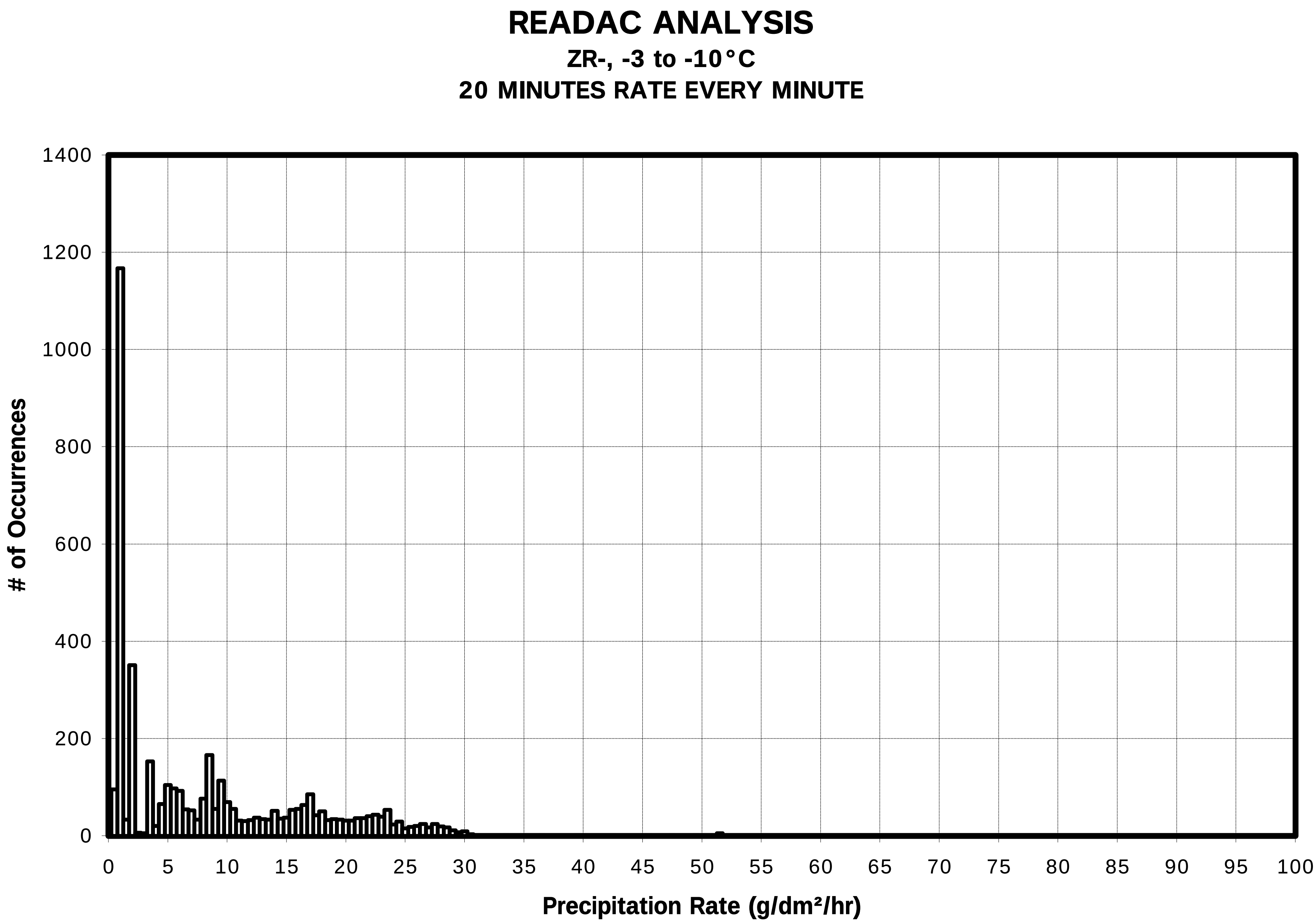

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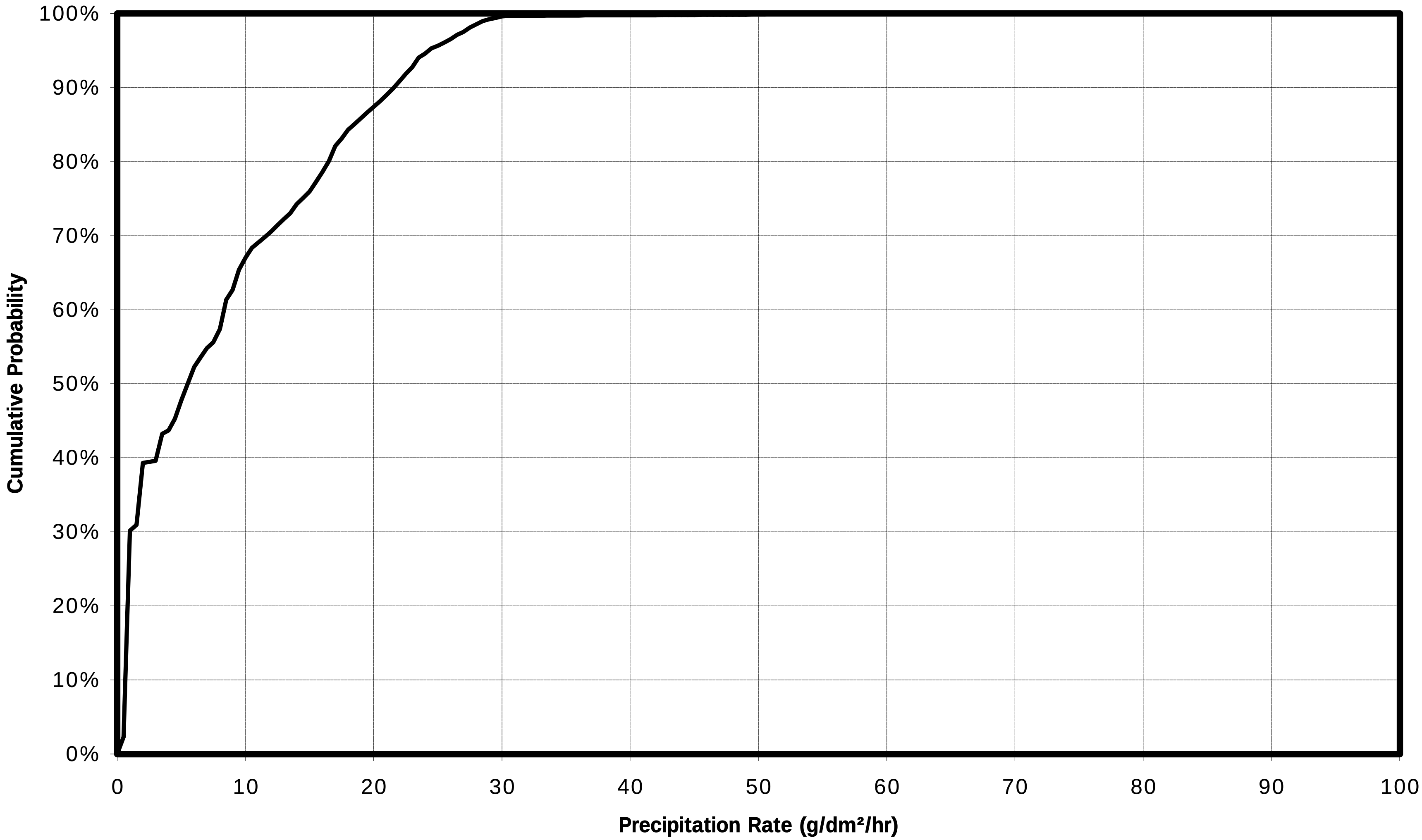
READAC ANALYSIS
ZR-, -3 to -10°C
20 MINUTES RATE EVERY MINUTE



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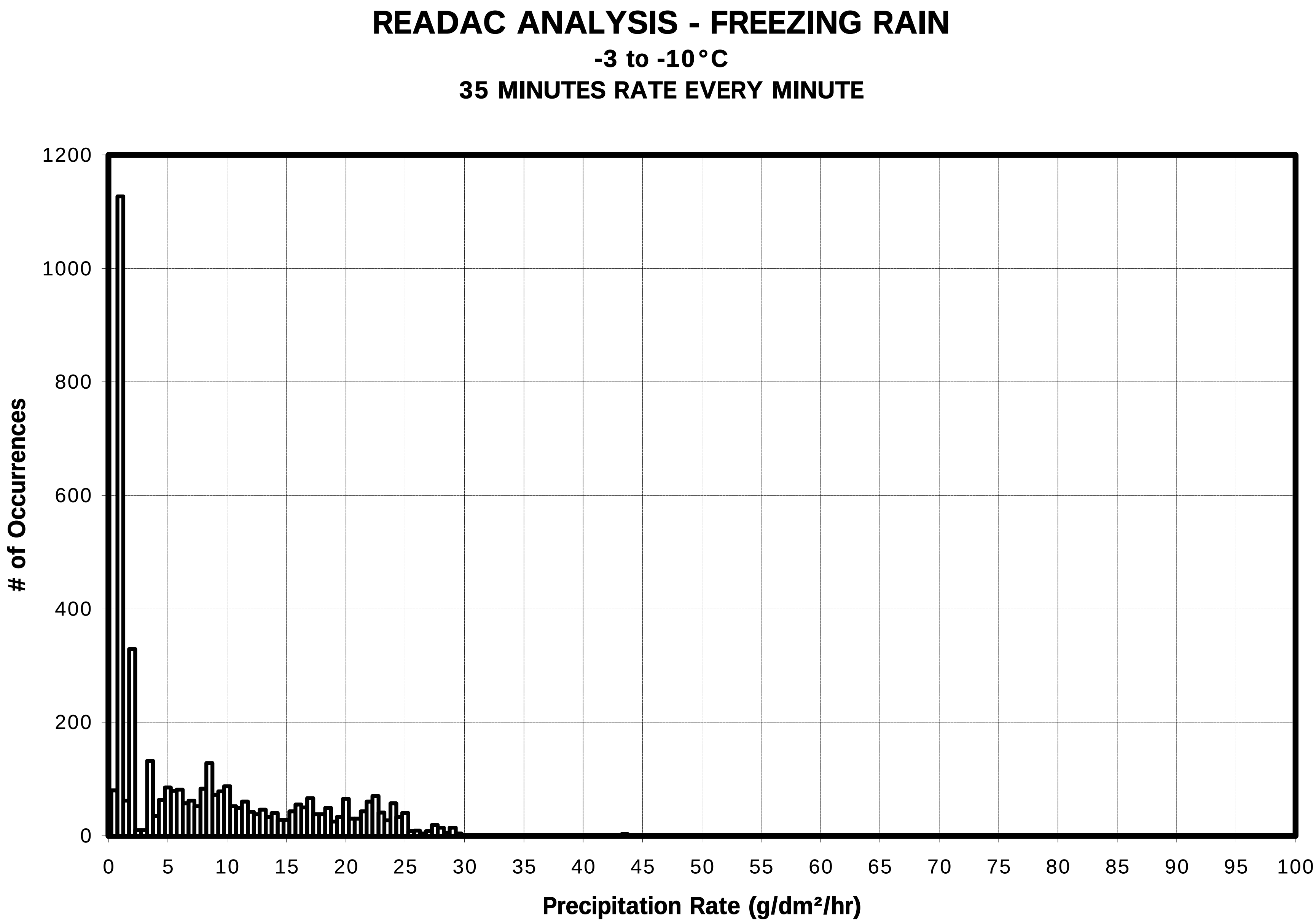

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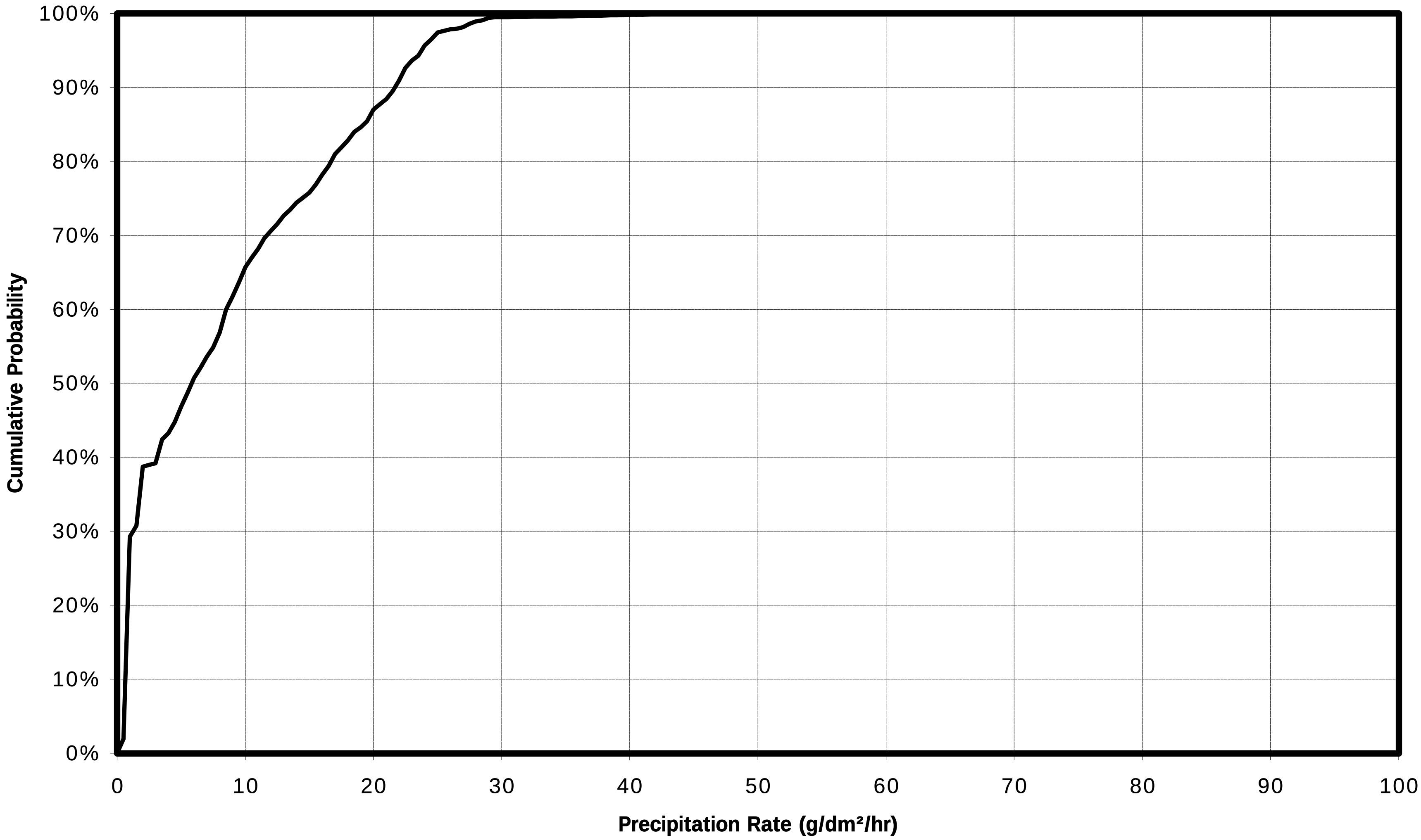
READAC ANALYSIS - FREEZING RAIN

-3 to -10°C

35 MINUTES RATE EVERY MINUTE



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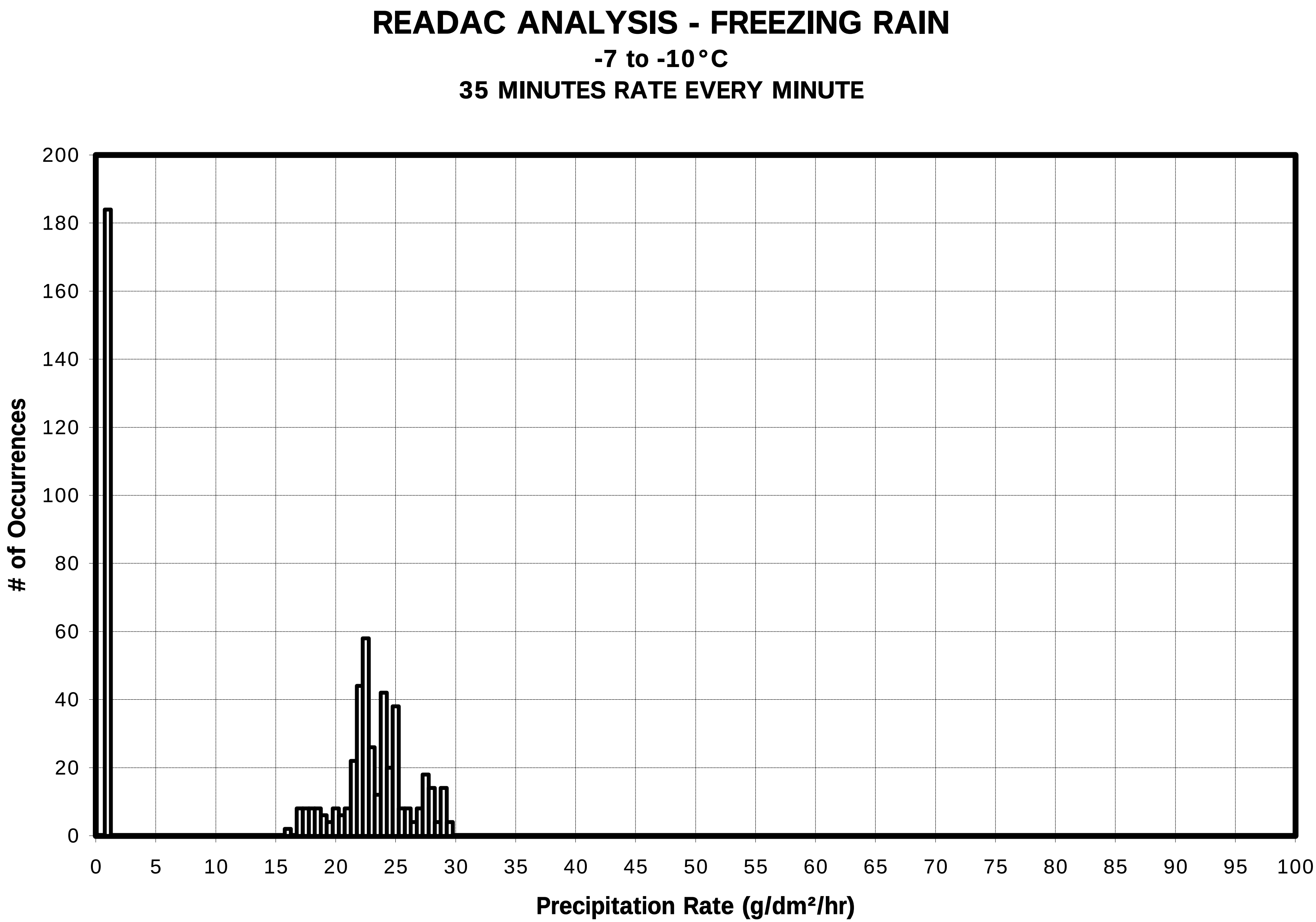

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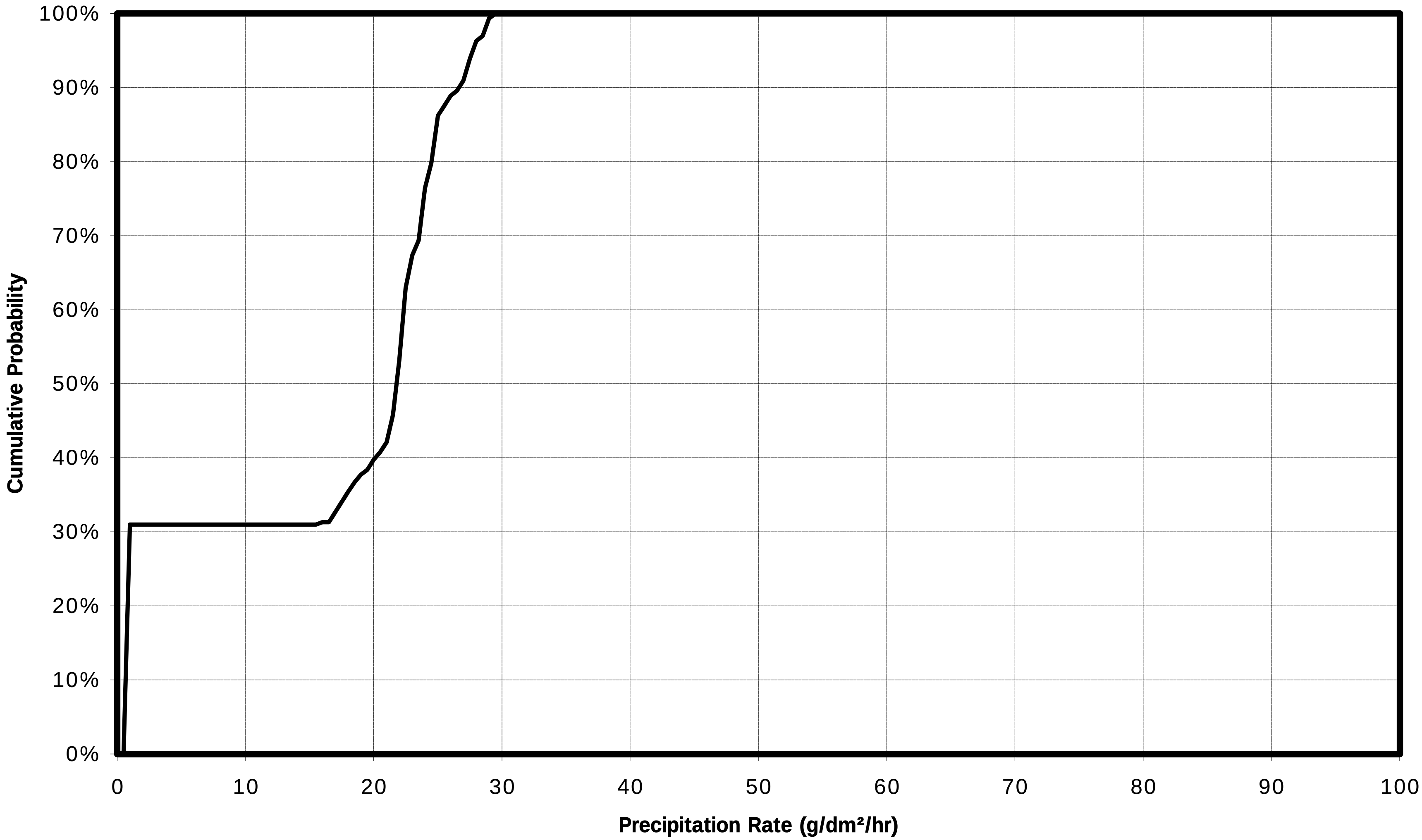
READAC ANALYSIS - FREEZING RAIN
-7 to -10°C
35 MINUTES RATE EVERY MINUTE



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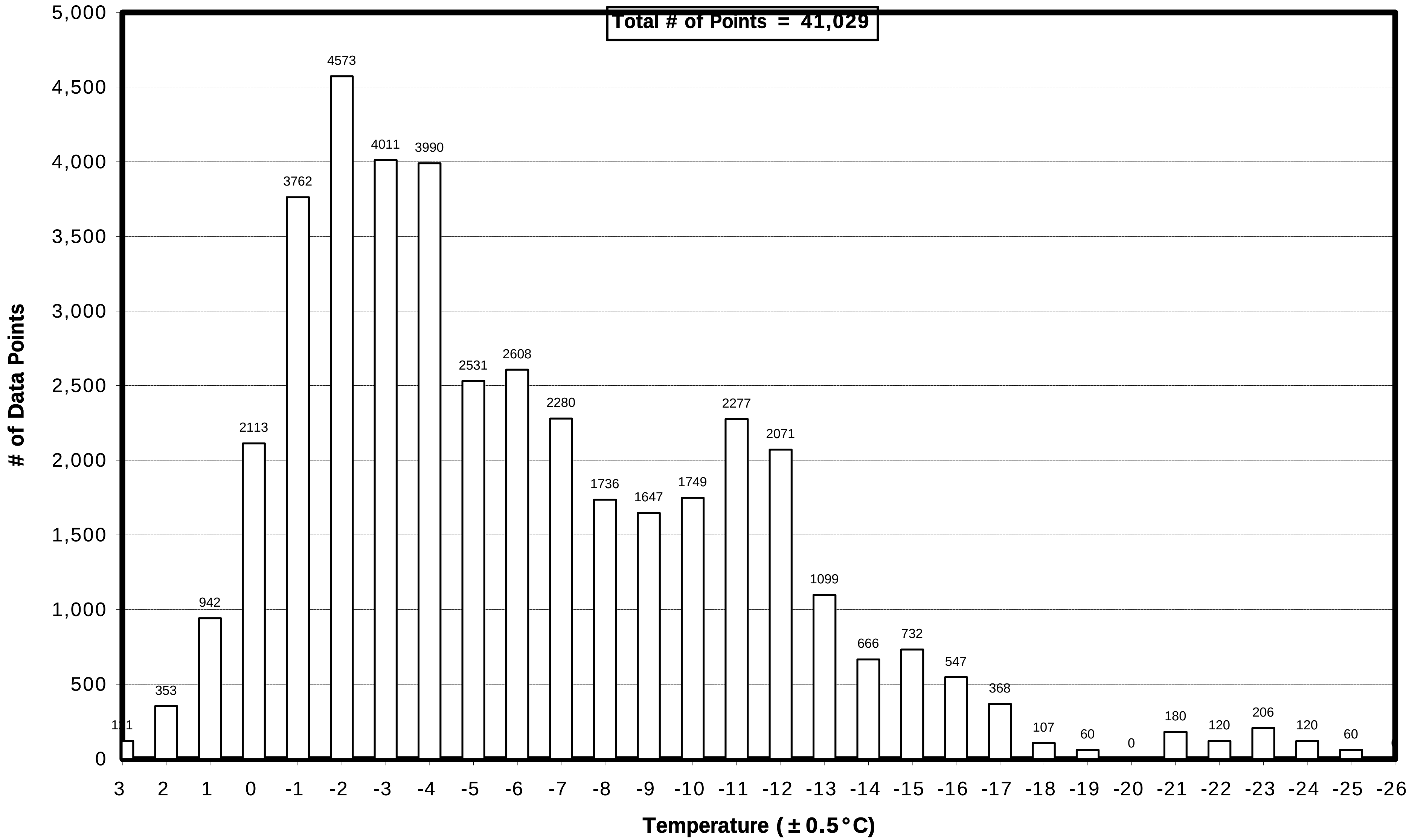
TEMPERATURE DISTRIBUTION

Natural Snow



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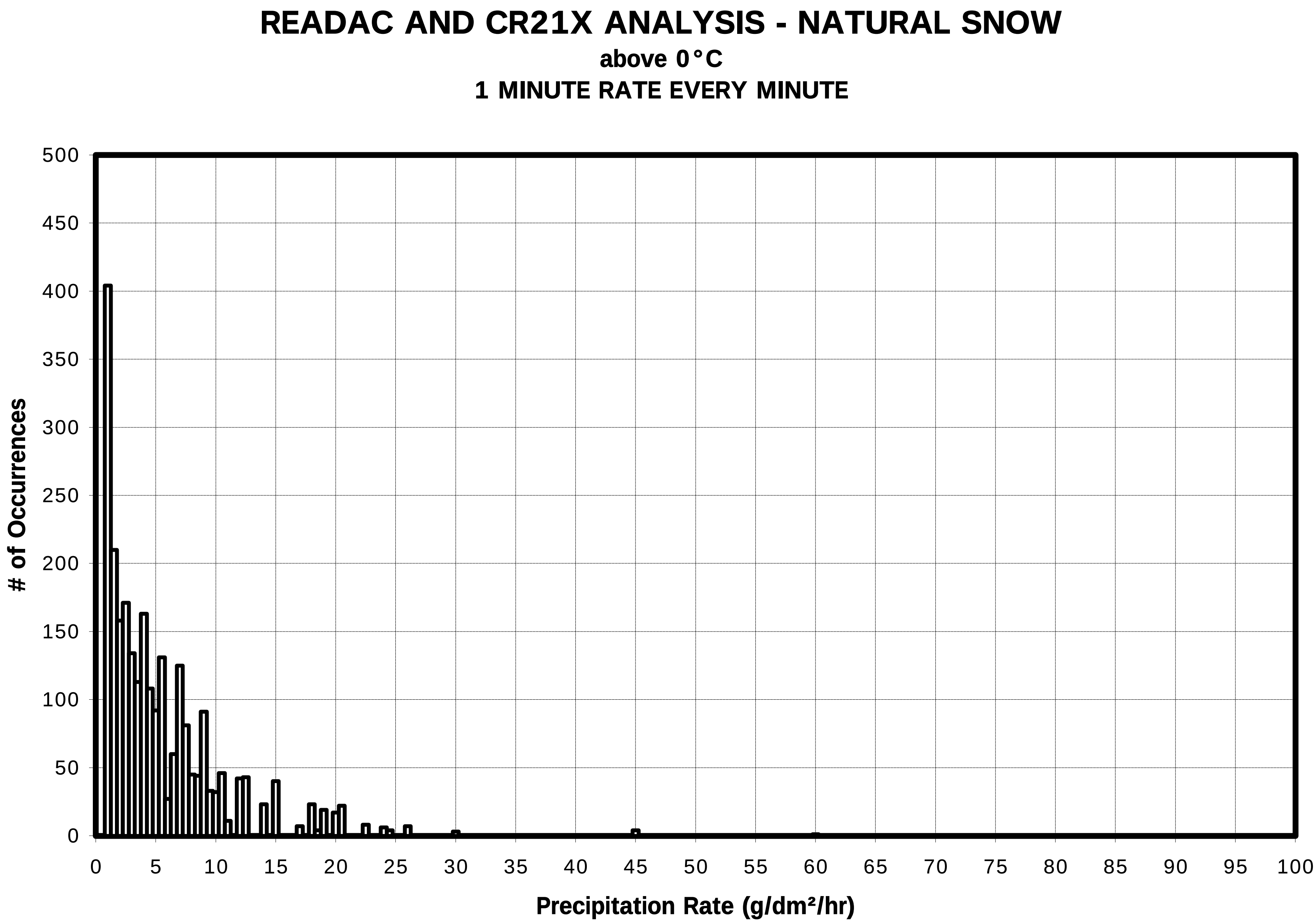

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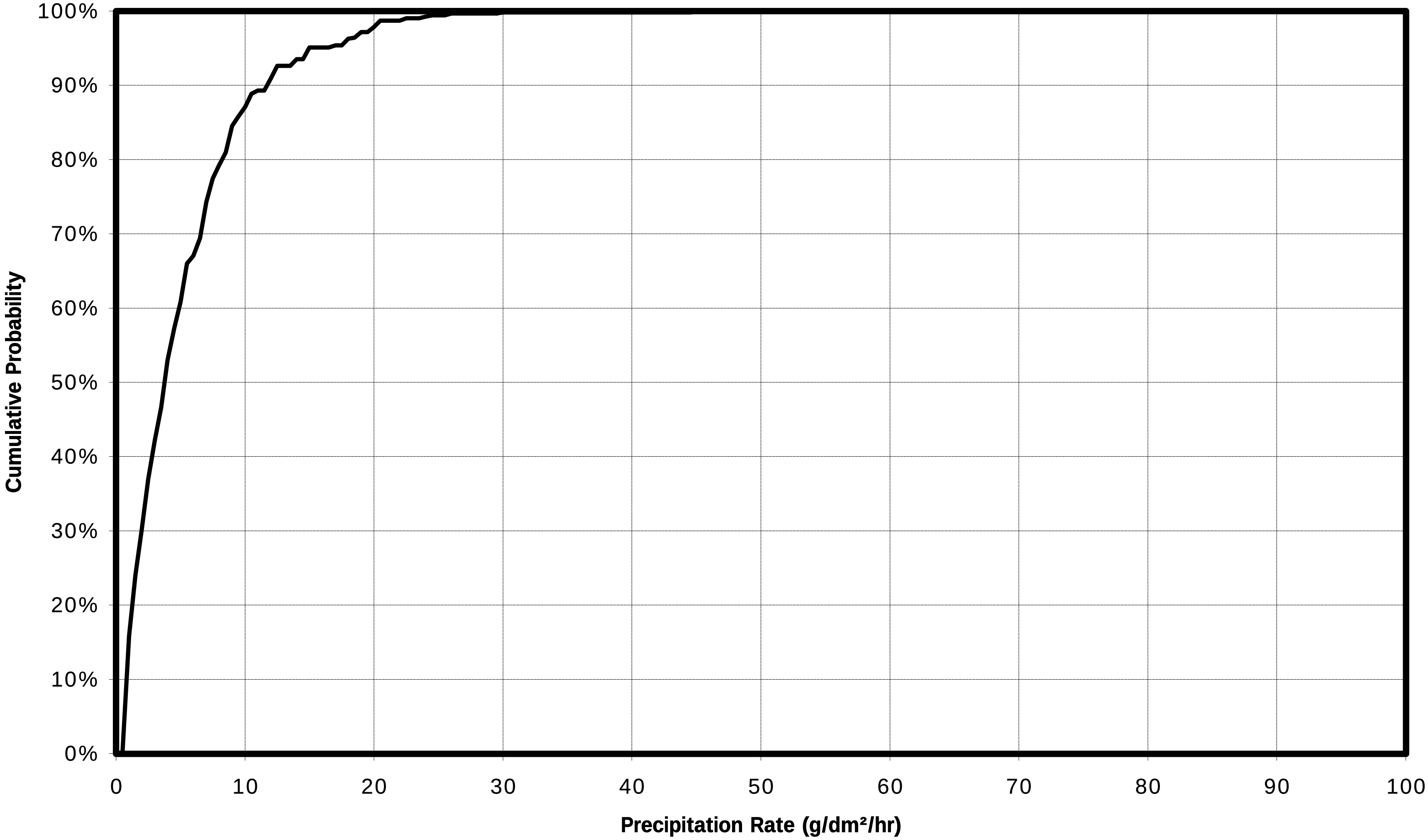
READADAC AND CR21X ANALYSIS - NATURAL SNOW

above 0°C

1 MINUTE RATE EVERY MINUTE



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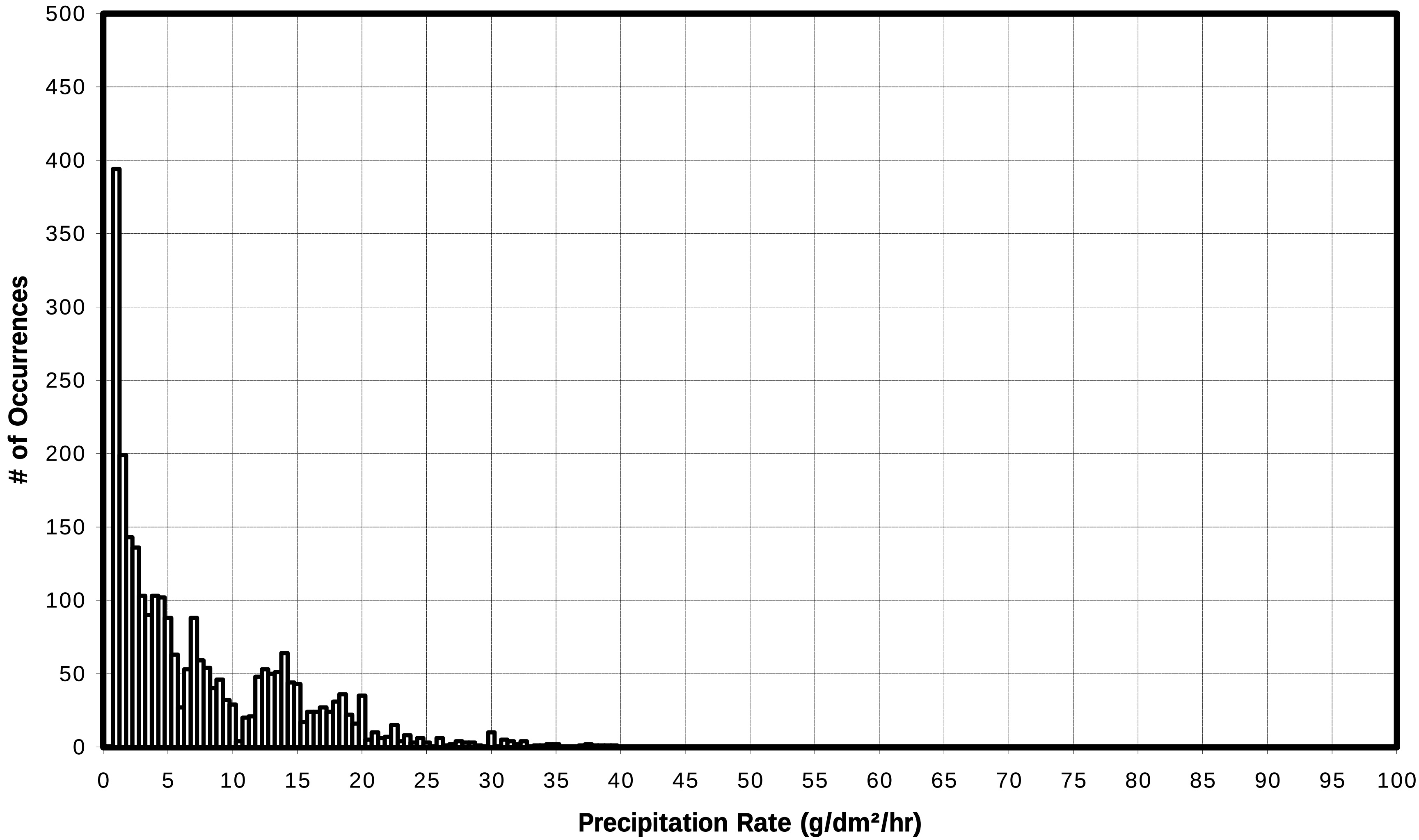
READAC AND CR21X ANALYSIS - NATURAL SNOW

above 0°C

6 MINUTES RATE EVERY MINUTE

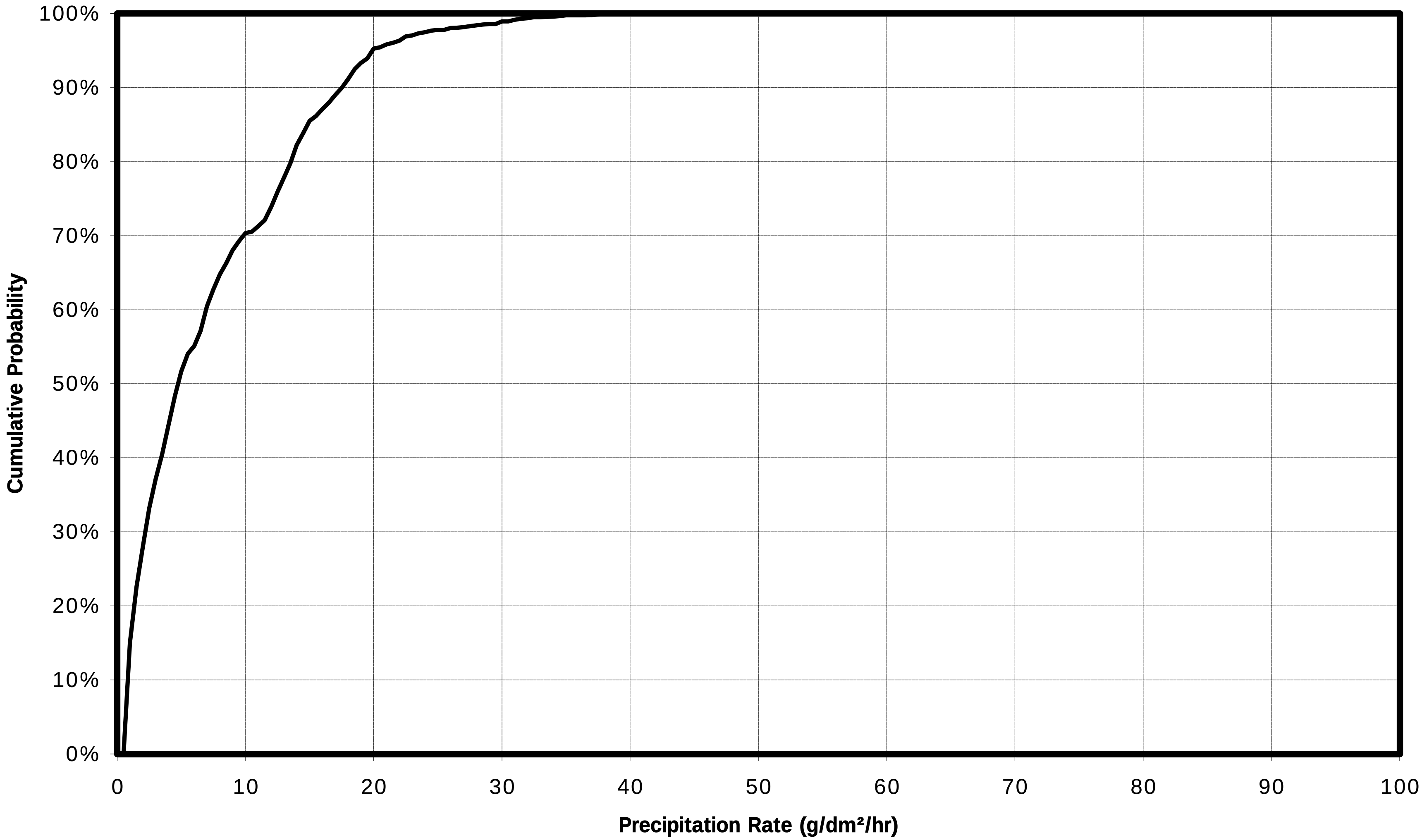


cm1380/readac/Anal_ab0.xls
At: 6 min Hist
7/23/02, 11:52 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

above 0°C

6 MINUTES RATE EVERY MINUTE

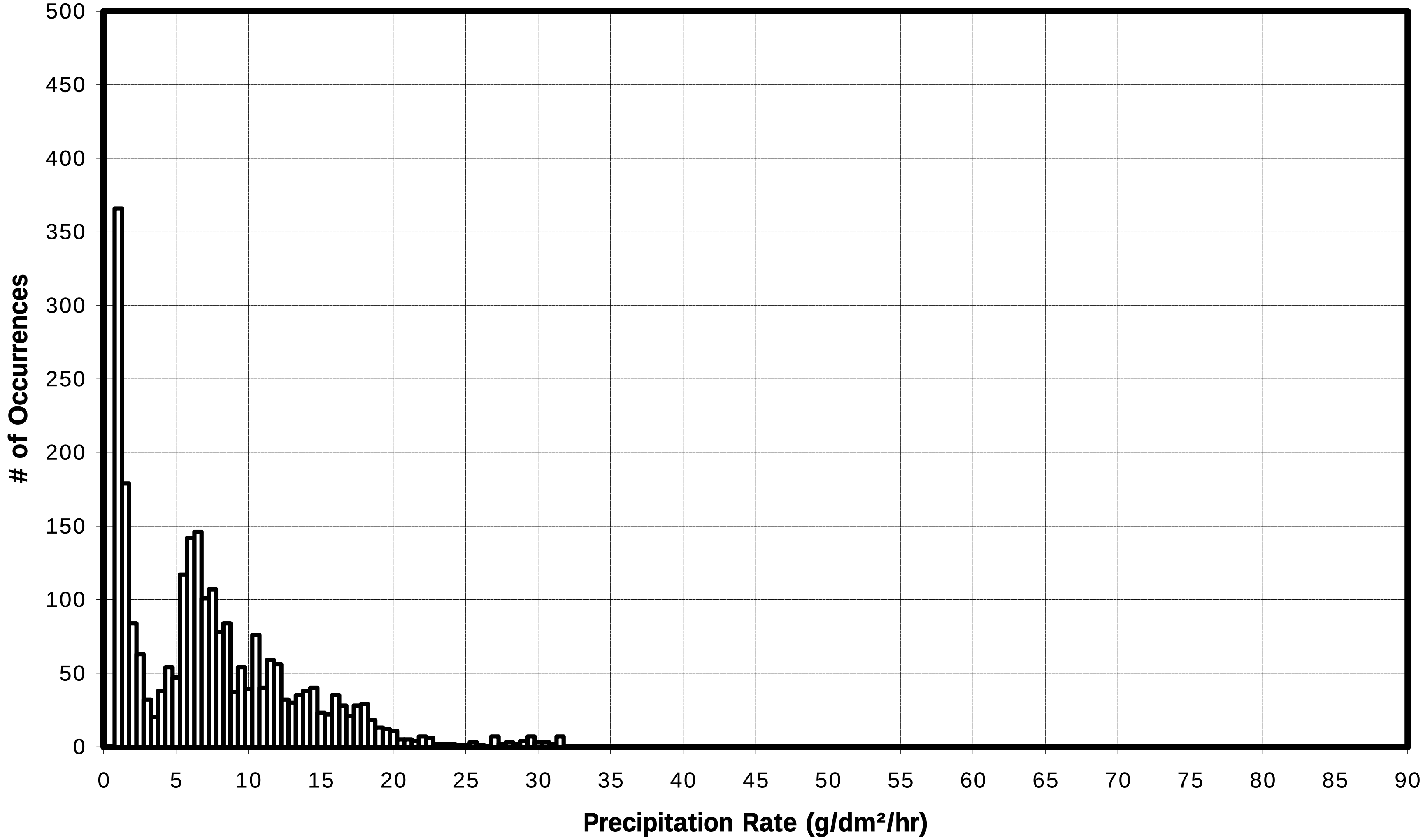


cm1380/readac/Anal_ab0.xls
At: 6 min Cuml.
7/23/02, 11:52 AM

READADC AND CR21X ANALYSIS - NATURAL SNOW

above 0°C

20 MINUTES RATE EVERY MINUTE

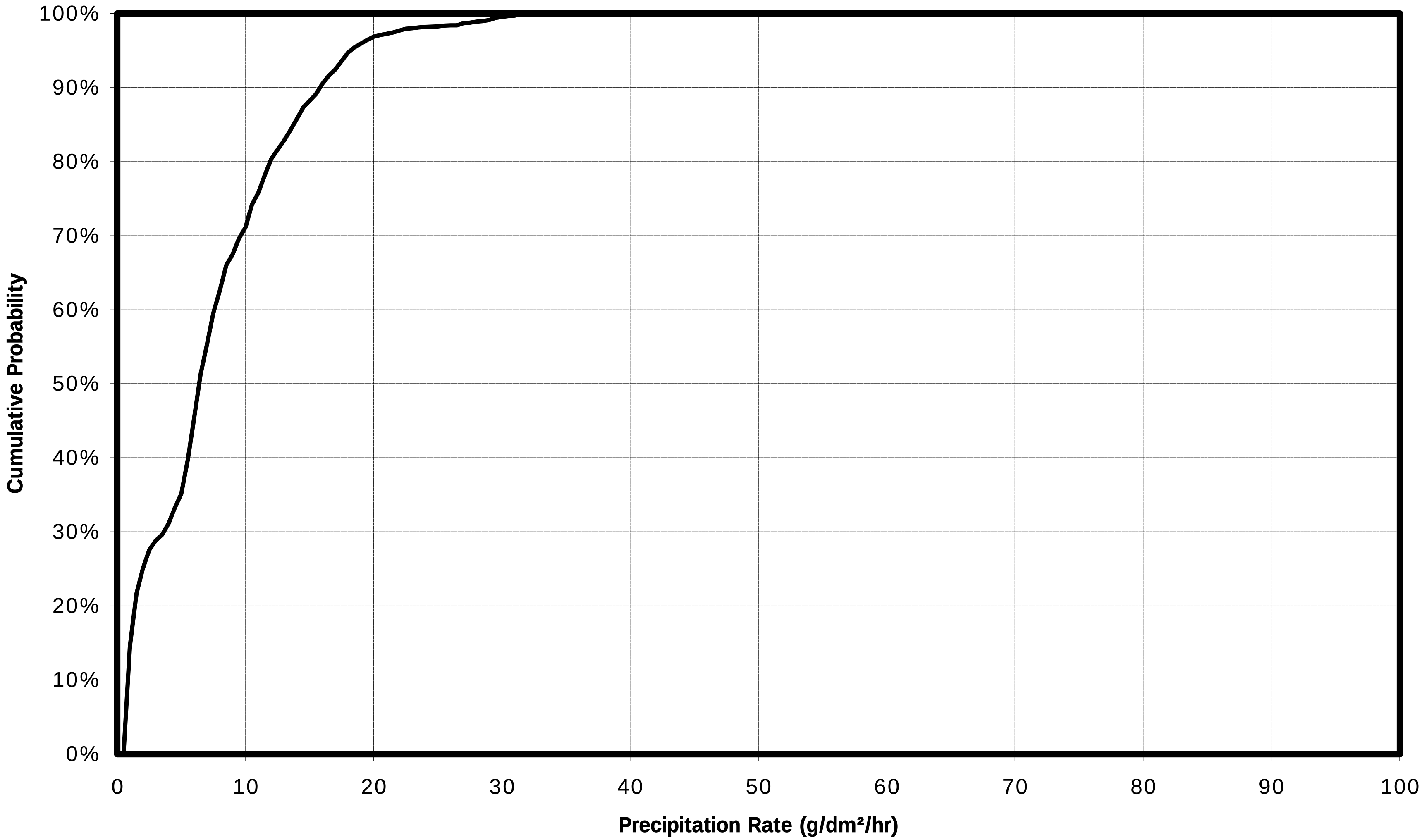


cm1380/readac/Anal_ab0.xls
At: 20 min Hist
7/23/02, 11:52 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

above 0°C

20 MINUTES RATE EVERY MINUTE



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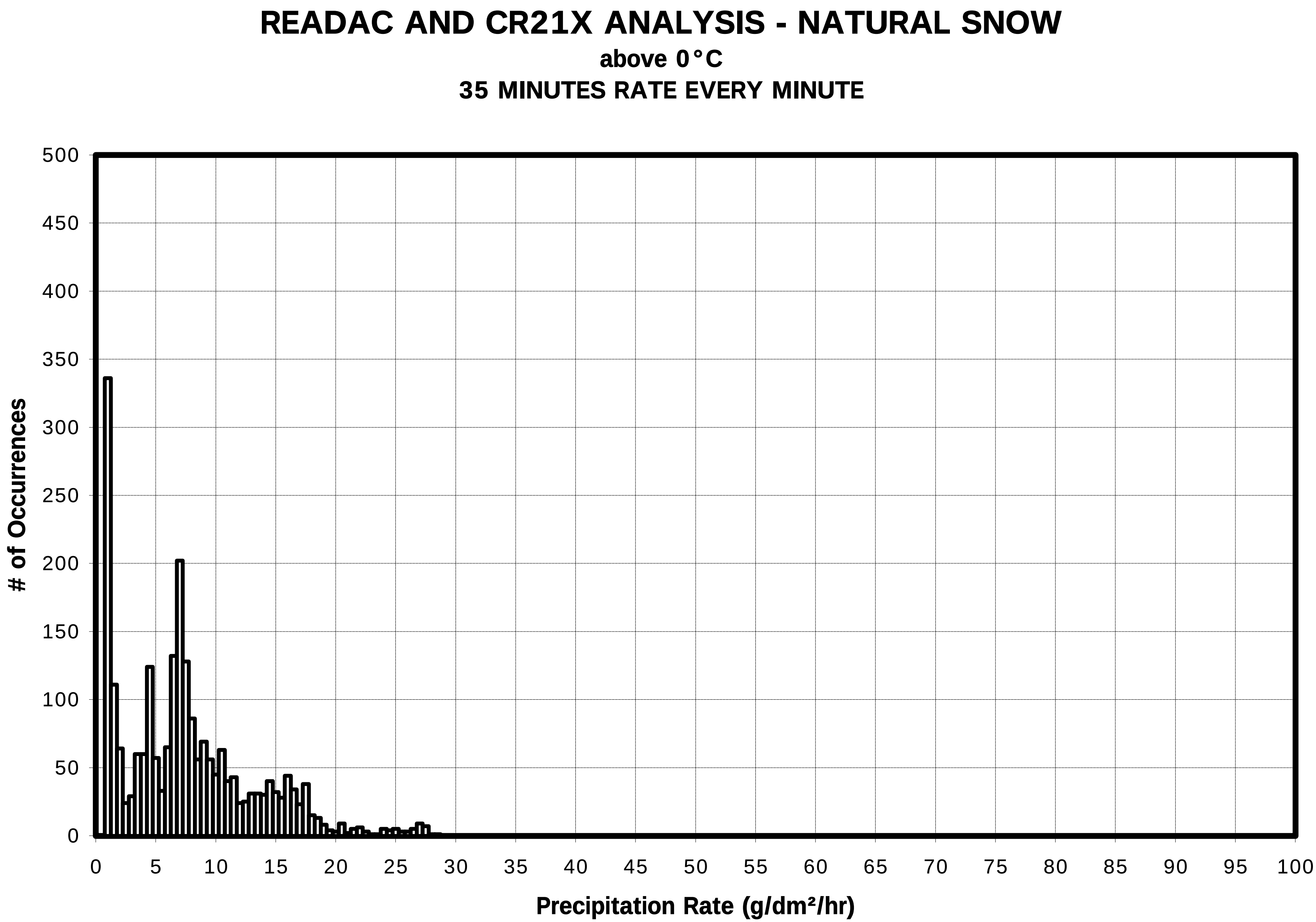
7/23/02, 11:52 AM



cm1380/readac/Anal_ab0.xls
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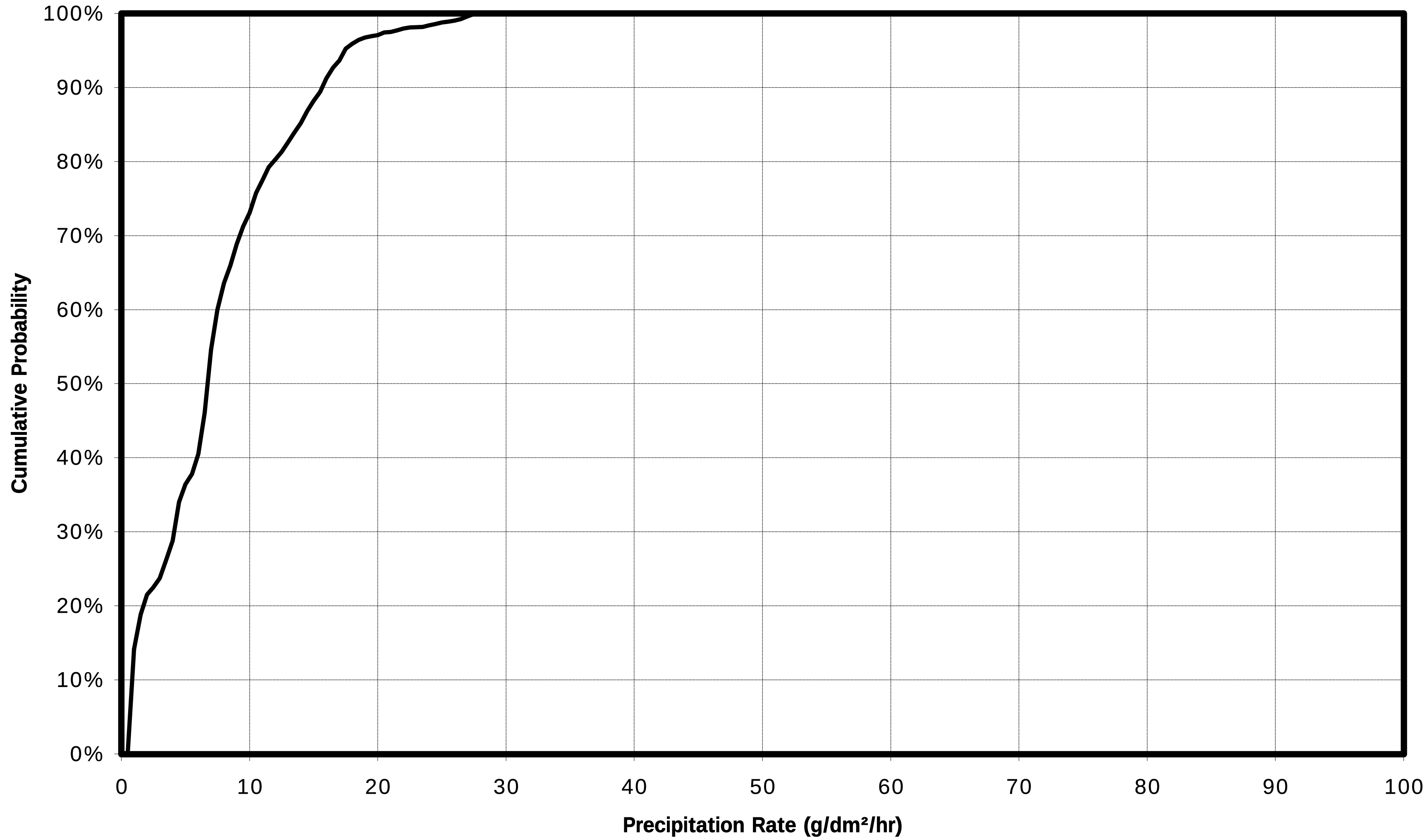
7/23/02, 11:52 AM

READADC AND CR21X ANALYSIS - NATURAL SNOW

above 0°C

35 MINUTES RATE EVERY MINUTE

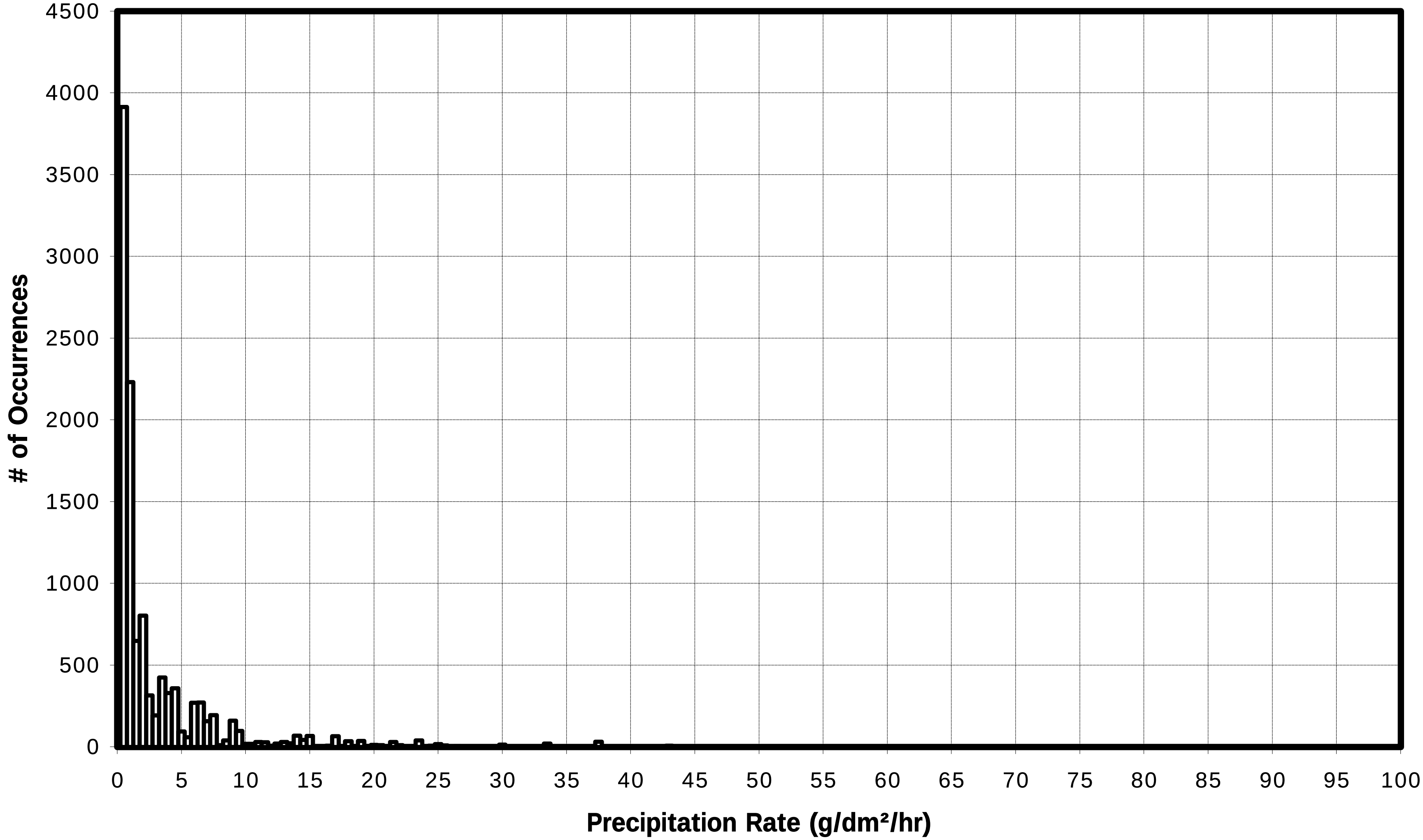


cm1380/readac/Anal_ab0.xls
At: 35 min Cuml.
7/23/02, 11:52 AM

READADC AND CR21X ANALYSIS - NATURAL SNOW

0 to -3°C

1 MINUTE RATE EVERY MINUTE

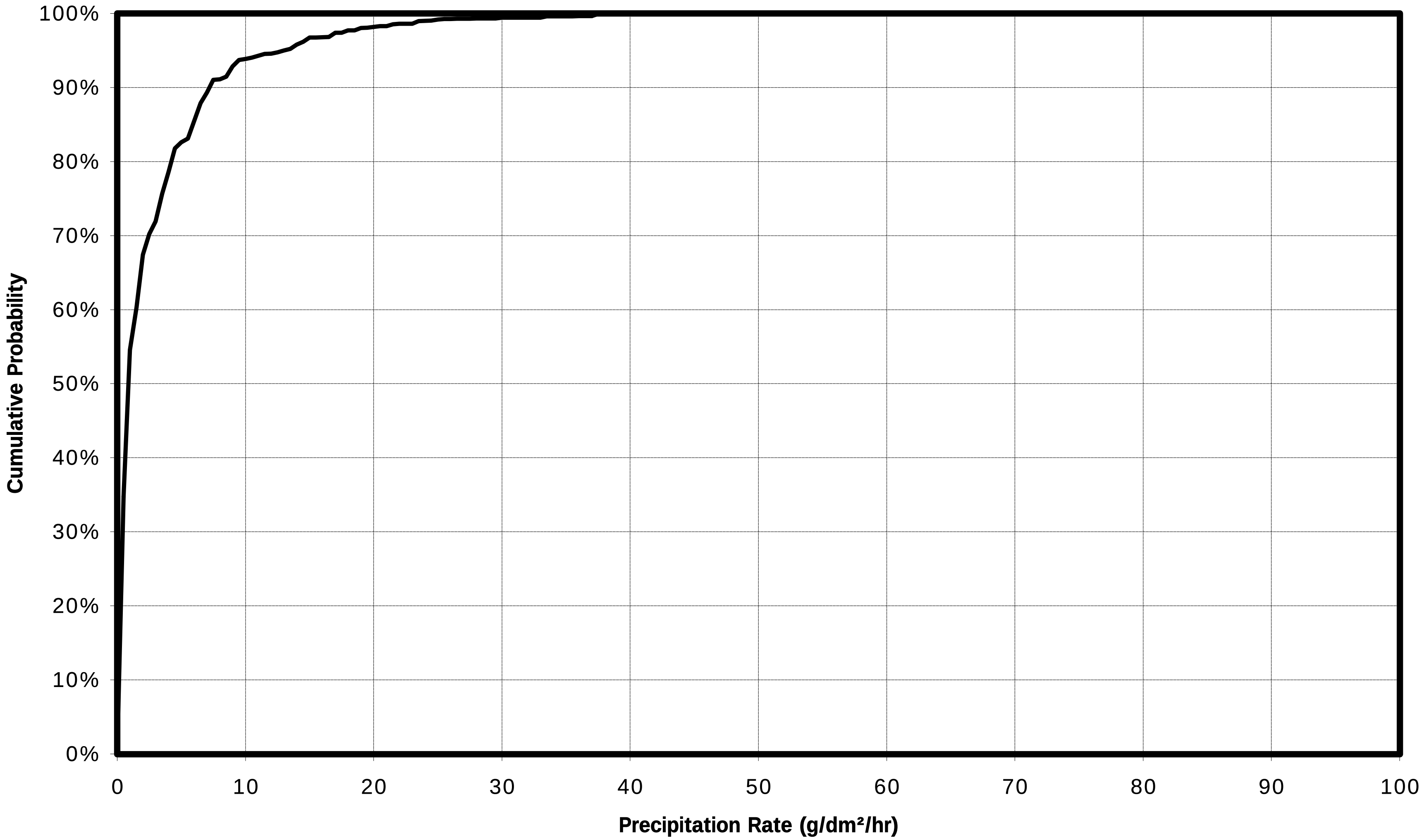


cm1380/readac/Anal_-3.xls
At: 1 min Hist
7/23/02, 11:54 AM

READADC AND CR21X ANALYSIS - NATURAL SNOW

0 to -3°C

1 MINUTE RATE EVERY MINUTE

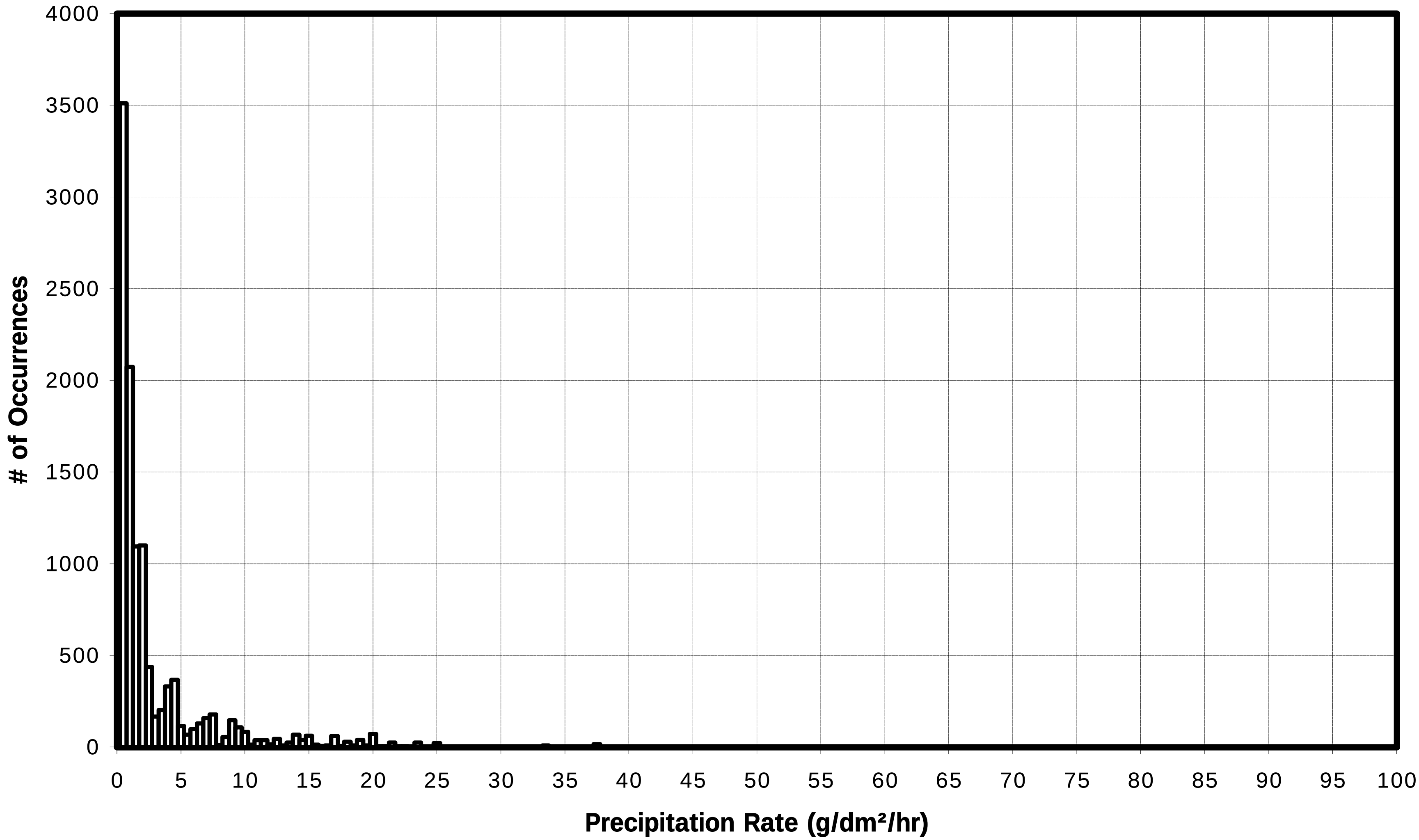


cm1380/readac/Anal_-3.xls
At: 1 min Cuml.
7/23/02, 11:54 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

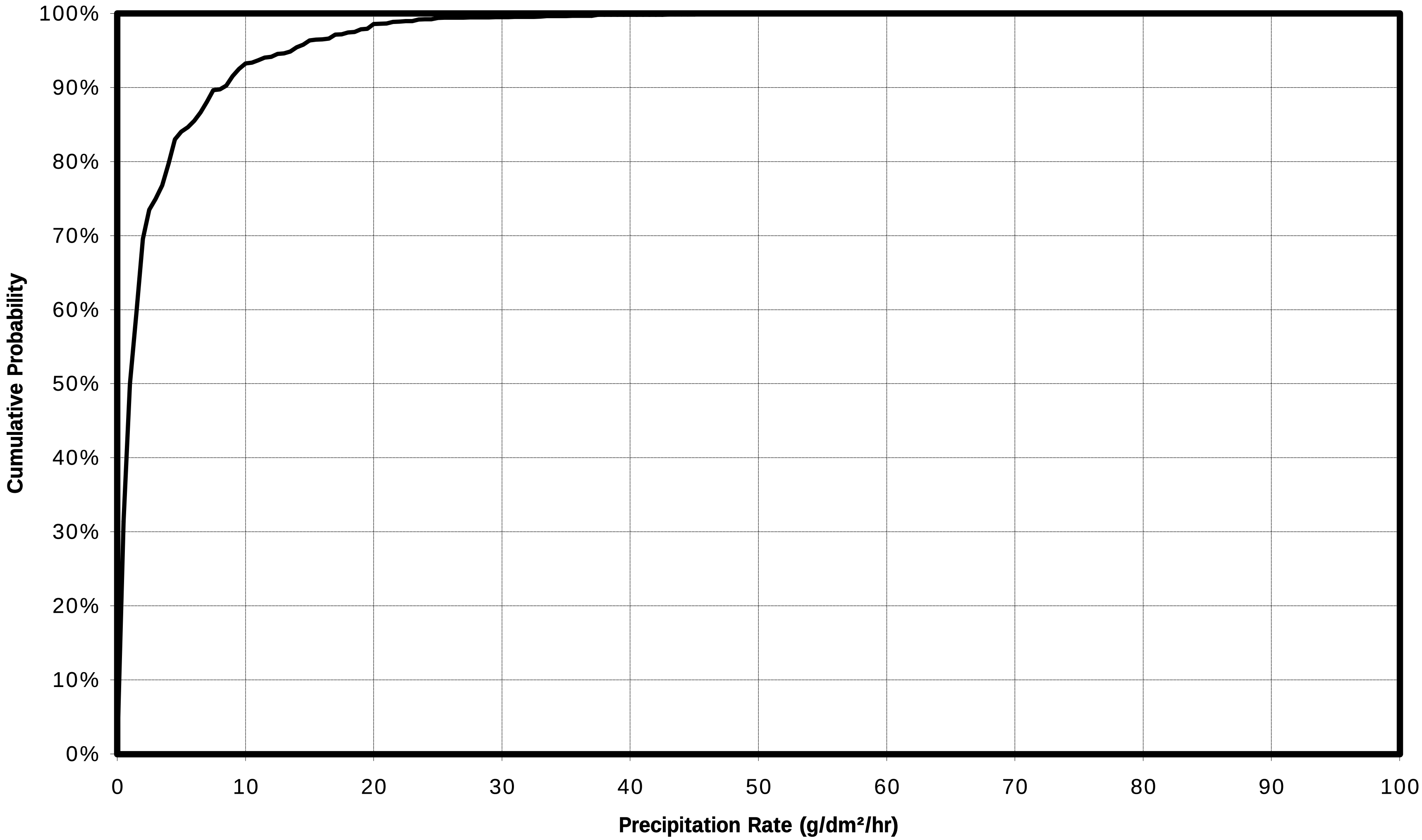
0 to -3°C

6 MINUTES RATE EVERY MINUTE



cm1380/readac/Anal_-3.xls
At: 6 min Hist
7/23/02, 11:54 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW
0 to -3°C
6 MINUTES RATE EVERY MINUTE



cm1380/readac/Anal_-3.xls
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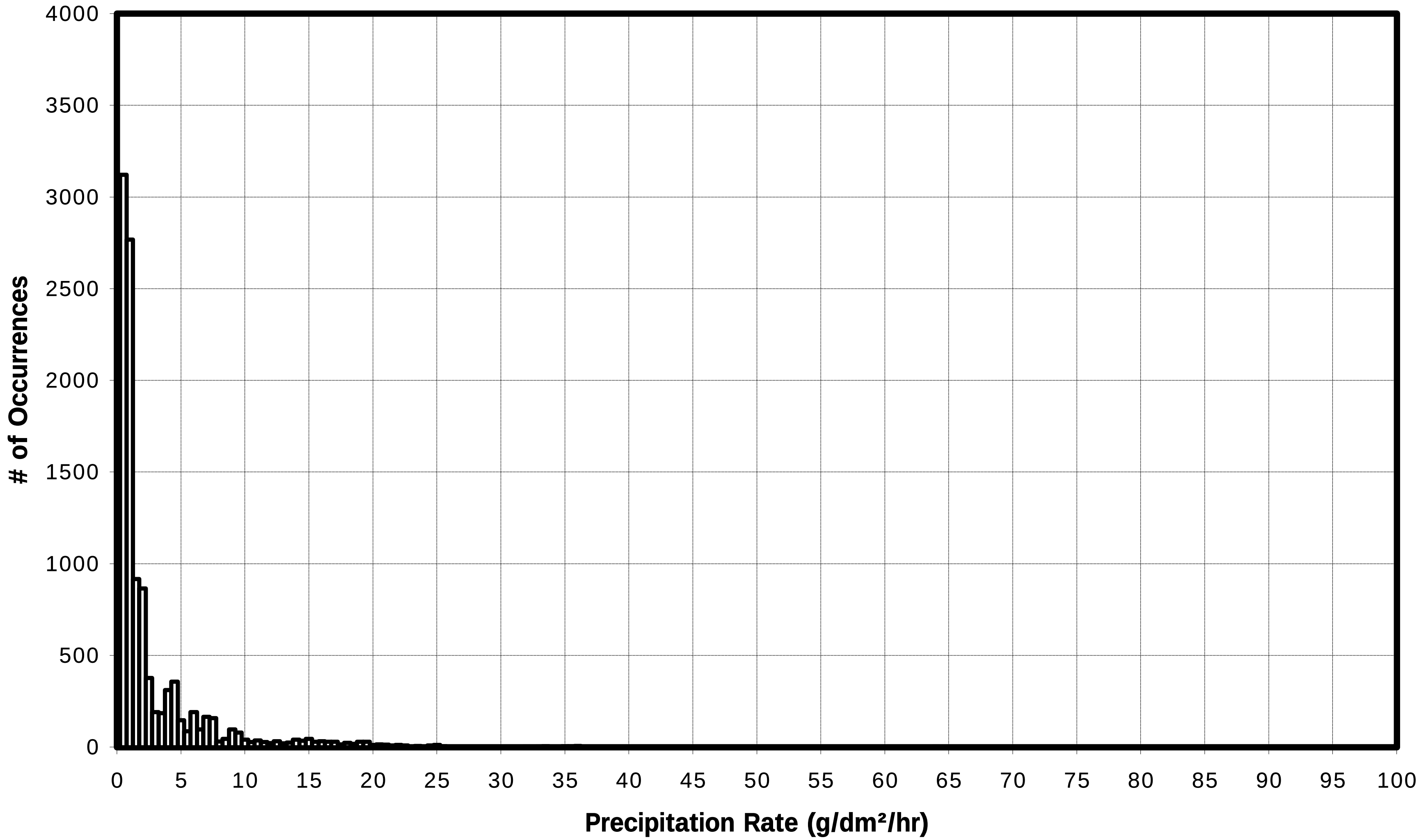
7/23/02, 11:54 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

0 to -3°C

20 MINUTES RATE EVERY MINUTE

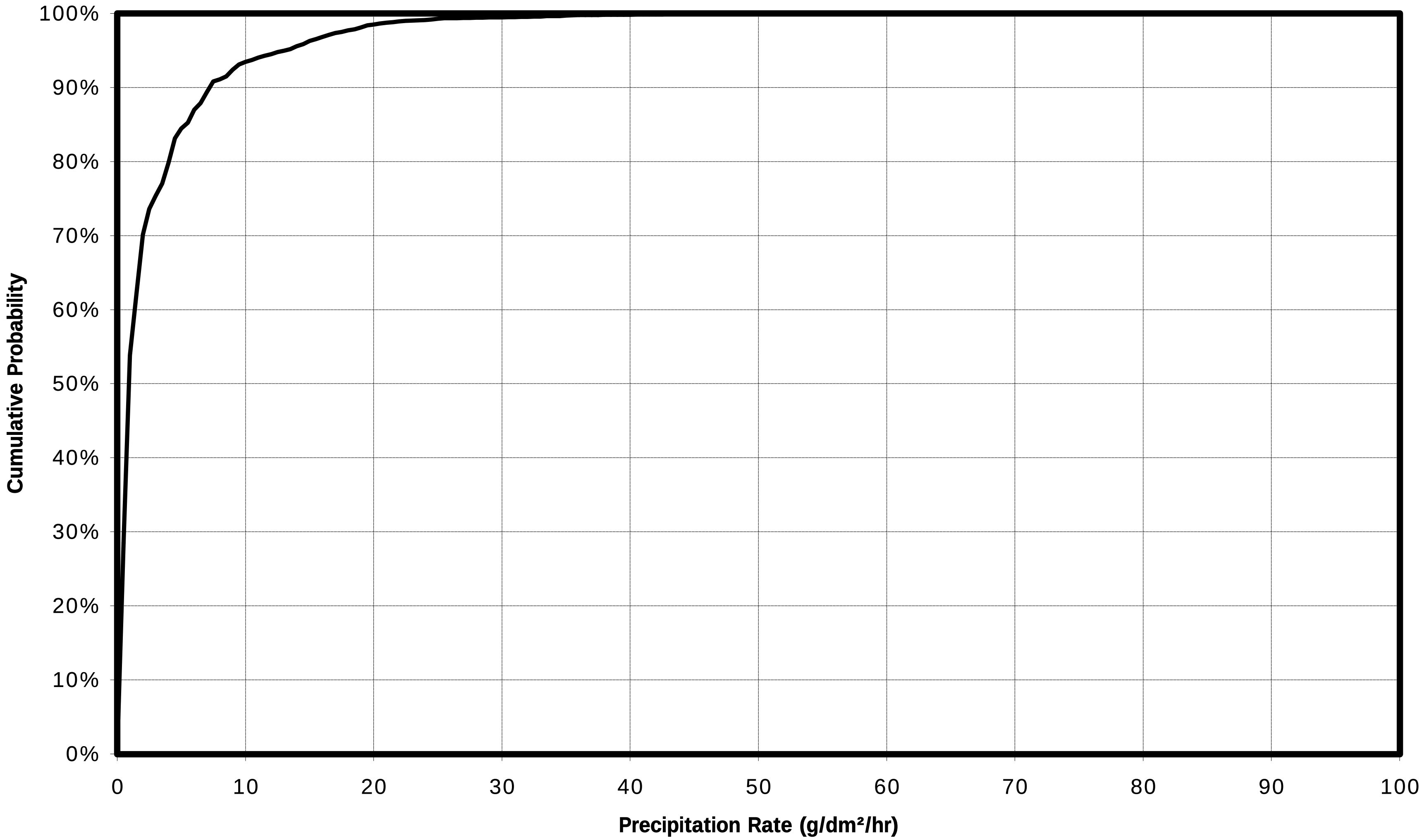


cm1380/readac/Anal_-3.xls
At: 20 min Hist
7/23/02, 11:54 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

0 to -3°C

20 MINUTES RATE EVERY MINUTE

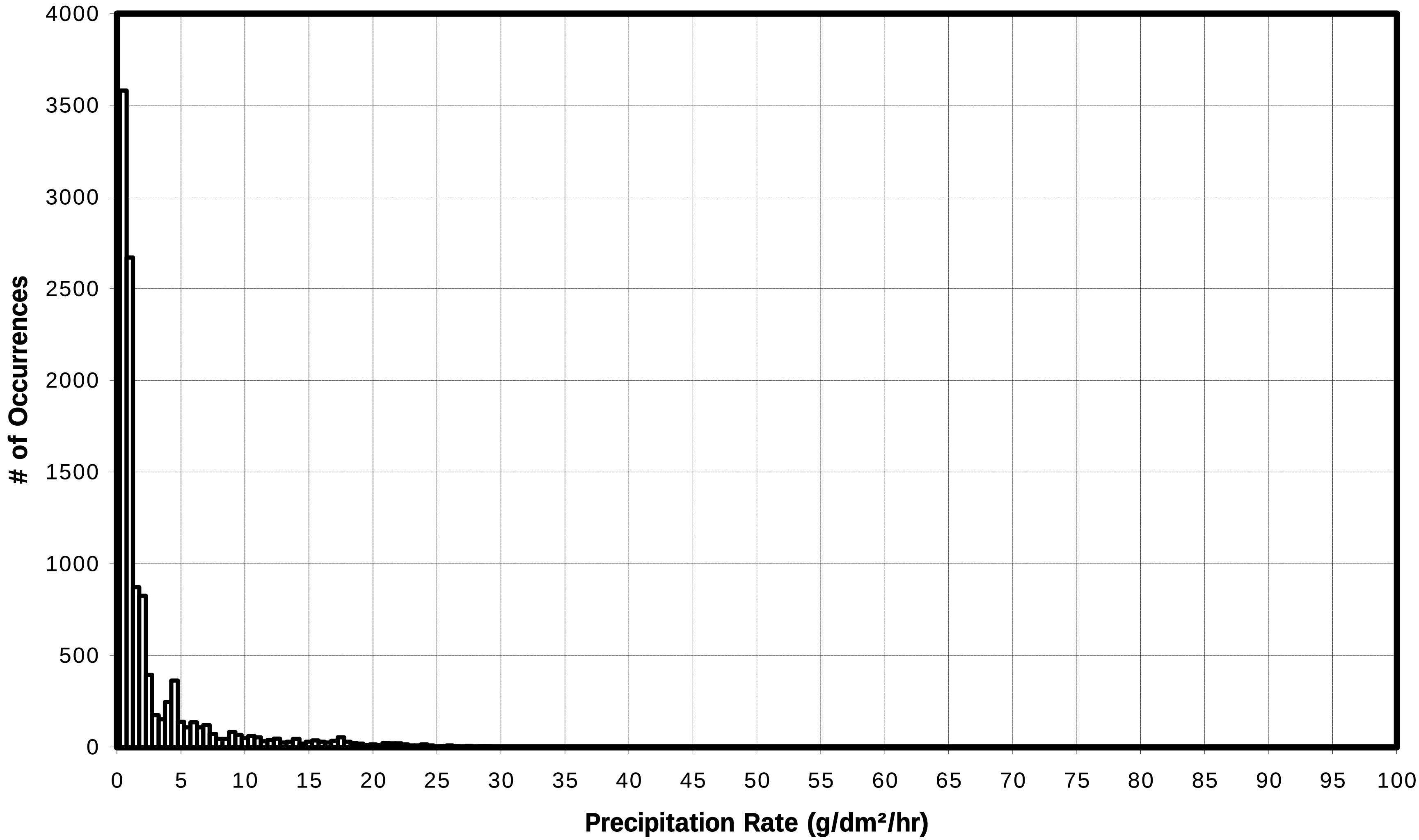


cm1380/readac/Anal_-3.xls
At: 20 min Cuml.
7/23/02, 11:54 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

0 to -3°C

35 MINUTES RATE EVERY MINUTE



cm1380/readac/Anal_-3.xls
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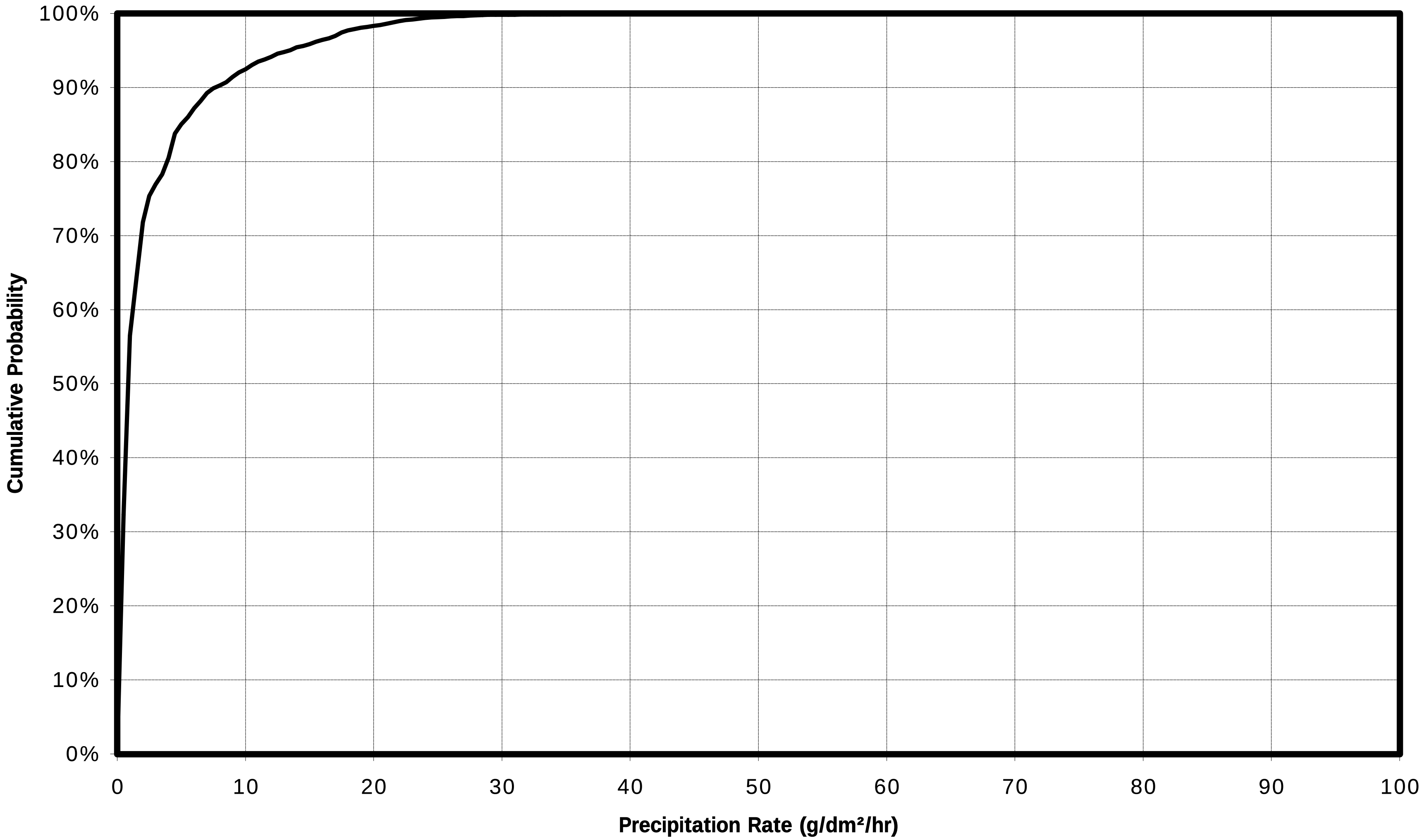
7/23/02, 11:54 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

0 to -3°C

35 MINUTES RATE EVERY MINUTE



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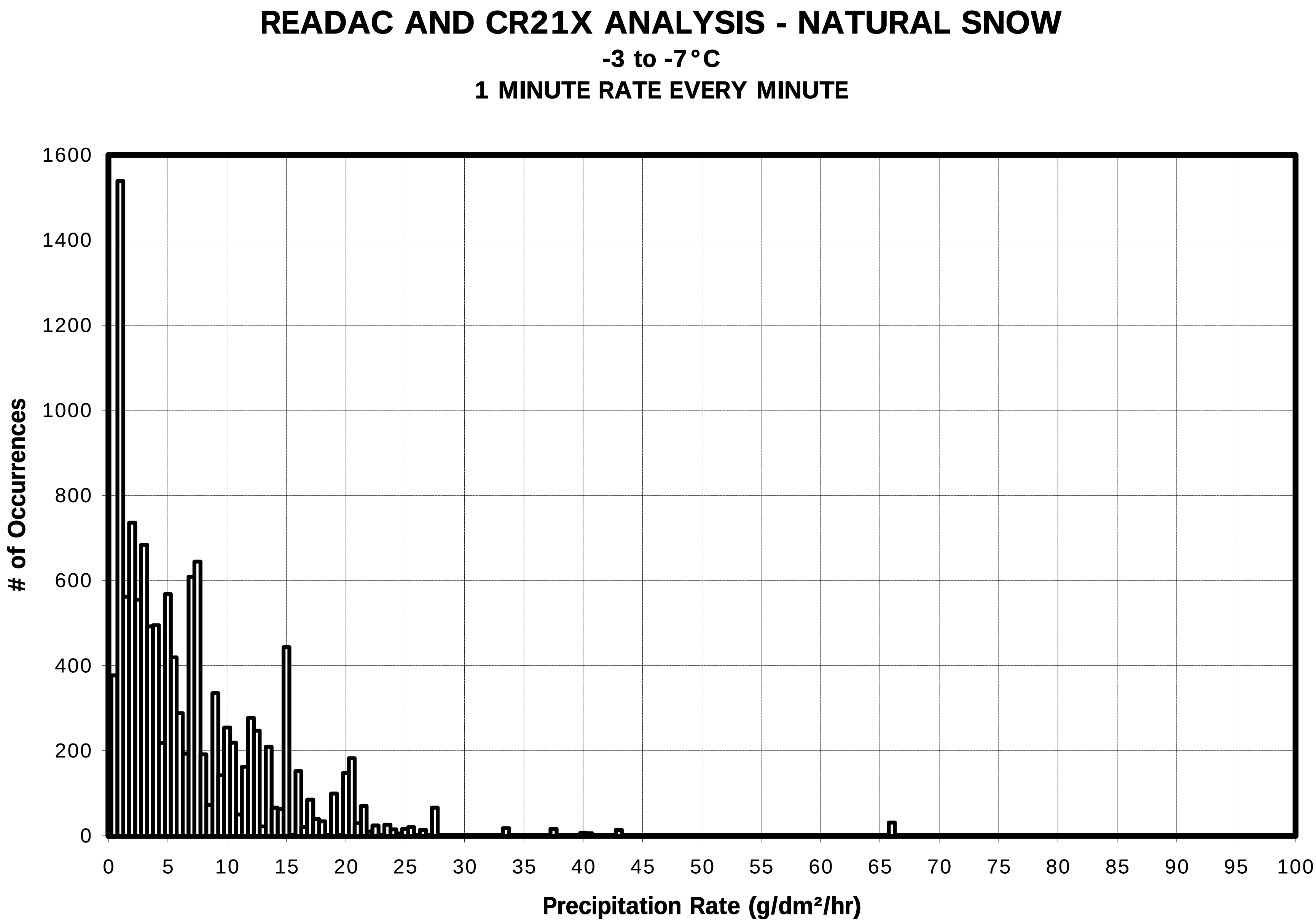
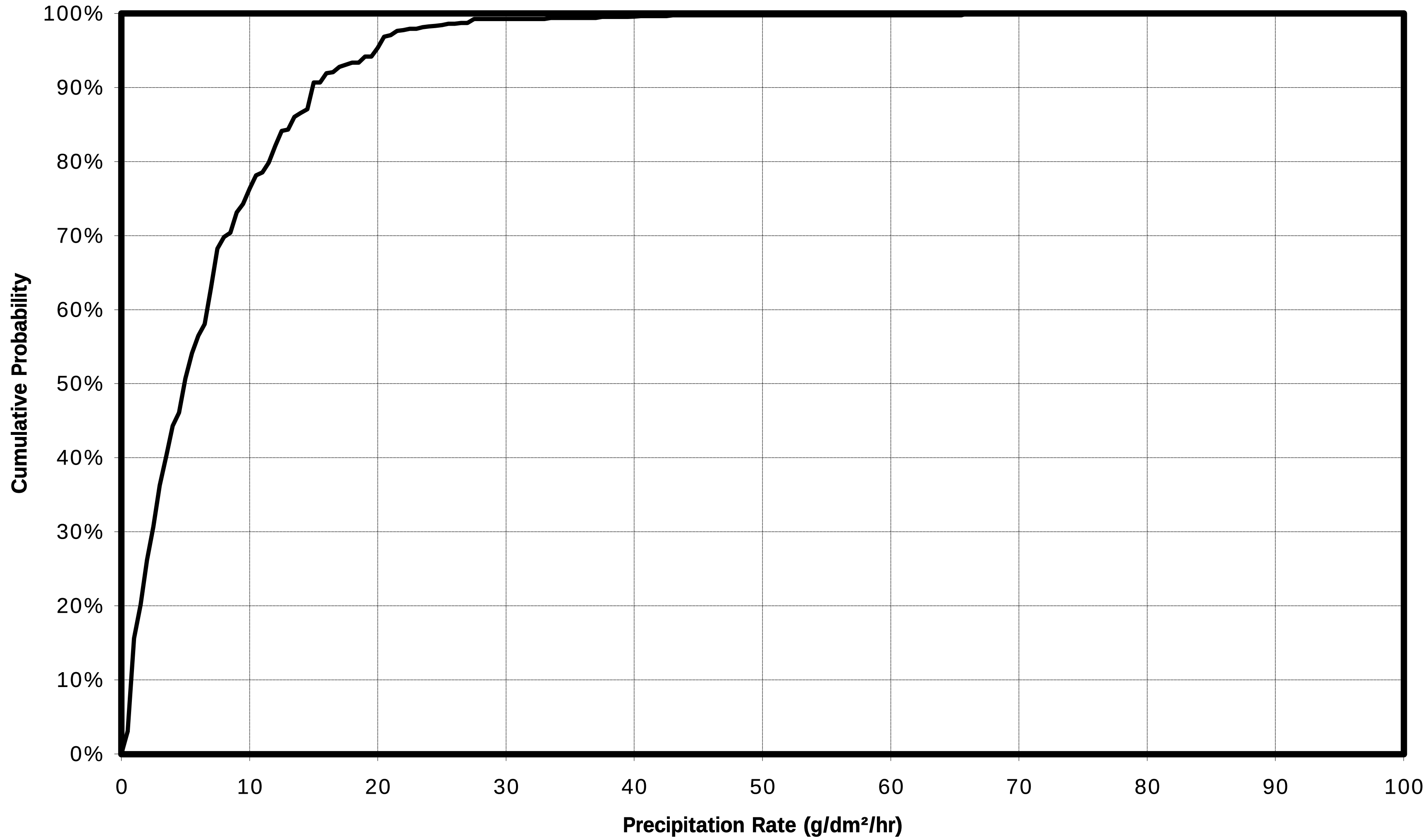
7/23/02, 11:54 AM



cm1380/readac/Anal_-7.xls
At: 1 min Hist
7/23/02, 11:56 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW
-3 to -7°C
1 MINUTE RATE EVERY MINUTE



cm1380/readac/Anal_-7.xls
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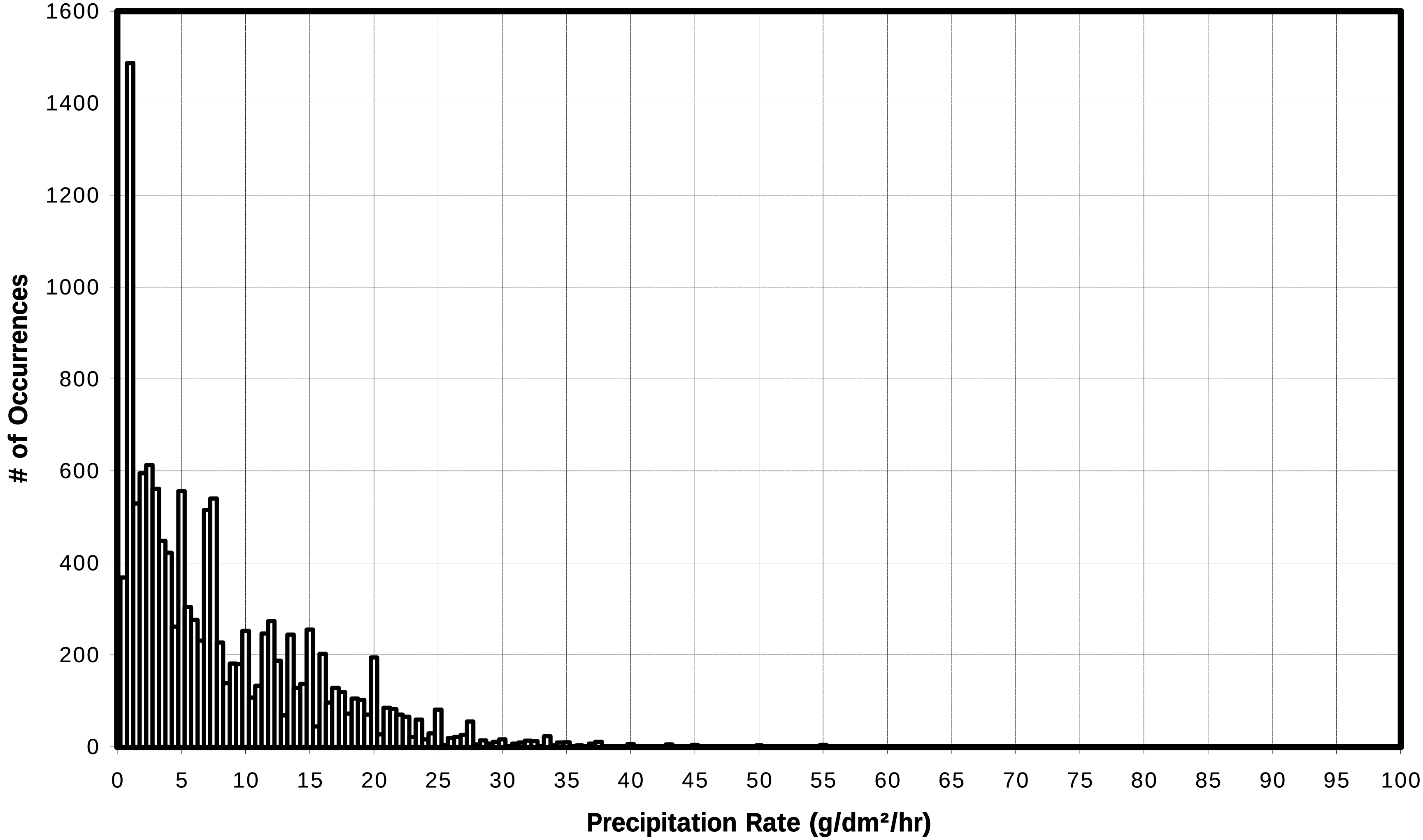
7/23/02, 11:56 AM

READADC AND CR21X ANALYSIS - NATURAL SNOW

-3 to -7°C

6 MINUTES RATE EVERY MINUTE

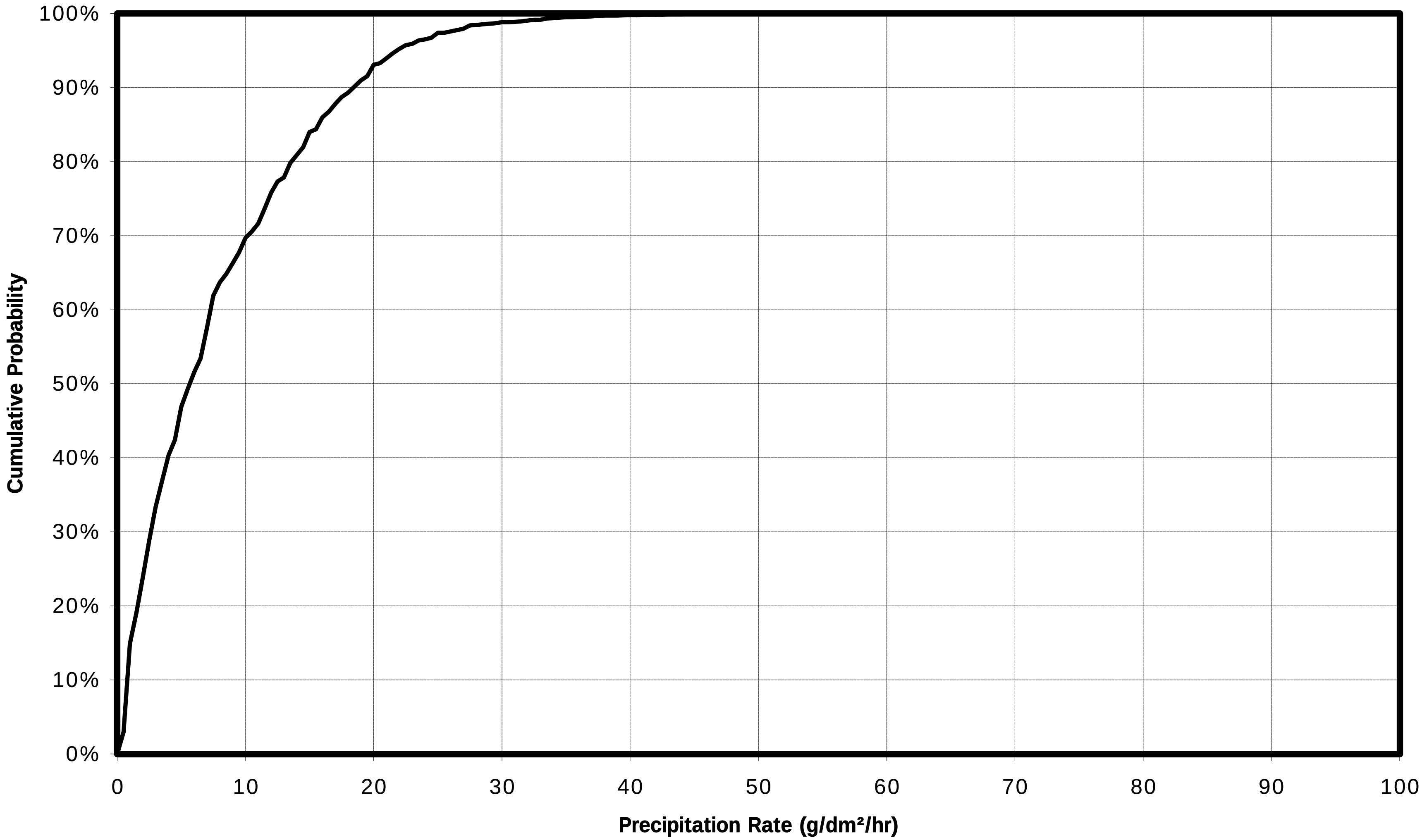


cm1380/readac/Anal_-7.xls
At: 6 min Hist
7/23/02, 11:56 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-3 to -7°C

6 MINUTES RATE EVERY MINUTE



cm1380/readac/Anal_-7.xls
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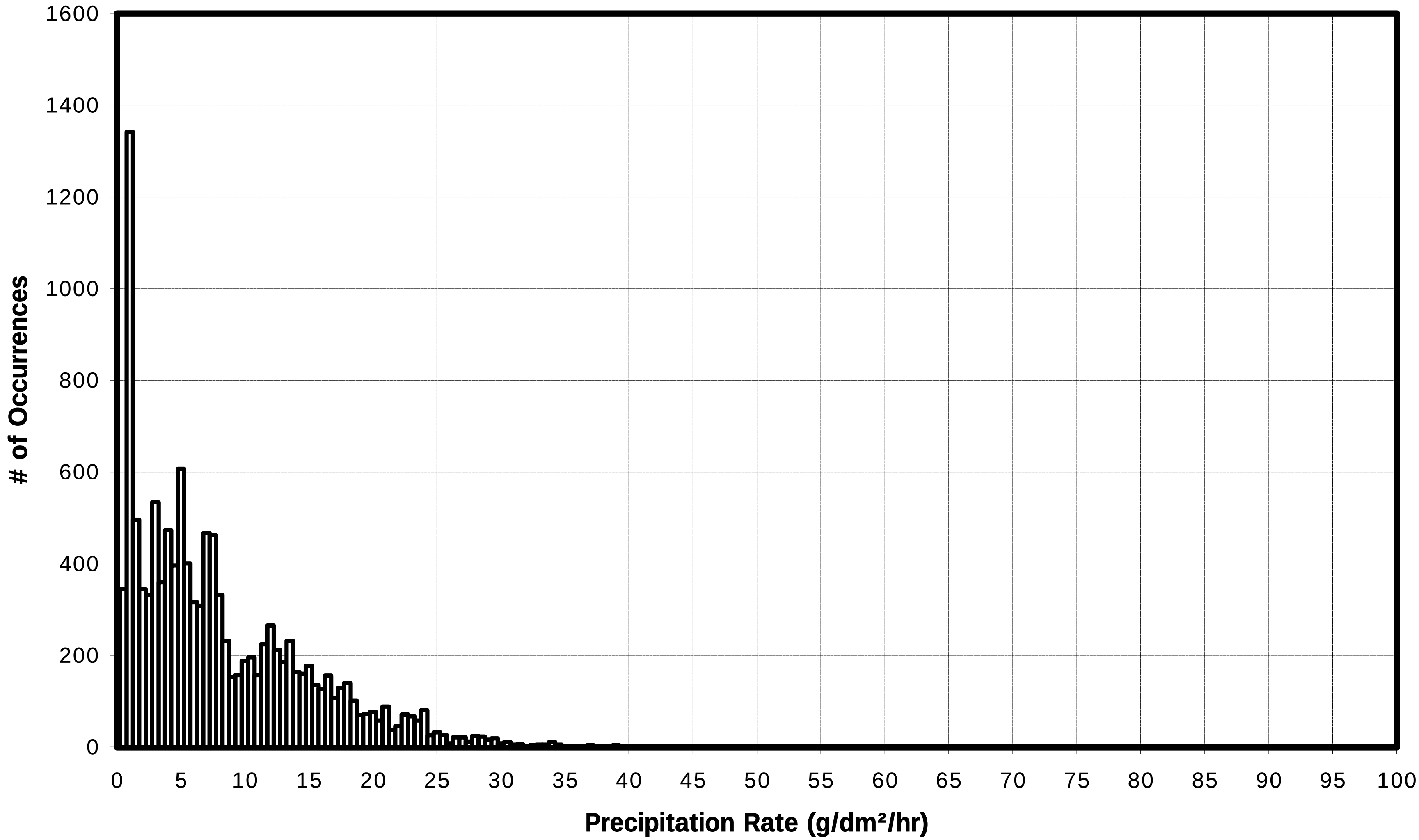
7/23/02, 11:56 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW
-3 to -7°C
20 MINUTES RATE EVERY MINUTE

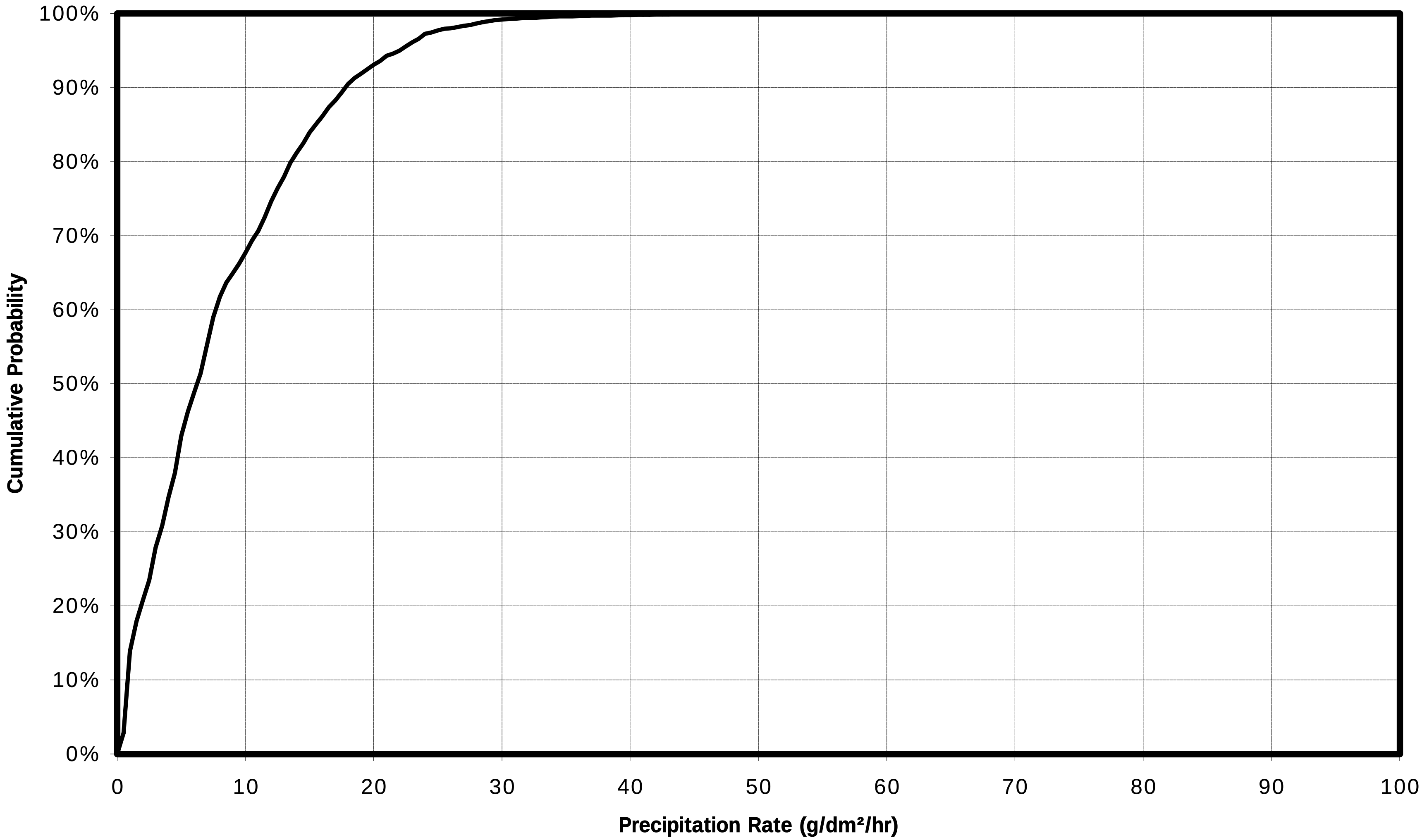


cm1380/readac/Anal_-7.xls
At: 20 min Hist
7/23/02, 11:56 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-3 to -7°C

20 MINUTES RATE EVERY MINUTE



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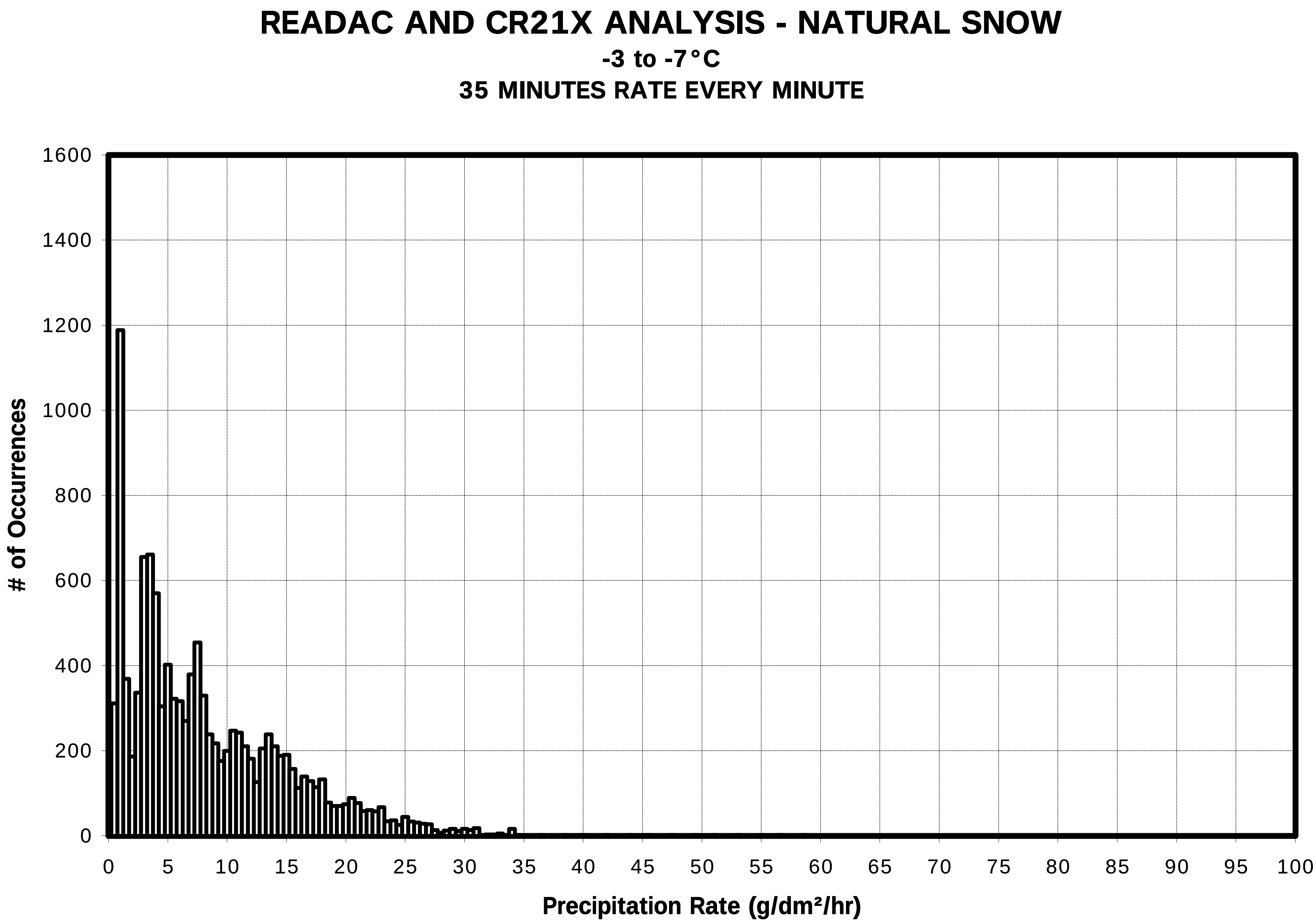

cm1380/readac/Anal_-7.xls
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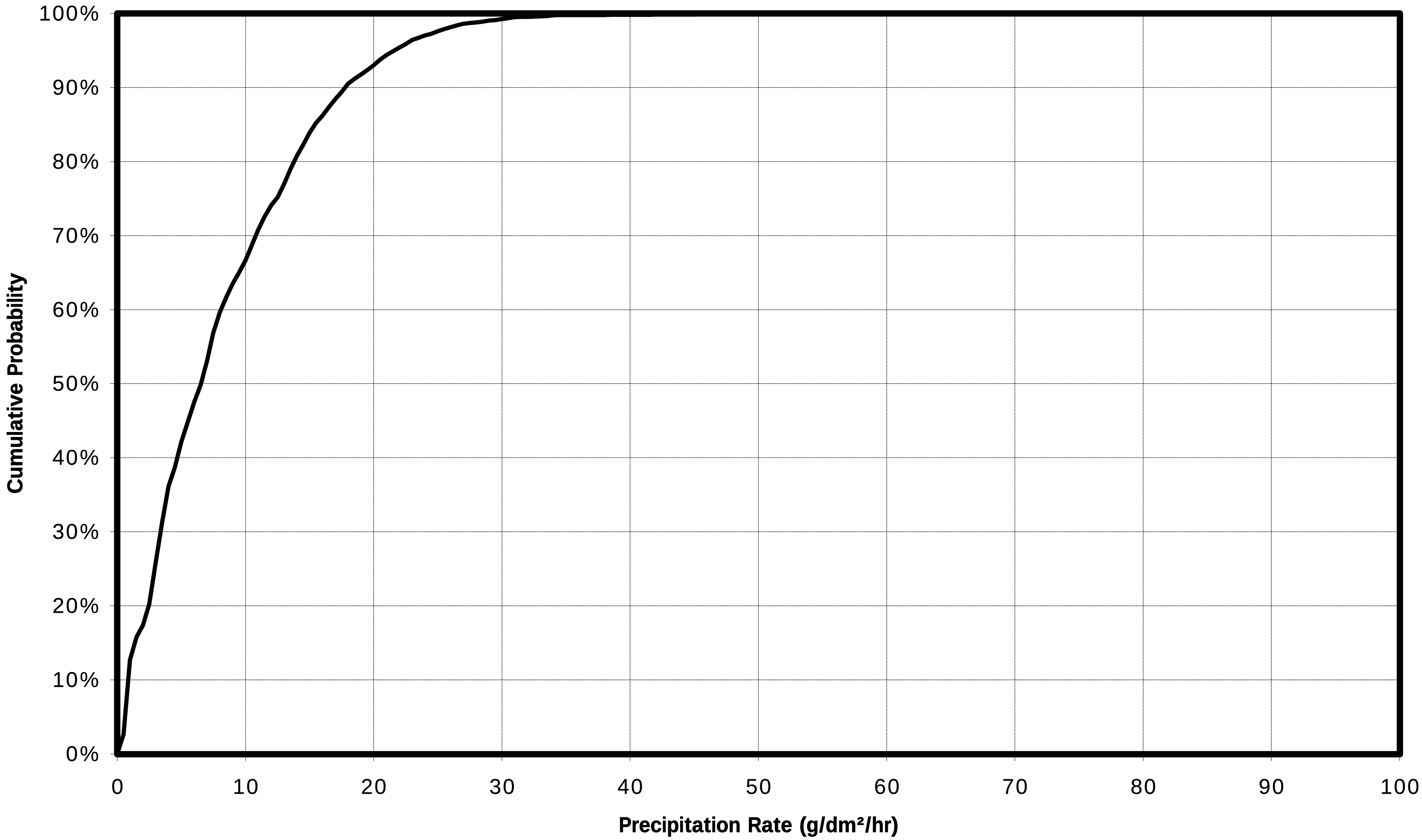
READAC AND CR21X ANALYSIS - NATURAL SNOW

-3 to -7°C

35 MINUTES RATE EVERY MINUTE



cm1380/readac/Anal_-7.xls
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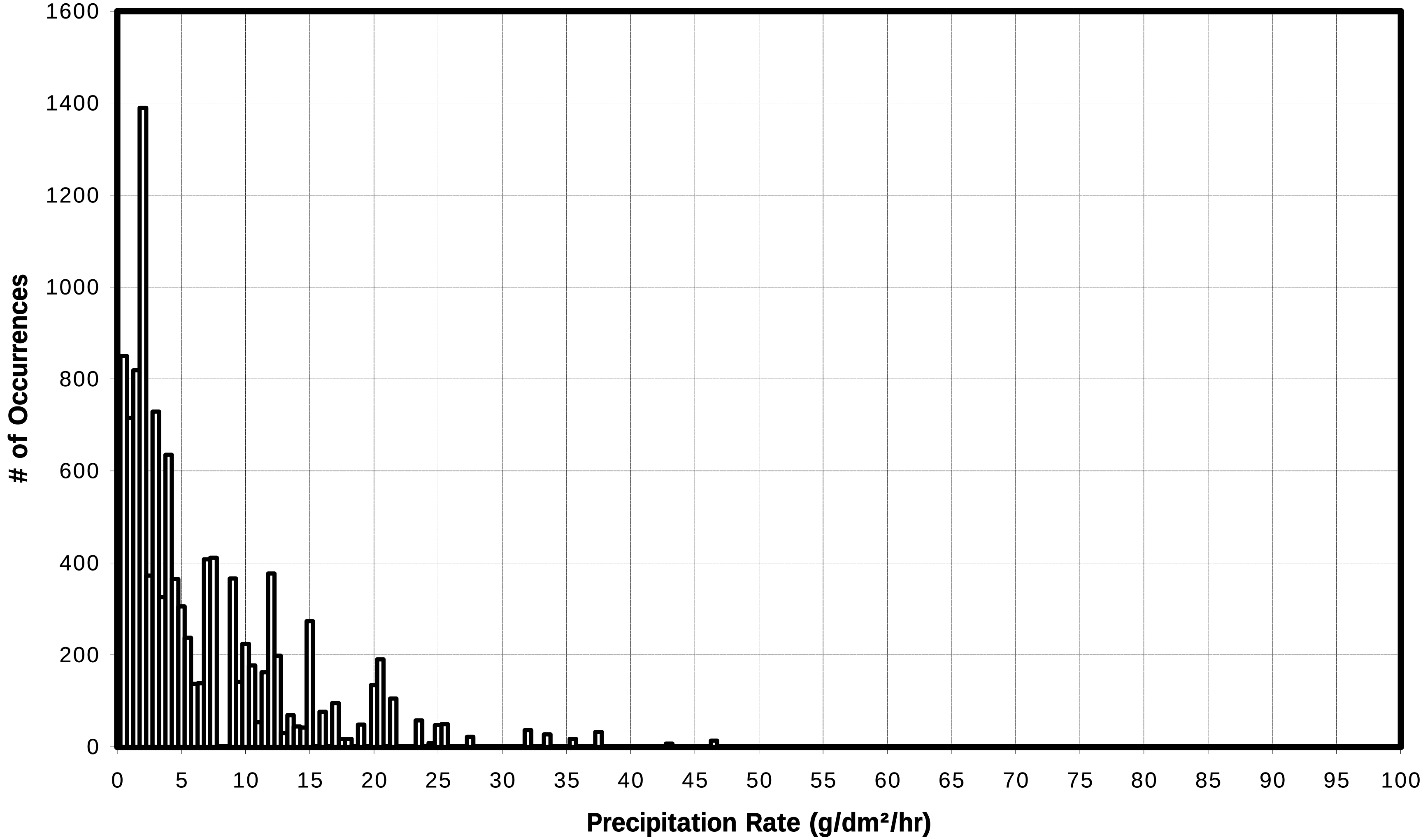
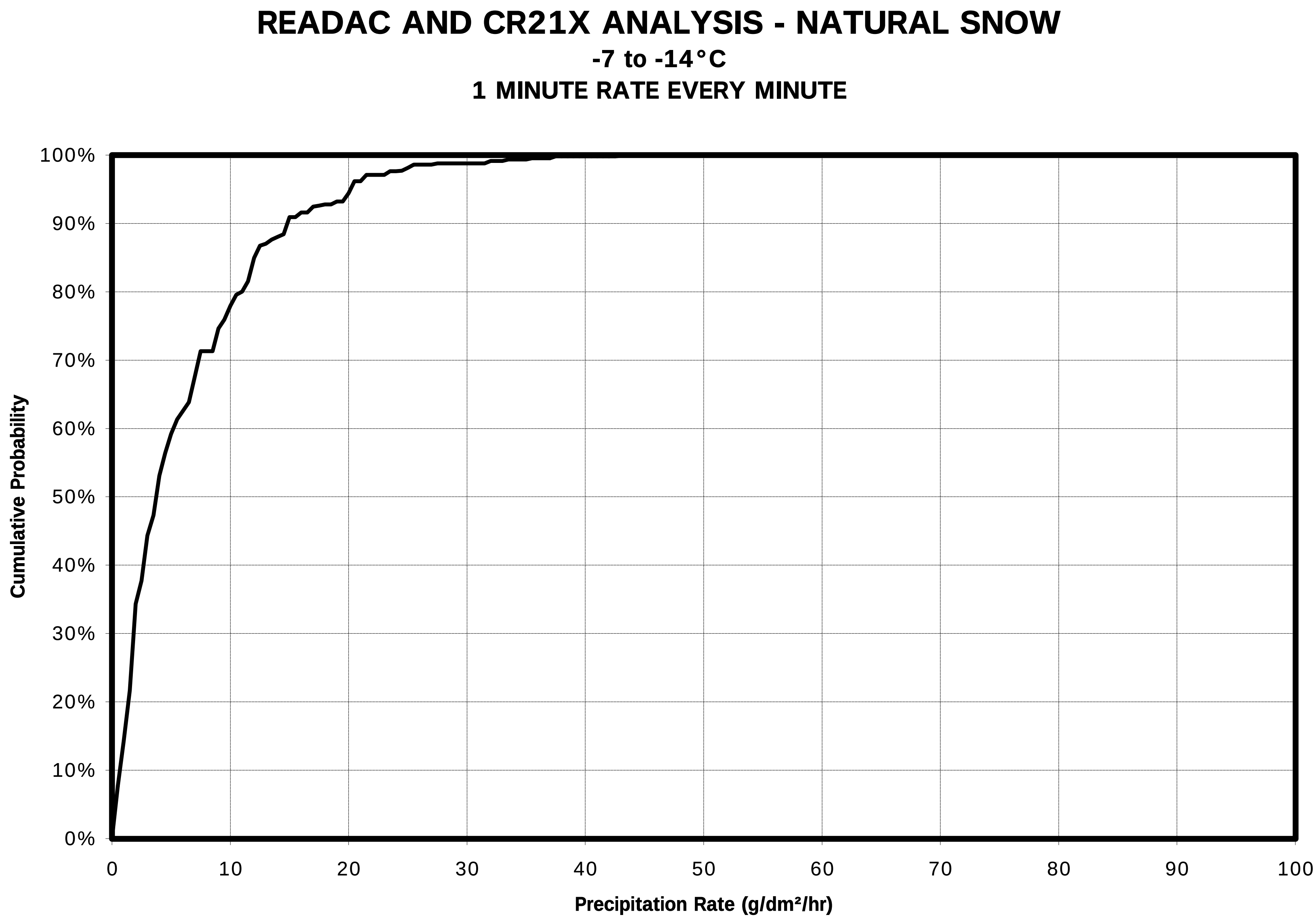
READAC AND CR21X ANALYSIS - NATURAL SNOW
-7 to -14°C
1 MINUTE RATE EVERY MINUTE



cm1380/readac/Anal_-14.xls
At: 1 min Hist
7/23/02, 11:57 AM

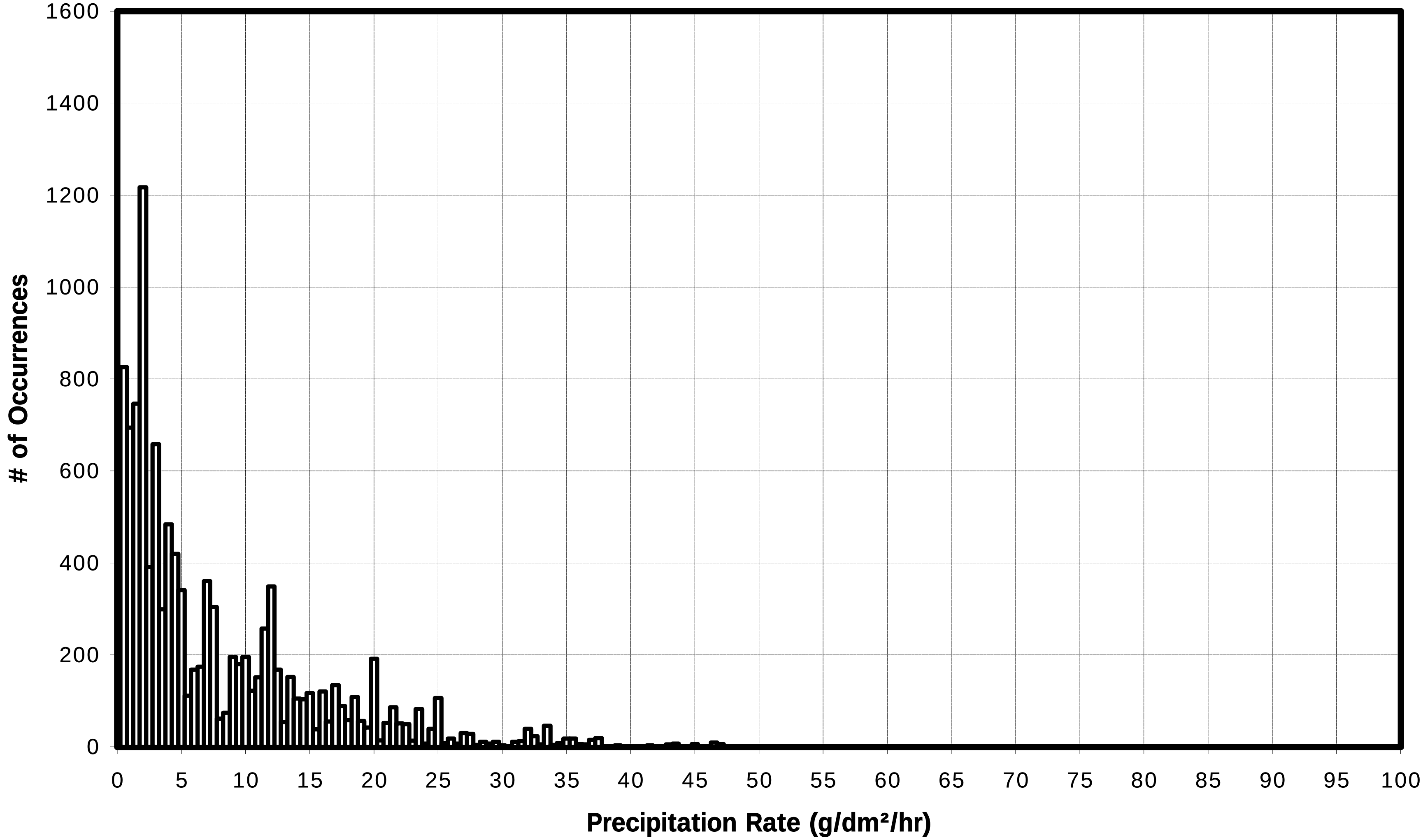


cm1380/readac/Anal_-14.xls
At: 1 min Cuml.
7/23/02, 11:57 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-7 to -14°C

6 MINUTES RATE EVERY MINUTE



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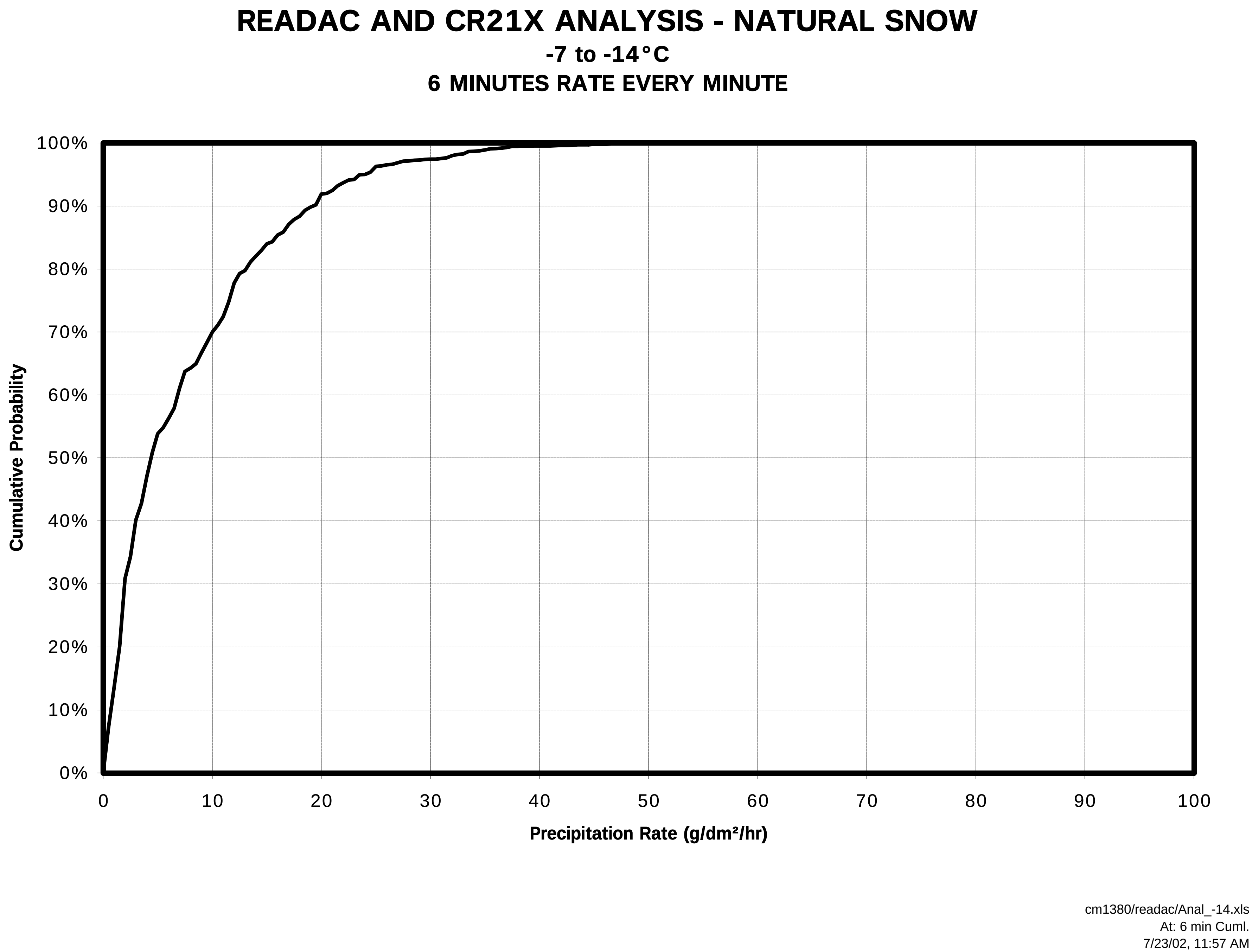
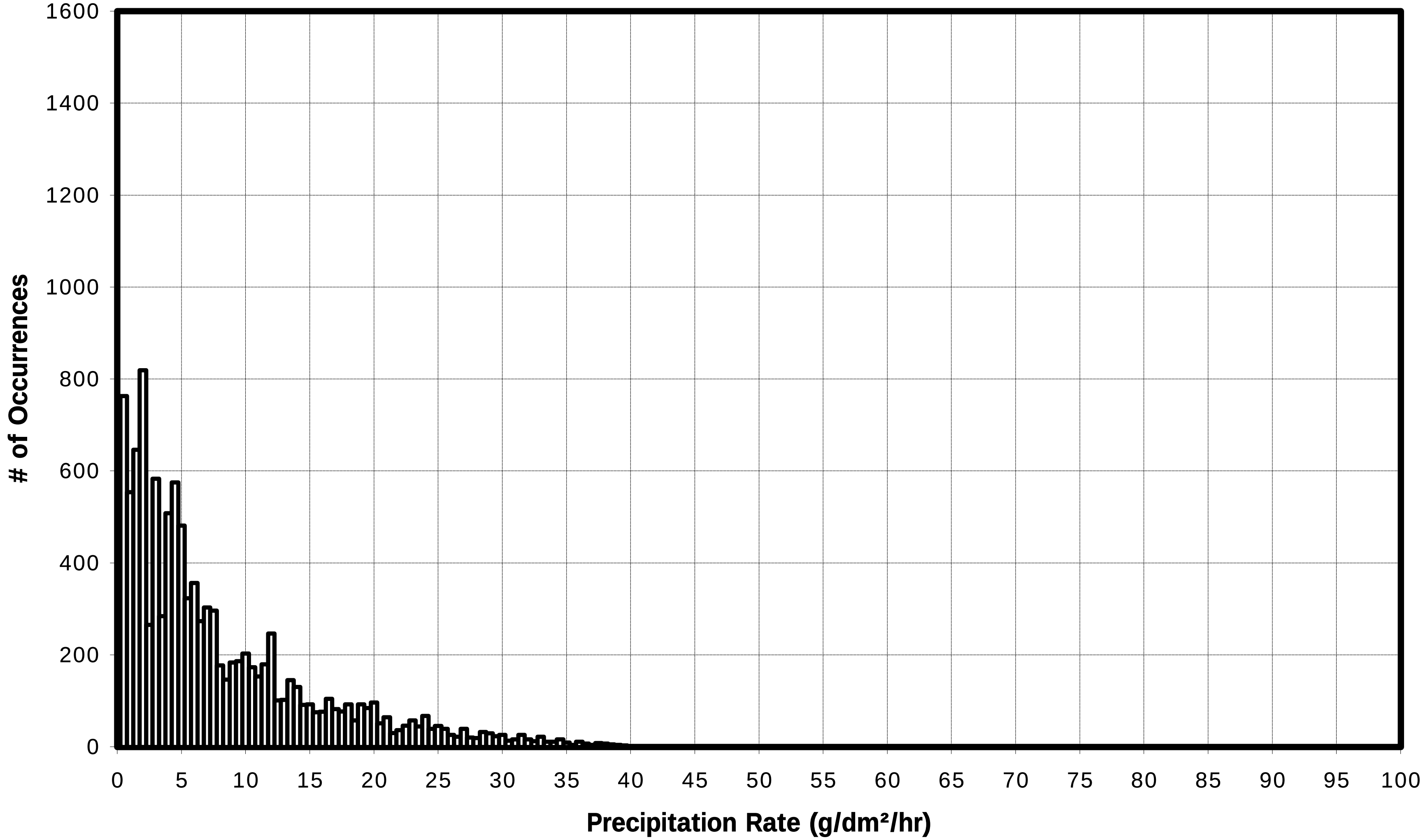
7/23/02, 11:57 AM


READADC AND CR21X ANALYSIS - NATURAL SNOW
-7 to -14°C
6 MINUTES RATE EVERY MINUTE
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative Probability
0
10
20
30
40
50
60
70
80
90
100
Precipitation Rate (g/dm²/hr)
cm1380/readac/Anal_-14.xls
At: 6 min Cuml.
7/23/02, 11:57 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-7 to -14°C

20 MINUTES RATE EVERY MINUTE



cm1380/readac/Anal_-14.xls
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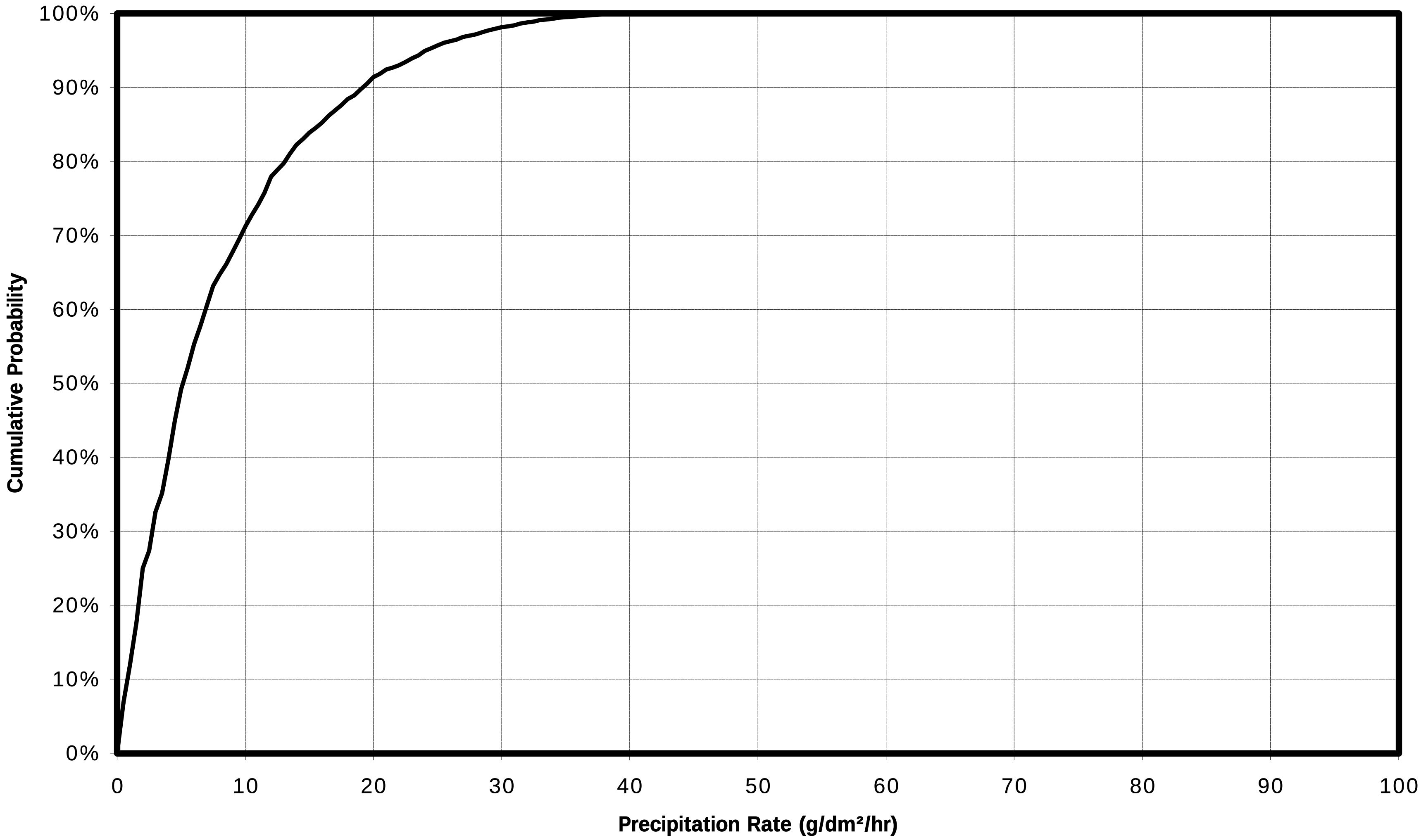
7/23/02, 11:57 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-7 to -14°C

20 MINUTES RATE EVERY MINUTE



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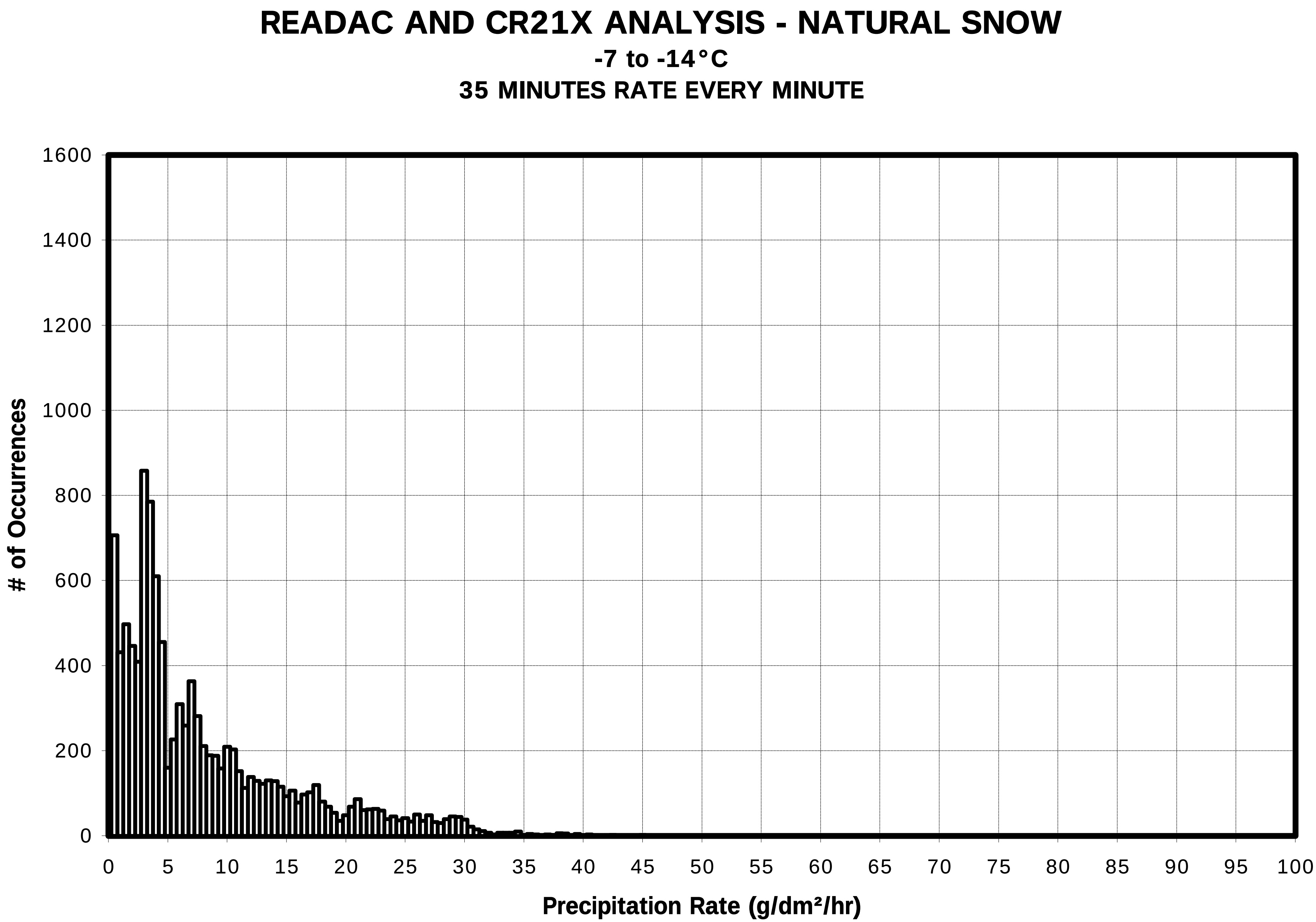

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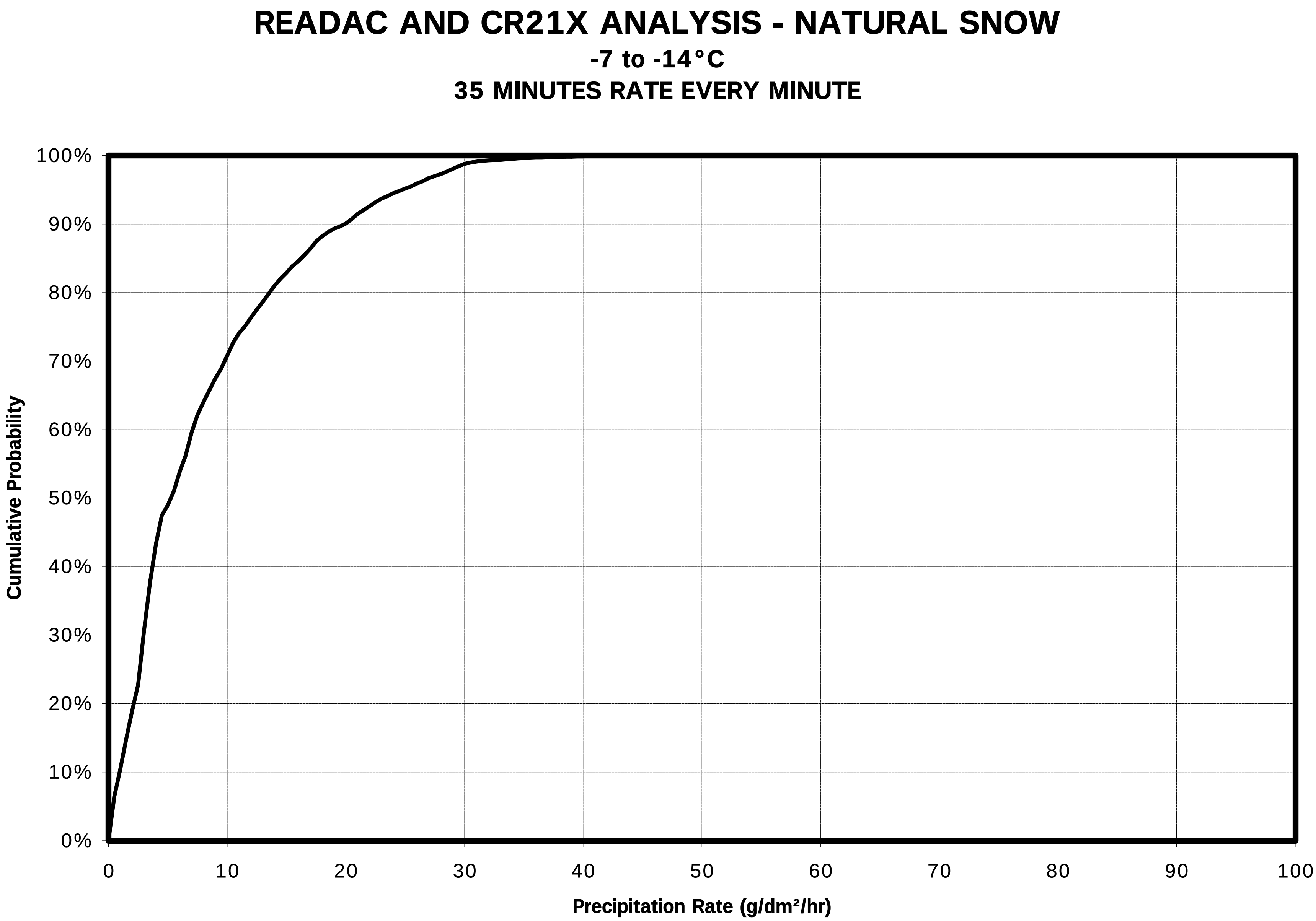

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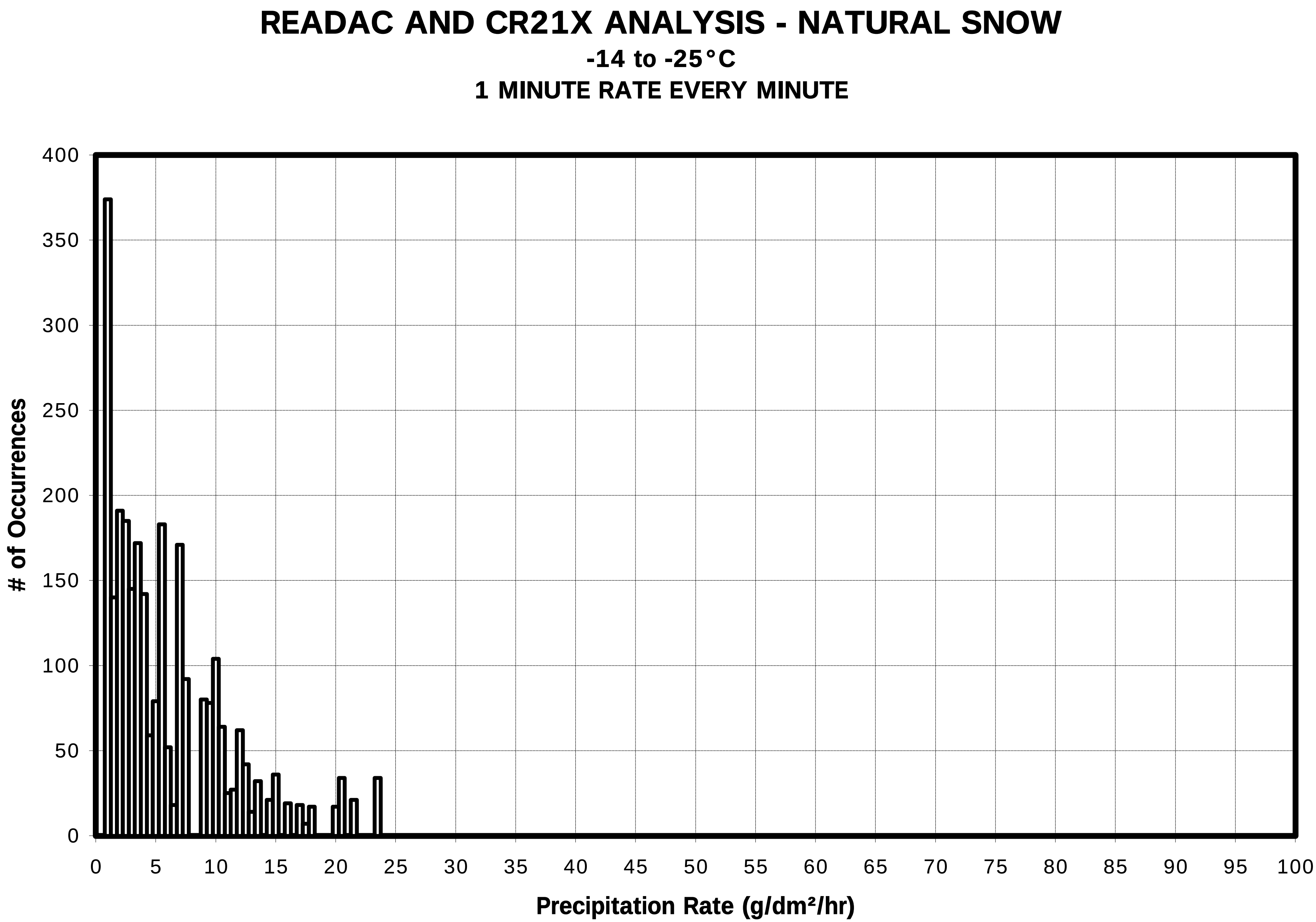

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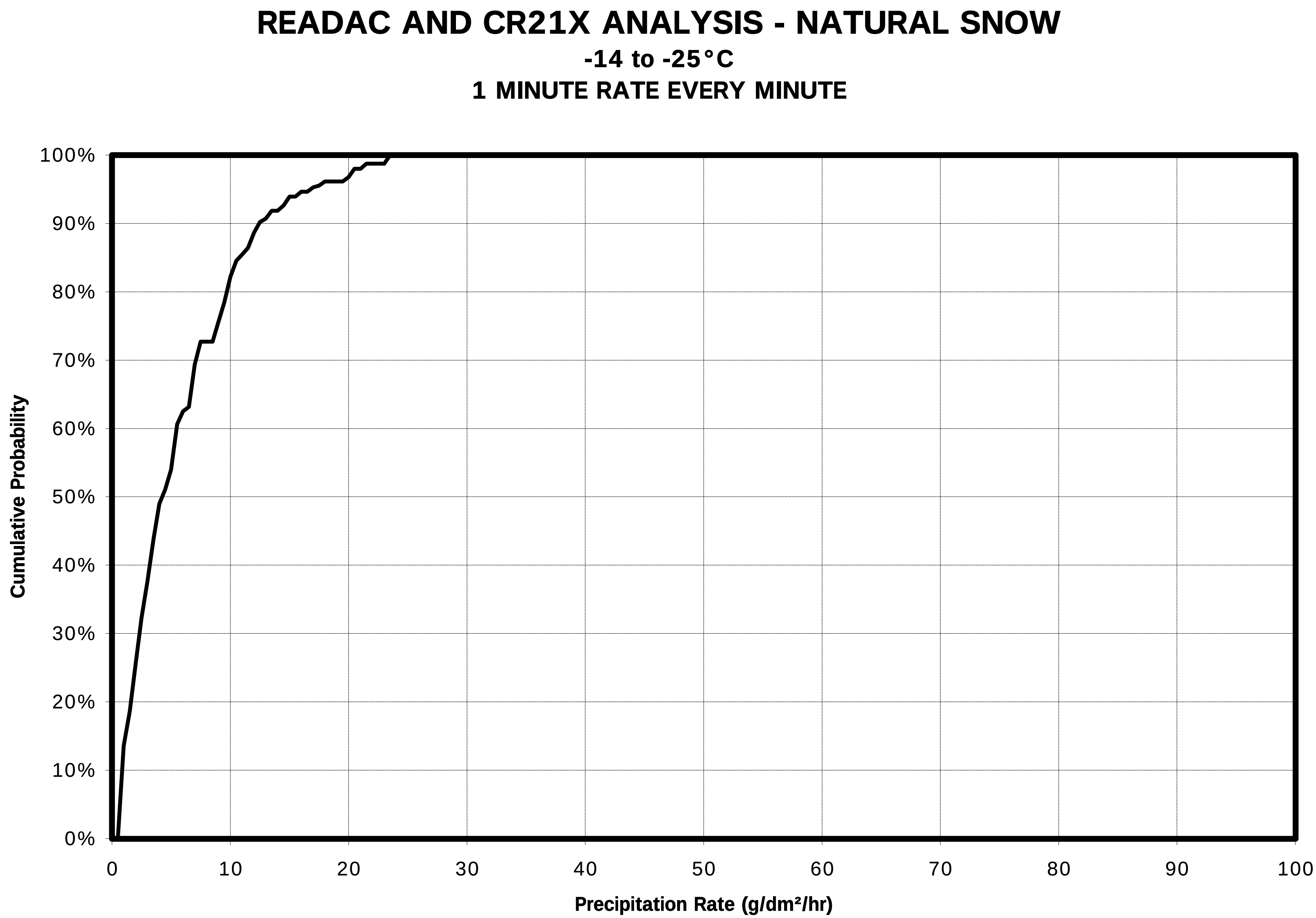
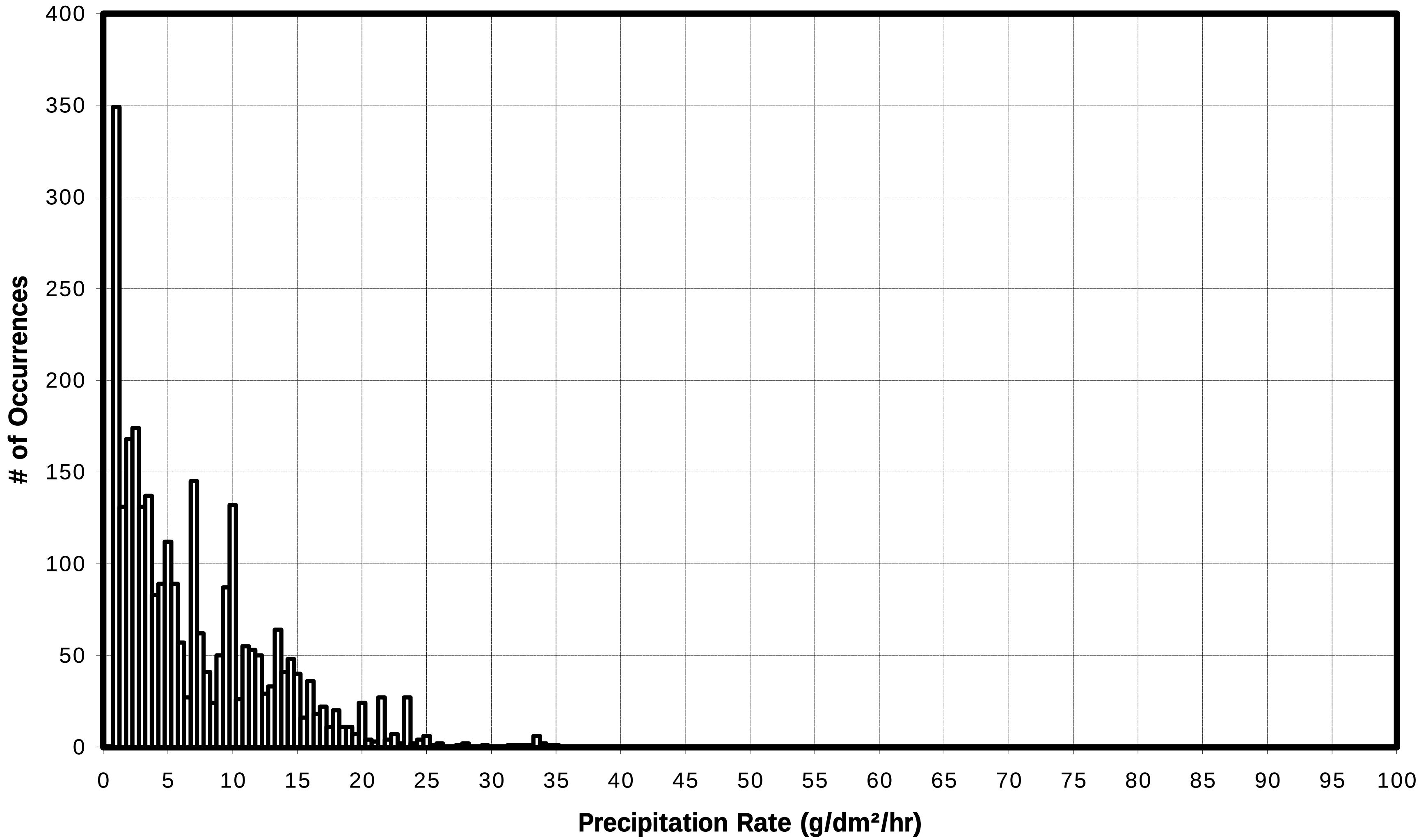


cm1380/readac/Anal_-25.xls
At: 1 min Cuml.
7/23/02, 11:59 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 to -25°C

6 MINUTES RATE EVERY MINUTE



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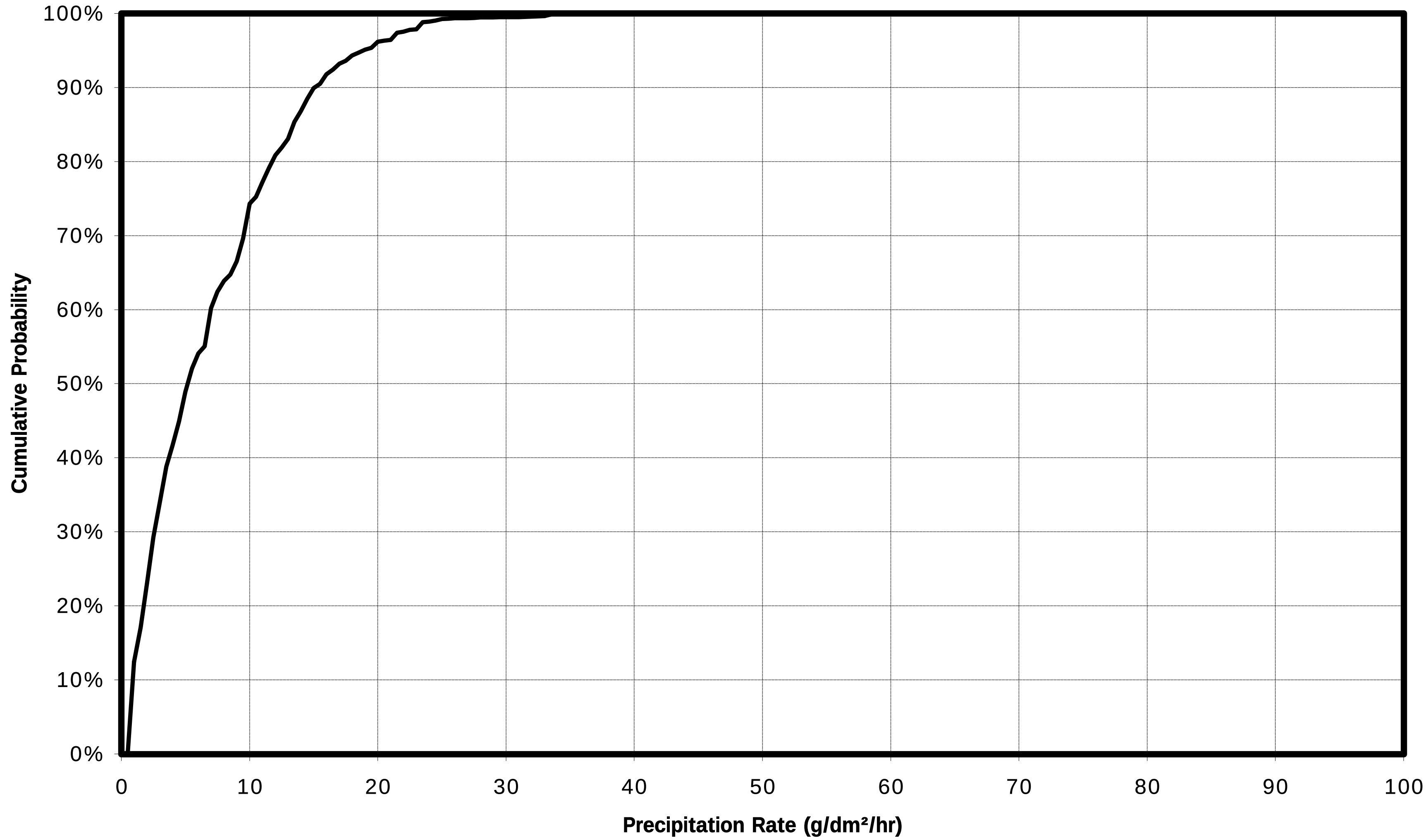
READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 to -25°C

6 MINUTES RATE EVERY MINUTE



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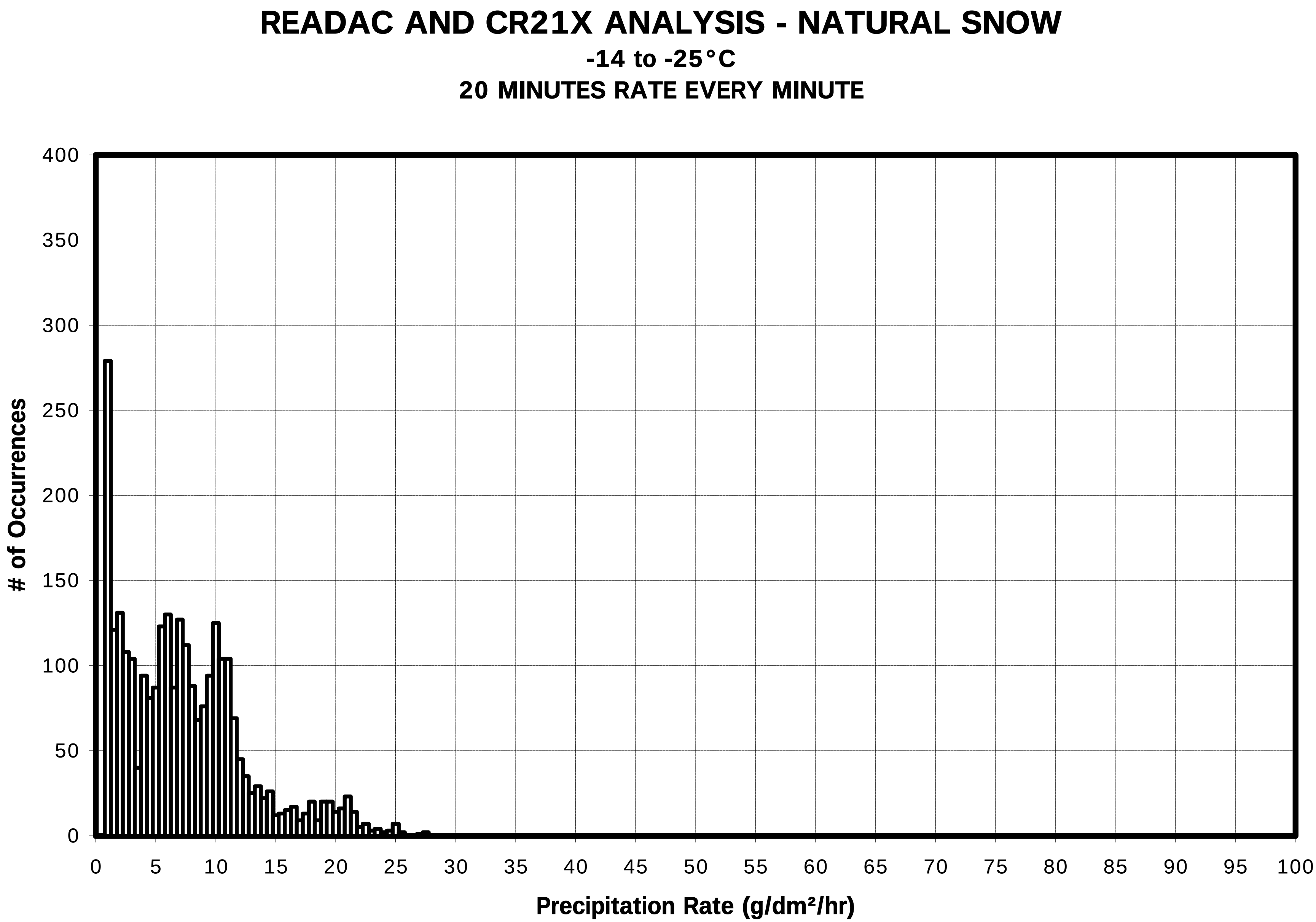

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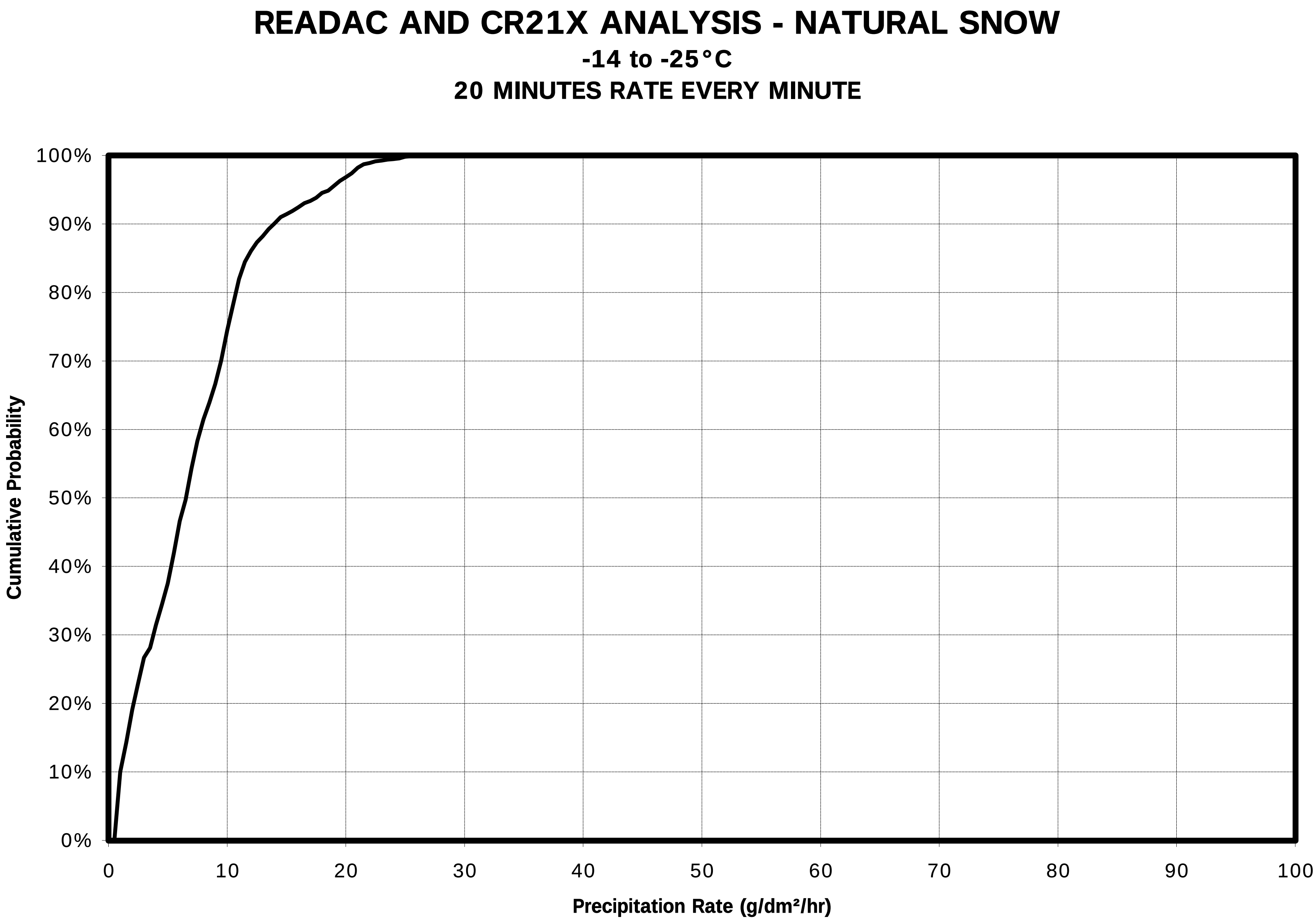
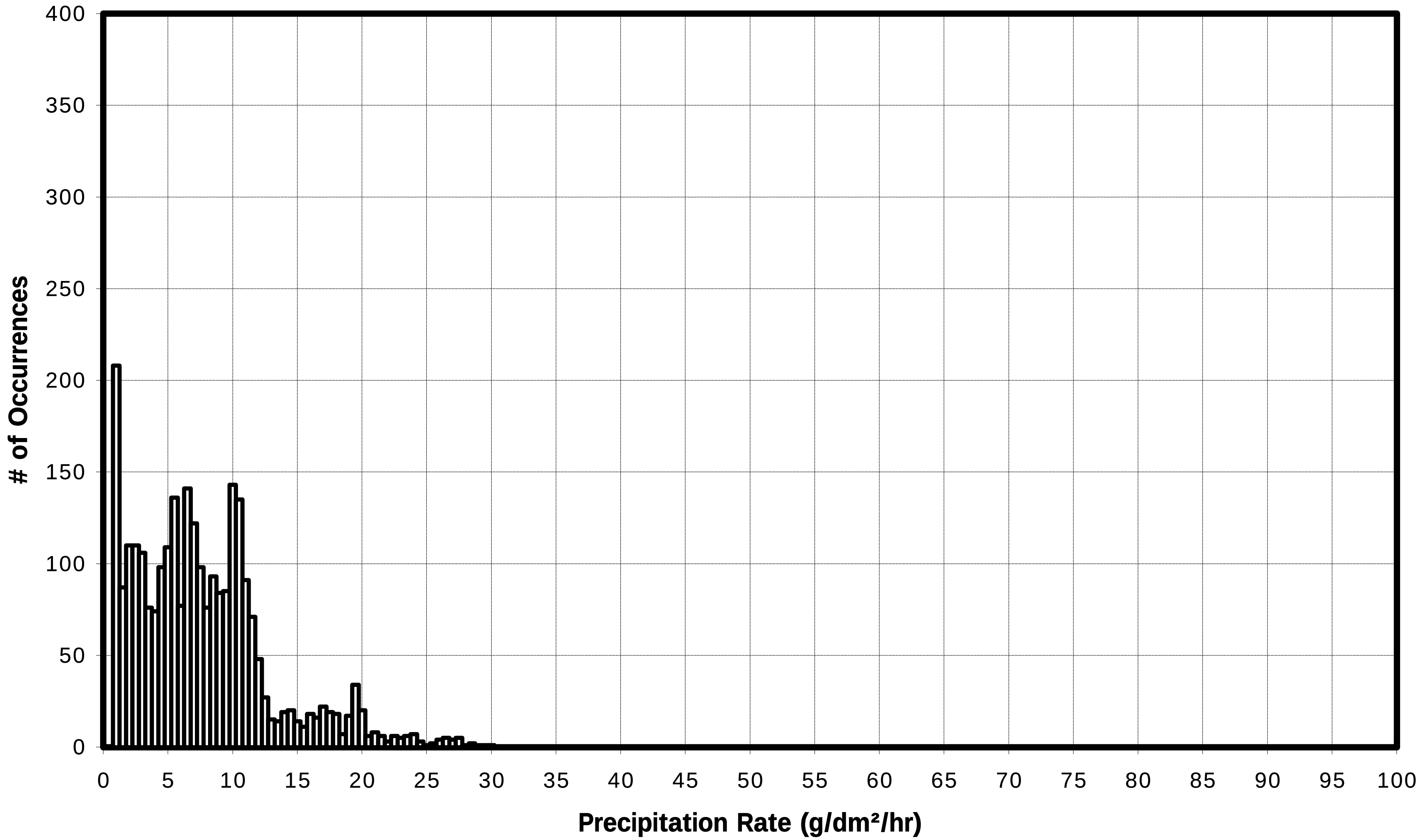


cm1380/readac/Anal_-25.xls
At: 20 min Cuml.
7/23/02, 11:59 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 to -25°C

35 MINUTES RATE EVERY MINUTE

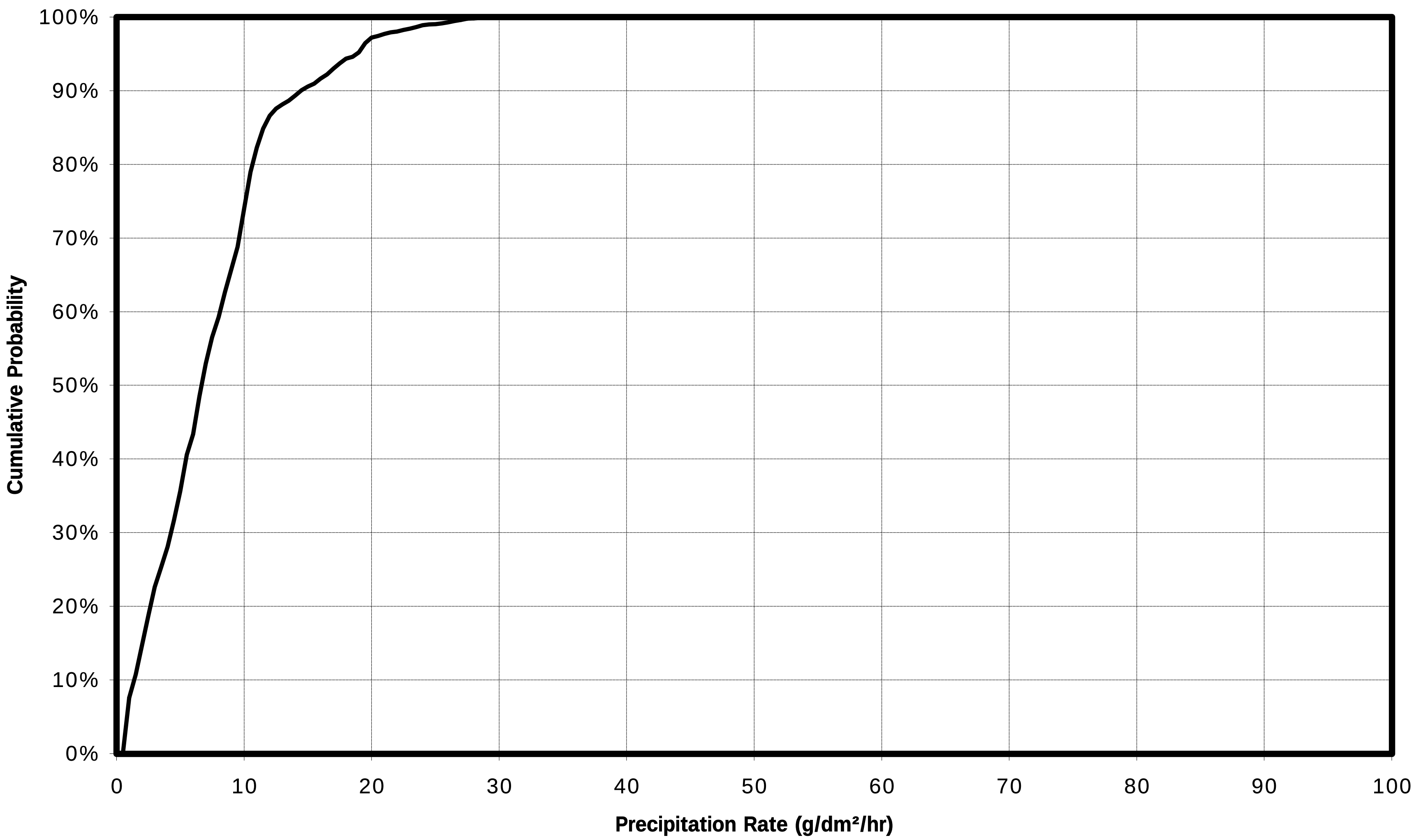


cm1380/readac/Anal_-25.xls
At: 35 min Hist
7/23/02, 11:59 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 to -25°C

35 MINUTES RATE EVERY MINUTE



cm1380/readac/Anal_-25.xls
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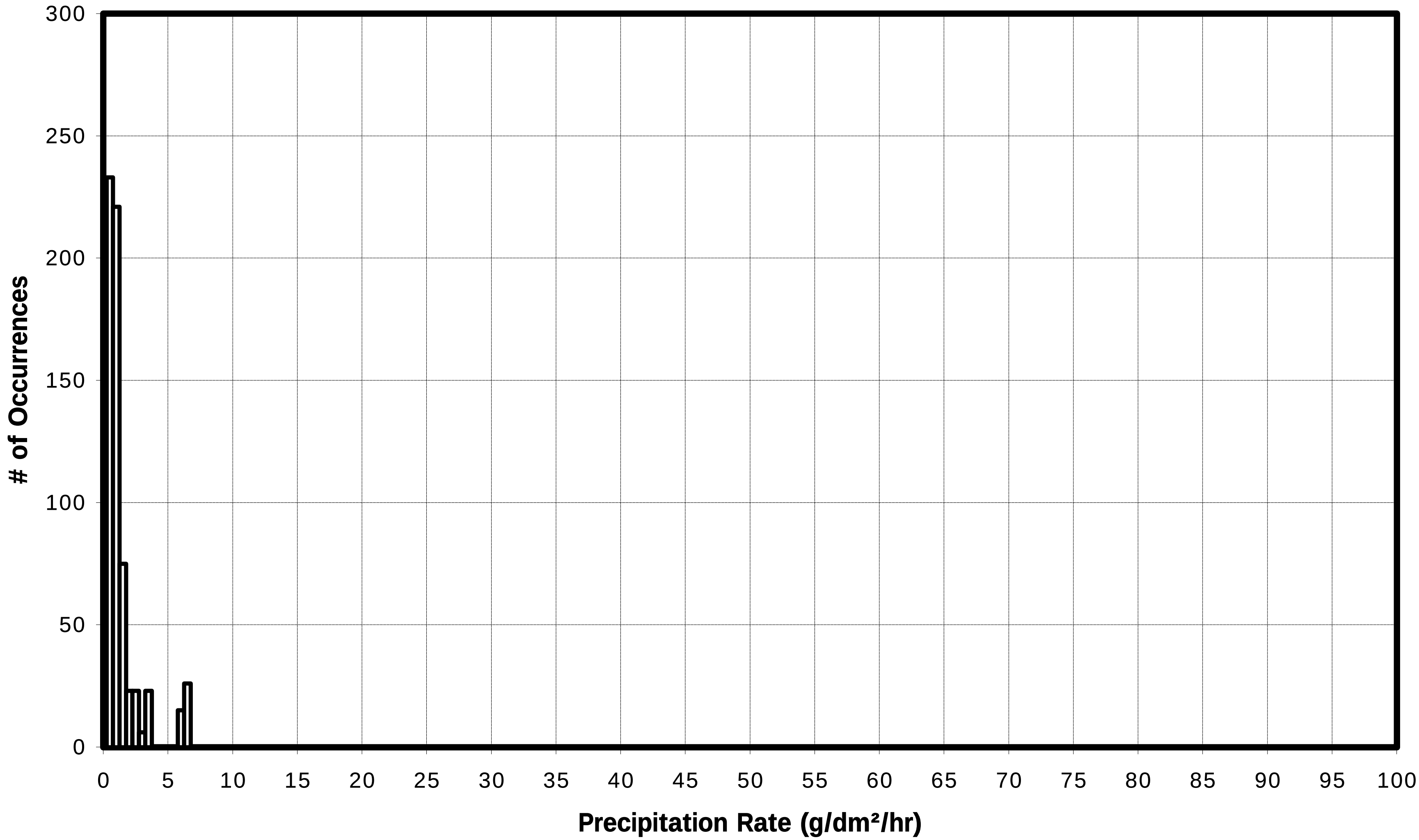
READADC AND CR21X ANALYSIS - NATURAL SNOW

-20 to -25°C

1 MINUTE RATE EVERY MINUTE



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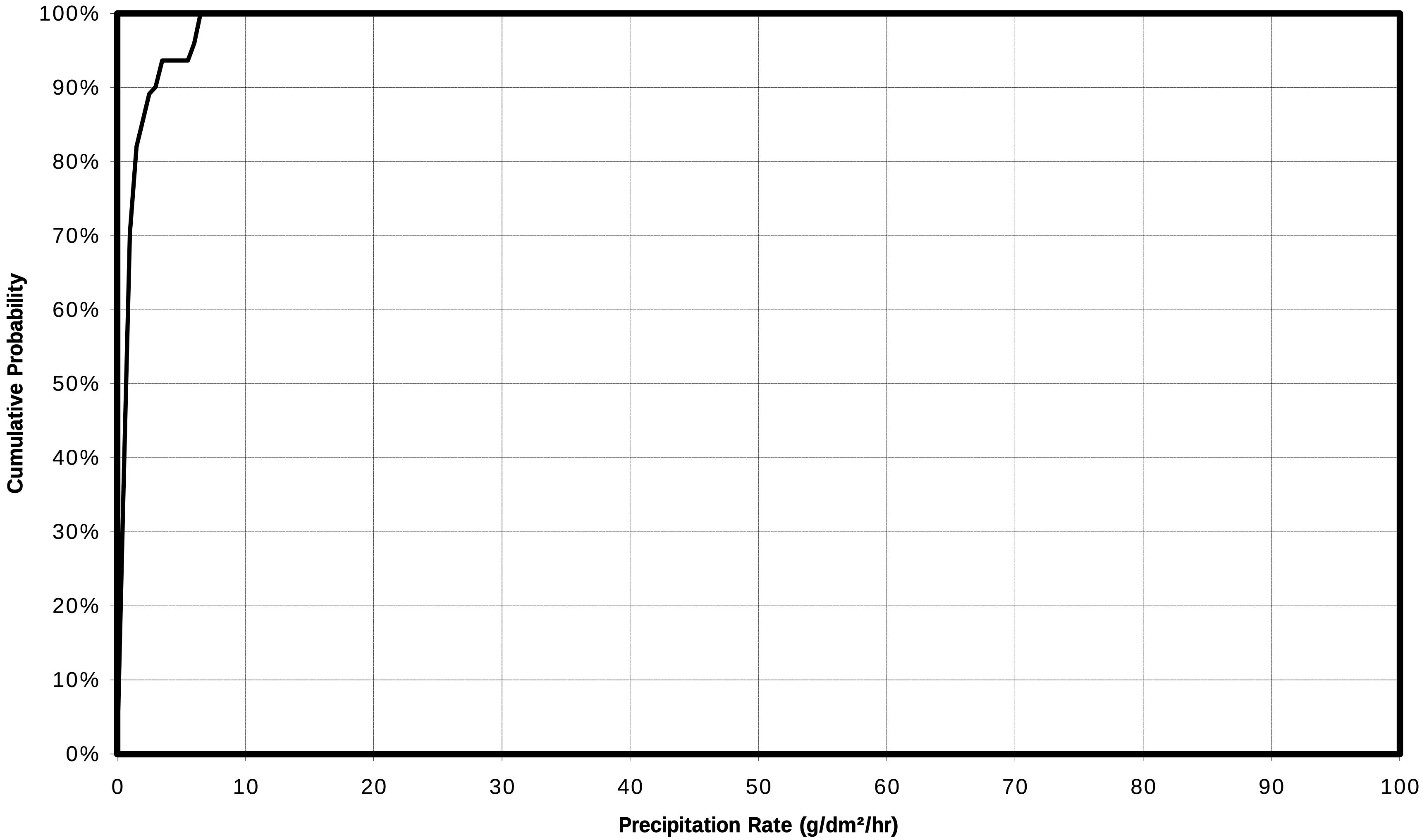
READADC AND CR21X ANALYSIS - NATURAL SNOW

-20 to -25°C

1 MINUTE RATE EVERY MINUTE



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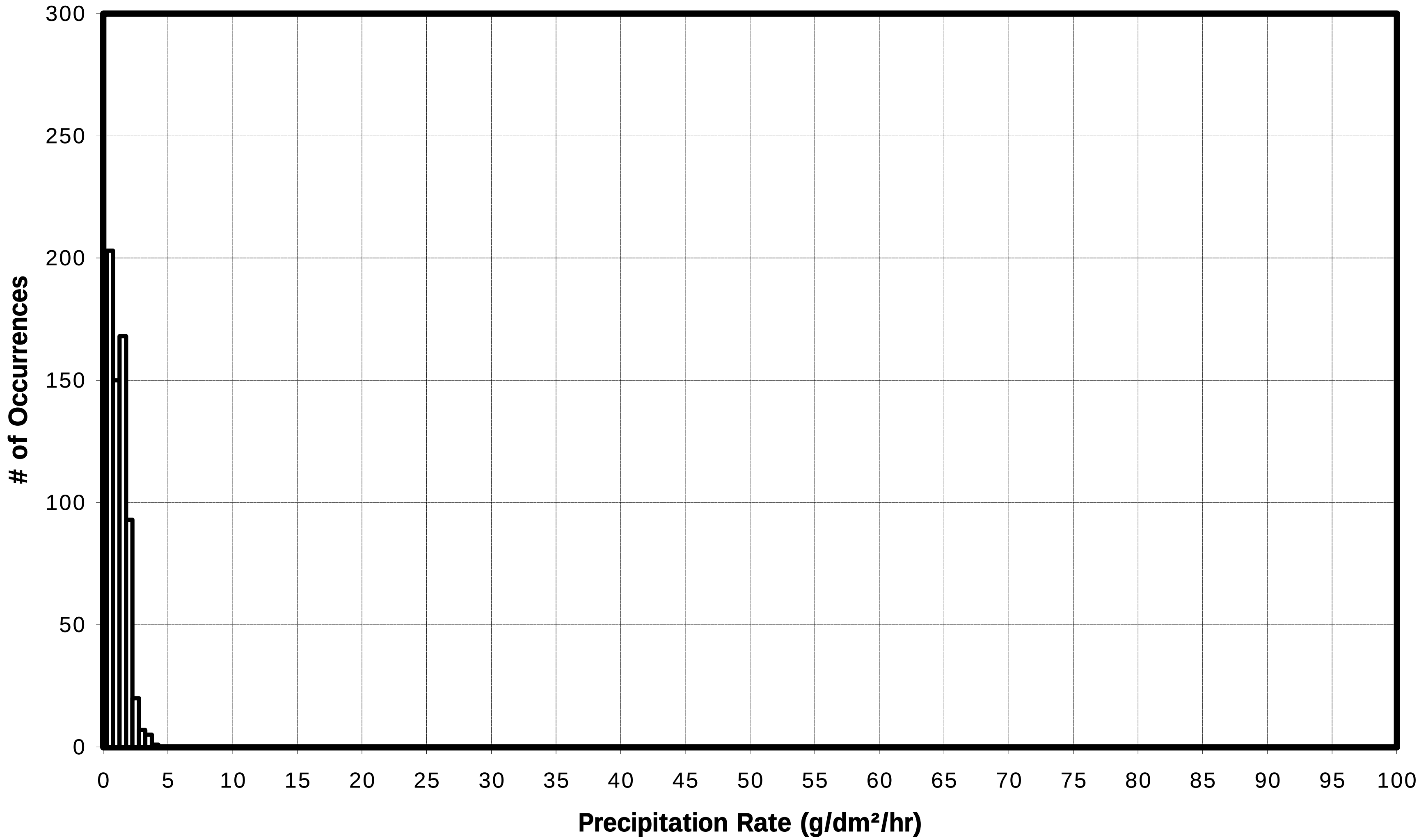
READAC AND CR21X ANALYSIS - NATURAL SNOW

-20 to -25°C

6 MINUTES RATE EVERY MINUTE



cm1380/readac/An20_-25.xls
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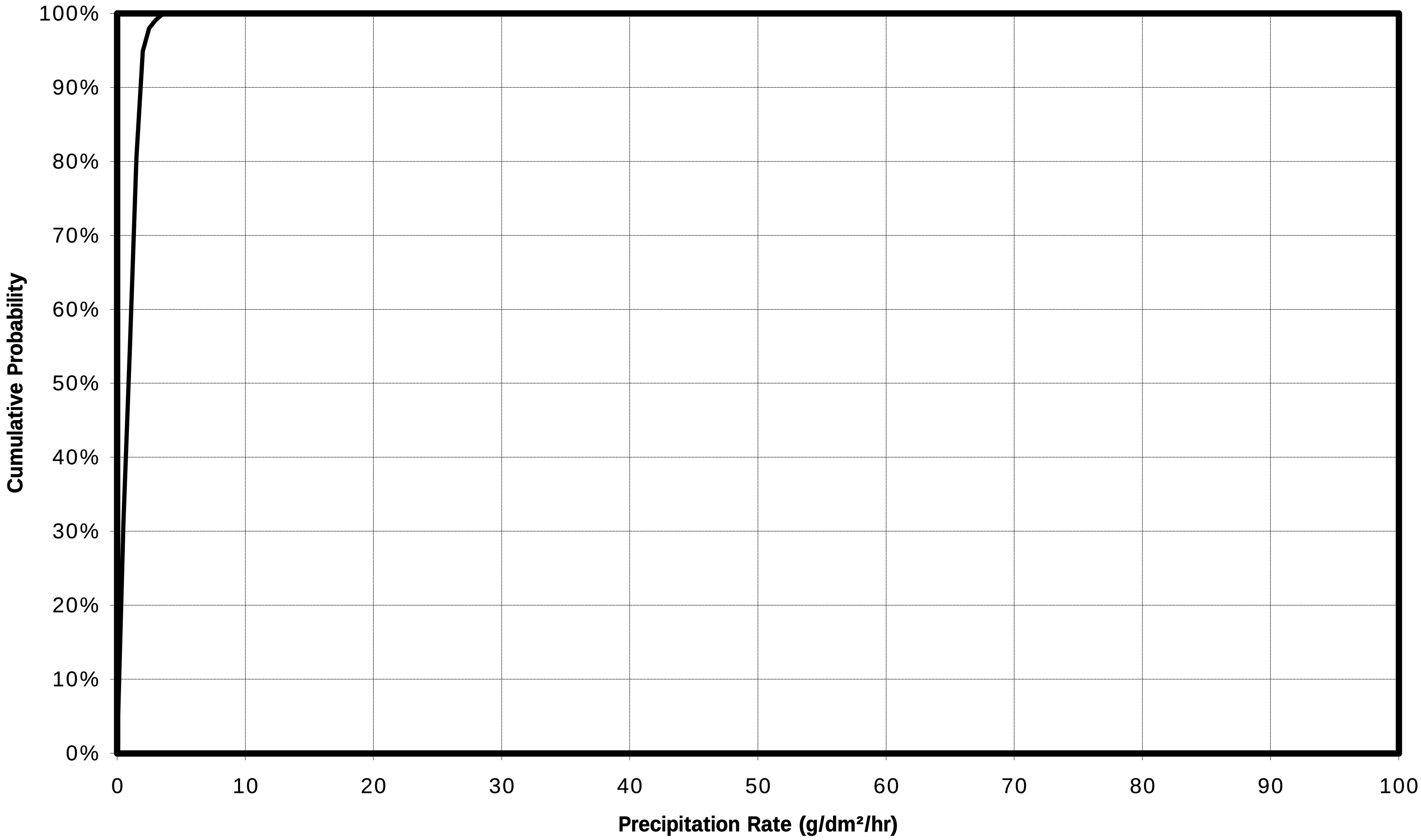
READAC AND CR21X ANALYSIS - NATURAL SNOW

-20 to -25°C

6 MINUTES RATE EVERY MINUTE



cm1380/readac/An20_-25.xls
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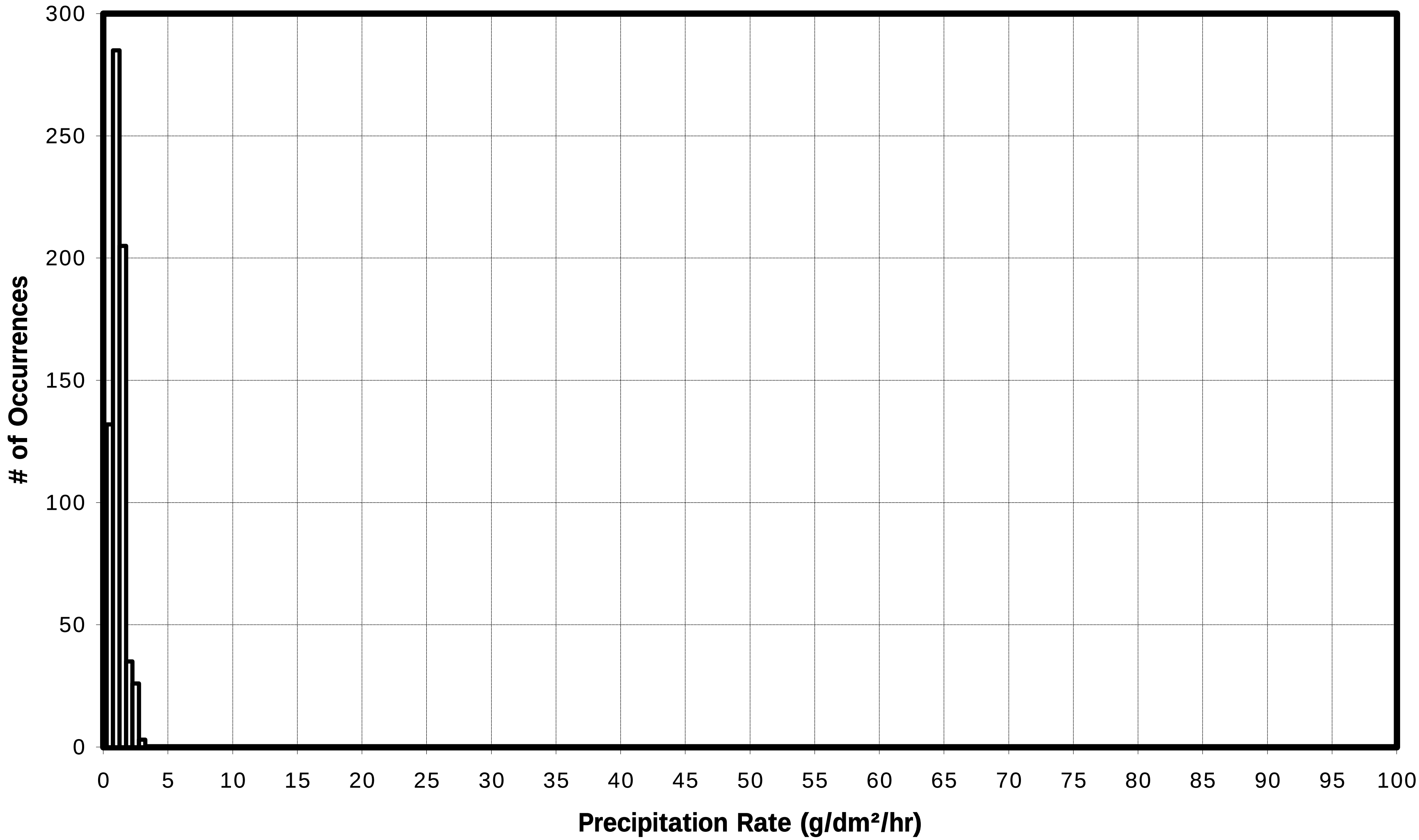
READAC AND CR21X ANALYSIS - NATURAL SNOW

-20 to -25°C

20 MINUTES RATE EVERY MINUTE

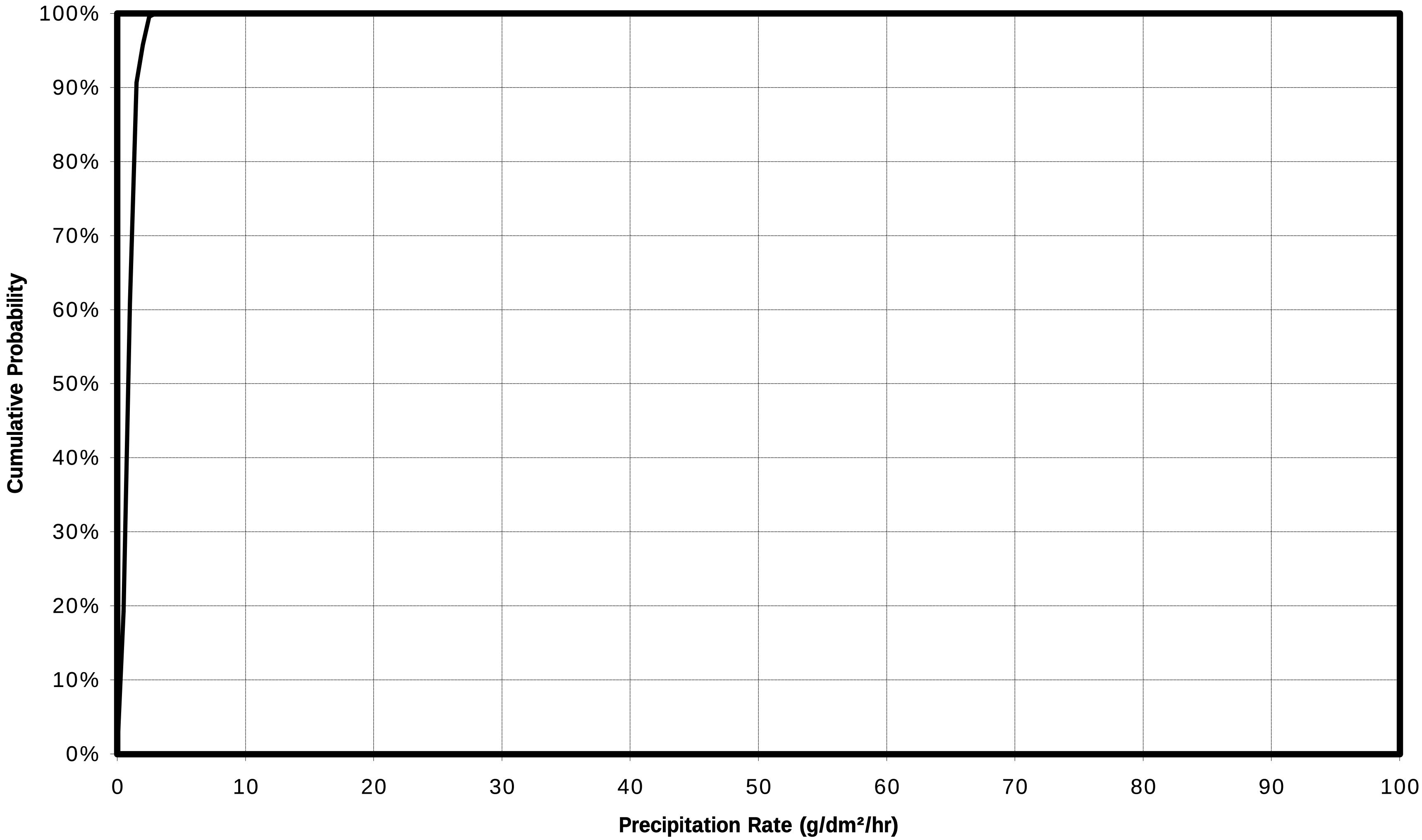


cm1380/readac/An20_-25.xls
At: 20 min Hist
7/23/02, 12:01 PM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-20 to -25°C

20 MINUTES RATE EVERY MINUTE

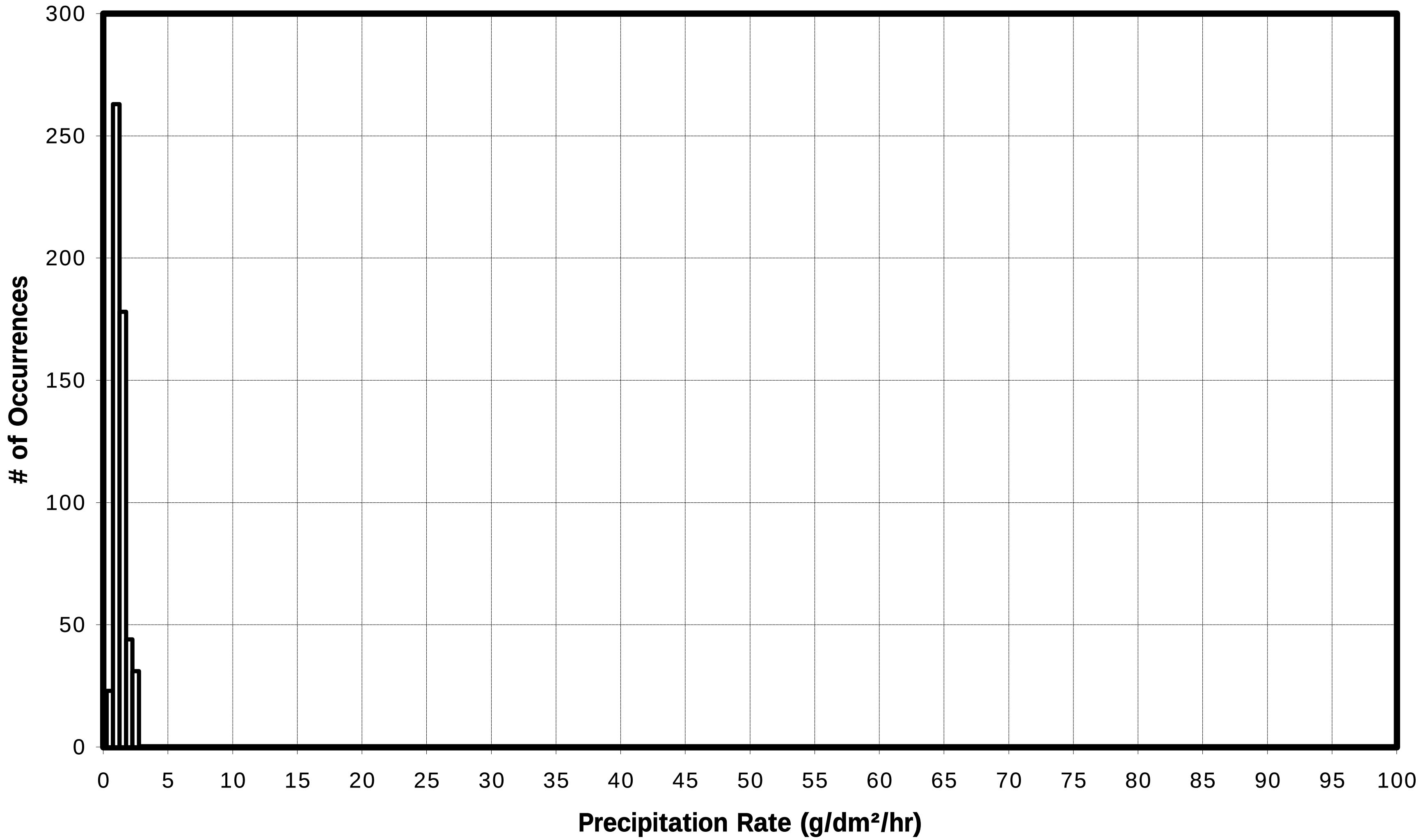


cm1380/readac/An20_-25.xls
At: 20 min Cuml.
7/23/02, 12:01 PM

READADC AND CR21X ANALYSIS - NATURAL SNOW

-20 to -25°C

35 MINUTES RATE EVERY MINUTE

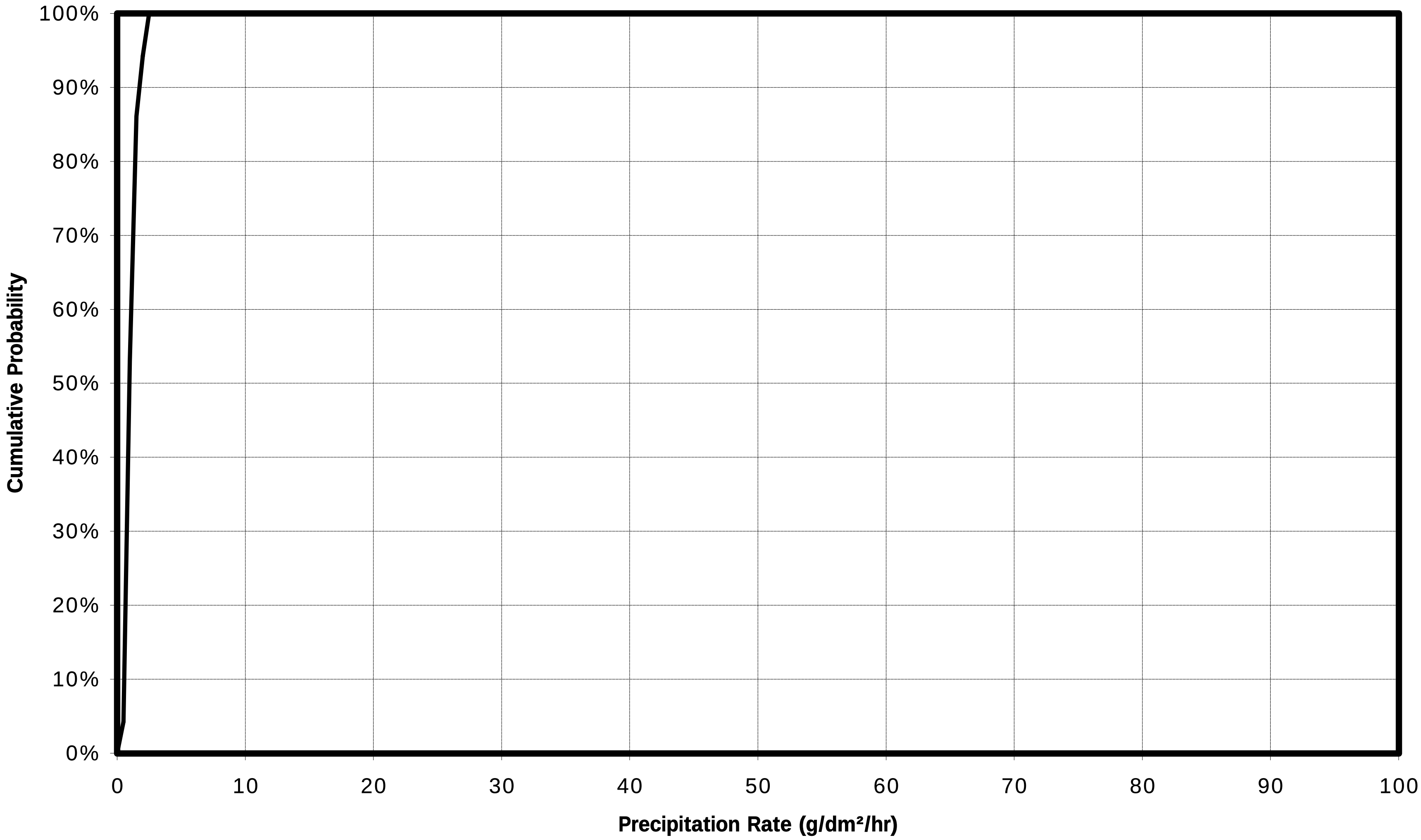


cm1380/readac/An20_-25.xls
At: 35 min Hist
7/23/02, 12:01 PM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-20 to -25°C

35 MINUTES RATE EVERY MINUTE



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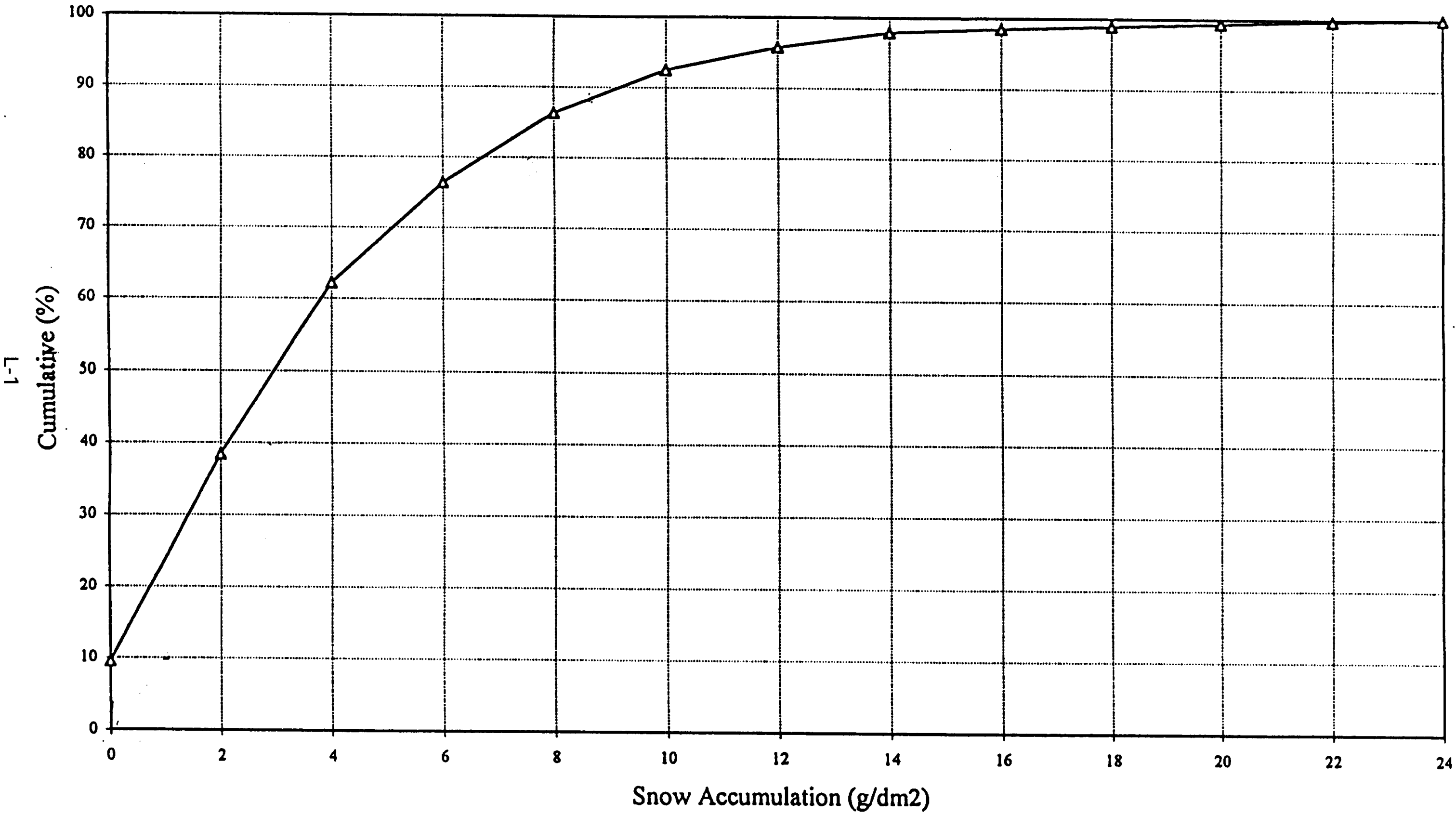
7/23/02, 12:01 PM

APPENDIX L

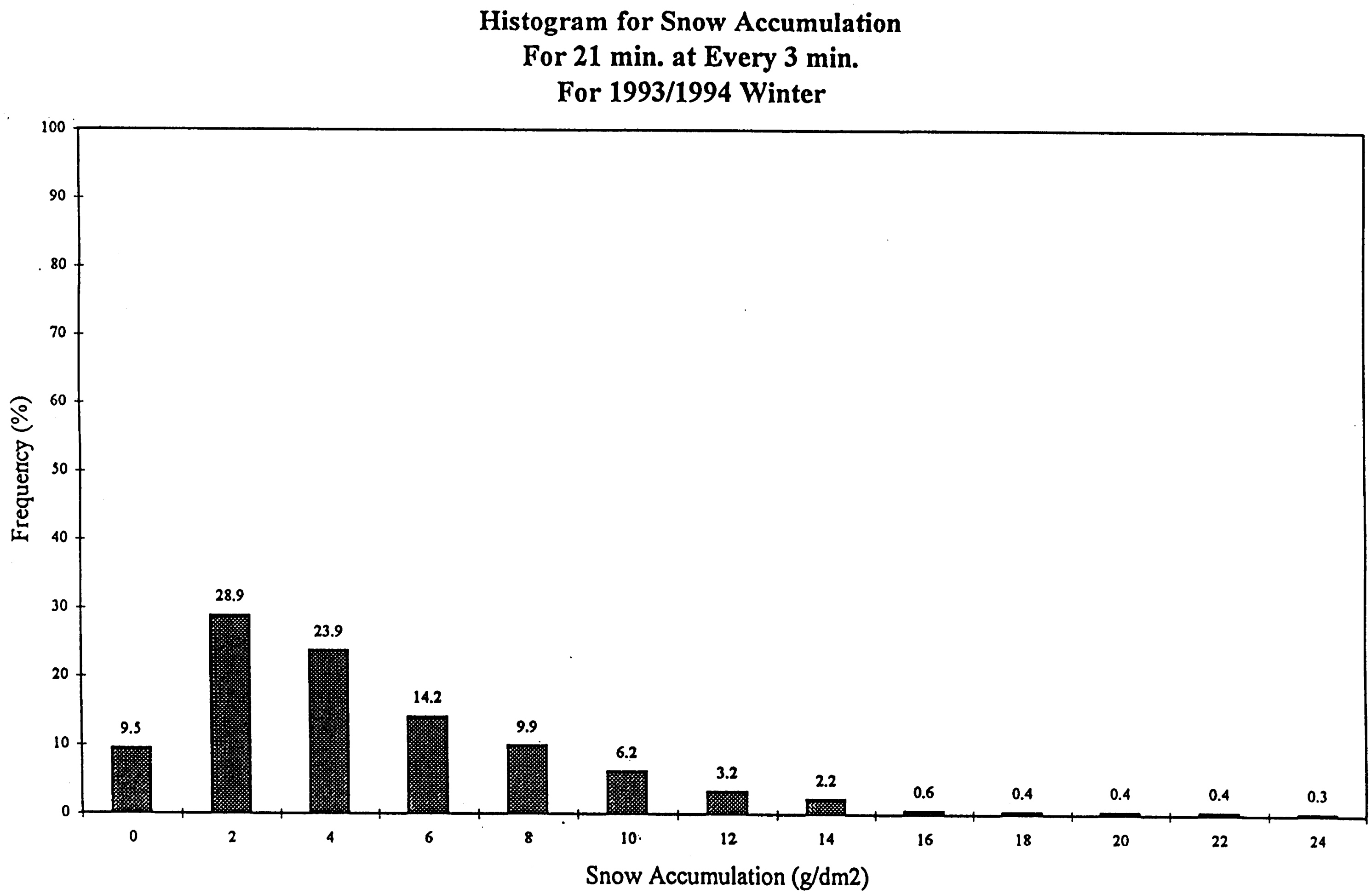
SNOW WEATHER DATA 1993/94 AND 1994/95

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/1994 Winter



18/8/95 15:29

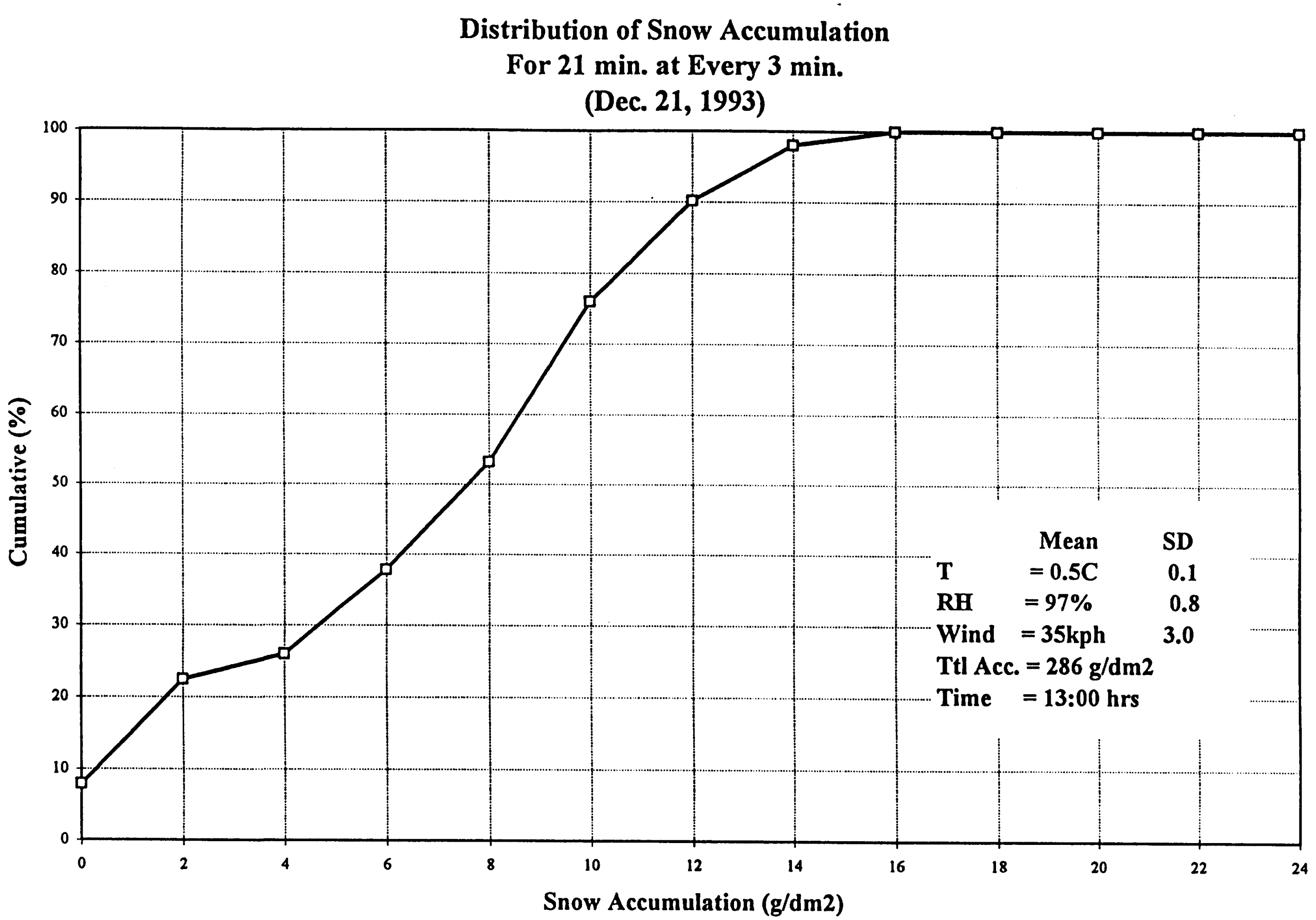
MHIST94.XLS



L-2

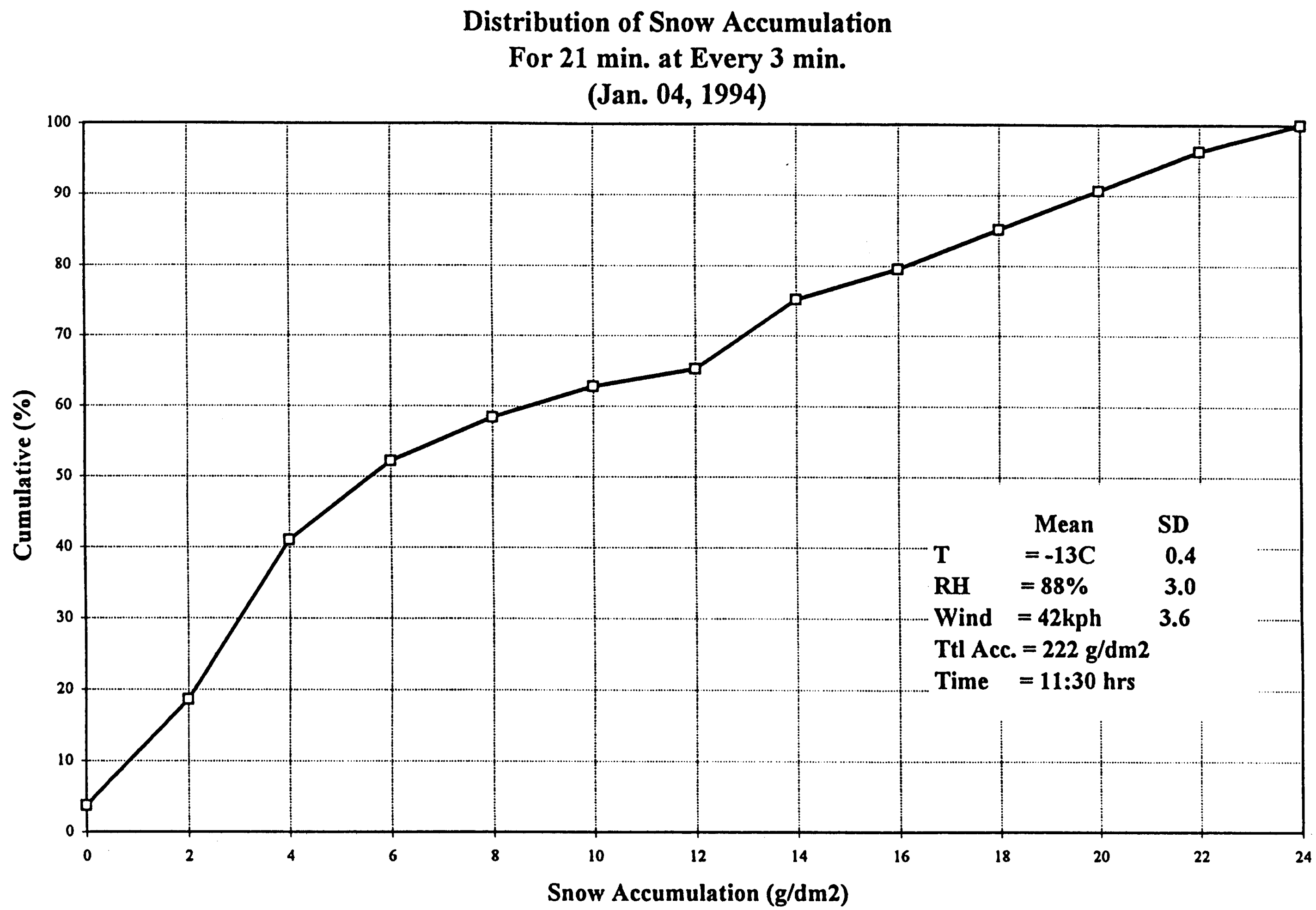
17/8/95 09:45

MHIST94.XLS

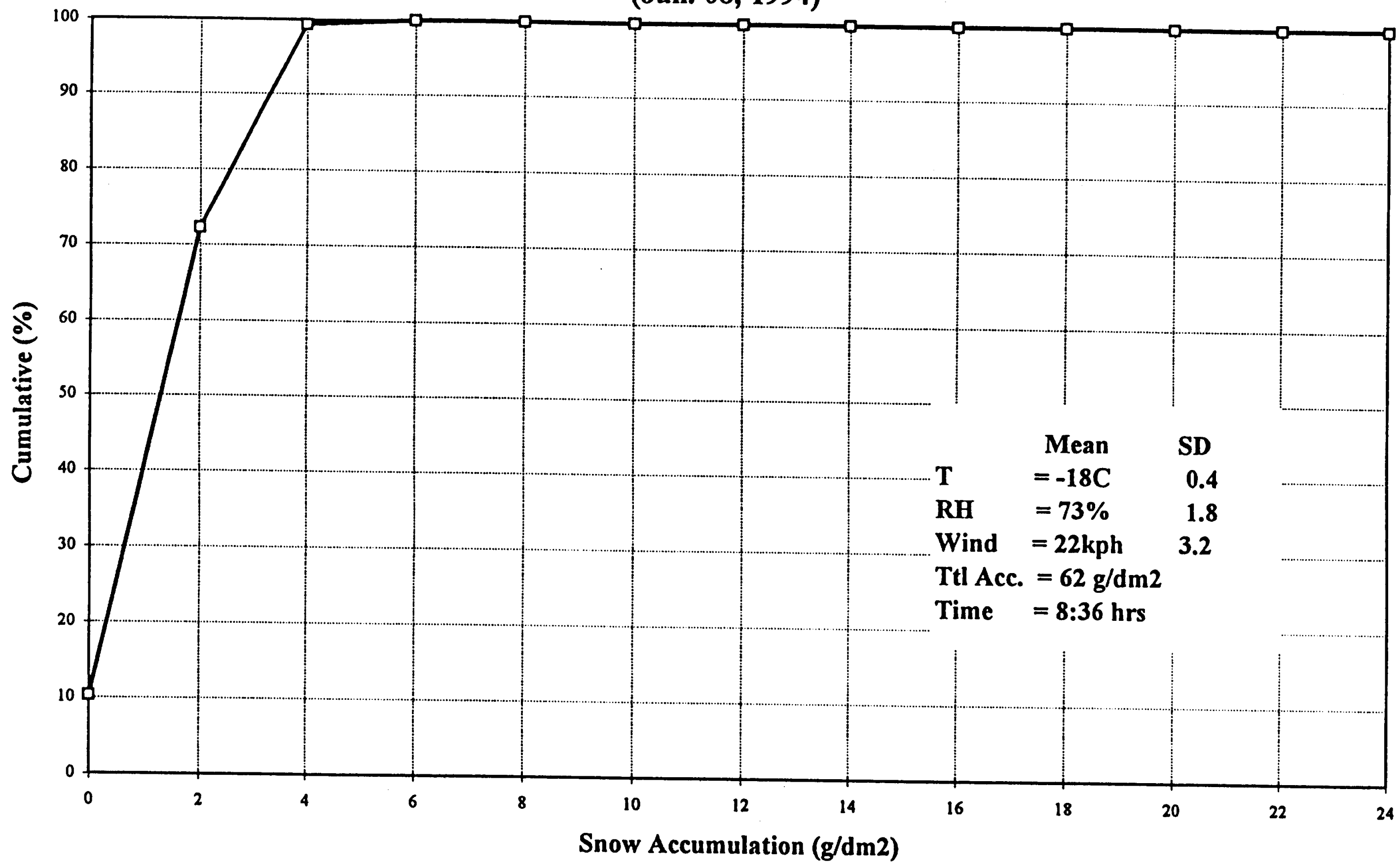


Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Dec. 21, 1993)
Cumulative (%)
Snow Accumulation (g/dm2)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
Mean SD
T = 0.5C 0.1
RH = 97% 0.8
Wind = 35kph 3.0
Ttl Acc. = 286 g/dm2
Time = 13:00 hrs

L-3


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

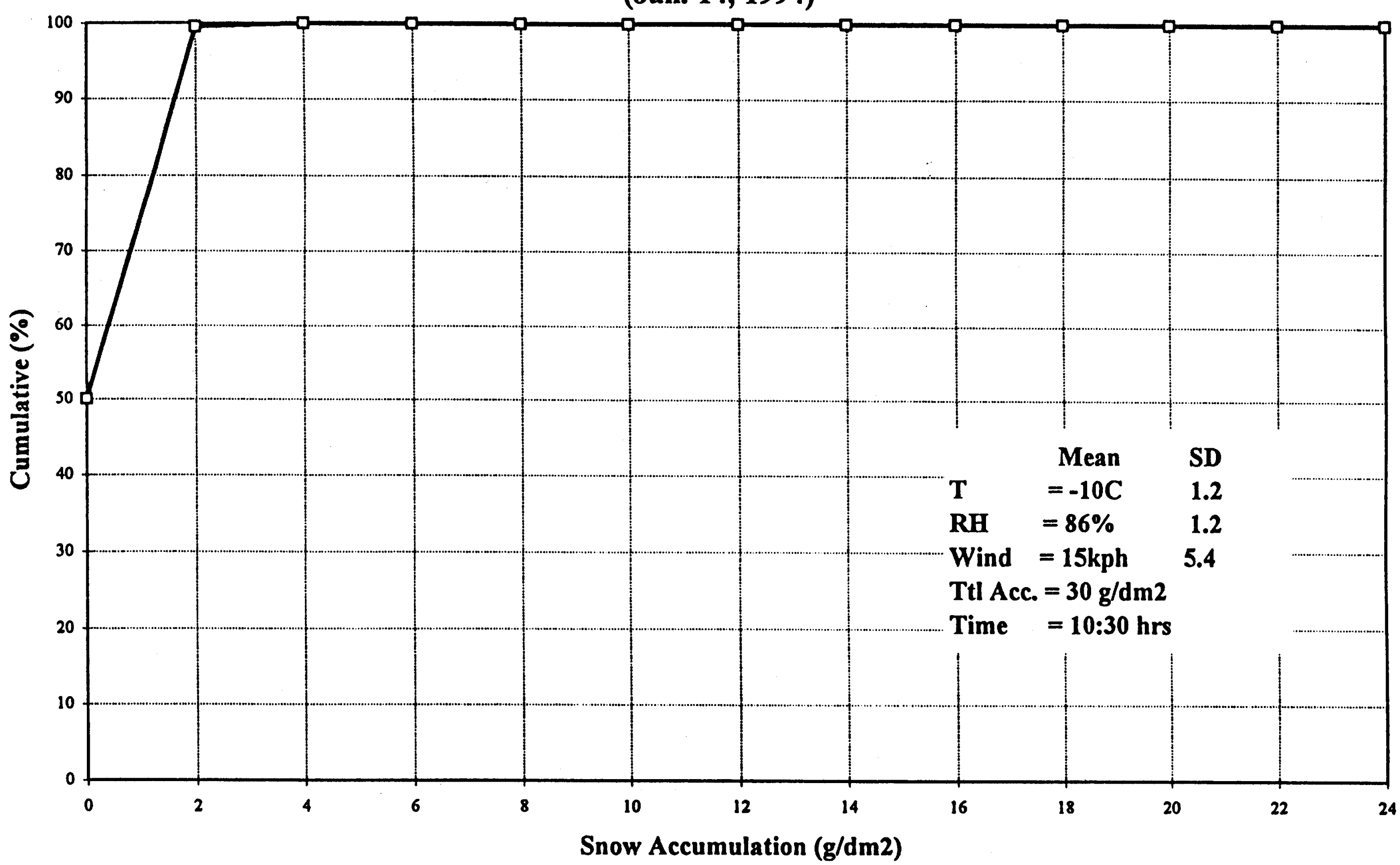
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 08, 1994)



8/8/95 16:23

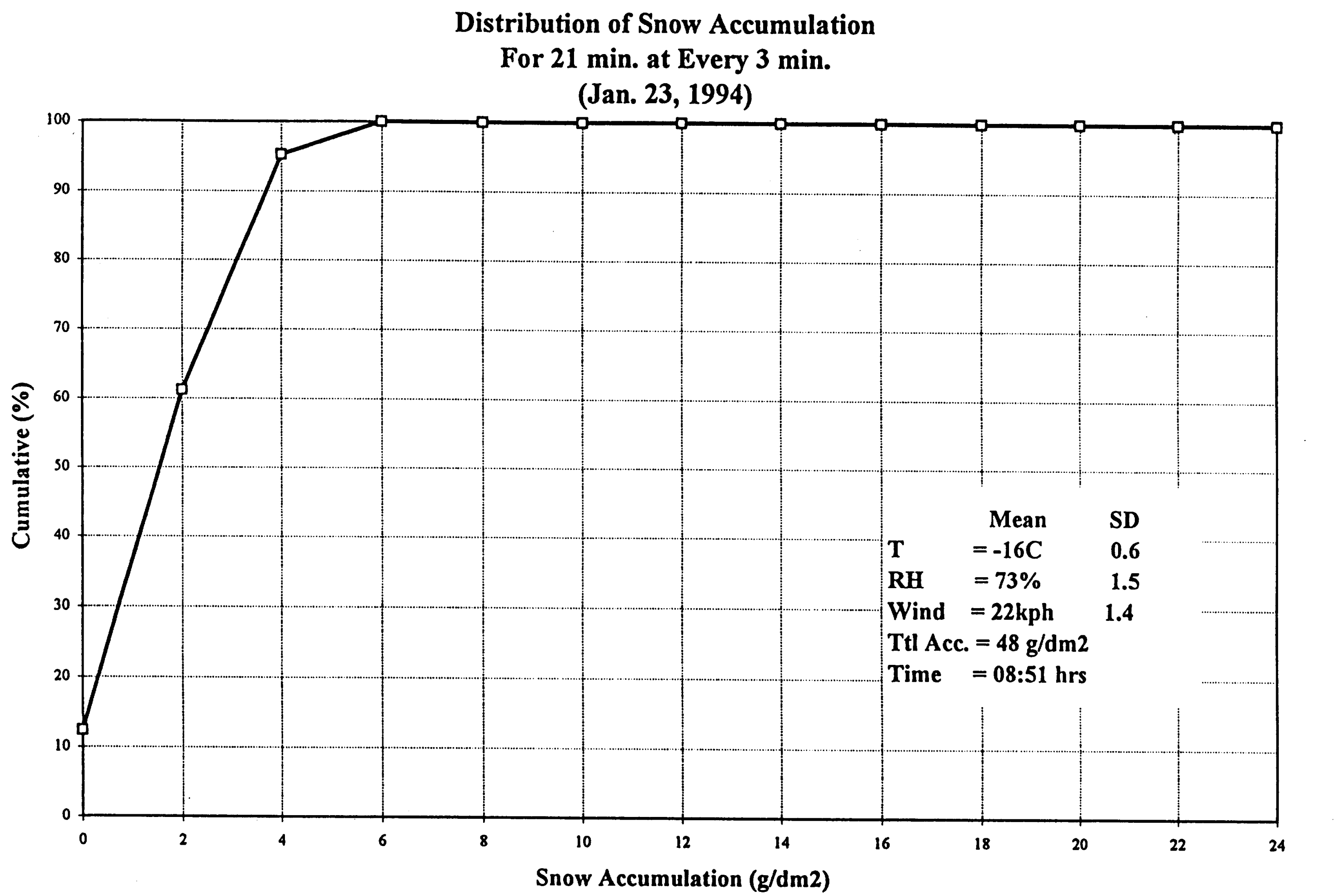
JAN0894.XLS

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 14, 1994)

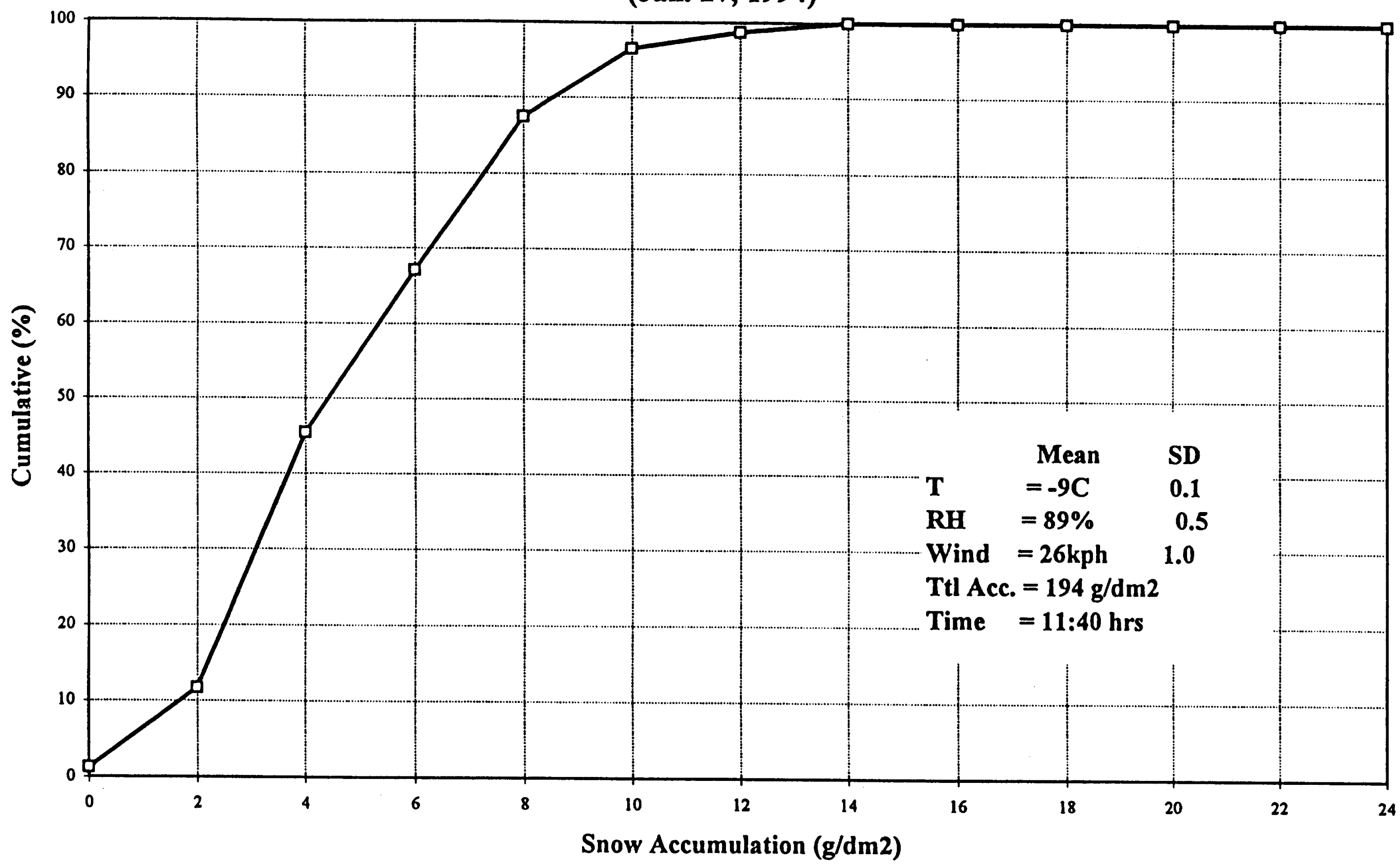


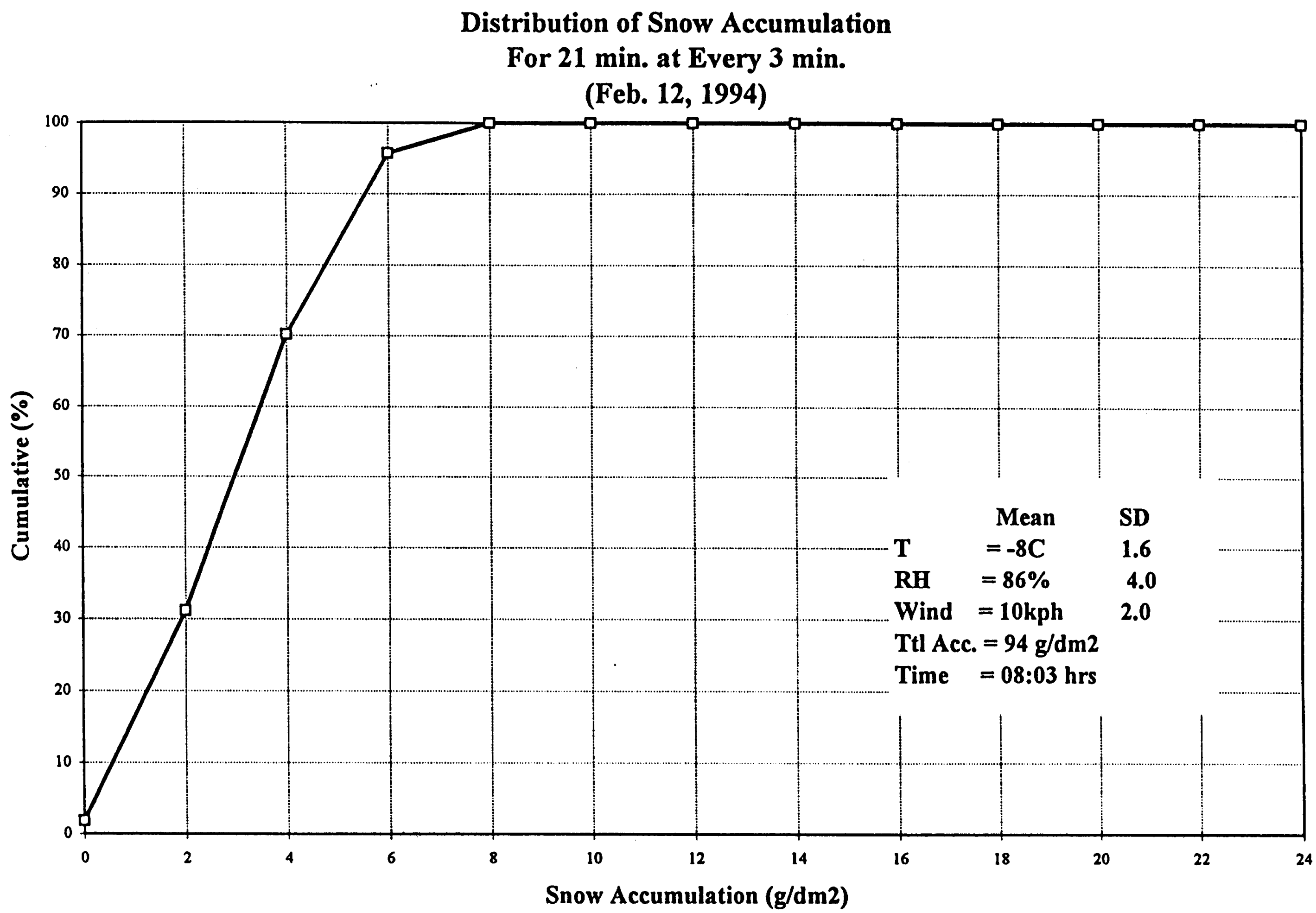
18/8/95 16:22

JAN1494.XLS


Distribution of Snow Accumulation
For 21 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
Mean
SD
T = -16C 0.6
RH = 73% 1.5
Wind = 22kph 1.4
Ttl Acc. = 48 g/dm2
Time = 08:51 hrs

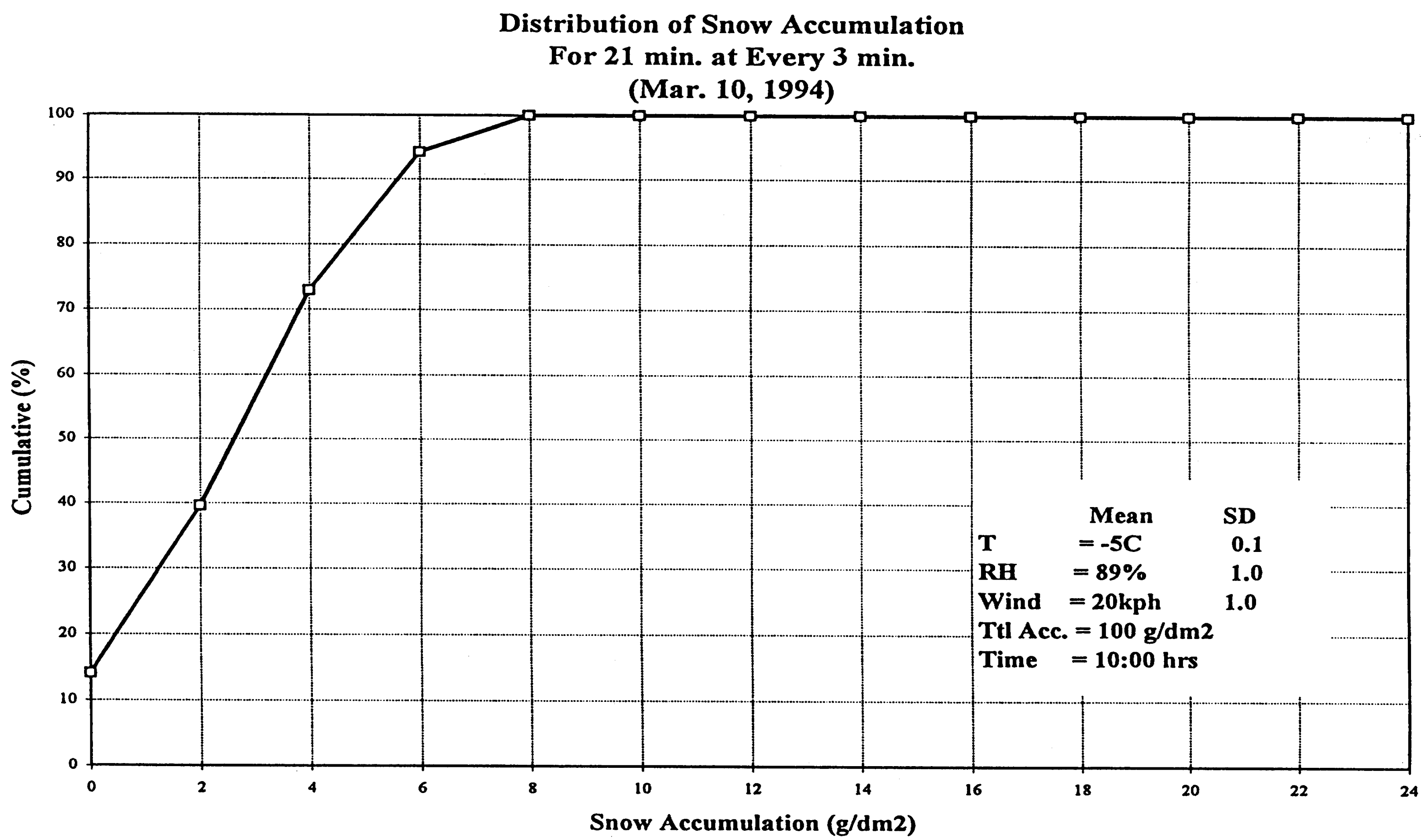
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 27, 1994)





16/8/95 15:19

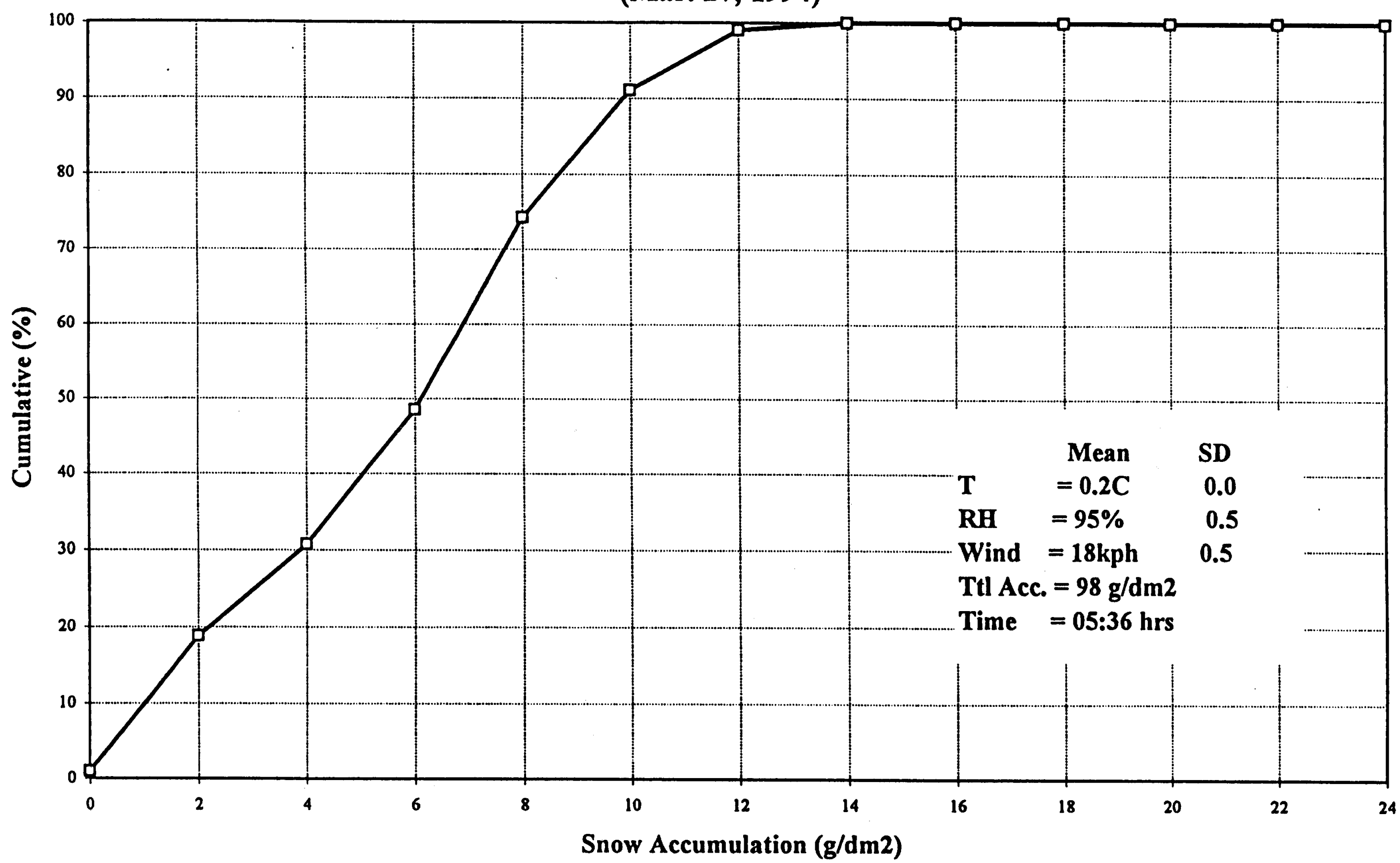
FEB1294.XLS



16/8/95 14:59

MAR1094.XLS

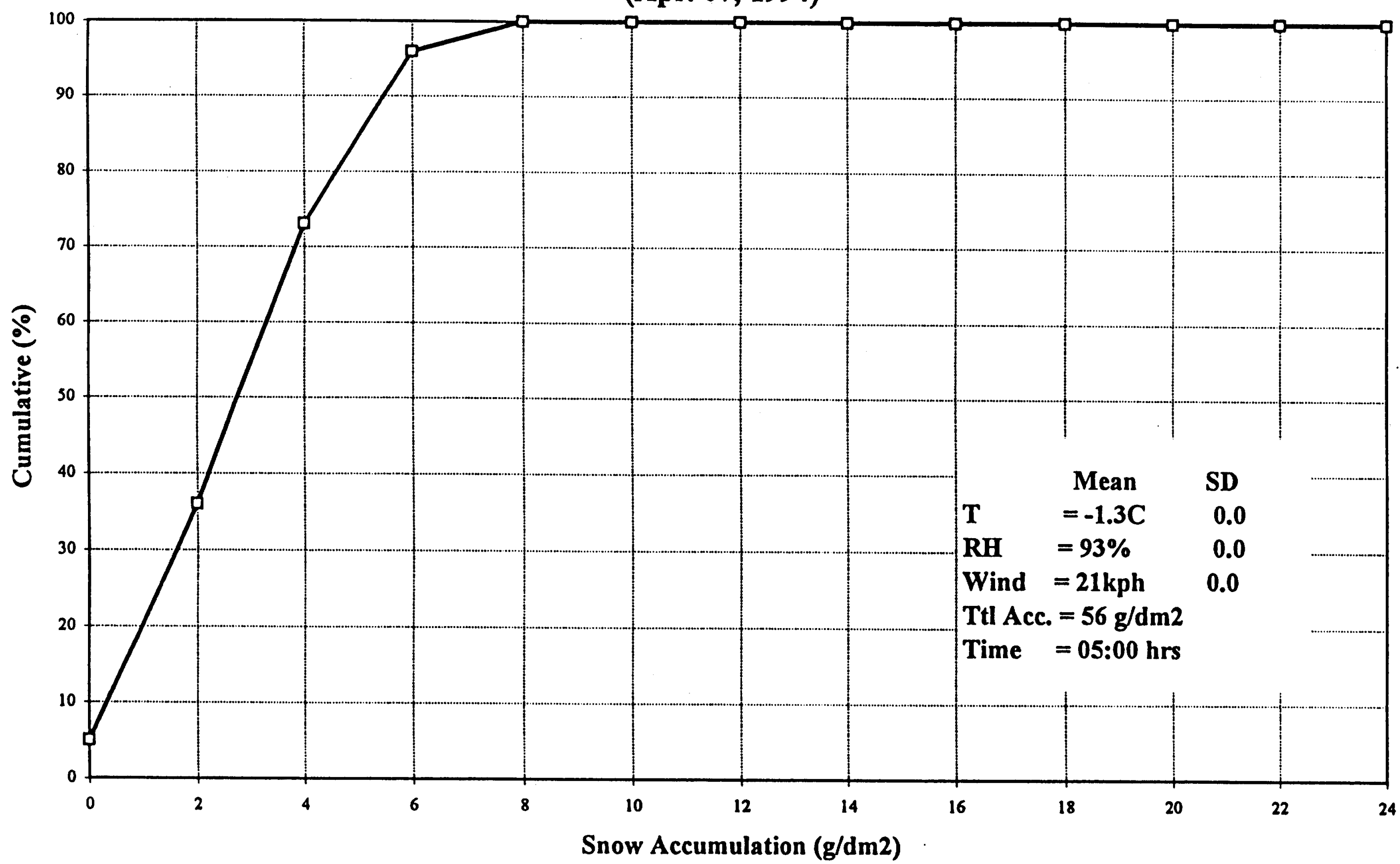
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Mar. 27, 1994)

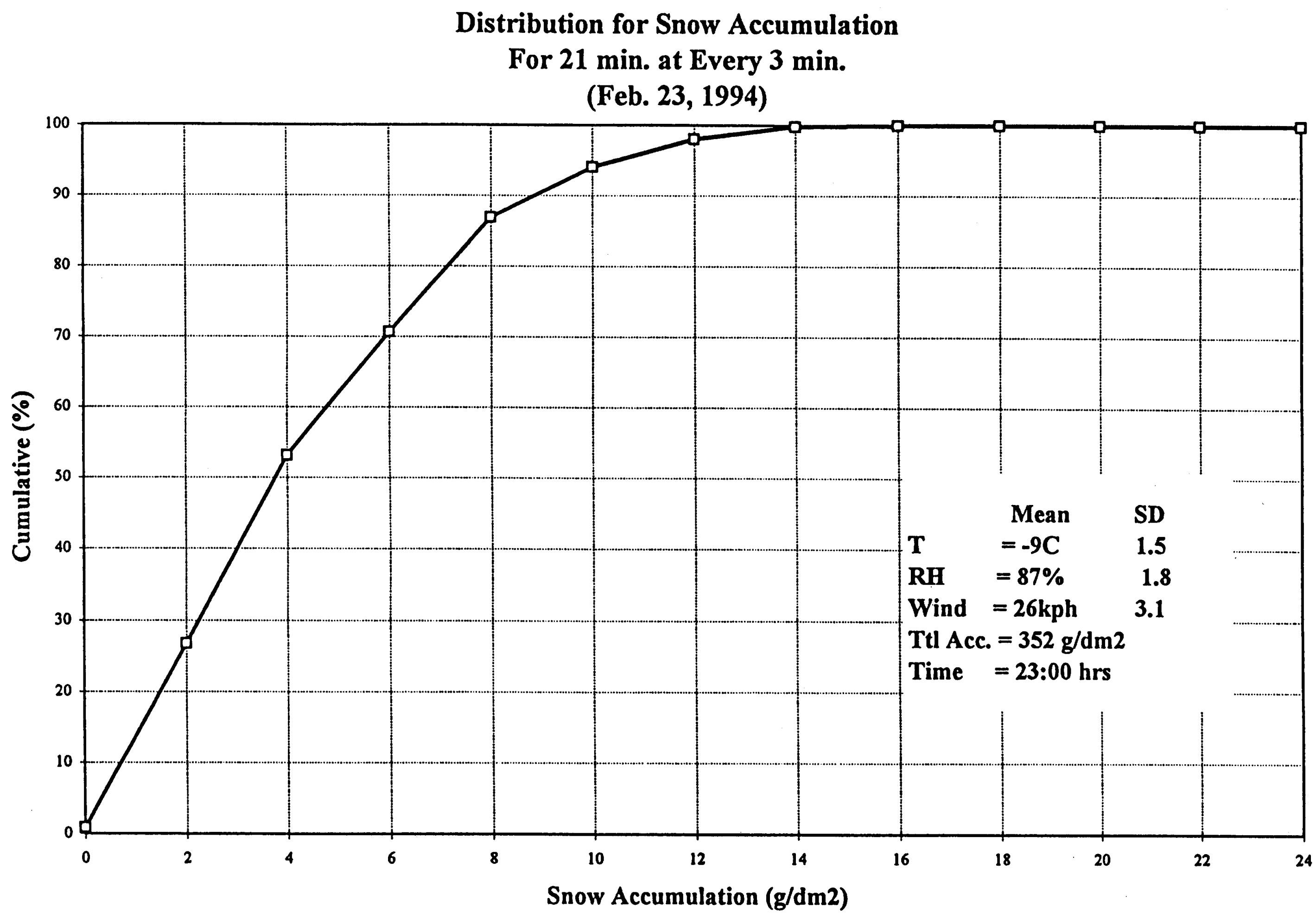


18/8/95 16:30

MAR2794.XLS

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Apr. 07, 1994)

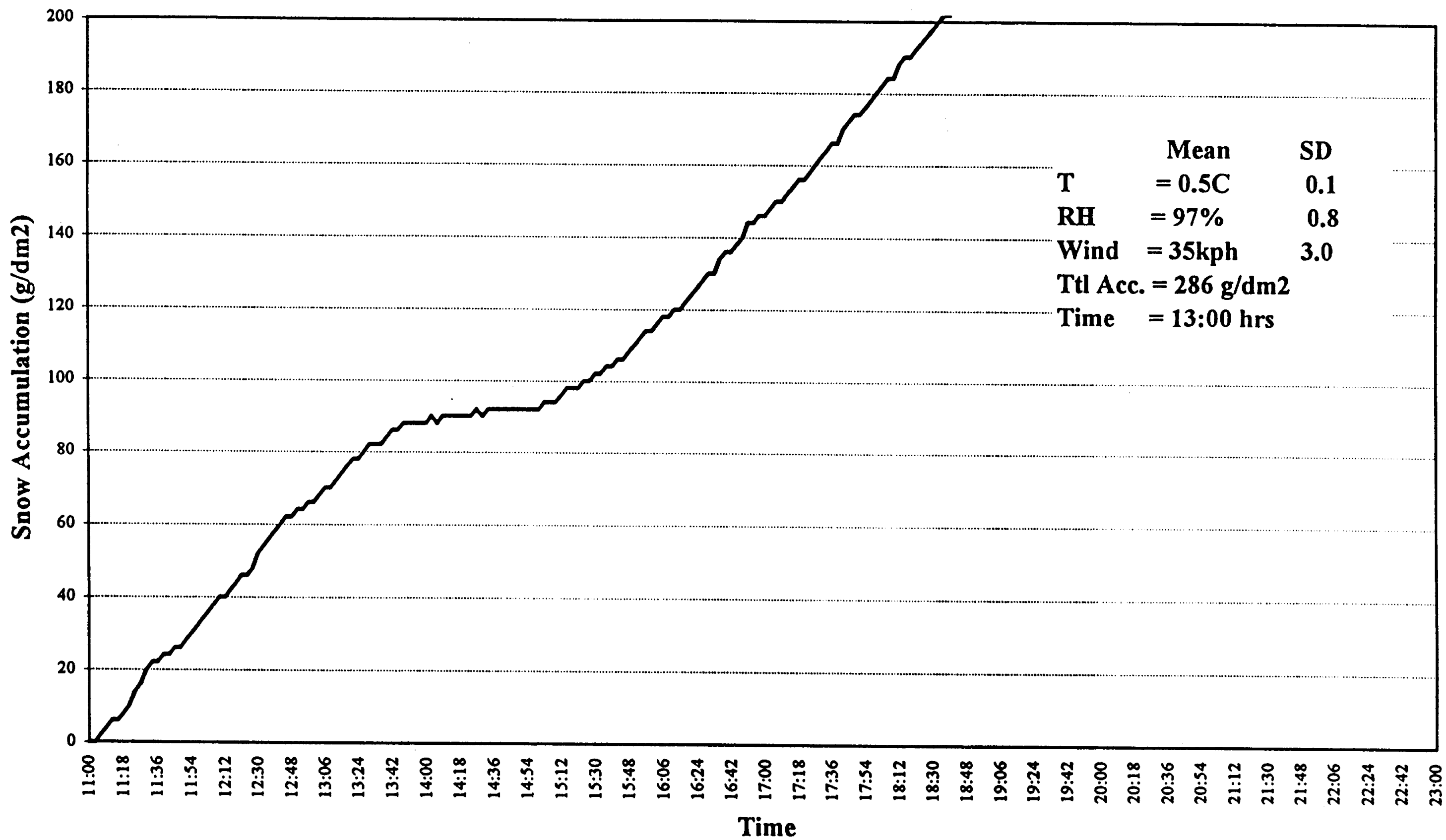




16/8/95 15:21

FEB2394.XLS

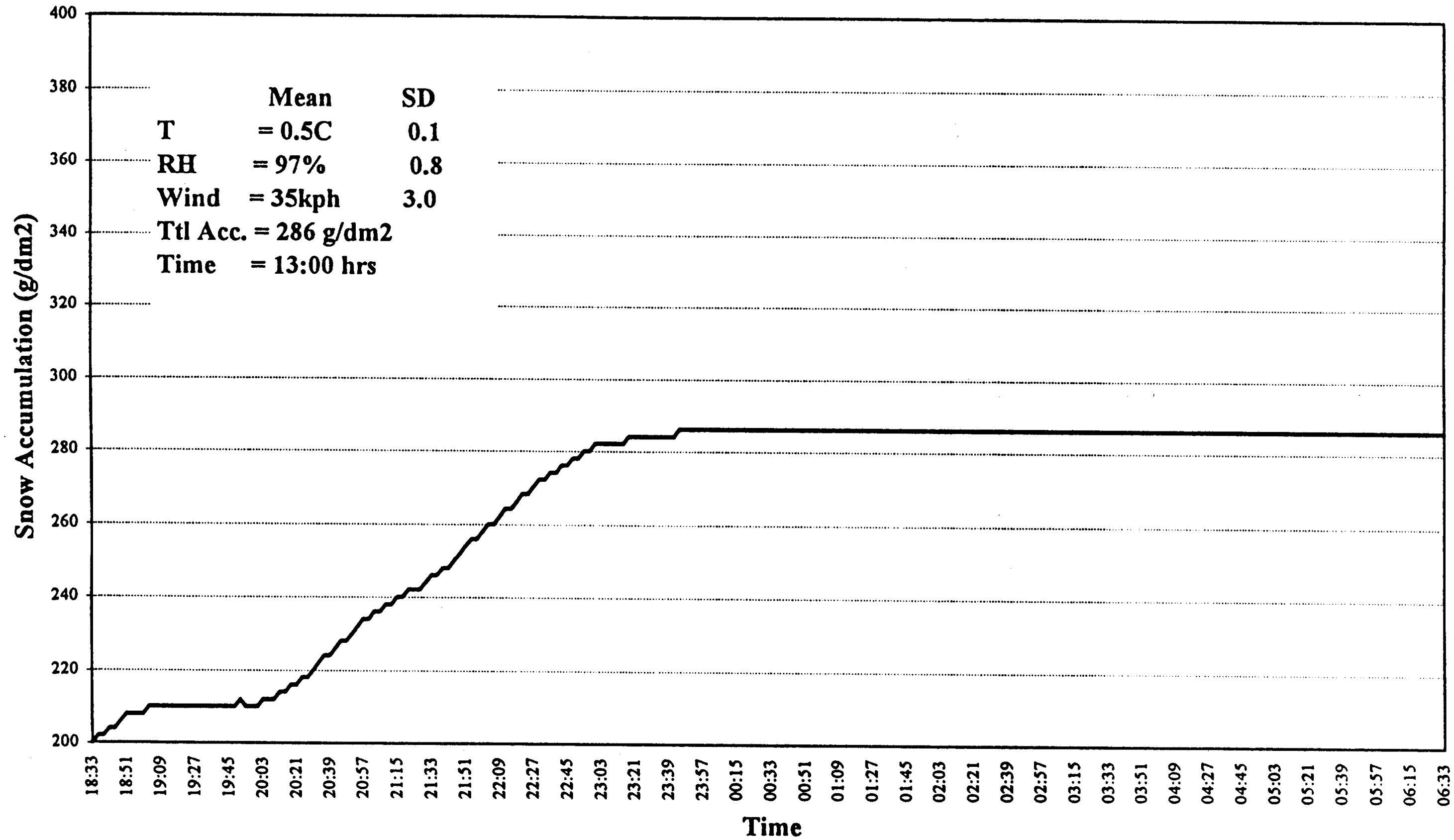
Total Snow Accumulation
for Dec. 21, 1993



14/8/95 15:04

DEC2193.XLS

Total Snow Accumulation for Dec. 21, 1993

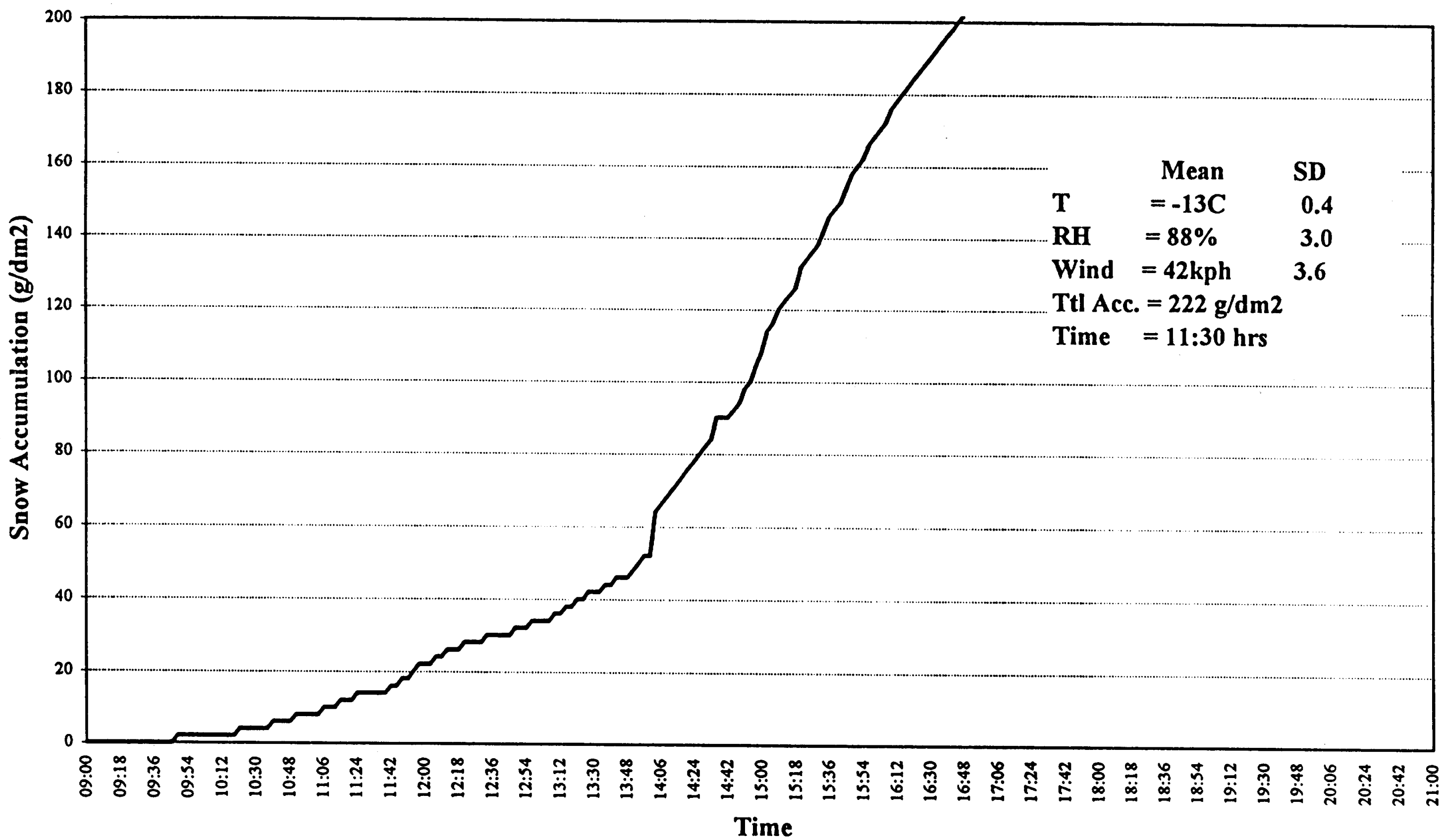


L-15

14/8/95 15:04

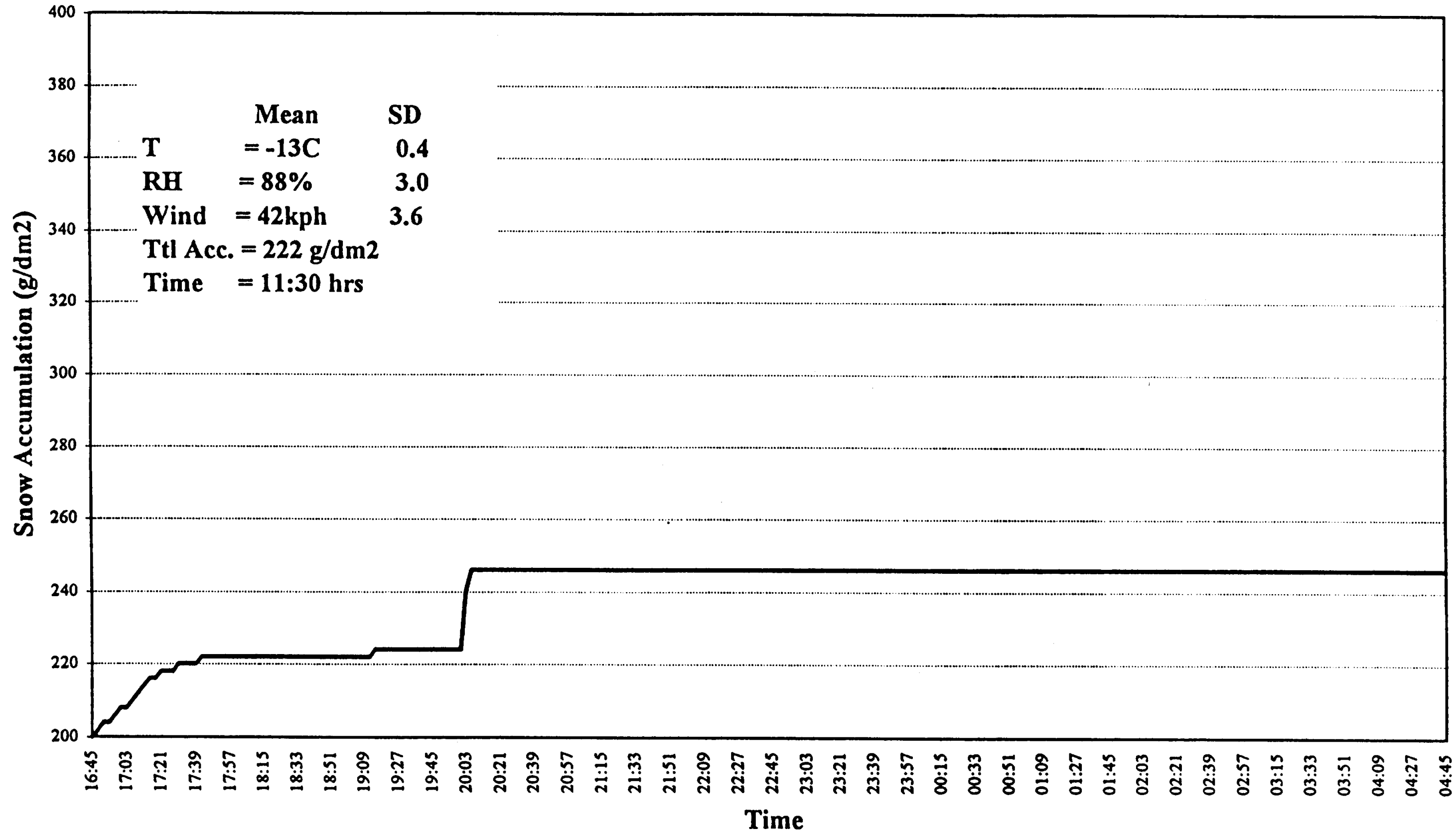
DEC2193.XLS

Total Snow Accumulation
for Jan 04, 1994

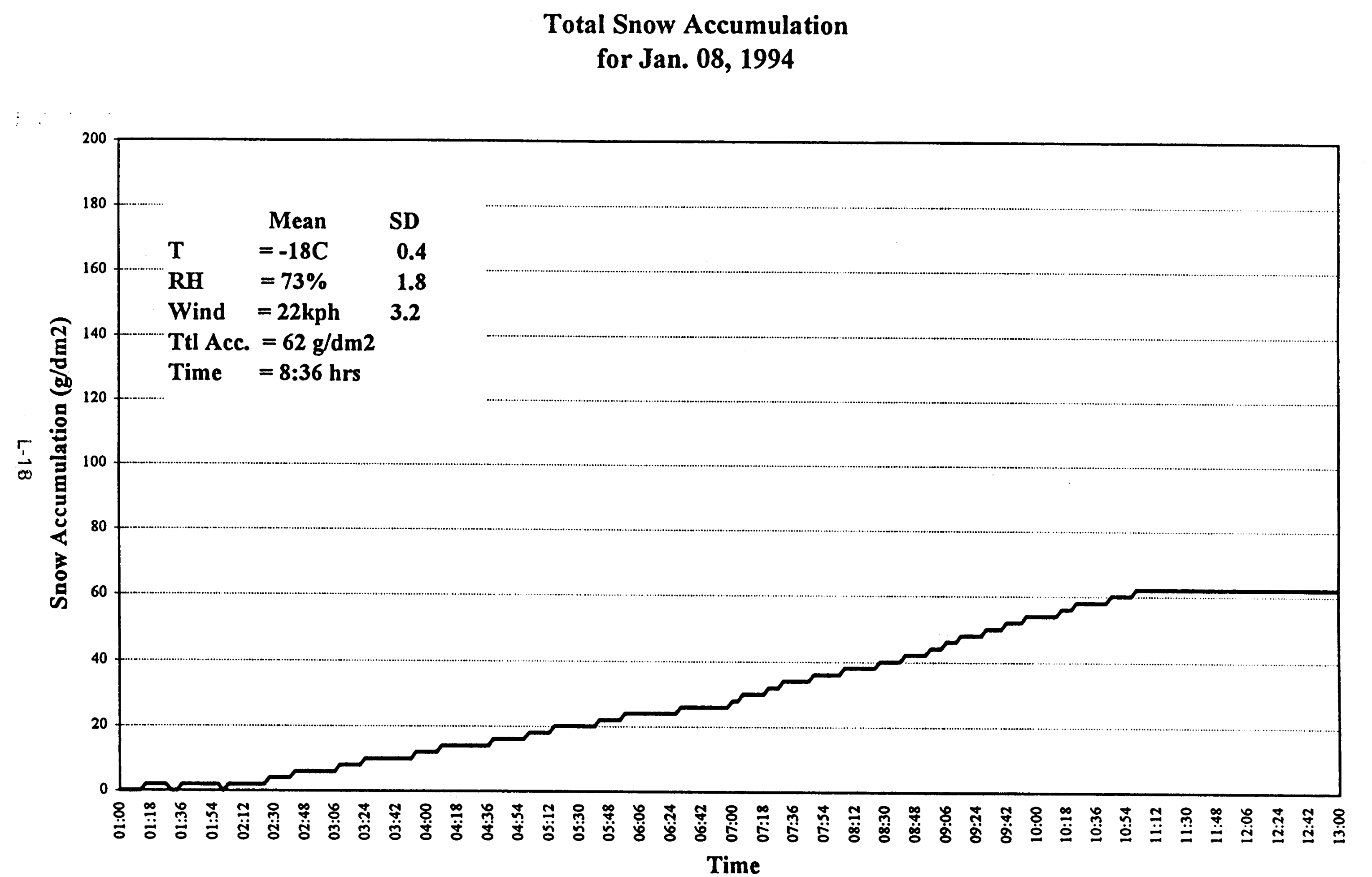


L-16

Total Snow Accumulation
for Jan 04, 1994



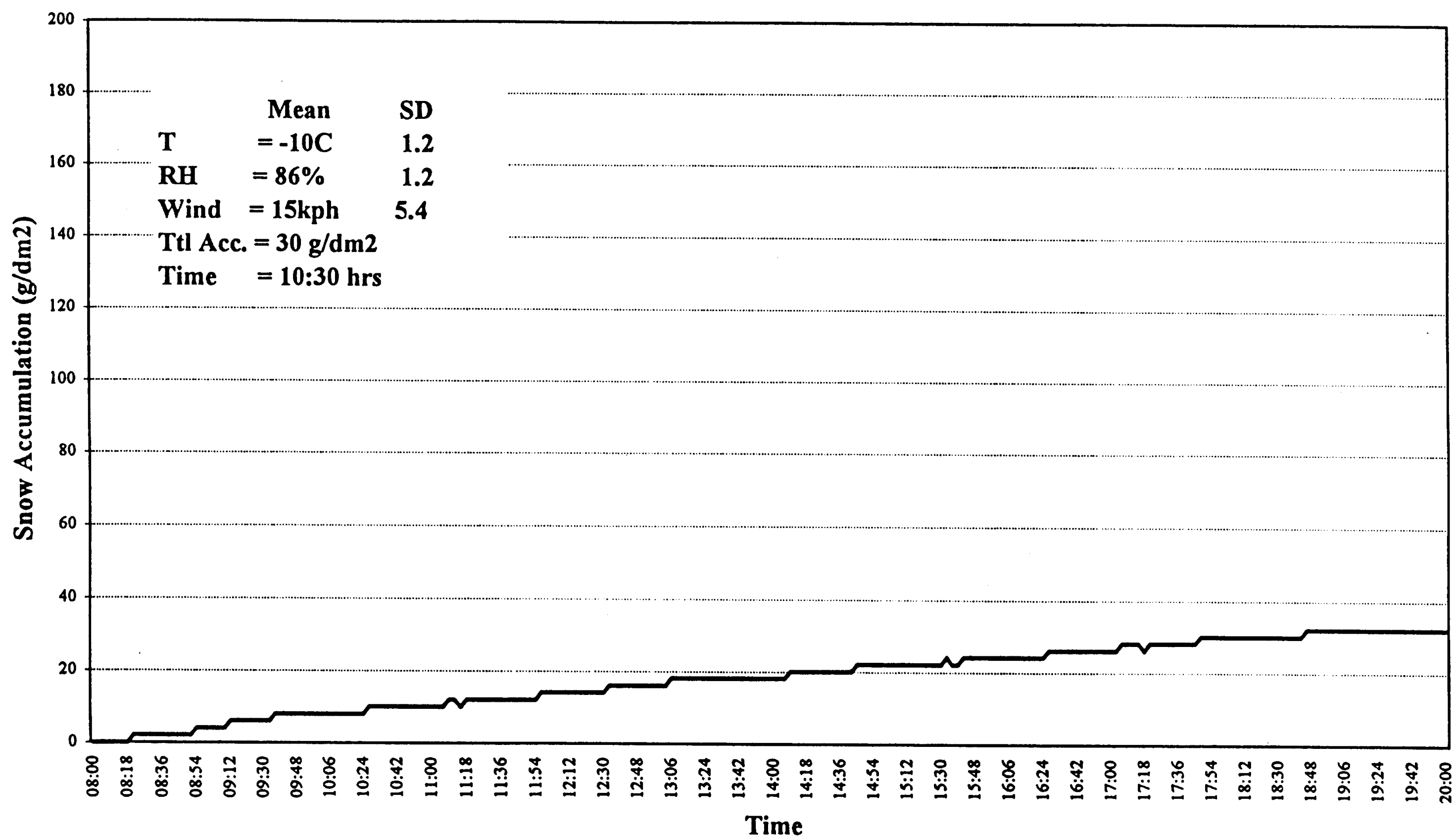
14/8/95 15:28 JAN0494.XLS



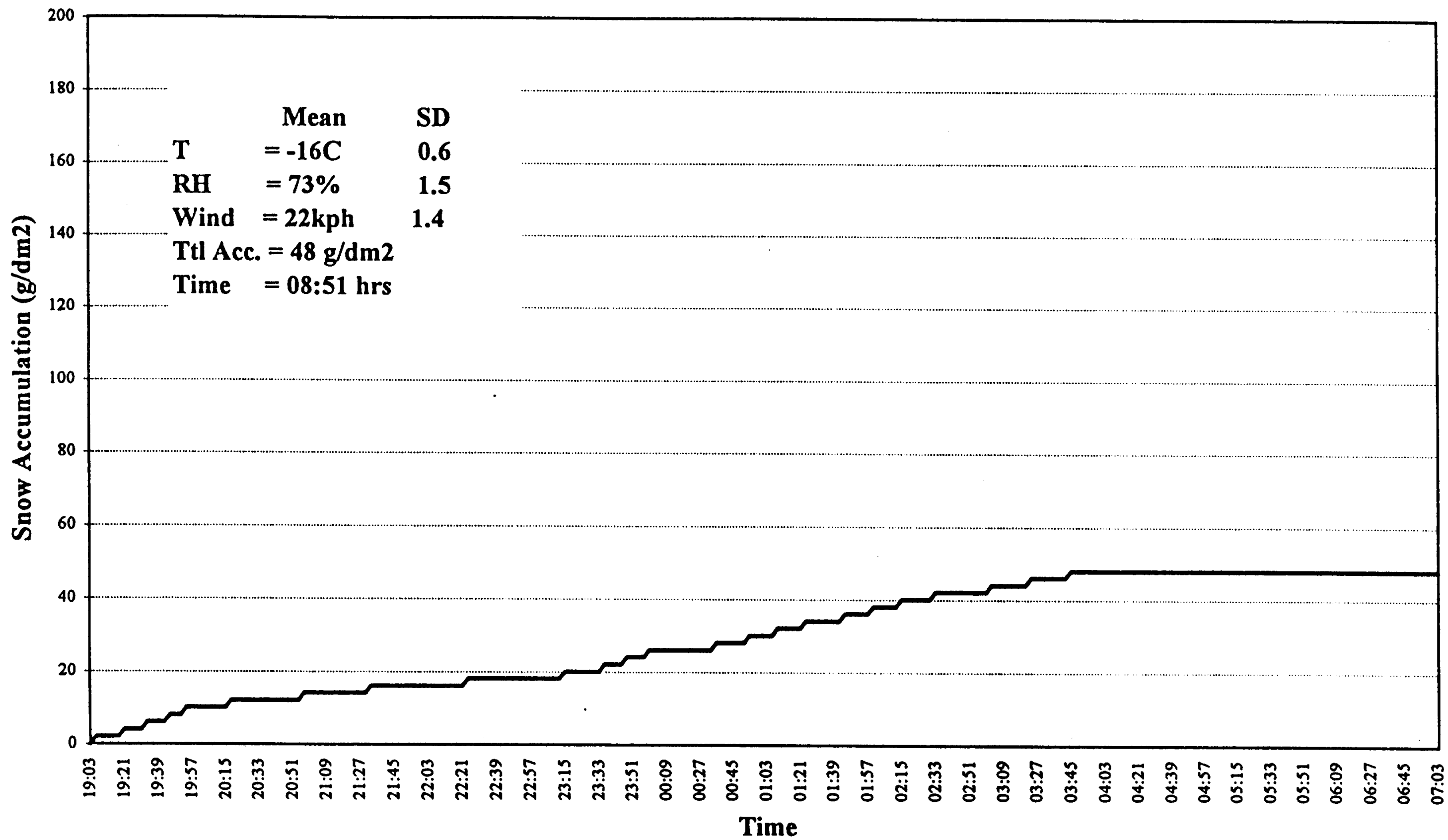
14/8/95 15:23

JAN0894.XLS

Total Snow Accumulation
for Jan 14, 1994



Total Snow Accumulation
for Jan. 23, 1994

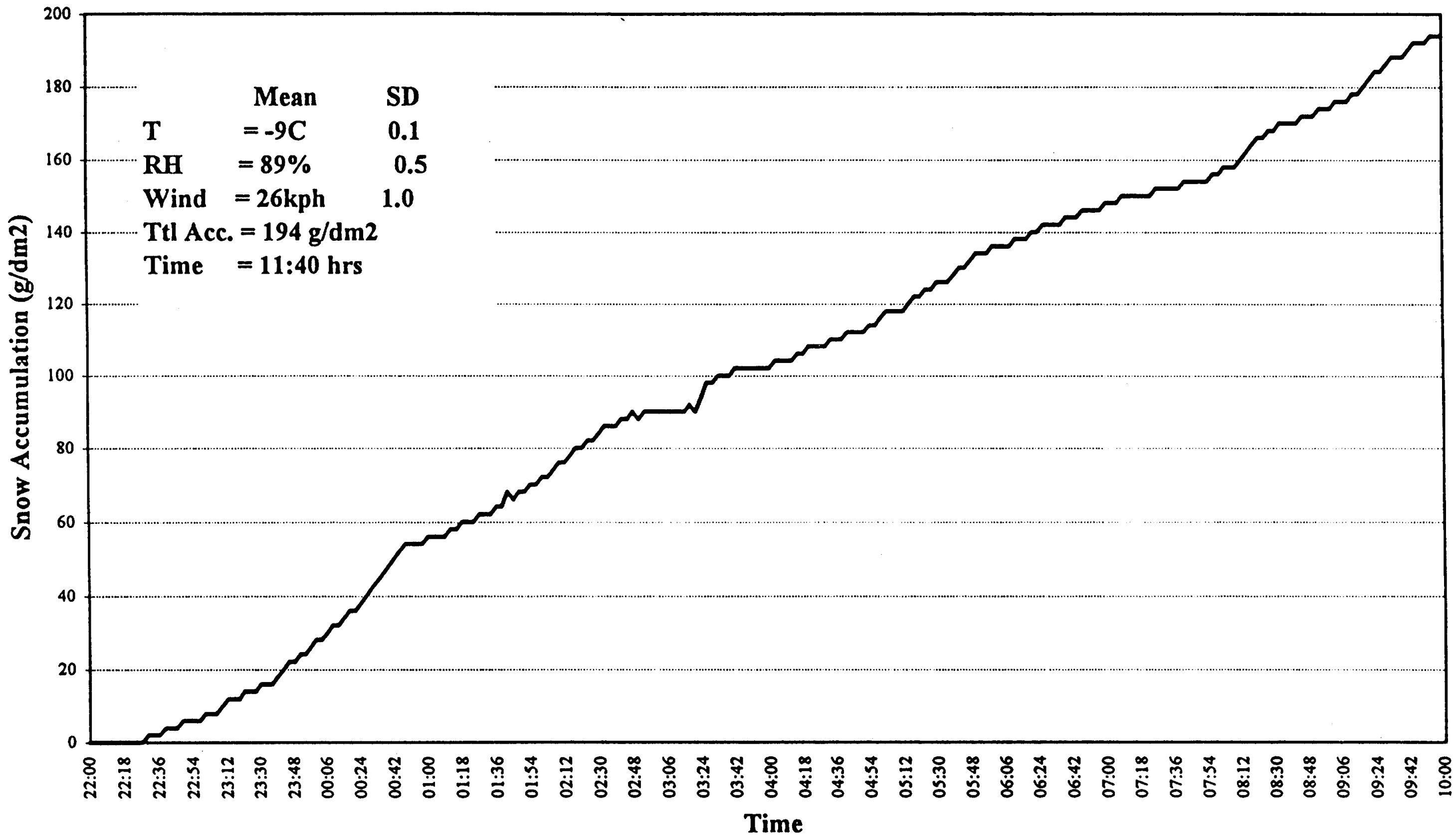


L-20

14/8/95 15:25

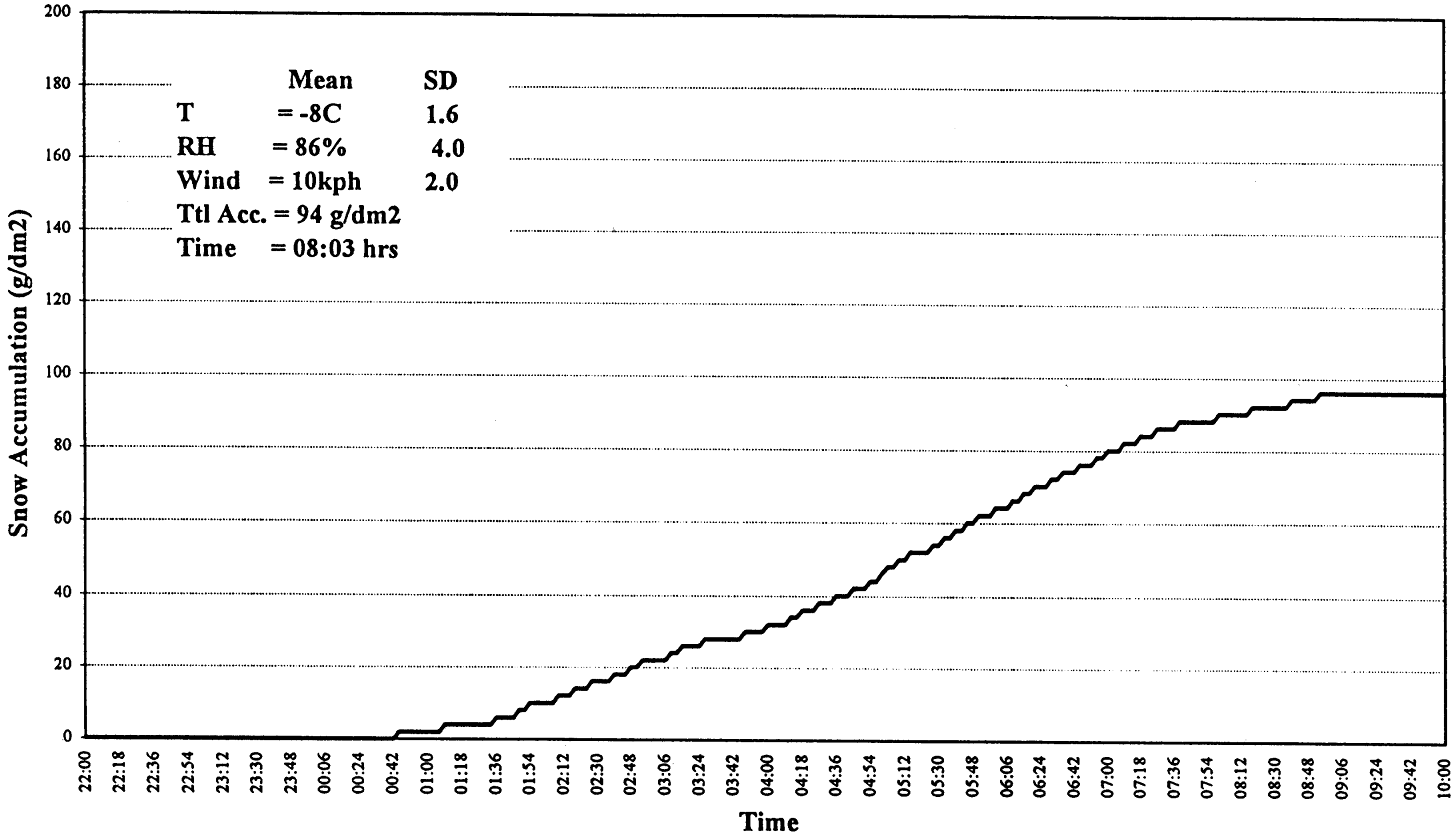
JAN2394.XLS

Total Snow Accumulation
for Jan. 27, 1993



L-21

Total Snow Accumulation
for Feb. 12-13, 1993

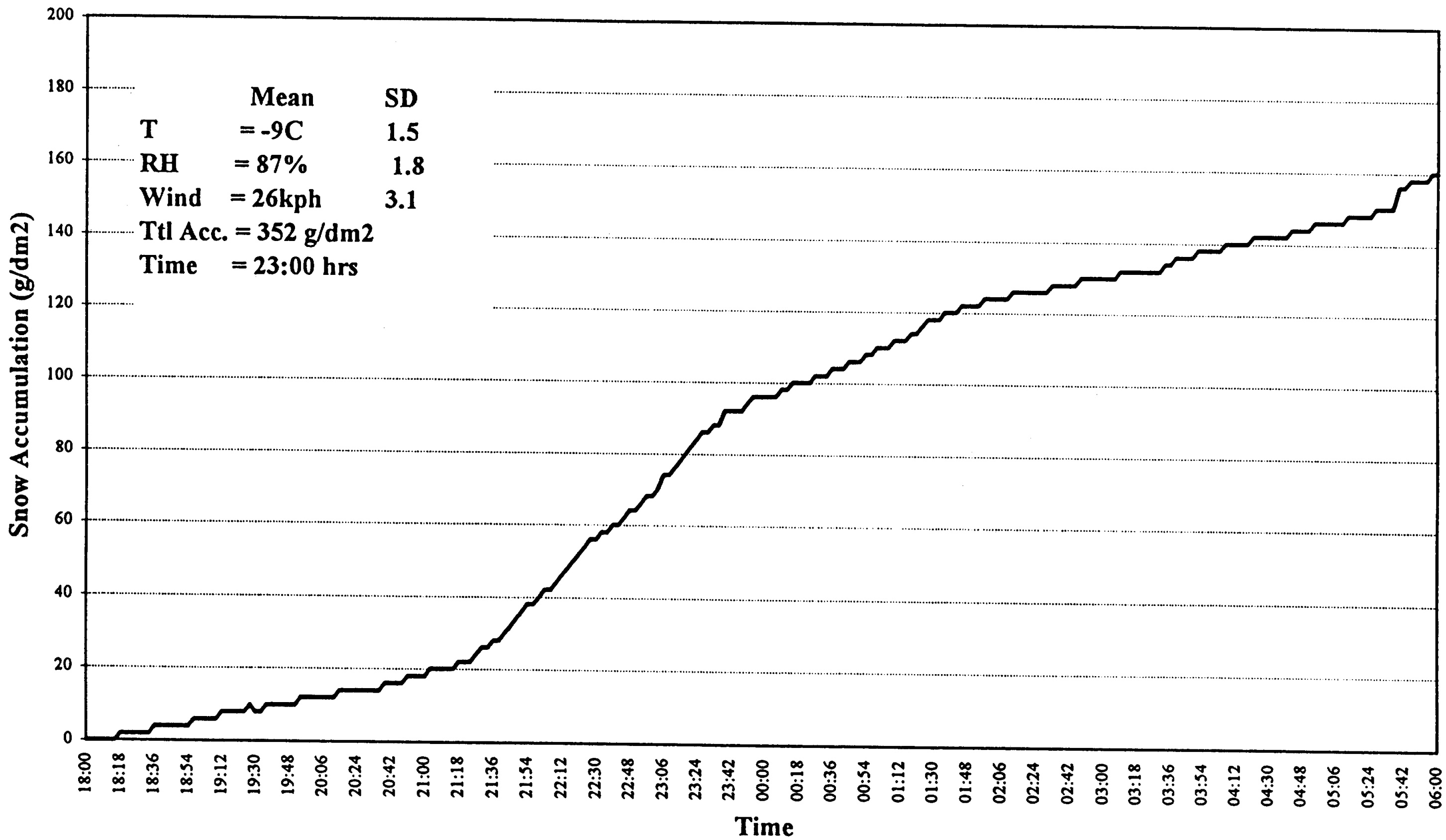


L-22

14/8/95 15:34

FEB1294.XLS

Total Snow Accumulation
for Feb 23-24, 1994

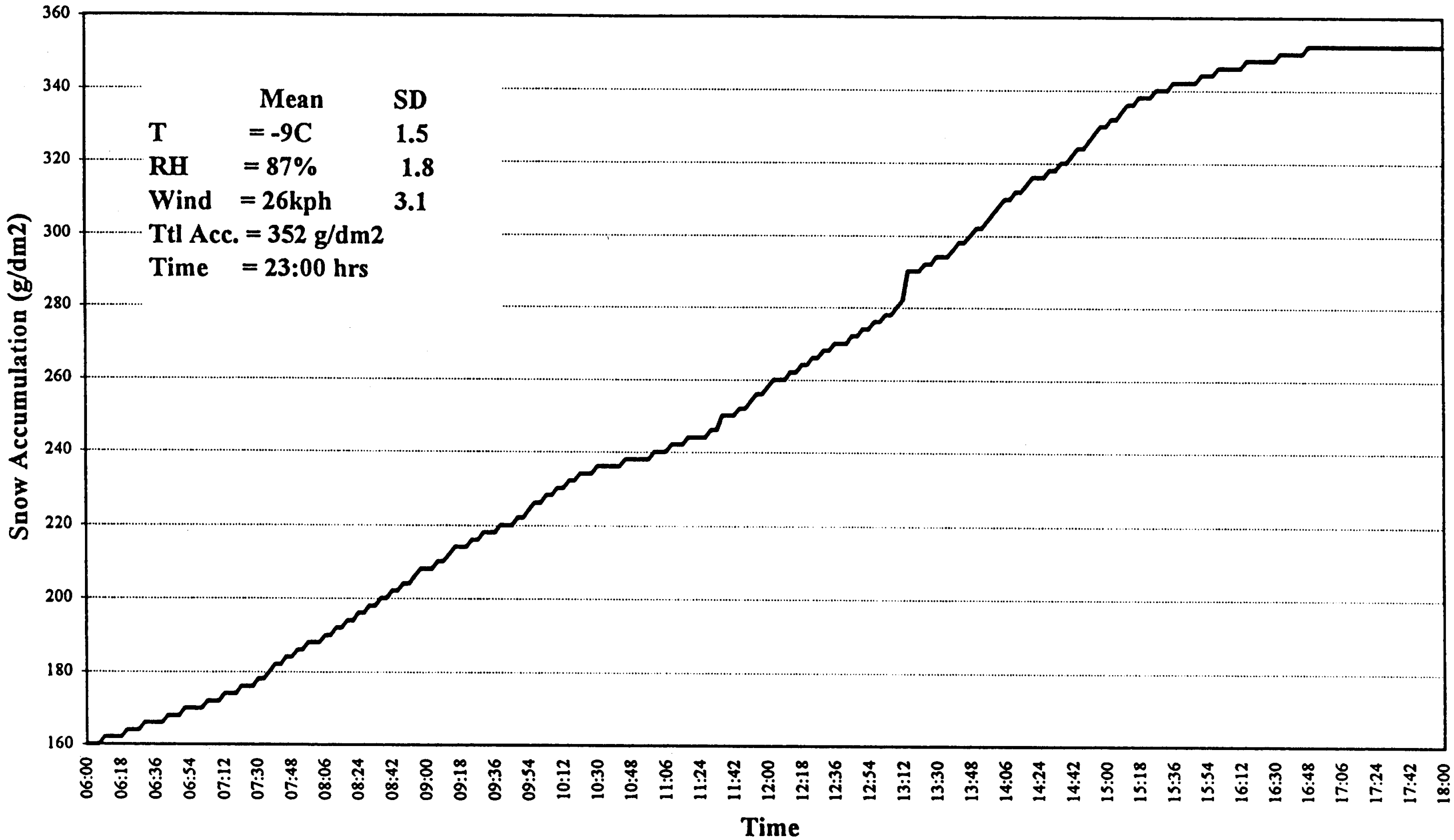


L-23

14/8/95 15:35

FEB2394.XLS

Total Snow Accumulation
for Feb 23-24, 1994

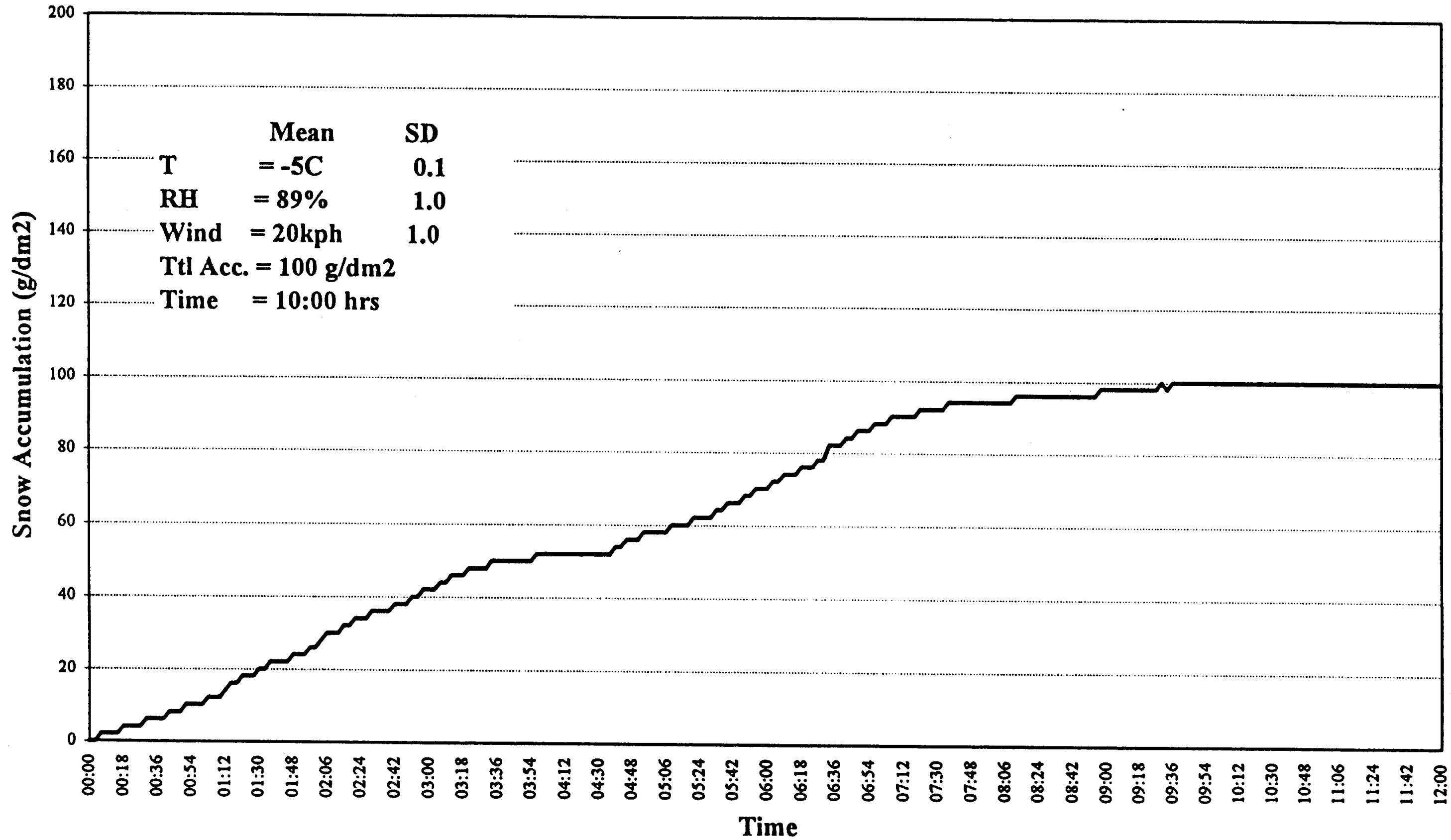


L-24

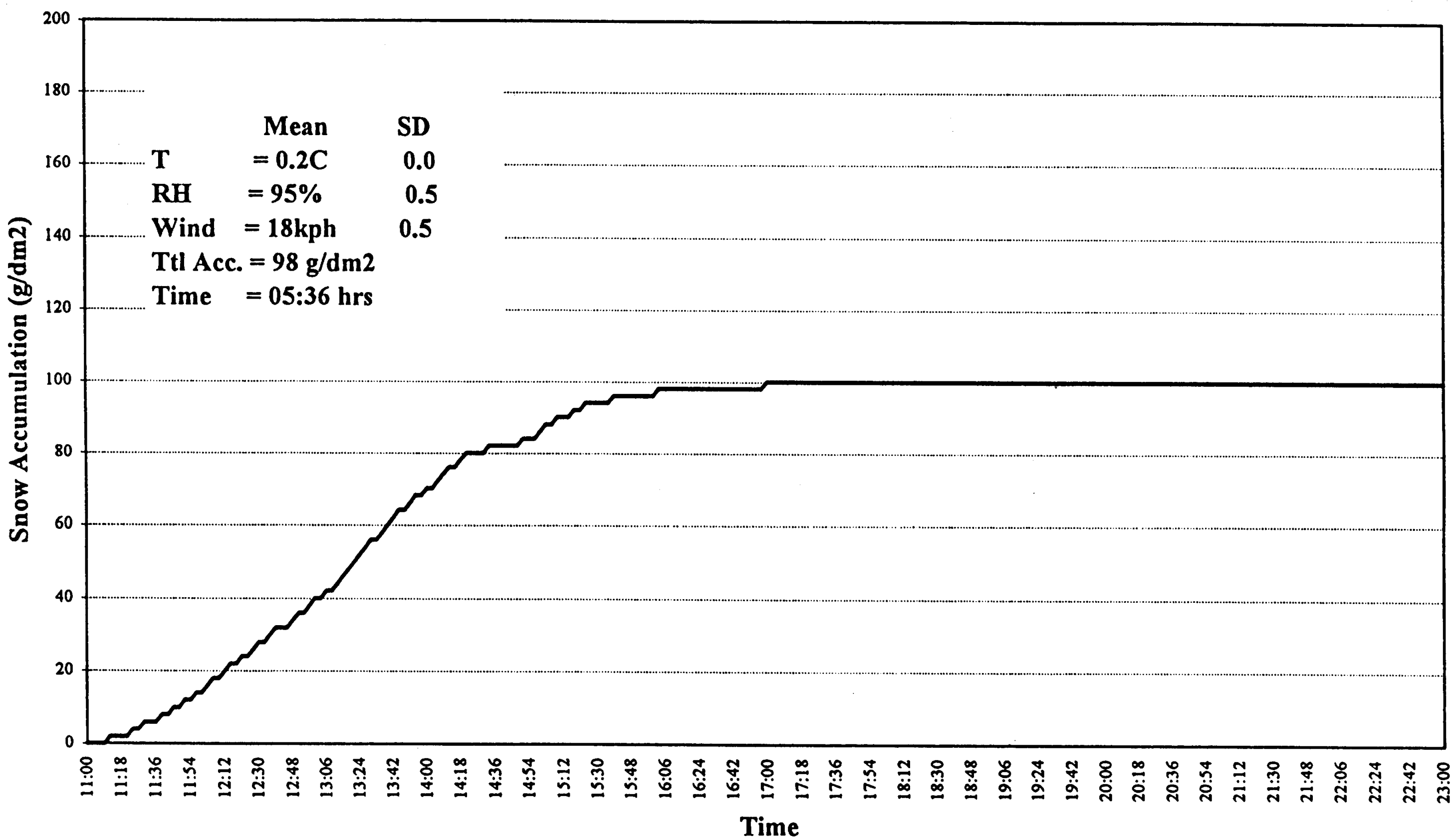
14/8/95 15:35

FEB2394.XLS

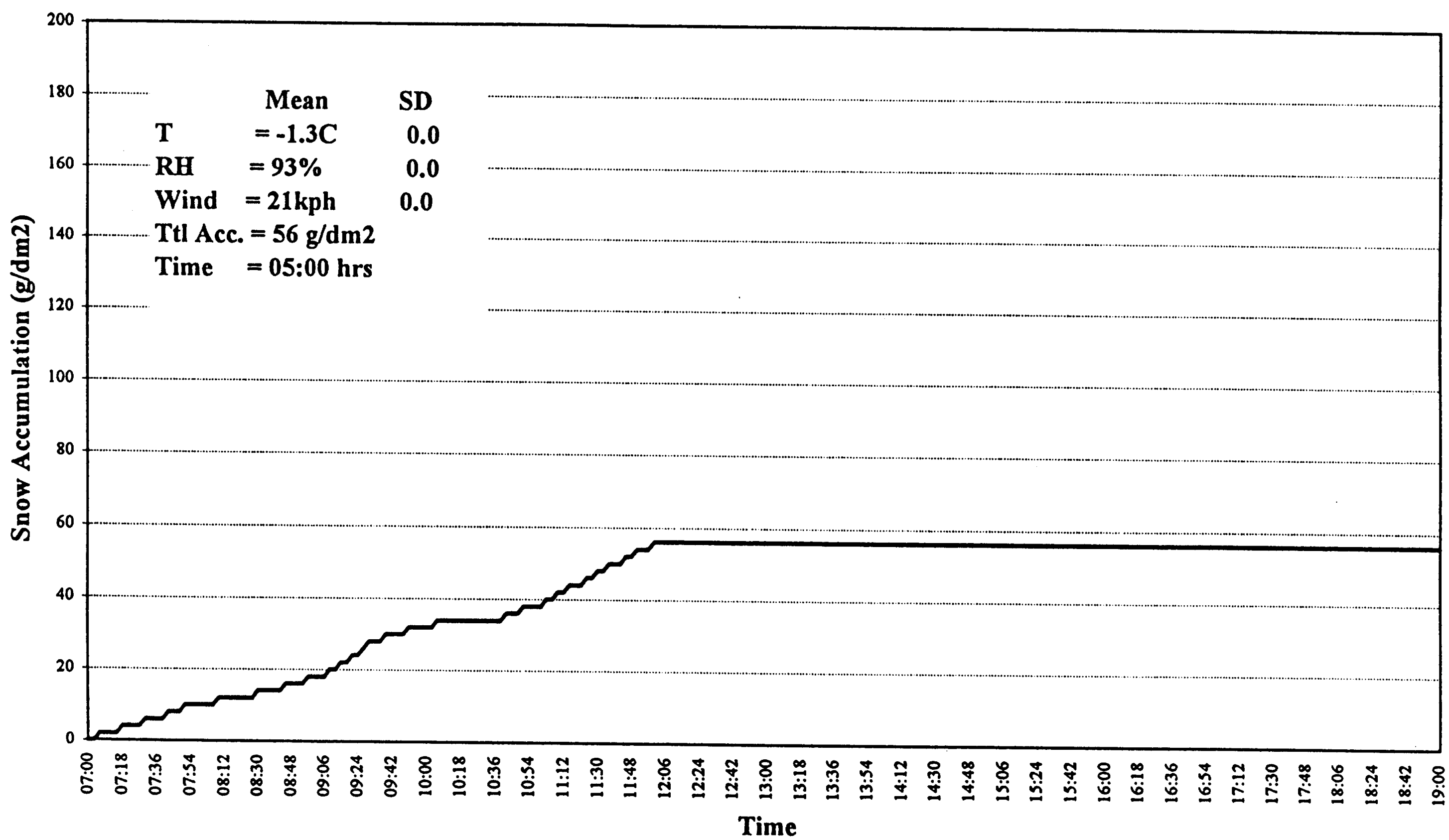
Total Snow Accumulation
for Mar. 10, 1994



Total Snow Accumulation for Mar. 27, 1994



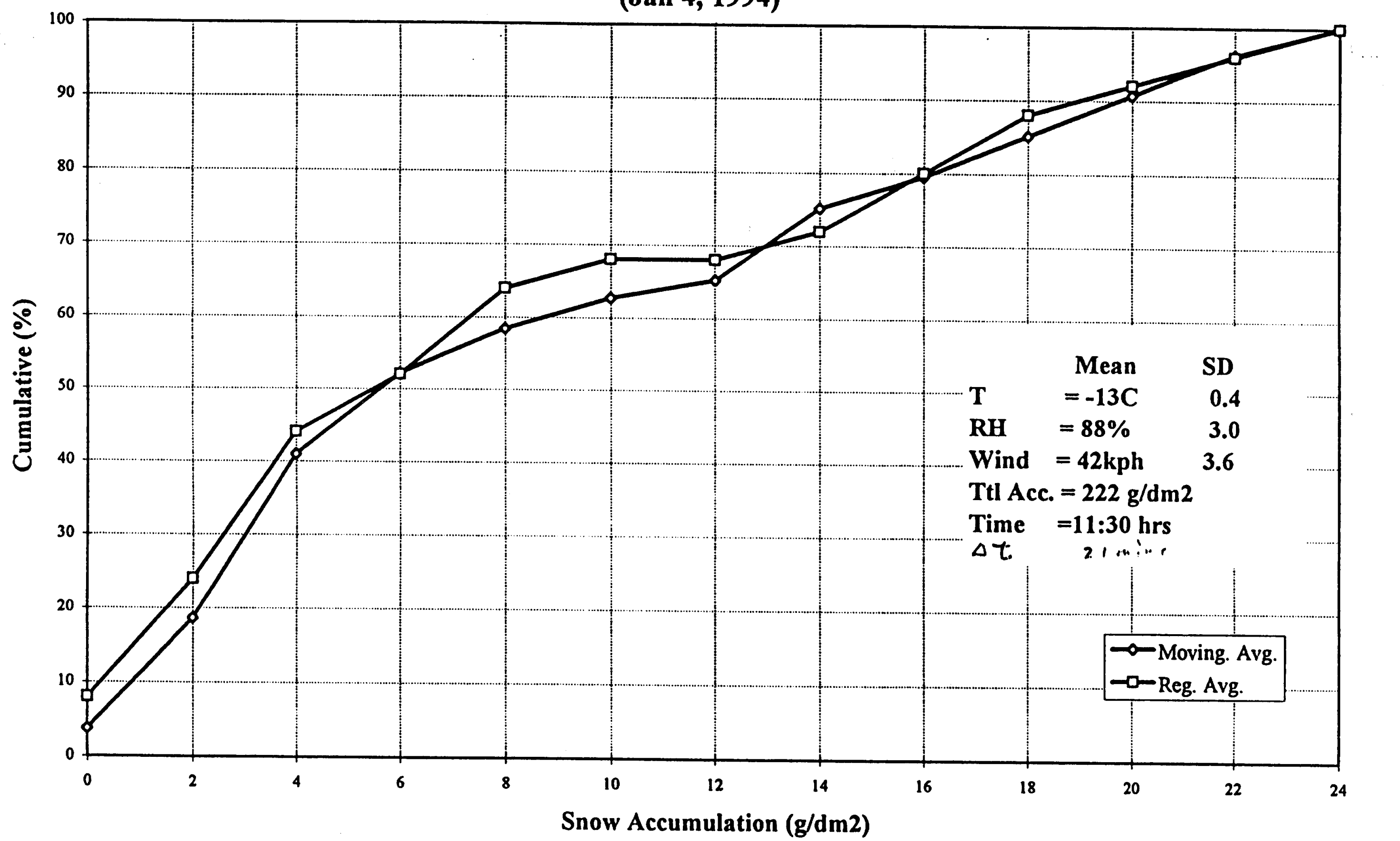
Total Snow Accumulation
for Apr. 07, 1994



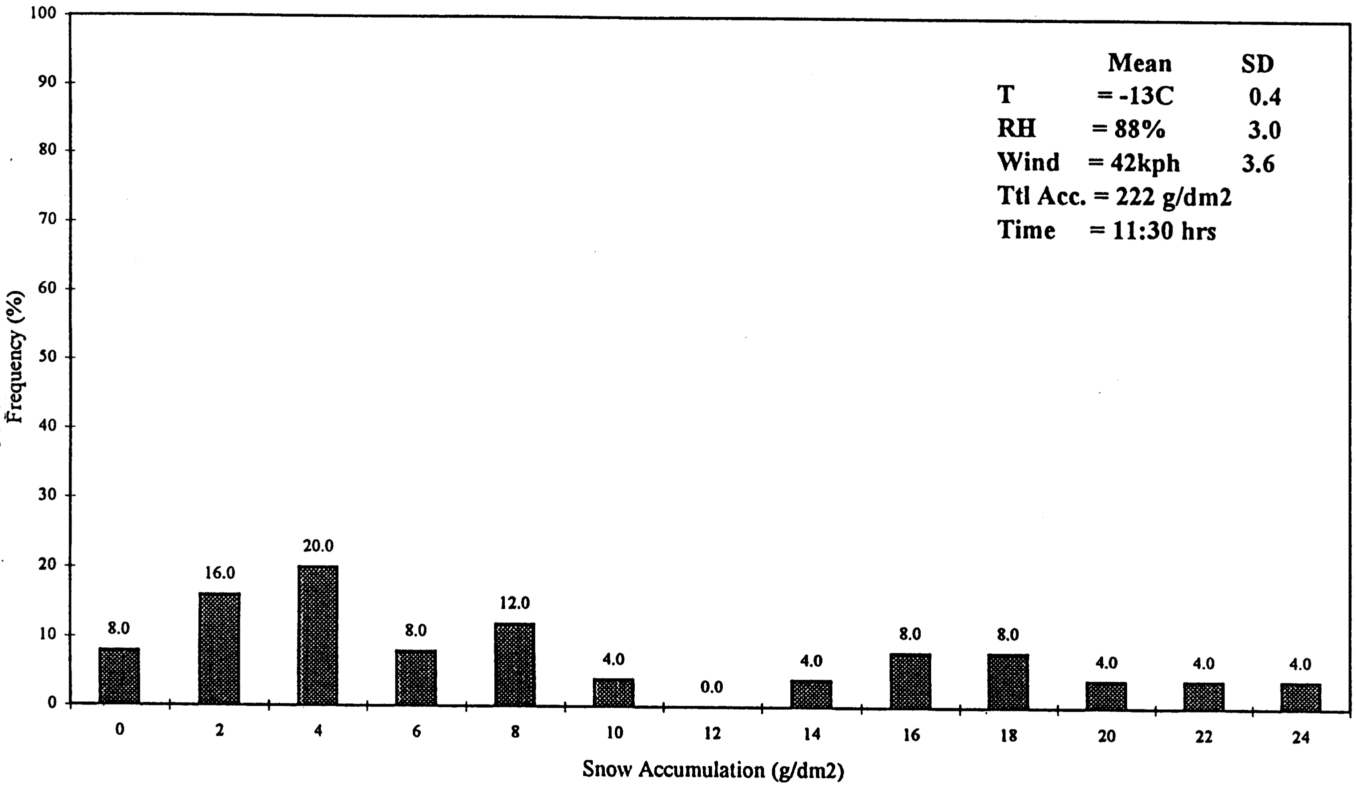
14/8/95 15:38

APR0794.XLS

Comparison Between Moving & Reg. Averages for Distribution for Snow Accumulation (Jan 4, 1994)

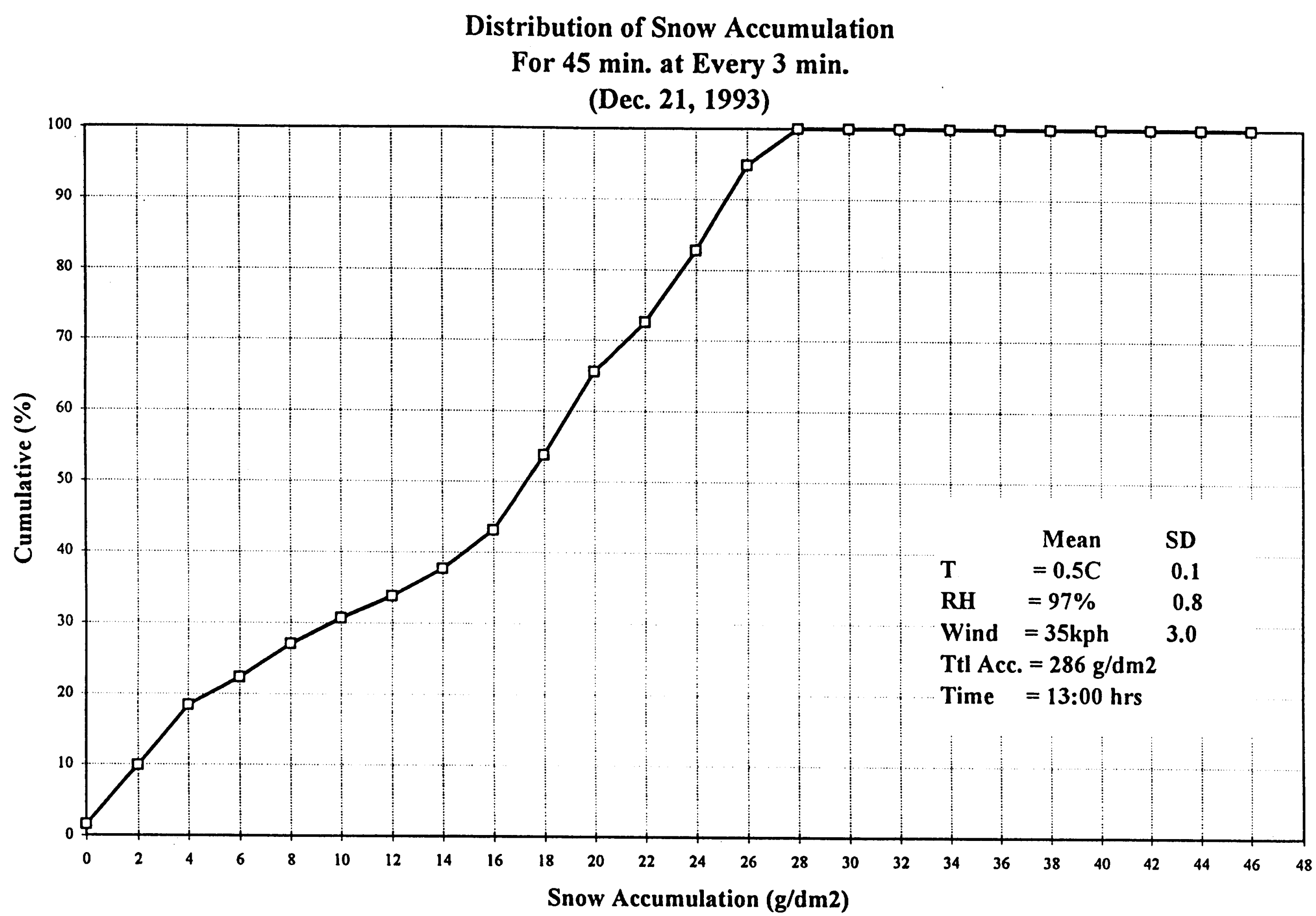


Histogram for Snow Accumulation
Every 21 min. (Series 1, Jan. 4, 1994)



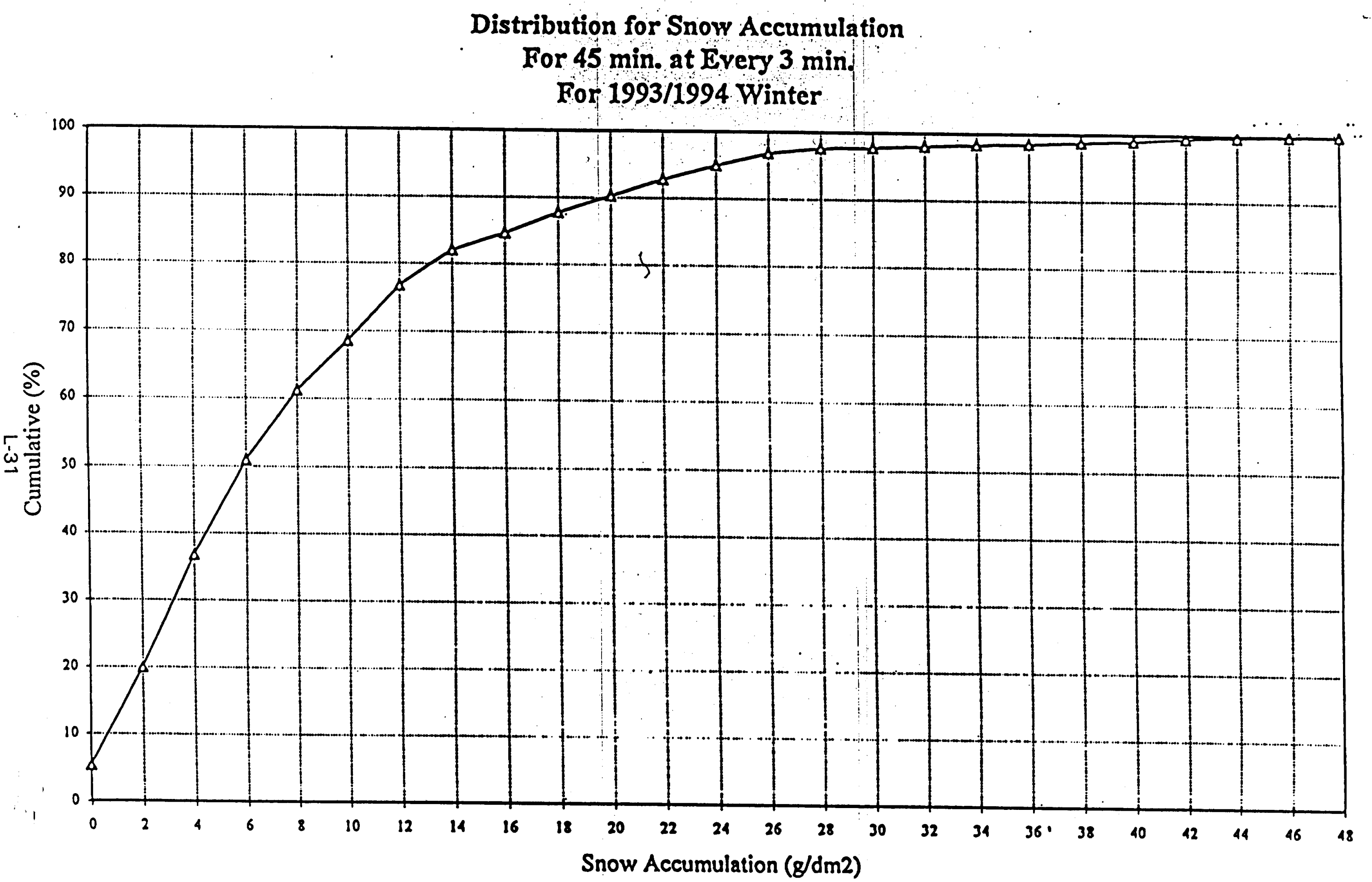
18/8/95 16:47

JAN0494.XLS



18/8/95 16:17

DEC2193.XLS

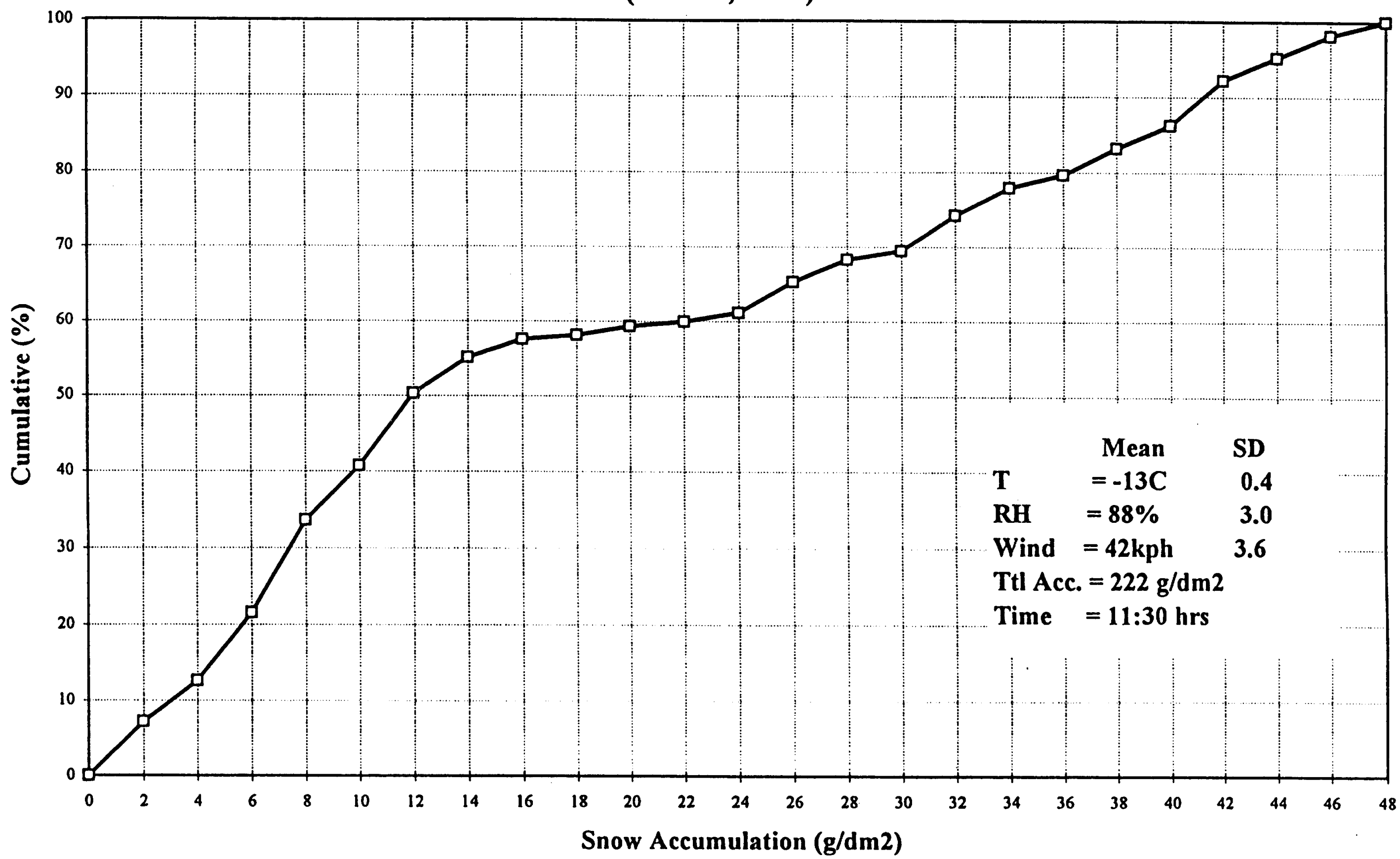


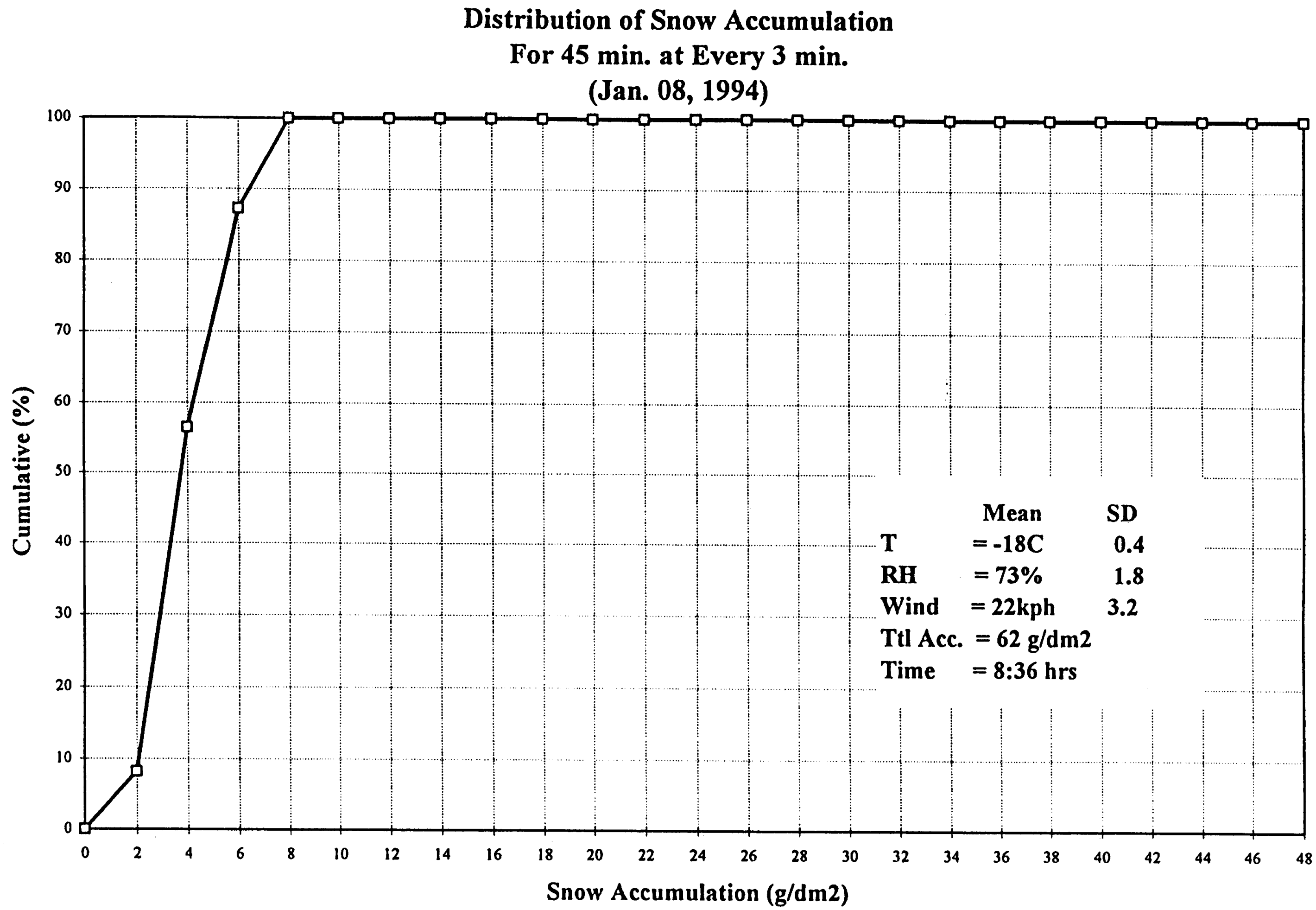
L-31

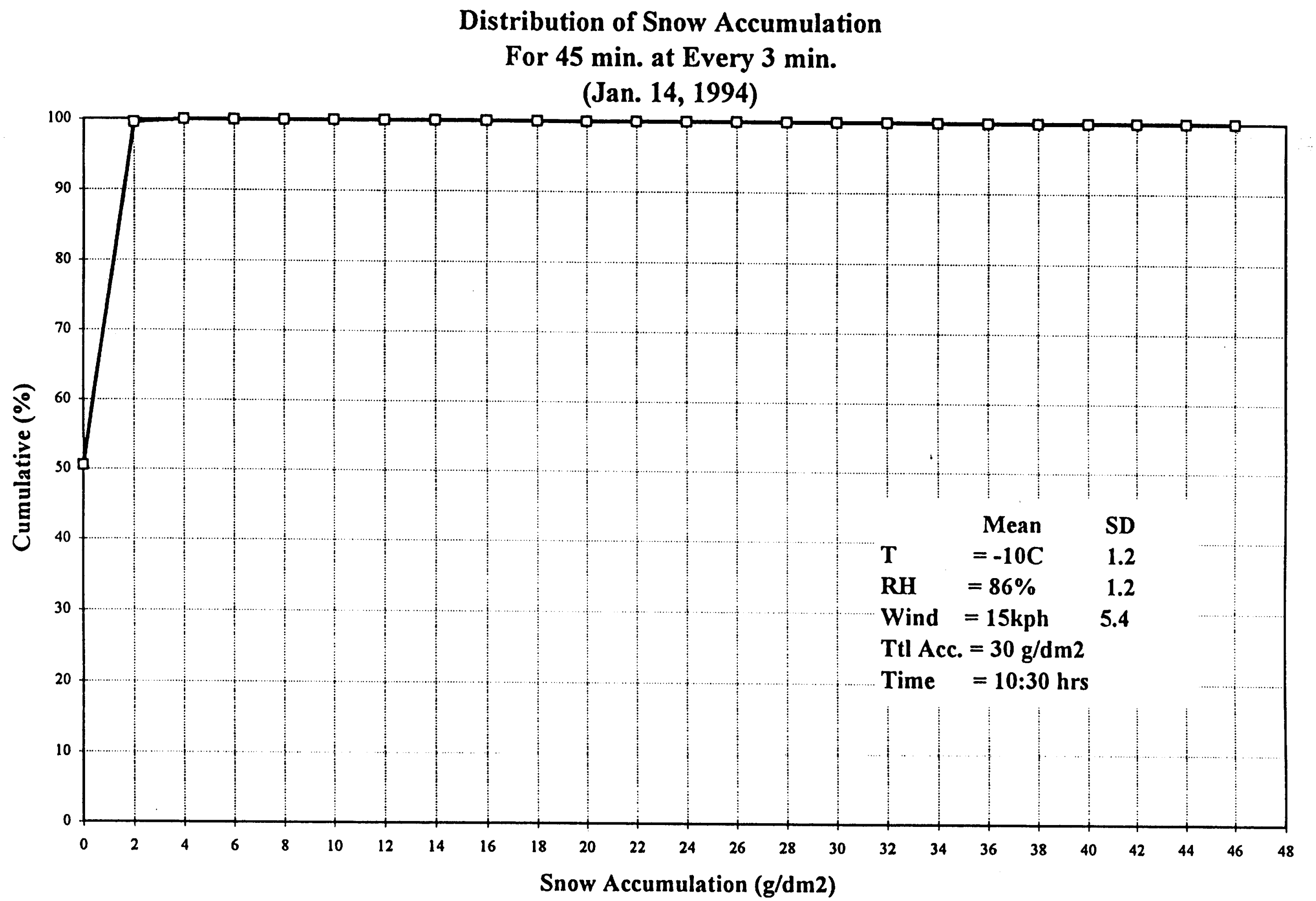
18/8/95 15:29

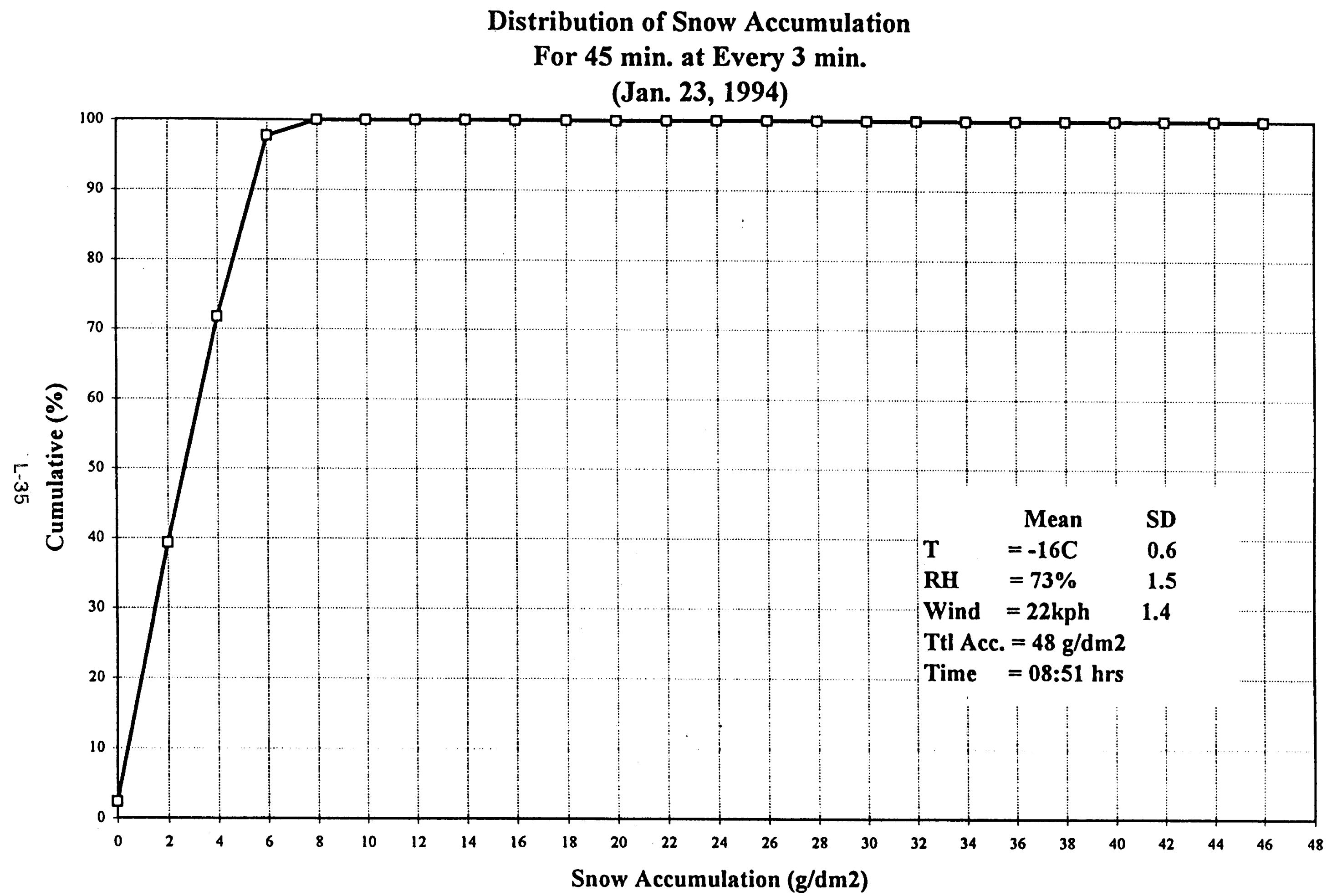
MHIST94.XLS

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 04, 1994)




Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 08, 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 = -18C 0.4
RH = 73% 1.8
Wind = 22kph 3.2
Ttl Acc. = 62 g/dm2
Time = 8:36 hrs

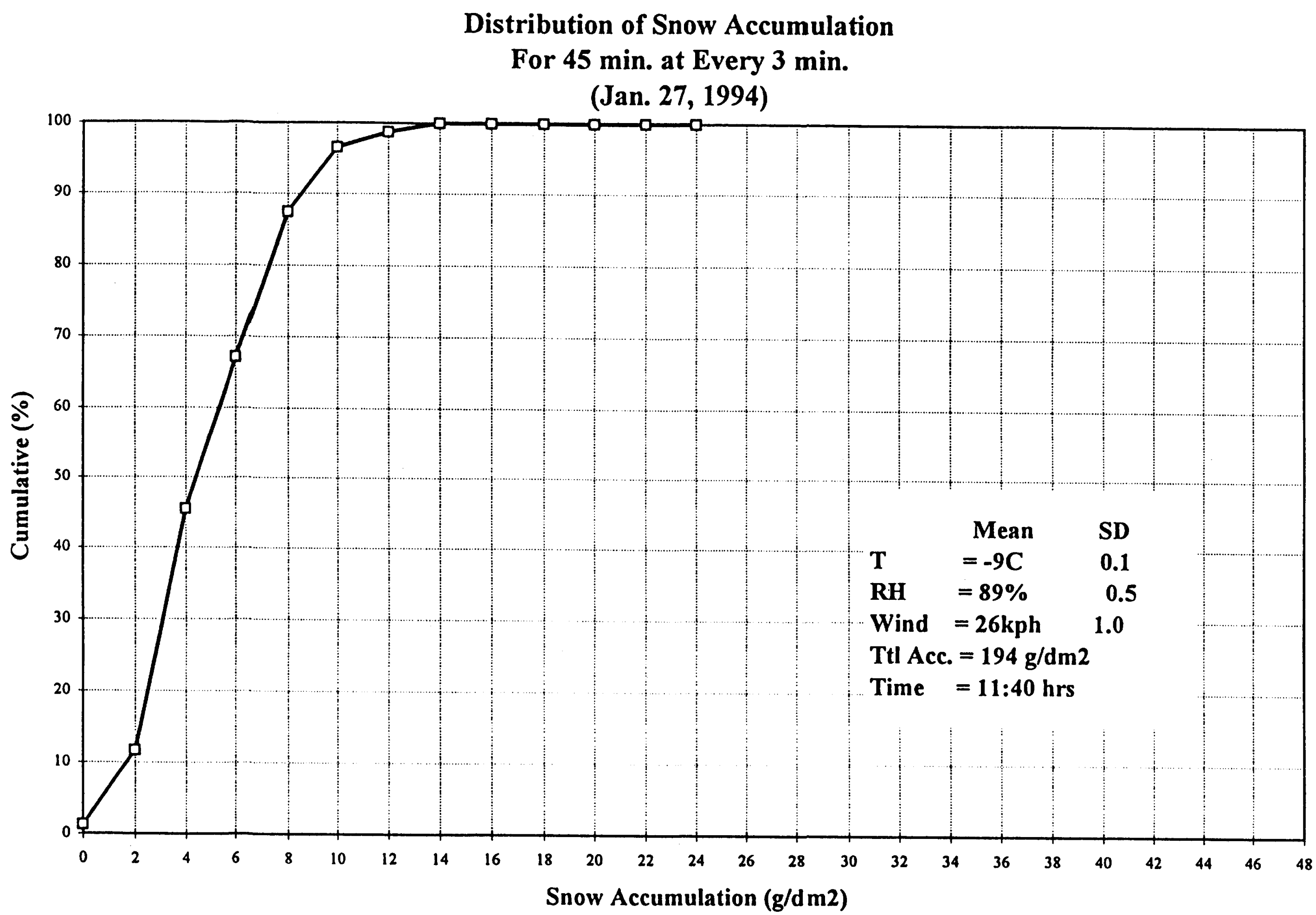

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 14, 1994)
Cumulative (%)
0
10
20
30
40
50
60
70
80
90
100
Snow Accumulation (g/dm2)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
Mean SD
T = -10C 1.2
RH = 86% 1.2
Wind = 15kph 5.4
Ttl Acc. = 30 g/dm2
Time = 10:30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



L-35

18/8/95 16:21

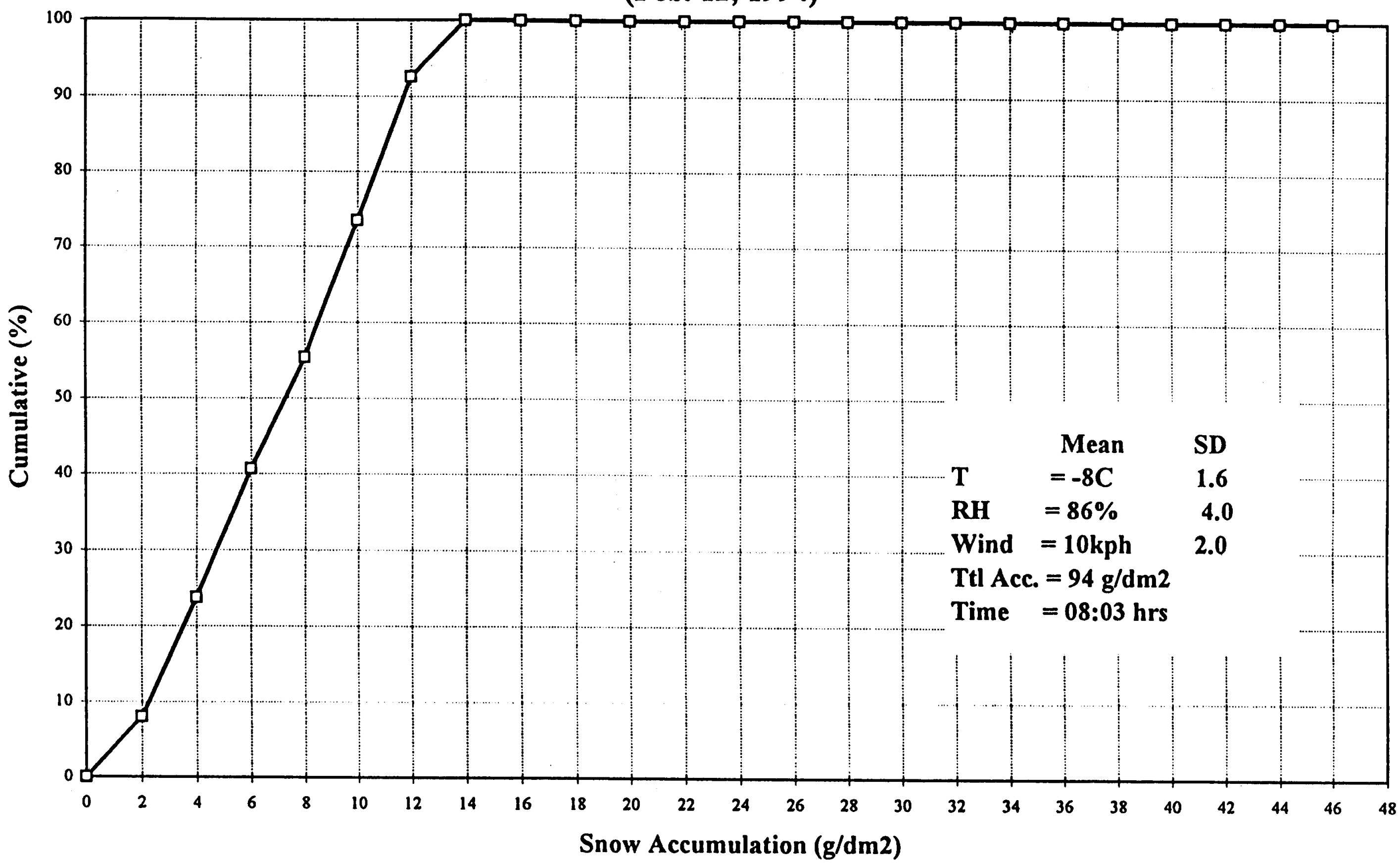
JAN2394.XLS

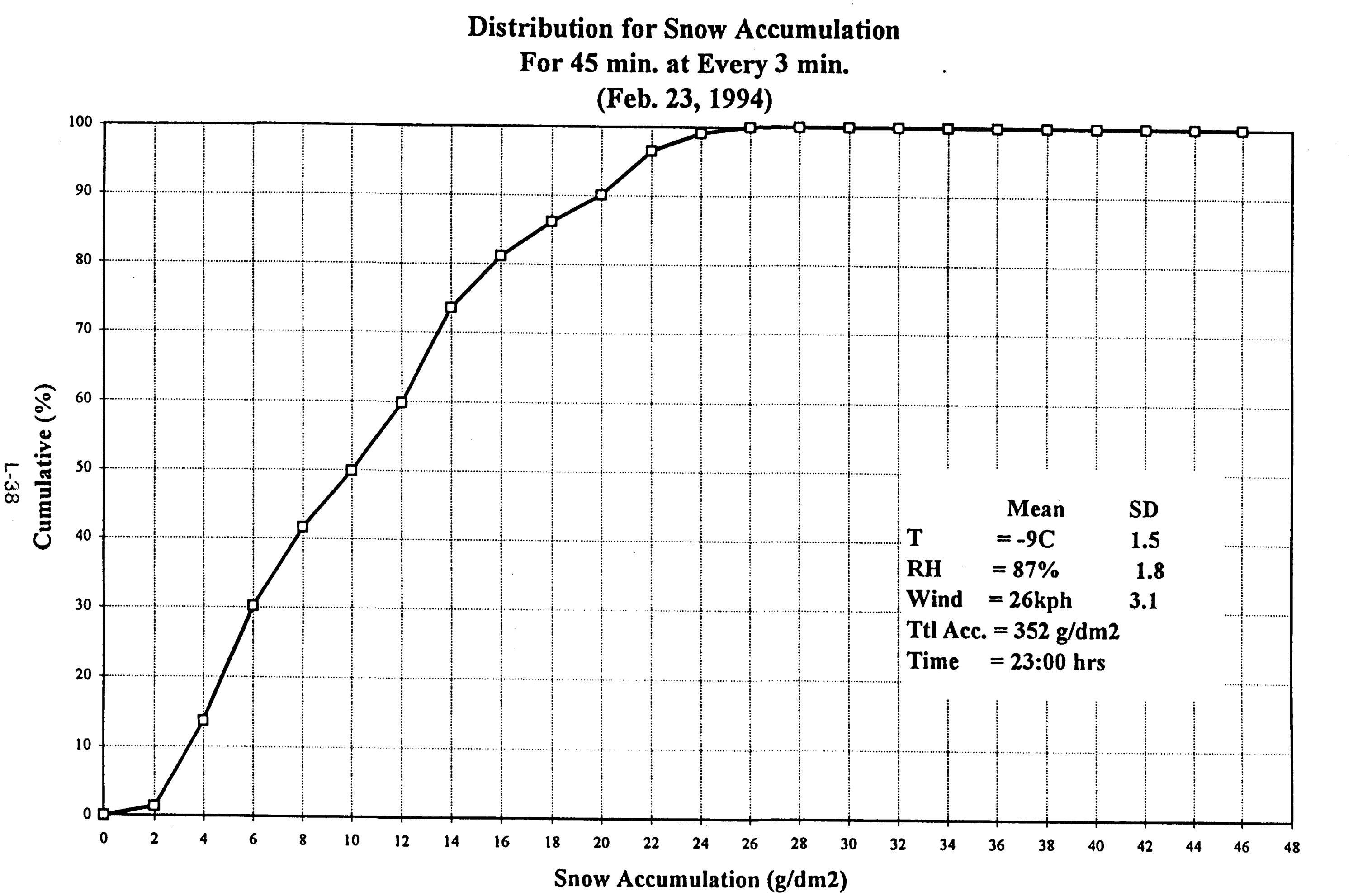


18/8/95 16:20

JAN2794.XLS

Distribution of Snow Accumulation For 45 min. at Every 3 min. (Feb. 12, 1994)



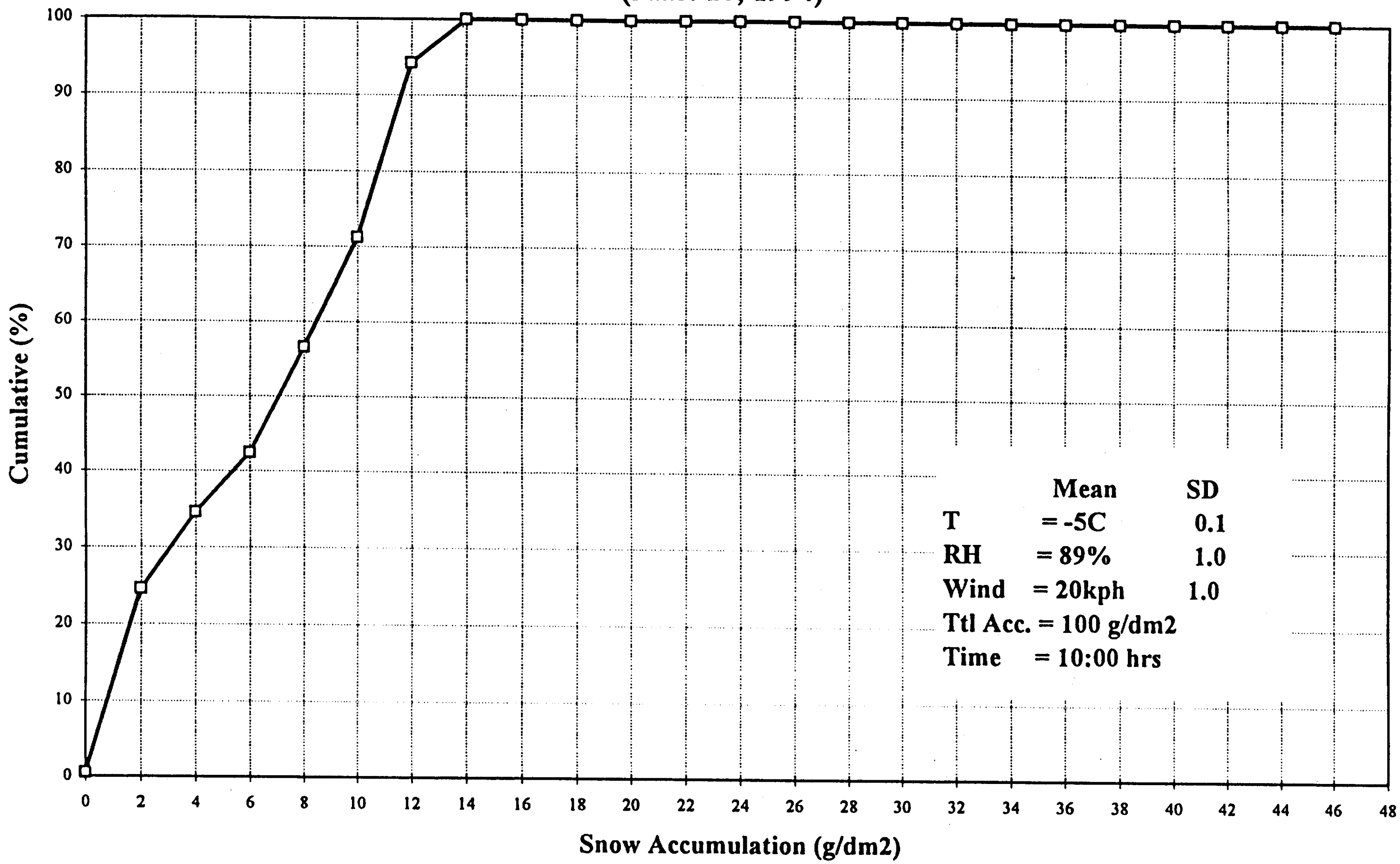


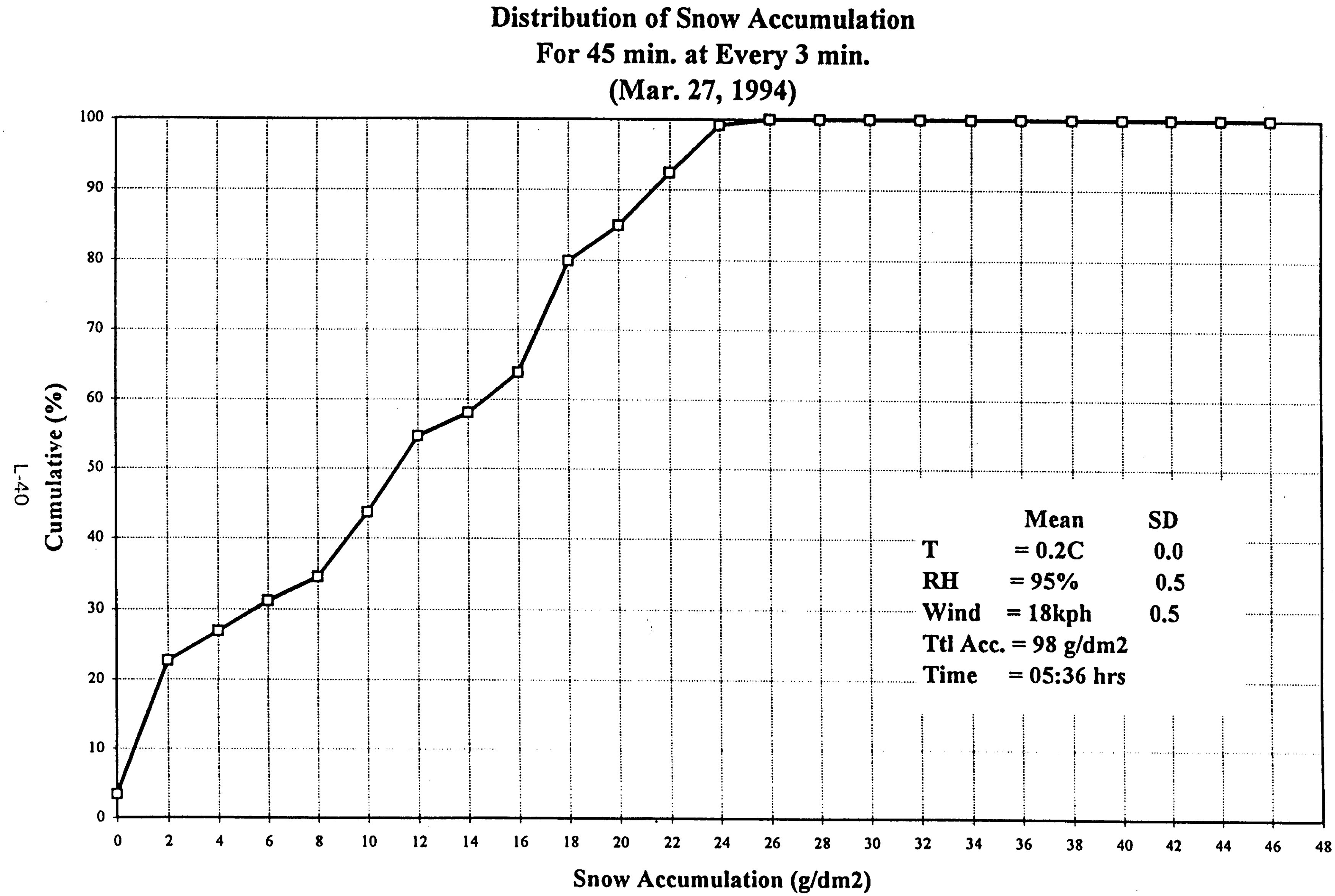
L-38

18/8/95 16:27

FEB2394.XLS

Distribution of Snow Accumulation For 45 min. at Every 3 min. (Mar. 10, 1994)

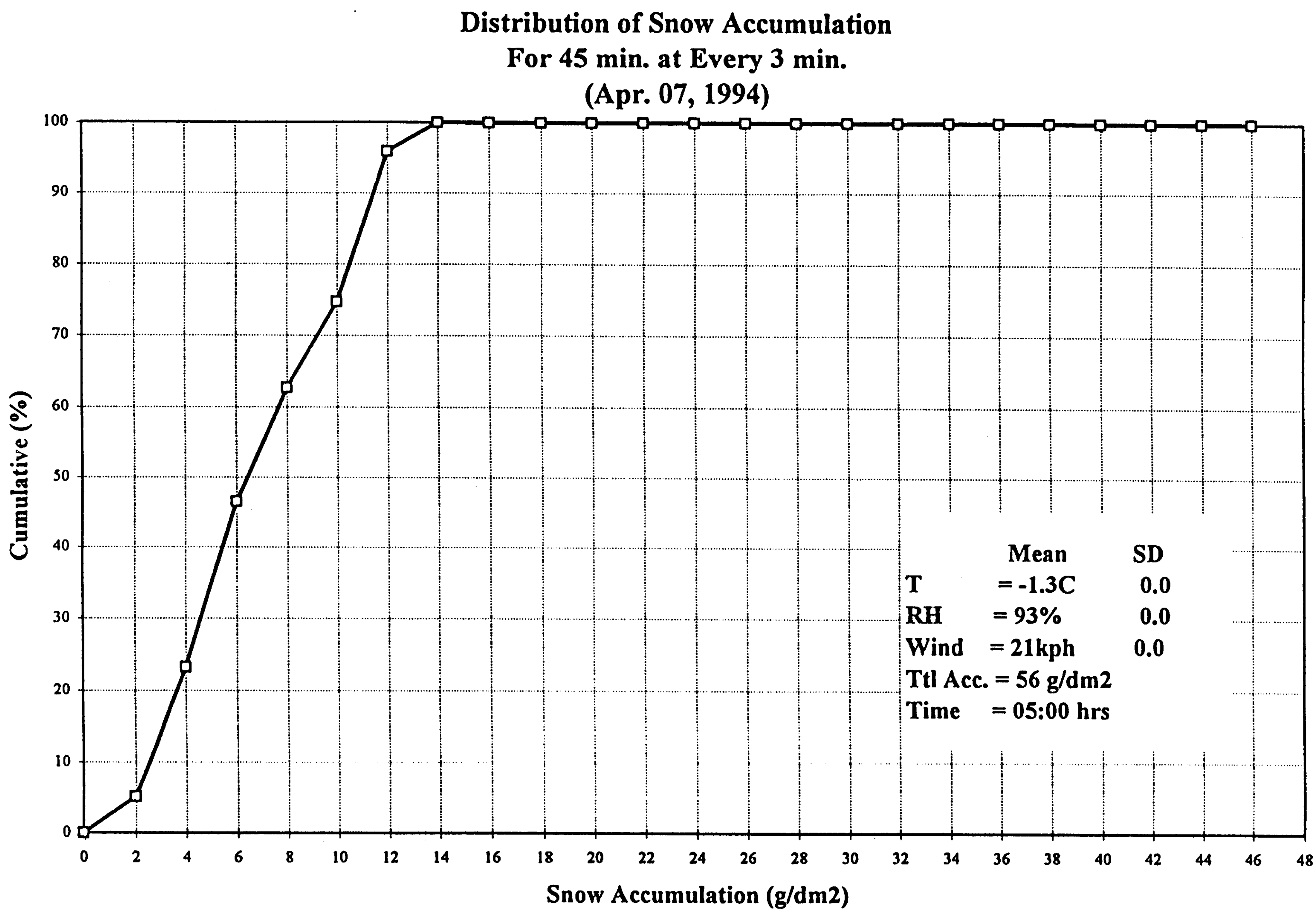




L-40

18/8/95 16:30

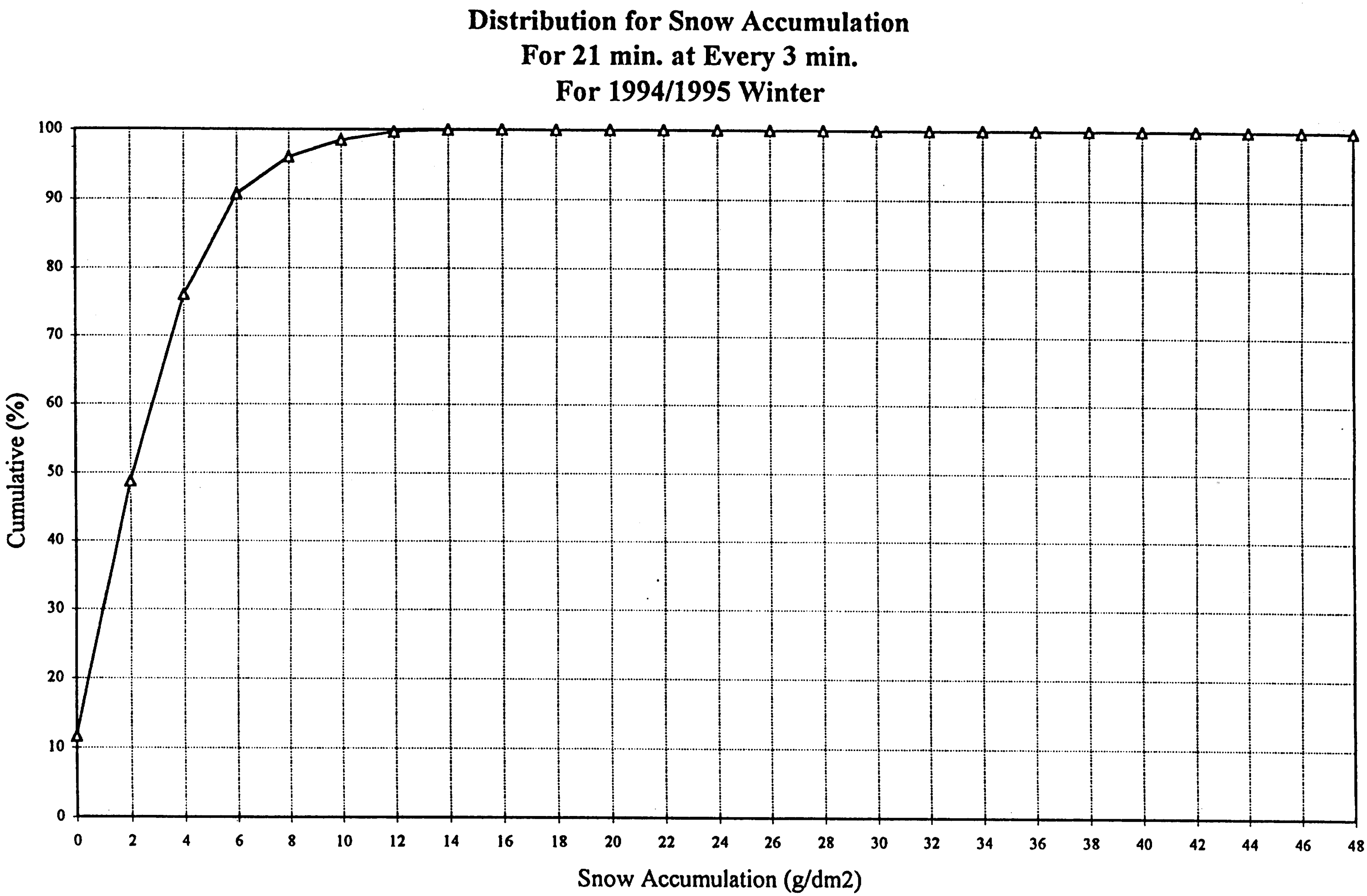
MAR2794.XLS



L-41

18/8/95 16:33

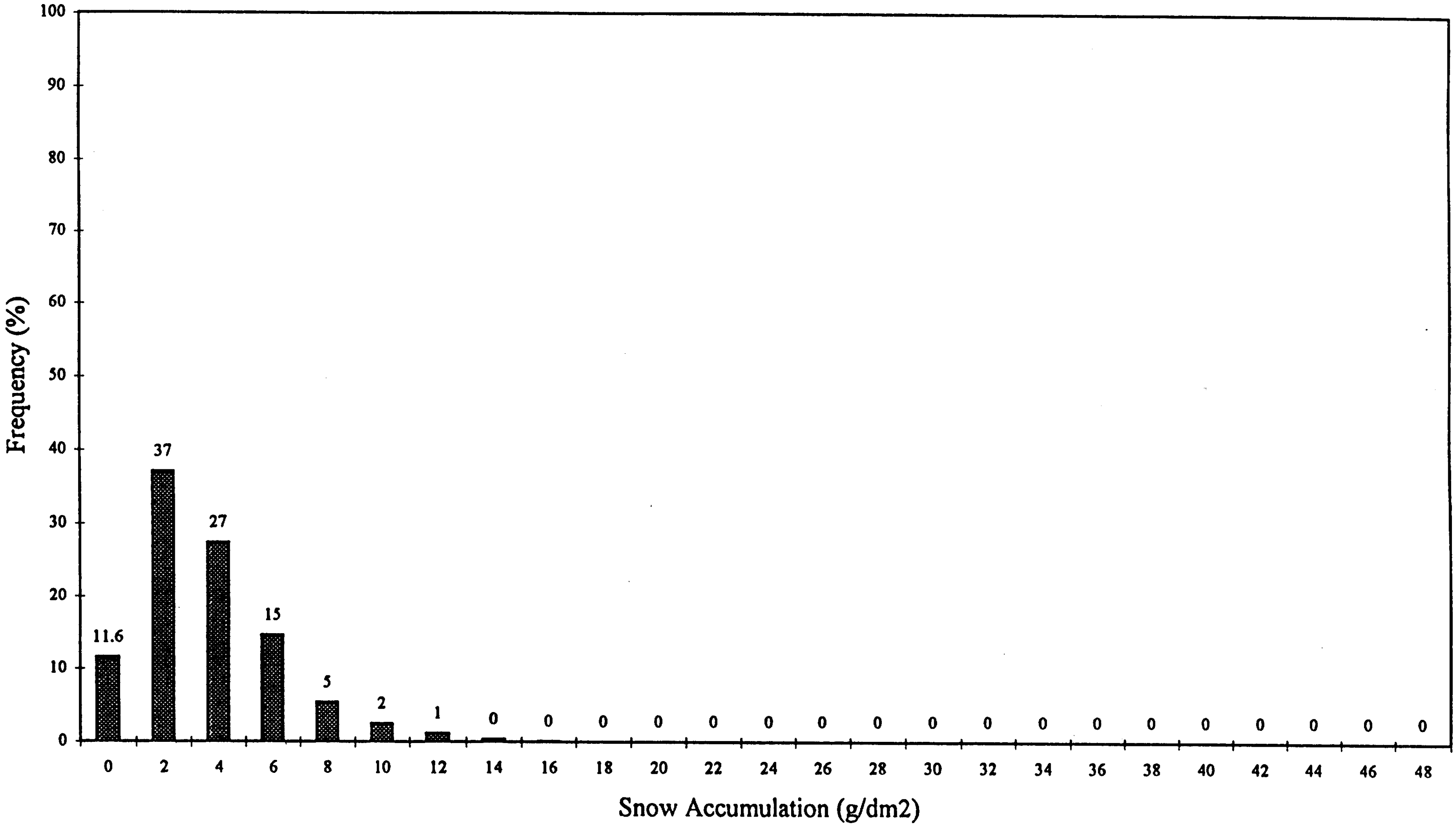
APR0794.XLS



18/8/95 15:25

MHIST95.XLS

Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1994/1995 Winter

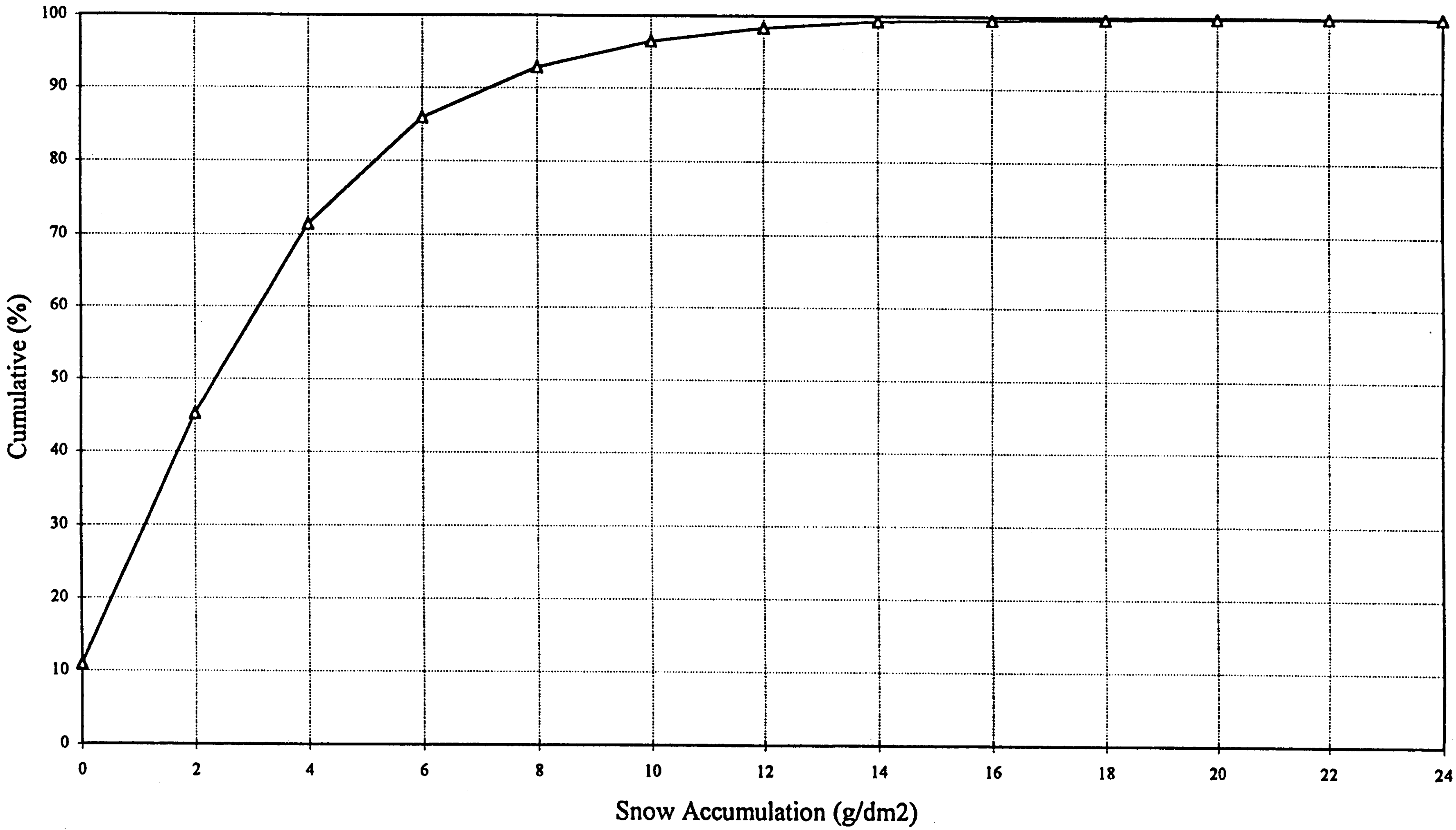


L-43

18/8/95 11:36

MHIST95.XLS

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/94-1994/95 Winters

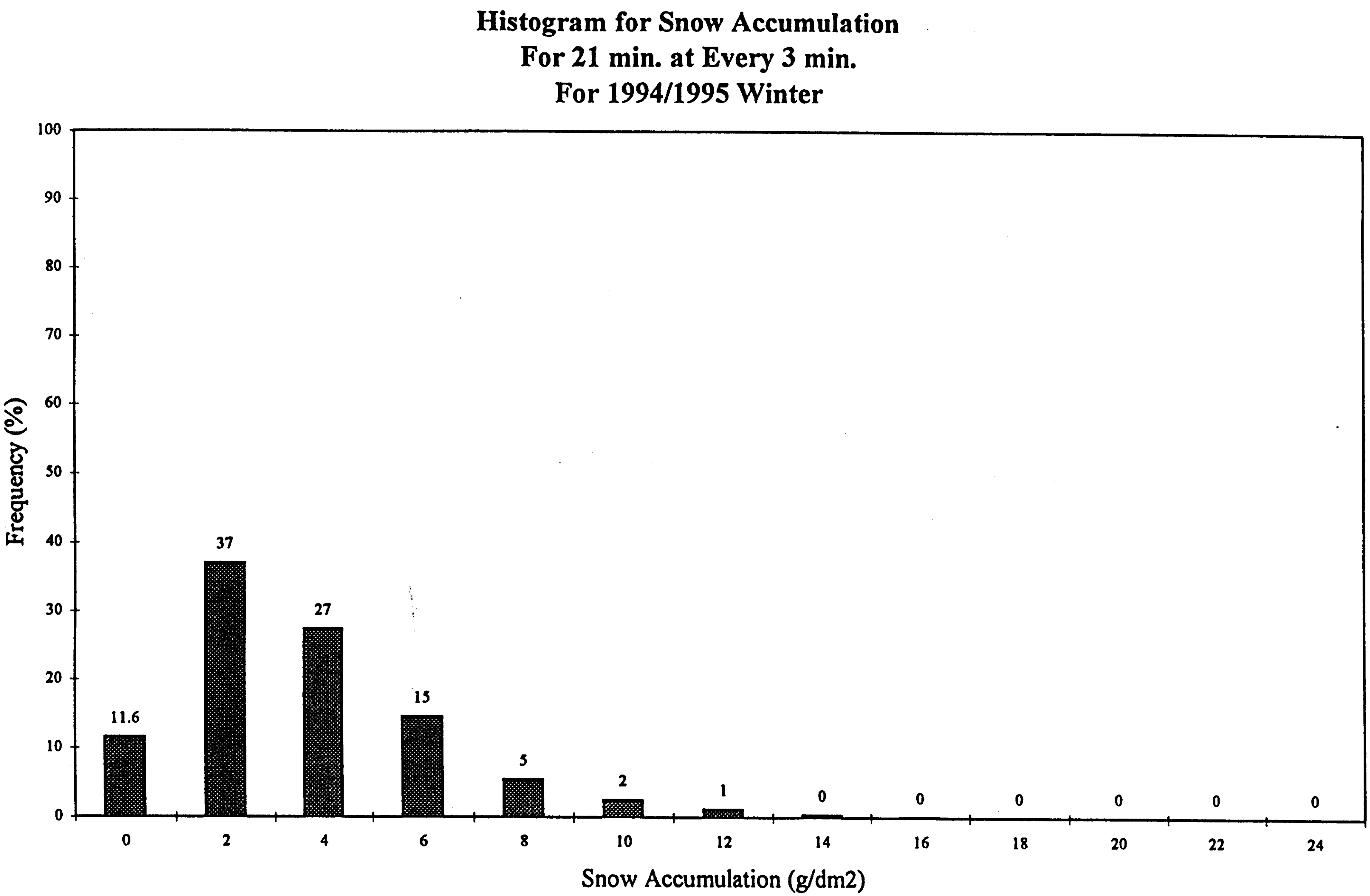


18/8/95 15:25

MHIST95.XLS

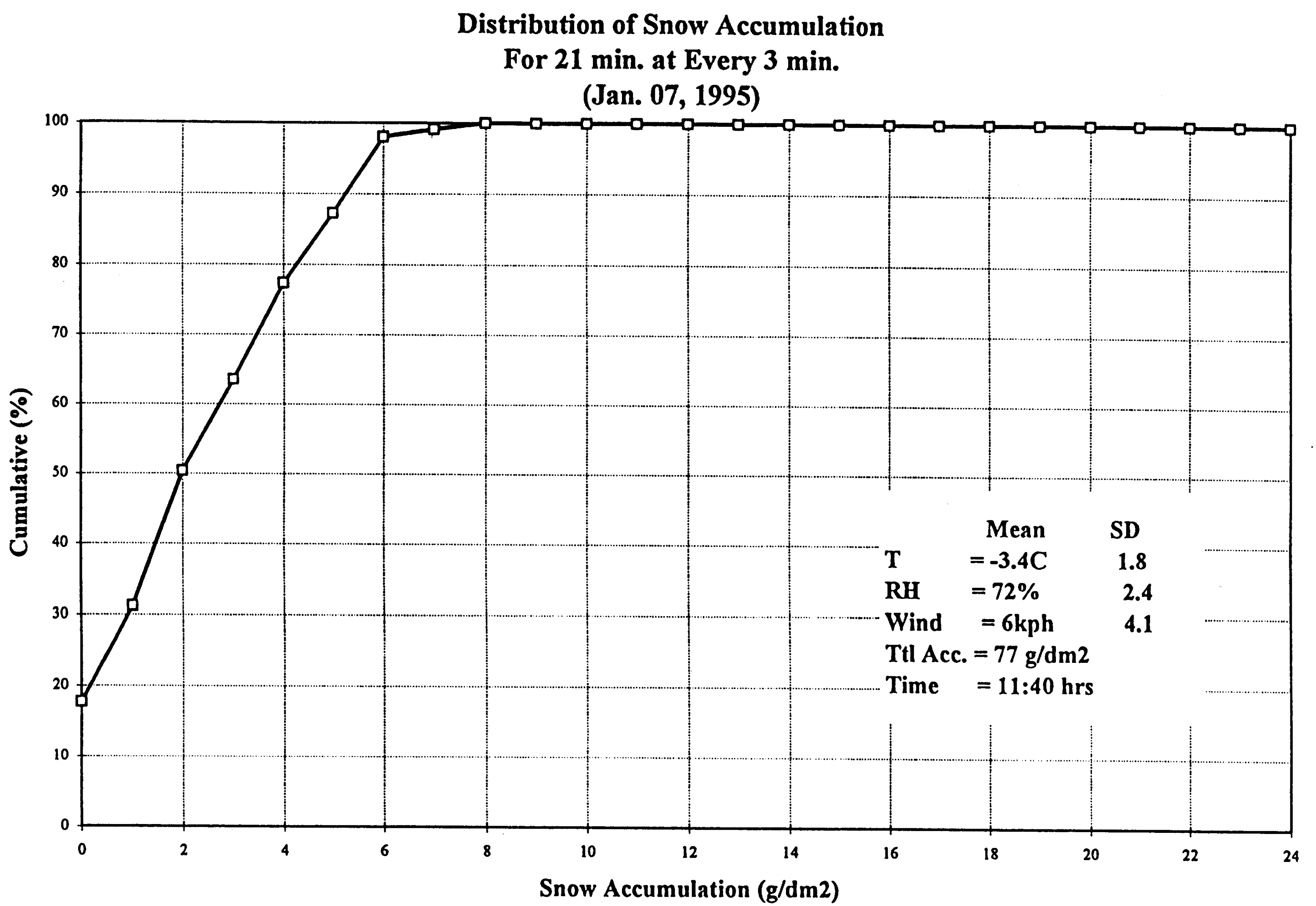
MOVING AVERAGE
1994/1995

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		



17/8/95 11:48

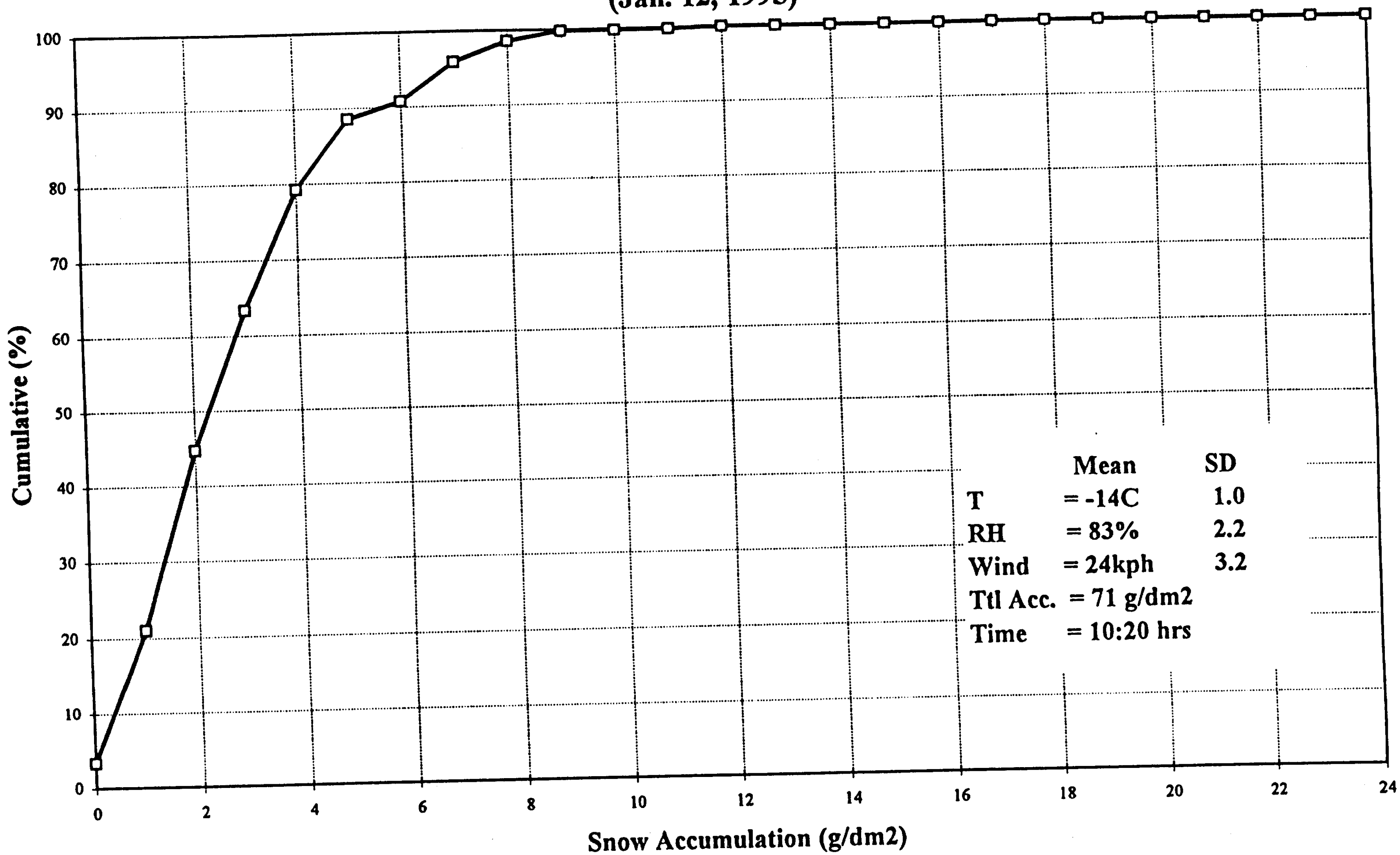
MHIST95.XLS



17/8/95 13:23

950107.XLS

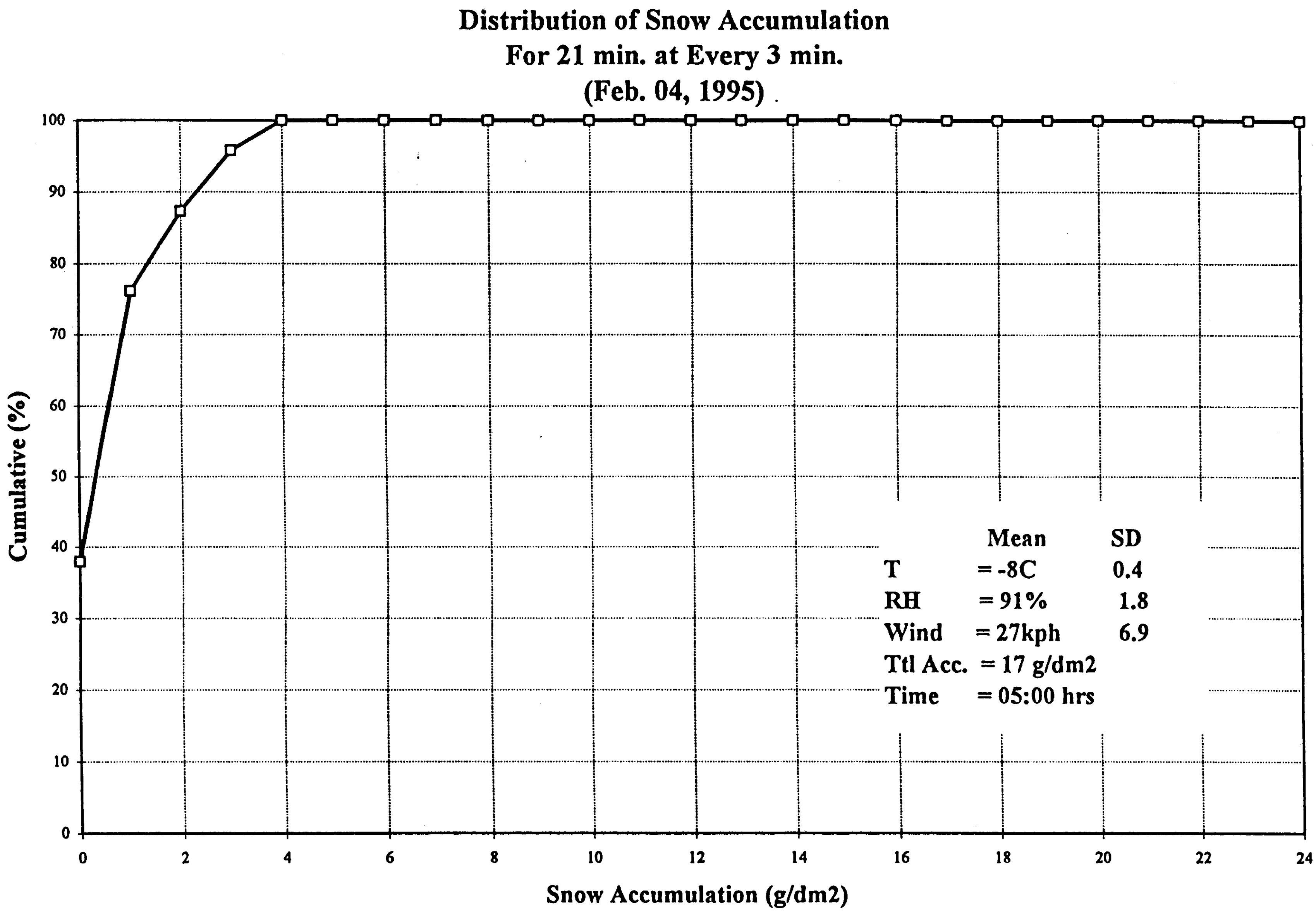
Distribution of Snow Accumulation For 21 min. at Every 3 min. (Jan. 12, 1995)



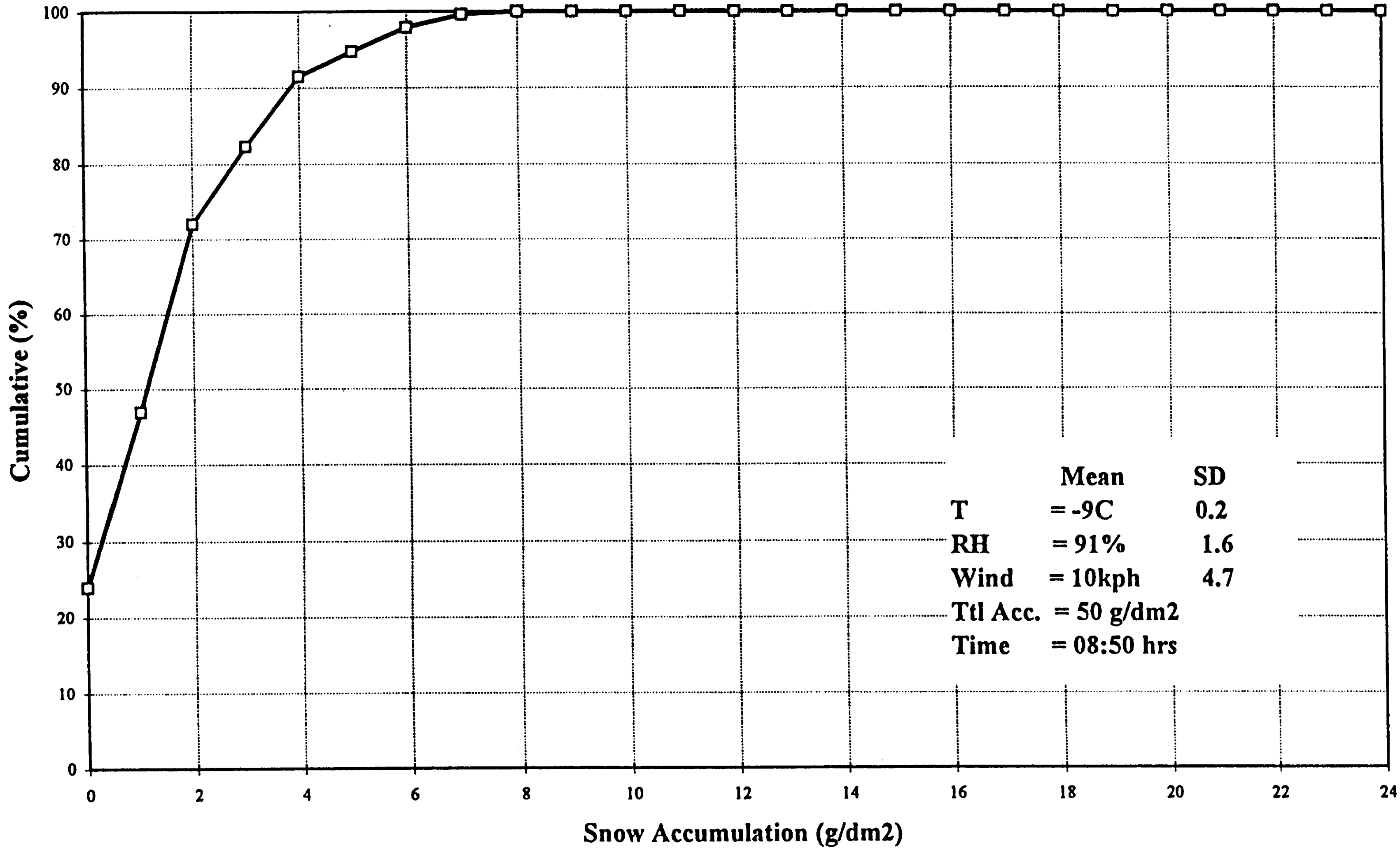
L-48

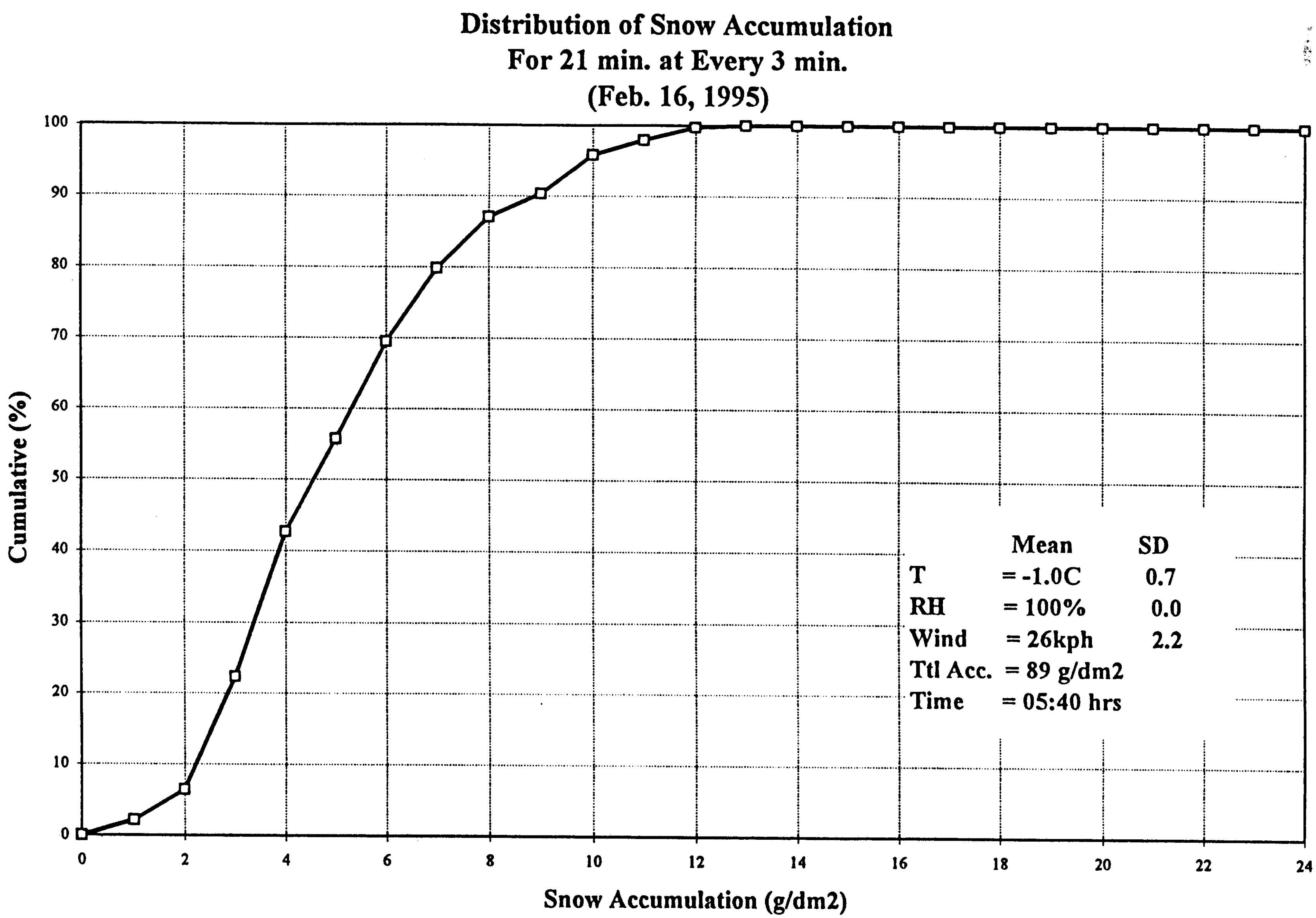
950112.XLS

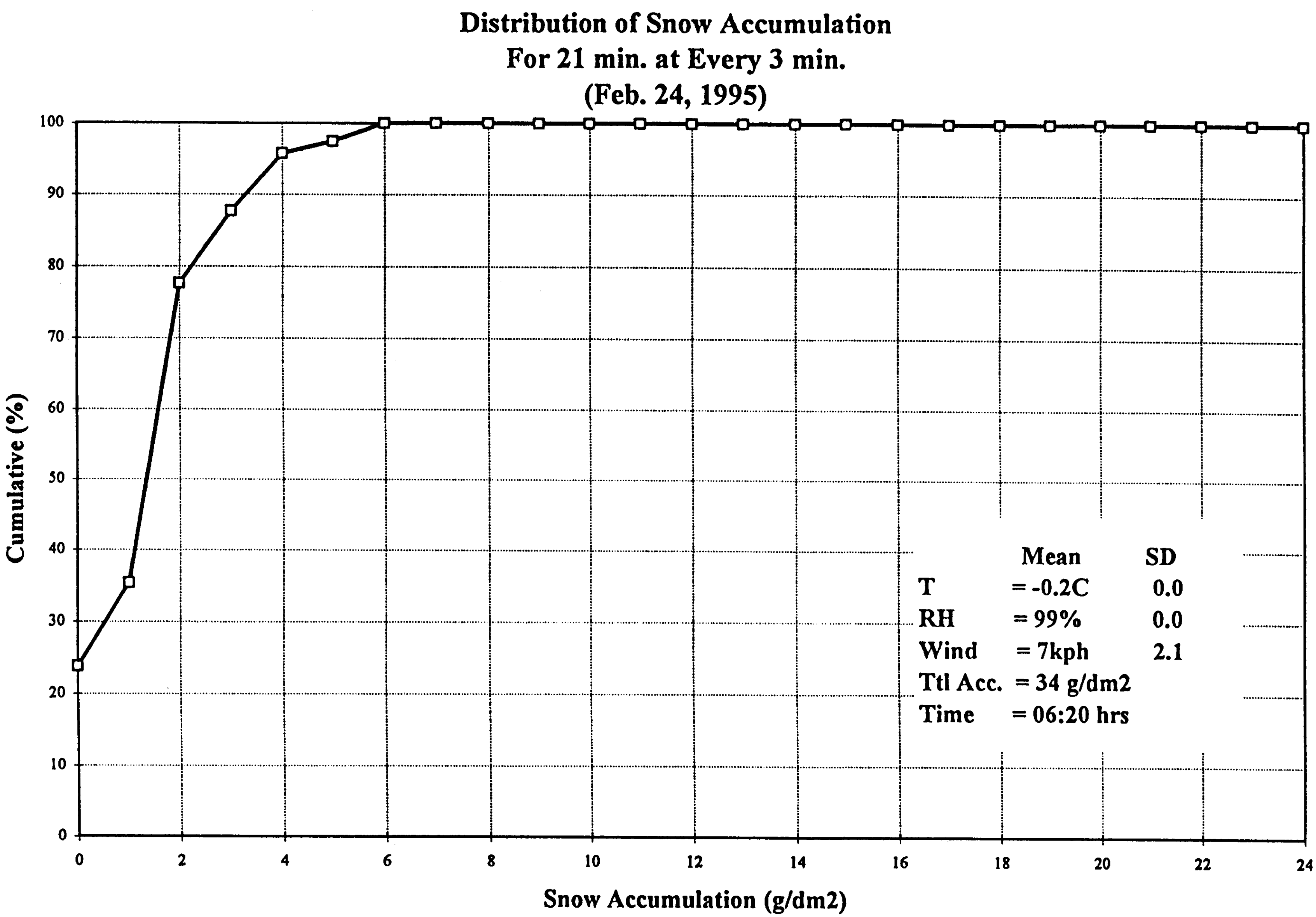
18/8/95 15:34


Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 04, 1995)
100
90
80
70
60
50
40
30
20
10
0
Cumulative (%)
0
2
4
6
8
10
12
14
16
18
20
22
24
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 21 min. at Every 3 min.
(Feb. 11, 1995)

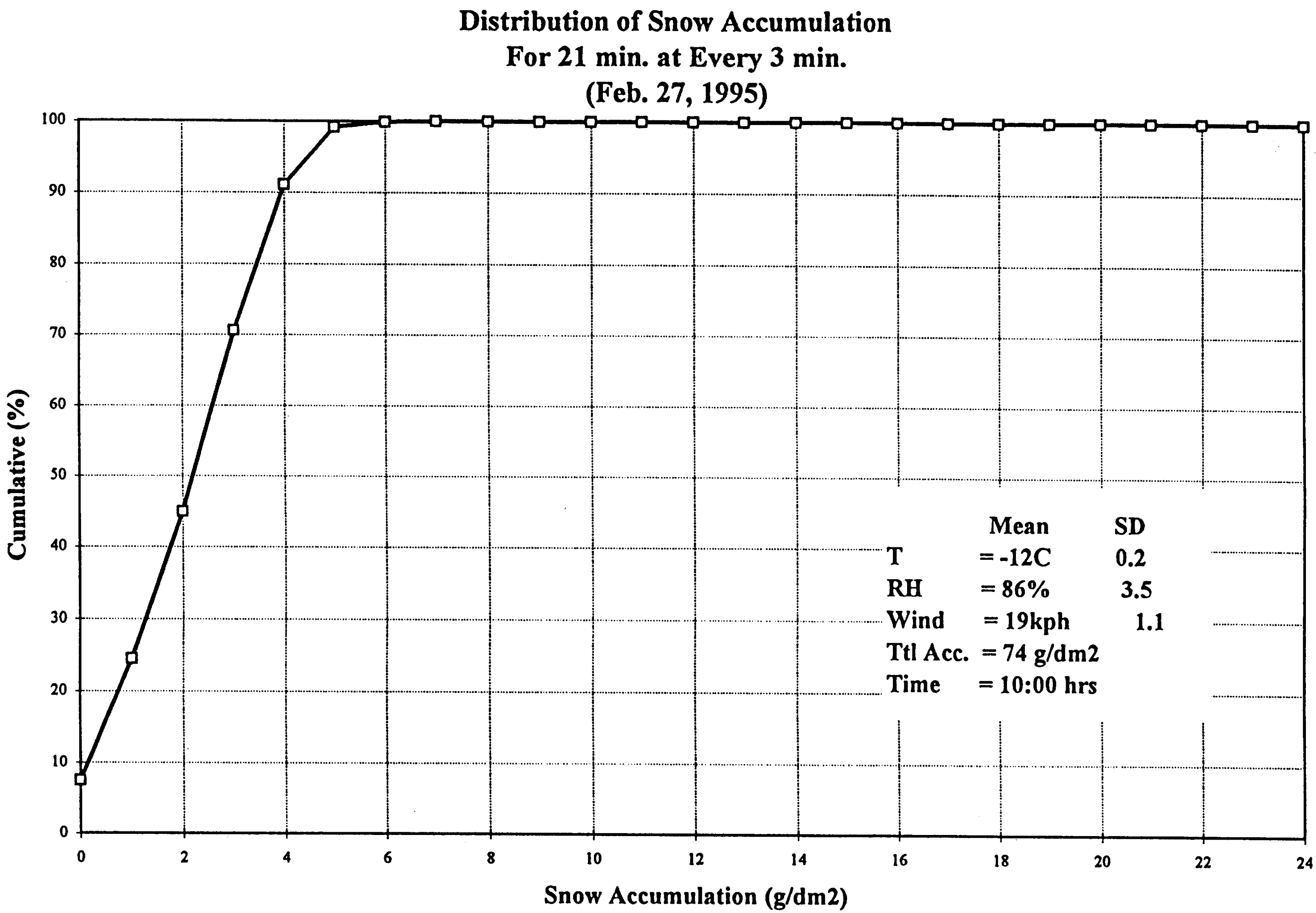



Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 16, 1995)
Cumulative (%)
Snow Accumulation (g/dm2)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
20
22
24
Mean
SD
T = -1.0C 0.7
RH = 100% 0.0
Wind = 26kph 2.2
Ttl Acc. = 89 g/dm2
Time = 05:40 hrs

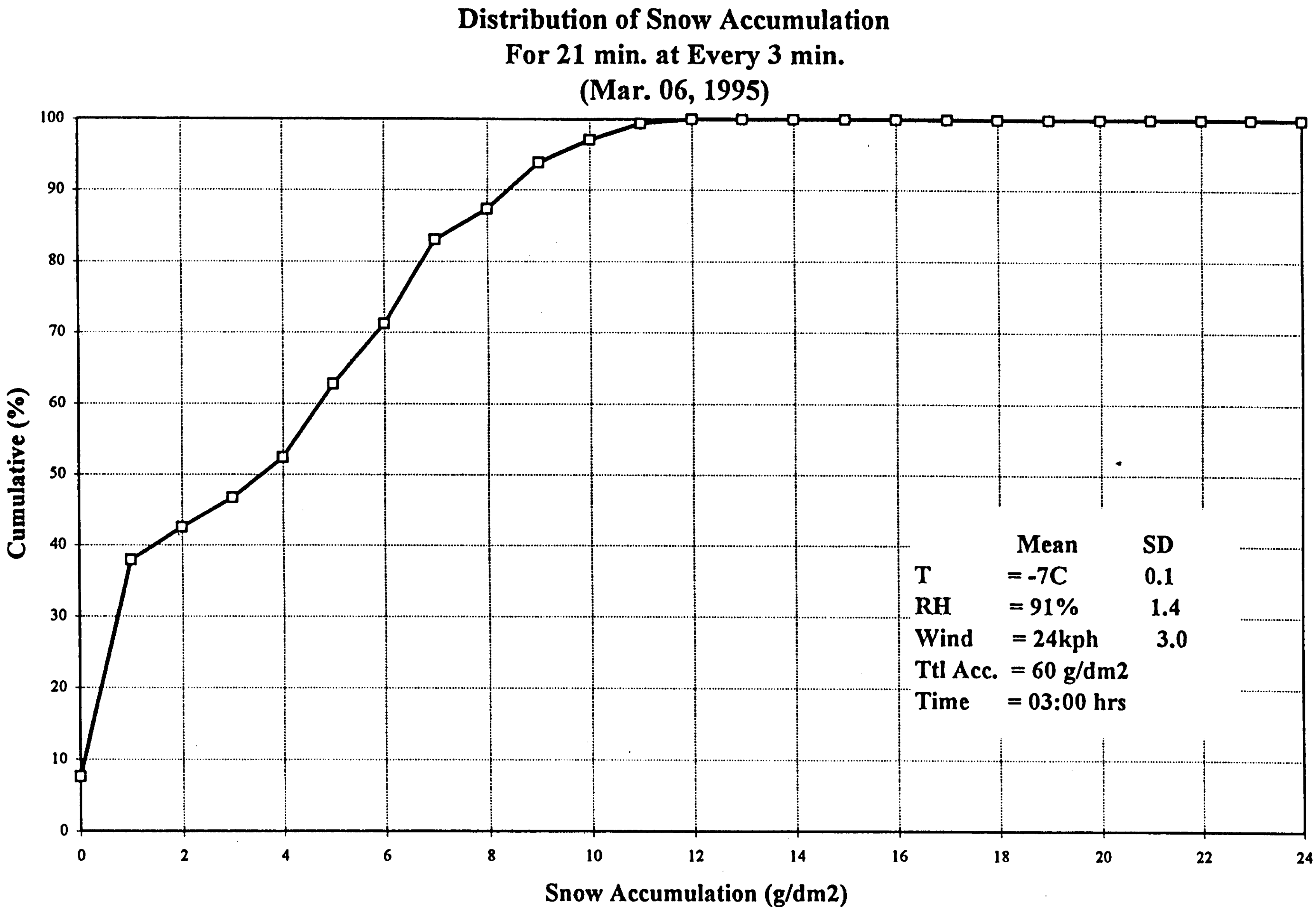


17/8/95 13:37

950224.XLS



Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 27, 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 = -12C 0.2
RH = 86% 3.5
Wind = 19kph 1.1
Ttl Acc. = 74 g/dm2
Time = 10:00 hrs



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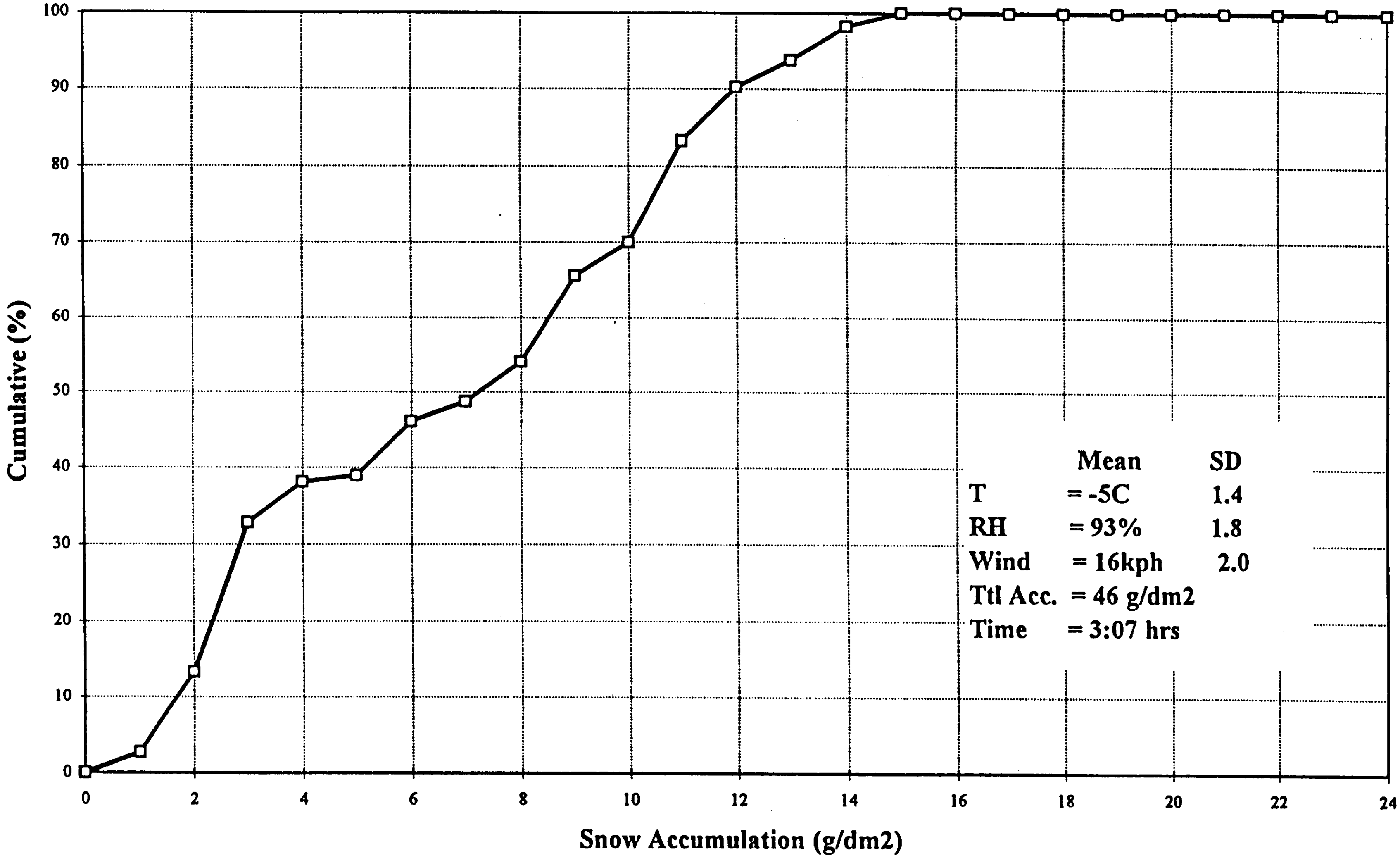
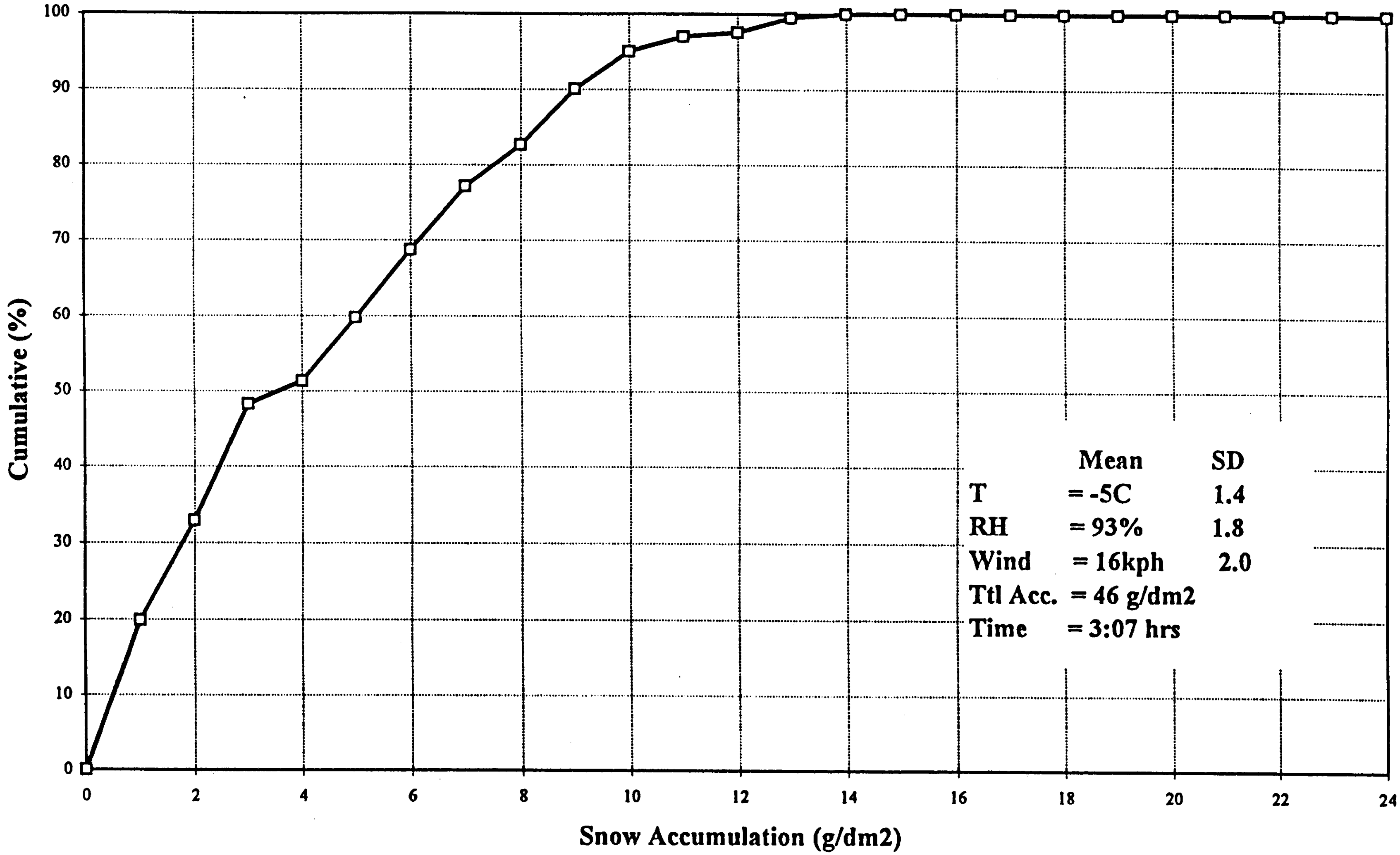
18/8/95 16:03

950306.XLS

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
Mar. 08, 1995. Moorning Storm

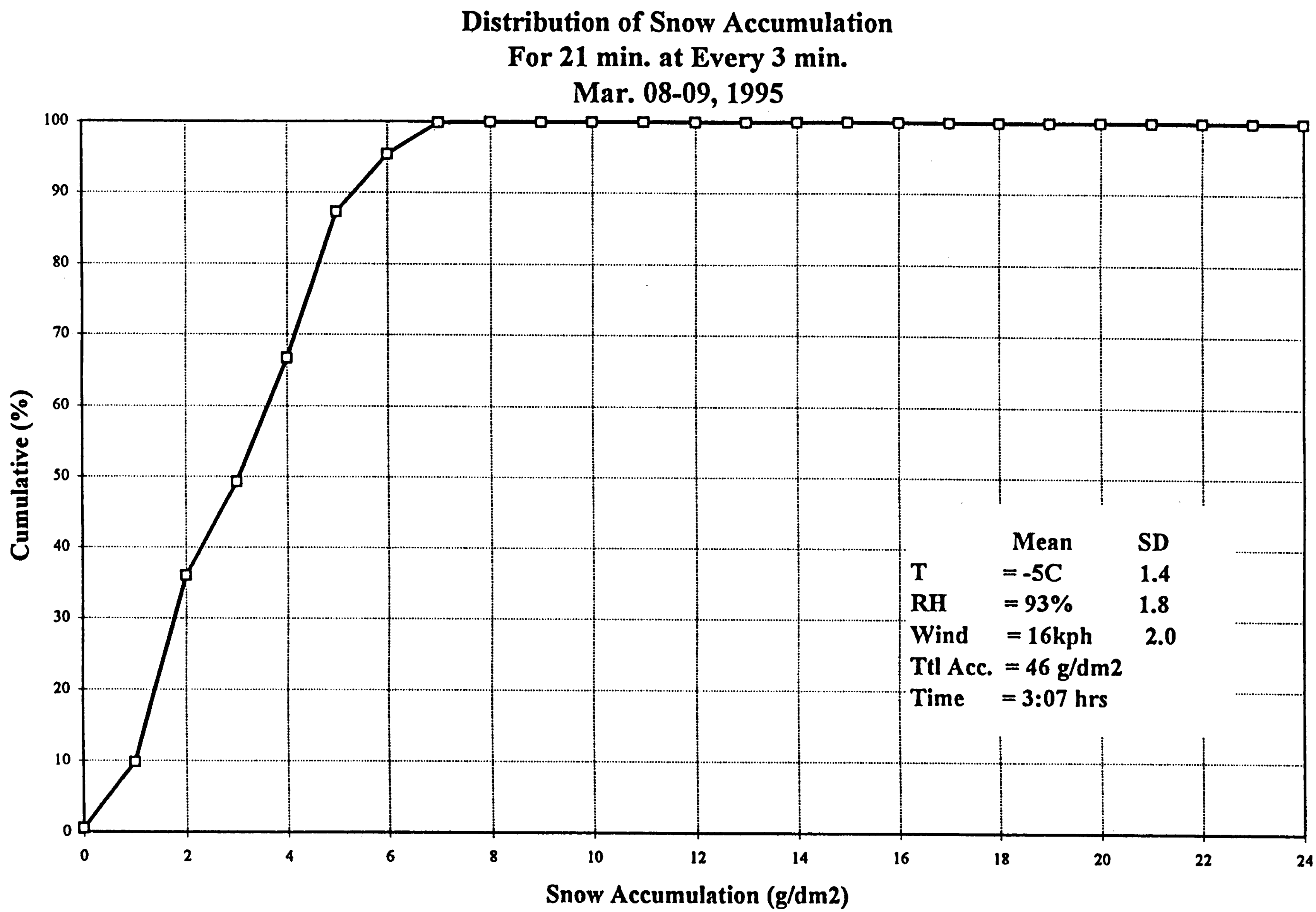


Distribution of Snow Accumulation
For 21 min. at Every 3 min.
Mar. 08, 1995. Afternoon Storm



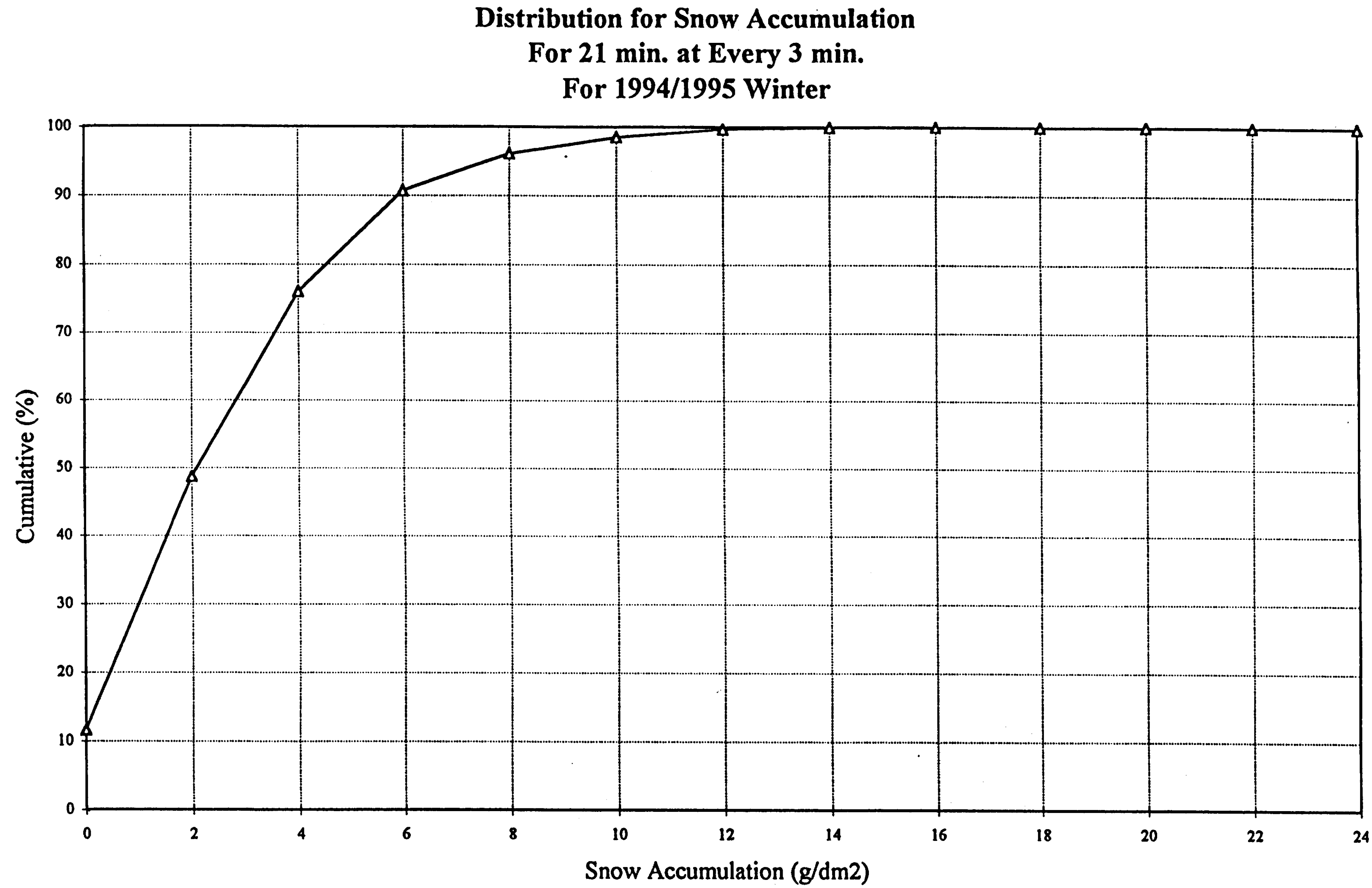
18/8/95 15:58

950308.XLS



17/8/95 13:43

950308.XLS



18/8/95 15:25

MHIST95.XLS

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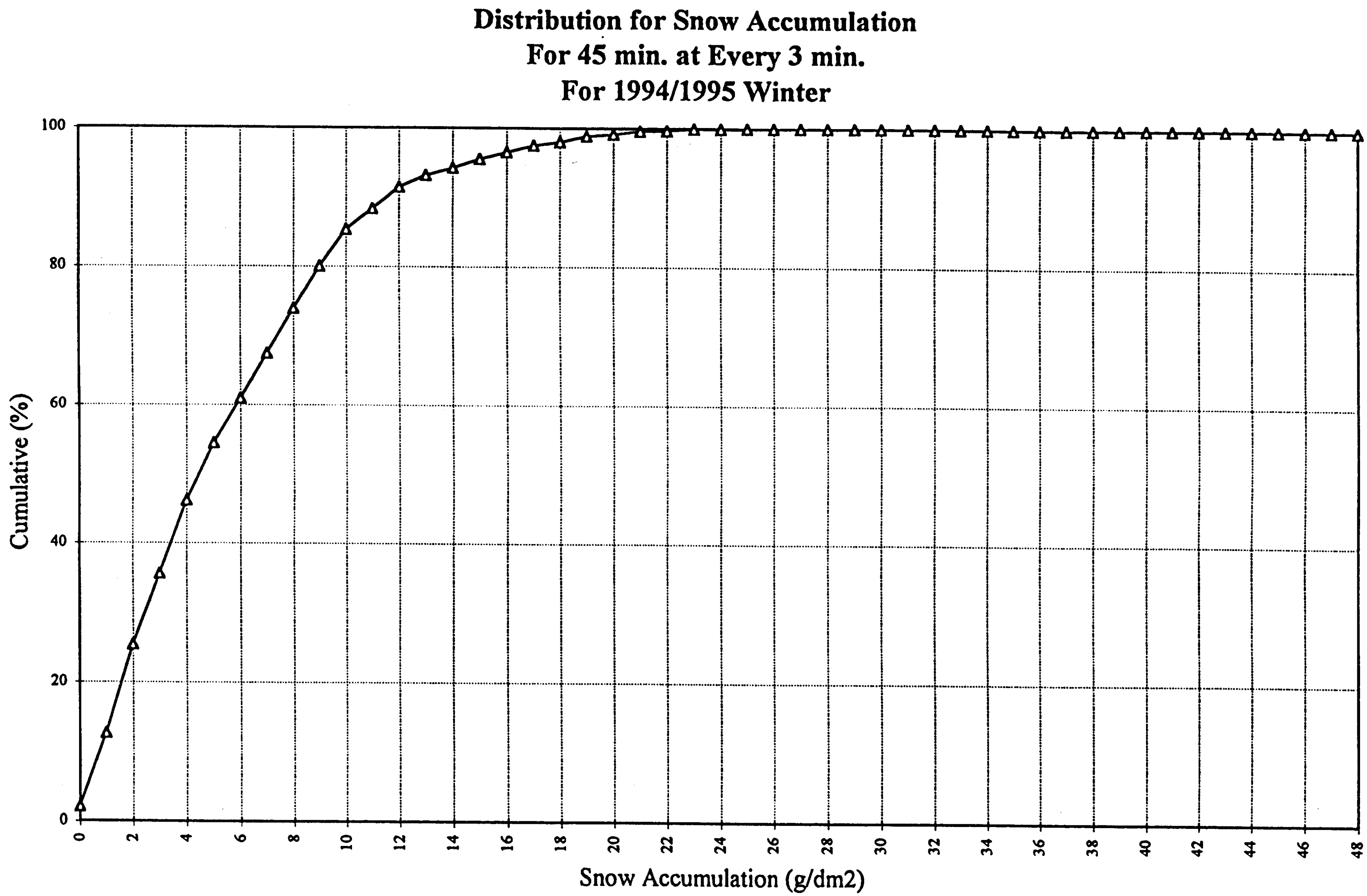
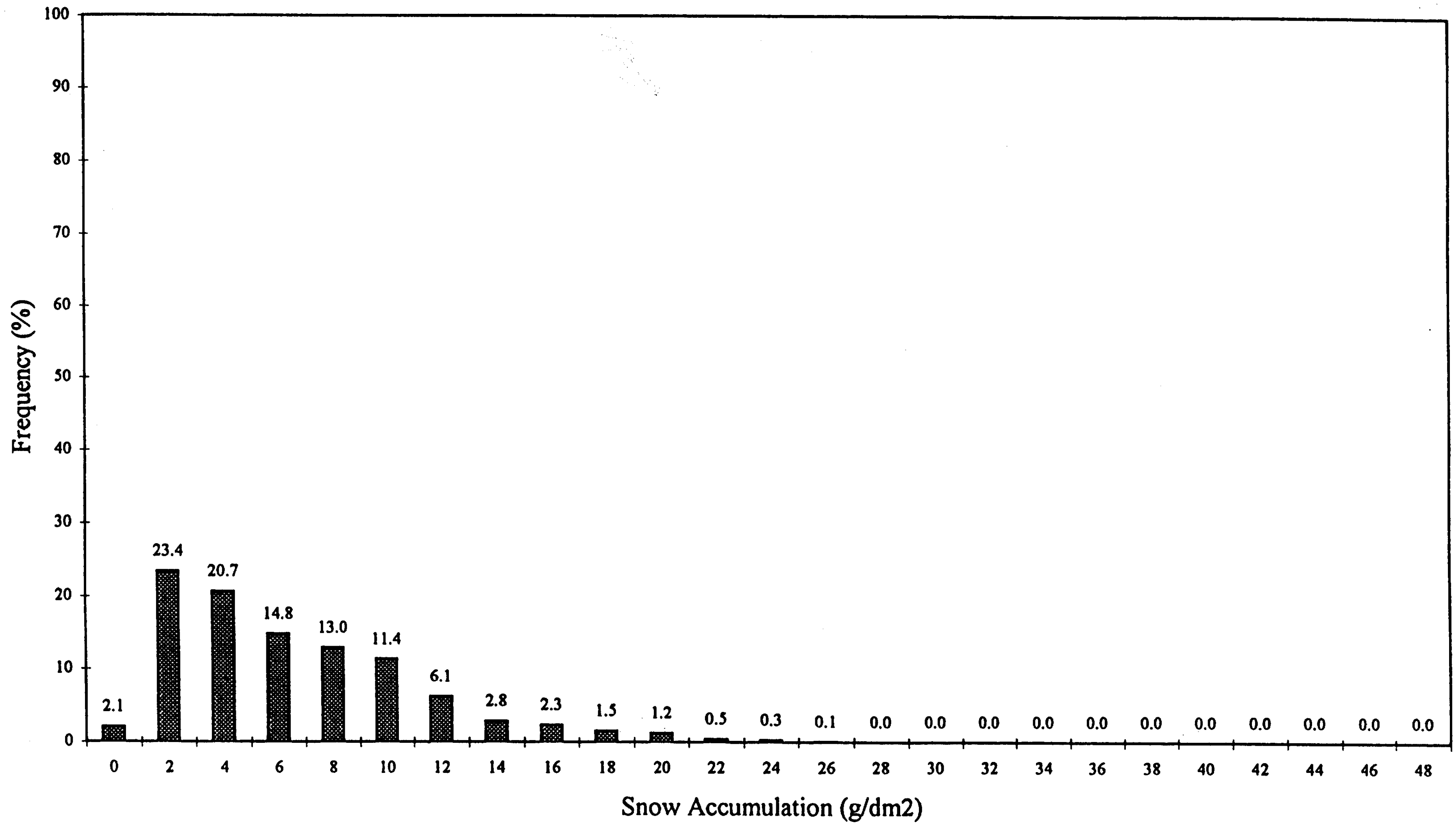


18/8/95 14:32

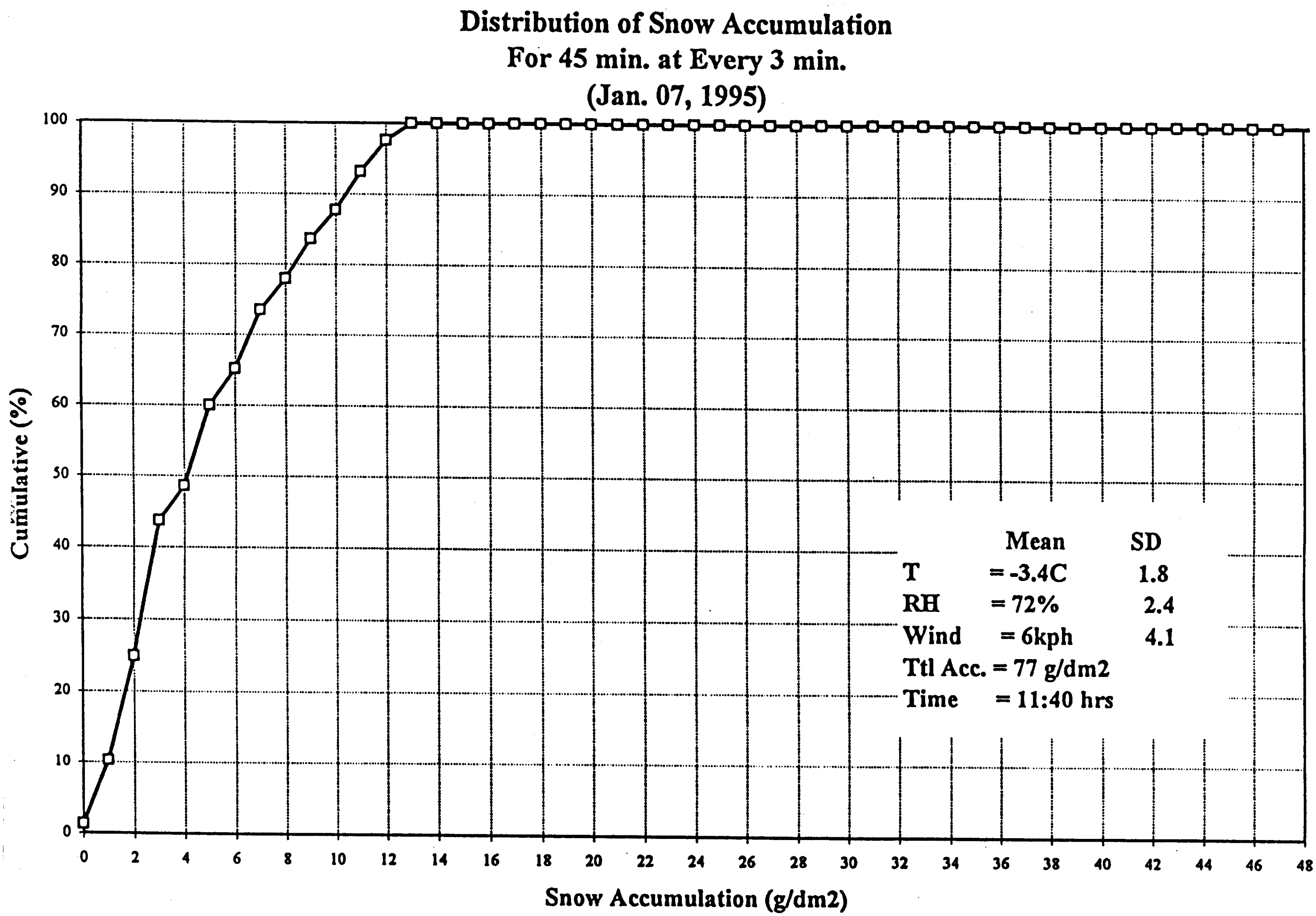
MHIST95.XLS

Histogram for Snow Accumulation
For 45 min. at Every 3 min.
For 1994/1995 Winter



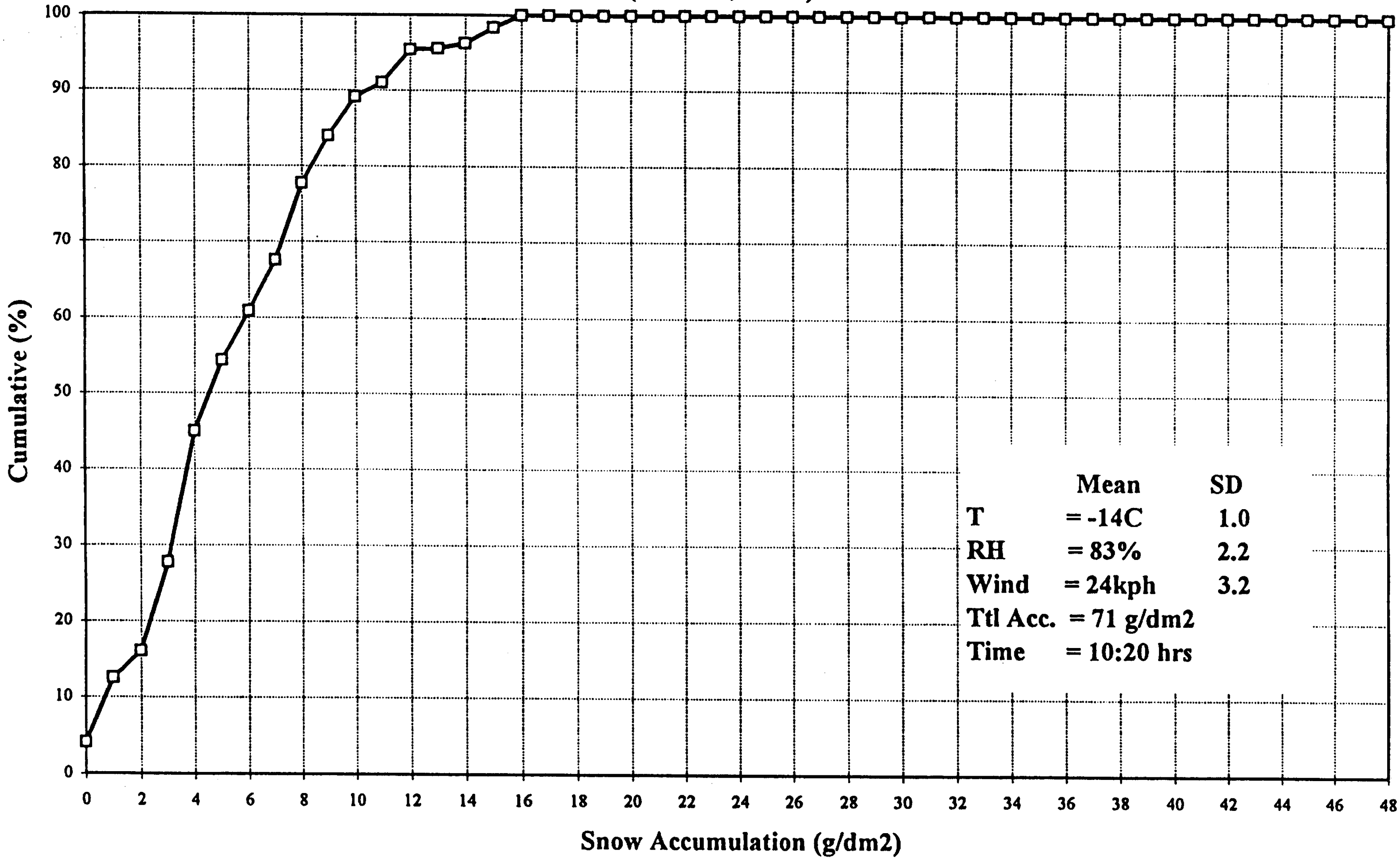
18/8/95 14:28

MHIST95.XLS



Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 07, 1995)
Cumulative (%)
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)



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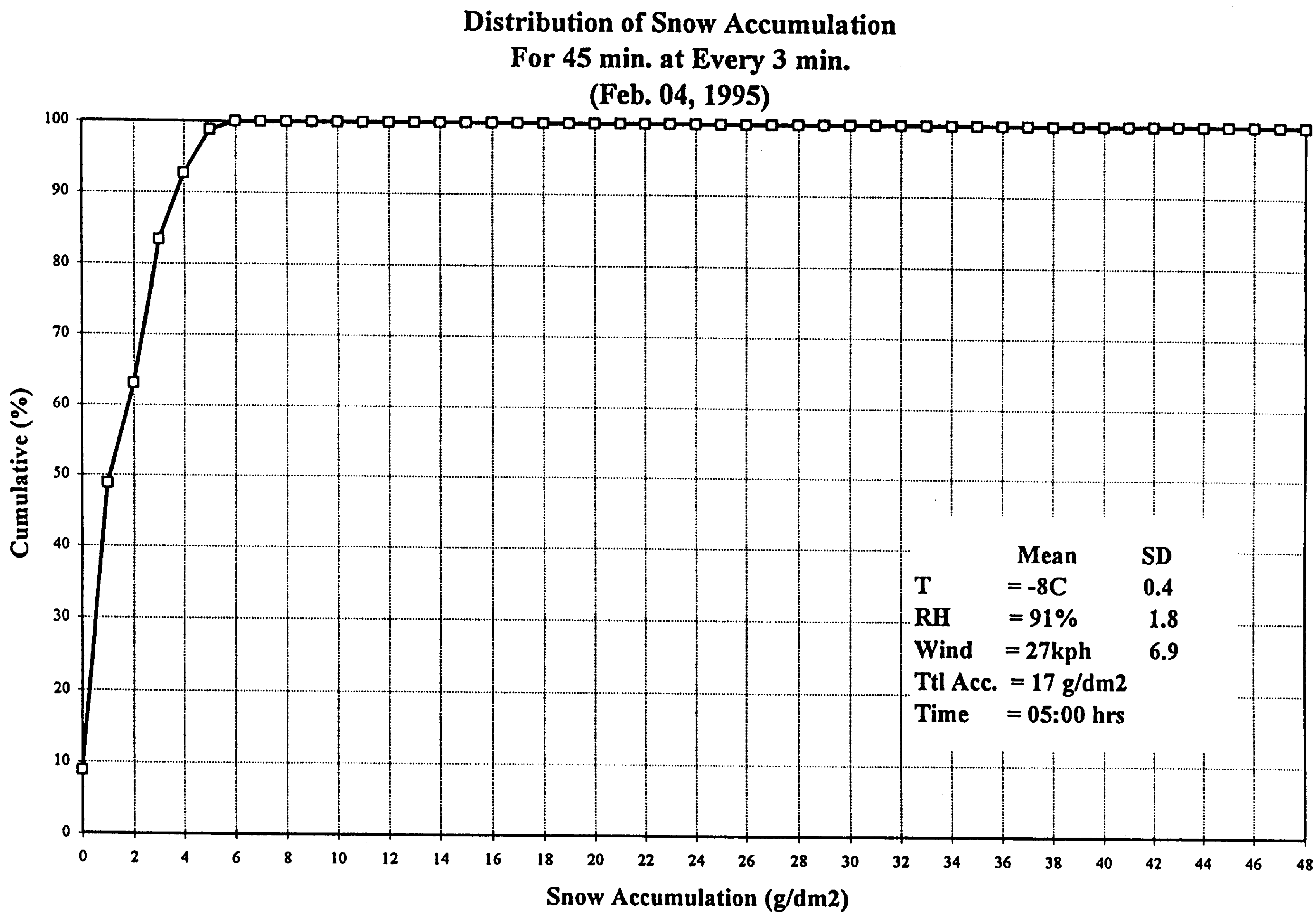
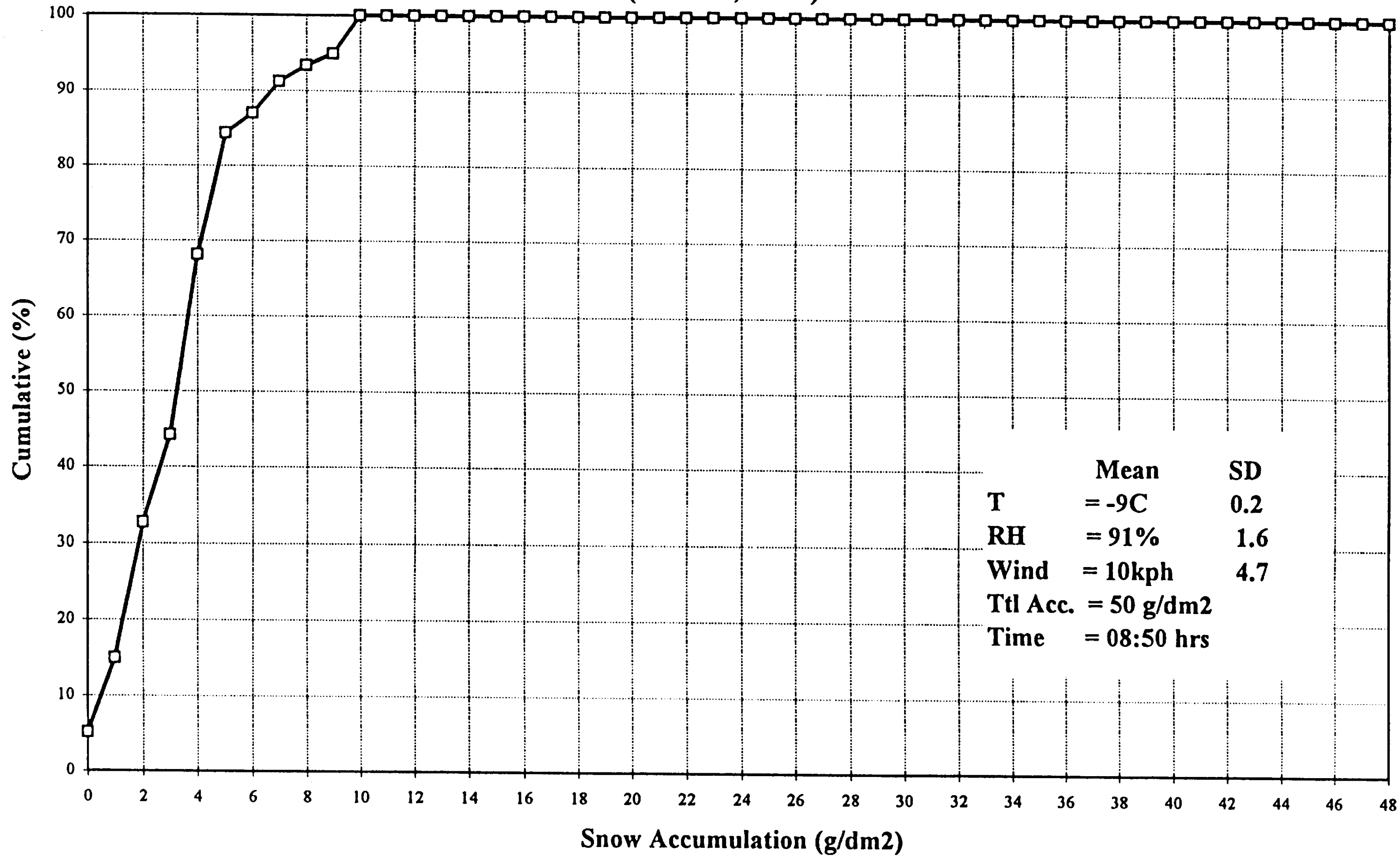
18/8/95 15:34

950112.XLS



Distribution of Snow Accumulation
For 45 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
26
28
30
32
34
36
38
40
42
44
46
48
Mean SD
T = -8C 0.4
RH = 91% 1.8
Wind = 27kph 6.9
Ttl Acc. = 17 g/dm2
Time = 05:00 hrs

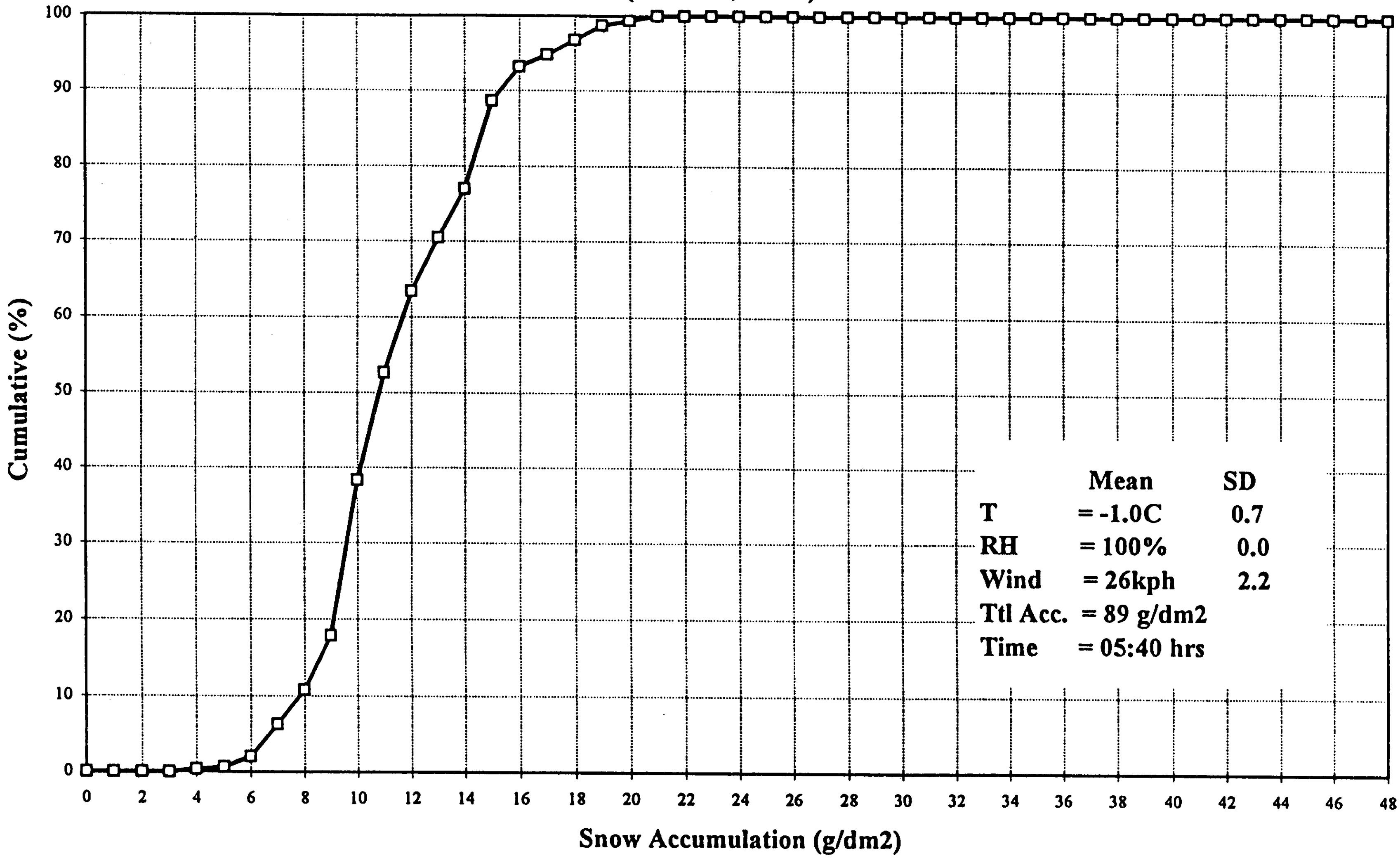
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 11, 1995)



18/8/95 15:49

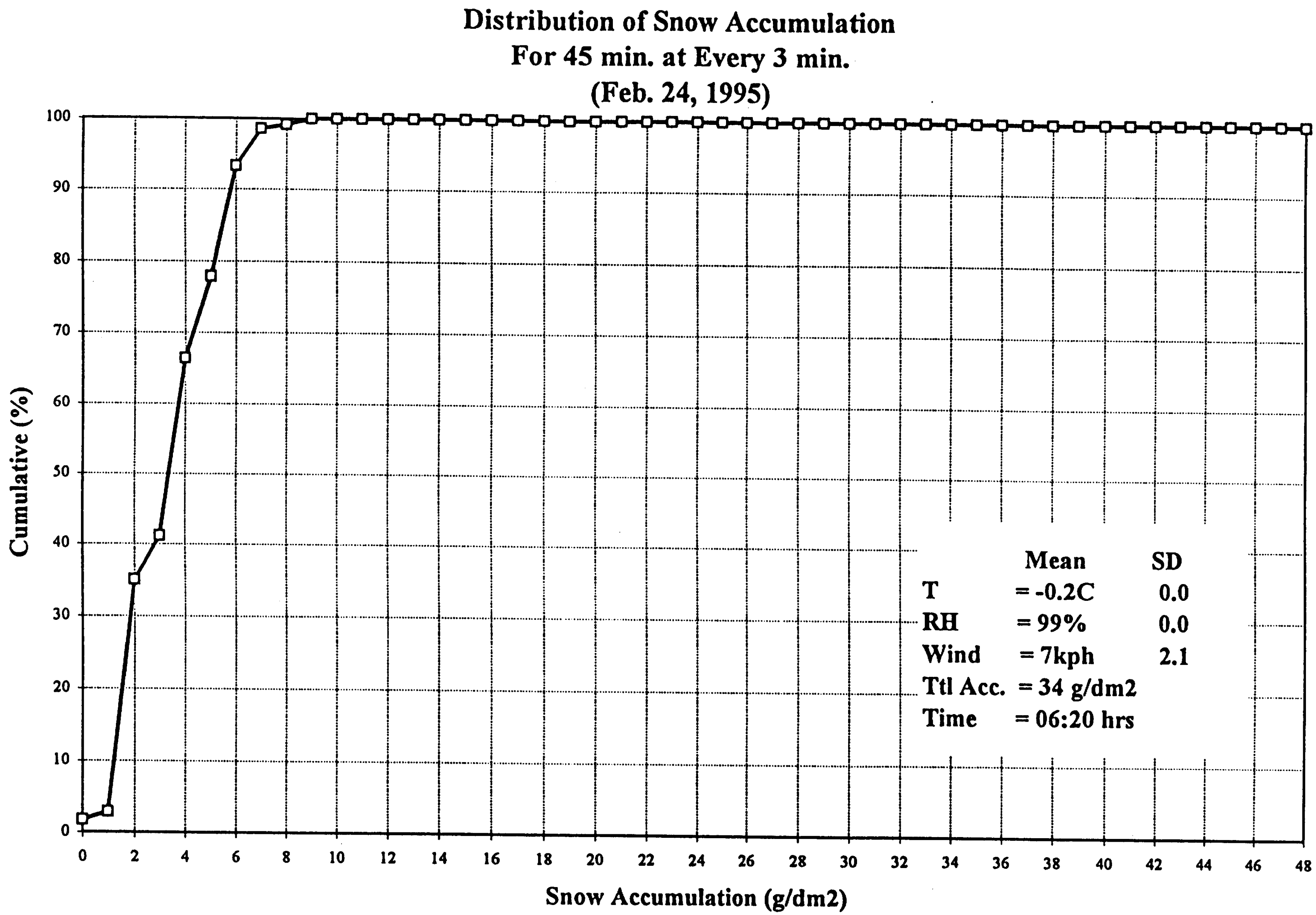
950211.XLS

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 16, 1995)



18/8/95 15:48

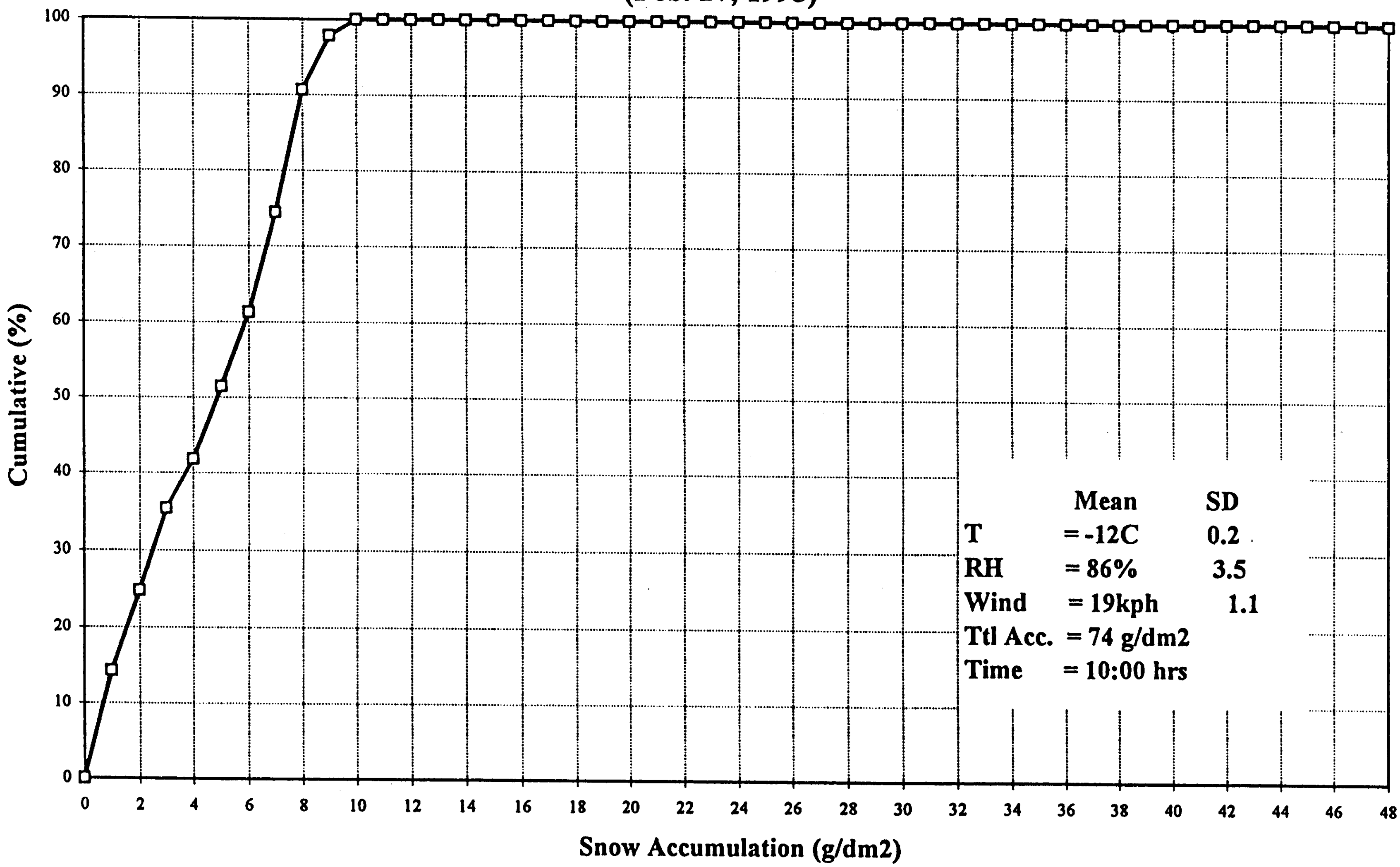
950216.XLS

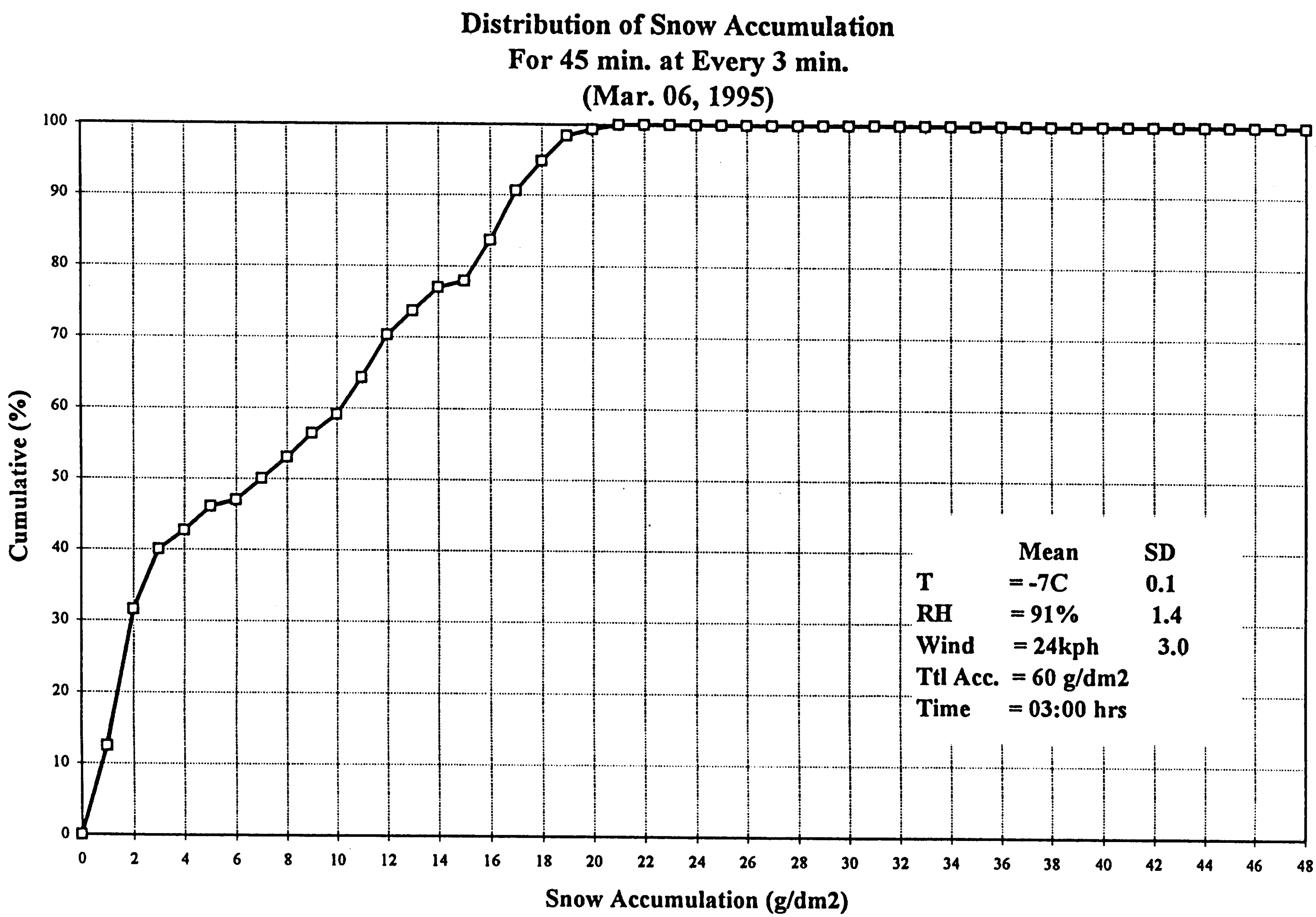


18/8/95 15:44

950224.XLS

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 27, 1995)

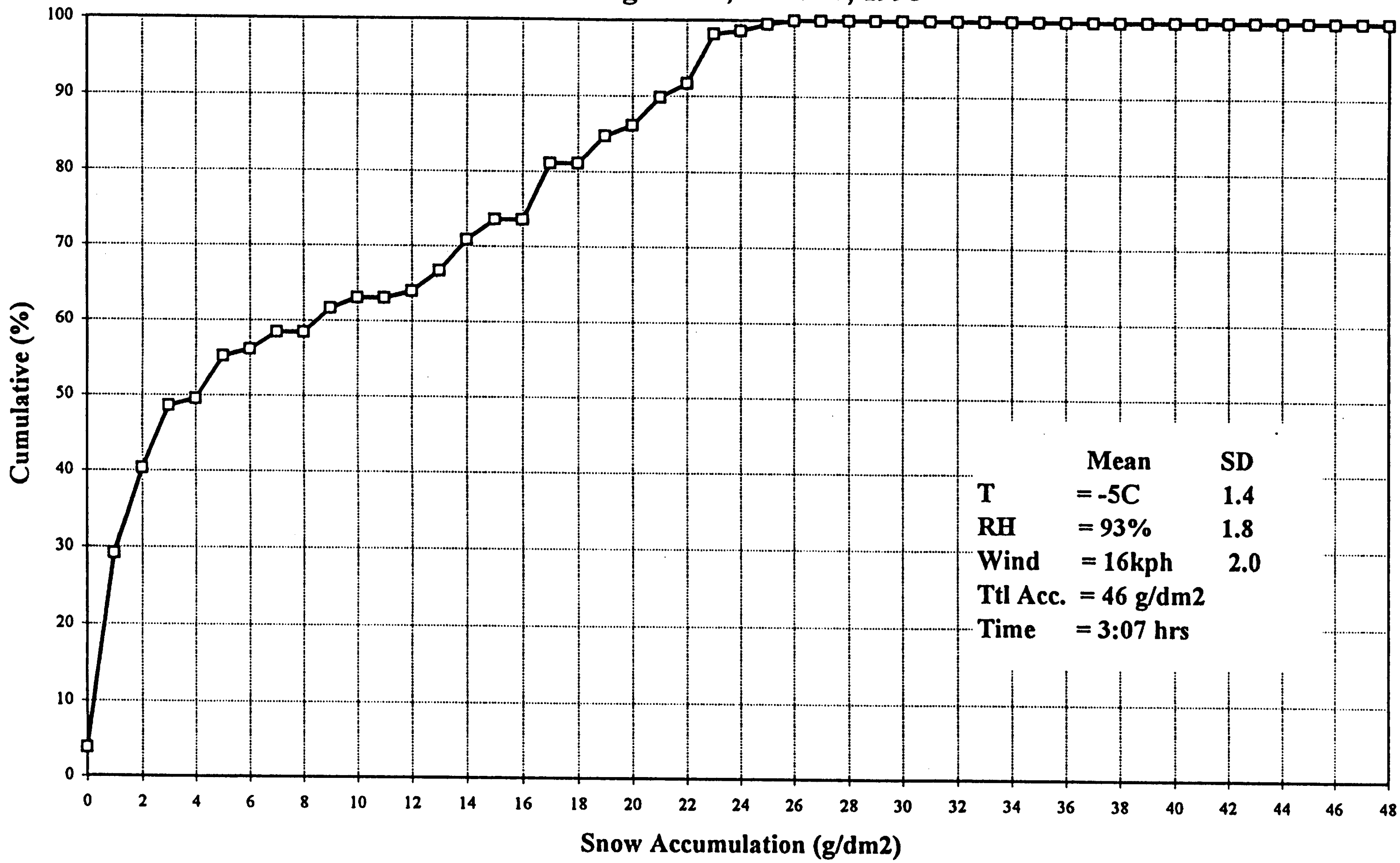




8/8/95 16:03

950306.XLS

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
Morning Storm, Mar. 08, 1995



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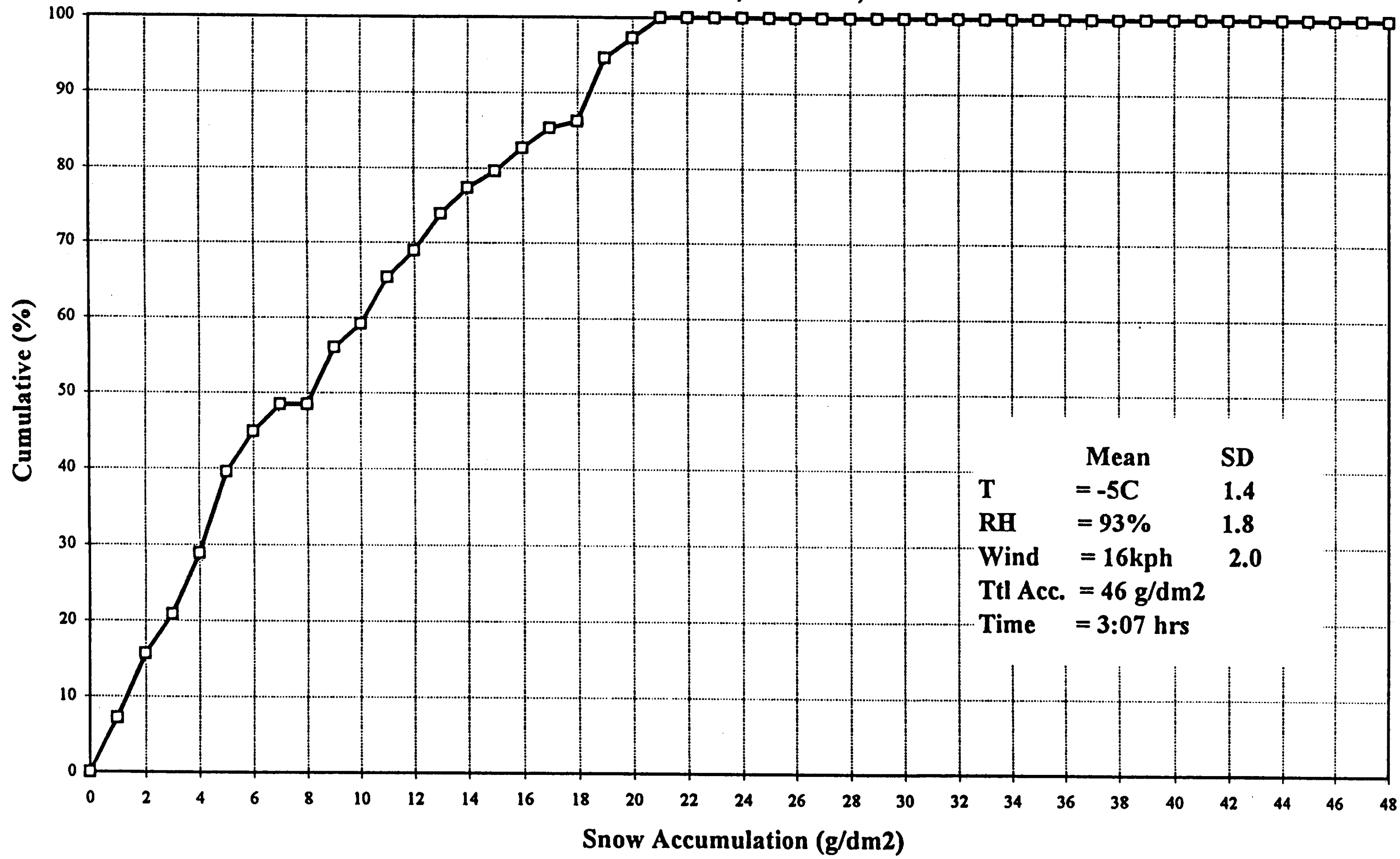
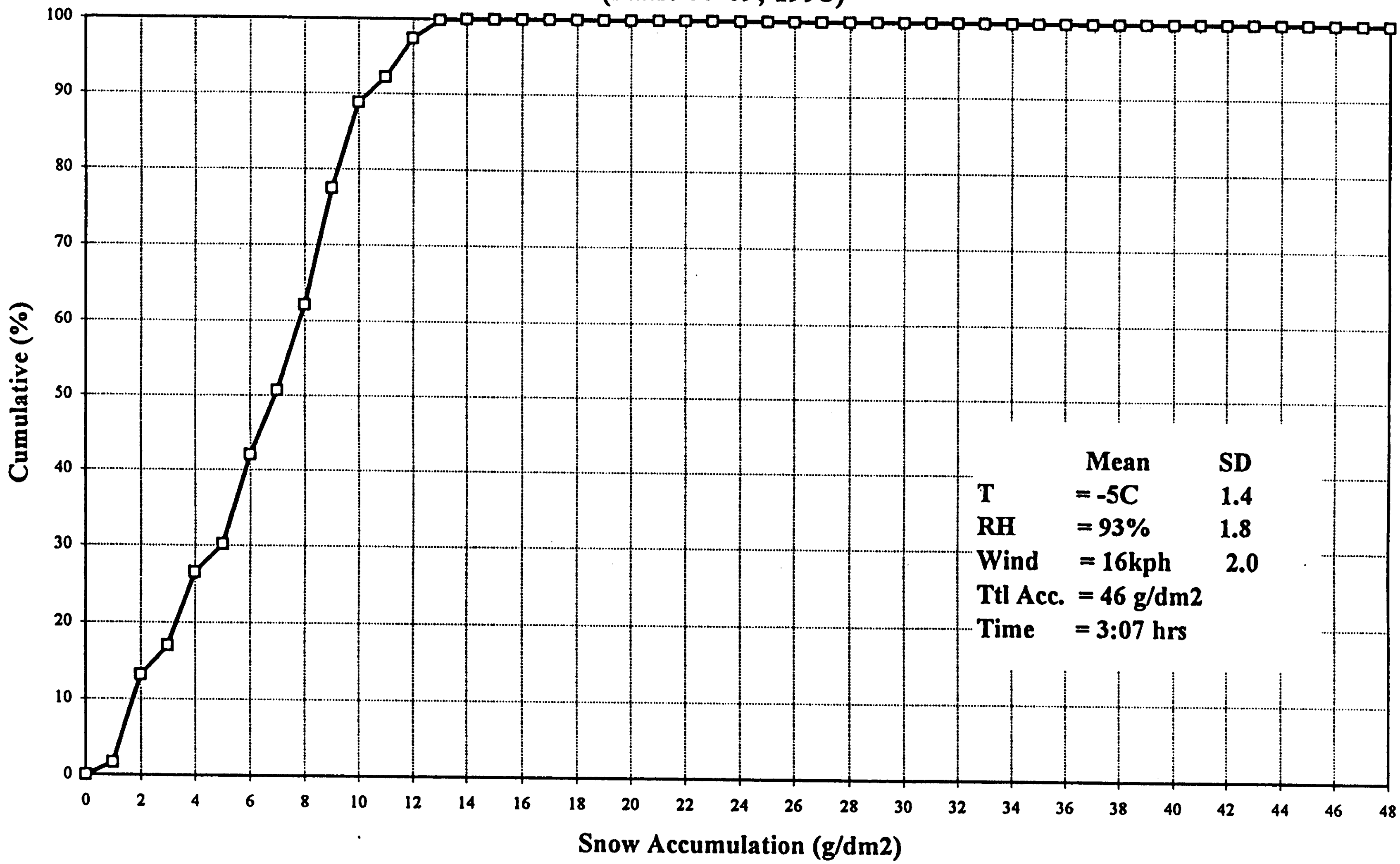
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
Afternoon Storm, Mar. 08, 1995



18/8/95 15:55

950308.XLS

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 08-09, 1995)



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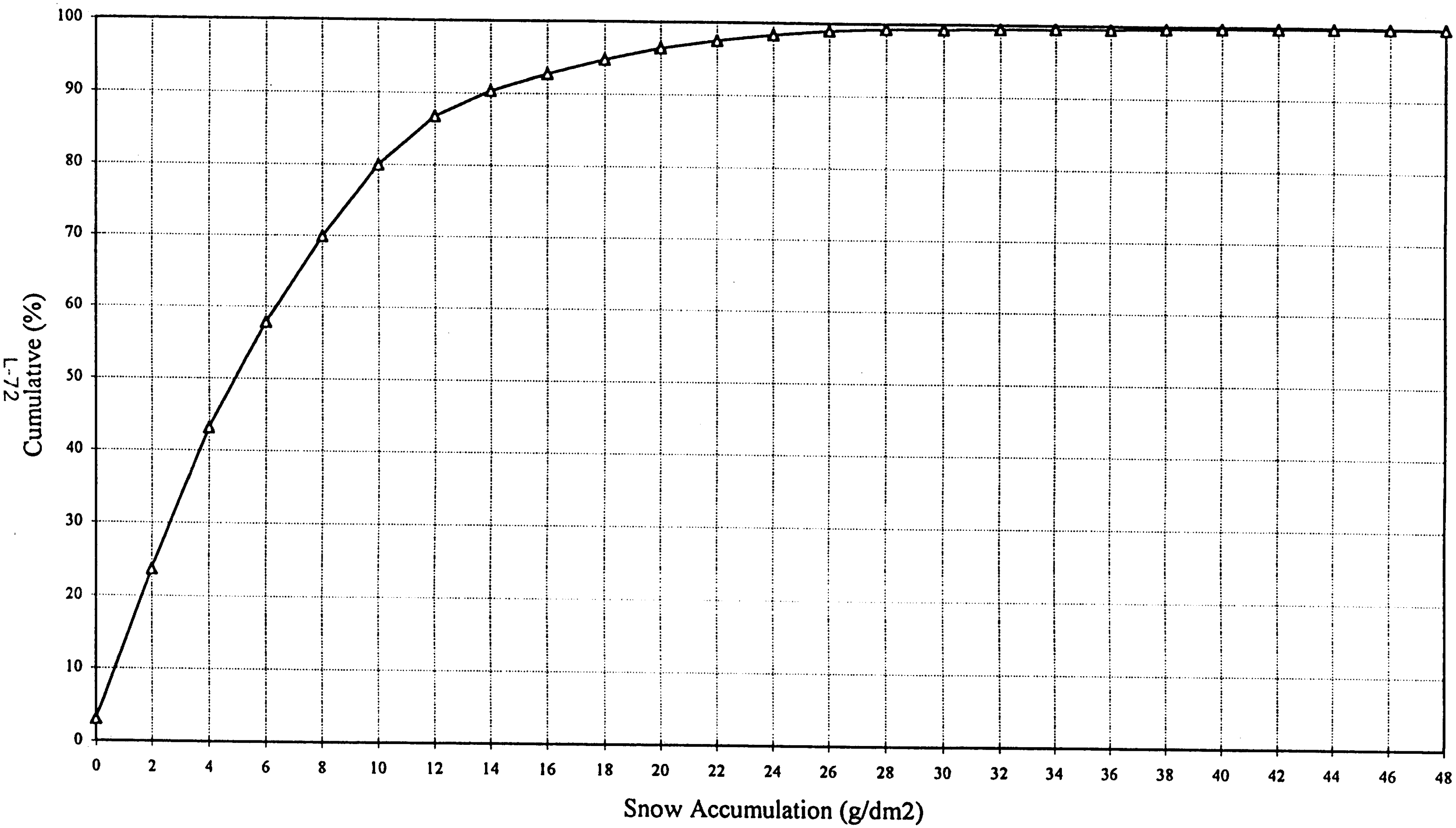
18/8/95 15:55

950308.XLS

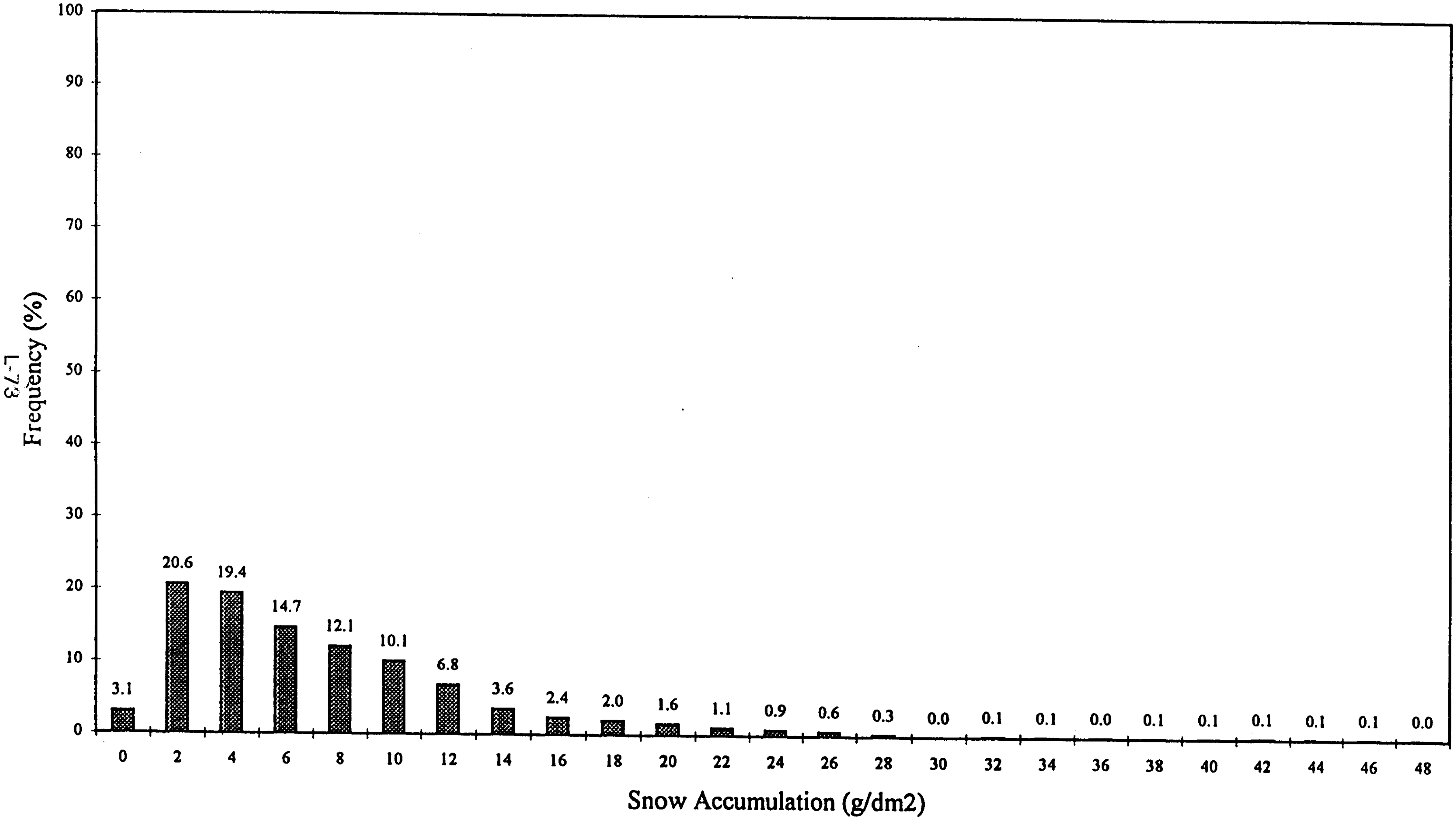
Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/94-1994/95 Winters



18/8/95 12:09

MHIST95.XLS

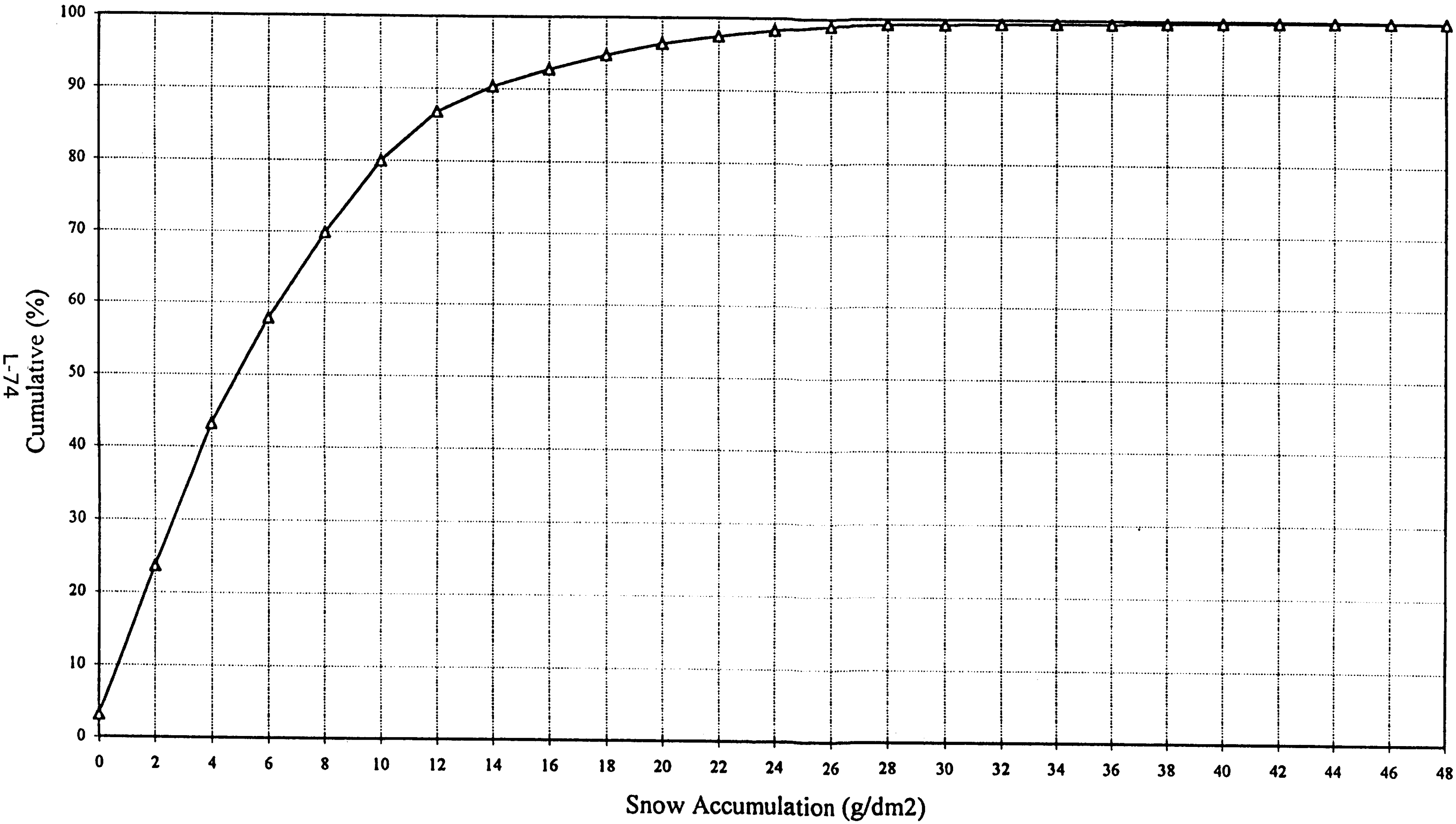
Histogram for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/94-1994/95 Winters



18/8/95 12:10

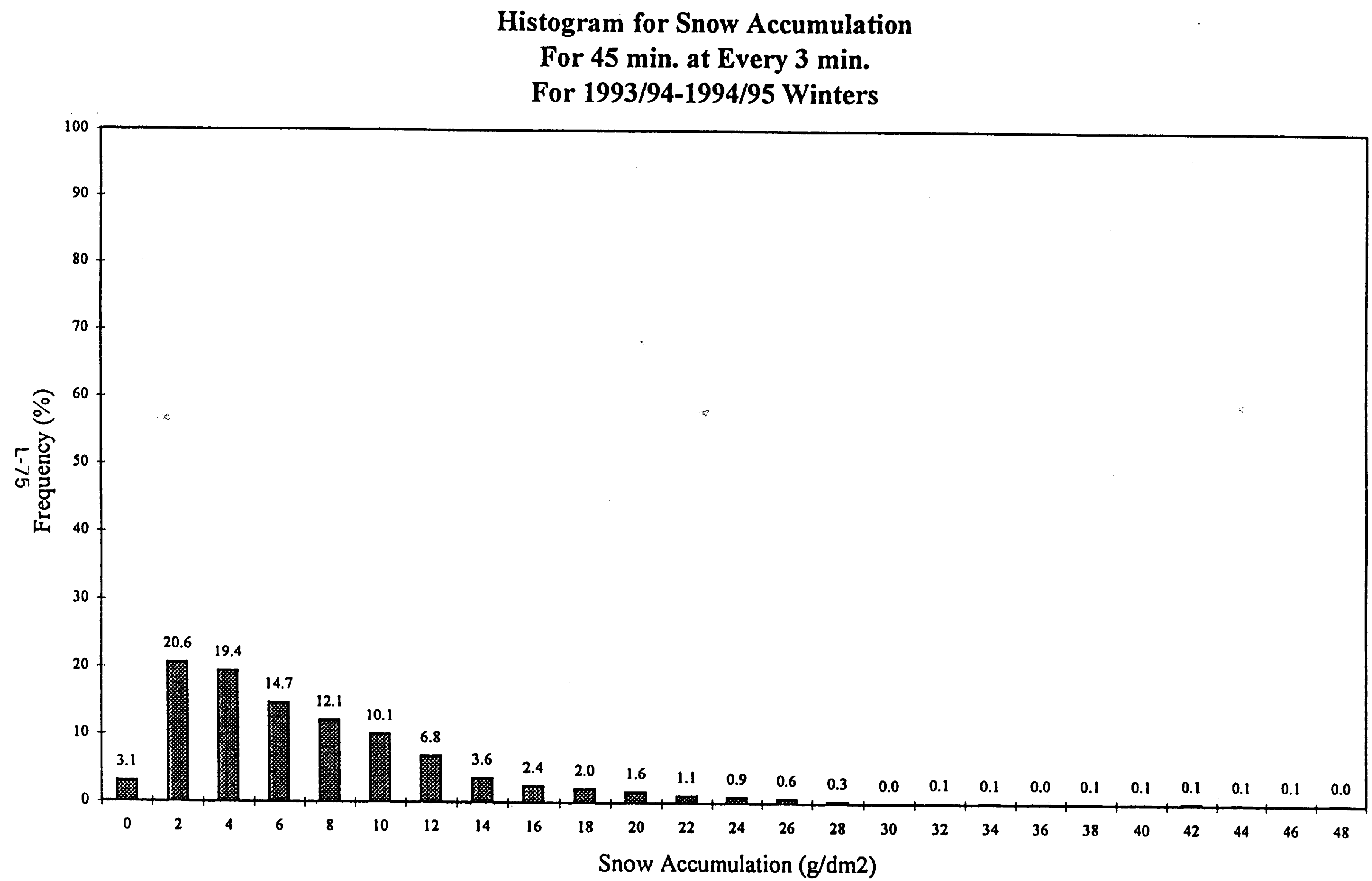
MHIST95.XLS

Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993/94-1994/95 Winters



18/8/95 12:09

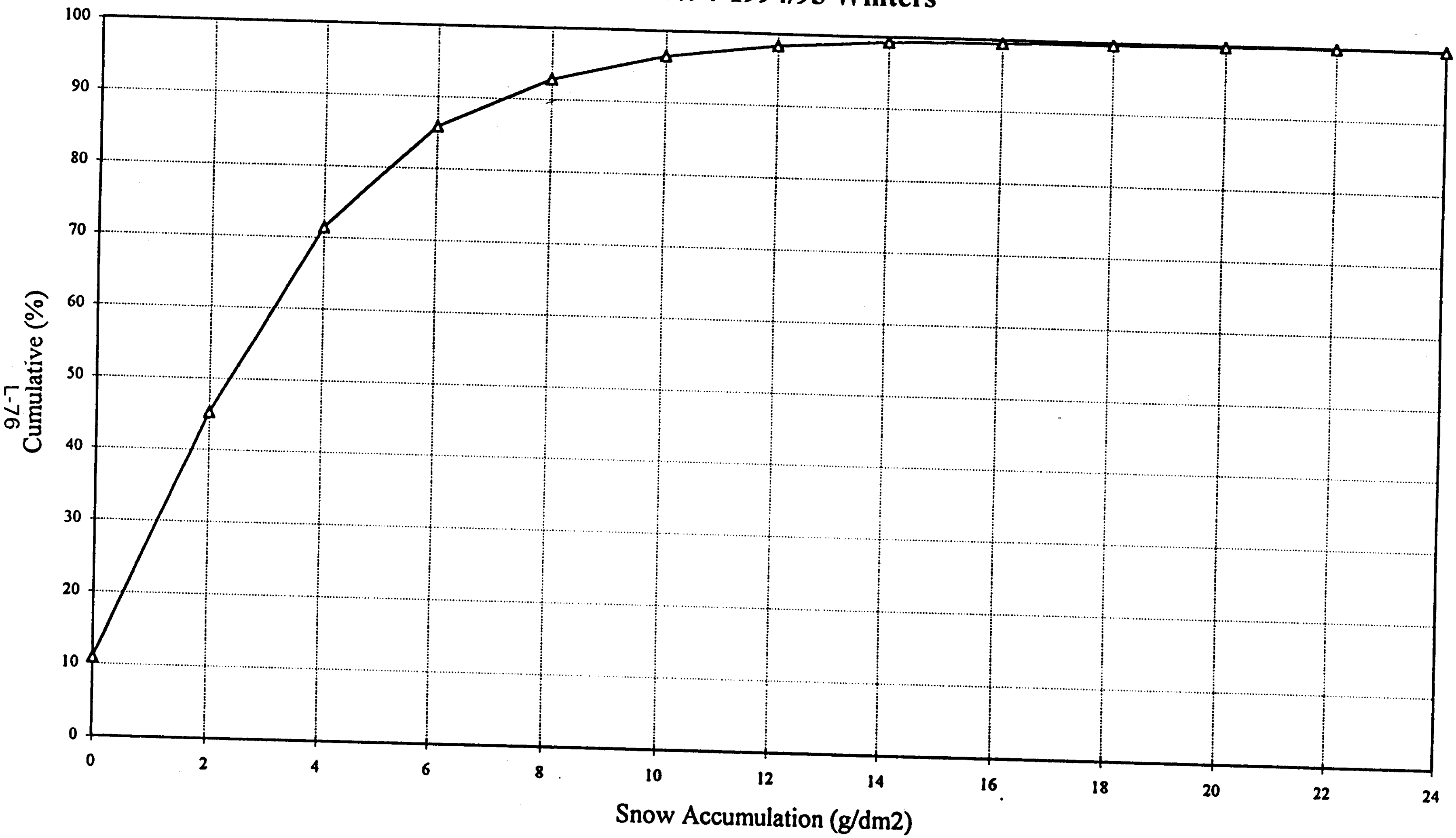
MHIST95.XLS



18/8/95 12:10

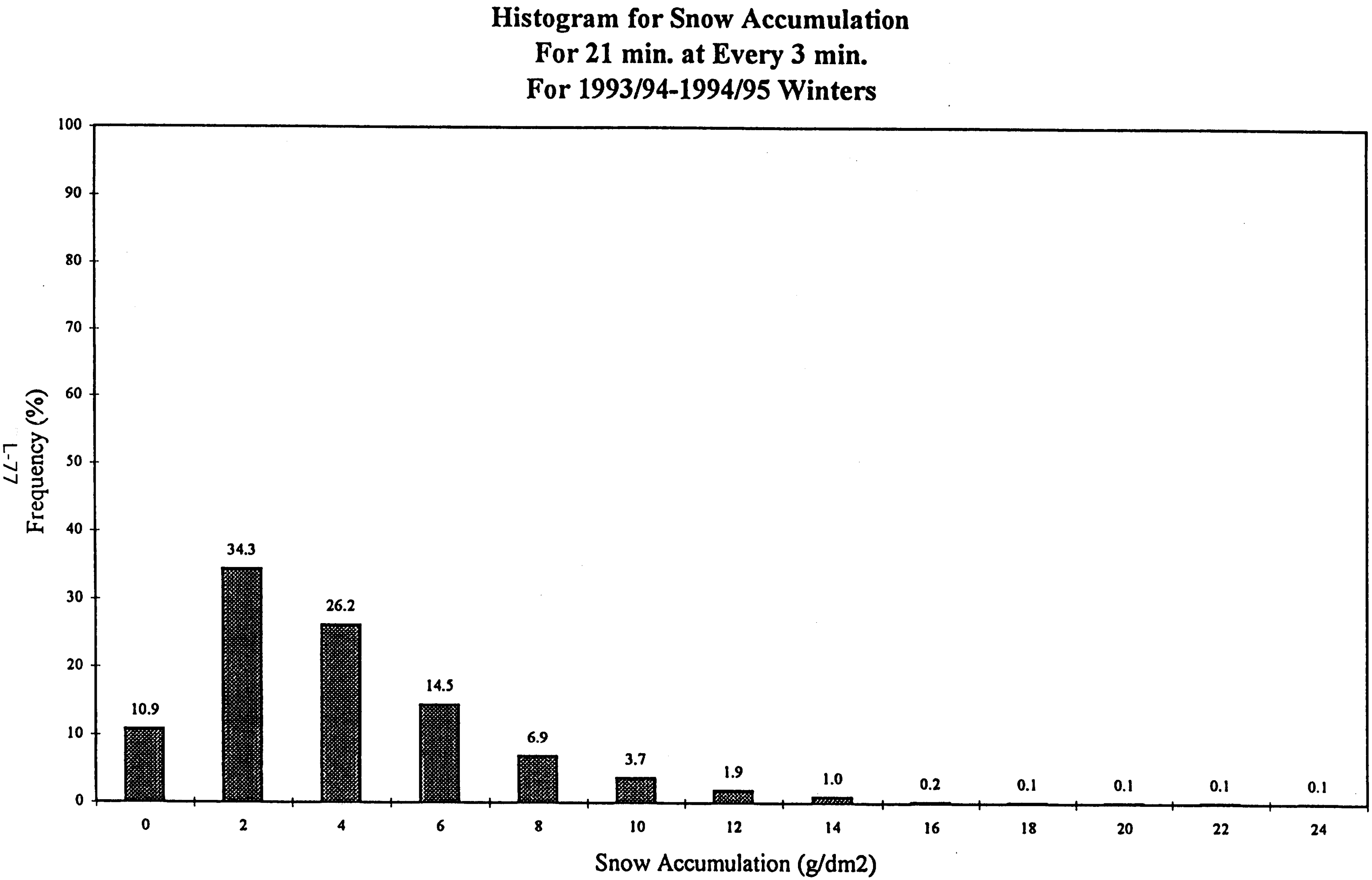
MHIST95.XLS

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993/94-1994/95 Winters



17/8/95 13:55

MHIST95.XLS



17/8/95 12:10

MHIST95.XLS