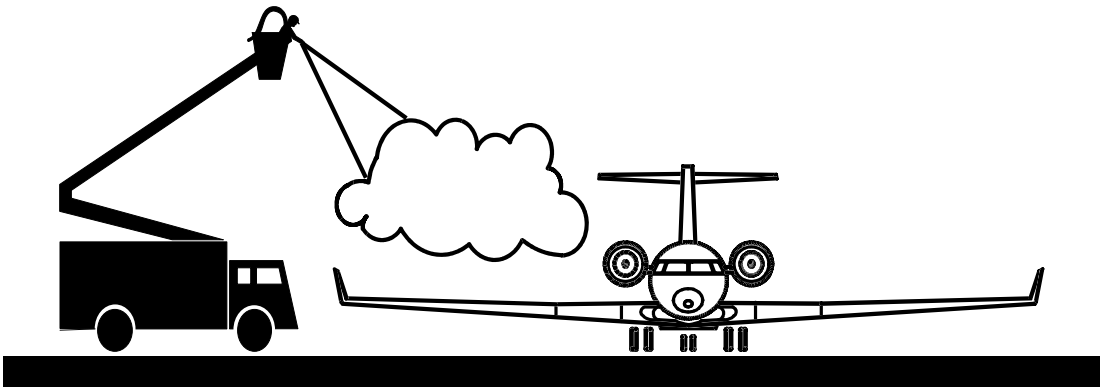
TP 13318E

# Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1997-98 Winter



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on behalf of

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**Safety and Security**
**Transport Canada**

and

**The Federal Aviation Administration**
**William J. Hughes Technical Centre**

by

*APS AVIATION INC.*

December 1998

Final Version 1.0

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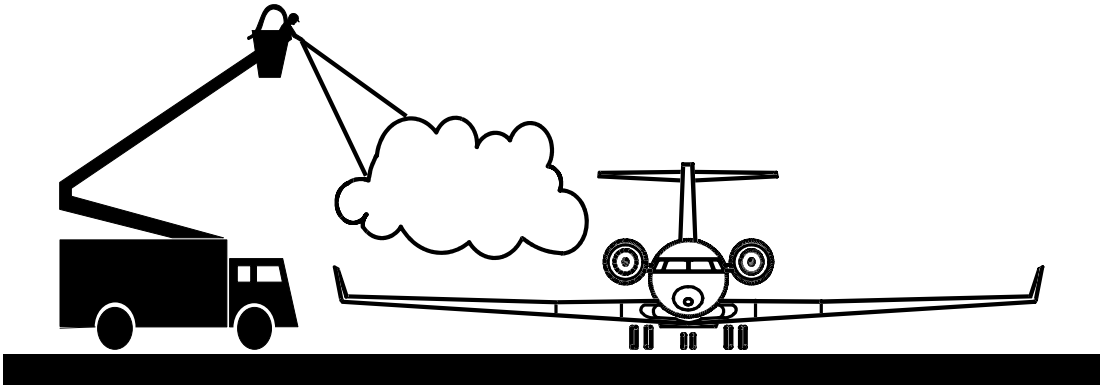

by

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APS AVIATION INC.

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

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

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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 to support the 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 tests 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 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;

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

• TP 13489E Deicing with a Mobile Infrared System.

This report, TP 13318E addresses the following objective:

- To conduct flat plate tests under conditions of natural snow and freezing precipitation to record the holdover times, and to develop individual holdover time tables based on samples of new and previously qualified Type IV fluids under as wide a range of conditions as possible.

This objective was met by conducting tests on different Type IV fluids in simulated freezing precipitation at National Research Council Canada's Climatic Engineering Facility in Ottawa, as well as tests in natural snow conditions at the APS test facility at Dorval Airport in Montreal.

## ACKNOWLEDGEMENTS

Research has been funded by the Civil Aviation Group, Transport Canada, with support from the Federal Aviation Administration and US Airways Inc. This research program could not have been accomplished without the participation of many organizations. APS would therefore like to thank Transport Canada's Transportation Development Centre, the U.S. Federal Aviation Administration, US Airways Inc., National Research Council Canada, Atmospheric Environment Services, and the fluid manufacturers for their contributions to, and assistance with, the program. Special thanks are extended to US Airways Inc., Air Canada, 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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Research reports produced on behalf of Transport Canada for testing during previous winters are available from the Transportation Development Centre (TDC). Six reports (including this one) were produced as part of this winter's research program (1997-98). Their subject matter is outlined in the preface.

16. Abstract


The primary objective of the 1997-98 holdover time test program was to evaluate the performance of new and previously qualified Type IV fluids over the entire range of conditions encompassed by the holdover time tables. Type IV fluid thickness was evaluated for all fluids used in holdover time testing. Additional tests evaluated the holdover time and compatibility performance of recycled fluids. The effect of different variables, such as test plate slope, wind velocity, and fluid application procedure, on the holdover time of Type IV fluids was also studied.

The holdover time test procedure consisted of pouring fluids onto clean aluminum test surfaces inclined at 10º and recording the onset of failure as a function of time in natural snow and in simulated freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. Type IV fluids, supplied by Clariant, Kilfrost, Octagon, SPCA, and Union Carbide, were tested in neat and diluted forms. Recycled fluids were supplied by Inland Technologies. Over 1200 holdover time tests were performed either at the APS Dorval Airport test facility or at National Research Council Canada's Climatic Engineering Facility in Ottawa.

Type IV fluid holdover times were determined using a multi-variable regression analysis, resulting in the generation of one generic SAE Type IV fluid table and seven *fluid-specific* Type IV fluid tables. Thickness profiles of the Type IV fluids were similar to those observed in 1996-97 tests. The performance of recycled fluids was similar to that of Type I fluids in holdover time and fluid compatibility tests.


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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 principal objectif du programme d'essais de durée d'efficacité de l'hiver 1997-1998 était d'évaluer la performance de liquides de type IV déjà ou nouvellement homologués, dans toute la gamme des conditions météorologiques couvertes par les tableaux des durées d'efficacité. Tous les essais comportaient la mesure de l'épaisseur de la couche de liquide. Des essais complémentaires ont été menés afin d'évaluer la durée d'efficacité et la compatibilité de liquides recyclés. L'effet de différentes variables, comme l'inclinaison de la plaque d'essai, la vitesse du vent et la méthode d'application du liquide, sur la durée d'efficacité des liquides de type IV a également été étudiée.

La procédure d'essai de durée d'efficacité consistait à verser les liquides sur des surfaces en aluminium propres, inclinées à 10°, et à noter ensuite l'amorce de la perte d'efficacité en fonction du temps, sous la neige naturelle et dans des conditions simulées de bruine verglaçante, de brouillard verglaçant, de pluie légère verglaçante et de pluie sur une aile sur-refroidie. Les liquides de type IV, fournis par Clariant, Kilfrost, Octagon, SPCA et Union Carbide, ont été essayés purs et dilués. Les liquides recyclés ont été fournis par Inland Technologies. Plus de 1 200 essais ont été réalisés soit au site d'essai d'APS Aviation Inc. à l'Aéroport de Dorval, soit à l'Installation de génie climatique du Conseil national de recherches du Canada à Ottawa.

Les durées d'efficacité des liquides de type IV, déterminées par une analyse de régression multi-dimensionnelle, ont mené à la création d'un tableau générique et de sept tableaux *spécifiques* des durées d'efficacité de liquides de type IV de la SAE. Les profils d'épaisseur des liquides de type IV étaient semblables aux profils observés au cours des essais de 1996-1997. Quant aux liquides recyclés, ils ont affiché une performance semblable à celle des liquides de type I aux essais de durée d'efficacité et de compatibilité.


| 17. Mots clés | 18. Diffusion |
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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 pre-flight deicing/anti-icing technology. Other related reports cover a number of the objectives of the test program. The primary objectives specifically addressed in this document were:

- To conduct flat plate tests under conditions of natural and simulated 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 the fluid manufacturers; and
- To conduct flat plate tests to validate *fluid-specific* and SAE tables that currently lack data.

The principal supplemental objectives addressed were:

- To evaluate the holdover time and compatibility performance of recycled fluids;
- To determine the effect of fluid temperature on the holdover time of Type IV fluids;
- To determine the influence of plate slope on the holdover time of Type IV fluids;
- To determine the influence of fluid application procedure on holdover time; and
- To determine the effect of wind on holdover time.

The project involved the participation of several de/anti-icing fluid manufacturers, the Transportation Development Centre of Transport Canada, National Research Council Canada (NRC), the U.S. Federal Aviation Administration, and Atmospheric Environment Services (AES) of Environment Canada.

Holdover time tests consist of pouring freezing point depressant fluids onto clean, flat, inclined, aircraft aluminum plates, which are exposed to an array of natural and artificially produced icing conditions. The elapsed time required to reach a pre-defined end condition is recorded. The end condition and the plate inclination are set according to SAE/ISO (Society of Automotive Engineers/International Organization for Standardization) G-12 Holdover Time Subcommittee guidelines.

The variables measured include failure time, type of precipitation, rate of precipitation, total precipitation, visibility, wind speed, wind direction, ambient temperature, test surface temperature, fluid brand, fluid type, and fluid concentration.

## Data Collection

During the 1997-98 test season, data were collected for tests conducted during natural precipitation events at the APS Dorval Airport test site. Data were also collected for artificial precipitation tests, which included simulated freezing drizzle, light freezing rain, freezing fog, and rain on cold-soaked surfaces. The artificial precipitation tests were performed indoors at NRC's Climatic Engineering Facility in Ottawa. As indicated in Table 1, the majority of the more than 1200 tests were carried out using Type IV fluids under natural snow conditions. The fluids included in the "other" category were Type I, Aeroflot, and recycled fluids.

**TABLE 1**
**TEST DISTRIBUTION**

| CONDITION<br>FLUID TYPE | Natural Snow | Freezing Drizzle | Light Freezing Rain | Freezing Fog | Cold-Soak | Total |
|---|---|---|---|---|---|---|
| Type IV (Neat) | 191 | 83 | 93 | 83 | 37 | 487 |
| Type IV (75/25) | 167 | 85 | 88 | 49 | 36 | 425 |
| Type IV (50/50) | 85 | 42 | 45 | 39 | - | 211 |
| Other | 82 | 31 | 8 | - | - | 121 |
| **Total** | **525** | **241** | **234** | **171** | **73** | **1244** |

## Meteorological Considerations

With the co-operation of AES, APS Aviation was able to obtain detailed meteorological information for the tests at the Dorval site. The data provided by AES instruments were automated and provided minute-by-minute information, such as total precipitation, wind speed and direction, visibility, and temperature. The precipitation collection devices used at the Dorval site consisted of plate pans. Data on precipitation rates for natural snowfall versus temperature were also collected to assist in the determination of precipitation rate limits; this is discussed in Transport Canada report TP 13314E.

## Thickness Tests

Thickness measurements were carried out on Type IV fluid films and thickness profiles for each fluid brand were plotted as a function of time. The thickness profiles for the new Type IV fluids were found to be similar to those observed in thickness tests conducted in 1996-97.

**Holdover Time Tests**

Holdover time tables were developed for seven SAE-qualified Type IV fluids. From the Type IV fluid holdover time tables, a generic SAE holdover time table, consisting of cells containing the worst-performing fluid holdover times, was also developed.

For the seven *fluid-specific* Type IV fluid holdover time tables, the categories of snow, freezing drizzle, and light freezing rain adopted the holdover times determined by using the regression analysis of the data collected for each specific fluid. The remaining categories adopted holdover times identical to the generic SAE table values.

No Type III tests were performed because no Type III fluids were available during the past season. The current Type III holdover time table is not valid, since the numbers within the table were generated using a fluid that is no longer commercially available.

No changes were made to the current Type I fluid holdover times.

Two reductions were made to Type II fluid holdover times. These changes were made to prevent any Type II fluid holdover times from being longer than the Type IV SAE table holdover times.

**Supplementary Tests**

Recycled fluids were subjected to holdover time and fluid compatibility tests, and demonstrated similar performance levels to those of Type I fluids.

A limited number of holdover time tests conducted with a fluid provided by Aeroflot revealed similar performance levels to those of commercial Type I fluids.

Several variables, such as plate slope, fluid application procedure, fluid temperature at application, wind velocity, test surface finish, and fluid viscosity, were studied and deemed to affect the holdover time of Type IV fluids to varying degrees. The most significant effect on holdover time (up to a 50 percent reduction) was observed in holdover time tests conducted with heated Type IV fluids. Because of insufficient test data, no other concrete conclusions were possible when studying other variables.

## Recommendations

Recommendations relating to procedures and equipment, holdover time tests, and supplementary tests are based on this year's tests and results.

## SOMMAIRE

À la demande du Centre de développement des transports de Transports Canada, APS Aviation Inc. a entrepris un programme de recherche qui vise à faire progresser la technologie de dégivrage et de protection antigivre des avions au sol. Plusieurs des objectifs assignés à ce programme sont traités dans une série de rapports déjà publiés. Les grands objectifs de la présente recherche étaient les suivants :

- mener des essais sur plaques planes sous précipitations naturelles et artificielles afin d'enregistrer la durée d'efficacité de liquides, et produire des tableaux individuels des durées d'efficacité à partir des résultats obtenus avec des échantillons de liquides de type IV déjà ou nouvellement homologués, fournis par les fabricants des liquides;
- mener des essais sur plaques planes afin de valider les tableaux *spécifiques* et les tableaux produits par la SAE pour lesquels les données sont actuellement insuffisantes.

D'autres objectifs étaient également poursuivis, soit :

- évaluer la durée d'efficacité et la compatibilité de liquides recyclés;
- déterminer l'effet de la température du liquide sur la durée d'efficacité des liquides de type IV;
- déterminer l'influence de l'inclinaison de la plaque d'essai sur la durée d'efficacité des liquides de type IV;
- déterminer l'influence de la méthode d'application du liquide sur la durée d'efficacité de celui-ci;
- déterminer l'effet du vent sur la durée d'efficacité.

Ont participé au projet plusieurs fabricants de liquides dégivrants/antigivre, le Centre de développement des transports de Transports Canada, le Conseil national de recherches du Canada, la Federal Aviation Administration des États-Unis et le Service de l'environnement atmosphérique (SEA) d'Environnement Canada.

Les essais de durée d'efficacité consistent à verser les liquides abaisseurs du point de congélation sur des plaques en aluminium d'aéronef planes, propres et inclinées, à les exposer à diverses formes de précipitations givrantes naturelles et artificielles, et à mesurer le temps écoulé jusqu'à un état final prédéfini. L'état final et l'inclinaison de la plaque sont établis conformément aux spécifications du Sous-comité G-12 SAE/ISO (Society of Automotive Engineers/Organisation internationale de normalisation) sur les durées d'efficacité.

Les variables mesurées comprennent la durée d'efficacité, le type et le taux de précipitation, la précipitation totale, la visibilité, la vitesse et la direction du vent, la température ambiante, la température des surfaces d'essai, la marque du fluide testé, son type et sa concentration.

### Collecte des données

Au cours de la saison hivernale 1997-1998, des données ont été colligées lors d'essais sous précipitations naturelles menés au site d'essai d'APS Aviation Inc. à l'Aéroport de Dorval. Des données ont aussi été recueillies sous précipitations artificielles à l'intérieur, dans l'Installation de génie climatique du Conseil national de recherches du Canada, à Ottawa. Les précipitations artificielles comprenaient de la bruine verglaçante, de la pluie légère verglaçante, du brouillard verglaçant et de la pluie sur des surfaces sur-refroidies. Comme l'indique le tableau 1, la plupart des 1 200 essais et plus ont été réalisés avec des fluides de type IV sous de la neige naturelle. La catégorie «autre» comprend des liquides de type 1, le liquide d'Aeroflot et des liquides recyclés.

**TABLEAU 1**
**RÉPARTITION DES ESSAIS**

| **PRÉCIPITATION** / **TYPE DE LIQUIDE** | **Neige naturelle** | **Bruine vergl.** | **Pluie légère vergl.** | **Brouillard vergl.** | **Pluie sur plaque sur-refroidie** | **Total** |
|---|---|---|---|---|---|---|
| Type IV (pur) | 191 | 83 | 93 | 83 | 37 | 487 |
| Type IV (75/25) | 167 | 85 | 88 | 49 | 36 | 425 |
| Type IV (50/50) | 85 | 42 | 45 | 39 | - | 211 |
| Autre | 82 | 31 | 8 | - | - | 121 |
| **Total** | **525** | **241** | **234** | **171** | **73** | **1 244** |

### Considérations météorologiques

Grâce à la collaboration du SEA, APS Aviation Inc. a pu obtenir des données météorologiques détaillées pour ses essais au site de Dorval. Les instruments du SEA transmettaient automatiquement, de minute en minute, l'information concernant la quantité totale de précipitation, la vitesse et la direction du vent, la visibilité et la température. Les accessoires utilisés à Dorval pour mesurer les précipitations étaient des bacs. Les taux de précipitation de neige naturelle en fonction de la température ont aussi été colligés, afin de déterminer des taux de précipitation limites (voir le rapport TP 13314E de Transports Canada).

**Essais d'épaisseur**

L'épaisseur des couches de liquides de type IV a été mesurée et des courbes de l'épaisseur en fonction du temps ont été tracées pour chaque marque de liquide. Les courbes d'épaisseur des nouveaux liquides de type IV se sont avérées semblables à celles obtenues lors des essais menés en 1996-1997.

**Essais de durée d'efficacité**

Des tableaux des durées d'efficacité ont été produits pour sept liquides de type IV homologués par la SAE. À partir de ces tableaux, un tableau générique de la SAE a été constitué, dans lequel figurent les durées d'efficacité du liquide le moins performant.

Les durées d'efficacité qui composent chacun des sept tableaux *spécifiques* ont été établies au terme de l'analyse de régression des résultats d'essai de chacun des liquides, pour les catégories *neige*, *bruine verglaçante* et *pluie légère verglaçante*. Pour les autres catégories, les durées d'efficacité étaient identiques aux valeurs du tableau générique de la SAE.

Aucun liquide de type III n'a été essayé car il n'existait alors sur le marché aucun liquide de ce type. À noter que le tableau actuel des durées d'efficacité des liquides de type III n'est pas valide, car il a été produit à l'aide d'un liquide disparu du marché.

Aucun changement n'a été apporté aux durées d'efficacité des liquides de type I.

Deux changements à la baisse ont été apportés aux durées d'efficacité des liquides de type II. Ces changements visent à faire en sorte que la durée d'efficacité d'un liquide de type II ne puisse jamais dépasser les durées d'efficacité du tableau de la SAE pour les liquides de type IV.

**Essais complémentaires**

Des liquides recyclés soumis à des essais de durée d'efficacité et de compatibilité ont affiché des niveaux de performance semblables à ceux des liquides de type I.

Un petit nombre d'essais de durée d'efficacité effectués à l'aide d'un liquide fourni par Aeroflot ont révélé des niveaux de performance semblables à ceux des liquides de type I offerts sur le marché.

Plusieurs variables, comme l'inclinaison de la plaque, la méthode d'application du liquide, la température du liquide au moment de son application, la vitesse du vent, le fini de la surface d'essai et la viscosité du fluide, ont été mesurées. Elles se sont révélées influer à des degrés variables sur la durée d'efficacité des liquides de type IV. C'est avec des liquides de type IV chauffés qu'a été observé l'effet le plus puissant sur la durée d'efficacité (diminution jusqu'à 50 p. 100); mais en raison de l'insuffisance de données d'essai, aucune autre conclusion n'a pu être dégagée de l'étude des autres variables.

**Recommandations**

Les essais de cette année et leurs résultats ont donné lieu à des recommandations touchant les procédures et le matériel d'essai, les essais de durée d'efficacité, et les essais complémentaires.

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## GLOSSARY

| | |
|---|---|
| AES | Atmospheric Environment Services |
| AMIL | Anti-icing Materials Icing Laboratory |
| AMS | Aerospace Material Specification |
| APS | APS Aviation Inc. |
| CEF | Climatic Engineering Facility |
| C/FIMS | Contamination/Fluid Integrity Monitoring System |
| FAA | Federal Aviation Administration |
| HHET | High Humidity Endurance Test |
| HOT | Holdover Time |
| ISO | International Organization for Standardization |
| LWC | Liquid Water Content |
| MVD | Median Volume Diameter |
| NCAR | National Center for Atmospheric Research |
| NRC | National Research Council Canada |
| POSS | Precipitation Occurrence Sensing System |
| READAC | Remote Environmental Automatic Data Acquisition Concept |
| RVSI | Robotic Vision System Inc. |
| SAE | Society of Automotive Engineers |
| SMI | Scientific Material International Inc. |
| TDC | Transportation Development Centre |
| UCAR | Union Carbide Corporation |
| UQAC | Université du Québec à Chicoutimi |
| WSET | Water Spray Endurance Test |

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# 1. INTRODUCTION

At the request of the Transportation Development Centre (TDC) of Transport Canada, APS Aviation Inc. undertook a research project to further advance ground aircraft de/anti-icing technology. This project involved the participation of TDC, Transport Canada, the U.S. Federal Aviation Administration, and several de/anti-icing fluid manufacturers.

Aircraft ground deicing/anti-icing has been the subject of concentrated industry attention over the past decade due the occurrence of several fatal icing-related aircraft accidents. Recent attention has been placed upon the enhancement of anti-icing fluids in order to provide an extended period of protection against further contamination following initial deicing. This emphasis has led to the development of de/anti-icing fluid holdover time tables for use by aircraft operators and accepted by regulatory authorities. New anti-icing formulations continue to be developed by leading manufacturers with the specific objective of prolonging fluid holdover times without compromising the aerodynamic features of the airfoil.

Flat plate tests, conducted in natural and simulated precipitation, are used to develop and substantiate fluid holdover time tables for current fluids and new formulations. Test procedures to measure duration of fluid protection against ice formation have evolved to a standard approach that has been followed by APS and others at a number of locations in previous years.

Aircraft are deiced using heated Type I fluids. These fluids are excellent for the removal of existing contamination on aircraft wings; however, they provide limited protection against further ice accumulation. Anti-icing fluids are applied following aircraft deicing. Type II fluids are thicker and more viscous than Type I deicing fluids. They form a thicker layer on application and provide a longer duration of protection against further contamination. Type III is an anti-icing fluid developed with shear and flow properties designed for aircraft with slower rotation speeds. Type IV fluids are the latest generation of anti-icing fluids and are designed to provide the utmost in holdover time protection. The results of Type IV fluid tests conducted during the 1997-98 winter season constitute the major focus of this report. Eight Type IV fluids were tested during the 1997-98 winter season, including five new fluid formulations.

Testing of these fluids has resulted in the development of holdover time tables. These tables provide guidelines for use in departure planning in adverse winter conditions and govern the holdover times for aircraft treated with a given fluid.

A new data analysis protocol was developed in 1996-97 wherein failure data for each fluid brand, for each cell of the holdover time tables, were subject to a multi-variable regression treatment. Type IV fluid holdover times were

determined using this method of analysis, resulting in one generic SAE Type IV fluid table and several *fluid-specific* Type IV fluid tables.

Over the past years, APS Aviation has completed substantial testing, on behalf of Transport Canada, relating to the determination of fluid holdover times and the substantiation of holdover time tables as well as to the research and development of deicing technology in general. A summary of the research relating to fluid holdover times is provided in Table 1.1.

## 1.1 Holdover Time Tables

The holdover time tables developed or in use for the 1997-98 winter season are shown in Tables 1.2 to 1.5: Table 1.2 is for Type I fluids; Table 1.3 is for Type II fluids; Table 1.4 is for Type III fluids; and Table 1.5 is the generic table for Type IV fluids. These tables contain the fluid holdover times that were provided to operators for use during the 1997-98 winter season. Each holdover time table is composed of cells, and each cell of the table contains a holdover time range which refers to a specific fluid type and dilution, temperature range, and category of precipitation. The time range in each cell is defined by a lower time and an upper time. These values represent the average failure time of the fluid at the upper and lower precipitation rate limits (defined in Subsection 2.9 for all categories of precipitation).

The holdover time tables shown in this section were first published in last year's (winter 1996-97) holdover time report, Transport Canada report TP 13131E (1). Analysis of the Type IV data from 1996-97 indicated a need to develop *fluid-specific* holdover time tables in addition to a generic or *worst case* SAE fluid holdover time table. The generic SAE table encompasses the performance behaviour of all qualifying Type IV fluids. The fluid-specific approach was taken due to wide variations in the performance of the different Type IV fluids tested. The fluid-specific holdover time tables for four Type IV fluids, Kilfrost *ABC-S*, Octagon MaxFlight, Union Carbide Ultra+ and Hoechst MPIV 1957, tested during 1996-97, are shown in Tables 1.6 to 1.9.

The primary effort of this year's study was directed toward the comprehensive testing of five new Type IV fluids, as well as the retesting of three certified Type IV fluids from previous years. Extensive natural precipitation tests were conducted by APS Aviation at the Dorval Airport test site. These included snow and non-snow precipitation events. Simulated freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked surface tests were conducted at the National Research Council Canada (NRC) Climatic Engineering Facility (CEF) in Ottawa. In total, 1 244 holdover time tests were conducted during the 1997-98 test season. The results of flat plate holdover time tests were presented to the SAE G-12 Holdover Time Subcommittee where they were reviewed and discussed; new holdover time

TABLE 1.1

## SUMMARY OF APS HOLDOVER TIME TESTING ACTIVITIES

| Year | Transport Canada (TDC) Report # | Conditions Tested | Primary Fluids Tested | Location of Testing |
|---|---|---|---|---|
| 1990-91 | TP 11206E | • Natural Precipitation (mostly snow) | Type II (100%) | Mostly Dorval, worldwide |
| 1991-92 | TP 11454E | • Natural Precipitation (mostly snow) | Type III | Mostly Dorval, St. John's |
| 1992-93 | TP 11836E | • Natural Precipitation (snow)<br>• Simulated Freezing Drizzle (preliminary)<br>• Simulated Freezing Fog (outdoor) | Type I (Standard) | Dorval and Ottawa (NRC) |
| 1993-94 | Summary Report Available | • Natural Precipitation<br>• Simulated Freezing Drizzle<br>• Simulated Light Freezing Rain<br>• Simulated Freezing Fog (outdoor) | Type II (75/25, 50/50) | Dorval and Ottawa (NRC) |
| 1994-95 | TP 12654E | • Natural Precipitation<br>• Simulated Freezing Drizzle<br>• Simulated Light Freezing Rain<br>• Simulated Freezing Fog (indoor)<br>• Rain on a Cold-Soaked Surface (preliminary) | • Type I (Diluted for 10ºC buffer)<br>• Type IV (Preliminary) | Dorval and Ottawa (NRC) |
| 1995-96 | TP 12896E | • Natural Precipitation<br>• Simulated Freezing Drizzle<br>• Simulated Light Freezing Rain<br>• Simulated Freezing Fog (indoor)<br>• Rain on a Cold-Soaked Surface | Type IV | Dorval and Ottawa (NRC) |
| 1996-97 | TP 13131E | • Natural Precipitation<br>• Simulated Freezing Drizzle<br>• Simulated Light Freezing Rain<br>• Simulated Freezing Fog (indoor)<br>• Rain on a Cold-Soaked Surface | • New Type IVs<br>• Type III | Dorval and Ottawa (NRC) |
| 1997-98 | TP 13318E | • Natural Precipitation<br>• Simulated Freezing Drizzle<br>• Simulated Light Freezing Rain<br>• Simulated Freezing Fog (indoor)<br>• Rain on a Cold-Soaked Surface | • New Type IVs | Dorval and Ottawa (NRC) |

TABLE 1.2

# SAE TYPE I HOLDOVER TIMES

Used During Winter 1997-98

| OAT | | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| °C | °F | *FROST | FREEZING FOG | SNOW | **FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 0:45 | 0:12-0:30 | 0:06-0:15 | 0:05-0:08 | 0:02-0:05 | 0:02-0:05 |
| 0 to -10 | 32 to 14 | 0:45 | 0:06-0:15 | 0:06-0:15 | 0:05-0:08 | 0:02-0:05 | |
| below -10 | below 14 | 0:45 | 0:06-0:15 | 0:06-0:15 | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

TABLE 1.3

# SAE TYPE II HOLDOVER TIMES

Used During Winter 1997-98

| OAT | | SAE Type II Fluid Concentration Neat-Fluid/Water (Vol%/Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 12:00 | 1:15-3:00 | 0:20-1:00 | 0:30-1:00 | 0:15-0:30 | 0:10-0:40 |
| | | 75/25 | 6:00 | 0:50-2:00 | 0:15-0:40 | 0:20-0:45 | 0:10-0:25 | 0:05-0:25 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | |
| 0 to -3 | 32 to 27 | 100/0 | 8:00 | 0:35-1:30 | 0:20-0:45 | 0:30-1:00 | 0:15-0:30 | |
| | | 75/25 | 5:00 | 0:25-1:00 | 0:15-0:30 | 0:20-0:45 | 0:10-0:25 | |
| | | 50/50 | 3:00 | 0:15-0:45 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:35-1:30 | 0:15-0:40 | **0:30-1:00 | **0:10-0:30 | |
| | | 75/25 | 5:00 | 0:25-1:00 | 0:15-0:30 | **0:20-0:45 | **0:10-0:25 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:20-1:30 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE II fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type II fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).

*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

TABLE 1.4

## SAE TYPE III HOLDOVER TIMES

Used During Winter 1997-98

| OAT | | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| °C | °F | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 05:00 | 50-90 | 15-30 | 25-50 | 15-25 | 5-35 |
| 0 to -3 | 32 to 27 | 04:00 | 50-90 | 15-25 | 25-50 | 15-25 | |
| below -3 to -14 | below 27 to 7 | 04:00 | 50-90 | 10-20 | **25-50 | **15-25 | |
| below -14 | below 7 | SAE TYPE III fluid may be used below -14°C (7°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type III fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10°C (14°F).

*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**Note:** Union Carbide issued a warning which stated that diluted forms of Ultra+ are not recommended for operational use due to performance deficiencies noted in qualifying tests.

TABLE 1.5

## SAE TYPE IV HOLDOVER TIMES

Used During Winter 1997-98

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:20-3:00 | 0:45-1:25 | 0:40-1:00 | 0:35-0:55 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:20-0:40 | 0:30-1:00 | 0:15-0:30 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:05-0:20 | 0:10-0:20 | 0:05-0:10 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:20-3:00 | 0:35-1:00 | 0:40-1:00 | 0:35-0:55 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:20-0:35 | 0:30-1:00 | 0:15-0:30 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:20-0:40 | **0:30-1:00 | **0:30-0:45 | |
| | | 75/25 | 5:00 | 0:35-2:00 | 0:15-0:30 | **0:30-1:00 | **0:15-0:30 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10°C (14°F).

*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

TABLE 1.6

## *FLUID-SPECIFIC* TYPE IV HOLDOVER TIMES

# KILFROST ABC-S

Used During Winter 1997-98

| OAT °C | OAT °F | Type IV Fluid Concentration Neat-Fluid/Water (% by volume) | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
|---|---|---|---|---|---|---|---|---|
| above 0º | above 32º | 100/0 | 18:00 | *2:20-3:00* | *1:10-2:00* | *1:20-1:50* | *1:00-1:25* | *0:10-0:50* |
| | | 75/25 | 6:00 | *1:05-2:00* | *0:35-1:05* | *0:50-1:25* | *0:35-0:50* | *0:05-0:35* |
| | | 50/50 | 4:00 | *0:20-0:45* | *0:05-0:20* | *0:15-0:25* | *0:10-0:15* | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | *2:20-3:00* | *1:00-1:40* | *1:20-1:50* | *1:00-1:25* | |
| | | 75/25 | 5:00 | *1:05-2:00* | *0:35-1:05* | *0:50-1:25* | *0:35-0:50* | |
| | | 50/50 | 3:00 | *0:20-0:45* | *0:05-0:15* | *0:15-0:25* | *0:10-0:15* | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | *0:40-3:00* | *0:45-1:20* | ***0:35-1:00* | ***0:30-0:45* | |
| | | 75/25 | 5:00 | *0:35-2:00* | *0:35-1:05* | ***0:50-1:25* | ***0:35-0:50* | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | *0:20-2:00* | *0:40-1:10* | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).

*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

TABLE 1.7

## *FLUID-SPECIFIC* TYPE IV HOL

# OCTAGON MAXFL

Used During Winter 19

| OAT °C | OAT °F | Type IV Fluid Concentration Neat-Fluid/Water (% by volume) | Approximate Holdover Various Weat (hours: *FROST | FREEZING FOG | SNOW | ***FR DRI |
|---|---|---|---|---|---|---|
| above 0º | above 32º | 100/0 | 18:00 | *2:20-3:00* | *1:15-2:00* | *0:55* |
| | | 75/25 | 6:00 | *1:05-2:00* | *1:20-2:00* | *1:15* |
| | | 50/50 | 4:00 | *0:20-0:45* | *0:40-1:20* | *0:55* |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | *2:20-3:00* | *0:50-1:35* | *0:55* |
| | | 75/25 | 5:00 | *1:05-2:00* | *0:45-1:45* | *1:15* |
| | | 50/50 | 3:00 | *0:20-0:45* | *0:40-1:20* | *0:55* |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | *0:40-3:00* | *0:25-0:50* | ***0:3* |
| | | 75/25 | 5:00 | *0:35-2:00* | *0:20-0:50* | ***0:3* |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | *0:20-2:00* | *0:20-0:40* | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-1 of the fluid is at least 7ºC (13ºF) below the OAT a criteria are met. Consider use of SAE Type I wh | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).

*** Use light freezing rain holdover times if positive identification of freezing drizzle is n



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TABLE 1.8

## *FLUID-SPECIFIC* TYPE IV HOLDOVER TIMES

# UNION CARBIDE ULTRA+

USED DURING WINTER 1997-98

| OAT °C | OAT °F | Type IV Fluid Concentration Neat-Fluid/Water (% by volume) | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
|---|---|---|---|---|---|---|---|---|
| above 0º | above 32º | 100/0 | 18:00 | *2:20-3:00* | *0:50-1:40* | *1:00-2:00* | *0:35-1:00* | *0:10-0:50* |
| | | 75/25(1) | 6:00 | *1:05-2:00* | *0:20-0:40* | *0:30-1:00* | *0:15-0:30* | *0:05-0:35* |
| | | 50/50(1) | 4:00 | *0:20-0:45* | *0:05-0:20* | *0:10-0:20* | *0:05-0:10* | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | *2:20-3:00* | *0:35-1:15* | *1:00-2:00* | *0:35-1:00* | |
| | | 75/25(1) | 5:00 | *1:05-2:00* | *0:20-0:35* | *0:30-1:00* | *0:15-0:30* | |
| | | 50/50(1) | 3:00 | *0:20-0:45* | *0:05-0:15* | *0:10-0:20* | *0:05-0:10* | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | *0:40-3:00* | *0:25-0:55* | ***0:50-1:35* | ***0:30-0:50* | |
| | | 75/25(1) | 5:00 | *0:35-2:00* | *0:15-0:30* | ***0:30-1:00* | ***0:15-0:30* | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | *0:20-2:00* | *0:20-0:45* | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).

*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

(1) Diluted forms of Ultra+ are not recommended for operational use due to performance deficiencies noted in qualifying tests.

TABLE 1.9

## *FLUID-SPECIFIC* TYPE IV HOL

# CLARIANT MPIV

USED DURING WINTER

| OAT °C | OAT °F | Type IV Fluid Concentration Neat-Fluid/Water (% by volume) | Approximate Holdover Various Wea (hours *FROST | FREEZING FOG | SNOW | ***FR DRI |
|---|---|---|---|---|---|---|
| above 0º | above 32º | 100/0 | 18:00 | *2:20-3:00* | *0:45-1:25* | *0:4C* |
| | | 75/25 | 6:00 | *1:05-2:00* | *0:35-1:10* | *0:4C* |
| | | 50/50 | 4:00 | *0:20-0:45* | *0:15-0:25* | *0:2C* |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | *2:20-3:00* | *0:35-1:00* | *0:4C* |
| | | 75/25 | 5:00 | *1:05-2:00* | *0:25-0:50* | *0:4C* |
| | | 50/50 | 3:00 | *0:20-0:45* | *0:15-0:25* | *0:2C* |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | *0:40-3:00* | *0:20-0:40* | ***0:4* |
| | | 75/25 | 5:00 | *0:35-2:00* | *0:15-0:30* | ***0:4* |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | *0:20-2:00* | *0:15-0:30* | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-1 of the fluid is at least 7ºC (13ºF) below the OAT criteria are met. Consider use of SAE Type I wh | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).

*** Use light freezing rain holdover times if positive identification of freezing drizzle is



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tables based largely on this work were proposed by the Subcommittee and accepted by the full SAE G-12 Committee. Their use is to be implemented worldwide during the 1998-99 winter season. The tables are presented in Subsection 5.6.

## 1.2 Objectives

The detailed objectives of the holdover time test program for the 1997-98 winter season are provided in the work statement (Appendix A). The primary objectives of the test program are summarized below:

- Conduct flat plate tests under conditions of natural and simulated 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 the fluid manufacturers; and

- Conduct flat plate tests to validate *fluid-specific* and SAE tables that currently lack sufficient supporting data.

## 1.3 Report Format

The following list provides short descriptions of the remaining sections of the report:

- Section 2 describes the test conditions and methodologies used as well as equipment and personnel requirements necessary to carry out testing;

- Section 3 describes the different conditions under which data were collected;

- Section 4 presents the results of fluid thickness tests conducted in periods of no precipitation and the results of these tests;

- Section 5 contains discussions of the data and results of holdover time testing. It also includes the most recently proposed holdover time tables and *fluid-specific* tables for use during the 1998-99 winter season;

- Section 6 presents information relating to supplementary tests performed during the winter 1997-98 test season along with results;

- Section 7 presents conclusions derived from the complete test program; and

- Section 8 lists recommendations for future testing.

# 2. METHODOLOGY

This chapter contains a description of the tests, equipment, and procedures used during the 1997-98 test season. It is divided into sections dealing with the definition of weather, test sites, test conditions, equipment, procedures, data forms, fluids, personnel, and analysis methodology.

## 2.1 Definition of Weather Conditions

Holdover times (see Tables 1.2 to 1.9) are provided as a function of *weather condition*, fluid mixture, and outside air temperature. The objective of the winter test program was to substantiate these holdover times or develop new ones based on the most recent test data.

Table 2.1 provides the definitions of most weather conditions experienced in winter operations, including the criteria used to determine precipitation intensity (light, moderate, heavy). This table was compiled by the National Center for Atmospheric Research (NCAR) from the *Guide to Meteorological Instruments and Methods of Observation* (2), the *Glossary of Meteorology* (3), and from *WSOH # 7 Manual of Surface Weather Observations* (4).

Table 2.1 includes definitions for the *weather conditions* described in the holdover time tables illustrated in Section 1 (frost, freezing fog, snow, freezing drizzle, light freezing rain, and rain). Definitions for snow pellets, snow grains, hail, and ice pellets are also presented.

Test methodology to determine fluid failure times has included generally accepted upper and lower limits for precipitation rates for each type of precipitation. These limits were discussed in detail at a 1997 meeting of the SAE G-12 Holdover Time Subcommittee where standard definitions of upper and lower rate limits were approved. Those limits are documented and discussed in Subsection 2.9.

### 2.1.1 Snow

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

- Light — Visibility is $\geq$ 1.0 km
- Moderate — Visibility is 0.5 km to $<$ 1.0 km
- Heavy — Visibility is $<$ 0.5 km

TABLE 2.1

## DEFINITION OF WEATHER PHENOMENA

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

### Intensity Criteria**

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

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

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

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

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

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

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

The reader is directed to the cautionary note that appears in Table 2.1; it states that visibility is only an indicator of snow intensity, and the two parameters are not always correlated.

Table 2.2 was devised by NCAR and Transport Canada. This table is based on NCAR field data and theoretical work on classes of snow. NCAR has classified the snow data by crystal arrangement and temperature and has correlated this information with visibility measurements. The table is a more detailed scheme than the one outlined in Table 2.1. It gives visibility in distance for three snowfall intensities both in daylight and in darkness (night). Table 2.2 is considered to be more accurate and has been adopted by Transport Canada.

### 2.1.2 Freezing Drizzle

Freezing drizzle is composed of closely spaced fine water droplets with a diameter less than 0.5 mm (see Table 2.1). The intensity of freezing drizzle is estimated, as for snow, through the measurement of horizontal visibility. The holdover time table has one column for freezing drizzle, but Table 2.1 shows three intensity levels (light, moderate, and heavy). For example, under moderate freezing drizzle, the rate of precipitation should range between 2.5 and 5.1 g/dm²/h. For heavy freezing drizzle, the definition indicates that the intensity is greater than 5 g/dm²/h. Discussions between United Airlines, NCAR, and NRC led to the upper limit value of 12.7 g/dm²/h for freezing drizzle. This value was also used as the lower limit for light freezing rain.

### 2.1.3 Freezing Rain

This form of precipitation exists either in the form of drops with diameters greater than 0.5 mm, or smaller drops which, in contrast to drizzle, are widely separated. For each of the three intensities of freezing rain given in Table 2.1, a visual description is supplied to provide a subjective guideline for the purpose of estimating rain intensity. However, the following definitions apply when an instrument is available to measure the intensity of precipitation:

- Light Precipitation rate is ≤25 g/dm²/h
- Moderate Precipitation rate is >25 g/dm²/h but ≤76 g/dm²/h
- Heavy Precipitation rate is >76 g/dm²/h

TABLE 2.2

# SNOW VISIBILITY CHART

| Lighting | Temp. Range | | Visibility | | |
|---|---|---|---|---|---|
| | °C | °F | Heavy | Moderate | Light |
| Daylight | Above -1 | Above 30 | < 1.6 km < 1 mi | 1.6 - 3.2 km 1 - 2 mi | > 3.2 km > 2 mi |
| | -1 to -7 | 30 to 19 | < 0.8 km < 1/2 mi | 0.8 - 2.0 km 1/2 - 1 1/4 mi | > 2.0 km > 1 1/4 mi |
| | Below -7 | Below 19 | < 0.6 km < 3/8 mi | 0.6 - 1.0 km 3/8 - 5/8 mi | > 1.0 km > 5/8 mi |
| Darkness | Above -1 | Above 30 | < 3.2 km < 2 mi | 3.2 - 6.4 km 2 - 4 mi | > 6.4 km > 4 mi |
| | -1 to -7 | 30 to 19 | < 1.6 km < 1 mi | 1.6 - 4.0 km 1 - 2 1/2 mi | > 4.0 km > 2 1/2 mi |
| | Below -7 | Below 19 | < 1.2 km < 3/4 mi | 1.2 - 2.0 km 3/4 - 1 1/4 mi | > 2.0 km > 1 1/4 mi |

Light snow intensity is defined as less than 1mm/h, moderate intensity as 1 mm/h to 2.5 mm/h, heavy as greater than 2.5 mm/h.

### 2.1.4 Freezing Fog

Freezing fog is defined as suspended minute water droplets which freeze upon impact with the ground or exposed objects. Table 2.1 does not provide any indication of intensity or liquid water content of the fog other than that the horizontal visibility is reduced to less than 1 km.

## 2.2 Test Sites

Natural snow testing for the 1997-98 winter was performed at the APS Dorval Airport test site. The location of the site is shown on the plan view of the airport in shown Figure 2.1. Photo 2.1 was taken at the site and shows a remote sensor mounted on top of the test stand on the left and the trailer at the back. The trailer used for the 1996-97 winter was kept in place for the 1997-98 winter. The test site is located adjacent to Environment Canada's Atmospheric Environment Services automated weather observation station (Photo 2.2).

Tests under conditions of freezing fog, rain on cold-soaked surface, freezing drizzle, and light freezing rain were conducted indoors at NRC's CEF, where precipitation was artificially produced.

The facility is divided into two sections separated by an insulated dividing door. Each partition can be separately controlled permitting different tests to be conducted simultaneously. Photo 2.3 provides a general indication of the size of the facility. Photos 2.4 and 2.5 provide interior images of the small and large ends of the facility. The facility was designed and built for the testing of locomotives. The size of the chamber is 30 m by 5.4 m and its total height is 8 m. The lowest temperature achievable is -46ºC.

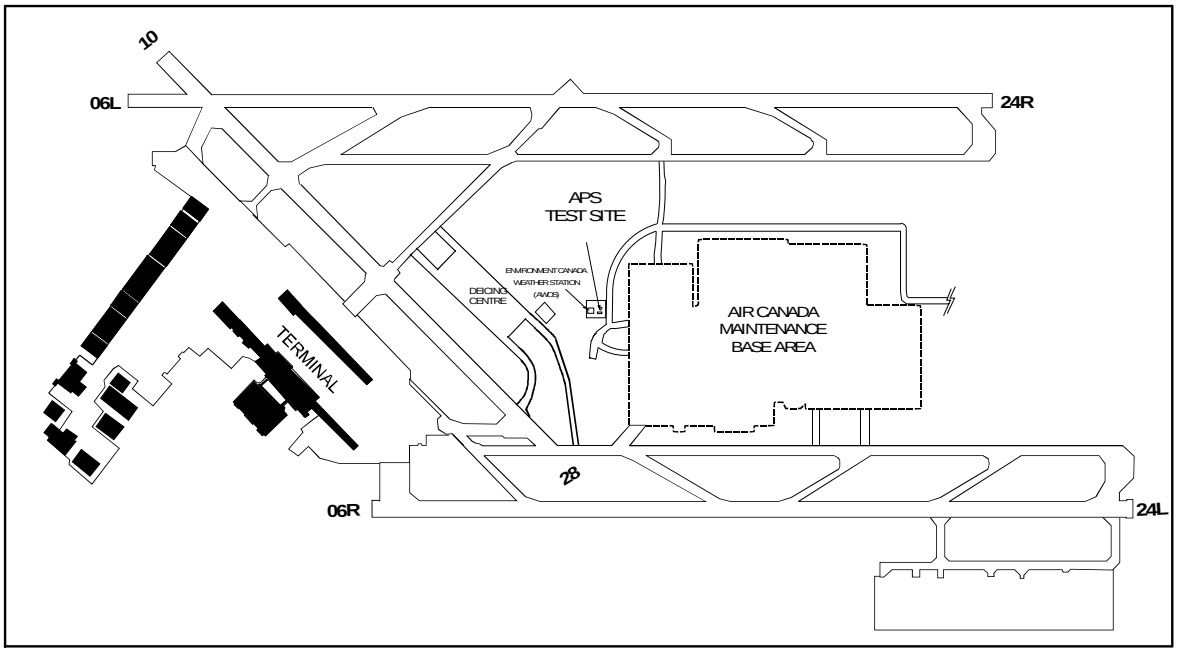


**Figure 2.1: APS Test Site Location at Dorval Airport**

## 2.3 Test Conditions

Outdoor testing was conducted during natural precipitation events. Supplementary tests to simulate freezing precipitation were carried out at NRC's CEF (see Photo 2.4). Subsections 2.3.1 and 2.3.2 provide a description of the spray assembly (see Photo 2.6) and of the methods used to produce and calibrate the fine water droplets in these artificial precipitation tests. Subsection 2.3.3 provides a summary of the categories and characteristics of each precipitation type produced for these tests.

### 2.3.1 Droplet Size and Rate of Precipitation

During recent years, much more attention has been given by the industry to the influence of droplet size on holdover time. To clarify this issue, experiments were performed to measure droplet size produced by different nozzles (various gauge hypodermic needle tips) and different pressures in the spray delivery unit. Although the gauge of the needles is an important factor in the production and size of the droplets, the air and water pressure levels in the sprayer system are as important. A new and improved sprayer assembly was developed by NRC and is shown in Photo 2.6. The new sprayer provides a larger scan area and improved spray uniformity over the coverage area. The scanner consists of a horizontal main shaft, supported by two bearings, and is controlled and moved in the x-axes by a step motor. A second-step motor with a spray nozzle (Photo 2.7) mounted on it, rotates the main shaft to produce the y-axes motion. The combined actions result in a complete coverage of the test area. Some calibration experiments were conducted prior to 1995 by NRC using an optical gauge manufactured by HSS (see Photo 2.8) to verify that the simulation of freezing fog, freezing drizzle and light freezing rain provided adequate droplet sizes.

Calibration of droplet size was also required for tests conducted under conditions of high moderate rain for the simulation of rain on a cold-soaked wing. The APS team carried out calibration experiments in 1995-96 using a manual dye-stain technique (5) employed by NRC's CEF. This technique consists of dusting Whatman # 1 filter paper discs with a water-activated, very finely divided powder form of methylene blue dye. The prepared discs are manually positioned (Photo 2.9) under artificial precipitation for a fixed time to acquire a droplet size pattern. Figure 2.2 illustrates the appearance of such a pattern acquired under conditions of light freezing rain. A calibration curve (Figure 2.3) developed from the dye-stain technique is then used to convert from the measured diameter of the droplets on the pattern to the experimental median volume diameter.

FIGURE 2.2

**DROPLET SIZE PATTERN PRODUCED AT NRC**

LIGHT FREEZING RAIN

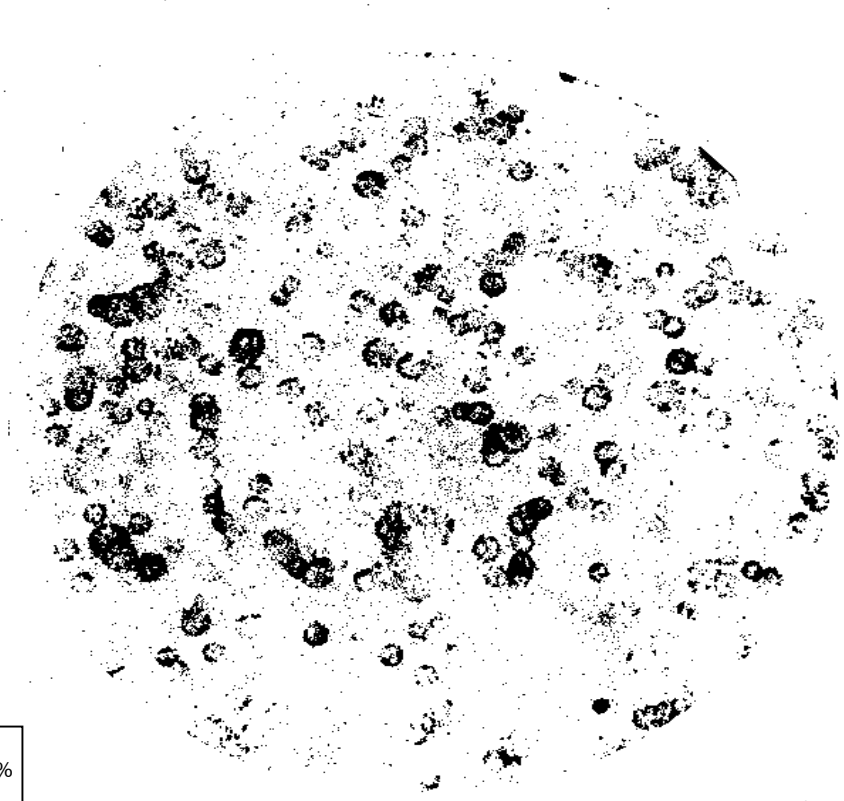

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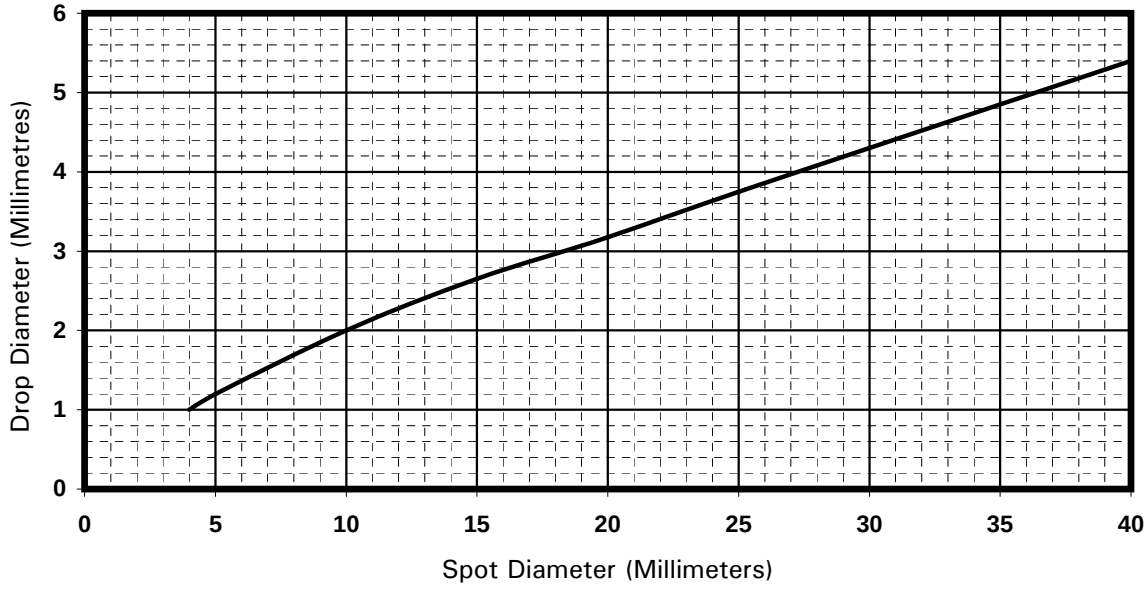
FIGURE 2.3

**CONVERSION OF SPOT DIAMETER TO DROP DIAMETER**

WHATMAN # 1 FILTER PAPER



To determine whether droplets produced in the cold chamber resembled droplets from natural precipitation, a test was conducted during natural light freezing rain conditions. The droplet sizes were measured and compared to the droplet sizes of simulated light freezing rain tests conducted at NRC. The results of these tests are shown below:

For the outdoor test:

| | |
|---|---|
| Location: | Dorval Airport |
| Precipitation: | Natural Light Freezing Rain |
| Precipitation Rate: | 20 g/dm²/h |
| Calibrated MVD: | 1.0 mm |

For the indoor test:

| | |
|---|---|
| Location: | National Research Council |
| Precipitation: | Simulated Light Freezing Rain |
| Precipitation Rate: | 25 g/dm²/h |
| Calibrated MVD: | 1.0 mm |

The median volume diameter for both natural and simulated light freezing rain was 1 mm.

### 2.3.2 Median Volume Diameter of Raindrops

The median volume diameter (MVD) of a rain droplet has been researched by NRC and found to be related to the precipitation rate as follows:

$$MVD = (rate/10)^{0.23}$$

where the MVD is in mm and the rate of precipitation is in g/dm²/h. At 25 g/dm²/h, this equation gives an MVD of 1.2 mm, and at 76 g/dm²/h the MVD is 1.6 mm.

The theoretical median volume diameters for rain at various rates were determined based upon this equation. These values are listed below beside the experimental MVDs for each precipitation condition.

| | Experimental MVD (mm) | Theoretical MVD (mm) |
|---|---|---|
| Moderate Rain (High rate: 76 g/dm²/h) | 1.4 | 1.6 |
| Light Rain (Low rate: 12.7 g/dm²/h) | 1.0 | < 1.1 |
| Light Rain (High rate: 25 g/dm²/h) | 1.0 | 1.2 |
| Drizzle (Low rate: 5 g/dm²/h) | 0.25 | < 0.5 |
| Drizzle (High rate: 12.7 g/dm²/h) | 0.35 | < 0.5 |
| Fog | < 0.1 | |

### 2.3.3 Characteristics of Precipitation Produced

The following is a point-form summary of the set of test conditions under which data for freezing drizzle, light freezing rain, rain on a cold-soaked surface, and freezing fog were collected:

i) Freezing Drizzle:

*High precipitation rate: 12.7 g/dm²/h;*
Droplet median volume diameter: 350 $\mu$m;
Droplets produced with two # 23 hypodermic needles; and
Air temperature: -3 and -10ºC.

*Low Precipitation rate: 5 g/dm²/h;*
Droplet median volume diameter: 250 $\mu$m;
Droplets produced with two # 24 hypodermic needles; and
Air temperature: -3 and -10ºC.

ii) Light Freezing Rain:

*High precipitation rate: 25 g/dm²/h;*
Droplet median volume diameter: 1 000 $\mu$m;
Droplets produced with two # 20 hypodermic needles; and
Air temperature: -3 and -10ºC.

*Low precipitation rate: 12.7 g/dm²/h;*
Droplet median volume diameter: 1 000 $\mu$m;
Droplets produced with two # 20 hypodermic needles; and
Air temperature: -3 and -10ºC.

iii) Drizzle on Cold-Soaked Surface:

Precipitation rate: 5 g/dm²/h;
Droplet median volume diameter: 250 $\mu$m;
Droplets produced with two # 24 hypodermic needles; and
Air temperature: + 1ºC.

iv) Moderate Rain on Cold-Soaked Surface:
Precipitation rate: 76 g/dm²/h;
Droplet median volume diameter: 1 400 $\mu$m;
Droplets produced with two # 17 hypodermic needles; and
Air temperature: + 1°C.

v) Freezing Fog:
Precipitation rate: 2 and 5 g/dm²/h;
Droplet median volume diameter: 30 $\mu$m; and
Air temperature: -3°C, -14°C and -25°C.

## 2.4 Equipment

Figure 2.4 shows a schematic of the stand used for testing. For natural snow tests, six test plates are normally mounted on the stand, inclined at a 10º slope. Each plate represents a *flat plate test*.

Figure 2.4 also depicts the size and surface markings of a standard flat plate. Three parallel lines are positioned at 2.5 cm (1 in.), 15 cm (6 in.) and 30 cm (12 in.) from the top of the plate. The plates were marked with 15 cross hairs used in determining whether end conditions (see Subsection 2.5.2 for definition) were achieved. Photo 2.10, taken outdoors at Dorval, shows six test plates mounted on a stand; two plates (u and w) are equipped with AlliedSignal Contaminant/Fluid Integrity Monitoring System (C/FIMS) ice detection sensors mounted at the 15 cm line. For simulated freezing precipitation tests at NRC, 12 plates were mounted on the stand, marked 1 to 12, as shown in Figure 2.4.

Figure 2.5 shows the collection (plate) pan which is of the same size as a standard plate and which is used for measuring amounts of precipitation for the outdoor tests. Photo 2.11 shows the collection pans used for measuring precipitation rates indoors at NRC.

A new snow gauge, CR21X, was made available to measure precipitation in the 1996-97 winter season, but did not give accurate results since it was not shielded. This season, the instrument was shielded and provided improved gauge output resolution over instrumentation used in previous seasons. A detailed analysis of the results obtained from the CR21X snow gauge is presented in Transport Canada report TP 13314E (6).

Sealed boxes (7.5 cm deep) were used for simulating a cold-soaked wing (see Figure 2.5). The top of the cold-soak box consists of an aluminum flat plate identical to the standard flat plate. A box shaped reservoir is welded to the bottom of the plate. The volume (depth) of the reservoir was selected based upon the analysis contained in the related Transport Canada report TP 12899E (7).

The fluid cooling unit, devised and constructed by APS personnel, used liquid nitrogen as a refrigerant and is shown in Photo 2.12. The unit was required to cool the glycol used to fill the cold-soak boxes. A mixer was added to the unit to stir the glycol inside the cooling unit to prevent excessive temperature gradients inside the cooling unit.

The freeze point of fluid sample collected from the plate was measured using a hand-held refractometer with a Brix-scale. Photo 2.13 shows the Misco refractometer.

FIGURE 2.4

# FLAT PLATE TEST SET-UP

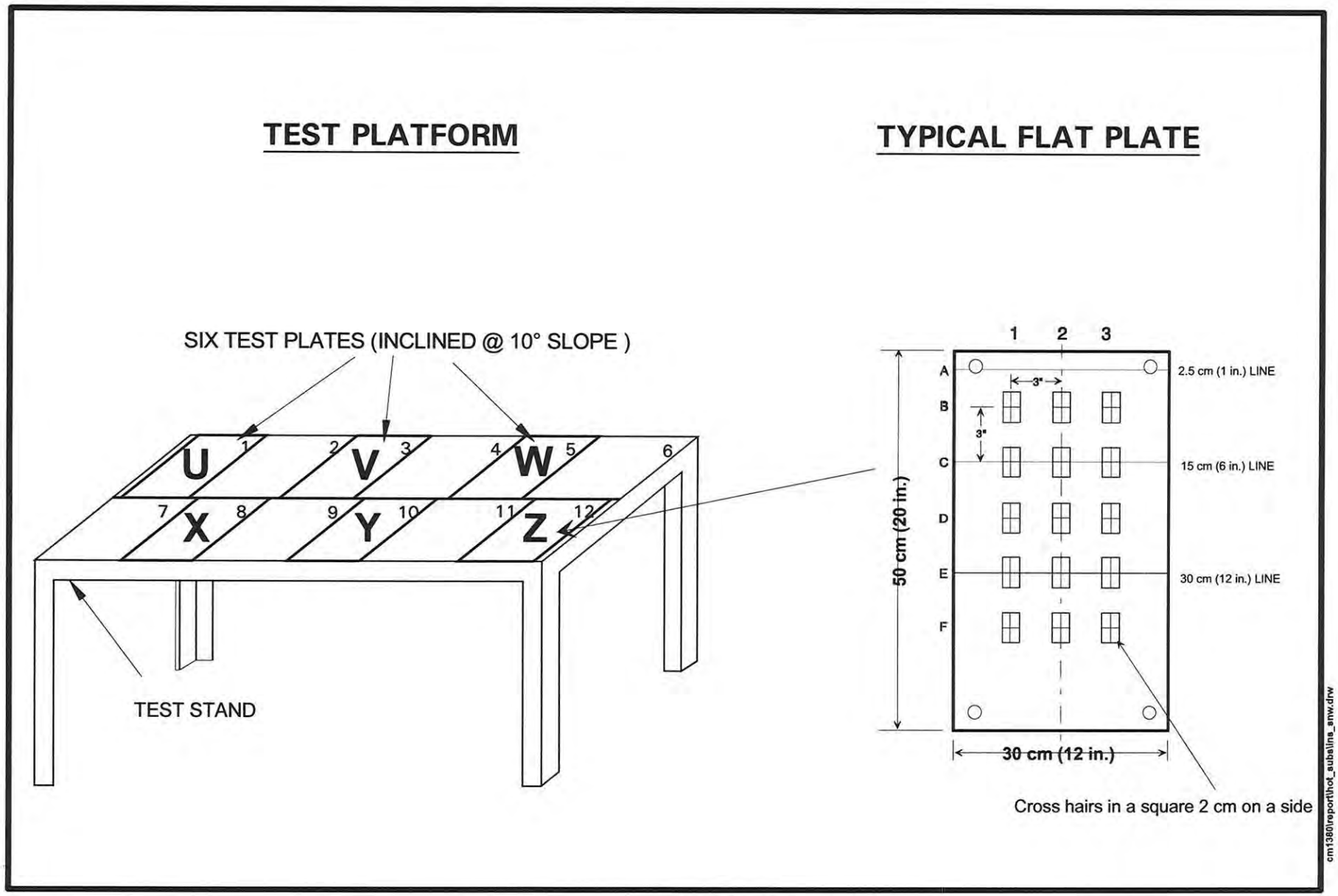
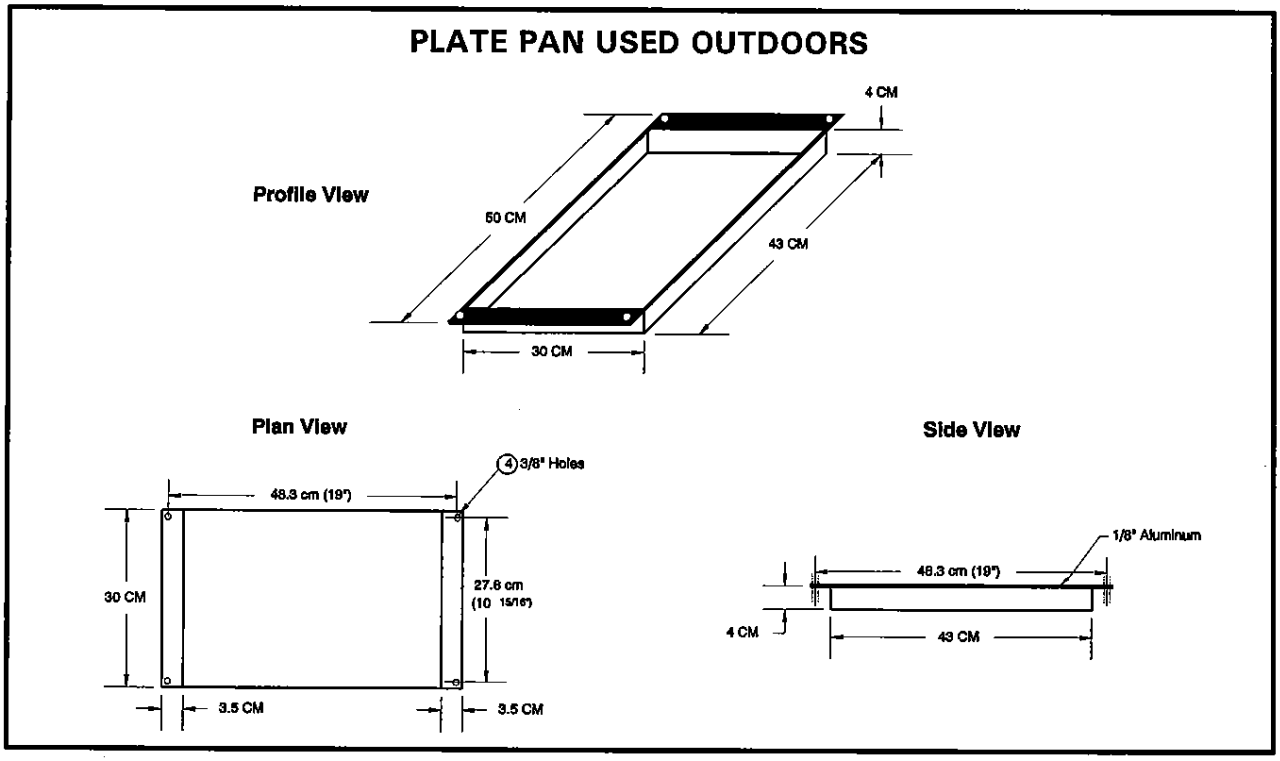
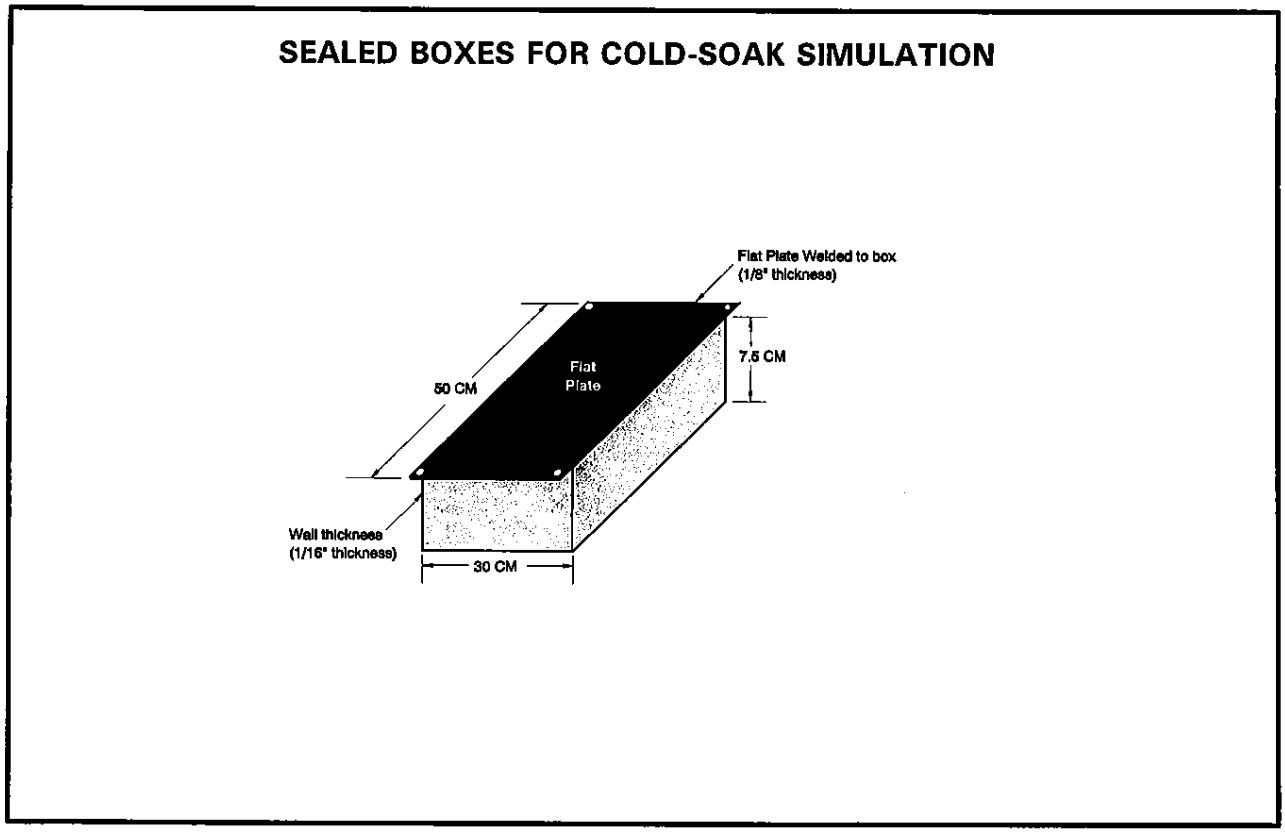


FIGURE 2.5

# SCHEMATICS OF PLATE PAN AND SEALED BOXES




cm1380\reporthot_sub\plan&box.dw

Equipment to measure temperature, wind speed and wind direction was purchased several years ago (see Photo 2.1). Additional measurement of these parameters is provided by Environment Canada's equipment seen in Photo 2.2.

Ice sensors used during natural snow outdoor tests, and at NRC's CEF in the 1997-98 season, included: four C/FIMS from AlliedSignal, two optical area sensors by Robotic Vision System Inc. (RVSI) (the portable one is shown in Photo 2.14), and one optical sensor by Spar/Cox, shown in Photo 2.15. The Spar/Cox sensor was made available only at the end of the 1997-98 winter season, but was used for testing at NRC.

In addition to the data collected using the meteorological equipment at the APS Dorval site, data from Environment Canada's automated weather observation equipment, located on a lot adjacent to the test site, were made available. The end of Appendix B shows a typical listing of the data provided by the Remote Environmental Automatic Data Acquisition Concept (READAC). This information was acquired from Atmospheric Environment Services magnetically on a minute-by-minute basis for the entire winter. The READAC equipment provides an indispensable means of monitoring meteorological conditions for test programs such as this. It consists of the following instruments:

i) *Relative Humidity Gauge and Thermometer.*

ii) *Anemometer and wind vane at a 10 m height.*

iii) *Precipitation Occurrence Sensing System (POSS):* The POSS system (instrument at rear of Photo 2.16) consists mainly of a Doppler radar set with a transmitter and a receiver as separate units (bi-static set-up).

The system is aimed at an area a few centimetres above it where it measures the rate of fall of hydrometers. The Doppler frequency shift of the returned signal provides the precipitation type, and the power spectrum of the returned signal provides a measure of the intensity (light, moderate or heavy) of precipitation. The output of the system consists of the start time, stop time, type, and intensity of precipitation.

iv) *Precipitation Gauge:* The READAC precipitation gauge (instrument at right of Photo 2.16) is a modified Belfort weighing gauge. A bucket is attached to a spring balance and cable pulley arrangement connected to a rotating shaft. The degree of shaft rotation corresponds to the amount of accumulated precipitation in the bucket. The total amount of precipitation is the only value returned

by the precipitation gauge arrangement. The gauge accuracy is subject to thermal expansion and contraction of the weighing mechanism. It is also affected by freezing precipitation that accumulates on the sides of the gauge and melts later on, which results in delayed and therefore erroneous output. The gauge output resolution is 0.5 mm (liquid water equivalent).

v) *Belfort Forward Scattermeter:* The Belfort Forward Scattermeter (instrument at left of Photo 2.16) provides an estimate of visibility. The system consists of a Zenon bulb transmitter and a receiver both at an angle of 22°C below the horizontal aimed at a 0.02 $m^3$ sample volume of air 2.5 m above the ground. The transmitter illuminates the sample volume of air. The receiver measures the amount of light scattering off the aerosols present in the sample volume of air. The measurement is inversely proportional to visibility. The instrument output scale is in units of miles. The measurements output by the instrument at any time are the time averaged signal envelopes from the previous ten minutes of monitoring.

## 2.5 Test Procedures

Tests consisted of pouring deicing or anti-icing fluids directly onto clean test panels (exposed to various winter precipitation conditions) and recording the elapsed time for each cross hair to fail until the test panels reached the defined end condition (see Subsection 2.5.2 below).

### 2.5.1 Test Protocol

For the tests at Dorval, a test stand contained six test plates, each plate representing a flat plate test. During each run with six plates, three different fluids were tested in duplicate.

The procedure for the natural snow flat plate tests was developed by the SAE G-12 Holdover Time Subcommittee. The procedure was slightly updated according to the recommendations in Transport Canada report TP 13131E (1).

The major changes this year were:

i) The precipitation rate measurement frequency was increased from once every 15 minutes to once every 10 minutes in normal conditions and once every 5 minutes in periods of high precipitation intensity;

ii) The start and end times of precipitation rate collected period were recorded in hours, minutes, and seconds rather than just in hours and minutes; and

iii) A sample of fluid was collected subsequent to failure on each plate, and the freeze point of the fluid was measured.

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

i) Synchronize all timepieces;
ii) Clean panels and start;
iii) Apply (pour) fluids (on) to test panels. Type I fluids are at room temperature (15°C to 20°C). Type II and Type IV fluid are at ambient temperature. Fluids are poured using a single-step fluid application;
iv) Record cross hair end condition times;
v) Continue testing until at least five cross hairs or 1/3 of the plate have failed;
vi) Measure the refractive index of fluid over the fifth failed cross hair;
vii) Record weather conditions; and
viii) Clean panels and restart.

The complete details of the actual test procedures are provided in Appendix B. Appendix C contains the procedure used for testing at NRC's CEF for freezing drizzle, light freezing rain, freezing fog, and cold-soaked surface rain tests.

For simulated freezing drizzle and light freezing rain conditions, two tests were conducted for each Type IV fluid, at the upper and lower precipitation rate limits, and at -3°C and -10°C. Additional tests were performed if the two tests conducted showed significant differences in holdover time.

Rain on cold-soaked wing tests were conducted using cold-soak boxes at NRC's CEF. The ambient temperature was set at +1ºC. The box reservoirs were filled with freezing point depressant fluid and cooled to below -10ºC using a custom-made cryostat that uses liquid nitrogen as the refrigerant. All box surfaces were insulated with 2.5 cm thick rigid Styrofoam sheeting. Top surface temperatures were recorded throughout the test using thermistors and/or hand-held temperature probes (see Photo 2.17).

### 2.5.2 End Condition Definitions

The procedure and the determination of the end condition evolved from the experiences of various test programs from previous winter seasons. Plate failure time is the time required for the end condition to be achieved. This occurs when the accumulating precipitation fails to be absorbed or ice forms at any five of the cross hair marks on the panels. A cross hair is considered failed:

- If there is a visible accumulation of snow bridging on top of the fluid at the cross hair when viewed from the front. There should be an indication that the fluid can no longer deice or absorb the precipitation at this point; or

- When precipitation or frosting produces a *loss of gloss* (i.e. dulling of the surface reflectivity) at any cross hair, or when ice (or dry snow) has formed or accumulated on the cross hair (look for ice crystals). This condition is *only* applicable during light freezing rain, freezing drizzle, ice pellets, freezing fog, rain on a cold-soaked surface, or during mixtures of snow, light freezing rain, freezing drizzle, and ice pellets.

## 2.6 Data Forms

Two data forms were used to manually record data at Dorval during the 1997-98 winter season. The form used to record fluid failure times for each cross hair on the plates is shown in Table 2.3. The second form (Table 2.4) is used to record data relating to meteorological conditions during tests. One half of the form is designated for plate pan precipitation rate measurements, and the rest of the page is reserved for documentation of meteorological conditions and any changes to them that may occur during tests.

It has been observed that the placement (positioning) of collection pans on the stand is more critical for laboratory tests than for outdoor tests. In the laboratory, the rate of precipitation over a plate is reproducible from test to test, but is different from plate to plate. For outdoor tests, the opposite is true. The rate of precipitation is the same from plate to plate, but is not reproducible from test to test. Consequently a special procedure was developed to measure precipitation rates at NRC's CEF, supported by a unique data form (Table 2.5).

TABLE 2.3

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

# END CONDITION DATA FORM

VERSION 5.0

**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 (**

**Time of Fluid Application:** _____ hr:min (U & X) _____ hr:min (V

| | Plate U | | | Plate V | | |
|---|---|---|---|---|---|---|
| **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 | | |
|---|---|---|---|---|---|---|
| **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 2.4

# 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 (hr:min) | t TIME AFTER (hr:min) | w WEIGHT BEFORE (grams) | w WEIGHT AFTER (grams) | COMPUTE RATE ($\triangle$ w*4.7/ $\triangle$t) ($g/dm^2/h$) |
|---|---|---|---|---|---|
| | | | | | |
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*measurements every 15 min. and at failure time of each test panel.

**METEO OBSERVATIONS ****

| TIME (hr:min) | TYPE ZR, ZL,S, SG IP, IC, BS, SP | CLASSIF. | If SNOW, WET or DRY |
|---|---|---|---|
| | | | |
| | | | |
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| | | | |
| | | | |

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

**TEMPERATURE AT START OF TEST** _____ °C

**WIND SPEED AT START OF TEST** _____ km/h

**WIND DIRECTION AT START OF TEST** _____ °

**COMMENTS :** _____

_____

_____

_____

| | PRINT | SIGN |
|---|---|---|
| **WRITTEN & PERFORMED BY :** | _____ | _____ |
| **VIDEO BY :** | _____ | _____ |
| **TEST SITE LEADER :** | _____ | _____ |

TABLE 2.5

## PRECIPITATION RATE MEASUREMENT AT CEF IN OTTAWA

Date: _____ **Needles Used:** _____

Start Time: _____ **Flow Rate of Water:** _____

Run # : _____ **Line Air Pressure:** _____

Stand: _____ **Line Air Temperature:** _____

Precipitation Type: _____ (ZD, ZR-, FZF, S) **Line Water Pressure:** _____

**Line Water Temperature:** _____

**Pan Location:**

| | | | | | |
|---|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** | **6** |
| **7** | **8** | **9** | **10** | **11** | **12** |

**Collection Pan:**

| Pan # | Area of Pan (dm²) | Location | Weight of Pan (g) Before | Weight of Pan (g) After | Collection Time (hr:mm:ss) Start | Collection Time (hr:mm:ss) End | Rate |
|---|---|---|---|---|---|---|---|
| 1 | 14.56 | 1 | | | | | |
| 2 | 14.56 | 2 | | | | | |
| 3 | 14.56 | 3 | | | | | |
| 4 | 14.56 | 4 | | | | | |
| 5 | 14.56 | 5 | | | | | |
| 6 | 14.56 | 6 | | | | | |
| 7 | 14.56 | 7 | | | | | |
| 8 | 14.56 | 8 | | | | | |
| 9 | 14.56 | 9 | | | | | |
| 10 | 14.56 | 10 | | | | | |
| 11 | 14.56 | 11 | | | | | |
| 12 | 14.56 | 12 | | | | | |

**Comments:** _____

**Handwritten by:** _____

**Measured by:** _____

## 2.7 Fluids

### 2.7.1 General

During the 1997-98 test season, a few Type I fluid tests were conducted. Type I fluids are usually obtained from manufacturers in standard dilution forms. Each manufacturer sets its own concentration based on performance requirements and cost. For example, one manufacturer's standard Type I fluid contains 57 percent glycol as delivered. These fluids are tested in their standard dilution forms and also in further diluted forms specific to particular test temperature requirements. The concentrations are adjusted by mixing with water and are verified by measurement of the resulting solution's refractive index. The freezing point of a solution is concentration-dependent and is raised by decreasing the glycol concentration. If a given test is to be performed at 0ºC, the fluid concentration will be adjusted to freeze at -10ºC. This diluted solution is now said to either *possess a 10ºC buffer* or *is buffered for 10ºC*.

Type IV fluids contain a minimum of 50 percent glycol and are *thickened* by incorporating rheological additives to the fluid formulations. These additives cause fluids to assume a thicker film and to remain on the aircraft surfaces until the time of takeoff. The fluids are often delivered to air carriers in this form and are designated as neat (100%) fluids. Sometimes (mostly in Europe) neat Type IV fluids are mixed with water as follows:

- 75 percent of neat formulation and 25 percent water by volume. This is designated Type IV 75/25; and

- 50 percent neat formulation and 50 percent water by volume. This is designated Type IV 50/50.

Fluid freeze points were measured using a Misco Brix-scale refractometer. The fluid freeze point can be determined using conversion charts for Ethylene- and Propylene-based glycol as shown in Figures 2.6 and 2.7. These charts were plotted using Brix and freeze points provided by the fluid manufacturers. The Brix values for Type IV fluids tested are summarized in Table 2.6.

FIGURE 2.6

## Freeze Point of Ethylene-Based Glycol

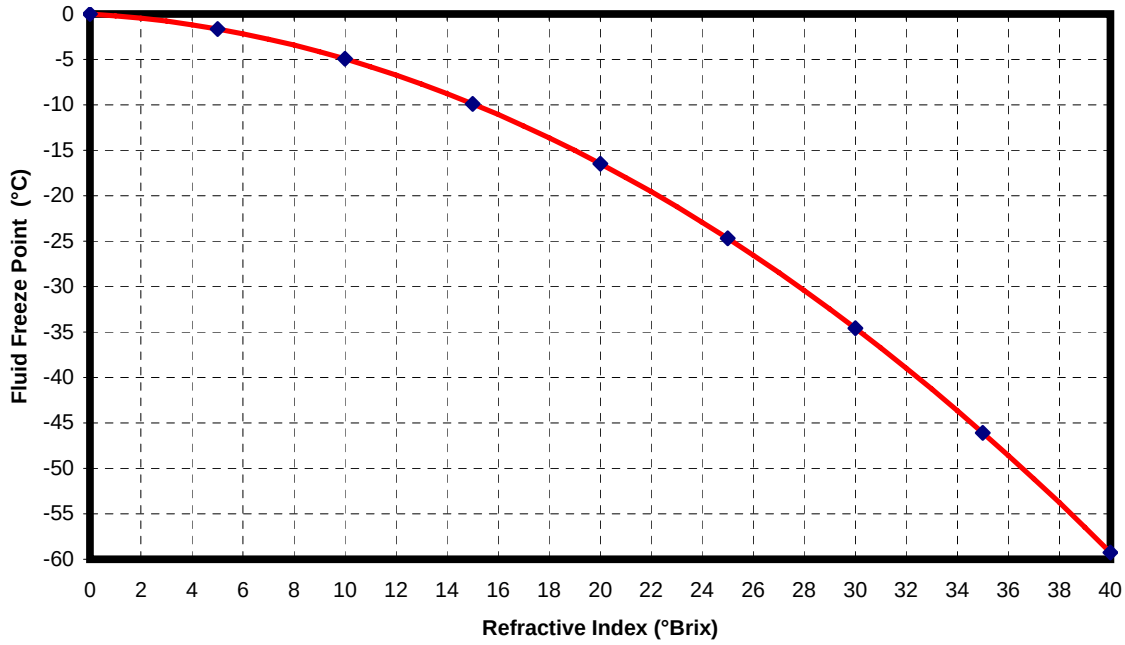



FIGURE 2.7

## Freeze Point of Propylene-Based Glycol

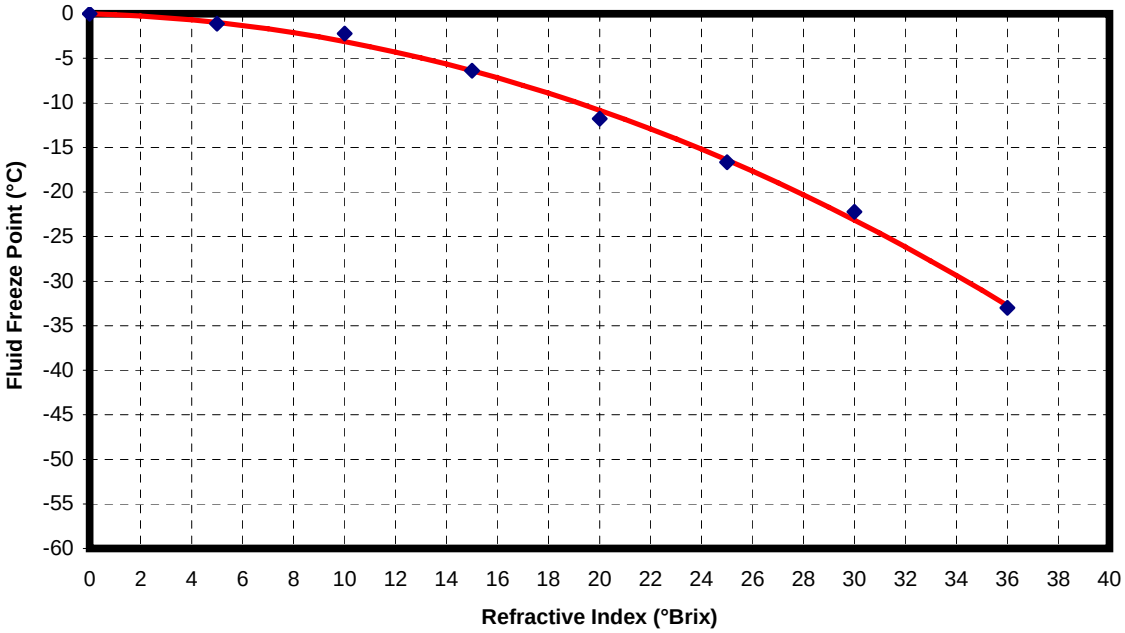


Table 2.6

## FLUID BRIX AND VISCOSITY VALUES
## (I$^{st}$ Shipment)

| Fluid | | | Manufacturers' Brix | Experimental Brix | EXPERIMENTAL Viscosity (cp) 0.3 rpm | EXPERIMENTAL Viscosity (cp) 6 rpm | EXPERIMENTAL Viscosity (cp) 30 rpm |
|---|---|---|---|---|---|---|---|
| Clariant | 2001 | 100/0 | 34 | 34 | 25800 | 2550 | 920 |
| | | 75/25 | 26 | | | | |
| | | 50/50 | 17 | | | | |
| | 1957 | 100/0 | 34 | 34 | 22400 | 2240 | 840 |
| | | 75/25 | 26 | | | | |
| | | 50/50 | 17 | | | | |
| Octagon | Maxflight | 100/0 | 36.25 | 36.25 | 6000 | 990 | 471 |
| | | 75/25 | 28.25 | | | | |
| | | 50/50 | 19.75 | | | | |
| Kilfrost | ABC-S | 100/0 | 35.75 | 35.75 | 15800 | 1970 | 782 |
| | | 75/25 | 27.50 | | | | |
| | | 50/50 | 19.00 | | | | |
| Union Carbide | Ultra IV | 100/0 | 33.25 | 32.75 | 30200 | 3440 | 1020 |
| | | 75/25 | 25 | | | | |
| | | 50/50 | 16.25 | | | | |
| | PG AAF | 100/0 | 36.75 | | | | |
| | | 75/25 | 27.5 | 27 | 11000 | 1630 | 512 |
| | | 50/50 | 18.5 | | | | |
| SPCA | AD-404 | 100/0 | 38.00 | | | | |
| | | 75/25 | 29.50 | 28.75 | 45200 | 4000 | 1196 |
| | | 50/50 | 20.00 | | | | |
| | AD-480 | 100/0 | 35.00 | | | | |
| | | 75/25 | 27.00 | 26 | 21600 | 1860 | 586 |
| | | 50/50 | 19.00 | | | | |

Note: Viscosity recorded using Brookfield LVII at 20$^{o}$C, SCR-16/8R, 10 rpm.

### 2.7.2 Fluid Tested

A limited number of tests were conducted with Union Carbide XL54 fluid, Inland recycled fluids and Octagon Type I fluid during the 1997-98 winter.

The Type IV fluids tested in 1997-98 are listed below along with their approximate delivery date:

| FLUIDS | GLYCOL BASE | 1st SHIPMENT | 2nd SHIPMENT |
|---|---|---|---|
| Clariant 1957 | Propylene | Jan 98 | Apr 98 |
| Clariant 2001 | Propylene | Feb 98 | Apr 98 |
| Kilfrost ABC-S | Propylene | Feb 98 | Apr 98 |
| Octagon MaxFlight | Propylene | Feb 98 | Apr 98 |
| Union Carbide PG AAF | Propylene | Jan 98 | Apr 98 |
| Union Carbide Ultra IV | Ethylene | Jan 98 | Apr 98 |
| SPCA AD-404 | Ethylene | Feb 98 | Apr 98 |
| SPCA AD-480 | Propylene | Feb 98 | Apr 98 |

These fluids were provided by the fluid manufacturers at the beginning of the 1997-98 season. At the SAE meeting in Vienna, Union Carbide indicated that Type IV fluids, Ultra IV, and PG AAF would not satisfy the SAE AMS 1428 C specification.

The fluids were received either in 20 L containers or in 200 L drums. The addition of water to obtain either 50/50 or 75/25 mixes was carried out by the fluid manufacturers in their production facilities.

### 2.7.3 Evolution of Type IV Fluids

Tests with several Type IV fluids were conducted in winter 1996-97; however, some of these fluids are no longer available or have been changed. A summary of the changes is provided below:

*Clariant/Hoechst:* Type IV Hoechst MPIV 1957 was first tested in winter 1996-97. In winter 1997-98, the manufacturer changed its name to Clariant and reformulated the MPIV 1957 product. For clarity, the fluid tested in 1996-97 is referred to as Hoechst MPIV 1957 while the fluid tested in 1997-98 is referred to as Clariant MPIV 1957. In addition, Clariant developed a new Type IV fluid, Clariant MPIV 2001, which was also tested in 1997-98.

*Union Carbide*: UCAR Ultra+ was not approved in diluted forms. Two new Union Carbide Type IV fluids, UCAR Ultra IV and UCAR PG AAF, were shipped and tested for the first time in January 1998. However, these new fluids did not satisfy SAE fluid specifications.

*SPCA*: SPCA AD-404 was first tested in winter 1995-96. A new Type IV fluid SPCA AD-480, was shipped for the first time in 1998.

Type IV Octagon MaxFlight and Kilfrost ABC-S fluids were not reformulated.

Different viscosity samples of the same Type IV fluid brand were provided by some fluid manufacturers. This and the effect of viscosity on holdover time is discussed in detail in Subsection 5.1.

Fluid-specific holdover time tables were developed and are described in detail in Subsection 5.6.

## 2.8 Personnel

The site at Dorval was staffed mainly by university students and supervised by APS staff. Depending on the rate and duration of precipitation, up to four test stands were in use at Dorval. To operate four test stands, nine testers with the following responsibilities (see Appendix B, Attachment III for details) were required.

***Test Site Leader (1):*** Supervise and train site personnel, ensure site is functional, and ensure that test procedures are adhered to. Video record fluid failure as required.

***End Condition (4):*** Record end condition times for each cross hair.

***Meteo (4):*** Record meteorological conditions during every test.

Prolonged precipitation events require backup personnel, so a fairly large number of students were trained to perform experiments. This personnel reservoir was also needed because the same individuals were not always available for tests due to other obligations. Due to the nature, scale, and schedule of the testing (both holdover time and full-scale), and the requirement to keep costs to a minimum, a pool of students was considered to be the best option for the manpower requirements of these tests.

The utilization of personnel for the cold chamber tests was slightly different. To ensure that the cold chamber facility was used at all times, dedicated technicians were often assigned specific tasks. For example, fluids were prepared, mixed, cooled, and replenished after every test. During cold-soak testing, a technician ensured the cryostat was maintained in operational status and the cold-soak boxes were properly thermostatted. To ensure accurate precipitation rate measurements, the rate measurement procedure was automated and a technician was assigned the task of calculating and displaying printed summaries of the precipitation rates. A laptop computer and printer were dedicated for this process alone.

To obtain consistent results from fluid failure calls, the same individual recorded the end conditions at the NRC freezing precipitation tests for the 1996-97 and 1997-98 test seasons. This individual, with pilot experience, was also available during all natural snow tests conducted at Dorval Airport and supervised most of the failure calls.

## 2.9 Analysis Methodology

### 2.9.1 General

This section of the report describes the various categories of precipitation and the precipitation rate limits used during the course of holdover time testing, as well as the process of data analysis used in the evaluation of fluid holdover times.

### 2.9.2 Description of Data Ranges and Precipitation Definitions

The test program developed to measure fluid failure times was carried out under four general categories of precipitation:

- Natural snow;
- Freezing drizzle and light freezing rain;
- Freezing fog; and
- Rain on a cold-soaked surface.

Tests were conducted over temperature and precipitation rate ranges specific to each category of precipitation. A multi-variable regression procedure was used to evaluate fluid holdover times (first presented in Transport Canada report, TP 13131E (1)) and is based on the refinement of an equation for a curve that best represents the fluid failure time test data, and then the solution to that equation at the upper and lower limits of a defined precipitation range. To support this procedure, precipitation rate limits for each specific category of precipitation were defined, reviewed, and approved.

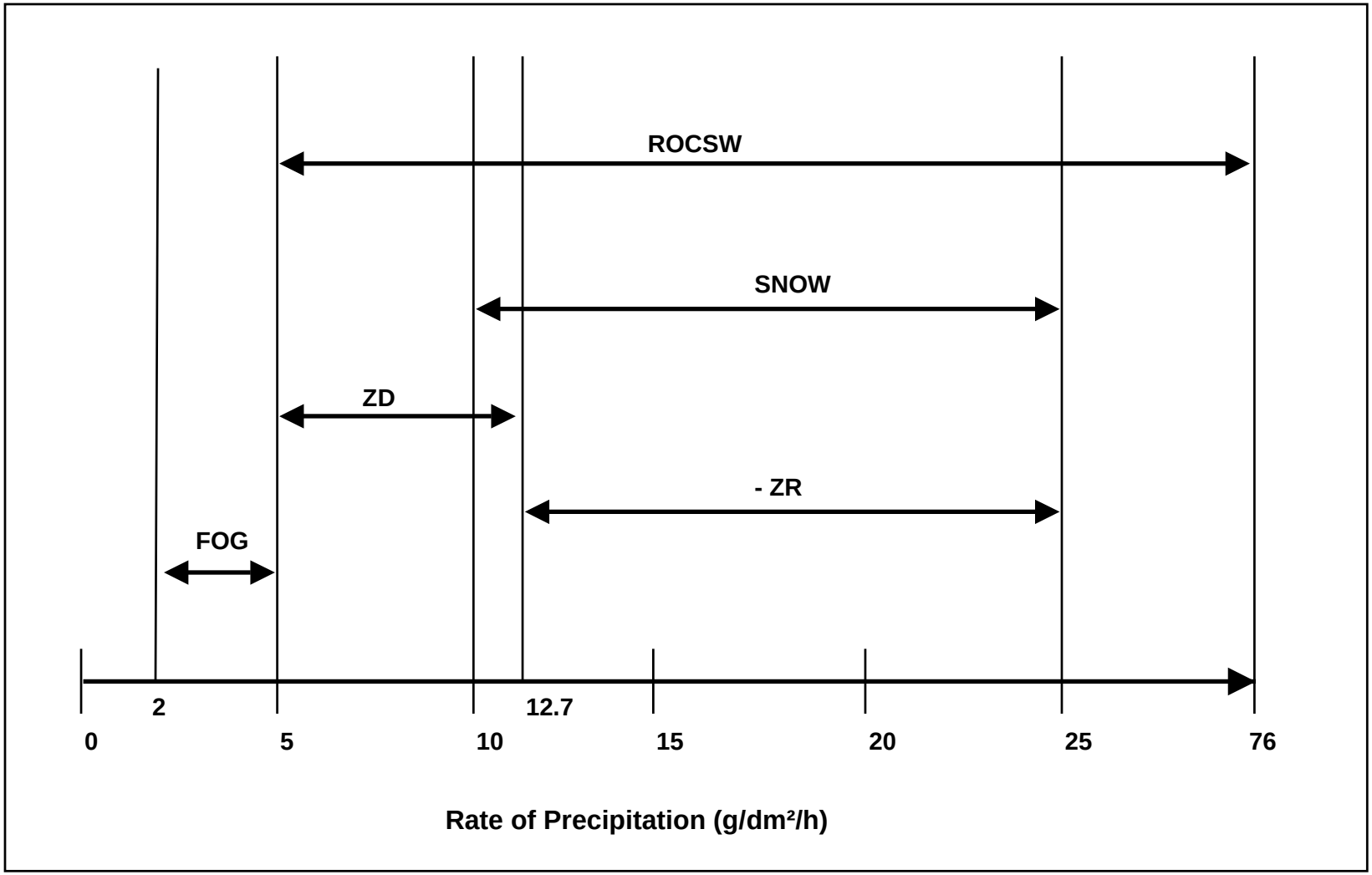
The precipitation rate limits used for the evaluation of holdover times are represented schematically in Figure 2.8. Detailed definitions and explanations of the data types and ranges are described in Subsections 2.9.2.1 to 2.9.2.5. Meteorologically accepted definitions of these conditions are outlined in Table 2.1.

#### *2.9.2.1 Natural snow*

All fluid failure tests in snow were conducted in natural conditions at the APS Dorval Airport test site. Data were collected for precipitation rates ranging from less than 10 g/dm$^2$/h to greater than 25 g/dm$^2$/h; however, lower and upper holdover times for each cell in this column were determined at rates of 10 and 25 g/dm$^2$/h, respectively.

FIGURE 2.8

## DATA RANGE USED FOR EVALUATION OF HOLDOVER TIME LIMITS



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If precipitation rates less than the lower limit (light snow) are encountered, the upper time limit of the holdover time range can be selected for use.

The upper precipitation rate limit (25 g/dm$^2$/h) corresponds to the onset of heavy snow. Above this rate, it is standard practice to refer to the cautionary note included in the holdover time tables indicating that the time of protection will be shortened in heavy weather conditions (i.e., heavy precipitation or high moisture content).

#### *2.9.2.2 Freezing drizzle*

Freezing drizzle is considered to occur over the range of 0 to 12.7 g/dm$^2$/h. The upper limit in this range, while not specifically defined in Table 2.1, has been adopted based on discussions with meteorological experts and operators on the SAE G-12 Holdover Time Subcommittee.

The precipitation rate spectrum for freezing drizzle for test purposes is confined to rates between 5 and 12.7 g/dm$^2$/h, inclusive. This range corresponds to heavy drizzle and has been chosen to provide aircraft operators with a greater margin of safety. A caution is included in the holdover time tables, indicating that if positive identification of freezing drizzle is not possible, the light freezing rain holdover time is recommended for use.

#### *2.9.2.3 Light freezing rain*

Freezing rain conditions as applied to the holdover time tables cover the range of precipitation rates from 12.7 to 25 g/dm$^2$/h, inclusive. This range falls in the category of light freezing rain and is the only freezing rain category considered, as operations in periods of moderate or heavy freezing rain are deemed unsafe.

#### *2.9.2.4 Freezing fog*

The precipitation rate limits for freezing fog were arrived at with input from meteorologists from NRC, who helped define an important parameter in the study of fog referred to as *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic metre of air, can generally assume values in the range of 0.2 to 0.6 g/m$^3$. The precipitation rate

for fog, referred to as *fog deposition* or simply as *deposition*, is given by the empirical expression

***Deposition = LWC x Wind Velocity x Sin 10° x Collection Efficiency***

where the Sin 10° term accounts for the 10° inclination of the test plates into the direction of the wind.

For a plate in fog with a 0.6 g/m$^3$ LWC, a wind velocity of 6 km/h, and a collection efficiency of 80 percent, a deposition of 5 g/dm$^2$/h is arrived at. For an aircraft taxiing at 12 km/h relative to the same wind in a 0.6 g/m$^3$ LWC fog, a collection efficiency of 40 percent might be expected in this situation, and again a deposition rate equal to 5 g/dm$^2$/h is achieved.

The meteorological circumstances (LWC value and wind speed) and the speed and orientation of the airfoil relative to the wind (stationary or taxiing), contribute to uncertainties in the values that the variables in the equation can assume. A deposition range of 2 to 10 g/dm$^2$/h is considered to be reasonable, and tests have been conducted in this range in previous years.

The upper and lower holdover times for freezing fog were determined subjectively from the test data in previous years. It was agreed upon (at the 1997 Chicago SAE G-12 Holdover Time Subcommittee meeting) that the lower and upper holdover times for fog be evaluated at rates of 5 g/dm$^2$/h and 2 g/dm$^2$/h, respectively. However, it was felt in Vienna that 2 g/dm²/h was not indicative of low rate natural fog. As a result, the upper holdover times in each of the freezing fog cells of the holdover time tables were left untouched from previous years.

### *2.9.2.5 Rain on a cold-soaked surface*

Data used for the evaluation of holdover times for this category of precipitation were limited to precipitation rates ranging from 5 to 76 g/dm$^2$/h, which encompasses drizzle (5 to 12.7 g/dm$^2$/h), light rain (12.7 to 25 g/dm$^2$/h), and moderate rain (25 to 76 g/dm$^2$/h). The heavy rain category is covered by the cautionary note at the bottom of the holdover time table regarding heavy weather conditions.

### 2.9.3 Protocol for the Determination of Holdover Times

Each cell in a holdover time table represents a range of time during which a fluid at a specified concentration will provide protection for a particular temperature range in a particular category of precipitation. Each holdover time table is composed of a maximum of 45 cells. Each cell contains a lower and upper time limit (except for frost) for a maximum of 81 time values.

Cell holdover time values are determined by plotting *failure time* versus *rate of precipitation* and recording the failure time at two pre-selected rate limits. In previous years, several protocols were employed in the determination of holdover times. Due to the subjective natures of these different protocols, different interpretations of the data were possible. A multi-variable regression approach was subsequently devised in 1996-97 (see Transport Canada report TP 13131E (1)) and has been used to evaluate fluid holdover times for the past two test seasons.

#### *2.9.3.1 Multi-variable regression protocol*

Data corresponding to each cell in the holdover time table were assembled and sorted according to precipitation type, fluid manufacturer, dilution factor, and temperature range. The data for each fluid and each cell in the holdover time table were plotted. The data points on each plot were used to fit an equation of the form

$$t = cR^aT^b$$

where

| | | |
|---|---|---|
| t | = | Time (minutes), |
| R | = | Rate of precipitation ($g/dm^2/h$), |
| T | = | Temperature (°C), and |
| a,b,c | = | coefficients determined from the regression. |

The coefficient c is a constant. The coefficients a and b give the rate and temperature dependency of the failure time, respectively.

Plots of **Log t** versus **Log R** are shown in Figure 2.9. The plots contain data from two temperature ranges for one 50/50 Type IV fluid in natural snow conditions. The best-fit regression lines are superimposed onto the plot and were obtained from the analysis using the lowest temperatures in each of the temperature ranges, from which the data were chosen.

FIGURE 2.9

**EXAMPLE OF REGRESSION METHOD ON LOG-LOG CHART**
**EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME**

CLARIANT 1957 TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997-98

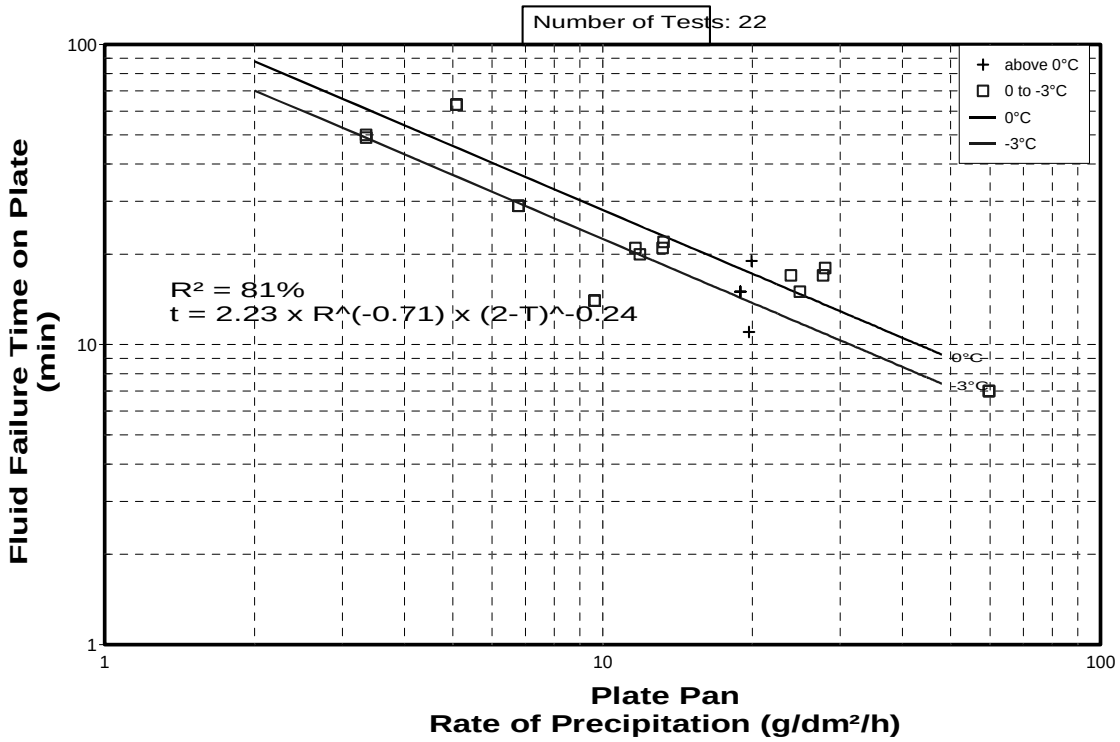


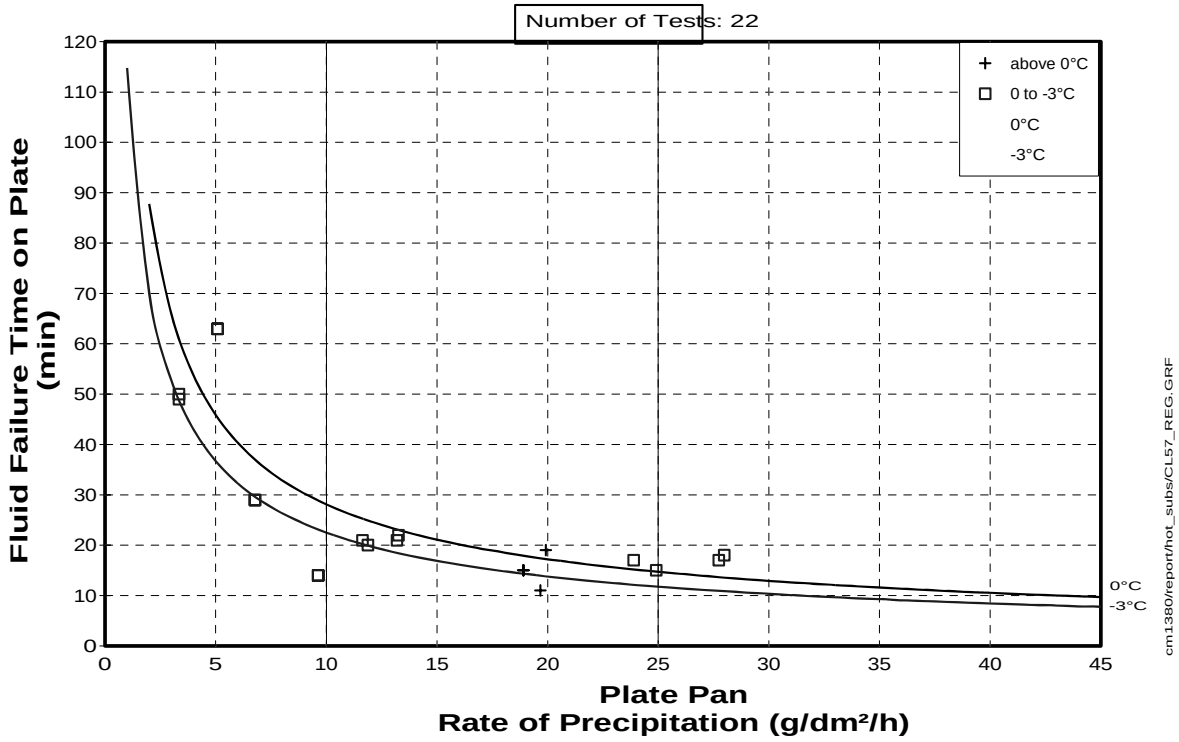

FIGURE 2.10

**EXAMPLE OF REGRESSION METHOD ON STANDARD CHART**
**EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME**

CLARIANT 1957 TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997-98



The same data plotted on a linear scale (failure time **t** versus precipitation rate **R**) are shown in Figure 2.10. The curves, generated from the power law form of the equation using the coefficients determined from the fit, are superimposed onto the plot. The holdover time range is determined from the intersections of the curve with the precipitation rate limits defined for snow.

The holdover times for this fluid from the upper curve (0°C) are 28 minutes at 10 g/dm$^2$/h and 15 minutes at 25 g/dm$^2$/h, establishing the holdover time range for this particular fluid. This illustrates the general approach used in t he determination of a fluid holdover time range for any given cell in the holdover time table.

Appendix F lists the results of all the regression analyses performed and includes all the corresponding equations with their associated coefficients and output summaries.

The categories of precipitation are separated into four groups: natural snow, freezing drizzle and light freezing rain, freezing fog, and rain on a cold-soaked surface. Each group was subject to a slightly modified version of the general equation given above, as described in Subsections 2.9.3.1.1 to 2.9.3.1.4.

#### 2.9.3.1.1 Natural snow

The general form of the regression equation was modified for natural snow by substituting 2-T for the variable T, in order to prevent taking the log of a negative number as natural snow can occur at temperatures approaching 2°C.

$$t = cR^a(2-T)^b$$

- Best-fit curves were plotted for each fluid in each cell of the snow column using the most restrictive (lowest) temperature for that cell. For example, in cases of natural snow tests conducted at ambient temperatures above 0°C, the value of temperature used in the fitting procedure was 0°C.

- The upper and lower holdover time values were determined from the points at which the best-fit curve intersects the lower and upper precipitation limits, respectively.

#### 2.9.3.1.2 Light freezing rain and freezing drizzle

The modified equation used to treat the data in these categories of precipitation is given by the expression below:

$$t = cR^a$$

- Tests in freezing drizzle and light freezing rain were conducted at predetermined temperature limits (-3 and -10°C during the past year). The best-fit curves for data corresponding to a given cell in the holdover time table in these conditions were also obtained by using the most restrictive (lowest) cell range temperature.

- The exception to this was made for the case of the temperature range above 0°C. Experiments for freezing drizzle and light freezing rain could not be performed artificially at temperatures above 0°C, and as such, the equation could not be calculated at the most restrictive temperature of 0°C. Therefore, holdover times for this temperature range were obtained by using the same values calculated at -3°C.

#### 2.9.3.1.3 Simulated freezing fog

The same method used to evaluate freezing fog data in 1996-97 (see Transport Canada report TP 13131E (1)) was also used to evaluate this year's freezing fog data. The equation used to treat data is given by the expression below:

$$t = cR^a T^b$$

#### 2.9.3.1.4 Rain on a cold-soaked wing

The same method for the evaluation of holdover times in light freezing rain and freezing drizzle was used for this category of precipitation with the following exceptions:

- Holdover times are based on the use of a cold-soak box with a depth of 7.5 cm only;

- Cold-soak tests were conducted at +1°C, instead of +2°C used in previous years; and

- The range of times represents conditions of heavy drizzle, light freezing rain, and moderate rain.

Photo 2.1
**View of Dorval Test Site and Associated Equipment**

Photo 2.2
**Environment Canada's Weather Observation Station at Dorval Airport**

Photo 2.3
**Outdoor View of NRC CEF**

Photo 2.4
**Inside view of Small End of Climatic Engineering Facility**

Photo 2.5
**Inside View of Large End of Climatic Engineering Facility**

Photo 2.6
**Sprayer Assembly Used at NRC**

Photo 2.7
**Sprayer Nozzle**

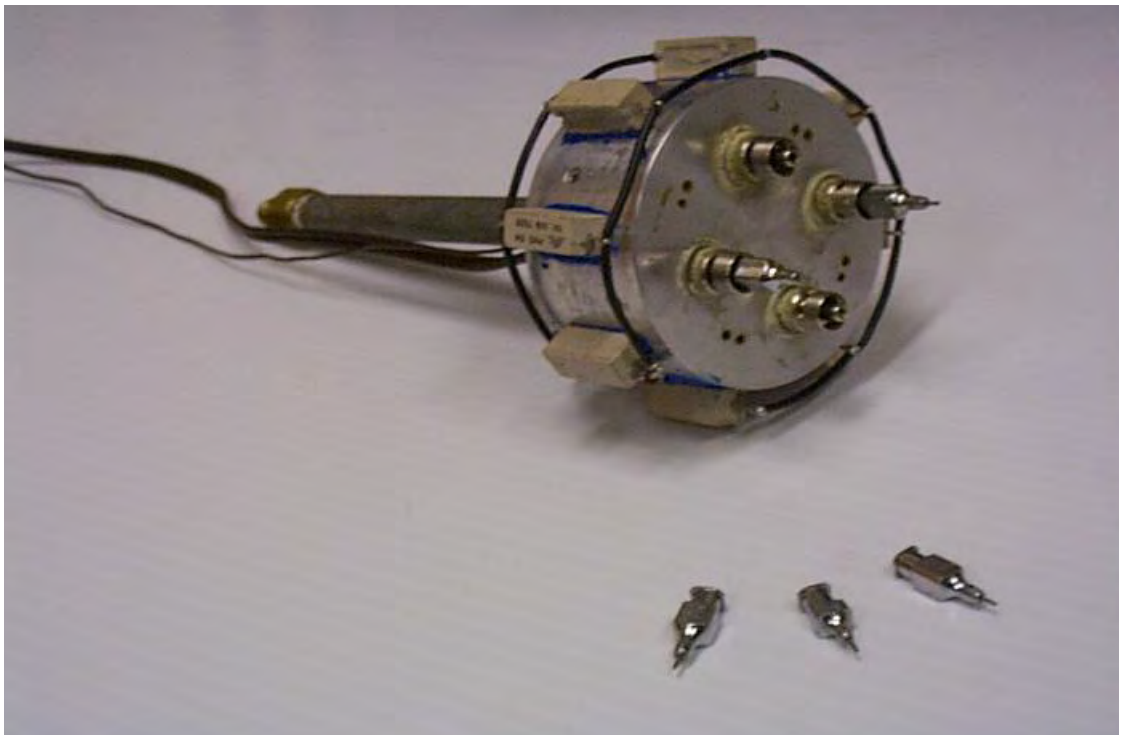


Photo 2.8
**Optical Gauge by HSS to Measure Droplet Size**

Photo 2.9
**Examples of Droplet Sizes Produced by NRC Spray System**

Photo 2.10
**Test Plates Mounted on a Stand**

Photo 2.11
**Collection Pans Used Indoors at the NRC**

Photo 2.12
**Cold-Soak Boxes Cooling Unit**

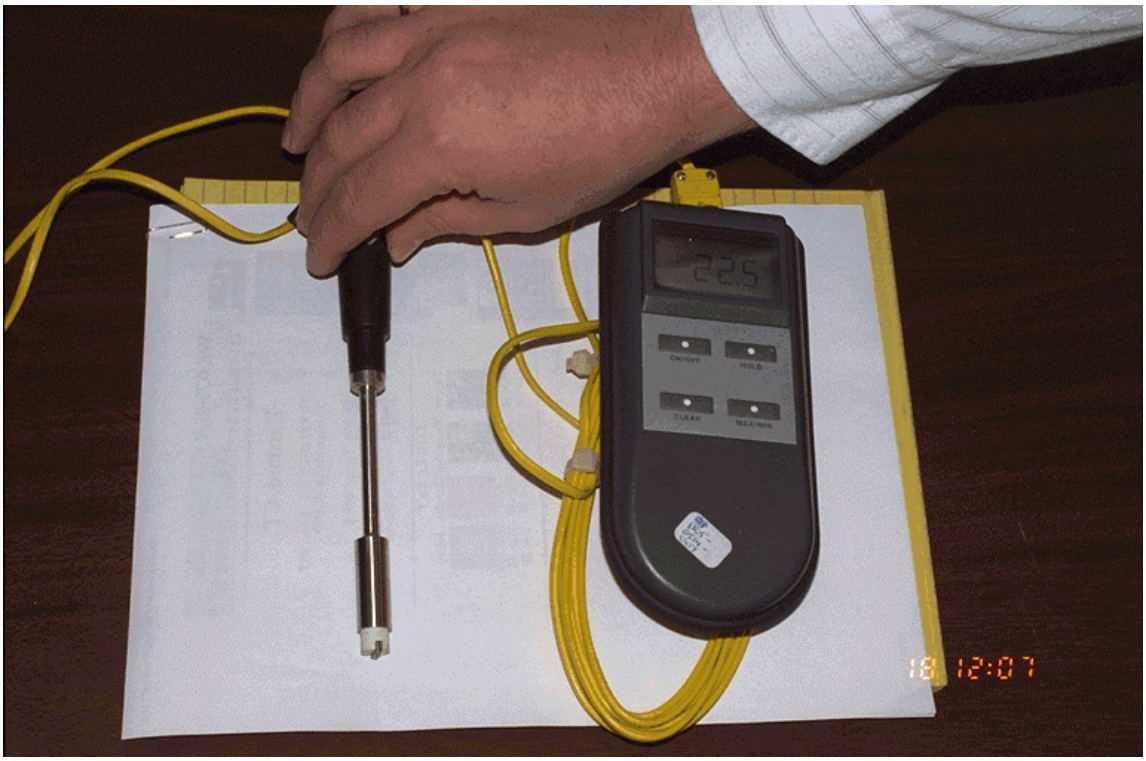
Photo 2.13
**Misco Refractometer Used to Measure Freeze Point**

Photo 2.14
**Hand-held RVSI Ice Detection Unit**

Photo 2.15
**Spar/Cox Ice Detection Unit**

Photo 2.16
**Atmospheric Environment Services Automated Weather Station Instruments**

Photo 2.17
**Hand-held Temperature Probe**



# 3. DESCRIPTION OF DATA

This section provides a summary of the number of tests conducted for natural snow, simulated light freezing rain and freezing drizzle, simulated freezing fog and cold-soaked boxes. Breakdowns are provided for quantity of tests performed versus fluid type and distributions of weather parameters such as temperature, precipitation rate, wind speed, and direction.

Natural snow tests were conducted at the APS test site, located at Dorval Airport. A total of 525 usable tests were conducted on nine days over the 1997-98 winter season. Most of the tests were conducted in the months of February and March since most of Type IV fluids were received late in the season.

Simulated light freezing rain, drizzle, fog and rain on cold-soak box tests were conducted at NRC's CEF in Ottawa.

A summary of the flat plate tests conducted at Dorval and at NRC is provided in Table 3.1.

## 3.1 Dorval Natural Snow Tests

### 3.1.1 Data Acquisition

The test plan developed for experiments to be conducted in natural snow conditions is described in Appendix B. During the 1997-98 test season, a total of 752 tests were conducted on flat plates at the APS test site at Dorval Airport. All of the 752 tests occurred during natural precipitation. Of this total, 525 data points were usable. A breakdown of data points collected is listed below.

| | **# of Tests** |
|---|---|
| Usable | 525 |
| Fluid not failed (e.g. snow stopped) | 130 |
| Different precipitation (ZR-, ZD, IP, ...) | 75 |
| Other (discontinued fluids) | 22 |
| Total tests conducted | **752** |

The tests referred to as different precipitation above are tests carried out under natural freezing conditions other than snow and are described separately in Subsection 6.1.

TABLE 3.1

# SUMMARY OF TESTS PERFORMED IN 1997-98

## Natural Snow Tests at Dorval

| Date | # of Tests | Total Precip. (for the day) (cm) | | Month | Total Precip (during tests) (cm) | Total Precip. of month (cm) | Normal Precip. of month (cm) |
|---|---|---|---|---|---|---|---|
| | | | | Nov-97 | | 37.2 | 24.1 |
| Dec-23-97 | 40 | 12.4 | | Dec-97 | 12.4 | 47.6 | 54.8 |
| Jan-23-98 | 116 | 23.6 | | Jan-98 | 23.6 | 65 | 47.7 |
| Feb-18-98 | 16 | 3.6 | | | | | |
| Feb-25-98 | 24 | 10.8 | | Feb-98 | 14.4 | 27.2 | 41.2 |
| Mar-10-98 | 12 | 2.2 | | | | | |
| Mar-14-98 | 69 | 9.6 | | | | | |
| Mar-19-98 | 132 | 9.6 | | | | | |
| Mar-21-98 | 16 | 4.6 | | | | | |
| Mar-22-98 | 100 | 23.2 | | Mar-98 | 49.2 | 56 | 31.3 |
| | | | | Apr-98 | | 0 | 10.9 |
| **Total** | **525** | **100** | | **Total** | **100** | **233** | **210** |

## Tests Performed at Climatic Engineering Facility

| Date | Condition Tested |
|---|---|
| April 03 - May 01, 98 | ZR-, ZD, Freezing Fog, Rain on Cold-Soak Boxes |

The breakdown, by fluid type, of the 525 usable tests conducted is shown in Figure 3.1 and summarized below.

| Fluid Type | # of Tests |
|---|---|
| Type IV Neat | 191 |
| Type IV 75/25 | 167 |
| Type IV 50/50 | 85 |
| Type I (standard) | 24 |
| Recycled Fluid | 40 |
| Aeroflot | 18 |
| Total Usable Tests | **525** |

### 3.1.2 Test Location and Fluids Tested

The Type I and Type IV fluids tested at Dorval Airport were manufactured by Clariant, Kilfrost, Octagon, SPCA, and Union Carbide. In addition, a Russian fluid provided by Aeroflot and two recycled fluids developed by Inland Technologies were also tested. Figure 3.1 shows all fluid brands tested and the distributor by fluid type of tests.

### 3.1.3 Distribution of Average Precipitation Rates

Precipitation at Dorval was measured using plate pans, and two automated gauges from Environment Canada (READAC and CR21X). The rates of precipitation used in this report were computed using the plate pan method. Environment Canada gauges were used as a backup and also for evaluation of weather snow data, described in detail in Transport Canada report TP 13314E (6).

The distribution of the average precipitation rate for the tests is summarized in Figure 3.2 for Type IV fluids.

### 3.1.4 Distribution of Other Meteorological Conditions

The air temperature, wind speed, and wind direction over the duration of the tests were obtained from the Environment Canada automated weather station (READAC). In previous years, these parameters were measured with instruments purchased by APS on behalf of Transport Canada. These instruments are still operational, and were used this year for weather monitoring purposes only.

FIGURE 3.1

# NUMBER OF NATURAL SNOW TESTS CONDUCTED

1997-98 TEST SEASON AT DORVAL

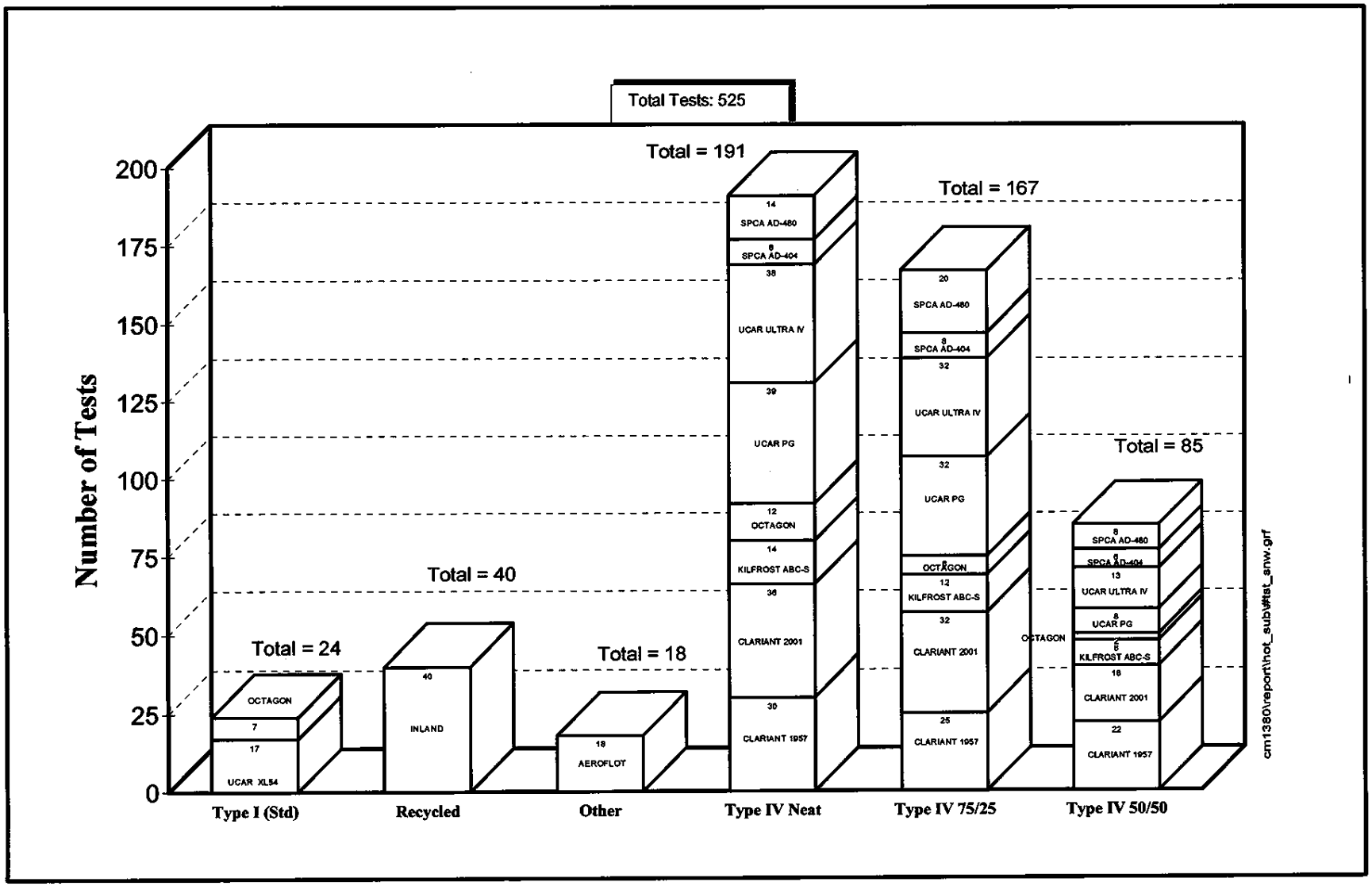
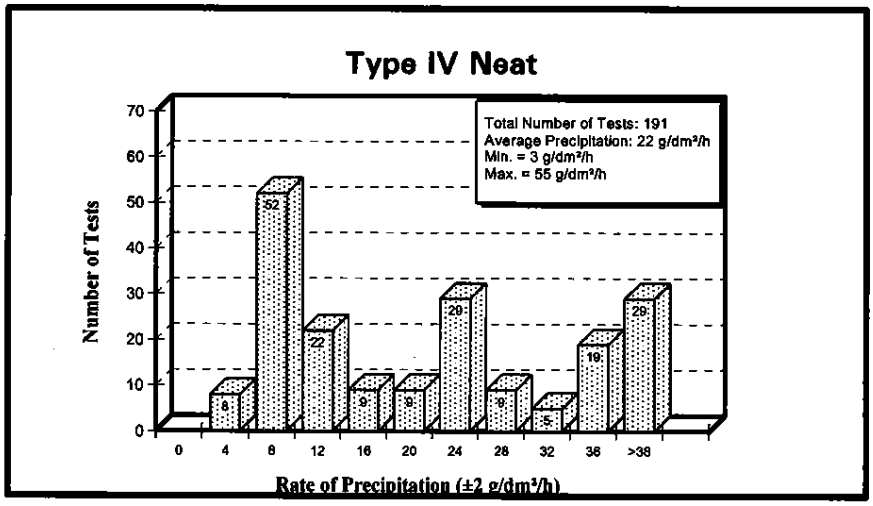


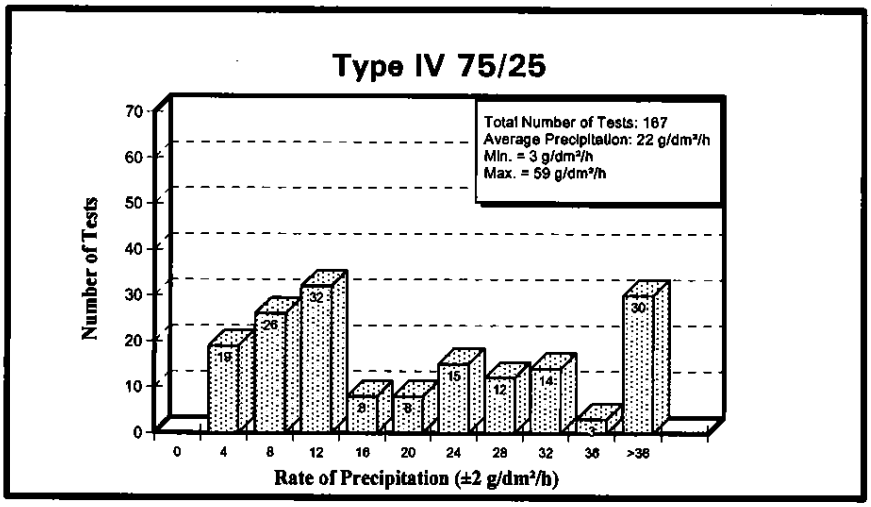
FIGURE 3.2

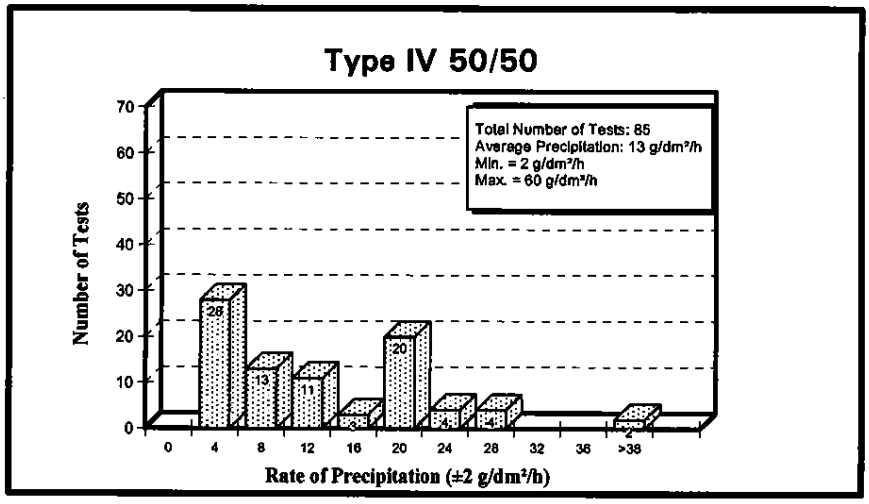
# DISTRIBUTION OF PRECIPITATION RATE - TYPE IV FLUIDS

Natural Snow Tests

1997-98

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A summary of the distribution of the READAC measurements for each Type IV fluid test is illustrated in Figures 3.3 to 3.5 as follows:

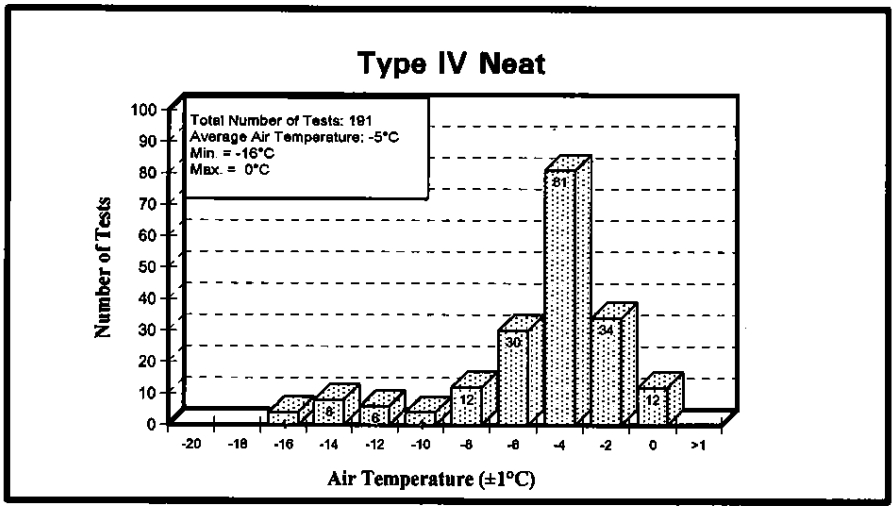
Figure 3.3 Distribution of Air Temperature for Type IV Fluids;
Figure 3.4 Distribution of Wind Speed for Type IV Fluids; and
Figure 3.5 Comparison of Wind Direction to Platform Direction.

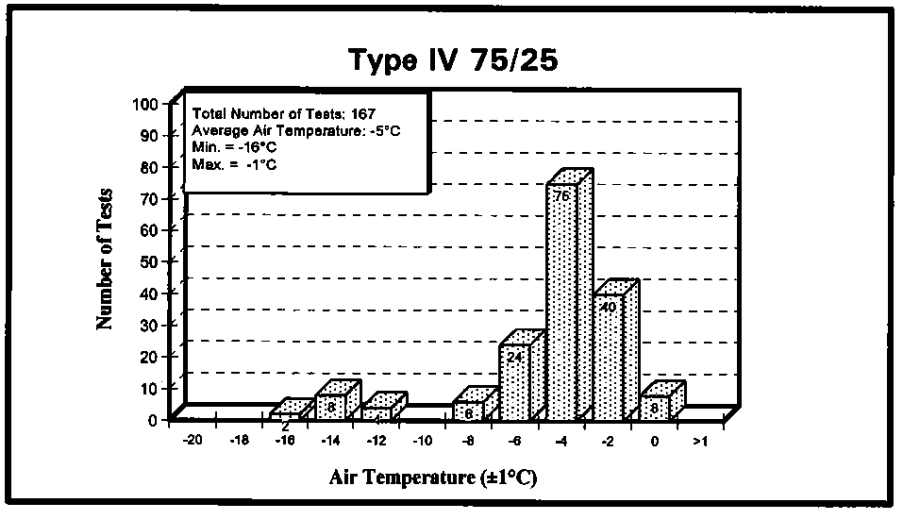
FIGURE 3.3

# DISTRIBUTION OF AIR TEMPERATURE - TYPE IV FLUIDS

Natural Snow Tests

1997-98



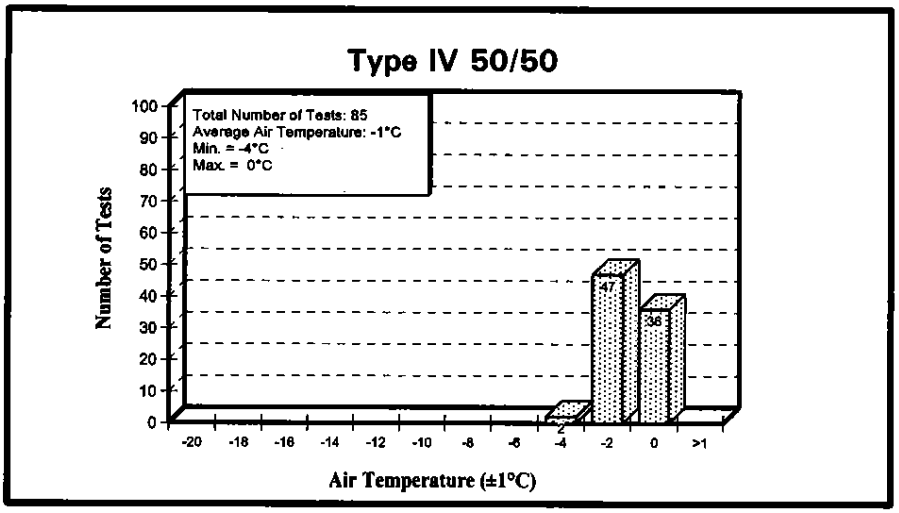




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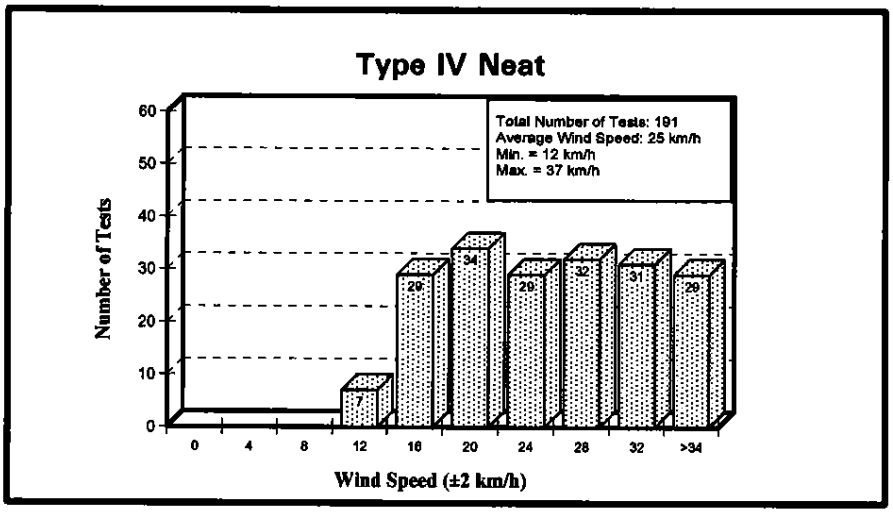
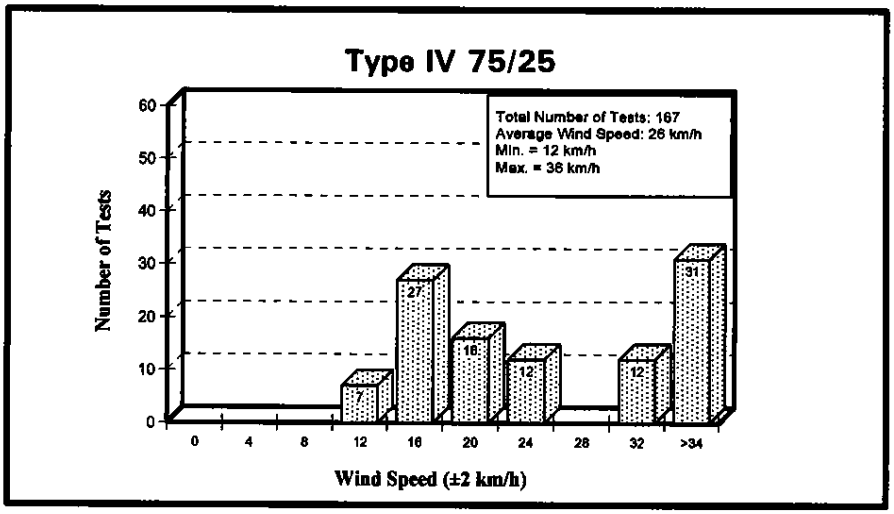
FIGURE 3.4

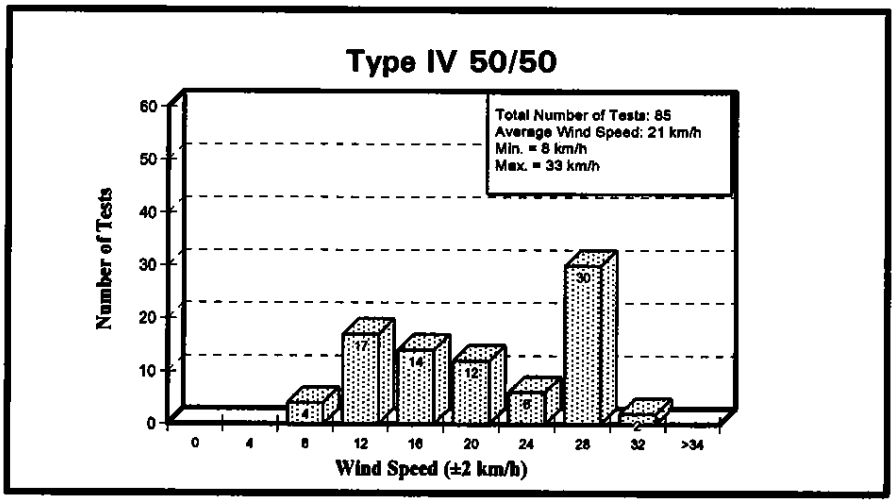
# DISTRIBUTION OF WIND SPEED - TYPE IV FLUIDS

Natural Snow Tests

1997-98

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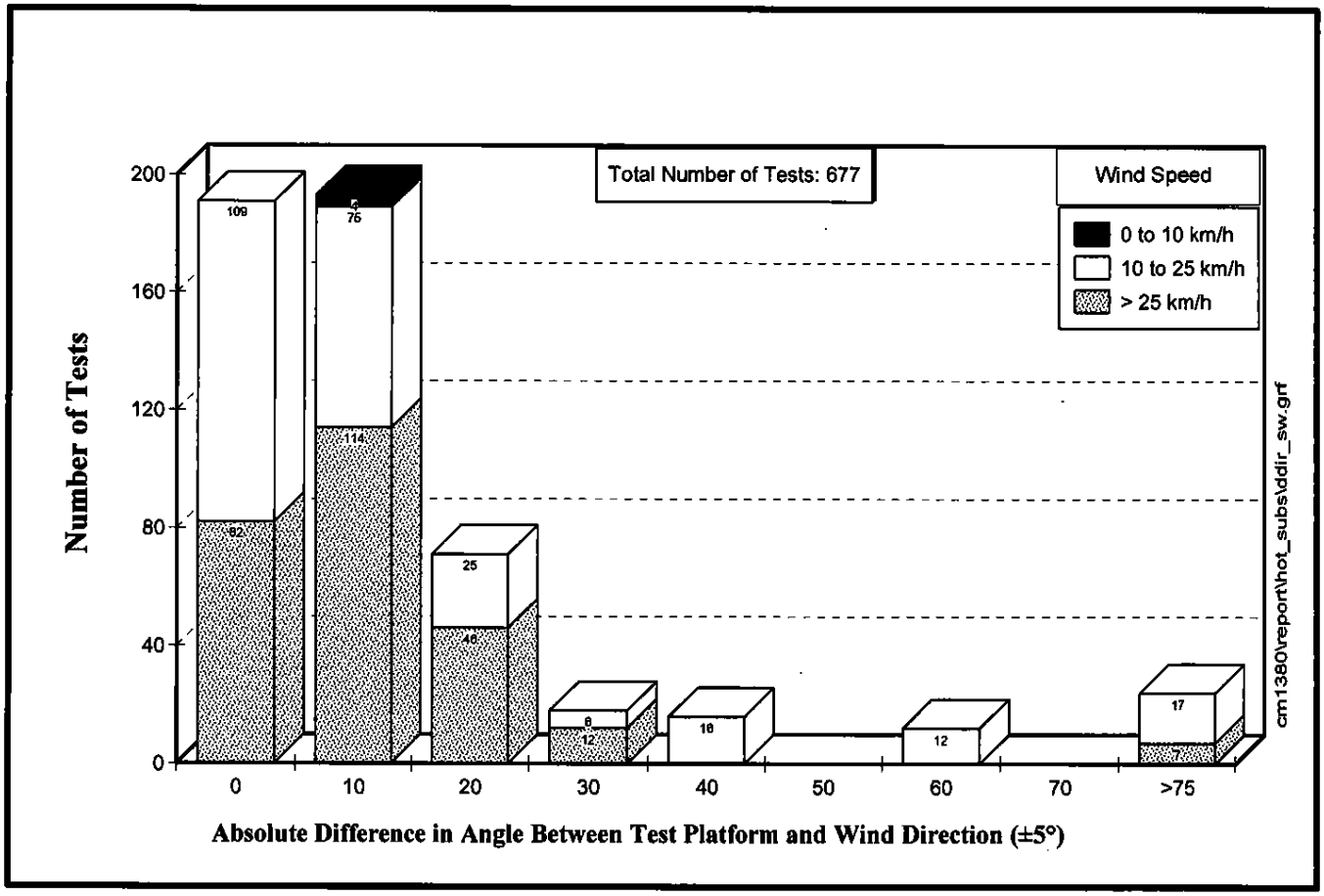
NB: Measured at 10 m height.

FIGURE 3.5

# COMPARISON OF WIND DIRECTION TO PLATFORM DIRECTION

Natural Snow Tests

1997-98



## 3.2 Freezing Drizzle and Light Freezing Rain Tests

### 3.2.1 Data Acquisition

The test plan developed for experiments to be conducted in freezing drizzle and light freezing rain is described in Appendix C. A total of 241 freezing drizzle and 234 light freezing rain tests were carried out in the 1997-98 winter, as shown in Figure 3.6.

### 3.2.2 Test Location and Fluids Tested

All of the 475 freezing precipitation tests were conducted at NRC's CEF in Ottawa. The fluids tested were supplied by Clariant, Kilfrost, Octagon, SPCA, Union Carbide, and Inland Technologies.

### 3.2.3 Distribution of Average Precipitation Rates

Figures 3.7 to 3.9 show the distribution of average precipitation rates recorded for all fluids tested. As described in Section 2, the average precipitation rates for freezing drizzle and light freezing rain were computed from weight measurements taken with plate pans. The pans were positioned on the stand at every plate position before and after each run for a minimum of two 10-minute periods. In addition, an automated tipping bucket was positioned next to the test stand to measure precipitation for monitoring purposes to ensure consistent rates during the test period.

All fluids were tested at the upper and lower precipitation rate limits. The limits were 5 and 13 g/dm²/h for freezing drizzle, and 13 and 25 g/dm²/h for light freezing rain.

### 3.2.4 Distribution of Other Meteorological Conditions

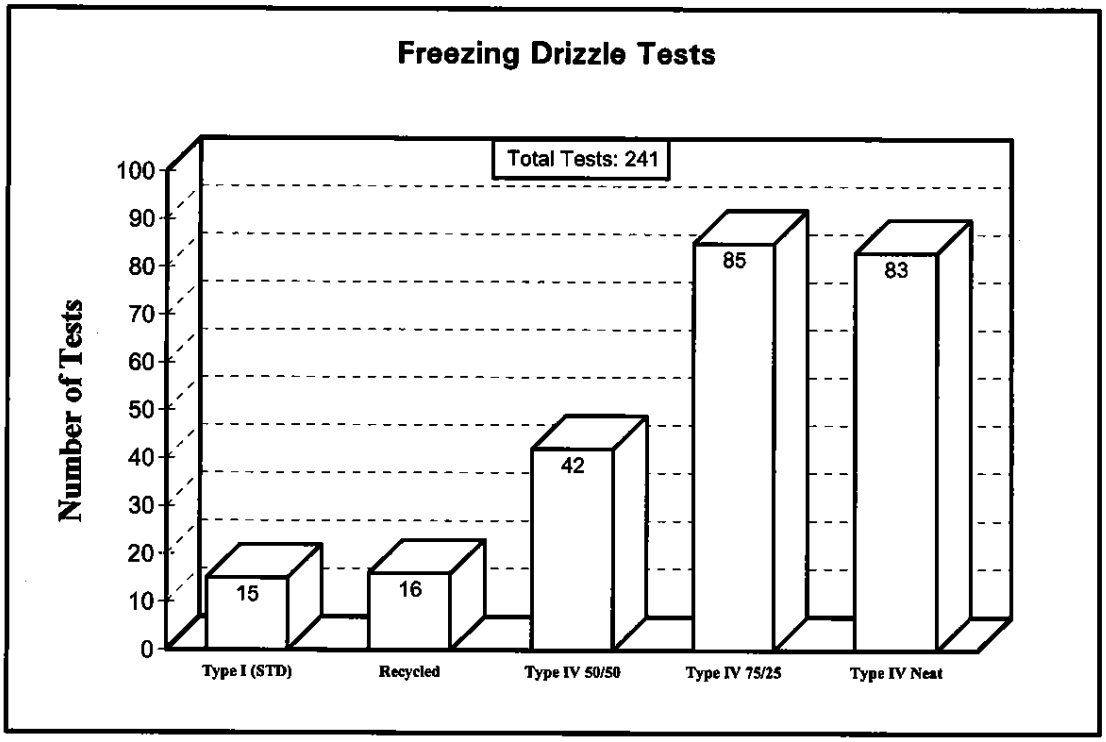
Air temperature was the only other meteorological factor that varied during the freezing drizzle and light freezing rain tests. The distribution of air temperatures is presented in Figures 3.10 to 3.12.

Special tests with wind were conducted to study the effect of wind on holdover times; these tests are described in detail in Subsection 6.8.

FIGURE 3.6

# NUMBER OF SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN TESTS

1997-98 TEST SEASON



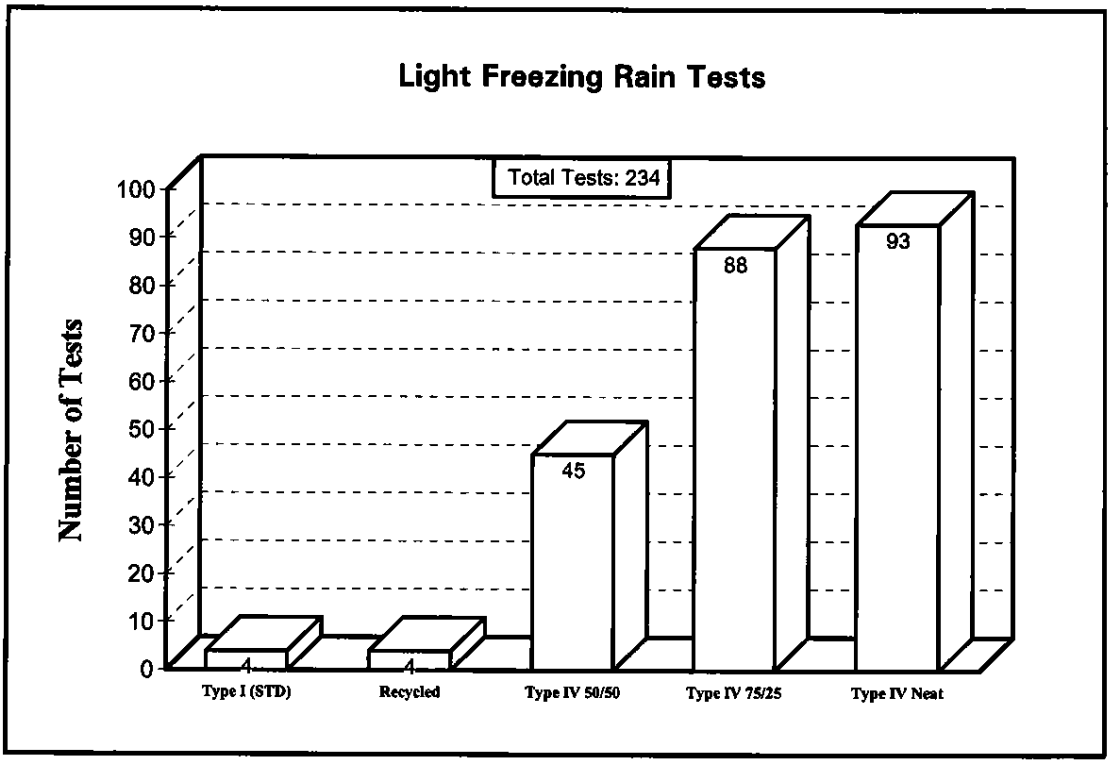




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FIGURE 3.7

## DISTRIBUTION OF PRECIPITATION RATE - TYPE I FLUIDS

Simulated Freezing Drizzle/Light Freezing Rain Tests

1997-98

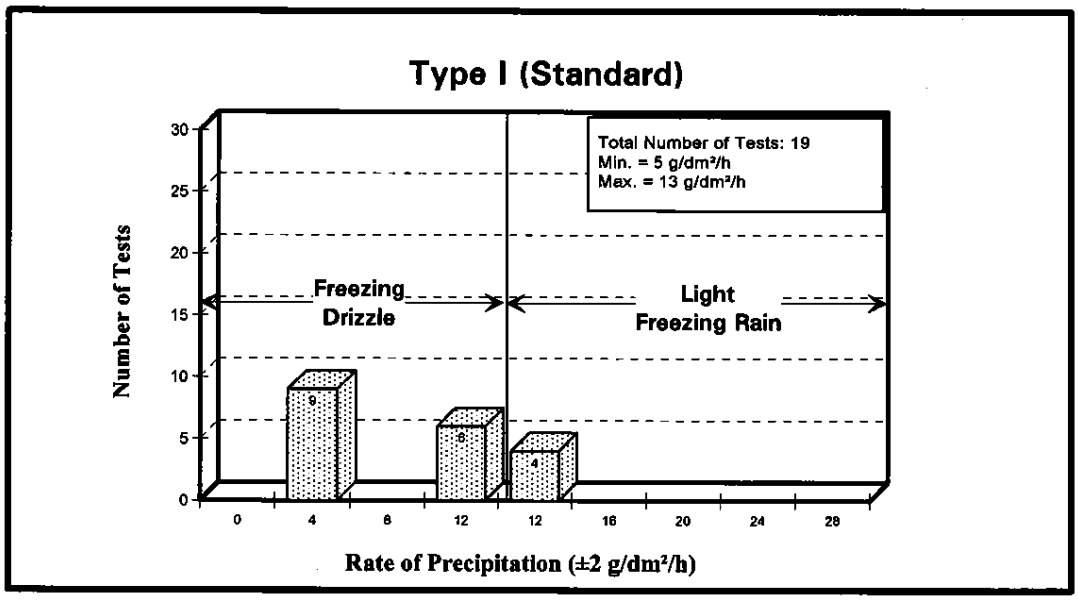


FIGURE 3.8

## DISTRIBUTION OF PRECIPITATION RATE - RECYCLED FLUIDS

Simulated Freezing Drizzle/Light Freezing Rain Tests

1997-98

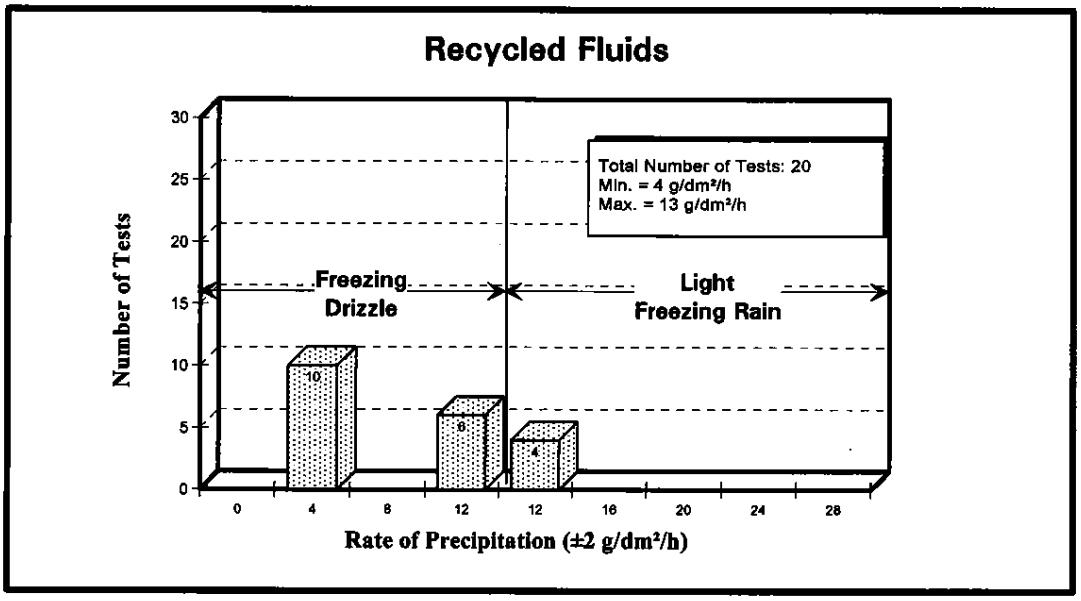


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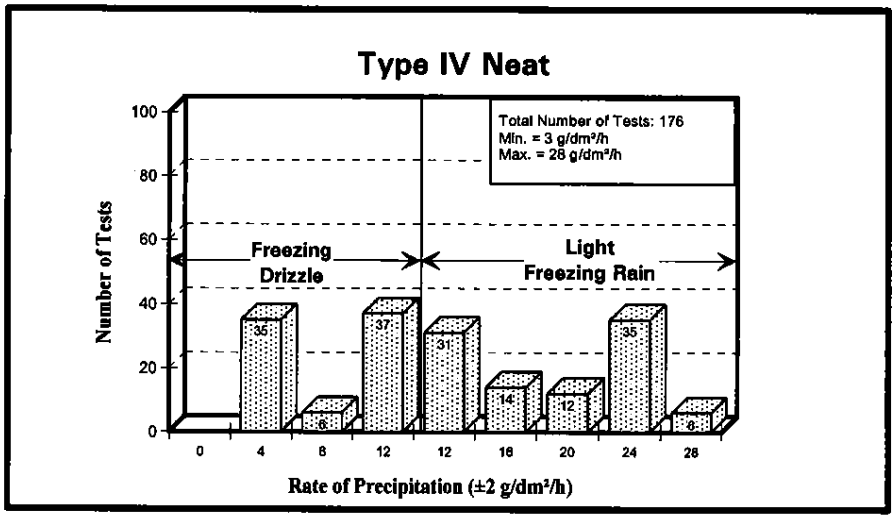
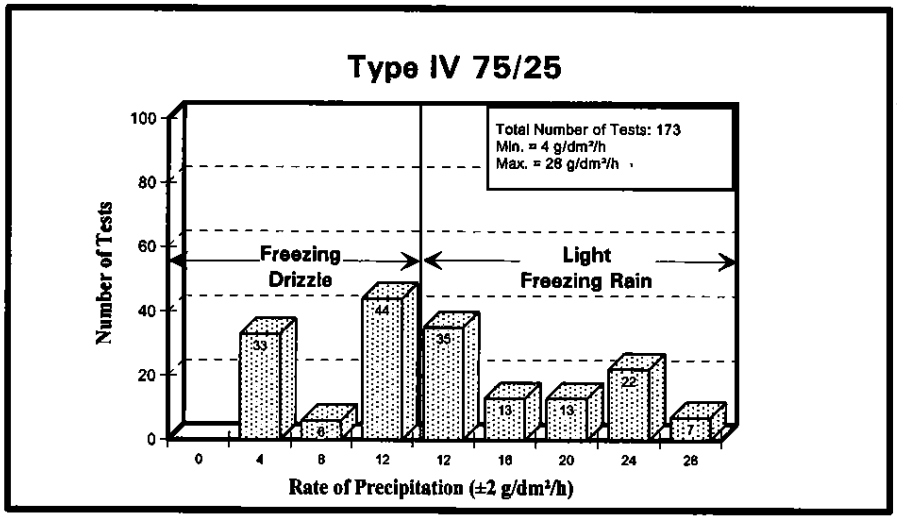
FIGURE 3.9

# DISTRIBUTION OF PRECIPITATION RATE - TYPE IV FLUIDS

Simulated Freezing Drizzle/Light Freezing Rain Tests

1997-98



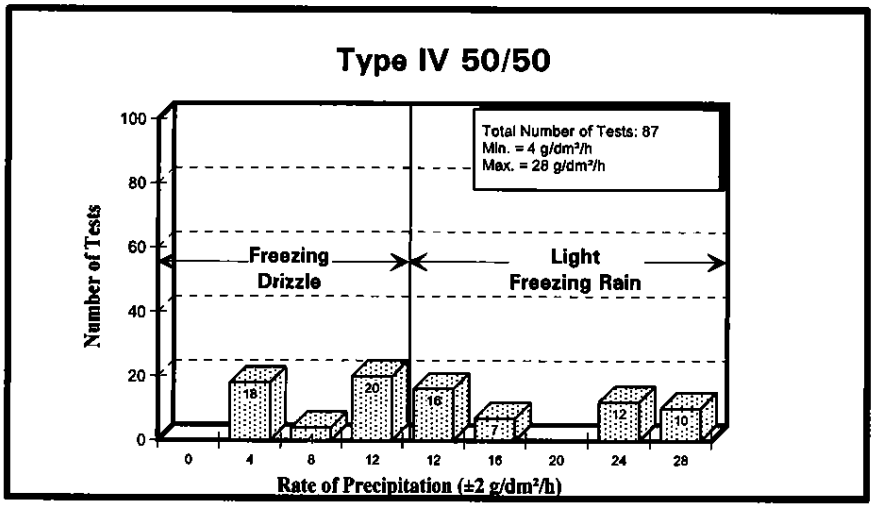




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FIGURE 3.10

## DISTRIBUTION OF AIR TEMPERATURE - TYPE I FLUIDS

Simulated Freezing Drizzle/Light Freezing Rain Tests

1997-98

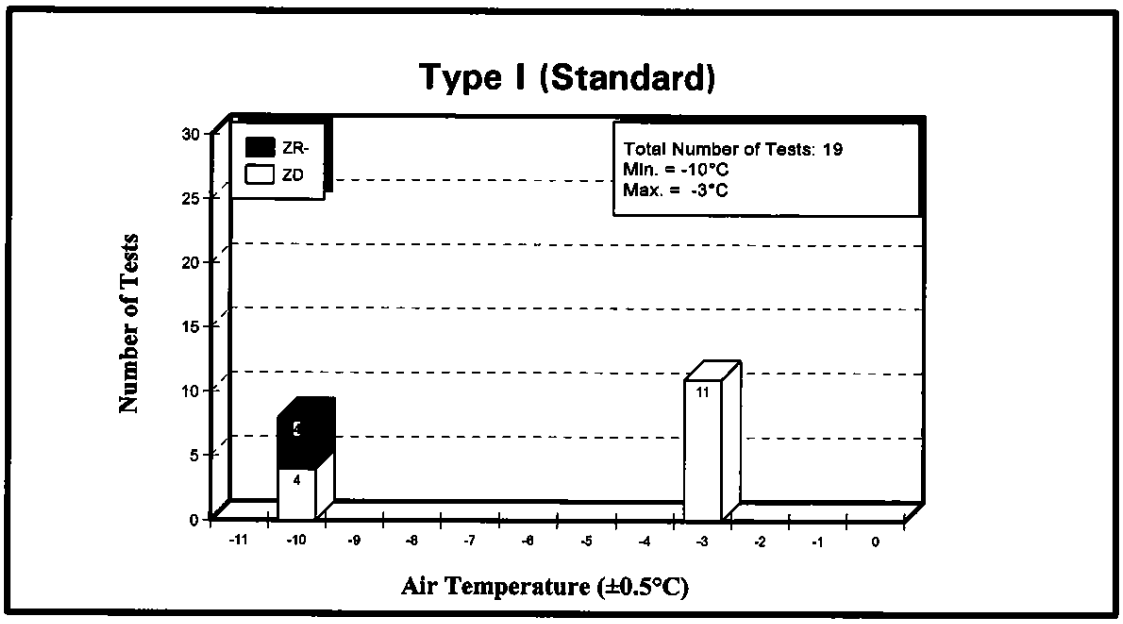


FIGURE 3.11

## DISTRIBUTION OF AIR TEMPERATURE - RECYCLED FLUIDS

Simulated Freezing Drizzle/Light Freezing Rain Tests

1997-98

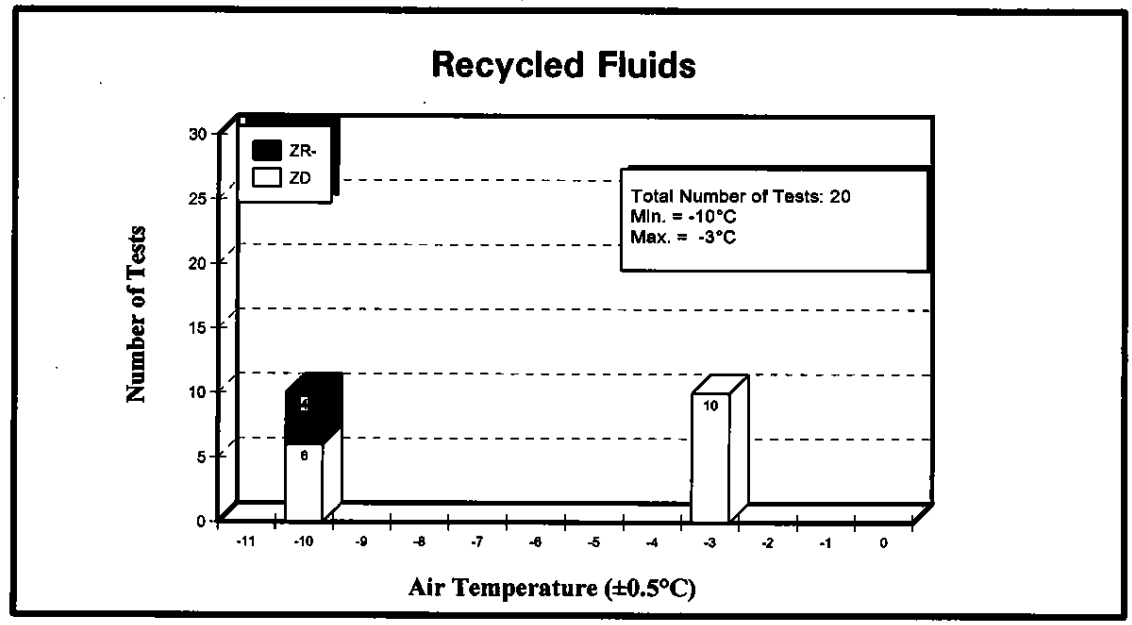


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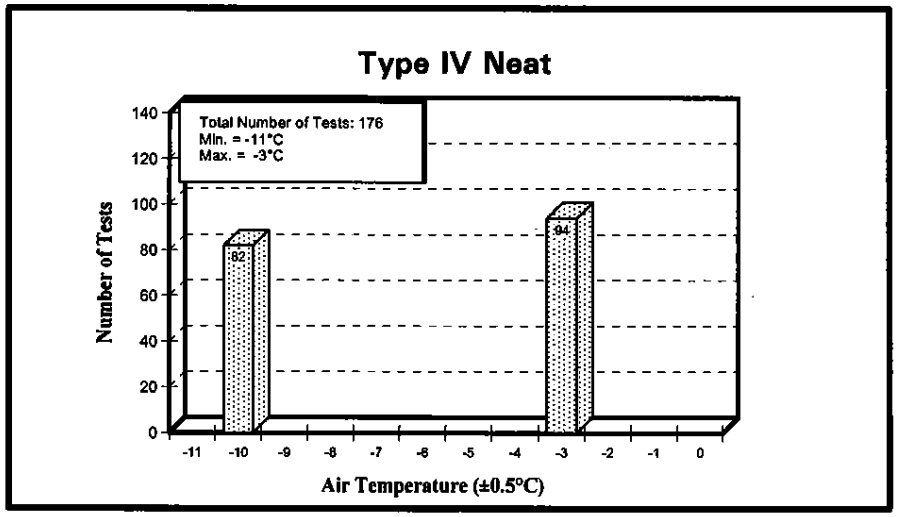
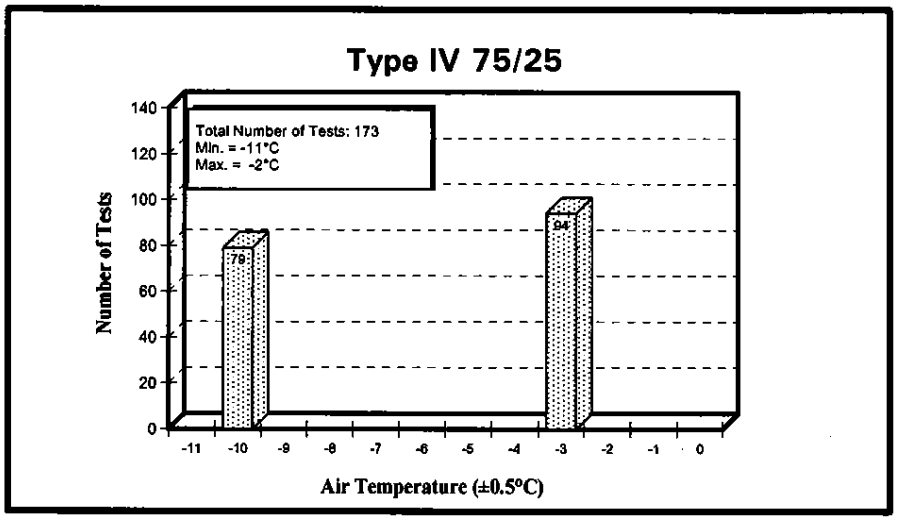
FIGURE 3.12

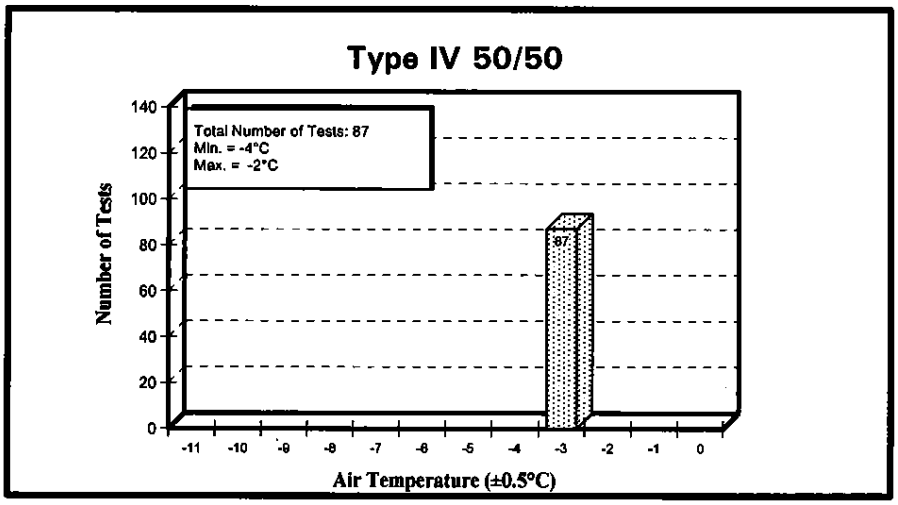
# DISTRIBUTION OF AIR TEMPERATURE - TYPE IV FLUIDS

Simulated Freezing Drizzle/Light Freezing Rain Tests

1997-98

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## 3.3 Simulated Freezing Fog Tests

### 3.3.1 Data Acquisition

A total of 171 tests were conducted with Type IV fluids in freezing fog conditions. The breakdown of these tests is shown in Figure 3.13.

### 3.3.2 Test Location and Fluids Tested

All of the 171 freezing fog tests were conducted at NRC's CEF in Ottawa. The fluids tested were Type IV fluids supplied by Clariant, Kilfrost, Octagon, SPCA and Union Carbide.

### 3.3.3 Distribution of Average Precipitation Rates

Figure 3.14 shows the distribution of average precipitation rates recorded for all the Type IV fluid tests. As described in Section 2, the average precipitation rates for freezing fog were computed from weight measurements taken with plate pans. The pans were positioned on the stand at every plate location before and after each run for two 10 to 15-minute periods. Precipitation rates for freezing fog were in the range of 2 to 7 g/dm²/h.

### 3.3.4 Distribution of Tests by Air Temperature

The other condition that varied during freezing fog tests was temperature. The distribution of air temperatures for freezing fog tests is presented in Figure 3.15.

FIGURE 3.13

# NUMBER OF SIMULATED FREEZING FOG TESTS

1997-98 TEST SEASON

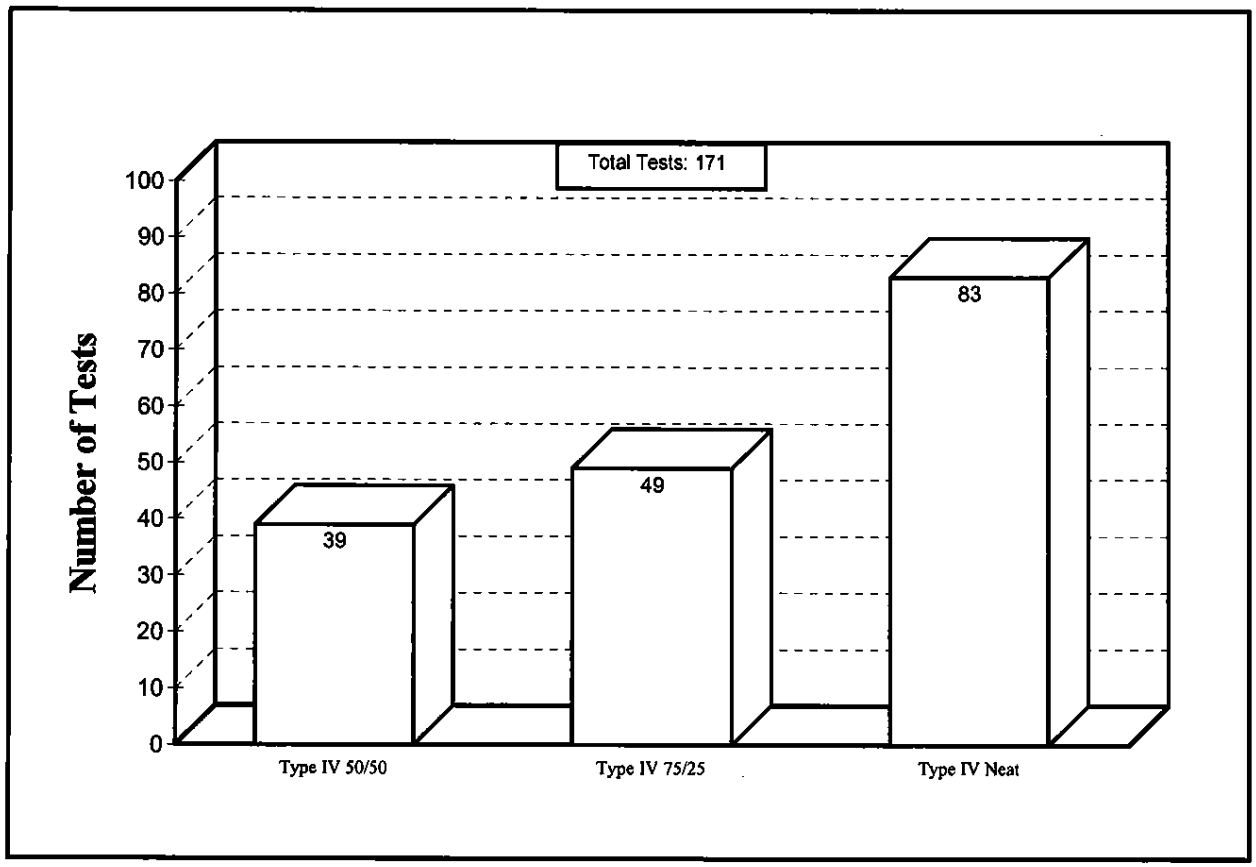
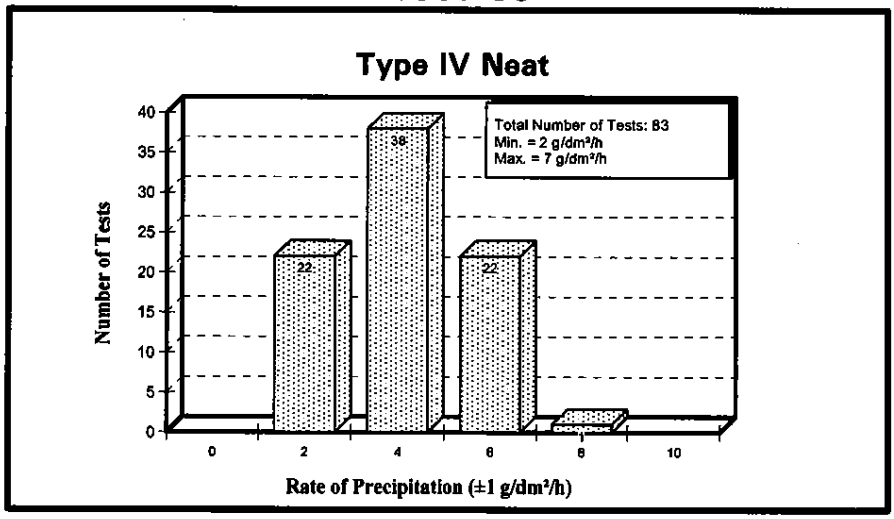


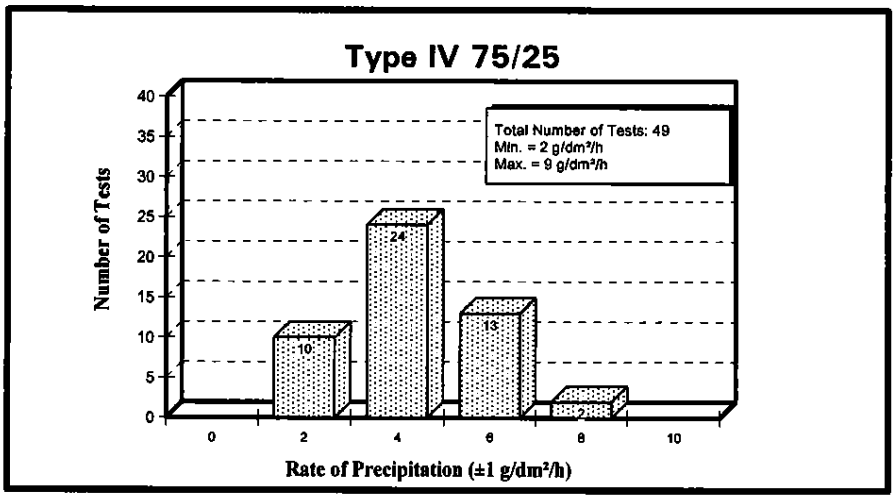
FIGURE 3.14

# DISTRIBUTION OF PRECIPITATION RATE - TYPE IV FLUIDS

Simulated Freezing Fog Tests

1997-98



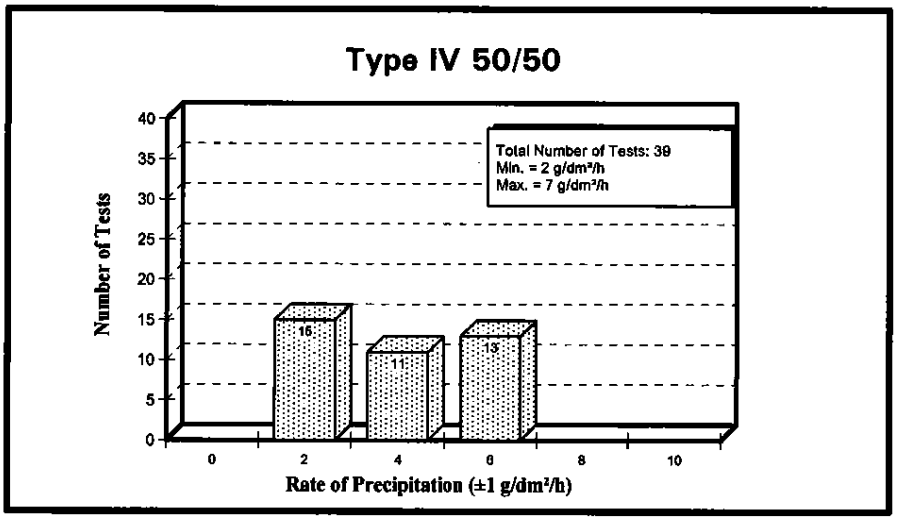




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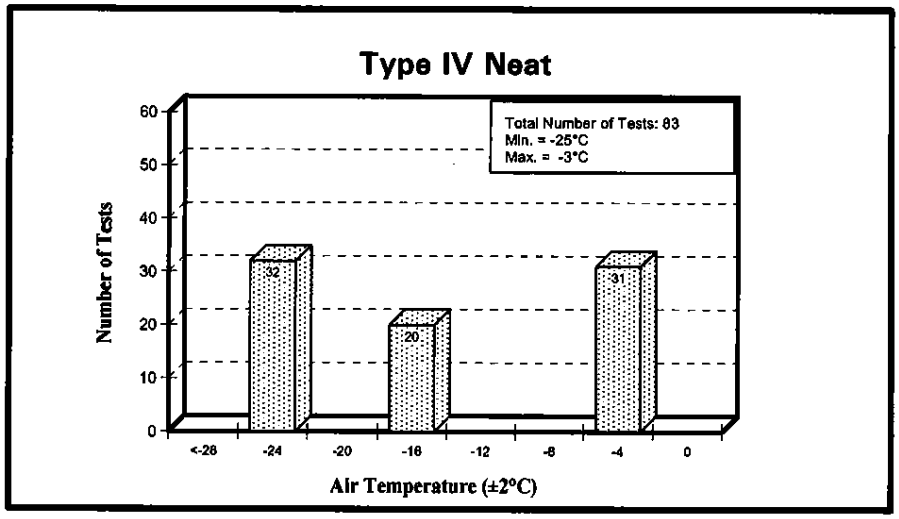
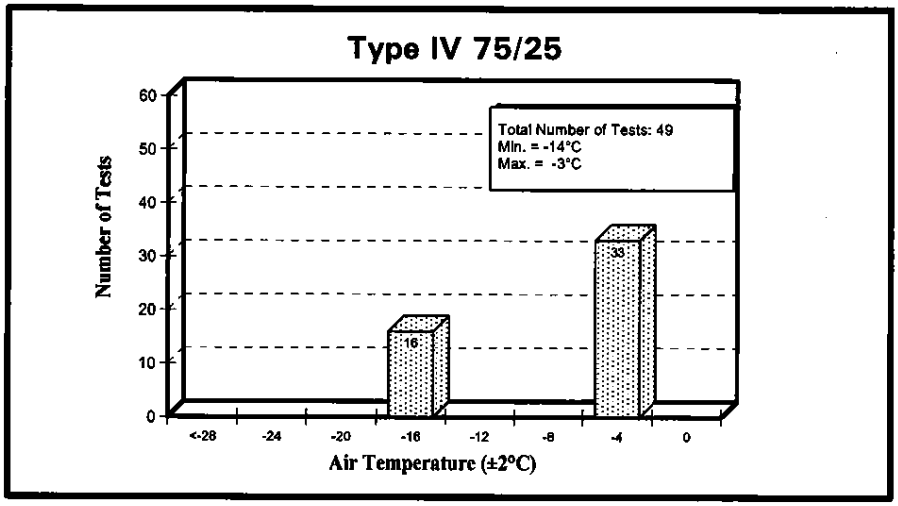
FIGURE 3.15

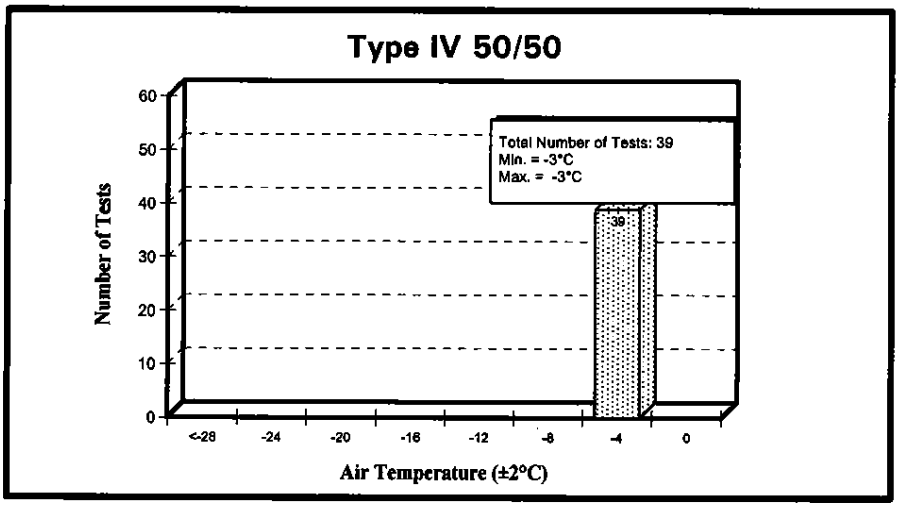
# DISTRIBUTION OF AIR TEMPERATURE - TYPE IV FLUIDS

Simulated Freezing Fog Tests

1997-98

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## 3.4 Simulated Rain on Cold-Soaked Surface Tests

### 3.4.1 Data Acquisition

A total of 73 cold-soak tests, using 7.5 cm deep sealed boxes, were conducted during the 1997-98 test season: 37 tests with Type IV Neat fluid and 36 tests with Type IV 75/25 fluid.

### 3.4.2 Test Location and Fluids Tested

All of the 73 freezing precipitation tests were conducted at NRC's CEF in Ottawa. The fluids tested were Type IV fluids supplied by Clariant, Kilfrost, Octagon, SPCA, and Union Carbide.

### 3.4.3 Distribution of Average Precipitation Rates

Figure 3.16 shows the distribution of precipitation intensity. The average precipitation rate was measured using plate pans. The precipitation for drizzle was produced using the same apparatus as was used for freezing drizzle. Moderate rain was also produced using the same apparatus, but with different hypodermic needles and water/air pressures.

### 3.4.4 Distribution of Tests by Average Surface Temperature

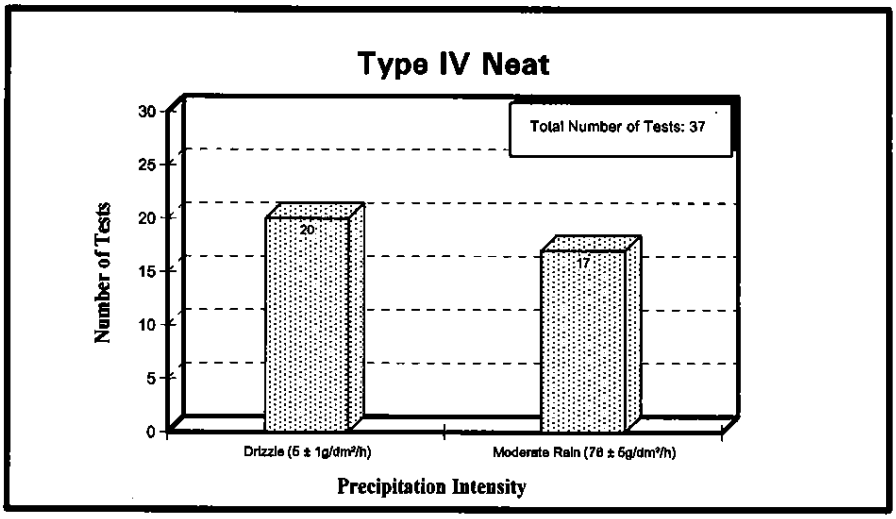
All of the rain on cold-soaked surface tests were conducted with an ambient air temperature of $+1^{\circ}C$. The temperature on the test surface was measured using two thermistor sensors mounted at 22.5 cm (9 in.) from the top of the test surface. A hand-held temperature probe was also used to confirm temperature readings. Figure 3.17 shows the distribution of skin temperature, calculated by averaging the temperature at the start and the end of the test.

FIGURE 3.16

# DISTRIBUTION OF PRECIPITATION INTENSITY - TYPE IV FLUIDS

Cold-Soak Box Tests

1997-98



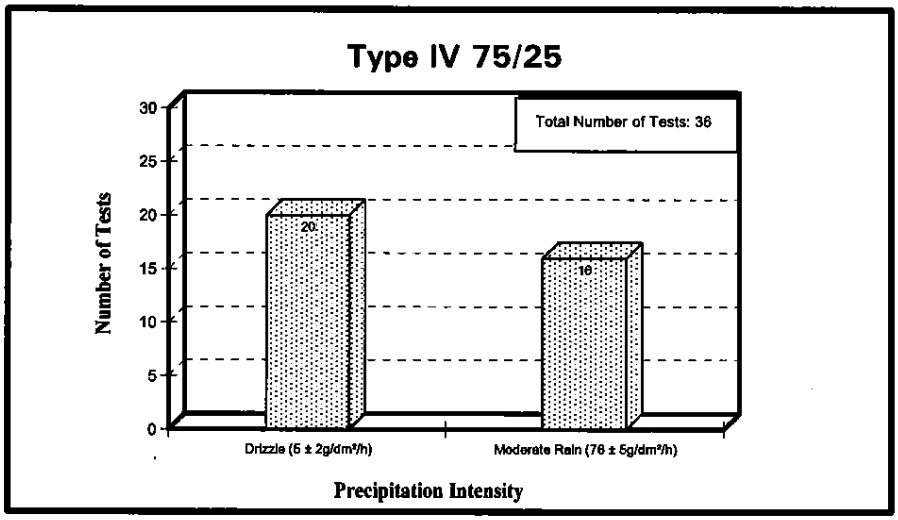




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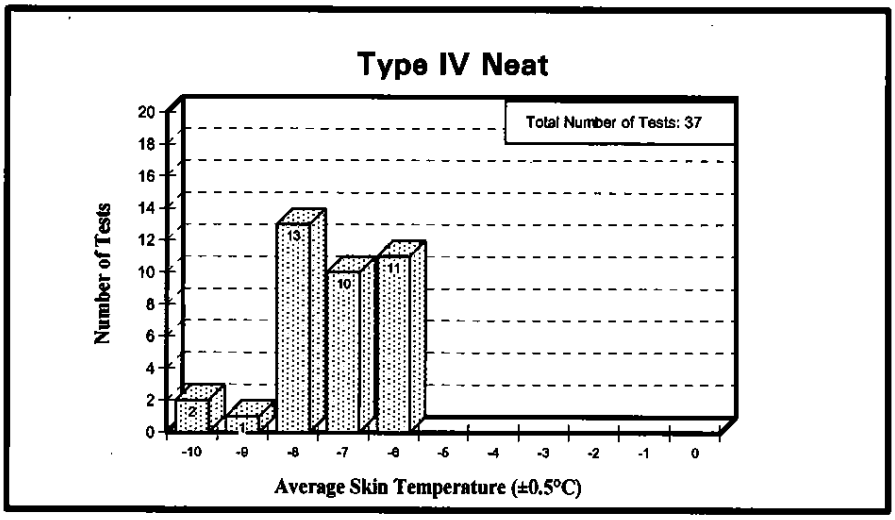
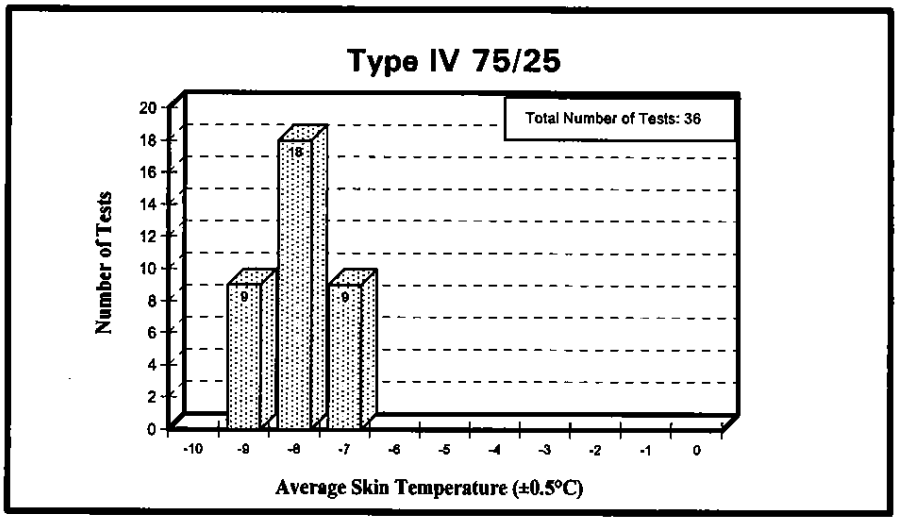
FIGURE 3.17

# DISTRIBUTION OF SKIN TEMPERATURE - TYPE IV FLUIDS

Cold-Soak Box Tests

1997-98

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# 4. FLUID THICKNESS TESTS ON FLAT PLATES

Type IV fluid thickness tests on flat plates were conducted at the APS site at Dorval Airport and at NRC's CEF, on six occasions during the 1997-98 test season. The purpose of these tests was to measure film thickness profiles of new fluids and to investigate the extent to which heated Type IV fluids reduce holdover times.

The listing of tests conducted is displayed in Table 4.1 and summarized below:

| Type IV Fluid | # of Tests |
|---|---|
| Neat | 27 |
| 75/25 | 24 |
| 50/50 | 25 |
| HOT Neat over HOT Type I | 25 |

In addition, four thickness tests were conducted with recycled fluids and eight tests were performed to study the effect of ICE-EX on holdover times.

## 4.1 General Procedures and Stabilized Neat Fluid Profiles

Thickness measurements were taken at regular time intervals over a period of 30 minutes, at 15 cm (6") lines on the 10º flat plates. A complete description of the film thickness test procedure is reported in Transport Canada report TP 12900E (8). The tests at Dorval were conducted indoors (see Photo 4.1) to exclude environmental factors such as natural precipitation and wind. The Dorval tests were conducted at an ambient temperature of -8ºC. Thickness tests at NRC were conducted at ambient temperature of -3°C; a few tests were performed at different ambient temperatures, but for the purpose of this report, only tests conducted at -3°C are considered.

Figure 4.1 illustrates the thickness decay at the 15 cm (6 in.) line of Type IV neat fluids tested during winter 1995-96. The results revealed that the Type IV fluids tested exhibited equivalent thickness profiles, and that fluid thickness started to stabilize after 10 minutes from the start of the test.

Figure 4.2 shows thickness decay curves for fluids tested in the 1996-97 winter season. A comparison of thickness decay of Type IV fluids tested during winter 1996-97 shows that the thickness measurements of these neat Type IV fluids were significantly different from the 1995-96 Type IV fluids and also different from one another; Ultra+ and Kilfrost were more

TABLE 4.1

# LOG OF FLUID THICKNESS TESTS

| Test # | Form # | Total Elapsed Time (min) | Test Date (1998) | Location | Fluid Type | Visc. | Fluid Concent. | Fluid Quantities (Litres) | Ambient Air Temp. (AAT, °C) | Fluid Temp. (°C) | Stabilized Thickness after 30 min. at 6" Line | Corrected Thickness (MILS) | Corrected Thickness (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 22 | 14-Jan-98 | YUL | CLARIANT 2001 | A | 75% | 1.5 | -8 | AAT | 25 | 27.5 | 0.70 |
| 2 | 1 | 20 | 14-Jan-98 | YUL | CLARIANT 2001 | A | Neat | 1.5 | -8 | AAT | 25 | 27.5 | 0.70 |
| 3 | 2 | 20 | 14-Jan-98 | YUL | CLARIANT 2001 | A | 50% | 1.5 | -8 | AAT | 7.9 | 9 | 0.23 |
| 4 | 3 | 20 | 15-Jan-98 | YUL | CLARIANT 1957 | A | Neat | 1.5 | -8 | AAT | 35 | 37.5 | 0.95 |
| 5 | 3 | 20 | 15-Jan-98 | YUL | CLARIANT 1957 | A | 75% | 1.5 | -8 | AAT | 35 | 37.5 | 0.95 |
| 6 | 1 | 20 | 15-Jan-98 | YUL | CLARIANT 1957 | A | 50% | 1.5 | -8 | AAT | 14.2 | 15.1 | 0.38 |
| 7 | 4 | 21 | 15-Jan-98 | YUL | CLARIANT 1957 | A | 50% | 1.5 | -8 | AAT | 12 | 13 | 0.33 |
| 8 | 4 | 20 | 15-Jan-98 | YUL | CLARIANT 2001 | A | 50% | 1.5 | -8 | AAT | 7.9 | 9 | 0.23 |
| 9 | 5 | 20 | 15-Jan-98 | YUL | CLARIANT 1957 | A | Neat | 1.5 | -8 | AAT | 40 | 43 | 1.09 |
| 10 | 6 | 20 | 15-Jan-98 | YUL | CLARIANT 1957 | A | 75% | 1.5 | -8 | AAT | 30 | 32.5 | 0.83 |
| 11 | 5 | 20 | 15-Jan-98 | YUL | CLARIANT 2001 | A | Neat | 1.5 | -8 | AAT | 30 | 32.5 | 0.83 |
| 12 | 6 | 20 | 15-Jan-98 | YUL | CLARIANT 2001 | A | 75% | 1.5 | -8 | AAT | 30 | 32.5 | 0.83 |
| 13 | 7 | 0 | 15-Jan-98 | YUL | XL54 / ICE-EX | A | Std/ICEX | 1.5 | -8 | AAT | 0 | | |
| 14 | 7 | 20 | 15-Jan-98 | YUL | ULTRA+/ICE-EX | A | Neat/ICEX | 1.5 | -8 | AAT | 40 | 43 | 1.09 |
| 15 | 8 | 32 | 9-Feb-98 | YOW | UCAR ULTRA IV | A | Neat | 1.5 | -1 | -1 | 70 | 72.5 | 1.84 |
| 16 | 8 | 32 | 9-Feb-98 | YOW | UCAR ULTRA IV | A | 75% | 1.5 | -1 | -3 | 40 | 43 | 1.09 |
| 17 | 8 | 30 | 9-Feb-98 | YOW | UCAR ULTRA IV | A | 50% | 1.5 | -1 | -3 | 20 | 21 | 0.53 |
| 18 | 8 | 30 | 9-Feb-98 | YOW | UCAR PG | A | Neat | 1.5 | -1 | -3 | 80 | 88 | 2.24 |
| 19 | 8 | 30 | 9-Feb-98 | YOW | UCAR PG | A | 75% | 1.5 | -1 | -3 | 45 | 47.5 | 1.21 |
| 20 | 8 | 30 | 9-Feb-98 | YOW | UCAR PG | A | 50% | 1.5 | -1 | -3 | 24 | 25 | 0.64 |
| 21 | 9 | 30 | 9-Feb-98 | YOW | OCTAGON MAXFLIGHT | A | Neat | 1.5 | -3.7 | -2 | 22 | 23 | 0.58 |
| 22 | 9 | 31 | 9-Feb-98 | YOW | OCTAGON MAXFLIGHT | A | 75% | 1.5 | -3.7 | -2 | 40 | 43 | 1.09 |
| 23 | 9 | 31 | 9-Feb-98 | YOW | OCTAGON MAXFLIGHT | A | 50% | 1.5 | -3.7 | -1 | 24 | 25 | 0.64 |
| 24 | 9 | 32 | 9-Feb-98 | YOW | UCAR ULTRA IV | A | Neat | 1.5 | -3.7 | -2 | 80 | 88 | 2.24 |
| 25 | 9 | 36 | 9-Feb-98 | YOW | UCAR ULTRA IV | A | 75% | 1.5 | -3.7 | -2 | 40 | 43 | 1.09 |
| 26 | 9 | 29 | 9-Feb-98 | YOW | UCAR ULTRA IV | A | 50% | 1.5 | -3.7 | -2 | 12 | 13 | 0.33 |
| 27 | 10 | 29 | 9-Feb-98 | YOW | UCAR PG | A | Neat | 1.5 | -3 | -3 | 70 | 72.5 | 1.84 |
| 28 | 10 | 30 | 9-Feb-98 | YOW | UCAR PG | A | 50% | 1.5 | -3 | -3 | 22 | 23 | 0.58 |
| 29 | 10 | 30 | 9-Feb-98 | YOW | UCAR PG | A | 75% | 1.5 | -3 | -3 | 40 | 43 | 1.09 |
| 30 | 10 | 29 | 9-Feb-98 | YOW | OCTAGON MAXFLIGHT | A | Neat | 1.5 | -3 | -2 | 18 | 19 | 0.48 |
| 31 | 10 | 31 | 9-Feb-98 | YOW | OCTAGON MAXFLIGHT | A | 75% | 1.5 | -3 | -2 | 45 | 47.5 | 1.21 |
| 32 | 10 | 33 | 9-Feb-98 | YOW | OCTAGON MAXFLIGHT | A | 50% | 1.5 | -3 | -2 | 22 | 23 | 0.58 |
| 33 | 11 | 29 | 9-Feb-98 | YOW | SPCA AD-480 | A | Neat | 1.5 | -3 | -3 | 26 | 27 | 0.69 |
| 34 | 11 | 27 | 9-Feb-98 | YOW | SPCA AD-480 | A | 75% | 1.5 | -3 | -3 | 35 | 37.5 | 0.95 |
| 35 | 11 | 31 | 9-Feb-98 | YOW | SPCA AD-480 | A | 50% | 1.5 | -3 | -3 | 16 | 17 | 0.43 |
| 36 | 11 | 32 | 9-Feb-98 | YOW | SPCA AD-404 | A | Neat | 1.5 | -3 | -3 | 65 | 67.5 | 1.71 |
| 37 | 11 | 36 | 9-Feb-98 | YOW | SPCA AD-404 | A | 75% | 1.5 | -3 | -3 | 45 | 47.5 | 1.21 |
| 38 | 11 | 34 | 9-Feb-98 | YOW | SPCA AD-404 | A | 50% | 1.5 | -3 | -3 | 24 | 25 | 0.64 |
| 39 | 12 | 32 | 9-Feb-98 | YOW | SPCA AD-480 | A | Neat | 1.5 | -3 | -3 | 26 | 27 | 0.69 |
| 40 | 13 | 29 | 11-Feb-98 | YOW | Hot C1957 / Hot H I | A | Neat / Std | 1.5/0.5 | -13.5 | 80/80 | 26 | 27 | 0.69 |
| 41 | 13 | 29 | 11-Feb-98 | YOW | Hot C1957 / Hot H I | A | Neat / Std | 1.5/0.5 | -13.5 | 80/80 | 24 | 25 | 0.64 |
| 42 | 13 | 30 | 11-Feb-98 | YOW | Hot C2001 / Hot H I | A | Neat / Std | 1.5/0.5 | -16.5 | 80/80 | 24 | 25 | 0.64 |
| 43 | 14 | 30 | 11-Feb-98 | YOW | Hot C2001 / Hot H I | A | Neat / Std | 1.5/0.5 | -17 | 80/80 | 30 | 32.5 | 0.83 |
| 44 | 14 | 30 | 11-Feb-98 | YOW | Hot OCT. IV / Hot OCT. I | A | Neat / Std | 1.5/0.5 | -8 | 80/80 | 11 | 11.5 | 0.29 |
| 45 | 11 | 31 | 11-Feb-98 | YOW | Hot OCT. IV / Hot OCT. I | A | Neat / Std | 1.5/0.5 | -9 | 80/80 | 11 | 11.5 | 0.29 |
| 46 | 15 | 29 | 11-Feb-98 | YOW | Hot UCAR PG / Hot XL54 | A | Neat / Std | 1.5/0.5 | -9.5 | 60/80 | 45 | 47.5 | 1.21 |
| 47 | 15 | 26 | 11-Feb-98 | YOW | Hot UCAR PG / Hot XL54 | A | Neat / Std | 1.5/0.5 | -9.5 | 70/80 | 40 | 43 | 1.09 |
| 48 | 16 | 27 | 14-Apr-98 | YOW | SPCA AD-480 | A | 75% | 1.5 | -3 | AAT | 40 | 43 | 1.09 |
| 49 | 16 | 26 | 14-Apr-98 | YOW | SPCA AD-404 | A | Neat | 1.5 | -3 | AAT | 35 | 37.5 | 0.95 |
| 50 | 17 | 25 | 14-Apr-98 | YOW | Hot SPCA AD-480 / Hot SPCA I | | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 30 | 32.5 | 0.83 |
| 51 | 17 | 24 | 14-Apr-98 | YOW | Hot SPCA AD-404 / Hot SPCA I | | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 16 | 17 | 0.43 |
| 52 | 18 | 19 | 14-Apr-98 | YOW | SPCA AD-404 | B | 75% | 1.5 | -3 | AAT | 30 | 32.5 | 0.83 |
| 53 | 18 | 29 | 14-Apr-98 | YOW | SPCA AD-404 | A | 50% | 1.5 | -3 | AAT | 28 | 29 | 0.74 |
| 54 | 19 | 32 | 14-Apr-98 | YOW | SPCA AD-480 | B | 50% | 1.5 | -3 | AAT | 26 | 27 | 0.69 |
| 55 | 19 | 30 | 14-Apr-98 | YOW | Hot SPCA AD-480 / Hot SPCA I | A | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 26 | 27 | 0.69 |
| 56 | 20 | 32 | 14-Apr-98 | YOW | Hot SPCA AD-404 / Hot SPCA I | A | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 11 | 11.5 | 0.29 |
| 57 | 21 | 26 | 14-Apr-98 | YOW | CLARIANT 2001 | B | 75% | 1.5 | -3 | AAT | 40 | 43 | 1.09 |
| 58 | 21 | 30 | 14-Apr-98 | YOW | CLARIANT 2001 | B | 50% | 1.5 | -3 | AAT | 14 | 15 | 0.38 |
| 59 | 22 | 29 | 14-Apr-98 | YOW | CLARIANT 2001 | B | 75% | 1.5 | -3 | AAT | 35 | 37.5 | 0.95 |
| 60 | 22 | 32 | 14-Apr-98 | YOW | CLARIANT 2001 | B | Neat | 1.5 | -3 | AAT | 35 | 37.5 | 0.95 |
| 61 | 23 | 28 | 14-Apr-98 | YOW | Hot C2001 / Hot H I | B | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 26 | 27 | 0.69 |
| 62 | 23 | 34 | 14-Apr-98 | YOW | CLARIANT 2001 | B | Neat | 1.5 | -3 | AAT | 30 | 32.5 | 0.83 |
| 63 | 24 | 26 | 14-Apr-98 | YOW | Hot OCT. IV / Hot OCT. I | A | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 14 | 15 | 0.38 |
| 64 | 24 | 30 | 14-Apr-98 | YOW | Hot C2001 / Hot H I | B | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 26 | 27 | 0.69 |

TABLE 4.1

# LOG OF FLUID THICKNESS TESTS

| Test # | Form # | Total Elapsed Time (min) | Test Date (1998) | Location | Fluid Type | Visc. | Fluid Concent. | Fluid Quantities (Litres) | Ambient Air Temp. (AAT, °C) | Fluid Temp. (°C) | Stabilized Thickness after 30 min. at 6" Line | Corrected Thickness (MILS) | Corrected Thickness (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | 25 | 26 | 14-Apr-98 | YOW | CLARIANT 1957 | B | 75% | 1.5 | -3 | AAT | 30 | 32.5 | 0.83 |
| 66 | 26 | 31 | 14-Apr-98 | YOW | Hot OCT. IV / Hot OCT. I | A | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 12 | 13 | 0.33 |
| 67 | 26 | 33 | 14-Apr-98 | YOW | CLARIANT 1957 | B | 50% | 1.5 | -3 | AAT | 16 | 17 | 0.43 |
| 68 | 27 | 29 | 14-Apr-98 | YOW | Hot C1957 / Hot H I | B | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 24 | 25 | 0.64 |
| 69 | 27 | 30 | 14-Apr-98 | YOW | CLARIANT 2001 | B | Neat | 1.5 | -3 | AAT | 30 | 32.5 | 0.83 |
| 70 | 28 | 30 | 14-Apr-98 | YOW | CLARIANT 1957 | B | Neat | 1.5 | -3 | AAT | 30 | 32.5 | 0.83 |
| 71 | 28 | 30 | 14-Apr-98 | YOW | CLARIANT 1957 | B | Neat | 1.5 | -3 | AAT | 28 | 29 | 0.74 |
| 72 | 29 | 31 | 14-Apr-98 | YOW | CLARIANT 1957 | B | 75% | 1.5 | -3 | AAT | 35 | 37.5 | 0.95 |
| 73 | 29 | 29 | 14-Apr-98 | YOW | Hot UCAR ULTRA IV / Hot XL54 | | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 40 | 43 | 1.09 |
| 74 | 30 | 30 | 14-Apr-98 | YOW | UCAR ULTRA IV | A | Neat | 1.5 | -3 | AAT | 70 | 72.5 | 1.84 |
| 75 | 30 | 31 | 14-Apr-98 | YOW | UCAR ULTRA IV | A | 50% | 1.5 | -3 | AAT | 18 | 19 | 0.48 |
| 76 | 31 | 27 | 14-Apr-98 | YOW | Hot UCAR ULTRA IV / Hot XL54 | | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 45 | 47.5 | 1.21 |
| 77 | 31 | 24 | 14-Apr-98 | YOW | UCAR ULTRA IV | A | 75% | 1.5 | -3 | AAT | 35 | 37.5 | 0.95 |
| 78 | 32 | 30 | 14-Apr-98 | YOW | Hot UCAR PG / Hot XL54 | | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 45 | 47.5 | 1.21 |
| 79 | 32 | 29 | 14-Apr-98 | YOW | UCAR PG | A | 50% | 1.5 | -3 | AAT | 20 | 21 | 0.53 |
| 80 | 33 | 31 | 14-Apr-98 | YOW | UCAR PG | A | 75% | 1.5 | -3 | AAT | 40 | 43 | 1.09 |
| 81 | 33 | 30 | 14-Apr-98 | YOW | UCAR PG | A | Neat | 1.5 | -3 | AAT | 70 | 72.5 | 1.84 |
| 82 | 34 | 32 | 14-Apr-98 | YOW | Hot UCAR PG / Hot XL54 | | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 50 | 52.5 | 1.33 |
| 83 | 34 | 32 | 14-Apr-98 | YOW | KILFROST ABC-S | B | Neat | 1.5 | -3 | AAT | 55 | 57.5 | 1.46 |
| 84 | 35 | 30 | 14-Apr-98 | YOW | KILFROST ABC-S | B | Neat | 1.5 | -3 | AAT | 65 | 67.5 | 1.71 |
| 85 | 37 | 29 | 15-Apr-98 | YOW | KILFROST ABC-S | B | 75% | 1.5 | -3 | AAT | 40 | 43 | 1.09 |
| 86 | 37 | 30 | 15-Apr-98 | YOW | KILFROST ABC-S | B | 75% | 1.5 | -3 | AAT | 40 | 43 | 1.09 |
| 87 | 39 | 30 | 15-Apr-98 | YOW | KILFROST ABC-S | B | 50% | 1.5 | -3 | AAT | 11 | 11.5 | 0.29 |
| 88 | 39 | 30 | 15-Apr-98 | YOW | KILFROST ABC-S | B | 50% | 1.5 | -3 | AAT | 12 | 13 | 0.33 |
| 89 | 41 | 30 | 15-Apr-98 | YOW | Hot KIL. IV / Hot KIL. I | B | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 40 | 43 | 1.09 |
| 90 | 41 | 30 | 15-Apr-98 | YOW | Hot KIL. IV / Hot KIL. I | B | Neat / Std | 1.5 / 0.5 | -3 | 40 / 80 | 35 | 37.5 | 0.95 |
| 91 | 43 | 0 | 15-Apr-98 | YOW | XL54 / ICE-EX | | Std/ICEX | 1.5 | -3 | AAT / AAT | 0 | | |
| 92 | 43 | 0 | 15-Apr-98 | YOW | XL54 / ICE-EX | | Std/ICEX | 1.5 | -3 | AAT / AAT | 0 | | |
| 93 | 45 | 31 | 15-Apr-98 | YOW | Hot UCAR ULTRA IV / ICE EX | | Neat/ICEX | 1.5 | -3 | 40 / AAT | 45 | 47.5 | 1.21 |
| 94 | 45 | 30 | 15-Apr-98 | YOW | UCAR ULTRA IV / ICE EX | | Neat/ICEX | 1.5 | -3 | AAT / AAT | 70 | 72.5 | 1.84 |
| 95 | 47 | 29 | 15-Apr-98 | YOW | Hot UCAR ULTRA IV/Hot XL54/ ICE EX | | Neat/Std/ICEX | 1.5 / 0.5 | -3 | 40 / 80 | 40 | 43 | 1.09 |
| 96 | 47 | 30 | 15-Apr-98 | YOW | Hot UCAR ULTRA IV/Hot XL54/ ICE EX | | Neat/Std/ICEX | 1.5 / 0.5 | -3 | AAT / 80 | 60 | 63 | 1.60 |
| 97 | 48 | 30.5 | 6-Jul-98 | YOW | SPCA AD-404 | A | Neat | 1.5 | -3 | AAT | 35 | 37.5 | 0.95 |
| 98 | 48 | 38 | 6-Jul-98 | YOW | SPCA AD-404 | B | 75% | 1.5 | -3 | AAT | 28 | 29 | 0.74 |
| 99 | 49 | 30 | 6-Jul-98 | YOW | TYPE 0 ETH | | STD | 1.5 | -3 | 20 | 1 | 1.5 | 0.04 |
| 100 | 49 | 31 | 6-Jul-98 | YOW | TYPE 0 PRO | | STD | 1.5 | -3 | 20 | 1 | 1.5 | 0.04 |
| 101 | 50 | 30 | 6-Jul-98 | YOW | TYPE 0 PRO | | STD | 1.5 | -3 | 20 | 1 | 1.5 | 0.04 |
| 102 | 50 | 30 | 6-Jul-98 | YOW | TYPE 0 ETH | | STD | 1.5 | -3 | 20 | 1 | 1.5 | 0.04 |
| 103 | 51 | 30 | 7-Jul-98 | YOW | CLARIANT 2001 | B | 50% | 1.5 | -3 | AAT | 12 | 13 | 0.33 |
| 104 | 51 | 30 | 7-Jul-98 | YOW | CLARIANT 1957 | B | 50% | 1.5 | -3 | AAT | 14 | 15 | 0.38 |
| 105 | 52 | 30 | 7-Jul-98 | YOW | SPCA AD-480 | B | 50% | 1.5 | -3 | AAT | 25 | 27.5 | 0.70 |
| 106 | 53 | 30 | 7-Jul-98 | YOW | OCTAGON MAXFLIGHT | Drum | Neat | 1.5 | -3 | AAT | 22 | 23 | 0.58 |
| 107 | 53 | 30 | 7-Jul-98 | YOW | KILFROST ABC-S | B | Neat | 1.5 | -3 | AAT | 70 | 72.5 | 1.84 |
| 108 | 54 | 30 | 7-Jul-98 | YOW | UCAR ULTRA IV | A | 50% | 1.5 | -3 | AAT | 9 | 9.5 | 0.24 |
| 109 | 54 | 30 | 7-Jul-98 | YOW | SPCA AD-404 | A | Neat | 1.5 | -3 | AAT | 40 | 43 | 1.09 |
| 110 | 55 | 30 | 8-Jul-98 | YOW | SPCA AD-480 | A | 50% | 1.5 | -3 | AAT | 24 | 25 | 0.64 |
| 111 | 55 | 30 | 8-Jul-98 | YOW | SPCA AD-404 | A | 75% | 1.5 | -3 | AAT | 30 | 32.5 | 0.83 |

| | Neat/ STD | 75/25 | 50/50 | Hot IV/ Hot I | ICEX |
|---|---|---|---|---|---|
| CLARIANT 1957 | 4 | 4 | 4 | 3 | |
| CLARIANT 2001 | 5 | 4 | 4 | 4 | |
| KILFROST ABC-S | 3 | 2 | 2 | 2 | |
| OCTAGON MAXFLIGHT | 3 | 2 | 2 | 4 | |
| SPCA AD-404 | 4 | 4 | 2 | 2 | |
| SPCA AD-480 | 2 | 2 | 4 | 2 | |
| UCAR PG | 3 | 3 | 3 | 4 | |
| UCAR ULTRA IV | 3 | 3 | 4 | 2 | |
| TYPE 0 ETHYLENE | 2 | | | | |
| TYPE 0 PROPYLENE | 2 | | | | |
| ICEX | | | | | 8 |
| | 31 | 24 | 25 | 23 | 8 |

| Total Tests | 111 |
|---|---|

FIGURE 4.1
**THICKNESS DECAY OF OLD TYPE IV NEAT FLUIDS**
1995-96

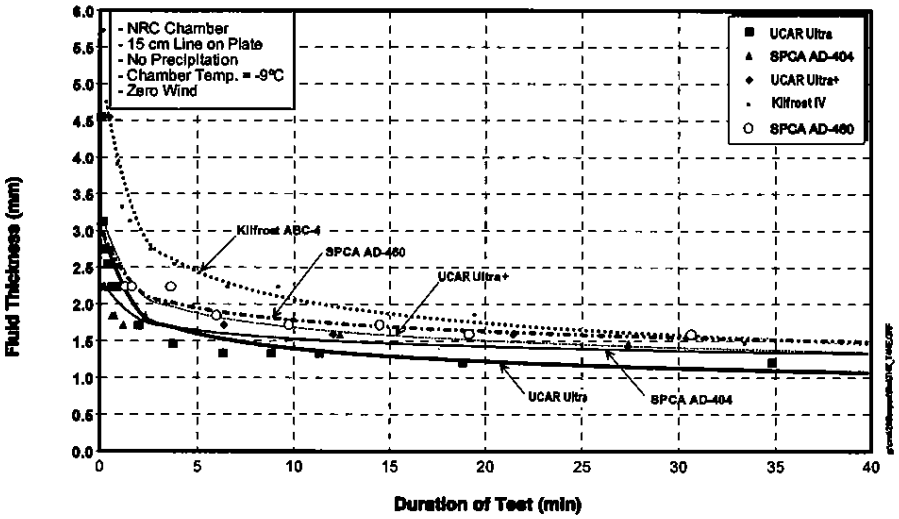



FIGURE 4.2
**THICKNESS DECAY OF TYPE IV NEAT FLUIDS**
1996-97

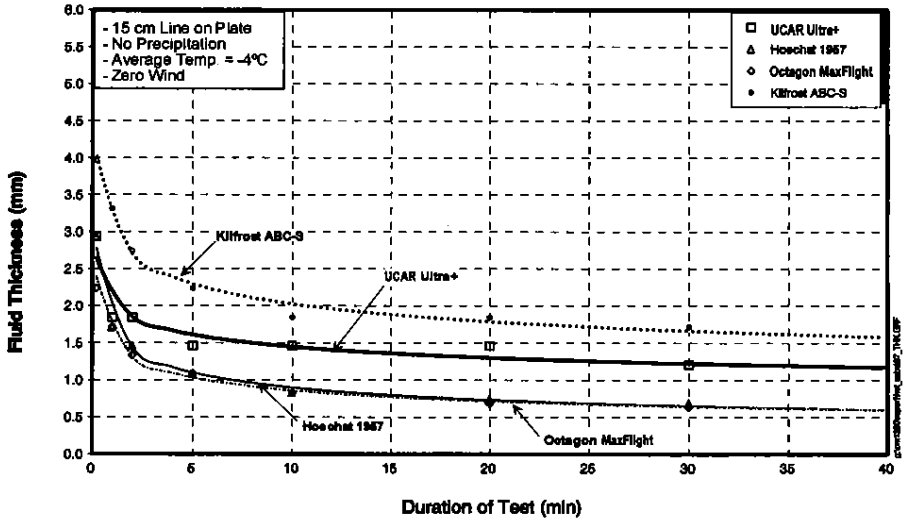
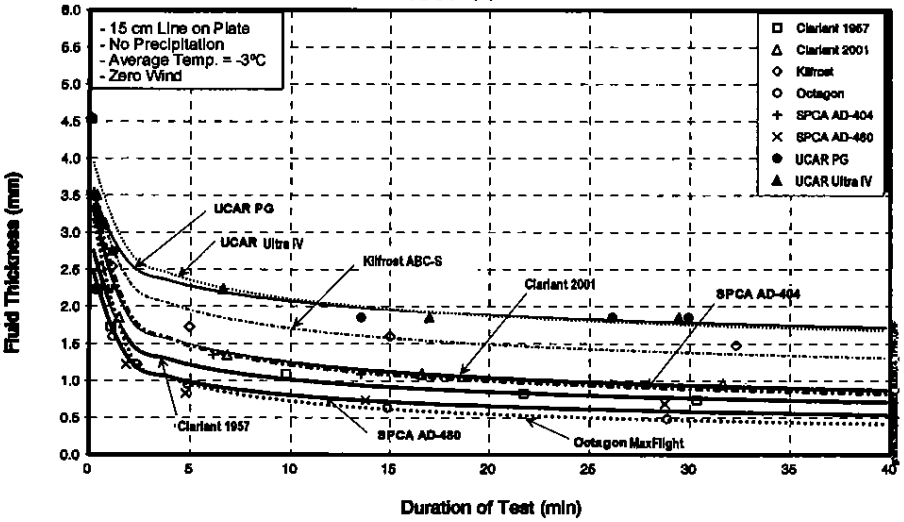



FIGURE 4.3
**THICKNESS DECAY OF TYPE IV NEAT FLUIDS**
1997-98



than twice the thickness of Octagon and Hoechst MPIV 1957, after 30 minutes.

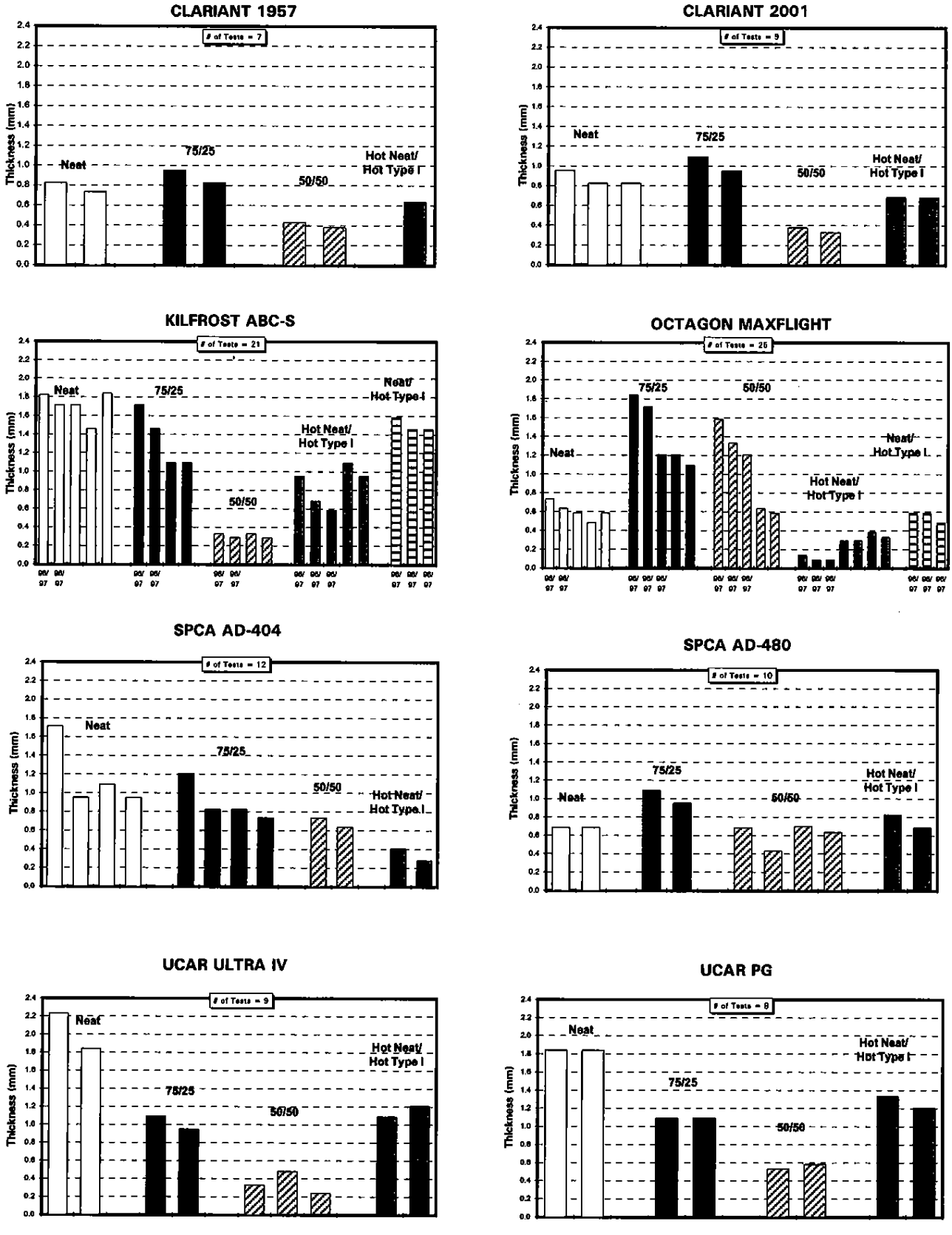
Figure 4.3 shows thickness decay curves for fluids tested in the 1997-98 winter season. Most of the fluids tested follow the same thickness profile as previous years' tests. UCAR Ultra IV and UCAR PG AAF, which did not satisfy SAE specifications, were almost twice the thickness of SPCA AD-404 and Clariant MPIV 2001, and almost four times the thickness of Octagon MaxFlight and SPCA AD-480.

Figure 4.4 shows eight bar graphs, each one corresponding to a specific Type IV fluid brand. Each bar gives the fluid thickness at the 15 cm line of a standard test plate, 30 minutes after fluid application. The number of tests used to produce each of the eight graphs is indicated in the small box (top centre) of each graph. Several tests were performed for each standard dilution (Neat, 75/25, and 50/50), as well as for two-step fluid applications. Results of thickness tests performed during the 1996-97 season were included for both Kilfrost ABC-S, and Octagon MaxFlight.

FIGURE 4.4

# STABILIZED FILM THICKNESS OF TYPE IV FLUIDS AT 15 CM LINE

OAT = -3 to -5°C, Each bar represents a test



## 4.2 Dilution Effect

The following is a point-form summary of some observations from Figure 4.4.

- Clariant MPIV 1957 and Clariant MPIV 2001 Type IV neat fluids showed increased thickness in diluted form 75/25, but the 50/50 formulation showed a decrease;

- Kilfrost ABC-S 75/25 showed only a slight decrease in thickness. The 50/50 thickness of the mix decreased significantly;

- Octagon Type IV fluid thickness increased two to three times when diluted;

- SPCA AD-404 75/25 and 50/50 both showed a slight decrease in thickness;

- SPCA AD-480 75/25 showed a slight increase in thickness; and

- UCAR Ultra IV and UCAR PG AAF both showed a significant decrease in thickness when diluted with water.

## 4.3 Tank Heating Effect

During the 1996-97 full-scale aircraft tests, it was observed that the Type IV fluid sprayed by the airlines was in many cases hot. This was caused by the heat transferred to the Type IV tank from the heated Type I tank situated in close proximity.

To study the effect of heat on Type IV fluids, several two-step fluid application tests were conducted in which the Type I and Type IV fluids were pre-heated to 80 and 40°C, respectively. Type IV fluids were heated to 40°C with 1000 W hot plate burners, using a double-boiler system (see Photo 4.2). The double-boiler system prevents any part of the fluid from exceeding temperatures greater than 100°C because the fluid and the first boiler are in contact with the water in the second boiler. It was found that most tests in which a heated Type IV fluid was applied over a heated Type I fluid a considerable decrease in thickness was observed relative to tests that were conducted with Type IV fluids at ambient temperatures. Consequently, potential reductions in holdover time protection can arise. This investigation is further detailed in Section 6.

Photo 4.1

**Setup for Thickness Tests Inside APS Trailer at Dorval Airport**

Photo 4.2

**Double-Boiler System Used for Heating Type IV Fluid to 80°C**

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# 5. HOLDOVER TIME TABLES, RESULTS, AND DISCUSSIONS

The methods used to evaluate the test data are reviewed in Subsection 2.9. In this section, the officially accepted holdover time tables are presented, and important findings are discussed. Beginning with Type IV fluid results in Subsection 5.2, the different categories of precipitation are presented one at a time, in a cell-by-cell fashion. Comments and discussions follow. Type III fluids are discussed in Subsection 5.3, Type I in Subsection 5.4, and Type II in Subsection 5.5.

Subsection 5.6 presents all the holdover time tables, including the generic Type IV SAE holdover time table and all the Type IV fluid-specific tables. These are the tables proposed for worldwide use during the 1998-99 winter season.

## 5.1 Background

Eight Type IV fluids were provided to APS for 1997-98 testing, including three fluids that had previously been tested: Kilfrost ABC-S, Octagon MaxFlight, and SPCA AD-404. Results of tests performed on these eight fluids were used to determine SAE holdover times for 1998-99. Two other certified fluids, Hoechst MPIV 1957 and Union Carbide Ultra +, were tested in 1996-97. Holdover time results of these fluids were also used in the determination of 1998-99 SAE holdover times.

Clariant MPIV 1957 is a reformulation of the Hoechst MPIV 1957 fluid. Prior to the writing of this report, APS was notified that Hoechst MPIV 1957 was no longer commercially available. As a result, *fluid-specific* holdover times for MPIV 1957 fluid will be those solely of the new Clariant formulation.

At the Workgroup meeting on Laboratory Methods to Derive Holdover Time Guidelines in Montreal in November 1997, it was decided that low viscosity fluid samples should be tested in future holdover time tests, as they represent the lowest on-wing viscosity expected in the field. This would result in more conservative holdover time values. Subsequently, APS requested that fluid manufacturers ship pre-sheared fluid representative of the lower end of the production viscosity range for 1997-98 test purposes.

Following several holdover time test sessions at the Dorval site, the results for Kilfrost fluid were found to be inferior to those obtained in previous tests conducted with the same fluid. As a result, APS examined the different batches of fluid delivered by the manufacturers. The Kilfrost fluid was found to have a viscosity level below the production range for this fluid. In fact, the samples provided to APS were those of the 80-minute Kilfrost fluid. Examination of the viscosity levels of the other fluids revealed other inconsistencies. The fluid samples for Clariant MPIV 1957 and MPIV 2001

were believed to be at the low end of the production range for these fluids. The remainder of the fluid samples provided to APS had viscosity levels representative of the mid-production range, not the lower end of the production range as requested. The normalized viscosity levels of the fluid samples sent to APS are shown at the bottom of Table 5.1.

For example, the viscosity of the first Clariant MPIV 1957 sample was approximately 20 percent below the lower viscosity production limit for this fluid. The second Clariant MPIV 1957 sample had viscosity levels representative of mid-production range viscosity fluid.

Prior to the start of freezing drizzle, light freezing rain, freezing fog, and rain on a cold-soaked wing testing at NRC's CEF in April 1998, APS requested that Kilfrost and Clariant provide mid-range viscosity fluids for these tests. This was done to ensure that all fluids were tested on an even basis.

Comparative holdover time tests were performed using the first and second batches of Clariant and Kilfrost fluids. In general, the mid-viscosity batches of Kilfrost ABC-S and Clariant MPIV 1957 fluids outperformed the low-viscosity batches of the same fluids. The holdover time results of the two batches of Clariant MPIV 2001 were similar. It was later discovered that the original Clariant MPIV 2001 samples, which were thought to be at the lower end of the production viscosity range, were in fact representative of mid-range viscosity fluid.

The holdover time results obtained with one Type IV fluid were lower than those achieved with the same fluid in the previous year. A series of holdover time tests were subsequently performed to compare the holdover times of 1996-97 and 1997-98 fluid samples in light freezing rain. When pouring the fluids onto the flat plates, it was immediately noticed that the appearance of the samples was significantly different. The 1996-97 sample was translucent, while the 1997-98 sample was murky (see Photo 5.1). The holdover times of the 1997-98 sample were inferior to those of the 1996-97 sample in all dilutions.

The data sets used to analyse the results and generate regression curves for each fluid are shown in Table 5.1.

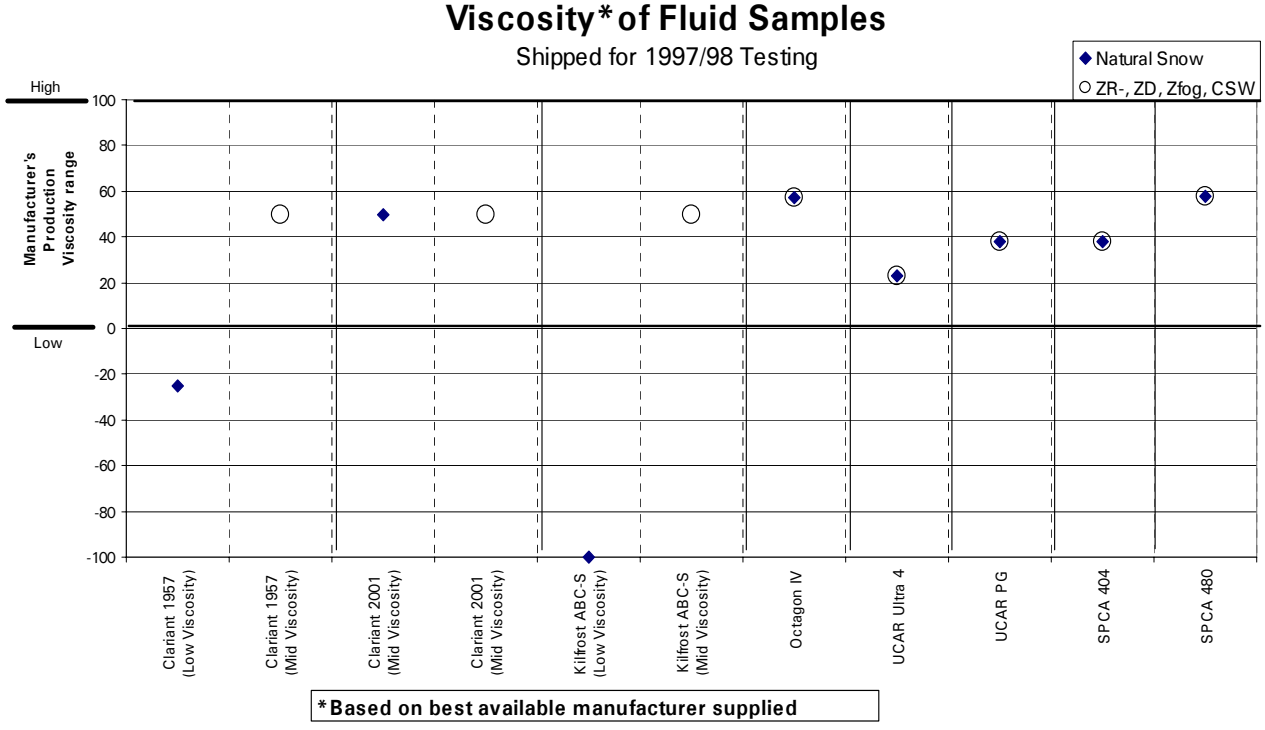
- For SPCA AD-480, mid-production range viscosity samples were used for all tests.

- Due to a lack of data points for SPCA AD-404 in snow, 1995-96 and 1997-98 results were combined. For all other conditions with this fluid, a mid-range viscosity sample was tested.

FIGURE 5.1

# DATA USED FOR EVALUATION OF HOLDOVER TIMES

| | Outdoor Snow | Cold Chamber | | |
|---|---|---|---|---|
| | | Freezing Drizzle/ Freezing Rain | Freezing Fog | Cold-Soaked Wing |
| Ultra IV | 1997-98 | 1997-98 | | |
| SPCA AD-480 | 1997-98 | 1997-98 | | |
| Clariant 2001 | 1997-98 | 1997-98 (mid-viscosity) | | |
| Clariant 1957 | 1997-98 | 1997-98 (mid-viscosity) | | |
| UCAR PG | 1997-98 | 1997-98 | | |
| Kilfrost ABC-S | 1996-97 | 1997-98 (mid-viscosity) | | |
| Octagon MaxFlight | 1996-97 | 1997-98 | | |
| SPCA AD-404 | 1995-96 & 1997-98 | 1997-98 | | |



- For Clariant MPIV 1957, the sample used in natural snow tests was below the lower end of the production viscosity range. For all other tests with this fluid, a mid-production range viscosity fluid was used.

- For Clariant MPIV 2001, mid-production range viscosity samples were used for all tests.

- Kilfrost ABC-S snow tests were performed with a low viscosity sample. In order not to penalize Kilfrost, the holdover time values for this fluid in snow were taken from the *fluid-specific* table developed for 1997-98 operations. A mid-production range viscosity sample was used for all other tests. The lowest of the 1997-98 and 1998-99 Kilfrost values in freezing drizzle and light freezing rain were selected for the new *fluid-specific* table for Kilfrost fluid.

- Due to a lack of data points for Octagon MaxFlight in snow, the holdover time values for this fluid are those that appear in the 1997-98 Octagon *fluid-specific* table. A mid-viscosity sample was used for all other conditions. The lowest of the 1997-98 and 1998-99 Octagon values in freezing drizzle and light freezing rain were chosen and placed in the new Octagon *fluid-specific* table.

- Union Carbide Ultra+ was not tested extensively in 1997-98 and, as such, the values in the *fluid-specific* table for Ultra+ are those from tests conducted in 1996-97.

## 5.2 Type IV Fluids

Eight Type IV fluids from five different manufacturers were tested during the winter 1997-98 test season. After considerable discussion at the SAE G-12 meetings in Vienna, it was determined that two fluids, Union Carbide PG AAF and Union Carbide Ultra 4, did not meet all qualifying criteria. APS had conducted 383 fluid failure tests with these two fluids in all precipitation conditions prior to this finding. In total, eight different fluids, tested in 1996-97 and 1997-98, were used to develop the SAE holdover time table for Type IV fluid: Clariant MPIV 1957, Clariant MPIV 2001, Hoechst MPIV 1957, Kilfrost ABC-S, Octagon MaxFlight, SPCA AD-404, SPCA AD-480, and Union Carbide Ultra+.

### 5.2.1 Natural Snow

The natural snow holdover time data originated from tests conducted by APS at the Dorval Airport test facility. The fluid failure time versus precipitation rate data have been plotted either as a function of temperature or as a function of fluid brand (see Appendix E). The latter plot format lends itself more easily to the cell-by-cell presentation of results for each category of precipitation. It is used here to present the changes proposed to the holdover times and to allow direct comparison with the numbers obtained from the regression analyses.

The following section contains comparisons between last year's and this year's holdover time results in the snow column. They are arranged in tabular form and follow the sequence of temperature ranges as they appear in the holdover time tables, from top to bottom.

#### *5.2.1.1 Changes to Type IV fluid holdover times for snow*

The tables are formatted to show columns containing the *1997-98 SAE, 1998-99 SAE*, and the *fluid-specific* holdover times for 1997-98 and 1998-99 for each cell in the holdover time tables. The first horizontal set of values is the SAE and fluid-specific holdover times used in operations in 1997-98. The second set of values is the SAE and fluid-specific holdover times accepted for use in 1998-99. The underlined holdover time values in each of the tables indicate the fluids responsible for the *SAE* holdover time.

Due to space limitations, the following fluid codes are used in each of the tables:

| Fluid | Code |
|---|---|
| Hoechst MPIV 1957 | H-1957 |
| Kilfrost ABC-S | K-ABC-S |
| Octagon MaxFlight | Oct Max |
| Union Carbide Ultra+ | Ultra+ |
| Clariant MPIV 1957 | C-1957 |
| Clariant MPIV 2001 | C-2001 |
| SPCA AD-404 | S-404 |
| SPCA AD-480 | S-480 |

i) Neat fluid, above 0°C, snow (Figure 5.1)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ | | | |
| 0:45-1:25 | 0:45-1:25 | 1:10-2:00 | 1:15-2:00 | 0:50-1:40 | | | |
| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
| 0:45-1:25 | 1:05-2:00 | 1:55-2:00 | 1:10-2:00 | 1:15-2:0 | 0:50-1:40 | 1:40-2:00 | 1:10-2:00 |

The SAE holdover time in this cell has not changed, and is based on the performance of a certified fluid tested last year. Once again, it was decided at the Vienna meeting that the SAE numbers would not be increased based on the results of current tests, since previously certified fluids with lower holdover times may still be in use. Several upper holdover times have been limited to two hours in order to prevent the appearance of excessively long holdover times in the holdover time tables.

ii) 75/25 fluid, above 0°C, snow (Figure 5.2)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) | | | |
| 0:20-0:40 | 0:35-1:00 | 0:35-1:05 | 1:20-2:00 | 0:20-0:40 | | | |
| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
| 0:20-0:40 | 0:45-1:25 | 0:50-1:25 | 0:35-1:05 | 1:20-2:00 | | 0:50-1:50 | 1:00-1:55 |

Once again, the SAE holdover time numbers in this cell remain unchanged from last year, and are based on the results of diluted Ultra+ fluid, tested last year. Prior to the publication of the 1997-98 holdover time tables, Union Carbide transmitted a notice stating that diluted forms of Ultra+ were no longer recommended for operational use due to performance deficiencies noted in qualifying tests. Holdover times for dilutions of this fluid will continue to be presented in this report only for the purpose of identifying the fluid(s) responsible for the SAE holdover times. The

FIGURE 5.1

**EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE IV NEAT (above 0°C)

NATURAL SNOW CONDITIONS

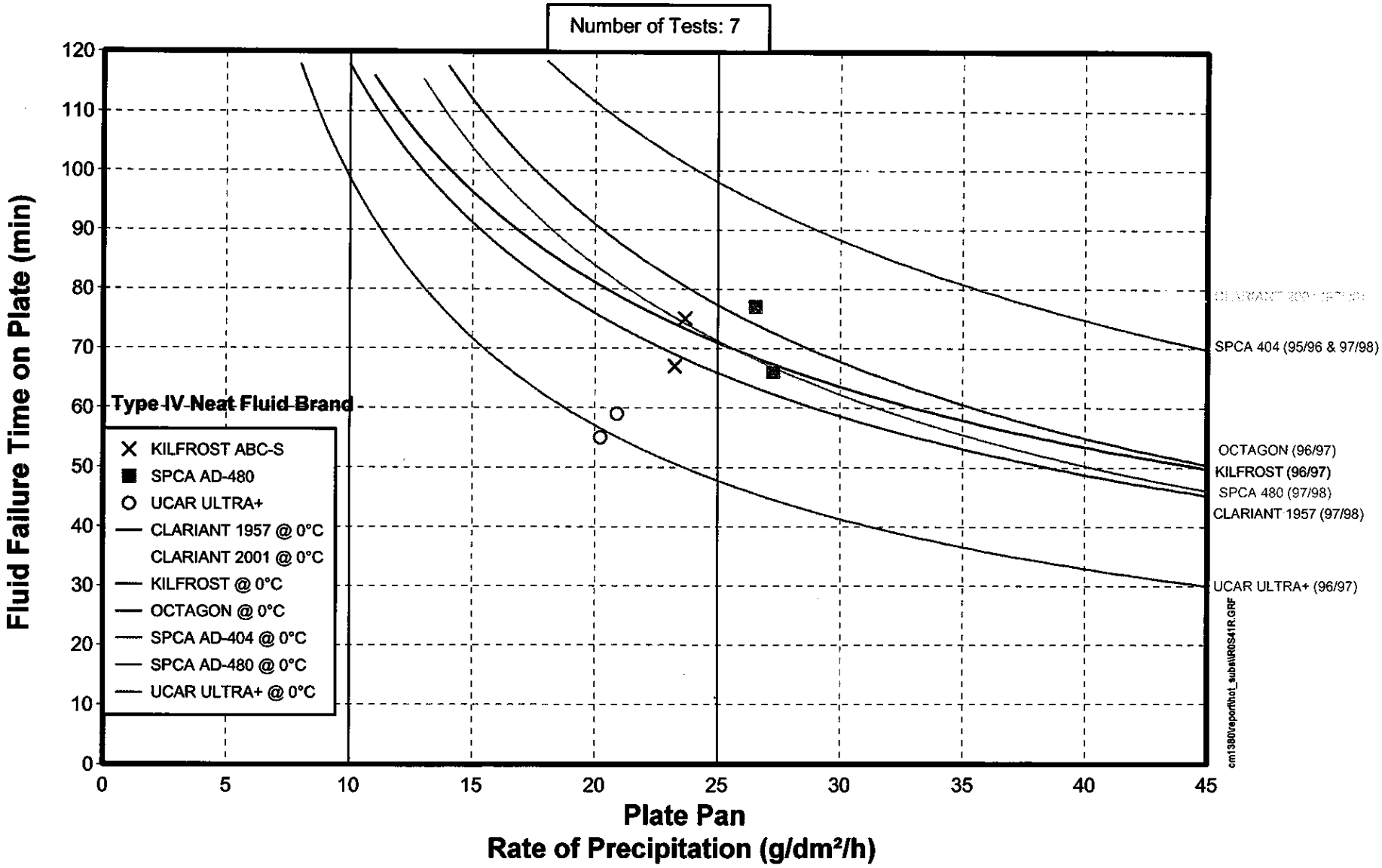
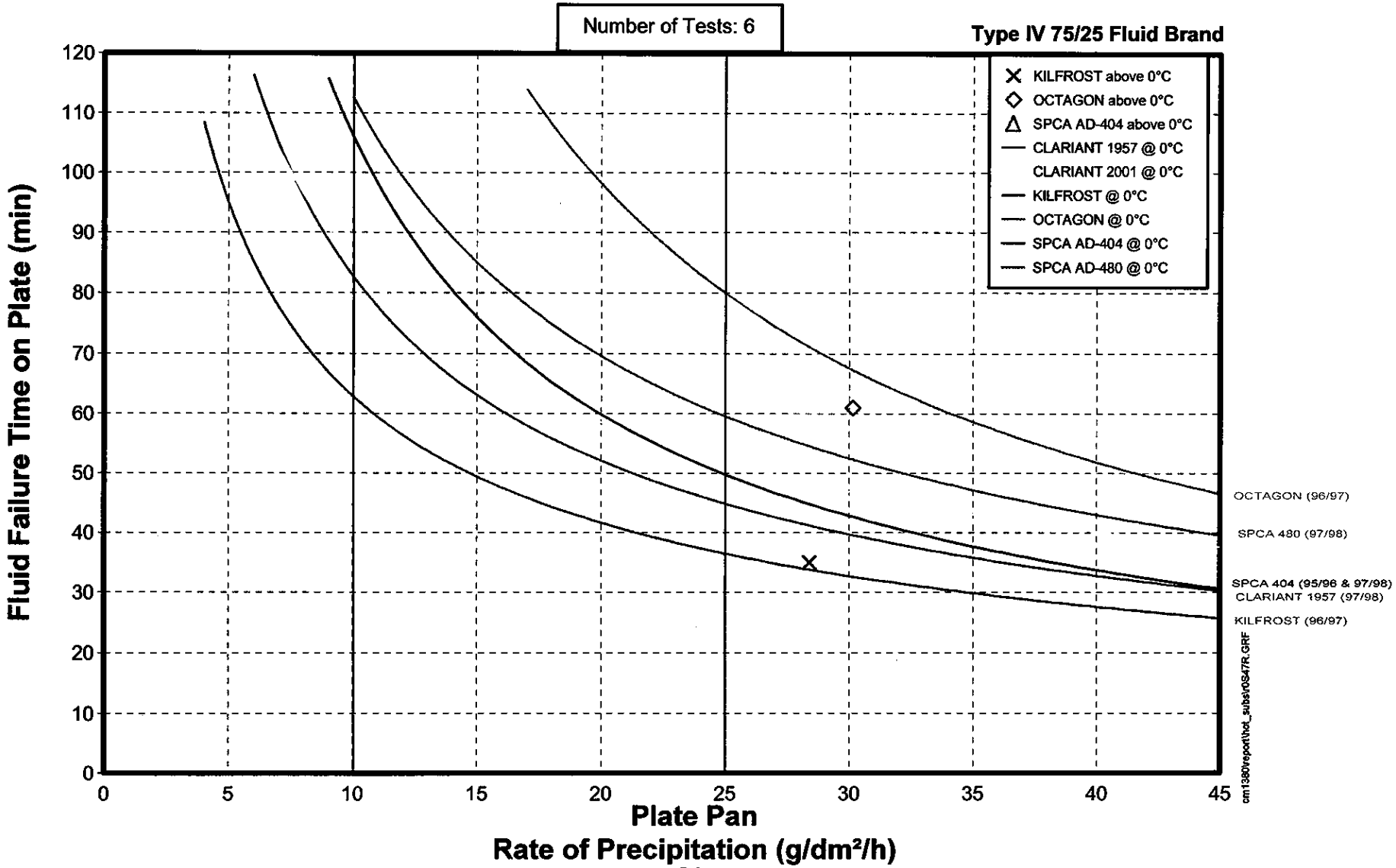


FIGURE 5.2

**EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE IV 75/25 (Above 0°C)

NATURAL SNOW CONDITIONS



holdover time of Octagon 75/25 fluid is slightly superior to that of the neat formulation in this temperature range and condition. This result is not completely unexpected, as the stabilized thickness of the MaxFlight fluid at the 75/25 dilution is superior to that of the neat formulation (see Figure 4.4). Octagon fluid fails by dilution at warmer temperatures, and therefore it is not unusual that the thicker film resists erosion for a longer period.

iii) 50/50 fluid, above 0°C, snow (Figure 5.3)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) |
|---|---|---|---|---|
| 0:05-0:20 | 0:15-0:25 | 0:05-0:20 | 0:40-1:20 | 0:05-0:20 |

| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
|---|---|---|---|---|---|---|---|
| 0:05-0-20 | 0:15-0:30 | 0:10-0:20 | 0:05-0:20 | 0:40-1:20 | | 0:20-0:45 | 0:15-0:35 |

The SAE holdover times in this cell are unchanged from last year. Kilfrost fluid is responsible for the SAE holdover times. Another fluid substantially outperforms the rest at this dilution.

iv) Neat fluid, 0°C to -3°C, snow (Figure 5.4)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ |
|---|---|---|---|---|
| 0:35-1:00 | 0:35-1:00 | 1:00-1:40 | 0:50-1:35 | 0:35-1:15 |

| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ | S-404 | S-480 |
|---|---|---|---|---|---|---|---|
| 0:35-1:00 | 0:45-1:25 | 1:00-1:55 | 1:00-1:40 | 0:50-1:35 | 0:35-1:15 | 1:00-1:45 | 1:05-2:00 |

The lower SAE holdover time at this temperature and concentration is generated by two fluids, both tested in 1996-97.

v) 75/25 fluid, 0°C to -3°C, snow (Figure 5.5)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) |
|---|---|---|---|---|
| 0:20-0:35 | 0:25-0:50 | 0:35-1:05 | 0:45-1:45 | 0:20-0:35 |

| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
|---|---|---|---|---|---|---|---|
| 0:20-0:35 | 0:30-1:00 | 0:35-1:00 | 0:35-1:05 | 0:45-1:45 | | 0:25-1:00 | 0:45-1:25 |

At this dilution, the holdover performances of the fluids were similar. The lower and upper SAE holdover times were those of diluted Ultra+.

FIGURE 5.3

**EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE IV 50/50 (Above 0°C)

NATURAL SNOW CONDITIONS

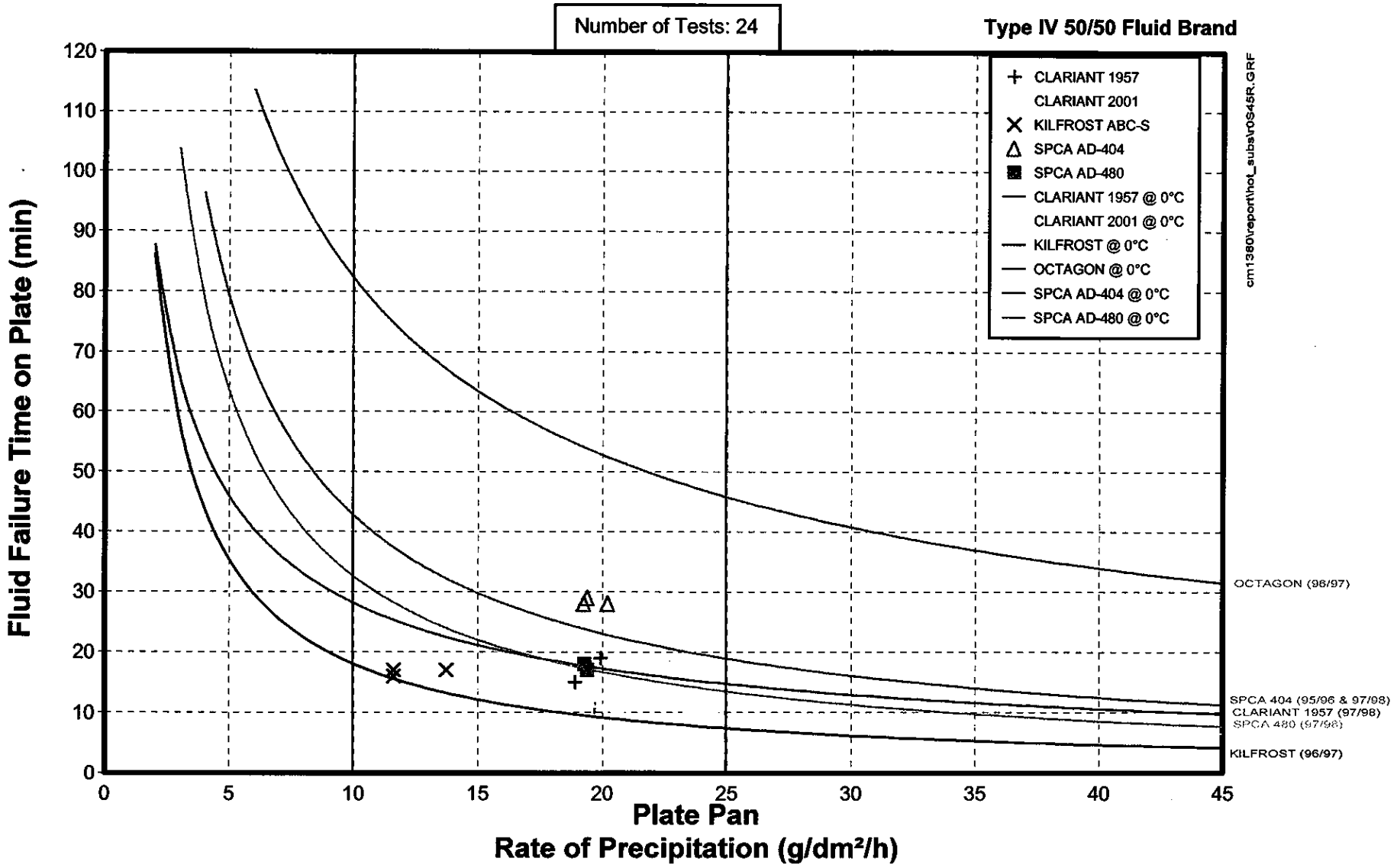


FIGURE 5.4

**EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE IV NEAT (0 to -3°C)

NATURAL SNOW CONDITIONS

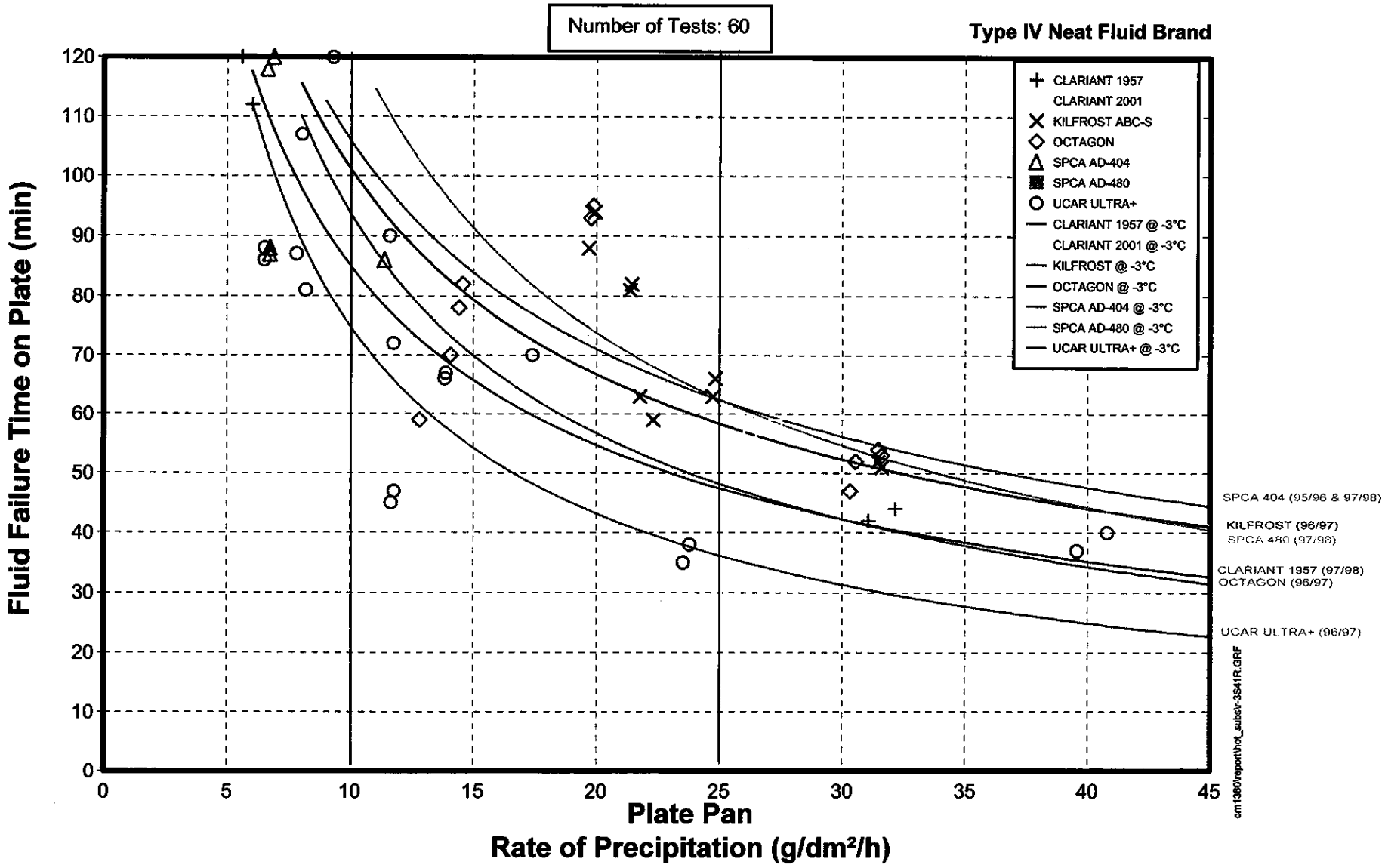
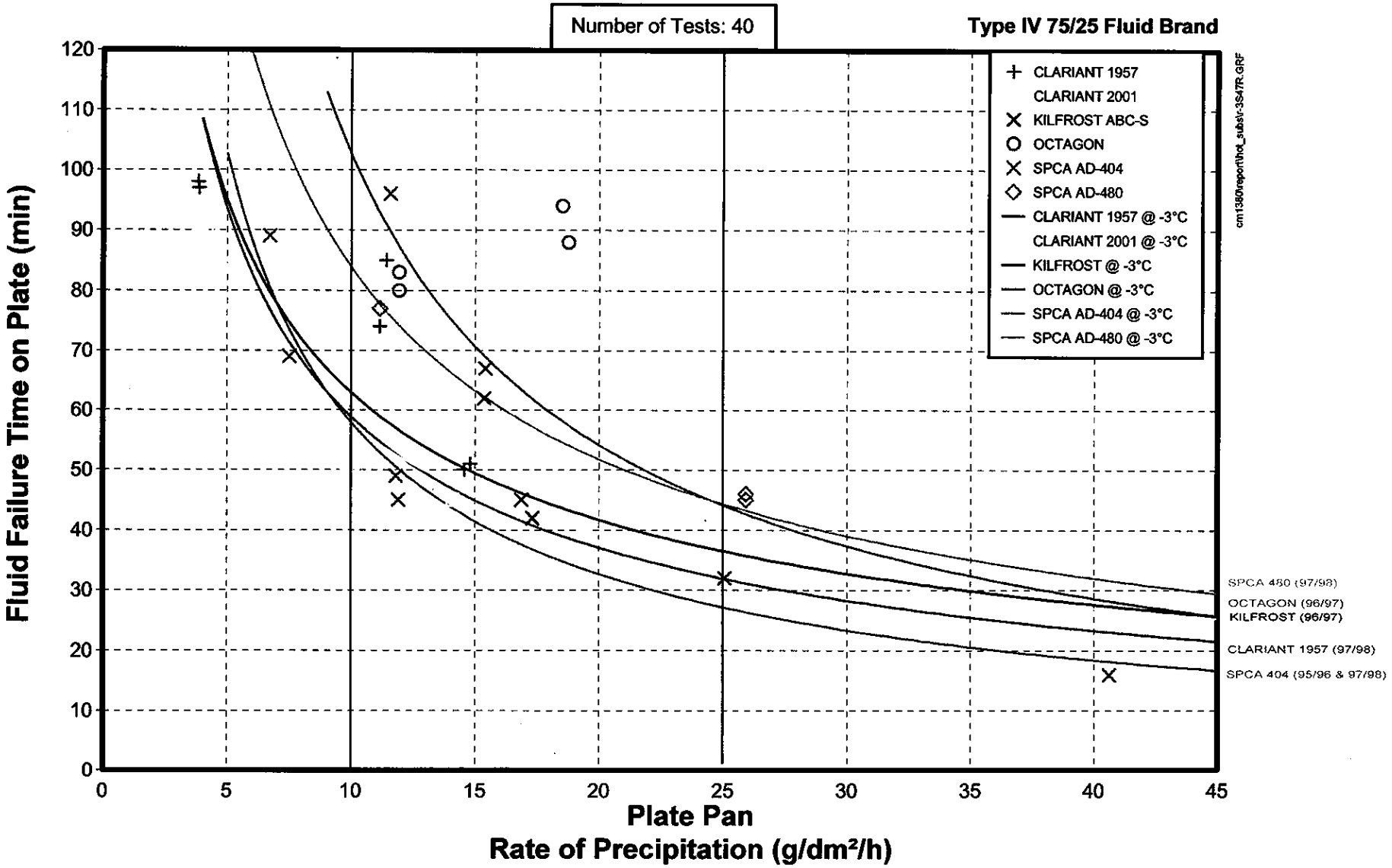


FIGURE 5.5

**EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE IV 75/25 (0 to -3°C)

NATURAL SNOW CONDITIONS



vi) 50/50 fluid, 0°C to -3°C, snow (Figure 5.6)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) |
|---|---|---|---|---|
| 0:05-0:15 | 0:15-0:25 | 0:05-0:15 | 0:40-1:20 | 0:05-0:15 |

| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
|---|---|---|---|---|---|---|---|
| 0:05-0:15 | 0:10-0:20 | 0:10-0:20 | 0:05-0:15 | 0:40-1:20 | | 0:15-0:30 | 0:10-0:30 |

The holdover time performances of the various fluids are quite similar at this dilution and temperature range, with the exception of one fluid, which greatly outperforms the rest (see Figure 5.6). The SAE holdover times were generated by Kilfrost and Ultra+ fluids.

vii) Neat fluid, -3°C to -14°C, snow (Figure 5.7)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ |
|---|---|---|---|---|
| 0:20-0:40 | 0:20-0:40 | 0:45-1:20 | 0:25-0:50 | 0:25-0:55 |

| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra | S-404 | S-480 |
|---|---|---|---|---|---|---|---|
| 0:20-0:40 | 0:30-0:55 | 0:30-0:50 | 0:45-1:20 | 0:25-0:50 | 0:25-0:55 | 0:35-1:00 | 0:20-0:40 |

The SAE holdover times for this temperature range and concentration are, once again, driven by test results obtained in previous years. In the case of SPCA AD-480, the holdover time range was reduced to equal that of the SAE holdover time range due to a lack of data points for this fluid below -7°C.

viii) 75/25 fluid, -3° C to -14°C, snow (Figure 5.8)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) |
|---|---|---|---|---|
| 0:15-0:30 | 0:15-0:30 | 0:35-1:05 | 0:20-0:50 | 0:15-0:30 |

| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
|---|---|---|---|---|---|---|---|
| 0:15-0:25 | 0:20-0:40 | 0:20-0:35 | 0:35-1:05 | 0:20-0:50 | | 0:15-0:25 | 0:15-0:25 |

The SAE upper holdover time in this cell has been reduced from 30 minutes to 25 minutes based on the results of one fluid. The holdover times for another fluid, SPCA AD-480, were reduced to match the SAE times due to a lack of data points for this fluid below -7°C.

FIGURE 5.6

**EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE IV 50/50 (0 to -3°C)

NATURAL SNOW CONDITIONS

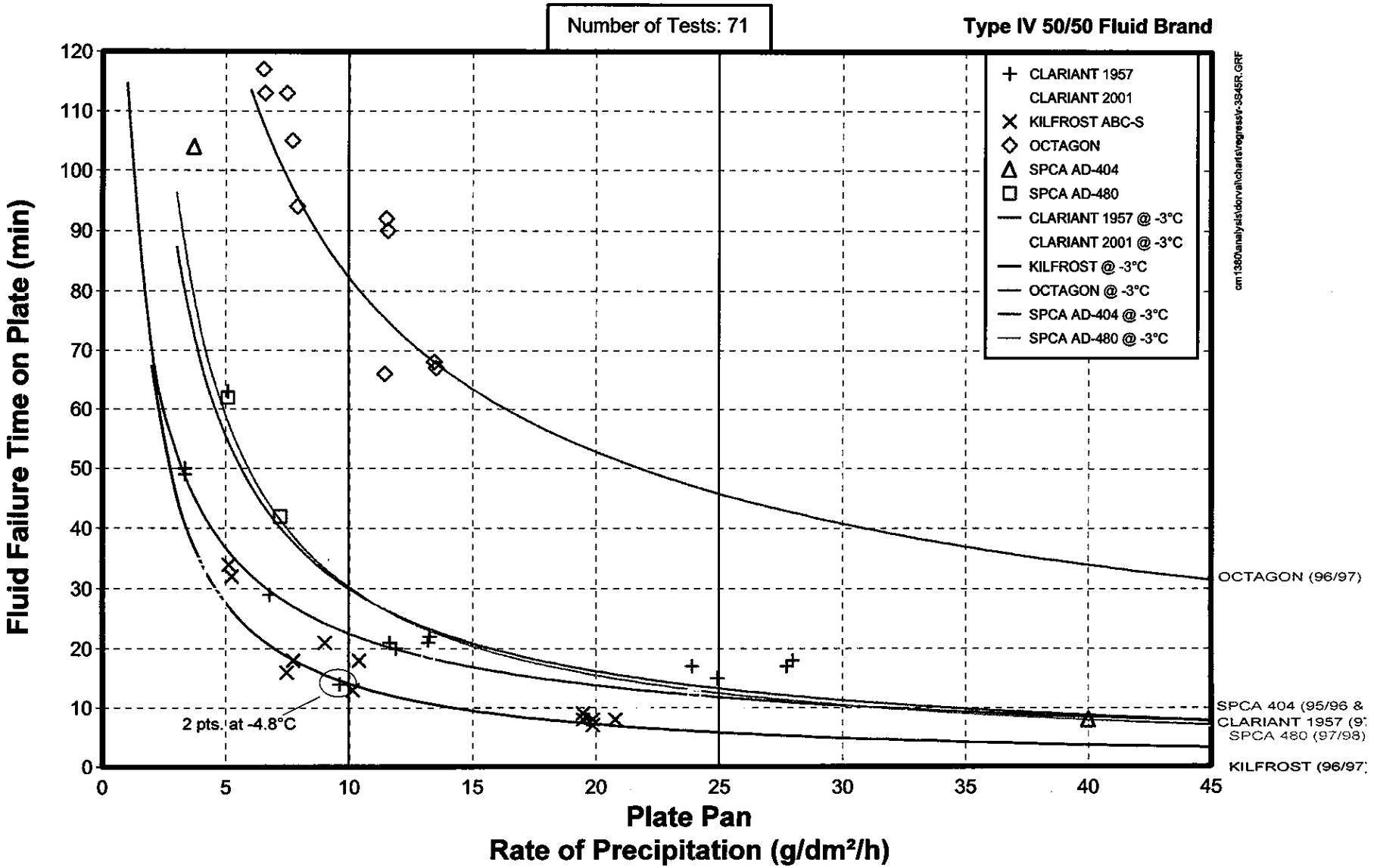


FIGURE 5.7

**EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE IV NEAT (-3 to -14°C)

NATURAL SNOW CONDITIONS

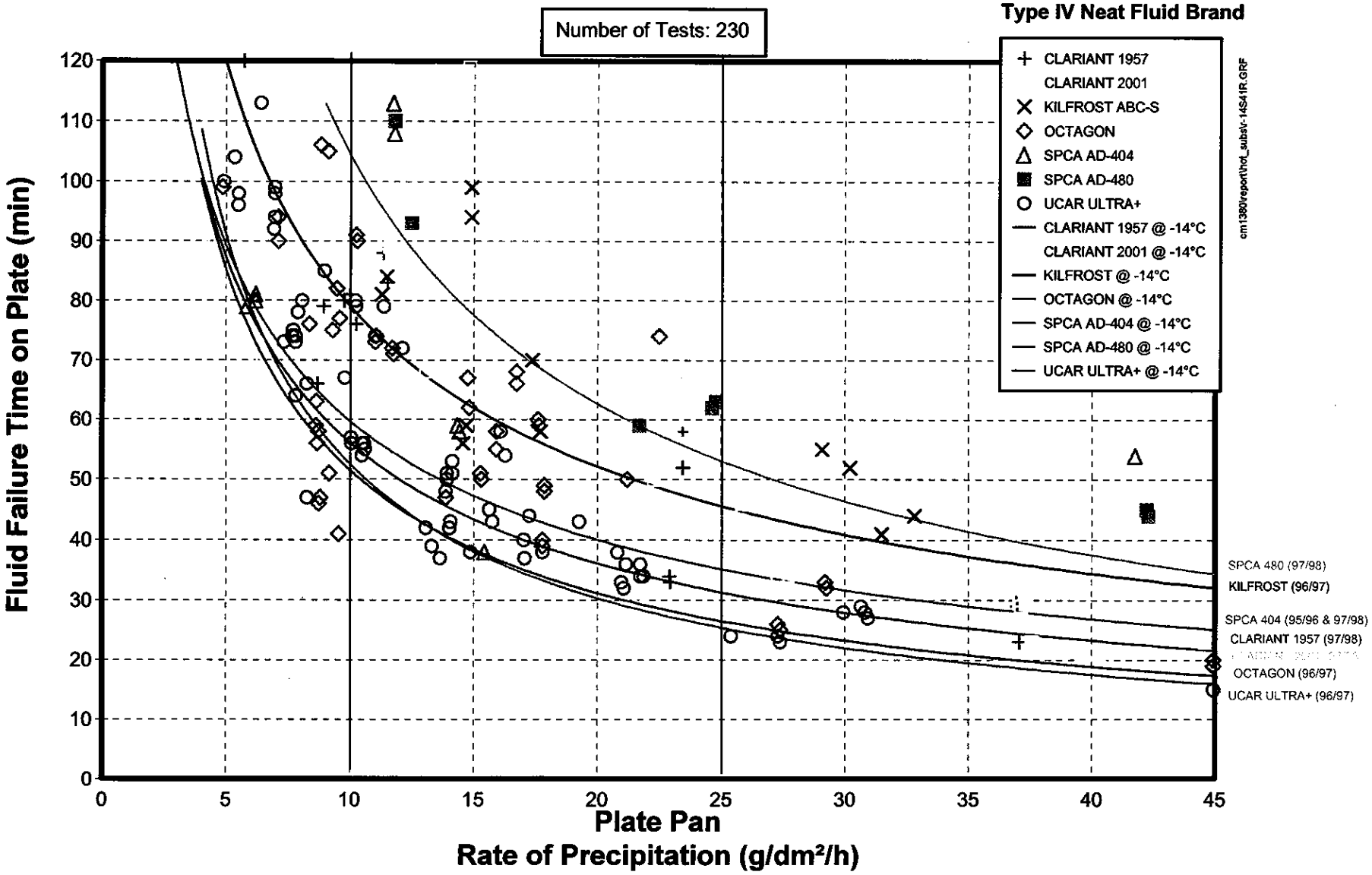
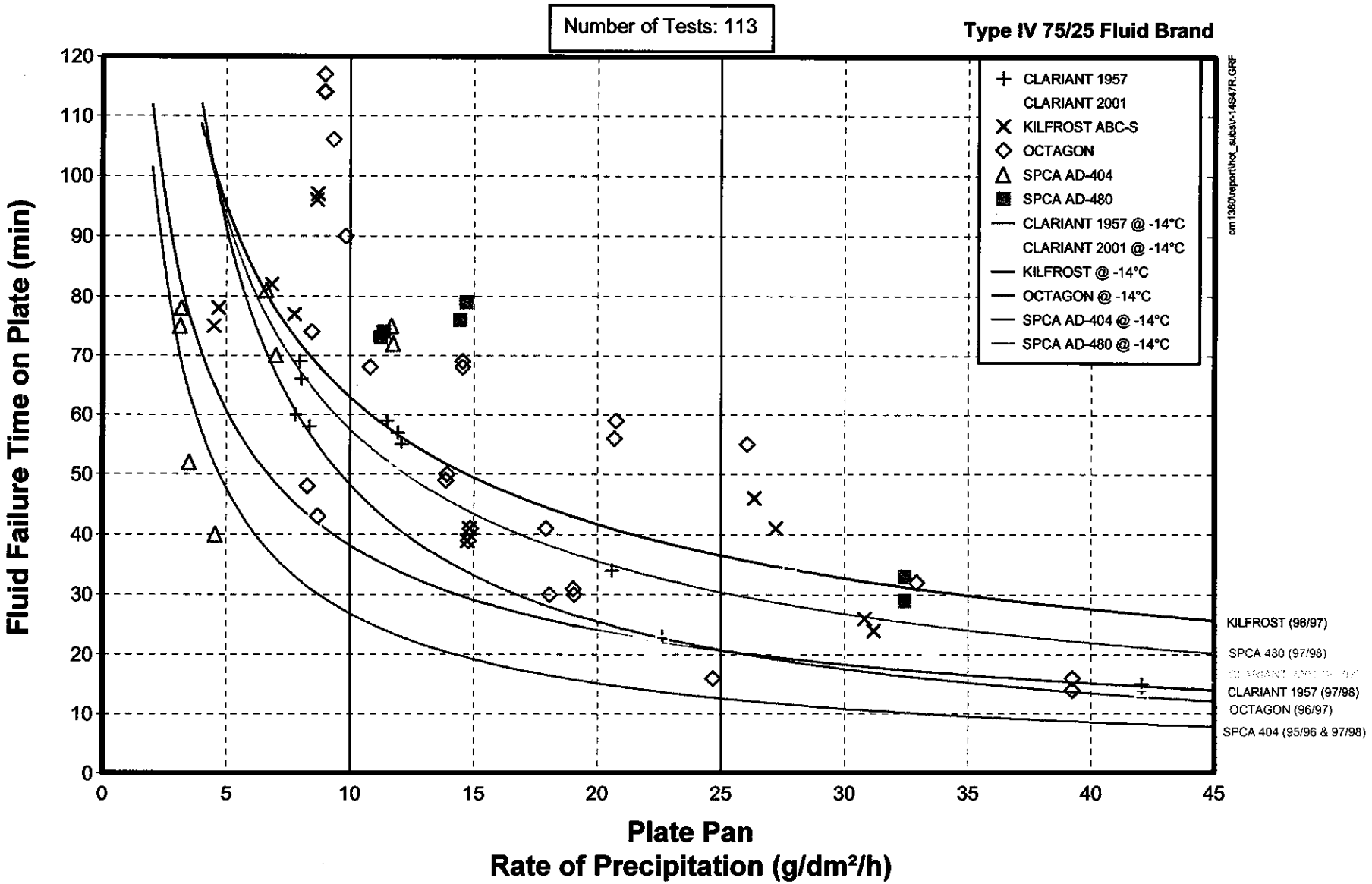


FIGURE 5.8

**EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE IV 75/25 (-3 to -14°C)

NATURAL SNOW CONDITIONS



ix) Neat fluid, -14°C to -25°C, snow (Figure 5.9)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra + | | | |
|---|---|---|---|---|---|---|---|
| 0:15-0:30 | 0:15-0:30 | 0:40-1:10 | 0:20-0:40 | 0:20-0:45 | | | |
| **1998-99 SAE** | **C-1957** | **C-2001** | **K-ABC-S** | **Oct Max** | **Ultra +** | **S-404** | **S-480** |
| 00:15-0:30 | 0:25-0:45 | 0:20-0:35 | 0:40-1:10 | 0:20-040 | 0:20-0:45 | 0:15-0:30 | 0:15-0:30 |

The SAE holdover times for this cell are unchanged from last year and are driven by results from the previous test season. Regression curves were generated using the most restrictive temperature in this range (-25°C). Due to a lack of data points for SPCA AD-404 and SPCA AD-480 in this cell, the holdover times for these fluids were reduced to match the SAE holdover times.

#### *5.2.1.2 Overall perspective on snow results*

With the exception of one change, the SAE holdover times for Type IV fluids in natural snow remain unchanged from those approved for operational use during the 1997-98 winter.

### 5.2.2 Freezing Drizzle

The following is a cell-by-cell summary of the holdover time performance of all Type IV fluid brands tested under conditions of simulated freezing drizzle. The results are arranged in the sequence of temperature ranges (from top to bottom) that appear in the corresponding columns of the holdover time tables. Since it is impossible to simulate freezing drizzle above 0°C, the holdover time results for this category of precipitation above 0°C are identical to those in the 0°C to -3°C range.

Each table shows columns containing the *1997-98 SAE, 1998-99 SAE*, and the *fluid-specific* holdover times.

The fluid failure time versus precipitation rate data for this category of precipitation are plotted either as a function of temperature or as as a function of fluid brand. The plots as a function of fluid brand are used to help present discussions regarding changes to holdover times and appear in the body of the text as Figures 5.10 to 5.14.

FIGURE 5.9

**EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE IV NEAT (-14 to -25°C)

NATURAL SNOW CONDITIONS

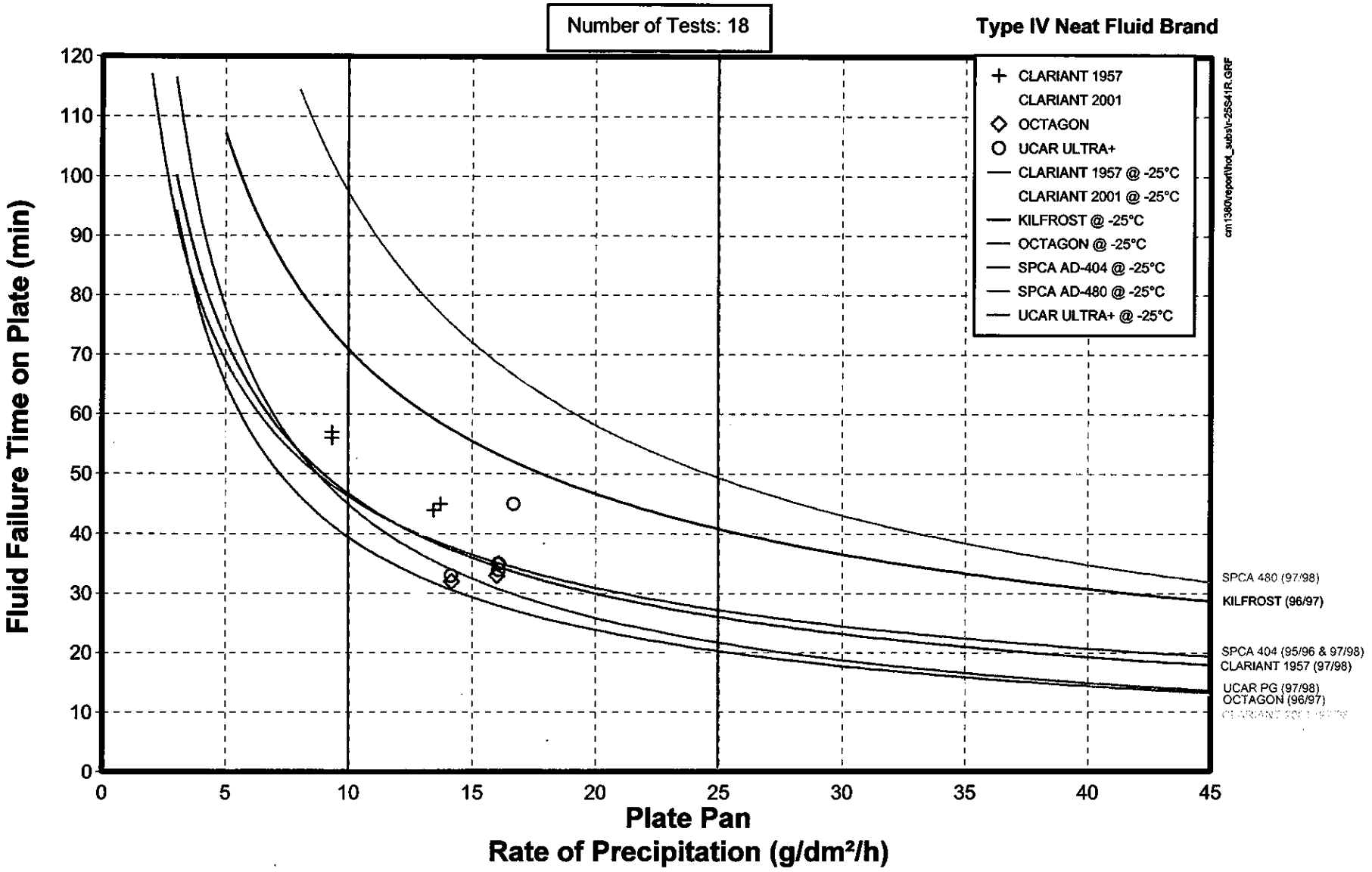


FIGURE 5.10

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT

### FREEZING DRIZZLE AT -3°C

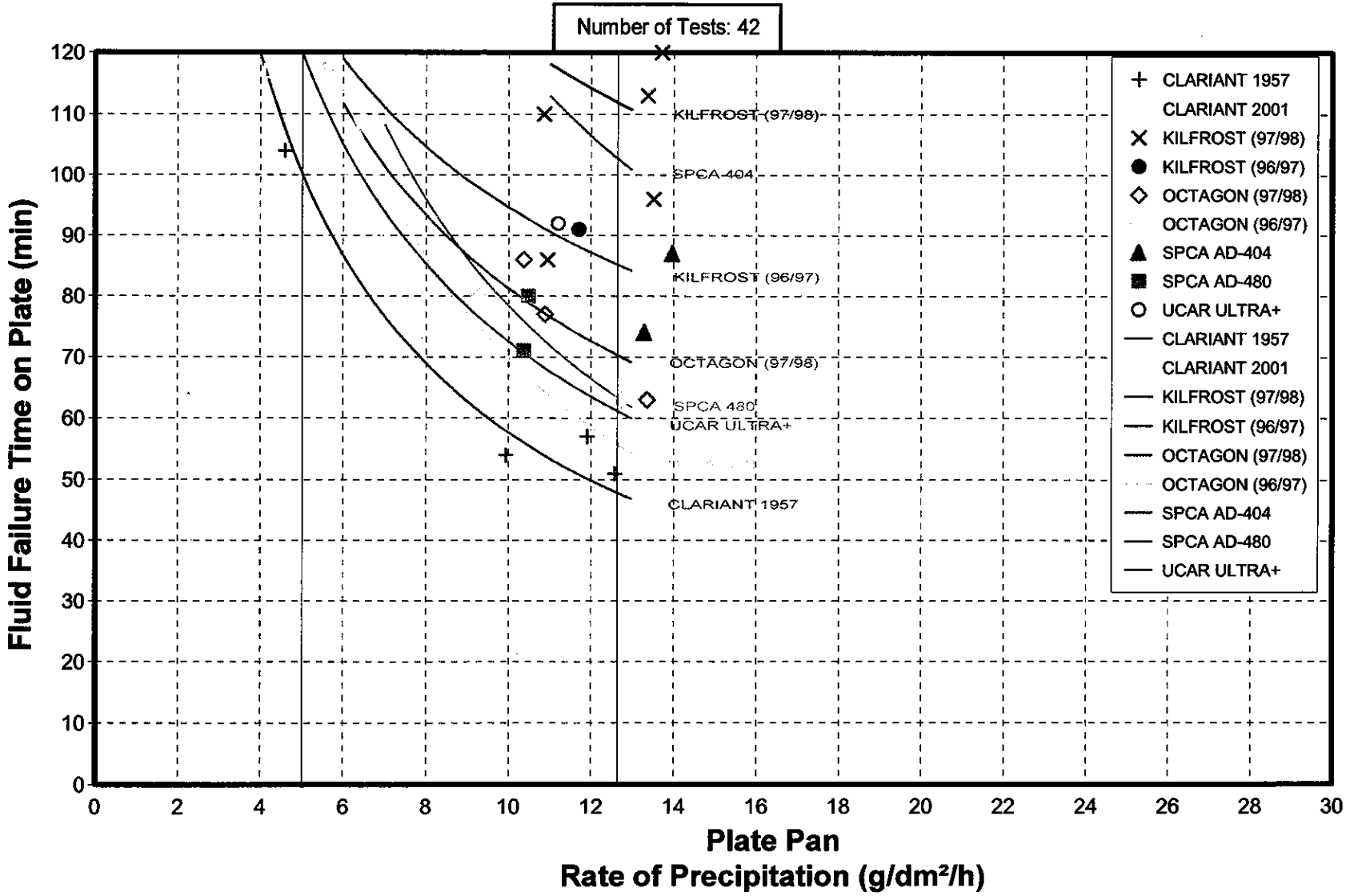


FIGURE 5.11

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25

### FREEZING DRIZZLE AT -3°C

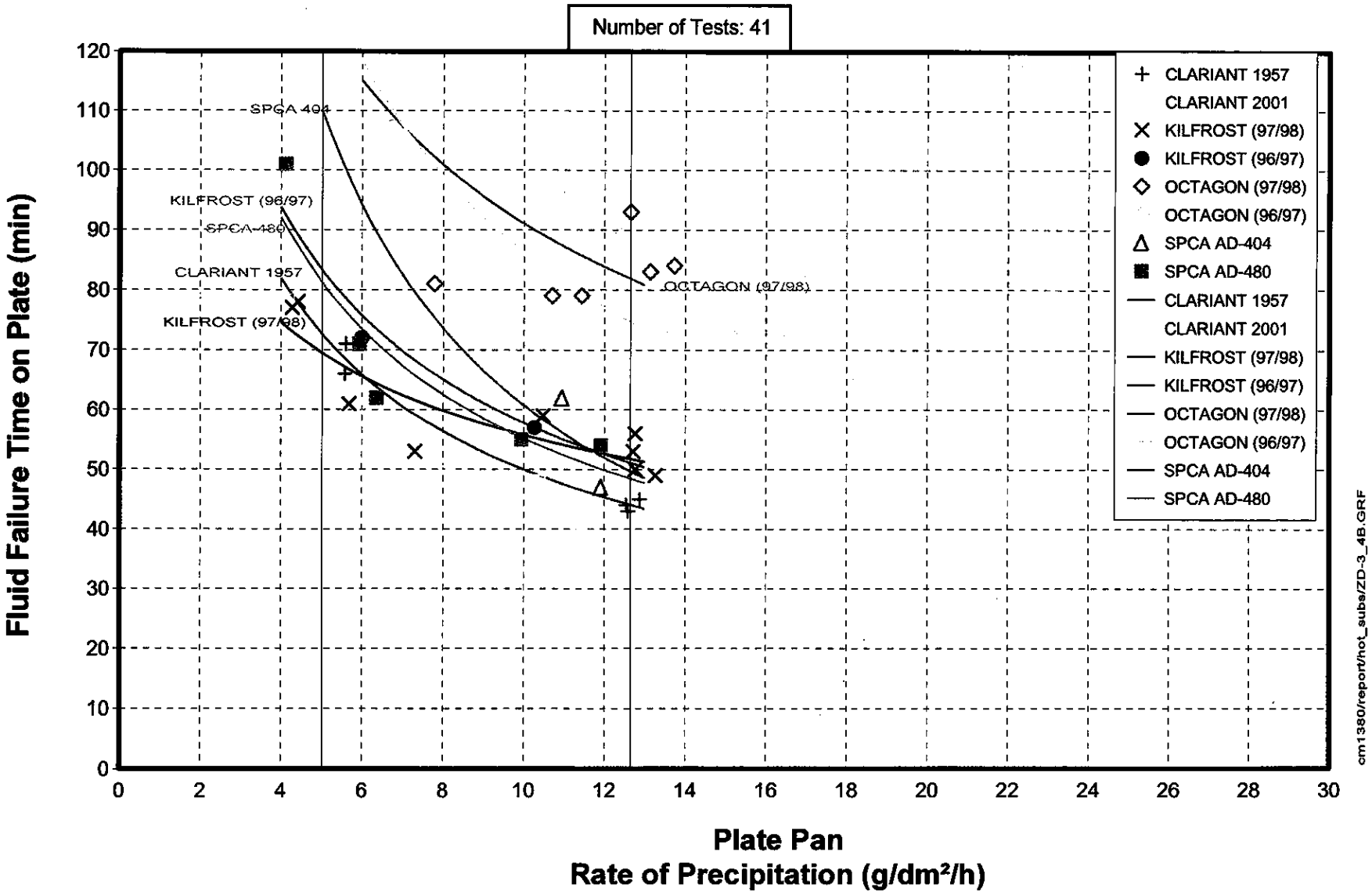


FIGURE 5.12

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 50/50

FREEZING DRIZZLE AT -3°C

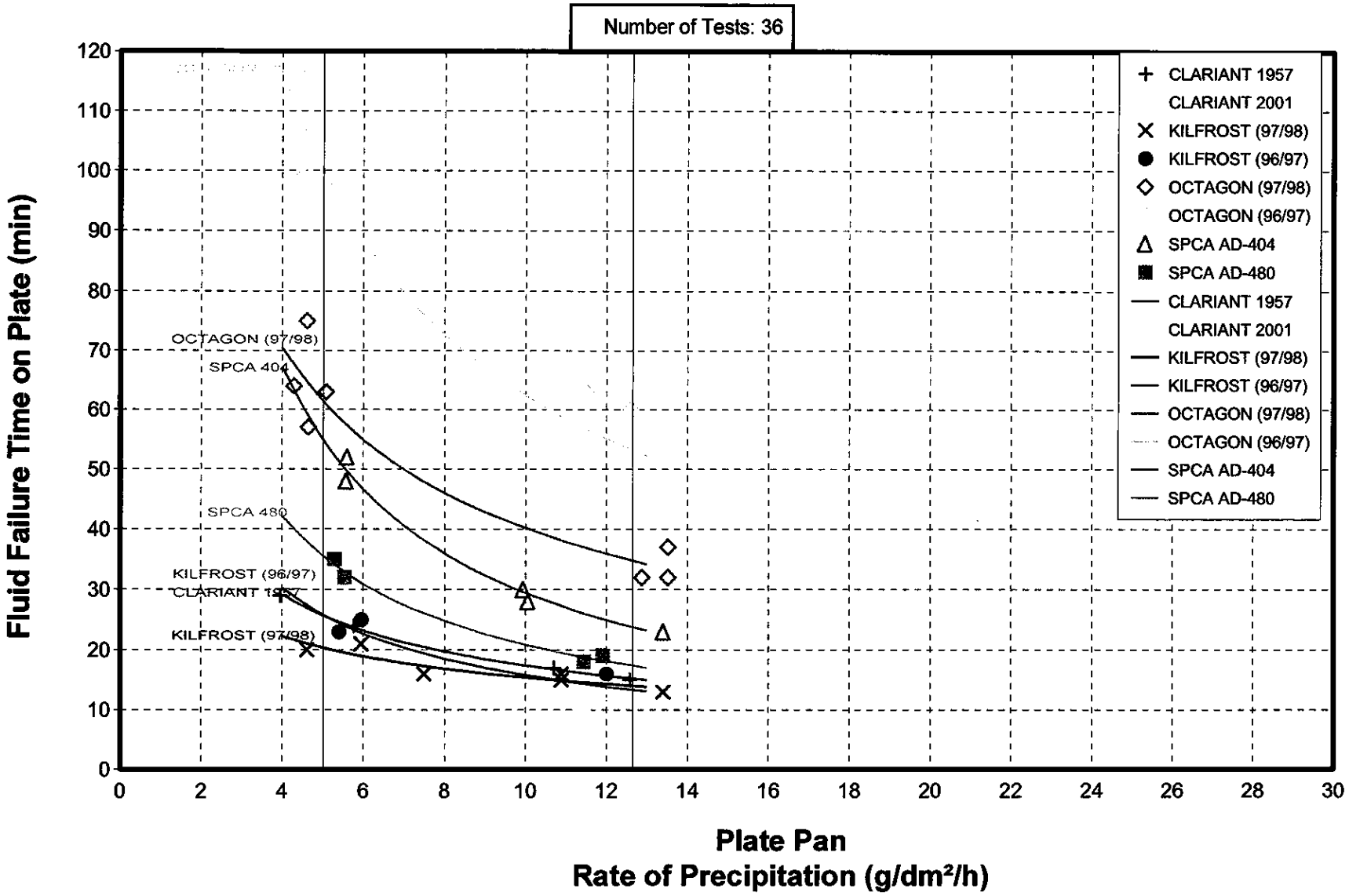


FIGURE 5.13

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT

### FREEZING DRIZZLE AT -10°C

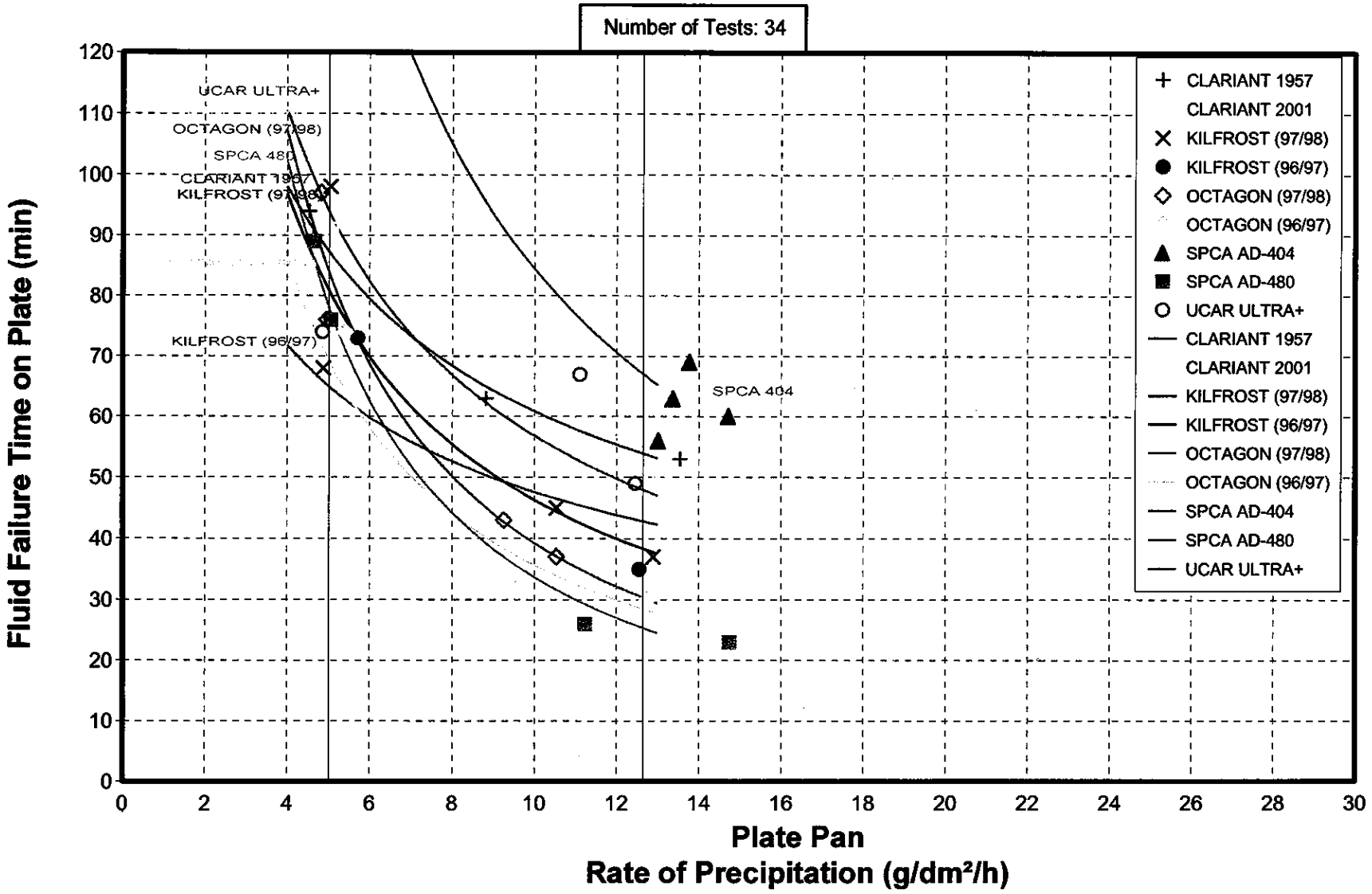
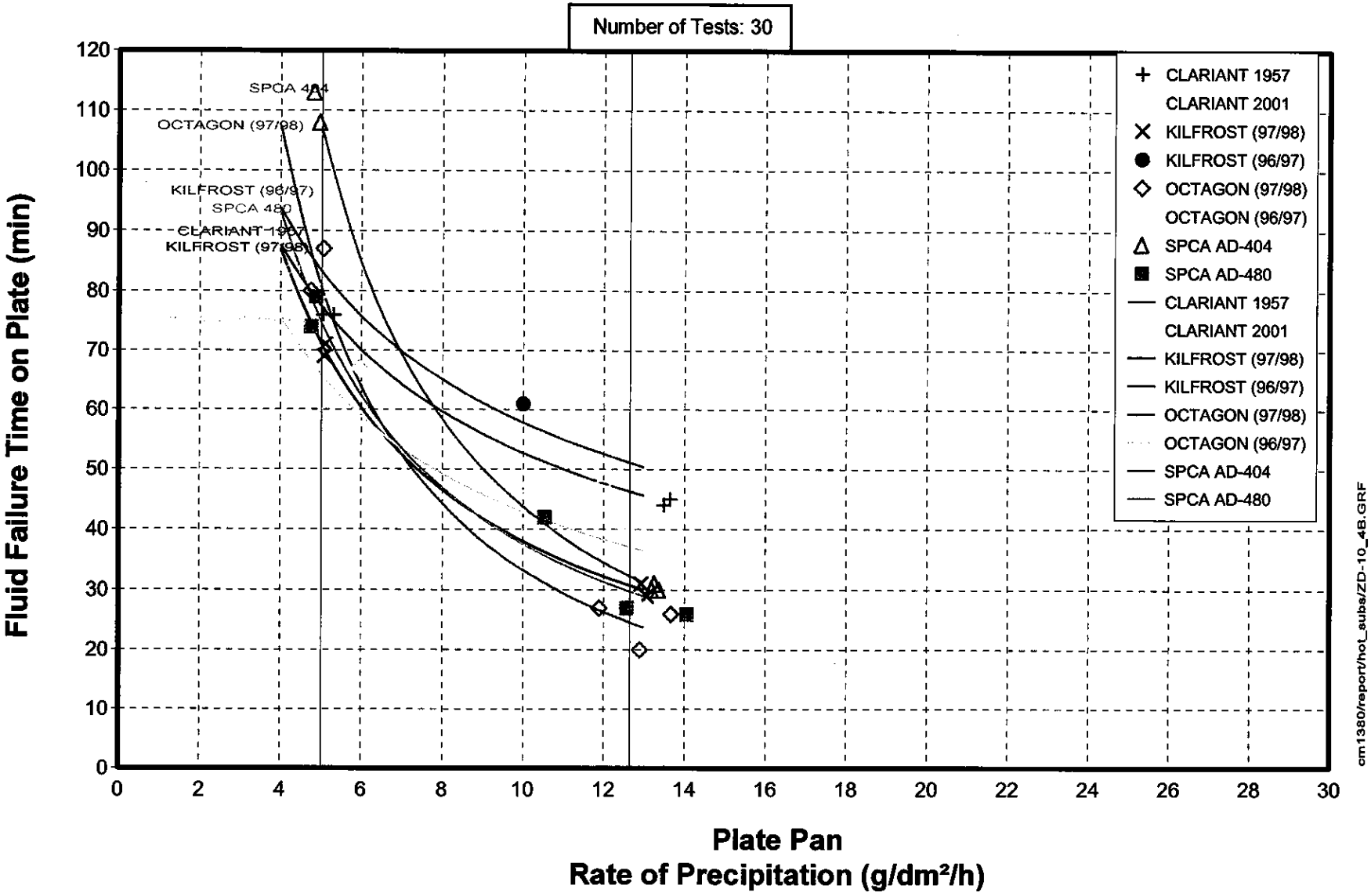


FIGURE 5.14

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25

### FREEZING DRIZZLE AT -10°C



### 5.2.2.1 Changes to Type IV fluid holdover times for freezing drizzle

i) Neat fluid, above 0°C and 0 to -3°C, freezing drizzle (Figure 5.10)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ | | | |
|---|---|---|---|---|---|---|---|
| 0:40-1:00 | 0:40-1:00 | 1:20-1:50 | 0:55-2:00 | 1:00-2:00 | | | |
| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ | S-404 | S-480 |
| 0:40-1:00 | 0:50-1:40 | 0:55-1:55 | 1:20-1:50 | 0:55-2:00 | 1:00-2:00 | 1:40-2:00 | 1:05-2:00 |

The SAE holdover times in the two cells remain unchanged from last year. Note that holdover times for several fluids were rounded off at two hours (Figure 5.10).

ii) 75/25 fluid, above 0°C and 0 to -3°C, freezing drizzle (Figure 5.11)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) | | | |
|---|---|---|---|---|---|---|---|
| 0:30-1:00 | 0:40-1:05 | 0:50-1:25 | 1:15-2:00 | 0:30-1:00 | | | |
| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
| 0:30-1:00 | 0:45-1:15 | 0:35-1:10 | 0:50-1:10 | 1:15-2:00 | | 0:50-1:50 | 0:50-1:20 |

All of the SAE holdover times remain unchanged in these two cells. The Kilfrost fluid has seen a reduction in the upper holdover time limit from last year. As a result, this lower number will appear in the fluid-specific table for this fluid.

iii) 50/50 fluid, above 0°C and 0°C to -3°C, freezing drizzle (Figure 5.12)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) | | | |
|---|---|---|---|---|---|---|---|
| 0:10-0:20 | 0:20-0:35 | 0:15-0:25 | 0:55-1:40 | 0:10-0:20 | | | |
| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
| 0:10-0:20 | 0:15-0:25 | 0:10-0:20 | 0:15-0:20 | 0:35-1:00 | | 0:25-0:55 | 0:15-0:35 |

The SAE holdover times for these two cells remain unchanged from last year. The SAE values are based on the results of three different fluids. The holdover times for both Kilfrost and Octagon fluids have been reduced from last year's results. This is due to differences in the batches provided to APS for test purposes. The lowest of the values will be included in the *fluid-specific* tables for these two fluids.

iv) Neat fluid, -3° C to -10°C, freezing drizzle (Figure 5.13)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra + |
|---|---|---|---|---|
| 0:30-1:00 | 0:40-1:00 | 0:35-1:00 | 0:30-1:10 | 0:50-1:35 |

| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra + | S-404 | S-480 |
|---|---|---|---|---|---|---|---|
| 0:25-1:00 | 0:55-1:25 | 0:55-1:35 | 0:35-1:00 | 0:30-1:10 | 0:50-1:35 | 1:05-2:00 | 0:25-1:20 |

The SAE lower limit holdover time for neat fluid in this temperature range for this precipitation type has been reduced from the previous SAE number. One fluid exhibits performance equal to the lower SAE number, while two fluids are responsible for the upper number.

v) 75/25 fluid, -3°C to -10°C, freezing drizzle (Figure 5.14)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra + (do not use) |
|---|---|---|---|---|
| 0:30-1:00 | 0:40-1:05 | 0:50-1:25 | 0:30-1:05 | 0:30-1:00 |

| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra + (do not use) | S-404 | S-480 |
|---|---|---|---|---|---|---|---|
| 0:25-1:00 | 0:45-1:15 | 0:40-1:10 | 0:30-1:10 | 0:25-1:05 | | 0:30-1:45 | 0:30-1:15 |

The SAE lower holdover time for 75/25 fluid in freezing drizzle was reduced by five minutes based on the results of the Octagon fluid. The lower limit holdover time for this fluid has been reduced from the previous number, and this change will be reflected in the *fluid-specific* table. The upper holdover time limit remains unchanged even though the fluid responsible for the number should not be used in diluted form. Holdover time values for Kilfrost fluid have also diminished from those obtained in 1996-97.

### *5.2.2.2 Overall perspective on freezing drizzle results*

Only two changes were made to the SAE holdover time table in freezing drizzle. All changes occurred in the -3°C to -10°C temperature range. Holdover times in these two cases were reduced slightly.

The identification of failures at these lower temperatures in freezing drizzle (and light freezing rain) remains a concern because of differences in fluid formulations that cause the failure mechanisms to vary from one fluid to the next.

A typical ethylene Type IV failure at -10°C occurs when the diluted fluid runs off the surface of the plate and its thickness is diminished until a thin layer of solidified precipitation has accumulated.

A typical propylene Type IV fluid fails by accumulation of precipitation in the upper fluid layers. The upper layers can flow, but damming of the failed surfaces eventually occurs, trapping the contamination in place. Failure occurs when 1/3 of the plate surface has accumulated contamination in the fluid. This situation is interpreted as a failure even though a considerable amount of *unfailed* fluid lies below the upper failed surface.

### 5.2.3 Light Freezing Rain

The following is a cell-by-cell summary of the holdover time performance of all Type IV fluid brands tested under conditions of simulated light freezing rain. The results are arranged in the sequence of temperature ranges (from top to bottom) that appear in the corresponding columns of the holdover time tables. Since it is impossible to simulate freezing precipitation above 0°C, the holdover time results for this category of precipitation above 0°C are identical to those in the range of 0°C to -3°C.

Each table shows the 1997-98 *SAE, 1998-99 SAE*, and the *fluid-specific* holdover times.

The fluid failure time versus precipitation rate data for this category of precipitation are plotted either as a function of temperature or as as a function of fluid brand. The plots as a function of fluid brand are used to help present discussions regarding changes to holdover times and appear in the body of the text as Figures 5.15 to 5.19.

#### *5.2.3.1 Changes to Type IV fluid holdover times for light freezing rain*

i) Neat fluid, above 0°C and 0 to -3°C, light freezing rain (Figure 5.15)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ |
|---|---|---|---|---|
| 0:35-0:55 | 0:40-0:55 | 1:00-1:25 | 0:40-1:15 | 0:35-1:00 |

| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ | S-404 | S-480 |
|---|---|---|---|---|---|---|---|
| 0:35-0:55 | 0:40-1:00 | 0:40-1:00 | 1:00-1:25 | 0:35-1:00 | 0:35-1:00 | 0:45-1:20 | 0:50-1:10 |

Two fluids are responsible for the lower 1998-99 SAE holdover time. Note that the Octagon results are different from those obtained last year. This is due to different batches of fluid received from the manufacturer. As a result, the lowest values will be displayed in the *fluid-specific* table for this fluid.

FIGURE 5.15

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT

### LIGHT FREEZING RAIN AT -3°C

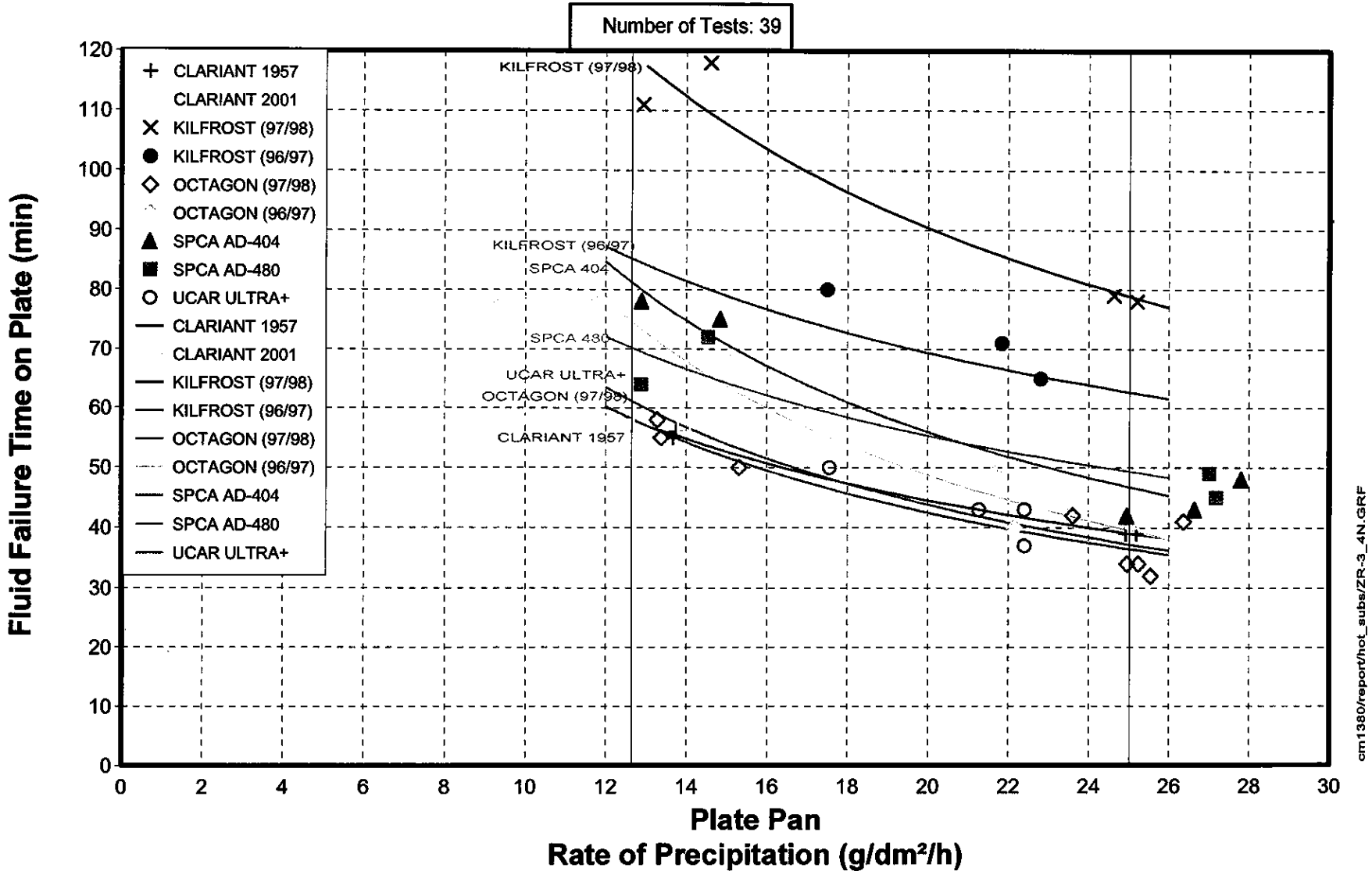


FIGURE 5.16

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25

### LIGHT FREEZING RAIN AT -3°C

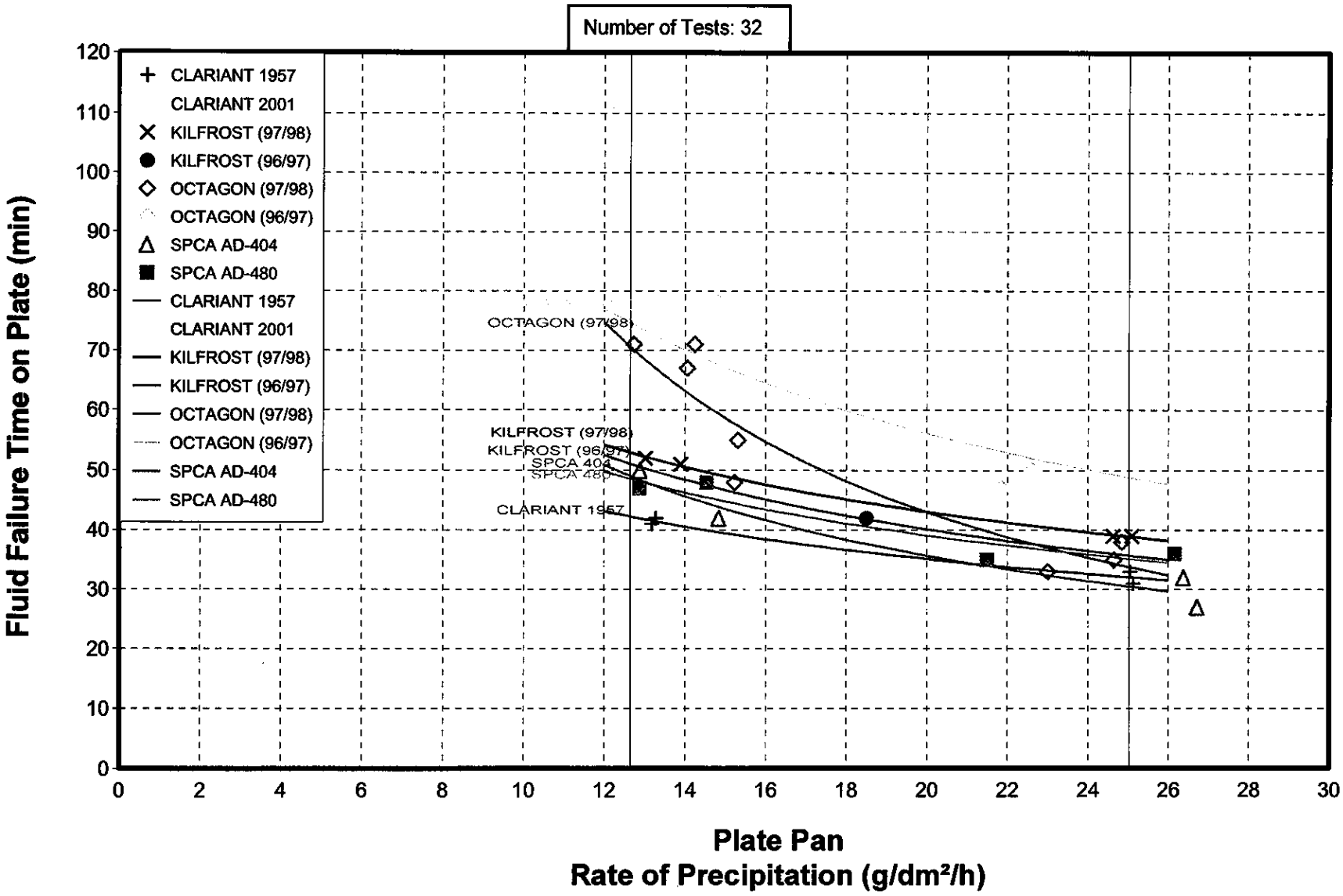


FIGURE 5.17

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 50/50

LIGHT FREEZING RAIN AT -3°C

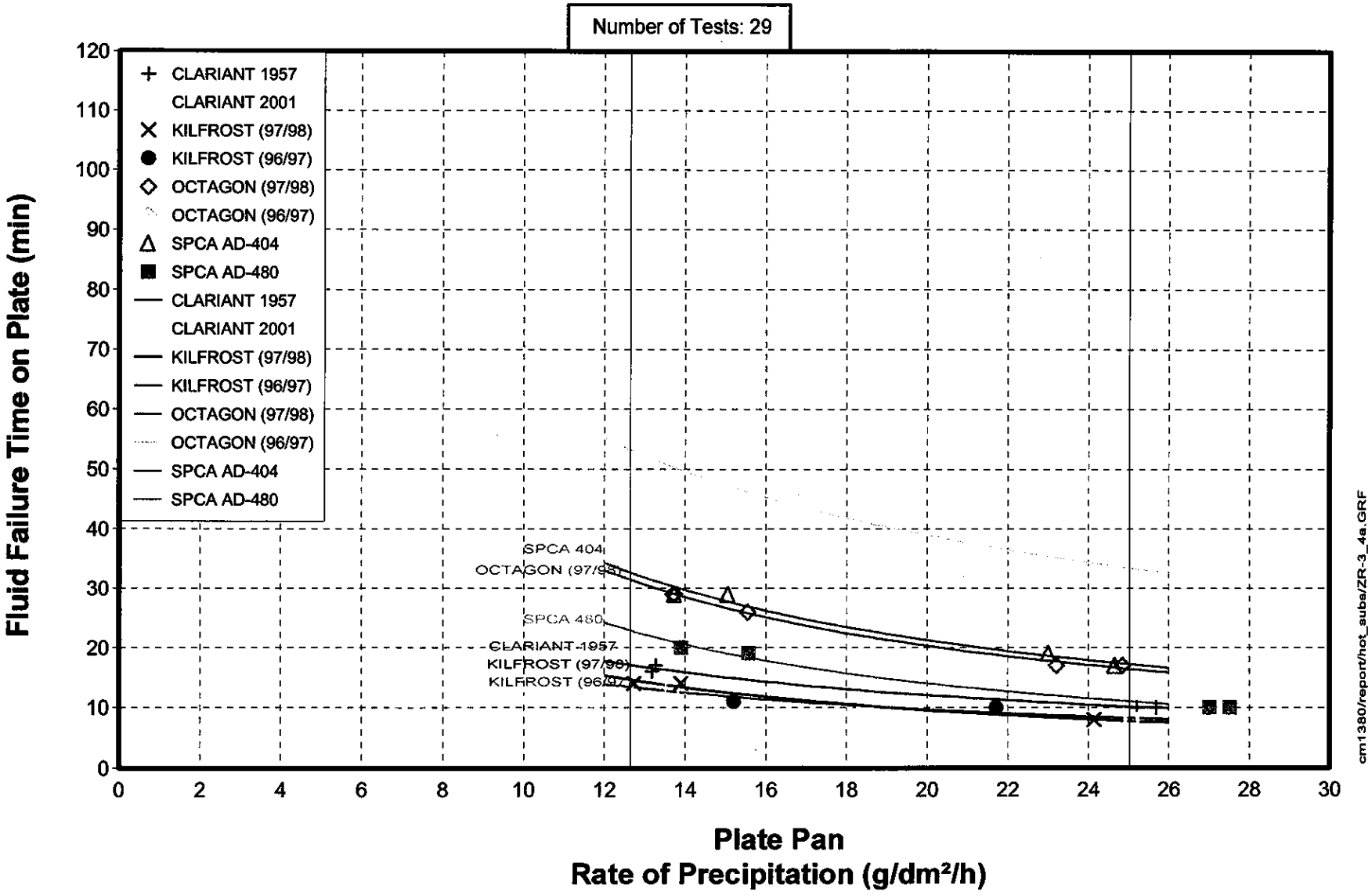


FIGURE 5.18

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT

### LIGHT FREEZING RAIN AT -10°C

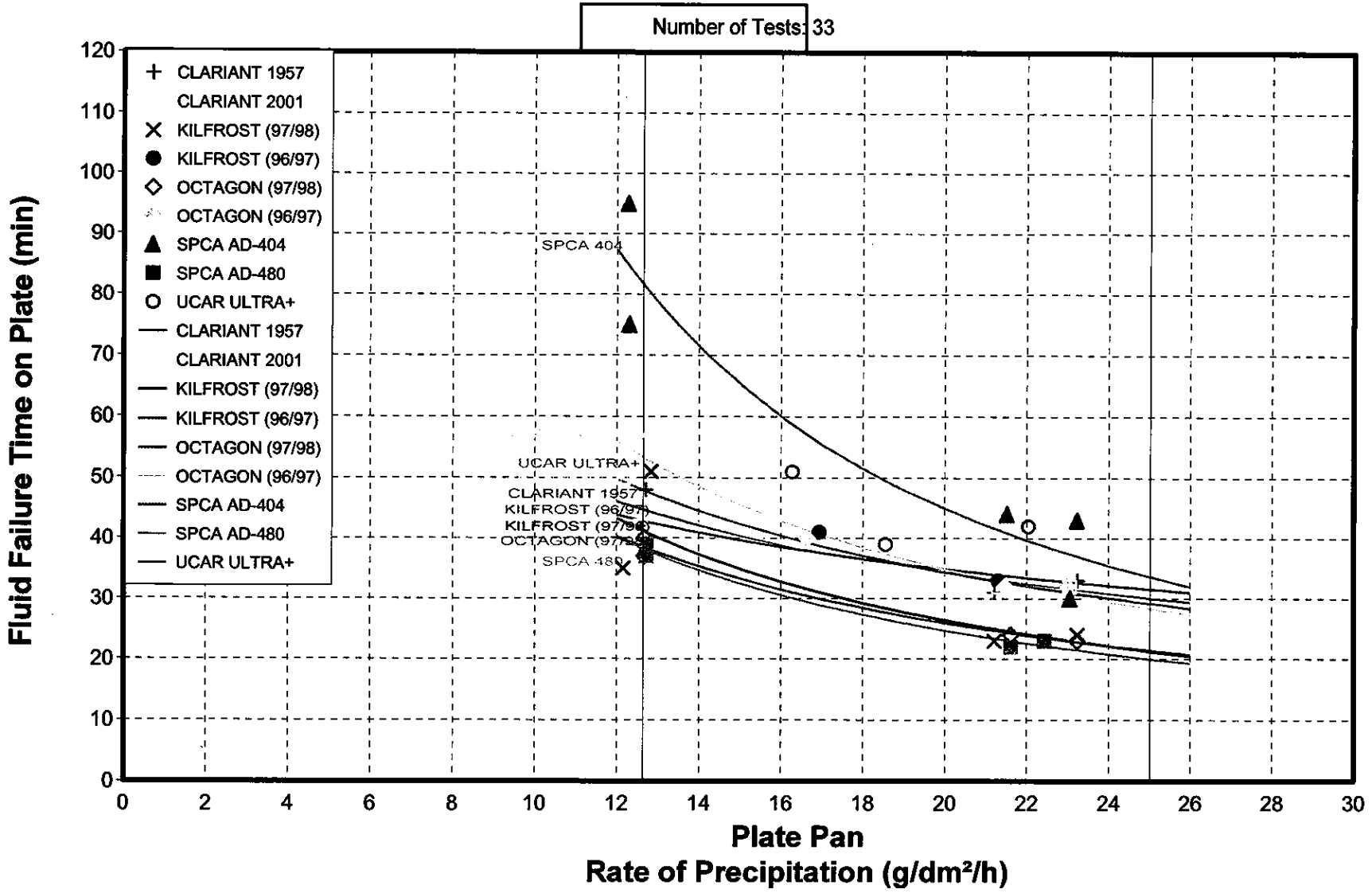
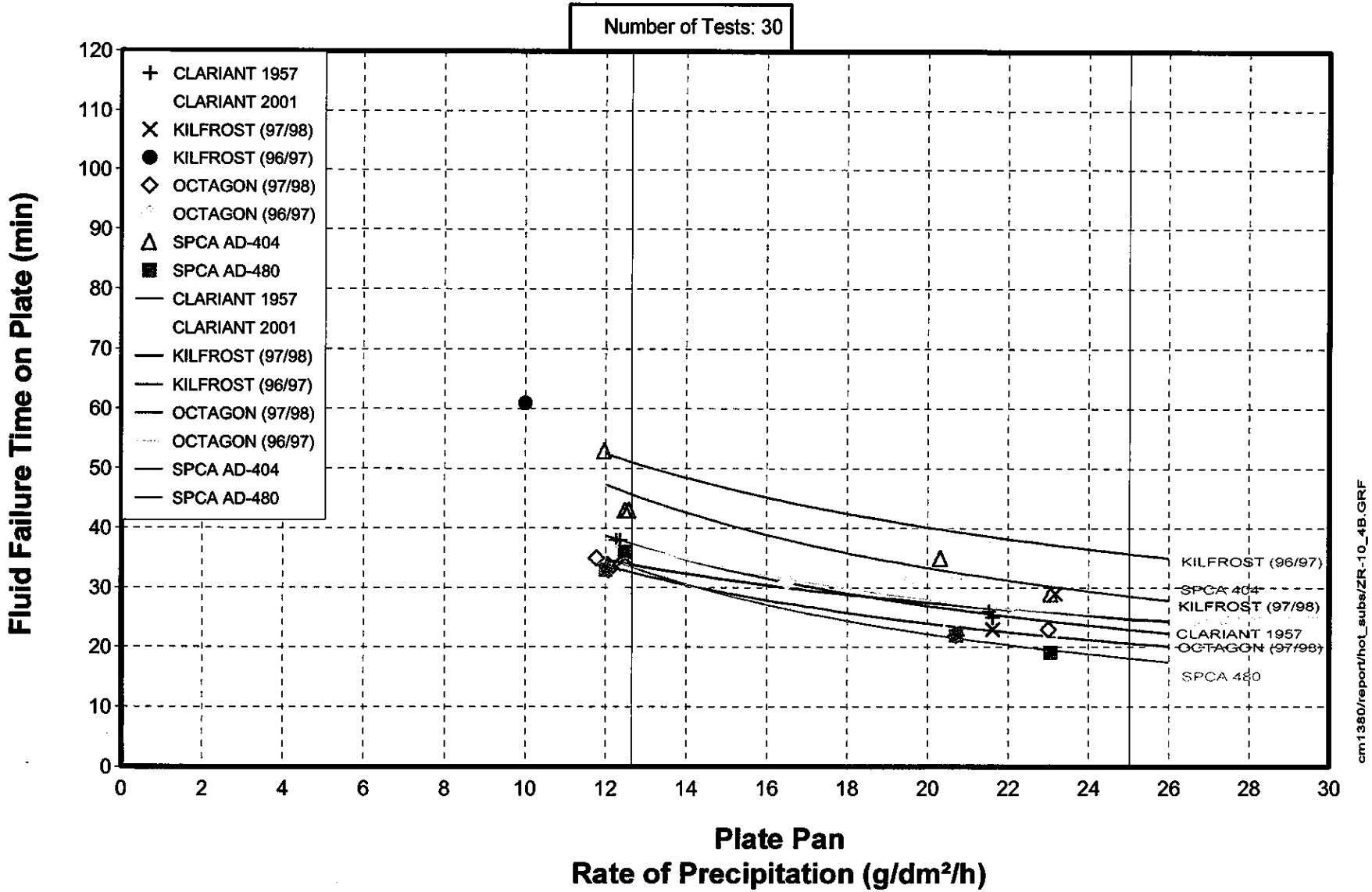


FIGURE 5.19

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25

### LIGHT FREEZING RAIN AT -10°C



ii) 75/25 fluid, above 0°C and 0 to -3°C, light freezing rain (Figure 5.16)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) | | | |
|---|---|---|---|---|---|---|---|
| 0:15-0:30 | 0:25-0:40 | 0:35-0:50 | 0:50-1:15 | 0:15-0:30 | | | |
| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
| 0:15-0:30 | 0:30-0:40 | 0:25-0:35 | 0:35-0:50 | 0:35-1:10 | | 0:30-0:50 | 0:35-0:50 |

The SAE holdover times remain unchanged in these two cells. Once again, the lowest of the Octagon fluid values will be included in the *fluid-specific* table.

iii) 50/50 fluid, above 0°C and 0 to -3°C, light freezing rain (Figure 5.17)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) | | | |
|---|---|---|---|---|---|---|---|
| 0:05-0:10 | 0:15-0:20 | 0:10-0:15 | 0:30-0:55 | 0:05-0:10 | | | |
| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
| 0:05-0:10 | 0:10--0:15 | 0:10-0:15 | 0:10-0:15 | 0:15-0:30 | | 0:15-0:35 | 0:10-0:25 |

The SAE values have not changed in these two cells. However, the Octagon fluid at this dilution exhibited a 50 percent reduction in holdover time. The lower values will appear in the *fluid-specific* table.

iv) Neat fluid, -3° C to -10°C, light freezing rain (Figure 5.18)

| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ | | | |
|---|---|---|---|---|---|---|---|
| 0:30-0:45 | 0:30-0:50 | 0:30-0:45 | 0:30-0:55 | 0:30-0:50 | | | |
| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ | S-404 | S-480 |
| 0:15-0:30 | 0:30-0:45 | 0:30-0:45 | 0:20-0:40 | 0:20-0:40 | 0:30-0:50 | 0:35-1:20 | 0:20-0:40 |

The SAE lower and upper limit holdover times for neat fluid in this temperature range for this precipitation type have been reduced from the previous SAE numbers. The lowest numbers for Kilfrost and Octagon fluids will appear in the *fluid-specific* tables.

At the May 1998 SAE G-12 meetings in Vienna, UQAC (AMIL) presented data suggesting that holdover times for three neat Type IV fluids in light freezing rain at -10°C were significantly lower than the 20 minutes suggested by APS Aviation. As a result, a recommendation to reduce the SAE holdover times in this cell to 15 to 30 minutes was sent out to the Holdover Time Subcommittee members by the co-chairmen. The suggested reduction in holdover time was based on a compromise between the APS and AMIL test data, and allowed for a more conservative number. The reduction went to ballot, and was accepted by the SAE G-12 Holdover Time Subcommittee.

Subsequently, a series of tests was performed by APS at the NRC's CEF in Ottawa to re-examine the suggested SAE holdover time for fluids in this cell, as well as to determine differences between the results of the two testing agencies. The tests were conducted in the presence of the SAE G-12 Holdover Time Subcommittee co-chairmen, as well as a representative from AMIL. Holdover time tests were performed on the three fluids in question, and the holdover time results obtained were identical to those presented by APS in Vienna.

The description of events leading to holdover time changes in this cell are presented in Subsection 5.2.3.2.

v) 75/25 fluid, -3°C to -10°C, light freezing rain (Figure 5.19)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1997-98 SAE | H-1957 | K-ABC-S | Oct Max | Ultra+ (do not use) | | | |
| 0:15-0:30 | 0:25-0:40 | 0:35-0:50 | 0:25-0:35 | 0:15-0:30 | | | |
| 1998-99 SAE | C-1957 | C-2001 | K-ABC-S | Oct Max | Ultra+ (do not use) | S-404 | S-480 |
| 0:15-0:30 | 0:25-0:35 | 0:20-0:30 | 0:25-0:35 | 0:20-0:30 | 0:15-0:30 | 0:30-0:45 | 0:20-0:35 |

The SAE holdover time in this cell has not changed. Values for Kilfrost and Octagon fluids have again been reduced. These values are reflected in the *fluid-specific* tables.

### *5.2.3.2 Detailed description of events leading to holdover time changes in light freezing rain at -10°C*

#### 5.2.3.2.1 Introduction

At the SAE G-12 meetings in Vienna in May 1998, APS presented the results of the Transport Canada- and FAA-sponsored holdover time test program. With the exception of one cell, holdover times in the SAE Type IV table were approved by the committee based on the data provided by APS. In the exceptional case, UQAC (AMIL) presented data suggesting that holdover times for three neat Type IV fluids – Union Carbide Ultra+, Octagon MaxFlight, and SPCA AD-480 – were significantly lower in light freezing rain conditions at -10°C than the times suggested by APS. The inconsistencies in holdover time caused substantial confusion and essentially put in doubt the validity of the remainder of the test data acquired by APS. As a result, no agreement was reached on the recommended holdover time for fluids in this cell.

Following several hours of discussion, it was decided that the co-chairmen of the SAE G-12 Holdover Time Subcommittee would review the APS and AMIL test data for fluids in this cell and recommend a solution through a vote by SAE members.

#### 5.2.3.2.2 Data

APS presented a complete set of data in Vienna for all conditions and fluids. AMIL data for light freezing rain at -10°C were acquired using three fluids. Upon return from Vienna, the test specifications for both the APS and AMIL data were requested by the co-chairmen of the SAE G-12 Holdover Time Subcommittee. The APS test specifications are shown in Annex I-I (Appendix I), while the AMIL document can be found in Annex I-II.

The holdover times obtained by APS and AMIL for the three fluids, in light freezing rain, at -10°C, and with rates of precipitation of 25 g/dm$^2$/h, are shown below:

| Fluid | AMIL values (mins) | APS values presented in Vienna (rounded) (mins) |
|---|---|---|
| Octagon MaxFlight (100%) | 7 | 20 |
| SPCA AD-480 (100%) | 7 | 20 |
| Union Carbide Ultra+ (100%) | 10 | 30 |

The test conditions were compared by the SAE G-12 Holdover Time Subcommittee co-chairmen, and were found to be identical or similar in most cases. The biggest difference was believed to be the method of calling failures employed by APS and AMIL. As a result of the wide variation in holdover times obtained by APS and AMIL, the co-chairmen of the SAE G-12 Holdover Time Subcommittee recommended that the holdover time value for Type IV fluids in this cell of the SAE Type IV fluid Holdover Time Table (light freezing rain, -3°C to -10°C) be reduced to 15 to 30 minutes. A recommendation was also made that subsequent testing be conducted to compare the AMIL and APS failure calls. The suggested reduction in holdover time in this cell was based primarily on a compromise between the APS and AMIL holdover time values. A ballot to approve the holdover time value in this cell was prepared by the SAE G-12 Holdover Time Subcommittee co-chairmen and was circulated to all those who attended the holdover time meetings in Vienna. A copy of this ballot appears in

Annex I-III (Appendix I). The 15-30 minute holdover time range for fluids in this cell was approved by the Subcommittee members.

#### 5.2.3.2.3 Testing

APS conducted a series of tests on July 10, 1998, at NRC's CEF, to compare APS and AMIL failure calls for the three previously mentioned fluids in light freezing rain conditions at -10°C. The tests were conducted by APS personnel using standard test procedures and were witnessed by representatives from Transport Canada, the FAA, and AMIL. Spar/Cox and AlliedSignal C/FIMS ice detection equipment was also employed for these tests.

A letter to the co-chairmen of the SAE G-12 Holdover Time Subcommittee, summarizing the results of the tests conducted on July 10, 1998, was prepared by APS and appears in Annex I-IV (Appendix I). The holdover time results for these tests are included in Table 1 of Annex I-IV. The two Ultra+ plates failed in 33 and 34 minutes, which is substantially longer than the AMIL failure time of 10 minutes. A photograph taken 14 minutes into the Ultra+ tests shows both plates to be clean of contamination at this time (see Photo 5.2). For the Octagon fluid, the two plates failed in 19 and 20 minutes. AMIL claimed that failure occurred after 7 minutes for this fluid. Finally, the SPCA AD-480 plates failed in 16 and 18 minutes. Once again, AMIL claimed that failure occurred after 7 minutes for this fluid. In all tests conducted with Octagon and SPCA fluids, it should also be noted that at the time when failure was observed by APS, all existing contamination on the plates was non-adhering and could easily be dislodged simply by blowing.

The Octagon and SPCA fluid data points were added to the appropriate charts and appear in Figures 1 and 2 in Annex I-IV. In both cases, the data appear to be consistent with previous test results. No chart was produced for Ultra+, since this fluid was not tested during the 1997-98 test season. The new data points were also added to the regression analyses for each fluid. No changes in holdover time were due to their inclusion.

The overall results of AMIL and APS tests are summarized below:

| Fluid | AMIL values (min.) | APS regression values presented in Vienna (min.) | APS regression values (rounded) including tests witnessed by TDC, FAA, AMIL on July 10, 1998 (min.) |
|---|---|---|---|
| Octagon MaxFlight (100%) | 7 | 20 | 20 |
| SPCA AD-480 (100%) | 7 | 20 | 20 |
| Union Carbide Ultra+ (100%) | 10 | 30 | 30 (or more) |

This test summary shows that the holdover time results presented by APS in Vienna were accurate and consistent.

The C/FIMS sensor trace data for each of the six plate tests, along with a series of photographs documenting the entire test process are also included in this document and appear in Annex I-V (Appendix I).

#### 5.2.3.2.4 Conclusion

The final position of the co-chairmen of the SAE G-12 Holdover Time Subcommittee on this matter is included in Annex I-VI (Appendix I). In this document, it was stated that when appropriate failure criteria were applied, all of the fluids tested by APS exhibited holdover times in excess of the 15 minute lower holdover time limit for fluids in this cell. The holdover time values obtained by AMIL were not observed, and as such, disregarded. Based on the results of these tests, the holdover time range for Type IV fluids in light freezing rain at -10°C remains at 15 to 30 minutes.

In summary:

- The 1997-98 SAE holdover time for Type IV neat fluid in the -3°C to -10°C cell was 30 to 45 minutes;
- At the Vienna meeting, APS presented data suggesting the SAE holdover times for use in 1998-99 be reduced for fluids in this cell to 20 to 40 minutes;
- AMIL presented data suggesting that the holdover times for fluids in this cell were lower than those proposed by APS; and
- Based on a compromise between APS and AMIL test results, the holdover time range for Type IV neat fluids in light freezing rain at -10°C will be 15 to 30 minutes.

### *5.2.3.3 Overall perspective on light freezing rain results*

Only two changes were made to the SAE holdover time table regarding light freezing rain. The changes occurred in the -3°C to -10°C temperature range for neat fluid. The upper and lower limit holdover times in this case were reduced.

## 5.2.4 Freezing Fog

The freezing fog category is divided into nine cells. The data were collected under precipitation rates of 2 and 5 g/dm$^2$/h. From these data, lower holdover times for each cell were determined at 5 g/dm$^2$/h. The upper holdover times were to be determined by tests conducted at 2 g/dm$^2$/h; however, it was felt in Vienna that this rate limit was not indicative of low rate natural fog. As a result, the upper holdover times in each of the fog cells were left untouched from previous years. The data from this year's testing are presented in Figures 5.20 to 5.25.

Failure times were measured at three different temperatures, -3°C, -14°C, and -25°C. Due to the inability to produce freezing fog at temperatures above 0°C, the holdover times for the temperature range above 0°C are identical to those in the range from 0 to -3°C.

This category of precipitation is one for which *fluid-specific* values were not adopted by the SAE G-12 Holdover Time Subcommittee. The holdover times for each fluid have not been included since they are identical to the 1998-99 SAE holdover times.

### *5.2.4.1 Changes to Type IV fluid holdover times for freezing fog*

i) Neat fluid, above 0°C and 0° to -3°C, freezing fog (Figure 5.20)

| 1997-98 SAE | 1998-99 SAE |
|---|---|
| 2:20-3:00 | 2:00-3:00 |

Three fluids fell below the current lower holdover time limit, and as such, the new SAE holdover times for fluids in these cells have been reduced. Note, once again, that *fluid-specific* holdover times for freezing fog were not adopted, and therefore, all individual fluid holdover times are identical to the SAE values.

ii) 75/25 fluid, above 0°C and 0 to -3°C, freezing fog (Figure 5.21)

| 1997-98 SAE | 1998-99 SAE |
|---|---|
| 1:05-2:00 | 1:05-2:00 |

The SAE holdover times for fluids in these cells are driven by the results of fluid holdover time tests conducted last year and remain unchanged.

FIGURE 5.20

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT AT -3°C

SIMULATED FREEZING FOG

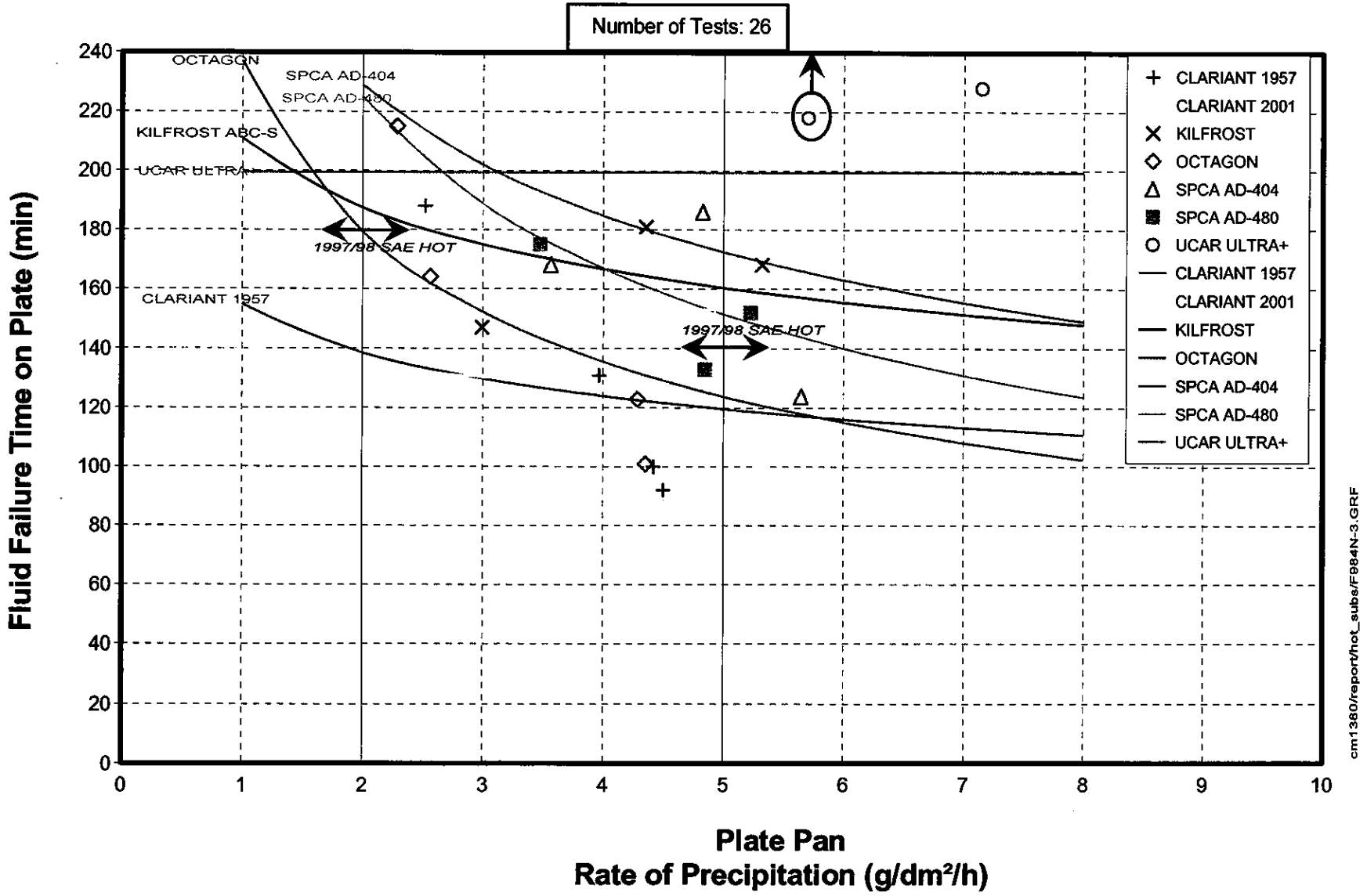


FIGURE 5.21

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25 AT -3°C

SIMULATED FREEZING FOG

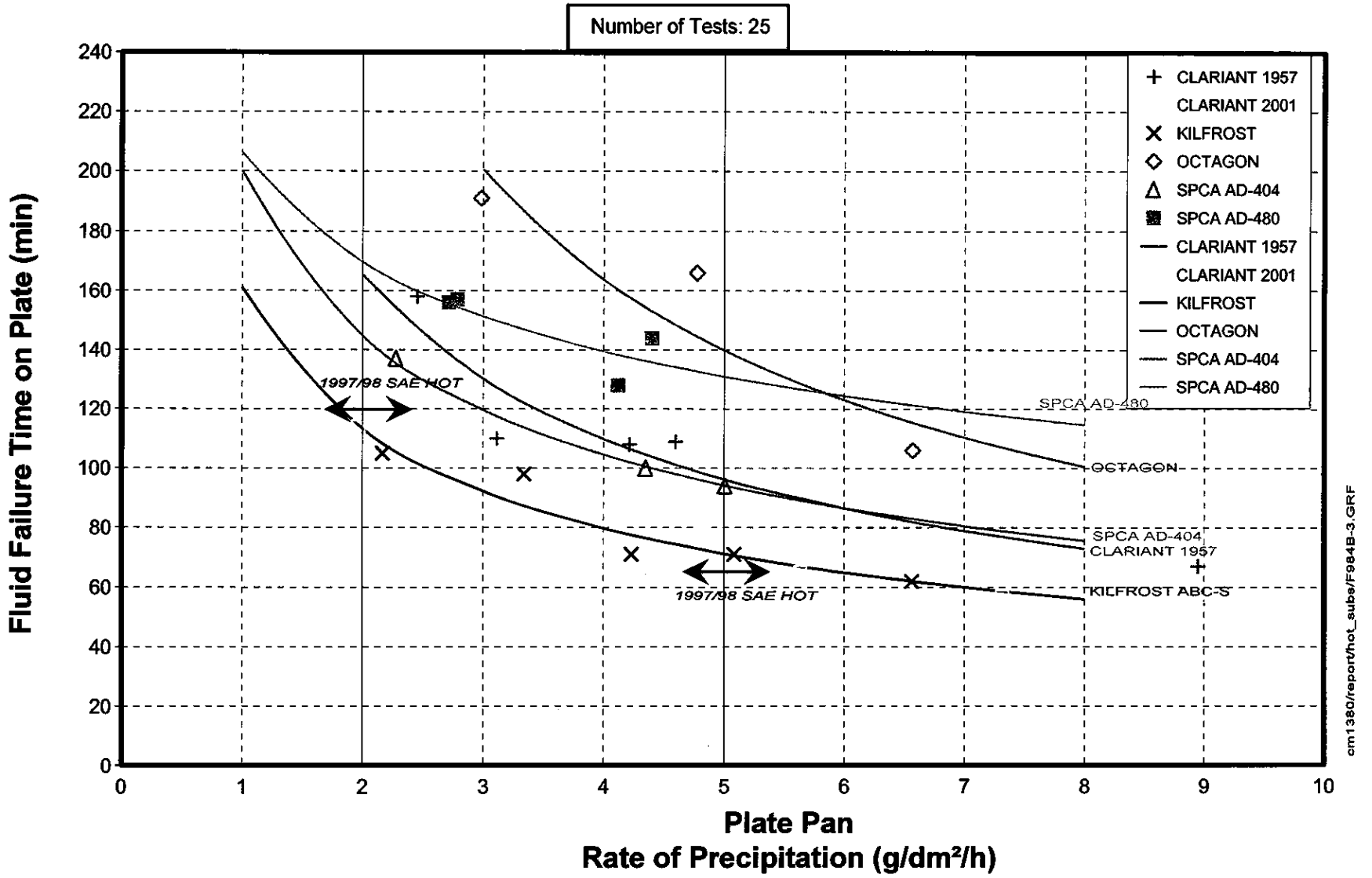


FIGURE 5.22

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 50/50 AT -3°C

SIMULATED FREEZING FOG

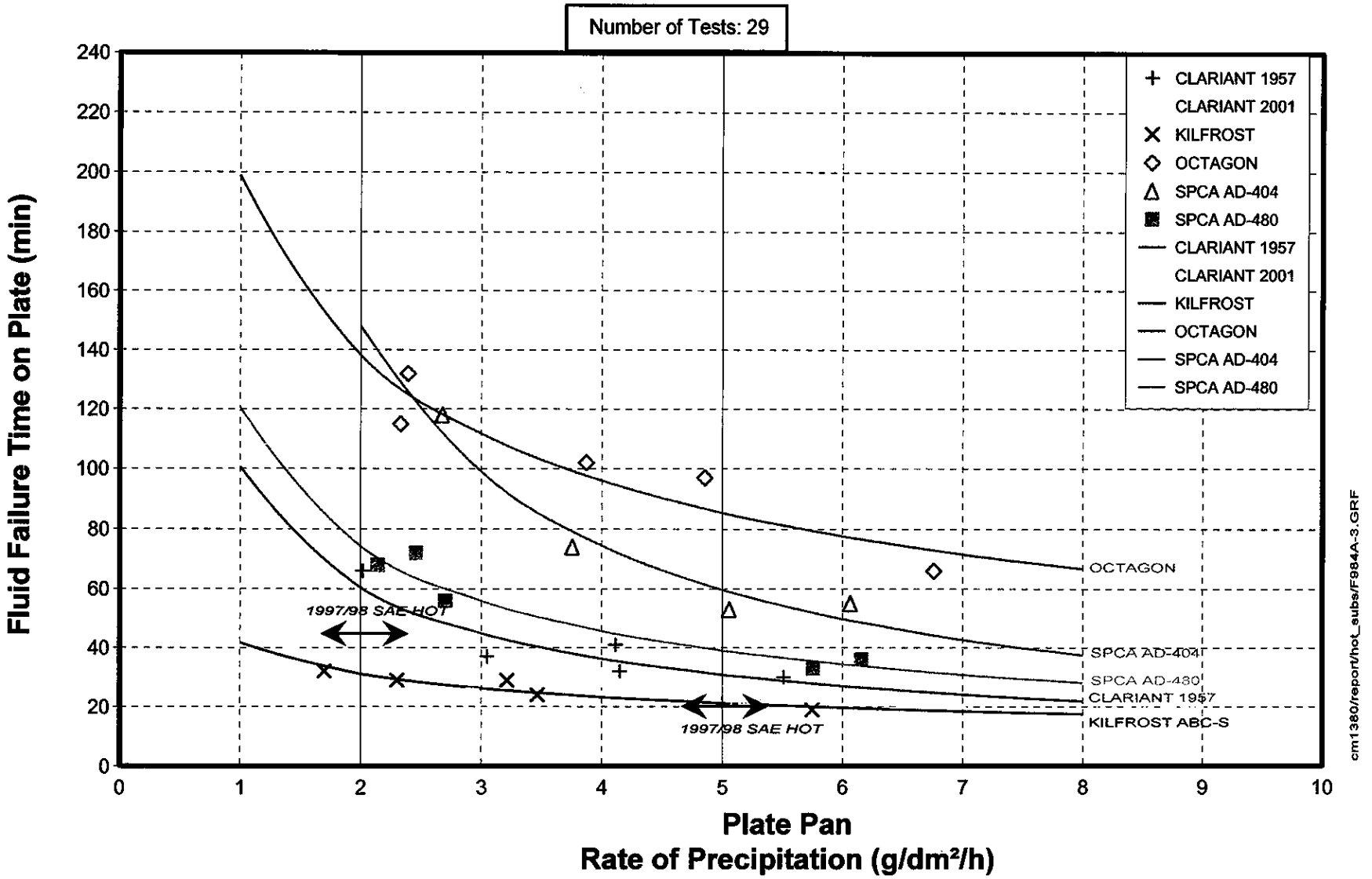


FIGURE 5.23

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT AT -14°C

### SIMULATED FREEZING FOG

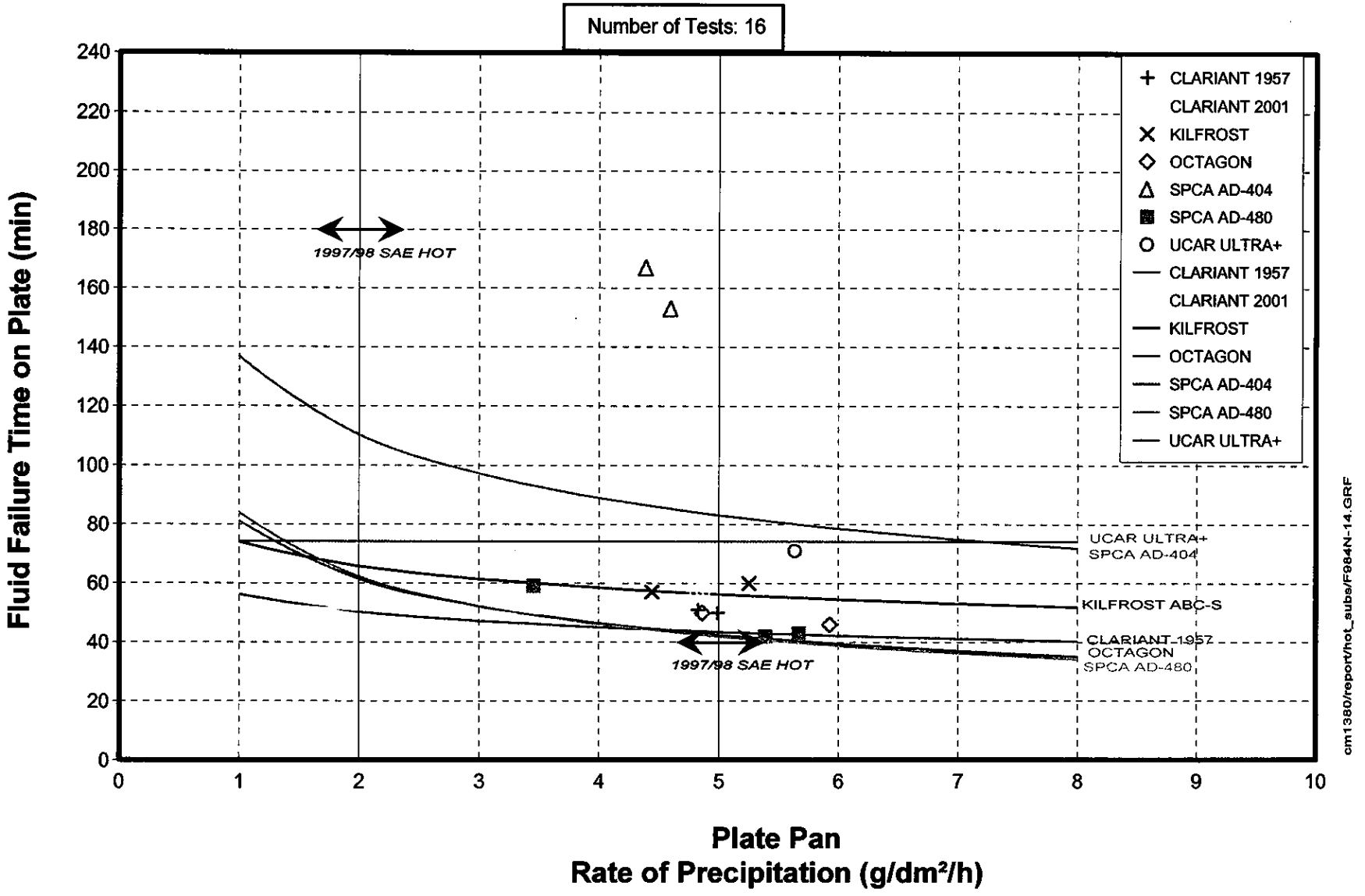


FIGURE 5.24

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25 AT -14°C

SIMULATED FREEZING FOG

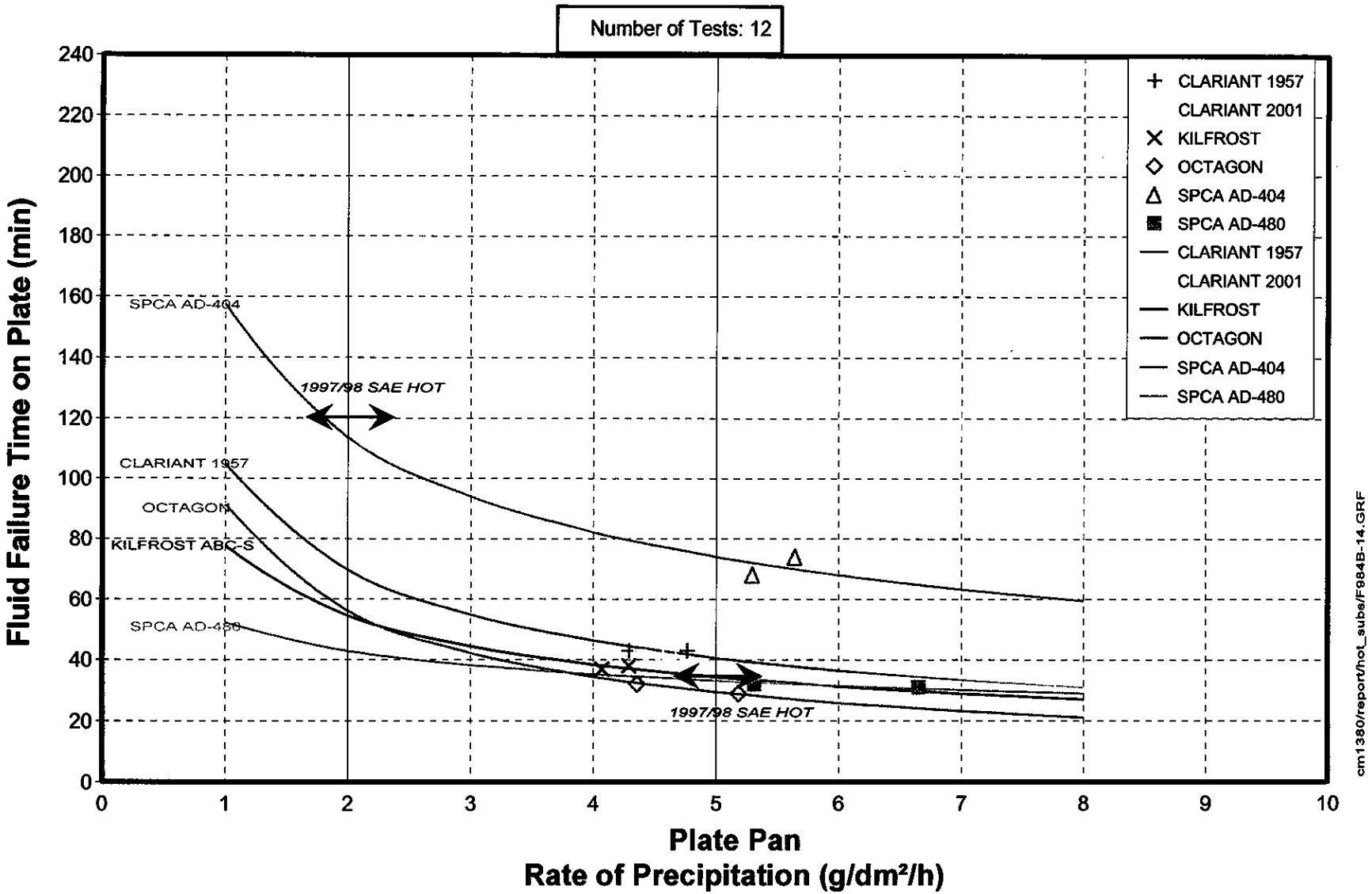
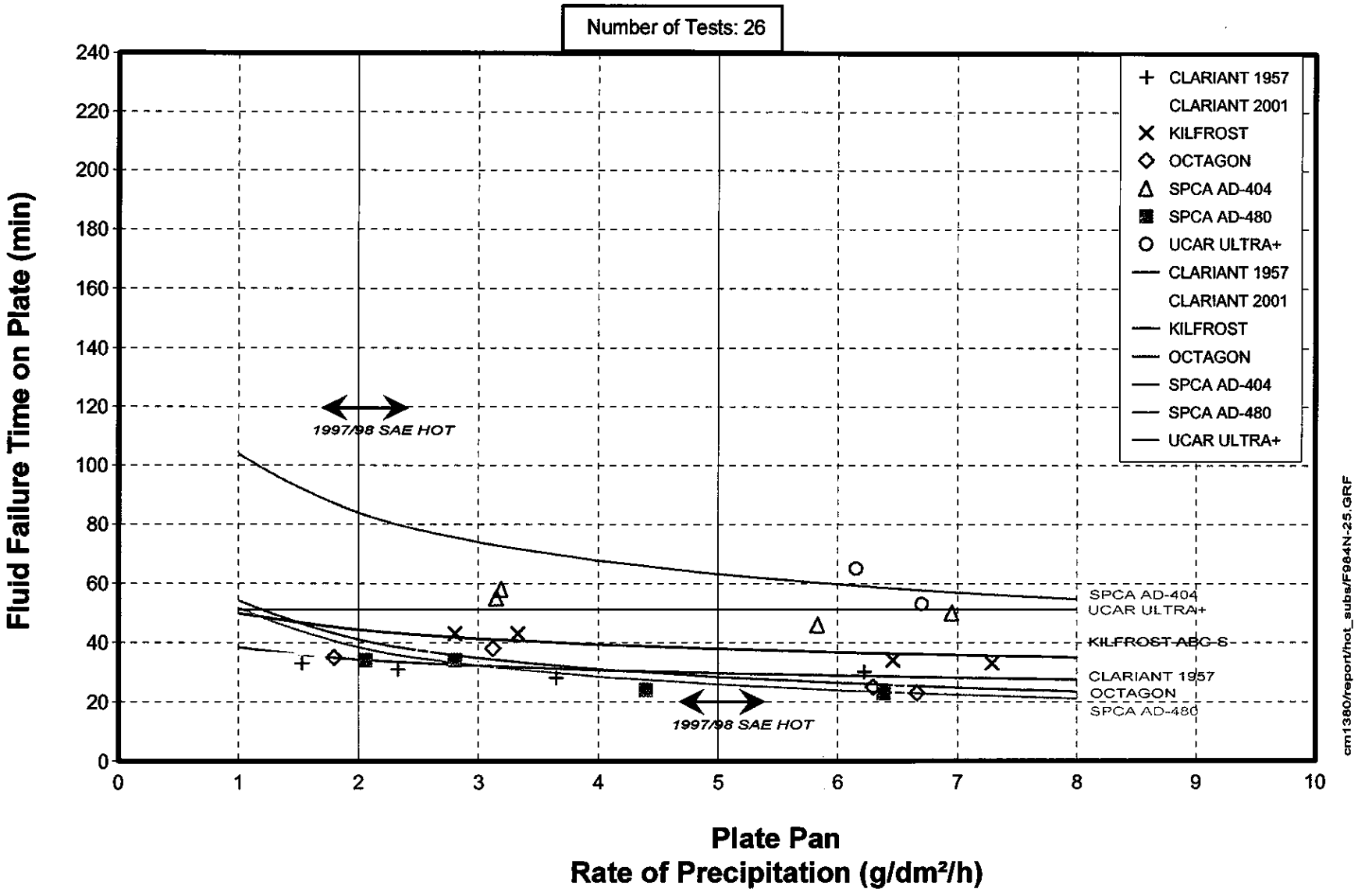


FIGURE 5.25

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT AT -25°C

### SIMULATED FREEZING FOG



iii) 50/50 fluid, above 0°C and 0 to -3°C, freezing fog (Figure 5.22)

| 1998 SAE | 1998-99 SAE |
|---|---|
| 0:20-0:45 | 0:20-0:45 |

The SAE holdover times for fluids in these cells remain unchanged from last year.

iv) Neat fluid, -3 to -14°C, freezing fog (Figure 5.23)

| 1997-98 SAE | 1998-99 SAE |
|---|---|
| 0:40-3:00 | 0:40-3:00 |

The SAE holdover times for fluids in this cell remain unchanged.

v) 75/25 fluid, -3 to -14°C, freezing fog (Figure 5.24)

| 1997-98 SAE | 1998-99 SAE |
|---|---|
| 0:35-2:00 | 0:30-2:00 |

The lower SAE holdover time in this cell has been reduced by five minutes based on the results of one fluid. It should be noted that this same fluid was responsible for driving the lower limit holdover time in last year's holdover time table. Differences in the fluid batches provided to APS for testing resulted in this reduction.

vi) Neat fluid, -14° to -25°C, freezing fog (Figure 5.25)

| 1997-98 SAE | 1998-99 SAE |
|---|---|
| 0:20-2:00 | 0:20-2:00 |

The SAE holdover time for fluids in this cell remain unchanged from last year.

### *5.2.4.2 Overall perspective on freezing fog results*

The upper holdover times for freezing fog were adopted from last year's SAE Type IV fluid table (Table 1.5, Section 1). Only two changes were made to the lower holdover times, in each case a slight reduction, due in large part to differences in the fluid samples tested. The lower precipitation rate limit has not been agreed on. A solution is proposed in Sections 7 and 8.

### 5.2.5 Rain on a Cold-Soaked Wing

The data used to evaluate the holdover times for this category of precipitation covered precipitation rates ranging from 5 g/dm$^2$/h to 76 g/dm$^2$/h. This encompasses heavy drizzle (5 to 12.7 g/dm$^2$/h), light rain (12.7 to 25 g/dm$^2$/h), and moderate rain (25 to 76 g/dm$^2$/h). The cold-soak test boxes were 7.5 cm deep. Dimensional details are described in Section 2. The box temperature prior to the start of testing was -10°C.

The data are plotted for two Type IV fluid concentrations: neat fluid and 75/25 fluid. Recall that this category of precipitation is not one for which fluid-specific holdover times have been adopted by the SAE G-12 Holdover Time Subcommittee. The holdover times for each individual fluid have not been included since they are identical to the 1998-99 SAE holdover times.

#### *5.2.5.1 Changes to Type IV fluid holdover times for rain on a cold-soaked wing*

i) Neat fluid, above 0°C, rain on a cold-soaked wing (Figure 5.26)

| 1997-98 SAE | 1998-99 SAE |
|---|---|
| 0:10-0:50 | 0:10-0:50 |

The regression curves generated from the neat fluid data plotted in Figure 5.26 indicate that the fluid driving the lower SAE holdover time (at 76 g/dm$^2$/h) was the same fluid responsible for the lower holdover time in this temperature range from tests conducted in previous seasons. All the regression curves generated from fluids tested this past season were above the SAE limits. The upper SAE holdover time is once again driven by the results of past testing.

ii) 75/25 fluid, above 0°C, rain on a cold-soaked wing (Figure 5.27)

| 1997-98 SAE | 1998-99 SAE |
|---|---|
| 0:05-0:35 | 0:05-0:35 |

For this concentration, the regression curves obtained from the data plotted in Figure 5.27 are tightly grouped at the 5 g/dm$^2$/h and 76 g/dm$^2$/h precipitation rate limits. The numbers remain unchanged from last year.

FIGURE 5.26

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT

### RAIN ON COLD-SOAKED SURFACE

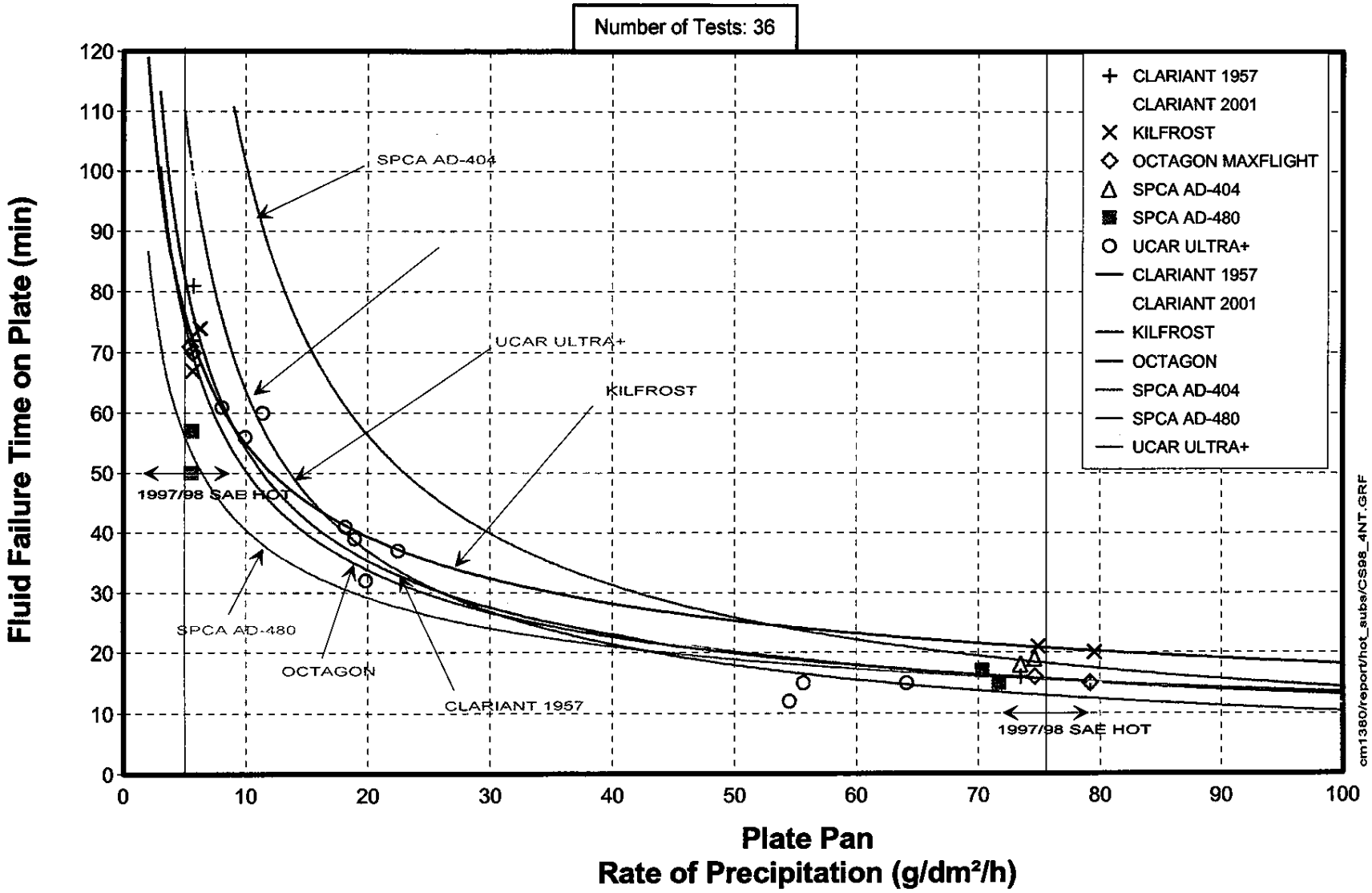
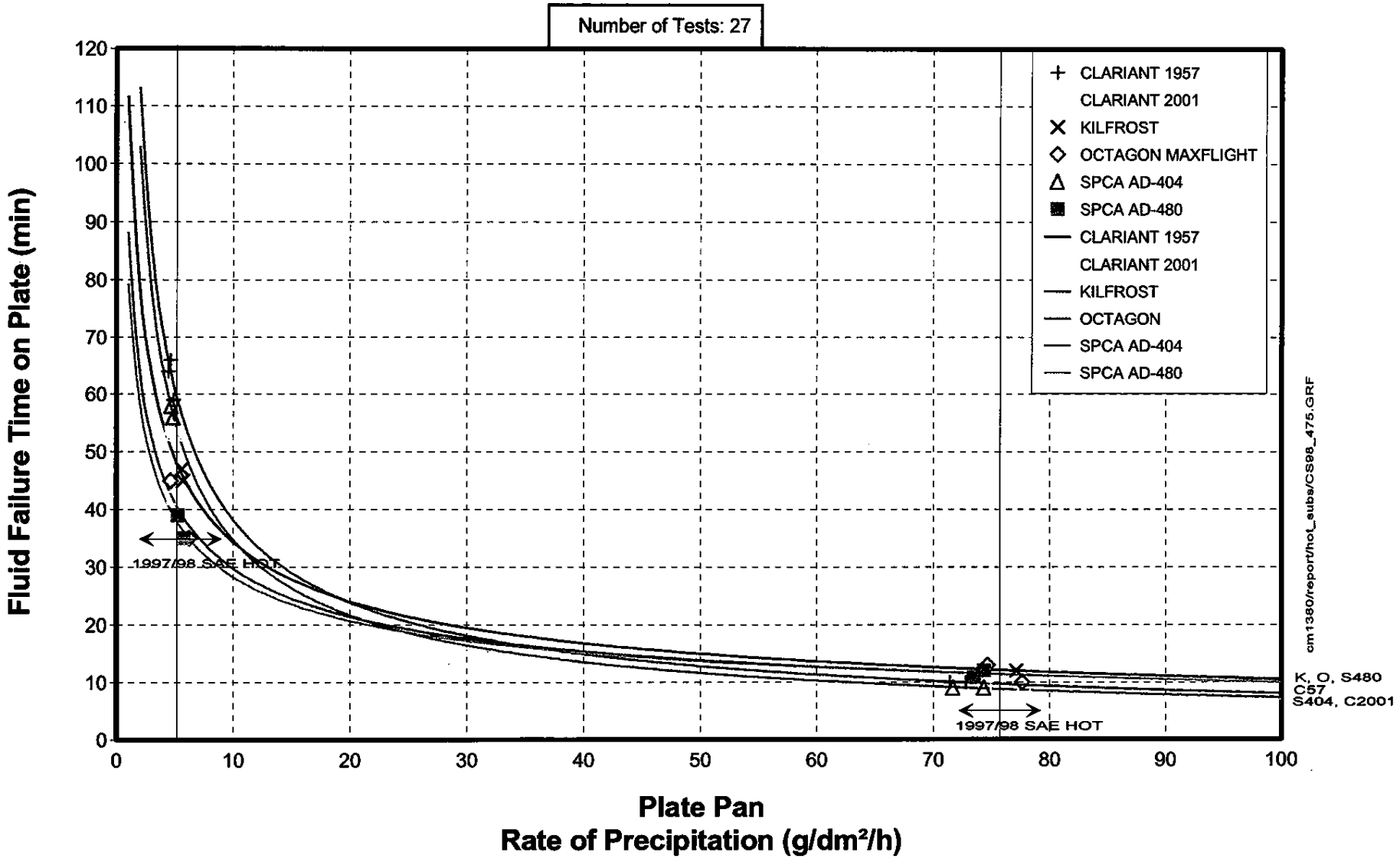


FIGURE 5.27

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25

RAIN ON COLD-SOAKED SURFACE



#### *5.2.5.2 Overall perspective on rain on a cold-soaked wing results*

No changes were made to the SAE holdover times in the rain on a cold-soaked wing condition. The data plotted in Figures 5.26 and 5.27 show a tight grouping of regression curves at the higher precipitation rate limit (once the Union Carbide Ultra IV and PG AAF curves have been removed), and provide confidence for the lower holdover time values adopted in each cell of this category. Considerable variations exist in the vicinity of the lower precipitation rate limit.

## 5.3 Type III Fluid Holdover Time Tests

Type III fluid is a thickened anti-icing fluid that exhibits shear, flow, and anti-icing properties that lie between Type I and Type IV fluids. The fluid was specifically designed for use on aircraft with lower rotation speeds.

The earliest holdover time tests with Type III fluid were carried out during the 1991-92 test season (see Transport Canada report TP 11454E (9)). The next series of Type III fluid tests are documented in Transport Canada report TP 11836E (10). These data are somewhat obsolete, as the fluid tested is no longer commercially available. The Type III fluid data for the last report cited were combined with 75/25 Type IV fluid data and provided the basis for a proposed Type III fluid holdover time table, which first appeared in Transport Canada report TP 12896E (11).

The latest Type III fluid test data were acquired during the 1996-97 test season using one fluid from one fluid manufacturer. The Type III fluid data were subject to the same regression method of analysis used to determine holdover times for Type IV fluids. The Type III fluid holdover table appears in Section 1 of this report (Table 1.4). The Type III fluid used in this latest testing has since been removed from the market.

No Type III fluids were available during the past test season, and therefore no testing of Type III fluids was performed by APS. As a result, the current Type III table is not valid, since the numbers within were substantiated using a fluid that is no longer available.

## 5.4 Type I Fluid Holdover Time Tests

Type I fluids are deicing fluids that are not thickened. They are used primarily to remove ice and snow from aircraft surfaces. They are applied at high pressures and elevated temperatures. These fluids do not offer the extended protection of thickened fluids, and so depending on weather conditions, anticipated taxi-times, or other pre-takeoff delays, an operator can choose to extend the time of fluid protection by application of Type II or Type IV anti-icing fluid on top of the Type I fluid.

Although the Type I holdover time table has been substantiated by tests conducted in previous years, 24 Type I fluid failure tests were performed by APS during the 1997-98 test season during natural snow conditions. Tests were conducted for the purpose of training personnel to identify Type I plate failures in this condition.

The data from the Type I tests conducted in 1997-98 are shown in Figures 5.28 and 5.29. All the data points are above the lower holdover time limit of six minutes for Type I fluids in natural snow.

FIGURE 5.28

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR XL54 TYPE I

NATURAL SNOW CONDITIONS

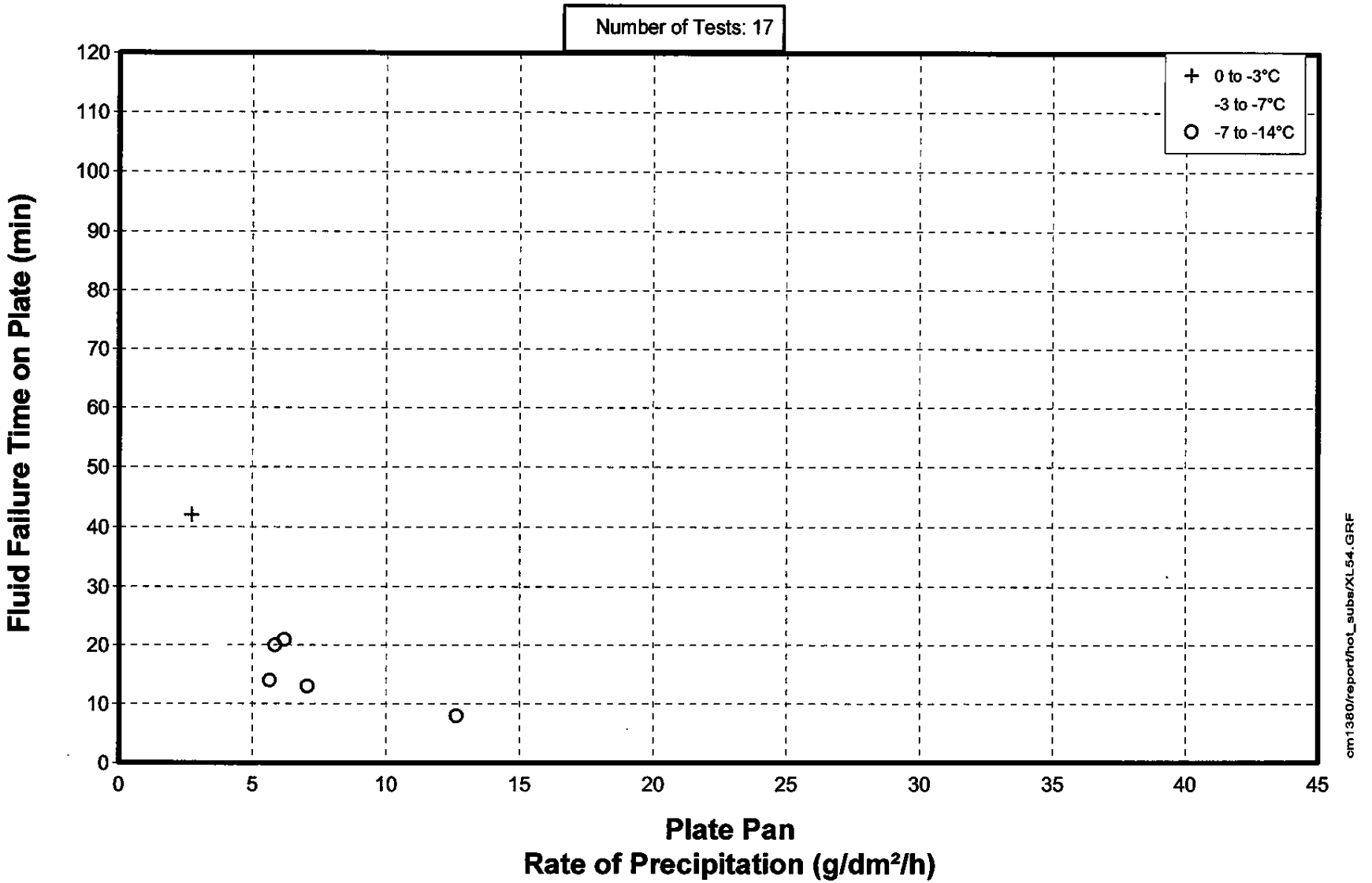


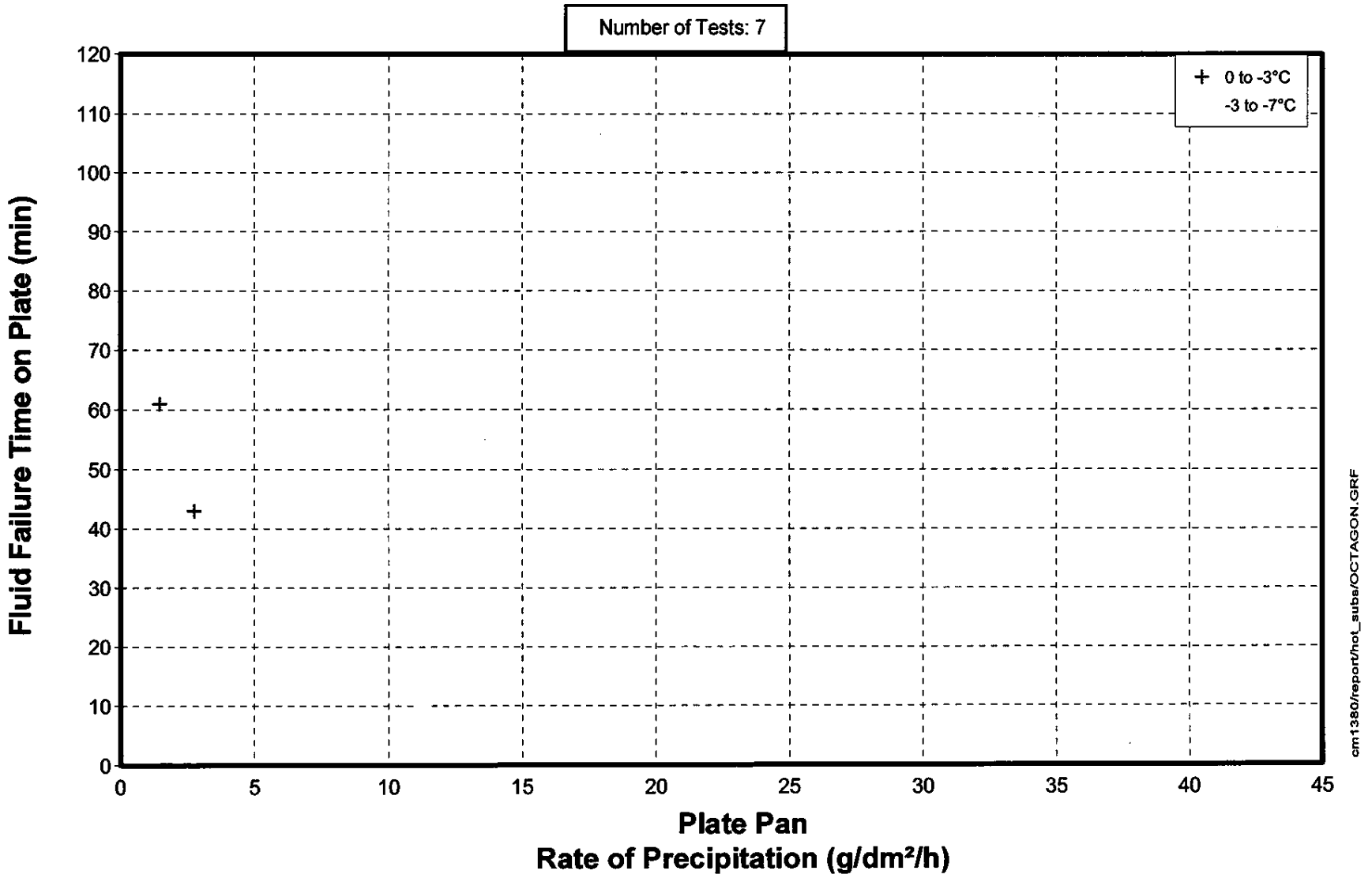
FIGURE 5.29

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE I

NATURAL SNOW CONDITIONS

1997-98



## 5.5 Type II Fluid Holdover Time Tests

Type II fluid is a thickened fluid used to provide anti-icing protection to aircraft surfaces following deicing. The Type II fluid holdover time table, substantiated by previous testing and accepted for use in 1997-98, is shown in Table 1.3 (Section 1). The new Type II holdover time table, which was accepted for use in 1998-99 by the SAE G-12 Holdover Time Subcommittee in Vienna, is shown in Table 5.3. The changes made to the previous Type II holdover time table are discussed in this section.

The SAE G-12 Holdover Time Subcommittee has stipulated that the holdover times for any cell in the Type II table may not exceed the holdover times for that same cell in the Type IV fluid table. This is primarily due to the fact that all Type IV fluids qualify as Type II fluids and are expected to exhibit superior performance over that of Type II fluids. Type II fluids, on the other hand, do not qualify as Type IV fluids. The imposing of holdover time reductions based on this consideration has been referred to as *Type IV fluid holdover time constraint*. No new Type II fluid failure tests were conducted by APS during the 1997-98 test season. Two changes, however, have been made to the Type II holdover time table based on the *Type IV fluid holdover time constraint.* The cells are affected on this basis only, and the specific holdover time changes contained therein are tabulated below:

| Category | Range (°C) | Dilution | 1997-98 Holdover Time (Min) | 1998-99 Holdover Time (Min) |
|---|---|---|---|---|
| Snow | -3°C to -14°C | 75/25 | 0:15-0:30 | 0:15-0:25 |
| ZD | -3°C to -10°C | Neat | 0:30-1:00 | 0:25-1:00 |

TABLE 5.2

# SAE TYPE I HOLDOVER TIMES

For Use in 1998-99

| OAT | | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| °C | °F | *FROST | FREEZING FOG | SNOW | **FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 0:45 | 0:12-0:30 | 0:06-0:15 | 0:05-0:08 | 0:02-0:05 | 0:02-0:05 |
| 0 to -10 | 32 to 14 | 0:45 | 0:06-0:15 | 0:06-0:15 | 0:05-0:08 | 0:02-0:05 | |
| below -10 | below 14 | 0:45 | 0:06-0:15 | 0:06-0:15 | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

TABLE 5.3

# SAE TYPE II HOLDOVER TIMES

For Use in 1998-99

| OAT | | SAE Type II Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (Vol%/Vol%) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 12:00 | 1:15-3:00 | 0:20-1:00 | 0:30-1:00 | 0:15-0:30 | 0:10-0:40 |
| | | 75/25 | 6:00 | 0:50-2:00 | 0:15-0:40 | 0:20-0:45 | 0:10-0:25 | 0:05-0:25 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | |
| 0 to -3 | 32 to 27 | 100/0 | 8:00 | 0:35-1:30 | 0:20-0:45 | 0:30-1:00 | 0:15-0:30 | |
| | | 75/25 | 5:00 | 0:25-1:00 | 0:15-0:30 | 0:20-0:45 | 0:10-0:25 | |
| | | 50/50 | 3:00 | 0:15-0:45 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:35-1:30 | 0:15-0:40 | **0:25-1:00 | **0:10-0:30 | |
| | | 75/25 | 5:00 | 0:25-1:00 | 0:15-0:25 | **0:20-0:45 | **0:10-0:25 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:20-1:30 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE II fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type II fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).

*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

## 5.6 Official and Proposed Holdover Time Tables for 1998-99

The officially accepted SAE holdover time tables for Type I, Type II, and Type IV fluids are presented here. These tables are proposed for worldwide use during the 1998-99 winter season.

Table 5.2 is the proposed and accepted holdover time table for Type I fluids. It is the result of material presented in Subsection 5.4.

Table 5.3 is the proposed and accepted holdover time table for Type II fluids. It is the result of material presented in Subsection 5.5.

There are eight Type IV fluid holdover time tables. The first, Table 5.4, is the new SAE Type IV fluid holdover time table. Tables 5.5 to 5.11 are the fluid-specific Type IV holdover time tables and correspond to Clariant MPIV 1957, Clariant MPIV 2001, Kilfrost ABC-S, Octagon MaxFlight, SPCA AD-404, SPCA AD-480, and Union Carbide Ultra+ fluids, respectively. These tables result from the material presented in Subsection 5.2.

The Transport Canada and FAA versions of the SAE holdover time tables are found in Appendices G and H, respectively. This section includes the same tables but in a format that facilitates viewing of the individual holdover time cells. This format contains only a small portion of the notes listed at the bottom of the tables intended for official use.

TABLE 5.4

# NEW SAE TYPE IV 1998-99 HOLDOVER TIMES

# SAE

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0º | above 32º | 100/0 | 18:00 | 2:00-3:00 | 0:45-1:25 | 0:40-1:00 | 0:35-0:55 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:20-0:40 | 0:30-1:00 | 0:15-0:30 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:05-0:20 | 0:10-0:20 | 0:05-0:10 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 0:35-1:00 | 0:40-1:00 | 0:35-0:55 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:20-0:35 | 0:30-1:00 | 0:15-0:30 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:20-0:40 | **0:25-1:00 | **0:15-0:30 | |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:15-0:25 | **0:25-1:00 | **0:15-0:30 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).



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At:Worst
Printed: 9:58 AM, 11/13/2006

TABLE 5.5

## *FLUID-SPECIFIC* TYPE IV HOLDOVER TIMES FOR 1998-99

# CLARIANT MPIV 1957 (1998-99)

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0º | above 32º | 100/0 | 18:00 | 2:00-3:00 | 1:05-2:00 | 0:50-1:40 | 0:40-1:00 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:45-1:25 | 0:45-1:15 | 0:30-0:40 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:15-0:30 | 0:15-0:25 | 0:10-0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 0:45-1:25 | 0:50-1:40 | 0:40-1:00 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:30-1:00 | 0:45-1:15 | 0:30-0:40 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:10-0:20 | 0:15-0:25 | 0:10-0:15 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:30-0:55 | **0:55-1:25 | **0:30-0:45 | |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:20-0:40 | **0:45-1:15 | **0:25-0:35 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:25-0:45 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).



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At:H 1957 98-99
11/13/2006

TABLE 5.6

## *FLUID-SPECIFIC* TYPE IV HOLDOVER TIMES FOR 1998-99

# CLARIANT MPIV 2001

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0º | above 32º | 100/0 | 18:00 | 2:00-3:00 | 1:55-2:00 | 0:55-1:55 | 0:40-1:00 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:50-1:25 | 0:35-1:10 | 0:25-0:35 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:10-0:20 | 0:10-0:20 | 0:10-0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 1:00-1:55 | 0:55-1:55 | 0:40-1:00 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:35-1:00 | 0:35-1:10 | 0:25-0:35 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:10-0:20 | 0:10-0:20 | 0:10-0:15 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:30-0:50 | **0:55-1:35 | **0:30-0:45 | |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:20-0:35 | **0:40-1:10 | **0:20-0:30 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:20-0:35 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).

TABLE 5.7

## *FLUID-SPECIFIC* TYPE IV HOLDOVER TIMES FOR 1998-99

# KILFROST ABC-S

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0º | above 32º | 100/0 | 18:00 | 2:00-3:00 | 1:10-2:00 | 1:20-1:50 | 1:00-1:25 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:35-1:05 | 0:50-1:10 | 0:35-0:50 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:05-0:20 | 0:15-0:20 | 0:10-0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 1:00-1:40 | 1:20-1:50 | 1:00-1:25 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:35-1:05 | 0:50-1:10 | 0:35-0:50 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:05-0:15 | 0:15-0:20 | 0:10-0:15 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:45-1:20 | **0:35-1:00 | **0:20-0:40 | |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:35-1:05 | **0:30-1:10 | **0:25-0:35 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:40-1:10 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).



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At:Kilfrost 98-99
11/13/2006

TABLE 5.8

## *FLUID-SPECIFIC* TYPE IV HOLDOVER TIMES FOR 1998-99

# OCTAGON MAXFLIGHT

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0º | above 32º | 100/0 | 18:00 | 2:00-3:00 | 1:15-2:00 | 0:55-2:00 | 0:35-1:00 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 1:20-2:00 | 1:15-2:00 | 0:35-1:10 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:40-1:20 | 0:35-1:00 | 0:15-0:30 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 0:50-1:35 | 0:55-2:00 | 0:35-1:00 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:45-1:45 | 1:15-2:00 | 0:35-1:10 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:40-1:20 | 0:35-1:00 | 0:15-0:30 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:25-0:50 | **0:30-1:10 | **0:20-0:40 | |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:20-0:50 | **0:25-1:05 | **0:20-0:30 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:20-0:40 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).



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At:Octagon 98-99
11/13/2006

TABLE 5.9

## *FLUID-SPECIFIC* TYPE IV HOLDOVER TIMES FOR 1998-99

# SPCA AD-404

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0º | above 32º | 100/0 | 18:00 | 2:00-3:00 | 1:40-2:00 | 1:40-2:00 | 0:45-1:20 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:50-1:45 | 0:50-1:50 | 0:30-0:50 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:20-0:45 | 0:25-0:55 | 0:15-0:35 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 1:00-1:45 | 1:40-2:00 | 0:45-1:20 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:25-1:00 | 0:50-1:50 | 0:30-0:50 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:15-0:30 | 0:25-0:55 | 0:15-0:35 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:35-1:00 | **1:05-2:00 | **0:35-1:20 | |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:15-0:25 | **0:30-1:45 | **0:30-0:45 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).



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At:SPCA 404 98-99
11/13/2006

TABLE 5.10

## *FLUID-SPECIFIC* TYPE IV HOLDOVER TIMES FOR 1998-99

# SPCA AD-480

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0º | above 32º | 100/0 | 18:00 | 2:00-3:00 | 1:10-2:00 | 1:05-2:00 | 0:50-1:10 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 1:00-1:55 | 0:50-1:20 | 0:35-0:50 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:15-0:35 | 0:15-0:35 | 0:10-0:25 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 1:05-2:00 | 1:05-2:00 | 0:50-1:10 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:45-1:25 | 0:50-1:20 | 0:35-0:50 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:10-0:30 | 0:15-0:35 | 0:10-0:25 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:20-0:40 | **0:25-1:20 | **0:20-0:40 | |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:15-0:25 | **0:30-1:15 | **0:20-0:35 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF)

TABLE 5.11

## *FLUID-SPECIFIC* TYPE IV HOLDOVER TIMES FOR 1998-99

# UNION CARBIDE ULTRA+

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (% by volume) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FRZ RAIN | RAIN ON COLD SOAKED WING |
| above 0º | above 32º | 100/0 | 18:00 | 2:00-3:00 | *0:50-1:40* | *1:00-2:00* | *0:35-1:00* | *0:10-0:50* |
| | | 75/25(1) | | | | | | |
| | | 50/50(1) | | | | | | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | *0:35-1:15* | *1:00-2:00* | *0:35-1:00* | |
| | | 75/25(1) | | | | | | |
| | | 50/50(1) | | | | | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | *0:25-0:55* | ***0:50-1:35* | ***0:30-0:50* | |
| | | 75/25(1) | | | | | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | *0:20-0:45* | | | |
| below -25 | below -13 | 100/0 | SAE TYPE IV fluid may be used below -25ºC (-13ºF) provided the freezing point of the fluid is at least 7ºC (13ºF) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10ºC (14ºF).

*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

(1) Diluted forms of Ultra+ are not recommended for operational use due to performance deficiencies noted in qualifying tests.

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Photo 5.1

**Comparison of Fluid Samples Provided for Holdover Time Testing**

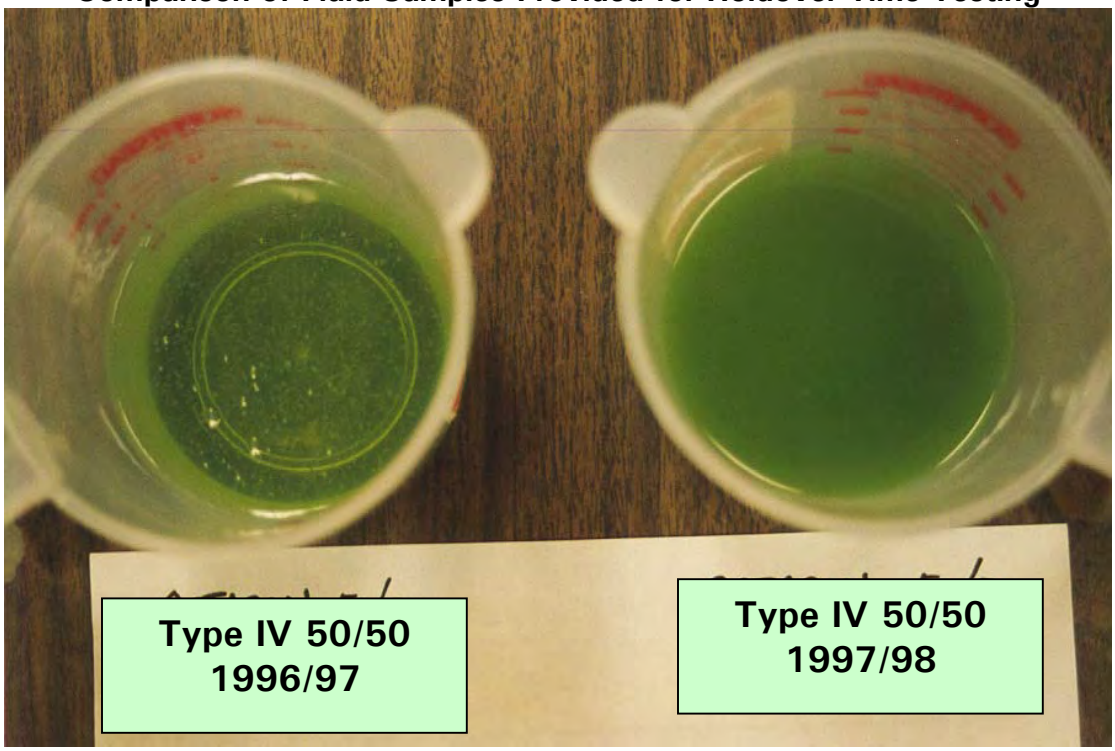
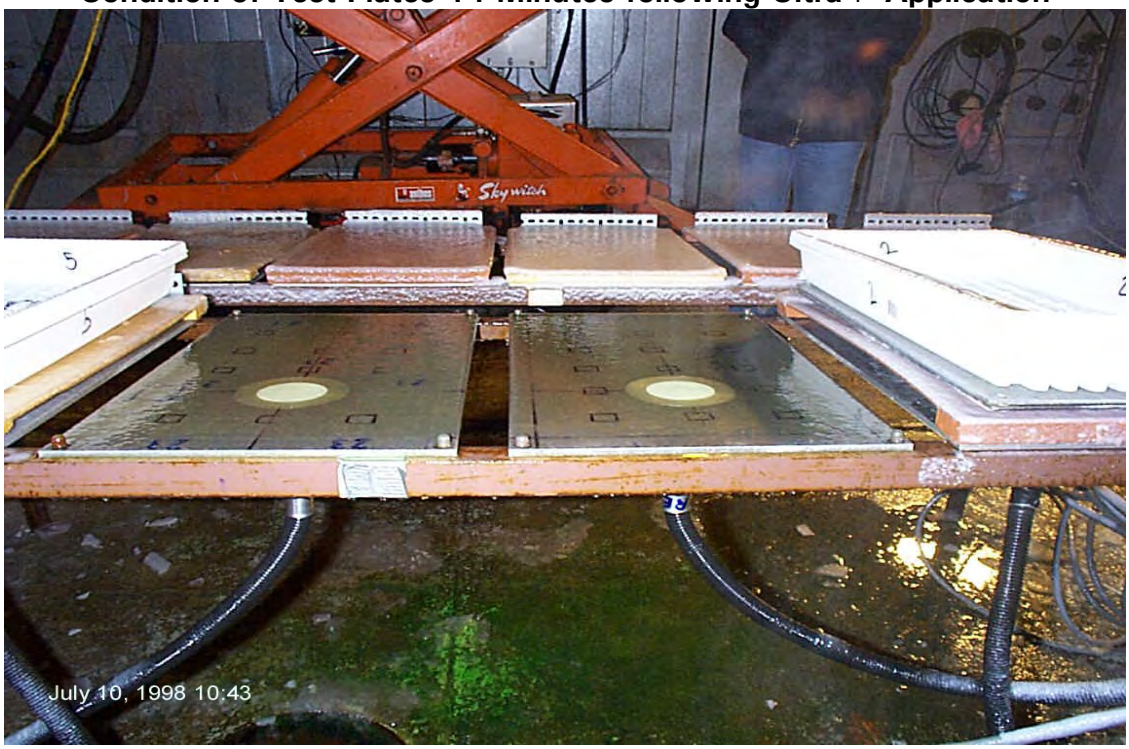



Photo 5.2

**Condition of Test Plates 14 Minutes following Ultra+ Application**



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# 6. SUPPLEMENTARY TESTS

APS conducted supplementary tests other than those specifically intended to determine the holdover times for qualified fluids. Supplementary tests and their corresponding results are presented in this section. These tests are listed below in order of presentation:

- In the course of outdoor testing during natural snow, there were occasions when precipitation fell in the form of ice pellets, or mixtures of snow and ice pellets. Data related to these conditions: Subsection 6.1;
- Evaluation of the holdover time and compatibility performance of Inland's recycled fluids: Subsection 6.2;
- Evaluation of the snow-making capability of NRC: Subsection 6.3;
- Evaluation of the holdover time of a fluid provided by Aeroflot: Subsection 6.4;
- Influence of plate slope on the holdover time of Type IV fluids: Subsection 6.5;
- Influence of fluid application procedure on holdover time: Subsection 6.6;
- Influence of Type IV fluid temperature on holdover time: Subsection 6.7;
- Influence of wind on holdover time: Subsection 6.8; and
- Influence of fluid viscosity on holdover time: Subsection 6.9.

## 6.1 Natural Freezing Precipitation Tests Excluding Snow

Holdover time tests conducted in natural freezing precipitation events other than snow were carried out at the APS Dorval airport test site during the 1997-98 winter season. A total of 75 tests were conducted with Type IV, Type I, Aeroflot, and recycled fluids. A breakdown of the 75 tests conducted, by fluid type, is summarized below.

| Fluid Type | # of Tests |
|---|---|
| Type IV Neat | 6 |
| Type IV 75/25 | 25 |
| Type IV 50/50 | 14 |
| Type I (Standard) | 12 |
| Recycled Fluid | 14 |
| Aeroflot | 14 |
| **TOTAL TESTS** | **75** |

Figures 6.1 to 6.3 contain Type IV fluid data plotted for three concentrations: neat, 75/25, and 50/50, respectively. Figure 6.4 contains the Aeroflot, Type I, and recycled fluid data. Only 58 tests were used for these plots; the remaining 17 tests were Union Carbide's Ultra IV and PG AAF, which did not satisfy SAE specifications. A list of all the natural freezing precipitation tests conducted at Dorval airport is included in Appendix D.

The 75 tests were conducted during conditions of ice pellets or mixtures of snow with ice pellets.

A comparison between the fluid failure times recorded in these freezing precipitation events and the *fluid-specific* holdover time tables shows that the failure time data points, lying approximately between 10 and 25 g/dm²/h, satisfy the holdover times for the snow category. Only two tests conducted with SPCA AD-404 neat fluid at +1°C were slightly below the holdover time range. These points are plotted along with two data points for SPCA AD-480.

Due to the ambiguities related to calling failures in the ice pellet conditions, failure times cited in these data may exhibit wide variations. Although the fluid failure times cited generally fall between the upper and lower holdover time limits, snow holdover times may not be severe enough to match ice accumulation rates in certain ice pellet and related conditions.

Additional data corresponding to similar tests carried out from 1991 to 1996 are compiled in Appendix F of Transport Canada report TP 12896E (11).

FIGURE 6.1

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT

ICE PELLETS OR SNOW MIXED WITH ICE PELLETS

1997-98

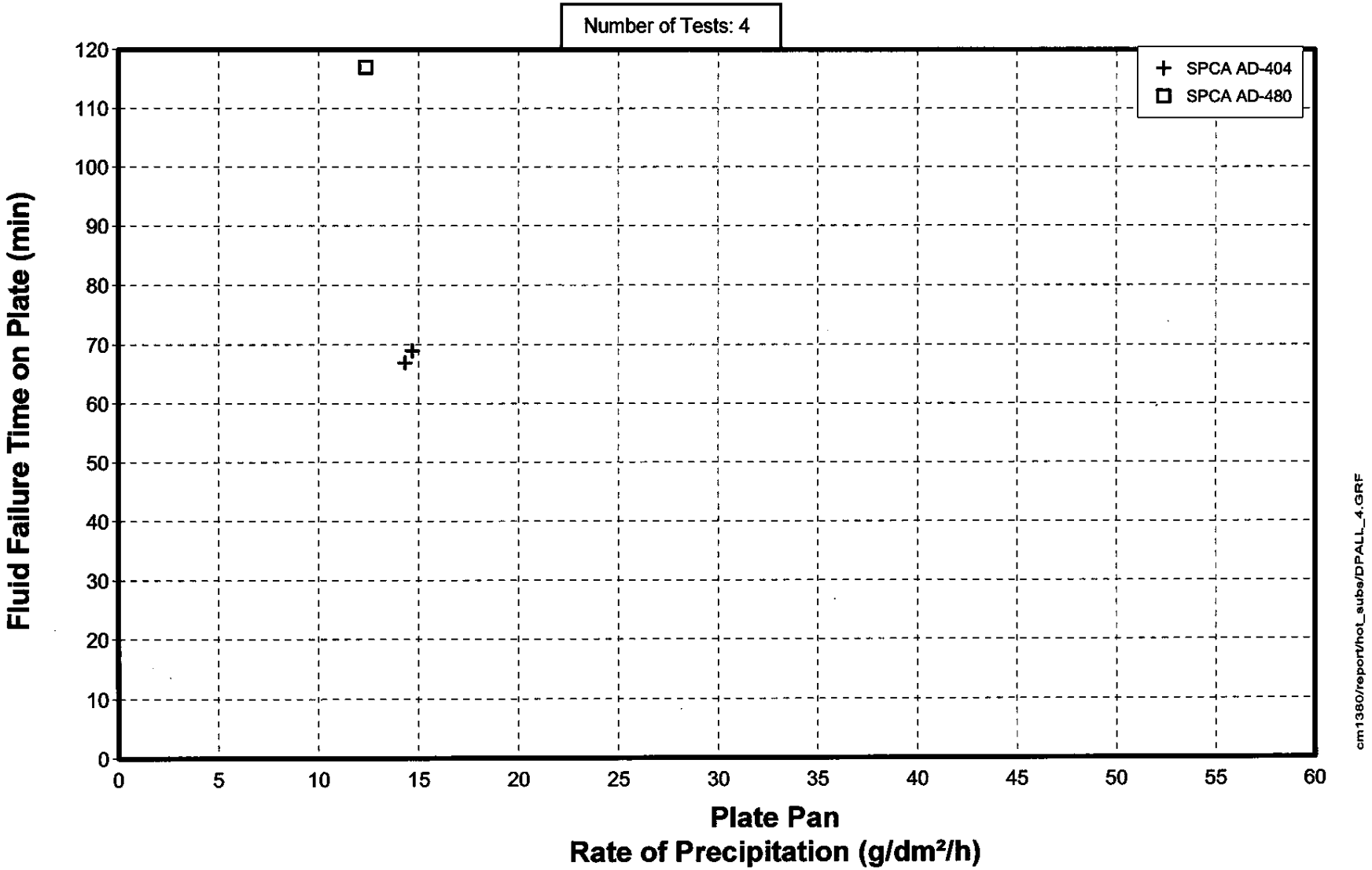


FIGURE 6.2

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25

ICE PELLETS OR SNOW MIXED WITH ICE PELLETS

1997-98

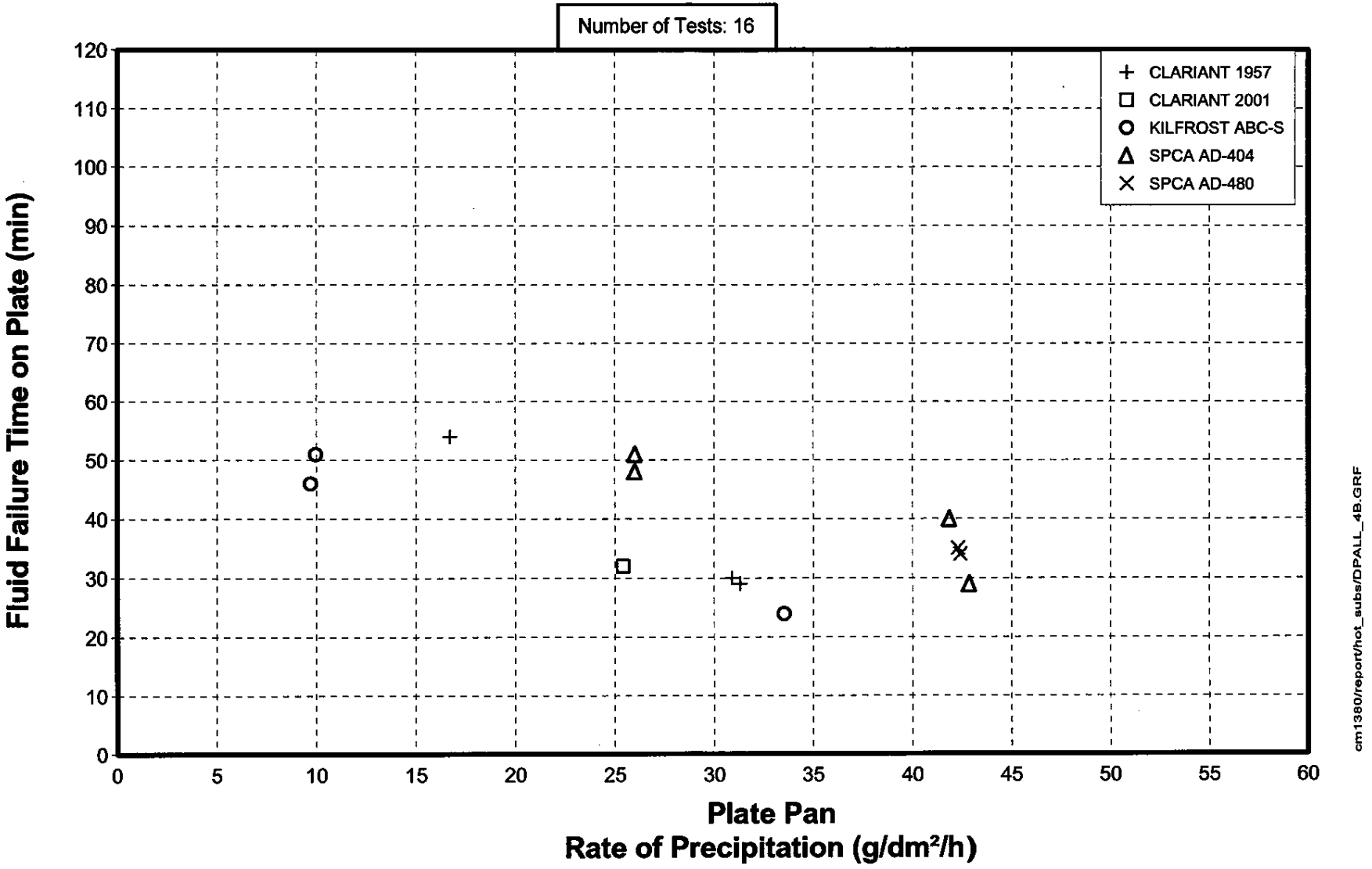


FIGURE 6.3

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 50/50

ICE PELLETS OR SNOW MIXED WITH ICE PELLETS

1997-98

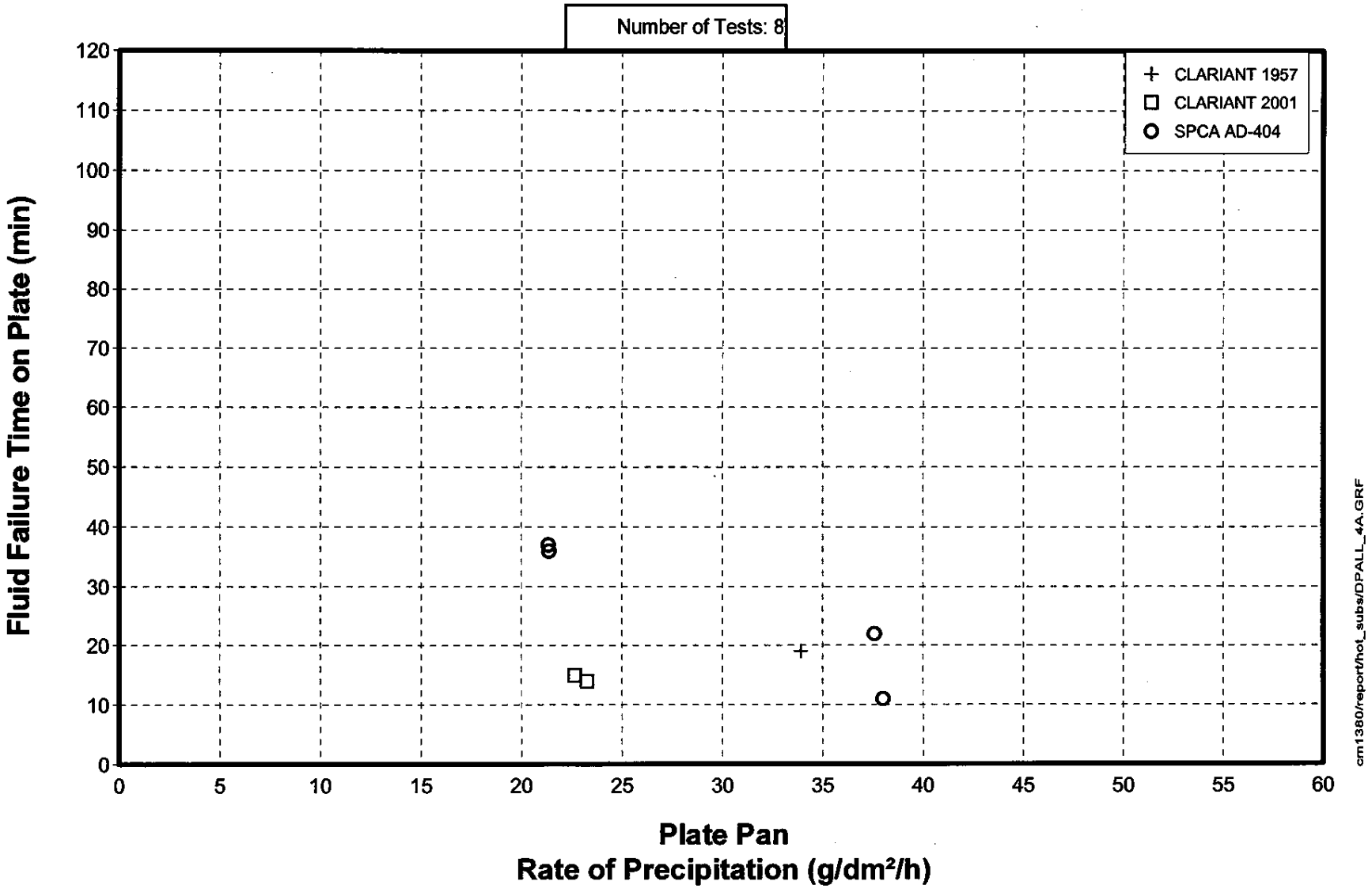


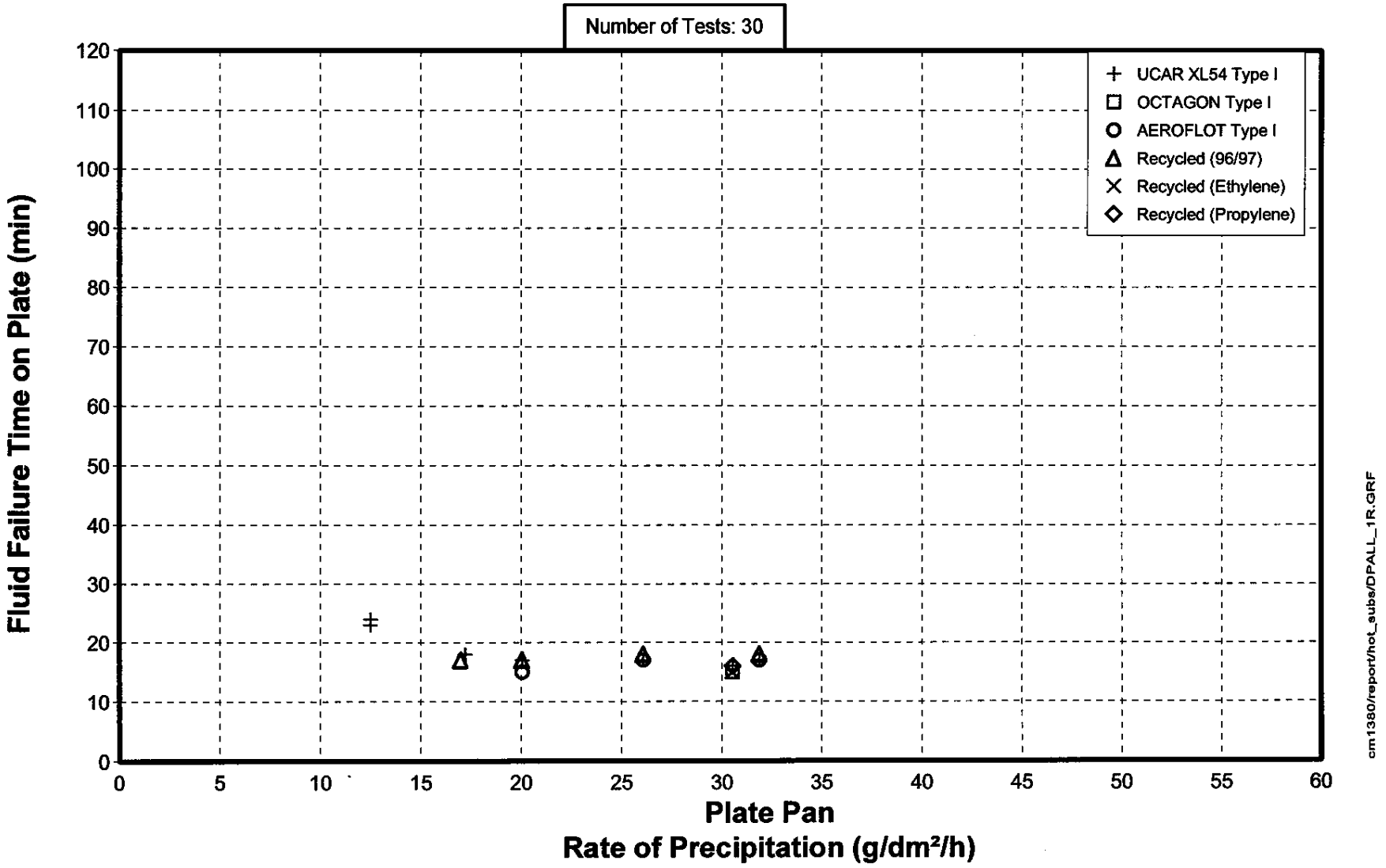
FIGURE 6.4

# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE I AND RECYCLED FLUIDS

ICE PELLETS OR SNOW MIXED WITH ICE PELLETS

1997-98



## 6.2 Evaluation of Recycled Fluids

At the request of TDC, APS Aviation was asked to evaluate the holdover time performance and fluid compatibility performance of two recycled fluids, one ethylene glycol-based and one propylene glycol-based. Both fluids were supplied by Inland Technologies Inc.

The fluids are currently being marketed as first-step or *washdown* fluids in two-step fluid applications; however, Inland is seeking certification of the fluids for potential future use on aircraft in the same capacity as commercial Type I fluids. The recycled Inland fluids are referred to as *recycled ethylene* and *recycled propylene* in this report. To gain acceptance for use of the fluids on aircraft, Inland is conducting corrosion tests with SMI, and WSET, HHET and aerodynamic acceptance tests with UQAC.

A series of preliminary holdover time and compatibility tests were also performed in Dorval by APS in 1996-97, using one batch of recycled ethylene fluid provided by Inland. The results of these tests appear in Transport Canada report TP 13131E (1).

### 6.2.1 Holdover Time

Over the past two test seasons, APS has conducted holdover time tests with Inland fluids in natural snow, light freezing rain, freezing drizzle, and rain on a cold-soaked wing conditions.

Holdover time tests in natural snow were performed at the APS Dorval Airport test facility in 1997-98. The procedures used in the conduct of outdoor tests on the recycled fluids are outlined in Appendix B.

In total, 40 holdover time tests in natural snow were conducted in 1997-98 with Inland fluids, which included:

- 12 tests with Inland recycled ethylene fluid provided in 1996-97;
- 13 tests with Inland recycled ethylene fluid provided in 1997-98; and
- 15 tests with Inland recycled propylene fluid provided in 1997-98.

The majority of holdover time tests with recycled fluids in natural snow were conducted alongside plates of commercial Type I fluids for holdover time comparison. The results of these snow tests, including the Type I results, are plotted in the form of fluid failure time versus rate of precipitation (as a function of fluid type) and are displayed in Figure 6.5.

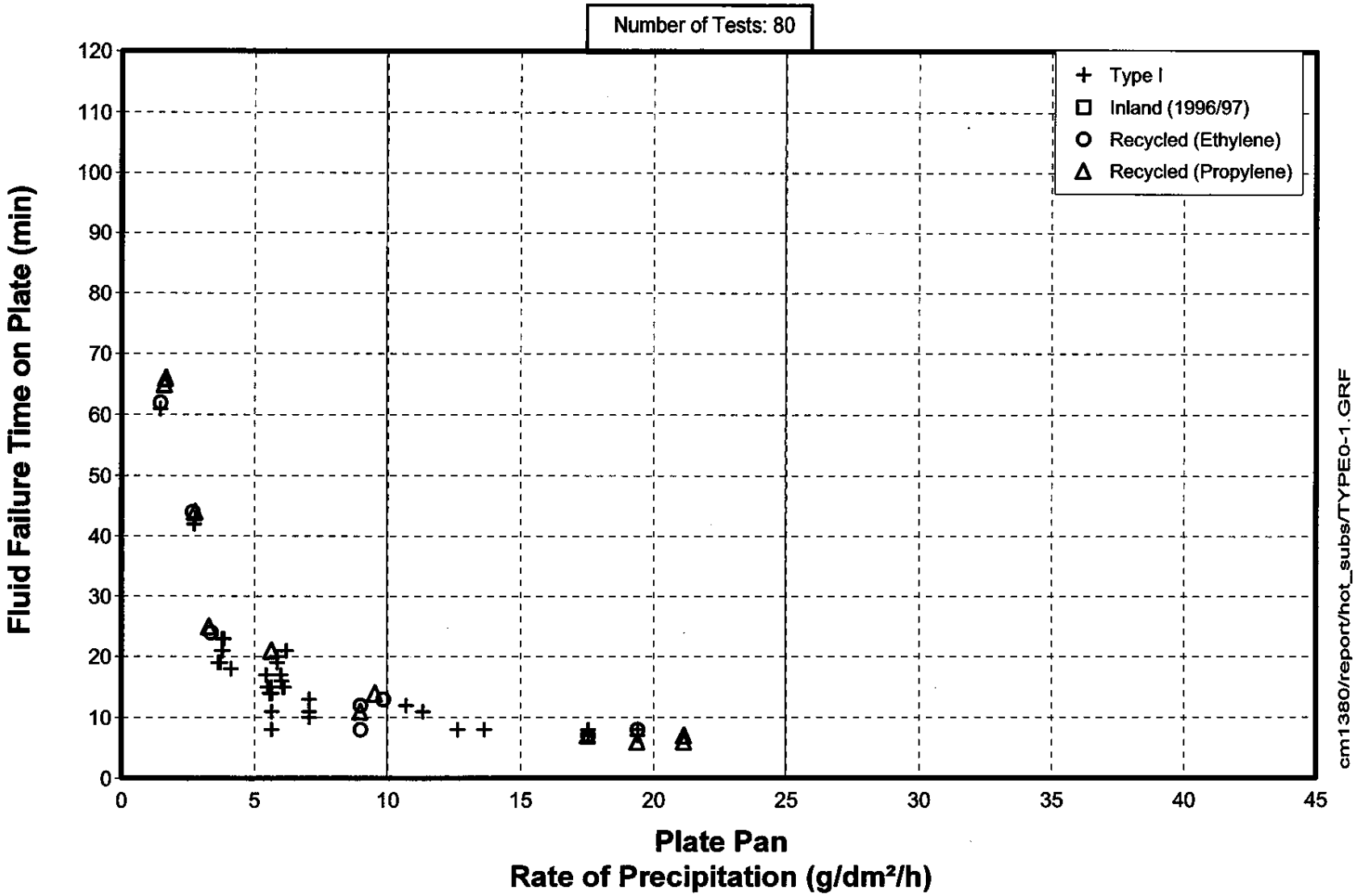
FIGURE 6.5

# EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE I AND RECYCLED FLUIDS

### NATURAL SNOW CONDITIONS

### 1997-98



In general, the holdover time results of Inland fluids in natural snow were very similar to those of the commercial Type I fluids tested, and fit in the 6- to 15-minute holdover time range for Type I fluid in snow.

Furthermore, 14 tests with recycled fluids were conducted in natural precipitation conditions other than snow. The results of these tests are displayed in Figure 6.4. In general, the holdover times of the recycled fluids resemble those of the TYPE I fluids tested.

Holdover time tests on Inland recycled fluids in freezing drizzle and light freezing rain were performed at NRC's CEF in Ottawa in 1996-97 and 1997-98. The procedures used in the conduct of indoor tests in simulated conditions appear in Appendix C.

Ten Inland recycled ethylene fluid tests were performed in 1996-97. The results of these tests were compared to 10 plates of standard Type I fluid. The holdover times of the Inland fluid plates resembled those of the Type I fluid plates (see Transport Canada report TP 13131 E (1)).

Twenty holdover time tests were performed in freezing drizzle and light freezing rain with Inland recycled fluids in 1997-98, including 10 with recycled ethylene and 10 with the recycled propylene. Tests were conducted at -3°C and -10°C, each at several different rates of precipitation. The results of these tests, including the Type I results, are plotted in the failure time versus rate of precipitation format (as a function of fluid type) and shown in Figure 6.6.

The holdover times from the Inland fluid tests are, once again, similar to those obtained from the Type I fluid tests; all are above the 5- to 8-minute Type I holdover time range for freezing drizzle and the 2- to 5-minute Type I holdover time range for light freezing rain.

One cold-soak box test using Inland recycled ethylene fluid was performed in 1996-97, and the result was compared to a box treated with a commercial Type I fluid. The boxes had identical failure times (Transport Canada report TP 13131E (1)).

### 6.2.2 Compatibility Tests

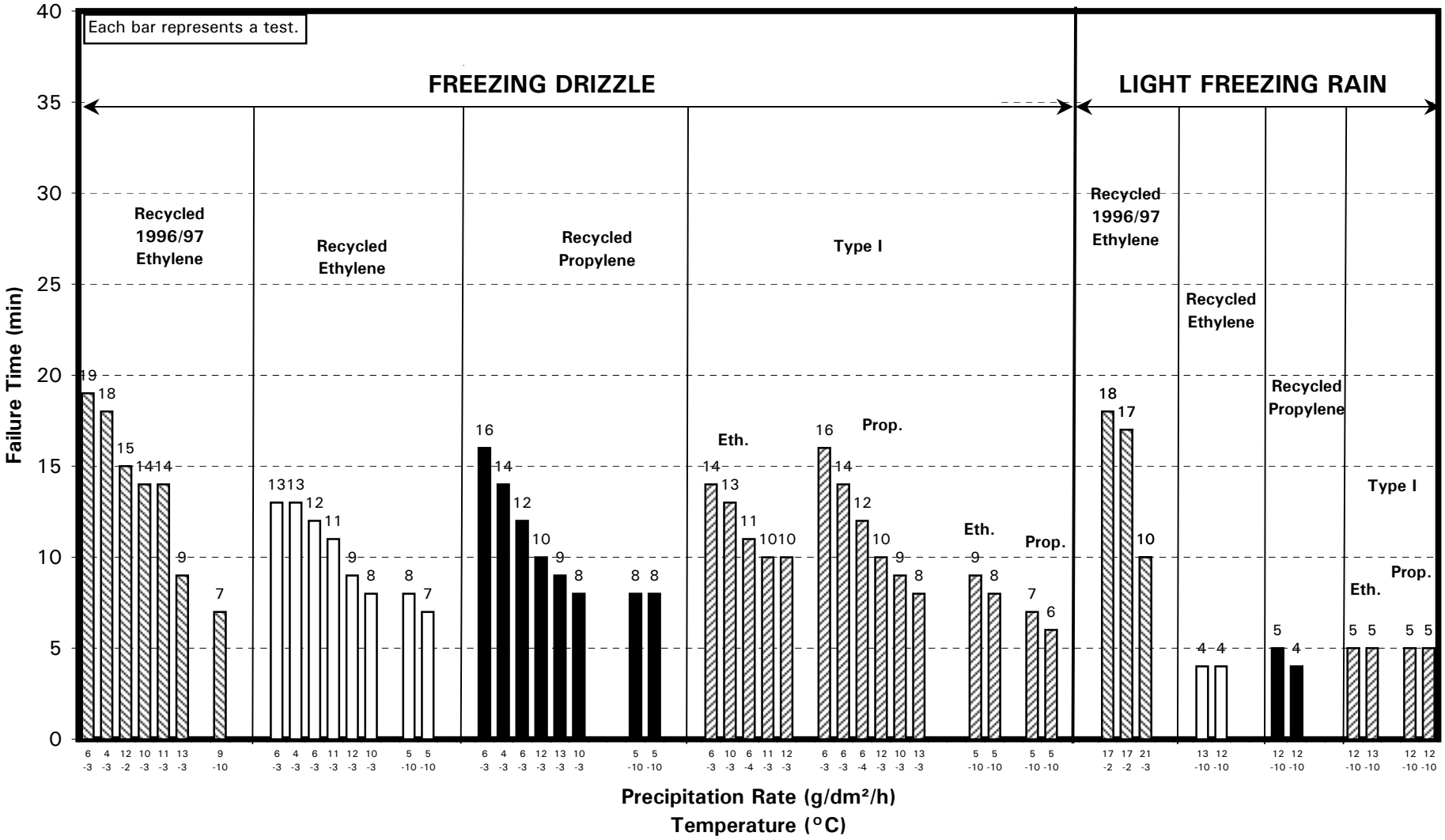
A series of preliminary tests, aimed at determining the compatibility of Inland recycled ethylene fluid with commercial ethylene Type I and Type IV fluids, were conducted in 1996-97. The results showed that the recycled fluid was compatible with all the Type I and Type IV fluids

FIGURE 6.6

**EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME**

TYPE I AND RECYCLED FLUID

**Freezing Drizzle and Light Freezing Rain**



tested. The complete result summary of these tests appears in Transport Canada report TP 13131E (1).

A more elaborate series of tests, involving various combinations of ethylene and propylene recycled fluids, as well as commercial ethylene and propylene Type I and Type IV fluids, were performed during the past test season in light freezing rain and freezing drizzle at the Climatic Engineering Facility in Ottawa. The plan for the conduct of compatibility tests appears in Appendix C. In general, the test procedure consisted of running standard holdover time tests with selected Type I and Type IV fluids, and then re-testing the same fluids in two-step applications, consisting of:

- Type IV fluids over Type I fluids;
- Type IV fluids over recycled fluids; and
- Type I fluids over recycled fluids.

Tests were conducted to determine the effect of the undercoat on the holdover time of the second-step fluid.

Compatibility tests were divided in two groups:

- Compatibility of recycled fluids with commercial Type I fluids; and
- Compatibility of recycled fluids with commercial Type IV fluids.

#### *6.2.2.1 Compatibility tests with Type I fluids*

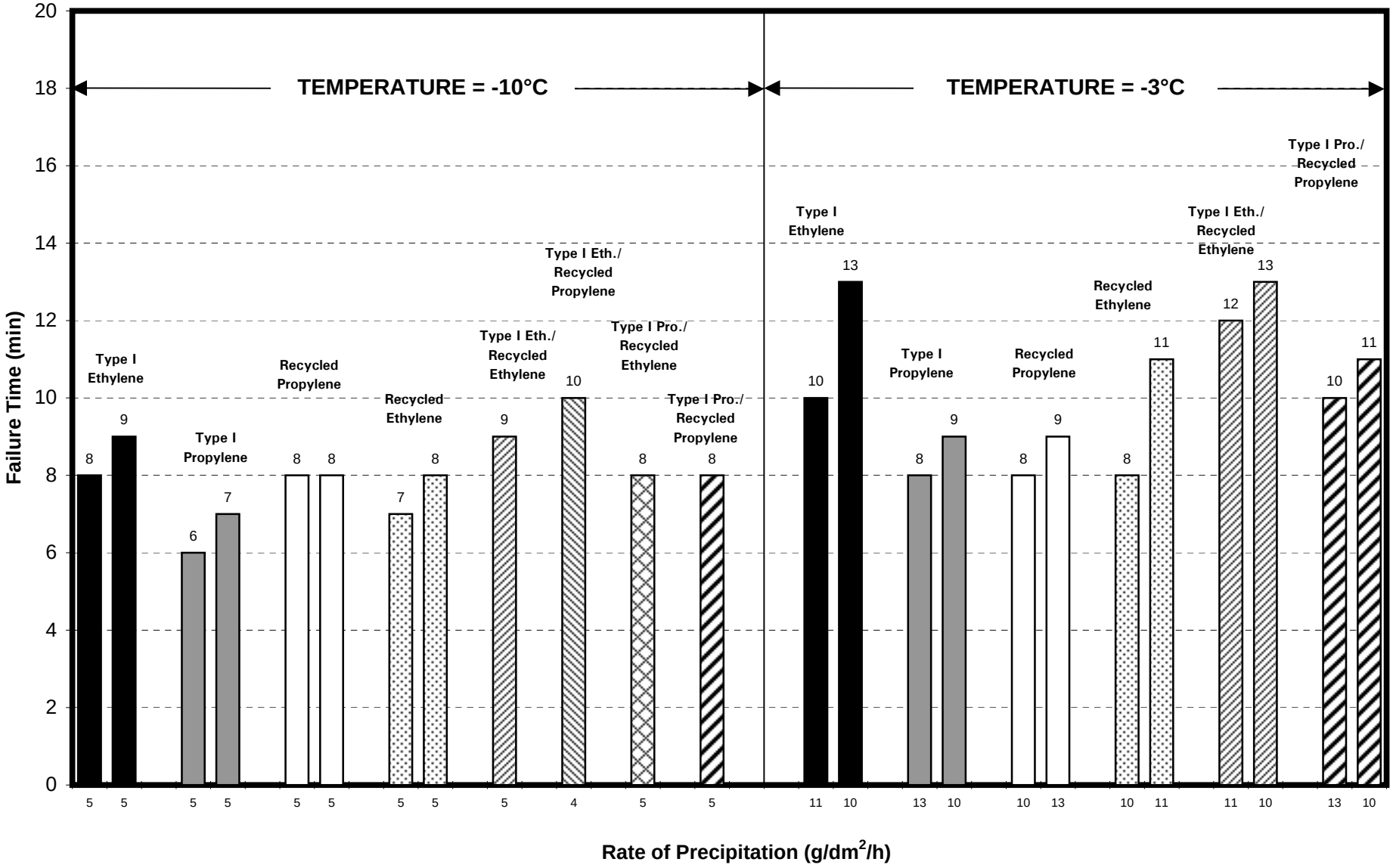
The results of tests conducted to determine the compatibility performance of recycled fluids and Type I fluids are shown in Figures 6.7 and 6.8.

Figure 6.7 shows the results of Type I tests conducted in freezing drizzle. Each bar represents the holdover time result (in minutes) of the fluid(s) tested. The rate of precipitation and the test temperature are displayed below each bar. The holdover times of the Type I fluids, as shown in Figure 6.7, have generally increased slightly when recycled fluids have been used as an undercoat, thus suggesting good compatibility between the fluids.

Figure 6.8 shows the results of Type I tests conducted in light freezing rain. The results show that recycled fluid undercoat does not affect the holdover time of the Type I fluid.

FIGURE 6.7

## COMPATIBILITY OF RECYCLED FLUIDS WITH TYPE I
## SIMULATED FREEZING DRIZZLE



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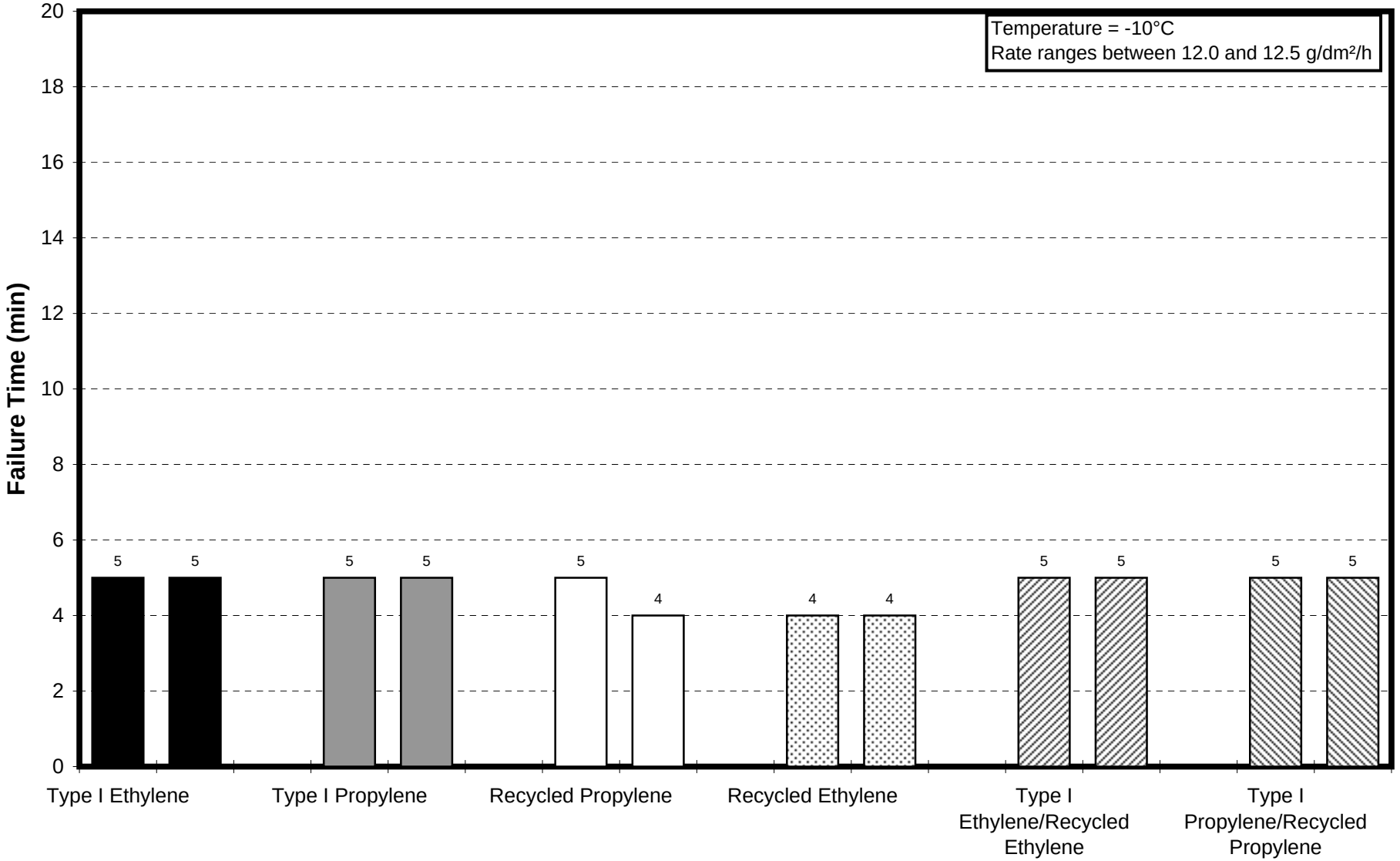
11/13/2006

FIGURE 6.8

**COMPATIBILITY OF RECYCLED FLUIDS WITH TYPE I**

# SIMULATED LIGHT FREEZING RAIN

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11/13/2006

### 6.2.2.2 Compatibility tests with Type IV fluid

The results of recycled fluid compatibility tests with Type IV fluids are displayed in Figures 6.9 through 6.12.

Previous compatibility tests suggested that the holdover times of Type IV fluids applied in two-step applications are lower than those of Type IV fluids applied without an undercoat (Transport Canada report TP 13131E (1)).

Figure 6.9 shows the results of compatibility tests using an ethylene Type IV fluid in freezing drizzle. In general, the holdover times of the Type IV fluid have been reduced by about 10 percent in tests where an ethylene Type I or recycled ethylene fluid has been applied prior to the ethylene Type IV. The largest difference in holdover time (21 percent reduction) exists when the propylene recycled fluid was used under the ethylene Type IV.

Figure 6.10 shows the results of compatibility tests using an ethylene Type IV fluid in light freezing rain. In general, the holdover times of the Type IV fluid have been reduced by about 10 percent when an ethylene fluid undercoat has been applied. Once again, the propylene recycled fluid undercoat results in a larger reduction in holdover time for this ethylene Type IV fluid (19 percent reduction, on average).

Figure 6.11 displays the results of compatibility tests using a propylene Type IV fluid in freezing drizzle. Although an overall reduction of up to 10 percent in the Type IV holdover time is evident when an undercoat has been applied, no individual undercoat had significantly worse effects on the holdover time performance of the Type IV fluid.

Figure 6.12 shows the results of compatibility tests using a propylene Type IV fluid in light freezing rain conditions. At -3°C, the propylene Type I fluid undercoat most adversely affects the holdover time of the propylene Type IV fluid (17 percent reduction, on average). At -10°C, the holdover time performance of the propylene Type IV fluid has actually improved when applied over Type I or recycled fluids. Failure of this particular Type IV fluid in light freezing rain conditions at -10°C is characterized by lack of fluid flow and ice formation in the upper fluid layers, which tends to *dam* at the bottom of the test panel. It is possible that the undercoat, in this case, has improved the Type IV fluid's ability to flow and slightly delays the damming of the fluid. The Type IV holdover times were increased by 7 percent, on average, when applied over propylene Type I and propylene recycled fluids, and by 2 percent, on average, when applied over recycled ethylene fluid.

FIGURE 6.9

## COMPATIBILITY OF RECYCLED FLUIDS WITH ETHYLENE TYPE IV

## SIMULATED FREEZING DRIZZLE

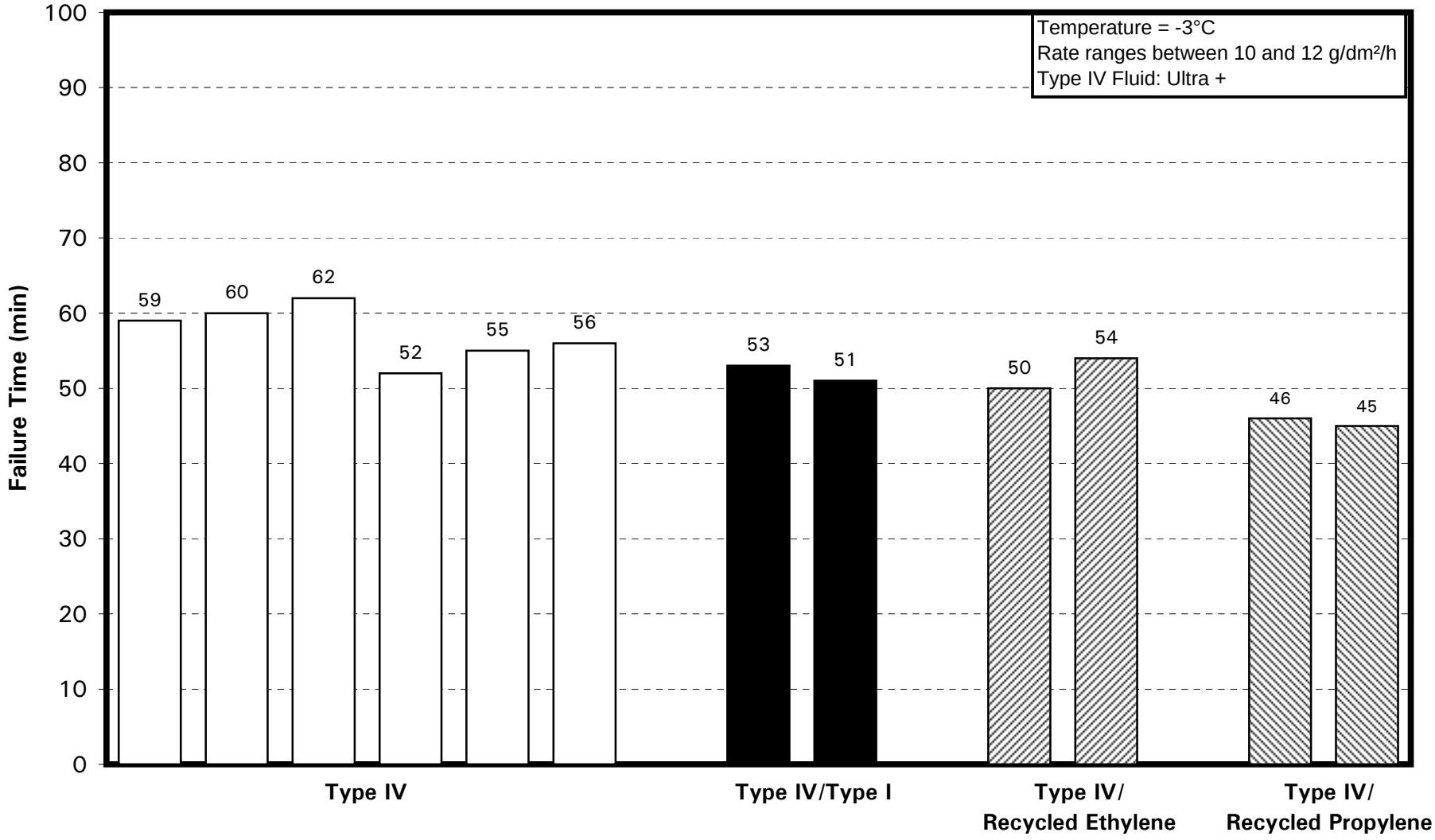


FIGURE 6.10

## COMPATIBILITY OF RECYCLED FLUIDS WITH ETHYLENE TYPE IV

## SIMULATED LIGHT FREEZING RAIN

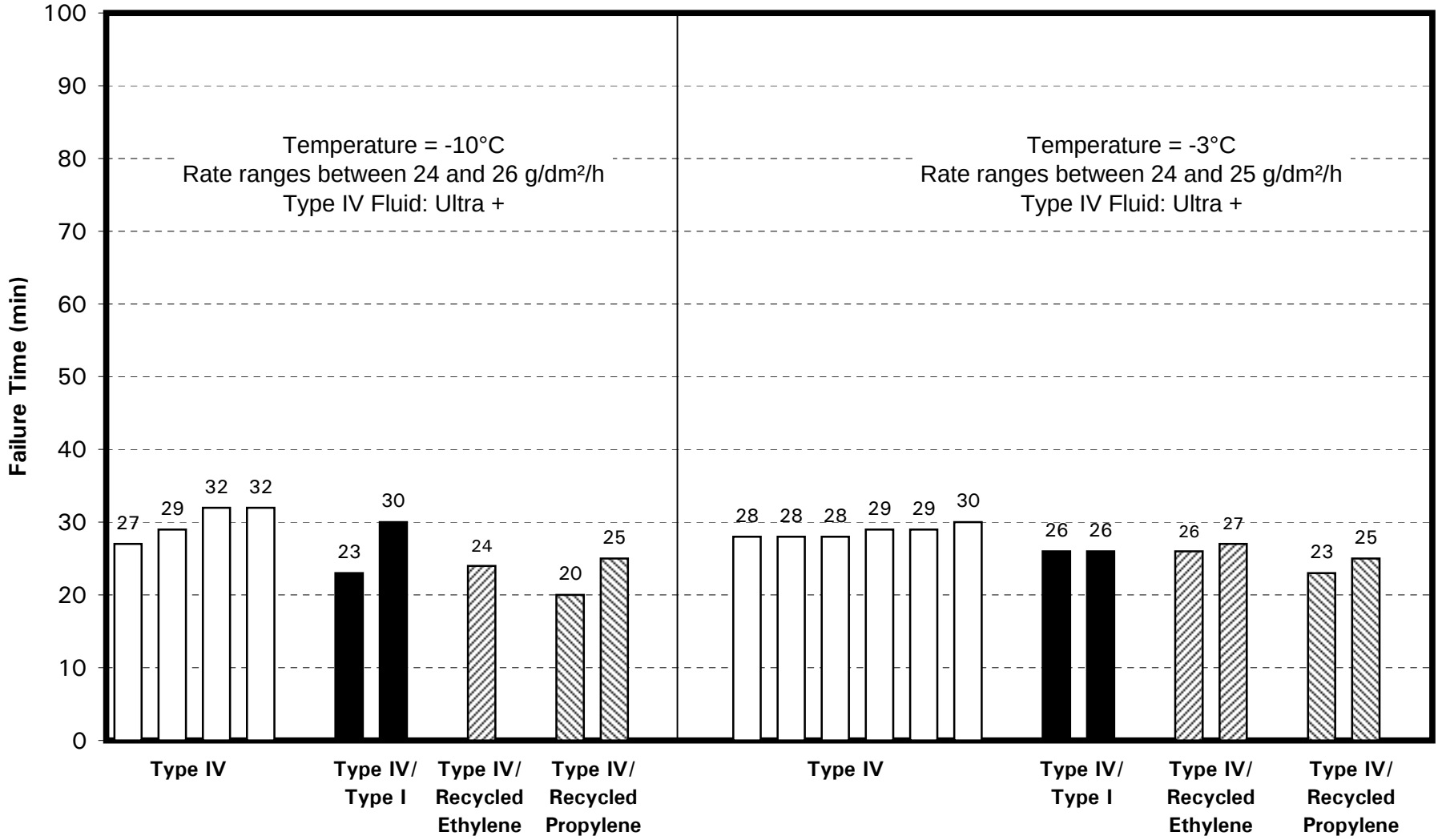


FIGURE 6.11

## COMPATIBILITY OF RECYCLED FLUIDS WITH PROPYLENE TYPE IV

## SIMULATED FREEZING DRIZZLE

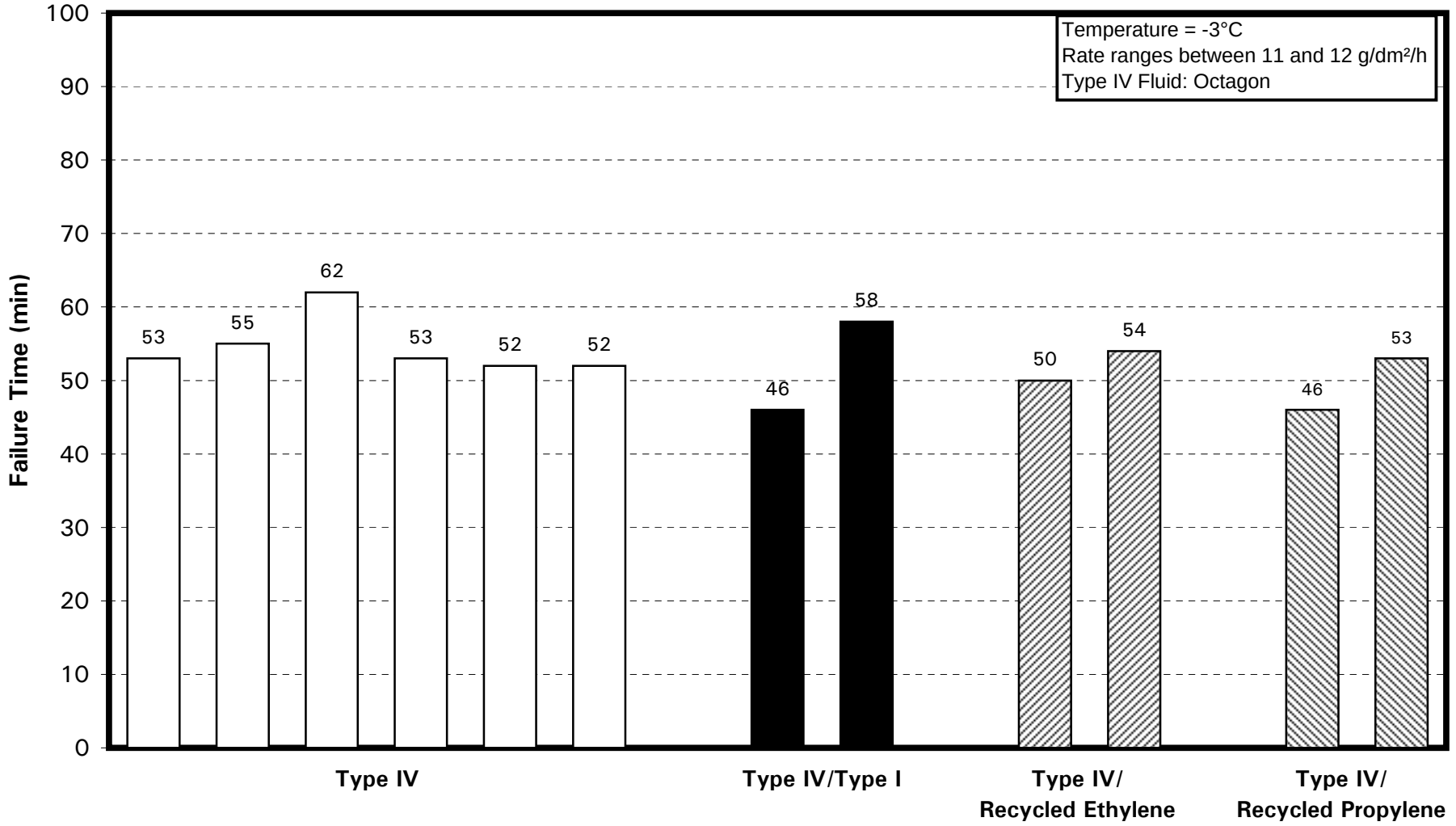
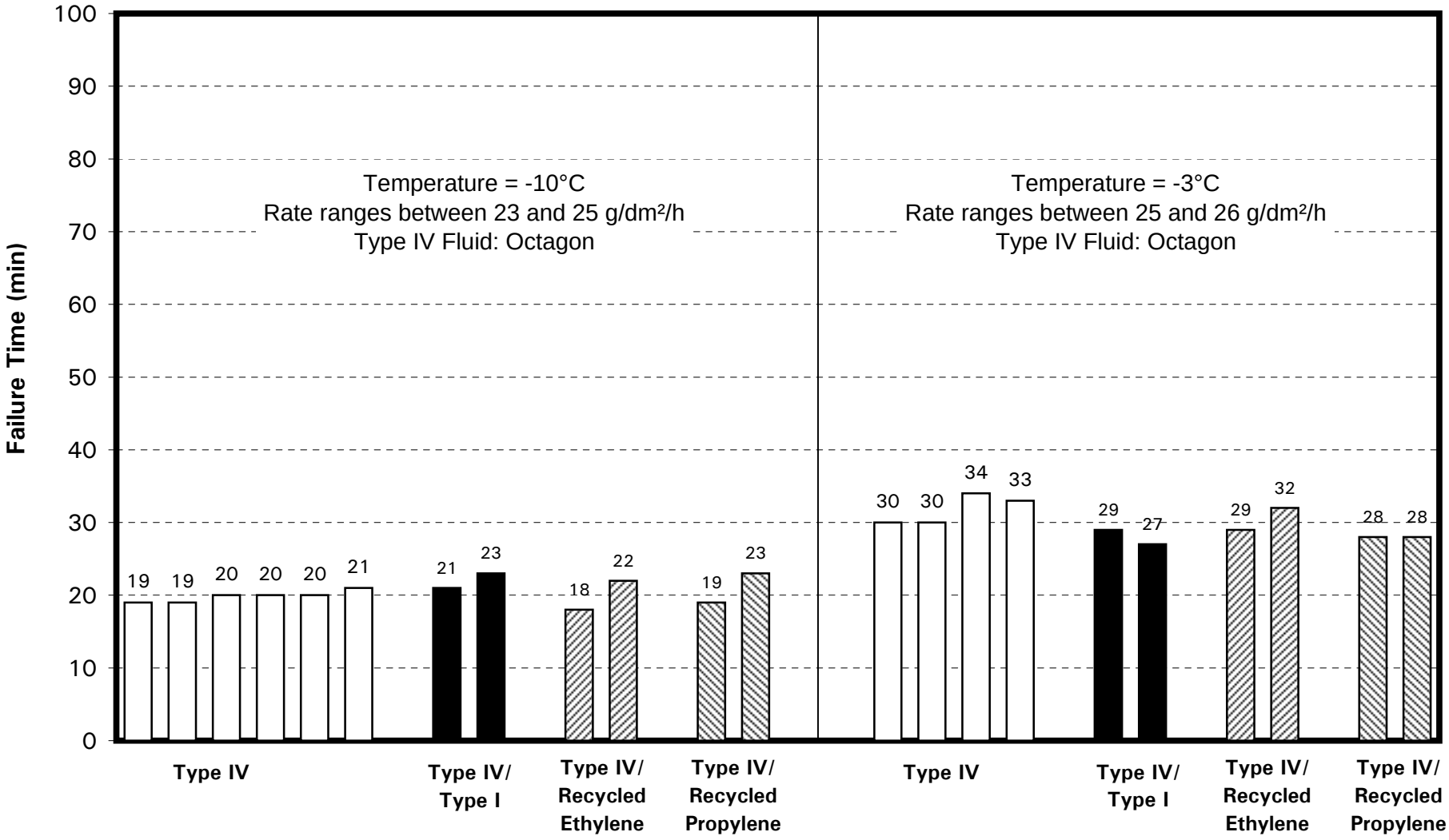


FIGURE 6.12

## COMPATIBILITY OF RECYCLED FLUIDS WITH PROPYLENE TYPE IV

# SIMULATED LIGHT FREEZING RAIN



### 6.2.3 Thickness Tests

Fluid thickness tests, aimed at comparing the stabilized film thickness profiles of the recycled propylene and ethylene fluids and commercial Type I fluids, were conducted at NRC's CEF in 1997-98. Procedures for the conduct of fluid thickness tests are outlined in Appendix C. Four plates were coated with Inland fluids, two with recycled ethylene and two with recycled propylene. Tests were performed at a temperature of -3°C in the absence of freezing precipitation. The fluids were applied to standard test plates at room temperature (20°C), and the stabilized thicknesses of the fluids were recorded after 30 minutes on the 15 cm line of the plates.

The test results indicate that all four plates had identical film thickness values of 0.04 mm after 30 minutes. The results of the thickness tests conducted with Type I fluid in 1995-96 (Transport Canada report TP 12900E (8)), showed stabilized thickness values of 0.03 mm.

### 6.2.4 Negative Buffer Deicing Fluid Tests / Deicing Only Fluid Tests

A series of experiments were undertaken by APS in 1997-98 at the NRC's CEF in Ottawa. The objectives of these tests were to:

- Determine the limits of the use of hot water and reduced glycol content deicing fluids under conditions of precipitation; and

- Develop a *deicing only* table for the removal of ice, slush, snow, or frost in the absence of precipitation.

Tests were conducted using water; recycled propylene and ethylene fluids; propylene and ethylene Type I fluids; and Type II and Type IV anti-icing fluids.

The results showed that Inland recycled fluids performed equal to commercial Type I fluids in all tests.

The complete results of these tests are published in Transport Canada report TP 13315E (12).

## 6.3 Evaluation of Snow-Making Capability at National Research Council Canada Climatic Engineering Facility

### 6.3.1 Background

Tests to evaluate fluid holdover times in snow conditions have in the past been limited to outdoor tests during periods of natural snowfall. Although best advantage was taken of snowstorms as they occurred, the chance nature of the combination of snowfall rate, air temperature, and winds has limited the opportunity to test at all desired experimental conditions. The ability to produce artificial snow in a cold chamber laboratory setting with controlled precipitation rates and assured consistency would enable more efficient and effective evaluation of fluids in snow conditions than is possible in natural freezing precipitation conditions.

### 6.3.2 Objective

The objective of this study was to evaluate the capability of NRC's CEF to produce artificial snow suitable for fluid holdover testing. The principal attributes to be examined were: ability to produce snow at a range of temperatures, ability to provide a consistent rate of snowfall over time and over a defined area, and ability to produce at a controlled (predefined) rate. The nature of the snow was also examined photographically and with a magnifying glass. Snow was generated for these tests using the spray nozzles designed to generate freezing fog conditions, with adjustments to system air and water pressures. Two spray bars, each equipped with eight nozzles, were used.

### 6.3.3 Procedure

The procedural steps followed were:

- Position a number of flat horizontal plates of known surface area on individual pedestals at fixed locations around a flat plate test stand. The pedestals were positioned around the perimeter of the test stand to provide a measure of the variation of snowfall at the extreme limits of an area of the same proportions but somewhat larger than the test stand;

- Produce snow, at various air temperature values for different tests;

- Catch snow on the plate over a 20- to 30-minute period, cut off snow accumulated past the plate edges, weigh plates with snow to determine rate, measure depth of snow to determine an average volume, use the mass and volume to compute the density; and

- Examine the nature of the snow particles.

With care, four downward cuts with a long spatula blade left the accumulated snow on the top of the plates intact. A square volume of snow with sides perpendicular to the surface and coincident with the plate edges remained.

Photo 6.1 shows the test set-up with flat horizontal plates on pedestals near and around the flat plate stand; Photo 6.2 shows the spray bars in operation; Photo 6.3 shows snow accumulated on the flat plate stand with lumps of snow that fell from overhead accumulations; and Photo 6.4 shows snow accumulation on the overhead structure.

### 6.3.4 Results

Data from the tests are provided in Appendix J. Comments based on data collected and observations follow:

a) Ability to produce snow at a range of temperatures;

The NRC's CEF staff indicated that snow production is difficult at warmer temperatures just under freezing. As a result, tests were conducted at colder temperatures. One test was performed at each of the three following air temperatures or ranges of temperatures, -10ºC, -10º to -15ºC, -15º to -20ºC, and four tests at -20ºC. Snow production at -3ºC would be necessary to satisfy experimental conditions for fluid tests.

b) Ability to provide a consistent rate of snowfall over time and over a defined area;

During the four tests at constant air temperature, precipitation rates for individual plate positions showed a wide range of values. One position ranged from 16 to 24 g/dm$^2$/h; another ranged from 13 to 21 g/dm$^2$/h.

Precipitation rates measured from one plate position to the next also showed a wide range of values, from 9 to 16 g/dm$^2$/h in one trial and 14 to 20 g/dm$^2$/h in another. These ranges are too great for experimentation; a target maximum variation in precipitation rate of 10 percent from plate to plate and from run to run is reasonable.

c) Ability to produce at a controlled (predefined) rate; and

No attempt was made to adjust the snow-making system controls to produce a predefined snowfall rate. Based on observations of the variation in rate over time and between positions, it would be difficult to control snow precipitation rates to within experimental requirements.

d) Nature of the snow particles.

The snow particles consisted of very small, fairly regular spherical agglomerations of microcrystalline ice particles, which are quite different from snowflakes observed in nature. Nevertheless, the measured density of accumulated snow was in a satisfactory range, providing density values in the neighbourhood of 0.05 to 0.1 g/cm$^3$. The consistency of the snow, however, more closely resembled heavy freezing fog, and failures also resembled those observed during freezing fog tests.

Snow particles accumulated on the overhead structure and cables in the facility, to develop large, loose formations that tended to break away and fall onto the test set-up below.

## 6.4 Evaluation of Aeroflot Fluid

Prior to the 1997-98 test season, APS was provided with a 200 L barrel of aircraft deicing fluid from Aeroflot. No documentation or fluid specifications were provided with the barrel of fluid. Aeroflot personnel suggested that the fluid be used for anti-icing purposes and that it was similar to Type II or Type IV. APS made several requests for fluid documentation prior to testing, but with no results.

Aeroflot fluid tests were conducted in natural snow conditions at the APS Dorval Airport test facility. The tests were performed according to the procedures outlined in Appendix B.

During transfer of this fluid from the barrel to smaller, more manageable containers, the fluid was observed to be unthickened. The fluid viscosity appeared similar to that of a Type I fluid. Eighteen holdover time tests were conducted in natural snow with the Aeroflot fluid. The failure time versus rate of precipitation data are plotted in Figure 6.13. Failure times were similar to commercial Type I tests conducted on the same day, and were all above the six-minute lower holdover time value for Type I.

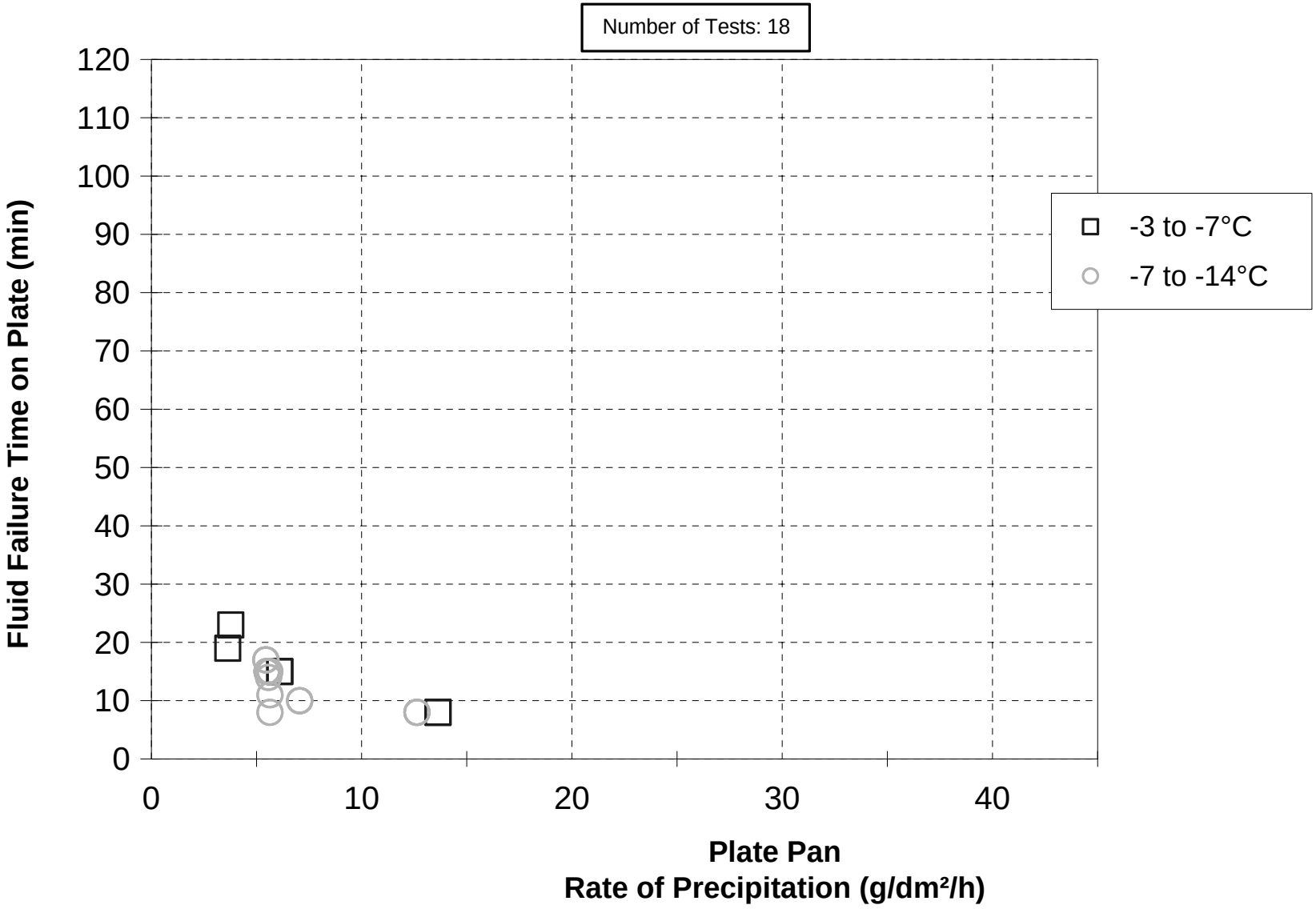
Testing of the fluid was limited to natural snow conditions, since it was determined that it was undoubtedly a deicing fluid.

FIGURE 6.13

## EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

AEROFLOT

NATURAL SNOW CONDITIONS




cm13380/report/hot_subs/AEROFLOT.FRG

## 6.5 Influence of Plate Slope on Holdover Time

A series of supplementary tests were conducted at NRC's CEF in Ottawa to determine the effect of plate slope variation on the holdover time of Type IV fluids. Standard test procedures for holdover time tests require that test surfaces be inclined at a 10° slope. The test stands employed by APS in holdover time testing are verified prior to each test session using an inclinometer to ensure accurate 10° inclination on each plate.

The procedure used for this series of tests appears in Appendix C. The inclination of test surfaces was adjusted by placing washers under the plates and verifying the subsequent slope with the inclinometer. For each fluid, tests were to be conducted on:

- Plates at reduced inclination (8° or 9°);
- Plates at standard inclination (10°); and
- Plates at increased inclination (11° or 12°).

Slope tests were performed on two separate occasions in light freezing rain, at temperatures of -3°C and -10°C. The results of these tests are shown in Figures 6.14 and 6.15.

Figure 6.14 shows the results of tests conducted on one occasion in light freezing rain at -10°C using Union Carbide Ultra+ fluid in its neat concentration. Two standard holdover time tests (10° slope) were performed to provide the baseline for comparison. Two tests were conducted alongside the standard tests, one on a plate inclined at 9°, the other on a plate inclined at 11°.

The tests conducted on the standard plates had identical holdover times of 32 minutes. The test conducted on the plate inclined at 11° had a holdover time of 30 minutes, and the plate at 9° had a holdover time of 35 minutes.

The results of the second set of slope tests are shown in Figure 6.15. Tests were performed in light freezing rain at -3°C, using four different Type IV fluids: Kilfrost ABC-S 50/50, SPCA AD-480 50/50, Octagon MaxFlight Neat, and Union Carbide Ultra+ Neat.

Four holdover time tests were completed using Kilfrost ABC-S 50/50 fluid, two on plates inclined at 10°, one at 8° and one at 12°. The average holdover time of the plates sloped at 10° was 11.5 minutes. The plate inclined at 8° had a holdover time result of 14 minutes, which represents a 22 percent increase over the standard test. The plate inclined at 12° failed in 10 minutes, a reduction of 15 percent over the 10° plate failure time.

FIGURE 6.14

## EFFECT OF SLOPE ON HOLDOVER TIMES

LIGHT FREEZING RAIN AT -10°C

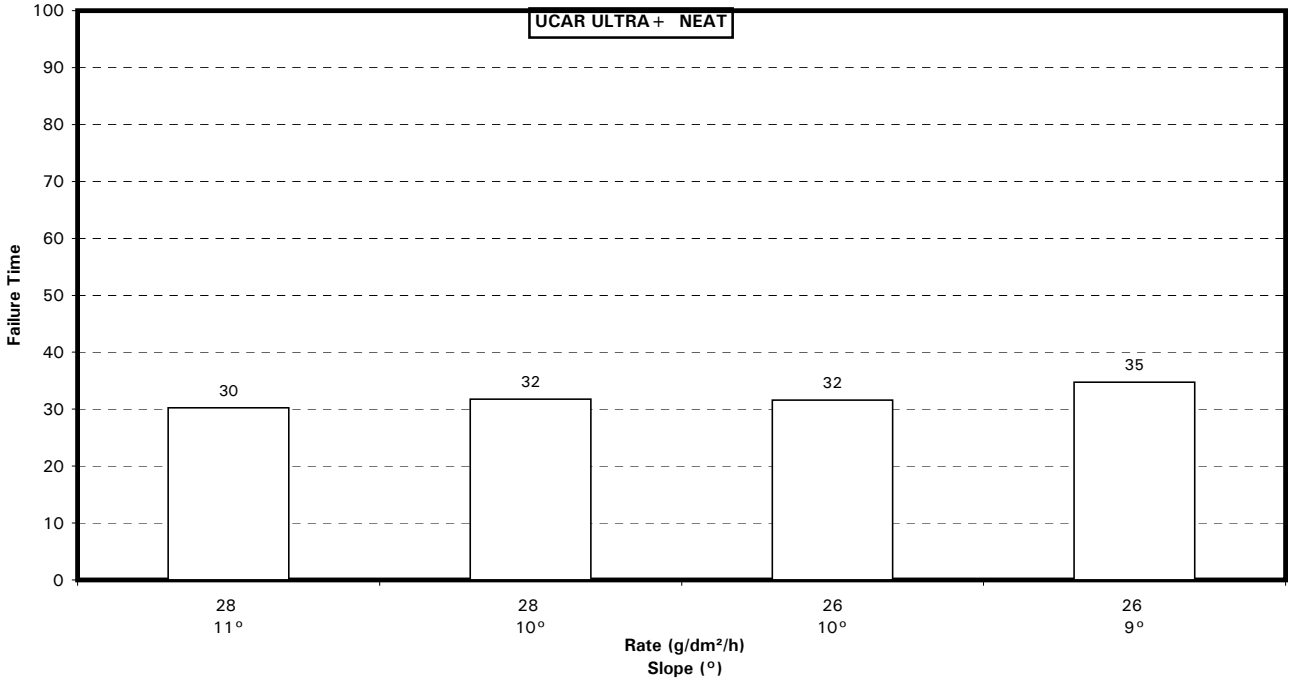
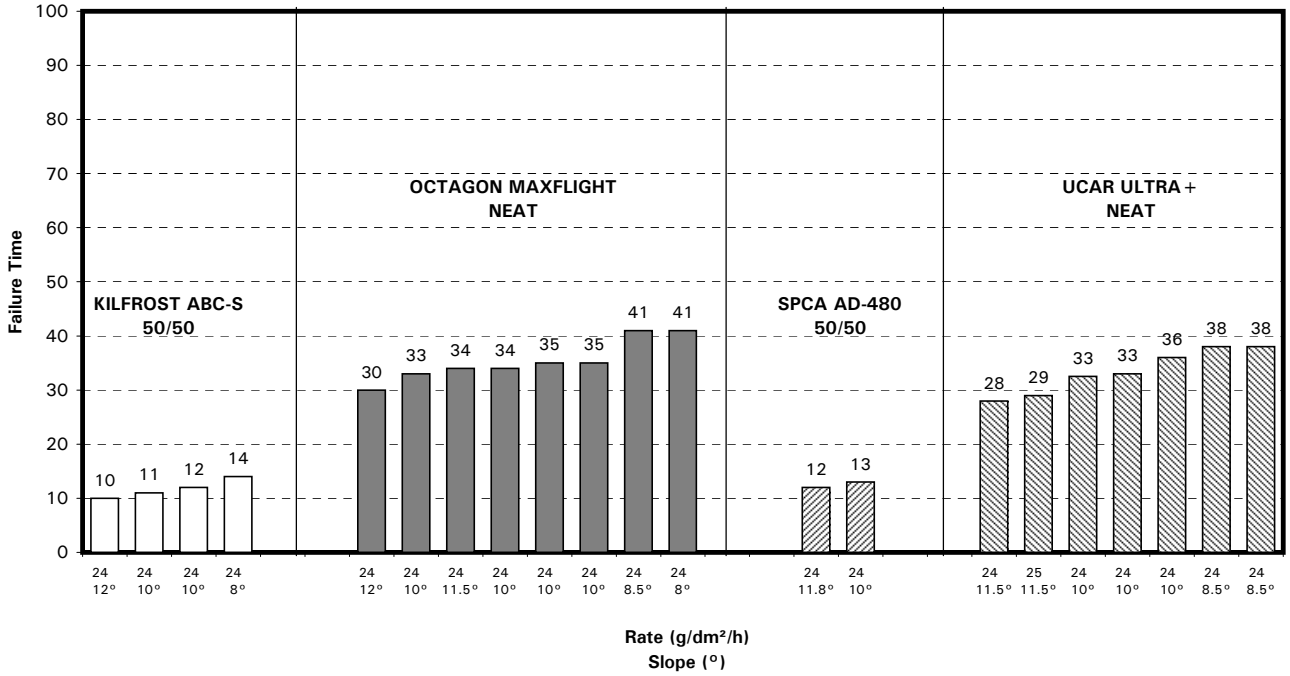



FIGURE 6.15

## EFFECT OF SLOPE ON HOLDOVER TIMES

LIGHT FREEZING RAIN AT -3°C



Only two tests were completed with SPCA AD-480 50/50 fluid, one inclined at 10°, the other at nearly 12°. The 12° inclined plate failed one minute prior to the standard plate, which, in this case, translates into an 8 percent decrease in holdover time.

Eight tests were conducted with Octagon fluid in its neat concentration, including four with 10° slopes, and one at each of following inclinations: 8°, 8.5°, 11.5°, and 12°. The standard tests (10° plates) had an average failure time of approximately 34 minutes. Tests on plates with reduced inclination had identical failure times of 41 minutes, an increase of 20 percent of the standard inclination plates. Plates with raised slopes failed on average two minutes sooner than the standard plates, which represents a 6 percent reduction in holdover time.

The final series of six tests were performed with neat Union Carbide Ultra+ fluid, including three on plates inclined at 10°, two on plates inclined at 8.5°, and one on a plate inclined at 11.5°. The average failure time for the plates at standard inclination was 34 minutes. The tests conducted on plates inclined at 8.5° had identical failure times of 38 minutes, which is equivalent to a 12 percent increase in holdover time. The plate inclined at 11.5° failed in 28 minutes, equivalent to a 21 percent reduction in holdover time.

### 6.5.1 Effect of Surface Finish on Holdover Time

A preliminary test was also performed to examine the influence of plate finish on Type IV fluid holdover time. A Type IV fluid was poured on two flat plates, one weathered (typical plate used in APS tests) with an average surface roughness of 0.4 microns, the other polished (new plate) to an average surface roughness of 0.2 microns. Both plates were then exposed to light freezing rain at an ambient air temperature of -8°C. The weathered plate failed in 32 minutes, while the polished plate failed in 30 minutes, representing a 7 percent difference in holdover time.

## 6.6 Influence of Application Procedure on Holdover Time

A series of tests was conducted at the NRC's CEF aimed at determining the effect of the fluid application method on the holdover time of Type IV fluids. The standard procedure for Type IV fluid application is to pour fluid onto the flat plates at ambient temperature from a manageable container until the entire test surface is covered by a uniform film of fluid. This procedure is described in Attachment B-II (Appendix B).

Anti-icing fluids are generally applied onto aircraft surfaces using vehicles equipped with fluid reservoirs, pumps, and a fluid delivery system with a specially designed nozzle. The Type IV fluid is subjected to shear when pumped through the nozzle and the fluid viscosity may be temporarily or permanently reduced, depending on which fluid is sprayed. Lower fluid viscosities tend to affect the holdover time. To possess fluid spraying capabilities, a mobile Type IV fluid sprayer (see Photos 6.5 and 6.6) with a Task Force Tips nozzle, was assembled during the past test season and used in the fluid application for these tests (see Transport Canada report TP 13314E (6)).

Fluid application tests were initiated in April 1998, but were rescheduled for July 1998, due to time constraints. The procedures for both series of tests are included in Appendix C. Tests were performed in light freezing rain at a temperature of -3°C.

The test plan consisted of spraying a Type IV fluid on two plates, and pouring the same fluid on two more plates. The plate holdover times were then compared. The results of fluid application tests appear in Figure 6.16.

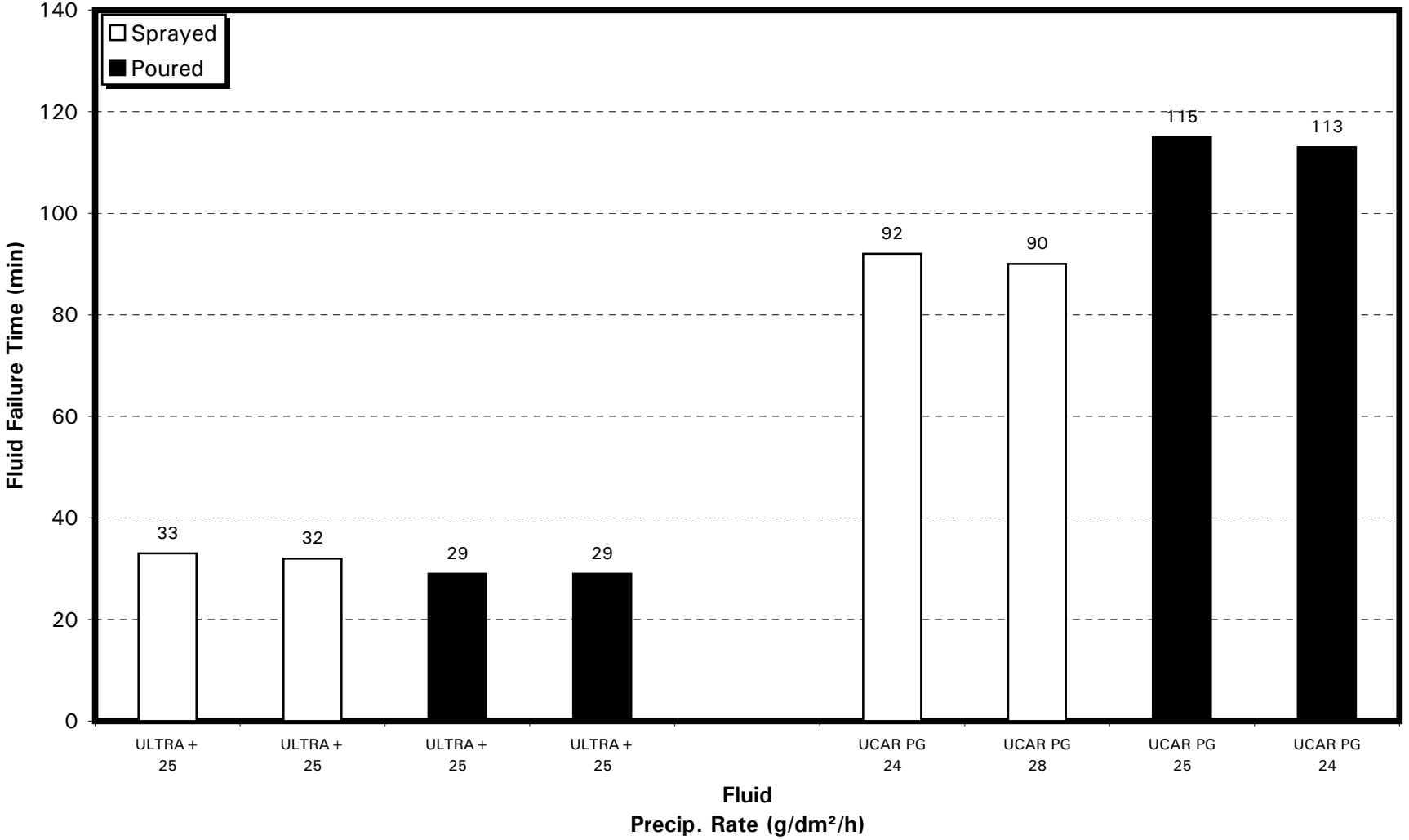
The holdover time comparison for Union Carbide Ultra+ Neat fluid reveals that the sprayed fluid lasted slightly longer on the plate than did the poured fluid.

A large difference in holdover time was observed with Union Carbide PG AAF, where the plates coated with poured fluid lasted on average 25 percent longer than the plates coated with sprayed fluid. The PG AAF was noted to be an extremely viscous fluid, and the performance was undoubtedly affected by the shearing of the fluid. Union Carbide PG AAF is not a certified fluid.

FIGURE 6.16

# APS SPRAYER TESTS

## LIGHT FREEZING RAIN AT -3°C






cm1380/report/hot_subs/SPRAYER
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## 6.7 Influence of Type IV Fluid Temperature on Holdover Time

Supplementary tests were conducted at NRC's CEF to determine the effect of fluid temperature on the holdover time of Type IV fluids.

The standard procedure for Type IV fluid application on flat plates for holdover time testing is shown in Attachment B-II of (Appendix B). Using this method, Type IV fluids are poured on the flat plates at ambient temperature.

Heated Type I deicing fluids are normally used to remove ice or snow contamination from aircraft surfaces prior to the application of a Type IV anti-icing fluid in two-step operations. Because of the design of fluid tankage on certain older deicing vehicles, Type I and Type IV fluid reservoirs are sometimes side by side sharing a common metal wall, which results in a heat transfer to from the heated Type I tank to the Type IV tank. The Type IV fluid would then be applied to the aircraft surfaces at greater than ambient temperatures. This situation is believed to be common in the industry. This scenario was also studied in a preliminary series of thickness tests conducted last year (see Transport Canada report TP 13131E (1)). The heated Type IV fluid film thickness measurements showed reductions up to 80 percent relative to those for unheated fluids. These observations stimulated the conduct of holdover time tests using heated Type IV fluids.

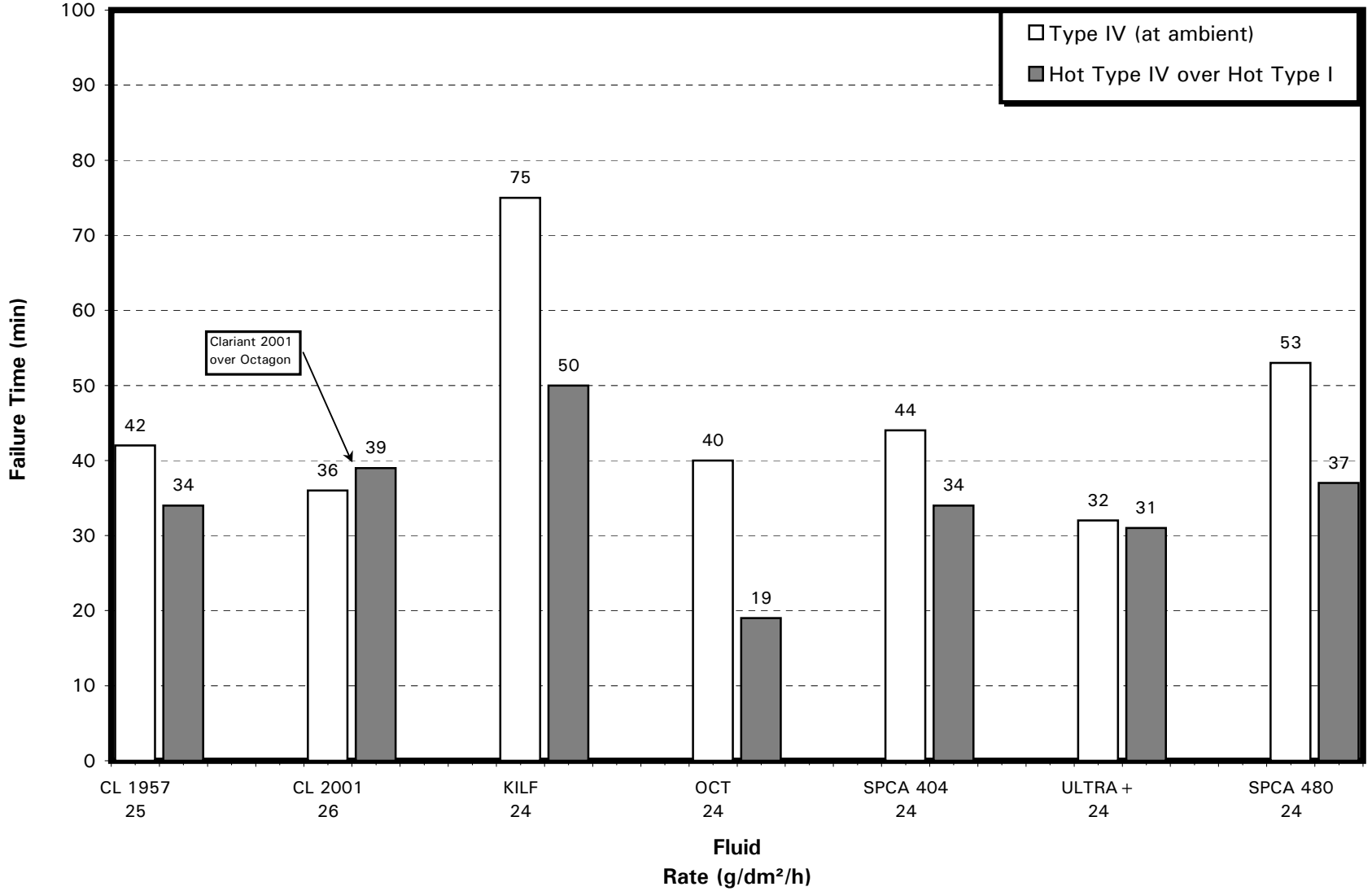
The procedure used in heated fluid tests is shown in Appendix C. As a baseline for comparison, one standard holdover time test was performed with each Type IV fluid at ambient temperature. As well, one holdover time test was conducted with each Type IV fluid (heated to 40°C) poured on top of the standard Type I fluid (heated to 80°C) from the same manufacturer. In the case of Clariant Type IV tests, Octagon Type I fluid was used as the first-step fluid since no Clariant Type I was available. Results of the heated versus ambient Type IV tests are compared in Figure 6.17.

Generally, the holdover times of the heated Type IV fluids are inferior to those of the ambient Type IV fluids. Kilfrost ABC-S, Octagon MaxFlight, and SPCA AD-480 showed the greatest reductions in holdover time (up to one half the standard holdover time). However, the heated Clariant MPIV 2001 plate actually saw an increase in holdover time compared to the ambient plate.

FIGURE 6.17

# EFFECT OF FLUID TEMPERATURE ON HOLDOVER TIMES

## LIGHT FREEZING RAIN AT -3°C






cm1380/report/hot_subs/EFF_TEMP
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## 6.8 Influence of Wind on Holdover Time

An exploratory series of tests was conducted at NRC's CEF aimed at determining the effect of wind on the holdover times of Type I and Type IV fluids. An attempt was made to achieve the same precipitation rate between two comparable tests.

Wind was generated using two large constant-speed fans positioned at distances that would provide the required wind speeds. The wind speed just above the test stand (1 m height) was measured using a hand-held anemometer.

The test consisted of pouring fluids onto flat plates, mounted on a test stand, and measuring the holdover times of the fluids when subjected to light freezing rain conditions (25 g/dm$^2$/m) at -3°C. In total, two runs were conducted using four different fluids. The first run was conducted on eight plates with the test stand positioned into a 10 km/h wind. The second run was conducted on the same plates in calm conditions. The results of the two runs are shown in Figure 6.18.

In the case of Type IV ABC-S 50/50 and Union Carbide Type I XL54 fluids, a one-minute reduction in holdover time was observed in all tests conducted with a 10 km/h wind, which is equivalent to a 9 percent reduction in holdover time for the Kilfrost fluid and a 20 percent reduction for the XL54 fluid. Since Type I fluid is applied warm, the fans may have accelerated plate cooling and failure rate.

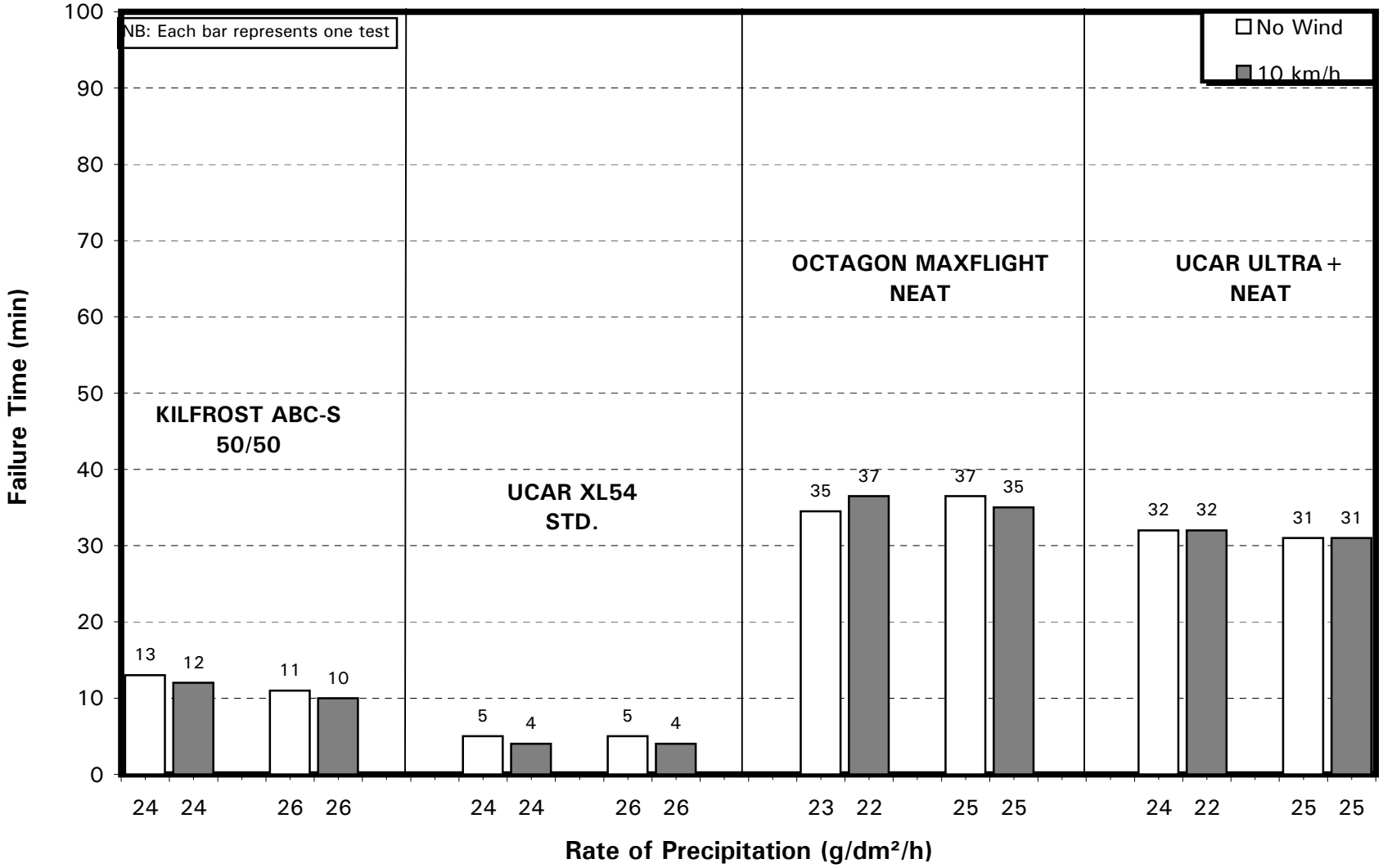
The same pattern did not occur for tests conducted with Type IV neat fluids. The failure times of the two plates conducted with wind using Ultra+ are identical to the no-wind plates. The results of the Octagon plates with and without wind are similar.

Due to the insufficient amount of data collected, no concrete conclusions can be made on the influence of wind on fluid holdover time.

FIGURE 6.18

# EFFECT OF WIND ON HOLDOVER TIMES

## LIGHT FREEZING RAIN AT -3°C



## 6.9 Influence of Fluid Viscosity on Holdover Time

It was decided at the Montreal meeting in November 1997, that low viscosity fluid samples should be tested in future holdover time tests as they represent the lowest viscosity to be shipped by the manufacturer and/or the lowest viscosity in the field. As a result, APS requested that the fluid manufacturers ship samples representative of the lower end of the production viscosity range for 1997-98 holdover time test purposes.

Following several holdover time sessions in natural snow, it was observed that holdover times for one Type IV fluid were below those obtained in previous years using the same fluid. It was later discovered that the samples provided to APS had viscosity levels well below the production specification range for this fluid. Prior to the start of testing in simulated conditions at NRC's CEF, APS requested that manufacturers provide mid-range viscosity samples for these tests. Not all manufacturers complied.

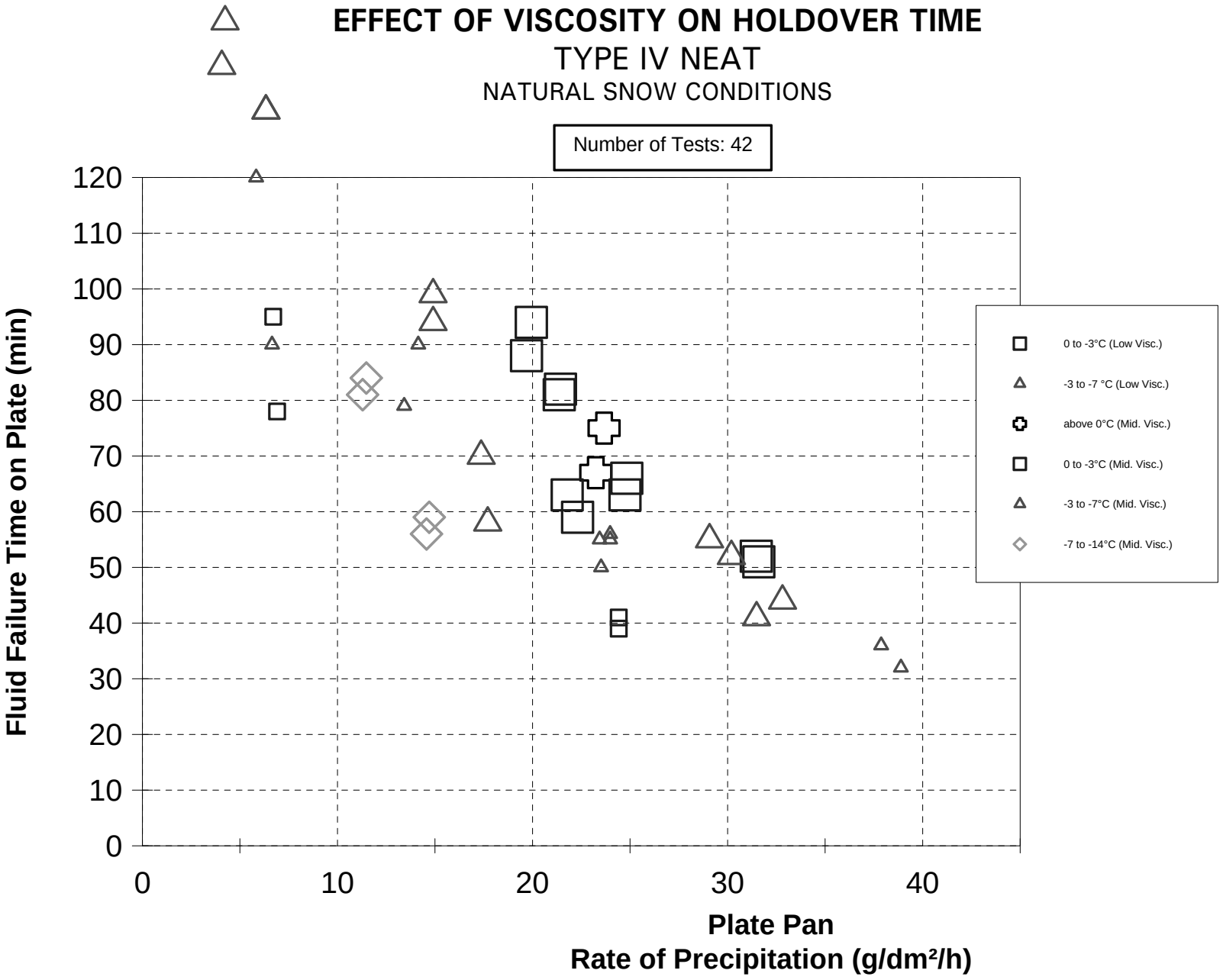
The natural snow holdover time results, obtained in previous years using a mid-range viscosity sample, were compared to the data acquired in 1997-98 with the low viscosity sample, and are shown in Figure 6.19. In general, the mid-range viscosity fluid outperformed the low viscosity fluid. Due to a lack of 1997-98 data points below -7°C, no holdover time comparisons can be made for this temperature range.

The availability of fluid samples from the same manufacturer with different viscosities also allowed APS to conduct comparative holdover time tests in simulated conditions. The results of one set of such tests, conducted in light freezing rain conditions, are shown in Figure 6.20.

The mid-range viscosity fluid (neat concentration) displayed substantially superior performance to that of the low viscosity fluid at -3°C. In fact, the holdover time of the mid-range viscosity fluid was 80 to 120 minutes, while the holdover time range of the low viscosity fluid was 50 to 70 minutes (a 40 percent reduction). This result was not unexpected, since failures for this fluid brand normally occur as a result of dilution at this temperature. The low viscosity fluid flowed more freely, and as a result, was prone to more rapid dilution.

The situation at -10°C was considerably different. At this temperature and in these conditions, the fluid did not flow so freely, and fluid failure occurred when ice was resting in the top layers of the fluid. Failure normally initiated when fluid at the bottom of the plate began to *dam*, due to a reduced rate of flow, and progressed upward. In this case, the low viscosity fluid outperformed the mid-range viscosity fluid, because the low viscosity fluid flowed more easily, and the damming of fluid at the bottom of the plate

FIGURE 6.19



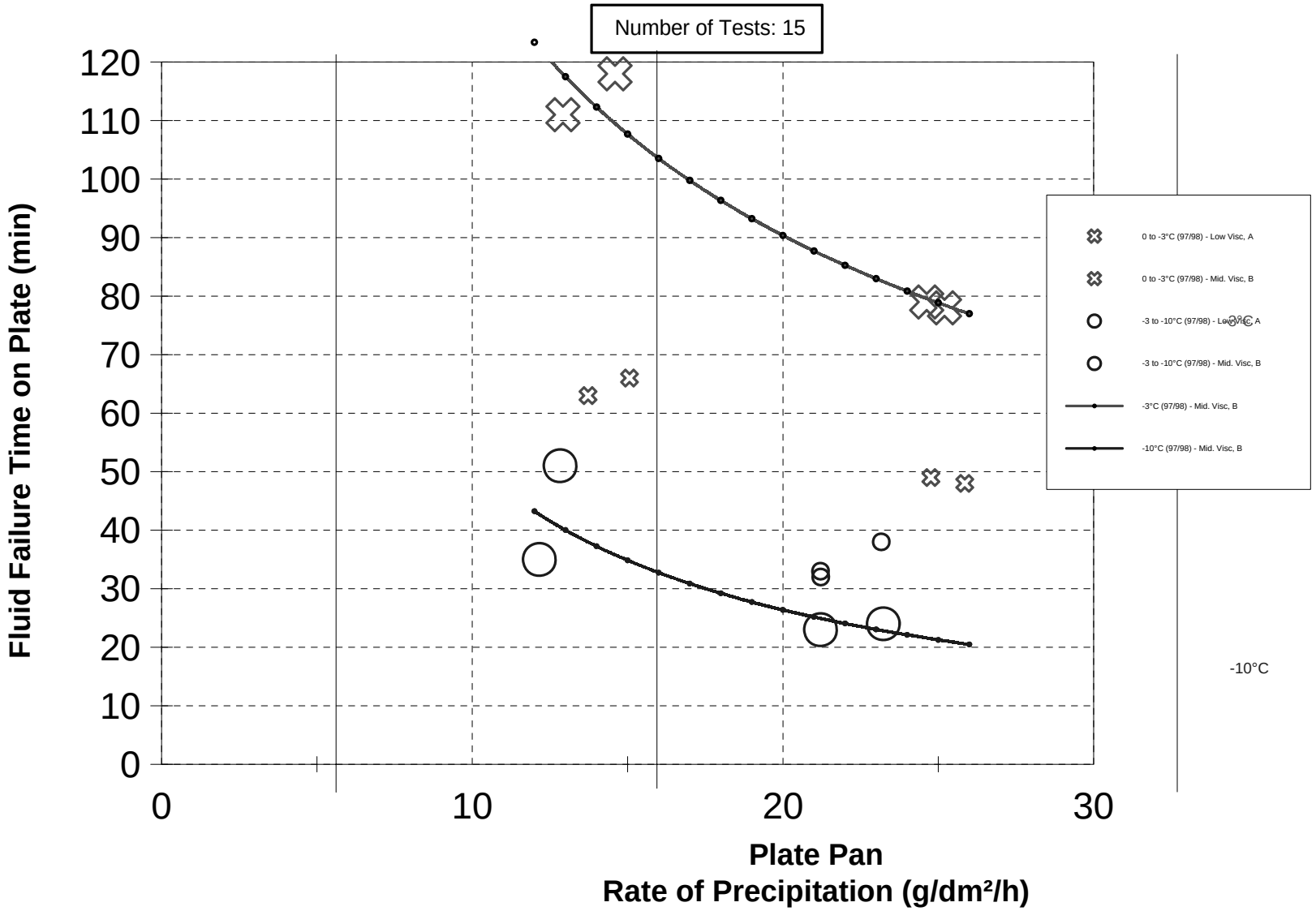

cm1380/report/hot_subs/968KIL_4.GRF

FIGURE 6.20

**EFFECT OF VISCOSITY ON HOLDOVER TIME**

TYPE IV NEAT

SIMULATED LIGHT FREEZING RAIN




cm1380/report/hot_subs/ZR_KIL4N.GRF

was delayed. The low viscosity fluid data collected near the upper precipitation rate limit at -10°C had holdover times approximately 40 percent longer than those of the mid-range viscosity fluid.

These tests demonstrate that fluid viscosity has a significant influence on fluid holdover times.

Differences in formulations among the various Type IV fluids are responsible for how the fluid rheologies vary in response to lower temperature and dilution factors, and are largely responsible for the different failure mechanisms observed.

Any given fluid may exhibit inferior or superior performance relative to other fluids, depending on the prevailing conditions and the fluid's rheological profile during tests.

## 6.10 Escaped Precipitation: What and Why?

During tests conducted to document the appearance of fluid failures in freezing drizzle and light freezing rain, it was observed that a significant fraction of the precipitation impinging on a test plate actually bounced off or rolled off the fluid-treated surface right after impact.

The fraction of precipitation that makes contact, but leaves the surface by either avenue (rolling or bouncing), is referred to as "escaped precipitation".

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Photo 6.1
**Test Setup showing Reduced Visibility during Snow Making**

Photo 6.2
**Snow Spray Bar in Operation**

Photo 6.3
**Test Setup with Flat Horizontal Plates on Pedestals**

Photo 6.4
**Accumulated Snow Following Test**

Photo 6.5
**Mobile Type IV Sprayer**

Photo 6.6
**Task Force Tip Nozzle**

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# 7. CONCLUSIONS

## 7.1 Holdover Time Determination

### 7.1.1 Type IV Fluids

The 1997-98 holdover time test program concentrated on the determination of holdover times for five new Type IV fluids, as well as the retesting of three certified Type IV fluids. The results of these tests revealed a wide variation in performance properties among the different fluid brands. In the determination of fluid holdover times, the data for each fluid and each cell of the tables were subjected to a regression analysis. From the results of the analyses, the SAE Type IV fluid holdover time table was devised, wherein each cell in the table contains the holdover times of the poorest performing fluid brand(s). Due to the widely varying performance of the Type IV fluids tested, *fluid-specific* holdover time tables were developed. Only the categories of snow, light freezing rain, and freezing drizzle were selected to take advantage of enhanced holdover times for individual fluids. The holdover times in the remaining precipitation categories assume values that are identical to those contained in the SAE Type IV fluid table.

i) Snow

Comparison of the Type IV fluid holdover times approved for operational use in 1997-98 in natural snow to those appearing in this year's (1998-99) SAE Type IV table shows that most of the holdover times remain virtually unchanged. In one cell (75/25 fluid, -3°C to -14°C), the SAE upper holdover time was reduced by five minutes, from 30 to 25 minutes.

The need still exists to firm up the Type IV fluid data base at colder temperatures, particularly at the precipitation rate limits. The conduct of snow tests in simulated conditions using a snow maker would alleviate this problem, allowing tests to be performed at controlled temperatures with specific rates of precipitation.

ii) Freezing Drizzle

Only two changes were made to the holdover times appearing in the 1997-98 SAE Type IV table in freezing drizzle. Both changes occurred in the -3°C to -10°C temperature range, and in both cases, the lower limit holdover times were reduced slightly.

iii) Light Freezing Rain

Holdover time changes were made to only one cell in the SAE Type IV table in light freezing rain conditions. The changes occurred in the -3°C to -10°C temperature range for neat fluid, and both the upper and lower holdover time limits were reduced by 15 minutes, from 30 to 45 minutes, to 15 to 30 minutes.

iv) Freezing Fog

The holdover time values in the freezing fog cells of the Type IV fluid-specific tables contain the SAE holdover times. Since it was decided in Vienna that the lower fog precipitation rate limit of 2 g/dm$^2$/h was not indicative of low rate natural fog, the upper holdover times in the freezing fog cells were adopted from last year's 1997-98 SAE Type IV fluid table. Two slight reductions were made to the lower limit holdover times, one for neat fluid in the 0°C to -3°C temperature range (from 140 minutes to 120 minutes), the other for 75/25 fluid in the -3°C to -14°C temperature range (from 35 minutes to 30 minutes).

v) Rain on a Cold-Soaked Wing

No changes were made to the SAE holdover times in the rain on a cold-soaked wing condition.

### 7.1.2 Type III Fluids

No Type III fluids were available during the past season and therefore no Type III holdover time testing was performed. Furthermore, the current Type III holdover time table is not valid since its numbers were generated using a fluid that is no longer commercially available.

### 7.1.3 Type I Fluids

Type I fluid holdover times remain unchanged from those used during the 1997-98 winter.

### 7.1.4 Type II Fluids

Two Type II fluid holdover times were reduced to match the Type IV fluid holdover times, because no Type II holdover time may exceed the corresponding Type IV fluid holdover time. The values were both

reduced from 30 minutes to 25 minutes; one was for snow and the second for freezing drizzle.

## 7.2 SUPPLEMENTARY TESTS

### 7.2.1 Evaluation of Recycled Fluids

- Holdover time tests conducted on propylene and ethylene recycled fluids manufactured by Inland Technologies showed them to exhibit performance levels equivalent to Type I fluids;

- The holdover times of Type IV fluids are generally reduced slightly when applied over an undercoat of Type I or recycled fluids; and

- Both recycled fluids also appear compatible with commercial Type IV fluids when intended as first-step fluids in a two-step application. No single undercoat fluid appeared to have a significantly worse effect on Type IV fluid holdover time in all conditions.

### 7.2.2 Evaluation of the Snow-Making Capability of NRC's CEF

The evidence from these brief tests indicates that the current ability of NRC's CEF to produce snow does not offer the level of controllability required to satisfy the experimental conditions. Further, the uncertainty of snow production at warmer temperatures such as -3°C is a concern.

### 7.2.3 Aeroflot Fluid

Aeroflot fluid holdover time tests were conducted in natural snow conditions only, and the failure times for the Aeroflot fluid were similar to commercial Type I tests conducted on the same day.

### 7.2.4 Influence of Plate Slope on Holdover Time

Plate slope has a notable effect on the holdover time of a given fluid. Standard holdover time tests are conducted on plates inclined at a 10° slope. When tests were performed on plates with a slight increase or decrease in plate inclination, for every 1° change in slope resulting holdover times were increased or decreased over the standard tests by as much as 10 percent.

### 7.2.5 Influence of Application Procedure on Holdover Time

The method of fluid application appears to affect the holdover time of Type IV fluids. Standard holdover time tests are conducted using poured fluids on flat plates. Fluids are applied to aircraft wings through pumps and hoses, which inevitably shear the fluids. In the comparative tests conducted, the holdover time of the sprayed fluids increased or decreased in comparison to the holdover time of the poured fluids, depending on the fluid tested. Further testing is required to obtain any conclusive results.

### 7.2.6 Influence of Type IV Fluid Temperature on Holdover Time

Generally, the holdover times of heated Type IV fluids are inferior to those of ambient Type IV fluids. For certain fluids, holdover times of heated fluids were lowered by more than 50 percent.

### 7.2.7 Influence of Wind on Holdover Time

Tests were conducted to determine the effect of wind on the holdover times of Type I and Type IV fluids. The results showed that holdover times were slightly reduced when plates were exposed to a 10 km/h wind in the tests conducted with Type I and Type IV 50/50 fluids. In tests using neat Type IV fluid, the holdover time results both with and without wind exposure were similar. It should be noted that these conclusions were drawn from a limited amount of data.

### 7.2.8 Influence of Fluid Viscosity on Holdover Time

Tests conducted using low and mid-range viscosity samples from the same fluid manufacturer showed that viscosity does affect the holdover time of a fluid. A high viscosity sample is more resistant to dilution and will generally outperform a low viscosity sample, except at colder temperatures (for certain fluids) where the fluid manufacturer's high viscosity sample did not flow as freely, and failures occur in the upper fluid layers.

# 8. RECOMMENDATIONS

This section provides a series of detailed recommendations based on the test results and conclusions.

## 8.1 Holdover Time Tests

It is recommended that:

- An artificial snow-making machine (possibly the system in development by NCAR) be evaluated; based on the evaluation, the system could be used for future snow holdover time testing;
- Future holdover time tests be conducted with all fluid types using the most restrictive temperature in each cell, and fluid samples from both the upper and lower end of the manufacturer's production viscosity range;
- Fog deposition measurements be conducted outdoors to determine the range of deposition rates that occur naturally in fog;
- Further tests in simulated freezing fog be conducted to evaluate upper holdover times at the lower precipitation rate limit, once an appropriate rate has been determined;
- Any new Type IV fluids be evaluated over the entire range of conditions of the holdover time tables; and
- The holdover time table for Type III fluids be re-evaluated if new Type III fluids become available for testing in 1998-99.

## 8.2 Test Procedures and Equipment

### 8.2.1 Procedures

- Measure and record viscosity of all Type IV fluids prior to testing; and
- Test Type IV fluids at different shear levels to determine the viscosity's effect on holdover time.

### 8.2.2 Equipment

- Further testing of the Spar/Cox ice detection camera should be implemented to compare its response to visual failure observations and the records from other sensors;

- A shed should be used to store test fluids; and

- Due to difficulties related to temperature data collection using thermistors mounted on the cold-soak boxes, alternative methods for monitoring box surface temperatures need to be investigated.

## 8.3 Supplementary Tests

### 8.3.1 Evaluation of Snow-Making at NRC's CEF

It is recommended that other systems for producing snow at controlled and predefined rates be explored, perhaps for installation in the current cold chamber. Relative cost effectiveness of alternate systems should be a factor in the evaluation.

### 8.3.2 Influence of Application Procedure on Holdover Time

Since the results of fluid application tests varied depending on the fluid tested, it is recommended that further tests to examine the effect of the fluid sprayer on holdover time be conducted for each Type IV fluid made available for testing.

### 8.3.3 Influence of Wind on Holdover Time

Tests aimed at determining the effect of wind on fluid holdover times were conducted using 10 km/h winds only. Future tests should be performed using a variety of wind speeds, test conditions, and fluids.

### 8.3.4 Influence of Fluid Viscosity on Holdover Time

Fluid viscosity appears to have a substantial effect on fluid holdover time. In the future, all fluid manufacturers should ship fluids representative of the manufacturer's lowest recommended on-wing viscosity for holdover time test purposes to allow equal evaluation of all fluids.

The low viscosity samples would yield more conservative holdover times in most conditions. Fluid samples representative of the high end of the manufacturer's production viscosity range should also be tested, especially in colder temperatures, since it has been observed that the high viscosity sample fails sooner for certain fluids.

### 8.3.5 Escaped Precipitation

One test that might be interesting to conduct in the future is to measure the test quantity of escaped precipitation. The data could be used to determine more precisely just what quantities of precipitation can actually be absorbed prior to failure in any test condition, and also to provide a measure of how much of the applied fluid drains from the plate surface.

Tests should be carried out with specially designed receptacles mounted just ahead of the lower flat plate edge to capture and subsequently weigh the fraction. A measure of the extent of fluid pickup by this escaped fraction would be determined from refractive index measurements of the collected fractions.

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## REFERENCES


1. D'Avirro, J., Peters, A., Hanna, M., Dawson, P., Chaput, M., *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1996-97 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, November 1997, TP 13131E, 232.

2. World Meteorological Organization, 1983: *Guide to Meteorological Instruments and Methods of Observation*.

3. American Meteorological Society, *Glossary of Meteorology, 1st ed., AMS, 1959.h*

4. American Meteorological Society, *Glossary of Meteorology WSDH #7 Manual of Surface Weather Observations* (MANOBS).

5. Naughton, I.I., and Wyat, J.G., *The Dye-Stain Technique for Measuring the Size of Rain Drops,* Royal Aircraft Establishment, July 1965, Report No. 65136.

6. Chaput, M., Dawson, P., D'Avirro, J., Hanna, M., Ruggi, E., Adam, S., *Research on Aircraft De-icing Operations for the 1997-98 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 1998, TP 13314E, 132.

7. Dawson, P., D'Avirro, J., *Validation of Methodology for Simulating a Cold-Soaked Wing*, APS Aviation Inc., Transportation Development Centre, Montreal, October 1996, TP 12899E, 118.

8. Dawson, P., D'Avirro, J., *Evaluation of Fluid Thickness to Locate Representative Surfaces*, APS Aviation Inc., Transportation Development Centre, Montreal, October 1996, TP 12900E, 109.

9. D'Avirro, J., Foo, H., Guy, C., Hoppe, A., McConachie, E., Spicer, S., *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1991-1992 Winter*, Aviation Planning Services Ltd., Transportation Development Centre, Montreal, August 1992, TP 11454E, 83.

10. Bilgen, E., Chan, G., Cleary, C., D'Avirro, J., Foo, H., *Aicraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1992-1993 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, October 1993, 11836E, 122.

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

12. Dawson, P., Hanna, M., Chaput, M., *Aircraft Deicing Fluid Freeze Point Buffer Requirements: Deicing Only and First Step of Two-Step Deicing*, APS Aviation Inc., Transportation Development Centre, Montreal, December 1998, TP 13315E, 168.

# 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 arrangents 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 mesurements and records of environmental conditions pertinent to the tests, measurements shall be made duing 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 $10^0$C ($18^0$F) for Type I, and $7^0$C ($13^0$F) 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 observervations.

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.

## 6. ROLE OF OTHER PARTIES

6.1 Airlines

Agreements as and when needed will be made by Transport Canada with the following airlines: Air Canada, American Airlines, Comair, Canadian Airlines International Ltd., US Airways and Canadian Regional Airlines Ltd. to provide aircraft, equipment and facilities for conduct of tests as outlined in the 'Detailed statement of work'.
Direct contact with appropriate personnel of the airlines is encouraged, however TDC shall be advised of all such contacts.

## 7. SPECIAL INSTRUCTIONS

7.1 Publicity

The contractor is encouraged to publicize his research: however all publicity is to be coordinated with the Project Officer, and credit must be given to the project sponsor, Transport Canada, as instructed.

7.2 Presentation Material and other Illustrative Deliverables

Suitable opportunities for visual material creation should be sought during the course of the contract in the form of slides, photographs, drawings or videotapes, illustrating the concepts and technical equipment being developed or tested and shall be delivered to TDC as determined by the

project officer. At the conclusion of the work, and no later than the submission of the final reports, a slide and/or videotaped presentation on the work carried out and on the results achieved shall be delivered to TDC.

7.3 Intellectual Property Rights

The intellectual property rights for the scientific data generated under this contract which do not involve proprietary information shall be vested in the Crown. The objective of the work includes the development of new knowledge on the subject matter; this knowledge will reduce the risk inherent in air transportation, and it is therefore intended that it be made freely available, subject to the restriction precluding disclosure of proprietary information given above, to the aviation industry and to the suppliers of materials and services to the industry.

## 8. PROJECT ADMINISTRATION

The Executive Director, Transportation Development Centre (TDC) has appointed Barry Myers to manage the project on behalf of TDC. A progress review committee will be convened to counsel the Project Officer, to monitor progress and comment on the work.

## 9. PROJECT CONTROL

The project shall be controlled by a CPM, PERT or equivalent responsibility assignment and scheduling method. Budgets for each project element should be prepared at the start of the project and monitored regularly to ensure resources available are compatible with estimates to complete the work.

## 10. REPORTING REQUIREMENTS

10.1 Progress Reports

To facilitate the management of the project, a minimum of three copies of the progress reports shall be submitted on a monthly basis to the TDC Project Officer with a copy to the DSS Science Procurement Manager. These reports shall be short and concise, not exceeding two typewritten pages; the format of the progress report shall be as follows:

10.1.1

A list of all persons actively engaged on the project and their functions.

10.1.2 Current status of the work for each numbered task in paragraph 5 "Detailed Statement of Work", containing:

a) The percentage of work completed,
b) Start and end date of each activity,
c) The actual cost of each completed task, and
d) Whether the project will be completed within the established schedule and financial limitation.

10.1.3 Work accomplished since the period last reported.

10.1.4 Problem areas.

10.1.5 Work to be addressed in the coming months.

10.1.6 Action required to be undertaken by TDC.

10.1.7 Contact made with outside agencies or companies, or major visits planned. Names and addresses of individuals or organizations shall be recorded and may be used to disseminate information at the end of the contract.

10.2 Final Reports and Publication Standards

Separate final reports shall be issued for each area of activity consistent with the project objectives.
All reports with the exception of progress reports and interim reports shall be prepared for publication in accordance with the principles of "Guidelines for TDC Report Format" and are thus subject to the following requirements:

10.2.1 Metric units (S.I.) shall be used in all reports (Unless special exception is warranted).

10.2.2 Reports shall be prepared in English or French.

10.2.3 Reports **must** include a summary in English and French, either as a section in the report or as a separate document.

10.2.4 A bilingual Publication Data Form (PDF) **must** be included in every report. Blank forms will be supplied by TDC;

10.2.5 Translation shall be provided in the case of :

a) The PDF by TDC;
b) The summary by TDC;
c) The report by TDC;

10.3 Publication Schedule

10.3.1 Reports shall be submitted in accordance with the following:

a) 5 copies each of:
-Draft reports (English **or** French); and
-Publication Data Form (English **and** French) delivered **1 month** after completion of work.

b) TDC comments on draft reports to contractor within not more than **4 weeks** after receipt.

c) **50 copies** of final published reports delivered **6 weeks** after receipt of TDC's comments.

d) A camera-ready (printed on one side only and unbound) paper copy of the report including black and white glossy photographic prints and originals or good quality copies of drawings, charts, graphs etc.

e) An IBM-compatible diskette containing the entire text of the report in one file and bearing a label identifying the word processing software version used the filename and the report TP number; the diskette should be a 3.5" high density format and the software Wordperfect 5.x, formatted preferably for a HP LaserJet III printer.

10.3.2 For control purposes, all reports, except progress reports, shall be delivered to:
Office Services Supervisor
Transportation Development Centre
800 Rene Levesque Blvd. W., Suite 600
Montreal, Quebec. H3B 1X9

## 11. LIST OF EQUIPMENT

Prepare and submit to TDC a list of all equipment, material and supplies procured under the contract, as well as prototype equipment or systems constructed under the contract. This list shall be forwarded to TDC together with the draft technical report.

## 12. DISPOSAL OF EQUIPMENT

12.1 All equipment procured or constructed at the expense of TDC during the contract shall be delivered or disposed of as directed by TDC at the completion of work.

12.2 All equipment provided on loan from TDC in the course of the work will be maintained and all legal charges paid by the contractor, and furthermore such equipment shall be returned as directed by TDC.

12.3 All source code for software developed under this contract shall be delivered on magnetic media along with a hard copy program listing.

12.4 All software licenses procured at the expense of TDC during the contract shall be transferred to TDC at the completion of work unless otherwise agreed to; the arrangements necessary to accomplish this transfer shall be made with the licensee at the time of purchase.

12.5 Any software developed by a third party for use in this project must be free from any encumbrances.

# APPENDIX B

# APS TEST PLAN AND PROCEDURES FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING

CM1380.001

# EXPERIMENTAL PROGRAM
# FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING

1997-98

APS AVIATION INC.

Version 4.1

# EXPERIMENTAL PROGRAM
# FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING
1997-98

## SCOPE

This document provides the detailed procedures and equipment required for the conduct of de/anti-icing fluid holdover time tests under natural snow conditions.

## 1. OBJECTIVE

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

## 2. TEST REQUIREMENTS (PLAN)

Attachment I provides the list (not in any order) of tests to be conducted at the Dorval test site located adjacent to the Atmospheric Environment Services. These tests shall be conducted during natural precipitation conditions.

## 3. EQUIPMENT

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

## 4. PERSONNEL (See Attachment B-II)

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

For one stand

1 x Test site Leader/video
1 x End condition tester
1 x Meteo tester

For two stands

1 x Test site leader/video
2 x End condition tester
2 x Meteo

## 5. PROCEDURE

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

Several changes have been made to the procedure in Attachment B-II:

- A refined procedure for the collection of precipitation rates has been developed and is shown in Attachment B-VII.

- Precipitation rates will now be collected at 10-minute intervals, and 5-minute intervals in periods of high precipitation rates and high winds.

- At the time of plate failure ($5^{th}$ crosshair failure), the refractive index of the failed fluid at the point of failure will be recorded using a hand-held refractometer.

## 6. DATA FORM

The data forms are included with Attachment B-II. One data form was developed for the end-condition tester (Table B-1) and one data form for the Meteo/video tester (Table B-2).

ATTACHMENT B-I

# NATURAL SNOW PRECIPITATION TEST PLAN / PRIORITIES

| Temperature Range | Type 0 Standard | Type I Standard | Type I Diluted | Type II Neat | Type II 75/25 | Type II 50/50 | Type IV* Neat | Type IV* 75/25 | Type IV* 50/50 | Type III** |
|---|---|---|---|---|---|---|---|---|---|---|
| >0°C | YES | NO | NO | NO | NO | NO | YES | YES | YES | YES |
| 0 to -3°C | YES | NO | NO | NO | NO | NO | YES | YES | YES | YES |
| -3 to -14°C | YES | NO | NO | NO | NO | | YES | YES | | YES |
| -14 to -25°C | YES | YES | YES | YES | | | YES | | | YES |
| below -25°C | YES | YES | YES | YES | | | YES | | | |

* Newly formulated fluids: Hoechst, SPCA and Aeroflot

** Newly formulated Ultra+ Type III

**Legend:** NO = no tests required; YES = tests required *Shaded* = no tests required

ATTACHMENT B-Ia

## ADDITIONAL NATURAL SNOW PRECIPITATION TEST / PRIORITIES

## TYPE IV FLUIDS

| | Neat | | | | | | 75/25 | | | | 50/50 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ultra + | | Octagon | | Kilfrost | | Octagon | | Kilfrost | | Octagon | | Kilfrost | |
| | 10 g/dm²/hr | 25 g/dm²/hr | 10 g/dm²/hr | 25 g/dm²/hr | 10 g/dm²/hr | 25 g/dm²/hr | 10 g/dm²/hr | 25 g/dm²/hr | 10 g/dm²/hr | 25 g/dm²/hr | 10 g/dm²/hr | 25 g/dm²/hr | 10 g/dm²/hr | 25 g/dm²/hr |
| > 0°C | YES | YES | YES | YES | YES | NO | YES | YES | YES | YES | YES | YES | NO | YES |
| 0 to -3°C | NO | NO | NO | NO | YES | NO | YES | NO | YES | NO | NO | YES | NO | NO |
| -3 to -14°C | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | | | | |
| -14 to -25°C | YES | YES | YES | YES | YES | YES | | | | | | | | |
| below -25°C | YES | YES | YES | YES | YES | YES | | | | | | | | |

**Legend:** NO = no tests required; YES = tests required Shaded cells = no tests required

# ATTACHMENT B-II
# FLAT PLATE FIELD TEST EQUIPMENT AND PROCEDURE
1997-98 (Version 8.0)

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

## 1. SCOPE

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

## 2. EQUIPMENT

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

### 2.1 Rain/Snow Gauge

The following equipment or equivalent are recommended:

#### 2.1.1 Cake Pan or Plate Pan (see Figure B-1)

A large low cakepan (15x15x5 cm (6x6x2") minimum) may be used to collect and weigh snow. A plate pan (the same area as a flat plate and 4 cm (1½") deep) may be preferable since it lies like the flat plates at a 10º incline. A schematic of the plate pan is provided as Figure B-1.

Note: When this method is used the bottom and sides of the pan MUST BE WETTED (before each pre-test weighing) with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The plate pans should be

carefully rotated every 10 minutes to prevent accumulating snow from blowing away. The time of rotation should be reduced to five minutes during heavy precipitation or high wind conditions.

#### 2.1.2 Tipping Bucket

##### *2.1.2.1 ETI snow gauge*

Electronic simulation of a tipping bucket with a 0.25 mm (0.01") accuracy. The instrument is not heated (anti freeze used to melt precipitation).

### 2.2 Temperature Gauge for Panels (Optional)

T or K Type thermocouple thermometer capable of measuring outside air and panel temperatures to an accuracy of 0.5°C (1°F) over the range +10 to -30°C (+50 to -20°F). This gauge is optional and should be used to verify that the panel temperatures are cold-soaked to the outside air temperature.

### 2.3 Test Stand

A typical test stand is illustrated in Figure B-1A; it may be altered to suit the location and facilities, but the angle for the panels, their arrangement and markings must all conform to Figures B-1A and B-2. There shall be no flanges or obstructions close to the edges of the panels that could interfere with the airflow over the panels.

### 2.4 Test Panels

#### 2.4.1 Material and Dimensions

Alclad Aluminum 2024-T6 or 5052-H32 polished standard roll mill finish 30x50x0.32 cm (12x20x1 1/6"), for a working area of 25x40 cm (10x16"). Thicker aluminum stock may be needed when an instrument is mounted on the plate.

### 2.4.2 Markings

Each panel shall be marked as shown in Figure 2 with lines at 2.5 and 15 cm (1 and 6") from the panel top edge, with 15 crosshair points and with vertical lines 2.5 cm (1") from each side; this marks off a working area of 25x45 cm (10x18") on each panel. All marks shall be made using a 0.3 cm (1/8") thick black marker or silk screen process, which does not come off with application of the test fluids or any of the cleaning agents. Remarking of the plates will be required as the markings fade because of the cleaning actions.

### 2.4.3 Attachment

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

## 2.5 Fluid Application

The fluid should be poured onto the plates from a manageable container, until the entire test section surface is saturated. Up to two litres of fluid may be applied to each panel. This amount is dependant upon the amount of ice/snow on the panels prior to the start of the test, and strong wind conditions will require greater amounts of fluid. For indoor tests at the National Research Council, about 1 litre of fluid per panel is sufficient.

## 2.6 Film Thickness Gauge

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

## 2.7 Video recording (optional)

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

## 2.8 Anemometer

Wind Minder Anemometer Model 2615 or equivalent. Available from Qualimetrics Inc., Princeton, New Jersey. To be mounted at 3 metres (10'). For wind data and calibration sources, see Transport Canada reports, TP12896E and TP12654E.

## 2.9 Wind Vane

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

## 2.10 Relative Humidity Meter

Relative humidity is provided by an automated weather station monitored by Atmospheric Environment Services and is located next to the test panels

## 2.11 Ice Detection Sensors

Where feasible surface or remotely mounted ice detection sensors should be used during the tests. Attachment B-IV provides a description of the sensor equipment and sensor procedures.

## 2.12 Additional Equipment

- Squeegee
- Extension power cords
- Water repellent paper
- Flood lights (2 x 500 watts)
- Stopwatches

# 3. DE/ANTI-ICING FLUIDS

## 3.1 Test Fluids

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

## 3.2 Certification

Type II and IV fluids shall be sheared by each manufacturer to that viscosity which would have been obtained by subjecting their fluids to the shear Stability Test found in the AEA Material specification, Revision C (October 1, 1988), Paragraph 4.2.8.2.2.

Each manufacturer shall provide samples and a certificate of compliance showing the viscosity of their test sample of fluid before and after the Shear Stabile Test. Test verifications of each fluid may be made at the Université du Québec à Chicoutimi.

## 3.3 Dye

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

## 3.4 Dilution of Type I Fluids

The samples shall be tested at dilutions where the freeze point is 10°C below the test air temperature. The dilutions shall be prepared using hard water, as defined in AMS 1424.

# 4. PROCEDURE

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

## 4.1 Start-up and Close-up

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

## 4.2 Set-up

### 4.2.1 Panel Test Stand

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

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

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

### 4.2.2 Tipping Bucket Precipitation Gauge

Place the precipitation gauge as close as possible to the test fixture. Ensure that the interior built-in level is used to indicate that the gauge is level. Ensure that the gauge is not shadowed by an object which would interfere with the collection of precipitation. If there is drifting snow it may be necessary to raise the snow gauge above the drift level but no higher than the test panel. The snow gauge measurements should be started as early as feasible and continue throughout the duration of all tests to provide a continuous record of precipitation.

### 4.2.3 Plate Pan Method

Add 0.6 cm (¼") anti-icing fluid (Type IV) to the bottom of the pan as well as wetting the inner sides of the pan. Weigh the wetted pan prior to testing to the nearest gram. Weigh the pan at 15-minute intervals over the course of the test (see Table B-2). Replace the pans on the test stand as long as the duration of the last test panel. Do not remove the contents of the pan until the test is complete. Weigh again after test completion of each panel to determine the true water content reading of the precipitation.

When using plate pans to measure precipitation rate, two plate pans shall be mounted on the test stand at the same orientation of the plates. Care must be taken to ensure that snow or ice does not fall into the pans when transporting them into the trailer.

## 4.3 Test Panel Preparation

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

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

4.3.3 Allow the panels to cool to outside air temperature.

## 4.4 Fluid Preparation and Application

### 4.4.1 Fluid Temperature

Except for Type I fluids, all fluids should be stored outside (cold-soaked to ambient temperature conditions).

### 4.4.2 Cleaning Panels

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

### 4.4.3 Order of Application

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

## 4.5 Holdover Time Testing

4.5.1 Commence monitoring the test with a video recorder until the test reaches the END CONDITION. See Section 5 for definition of end condition.

4.5.2 Record the elapsed time (holdover time) required for the fluid to achieve the test END CONDITION.

4.5.3 In heavy precipitation, continue the test until the precipitation reaches the bottom of the panel. Record the time for this event.

## 4.6 Video Recording (no longer performed routinely)

Video record each test with a hand-held camera in the following sequences:

1) General outdoor condition prior to test (get good view of snow falling).

2) Video record the data forms.

3) Video record pouring. Ensure that name of fluids are captured, testers faces, your voice, name and stand # (ensure date and time are available and synchronized).

4) Record pans being weighed and brought out.

5) Record timer/clock (at beginning of run and during the run).

6) Record establishing shot of test stand (all the plates).

7) Record establishing shot of each plate, followed by a close-up of the plate (scan the plate slowly), then returning to wide shot of the plate. Repeat this with each plate in sequence, beginning from left to right, top to bottom. Always follow the same sequence. Ensure that each plate has a tag marked with the type of fluid used on the plate and that the plate itself is marked with its corresponding letter (X, Y, Z...). Record the clock/timer often.

8) For each failure, record an overview of the plates, followed by a wide shot of the plate, zooming in into a close-up of the failure. Return to the establishing shot at the end of the procedure. Repeat this procedure for each failure.

9) Ensure that the lighting is appropriate for video purposes.

10) Ensure that the video camera is in fact recording. At the end of a test, rewind a few seconds and check that the test was recorded.

## 4.7 Plate Pan Measurements

Measure the quantity (rate) of precipitation using at least two plate pans mounted on the test stand. One pan shall be mounted on top of the test structure and one at the bottom. Record these measurements on the Form (Table B-2) at the following times:

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

The time weighted average of the individual precipitation rates, collected over the course of the test, is computed for each plate pan. The precipitation rate for a test is the average of the value computed for the upper and lower pan.

## 4.8 Meteorological Observations

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

### 4.8.1 Type of Precipitation

Note the type of precipitation (refer to Figure B-4 for the codes). This is a subjective determination. If two or three forms of precipitation co-exist, then note all of these.

### 4.8.2 Classification of Precipitation

While many different classifications are available, a simple classification of ten forms of solid precipitation is shown in Figure B-3. Use of black velvet to collect the snow and inspect it, will facilitate the identification.

### 4.8.3 Determination of Wet or Dry Snow

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

### 4.8.4 Temperature and Wind Measurements

These are to be recorded from the computer monitor at the site at the start of the test.

### 4.8.5 Visibility

This is a measure using Environment Canada's automated weather observation

station. The instrument, a Belfort Forward Scattermeter, is situated 100 metres from the test panels.

### 4.9 Video Organization

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

## 5. END CONDITION

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

A crosshair is considered failed if:

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

OR

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

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

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

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

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

## 6. END OF TEST

Run test at least 10% longer than the time to reach the end condition on the last panel. This will allow the sensor traces to be longer for analysis. Once the test has ended, restart the testing procedure and continue as long as the weather conditions warrant.

## 7. REPORTING AND OBSERVATIONS

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

# ATTACHMENT B-III
# PERSONNEL RESPONSIBILITY

## Test Site Leader

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

## End Condition Tester

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

## Meteo Tester

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

## Video Tester

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

ATTACHMENT B-IV

# ICE SENSORS SYSTEM MANAGEMENT AND PROCEDURES

# Table of Contents:


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Overall Hardware Diagram.....
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CFIMS procedures.....
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Getting Started.....
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End of Night.....

# System management and procedures

OBJECTIVE:

The object of this report is to provide written procedures to follow for each test session at the APS trailer site. These procedures are intended for normal operations during testing but will offer guidelines in the case of abnormalities such as computer breakdown.

An introductory section will describe the general aspects of the computer systems as well as the peripheral components involved in their functioning and test operations.

Procedures will be placed in a black binder that will determine procedures for anti icing and computer operations.

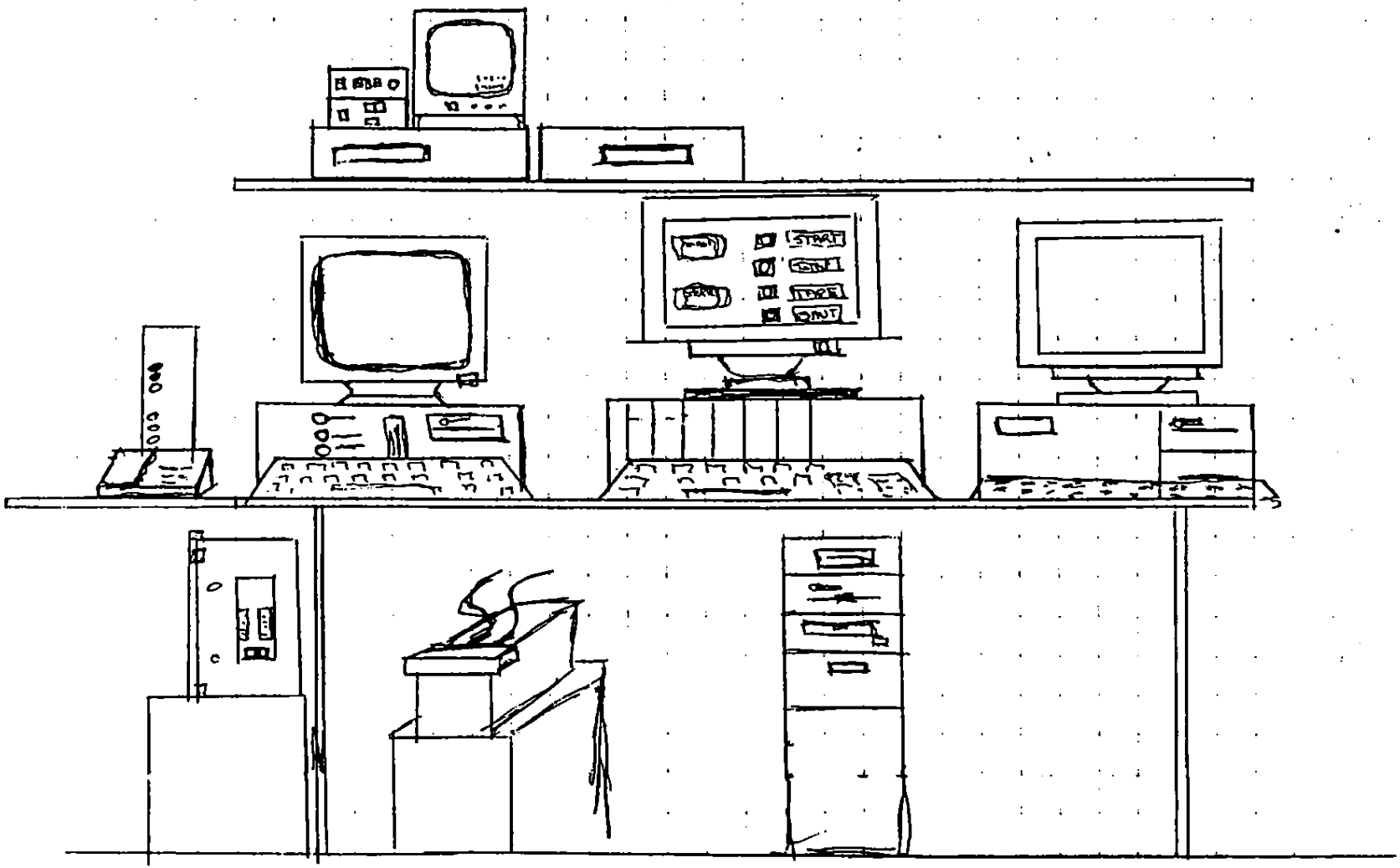
## Introduction

There are three computer systems running at the same time to ensure proper data collection at the APS site. The primary functions of these computers are to provide meteorological data as well as sensor data. The three computer systems are called:

1. MET computer;
2. RVSI;
3. CFIMS (or CWDS).

Along with these systems are the video recording equipment, as well as various power unit boxes that assure a proper power supply .

NPS TRAILER SITE SYSTEM SETUP FOR SYSTEMS MANAGEMENT REPORT. (Feb 4 '95).



- DC Power Source.

## MET COMPUTER

MET is the chosen abbreviation for meteorological computer. The computer may also be referred to as the WX station, for weather station. This computer is hooked up to a series of reading instruments located on the outside that provide necessary information such as ambient temperature, wind speed, etc.. The information is obtained through a program called GET-DATA. It is vital to set proper time and date on this computer before the start of any experiment.

The computer is equipped with a 5¼ floppy drive and is running in the DOS 5.0 environment. Usually the computer is running on a 24 hr. basis.

Table of commands for the MET Computer:

| COMMANDS | DESCRIPTION |
|---|---|
| **Alt-X or Ctrl-Esc** | to exit the program GET-DATA and go into DOS. You may go back to the program by typing GET-DATA. When turning on the computer, a window will pop up asking if the user wishes to append the unsaved data or overwrite onto the file. |
| **F5** | to start a new test file. A test file is started at the beginning of the session when testing starts. |
| **F6** | to close a test file. A test file is closed when all testing is completed for the night. |
| **Alt-F10** | to escape to DOS temporarily (10 to 15 min.) also called shelling to DOS. |
| **Alt-H** | for HELP |
| DIAGNOSTIC / MAINTENANCE FUNCTIONS<br>** Warning: Data collection will be interrupted with these: | |
| **Ctrl-F2** | Debug / Diagnostic Mode ON/OFF |
| **F4** | DOS / Module Time Toggle |
| **Alt-F4** | Read in new DEFAULTS/ PARAMETERS |
| **F8** | Sync. time |
| **Ctrl-F8** | Sync. time now |

The accumulated data is going to be stored in files ( located in directory **c:\1100\DATA**) that are labeled under three categories:

i) **S** for scan 24 hr. data (backup), extension .CVS (Direct read excel)
ii) **L** for log, running log that keeps track of events on computer, extension .LOG
iii) **T** for test file, actual experiment.

These files are saved according to their category followed by the date sequence **YYMMDD**. Note that all files are denoted by date in this form as presented in the following example:

ex: S941201.CVS
L940302.LOG

Once the files are saved, they are compressed through a ZIP program.

**MET COMPUTER PROCEDURES**

1) Turn on the screen (bottom right hand side, on the side), the terminal itself is usually running 24 hrs.
2) Call **FSS**: 633-3345, to get a time check to set the computer:
note:
UTC time = Zulu time, i.e. you must subtract 5 hrs. to get E.S.T.
for example: 18:15 Zulu time → 13:15 E.S.T.
or request EST time (i.e. Local time check)

3) Enter the new time in the computer:
- **Alt-F10** to DOS
- set the time
- type in **exit** then press **enter**
- press **F7** and confirm **yes** to reset the data module

4) Open the test file: press **F5**
-you'll see that in the running log the test file is open
(remember to close the test file at the end of the night : press **F6**).

## RVSI

This system is named after the developers, *Robotics Vision Systems Inc.*. This system is hooked up to the testing stand, and includes a photo-scanner that relays information back to the computer to display on screen the state of the aluminum plates. The software runs in the OS/2 environment. The computer runs in conjunction with a gray power supply box located under the desk.

This gray power unit also supplies power to heat the RVSI and the scaffolding at the test stand.

While the RVSI is running, a main menu is displayed on screen featuring options to proceed with the tests. The menu options are presented in the following table.

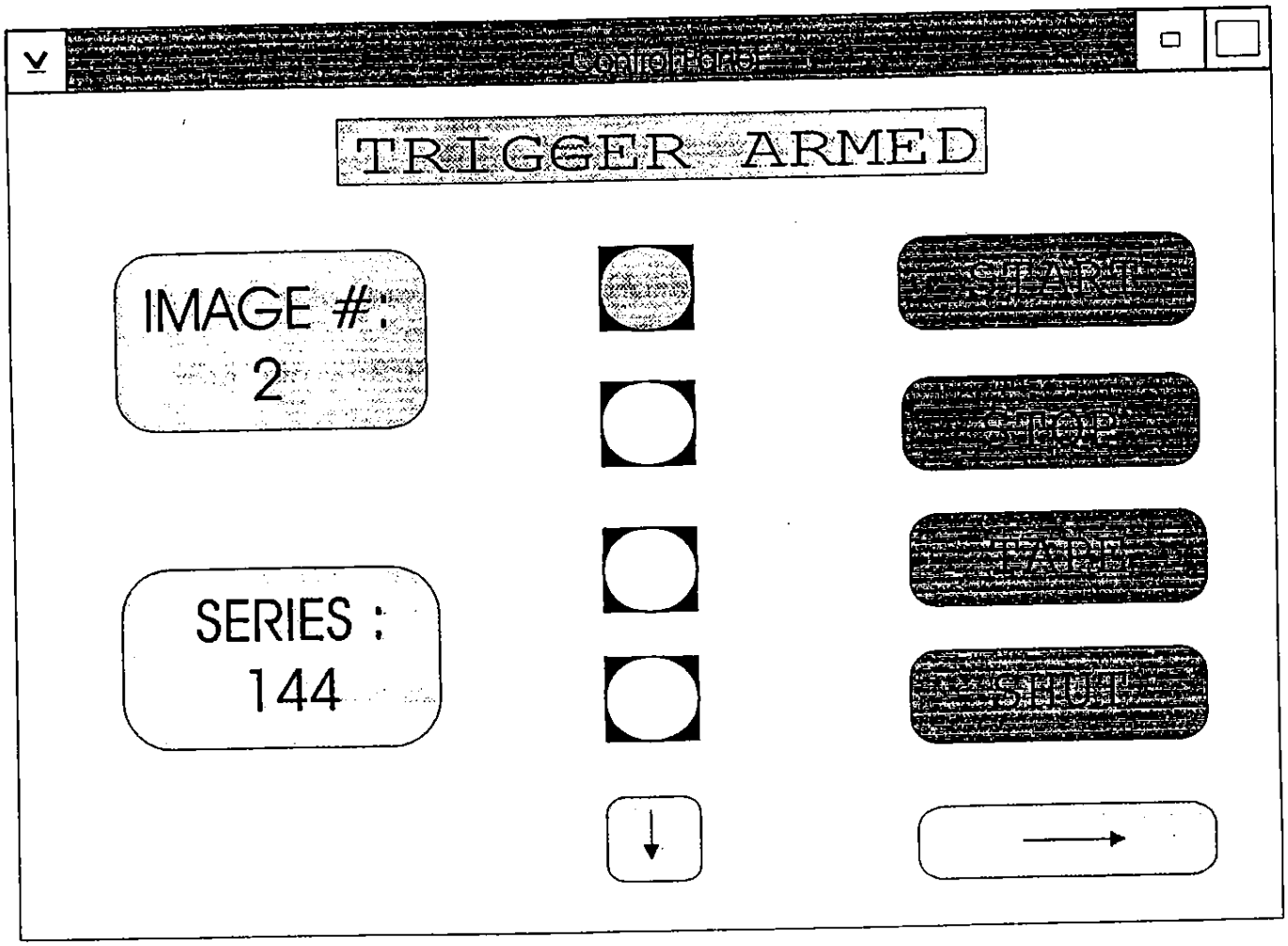
Table of menu options for the RVSI:

| MENU | DESCRIPTION |
|---|---|
| **RUN** | commence scanning and reads data |
| **STOP** | displays " Compressing the image sequence. Please wait..."<br>- after a scanning sequence was run, you have to go to STOP to compress the data. Once that has occurred, the program takes you back to the main menu and stores the data on the hard drive. |
| **TAPE** | to transfer the data to a tape backup, this option temporarily takes you into a yellow screen. |
| **SHUT** | goes through the proper shut down sequence to exit the program. When you shut down the application, the computer displays some difficulty in terminating the shut down sequence where after a certain delay, when not registering any hard drive activity, it is safe to turn off the computer. |

Operating keys to select an item on the MENU are as follows:

- ↓ down arrow to scroll through the menu;
- → right arrow to select an option;
- ← the left arrow will give you an instantaneous scanning
  and also exits back to the menu (in control panel) if you are in scan mode already.

# RVSI SCREEN



**RVSI PROCEDURES**

1) Turn on the RVSI monitor (bottom right on the face) & CPU (slim gray button on tower).
2) Turn on the gray power supply box in order to have the "result" screen (do not touch the heater power switch, the heater remains on at all times).
3) Set the time on the RVSI
   - click the upper left hand corner with the mouse and go into "window list"
   - select DATETIME.CMD icon to change the date and time, once the date and time have been entered the screen disappears and takes you back to the main menu.
   - If it doesn't exist then select the STARTUP menu, then select DATETIME.CMD icon.
   - Exit the DATETIME.CMD application by selecting the corner of the STATRTUP menu and then selecting close.
4) When the "control panel" menu appears (and the test is ready to start), select RUN this will take you into a "result" screen.
5) At the end of the experiment, press left arrow to exit the "result" screen
6) Then select STOP, in order to save the data (after each test run go to STOP to compress the images).
7) At the end of the night select SHUT
   - if a screen prompts you that there is another application, select YES to shut it down.
8) Shut the gray power supply box as well to save on energy.

## Accessing the FILE MANAGER in the RVSI computer:

To view the directories and files in a global manner and perhaps copy them to diskette, it is easier to work through the File Manager in OS/2 Windows. To access the File Manager through complex maze of windows, you might use the following procedure:

1) Starting from the RVSI menu screen, go to the upper right hand corner and click on the small box (the box on the left).
   (there may be a delayed response, avoid the temptation of repeatedly clicking )
2) The DATETIME.CMD screen appears, click on the small box of that screen.
3) The Monitor Window appears (with a list of commands), press on the small box of that screen.
4) Then you'll find yourself in a light blue screen: double click on the OS/2 System icon which is on the bottom left hand corner.
5) That will take you to a black screen called OS/2 System-Icon View: double click on the folder located on the bottom left (first in the second row).
6) That takes you to a white screen called Windows Programs-Icon View, double click on the Program Manager icon
7) When the Program Manager screen pops up, select the File Manager (double click or press enter).
8) View the files, copy etc.
9) When finished, go to the top left box of the Program Manager Screen & select close
10) press OK to end WIN-OS/2 session
11) go to top left corner of Windows Programs-Icon View screen and click on the gray file on the top left corner, and select close
12) Go to top left corner of OS/2 System-Icon View screen and click on gray circle, and select close.
13) Go to the top left corner and double click on the start up file
14) Start up screen appears with DATETIME.CMD and Ice Detection icons
15) Double click on the Ice Detection icon and you'll be back to the RVSI screen.

## CFIMS

The CFIMS is hooked up to a data logger called the LRU which in turn is connected to the ice sensors. This computer runs on a software called FLUIDSTY that analyses the temperature on the ice sensors.

The FLUIDSTY program is located in the **c:\fluidsty** directory. Usually when the computer is powered on, the program is run automatically. Should the user have exited the program, he needs to type in **fluisty** and press **enter** in order to have it run again.

When running the FLUISTY program, the user will encounter five typical screens, not including error messages. These screens guide the user to select or enter the data pertinent to the test such as: the number of sensors used, the snow type, the fluid name, the mounting as well as comments.

Before each test conducted on the test stand #1, it is important to repower the LRU ( turn it off then back on). Otherwise an error message will be pop up. (the LRU is the gray box with the switch on the right hand side next to the power cord). On the LRU test panel (the gray box), the Fault light that is not lit, or off, indicates that the sensor is connected correctly. A fault light that is lit, or on, indicates that a sensor is either not connected or not connected correctly.

**CFIM PROCEDURE**

1) Power on the screen, the computer and the LRU
2) "doskey installed" will pop up, press any key to continue.
3) It will automatically prompt you to set the time and date, use the FSS time.
4) Press **Esc** to accept and continue.
5) On the bottom of the screen it indicates to "Repower LRU", it means to reset the LRU test panel (turn it off then on)
6) When the LRU is reset, you are ready to start sampling.
7) Select "S" to start sampling.
8) Enter the necessary information in each field.
9) Press Esc to accept the configured data.
10) A data collecting screen will appear during the length of the test.
11) At the end of the test, press Ctrl-Q to stop sampling.
12) Enter the test comments to conclude the experiment.
13) Press Esc to accept, and we go back to the first screen.
14) At the end of the night select Q to quit, then it will save all the data.

Fluid Study Software

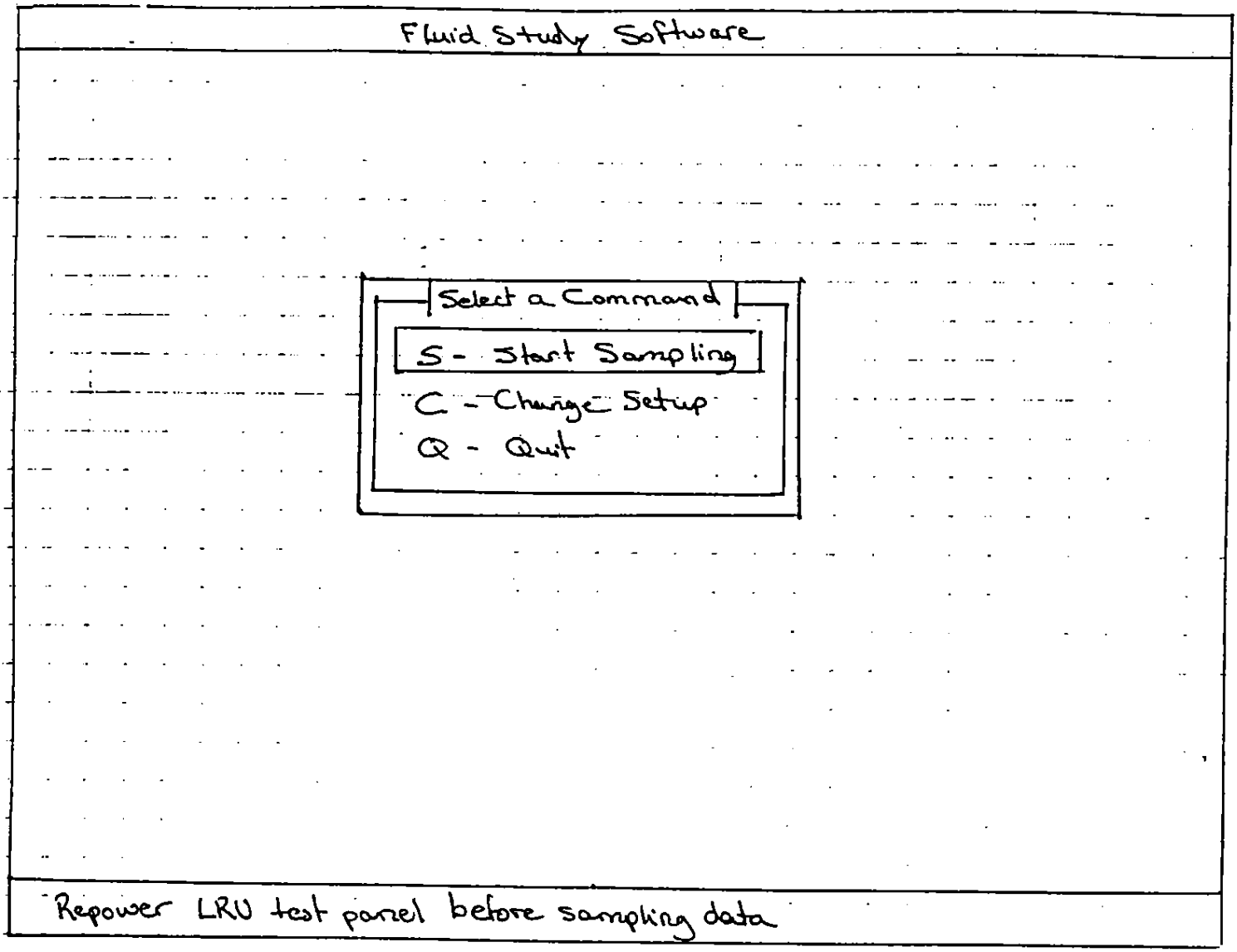
Enter Test Configuration :

Number of CWDS Sensors [1 or 2]: 2

Use TAB or ENTER to skip between fields. Press ESC to accept.

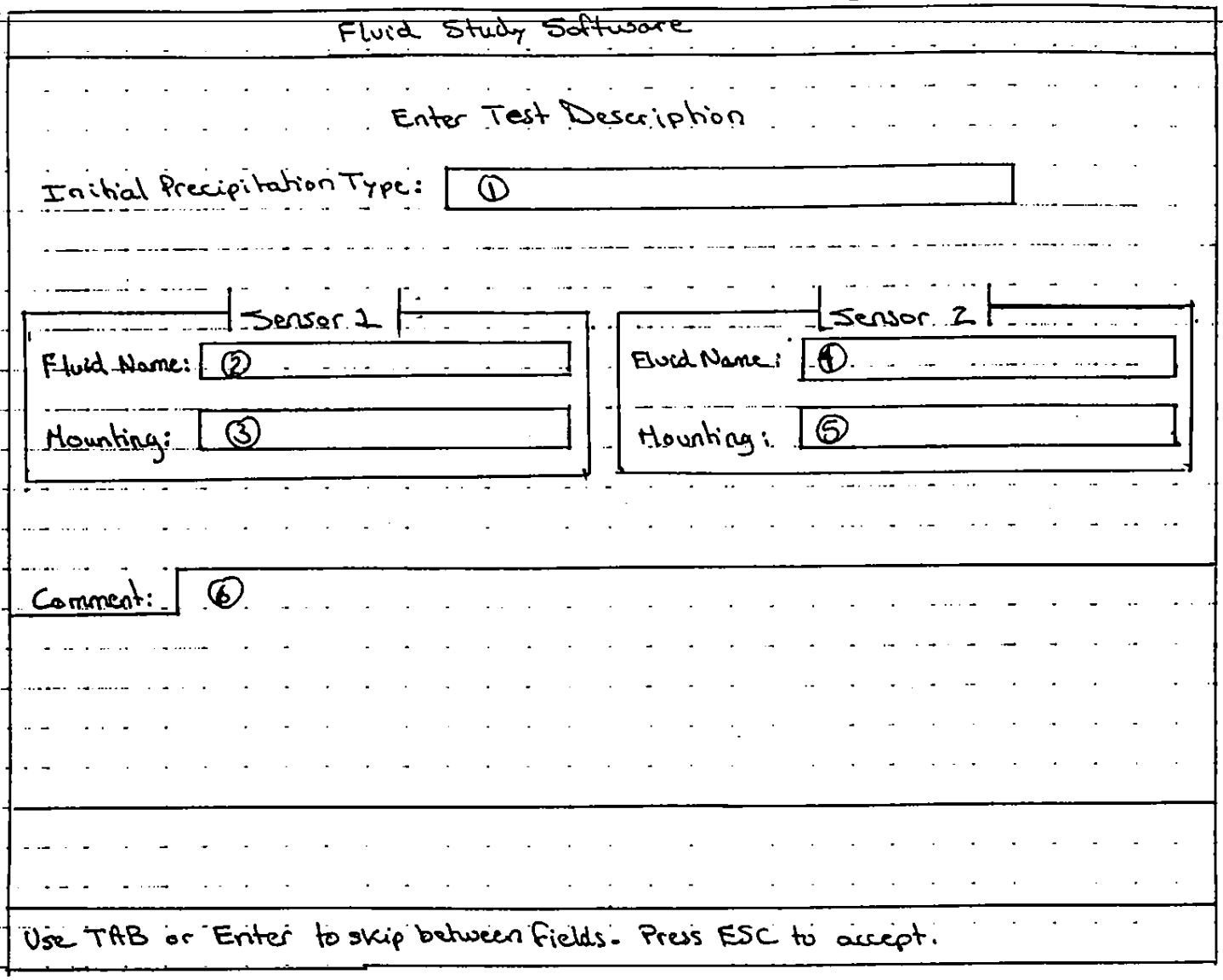
≤ First screen that pops up after the time & date were entered.

- Press ESC to accept.




* Repower LRU
* ~~arrow~~ Press enter to Start Sampling.

- Be sure to start video tape recording also.




① type of snow or precipitation ex: F1-F2.
The reference to the categories of snow are listed on the appendix C chart pasted on the wall next to the door

②,④ manufacturer / commercial name (fluid name) / type of fluid
ex: UCAR / ULTRA / type 2
or UCAR / XL54 / 23% / Type 1

③,⑤ select 10° incline

⑥ comments like FSS weather data, other

Fluid Study Software 02/08/95 23:02:18

| CWDS Sensor 1 |
|---|
| 206 |
| 29 |
| 191 |
| -12 |
| 107 |
| -5 |
| -12.524C |

| CWDS Sensor 2 |
|---|
| 193 |
| 12 |
| 167 |
| -19 |
| 89 |
| -10 |
| -12.622C |

Sampling data. Press Ctrl+Q to stop sampling.

Fluid Study Software

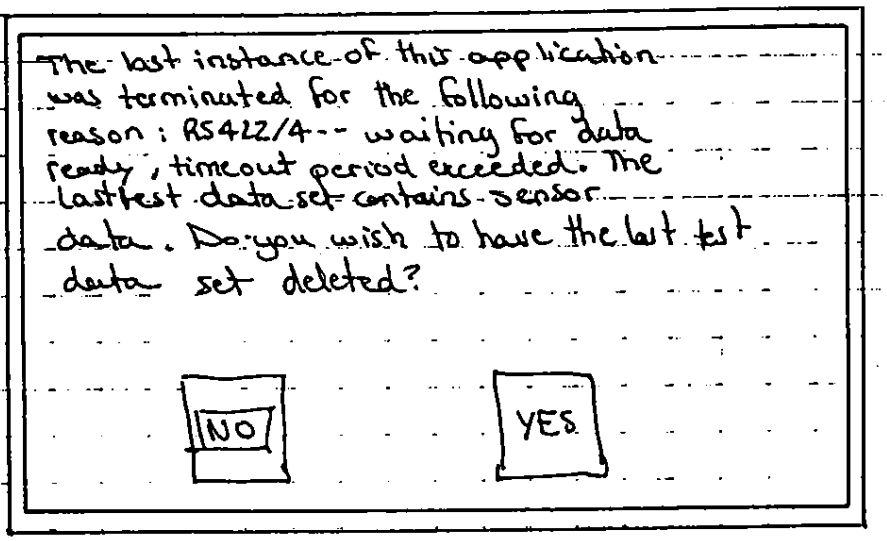
Enter End-of-Test Comment

Comment :

Enter comment. Press ESC to accept.

- Esc to accept - remember to repower LRU
  * turn off UCR - stop recording.

Fluid Study Software




Repower WRU test panel before sampling data

* select no to save data & proceed to screen one

Fluid Study Software

The following error was encountered: RS422/4 -- waiting for data ready, timeout period exceeded. Repower LRU test panel & try again. Terminating the application. Press any key to exit.

Repower LRU test panel before sampling data

* when going ahead without repowering.

## VIDEO CAMERA

The video monitor is observing the test stand #1. It is hooked up with a time lapse VCR. The VCR must be turned on in order to receive a picture. There are also two black scan control boxes next to the monitor that permit panning and zooming with the camera. During a test, the scan control will be on the automatic mode in order to pan continuously on the three panels. Behind the RVSI power source is a small DC power source that must be on to power the VCR. The scan control must be set up to focus on the top three plates, on the top third of the plates, i.e. from the top to the 6" line. Then, in order to record the test, it is important to press **play-record** (ensure there is a tape inside) at the beginning of each test and **stop** at the end of each test.

**GETTING STARTED:**

1A) Call FSS, get TIME & WEATHER check
- synchronize all computers and watches
- type in the FSS weather data in the CFIM comment box

1) Met Computer ON
- F5 to start new test
- Alt-F10, set time, exit
- F7 to reset data module

2) RVSI computer ON
- set the time
- make sure the screen is right
- note down the image # and the series #

3) CFIM computer ON
- set the time

4) Press left arrow to start sampling RVSI
Press "S" to start sampling CFIM , enter data and Esc to accept
VCR ON, press Play-Record

5) START TEST

**END OF TEST:**

1) Down Arrow to STOP, Right Arrow to select STOP on RVSI
2) STOP VCR
3) Ctrl-Q to end CFIM data collection, Repower LRU

**END OF NIGHT:**

1) F6 on MET
2) SHUT on RVSI
3) Quit on CFIM
4) Turn off all monitors, CFIM and RVSI computers, VCR and gray power supply box

# ATTACHMENT B-V
# SUMMARY OF STEPS TO CONDUCT TESTS

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

## Upon Entering Trailer

1) Turn on lights (outside and inside) and sign-in.
2) Determine tests to be conducted and fluids (Type II, IV to be placed outdoors).
3) Remove snow and clear access to stands.
4) Turn on RVSI computer and C/FIMS computers.
5) Synchronize all clocks on all equipment in 4) and stop watches.
6) Start MET equipment data collection file.

## For Each Test

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

## To Close Trailer

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

ATTACHMENT B-VI

# CHECKLIST FOR SITE LEADER FOR END OF TESTING

| | ENTER DATE | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ITEM** | | | | | | | | | | | | | | | |
| ALL FLUIDS BROUGHT IN | | | | | | | | | | | | | | | |
| ALL FLUIDS REPLENISHED | | | | | | | | | | | | | | | |
| WASTE FLUIDS BROUGHT IN | | | | | | | | | | | | | | | |
| HANDHELD CAMERAS BROUGHT IN | | | | | | | | | | | | | | | |
| OUTDOOR AND STAND LIGHTS TURNED OFF | | | | | | | | | | | | | | | |
| C/FIMS COMPUTER TURNED OFF | | | | | | | | | | | | | | | |
| MET FILE CLOSED AND NEW FILE OPENED (MET COMPUTER KEPT ON) | | | | | | | | | | | | | | | |
| RVSI FILES COMPRESSED AND SAVED TO TAPE | | | | | | | | | | | | | | | |
| RVSI/Spar COMPUTERS TURNED OFF | | | | | | | | | | | | | | | |
| WRIST WATCHES HANDED IN | | | | | | | | | | | | | | | |
| ALL TEST MEDIA PROPERLY LABELED (HI 8, RVSI, C/FIMS) | | | | | | | | | | | | | | | |
| DATA FORMS CHECKED AND SIGNED | | | | | | | | | | | | | | | |
| ALL PERSONNEL SIGNED OUT | | | | | | | | | | | | | | | |
| TRAILER CLEANED UP | | | | | | | | | | | | | | | |
| TRAILER HEATER KEPT AT +17°C | | | | | | | | | | | | | | | |
| *SITE LEADER INITIALS* | | | | | | | | | | | | | | | |

ATTACHMENT B-VII
**AMENDED PROCEDURE FOR THE COLLECTION OF PRECIPITATION**

***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 10 minutes in normal conditions and every 5 minutes in periods of high precipitation rates and high winds.

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) For recording start and end times for the collection of precipitation, record the time when exiting the trailer for the start time and record the rime when entering the trailer for the end time.

***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 trailer 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 trailer to re-weigh the pans. Do not rest the pans on top of one another while transporting. Once inside the trailer, rest the pans on a clean dry table surface;

viii) Upon entering the trailer, 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;

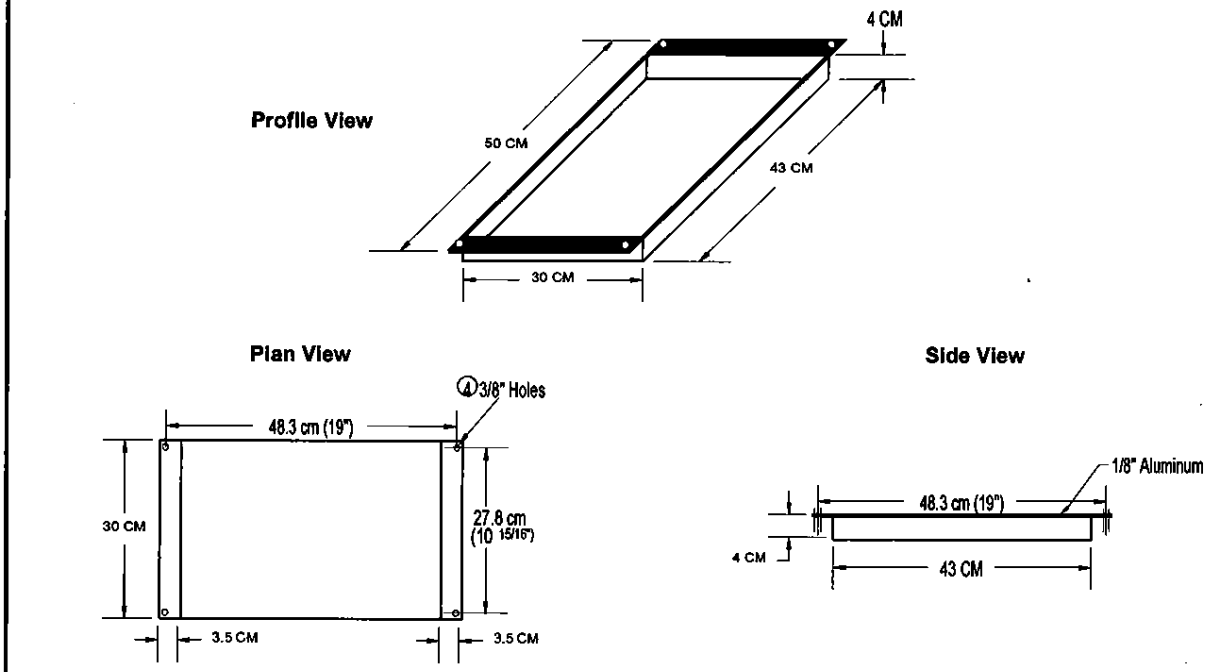
xii) Start time from the timepiece near the rate station; and

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

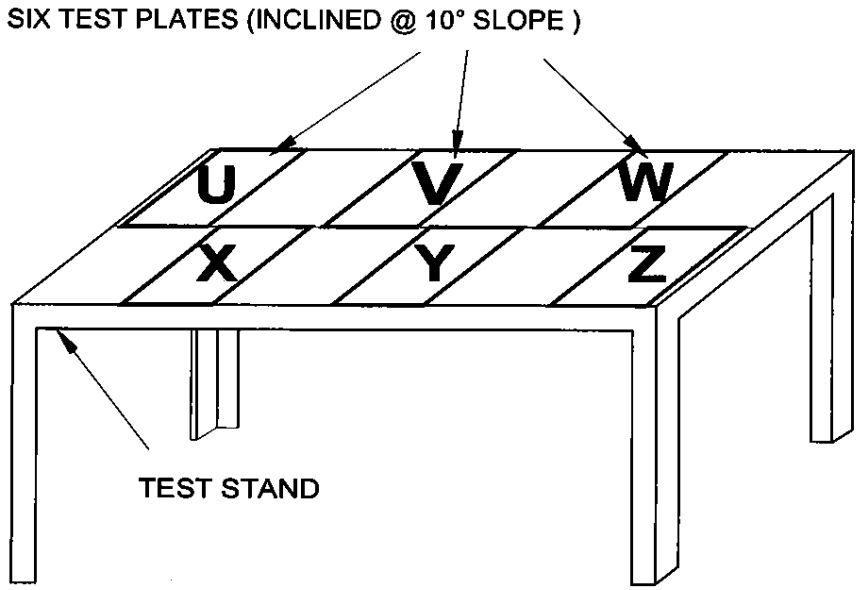
FIGURE B-1

# SCHEMATICS OF PLATE PAN AND TEST STAND

## PLATE PAN



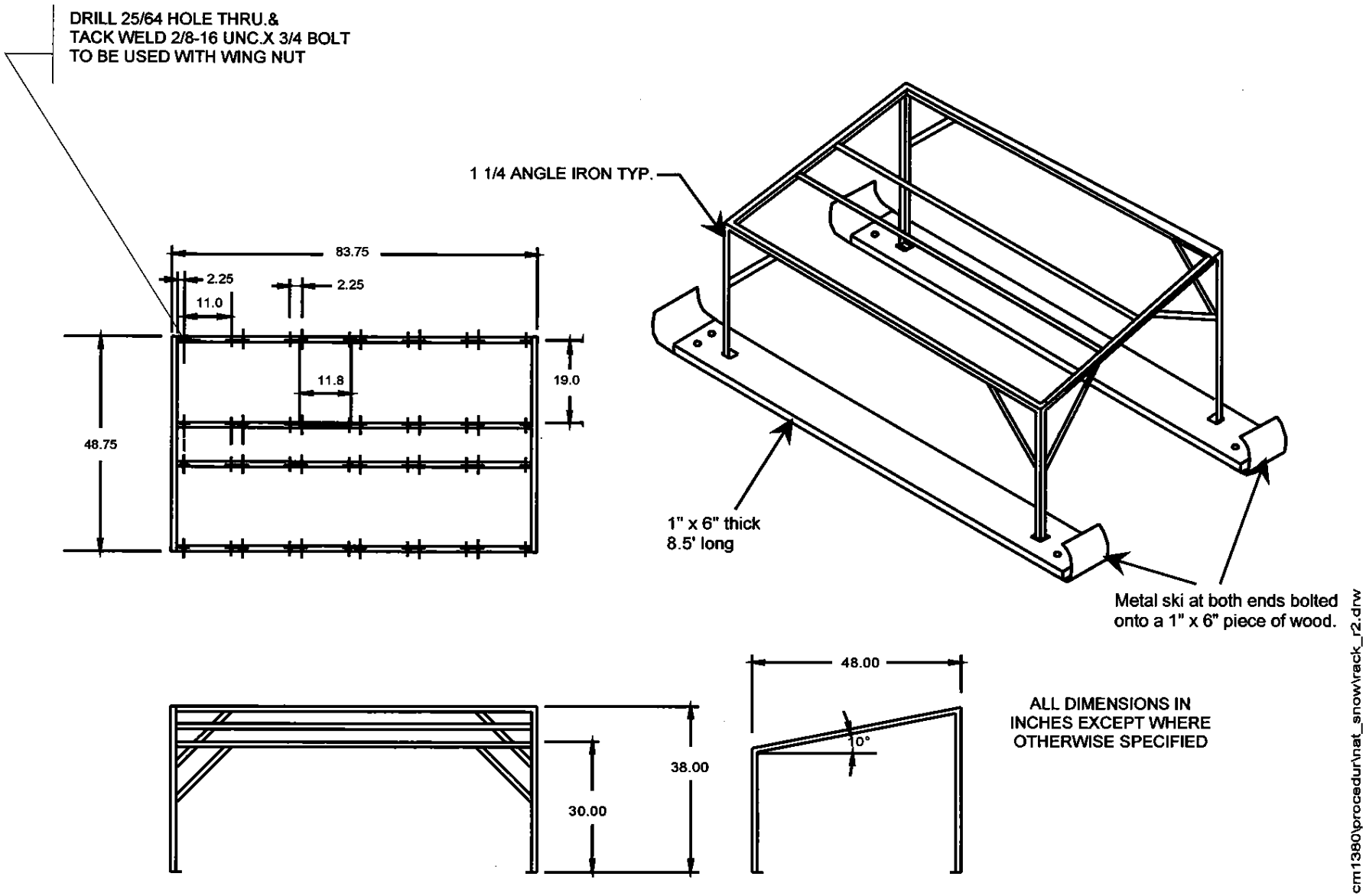

## TEST STAND




cm1380\procedur\nat_snow\pan&stnd.drw

FIGURE B-1A

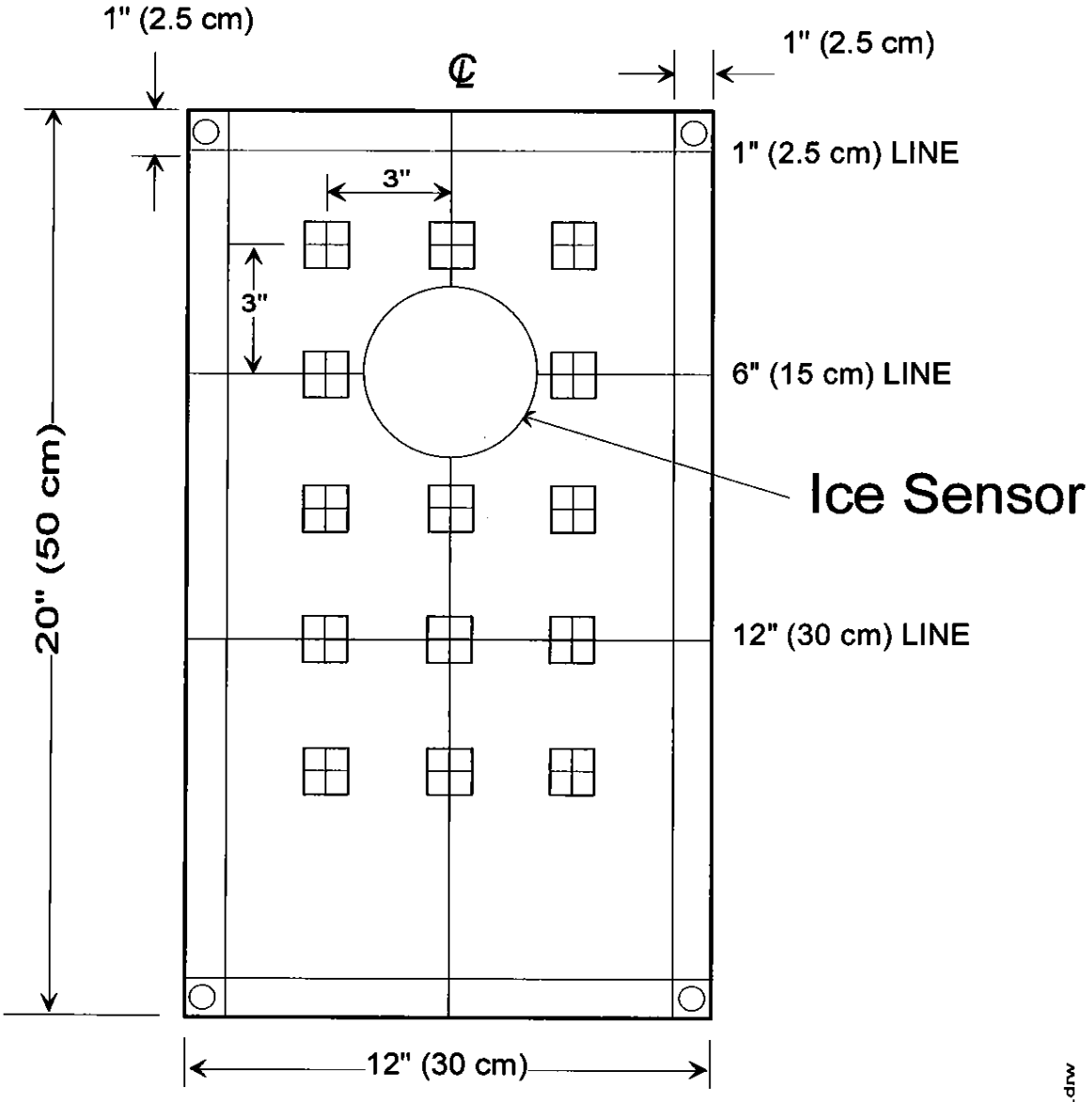
# TEST STAND




cm1380\procedur\nat_snow\rack_r2.drw

FIGURE B-2

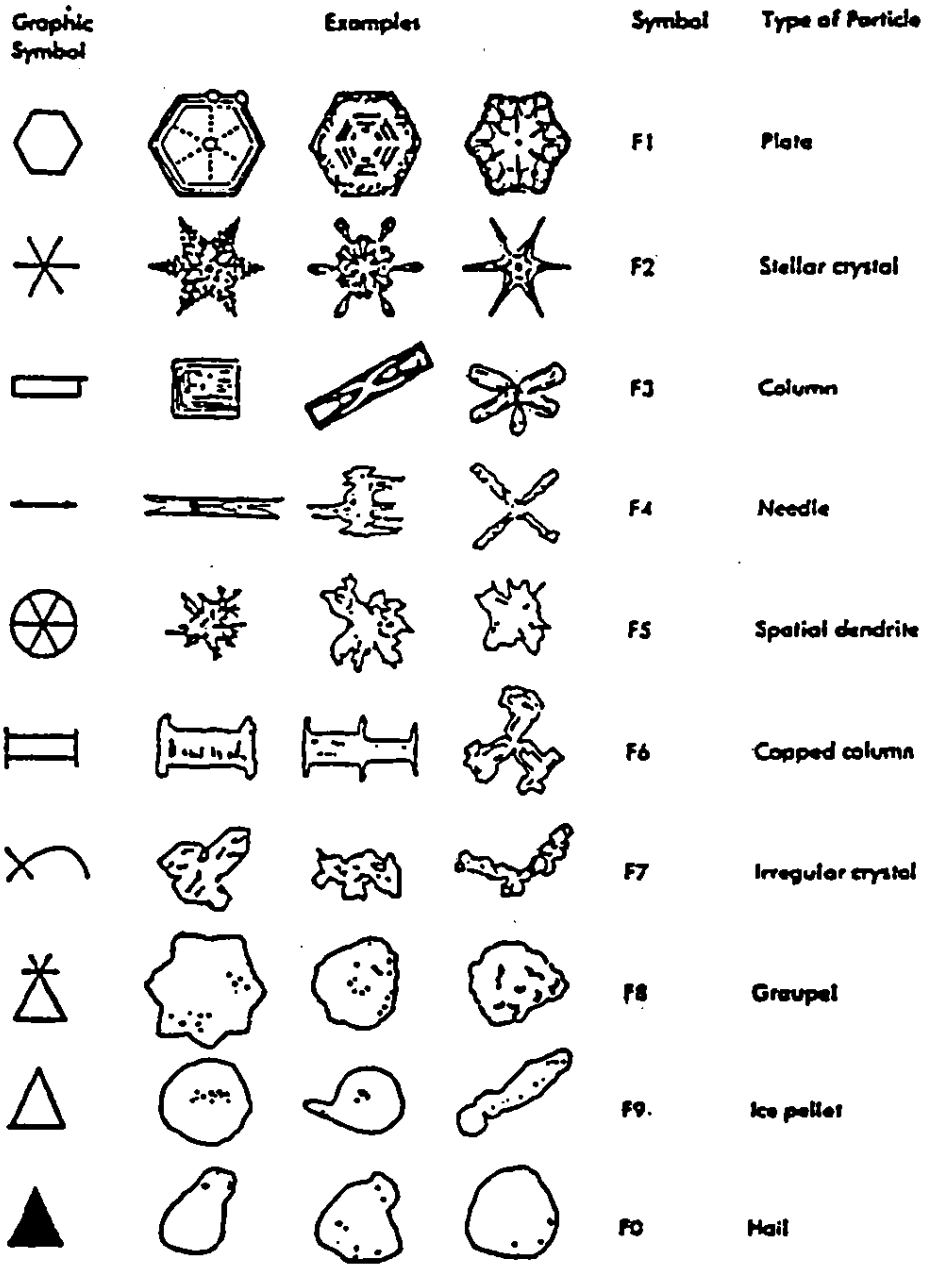
# TYPICAL ICE SENSOR FLAT PLATE MARKINGS




380\procedur\nat_snow\plate.drw

FIGURE B-3

# INTERNATIONAL CLASSIFICATION FOR SOLID PRECIPITATION




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

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

FIGURE B-4

## WEATHER PHENOMENA AND SYMBOLS

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

TABLE B-1

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

# END CONDITION DATA FORM

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)

| FLUID NAME | Plate U | | | Plate V | | | Plate W | | |
|---|---|---|---|---|---|---|---|---|---|
| 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 | | | | | | | | | |

| FLUID NAME | Plate X | | | Plate Y | | | Plate Z | | |
|---|---|---|---|---|---|---|---|---|---|
| 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 B-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 (hr:min) | t TIME AFTER (hr:min) | w WEIGHT BEFORE (grams) | w WEIGHT AFTER (grams) | COMPUTE RATE ($\Delta$ w*4.7/$\Delta$t) (g/dm$^2$/h) |
|---|---|---|---|---|---|
| | | | | | |
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*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 |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
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| | | | |

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

**TEMPERATURE AT START OF TEST** _____ °C

**WIND SPEED AT START OF TEST** _____ kph

**WIND DIRECTION AT START OF TEST** _____ °

**COMMENTS :** _____

_____

_____

_____

| | PRINT | SIGN |
|---|---|---|
| **WRITTEN & PERFORMED BY :** | _____ | _____ |
| **VIDEO BY :** | _____ | _____ |
| **TEST SITE LEADER :** | _____ | _____ |

# APPENDIX C

# DETAILED PLAN OF NRC

# COLD CHAMBER TESTING

CM1380.001

# DETAILED PLAN OF
# NRC COLD CHAMBER TESTING

Winter 1997-98

- Freezing Fog
- Freezing Drizzle and Light Freezing Rain
- Rain on a Cold-Soaked Surface

APS AVIATION INC.

April 1998
Version 5.0

# DETAILED PLAN OF NATIONAL RESEARCH COUNCIL COLD CHAMBER TESTING

Winter 1997-98

This document provides the detailed procedures and equipment required for the conduct of simulated freezing fog, freezing drizzle/rain and rain on a cold-soaked surface tests. These tests will be conducted at NRC's Climatic Engineering Facility (CEF) in Ottawa.

## 1. OBJECTIVES

This test program was developed to test samples of the new Type IV fluids to substantiate or establish new holdover times over the full range of HOT table conditions. Scheduling of the indoor tests will be coordinated with the NRC. Duration of tests will be 23 working days, including set-up time. Fluid failure will be determined by visual observation and supported by any instruments as these are made available.

The anticipated schedule of tests is provided in Attachment C-V.

## 2. PERSONNEL

An indication of the personnel required is provided in Attachment C-V.

*Failure*: Determine test fluids and positioning of tests on stand. Determine failure times.

*Rate 1/2/3*: Measure precipitation rates.

*Fluids* Measure Brix at pour and failure; measure temperature at pour; prepare fluids for next tests.

*Mgr/Data Entry*: Manage tests; enter data (rates and failure times) as collected. Ensure C/FIMS is functional.

*Fluid Application*: Ensure plates are clean; application of fluids.

## 3. PROCEDURES

The procedures for these tests are contained in Attachment C-XIII. The data forms used for the tests as well as the rate forms are attached to this document. The following notes apply to the CEF testing:

a) Rates will be measured before and after each run and sub-run at all tested locations. For sub-runs, rates for only the concerned plates should be measured;

b) The sealed boxes for cold-soaked testing should be prepared in advance;

c) Any special event should be video recorded using a hand held camera; and

d) Refer to Attachment C-VIII for the thermistor mounting procedure.

## 4. TEST PLAN AND EQUIPMENT LIST

Attachment C-VII provides the equipment list for March 1998 and Attachment C-XI provides the supplemental equipment list for July 1998. Attachment C-VI provides a day by day test schedule, while Attachment C-V provides the more general test plan.

Attachment C-IX shows the HOT test schedule at the NRC's CEF for July 6-10, 1998.

## 5. DATA FORM

The data forms are as follows:

- De/anti-icing data form for freezing precipitation, Attachment C-I;
- De/anti-icing data form for cold-soak box, Attachment C-II;
- Precipitation rate measurement, Attachment C-III;
- Detailed precipitation rate measurement form, Attachment C-IIIA;
- Continuous precipitation measurement form, Attachment C-IIIB; and
- Cold-soak precipitation rate measurement, Attachment C-IV.

ATTACHMENT C-I

# DE/ANTI-ICING DATA FORM FOR FREEZING PRECIPITATION

REMEMBER TO SYNCHRONIZE TIME VER

**LOCATION: CEF (Ottawa)** **DATE:** **RUN NUMBER:**

**TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)**

| | Plate 1 | Plate 2 | Plate 3 | Plate 4 | Plate 5 |
|---|---|---|---|---|---|
| **Time of Fluid Application:** | | | | | |
| **Initial Brix** | | | | | |
| **Initial Fluid Temperatrure** | | | | | |
| **FLUID NAME/BATCH** | | | | | |
| **B1 B2 B3** | | | | | |
| **C1 C2 C3** | | | | | |
| **D1 D2 D3** | | | | | |
| **E1 E2 E3** | | | | | |
| **F1 F2 F3** | | | | | |
| TIME TO FIRST PLATE FAILURE WITHIN WORK AREA | | | | | |
| **FAILURE CALL** | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. |
| **C/FIMS** | | | | | |

| | Plate 7 | Plate 8 | Plate 9 | Plate 10 | Plate 11 |
|---|---|---|---|---|---|
| **Time of Fluid Application:** | | | | | |
| **Initial Brix** | | | | | |
| **Initial Fluid Temperatrure** | | | | | |
| **FLUID NAME/BATCH** | | | | | |
| **B1 B2 B3** | | | | | |
| **C1 C2 C3** | | | | | |
| **D1 D2 D3** | | | | | |
| **E1 E2 E3** | | | | | |
| **F1 F2 F3** | | | | | |
| TIME TO FIRST PLATE FAILURE WITHIN WORK AREA | | | | | |
| **FAILURE CALL** | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. Easy | V. Difficult Difficult. |
| **C/FIMS** | | | | | |

**PRECIP:** **ZF , ZD , ZR-, MOD** **AMBIENT TEMPERATURE:** _____ **°C**

**COMMENTS:** _____

**FAILURES CALLED BY :** _____

**HAND WRITTTEN BY :** _____

* To Compare to previous years of testing, subtract "Time of Fluid Application".

ATTACHMENT C-II

## DE/ANTI-ICING DATA FORM FOR COLD SOAK BOX

REMEMBER TO SYNCHRONIZE TIME

**LOCATION:** CEF (Ottawa) **DATE:** April, 1998 **RUN NUMBER:** **ST**

**TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)**

| | | | | | |
|---|---|---|---|---|---|
| **Time of Fluid Application** | | | | | |
| **Initial Brix** | | | | | |
| **Fluid Temperature** | | | | | |
| **Intial Box Temperature** | | | | | |
| **Enter Box Number** | **Box #** | **Box #** | **Box #** | **Box #** | **Bo** |
| **FLUID NAME/BATCH** | | | | | |
| **B1 B2 B3** | | | | | |
| **C1 C2 C3** | | | | | |
| **D1 D2 D3** | | | | | |
| **E1 E2 E3** | | | | | |
| **F1 F2 F3** | | | | | |
| TIME TO FIRST PLATE FAILURE WITHIN WORK AREA | | | | | |
| **Final Brix** | | | | | |
| **Final Box Temperature** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Time of Fluid Application** | | | | | |
| **Initial Brix** | | | | | |
| **Fluid Temperature** | | | | | |
| **Intial Box Temperature** | | | | | |
| **Enter Box Number** | **Box #** | **Box #** | **Box #** | **Box #** | **Bo** |
| **FLUID NAME/BATCH** | | | | | |
| **B1 B2 B3** | | | | | |
| **C1 C2 C3** | | | | | |
| **D1 D2 D3** | | | | | |
| **E1 E2 E3** | | | | | |
| **F1 F2 F3** | | | | | |
| TIME TO FIRST PLATE FAILURE WITHIN WORK AREA | | | | | |
| **Final Brix** | | | | | |
| **Final Box Temperature** | | | | | |

**AMBIENT TEMPERATURE:** _____ **°C**

**COMMENTS:** _____

**FAILURES CALLED BY :** _____

**HAND WRITTTEN BY :** _____

* To Compare to previous years of testing, subtract "Time of Fluid Apllication".

# PRECIPITATION RATE MEASUREMENT AT CEF IN OTTAWA

Date: _____ **Needles used:** _____

Start Time: _____ **Flow Rate of Water:** _____

Run # : _____ **Line Air Pressure:** _____

Stand: _____ **Line Air Temperature:** _____

Precip Type: _____ (ZD, ZR-, FZF, S) **Line Water Pressure:** _____

**Line Water Temperature:** _____

**Pan Location:**

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 |

**Collection Pan:**

| Pan # | Area of Pan (dm²) | Location | Weight of Pan (g) Before | Weight of Pan (g) After | Collection Time (hr:mm:ss) Start | Collection Time (hr:mm:ss) End | Rate |
|---|---|---|---|---|---|---|---|
| 1 | 14.56 | 1 | | | | | |
| 2 | 14.56 | 2 | | | | | |
| 3 | 14.56 | 3 | | | | | |
| 4 | 14.56 | 4 | | | | | |
| 5 | 14.56 | 5 | | | | | |
| 6 | 14.56 | 6 | | | | | |
| 7 | 14.56 | 7 | | | | | |
| 8 | 14.56 | 8 | | | | | |
| 9 | 14.56 | 9 | | | | | |
| 10 | 14.56 | 10 | | | | | |
| 11 | 14.56 | 11 | | | | | |
| 12 | 14.56 | 12 | | | | | |
| 13 | 14.56 | 13 | | | | | |
| 14 | 14.56 | 14 | | | | | |
| 15 | 14.56 | 15 | | | | | |
| 16 | 14.56 | 16 | | | | | |

**Comments:** _____

**Handwritten by:** _____

**Measured by:** _____

ATTACHMENT C-IIIA

# DETAILED PRECIPITATION RATE MEASUREMENT AT CEF IN OTTAWA

Date: _____

Start Time: _____

Run # : _____

Stand: _____

Precip Type: _____ (ZD, ZR-)

PLATE

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 5 | 6 |
| 7 | 8 | 9 |

**Pan Location (Circle):**

| | | | | | |
|---|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** | **6** |
| **7** | **8** | **9** | **10** | **11** | **12** |

**Collection Pan:**

| Pan/ # | Area of Pan ($dm^2$) | Weight of Pan (g) Before | Weight of Pan (g) After | Collection Time (hr:mm:ss) Start | Collection Time (hr:mm:ss) End | Rate |
|---|---|---|---|---|---|---|
| 1 | 1.12 | | | | | |
| 2 | 1.12 | | | | | |
| 3 | 1.12 | | | | | |
| 4 | 1.12 | | | | | |
| 5 | 1.12 | | | | | |
| 6 | 1.12 | | | | | |
| 7 | 1.12 | | | | | |
| 8 | 1.12 | | | | | |
| 9 | 1.12 | | | | | |

**Comments:** _____

**Handwritten by:** _____

**Measured by:** _____

ATTACHMENT C-IIIB

## CONTINUOUS PRECIPITATION RATE MEASUREMENT AT CEF IN OTTAWA

Date: _____

Start Time: _____

Run # : _____

Stand: _____

Precip Type: _____ (ZD, ZR-, FZF, S, CS)

**Pan Location:**

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 |

**Collection Pan:**

| Pan # | Area of Pan ($dm^2$) | Location | Weight of Pan (g) Before | Weight of Pan (g) After | Collection Time (hr:mm:ss) Start | Collection Time (hr:mm:ss) End | Rate |
|---|---|---|---|---|---|---|---|
| 1 | 14.56 | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 1 | | | | | | | |
| 2 | | | | | | | |

**Comments:** _____

**Handwritten by:** _____

**Measured by:** _____

ATTACHMENT C-IV

# COLD SOAK PRECIPITATION RATE MEASUREMENT AT CEF IN OTTAWA

Date: _____

Start Time: _____

Run # : _____

Precip Type: _____ (Drizzle, Light Rain, Moderate Rain, Heavy Rain)

**Pan Location:**

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 |

**Collection Pan:**

| Pan # | Area of Pan ($dm^2$) | Location | | Weight of Pan (g) Before | Weight of Pan (g) After | Collection Time (hr:mm:ss) Start | Collection Time (hr:mm:ss) End | RATE |
|---|---|---|---|---|---|---|---|---|
| 1 | 14.56 | 1 | = | | | | | |
| 2 | 14.56 | 2 | = | | | | | |
| 3 | 14.56 | 3 | = | | | | | |
| 4 | 14.56 | 4 | = | | | | | |
| 5 | 14.56 | 5 | = | | | | | |
| 6 | 14.56 | 6 | = | | | | | |
| 7 | 14.56 | 7 | = | | | | | |
| 8 | 14.56 | 8 | = | | | | | |
| 9 | 14.56 | 9 | = | | | | | |
| 10 | 14.56 | 10 | = | | | | | |

**Comments:** _____

**Handwritten by:** _____

**Measured by:** _____

# ATTACHMENT C-V

## HOT TESTS AT CEF - NRC
## March 30 to May 1 1998 (Week 1 of 5)

| | | Monday 30-Mar | | Tuesday 31-Mar | Wednesday 1-Apr | Thursday 2-Apr | Friday 3-Apr |
|---|---|---|---|---|---|---|---|
| Small End | | | **EVENING**<br>2 Hours<br>-ZR<br>R=25<br>-5 °C | **CALIBRATION** | First Step (FS)<br>8 Hours<br>-10°C<br>with<br>Wind 0,5,10,20kph | Heated Fluids/ Fluid Application<br>**Runs H1-H4**<br>6.0 Hours<br>-ZR<br>R=25<br>-3 °C | Run Fl. Appl. part of Runs S1 to S4<br>* Check water Temp.<br>**Runs 7-9**<br>5.0 Hours<br>-ZR<br>R=25<br>-3 °C |
| Large End | Deicing Only (DO 1) | | Evaluate Wind Capability | Deicing Only (DO 3,2) | | Snow **Capability**<br>Snow<br>7.0 Hours<br>R = ?<br>-7 °C | |
| | Setup | Wind 0, 5, 10, 20kph<br>-5°C | | Wind 0, 5, 10, 20kph<br>-35°C, -25°C | | | |

### Personnel

| | | | | | |
|---|---|---|---|---|---|
| Failure | | | | MC | MC |
| Rate 1 | | | | CB | CB |
| Rate 2 | | | | TH | TH |
| Fluids Prep. | | | | NB | NB |
| Mgr/ Data / Tip Bucket | | PT | PT | MH/PT | MH/PT |
| Fluid Application | | ML | ML | ML | ML |
| Extra people | MC,CB,TH,NB,MH,PD | MC,CB,TH,NB,MH,PD | MC,CB,TH,NB,MH,PD | AP / PD | |



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HOT Tests
Printed at 9:57 AM on 11/3/98

# ATTACHMENT V
# HOT TESTS AT CEF - NRC
# March 30 to May 1 1998 (Week 2 of 5)

| | Monday 6-Apr | Tuesday 7-Apr | Wednesday 8-Apr | Thursday 9-Apr | Friday 10-Apr |
|---|---|---|---|---|---|
| Small End | ROCSW | ROCSW | Thickness Tests: See Attachment T | | Easter |
| | **Runs 53-56**<br>5.0 Hours<br>Drizzle<br>R = 5<br>+1 °C | **Runs 57-60**<br>3.0 Hours<br>Rain<br>R = 76<br>+1 °C | **Runs 1-3**<br>6.0 Hours<br>-ZR<br>R = 13<br>-3 °C | **Runs 21-24**<br>6.5 Hours<br>ZD<br>R = 13<br>-3 °C | |
| Large End | | | | | Easter |

## Personnel

| | | | | | |
|---|---|---|---|---|---|
| Failure/ Mgr | MC | MC | MC | MC | |
| Rate 1 | CB | CB | CB | CB | |
| Rate 2 | TH | TH | TH | TH | |
| Fluids Prep. | NB/MA | MA | NB/MA | NB/MA | |
| Data | PT | PT | PT | PT | |
| Fluid Application | ML | ML | ML | ML | |
| Extra people | MH/ER | ER/MH | CP/AP | | |



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HOT Tests
Printed at 4:59 PM on 11/21/2006

# ATTACHMENT C-V

## HOT TESTS AT CEF - NRC

## March 30 to May 1 1998 (Week 3 of 5)

| | Monday 13-Apr | Tuesday 14-Apr | Wednesday 15-Apr | | Thursday 16-Apr | | Friday 17-Apr | |
|---|---|---|---|---|---|---|---|---|
| Small End | | Thickness Tests: See Attachment T | | | | | | |
| | Easter | **Runs 13-15**<br>7.0 Hours<br>ZD<br>R=5<br>-3 °C | **Runs 16**<br>2.0 Hours<br>ZD<br>R=5<br>-3 °C | **Type 0**<br>4.0 Hours<br>ZD (x 1)<br>R=12<br>-3 °C | **Runs 4-6**<br>4.5 Hours<br>-ZR<br>R=13<br>-10 °C | **Runs 10-12**<br>3.5 Hours<br>-ZR<br>R=25<br>-10 °C | **Type 0**<br>3.0 Hours<br>-ZR (x 1)<br>R=25<br>-10 °C | **Runs 17-20**<br>6.5 Hours<br>ZD<br>R=5<br>-10 °C |
| Large End | | | Snow Capability | | | | | |
| | Easter | | Snow<br>7.0 Hours<br>R=?<br>-7 °C | | | | | |

### Personnel

| | | | | | |
|---|---|---|---|---|---|
| Failure/ Mgr | MC | MC | MC | | MC |
| Rate 1 | CB | CB | CB | | CB |
| Rate 2/3 | TH | TH | TH | | TH |
| Fluid Prep. | NB/MA | MA | MA | | MA |
| Data | PT | PT | PT | | EM |
| Fluid Application | ML | ML | ML | | ML |
| Extra people | CP/AP | PD/AP | | | |

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HOT Tests
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ATTACHMENT C-V

# HOT TESTS AT CEF - NRC

## March 30 to May 1 1998 (Week 4 of 5)

| | Monday 20-Apr | Tuesday 21-Apr | Wednesday 22-Apr | Thursday 23-Apr | Friday 24-Apr |
|---|---|---|---|---|---|
| Small End | **Runs 25-28**<br>6.5 Hours<br>ZD<br>R=12<br>-10 °C | | | | |
| Large End | **Runs 43-46**<br>4.5 Hours<br>ZFog<br>R=5<br>-3 °C | **Runs 41-42**<br>6.5 Hours<br>ZFog<br>R=5<br>-3 °C | **Runs 31-34**<br>7.0 Hours<br>ZFog<br>R=2<br>-3 °C | **Runs 47-50**<br>5.0 Hours<br>ZFog<br>R=5<br>-14 °C | **Runs 29-30**<br>6.0 Hours<br>ZFog<br>R=2<br>-3 °C |

## Personnel

| | | | | | |
|---|---|---|---|---|---|
| Failure/ Mgr | MC | MC | MC | MC | MC |
| Rate 1 | CB | CB | CB | CB | CB |
| Rate 2/3 | TH / PT | TH / JM | TH / JM | TH/JM | TH/JM |
| Fluid Prep. | MA | MA | MA | MA | MA |
| Data | MH | PT | PT | PT | PT |
| Fluid Application | ML | ML | ML | ML | ML |
| Extra people | | | | | |

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HOT Tests
Printed at 10:35 AM on 11/2/98

# ATTACHMENT C-V

## HOT TESTS AT CEF - NRC

## March 30 to May 1 1998 (Week 5 of 5)

| | Monday 27-Apr | Tuesday 28-Apr | Wednesday 29-Apr | | Thursday 30-Apr | | Friday 1-May |
|---|---|---|---|---|---|---|---|
| Small End | | | | | Slope Runs<br>S1 to S4<br>5 Hours<br>-ZR<br>R=25<br>-3°C | Type 0<br>1.5 Hours<br>-ZR (x 1)<br>R=25<br>-3 °C | HOTs with Wind<br>**Runs W1-W3**<br>5.0 Hours<br>-ZR<br>R=25<br>-3 °C<br><br>with<br>**Wind** |
| Large End | **Runs 35-36**<br>7.0 Hours<br>ZFog<br>R=2<br>-14 °C | **Runs 37-38**<br>5.5 Hours<br>ZFog<br>R=2<br>-14 °C | **Runs 39-40**<br>5.0 Hours<br>ZFog<br>R=2<br>-25 °C | **Runs 51-52**<br>1.5 Hours<br>ZFog<br>R=5<br>-25 °C | | | |

### Personnel

| | | | | | |
|---|---|---|---|---|---|
| Failure/ Mgr | MC | MC | MC | MC | MC |
| Rate 1 | CB | CB | CB | CB | CB |
| Rate 2/3 | TH / JM | TH / JM | TH / JM | TH | TH |
| Fluid Prep. | MA | MA | MA | MA | MA |
| Data | PT | PT | PT | PT | PT |
| Fluid Application | ML | ML | ML | ML | ML |
| Extra people | | | | | MH |

* Use large fans, measure rates for 0 wind and at least high wind, use 12 g/dm²/hr rate

**ATTACHMENT C-V**

# EXTRA TESTS
# HOT TESTS AT CEF - NRC

| DOC. Fail |
|---|
| **Runs D 3,4,6,7** |
| 1.0 Hours |
| ZD |
| R=12 |
| -10 °C |

| DOC. Fail |
|---|
| **Runs D 3,4,6,7** |
| 2.0 Hours |
| -ZR |
| R=25 |
| -10 °C |

# Freezing Rain

## Low Rate

| Run # | Temperature (deg C) | Test beds | | | | | | Time |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 to -3 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | H 2001 (100%)1 | 1.5 |
| | Low Rate | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (75%)1/ Oct (50%)1 | Kil (75%)1/ Kil (50%)1 | UCAR PG(75%)1/ UCAR PG(50%)1 | Ultra 4(75%)1/ Ultra 4(50%)1 | |
| 2 | 0 to -3 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | H 2001 (100%)2 | 1.5 |
| | Low Rate | SPC 404 (100%)2 | SPC 480 (100%)2 | H 1957 (75%)1/ H 1957 (50%)1 | H 2001 (75%)1/ H 2001 (50%)1 | SPC 404 (75%)1/ SPC 404 (50%)1 | SPC 480 (75%)1/ SPC 480 (50%)1 | |
| 3 | 0 to -3 | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | H 2001 (75%)2 | 1 |
| | Low Rate | SPC 404 (75%)2 | SPC 480 (75%)2 | Oct (50%)2/ Kil (50%)2 | UCAR PG(50%)2/ Ultra 4(50%)2 | H 1957 (50%)2/ H 2001 (50%)2 | SPC 404 (50%)2/ SPC 480 (50%)2 | |
| 4 | -3 to -14 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | H 2001 (100%)1 | 1 |
| | Low Rate | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (75%)1 | Kil (75%)1 | UCAR PG(75%)1 | Ultra 4(75%)1 | |
| 5 | -3 to -14 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | H 2001 (100%)2 | 0.75 |
| | Low Rate | SPC 404 (100%)2 | SPC 480 (100%)2 | | | | | |
| 6 | -3 to -14 | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | H 2001 (75%)2 | 1 |
| | Low Rate | SPC 404 (75%)2 | SPC 480 (75%)2 | H 1957 (75%)1 | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | |
| | | Total | | | | | | 6.75 |

**Total Time for all Freezing Rain Tests** **11.5**

**Total # of Freezing Rain tests** **160**

# ATTACHMENT C-VI

## Freezing Rain

### High Rate

| Run # | Temperature (deg C) | Test beds | | | | | | Time |
|---|---|---|---|---|---|---|---|---|
| 7 | 0 to -3 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | H 2001 (100%)1 | 1 |
| | High Rate | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (75%)1/ Oct (50%)1 | Kil (75%)1/ Kil (50%)1 | UCAR PG(75%)1/ UCAR PG(50%)1 | Ultra 4(75%)1/ Ultra 4(50%)1 | |
| 8 | 0 to -3 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | H 2001 (100%)2 | 1 |
| | High Rate | SPC 404 (100%)2 | SPC 480 (100%)2 | H 1957 (75%)1/ H 1957 (50%)1 | H 2001 (75%)1/ H 2001 (50%)1 | SPC 404 (75%)1/ SPC 404 (50%)1 | SPC 480 (75%)1/ SPC 480 (50%)1 | |
| 9 | 0 to -3 | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | H 2001 (75%)2 | 0.75 |
| | High Rate | SPC 404 (75%)2 | SPC 480 (75%)2 | Oct (50%)2/ Kil (50%)2 | UCAR PG(50%)2/ Ultra 4(50%)2 | H 1957 (50%)2/ H 2001 (50%)2 | SPC 404 (50%)2/ SPC 480 (50%)2 | |
| 10 | -3 to -14 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | H 2001 (100%)1 | 0.75 |
| | High Rate | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (75%)1 | Kil (75%)1 | UCAR PG(75%)1 | Ultra 4(75%)1 | |
| 11 | -3 to -14 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | H 2001 (100%)2 | 0.5 |
| | High Rate | SPC 404 (100%)2 | SPC 480 (100%)2 | | | | | |
| 12 | -3 to -14 | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | H 2001 (75%)2 | 0.75 |
| | High Rate | SPC 404 (75%)2 | SPC 480 (75%)2 | H 1957 (75%)1 | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | |
| | | | | | | | | 4.75 |

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Freezing Rain
10:36 AM on 11/2/98

# ATTACHMENT C-VI

## Freezing Drizzle
### Low Rate

| Run # | Temperature (deg C) | | | | | | Time |
|---|---|---|---|---|---|---|---|
| 13 | 0 to -3 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 2 |
| | Low Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | Ultra 4 (100%)2 | H 1957 (100%)2 | |
| 14 | 0 to -3 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Oct (75%)1 / Oct (50%)1 | Kil (75%)1 / Kil (50%)1 | 2 |
| | Low Rate | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | UCAR PG(75%)1 / UCAR PG(50%)1 | Ultra 4(75%)1 / Ultra 4(50%)1 | |
| 15 | 0 to -3 | H 1957 (75%)1 | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | SPC 480 (75%)2 | 1.5 |
| | Low Rate | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | |
| 16 | 0 to -3 | Oct (50%)2 | Kil (50%)2 | UCAR PG(50%)2 | Ultra 4(50%)2 | H 1957 (50%)2 / H 1957 (50%)1 | 1.5 |
| | Low Rate | H 2001 (75%)2 | SPC 404 (75%)2 | H 2001 (50%)1 / H 2001 (50%)2 | SPC 404 (50%)1 / SPC 404 (50%)2 | SPC 480 (50%)1 / SPC 480 (50%)2 | |
| 17 | -3 to -14 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 1 |
| | Low Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | | | |
| 18 | -3 to -14 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 1 |
| | Low Rate | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | | | |
| 19 | -3 to -14 | Oct (75%)1 | Kil (75%)1 | UCAR PG(75%)1 | Ultra 4(75%)1 | H 1957 (75%)1 | 1.5 |
| | Low Rate | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | | | |
| 20 | -3 to -14 | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | 1.5 |
| | Low Rate | H 2001 (75%)2 | SPC 404 (75%)2 | SPC 480 (75%)2 | | | |
| | Total | | | | | | 10 |

**Total Time for all Freezing Drizzle Tests** **17**
**Total # of Tests** **160**

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Freezing Drizzle
10:36 AM on 11/2/98

# ATTACHMENT C-VI

## Freezing Drizzle
### High Rate

| Run # | Temperature (deg C) | | | | | | Time |
|---|---|---|---|---|---|---|---|
| 21 | 0 to -3 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 1.5 |
| | High Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | Ultra 4 (100%)2 | H 1957 (100%)2 | |
| 22 | 0 to -3 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Oct (75%)1 / Oct (50%)1 | Kil (75%)1 / Kil (50%)1 | 1.5 |
| | High Rate | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | UCAR PG(75%)1 / UCAR PG(50%)1 | Ultra 4(75%)1 / Ultra 4(50%)1 | |
| 23 | 0 to -3 | H 1957 (75%)1 | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | SPC 480 (75%)2 | 1 |
| | High Rate | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | |
| 24 | 0 to -3 | Oct (50%)2 | Kil (50%)2 | UCAR PG(50%)2 | Ultra 4(50%)2 | H 1957 (50%)2 / H 1957 (50%)1 | 1 |
| | High Rate | H 2001 (75%)2 | SPC 404 (75%)2 | H 2001 (50%)1 / H 2001 (50%)2 | SPC 404 (50%)1 / SPC 404 (50%)2 | SPC 480 (50%)1 / SPC 480 (50%)2 | |
| 25 | -3 to -14 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 0.75 |
| | High Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | | | |
| 26 | -3 to -14 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 0.75 |
| | High Rate | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | | | |
| 27 | -3 to -14 | Oct (75%)1 | Kil (75%)1 | UCAR PG(75%)1 | Ultra 4(75%)1 | H 1957 (75%)1 | 1 |
| | High Rate | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | | | |
| 28 | -3 to -14 | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | 1 |
| | High Rate | H 2001 (75%)2 | SPC 404 (75%)2 | SPC 480 (75%)2 | | | |
| | | | | | | | 7 |

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Freezing Drizzle
10:36 AM on 11/2/98

# ATTACHMENT C-VI

## Freezing Fog
### Low Rate

| Run # | Temperature (deg C) | | | | | Run # | | | | | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | 0 to -3 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 30 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 3 |
| | Low Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (100%)1 | | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | Oct (100%)2 | 3 |
| 31 | 0 to -3 | Kil (75%)1 | UCAR PG (75%)1 | Ultra 4 (75%)1 | H 1957 (75%)1 | 32 | Kil (75%)2 | UCAR PG (75%)2 | Ultra 4 (75%)2 | H 1957 (75%)2 | 2 |
| | Low Rate | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | Oct (75%)1 | | H 2001 (75%)2 | SPC 404 (75%)2 | SPC 480 (75%)2 | Oct (75%)2 | 2 |
| 33 | 0 to -3 | Kil (50%)1 | UCAR PG (50%)1 | Ultra 4 (50%)1 | H 1957 (50%)1 | 34 | Kil (50%)2 | UCAR PG (50%)2 | Ultra 4 (50%)2 | H 1957 (50%)2 | 0.75 |
| | Low Rate | H 2001 (50%)1 | SPC 404 (50%)1 | SPC 480 (50%)1 | Oct (50%)1 | | H 2001 (50%)2 | SPC 404 (50%)2 | SPC 480 (50%)2 | Oct (50%)2 | 0.75 |
| 35 | -3 to -14 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 36 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 3 |
| | Low Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (100%)1 | | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | Oct (100%)2 | 3 |
| 37 | -3 to -14 | Kil (75%)1 | UCAR PG (75%)1 | Ultra 4 (75%)1 | H 1957 (75%)1 | 38 | Kil (75%)2 | UCAR PG (75%)2 | Ultra 4 (75%)2 | H 1957 (75%)2 | 2 |
| | Low Rate | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | Oct (75%)1 | | H 2001 (75%)2 | SPC 404 (75%)2 | SPC 480 (75%)2 | Oct (75%)2 | 2 |
| 39 | -14 to -25 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 40 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 2 |
| | Low Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (100%)1 | | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | Oct (100%)2 | 2 |
| | | | | | | | | | | Total | 25.5 |

**Total Time for all Freezing Rain Fog** **37.5**
**Total # of Freezing Fog Tests** **192**

# ATTACHMENT C-VI

## Freezing Fog
### High Rate

| Run # | Temperature (deg C) | | | | | Run # | | | | | Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 0 to -3 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 42 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 2.5 |
| | High Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (100%)1 | | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | Oct (100%)2 | 2.5 |
| 43 | 0 to -3 | Kil (75%)1 | UCAR PG (75%)1 | Ultra 4 (75%)1 | H 1957 (75%)1 | 44 | Kil (75%)2 | UCAR PG (75%)2 | Ultra 4 (75%)2 | H 1957 (75%)2 | 1 |
| | High Rate | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | Oct (75%)1 | | H 2001 (75%)2 | SPC 404 (75%)2 | SPC 480 (75%)2 | Oct (75%)2 | 1 |
| 45 | 0 to -3 | Kil (50%)1 | UCAR PG (50%)1 | Ultra 4 (50%)1 | H 1957 (50%)1 | 46 | Kil (50%)2 | UCAR PG (50%)2 | Ultra 4 (50%)2 | H 1957 (50%)2 | 0.5 |
| | High Rate | H 2001 (50%)1 | SPC 404 (50%)1 | SPC 480 (50%)1 | Oct (50%)1 | | H 2001 (50%)2 | SPC 404 (50%)2 | SPC 480 (50%)2 | Oct (50%)2 | 0.5 |
| 47 | -3 to -14 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 48 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 0.75 |
| | High Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (100%)1 | | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | Oct (100%)2 | 0.75 |
| 49 | -3 to -14 | Kil (75%)1 | UCAR PG (75%)1 | Ultra 4 (75%)1 | H 1957 (75%)1 | 50 | Kil (75%)2 | UCAR PG (75%)2 | Ultra 4 (75%)2 | H 1957 (75%)2 | 0.75 |
| | High Rate | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | Oct (75%)1 | | H 2001 (75%)2 | SPC 404 (75%)2 | SPC 480 (75%)2 | Oct (75%)2 | 0.75 |
| 51 | -14 TO -25 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 52 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 0.5 |
| | High Rate | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | Oct (100%)1 | | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | Oct (100%)2 | 0.5 |

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Freezing Fog
10:37 AM on 11/2/98

# Rain on Cold Soaked Wing

## Low Rate

| Run # | Temperature (deg C) | Test beds | | | | | Time |
|---|---|---|---|---|---|---|---|
| 53 | above 0 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 1 |
| | Low Rate | | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | | |
| 54 | above 0 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 1 |
| | Low Rate | | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | | |
| 55 | above 0 | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | 0.75 |
| | Low Rate | | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | | |
| 56 | above 0 | Oct (75%)1 | Kil (75%)1 | UCAR PG(75%)1 | Ultra 4(75%)1 | H 1957 (75%)1 | 0.75 |
| | Low Rate | | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | | |
| | | Total | | | | | 3.5 |

**Total Time for all CSW Tests** **4.5**

**Total # of CSW Tests** **64**

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Rain on Cold Soaked Wing
10:37 AM on 11/2/98

# Rain on Cold Soaked Wing

## High Rate

| Run # | Temperature (deg C) | Test beds | | | | | Time |
|---|---|---|---|---|---|---|---|
| 57 | above 0 | Oct (100%)1 | Kil (100%)1 | UCAR PG (100%)1 | Ultra 4 (100%)1 | H 1957 (100%)1 | 0.25 |
| | High Rate | | H 2001 (100%)1 | SPC 404 (100%)1 | SPC 480 (100%)1 | | |
| 58 | above 0 | Oct (100%)2 | Kil (100%)2 | UCAR PG (100%)2 | Ultra 4 (100%)2 | H 1957 (100%)2 | 0.25 |
| | High Rate | | H 2001 (100%)2 | SPC 404 (100%)2 | SPC 480 (100%)2 | | |
| 59 | above 0 | Oct (75%)2 | Kil (75%)2 | UCAR PG(75%)2 | Ultra 4(75%)2 | H 1957 (75%)2 | 0.25 |
| | High Rate | | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | | |
| 60 | above 0 | Oct (75%)1 | Kil (75%)1 | UCAR PG(75%)1 | Ultra 4(75%)1 | H 1957 (75%)1 | 0.25 |
| | High Rate | | H 2001 (75%)1 | SPC 404 (75%)1 | SPC 480 (75%)1 | | |

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ATTACHMENT C-VI

**EFFECT OF SLOPE / EFFECT OF FLUID APPLICATION METHOD**
**CEF DETAILED TEST PLAN**
SPECIAL HOLDOVER TIME TESTS
FREEZING RAIN

Run # : S1 Rate: 25 g/dm$^2$/hr
Temperature : -3°

1 Hour

| | | | | | |
|---|---|---|---|---|---|
| CLARIANT 1957<br>100/0<br>SPRAYED | UCAR ULTRA IV<br>100/0<br>(10°C)* | UCAR ULTRA IV<br>100/0<br>(10°C) | UCAR PG<br>100/0<br>(10°C) | UCAR PG<br>100/0<br>(10°C) | CLARIANT 2001<br>100/0<br>POURED |
| CLARIANT 1957<br>100/0<br>SPRAYED | UCAR ULTRA IV<br>100/0<br>(10°C) | UCAR ULTRA IV<br>100/0<br>(10°C) | UCAR PG<br>100/0<br>(10°C) | UCAR PG<br>100/0<br>(10°C) | CLARIANT 2001<br>100/0<br>POURED |

Run # : S2 Rate: 25 g/dm$^2$/hr
Temperature : -3°C

| | | | | | |
|---|---|---|---|---|---|
| CLARIANT 1957<br>100/0<br>POURED | UCAR ULTRA IV<br>100/0<br>(8°C) | UCAR ULTRA IV<br>100/0<br>(12°C) | UCAR PG<br>100/0<br>(8°C) | UCAR PG<br>100/0<br>(12°C) | CLARIANT 2001<br>100/0<br>SPRAYED |
| CLARIANT 1957<br>100/0<br>POURED | UCAR ULTRA IV<br>100/0<br>(12°C) | UCAR ULTRA IV<br>100/0<br>(8°C) | UCAR PG<br>100/0<br>(12°C) | UCAR PG<br>100/0<br>(8°C) | CLARIANT 2001<br>100/0<br>SPRAYED |

* Use fluid applicators, 1 litre of fluid, fluid at OAT, refer to "Test Plan Effect of Slope on HOT."

ATTACHMENT C-VI

**EFFECT OF SLOPE / EFFECT OF FLUID APPLICATION METHOD**
**CEF DETAILED TEST PLAN**
SPECIAL HOLDOVER TIME TESTS
FREEZING RAIN

Run # : S3 Rate: 25 g/dm$^2$/hr
Temperature : -3°

| | | | | | |
|---|---|---|---|---|---|
| UCAR PG 100/0 SPRAYED | UCAR ULTRA IV 50/50 (10°C) | UCAR ULTRA IV 50/50 (10°C) | UCAR ULTRA IV 100/0 POURED | | |
| UCAR PG 100/0 SPRAYED | UCAR ULTRA IV 50/50 (10°C) | UCAR ULTRA IV 50/50 (10°C) | UCAR ULTRA IV 100/0 POURED | | |

Run # : S4 Rate: 25 g/dm$^2$/hr
Temperature : -3°C

| | | | | | |
|---|---|---|---|---|---|
| UCAR PG 100/0 POURED | UCAR ULTRA IV 50/50 (8°C) | UCAR ULTRA IV 50/50 (12°C) | UCAR ULTRA IV 100/0 SPRAYED | | |
| UCAR PG 100/0 POURED | UCAR ULTRA IV 50/50 (12°C) | UCAR ULTRA IV 50/50 (8°C) | UCAR ULTRA IV 100/0 SPRAYED | | |

ATTACHMENT C-VI

**EFFECT OF FLUID TEMPERATURE / EFFECT OF FLUID APPLICATION METHOD**
**CEF DETAILED TEST PLAN**
SPECIAL HOLDOVER TIME TESTS
FREEZING RAIN

Run # : H1 Rate: 25 g/dm$^2$/hr
Temperature : -3°

1 Hour

| | | | | | |
|---|---|---|---|---|---|
| UCAR ULTRA IV<br>100/0<br>SPRAYED | OCTAGON MAX.<br>100/0<br>(HOT)* | KILFROST ABC-S<br>100/0<br>(HOT) | SPCA AD-404<br>100/0<br>(AMB) | SPCA AD-480<br>100/0<br>(AMB) | UCAR PG<br>100/0<br>POURED |
| UCAR ULTRA IV<br>100/0<br>SPRAYED | OCTAGON MAX.<br>100/0<br>(HOT) | KILFROST ABC-S<br>100/0<br>(HOT) | SPCA AD-404<br>100/0<br>(AMB) | SPCA AD-480<br>100/0<br>(AMB) | UCAR PG<br>100/0<br>POURED |

Run # : H2 Rate: 25 g/dm$^2$/hr
Temperature : -3°C

1 Hour

| | | | | | |
|---|---|---|---|---|---|
| UCAR ULTRA IV<br>100/0<br>POURED | OCTAGON MAX.<br>100/0<br>(AMB) | KILFROST ABC-S<br>100/0<br>(AMB) | SPCA AD-404<br>100/0<br>(HOT) | SPCA AD-480<br>100/0<br>(HOT) | UCAR PG<br>100/0<br>SPRAYED |
| UCAR ULTRA IV<br>100/0<br>POURED | OCTAGON MAX.<br>100/0<br>(AMB) | KILFROST ABC-S<br>100/0<br>(AMB) | SPCA AD-404<br>100/0<br>(HOT) | SPCA AD-480<br>100/0<br>(HOT) | UCAR PG<br>100/0<br>SPRAYED |

*** Hot Type IV fluids should be heated to 30°C.**

ATTACHMENT C-VI

**EFFECT OF FLUID TEMPERATURE / EFFECT OF FLUID APPLICATION METHOD**
**CEF DETAILED TEST PLAN**
SPECIAL HOLDOVER TIME TESTS
FREEZING RAIN

Run # : H3 Rate: 25 g/dm$^2$/hr
Temperature : -3°

| | | | | | |
|---|---|---|---|---|---|
| SPCA AD-404<br>100/0<br>SPRAYED | CLARIANT 1957<br>100/0<br>(HOT) | CLARIANT 2001<br>100/0<br>(HOT) | UCAR PG<br>100/0<br>(AMB) | UCAR ULTRA IV<br>100/0<br>(AMB) | SPCA AD-480<br>100/0<br>POURED |
| SPCA AD-404<br>100/0<br>SPRAYED | CLARIANT 1957<br>100/0<br>(HOT) | CLARIANT 2001<br>100/0<br>(HOT) | UCAR PG<br>100/0<br>(AMB) | UCAR ULTRA IV<br>100/0<br>(AMB) | SPCA AD-480<br>100/0<br>POURED |

Run # : H4 Rate: 25 g/dm$^2$/hr
Temperature : -3°C

| | | | | | |
|---|---|---|---|---|---|
| SPCA AD-404<br>100/0<br>POURED | CLARIANT 1957<br>100/0<br>(AMB) | CLARIANT 2001<br>100/0<br>(AMB) | UCAR PG<br>100/0<br>(HOT) | UCAR ULTRA IV<br>100/0<br>(HOT) | SPCA AD-480<br>100/0<br>SPRAYED |
| SPCA AD-404<br>100/0<br>POURED | CLARIANT 1957<br>100/0<br>(AMB) | CLARIANT 2001<br>100/0<br>(AMB) | UCAR PG<br>100/0<br>(HOT) | UCAR ULTRA IV<br>100/0<br>(HOT) | SPCA AD-480<br>100/0<br>SPRAYED |

*** Hot Type IV fluids should be heated to 40°C and Type I to 80°C**

# ATTACHMENT C-VI

## Attachment T

| Run # | Test # | Date | Fluid Type | Temp | Application |
|---|---|---|---|---|---|
| | 1 | | SPCA 404 (100%) | -3 | pour 1.5L over bare plate |
| | 2 | | SPCA 404 (75%) | -3 | pour 1.5L over bare plate |
| | 3 | | SPCA 404 (50%) | -3 | pour 1.5L over bare plate |
| | 4 | | SPCA 404/Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 5 | | SPCA 404/Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 6 | | SPCA 480 (75%) | -3 | pour 1.5L over bare plate |
| | 7 | | SPCA 480 (50%) | -3 | pour 1.5L over bare plate |
| | 8 | | SPCA 480 / Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 9 | | SPCA 480 / Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 10 | | Octagon 4/Octagan 1 (Hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 11 | | Octagon 4/Octagan 1 (Hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 12 | | Hoescht 2001 (100%) | -3 | pour 1.5L over bare plate |
| | 13 | | Hoescht 2001 (100%) | -3 | pour 1.5L over bare plate |
| | 14 | | Hoescht 2001 (75%) | -3 | pour 1.5L over bare plate |
| | 15 | | Hoescht 2001 (75%) | -3 | pour 1.5L over bare plate |
| | 16 | | Hoescht 2001 (50%) | -3 | pour 1.5L over bare plate |
| | 17 | | Hoescht 2001 (50%) | -3 | pour 1.5L over bare plate |
| | 18 | | Hoescht 2001/Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 19 | | Hoescht 2001/Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 20 | | Hoescht 1957 (100%) | -3 | pour 1.5L over bare plate |
| | 21 | | Hoescht 1957 (100%) | -3 | pour 1.5L over bare plate |
| | 22 | | Hoescht 1957 (75%) | -3 | pour 1.5L over bare plate |
| | 23 | | Hoescht 1957 (75%) | -3 | pour 1.5L over bare plate |
| | 24 | | Hoescht 1957 (50%) | -3 | pour 1.5L over bare plate |
| | 25 | | Hoescht 1957 (50%) | -3 | pour 1.5L over bare plate |
| | 26 | | Hoescht 1957/Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 27 | | Hoescht 1957/Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 28 | | Ultra 4 (100%) | -3 | pour 1.5L over bare plate |
| | 29 | | Ultra 4 (75%) | -3 | pour 1.5L over bare plate |
| | 30 | | Ultra 4 (50%) | -3 | pour 1.5L over bare plate |
| | 31 | | Ultra 4/Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 32 | | Ultra 4/Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 33 | | Ucar PG (100%) | -3 | pour 1.5L over bare plate |
| | 34 | | Ucar PG (75%) | -3 | pour 1.5L over bare plate |
| | 35 | | Ucar PG (50%) | -3 | pour 1.5L over bare plate |
| | 36 | | Ucar PG / Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 37 | | Ucar PG / Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 38 | | Kilfrost (100%) | -3 | pour 1.5L over bare plate |
| | 39 | | Kilfrost (100%) | -3 | pour 1.5L over bare plate |
| | 40 | | Kilfrost (75%) | -3 | pour 1.5L over bare plate |
| | 41 | | Kilfrost (75%) | -3 | pour 1.5L over bare plate |
| | 42 | | Kilfrost (50%) | -3 | pour 1.5L over bare plate |
| | 43 | | Kilfrost (50%) | -3 | pour 1.5L over bare plate |
| | 44 | | Kilfrost / Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 45 | | Kilfrost / Type 1* (hot) | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over bare plate |
| | 46 | | XL54 / ICE-EX- | -3 | pour 1.5L type IV (Room Temp) over ICE-EX- |
| | 47 | | XL54 (hot)/ ICE-EX- | -3 | pour 1.5L type IV (80°C) over ICE-EX- |
| | 48 | | Ultra Plus/ ICE-EX- | -3 | pour 1.5L type IV (Room Temp) over ICE-EX- |
| | 49 | | Ultra Plus (hot)/ ICE-EX- | -3 | pour 1.5L type IV (40°C) over ICE-EX- |
| | 50 | | Ultra Plus (hot) / XL54 (hot) / ICE-EX- | -3 | pour 1.5L type IV (40°C) over 0.5 L type I (80°C) over ICE-EX- on bare plate |
| | 51 | | Ultra Plus / XL54 (hot) / ICE-EX- | -3 | pour 1.5L type IV (Room Temp) over 0.5 L type I (80°C) over ICE-EX- on bare plate |

* Use Manufacturer type I fluid (STD mix) and specify type in data sheets

ATTACHMENT C-VI

**TYPE 0 HOLDOVER TIME / COMPATIBILITY TESTS**
**CEF DETAILED TEST PLAN**
FREEZING RAIN

Run # : R1 Rate: 25 g/dm$^2$/hr
Temperature : -10°

| | | | | | |
|---|---|---|---|---|---|
| UCAR XL54 | UCAR XL54 | OCTAGON I | OCTAGON I | TYPE 0 | TYPE 0 |
| UCAR ULTRA IV 100/0 | UCAR ULTRA IV 100/0 | UCAR ULTRA IV 100/0 | | OCTAGON I | OCTAGON I |

Run # : R2 Rate: 25 g/dm$^2$/hr
Temperature : -10°

| | | | | | |
|---|---|---|---|---|---|
| TYPE 0 PORPYLENE | TYPE 0 ETHYLENE | TYPE 0 PORPYLENE | TYPE 0 ETHYLENE | UCAR XL54 OVER TYPE O ETH. | UCAR XL54 OVER TYPE O ETH. |
| UCAR ULTRA IV 100/0 OVER TYPE 0 ETH. | UCAR ULTRA IV 100/0 OVER TYPE 0 PRO. | UCAR ULTRA IV 100/0 OVER UCAR XL54 | | OCTAGON I OVER TYPE 0 ETH. | OCTAGON I OVER TYPE 0 PRO. |

* Ensure that plates have similatr starting rate.

ATTACHMENT C-VI

**TYPE 0 HOLDOVER TIME / COMPATIBILITY TESTS**
**CEF DETAILED TEST PLAN**
FREEZING RAIN

Run # : R3 Rate: 25 g/dm$^2$/hr
Temperature : -10°

| | | | | | |
|---|---|---|---|---|---|
| | OCTAGON MAX. 100/0 | OCTAGON MAX. 100/0 | OCTAGON MAX. 100/0 | | |
| | | | | | |

Run # : R4 Rate: 25 g/dm$^2$/hr
Temperature : -10°

| | | | | | |
|---|---|---|---|---|---|
| | OCTAGON MAX. 100/0 OVER TYPE 0 PRO. | OCTAGON MAX. 100/0 OVER TYPE 0 ETH. | OCTAGON MAX. 100/0 OVER OCTAGON I | | |
| | | | | | |

ATTACHMENT C-VI

**SPECIAL HOLDOVER TIME TESTS WITH WIND**
**CEF DETAILED TEST PLAN**
FREEZING RAIN

Run # : W1 Rate: 25 g/dm$^2$/hr
Temperature : -3° Wind: 0 KPH

| | | | | | |
|---|---|---|---|---|---|
| **Rate Plate Pan** | UCAR ULTRA IV 100/0 | UCAR ULTRA IV 75/25 | UCAR XL54 STD | UCAR ULTRA IV 50/50 | UCAR PG 100/0 |
| **Rate Plate Pan** | UCAR XL54 STD | UCAR ULTRA IV 50/50 | UCAR ULTRA IV 100/0 | UCAR PG 100/0 | UCAR ULTRA IV 75/25 |

Run # : W2 Rate: 25 g/dm$^2$/hr
Temperature : -3° Wind: 5 kph

| | | | | | |
|---|---|---|---|---|---|
| **Rate Plate Pan** | UCAR ULTRA IV 100/0 | UCAR ULTRA IV 75/25 | UCAR XL54 STD | UCAR ULTRA IV 50/50 | UCAR PG 100/0 |
| **Rate Plate Pan** | UCAR XL54 STD | UCAR ULTRA IV 50/50 | UCAR ULTRA IV 100/0 | UCAR PG 100/0 | UCAR ULTRA IV 75/25 |

Run # : W3 Rate: 25 g/dm$^2$/hr
Temperature : -3° Wind: 10 kph

| | | | | | |
|---|---|---|---|---|---|
| **Rate Plate Pan** | UCAR ULTRA IV 100/0 | UCAR ULTRA IV 75/25 | UCAR XL54 STD | UCAR ULTRA IV 50/50 | UCAR PG 100/0 |
| **Rate Plate Pan** | UCAR XL54 STD | UCAR ULTRA IV 50/50 | UCAR ULTRA IV 100/0 | UCAR PG 100/0 | UCAR ULTRA IV 75/25 |

# ATTACHMENT C-VI
## FIRST STEP FLUID TRIALS (FS)

*Further Trials at National Research Council Climatic Engineering Facility*

## 1. OBJECTIVES

- Quantity impact of wind on time to freeze for different fluid strenghts; and
- Measure dilution curves for different fluid strengths at two different precipitation rates.

## 2. CONDITIONS

*Rates (Freezing Rain)*: 25 g/dm²/hr
12 g/dm²/hr

*Outside Air Temperature*: -10°C

| *Fluid* | *Wind Speed* | | | |
|---|---|---|---|---|
| | Calm | 5 kph | 10 kph | 20 kph |
| Water | X | X | X | X |
| ADF -3°C | X | X | X | X |
| ADF -7°C | X | X | X | X |
| XL 54 | X | X | X | X |

# ATTACHMENT C-VI
## DEICING ONLY TABLE

*Further Trials at National Research Council Climatic Engineering Facility*

## 1. OBJECTIVES

- Collect Brix profiles over time for indicated outside air temperatures and fluids at indicated wind speeds; and
- Conduct final plate condition tests for above conditions using separate uninterrupted plates.

| | *Fluids at Freeze Point* | | | | *Wind kph* | | | |
|---|---|---|---|---|---|---|---|---|
| OAT °C | Type 1 EG | Type 1 PG | Type II ABC-3 | Type IV Ultra 4 | 0 | 5 | 10 | 20 |
| -5 | -2 | -2 | -2 | -2 | X | X | X | X |
| -25 | -22 | -22 | -22 | -22 | X | X | X | X |
| -35 | -32 | -32 | -32 | -32 | | | X | X |

# ATTACHMENT C-VI

## DOCUMENTATION OF FAILURE
## CEF DETAILED TEST PLAN
FREEZING RAIN

Run # : DOC 3
Temperature : -10°

Rate: 25 g/dm$^2$/hr
Freezing Rain

| | | | | | |
|---|---|---|---|---|---|
| | | KILFROST ABC-S 100/0 | OCTAGON MAX 100/0 | UCAR ULTRA IV 100/0 | |
| | | KILFROST ABC-S 100/0 | OCTAGON MAX 100/0 | UCAR ULTRA IV 100/0 | |

Run # : DOC 3
Temperature : -10°

Rate: 25 g/dm$^2$/hr
Freezing Drizzle

| | | | | | |
|---|---|---|---|---|---|
| | | KILFROST ABC-S 100/0 | OCTAGON MAX 100/0 | UCAR ULTRA IV 100/0 | |
| | | KILFROST ABC-S 100/0 | OCTAGON MAX 100/0 | UCAR ULTRA IV 100/0 | |

# ATTACHMENT C-VI

**DOCUMENTATION OF FAILURE**
**CEF DETAILED TEST PLAN**
FREEZING RAIN

Run # : DOC 4
Temperature : -10°

Rate: 25 g/dm$^2$/hr
Freezing Drizzle

| | | | | | |
|---|---|---|---|---|---|
| | | UCAR ULTRA + 100/0 | OCTAGON MAX 100/0 | KILFROST ABC-S 100/0 | |
| | | KILFROST ABC-S 100/0 | UCAR ULTRA + 100/0 | OCTAGON MAX 100/0 | |

# ATTACHMENT C-VI

**DOCUMENTATION OF FAILURE**
**CEF DETAILED TEST PLAN**
FREEZING RAIN

Run # : DOC 6
Temperature : -3°

Rate: 25 g/dm$^2$/hr
Freezing Rain

| | | | | | |
|---|---|---|---|---|---|
| | | UCAR XL54<br>STD | UCAR ULTRA+<br>100/0 | | |
| | | UCAR ULTRA+<br>100/0 | UCAR XL54<br>STD | | |

Run # : DOC 7
Temperature : -3°

Rate: 25 g/dm$^2$/hr
Freezing Rain

| | | | | | |
|---|---|---|---|---|---|
| | | UCAR XL54<br>STD | UCAR ULTRA IV<br>50/50 | CLARIANT 2001<br>50/50 | |
| | | CLARIANT 2001<br>50/50 | UCAR XL54<br>STD | UCAR ULTRA IV<br>50/50 | |

# ATTACHMENT C-VI

## DOCUMENTATION OF FAILURES

| # | Activity Description | Location | Temp °C | Wind | Precip. type | Rate g/dm2/hr | Fluid brand | Fluid Type | Concentration |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Appearance of Type I vs Type IV failures | AES | 0 to -5 | <10kph | Snow | 5 to 20 | UCAR ADF<br>UCAR Ultra+ | I<br>IV | XL54<br>Neat |
| 2 | Appearance of Type I vs Type IV failures in high wind conditions | AES | 0 to -5 | >20kph | Snow | 5 to 20 | UCAR ADF<br>UCAR Ultra+ | I<br>IV | XL54<br>Neat |
| 3 | Appearance of Type IV failures in ZD vs Type IV failures in ZR | NRC | -10 | N/A | ZD/ZR | | Kilfrost ABC-4<br>Octagon Maxfight | IV<br>IV | Neat<br>Neat |
| 4 | Ethylene vs propylene Type IV failures in ZD | NRC | -10 | N/A | ZD | | UCAR Ultra+<br>Kilfrost/Octagon | IV<br>IV | Neat<br>Neat |
| 5 | Time for Type I and Type IV failures to adhere to the plate following failure | AES | 0 to -5 | N/A | Snow | 5 to20 | UCAR ADF<br>UCAR Ultra+ | I<br>IV | XL54<br>Neat |
| 6 | Time for Type I and Type IV failures to adhere to the plate following failure | NRC | | N/A | ZR | | UCAR ADF<br>UCAR Ultra+ | I<br>IV | XL54<br>Neat |
| 7 | *Flash freeze* of Type I or Type IV 50/50 in ZD/ZR. | NRC | 0 to -3 | N/A | ZD/ZR | | UCAR ADF<br>Hoechst | I<br>IV | XL54<br>50/50 |
| 8 | Appearance of failures in wet vs dry snow | AES | 0 to -5 | N/A | Snow | 5 to 20 | UCAR Ultra+ | IV | Neat |
| 9 | Appearance of high rate vs low rate Type IV fluid failures (snow bridging). | AES | 0 to -5 | N/A | Snow | 5 to 10<br>>20 | UCAR Ultra+ | IV | Neat |

# ATTACHMENT C-VI
## EVALUATION OF ARTIFICIAL SNOW AT THE NRC CEF

## 1. GENERAL NOTES AND PROCEDURES

- Conduct feasibility (evaluation) tests over a two day period;
- Day one is for evaluation of rates and consistency of rates; day two is one week later for evaluation of other parameters (e.g. temperature);
- On day one, temperature should be set to -7°C (check with the National Research Council);
- Set out a stand with flat plates;
- Determine temperature limitations;
- Measure rates on each plate (for 15-minute intervals);
- Determine rate limitations;
- Use plate pans and consider tipping buckets to measure rate;
- Measure density of snow;
- Apply Type IV neat fluid on at least two plates and Type I fluid on one plate to determine if the appearance of failure in these conditions is similar to outdoor conditions (take video during failure for one or two minutes);
- Utilize data forms from standard flat plate procedure to record information, otherwise record directly on this sheet; and
- Two testers required (e.g. PD and AP).

# ATTACHMENT C-VI
## CALIBRATION PLAN

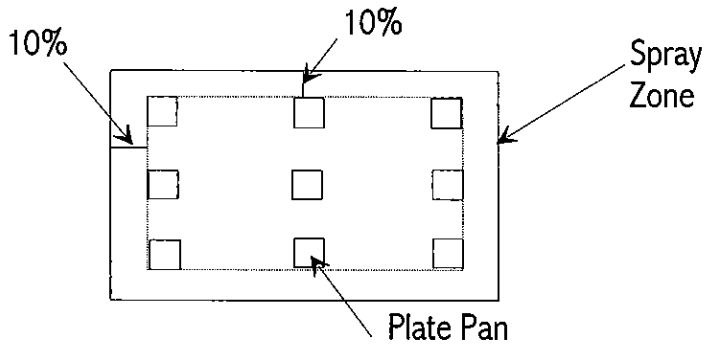
mvd = $(rate/10)^{0.23}$

1 hour each test

| | Drop size |
|---|---|
| ZR-, 25 g\dm²\hr | 1,000 $\mu$m |
| ZR-, 13 g\dm²\hr | 1,000 $\mu$m |
| ZD, 13 g\dm²\hr | 300 $\mu$m |
| ZD, 5 g\dm²\hr | 300 $\mu$m |

Questions

- What is surface area covered (use brown paper).
- What needles are used.
- Measure rates with pans (2 times at 10 minutes) at nine locations (see below).
- Ensure measurement of rates is in about 10% of distance.




- Report best setting.

# ATTACHMENT C-VII

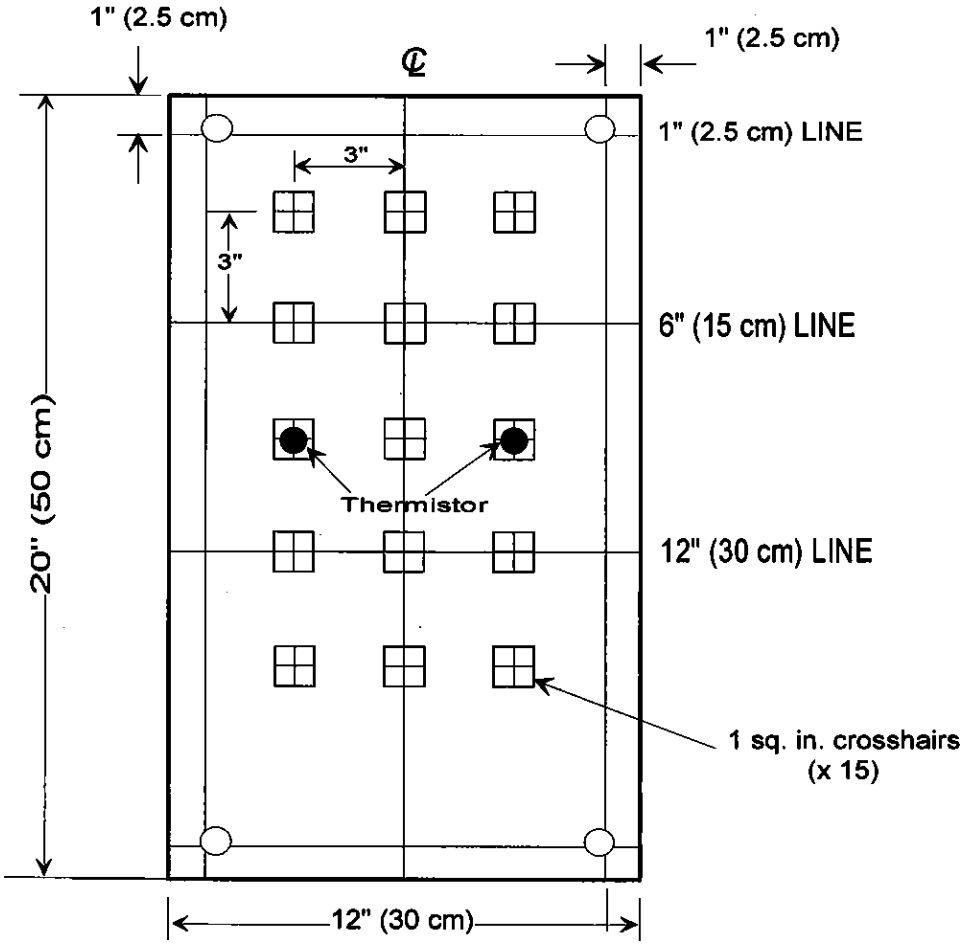
## NRC COLD CHAMBER TESTS MARCH 1998

### TEST EQUIPMENT CHECKLIST

| *TASK* | *NRC Cold Chamber* | |
|---|---|---|
| | Resp. | Status |
| **Logistics for Every Test** | | |
| Make Hotel reservations | | |
| Rent Van/Car | | |
| Call Site Personnel | | |
| Call RVSI Personnel | | |
| | | |
| **Test Equipment** | | |
| Stand x 1 | | |
| C/FIMS (Computers, cables, ...) X 3 | | |
| Labtop Computer | | |
| Still Photo Camera | | |
| Weigh Scale (backup) | | |
| Video Camera X 2 (Surf & Snow) + Access. | | |
| Reg. Plates (wing nuts) X 12+12 | | |
| Data Forms for plates | MC | |
| Precipitation rate Data Forms | MC | |
| Reports + Tables (Temperature conversion, Dilution, ..) | | |
| Large Precipitation Pans x 36 | | |
| Type I Fluids | | |
| Type II Fluids, Type IV Fluids | | |
| Clipboards x 3 | | |
| Pencils + Space pens x 4 | | |
| Paper Towels | | |
| Rubber squeegees | | |
| Plastic Refills for Fluids and funnels | | |
| Electrical Extension Cords | | |
| Lighting x 2 | | |
| Stop watches x 4 | | |
| Storage bins for small equipment | | |
| Protective clothing (2) | | |
| Brixometer X 3 | | |
| Thermometers | | |
| Tie wraps | | |
| Funnels | | |
| Temperture Probes | | |
| Thickness Gauges | | |
| Fluid Sampling Kit | | |
| Scrapers | | |
| Infra-red Thermometer | | |
| Ice-Ex | | |
| Watches | | |
| Cooling Unit | | |
| Cold-Soaked Boxes 7.5 cm X 6 cm | | |
| Thermistor Kit + Logger | | |
| Anemometer (hand-held) | | |
| Inclinometer | | |
| Fluid Spreaders | | |
| Electric Stoves | | |
| Double Boilers | | |
| Test Procedures X 10 | | |
| Thermos Containers | | |
| Wind Vane | | |

ATTACHMENT C-VIII

# THERMISTOR MOUNTING PROCEDURE
# TYPICAL BOX




- Ensure that there are 2 operational thermistors for each box.
- Mount thermistors on crosshair C1 and C3 of the 9" line.

h:\cm1380\procedur\ce\THK_PLT3.DRW

ATTACHMENT C-IX

# HOT TESTS AT CEF - NRC

July 6 - 10, 1998

| MONDAY<br>July 6 | TUESDAY<br>July 7 | WEDNESDAY<br>July 8 | THURSDAY<br>July 9 | FRIDAY<br>July 10 |
|---|---|---|---|---|
| **NRC Wind Capability**<br>**HOTs with Wind**<br>Runs W1-W3<br>3.0 Hours<br>-ZR<br>R = 25<br>-3°C<br>With<br>**WIND** | **TYPE 0**<br>Runs: R1-R2<br>3.0 Hours<br>-ZR (x 1)<br>R = 25<br>-10°C | **DOC. Fail**<br>Runs: 2a, 5, 1, 3b<br>6.5 Hours<br><br>-ZR, -10°C,R = 25<br>-ZR, -3°C,R = 25<br>ZD, -3°C,R = 13 | **DOC. Fail**<br>Runs: 2b, 3a, 4<br>6.5 Hours<br><br>ZD, -10°C,R = 5<br>ZD, -10°C,R = 13<br>-ZR, -10°C,R = 25 | **Test with AMIL**<br>-ZR<br>R = 25<br>-10°C |
| **Effect of Slope**<br>**Fluid Application**<br>Runs 7-9<br>3.0 Hours<br>-ZR<br>R = 25<br>-3°C | **TYPE 0**<br>**Runs: R5-R6**<br>2.0 Hours<br>-ZR (x 1)<br>R = 25<br>-3°C<br>**Runs: R3-R4, R4a**<br>2.0 Hours<br>ZD (x 1)<br>R = 12<br>-3°C | | | **Effect of**<br>**Fluid Temperature**<br>**Fluid Application**<br>Runs H1-H4<br>5.0 Hours<br>-ZR<br>R = 25<br>-3°C |
| **THICKNESS TESTS** | | | | |
| **RATE DISTRIBUTION** | | | | |

## Personnel

| | | | | | |
|---|---|---|---|---|---|
| Failure | MC | MC | MC | MC | MC |
| Rate 1 | CB | CB | CB | CB | CB |
| Fluid Prep/Application | ER/ML | ER/ML | ER/ML | ER/ML | ER/ML |
| Data | MH | MH | MH | MH | MH |
| Extra people | NB (th, rate, fl) | NB (th, rate) | NB (jd)/PD/JM/DR/AP | NB(jd)/PD/JM/DR/AP | NB (fla, heat) |

ATTACHMENT C-X

# DETAILED PRECIPITATION RATE MEASUREMENT

During indoor testing, variation in precipitation rate occur from one plate pan to the next. On some occasions, plates may fail from bottom to top due to variations of rate of precipitation rate from crosshair to crosshair on each plate.

**OBJECTIVE**

To determine the variablity in the rate of precipitation on test plate.

**EQUIPMENT**

- Plate pan with nine containers mounted inside
- Weigh scale

**DATA FORMS**

Detailed precipitation rate measurement form is enclosed in attachment XIIIa

**PROCEDURE**

- Clean and weigh each small pan
- Position Plate pan on stand.
- Collect precipitation for 15 to 30 minutes, depending on rate of precipitation.
- Re-weigh the small pans and calculate the rate

ATTACHMENT C-XI

# NRC COLD CHAMBER TESTS JULY 1998

## SUPPLEMENTAL TEST EQUIPMENT CHECKLIST

| Test Equipment | Resp. |
|---|---|
| Nick's brush | ER |
| Washer for slope test | ER |
| Inclinometer (old & new) (office & site) | ER |
| Dental probe (charger) | JD |
| C/FIMS( computer , cables) | ER |
| Laptop comp. | MH |
| Still photo camera ( digital + regular) | JD |
| Call Don Coveney in Ottawa, ask what needs to be put in the chambre on Fri. | MC |
| Video cameras ( surf & snow) from office | ER,JM |
| Bring extra plates from site | ER |
| Bring board from the office | ER |
| Bring a copy of hold over report | ER,JD |
| procedure & data forms | ER,MH |
| Give Jeff instructions (dig. Video, reg video, dickie moore) | ER |
| Fluids for Ottawa | MC |
| Clipboards | ER |
| Pencils & pens | ER |
| Rags & paper towels | ER |
| Plastic funnels and refills / ext. cords / norm. lighting/squeegees | ER |
| Brixometer | ER |
| Tie wraps | ER |
| Temp Probes | ER |
| Thickness guages {square +octogonal} (ER) | ER |
| Fluid sampling bottles | ER |
| Plastic scraper & transparency for taking fluid sample (ER) | ER |
| Bring Printer (brother) & paper (office) | ER |
| Where are the special rate pans (site) | ER |
| Infrared Thermometer (office) | ER |
| Viscometer (office) | ER |
| Syringe (office) | ER |
| Plexi glass plate | ER |
| Pallets (return to Rona) | ER,MC |

ATTACHMENT C-XII
**EXPERIMENTAL PROGRAM**
**PROCEDURE FOR THE DOCUMENTATION OF THE APPEARANCE OF FAILED FLUIDS**
Winter 1997-98

## 1. OBJECTIVES

APS will conduct flat plate tests in the National Research Council Climatic Engineering Facility 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 snowfall;
- 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; and
- Do strong winds significantly affect failure appearance.

## 2. TEST PROCEDURES

- Flat plate tests will be conducted at the Dorval test site and at the National Research Council Climatic Engineering Facility in Ottawa for comparison purposes.

- Flat plate tests will be conducted using the same procedures as shown in the *Experimental Program for Dorval Natural Precipitation Flat Plate Testing*.

- For each test, the following additional information should also be recorded:
  i) Fluid thickness at selected locations;
  ii) Fluid viscosity at selected locations;
  iii) Refractive index (Brix) at selected locations;
  iv) Video and photos of the plate and crosshairs at the time of fluid failure;
  v) RVSI sensor record of fluid failure;
  vi) Spar/Cox sensor record of fluid failure;
  vii) C/FIMS point sensor record of fluid failure; and
  viii) Fluid adherence at selected locations.

- Plate pan rates should be measured every five minutes. Three or four pans should be used.

- Fluid thickness measurements should be taken at the 15 cm (6") line at the start of the test and every two minutes thereafter for Type I tests and at the

start of the test and every five minutes thereafter for Type IV tests. Thickness measurements and times should be noted on the data form (Figure 1). Refer to the detailed procedure in Transport Canada report, TP 13130E, Appendix C (Attachment VI).

- Fluid quantity applied to plate should be 1.5 l for outdoor tests and tests conducted at the National Research Council Climatic Engineering Facility.

- A Fluid viscosity sample should be collected at the time and point of fifth crosshair failure, and also at B2, F2 and adjacent to the 5$^{th}$ crosshair after complete plate failure. A 10 ml sample should be collected using a spatula and placed in an airtight sample container. Sample containers should be labelled with a date, sample collection time, stand and run number, fluid type and plate number. Due to the destructive nature of the sample process, it is recommended that a separate plate be run solely for the purpose of collecting samples.

- The refractive index of each fluid should be taken prior to application using a hand-held refractometer and recorded on the Brix data form (see Figure 2). For Type I tests, samples should be collected at two-minute intervals thereafter on a crosshair adjacent to the C/FIMS. For Type IV tests, top and bottom fluid samples will be collected at five-minute intervals on a crosshair adjacent to the C/FIMS. Top samples will be obtained by resting a piece of plastic film on the surface of the fluid. Bottom samples will be taken with a syringe by drawing small amounts of fluid at several points near the sample location. Brix values and corresponding sample times should be recorded accurately on the Brix data form (use one form per test plate). Brix of the mixed fluid should also be measured on an adjacent location.

- Fluid application, initial plate failure, 7.5 cm (3") failure, 15 cm (6") failure (15 crosshairs) and entire plate failure should be recorded using a digital video camera and 35 mm still camera. Records should be taken from the front and back of the stand. In addition, a video camera mounted on a tripod should be focused on one crosshair on the 15 cm (6") line to record precipitation absorbency.

- Personnel must ensure that the RVSI and Spar/Cox sensors, and C/FIMS point sensors are operational prior to each test and are left running until complete plate failure. Also, when measuring brix and thickness etc. on the 15 cm (6") line, do not disrupt the fluid over the C/FIMS sensor head (take measurements on an adjacent crosshair).

- Fluid adherence should be determined at the 5$^{th}$ crosshair immediately following failure at this location (not over the C/FIMS) and at location B2. When the entire plate (15 crosshairs) has failed, again verify the fluid adherence at the 15 cm (6") line on the opposite crosshair, and at all crosshairs B2, C2, D2, E2 and F2. Adherence should be noted by the plate observer on the special data form.

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# DOCUMENTATION OF FAILURE

# OBSERVER ACCESS TO TEST PLATES

## Sequence of Activities Triggered by Condition Call

| Activity | Person | Preparation | Application | Initial Failure | Plate Failure 5th Crosshair or 1/3 Plate | Complete Plate Failure |
|---|---|---|---|---|---|---|
| Condition Call | MC | | | x1 | x1 | x1 |
| Adherence | MC | | | | x5 | x4 |
| Brix (Plate Failure) | MC | | | | x4 | |
| Viscosity Sample | NB | | | | x6 | x5 |
| Description | AP | | x2 | x2 | x2 | x2 |
| Photo | JM | | x2 | x2 | x2 | x2 |
| Video | DR | | x3 | x3 | x3 | x3 |
| Brix (Continuous) | ER | x | | **<u>After Application</u>:**<br>Type I: 2 minute Intervals<br>Type IV: 5 minute Intervals<br>Defer to activities triggered by plate condition calls | | |
| Thickness (Continuous) | NB | | x1 | | | |

# ATTACHMENT C-XII
# INDOOR FLAT PLATE TEST EQUIPMENT AND PROCEDURE
# 1997-98

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

## 1. SCOPE

This procedure describes the equipment and generalized steps to follow in order to standardize the method to be used to establish the time period for which freezing point depressant fluids provide protection to test panels during simulated winter conditions.

## 2. EQUIPMENT

The following equipment is required:

### 2.1 Plate Pans

Plate pans (27.7cm x 54cm), placed at a 10º inclination on the test stand will be used to collect and weigh freezing precipitation.

### 2.2 Temperature Gauge for Panels

Plate temperatures will be measured using thermocouples mounted directly underneath the test plate. All thermocouples will be capable of measuring panel temperatures to an accuracy of 0.5ºC (1ºF) over the range +10 to -30ºC (+50 to -20ºF). and will be linked to an electronic data acquisition system.

### 2.3 Test Stand

A typical test stand is illustrated in Figure B-1A (Appendix B); it may be altered to suit the location and facilities, but the angle for the panels, their arrangement and markings must all conform to Figures B-1A and B-2 (Appendix B). There shall be no flanges or obstructions close to the edges of the panels that could

interfere with the airflow over the panels. Test panels should be positioned on the test stand at a 10° ± 0.2° angle from the horizontal.

## 2.4 Test Panels

### 2.4.1 Material and Dimensions

Test panels are made of Alclad Aluminum 2024-T6 or 5052-H32 polished standard roll mill finish. The test panel dimensions are 300 x 500 x 3.2 mm, with a working area of 250 x 450 mm. Thicker aluminum stock may be needed when an instrument is mounted on the plate (CFIMS Sensor required 6.4 mm). Typical plate roughness used in APS Holdover time trials is 0.4 microns, measured parallel to the long axis of the plate.

### 2.4.2 Markings

Each panel shall be marked (as shown in Figure B-2 of Appendix B) with lines at 25 and 150 mm from the panel top edge, with 15 crosshair points and with vertical lines 25 mm from each side; this marks off a working area of 250 x 450 mm on each panel. All marks shall be made using a 30 mm thick black marker or silk screen process, which does not come off with application of the test fluids or any of the cleaning agents. Re-marking of the plates will be required as the markings fade because of the cleaning actions.

### 2.4.3 Attachment of Test Panels

For attachment to the test stand, at least four holes shall be made, spaced along the two sides of each panel; the holes shall be within 20 mm (0.8") from the panel edge.

## 2.5 Fluid Application

The fluid should be poured onto the plates from a manageable container, until the entire test section surface is saturated and a consistent fluid thickness over the entire plate surface is obtained. For indoor tests at the National Research Council, about 1 litre of fluid per panel is sufficient.

## 2.6 Film Thickness Gauge

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

## 2.7 Video recording (optional)

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

## 2.8 Relative Humidity Meter

Relative humidity in the test chamber will be recorded using a Vaisala RH Meter.

## 2.9 Ice Detection Sensors

Where feasible surface or remotely mounted ice detection sensors should be used during the tests. Appendix B provides a description of the sensor equipment and sensor procedures.

## 2.10 Addition Equipment

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

## 2.11 Test Chamber

Tests in simulated conditions will be conducted at the NRC, Climatic Engineering Facility in Ottawa. The chamber air temperature control is within 0.5°C based on the average air temperature measured at one-minute intervals. Temperature data is stored on the CEF data acquisition system. A minimum of three thermocouples are mounted in close proximity to the test stands and are monitored throughout the test set-up. The horizontal air velocity at the test stand is less than 1.0 m/s. The distance between nozzle and test plate is 6.5 to 6.7 meters, depending on the location of the plate on the test stand. The test chamber is equipped with artificial lighting, arranged such that it does not interfere with the precipitation or with the air, fluid and plate temperatures.

## 2.12 Spray Equipment

### 2.12.1 Water supply

Water supply to the freezing rain scanner is well water from the NRC test site. An analysis of the water was completed in June of 1998.

### 2.12.2 Characteristics of Precipitation Produced

The following is a point-form summary of the set of test conditions under which data for freezing drizzle, light freezing rain, rain on a cold-soaked surface, and freezing fog are collected:

- Freezing Drizzle:
  *High Precipitation rate: 12.7g/dm$^2$/h;*
  Droplet median volume diameter: 350$\mu$m;
  Droplets produced with two #23 nozzles; and
  Air temperature: -3°C and -10°C.

  *Low Precipitation rate: 5g/dm$^2$/h;*
  Droplet median volume diameter: 250$\mu$m;
  Droplets produced with two #24 nozzles; and
  Air temperature: -3°C and -10°C.

- Light Freezing Rain:
  *High Precipitation rate: 25g/dm$^2$/h;*
  Droplet median volume diameter: 1,000$\mu$m;
  Droplets produced with two #20 nozzles; and
  Air temperature: -3°C and -10°C.

  *Low Precipitation rate:12.7/dm$^2$/h;*
  Droplet median volume diameter: 1,000$\mu$m;
  Droplets produced with two #20 nozzles; and
  Air temperature: -3°C and -10°C.

- Drizzle on Cold-Soaked Surface:
  Precipitation rate: 5g/dm$^2$/h;
  Droplet median volume diameter: 250$\mu$m;
  Droplets produced with two #24 nozzles; and
  Air temperature: +1°C.

- Moderate Rain on Cold-Soaked Surface:
  Precipitation rate: 76g/dm$^2$/h;
  Droplet median volume diameter: 1,400$\mu$m;
  Droplets produced with two #17 nozzles; and
  Air temperature: +1°C.

- Freezing Fog:
  Precipitation rate: 2 and 5g/dm$^2$/h;
  Droplet median volume diameter: 30$\mu$m;
  Air temperature: -3°C, -14°C.and -25°C.

### 2.12.3 Droplet Size determination

The droplet size determination and distribution can be determined using the Dye Stain Method. The Dye Stain Method technique consists of dusting filter paper disks with a water activated, very finely divided, powder form of methylene blue dye. The prepared disks are manually positioned under precipitation for a fixed time in order to acquire a droplet size pattern. A calibration curve is then used to convert from the measured diameter of the droplets on the pattern to the experimental median volume diameter. This method of droplet size determination has been used for several years (see Transport Canada Reports TP 12654E, TP 12896E, TP 13131E, TP 13318E).

### 2.12.4 Distribution

The water spray shall be evenly distributed over the entire area of each test plate. Even distribution is verified by exposing either a clean test plate or sheet of paper briefly to the spray. Drop distribution on the plate or paper is visually evaluated. Uneven distribution requires that the spray equipment be adjusted (step size and spray head speed) until even distribution is achieved.

### 2.12.5 Spray Equipment

The nozzles used for the freezing rain and freezing drizzle are of an external mix, air-atomizing type. This type of nozzle arrangement allows for more control of air and water pressures at the nozzle to obtain correct drop sizes. The spray head is designed to have air under pressure impinge on the water stream leaving the nozzles (at a 7° angle in the NRC device). Nozzles are easily interchangeable through use of a positive twist lock fastening system, allowing for varying the nozzle diameter to achieve the required drop sizes. The number of nozzles can also be changed easily from 2 to 4 to permit an approximate doubling of rates delivered. This facilitates testing at different rate conditions. The sprayer head is driven in two axes by two independent stepper motors and controllers. By varying the motor speeds and step sizes the spray pattern can be set up to deliver uniform rates over given test areas. Thus the key control parameters to run a test are motor speed and step arrangement, nozzle size and number, water pressure and flow rate, and air pressure.

## 2.13 Calibration of Test Equipment

All temperature sensors, humidity sensors, electronic balances, anemometers, and timing devices shall be maintained in a known state of calibration. Experience indicates that a one-year calibration interval is sufficient.

## 3. DE/ANTI-ICING FLUIDS

### 3.1 Test Fluids

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

### 3.2 Certification

Type IV fluids shall be pre-sheared by each manufacturer. Each manufacturer shall provide samples and a certificate of compliance showing the viscosity of their test sample of fluid before and after shearing, as well as information pertaining to the freeze point and refractive index of the fluid and other fluid parameters as usually provided to the end users. Viscosity and refractive index verifications of each fluid may be made by the test organization upon receipt of fluid from the manufacturer.

### 3.3 Fluid Dye

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

## 4. PROCEDURE

### 4.1 Rate Procedure

The procedure for rate calculation is shown in Section 6.

### 4.2 Test Panel Preparation

4.2.1

Before the start of each day's testing, ensure the panels are clean using the procedure outlined in 4.3.2.

4.2.2

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

4.2.3

Allow the panels to cool to chamber temperature. The temperature may be verified using the thermistors attached to each plate.

## 4.3 Fluid Preparation and Application

4.3.1 Fluid Temperature

Except for Type I fluids, all fluids should be cold-soaked to ambient temperature conditions prior to the start of the test session.

4.3.2 Cleaning Panels

The test panels must be clean of all contamination prior to the start of any test. This is accomplished by scrapping off contamination, or when a different type of fluid is to be tested, a hot water wash is used to remove traces of the previous fluid. Before applying test fluid to any test panel, apply a small quantity of the fluid being used for the test and spread it over the entire test surface. Squeegee off any remaining fluid from the plate surface prior to the start of the test. Fluid for test is applied following procedure 4.3.3.

4.3.3 Fluid Application

Apply the fluids at chamber ambient test temperature $\pm 1.0^{\circ}C$ to the panels, commencing at the upper edge of the test panel and working downwards to the lower edge. Ensure complete and consistent coverage by applying the fluid in a flooding manner (1 litre of fluid should suffice). Start time of the test begins immediately following completion of the fluid application.

## 4.4 Holdover Time Testing

4.4.1

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

## 4.5 Video Recording (not performed routinely)

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

1) General laboratory conditions prior to test.
2) Video record the data forms.

3) Video record pouring. Ensure that name of fluids are captured, testers faces, your voice, name and stand # (ensure date and time are available and synchronized).
4) Record pans being weighed and brought out.
5) Record establishing shot of test stand (all the plates).
6) Record establishing shot of each plate, followed by a close-up of the plate (scan the plate slowly), then returning to wide shot of the plate. Repeat this with each plate in sequence. Record the clock/timer often.
7) For each failure, record an overview of the plates, followed by a wide shot of the plate, zooming in into a close-up of the failure. Return to the establishing shot at the end of the procedure. Repeat this procedure for each failure.
8) Ensure that the lighting is appropriate for video purposes.
9) Ensure that the video camera is in fact recording. At the end of a test, rewind a few seconds and check that the test was recorded.

## 5. END CONDITION

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

A crosshair is considered failed if:

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

OR

- When precipitation or frosting produces a loss of gloss (i.e. a dulling of the surface reflectivity) or a change in colour (dye) to grey or grayish appearance at any five crosshairs (or 1/3 of the plate area), or ice (or crusty snow) has formed (look for ice crystals). This condition is only applicable during freezing rain/drizzle, ice pellets, freezing fog or during a mixture of snow and freezing rain/drizzle and ice pellets.

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

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

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

## 6 PROCEDURE FOR THE COLLECTION OF PRECIPITATION FOR HOLDOVER TIME TRIALS

The precipitation rate procedure outlined below is for use in 1997-98 holdover time trials. A concentrated effort has been made on an annual basis to improve this procedure based on the experiences gained through testing.

Below is an example of a typical test stand used for the conduct of holdover time tests. Each number represents a test location (plate location) on the test stand.

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 |

Prior to the start of the rate collection period, the proper needles and nozzles are installed in the spraying device, and the various pressure settings are adjusted. Water spray calibration is performed by placing catch pans on the test stand, each pan marked with a number identifying the collection location on the test stand, and exposing the pans to a predetermined collection period.

The pans are weighed prior to exposure to precipitation and the weights are recorded. Prior to the start of the precipitation catch period, the exact time (hh:mm:ss) is recorded. The pans are re-weighed following this period and the precipitation rates over the area of the test stand are examined. If the rates are unacceptable, re-calibration of the water spray is necessary. If the rates are deemed to be acceptable, the pans are weighed and placed on the stand for a second collection period. After the second collection period has expired, the pans are again re-weighed and the rates computed.

Once two rates have been collected at each test location, the catch rates of the first and second collection are compared. If the average catch rate for any location is close to the precipitation rate required for the condition, then the pouring of fluids may begin at this location.

Rates will continuously be monitored at a minimum of two locations during a test in order to ensure there are no significant rate fluctuations. Pans will be placed at these locations and be re-weighed at fixed intervals (15 minutes, typically) during the course of a test. If a rate fluctuation occurs, the test is stopped.

Following the failure of a test plate, a rate collection pan is weighed and placed at the plate location for a predetermined time interval. It is then re-weighed and placed again on the stand in order to collect a minimum of two rates at this location.

The rate of precipitation for any location on the stand is calculated by averaging the two rates collected prior to the test and the two rates collected following the test.

The following is an example of a test run conducted in light freezing rain conditions. The desired rate of precipitation for this run is 25 $g/dm^2/h$.

Prior to the start of the test, collection pans are placed at each of the locations on the stand. Following a collection period, the pans are re-weighed. The following rates were recorded.

Rate collection #1

| | | | | | |
|---|---|---|---|---|---|
| 1<br>24.5<br>$g/dm^2/hr$ | 2<br>24.6<br>$g/dm^2/hr$ | 3<br>24.2<br>$g/dm^2/hr$ | 4<br>23.9<br>$g/dm^2/hr$ | 5<br>25.0<br>$g/dm^2/hr$ | 6<br>26.4<br>$g/dm^2/hr$ |
| 7<br>26.2<br>$g/dm^2/hr$ | 8<br>25.6<br>$g/dm^2/hr$ | 9<br>25.3<br>$g/dm^2/hr$ | 10<br>25.1<br>$g/dm^2/hr$ | 11<br>25.7<br>$g/dm^2/hr$ | 12<br>26.1<br>$g/dm^2/hr$ |

The rates are deemed to be acceptable, and therefore the pans are immediately returned to the test stand and a second rate collection period is initiated. Following the collection period, the pans are again re-weighed.

Rate collection #2

| | | | | | |
|---|---|---|---|---|---|
| 1<br>25.1<br>g/dm$^2$/hr | 2<br>24.8<br>g/dm$^2$/hr | 3<br>24.9<br>g/dm$^2$/hr | 4<br>25.9<br>g/dm$^2$/hr | 5<br>25.8<br>g/dm$^2$/hr | 6<br>25.4<br>g/dm$^2$/hr |
| 7<br>25.9<br>g/dm$^2$/hr | 8<br>25.3<br>g/dm$^2$/hr | 9<br>25.2<br>g/dm$^2$/hr | 10<br>25.0<br>g/dm$^2$/hr | 11<br>25.1<br>g/dm$^2$/hr | 12<br>26.4<br>g/dm$^2$/hr |

A calculation of the precipitation rates reveals that the rates are consistent As a result, holdover time tests will be conducted on plates 1, 2, 3, 4, 5, 6, 8, 9, 10 and 11. Collection pans will be re-weighed and placed on locations 7 and 12 in order to provide continuous monitoring of the rates during the test period.

Following the failure of the plates, the collection pans are weighed and once again placed on the test stand at their respective locations. Following the precipitation collection period, the pans are re-weighed.

Rate collection #3 (following plate failure)

| | | | | | |
|---|---|---|---|---|---|
| 1<br>25.4<br>g/dm$^2$/hr | 2<br>24.9<br>g/dm$^2$/hr | 3<br>25.5<br>g/dm$^2$/hr | 4<br>26.7<br>g/dm$^2$/hr | 5<br>25.2<br>g/dm$^2$/hr | 6<br>26.5<br>g/dm$^2$/hr |
| 7<br>26.3<br>g/dm$^2$/hr | 8<br>25.4<br>g/dm$^2$/hr | 9<br>24.6<br>g/dm$^2$/hr | 10<br>25.5<br>g/dm$^2$/hr | 11<br>24.3<br>g/dm$^2$/hr | 12<br>26.3<br>g/dm$^2$/hr |

The pans are returned to the stand. Following another collection period, they are re-weighed for the final time.

Rate collection #4 (following plate failure)

| | | | | | |
|---|---|---|---|---|---|
| 1<br>25.2<br>g/dm$^2$/hr | 2<br>25.7<br>g/dm$^2$/hr | 3<br>25.1<br>g/dm$^2$/hr | 4<br>24.3<br>g/dm$^2$/hr | 5<br>25.7<br>g/dm$^2$/hr | 6<br>26.9<br>g/dm$^2$/hr |
| 7<br>26.7<br>g/dm$^2$/hr | 8<br>25.4<br>g/dm$^2$/hr | 9<br>24.6<br>g/dm$^2$/hr | 10<br>25.5<br>g/dm$^2$/hr | 11<br>24.3<br>g/dm$^2$/hr | 12<br>26.3<br>g/dm$^2$/hr |

The rate of precipitation for any location on the stand may be calculated by averaging the four rates obtained for this location. Below are the calculated precipitation rates for the example run.

Average Precipitation Rates

| | | | | | |
|---|---|---|---|---|---|
| 1<br>25.1<br>g/dm$^2$/hr | 2<br>25.0<br>g/dm$^2$/hr | 3<br>24.9<br>g/dm$^2$/hr | 4<br>25.2<br>g/dm$^2$/hr | 5<br>25.4<br>g/dm$^2$/hr | 6<br>26.3<br>g/dm$^2$/hr |
| 7<br>26.3<br>g/dm$^2$/hr | 8<br>25.4<br>g/dm$^2$/hr | 9<br>24.9<br>g/dm$^2$/hr | 10<br>25.3<br>g/dm$^2$/hr | 11<br>24.9<br>g/dm$^2$/hr | 12<br>26.3<br>g/dm$^2$/hr |

The normal procedure is to conduct two tests at about 25 g/dm$^2$/hr and two tests at about 13 g/dm$^2$/hr for light freezing rain. Each of these tests are conducted at the same temperature (i.e. –3ºC). The average values obtained for precipitation rate at each position is used for each test. The HOT value at the required precipitation rate (for example at 25 g/dm$^2$/hr) is obtained by producing a "best fit" regression curve through the points using a "log-log" transformation based on the test points collected at around 13 g/dm$^2$/hr and 25 g/dm$^2$/hr. Similarly, the HOT value at 13 g/dm$^2$/h is obtained using the same curve. This method is repeated for all other conditions and associated temperatures described in 2.12.2, for each fluid.

FIGURE C-I

## DE/ANTI-ICING DATA FORM FOR FREEZING PRECIPITATION

REMEMBER TO SYNCHRONIZE TIME VER

**LOCATION: CEF (Ottawa)** **DATE: July ,1998** **RUN NUMBER:**

**TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)**

| | Plate 1 | Plate 2 | Plate 3 | Plate 4 | Plate 5 |
|---|---|---|---|---|---|
| **Time of Fluid Application:** | | | | | |
| **Initial Brix** | | | | | |
| **Initial Fluid Temperatrure** | | | | | |
| **FLUID NAME/BATCH** | | | | | |
| **B1 B2 B3** | | | | | |
| **C1 C2 C3** | | | | | |
| **D1 D2 D3** | | | | | |
| **E1 E2 E3** | | | | | |
| **F1 F2 F3** | | | | | |
| TIME TO FIRST PLATE FAILURE WITHIN WORK AREA | | | | | |
| **Final Brix** | | | | | |
| **C/FIMS** | | | | | |

| | Plate 7 | Plate 8 | Plate 9 | Plate 10 | Plate 11 |
|---|---|---|---|---|---|
| **Time of Fluid Application:** | | | | | |
| **Initial Brix** | | | | | |
| **Initial Fluid Temperatrure** | | | | | |
| **FLUID NAME/BATCH** | | | | | |
| **B1 B2 B3** | | | | | |
| **C1 C2 C3** | | | | | |
| **D1 D2 D3** | | | | | |
| **E1 E2 E3** | | | | | |
| **F1 F2 F3** | | | | | |
| TIME TO FIRST PLATE FAILURE WITHIN WORK AREA | | | | | |
| **Final Brix** | | | | | |
| **C/FIMS** | | | | | |

**PRECIP:** **ZF , ZD , ZR-, MOD** **AMBIENT TEMPERATURE:** _____ **°C**

**COMMENTS:** **FAILURES CALLED BY :** _____

**HAND WRITTTEN BY :** _____

* To Compare to previous years of testing, subtract "Time of Fluid Application".

FIGURE C-2

# PRECIPITATION RATE MEASUREMENT AT CEF IN OTTAWA

Date: _____ Needles used: _____

Start Time: _____ Flow Rate of Water: _____

Run # : _____ Line Air Pressure: _____

Stand: _____ Line Air Temperature: _____

Precip Type: _____ (ZD, ZR-, FZF, S) Line Water Pressure: _____

Line Water Temperature: _____

**Pan Location:**

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 |

**Collection Pan:**

| Pan # | Area of Pan ($dm^2$) | Location | Weight of Pan (g) Before | Weight of Pan (g) After | Collection Time (hr:mm:ss) Start | Collection Time (hr:mm:ss) End | Rate |
|---|---|---|---|---|---|---|---|
| 1 | 14.56 | 1 | | | | | |
| 2 | 14.56 | 2 | | | | | |
| 3 | 14.56 | 3 | | | | | |
| 4 | 14.56 | 4 | | | | | |
| 5 | 14.56 | 5 | | | | | |
| 6 | 14.56 | 6 | | | | | |
| 7 | 14.56 | 7 | | | | | |
| 8 | 14.56 | 8 | | | | | |
| 9 | 14.56 | 9 | | | | | |
| 10 | 14.56 | 10 | | | | | |
| 11 | 14.56 | 11 | | | | | |
| 12 | 14.56 | 12 | | | | | |
| 13 | 14.56 | 13 | | | | | |
| 14 | 14.56 | 14 | | | | | |
| 15 | 14.56 | 15 | | | | | |
| 16 | 14.56 | 16 | | | | | |

**Comments:** _____

**Handwritten by:** _____

**Measured by:** _____

FIGURE C-2A

## DETAILED PRECIPITATION RATE MEASUREMENT AT CEF IN OTTAWA

Date: _____

Start Time: _____

Run # : _____

Stand: _____

Precip Type: _____ (ZD, ZR-)

PLATE

| | | |
|---|---|---|
| 1 | 2 | 3 |
| 4 | 5 | 6 |
| 7 | 8 | 9 |

**Pan Location (Circle):**

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 |

**Collection Pan:**

| Pan/ # | Area of Pan ($dm^2$) | Weight of Pan (g) Before | Weight of Pan (g) After | Collection Time (hr:mm:ss) Start | Collection Time (hr:mm:ss) End | Rate |
|---|---|---|---|---|---|---|
| 1 | 1.12 | | | | | |
| 2 | 1.12 | | | | | |
| 3 | 1.12 | | | | | |
| 4 | 1.12 | | | | | |
| 5 | 1.12 | | | | | |
| 6 | 1.12 | | | | | |
| 7 | 1.12 | | | | | |
| 8 | 1.12 | | | | | |
| 9 | 1.12 | | | | | |

**Comments:** _____

**Handwritten by:** _____

**Measured by:** _____

FIGURE C-3

# FLUID THICKNESS ON FLAT PLATES

**DATE:** _____ **OAT (°C):** _____

**RUN NUMBERS:** _____ **PERFORMED BY:** _____

**LOCATION:** NRC **WRITTEN BY:** _____

| THICKNESS (mil) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Plate: Fluid: Fluid Application Time: | | | | Plate: Fluid: Fluid Application Time: | | | |
| TIME | 1" LINE | 6" LINE | 12" LINE | TIME | 1" LINE | 6" LINE | 12" LINE |
| | | | | | | | |
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FIGURE C-4

# DOCUMENTATION OF FAILURE

## General Form (Every Run)

**Location:** CEF Ottawa **Date:** July , 1998 **Time:** _____

**Run #:** _____ **Ambient Temperature:** _____ (°C) **Precip. Type: ZR-, ZD**

**Run Objective:** _____

_____

**Plate Location:**

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 |

**Plate Documentation:**

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Fluid Type/Mix | | | | |
| C/FIMS | | | | |
| RVSI | | | | |
| Cox | | | | |
| Adherence | | | | |
| Brix | | | | |
| Thickness | | | | |
| Viscosity | | | | |
| Description | | | | |
| Photo | | | | |
| Video | | | | |

FIGURE C-5

# BRIX SAMPLING FORM

**Location:** CEF Ottawa **Date:** July , 1998

**Run #:** _____ **C/FIMS #:** _____

**Ambient Temperature:** _____ (°C) **Precip Type: ZR-, ZD**

**Plate Location:**

| | | | | | |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 7 | 8 | 9 | 10 | 11 | 12 |

**Fluid:** _____ **Initial Brix:** _____

| Time | Brix Top | Brix Bottom | Average Brix |
|---|---|---|---|
| | | | |
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FIGURE C-6

# VISCOSITY SAMPLING FORM

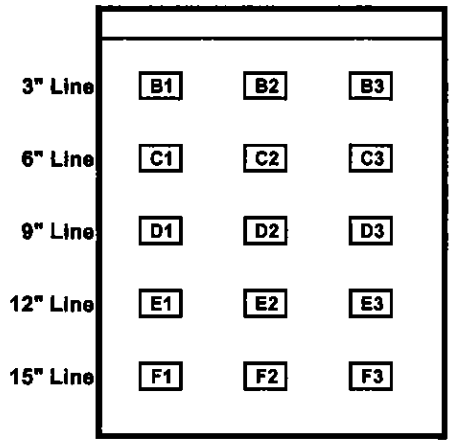
**Location:** CEF Ottawa

**Date:** July , 1998

**Run #:** _____

**Temperature:** _____ (°C)

**Precip Type:** ZR-, ZD




| Time | Fluid | Plate # | Sample Location | Bottle # | Viscosity |
|---|---|---|---|---|---|
| | | | | | |
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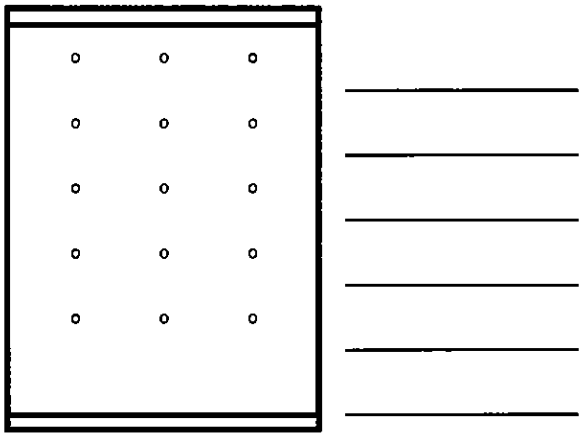
FIGURE C-7

# ADHERENCE OF FLUID FAILURE

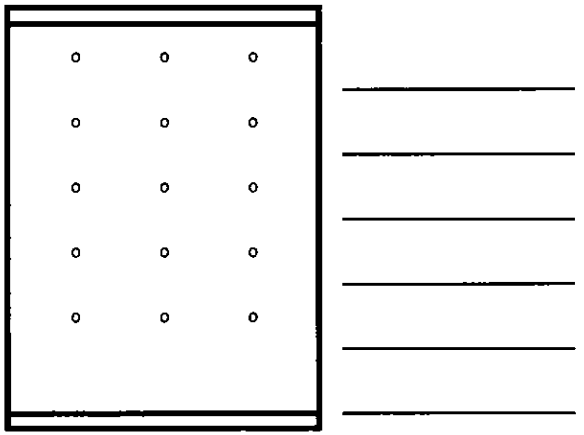
Date: _____ Time: _____ Plate Location: _____

Run #: _____ Fluid Name: _____ Fluid Dilution: _____

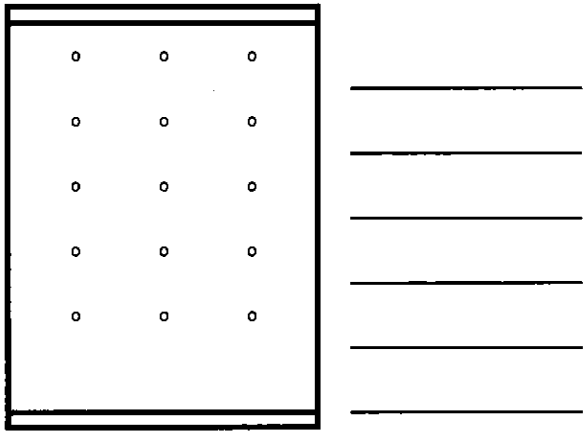
t =



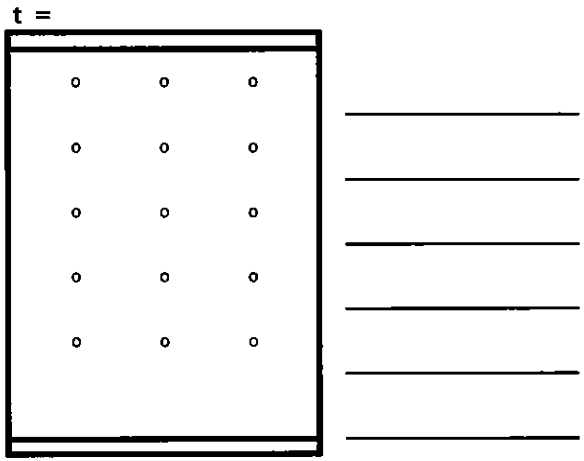
t =



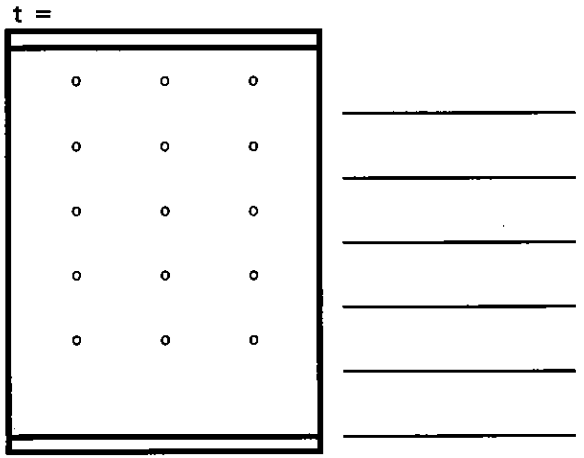
t =



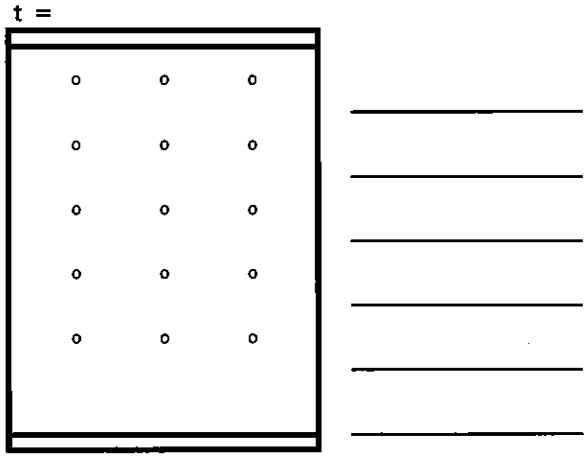
t =



t =



t =



Note: Ensure observations made 5th crosshair, whole plate
Make observations on C/FIMS

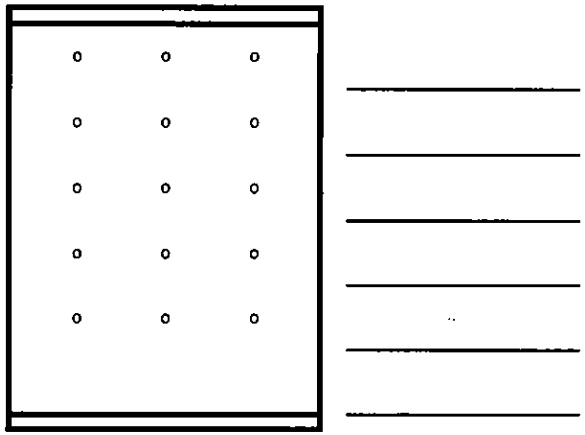
FIGURE C-8

# SUBJECTIVE APPEARANCE OF FLUID FAILURE

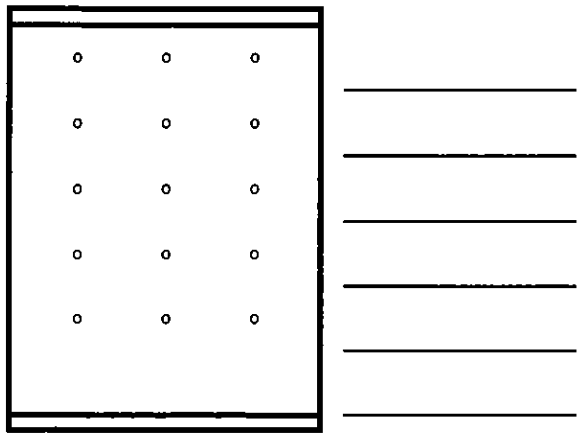
Date: _____ Time: _____ Plate Location: _____

Run #: _____ Fluid Name: _____ Fluid Dilution: _____

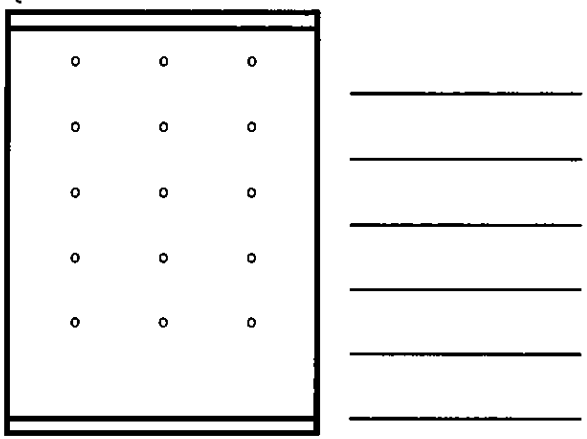
t =



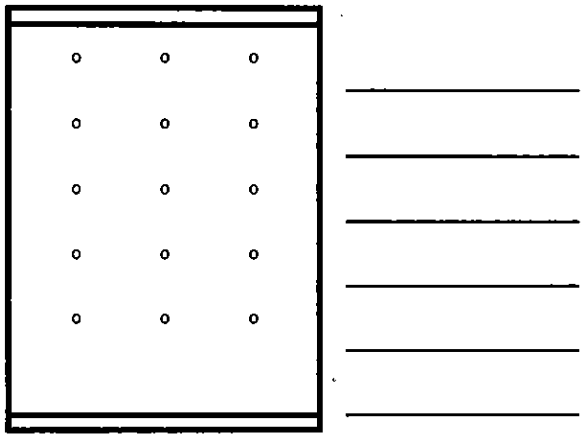
t =



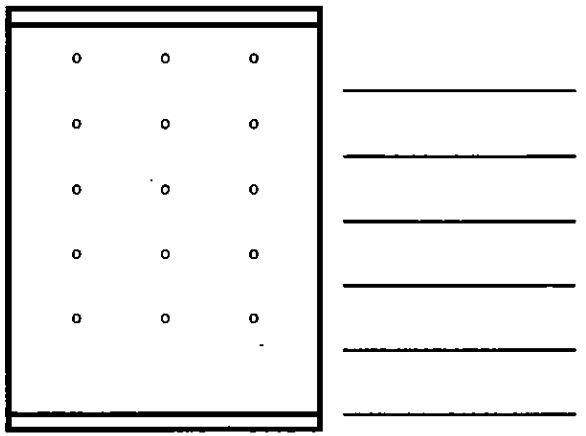
t =



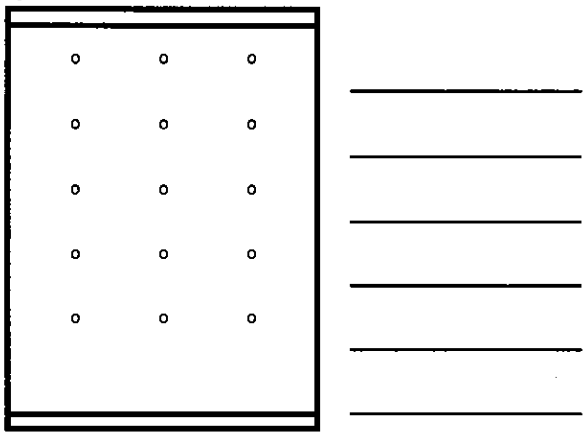
t =



t =



t =



Note: Ensure observations made at t=0, 1st failure, 5th crosshair, whole plate
Make observations on C/FIMS

# APPENDIX D

# LISTING OF FLAT PLATE TESTS CONDUCTED DURING 1997-98

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 1 | Dec-23-97 | Std. | AEROFLOT | 1 | 11 | 15 | 5.5 | -10.2 | 19 |
| 2 | Dec-23-97 | Std. | AEROFLOT | 1 | 11 | 15 | 5.5 | -10.2 | 19 |
| 3 | Dec-23-97 | Std. | AEROFLOT | 1 | 10 | 14 | 5.6 | -10.2 | 19 |
| 4 | Dec-23-97 | Std. | AEROFLOT | 1 | 10 | 15 | 5.6 | -10.2 | 19 |
| 5 | Dec-23-97 | Std. | AEROFLOT | 1 | 11 | 8 | 5.6 | -9.7 | 18 |
| 6 | Dec-23-97 | Std. | AEROFLOT | 1 | 11 | 11 | 5.6 | -9.7 | 18 |
| 7 | Dec-23-97 | Std. | INLAND | 0 | 13 | 8 | 5.6 | -9.7 | 18 |
| 8 | Dec-23-97 | Std. | INLAND | 0 | 13 | 8 | 5.6 | -9.7 | 18 |
| 9 | Dec-23-97 | Std. | UCAR XL54 | 1 | 14 | 14 | 5.6 | -9.6 | 18 |
| 10 | Dec-23-97 | Std. | UCAR XL54 | 1 | N/A | 14 | 5.6 | -9.6 | 18 |
| 11 | Dec-23-97 | Std. | UCAR XL54 | 1 | N/A | 20 | 5.8 | -8.5 | 15 |
| 12 | Dec-23-97 | Std. | UCAR XL54 | 1 | 9 | 21 | 6.2 | -8.5 | 15 |
| 13 | Dec-23-97 | Std. | INLAND | 0 | N/A | 19 | 5.8 | -8.5 | 15 |
| 14 | Dec-23-97 | Std. | INLAND | 0 | 9 | 19 | 5.8 | -8.5 | 15 |
| 15 | Dec-23-97 | Std. | AEROFLOT | 1 | 10 | 17 | 5.4 | -8.5 | 15 |
| 16 | Dec-23-97 | Std. | AEROFLOT | 1 | N/A | 17 | 5.4 | -8.5 | 15 |
| 17 | Dec-23-97 | Std. | AEROFLOT | 1 | N/A | 8 | 12.6 | -7.6 | 15 |
| 18 | Dec-23-97 | Std. | AEROFLOT | 1 | N/A | 8 | 12.6 | -7.6 | 15 |
| 19 | Dec-23-97 | Std. | INLAND | 0 | N/A | 8 | 12.6 | -7.6 | 15 |
| 20 | Dec-23-97 | Std. | INLAND | 0 | N/A | 8 | 12.6 | -7.6 | 15 |
| 21 | Dec-23-97 | Std. | UCAR XL54 | 1 | N/A | 8 | 12.6 | -7.6 | 14 |
| 22 | Dec-23-97 | Std. | UCAR XL54 | 1 | N/A | 8 | 12.6 | -7.6 | 14 |
| 23 | Dec-23-97 | Std. | AEROFLOT | 1 | N/A | 10 | 7.1 | -7.3 | 17 |
| 24 | Dec-23-97 | Std. | AEROFLOT | 1 | N/A | 10 | 7.1 | -7.3 | 17 |
| 25 | Dec-23-97 | Std. | INLAND | 0 | N/A | 10 | 7.1 | -7.2 | 16 |
| 26 | Dec-23-97 | Std. | INLAND | 0 | N/A | 11 | 7.1 | -7.2 | 17 |
| 27 | Dec-23-97 | Std. | UCAR XL54 | 1 | N/A | 13 | 7.1 | -7.2 | 17 |
| 28 | Dec-23-97 | Std. | UCAR XL54 | 1 | N/A | 13 | 7.1 | -7.2 | 17 |
| 29 | Dec-23-97 | Std. | AEROFLOT | 1 | N/A | 19 | 3.6 | -7.0 | 14 |
| 30 | Dec-23-97 | Std. | AEROFLOT | 1 | 7 | 23 | 3.8 | -7.0 | 14 |
| 31 | Dec-23-97 | Std. | INLAND | 0 | N/A | 19 | 3.7 | -7.0 | 14 |
| 32 | Dec-23-97 | Std. | INLAND | 0 | 8 | 21 | 3.8 | -7.0 | 14 |
| 33 | Dec-23-97 | Std. | UCAR XL54 | 1 | N/A | 23 | 3.8 | -6.9 | 14 |
| 34 | Dec-23-97 | Std. | UCAR XL54 | 1 | 8 | 23 | 3.8 | -6.9 | 14 |
| 35 | Dec-23-97 | Std. | AEROFLOT | 1 | N/A | 15 | 6.1 | -6.0 | 13 |
| 36 | Dec-23-97 | Std. | AEROFLOT | 1 | 5 | 15 | 6.1 | -6.0 | 13 |
| 37 | Dec-23-97 | Std. | INLAND | 0 | N/A | 15 | 6.1 | -6.0 | 13 |
| 38 | Dec-23-97 | Std. | INLAND | 0 | 5 | 15 | 6.1 | -6.0 | 13 |
| 39 | Dec-23-97 | Std. | UCAR XL54 | 1 | 7 | 16 | 6.0 | -6.0 | 14 |
| 40 | Dec-23-97 | Std. | UCAR XL54 | 1 | N/A | 17 | 6.0 | -6.0 | 14 |
| 41 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 21 | 54 | 8.6 | -15.7 | 20 |
| 42 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 21 | 54 | 8.6 | -15.7 | 20 |
| 43 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 15 | 46 | 6.6 | -15.7 | 19 |
| 44 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 17 | 45 | 6.6 | -15.7 | 19 |
| 45 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 21 | 56 | 9.3 | -15.6 | 20 |
| 46 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 21 | 57 | 9.3 | -15.6 | 20 |
| 47 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 21 | 45 | 13.7 | -14.6 | 23 |
| 48 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 22 | 44 | 13.4 | -14.6 | 23 |



h:\cm1380/report/hot_subs/978_SNOW
At: DRVL_LOG
11/22/20063:54 PM

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 49 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 19 | 34 | 11.7 | -14.6 | 23 |
| 50 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 19 | 34 | 11.7 | -14.6 | 23 |
| 51 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 20 | 41 | 13.1 | -14.6 | 23 |
| 52 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 21 | 41 | 13.1 | -14.6 | 23 |
| 53 | Jan-23-98 | neat | ULTRA IV | 4 | 20 | 54 | 30.2 | -13.8 | 24 |
| 54 | Jan-23-98 | neat | ULTRA IV | 4 | 17 | 67 | 28.9 | -13.7 | 24 |
| 55 | Jan-23-98 | 75% | ULTRA IV | 4b | 13 | 35 | 25.5 | -14.0 | 24 |
| 56 | Jan-23-98 | 75% | ULTRA IV | 4b | 14 | 35 | 25.5 | -14.0 | 24 |
| 57 | Jan-23-98 | neat | UCAR PG | 4 | 24 | 54 | 29.4 | -13.8 | 24 |
| 58 | Jan-23-98 | neat | UCAR PG | 4 | 22 | 66 | 27.5 | -13.6 | 24 |
| 59 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 20 | 34 | 22.9 | -12.9 | 23 |
| 60 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 20 | 33 | 22.9 | -12.9 | 23 |
| 61 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 20 | 23 | 22.6 | -13.0 | 22 |
| 62 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 21 | 23 | 22.6 | -13.0 | 22 |
| 63 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 21 | 21 | 22.3 | -13.0 | 22 |
| 64 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 21 | 22 | 22.6 | -13.0 | 22 |
| 65 | Jan-23-98 | neat | UCAR PG | 4 | 17 | 51 | 39.5 | -11.0 | 19 |
| 66 | Jan-23-98 | neat | UCAR PG | 4 | 18 | 58 | 36.6 | -10.8 | 18 |
| 67 | Jan-23-98 | 75% | UCAR PG | 4b | 16 | 26 | 42.7 | -11.6 | 21 |
| 68 | Jan-23-98 | 75% | UCAR PG | 4b | 16 | 24 | 41.5 | -11.6 | 20 |
| 69 | Jan-23-98 | neat | ULTRA IV | 4 | 15 | 55 | 37.0 | -10.8 | 18 |
| 70 | Jan-23-98 | neat | ULTRA IV | 4 | 14 | 56 | 36.6 | -10.7 | 18 |
| 71 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 19 | 30 | 37.0 | -11.6 | 21 |
| 72 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 19 | 29 | 37.1 | -11.6 | 21 |
| 73 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 17 | 22 | 35.4 | -11.7 | 20 |
| 74 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 17 | 21 | 33.4 | -11.7 | 20 |
| 75 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 19 | 29 | 37.0 | -11.4 | 20 |
| 76 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 20 | 30 | 36.9 | -11.4 | 20 |
| 77 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 16 | 26 | 48.1 | -7.9 | 18 |
| 78 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 16 | 26 | 48.1 | -7.9 | 18 |
| 79 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 16 | 17 | 50.4 | -8.0 | 18 |
| 80 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 16 | 17 | 50.4 | -8.0 | 18 |
| 81 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 17 | 25 | 47.4 | -7.9 | 18 |
| 82 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 17 | 23 | 48.9 | -7.9 | 18 |
| 83 | Jan-23-98 | neat | UCAR PG | 4 | 13 | 58 | 23.5 | -7.5 | 19 |
| 84 | Jan-23-98 | neat | UCAR PG | 4 | 14 | 59 | 23.5 | -7.4 | 20 |
| 85 | Jan-23-98 | 75% | UCAR PG | 4b | 16 | 23 | 31.3 | -7.8 | 18 |
| 86 | Jan-23-98 | 75% | UCAR PG | 4b | 16 | 23 | 31.3 | -7.8 | 18 |
| 87 | Jan-23-98 | neat | ULTRA IV | 4 | 13 | 66 | 24.2 | -7.3 | 20 |
| 88 | Jan-23-98 | neat | ULTRA IV | 4 | 13 | 65 | 24.0 | -7.4 | 20 |
| 89 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 19 | 22 | 37.9 | -7.1 | 23 |
| 90 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 19 | 23 | 37.6 | -7.1 | 23 |
| 91 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 16 | 20 | 37.7 | -7.1 | 23 |
| 92 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 16 | 20 | 37.7 | -7.1 | 23 |
| 93 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 19 | 23 | 37.1 | -7.0 | 23 |
| 94 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 19 | 23 | 37.1 | -7.0 | 23 |
| 95 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 15 | 23 | 52.4 | -6.9 | 17 |
| 96 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 16 | 21 | 54.7 | -6.9 | 17 |

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 97 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 16 | 17 | 48.7 | -6.9 | 17 |
| 98 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 17 | 18 | 51.0 | -6.9 | 17 |
| 99 | Jan-23-98 | neat | ULTRA IV | 4 | 13 | 58 | 40.4 | -6.9 | 16 |
| 100 | Jan-23-98 | neat | ULTRA IV | 4 | 13 | 54 | 41.5 | -6.9 | 16 |
| 101 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 18 | 26 | 54.4 | -6.9 | 17 |
| 102 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 18 | 26 | 54.4 | -6.9 | 17 |
| 103 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 14 | 20 | 53.1 | -6.9 | 17 |
| 104 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 13 | 20 | 53.1 | -6.9 | 17 |
| 105 | Jan-23-98 | neat | UCAR PG | 4 | 15 | 52 | 43.7 | -6.9 | 15 |
| 106 | Jan-23-98 | neat | UCAR PG | 4 | 15 | 52 | 43.7 | -6.9 | 15 |
| 107 | Jan-23-98 | 75% | UCAR PG | 4b | N/A | 15 | 40.0 | -6.9 | 17 |
| 108 | Jan-23-98 | 75% | UCAR PG | 4b | N/A | 15 | 40.0 | -6.9 | 17 |
| 109 | Jan-23-98 | 75% | UCAR PG | 4b | N/A | 14 | 40.0 | -6.9 | 17 |
| 110 | Jan-23-98 | 75% | UCAR PG | 4b | N/A | 14 | 40.0 | -6.9 | 17 |
| 111 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 15 | 20 | 43.8 | -7.0 | 17 |
| 112 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 15 | 23 | 44.6 | -7.0 | 17 |
| 113 | Jan-23-98 | 75% | UCAR PG | 4b | 15 | 20 | 30.2 | -6.8 | 15 |
| 114 | Jan-23-98 | 75% | UCAR PG | 4b | 15 | 21 | 30.2 | -6.8 | 15 |
| 115 | Jan-23-98 | 75% | ULTRA IV | 4b | 13 | 21 | 30.2 | -6.8 | 16 |
| 116 | Jan-23-98 | 75% | ULTRA IV | 4b | 12 | 22 | 30.2 | -6.8 | 16 |
| 117 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 14 | 32 | 27.7 | -6.8 | 16 |
| 118 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 16 | 34 | 27.3 | -6.8 | 16 |
| 119 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 15 | 46 | 25.8 | -6.7 | 18 |
| 120 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 15 | 48 | 25.9 | -6.7 | 18 |
| 121 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 12 | 37 | 26.6 | -6.7 | 18 |
| 122 | Jan-23-98 | 75% | CLARIANT 2001 | 4b | 11 | 37 | 26.6 | -6.7 | 18 |
| 123 | Jan-23-98 | 75% | UCAR PG | 4b | 13 | 38 | 26.5 | -6.7 | 18 |
| 124 | Jan-23-98 | 75% | UCAR PG | 4b | 15 | 38 | 26.5 | -6.7 | 18 |
| 125 | Jan-23-98 | neat | ULTRA IV | 4 | 11 | 88 | 17.1 | -6.5 | 19 |
| 126 | Jan-23-98 | neat | ULTRA IV | 4 | 9 | 86 | 17.2 | -6.5 | 19 |
| 127 | Jan-23-98 | neat | UCAR PG | 4 | 14 | 64 | 17.3 | -6.7 | 20 |
| 128 | Jan-23-98 | neat | UCAR PG | 4 | 12 | 75 | 17.1 | -6.6 | 19 |
| 129 | Jan-23-98 | 75% | ULTRA IV | 4b | 10 | 33 | 21.5 | -6.7 | 20 |
| 130 | Jan-23-98 | 75% | ULTRA IV | 4b | 10 | 33 | 21.5 | -6.7 | 20 |
| 131 | Jan-23-98 | neat | UCAR PG | 4 | 13 | 93 | 21.0 | -6.3 | 18 |
| 132 | Jan-23-98 | neat | UCAR PG | 4 | 12 | 94 | 20.9 | -6.3 | 18 |
| 133 | Jan-23-98 | neat | ULTRA IV | 4 | 10 | 131 | 22.4 | -6.0 | 16 |
| 134 | Jan-23-98 | neat | ULTRA IV | 4 | 11 | 100 | 19.7 | -6.3 | 17 |
| 135 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 15 | 50 | 22.3 | -6.4 | 18 |
| 136 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 16 | 51 | 22.3 | -6.4 | 18 |
| 137 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 10 | 76 | 10.2 | -5.1 | 15 |
| 138 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 10 | 76 | 10.2 | -5.1 | 15 |
| 139 | Jan-23-98 | neat | UCAR PG | 4 | 10 | 139 | 8.9 | -4.7 | 14 |
| 140 | Jan-23-98 | neat | UCAR PG | 4 | 10 | 153 | 9.6 | -4.7 | 14 |
| 141 | Jan-23-98 | 75% | UCAR PG | 4b | 10 | 65 | 10.3 | -5.1 | 15 |
| 142 | Jan-23-98 | 75% | UCAR PG | 4b | 10 | 67 | 10.3 | -5.1 | 15 |
| 143 | Jan-23-98 | neat | ULTRA IV | 4 | 7 | 128 | 10.6 | -4.7 | 14 |
| 144 | Jan-23-98 | neat | ULTRA IV | 4 | 9 | 129 | 10.7 | -4.7 | 14 |

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 145 | Jan-23-98 | neat | UCAR PG | 4 | 11 | 127 | 10.6 | -4.7 | 14 |
| 146 | Jan-23-98 | neat | UCAR PG | 4 | 12 | 148 | 11.4 | -4.7 | 14 |
| 147 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 9 | 68 | 13.1 | -4.9 | 15 |
| 148 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 9 | 89 | 11.6 | -4.8 | 15 |
| 149 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 11 | 80 | 9.8 | -4.4 | 14 |
| 150 | Jan-23-98 | neat | CLARIANT 1957 | 4 | 12 | 81 | 10.0 | -4.4 | 14 |
| 151 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 10 | 60 | 7.8 | -4.3 | 14 |
| 152 | Jan-23-98 | 75% | CLARIANT 1957 | 4b | 9 | 58 | 8.4 | -4.3 | 14 |
| 153 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 11 | 107 | 8.4 | -4.5 | 14 |
| 154 | Jan-23-98 | neat | CLARIANT 2001 | 4 | 11 | 107 | 8.4 | -4.5 | 14 |
| 155 | Jan-23-98 | Std. | AEROFLOT | 1 | 6 | 8 | 13.6 | -5.0 | 17 |
| 156 | Jan-23-98 | Std. | AEROFLOT | 1 | 6 | 8 | 13.6 | -5.0 | 17 |
| 157 | Feb-18-98 | Std. | TYPE 0 ETH | 0 | N/A | 2 | 59.7 | -0.6 | 16 |
| 158 | Feb-18-98 | Std. | TYPE 0 ETH | 0 | N/A | 3 | 59.7 | -0.6 | 15 |
| 159 | Feb-18-98 | Std. | TYPE 0 PRO | 0 | N/A | 3 | 59.7 | -0.6 | 15 |
| 160 | Feb-18-98 | Std. | TYPE 0 PRO | 0 | N/A | 3 | 59.7 | -0.6 | 15 |
| 161 | Feb-18-98 | 50% | CLARIANT 1957 | 4a | 5 | 7 | 59.7 | -0.6 | 15 |
| 162 | Feb-18-98 | 50% | CLARIANT 1957 | 4a | 6 | 7 | 59.7 | -0.6 | 15 |
| 163 | Feb-18-98 | 50% | CLARIANT 2001 | 4a | 5 | 9 | 21.9 | -0.9 | 14 |
| 164 | Feb-18-98 | 50% | CLARIANT 2001 | 4a | 6 | 9 | 21.2 | -0.9 | 14 |
| 165 | Feb-18-98 | Std. | TYPE 0 ETH | 0 | 4 | 5 | 21.2 | -0.9 | 13 |
| 166 | Feb-18-98 | Std. | TYPE 0 ETH | 0 | 4 | 5 | 21.2 | -0.9 | 13 |
| 167 | Feb-18-98 | Std. | TYPE 0 PRO | 0 | 3 | 7 | 21.2 | -0.9 | 13 |
| 168 | Feb-18-98 | Std. | TYPE 0 PRO | 0 | 4 | 6 | 21.2 | -0.9 | 13 |
| 169 | Feb-18-98 | 50% | CLARIANT 2001 | 4a | 5 | 7 | 29.1 | -0.9 | 13 |
| 170 | Feb-18-98 | 50% | CLARIANT 2001 | 4a | 5 | 7 | 29.1 | -0.9 | 13 |
| 171 | Feb-18-98 | 50% | CLARIANT 1957 | 4a | 5 | 17 | 23.9 | -0.9 | 14 |
| 172 | Feb-18-98 | 50% | CLARIANT 1957 | 4a | 5 | 15 | 24.9 | -0.9 | 14 |
| 173 | Feb-25-98 | neat | UCAR PG | 4 | 3 | 91 | 25.5 | 0.5 | 19 |
| 174 | Feb-25-98 | neat | UCAR PG | 4 | 3 | 95 | 24.1 | 0.5 | 19 |
| 175 | Feb-25-98 | neat | ULTRA IV | 4 | 4 | 92 | 24.4 | 0.5 | 19 |
| 176 | Feb-25-98 | neat | ULTRA IV | 4 | 1 | 100 | 23.4 | 0.5 | 19 |
| 177 | Feb-25-98 | neat | SPCA AD-480 | 4 | 3 | 66 | 27.3 | 0.5 | 21 |
| 178 | Feb-25-98 | neat | SPCA AD-480 | 4 | 2 | 77 | 26.5 | 0.5 | 20 |
| 179 | Feb-25-98 | 50% | CLARIANT 1957 | 4a | 3 | 15 | 18.9 | 0.4 | 19 |
| 180 | Feb-25-98 | 50% | CLARIANT 1957 | 4a | 2 | 15 | 18.9 | 0.4 | 19 |
| 181 | Feb-25-98 | 50% | CLARIANT 2001 | 4a | 3 | 11 | 20.6 | 0.4 | 19 |
| 182 | Feb-25-98 | 50% | CLARIANT 2001 | 4a | 3 | 12 | 19.9 | 0.4 | 19 |
| 183 | Feb-25-98 | 50% | SPCA AD-480 | 4a | 3 | 17 | 19.4 | 0.4 | 17 |
| 184 | Feb-25-98 | 50% | SPCA AD-480 | 4a | 3 | 17 | 19.4 | 0.4 | 17 |
| 185 | Feb-25-98 | 50% | SPCA AD-480 | 4a | 2 | 18 | 19.3 | 0.4 | 15 |
| 186 | Feb-25-98 | 50% | SPCA AD-480 | 4a | 3 | 18 | 19.3 | 0.4 | 15 |
| 187 | Feb-25-98 | 50% | SPCA AD-404 | 4a | 3 | 28 | 20.2 | 0.4 | 15 |
| 188 | Feb-25-98 | 50% | SPCA AD-404 | 4a | 3 | 28 | 20.2 | 0.4 | 15 |
| 189 | Feb-25-98 | 50% | CLARIANT 1957 | 4a | 2 | 19 | 19.9 | 0.4 | 15 |
| 190 | Feb-25-98 | 50% | CLARIANT 1957 | 4a | 4 | 11 | 19.7 | 0.4 | 16 |
| 191 | Feb-25-98 | 50% | CLARIANT 2001 | 4a | 2 | 13 | 19.5 | 0.4 | 13 |
| 192 | Feb-25-98 | 50% | CLARIANT 2001 | 4a | 2 | 12 | 19.6 | 0.4 | 13 |

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 193 | Feb-25-98 | 50% | SPCA AD-404 | 4a | 3 | 29 | 19.4 | 0.4 | 13 |
| 194 | Feb-25-98 | 50% | SPCA AD-404 | 4a | 2 | 28 | 19.2 | 0.4 | 13 |
| 195 | Feb-25-98 | 50% | ULTRA IV | 4a | 2 | 22 | 18.5 | 0.4 | 13 |
| 196 | Feb-25-98 | 50% | ULTRA IV | 4a | 3 | 22 | 18.5 | 0.4 | 13 |
| 197 | Mar-10-98 | neat | CLARIANT 1957 | 4 | 9 | 83 | 11.5 | -4.8 | 34 |
| 198 | Mar-10-98 | neat | CLARIANT 1957 | 4 | 9 | 88 | 11.3 | -4.8 | 34 |
| 199 | Mar-10-98 | neat | ULTRA IV | 4 | 8 | 144 | 8.8 | -5.3 | 35 |
| 200 | Mar-10-98 | neat | ULTRA IV | 4 | 8 | 143 | 8.8 | -5.3 | 35 |
| 201 | Mar-10-98 | 50% | CLARIANT 1957 | 4a | 7 | 14 | 9.6 | -4.8 | 33 |
| 202 | Mar-10-98 | 50% | CLARIANT 1957 | 4a | 8 | 14 | 9.6 | -4.8 | 33 |
| 203 | Mar-10-98 | 75% | CLARIANT 2001 | 4b | 9 | 42 | 8.6 | -5.2 | 34 |
| 204 | Mar-10-98 | 75% | CLARIANT 2001 | 4b | 9 | 43 | 8.6 | -5.2 | 35 |
| 205 | Mar-10-98 | 75% | ULTRA IV | 4b | 8 | 51 | 8.7 | -5.3 | 35 |
| 206 | Mar-10-98 | 75% | ULTRA IV | 4b | 8 | 52 | 8.7 | -5.3 | 35 |
| 207 | Mar-14-98 | 75% | ULTRA IV | 4b | 4 | 120 | 5.9 | -2.7 | 26 |
| 208 | Mar-14-98 | 75% | ULTRA IV | 4b | 2 | 119 | 5.9 | -2.7 | 26 |
| 209 | Mar-14-98 | 75% | UCAR PG | 4b | 5 | 121 | 5.9 | -2.7 | 26 |
| 210 | Mar-14-98 | 75% | UCAR PG | 4b | 5 | 119 | 5.9 | -2.7 | 26 |
| 211 | Mar-14-98 | 75% | SPCA AD-480 | 4b | 3 | 128 | 5.9 | -2.7 | 26 |
| 212 | Mar-14-98 | 75% | SPCA AD-480 | 4b | 4 | 168 | 6.0 | -2.6 | 25 |
| 213 | Mar-14-98 | 50% | KILFROST ABC-S | 4a | 2 | 41 | 6.7 | -2.2 | 21 |
| 214 | Mar-14-98 | 50% | KILFROST ABC-S | 4a | 3 | 41 | 6.7 | -2.2 | 21 |
| 215 | Mar-14-98 | 50% | UCAR PG | 4a | 4 | 45 | 7.3 | -2.2 | 21 |
| 216 | Mar-14-98 | 50% | UCAR PG | 4a | 4 | 49 | 7.4 | -2.2 | 21 |
| 217 | Mar-14-98 | neat | SPCA AD-480 | 4 | 4 | 159 | 6.2 | -2.6 | 25 |
| 218 | Mar-14-98 | neat | SPCA AD-480 | 4 | 5 | 169 | 6.1 | -2.6 | 25 |
| 219 | Mar-14-98 | neat | CLARIANT 1957 | 4 | 2 | 120 | 5.6 | -2.7 | 26 |
| 220 | Mar-14-98 | neat | CLARIANT 1957 | 4 | 5 | 112 | 6.0 | -2.7 | 26 |
| 221 | Mar-14-98 | neat | CLARIANT 2001 | 4 | 2 | 135 | 6.3 | -2.7 | 26 |
| 222 | Mar-14-98 | neat | CLARIANT 2001 | 4 | 1 | 128 | 6.2 | -2.7 | 26 |
| 223 | Mar-14-98 | neat | OCTAGON MAXFLIGHT | 4 | 2 | 135 | 7.3 | -2.7 | 25 |
| 224 | Mar-14-98 | neat | OCTAGON MAXFLIGHT | 4 | 3 | 127 | 7.3 | -2.7 | 26 |
| 225 | Mar-14-98 | neat | UCAR PG | 4 | 3 | 160 | 7.1 | -2.6 | 25 |
| 226 | Mar-14-98 | neat | UCAR PG | 4 | 3 | 160 | 7.1 | -2.6 | 25 |
| 227 | Mar-14-98 | neat | ULTRA IV | 4 | 3 | 170 | 6.9 | -2.6 | 24 |
| 228 | Mar-14-98 | neat | ULTRA IV | 4 | 3 | 170 | 6.9 | -2.6 | 24 |
| 229 | Mar-14-98 | Std. | TYPE 0 PRO | 0 | 3 | 21 | 5.6 | -2.2 | 21 |
| 230 | Mar-14-98 | Std. | TYPE 0 PRO | 0 | 4 | 21 | 5.6 | -2.2 | 21 |
| 231 | Mar-14-98 | neat | UCAR PG | 4 | 1 | 168 | 6.7 | -2.6 | 24 |
| 232 | Mar-14-98 | neat | UCAR PG | 4 | 1 | 168 | 6.7 | -2.6 | 24 |
| 233 | Mar-14-98 | neat | ULTRA IV | 4 | 1 | 173 | 6.9 | -2.5 | 24 |
| 234 | Mar-14-98 | neat | ULTRA IV | 4 | 1 | 182 | 7.1 | -2.5 | 23 |
| 235 | Mar-14-98 | neat | KILFROST ABC-S | 4 | 5 | 78 | 6.9 | -2.7 | 26 |
| 236 | Mar-14-98 | neat | KILFROST ABC-S | 4 | 4 | 95 | 6.7 | -2.7 | 26 |
| 237 | Mar-14-98 | 50% | SPCA AD-480 | 4a | 3 | 42 | 7.2 | -2.1 | 20 |
| 238 | Mar-14-98 | 50% | SPCA AD-480 | 4a | 1 | 42 | 7.2 | -2.1 | 20 |
| 239 | *Mar-14-98* | *75%* | *SPCA AD-480* | *4b* | *N/A* | *77* | 11.1 | *-1.7* | *15* |
| 240 | *Mar-14-98* | *75%* | *SPCA AD-480* | *4b* | *N/A* | *77* | 11.1 | *-1.7* | *15* |

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 241 | *Mar-14-98* | *75%* | *SPCA AD-404* | *4b* | *2* | *96* | 11.6 | *-1.6* | *15* |
| 242 | *Mar-14-98* | *75%* | *SPCA AD-404* | *4b* | *0* | *122* | 11.5 | *-1.5* | *16* |
| 243 | *Mar-14-98* | *75%* | *CLARIANT 1957* | *4b* | *N/A* | *85* | 11.4 | *-1.6* | *15* |
| 244 | *Mar-14-98* | *75%* | *CLARIANT 1957* | *4b* | *N/A* | *74* | 11.1 | *-1.7* | *15* |
| 245 | Mar-14-98 | 50% | CLARIANT 1957 | 4a | 2 | 22 | 13.3 | -2.0 | 14 |
| 246 | Mar-14-98 | 50% | CLARIANT 1957 | 4a | 2 | 21 | 13.2 | -2.0 | 14 |
| 247 | Mar-14-98 | 50% | CLARIANT 2001 | 4a | 2 | 19 | 13.2 | -2.0 | 14 |
| 248 | Mar-14-98 | 50% | CLARIANT 2001 | 4a | 3 | 19 | 13.2 | -2.0 | 14 |
| 249 | Mar-14-98 | 50% | ULTRA IV | 4a | 3 | 28 | 13.5 | -2.0 | 14 |
| 250 | Mar-14-98 | 50% | ULTRA IV | 4a | 2 | 25 | 13.5 | -2.0 | 14 |
| 251 | Mar-14-98 | 50% | ULTRA IV | 4a | 2 | 24 | 14.1 | -2.0 | 14 |
| 252 | Mar-14-98 | 50% | KILFROST ABC-S | 4a | 2 | 22 | 14.1 | -2.0 | 14 |
| 253 | Mar-14-98 | 50% | KILFROST ABC-S | 4a | 2 | 23 | 14.1 | -2.0 | 14 |
| 254 | Mar-14-98 | 75% | KILFROST ABC-S | 4b | 0 | 53 | 10.1 | -1.4 | 16 |
| 255 | Mar-14-98 | 75% | CLARIANT 2001 | 4b | N/A | 51 | 9.8 | -1.4 | 16 |
| 256 | Mar-14-98 | 75% | ULTRA IV | 4b | 0 | 125 | 10.8 | -1.1 | 15 |
| 257 | Mar-14-98 | 75% | KILFROST ABC-S | 4b | 0 | 51 | 8.8 | -1.0 | 16 |
| 258 | Mar-14-98 | 75% | KILFROST ABC-S | 4b | 0 | 69 | 8.8 | -1.0 | 15 |
| 259 | Mar-21-98 | 75% | ULTRA IV | 4b | 7 | 43 | 20.1 | -4.0 | 29 |
| 260 | Mar-21-98 | 75% | ULTRA IV | 4b | 8 | 44 | 20.0 | -4.0 | 29 |
| 261 | Mar-21-98 | 75% | UCAR PG | 4b | 8 | 44 | 20.0 | -4.0 | 29 |
| 262 | Mar-21-98 | 75% | UCAR PG | 4b | 9 | 44 | 20.0 | -4.0 | 29 |
| 263 | Mar-21-98 | 75% | CLARIANT 1957 | 4b | 9 | 34 | 20.6 | -4.0 | 30 |
| 264 | Mar-21-98 | 75% | CLARIANT 1957 | 4b | 9 | 34 | 20.6 | -4.0 | 30 |
| 265 | Mar-21-98 | 75% | SPCA AD-404 | 4b | 7 | 70 | 7.0 | -3.5 | 31 |
| 266 | Mar-21-98 | 75% | SPCA AD-404 | 4b | 8 | 81 | 6.6 | -3.5 | 31 |
| 267 | Mar-21-98 | 75% | CLARIANT 2001 | 4b | 8 | 58 | 7.3 | -3.5 | 31 |
| 268 | Mar-21-98 | 75% | CLARIANT 2001 | 4b | 8 | 60 | 7.3 | -3.5 | 31 |
| 269 | Mar-21-98 | Std. | OCTAGON | 1 | 8 | 18 | 4.1 | -3.5 | 34 |
| 270 | Mar-21-98 | Std. | UCAR XL54 | 1 | 8 | 21 | 3.8 | -3.5 | 34 |
| 271 | Mar-21-98 | Std. | TYPE 0 ETH | 0 | 8 | 24 | 3.4 | -3.5 | 33 |
| 272 | Mar-21-98 | Std. | TYPE 0 PRO | 0 | 8 | 25 | 3.3 | -3.5 | 33 |
| 273 | Mar-22-98 | neat | ULTRA IV | 4 | 6 | 171 | 7.0 | -3.3 | 33 |
| 274 | Mar-22-98 | neat | ULTRA IV | 4 | 6 | 170 | 7.0 | -3.3 | 33 |
| 275 | Mar-22-98 | neat | UCAR PG | 4 | 8 | 168 | 7.0 | -3.3 | 33 |
| 276 | Mar-22-98 | neat | CLARIANT 1957 | 4 | 8 | 120 | 5.7 | -3.2 | 32 |
| 277 | Mar-22-98 | neat | CLARIANT 1957 | 4 | 8 | 125 | 5.8 | -3.2 | 32 |
| 278 | Mar-22-98 | Std. | UCAR XL54 | 1 | 7 | 7 | 17.5 | -3.5 | 34 |
| 279 | Mar-22-98 | Std. | OCTAGON | 1 | 8 | 8 | 17.5 | -3.5 | 34 |
| 280 | Mar-22-98 | Std. | TYPE 0 ETH | 0 | 8 | 7 | 17.5 | -3.5 | 34 |
| 281 | Mar-22-98 | Std. | TYPE 0 PRO | 0 | 9 | 7 | 17.5 | -3.5 | 34 |
| 282 | Mar-22-98 | 75% | CLARIANT 2001 | 4b | 9 | 43 | 13.6 | -3.4 | 34 |
| 283 | Mar-22-98 | 75% | CLARIANT 2001 | 4b | 10 | 44 | 13.7 | -3.4 | 34 |
| 284 | Mar-22-98 | 75% | ULTRA IV | 4b | 6 | 72 | 8.0 | -3.3 | 29 |
| 285 | Mar-22-98 | 75% | ULTRA IV | 4b | 7 | 84 | 8.0 | -3.3 | 30 |
| 286 | Mar-22-98 | 75% | UCAR PG | 4b | 9 | 84 | 8.0 | -3.3 | 30 |
| 287 | Mar-22-98 | 75% | UCAR PG | 4b | 10 | 81 | 8.0 | -3.3 | 30 |
| 288 | Mar-22-98 | 75% | CLARIANT 1957 | 4b | 9 | 66 | 8.0 | -3.3 | 29 |

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 289 | Mar-22-98 | 75% | CLARIANT 1957 | 4b | 9 | 69 | 8.0 | -3.3 | 29 |
| 290 | Mar-22-98 | neat | SPCA AD-480 | 4 | 8 | 176 | 6.9 | -3.3 | 33 |
| 291 | Mar-22-98 | neat | SPCA AD-480 | 4 | 8 | 190 | 7.8 | -3.3 | 33 |
| 292 | Mar-22-98 | neat | SPCA AD-404 | 4 | 7 | 188 | 7.8 | -3.3 | 33 |
| 293 | Mar-22-98 | neat | SPCA AD-404 | 4 | 7 | 219 | 9.2 | -3.3 | 33 |
| 294 | Mar-22-98 | neat | KILFROST ABC-S | 4 | 8 | 90 | 6.6 | -3.3 | 30 |
| 295 | Mar-22-98 | neat | KILFROST ABC-S | 4 | 7 | 120 | 5.8 | -3.3 | 31 |
| 296 | Mar-22-98 | neat | CLARIANT 1957 | 4 | 7 | 66 | 8.7 | -3.4 | 34 |
| 297 | Mar-22-98 | neat | CLARIANT 1957 | 4 | 7 | 79 | 8.9 | -3.4 | 34 |
| 298 | Mar-22-98 | neat | OCTAGON MAXFLIGHT | 4 | 9 | 131 | 6.7 | -3.2 | 33 |
| 299 | Mar-22-98 | neat | OCTAGON MAXFLIGHT | 4 | 9 | 132 | 6.7 | -3.2 | 33 |
| 300 | Mar-22-98 | neat | ULTRA IV | 4 | 7 | 140 | 7.0 | -3.2 | 33 |
| 301 | Mar-22-98 | neat | ULTRA IV | 4 | 7 | 140 | 7.0 | -3.2 | 33 |
| 302 | Mar-22-98 | neat | UCAR PG | 4 | 10 | 139 | 7.0 | -3.2 | 33 |
| 303 | Mar-22-98 | neat | UCAR PG | 4 | 10 | 136 | 6.9 | -3.2 | 33 |
| 304 | Mar-22-98 | 75% | CLARIANT 2001 | 4b | 7 | 52 | 11.9 | -3.2 | 35 |
| 305 | Mar-22-98 | 75% | CLARIANT 2001 | 4b | 8 | 53 | 11.9 | -3.2 | 35 |
| 306 | Mar-22-98 | 75% | CLARIANT 1957 | 4b | 9 | 55 | 12.1 | -3.2 | 35 |
| 307 | Mar-22-98 | 75% | SPCA AD-480 | 4b | 9 | 76 | 14.4 | -3.2 | 36 |
| 308 | Mar-22-98 | 75% | SPCA AD-480 | 4b | N/A | 79 | 14.7 | -3.3 | 35 |
| 309 | Mar-22-98 | Std. | UCAR XL54 | 1 | 6 | 8 | 19.4 | -3.5 | 30 |
| 310 | Mar-22-98 | Std. | OCTAGON | 1 | 9 | 7 | 19.4 | -3.5 | 30 |
| 311 | Mar-22-98 | Std. | TYPE 0 ETH | 0 | 7 | 8 | 19.4 | -3.5 | 30 |
| 312 | Mar-22-98 | Std. | TYPE 0 PRO | 0 | 9 | 6 | 19.4 | -3.6 | 31 |
| 313 | Mar-22-98 | neat | ULTRA IV | 4 | 9 | 92 | 19.8 | -3.6 | 34 |
| 314 | Mar-22-98 | neat | ULTRA IV | 4 | 9 | 85 | 19.8 | -3.6 | 34 |
| 315 | Mar-22-98 | neat | UCAR PG | 4 | 10 | 87 | 19.8 | -3.6 | 34 |
| 316 | Mar-22-98 | neat | UCAR PG | 4 | 10 | 84 | 19.8 | -3.6 | 34 |
| 317 | Mar-22-98 | neat | SPCA AD-480 | 4 | 10 | 59 | 21.7 | -3.6 | 34 |
| 318 | Mar-22-98 | neat | SPCA AD-480 | 4 | 10 | 59 | 21.7 | -3.6 | 34 |
| 319 | Mar-22-98 | 75% | KILFROST ABC-S | 4b | 9 | 31 | 27.6 | -3.7 | 35 |
| 320 | Mar-22-98 | 75% | KILFROST ABC-S | 4b | 9 | 33 | 27.7 | -3.7 | 35 |
| 321 | Mar-22-98 | 75% | OCTAGON MAXFLIGHT | 4b | 12 | 50 | 28.2 | -3.7 | 34 |
| 322 | Mar-22-98 | 75% | OCTAGON MAXFLIGHT | 4b | 12 | 50 | 28.2 | -3.7 | 34 |
| 323 | Mar-22-98 | 75% | CLARIANT 2001 | 4b | 10 | 34 | 27.8 | -3.7 | 34 |
| 324 | Mar-22-98 | 75% | CLARIANT 2001 | 4b | 10 | 35 | 27.8 | -3.7 | 34 |
| 325 | Mar-22-98 | neat | KILFROST ABC-S | 4 | 11 | 55 | 24.0 | -3.7 | 34 |
| 326 | Mar-22-98 | neat | KILFROST ABC-S | 4 | 9 | 56 | 24.0 | -3.7 | 34 |
| 327 | Mar-22-98 | neat | OCTAGON MAXFLIGHT | 4 | 9 | 53 | 24.0 | -3.7 | 34 |
| 328 | Mar-22-98 | neat | OCTAGON MAXFLIGHT | 4 | 11 | 54 | 23.8 | -3.7 | 34 |
| 329 | Mar-22-98 | neat | SPCA AD-480 | 4 | 10 | 62 | 24.6 | -3.8 | 34 |
| 330 | Mar-22-98 | neat | SPCA AD-480 | 4 | 11 | 63 | 24.8 | -3.8 | 34 |
| 331 | Mar-22-98 | neat | CLARIANT 2001 | 4 | 7 | 58 | 23.4 | -3.8 | 34 |
| 332 | Mar-22-98 | neat | CLARIANT 2001 | 4 | 7 | 63 | 23.4 | -3.8 | 34 |
| 333 | Mar-22-98 | neat | CLARIANT 1957 | 4 | 7 | 52 | 23.4 | -3.7 | 34 |
| 334 | Mar-22-98 | neat | CLARIANT 1957 | 4 | 7 | 58 | 23.4 | -3.8 | 34 |
| 335 | Mar-22-98 | neat | KILFROST ABC-S | 4 | 7 | 50 | 23.5 | -3.7 | 34 |
| 336 | Mar-22-98 | neat | KILFROST ABC-S | 4 | 7 | 55 | 23.4 | -3.8 | 34 |

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 337 | Mar-22-98 | 75% | CLARIANT 1957 | 4b | 8 | 15 | 42.1 | -4.0 | 35 |
| 338 | Mar-22-98 | 75% | CLARIANT 1957 | 4b | 8 | 14 | 42.1 | -4.0 | 35 |
| 339 | Mar-22-98 | 75% | CLARIANT 2001 | 4b | 9 | 12 | 42.1 | -4.0 | 35 |
| 340 | Mar-22-98 | 75% | CLARIANT 2001 | 4b | 8 | 13 | 42.1 | -4.0 | 36 |
| 341 | Mar-22-98 | 75% | KILFROST ABC-S | 4b | 9 | 11 | 42.1 | -4.0 | 35 |
| 342 | Mar-22-98 | 75% | KILFROST ABC-S | 4b | 9 | 11 | 42.1 | -4.0 | 35 |
| 343 | Mar-22-98 | 75% | ULTRA IV | 4b | 8 | 21 | 58.2 | -4.1 | 35 |
| 344 | Mar-22-98 | 75% | ULTRA IV | 4b | 8 | 21 | 58.2 | -4.1 | 35 |
| 345 | Mar-22-98 | 75% | UCAR PG | 4b | 13 | 22 | 58.7 | -4.1 | 34 |
| 346 | Mar-22-98 | 75% | UCAR PG | 4b | 13 | 22 | 58.7 | -4.1 | 34 |
| 347 | Mar-22-98 | 75% | SPCA AD-480 | 4b | 13 | 24 | 59.3 | -4.1 | 34 |
| 348 | Mar-22-98 | 75% | SPCA AD-480 | 4b | 12 | 25 | 59.5 | -4.1 | 34 |
| 349 | Mar-22-98 | neat | ULTRA IV | 4 | 9 | 59 | 37.4 | -4.2 | 35 |
| 350 | Mar-22-98 | neat | ULTRA IV | 4 | 9 | 66 | 38.1 | -4.2 | 35 |
| 351 | Mar-22-98 | neat | UCAR PG | 4 | 11 | 60 | 37.4 | -4.2 | 35 |
| 352 | Mar-22-98 | neat | UCAR PG | 4 | 11 | 60 | 37.4 | -4.2 | 35 |
| 353 | Mar-22-98 | neat | KILFROST ABC-S | 4 | 10 | 32 | 38.9 | -4.2 | 36 |
| 354 | Mar-22-98 | neat | KILFROST ABC-S | 4 | 11 | 36 | 37.9 | -4.2 | 36 |
| 355 | Mar-22-98 | neat | OCTAGON MAXFLIGHT | 4 | 10 | 42 | 42.3 | -4.2 | 36 |
| 356 | Mar-22-98 | neat | OCTAGON MAXFLIGHT | 4 | 10 | 44 | 42.3 | -4.2 | 35 |
| 357 | Mar-22-98 | neat | SPCA AD-480 | 4 | 9 | 44 | 42.3 | -4.2 | 35 |
| 358 | Mar-22-98 | neat | SPCA AD-480 | 4 | 10 | 45 | 42.2 | -4.2 | 35 |
| 359 | Mar-22-98 | neat | SPCA AD-404 | 4 | 9 | 54 | 41.8 | -4.2 | 35 |
| 360 | Mar-22-98 | neat | SPCA AD-404 | 4 | 9 | 54 | 41.8 | -4.2 | 35 |
| 361 | Mar-22-98 | neat | ULTRA IV | 4 | 7 | 63 | 40.1 | -4.3 | 35 |
| 362 | Mar-22-98 | neat | ULTRA IV | 4 | 6 | 62 | 40.3 | -4.3 | 35 |
| 363 | Mar-22-98 | neat | UCAR PG | 4 | 11 | 48 | 42.6 | -4.2 | 35 |
| 364 | Mar-22-98 | neat | UCAR PG | 4 | 11 | 49 | 42.6 | -4.3 | 35 |
| 365 | Mar-22-98 | neat | CLARIANT 2001 | 4 | 11 | 37 | 46.9 | -4.2 | 35 |
| 366 | Mar-22-98 | neat | CLARIANT 2001 | 4 | 11 | 37 | 46.9 | -4.2 | 35 |
| 367 | Mar-22-98 | 75% | UCAR PG | 4b | 9 | 31 | 32.4 | -4.5 | 35 |
| 368 | Mar-22-98 | 75% | UCAR PG | 4b | 9 | 34 | 32.4 | -4.6 | 36 |
| 369 | Mar-22-98 | 75% | ULTRA IV | 4b | 8 | 30 | 32.4 | -4.5 | 35 |
| 370 | Mar-22-98 | 75% | ULTRA IV | 4b | 9 | 33 | 32.4 | -4.6 | 36 |
| 371 | Mar-22-98 | 75% | SPCA AD-480 | 4b | 9 | 29 | 32.4 | -4.6 | 36 |
| 372 | Mar-22-98 | 75% | SPCA AD-480 | 4b | 9 | 33 | 32.4 | -4.6 | 36 |
| 373 | Mar-19-98 | Std. | TYPE 0 ETH | 0 | 5 | 62 | 1.5 | -0.6 | 22 |
| 374 | Mar-19-98 | Std. | TYPE 0 ETH | 0 | 5 | 62 | 1.5 | -0.6 | 22 |
| 375 | Mar-19-98 | Std. | TYPE 0 PRO | 0 | 6 | 65 | 1.6 | -0.6 | 22 |
| 376 | Mar-19-98 | Std. | TYPE 0 PRO | 0 | 5 | 66 | 1.7 | -0.7 | 22 |
| 377 | Mar-19-98 | Std. | OCTAGON | 1 | 6 | 61 | 1.5 | -0.6 | 22 |
| 378 | Mar-19-98 | Std. | OCTAGON | 1 | 5 | 61 | 1.5 | -0.6 | 22 |
| 379 | Mar-19-98 | 50% | UCAR PG | 4a | 8 | 89 | 3.0 | -0.9 | 22 |
| 380 | Mar-19-98 | 50% | UCAR PG | 4a | 7 | 93 | 3.3 | -1.0 | 22 |
| 381 | Mar-19-98 | 50% | ULTRA IV | 4a | 6 | 78 | 2.5 | -0.8 | 22 |
| 382 | Mar-19-98 | 50% | ULTRA IV | 4a | 5 | 78 | 2.5 | -0.8 | 22 |
| 383 | Mar-19-98 | 50% | KILFROST ABC-S | 4a | 8 | 70 | 2.2 | -0.7 | 22 |
| 384 | Mar-19-98 | 50% | KILFROST ABC-S | 4a | 8 | 70 | 2.2 | -0.7 | 22 |

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 385 | Mar-19-98 | Std. | TYPE 0 ETH | 0 | 6 | 8 | 9.0 | -2.0 | 25 |
| 386 | Mar-19-98 | Std. | TYPE 0 ETH | 0 | 6 | 12 | 9.0 | -2.1 | 26 |
| 387 | Mar-19-98 | Std. | TYPE 0 PRO | 0 | 5 | 11 | 9.0 | -2.1 | 26 |
| 388 | Mar-19-98 | Std. | TYPE 0 PRO | 0 | 5 | 11 | 9.0 | -2.1 | 26 |
| 389 | Mar-19-98 | 75% | CLARIANT 1957 | 4b | 5 | 97 | 3.9 | -2.3 | 27 |
| 390 | Mar-19-98 | 75% | CLARIANT 1957 | 4b | 6 | 98 | 3.8 | -2.3 | 27 |
| 391 | Mar-19-98 | 75% | CLARIANT 2001 | 4b | 6 | 91 | 4.0 | -2.3 | 27 |
| 392 | Mar-19-98 | 75% | CLARIANT 2001 | 4b | 6 | 91 | 4.0 | -2.3 | 27 |
| 393 | Mar-19-98 | 50% | CLARIANT 2001 | 4a | 6 | 28 | 4.7 | -2.7 | 28 |
| 394 | Mar-19-98 | 50% | CLARIANT 2001 | 4a | 6 | 29 | 4.7 | -2.7 | 28 |
| 395 | Mar-19-98 | 50% | ULTRA IV | 4a | 5 | 36 | 5.1 | -2.7 | 28 |
| 396 | Mar-19-98 | 50% | ULTRA IV | 4a | 6 | 37 | 5.2 | -2.7 | 28 |
| 397 | Mar-19-98 | Std. | OCTAGON | 1 | 6 | 43 | 2.8 | -2.8 | 27 |
| 398 | Mar-19-98 | Std. | TYPE 0 PRO | 0 | 6 | 44 | 2.8 | -2.8 | 26 |
| 399 | Mar-19-98 | Std. | UCAR XL54 | 1 | 5 | 42 | 2.7 | -2.8 | 26 |
| 400 | Mar-19-98 | Std. | TYPE 0 ETH | 0 | 6 | 44 | 2.7 | -2.8 | 27 |
| 401 | Mar-19-98 | 50% | UCAR PG | 4a | 6 | 85 | 2.8 | -2.5 | 28 |
| 402 | Mar-19-98 | 50% | UCAR PG | 4a | 6 | 93 | 3.3 | -2.5 | 28 |
| 403 | Mar-19-98 | 50% | ULTRA IV | 4a | 6 | 62 | 2.6 | -2.4 | 29 |
| 404 | Mar-19-98 | 50% | ULTRA IV | 4a | 5 | 58 | 2.7 | -2.4 | 29 |
| 405 | Mar-19-98 | 50% | SPCA AD-404 | 4a | 5 | 104 | 3.7 | -2.5 | 28 |
| 406 | Mar-19-98 | 50% | SPCA AD-404 | 4a | 5 | 104 | 3.7 | -2.5 | 28 |
| 407 | Mar-19-98 | 50% | CLARIANT 1957 | 4a | 6 | 49 | 3.3 | -2.4 | 29 |
| 408 | Mar-19-98 | 50% | CLARIANT 1957 | 4a | 6 | 50 | 3.3 | -2.4 | 29 |
| 409 | Mar-19-98 | 50% | CLARIANT 1957 | 4a | 5 | 29 | 6.8 | -2.7 | 28 |
| 410 | Mar-19-98 | 50% | CLARIANT 1957 | 4a | 6 | 29 | 6.8 | -2.7 | 28 |
| 411 | Mar-19-98 | 50% | KILFROST ABC-S | 4a | 6 | 45 | 4.0 | -2.8 | 29 |
| 412 | Mar-19-98 | 50% | KILFROST ABC-S | 4a | 6 | 45 | 4.0 | -2.8 | 29 |
| 413 | Mar-19-98 | 50% | ULTRA IV | 4a | 5 | 49 | 4.1 | -2.8 | 29 |
| 414 | Mar-19-98 | 50% | ULTRA IV | 4a | 6 | 48 | 4.1 | -2.8 | 29 |
| 415 | Mar-19-98 | 50% | CLARIANT 2001 | 4a | 6 | 33 | 3.9 | -2.8 | 29 |
| 416 | Mar-19-98 | 50% | CLARIANT 2001 | 4a | 5 | 34 | 3.9 | -2.8 | 29 |
| 417 | Mar-19-98 | 50% | CLARIANT 1957 | 4a | 6 | 20 | 11.9 | -1.5 | 26 |
| 418 | Mar-19-98 | 50% | CLARIANT 1957 | 4a | 6 | 21 | 11.6 | -1.5 | 26 |
| 419 | Mar-19-98 | 50% | OCTAGON MAXFLIGHT | 4a | 6 | 56 | 12.8 | -1.8 | 27 |
| 420 | Mar-19-98 | 50% | OCTAGON MAXFLIGHT | 4a | 7 | 60 | 13.7 | -1.8 | 27 |
| 421 | Mar-19-98 | 50% | UCAR PG | 4a | 6 | 36 | 9.4 | -1.7 | 27 |
| 422 | Mar-19-98 | 50% | UCAR PG | 4a | 7 | 37 | 9.3 | -1.7 | 27 |
| 423 | Mar-19-98 | 50% | CLARIANT 2001 | 4a | 7 | 19 | 10.0 | -1.9 | 28 |
| 424 | Mar-19-98 | 50% | CLARIANT 2001 | 4a | 7 | 20 | 10.5 | -1.9 | 28 |
| 425 | Mar-19-98 | 75% | CLARIANT 1957 | 4b | 7 | 50 | 14.6 | -1.9 | 27 |
| 426 | Mar-19-98 | 75% | CLARIANT 1957 | 4b | 7 | 51 | 14.8 | -1.9 | 27 |
| 427 | Mar-19-98 | 75% | CLARIANT 2001 | 4b | 7 | 45 | 14.1 | -1.9 | 27 |
| 428 | Mar-19-98 | 75% | CLARIANT 2001 | 4b | 6 | 54 | 15.6 | -1.9 | 27 |
| 429 | Mar-19-98 | 75% | UCAR PG | 4b | 8 | 62 | 16.5 | -2.0 | 28 |
| 430 | Mar-19-98 | 75% | UCAR PG | 4b | 8 | 64 | 17.0 | -2.0 | 28 |
| 431 | Mar-19-98 | 50% | CLARIANT 1957 | 4a | 8 | 18 | 28.0 | -2.3 | 30 |
| 432 | Mar-19-98 | 50% | CLARIANT 1957 | 4a | 8 | 17 | 27.7 | -2.3 | 30 |

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 433 | Mar-19-98 | 50% | CLARIANT 2001 | 4a | 8 | 12 | 24.0 | -2.2 | 30 |
| 434 | Mar-19-98 | 50% | CLARIANT 2001 | 4a | 8 | 12 | 24.0 | -2.2 | 30 |
| 435 | Mar-19-98 | 75% | ULTRA IV | 4b | 5 | 43 | 25.9 | -2.3 | 28 |
| 436 | Mar-19-98 | 75% | ULTRA IV | 4b | 7 | 45 | 25.9 | -2.4 | 29 |
| 437 | Mar-19-98 | 75% | SPCA AD-480 | 4b | 7 | 45 | 25.9 | -2.4 | 29 |
| 438 | Mar-19-98 | 75% | SPCA AD-480 | 4b | 5 | 46 | 25.9 | -2.4 | 29 |
| 439 | Mar-19-98 | 75% | OCTAGON MAXFLIGHT | 4b | 5 | 67 | 31.2 | -2.5 | 29 |
| 440 | Mar-19-98 | 75% | OCTAGON MAXFLIGHT | 4b | 9 | 80 | 27.4 | -2.6 | 28 |
| 441 | Mar-19-98 | neat | UCAR PG | 4 | 8 | 80 | 31.0 | -2.7 | 28 |
| 442 | Mar-19-98 | neat | UCAR PG | 4 | 8 | 81 | 31.0 | -2.7 | 28 |
| 443 | Mar-19-98 | neat | KILFROST ABC-S | 4 | 7 | 39 | 24.4 | -2.5 | 28 |
| 444 | Mar-19-98 | neat | KILFROST ABC-S | 4 | 8 | 41 | 24.4 | -2.6 | 28 |
| 445 | Mar-19-98 | neat | CLARIANT 2001 | 4 | 8 | 58 | 27.3 | -2.6 | 28 |
| 446 | Mar-19-98 | neat | CLARIANT 2001 | 4 | 7 | 57 | 26.2 | -2.6 | 28 |
| 447 | Mar-19-98 | neat | OCTAGON MAXFLIGHT | 4 | 12 | 53 | 34.0 | -2.7 | 28 |
| 448 | Mar-19-98 | neat | OCTAGON MAXFLIGHT | 4 | 11 | 53 | 34.0 | -2.7 | 28 |
| 449 | Mar-19-98 | neat | CLARIANT 1957 | 4 | 10 | 42 | 31.1 | -2.7 | 28 |
| 450 | Mar-19-98 | neat | CLARIANT 1957 | 4 | 10 | 44 | 32.2 | -2.7 | 28 |
| 451 | Mar-19-98 | neat | CLARIANT 2001 | 4 | 10 | 57 | 34.2 | -2.8 | 28 |
| 452 | Mar-19-98 | neat | CLARIANT 2001 | 4 | 10 | 57 | 34.2 | -2.8 | 28 |
| 453 | Mar-19-98 | 75% | ULTRA IV | 4b | 7 | 30 | 44.2 | -2.8 | 28 |
| 454 | Mar-19-98 | 75% | ULTRA IV | 4b | 7 | 28 | 45.6 | -2.8 | 28 |
| 455 | Mar-19-98 | 75% | UCAR PG | 4b | 10 | 30 | 42.9 | -2.8 | 28 |
| 456 | Mar-19-98 | 75% | UCAR PG | 4b | 10 | 30 | 42.9 | -2.8 | 28 |
| 457 | Mar-19-98 | 75% | SPCA AD-480 | 4b | 11 | 27 | 45.6 | -2.8 | 28 |
| 458 | Mar-19-98 | 75% | SPCA AD-480 | 4b | 9 | 27 | 45.6 | -2.8 | 28 |
| 459 | Mar-19-98 | neat | SPCA AD-480 | 4 | 9 | 93 | 12.5 | -3.3 | 29 |
| 460 | Mar-19-98 | neat | SPCA AD-480 | 4 | 9 | 110 | 11.8 | -3.4 | 28 |
| 461 | Mar-19-98 | neat | SPCA AD-404 | 4 | 6 | 108 | 11.8 | -3.4 | 28 |
| 462 | Mar-19-98 | neat | SPCA AD-404 | 4 | 7 | 113 | 11.8 | -3.4 | 28 |
| 463 | Mar-19-98 | neat | OCTAGON MAXFLIGHT | 4 | 8 | 112 | 11.8 | -3.4 | 28 |
| 464 | Mar-19-98 | neat | OCTAGON MAXFLIGHT | 4 | 9 | 113 | 11.9 | -3.4 | 28 |
| 465 | Mar-19-98 | 75% | ULTRA IV | 4b | 7 | 68 | 12.0 | -3.3 | 29 |
| 466 | Mar-19-98 | 75% | ULTRA IV | 4b | 7 | 63 | 11.7 | -3.3 | 29 |
| 467 | Mar-19-98 | 75% | SPCA AD-404 | 4b | 7 | 72 | 11.7 | -3.3 | 29 |
| 468 | Mar-19-98 | 75% | SPCA AD-404 | 4b | 7 | 75 | 11.7 | -3.3 | 29 |
| 469 | Mar-19-98 | 75% | KILFROST ABC-S | 4b | 10 | 38 | 12.8 | -3.2 | 28 |
| 470 | Mar-19-98 | 75% | KILFROST ABC-S | 4b | 9 | 38 | 12.8 | -3.2 | 28 |
| 471 | Mar-19-98 | neat | KILFROST ABC-S | 4 | 7 | 79 | 13.4 | -3.3 | 29 |
| 472 | Mar-19-98 | neat | KILFROST ABC-S | 4 | 9 | 90 | 14.1 | -3.3 | 29 |
| 473 | Mar-19-98 | neat | ULTRA IV | 4 | 7 | 134 | 16.7 | -3.4 | 28 |
| 474 | Mar-19-98 | neat | ULTRA IV | 4 | 7 | 134 | 16.7 | -3.4 | 28 |
| 475 | Mar-19-98 | neat | CLARIANT 2001 | 4 | 8 | 119 | 14.8 | -3.4 | 28 |
| 476 | Mar-19-98 | neat | CLARIANT 2001 | 4 | 8 | 119 | 14.8 | -3.4 | 28 |
| 477 | Mar-19-98 | 75% | SPCA AD-480 | 4b | 9 | 74 | 11.3 | -3.3 | 29 |
| 478 | Mar-19-98 | 75% | SPCA AD-480 | 4b | 9 | 73 | 11.2 | -3.3 | 29 |
| 479 | Mar-19-98 | 75% | OCTAGON MAXFLIGHT | 4b | 8 | 117 | 11.7 | -3.4 | 28 |
| 480 | Mar-19-98 | 75% | OCTAGON MAXFLIGHT | 4b | 8 | 117 | 11.7 | -3.4 | 28 |

# NATURAL SNOW TESTS AT DORVAL 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] |
| 481 | Mar-19-98 | 75% | CLARIANT 1957 | 4b | 8 | 57 | 11.9 | -3.3 | 29 |
| 482 | Mar-19-98 | 75% | CLARIANT 1957 | 4b | 8 | 59 | 11.5 | -3.3 | 29 |
| 483 | Mar-19-98 | Std. | OCTAGON | 1 | 8 | 11 | 11.3 | -3.6 | 28 |
| 484 | Mar-19-98 | Std. | UCAR XL54 | 1 | 7 | 12 | 10.7 | -3.6 | 28 |
| 485 | Mar-19-98 | Std. | TYPE 0 PRO | 0 | 7 | 14 | 9.5 | -3.6 | 28 |
| 486 | Mar-19-98 | Std. | TYPE 0 ETH | 0 | 8 | 13 | 9.8 | -3.6 | 28 |
| 487 | Mar-19-98 | 75% | ULTRA IV | 4b | 8 | 53 | 22.2 | -3.7 | 27 |
| 488 | Mar-19-98 | 75% | ULTRA IV | 4b | 8 | 47 | 23.7 | -3.7 | 27 |
| 489 | Mar-19-98 | 75% | UCAR PG | 4b | 10 | 42 | 26.2 | -3.7 | 27 |
| 490 | Mar-19-98 | 75% | UCAR PG | 4b | 11 | 46 | 23.7 | -3.7 | 27 |
| 491 | Mar-19-98 | 75% | CLARIANT 2001 | 4b | 9 | 42 | 25.5 | -3.7 | 27 |
| 492 | Mar-19-98 | 75% | CLARIANT 2001 | 4b | 10 | 42 | 25.5 | -3.7 | 27 |
| 493 | Mar-19-98 | 75% | KILFROST ABC-S | 4b | N/A | 121 | 4.3 | -3.6 | 26 |
| 494 | Mar-19-98 | 75% | KILFROST ABC-S | 4b | N/A | 121 | 4.3 | -3.6 | 26 |
| 495 | Mar-19-98 | 75% | SPCA AD-480 | 4b | N/A | 122 | 4.3 | -3.6 | 26 |
| 496 | Mar-19-98 | 75% | SPCA AD-480 | 4b | N/A | 122 | 4.3 | -3.6 | 26 |
| 497 | Mar-19-98 | 75% | ULTRA IV | 4b | N/A | 125 | 4.3 | -3.6 | 26 |
| 498 | Mar-19-98 | 75% | ULTRA IV | 4b | N/A | 125 | 4.3 | -3.6 | 26 |
| 499 | Mar-19-98 | neat | UCAR PG | 4 | N/A | 201 | 3.5 | -2.7 | 29 |
| 500 | Mar-19-98 | neat | UCAR PG | 4 | N/A | 201 | 3.5 | -2.7 | 29 |
| 501 | Mar-19-98 | neat | ULTRA IV | 4 | N/A | 203 | 3.5 | -2.7 | 29 |
| 502 | Mar-19-98 | neat | ULTRA IV | 4 | N/A | 203 | 3.5 | -2.7 | 29 |
| 503 | Mar-19-98 | 75% | SPCA AD-404 | 4b | N/A | 247 | 3.4 | -2.6 | 28 |
| 504 | Mar-19-98 | 75% | SPCA AD-404 | 4b | N/A | 247 | 3.4 | -2.6 | 28 |
| 505 | Mar-21-98 | 75% | SPCA AD-480 | 4b | N/A | 131 | 5.3 | -3.5 | 32 |
| 506 | Mar-21-98 | 75% | SPCA AD-480 | 4b | N/A | 131 | 5.3 | -3.5 | 32 |
| 507 | Mar-14-98 | 75% | UCAR PG | 4b | N/A | 165 | 8.8 | -0.7 | 12 |
| 508 | Mar-14-98 | 75% | UCAR PG | 4b | N/A | 165 | 8.8 | -0.7 | 12 |
| 509 | Mar-14-98 | 75% | ULTRA IV | 4b | N/A | 163 | 8.8 | -0.7 | 12 |
| 510 | Mar-14-98 | 75% | ULTRA IV | 4b | N/A | 163 | 8.8 | -0.7 | 12 |
| 511 | Mar-14-98 | neat | SPCA AD-404 | 4 | N/A | 182 | 9.2 | -0.8 | 12 |
| 512 | Mar-14-98 | neat | SPCA AD-404 | 4 | N/A | 182 | 9.2 | -0.8 | 12 |
| 513 | Mar-14-98 | neat | UCAR PG | 4 | N/A | 184 | 9.2 | -0.8 | 12 |
| 514 | Mar-14-98 | neat | UCAR PG | 4 | N/A | 184 | 9.2 | -0.8 | 12 |
| 515 | Mar-14-98 | neat | ULTRA IV | 4 | N/A | 185 | 9.2 | -0.8 | 12 |
| 516 | Mar-14-98 | neat | ULTRA IV | 4 | N/A | 185 | 9.2 | -0.8 | 12 |
| 517 | Mar-14-98 | 75% | CLARIANT 2001 | 4b | N/A | 196 | 10.1 | -0.9 | 13 |
| 518 | Mar-14-98 | 75% | KILFROST ABC-S | 4b | N/A | 198 | 10.1 | -0.9 | 13 |
| 519 | Mar-14-98 | 75% | ULTRA IV | 4b | N/A | 195 | 10.1 | -0.8 | 13 |
| 520 | Mar-14-98 | 50% | CLARIANT 1957 | 4a | N/A | 63 | 5.1 | -0.3 | 9 |
| 521 | Mar-14-98 | 50% | CLARIANT 1957 | 4a | N/A | 63 | 5.1 | -0.2 | 8 |
| 522 | Mar-14-98 | 50% | SPCA AD-480 | 4a | N/A | 62 | 5.1 | -0.2 | 9 |
| 523 | Mar-14-98 | 50% | SPCA AD-480 | 4a | N/A | 62 | 5.1 | -0.2 | 9 |
| 524 | Mar-10-98 | neat | UCAR PG | 4 | N/A | 156 | 8.8 | -5.4 | 36 |
| 525 | Mar-10-98 | neat | UCAR PG | 4 | N/A | 156 | 8.8 | -5.8 | 37 |

# NATURAL SNOW TESTS AT DORVAL 1997/98 (DIFFERENT PRECIPITATION)

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] | |
| 1 | Jan-07-98 | Std. | UCAR XL54 | 1 | 4 | 23 | 12.5 | -4.5 | 17 | IP |
| 2 | Jan-07-98 | Std. | UCAR XL54 | 1 | 3 | 24 | 12.5 | -4.5 | 17 | IP |
| 3 | Jan-07-98 | Std. | INLAND | 0 | 3 | 17 | 17.0 | -3.9 | 17 | IP |
| 4 | Jan-07-98 | Std. | INLAND | 0 | 3 | 17 | 17.0 | -3.9 | 17 | IP |
| 5 | Jan-07-98 | Std. | UCAR XL54 | 1 | 3 | 18 | 17.2 | -3.9 | 17 | IP |
| 6 | Jan-07-98 | Std. | UCAR XL54 | 1 | 3 | 18 | 17.2 | -3.9 | 17 | IP |
| 7 | Jan-07-98 | Std. | INLAND | 0 | 4 | 18 | 31.9 | -4.2 | 26 | IP |
| 8 | Jan-07-98 | Std. | INLAND | 0 | 5 | 18 | 26.1 | -4.2 | 26 | IP |
| 9 | Jan-07-98 | Std. | UCAR XL54 | 1 | 3 | 17 | 31.9 | -4.2 | 27 | IP |
| 10 | Jan-07-98 | Std. | UCAR XL54 | 1 | 5 | 17 | 26.1 | -4.2 | 27 | IP |
| 11 | Jan-07-98 | Std. | AEROFLOT | 1 | 4 | 17 | 31.9 | -4.2 | 27 | IP |
| 12 | Jan-07-98 | Std. | AEROFLOT | 1 | 6 | 17 | 26.1 | -4.2 | 27 | IP |
| 13 | Jan-07-98 | Std. | UCAR XL54 | 1 | 3 | 17 | 20.1 | -4.3 | 23 | IP |
| 14 | Jan-07-98 | Std. | UCAR XL54 | 1 | 5 | 17 | 20.1 | -4.3 | 23 | IP |
| 15 | Jan-07-98 | Std. | AEROFLOT | 1 | 5 | 15 | 20.1 | -4.3 | 22 | IP |
| 16 | Jan-07-98 | Std. | AEROFLOT | 1 | 5 | 15 | 20.1 | -4.3 | 22 | IP |
| 17 | Jan-07-98 | Std. | INLAND | 0 | 6 | 17 | 20.1 | -4.3 | 23 | IP |
| 18 | Jan-07-98 | Std. | INLAND | 0 | 5 | 17 | 20.1 | -4.3 | 23 | IP |
| 19 | Feb-18-98 | 50% | SPCA AD-404 | 4a | 3 | 36 | 21.4 | -0.9 | 14 | S,IP |
| 20 | Feb-18-98 | 50% | SPCA AD-404 | 4a | 4 | 37 | 21.3 | -0.9 | 14 | S,IP |
| 21 | Feb-18-98 | 50% | CLARIANT 2001 | 4a | 3 | 14 | 23.3 | -0.9 | 14 | S,IP |
| 22 | Feb-18-98 | 50% | CLARIANT 2001 | 4a | 3 | 15 | 22.6 | -0.9 | 14 | S,IP |
| 23 | Feb-18-98 | 50% | ULTRA IV | 4a | 3 | 23 | 21.0 | -0.9 | 14 | S,IP |
| 24 | Feb-18-98 | 50% | ULTRA IV | 4a | 3 | 24 | 20.7 | -0.9 | 14 | S,IP |
| 25 | Feb-18-98 | 50% | UCAR PG | 4a | 2 | 28 | 20.1 | -0.9 | 14 | S,IP |
| 26 | Feb-18-98 | 50% | UCAR PG | 4a | 2 | 28 | 20.1 | -0.9 | 14 | S,IP |
| 27 | Feb-18-98 | 75% | ULTRA IV | 4b | 2 | 56 | 23.1 | -0.9 | 16 | S,IP |
| 28 | Feb-18-98 | 75% | ULTRA IV | 4b | 2 | 57 | 23.0 | -0.9 | 16 | S,IP |
| 29 | Feb-18-98 | 75% | UCAR PG | 4b | 4 | 58 | 22.6 | -0.9 | 16 | S,IP |
| 30 | Feb-18-98 | 75% | UCAR PG | 4b | 4 | 58 | 22.6 | -0.9 | 16 | S,IP |
| 31 | Feb-18-98 | 75% | CLARIANT 2001 | 4b | 2 | 32 | 25.4 | -0.9 | 18 | S,IP |
| 32 | Feb-18-98 | 75% | CLARIANT 2001 | 4b | 2 | 32 | 25.4 | -0.9 | 18 | S,IP |
| 33 | Feb-18-98 | 75% | CLARIANT 1957 | 4b | 2 | 54 | 16.7 | -0.9 | 19 | S,IP |
| 34 | Feb-18-98 | 75% | CLARIANT 1957 | 4b | 2 | 54 | 16.7 | -0.9 | 19 | S,IP |
| 35 | Feb-18-98 | 75% | KILFROST ABC-S | 4b | 4 | 46 | 9.7 | -0.9 | 19 | S,IP |
| 36 | Feb-18-98 | 75% | KILFROST ABC-S | 4b | 3 | 51 | 10.0 | -0.9 | 19 | S,IP |
| 37 | Feb-18-98 | 75% | ULTRA IV | 4b | N/F | 65 | 10.4 | -0.9 | 20 | S,IP |
| 38 | Feb-24-98 | neat | UCAR PG | 4 | 2 | 107 | 12.0 | 1.2 | 29 | S,IP |
| 39 | Feb-24-98 | neat | UCAR PG | 4 | 2 | 108 | 12.1 | 1.2 | 29 | S,IP |
| 40 | Feb-24-98 | neat | SPCA AD-480 | 4 | 2 | 117 | 12.4 | 1.2 | 29 | S,IP |
| 41 | Feb-24-98 | neat | SPCA AD-480 | 4 | 3 | 117 | 12.4 | 1.2 | 29 | S,IP |
| 42 | Feb-24-98 | neat | SPCA AD-404 | 4 | 4 | 67 | 14.3 | 0.9 | 32 | S,IP |
| 43 | Feb-24-98 | neat | SPCA AD-404 | 4 | 4 | 69 | 14.7 | 1.1 | 29 | S,IP |
| 44 | Feb-24-98 | 50% | SPCA AD-404 | 4a | 3 | 11 | 38.0 | 0.4 | 35 | S,IP |
| 45 | Feb-24-98 | 50% | SPCA AD-404 | 4a | 4 | 22 | 37.6 | 0.4 | 35 | S,IP |
| 46 | Feb-24-98 | 75% | SPCA AD-404 | 4b | 3 | 29 | 42.9 | 0.4 | 35 | S,IP |
| 47 | Feb-24-98 | 75% | SPCA AD-480 | 4b | 4 | 34 | 42.4 | 0.8 | 30 | S,IP |
| 48 | Feb-24-98 | 75% | SPCA AD-480 | 4b | 4 | 35 | 42.3 | 0.4 | 35 | S,IP |

# NATURAL SNOW TESTS AT DORVAL 1997/98 (DIFFERENT PRECIPITATION)

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | READAC Data | | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Temp [C] | Wind Sp [kph] | |
| 49 | Feb-24-98 | 75% | SPCA AD-404 | 4b | 4 | 40 | 41.9 | 0.4 | 35 | S,IP |
| 50 | Feb-24-98 | 50% | UCAR PG | 4a | 3 | 20 | 67.4 | 0.4 | 34 | IP |
| 51 | Feb-24-98 | 50% | UCAR PG | 4a | 4 | 20 | 67.4 | 0.4 | 34 | IP |
| 52 | Feb-25-98 | Std. | TYPE 0 PRO | 0 | 2 | 16 | 30.6 | 0.9 | 24 | IP,S |
| 53 | Feb-25-98 | Std. | TYPE 0 PRO | 0 | 2 | 16 | 30.6 | 0.9 | 24 | IP,S |
| 54 | Feb-25-98 | Std. | OCTAGON | 1 | 3 | 15 | 30.6 | 0.9 | 24 | IP,S |
| 55 | Feb-25-98 | Std. | UCAR XL54 | 1 | 2 | 16 | 30.6 | 0.9 | 24 | IP,S |
| 56 | Feb-25-98 | Std. | TYPE 0 ETH | 0 | 3 | 15 | 30.6 | 0.9 | 24 | IP,S |
| 57 | Feb-25-98 | Std. | TYPE 0 ETH | 0 | 2 | 15 | 30.5 | 0.9 | 24 | IP,S |
| 58 | Feb-25-98 | Std. | OCTAGON | 1 | 1 | 10 | 64.4 | 0.8 | 22 | IP,S |
| 59 | Feb-25-98 | Std. | TYPE 0 PRO | 0 | 1 | 10 | 64.4 | 0.8 | 22 | IP,S |
| 60 | Feb-25-98 | Std. | UCAR XL54 | 1 | 1 | 10 | 64.4 | 0.8 | 22 | IP,S |
| 61 | Feb-25-98 | Std. | TYPE 0 ETH | 0 | 1 | 9 | 64.4 | 0.8 | 22 | IP,S |
| 62 | Feb-25-98 | Std. | TYPE 0 PRO | 0 | 1 | 11 | 64.4 | 0.8 | 22 | IP,S |
| 63 | Feb-25-98 | Std. | TYPE 0 ETH | 0 | 1 | 10 | 64.4 | 0.8 | 22 | IP,S |
| 64 | Feb-25-98 | 50% | CLARIANT 1957 | 4a | 1 | 19 | 33.9 | 0.8 | 23 | IP,S |
| 65 | Feb-25-98 | 50% | CLARIANT 1957 | 4a | 2 | 19 | 33.9 | 0.8 | 23 | IP,S |
| 66 | Feb-25-98 | 75% | KILFROST ABC-S | 4b | 3 | 24 | 33.5 | 0.8 | 23 | IP,S |
| 67 | Feb-25-98 | 75% | KILFROST ABC-S | 4b | 3 | 24 | 33.5 | 0.8 | 23 | IP,S |
| 68 | Feb-25-98 | 75% | CLARIANT 1957 | 4b | 3 | 29 | 31.3 | 0.7 | 23 | IP,S |
| 69 | Feb-25-98 | 75% | CLARIANT 1957 | 4b | 2 | 30 | 30.9 | 0.7 | 22 | IP,S |
| 70 | Feb-25-98 | 75% | ULTRA IV | 4b | 2 | 35 | 25.4 | 0.6 | 21 | IP,S |
| 71 | Feb-25-98 | 75% | UCAR PG | 4b | 2 | 40 | 25.7 | 0.6 | 21 | IP,S |
| 72 | Feb-25-98 | 75% | UCAR PG | 4b | 2 | 41 | 25.9 | 0.6 | 21 | IP,S |
| 73 | Feb-25-98 | 75% | ULTRA IV | 4b | 2 | 40 | 25.9 | 0.6 | 21 | IP,S |
| 74 | Feb-25-98 | 75% | SPCA AD-404 | 4b | 3 | 48 | 26.0 | 0.6 | 21 | IP,S |
| 75 | Feb-25-98 | 75% | SPCA AD-404 | 4b | 2 | 51 | 26.0 | 0.6 | 21 | IP,S |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Apr-03-98 | OCTAGON | Neat | 4 | A | 37.5 | 3 | 34 | 25.2 | -3.0 | lfrz_rain |
| 2 | Apr-03-98 | KILFROST ABC-S | Neat | 4 | A | 37.5 | 2.5 | 49 | 24.8 | -3.0 | lfrz_rain |
| 3 | Apr-03-98 | UCAR PG | Neat | 4 | A | 37 | N/A | 113 | 23.6 | -3.0 | lfrz_rain |
| 4 | Apr-03-98 | ULTRA IV | Neat | 4 | A | 33.5 | 2 | 96 | 23.9 | -3.0 | lfrz_rain |
| 5 | Apr-03-98 | CLARIANT 1957 | Neat | 4 | A | 36.25 | 1.5 | 41 | 25.9 | -3.0 | lfrz_rain |
| 6 | Apr-03-98 | CLARIANT 2001 | Neat | 4 | A | 37 | 1 | 54 | 26.1 | -3.0 | lfrz_rain |
| 7 | Apr-03-98 | SPCA AD-404 | Neat | 4 | A | 37 | 1 | 43 | 26.6 | -3.0 | lfrz_rain |
| 8 | Apr-03-98 | SPCA AD-480 | Neat | 4 | A | 40 | 2 | 45 | 27.2 | -3.0 | lfrz_rain |
| 9 | Apr-03-98 | KILFROST ABC-S | 75% | 4b | A | 29.5 | 3 | 20 | 28.1 | -3.0 | lfrz_rain |
| 10 | Apr-03-98 | ULTRA IV | Neat | 4 | A | 33.5 | 2.5 | 94 | 25.2 | -3.0 | lfrz_rain |
| 11 | Apr-03-98 | KILFROST ABC-S | Neat | 4 | A | 37.5 | 2 | 48 | 25.9 | -3.0 | lfrz_rain |
| 12 | Apr-03-98 | SPCA AD-404 | Neat | 4 | A | 37 | 1 | 48 | 27.8 | -3.0 | lfrz_rain |
| 13 | Apr-03-98 | OCTAGON | Neat | 4 | A | 37.5 | 1.5 | 42 | 23.6 | -2.6 | lfrz_rain |
| 14 | Apr-03-98 | UCAR PG | 75% | 4b | A | 29.5 | 2.25 | 47 | 24.4 | -2.6 | lfrz_rain |
| 15 | Apr-03-98 | CLARIANT 1957 | Neat | 4 | A | 36 | 3 | 48 | 23.6 | -2.6 | lfrz_rain |
| 16 | Apr-03-98 | CLARIANT 2001 | Neat | 4 | A | 37 | 3 | 55 | 21.6 | -2.8 | lfrz_rain |
| 17 | Apr-03-98 | ULTRA IV | 75% | 4b | A | 27 | 2 | 41 | 21.5 | -2.5 | lfrz_rain |
| 18 | Apr-03-98 | OCTAGON | 75% | 4b | A | 30 | 1.5 | 33 | 23.0 | -2.6 | lfrz_rain |
| 19 | Apr-03-98 | SPCA AD-404 | 75% | 4b | A | 28 | 2.5 | 27 | 26.7 | -3.3 | lfrz_rain |
| 20 | Apr-03-98 | UCAR PG | Neat | 4 | A | 37.5 | 1.5 | 115 | 24.9 | -3.3 | lfrz_rain |
| 21 | Apr-03-98 | CLARIANT 1957 | 75% | 4b | A | 29 | 1.5 | 28 | 27.1 | -2.6 | lfrz_rain |
| 22 | Apr-03-98 | SPCA AD-480 | Neat | 4 | A | 40 | 2 | 49 | 27.0 | -2.8 | lfrz_rain |
| 23 | Apr-03-98 | CLARIANT 2001 | 75% | 4b | A | 29 | 2 | 25 | 26.2 | -2.6 | lfrz_rain |
| 24 | Apr-03-98 | SPCA AD-404 | 75% | 4b | A | 28 | 1 | 32 | 26.4 | -2.5 | lfrz_rain |
| 25 | Apr-03-98 | UCAR PG | 75% | 4b | A | 29.5 | N/A | 41 | 24.4 | -3.3 | lfrz_rain |
| 26 | Apr-03-98 | ULTRA IV | 75% | 4b | A | 27 | 2.5 | 38 | 23.6 | -3.2 | lfrz_rain |
| 27 | Apr-03-98 | SPCA AD-480 | 75% | 4b | A | 30 | 3.5 | 35 | 21.5 | -3.5 | lfrz_rain |
| 28 | Apr-03-98 | CLARIANT 1957 | 75% | 4b | A | 29 | 2.5 | 29 | 23.0 | -3.2 | lfrz_rain |
| 29 | Apr-03-98 | CLARIANT 2001 | 75% | 4b | A | 29 | 2.5 | 23 | 27.1 | -3.0 | lfrz_rain |
| 30 | Apr-03-98 | ULTRA IV | 50% | 4a | A | 19 | 2.5 | 10 | 27.0 | -3.9 | lfrz_rain |
| 31 | Apr-03-98 | SPCA AD-480 | 75% | 4b | A | 30 | 3 | 36 | 26.2 | -3.3 | lfrz_rain |
| 32 | Apr-03-98 | SPCA AD-404 | 50% | 4a | A | 19.5 | 2.5 | 19 | 23.0 | -3.6 | lfrz_rain |
| 33 | Apr-03-98 | KILFROST ABC-S | 50% | 4a | A | 23.5 | 3 | 9 | 27.1 | -3.9 | lfrz_rain |
| 34 | Apr-03-98 | KILFROST ABC-S | 50% | 4a | A | 23.5 | 2.5 | 10 | 27.1 | -3.4 | lfrz_rain |
| 35 | Apr-03-98 | ULTRA IV | 50% | 4a | A | 19 | N/A | 10 | 27.0 | -3.5 | lfrz_rain |
| 36 | Apr-06-98 | ULTRA IV | Neat | 4 | A | 34.5 | 2.5 | 132 | 13.9 | -3.3 | lfrz_rain |
| 37 | Apr-06-98 | KILFROST ABC-S | Neat | 4 | A | 37 | 2.5 | 63 | 13.7 | -3.3 | lfrz_rain |
| 38 | Apr-06-98 | OCTAGON | Neat | 4 | A | 37.25 | 3.5 | 55 | 13.4 | -3.3 | lfrz_rain |
| 39 | Apr-06-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 4 | 64 | 12.9 | -3.3 | lfrz_rain |
| 40 | Apr-06-98 | SPCA AD-404 | Neat | 4 | A | 39.25 | 2 | 78 | 12.9 | -3.3 | lfrz_rain |
| 41 | Apr-06-98 | UCAR PG | Neat | 4 | A | 38 | 4 | 137 | 15.5 | -3.2 | lfrz_rain |
| 42 | Apr-06-98 | ULTRA IV | Neat | 4 | A | 34.5 | N/A | 133 | 15.6 | -3.2 | lfrz_rain |
| 43 | Apr-06-98 | KILFROST ABC-S | Neat | 4 | A | 37 | 2.5 | 66 | 15.1 | -3.2 | lfrz_rain |
| 44 | Apr-06-98 | OCTAGON | Neat | 4 | A | 37.25 | 3.25 | 50 | 15.3 | -3.3 | lfrz_rain |
| 45 | Apr-06-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 2.25 | 72 | 14.5 | -3.2 | lfrz_rain |
| 46 | Apr-06-98 | SPCA AD-404 | Neat | 4 | A | 39.25 | 4 | 75 | 14.8 | -3.2 | lfrz_rain |
| 47 | Apr-06-98 | CLARIANT 2001 | Neat | 4 | A | 36.5 | 3 | 66 | 12.7 | -3.3 | lfrz_rain |
| 48 | Apr-06-98 | CLARIANT 2001 | Neat | 4 | A | 36.5 | 3.5 | 60 | 15.2 | -3.3 | lfrz_rain |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | Apr-06-98 | CLARIANT 1957 | Neat | 4 | A | 36 | 3.25 | 64 | 13.4 | -3.2 | lfrz_rain |
| 51 | Apr-06-98 | ULTRA IV | 75% | 4b | A | 24.5 | 3 | 47 | 12.9 | -3.2 | lfrz_rain |
| 52 | Apr-06-98 | CLARIANT 1957 | 75% | 4b | A | 26 | 3 | 37 | 12.9 | -3.2 | lfrz_rain |
| 53 | Apr-06-98 | UCAR PG | 75% | 4b | A | 29 | 3 | 59 | 15.1 | -3.2 | lfrz_rain |
| 54 | Apr-06-98 | CLARIANT 1957 | Neat | 4 | A | 36 | 2.75 | 72 | 15.3 | -3.2 | lfrz_rain |
| 55 | Apr-06-98 | CLARIANT 2001 | 75% | 4b | A | 29 | 3 | 34 | 14.5 | -3.2 | lfrz_rain |
| 56 | Apr-06-98 | CLARIANT 1957 | 75% | 4b | A | 26 | 3 | 38 | 14.8 | -3.2 | lfrz_rain |
| 57 | Apr-06-98 | CLARIANT 2001 | 75% | 4b | A | 29 | N/A | 33 | 12.7 | -3.1 | lfrz_rain |
| 58 | Apr-06-98 | ULTRA IV | 75% | 4b | A | 24.5 | N/A | 49 | 15.2 | -3.0 | lfrz_rain |
| 59 | Apr-06-98 | OCTAGON | 75% | 4b | A | 29 | 3.5 | 71 | 14.2 | -3.0 | lfrz_rain |
| 60 | Apr-06-98 | SPCA AD-480 | 75% | 4b | A | 28 | 3.25 | 47 | 12.9 | -3.0 | lfrz_rain |
| 61 | Apr-06-98 | SPCA AD-404 | 75% | 4b | A | 31 | 2.5 | 50 | 12.9 | -3.0 | lfrz_rain |
| 62 | Apr-06-98 | SPCA AD-480 | 75% | 4b | A | 28 | 2.5 | 48 | 14.5 | -3.0 | lfrz_rain |
| 63 | Apr-06-98 | SPCA AD-404 | 75% | 4b | A | 31 | 3 | 42 | 14.8 | -3.0 | lfrz_rain |
| 64 | Apr-06-98 | KILFROST ABC-S | 75% | 4b | A | 28.75 | 4 | 27 | 13.9 | -3.1 | lfrz_rain |
| 65 | Apr-06-98 | OCTAGON | 50% | 4a | A | 21 | 4 | 29 | 13.7 | -3.1 | lfrz_rain |
| 66 | Apr-06-98 | UCAR PG | 50% | 4a | A | 21.25 | 3 | 28 | 13.4 | -3.1 | lfrz_rain |
| 67 | Apr-06-98 | OCTAGON | 50% | 4a | A | 21 | 3.5 | 26 | 15.5 | -3.1 | lfrz_rain |
| 68 | Apr-06-98 | KILFROST ABC-S | 75% | 4b | A | 28.75 | 4 | 28 | 15.6 | -3.1 | lfrz_rain |
| 69 | Apr-06-98 | UCAR PG | 50% | 4a | A | 21.25 | 5 | 27 | 15.1 | -3.1 | lfrz_rain |
| 70 | Apr-06-98 | ULTRA IV | 50% | 4a | A | 18.5 | 2.5 | 16 | 15.3 | -3.1 | lfrz_rain |
| 71 | Apr-06-98 | ULTRA IV | 50% | 4a | A | 18.5 | 3 | 17 | 12.7 | -3.1 | lfrz_rain |
| 72 | Apr-06-98 | OCTAGON | 75% | 4b | A | 29 | 3.5 | 48 | 15.2 | -3.1 | lfrz_rain |
| 73 | Apr-06-98 | SPCA AD-480 | 50% | 4a | A | 19 | 3.5 | 20 | 13.9 | -2.4 | lfrz_rain |
| 74 | Apr-06-98 | SPCA AD-404 | 50% | 4a | A | 21 | 2.5 | 29 | 13.7 | -2.2 | lfrz_rain |
| 75 | Apr-06-98 | CLARIANT 2001 | 50% | 4a | A | 19.75 | 3 | 11 | 13.4 | -2.5 | lfrz_rain |
| 76 | Apr-06-98 | KILFROST ABC-S | 50% | 4a | A | 20 | 3 | 16 | 12.9 | -2.7 | lfrz_rain |
| 77 | Apr-06-98 | CLARIANT 1957 | 50% | 4a | A | 19 | 3 | 12 | 12.9 | -2.7 | lfrz_rain |
| 78 | Apr-06-98 | CLARIANT 2001 | 50% | 4a | A | 19.75 | 3 | 11 | 15.5 | -2.5 | lfrz_rain |
| 79 | Apr-06-98 | SPCA AD-480 | 50% | 4a | A | 19 | 3 | 19 | 15.6 | -2.3 | lfrz_rain |
| 80 | Apr-06-98 | SPCA AD-404 | 50% | 4a | A | 21 | 2.75 | 29 | 15.1 | -2.1 | lfrz_rain |
| 81 | Apr-06-98 | OCTAGON | 75% | 4b | A | 29 | 3 | 55 | 15.3 | -2.2 | lfrz_rain |
| 82 | Apr-06-98 | CLARIANT 1957 | 50% | 4a | A | 19 | 3 | 13 | 14.8 | -2.7 | lfrz_rain |
| 83 | Apr-06-98 | KILFROST ABC-S | 50% | 4a | A | 20 | 2.75 | 15 | 12.7 | -2.7 | lfrz_rain |
| 84 | Apr-06-98 | OCTAGON | Neat | 4 | A | 37.25 | 3 | 41 | 26.4 | -3.2 | lfrz_rain |
| 85 | Apr-06-98 | UCAR PG | 50% | 4a | A | 21.25 | 2.5 | 19 | 25.7 | -3.3 | lfrz_rain |
| 86 | Apr-06-98 | SPCA AD-404 | 50% | 4a | A | 21 | 2.5 | 17 | 24.7 | -3.3 | lfrz_rain |
| 87 | Apr-06-98 | UCAR PG | 50% | 4a | A | 21.25 | 3.5 | 19 | 23.7 | -3.3 | lfrz_rain |
| 88 | Apr-06-98 | OCTAGON | 50% | 4a | A | 21 | 2.75 | 17 | 23.2 | -3.3 | lfrz_rain |
| 89 | Apr-06-98 | SPCA AD-480 | 50% | 4a | A | 19.5 | 3 | 10 | 27.0 | -3.3 | lfrz_rain |
| 90 | Apr-06-98 | CLARIANT 1957 | 50% | 4a | A | 19 | 3.5 | 9 | 27.4 | -3.3 | lfrz_rain |
| 91 | Apr-06-98 | SPCA AD-480 | 50% | 4a | A | 19.5 | 3 | 10 | 27.5 | -3.3 | lfrz_rain |
| 92 | Apr-06-98 | CLARIANT 2001 | 50% | 4a | A | 19.75 | 3 | 8 | 27.6 | -3.3 | lfrz_rain |
| 93 | Apr-06-98 | CLARIANT 1957 | 50% | 4a | A | 19 | 2.5 | 8 | 28.1 | -3.2 | lfrz_rain |
| 94 | Apr-06-98 | CLARIANT 2001 | 50% | 4a | A | 19.75 | 2.5 | 8 | 27.4 | -3.2 | lfrz_rain |
| 95 | Apr-07-98 | SPCA AD-404 | 75% | 4b | A | 30.5 | 3 | 127 | 4.7 | -3.2 | frz_drizzle |
| 96 | Apr-07-98 | UCAR PG | 75% | 4b | A | 29 | 5 | 84 | 5.3 | -3.2 | frz_drizzle |
| 97 | Apr-07-98 | ULTRA IV | 75% | 4b | A | 25.5 | 4 | 74 | 5.5 | -3.2 | frz_drizzle |
| 98 | Apr-07-98 | CLARIANT 1957 | 75% | 4b | B | 27 | 3.5 | 66 | 5.6 | -3.1 | frz_drizzle |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 99 | Apr-07-98 | CLARIANT 2001 | 75% | 4b | B | 28 | 3.25 | 62 | 5.7 | -3.1 | frz_drizzle |
| 100 | Apr-07-98 | SPCA AD-480 | 75% | 4b | A | 27.5 | 4.5 | 71 | 5.9 | -3.2 | frz_drizzle |
| 101 | Apr-07-98 | SPCA AD-404 | 75% | 4b | A | 30.5 | 3.5 | 124 | 3.9 | -3.2 | frz_drizzle |
| 102 | Apr-07-98 | UCAR PG | 75% | 4b | A | 29 | 5 | 79 | 4.6 | -3.2 | frz_drizzle |
| 103 | Apr-07-98 | ULTRA IV | 75% | 4b | A | 25.5 | 5 | 60 | 5.1 | -3.1 | frz_drizzle |
| 104 | Apr-07-98 | CLARIANT 1957 | 75% | 4b | B | 27 | 4.5 | 71 | 5.6 | -3.2 | frz_drizzle |
| 105 | Apr-07-98 | CLARIANT 2001 | 75% | 4b | B | 28 | 3.25 | 62 | 5.9 | -3.1 | frz_drizzle |
| 106 | Apr-07-98 | SPCA AD-480 | 75% | 4b | A | 27.5 | 4 | 62 | 6.4 | -3.2 | frz_drizzle |
| 107 | Apr-07-98 | OCTAGON | 75% | 4b | A | 29 | 4.5 | 129 | 5.8 | -3.3 | frz_drizzle |
| 108 | Apr-07-98 | KILFROST ABC-S | 75% | 4b | B | 28.75 | 3 | 61 | 5.7 | -3.3 | frz_drizzle |
| 109 | Apr-07-98 | OCTAGON | 75% | 4b | A | 29 | 3 | 81 | 7.8 | -3.3 | frz_drizzle |
| 110 | Apr-07-98 | KILFROST ABC-S | 75% | 4b | B | 28.75 | 3 | 53 | 7.3 | -3.3 | frz_drizzle |
| 111 | Apr-07-98 | SPCA AD-480 | 50% | 4a | A | 19 | 4 | 35 | 5.3 | -3.4 | frz_drizzle |
| 112 | Apr-07-98 | SPCA AD-480 | 50% | 4a | A | 19 | 5 | 32 | 5.5 | -3.4 | frz_drizzle |
| 113 | Apr-07-98 | SPCA AD-404 | 50% | 4a | A | 20 | 4 | 48 | 5.6 | -3.4 | frz_drizzle |
| 114 | Apr-07-98 | UCAR PG | 50% | 4a | A | 21 | 4 | 41 | 5.7 | -3.4 | frz_drizzle |
| 115 | Apr-07-98 | ULTRA IV | 50% | 4a | A | 18 | 3 | 24 | 5.9 | -3.4 | frz_drizzle |
| 116 | Apr-07-98 | OCTAGON | 50% | 4a | A | 20 | 4.75 | 57 | 4.6 | -3.4 | frz_drizzle |
| 117 | Apr-07-98 | OCTAGON | 50% | 4a | A | 20 | N/A | 63 | 5.1 | -3.4 | frz_drizzle |
| 118 | Apr-07-98 | SPCA AD-404 | 50% | 4a | A | 20 | 4.75 | 52 | 5.6 | -3.4 | frz_drizzle |
| 119 | Apr-07-98 | UCAR PG | 50% | 4a | A | 21 | 3.5 | 38 | 5.9 | -3.4 | frz_drizzle |
| 120 | Apr-07-98 | ULTRA IV | 50% | 4a | A | 18 | 2.5 | 21 | 6.4 | -3.4 | frz_drizzle |
| 121 | Apr-07-98 | KILFROST ABC-S | 50% | 4a | B | 19.5 | 3.5 | 21 | 5.9 | -3.5 | frz_drizzle |
| 122 | Apr-07-98 | KILFROST ABC-S | 50% | 4a | B | 19.5 | 4 | 16 | 7.5 | -3.5 | frz_drizzle |
| 123 | Apr-07-98 | CLARIANT 1957 | 50% | 4a | B | 18.5 | 3 | 29 | 4.0 | -3.4 | frz_drizzle |
| 124 | Apr-07-98 | CLARIANT 1957 | 50% | 4a | B | 18.5 | 3 | 24 | 5.8 | -3.4 | frz_drizzle |
| 125 | Apr-07-98 | CLARIANT 2001 | 50% | 4a | B | 19 | N/A | 21 | 5.9 | -3.4 | frz_drizzle |
| 126 | Apr-07-98 | CLARIANT 2001 | 50% | 4a | B | 19 | 4 | 17 | 6.4 | -3.4 | frz_drizzle |
| 127 | Apr-14-98 | UCAR PG | Neat | 4 | A | 36.5 | 5 | 196 | 4.8 | -3.5 | frz_drizzle |
| 128 | Apr-14-98 | ULTRA IV | Neat | 4 | A | 33.5 | 6 | 230 | 4.8 | -3.5 | frz_drizzle |
| 129 | Apr-14-98 | OCTAGON | Neat | 4 | A | 36.5 | 6 | 135 | 4.8 | -3.6 | frz_drizzle |
| 130 | Apr-14-98 | CLARIANT 1957 | Neat | 4 | B | 35.5 | 5.5 | 104 | 4.6 | -3.6 | frz_drizzle |
| 131 | Apr-14-98 | CLARIANT 2001 | Neat | 4 | B | 35.5 | 5 | 117 | 4.3 | -3.6 | frz_drizzle |
| 132 | Apr-14-98 | KILFROST ABC-S | Neat | 4 | B | 36 | 5 | 205 | 3.7 | -3.5 | frz_drizzle |
| 133 | Apr-14-98 | SPCA AD-480 | Neat | 4 | A | 36 | 5 | 124 | 6.0 | -3.6 | frz_drizzle |
| 134 | Apr-14-98 | SPCA AD-404 | Neat | 4 | A | 39 | 4.75 | 232 | 6.2 | -3.6 | frz_drizzle |
| 135 | Apr-14-98 | OCTAGON | 75% | 4b | A | 29 | 5.5 | 124 | 6.4 | -3.6 | frz_drizzle |
| 136 | Apr-14-98 | SPCA AD-480 | Neat | 4 | A | 36 | 4.5 | 126 | 6.0 | -3.5 | frz_drizzle |
| 137 | Apr-14-98 | UCAR PG | Neat | 4 | A | 36.5 | 6.5 | 156 | 6.1 | -3.5 | frz_drizzle |
| 138 | Apr-14-98 | ULTRA IV | Neat | 4 | A | 34 | 5.5 | 204 | 6.4 | -3.5 | frz_drizzle |
| 139 | Apr-14-98 | CLARIANT 1957 | Neat | 4 | B | 35.5 | 6 | 124 | 4.0 | -3.5 | frz_drizzle |
| 140 | Apr-14-98 | KILFROST ABC-S | Neat | 4 | B | 36 | 6 | 167 | 4.9 | -3.5 | frz_drizzle |
| 141 | Apr-14-98 | SPCA AD-404 | Neat | 4 | A | 39 | N/A | 241 | 3.2 | -3.5 | frz_drizzle |
| 142 | Apr-14-98 | OCTAGON | Neat | 4 | A | 36.5 | 7 | 142 | 3.7 | -3.5 | frz_drizzle |
| 143 | Apr-14-98 | CLARIANT 2001 | Neat | 4 | B | 35.5 | 5 | 130 | 5.4 | -3.5 | frz_drizzle |
| 144 | Apr-14-98 | KILFROST | std | 1 | | 30 | 4 | 12 | 5.9 | -3.6 | frz_drizzle |
| 145 | Apr-14-98 | UCAR XL54 | std | 1 | | 34.5 | 4.5 | 11 | 5.9 | -3.6 | frz_drizzle |
| 146 | Apr-14-98 | TYPE 0 PRO | std | 0 | | 37 | 1 | 16 | 5.9 | -3.5 | frz_drizzle |
| 147 | Apr-14-98 | TYPE 0 ETH | std | 0 | | 32 | 1 | 13 | 5.9 | -3.5 | frz_drizzle |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 148 | Apr-14-98 | TYPE 0 ETH | std | 0 | | 32 | 3 | 13 | 4.1 | -3.5 | frz_drizzle |
| 149 | Apr-14-98 | TYPE 0 PRO | std | 0 | | 37 | 4 | 14 | 4.1 | -3.5 | frz_drizzle |
| 150 | Apr-14-98 | UCAR XL54 | std | 1 | | 34.5 | 1 | 14 | 5.9 | -3.5 | frz_drizzle |
| 151 | Apr-14-98 | KILFROST | std | 1 | | 30 | N/A | 16 | 5.9 | -3.4 | frz_drizzle |
| 152 | Apr-14-98 | KILFROST | std | 1 | | 30 | 2 | 14 | 5.9 | -3.3 | frz_drizzle |
| 153 | Apr-14-98 | TYPE 0 ETH | std | 0 | | 32 | 1 | 12 | 5.9 | -3.3 | frz_drizzle |
| 154 | Apr-14-98 | TYPE 0 PRO | std | 0 | | 37 | 3 | 12 | 6.0 | -3.3 | frz_drizzle |
| 155 | Apr-15-98 | UCAR PG | Neat | 4 | A | 39 | 6.5 | 149 | 10.5 | -3.2 | frz_drizzle |
| 156 | Apr-15-98 | ULTRA IV | Neat | 4 | A | 35 | 7 | 153 | 10.9 | -3.2 | frz_drizzle |
| 157 | Apr-15-98 | OCTAGON | Neat | 4 | A | 38.5 | 6.5 | 77 | 10.9 | -3.2 | frz_drizzle |
| 158 | Apr-15-98 | KILFROST ABC-S | Neat | 4 | B | 37.5 | 5 | 110 | 10.9 | -3.2 | frz_drizzle |
| 159 | Apr-15-98 | SPCA AD-404 | Neat | 4 | A | 39.5 | 6 | 133 | 10.1 | -3.2 | frz_drizzle |
| 160 | Apr-15-98 | SPCA AD-480 | Neat | 4 | A | 35.5 | 6.5 | 71 | 10.4 | -3.2 | frz_drizzle |
| 161 | Apr-15-98 | CLARIANT 1957 | Neat | 4 | B | 35.5 | 8 | 54 | 9.9 | -3.2 | frz_drizzle |
| 162 | Apr-15-98 | CLARIANT 2001 | Neat | 4 | B | 35.5 | 8 | 60 | 10.7 | -3.2 | frz_drizzle |
| 163 | Apr-15-98 | OCTAGON | 75% | 4b | A | 30.5 | 6 | 79 | 11.4 | -3.2 | frz_drizzle |
| 164 | Apr-15-98 | SPCA AD-404 | 75% | 4b | A | 31 | 6 | 47 | 11.9 | -3.2 | frz_drizzle |
| 165 | Apr-15-98 | UCAR PG | 75% | 4b | A | 29.5 | 5 | 50 | 13.5 | -3.2 | frz_drizzle |
| 166 | Apr-15-98 | KILFROST ABC-S | 50% | 4a | B | N/A | 6 | 15 | 10.9 | -3.2 | frz_drizzle |
| 167 | Apr-15-98 | UCAR PG | 50% | 4a | A | N/A | 5 | 30 | 10.4 | -3.2 | frz_drizzle |
| 168 | Apr-15-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 5.75 | 40 | 9.9 | -3.2 | frz_drizzle |
| 169 | Apr-15-98 | ULTRA IV | 75% | 4b | A | 25 | 5.5 | 53 | 10.7 | -3.2 | frz_drizzle |
| 170 | Apr-15-98 | ULTRA IV | 50% | 4a | A | N/A | 4 | 15 | 11.4 | -3.2 | frz_drizzle |
| 171 | Apr-15-98 | SPCA AD-480 | 75% | 4b | A | 28.5 | 6.5 | 54 | 11.9 | -3.2 | frz_drizzle |
| 172 | Apr-15-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 7 | 43 | 12.6 | -3.2 | frz_drizzle |
| 173 | Apr-15-98 | OCTAGON | 50% | 4a | A | 21.5 | 6 | 37 | 13.5 | -3.2 | frz_drizzle |
| 174 | Apr-15-98 | SPCA AD-480 | Neat | 4 | A | 35.5 | 6 | 80 | 10.5 | -3.2 | frz_drizzle |
| 175 | Apr-15-98 | KILFROST ABC-S | Neat | 4 | A | 37.5 | 7.5 | 86 | 10.9 | -3.2 | frz_drizzle |
| 176 | Apr-15-98 | ULTRA IV | Neat | 4 | A | 35 | 7 | 161 | 10.9 | -3.2 | frz_drizzle |
| 177 | Apr-15-98 | SPCA AD-404 | Neat | 4 | A | 39.5 | 4 | 153 | 10.3 | -3.2 | frz_drizzle |
| 178 | Apr-15-98 | UCAR PG | Neat | 4 | A | 38.5 | 7 | 143 | 10.1 | -3.2 | frz_drizzle |
| 179 | Apr-15-98 | OCTAGON | Neat | 4 | A | 38.5 | 6 | 86 | 10.4 | -3.2 | frz_drizzle |
| 181 | Apr-15-98 | OCTAGON | 75% | 4b | A | 30.5 | 5.5 | 79 | 10.7 | -3.2 | frz_drizzle |
| 182 | Apr-15-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 7 | 62 | 11.4 | -3.2 | frz_drizzle |
| 183 | Apr-15-98 | CLARIANT 1957 | Neat | 4 | A | 36.5 | 6 | 57 | 11.9 | -3.2 | frz_drizzle |
| 184 | Apr-15-98 | CLARIANT 1957 | Neat | 4 | B | 36 | 7.5 | 51 | 12.6 | -3.2 | frz_drizzle |
| 185 | Apr-15-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 7 | 96 | 13.5 | -3.2 | frz_drizzle |
| 186 | Apr-15-98 | KILFROST ABC-S | 75% | 4b | B | 30 | 7 | 59 | 10.5 | -3.2 | frz_drizzle |
| 187 | Apr-15-98 | SPCA AD-404 | 75% | 4b | A | 31 | 7 | 62 | 10.9 | -3.2 | frz_drizzle |
| 188 | Apr-15-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 7 | 48 | 10.4 | -3.2 | frz_drizzle |
| 189 | Apr-15-98 | SPCA AD-480 | 75% | 4b | A | 28.5 | 7.5 | 55 | 9.9 | -3.2 | frz_drizzle |
| 190 | Apr-15-98 | UCAR PG | 75% | 4b | A | 29.5 | 5 | 55 | 10.7 | -3.2 | frz_drizzle |
| 191 | Apr-15-98 | ULTRA IV | 75% | 4b | A | 25 | 6 | 53 | 11.4 | -3.2 | frz_drizzle |
| 192 | Apr-15-98 | CLARIANT 1957 | 75% | 4b | A | 28.5 | 7 | 32 | 12.6 | -3.2 | frz_drizzle |
| 193 | Apr-15-98 | OCTAGON | 50% | 4a | A | 21.5 | 7 | 32 | 13.5 | -3.2 | frz_drizzle |
| 194 | Apr-15-98 | CLARIANT 2001 | 50% | 4a | B | 19.5 | 5 | 11 | 11.4 | -3.2 | frz_drizzle |
| 195 | Apr-15-98 | UCAR PG | 50% | 4a | A | 21.75 | 6 | 23 | 11.9 | -3.2 | frz_drizzle |
| 196 | Apr-15-98 | ULTRA IV | 50% | 4a | A | 19 | 4 | 13 | 12.6 | -3.1 | frz_drizzle |
| 197 | Apr-15-98 | KILFROST ABC-S | 50% | 4a | B | 20 | 5 | 16 | 10.9 | -3.2 | frz_drizzle |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 198 | Apr-15-98 | SPCA AD-404 | 50% | 4a | A | 23 | 7 | 28 | 10.1 | -3.2 | frz_drizzle |
| 199 | Apr-15-98 | CLARIANT 1957 | 50% | 4a | B | 19.5 | 8 | 15 | 12.6 | -3.2 | frz_drizzle |
| 200 | Apr-15-98 | TYPE 0 ETH | std | 0 | | 32 | 5 | 8 | 10.5 | -3.2 | frz_drizzle |
| 201 | Apr-15-98 | TYPE 0 PRO | std | 0 | | 37 | 6 | 8 | 10.4 | -3.2 | frz_drizzle |
| 202 | Apr-15-98 | SPCA AD-404 | 50% | 4a | A | N/A | 5 | 30 | 9.9 | -3.1 | frz_drizzle |
| 203 | Apr-15-98 | CLARIANT 1957 | 50% | 4a | B | N/A | 6.5 | 17 | 10.7 | -3.2 | frz_drizzle |
| 204 | Apr-15-98 | SPCA AD-480 | 50% | 4a | A | N/A | 6 | 18 | 11.4 | -3.2 | frz_drizzle |
| 205 | Apr-15-98 | SPCA AD-480 | 50% | 4a | A | N/A | 6.5 | 19 | 11.9 | -3.2 | frz_drizzle |
| 206 | Apr-15-98 | CLARIANT 2001 | 50% | 4a | B | N/A | N/A | 12 | 13.5 | -3.2 | frz_drizzle |
| 207 | Apr-15-98 | UCAR XL54 | std | 1 | | 34 | N/A | 13 | 10.5 | -2.9 | frz_drizzle |
| 208 | Apr-15-98 | UCAR XL54 | std | 1 | | 34 | N/A | 10 | 10.9 | -2.9 | frz_drizzle |
| 209 | Apr-15-98 | KILFROST | std | 1 | | 30 | N/A | 9 | 10.4 | -2.9 | frz_drizzle |
| 210 | Apr-15-98 | KILFROST | std | 1 | | 30 | N/A | 8 | 12.6 | -2.9 | frz_drizzle |
| 211 | Apr-15-98 | TYPE 0 ETH | std | 0 | | 32 | N/A | 11 | 10.9 | -2.8 | frz_drizzle |
| 212 | Apr-15-98 | TYPE 0 PRO | std | 0 | | 37 | N/A | 9 | 12.6 | -2.9 | frz_drizzle |
| 213 | Apr-16-98 | OCTAGON | Neat | 4 | A | 37.5 | 21 | 37 | 10.5 | -10.2 | frz_drizzle |
| 214 | Apr-16-98 | CLARIANT 1957 | Neat | 4 | B | 37 | 15 | 63 | 8.8 | -10.2 | frz_drizzle |
| 215 | Apr-16-98 | SPCA AD-480 | Neat | 4 | A | N/A | 26 | 26 | 11.2 | -10.2 | frz_drizzle |
| 216 | Apr-16-98 | CLARIANT 2001 | Neat | 4 | A | 36 | 12.5 | 56 | 12.4 | -10.2 | frz_drizzle |
| 217 | Apr-16-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 13 | 50 | 13.0 | -10.2 | frz_drizzle |
| 218 | Apr-16-98 | SPCA AD-404 | Neat | 4 | A | 39.5 | N/A | 63 | 13.4 | -10.2 | frz_drizzle |
| 219 | Apr-16-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 27 | 23 | 14.7 | -10.3 | frz_drizzle |
| 220 | Apr-16-98 | KILFROST ABC-S | Neat | 4 | B | 37.5 | 17 | 45 | 10.5 | -10.2 | frz_drizzle |
| 221 | Apr-16-98 | KILFROST ABC-S | Neat | 4 | B | 37.5 | 21 | 37 | 12.9 | -10.3 | frz_drizzle |
| 222 | Apr-16-98 | CLARIANT 1957 | Neat | 4 | B | 36.5 | 11 | 53 | 13.5 | -10.4 | frz_drizzle |
| 223 | Apr-16-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 14 | 55 | 14.2 | -10.3 | frz_drizzle |
| 224 | Apr-16-98 | CLARIANT 2001 | Neat | 4 | A | 36 | 20.5 | 54 | 14.6 | -10.4 | frz_drizzle |
| 225 | Apr-16-98 | OCTAGON | Neat | 4 | A | 37.5 | 20 | 43 | 9.3 | -10.3 | frz_drizzle |
| 226 | Apr-16-98 | OCTAGON | 75% | 4b | A | 28.5 | 28 | 20 | 12.9 | -10.3 | frz_drizzle |
| 227 | Apr-16-98 | ULTRA IV | 75% | 4b | A | 27 | 11 | 44 | 14.9 | -10.2 | frz_drizzle |
| 228 | Apr-16-98 | SPCA AD-480 | 75% | 4b | A | N/A | N/A | 42 | 10.5 | -10.1 | frz_drizzle |
| 229 | Apr-16-98 | ULTRA IV | Neat | 4 | A | 24.5 | 11 | 136 | 12.9 | -10.1 | frz_drizzle |
| 230 | Apr-16-98 | KILFROST ABC-S | 75% | 4b | A | 29.5 | 13 | 37 | 13.6 | -10.2 | frz_drizzle |
| 231 | Apr-16-98 | ULTRA IV | 75% | 4b | A | 27 | 11 | 42 | 13.8 | -10.1 | frz_drizzle |
| 232 | Apr-16-98 | SPCA AD-404 | Neat | 4 | A | 39.5 | 18 | 60 | 14.7 | -10.1 | frz_drizzle |
| 233 | Apr-17-98 | OCTAGON | Neat | 4 | A | 37.5 | 31 | 23 | 23.2 | -10.4 | lfrz_rain |
| 234 | Apr-17-98 | ULTRA IV | Neat | 4 | A | 34 | N/A | 46 | 23.0 | -10.4 | lfrz_rain |
| 235 | Apr-17-98 | UCAR PG | Neat | 4 | A | 38 | 33 | 14 | 23.1 | -10.4 | lfrz_rain |
| 236 | Apr-17-98 | KILFROST ABC-S | Neat | 4 | A | 37 | 15 | 38 | 23.2 | -10.4 | lfrz_rain |
| 237 | Apr-17-98 | CLARIANT 1957 | Neat | 4 | A | 36 | 17 | 33 | 23.2 | -10.4 | lfrz_rain |
| 238 | Apr-17-98 | CLARIANT 2001 | Neat | 4 | A | 36 | 17 | 32 | 23.0 | -10.4 | lfrz_rain |
| 239 | Apr-17-98 | SPCA AD-480 | Neat | 4 | A | 36 | 31 | 22 | 21.6 | -10.4 | lfrz_rain |
| 240 | Apr-17-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 28 | 23 | 21.2 | -10.4 | lfrz_rain |
| 241 | Apr-17-98 | CLARIANT 1957 | Neat | 4 | B | 37 | 18 | 31 | 21.2 | -10.4 | lfrz_rain |
| 242 | Apr-17-98 | CLARIANT 2001 | Neat | 4 | B | 37 | 17.5 | 32 | 21.3 | -10.4 | lfrz_rain |
| 243 | Apr-17-98 | ULTRA IV | Neat | 4 | A | 34 | N/A | 41 | 20.7 | -10.3 | lfrz_rain |
| 244 | Apr-17-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 27 | 24 | 23.2 | -10.4 | lfrz_rain |
| 245 | Apr-17-98 | UCAR PG | Neat | 4 | A | 38 | 27 | 15 | 23.1 | -10.3 | lfrz_rain |
| 246 | Apr-17-98 | SPCA AD-404 | Neat | 4 | A | 40 | 9 | 44 | 21.5 | -10.3 | lfrz_rain |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 247 | Apr-17-98 | OCTAGON | Neat | 4 | A | 37.5 | 20 | 24 | 21.6 | -10.4 | lfrz_rain |
| 248 | Apr-17-98 | KILFROST ABC-S | Neat | 4 | A | 37 | 20 | 33 | 21.2 | -10.4 | lfrz_rain |
| 249 | Apr-17-98 | SPCA AD-404 | Neat | 4 | A | 40 | 9 | 30 | 23.1 | -10.3 | lfrz_rain |
| 250 | Apr-17-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 28 | 23 | 22.4 | -10.4 | lfrz_rain |
| 251 | Apr-17-98 | CLARIANT 2001 | Neat | 4 | A | 35 | N/A | 35 | 20.6 | -10.3 | lfrz_rain |
| 252 | Apr-17-98 | OCTAGON | 75% | 4b | A | 30 | 16 | 23 | 23.0 | -10.3 | lfrz_rain |
| 253 | Apr-17-98 | ULTRA IV | Neat | 4 | A | 34 | 18 | 50 | 23.1 | -10.3 | lfrz_rain |
| 254 | Apr-17-98 | UCAR PG | Neat | 4 | A | 38 | 31 | 17 | 23.2 | -10.3 | lfrz_rain |
| 255 | Apr-17-98 | CLARIANT 1957 | Neat | 4 | B | 37 | 16 | 33 | 23.2 | -10.3 | lfrz_rain |
| 256 | Apr-17-98 | CLARIANT 2001 | Neat | 4 | B | 37 | 16.5 | 32 | 23.0 | -10.3 | lfrz_rain |
| 257 | Apr-17-98 | KILFROST ABC-S | Neat | 4 | A | 37 | 17 | 32 | 21.2 | -10.3 | lfrz_rain |
| 258 | Apr-17-98 | CLARIANT 1957 | Neat | 4 | A | 36 | 13 | 32 | 21.3 | -10.3 | lfrz_rain |
| 259 | Apr-17-98 | OCTAGON | 75% | 4b | A | 30 | 17 | 22 | 20.7 | -10.3 | lfrz_rain |
| 260 | Apr-17-98 | SPCA AD-404 | Neat | 4 | A | 40 | 12 | 43 | 23.2 | -10.2 | lfrz_rain |
| 261 | Apr-17-98 | UCAR PG | 75% | 4b | A | 29 | 25 | 16 | 23.2 | -10.2 | lfrz_rain |
| 262 | Apr-17-98 | UCAR PG | 75% | 4b | A | 29 | 24 | 15 | 21.5 | -10.2 | lfrz_rain |
| 263 | Apr-17-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 19 | 23 | 21.6 | -10.2 | lfrz_rain |
| 264 | Apr-17-98 | ULTRA IV | 75% | 4b | A | 27 | 15 | 29 | 21.2 | -10.2 | lfrz_rain |
| 265 | Apr-17-98 | SPCA AD-404 | 75% | 4b | A | 31 | 11 | 29 | 23.1 | -10.2 | lfrz_rain |
| 266 | Apr-17-98 | ULTRA IV | 75% | 4b | A | 27 | N/A | 28 | 22.4 | -10.2 | lfrz_rain |
| 267 | Apr-17-98 | SPCA AD-404 | 75% | 4b | A | 31 | 12 | 35 | 20.3 | -10.2 | lfrz_rain |
| 268 | Apr-17-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 17 | 24 | 20.6 | -10.2 | lfrz_rain |
| 269 | Apr-17-98 | CLARIANT 1957 | 75% | 4b | A | 29 | 13 | 24 | 23.0 | -10.2 | lfrz_rain |
| 270 | Apr-17-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 13.5 | 21 | 23.1 | -10.2 | lfrz_rain |
| 271 | Apr-17-98 | KILFROST ABC-S | 75% | 4b | B | 29.5 | 19 | 29 | 23.2 | -10.2 | lfrz_rain |
| 272 | Apr-17-98 | CLARIANT 2001 | 75% | 4b | A | 29 | 14 | 23 | 23.2 | -10.2 | lfrz_rain |
| 273 | Apr-17-98 | SPCA AD-480 | 75% | 4b | A | 27 | 19 | 19 | 23.0 | -10.2 | lfrz_rain |
| 274 | Apr-17-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 14 | 26 | 21.5 | -10.2 | lfrz_rain |
| 275 | Apr-17-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 13.5 | 25 | 21.6 | -10.2 | lfrz_rain |
| 276 | Apr-17-98 | CLARIANT 1957 | 75% | 4b | A | 29 | 13.5 | 26 | 21.2 | -10.2 | lfrz_rain |
| 277 | Apr-17-98 | CLARIANT 2001 | 75% | 4b | A | 29 | 14 | 20 | 21.3 | -10.2 | lfrz_rain |
| 278 | Apr-17-98 | SPCA AD-480 | 75% | 4b | A | 29 | 18 | 22 | 20.7 | -10.2 | lfrz_rain |
| 279 | Apr-17-98 | ULTRA IV | Neat | 4 | A | 33.5 | 16 | 105 | 12.5 | -10.7 | lfrz_rain |
| 280 | Apr-17-98 | UCAR PG | Neat | 4 | A | 38 | 31 | 31 | 12.4 | -10.8 | lfrz_rain |
| 281 | Apr-17-98 | CLARIANT 1957 | Neat | 4 | B | 37 | 14 | 48 | 12.7 | -10.8 | lfrz_rain |
| 282 | Apr-17-98 | CLARIANT 2001 | Neat | 4 | B | 37 | 14.5 | 50 | 12.2 | -10.8 | lfrz_rain |
| 283 | Apr-17-98 | OCTAGON | Neat | 4 | A | 38 | 21 | 37 | 12.7 | -10.8 | lfrz_rain |
| 284 | Apr-17-98 | KILFROST ABC-S | Neat | 4 | B | 37 | N/A | 51 | 12.8 | -10.8 | lfrz_rain |
| 285 | Apr-17-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 24 | 37 | 12.7 | -10.8 | lfrz_rain |
| 286 | Apr-17-98 | ULTRA IV | 75% | 4b | A | 27 | N/A | 42 | 12.5 | -10.8 | lfrz_rain |
| 287 | Apr-17-98 | UCAR PG | 75% | 4b | A | 29 | 15 | 50 | 12.2 | -10.8 | lfrz_rain |
| 288 | Apr-17-98 | SPCA AD-404 | 75% | 4b | A | 31 | 14 | 43 | 12.5 | -10.8 | lfrz_rain |
| 289 | Apr-17-98 | OCTAGON | 75% | 4b | A | 29.75 | 26 | 35 | 11.8 | -10.8 | lfrz_rain |
| 290 | Apr-17-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 17 | 38 | 12.3 | -10.8 | lfrz_rain |
| 291 | Apr-17-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 16 | 36 | 12.3 | -10.8 | lfrz_rain |
| 292 | Apr-17-98 | KILFROST ABC-S | 75% | 4b | B | 29.5 | 24 | 35 | 12.5 | -10.8 | lfrz_rain |
| 293 | Apr-17-98 | SPCA AD-480 | 75% | 4b | B | 29 | 23 | 36 | 12.5 | -10.8 | lfrz_rain |
| 294 | Apr-17-98 | UCAR PG | Neat | 4 | A | 38 | 28 | 32 | 12.4 | -10.8 | lfrz_rain |
| 295 | Apr-17-98 | OCTAGON | Neat | 4 | A | 30 | 21 | 40 | 12.7 | -10.6 | lfrz_rain |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 296 | Apr-17-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 23 | 39 | 12.7 | -10.6 | lfrz_rain |
| 297 | Apr-20-98 | SPCA AD-404 | Neat | 4 | A | 40 | 15 | 95 | 12.3 | -10.2 | lfrz_rain |
| 298 | Apr-20-98 | ULTRA IV | Neat | 4 | A | 35 | N/A | 100 | 12.4 | -10.2 | lfrz_rain |
| 299 | Apr-20-98 | SPCA AD-404 | Neat | 4 | A | 40 | 14 | 75 | 12.3 | -10.2 | lfrz_rain |
| 300 | Apr-20-98 | CLARIANT 1957 | Neat | 4 | B | 37 | 15 | 42 | 12.6 | -10.2 | lfrz_rain |
| 301 | Apr-20-98 | CLARIANT 2001 | Neat | 4 | B | 37 | 17 | 42 | 12.6 | -10.2 | lfrz_rain |
| 302 | Apr-20-98 | KILFROST ABC-S | Neat | 4 | B | 37.5 | N/A | 35 | 12.2 | -10.2 | lfrz_rain |
| 303 | Apr-20-98 | ULTRA IV | 75% | 4b | A | 28 | 15 | 44 | 12.3 | -10.2 | lfrz_rain |
| 304 | Apr-20-98 | UCAR PG | 75% | 4b | A | 29.5 | 27 | 30 | 12.5 | -10.2 | lfrz_rain |
| 305 | Apr-20-98 | SPCA AD-404 | 75% | 4b | A | 32 | 15 | 53 | 12.0 | -10.2 | lfrz_rain |
| 306 | Apr-20-98 | OCTAGON | 75% | 4b | A | 30 | 25 | 33 | 12.1 | -10.2 | lfrz_rain |
| 307 | Apr-20-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 17 | 38 | 12.4 | -10.2 | lfrz_rain |
| 308 | Apr-20-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 17 | 31 | 12.2 | -10.2 | lfrz_rain |
| 309 | Apr-20-98 | CLARIANT 2001 | Neat | 4 | A | 37.5 | 16 | 50 | 12.2 | -10.2 | lfrz_rain |
| 310 | Apr-20-98 | CLARIANT 1957 | Neat | 4 | A | 37.5 | 18 | 50 | 11.8 | -10.2 | lfrz_rain |
| 311 | Apr-20-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 21 | 34 | 12.2 | -10.2 | lfrz_rain |
| 312 | Apr-20-98 | SPCA AD-480 | 75% | 4b | A | 29 | 20 | 33 | 12.0 | -10.2 | lfrz_rain |
| 313 | Apr-20-98 | CLARIANT 2001 | 75% | 4b | B | N/A | 14 | 30 | 12.6 | -10.2 | lfrz_rain |
| 314 | Apr-20-98 | SPCA AD-404 | 75% | 4b | A | N/A | 13 | 43 | 12.6 | -10.3 | lfrz_rain |
| 315 | Apr-20-98 | CLARIANT 1957 | 75% | 4b | A | N/A | 16 | 30 | 12.2 | -10.2 | lfrz_rain |
| 316 | Apr-20-98 | UCAR PG | 75% | 4b | A | 30 | 21 | 28 | 12.5 | -10.2 | lfrz_rain |
| 317 | Apr-20-98 | CLARIANT 2001 | 75% | 4b | A | N/A | 17 | 29 | 12.1 | -10.2 | lfrz_rain |
| 318 | Apr-20-98 | TYPE 0 ETH | std | 0 |  | 32 | 5 | 4 | 12.5 | -10.4 | lfrz_rain |
| 319 | Apr-20-98 | TYPE 0 PRO | std | 0 |  | 37 | 12 | 5 | 12.0 | -10.3 | lfrz_rain |
| 320 | Apr-20-98 | UCAR XL54 | std | 1 |  | 34 | 11 | 5 | 12.4 | -10.2 | lfrz_rain |
| 321 | Apr-20-98 | KILFROST | std | 1 |  | 37 | 14 | 5 | 12.2 | -10.2 | lfrz_rain |
| 322 | Apr-20-98 | UCAR XL54 | std | 1 |  | 34 | 9 | 5 | 12.5 | -10.2 | lfrz_rain |
| 323 | Apr-20-98 | KILFROST | std | 1 |  | 30 | 14 | 5 | 12.0 | -10.2 | lfrz_rain |
| 324 | Apr-20-98 | TYPE 0 ETH | std | 0 |  | 32 | 10 | 4 | 12.4 | -10.2 | lfrz_rain |
| 325 | Apr-20-98 | TYPE 0 PRO | std | 0 |  | 37 | 16 | 4 | 12.2 | -10.2 | lfrz_rain |
| 326 | Apr-20-98 | SPCA AD-404 | Neat | 4 | A | 40 | 13 | 175 | 4.8 | -10.7 | frz_drizzle |
| 327 | Apr-20-98 | ULTRA IV | Neat | 4 | A | 35 | 12 | 218 | 4.6 | -10.5 | frz_drizzle |
| 328 | Apr-20-98 | SPCA AD-480 | Neat | 4 | A | 37 | 24.5 | 89 | 4.6 | -11.0 | frz_drizzle |
| 329 | Apr-20-98 | CLARIANT 1957 | Neat | 4 | B | 36.5 | 19.5 | 90 | 4.6 | -11.0 | frz_drizzle |
| 330 | Apr-20-98 | CLARIANT 1957 | Neat | 4 | A | 37.5 | 20 | 88 | 5.0 | -11.0 | frz_drizzle |
| 331 | Apr-20-98 | KILFROST ABC-S | Neat | 4 | A | 37 | 24 | 80 | 5.1 | -11.0 | frz_drizzle |
| 332 | Apr-20-98 | KILFROST ABC-S | Neat | 4 | B | 37.5 | 29 | 68 | 4.9 | -11.0 | frz_drizzle |
| 333 | Apr-20-98 | CLARIANT 2001 | Neat | 4 | A | 37.5 | 17 | 88 | 4.7 | -11.1 | frz_drizzle |
| 334 | Apr-20-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 17.5 | 91 | 5.1 | -11.1 | frz_drizzle |
| 335 | Apr-20-98 | OCTAGON | Neat | 4 | A | 39 | 25.5 | 76 | 5.0 | -11.0 | frz_drizzle |
| 336 | Apr-20-98 | SPCA AD-404 | 75% | 4b | A | 32 | 15 | 113 | 4.8 | -11.0 | frz_drizzle |
| 337 | Apr-20-98 | ULTRA IV | 75% | 4b | A | 28 | 13 | 97 | 5.1 | -9.9 | frz_drizzle |
| 338 | Apr-20-98 | ULTRA IV | 75% | 4b | A | 28 | 11 | 104 | 4.8 | -10.2 | frz_drizzle |
| 339 | Apr-20-98 | ULTRA IV | Neat | 4 | A | 35 | 12.5 | 235 | 4.6 | -10.1 | frz_drizzle |
| 340 | Apr-20-98 | UCAR PG | Neat | 4 | A | 29.5 | 17 | 221 | 4.6 | -10.1 | frz_drizzle |
| 341 | Apr-20-98 | SPCA AD-480 | Neat | 4 | A | 37 | 17 | 76 | 5.0 | -10.0 | frz_drizzle |
| 342 | Apr-20-98 | UCAR PG | 75% | 4b | A | 30 | 16 | 80 | 5.1 | -9.9 | frz_drizzle |
| 343 | Apr-20-98 | SPCA AD-404 | Neat | 4 | A | 40 | 15 | 172 | 4.9 | -10.2 | frz_drizzle |
| 344 | Apr-20-98 | SPCA AD-480 | 75% | 4b | B | 29 | 14 | 74 | 4.7 | -9.9 | frz_drizzle |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 345 | Apr-20-98 | OCTAGON | 75% | 4b | A | 30 | 25 | 87 | 5.1 | -9.8 | frz_drizzle |
| 346 | Apr-20-98 | SPCA AD-404 | 75% | 4b | A | 32 | 13 | 108 | 5.0 | -10.0 | frz_drizzle |
| 347 | Apr-20-98 | OCTAGON | Neat | 4 | A | 30 | 27.5 | 97 | 4.8 | -10.0 | frz_drizzle |
| 348 | Apr-20-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 23 | 69 | 5.1 | -10.3 | frz_drizzle |
| 349 | Apr-20-98 | CLARIANT 1957 | 75% | 4b | A | 29.5 | 13 | 67 | 4.6 | -10.3 | frz_drizzle |
| 350 | Apr-20-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 15 | 76 | 5.0 | -10.3 | frz_drizzle |
| 351 | Apr-20-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 22 | 71 | 5.1 | -10.4 | frz_drizzle |
| 352 | Apr-20-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 13 | 67 | 4.7 | -10.4 | frz_drizzle |
| 353 | Apr-20-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 14 | 80 | 5.1 | -10.3 | frz_drizzle |
| 354 | Apr-20-98 | UCAR PG | 75% | 4b | A | 30 | 19 | 83 | 5.0 | -10.2 | frz_drizzle |
| 355 | Apr-20-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 17 | 104 | 4.8 | -10.1 | frz_drizzle |
| 356 | Apr-20-98 | CLARIANT 1957 | Neat | 4 | B | 37 | 16 | 94 | 4.5 | -10.1 | frz_drizzle |
| 357 | Apr-20-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 17 | 76 | 5.3 | -10.4 | frz_drizzle |
| 358 | Apr-20-98 | KILFROST ABC-S | Neat | 4 | B | 37.5 | 27 | 98 | 5.0 | -10.1 | frz_drizzle |
| 359 | Apr-20-98 | SPCA AD-480 | 75% | 4b | B | 29 | 21 | 79 | 4.9 | -10.1 | frz_drizzle |
| 360 | Apr-20-98 | OCTAGON | 75% | 4b | A | 30 | 21 | 80 | 4.7 | -10.0 | frz_drizzle |
| 361 | Apr-20-98 | UCAR XL54 | std | 1 |  | 34 | 11.5 | 8 | 4.5 | -10.2 | frz_drizzle |
| 362 | Apr-20-98 | KILFROST | std | 1 |  | 30 | 12.5 | 6 | 4.8 | -10.2 | frz_drizzle |
| 363 | Apr-20-98 | TYPE 0 ETH | std | 0 |  | 32 | 8 | 8 | 4.6 | -10.2 | frz_drizzle |
| 364 | Apr-20-98 | TYPE 0 PRO | std | 0 |  | 37 | 13.5 | 8 | 5.1 | -10.1 | frz_drizzle |
| 365 | Apr-20-98 | TYPE 0 ETH | std | 0 |  | 32 | 9.5 | 7 | 4.5 | -10.1 | frz_drizzle |
| 366 | Apr-20-98 | TYPE 0 PRO | std | 0 |  | 37 | 12 | 8 | 4.8 | -10.1 | frz_drizzle |
| 367 | Apr-20-98 | UCAR XL54 | std | 1 |  | 34 | 9.5 | 9 | 4.6 | -10.1 | frz_drizzle |
| 368 | Apr-20-98 | KILFROST | std | 1 |  | 30 | 12 | 7 | 5.1 | -10.1 | frz_drizzle |
| 369 | Apr-29-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 5 | 120 | 13.7 | -3.2 | frz_drizzle |
| 370 | Apr-29-98 | UCAR PG | Neat | 4 | A | 38 | 6 | 125 | 13.6 | -3.2 | frz_drizzle |
| 371 | Apr-29-98 | SPCA AD-404 | Neat | 4 | A | 39 | 5 | 74 | 13.3 | -3.2 | frz_drizzle |
| 372 | Apr-29-98 | KILFROST ABC-S | 50% | 4a | B | 19.5 | 5 | 13 | 13.4 | -3.3 | frz_drizzle |
| 373 | Apr-29-98 | OCTAGON | Neat | 4 | A | 38 | 6 | 63 | 13.3 | -3.2 | frz_drizzle |
| 374 | Apr-29-98 | OCTAGON | 75% | 4b | A | 29.5 | 5.5 | 93 | 12.7 | -3.2 | frz_drizzle |
| 375 | Apr-29-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 5 | 56 | 12.8 | -3.2 | frz_drizzle |
| 376 | Apr-29-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 5.5 | 45 | 12.9 | -3.2 | frz_drizzle |
| 377 | Apr-29-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 3.5 | 36 | 12.8 | -3.3 | frz_drizzle |
| 378 | Apr-29-98 | CLARIANT 1957 | 50% | 4a | A | 19.75 | 6 | 15 | 13.1 | -3.2 | frz_drizzle |
| 379 | Apr-29-98 | OCTAGON | 75% | 4b | A | 29.5 | 4.5 | 84 | 13.7 | -3.2 | frz_drizzle |
| 380 | Apr-29-98 | SPCA AD-404 | 50% | 4a | A | 21 | 5 | 23 | 13.4 | -3.2 | frz_drizzle |
| 381 | Apr-29-98 | OCTAGON | 50% | 4a | A | 21 | 7 | 32 | 12.9 | -3.2 | frz_drizzle |
| 382 | Apr-29-98 | CLARIANT 2001 | 50% | 4a | A | 19.5 | 5 | 9 | 13.1 | -3.2 | frz_drizzle |
| 383 | Apr-29-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 3 | 53 | 12.7 | -3.2 | frz_drizzle |
| 384 | Apr-29-98 | ULTRA IV | 75% | 4b | A | 26.5 | 6 | 64 | 12.6 | -3.2 | frz_drizzle |
| 385 | Apr-29-98 | SPCA AD-404 | Neat | 4 | A | 39 | 6 | 169 | 4.4 | -3.0 | frz_drizzle |
| 386 | Apr-29-98 | KILFROST ABC-S | Neat | 4 | B | 36.5 | 7 | 154 | 4.4 | -3.0 | frz_drizzle |
| 387 | Apr-29-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 5 | 77 | 4.3 | -3.1 | frz_drizzle |
| 388 | Apr-29-98 | KILFROST ABC-S | Neat | 4 | B | 36.5 | 8 | 158 | 4.4 | -3.0 | frz_drizzle |
| 389 | Apr-29-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 5.5 | 78 | 4.4 | -3.1 | frz_drizzle |
| 390 | Apr-29-98 | KILFROST ABC-S | 50% | 4a | B | 19.25 | 6 | 20 | 4.6 | -3.1 | frz_drizzle |
| 391 | Apr-29-98 | CLARIANT 1957 | 50% | 4a | A | 19.25 | 6 | 22 | 4.3 | -3.1 | frz_drizzle |
| 392 | Apr-29-98 | SPCA AD-480 | 75% | 4b | B | 28.5 | 7 | 101 | 4.1 | -3.0 | frz_drizzle |
| 393 | Apr-29-98 | OCTAGON | 50% | 4a | A | 21 | 6 | 64 | 4.3 | -3.0 | frz_drizzle |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 394 | Apr-29-98 | UCAR PG | Neat | 4 | A | 38 | 6 | 174 | 4.9 | -3.0 | frz_drizzle |
| 395 | Apr-29-98 | CLARIANT 2001 | 50% | 4a | A | 19.25 | 6 | 18 | 5.0 | -3.0 | frz_drizzle |
| 396 | Apr-29-98 | OCTAGON | 50% | 4a | A | 21 | 6 | 75 | 4.6 | -3.0 | frz_drizzle |
| 397 | Apr-30-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 2 | 79 | 24.6 | -3.3 | lfrz_rain |
| 398 | Apr-30-98 | CLARIANT 1957 | Neat | 4 | B | 37 | 6 | 39 | 24.9 | -3.4 | lfrz_rain |
| 399 | Apr-30-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 6 | 31 | 25.1 | -3.4 | lfrz_rain |
| 400 | Apr-30-98 | CLARIANT 1957 | 50% | 4a | B | 20.5 | 5.5 | 10 | 25.2 | -3.7 | lfrz_rain |
| 401 | Apr-30-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 9 | 41 | 25.1 | -3.4 | lfrz_rain |
| 402 | Apr-30-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 4 | 24 | 25.2 | -3.5 | lfrz_rain |
| 403 | Apr-30-98 | CLARIANT 2001 | 50% | 4a | B | 19 | 5 | 8 | 25.0 | -3.8 | lfrz_rain |
| 404 | Apr-30-98 | OCTAGON | Neat | 4 | A | 38.5 | 2 | 34 | 25.0 | -3.4 | lfrz_rain |
| 405 | Apr-30-98 | OCTAGON | 75% | 4b | A | 30 | 4 | 35 | 24.6 | -3.4 | lfrz_rain |
| 406 | Apr-30-98 | OCTAGON | 50% | 4a | A | 21 | 3 | 17 | 24.8 | -3.7 | lfrz_rain |
| 407 | Apr-30-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 4 | 23 | 24.9 | -3.2 | lfrz_rain |
| 408 | Apr-30-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 3 | 42 | 25.1 | -3.2 | lfrz_rain |
| 409 | Apr-30-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 6 | 78 | 25.2 | -3.2 | lfrz_rain |
| 410 | Apr-30-98 | CLARIANT 2001 | 50% | 4a | B | 19 | 6 | 8 | 25.1 | -3.2 | lfrz_rain |
| 411 | Apr-30-98 | CLARIANT 1957 | Neat | 4 | B | 36.5 | 4 | 39 | 25.2 | -3.2 | lfrz_rain |
| 412 | Apr-30-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 3 | 33 | 25.0 | -3.2 | lfrz_rain |
| 413 | Apr-30-98 | SPCA AD-404 | Neat | 4 | A | 39.5 | 4 | 42 | 25.0 | -3.2 | lfrz_rain |
| 414 | Apr-30-98 | OCTAGON | 75% | 4b | A | 30 | N/A | 38 | 24.8 | -3.2 | lfrz_rain |
| 415 | Apr-30-98 | CLARIANT 1957 | 50% | 4a | B | 20.5 | 3.5 | 10 | 25.7 | -3.2 | lfrz_rain |
| 416 | Apr-30-98 | ULTRA IV | Neat | 4 | A | 35 | 2 | 95 | 24.8 | -3.2 | lfrz_rain |
| 417 | Apr-30-98 | OCTAGON | Neat | 4 | A | 38 | 3 | 32 | 25.5 | -3.2 | lfrz_rain |
| 418 | Apr-30-98 | KILFROST ABC-S | 75% | 4b | B | 29.5 | 2.5 | 39 | 24.6 | -3.2 | lfrz_rain |
| 419 | Apr-30-98 | KILFROST ABC-S | 75% | 4b | B | 29.5 | 4 | 39 | 25.1 | -3.2 | lfrz_rain |
| 420 | Apr-30-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 4 | 118 | 14.6 | -3.1 | lfrz_rain |
| 421 | Apr-30-98 | OCTAGON | Neat | 4 | A | 38.5 | 8 | 58 | 13.3 | -3.2 | lfrz_rain |
| 422 | Apr-30-98 | OCTAGON | 75% | 4b | A | 30 | 5 | 67 | 14.1 | -3.2 | lfrz_rain |
| 423 | Apr-30-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 7 | 111 | 12.9 | -3.1 | lfrz_rain |
| 424 | Apr-30-98 | CLARIANT 1957 | Neat | 4 | B | 37 | N/A | 55 | 13.7 | -3.2 | lfrz_rain |
| 425 | Apr-30-98 | CLARIANT 2001 | Neat | 4 | B | 37 | 7 | 57 | 12.5 | -3.2 | lfrz_rain |
| 426 | Apr-30-98 | OCTAGON | 75% | 4b | A | 30 | 4 | 71 | 12.7 | -3.2 | lfrz_rain |
| 427 | Apr-30-98 | KILFROST ABC-S | 75% | 4b | B | 29.5 | 6 | 51 | 13.9 | -3.2 | lfrz_rain |
| 428 | Apr-30-98 | CLARIANT 1957 | Neat | 4 | B | 37 | 7 | 56 | 13.7 | -3.2 | lfrz_rain |
| 429 | Apr-30-98 | CLARIANT 2001 | Neat | 4 | B | 37 | 8 | 57 | 13.9 | -3.2 | lfrz_rain |
| 430 | Apr-30-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 7 | 41 | 13.2 | -3.2 | lfrz_rain |
| 431 | Apr-30-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 8 | 32 | 13.7 | -3.2 | lfrz_rain |
| 432 | Apr-30-98 | KILFROST ABC-S | 75% | 4b | B | 29.5 | 7 | 52 | 13.0 | -3.1 | lfrz_rain |
| 433 | Apr-30-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 7 | 42 | 13.3 | -3.1 | lfrz_rain |
| 434 | Apr-30-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 5 | 33 | 13.1 | -3.1 | lfrz_rain |
| 435 | Apr-30-98 | CLARIANT 1957 | 50% | 4a | B | 20.5 | 6 | 17 | 13.3 | -3.0 | lfrz_rain |
| 436 | Apr-30-98 | CLARIANT 2001 | 50% | 4a | B | 19.5 | 5 | 13 | 13.7 | -3.0 | lfrz_rain |
| 437 | Apr-30-98 | CLARIANT 2001 | 50% | 4a | B | 19.5 | 5 | 13 | 12.5 | -3.0 | lfrz_rain |
| 438 | Apr-30-98 | KILFROST ABC-S | 50% | 4a | B | 21 | 4 | 14 | 12.7 | -3.1 | lfrz_rain |
| 439 | Apr-30-98 | KILFROST ABC-S | 50% | 4a | B | 21 | 5 | 14 | 13.9 | -3.1 | lfrz_rain |
| 440 | Apr-30-98 | CLARIANT 1957 | 50% | 4a | B | 20.5 | 6 | 16 | 13.2 | -3.1 | lfrz_rain |
| 441 | Apr-30-98 | OCTAGON | 50% | 4a | A | 21 | 4 | 29 | 13.7 | -3.1 | lfrz_rain |
| 442 | Apr-30-98 | KILFROST ABC-S | 50% | 4a | B | 21 | 4 | 8 | 24.1 | -3.0 | lfrz_rain |

# SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF FOR 1997/98

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 443 | Apr-30-98 | KILFROST ABC-S | 50% | 4a | B | 21 | 4 | 8 | 24.1 | -2.9 | lfrz_rain |
| 444 | Apr-30-98 | SPCA AD-404 | Neat | 4 | A | 40 | 4 | 87 | 14.0 | -3.1 | frz_drizzle |
| 445 | Apr-30-98 | ULTRA IV | 75% | 4b | A | 27 | 4 | 53 | 13.8 | -3.1 | frz_drizzle |
| 446 | Apr-30-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 6 | 113 | 13.4 | -3.1 | frz_drizzle |
| 447 | Apr-30-98 | OCTAGON | 75% | 4b | A | 30 | 6.5 | 83 | 13.1 | -3.1 | frz_drizzle |
| 448 | Apr-30-98 | KILFROST ABC-S | Neat | 4 | B | 37 | 7 | 121 | 12.6 | -3.1 | frz_drizzle |
| 449 | Apr-30-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 5 | 44 | 12.5 | -3.1 | frz_drizzle |
| 450 | Apr-30-98 | KILFROST ABC-S | 75% | 4b | B | 29.5 | 6 | 50 | 12.8 | -3.1 | frz_drizzle |
| 451 | Apr-30-98 | KILFROST ABC-S | 75% | 4b | B | 29.5 | 6.5 | 49 | 13.3 | -3.1 | frz_drizzle |
| 452 | May-01-98 | ULTRA IV | Neat | 4 | A | 35 | 14 | 135 | 14.3 | -10.4 | frz_drizzle |
| 453 | May-01-98 | UCAR PG | Neat | 4 | A | 37.5 | 27 | 37 | 14.0 | -10.4 | frz_drizzle |
| 454 | May-01-98 | SPCA AD-404 | Neat | 4 | A | 39 | 16 | 69 | 13.8 | -10.4 | frz_drizzle |
| 455 | May-01-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 15 | 47 | 12.0 | -10.4 | frz_drizzle |
| 456 | May-01-98 | ULTRA IV | 75% | 4b | A | 27 | 11 | 55 | 10.6 | -10.4 | frz_drizzle |
| 457 | May-01-98 | UCAR PG | Neat | 4 | A | 37.5 | 27 | 41 | 11.6 | -10.4 | frz_drizzle |
| 458 | May-01-98 | SPCA AD-404 | Neat | 4 | A | 39 | 17 | 56 | 13.0 | -10.4 | frz_drizzle |
| 459 | May-01-98 | UCAR PG | 75% | 4b | A | 29.5 | 28 | 32 | 13.1 | -10.4 | frz_drizzle |
| 460 | May-01-98 | SPCA AD-404 | 75% | 4b | B | 31 | 11 | 30 | 13.2 | -10.4 | frz_drizzle |
| 461 | May-01-98 | OCTAGON | 75% | 4b | A | 30 | 24 | 26 | 13.7 | -10.4 | frz_drizzle |
| 462 | May-01-98 | SPCA AD-480 | 75% | 4b | B | 29 | N/A | 27 | 12.6 | -10.4 | frz_drizzle |
| 463 | May-01-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 22 | 31 | 12.9 | -10.3 | frz_drizzle |
| 464 | May-01-98 | UCAR PG | 75% | 4b | A | 29.5 | 20 | 44 | 10.1 | -10.3 | frz_drizzle |
| 465 | May-01-98 | SPCA AD-480 | 75% | 4b | B | 29 | 19 | 26 | 14.1 | -10.4 | frz_drizzle |
| 466 | May-01-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 14 | 45 | 13.6 | -10.3 | frz_drizzle |
| 467 | May-01-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 16 | 44 | 13.5 | -10.3 | frz_drizzle |
| 468 | May-01-98 | SPCA AD-404 | 75% | 4b | B | 31 | 14 | 30 | 13.4 | -10.4 | frz_drizzle |
| 469 | May-01-98 | CLARIANT 2001 | 75% | 4b | B | 29 | 17 | 34 | 13.3 | -10.3 | frz_drizzle |
| 470 | May-01-98 | SPCA AD-404 | 75% | 4b | B | 31 | 13 | 31 | 13.3 | -10.4 | frz_drizzle |
| 471 | May-01-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 24 | 29 | 13.1 | -10.4 | frz_drizzle |
| 472 | May-01-98 | OCTAGON | 75% | 4b | A | 30 | 26 | 27 | 11.9 | -10.4 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR XL54 | std | 1 | | | | 10 | 11.9 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON | std | 1 | | | | 10 | 11.8 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | TYPE 0 PRO. | std | 0 | | | | 10 | 11.6 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | TYPE 0 ETH. | std | 0 | | | | 9 | 11.5 | -3.1 | frz_drizzle |

## SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN @ CEF FOR 1997/98 SPECIAL HOLDOVER TIME TESTS

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|
| 227 | Apr-15-98 | UCAR XL54 / TYPE 0 ETH | std | 1/0 | 13 | 10.5 | -3.0 | frz_drizzle |
| 229 | Apr-15-98 | KILFROST / TYPE 0 PRO | std | 1/0 | 11 | 10.4 | -3.0 | frz_drizzle |
| 231 | Apr-15-98 | UCAR XL54 / TYPE 0 ETH | std | 1/0 | 12 | 10.9 | -3.0 | frz_drizzle |
| 232 | Apr-15-98 | KILFROST / TYPE 0 PRO | STD | 1/0 | 10 | 12.6 | -3.0 | frz_drizzle |
| 367 | Apr-20-98 | UCAR XL54 / TYPE 0 ETH | STD | 1/0 | 5 | 12.5 | -10.0 | lfrz_rain |
| 368 | Apr-20-98 | KILFROST / TYPE 0 PRO | STD | 1/0 | 5 | 12.0 | -10.0 | lfrz_rain |
| 369 | Apr-20-98 | UCAR XL54 / TYPE 0 PRO | STD | 1/0 | 5 | 12.4 | -10.0 | lfrz_rain |
| 370 | Apr-20-98 | KILFROST / TYPE 0 ETH | STD | 1/0 | 5 | 12.2 | -10.0 | lfrz_rain |
| 406 | Apr-20-98 | UCAR XL54 / TYPE 0 ETH | STD | 1/0 | 9 | 4.9 | -10.0 | frz_drizzle |
| 407 | Apr-20-98 | KILFROST / TYPE 0 PRO | STD | 1/0 | 8 | 4.7 | -10.0 | frz_drizzle |
| 408 | Apr-20-98 | UCAR XL54 / TYPE 0 PRO | STD | 1/0 | 10 | 4.5 | -10.0 | frz_drizzle |
| 409 | Apr-20-98 | KILFROST / TYPE 0 ETH | STD | 1/0 | 8 | 4.9 | -10.0 | frz_drizzle |
| 465 | Apr-30-98 | OCTAGON / TYPE 0 ETH | N/Std | 4/0 | 33 | 25.7 | -3.0 | lfrz_rain |
| 464 | Apr-30-98 | OCTAGON / TYPE 0 PRO | N/Std | 4/0 | 34 | 25.0 | -3.0 | lfrz_rain |
| 457 | Apr-30-98 | OCTAGON IV / OCTAGON I | N/Std | 4/1 | 30 | 24.9 | -3.0 | lfrz_rain |
| R1 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 32 | 26.3 | -10.0 | lfrz_rain |
| R1 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 32 | 25.8 | -10.0 | lfrz_rain |
| R1 | Jul-07-98 | OCTAGON | Neat | 4 | 19 | 24.9 | -10.0 | lfrz_rain |
| R1 | Jul-07-98 | OCTAGON | Neat | 4 | 19 | 24.8 | -10.0 | lfrz_rain |
| R1 | Jul-07-98 | OCTAGON | Neat | 4 | 20 | 25.0 | -10.0 | lfrz_rain |
| R1 | Jul-07-98 | UCAR ULTRA + / TYPE 0 PRO | N/Std | 4/0 | 25 | 23.8 | -10.0 | lfrz_rain |
| R1 | Jul-07-98 | UCAR ULTRA + / XL54 | N/Std | 4/1 | 30 | 23.6 | -10.0 | lfrz_rain |
| R1 | Jul-07-98 | OCTAGON / TYPE 0 ETH | N/Std | 4/0 | 22 | 23.7 | -10.0 | lfrz_rain |
| R1 | Jul-07-98 | OCTAGON / TYPE 0 PRO | N/Std | 4/0 | 23 | 22.8 | -10.0 | lfrz_rain |
| R1 | Jul-07-98 | OCTAGON IV / OCTAGON I | N/Std | 4/1 | 23 | 22.9 | -10.0 | lfrz_rain |
| R2 | Jul-07-98 | UCAR ULTRA + / TYPE 0 PRO | N/Std | 4/0 | 20 | 26.3 | -9.9 | lfrz_rain |
| R2 | Jul-07-98 | UCAR ULTRA + / XL54 | N/Std | 4/1 | 23 | 25.8 | -9.8 | lfrz_rain |
| R2 | Jul-07-98 | OCTAGON / TYPE 0 ETH | N/Std | 4/0 | 18 | 24.9 | -9.9 | lfrz_rain |
| R2 | Jul-07-98 | OCTAGON / TYPE 0 PRO | N/Std | 4/0 | 19 | 24.8 | -9.9 | lfrz_rain |
| R2 | Jul-07-98 | OCTAGON IV / OCTAGON I | N/Std | 4/1 | 21 | 25.0 | -9.9 | lfrz_rain |
| R2 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 27 | 23.8 | -9.9 | lfrz_rain |
| R2 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 29 | 23.6 | -9.9 | lfrz_rain |
| R2 | Jul-07-98 | OCTAGON | Neat | 4 | 20 | 23.7 | -9.9 | lfrz_rain |
| R2 | Jul-07-98 | OCTAGON | Neat | 4 | 20 | 22.8 | -9.9 | lfrz_rain |
| R2 | Jul-07-98 | OCTAGON | Neat | 4 | 21 | 22.9 | -9.8 | lfrz_rain |
| R2 | Jul-07-98 | UCAR ULTRA + / TYPE 0 ETH | N/Std | 4/0 | 24 | 25.8 | -10.0 | lfrz_rain |
| R2 | Jul-07-98 | SPCA AD-480 | Neat | 4 | 17 | 22.9 | -10.0 | lfrz_rain |
| R5-R6 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 30 | 25.1 | -3.4 | lfrz_rain |
| R5-R6 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 29 | 25.3 | -3.4 | lfrz_rain |
| R5-R6 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 29 | 25.2 | -3.4 | lfrz_rain |
| R5-R6 | Jul-07-98 | OCTAGON | Neat | 4 | 34 | 25.5 | -3.4 | lfrz_rain |
| R5-R6 | Jul-07-98 | OCTAGON | Neat | 4 | 33 | 25.8 | -3.4 | lfrz_rain |
| R5-R6 | Jul-07-98 | UCAR ULTRA + / TYPE 0 ETH | N/Std | 4/0 | 26 | 23.7 | -3.4 | lfrz_rain |
| R5-R6 | Jul-07-98 | UCAR ULTRA + / TYPE 0 PRO | N/Std | 4/0 | 25 | 23.9 | -3.4 | lfrz_rain |
| R5-R6 | Jul-07-98 | UCAR ULTRA + / XL54 | N/Std | 4/1 | 26 | 24.4 | -3.4 | lfrz_rain |

## SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN @ CEF FOR 1997/98 SPECIAL HOLDOVER TIME TESTS

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|
| R5-R6 | Jul-07-98 | OCTAGON | Neat | 4 | 30 | 25.3 | -3.5 | lfrz_rain |
| R5-R6 | Jul-07-98 | OCTAGON IV / OCTAGON I | N/Std | 4/1 | 29 | 25.5 | -3.5 | lfrz_rain |
| R5-R6 | Jul-07-98 | OCTAGON IV / OCTAGON I | N/Std | 4/1 | 27 | 25.8 | -3.5 | lfrz_rain |
| R3-R4 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 59 | 12.2 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 60 | 11.9 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 62 | 11.8 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON | Neat | 4 | 53 | 11.6 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON | Neat | 4 | 55 | 11.5 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON | Neat | 4 | 62 | 11.1 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + / TYPE 0 ETH | N/Std | 4/0 | 50 | 9.8 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + / TYPE 0 PRO | N/Std | 4/0 | 46 | 10.3 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + / XL54 | N/Std | 4/1 | 53 | 10.4 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON / TYPE 0 ETH | N/Std | 4/0 | 50 | 11.0 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON / TYPE 0 PRO | N/Std | 4/0 | 46 | 11.4 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON IV / OCTAGON I | N/Std | 4/1 | 46 | 11.8 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + / TYPE 0 ETH | N/Std | 4/0 | 54 | 12.2 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + / TYPE 0 PRO | N/Std | 4/0 | 45 | 11.9 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + / XL54 | N/Std | 4/1 | 51 | 11.8 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON / TYPE 0 ETH | N/Std | 4/0 | 54 | 11.6 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON / TYPE 0 PRO | N/Std | 4/0 | 53 | 11.5 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON IV / OCTAGON I | N/Std | 4/1 | 58 | 11.1 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 52 | 9.8 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 55 | 10.3 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | UCAR ULTRA + | Neat | 4 | 56 | 10.4 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON | Neat | 4 | 53 | 11.0 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON | Neat | 4 | 52 | 11.4 | -3.1 | frz_drizzle |
| R3-R4 | Jul-07-98 | OCTAGON | Neat | 4 | 52 | 11.8 | -3.1 | frz_drizzle |

# SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN @ CEF FOR 1997/98

## SPRAYER TESTS

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R5-R6 | Jul-07-98 | UCAR ULTRA + (SPRAYED) | Neat | 4 | | | | 33 | 25.3 | -3.4 | lfrz_rain | SPRAYER TEST |
| R5-R6 | Jul-07-98 | UCAR ULTRA + (SPRAYED) | Neat | 4 | | | | 32 | 25.5 | -3.4 | lfrz_rain | SPRAYER TEST |
| R5-R6 | Jul-07-98 | UCAR ULTRA + (POURED) | Neat | 4 | | | | 29 | 25.3 | -3.5 | lfrz_rain | POURED |
| R5-R6 | Jul-07-98 | UCAR ULTRA + (POURED) | Neat | 4 | | | | 29 | 25.5 | -3.5 | lfrz_rain | POURED |
| R5-R6 | Jul-07-98 | OCTAGON (SPRAYED) | Neat | 4 | | | | 18 | 25.3 | -3.5 | lfrz_rain | SPRAYER TEST |
| R5-R6 | Jul-07-98 | OCTAGON (SPRAYED) | Neat | 4 | | | | 18 | 25.5 | -3.5 | lfrz_rain | SPRAYER TEST |
| 11 | Apr-03-98 | UCAR PG | Neat | 4 | | N/A | 1.5 | 92 | 24.3 | -3.0 | lfrz_rain | Sprayer Test |
| 12 | Apr-03-98 | UCAR PG | Neat | 4 | | N/A | 1.5 | 90 | 28.2 | -3.0 | lfrz_rain | Sprayer Test |

## EFFECT OF TEMPERATURE

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Batch # | Inital Fluid Temp | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H1-H4 | Jul-10-98 | OCT. IV / OCT. I | N/Std | 4/1 | | 40/80 | N/A | 19 | 24.1 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | KILFROST IV / KILFROST I | N/Std | 4/1 | | 40/80 | 15 | 50 | 24.2 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | SPCA AD-404 | Neat | 4 | A | -3 | 17 | 44 | 24.5 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | SPCA AD-480 | Neat | 4 | A | -3 | 23 | 53 | 24.6 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | CLARIANT 1957 / CLARIANT I | N/Std | 4 | A | 40/80 | 18 | 34 | 24.8 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | CLARIANT 2001 | Neat | 4 | | -3 | N/A | 36 | 26.1 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | UCAR ULTRA + | Neat | 4 | | -3 | N/A | 32 | 24.2 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | OCTAGON | Neat | 4 | | -3 | N/A | 40 | 24.1 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | SPCA AD-404 / SPCA I | N/Std | 4/1 | | 40/80 | N/A | 34 | 24.5 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | CLARIANT 1957 | Neat | 4 | B | -3 | N/A | 42 | 24.8 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | CLARIANT 2001 / OCT. I | N/Std | 4/1 | | 40/80 | N/A | 39 | 26.1 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | UCAR ULTRA + / XL54 | N/Std | 4/1 | | 40/80 | N/A | 31 | 24.2 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | KILFROST ABC-S | Neat | 4 | B | -3 | N/A | 75 | 24.2 | -3.5 | lfrz_rain | Effect of Temperature |
| H1-H4 | Jul-10-98 | SPCA AD-480 / SPCA I | N/Std | 4/1 | | 40/80 | N/A | 37 | 24.4 | -3.5 | lfrz_rain | Effect of Temperature |

## SIMULATED LIGHT FRZ RAIN AT CEF - JULY 10, 1998

| test no. | date | fluid name | fld dilution | fld type | Initial Brix | Inital Fluid Temp | fail time [min.] | rate of precep. g/dm*2/hr | Ambient temp [C] | Avg. For APS Fail Time | Precip Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| test | date | fld_name | dil | fld_type | ini_brix | fld_temp | fail | rate | temp | temp | prec |
| 1 | Jul-10-98 | UCAR ULTRA + | Neat | 4 | 39.5 | -10 | 34 | 25.1 | -10.1 | -8 | lfrz_rain |
| 2 | Jul-10-98 | UCAR ULTRA + | Neat | 4 | 40 | -10 | 33 | 25.3 | -10.1 | -8 | lfrz_rain |
| 3 | Jul-10-98 | OCTAGON MAXFLIGHT | Neat | 4 | 37 | -10 | 20 | 25.0 | -9.9 | -8 | lfrz_rain |
| 4 | Jul-10-98 | OCTAGON MAXFLIGHT | Neat | 4 | 37 | -10 | 19 | 25.4 | -9.9 | -8 | lfrz_rain |
| 5 | Jul-10-98 | SPCA AD-480 | Neat | 4 | 35.5 | -10 | 18 | 25.0 | -9.8 | -8 | lfrz_rain |
| 6 | Jul-10-98 | SPCA AD-480 | Neat | 4 | 35.5 | -10 | 16 | 25.4 | -9.8 | -8 | lfrz_rain |

# SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN AT CEF FOR 1997/98
# EFFECT OF WIND AND SLOPE

| Test No. | Date | Fluid Name | Fluid Dilution | Fluid Type | Slope ° | Wind (kph) | Initial Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feb-11-98 | UCAR ULTRA + | Neat | | 11 | | | 30 | 28.3 | -9.5 | lfrz_rain | Effect of Slope |
| | Feb-11-98 | UCAR ULTRA + | Neat | | 9 | | | 35 | 25.8 | -9.5 | lfrz_rain | Effect of Slope |
| | Feb-11-98 | UCAR ULTRA + | Neat | | 10 | | | 32 | 28.3 | -9.5 | lfrz_rain | Effect of Slope |
| | Feb-11-98 | UCAR ULTRA + | Neat | | 10 | | | 32 | 25.8 | -9.5 | lfrz_rain | Effect of Slope |
| W1 | Jul-06-98 | OCTAGON | Neat | 4 | | 10 | 37 | 35 | 24.7 | -3.7 | lfrz_rain | Effect of wind |
| W1 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | | 10 | 40.5 | 31 | 25.3 | -3.7 | lfrz_rain | Effect of wind |
| W1 | Jul-06-98 | UCAR XL54 | Std | 1 | | 10 | 34.5 | 4 | 25.5 | -3.7 | lfrz_rain | Effect of wind |
| W1 | Jul-06-98 | OCTAGON | Neat | 4 | | 10 | 37 | 37 | 22.3 | -3.7 | lfrz_rain | Effect of wind |
| W1 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | | 10 | 40.5 | 32 | 22.3 | -3.7 | lfrz_rain | Effect of wind |
| W1 | Jul-06-98 | UCAR XL54 | Std | 1 | | 10 | 34.5 | 4 | 23.8 | -3.7 | lfrz_rain | Effect of wind |
| W1 | Jul-06-98 | KILFROST ABC-S | 50% | 4a | | 10 | 19.5 | 10 | 25.5 | -3.7 | lfrz_rain | Effect of wind |
| W1 | Jul-06-98 | KILFROST ABC-S | 50% | 4a | | 10 | 19.5 | 12 | 23.8 | -3.7 | lfrz_rain | Effect of wind |
| W2 | Jul-06-98 | OCTAGON | Neat | 4 | | 0 | | 37 | 24.7 | -2.9 | lfrz_rain | Effect of wind |
| W2 | Jul-06-98 | UCAR XL54 | Std | 1 | | 0 | | 5 | 24.0 | -2.8 | lfrz_rain | Effect of wind |
| W2 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | | 0 | | 31 | 24.7 | -2.9 | lfrz_rain | Effect of wind |
| W2 | Jul-06-98 | UCAR XL54 | Std | 1 | | 0 | | 5 | 25.6 | -2.9 | lfrz_rain | Effect of wind |
| W2 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | | 0 | | 32 | 23.5 | -2.9 | lfrz_rain | Effect of wind |
| W2 | Jul-06-98 | OCTAGON | Neat | 4 | | 0 | | 35 | 23.4 | -2.9 | lfrz_rain | Effect of wind |
| W2 | Jul-06-98 | KILFROST ABC-S | 50% | 4a | | 0 | | 13 | 24.0 | -2.9 | lfrz_rain | Effect of wind |
| W2 | Jul-06-98 | KILFROST ABC-S | 50% | 4a | | 0 | | 11 | 25.6 | -2.8 | lfrz_rain | Effect of wind |
| S1 | Jul-06-98 | SPCA AD-480 | 50% | 4a | 10 | | | 17 | 25.0 | -2.5 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | 10 | | | 40 | 24.6 | -2.4 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | 10 | | | 36 | 24.2 | -2.5 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | OCTAGON | Neat | 4 | 10 | | | 35 | 24.3 | -2.4 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | OCTAGON | Neat | 4 | 10 | | | 35 | 24.2 | -2.4 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | KILFROST ABC-S | 50% | 4a | 10 | | | 12 | 24.3 | -2.5 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | SPCA AD-480 | 50% | 4a | 10 | | | 13 | 23.8 | -2.4 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | 10 | | | 33 | 24.4 | -2.5 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | 10 | | | 33 | 24.5 | -2.5 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | OCTAGON | Neat | 4 | 10 | | | 34 | 23.9 | -2.4 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | OCTAGON | Neat | 4 | 10 | | | 33 | 24.1 | -2.4 | lfrz_rain | Effect of Slope |
| S1 | Jul-06-98 | KILFROST ABC-S | 50% | 4a | 10 | | | 11 | 24.0 | -2.6 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | SPCA AD-480 | 50% | 4a | 8.5 | | | 34 | 25.0 | -2.1 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | 11.5 | | | 29 | 24.6 | -2.0 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | 8.5 | | | 38 | 24.2 | -2.0 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | OCTAGON | Neat | 4 | 8.5 | | | 41 | 24.3 | -2.1 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | OCTAGON | Neat | 4 | 11.5 | | | 34 | 24.2 | -2.1 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | KILFROST ABC-S | 50% | 4a | 8 | | | 14 | 24.3 | -2.1 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | SPCA AD-480 | 50% | 4a | 11.75 | | | 12 | 23.8 | -2.3 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | 8.5 | | | 38 | 24.4 | -2.0 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | UCAR ULTRA + | Neat | 4 | 11.5 | | | 28 | 24.5 | -2.0 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | OCTAGON | Neat | 4 | 8 | | | 41 | 23.9 | -2.0 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | OCTAGON | Neat | 4 | 12 | | | 30 | 24.1 | -2.0 | lfrz_rain | Effect of Slope |
| S2 | Jul-06-98 | KILFROST ABC-S | 50% | 4a | 12 | | | 10 | 24.0 | -2.1 | lfrz_rain | Effect of Slope |

# SIMULATED FREEZING FOG AT CEF FOR 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Apr-22-98 | KILFROST ABC-S | 75% | 4b | B | 30.5 | 6 | 98 | 3.3 | -3.3 | frz_fog |
| 2 | Apr-22-98 | UCAR PG | 75% | 4b | A | 29 | 6 | 120 | 2.9 | -3.3 | frz_fog |
| 3 | Apr-22-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 6 | 78 | 4.8 | -3.3 | frz_fog |
| 4 | Apr-22-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 6.5 | 108 | 4.2 | -3.3 | frz_fog |
| 5 | Apr-22-98 | KILFROST ABC-S | 50% | 4a | B | 19 | 7 | 29 | 3.2 | -3.2 | frz_fog |
| 6 | Apr-22-98 | UCAR PG | 50% | 4a | A | N/A | 6 | 74 | 3.2 | -3.3 | frz_fog |
| 7 | Apr-22-98 | ULTRA IV | 50% | 4a | A | N/A | 6 | 49 | 3.6 | -3.3 | frz_fog |
| 8 | Apr-22-98 | OCTAGON | 50% | 4a | A | 20 | 6 | 97 | 4.9 | -3.3 | frz_fog |
| 9 | Apr-22-98 | CLARIANT 1957 | 50% | 4a | B | N/A | 8 | 37 | 3.0 | -3.4 | frz_fog |
| 10 | Apr-22-98 | CLARIANT 2001 | 50% | 4a | B | N/A | 7 | 24 | 2.9 | -3.3 | frz_fog |
| 11 | Apr-22-98 | SPCA AD-480 | 50% | 4a | B | 20 | N/A | 56 | 2.7 | -3.3 | frz_fog |
| 12 | Apr-22-98 | CLARIANT 2001 | Neat | 4 | B | 37.5 | 5 | 124 | 2.6 | -3.3 | frz_fog |
| 13 | Apr-23-98 | UCAR PG | Neat | 4 | A | N/A | 18 | 66 | 4.0 | -15.8 | frz_fog |
| 14 | Apr-23-98 | CLARIANT 2001 | Neat | 4 | B | N/A | 22 | 60 | 4.7 | -15.9 | frz_fog |
| 15 | Apr-23-98 | SPCA AD-480 | Neat | 4 | A | N/A | 23 | 59 | 3.5 | -16.0 | frz_fog |
| 16 | Apr-23-98 | ULTRA IV | Neat | 4 | A | 36 | 22 | 99 | 5.3 | -14.5 | frz_fog |
| 17 | Apr-23-98 | SPCA AD-404 | Neat | 4 | A | 40 | 22 | 153 | 4.6 | -14.5 | frz_fog |
| 18 | Apr-23-98 | CLARIANT 1957 | Neat | 4 | B | 37.5 | 30 | 50 | 5.0 | -14.4 | frz_fog |
| 19 | Apr-23-98 | SPCA AD-480 | Neat | 4 | A | 38 | 28 | 43 | 5.7 | -14.3 | frz_fog |
| 20 | Apr-23-98 | SPCA AD-480 | Neat | 4 | A | 38 | 30 | 42 | 5.4 | -14.4 | frz_fog |
| 21 | Apr-23-98 | OCTAGON | Neat | 4 | A | 39.5 | 30 | 50 | 4.9 | -14.3 | frz_fog |
| 22 | Apr-23-98 | KILFROST ABC-S | Neat | 4 | B | 38.5 | 32 | 57 | 4.4 | -14.4 | frz_fog |
| 23 | Apr-23-98 | UCAR PG | 75% | 4b | A | 31 | 25 | 37 | 4.6 | -14.3 | frz_fog |
| 24 | Apr-23-98 | UCAR PG | Neat | 4 | A | 39.5 | 28 | 58 | 4.4 | -14.4 | frz_fog |
| 25 | Apr-23-98 | CLARIANT 2001 | Neat | 4 | B | 37.5 | 26 | 58 | 4.9 | -14.4 | frz_fog |
| 26 | Apr-23-98 | ULTRA IV | Neat | 4 | A | 36 | 25 | 98 | 5.9 | -14.5 | frz_fog |
| 27 | Apr-23-98 | SPCA AD-404 | 75% | 4b | B | 32 | 25 | 74 | 5.6 | -14.5 | frz_fog |
| 28 | Apr-23-98 | SPCA AD-480 | 75% | 4b | B | 30.5 | 28 | 32 | 5.3 | -14.3 | frz_fog |
| 29 | Apr-23-98 | ULTRA IV | 75% | 4b | A | 28 | N/A | 54 | 4.9 | -14.4 | frz_fog |
| 30 | Apr-23-98 | OCTAGON | 75% | 4b | A | 32 | 28 | 32 | 4.4 | -14.3 | frz_fog |
| 31 | Apr-23-98 | KILFROST ABC-S | 75% | 4b | B | 30 | 28 | 37 | 4.1 | -14.3 | frz_fog |
| 32 | Apr-23-98 | CLARIANT 1957 | 75% | 4b | B | 29.5 | 27 | 43 | 4.8 | -14.4 | frz_fog |
| 33 | Apr-23-98 | CLARIANT 2001 | 75% | 4b | B | 29.5 | N/A | 42 | 4.6 | -14.4 | frz_fog |
| 34 | Apr-23-98 | SPCA AD-404 | Neat | 4 | A | 40 | 19 | 167 | 4.4 | -14.3 | frz_fog |
| 35 | Apr-23-98 | UCAR PG | Neat | 4 | A | 39.5 | 34 | 60 | 4.1 | -14.5 | frz_fog |
| 36 | Apr-23-98 | SPCA AD-480 | 75% | 4b | B | 30.5 | 27 | 31 | 6.6 | -14.5 | frz_fog |
| 37 | Apr-23-98 | CLARIANT 2001 | Neat | 4 | B | 37.5 | 31 | 56 | 4.8 | -14.6 | frz_fog |
| 38 | Apr-23-98 | KILFROST ABC-S | Neat | 4 | B | 38.5 | 29 | 60 | 5.3 | -14.6 | frz_fog |
| 39 | Apr-23-98 | OCTAGON | 75% | 4b | A | 32 | 27 | 29 | 5.2 | -14.6 | frz_fog |
| 40 | Apr-23-98 | OCTAGON | Neat | 4 | A | 39.5 | 32 | 46 | 5.9 | -14.6 | frz_fog |
| 41 | Apr-23-98 | CLARIANT 1957 | Neat | 4 | B | 37.5 | 27 | 51 | 4.8 | -14.6 | frz_fog |
| 42 | Apr-23-98 | KILFROST ABC-S | 75% | 4b | B | 30.5 | 26 | 38 | 4.3 | -14.5 | frz_fog |
| 43 | Apr-23-98 | CLARIANT 2001 | Neat | 4 | B | 37.5 | 30 | 62 | 4.1 | -14.6 | frz_fog |
| 44 | Apr-23-98 | SPCA AD-404 | 75% | 4b | B | 32 | 19 | 68 | 5.3 | -14.5 | frz_fog |
| 45 | Apr-23-98 | ULTRA IV | 75% | 4b | A | 28 | 21 | 54 | 5.1 | -14.6 | frz_fog |
| 46 | Apr-23-98 | UCAR PG | 75% | 4b | A | 31 | 24 | 40 | 4.4 | -14.5 | frz_fog |
| 47 | Apr-23-98 | CLARIANT 1957 | 75% | 4b | B | 29.5 | 25 | 43 | 4.3 | -14.5 | frz_fog |
| 48 | Apr-23-98 | CLARIANT 2001 | 75% | 4b | B | 29.5 | 26 | 41 | 4.4 | -14.5 | frz_fog |
| 49 | Apr-24-98 | KILFROST ABC-S | Neat | 4 | B | 39.5 | 34 | 43 | 3.3 | -25.3 | frz_fog |
| 50 | Apr-24-98 | SPCA AD-404 | Neat | 4 | A | 41 | 34 | 58 | 3.2 | -25.3 | frz_fog |

# SIMULATED FREEZING FOG AT CEF FOR 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 51 | Apr-24-98 | UCAR PG | Neat | 4 | A | 40 | 33 | 41 | 2.1 | -25.3 | frz_fog |
| 52 | Apr-24-98 | KILFROST ABC-S | Neat | 4 | B | 39.5 | 30 | 43 | 2.8 | -25.3 | frz_fog |
| 53 | Apr-24-98 | ULTRA IV | Neat | 4 | A | 40 | 30 | 44 | 3.5 | -25.2 | frz_fog |
| 54 | Apr-24-98 | SPCA AD-404 | Neat | 4 | A | 41 | 38 | 55 | 3.2 | -25.2 | frz_fog |
| 55 | Apr-24-98 | OCTAGON | Neat | 4 | A | 37.5 | 34 | 38 | 3.1 | -25.2 | frz_fog |
| 56 | Apr-24-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 27 | 34 | 2.8 | -25.2 | frz_fog |
| 57 | Apr-24-98 | CLARIANT 1957 | Neat | 4 | B | 36.5 | 32 | 31 | 2.3 | -25.2 | frz_fog |
| 58 | Apr-24-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 31 | 38 | 2.5 | -25.2 | frz_fog |
| 59 | Apr-24-98 | ULTRA IV | Neat | 4 | A | 35 | N/A | 43 | 2.2 | -25.2 | frz_fog |
| 60 | Apr-24-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 29 | 34 | 2.1 | -25.2 | frz_fog |
| 61 | Apr-24-98 | UCAR PG | Neat | 4 | A | 37.5 | 36 | 37 | 2.0 | -25.2 | frz_fog |
| 62 | Apr-24-98 | OCTAGON | Neat | 4 | A | 37.5 | 33 | 35 | 1.8 | -25.2 | frz_fog |
| 63 | Apr-24-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 32 | 33 | 1.7 | -25.2 | frz_fog |
| 64 | Apr-24-98 | CLARIANT 1957 | Neat | 4 | B | 36.5 | 31 | 33 | 1.5 | -25.2 | frz_fog |
| 65 | Apr-24-98 | SPCA AD-404 | Neat | 4 | A | 41 | 33 | 50 | 7.0 | -25.0 | frz_fog |
| 66 | Apr-24-98 | ULTRA IV | Neat | 4 | A | 35 | 33 | 37 | 5.8 | -25.0 | frz_fog |
| 67 | Apr-24-98 | UCAR PG | Neat | 4 | A | 37.5 | 34 | 23 | 4.5 | -25.0 | frz_fog |
| 68 | Apr-24-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 28 | 24 | 4.4 | -25.0 | frz_fog |
| 69 | Apr-24-98 | CLARIANT 1957 | Neat | 4 | B | 36.5 | 32 | 28 | 3.6 | -25.0 | frz_fog |
| 70 | Apr-24-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 28 | 25 | 3.3 | -25.0 | frz_fog |
| 71 | Apr-24-98 | KILFROST ABC-S | Neat | 4 | B | 36.5 | 33 | 34 | 6.5 | -25.0 | frz_fog |
| 72 | Apr-24-98 | OCTAGON | Neat | 4 | A | 37.5 | 36 | 25 | 6.3 | -25.0 | frz_fog |
| 73 | Apr-24-98 | SPCA AD-404 | Neat | 4 | A | 41 | 34 | 46 | 5.8 | -25.1 | frz_fog |
| 74 | Apr-24-98 | ULTRA IV | Neat | 4 | A | 35 | 34 | 39 | 5.8 | -25.1 | frz_fog |
| 75 | Apr-24-98 | UCAR PG | Neat | 4 | A | 37.5 | 34 | 21 | 6.7 | -25.1 | frz_fog |
| 76 | Apr-24-98 | KILFROST ABC-S | Neat | 4 | B | 36.5 | 34 | 33 | 7.3 | -25.1 | frz_fog |
| 77 | Apr-24-98 | OCTAGON | Neat | 4 | A | 37.5 | 35 | 23 | 6.7 | -25.1 | frz_fog |
| 78 | Apr-24-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 30 | 23 | 6.4 | -25.0 | frz_fog |
| 79 | Apr-24-98 | CLARIANT 1957 | Neat | 4 | B | 36.5 | 31 | 30 | 6.2 | -25.1 | frz_fog |
| 80 | Apr-24-98 | CLARIANT 2001 | Neat | 4 | B | 36.5 | 31 | 24 | 6.5 | -25.1 | frz_fog |
| 81 | Apr-27-98 | UCAR PG | Neat | 4 | A | 40 | 6 | 205 | 4.6 | -2.6 | frz_fog |
| 82 | Apr-27-98 | SPCA AD-404 | Neat | 4 | A | 40 | 5 | 124 | 5.6 | -2.3 | frz_fog |
| 83 | Apr-27-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 3 | 133 | 4.8 | -2.3 | frz_fog |
| 84 | Apr-27-98 | CLARIANT 1957 | Neat | 4 | B | 37 | 3.5 | 100 | 4.4 | -2.4 | frz_fog |
| 85 | Apr-27-98 | CLARIANT 2001 | Neat | 4 | B | 37 | 1.5 | 106 | 5.8 | -2.4 | frz_fog |
| 86 | Apr-27-98 | CLARIANT 1957 | 75% | 4b | B | 28 | 3 | 109 | 4.6 | -2.4 | frz_fog |
| 87 | Apr-27-98 | SPCA AD-480 | 75% | 4b | B | 29 | 2 | 128 | 4.1 | -2.3 | frz_fog |
| 88 | Apr-27-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 4 | 71 | 4.2 | -2.5 | frz_fog |
| 89 | Apr-27-98 | ULTRA IV | Neat | 4 | A | 34 | 4.5 | 148 | 4.4 | -2.4 | frz_fog |
| 90 | Apr-27-98 | OCTAGON | Neat | 4 | A | 38 | 3 | 101 | 4.4 | -2.4 | frz_fog |
| 91 | Apr-27-98 | UCAR PG | 75% | 4b | A | 29 | 3 | 102 | 3.0 | -2.3 | frz_fog |
| 92 | Apr-27-98 | ULTRA IV | 75% | 4b | A | 26.5 | 3 | 118 | 2.5 | -2.3 | frz_fog |
| 93 | Apr-27-98 | SPCA AD-404 | 75% | 4b | B | 30.75 | 4 | 137 | 2.3 | -2.4 | frz_fog |
| 94 | Apr-27-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 2 | 97 | 3.1 | -2.3 | frz_fog |
| 95 | Apr-27-98 | OCTAGON | 50% | 4a | A | 22 | 4 | 115 | 2.3 | -2.3 | frz_fog |
| 96 | Apr-27-98 | KILFROST ABC-S | 50% | 4a | B | 20.25 | 8 | 29 | 2.3 | -2.6 | frz_fog |
| 97 | Apr-27-98 | ULTRA IV | 50% | 4a | A | 20 | 6 | 41 | 2.5 | -2.4 | frz_fog |
| 98 | Apr-27-98 | UCAR PG | Neat | 4 | A | 40 | 3 | 198 | 4.4 | -3.1 | frz_fog |
| 99 | Apr-27-98 | SPCA AD-404 | Neat | 4 | A | 40 | 4 | 168 | 3.6 | -3.1 | frz_fog |
| 100 | Apr-27-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 5 | 175 | 3.5 | -3.1 | frz_fog |

# SIMULATED FREEZING FOG AT CEF FOR 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 101 | Apr-27-98 | UCAR PG | 50% | 4a | A | 21 | 5 | 78 | 2.9 | -3.2 | frz_fog |
| 102 | Apr-27-98 | SPCA AD-404 | 50% | 4a | A | 20 | 6 | 55 | 6.1 | -3.3 | frz_fog |
| 103 | Apr-27-98 | CLARIANT 1957 | 50% | 4a | B | 19.25 | 6 | 41 | 4.1 | -3.3 | frz_fog |
| 104 | Apr-27-98 | CLARIANT 2001 | 50% | 4a | B | 19.25 | 5 | 29 | 4.0 | -3.4 | frz_fog |
| 105 | Apr-27-98 | SPCA AD-480 | 75% | 4b | A | 28.75 | 2 | 144 | 4.4 | -3.1 | frz_fog |
| 106 | Apr-27-98 | OCTAGON | 50% | 4a | A | 22 | N/A | 132 | 2.4 | -3.1 | frz_fog |
| 107 | Apr-27-98 | KILFROST ABC-S | 50% | 4a | B | 19 | 6 | 32 | 1.7 | -3.3 | frz_fog |
| 108 | Apr-27-98 | SPCA AD-480 | 50% | 4a | A | 19 | 6 | 72 | 2.5 | -3.2 | frz_fog |
| 109 | Apr-27-98 | SPCA AD-404 | 50% | 4a | A | 20 | 5 | 118 | 2.7 | -3.1 | frz_fog |
| 110 | Apr-27-98 | UCAR PG | 50% | 4a | A | 21 | 4 | 89 | 2.4 | -3.3 | frz_fog |
| 111 | Apr-27-98 | SPCA AD-480 | 50% | 4a | A | 19 | 5 | 68 | 2.1 | -3.2 | frz_fog |
| 112 | Apr-27-98 | KILFROST ABC-S | Neat | 4 | B | 38 | 5 | 147 | 3.0 | -3.1 | frz_fog |
| 113 | Apr-27-98 | OCTAGON | Neat | 4 | A | 38 | 3 | 164 | 2.6 | -3.0 | frz_fog |
| 114 | Apr-27-98 | ULTRA IV | 50% | 4a | A | 20 | 3.5 | 53 | 2.2 | -3.2 | frz_fog |
| 115 | Apr-27-98 | CLARIANT 1957 | 50% | 4a | B | 19.25 | 5 | 66 | 2.0 | -3.2 | frz_fog |
| 116 | Apr-27-98 | CLARIANT 2001 | 50% | 4a | B | 19.25 | 6 | 36 | 2.1 | -3.2 | frz_fog |
| 117 | Apr-27-98 | CLARIANT 2001 | Neat | 4 | B | 36 | 4 | 131 | 3.6 | -2.9 | frz_fog |
| 118 | Apr-27-98 | CLARIANT 1957 | 75% | 4b | B | 28 | 6 | 110 | 3.1 | -2.9 | frz_fog |
| 119 | Apr-27-98 | CLARIANT 1957 | Neat | 4 | B | 36 | 6 | 131 | 4.0 | -2.9 | frz_fog |
| 120 | Apr-27-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 5 | 105 | 2.2 | -2.8 | frz_fog |
| 121 | Apr-27-98 | CLARIANT 2001 | 75% | 4b | B | 28 | 6.5 | 114 | 2.0 | -3.6 | frz_fog |
| 122 | Apr-27-98 | ULTRA IV | 75% | 4b | A | 36.5 | 5 | 113 | 1.9 | -2.9 | frz_fog |
| 123 | Apr-28-98 | CLARIANT 1957 | Neat | 4 | B | 35 | 4 | 188 | 2.5 | -3.0 | frz_fog |
| 124 | Apr-28-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 6 | 158 | 2.5 | -3.1 | frz_fog |
| 125 | Apr-28-98 | UCAR PG | Neat | 4 | A | 37.5 | N/A | 241 | 2.0 | -3.0 | frz_fog |
| 126 | Apr-28-98 | ULTRA IV | Neat | 4 | A | 34 | N/A | 241 | 1.8 | -3.0 | frz_fog |
| 127 | Apr-28-98 | SPCA AD-404 | Neat | 4 | A | 40 | N/A | 241 | 1.8 | -3.0 | frz_fog |
| 128 | Apr-28-98 | ULTRA IV | Neat | 4 | A | 34 | N/A | 241 | 2.0 | -3.0 | frz_fog |
| 129 | Apr-28-98 | UCAR PG | Neat | 4 | A | 37.5 | N/A | 241 | 1.9 | -3.0 | frz_fog |
| 130 | Apr-28-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | N/A | 241 | 1.9 | -3.0 | frz_fog |
| 131 | Apr-28-98 | CLARIANT 2001 | Neat | 4 | B | 36 | N/A | 151 | 4.9 | -3.1 | frz_fog |
| 132 | Apr-28-98 | SPCA AD-480 | 75% | 4b | B | 26.5 | 3 | 156 | 2.7 | -3.1 | frz_fog |
| 133 | Apr-28-98 | SPCA AD-480 | 75% | 4b | B | 26.5 | 3.5 | 157 | 2.8 | -3.1 | frz_fog |
| 134 | Apr-28-98 | OCTAGON | 75% | 4b | A | 29 | 6 | 191 | 3.0 | -3.0 | frz_fog |
| 135 | Apr-28-98 | OCTAGON | Neat | 4 | A | 36 | 5 | 215 | 2.3 | -3.0 | frz_fog |
| 136 | Apr-28-98 | SPCA AD-480 | Neat | 4 | A | 36.5 | 5.5 | 152 | 5.2 | -3.1 | frz_fog |
| 137 | Apr-28-98 | SPCA AD-404 | Neat | 4 | A | 40 | 4 | 186 | 4.8 | -3.1 | frz_fog |
| 138 | Apr-28-98 | KILFROST ABC-S | Neat | 4 | B | 36.5 | 3 | 181 | 4.4 | -3.1 | frz_fog |
| 139 | Apr-28-98 | OCTAGON | Neat | 4 | A | 36 | 3 | 123 | 4.3 | -3.1 | frz_fog |
| 140 | Apr-28-98 | CLARIANT 1957 | Neat | 4 | B | 35 | 4 | 92 | 4.5 | -3.4 | frz_fog |
| 141 | Apr-28-98 | CLARIANT 2001 | Neat | 4 | B | 36 | 3.5 | 102 | 5.3 | -3.3 | frz_fog |
| 142 | Apr-28-98 | KILFROST ABC-S | Neat | 4 | B | 36.5 | 4.5 | 168 | 5.3 | -3.1 | frz_fog |
| 143 | Apr-28-98 | OCTAGON | 75% | 4b | A | 29 | 5 | 166 | 4.8 | -3.1 | frz_fog |
| 144 | Apr-28-98 | UCAR PG | 75% | 4b | A | 29 | 5 | 99 | 4.6 | -3.3 | frz_fog |
| 145 | Apr-28-98 | SPCA AD-404 | 75% | 4b | B | 30.5 | N/A | 100 | 4.3 | -3.3 | frz_fog |
| 146 | Apr-28-98 | ULTRA IV | 75% | 4b | A | 27 | 4 | 65 | 5.8 | -3.4 | frz_fog |
| 147 | Apr-28-98 | UCAR PG | 50% | 4a | A | 21 | 5 | 37 | 6.7 | -3.4 | frz_fog |
| 148 | Apr-28-98 | ULTRA IV | 50% | 4a | A | 18.5 | 4 | 25 | 6.2 | -3.5 | frz_fog |
| 149 | Apr-28-98 | SPCA AD-404 | 50% | 4a | A | 21 | 5 | 53 | 5.1 | -3.5 | frz_fog |
| 150 | Apr-28-98 | KILFROST ABC-S | 75% | 4b | B | 29 | N/A | 62 | 6.6 | -3.4 | frz_fog |

# SIMULATED FREEZING FOG AT CEF FOR 1997/98

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 151 | Apr-28-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 3 | 67 | 8.9 | -3.4 | frz_fog |
| 152 | Apr-28-98 | CLARIANT 2001 | 50% | 4a | B | 19 | 3 | 21 | 5.1 | -3.4 | frz_fog |
| 153 | Apr-28-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 4 | 65 | 5.6 | -3.4 | frz_fog |
| 154 | Apr-28-98 | KILFROST ABC-S | 50% | 4a | B | 19.5 | N/A | 24 | 3.5 | -3.3 | frz_fog |
| 155 | Apr-28-98 | UCAR PG | 50% | 4a | A | 21 | 3 | 41 | 6.8 | -2.9 | frz_fog |
| 156 | Apr-28-98 | CLARIANT 2001 | 75% | 4b | B | 28 | 4 | 57 | 7.3 | -2.9 | frz_fog |
| 157 | Apr-28-98 | OCTAGON | 50% | 4a | A | 20.5 | 4 | 66 | 6.8 | -3.0 | frz_fog |
| 158 | Apr-28-98 | SPCA AD-404 | 75% | 4b | B | 30.5 | 3 | 94 | 5.0 | -2.9 | frz_fog |
| 159 | Apr-28-98 | OCTAGON | 50% | 4a | A | 20.5 | 5 | 102 | 3.9 | -2.9 | frz_fog |
| 160 | Apr-28-98 | ULTRA IV | 50% | 4a | A | 18.5 | 4 | 20 | 6.8 | -4.0 | frz_fog |
| 161 | Apr-28-98 | OCTAGON | 75% | 4b | A | 29 | 6 | 106 | 6.6 | -3.0 | frz_fog |
| 162 | Apr-28-98 | UCAR PG | 75% | 4b | A | 29 | 2 | 70 | 5.4 | -2.9 | frz_fog |
| 163 | Apr-28-98 | SPCA AD-404 | 50% | 4a | A | 21 | 5 | 74 | 3.8 | -4.0 | frz_fog |
| 164 | Apr-28-98 | ULTRA IV | 75% | 4b | A | 27 | 4 | 90 | 3.8 | -2.9 | frz_fog |
| 165 | Apr-28-98 | KILFROST ABC-S | 50% | 4a | B | 19.5 | 5 | 19 | 5.7 | -4.0 | frz_fog |
| 166 | Apr-28-98 | SPCA AD-480 | 50% | 4a | A | 19 | 4 | 36 | 6.2 | -4.0 | frz_fog |
| 167 | Apr-28-98 | CLARIANT 2001 | 50% | 4a | B | 19 | 4 | 23 | 5.2 | -4.0 | frz_fog |
| 168 | Apr-28-98 | CLARIANT 1957 | 50% | 4a | B | 19 | 6 | 32 | 4.1 | -4.0 | frz_fog |
| 169 | Apr-28-98 | KILFROST ABC-S | 75% | 4b | B | 29 | 4 | 71 | 5.1 | -2.9 | frz_fog |
| 170 | Apr-28-98 | CLARIANT 1957 | 50% | 4a | B | 19 | 6 | 29 | 5.5 | -4.0 | frz_fog |
| 171 | Apr-28-98 | SPCA AD-480 | 50% | 4a | A | 19 | 5 | 33 | 5.8 | -4.0 | frz_fog |

## COLD SOAK DATA AT CEF FOR 1997/98 TEST SEASON

## 7.5 cm BOX

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip (g/dm²/hr) | Average Skin Temp [°C] | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Apr-08-98 | ULTRA IV | Neat | 4 | A | 34 | 2 | 38 | 74.9 | -7.8 | 0.9 | mod_rain |
| 2 | Apr-08-98 | OCTAGON MAXFLIGHT | Neat | 4 | A | 36.5 | 7 | 16 | 74.7 | -7.4 | 0.9 | mod_rain |
| 3 | Apr-08-98 | CLARIANT 1957 | Neat | 4 | B | 35.5 | 8 | 16 | 73.5 | -6.3 | 0.9 | mod_rain |
| 4 | Apr-08-98 | CLARIANT 2001 | Neat | 4 | B | 35.5 | 4 | 15 | 71.7 | -7.8 | 0.8 | mod_rain |
| 5 | Apr-08-98 | UCAR PG | Neat | 4 | A | 37.5 | 2 | 52 | 79.2 | -5.9 | 0.9 | mod_rain |
| 6 | Apr-08-98 | KILFROST ABC-S | Neat | 4 | B | 36 | 2 | 20 | 79.5 | -7.9 | 0.8 | mod_rain |
| 7 | Apr-08-98 | SPCA AD-404 | Neat | 4 | A | 39.5 | 3 | 19 | 74.7 | -7.3 | 0.9 | mod_rain |
| 8 | Apr-08-98 | SPCA AD-480 | Neat | 4 | A | 35.5 | 9 | 17 | 70.3 | -6.6 | 0.8 | mod_rain |
| 9 | Apr-08-98 | UCAR PG | Neat | 4 | A | 37.5 | 5 | 24 | 74.9 | -6.2 | 0.8 | mod_rain |
| 10 | Apr-08-98 | KILFROST ABC-S | Neat | 4 | B | 35.75 | 4.5 | 21 | 74.9 | -7.1 | 0.8 | mod_rain |
| 11 | Apr-08-98 | ULTRA IV | Neat | 4 | A | 34 | 3.75 | 38 | 74.7 | -6.2 | 0.8 | mod_rain |
| 12 | Apr-08-98 | SPCA AD-404 | Neat | 4 | A | 39.5 | 7 | 18 | 73.5 | -7.9 | 0.8 | mod_rain |
| 13 | Apr-08-98 | SPCA AD-480 | Neat | 4 | A | 35.5 | 7 | 15 | 71.7 | -7.6 | 0.9 | mod_rain |
| 14 | Apr-08-98 | CLARIANT 1957 | Neat | 4 | B | 35.5 | 8 | 15 | 79.2 | -5.6 | 0.8 | mod_rain |
| 15 | Apr-08-98 | CLARIANT 2001 | Neat | 4 | B | 35.5 | 8 | 14 | 79.5 | -6.0 | 0.8 | mod_rain |
| 16 | Apr-08-98 | ULTRA IV | 75% | 4b | A | 25 | 7 | 15 | 70.3 | -6.8 | 0.8 | mod_rain |
| 17 | Apr-08-98 | OCTAGON MAXFLIGHT | Neat | 4 | A | 36.5 | 7 | 15 | 79.2 | -7.8 | 0.8 | mod_rain |
| 18 | Apr-08-98 | UCAR PG | Neat | 4 | A | 37.5 | N/A | 22 | 79.5 | -6.0 | 0.8 | mod_rain |
| 19 | Apr-08-98 | OCTAGON MAXFLIGHT | 75% | 4b | A | 28.5 | 10 | 13 | 74.7 | -7.2 | 0.8 | mod_rain |
| 20 | Apr-08-98 | SPCA AD-480 | 75% | 4b | A | 28 | 8 | 11 | 73.5 | -7.1 | 0.8 | mod_rain |
| 21 | Apr-08-98 | SPCA AD-404 | 75% | 4b | A | 30 | 9 | 9 | 71.7 | -8.0 | 0.8 | mod_rain |
| 22 | Apr-08-98 | KILFROST ABC-S | 75% | 4b | B | 28.5 | 7.5 | 12 | 77.1 | -7.8 | 0.8 | mod_rain |
| 23 | Apr-08-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 8 | 9 | 74.4 | -8.2 | 0.8 | mod_rain |
| 24 | Apr-08-98 | SPCA AD-404 | 75% | 4b | A | 30 | 8.25 | 9 | 74.3 | -8.6 | 0.8 | mod_rain |
| 25 | Apr-08-98 | ULTRA IV | 75% | 4b | A | 25 | 7.25 | 13 | 72.8 | -7.7 | 0.8 | mod_rain |
| 26 | Apr-08-98 | CLARIANT 1957 | 75% | 4b | B | 27.5 | 8.5 | 10 | 71.4 | -7.2 | 0.8 | mod_rain |
| 27 | Apr-08-98 | OCTAGON MAXFLIGHT | 75% | 4b | A | 28.5 | 7 | 10 | 77.6 | -7.4 | 0.8 | mod_rain |
| 28 | Apr-08-98 | UCAR PG | 75% | 4b | A | 28.5 | 7 | 5 | 80.4 | -8.4 | 0.8 | mod_rain |
| 29 | Apr-08-98 | KILFROST ABC-S | 75% | 4b | B | 28.5 | 8.5 | 12 | 77.1 | -7.8 | 0.9 | mod_rain |
| 30 | Apr-08-98 | UCAR PG | 75% | 4b | A | 28.5 | 10 | 5 | 74.4 | -7.1 | 0.8 | mod_rain |
| 31 | Apr-08-98 | SPCA AD-480 | 75% | 4b | A | 28 | 9 | 12 | 74.3 | -7.5 | 0.8 | mod_rain |
| 32 | Apr-08-98 | CLARIANT 1957 | 75% | 4b | B | 27.5 | 9.5 | 10 | 72.8 | -7.6 | 0.7 | mod_rain |
| 33 | Apr-08-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 8.5 | 8 | 77.8 | -7.2 | 0.8 | mod_rain |
| 34 | Apr-09-98 | UCAR PG | Neat | 4 | A | 36.5 | 9 | 179 | 5.8 | -5.7 | 0.9 | drizzle |
| 35 | Apr-09-98 | ULTRA IV | Neat | 4 | A | 34 | 11 | 187 | 5.7 | -6.7 | 0.9 | drizzle |
| 36 | Apr-09-98 | SPCA AD-404 | Neat | 4 | A | 39 | 17 | 181 | 5.6 | -7.4 | 0.9 | drizzle |
| 37 | Apr-09-98 | SPCA AD-480 | Neat | 4 | A | 35.5 | 18 | 57 | 5.6 | -9.8 | 0.9 | drizzle |
| 38 | Apr-09-98 | KILFROST ABC-S | Neat | 4 | B | 36.25 | 19 | 67 | 5.7 | -9.6 | 1.0 | drizzle |
| 39 | Apr-09-98 | OCTAGON MAXFLIGHT | Neat | 4 | A | 36.5 | 14 | 71 | 5.5 | -9.2 | 0.9 | drizzle |
| 40 | Apr-09-98 | CLARIANT 2001 | Neat | 4 | B | 35.5 | 13 | 101 | 5.8 | -8.0 | 0.8 | drizzle |
| 41 | Apr-09-98 | ULTRA IV | Neat | 4 | A | 34 | 10.25 | 157 | 5.6 | -7.2 | 0.8 | drizzle |
| 42 | Apr-09-98 | CLARIANT 1957 | Neat | 4 | B | 35.5 | 9 | 72 | 5.7 | -8.4 | 0.9 | drizzle |
| 43 | Apr-09-98 | SPCA AD-404 | Neat | 4 | A | 39 | 9.5 | 150 | 5.5 | -8.0 | 0.8 | drizzle |
| 44 | Apr-09-98 | CLARIANT 2001 | Neat | 4 | B | 35.5 | 14 | 98 | 6.3 | -7.8 | 0.9 | drizzle |
| 45 | Apr-09-98 | UCAR PG | Neat | 4 | A | 36.5 | 29 | 60 | 6.8 | -7.3 | 0.8 | drizzle |
| 46 | Apr-09-98 | CLARIANT 1957 | Neat | 4 | B | 35.5 | 9.5 | 81 | 5.7 | -6.5 | 0.8 | drizzle |
| 47 | Apr-09-98 | SPCA AD-480 | Neat | 4 | A | 35.5 | N/A | 50 | 5.6 | -7.6 | 0.8 | drizzle |
| 48 | Apr-09-98 | OCTAGON MAXFLIGHT | Neat | 4 | A | 36.5 | 13 | 70 | 5.7 | -7.3 | 0.8 | drizzle |
| 49 | Apr-09-98 | KILFROST ABC-S | Neat | 4 | B | 36 | 15 | 74 | 6.3 | -8.0 | 0.8 | drizzle |



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## COLD SOAK DATA AT CEF FOR 1997/98 TEST SEASON

## 7.5 cm BOX

| Test No. | Date | Fluid Dilution | Fluid Name | Fluid Type | Batch # | Initial Brix | Final Brix | Fail Time [min.] | Rate of Precip ($g/dm^2/hr$) | Average Skin Temp [°C] | Ambient Temp. [°C] | Precipitation Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | Apr-09-98 | UCAR PG | Neat | 4 | A | 36.5 | 24 | 80 | 6.8 | -7.8 | 0.8 | drizzle |
| 51 | Apr-09-98 | SPCA AD-480 | 75% | 4b | A | 27.75 | 15 | 35 | 5.7 | -9.5 | 0.8 | drizzle |
| 52 | Apr-09-98 | KILFROST ABC-S | 75% | 4b | B | 28.5 | 14.5 | 47 | 5.6 | -7.0 | 0.9 | drizzle |
| 53 | Apr-09-98 | KILFROST ABC-S | 75% | 4b | B | 28.5 | 16 | 45 | 5.7 | -7.4 | 0.8 | drizzle |
| 54 | Apr-21-98 | SPCA AD-404 | 75% | 4b | A | 31 | 14 | 56 | 4.9 | -9.2 | 0.7 | drizzle |
| 55 | Apr-21-98 | UCAR PG | 75% | 4b | A | 29 | 21 | 43 | 4.7 | -9.3 | 0.7 | drizzle |
| 56 | Apr-21-98 | UCAR PG | Neat | 4 | A | 38 | 9 | 187 | 4.5 | -6.4 | -0.2 | drizzle |
| 57 | Apr-21-98 | ULTRA IV | 75% | 4b | A | 26 | 12 | 89 | 4.2 | -8.5 | -1.3 | drizzle |
| 58 | Apr-21-98 | OCTAGON MAXFLIGHT | 75% | 4b | A | 29.5 | 23 | 45 | 4.6 | -9.2 | 0.7 | drizzle |
| 59 | Apr-21-98 | SPCA AD-480 | 75% | 4b | B | 28.5 | 20 | 39 | 5.2 | -8.8 | 0.7 | drizzle |
| 60 | Apr-21-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 17 | 53 | 4.9 | -8.9 | 0.8 | drizzle |
| 61 | Apr-21-98 | ULTRA IV | 75% | 4b | A | 26 | 12 | 70 | 4.7 | -8.2 | 0.8 | drizzle |
| 62 | Apr-21-98 | CLARIANT 1957 | 75% | 4b | B | 29 | 14 | 66 | 4.6 | -8.7 | 0.8 | drizzle |
| 63 | Apr-21-98 | ULTRA IV | Neat | 4 | A | 38 | 6 | 223 | 5.2 | -6.5 | -0.1 | drizzle |
| 64 | Apr-21-98 | SPCA AD-404 | Neat | 4 | A | 40 | 9 | 170 | 5.7 | -6.4 | -0.3 | drizzle |
| 65 | Apr-21-98 | CLARIANT 2001 | 75% | 4b | A | 28.5 | 19 | 54 | 4.7 | -8.5 | 0.5 | drizzle |
| 66 | Apr-21-98 | CLARIANT 2001 | 75% | 4b | A | 28.5 | 18 | 42 | 4.9 | -8.3 | 0.8 | drizzle |
| 67 | Apr-21-98 | SPCA AD-404 | 75% | 4b | B | 31 | 15 | 58 | 4.7 | -8.4 | 0.6 | drizzle |
| 68 | Apr-21-98 | UCAR PG | 75% | 4b | A | 26 | 22 | 44 | 4.5 | -8.6 | 0.6 | drizzle |
| 69 | Apr-21-98 | ULTRA IV | 75% | 4b | A | 26 | 12 | 76 | 5.5 | -8.2 | 0.8 | drizzle |
| 70 | Apr-21-98 | CLARIANT 1957 | 75% | 4b | A | 29 | 18 | 59 | 4.9 | -8.2 | 0.6 | drizzle |
| 71 | Apr-21-98 | CLARIANT 1957 | 75% | 4b | B | 28.5 | 16 | 64 | 4.5 | -7.9 | 0.5 | drizzle |
| 72 | Apr-21-98 | CLARIANT 2001 | 75% | 4b | B | 28.5 | 18 | 53 | 5.2 | -8.3 | 0.5 | drizzle |
| 73 | Apr-21-98 | OCTAGON MAXFLIGHT | 75% | 4b | A | 29.5 | 23 | 35 | 6.2 | -8.2 | 0.5 | drizzle |



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# APPENDIX E

# EVALUATION OF TYPE IV TEST DATA USING REGRESSION METHOD

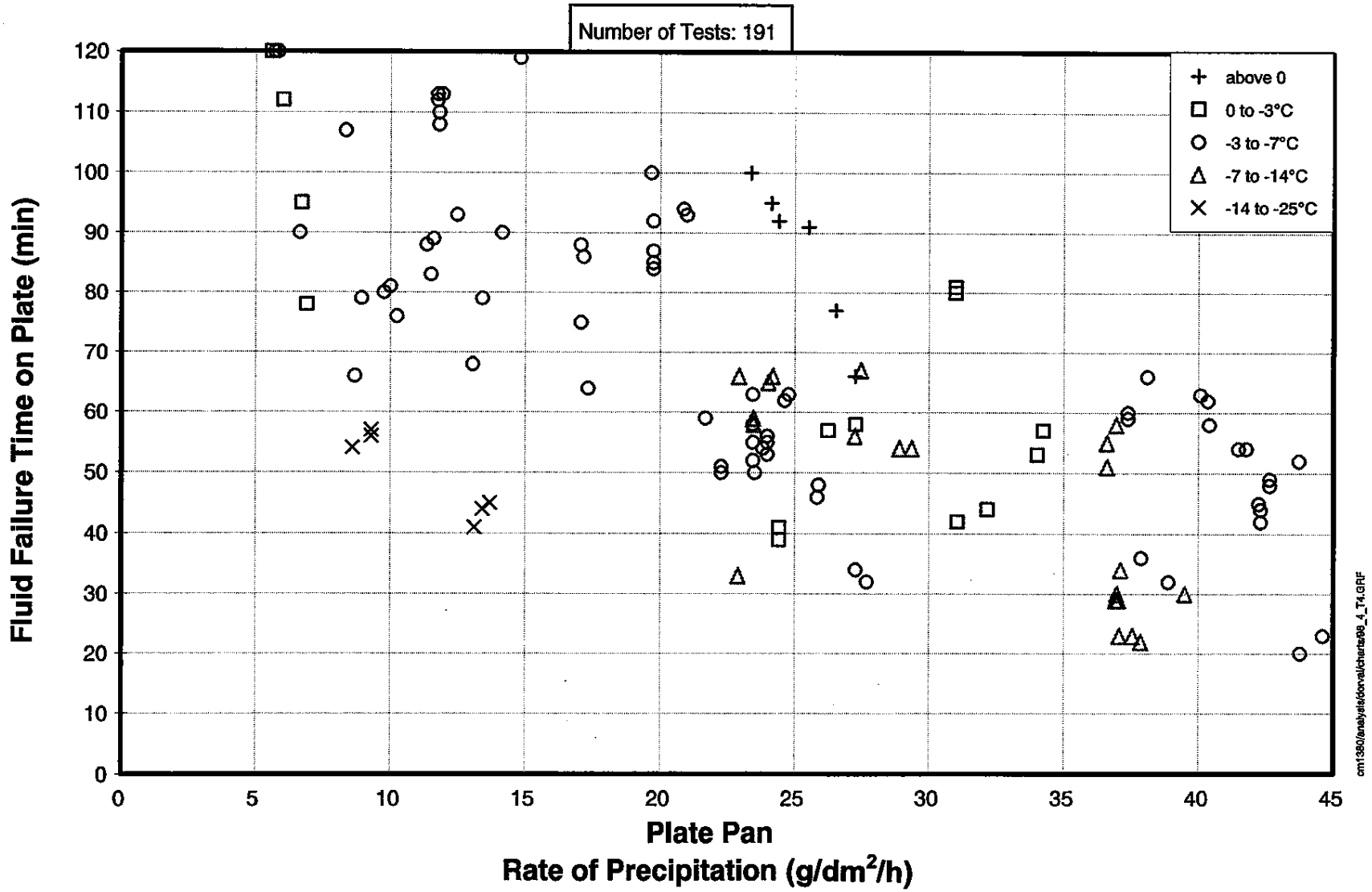
# FOR WINTER 1997-98

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT

NATURAL SNOW CONDITIONS

1997/98

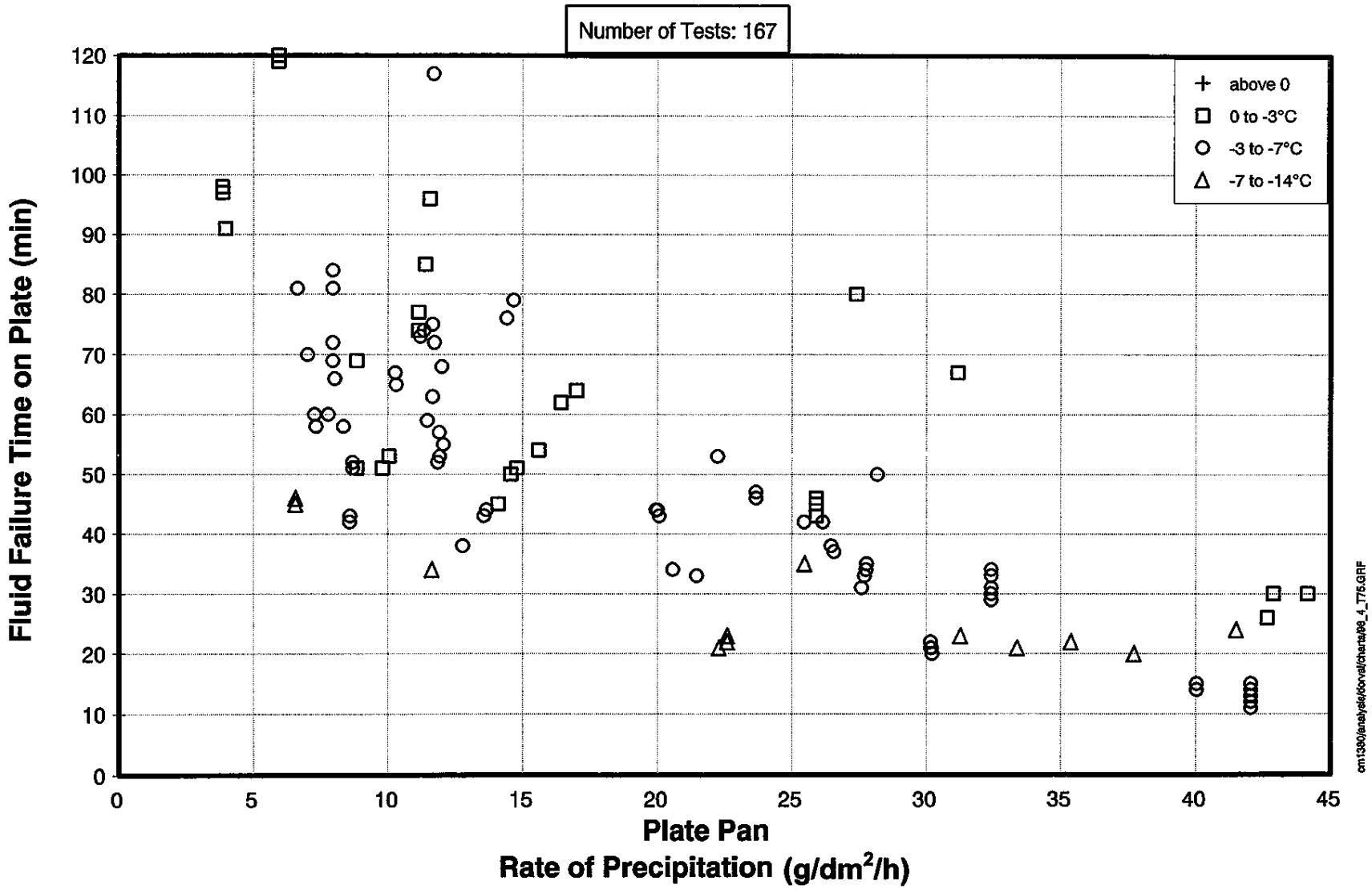


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25

NATURAL SNOW CONDITIONS

1997/98

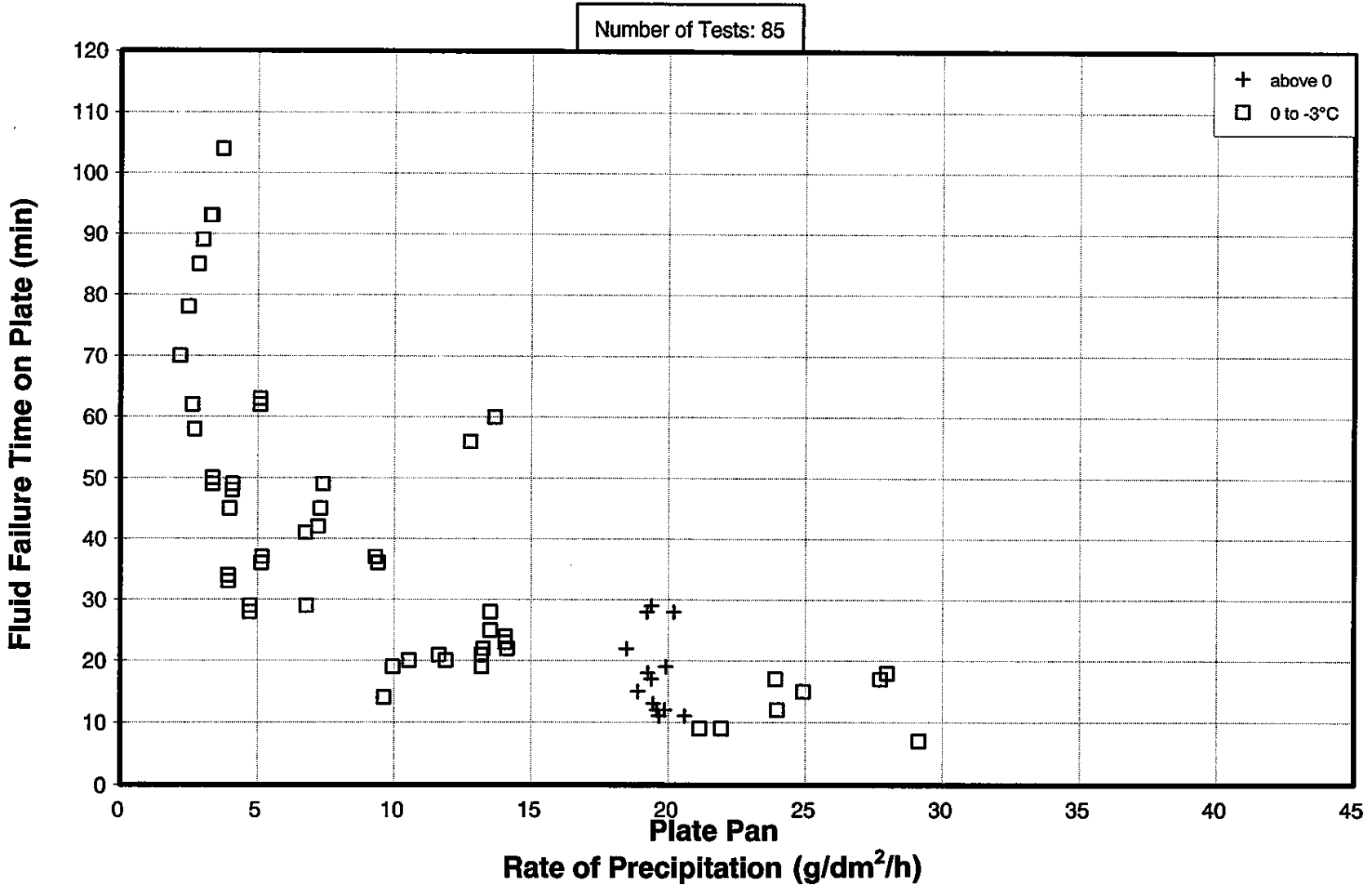


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997/98

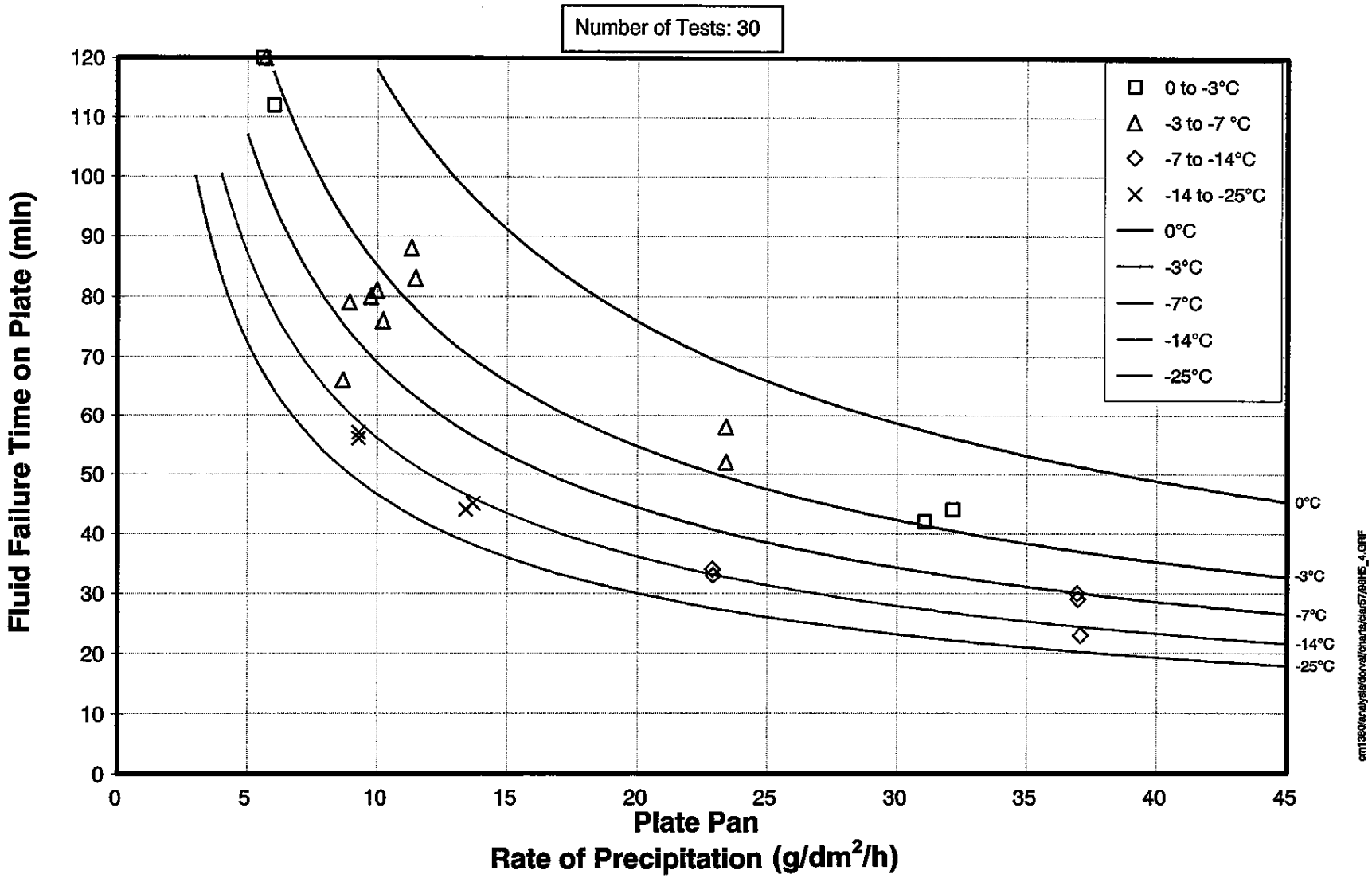


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 1957 TYPE IV NEAT

NATURAL SNOW CONDITIONS

1997/98

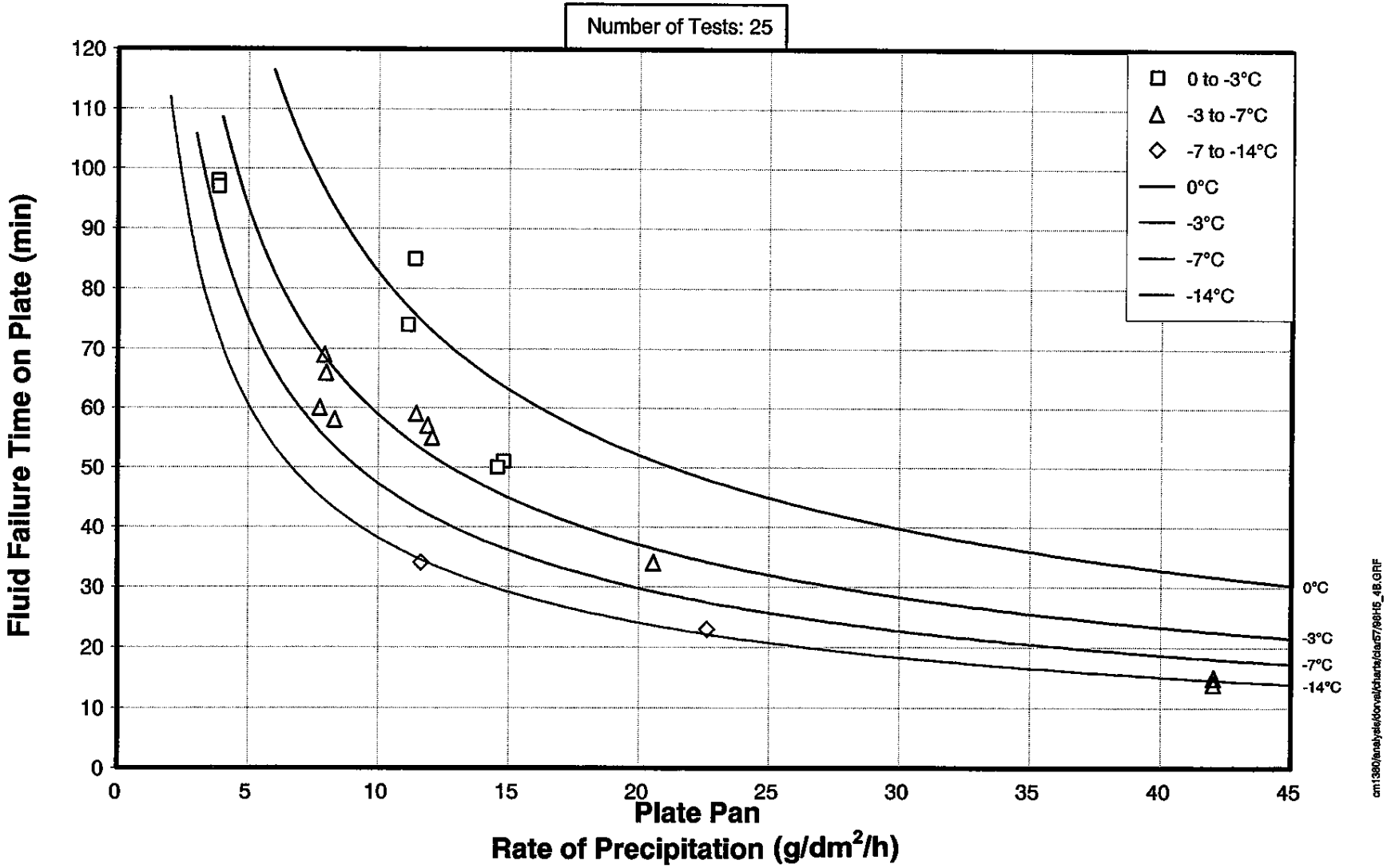


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 1957 TYPE IV 75/25

NATURAL SNOW CONDITIONS

1997/98

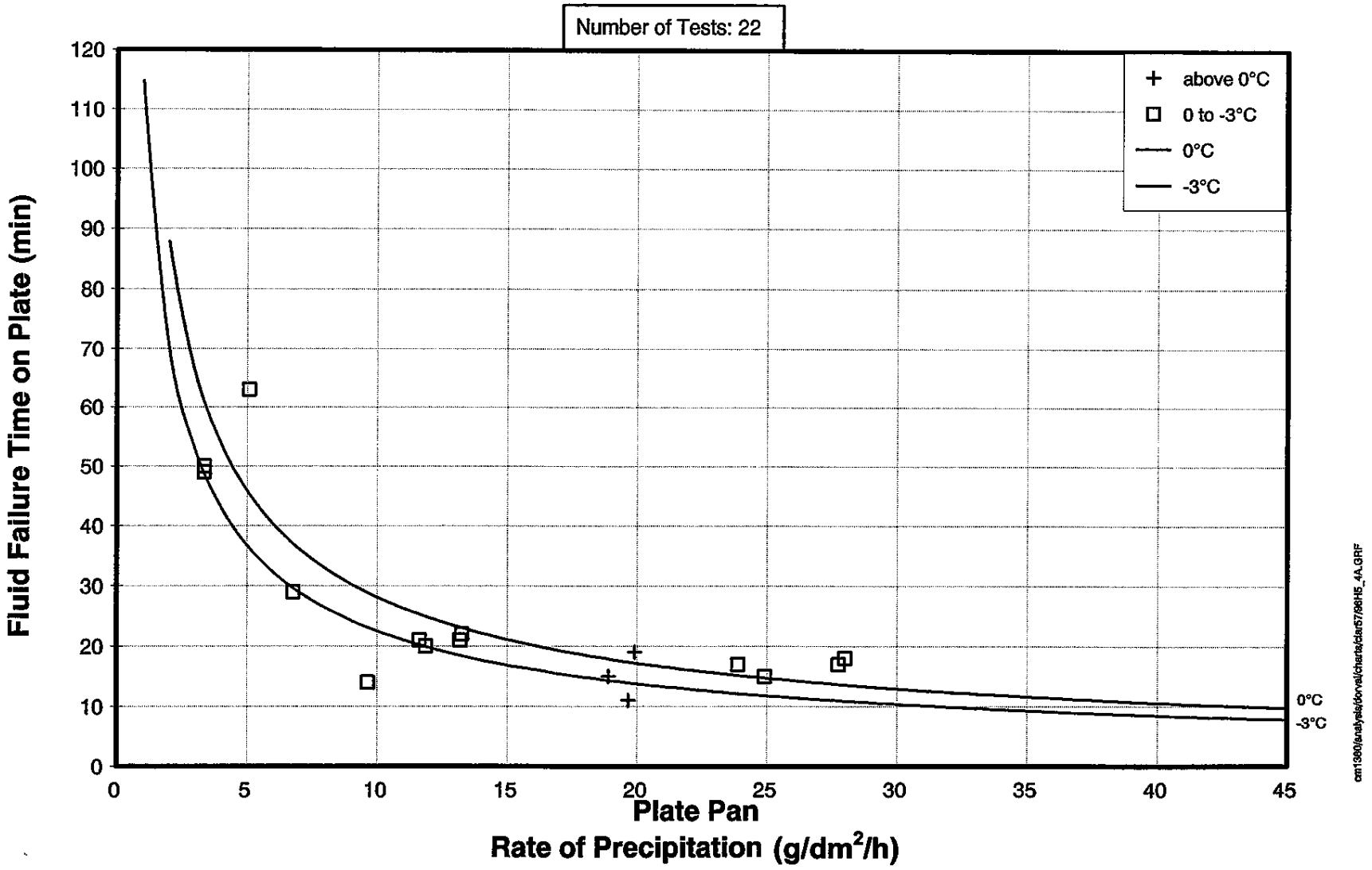


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 1957 TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997/98

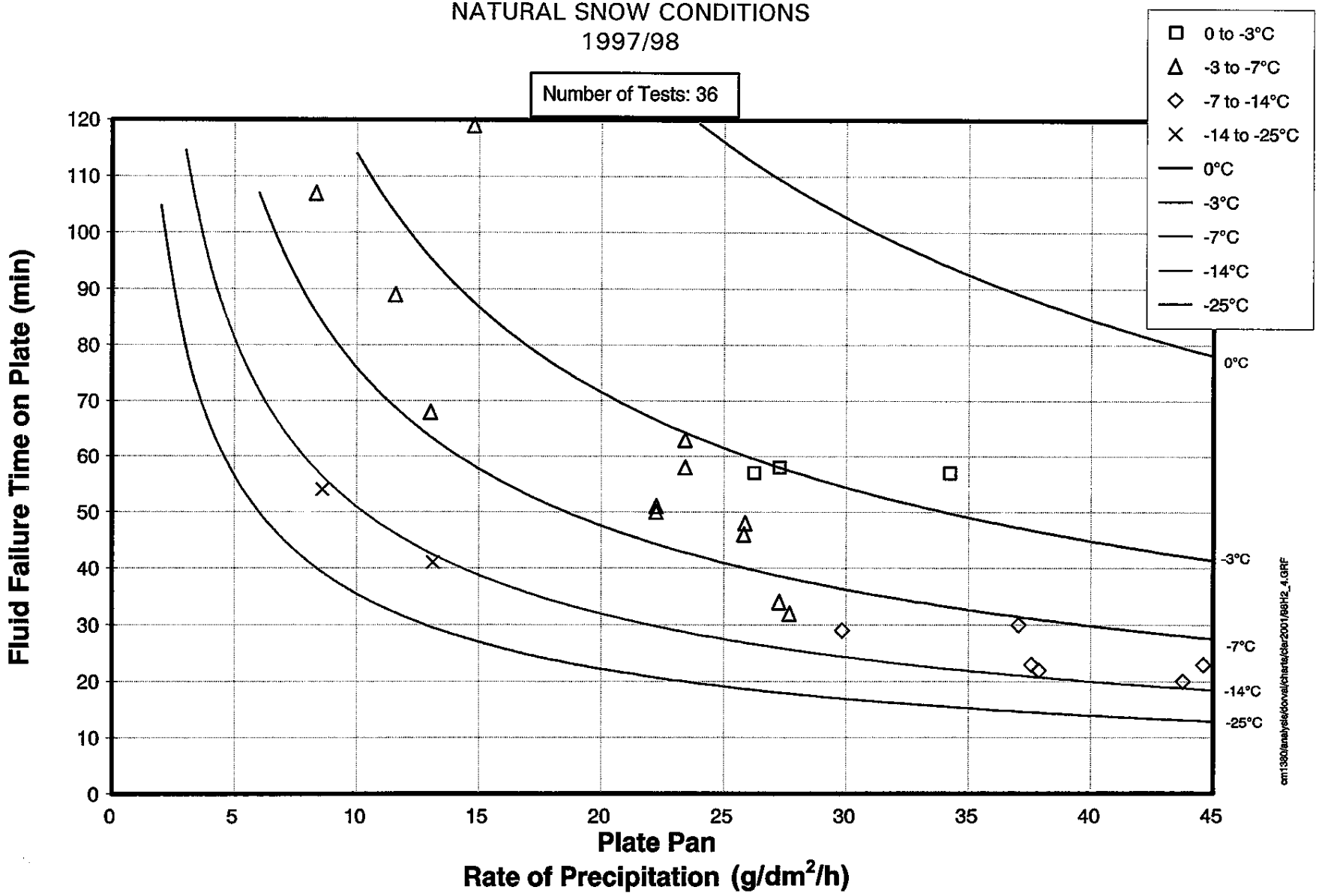


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 2001 TYPE IV NEAT

NATURAL SNOW CONDITIONS

1997/98

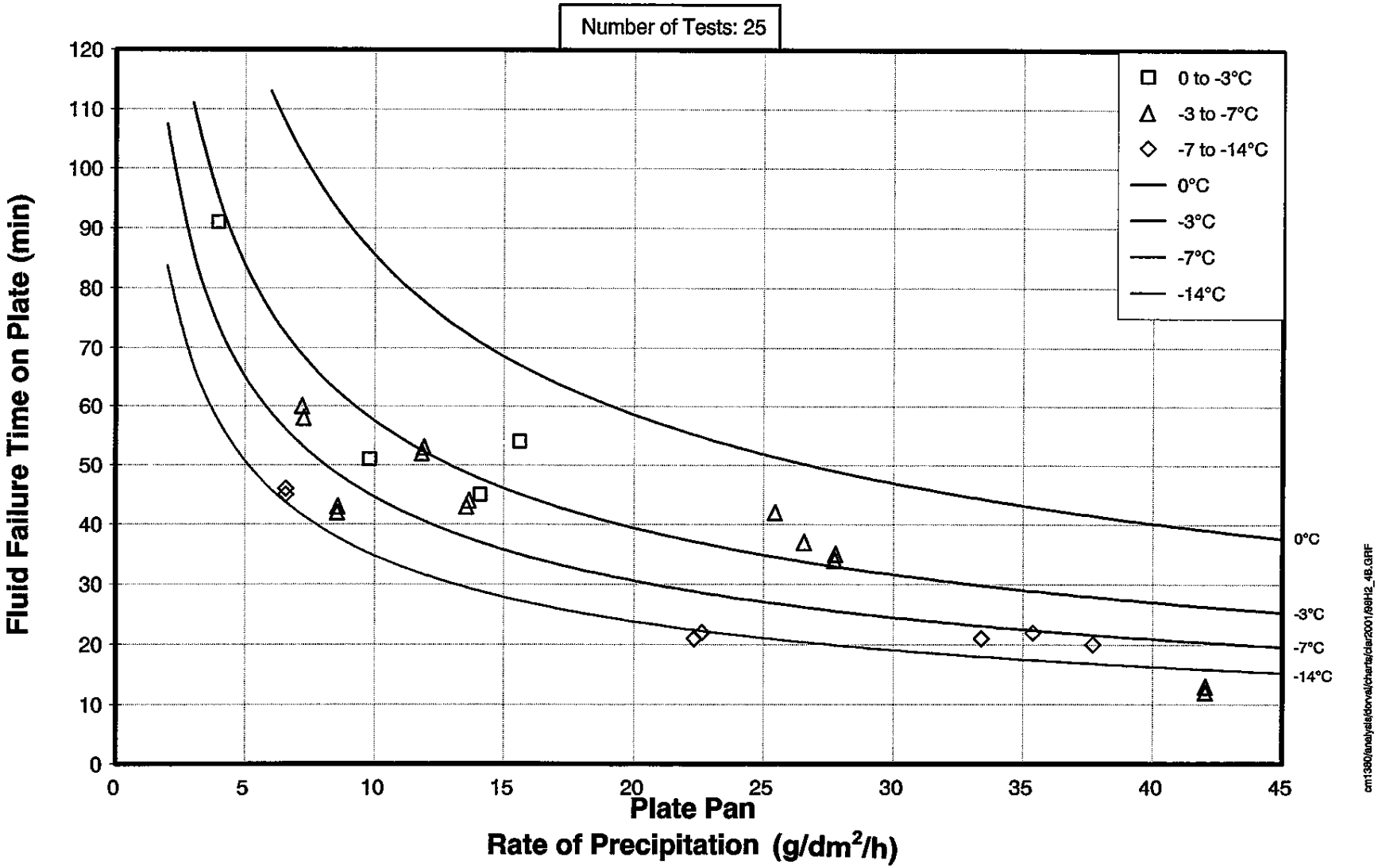


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 2001 TYPE IV 75/25

NATURAL SNOW CONDITIONS

1997/98

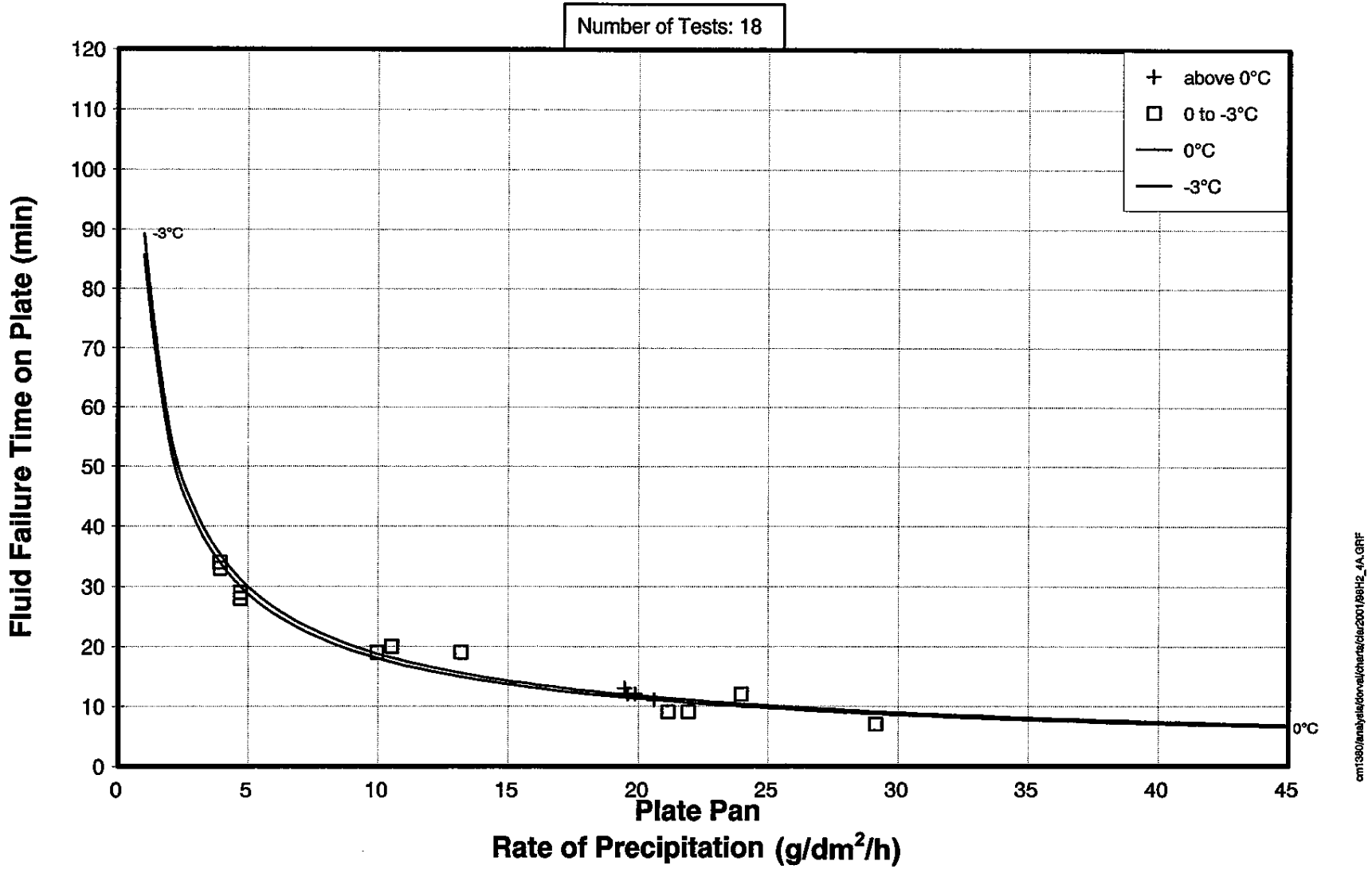


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 2001 TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997/98



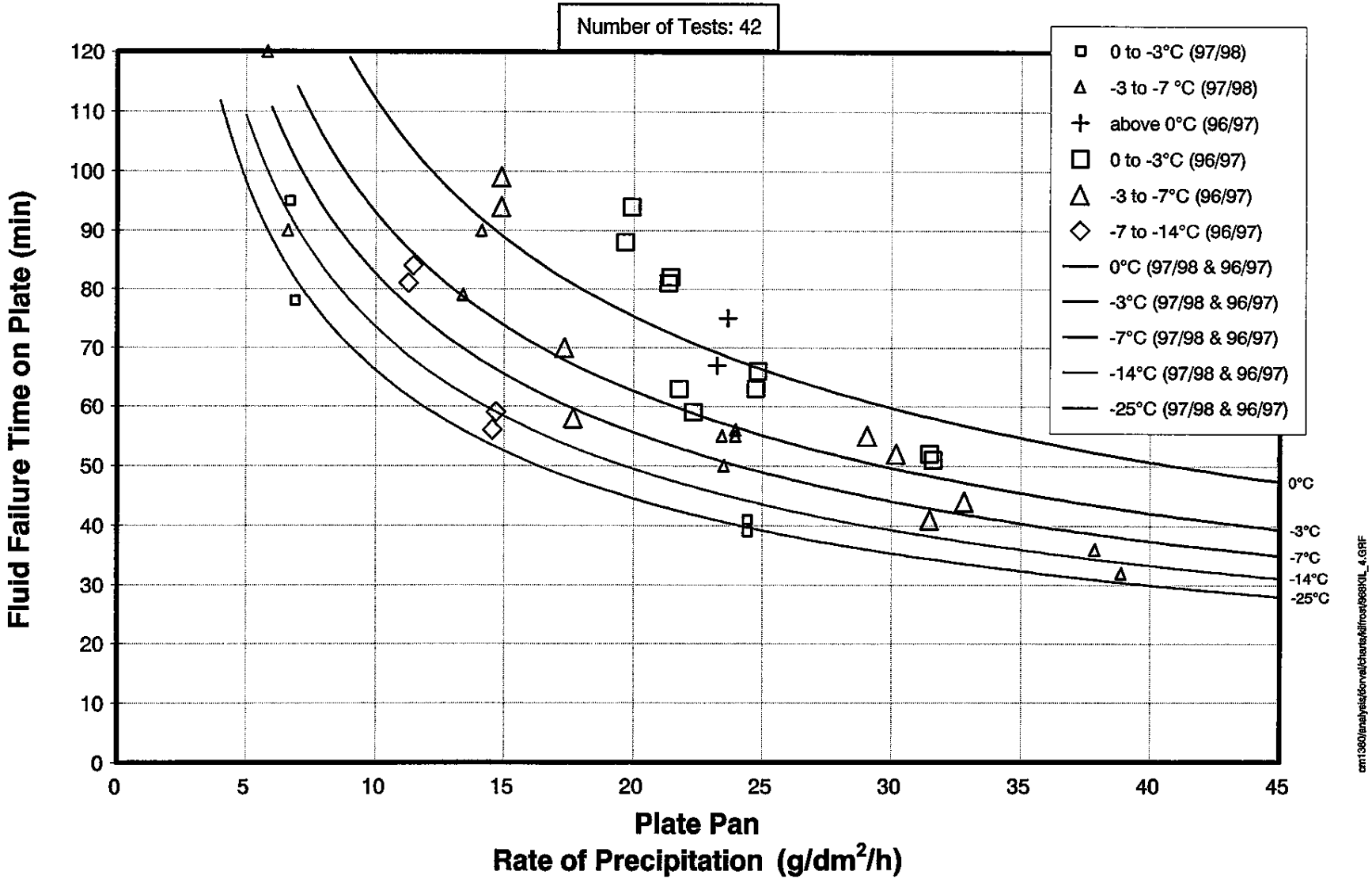

cm1380/analyst/dorval/charts/clar2001/98H2_4A.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV NEAT

### NATURAL SNOW CONDITIONS

### 1996/97 & 1997/98



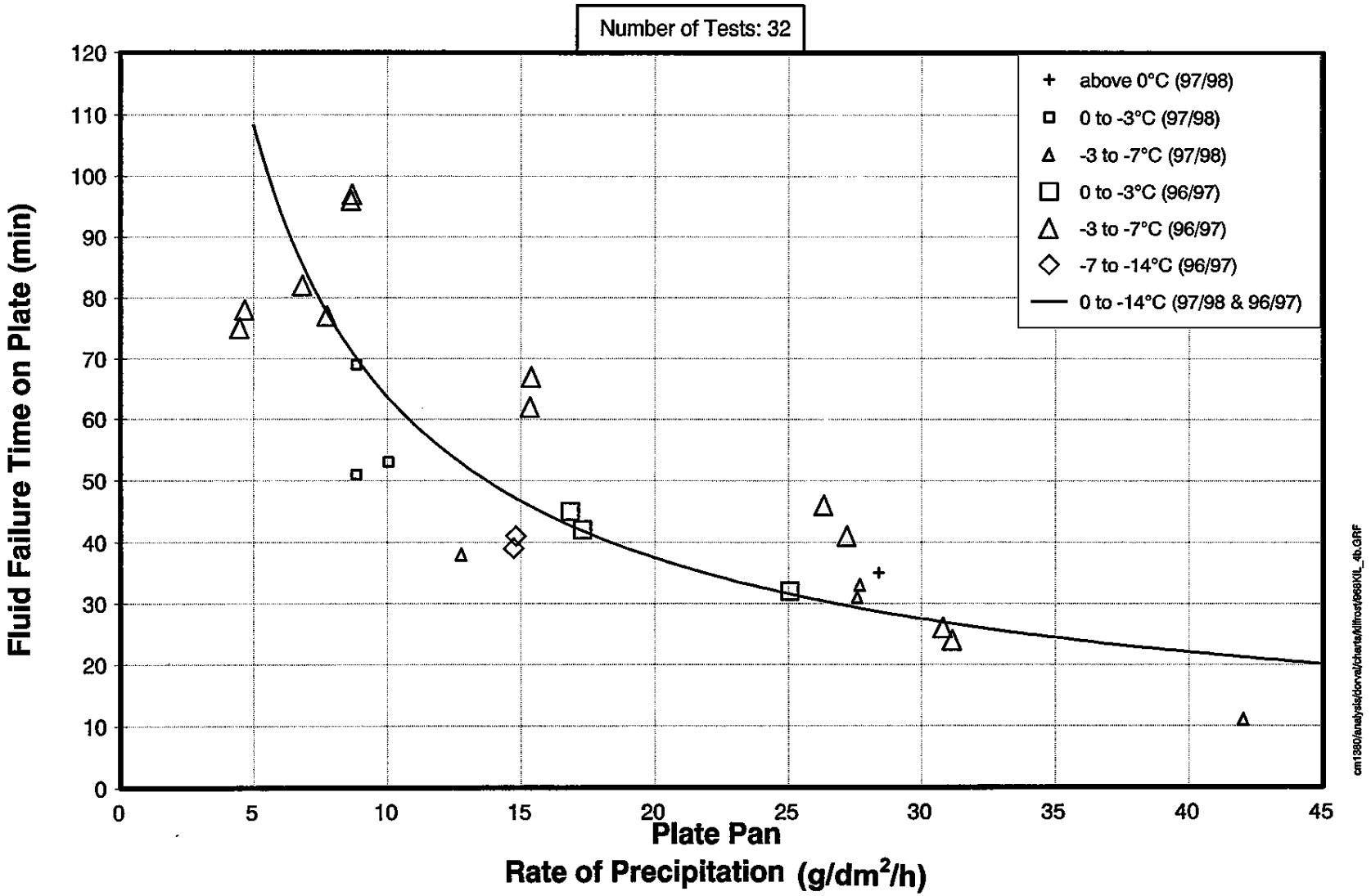

cm1360/analysis/konval/charts/kilfrost96KIL_4.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV 75/25

NATURAL SNOW CONDITIONS

1996/97 & 1997/98

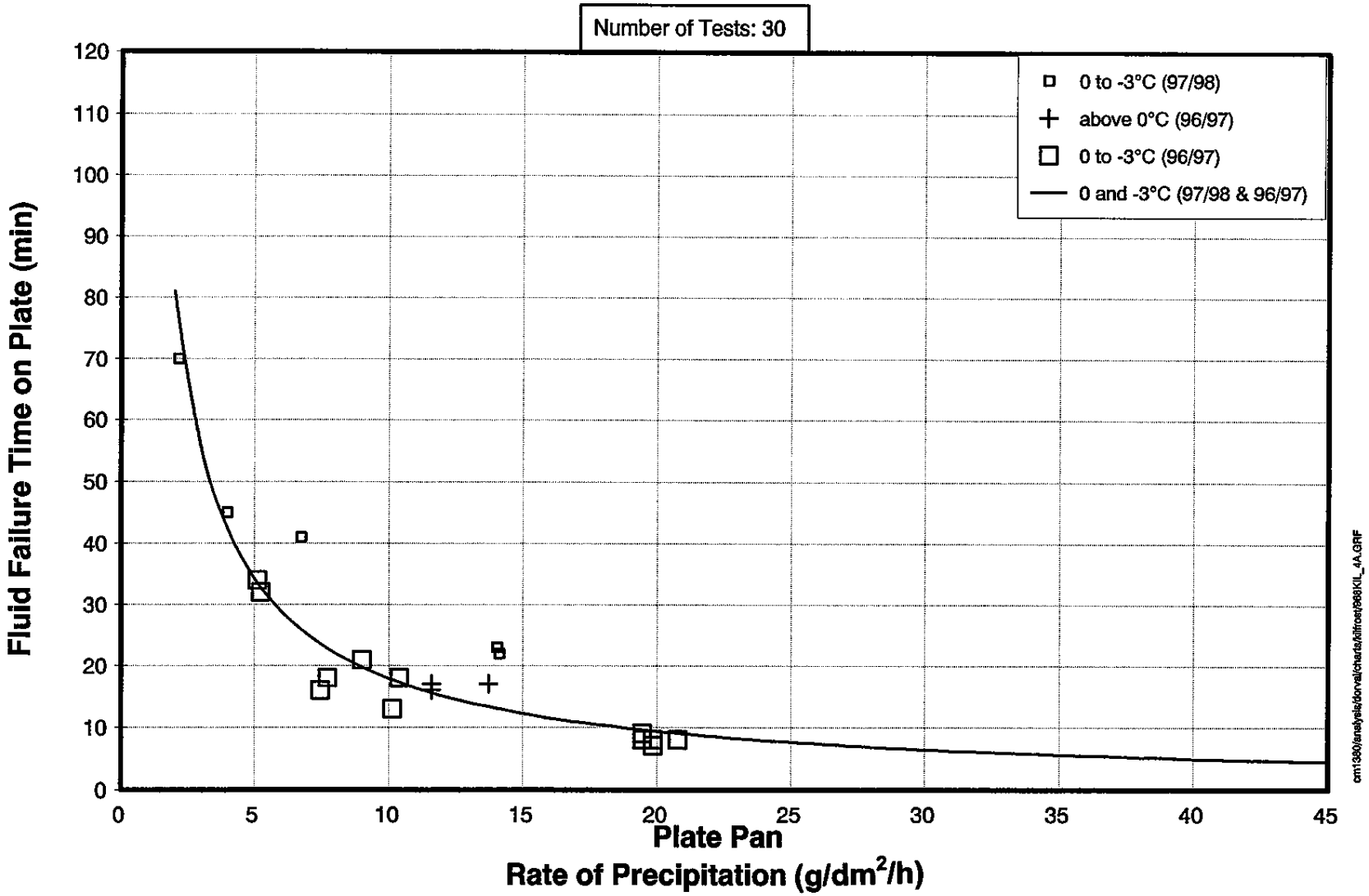


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/97 & 1997/98

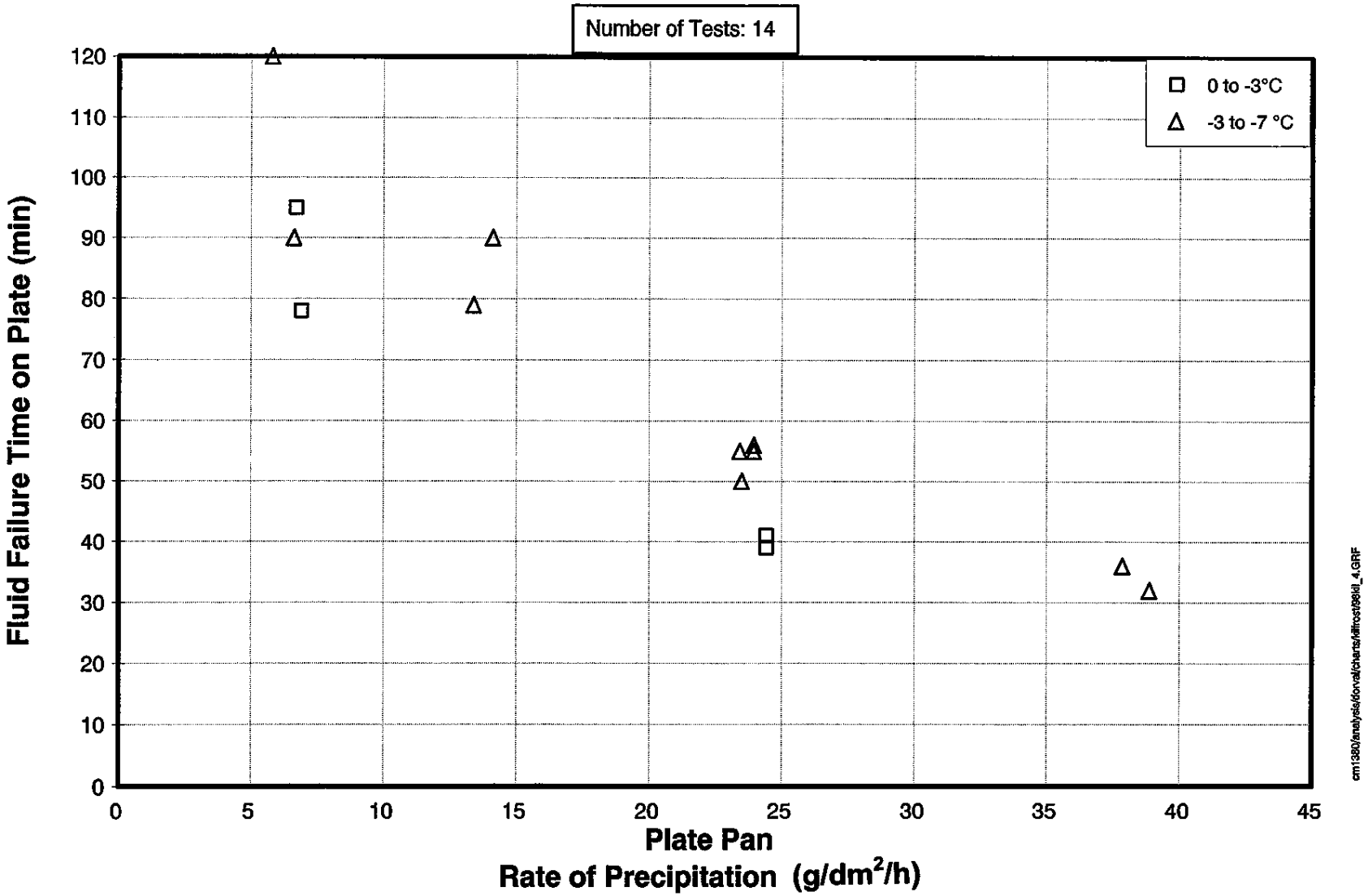


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV NEAT

NATURAL SNOW CONDITIONS

1997/98

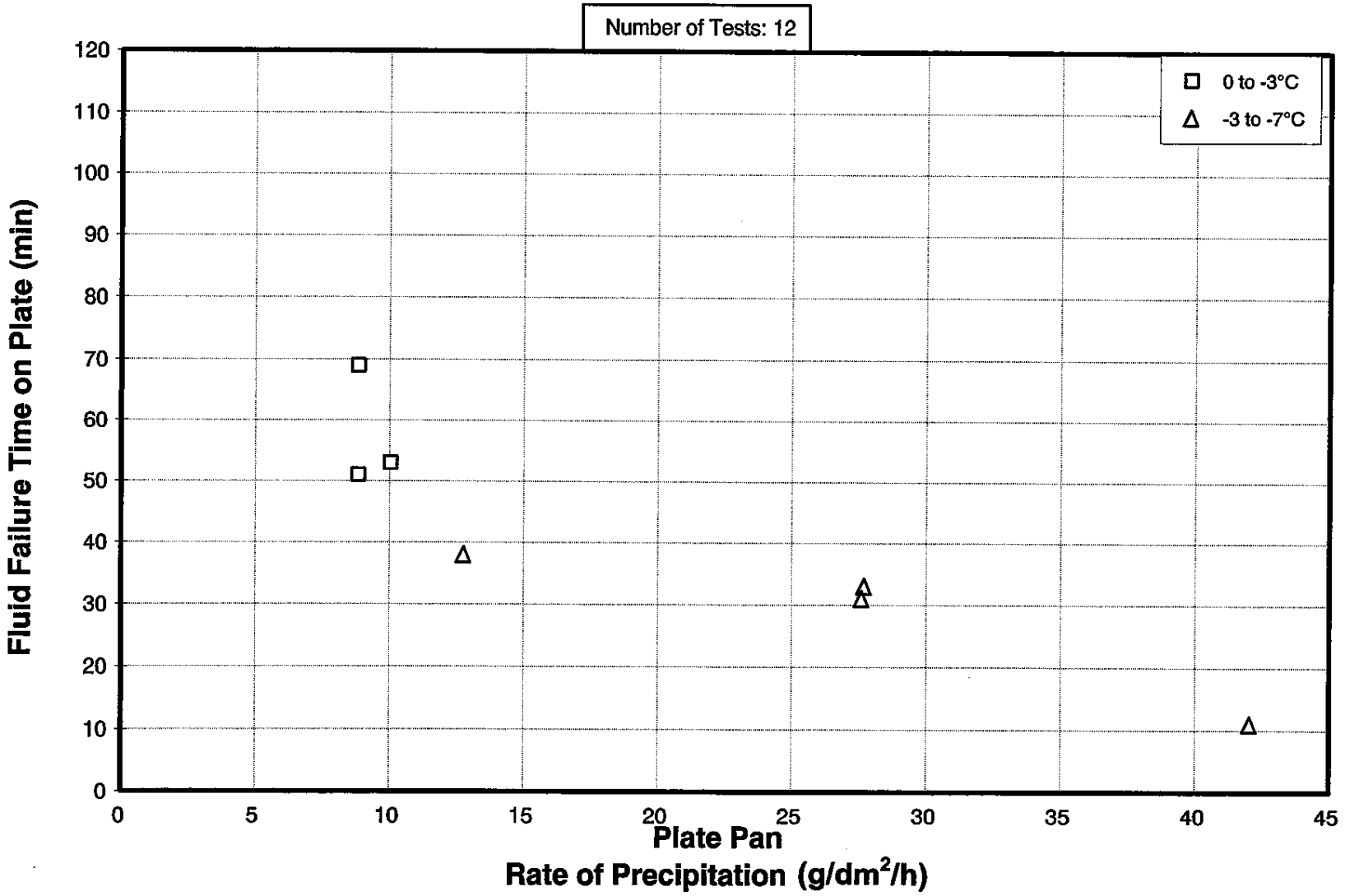


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV 75/25

NATURAL SNOW CONDITIONS

1997/98



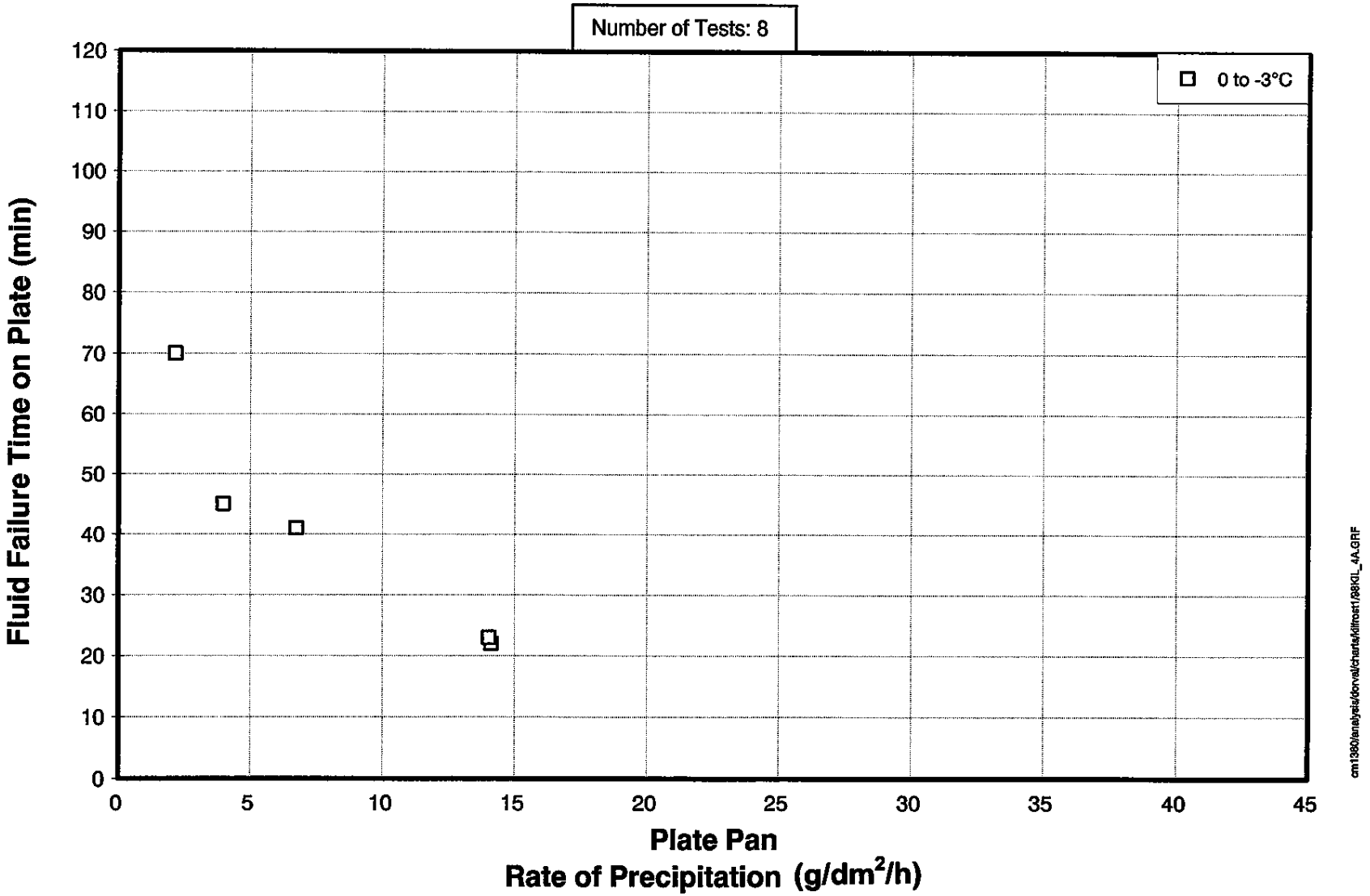

cm1380/analyse/donvet/charts/kilfrost98/KIL_4B.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV 50/50

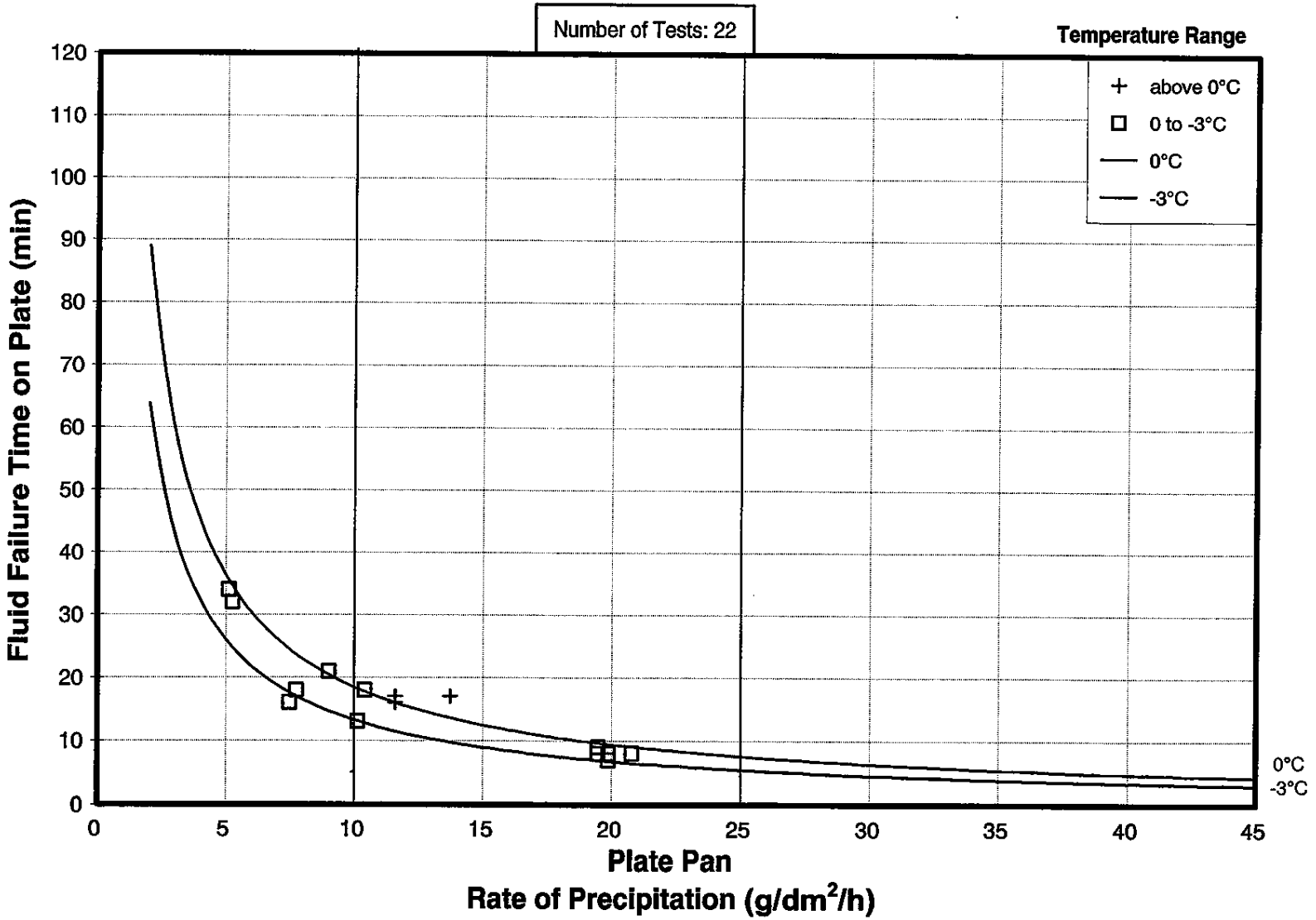
NATURAL SNOW CONDITIONS

1997/98



# EXAMPLE OF REGRESSION METHOD

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
KILFROST TYPE IV 50/50
NATURAL SNOW CONDITIONS
1996/97




cm1338\analyreg\K97NS45c.GRF

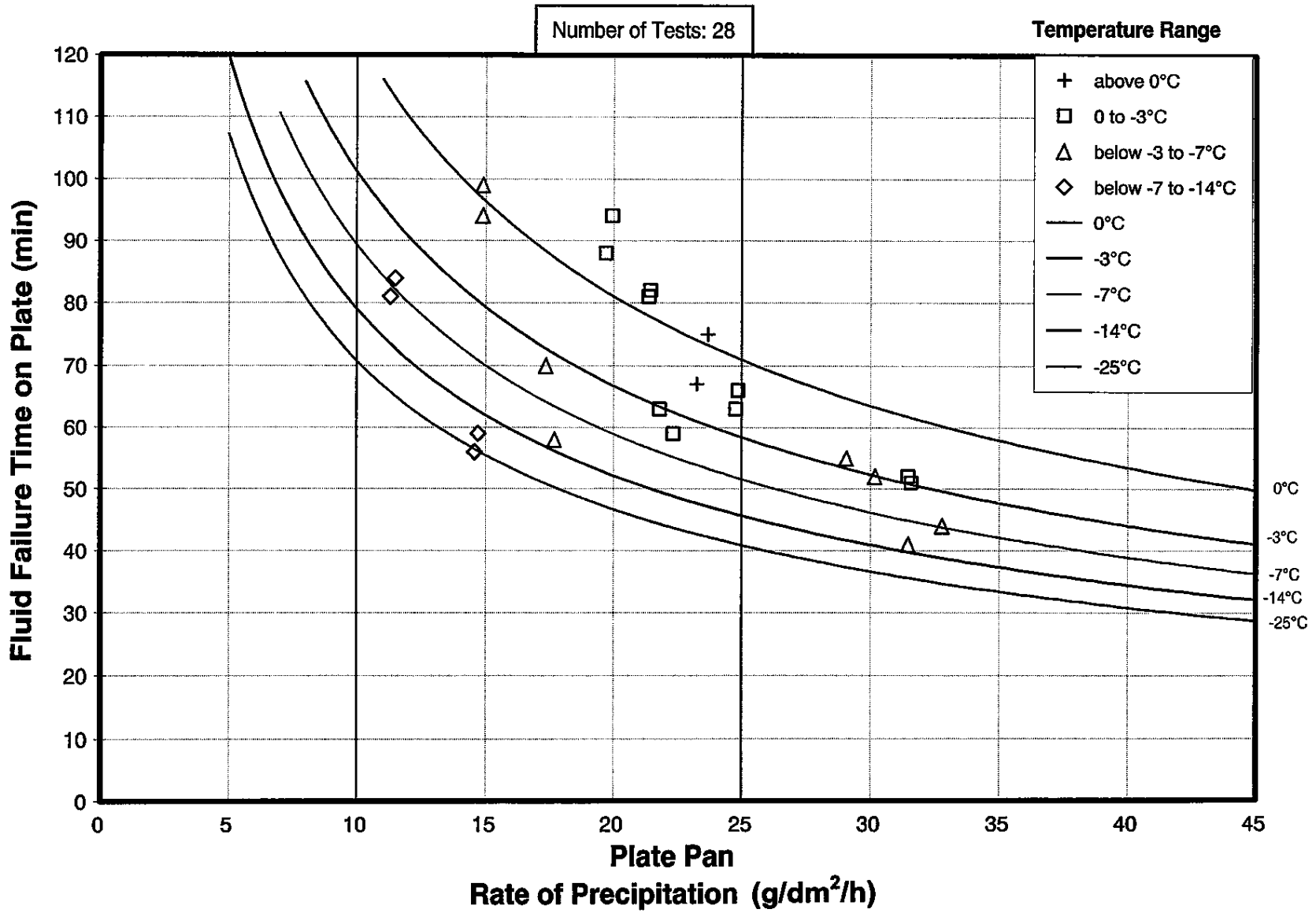
4b

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

KILFROST TYPE IV NEAT

NATURAL SNOW CONDITIONS

1996/97




cm1338analysisvegressK97NS41C.GRF

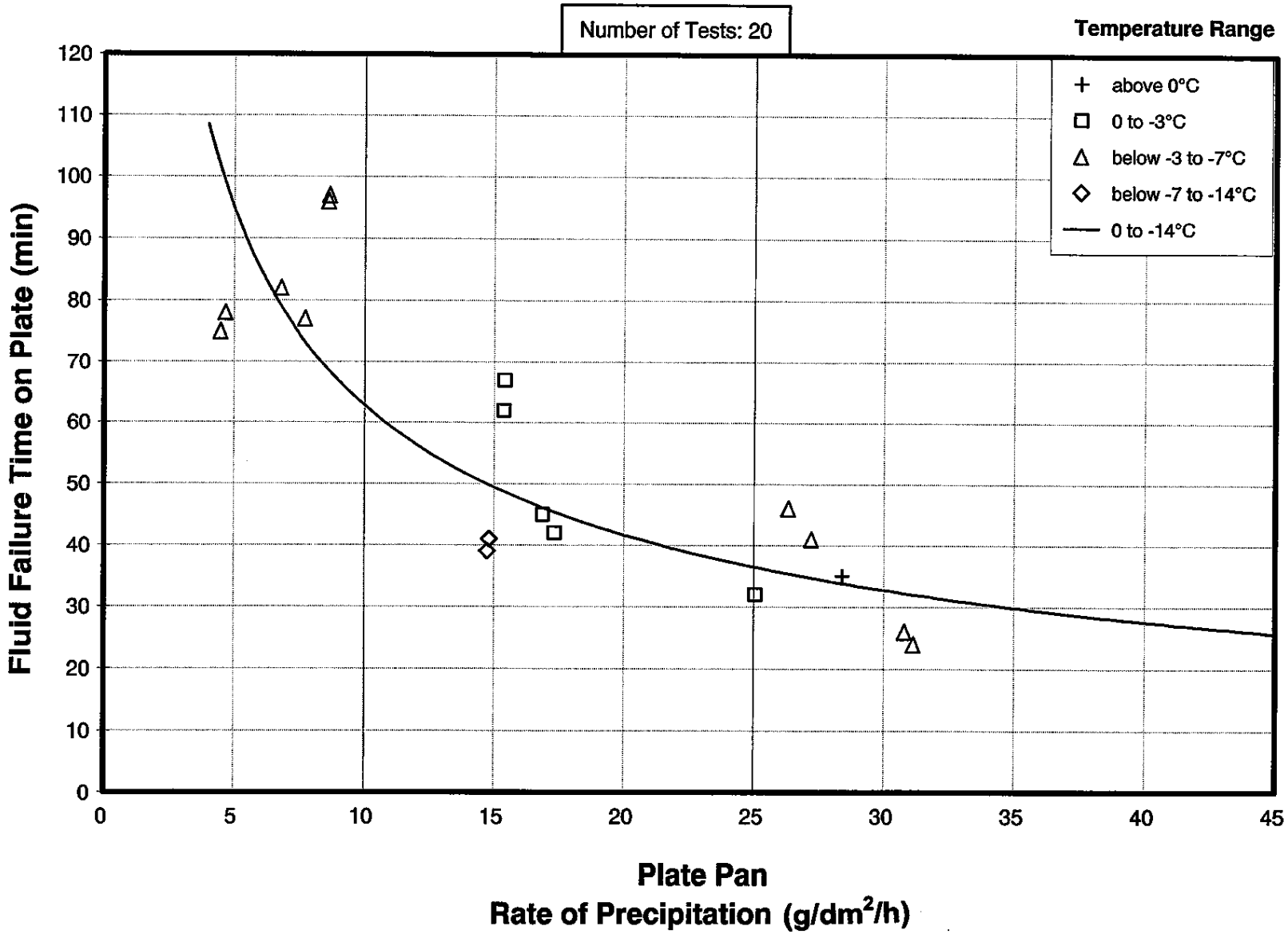
4b

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV 75/25

### NATURAL SNOW CONDITIONS

### 1996/97



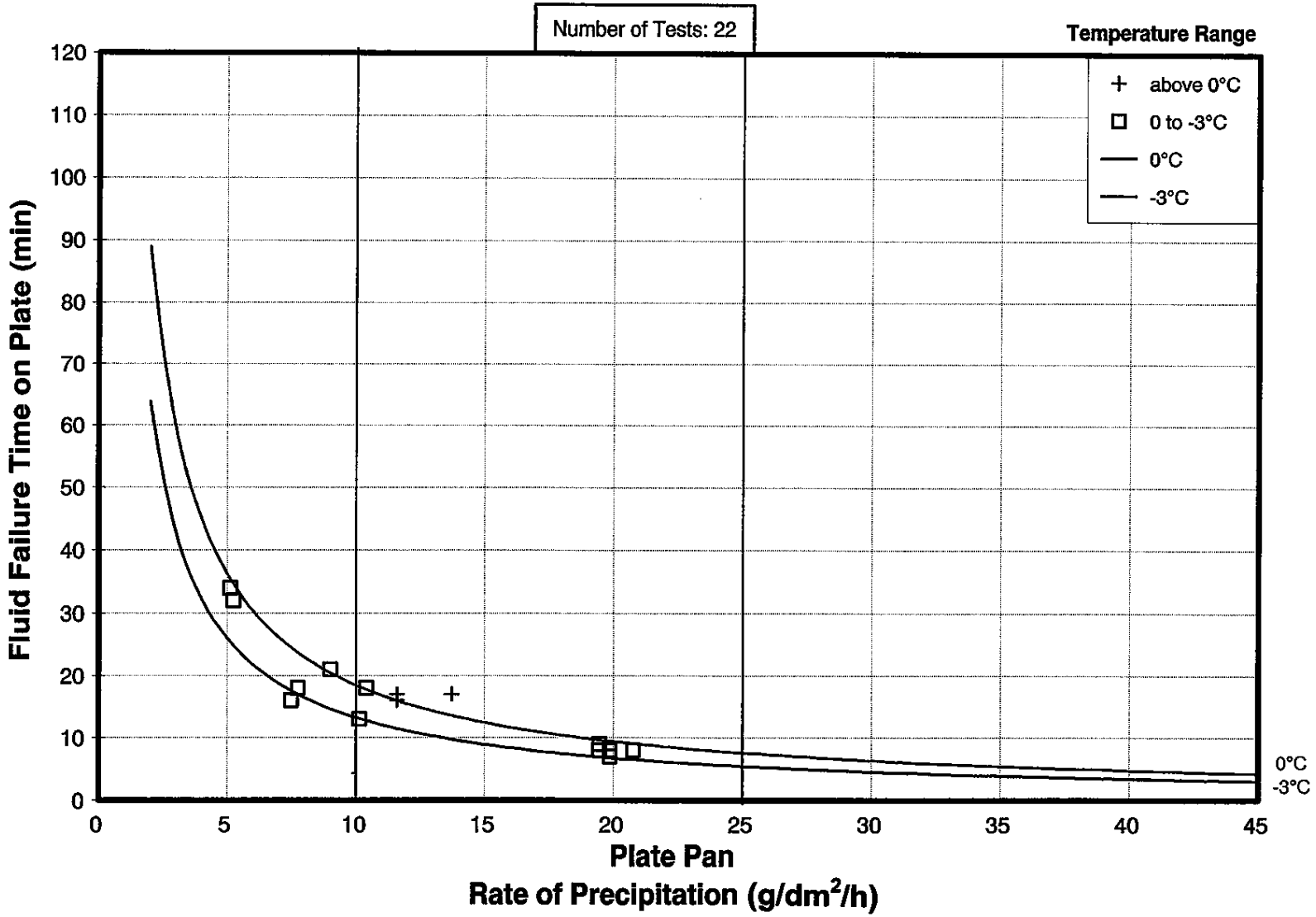

cm1338\analysis\regress\K97NS47C.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

KILFROST TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/97




cm1338\analyreg\X97NS45c.GRF

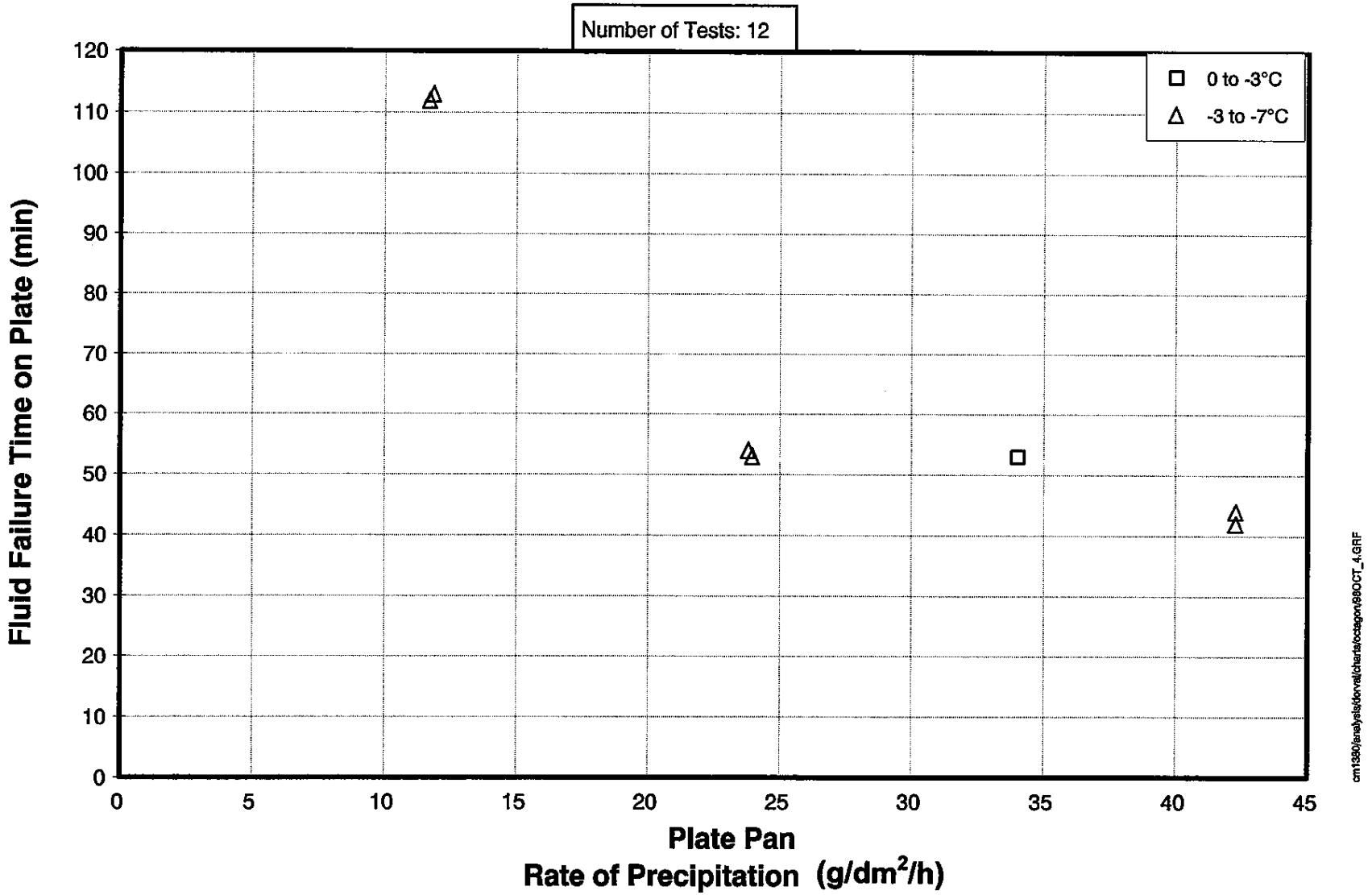
4b

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON MAXFLIGHT TYPE IV NEAT

NATURAL SNOW CONDITIONS

1997/98

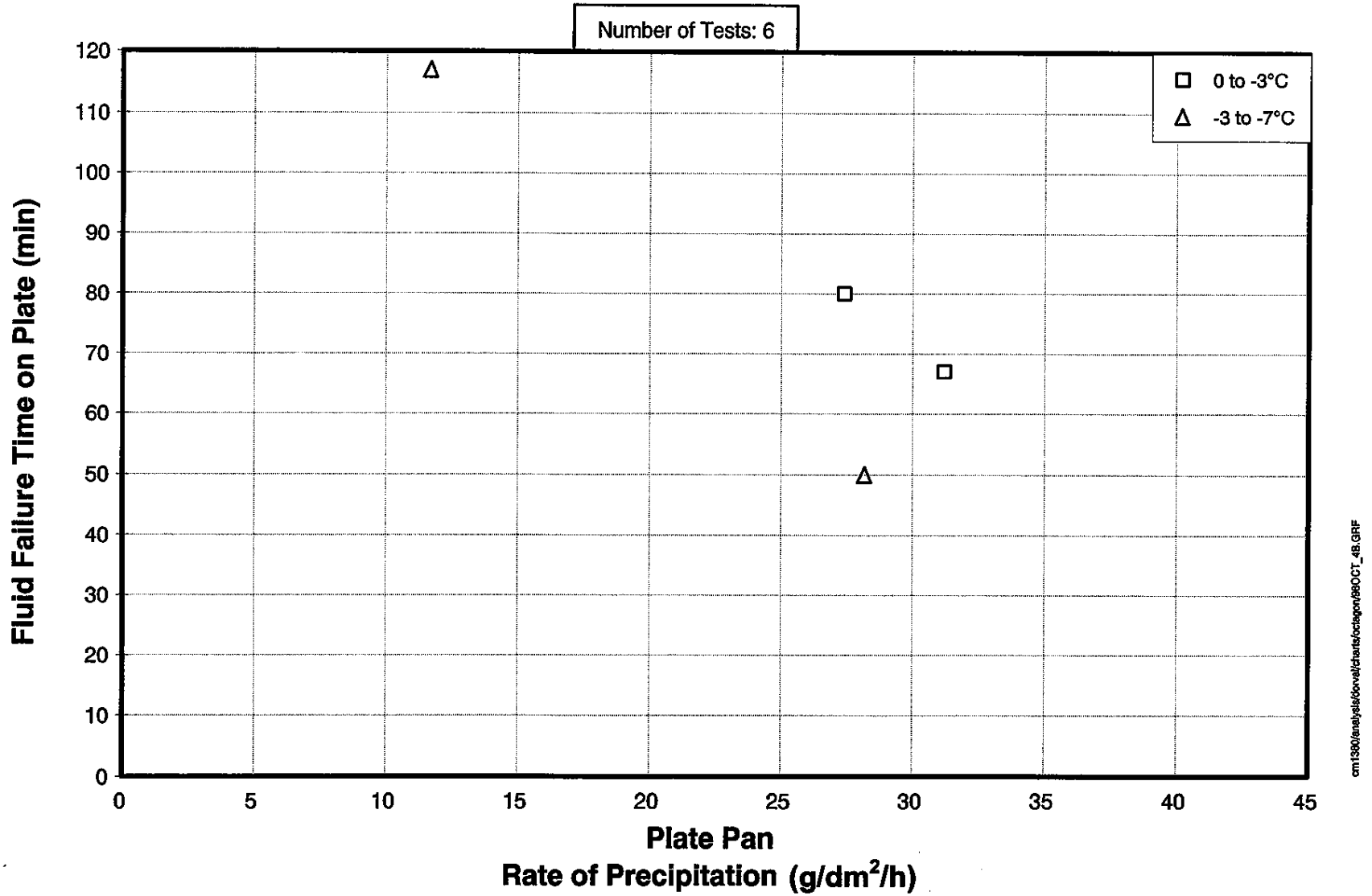


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON MAXFLIGHT TYPE IV 75/25

NATURAL SNOW CONDITIONS

1997/98

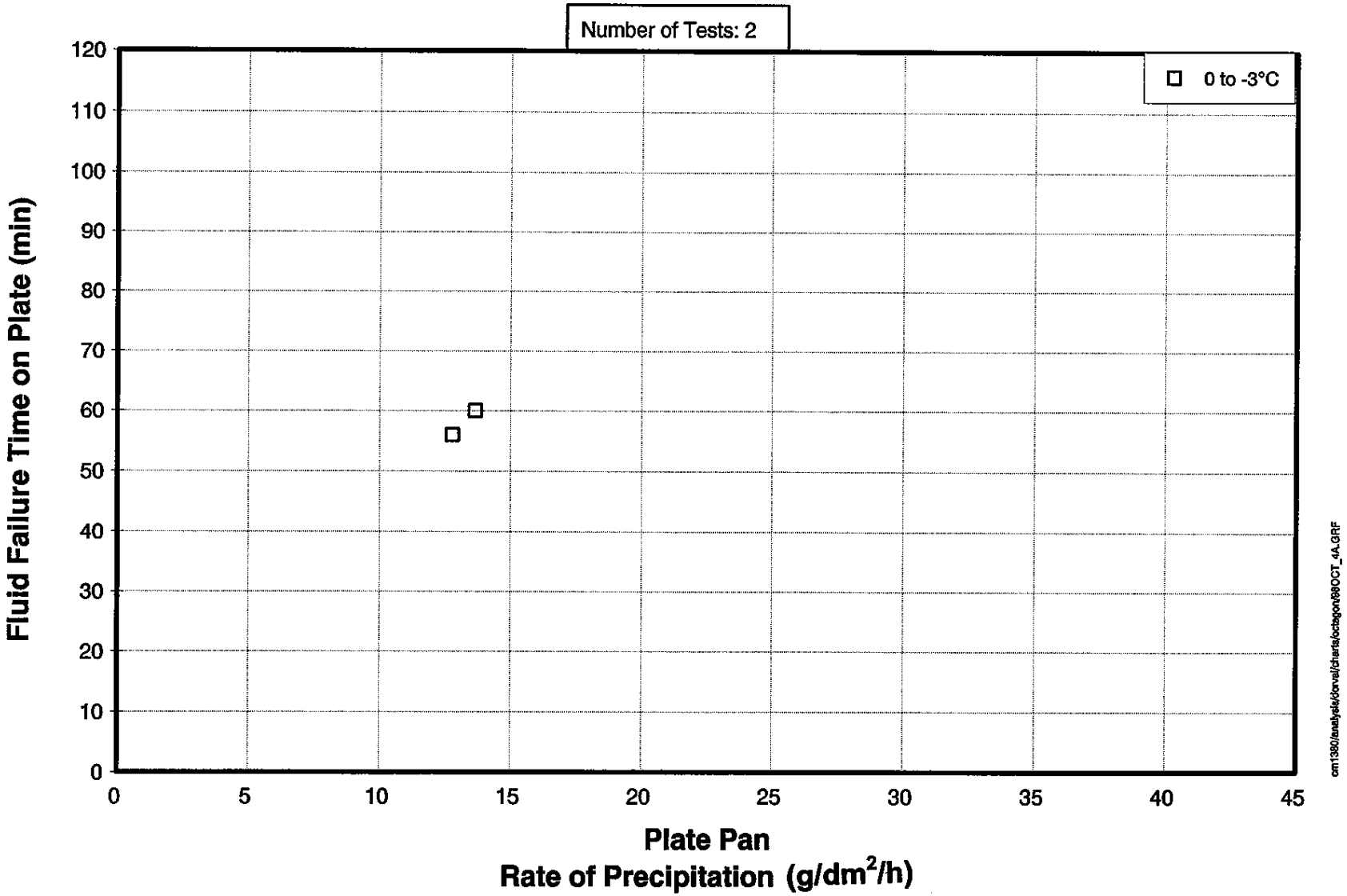


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON MAXFLIGHT TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997/98

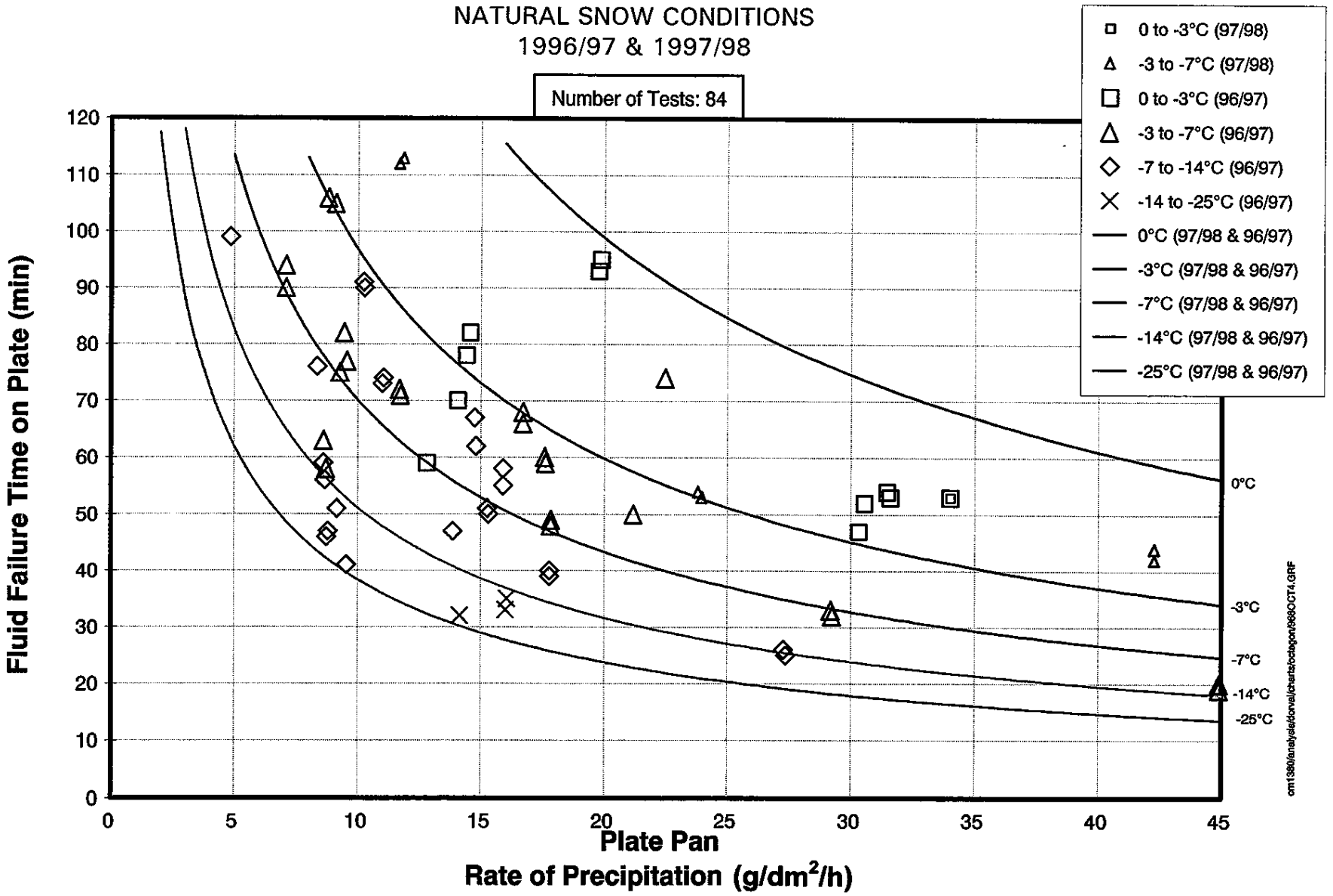


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON MAXFLIGHT TYPE IV NEAT

NATURAL SNOW CONDITIONS

1996/97 & 1997/98

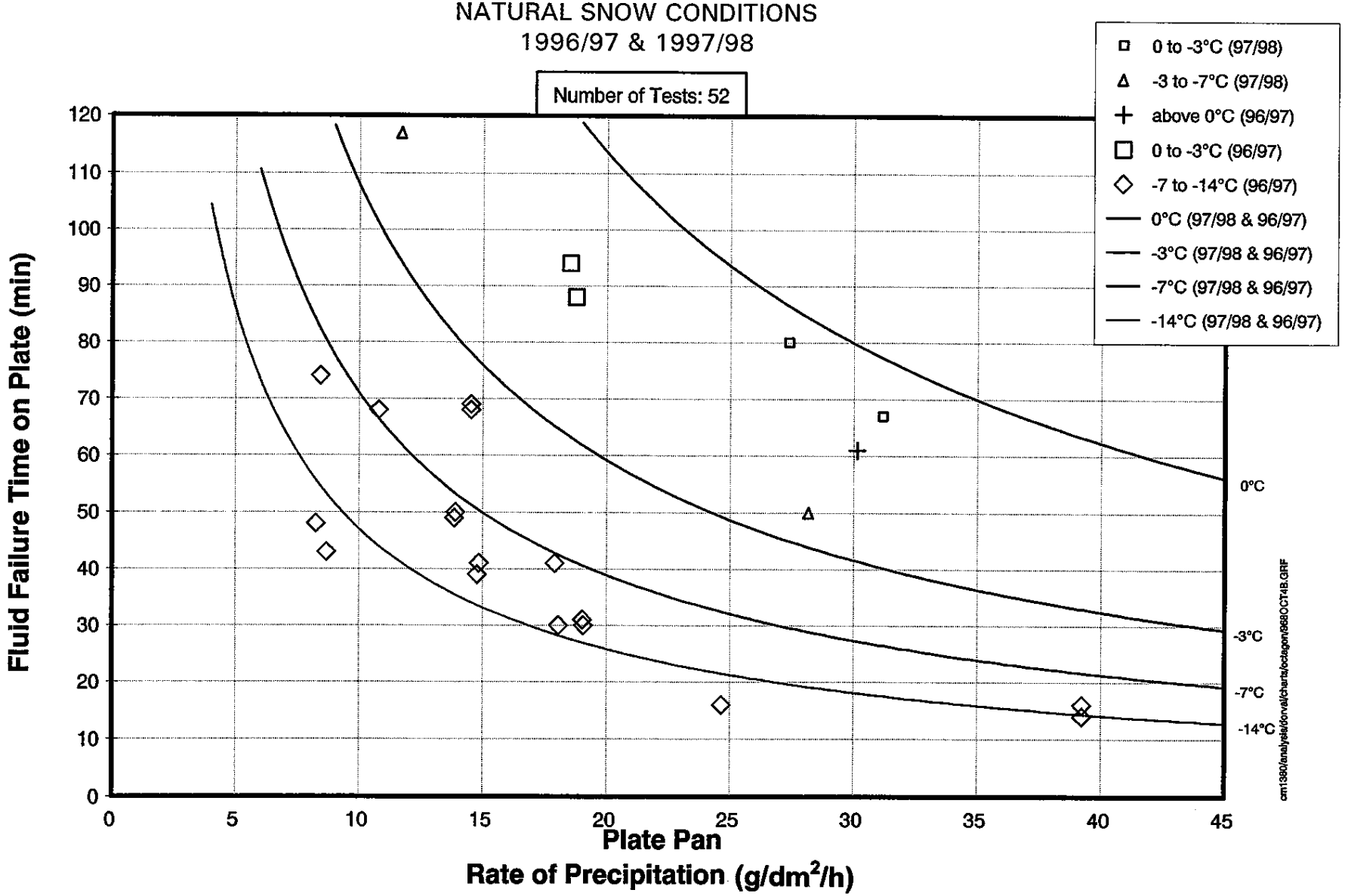


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON MAXFLIGHT TYPE IV 75/25

NATURAL SNOW CONDITIONS

1996/97 & 1997/98

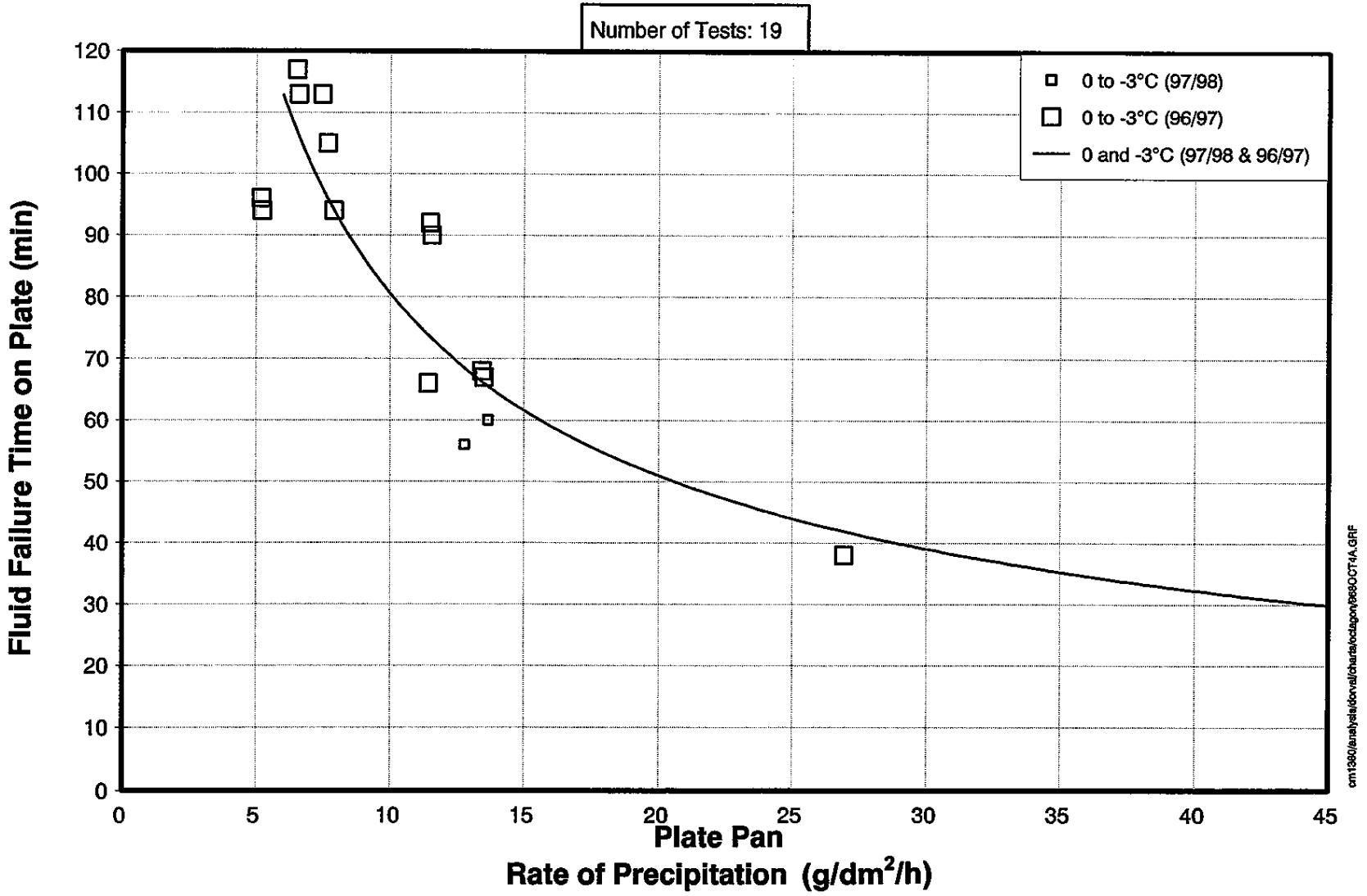


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON MAXFLIGHT TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/97 & 1997/98

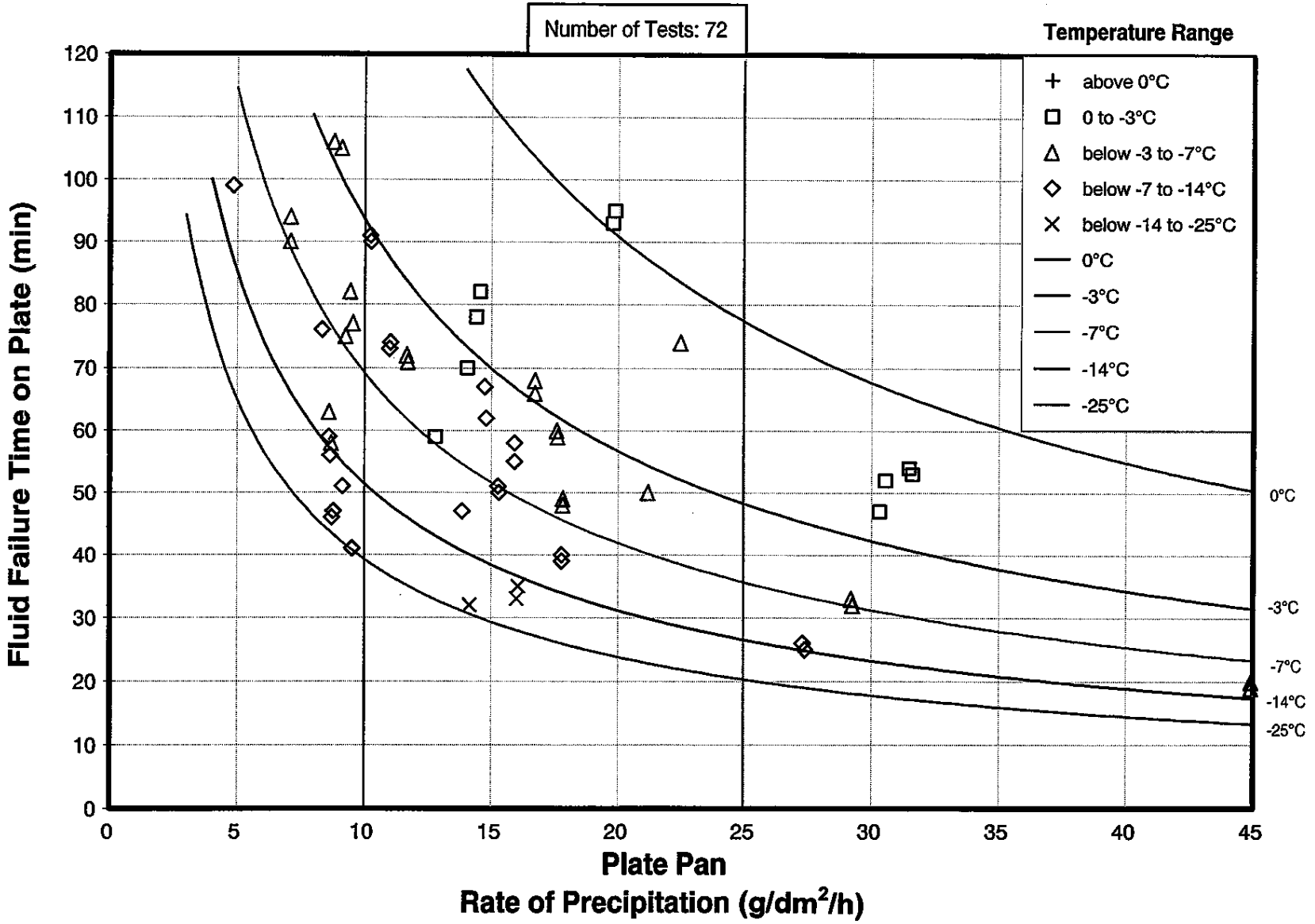


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE IV NEAT

## NATURAL SNOW CONDITIONS

## 1996/97




cm1338\analy\regress\C97NS41c.GRF

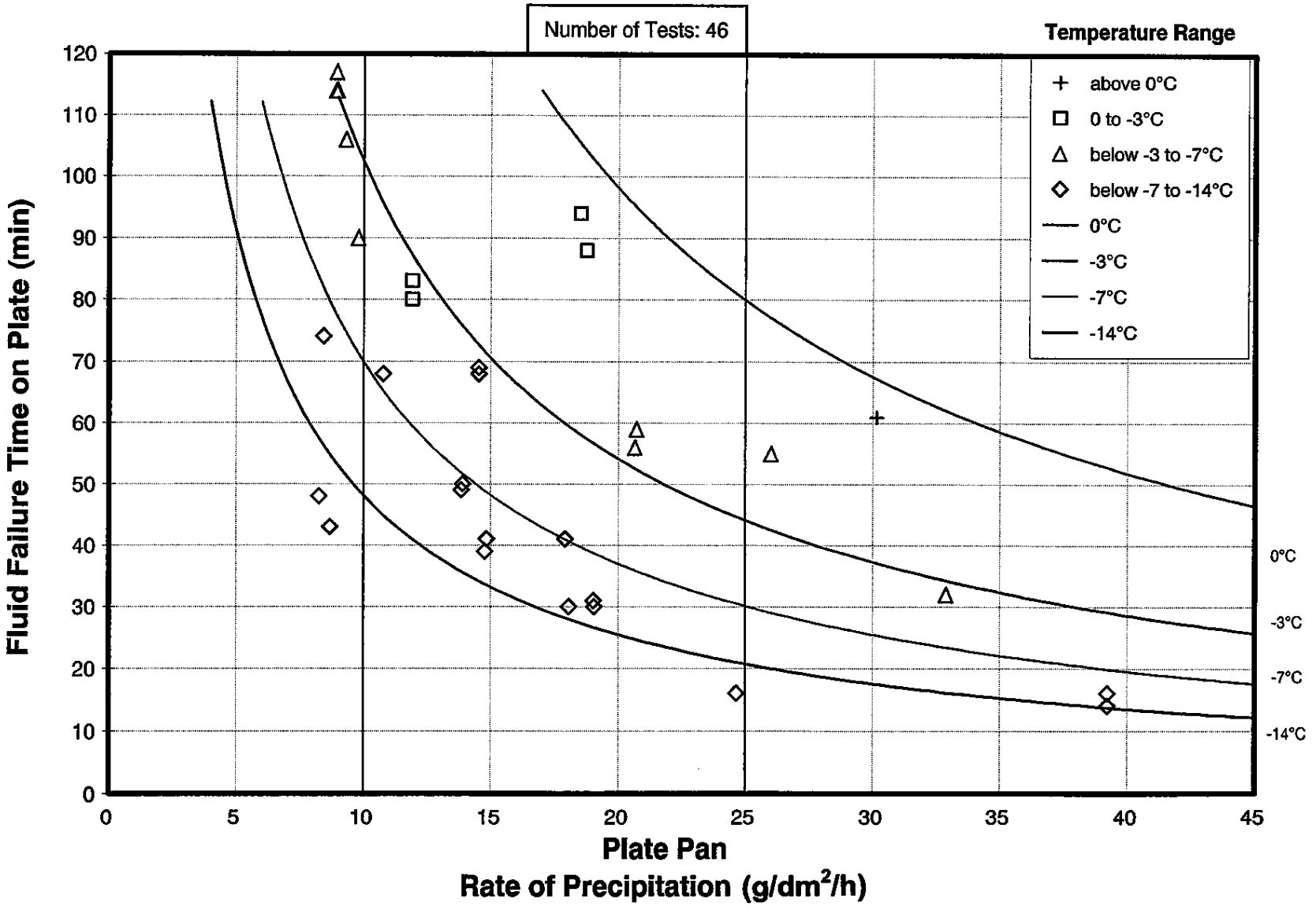
4b

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE IV 75/25

## NATURAL SNOW CONDITIONS

## 1996/97

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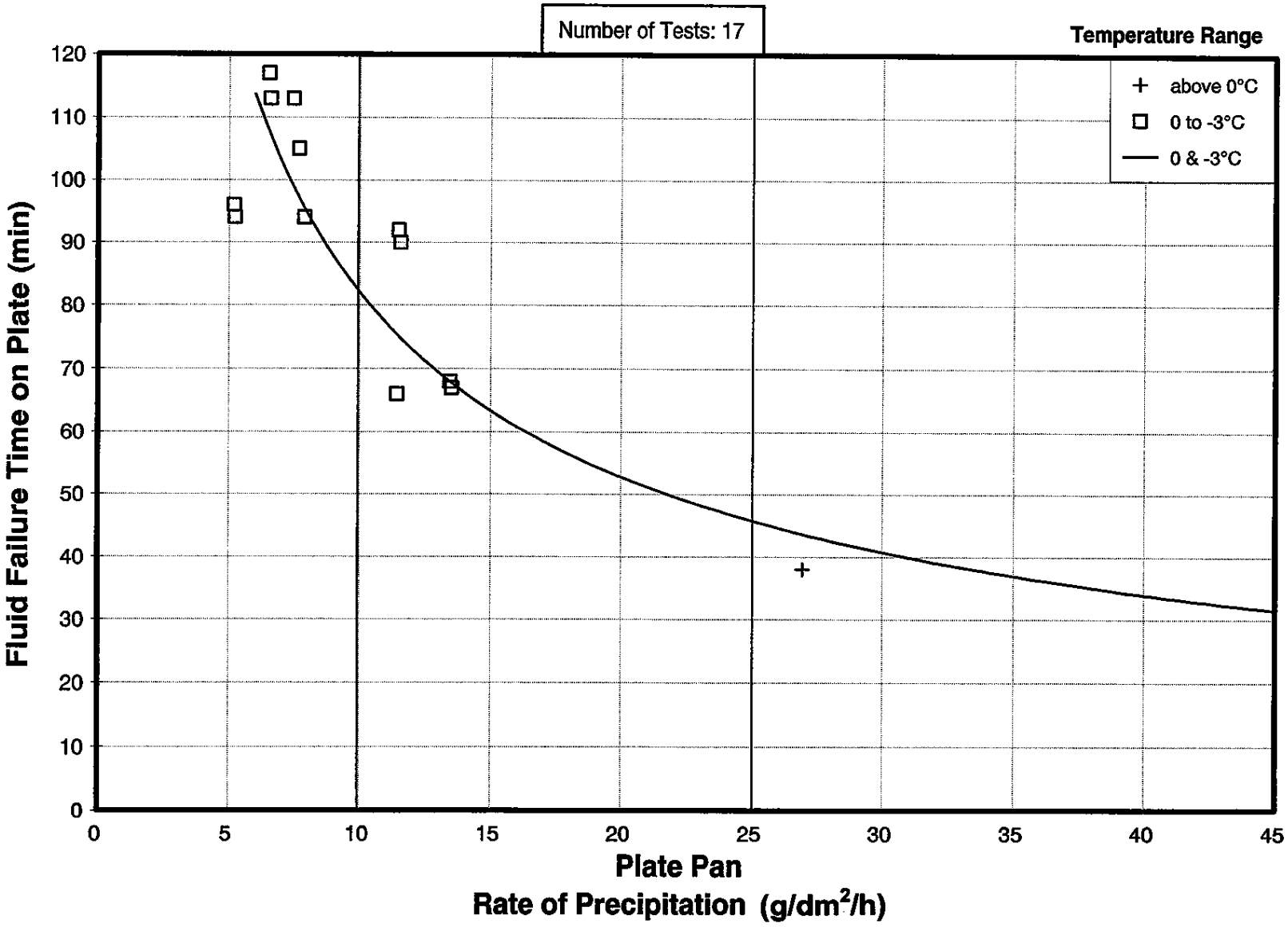
4b

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

OCTAGON TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/97

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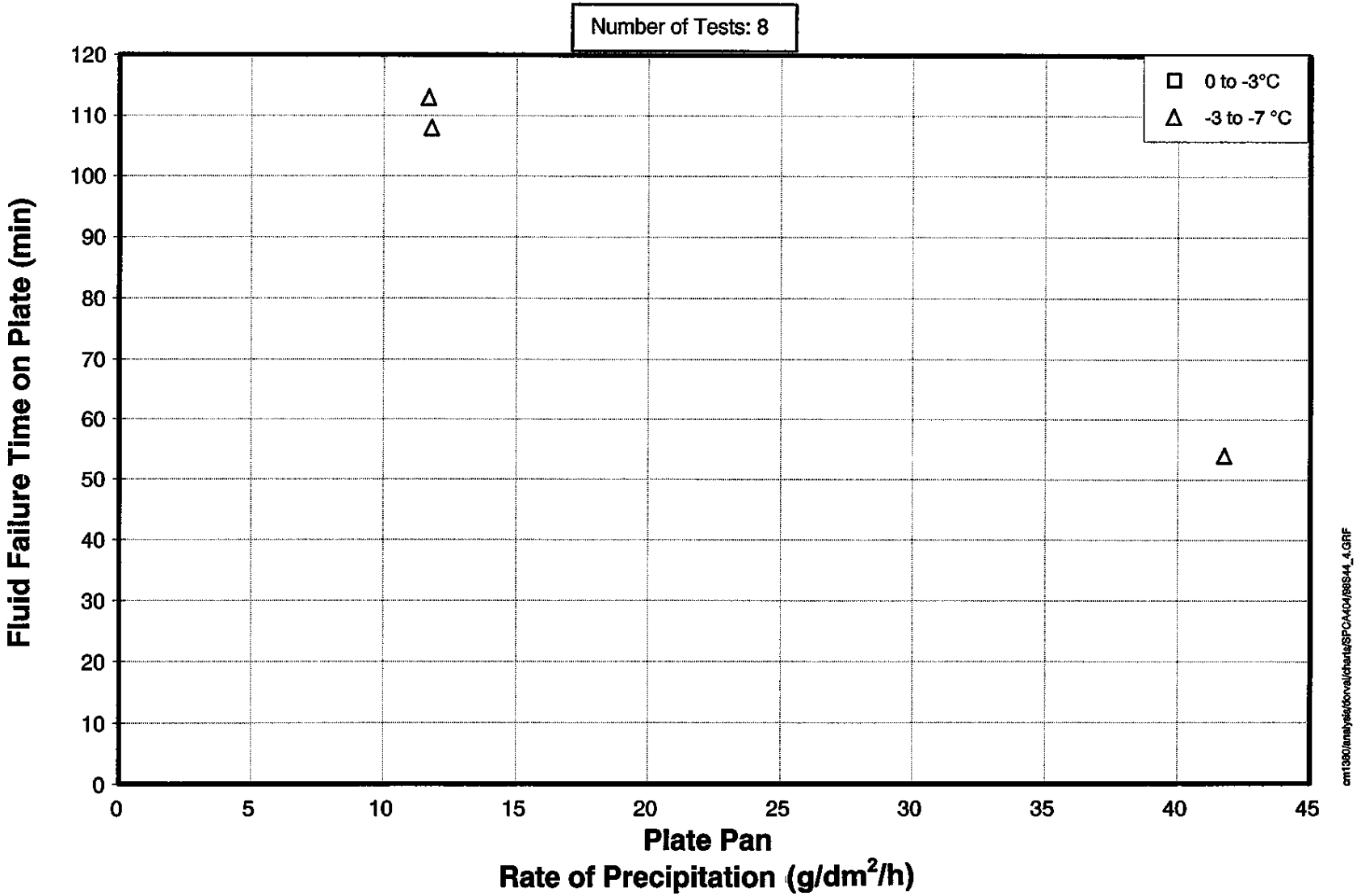
4b

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV NEAT

NATURAL SNOW CONDITIONS

1997/98

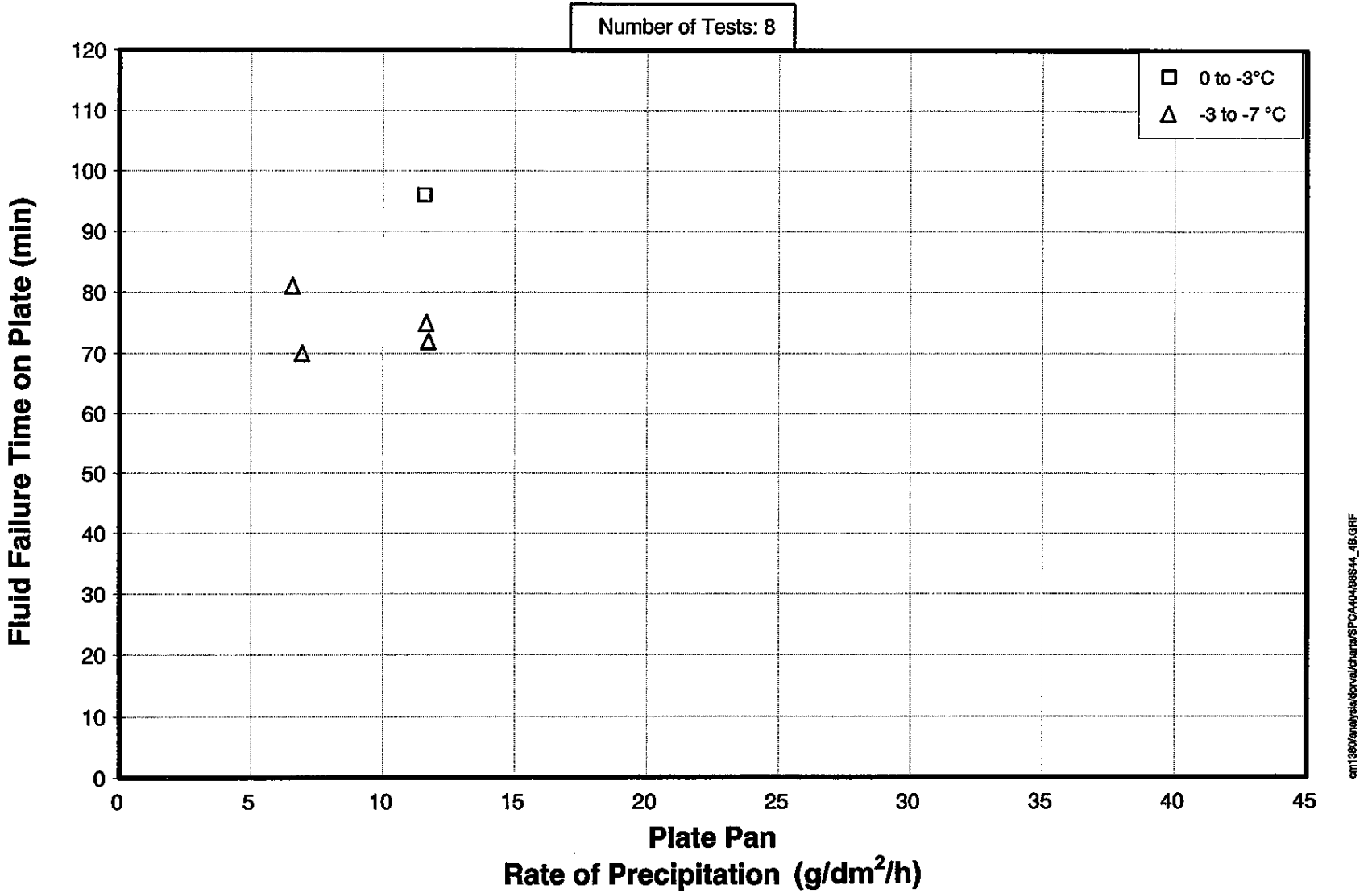


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV 75/25

NATURAL SNOW CONDITIONS

1997/98



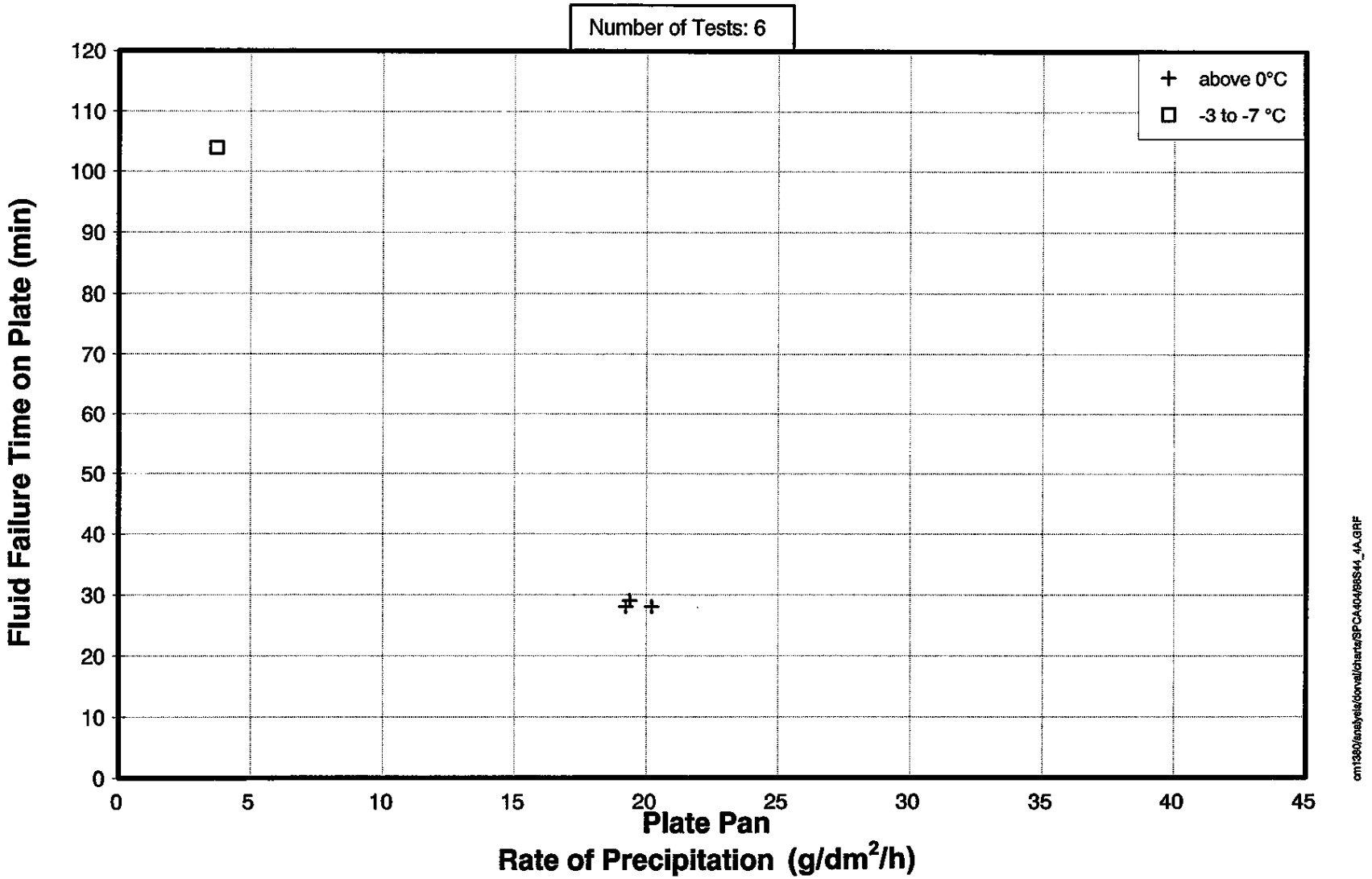

cm1380/analysis/dorval/charts/SPCA404SS44_4B.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997/98

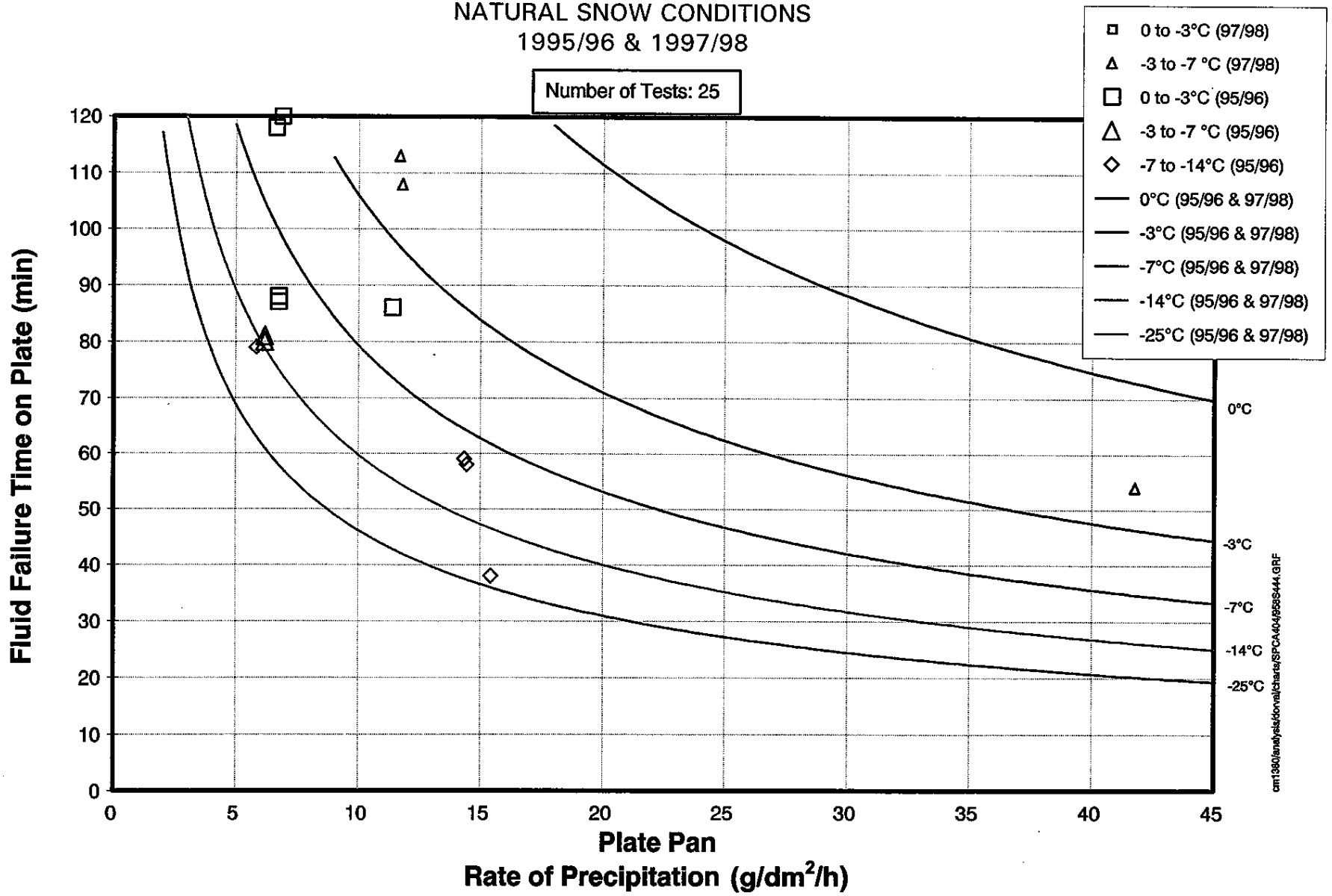



cm1380/testyels/donvall/charts/SPCA404/98S44_4A.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV NEAT

NATURAL SNOW CONDITIONS
1995/96 & 1997/98

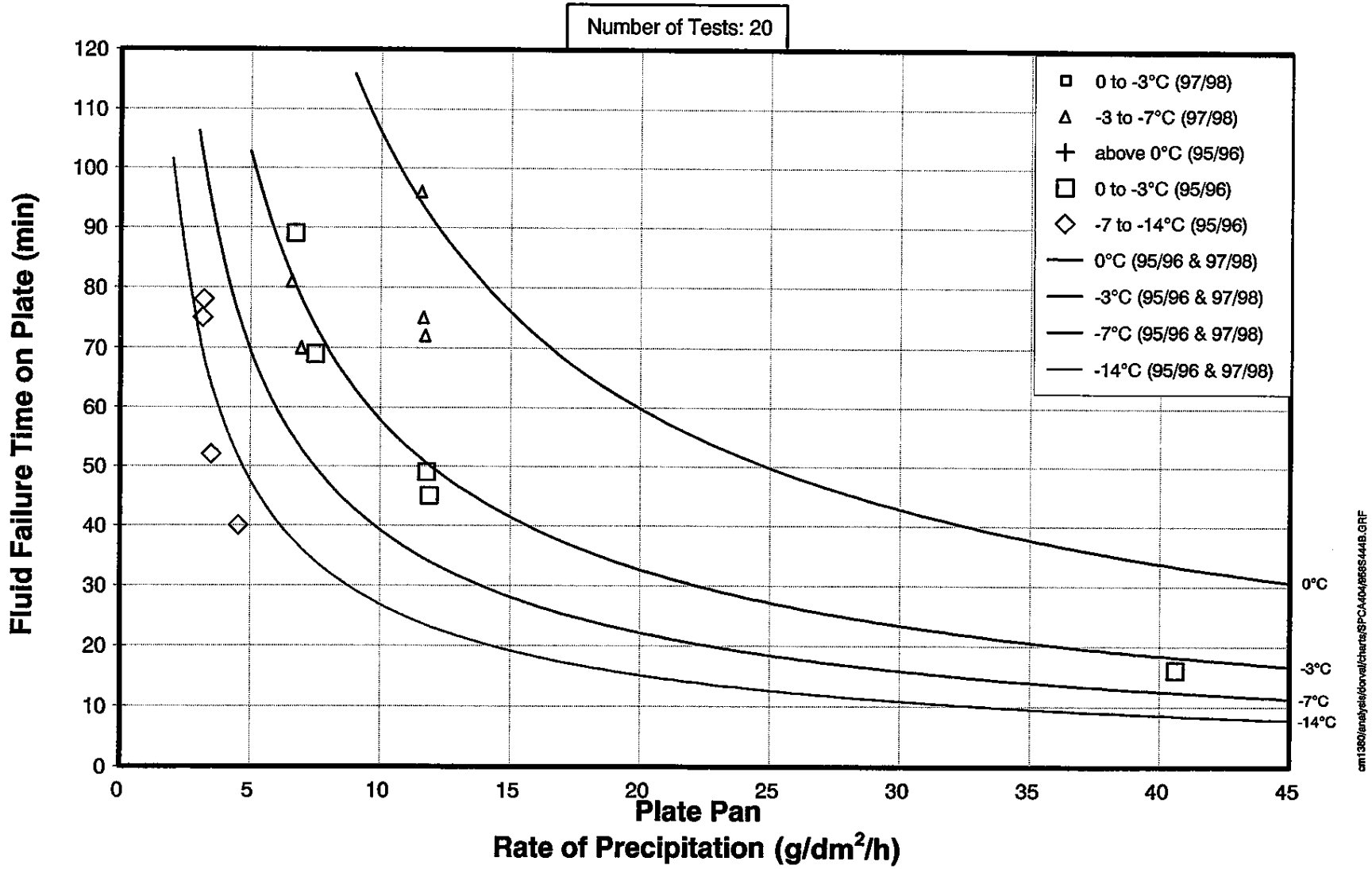


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV 75/25

NATURAL SNOW CONDITIONS

1995/96 & 1997/98

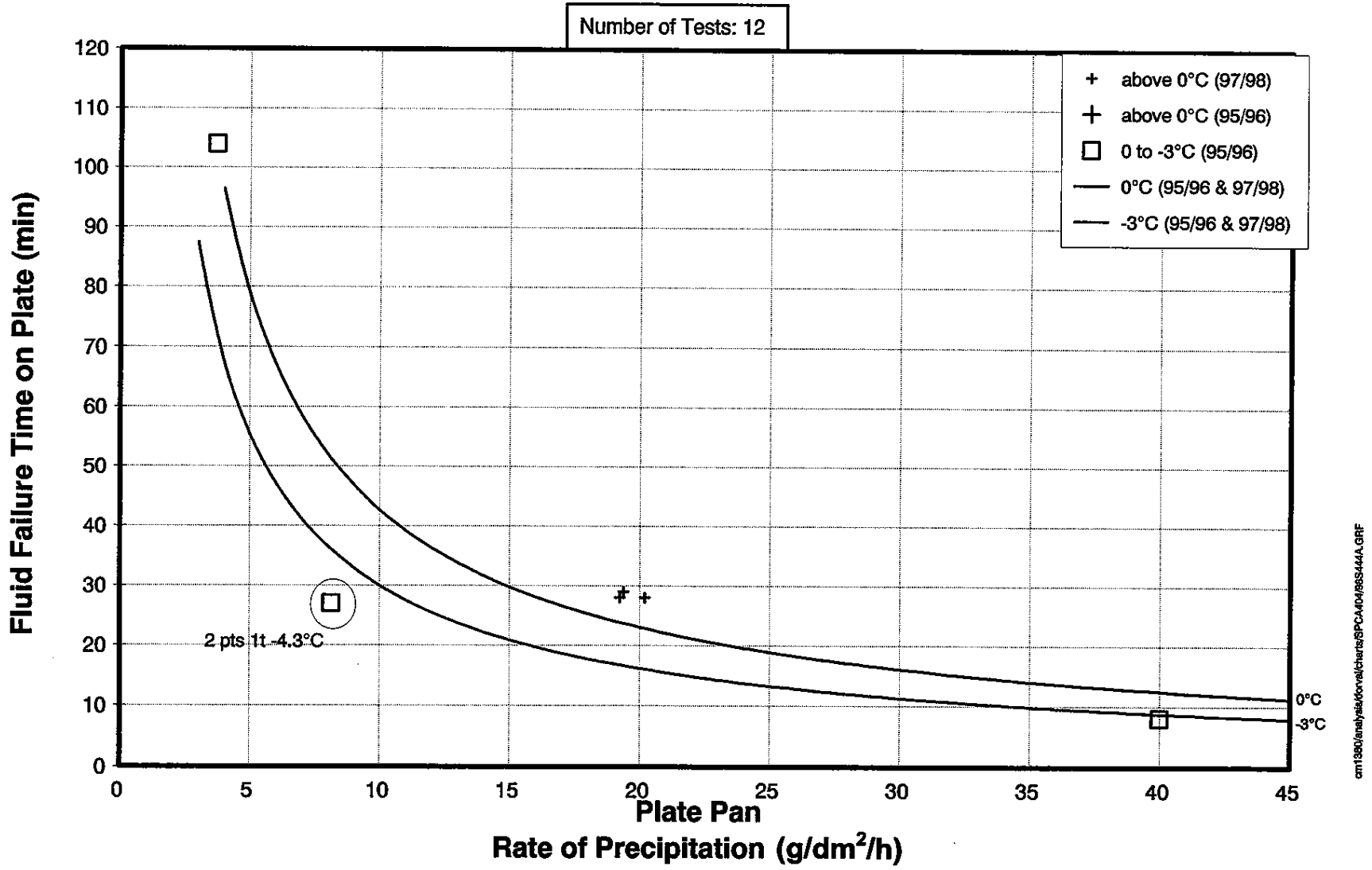


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV 50/50

NATURAL SNOW CONDITIONS

1995/96 & 1997/98

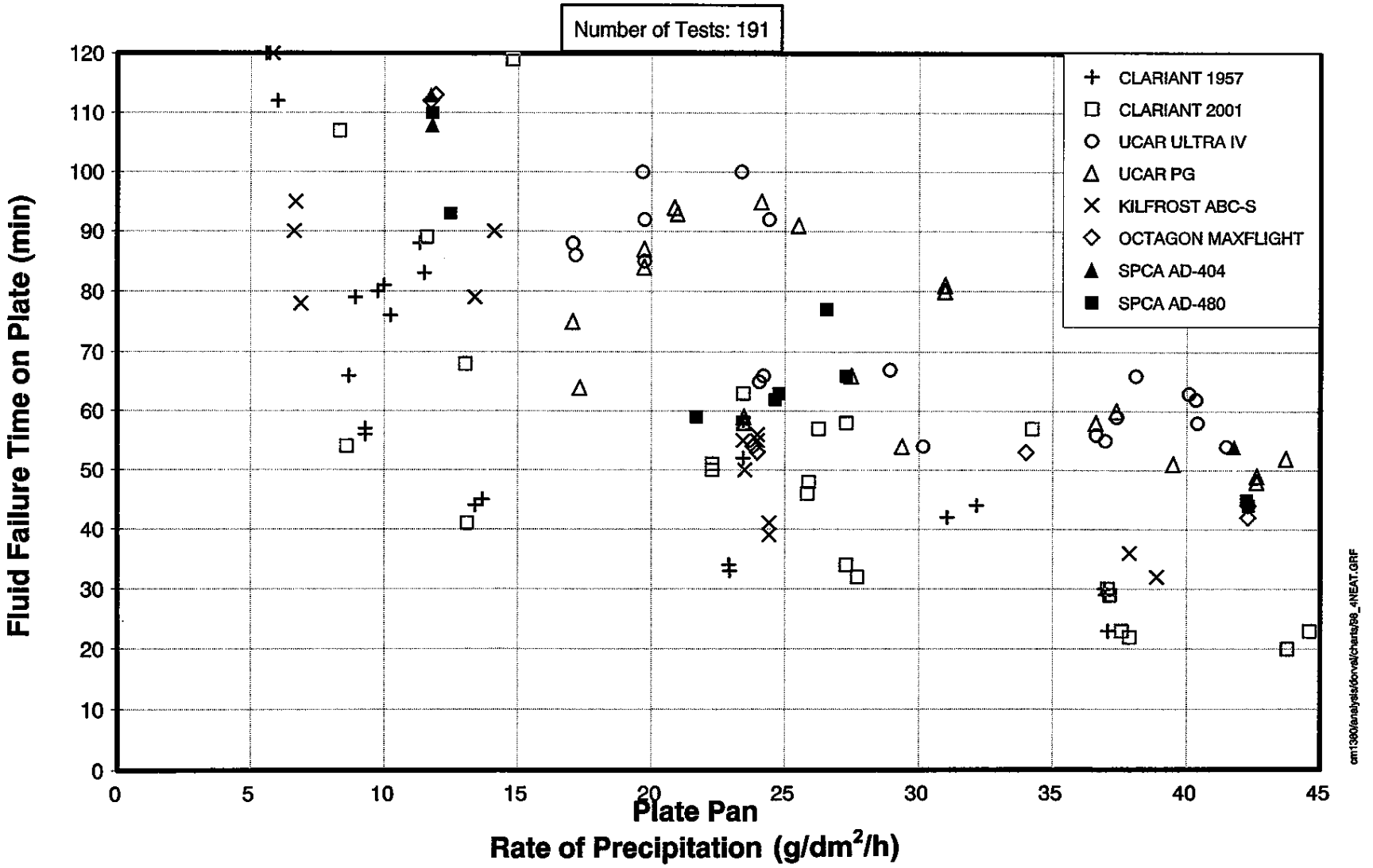


# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV NEAT

NATURAL SNOW CONDITIONS

1997/98

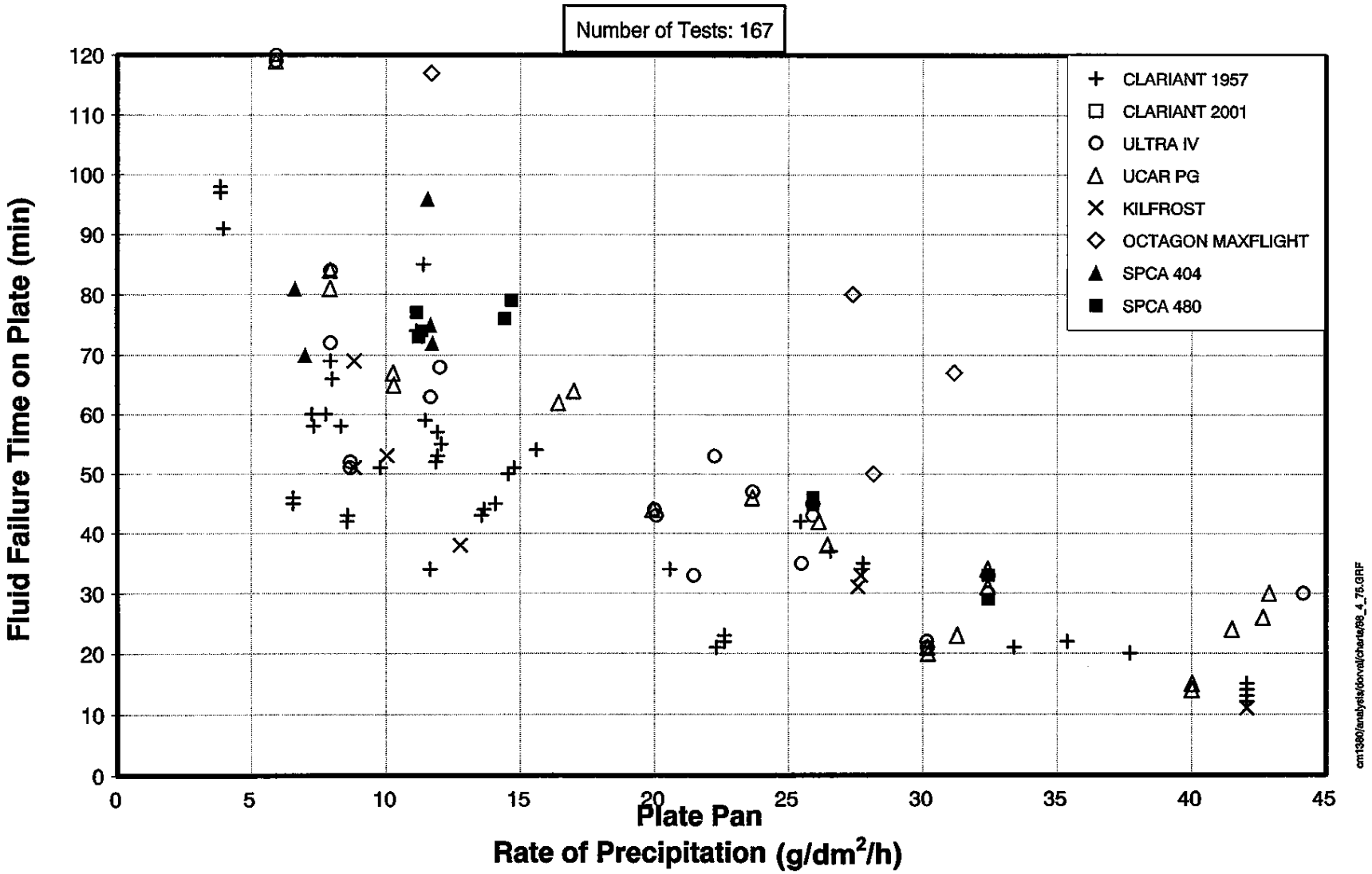


# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 75/25

NATURAL SNOW CONDITIONS

1997/98

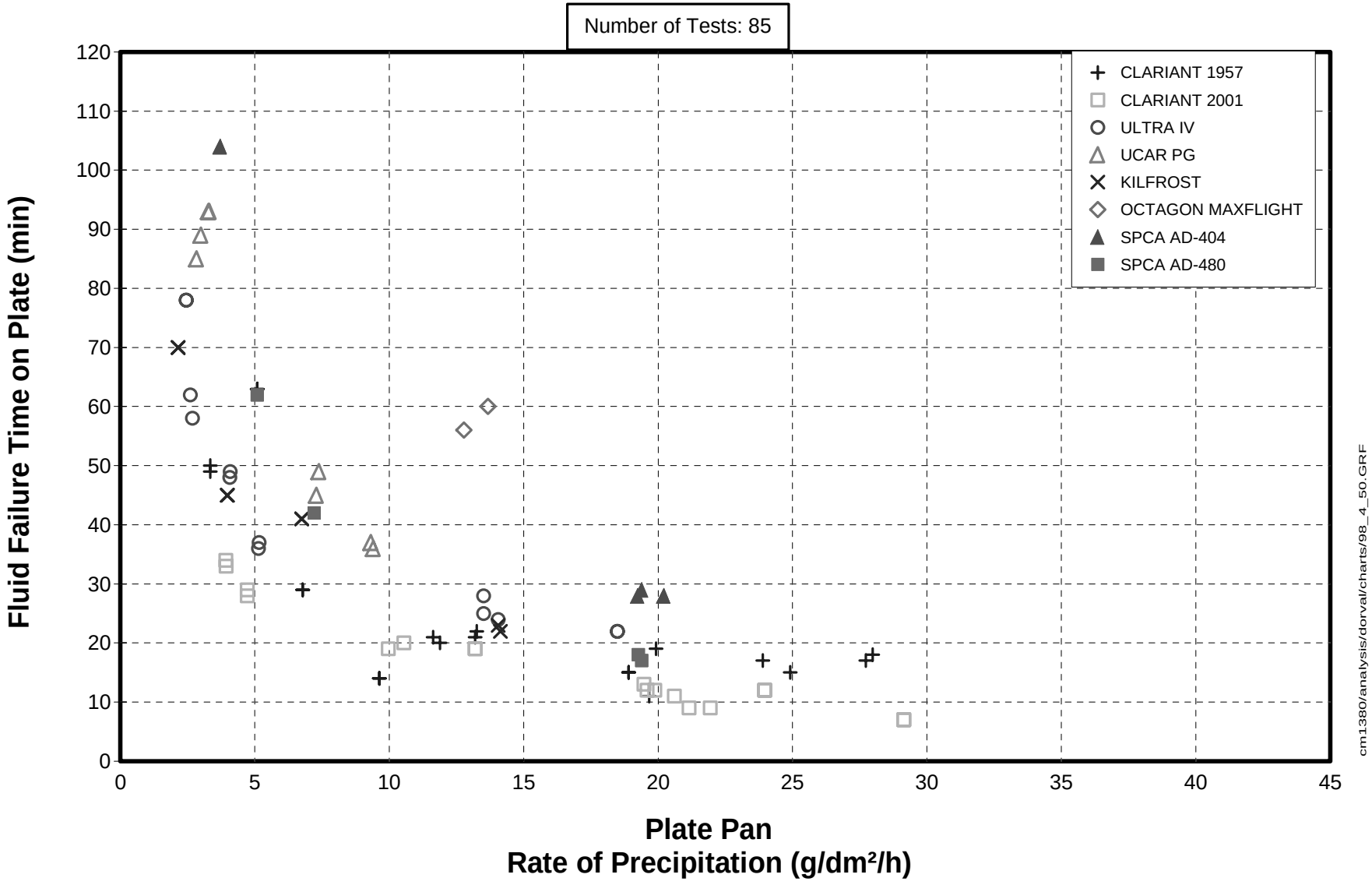


# EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

## TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997/98

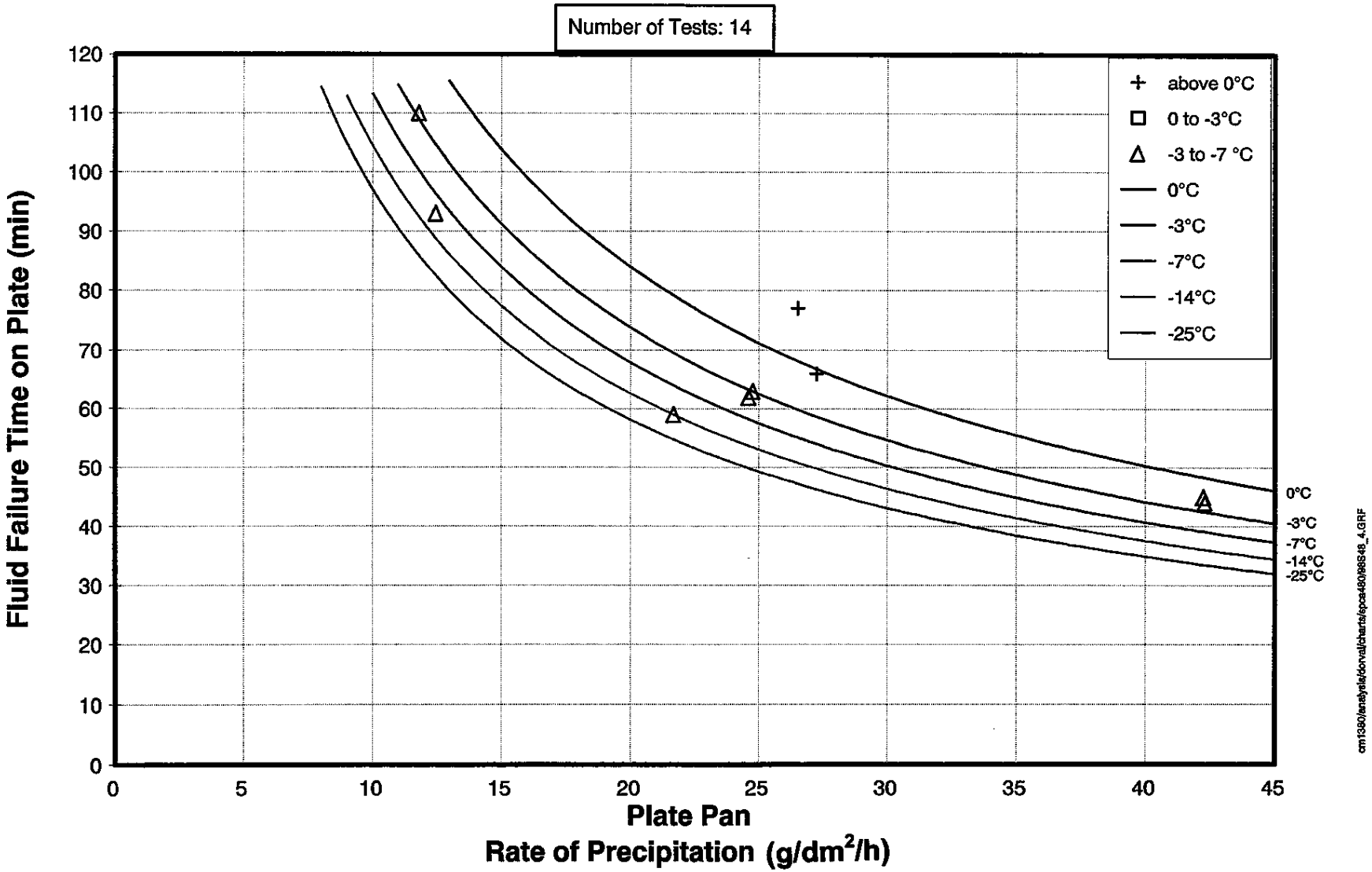


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV NEAT

NATURAL SNOW CONDITIONS

1997/98

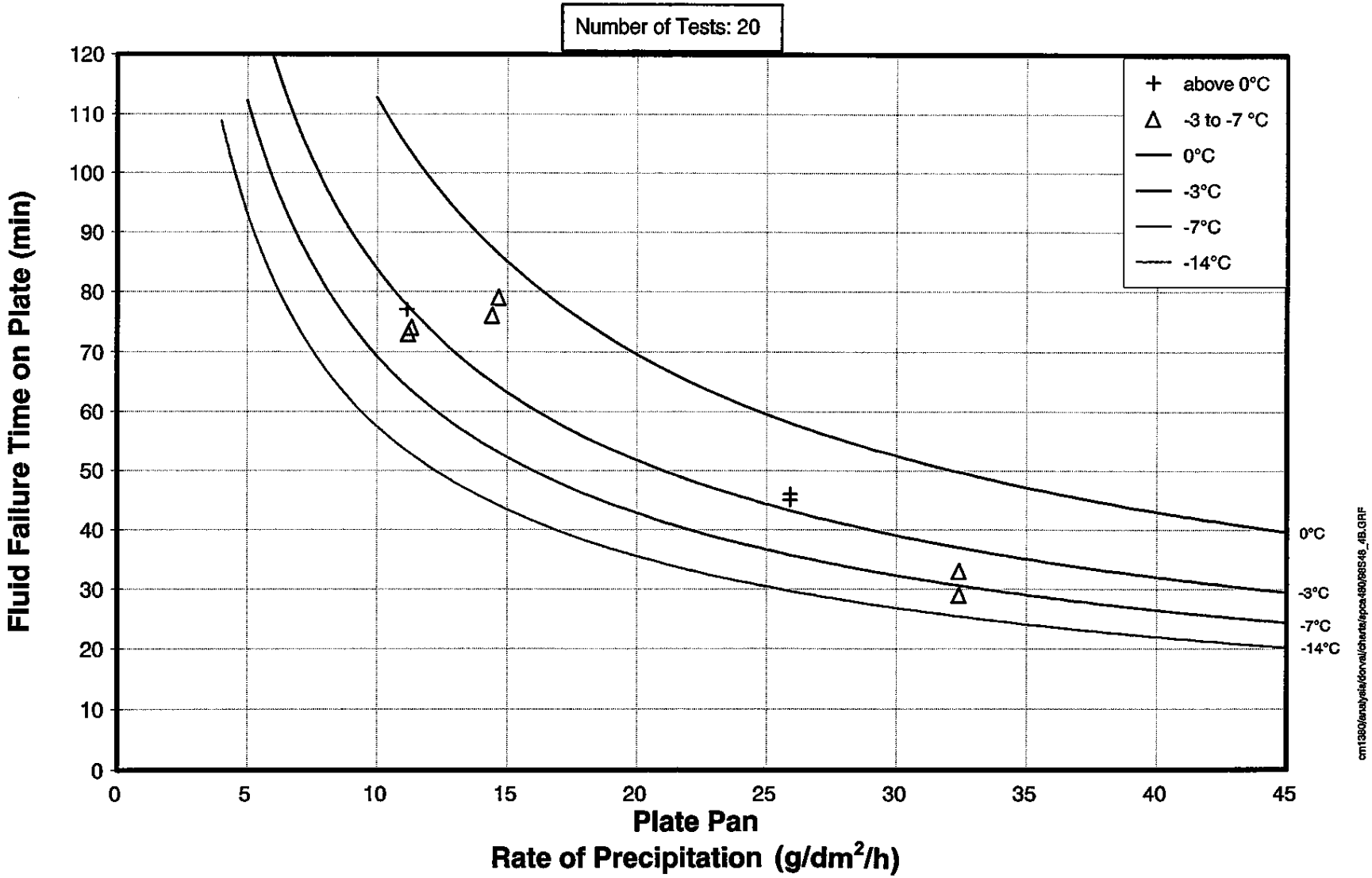


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV 75/25

NATURAL SNOW CONDITIONS

1997/98

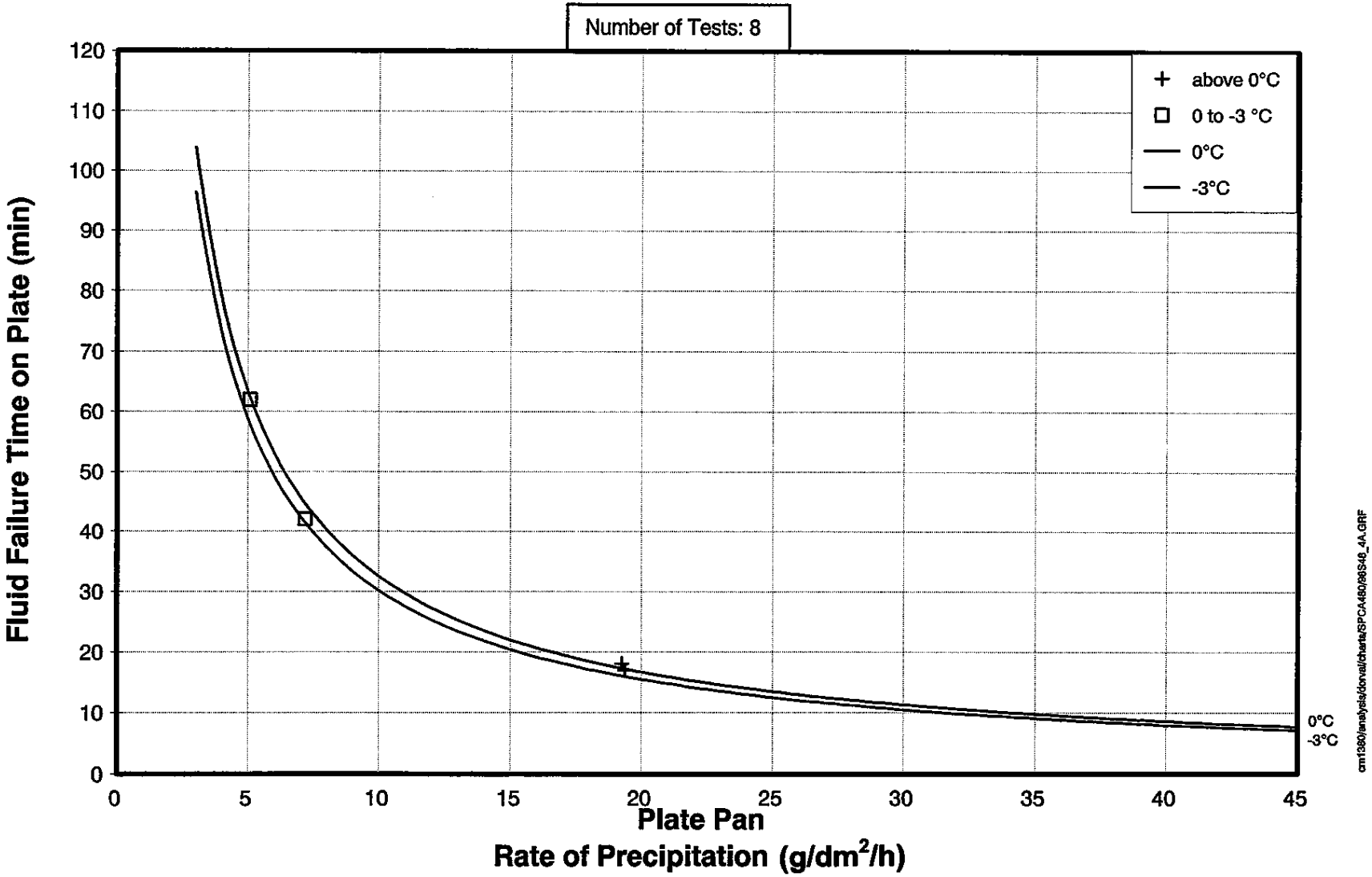


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997/98

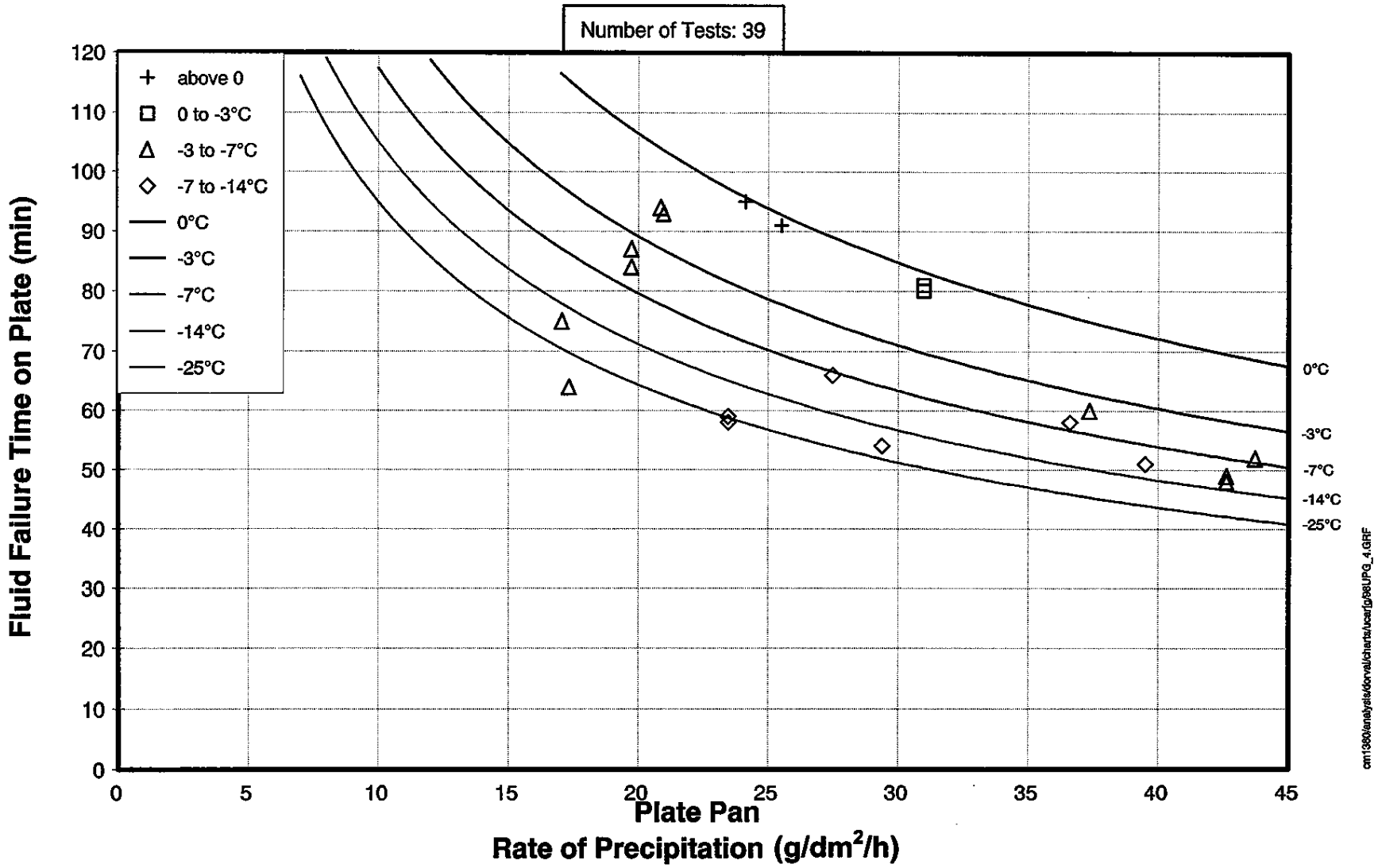


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR PG TYPE IV NEAT

NATURAL SNOW CONDITIONS

1997/98

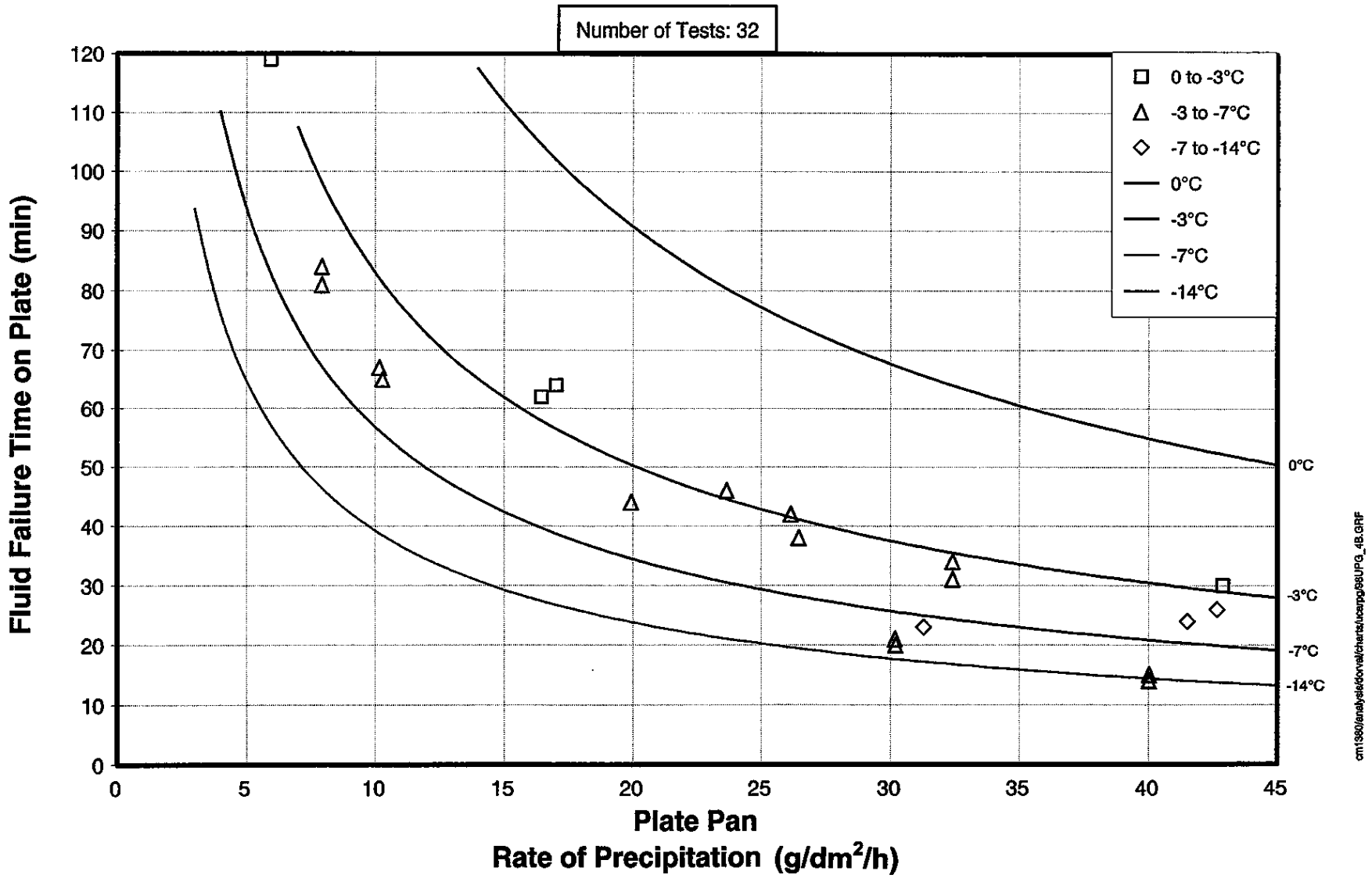


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR PG TYPE IV 75/25

NATURAL SNOW CONDITIONS

1997/98

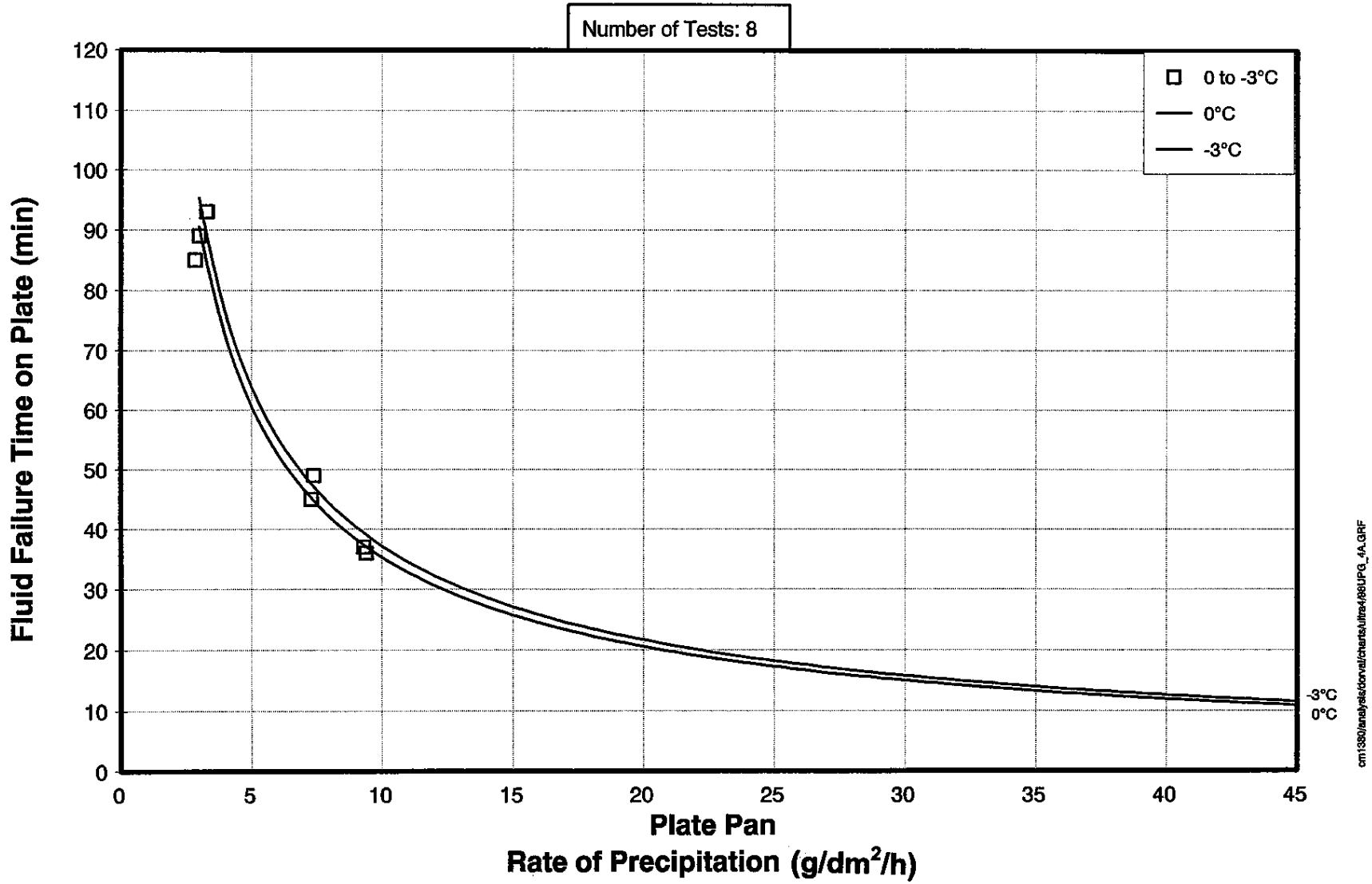


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR PG TYPE IV 50/50

NATURAL SNOW CONDITIONS

1997/98



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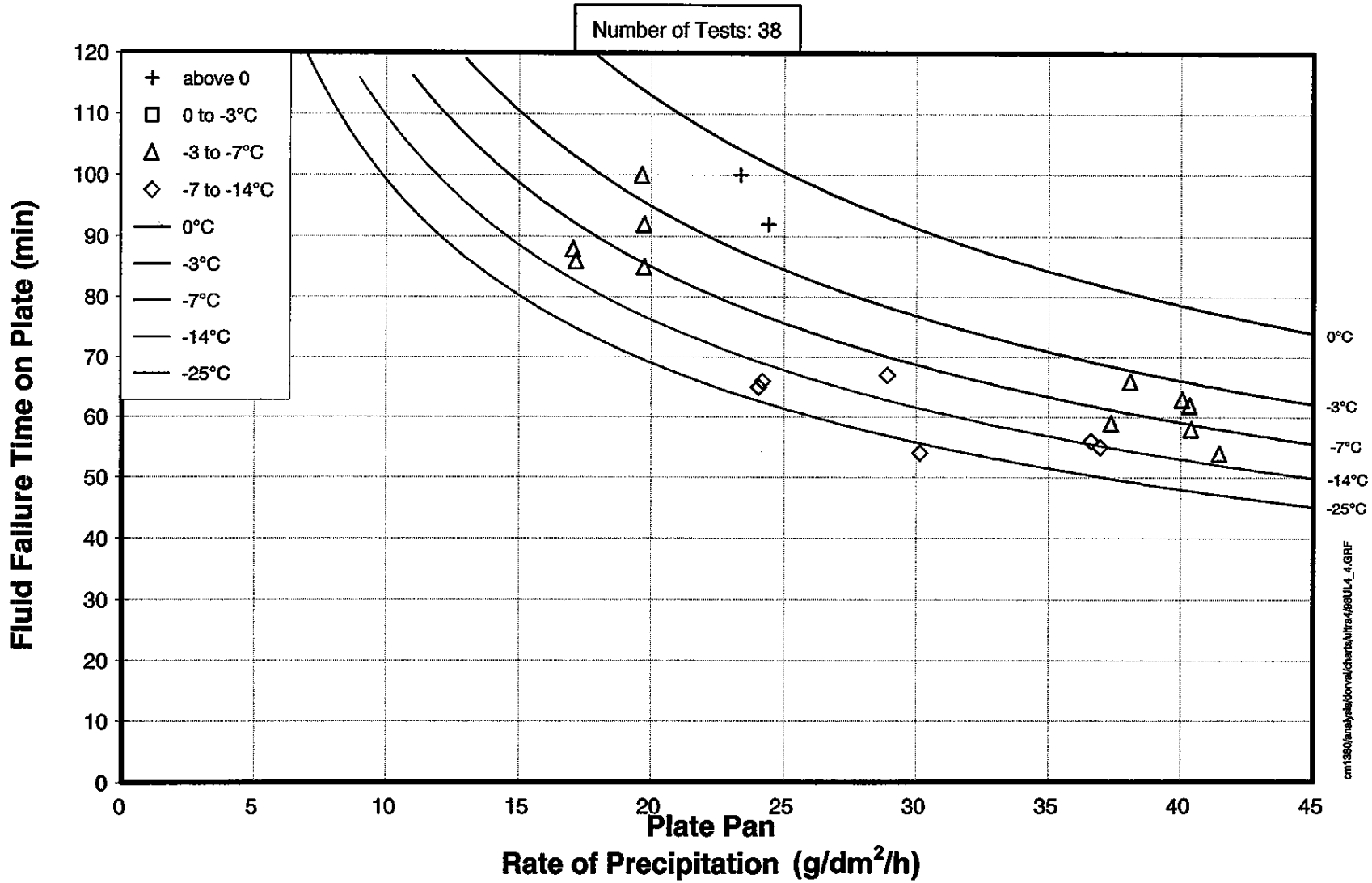
# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV NEAT

NATURAL SNOW CONDITIONS

1997/98

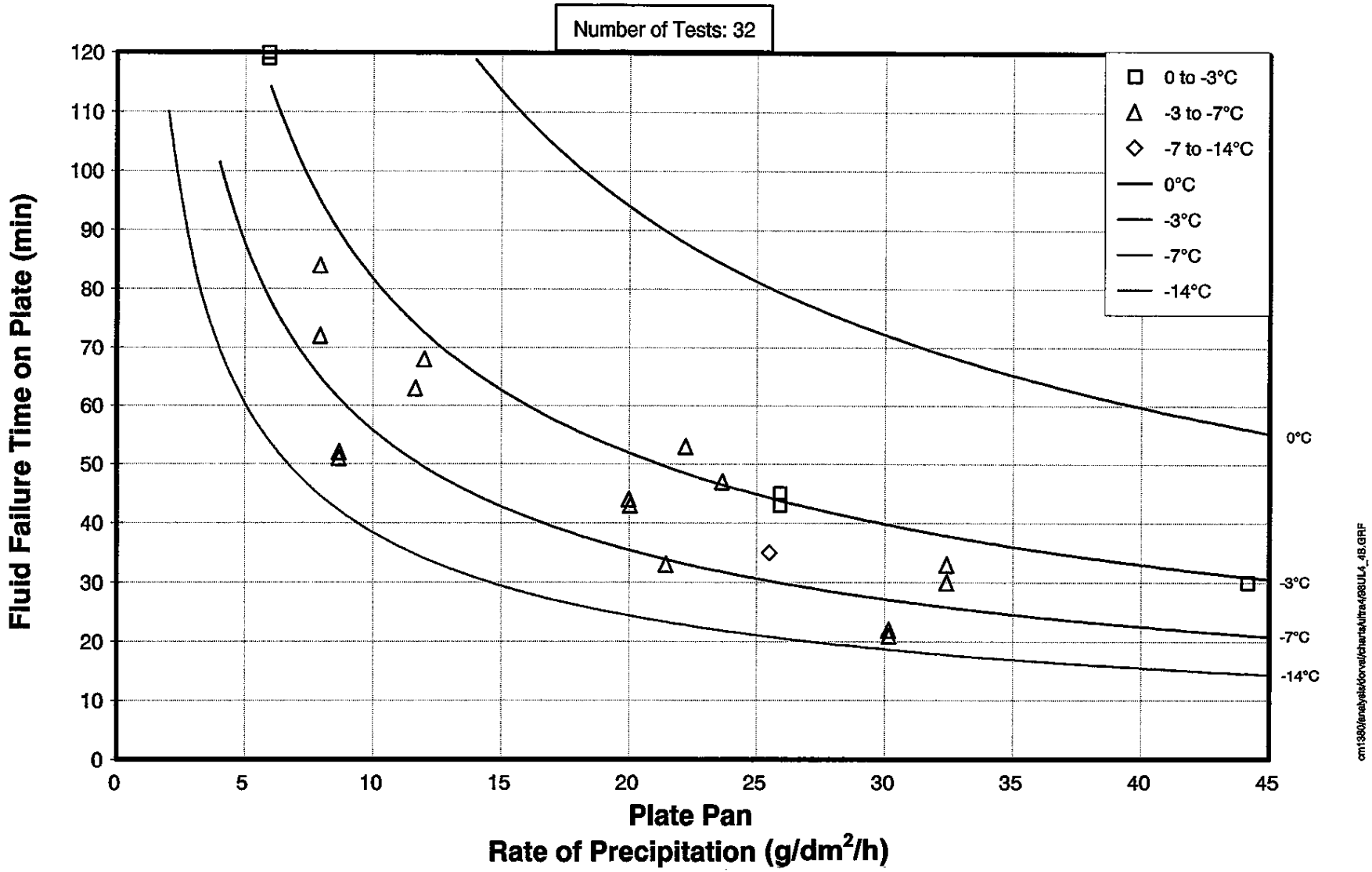


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV 75/25

NATURAL SNOW CONDITIONS

1997/98

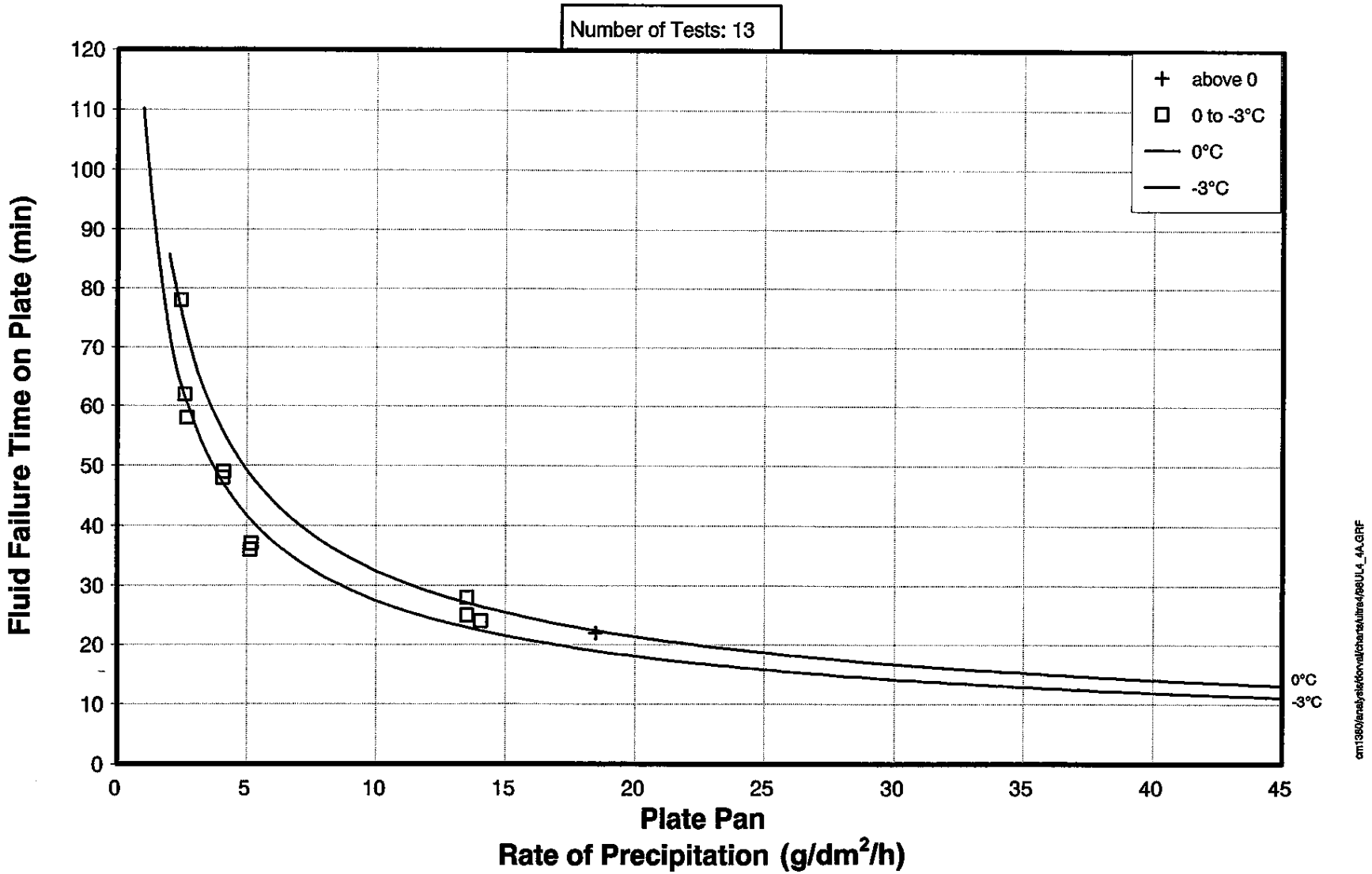


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV 50/50

NATURAL SNOW CONDITIONS

1997/98

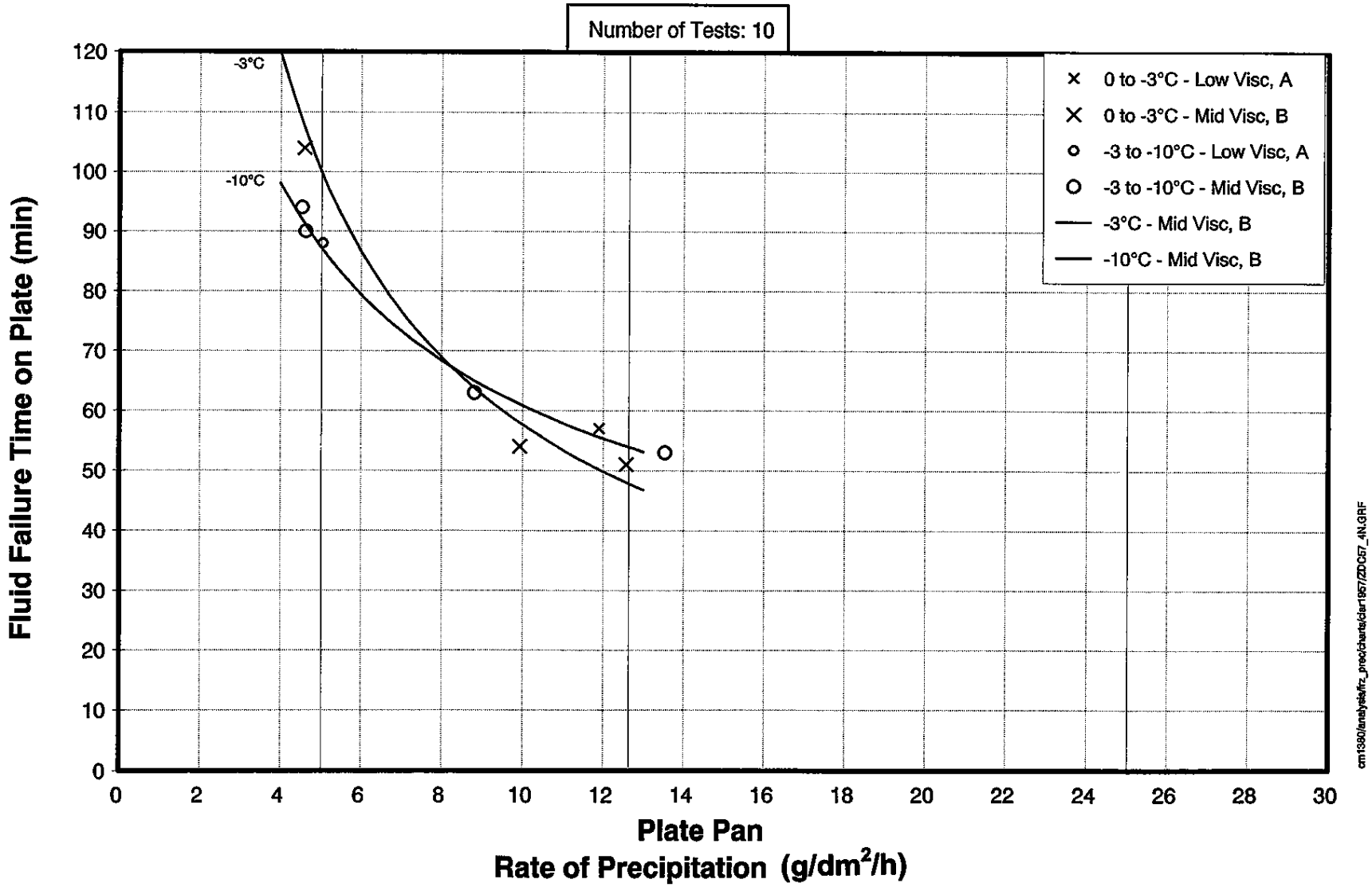


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 1957 TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1997/98

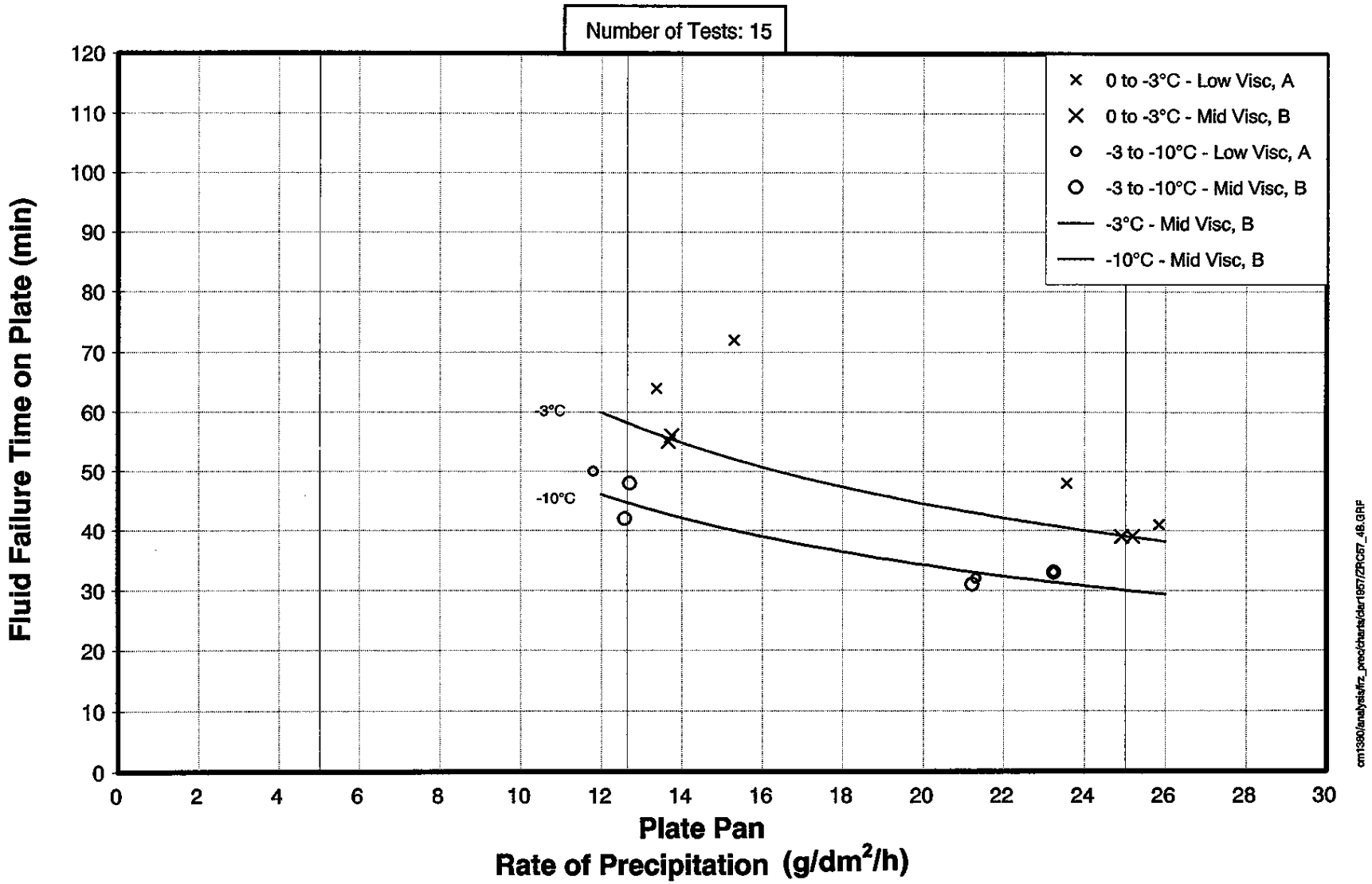


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 1957 TYPE IV NEAT

SIMULATED LIGHT FREEZING RAIN

1997/98

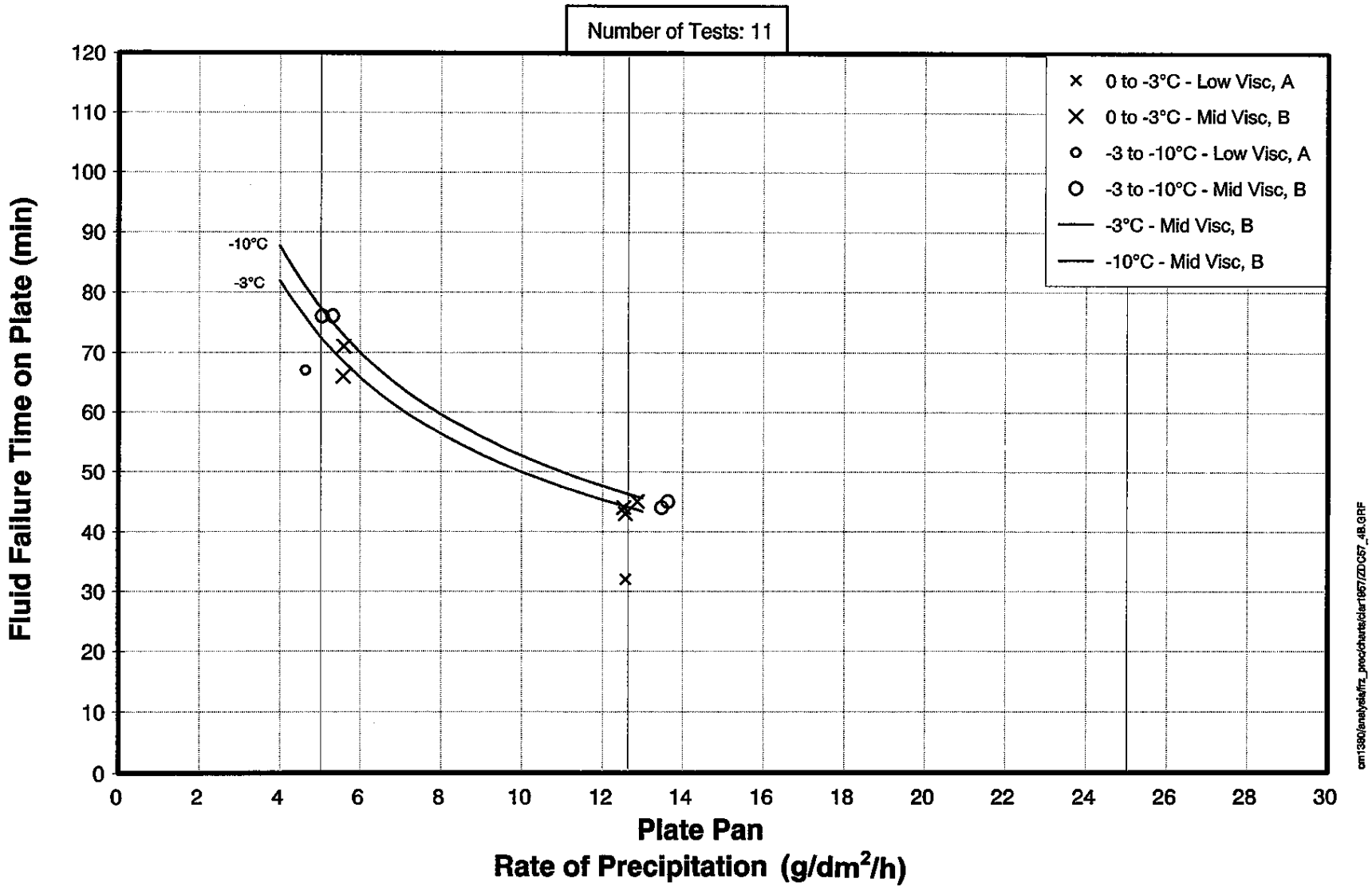


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 1957 TYPE IV 75/25

SIMULATED FREEZING DRIZZLE

1997/98



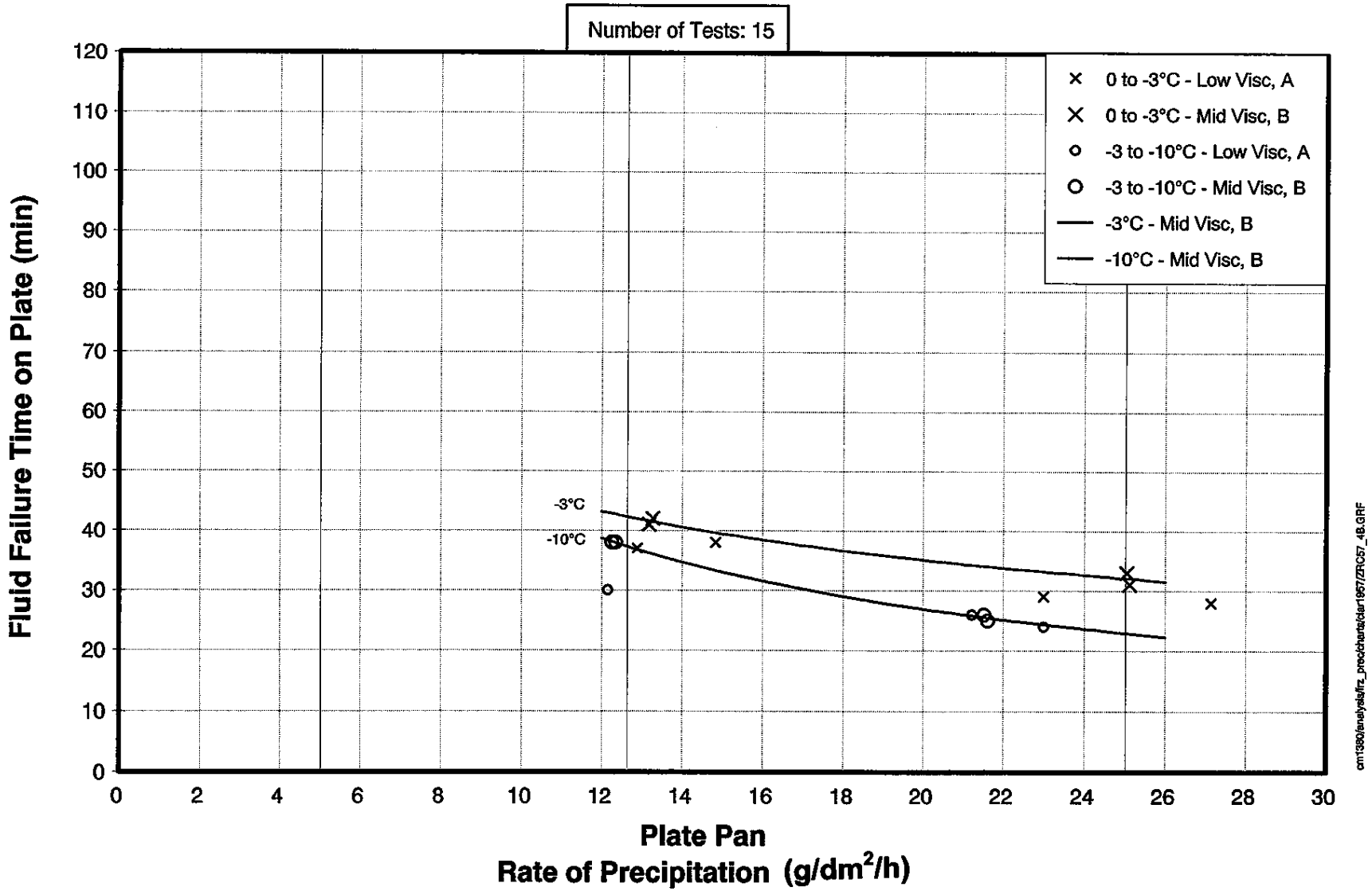

cm1380/analysis/frz_prec/charts/clar1957/ZDC57_4B.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 1957 TYPE IV 75/25

SIMULATED LIGHT FREEZING RAIN

1997/98

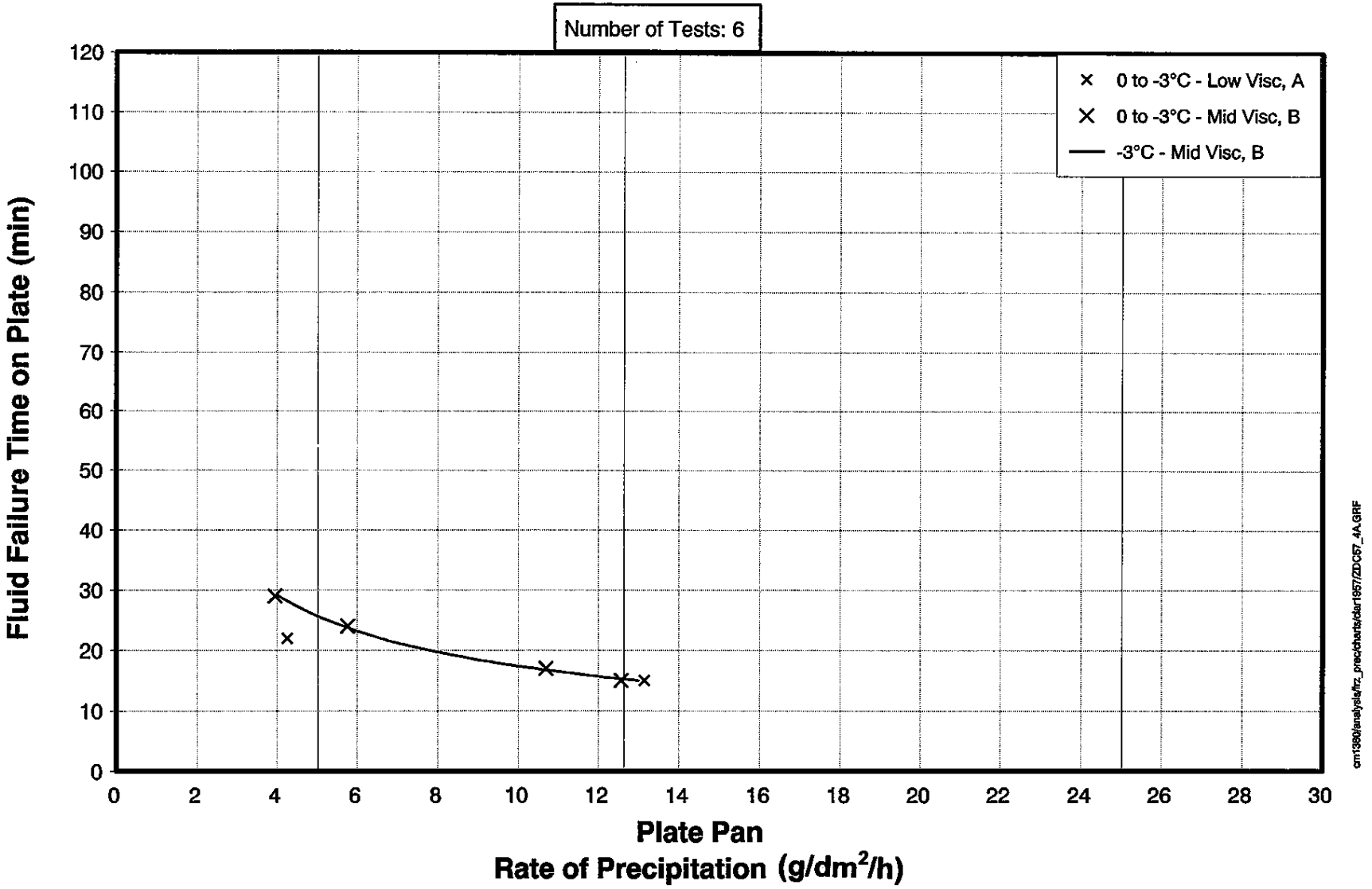


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 1957 TYPE IV 50/50

SIMULATED FREEZING DRIZZLE

1997/98

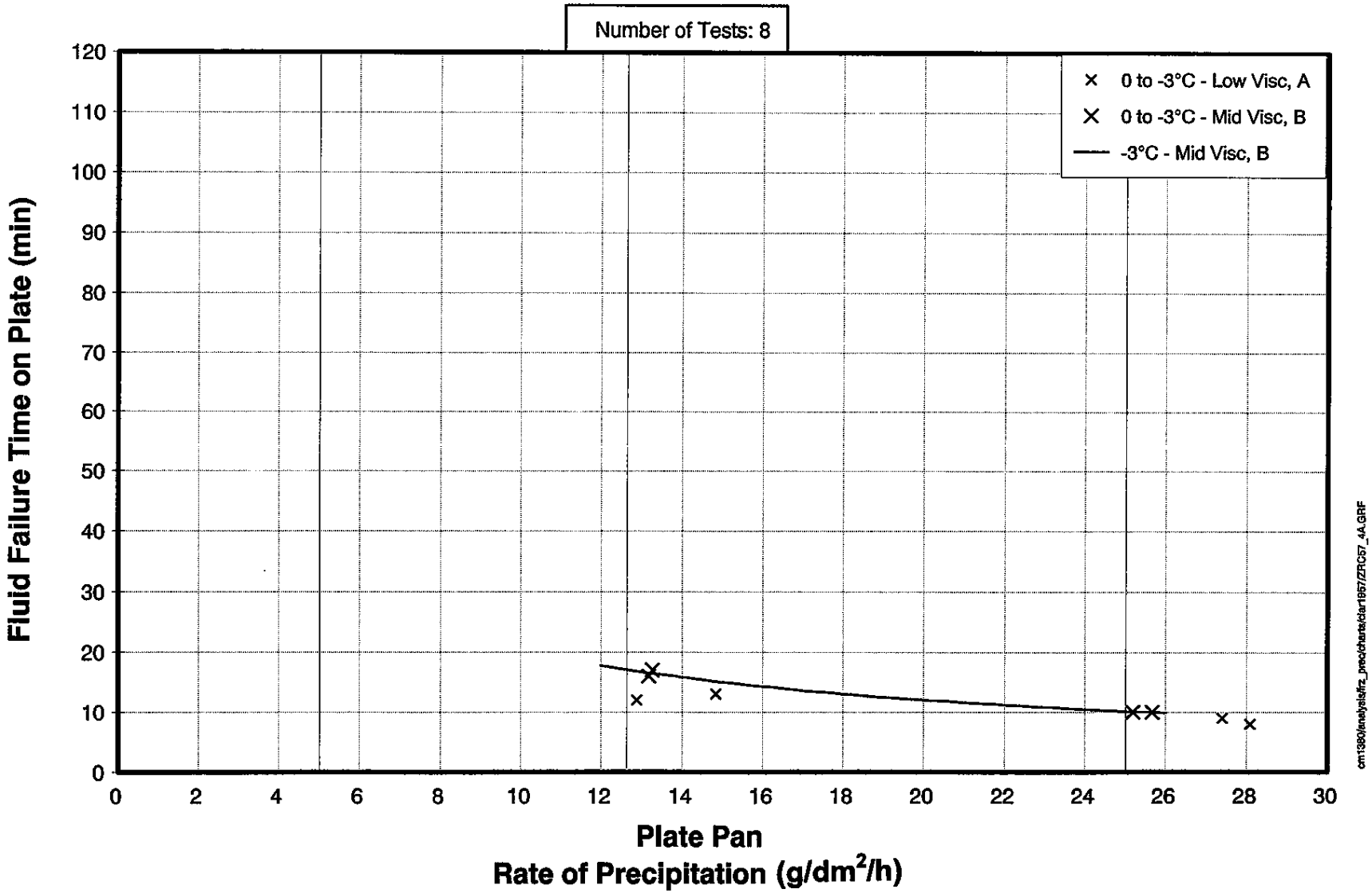


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 1957 TYPE IV 50/50

SIMULATED LIGHT FREEZING RAIN

1997/98

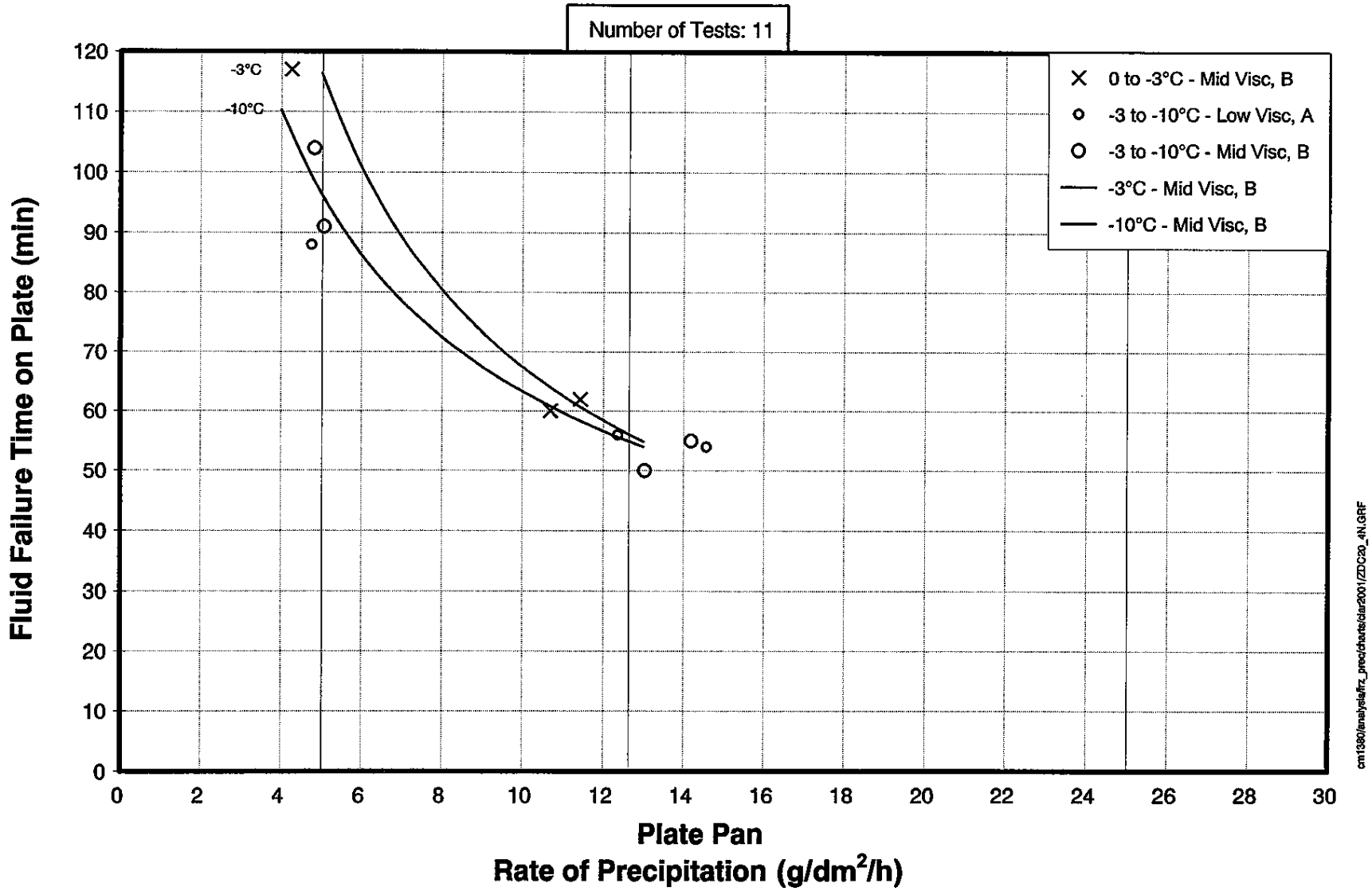


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 2001 TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1997/98

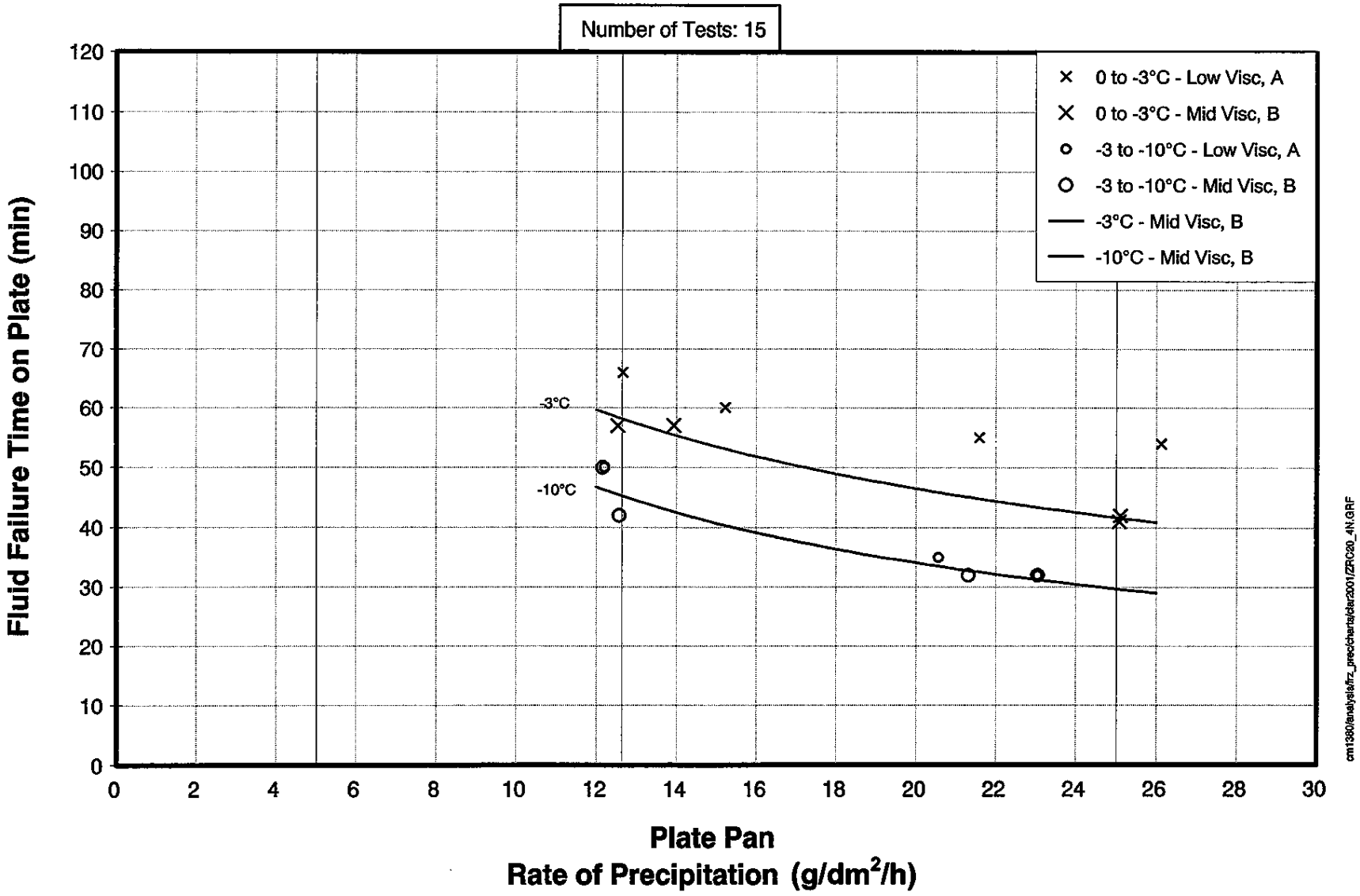


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 2001 TYPE IV NEAT

SIMULATED FREEZING RAIN

1997/98

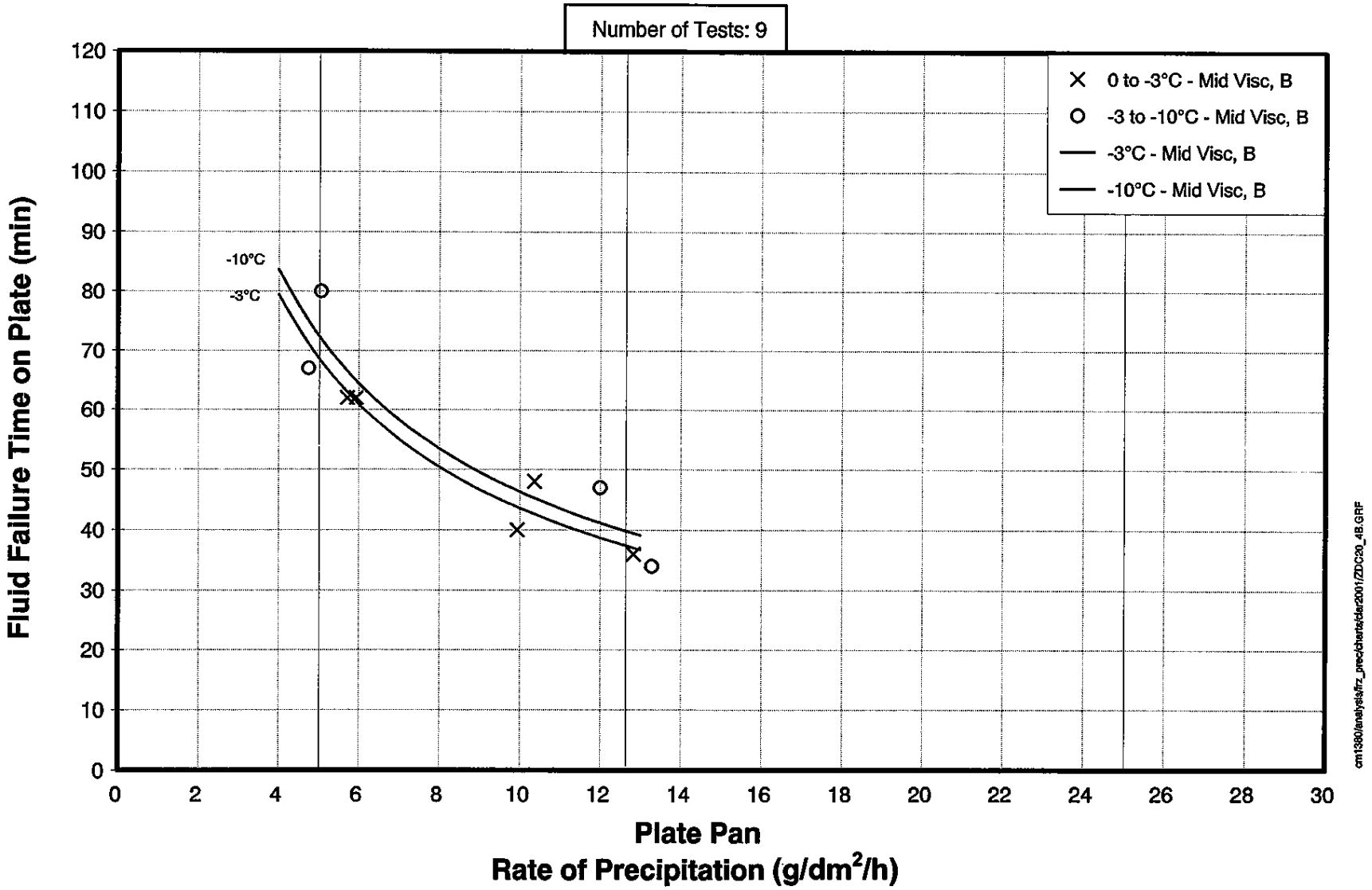


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 2001 TYPE IV 75/25

SIMULATED FREEZING DRIZZLE

1997/98

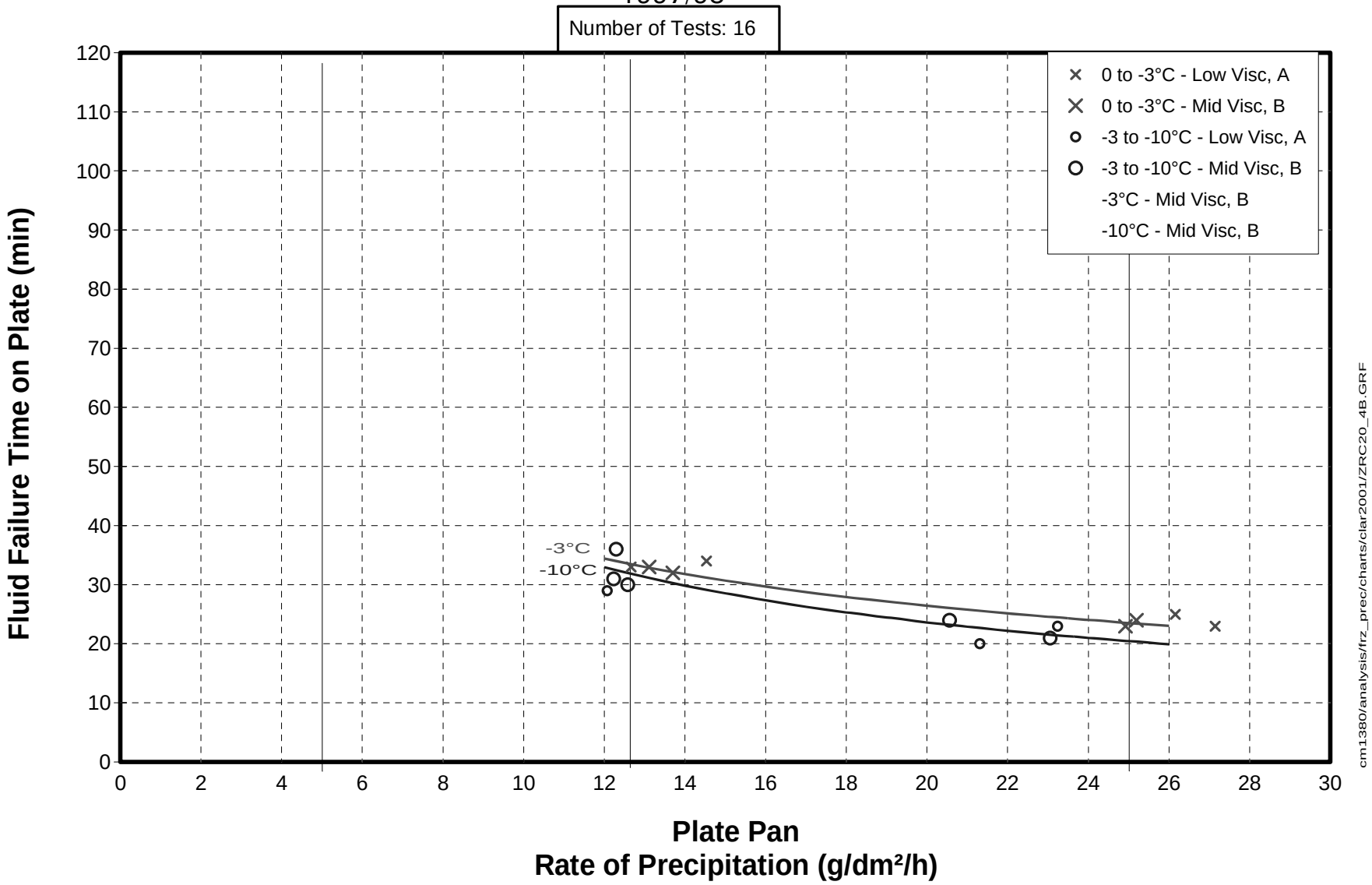


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 2001 TYPE IV 75/25

SIMULATED FREEZING RAIN

1997/98

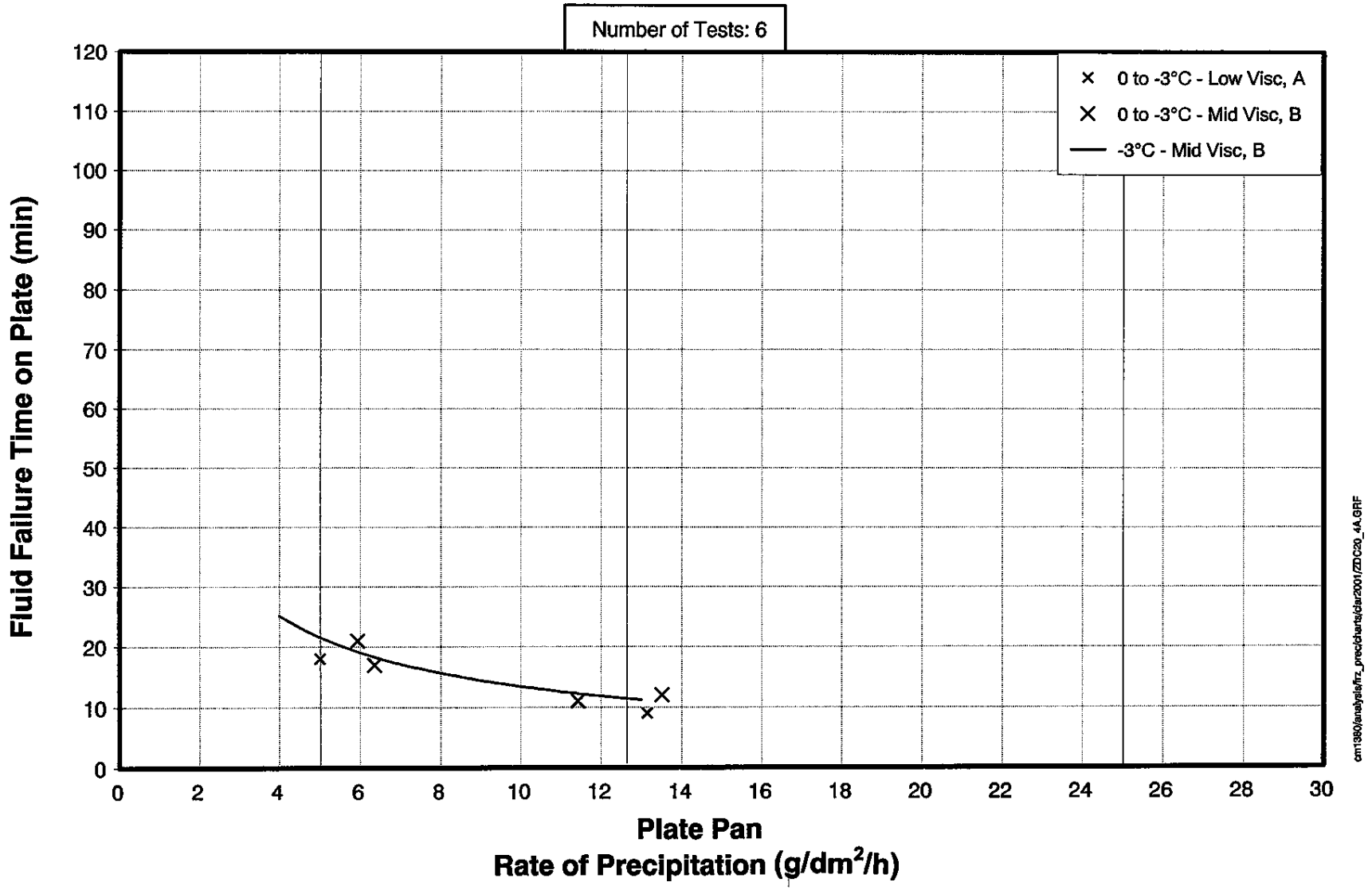


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 2001 TYPE IV 50/50

SIMULATED FREEZING DRIZZLE

1997/98

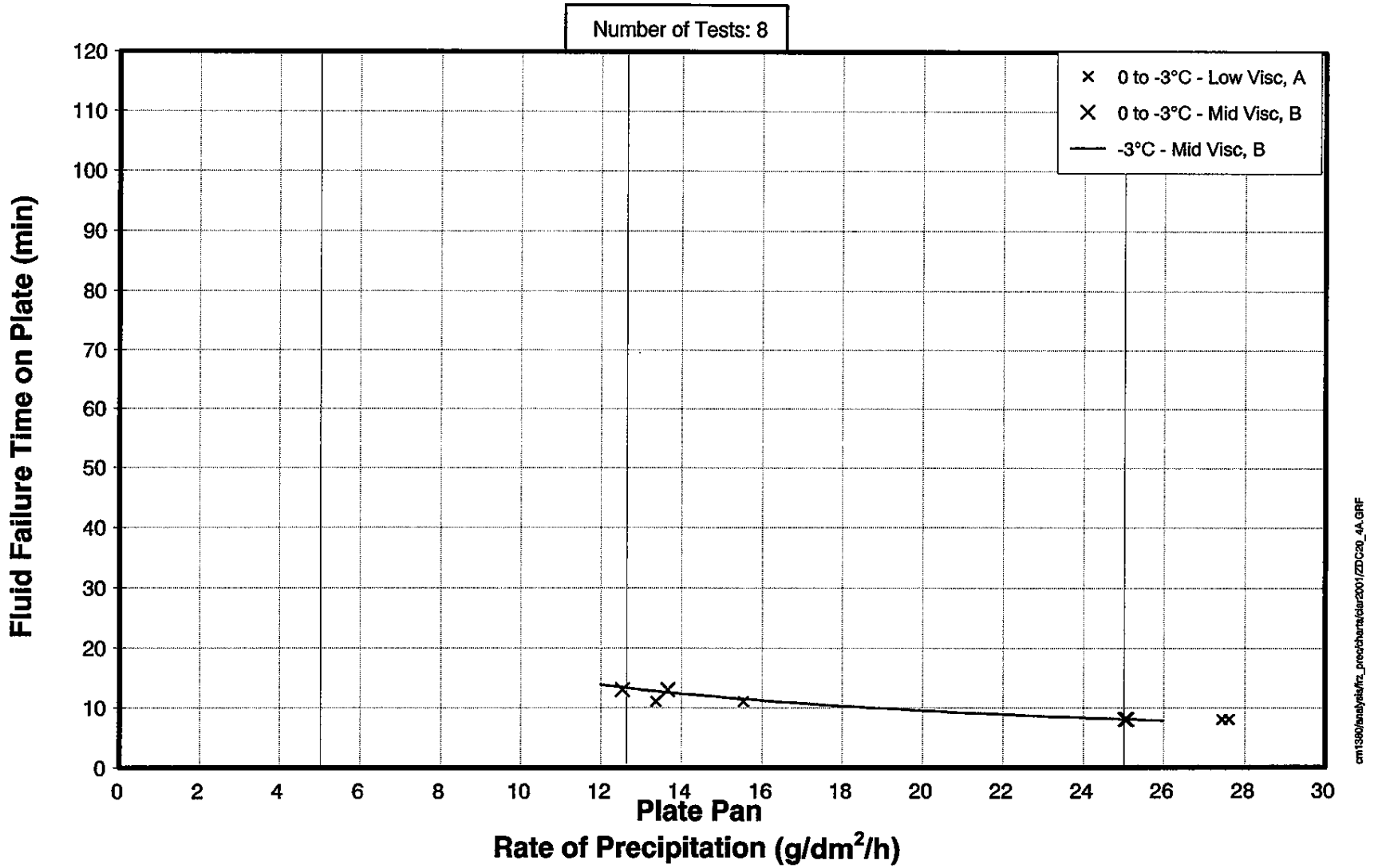


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## CLARIANT 2001 TYPE IV 50/50

SIMULATED FREEZING RAIN

1997/98

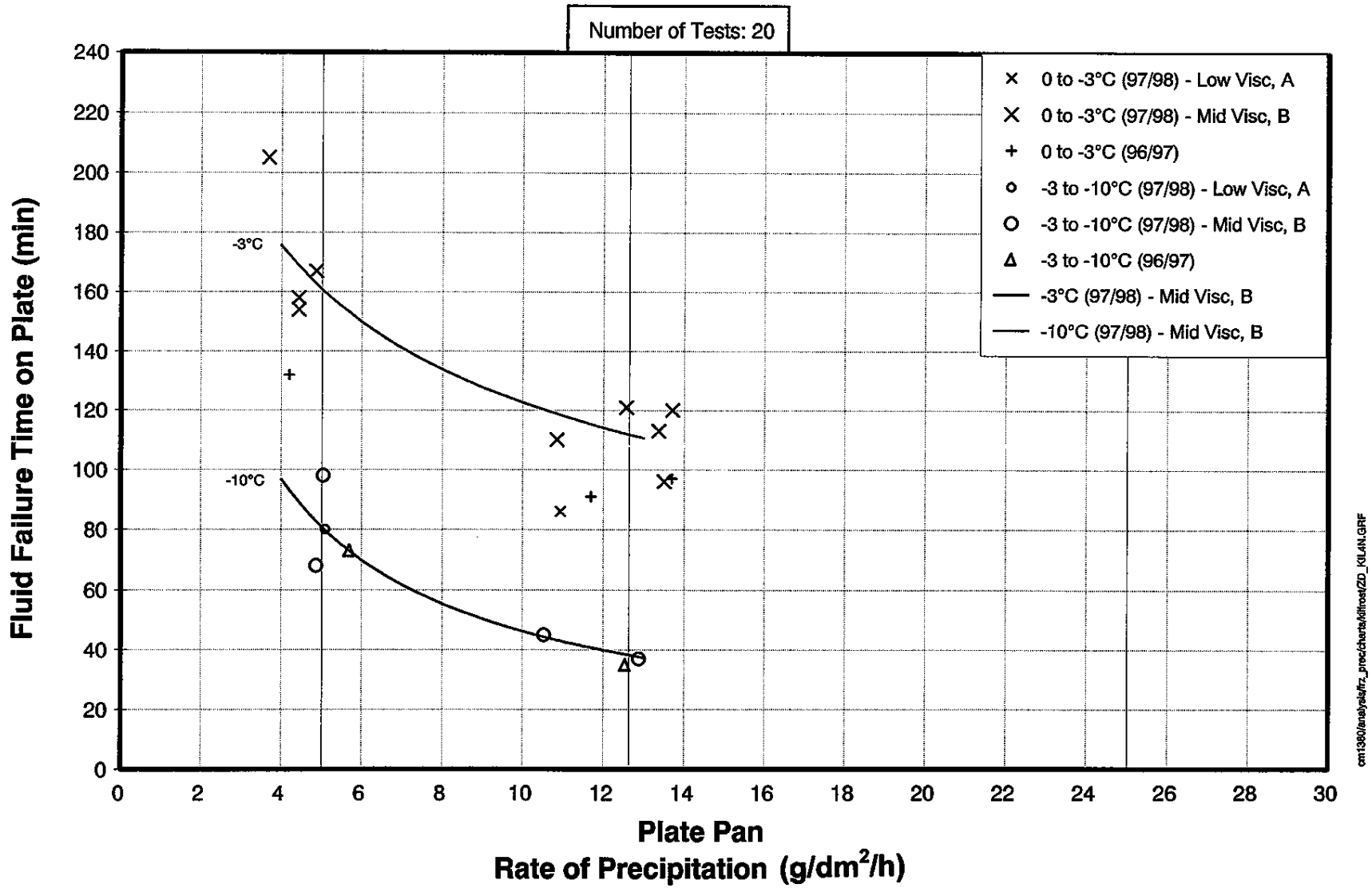


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1996/97 & 1997/98

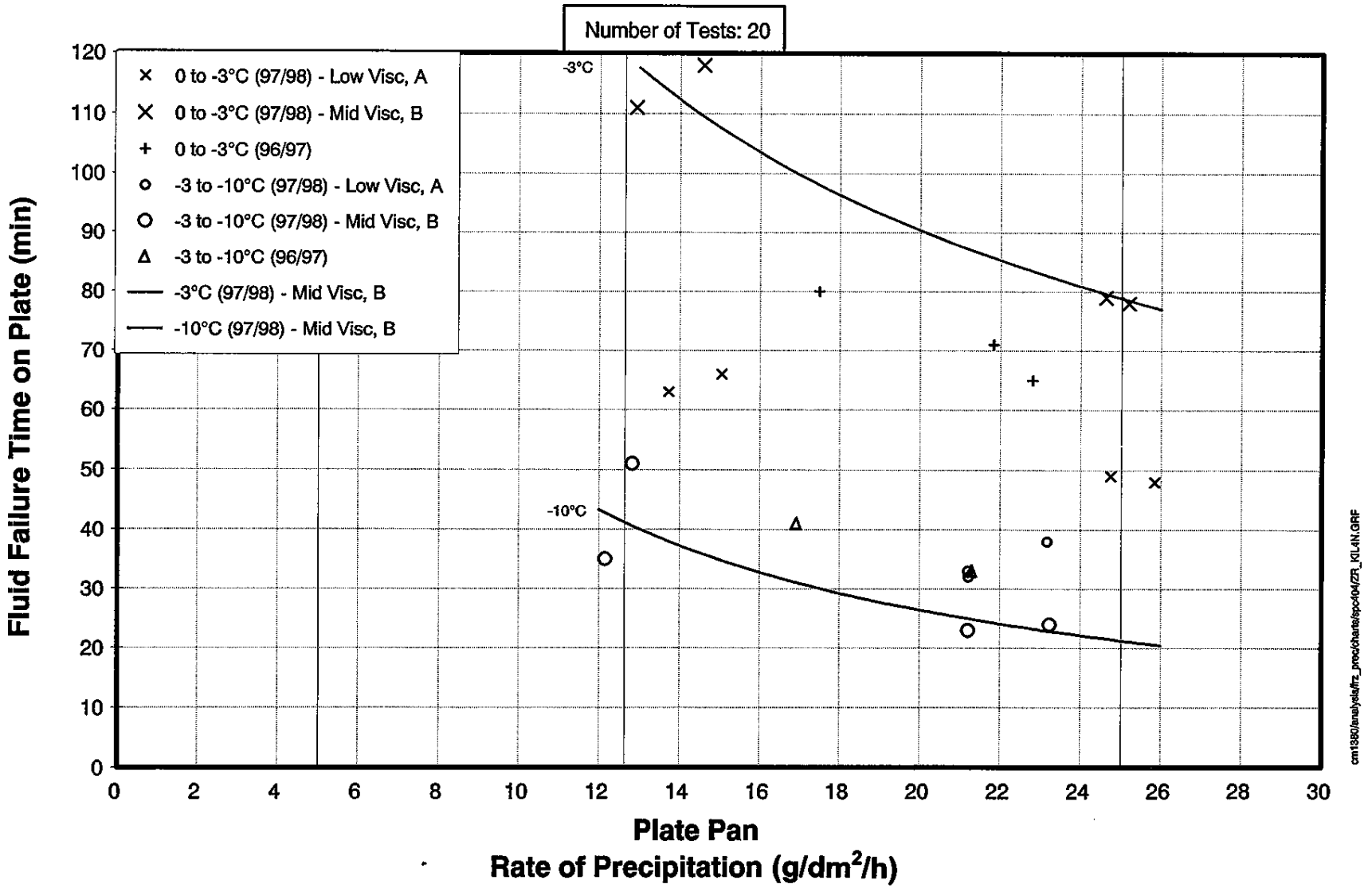


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV NEAT

SIMULATED LIGHT FREEZING RAIN

1996/97 & 1997/98

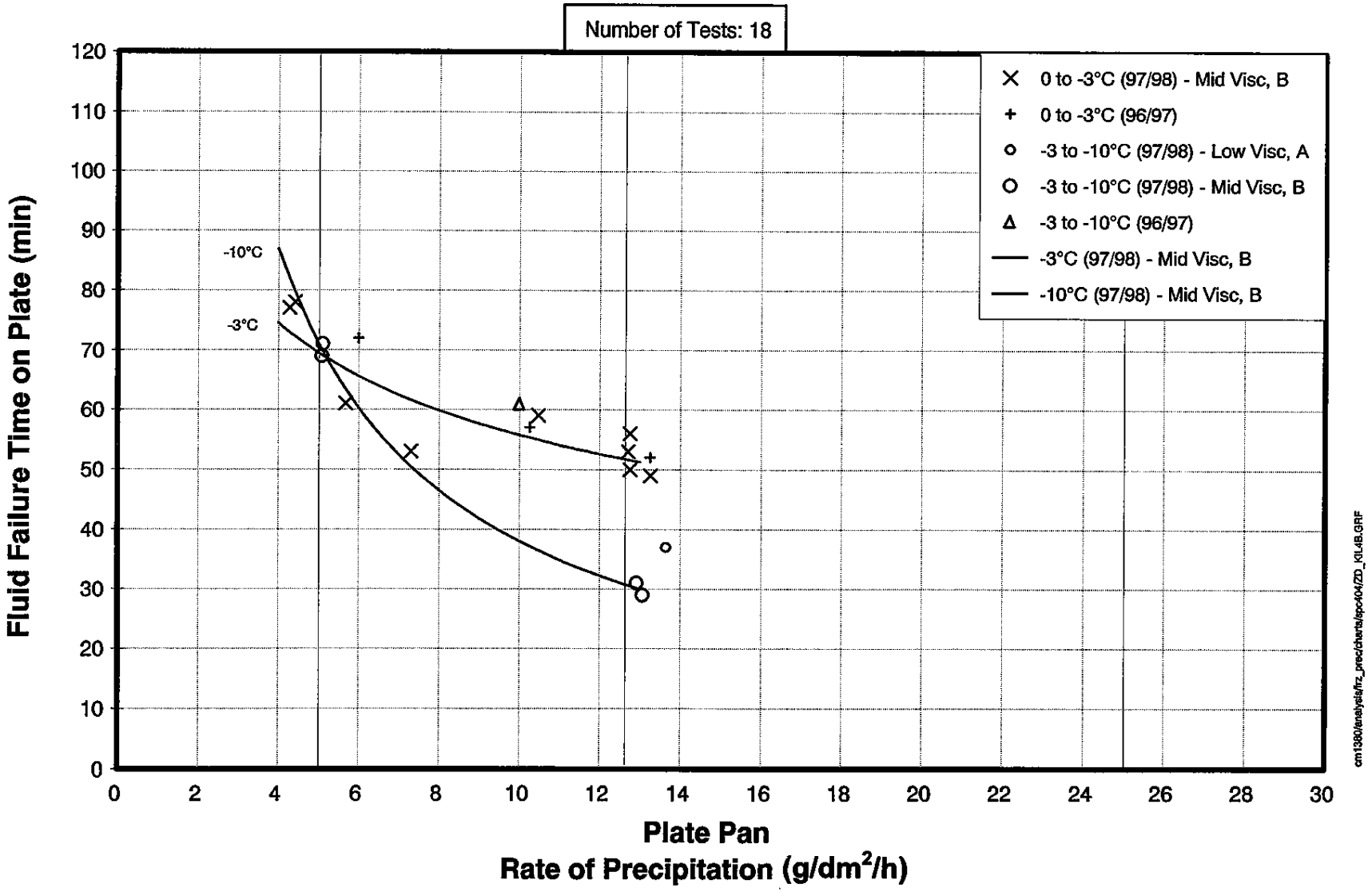


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV 75/25

SIMULATED FREEZING DRIZZLE

1996/97 & 1997/98

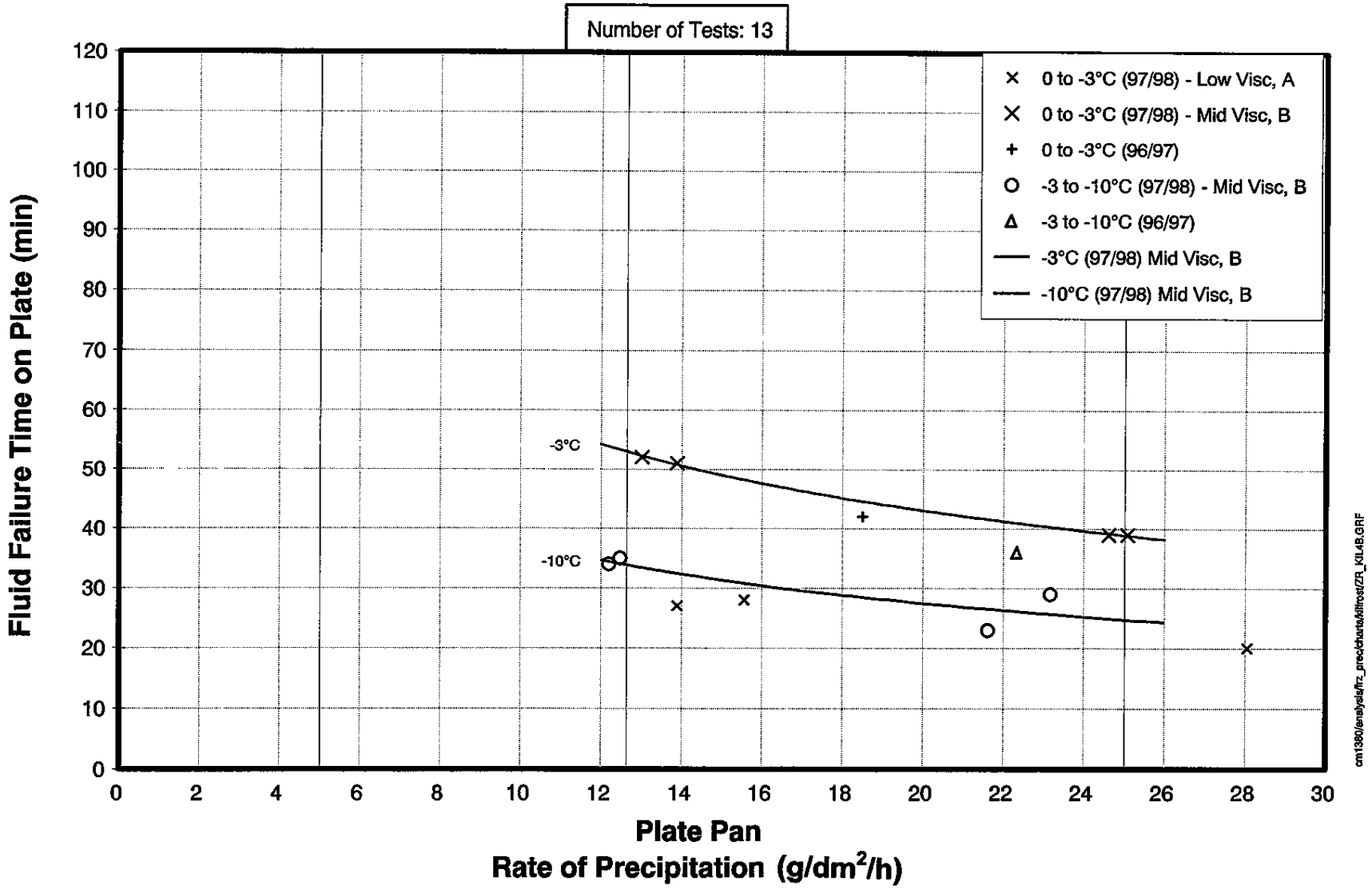


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV 75/25

SIMULATED LIGHT FREEZING RAIN

1996/97 & 1997/98

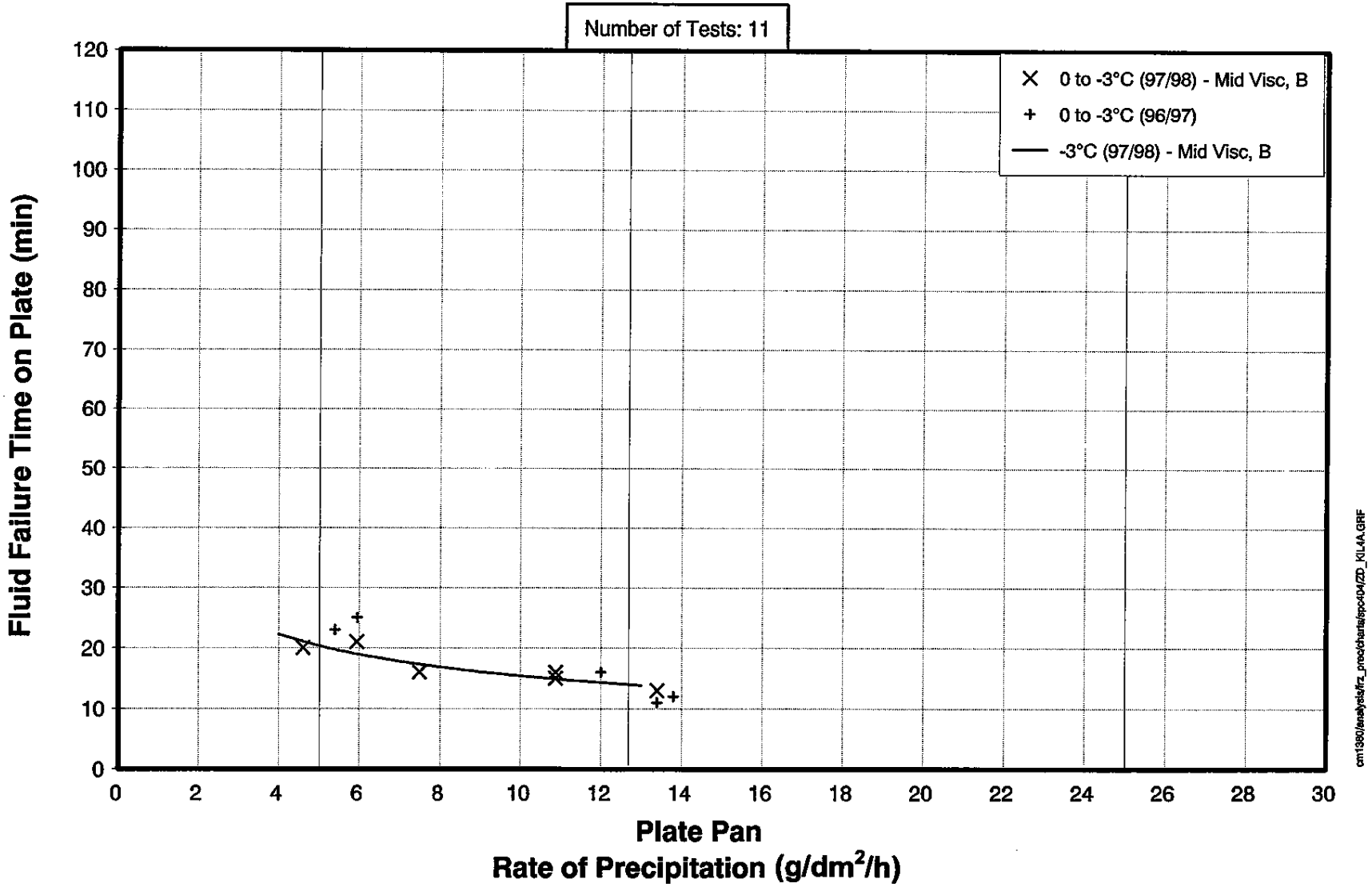


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV 50/50

SIMULATED FREEZING DRIZZLE

1996/97 & 1997/98

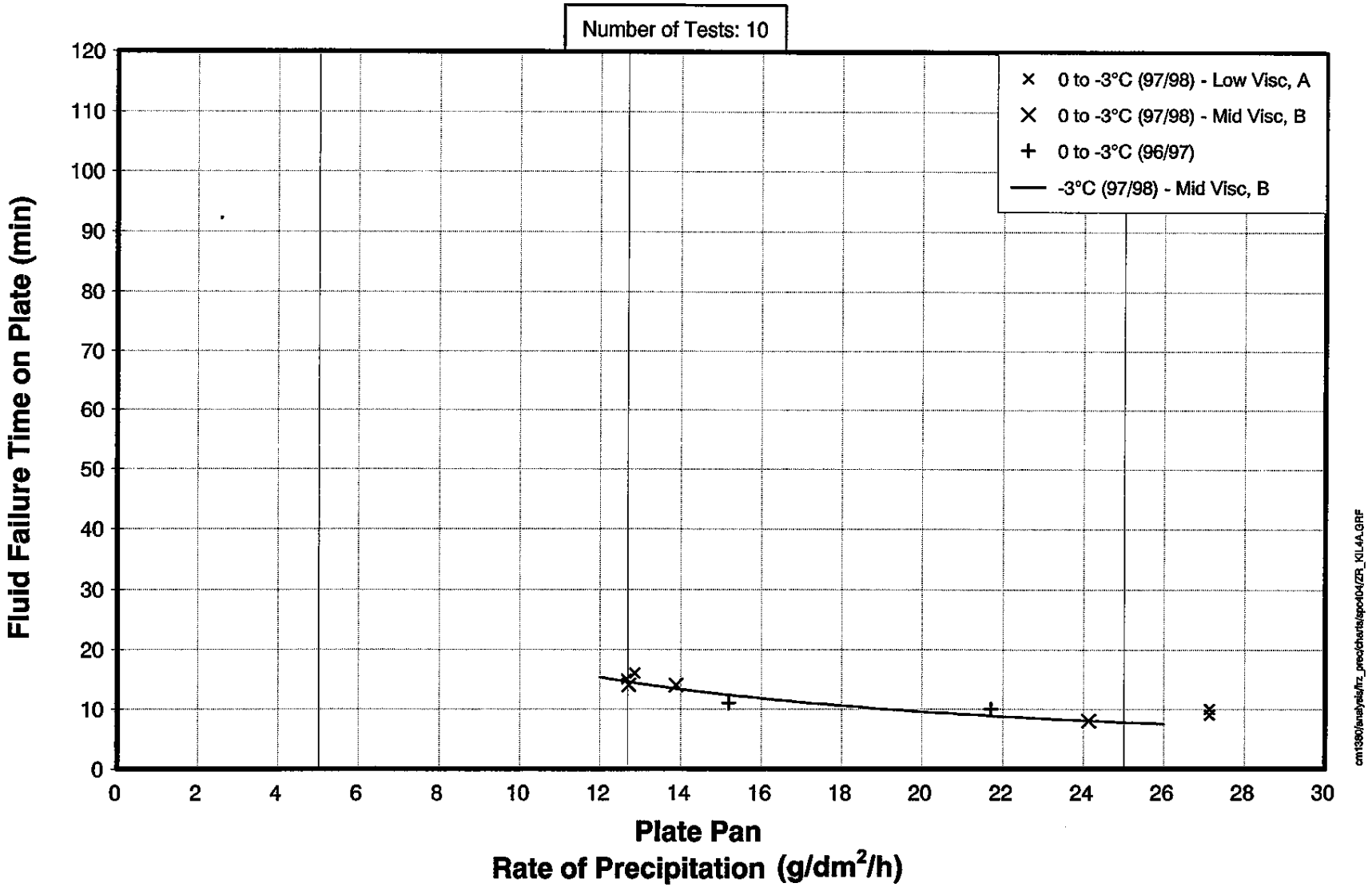


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## KILFROST TYPE IV 50/50

SIMULATED LIGHT FREEZING RAIN

1996/97 & 1997/98

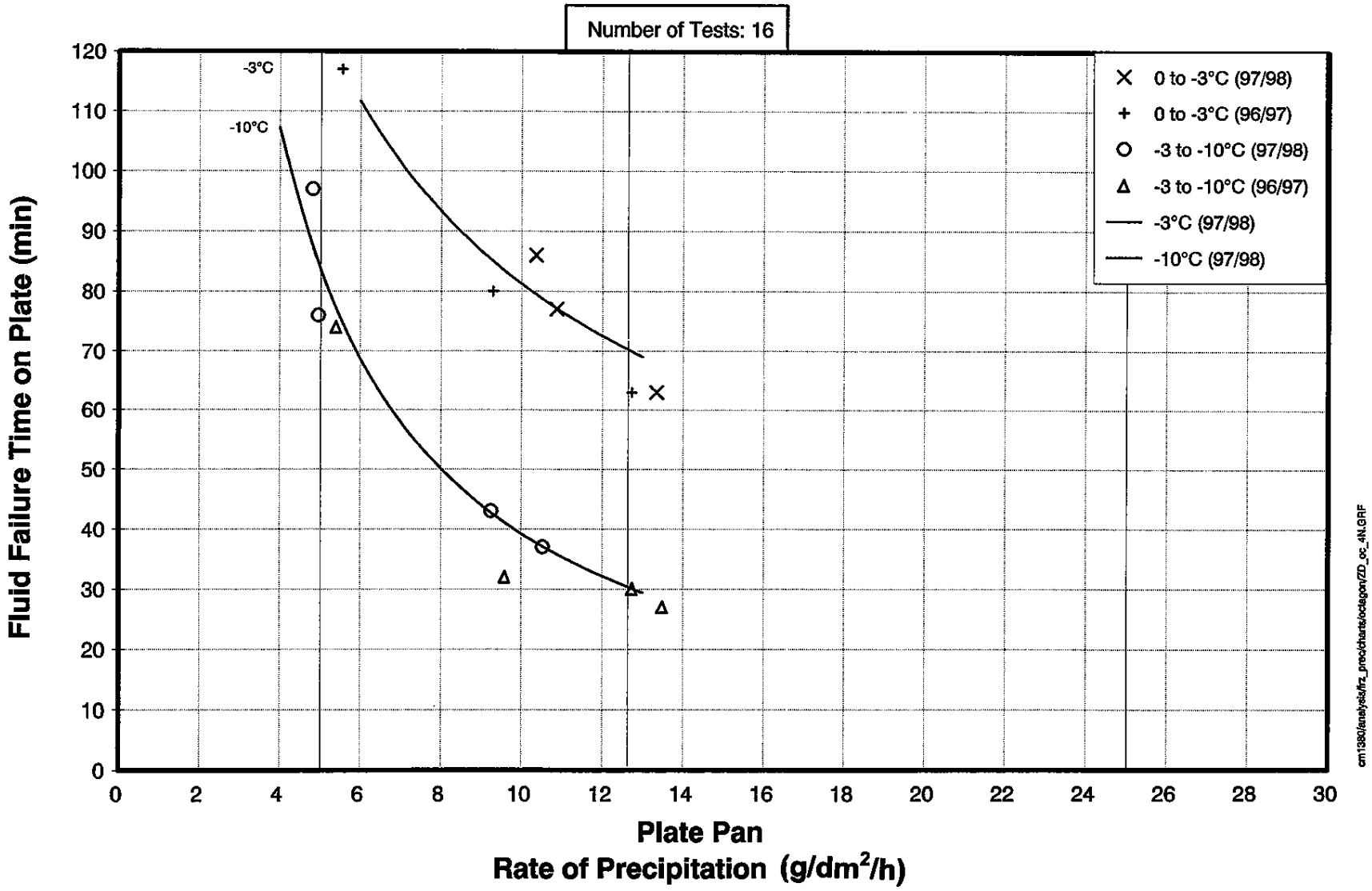


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1996/97 & 1997/98



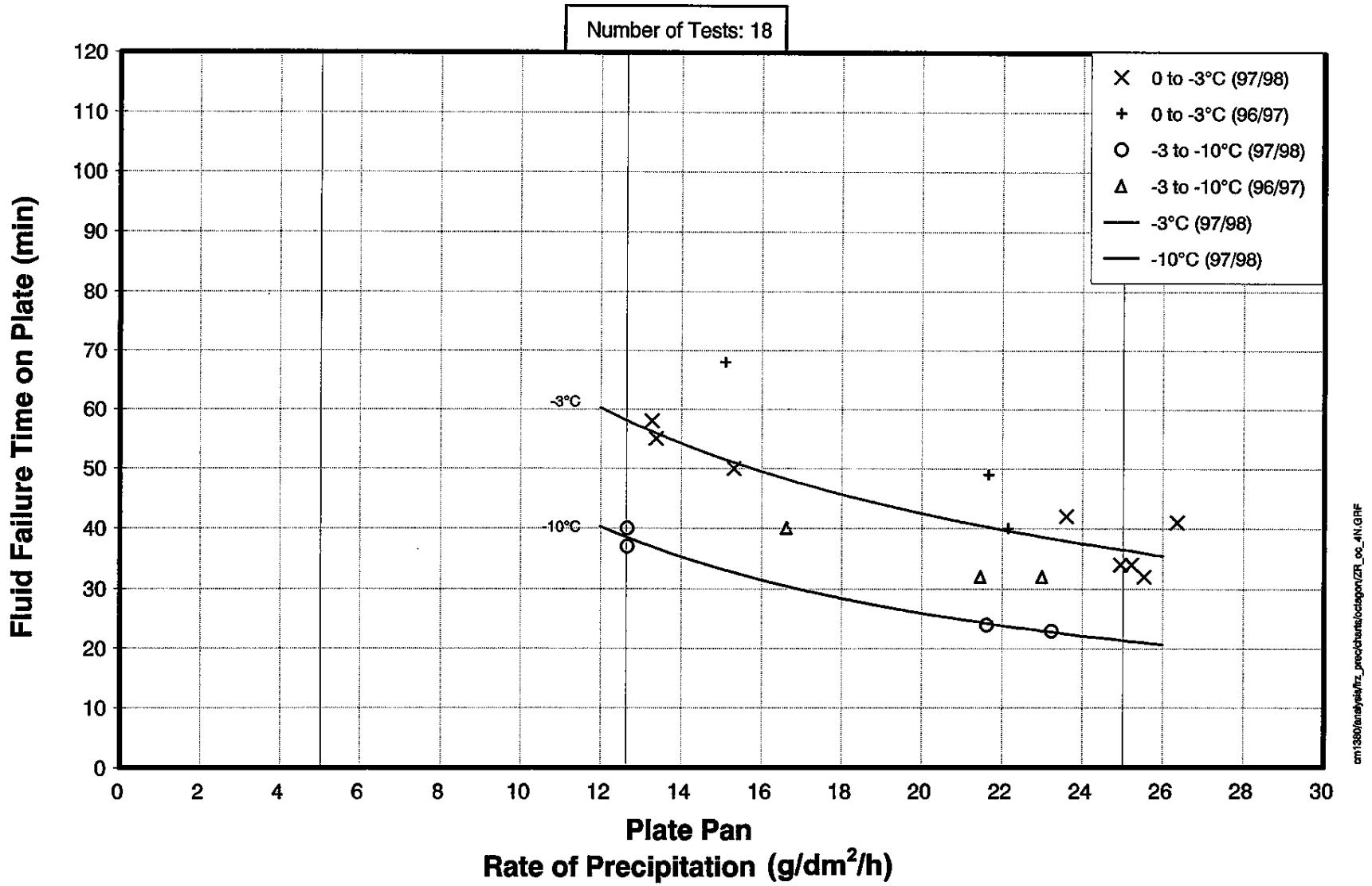

cm1380/analysis/frz_pnoc/charts/octagon/ZD_oc_4N.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE IV NEAT

SIMULATED FREEZING RAIN

1996/97 & 1997/98

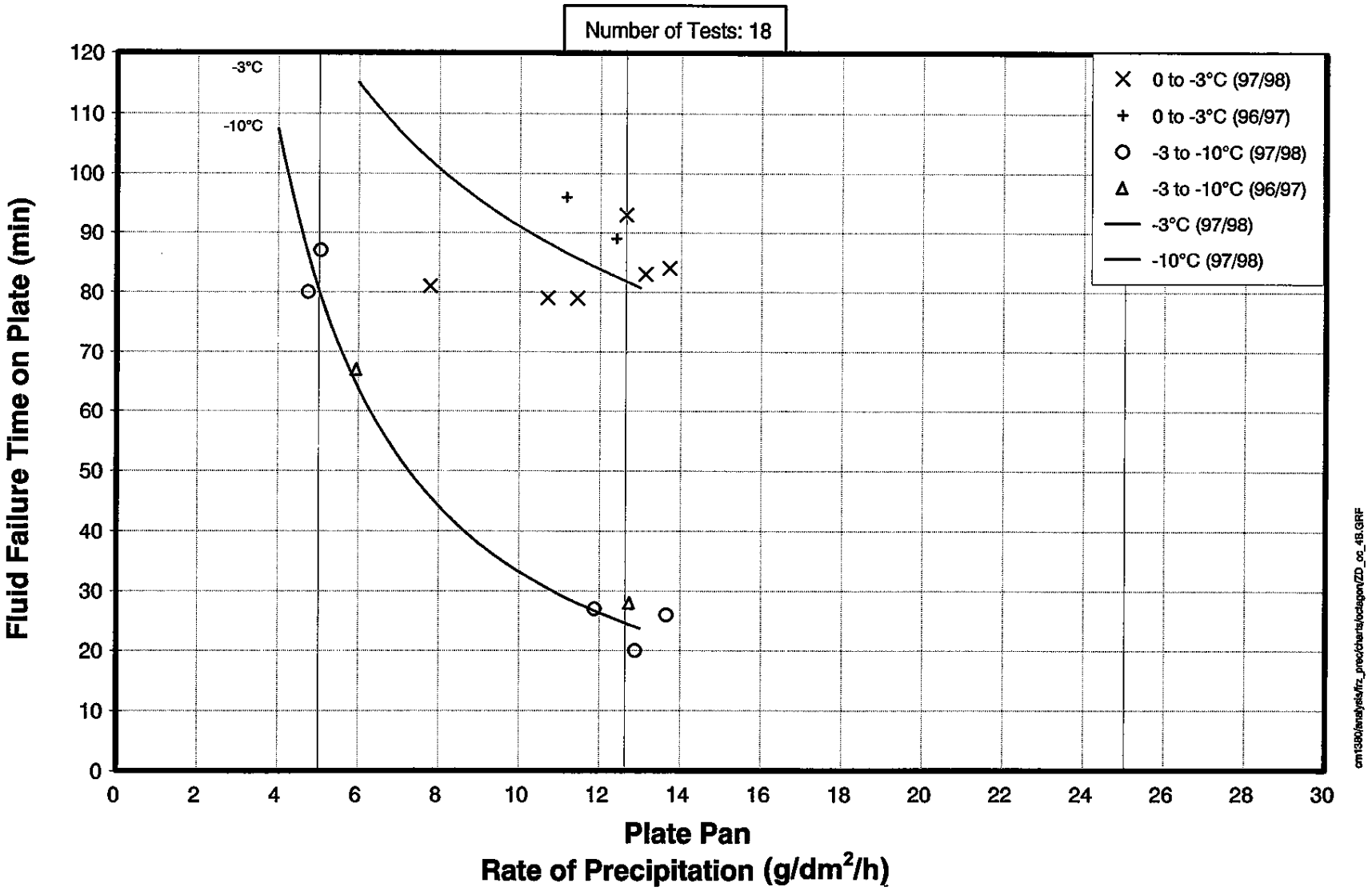


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE IV 75/25

SIMULATED FREEZING DRIZZLE

1996/97 & 1997/98



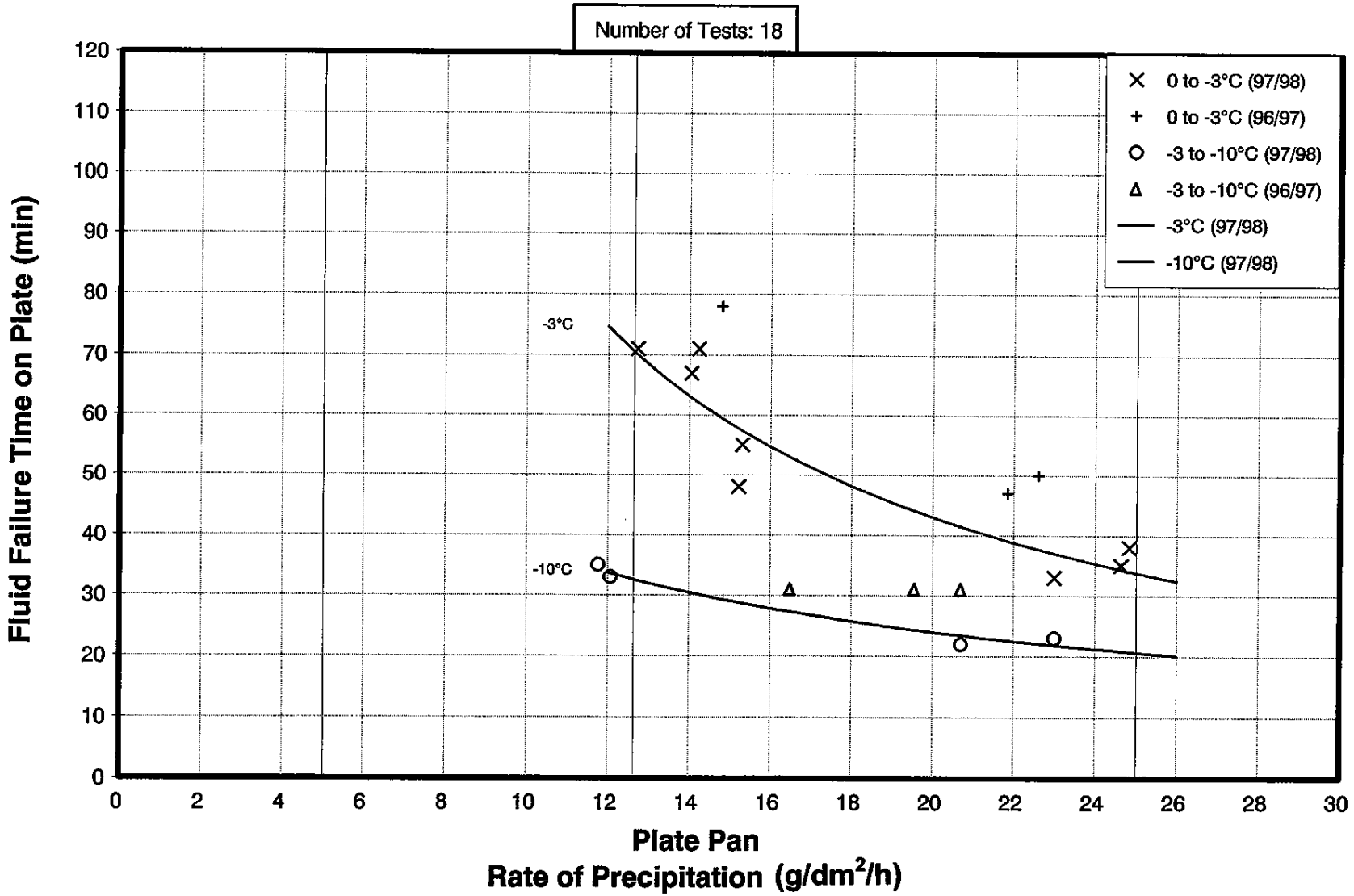

cm1380/analysis/frz_prec/charts/octagon/ZD_oc_48.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE IV 75/25

SIMULATED FREEZING RAIN

1996/97 & 1997/98



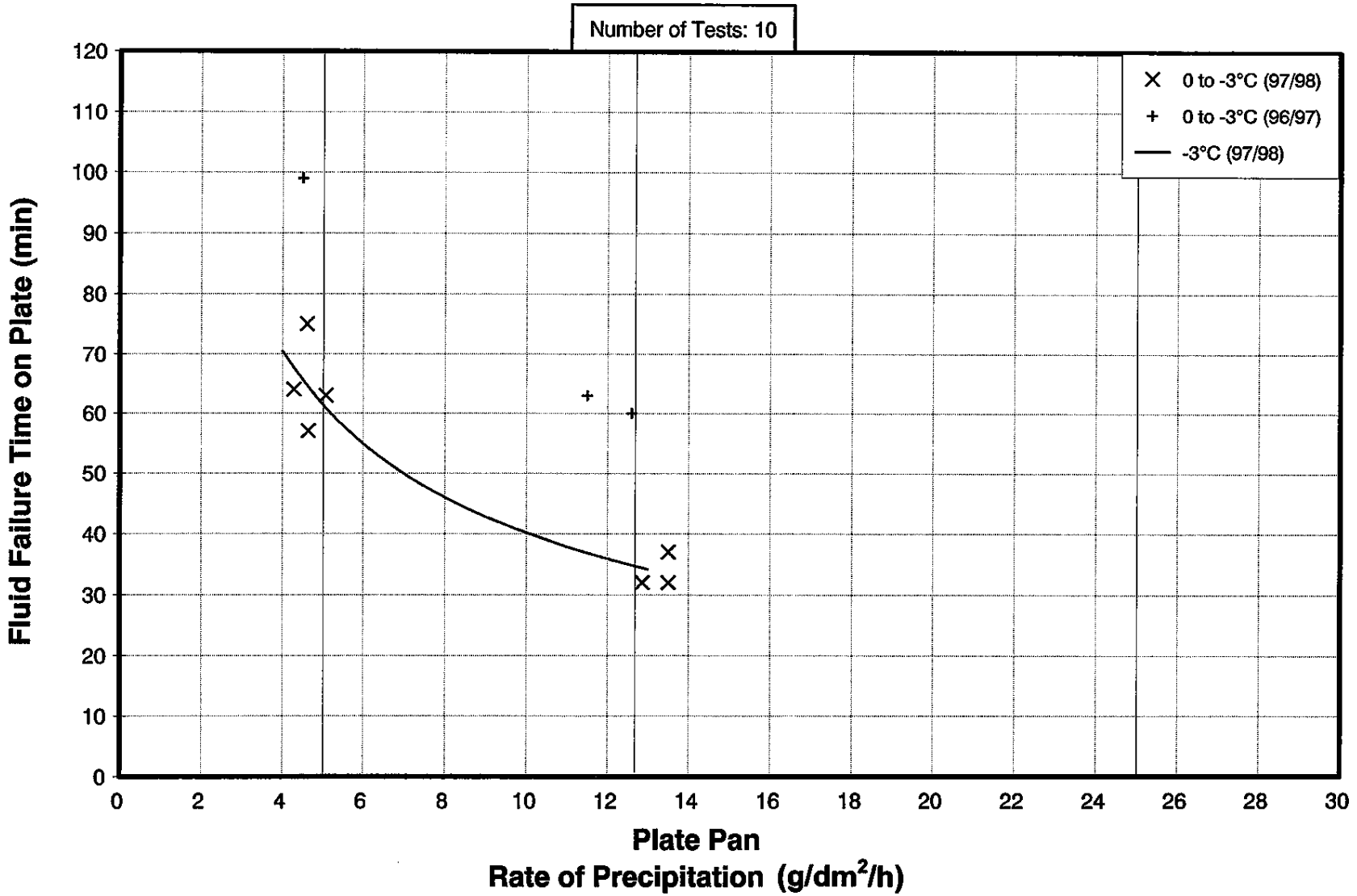

cm1390/analysis/frz_prec/charts/octagon/ZR_oc_4B.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE IV 50/50

SIMULATED FREEZING DRIZZLE

1996/97 & 1997/98

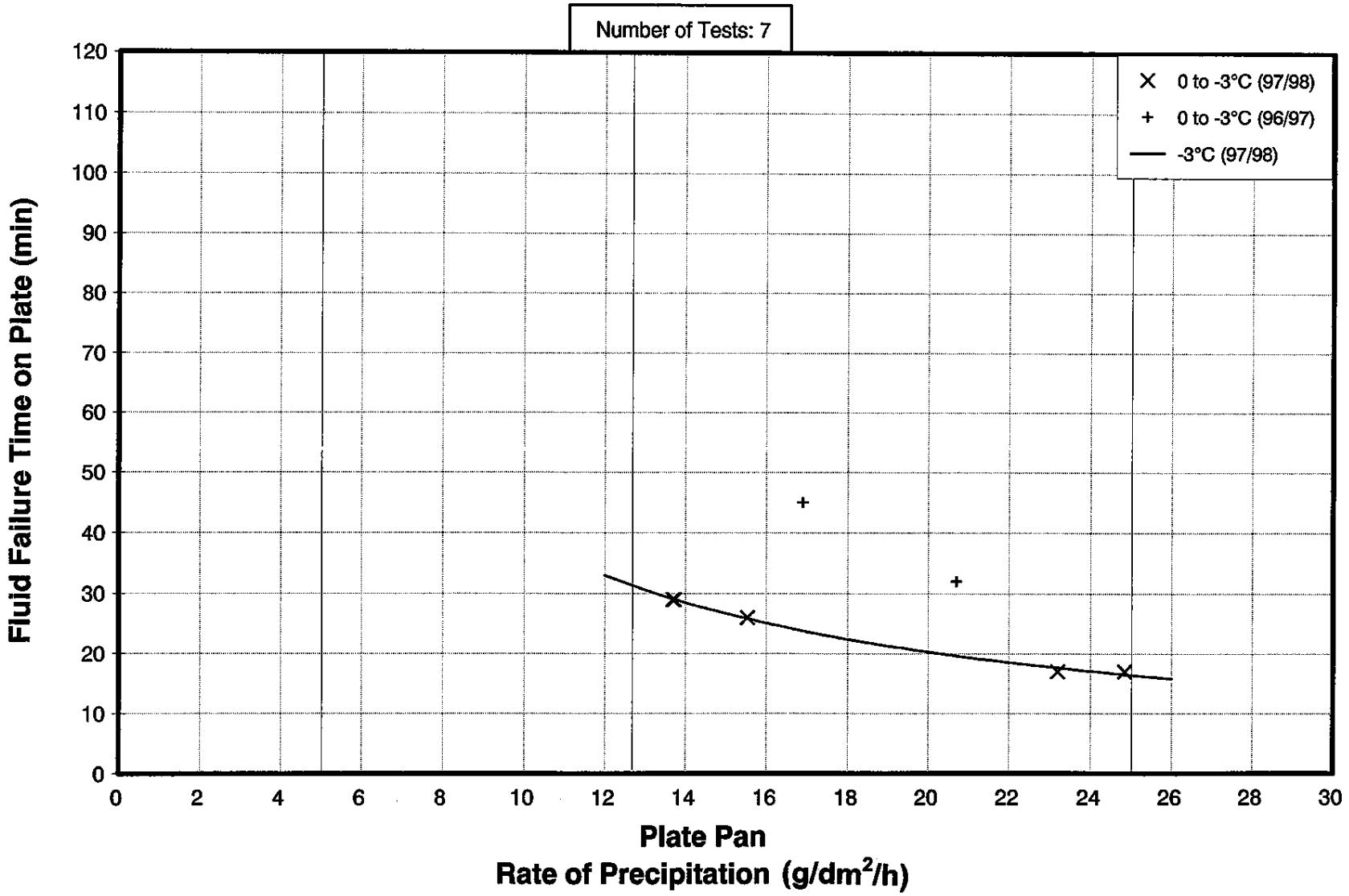


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE IV 50/50

SIMULATED FREEZING RAIN

1996/97 & 1997/98

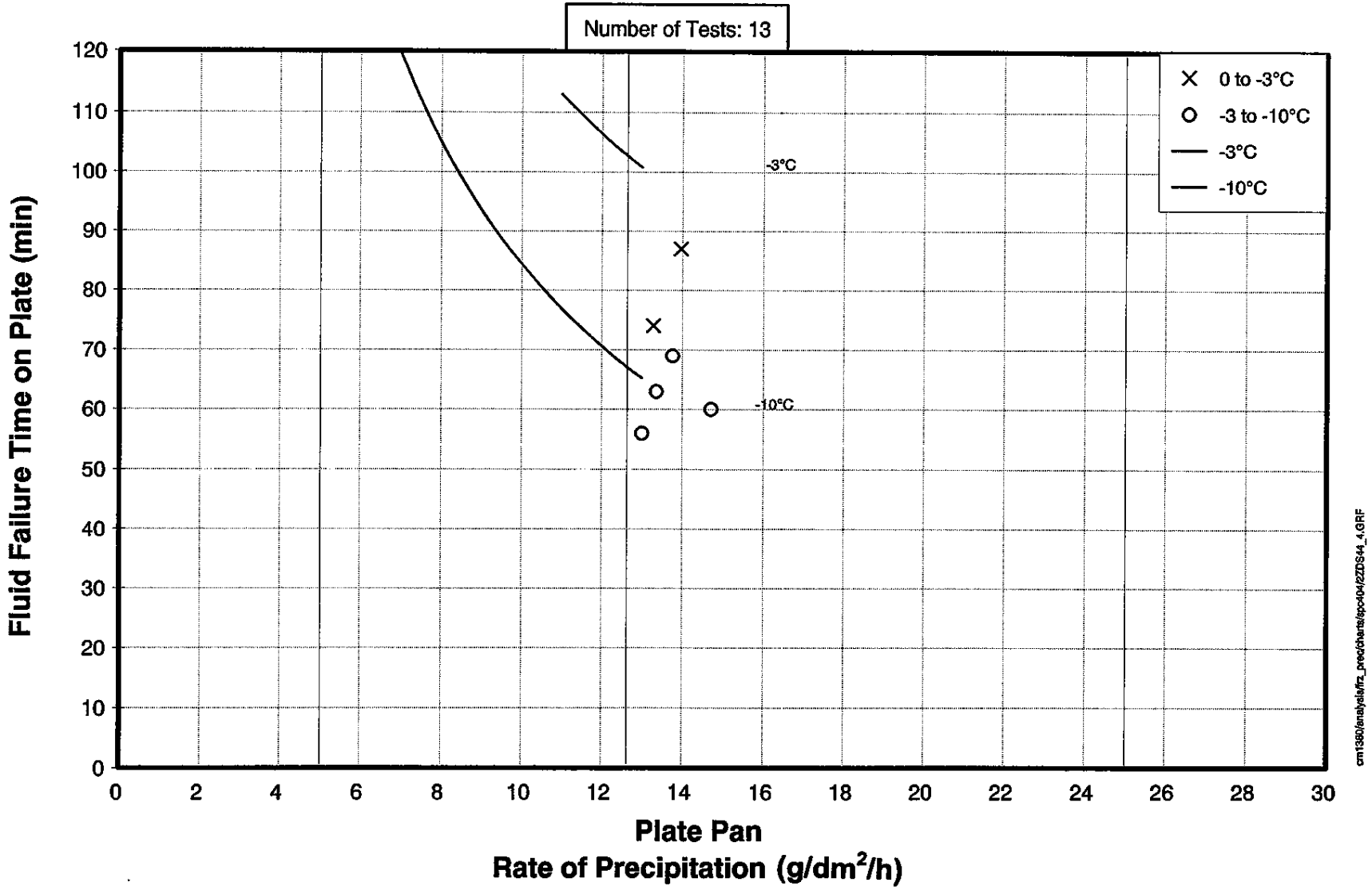


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1997/98

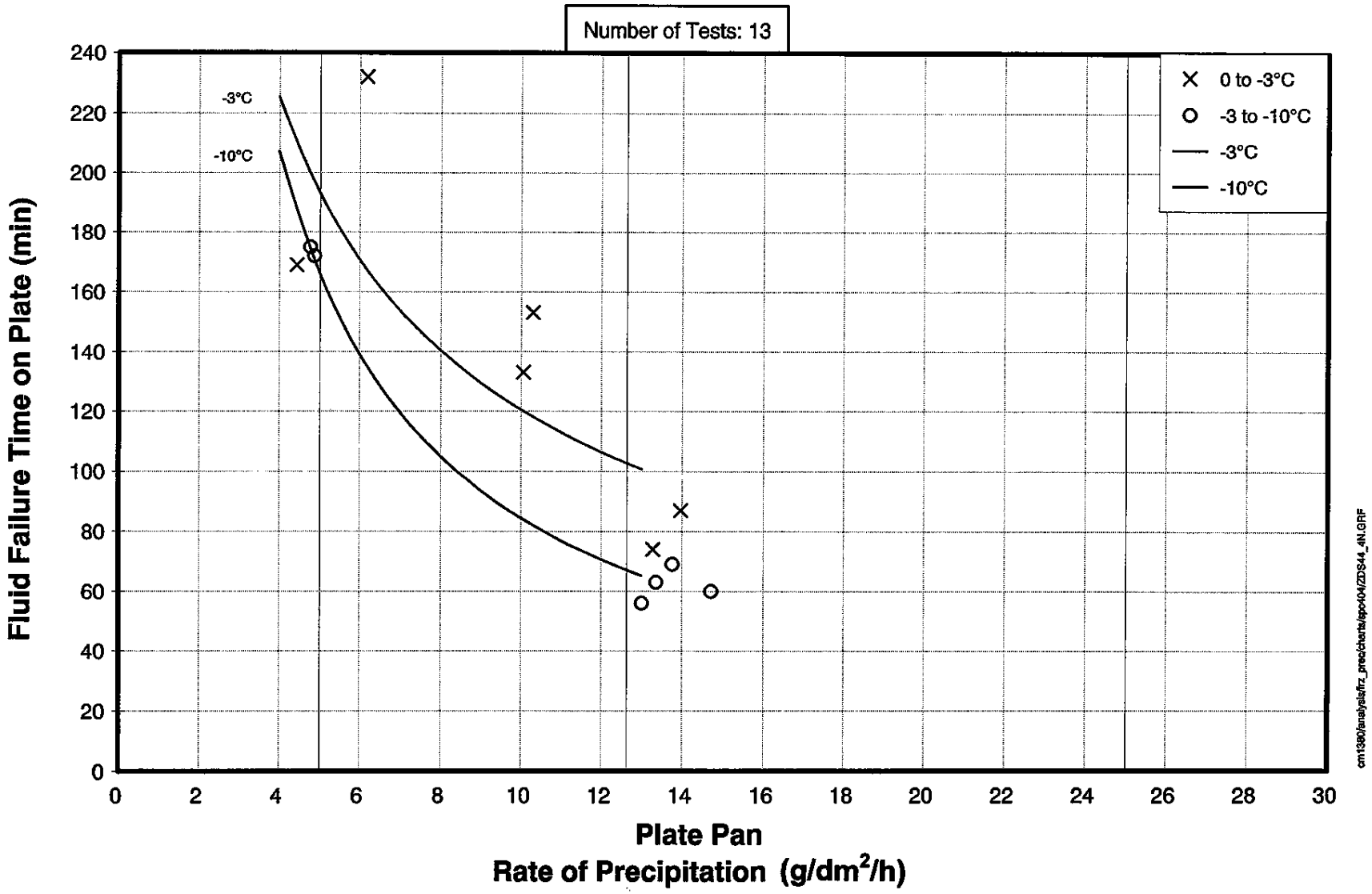


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1997/98

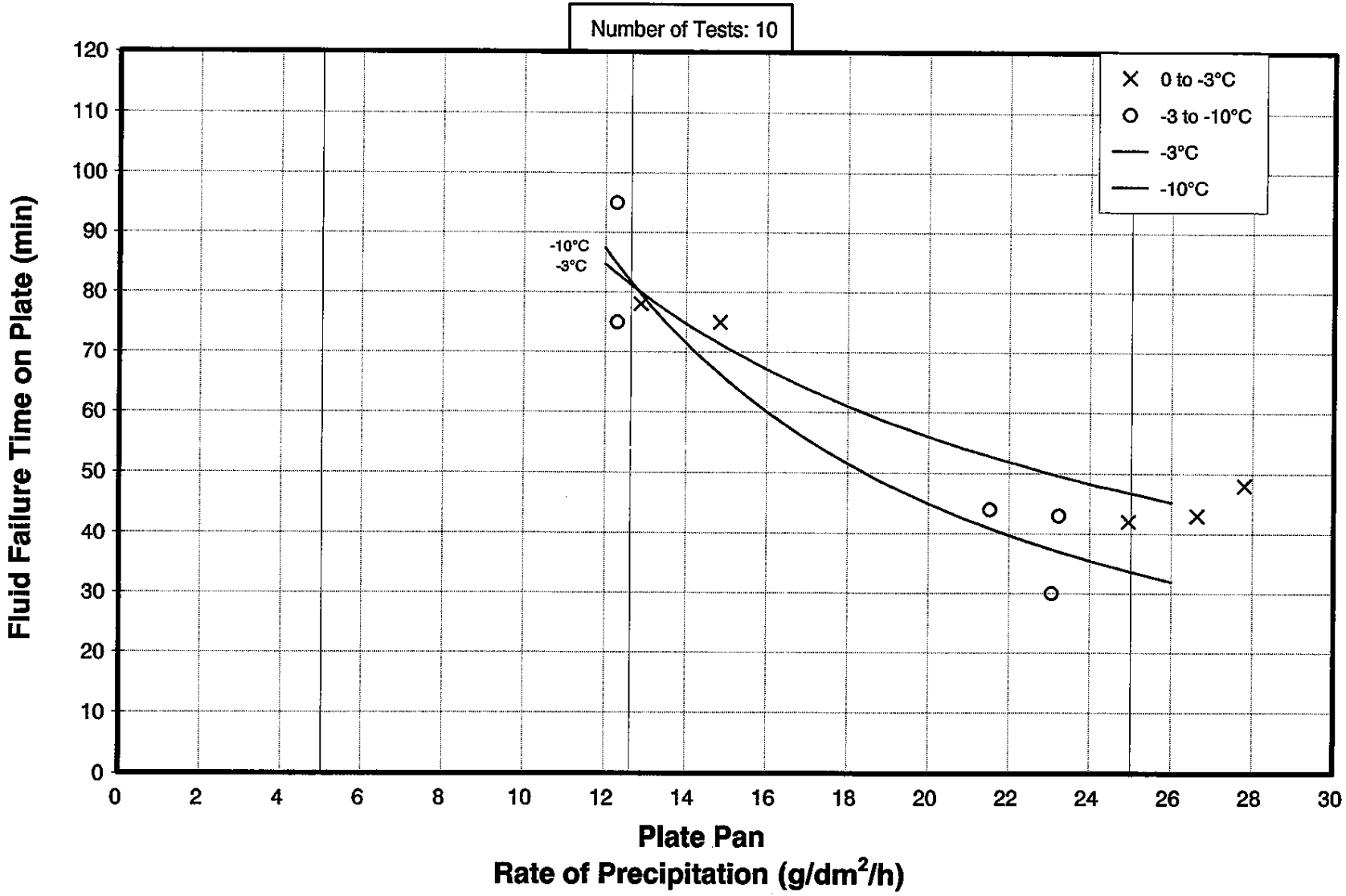


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV NEAT

SIMULATED LIGHT FREEZING RAIN

1997/98

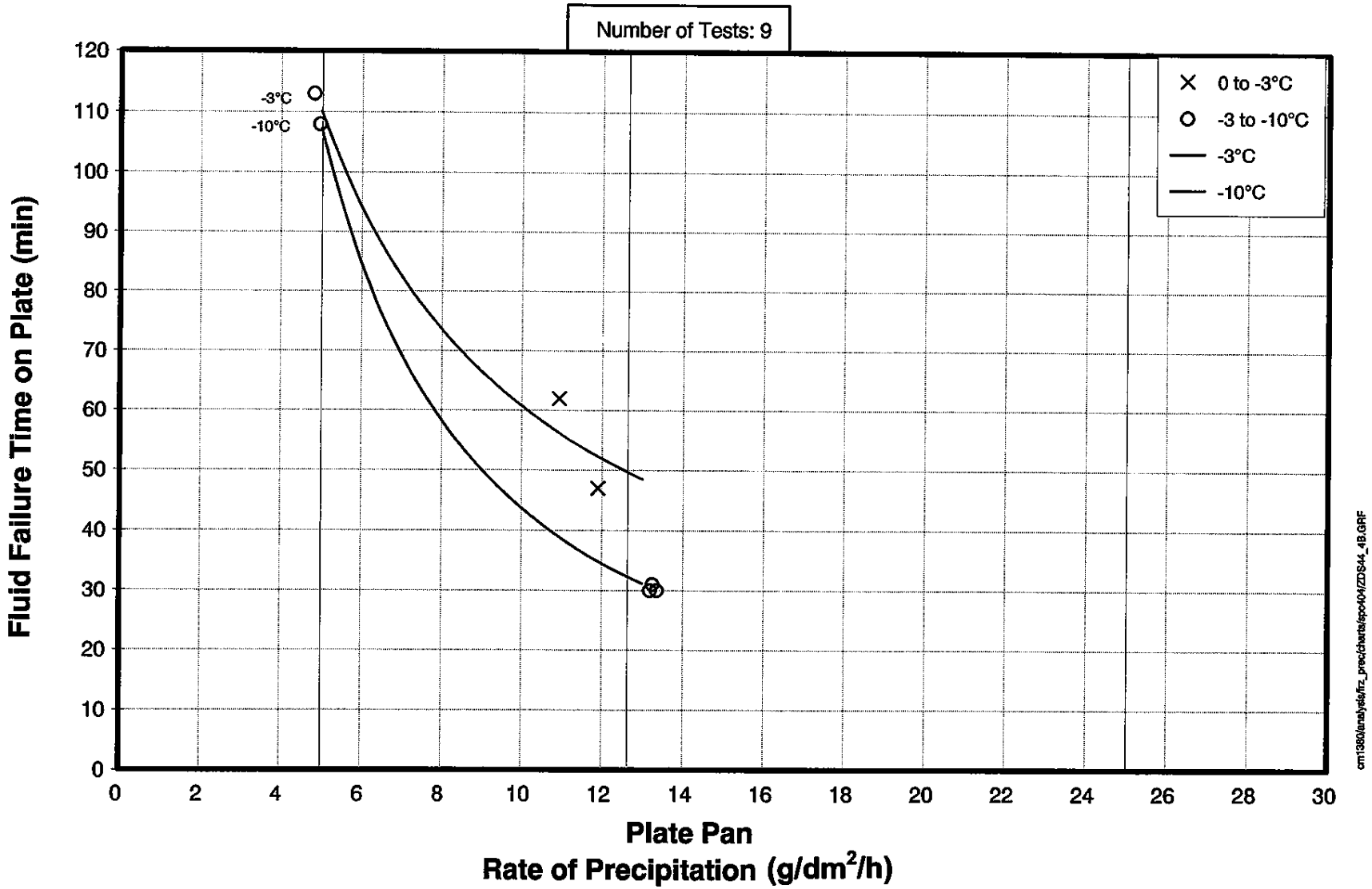


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV 75/25

SIMULATED FREEZING DRIZZLE

1997/98

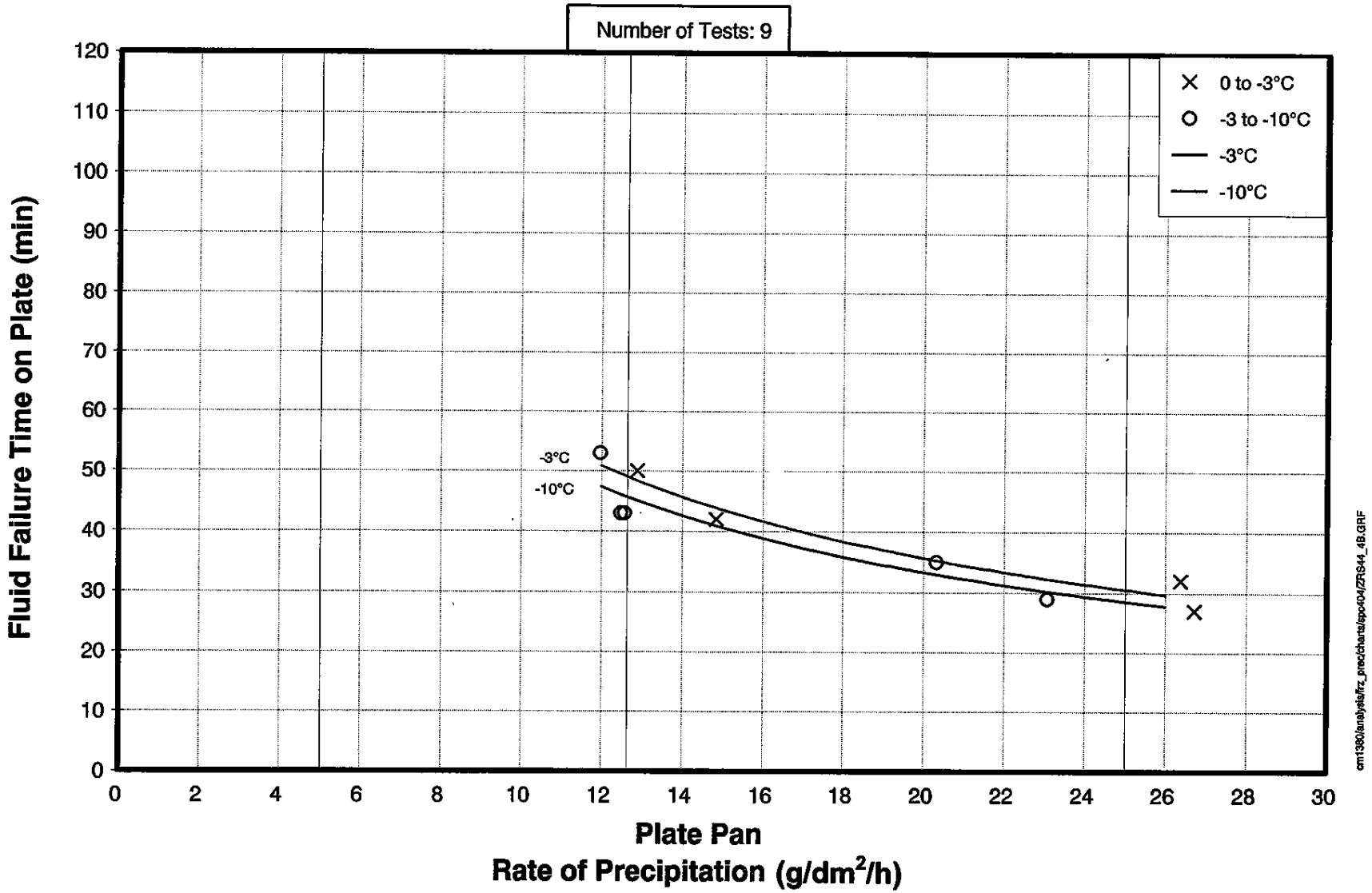


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV 75/25

SIMULATED LIGHT FREEZING RAIN

1997/98



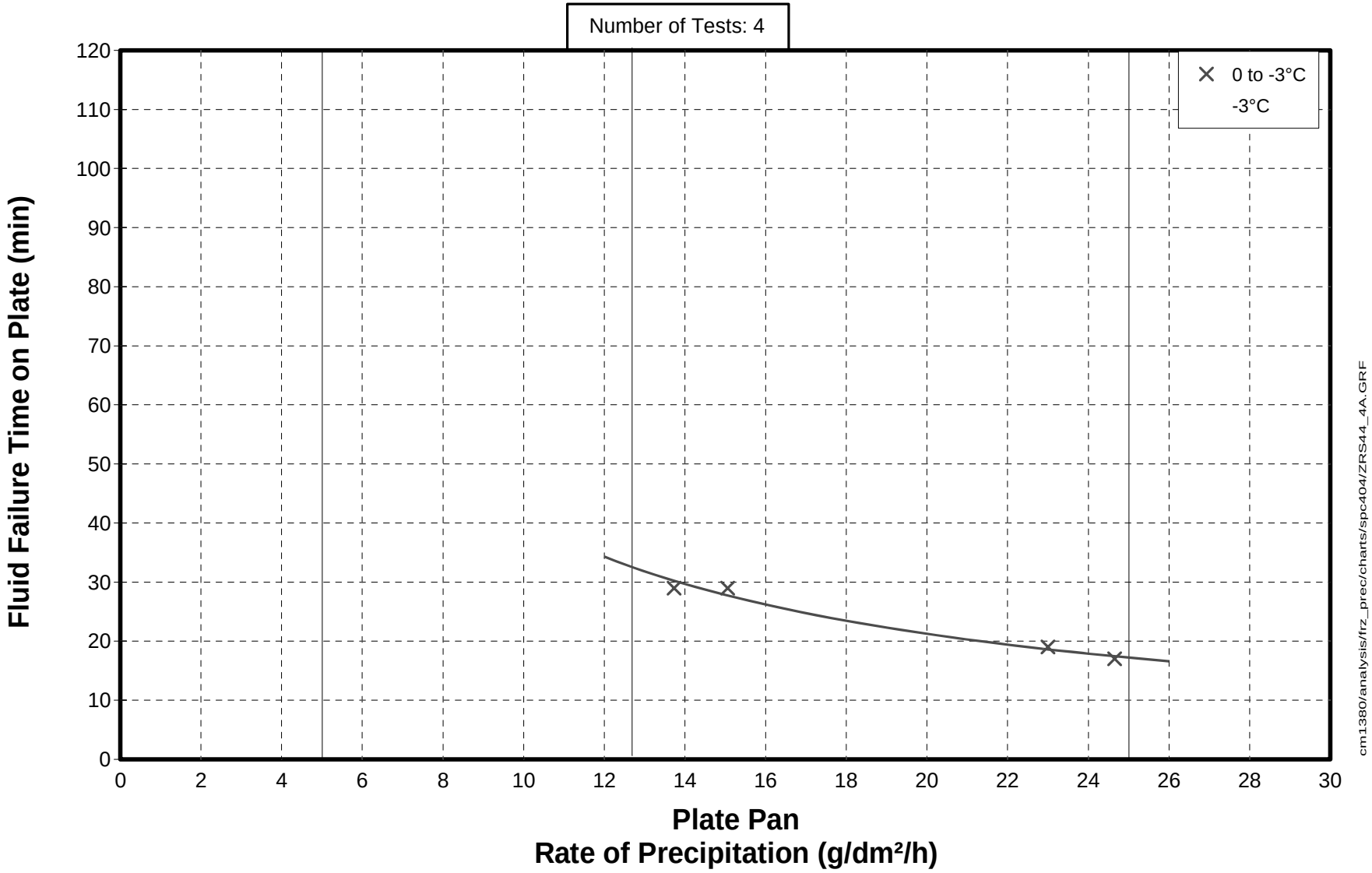

cm1380/analysis/frz_prec/charts/spc404ZR644_4B.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV 50/50

SIMULATED LIGHT FREEZING RAIN

1997/98

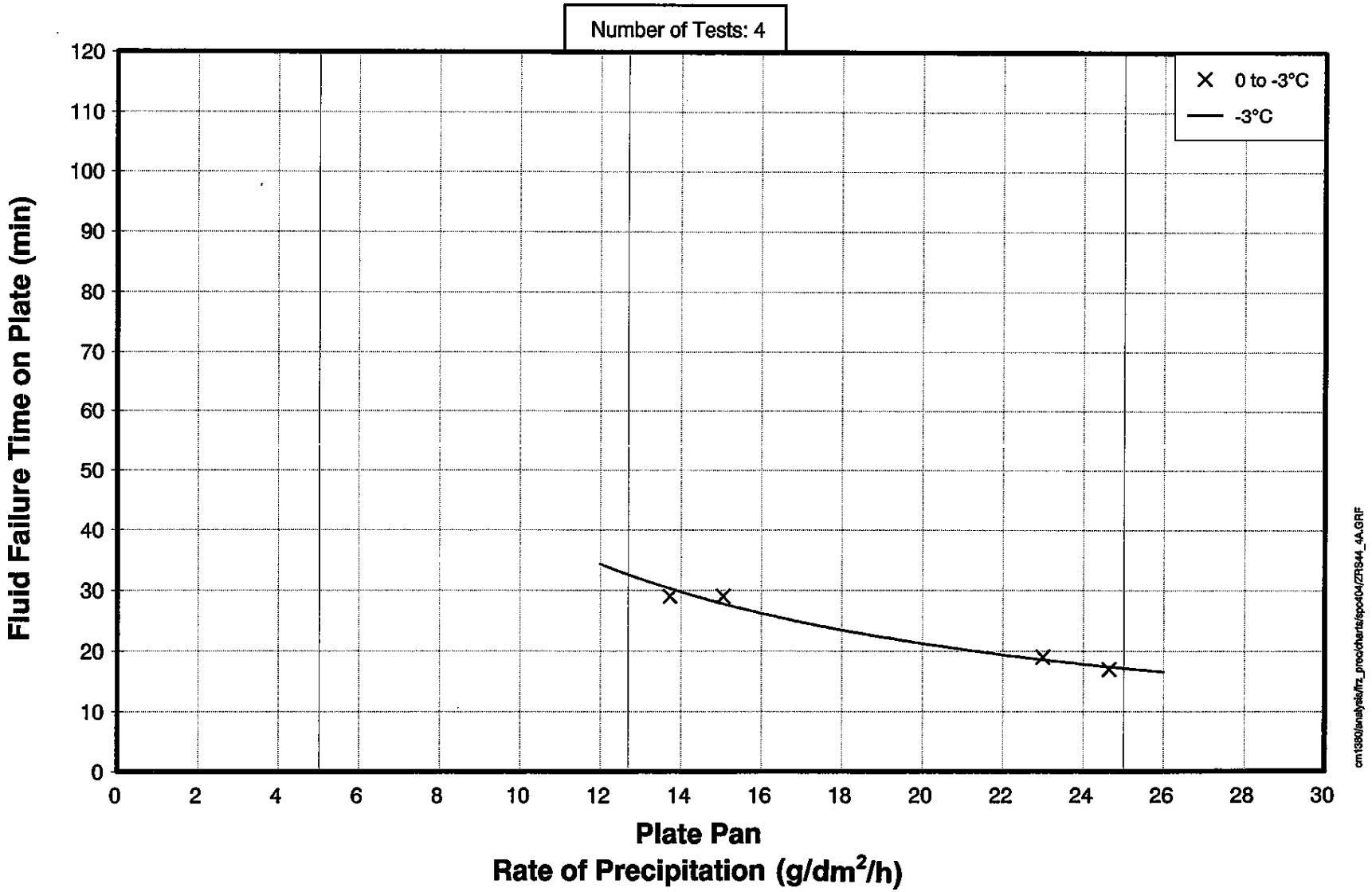


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-404 TYPE IV 50/50

SIMULATED LIGHT FREEZING RAIN

1997/98

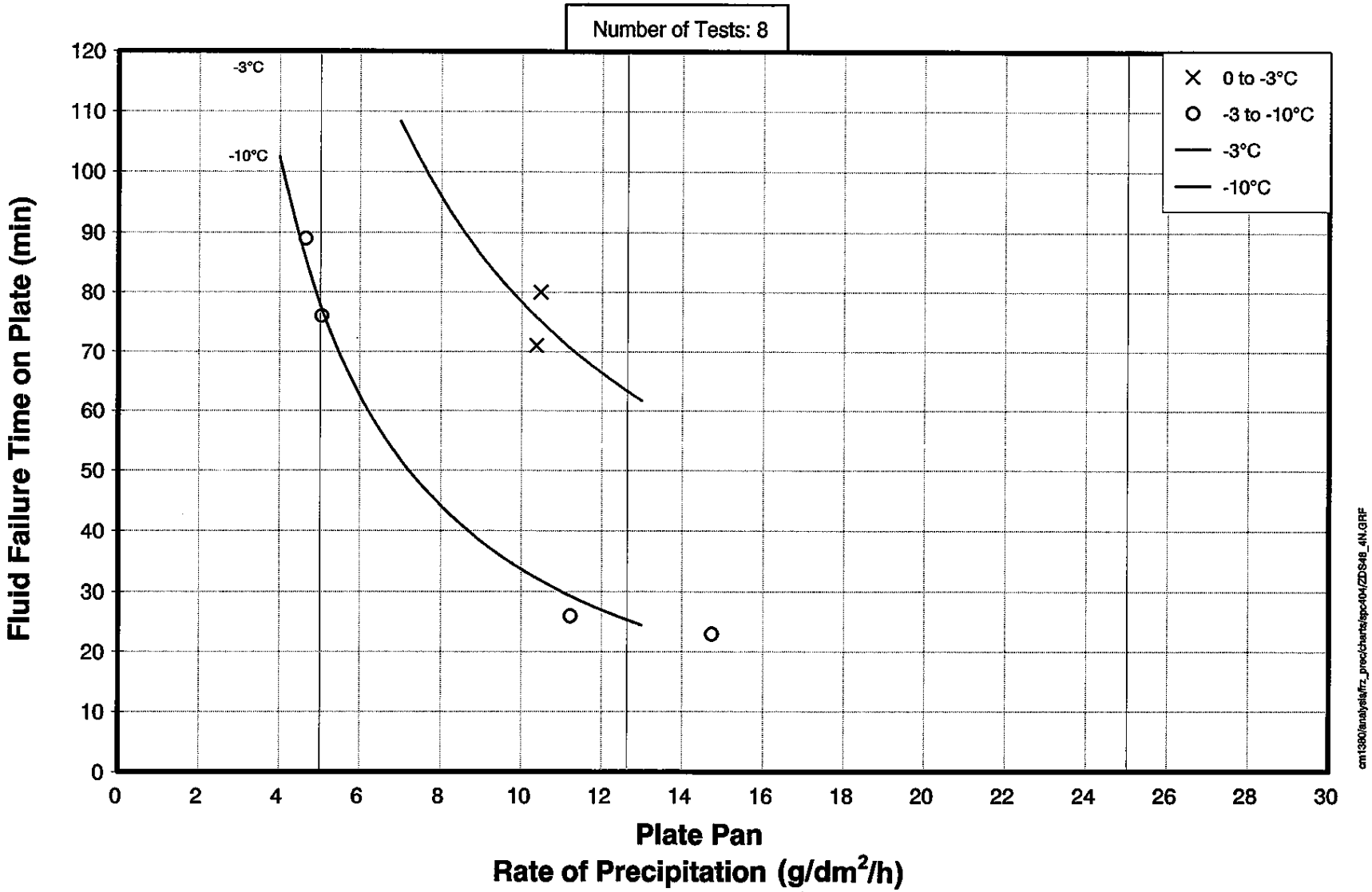


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1997/98

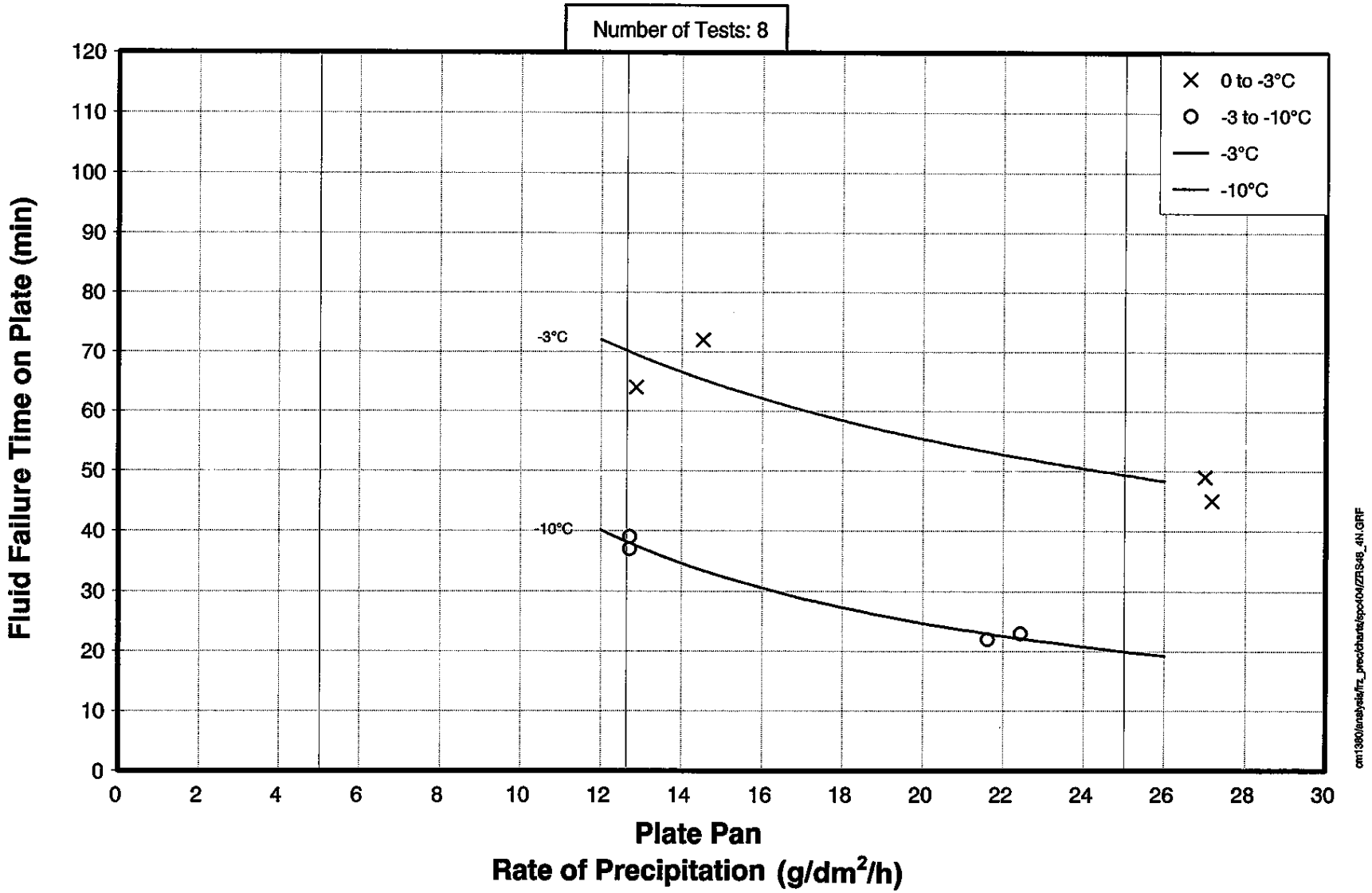


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV NEAT

SIMULATED LIGHT FREEZING RAIN

1997/98

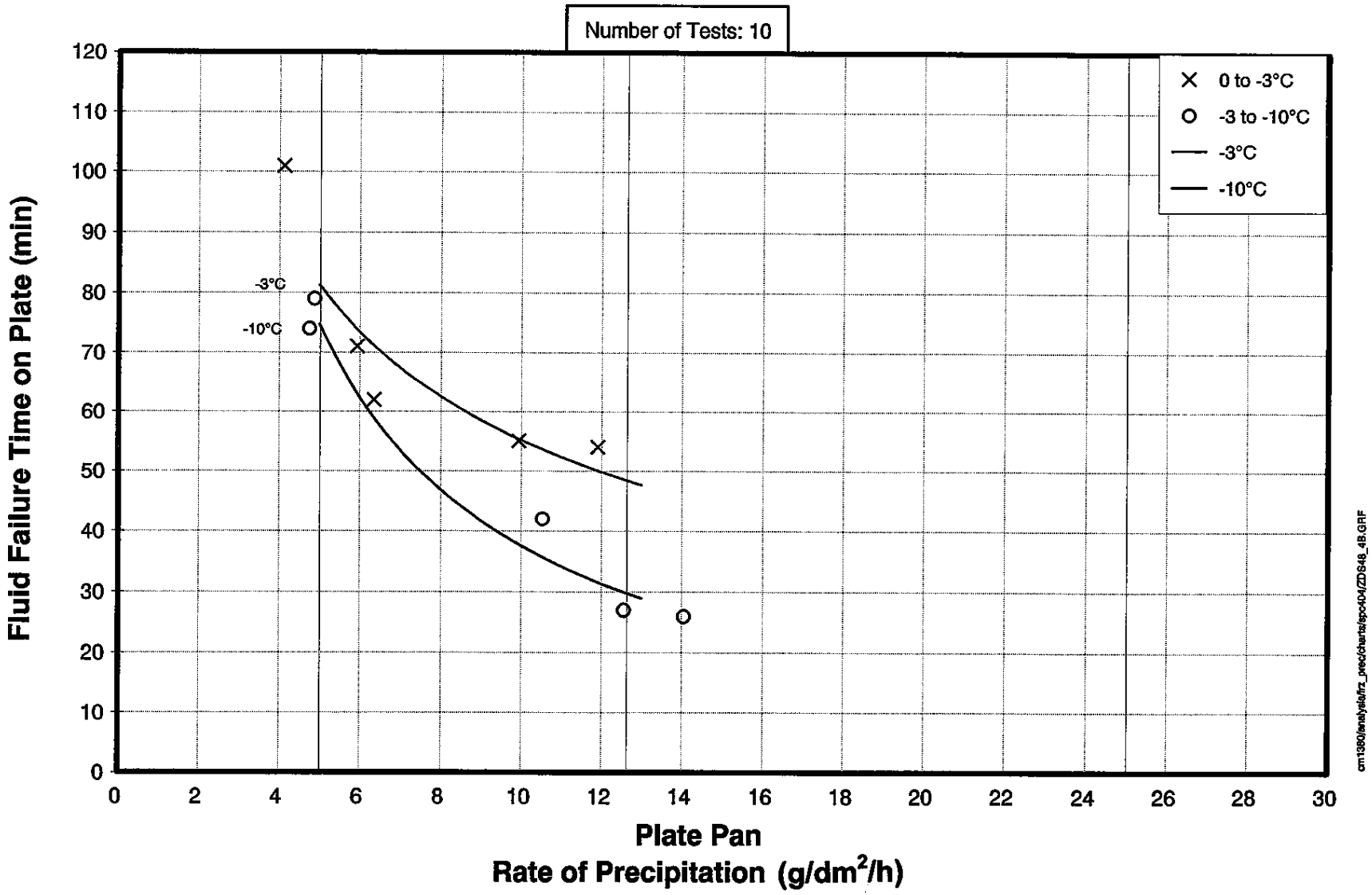


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV 75/25

SIMULATED FREEZING DRIZZLE

1997/98

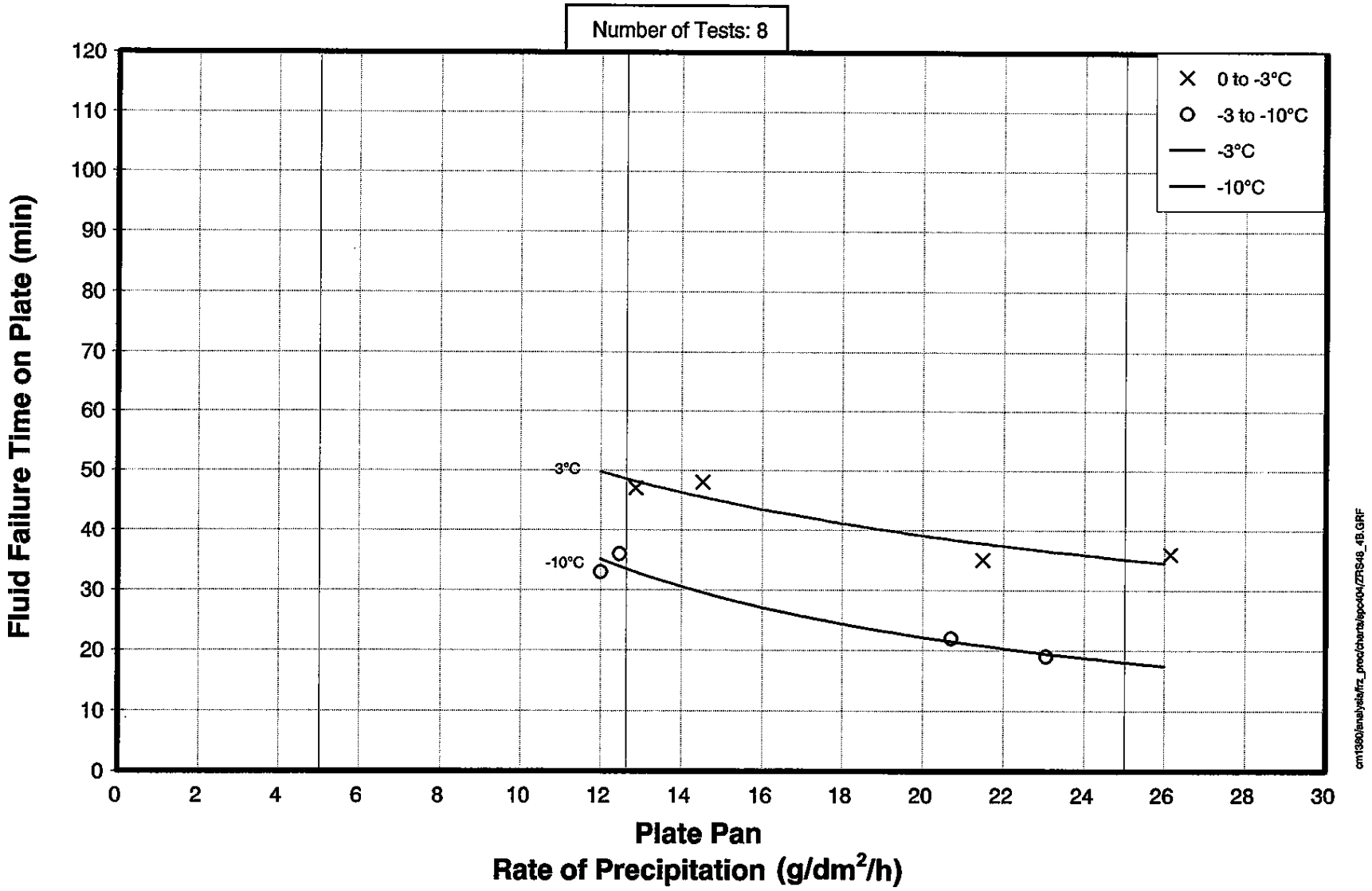


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV 75/25

SIMULATED LIGHT FREEZING RAIN

1997/98

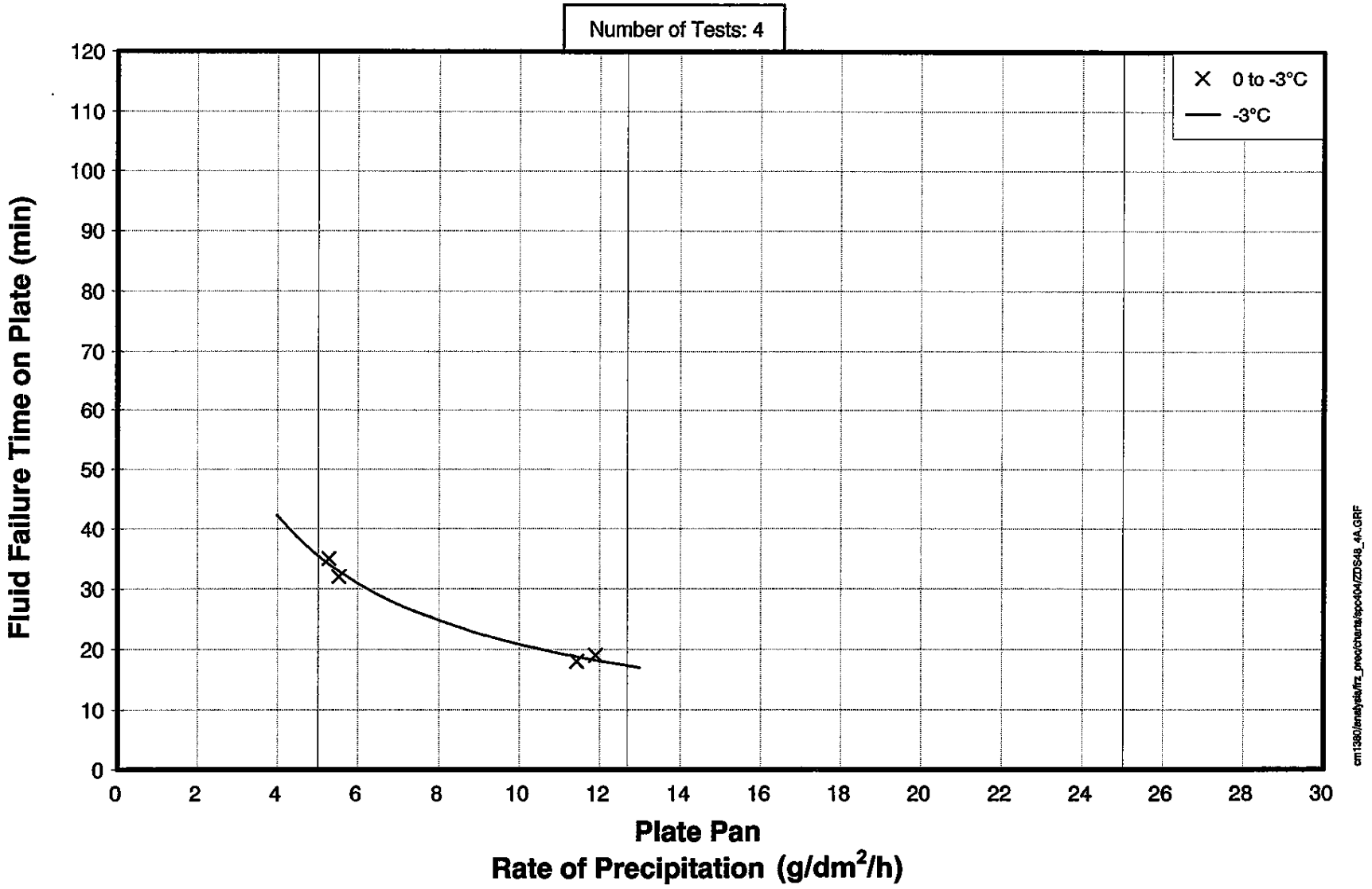


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV 50/50

SIMULATED FREEZING DRIZZLE

1997/98

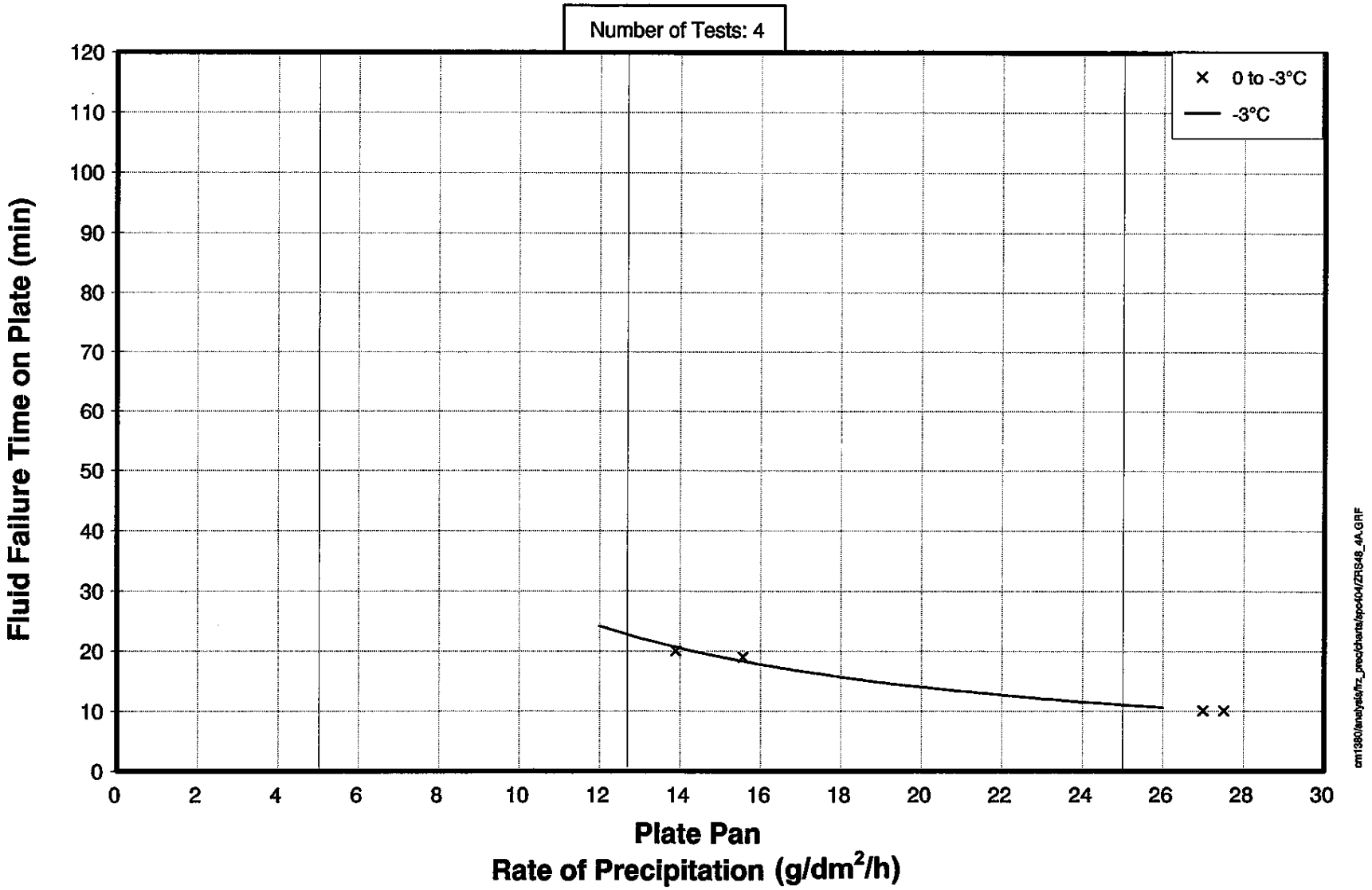


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV 50/50

SIMULATED LIGHT FREEZING RAIN

1997/98

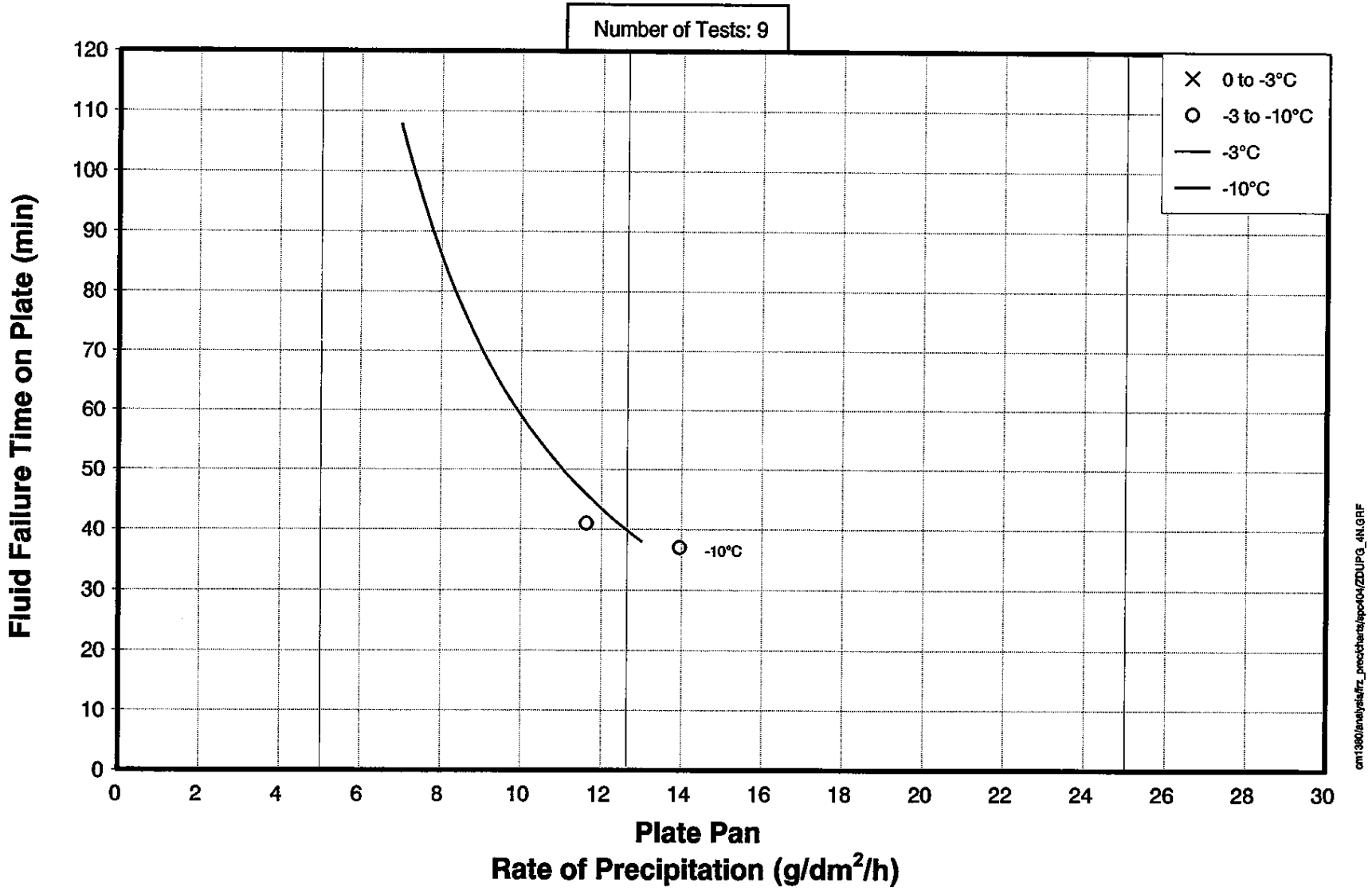


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR PG TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1997/98

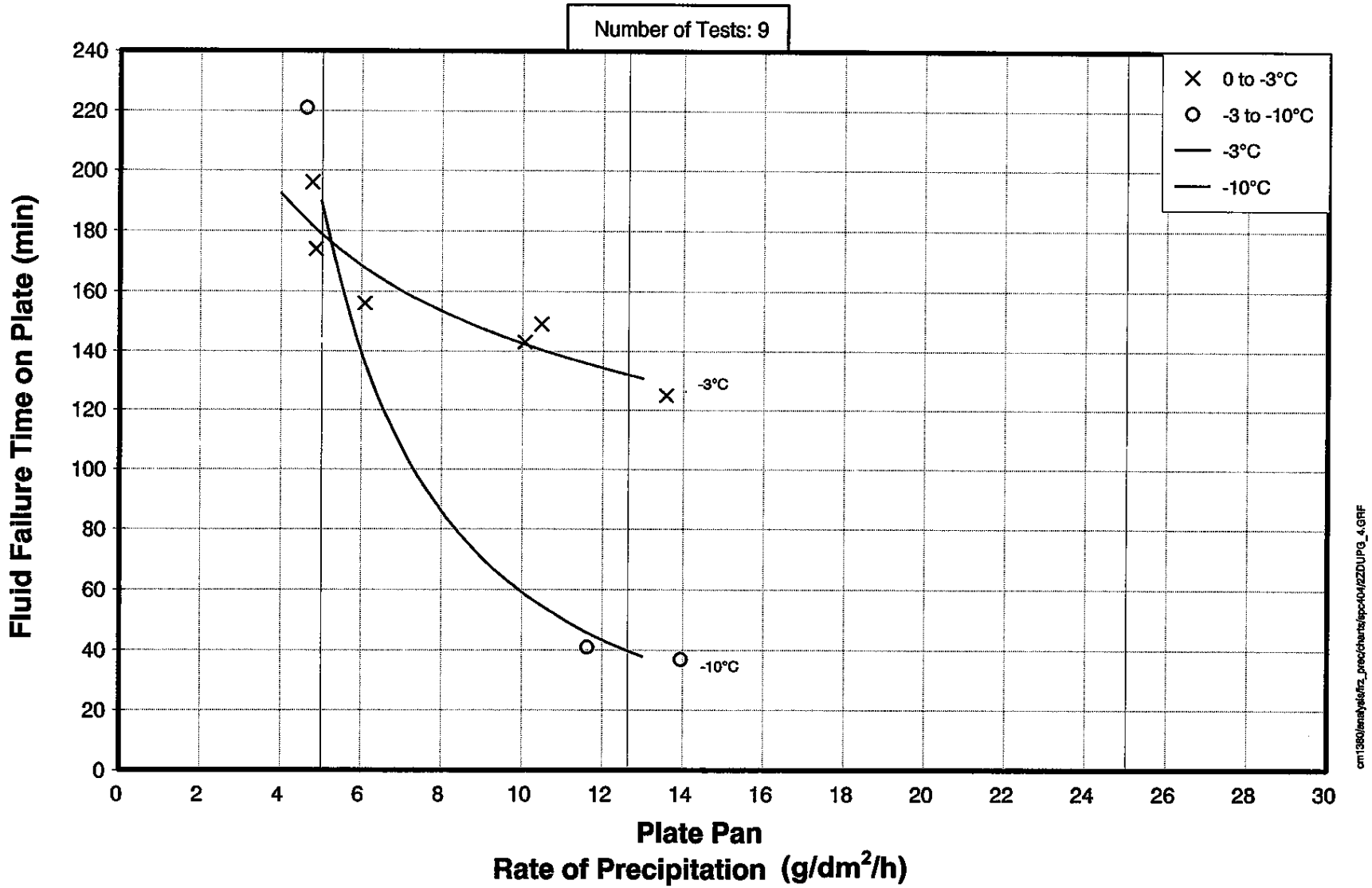


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR PG TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1997/98



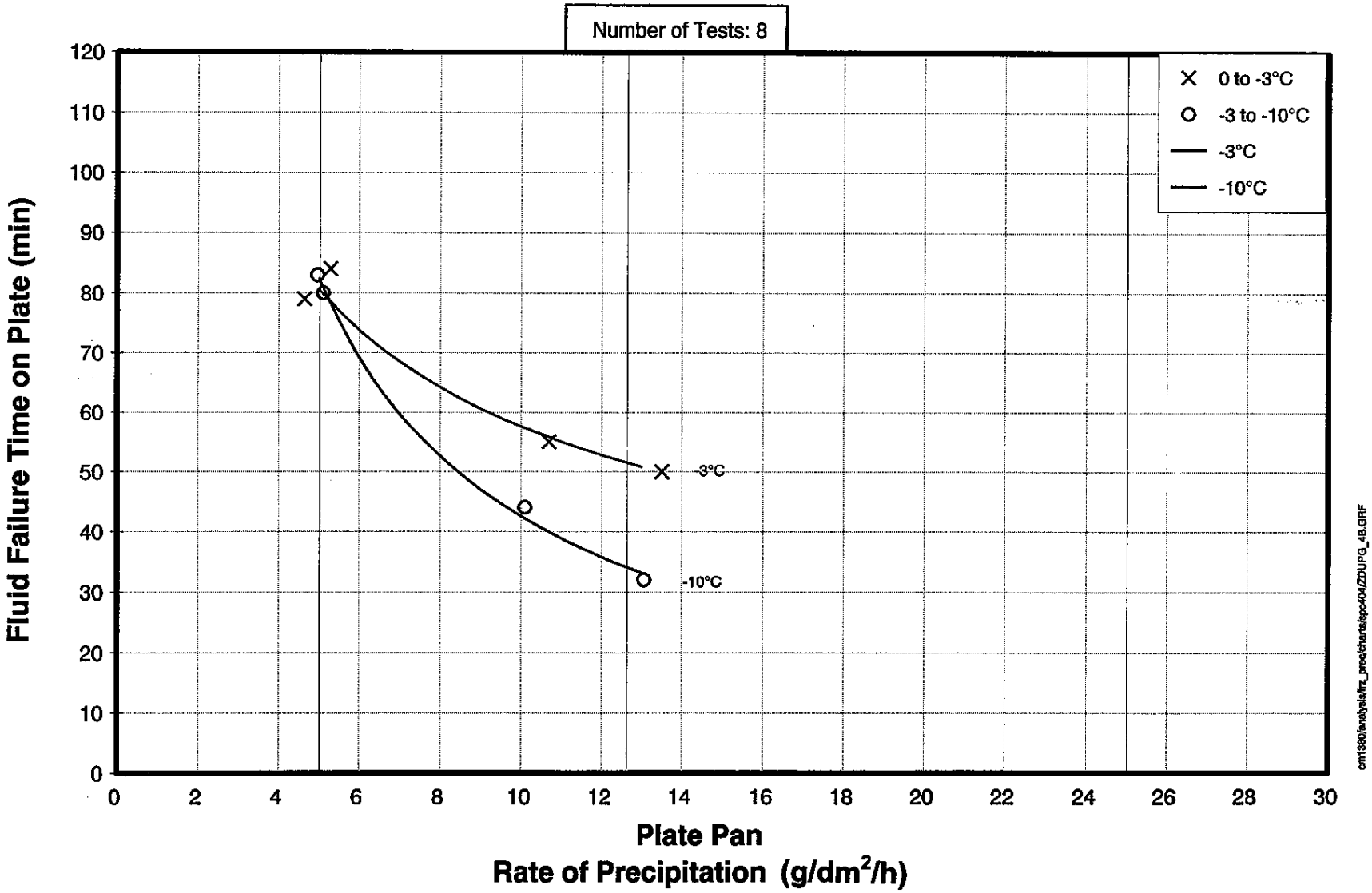

cm13800/analysis/frz_prec/charts/spc404/jZZDUPG_4.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR PG TYPE IV 75/25

SIMULATED FREEZING DRIZZLE

1997/98

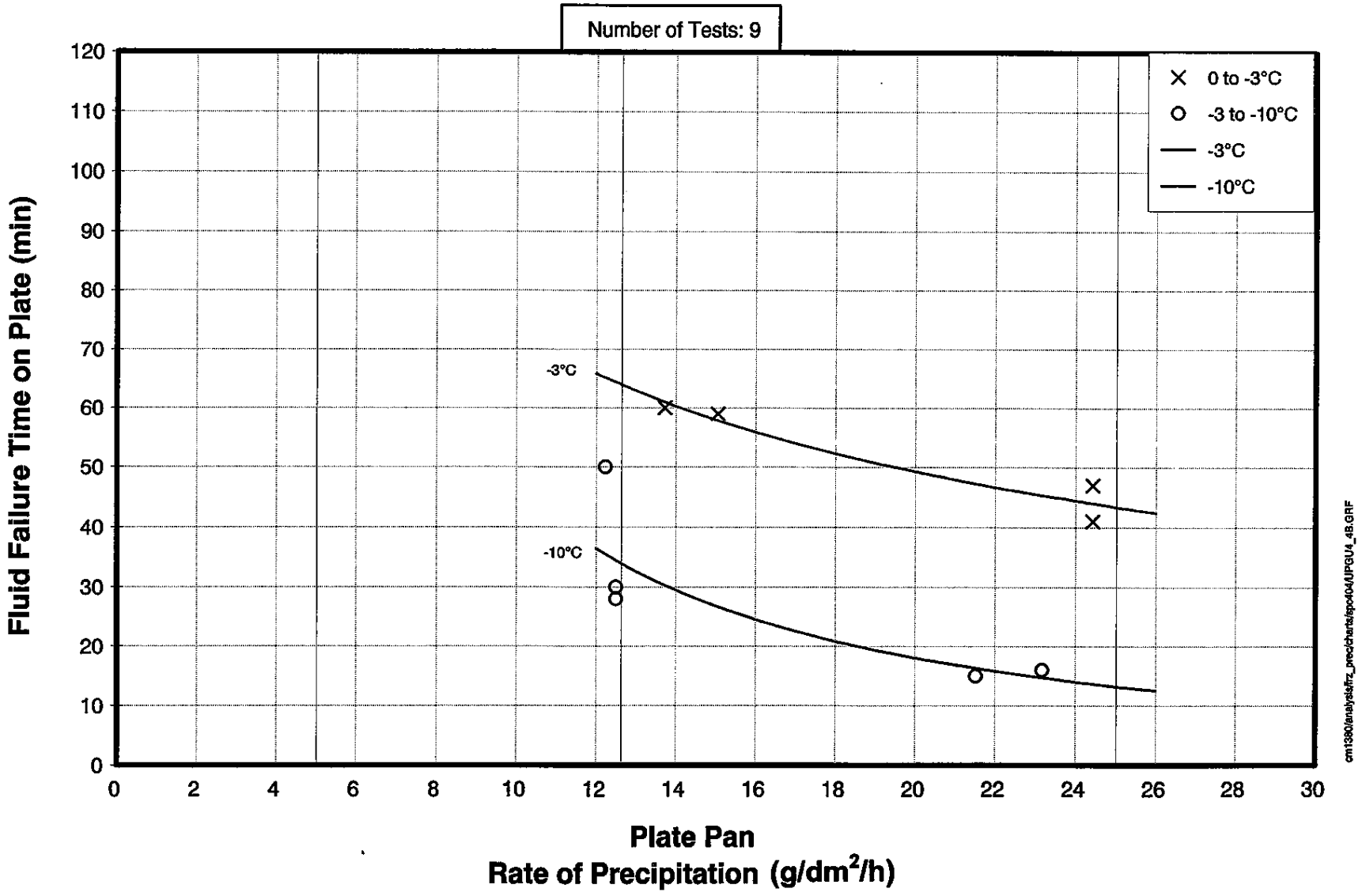


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR PG TYPE IV 75/25

SIMULATED LIGHT FREEZING RAIN

1997/98

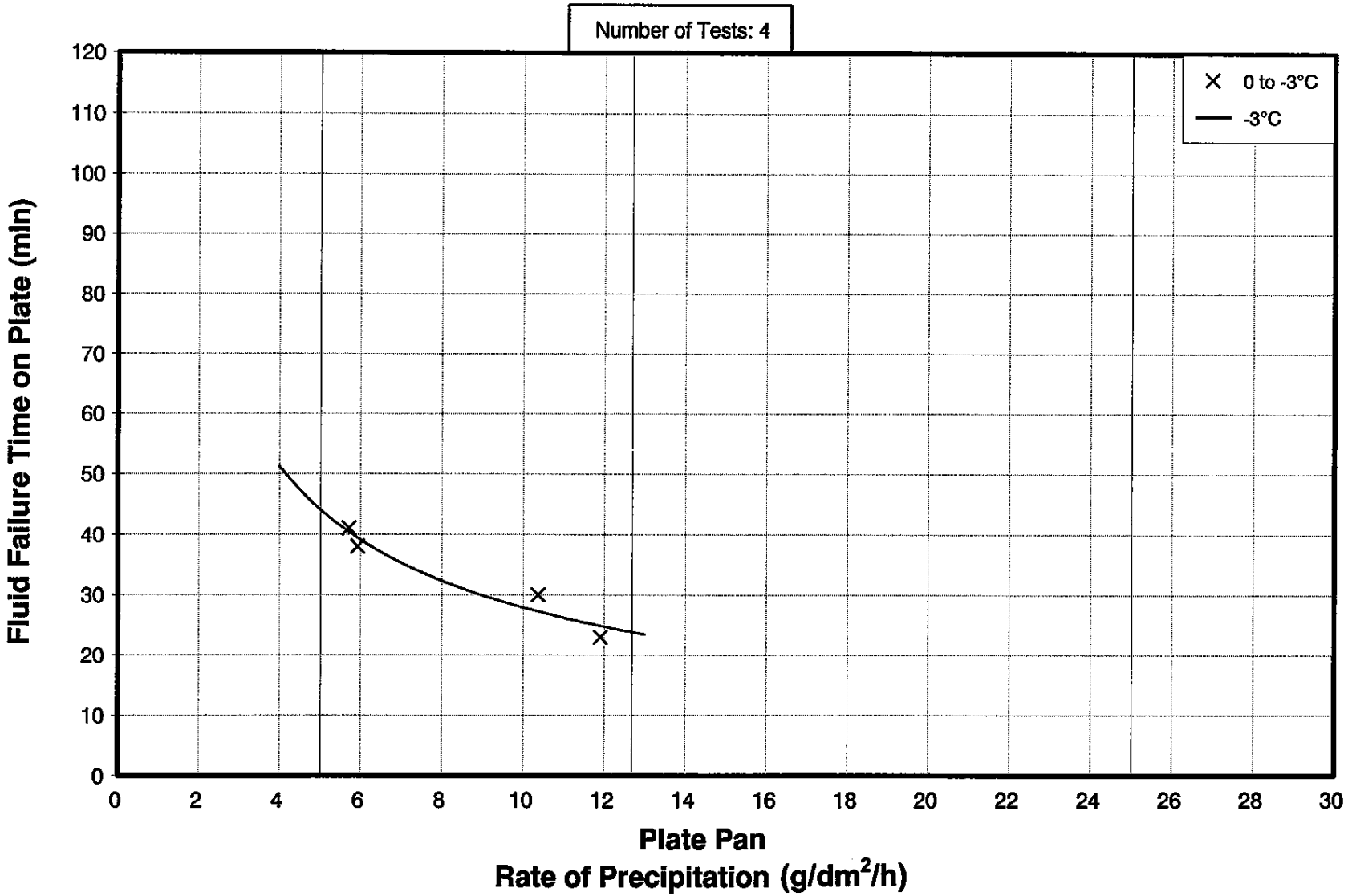


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR PG TYPE IV 50/50

SIMULATED FREEZING DRIZZLE

1997/98

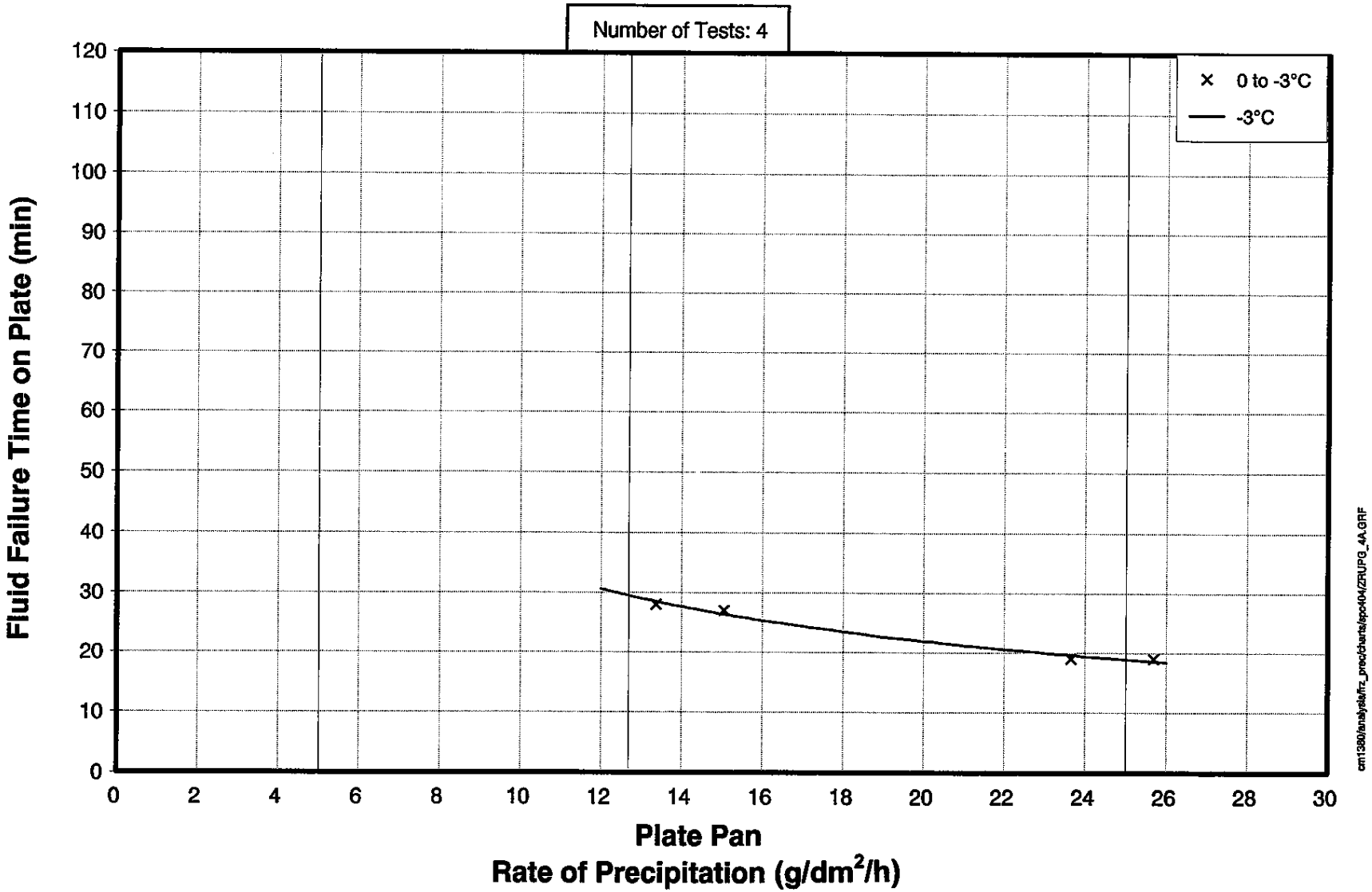


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## UCAR PG TYPE IV 50/50

SIMULATED LIGHT FREEZING RAIN

1997/98

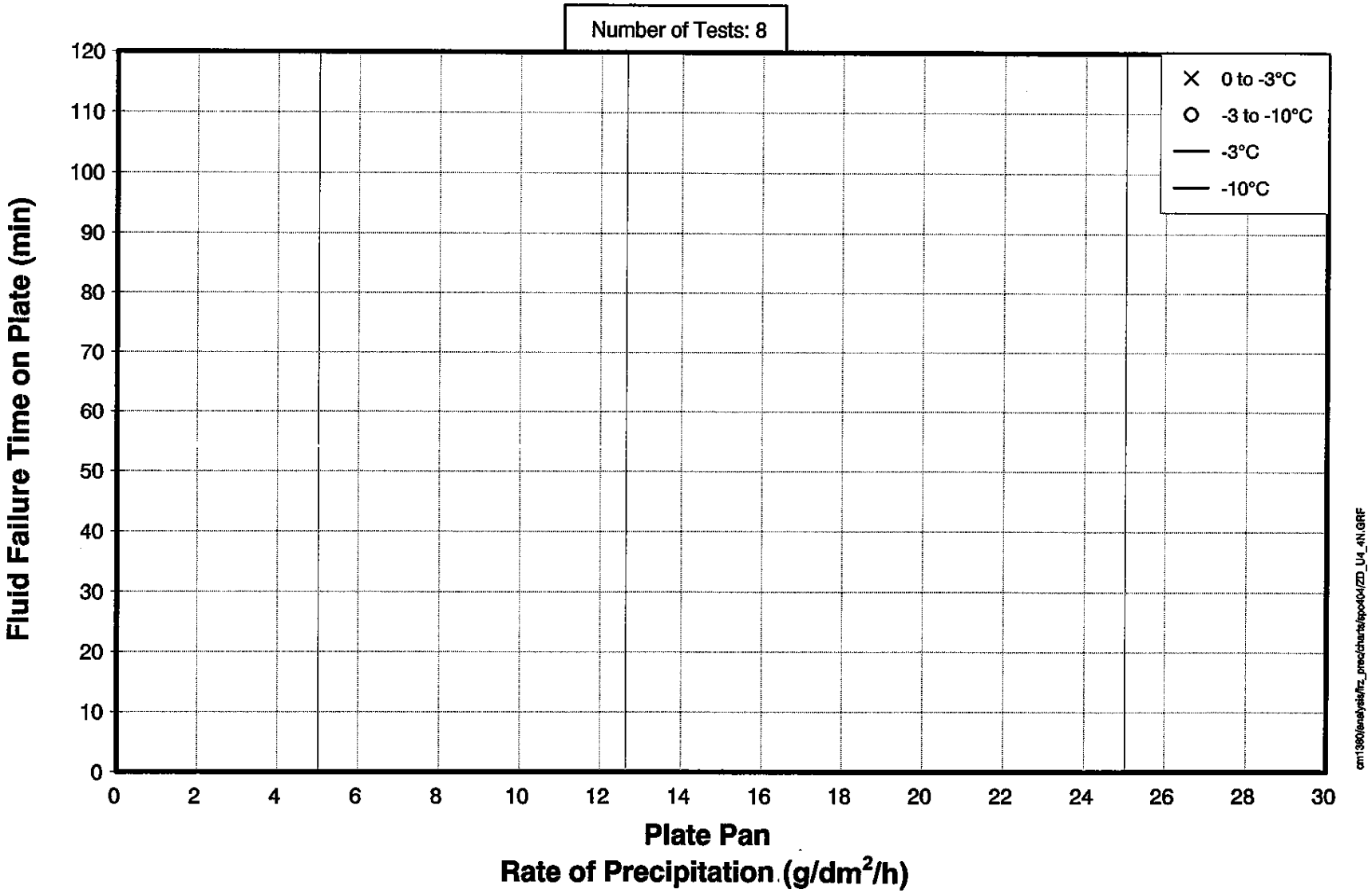


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1997/98

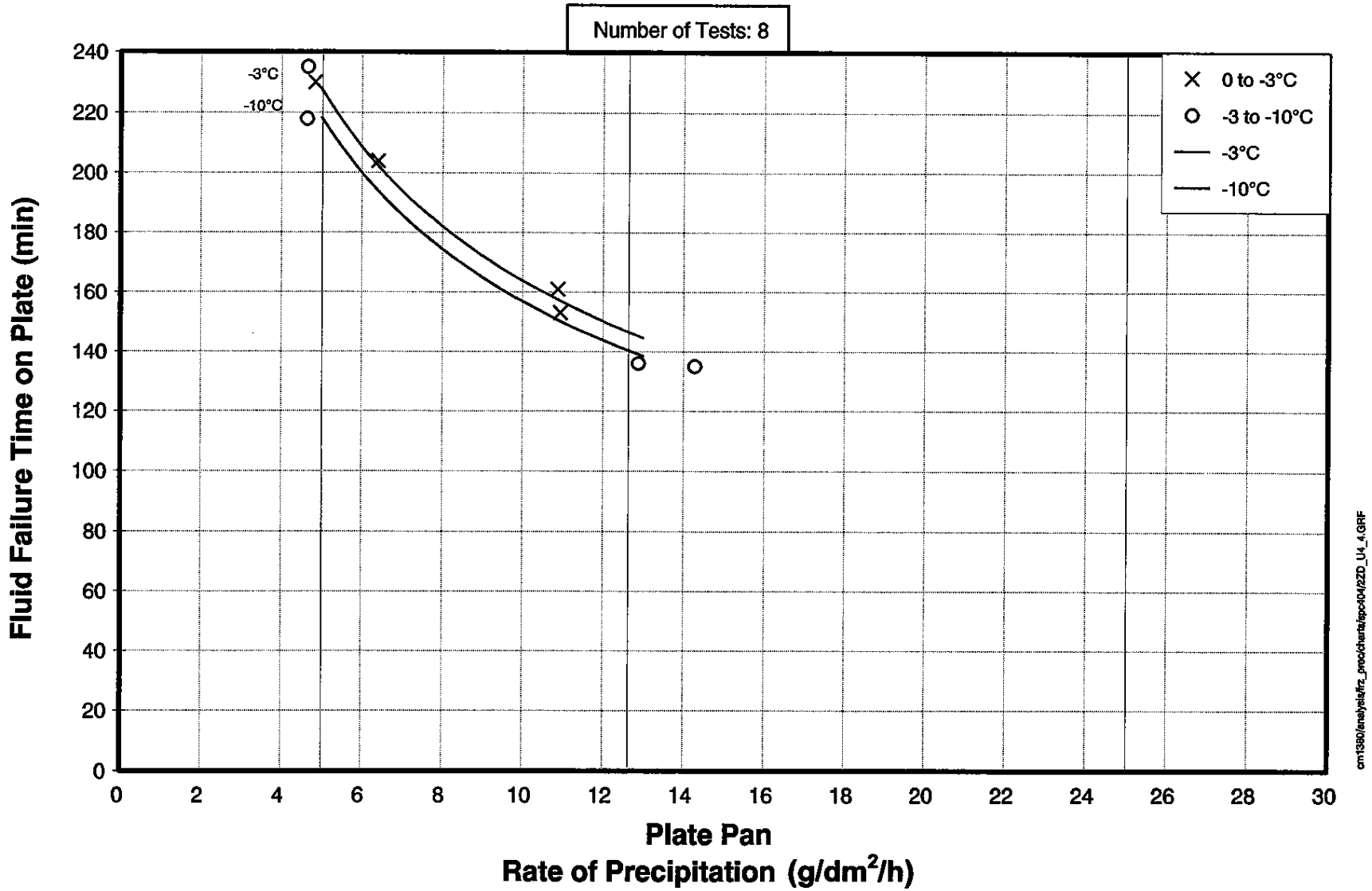


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV TYPE IV NEAT

SIMULATED FREEZING DRIZZLE

1997/98

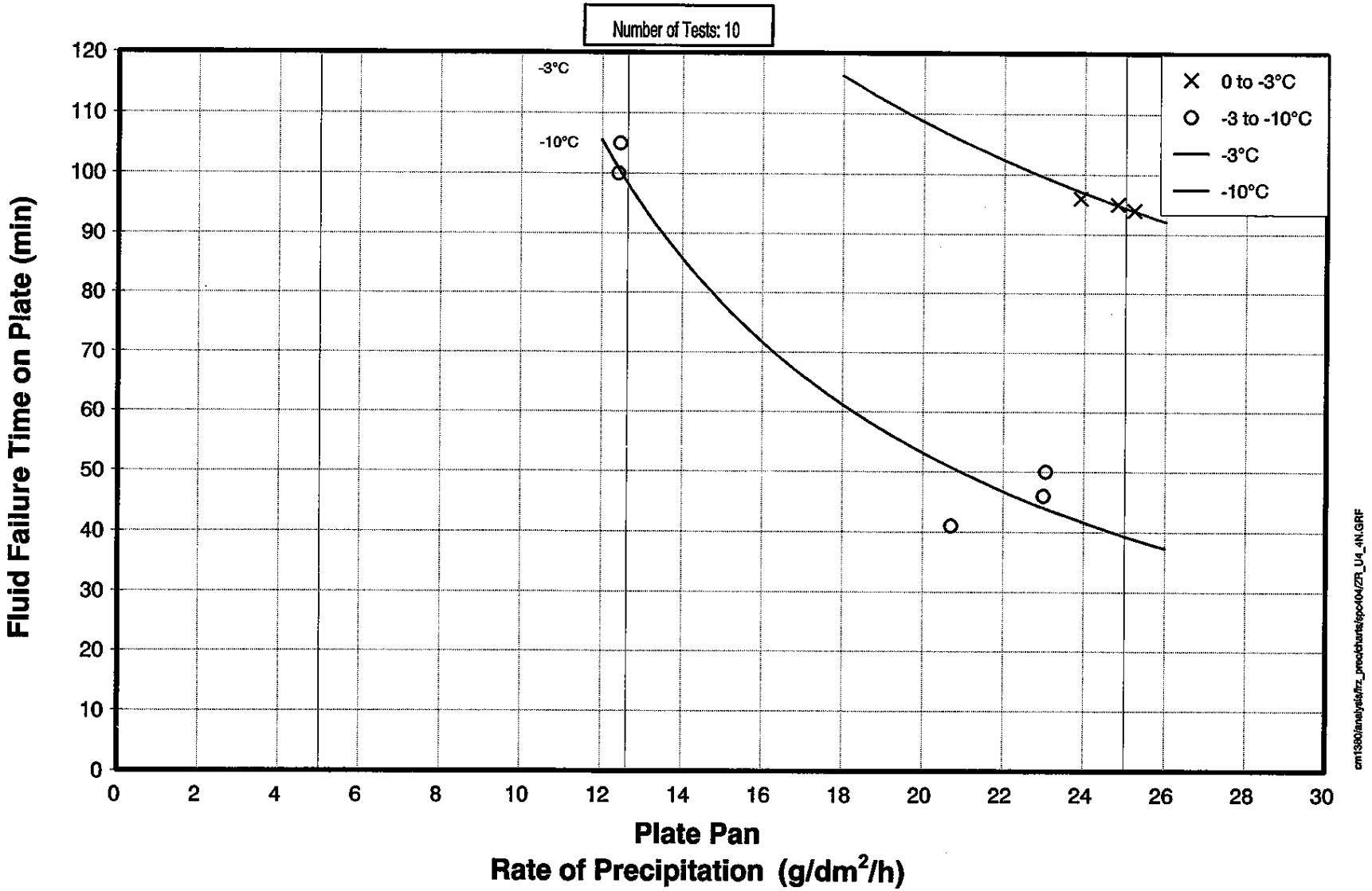


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV TYPE IV NEAT

SIMULATED LIGHT FREEZING RAIN

1997/98

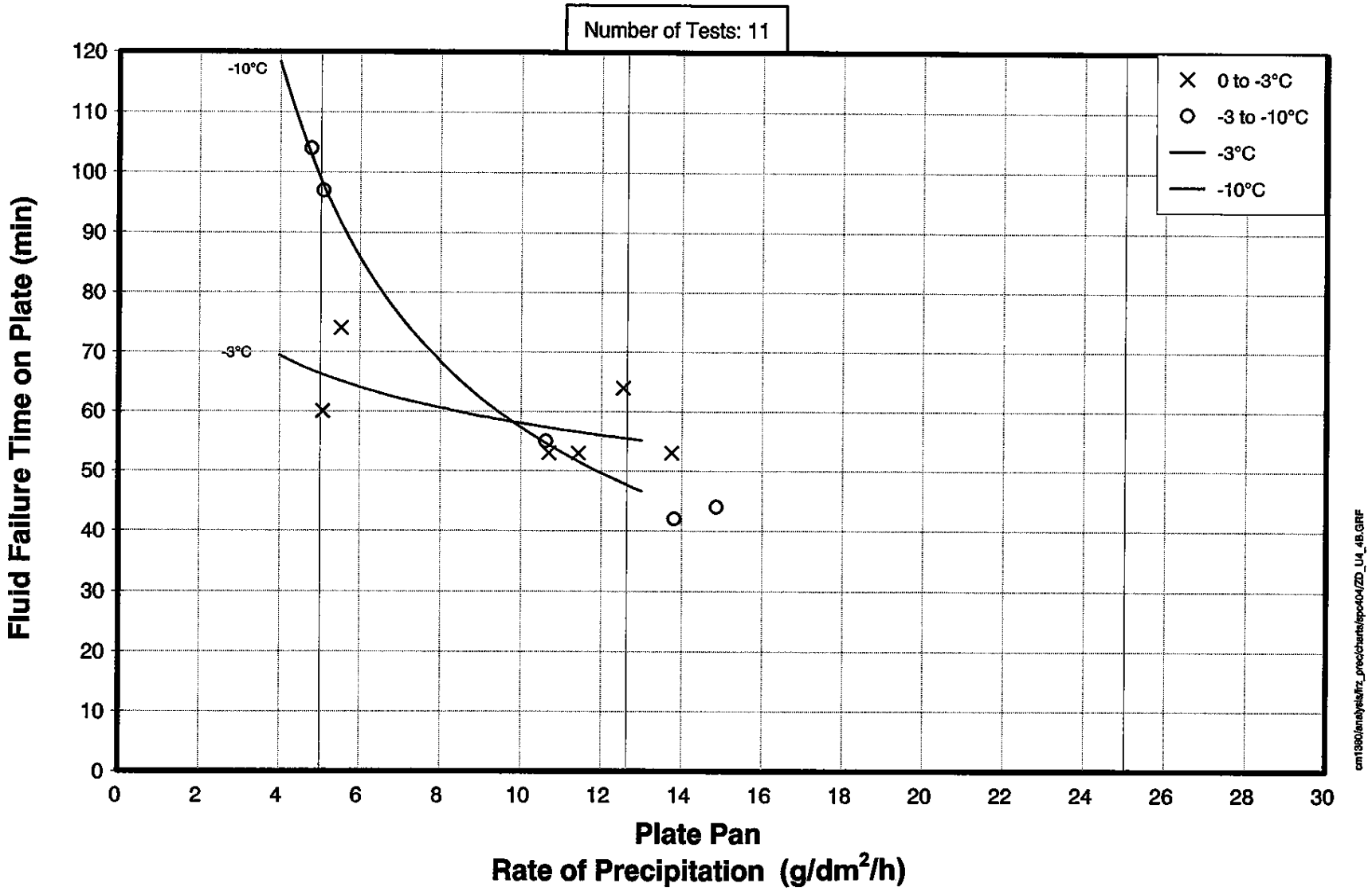


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV TYPE IV 75/25

SIMULATED FREEZING DRIZZLE

1997/98

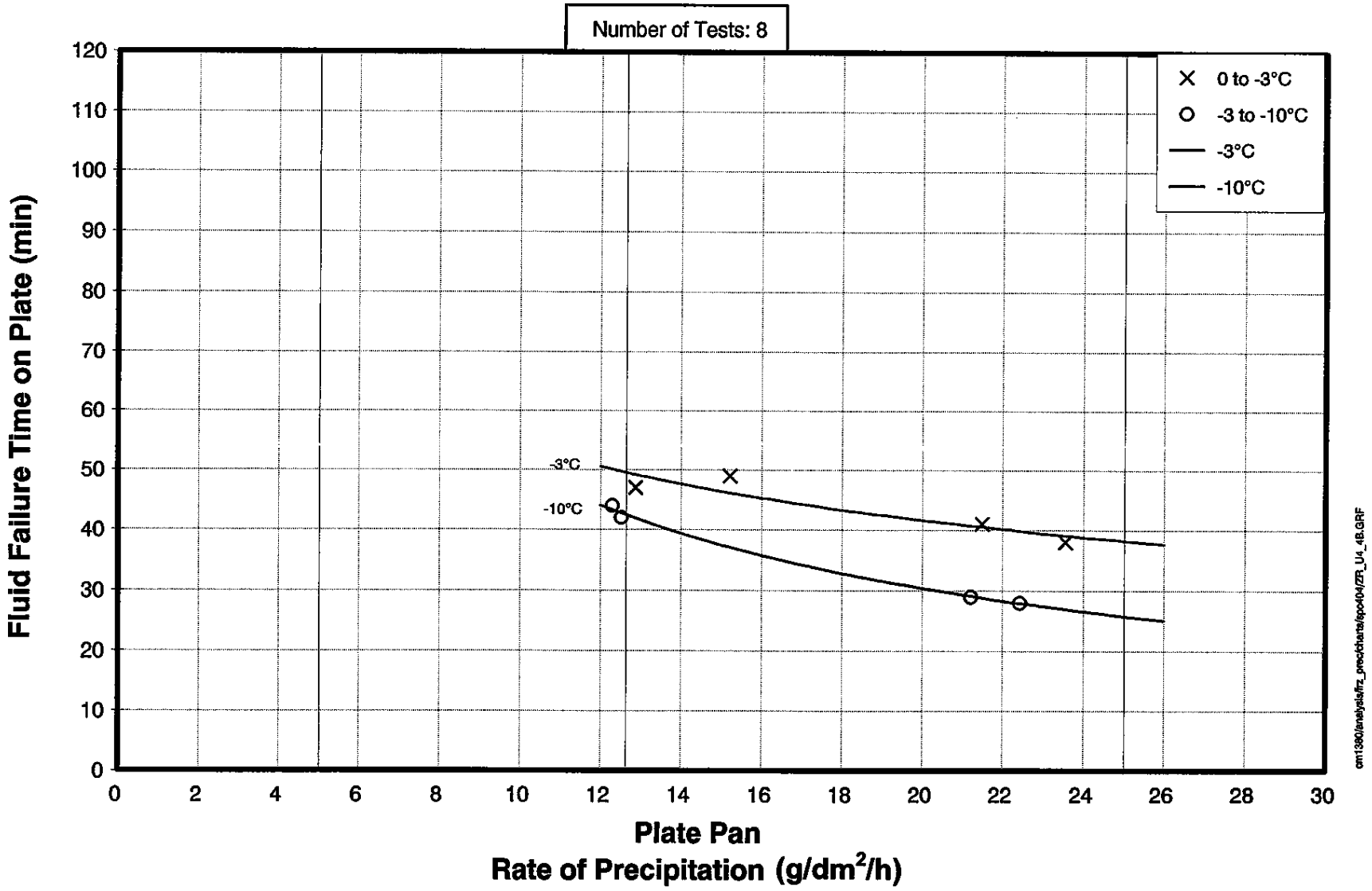


# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV TYPE IV 75/25

SIMULATED LIGHT FREEZING RAIN

1997/98



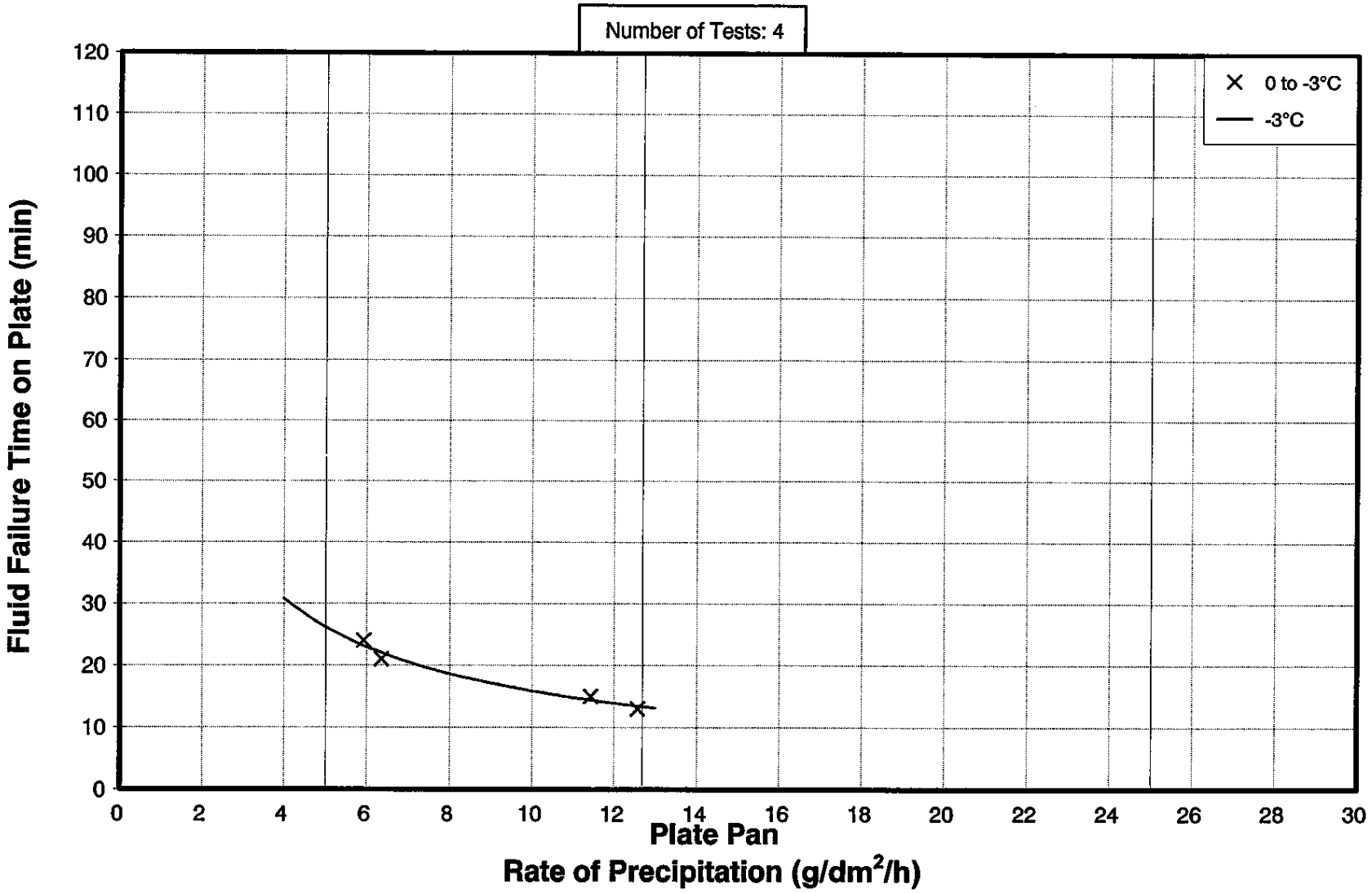

cm1380/analysis/frz_precchans/epo404/ZR_U4_4B.GRF

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV TYPE IV 50/50

SIMULATED FREEZING DRIZZLE

1997/98

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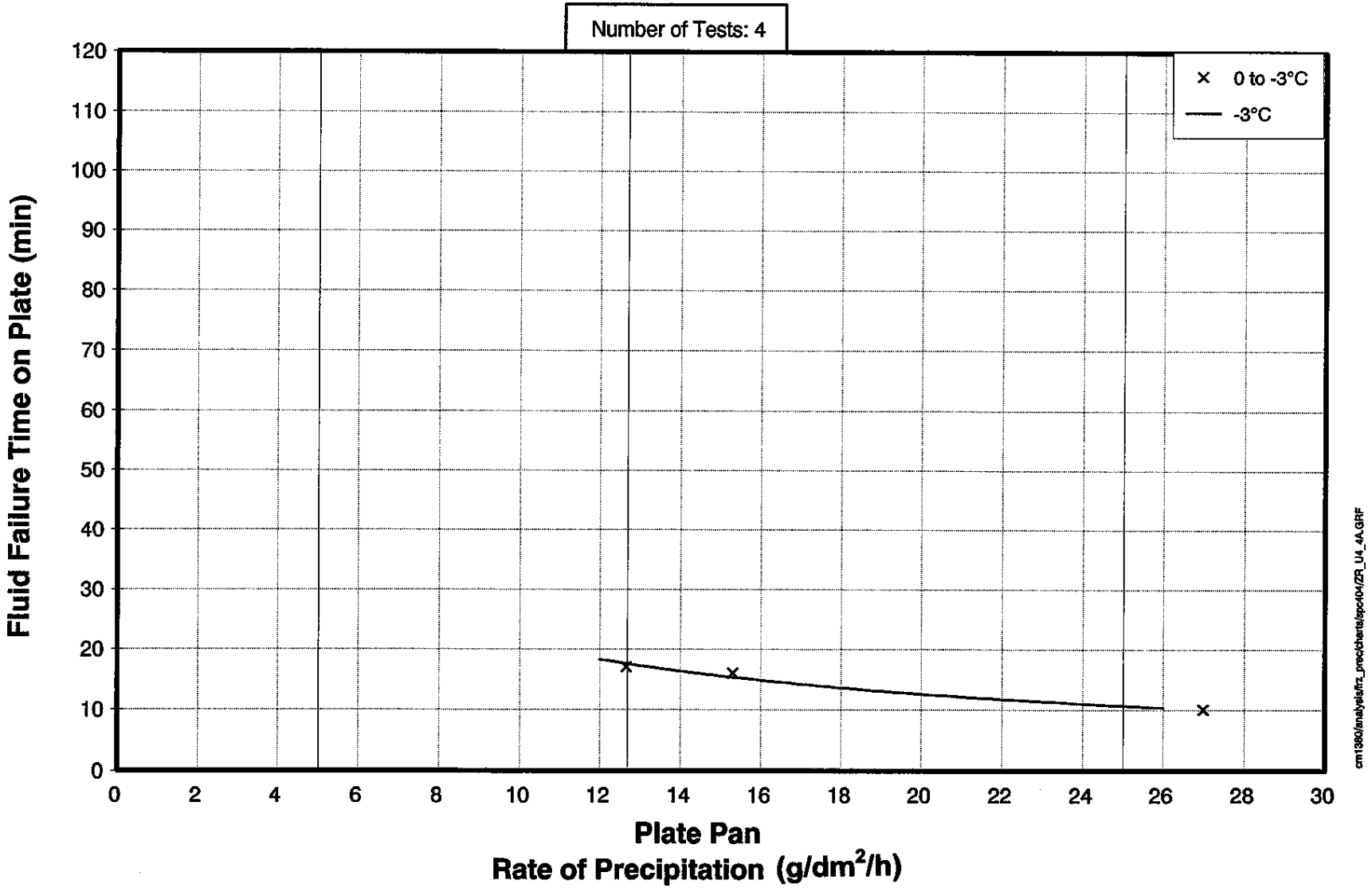
# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## ULTRA IV TYPE IV 50/50

SIMULATED LIGHT FREEZING RAIN

1997/98



# VISCOSITY RANGE FOR TYPE IV FLUIDS USED IN TESTING 1998

| | Lower Production Viscosity | Upper Production Viscosity | Viscosity of Fluids Shipped |
|---|---|---|---|
| CLARIANT 1957 | 23000 mPas | 27000 mPas | 22000 mPas |
| CLARIANT 2001 | 15000 mPas | 25000 mPas | 20000 mPas |
| KILFROST ABC-S | 20000 mPas | 27000 mPas | 13000 mPas |
| OCTAGON MAXFLIGHT | 6500 mPas | 10000 mPas | 8500 mPas |
| UCAR ULTRA IV | 45000 mPas | 58000 mPas | 48000 mPas |
| UCAR PG AAF | 45000 mPas | 58000 mPas | 50000 mPas |
| SPCA AD-404* | 28000 mPas | 38000 mPas | 31800 mPas |
| SPCA AD-480* | 17000 mPas | 23000 mPas | 20500 mPas |

* values need to be confirmed

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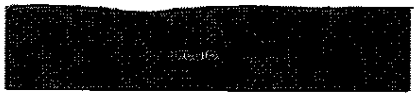
# TYPE IV ETHYLENE vs TYPE IV PROPYLENE
## SCHEMATIC OF FAILURE MECHANISM
### FREEZING DRIZZLE; T = -10°C, Rate = 5g/dm²/hr

| Time (min) | TYPE IV ETHYLENE | TYPE IV PROPYLENE | Time (min) |
|---|---|---|---|
| 5 | 1.5 mm | 1.6 mm | 5 |
| 10 | | | 10 |
| 15 |  1.2 mm | 1.2 mm | 15 |
| 20 | | | 20 |
| 25 | | | 25 |
| 30 | | 1.2 mm | 30 |
| 35 | | FAILURE CALL | 35 |
| 40 | 1.0 mm | | 40 |
| 45 | | Fluid thickness stabilizes shortly after pouring. The fluid resists dilution at this temperature. Failure was called when contamination suspended in the fluid covered more than 1/3 of the plate. Note that this contamination could be easily dislodged by blowing a stream of air onto the fluid surface. | 45 |
| 50 | | | 50 |
| 55 | | | 55 |
| 60 | 0.5 mm<br>FAILURE CALL | | 60 |
| | Fluid thickness **decreased** with dilution. At failure, a layer of ice covered the plate. | | |

# APPENDIX F

# STATISTICAL MULTI-VARIABLE REGRESSION ANALYSIS

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# CLARIANT MPIV 1957 TYPE IV NEAT (#1)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.974432899 |
| R Square | 0.949519475 |
| Adjusted R Square | 0.945780177 |
| Standard Error | 0.056652103 |
| Observations | 30 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.629955879 | 0.81497794 | 253.9298641 | 3.10579E-18 |
| Residual | 27 | 0.086655441 | 0.00320946 | | |
| Total | 29 | 1.71661132 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.815756804 | 0.056574721 | 49.7705825 | 4.22685E-28 | 2.699675143 | 2.93183846 | 2.699675143 | 2.931838465 |
| log_rate | -0.636546866 | 0.034083475 | -18.676114 | 5.7387E-17 | -0.706480333 | -0.5666134 | -0.706480333 | -0.566613399 |
| log_tem_C | -0.357117839 | 0.056298731 | -6.3432663 | 8.60727E-07 | -0.472633215 | -0.24160246 | -0.472633215 | -0.241602463 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# CLARIANT MPIV 1957 TYPE IV 75/25 (#2)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.969183845 |
| R Square | 0.939317325 |
| Adjusted R Square | 0.933800718 |
| Standard Error | 0.070194225 |
| Observations | 25 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.677927001 | 0.8389635 | 170.2708487 | 4.10877E-14 |
| Residual | 22 | 0.108399043 | 0.00492723 | | |
| Total | 24 | 1.786326044 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.698390516 | 0.066099872 | 40.8229307 | 3.1082E-22 | 2.561307623 | 2.83547341 | 2.561307623 | 2.835473408 |
| log_rate | -0.668589383 | 0.047204889 | -14.163562 | 1.54939E-12 | -0.766486437 | -0.57069233 | -0.766486437 | -0.570692329 |
| log_tem_C | -0.372099826 | 0.075758675 | -4.9116464 | 6.52668E-05 | -0.529213871 | -0.21498578 | -0.529213871 | -0.214985782 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# CLARIANT MPIV 1957 TYPE IV 50/50 (#3)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.899474879 |
| R Square | 0.809055058 |
| Adjusted R Square | 0.788955591 |
| Standard Error | 0.120754371 |
| Observations | 22 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.173894961 | 0.58694748 | 40.25256177 | 1.47444E-07 |
| Residual | 19 | 0.277050742 | 0.01458162 | | |
| Total | 21 | 1.450945703 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.230019583 | 0.136968512 | 16.2812573 | 1.29091E-12 | 1.943341103 | 2.51669806 | 1.943341103 | 2.516698062 |
| log_rate | -0.70808442 | 0.079936582 | -8.8580773 | 3.57378E-08 | -0.875393661 | -0.54077518 | -0.875393661 | -0.54077518 |
| log_tem_C | -0.243454151 | 0.144666614 | -1.6828634 | 0.108762276 | -0.546244947 | 0.05933665 | -0.546244947 | 0.059336646 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# CLARIANT MPIV 2001 TYPE IV NEAT (#4)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.952918377 |
| R Square | 0.908053433 |
| Adjusted R Square | 0.902480914 |
| Standard Error | 0.075514229 |
| Observations | 36 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.858435141 | 0.92921757 | 162.9520508 | 7.91291E-18 |
| Residual | 33 | 0.188179159 | 0.0057024 | | |
| Total | 35 | 2.0466143 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.216582981 | 0.089275075 | 36.0300226 | 4.46886E-28 | 3.03495133 | 3.39821463 | 3.03495133 | 3.398214631 |
| log_rate | -0.674580496 | 0.044873486 | -15.032942 | 2.53236E-16 | -0.765876362 | -0.58328463 | -0.765876362 | -0.583284629 |
| log_tem_C | -0.693422385 | 0.073763736 | -9.4005865 | 7.43627E-11 | -0.843495955 | -0.54334882 | -0.843495955 | -0.543348816 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# CLARIANT MPIV 2001 TYPE IV 75/25 (#5)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.869081551 |
| R Square | 0.755302743 |
| Adjusted R Square | 0.73842707 |
| Standard Error | 0.130118442 |
| Observations | 32 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.515540928 | 0.75777046 | 44.75689634 | 1.36497E-09 |
| Residual | 29 | 0.490993461 | 0.01693081 | | |
| Total | 31 | 2.006534389 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.608764204 | 0.11591699 | 22.5054517 | 6.54791E-20 | 2.371687211 | 2.8458412 | 2.371687211 | 2.845841196 |
| log_rate | -0.546308471 | 0.075343501 | -7.2509037 | 5.52207E-08 | -0.700403318 | -0.39221362 | -0.700403318 | -0.392213625 |
| log_tem_C | -0.433202812 | 0.116077657 | -3.7320086 | 0.000823924 | -0.670608406 | -0.19579722 | -0.670608406 | -0.195797218 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# CLARIANT MPIV 2001 TYPE IV 50/50 (#6)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.955355762 |
| R Square | 0.912704632 |
| Adjusted R Square | 0.90106525 |
| Standard Error | 0.069221675 |
| Observations | 18 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.751474969 | 0.37573748 | 78.41521192 | 1.14139E-08 |
| Residual | 15 | 0.071874604 | 0.00479164 | | |
| Total | 17 | 0.823349573 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.919463164 | 0.123108433 | 15.5916464 | 1.123E-10 | 1.657063589 | 2.18186274 | 1.657063589 | 2.181862739 |
| log_rate | -0.677478375 | 0.068870581 | -9.8369777 | 6.20053E-08 | -0.824272634 | -0.53068411 | -0.824272634 | -0.530684115 |
| log_tem_C | 0.044566888 | 0.116414601 | 0.38282903 | 0.707216933 | -0.203565112 | 0.29269889 | -0.203565112 | 0.292698889 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# KILFROST ABC-S TYPE IV NEAT (#7)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.914744106 |
| R Square | 0.836756779 |
| Adjusted R Square | 0.823697322 |
| Standard Error | 0.063167177 |
| Observations | 28 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.511313237 | 0.25565662 | 64.07285827 | 1.4469E-10 |
| Residual | 25 | 0.099752307 | 0.00399009 | | |
| Total | 27 | 0.611065544 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.753637902 | 0.092137256 | 29.8862589 | 4.38304E-21 | 2.563877803 | 2.943398 | 2.563877803 | 2.943398001 |
| log_rate | -0.600332382 | 0.053561138 | -11.208357 | 3.05735E-11 | -0.710643534 | -0.49002123 | -0.710643534 | -0.49002123 |
| log_tem_C | -0.212188024 | 0.05753722 | -3.6878394 | 0.001099297 | -0.330688063 | -0.09368799 | -0.330688063 | -0.093687985 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# KILFROST ABC-S TYPE IV 75/25 (#8)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.863488556 |
| R Square | 0.745612487 |
| Adjusted R Square | 0.731479847 |
| Standard Error | 0.097821659 |
| Observations | 20 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.504847177 | 0.50484718 | 52.7581901 | 9.42618E-07 |
| Residual | 18 | 0.172243384 | 0.00956908 | | |
| Total | 19 | 0.677090561 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.393673174 | 0.099287032 | 24.1086185 | 3.74427E-15 | 2.185078699 | 2.60226765 | 2.185078699 | 2.602267648 |
| log_rate | -0.595007356 | 0.081917632 | -7.2634833 | 9.42618E-07 | -0.767110048 | -0.42290466 | -0.767110048 | -0.422904664 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# KILFROST ABC-S TYPE IV 50/50 (#9)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.946357801 |
| R Square | 0.895593087 |
| Adjusted R Square | 0.884602885 |
| Standard Error | 0.065293634 |
| Observations | 22 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.694827121 | 0.34741356 | 81.49014338 | 4.76352E-10 |
| Residual | 19 | 0.081001915 | 0.00426326 | | |
| Total | 21 | 0.775829035 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.31003605 | 0.094055145 | 24.5604431 | 7.39024E-16 | 2.113176307 | 2.50689579 | 2.113176307 | 2.506895793 |
| log_rate | -0.975114658 | 0.076612548 | -12.727871 | 9.52313E-11 | -1.135466614 | -0.8147627 | -1.135466614 | -0.814762703 |
| log_tem_C | -0.267958194 | 0.072836353 | -3.6789073 | 0.001594587 | -0.420406481 | -0.11550991 | -0.420406481 | -0.115509907 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# OCTAGON MAXFLIGHT TYPE IV NEAT (#10)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.891302295 |
| R Square | 0.79441978 |
| Adjusted R Square | 0.788460933 |
| Standard Error | 0.091429279 |
| Observations | 72 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 2.228888814 | 1.11444441 | 133.3177017 | 1.98544E-24 |
| Residual | 69 | 0.576792602 | 0.00835931 | | |
| Total | 71 | 2.805681416 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.057278412 | 0.083358892 | 36.6760924 | 5.49341E-47 | 2.890982025 | 3.2235748 | 2.890982025 | 3.223574799 |
| log_rate | -0.725599051 | 0.046901419 | -15.470727 | 4.00683E-24 | -0.819164793 | -0.63203331 | -0.819164793 | -0.632033309 |
| log_tem_C | -0.51456759 | 0.054914288 | -9.3703771 | 6.34826E-14 | -0.624118564 | -0.40501662 | -0.624118564 | -0.405016616 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# OCTAGON MAXFLIGHT TYPE IV 75/25 (#11)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.90591522 |
| R Square | 0.820682385 |
| Adjusted R Square | 0.812342031 |
| Standard Error | 0.112703538 |
| Observations | 46 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 2.499745017 | 1.24987251 | 98.39898495 | 8.97209E-17 |
| Residual | 43 | 0.546189759 | 0.01270209 | | |
| Total | 45 | 3.045934776 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.386492353 | 0.120344861 | 28.1399 | 2.50373E-29 | 3.143793977 | 3.62919073 | 3.143793977 | 3.629190728 |
| log_rate | -0.921599229 | 0.072282331 | -12.749993 | 3.32974E-16 | -1.067370341 | -0.77582812 | -1.067370341 | -0.775828117 |
| log_tem_C | -0.649244293 | 0.079253523 | -8.1919928 | 2.53874E-10 | -0.809074145 | -0.48941444 | -0.809074145 | -0.489414442 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# OCTAGON MAXFLIGHT TYPE IV 50/50 (#12)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.902025776 |
| R Square | 0.8136505 |
| Adjusted R Square | 0.8012272 |
| Standard Error | 0.073212937 |
| Observations | 17 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.35105615 | 0.35105615 | 65.49391072 | 7.46822E-07 |
| Residual | 15 | 0.080402013 | 0.00536013 | | |
| Total | 16 | 0.431458163 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.551775562 | 0.077599612 | 32.88387 | 2.13977E-15 | 2.386375802 | 2.71717532 | 2.386375802 | 2.717175322 |
| log_rate | -0.637563057 | 0.078781216 | -8.0928308 | 7.46822E-07 | -0.805481348 | -0.46964477 | -0.805481348 | -0.469644765 |

# MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# UCAR PG TYPE IV NEAT (#13)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.95850675 |
| R Square | 0.918735189 |
| Adjusted R Square | 0.914220478 |
| Standard Error | 0.061200543 |
| Observations | 39 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.524406783 | 0.76220339 | 203.4980861 | 2.38916E-20 |
| Residual | 36 | 0.134838232 | 0.00374551 | | |
| Total | 38 | 1.659245015 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.815828594 | 0.045166688 | 62.3430391 | 2.82926E-38 | 2.724226426 | 2.90743076 | 2.724226426 | 2.907430762 |
| log_rate | -0.561669344 | 0.032406595 | -17.331946 | 4.72187E-19 | -0.627392878 | -0.49594581 | -0.627392878 | -0.49594581 |
| log_tem_C | -0.193200739 | 0.047244711 | -4.0893623 | 0.000232077 | -0.289017328 | -0.09738415 | -0.289017328 | -0.097384151 |

# MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# UCAR PG TYPE IV 75/25 (#14)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.951123425 |
| R Square | 0.90463577 |
| Adjusted R Square | 0.898058926 |
| Standard Error | 0.097934135 |
| Observations | 32 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 2.638483806 | 1.3192419 | 137.5486244 | 1.58888E-15 |
| Residual | 29 | 0.278141751 | 0.00959109 | | |
| Total | 31 | 2.916625557 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.093675571 | 0.094223508 | 32.8333728 | 1.72522E-24 | 2.900966754 | 3.28638439 | 2.900966754 | 3.286384389 |
| log_rate | -0.723970617 | 0.072732308 | -9.9539068 | 7.32842E-11 | -0.87272497 | -0.57521626 | -0.87272497 | -0.575216264 |
| log_tem_C | -0.644420493 | 0.126226296 | -5.1052793 | 1.89303E-05 | -0.902582396 | -0.38625859 | -0.902582396 | -0.386258589 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# UCAR PG TYPE IV 50/50 (#15)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.985017337 |
| R Square | 0.970259154 |
| Adjusted R Square | 0.958362815 |
| Standard Error | 0.037851568 |
| Observations | 8 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.233707243 | 0.11685362 | 81.55947776 | 0.00015254 |
| Residual | 5 | 0.007163706 | 0.00143274 | | |
| Total | 7 | 0.240870949 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.3692047 | 0.115394195 | 20.5314027 | 5.07265E-06 | 2.072574962 | 2.66583444 | 2.072574962 | 2.665834438 |
| log_rate | -0.781552544 | 0.062534179 | -12.498006 | 5.81785E-05 | -0.942301507 | -0.62080358 | -0.942301507 | -0.620803581 |
| log_tem_C | -0.056630576 | 0.197641729 | -0.2865315 | 0.785964433 | -0.564683984 | 0.45142283 | -0.564683984 | 0.451422832 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# UCAR ULTRA IV TYPE IV NEAT (#16)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.952789362 |
| R Square | 0.907807568 |
| Adjusted R Square | 0.902539429 |
| Standard Error | 0.061228454 |
| Observations | 38 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.292031684 | 0.64601584 | 172.3203538 | 7.62373E-19 |
| Residual | 35 | 0.131212326 | 0.00374892 | | |
| Total | 37 | 1.423244011 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.791419701 | 0.044881575 | 62.1952259 | 1.99476E-37 | 2.700305148 | 2.88253425 | 2.700305148 | 2.882534253 |
| log_rate | -0.523730441 | 0.034430644 | -15.211172 | 5.37716E-17 | -0.593628449 | -0.45383243 | -0.593628449 | -0.453832434 |
| log_tem_C | -0.189358147 | 0.049054663 | -3.8601457 | 0.000466948 | -0.288944529 | -0.08977177 | -0.288944529 | -0.089771765 |

# MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# UCAR ULTRA IV TYPE IV 75/25 (#17)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.947427762 |
| R Square | 0.897619364 |
| Adjusted R Square | 0.89055863 |
| Standard Error | 0.095612126 |
| Observations | 32 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 2.324332948 | 1.16216647 | 127.1283442 | 4.44794E-15 |
| Residual | 29 | 0.265108682 | 0.00914168 | | |
| Total | 31 | 2.58944163 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.021550811 | 0.086020392 | 35.1259829 | 2.55247E-25 | 2.84561926 | 3.19748236 | 2.84561926 | 3.197482362 |
| log_rate | -0.655272937 | 0.056607956 | -11.575633 | 2.16167E-12 | -0.771049269 | -0.53949661 | -0.771049269 | -0.539496605 |
| log_tem_C | -0.649506644 | 0.101376912 | -6.4068497 | 5.25034E-07 | -0.856845824 | -0.44216746 | -0.856845824 | -0.442167465 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# UCAR ULTRA IV TYPE IV 50/50 (#18)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.9826735 |
| R Square | 0.965647207 |
| Adjusted R Square | 0.958776648 |
| Standard Error | 0.041319172 |
| Observations | 13 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.479909839 | 0.23995492 | 140.5485723 | 4.78421E-08 |
| Residual | 10 | 0.01707274 | 0.00170727 | | |
| Total | 12 | 0.496982579 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.169908948 | 0.063230335 | 34.3175302 | 1.04498E-11 | 2.029022956 | 2.31079494 | 2.029022956 | 2.310794939 |
| log_rate | -0.604101063 | 0.038144814 | -15.837043 | 2.07262E-08 | -0.689093019 | -0.51910911 | -0.689093019 | -0.519109107 |
| log_tem_C | -0.182643759 | 0.077945663 | -2.343219 | 0.041113307 | -0.356317551 | -0.00896997 | -0.356317551 | -0.008969968 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# SPCA AD-404 TYPE IV NEAT (#13)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.797556521 |
| R Square | 0.636096405 |
| Adjusted R Square | 0.60301426 |
| Standard Error | 0.139765951 |
| Observations | 25 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.751211181 | 0.37560559 | 19.22778601 | 1.48201E-05 |
| Residual | 22 | 0.429759463 | 0.01953452 | | |
| Total | 24 | 1.180970645 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.948223836 | 0.166348238 | 17.7232045 | 1.63893E-14 | 2.603238335 | 3.29320934 | 2.603238335 | 3.293209337 |
| log_rate | -0.578307625 | 0.098929237 | -5.8456695 | 6.99284E-06 | -0.783474525 | -0.37314073 | -0.783474525 | -0.373140725 |
| log_tem_C | -0.493008689 | 0.132475976 | -3.721495 | 0.001186713 | -0.767747343 | -0.21827004 | -0.767747343 | -0.218270035 |

# MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# SPCA AD-404 TYPE IV 75/25 (#14)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.872884792 |
| R Square | 0.76192786 |
| Adjusted R Square | 0.733919372 |
| Standard Error | 0.165650074 |
| Observations | 20 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.492923197 | 0.7464616 | 27.2034636 | 5.03527E-06 |
| Residual | 17 | 0.466479099 | 0.02743995 | | |
| Total | 19 | 1.959402296 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.052933042 | 0.170037223 | 17.9544983 | 1.73161E-12 | 2.694185359 | 3.41168073 | 2.694185359 | 3.411680725 |
| log_rate | -0.8274871 | 0.12014308 | -6.8875136 | 2.63078E-06 | -1.080967196 | -0.574007 | -1.080967196 | -0.574007004 |
| log_tem_C | -0.662021842 | 0.150323765 | -4.4039733 | 0.000387864 | -0.979177705 | -0.34486598 | -0.979177705 | -0.344865979 |

# MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# SPCA AD-404 TYPE IV 50/50 (#15)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.97813201 |
| R Square | 0.956742229 |
| Adjusted R Square | 0.947129391 |
| Standard Error | 0.098693746 |
| Observations | 12 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.938887365 | 0.96944368 | 99.52755175 | 7.28264E-07 |
| Residual | 9 | 0.087664099 | 0.00974046 | | |
| Total | 11 | 2.026551464 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.63691503 | 0.083148658 | 31.7132602 | 1.51312E-10 | 2.448819554 | 2.82501051 | 2.448819554 | 2.825010506 |
| log_rate | -0.890512427 | 0.067858713 | -13.123037 | 3.58117E-07 | -1.044019617 | -0.73700524 | -1.044019617 | -0.737005237 |
| log_tem_C | -0.386741056 | 0.103766461 | -3.7270333 | 0.004719047 | -0.621477279 | -0.15200483 | -0.621477279 | -0.152004834 |

## MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# SPCA AD-480 TYPE IV NEAT (#16)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.97564818 |
| R Square | 0.95188937 |
| Adjusted R Square | 0.943141983 |
| Standard Error | 0.053584208 |
| Observations | 14 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.624901767 | 0.31245088 | 108.819851 | 5.65361E-08 |
| Residual | 11 | 0.031583941 | 0.00287127 | | |
| Total | 13 | 0.656485708 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.928893599 | 0.083153935 | 35.2225495 | 1.16026E-12 | 2.745872929 | 3.11191427 | 2.745872929 | 3.111914269 |
| log_rate | -0.739672253 | 0.050138483 | -14.752586 | 1.35754E-08 | -0.850026365 | -0.62931814 | -0.850026365 | -0.629318141 |
| log_tem_C | -0.141202052 | 0.07171567 | -1.9689149 | 0.074669955 | -0.299047258 | 0.01664315 | -0.299047258 | 0.016643153 |

# MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# SPCA AD-480 TYPE IV 75/25 (#17)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.979844313 |
| R Square | 0.960094877 |
| Adjusted R Square | 0.955400157 |
| Standard Error | 0.059803242 |
| Observations | 20 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.462796369 | 0.73139818 | 204.5052337 | 1.28453E-12 |
| Residual | 17 | 0.060799271 | 0.00357643 | | |
| Total | 19 | 1.52359564 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.845419481 | 0.140781062 | 20.2116637 | 2.51948E-13 | 2.548396988 | 3.14244197 | 2.548396988 | 3.142441973 |
| log_rate | -0.696054274 | 0.035688071 | -19.503836 | 4.51017E-13 | -0.771349627 | -0.62075892 | -0.771349627 | -0.620758922 |
| log_tem_C | -0.323497117 | 0.199729464 | -1.6196765 | 0.123702457 | -0.74489004 | 0.09789581 | -0.74489004 | 0.097895806 |

# MULTI-VARIABLE REGRESSION OUTPUT
# NATURAL SNOW CONDITIONS
# SPCA AD-480 TYPE IV 50/50 (#18)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999464227 |
| R Square | 0.99892874 |
| Adjusted R Square | 0.998500236 |
| Standard Error | 0.009944789 |
| Observations | 8 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.461106055 | 0.23055303 | 2331.200673 | 3.7561E-08 |
| Residual | 5 | 0.000494494 | 9.8899E-05 | | |
| Total | 7 | 0.461600549 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.501872412 | 0.026184528 | 95.5477382 | 2.38063E-09 | 2.43456305 | 2.56918177 | 2.43456305 | 2.569181774 |
| log_rate | -0.96534001 | 0.017991746 | -53.654604 | 4.25259E-08 | -1.01158919 | -0.91909083 | -1.01158919 | -0.91909083 |
| log_tem_C | -0.081799484 | 0.02802361 | -2.9189489 | 0.03305408 | -0.153836348 | -0.00976262 | -0.153836348 | -0.00976262 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# CLARIANT MPIV 1957 TYPE IV NEAT (#1)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.998457569 |
| R Square | 0.996917517 |
| Adjusted R Square | 0.995376275 |
| Standard Error | 0.027246672 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.480192519 | 0.48019252 | 646.8274966 | 0.001542431 |
| Residual | 2 | 0.001484762 | 0.00074238 | | |
| Total | 3 | 0.481677281 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.348038639 | 0.034695386 | 67.6758178 | 0.000218268 | 2.198756337 | 2.49732094 | 2.198756337 | 2.497320941 |
| Log_rate | -0.61509248 | 0.024185005 | -25.432804 | 0.001542431 | -0.71915223 | -0.51103273 | -0.71915223 | -0.51103273 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# CLARIANT MPIV 1957 TYPE IV 75/25 (#2)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999758471 |
| R Square | 0.999517 |
| Adjusted R Square | 0.9992755 |
| Standard Error | 0.012632948 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.660514672 | 0.66051467 | 4138.786629 | 0.000241529 |
| Residual | 2 | 0.000319183 | 0.00015959 | | |
| Total | 3 | 0.660833855 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.258173839 | 0.014669101 | 153.940846 | 4.21954E-05 | 2.195057747 | 2.32128993 | 2.195057747 | 2.321289931 |
| Log_rate | -0.6771303 | 0.01052533 | -64.333402 | 0.000241529 | -0.722417172 | -0.63184343 | -0.722417172 | -0.631843428 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# CLARIANT MPIV 2001 TYPE IV NEAT (#3)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999916655 |
| R Square | 0.999833318 |
| Adjusted R Square | 0.999749976 |
| Standard Error | 0.00764094 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.700424651 | 0.70042465 | 11996.86808 | 8.33447E-05 |
| Residual | 2 | 0.000116768 | 5.8384E-05 | | |
| Total | 3 | 0.700541419 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.592296018 | 0.010005389 | 259.089991 | 1.48967E-05 | 2.549246276 | 2.63534576 | 2.549246276 | 2.63534576 |
| Log_rate | -0.761969705 | 0.006956708 | -109.53022 | 8.33447E-05 | -0.791902024 | -0.73203739 | -0.791902024 | -0.732037386 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# CLARIANT MPIV 2001 TYPE IV 75/25 (#4)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999252989 |
| R Square | 0.998506537 |
| Adjusted R Square | 0.997759805 |
| Standard Error | 0.021763595 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.633355652 | 0.63335565 | 1337.169289 | 0.000747011 |
| Residual | 2 | 0.000947308 | 0.00047365 | | |
| Total | 3 | 0.63430296 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.199789266 | 0.026244734 | 83.8183091 | 0.000142308 | 2.086867209 | 2.31271132 | 2.086867209 | 2.312711323 |
| Log_rate | -0.675652685 | 0.018476951 | -36.567325 | 0.000747011 | -0.755152645 | -0.59615273 | -0.755152645 | -0.596152725 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# KILFROST ABC-S TYPE IV NEAT (#5)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.996301982 |
| R Square | 0.99261764 |
| Adjusted R Square | 0.98892646 |
| Standard Error | 0.032631896 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.286352749 | 0.28635275 | 268.9160658 | 0.003698018 |
| Residual | 2 | 0.002129681 | 0.00106484 | | |
| Total | 3 | 0.28848243 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.220661951 | 0.042358414 | 52.4255222 | 0.000363645 | 2.03840828 | 2.40291562 | 2.03840828 | 2.402915622 |
| Log_rate | -0.481262356 | 0.029347663 | -16.39866 | 0.003698018 | -0.607535245 | -0.35498947 | -0.607535245 | -0.354989467 |

## MULTI-VARIABLE REGRESSION OUTPUT
## COLD-SOAKED BOXES
## KILFROST ABC-S TYPE IV 75/25 (#6)

SUMMARY OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99981401 |
| R Square | 0.99962805 |
| Adjusted R Squa | 0.99944208 |
| Standard Error | 0.00795904 |
| Observations | 4 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *ignificance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.340493474 | 0.340493 | 5375.11556 | 0.00018599 |
| Residual | 2 | 0.000126693 | 6.33E-05 | | |
| Total | 3 | 0.340620167 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.04841244 | 0.010061301 | 203.5932 | 2.4124E-05 | 2.00512213 | 2.0917028 | 2.005122127 | 2.091702759 |
| Log_rate | -0.5135786 | 0.007005078 | -73.3152 | 0.00018599 | -0.543719 | -0.483438 | -0.543719 | -0.483438125 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# OCTAGON MAXFLIGHT TYPE IV NEAT (#7)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999893637 |
| R Square | 0.999787285 |
| Adjusted R Square | 0.999680928 |
| Standard Error | 0.00678991 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.433379086 | 0.43337909 | 9400.261469 | 0.000106363 |
| Residual | 2 | 9.22058E-05 | 4.6103E-05 | | |
| Total | 3 | 0.433471291 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.279021172 | 0.008541153 | 266.828276 | 1.40452E-05 | 2.24227153 | 2.31577081 | 2.24227153 | 2.315770813 |
| Log_rate | -0.577426029 | 0.005955612 | -96.954946 | 0.000106363 | -0.603050977 | -0.55180108 | -0.603050977 | -0.551801081 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# OCTAGON MAXFLIGHT TYPE IV 75/25 (#8)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.988816037 |
| R Square | 0.977757155 |
| Adjusted R Square | 0.966635733 |
| Standard Error | 0.058322524 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.299049643 | 0.29904964 | 87.91655706 | 0.011183963 |
| Residual | 2 | 0.006803034 | 0.00340152 | | |
| Total | 3 | 0.305852677 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.945951225 | 0.07208735 | 26.9943508 | 0.001369498 | 1.635784174 | 2.25611828 | 1.635784174 | 2.256118275 |
| Log_rate | -0.473382591 | 0.050486696 | -9.3763829 | 0.011183963 | -0.690609461 | -0.25615572 | -0.690609461 | -0.256155722 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# UCAR PG TYPE IV NEAT (#9)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.855849648 |
| R Square | 0.73247862 |
| Adjusted R Square | 0.678974344 |
| Standard Error | 0.21088393 |
| Observations | 7 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.608826342 | 0.60882634 | 13.69009499 | 0.01399922 |
| Residual | 5 | 0.22236016 | 0.04447203 | | |
| Total | 6 | 0.831186502 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.466667808 | 0.19545006 | 12.6204505 | 5.54817E-05 | 1.964248255 | 2.96908736 | 1.964248255 | 2.969087361 |
| Log_rate | -0.528235074 | 0.142765741 | -3.7000128 | 0.01399922 | -0.895225495 | -0.16124465 | -0.895225495 | -0.161244653 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# UCAR PG TYPE IV 75/25 (#10)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999800494 |
| R Square | 0.999601027 |
| Adjusted R Square | 0.999401541 |
| Standard Error | 0.013269706 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.882340188 | 0.88234019 | 5010.873768 | 0.000199506 |
| Residual | 2 | 0.00035217 | 0.00017609 | | |
| Total | 3 | 0.882692358 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.143796007 | 0.015289379 | 140.214721 | 5.08604E-05 | 2.078011073 | 2.20958094 | 2.078011073 | 2.209580941 |
| Log_rate | -0.765013774 | 0.010807183 | -70.787526 | 0.000199506 | -0.811513364 | -0.71851418 | -0.811513364 | -0.718514184 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# UCAR ULTRA IV TYPE IV NEAT (#11)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99210729 |
| R Square | 0.984276876 |
| Adjusted R Square | 0.979035834 |
| Standard Error | 0.055448905 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.577411776 | 0.57741178 | 187.8017718 | 0.000840733 |
| Residual | 3 | 0.009223743 | 0.00307458 | | |
| Total | 4 | 0.58663552 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.727103121 | 0.058888878 | 46.3093072 | 2.21686E-05 | 2.539692254 | 2.91451399 | 2.539692254 | 2.914513988 |
| Log_rate | -0.612674435 | 0.044707452 | -13.704079 | 0.000840733 | -0.754953634 | -0.47039524 | -0.754953634 | -0.470395237 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# UCAR ULTRA IV TYPE IV 75/25 (#12)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.996198056 |
| R Square | 0.992410567 |
| Adjusted R Square | 0.989880757 |
| Standard Error | 0.04137576 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.671576209 | 0.67157621 | 392.2864688 | 0.000281251 |
| Residual | 3 | 0.005135861 | 0.00171195 | | |
| Total | 4 | 0.67671207 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.321038234 | 0.041149674 | 56.4047775 | 1.22753E-05 | 2.190081482 | 2.45199499 | 2.190081482 | 2.451994986 |
| Log_rate | -0.634025111 | 0.032011409 | -19.806223 | 0.000281251 | -0.735899798 | -0.53215042 | -0.735899798 | -0.532150424 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# SPCA AD-404 TYPE IV NEAT (#9)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.997847983 |
| R Square | 0.995700597 |
| Adjusted R Square | 0.994267462 |
| Standard Error | 0.039646104 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 1.092050794 | 1.09205079 | 694.7712145 | 0.000119802 |
| Residual | 3 | 0.004715441 | 0.00157181 | | |
| Total | 4 | 1.096766234 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.855357564 | 0.042417686 | 67.3152604 | 7.22412E-06 | 2.72036543 | 2.9903497 | 2.72036543 | 2.990349698 |
| Log_rate | -0.849340797 | 0.032222637 | -26.358513 | 0.000119802 | -0.951887705 | -0.74679389 | -0.951887705 | -0.746793889 |

# MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# SPCA AD-404 TYPE IV 75/25 (#10)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999948218 |
| R Square | 0.999896439 |
| Adjusted R Square | 0.999844659 |
| Standard Error | 0.005768474 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.64255683 | 0.64255683 | 19310.33175 | 5.17817E-05 |
| Residual | 2 | 6.65506E-05 | 3.3275E-05 | | |
| Total | 3 | 0.64262338 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.216567705 | 0.006837914 | 324.158447 | 9.51654E-06 | 2.187146514 | 2.2459889 | 2.187146514 | 2.245988897 |
| Log_rate | -0.677431465 | 0.004874954 | -138.96162 | 5.17817E-05 | -0.698406713 | -0.65645622 | -0.698406713 | -0.656456218 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# SPCA AD-480 TYPE IV NEAT (#11)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.994627574 |
| R Square | 0.98928401 |
| Adjusted R Square | 0.983926015 |
| Standard Error | 0.038582679 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.274854888 | 0.27485489 | 184.6369825 | 0.005372426 |
| Residual | 2 | 0.002977246 | 0.00148862 | | |
| Total | 3 | 0.277832134 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.081739104 | 0.049294261 | 42.2308617 | 0.000560241 | 1.869642871 | 2.29383534 | 1.869642871 | 2.293835337 |
| Log_rate | -0.474554432 | 0.034924218 | -13.588119 | 0.005372426 | -0.624821317 | -0.32428755 | -0.624821317 | -0.324287546 |

## MULTI-VARIABLE REGRESSION OUTPUT
# COLD-SOAKED BOXES
# SPCA AD-480 TYPE IV 75/25 (#12)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.997618981 |
| R Square | 0.995243631 |
| Adjusted R Square | 0.992865446 |
| Standard Error | 0.024825554 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.257918059 | 0.25791806 | 418.488805 | 0.002381019 |
| Residual | 2 | 0.001232616 | 0.00061631 | | |
| Total | 3 | 0.259150675 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.899762377 | 0.031211841 | 60.8667193 | 0.000269814 | 1.76546857 | 2.03405618 | 1.76546857 | 2.034056185 |
| Log_rate | -0.449317899 | 0.021964018 | -20.456999 | 0.002381019 | -0.543821508 | -0.35481429 | -0.543821508 | -0.35481429 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# CLARIANT MPIV 1957 TYPE IV NEAT (#1)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.963203277 |
| R Square | 0.927760553 |
| Adjusted R Square | 0.90712071 |
| Standard Error | 0.091148899 |
| Observations | 10 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.746899871 | 0.37344994 | 44.949983 | 0.000101324 |
| Residual | 7 | 0.058156853 | 0.00830812 | | |
| Total | 9 | 0.805056724 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.503869583 | 0.12740776 | 19.6524104 | 2.20592E-07 | 2.202598321 | 2.80514085 | 2.202598321 | 2.805140846 |
| log_rate | -0.160211403 | 0.166117315 | -0.9644473 | 0.366949388 | -0.553016155 | 0.23259335 | -0.553016155 | 0.232593348 |
| log_temp | -0.65840345 | 0.069600588 | -9.4597398 | 3.08164E-05 | -0.822982571 | -0.49382433 | -0.822982571 | -0.49382433 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# CLARIANT MPIV 1957 TYPE IV 75/25 (#2)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.988573927 |
| R Square | 0.977278409 |
| Adjusted R Square | 0.965917613 |
| Standard Error | 0.04071823 |
| Observations | 7 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.285244533 | 0.14262227 | 86.02200359 | 0.000516271 |
| Residual | 4 | 0.006631897 | 0.00165797 | | |
| Total | 6 | 0.29187643 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.664197032 | 0.068543116 | 38.8689218 | 2.61714E-06 | 2.473890437 | 2.85450363 | 2.473890437 | 2.854503626 |
| log_rate | -0.590900118 | 0.095434579 | -6.1916773 | 0.003458852 | -0.855869537 | -0.3259307 | -0.855869537 | -0.325930699 |
| log_temp | -0.561477231 | 0.051113392 | -10.984934 | 0.000390248 | -0.703391052 | -0.41956341 | -0.703391052 | -0.419563409 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# CLARIANT MPIV 1957 TYPE IV 50/50 (#3)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.900736518 |
| R Square | 0.811326274 |
| Adjusted R Square | 0.748435032 |
| Standard Error | 0.067947677 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.059559987 | 0.05955999 | 12.90046514 | 0.036978026 |
| Residual | 3 | 0.01385066 | 0.00461689 | | |
| Total | 4 | 0.073410647 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.002786562 | 0.117111725 | 17.1015033 | 0.00043556 | 1.630084434 | 2.37548869 | 1.630084434 | 2.375488689 |
| log_rate | -0.735584068 | 0.204799848 | -3.5917218 | 0.036978026 | -1.387349199 | -0.08381894 | -1.387349199 | -0.083818938 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# CLARIANT MPIV 2001 TYPE IV NEAT (#4)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.947754532 |
| R Square | 0.898238653 |
| Adjusted R Square | 0.877886383 |
| Standard Error | 0.095423028 |
| Observations | 13 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.803739442 | 0.40186972 | 44.13456952 | 1.09122E-05 |
| Residual | 10 | 0.091055543 | 0.00910555 | | |
| Total | 12 | 0.894794986 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.450132697 | 0.136652507 | 17.9296578 | 6.22865E-09 | 2.145651884 | 2.75461351 | 2.145651884 | 2.75461351 |
| log_rate | -0.07217002 | 0.169442167 | -0.4259272 | 0.679182846 | -0.44971076 | 0.30537072 | -0.44971076 | 0.30537072 |
| log_temp | -0.629680615 | 0.068522727 | -9.1893688 | 3.43019E-06 | -0.782358792 | -0.47700244 | -0.782358792 | -0.477002438 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# CLARIANT MPIV 2001 TYPE IV 75/25 (#5)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99369397 |
| R Square | 0.987427705 |
| Adjusted R Square | 0.981141558 |
| Standard Error | 0.023449263 |
| Observations | 7 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.172746456 | 0.08637323 | 157.0799462 | 0.000158063 |
| Residual | 4 | 0.002199472 | 0.00054987 | | |
| Total | 6 | 0.174945928 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.420712742 | 0.037612821 | 64.3587132 | 3.49159E-07 | 2.316282594 | 2.52514289 | 2.316282594 | 2.52514289 |
| log_rate | -0.536466695 | 0.052047246 | -10.307302 | 0.000499803 | -0.680973314 | -0.39196007 | -0.680973314 | -0.391960075 |
| log_temp | -0.394599036 | 0.029453539 | -13.397339 | 0.000179521 | -0.476375338 | -0.31282273 | -0.476375338 | -0.312822733 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# CLARIANT MPIV 2001 TYPE IV 50/50 (#6)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.802323837 |
| R Square | 0.643723539 |
| Adjusted R Square | 0.524964719 |
| Standard Error | 0.064339589 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.022438307 | 0.02243831 | 5.420427201 | 0.102317354 |
| Residual | 3 | 0.012418748 | 0.00413958 | | |
| Total | 4 | 0.034857055 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.661205677 | 0.108943549 | 15.2483161 | 0.000612522 | 1.314498356 | 2.007913 | 1.314498356 | 2.007912997 |
| log_rate | -0.434972744 | 0.186829429 | -2.3281811 | 0.102317354 | -1.029547928 | 0.15960244 | -1.029547928 | 0.15960244 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# KILFROST ABC-S TYPE IV NEAT (#7)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.991842703 |
| R Square | 0.983751948 |
| Adjusted R Square | 0.978335931 |
| Standard Error | 0.044291587 |
| Observations | 9 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.712652853 | 0.35632643 | 181.6375178 | 4.28947E-06 |
| Residual | 6 | 0.011770468 | 0.00196174 | | |
| Total | 8 | 0.724423321 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.649062697 | 0.07622857 | 34.7515726 | 3.78274E-08 | 2.462537968 | 2.83558743 | 2.462537968 | 2.835587425 |
| log_rate | -0.170810214 | 0.109258055 | -1.563365 | 0.168997554 | -0.438155238 | 0.09653481 | -0.438155238 | 0.096534811 |
| log_temp | -0.68067242 | 0.036865794 | -18.463523 | 1.6275E-06 | -0.770879834 | -0.59046501 | -0.770879834 | -0.590465005 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# KILFROST ABC-S TYPE IV 75/25 (#8)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.988336797 |
| R Square | 0.976809625 |
| Adjusted R Square | 0.965214438 |
| Standard Error | 0.033415252 |
| Observations | 7 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.188127216 | 0.09406361 | 84.24267681 | 0.000537793 |
| Residual | 4 | 0.004466316 | 0.00111658 | | |
| Total | 6 | 0.192593533 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.433814259 | 0.061590834 | 39.5158515 | 2.45027E-06 | 2.262810334 | 2.60481818 | 2.262810334 | 2.604818183 |
| log_rate | -0.508266317 | 0.09087325 | -5.5931346 | 0.005014365 | -0.76057143 | -0.2559612 | -0.76057143 | -0.255961204 |
| log_temp | -0.474801151 | 0.041871562 | -11.339466 | 0.00034482 | -0.591055484 | -0.35854682 | -0.591055484 | -0.358546818 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# KILFROST ABC-S TYPE IV 50/50 (#9)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.934723579 |
| R Square | 0.873708169 |
| Adjusted R Square | 0.831610892 |
| Standard Error | 0.036905945 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.028268649 | 0.02826865 | 20.75450559 | 0.019823013 |
| Residual | 3 | 0.004086146 | 0.00136205 | | |
| Total | 4 | 0.032354796 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.620163864 | 0.047390693 | 34.1873851 | 5.50221E-05 | 1.469345387 | 1.77098234 | 1.469345387 | 1.77098234 |
| log_rate | -0.421964918 | 0.092623279 | -4.5557113 | 0.019823013 | -0.716733806 | -0.12719603 | -0.716733806 | -0.127196031 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# OCTAGON MAXFLIGHT TYPE IV NEAT (#10)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.979198205 |
| R Square | 0.958829125 |
| Adjusted R Square | 0.947066018 |
| Standard Error | 0.079584332 |
| Observations | 10 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.03253388 | 0.51626694 | 81.5115523 | 1.41601E-05 |
| Residual | 7 | 0.044335661 | 0.00633367 | | |
| Total | 9 | 1.076869541 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.707183274 | 0.09123072 | 29.6740317 | 1.27186E-08 | 2.491457056 | 2.92290949 | 2.491457056 | 2.922909493 |
| log_rate | -0.403649955 | 0.13905648 | -2.902777 | 0.022895078 | -0.732466044 | -0.07483387 | -0.732466044 | -0.074833866 |
| log_temp | -0.69603846 | 0.062201555 | -11.190049 | 1.01488E-05 | -0.84312166 | -0.54895526 | -0.84312166 | -0.54895526 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# OCTAGON MAXFLIGHT TYPE IV 75/25 (#11)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.995420337 |
| R Square | 0.990861646 |
| Adjusted R Square | 0.981723293 |
| Standard Error | 0.052826451 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.605170748 | 0.30258537 | 108.4289027 | 0.009138354 |
| Residual | 2 | 0.005581268 | 0.00279063 | | |
| Total | 4 | 0.610752015 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.121816918 | 0.147999884 | 21.0933741 | 0.002239993 | 2.48502437 | 3.75860947 | 2.48502437 | 3.758609467 |
| log_rate | -0.704758696 | 0.2113901 | -3.3339248 | 0.07940047 | -1.614297518 | 0.20478013 | -1.614297518 | 0.204780126 |
| log_temp | -1.013112375 | 0.072352609 | -14.00243 | 0.005061579 | -1.324420744 | -0.70180401 | -1.324420744 | -0.701804006 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# OCTAGON MAXFLIGHT TYPE IV 50/50 (#12)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.9283856 |
| R Square | 0.861899822 |
| Adjusted R Square | 0.815866429 |
| Standard Error | 0.048468649 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.043985105 | 0.04398511 | 18.72336084 | 0.022756911 |
| Residual | 3 | 0.00704763 | 0.00234921 | | |
| Total | 4 | 0.051032735 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.298680518 | 0.072517849 | 31.6981344 | 6.89947E-05 | 2.067896142 | 2.52946489 | 2.067896142 | 2.529464894 |
| log_rate | -0.525457732 | 0.121435561 | -4.3270499 | 0.022756911 | -0.911920247 | -0.13899522 | -0.911920247 | -0.138995217 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# UCAR PG TYPE IV NEAT (#13)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.986067786 |
| R Square | 0.972329678 |
| Adjusted R Square | 0.965412097 |
| Standard Error | 0.075302237 |
| Observations | 11 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.594061496 | 0.79703075 | 140.5592135 | 5.86215E-07 |
| Residual | 8 | 0.045363415 | 0.00567043 | | |
| Total | 10 | 1.639424912 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.943664453 | 0.081488317 | 36.1237606 | 3.77849E-10 | 2.755751936 | 3.13157697 | 2.755751936 | 3.13157697 |
| log_rate | -0.328938969 | 0.124483495 | -2.6424304 | 0.029601465 | -0.615998609 | -0.04187933 | -0.615998609 | -0.04187933 |
| log_temp | -0.901565782 | 0.057415195 | -15.702564 | 2.70097E-07 | -1.033965545 | -0.76916602 | -1.033965545 | -0.76916602 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# UCAR PG TYPE IV 75/25 (#14)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.983082621 |
| R Square | 0.966451439 |
| Adjusted R Square | 0.944085732 |
| Standard Error | 0.051784198 |
| Observations | 6 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.231751154 | 0.11587558 | 43.21130661 | 0.006144844 |
| Residual | 3 | 0.00804481 | 0.0026816 | | |
| Total | 5 | 0.239795964 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.611089861 | 0.1322573 | 19.7425008 | 0.000283967 | 2.19018771 | 3.03199201 | 2.19018771 | 3.031992013 |
| log_rate | -0.639476369 | 0.225275012 | -2.8386476 | 0.065719701 | -1.35640267 | 0.07744993 | -1.35640267 | 0.077449932 |
| log_temp | -0.532873294 | 0.070345243 | -7.5751148 | 0.004772065 | -0.756743462 | -0.30900313 | -0.756743462 | -0.309003126 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# UCAR PG TYPE IV 50/50 (#15)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.992473527 |
| R Square | 0.985003701 |
| Adjusted R Square | 0.980004934 |
| Standard Error | 0.024697808 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.120196506 | 0.12019651 | 197.0493569 | 0.000782943 |
| Residual | 3 | 0.001829945 | 0.00060998 | | |
| Total | 4 | 0.122026451 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.271981142 | 0.036859828 | 61.6384088 | 9.40817E-06 | 2.154676609 | 2.38928568 | 2.154676609 | 2.389285675 |
| log_rate | -0.818729374 | 0.058324747 | -14.037427 | 0.000782943 | -1.004344922 | -0.63311383 | -1.004344922 | -0.633113825 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# UCAR ULTRA IV TYPE IV NEAT (#16)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.948381967 |
| R Square | 0.899428356 |
| Adjusted R Square | 0.865904474 |
| Standard Error | 0.122154801 |
| Observations | 9 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.800688067 | 0.40034403 | 26.82948151 | 0.001017248 |
| Residual | 6 | 0.089530772 | 0.0149218 | | |
| Total | 8 | 0.890218839 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.701043792 | 0.133689039 | 20.2039285 | 9.55104E-07 | 2.373918259 | 3.02816933 | 2.373918259 | 3.028169326 |
| log_rate | -0.040491173 | 0.235217913 | -0.1721432 | 0.868984514 | -0.616049094 | 0.53506675 | -0.616049094 | 0.535066747 |
| log_temp | -0.724081164 | 0.115664762 | -6.2601708 | 0.000771067 | -1.007102847 | -0.44105948 | -1.007102847 | -0.441059481 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# UCAR ULTRA IV TYPE IV 75/25 (#17)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.981167501 |
| R Square | 0.962689664 |
| Adjusted R Square | 0.937816107 |
| Standard Error | 0.038531343 |
| Observations | 6 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.114922931 | 0.05746147 | 38.70333707 | 0.007206821 |
| Residual | 3 | 0.004453993 | 0.00148466 | | |
| Total | 5 | 0.119376925 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.341230181 | 0.054664466 | 42.8291051 | 2.80157E-05 | 2.167263289 | 2.51519707 | 2.167263289 | 2.515197074 |
| log_rate | -0.537137799 | 0.106570809 | -5.0401963 | 0.015058046 | -0.876293993 | -0.1979816 | -0.876293993 | -0.197981604 |
| log_temp | -0.203255021 | 0.058746955 | -3.4598393 | 0.040644905 | -0.390214226 | -0.01629582 | -0.390214226 | -0.016295816 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# UCAR ULTRA IV TYPE IV 50/50 (#18)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.907346319 |
| R Square | 0.823277343 |
| Adjusted R Square | 0.764369791 |
| Standard Error | 0.090476708 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.11440599 | 0.11440599 | 13.97575201 | 0.033380906 |
| Residual | 3 | 0.024558104 | 0.00818603 | | |
| Total | 4 | 0.138964094 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.993429378 | 0.126530204 | 15.7545733 | 0.000555888 | 1.590753418 | 2.39610534 | 1.590753418 | 2.396105337 |
| log_rate | -0.763712217 | 0.204287665 | -3.7384157 | 0.033380906 | -1.413847352 | -0.11357708 | -1.413847352 | -0.113577081 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# SPCA AD-404 TYPE IV NEAT (#13)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.834680087 |
| R Square | 0.696690848 |
| Adjusted R Square | 0.610031091 |
| Standard Error | 0.172104859 |
| Observations | 10 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.476254282 | 0.23812714 | 8.039381452 | 0.015367361 |
| Residual | 7 | 0.207340577 | 0.02962008 | | |
| Total | 9 | 0.683594858 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.679184864 | 0.226031082 | 11.8531701 | 6.90569E-06 | 2.144706668 | 3.21366306 | 2.144706668 | 3.213663061 |
| log_rate | -0.310009999 | 0.349282621 | -0.887562 | 0.404239377 | -1.135931565 | 0.51591157 | -1.135931565 | 0.515911567 |
| log_temp | -0.47386117 | 0.134650028 | -3.5192059 | 0.009738044 | -0.792257663 | -0.15546468 | -0.792257663 | -0.155464676 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# SPCA AD-404 TYPE IV 75/25 (#14)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.989158347 |
| R Square | 0.978434235 |
| Adjusted R Square | 0.956868469 |
| Standard Error | 0.024893293 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.056229144 | 0.02811457 | 45.36978938 | 0.021565765 |
| Residual | 2 | 0.001239352 | 0.00061968 | | |
| Total | 4 | 0.057468496 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.376347131 | 0.050587916 | 46.9746001 | 0.000452875 | 2.158684744 | 2.59400952 | 2.158684744 | 2.594009518 |
| log_rate | -0.469165968 | 0.095912977 | -4.8915797 | 0.039342944 | -0.881846488 | -0.05648545 | -0.881846488 | -0.056485448 |
| log_temp | -0.156501036 | 0.042037074 | -3.7229288 | 0.065174787 | -0.337372093 | 0.02437002 | -0.337372093 | 0.024370022 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# SPCA AD-404 TYPE IV 50/50 (#15)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.960136169 |
| R Square | 0.921861463 |
| Adjusted R Square | 0.882792195 |
| Standard Error | 0.0549977 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.071370615 | 0.07137061 | 23.5955651 | 0.039863831 |
| Residual | 2 | 0.006049494 | 0.00302475 | | |
| Total | 3 | 0.077420109 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.468700314 | 0.130014715 | 18.9878531 | 0.002762142 | 1.909291756 | 3.02810887 | 1.909291756 | 3.028108872 |
| log_rate | -0.991636312 | 0.204144287 | -4.8575266 | 0.039863831 | -1.869998896 | -0.11327373 | -1.869998896 | -0.113273728 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# SPCA AD-480 TYPE IV NEAT (#16)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.993448173 |
| R Square | 0.986939273 |
| Adjusted R Square | 0.983674091 |
| Standard Error | 0.047084321 |
| Observations | 11 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1.340187905 | 0.67009395 | 302.2616664 | 2.90984E-08 |
| Residual | 8 | 0.017735466 | 0.00221693 | | |
| Total | 10 | 1.357923372 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.880349553 | 0.060338996 | 47.7361197 | 4.10168E-11 | 2.741207488 | 3.01949162 | 2.741207488 | 3.019491618 |
| log_rate | -0.431826583 | 0.083798529 | -5.1531523 | 0.000870946 | -0.625066463 | -0.2385867 | -0.625066463 | -0.238586704 |
| log_temp | -0.834721008 | 0.035251707 | -23.678882 | 1.0769E-08 | -0.916011643 | -0.75343037 | -0.916011643 | -0.753430374 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# SPCA AD-480 TYPE IV 75/25 (#17)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.998374945 |
| R Square | 0.996752531 |
| Adjusted R Square | 0.994587552 |
| Standard Error | 0.025390449 |
| Observations | 6 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 0.593614327 | 0.29680716 | 460.3981978 | 0.000185062 |
| Residual | 3 | 0.001934025 | 0.00064467 | | |
| Total | 5 | 0.595548351 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.74072754 | 0.051973776 | 52.7328927 | 1.50198E-05 | 2.575323634 | 2.90613145 | 2.575323634 | 2.906131446 |
| log_rate | -0.282260958 | 0.125074427 | -2.256744 | 0.109254289 | -0.68030398 | 0.11578206 | -0.68030398 | 0.115782065 |
| log_temp | -0.893466576 | 0.055574514 | -16.076912 | 0.000523416 | -1.07032965 | -0.7166035 | -1.07032965 | -0.716603503 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING FOG
# SPCA AD-480 TYPE IV 50/50 (#18)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.972052443 |
| R Square | 0.944885951 |
| Adjusted R Square | 0.926514602 |
| Standard Error | 0.042471573 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.092775867 | 0.09277587 | 51.43258232 | 0.005584967 |
| Residual | 3 | 0.005411504 | 0.00180383 | | |
| Total | 4 | 0.09818737 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.081176303 | 0.056105093 | 37.0942491 | 4.30939E-05 | 1.902624689 | 2.25972792 | 1.902624689 | 2.259727917 |
| log_rate | -0.700774569 | 0.097714535 | -7.1716513 | 0.005584967 | -1.01174612 | -0.38980302 | -1.01174612 | -0.389803017 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# CLARIANT MPIV 1957 TYPE IV NEAT (#1)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999004757 |
| R Square | 0.998010504 |
| Adjusted R Square | 0.997015757 |
| Standard Error | 0.00483536 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.023457391 | 0.02345739 | 1003.279915 | 0.000995243 |
| Residual | 2 | 4.67614E-05 | 2.3381E-05 | | |
| Total | 3 | 0.023504152 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.408783868 | 0.023522316 | 102.404195 | 9.5346E-05 | 2.307575439 | 2.5099923 | 2.307575439 | 2.509992297 |
| Log_rate | -0.584523999 | 0.018454033 | -31.674594 | 0.000995243 | -0.663925349 | -0.50512265 | -0.663925349 | -0.50512265 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# CLARIANT MPIV 1957 TYPE IV 75/25 (#2)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.983826833 |
| R Square | 0.967915237 |
| Adjusted R Square | 0.951872856 |
| Standard Error | 0.014557572 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.012786344 | 0.01278634 | 60.334885 | 0.016173167 |
| Residual | 2 | 0.000423846 | 0.00021192 | | |
| Total | 3 | 0.01321019 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.074433523 | 0.066438265 | 31.2234753 | 0.001024165 | 1.788572542 | 2.3602945 | 1.788572542 | 2.360294504 |
| Log_rate | -0.406949529 | 0.052390954 | -7.7675533 | 0.016173167 | -0.632369766 | -0.18152929 | -0.632369766 | -0.181529291 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# CLARIANT MPIV 1957 TYPE IV 50/50 (#3)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.995451431 |
| R Square | 0.990923552 |
| Adjusted R Square | 0.986385328 |
| Standard Error | 0.014691291 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.047127472 | 0.04712747 | 218.3505132 | 0.004548569 |
| Residual | 2 | 0.000431668 | 0.00021583 | | |
| Total | 3 | 0.04755914 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.074172646 | 0.065753063 | 31.5448826 | 0.001003432 | 1.791259854 | 2.35708544 | 1.791259854 | 2.357085438 |
| Log_rate | -0.764151666 | 0.051713324 | -14.776688 | 0.004548569 | -0.986656296 | -0.54164704 | -0.986656296 | -0.541647035 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# CLARIANT MPIV 1957 TYPE IV NEAT (#4)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.932107184 |
| R Square | 0.868823802 |
| Adjusted R Square | 0.803235704 |
| Standard Error | 0.039467628 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.020634252 | 0.02063425 | 13.24666851 | 0.067892816 |
| Residual | 2 | 0.003115387 | 0.00155769 | | |
| Total | 3 | 0.023749639 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.292665776 | 0.197185884 | 11.6269265 | 0.007316168 | 1.444242805 | 3.14108875 | 1.444242805 | 3.141088747 |
| Log_rate | -0.583319536 | 0.160270351 | -3.6395973 | 0.067892816 | -1.272907678 | 0.10626861 | -1.272907678 | 0.106268606 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# CLARIANT MPIV 1957 TYPE IV NEAT (#5)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.997921958 |
| R Square | 0.995848235 |
| Adjusted R Square | 0.993772353 |
| Standard Error | 0.007916139 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.030061957 | 0.03006196 | 479.7228518 | 0.002078042 |
| Residual | 2 | 0.000125331 | 6.2665E-05 | | |
| Total | 3 | 0.030187288 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.355402414 | 0.039567456 | 59.5287809 | 0.000282073 | 2.185157273 | 2.52564755 | 2.185157273 | 2.525647554 |
| Log_rate | -0.711529945 | 0.03248613 | -21.902576 | 0.002078042 | -0.851306578 | -0.57175331 | -0.851306578 | -0.571753311 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# CLARIANT MPIV 2001 TYPE IV NEAT (#6)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.991773049 |
| R Square | 0.98361378 |
| Adjusted R Square | 0.97542067 |
| Standard Error | 0.012496318 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.018747353 | 0.01874735 | 120.0537741 | 0.008226951 |
| Residual | 2 | 0.000312316 | 0.00015616 | | |
| Total | 3 | 0.019059669 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.302794151 | 0.056552642 | 40.7194798 | 0.000602564 | 2.059467603 | 2.5461207 | 2.059467603 | 2.546120699 |
| Log_rate | -0.488540835 | 0.044587484 | -10.956905 | 0.008226951 | -0.680385426 | -0.29669624 | -0.680385426 | -0.296696244 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# CLARIANT MPIV 2001 TYPE IV 75/25 (#7)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.994401767 |
| R Square | 0.988834874 |
| Adjusted R Square | 0.983252311 |
| Standard Error | 0.010593515 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.019877892 | 0.01987789 | 177.1291913 | 0.005598233 |
| Residual | 2 | 0.000224445 | 0.00011222 | | |
| Total | 3 | 0.020102337 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.096020991 | 0.049470699 | 42.3689384 | 0.000556599 | 1.883165606 | 2.30887638 | 1.883165606 | 2.308876377 |
| Log_rate | -0.518284547 | 0.038942443 | -13.308989 | 0.005598233 | -0.685840471 | -0.35072862 | -0.685840471 | -0.350728623 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# CLARIANT MPIV 2001 TYPE IV 50/50 (#8)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.995679708 |
| R Square | 0.991378081 |
| Adjusted R Square | 0.987067122 |
| Standard Error | 0.013844188 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.044075819 | 0.04407582 | 229.9669288 | 0.004320292 |
| Residual | 2 | 0.000383323 | 0.00019166 | | |
| Total | 3 | 0.044459142 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.940789714 | 0.06186516 | 31.3712872 | 0.001014551 | 1.674605227 | 2.2069742 | 1.674605227 | 2.206974201 |
| Log_rate | -0.741017417 | 0.048864755 | -15.164661 | 0.004320292 | -0.951265634 | -0.5307692 | -0.951265634 | -0.530769201 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# CLARIANT MPIV 2001 TYPE IV NEAT (#9)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.953757294 |
| R Square | 0.909652975 |
| Adjusted R Square | 0.864479463 |
| Standard Error | 0.035046801 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.024733675 | 0.02473368 | 20.13686617 | 0.046242706 |
| Residual | 2 | 0.002456557 | 0.00122828 | | |
| Total | 3 | 0.027190232 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.336121444 | 0.168713371 | 13.8466882 | 0.005175194 | 1.610205894 | 3.06203699 | 1.610205894 | 3.062036995 |
| Log_rate | -0.617749564 | 0.137662771 | -4.487412 | 0.046242706 | -1.210065072 | -0.02543406 | -1.210065072 | -0.025434056 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# CLARIANT MPIV 2001 TYPE IV 75/25 (#10)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.947288986 |
| R Square | 0.897356422 |
| Adjusted R Square | 0.863141897 |
| Standard Error | 0.034526407 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.031264913 | 0.03126491 | 26.22735226 | 0.014411925 |
| Residual | 3 | 0.003576218 | 0.00119207 | | |
| Total | 4 | 0.034841131 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.220841512 | 0.152192874 | 14.5922832 | 0.000697922 | 1.736495408 | 2.70518762 | 1.736495408 | 2.705187616 |
| Log_rate | -0.651306119 | 0.127176812 | -5.1212647 | 0.014411925 | -1.056039874 | -0.24657236 | -1.056039874 | -0.246572364 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# KILFROST ABC-S TYPE IV NEAT (#11)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.966908565 |
| R Square | 0.934912173 |
| Adjusted R Square | 0.902368259 |
| Standard Error | 0.029740906 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.025410279 | 0.02541028 | 28.72771172 | 0.033091435 |
| Residual | 2 | 0.001769043 | 0.00088452 | | |
| Total | 3 | 0.027179322 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.749213326 | 0.144889568 | 18.9745429 | 0.002766002 | 2.125803396 | 3.37262326 | 2.125803396 | 3.372623256 |
| Log_rate | -0.609668639 | 0.113747887 | -5.3598239 | 0.033091435 | -1.099086637 | -0.12025064 | -1.099086637 | -0.120250641 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# KILFROST ABC-S TYPE IV 75/25 (#12)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99944725 |
| R Square | 0.998894806 |
| Adjusted R Square | 0.998342208 |
| Standard Error | 0.002841322 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.014593251 | 0.01459325 | 1807.636494 | 0.00055275 |
| Residual | 2 | 1.61462E-05 | 8.0731E-06 | | |
| Total | 3 | 0.014609397 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.221398187 | 0.013481039 | 164.779454 | 3.68273E-05 | 2.163393919 | 2.27940245 | 2.163393919 | 2.279402455 |
| Log_rate | -0.451604441 | 0.010621911 | -42.516309 | 0.00055275 | -0.497306867 | -0.40590202 | -0.497306867 | -0.405902016 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# KILFROST ABC-S TYPE IV 50/50 (#13)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.994583543 |
| R Square | 0.989196425 |
| Adjusted R Square | 0.983794637 |
| Standard Error | 0.017862532 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.058429353 | 0.05842935 | 183.1239046 | 0.005416457 |
| Residual | 2 | 0.00063814 | 0.00031907 | | |
| Total | 3 | 0.059067493 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.188241855 | 0.086451688 | 25.3117307 | 0.001557188 | 1.816270002 | 2.56021371 | 1.816270002 | 2.560213707 |
| Log_rate | -0.928517826 | 0.068614788 | -13.532328 | 0.005416457 | -1.223743637 | -0.63329202 | -1.223743637 | -0.633292016 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# KILFROST ABC-S TYPE IV NEAT (#14)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.870014528 |
| R Square | 0.756925278 |
| Adjusted R Square | 0.635387918 |
| Standard Error | 0.097667457 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.059407731 | 0.05940773 | 6.227922618 | 0.129985472 |
| Residual | 2 | 0.019077864 | 0.00953893 | | |
| Total | 3 | 0.078485596 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.680316173 | 0.476116935 | 5.62953336 | 0.030135008 | 0.631748915 | 4.72888343 | 0.631748915 | 4.728883431 |
| Log_rate | -0.967671693 | 0.387754131 | -2.4955806 | 0.129985472 | -2.636044225 | 0.70070084 | -2.636044225 | 0.700700838 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# KILFROST ABC-S TYPE IV 75/25 (#15)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.823212903 |
| R Square | 0.677679484 |
| Adjusted R Square | 0.516519226 |
| Standard Error | 0.058105488 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.014197134 | 0.01419713 | 4.205003724 | 0.176787097 |
| Residual | 2 | 0.006752495 | 0.00337625 | | |
| Total | 3 | 0.02094963 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.035347082 | 0.274838418 | 7.40561345 | 0.017749809 | 0.85281199 | 3.21788217 | 0.85281199 | 3.217882174 |
| Log_rate | -0.459178709 | 0.223922921 | -2.0506106 | 0.176787097 | -1.422641947 | 0.50428453 | -1.422641947 | 0.504284528 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# OCTAGON MAXFLIGHT TYPE IV NEAT (#16)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.918101526 |
| R Square | 0.842910411 |
| Adjusted R Square | 0.816728813 |
| Standard Error | 0.042793418 |
| Observations | 8 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.05895752 | 0.05895752 | 32.1947655 | 0.001290334 |
| Residual | 6 | 0.01098766 | 0.00183128 | | |
| Total | 7 | 0.06994518 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.518575378 | 0.158058521 | 15.9344486 | 3.87835E-06 | 2.131819826 | 2.90533093 | 2.131819826 | 2.90533093 |
| Log_rate | -0.684429282 | 0.120624617 | -5.6740431 | 0.001290334 | -0.979587304 | -0.38927126 | -0.979587304 | -0.389271261 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# OCTAGON MAXFLIGHT TYPE IV 75/25 (#17)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.939962202 |
| R Square | 0.883528942 |
| Adjusted R Square | 0.864117099 |
| Standard Error | 0.051254523 |
| Observations | 8 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.119568944 | 0.11956894 | 45.51494373 | 0.000516952 |
| Residual | 6 | 0.015762157 | 0.00262703 | | |
| Total | 7 | 0.135331101 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.038423296 | 0.19935165 | 15.2415257 | 5.03562E-06 | 2.550627025 | 3.52621957 | 2.550627025 | 3.526219566 |
| Log_rate | -1.079846501 | 0.160060814 | -6.7464764 | 0.000516952 | -1.471501489 | -0.68819151 | -1.471501489 | -0.688191513 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# OCTAGON MAXFLIGHT TYPE IV 50/50 (#18)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.996339752 |
| R Square | 0.992692902 |
| Adjusted R Square | 0.990257202 |
| Standard Error | 0.011840523 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.05713905 | 0.05713905 | 407.5596895 | 0.000265681 |
| Residual | 3 | 0.000420594 | 0.0001402 | | |
| Total | 4 | 0.057559644 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.544280862 | 0.058894226 | 43.2008543 | 2.72996E-05 | 2.356852975 | 2.73170875 | 2.356852975 | 2.731708749 |
| Log_rate | -0.950876289 | 0.047100813 | -20.188108 | 0.000265681 | -1.100772239 | -0.80098034 | -1.100772239 | -0.800980339 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# OCTAGON MAXFLIGHT TYPE IV NEAT (#19)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.993430299 |
| R Square | 0.986903758 |
| Adjusted R Square | 0.980355637 |
| Standard Error | 0.017470028 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.045998676 | 0.04599868 | 150.7155674 | 0.006569701 |
| Residual | 2 | 0.000610404 | 0.0003052 | | |
| Total | 3 | 0.04660908 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.535911842 | 0.086610361 | 29.2795435 | 0.001164427 | 2.163257275 | 2.90856641 | 2.163257275 | 2.908566408 |
| Log_rate | -0.862478962 | 0.070253741 | -12.276627 | 0.006569701 | -1.164756622 | -0.5602013 | -1.164756622 | -0.560201302 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# OCTAGON MAXFLIGHT TYPE IV 75/25 (#20)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.977873934 |
| R Square | 0.956237431 |
| Adjusted R Square | 0.934356146 |
| Standard Error | 0.026720985 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.031203108 | 0.03120311 | 43.70115597 | 0.022126066 |
| Residual | 2 | 0.001428022 | 0.00071401 | | |
| Total | 3 | 0.03263113 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.247564213 | 0.122635786 | 18.3271482 | 0.002963985 | 1.719904648 | 2.77522378 | 1.719904648 | 2.775223778 |
| Log_rate | -0.66736309 | 0.100952185 | -6.610685 | 0.022126066 | -1.101725585 | -0.2330006 | -1.101725585 | -0.233000596 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# SPCA AD-404 TYPE IV NEAT (#21)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.960566638 |
| R Square | 0.922688265 |
| Adjusted R Square | 0.896917687 |
| Standard Error | 0.042412518 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.064404906 | 0.06440491 | 35.80394104 | 0.009344239 |
| Residual | 3 | 0.005396465 | 0.00179882 | | |
| Total | 4 | 0.069801371 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.80251668 | 0.178410458 | 15.7082534 | 0.000560773 | 2.234734445 | 3.37029891 | 2.234734445 | 3.370298915 |
| Log_rate | -0.810478691 | 0.135449119 | -5.9836394 | 0.009344239 | -1.241538644 | -0.37941874 | -1.241538644 | -0.379418739 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# SPCA AD-404 TYPE IV 75/25 (#22)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.96412053 |
| R Square | 0.929528396 |
| Adjusted R Square | 0.894292594 |
| Standard Error | 0.038825639 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.039766349 | 0.03976635 | 26.3802252 | 0.03587947 |
| Residual | 2 | 0.00301486 | 0.00150743 | | |
| Total | 3 | 0.042781209 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.45712942 | 0.174838261 | 14.0537283 | 0.005024974 | 1.704860576 | 3.20939826 | 1.704860576 | 3.209398263 |
| Log_rate | -0.695880342 | 0.13548628 | -5.1361683 | 0.03587947 | -1.27883116 | -0.11292952 | -1.27883116 | -0.112929523 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# SPCA AD-404 TYPE IV 50/50 (#23)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.989578458 |
| R Square | 0.979265525 |
| Adjusted R Square | 0.968898288 |
| Standard Error | 0.021441714 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.043426661 | 0.04342666 | 94.45771285 | 0.010421542 |
| Residual | 2 | 0.000919494 | 0.00045975 | | |
| Total | 3 | 0.044346155 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.548283633 | 0.122887708 | 20.7366846 | 0.002317446 | 2.019540133 | 3.07702713 | 2.019540133 | 3.077027132 |
| Log_rate | -0.938875609 | 0.096602718 | -9.7189358 | 0.010421542 | -1.354523845 | -0.52322737 | -1.354523845 | -0.523227373 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# SPCA AD-404 TYPE IV NEAT (#24)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.938066372 |
| R Square | 0.879968519 |
| Adjusted R Square | 0.839958026 |
| Standard Error | 0.080705916 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.143253081 | 0.14325308 | 21.99344322 | 0.018329363 |
| Residual | 3 | 0.019540335 | 0.00651344 | | |
| Total | 4 | 0.162793416 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.346312176 | 0.3483662 | 9.60573149 | 0.00239436 | 2.237654411 | 4.45496994 | 2.237654411 | 4.454969942 |
| Log_rate | -1.301879148 | 0.277602938 | -4.6897168 | 0.018329363 | -2.18533642 | -0.41842188 | -2.18533642 | -0.418421875 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# SPCA AD-404 TYPE IV 75/25 (#25)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.935025619 |
| R Square | 0.874272908 |
| Adjusted R Square | 0.832363877 |
| Standard Error | 0.040813385 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.034749187 | 0.03474919 | 20.86120561 | 0.0196865 |
| Residual | 3 | 0.004997197 | 0.00166573 | | |
| Total | 4 | 0.039746384 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.418112224 | 0.1801483 | 13.4228978 | 0.000893968 | 1.844799395 | 2.99142505 | 1.844799395 | 2.991425054 |
| Log_rate | -0.688529918 | 0.15074854 | -4.5674069 | 0.0196865 | -1.168279502 | -0.20878033 | -1.168279502 | -0.208780334 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# SPCA AD-480 TYPE IV NEAT (#26)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.929634806 |
| R Square | 0.864220873 |
| Adjusted R Square | 0.79633131 |
| Standard Error | 0.043293761 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.023860106 | 0.02386011 | 12.72980455 | 0.070365194 |
| Residual | 2 | 0.003748699 | 0.00187435 | | |
| Total | 3 | 0.027608805 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.414776359 | 0.187093784 | 12.9067696 | 0.005949434 | 1.609776218 | 3.2197765 | 1.609776218 | 3.2197765 |
| Log_rate | -0.516247435 | 0.144692839 | -3.5678852 | 0.070365194 | -1.138810909 | 0.10631604 | -1.138810909 | 0.106316039 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# SPCA AD-480 TYPE IV 75/25 (#27)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.931076046 |
| R Square | 0.866902603 |
| Adjusted R Square | 0.800353905 |
| Standard Error | 0.032747924 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.01397006 | 0.01397006 | 13.02658989 | 0.068923954 |
| Residual | 2 | 0.002144853 | 0.00107243 | | |
| Total | 3 | 0.016114914 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.208574894 | 0.165706627 | 13.3282231 | 0.005582222 | 1.495596328 | 2.92155346 | 1.495596328 | 2.92155346 |
| Log_rate | -0.474059688 | 0.131346243 | -3.6092367 | 0.068923954 | -1.039197354 | 0.09107798 | -1.039197354 | 0.091077978 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# SPCA AD-480 TYPE IV 50/50 (#28)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.996965931 |
| R Square | 0.993941068 |
| Adjusted R Square | 0.990911602 |
| Standard Error | 0.015979352 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.083774694 | 0.08377469 | 328.0911705 | 0.003034069 |
| Residual | 2 | 0.000510679 | 0.00025534 | | |
| Total | 3 | 0.084285374 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.539514504 | 0.077404918 | 32.8081801 | 0.00092775 | 2.206467788 | 2.87256122 | 2.206467788 | 2.872561219 |
| Log_rate | -1.071419905 | 0.059151047 | -18.113287 | 0.003034069 | -1.325926498 | -0.81691331 | -1.325926498 | -0.816913312 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# SPCA AD-480 TYPE IV NEAT (#29)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.991693067 |
| R Square | 0.983455139 |
| Adjusted R Square | 0.975182708 |
| Standard Error | 0.020786331 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.051366158 | 0.05136616 | 118.883454 | 0.008306933 |
| Residual | 2 | 0.000864143 | 0.00043207 | | |
| Total | 3 | 0.052230301 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.627805262 | 0.107073679 | 24.5420283 | 0.001656148 | 2.167104084 | 3.08850644 | 2.167104084 | 3.08850644 |
| Log_rate | -0.949631738 | 0.087095259 | -10.903369 | 0.008306933 | -1.324372652 | -0.57489082 | -1.324372652 | -0.574890824 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# SPCA AD-480 TYPE IV 75/25 (#30)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.984855623 |
| R Square | 0.969940598 |
| Adjusted R Square | 0.954910898 |
| Standard Error | 0.028538266 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.052559347 | 0.05255935 | 64.53492404 | 0.015144377 |
| Residual | 2 | 0.001628865 | 0.00081443 | | |
| Total | 3 | 0.054188212 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.518519632 | 0.136992142 | 18.3844095 | 0.002945632 | 1.929089608 | 3.10794966 | 1.929089608 | 3.107949656 |
| Log_rate | -0.902043374 | 0.11228714 | -8.0333632 | 0.015144377 | -1.385176278 | -0.41891047 | -1.385176278 | -0.41891047 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# CLARIANT MPIV 1957 TYPE IV 75/25 (#2)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.990330563 |
| R Square | 0.980754625 |
| Adjusted R Square | 0.974339499 |
| Standard Error | 0.016980283 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.044080353 | 0.04408035 | 152.8816041 | 0.001139737 |
| Residual | 3 | 0.00086499 | 0.00028833 | | |
| Total | 4 | 0.044945343 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.237862292 | 0.04255085 | 52.5926577 | 1.51402E-05 | 2.102446369 | 2.37327821 | 2.102446369 | 2.373278214 |
| Log_rate | -0.539057673 | 0.043597102 | -12.36453 | 0.001139737 | -0.677803238 | -0.40031211 | -0.677803238 | -0.400312108 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# CLARIANT MPIV 1957 TYPE IV NEAT (#1)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.990672695 |
| R Square | 0.981432389 |
| Adjusted R Square | 0.972148584 |
| Standard Error | 0.032762016 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.11346857 | 0.11346857 | 105.7144513 | 0.009327305 |
| Residual | 2 | 0.002146699 | 0.00107335 | | |
| Total | 3 | 0.11561527 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.558907755 | 0.067314298 | 38.0143271 | 0.000691281 | 2.269277504 | 2.84853801 | 2.269277504 | 2.848538006 |
| Log_rate | -0.797815599 | 0.077595287 | -10.281753 | 0.009327305 | -1.131681405 | -0.46394979 | -1.131681405 | -0.463949794 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# CLARIANT MPIV 1957 TYPE IV 50/50 (#3)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.998455528 |
| R Square | 0.996913441 |
| Adjusted R Square | 0.995370162 |
| Standard Error | 0.00899212 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.052232049 | 0.05223205 | 645.9707767 | 0.001544472 |
| Residual | 2 | 0.000161716 | 8.0858E-05 | | |
| Total | 3 | 0.052393765 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.803322973 | 0.019836229 | 90.9105735 | 0.000120974 | 1.717974508 | 1.88867144 | 1.717974508 | 1.888671438 |
| Log_rate | -0.563300889 | 0.022163278 | -25.415955 | 0.001544472 | -0.658661845 | -0.46793993 | -0.658661845 | -0.467939932 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# CLARIANT MPIV 1957 TYPE IV NEAT (#4)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99580671 |
| R Square | 0.991631003 |
| Adjusted R Square | 0.987446504 |
| Standard Error | 0.013530402 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.043383849 | 0.04338385 | 236.9772622 | 0.00419329 |
| Residual | 2 | 0.000366144 | 0.00018307 | | |
| Total | 3 | 0.043749993 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.304802552 | 0.029502137 | 78.1232408 | 0.000163807 | 2.177865013 | 2.43174009 | 2.177865013 | 2.43174009 |
| Log_rate | -0.520354379 | 0.033802271 | -15.394066 | 0.00419329 | -0.665793912 | -0.37491485 | -0.665793912 | -0.374914846 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# CLARIANT MPIV 1957 TYPE IV 75/25 (#5)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.998587997 |
| R Square | 0.997177988 |
| Adjusted R Square | 0.995766982 |
| Standard Error | 0.008736614 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.053942384 | 0.05394238 | 706.7142813 | 0.001412003 |
| Residual | 2 | 0.000152657 | 7.6328E-05 | | |
| Total | 3 | 0.054095041 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.277225148 | 0.019772734 | 115.169969 | 7.53828E-05 | 2.192149882 | 2.36230041 | 2.192149882 | 2.362300415 |
| Log_rate | -0.555283394 | 0.020887802 | -26.584098 | 0.001412003 | -0.645156417 | -0.46541037 | -0.645156417 | -0.465410371 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# CLARIANT MPIV 2001 TYPE IV NEAT (#6)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.952510162 |
| R Square | 0.907275609 |
| Adjusted R Square | 0.860913413 |
| Standard Error | 0.066246052 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.085880633 | 0.08588063 | 19.56929775 | 0.047489838 |
| Residual | 2 | 0.008777079 | 0.00438854 | | |
| Total | 3 | 0.094657712 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.615159606 | 0.156580239 | 16.7017218 | 0.003565741 | 1.941448742 | 3.28887047 | 1.941448742 | 3.28887047 |
| Log_rate | -0.786061948 | 0.177692522 | -4.4237199 | 0.047489838 | -1.550611697 | -0.0215122 | -1.550611697 | -0.021512199 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# CLARIANT MPIV 2001 TYPE IV 75/25 (#7)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.950831702 |
| R Square | 0.904080925 |
| Adjusted R Square | 0.8721079 |
| Standard Error | 0.0385675 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.042059738 | 0.04205974 | 28.27636512 | 0.012990696 |
| Residual | 3 | 0.004462356 | 0.00148745 | | |
| Total | 4 | 0.046522094 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.294583973 | 0.115949267 | 19.7895514 | 0.000281958 | 1.925581311 | 2.66358663 | 1.925581311 | 2.663586635 |
| Log_rate | -0.655195812 | 0.123213792 | -5.3175525 | 0.012990696 | -1.047317455 | -0.26307417 | -1.047317455 | -0.263074168 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# CLARIANT MPIV 2001 TYPE IV 50/50 (#8)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.935727524 |
| R Square | 0.875585999 |
| Adjusted R Square | 0.813378999 |
| Standard Error | 0.056656503 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.045181337 | 0.04518134 | 14.07536119 | 0.064272476 |
| Residual | 2 | 0.006419919 | 0.00320996 | | |
| Total | 3 | 0.051601256 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.810875982 | 0.173599404 | 10.4313491 | 0.009065298 | 1.063937511 | 2.55781445 | 1.063937511 | 2.557814453 |
| Log_rate | -0.68257377 | 0.181936494 | -3.7517144 | 0.064272476 | -1.465383867 | 0.10023633 | -1.465383867 | 0.100236327 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# CLARIANT MPIV 2001 TYPE IV NEAT (#9)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.979289461 |
| R Square | 0.959007848 |
| Adjusted R Square | 0.938511772 |
| Standard Error | 0.039092356 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.071504789 | 0.07150479 | 46.78982682 | 0.020710539 |
| Residual | 2 | 0.003056425 | 0.00152821 | | |
| Total | 3 | 0.074561214 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.407068838 | 0.083204471 | 28.9295611 | 0.001192721 | 2.049068642 | 2.76506903 | 2.049068642 | 2.765069033 |
| Log_rate | -0.605693323 | 0.088547656 | -6.840309 | 0.020710539 | -0.986683401 | -0.22470325 | -0.986683401 | -0.224703246 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# CLARIANT MPIV 2001 TYPE IV 75/25 (#10)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.93194185 |
| R Square | 0.868515611 |
| Adjusted R Square | 0.802773417 |
| Standard Error | 0.073383606 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.071142895 | 0.0711429 | 13.21093128 | 0.06805815 |
| Residual | 2 | 0.010770307 | 0.00538515 | | |
| Total | 3 | 0.081913203 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.311630169 | 0.163320773 | 14.1539262 | 0.004954606 | 1.608917111 | 3.01434323 | 1.608917111 | 3.014343226 |
| Log_rate | -0.645856471 | 0.177692582 | -3.6346845 | 0.06805815 | -1.410406476 | 0.11869353 | -1.410406476 | 0.118693535 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# KILFROST ABC-S TYPE IV NEAT (#11)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.926712437 |
| R Square | 0.85879594 |
| Adjusted R Square | 0.838623932 |
| Standard Error | 0.042618966 |
| Observations | 9 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.077329757 | 0.07732976 | 42.57364552 | 0.000326427 |
| Residual | 7 | 0.012714634 | 0.00181638 | | |
| Total | 8 | 0.090044391 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.48063599 | 0.055759884 | 44.4878254 | 7.57385E-10 | 2.34878491 | 2.61248707 | 2.34878491 | 2.61248707 |
| Log_rate | -0.391994645 | 0.060077204 | -6.5248483 | 0.000326427 | -0.534054558 | -0.24993473 | -0.534054558 | -0.249934733 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# KILFROST ABC-S TYPE IV 75/25 (#12)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.878280493 |
| R Square | 0.771376624 |
| Adjusted R Square | 0.738716142 |
| Standard Error | 0.038240699 |
| Observations | 9 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.034537868 | 0.03453787 | 23.6180415 | 0.001835492 |
| Residual | 7 | 0.010236457 | 0.00146235 | | |
| Total | 8 | 0.044774325 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.063328104 | 0.06189755 | 33.3345682 | 5.66273E-09 | 1.91696376 | 2.20969245 | 1.91696376 | 2.209692447 |
| Log_rate | -0.317173755 | 0.065264243 | -4.8598397 | 0.001835492 | -0.471499055 | -0.16284845 | -0.471499055 | -0.162848454 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# KILFROST ABC-S TYPE IV 50/50 (#13)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.914371171 |
| R Square | 0.836074639 |
| Adjusted R Square | 0.795093299 |
| Standard Error | 0.035466967 |
| Observations | 6 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.025662974 | 0.02566297 | 20.40134932 | 0.010684516 |
| Residual | 4 | 0.005031623 | 0.00125791 | | |
| Total | 5 | 0.030694597 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.589254965 | 0.082968693 | 19.1548752 | 4.37707E-05 | 1.358896466 | 1.81961346 | 1.358896466 | 1.819613464 |
| Log_rate | -0.401582799 | 0.088908986 | -4.5167853 | 0.010684516 | -0.648434229 | -0.15473137 | -0.648434229 | -0.154731369 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# KILFROST ABC-S TYPE IV NEAT (#14)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.928191415 |
| R Square | 0.861539304 |
| Adjusted R Square | 0.792308955 |
| Standard Error | 0.086030101 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.092104201 | 0.0921042 | 12.44453229 | 0.071808585 |
| Residual | 2 | 0.014802356 | 0.00740118 | | |
| Total | 3 | 0.106906558 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.471516264 | 0.20587417 | 12.0049847 | 0.006867286 | 1.585710586 | 3.35732194 | 1.585710586 | 3.357321941 |
| Log_rate | -0.806235798 | 0.22854556 | -3.5276809 | 0.071808585 | -1.789588658 | 0.17711706 | -1.789588658 | 0.177117063 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# KILFROST ABC-S TYPE IV 75/25 (#15)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.998534947 |
| R Square | 0.99707204 |
| Adjusted R Square | 0.99560806 |
| Standard Error | 0.014112838 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.1356501 | 0.1356501 | 681.0694584 | 0.001465053 |
| Residual | 2 | 0.000398344 | 0.00019917 | | |
| Total | 3 | 0.136048444 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.484322141 | 0.032328935 | 76.8451593 | 0.0001693 | 2.345221865 | 2.62342242 | 2.345221865 | 2.623422417 |
| Log_rate | -0.904682296 | 0.034665733 | -26.097307 | 0.001465053 | -1.053837011 | -0.75552758 | -1.053837011 | -0.755527581 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# OCTAGON MAXFLIGHT TYPE IV NEAT (#16)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.981395938 |
| R Square | 0.963137987 |
| Adjusted R Square | 0.95085065 |
| Standard Error | 0.03429746 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.092205038 | 0.09220504 | 78.38459565 | 0.003037595 |
| Residual | 3 | 0.003528947 | 0.00117632 | | |
| Total | 4 | 0.095733985 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.532317901 | 0.064177262 | 39.4581791 | 3.58143E-05 | 2.328077018 | 2.73655878 | 2.328077018 | 2.736558783 |
| Log_rate | -0.622424438 | 0.070302582 | -8.8535075 | 0.003037595 | -0.84615884 | -0.39869004 | -0.84615884 | -0.398690036 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# OCTAGON MAXFLIGHT TYPE IV 7525 (#17)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.773842035 |
| R Square | 0.598831495 |
| Adjusted R Square | 0.531970077 |
| Standard Error | 0.059942611 |
| Observations | 8 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.032181062 | 0.03218106 | 8.956308694 | 0.024235249 |
| Residual | 6 | 0.0215587 | 0.00359312 | | |
| Total | 7 | 0.053739762 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.417952665 | 0.152845521 | 15.8195847 | 4.04684E-06 | 2.043952874 | 2.79195246 | 2.043952874 | 2.791952456 |
| Log_rate | -0.458519719 | 0.15321225 | -2.9927093 | 0.024235249 | -0.833416864 | -0.08362257 | -0.833416864 | -0.083622574 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# OCTAGON MAXFLIGHT TYPE IV 50/50 (#18)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.96159614 |
| R Square | 0.924667137 |
| Adjusted R Square | 0.909600565 |
| Standard Error | 0.047090618 |
| Observations | 7 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.136094238 | 0.13609424 | 61.37209603 | 0.000543747 |
| Residual | 5 | 0.011087632 | 0.00221753 | | |
| Total | 6 | 0.147181869 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.217536105 | 0.06991672 | 31.7168213 | 5.85115E-07 | 2.037809749 | 2.39726246 | 2.037809749 | 2.397262461 |
| Log_rate | -0.614001442 | 0.078376148 | -7.8340345 | 0.000543747 | -0.815473414 | -0.41252947 | -0.815473414 | -0.412529469 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# OCTAGON MAXFLIGHT TYPE IV NEAT (#19)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.981921275 |
| R Square | 0.96416939 |
| Adjusted R Square | 0.946254085 |
| Standard Error | 0.04609588 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.114354523 | 0.11435452 | 53.81819548 | 0.018078725 |
| Residual | 2 | 0.00424966 | 0.00212483 | | |
| Total | 3 | 0.118604183 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.690713049 | 0.127963511 | 21.0271899 | 0.002254069 | 2.140130115 | 3.24129598 | 2.140130115 | 3.241295983 |
| Log_rate | -1.097053458 | 0.149542014 | -7.3360886 | 0.018078725 | -1.74048126 | -0.45362566 | -1.74048126 | -0.453625656 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# OCTAGON MAXFLIGHT TYPE IV 75/25 (#20)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.981224491 |
| R Square | 0.962801501 |
| Adjusted R Square | 0.950402002 |
| Standard Error | 0.066735027 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.345812182 | 0.34581218 | 77.64841624 | 0.003079602 |
| Residual | 3 | 0.013360692 | 0.00445356 | | |
| Total | 4 | 0.359172874 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.80201251 | 0.139857849 | 20.0347176 | 0.000271794 | 2.356921996 | 3.24710302 | 2.356921996 | 3.247103024 |
| Log_rate | -1.280693476 | 0.145337905 | -8.8118339 | 0.003079602 | -1.74322399 | -0.81816296 | -1.74322399 | -0.818162963 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# SPCA AD-404 TYPE IV NEAT (#21)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.853359307 |
| R Square | 0.728222108 |
| Adjusted R Square | 0.673866529 |
| Standard Error | 0.112076786 |
| Observations | 7 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.168287196 | 0.1682872 | 13.39737572 | 0.014591209 |
| Residual | 5 | 0.06280603 | 0.01256121 | | |
| Total | 6 | 0.231093226 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.763680394 | 0.171315031 | 16.1321536 | 1.66773E-05 | 2.323301808 | 3.20405898 | 2.323301808 | 3.204058981 |
| Log_rate | -0.682478986 | 0.18645731 | -3.6602426 | 0.014591209 | -1.161781977 | -0.20317599 | -1.161781977 | -0.203175994 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# SPCA AD-404 TYPE IV 75/25 (#22)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.974145763 |
| R Square | 0.948959967 |
| Adjusted R Square | 0.923439951 |
| Standard Error | 0.060095394 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.134291743 | 0.13429174 | 37.18492778 | 0.025854237 |
| Residual | 2 | 0.007222913 | 0.00361146 | | |
| Total | 3 | 0.141514656 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.641347838 | 0.122776863 | 21.5134007 | 0.00215366 | 2.113081268 | 3.16961441 | 2.113081268 | 3.169614409 |
| Log_rate | -0.857703847 | 0.140654583 | -6.0979446 | 0.025854237 | -1.462892093 | -0.2525156 | -1.462892093 | -0.252515601 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -3°C
# SPCA AD-404 TYPE IV 50/50 (#23)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.994042957 |
| R Square | 0.988121401 |
| Adjusted R Square | 0.984161868 |
| Standard Error | 0.019417634 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.094093362 | 0.09409336 | 249.5550407 | 0.000551431 |
| Residual | 3 | 0.001131134 | 0.00037704 | | |
| Total | 4 | 0.095224495 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.371121253 | 0.053532626 | 44.293012 | 2.5332E-05 | 2.200756385 | 2.54148612 | 2.200756385 | 2.541486121 |
| Log_rate | -0.902847208 | 0.057151954 | -15.797311 | 0.000551431 | -1.084730405 | -0.72096401 | -1.084730405 | -0.720964011 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# SPCA AD-404 TYPE IV NEAT (#24)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.986981248 |
| R Square | 0.974131984 |
| Adjusted R Square | 0.967664979 |
| Standard Error | 0.041953912 |
| Observations | 6 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.26513044 | 0.26513044 | 150.6311063 | 0.000253129 |
| Residual | 4 | 0.007040523 | 0.00176013 | | |
| Total | 5 | 0.272170963 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.906246807 | 0.08052875 | 36.0895556 | 3.51889E-06 | 2.68266269 | 3.12983092 | 2.68266269 | 3.129830924 |
| Log_rate | -0.979888229 | 0.079839757 | -12.273186 | 0.000253129 | -1.201559391 | -0.75821707 | -1.201559391 | -0.758217067 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED FREEZING DRIZZLE AT -10°C
# SPCA AD-404 TYPE IV 75/25 (#25)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.999801221 |
| R Square | 0.999602482 |
| Adjusted R Square | 0.999469975 |
| Standard Error | 0.007082007 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.378358972 | 0.37835897 | 7543.820561 | 3.36416E-06 |
| Residual | 3 | 0.000150464 | 5.0155E-05 | | |
| Total | 4 | 0.378509437 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.934819782 | 0.014493354 | 202.494175 | 2.6558E-07 | 2.888695417 | 2.98094415 | 2.888695417 | 2.980944146 |
| Log_rate | -1.294088867 | 0.014899388 | -86.85517 | 3.36416E-06 | -1.341505413 | -1.24667232 | -1.341505413 | -1.24667232 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# SPCA AD-480 TYPE IV NEAT (#26)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.983790119 |
| R Square | 0.967842999 |
| Adjusted R Square | 0.951764499 |
| Standard Error | 0.028252776 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.048048698 | 0.0480487 | 60.19485456 | 0.016209881 |
| Residual | 2 | 0.001596439 | 0.00079822 | | |
| Total | 3 | 0.049645137 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.802969883 | 0.106110612 | 26.4155472 | 0.001430041 | 2.34641245 | 3.25952731 | 2.34641245 | 3.259527315 |
| Log_rate | -0.908934907 | 0.117152915 | -7.7585343 | 0.016209881 | -1.413003566 | -0.40486625 | -1.413003566 | -0.404866248 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# SPCA AD-480 TYPE IV 75/25 (#27)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.92513862 |
| R Square | 0.855881467 |
| Adjusted R Square | 0.807841956 |
| Standard Error | 0.04883551 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.042489977 | 0.04248998 | 17.81619853 | 0.024309877 |
| Residual | 3 | 0.007154721 | 0.00238491 | | |
| Total | 4 | 0.049644698 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.300215752 | 0.11488319 | 20.0222135 | 0.0002723 | 1.934605827 | 2.66582568 | 1.934605827 | 2.665825677 |
| Log_rate | -0.558253594 | 0.132258626 | -4.2209239 | 0.024309877 | -0.979159963 | -0.13734722 | -0.979159963 | -0.137347224 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -3°C
# SPCA AD-480 TYPE IV 50/50 (#28)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99284886 |
| R Square | 0.985748858 |
| Adjusted R Square | 0.978623287 |
| Standard Error | 0.021913072 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.066428301 | 0.0664283 | 138.3396301 | 0.00715114 |
| Residual | 2 | 0.000960365 | 0.00048018 | | |
| Total | 3 | 0.067388667 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.08874776 | 0.059924396 | 34.8563837 | 0.000822053 | 1.830913712 | 2.34658181 | 1.830913712 | 2.346581807 |
| Log_rate | -0.769869468 | 0.065455145 | -11.761787 | 0.00715114 | -1.051500424 | -0.48823851 | -1.051500424 | -0.488238513 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# SPCA AD-480 TYPE IV NEAT (#29)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.991937909 |
| R Square | 0.983940815 |
| Adjusted R Square | 0.975911223 |
| Standard Error | 0.047520609 |
| Observations | 4 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.276719323 | 0.27671932 | 122.5393247 | 0.008062091 |
| Residual | 2 | 0.004516417 | 0.00225821 | | |
| Total | 3 | 0.281235739 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.74164295 | 0.10128541 | 27.0684885 | 0.001362022 | 2.305846702 | 3.1774392 | 2.305846702 | 3.177439197 |
| Log_rate | -1.214486279 | 0.109712187 | -11.069748 | 0.008062091 | -1.686540048 | -0.74243251 | -1.686540048 | -0.742432511 |

## MULTI-VARIABLE REGRESSION OUTPUT
# SIMULATED LIGHT FREEZING RAIN AT -10°C
# SPCA AD-480 TYPE IV 75/25 (#30)

**SUMMARY OUTPUT**

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.980749264 |
| R Square | 0.96186912 |
| Adjusted R Square | 0.949158826 |
| Standard Error | 0.05204385 |
| Observations | 5 |

**ANOVA**

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.204974221 | 0.20497422 | 75.67638958 | 0.003197031 |
| Residual | 3 | 0.008125687 | 0.00270856 | | |
| Total | 4 | 0.213099908 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.567714452 | 0.10833524 | 23.7015624 | 0.000164575 | 2.222943045 | 2.91248586 | 2.222943045 | 2.91248586 |
| Log_rate | -0.993268083 | 0.114179011 | -8.6992178 | 0.003197031 | -1.356636997 | -0.62989917 | -1.356636997 | -0.62989917 |

# APPENDIX G

# OFFICIAL TRANSPORT CANADA HOLDOVER TIME TABLES FOR USE DURING WINTER 1998-99

**XEEE**

**1998.10.23**

## AIRCRAFT GROUND ICING UPDATE

## MISE À JOUR SUR LE DÉGIVRAGE AU SOL DES AÉRONEFS

### PURPOSE

This Commercial and Business Aviation Advisory Circular (CBAAC) is intended to inform air operator personnel of recent developments and issues pertaining to aircraft ground icing operations.

This CBAAC replaces Air Carrier Advisory Circular (ACAC) 0113R dated 1997.09.22.

### OBJET

La présente Circulaire d'information de l'Aviation commerciale et d'affaires (CIACA) vise à informer les exploitants aériens et leur personnel des progrès accomplis concernant les opérations des aéronefs dans des conditions de givrage au sol.

La présente CIACA remplace la Circulaire d'information aux transporteurs aériens (CITA) 0113R, datée du 22 septembre 1997.

### ATTACHMENTS

Table 1: SAE Type I Fluid Holdover Time Table

Table 2: SAE Type II Fluid Holdover Time Table

Table 3: SAE Type III Fluid Holdover Time Table

Table 4: SAE Type IV Composite Fluid Holdover Time Table

Table 4 C1a: CLARIANT Type IV Fluid Holdover Time Table - (SAFEWING MP IV

### PIÈCES JOINTES

Tableau 1 : Tableau des durées d'efficacité des liquides de type I de la SAE

Tableau 2 : Tableau des durées d'efficacité des liquides de type II de la SAE

Tableau 3 : Tableau des durées d'efficacité des liquides de type III de la SAE

Tableau 4 : Tableau des durées d'efficacité des liquides génériques de type IV de la SAE

Tableau 4 C1a : Tableau des durées d'efficacité des liquides de type IV de CLARIANT

1957)

Table 4 C2: CLARIANT Type IV Fluid Holdover Time Table (Safewing MPIV2001)

Table 4 K: KILFROST Type IV Fluid Holdover Time Table - (ABC - S)

Table 4 O: OCTAGON Type IV Fluid Holdover Time Table - (MAX-FLIGHT)

Table 4 S1: SPCA Type IV Fluid Holdover Time Table - (AD-404)

Table 4 S2: SPCA Type IV Fluid Holdover Time Table - (AD-480)

Table 4 U: UNION CARBIDE Type IV Fluid Holdover Time Table - (ULTRA PLUS)

Table 5: SAE Qualified Fluids Listing

Table 6: SAE Type I Fluid Application Guidelines

Table 7: SAE Type II/IV Fluid Application Guidelines

Table 8: Visibility in snow vs. snowfall intensity table

(SAFEWING MP IV 1957)

Tableau 4C2: Tableau des durées défficacité des ligues de type Ivd Clariant (Safewing MPIV20001)

Tableau 4 K : Tableau des durées d'efficacité des liquides de type IV de KILFROST (ABC - S)

Tableau 4 O : Tableau des durées d'efficacité des liquides de type IV d'OCTAGON (MAX-FLIGHT)

Tableau 4 S1 : Tableau des durées d'efficacité des liquides de type IV de SPCA (AD-404)

Tableau 4 S2 : Tableau des durées d'efficacité des liquides de type IV de SPCA (AD-480)

Tableau 4 U : Tableau des durées d'efficacité des liquides de type IV d'UNION CARBIDE (ULTRA PLUS)

Tableau 5 : Liste des liquides approuvés de la SAE

Tableau 6 : Lignes directrices pour l'application des liquides de type I de la SAE

Tableau 7 : Lignes directrices pour l'application des liquides de type II et IV de la SAE

Tableau 8 : Visibilité dans la neige par rapport à l'intensité des précipitations

**BACKGROUND**

Transport Canada Civil Aviation endeavours to provide timely information to the aviation industry regarding developments in the areas of icing regulation, standards, procedures and research. The Standing Committee on Operations Under Icing Conditions was established in 1994 to provide a

**CONTEXTE**

La Direction générale de l'aviation civile de Transports Canada se propose de fournir à l'industrie aéronautique de l'information pertinente relative aux progrès accomplis dans les domaines de la réglementation, des normes, des procédures et de la recherche en matière de givrage. Le Comité

vehicle for open discussion of current aircraft icing operation issues and draws membership from various government departments as well as a broad cross-section of the aviation industry. This Committee meets twice per year, prior to and following the winter operating season. Operators are encouraged, at any time, to forward their issues and concerns regarding winter operations for consideration by the Standing Committee. (Please see contact information at the end of this circular.)

permanent sur les opérations dans des conditions de givrage de Transports Canada, mis en place en 1994, sert de forum pour les discussions ouvertes sur les questions relatives aux opérations dans des conditions de givrage. Composé de représentants de plusieurs ministères et d'un groupe représentatif de l'industrie aéronautique, le Comité se réunit deux fois l'an, avant et après les opérations hivernales. On invite les exploitants à acheminer les questions sur les opérations hivernales qu'ils aimeraient porter à l'attention du Comité permanent (voir les coordonnées de la personne-ressource à la fin de la présente circulaire).

## CHANGES TO HOLDOVER TIME (HOT) TABLES

The HOT table changes from the previous ACAC (0113R) are indicated herein.

Type 1 Fluid - no change.

Type II Fluid - Change in cell value for freezing drizzle column, at 100/0 concentration, and -3 to -14C temperature range.

Type III Fluid - No change in HOT values.

**No Type III Fluids are known to be qualified for use as of August 1998.

Type IV Fluid - It should be considered that all of the Type IV Fluids have changed for this years HOT table purposes.

### Additional HOT Table Information

The manufacturers of Type IV fluids made formulation changes to their fluids which required re-evaluation and establishing of revised HOT tables.
The Composite Type IV HOT table can be used for any Type IV fluid. The "fluid specific" Type IV HOT tables may be used in lieu of the Composite

## MODIFICATIONS APPORTÉES AUX TABLEAUX DES DURÉES D'EFFICACITÉ

Les modifications apportées aux tableaux des durées d'efficacité de la CITA précédente (0113R) sont indiquées ci-dessous.

Liquide de type I - aucun changement.

Liquide de type II - changement de plage dans la colonne de bruine verglaçante, concentration 100/0, plage de température -3 à -14 °C.

Liquide de type III - aucun changement.

**Aucun liquide de type III n'a été approuvé et ne peut être utilisé à partir d'août 1998.

Liquide de type IV - tous les liquides de type IV ont été modifiés dans les tableaux des durées d'efficacité de cette année.

### Information supplémentaire sur les tableaux des durées d'efficacité

Les fabricants des liquides de type IV ont changé la formule de leurs liquides. Par conséquent, il a fallu réévaluer et réviser les tableaux des durées d'efficacité.
Le tableau des durées d'efficacité des liquides génériques de type IV peut être utilisé pour tous les liquides de type IV. Les tableaux des durées

table providing that the named fluid is being used. A careful comparison will show that in specific circumstances some fluids perform better that the Composite table values.

d'efficacité des liquides spécifiques de type IV peuvent être utilisés à la place du tableau générique à condition que le liquide en question soit utilisé. Si l'on compare attentivement les deux, on peut constater que, dans certains cas, les liquides spécifiques ont une meilleure performance que les liquides génériques.

The number of Type IV HOT Tables has risen to eight (8) this year. It is recommended that operators only reproduce the tables which they will use as part of their program. It is therefore suggested that an operator duplicate the SAE Composite Holdover Time Table, which may be used in all cases, and the pertinent specific fluid table consistent with the fluid in use.

Le nombre de tableaux des durées d'efficacité des liquides de type IV est passé à huit (8) cette année. On recommande aux exploitants de reproduire seulement les tableaux qu'ils utiliseront pour leur programme. On leur suggère de copier le tableau des durées d'efficacité des liquides génériques de la SAE, qui sera utile dans tous les cas, ainsi que le tableau correspondant au liquide spécifique utilisé.

A comparison of the old and new (attached) HOT tables is suggested to ensure a thorough knowledge of all changes.

On suggère de comparer les anciens tableaux avec les nouveaux (ci-joints) afin de s'assurer de prendre connaissance de tous les changements.

**Type III Fluid Availability**

The SAE has approved a specification for Type III anti-icing fluids that can be used on those aircraft with rotation speeds significantly lower than the large jet rotation speeds, which are 100 knots or greater.

The attached Type III HOT table (Table 3) may be used for qualified Type III fluids.

Note: At the time of writing this document (August 1998) there were no qualified Type III fluids available for operational use.

**Disponibilité des liquides de type III**

La SAE a approuvé des spécifications pour les liquides antigivrants de type III pouvant être utilisés sur les aéronefs dont les vitesses de rotation sont considérablement plus basses que celles des gros avions à réaction, soit 100 noeuds ou plus.

Le (tableau 3) durées d'efficacité des liquides de type III peut être utilisé pour les liquides approuvés de ce type.

Nota : Au moment de rédiger ce document (août 1998), aucun liquide de type III approuvé n'était offert.

**Type III Fluid Application Guidelines**

SAE Guidelines for the Application of Type III Anti-Icing Fluids have not yet been published. Until

**Lignes directrices pour l'application des liquides de type III**

Les lignes directrices de la SAE pour l'application des liquides antigivrants de type III n'ont pas encore

such a document is published, it is recommended that the Type II/IV Guidelines be utilized.

été publiées. On recommande d'utiliser les lignes directrices pour les liquides de type II et IV jusqu'à ce qu'un document soit publié pour le type III.

## DE-ICING AND ANTI-ICING FLUID COMPATIBILITY

### Type IV Fluid

Research has indicated that the effectiveness of a Type IV fluid can be seriously diminished if proper procedures are not followed when applying it over a Type I fluid. Operators should ensure that the Type I and Type IV fluids being used on their aircraft are compatible. This can be accomplished by contacting the respective fluid manufacturer.

### Type III Fluid

The compatibility of Type I and Type III fluids has not been completely investigated in field testing. Therefore, the user of Type III fluid should ascertain from the Type III fluid manufacturer that the Type I (de-icing) fluid being used is compatible with the Type III (anti-icing) fluid being used.

## FLUID APPLICATION TECHNIQUE

Research has indicated that if the fluid is not applied correctly, the HOT table values are not achievable.

Proper fluid coverage is absolutely essential for proper fluid performance. It is imperative that the personnel applying the fluid be properly trained and that a consistent fluid application technique be utilized.

## COMPATIBILITÉ DES LIQUIDES DÉGIVRANTS ET ANTIGIVRANTS

### Liquide de type IV

Les recherches ont démontré que l'efficacité d'un liquide de type IV peut être considérablement réduite si les procédures appropriées ne sont pas suivies lorsqu'on applique ce liquide sur un liquide de type I. Les exploitants doivent s'assurer que les liquides de type I et IV qu'ils utilisent sur leurs aéronefs sont compatibles. Ils peuvent se renseigner auprès du fabricant du liquide en question.

### Liquide de type III

La compatibilité des liquides de type I et de type III n'a pas été évaluée complètement à l'aide d'essais sur le terrain. Par conséquent, l'utilisateur d'un liquide de type III devrait vérifier auprès du fabricant si ce liquide (antigivrant) est compatible avec le liquide (dégivrant) de type I.

## MÉTHODE D'APPLICATION DU LIQUIDE

Des recherches ont montré qu'il est impossible d'obtenir les chiffres indiqués dans les tableaux des durées d'efficacité si le liquide n'est pas appliqué correctement.

Pour que le liquide soit efficace, il faut absolument qu'il soit appliqué de la bonne façon. Il est impératif que le personnel chargé de l'application du liquide ait reçu la formation appropriée et qu'une méthode d'application uniforme du liquide soit utilisée.

Several international operators have noted what appeared to be early fluid failure during precipitation conditions. The subsequent evaluation revealed that inappropriate application technique was apparently at issue. Canadian operators that encounter apparent early fluid failure are requested to advise Transport Canada.

Plusieurs exploitants internationaux ont remarqué ce qui semblait être une perte d'efficacité prématurée des liquides pendant des précipitations. L'étude qui en a résulté a révélé que le problème semblait apparemment lié à une mauvaise méthode d'application. Les exploitants canadiens aux prises avec d'apparentes pertes d'efficacité prématurées des liquides sont priés d'avertir Transports Canada.

**ICE PELLETS**

The meteorological definition of Ice Pellets is: "A type of precipitation consisting of transparent or translucent pellets of ice, 5 mm or less in diameter. They may be spherical, irregular, or (rarely) conical in shape. Ice pellets usually bounce when hitting hard ground, and make a sound upon impact. Now internationally recognized, *ice pellets* include two basically different types of precipitation, those which are known in the United States as (a) *sleet*, and (b) *small hail*. Thus a two-part definition is given:

*(a) Sleet or grains of ice:* generally transparent, globular, solid grains of ice which have formed from the freezing of raindrops or the refreezing of largely melted snowflakes when falling through a below-freezing layer of air near the earth's surface.

*(b) Small hail:* generally translucent particles, consisting of snow pellets encased in a thin layer of ice. The ice layer may form either by the accretion of droplets upon the snow pellet, or by the melting and refreezing of the surface of the snow pellet."

When an Ice Pellet event occurs after the

**GRANULES DE GLACE**

La définition météorologique de granules de glace est : « Un type de précipitation composé de granules de glace transparents ou translucides, de 5 mm de diamètre ou moins. Ils peuvent être sphériques, irréguliers ou, plus rarement, de forme conique. Les granules de glace rebondissent habituellement lorsqu'ils tombent sur du terrain dur et émettent un bruit au moment de l'impact. Dorénavant reconnus à l'échelle internationale, les *granules de glace* comprennent deux différents types de précipitations de base, celles qui, aux États-Unis, sont connues sous le nom de a) *grésil* et b) *petits grêlons*. Par conséquent, la définition comporte deux parties :

*a) Grésil ou grains de glace* : habituellement des grains de glace transparents, globulaires et solides qui se sont formés à partir de la congélation des gouttes de pluie ou de la recongélation de flocons de neige pratiquement fondus au moment où ils passent au travers d'une couche d'air au-dessous du point de congélation près de la surface de la terre.

*b) Petits grêlons* : habituellement des particules translucides, composés de granules de neige enchassés dans une fine couche de glace. La couche de glace peut se former soit par l'accumulation de gouttelettes sur le granule de neige, soit par la fonte et la recongélation de la surface du granule de neige. »

Lorsqu'il y a formation de granules de neige après

application of a de/anti-icing fluid to an aircraft, the fluid is susceptible to very rapid failure.

It is believed that the Ice Pellets are capable of penetrating the fluid and have enough momentum to contact the aircraft's surface beneath the fluid. Additionally, the Ice Pellets are of significant mass and therefore local dilution of the fluid by the Ice Pellet would result in the very rapid failure of the fluid.

The Holdover Time (HOT) tables do not address the Ice Pellet precipitation scenario. The fluids have not been scientifically tested in such conditions.

Operationally, in conditions of Ice Pellets, extra caution should be taken and extra inspections conducted, because there is believed to be a high risk of rapid fluid failure and the attendant wing contamination. The HOT tables are not a reliable source of predicting fluid failure under Ice Pellets conditions.

avoir appliqué un liquide dégivrant ou antigivrant sur un aéronef, il est possible que le liquide ne résiste pas très longtemps.

On croit que les granules de neige peuvent pénétrer le liquide et qu'ils ont une vitesse suffisante leur permettant d'entrer en contact avec la surface de l'aéronef sous le liquide. De plus, les granules de glace possèdent une masse considérable. Par conséquent, la dilution locale du liquide causée par le granule de neige annulerait très rapidement l'effet du liquide.

Les tableaux des durées d'efficacité ne tiennent pas compte des précipitations de granules de glace. Les liquides n'ont pas été scientifiquement mis à l'essai dans de telles conditions.

Du point de vue opérationnel, dans le cas des précipitations de granules de glace, on devrait faire plus attention et effectuer des inspections supplémentaires. En effet, il y a de fortes raisons de croire qu'il existe un risque élevé de détérioration du liquide et de contamination des ailes annexes. Les tableaux des durées d'efficacité ne constituent pas une source fiable pour prévoir l'inefficacité du liquide dans le cas des précipitations de granules de glace.

**VISIBILITY IN SNOW VERSUS SNOWFALL RATE TABLE**

Recent scientific research has indicated that the use of visibility in snow as the sole criteria for establishing snowfall rate/intensity is invalid. The evidence indicates that a visibility and temperature pair needs to be used for establishing more accurate snowfall rates. The highest snowfall rates occur near $0^0$C.

**TABLEAU DE LA VISIBILITÉ DANS LA NEIGE PAR RAPPORT AU TAUX DE PRÉCIPITATIONS**

Les recherches scientifiques récentes démontrent que l'utilisation de la visibilité dans la neige comme seul critère pour établir le taux et l'intensité des précipitations de neige est invalide. Il faut tenir compte de la visibilité et de la température pour établir des taux de précipitations exacts. Les plus fortes précipitations de neige se produisent à

environ 0 °C.

For example, assume that the daytime visibility in snowfall is 1 statute mile and that the temperature is $-7^0$C. Using Table 8 for this example, we conclude that the snowfall rate is moderate. This snowfall rate will be used to determine which HOT table value will be appropriate for the fluid in use.

Par exemple, supposons que la visibilité de jour dans la neige est d'un mille terrestre et que la température est de -7 °C. À l'aide du tableau 8, nous pouvons conclure que le taux de précipitations est modéré. Ce taux sera utilisé pour déterminer quelle valeur dans le tableau de durées d'efficacité est la plus appropriée pour le liquide utilisé.

**QUALIFIED FLUIDS**

A revised list of Qualified De-icing/Anti-icing Fluids is attached as Table 5. Qualified fluids have undergone laboratory testing to qualify their protection times and to confirm aerodynamic acceptability. The operator is ultimately responsible for ensuring that only qualified fluids are used when the HOT tables are being utilized.

**LIQUIDES APPROUVÉS**

Une liste révisée des liquides dégivrants et antigivrants approuvés est annexée au tableau 5. Les liquides approuvés ont été testés en laboratoire afin de quantifier leurs durées de protection et de confirmer s'ils sont acceptables du point de vue aérodynamique. Il incombe à l'exploitant de s'assurer que seuls les liquides approuvés sont utilisés lorsque les tableaux des durées d'efficacité sont consultés.

**REPRESENTATIVE SURFACES**

Representative surfaces that can be clearly observed by flight crew from inside the aircraft may be suitable for judging whether or not critical surfaces are contaminated.

**SURFACES REPRÉSENTATIVES**

Les surfaces représentatives pouvant être clairement observées par l'équipage de conduite depuis l'intérieur de l'aéronef peuvent servir de référence pour déterminer si les surfaces critiques sont contaminées ou non.

Research has indicated that fluid failure occurs last at the mid chord sections of wings. Therefore, whether painted or not, areas located at mid chord sections of wings and previously used for checking fluid conditions are not suitable for evaluating fluid failure and should no longer be used as representative surfaces.

Les recherches démontrent que le liquide se détériore en dernier à la corde moyenne de l'aile. Par conséquent, les parties (peinturées ou non) qui sont situées à la corde moyenne des ailes et qui ont été utilisées précédemment pour vérifier les conditions des liquides ne peuvent être utilisées pour évaluer l'inefficacité des liquides. De plus, elle ne doivent plus être utilisées comme surfaces représentatives.

Pre-take-off contamination inspections should be concentrated on the leading edge in conjunction with the trailing edge of the wing. Dependent upon

Au moment des inspections de contamination avant le décollage, il convient de s'attarder au bord d'attaque et au bord de fuite de l'aile. Selon la

aircraft configuration, wing spoilers may also be used to provide an indication of fluid condition.

configuration de l'aéronef, les déporteurs d'aile peuvent aussi être utilisés pour évaluer les conditions des liquides.

**SEGMENTING SNOW COLUMN CELLS OF HOT TABLES**

**SEGMENTATION DES PLAGES DES TABLEAUX DES DURÉES D'EFFICACITÉ DANS LA COLONNE RÉSERVÉE À LA NEIGE**

Previously Air Carrier Advisory Circular (ACAC) 0092, dated December 8, 1995, provided guidance regarding a technique for dividing published holdover time ranges into segments dependent upon the intensity of the prevailing snow conditions. The method is no longer acceptable and therefore ACAC 0092 is rescinded.

La Circulaire d'information aux transporteurs aériens (CITA) 0092, datée du 8 décembre 1995, fournissait des lignes directrices pour diviser les plages de durées d'efficacité en segments selon l'intensité des conditions de neige qui prévalent. Cette méthode n'est plus acceptable. Par conséquent, la CITA 0092 a été annulée.

The lowest/minimum fluid holdover time for snow in any particular cell is based upon a moderate snowfall rate. The capability of anti-icing fluid to tolerate a heavy snowfall rate has not been evaluated, therefore holdover times for heavy snow conditions have not been generated.

La durée d'efficacité minimale des liquides dans des conditions de neige est calculée d'après un taux de précipitations modéré. La capacité de tolérance des liquides antigivrants dans des conditions de forte neige n'a pas été évaluée; par conséquent, les durées d'efficacité dans des conditions de forte neige n'ont pas été établies.

Operations during heavy snow conditions will require that an inspection be conducted immediately prior to take-off to ensure that contamination is not adhering to the critical surfaces. This inspection is required irrespective of the time that has elapsed since anti-icing occurred. Take-off needs to be initiated within 5 minutes of the inspection, otherwise the inspection must be repeated or the aircraft must be de/anti-iced again. Type I fluids should not be used as an anti-icing fluid during heavy snow conditions.

Avant d'effectuer des opérations dans des conditions de forte neige, une inspection doit être menée immédiatement avant le décollage afin de prévenir la contamination des surfaces critiques. Cette inspection doit se faire, peu importe le temps qui s'est écoulé depuis l'antigivrage. Le décollage doit se faire cinq minutes après l'inspection. Sinon, celle-ci doit être répétée, ou l'aéronef doit être dégivré/antigivré de nouveau. Les liquides de type I ne doivent pas être utilisés comme liquide antigivrant dans des conditions de forte neige.

During moderate snow conditions a take-off may be initiated without inspection provided that the lowest number/value in the appropriate snow cell range has not been exceeded.

Dans des conditions de neige modérée, un décollage peut être effectué sans inspection, à condition de ne pas dépasser le plus court délai indiqué dans la plage appropriée.

During light snow conditions a take-off may be initiated without inspection provided that the highest/top value in the snow cell range has not

Dans des conditions de neige légère, un décollage peut être effectué sans inspection, à condition de ne pas dépasser le plus grand délai indiqué dans la plage

been exceeded.

**INCORPORATING CONTENTS OF CBAAC**

In accordance with the Ground Icing Operations Standard, you are reminded that icing operations training programs must be revised to include the information contained in this CBAAC. In addition, it is recommended that all persons in your organization who have duties and responsibilities with respect to aircraft ground icing operations be made aware of the contents of this CBAAC.

**FEEDBACK**

Any comments or questions should be directed to:

Transport Canada
Commercial & Business Aviation Branch
Operational Standards (AARXB)
Place de Ville, Tower "C"
330 Sparks Street, 4th Floor
Ottawa, Ontario
K1A 0N8

Telephone: (613) 990-8943
Facsimile: (613) 954-1602
E-mail: walperk@tc.gc.ca

**CONCLUSION**

The *Canadian Aviation Regulations (CARs)* and the *Commercial Air Services Standards (CASS)* will be amended to reflect the above policy. Operators should contact their Regional Office for further information.

appropriée.

**INCORPORATION DU CONTENU DE LA CIACA**

Conformément à la *Norme sur les opérations dans des conditions de givrage au sol*, on vous rappelle que les programmes de formation sur les opérations dans des conditions de givrage doivent être mis à jour afin de refléter l'information contenue dans la présente CIACA. De plus, on recommande que toutes les personnes de votre organisation dont les tâches et responsabilités touchent aux opérations d'aéronefs dans des conditions de givrage au sol soient mises au courant du contenu de la présente CIACA.

**RÉTROACTION**

Veuillez acheminer vos commentaires ou vos questions à :

Transports Canada
Direction de l'aviation commerciale et d'affaires
Normes opérationnelles (AARXB)
Place de Ville, Tour C
330, rue Sparks, 4e étage
Ottawa (Ontario)
K1A 0N8

Téléphone : (613) 990-8943
Télécopieur : (613) 954-1602
courrier électronique: walperk@tc.gc.ca

**CONCLUSION**

Le *Règlement de l'aviation canadien (RAC)* et les *Normes de service aérien commercial (NSAC)* seront modifiés de façon à tenir compte de ce qui précède. Nous invitons les exploitants à communiquer avec leur bureau régional pour obtenir de plus amples renseignements.

Le directeur
Aviation commerciale et d'affaires

M.R. Preuss
Director
Commercial & Business Aviation

Attach. p.j.

Commercial & Business Aviation Advisory Circulars (CBAAC) are intended to provide information and guidance regarding operation matters. A CBAAC may describe an acceptable, but not the only, means of demonstrating compliance with existing regulations. CBAACs in and of themselves do not change, create any additional, authorize changes in, or permit deviations from regulatory requirements. CBAACs are available electronically on the TC Web site, at www.tc.gc.ca/aviation/commerce/advisory/acacsu-e.htm.

Les Circulaires d'information de l'Aviation commerciale et d'affaires (CIACA) visent à fournir de l'information et des directives concernant les questions opérationnelles. Une CIACA peut servir à décrire un moyen acceptable, mais non le seul, de se conformer au règlement existant. Cependant, en soi, une CIACA ne peut modifier ou créer une exigence réglementaire, ni peut-elle autoriser de changements ou des dérogations aux exigences réglementaires. Les CIACA sont aussi disponibles sur l'Internet au: www.tc.gc.ca/aviation/commerce/advisory/acacsu-f.htm.

**TABLE 1**

# SAE TYPE I FLUID HOLDOVER TABLE

Guideline for Holdover Times Anticipated for SAE Type I Fluid Mixture as a Function of Weather Conditions and OAT

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

| OAT | | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| °C | °F | *FROST | FREEZING FOG | SNOW | **FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 0:45 | 0:12 - 0:30 | 0:06 - 0:15 | 0:05 - 0:08 | 0:02 - 0:05 | 0:02 - 0:05 |
| 0 to -10 | 32 to 14 | 0:45 | 0:06 - 0:15 | 0:06 - 0:15 | 0:05 - 0:08 | 0:02 - 0:05 | |
| below -10 | below 14 | 0:45 | 0:06 - 0:15 | 0:06 - 0:15 | | | |

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

*** During conditions that apply to aircraft protection for ACTIVE FROST**
****Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.**

**SAE Type I Fluid / Water Mixture is selected so that the FP of the mixture is at least 10° C(18° F) below OAT**

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA : AUGUST 1998**

## TABLEAU 1

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE I DE LA SAE

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type I de la SAE
en fonction des conditions météorologiques et de la température extérieure (OAT)

**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| °C | °F | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | **BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 0:45 | 0:12 - 0:30 | 0:06 - 0:15 | 0:05 - 0:08 | 0:02 - 0:05 | 0:02 - 0:05 |
| de 0 à -10 | de 32 à 14 | 0:45 | 0:06 - 0:15 | 0:06 - 0:15 | 0:05 - 0:08 | 0:02 - 0:05 | |
| au-dessous de -10 | au-dessous de 14 | 0:45 | 0:06 - 0:15 | 0:06 - 0:15 | | | |

**°C = Degrés Celsius**
**°F = Degrés Fahrenheit**
**OAT = Température extérieure**
**FP = Point de congélation**

*** Pour protéger l'aéronef contre le GIVRE.**
**** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.**

**Le mélange de liquide de type I de la SAE et d'eau doit être choisi de façon que le FP du mélange soit inférieur à l'OAT d'au moins 10 °C (18 °F).**

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**

**TABLE 2**

# SAE TYPE II FLUID HOLDOVER TABLE

Guideline for Holdover Times Anticipated for SAE Type II Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | SAE Type II Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat - Fluid / Water (Vol% / Vol%) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 12:00 | 1:15 - 3:00 | 0:20 - 1:00 | 0:30 -1:00 | 0:15 - 0:30 | 0:10 - 0:40 |
| | | 75/25 | 6:00 | 0:50 - 2:00 | 0:15 - 0:40 | 0:20 -0:45 | 0:10 - 0:25 | 0:05 - 0:25 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:05 - 0:15 | 0:10 - 0:20 | 0:05 - 0:10 | |
| 0 to -3 | 32 TO 27 | 100/0 | 8:00 | 0:35 - 1:30 | 0:20 - 0:45 | 0:30 - 1:00 | 0:15 - 0:30 | |
| | | 75/25 | 5:00 | 0:25 - 1:00 | 0:15 - 0:30 | 0:20 - 0:45 | 0:10 - 0:25 | |
| | | 50/50 | 3:00 | 0:15 - 0:45 | 0:05 - 0:15 | 0:10 - 0:20 | 0:05 - 0:10 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:35 - 1:30 | 0:15 - 0:40 | **0:25 - 1:00 | **0:10 - 0:30 | |
| | | 75/25 | 5:00 | 0:25 - 1:00 | 0:15 - 0:30 | **0:20 - 0:45 | **0:10 - 0:25 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:20 - 1:30 | 0:15 - 0:30 | | | |
| below -25 | below -13 | 100/0 | SAE Type II fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when SAE Type II fluid cannot be used. | | | | | |

**°C = Degrees Celsius**
**°F = Degrees Farenheit**
**OAT = Outside Air Temperature**
**FP = Freezing Point**
*** During conditions that apply to aircraft protection for ACTIVE FROST**
****The lowest use temperature is limited to -10° C (14° F)**
*****Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.**

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL**

**.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA AUGUST 1998**

## TABLEAU 2

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE II DE LA SAE

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type II de la SAE
en fonction des conditions météorologiques et de la température extérieure (OAT)

**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Concentration liquide type II SAE | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Liquide pur/Eau (Vol %/Vol %) | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | ***BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 100/0 | 12:00 | 1:15 - 3:00 | 0:20 - 1:00 | 0:30 - 1:00 | 0:15 - 0:30 | 0:10 - 0:40 |
| | | 75/25 | 6:00 | 0:50 - 2:00 | 0:15 - 0:40 | 0:20 - 0:45 | 0:10 - 0:25 | 0:05 - 0:25 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:05 - 0:15 | 0:10 - 0:20 | 0:05 - 0:10 | |
| de 0 à -3 | de 32 à 27 | 100/0 | 8:00 | 0:35 - 1:30 | 0:20 - 0:45 | 0:30 - 1:00 | 0:15 - 0:30 | |
| | | 75/25 | 5:00 | 0:25 - 1:00 | 0:15 - 0:30 | 0:20 - 0:45 | 0:10 - 0:25 | |
| | | 50/50 | 3:00 | 0:15 - 0:45 | 0:05 - 0:15 | 0:10 - 0:20 | 0:05 - 0:10 | |
| au-dessous de -3 à -14 | au-dessous de 27 à 7 | 100/0 | 8:00 | 0:35 - 1:30 | 0:15 - 0:40 | **0:25 - 1:00 | **0:10 - 0:30 | |
| | | 75/25 | 5:00 | 0:25 - 1:00 | 0:15 - 0:30 | **0:20 - 0:45 | **0:10 - 0:25 | |
| au-dessous de -14 à -25 | au-dessous de 7 à -13 | 100/0 | 8:00 | 0:20 - 1:30 | 0:15 - 0:30 | | | |
| au-dessous de -25 | au-dessous de -13 | 100/0 | Le liquide de type II de la SAE peut être utilisé au-dessous de -25 °C (-13 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type II s'avère impossible. | | | | | |

**°C = Degrés Celsius**
**°F = Degrés Fahrenheit**
**OAT = Température extérieure**
**FP = Point de congélation**
*** Pour protéger l'aéronef contre le GIVRE.**
**** La température d'utilisation la plus basse est fixée à -10 °C (14 °F).**
***** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.**

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**

**TABLE 3**

# SAE TYPE III FLUID HOLDOVER TABLE

Guideline for Holdover Times Anticipated for SAE Type III Fluid Mixture as a Function of Weather Conditions and OAT

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

| OAT | | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| °C | °F | *FROST | FREEZING FOG | SNOW | **FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0 | above 32 | 5:00 | 0:50 - 1:30 | 0:15 - 0:30 | 0:25 - 0:50 | 0:15 - 0:25 | 0:05 - 0:35 |
| 0 to -3 | 32 to 27 | 4:00 | 0:50 - 1:30 | 0:15 - 0:25 | 0:25 - 0:50 | 0:15 - 0:25 | |
| below -3 to -14 | below 27 to 7 | 4:00 | 0:50 - 1:30 | 0:10 - 0:20 | 0:25 - 0:50 | 0:15 - 0:25 | |
| below -14 | below 7 | SAE Type III fluid may be used below -14°C (7°F) provided the freezing point of the fluid is at least 7°C(13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type III fluid cannot be used | | | | | |

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

*** During conditions that apply to aircraft protection for ACTIVE FROST**
****Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.**

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA, AUGUST 1998**

## TABLEAU 3

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE III DE LA SAE

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type III de la SAE
en fonction des conditions météorologiques et de la température extérieure (OAT)

**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| °C | °F | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | **BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 5:00 | 0:50 - 1:30 | 0:15 - 0:30 | 0:25 - 0:50 | 0:15 - 0:25 | 0:05 - 0:35 |
| de 0 à -3 | de 32 à 27 | 4:00 | 0:50 - 1:30 | 0:15 - 0:25 | 0:25 - 0:50 | 0:15 - 0:25 | |
| au-dessous de -3 à -14 | au-dessous de 27 à 7 | 4:00 | 0:50 - 1:30 | 0:10 - 0:20 | 0:25 - 0:50 | 0:15 - 0:25 | |
| au-dessous de -14 | au-dessous de 7 | Le liquide de type III de la SAE peut être utilisé au-dessous de -14 °C (7 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type III s'avère impossible. | | | | | |

**°C = Degrés Celsius**
**°F = Degrés Fahrenheit**
**OAT = Température extérieure**
**FP = Point de congélation**

*** Pour protéger l'aéronef contre le GIVRE.**
**** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.**

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**

**TABLE 4**

# SAE TYPE IV COMPOSITE FLUID HOLDOVER TABLE

Guideline for Holdover Times Anticipated for SAE Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat - Fluid / Water (Vol% / Vol%) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 0:45 - 1:25 | 0:40 - 1:00 | 0:35 - 0:55 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:20 - 0:40 | 0:30 - 1:00 | 0:15 - 0:30 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:05 - 0:20 | 0:10 - 0:20 | 0:05 - 0:10 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:35 - 1:00 | 0:40 - 1:00 | 0:35 - 0:55 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:20 - 0:35 | 0:30 - 1:00 | 0:15 - 0:30 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:05 - 0:15 | 0:10 - 0:20 | 0:05 - 0:10 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:20 - 0:40 | **0:25 - 1:00 | **0:15 - 0:30 | |
| | | 75/25 | 5:00 | 0:35 - 2:00 | 0:15 - 0:25 | **0:25 - 1:00 | **0:15 - 0:30 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:15 - 0:30 | | | |
| below -25 | below -13 | 100/0 | SAE Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

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

*** During conditions that apply to aircraft protection for ACTIVE FROST.**
**** The lowest use temperature is limited to -10° C (14° F).**
*****Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.**

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA , AUGUST 1998**

**TABLEAU 4 C1a**

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE IV DE CLARIANT
## SAFEWING MPIV 1957

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type IV
en fonction des conditions météorologiques et de la température extérieure (OAT)
**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Concentration liquide type IV | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Liquide pur / Eau (Vol % / Vol %) | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | ***BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 100/0 | 18:00 | 2:00 - 3:00 | 1:05 - 2:00 | 0:50 - 1:40 | 0:40 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:45 - 1:25 | 0:45 - 1:15 | 0:30 - 0:40 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:15 - 0:30 | 0:15 - 0:25 | 0:10 - 0:15 | |
| de 0 à -3 | de 32 à 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:45 - 1:25 | 0:50 - 1:40 | 0:40 - 1:00 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:30 - 1:00 | 0:45 - 1:15 | 0:30 - 0:40 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:10 - 0:20 | 0:15 - 0:25 | 0:10 - 0:15 | |
| au-dessous de -3 à -14 | au-dessous de 27 à 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:30 - 0:55 | **0:55 - 1:25 | **0:30 - 0:45 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:20 - 0:45 | **0:45 - 1:15 | **0:25 - 0:35 | |
| au-dessous de -14 à -25 | au-dessous de 7 à -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:25 - 0:45 | | | |
| au-dessous de -25 | au-dessous de -13 | 100/0 | Le liquide de type IV peut être utilisé au-dessous de -25 °C (-13 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type IV s'avère impossible. | | | | | |

**°C = Degrés Celsius**
**°F = Degrés Fahrenheit**
**OAT = Température extérieure**
**FP = Point de congélation**
*** Pour protéger l'aéronef contre le GIVRE.**
**** La température d'utilisation la plus basse est fixée à -10 °C (14 °F).**
***** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.**

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**
**(révisé en septembre 1998)**

**TABLE 4 C1**

# CLARIANT TYPE IV FLUID HOLDOVER TABLE

# SAFEWING MPIV 1957

Guideline for Holdover Times Anticipated for Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat - Fluid / Water (Vol% / Vol%) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 1:05 - 2:00 | 0:50 - 1:40 | 0:40 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:45 - 1:25 | 0:45 - 1:15 | 0:30 - 0:40 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:15 - 0:30 | 0:15 - 0:25 | 0:10 - 0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:45 - 1:25 | 0:50 - 1:40 | 0:40 - 1:00 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:30 - 1:00 | 0:45 - 1:15 | 0:30 - 0:40 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:10 - 0:20 | 0:15 - 0:25 | 0:10 - 0:15 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:30 - 0:55 | **0:55 - 1:25 | **0:30 -0:45 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:20 - 0:45 | **0:45 - 1:55 | **0:25 - 0:35 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:25 - 0:45 | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when Type IV fluid cannot be used. | | | | | |

**°C = Degrees Celsius**
**°F = Degrees Farenheit**
**OAT = Outside Air Temperature**
**FP = Freezing Point**
*** During conditions that apply to aircraft protection for ACTIVE FROST.**
**** The lowest use temperature is limited to -10° C (14° F).**
*****Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.**

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA , AUGUST 1998**

TABLE 4 C1a

# CLARIANT TYPE IV FLUID HOLDOVER TABLE

## SAFEWING MPIV 1957

Guideline for Holdover Times Anticipated for Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | Type IV Fluid Concentration Neat - Fluid / Water (Vol% / Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 1:05 - 2:00 | 0:50 - 1:40 | 0:40 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:45 - 1:25 | 0:45 - 1:15 | 0:30 - 0:40 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:15 - 0:30 | 0:15 - 0:25 | 0:10 - 0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:45 - 1:25 | 0:50 - 1:40 | 0:40 - 1:00 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:30 - 1:00 | 0:45 - 1:15 | 0:30 - 0:40 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:10 - 0:20 | 0:15 - 0:25 | 0:10 - 0:15 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:30 - 0:55 | **0:55 - 1:25 | **0:30 -0:45 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:20 - 0:45 | **0:45 - 1:15 | **0:25 - 0:35 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:25 - 0:45 | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when Type IV fluid cannot be used. | | | | | |

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

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10° C (14° F).

***Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA , AUGUST 1998**
**(Revised September, 1998)**

## TABLEAU 4 C1a

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE IV DE CLARIANT
## SAFEWING MPIV 1957

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type IV
en fonction des conditions météorologiques et de la température extérieure (OAT)
**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Concentration liquide type IV | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Liquide pur / Eau (Vol % / Vol %) | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | ***BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 100/0 | 18:00 | 2:00 - 3:00 | 1:05 - 2:00 | 0:50 - 1:40 | 0:40 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:45 - 1:25 | 0:45 - 1:15 | 0:30 - 0:40 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:15 - 0:30 | 0:15 - 0:25 | 0:10 - 0:15 | |
| de 0 à -3 | de 32 à 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:45 - 1:25 | 0:50 - 1:40 | 0:40 - 1:00 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:30 - 1:00 | 0:45 - 1:15 | 0:30 - 0:40 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:10 - 0:20 | 0:15 - 0:25 | 0:10 - 0:15 | |
| au-dessous de -3 à -14 | au-dessous de 27 à 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:30 - 0:55 | **0:55 - 1:25 | **0:30 - 0:45 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:20 - 0:45 | **0:45 - 1:15 | **0:25 - 0:35 | |
| au-dessous de -14 à -25 | au-dessous de 7 à -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:25 - 0:45 | | | |
| au-dessous de -25 | au-dessous de -13 | 100/0 | Le liquide de type IV peut être utilisé au-dessous de -25 °C (-13 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type IV s'avère impossible. | | | | | |

°C = Degrés Celsius
°F = Degrés Fahrenheit
OAT = Température extérieure
FP = Point de congélation

* Pour protéger l'aéronef contre le GIVRE.

** La température d'utilisation la plus basse est fixée à -10 °C (14 °F).

*** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**
**(révisé en septembre 1998)**

TABLE 4 C2

# CLARIANT TYPE IV FLUID HOLDOVER TABLE

## SAFEWING MPIV 2001

Guideline for Holdover Times Anticipated for Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | Type IV Fluid Concentration Neat - Fluid / Water (Vol% / Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 1:55 - 2:00 | 0:55 - 1:55 | 0:40 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:50 - 1:25 | 0:35 - 1:10 | 0:25 - 0:35 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:10 - 0:20 | 0:10 - 0:20 | 0:10 - 0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 1:00 - 1:55 | 0:55 - 1:55 | 0:40 - 1:00 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:35 - 1:00 | 0:35 - 1:10 | 0:25 - 0:35 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:10 - 0:20 | 0:10 - 0:20 | 0:10 - 0:15 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:30 - 0:50 | **0:55 - 1:35 | **0:30 -0:45 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:20 - 0:35 | **0:40 - 1:10 | **0:20 - 0:30 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:20 - 0:35 | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when Type IV fluid cannot be used. | | | | | |

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

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10° C (14° F).

***Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA , AUGUST 1998**

## TABLEAU 4 C2

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE IV DE CLARIANT

# SAFEWING MPIV 2001

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type IV
en fonction des conditions météorologiques et de la température extérieure (OAT)
**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Concentration liquide type IV | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Liquide pur / Eau (Vol % / Vol %) | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | ***BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 100/0 | 18:00 | 2:00 - 3:00 | 1:55 - 2:00 | 0:55 - 1:55 | 0:40 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:50 - 1:25 | 0:35 - 1:10 | 0:25 - 0:35 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:10 - 0:20 | 0:10 - 0:20 | 0:10 - 0:15 | |
| de 0 à -3 | de 32 à 27 | 100/0 | 12:00 | 2:00 - 3:00 | 1:00 - 1:55 | 0:55 - 1:55 | 0:40 - 1:00 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:35 - 1:00 | 0:35 - 1:10 | 0:25 - 0:35 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:10 - 0:20 | 0:10 - 0:20 | 0:10 - 0:15 | |
| au-dessous de -3 à -14 | au-dessous de 27 à 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:30 - 0:50 | **0:55 - 1:35 | **0:30 - 0:45 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:20 - 0:35 | **0:40 - 1:10 | **0:20 - 0:30 | |
| au-dessous de -14 à -25 | au-dessous de 7 à -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:20 - 0:35 | | | |
| au-dessous de -25 | au-dessous de -13 | 100/0 | Le liquide de type IV peut être utilisé au-dessous de -25 °C (-13 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type IV s'avère impossible. | | | | | |

°C = Degrés Celsius
°F = Degrés Fahrenheit
OAT = Température extérieure
FP = Point de congélation

* Pour protéger l'aéronef contre le GIVRE.

** La température d'utilisation la plus basse est fixée à -10 °C (14 °F).

*** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**

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## TABLE 4 K

# KILFROST TYPE IV FLUID HOLDOVER TABLE

# ABC-S

Guideline for Holdover Times Anticipated for Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | Type IV Fluid Concentration Neat - Fluid / Water (Vol% / Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 1:10 - 2:00 | 1:20 - 1:50 | 1:00 - 1:25 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:35 - 1:05 | 0:50 - 1:10 | 0:35 - 0:50 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:05 - 0:20 | 0:15 - 0:20 | 0:10 - 0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 1:00 - 1:40 | 1:20 - 1:50 | 1:00 - 1:25 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:35 - 1:05 | 0:50 - 1:10 | 0:35 - 0:50 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:05 - 0:15 | 0:15 - 0:20 | 0:10 - 0:15 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:45 - 1:20 | **0:35 - 1:00 | **0:20 - 0:40 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:35 - 1:05 | **0:30 - 1:10 | **0:25 - 0:35 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:40 - 1:10 | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when Type IV fluid cannot be used. | | | | | |

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

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10° C (14° F).

***Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA , AUGUST 1998**
**(Revised November, 1998)**

## TABLEAU 4 K

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE IV DE KILFROST

## ABC-S

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type IV
en fonction des conditions météorologiques et de la température extérieure (OAT)

**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Concentration liquide type IV | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Liquide pur / Eau (Vol % / Vol %) | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | ***BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 100/0 | 18:00 | 2:00 - 3:00 | 1:10 - 2:00 | 1:20 - 1:50 | 1:00 - 1:25 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:35 - 1:05 | 0:50 - 1:25 | 0:35 - 0:50 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:05 - 0:20 | 0:15 - 0:20 | 0:10 - 0:15 | |
| de 0 à -3 | de 32 à 27 | 100/0 | 12:00 | 2:00 - 3:00 | 1:00 - 1:40 | 1:20 - 1:50 | 1:00 - 1:25 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:35 - 1:05 | 0:50 - 1:25 | 0:35 - 0:50 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:05 - 0:15 | 0:15 - 0:20 | 0:10 - 0:15 | |
| au-dessous de -3 à -14 | au-dessous de 27 à 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:45 - 1:20 | **0:35 - 1:00 | **0:20 - 0:40 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:35 - 1:05 | **0:30 - 1:10 | **0:25 - 0:35 | |
| au-dessous de -14 à -25 | au-dessous de 7 à -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:40 - 1:10 | | | |
| au-dessous de -25 | au-dessous de -13 | 100/0 | Le liquide de type IV peut être utilisé au-dessous de -25 °C (-13 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type IV s'avère impossible. | | | | | |

°C = Degrés Celsius
°F = Degrés Fahrenheit
OAT = Température extérieure
FP = Point de congélation

* Pour protéger l'aéronef contre le GIVRE.

** La température d'utilisation la plus basse est fixée à -10 °C (14 °F).

*** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**

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4/24/2006bm

TABLE 4 O

# OCTAGON TYPE IV FLUID HOLDOVER TABLE

# MAX-FLIGHT

Guideline for Holdover Times Anticipated for Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | Type IV Fluid Concentration Neat - Fluid / Water (Vol% / Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 1:15 - 2:00 | 0:55 - 2:00 | 0:35 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 1:20 - 2:00 | 1:15 - 2:00 | 0:35 - 1:10 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:40 - 1:20 | 0:35 - 1:00 | 0:15 - 0:30 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:50 - 1:35 | 0:55 - 2:00 | 0:35 - 1:00 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:45 - 1:45 | 1:15 - 2:00 | 0:35 - 1:10 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:40 - 1:20 | 0:35 - 1:00 | 0:15 - 0:30 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:25 - 0:50 | **0:30 - 1:10 | **0:20 - 0:40 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:20 - 0:50 | **0:25 - 1:05 | **0:20 - 0:30 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:20 - 0:40 | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when Type IV fluid cannot be used. | | | | | |

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

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10° C (14° F).

***Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA , AUGUST 1998**

## TABLEAU 4 O

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE IV D'OCTAGON

# MAX-FLIGHT

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type IV
en fonction des conditions météorologiques et de la température extérieure (OAT)

**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Concentration liquide type IV | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Liquide pur / Eau (Vol % / Vol %) | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | ***BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 100/0 | 18:00 | 2:00 - 3:00 | 1:15 - 2:00 | 0:55 - 2:00 | 0:35 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 1:20 - 2:00 | 1:15 - 2:00 | 0:35 - 1:10 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:40 - 1:20 | 0:35 - 1:00 | 0:15 - 0:30 | |
| de 0 à -3 | de 32 à 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:50 - 1:35 | 0:55 - 2:00 | 0:35 - 1:00 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:45 - 1:45 | 1:15 - 2:00 | 0:35 - 1:10 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:40 - 1:20 | 0:35 - 1:00 | 0:15 - 0:30 | |
| au-dessous de -3 à -14 | au-dessous de 27 à 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:25 - 0:50 | **0:30 - 1:10 | **0:20 - 0:40 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:20 - 0:50 | **0:30 - 1:05 | **0:20 - 0:30 | |
| au-dessous de -14 à -25 | au-dessous de 7 à -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:20 - 0:40 | | | |
| au-dessous de -25 | au-dessous de -13 | 100/0 | Le liquide de type IV peut être utilisé au-dessous de -25 °C (-13 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type IV s'avère impossible. | | | | | |

°C = Degrés Celsius
°F = Degrés Fahrenheit
OAT = Température extérieure
FP = Point de congélation

* Pour protéger l'aéronef contre le GIVRE.

** La température d'utilisation la plus basse est fixée à -10 °C (14 °F).

*** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**

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TABLE 4 S1

# SPCA TYPE IV FLUID HOLDOVER TABLE

# AD-404

Guideline for Holdover Times Anticipated for Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | Type IV Fluid Concentration Neat - Fluid / Water (Vol% / Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 1:40 - 2:00 | 1:40 - 2:00 | 0:45 - 1:20 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:50 - 1:45 | 0:50 - 1:50 | 0:30 - 0:50 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:20 - 0:45 | 0:25 - 0:55 | 0:15 - 0:35 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 1:00 - 1:45 | 1:40 - 2:00 | 0:45 - 1:20 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:25 - 1:00 | 0:50 - 1:50 | 0:30 - 0:50 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:15 - 0:30 | 0:25 - 0:55 | 0:15 - 0:35 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:35 - 1:00 | **1:05 - 2:00 | **0:35 - 1:20 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:15 - 0:25 | **0:30 - 1:45 | **0:30 - 0:45 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:15 - 0:30 | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when Type IV fluid cannot be used. | | | | | |

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

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10° C (14° F).

***Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**
**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA, AUGUST 1998**

TABLE 4 S2

# SPCA TYPE IV FLUID HOLDOVER TABLE

## AD-480

Guideline for Holdover Times Anticipated for Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | Type IV Fluid Concentration Neat - Fluid / Water (Vol% / Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 1:10 - 2:00 | 1:05 - 2:00 | 0:50 - 1:10 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 1:00 - 1:55 | 0:50 - 1:20 | 0:35 - 0:50 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:15 - 0:35 | 0:15 - 0:35 | 0:10 - 0:25 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 1:05 - 2:00 | 1:05 - 2:00 | 0:50 - 1:10 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:45 - 1:25 | 0:50 - 1:20 | 0:35 - 0:50 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:10 - 0:30 | 0:15 - 0:35 | 0:10 - 0:25 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:20 - 0:40 | **0:25 - 1:20 | **0:20 - 0:40 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:15 - 0:25 | **0:30 - 1:15 | **0:20 - 0:35 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:15 - 0:30 | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when Type IV fluid cannot be used. | | | | | |

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

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10° C (14° F).

***Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIME TABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA, AUGUST 1998**
**(Revised November, 1998)**

## TABLEAU 4 S2

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE IV DE SPCA

## AD-480

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type IV
en fonction des conditions météorologiques et de la température extérieure (OAT)
**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Concentration liquide type IV | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Liquide pur / Eau (Vol % / Vol %) | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | ***BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 100/0 | 18:00 | 2:00 - 3:00 | 1:10 - 2:00 | 1:05 - 2:00 | 0:50 - 1:10 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 1:00 - 1:55 | 0:50 - 1:20 | 0:35 - 0:50 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:15 - 0:35 | 0:15 - 0:35 | 0:10 - 0:25 | |
| de 0 à -3 | de 32 à 27 | 100/0 | 12:00 | 2:00 - 3:00 | 1:05 - 2:00 | 1:05 - 2:00 | 0:50 - 1:10 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:45 - 1:25 | 0:50 - 1:20 | 0:35 - 0:50 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:10 - 0:30 | 0:15 - 0:35 | 0:10 - 0:25 | |
| au-dessous de -3 à -14 | au-dessous de 27 à 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:20 - 0:40 | **0:25 - 1:15 | **0:20 - 0:40 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:15 - 0:25 | **0:30 - 1:15 | **0:20 - 0:35 | |
| au-dessous de -14 à -25 | au-dessous de 7 à -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:15 - 0:30 | | | |
| au-dessous de -25 | au-dessous de -13 | 100/0 | Le liquide de type IV peut être utilisé au-dessous de -25 °C (-13 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type IV s'avère impossible. | | | | | |

°C = Degrés Celsius
°F = Degrés Fahrenheit
OAT = Température extérieure
FP = Point de congélation

* Pour protéger l'aéronef contre le GIVRE.

** La température d'utilisation la plus basse est fixée à -10 °C (14 °F).

*** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**

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TABLE 4 U

# UNION CARBIDE TYPE IV FLUID HOLDOVER TABLE

## ULTRA+

Guideline for Holdover Times Anticipated for Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

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

| OAT | | Type IV Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat - Fluid / Water (Vol% / Vol%) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 0:50 - 1:40 | 1:00- -2:00 | 0:35 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | - | - | - | - | - | - |
| | | 50/50 | - | - | - | - | - | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:35 - 1:15 | 1:00- -2:00 | 0:35 - 1:00 | |
| | | 75/25 | - | - | - | - | - | |
| | | 50/50 | - | - | - | - | - | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:25 - 0:55 | **0:50 - 1:35 | **0:30 - 0:50 | |
| | | 75/25 | - | - | - | - | - | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:20 - 0:45 | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when Type IV fluid cannot be used. | | | | | |

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

* During conditions that apply to aircraft protection for ACTIVE FROST.

** The lowest use temperature is limited to -10° C (14° F).

***Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE DECISION CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE HOLDOVER TIMETABLE CELL.**

**FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT**

**TRANSPORT CANADA, AUGUST 1998**

## TABLEAU 4 U

## TABLEAU DES DURÉES D'EFFICACITÉ DES LIQUIDES DE TYPE IV DE UNION CARBIDE ULTRA+

Lignes directrices pour les durées d'efficacité prévues des mélanges liquides de type IV en fonction des conditions météorologiques et de la température extérieure (OAT)

**L'UTILISATION DE CES DONNÉES DEMEURE LA RESPONSABILITÉ DE L'UTILISATEUR**

| OAT | | Concentration liquide type IV | Durées d'efficacité approximatives en fonction de diverses conditions météorologiques (heures : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Liquide pur / Eau (Vol % / Vol %) | *GIVRE | BROUILLARD VERGLAÇANT | NEIGE | ***BRUINE VERGLAÇANTE | PLUIE VERGLAÇANTE LÉGÈRE | PLUIE SUR AILE IMPRÉGNÉE DE FROID |
| au-dessus de 0 | au-dessus de 32 | 100/0 | 18:00 | 2:00 - 3:00 | 0:50 - 1:40 | 1:00 - 2:00 | 0:35 - 1:00 | 0:10 - 0:50 |
| | | 75/25 | | | | | | |
| | | 50/50 | | | | | | |
| de 0 à -3 | de 32 à 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:35 - 1:15 | 1:00 - 2:00 | 0:35 - 1:00 | |
| | | 75/25 | | | | | | |
| | | 50/50 | | | | | | |
| au-dessous de -3 à -14 | au-dessous de 27 à 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:25 - 0:55 | **0:50 - 1:35 | **0:30 - 0:50 | |
| | | 75/25 | | | | | | |
| au-dessous de -14 à -25 | au-dessous de 7 à -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:20 - 0:45 | | | |
| au-dessous de -25 | au-dessous de -13 | 100/0 | Le liquide de type IV peut être utilisé au-dessous de -25 °C (-13 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type IV s'avère impossible. | | | | | |

°C = Degrés Celsius
°F = Degrés Fahrenheit
OAT = Température extérieure
FP = Point de congélation

* Pour protéger l'aéronef contre le GIVRE.

** La température d'utilisation la plus basse est fixée à -10 °C (14 °F).

*** Utiliser les durées d'efficacité de la pluie verglaçante légère s'il est impossible de déterminer avec certitude qu'il s'agit de bruine verglaçante.

**MISE EN GARDE : LA DURÉE DE PROTECTION SERA RACCOURCIE EN CAS DE CONDITIONS MÉTÉOROLOGIQUES RIGOUREUSES, DE FORTES PRÉCIPITATIONS OU DE HAUTS TAUX D'HUMIDITÉ. UN VENT VIOLENT OU UN SOUFFLE RÉACTEUR ÉLEVÉ PEUVENT RÉDUIRE LES DURÉES D'EFFICACITÉ AU-DESSOUS DE LA DURÉE LA PLUS COURTE INDIQUÉE DANS LA PLAGE PERTINENTE. LES DURÉES D'EFFICACITÉ PEUVENT ÉGALEMENT ÊTRE MOINDRES SI LA TEMPÉRATURE DES SURFACES DE L'AÉRONEF EST INFÉRIEURE À L'OAT. LA SEULE DURÉE D'EFFICACITÉ QUI PEUT SERVIR DE CRITÈRE DE PRISE DE DÉCISION EST LA DURÉE LA PLUS COURTE FIGURANT À LA PLAGE PERTINENTE DU TABLEAU.**

**LES LIQUIDES DE DÉGIVRAGE AU SOL NE SONT AUCUNEMENT CONÇUS POUR OFFRIR UNE PROTECTION CONTRE LE GIVRAGE EN VOL.**

**TRANSPORTS CANADA, AOÛT 1998**

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# TABLE 5 †

## Table 5-1: Qualified Type I De-Icing Fluids

| COMPANY NAME | FLUID NAME |
|---|---|
| ARCO CHEMICAL | Arcoplus™ |
| BASF AG | Aerex 102 |
| CLARIANT | Safewing MP I 1938 |
| CLARIANT | Safewing DG I 1937 |
| KILFROST | KILFROST DF |
| OCTAGON PROCESS. | OCTAFLO™ |
| SPCA | SPCA DE-910 |
| SPCA | SPCA DE-825 |
| UNION CARBIDE | UCAR® ADF XL 54 |

## Table 5-2: Qualified Type II Anti-Icing Fluids

| COMPANY NAME | FLUID NAME |
|---|---|
| CLARIANT | Safewing MP II 1951 |
| KILFROST | Kilfrost ABC-3 |
| OCTAGON PROCESS. | OCTAGON FORTY BELOW™ |
| SPCA | SPCA AD-104/N |

## Table 5-3: Qualified Type III Anti-Icing Fluids

| COMPANY NAME | FLUID NAME |
|---|---|
| | |

## Table-5-4: Qualified Type IV Anti-Icing Fluids

| COMPANY NAME | FLUID NAME |
|---|---|
| CLARIANT | Safewing MP IV 1957 |
| CLARIANT | Safewing MP IV 2001 |
| KILFROST | ABC-S |
| OCTAGON PROCESS INC. | MAX-FLIGHT |
| SPCA | SPCA AD-404 |
| SPCA | SPCA AD-480 |
| UNION CARBIDE | UCAR®AAF ULTRA+ |

† Qualified at: *Anti-icing Materials International Laboratory, Universite du Quebec a Chicoutimi*

**TRANSPORT CANADA, AUGUST 1998**

# TABLEAU 5 †

**Tableau 5-1 : Liste des liquides dégivrants de type I approuvés**

| FABRICANT | NOM DU LIQUIDE |
|---|---|
| ARCO CHEMICAL | Arcoplus[MC] |
| BASF AG | Aerex 102 |
| CLARIANT | Safewing MP I 1938 |
| CLARIANT | Safewing DG I 1937 |
| KILFROST | KILFROST DF |
| OCTAGON PROCESS INC. | OCTAFLO[MC] |
| SPCA | SPCA DE-910 |
| SPCA | SPCA DE-825 |
| UNION CARBIDE | UCAR® ADF XL 54 |

**Tableau 5-2 : Liste des liquides antigivrants de type II approuvés**

| FABRICANT | NOM DU LIQUIDE |
|---|---|
| CLARIANT | Safewing MP II 1951 |
| KILFROST | KILFROST ABC-3 |
| OCTAGON PROCESS INC. | OCTAGON FORTY BELOW[MC] |
| SPCA | SPCA AD-104/N |

**Tableau 5-3 : Liste des liquides antigivrants de type III approuvés**

| FABRICANT | NOM DU LIQUIDE |
|---|---|
| | |

**Tableau-5-4 : Liste des liquides antigivrants de type IV approuvés**

| FABRICANT | NOM DU LIQUIDE |
|---|---|
| CLARIANT | Safewing MP IV 1957 |
| CLARIANT | Safewing MP IV 2001 |
| KILFROST | ABC-S |
| OCTAGON PROCESS INC. | MAX-FLIGHT |
| SPCA | SPCA AD-404 |
| SPCA | SPCA AD-480 |
| UNION CARBIDE | UCAR®AAF ULTRA+ |

† Approbation obtenue au *Laboratoire international des produits d'antigivrage, Université du Québec à Chicoutimi*

**Transports Canada, Août 1998**

## TABLE 6

# SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

| Outside Air Temperature OAT | One-step Procedure | Two-step Procedure | |
|---|---|---|---|
| | Deicing/anti-icing | First step: Deicing | Second step Anti-icing [1] |
| -3°C (27°F) and above | FP of heated fluid[2] mixture shall be at least | Water heated to 60°C (140°F) minimum at the nozzle or a heated mix of fluid and water | FP of fluid mixture shall be at least |
| Below -3°C (27°F) | 10° C (18°F) below OAT | FP of heated fluid mixture shall not be more than 3°C (5°F) above OAT | 10°C (18°F) below OAT |

Note: For heated fluids, a fluid temperature not less than 60°C (140°F) at the nozzle is desirable. Upper temperature limit shall not exceed fluid and aircraft manufacturers recommendations.

Caution: Wing skin temperatures may differ and in some cases may be lower than OAT. A stronger mix(more Glycol) can be used under the latter conditions.

1) To be applied before first step fluid freezes, typically within 3 minutes.
2) Clean aircraft may be anti-iced with unheated fluid.

**TRANSPORT CANADA, AUGUST 1998**

## TABLEAU 6

# PROCÉDURES D'APPLICATION DES LIQUIDES DÉGIVRANTS DE TYPE 1 DE LA SAE

Lignes directrices pour l'application des liquides de type 1 de la SAE (concentrations minimales) en fonction de la température extérieure (OAT).

<table>
<tr><th rowspan="2">Température extérieure OAT</th><th rowspan="2">Méthode en une étape<br>Dégivrage/antigivrage</th><th colspan="2">Méthode en deux étapes</th></tr>
<tr><th>Un : dégivrage</th><th>Deux : antigivrage[1]</th></tr>
<tr><td>-3 °C (27 °F) et au-dessus</td><td rowspan="2">Le point de congélation des mélanges de liquides chauffés[2] doit être inférieur d'au moins 10 °C (18 °F) par rapport à l'OAT</td><td>Eau chauffée à un minimum de 60 °C (140 °F) à la buse ou mélange chauffé de liquide et d'eau</td><td rowspan="2">Le point de congélation des mélanges de liquides doit être inférieur d'au moins 10 °C (18 °F) par rapport à l'OAT</td></tr>
<tr><td>Au-dessous de -3 °C (27 °F)</td><td>Le point de congélation des mélanges de liquides chauffés ne doit pas être supérieur de plus de 3 °C (5 °F) par rapport à l'OAT</td></tr>
</table>

NOTA : Dans le cas des liquides chauffés, il est souhaitable que la température du liquide à la sortie de la buse ne soit pas inférieure à 60 °C (140 °F). La limite supérieure de température ne doit pas dépasser les recommandations des fabricants de liquides et des avionneurs.

MISE EN GARDE : Les températures à la surface d'une aile peuvent être différentes de l'OAT et, dans certains cas, elles peuvent être inférieures. Dans une telle éventualité, un mélange plus puissant (plus de glycol) sera peut-être nécessaire.

[1] À appliquer avant que le liquide de la première étape ne gèle, normalement dans les 3 minutes qui suivent.

[2] On peut appliquer un liquide antigivrant froid sur un aéronef propre.

**TRANSPORTS CANADA, AOÛT 1998**

## TABLE 7

# SAE TYPE II and TYPE IV ANTI-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type II and IV fluid mixtures (minimum concentrations in % by volume) as a Function of Outside Air Temperature (OAT)

| Outside Air Temperature OAT | One-step Procedure | Two-step Procedure | |
|---|---|---|---|
| | Deicing/anti-icing | First step Deicing | Second step Anti-icing [1] |
| -3°C (27°F) and above | 50/50 Heated [2] Type II/IV | Heated water or a heated mix of Type I, II or IV with water | 50/50 Type II/IV |
| Below -3°C (27°F) to -14°C (7° F) | 75/25 Heated [2] Type II/IV | Heated suitable mix of Type I, Type II/IV and water with FP not more than 3°C (5°F) above actual OAT | 75/25 Type II/IV |
| Below -14°C (7°F) to -25°C (-13°F) | 100/0 Heated [2] Type II/IV | Heated suitable mix of Type I, Type II/IV and water with FP not more than 3°C (5°F) above actual OAT | 100/0 Type II/IV |
| Below -25°C (-13°F) | SAE Type II/IV fluid may be used below -25°C (-13°F) provided that the freezing point of the fluid is at least a 7°C (13°F) below OAT and that aerodynamic acceptance criteria are met. Consider the use of SAE Type I when Type II/IV fluid cannot be used (see Table 6). | | |

NOTE: For heated fluids, a fluid temperature not less than 60°C (140°F) at the nozzle is desirable. Upper temperature limit shall not exceed fluid and aircraft manufacturers recommendations.

CAUTION: Wing skin temperatures may differ and in some cases may be lower than OAT. A stronger mix can be used under the latter conditions.

An insufficient amount of anti-icing fluid may cause a substantial loss of holdover time. This is particularly true when using a Type I fluid mixture for the first step in a two step procedure

[1]) To be applied before first step fluid freezes, typically within 3 minutes.
[2]) Clean aircraft may be anti-iced with unheated fluid.

**TRANSPORT CANADA, AUGUST 1998**

## TABLEAU 7

# PROCÉDURES D'APPLICATION DES LIQUIDES ANTIGIVRANTS DE TYPE II ET IV DE LA SAE

Lignes directrices pour l'application de mélanges de liquides de type II et IV de la SAE (concentrations minimales en % par volume) en fonction de la température extérieure (OAT).

| Température extérieure OAT | Méthode en une étape | Méthode en deux étapes | |
|---|---|---|---|
| | Dégivrage/antigivrage | Un : dégivrage | Deux : antigivrage[1] |
| -3 °C (27 °F) et au-dessus | Type II/IV 50/50 chauffé [2] | Eau chauffée ou mélange chauffé de liquide de type I, II ou IV et d'eau | Type II/IV 50/50 |
| Au-dessous de -3 °C (27 °F) à -14 °C (7 °F) | Type II/IV 75/25 chauffé [2] | Mélange chauffé approprié de liquide de type I, de type II/IV et d'eau dont le FP ne dépasse pas de plus de 3 °C (5 °F) l'OAT réelle | Type II/IV 75/25 |
| Au-dessous de -14 °C (7 °F) à -25 °C (-13 °F) | Type II/IV 100/0 chauffé[2] | Mélange chauffé approprié de liquide de type I, de type II/IV et d'eau dont le FP ne dépasse pas de plus de 3 °C (5 °F) l'OAT réelle | Type II/IV 100/0 |
| Au-dessous de -25 °C (-13 °F) | Les liquides de type II/IV de la SAE peuvent être utilisés sous -25 °C (-13 °F) pourvu que le point de congélation du liquide soit inférieur d'au moins 7 °C (13 °F) à l'OAT et que les critères aérodynamiques soient respectés. Envisager l'utilisation d'un liquide de type I de la SAE si l'utilisation d'un liquide de type II ou IV s'avère impossible (voir tableau 6). | | |

NOTA : Dans le cas des liquides chauffés, il est souhaitable que la température du liquide à la sortie de la buse ne soit pas inférieure à 60 °C (140 °F). La limite supérieure de température ne doit pas dépasser les recommandations des fabricants de liquides et des avionneurs.

MISE EN GARDE : Les températures à la surface d'une aile peuvent être différentes de l'OAT et, dans certains cas, elles peuvent être inférieures. Dans une telle éventualité, un mélange plus puissant sera peut-être nécessaire.

Une quantité insuffisante de liquide antigivrant peut causer une diminution importante de la durée d'efficacité. Cela est particulièrement vrai lorsqu'un mélange de type I est utilisé à la première étape de la méthode en deux étapes.

[1] À appliquer avant que le liquide de la première étape ne gèle, normalement dans les 3 minutes qui suivent.
[2] On peut appliquer un liquide antigivrant froid sur un aéronef propre.

**TRANSPORTS CANADA, AOÛT 1998**

**TABLE 8**

# SNOW VISIBILITY VS SNOWFALL INTENSITY CHART

| Lighting | Temperature Range | | Visibility in statute miles | | |
|---|---|---|---|---|---|
| | $^0$C | $^0$F | Heavy* | Moderate* | Light* |
| Daylight | Above -1 | Above 30 | <1 | 1 - 2 | >2 |
| | -1 to -7 | 30 to 19 | <1/2 | 1\2 - 1 1\4 | >1 1\4 |
| | Below -7 | Below 19 | <3\8 | 3\8 - 5\8 | >5\8 |
| Darkness | Above -1 | Above 30 | <2 | 2 - 4 | >4 |
| | -1 to -7 | 30 to 19 | <1 | 1 - 2 1\2 | >2 1\2 |
| | Below -7 | Below 19 | <3\4 | 3\4 - 1 1\4 | >1 1\4 |

* Light snow intensity is defined as less then 1mm/hr equivalent liquid water, moderate intensity as 1 mm/hr to 2.5mm/hr equivalent liquid water, and heavy as greater than 2.5mm/hr equivalent liquid water.

**TRANSPORT CANADA, AUGUST 1998**

**TABLEAU 8**

# VISIBILITÉ DANS LA NEIGE PAR RAPPORT À L'INTENSITÉ DES PRÉCIPITATIONS

| Éclairage ambiant | Plage de températures | | Visibilité en milles terrestres | | |
|---|---|---|---|---|---|
| | °C | °F | Fortes* | Modérées* | Légères* |
| Lumière du jour | Au-dessus de -1 | Au-dessus de 30 | <1 | 1 - 2 | >2 |
| | De -1 à -7 | De 30 à 19 | <1/2 | 1\2 - 1 1\4 | >1 1\4 |
| | Au-dessous de -7 | Au-dessous de 19 | <3\8 | 3\8 - 5\8 | >5\8 |
| Obscurité | Au-dessus de -1 | Au-dessus de 30 | <2 | 2 - 4 | >4 |
| | De -1 à -7 | De 30 à 19 | <1 | 1 - 2 1\2 | >2 1\2 |
| | Au-dessous de -7 | Au-dessous de 19 | <3\4 | 3\4 - 1 1\4 | >1 1\4 |

* Les chutes de neige sont légères si elles sont inférieures à 1 mm/hr (en eau liquide), modérées si elles sont comprises entre 1 mm/hr et 2,5 mm/hr (en eau liquide), et fortes si elles sont supérieures à 2,5 mm/hr (en eau liquide).

**TRANSPORTS CANADA, AOÛT 1998**

# APPENDIX H

# OFFICIAL FAA HOLDOVER TIME TABLES FOR USE DURING WINTER 1998-99

ORDER: 8400.10

APPENDIX: 4

BULLETIN TYPE: Flight Standards Information Bulletin for Air Transportation (FSAT)

BULLETIN NUMBER: FSAT 98-17B (AMENDED)

BULLETIN TITLE: FAA-Approved Deicing Program Updates, Winter 1998-99

EFFECTIVE DATE: 09-08-98

AMENDED DATE: 09-24-98

TRACKING NUMBER: N/A

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NOTE: THIS BULLETIN REQUIRES PTRS INPUT. SEE ITEM 5.

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1. PURPOSE. This bulletin provides revised Society of Automotive Engineers (SAE) approved holdover timetables and the associated guidelines for the application of Types I, II, and IV deicing/anti-icing fluid mixtures. This bulletin also includes seven additional FAA approved manufacturer specific Type IV deicing/anti-icing holdover timetables (i.e. UNION CARBIDE® ULTRA+, OCTAGON® MAX-FLIGHT, KILFROST® ABC-S, SAFEWING MPIV 1957, SAFEWING MPIV 2001, SPCA AD-404 and SPCA AD-480). In addition, this bulletin presents a listing of qualified Type I, Type II and Type IV deicing/anti-icing fluids for the 1998-99 winter icing season. Also, this bulletin includes updated information and recommendations on various other ground deicing/anti-icing findings that have surfaced over the past year. This bulletin cancels the bulletins FSAT 97-10, FSAT 97-10A and FSAT 97-10B which contained previously issued holdover timetables.

2. BACKGROUND.

A. Title 14 of the Code of Federal Regulations (14 CFR) part 121, section 121.629(c) requires that part 121 certificate holders have an approved ground deicing/anti-icing program unless the certificate holder complies with section 121.629(d). Advisory Circular (AC) 120-60, Ground Deicing And Anti-Icing Program, provides guidance for obtaining approval of a ground deicing/anti-icing program and discusses the use of holdover times. Title 14 CFR part 135, section 135.227(b)(3) allows a part 135 certificate holder to comply with a part 121 approved program.

B. Additional guidance on holdover timetables is contained in AC 120-58, Pilot Guide For Large Aircraft Ground Deicing, AC 135-17, Pilot Guide-Small Aircraft Ground Deicing, and AC 20-117, Hazards Following Ground Deicing And Ground Operations In Conditions Conducive To Aircraft Icing. As of the publication of this bulletin the above referenced advisory material is being updated. Revised material will be distributed as soon as it becomes available.

3. DISCUSSION.

A. Attached are revised FAA-approved SAE holdover timetables as well as FAA-approved SAE guidelines for the application of Types I, II, and IV deicing/anti-icing fluids. Because of the difference in performance of the Type IV deicing/anti-icing fluids available for this winter season, seven different approved Type IV holdover timetables are attached. These Type IV tables include SAE Type IV, UNION CARBIDE® ULTRA+, OCTAGON® MAX-FLIGHT, KILFROST® ABC-S, CLARIANT MPIV 1957, CLARIANT MPIV 2001, SPCA AD-404 and SPCA AD-480. Air carriers may only use these manufacturer specific tables when these specific fluids are used during the deicing/ anti-icing process. If it can not be positively determined which specific Type IV fluid was used during the deicing/anti-icing process air carriers must use the holdover times from the SAE Type IV fluid holdover timetable. As initially indicated in FSAT 97-10B, the holdover times for ® ULTRA+ Type IV fluid is valid only when it is applied in the 100/0 concentration. Also included is a list, by manufacturer brand name, of qualified Type I, Type II and Type IV deicing/anti-icing fluids.

B. These tables should be distributed to all part 121 and part 135 certificate holders who have an approved part 121 deicing/anti-icing programs. These holdover timetables and associated guidelines should also be distributed to operators who are not required to have an approved program, but who deice or anti-ice with fluids and use holdover timetables during winter weather operations. The attached timetables and guidelines supersede all previously approved holdover timetables and guidelines for the application of deicing/anti-icing fluid mixtures.

C. The addition of water to some neat fluids can enhance their performance up to a certain point. Octagon Maxflight is one of those fluids. Adding water has the effect of allowing the fluid to build up thicker on a surface. Thicker in this instance does not mean a higher viscosity. Neat Octagon Maxflight Type IV fluid, during Hold Over Time frosticator plate testing, typically exhibited a thickness on the order of 0.7mm. When neat Maxflight Type IV fluid was diluted with water to a 75/25 mix, the mix typically exhibited a thickness on the order of 1.4mm. Some of the tabular data for the Maxflight Type IV fluid indicates this effect.

Without knowing about this particular fluid mix phenomenon an air carrier may think that the data presented in the tables is in error. Fluid failure is complex, dependent on OAT, percent mix, type and rate of precipitation, and other variables. One should keep in mind that the phenomenon exhibited by mixing water with Maxflight Type IV fluid is not consistent with all variables or for other neat fluids.

4. ACTION.

A. Principal operations inspectors (POI) shall ensure that the attached approved holdover timetables and application guidelines are made available to affected certificate holders and incorporated into their procedures or programs. Certificate holders should use these tables and application guidelines or use the data contained in the attached tables and guidelines to develop tables and guidelines that are acceptable to the Administrator.

B. Principal operations inspectors shall ensure their assigned air carrier's approved ground deicing/anti-icing program is revised to include the following updates for the 1998-99 winter season:

(1) Fluid Application.

(a) Surveillance of deicing/anti-icing operations during prior seasons have indicated several problems in the fluid application area. These findings include:

(i) Instances when the application of fluid was applied in the reverse order of company approved procedures, (e.g., approved procedure being wing tip to wing root),

(ii) Insufficient fluid temperature buffer, and

(iii) Incomplete removal of contamination.

(b) Also ground testing of Type II and IV fluids indicates that the effectiveness of these fluids is highly dependent on the training and skill of the individual applying the fluid. When these fluids are used, ground personnel should ensure that they are evenly applied so that all critical surfaces, especially the leading edge of the wings, are covered with fluid. In addition, it has been indicated that an insufficient amount of anti-icing fluid, especially in the second step of a two step procedure may cause reduced holdover times due to the uneven application of the second step fluid. The effects of trace icing on aircraft performance vary according to the type of aircraft. Many aircraft experience little or no noticeable effect while other types may experience significant loss of performance or controllability. A report of trace icing

should not be disregarded. All reports of inflight icing should be considered as potentially hazardous.

(2) Communication.

(a) Communication between all personnel involved in the air carrier's approved program is critical to ensuring the pilot has the information needed to make the final determination that the aircraft is free of contamination prior to flight. Approved programs should emphasize that all personnel, (e.g., management personnel, dispatchers, ground personnel, and flight crewmembers), who perform duties as outlined in the approved program, communicate clearly and concisely essential information needed to ensure the clean air concept is attained.

(b) Specifically, approved programs should be reviewed to ensure that ground personnel accomplishing the deicing/anti-icing procedure communicates to the pilot, the Type fluid used (for Type IV fluids the specific manufacturer name and Type fluid or SAE Type IV), the percentage of fluid within the fluid/water mixture, and the local time the beginning of the final deicing/anti-icing began. The results of the post-deicing/anti-icing check should also be reported to the pilot unless the approved program has other procedures for ensuring this information is conveyed to the pilot. Although reporting the results of the post-deicing/anti-icing check may be redundant in some cases, it is one method to confirm to the pilot that all contamination has been removed from the aircraft.

(3) Representative Surfaces/where Fluids Tend to Fail First. Preliminary aircraft testing during the past year indicates that the first fluid failures on test aircraft appear to occur on the leading or trailing edges of the wing's surface rather than the mid-chord section of the wing. Tests also indicate that fluid failures may be difficult to identify. Principal operations inspectors should reevaluate those aircraft representative surfaces currently included within the air carrier's approved program to ensure that representative surfaces provide the pilot a proper indication of the status of the aircraft's critical surfaces. Where possible, representative surfaces should include at least a portion of the wing leading edge.

(4) Type III Deicing/Anti-icing Fluids. It is not anticipated that Type III deicing/anti-icing will be available during the 1998-99 winter icing season.

(5) New Technology.

(a) Principal operations inspectors should make their assigned air carriers aware of the new technology that has been introduced or improved over the last year. There have been several

ice detection systems developed and tested during the past year. These include wide area hand held ice detection systems that use advanced optical technology capable of quickly detecting aircraft contamination from distances up to 200 feet from the aircraft. One of these advance optical systems has been approved as part of an air carrier's approved program. Another, a vehicular mounted ice detection system is anticipated to be put into operations this winter icing season at a centralized deicing facility in Canada. This optical system employs a video based sensor mounted on the boom of the deicing trucks with a display mounted in the cab or in the deicing bucket.

(b) A mobile infrared deicing system is being developed, which melts frozen contaminants from exposed aircraft surfaces. This system consists of a moveable, boom mounted heating panel installed on a truck. During operations these heater panels are normally situated several feet from the aircraft surfaces and employ temperature sensors to measure aircraft surface temperatures. It is anticipated that these units will usually be employed in pairs (or more). Another manufacturer is developing a deicing system employing a nozzle that combines both hot air and deicing fluid that may significantly reduce the use of deicing fluids. Additionally, under development is a system whereby fuel temperature is elevated above freezing (typically 80-85 degrees Fahrenheit) and transferred to an aircraft's fuel tanks. Heat transfer from the warmer fuel to the aircraft structure is intended to facilitate deicing by reducing the amount of glycol required in the deicing process.

(c) Federal Aviation's Air Transportation Operations Division (AFS-200) is currently developing guidance for approving these advanced technology systems and facilities. For further information concerning these innovations, POIs may contact AFS-200 at (202) 267-8166.

(6) Operations during Light Freezing Rain/Freezing Drizzle.

(a) Principal operations inspectors should strongly encourage air carriers electing to operate in light freezing rain or freezing drizzle weather conditions to use Type II or IV anti-icing fluids. Also, POIs should ensure that approved programs clearly state that deicing/anti-icing fluids do not provide any protection from contamination once the aircraft is airborne.

(b) Principal operations inspectors should ensure that air carriers who elect not to use Type II or Type IV anti-icing fluids during light freezing rain or freezing drizzle conditions, develop and use special procedures for operating during these weather conditions. Examples of special procedures would include an approved external pre-takeoff contamination check, a remote deicing capability, or other special means of enhancing the safety of

operation during these conditions such as the use of advanced wide area optical technology capable of detecting aircraft contamination.

(c) Principal operations inspectors should use special emphasis surveillance during periods of light freezing rain and freezing drizzle to ensure that approved checks or other special procedures, as stated above, are effective and conducted in accordance with the air carrier's approved deicing/anti-icing program.

5. PROGRAM TRACKING AND REPORTING SUBSYSTEM (PTRS) INPUT. Principal operations inspectors shall make a PTRS entry to record the actions directed by this bulletin with each of their operators as outlined in HBAT 94-08. The PTRS entry shall be listed as Activity Code No. 1381 and entered into the National Use field as FSAT9817. Principal operations inspectors should use the comments section to record comments of interaction with the operators.

6. INQUIRIES. This bulletin was developed by AFS-200. Any questions or comments should be directed to Daniel Meier, AFS-220, at (202) 267-3749.

7. EXPIRATION. This bulletin expires October 31, 1999.

/s/ Tom K. Toula for
Gary E. Davis
Acting Manager, Air Transportation Division

ATTACHMENTS

**TABLE 1 - Guideline for Holdover Times Anticipated for SAE Type I Fluid Mixture as a Function of Weather Conditions and OAT**

CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

| OAT | | Approximate Holdover Times Under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| °C | °F | *FROST | FREEZING FOG | SNOW | **FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0 | above 32 | 0:45 | 0:12-0:30 | 0:06-0:15 | 0:05-0:08 | 0:02-0:05 | 0:02-0:05 |
| 0 to -10 | 32 to 14 | 0:45 | 0:06-0:15 | 0:06-0:15 | 0:05-0:08 | 0:02-0:05 | CAUTION: Clear ice may require touch for confirmation |
| below -10 | below 14 | 0:45 | 0:06-0:15 | 0:06-0:15 | | | |

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

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

SAE Type I fluid/water mixture is selected so that the FP of the mixture is at least 10°C (18°F) below OAT

**CAUTION**: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST WILL REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

**CAUTION**: SAE TYPE I FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective: October 1, 1998

**TABLE 1A - Guidelines for the application of SAE Type I fluid mixtures.**
**Minimum Concentrations as a Function of Outside Air Temperature(OAT)**
Concentrations in % V/V

| Outside Air Temperature OAT | One-step Procedure Deicing/anti-icing | Two-step Procedure | |
|---|---|---|---|
| | | First step: Deicing | Second step Anti-icing [1] |
| -3° C (27° F) and above | FP of heated fluid[2] mixture shall be at least 10° C (18°F) below OAT | Water heated to 60° C (140° F) minimum at the nozzle or a heated mix of fluid and water | FP of fluid mixture shall be at least 10° C (18° F) below actual OAT |
| Below -3° C (27° F) | | FP of heated fluid mixture shall not be more than 3° C (5° F) above OAT | |

Note: For heated fluids, a fluid temperature not less than 60° C (140° F) at the nozzle is desirable. Upper temperature limit shall not exceed fluid and aircraft manufacturers recommendations.

Caution: Wing skin temperatures may differ and in some cases may be lower than OAT. A stronger mix(more Glycol) can be used under the latter conditions.

1) To be applied before first step fluid freezes, typically within 3 minutes.
2) Clean aircraft may be anti-iced with unheated fluid.

Effective October 1, 1998

**TABLE 2 - Guideline for Holdover Times Anticipated for SAE Type II Fluid Mixtures as a Function of Weather Conditions and OAT**

**CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.**

| OAT | | SAE Type II Fluid Concentration | Approximate Holdover Times under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (Vol. %/Vol. %) | *Frost | Freezing Fog | Snow | ***Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 12:00 | 1:15-3:00 | 0:20-1:00 | 0:30-1:00 | 0:15-0:30 | 0:10-0:40 |
| | | 75/25 | 6:00 | 0:50-2:00 | 0:15-0:40 | 0:20-0:45 | 0:10-0:25 | 0:05-0:25 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | CAUTION: Clear ice may require touch for confirmation |
| 0 to -3 | 32 to 27 | 100/0 | 8:00 | 0:35-1:30 | 0:20-0:45 | 0:30-1:00 | 0:15-0:30 | |
| | | 75/25 | 5:00 | 0:25-1:00 | 0:15-0:30 | 0:20-0:45 | 0:10-0:25 | |
| | | 50/50 | 3:00 | 0:15-0:45 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:35-1:30 | 0:15-0:40 | **0:25-1:00 | **0:10-0:30 | |
| | | 75/25 | 5:00 | 0:25-1:00 | 0:15-0:25 | **0:20-0:45 | **0:10-0:25 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:20-1:30 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | SAE Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type II fluid cannot be used. | | | | | |

**°C** **Celsius**
**°F** **Degrees Fahrenheit**
**OAT** **Outside Air Temperature**
**VOL** **Volume**

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest use temperature is limited to -10 °C (14 °F)
*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

**CAUTION**: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

**CAUTION**: SAE TYPE II FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective :October1, 1998

TABLE 4 - Guideline for Holdover Times Anticipated for SAE Type IV Fluid Mixtures as a Function of Weather Conditions and OAT

**CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.**

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (Vol. %/Vol. %) | *Frost | Freezing Fog | Snow | ***Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 18:00 | 2:00-3:00 | 0:45-1:25 | 0:40-1:00 | 0:35-0:55 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:20-0:40 | 0:30-1:00 | 0:15-0:30 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:05-0:20 | 0:10-0:20 | 0:05-0:10 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 0:35-1:00 | 0:40-1:00 | 0:35-0:55 | CAUTION: |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:20-0:35 | 0:30-1:00 | 0:15-0:30 | Clear ice |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | may require |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:20-0:40 | **0:25-1:00 | **0:15-0:30 | touch for |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:15-0:25 | **0:25-1:00 | **0:15-0:30 | confirmation |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | SAE Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C(13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

**°C** **Celsius**
**°F** **Degrees Fahrenheit**
**OAT** **Outside Air Temperature**
**VOL** **Volume**

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest use temperature is limited to -10 °C (14 °F)
*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

**CAUTION:** THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

**CAUTION:** SAE TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective October1, 1998

**TABLE 4A - Guideline for Holdover Times Anticipated for ULTRA+® Type IV Fluid Mixtures as a Function of Weather Conditions and OAT**

**CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.**

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (Vol. %/Vol. %) | *Frost | Freezing Fog | Snow | ***Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 18:00 | 2:00-3:00 | 0:50-1:40 | 1:00-2:00 | 0:35-1:00 | 0:10-0:50 |
| | | ****75/25 | | | | | | |
| | | ****50/50 | | | | | | CAUTION: Clear ice may require touch for confirmation |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 0:35-1:15 | 1:00-2:00 | 0:35-1:00 | |
| | | ****75/25 | | | | | | |
| | | ****50/50 | | | | | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:25-0:55 | **0:50-1:35 | **0:30-0:50 | |
| | | ****75/25 | | | | | | |
| below -14 to –24 | below 7 to -11 | 100/0 | 12:00 | 0:20-2:00 | 0:20-0:45 | | | |
| below -24 | below -11 | 100/0 | **ULTRA+®** Type IV fluid should not be used below -24°C (-13°F). Consider use of SAE Type I when **ULTRA+®** Type IV fluid cannot be used. | | | | | |

**°C** **Celsius**
**°F** **Degrees Fahrenheit**
**OAT** **Outside Air Temperature**
**VOL** **Volume**

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest use temperature is limited to -10 °C (14 °F)
*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible
**** Holdover times for 50/50 and 75/25 mixtures are no longer valid

**CAUTION:** THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

**CAUTION:** ULTRA+® TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.
Effective October 1, 1998

**TABLE 4B - Guideline for Holdover Times Anticipated for OCTAGON MAX-FLIGHT® Type IV Fluid Mixtures as a Function of Weather Conditions and OAT**

**CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.**

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (Vol. %/Vol. %) | *Frost | Freezing Fog | Snow | ***Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 18:00 | 2:00-3:00 | 1:15-2:00 | 0:55-2:00 | 0:35-1:00 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 1:20-2:00 | 1:15-2:00 | 0:35-1:10 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:40-1:20 | 0:35-1:00 | 0:15-0:30 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 0:50-1:35 | 0:55-2:00 | 0:35-1:00 | CAUTION: |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:45-1:45 | 1:15-2:00 | 0:35-1:10 | Clear ice |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:40-1:20 | 0:35-1:00 | 0:15-0:30 | may require |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:25-0:50 | **0:30-1:10 | **0:20-0:40 | touch for |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:20-0:50 | **0:25-1:05 | **0:20-0:30 | confirmation |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:20-0:40 | | | |
| below -25 | below -13 | 100/0 | **OCTAGON MAX-FLIGHT®** Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when **OCTAGON MAX-FLIGHT®** Type IV fluid cannot be used. | | | | | |

**°C** Celsius
**°F** Degrees Fahrenheit
**OAT** Outside Air Temperature
**VOL** Volume

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest use temperature is limited to -10 °C (14 °F)
*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

**CAUTION:** THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

**CAUTION: OCTAGON MAX-FLIGHT® TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.**

Effective October 1, 1998

**TABLE 4C- Guideline for Holdover Times Anticipated for KILFROST®ABC-S Type IV Fluid Mixtures as a Function of Weather Conditions and OAT**

**CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.**

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat-Fluid/Water (Vol. %/Vol. %) | *Frost | Freezing Fog | Snow | ***Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 18:00 | 2:00-3:00 | 1:10-2:00 | 1:20-1:50 | 1:00-1:25 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:35-1:05 | 0:50-1:10 | 0:35-0:50 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:05-0:20 | 0:15-0:20 | 0:10-0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 1:00-1:40 | 1:20-1:50 | 1:00-1:25 | CAUTION: |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:35-1:05 | 0:50-1:10 | 0:35-0:50 | Clear ice |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:05-0:15 | 0:15-0:20 | 0:10-0:15 | may require |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:45-1:20 | **0:35-1:00 | **0:20-0:40 | touch for |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:35-1:05 | **0:30-1:10 | **0:25-0:35 | confirmation |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:40-1:10 | | | |
| below -25 | below -13 | 100/0 | **KILFROST®ABC-S** Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C(13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when **KILFROST®ABC-S** Type IV fluid cannot be used. | | | | | |

**°C** **Celsius**
**°F** **Degrees Fahrenheit**
**OAT** **Outside Air Temperature**
**VOL** **Volume**

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest use temperature is limited to -10 °C (14 °F)
*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

**CAUTION:** THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

**CAUTION:** **KILFROST®ABC-S** TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective October 1, 1998

**TABLE 4D - Guideline for Holdover Times Anticipated for SAFEWING MP IV 1957 Type IV Fluid Mixtures as a Function of Weather Conditions and OAT**

**CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.**

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| C | °F | Neat-Fluid/Water (Vol. %/Vol. %) | *Frost | Freezing Fog | Snow | ***Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 18:00 | 2:00-3:00 | 1:05-2:00 | 0:50-1:40 | 0:40-1:00 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:45-1:25 | 0:45-1:15 | 0:30-0:40 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:15-0:30 | 0:15-0:25 | 0:10-0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 0:45-1:25 | 0:50-1:40 | 0:40-1:00 | CAUTION: |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:30-1:00 | 0:45-1:15 | 0:30-0:40 | Clear ice |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:10-0:20 | 0:15-0:25 | 0:10-0:15 | may require |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:30-0:55 | **0:55-1:25 | **0:30-0:45 | touch for |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:20-0:40 | **0:45-1:15 | **0:25-0:35 | confirmation |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:25-0:45 | | | |
| below -25 | below -13 | 100/0 | **SAFEWING® MP IV 1957** Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C(13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when **SAFEWING® MP IV1957** Type IV fluid cannot be used. | | | | | |

**°C** **Celsius**
**°F** **Degrees Fahrenheit**
**OAT** **Outside Air Temperature**
**VOL** **Volume**

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest use temperature is limited to -10 °C (14 °F)
*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

**CAUTION**: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.
**CAUTION**: CLARIANT SAFEWING **MPIV 1957** TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective October 1, 1998

**TABLE 4E - Guideline for Holdover Times Anticipated for SAFEWING MP IV 2001 Type IV Fluid Mixtures as a Function of Weather Conditions and OAT**

**CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.**

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| C | °F | Neat-Fluid/Water (Vol. %/Vol. %) | *Frost | Freezing Fog | Snow | ***Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 18:00 | 2:00-3:00 | 1:55-2:00 | 0:55-1:55 | 0:40-1:00 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:50-1:25 | 0:35-1:10 | 0:25-0:35 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:10-0:20 | 0:10-0:20 | 0:10-0:15 | CAUTION: Clear ice may require touch for confirmation |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 1:00-1:55 | 0:55-1:55 | 0:40-1:00 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:35-1:00 | 0:35-1:10 | 0:25-0:35 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:10-0:20 | 0:10-0:20 | 0:10-0:15 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:30-0:50 | **0:55-1:35 | **0:30-0:45 | |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:20-0:35 | **0:40-1:10 | **0:20-0:30 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:20-0:35 | | | |
| below -25 | below -13 | 100/0 | **SAFEWING® MP IV 2001** Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C(13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when **SAFEWING® MP IV 2001** Type IV fluid cannot be used. | | | | | |

**°C** **Celsius**
**°F** **Degrees Fahrenheit**
**OAT** **Outside Air Temperature**
**VOL** **Volume**

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest use temperature is limited to -10 °C (14 °F)
*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

**CAUTION:** THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

**CAUTION: CLARIANT SAFEWING MPIV 2001** TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective October 1, 1998

**TABLE 4F - Guideline for Holdover Times Anticipated for SPCA AD-404 Type IV Fluid Mixtures as a Function of Weather Conditions and OAT**

**CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.**

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| C | °F | Neat-Fluid/Water (Vol. %/Vol. %) | *Frost | Freezing Fog | Snow | ***Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 18:00 | 2:00-3:00 | 1:40-2:00 | 1:40-2:00 | 0:45-1:20 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 0:50-1:45 | 0:50-1:50 | 0:30-0:50 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:20-0:45 | 0:25-0:55 | 0:15-0:35 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 1:00-1:45 | 1:40-2:00 | 0:45-1:20 | CAUTION: |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:25-1:00 | 0:50-1:50 | 0:30-0:50 | Clear ice |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:15-0:30 | 0:25-0:55 | 0:15-0:35 | may require |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:35-1:00 | **1:05-2:00 | **0:35-1:20 | touch for |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:15-0:25 | **0:30-1:45 | **0:30-0:45 | confirmation |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | **SPCA AD-404** Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C(13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when **SPCA AD-404** Type IV fluid cannot be used. | | | | | |

**°C** **Celsius**
**°F** **Degrees Fahrenheit**
**OAT** **Outside Air Temperature**
**VOL** **Volume**

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest use temperature is limited to -10 °C (14 °F)
*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

**CAUTION**: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

**CAUTION**: SPCA AD-404 TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective October 1, 1998

**TABLE 4G - Guideline for Holdover Times Anticipated for SPCA AD-480 Type IV Fluid Mixtures as a Function of Weather Conditions and OAT**

**CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY, AND IT SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.**

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times under Various Weather Conditions (hours: minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| C | °F | Neat-Fluid/Water (Vol. %/Vol. %) | *Frost | Freezing Fog | Snow | ***Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 18:00 | 2:00-3:00 | 1:10-2:00 | 1:05-2:00 | 0:50-1:10 | 0:10-0:50 |
| | | 75/25 | 6:00 | 1:05-2:00 | 1:00-1:55 | 0:50-1:20 | 0:35-0:50 | 0:05-0:35 |
| | | 50/50 | 4:00 | 0:20-0:45 | 0:15-0:35 | 0:15-0:35 | 0:10-0:25 | CAUTION: Clear ice may require touch for confirmation |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00-3:00 | 1:05-2:00 | 1:05-2:00 | 0:50-1:10 | |
| | | 75/25 | 5:00 | 1:05-2:00 | 0:45-1:25 | 0:50-1:20 | 0:35-0:50 | |
| | | 50/50 | 3:00 | 0:20-0:45 | 0:10-0:30 | 0:15-0:35 | 0:10-0:25 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40-3:00 | 0:20-0:40 | **0:25-1:20 | **0:20-0:40 | |
| | | 75/25 | 5:00 | 0:30-2:00 | 0:15-0:25 | **0:30-1:15 | **0:20-0:35 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20-2:00 | 0:15-0:30 | | | |
| below -25 | below -13 | 100/0 | **SPCA AD-480** Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C(13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when **SPCA AD-480** Type IV fluid cannot be used. | | | | | |

**°C** **Celsius**
**°F** **Degrees Fahrenheit**
**OAT** **Outside Air Temperature**
**VOL** **Volume**

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

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest use temperature is limited to -10 °C (14 °F)
*** Use light freezing rain holdover times if positive identification of freezing drizzle is not possible

**CAUTION:** THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS. HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT, HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

**CAUTION: SPCA AD-480** TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective October 1, 1998

**TABLE 5 - Guidelines for the application of SAE Type II and Type IV fluid mixtures.**
**Minimum Concentrations as a Function of Outside Air Temperature(OAT)**
Concentrations in % V/V

| Outside Air Temperature OAT | One-step Procedure Deicing/anti-icing | Two-step Procedure | |
|---|---|---|---|
| | | First step: Deicing | Second step Anti-icing [1] |
| -3° C (27° F) and above | 50/50 Heated [2] Type II/IV | Water heated or a heated mix of Type I, II or IV with water | 50/50 Type II/IV |
| Below -3° C (27° F) to -14° C (7° F) | 75/25 Heated [2] Type II/IV | Heated suitable mix of Type I, Type II/IV and water with FP not more than 3° C (5° F) above actual OAT | 75/25 Type II/IV |
| Below -14° C (7° F) to -25° C (-13° F) | 100/0 Heated [2] Type II/IV | Heated suitable mix of Type I, Type II/IV and water with FP not more than 3° C (5° F) above actual OAT | 100/0 Type II/IV |
| Below -25° C (-13° F) | SAE Type II/IV fluid may be used below -25° C (-13° F) provided that the freezing point of the fluid is at least a 7° C (13° F) below OAT and that aerodynamic acceptance criteria are met. Consider the use of SAE Type I when Type II/IV fluid cannot be used (see table 1). | | |

NOTE: For heated fluids, a fluid temperature not less than 60° C (140° F) at the nozzle is desirable. Upper temperature limit shall not exceed fluid and aircraft manufacturers recommendations.

CAUTION: Wing skin temperatures may differ and in some cases may be lower than OAT. A stronger mix can be used under the latter conditions.

[1]) To be applied before first step fluid freezes, typically within 3 minutes.
[2]) Clean aircraft may be anti-iced with unheated fluid.

Effective October 1, 1998

## TABLE 6. List of Qualified Deicing/Anti-Icing Fluids – Winter 1998-99

### Qualified Type I Deicing/Anti-Icing Fluids

| Company Name | Fluid Name |
|---|---|
| ARCO | ARCOPlus |
| ARCO | ARCOPlus Dilute(48) |
| ARCO | ARCOPlus Canadian Dilute(56) |
| BASF AG | Aerex 102 |
| Clariant | Safewing DG I 1937 |
| Clariant | Safewing MP I 1938 |
| Kilfrost | Kilfrost DF |
| Octagon Process | Octaflo |
| Octagon Process | Octaflo Dilute |
| SPCA | SPCA DE-825 |
| SPCA | SPCA DE-910 |
| Union Carbide | UCAR® ADF Concentrate |
| Union Carbide | UCAR® ADF 50/50 |
| Union Carbide | UCAR® ADF XL 54 |

### Qualified Type II Deicing/Anti-Icing Fluids

| Company Name | Fluid Name |
|---|---|
| Clariant | Safewing MP II 1951 |
| Kilfrost | KilfrostABC-3 |
| Octagon Process | Forty Below |
| SPCA | SPCA AD-104/N |

### Qualified Type IV Deicing/Anti-Icing Fluids

| Company Name | Fluid Name |
|---|---|
| Clariant | Safewing MP IV 1957 |
| Clariant | Safewing MP IV 2001 |
| Kilfrost | KilfrostABC-S |
| Octagon Process | Max Flight |
| SPCA | SPCA AD-404 |
| SPCA | SPCA AD-480 |
| Union Carbide | UCAR® ADF/AAF ULTRA+ |

# APPENDIX I

## DETAILED REFERENCES RELATED TO HOLDOVER TIME CHANGES

## TO LIGHT FREEZING RAIN AT -10°C

# Annex I-I
# LIGHT FREEZING RAIN TEST SPECIFICATIONS

| | | |
|---|---|---|
| | Fluid Name: | Refer to Table I-1 |
| 1. | Fluid Viscosity: | Refer to Table I-1 and Table I-2 |
| 2. | Air Temperature: | Refer to Table I-1 |
| 3. | Fluid Temperature | Refer to Table I-1 |
| 4. | Type of Water | Softened Well water |
| 5. | Water Temperature at spray nozzle | +3°C (approx) or colder |
| 6. | Height of nozzle above plate | 7.0 metres (average) |
| 7. | Height of plate above floor | 0.9 metres (average) |
| 8. | Distance of plates from chamber walls | 3m, 3m, 2.4m, 7m |
| 9. | Droplet size distribution | MVD = 1.0 mm |
| 10. | Length and width of plate | 20" (50 cm) x 12" (30 cm) |
| 11. | Plate surface finish | Plate condition at purchase: 5052-H32 polished standard roll mill finish<br>Plate condition in 1998: matt, scratched, worn |
| 12. | Plate cleaning process prior to Type IV | a) Plate surface squeegeed to remove any contamination<br>b) Fluid being used for the test is poured and squeegeed to clean surface<br>c) Fluid is applied immediately after cleaning |
| 13. | Precipitation rate | Refer to Table I-1 |
| 14. | Tolerance | Refer to Table I-1 |
| | Chamber Humidity | 60 to 70% (estimate) |
| 15. | Basis of failure call | See Attachment I-1 |
| **Other Items** | Shearing | Fluids were pre-sheared by the manufacturers prior to shipping |
| | a) Quantity of fluid | Fluid was applied such that the plate is flooded |

TABLE I-1

# SIMULATED LIGHT FRZ RAIN AT CEF FOR 1997/98

| | | | | | | | | | | | Precipitation Rate g/dm²/hr | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| test no. | form no. | date | Stand # | fluid name | fld dilution | plate location | Batch # | Inital Fluid Temp | fail time [min.] | rate of precep. [g/dm²/hr] | Standard Deviation | 95% lower Range | 95% upper Range | Ambient temp [C] | Estimate of Viscosity (mPas) |
| 241 | 52 | Apr-17-98 | 1 | CLARIANT 1957 | Neat | 10 | B | -10 | 31 | 21.2 | 0.7 | 19.9 | 22.5 | -10.4 | 25,000 |
| 255 | 55 | Apr-17-98 | 1 | CLARIANT 1957 | Neat | 5 | B | -10 | 33 | 23.2 | 0.8 | 21.7 | 24.8 | -10.3 | 25,000 |
| 242 | 52 | Apr-17-98 | 1 | CLARIANT 2001 | Neat | 11 | B | -10 | 32 | 21.3 | 0.7 | 20.0 | 22.6 | -10.4 | 20,000 |
| 256 | 55 | Apr-17-98 | 1 | CLARIANT 2001 | Neat | 6 | B | -10 | 32 | 23.0 | 0.5 | 22.1 | 24.0 | -10.3 | 20,000 |
| 240 | 52 | Apr-17-98 | 1 | KILFROST ABC-S | Neat | 9 | B | -10 | 23 | 21.2 | 0.4 | 20.5 | 21.9 | -10.4 | 23,500 |
| 244 | 53 | Apr-17-98 | 1 | KILFROST ABC-S | Neat | 1 | B | -10 | 24 | 23.2 | 1.3 | 20.7 | 25.7 | -10.4 | 23,500 |
| 233 | 52 | Apr-17-98 | 1 | OCTAGON | Neat | 1 | A | -10 | 23 | 23.2 | 1.3 | 20.7 | 25.7 | -10.4 | 8,500 |
| 247 | 53 | Apr-17-98 | 1 | OCTAGON | Neat | 8 | A | -10 | 24 | 21.6 | 0.5 | 20.6 | 22.7 | -10.4 | 8,500 |
| 249 | 54 | Apr-17-98 | 2 | SPCA AD-404 | Neat | 1 | A | -10 | 30 | 23.1 | 0.4 | 22.3 | 23.9 | -10.3 | 31,800 |
| 246 | 53 | Apr-17-98 | 1 | SPCA AD-404 | Neat | 7 | A | -10 | 44 | 21.5 | 0.6 | 20.4 | 22.7 | -10.3 | 31,800 |
| 260 | 56 | Apr-17-98 | 1 | SPCA AD-404 | Neat | 1 | A | -10 | 43 | 23.2 | 1.3 | 20.7 | 25.7 | -10.2 | 31,800 |
| 239 | 52 | Apr-17-98 | 2 | SPCA AD-480 | Neat | 8 | A | -10 | 22 | 21.6 | 0.6 | 20.4 | 22.8 | -10.4 | 20,500 |
| 250 | 54 | Apr-17-98 | 1 | SPCA AD-480 | Neat | 2 | A | -10 | 23 | 22.4 | 0.6 | 21.3 | 23.5 | -10.4 | 20,500 |
| 235 | 52 | Apr-17-98 | 1 | UCAR PG | Neat | 3 | A | -10 | 14 | 23.1 | 0.4 | 22.2 | 23.9 | -10.4 | 50,000 |
| 254 | 55 | Apr-17-98 | 1 | UCAR PG | Neat | 4 | A | -10 | 17 | 23.2 | 0.4 | 22.3 | 24.0 | -10.3 | 50,000 |
| 245 | 53 | Apr-17-98 | 1 | UCAR PG | Neat | 3 | A | -10 | 15 | 23.1 | 0.4 | 22.2 | 23.9 | -10.3 | 50,000 |
| 234 | 52 | Apr-17-98 | 1 | ULTRA IV | Neat | 2 | A | -10 | 46 | 23.0 | 0.6 | 21.9 | 24.1 | -10.4 | 48,000 |
| 243 | 52 | Apr-17-98 | 1 | ULTRA IV | Neat | 12 | A | -10 | 41 | 20.7 | 0.7 | 19.4 | 22.0 | -10.3 | 48,000 |
| 253 | 55 | Apr-17-98 | 1 | ULTRA IV | Neat | 3 | A | -10 | 50 | 23.1 | 0.4 | 22.2 | 23.9 | -10.3 | 48,000 |

TABLE I-2

## VISCOSITY RANGE FOR TYPE IV FLUIDS USED IN TESTING AT NRC IN 1998

| | Lower Production Viscosity | Upper Production Viscosity |
|---|---|---|
| **CLARIANT 1957** | 23000 mPas | 27000 mPas |
| **CLARIANT 2001** | 15000 mPas | 25000 mPas |
| **KILFROST ABC-S** | 20000 mPas | 27000 mPas |
| **OCTAGON MAXFLIGHT** | 6500 mPas | 10000 mPas |
| **UCAR ULTRA IV** | 45000 mPas | 58000 mPas |
| **UCAR PG AAF** | 45000 mPas | 58000 mPas |
| **SPCA AD-404** | 28000 mPas | 38000 mPas |
| **SPCA AD-480** | 17000 mPas | 23000 mPas |

ATTACHMENT I-1

## BASIS OF FAILURE CALL

The APS failure call has been based on a procedure developed several years ago by the SAE G-12 Holdover Time Subcommittee. Observers have been trained the same way from year to year. More specifically, in the last two years, all failures have been determined by one trained observer with piloting experience. It is based on ice formation on 1/3 of the plate or 5 crosshairs, whichever comes first.

For the tests in question, failures occurred when ice in the fluid solidified and covered 1/3 of the surface of the plate. In most tests performed at colder temperatures with freezing precipitation, fluids failed from the bottom up, due to a *damming* of the fluid at the bottom of the plate. This is undoubtedly a viscosity issue, since fluid has difficulty flowing on the plate at these temperatures.

# ANNEX I-II

# AMIL Test Specifications

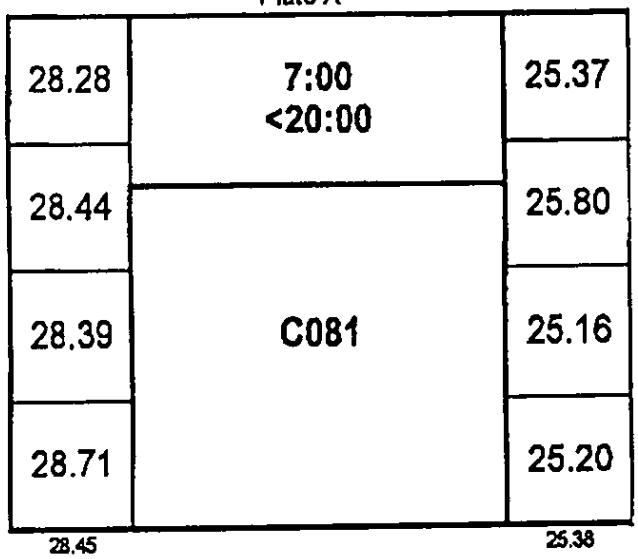
# FLUID HOLDOVER

| | | | | | |
|---|---|---|---|---|---|
| TEST N° | ZL011 | | Water Pressure | 80 | psi |
| Date | 98-03-17 | | Fan Frequency(Hz) | 40 | |
| Duration | 32 | (min) | %Rh | | |
| T(air) | -10 | °C | Support Position | x,y=106cm, 66.5cm | |
| T(plate) | -10 | °C | Panel Position | closed | |
| T(on/off) | 0.5/12 | (sec.) | Plate Angle | 10° | |
| Nozzle Oscillation: | 5.5 | (Hz) | | | |

ZL011 .xls

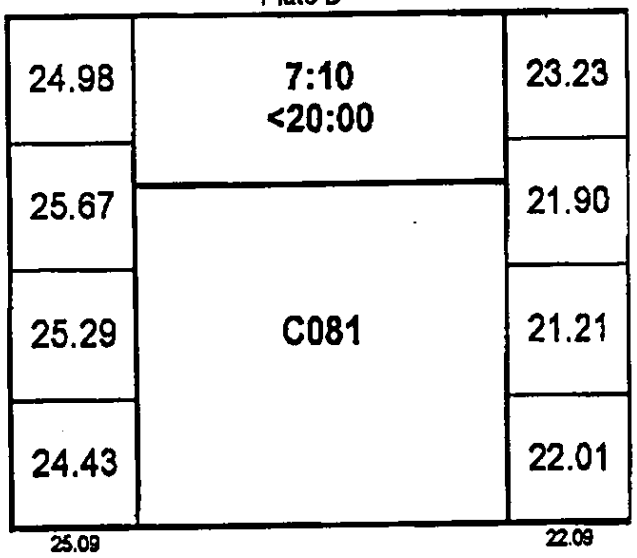
F

Plate A




Icing intensity estimated using
calibration cafr012: **25.88** g/dm²/h

Plate B




Icing intensity estimated using
calibration cafr012: **24.07** g/dm²/h

## Hold Over Time Light Freezing Rain Tests Discrepancies

| Fluid Name | | SPCA | Ocatagon | Union Carbide | |
|---|---|---|---|---|---|
| | | AD-480 | Maxflight | Ultra+ | Ultra+ |
| lot# | | 702 | F-20925-T | 407400 | 407400 |
| AMIL name | | C081 | C052 | B950 | B950 |
| viscosity | | | | | |
| test # | | ZL011 | ZL010 | ZL009 | ZL007 |
| Hold Over Time | plate A | 7min00sec | 7min00sec | 9min30sec | 10min00sec |
| | plate B | 7min10sec | 8min00sec | 10min00sec | 10min00sec |

# ICE DISTRIBUTION (CHAMBRE 9M)

| | | | | | |
|---|---|---|---|---|---|
| TEST N° | cafr012 | | Water Pressure | 80 | psi |
| Date | 98-03-13 | | Fan Frequency (Hz) | 40 | (en bas) |
| Test Duration | 30 | (min) | %Rh | | |
| T(air) | -10 | °C | Support position | x,y=106cm, 66.5cm | |
| T(plate) | -10 | °C | Panel Position | closed | |
| T(on/off) | 0.5/12 | (sec.) | Plate Angle | 10° | |
| Nozzle Oscillation | 5.5 | (Hz) | | | cafr012 .xls |

| | | | | | | |
|---|---|---|---|---|---|---|
| 22.28 | 21.66 | 21.34 | 22.30 | 21.90 | 2% | B(2-3-4)= 24.63 |
| 23.68 | 23.42 | 23.76 | 23.82 | 23.67 | 1% | B1= 89% |
| 25.04 | 25.20 | 24.70 | 24.90 | 24.96 | 1% | B5= 108% |
| 25.02 | 25.24 | 25.42 | 25.34 | 25.26 | 1% | B(1-5)= 98% (estimation factor) |
| 26.36 | 26.72 | 26.82 | 26.40 | 26.58 | 1% | Écart Type(%)= 3.00% |
| 24.48 | 24.45 | 24.41 | 24.55 | | | |
| 6% | 8% | 8% | 6% | | | |

| Intensité: | |
|---|---|
| Min. | Max. |
| 23.4 | 25.4 |
| 5% | 3% |

| | | | | | | |
|---|---|---|---|---|---|---|
| 27.48 | 27.40 | 26.64 | 26.18 | 26.93 | 2% | A(2-3-4)= 27.02 |
| 27.46 | 27.56 | 26.78 | 25.26 | 26.77 | 4% | A1= 100% |
| 27.32 | 27.16 | 27.00 | 26.40 | 26.97 | 1% | A5= 108% |
| 27.46 | 27.46 | 27.42 | 27.00 | 27.34 | 1% | A(1-5)= 104% (estimation factor) |
| 29.00 | 29.22 | 29.50 | 28.88 | 29.15 | 1% | Écart Type(%)= 2.41% |
| 27.74 | 27.76 | 27.47 | 26.74 | | | |
| 3% | 3% | 4% | 5% | | | |

| Intensité: | |
|---|---|
| Min. | Max. |
| 26.3 | 27.5 |
| 7% | 2% |

## Hold Over Time Light Freezing Rain Tests Discrepancies

| | | |
|---|---|---|
| 1 | *air temp at plate level* | -10°C |
| 2 | *fluid temperature prior to application on plate* | -10°C (test temperature) |
| 3 | *type of water used in the spray* | demineralised |
| 4 | *water temperature at spray nozzle* | 10°C in pipe |
| 5 | *height of nozzle above plate* | 6 meters |
| 6 | *height of plate above floor* | 85 cm |
| 7 | *distance of plate from chamber walls* | x,y = 106 cm, 66.5 cm |
| 8 | *droplet size distribution* | MVD : 970 µm (see fig. 7 and 8) |
| 9 | *lenght and width of plate* | 30 x 50 cm |
| 10 | *plate surface finish* | polished |
| 11 | *plate cleaning process prior to Type IV app.* | hot water, ethanol |
| 12 | *precipitation rate and tolerance* | 25 g/dm²/h (see calibration table test# cafr012) |
| 13 | *chamber humidity* | 65 %Rh |
| 14 | *basis of failure call* | 30% of plate covered with slush or ice |

# FLUID HOLDOVER

| | | |
|---|---|---|
| TEST N° | ZL007 | |
| Date | 98-03-13 | |
| Duration | 34 | (min) |
| T(air) | -10 | °C |
| T(plate) | -10 | °C |
| T(on/off) | 0.5/12 | (sec.) |
| Nozzle Oscillation: | 5.5 | (Hz) |

| | |
|---|---|
| Water Pressure | 80 psi |
| Fan Frequency(Hz) | 40 |
| %Rh | |
| Support Position | x,y=106cm, 66.5cm |
| Panel Position | closed |
| Plate Angle | 10° |

ZL007 .xls

F

Plate A

| | | |
|---|---|---|
| 29.03 | 10 MIN | 25.46 |
| 27.97 | | 25.25 |
| 27.79 | B950 | 23.88 |
| 26.28 | | 23.77 |
| 27.77 | | 24.59 |

Icing intensity estimated using calibration cafr012: **25.17** g/dm²/h

Plate B

| | | |
|---|---|---|
| 24.26 | 10 MIN | 23.36 |
| 24.49 | | 22.20 |
| 24.51 | B950 | 22.68 |
| 24.26 | | 23.75 |
| 24.38 | | 23.00 |

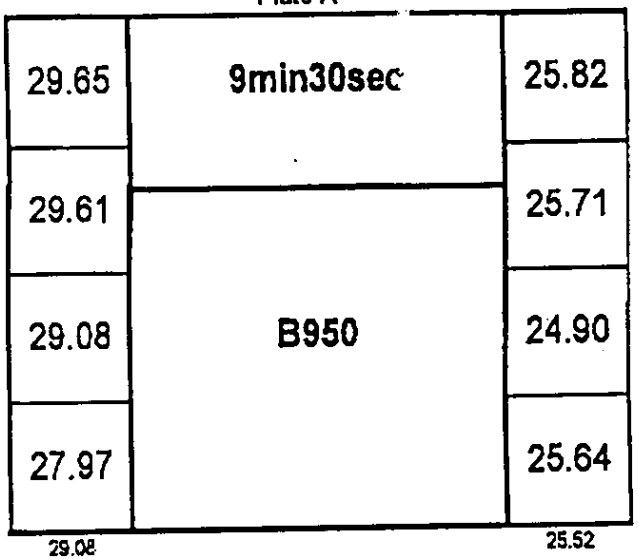
Icing intensity estimated using calibration cafr012: **24.17** g/dm²/h

# FLUID HOLDOVER

| | | | | | |
|---|---|---|---|---|---|
| TEST N° | ZL009 | | Water Pressure | 80 | psi |
| Date | 98-03-17 | | Fan Frequency(Hz) | 40 | |
| Duration | 34 | (min) | %Rh | | |
| T(air) | -10 | °C | Support Position | x,y=106cm, 66.5cm | |
| T(plate) | -10 | °C | Panel Position | closed | |
| T(on/off) | 0.5/12 | (sec.) | Plate Angle | 10° | |
| Nozzle Oscillation: | 5.5 | (Hz) | | | |

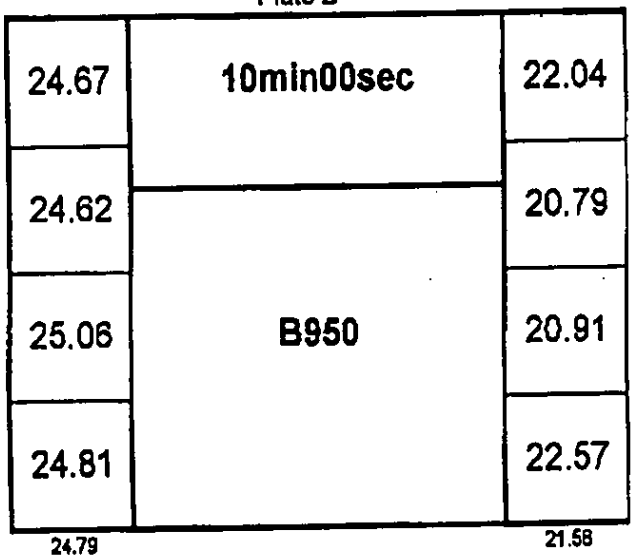
ZL009 .xls

Plate A




Icing tintensity estimated using
calibration cafr012: **26.25** g/dm²/h

Plate B




Icing intensity estimated using
calibration cafr012: **23.66** g/dm²/h

# FLUID HOLDOVER

| | | |
|---|---|---|
| TEST N° | ZL010 | |
| Date | 98-03-17 | |
| Duration | 15 | (min) |
| T(air) | -10 | °C |
| T(plate) | -10 | °C |
| T(on/off) | 0.5/12 | (sec.) |
| Nozzle Oscillation: | 5.5 | (Hz) |

| | |
|---|---|
| Water Pressure | 80 psi |
| Fan Frequency(Hz) | 40 |
| %Rh | |
| Support Position | x,y=106cm, 66.5cm |
| Panel Position | closed |
| Plate Angle | 10° |

ZL010 .xls

Plate A

| | | |
|---|---|---|
| 29.40 | 7 MIN. | 25.44 |
| 30.00 | | 25.40 |
| 28.60 | C052 | 24.24 |
| 28.44 | | 26.36 |

29.11 25.36

F

Icing intensity estimated using calibration cafr012: **26.19** g/dm²/h

Plate B

| | | |
|---|---|---|
| 23.40 | 8 MIN. | 21.52 |
| 24.72 | | 19.84 |
| 24.36 | C052 | 19.68 |
| 24.40 | | 20.68 |

24.22 20.43

Icing intensity estimated using calibration cafr012: **22.78** g/dm²/h

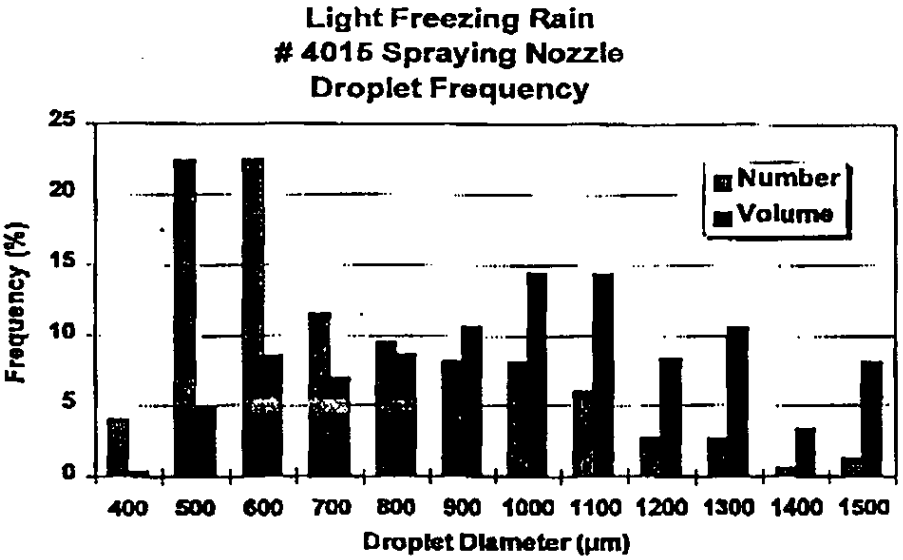



*Figure 7: Light Freezing Rain # 4015 Spraying Nozzle: Droplet Frequency*

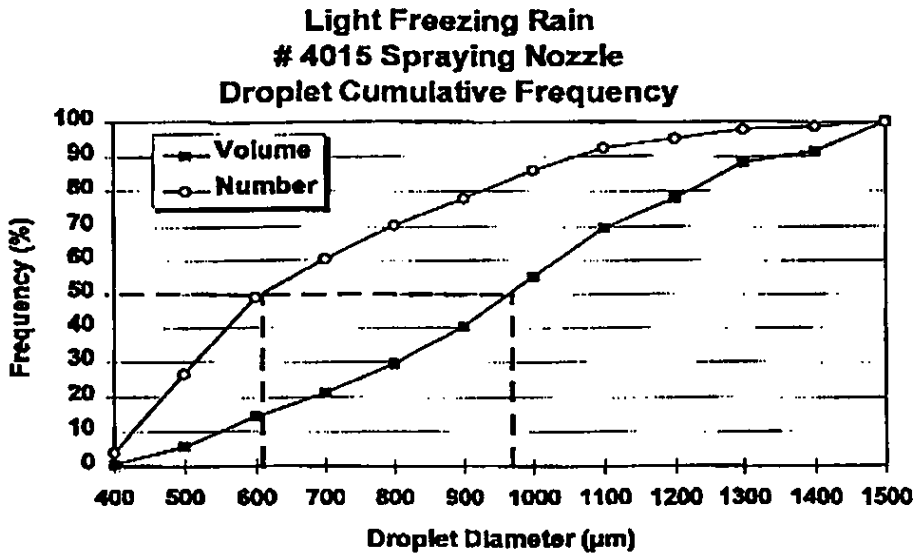



*Figure 8: Light Freezing Rain # 4015 Spraying Nozzle: Droplet Cumulative Frequency*

# ANNEX I-III

## Ballot to SAE Members for Approval

**Resolution of the Differences between the APS and AMIL Holdover Time Values for the Worse Case Type IV SAE Anti-Icing Fluid for the Light Freezing Rain Cell at B 10 degrees Celsius**

**Summary:**
At the SAE Holdover Time Meeting in Vienna APS presented the results of the Transport Canada/FAA sponsored holdover time testing program. Values were derived from the APS provided data to give recommended times for each cell of the SAE Type IV table. Holdover time values for all cells, except one were approved by the committee.

For that one cell in the Type IV table, (light freezing rain at B10 degrees Celsius), AMIL presented results for two fluids that indicated substantially shorter times to fluid failure. They also mentioned that they did have data that at -3 Celsius was not much different than the APS data (AMIL in fact shows longer times than APS at B3 degrees Celsius).

At the meeting several approaches were suggested including putting a note on the SAE Table or in the ARP 4737 Methods Document to indicate the need for a pre-take off contamination check for this light freezing rain conditions. (In retrospect the use of a pretakeoff contamination check would not have been appropriate for the SAE generic Type IV table, since all airlines do not employ such a procedure). Following some confusion regarding the outcome of a motion to pass the necessary information to the Methods Committee it was decided that the Co-chairs of the HOT Committee should review the data and recommend action through an informal ballot of those members of the committee that were present in Vienna.

Test conditions and setups for APS and AMIL have been compared and in most instances they are the same or similar; there is a difference in the precipitation rates but it amounts to only about 3 gm/dm2 in 25 (see table). Two test condition differences noted were, possible differences in the fluid viscosity and the amount of fluid poured on the plate: the AMIL fluids were received unsheared and used as such; APS requested the manufacturers to provide sheared fluids; for the amounts used, AMIL poured half a liter whereas APS poured one to one and a half liters per test plate. These difference were not deemed as the likely cause of the differences in holdover times recorded.
The major difference is most likely attributed to be in the failure call employed by the two team. This difference has been observed since earlier holdover time substantiaton testing dating back to 1992. Differences between APS calls and NRC calls and NCAR failure calls have been ironed out in the past; Also, AMIL 's failure calls on low temperature light freezing rain were the subject of some concern following both the 94/95 and the 95/96 winter testing.
In this case, substantial testing was undertaken for light freezing rain at -7 degrees Celsius to compare with the 17 minute values that AMIL indicated for neat Type IV and 11 minutes for Type II. APS data

indicated 30+ for Type IV and 23+ for Type II. These data have been published in Transport Canada Report TP 12896E.
Subsequent to these considerations, several options were entertained as identified in Table 1. The chairmen finally opted for the approach described in the following recommendation. This results in the SAE Type IV table as shown in Table 2.
Please respond with your position using the first sheet of this document on or before 26 June 1998.

Barry Myers and Charles Masters, Co-Chairs Holdover Time Subcommittee, SAE G-12
33RECOMMENDATION (FOR HOT IN TIV NEAT -10 ZLR):

**It is recommended that the Holdover Time values for Type IV Fluids for the light freezing rain cell for the SAE worse case table at B10 degrees Celsius be 15 to 30 minutes.**

Rationale:

1. This is a compromise value between the APS value of 20 minutes and the AMIL value of 10 minutes.

2. The **approved** values of the 75/25 mix for the 1998-99 winter icing season for BZR is 15 to 30 minutes. Thus, the cell for -ZR for the 100/0 and the 75/25 mix would be the same.

3. The **approved** values of the ZL mix for both the 100/0 and the 72/25 mix are the same at 25 minutes to 1 Hour.

4. The holdover times for this BZR cell for the 1997-98 winter icing season was 30 to 45 minutes.

5. The holdover times for this BZR cell for the 1996-97 winter icing season was 30 to 55 minutes.

6. The holdover times for this BZR cell for ULTRA (the first type IV) for the 1995-96 winter icing season was 22 to 45 minutes.

7. There have been no reports that any of these values used over the past 3 winter icing seasons have been shown to be unacceptable, or have met with conditions in which the fluids have failed before the holdover times have been exceeded.

8. The probability of encountering freezing rain at 25 gm/dm2 at B10 degrees Celsius is very unlikely.

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9. The preponderance of data supports the higher value of 20-40 minutes for this cell, however a significant amount of co-testing between APS and AMIL is deemed as one of the few methods to resolve the differences in failure calls. There is not enough time available to accomplish this co-testing in a timely manner to affect Holdover Time tables for the upcoming 1998-99 winter icing season.

TABLE 1

## ALTERNATIVES FOR THE -ZLR VALUES IN SAE TYPE IV TABLE 1998-99

1. Use values/data from AMIL where applicable as lowest times

2. Use values/data from APS. Do not include Data from AMIL.

3. Let the regression analysis serve as the basis for establishment of the ranges.
   Recompute values using data from both AMIL and APS

4. Give no value for this -ZR column.
   Issue a statement for a Pre Takeoff Contamination Check/Thorough Inspection prior to Takeoff.

5. Issue no values for this Column.
   Tell airlines to derive their own. Give them all of the data which is available.

6. Defray any issuance of HOT until a meeting between APS and AMIL can take place and it is resolved between **them.**

   a. Do this for the one cell in -ZR that is affected.

   b. Do this for all cells affected indirectly.

   c. Do this for all HOT's.

7. Conduct tests at NRC with AMIL present and get concurrence on the Failure calls.
   Have the RVSI or Cox sensor present to record/call failures.
   Get this done by August 1998.

8. Use the APS values of 24-40 minutes
   Add a note to the tables:
   USE IN CONJUNCTION WITH A PRETAKEOFF CONTAMINATION CHECK OR WITH A CLOSE PRETAKEOFF CHECK.

9. Use a compromise value between the AMIL and the the APS values and follow up with additional testing in July comparing AMIL and APS failure call

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TABLE 2

# PROPOSED *SAE TYPE IV FLUID HOLDOVER TABLE*

Guideline for Holdover Times Anticipated for SAE Type IV Fluid Mixtures as a Function of Weather Conditions and OAT
**THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER**

| OAT | | SAE Type IV Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours : minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | Neat - Fluid / Water (Vol% / Vol%) | *FROST | FREEZING FOG | SNOW | ***FREEZING DRIZZLE | LIGHT FREEZING RAIN | RAIN ON COLD SOAKED WING |
| above 0° | above 32° | 100/0 | 18:00 | 2:00 - 3:00 | 0:45 - 1:25 | 0:40 - 1:00 | 0:35 - 0:55 | 0:10 - 0:50 |
| | | 75/25 | 6:00 | 1:05 - 2:00 | 0:20 - 0:40 | 0:30 - 1:00 | 0:15 - 0:30 | 0:05 - 0:35 |
| | | 50/50 | 4:00 | 0:20 - 0:45 | 0:05 - 0:20 | 0:10 - 0:20 | 0:05 - 0:10 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 2:00 - 3:00 | 0:35 - 1:00 | 0:40 - 1:00 | 0:35 - 0:55 | |
| | | 75/25 | 5:00 | 1:05 - 2:00 | 0:20 - 0:35 | 0:30 - 1:00 | 0:15 - 0:30 | |
| | | 50/50 | 3:00 | 0:20 - 0:45 | 0:05 - 0:15 | 0:10 - 0:20 | 0:05 - 0:10 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:40 - 3:00 | 0:20 - 0:40 | **0:25 - 1:00 | **0:15 - 0:30 | |
| | | 75/25 | 5:00 | 0:30 - 2:00 | 0:15 - 0:25 | **0:25 - 1:00 | **0:15 - 0:30 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 - 2:00 | 0:15 - 0:30 | | | |
| below -25 | below -13 | 100/0 | SAE Type IV fluid may be used below -25° C (-13° F) provided the freezing point of the fluid is at least 7° C (13° F) below the OAT and the aerodynamic acceptance criteria are met . Consider use of SAE Type I when SAE Type IV fluid cannot be used. | | | | | |

* During conditions that apply to aircraft protection for ACTIVE FROST.
** The lowest use temperature is limited to -10° C (14° F).
***Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

CAUTION: THE TIME OF PROTECTION WILL BE SHORTENED IN HEAVY WEATHER CONDITIONS, HEAVY PRECIPITATION RATES OR HIGH MOISTURE CONTENT. HIGH WIND VELOCITY OR JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY ALSO BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT.

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6/12/98bm

# ANNEX I-IV

## Special Tests Conducted on July 10, 1998

APS AVIATION INC.

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TEL : (514) 878-4388
FAX : (514) 861-6310

REF: CM1380.001

July 14, 1998

**LETTER BY FAX: (609) 485-4005**

Mr. Charles Masters
FAA Technical Centre
Building 210 AAR 421
Atlantic City International Airport
Atlantic City, NJ 08405

Dear Mr. Masters:

As per your request, please find attached the following:

1) Table of tests and conditions for light freezing rain, -10°C tests witnessed by Transport Canada, FAA, AMIL; and
2) Charts with regressions of Octagon and SPCA 480.

Background: APS presented complete data in Vienna for all conditions and all fluids. AMIL indicated that the holdover times at –10°C, light freezing rain, 25 g/dm²/hr were high, as summarized below:

| | AMIL Values (min.) | APS Regression Values at Vienna (Rounded) (min.) | APS Regression Values (rounded) Including tests witnessed by TC, FAA, AMIL on July 10th (min.) |
|---|---|---|---|
| Octagon Maxflight (100%) | 7 | 20 | 20 |
| SPCA 480 (100%) | 7 | 20 | 20 |
| UCAR Ultra + (100%) | 10 | 30 | 30 (or more) |

APS conducted tests on July 10th, 1998 which were witnessed by Transport Canada, FAA, AMIL and included the use of ice detection equipment. This summary shows that the test results presented by APS in Vienna are consistent and accurate, and are based on earlier protocols developed by the SAE G-12 Holdover Time Sub-Committee.

Yours truly,

John D'Avirro
Program Manager
E-mail: j.davirro@adga.ca

JD/jal
Encl.

c.c. B. Myers, Transport Canada

H:\CM1380\LETTER\faa.doc

# TABLE I-3

## SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN AT CEF - JULY 10, 1998

| test no. | Test Season | form no. | date | stand no. | start time (Local) | end time (Local) | fluid name | fld dilution | fld type | plate location | C/FIMS # | Initial Brix | Inital Fluid Temp | fail time [min.] | rate of precep. [g/dm^2/hr | Ambient temp (C) | Plate Temp (°C) Avg. For APS Fail Time | Plate Temp (°C) Avg. for UQAC Fail Time | Precip Type | comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1998 | 1 | Jul-10-98 | 1 | 10:29 | 11:03 | UCAR ULTRA+ | Neat | 4 | 3 | 17 | 39.5 | -10 | 34 | 25.1 | -10.1 | -8 | -10 | frz_rain | |
| 2 | 1998 | 1 | Jul-10-98 | 1 | 10:30 | 11:04 | UCAR ULTRA+ | Neat | 4 | 4 | 23 | 40 | -10 | 33 | 25.3 | -10.1 | -8 | -10 | frz_rain | |
| 3 | 1998 | 2 | Jul-10-98 | 1 | 11:33 | 11:53 | OCTAGON MAXFLIGHT | Neat | 4 | 3 | 17 | 37 | -10 | 20 | 25.0 | -9.9 | -8 | -9 | frz_rain | |
| 4 | 1998 | 2 | Jul-10-98 | 1 | 11:34 | 11:53 | OCTAGON MAXFLIGHT | Neat | 4 | 4 | 23 | 37 | -10 | 19 | 25.4 | -9.9 | -8 | -10 | frz_rain | |
| 5 | 1998 | 3 | Jul-10-98 | 1 | 12:05 | 12:23 | SPCA AD-480 | Neat | 4 | 3 | 17 | 35.5 | -10 | 18 | 25.0 | -9.8 | -8 | -8 | frz_rain | |
| 6 | 1998 | 3 | Jul-10-98 | 1 | 12:05 | 12:22 | SPCA AD-480 | Neat | 4 | 4 | 23 | 35.5 | -10 | 16 | 25.4 | -9.8 | -8 | -8 | frz_rain | |

**FIGURE I-1**

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## OCTAGON TYPE IV NEAT

SIMULATED FREEZING RAIN

1997/98

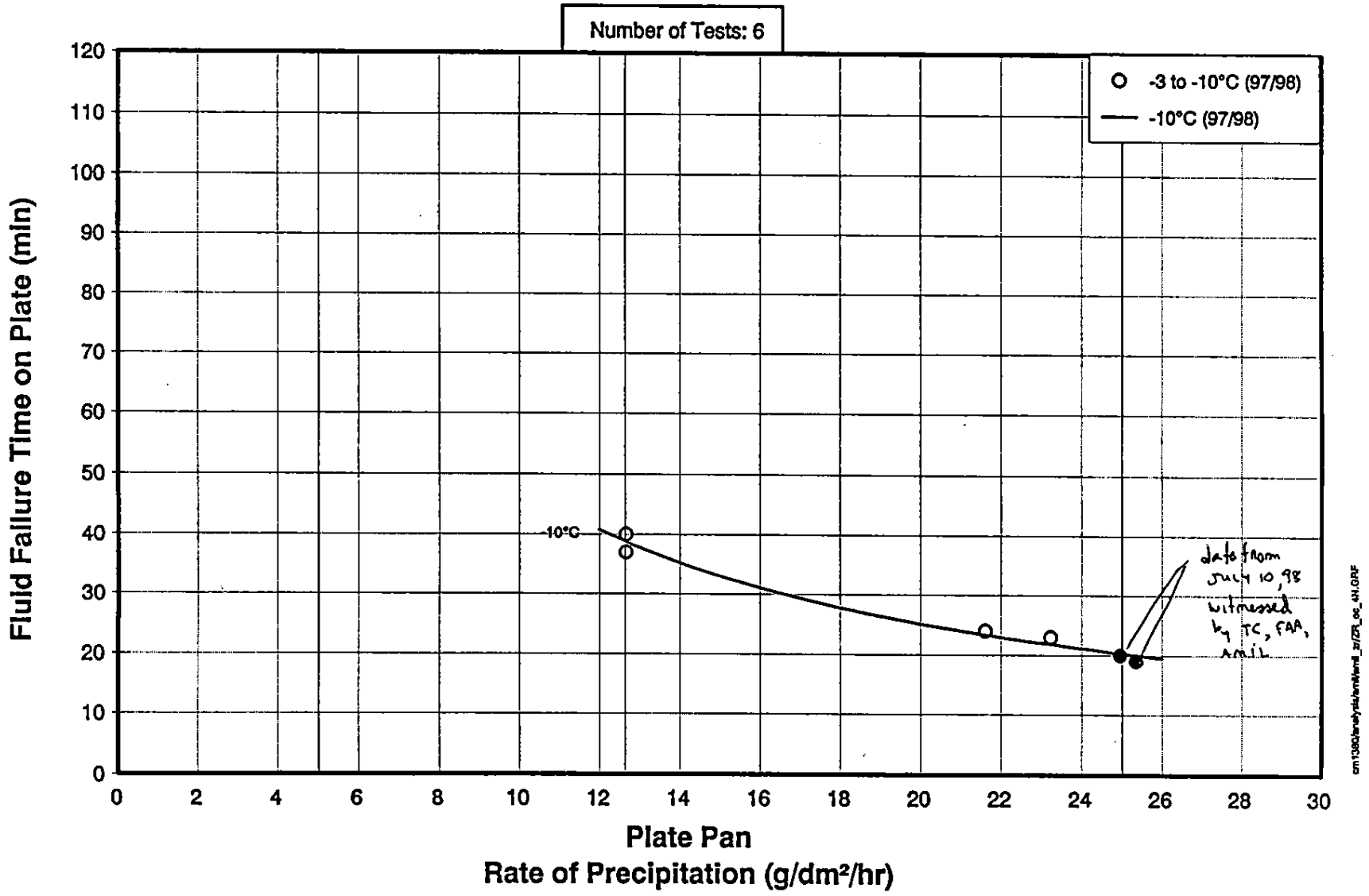


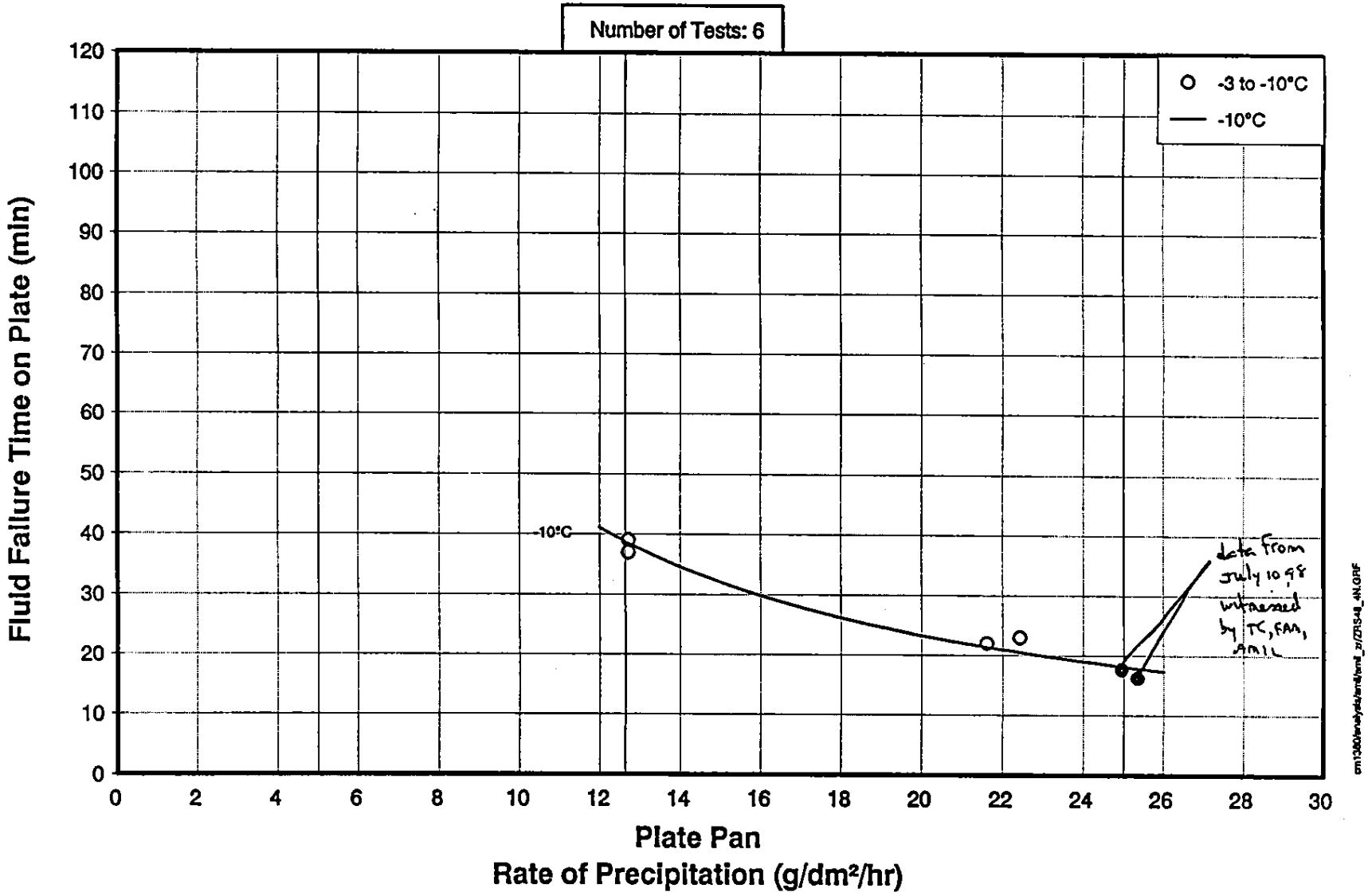
FIGURE I-2

# EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

## SPCA AD-480 TYPE IV NEAT

### SIMULATED LIGHT FREEZING RAIN

### 1997/98



# ANNEX I-V

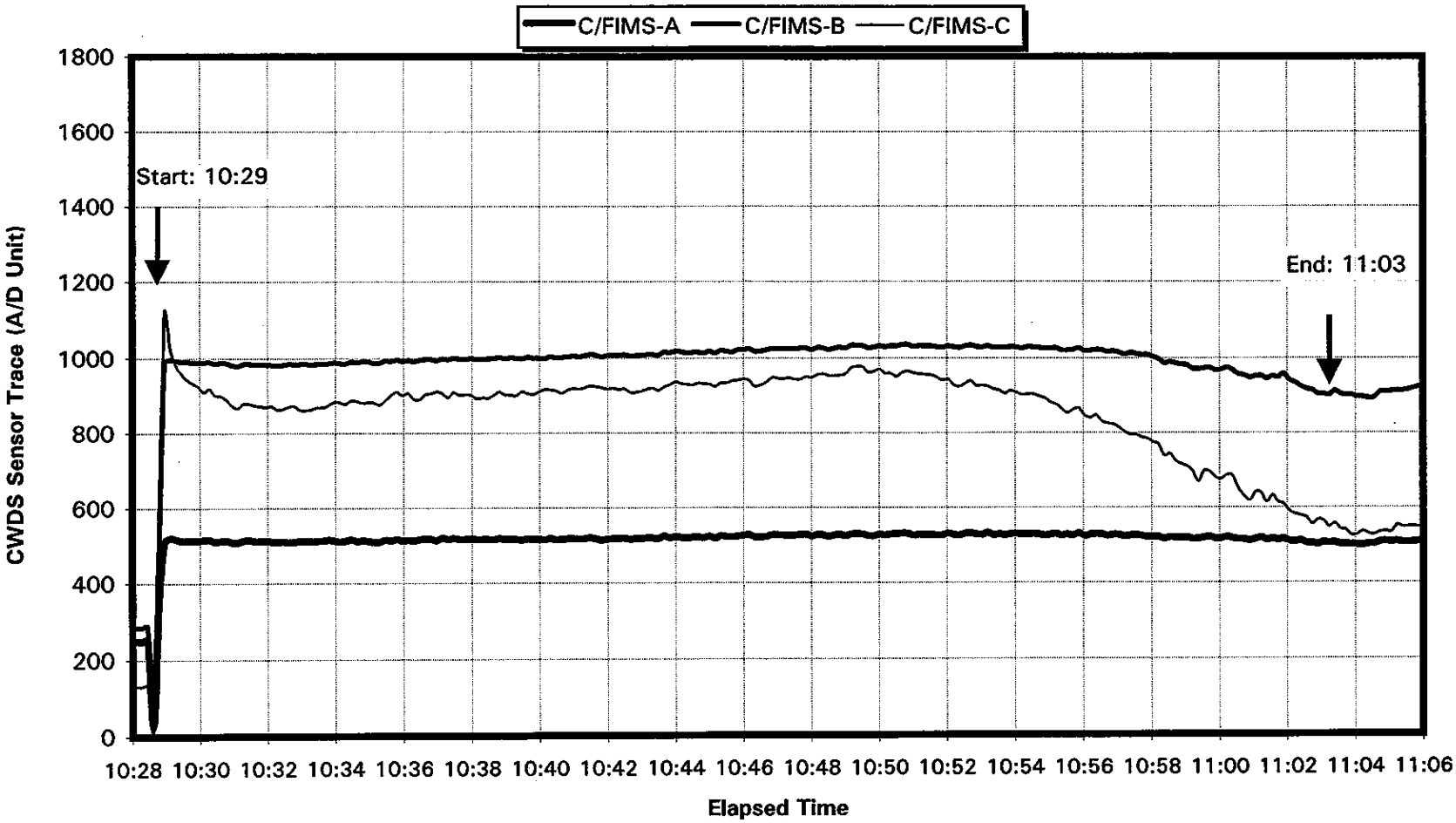
## C/FIMS Traces of July 10th Tests

# C/FIMS SENSOR TRACE

## SIMULATED LIGHT FREEZING RAIN

UCAR ULTRA + Neat

July 10, 1998, Plate 3, T = -10°C, R = 25 g/dm²/hr



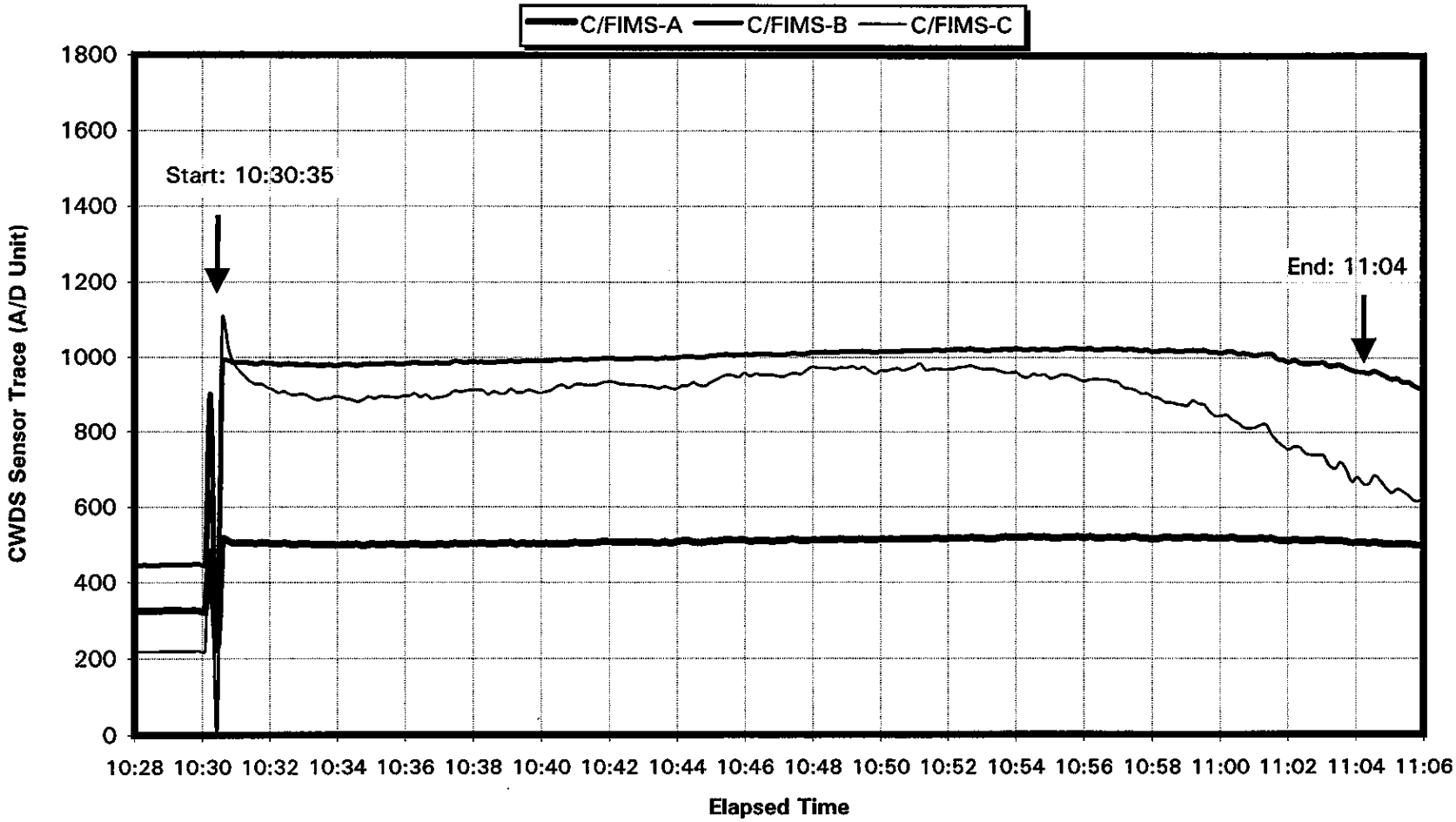

File:g:\cm1380\analysis\cfims\J110-s17
At: U+
Printed: 11/2/98

# C/FIMS SENSOR TRACE

## SIMULATED LIGHT FREEZING RAIN

UCAR ULTRA + Neat

July 10, 1998, Plate 4, T = -10°C, R = 25 g/dm²/hr



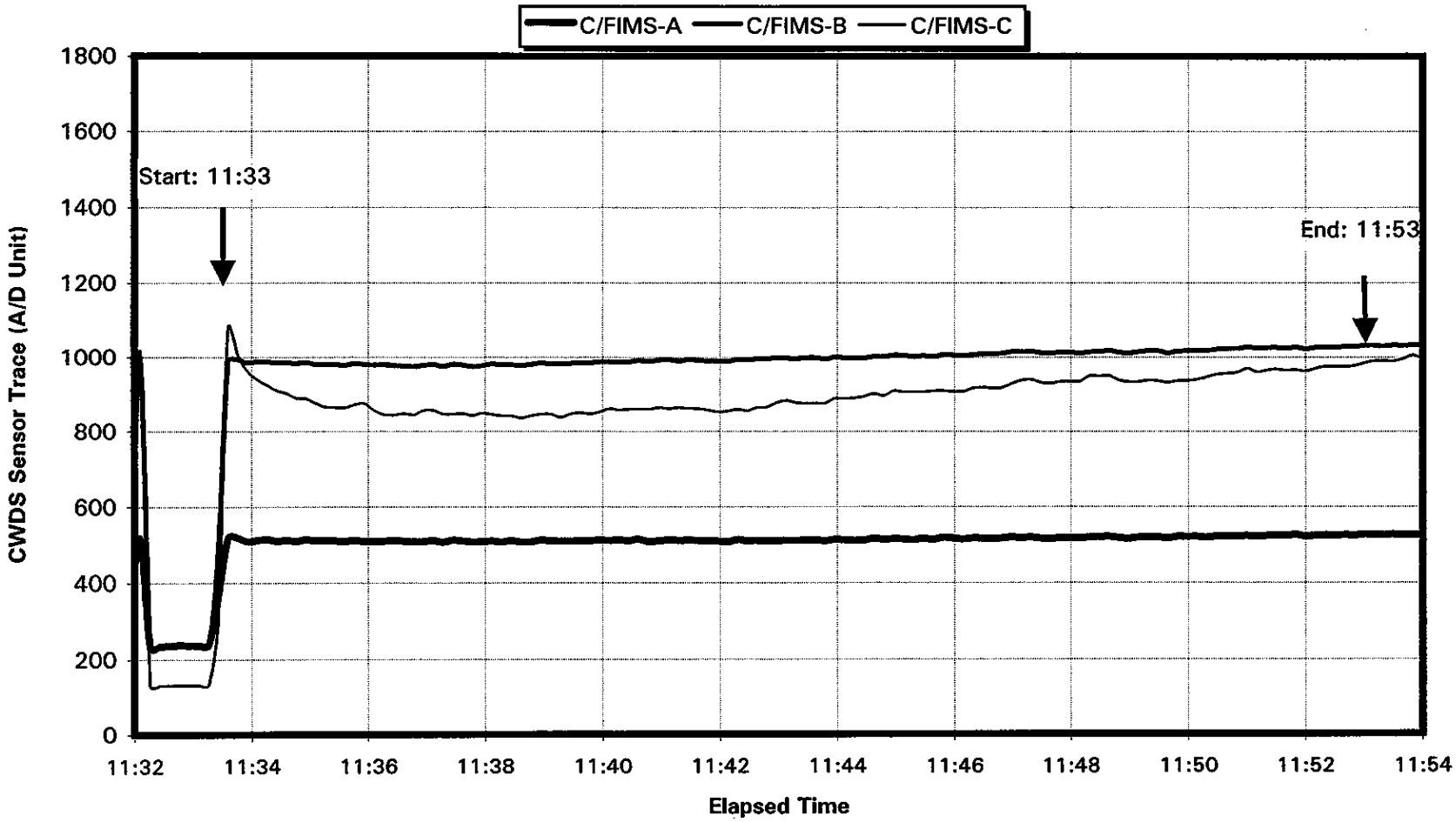

File:g:\cm1380\analysis\cfims\J110-s23
At: U+
Printed: 11/2/98

# C/FIMS SENSOR TRACE

## SIMULATED LIGHT FREEZING RAIN

Octagon Maxflight Neat

July 10, 1998, Plate 3, T = -10°C, R = 25 g/dm²/hr



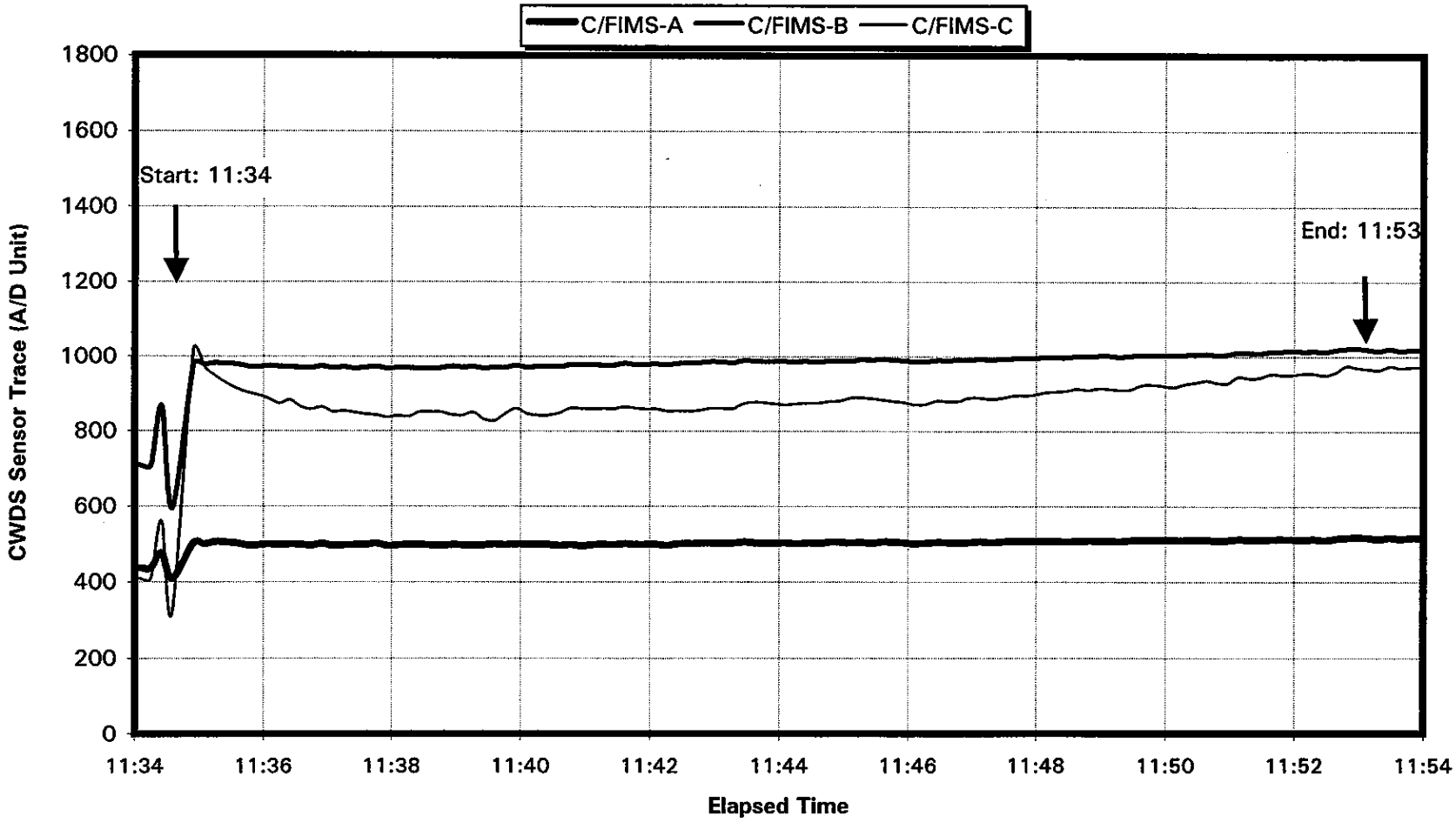

File:g:\cm1380\analysis\cfims\J110-s17
At: O IV
Printed: 11/2/98

# C/FIMS SENSOR TRACE

## SIMULATED LIGHT FREEZING RAIN

Octagon Maxflight Neat

July 10, 1998, Plate 4, T = -10°C, R= 25 g/dm²/hr



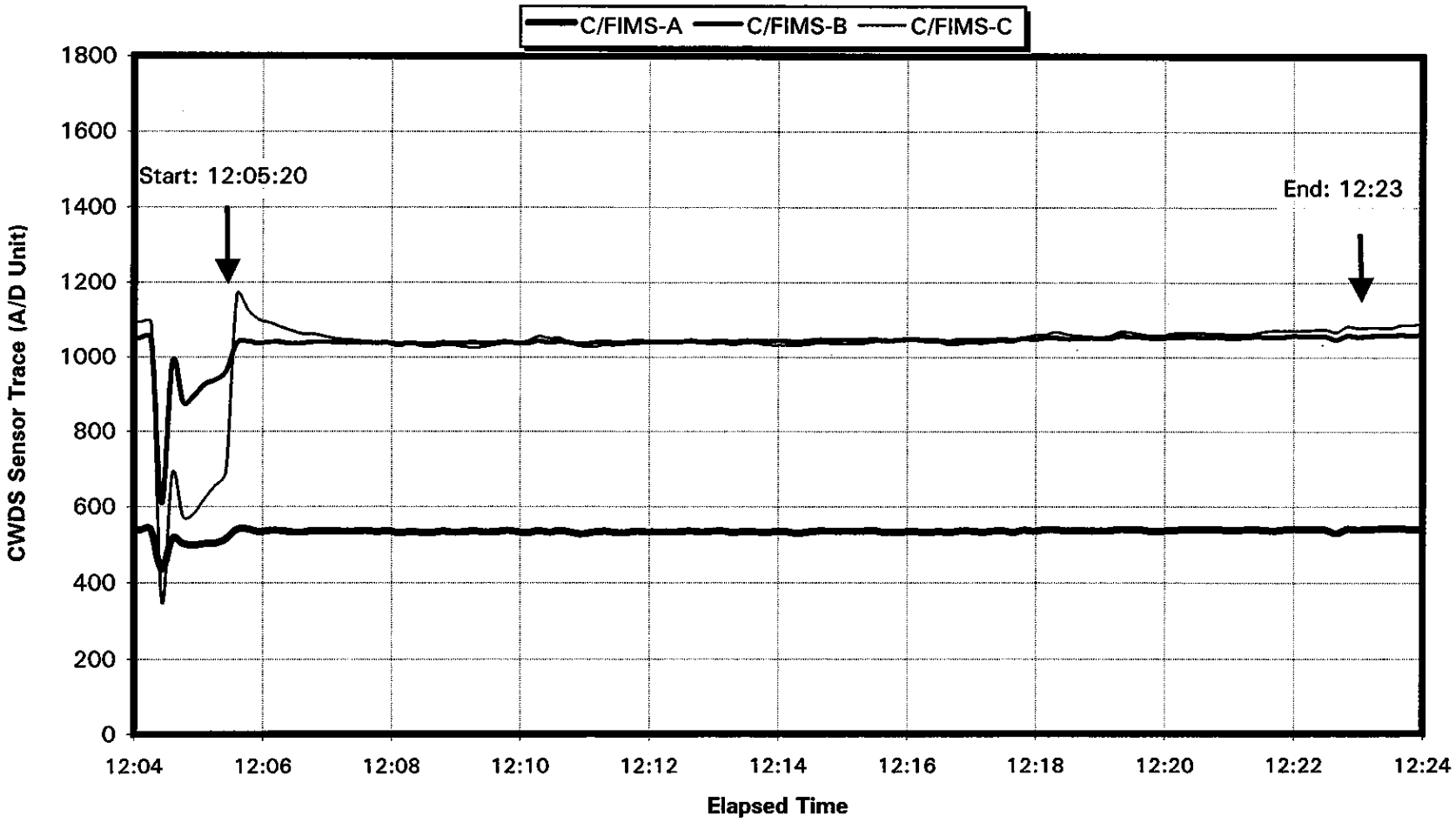

File:g:\cm1380\analysis\cfims\J110-s23
At: O IV
Printed: 11/2/98

# C/FIMS SENSOR TRACE

## SIMULATED LIGHT FREEZING RAIN

SPCA AD-480 Neat

July 10, 1998, Plate 3, T = -10°C, R= 25 g/dm²/hr



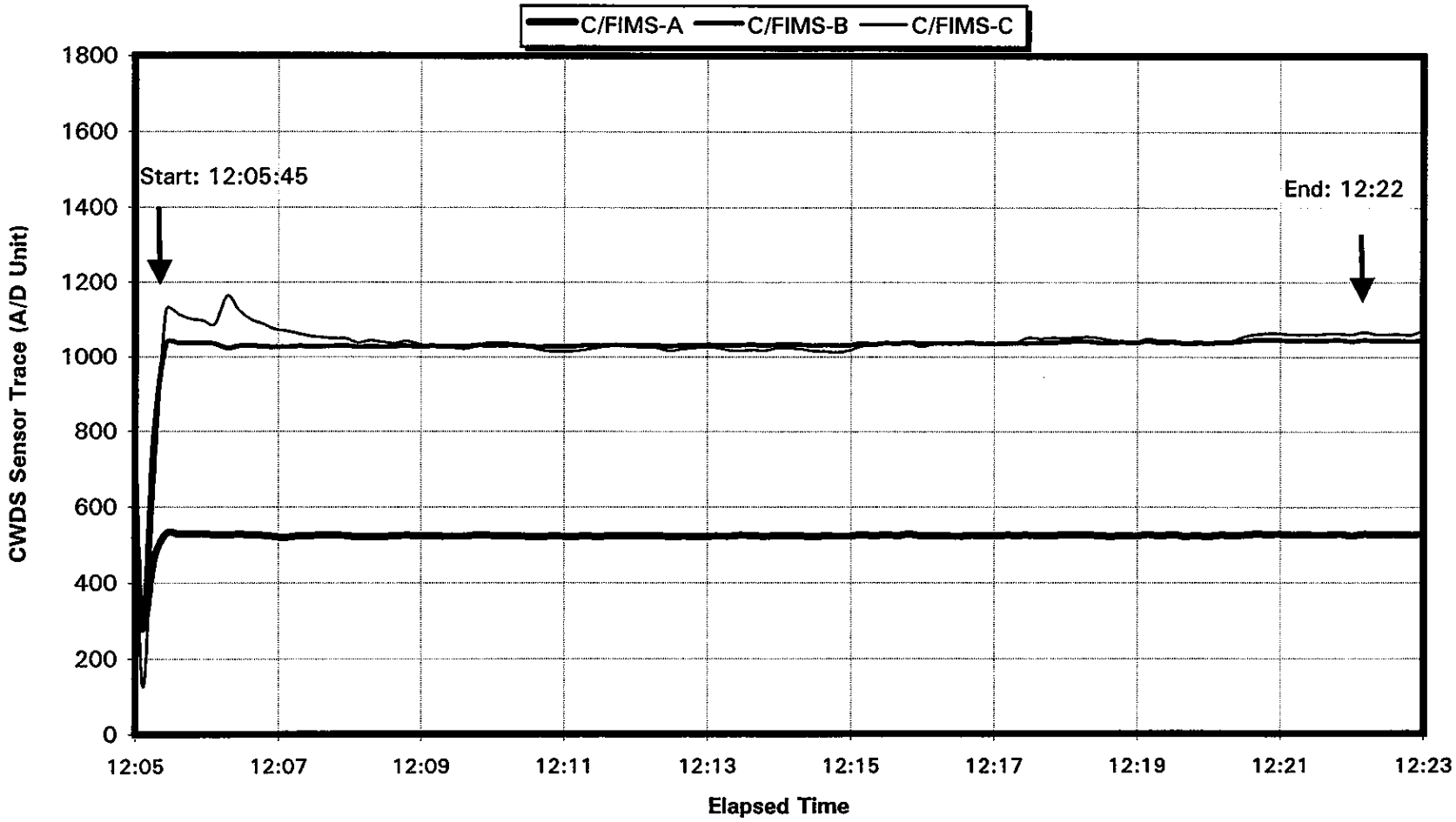

File:g:\cm1380\analysis\cfims\J110-s17
At: S480
Printed: 11/2/98

# C/FIMS SENSOR TRACE

## SIMULATED LIGHT FREEZING RAIN

SPCA AD-480 Neat

July 10, 1998, Plate 4, T = -10°C, R= 25 g/dm²/hr




File:g:\cm1380\analysis\cfims\J110-s23
At: S480
Printed: 11/2/98

# ANNEX I-VI

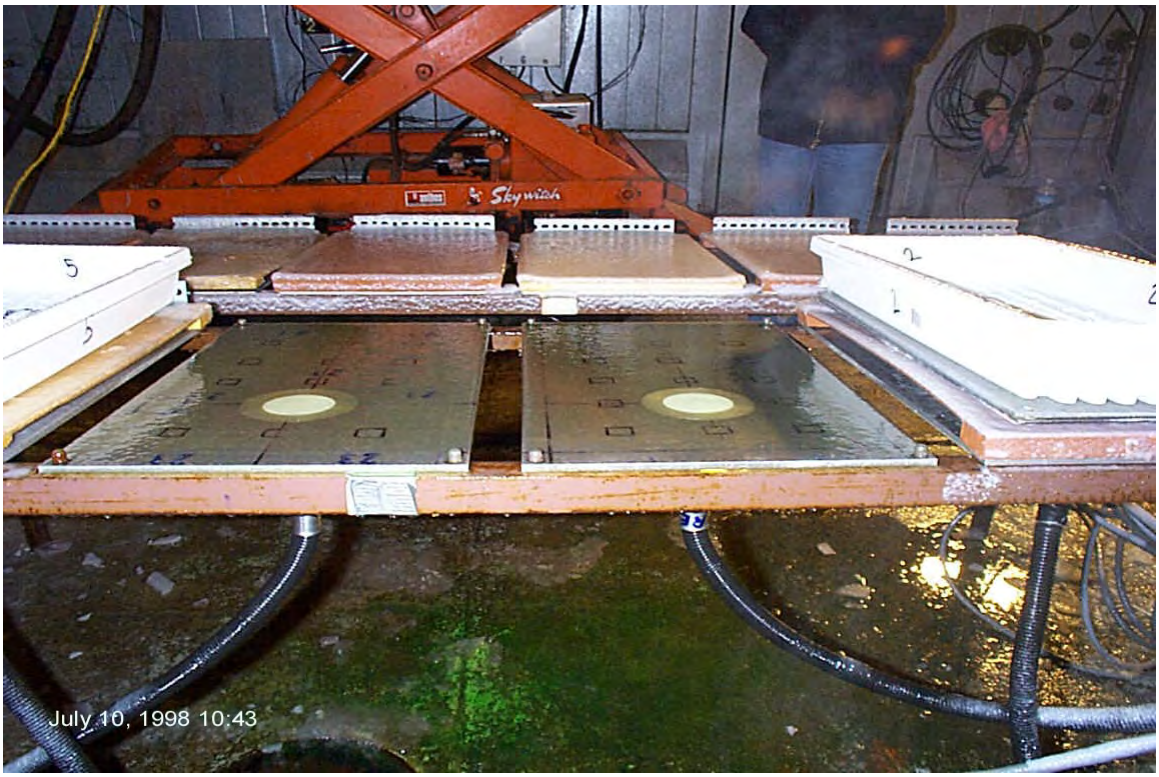
## Photos Taken during Special Tests Under Light Freezing Rain at -10°C on July 10, 1998 at NRC

July 10, 1998 10:29

July 10, 1998 10:42

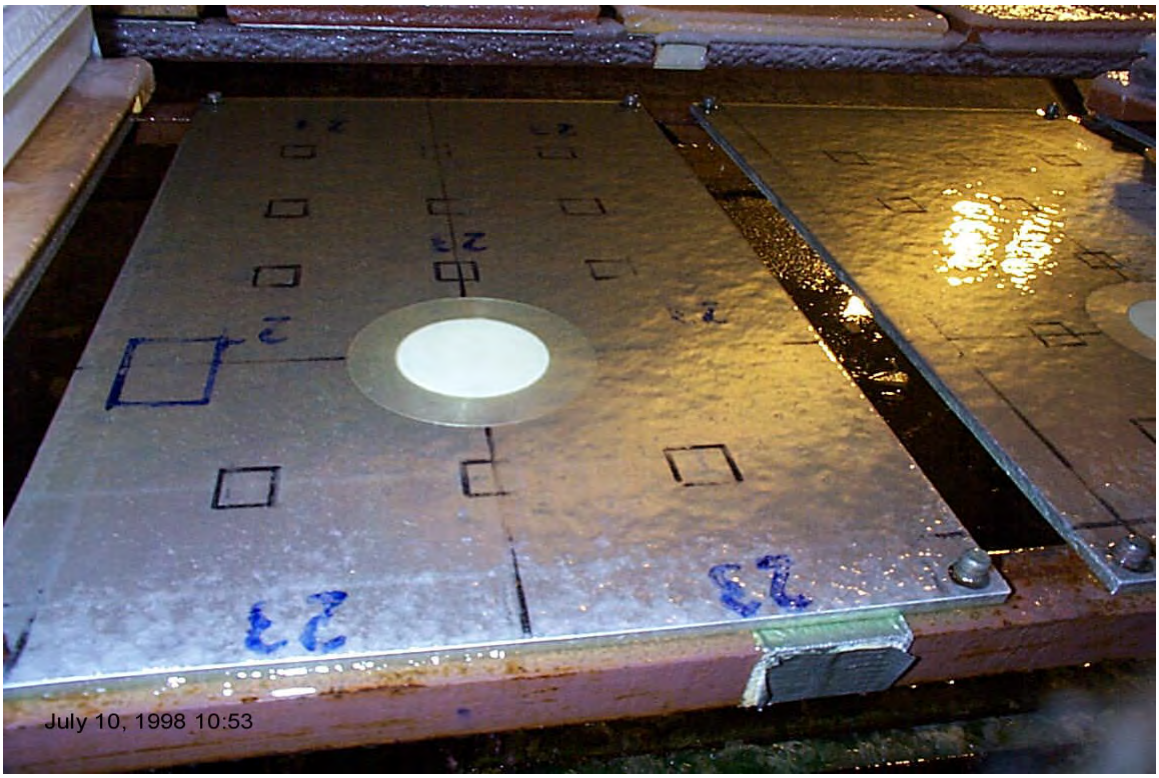
July 10, 1998 10:42

July 10, 1998 10:42


July 10, 1998 10:43

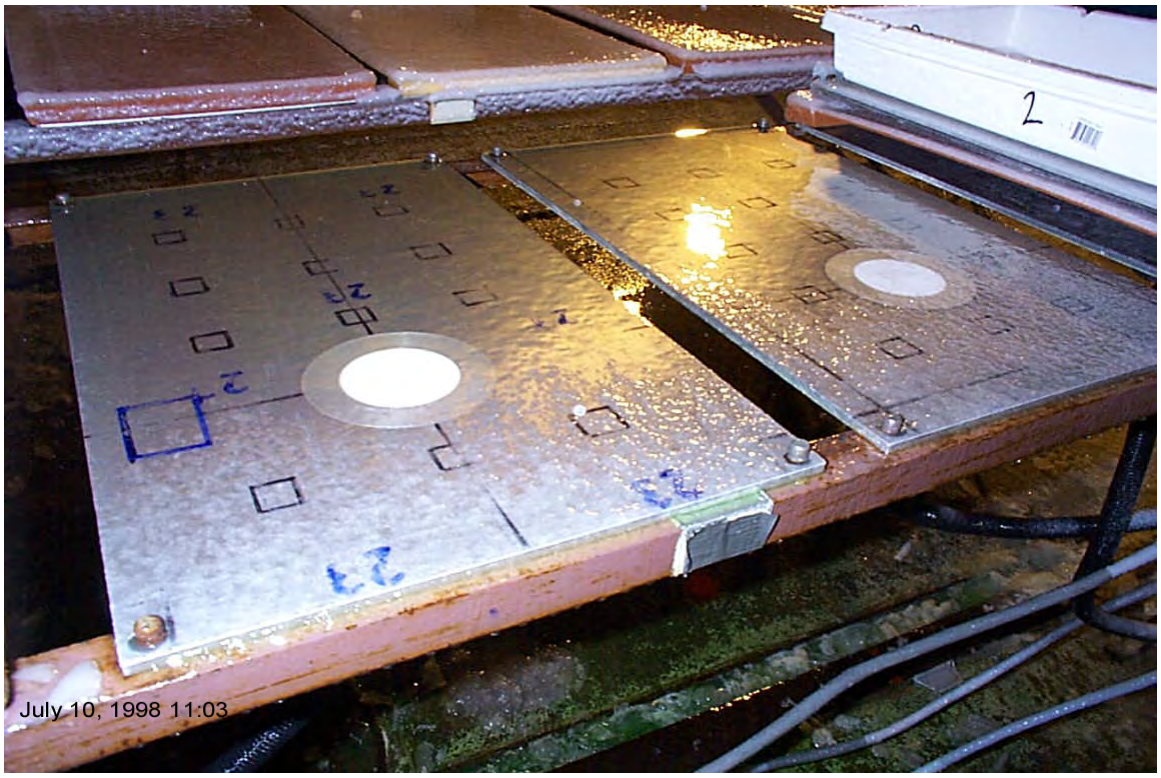
July 10, 1998 10:52

July 10, 1998 10:52


July 10, 1998 10:53

July 10, 1998 11:03

10/07/1998 11:03

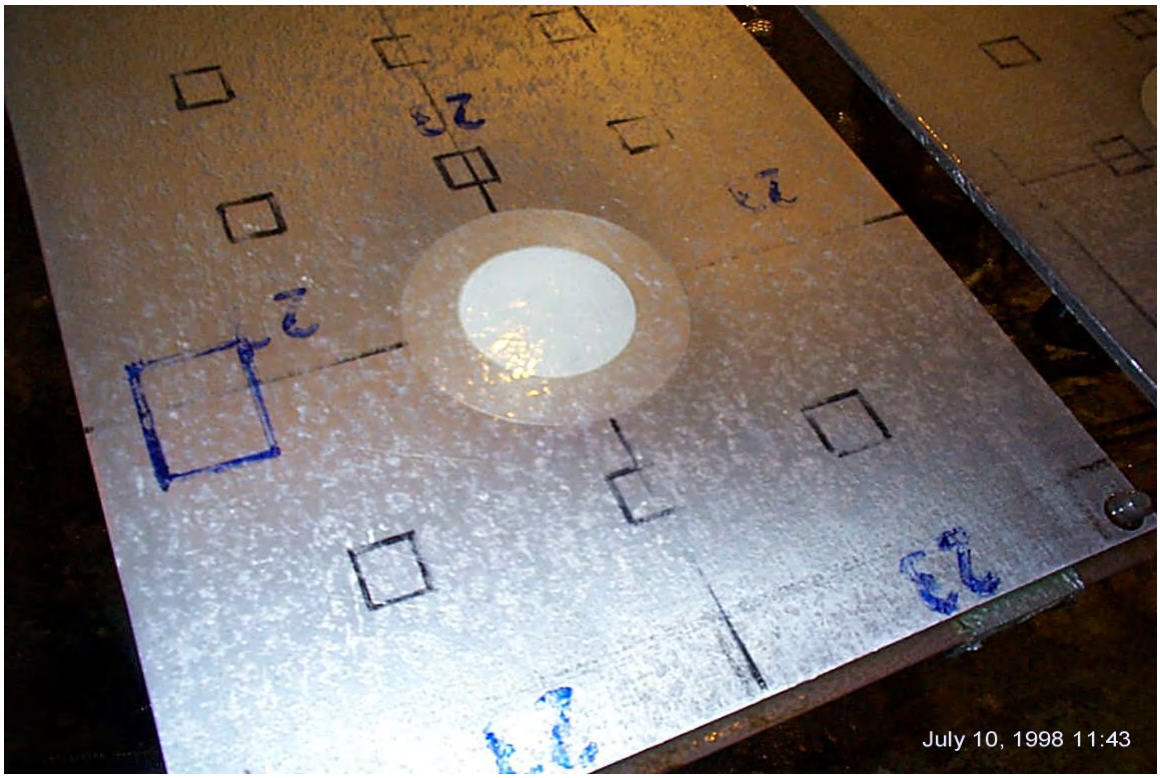

July 10, 1998 11:03

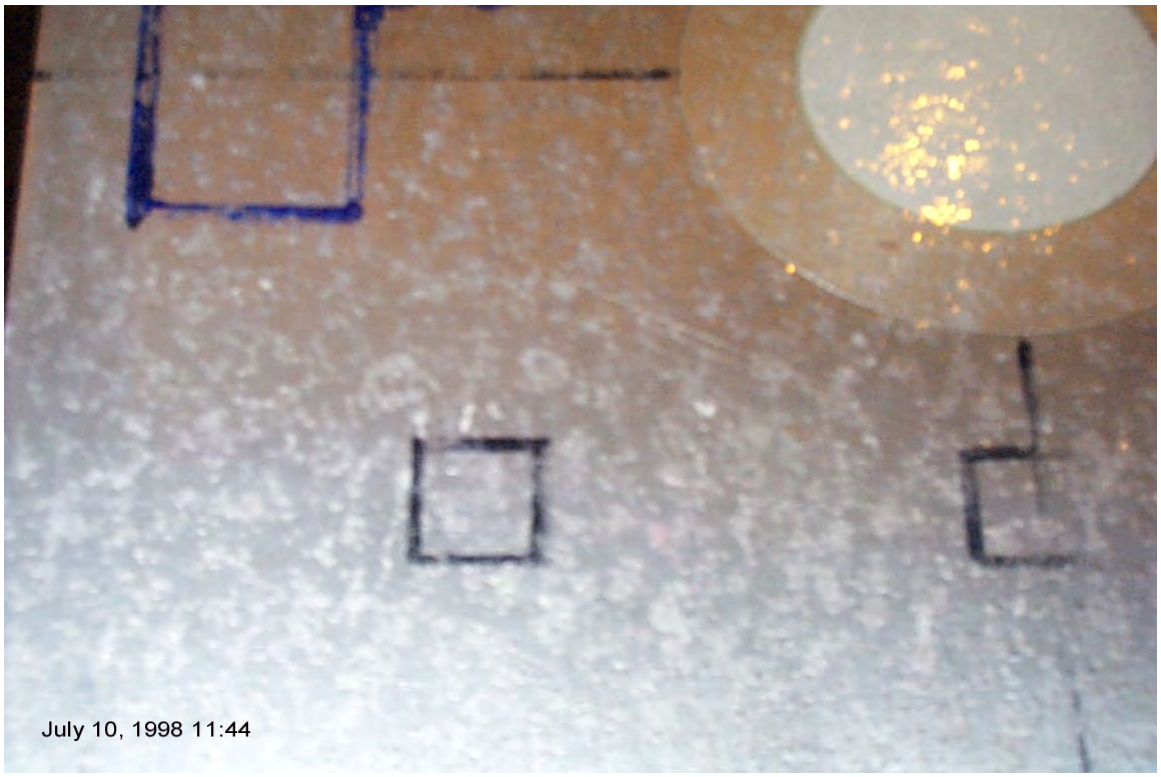
July 10, 1998 11:36

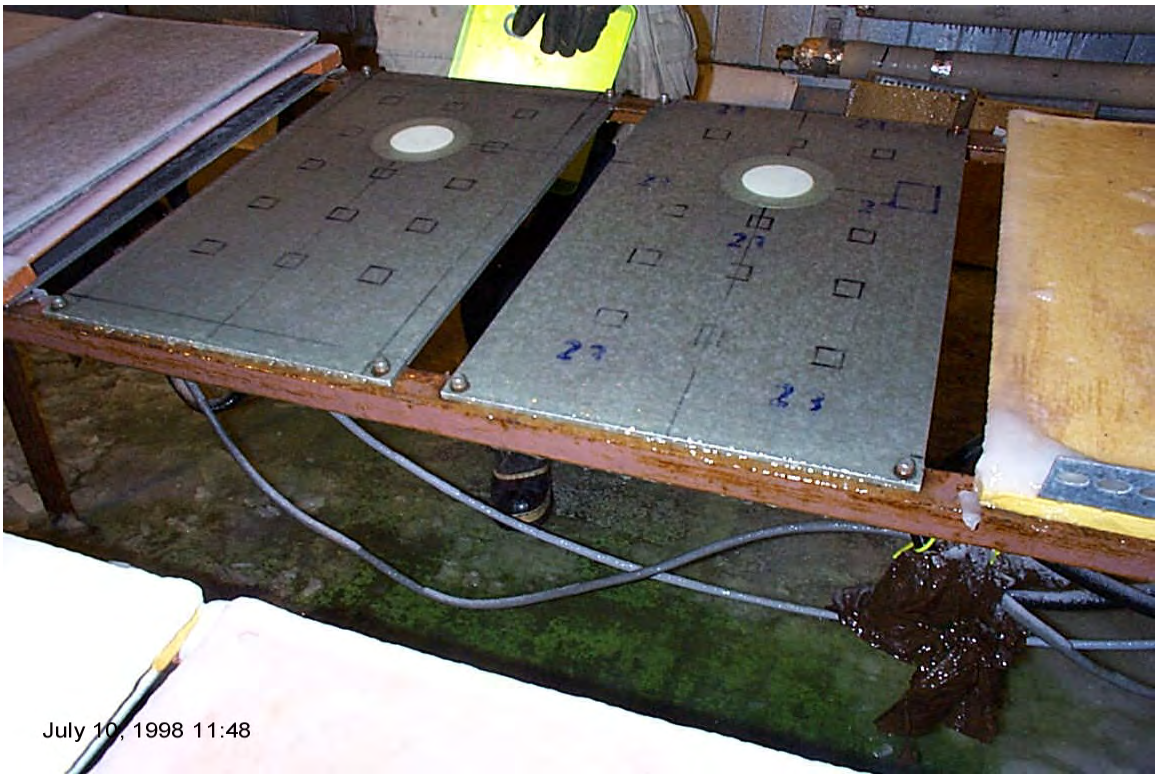
Jul 10, 1998 11:40

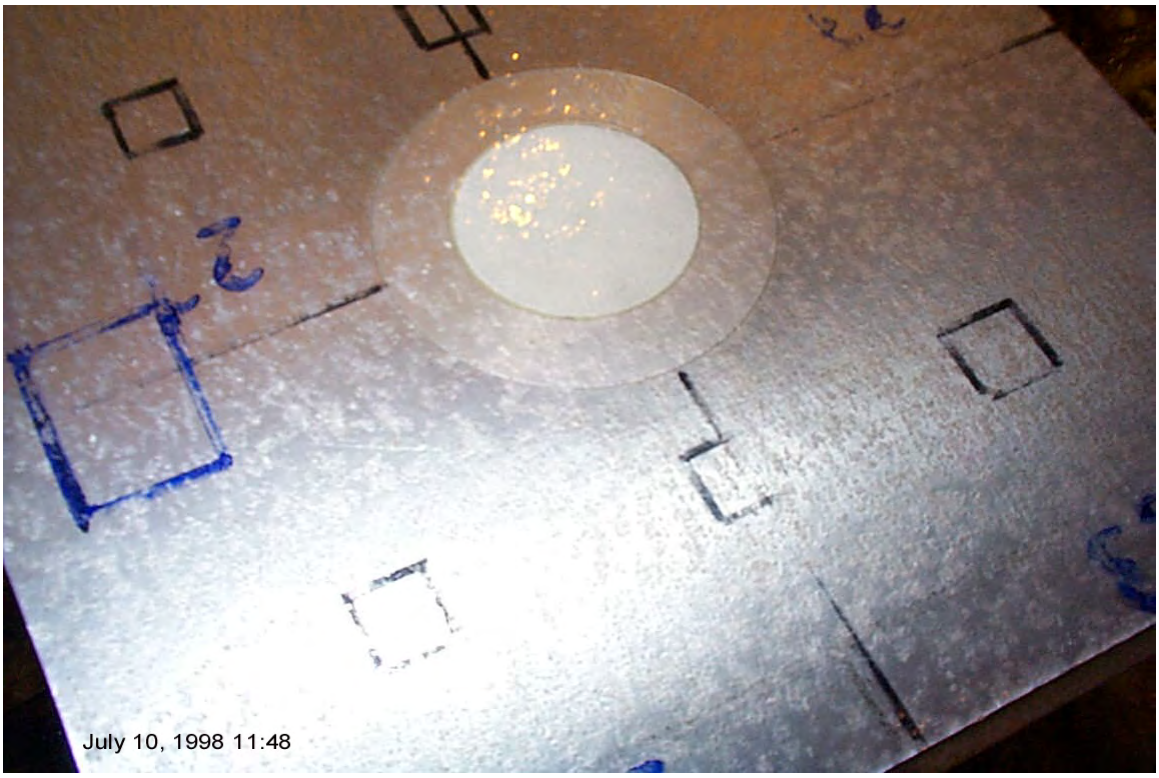
July 10, 1998 11:40

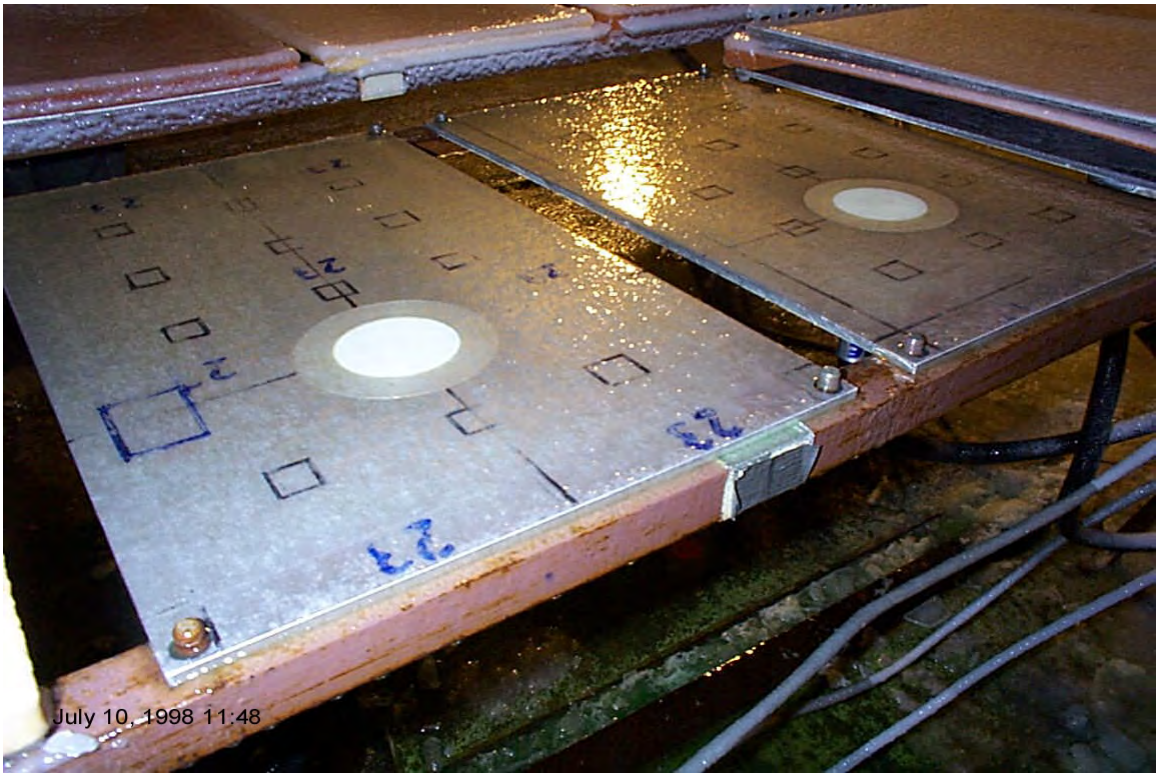
July 10, 1998 11:41


July 10, 1998 11:43


July 10, 1998 11:44


July 10, 1998 11:48

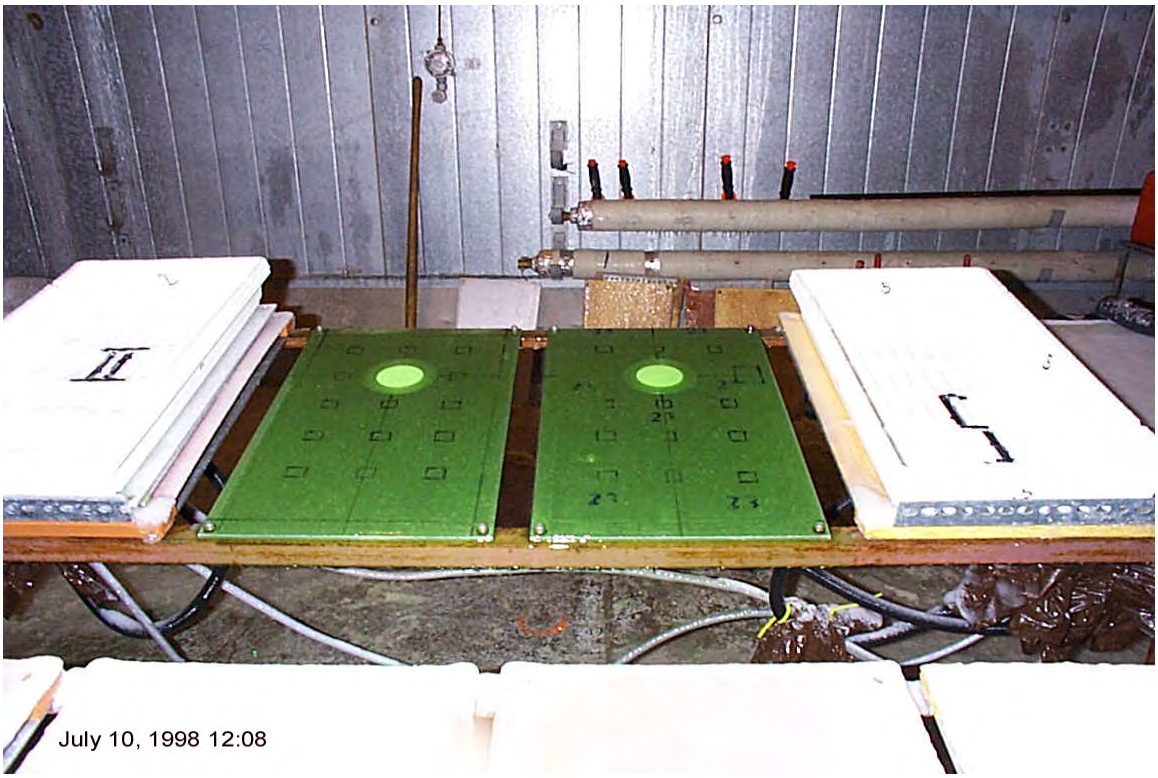

July 10, 1998 11:48


July 10, 1998 11:48

July 10, 1998 11:55

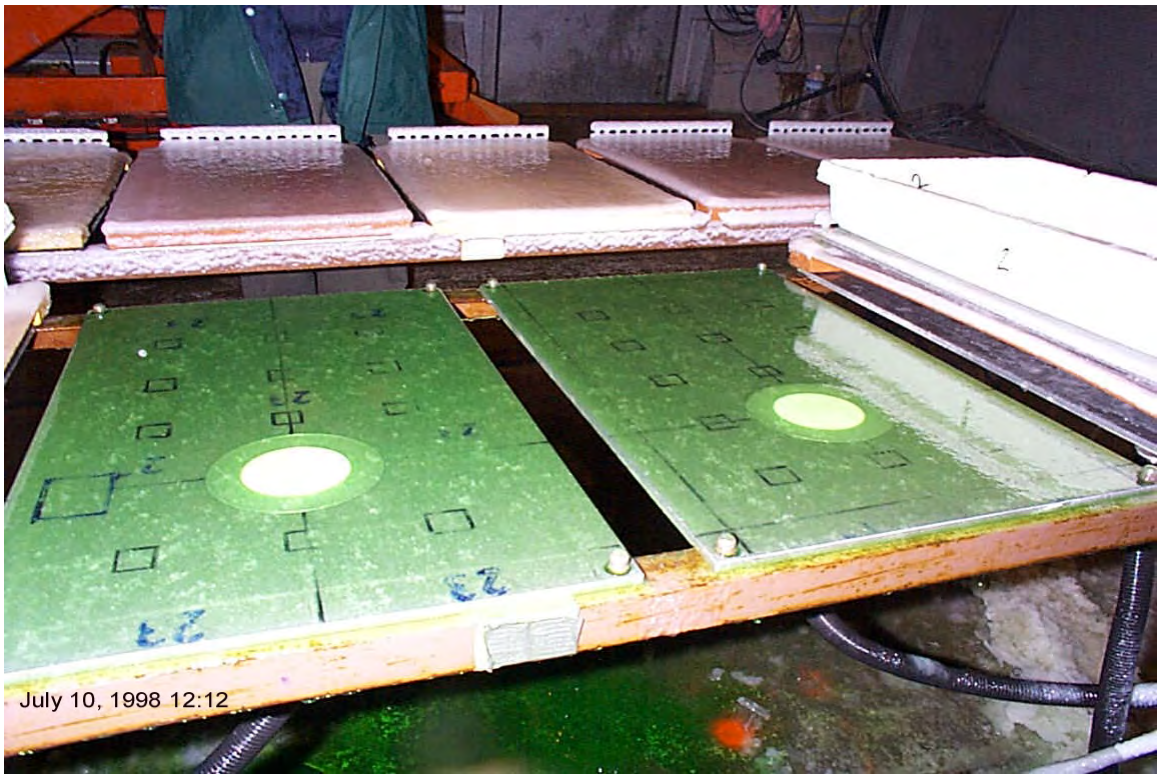
July 10, 1998 11:58

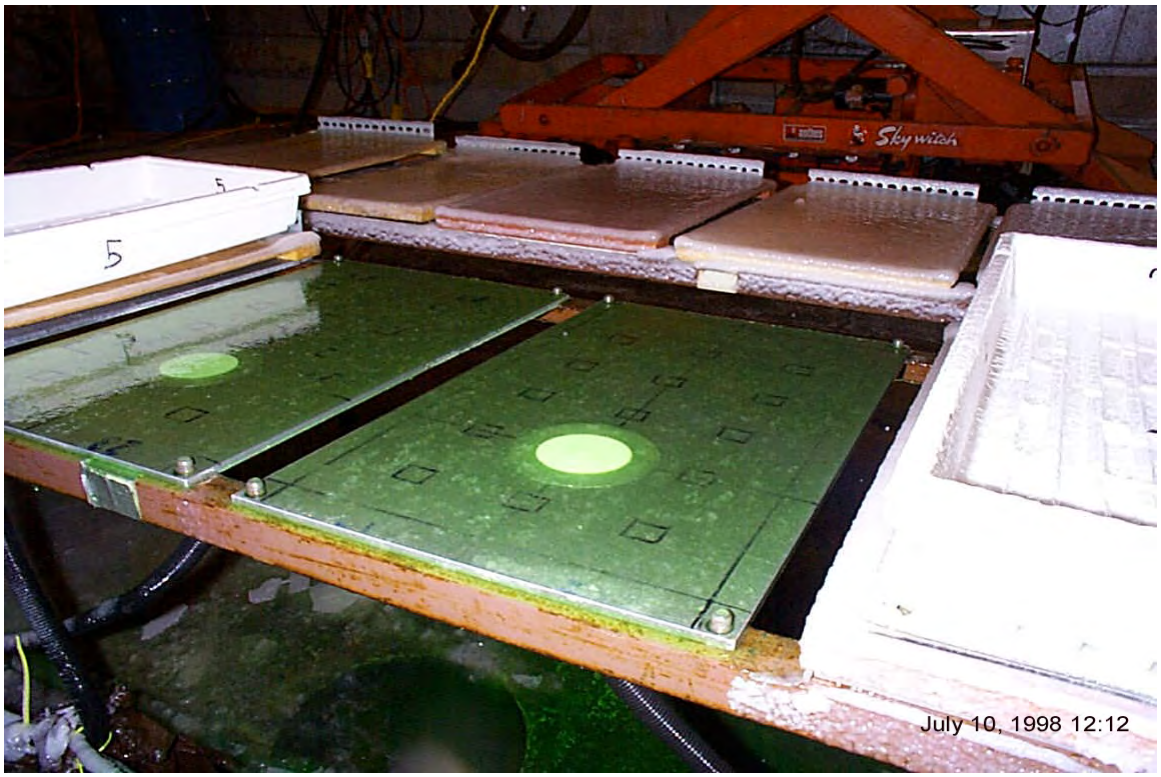
July 10, 1998 11:59

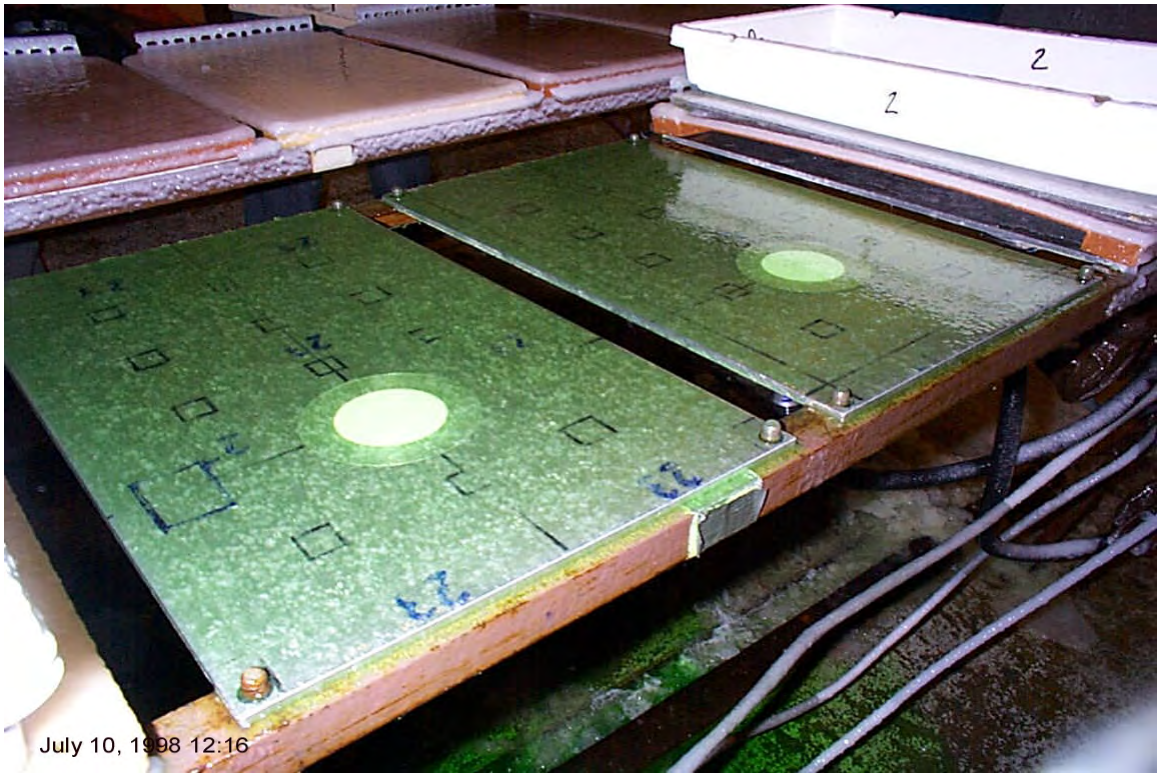


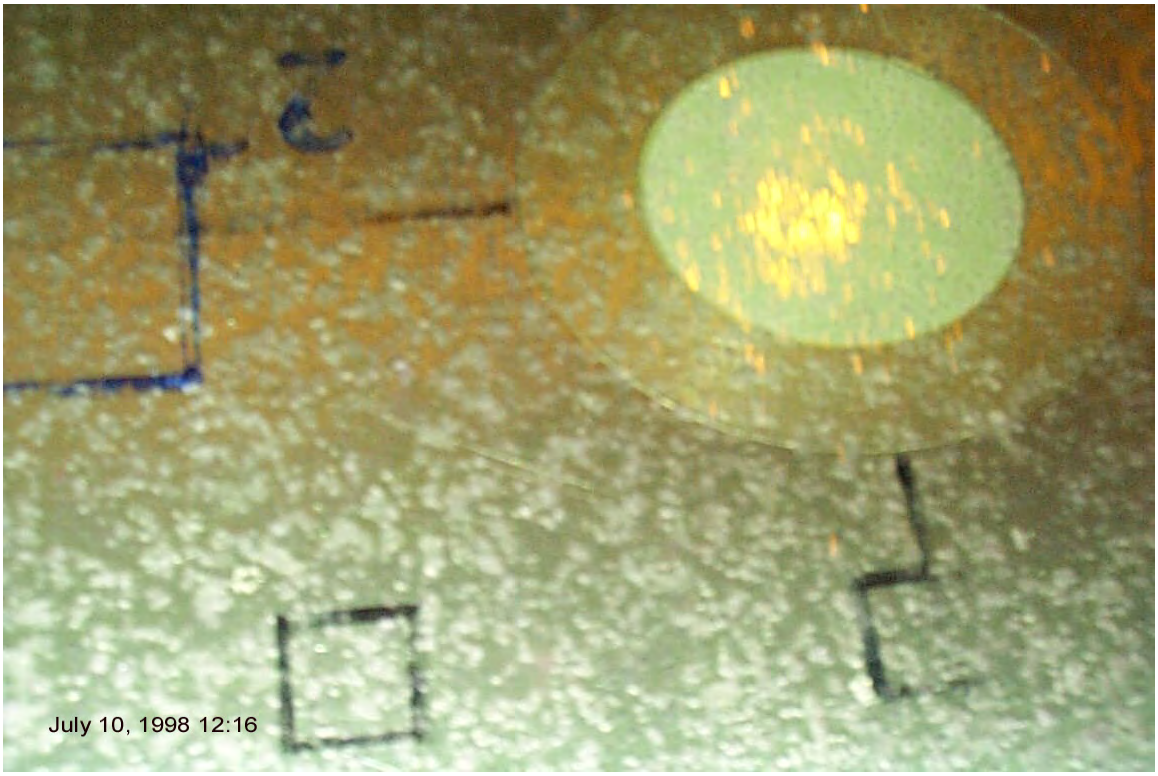
July 10, 1998 12:08

July 10, 1998 12:11


July 10, 1998 12:12


5
July 10, 1998 12:12


2
2
July 10, 1998 12:16


July 10, 1998 12:16

July 10, 1998 12:17

July 10, 1998 12:22

July 10, 1998 12:23

# ANNEX I-VII

## EMAIL DETAILING FINAL POSITION OF HOT SUBCOMMITTEE CHAIRMAN ON INFORMAL BALLOT JULY 24, 1998

Subject: Type IV Fluid HOT value for -ZR Cell at -10 degrees C
Author: Charles Masters at ct27
Date: 7/24/98 5:48 PM

To: Sylvie, Roy, Keith, Uffe, Woody and Dan:
CC: Adriaan, Warren, Jack

Everyone:

The results of the informal ballot on the subject cell for the SAE Type IV fluid HOT value for -ZR indicated 21 approvals, 2 waives, and 6 disapprovals. The disapprovals have been discussed with several of you, however, this email is intended to convey the final position of the co-chairmen of the HOT subcommittee on the subject.

The HOT SAE Generic Table for Type IV fluids for the 1998-99 winter icing season is being sent forward to the Methods subcommittee with the value that were voted on and approved by the informal ballot. This value for this cell is "15 to 30 minutes."

On July 10, HOT tests for this cell for the Type IV fluids in question were conducted in the NRC Climatic Facility at Ottawa Canada. Fluids tested included Octagon Maxflight(100/0), SPCA 480(100/0) and UCAR Ultra+(100/0). In attendance at these tests were the HOT subcommittee Co-chairmen (B. Myers & C. Masters) and representatives of AMIL from the University of Quebec at Chicoutimi, and test personnel from APS Aviation of Montreal. Test conditions in the chamber were a nominal -10 degrees C and rain rate was 25gm/dm2/hr. When appropriate failure criteria was applied, all fluids exhibited HOT's in excess of the 15 minutes currently approved. The AMIL values of 7, 7, and 10 minutes as had been reported earlier were not observed. All test results observed during this period reinforced the need for mechanization and standardization of fluid failure calls and standardization of fluid viscosity at the start of the tests. It is noted that at -10 degrees C fluid failure mechanism and appearances are different for the EG based fluids (Ultra+) than for the PG based fluids (SPCA AD 480 and Octagon Maxflight).

I reiterate: the values for this cell is: 15 to 30 minutes.

I may be contacted at 609-485-4135 for further technical discussions. Barry is currently on vacation.

# APPENDIX J

## DATA FROM TESTS OF ARTIFICIAL SNOW AT

## NATIONAL RESEARCH COUNCIL CANADA CLIMATIC ENGINEERING FACILITY

# Some Aspects in View of the Snow-Making Capability of the NRC-CEF, Ottawa.

## Summary of Data and Results

**Experiments conducted April 02, 1998.**
**NRC Climatic Engineering Facility, Ottawa.**

**Coordinator: Peter Dawson**
**Personnel: Peter Dawson, Antoni Peters**
**Support: APS Test Team, NRC-CEF Staff**

**APS Aviation Inc.**
**1998**

Objectives

Characterize snow produced; crystallinity, agglomeration

Measurement of snow density and precipitation rates as a function of temperature

Optimum positioning of test surfaces for consistency in precipitation rates

Introduction

Snow precipitation rates and rough estimates of snow densities were determined in experiments carried out at the NRC-CEF in Ottawa on April 02, 1988. Temperatures were maintained at -20°C during the morning and allowed to warm to -10°C over the latter course of the afternoon. Snow production was initiated on the first four snow bars situated near the rail entrance of the control side, in the longer portion of the chamber. No fans were employed. The accumulation was subject only to air currents prevaling as a consequence of chamber operation in these conditions.

Once the system equilibrated, five 16" X 16" pre-weighed test plates were positioned around a standard flat-plate test stand. The plates were recovered in measured time intervals before which average heights of snow on each plate were measured using a thin metal ruler, and the snow mass was determined by difference. Snow accumulation was also recorded photographically during the day, and the snow was visually inspected with and without magnification at random intervals during the day.

Data and Results

Snow turned on at 12:45

| Plate No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Tare (+/-1g) | 996 | 1010 | 1019 | 954 | 1206 |
| Area: 16.52dm$^2$ (+/-1mm$^2$) | | | | | |

RUN No. 01
Temp. -20°C
Time 13:10

| Plate No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Gross (+/-1g) | 1117 | 1098 | 1119 | 1019 | ---- |
| Height (+/-1mm) | 7 | 6 | 6 | 4 | |
| Mass (+/-2g) | 121 | 88 | 100 | 65 | ---- |
| Volume (cm$^3$ +/-1mm$^3$) | 1156 | 991 | 991 | 661 | ---- |
| Density (g/cm$^3$) | . 105 | .089 | .101 | .098 | ---- |
| Time (min) | 27 | 27 | 27 | 27 | ---- |
| Rate (g/dm$^2$hr) | 16 | 12 | 13 | 9 | ---- |

RUN No. 02
Temp. -20°C
Time 13:40

| Plate No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Gross (+/-1g) | 1135 | 1072 | 1089 | 1076 | 1141 |
| Height (+/-1mm) | 11 | 5 | 7 | 10 | 17 |
| Mass (+/-2g) | 139 | 62 | 122 | 57 | 157 |
| Volume (cm$^3$ +/-1mm$^3$) | 1817 | 826 | 1156 | 1652 | 2808 |
| Density (g/cm$^3$) | .076 | .075 | .106 | .034 | .056 |
| Time (min) | 25 | 22 | 21 | 15 | 19 |
| Rate (g/dm$^2$hr) | 20 | 10 | 21 | 14 | 30 |

RUN No. 03
Temp. -20°C
Time 14:00

| Plate No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Gross (+/-1g) | 1182 | 1072 | 1158 | 1062 | 1107 |
| Height (+/-1mm) | 14 | 5 | 10 | 16 | 10 |
| Mass (+/-2g) | 186 | 62 | 139 | 108 | 123 |
| Volume ($cm^3$ +/-1$mm^3$) | 2313 | 826 | 1652 | 2643 | 1652 |
| Density ($g/cm^3$) | .080 | .075 | .084 | .041 | .074 |
| Time (min) | 28 | 26 | 31 | 31 | 34 |
| Rate ($g/dm^2hr$) | 24 | 9 | 16 | 13 | 13 |

RUN No. 04
Temp. -20°C
Time 14:40

| Plate No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Gross (+/-1g) | 1155 | 1116 | 1193 | 1091 | 1072 |
| Height (+/-1mm) | 12 | 8 | 9 | 11 | 10 |
| Mass (+/-2g) | 159 | 106 | 174 | 137 | 112 |
| Volume ($cm^3$ +/-1$mm^3$) | 1982 | 1322 | 1487 | 1817 | 1652 |
| Density ($g/cm^3$) | .080 | .080 | .117 | .075 | .068 |
| Time (min) | 31 | 32 | 34 | 35 | 33 |
| Rate ($g/dm^2hr$) | 19 | 12 | 19 | 14 | 12 |

RUN No. 05
Temp. -20°C to -15°C
Time 15:00

| Plate No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Gross (+/-1g) | 1201 | 1201 | 1205 | 1077 | 1164 |
| Height (+/-1mm) | 12 | 10 | 13 | 10 | 11 |
| Mass (+/-2g) | 205 | 191 | 186 | 123 | 180 |
| Volume ($cm^3$ +/-1$mm^3$) | 1982 | 1652 | 2148 | 1652 | 1817 |
| Density ($g/cm^3$) | .103 | .116 | .087 | .105 | .099 |
| Time (min) | 29 | 30 | 28 | 32 | 29 |
| Rate ($g/dm^2hr$) | 26 | 23 | 24 | 14 | 23 |

RUN No. 06
Temp. -15°C to -10°C
Time 16:15

| Plate No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Gross (+/-1g) | 1435 | 1375 | 1347 | 1217 | 1318 |
| Height (+/-1mm) | 25 | 22 | 22 | 18 | 22 |
| Mass (+/-2g) | 439 | 363 | 328 | 263 | 326 |
| Volume ($cm^3$ +/-1$mm^3$) | 4130 | 3634 | 3634 | 2974 | 3634 |
| Density ($g/cm^3$) | .106 | .100 | .090 | .088 | .090 |
| Time (min) | 43 | 44 | 44 | 44 | 48 |
| Rate ($g/dm^2hr$) | 37 | 30 | 27 | 22 | 25 |

RUN No. 07
Temp. -10°C
Time 17:05

| Plate No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Gross (+/-1g) | 1431 | 1140 | 1295 | 1518 | 1520 |
| Height (+/-1mm) | 21 | 6 | 16 | 24 | 24 |
| Mass (+/-2g) | 431 | 130 | 276 | 564 | 536 |
| Volume ($cm^3$ +/-1$mm^3$) | 3469 | 991 | 2643 | 3965 | 3965 |
| Density ($g/cm^3$) | .124 | .131 | .104 | .142 | .136 |
| Time (min) | 32 | 32 | 33 | 34 | 30 |
| Rate ($g/dm^2hr$) | 49 | 15 | 30 | 60 | 65 |

Observations and Discussion

Origin of Errors; mass, height, area, procedural, falling debris (clumps of snow falling of of high-accumulation surfaces in the chamber.

Two nozzles on the lower left snow bar were partially blocked during some of the test period.

Door opened; run 6

Door closed; run 7

Recommendations

Tent to reduce clumps of snow from falling off high-accumulation surfaces
Realization that this would perturb the present air circulation pattern to an unknown extent.