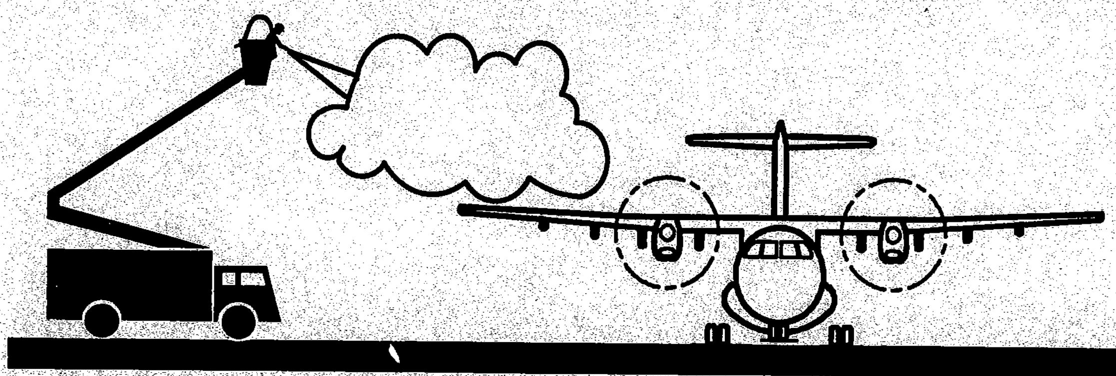
TP 13131E

Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1996/97 Winter



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Transport Canada

and

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William J. Hughes Technical Centre

by

APS AVIATION INC.

October 1997

Final - Version 4.1

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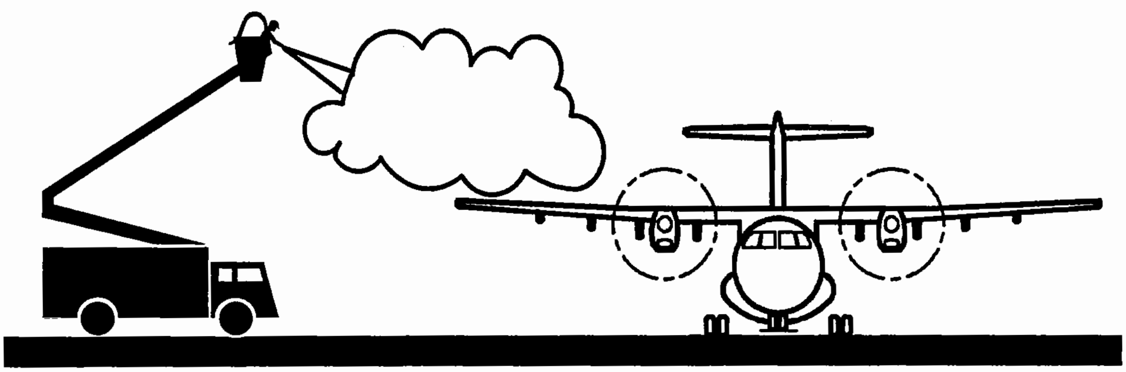

by

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The Transportation Development Centre does not endorse products of 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 complete the substantiation of holdover time tables and evaluate those parameters that may reduce holdover times for currently available and properly qualified SAE deicing and anti-icing fluids (Type I, Type II, Type III, and Type IV);

- To collect weather data on winter storms at airports and to assess the precipitation, wind and temperature values that bound the holdover time ranges given in the tables;

- To develop a procedure for the evaluation of fluid dry-out characteristics and to determine the dry-out characteristics of fluids;

- To determine the influence of fluid type, precipitation, and wind on location and time to fluid failure initiation, and also failure progression on service aircraft; and

- To review, from an operations standpoint, those factors that contribute to the need for a freeze point buffer and make recommendations for possible revisions.

The research activities of the program conducted on behalf of Transport Canada during the 1996/97 winter season are documented in three separate reports. The titles of these reports are as follows:

- TP 13131E Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1996/97 Winter;
- TP 13130E Aircraft Full-Scale Test Program for the 1996/97 Winter; and
- TP 13129E Examination of the Role of Fluid Freeze Point Buffers.

This report, TP 13131E, addresses the objectives to:

- Complete the substantiation of holdover time tables for currently available and properly qualified SAE deicing and anti-icing fluids (Type I, Type II, Type III, and Type IV).

  This objective was addressed by conducting holdover time tests for Type I and Type II fluids in freezing fog at low temperatures and in cold-soaked conditions at precipitation rates up to 76 g/dm²/hr; conducting holdover time tests on Type III fluid over the entire range of conditions covered by the tables; and conducting holdover time tests on all qualified Type IV fluids over the entire range of conditions covered by the tables. Note that the Type III fluid and all Type IV fluids were new formulations released by the manufacturers prior to the test period.

- Collect weather data on winter storms to assess the precipitation, wind, and temperature values, which impose boundary conditions to the holdover time ranges given in the tables.

  This second objective was met as a consequence of outdoor tests conducted at the APS Dorval test site during natural freezing precipitation events.

- Develop a procedure for evaluation of fluid dry-out characteristics and determine the dry-out characteristics of these fluids.

  The third objective was met by performing a preliminary test procedure in an altitude chamber wherein fluids were subjected to simulated flight profiles of typical altitude, temperature and duration.

Research has been funded by the Civil Aviation Group, Transport Canada, with support from the Federal Aviation Administration. This program of research could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre, the Federal Aviation Administration, the National Research Council Canada, Atmospheric Environment Services, Transport Canada, and the fluid manufacturers for their contributions to and assistance with the project. Special thanks are extended to Air Canada, AeroMag 2000, American Airlines, Canadian Airlines International, CanAir Cargo, the Department of National Defence, and Inter-Canadien for provision of personnel and facilities, and for their cooperation on the test program. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data 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). Three reports (including this one) were produced as part of this winter's research program. The subject matter of these reports is provided in the preface.

16. Abstract

The primary objectives of the 1996/97 holdover time test program were to evaluate the performance of the new Type III and Type IV fluids over the entire range of conditions encompassed by the holdover time tables. Additional tests were also performed and include evaluation of fluid thickness on surfaces and development of a method to evaluate and determine fluid dry-out properties.

The holdover time test procedure consisted of pouring fluids onto clean aluminum test surfaces inclined at 10°; failures were recorded as a function of time under conditions of natural snow and simulated freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. The new fluids were supplied by Union Carbide, Hoechst, Kilfrost, and Octagon and were tested neat and in diluted forms. Over 1 000 holdover time tests were performed either at the APS outdoor test site or at the National Research Council Climatic Engineering Facility (Ottawa).

Thickness profiles of new Type IV fluids are considerably different from those of earlier versions. Wide variations in current (Winter 1996/97) fluid performance among different Type IV fluid brands forced development of *fluid-brand specific* holdover time tables. A new data analysis protocol was developed wherein failure data for each fluid brand, for each cell of the tables, were subject to a multi-variable regression treatment. Type III and Type IV fluid holdover times were determined using this method of analysis, resulting in generation of one Type III fluid table, one *generic* SAE Type IV fluid table, and four *fluid-specific* Type IV fluid tables. The holdover times in the *generic* SAE table were 10% lower than those in use during the 1996/97 winter and holdover times in *fluid-specific* tables were 15 to 150% higher, depending on the fluid brand.

A basic dry-out test procedure was developed. Preliminary tests were conducted in an altitude chamber with Type II and Type IV fluids; they indicated that testing at altitude was unnecessary and that a humidity chamber at ground level may be sufficient.

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

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). Trois rapports, dont le présent, ont été produits dans le cadre des recherches menées pendant l'hiver 1996-1997. Leur objet est précisé dans l'avant-propos.

16. Résumé

Le programme d'essais 1996-1997 avait comme principal objectif d'évaluer la performance des nouveaux fluides de type III et de type IV dans toute la gamme des conditions couvertes par les tables de durées d'efficacité. Des essais complémentaires ont aussi été réalisés, qui visaient à examiner certains facteurs influant sur l'épaisseur des fluides sur les surfaces et à élaborer une méthode pour caractériser le phénomène d'assèchement des fluides.

Les essais de durée d'efficacité consistaient à verser les fluides sur des surfaces d'aluminium propres inclinées de 10°, puis à noter la perte d'efficacité des fluides en fonction du temps, sous neige naturelle et sous précipitations artificielles de brouillard verglaçant, de bruine verglaçante, de pluie légère verglaçante, et de pluie sur une aile sur-refroidie. Les nouveaux fluides étudiés ont été fournis par Union Carbide, Hoechst, Kilfrost et Octagon, et ont été essayés sous forme diluée et non diluée. En tout, plus de 1 000 essais de durée d'efficacité ont été effectués, au site d'essai extérieur de APS et dans le laboratoire de recherches climatiques du Conseil national de recherches, à Ottawa.

Les nouveaux fluides de type IV se caractérisent par des profils d'épaisseur très différents de ceux de leurs prédécesseurs. Les larges écarts de performance entre les fluides de type IV de différentes marques mis en lumière par les essais de 1996-1997 ont commandé l'élaboration de tables de durées d'efficacité *spécifiques*, selon la marque du fluide. Un nouveau protocole d'analyse des données a été mis au point, en vertu duquel les résultats inscrits dans chaque case des tableaux d'essais de durée d'efficacité de chaque marque de fluide ont été soumis à une analyse de régression multidimensionnelle. Ce protocole a servi à établir les durées d'efficacité des fluides de type III et de type IV et, ultimement, à produire une table pour les fluides de type III, une table *générique* SAE pour les fluides de type IV, et quatre tables *spécifiques* pour différentes marques de fluides de type IV. Les durées d'efficacité qui figurent sur la table *générique* SAE sont de 10 % inférieures à celles qui étaient en vigueur pendant l'hiver 1996-1997, tandis que celles des tables *spécifiques* se révèlent de 15 % à 150 % supérieures aux valeurs en vigueur, selon la marque du fluide.

Une procédure de base pour les essais d'assèchement a été mise au point. Selon les résultats des essais préliminaires réalisés dans un caisson d'altitude avec des fluides de type II et de type IV, les essais en altitude ne sont pas nécessaires : une enceinte humide à pression normale pourrait suffire.

17. Mots clés Antigivrage, dégivrage, liquide de dégivrage, durées d'efficacité, précipitation	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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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. While a number of objectives of the test program are covered by other related reports, the primary objectives specifically addressed in this document were:

- To test the new Type III and Type IV fluids over the entire range of conditions covered by the holdover time tables;
- To conduct laboratory cold-soak and low temperature freezing fog tests to complete the substantiation of the Type I and Type II holdover time tables;
- To collect weather data on winter storms to assess the precipitation, wind, and temperature values which impose boundary conditions to the holdover times given in the tables; and
- To develop a procedure for the evaluation of fluid dry-out characteristics and to determine the dry-out characteristics of fluids.

Several supplemental objectives were addressed of which the principal ones were:

- To investigate fluid concentration gradients; and
- To conduct evaporation tests to examine the potential development of a *Deicing Only* table.

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

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 the SAE/ISO (Society of Automotive Engineers/International Organization for Standardization) G-12 Holdover Time Subcommittee guidelines. The end condition has been termed as "fluid failure".

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 1996/97 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 performed indoors at the Climatic Engineering Facility of the National Research Council in Ottawa. These included test conditions simulating freezing drizzle, light freezing rain, freezing fog, and rain on cold-soaked surfaces. The listing below indicates that the majority of the more than 1 000 tests were carried out either with Type IV fluids or under natural snow conditions.

CONDITION	Natural Snow	Freezing Drizzle	Light Freezing Rain	Freezing Fog	Cold-Soak	Total
FLUID TYPE						
Type I & II	34	3	7	44	1	**89**
Type III	90	8	9	7	14	**128**
Type IV	553	54	59	57	63	**786**
Total	**677**	**65**	**75**	**108**	**78**	**1 003**

From these tests, 288 holdover times (2 per cell) were determined for Type IV fluids and 26 holdover times were determined for Type III fluids.

Meteorological Considerations

With the cooperation of the Atmospheric Environment Service, APS Aviation was able to obtain detailed meteorological information for the tests at the Dorval site.

Data on precipitation rates for natural snowfall versus temperature were collected to assist in the determination of precipitation rate limits.

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 behaviour of the new Type IV fluids was distinctly different from the behaviour observed for last year's Type IV fluid formulations. Each of the new fluids exhibited different patterns of behaviour upon dilution.

Tests were also conducted to investigate the effect Type I fluids have on stabilized fluid film thickness when overcoated with Type IV fluids. It was found that the first step in two-step fluid applications reduces the combined film thickness by about 10% relative to Type IV fluids alone on dry metal plates.

The effects of heat transfer between heated and unheated fluid reservoirs in thermal contact on deicing vehicles were also investigated. It was found that heated Type IV fluid applied over heated Type I fluid could affect the combined fluid film thickness by reducing it up to one sixth of the film thickness obtained in tests of ambient Type IV fluid over heated Type I fluid.

Analysis Methodology

Wide variations in fluid performance were observed for the different brands of Type IV fluids. Review of the holdover time results by the SAE G-12 Holdover Time Subcommittee at the annual conference on aircraft ground deicing urged the need for a reliable and reproducible *protocol* for the determination of holdover times from the data. A multiple *regression protocol* was devised in which the data for each fluid brand for each precipitation category of the tables were subject to a least squares treatment which determines the power low dependency of failure time on temperature and precipitation rate. The general form of the model equation is given by

$$t = cR^aT^b$$

where t = time; R = rate of precipitation; T = temperature; and a, b, and c are the coefficients to be determined from the fit. The analysis is carried out in a stepwise fashion in which all the data are included in the fit and variables are eliminated if they are found not to influence the failure time. About 70 distinct equations were developed to characterize all Type IV fluid behaviour using this approach. The method was also used to evaluate holdover times for Types I and III fluids, and Type II fluid data for the rain on a cold-soaked wing category.

Holdover Time Tests

Holdover time tables were developed for all SAE-qualified Type IV fluids and one Type III fluid. From the Type IV fluid holdover time tables, one generic SAE *worst case* holdover time table consisting of cells containing the worst-performing fluid holdover times was also developed. The holdover times in this table are on average 10% lower than last year's Type IV fluid holdover times and 40% higher than this year's Type II fluid holdover times.

For the four *fluid-specific* Type IV tables, the categories of snow, freezing drizzle, and light freezing rain adopted the holdover times determined from the regression analysis of each specific fluid. The remaining categories adopt holdover times that are identical to this year's generic SAE *worst case* table values. The holdover times contained in the *fluid-specific* tables (on average) are 15 to 150% longer than those from last year's Type IV fluid table, depending on the fluid brand. The performances of two fluids were found to be superior to the other two fluids in most conditions. One of the former fluids retained its high performance at lower concentrations while the other fluid was severely compromised at the 50/50 dilution, but retained its high performance at low temperatures. Although the performances of the other two fluids were not outstanding, one of them performed relatively well at cold temperature.

The Type III fluid holdover time data were also subject to the regression analysis, and resulted in a new Type III holdover time table that was approved by the SAE G-12 Holdover Time Subcommittee for use during the 1997/98 winter season. Subsequent to testing, the manufacturer of the only available Type III fluid, Union Carbide, issued a warning that diluted forms of Ultra+ fluid are not approved for operational use due to performance deficiencies noted in qualifying tests.

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

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

Fluid Dry-Out

A basic test procedure to examine fluid dry-out characteristics in an altitude chamber was developed and preliminary tests were conducted. Four Type IV fluids and one Type II fluid were subjected to a series of tests simulating flight profiles of typical duration, altitude, and temperature, as well as tests exposing fluids to ambient ground level conditions. Tests indicated that fluid loss at altitude proceeded very slowly, and that fluid loss during aircraft ground time may be a principal consideration in progression of fluid toward dry-out. Based on initial findings, the project was halted, with the general recommendation that any future tests should consider the use of humidity chambers at ground level.

Supplementary Tests

A recycled fluid was subjected to limited holdover time tests and performed as well as one of the Type I fluids.

A successful method was devised for sampling any fluid to determine the existence and magnitude of a concentration gradient established across the fluid thickness during tests. It was found for one fluid that a large concentration gradient is established early in tests, but it is progressively diminished as the fluid thins on its approach to failure, and is ultimately eliminated by the time failure occurs.

Tests were conducted to examine the extent of evaporation and to identify the major volatile components in heated, low concentration aqueous solutions of deicing fluids. Large test surface areas dried completely and the concentration of the solution remaining on the surface increased dramatically relative to its concentration at the start of tests, mostly due to the evaporation of water. This indicates that an inherent temperature buffer exists for applications of heated Type I fluids.

Recommendations

The report lists recommendations based on this year's tests and results. Recommendations were made relating to procedures and equipment, Type II, Type III, and Type IV fluids, and supplementary tests.

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SOMMAIRE

À la demande du Centre de développement des transports de Transports Canada, APS Aviation Inc. a entrepris un programme de recherche visant à faire progresser la technologie sous-jacente aux opérations de dégivrage des avions au sol. On trouvera dans divers autres rapports publiés dans la foulée de ce programme les résultats obtenus à l'égard d'un certain nombre d'objectifs du programme. Le présent rapport rend compte des résultats au regard des objectifs suivants :

- essai des nouveaux fluides de type III et de type IV sous toute la gamme des conditions couvertes par les tables de durées d'efficacité;
- essais en laboratoire mettant en jeu de la pluie sur une aile sur-refroidie et du brouillard verglaçant à basse température, destinés à achever la validation des tables de durées d'efficacité des fluides de type I et de type II;
- collecte de données météorologiques sur les tempêtes hivernales, en vue de déterminer les valeurs de précipitation, de vent et de température figurant des conditions limites aux durées d'efficacité données par les tables;
- élaboration d'une procédure pour évaluer et caractériser le phénomène d'assèchement des fluides.

La recherche visait également plusieurs objectifs complémentaires, dont voici les principaux :

- étudier les gradients de concentration des fluides;
- mener des essais d'évaporation en vue d'examiner la possibilité de mettre au point des tables de durées d'efficacité pour des liquides de *dégivrage seulement.*

Ont participé au programme plusieurs fabricants de liquides dégivrants/antigivrage, le Centre de développement des transports de Transports Canada, le Conseil national de recherches du Canada, la Federal Aviation Administration et le Service de l'environnement atmosphérique.

Les essais de durée d'efficacité consistaient à verser des liquides abaisseurs du point de congélation sur des plaques d'aluminium d'avions propres, plates et inclinées, sous une gamme de conditions verglaçantes, naturelles et simulées. On notait ensuite le temps nécessaire pour qu'une condition prédéterminée, indicatrice de la «perte d'efficacité» du liquide, soit remplie. Cette condition et l'angle d'inclinaison des plaques ont été déterminés en fonction des lignes directrices du Comité G-12 SAE/ISO (Society of Automotive Engineers/Organisation internationale de normalisation) sur les durées d'efficacité.

Les variables mesurées comprenaient le temps couru jusqu'à la perte d'efficacité, le type de précipitation, le taux de précipitation, la précipitation totale, la visibilité, la vitesse du vent, la direction du vent, la température ambiante, la température des surfaces d'essai, la marque du fluide, le type du fluide et la concentration du fluide.

Saisie des données

Les données colligées au cours de la campagne d'essais 1996-1997 se rapportaient à des essais sous précipitations naturelles menés au site d'essais de APS à l'aéroport de Dorval et à des essais sous précipitations artificielles menés à l'intérieur, au laboratoire de recherches climatiques du Conseil national de recherches, à Ottawa. Les conditions d'essai simulées comprenaient des précipitations de bruine verglaçante, de pluie légère verglaçante, de brouillard verglaçant, et de pluie sur des surfaces sur-refroidies. Comme le montre la liste ci-après, la majorité des plus de 1 000 essais mettaient en jeu des fluides de type IV sous des précipitations de neige naturelle.

CONDITION	**Neige naturelle**	**Bruine vergl.**	**Pluie légère vergl.**	**Brouillard vergl.**	**Pluie sur surf. sur-ref.**	**Total**
TYPE FLUIDE						
Type I & II	34	3	7	44	1	89
Type III	90	8	9	7	14	**128**
Type IV	553	54	59	57	63	**786**
Total	**677**	**65**	**75**	**108**	**78**	**1 003**

À partir de ces essais, 288 durées d'efficacité (2 par case) ont été déterminées pour les fluides de type IV et 26 durées d'efficacité pour les fluides de type III.

Facteurs météorologiques

Grâce à la collaboration du Service d'environnement atmosphérique, APS Aviation a pu obtenir des données météorologiques détaillées pour ses essais à Dorval.

Des données sur les taux de précipitation de neige naturelle en fonction de la température ont été colligées, qui seront utiles pour déterminer des taux de précipitation limites.

Essais d'épaisseur

Des mesures d'épaisseur ont été effectuées sur les films de fluides de type IV, et des courbes d'épaisseur en fonction du temps ont été établies pour chaque marque de fluide. Le comportement des nouveaux fluides de type IV s'est révélé sensiblement différent de celui observé chez les fluides de type IV utilisés l'année dernière, dont la formulation était différente. Chacun des nouveaux fluides se comportait différemment, selon qu'il était dilué ou non.

Des essais ont également été menés en vue d'étudier l'effet de la présence d'un fluide de type I sur l'épaisseur stabilisée du film composé d'un fluide de type I recouvert d'un fluide de type IV. Il a été déterminé que la première étape d'une procédure d'application en deux étapes réduit l'épaisseur des films combinés d'environ 10 % par rapport à l'épaisseur d'un fluide de type IV appliqué seul sur une plaque métallique sèche.

Les effets du transfert de chaleur entre des réservoirs de fluide chauffé et non chauffé se trouvant en contact thermique à bord des véhicules de dégivrage ont également été examinés. On a constaté que l'application d'un fluide de type IV réchauffé par transfert thermique par-dessus un fluide de type I chauffé pouvait, de fait, avoir un effet sur l'épaisseur des deux films combinés : l'épaisseur totale des films était diminuée d'une proportion pouvant aller jusqu'à un sixième de celle obtenue en appliquant un fluide de type IV à la température ambiante par-dessus un fluide de type I chauffé.

Méthode d'analyse

De larges écarts ont été observés dans la performance des fluides de type IV, selon la marque de ces fluides. Après examen des résultats des essais de durée d'efficacité, le Sous-comité G-12 de la SAE sur les durées d'efficacité a insisté, à la conférence annuelle sur le dégivrage des avions, sur la nécessité de mettre au point un *protocole* fiable et reproductible pour la détermination des durées d'efficacité à partir des résultats d'essais. Un *protocole d'analyse par la méthode de régression multiple* a été établi, en vertu duquel les résultats obtenus pour chaque marque de fluide et pour chaque type de précipitation couvert par les tables ont été soumis à la méthode des moindres carrés, qui permet de déterminer le seuil de dépendance de la durée d'efficacité par rapport à la température et au taux de précipitation. La forme générale de l'équation est :

$$t = cR^aT^b$$

où t = temps; R = taux de précipitation; T = température; et où a, b, et c sont les coefficients à déterminer à partir de l'ajustement. L'analyse est effectuée par degrés, c'est-à-dire que toutes les données sont prises en compte dans l'ajustement, les variables se révélant sans effet sur la durée d'efficacité étant éliminées. Environ 70 équations distinctes ont ainsi été élaborées pour caractériser le comportement de tous les fluides de type IV. La méthode a également servi à évaluer les durées d'efficacité des fluides de types I et III, ainsi que les résultats des essais de fluides de type II sous précipitations de pluie sur une aile sur-refroidie.

Essais de durée d'efficacité

Des tables de durée d'efficacité ont été établies pour tous les fluides de type IV homologués par la SAE et pour un fluide de type III. À partir des tables des fluides de type IV a été établie une table générique SAE, dite des *cas pires*, reprenant les cases correspondant aux durées d'efficacité des fluides les moins performants. Les durées d'efficacité de cette table sont en moyenne 10 % inférieures aux durées d'efficacité observées l'an dernier pour les fluides de type IV, et 40 % supérieures aux durées enregistrées cette année pour les fluides de type II.

Pour établir les tables *spécifiques* visant les quatre marques de fluides de type IV, les durées d'efficacité obtenues au terme de l'analyse de régression des résultats d'essais de chaque fluide ont été inscrites dans les cases correspondant aux conditions de neige naturelle, de bruine verglaçante, et de pluie légère verglaçante. Pour les autres catégories, on a utilisé des durées d'efficacité identiques à celles de la table générique SAE des *cas pires* découlant des essais de cette année. Les durées d'efficacité figurant dans ces tables *spécifiques* sont (en moyenne) de 15 % à 150 %, selon la marque du fluide, supérieures à celles figurant dans la table des fluides de type IV de l'an dernier. Deux des quatre fluides ont obtenu des performances supérieures, dans la plupart des conditions. Un de ceux-là atteignait un niveau de performance élevé, même à des concentrations plus faibles, tandis que l'autre était beaucoup moins performant lorsque dilué à 50/50, mais demeurait puissant à basse température. Les performances des deux autres fluides ne peuvent être qualifiées d'exceptionnelles, mais l'un d'eux s'est révélé relativement performant à basse température.

Les durées d'efficacité des fluides de type III ont également été soumises à une analyse de régression, après quoi une nouvelle table de durées d'efficacité de ces fluides a été établie, puis approuvée par le Sous-comité G-12 de la SAE pour utilisation pendant l'hiver 1997-1998. À la suite des essais, le fabricant du seul fluide de type III sur le marché, Union Carbide, a émis un avertissement selon lequel les formes diluées du fluide Ultra+ ne sont pas approuvées pour une utilisation opérationnelle, en raison des déficiences constatées lors des essais de qualification.

Aucune modification n'a été apportée aux durées d'efficacité des fluides de type I actuellement en vigueur.

Les durées d'efficacité des fluides de type II ont été l'objet de plusieurs révisions à la baisse, afin de les ramener sous les durées d'efficacité des fluides de type IV homologués par la SAE.

Assèchement des fluides

Une procédure d'essai de base pour l'étude de l'assèchement des fluides dans un caisson d'altitude a été mise au point et des essais préliminaires ont été menés. Quatre fluides de type IV et un fluide de type II ont été soumis à une série d'essais simulant des conditions de vol types (durée, altitude, température) et à d'autres essais reproduisant les conditions ambiantes au sol. Ces essais ont révélé que la perte de fluide en altitude est un processus très lent et que la perte de fluide pendant le temps passé au sol pourrait jouer le rôle principal dans la progression du fluide vers le point d'assèchement. À la lumière de ces premiers résultats, il a été convenu de ne pas avancer plus loin dans cette direction; il a en outre été recommandé d'envisager le recours à des enceintes humides à la pression normale pour les essais futurs.

Essais complémentaires

Un fluide recyclé a été soumis à des essais limités de durée d'efficacité; il s'est révélé aussi performant que l'un des fluides de type I.

Une méthode a été mise au point pour échantillonner un fluide en vue de déterminer l'existence d'un gradient de concentration dans la couche de fluide pendant les essais et, le cas échéant, la valeur de ce gradient. Dans le cas d'un des fluides, un important gradient de concentration a été noté au début des essais, celui-ci diminuant graduellement à mesure de la dilution du fluide et de sa progression vers la perte d'efficacité, jusqu'à devenir nul au moment de la perte d'efficacité.

Des essais ont été réalisés pour examiner le degré d'évaporation de fluides dégivrants en solutions aqueuses faiblement concentrées et chauffés, et pour caractériser leurs principaux composés volatils. Sur des surfaces d'essai de grande superficie complètement asséchées, la concentration de la solution subsistant sur la surface était considérablement supérieure à sa concentration au début des essais, en raison surtout de l'évaporation d'eau. On peut en déduire qu'il existe une marge de sécurité inhérente pour ce qui est de la température d'application des fluides de type I chauffés.

Recommandations

Le rapport énumère une série de recommandations découlant des essais et des résultats de cette année. Ces recommandations touchent les procédures et le matériel d'essai, les fluides de types II, III et IV, et les essais complémentaires à effectuer.

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GLOSSARY

APS	APS Aviation Inc.
C/FIMS	Contamination/Fluid Integrity Monitoring System
HOT	Holdover Time
ISO	International Organization for Standardization
LWC	Liquid Water Content
MVD	Median Volume Diameter
POSS	Precipitation Occurrence Sensing System
READAC	Remote Environmental Automatic Data Acquisition Concept
ROCSW	Rain on a Cold-Soaked Wing
RVSI	Robotic Vision Systems Inc.
SAE	Society of Automotive Engineers
UQAC	Université du Québec à Chicoutimi
WSET	Water Spray Endurance Test
ZD	Freezing Drizzle
-ZR	Light Freezing Rain

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1. INTRODUCTION

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. undertook a research project to further advance pre-flight aircraft de/anti-icing technology.

Over the years APS Aviation has completed substantial testing on behalf of Transport Canada relating not only to the determination of fluid holdover times, but also to the development of deicing technology in general. A summary of research activities related to fluid holdover time testing is provided in Table 1.1.

Ice formation and accumulation on flight surfaces has been the subject of concentrated industry attention due to a number of related fatal aviation accidents over the past two decades. Much of this attention has been focused on ground-based deicing and anti-icing operations and technologies.

Particular emphasis has been placed upon the enhancement of anti-icing fluid properties and performance. In order to extend the duration of protection against the accumulation of freezing precipitation on flight surfaces, thickened anti-icing fluids are used subsequent to initial deicing. New anti-icing aviation fluids continue to be developed by leading manufacturers with the specific objective of extending holdover times without compromising aerodynamics.

Aircraft are deiced using heated Type I fluids. These fluids are excellent for ice and snow removal, but provide limited protection against further ice accumulation. Type II fluids are thicker and much more viscous than Type I fluids. They assume a thicker film layer on application and provide a longer duration of protection. Type III fluid is also a thickened fluid with physical properties that lie between Type I and Type II fluids. Type III fluid shear and flow properties are designed for aircraft with lower take-off speeds. Type IV fluids are the latest generation of anti-icing fluids and have been developed to provide the maximum anti-icing holdover time protection. The results of Type IV fluid tests conducted during the 1996/97 winter season constitute the major focus of this report. All Type IV fluids tested during the 1996/97 winter season were new formulations developed by competing fluid manufacturers.

Testing of these fluids has resulted in the development of holdover time tables. These reference tables provide airline operators with guidelines for use in departure planning. The tables take into consideration the following: fluid type, fluid concentration, outside air temperature, type of precipitation, and rate of precipitation. The tables are recognized and accepted by aviation regulatory authorities and endorsed for use worldwide by aircraft operators.

TABLE 1.1

SUMMARY OF APS HOLDOVER TIME TESTING ACTIVITIES

Year	Transport Canada 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) • Simulated Freezing Drizzle (preliminary) • Simulated Freezing Fog (outdoor)	Type I (Standard)	Dorval and Ottawa (NRC)
1993/94	Summary Report Available	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (outdoor)	Type II (75/25, 50/50)	Dorval and Ottawa (NRC)
1994/95	TP 12654E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface (preliminary)	• Type I (Diluted for 10°C buffer) • Type IV (Preliminary)	Dorval and Ottawa (NRC)
1995/96	TP 12896E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	Type IV	Dorval and Ottawa (NRC)
1996/97	TP 13131E	• Natural Precipitation • Simulated Freezing Drizzle • Simulated Light Freezing Rain • Simulated Freezing Fog (indoor) • Rain on a Cold-Soaked Surface	• New Type IV's • Type III	Dorval and Ottawa (NRC)

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Printed: 7/28/98

1.1 Holdover Time Tables

Holdover time tables for each fluid type 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 fluid; and Table 1.5 is for Type IV fluids. These tables contain the holdover times which were in use during the 1996/97 winter season. Note that each table is composed of cells, and each cell contains a holdover time range which corresponds to a particular fluid dilution (neat, 75/25, or 50/50), temperature range, and category of precipitation. The range is defined by a lower time and an upper time.

The holdover time tables shown here were first published in last year's holdover time report, Transport Canada report TP 12896E (1). Each cell in each table is labelled with an indicator designating its status at the time of publication. The *S* designation indicates holdover times for which specific conditions and fluids had been substantiated. The *NS* designation indicates holdover times which had not been substantiated. These tables provided the basis for selecting tests to be performed during the 1996/97 winter season and serve as a reference point for discussions and analyses of the most recent data collected.

Tests on Type I and Type II fluids were carried out largely to eliminate the *NS* designations remaining in the respective holdover time tables and to confirm the reproducibility of test condition simulation and the consistency in calling of failures. Tests on Type III fluid were conducted to fully evaluate Type III fluid performance and to generate an operational Type III fluid holdover time table. The primary effort, however, was directed toward the comprehensive testing of four new Type IV fluid brands. Analysis of the data indicated a need to develop *fluid-specific* holdover time tables in addition to a generic or *worst case* fluid holdover time table encompassing the behaviour of all qualifying Type IV fluids. This approach was taken due to wide variations in performance observed among the different brands of Type IV fluid. In total, 1 003 holdover time tests were conducted during the 1996/97 test season.

Extensive natural precipitation tests were carried out at the APS Dorval test site. These included snow and non-snow natural precipitation events as well as fluid thickness tests. Freezing drizzle, light freezing rain, freezing fog, rain on a cold-soaked surface, and fluid thickness tests were also conducted at the Climatic Engineering Facility of the National Research Council in Ottawa. 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 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 1997/98 winter season. The tables are presented in Subsection 6.5.

TABLE 1.2

SAE/ISO HOLDOVER TIME TABLE FOR TYPE I FLUIDS USED IN 1996/97

Guideline for Holdover Times Anticipated for SAE Type I and ISO Type I Fluid Mixtures as a Function of Weather Conditions and OAT.

The responsibility for the application of these data remains with the user.

SAE TYPE I

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°	00:45 S	0:12-0:30 NS	0:06-0:15 S	0:05-0:08 S	0:02-0:05 S	0:02-0:05 NS
0 to -10	32 to 14	00:45 S	0:06-0:15 S	0:06-0:15 S	0:05-0:08 S	0:02-0:05 S	
below -10	below 14	00:45 S	0:06-0:15 S	0:06-0:15 S			

°C = Degrees Celsius
°F = Degrees Fahrenheit
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 TIMETABLE CELL.

S = Substantiated
NS = Not Substantiated

TABLE 1.3

SAE/ISO HOLDOVER TIME TABLE FOR TYPE II FLUIDS USED IN 1996/97

Guideline for Holdover Times Anticipated for SAE Type II and ISO Type II Fluid Mixtures as a Function of Weather Conditions and OAT.
The responsibility for the application of these data remains with the user.

SAE TYPE II

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 S	1:15-3:00 NS	0:20-1:00 S	0:30-1:00 S	0:15-0:30 S	0:20-0:40 NS
		75/25	06:00 S	0:50-2:00 NS	0:15-0:45 S	0:20-0:45 S	0:10-0:25 S	0:10-0:25 NS
		50/50	04:00 S	0:35-1:30 NS	0:05-0:15 S	0:15-0:25 S	0:05-0:15 S	
0 to -3	32 to 27	100/0	08:00 S	0:35-1:30 S	0:20-0:45 S	0:30-1:00 S	0:15-0:30 S	
		75/25	05:00 S	0:25-1:00 S	0:15-0:30 S	0:20-0:45 S	0:10-0:25 S	
		50/50	03:00 S	0:15-0:45 S	0:05-0:15 S	0:15-0:25 S	0:05-0:15 S	
below -3 to -14	below 27 to 7	100/0	08:00 S	0:35-1:30 S	0:20-0:45 S	**0:30-1:00 S	**0:10-0:30 S	
		75/25	05:00 S	0:25-1:00 S	0:15-0:30 S	**0:20-0:45 S	**0:10-0:25 S	
below -14 to -25	below 7 to -13	100/0	08:00 NS	0:35-1:30 S	0:20-0:45 S			
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. NS	NS				

°C = Degrees Celsius
°F = Degrees Fahrenheit
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 WIN 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 DECISIOIN CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE TIME TABLE CELL.

S = Substantiated
NS = Not Substantiated

TABLE 1.4

PRELIMINARY HOLDOVER TIME TABLE FOR TYPE III FLUID

Guideline for Holdover Times Anticipated for SAE Type III and ISO Type III Fluid Mixtures as a Function of Weather Conditions and OAT. The responsibility for the application of these data remains with the user.

SAE TYPE III FLUID

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 NS	00:40 to 02:00 NS	00:15 to 01:00 NS	00:20 to 01:00 NS	00:15 to 00:30 NS	00:10 to 00:25 NS
0 to -3	32 to 27	05:00 NS	00:40 to 02:00 NS	00:15 to 01:00 NS	00:20 to 01:00 NS	00:15 to 00:30 NS	
below -3 to ??	below 27 to ??	05:00 NS	00:40 to 02:00 NS	00:15 to 01:00 NS	00:20 to 01:00 NS	00:10 to 00:25 NS	

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

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 TIMETABLE CELL.

NS = Not Substantiated

TABLE 1.5

SAE/ISO HOLDOVER TIME TABLE FOR TYPE IV FLUIDS USED IN 1996/97

Guidelines for Holdover Times Anticipated for SAE Type IV and ISO Type IV Fluid Mixtures as a Function of Weather Conditions and OAT. The responsibility for the application of these data remains with the user.

SAE TYPE IV

OAT °C	OAT °F	SAE Type IV Fluid Concentration Neat-Fluid/Water (Vol %/Vol %)	*FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING
			Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
above 0°	above 32°	100/0	18:00 S	2:00-3:00 S	0:55-1:40 S	0:45-1:50 S	0:30-1:00 S	0:20-0:40 NS
		75/25	06:00 S	0:40-2:00 S	0:20-1:00 S	0:20-1:00 S	0:15-0:30 S	0:10-0:25 NS
		50/50	04:00 S	0:15-0:45 S	0:05-0:25 S	0:07-0:15 S	0:05-0:10 S	
0 to -3	32 to 27	100/0	12:00 S	2:00-3:00 S	0:45-1:40 S	0:45-1:50 S	0:30-1:00 S	
		75/25	05:00 S	0:40-2:00 S	0:15-1:00 S	0:20-1:00 S	0:15-0:30 S	
		50/50	03:00 S	0:15-0:45 S	0:05-0:20 S	0:07-0:15 S	0:05-0:10 S	
below -3 to -14	below 27 to 7	100/0	12:00 S	2:00-3:00 S	0:35-1:15 S	**0:45-1:50 S	**0:30-0:55 S	
		75/25	05:00 S	0:40-2:00 S	0:15-1:00 S	**0:20-1:00 S	**0:10-0:25 S	
below -14 to -25	below 7 to -13	100/0	12:00 S	1:00-2:00 S	0:30-1:10 S			
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
FP = Freezing Point

* During conditions that apply to aircraft protection for ACTIVE FROST
** The lowest temperature is limited to -10°C(14°F)
*** Use light freezing rain holdover times is 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 VELOICTY OF JET BLAST MAY REDUCE HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME BELOW THE LOWEST TIME STATED IN THE RANGE. HOLDOVER TIME MAY BE REDUCED WHEN THE AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT. THE ONLY ACCEPTABLE CRITERIA TIME IS THE SHORTEST TIME WITHIN THE APPLICABLE TIME TABLE CELL.

S = Substantiated

NS = Not Substantiated

1.2 Objectives

The detailed objectives of the holdover test program to be carried out during the 1996/97 winter season are provided in the work statement included as Appendix A. The primary objectives of the program are summarized below:

- To test the new Type III and Type IV fluids over the entire range of conditions covered by the holdover time tables;
- To conduct laboratory cold-soak and low temperature freezing fog tests to complete the substantiation of the Type I and Type II holdover time tables;
- To collect weather data on winter storms to assess the precipitation, wind and temperatures values which impose boundary conditions to the holdover times given in the tables; and
- To develop a procedure for the evaluation of fluid dry-out characteristics and to determine the dry-out characteristics of fluids.

Several supplemental objectives were addressed of which the principal ones were:

- Investigation of fluid concentration gradients; and
- Evaporation tests to examine the potential development of a *Deicing Only* table.

1.3 Report Format

The following list provides short descriptions of the contents of the remaining sections of this 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 data acquisition, test locations, and distributions of precipitation rates and related meteorological information for all categories of precipitation covered by this report. It also includes a comparison of APS meteorological data with Atmospheric Environment Services READAC data;
- Section 4 presents fluid thickness tests and results in controlled non-precipitation conditions;

- Section 5 presents the methodology used in the analysis of data. This section describes the precipitation rate ranges as well as the new *protocols* for the determination of holdover times. The concept of a *worst case* (generic) fluid and the development of *fluid-specific* holdover time tables are also explained;

- Section 6 presents the results of holdover time tests, discussions on fluid performance and the holdover time tables to be used during the 1997/98 winter season;

- Section 7 presents supplementary tests carried out during the 1996/97 test season and results. The evaluation of fluid dry-out characteristics has been included as part of this section;

- Section 8 presents conclusions derived from the complete test program and evaluation of the data; and

- Section 9 lists the recommendations for further testing.

The data for all 1996/97 winter season tests are listed in Appendix D of this report.

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2. METHODOLOGY

This chapter contains descriptions of the tests, equipment, and procedures used during the 1996/97 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 are sub-divided 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 upon 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 Centre for Atmospheric Research from the World Meteorological Organization Guide to Meteorological Instruments and Methods of Observation (1983), and from the American Meteorological Society, Glossary of Meteorology WSOH # 7 Manual of Surface Weather Observations (MANOBS) (3/94). This table is a revised version of the one which was included in Transport Canada report, TP 12896E.

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 holdover 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 Section 5.

2.1.1 Snow

Table 2.1 provides the criteria used to estimate the intensity of snow. This is based upon horizontal visibility as follows:

- Light — Visibility is ≥ 1.0 km
- Moderate — Visibility is 0.5 km to < 1.0 km
- Heavy — Visibility is < 0.5 km

TABLE 2.1
DEFINITIONS OF WEATHER PHENOMENA

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

Intensity Criteria**

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

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

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

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

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

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

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

Visibility is, however, only an indicator of the snow intensity (see Table 2.1), and the two parameters are not always correlated.

This table also contains proposed definitions for Liquid Equivalent Snow Intensity which correspond to the distances described above. These values correspond to the values adopted by the SAE G-12 Holdover Time Subcommittee for use in the development of the holdover time tables.

Table 2.2 has been devised by the National Centre for Atmospheric Research and Transport Canada in order to counter inadequacies in the standard definition. This table is based on the National Centre for Atmospheric Research field data and theoretical work on classes of snow. The National Centre for Atmospheric Research has classified the snow data by crystal arrangement and temperature and correlated this information with visibility measurements. The table is a more detailed scheme than the one outlined above. It gives visibility in distance for three snowfall intensities both in daylight and darkness (night). Table 2.2 is being adopted by Transport Canada.

2.1.2 Freezing Drizzle

Freezing drizzle is composed exclusively of closely packed fine droplets with a diameter less than 0.5 mm (see Table 2.1). The intensity is determined, as for snow, through the measurement of visibility. The holdover time table has one column for freezing drizzle; however, 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/hr. For heavy freezing drizzle, the definition indicates that the intensity is greater than 5 g/dm²/hr. Discussions between United Airlines, National Centre for Atmospheric Research and the National Research Council led to the adoption of the upper limit value of 12.7 g/dm²/hr for freezing drizzle. This value was also used as the lower limit for light freezing rain.

2.1.3 Freezing Rain and 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. As with snow and drizzle, three intensity levels are defined, and for each level, a (subjective) guideline is provided in Table 2.1 for an observer to determine whether the intensity is light, moderate or heavy. The following definitions apply when an instrument is available to measure the intensity of precipitation:

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/hr, moderate intensity as 1 mm/hr to 2.5 mm/hr, heavy as greater than 2.5 mm/hr (Heavy snow is rarely seen at the lower temperatures).

* Draft Version

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

2.1.4 Freezing Fog

Freezing Fog is defined as a low altitude aerosol or suspension of ultrafine liquid water particles in air. At temperatures below 0°C, these particles 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 1996/97 winter was performed at Montreal's Dorval airport. The location of the site at Dorval is shown on the plan view of the airport in Figure 2.1 (this figure is included at the end of this section). Photo 2.1 was taken at the site and shows a remote icing sensor mounted on top of the test stand on the left and the trailer at the back. The trailer used for the 1995/96 winter was reused for the 1996/97 winter. An additional door was installed on the side facing the test stands to facilitate access for measurement of total precipitation. The test site is located adjacent to Environment Canada's Atmospheric Environment Services automated weather observation station (Photo 2.2) at Dorval airport. Some in-situ testing was also carried out by the National Centre for Atmospheric Research at Denver and results from these tests have been incorporated into this report.

Freezing Fog, Freezing Drizzle and Light Freezing Rain are not sufficiently encountered to provide adequate test data. As a result these conditions have been simulated. Tests under conditions of freezing fog, rain on a cold-soaked surface, freezing drizzle, and light freezing rain were conducted at the National Research Council's indoor Climatic Engineering Facility, where precipitation was artificially produced.

Photo 2.3 provides a general indication of the size of the facility. Photo 2.4 is an interior shot, showing testing underway. 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 -46°C.

2.3 Test Conditions

Outdoor tests were conducted during natural freezing precipitation events. Tests to simulate freezing precipitation were carried out at the National Research Council Climatic Engineering Facility. Subsection 2.3.1 and 2.3.2 provide a description of the spray assembly (see Photo 2.5) 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

Over the last 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. The actual spray assembly consists of two to four droplet delivery nozzles, attached to the end of a rocker arm. The rocker arm is centre-mounted to a rotating shaft. A drive mechanism imparts a smooth see-saw motion to the shaft which is synchronously translated back-and-forth along its axis of rotation. The combined actions result in a circle-eight-shaped droplet pattern. Some calibration experiments were conducted prior to 1995 by the National Research Council using an optical gauge manufactured by HSS (see Photo 2.6) to verify that the simulation of freezing fog, freezing drizzle and light freezing rain duplicated natural conditions.

Calibration of droplet size was also required for tests conducted under conditions of moderate and heavy 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* employed by the National Research Council at the Climatic Engineering Facility. 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 2.7) under artificial precipitation for a fixed time in order to acquire a droplet size pattern. Figure 2.2 illustrates the appearance of such a pattern acquired under conditions of drizzle. A calibration curve (Figure 2.3), is than used to convert from the measured diameter of the droplets on the pattern to the experimental median volume diameter.

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

FIGURE 2.2

DROPLET SIZE PATTERN PRODUCED AT NATIONAL RESEARCH COUNCIL FREEZING DRIZZLE

This figure was reduced by 50%.

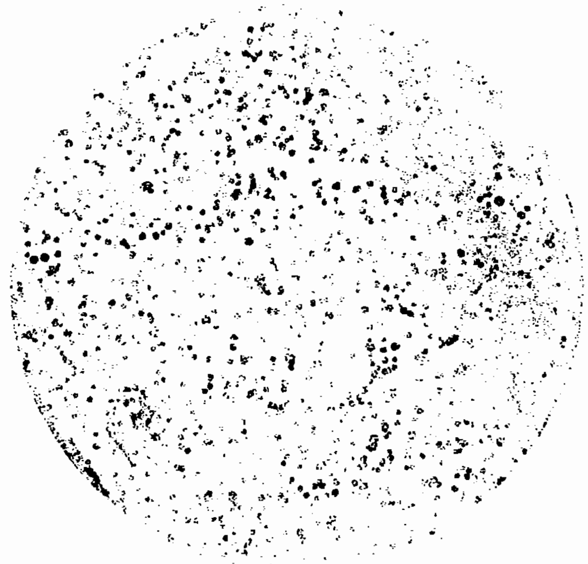
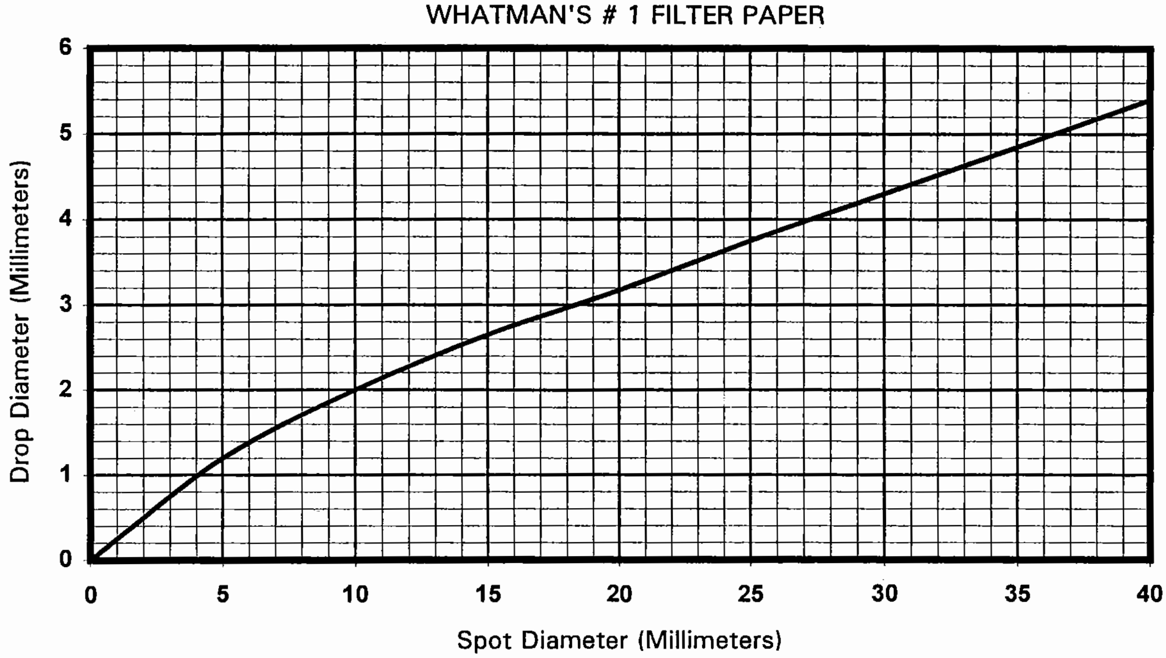


FIGURE 2.3

CONVERSION OF SPOT DIAMETER TO DROP DIAMETER

WHATMAN'S # 1 FILTER PAPER



2.3.2 Median Volume Diameter of Rain Drops

The median volume diameter (MVD) of a rain droplet has been researched 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/hr. At 25 g/dm²/hr, this equation gives an MVD of 1.2 mm, at 76 g/dm²/hr the MVD is 1.6 mm, and for 150 g/dm²/hr the MVD is 1.9 mm.

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

	Experimental MVD (mm)	**Theoretical Range of MVD (mm)**
Heavy Rain	1.6	$>$ 1.6
Moderate Rain	1.4	1.2 to 1.6
Light Rain	1.0	$<$ 1.2
Drizzle	0.3	$<$ 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:
- Droplet median volume diameter: 300 µm;
- Precipitation rate: less than 12.7 g/dm²/hr;
- Droplets produced with two # 24 hypodermic needles; and
- Air temperature: 0 to -10°C.

ii) Light Freezing Rain:
- Droplet median volume diameter: 1 000 µm;
- Precipitation rate: 12.7 to 25 g/dm²/hr;
- Droplets produced with two # 20 hypodermic needles; and
- Air temperature: 0 to -10°C.

iii) Drizzle and Light Rain on a Cold-Soaked Surface:
- Same as items i) and ii), except air temperature was +2°C.

iv) Moderate Rain on a Cold-Soaked Surface:
- Droplet median volume diameter: 1 400 μm;
- Precipitation rate: 25 to 76 g/dm²/hr;
- Droplets produced with two # 17 hypodermic needles; and
- Air temperature: +2°C.

v) Heavy Rain on a Cold-Soaked Surface:
- Droplet median volume diameter: 1 600 μm;
- Precipitation rate: more than 76 g/dm²/hr;
- Droplets produced with two # 17 and two # 18 hypodermic needles; and
- Air temperature: +2°C.

vi) Freezing Fog:
- Droplet median volume diameter: 30 to 60 μm;
- Liquid water content: 0.2 to 0.6 gm³;
- Air temperature: 0 to -27°C;
- Precipitation rate: 2 to 10 g/dm²/hr; and
- Fog was produced with two bars of four 20 mm/50 mm spraying nozzles (20 mm represents the bore of each nozzle, while 50 mm represents the outside diameter of each nozzle).

2.4 Equipment

Figure 2.4 shows a schematic of the stand used for testing. Six test plates are normally mounted on the stand, inclined at a 10° 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"), 15 cm (6") and 30 cm (12") from the top of the plate. The plates were marked with 15 crosshairs used in determining whether end conditions (see Subsection 2.5.2 for definition) were achieved. Photo 2.8, 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 (6") line.

The top of 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. Two plate pans are used during a test with six panels to measure the quantity of precipitation. The pans are weighed every 15 minutes.

FIGURE 2.4

FLAT PLATE TEST SET-UP

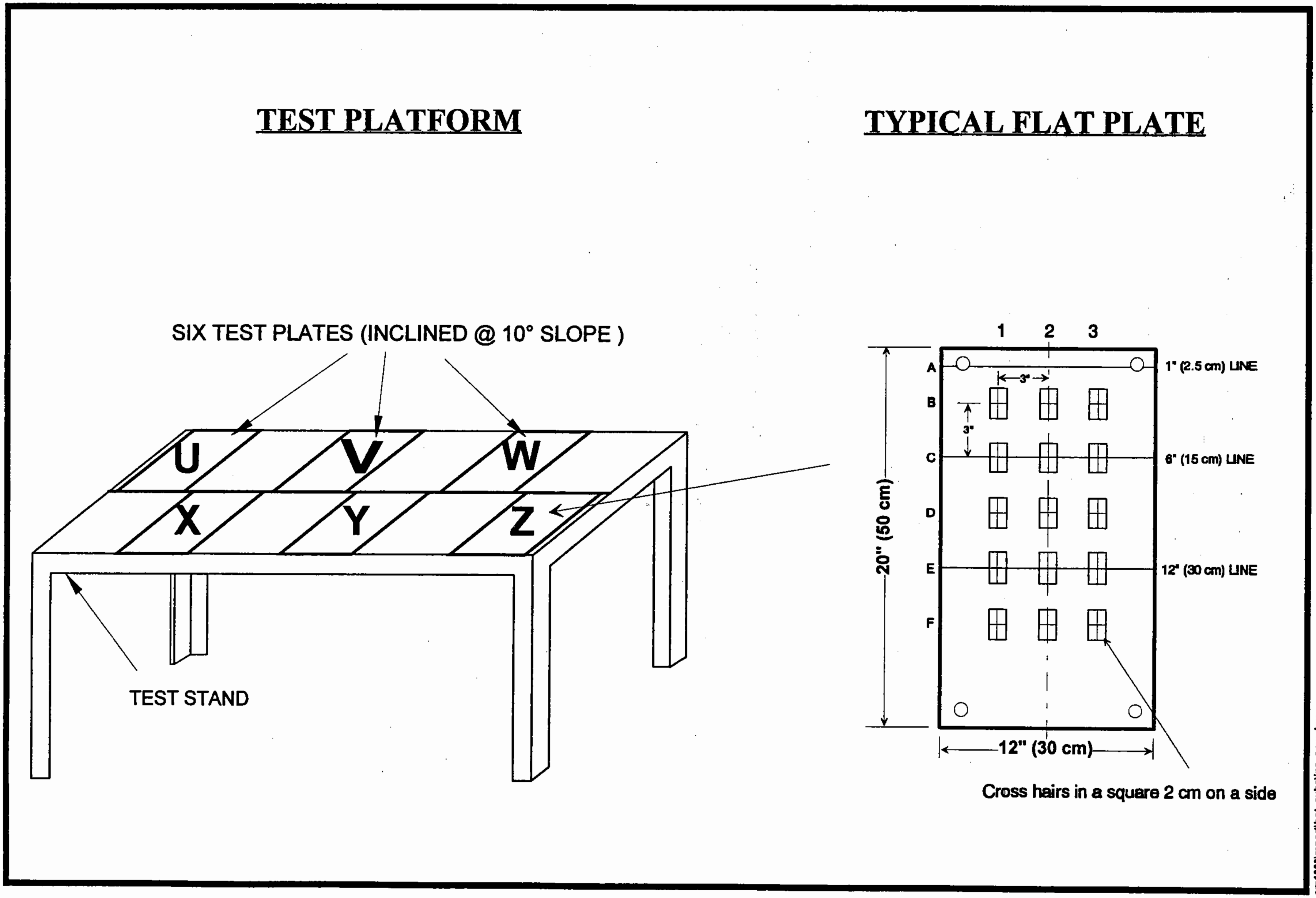
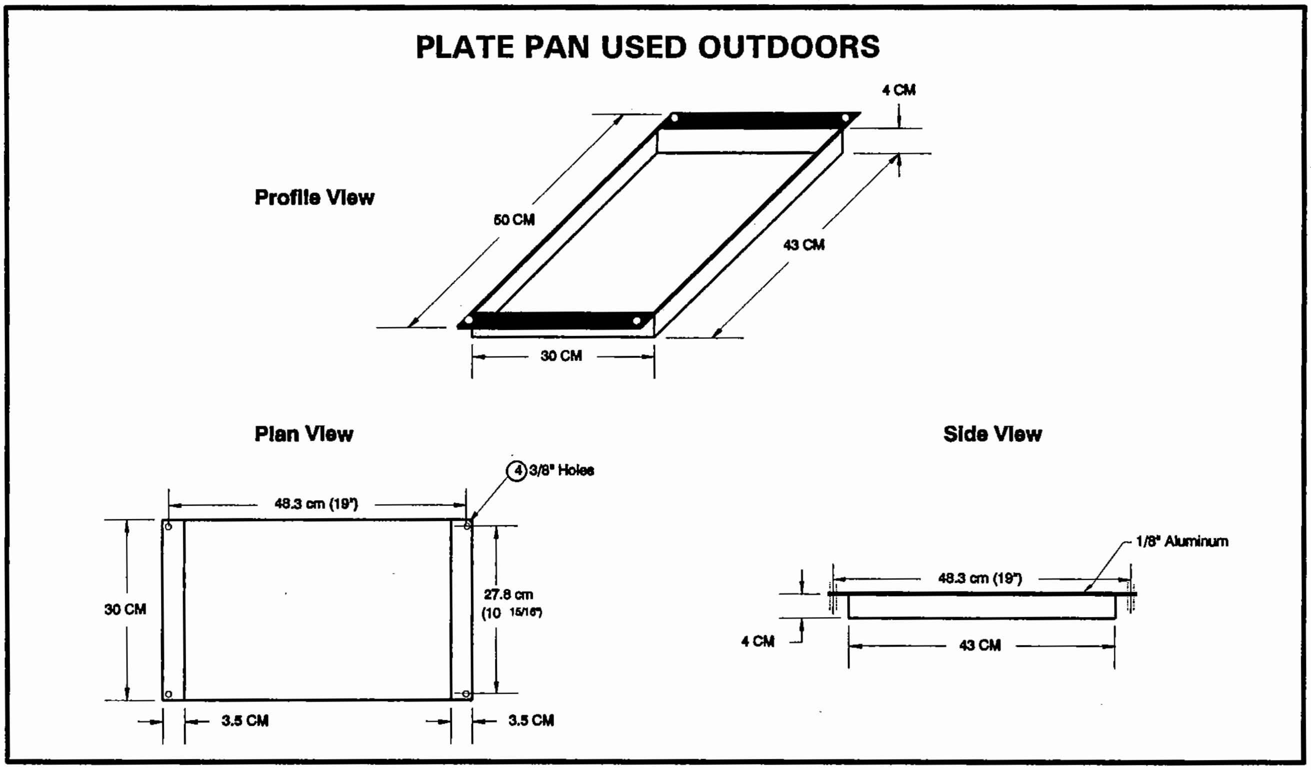
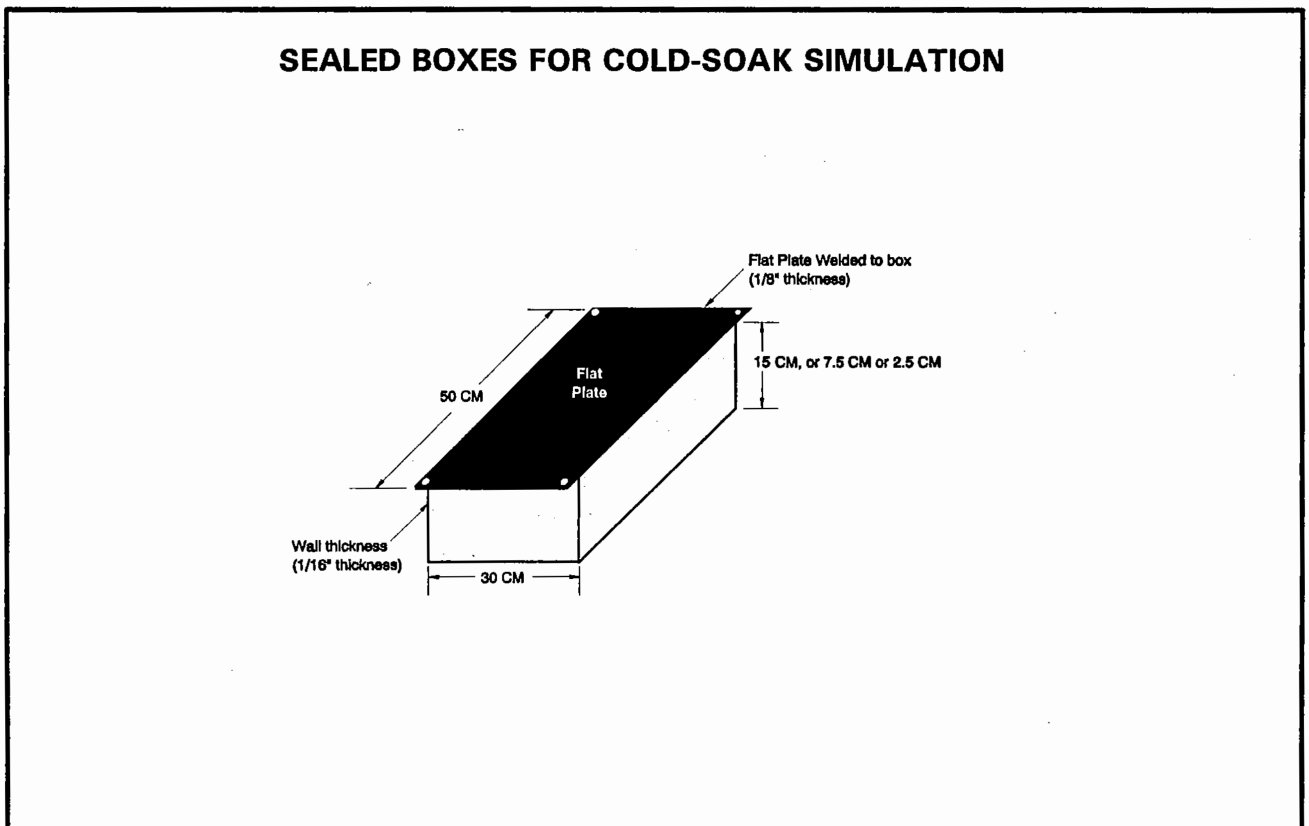


FIGURE 2.5

SCHEMATICS OF PLATE PAN AND SEALED BOXES





cm1338\report\hot_subs\pan&box.drw

The average rate of precipitation for each test is computed by dividing the total precipitation recorded by the total time that the plate pans were outside collecting precipitation. Photo 2.9 shows the collection pans used for measuring precipitation rates indoors at the National Research Council.

A snow gauge, manufactured by ETI, was available at the Dorval test site and served as back-up in the measurement of precipitation rates. A new snow gauge (CR21X) was made available to measure precipitation in the 1996/97 winter season. This instrument provided improved gauge output resolution over instrumentation used in previous seasons. It was installed for APS by Environment Canada in February 1997.

Sealed boxes (15 cm, 7.5 cm and 2.5 cm deep) were used for simulating a cold-soaked wing (see bottom of Figure 2.5). The top of the cold-soaked box consists of an aluminium 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 (2).

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 in the 1996/97 season included four C/FIMS from AlliedSignal and one external optical area sensor by Robotic Vision Systems Inc. (RVSI) of New York. These sensors were used primarily during the natural snow outdoor tests. Photo 2.10 shows the computer data acquisition installations inside the trailer at the Dorval test site.

In addition to the equipment at the APS Dorval site, data from Environment Canada's automated weather observation equipment installed adjacent to APS's site were acquired. A typical listing of the data provided by the Remote Environmental Automatic Data Acquisition Concept (READAC) is included at the end of Appendix B. Temperature, precipitation rate, visibility, wind speed and wind direction are among the parameters measured by READAC on a minute-by-minute basis, and this was provided to APS on computer diskettes. The READAC equipment provides an indispensable means of monitoring meteorological conditions for test programs such as this. It consists of the following instruments:

i) *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 2.11) 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 hydrometeors. The Doppler frequency shift of the returned signal provides the precipitation type, and the spectra power of the returned signal provides the intensity (light, moderate or heavy) and amount 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 2.11) 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 rotation of the shaft 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 accumulating on the sides of the gauge and melting later on, therefore resulting in a delayed and 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 2.11) 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

Testing consisted of pouring deicing or anti-icing fluids onto clean test panels (which were exposed to various winter precipitation conditions) and recording the elapsed time for each crosshair 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 major steps follow:

- Synchronize all times;
- Clean panels and start;
- Apply (pour) fluids to test panels. Type I fluids are at room temperature (15°C to 20°C). Type II, Type III and Type IV fluid are at ambient temperature. Fluids are poured from a container using a One-Step fluid application;
- Record crosshair end condition times;
- Continue testing until at least five crosshairs have failed;
- Record weather conditions; and
- Clean panels and restart.

The complete details of the actual test procedure are provided in Appendix B. Appendix C contains the procedure used for testing at the Climatic Engineering Facility during freezing drizzle, light freezing rain, freezing fog and cold-soaked surface rain tests. The same procedure was followed for tests conducted under the simulated conditions, except that there was control of temperature and precipitation rate.

Cold-soaked surface tests were conducted with the use of cold-soaked boxes (Figure 2.5). The ambient temperature was set at +2°C. The box reservoirs were filled with freezing point depressant fluid and cooled to below -10°C using a liquid nitrogen cryostat. All box surfaces except the top 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 2.12).

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 that 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 crosshair marks on the panels. A crosshair is considered failed if:

- There is a visible accumulation of snow bridging on top of the fluid plate at the crosshair 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) or a change in colour (dye) to grey or greyish appearance at any crosshair, or ice (or crusty snow) has formed on the crosshair (look for ice crystals). This condition is usually applicable during light freezing rain, freezing drizzle, ice pellets, freezing fog, rain on a cold-soaked surface or during a mixture of snow and light freezing rain, freezing drizzle and ice pellets.

2.6 Data Forms

Two data collection forms were used at Dorval during the 1996/97 winter season. The form used to record the fluid failure times over each crosshair 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 a test. 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 in weather which prevail during the test.

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 generally the same from plate to plate, but is not reproducible from test to test. Consequently a different procedure was used to measure precipitation rates (see Appendix C) at the Climatic Engineering Facility, supported by a unique data form (Table 2.5).

TABLE 2.3

END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME   VERSION 4.0   Winter 96/97

LOCATION:	DATE:	RUN # :	STAND # :

RVSI Series # : ____________________

CIRCLE SENSOR PLATE: u v w x y z

SENSOR NAME: ____ ____ ____ ____ ____ ____

DIRECTION OF STAND: ________ °

OTHER COMMENTS (Fluid Batch, etc):

____

____

____

____

____

____

____

____

	PRINT	SIGN
FAILURES CALLED BY :	____________	____________
HAND WRITTTEN BY :	____________	____________
TEST SITE LEADER :	____________	____________

***TIME (After Fluid Application) TO FAILURE FOR INDIVIDUAL CROSSHAIRS (hr:min)**

Time of Fluid Application: ________ hr:min (U & X) ________ hr:min (V & Y) ________ hr:min (W & Z)

	Plate U			Plate V			Plate W		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									

	Plate X			Plate Y			Plate Z		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									

TABLE 2.4

METEO/PLATE PAN DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME VERSION 4.0 Winter 96/97

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 ($\Delta w*4/\Delta t$) ($g/dm^2/h$)

*measurements every 15 min. and at failure time of each test panel.

METEO OBSERVATIONS **

TIME (hr:min)	TYPE (Fig. 4) ZR, ZL,S, SG IP, IC, BS, SP	CLASSIF. (See Fig. 3)	Visibility (day only)	If SNOW, WET or DRY

**observations at beginning, end, and every 15 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 :	________	________

File g:\cm1338\report\hot_subs\PFORM4.XLS At:Meteo & Pan

TABLE 2.5

PRECIPITATION RATE MEASUREMENT AT CLIMATIC ENGINEERING FACILITY IN OTTAWA

Date: ____________ **Needles usad:** ________

Start Time: ____________ am/pm **Flow Rate of Water:** ________

Run # : ____________ **Line Air Pressure:** ________

Stand: ____________ **Line Air Temperature:** ________

Precip Type: ____________ (FZD, FZR, FZF, S) **Line Water Pressure:** ________

Line Water Temperature: ________

Pan Location:

U	UU	V	VV	W	WW
XX	X	YY	Y	ZZ	Z

Collection Pan:

Pan/ Cup #	Area of Pan (dm²)	Location		Weight of Pan (g) Before	After	Collection Time (min) Start	End	Rate
1		U	=					
2		UU	=					
3		V	=					
4		VV	=					
5		W	=					
6		WW	=					
7		XX	=					
8		X	=					
9		YY	=					
10		Y	=					
11		ZZ	=					
12		Z	=					

Comments: ______________________________

Handwritten by: ____________

Measured by: ____________

Precipitation Rate = Δg/area (dm²)/hr

File:g:/cm1338/report/hot_subs/RATE_FRM.XLS
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2.7 Fluids

A considerable number and variety of fluids have been tested by APS over the past few years. These are listed in Figure 2.6 along with their codes. The codes are published in this report (in contrast to previous years), because *fluid-specific* tables were developed, and several SAE G-12 Holdover Time Subcommittee members requested that the names be published. Fluid manufacturers have been advised of this.

Type I fluids are primarily used for deicing and are 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% glycol as delivered. These fluids are tested in their standard dilution forms and also in further diluted forms specific to particular test temperature requirements. Concentrations are adjusted according to refractive index. The freezing point of a solution is concentration dependent and is lowered by increasing the concentration. For example, if a given test is to be performed at 0°C, the fluid concentration can be adjusted to freeze at -10°C. This diluted solution is now said to either *possess a 10°C buffer* or *is buffered for 10°C*.

Type II and Type IV fluids contain a minimum of 50 percent glycol as received and are considered *thickened* due to the addition of theology-modifying agents. These agents allow fluids to be deposited in a thicker film and to remain on aircraft surfaces until the time of take-off. These fluids are often delivered to air carriers in this form and are designated as neat (100%) fluids. Sometimes (mostly in Europe where, due to less severe ambient temperatures, the full-strenght fluid is not required) neat Type II and Type IV fluids are mixed with water as follows:

- 75% neat formulation and 25% water (Type II 75/25 or Type IV 75/25); and

- 50% neat formulation and 50% water (Type II 50/50 or Type IV 50/50).

Type III fluid is a thickened fluid which has properties that lie between Type I and Type II. Its shearing and flow off characteristics are designed for aircraft with lower take-off speeds.

Type IV fluids are a class of anti-icing fluids with properties similar to Type II fluids. The manufacturers of these fluids have modified the formulations to try to provide them with the most desirable characteristics for the aviation industry. They are designed to remain in a high-build state once applied to a surface, to exhibit anti-freeze properties, to resist dilution, to shear off lift and control surfaces upon take-off, and to leave minimal solid residue upon evaporation.

FIGURE 2.6

FLUID LIST

TYPE I (STANDARD)

B-203	-	DOW 146AR
B-204*	-	*OCTAGON ADF
B-206*	-	*FG 1000
B-207*	-	*U.C. ADF/2D
B-209	-	BASF AEREX
B-210	-	HOECHST 1732
B-211	-	KILFROST DF1D
B-212*	-	*TEXACO WD20
B-213	-	U.C. XL54
B-214	-	Hoechst MPI 1938
B-215	-	ARCO + (95/96)
B-216	-	Kilfrost (95/96)
B-220	-	ARCO +
B-221	-	OCTAGON (94/95)
B-222	-	HOECHST (94/95-MPI 1898)
B-230	-	SPCA DE-825
B-231	-	SPCA DE-910

TYPE II (NEAT)

A-199*	-	*U.C. 5.1
A-201	-	KILFROST ABC
A-202	-	SPCA AD104 (new formulation)
A-203*	-	*DOW FG 2000
A-205	-	OCTAGON 40 Below
A-208*	-	*HOECHST 1704
A-209*	-	*TEXACO
A-300*	-	*ULTRA - Type IV
A-303*	-	*ULTRA (94/95 & 95/96) - Type IV
A-100	-	SPCA AD-104
A-101	-	Hoechst MPII 1906

TYPE II (50/50 DILUTED)

A-210	-	OCTAGON 40 Below
A-211*	-	*U.C. 5.1
A-400*	-	*ULTRA - Type IV
A-401	-	KILFROST ABC
A-402*	-	*HOECHST 1704
A-403*	-	*ULTRA (94/95 & 95/96) - Type IV
A-510	-	SPCA AD-104
A-511	-	Hoechst MPII 1906

TYPE II (75/25 DILUTED)

A-212	-	OCTAGON 40 Below
A-213*	-	*U.C. 5.1
A-500*	-	*ULTRA - Type IV
A-501	-	KILFROST ABC
A-502*	-	*HOECHST 1704
A-503*	-	*ULTRA (94/95 & 95/96) - Type IV
A-700	-	SPCA AD-104
A-701	-	Hoechst MPII 1906

* Fluid not commercially available

Note: The purpose of this table is to decode the fluids used in this report. For an official list of certified fluids, consult Transport Canada or the Federal Aviation Administration.

TYPE I (DILUTED)

B-250	-	ARCO +
B-251	-	OCTAGON (94/95)
B-252	-	HOECHST (94/95)
B-253	-	U.C. XL54
B-254	-	Hoechst MPI 1938
B-255	-	ARCO + (95/96)
B-256	-	Kilfrost (95/96)
B-330	-	SPCA DE-825
B-331	-	SPCA DE-910

TYPE III

A-200*	-	*U.C. 250-3
A-600*	-	*UCAR
A-650	-	UCAR ULTRA+

TYPE IV (NEAT)

C-100	-	Ultra +
C-102	-	SPCA AD-404
C-103*	-	*SPCA AD-460
C-105*	-	*Kilfrost ABC-4
C-106*	-	*Hoechst MPIV 1934
C-107	-	Hoechst MPIV 1957
C-108	-	OCTAGON Maxflight
C-109	-	Kilfrost ABC-S

TYPE IV (75/25 DILUTED)

C-700	-	Ultra +
C-702	-	SPCA AD-404
C-703*	-	*SPCA AD-460
C-705*	-	*Kilfrost ABC-4
C-706*	-	*Hoechst MPIV 1934
C-707	-	Hoechst MPIV 1957
C-708	-	OCTAGON Maxflight
C-709	-	Kilfrost ABC-S

TYPE IV (50/50 DILUTED)

C-500	-	Ultra +
C-502	-	SPCA AD-404
C-503*	-	*SPCA AD-460
C-505*	-	*Kilfrost ABC-4
C-506*	-	*Hoechst MPIV 1934
C-507	-	Hoechst MPIV 1957
C-508	-	OCTAGON Maxflight
C-509	-	Kilfrost ABC-S

They are ultimately designed to offer superior holdover time protection over the existing Type II anti-icing fluids. By incorporating certain agents, additives and/or combinations thereof, the manufacturers have achieved a particular set of fluid properties. However, the different manufacturers' formulations lead to widely varying fluid properties under the various conditions specified by the holdover time tables. Therefore, *fluid-specific* tables were generated so airline operators could take advantage of the protective properties imparted by each fluid.

2.7.1 Fluids Tested

The fluid tests carried out during the 1996/97 winter season are summarized in Subsection 3.1. Only a limited number of tests were conducted with Type I and Type II fluids during the 1996/97 winter. Most of the Type I tests were done with Union Carbide XL54 fluid. The Type II fluids tested were Octagon 40 below, Kilfrost ABC-3 and Hoechst MPII 1906.

One of the objectives of this winter's testing was to develop a new Type III holdover time table. The fluid was received from only one fluid manufacturer (Union Carbide), and holdover time tests were conducted with this fluid (Ultra+ 67/33).

The Type IV fluids tested during the 1996/97 winter season are listed below along with their delivery dates:

FLUIDS	GLYCOL BASE	INITIAL DELIVERY DATE
Hoechst MPIV (1957)	Propylene	Summer 1996
Kilfrost (ABC-S)	Propylene	Feb. 1997
Octagon (Maxflight)	Propylene	Dec. 1996
Union Carbide (Ultra+)	Ethylene	Spring 1996

These fluids all meet the SAE specification, however when two samples (one green and one clear) of the Hoechst MPIV 1957 were sent to Université du Québec à Chicoutimi for verification, it was found that the WSET time was 77 minutes for both samples, just below the required time of 80 minutes. In addition to these fluids, one other fluid SPCA AD 404 (Ethylene based) also satisfies fluid specifications (as of June 1997), however members of the SAE G-12 Holdover Time Subcommittee indicated that this fluid may not satisfy the revised SAE specification.

At the time of writing this report, Union Carbide issued a warning which stated that diluted forms of Ultra+ fluid are not approved for operational use due to performance deficiencies noted in qualifying tests.

The fluids tested by APS Aviation were received in neat and diluted concentrations. The addition of water to obtain either 50/50 or 75/25 mixes was carried out by the fluid manufacturers in their laboratories. APS Aviation was informed at the SAE G-12 Holdover Time Subcommittee meeting in Chicago that each fluid manufacturer had used similar non-distilled water in the dilution of their fluids.

A comparison of the Type IV fluid freeze points (Figure 2.7) at each dilution (Neat, 75/25, 50/50) shows that the freeze points of the propylene products are similar to one another, but somewhat different to the ethylene brands.

2.7.2 Evolution of Type IV Fluid Formulations

Tests with several Type IV fluids were conducted in winter 1995/96, however many of these fluids are no longer available or have been changed. A summary of the changes is provided below:

Hoechst: Hoechst Type IV MPIV 1934 was tested in winter 1995/96 and was replaced by Type IV MPIV 1957. MPIV 1957 was shipped in the summer of 1996 and very limited tests were conducted with this fluid for winter 1995/96. MPIV 1957 was tested extensively during winter 1996/97.

Kilfrost: Kilfrost Type IV fluid ABC-4 was tested in winter 1995/96 only. It was replaced by ABC-S and this fluid was tested in winter 1996/97. ABC-S was shipped for the first time in February 1997.

Octagon: Octagon Type IV Maxflight was shipped for the first time in December 1996 for testing during winter 1996/97.

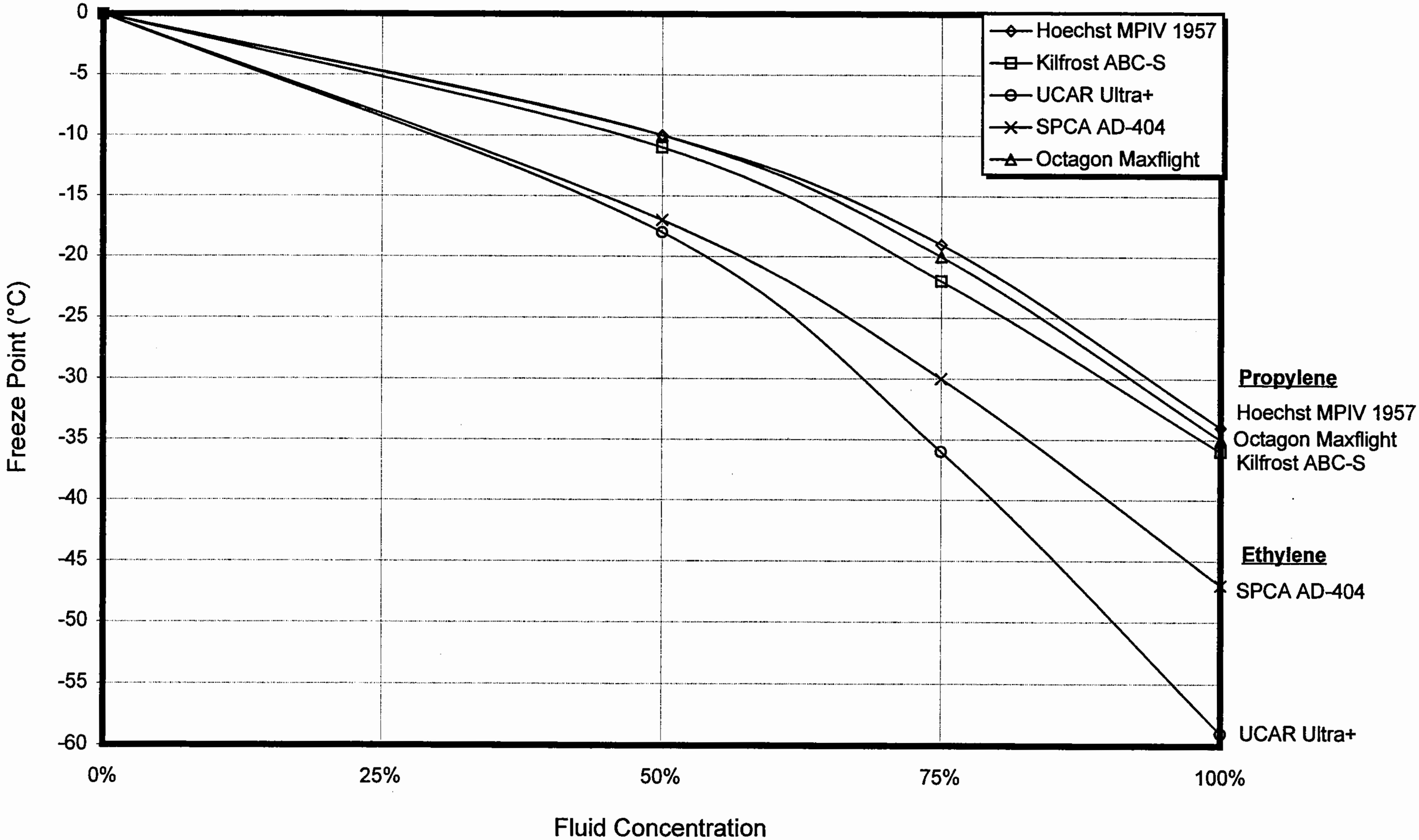
SPCA: SPCA AD-404 and AD-460 were tested in winter 1995/96 only. Several SAE officials indicated that these fluids may not satisfy the new SAE fluid specification. The number of tests conducted with these fluids were limited.

Union Carbide: Type IV Ultra was reformulated and renamed to Ultra+. Limited tests were conducted with Ultra+ in winter 1995/96 because the certified fluid was only received at the end of the winter. Ultra+ was tested extensively in 1996/97.

Because of the changes described above, the Type IV fluid holdover time tables developed for use during winter 1996/97 (from tests conducted in winter 1995/96) needed updating. The old Type IV table was based upon fluids which no longer existed or fluids which had not been subjected to extensive testing.

FIGURE 2.7

COMPARISON OF TYPE IV FLUID FREEZE POINTS



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2.8 Personnel

The site at Dorval was staffed mainly by a part-time crew and supervised by permanent APS staff. Depending on the rate and duration of precipitation, up to two test stands were in use at Dorval. To operate two test stands, four testers with the following responsibilities (see Appendix B, Attachment III for details) were utilized.

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

End Condition (2): Record end condition times for each crosshair.

Meteo (1): Record meteorological conditions during every test.

Prolonged precipitation events require backup personnel, so a fairly large crew was trained to perform experiments. This personnel reservoir was also needed because the same individuals were not always available for tests due 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 large crew 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 utilized at all times, dedicated technicians were often assigned specific tasks. For example, fluids were prepared, mixed, cooled and replenished after every test. During cold-soaked testing, a technician was dedicated to ensuring the cryostat was maintained in operational status and the cold-soaked boxes were properly thermostatted.

2.9 Analysis Methodology

Before all the collected data were analysed, the raw data underwent verification to correct or remove any obvious errors. The primary data parameters and the units used in the final analysis are listed below:

- Precipitation rate - ($g/dm^2/hr$) averaged over test;
- Air temperature - (°C) averaged over test;
- Surface temperature (boxes) - (°C) averaged over test;
- Wind speed - (kph) averaged over test;
- Wind direction - (degrees from true north) averaged over test;
- Platform angle - (degrees from true north); and
- Time to failure of five crosshairs - (minutes).

Data on other parameters were also collected by the automated station at Dorval for the natural snow tests. The data for these other parameters (see Appendix B) is available at one minute intervals for each test.

The analysis was performed in two stages. Analysis for the first stage was driven by the requirement to present results to the SAE G-12 Holdover Time Subcommittee meeting in Pittsburgh. The second stage was determined by the events following this meeting and are fully explained in Section 5.

Figure 2.1
Test Site at Dorval Airport

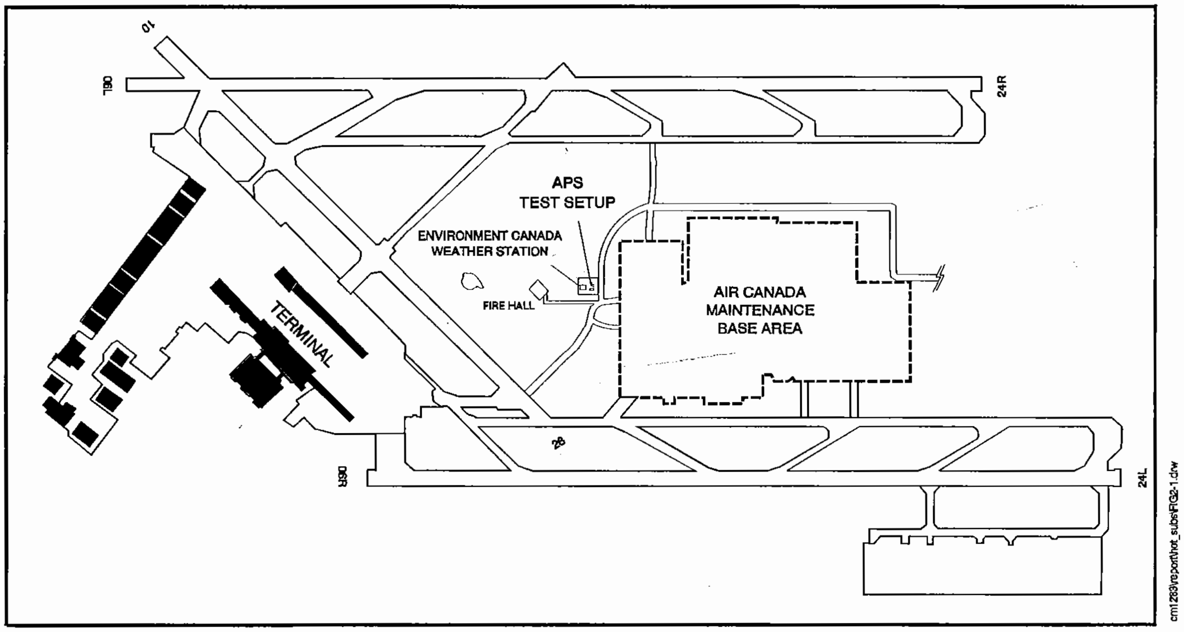


Photo 2.1
View of Dorval Test Site and Associated Equipment

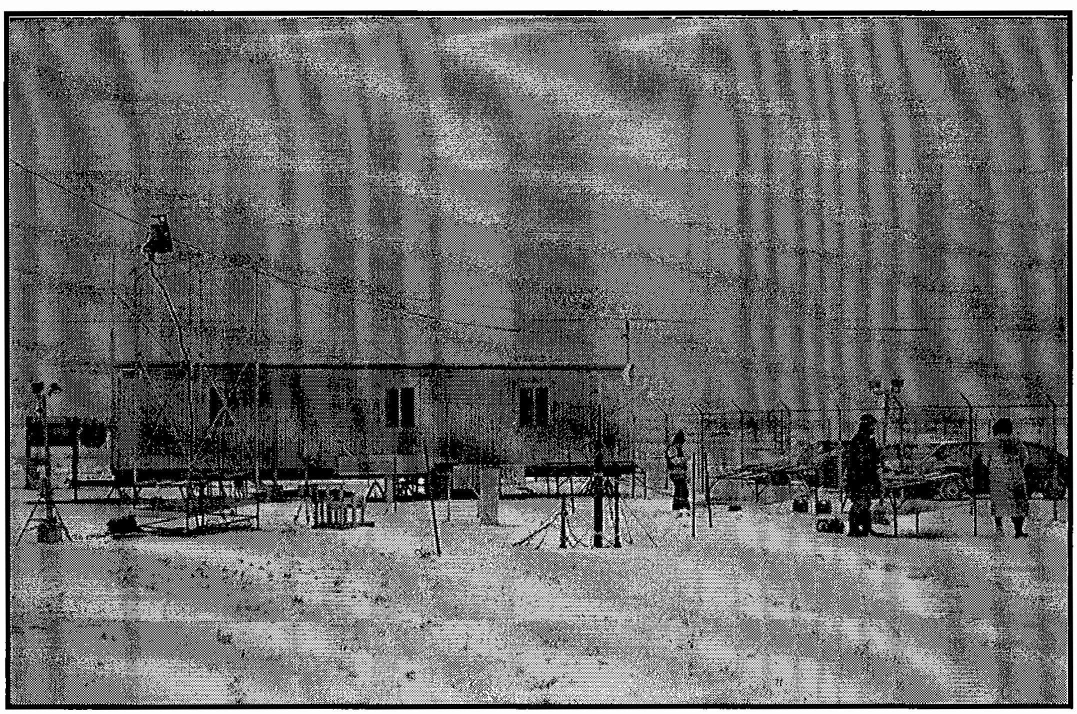


Photo 2.2
Environment Canada's Weather Observation Station at Dorval Airport

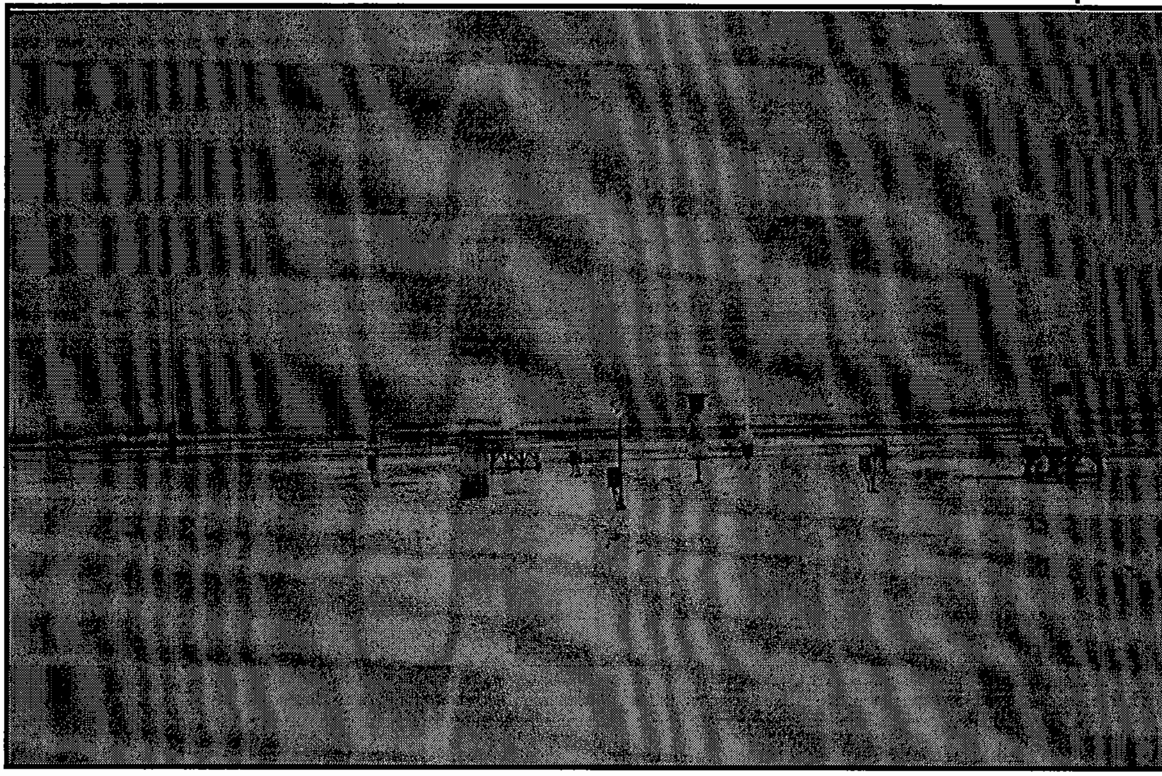


Photo 2.3
Outdoor View of National Research Council Climatic Engineering Facility

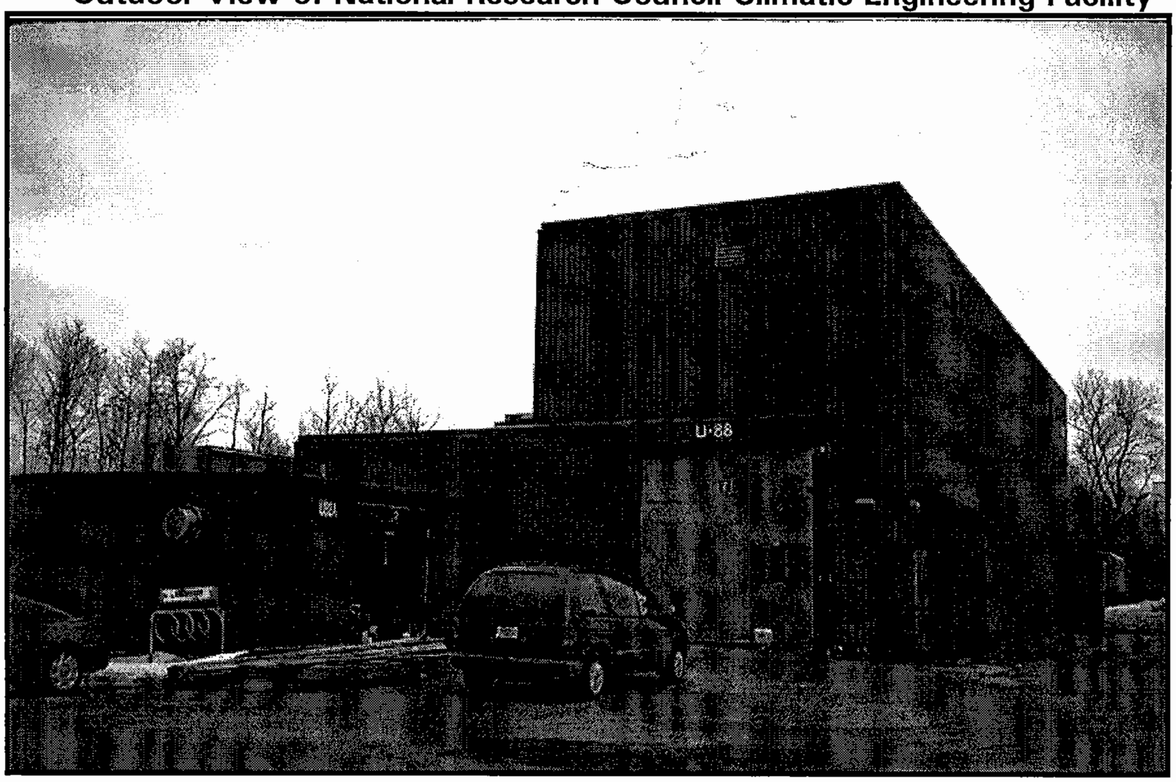


Photo 2.4
Inside View of National Research Council Climatic Engineering Facility

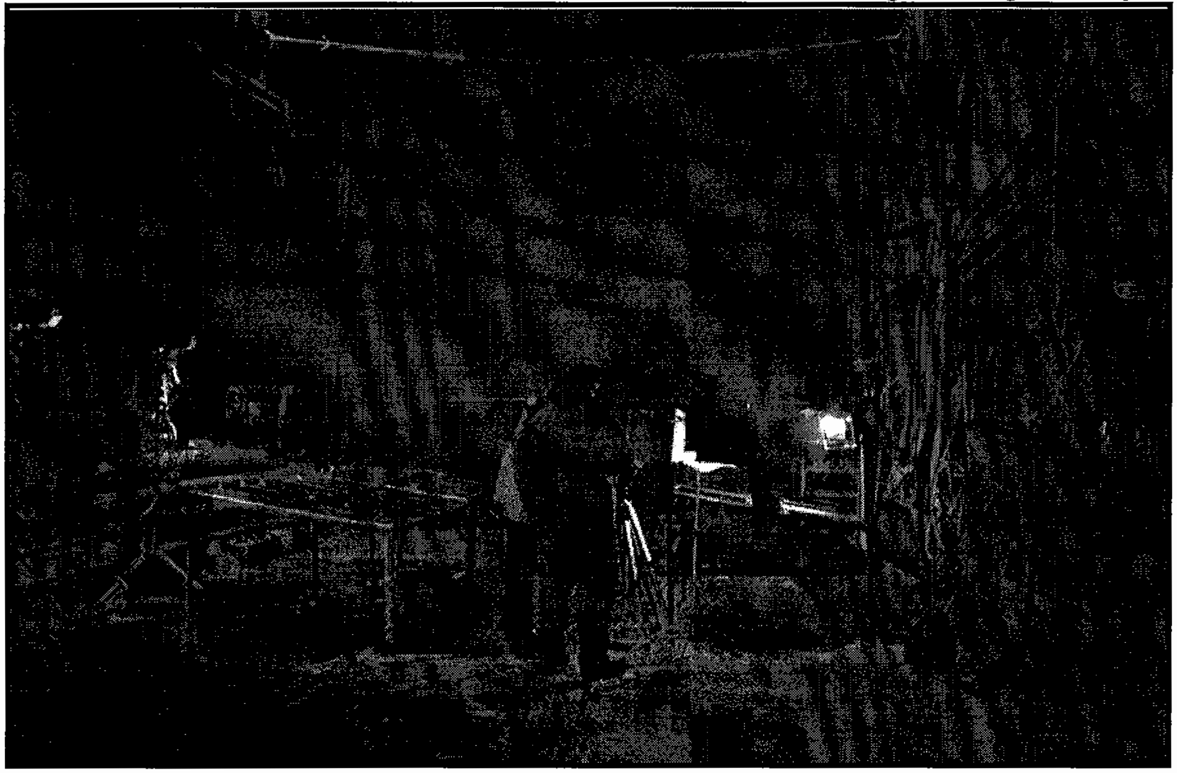


Photo 2.5
Sprayer Assembly Used to Produce Fine Droplets

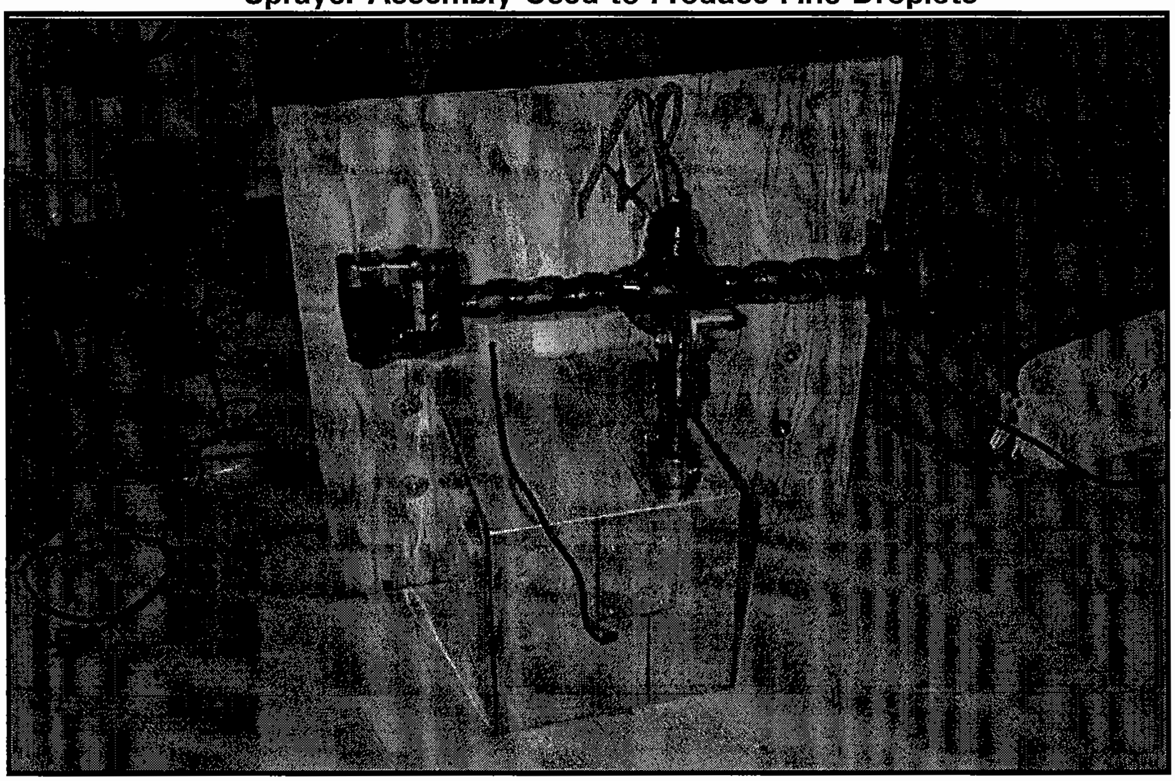


Photo 2.6
Optical Gauge by HSS to Measure Droplet Size

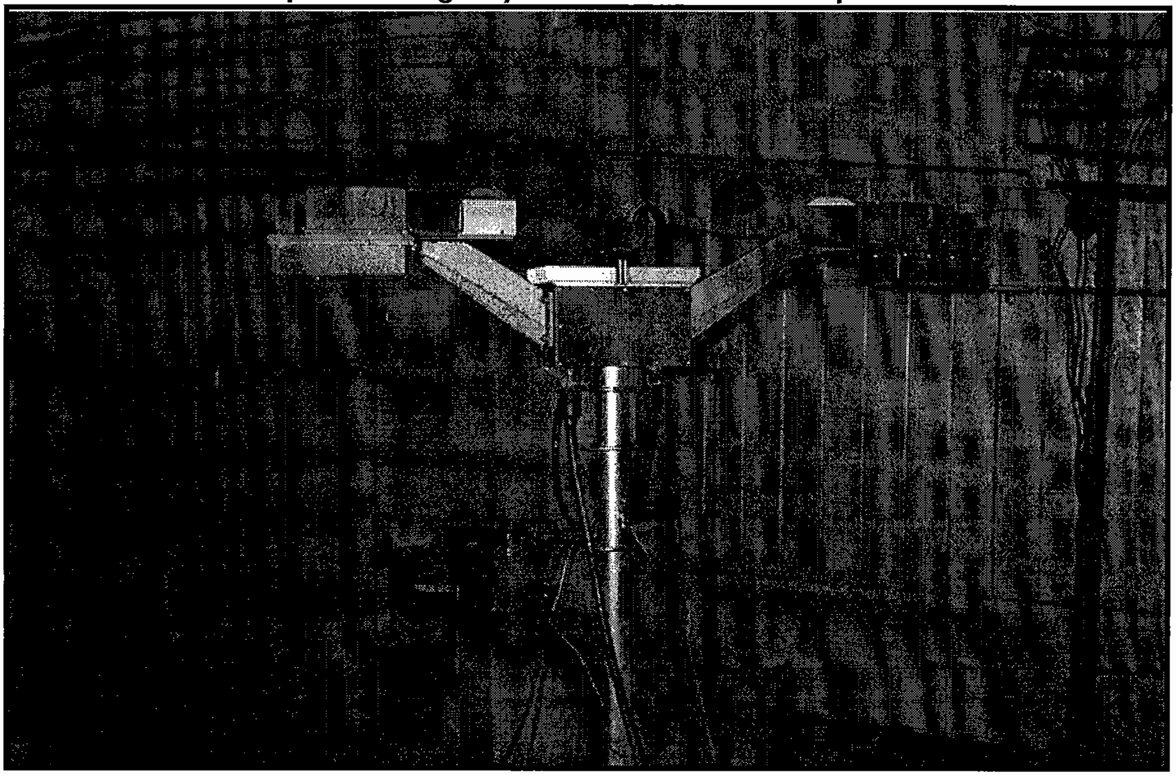


Photo 2.7
Examples of Droplet Sizes Produced by National Research Council Spray System

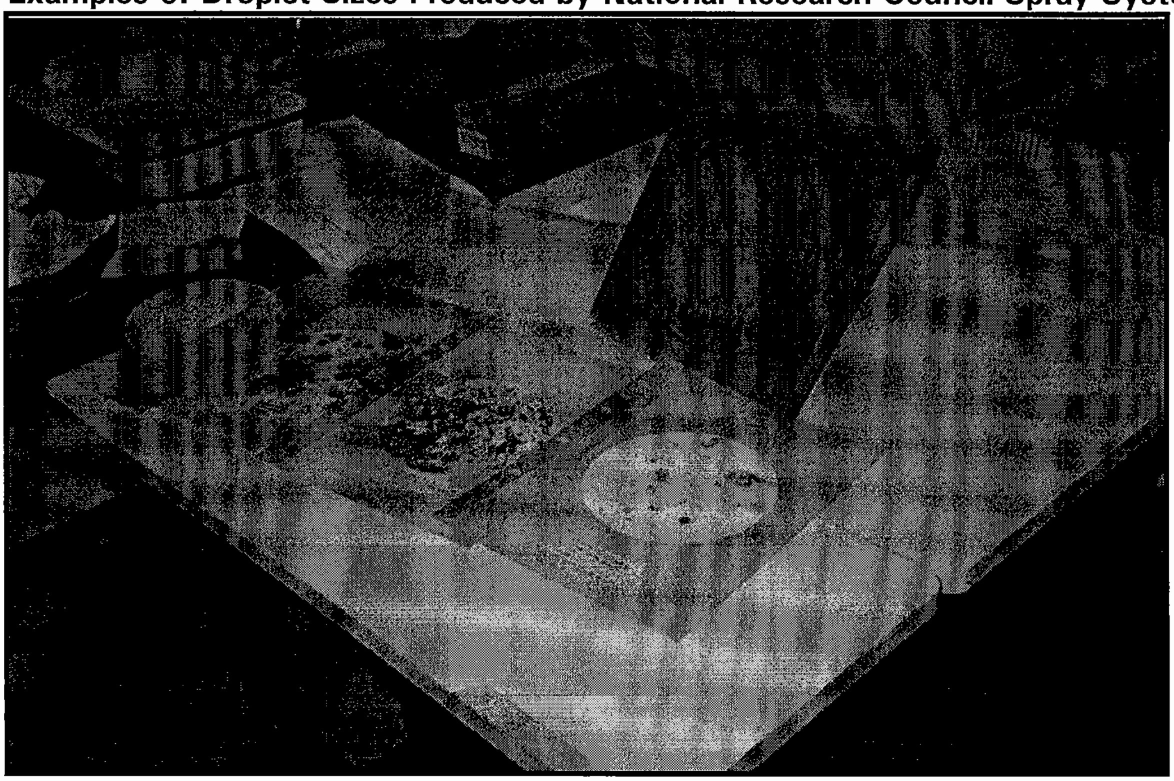


Photo 2.8
Test Plates Mounted on a Stand

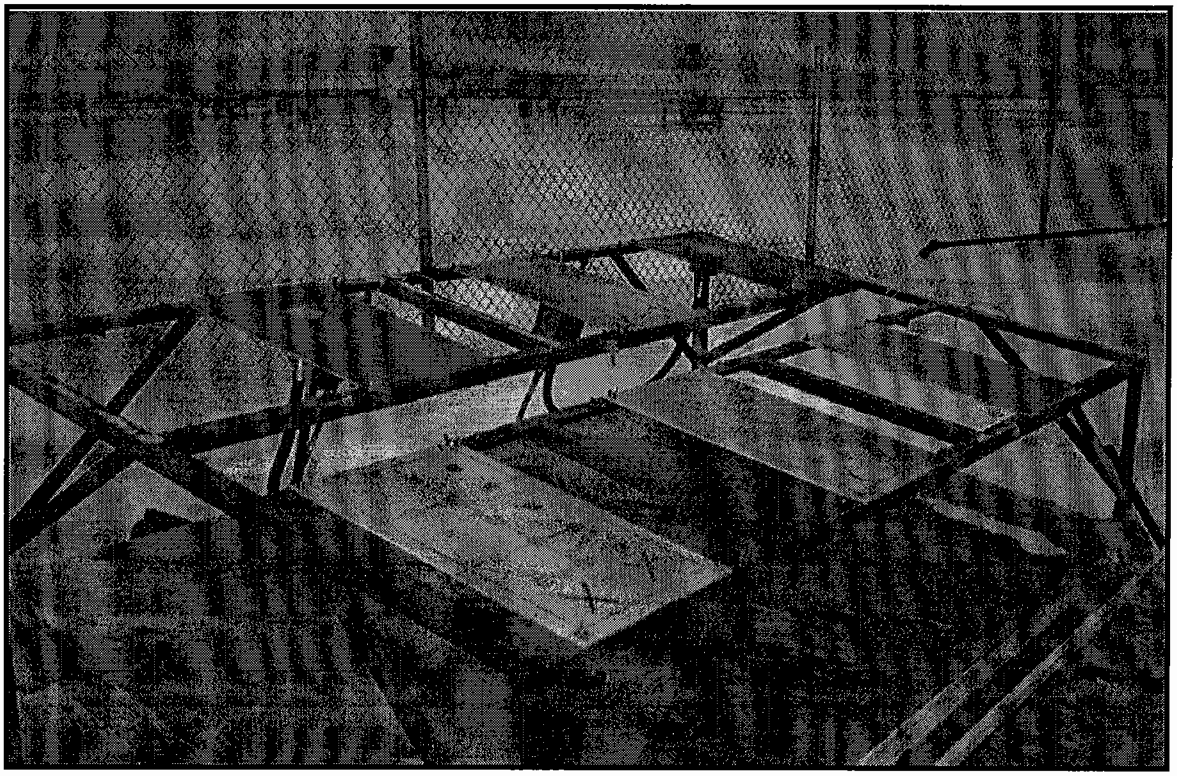


Photo 2.9
Collection Pans Used Indoors at the National Research Council

Photo 2.10
Computer Installations Used for Data Acquisition

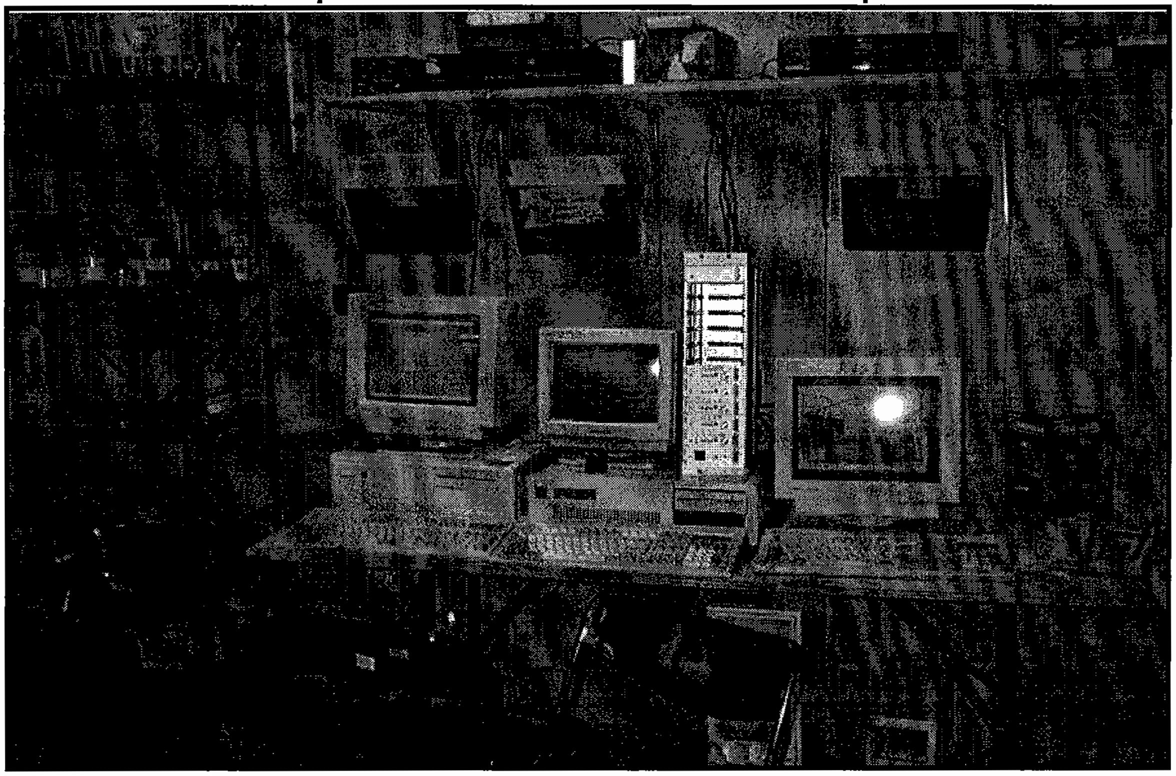
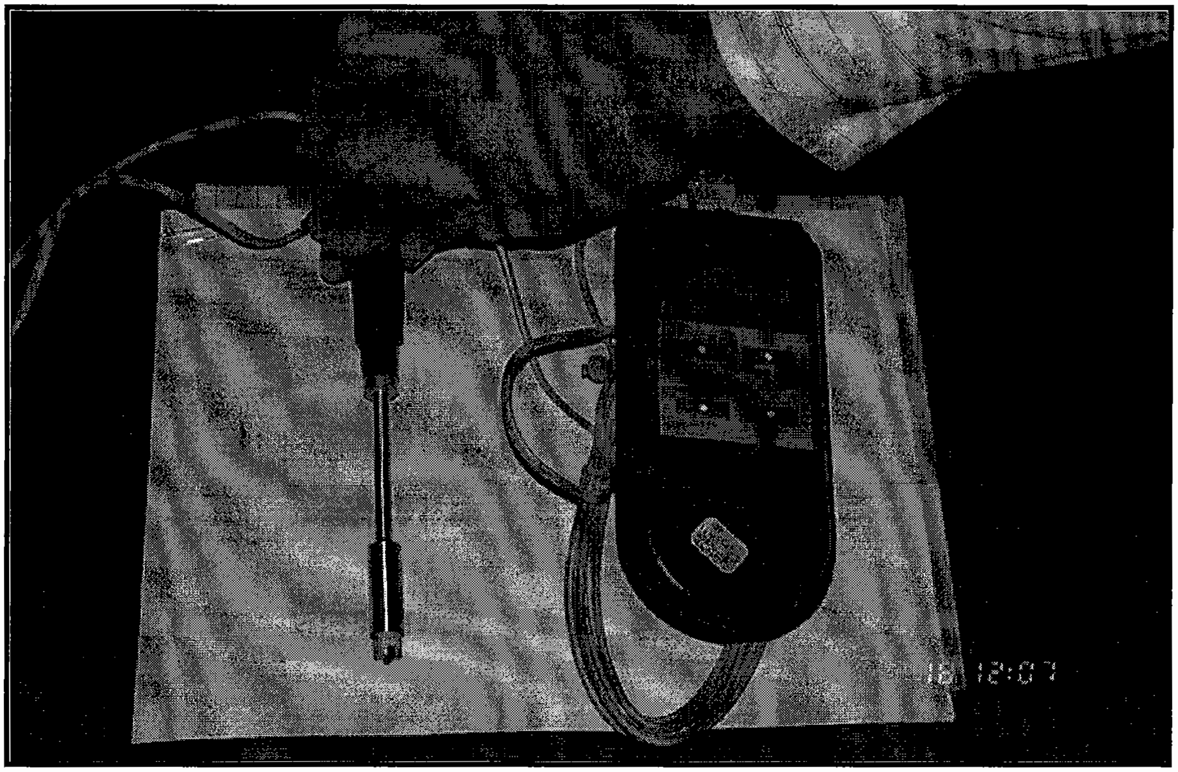


Photo 2.11
Atmospheric Environment Services Automated Weather Station Instruments

Photo 2.12
Hand-Held Temperature Probe



3. DESCRIPTION OF DATA

Appendices B and C contain detailed tables showing the tests which were planned prior to the winter. Since test conditions in natural precipitation cannot be controlled, the test strategy consisted of performing as many tests as possible under conditions of natural freezing precipitation.

Table 3.1 provides a summary of the flat plate tests which were conducted both at Dorval and at the National Research Council. At Dorval, 677 tests were conducted during natural snow precipitation on 25 days over the 1996/97 winter. The number of tests conducted during the 1996/97 winter was high in relation to previous winters, especially considering that Type IV fluids take longer to fail. In addition, the total precipitation that occurred from December 1996 to April 1997 was 50% above the 30 year average for that period.

At the National Research Council, tests were conducted on two different occasions. The selection of the dates (see Table 3.1) was based upon the availability of the chamber and sprayer system, and Transport Canada requirements.

This section provides a summary of the volume of data collected. Breakdowns are provided for quantity of data collected, versus fluid type and distributions of basic weather parameters such as temperature, precipitation rate, wind speed and direction over the range of the tests collected. This is presented separately for the natural snow tests conducted at Dorval, and light freezing rain, freezing drizzle, freezing fog and cold-soaked tests conducted in Ottawa.

TABLE 3.1

SUMMARY OF TESTS PERFORMED IN 1996/97

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)
Dec-19-96	19	2.8				
Dec-20-96	5	1				
Dec-26-96	12	6.2				
Dec-27-96	6	0.8	Dec-96	10.8	35.2	54.8
Jan-02-97	13	2.2				
Jan-03-97	35	4.4				
Jan-09-97	42	9				
Jan-10-97	77	13.2				
Jan-20-97	11	3.8				
Jan-22-97	6	1.2				
Jan-24-97	52	15.4				
Jan-25-97	14	1				
Jan-27-97	36	11.8				
Jan-28-97	46	9.6				
Jan-31-97	17	6.8	Jan-97	78.4	83.8	47.7
Feb-04-97	24	6.8				
Feb-05-97	70	16.5				
Feb-14-97	36	10.8	Feb-97	34.1	70.5	41.2
Mar-04-97	22	8.6				
Mar-06-97	20	17.6				
Mar-10-97	44	5.2				
Mar-17-97	8	3.5				
Mar-21-97	27	4.2				
Mar-25-97	19	5.2	Mar-97	44.3	72.5	31.3
Apr-12-97	16	5	Apr-97	5	26.6	10.9
Total	**677**	**173**		**173**	**289**	**186**

Tests Performed at Climatic Engineering Facility

Date	Condition Tested
March 24-27, 1997	Freezing Fog
April 14-24, 1997	-ZR, ZD, Cold-Soaked Boxes, Verification of FZF Holdover Time range for Type II and Type IV.

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3.1 Dorval Natural Snow Tests

3.1.1 Data Acquisition

During the 1996/97 test season, a total of 996 tests were started on the two stands at Dorval. Of this total, 677 points were usable and 132 points were discarded (see listing below). All of the 677 tests occurred during natural snow conditions and are considered in detail in Section 6. The tests referred to as *Different precipitation* below are tests carried out under freezing precipitation conditions other than snow and are described separately in Subsection 7.1.

	# of Tests
Usable	677
Different precipitation (ZR, ZD, IP, ...)	187
Fluids did not fail (e.g. snow stopped)	126
Other (wrong fluid mixture, ...)	6
Total Tests Started	996

The breakdown by fluid type of the 677 tests is shown in Figure 3.1 and summarized below. The majority of tests were conducted using Type III and Type IV fluids.

	# of Tests
Type I (standard)	8
Type II Neat	26
Type III	90
Type IV Neat	285
Type IV 75/25	173
Type IV 50/50	95
Total Usable Tests	677

3.1.2 Test Location and Fluids Tested

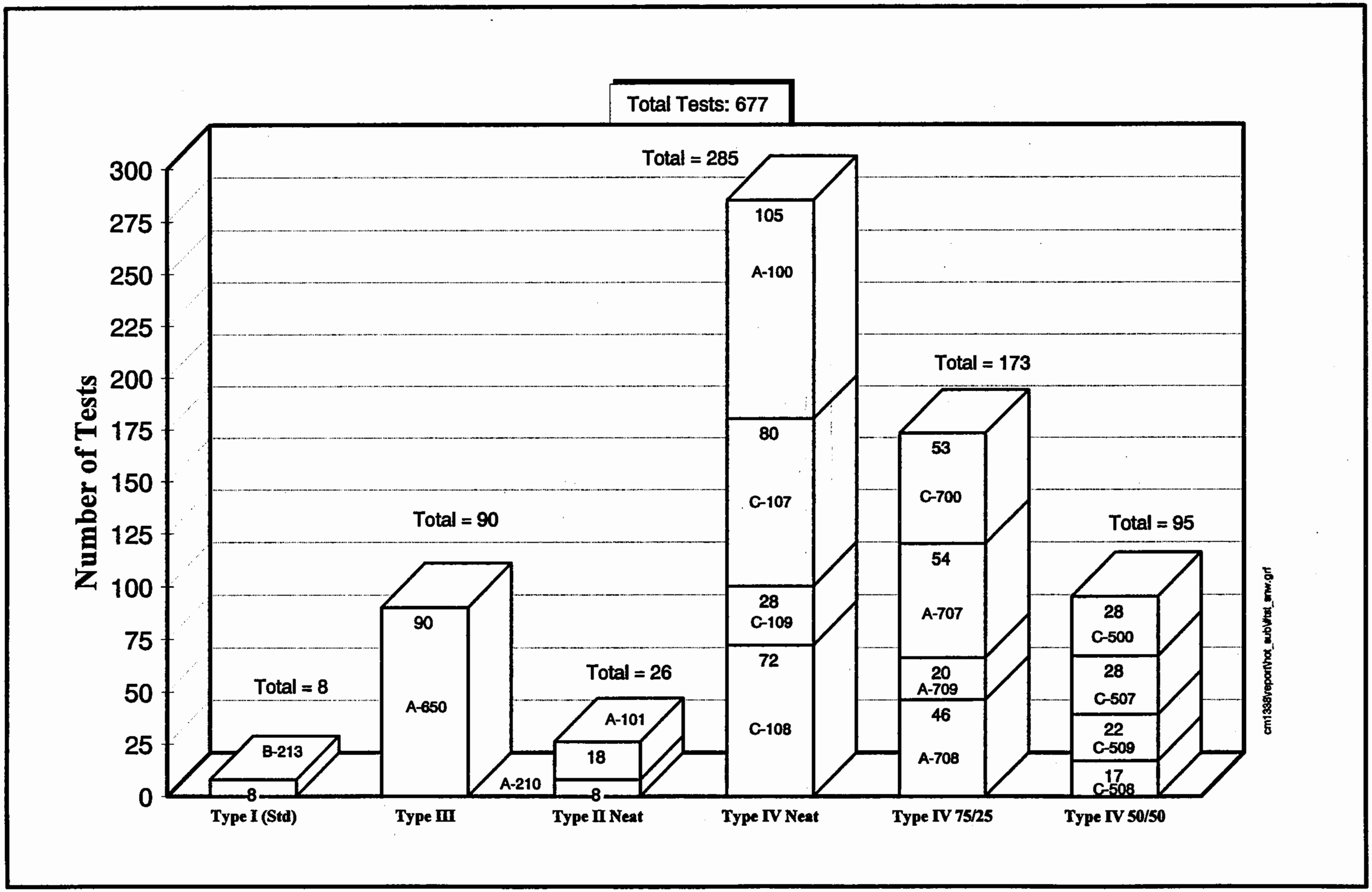
In addition to the 677 tests carried out at Dorval, 50 tests were conducted at Denver by the National Centre for Atmospheric Research with Type IV neat Fluids C-100 (Union Carbide) and C-107 (Hoechst), and Type IV 75/25 Fluids C-700 (Union Carbide) and C-707 (Hoechst) during the 1996/97 winter. The National Centre for Atmospheric Research tests are not included in the totals of this section, but the data are described in Section 5.

Tests at Dorval were conducted with fluids manufactured by Octagon, Union Carbide, Hoechst and Kilfrost. Figure 3.1 shows concisely how many fluids brands were tested for each fluid type.

FIGURE 3.1

NUMBER OF NATURAL SNOW TESTS CONDUCTED

1996/97 TEST SEASON AT DORVAL



3.1.3 Distribution of Average Precipitation Rates

Accumulation of precipitation at Dorval was measured using plate pans, the ETI precipitation gauge and two precipitation gauges from Environment Canada. The rates of precipitation used in this report were computed with the plate pan data, since this method gives a more accurate depiction of the catch rate on the plates. The three precipitation gauges were used as back-up or to investigate outlying test points.

The distribution of the average precipitation rate for the tests is summarized in Figure 3.2 for Type II, Figure 3.3 for Type III and Figure 3.4 for Type IV fluids.

3.1.4 Distribution of Other Meteorological Conditions

The air temperature, wind speed, and wind direction were measured for every test over the duration of the test. These parameters were measured with instruments purchased by APS on behalf of Transport Canada, and also with instruments at Environment Canada's automated weather station. A comparison of the measurements from each instrument is provided in Subsection 3.1.6. A summary of the distribution of the APS measures for each test is illustrated in Figures 3.5 to 3.11 as follows:

Figure 3.5	Distribution of Air Temperature for Type II Fluids;
Figure 3.6	Distribution of Air Temperature for Type III Fluid;
Figure 3.7	Distribution of Air Temperature for Type IV Fluids;
Figure 3.8	Distribution of Wind Speed for Type II Fluids;
Figure 3.9	Distribution of Wind Speed for Type III Fluid;
Figure 3.10	Distribution of Wind Speed for Type IV Fluids; and
Figure 3.11	Comparison of Wind Direction to Platform Direction.

3.1.5 Comparison of Meteorological Measurements

The top of Figure 3.12 shows the comparison of test site wind speed measurements versus Environment Canada's READAC wind speed measurements. In both cases, wind speed is computed to be the average wind speed over the duration of the test. The test site measurements were on average only 55% as high as the measurements from READAC. The READAC measurements are taken at a height of 10 m, whereas the wind at the test site is measured 3 m above the ground to more accurately monitor wind flow over the test plates.

The bottom of Figure 3.12 shows the comparison of wind direction from the APS test site wind vane and from the READAC instrument. The chart shows

FIGURE 3.2

DISTRIBUTION OF PRECIPITATION RATE - TYPE II FLUIDS

Natural Snow Tests

1996/97

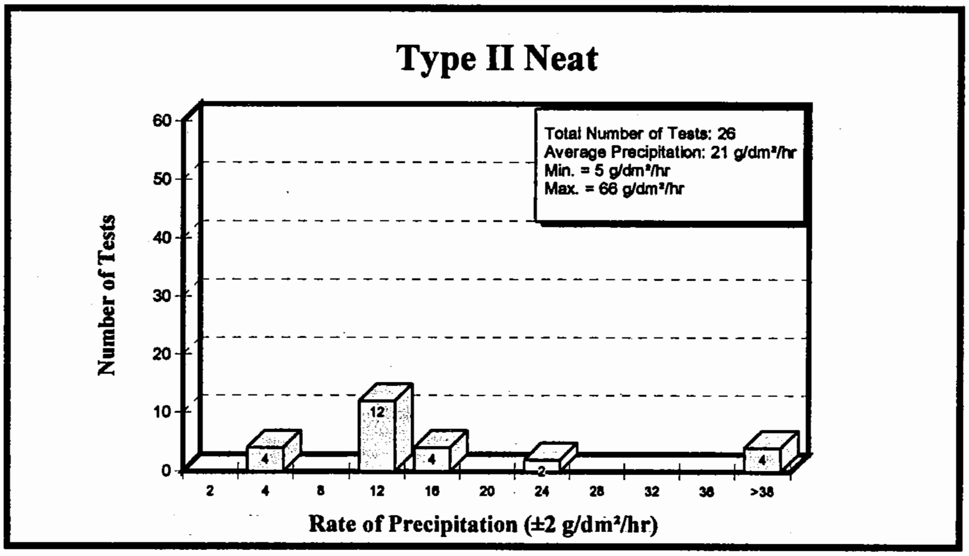


FIGURE 3.3

DISTRIBUTION OF PRECIPITATION RATE - TYPE III FLUID

Natural Snow Tests

1996/97

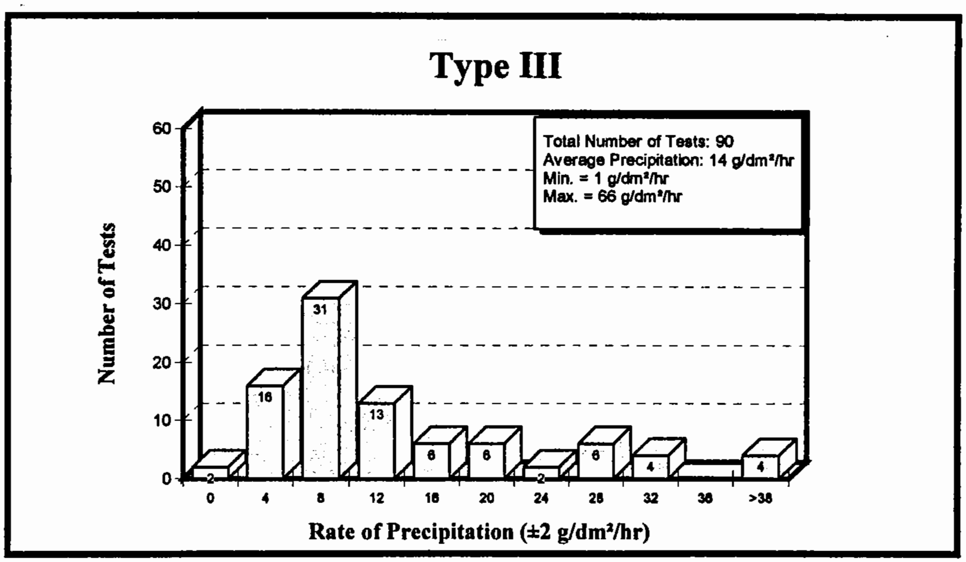


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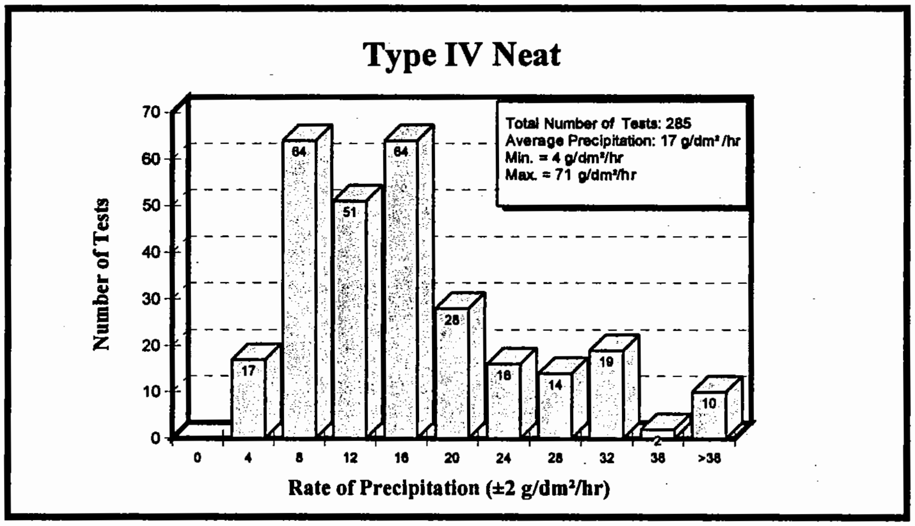
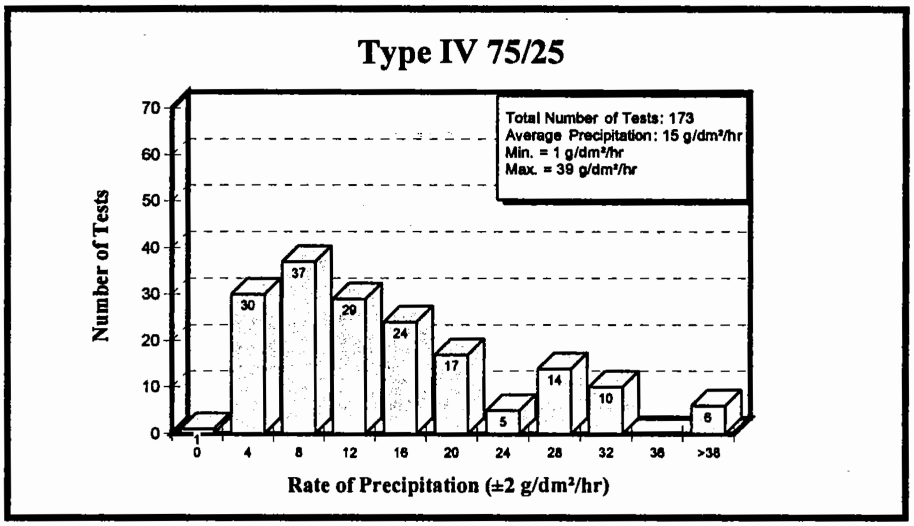
FIGURE 3.4

DISTRIBUTION OF PRECIPITATION RATE - TYPE IV FLUIDS

Natural Snow Tests

1996/97





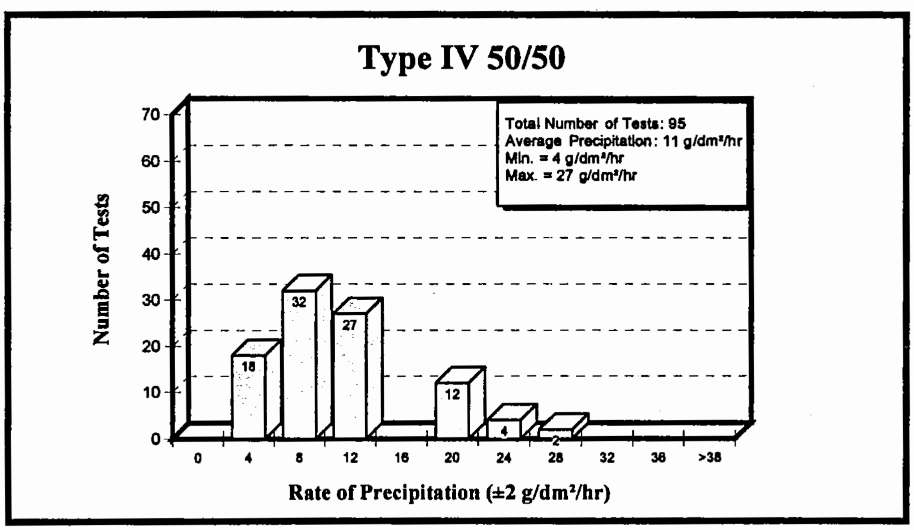


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FIGURE 3.5

DISTRIBUTION OF AIR TEMPERATURE - TYPE II FLUIDS

Natural Snow Tests

1996/97

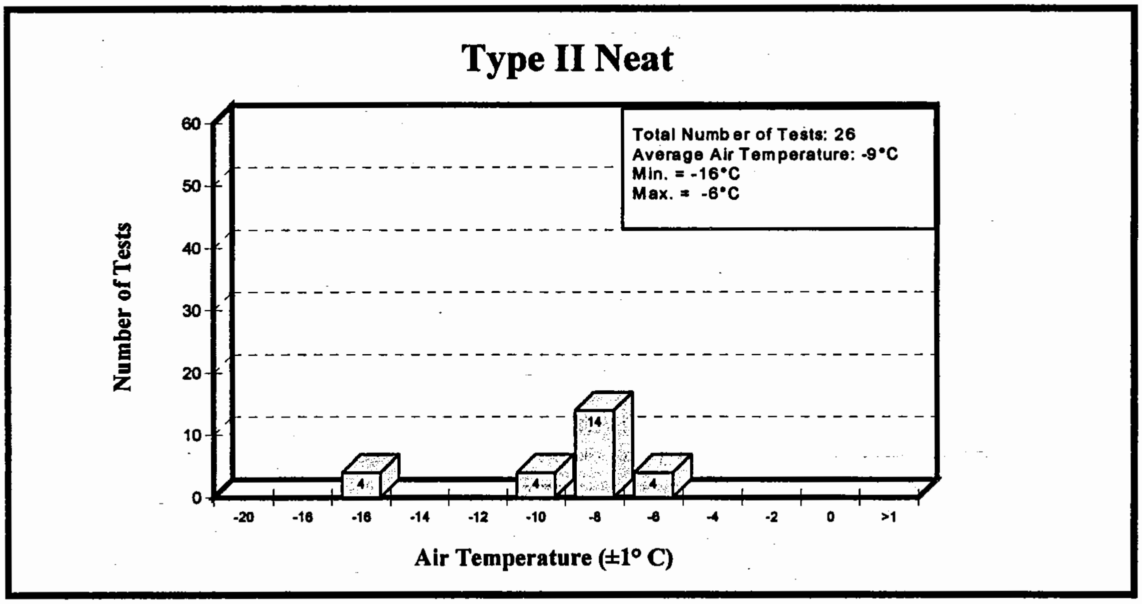

FIGURE 3.6

DISTRIBUTION OF AIR TEMPERATURE - TYPE III FLUID

Natural Snow Tests

1996/97

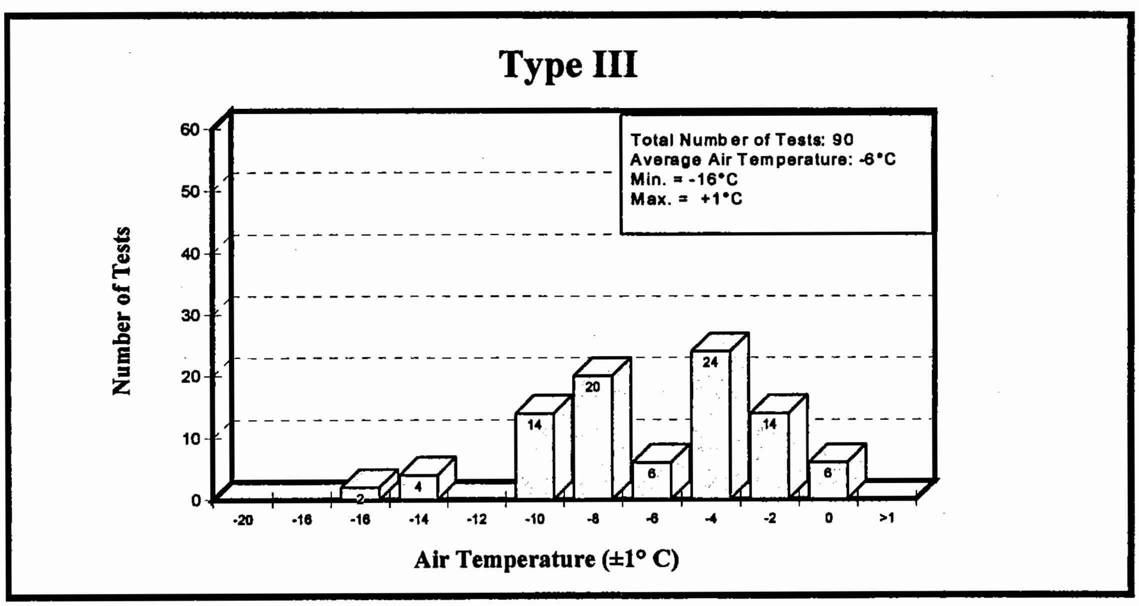

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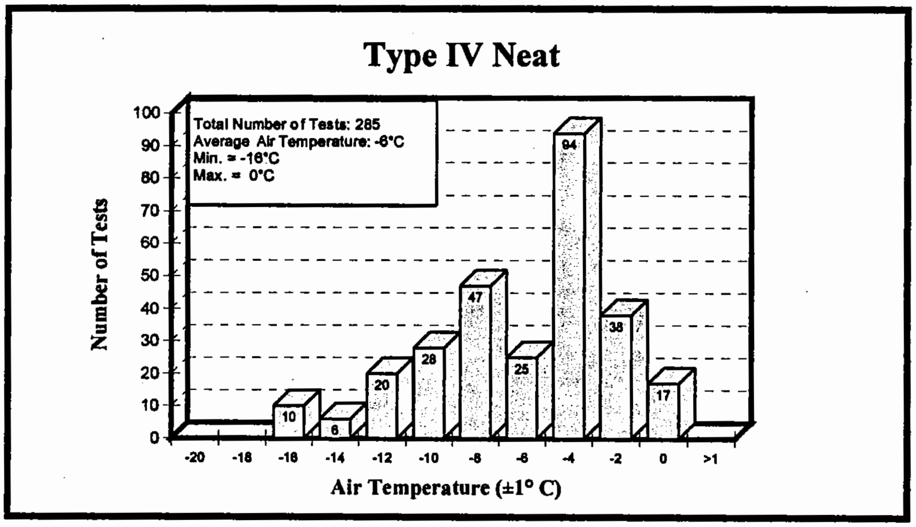
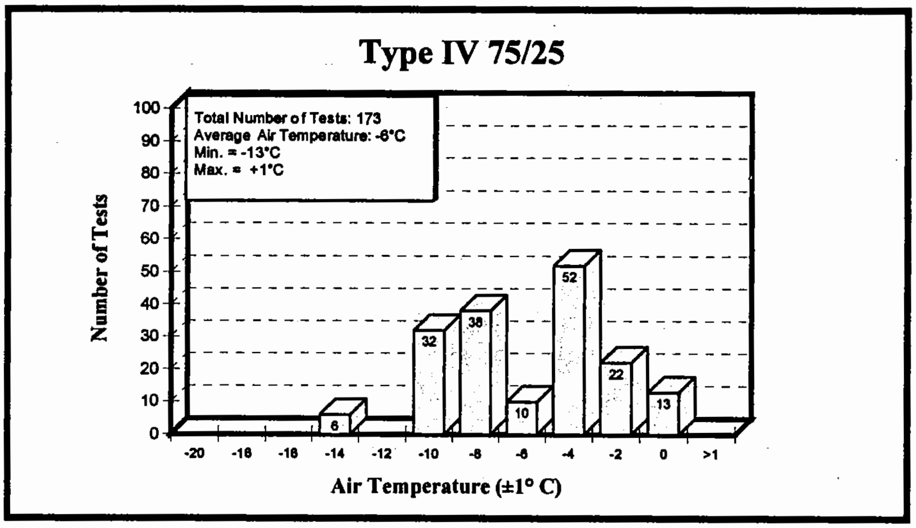
FIGURE 3.7

DISTRIBUTION OF AIR TEMPERATURE - TYPE IV FLUIDS

Natural Snow Tests

1996/97





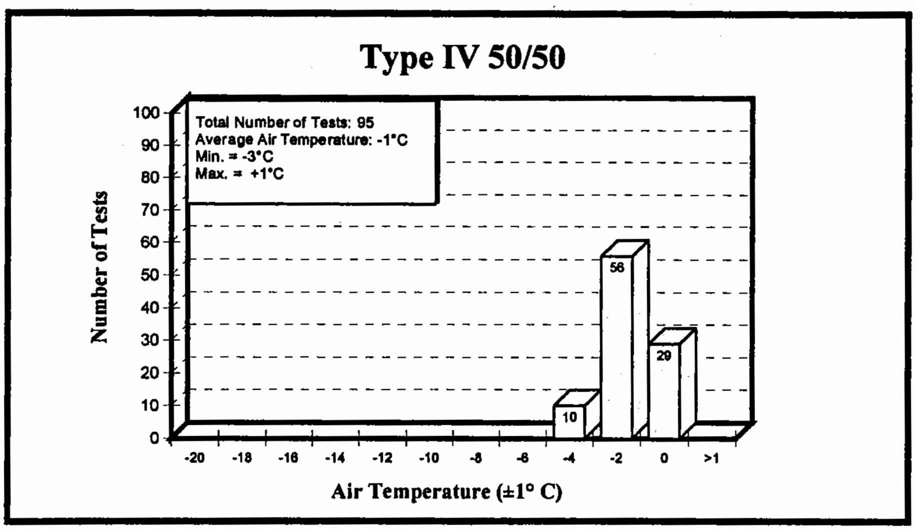


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FIGURE 3.8

DISTRIBUTION OF WIND SPEED - TYPE II FLUIDS

Natural Snow Tests

1996/97

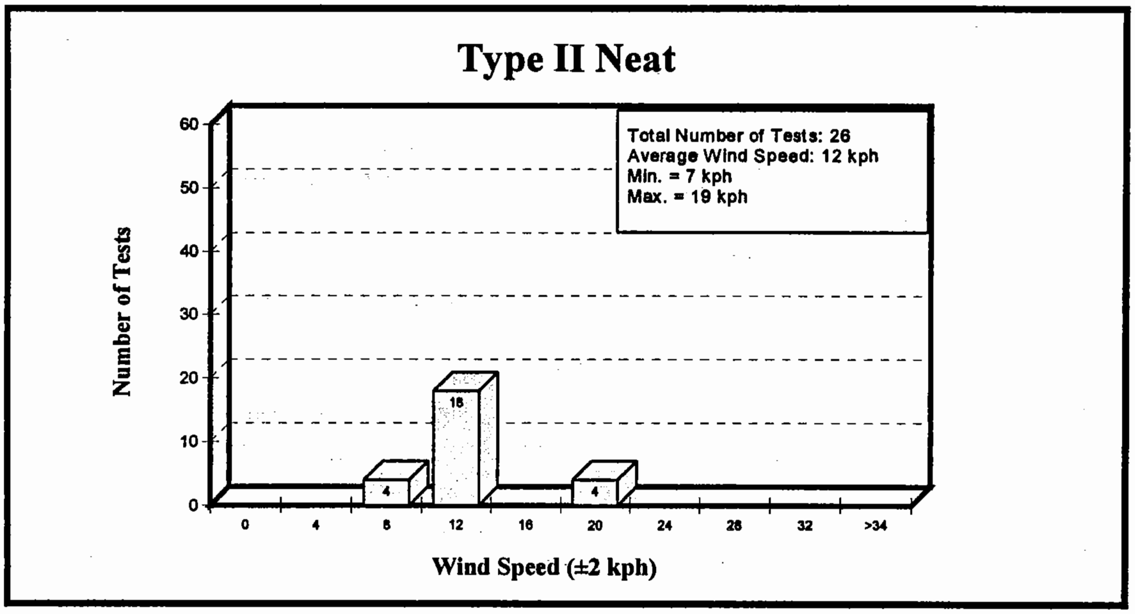

FIGURE 3.9

DISTRIBUTION OF WIND SPEED - TYPE III FLUID

Natural Snow Tests

1996/97

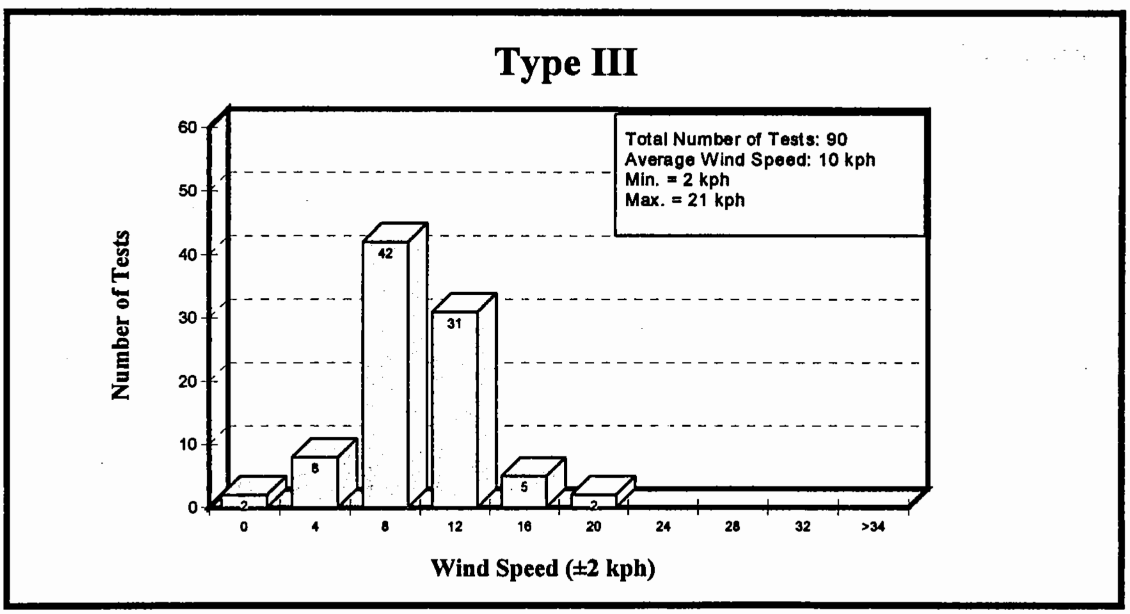

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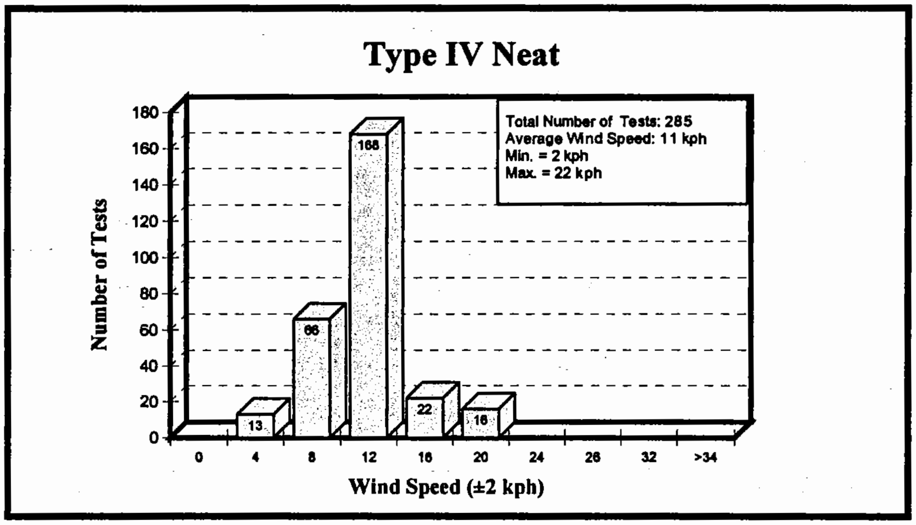
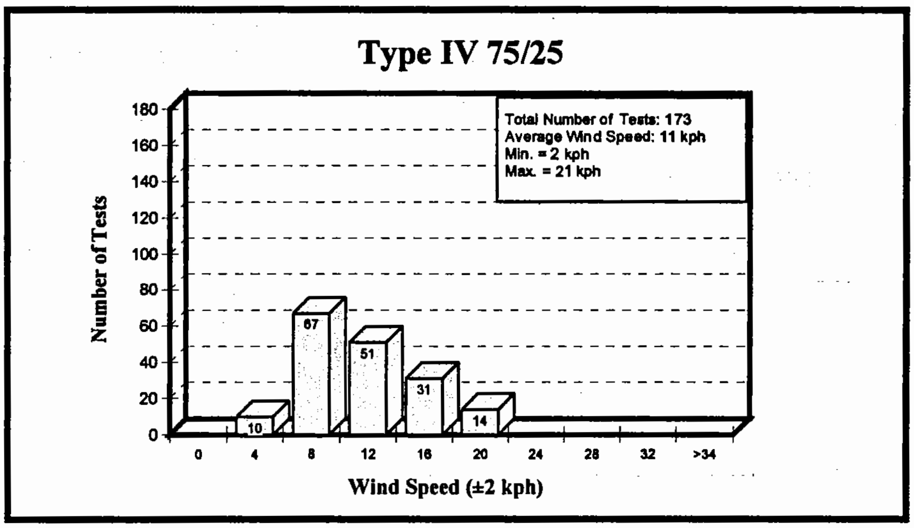
FIGURE 3.10

DISTRIBUTION OF WIND SPEED - TYPE IV FLUIDS

Natural Snow Tests

1996/97





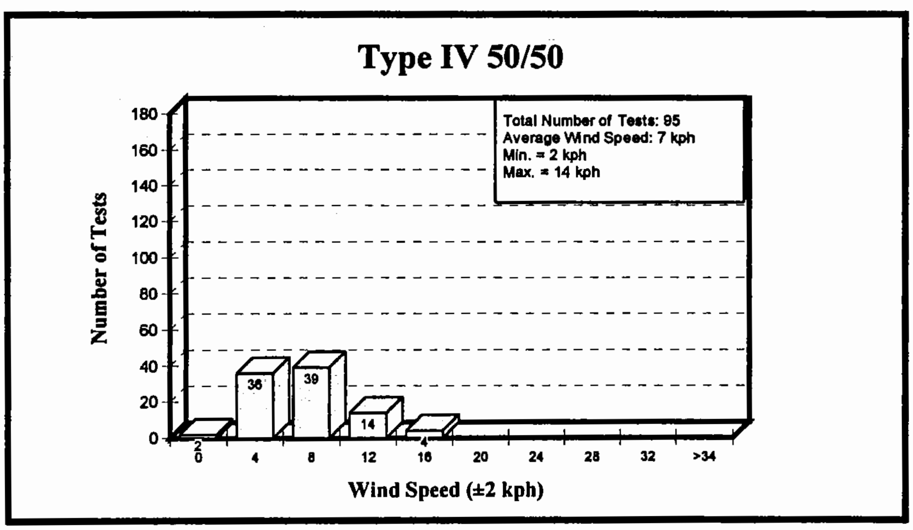


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FIGURE 3.11

COMPARISON OF WIND DIRECTION TO PLATFORM DIRECTION

Natural Snow Tests

1996/97

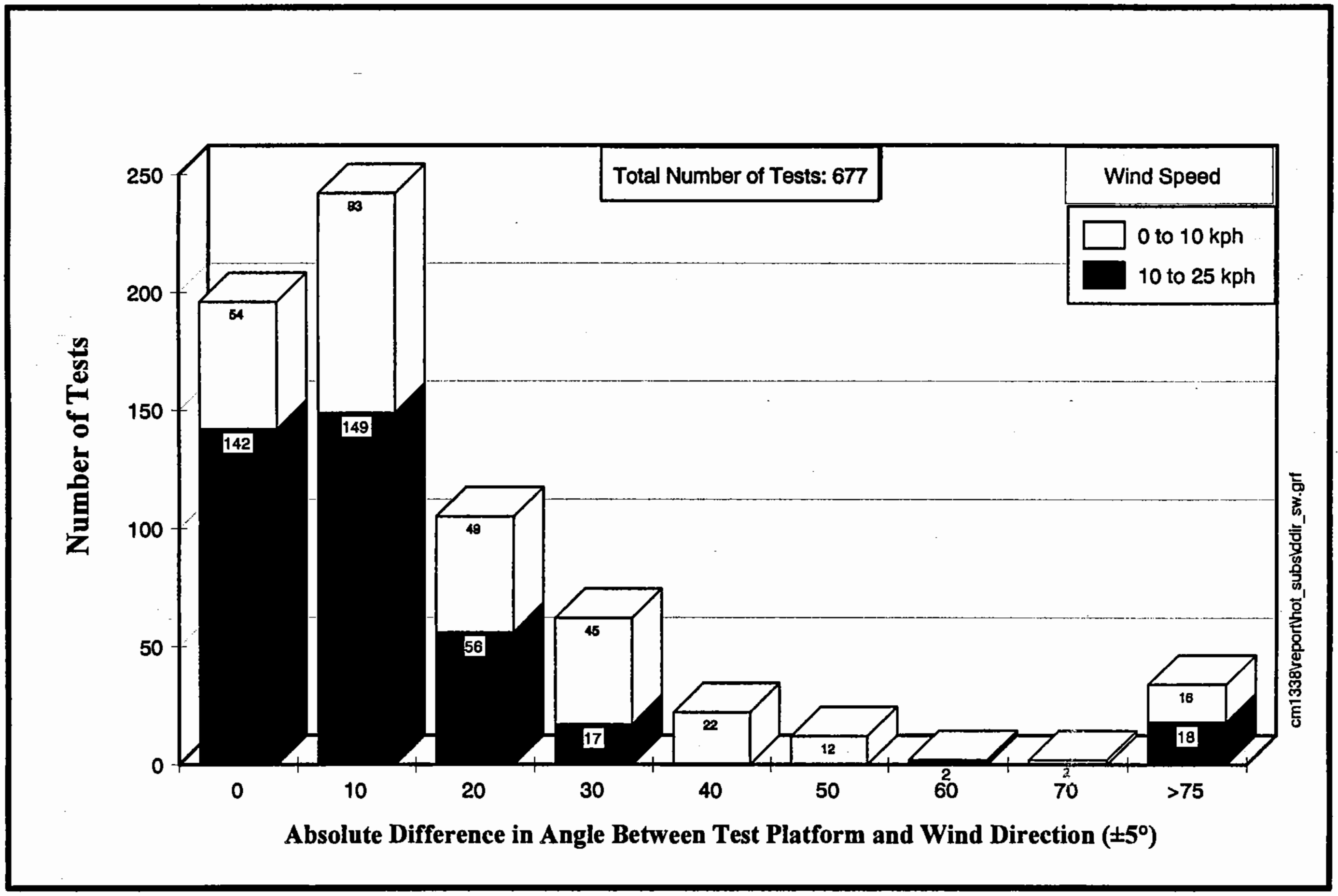
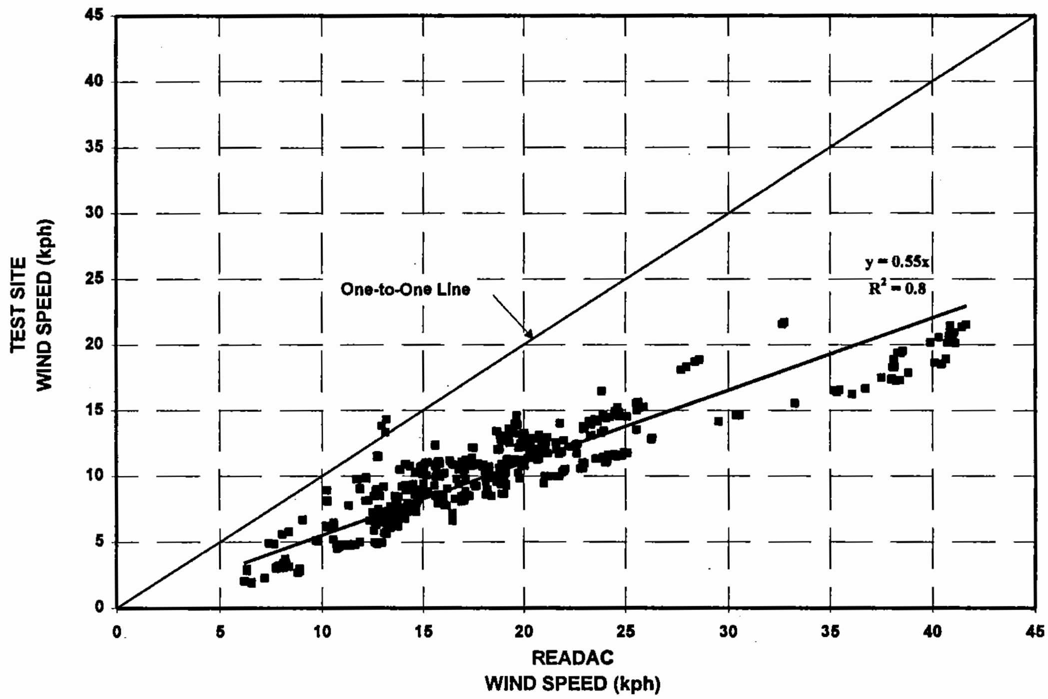
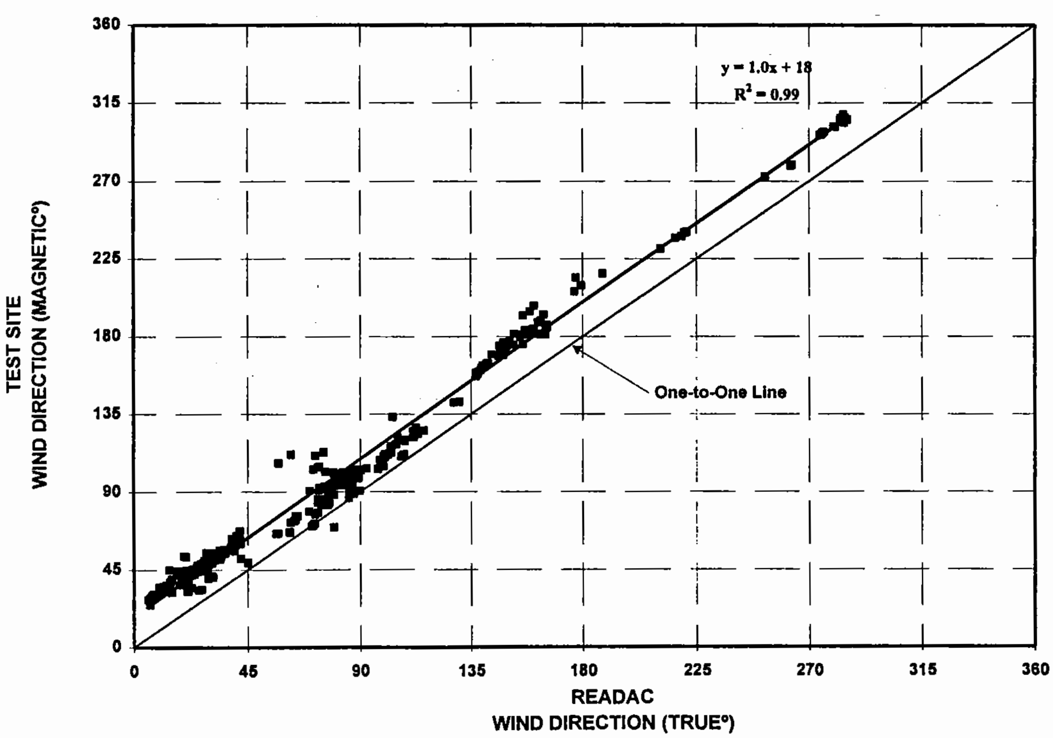


FIGURE 3.12
COMPARISON OF APS AND READAC WIND DATA
1996/97

WIND SPEED



WIND DIRECTION



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At: Wind
Printed: 07/11/97, 03:15 PM

that, if the applicable 16° declination between Magnetic and True North was applied, the correlation between the two instruments is very good.

Figure 3.13 shows the comparison of temperature data, which shows excellent correlation between Atmospheric Environment Services' instrument and the test site instrument.

The operational and maintenance costs of running a separate dedicated set of instruments is not justified by the minor differences in meteorological data observed between these two sources. The READAC resources are obtained at a premium so it is recommended that future meteorological data acquisition rely uniquely on READAC. Plate pan measurements of precipitation rates should be maintained as this is the most reliable and accurate means of measuring accumulation. (Recommendations have been made relating to the future use of these instruments in Subsection 9.3.)

A meeting between APS, Transport Canada and Atmospheric Environment Services was held in February, 1997 to examine the need of having a more precise precipitation gauge. An agreement was reached to install a new gauge (CR21X) with a precision of 1 g/dm^2 - instead of the current READAC gauge with precision of 5 g/dm^2. Atmospheric Environment Services took on the task of installing the gauge at Dorval airport.

Analysis of the data obtained from the CR21X and READAC gauges was conducted and found no correlation between the two. It was determined that the CR21X was installed without a windshield. As a result, the gauge was not collecting accurate precipitation readings due to wind effects. Further discussions with Atmospheric Environment Services are needed to determine whether a sheilded CR21X could be operational for 1997/98 winter season.

3.1.6 Weather Data to Determine Precipitation Boundary Conditions

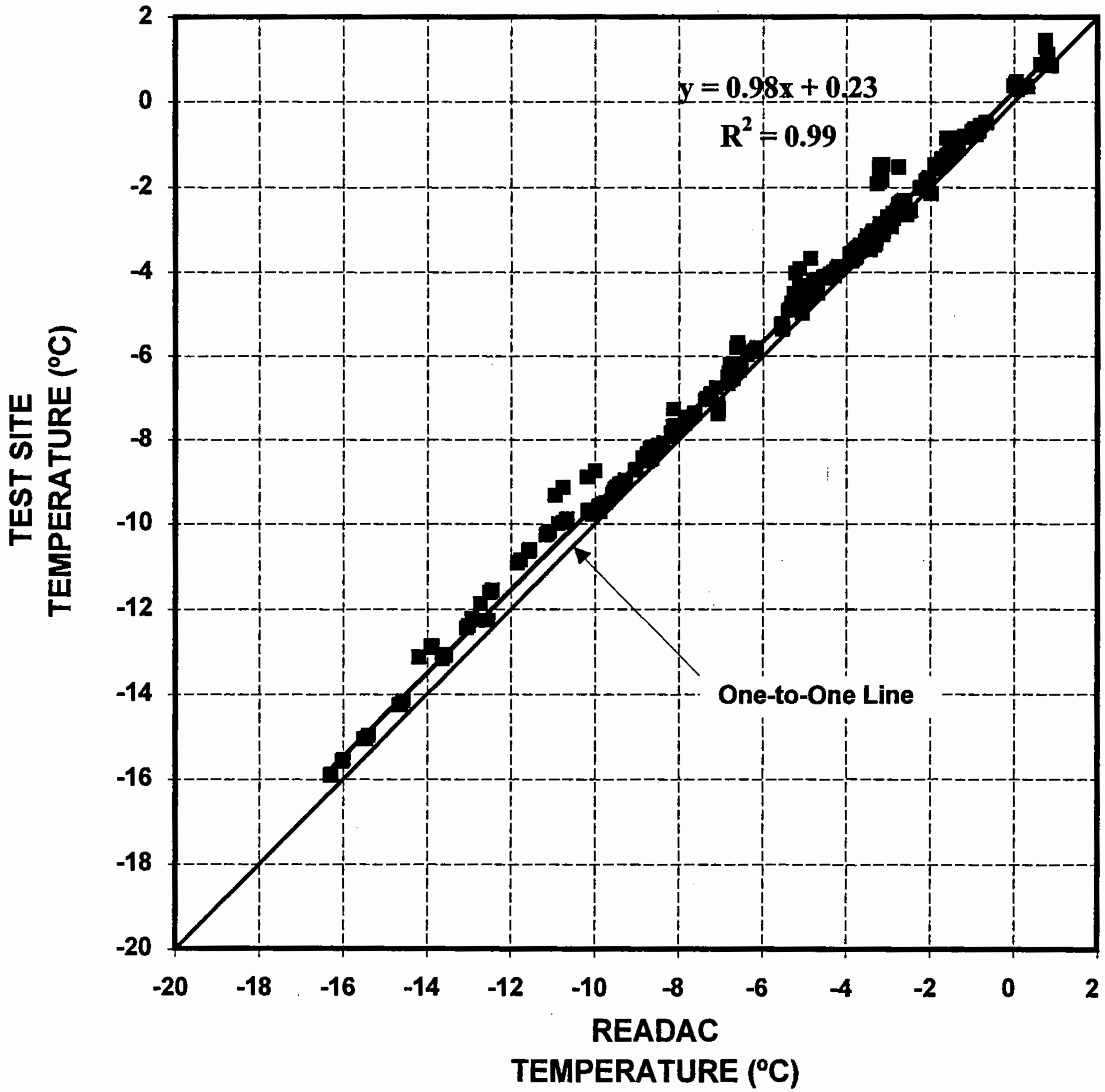
Data on rates of precipitation for natural snowfall versus outside air temperature was collected for analysis to determine typical rates for various temperature values. The data from plate pan measurements during winter 1996/97 tests are depicted in a scatter plot (Figure 3.14).

FIGURE 3.13

COMPARISON OF TEMPERATURE DATA

APS DATA vs. READAC DATA

1996 - 1997



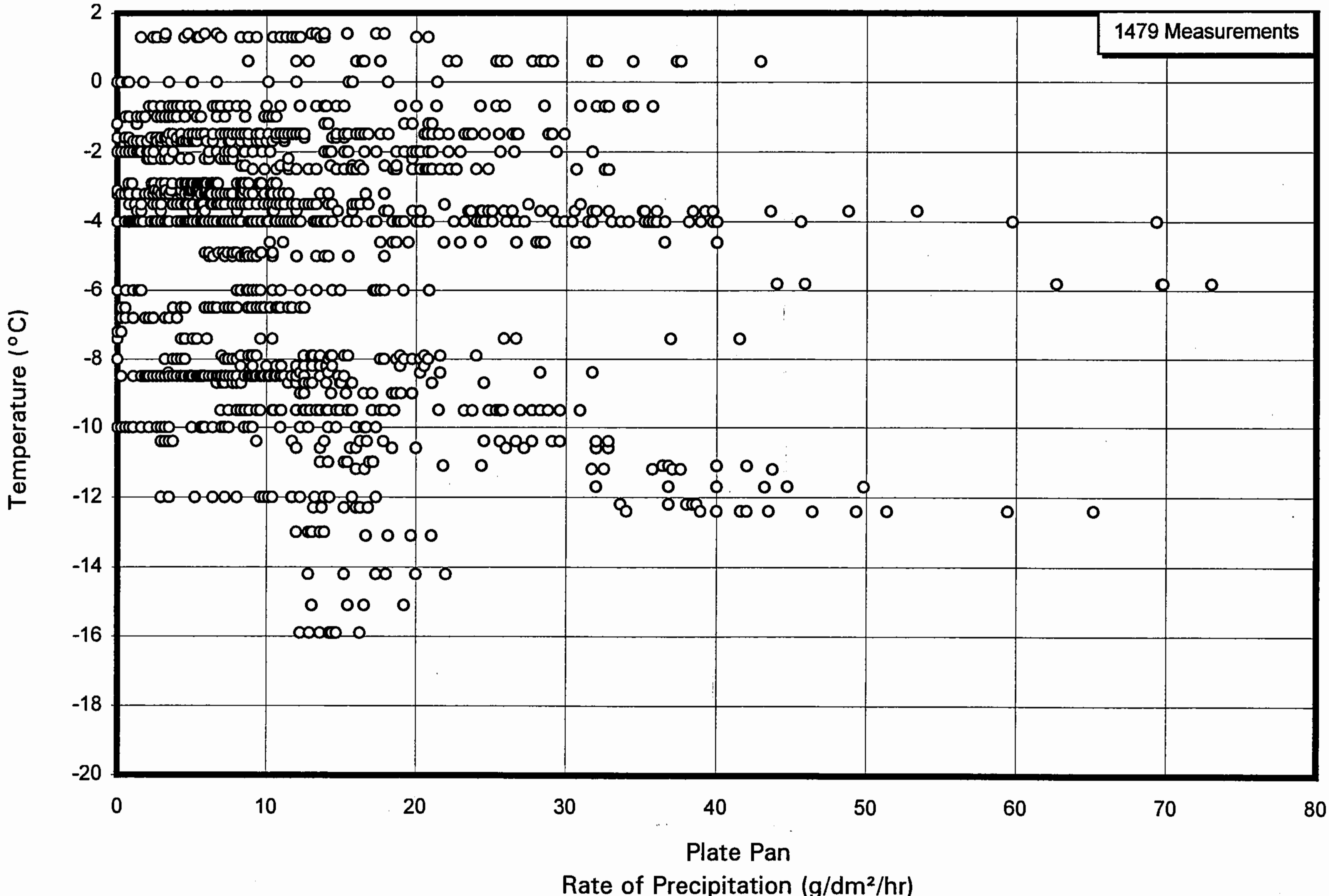
g:\cm1338\report\hot_subs\REDC_APS.XLS
At: Temperature Printed: 07/11/97

FIGURE 3.14

SCATTER PLOT OF TEMPERATURE vs PRECIPITATION RATE

NATURAL PRECIPITATION

1996/97



File:g:\cm1338\analysis\dorval\SNW_DIST.XLS
At: Temp
Printed: 07/11/97 , 03:18 PM

3.2 Simulated Freezing Drizzle and Light Freezing Rain

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, Detailed Plan of the National Research Council Cold Chamber Testing. Figure 3.15 shows that 75 freezing drizzle and 65 light freezing rain flat plate tests were carried out in the 1996/97 winter.

3.2.2 Test Location and Fluids Tested

All of the 140 tests were conducted at the National Research Council Climatic Engineering Facility in Ottawa. The fluids tested were supplied by Union Carbide, Octagon, Kilfrost and Hoechst.

3.2.3 Distribution of Average Precipitation Rates

The average precipitation rates for freezing drizzle and light freezing rain were computed from weight measurements taken with plate pans (see Section 2). Pans were positioned on the stand at every plate position before and after each run for two 15 minute periods. The distribution of average precipitation rate measured for the tests is shown in Figures 3.16 to 3.18 for Type I, Type III and Type IV fluids, respectively.

Precipitation rates for freezing drizzle were in the 2 to 12.7 g/dm²/hr range, and for light freezing rain, in the 12.7 to 25 g/dm²/hr range.

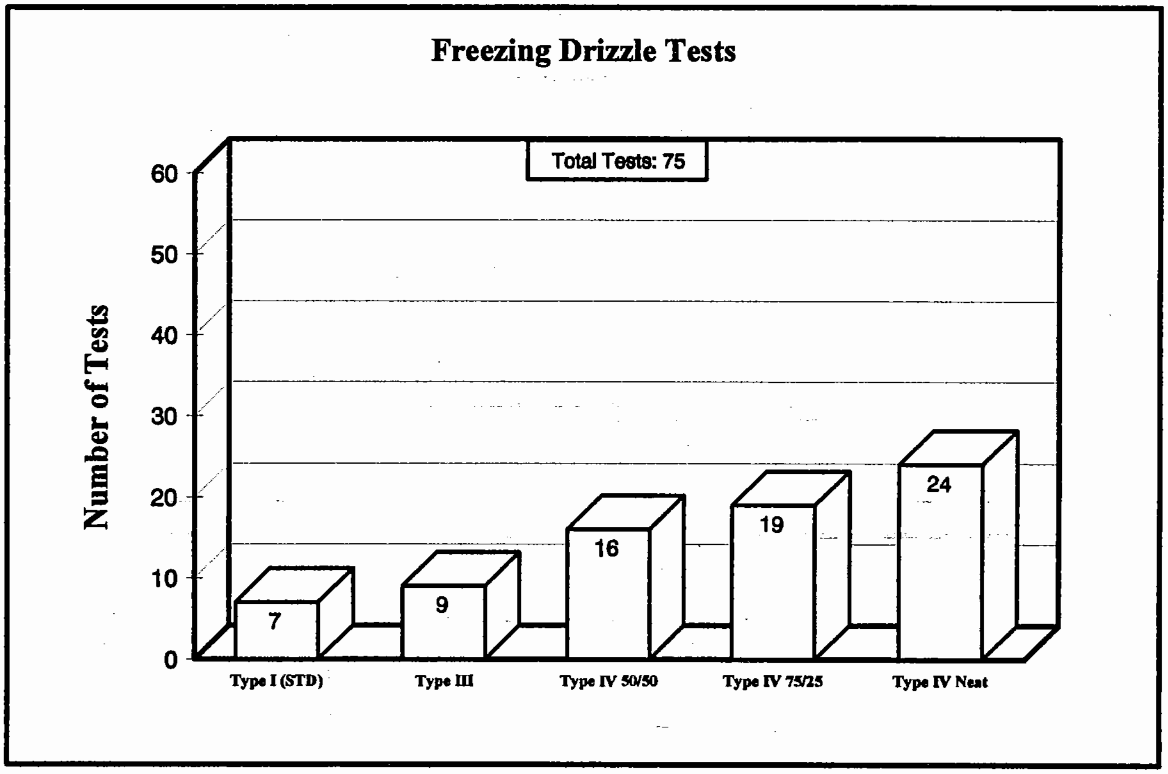
3.2.4 Distribution of Other Meteorological Conditions

The only other meteorological factor which was varied during the freezing drizzle and light freezing rain tests was air temperature. The distribution of the air temperatures is presented in Figures 3.19 to 3.21, which show that the tests were normally conducted with air temperatures of -10°C, and -3°C.

FIGURE 3.15

NUMBER OF SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN TESTS

1996/97 TEST SEASON



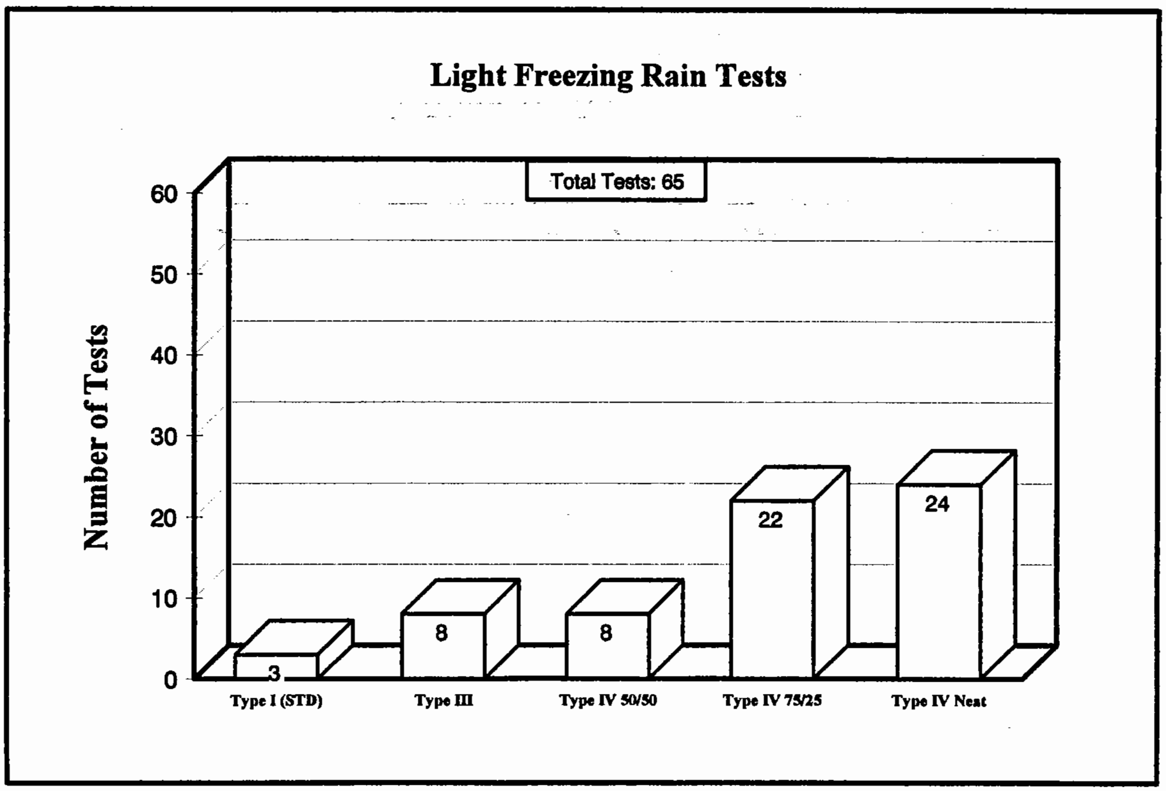


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FIGURE 3.16

DISTRIBUTION OF PRECIPITATION RATE - TYPE I FLUIDS

Simulated Freezing Drizzle/Light Freezing Rain Tests

1996/97

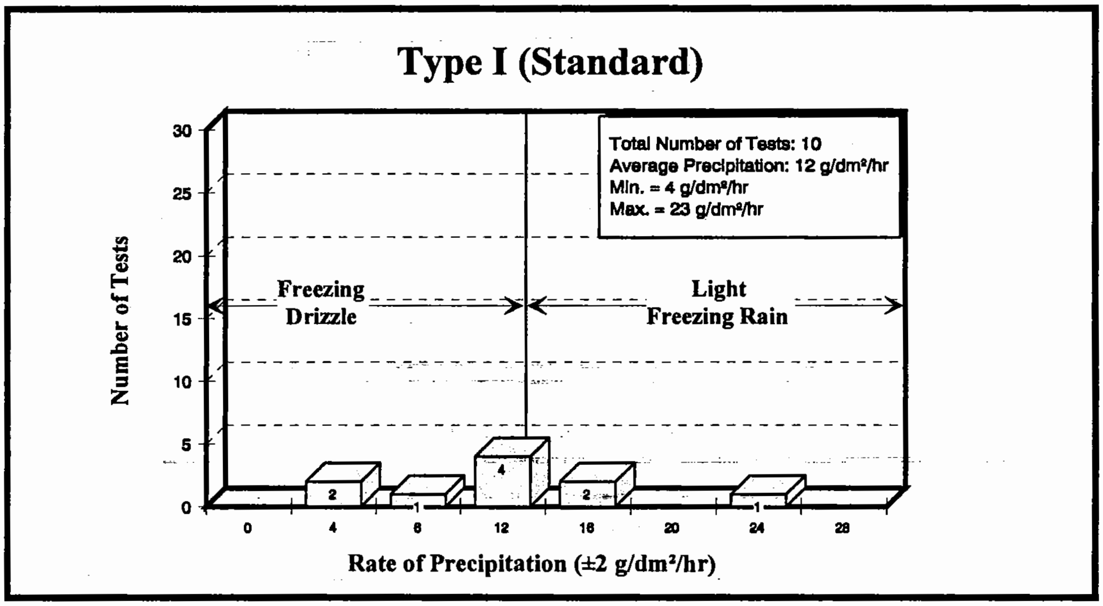

FIGURE 3.17

DISTRIBUTION OF PRECIPITATION RATE - TYPE III FLUID

Simulated Freezing Drizzle/Light Freezing Rain Tests

1996/97

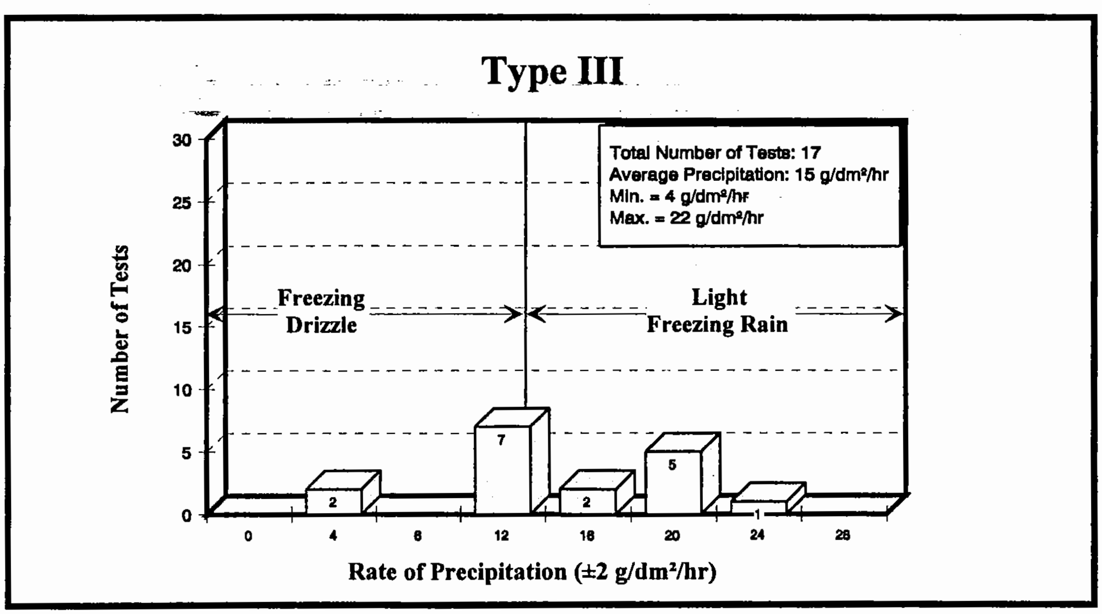

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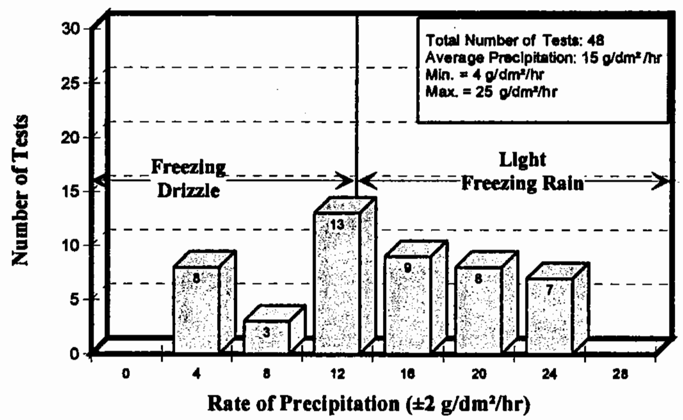
FIGURE 3.18

DISTRIBUTION OF PRECIPITATION RATE - TYPE IV FLUIDS

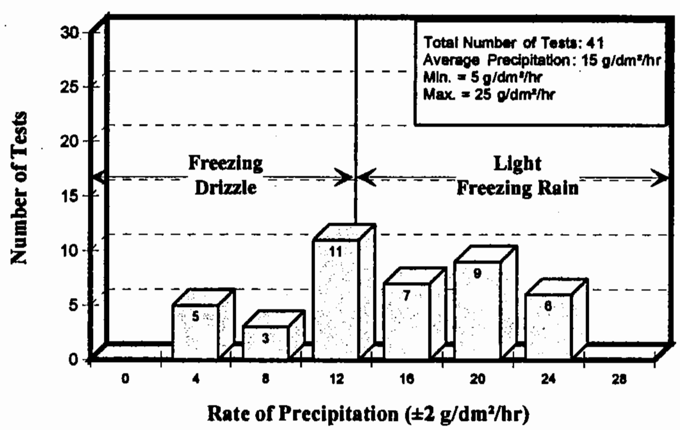
Simulated Freezing Drizzle/Light Freezing Rain Tests

1996/97

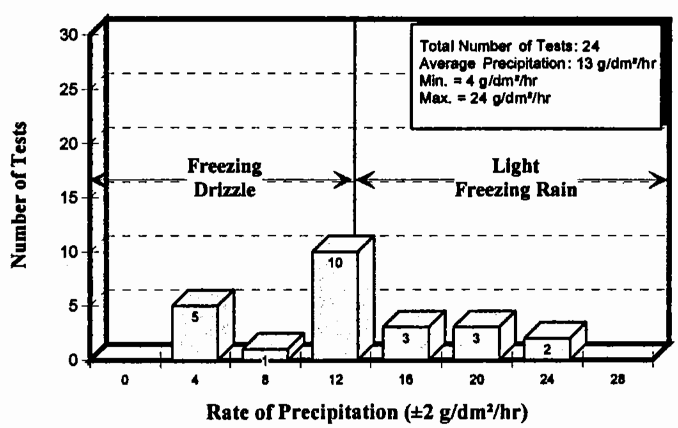
Type IV Neat



Type IV 75/25



Type IV 50/50



cm1338\report\hot_sub\dpre_dr4.grf

FIGURE 3.19

DISTRIBUTION OF AIR TEMPERATURE - TYPE I FLUIDS

Simulated Freezing Drizzle/Light Freezing Rain Tests

1996/97

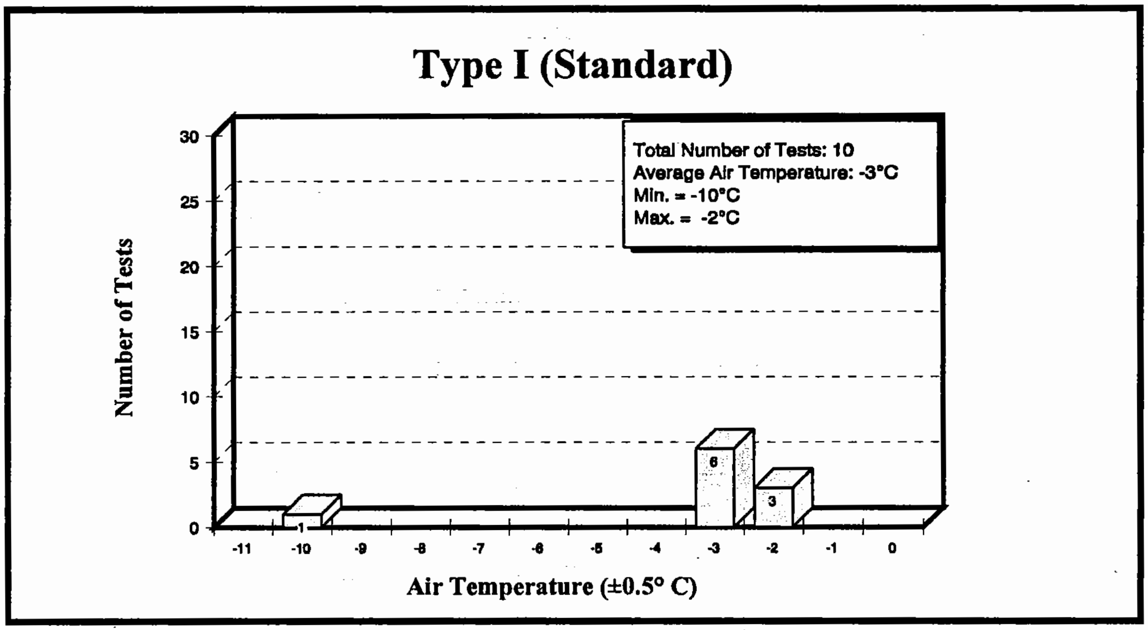
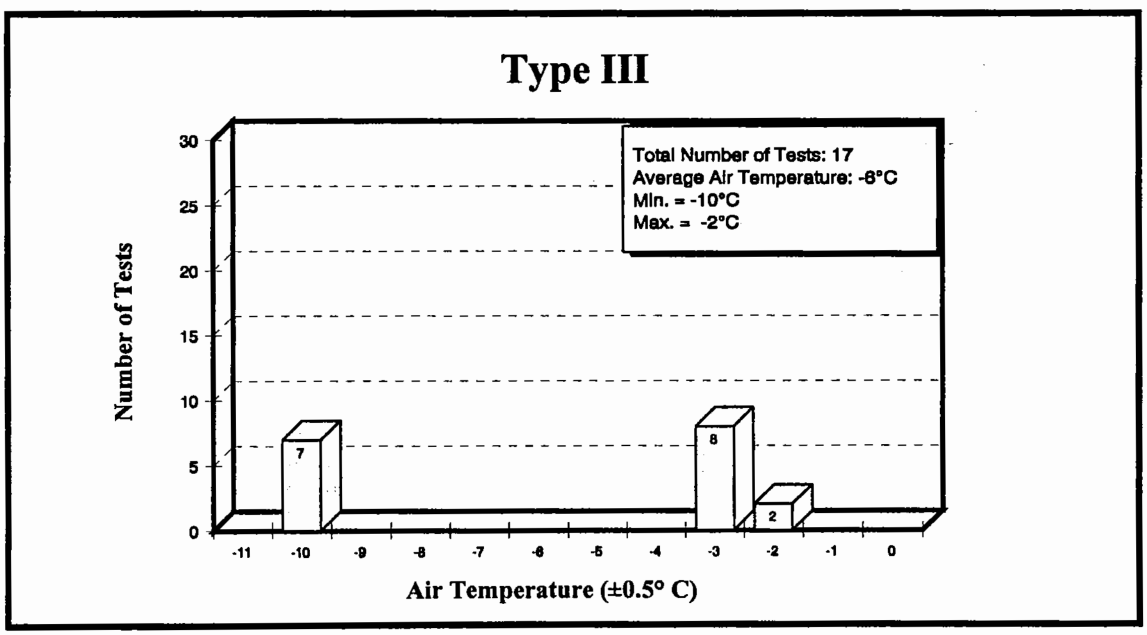


FIGURE 3.20

DISTRIBUTION OF AIR TEMPERATURE - TYPE III FLUID

Simulated Freezing Drizzle/Light Freezing Rain Tests

1996/97

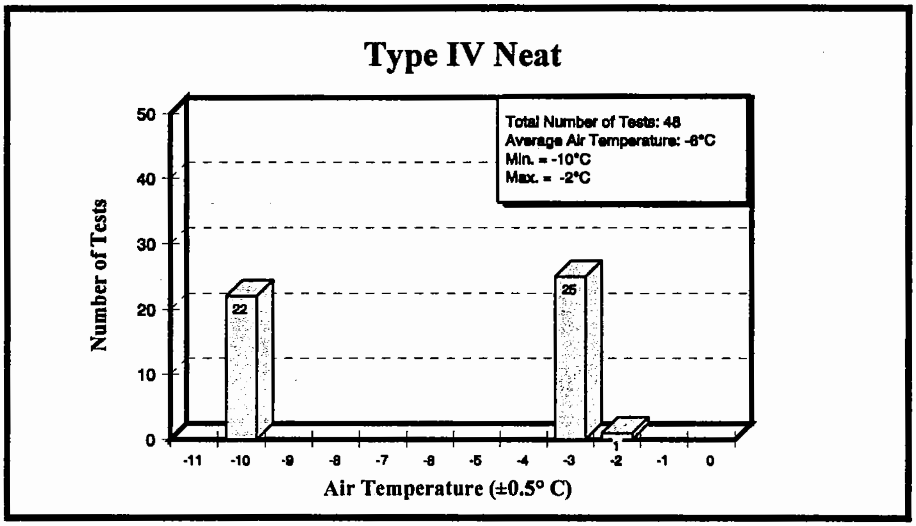


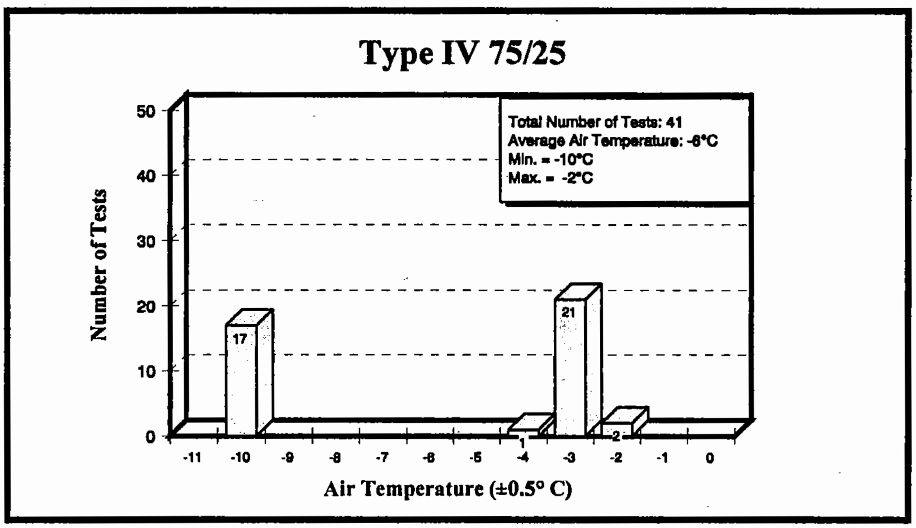
cm1338\report\hot_sub\dtem_dr1.grf

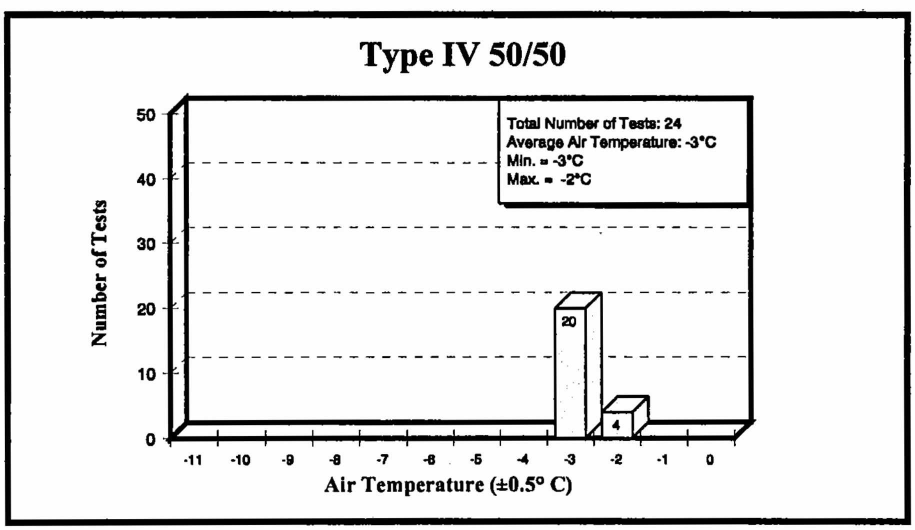
FIGURE 3.21

DISTRIBUTION OF AIR TEMPERATURE - TYPE IV FLUIDS

Simulated Freezing Drizzle/Light Freezing Rain Tests
1996/97







cm1338\report\hot_sub\dtem_dr4.grf

3.3 Simulated Freezing Fog Tests

3.3.1 Data Acquisition

A total of 108 tests were carried out under simulated freezing fog in the 1996/97 winter. The breakdown of these tests is shown in Figure 3.22 and summarized as follows:

	# of Tests
Type I (standard)	15
Type II Neat	29
Type III	7
Type IV Neat	33
Type IV 75/25	15
Type IV 50/50	9
Total Usable Tests	108

3.3.2 Test Location and Fluids Tested

All of the tests were conducted at the National Research Council cold chamber in Ottawa. The fluids tested were supplied by Union Carbide, Octagon, Kilfrost, SPCA and Hoechst.

3.3.3 Distribution of Average Precipitation Rates

The average precipitation rates for freezing fog were computed from weight measurements taken with plate pans. Pans were positioned on the stand at every plate position before and after each run for two 15 minute periods. The distribution of average precipitation rate measured for the tests is shown in Figure 3.23 to 3.26 for Type I, Type II, Type III and Type IV fluids. Precipitation rates for freezing fog ranged from 2 to 10 g/dm²/hr.

3.3.4 Distribution of Tests by Air Temperature

The other condition which was varied during the freezing fog tests was the temperature. The distribution of temperatures is presented in Figures 3.27 to 3.30 for Type I, Type II, Type III and Type IV fluids.

FIGURE 3.22

NUMBER OF SIMULATED FREEZING FOG TESTS

1996/97 TEST SEASON

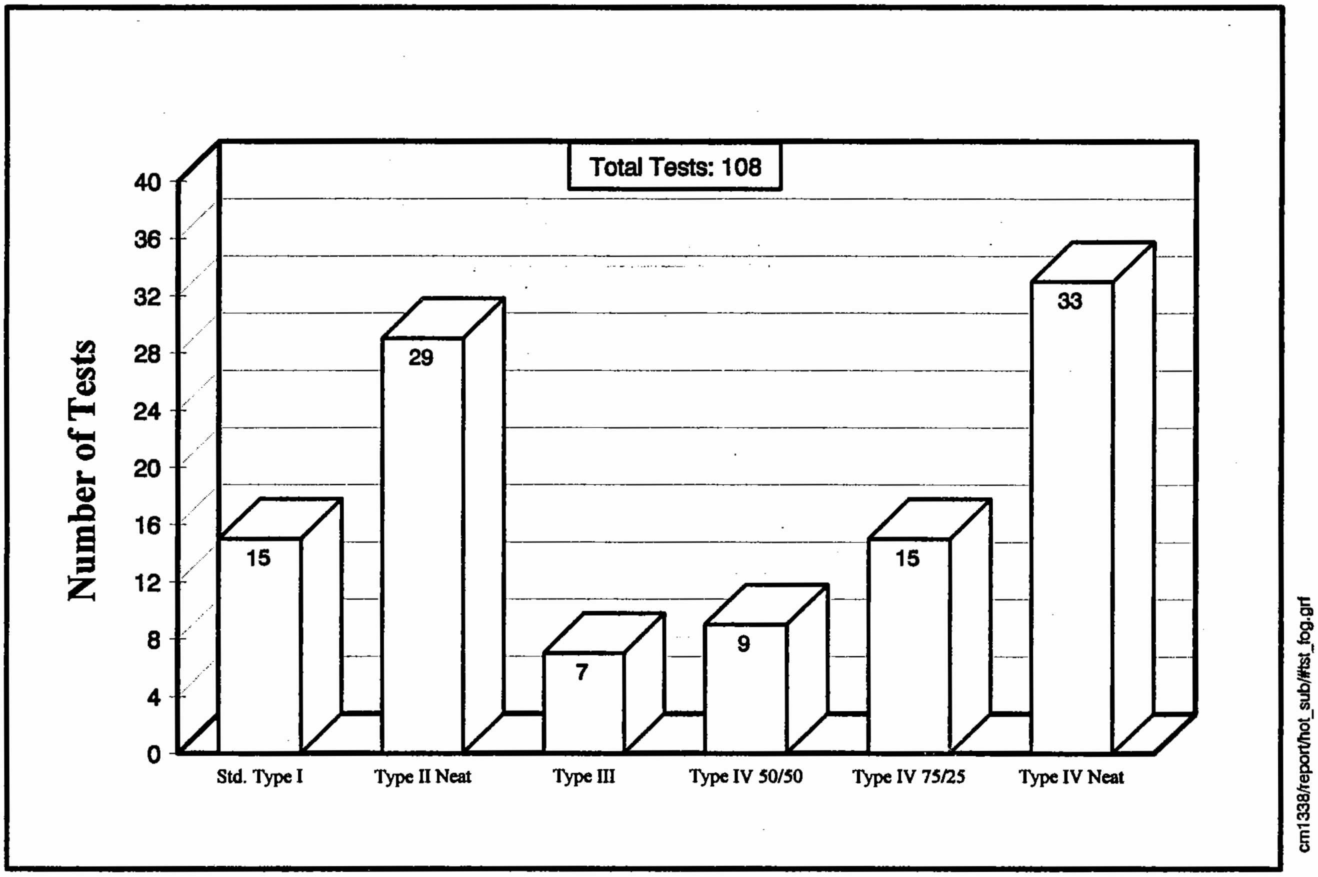


FIGURE 3.23

DISTRIBUTION OF PRECIPITATION RATE - TYPE I FLUIDS

Simulated Freezing Fog Tests

1996/97

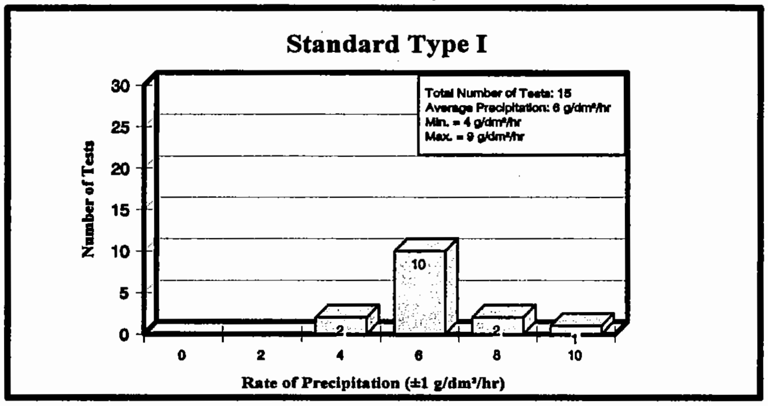


FIGURE 3.24

DISTRIBUTION OF PRECIPITATION RATE - TYPE II FLUIDS

Simulated Freezing Fog Tests

1996/97

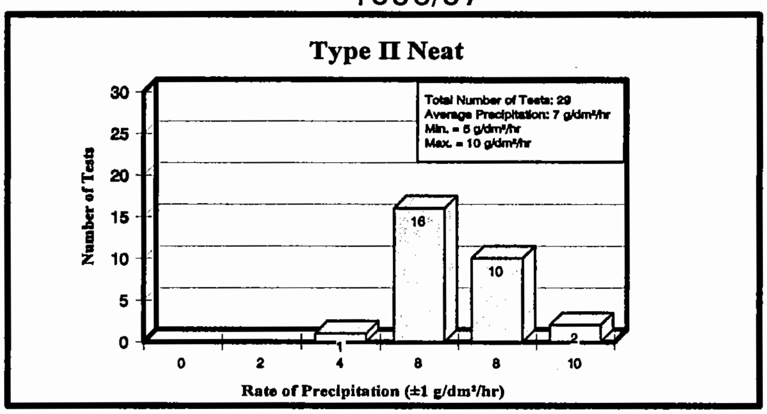


FIGURE 3.25

DISTRIBUTION OF PRECIPITATION RATE - TYPE III FLUID

Simulated Freezing Fog Tests

1996/97

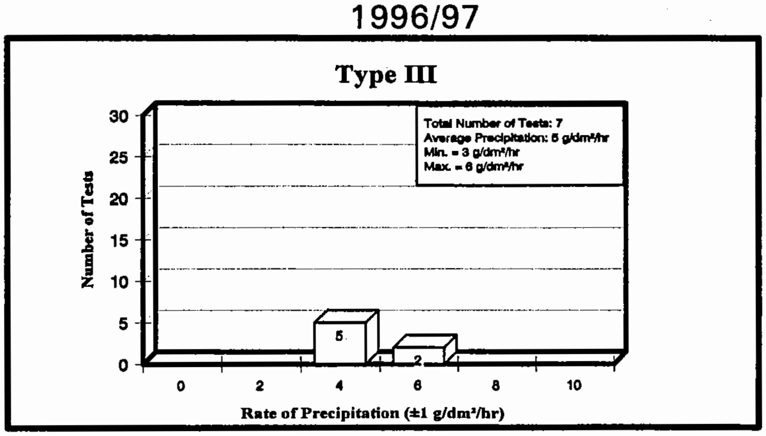
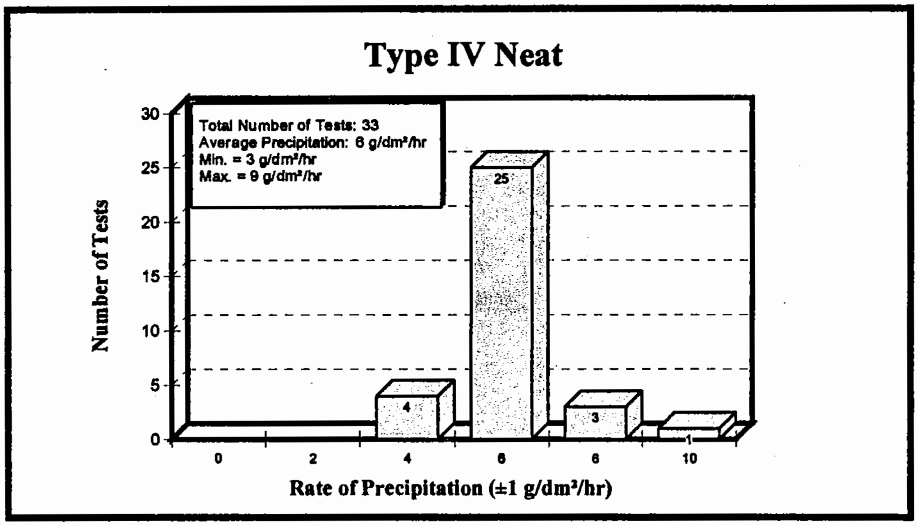


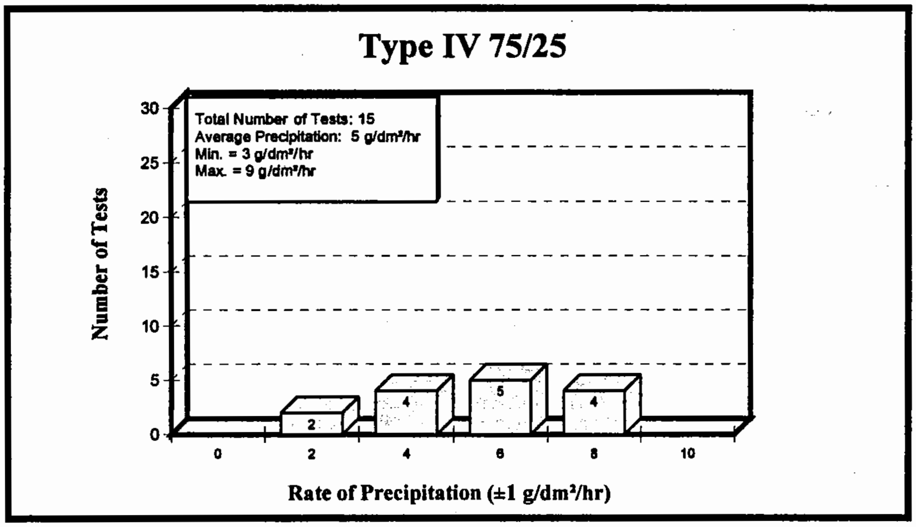
FIGURE 3.26

DISTRIBUTION OF PRECIPITATION RATE - TYPE IV FLUIDS

Simulated Freezing Fog Tests

1996/97





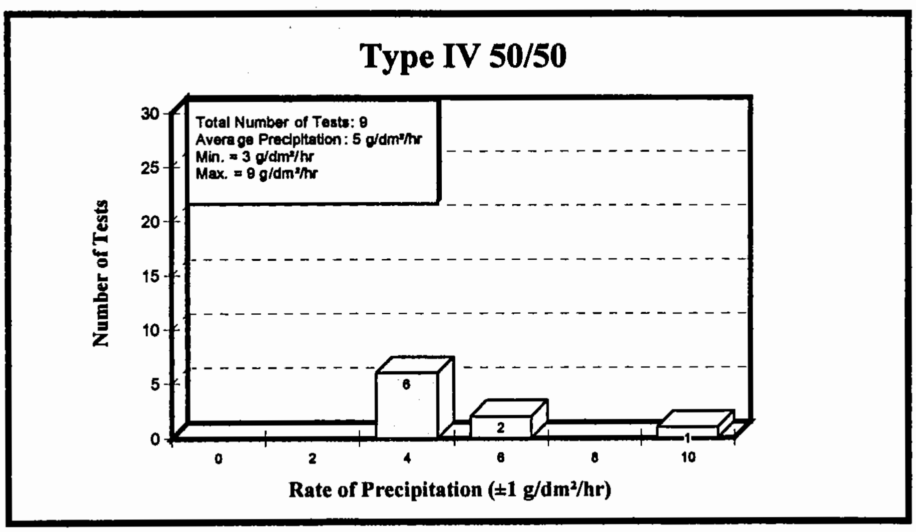


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FIGURE 3.27

DISTRIBUTION OF AIR TEMPERATURE - TYPE I FLUIDS

Simulated Freezing Fog Tests

1996/97

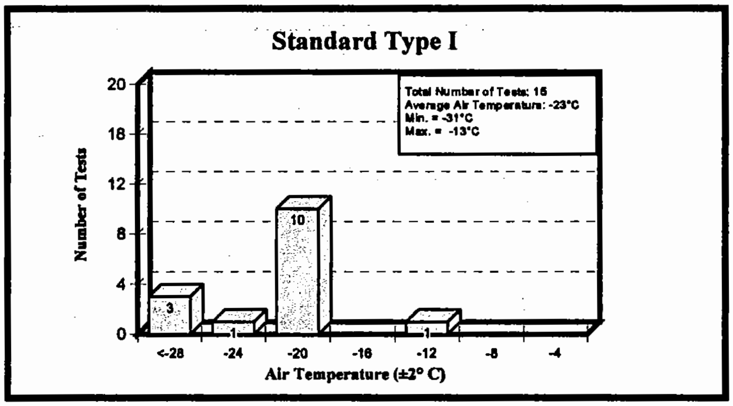

FIGURE 3.28

DISTRIBUTION OF AIR TEMPERATURE - TYPE II FLUIDS

Simulated Freezing Fog Tests

1996/97

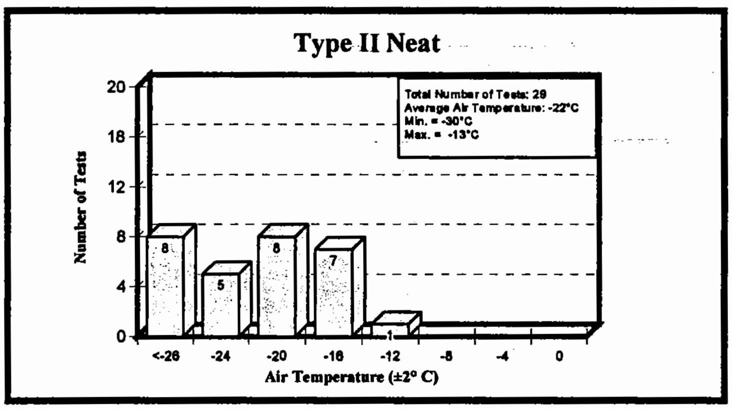

FIGURE 3.29

DISTRIBUTION OF AIR TEMPERATURE - TYPE III FLUID

Simulated Freezing Fog Tests

1996/97

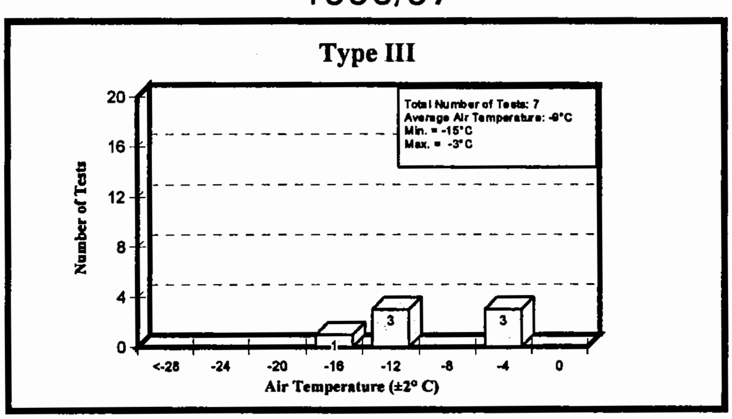

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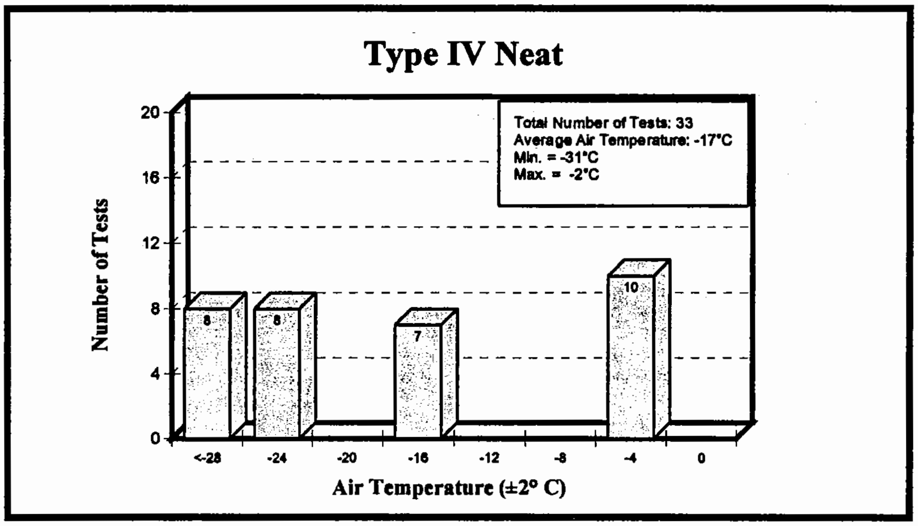
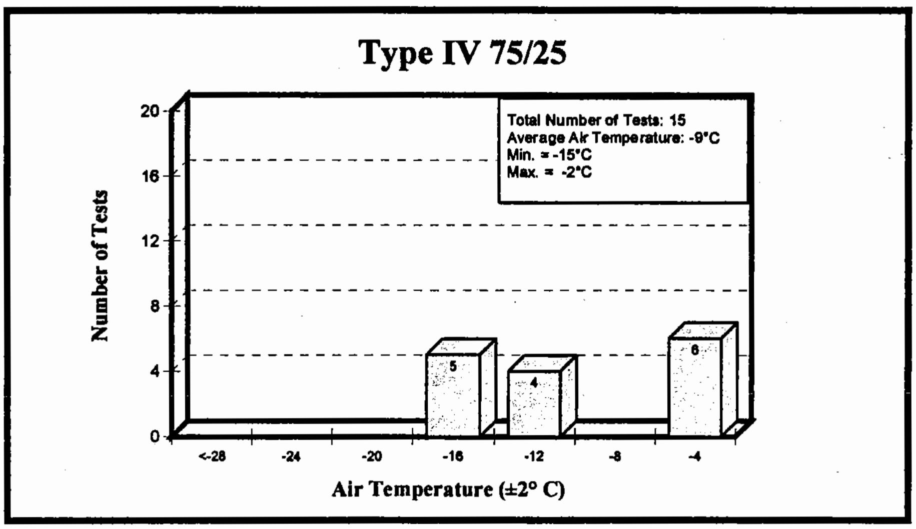
FIGURE 3.30

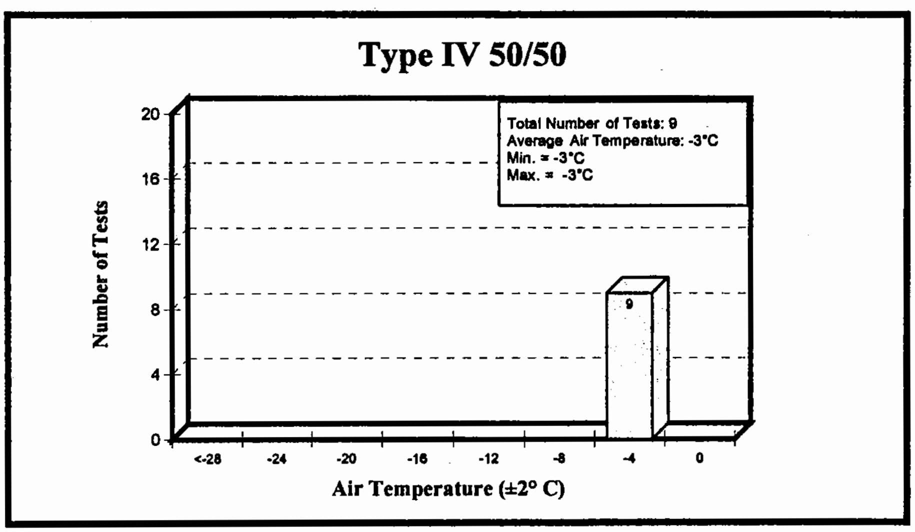
DISTRIBUTION OF AIR TEMPERATURE - TYPE IV FLUIDS

Simulated Freezing Fog Tests

1996/97







cm1338\report\hot_sub\dtem_fg4.grf

3.4 Simulated Rain on Cold-Soaked Surface Tests

3.4.1 Data Acquisition

A total of 78 cold-soaked tests using sealed boxes were conducted during the 1996/97 test season. The breakdown of tests, by size of sealed box and by fluid type, is shown in Figure 3.31.

3.4.2 Test Location and Fluids Tested

All 78 tests were completed at the National Research Council cold chamber in Ottawa. The fluids tested were supplied by Union Carbide, Octagon, Kilfrost, and Hoechst.

3.4.3 Distribution of Average Precipitation Rates

Precipitation for the drizzle and light rain on cold-soaked surface tests was produced using the same apparatus as was used for freezing drizzle and light freezing rain tests. Moderate rain and heavy rain precipitation were also produced using the same apparatus, but with different hypodermic needles and water/air pressures. The distribution of tests conducted as a function of the intensity of precipitation (see Subsection 2.3) is shown in Figure 3.32 for Type III fluid, and Figure 3.33 for Type IV fluid.

Only a limited number of tests were carried out during heavy rain with precipitation rates exceeding 76 g/dm²/hr. In practice, fluid applied on a wing in this condition would probably be washed away quickly.

3.4.4 Distribution of Tests by Average Surface Temperature

The ambient air temperature was set to +2°C during the rain on cold-soaked surface tests. The temperature on the test surface (sealed box) was measured with either a thermistor sensor or a hand-held surface temperature probe. The instrument was positioned above a crosshair marking located 22.5 cm (9") from the top of the test surface (see Appendix C, Attachment IX). The intent was to start tests when the surface temperature was -10°C.

To obtain the average temperature over a test, the final surface temperature was also measured at the completion of the test. Figure 3.34 shows the response curves for two thermistors mounted at different positions on the test

FIGURE 3.31

NUMBER OF COLD-SOAKED TESTS

1996/97 TEST SEASON

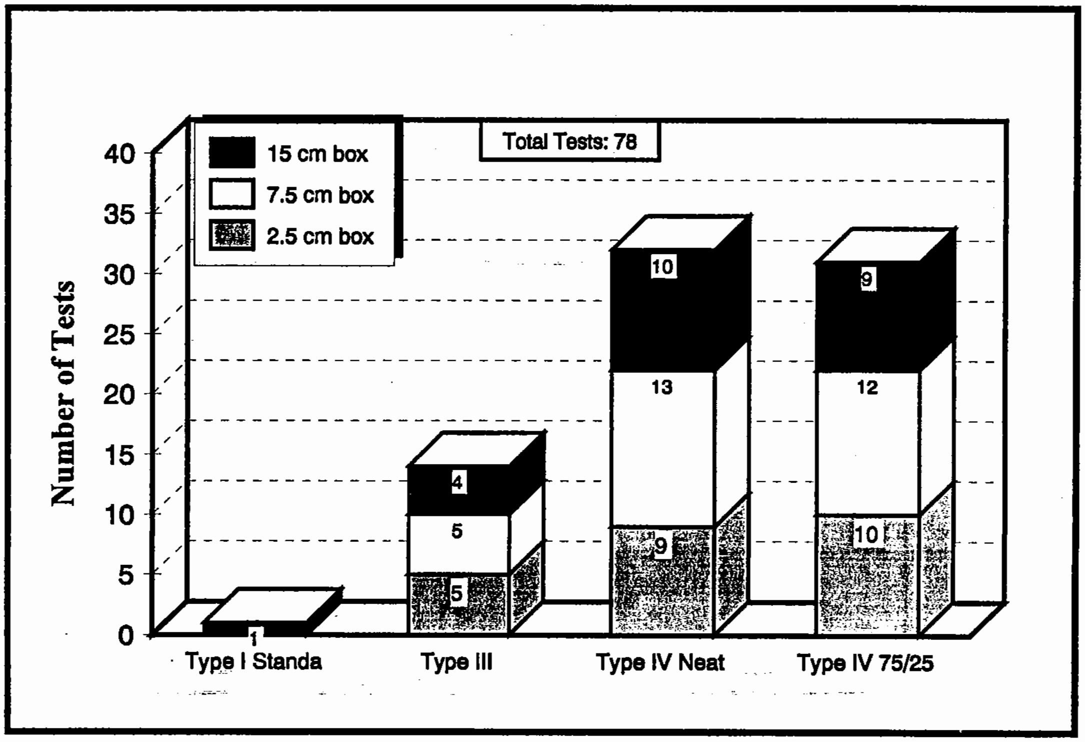


FIGURE 3.32

DISTRIBUTION OF PRECIPITATION INTENSITY - TYPE III FLUID

Cold-Soaked Box Tests

1996/97

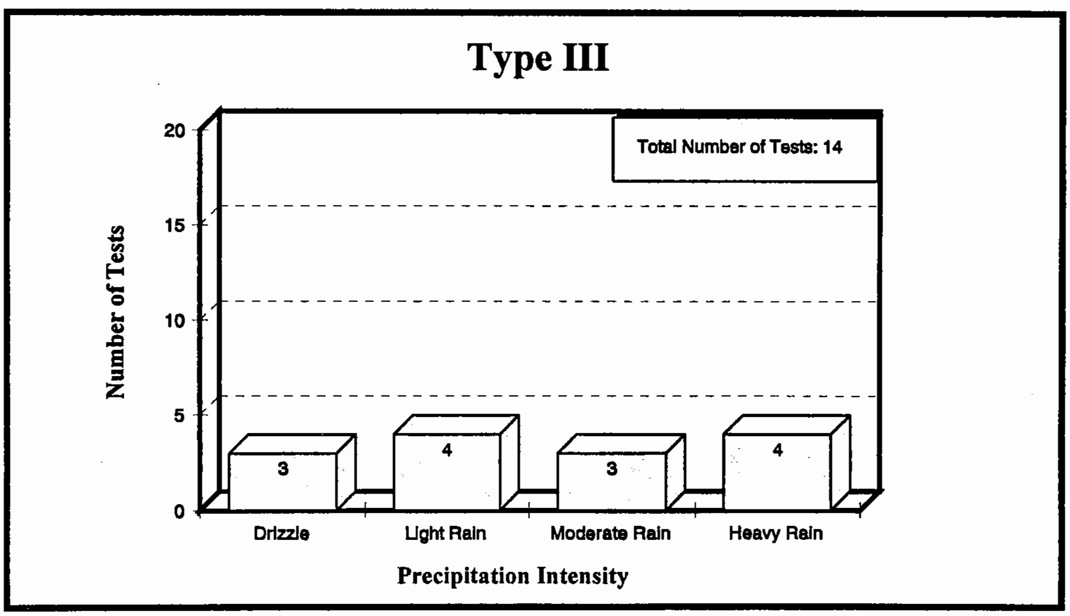


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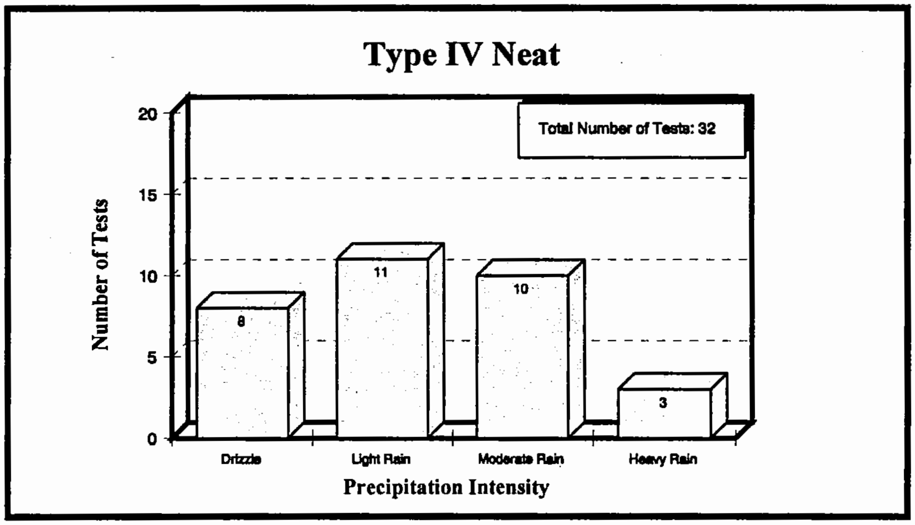
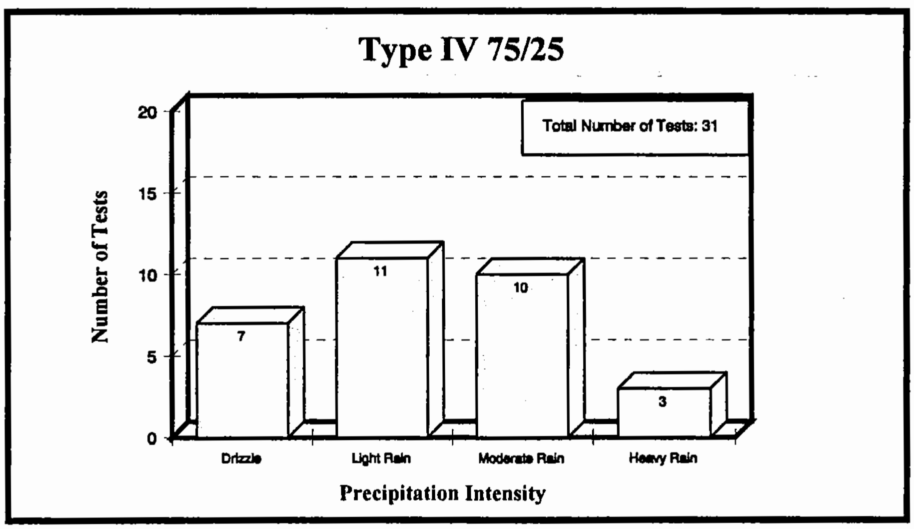
FIGURE 3.33

DISTRIBUTION OF PRECIPITATION INTENSITY - TYPE IV FLUIDS

Cold-Soaked Box Tests

1996/97



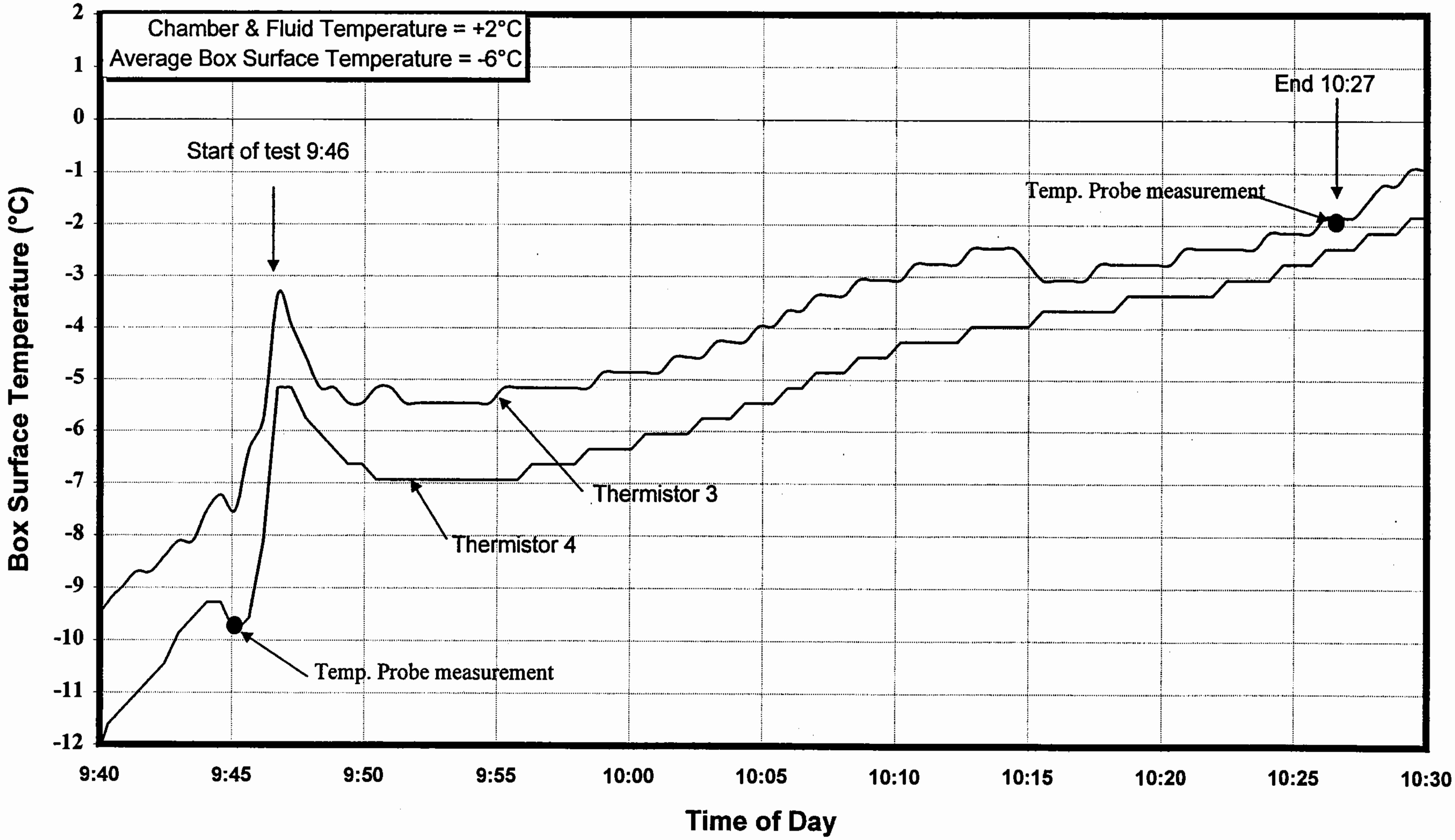


cm1338\report\hot_sub\dpre_bx4.grf

FIGURE 3.34

TEMPERATURE INCREASE OF A COLD-SOAKED BOX
TYPE IV UCAR ULTRA+ FLUID

April 23, 1997 - Box E, Thermistors 3 & 4



File:g:\cm1338\report\hot_subs\Ap23_t34
At: Box E
Printed: 11/11/97 , 2:54 AM

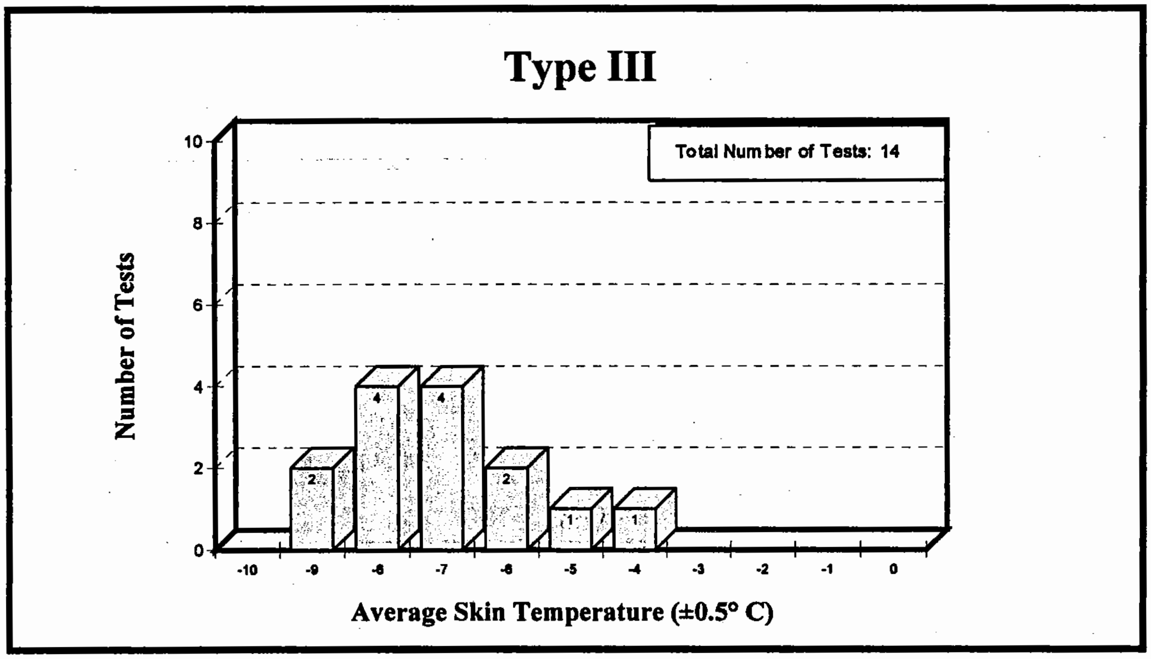
box surface. It also shows two probe measurements of the surface temperature, one taken before fluid application, and one taken at the end of the test. The spike at the start of the test is due to fluid application. After this, the temperature falls quickly, but then rises steadily over the test period. Failure occurs at -2°C, midway between ambient chamber temperature (2°C) and the average box temperature (-6°C). Although the absolute temperature response of each thermistor is not identical, the variation in temperature detected by each thermistor over the test period is consistent. Consistency between thermistor response and temperature probe measurements are also observed.

Figure 3.35 and 3.36 gives the number of Type III and Type IV fluids tests conducted as a function of average test surface skin temperature.

FIGURE 3.35

DISTRIBUTION OF SKIN TEMPERATURE - TYPE III FLUIDS

Cold-Soaked Box Tests
1996/97



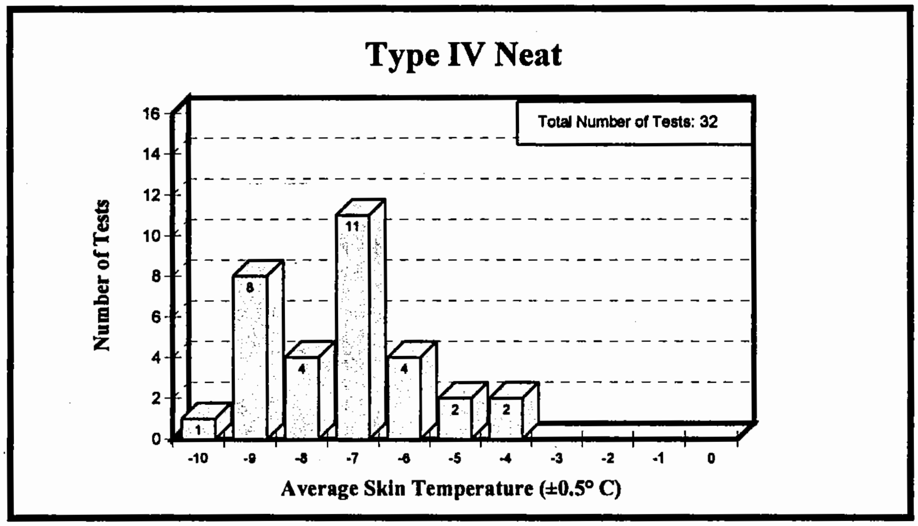
cm1338\report\hot_sub\dtem_bx3.grf

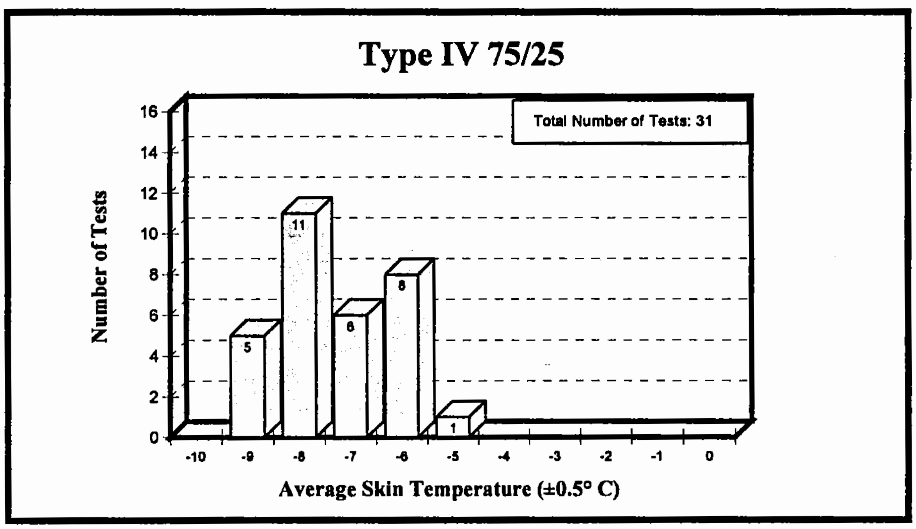
FIGURE 3.36

DISTRIBUTION OF SKIN TEMPERATURE - TYPE IV FLUIDS

Cold-Soaked Box Tests

1996/97





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4. FLUID THICKNESS TESTS ON FLAT PLATES

Type IV fluid thickness tests on plates were conducted at the APS site at Dorval airport and at the National Research Council Climatic Engineering Facility, on four different occasions during the 1996/97 test season. The listing of tests conducted are displayed in Table 4.1. The purpose of these tests was to study the effect of fluid dilution and undercoating (Type IV over Type I) on fluid thickness. The effect of increased fluid temperature on Type IV fluid thickness was also examined. In addition, the Type IV fluid thickness measurements using this year's new fluids are compared to last year's measures. Film thickness was measured for four different Type IV fluids, for each standard fluid concentration (Neat, 75/25 and 50/50).

4.1 General Procedures and Stabilized Neat Fluid Profiles

Thickness measurements were taken at regular time intervals over a period of 30 minutes, at 2.5 cm (1") and 15 cm (6") lines on the 10° flat plates. A complete description of the film thickness test procedure is reported in the 1996/97 Evaluation of Fluid Thickness Transport Canada report, TP 12900E (3). The tests at Dorval were conducted indoors (see Photo 4.1) to exclude environmental factors such as natural precipitation and wind. The ambient temperature for these tests varied from 0°C to -5°C.

Figure 4.1 illustrates the thickness decay at the 15 cm (6") 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 ten minutes from the start of the test. Figure 4.2 shows thickness decay curves for the new fluids tested in the 1996/97 winter season. A comparison of thickness decay of new Type IV fluids tested during winter 1996/97 shows that the thickness measurements of these neat Type IV fluids were significantly different from the old Type IV fluids and also different from one another; Ultra+ and Kilfrost were more than twice the thickness of Octagon and Hoechst after 30 minutes.

4.2 Dilution Effect

Figure 4.3 shows 4 bar graphs, each corresponding to a specific new Type IV fluid brand. Each bar gives the fluid thickness at the 6" (15 cm) line of a standard test plate, 30 minutes after fluid application. The number of tests used to produce each of the 4 graphs is indicated in the small box (top centre) of each graph. Several tests (2 to 4) were performed for each standard dilution (Neat, 75/25, and 50/50), as well as for two-step fluid applications. Each bar represents one test or run.

- Ultra+ showed significant decrease in thickness when diluted with water;
- Kilfrost 75/25 showed only slight decrease in thickness. The 50/50 thickness of the mix decreased significantly;

TABLE 4.1

LOG OF FLUID THICKNESS TESTS

ID #	Test Date (1997)	Fluid Type	Fluid Concentration	Fluid Quantities (Litres)	Ambient Air Temperature (AAT, °C)	Fluid Temp. (°C)	Stabilized Thickness after 30 min. at 6" Line (MILS)	Objectives
1	3-Mar-97	Ultra +	Neat	1.5	-3	AAT	52.5	Baseline
2	3-Mar-97	Ultra +	75%	1.5	-3	AAT	25	Dilution effect
3	3-Mar-97	Ultra +	50%	1.5	-3	AAT	11.5	Dilution effect
4	3-Mar-97	Kilfrost IV	Neat	1.5	-3	AAT	72	Baseline
5	3-Mar-97	Kilfrost IV	75%	1.5	-3	AAT	67.5	Dilution effect
6	3-Mar-97	Kilfrost IV	50%	1.5	-3	AAT	13	Dilution effect
7	3-Mar-97	Octagon IV	Neat	1.5	-3	AAT	29	Baseline
8	3-Mar-97	Octagon IV	75%	1.5	-3	AAT	67.5	Dilution effect
9	3-Mar-97	Octagon IV	50%	1.5	-3	AAT	62.5	Dilution effect
10	3-Mar-97	Hoechst IV	Neat	1.5	-3	AAT	27	Baseline
11	3-Mar-97	Hoechst IV	75%	1.5	-3	AAT	32.5	Dilution effect
12	3-Mar-97	Hoechst IV	50%	1.5	-3	AAT	19	Dilution effect
13	3-Mar-97	U+/XL54	Neat/XL54	1.5/0.5	-4	AAT/80	47.5	Undercoat effect
14	3-Mar-97	K IV/K I	Neat/K I	1.5/0.5	-4	AAT/80	62.5	Undercoat effect
15	3-Mar-97	O IV/O I	Neat/O I	1.5/0.5	-4	AAT/80	23	Undercoat effect
16	3-Mar-97	H IV/H I	Neat/H I	1.5/0.5	-4	AAT/80	21	Undercoat effect
17	3-Mar-97	U+/XL54	Neat/XL54	1.5/0.5	-4	80/80	10.5	Tank heat transfer effect
18	3-Mar-97	K IV/K I	Neat/K I	1.5/0.5	-4	80/80	27	Tank heat transfer effect
19	3-Mar-97	O IV/O I	Neat/O I	1.5/0.5	-4	80/80	3.5	Tank heat transfer effect
20	3-Mar-97	H IV/H I	Neat/H I	1.5/0.5	-4	80/80	23	Tank heat transfer effect
21	12-Mar-97	Ultra +	Neat	1.5	-5	AAT	47.5	Duplicate of test #1
22	12-Mar-97	Ultra +	75%	1.5	-5	AAT	23	Duplicate of test #2
23	12-Mar-97	Ultra +	50%	1.5	-5	AAT	6.4	Duplicate of test #3
24	12-Mar-97	Kilfrost IV	Neat	1.5	-5	AAT	67.5	Duplicate of test # 4
25	12-Mar-97	Kilfrost IV	75%	1.5	-5	AAT	57.5	Duplicate of test #5
26	12-Mar-97	Kilfrost IV	50%	1.5	-5	AAT	11.5	Duplicate of test #6
27	12-Mar-97	Octagon IV	Neat	1.5	-5	AAT	25	Duplicate of test #7
28	12-Mar-97	Octagon IV	75%	1.5	-5	AAT	47.5	Duplicate of test #8
29	12-Mar-97	Octagon IV	50%	1.5	-5	AAT	47.5	Duplicate of test #9
30	12-Mar-97	Hoechst IV	Neat	1.5	-5	AAT	27	Duplicate of test #10
31	12-Mar-97	Hoechst IV	75%	1.5	-5	AAT	32.5	Duplicate of test #11
32	12-Mar-97	Hoechst IV	50%	1.5	-5	AAT	17.5	Duplicate of test #12
33	12-Mar-97	U+/XL54	Neat/XL54	1.5/0.5	-5	AAT/80	43	Duplicate of test #13
34	12-Mar-97	K IV/K I	Neat/K I	1.5/0.5	-5	AAT/80	57.5	Duplicate of test #14
35	12-Mar-97	O IV/O I	Neat/O I	1.5/0.5	-5	AAT/80	19	Duplicate of test #15
36	12-Mar-97	H IV/H I	Neat/H I	1.5/0.5	-5	AAT/80	27	Duplicate of test #16
37	12-Mar-97	U+/XL54	Neat/XL54	1.5/0.5	-5	80/80	4.5	Duplicate of test #17 (double boiler)
38	12-Mar-97	K IV/K I	Neat/K I	1.5/0.5	-5	80/80	37.5	Duplicate of test #18 (double boiler)
39	12-Mar-97	O IV/O I	Neat/O I	1.5/0.5	-5	80/80	5.5	Duplicate of test #19
40	12-Mar-97	H IV/H I	Neat/H I	1.5/0.5	-5	80/80	19	Duplicate of test #20
41	12-Mar-97	U+/XL54	Neat/XL54	1.5/0.5	-5	AAT/15	43	Corrolation with old tests
42	12-Mar-97	O IV/O I	Neat/O I	1.5/0.5	-5	AAT/15	23	Corrolation with old tests
43	12-Mar-97	H IV/H I	Neat/H I	1.5/0.5	-5	AAT/15	21	Corrolation with old tests
44	12-Mar-97	K IV/K I	Neat/K I	1.5/0.5	-5	AAT/15	57.5	Corrolation with old tests
45	18-Mar-97	U+/XL54	Neat/XL54	1.5/0.5	-2	80/80	3.5	Double boiling test
46	18-Mar-97	K IV/K I	Neat/K I	1.5/0.5	-2	80/80	23	Double boiling test
47	18-Mar-97	Ultra +	50%	1.5	0	AAT	7.5	Retest #3
48	18-Mar-97	Hoechst IV	75%	1.5	0	AAT	32.5	Retest #11
49	18-Mar-97	Hoechst IV	50%	1.5	0	AAT	15	Retest #12
50	15-Apr-97	Octagon IV	75%	1.5	-3	AAT	72.5	Retest # 8
51	15-Apr-97	Octagon IV	50%	1.5	-3	AAT	52.5	Duplicate of test #9
52	15-Apr-97	O IV/O I	Neat/O I	1.5/0.5	-3	80/80	3.5	Heating effect
53	15-Apr-97	H IV/H I	Neat/H I	1.5/0.5	-3	80/80	8.5	Heating effect
54	15-Apr-97	U+/XL54	Neat/Std	1.5/0.5	-3	AAT/80	43	Baseline to Type 0 under U+ IV
55	*15-Apr-97*	*U+IV/Type 0*	*Neat/0*	*1.5/0.5*	*-3*	*AAT/80*	*43*	*Type 0 undercoat effect*
56	*15-Apr-97*	*XL54*	*Std*	*1.5*	*-3*	*80*	*2.5*	*Comp. baseline to type 0*
57	*15-Apr-97*	*Type 0*	*Std*	*1.5*	*-3*	*80*	*1.5*	*Type 0 alone*
58	*15-Apr-97*	*XL54/Type 0*	*Std/0*	*1.5/0.5*	*-3*	*80/80*	*1.5*	*Compatibility of XL54 with T 0*
59	*15-Apr-97*	*XL54/Type 0*	*Std/0*	*1.5/0.5*	*-3*	*80/80*	*1.5*	*Duplicate of #58*
60	15-Apr-97	XL54	Std	0.5	-3	16	1.5	Room temperature baseline
61	*15-Apr-97*	*Type 0*	*Std*	*0.5*	*-3*	*16*	*1.5*	*Type 0 - XL54 comparison*
62	*15-Apr-97*	*XL54/Type 0*	*Std/0*	*1.5/0.5*	*-3*	*16/16*	*1.5*	*Compatibility of XL54 with T 0*

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FIGURE 4.1

THICKNESS DECAY OF OLD TYPE IV FLUIDS

1995/96

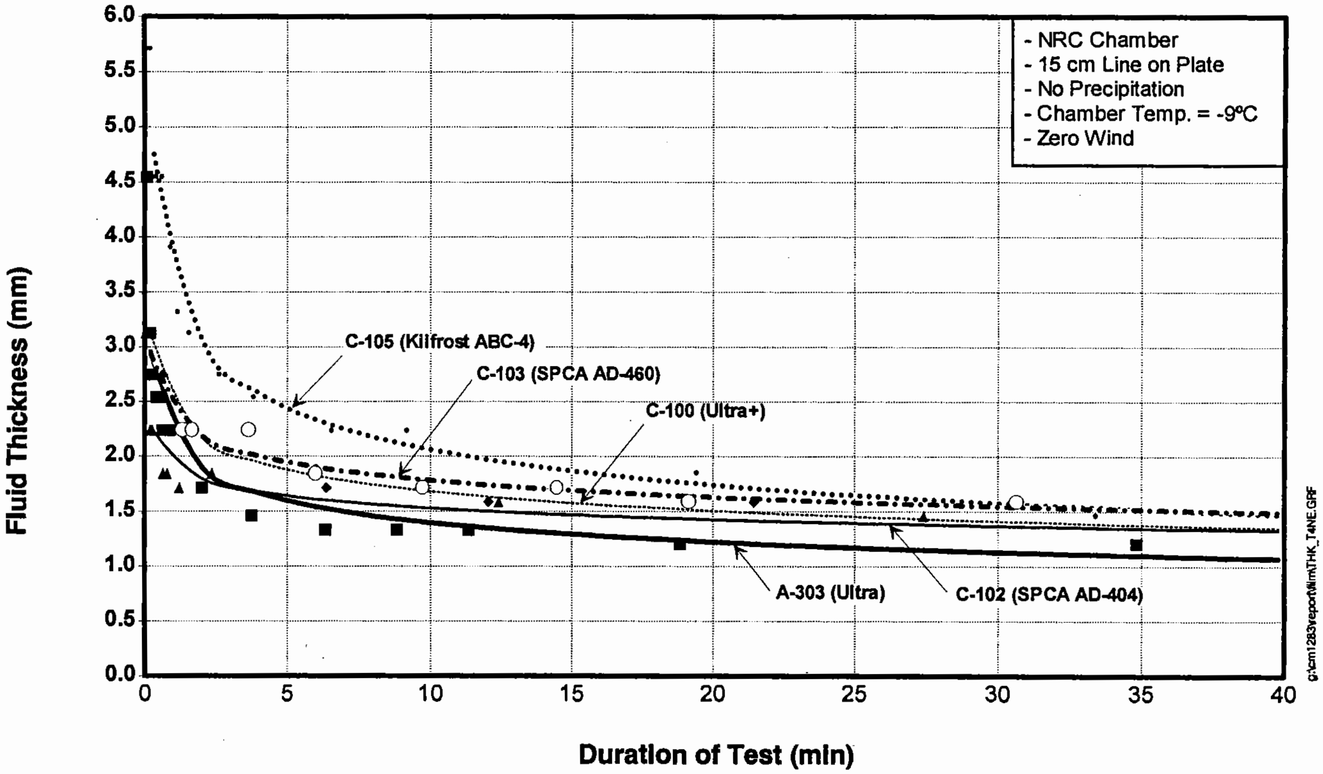

FIGURE 4.2

THICKNESS DECAY OF NEW TYPE IV NEAT FLUIDS

1996/97

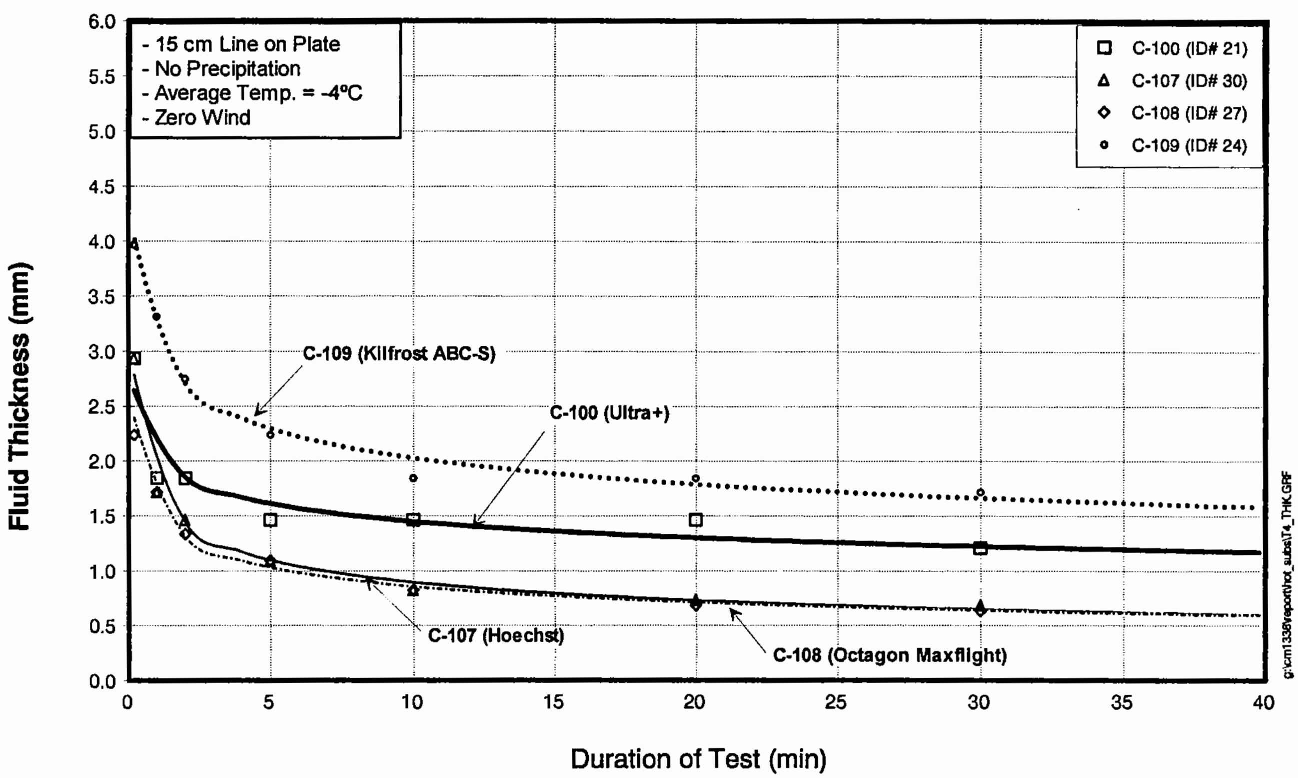

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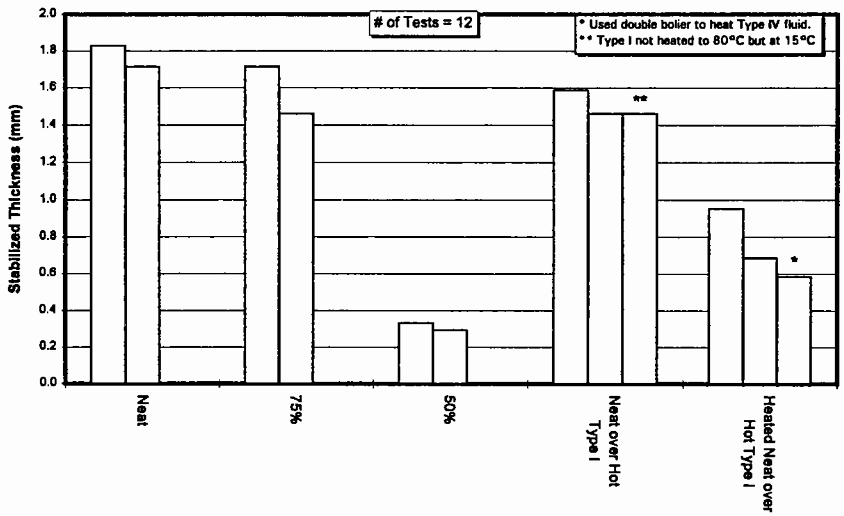
FIGURE 4.3

FILM THICKNESS OF VARIOUS TYPE IV FLUIDS

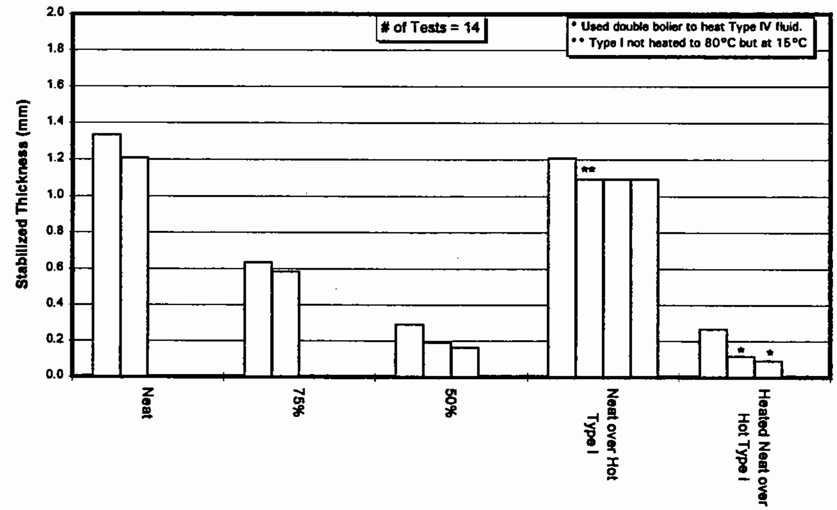
WINTER 1996/97

OAT = 0 to -5°C

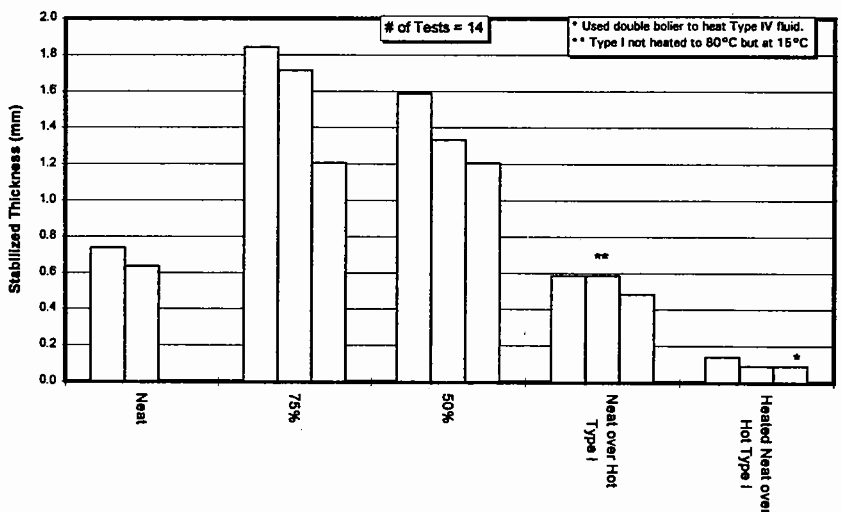
STABILIZED THICKNESS OF TYPE IV FLUIDS AT 15 CM (6") LINE
Kilfrost



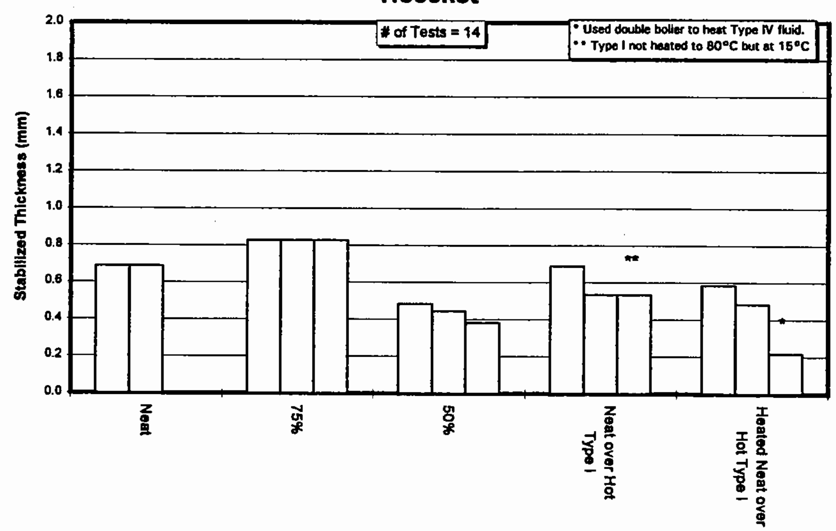
STABILIZED THICKNESS OF TYPE IV FLUIDS AT 15 CM (6") LINE
Ultra+



STABILIZED THICKNESS OF TYPE IV FLUIDS AT 15 CM (6") LINE
Octagon



STABILIZED THICKNESS OF TYPE IV FLUIDS AT 15 CM (6") LINE
Hoechst



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- Octagon Type IV fluid increased in thickness when diluted;
- Hoechst Type IV neat fluid increased in thickness when diluted to 75/25, but decreased when diluted to 50/50;
- The stabilized thickness of Octagon 50/50 is more than three times the thickness of the other three fluids; and
- The stabilized thickness of Octagon 75/25 and Kilfrost 75/25 is about twice the thickness of the corresponding fluids from Hoechst and Union Carbide.

4.3 Application Over Hot Type I

This Two-Step fluid application process consists of applying Type IV fluid over Type I fluid. The two fluids used in the process were from the same manufacturer. The procedure was to apply 0.5 L of Type I fluid heated to 80°C followed by 1.5 L of Type IV at ambient temperature. Film thickness results showed about a 10% decrease in thickness, when compared with Type IV applied to a bare plate at ambient temperature.

Additional Type IV over Type I tests were conducted with Type IV at ambient temperature and Type I at 15°C to correlate with tests conducted in previous winters. It was found that the stabilized thickness was the same as the thickness of the 80°C fluid tests. This shows that the heating of Type I has no effect on combined fluid thickness, when used as undercoat with Type IV.

4.4 Tank Heating Effect

During 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 from the hot Type I tank to the Type IV tank situated in close proximity to the heated Type I tank.

To study the effect of heat on Type IV fluids, several Two-Step fluid application tests were conducted, with both fluids heated to 80°C. Type IV fluids were heated to 80°C with a standard kettle used to boil water. Additional tests were conducted with the Type IV fluids heated to 80°C 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. The results of the tests showed that the Type IV over heated Type I was significantly thicker (up to 6 times) when compared with heated Type IV over heated Type I. The difference in thickness is probably a result of the lower fluid viscosity caused by heating the viscous Type IV fluid.

Photo 4.1
Setup for Thickness Tests Inside APS Trailer

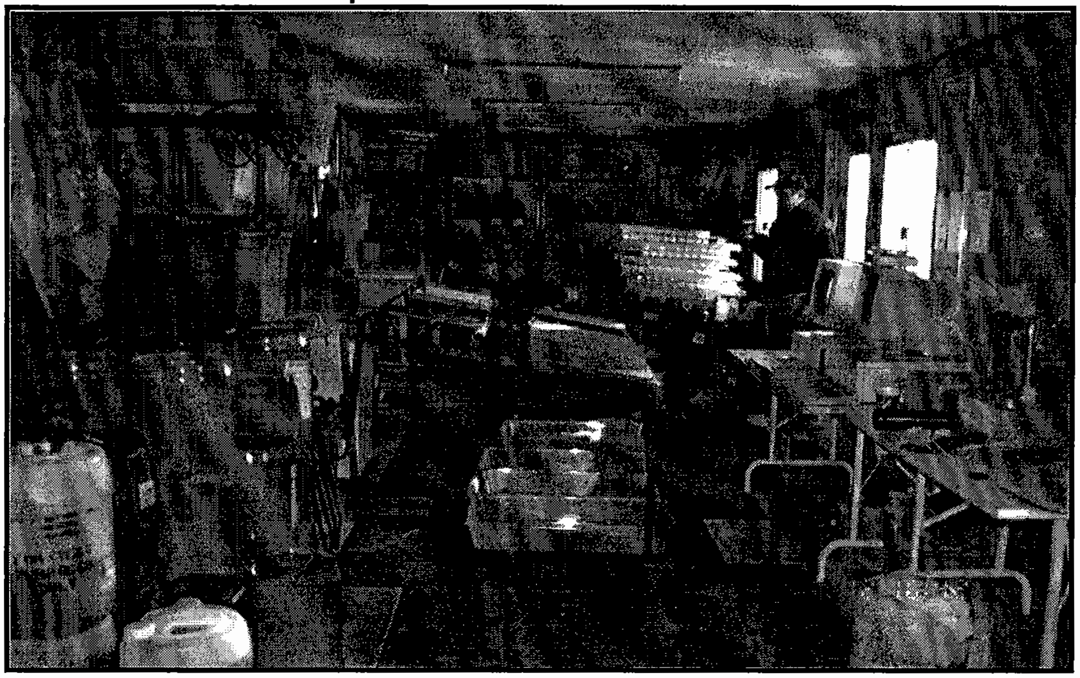
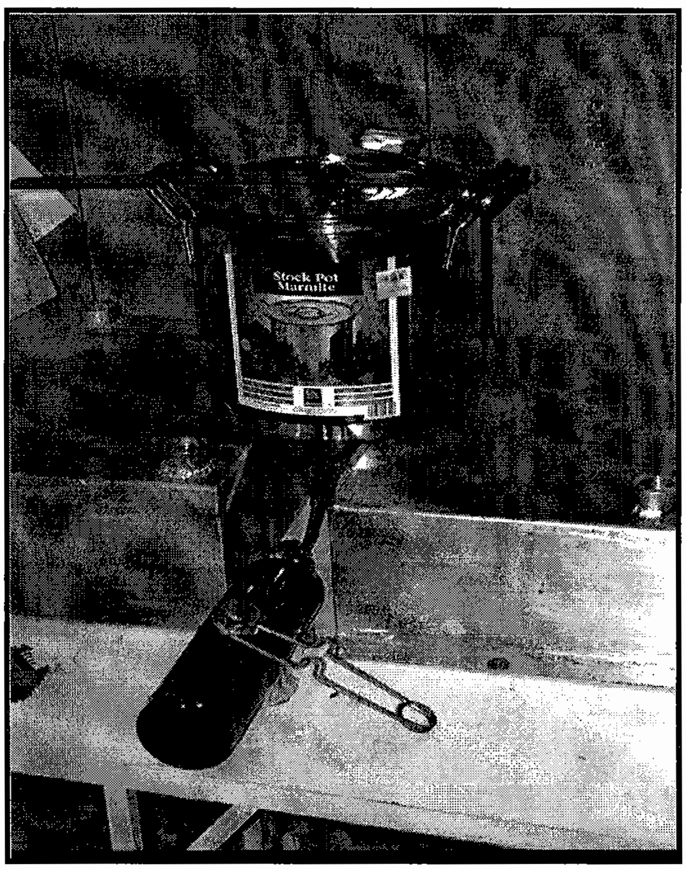


Photo 4.2
***Double-Boiler* System Used for Heating Type IV Fluid to 80°C**



5. METHODOLOGY FOR ANALYSIS OF DATA

5.1 General

This section describes how the process of data analysis in the determination of fluid holdover times has evolved from previous seasons. This evolution resulted from the wide variations in holdover time performance observed for the different brands of Type IV fluid. Initial presentation of the 1996/97 test results to the SAE G-12 Holdover Time Subcommittee prompted committee requests for a change in the approach to analyzing the data to produce the holdover times. A systematic and numerically reproducible approach to data analysis and ultimately, the determination of holdover times has been developed.

Definitions and rate limits for the various types of precipitation were drawn up and different *protocols* for the generation of fluid holdover times from the raw data were evaluated.

This section documents the rationale and concerns that led to the new analytical process, providing a historical reference for future developments. The justification for development of *fluid-specific* table is discussed, and the final form of the new procedure is described, as are the resultant holdover time tables.

The breakdown of Section 5 proceeds as follows:

- Subsection 5.2 and 5.3 describe the chronology of events leading to the concept of *fluid-specific* holdover time tables, and contain the definitions of precipitation types and precipitation rate limits agreed upon by the SAE G-12 Holdover Time Subcommittee;

- Subsection 5.4 considers the *protocols* used to determine holdover times in previous years and also describes two new protocols. The first new *protocol* was developed at the request of the SAE G-12 Holdover Time Subcommittee and is referred to as the Straight Line *Protocol*. The second new *protocol* was developed through an initiative taken jointly by APS, Transport Canada and the Federal Aviation Administration and is referred to as the *Multiple Regression Protocol*. This second new *protocol* was accepted by the SAE G-12 Holdover Time Subcommittee;

- Subsection 5.5 provides the upper limits used for the holdover time values;

- Subsection 5.6 presents the concept of a *worst case* (generic) holdover time table for Type IV fluids;

- Subsection 5.7 presents a comparison of the two new *protocols*; and

- Subsection 5.8 presents the concept of *fluid-specific* holdover time tables for Type IV fluids.

5.2 Chronology of Events

In May 1997, a draft of the holdover time tables for all fluid types (see Appendix J) was sent to members of the SAE G-12 Holdover Time Subcommittee to acquaint them with proposed changes prior to the June meeting in Pittsburgh. The draft holdover time tables were based on the previous year's tables given in Section 1 of this report, and modified by proposed changes resulting from 1996/97 winter tests. Major changes were proposed primarily in the Type IV fluid category.

At the June meeting in Pittsburgh, the newly proposed holdover time tables were to be presented by APS. The time frame allotted for the presentation of this material was considerably reduced from previous years (½ day versus the usual 2 days), on the expectation that changes would be few; however the time was insufficient to fully present the material because there were significant changes to the Type IV Table.

In the course of presentation of Type IV fluid holdover time test results, a committee member requested a caucus to consist of airline, original equipment manufacturer, and regulatory staff. The caucus decided that Type I and Type II fluid tables would remain unchanged. However, because a clearly defined *analysis protocol* for deciding upper and lower limits to the holdover times of Type IV fluids had never been defined, the Federal Aviation Administration, Transport Canada and APS were requested to assemble all the Type IV fluid data and subject it to a straight line *protocol*. In this *protocol* the poorest performing fluid was to be used to establish the high and low values for every cell in the holdover time table (Subsection 5.4.2). The results of this treatment were to be sent to all voting members of the committee and to the fluid vendors for evaluation and balloting prior to the next committee meeting, scheduled for July 1997 in Chicago.

Data analysis in accordance with the straight line *protocol* resulted in the Type IV fluid holdover time table that had many values substantially lower than the previously accepted table. The low values were attributed to widely differing properties of Type IV fluids from the various manufacturers. Each fluid exhibited different strengths and weaknesses in performance at specific locations within the range of test conditions. Transport Canada notified the SAE G-12 Holdover Time Subcommittee of these findings and also communicated that a multiple regression approach was being pursued to fit the data, and that approach supported the development of *fluid-specific* holdover time tables. Hence, the originally proposed ballot was not implemented and the results of the two treatments were scheduled for review and discussion at the Chicago meeting. The results of the straight line approach was sent to the SAE G-12 Holdover Time Subcommittee members for review in advance of the Chicago meeting.

At the Chicago meeting, findings based on both straight line and regression approaches were presented. The regression analyses gave more representative holdover times than the straight line approach, but the values were still low relative to the previous table used in 1996/97. This was again attributed to basing the holdover times on the poorest performing fluid which did not acknowledge any one fluid's stronger performance characteristics (see note below). The results of the *fluid-specific* treatments, however, were encouraging. The method , considered to be the best avenue of approach for holdover time table development, was accepted by the SAE G-12 Holdover Time Subcommittee.

Note: Despite the fact that 553 tests of Type IV fluid were carried out, once the various fluid brands were treated separately for each of the 45 cells of the holdover time table, it became apparent in some cases, for a specific fluid brand, that very few data points were involved in the analysis. In these instances, the straight line approach often gave exaggeratedly high or low holdover time values at the conditions prescribed for use in the tables.

5.3 Description of Data Ranges and Precipitation Definitions

The test programs developed to measure fluid failure times were 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. The new procedure used to generate holdover times is based on the refinement of an equation for a curve which best represents the fluid failure time test data, and then solving that equation at the upper and lower limits of a defined precipitation range. To support this procedure, limits for precipitation ranges were defined, reviewed and approved.

These limits are represented schematically in Figure 5.1 and on Page E-5 in Appendix E. Detailed definitions and explanations of data types and ranges are described in the following subsections. Meteorologically accepted definitions of these conditions are contained in Table 2.1.

5.3.1 Natural Snow

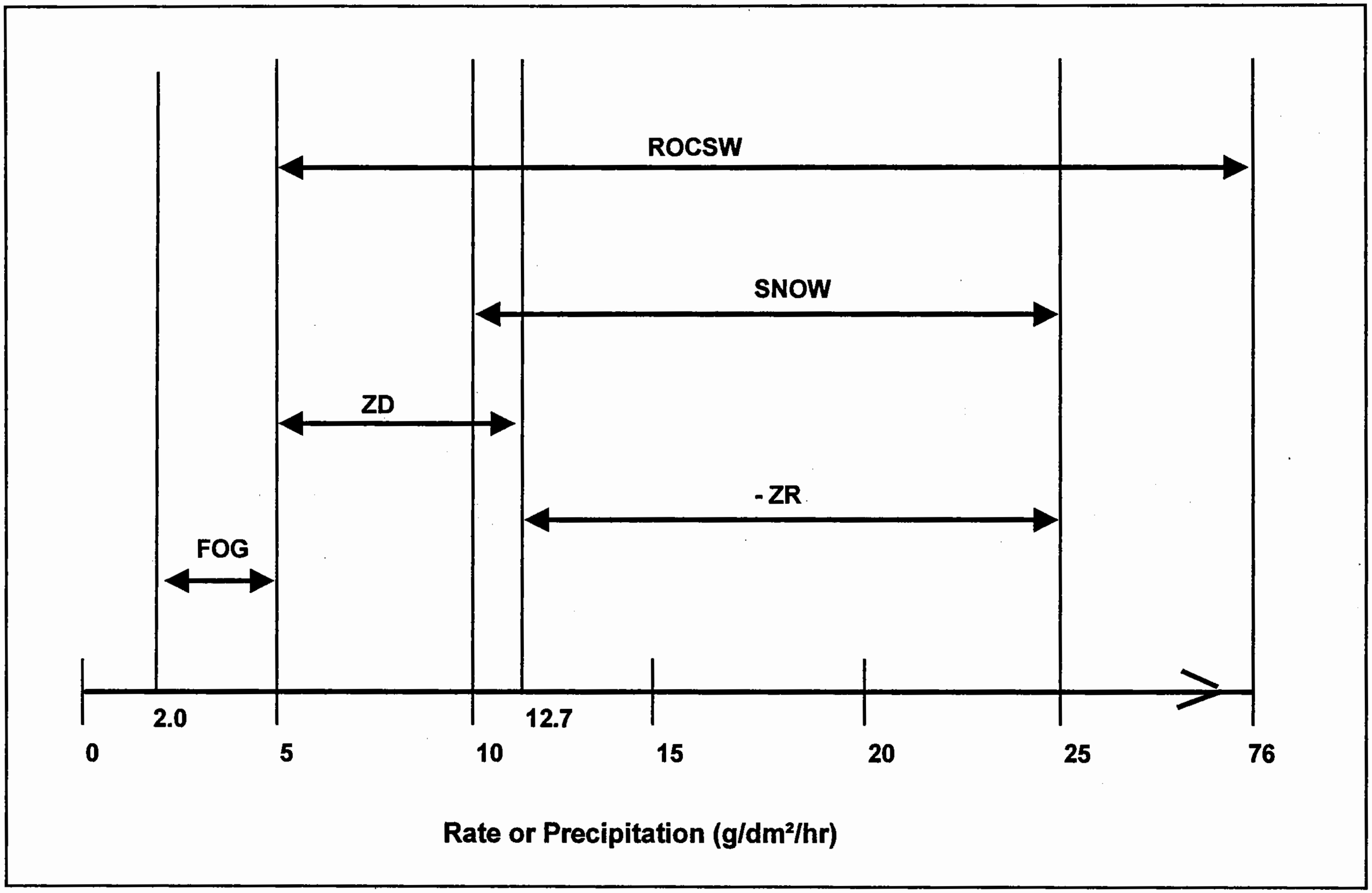
All fluid tests in snow were conducted under natural outdoor conditions. Data was collected for precipitation rates ranging from less than 10 g/dm²/hr to greater than 25 g/dm²/hr, however, lower and upper holdover times for each cell in this column were determined at 10 and 25 g/dm²/hr, respectively.

The lower precipitation rate limit (10 g/dm²/hr) represents the upper limit of light snow. If light snow (i.e., precipitation rates less than this lower limit) is encountered, the pilot can then elect to follow the upper limit of the holdover time range.

The upper limit of precipitation (25 g/dm²/hr) corresponds to the onset of a 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).

FIGURE 5.1

DATA RANGE USED FOR EVALUATION OF HOLDOVER TIME LIMITS



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5.3.2 Freezing Drizzle

Freezing drizzle is considered to occur over the range of 0 to 12.7 g/dm²/hr. The upper limit of this range, while not specifically defined in Table 2.1, has been adopted based on discussions (2-3 years ago) with meteorological experts and operators who are part of the SAE G-12 Holdover Time Subcommittee.

At the Chicago SAE G-12 Holdover Time Subcommittee meeting, it was agreed to restrict the precipitation rate spectrum for freezing drizzle to rates between 5 and 12.7 g/dm²/hr. This range corresponds to heavy drizzle and has been chosen to provide airline operators with the greatest margin of safety in practice. A caution note is included in the holdover times tables indicating that if positive identification of drizzle is not possible, use of light freezing rain holdover times is recommended.

5.3.3 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/dm²/hr, inclusive. This range falls in the category of light freezing rain and is the only freezing rain category considered, as airlines do not operate in moderate or heavy freezing rain.

5.3.4 Freezing Fog

The precipitation rate limits for freezing fog were arrived at with input from meteorologists at the National Research Council. They helped define an important parameter in the study of fog referred to as the *Liquid Water Content* (LWC). This quantity, expressed in density terms as the mass of water in grams contained in one cubic meter of air, can generally assume values in the range of 0.2 to 0.6 g/m³. The precipitation rate, referred to as the fog *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° tilt of the test plates into the direction of the wind.

For a plate in 0.6 g/m³ LWC fog, a wind velocity of 6 km/hr, and a collection efficiency of 80%, a deposition of 5 g/dm²/hr is arrived at. For an aircraft taxiing at 12 km/hr relative to the same wind in a 0.6 g/m³ LWC fog, a collection efficiency of 40% might be achieved in this situation, and one would also arrive at a deposition equal to 5 g/dm²/hr.

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 which the factors in the equation can assume. A deposition range of 2 to 10 g/dm²/hr is considered to be reasonable, and tests have been conducted in this range in previous years.

In the 1996/97 tests, a single central rate of deposition (5 g/dm²/hr) was selected and holdover times were evaluated at this rate only (no range).

At the Chicago meeting, the consensus of the committee required a range of rates with an upper time as well as a lower time for each cell in the fog column. In previous years, the upper and lower holdover times for freezing fog were determined subjectively from the test data. It was agreed that the lower time for each cell of the holdover time table be evaluated at 5 g/dm²/hr. It was also agreed that the upper holdover times for cells in the fog column of this year's tables adopt those values determined at the precipitation rate or deposition of 2 g/dm²/hr, based on tests conducted during the 1995/96 year with the old fluids.

Therefore, there still remains a need to verify upper holdover times by collecting fresh data with the new fluids at the lower deposition limit of 2 g/dm²/hr. This is one of the items listed in the recommendations (Section 9).

5.3.5 Rain on a Cold-Soaked Wing (ROCSW)

Data used for the holdover time tables for this category of precipitation were limited to precipitation rates ranging from 5 g/dm²/hr to 76 g/dm²/hr. This encompasses drizzle (5 to 12.7 g/dm²/hr), light rain (12.7 to 25 g/dm²/hr), and moderate rain (25 to 76 g/dm²/hr). The heavy rain category is covered by the cautionary note regarding heavy weather conditions.

At the Pittsburgh meeting, APS and Transport Canada proposed to split the rain on a cold-soaked wing column into two columns: One covering precipitation rates between 5 and 25 g/dm²/hr, corresponding to heavy drizzle and light rain; and one covering precipitation rates between 25 and 76 g/dm²/hr, corresponding to moderate and heavy rain.

Justification for this proposal arose from the rain on a cold-soaked wing data which exhibited two separate groupings. One group of data points fell into the drizzle and light rain category, while the other group of data points fell into the moderate and heavy rain category. The data supporting the proposal have been published in Transport Canada report, TP 12896E. In response to this proposal, a motion was passed and accepted to rename the current rain on a cold-soaked wing column to read *Light Rain on a Cold-Soaked Wing*. This was to limit the rain on a cold-soaked wing category in the holdover time tables to conditions of drizzle and light rain. It was decided that two columns for the rain on a cold-soaked wing made the table too complex.

At the Chicago meeting, a discussion regarding this ballot ensued. Certain committee members voiced reservations concerning the possibility of halting flight operations under heavier weather conditions than light rain. The outcome of this discussion was to leave the heading in the tables as they were, to incorporate the data for moderate rain (up to 76 g/dm²/hr) into the tables, and be satisfied with the resultant reductions in holdover times in this category. Conditions of heavy rain (greater than 76 g/dm²/hr) would be covered by the cautionary note regarding heavy weather conditions.

5.4 *Protocols* 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. There is a maximum of 45 cells in the tables for any given fluid. Each cell except frost contains an upper and a lower time limit resulting in a total of 81 time values. In the generation of a holdover time table covering the behaviour of four Type IV fluid brands, 324 time values must be determined before deciding the actual time ranges to be published for operational use.

Cell holdover time ranges are determined by plotting *Failure Time* versus *Rate of Precipitation* and recording the failure time at two pre-selected limits on the precipitation rate scale. These limits were defined in Subsection 5.3. The following sections describe the *protocol* used to evaluate holdover times in previous years (Subsection 5.4.1), and the new protocols devised for the evaluation of holdover times from the most recent data collected (Subsection 5.4.2 and Subsection 5.4.3).

5.4.1 Previous *Protocol*

Lower Holdover Time Number:
Select by inspection either the shortest failure time for the highest precipitation rate in the range or a more conservative time. Consistency with adjacent cells of the holdover time table was maintained.

Upper Holdover Time Number:
Select a time representing most or all of the data points within the precipitation rate range.

This procedure gave rise to ambiguities in the determination of holdover times. Different interpretations of the data were possible due to the subjective nature of this approach.

5.4.2 Straight Line *Protocol*

Data corresponding to each cell in the holdover time table were assembled and sorted according to precipitation category, fluid manufacturer, dilution factor, and temperature range. For each cell in the holdover time table the data for each fluid were plotted. As an example, Figure 5.2 shows Type IV 75/25 fluid C-707 in freezing drizzle and light freezing rain from 0 to -3°C.

FIGURE 5.2

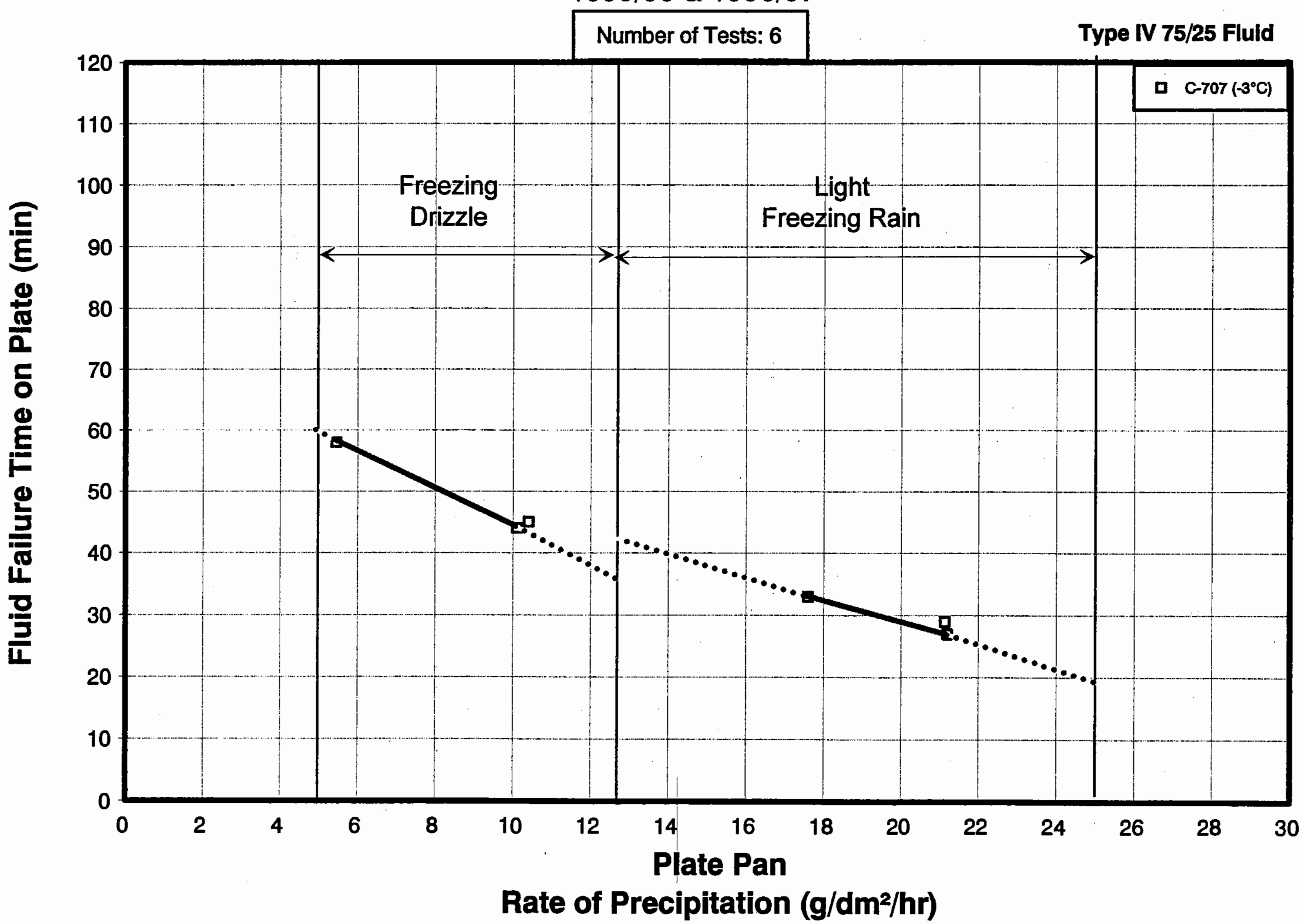
EXAMPLE OF LINEAR METHOD

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

C-707 TYPE IV 75/25

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1995/96 & 1996/97



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The lowest data points for each fluid brand were connected by straight line segments and extrapolated (if necessary) to the pre-defined precipitation rate limits. In certain instances, the gradient (slope) of the high precipitation rate extreme of the data range was reduced and that of the low precipitation rate extreme of the data range was increased, based on knowledge of and familiarity with the physical properties of the fluids (Figure 5.3).

From such plots, the worst performing fluid was selected and failure times were determined at the pre-defined precipitation rate limits. These values define the time range of the cell.

The upper time values were capped at 120 minutes for all categories of precipitation except for the fog category, which was capped at 240 minutes.

This *protocol* was repeated for each cell in holdover time table and led to the generation of a *worst case* (generic) holdover time table (Table 5.1).

The time ranges for cells comprising this *worst case* Type IV fluid holdover time table were found to be, on average, shorter than those determined from the previous year's testing (shown in Section 1 and also referred to as *current* or 1996/97 SAE holdover times).

5.4.3 Multi-Variable Regression *Protocol*

The regression approach made use of plots initially prepared for the straight line *protocol*. The data points on each plot were used to fit an equation of the form

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

where

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

The coefficient c is related to the intercept. The coefficients a and b give the Rate and Temperature dependency of the failure time, respectively. Temperature is always below zero*.

To simplify graphical presentation of regression-generated curves, extrapolation to precipitation rate limits (required to determine holdover times for some cells)

* Temperature should be the difference between outside air temperature and fluid freeze point (not pour point).

FIGURE 5.3

EXAMPLE OF LINEAR METHOD
EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-509 TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/97

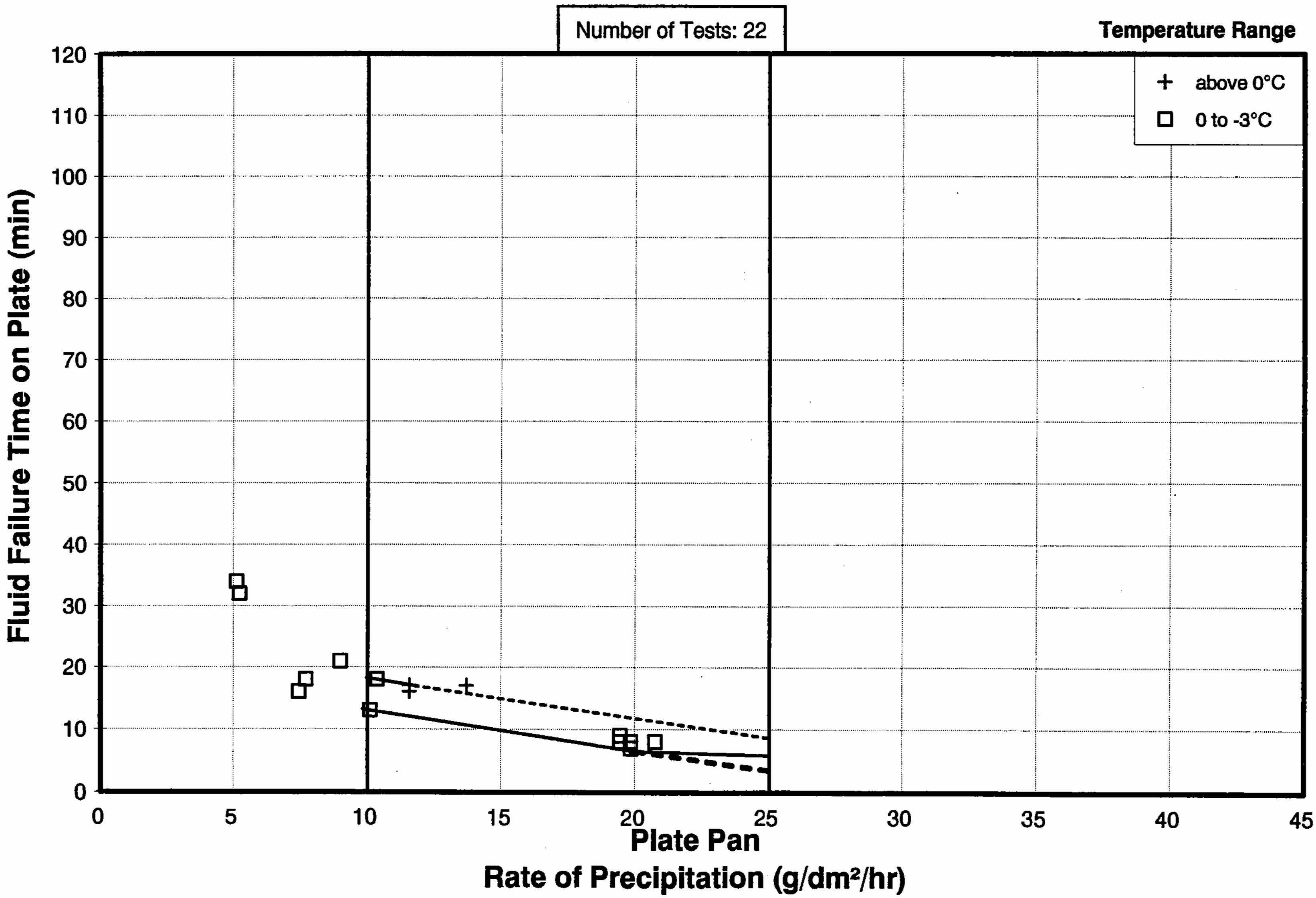

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TABLE 5.1

SAE TYPE IV CURRENT AND PROPOSED HOLDOVER TIMES

STRAIGHT LINE *PROTOCOL* METHOD

*"*WORST CASE*" FLUID BY CELL

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	*DRIZZLE OR LIGHT* RAIN ON COLD SOAKED WING
above 0°	above 32°	100/0	18:00	2:00-3:00 ***155***	0:55-1:40 30-57	0:45-1:50 40-56	0:30-1:00 30-45	0:20-0:40 18-43
		75/25	6:00	0:40-2:00 ***65***	0:20-1:00 15-24	0:20-1:00 30-60	0:15-0:30 16-27	0:10-0:25 14-***33***
		50/50	4:00	0:15-0:45 20	0:05-0:25 ***8***-18	0:07-0:15 10-18	0:05-0:10 8-11	
0 to -3	32 to 27	100/0	12:00	2:00-3:00 ***155***	0:45-1:40 30-57	0:45-1:50 40-56	0:30-1:00 30-***45***	
		75/25	5:00	0:40-2:00 ***65***	0:15-1:00 15-24	0:20-1:00 30-60	0:15-0:30 16-27	
		50/50	3:00	0:15-0:45 20	0:05-0:20 5-13	0:07-0:15 10-18	0:05-0:10 8-11	
below -3 to -14	below 27 to 7	100/0	12:00	2:00-3:00 40	0:35-1:15 17-40	**0:45-1:50 30-60	**0:30-0:55 25-45	
		75/25	5:00	0:40-2:00 35	0:15-1:00 15-26	**0:20-1:00 23-47	**0:10-0:25 16-25	
below -14 to -25	below 7 to -13	100/0	12:00	1:00-2:00 ***25***	0:30-1:10 ***13-33***			
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.					

* Adjusted based upon coding - insufficient data not used as criteria.

Legend:

0:35-1:15	- Holdover time in use for 1996/97.
17-40	- Proposed holdover time based on straight line method (not rounded).

Firm

Insufficient Data

Conservative

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At:LINEAR
Printed: 9:44 AM, 8/3/98

is not explicity shown in the figures. There is a need to acquire data at these limits (This is acknowledged in the conclusions, Section 8, and recommended in Section 9).

Plots of **log t** versus **log R** are shown in Figure 5.4. 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. These were obtained from the analysis using the lowest temperatures in each of the temperature ranges from which the data were chosen.

The same data plotted on a linear scale (failure time **t** versus precipitation rate **R**), are shown in Figure 5.5. 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 18 minutes at 10 g/dm²/hr and 7 minutes at 25 g/dm²/hr, thus establishing a cell holdover time range for this particular fluid. This illustrates the general approach to the determination of holdover time ranges for any given cell in the holdover time table.

As an example, consider the experimental data in Table 5.2 for neat Octagon fluid in natural snow conditions. The table lists failure times, temperatures, and precipitation rates for each test. The list also includes columns containing the data in logarithmic form. The log terms used in the fitting routine are: the dependent variable (log t), and the two independent variables (log Rate, and log Temperature).

The equation was cast in logarithmic form and a stepwise fitting procedure was implemented using Microsoft's Excel software. The output was inspected to examine the dependency of each variable in the equation and to evaluate the integrity of coefficients determined for each variable. The output statistics are shown in Table 5.3. The primary indicators of the integrity of the fit are:

- R and R^2 (goodness of fit increases as R approaches unity) - the result for this fit is >0.89 or 89%;
- F-value (included in the ANOVA table, should be greater than 10) - is determined to be 133; and
- P-value (which should be less than 0.05), is determined to be a much smaller number for each of the coefficients.

The equation used to generate the best curve (from which holdover times were determined) is shown in Appendix G, Page G-1 (equation # 7) and has been reproduced below. The variable (2-T) is explained in Subsection 5.4.3.1.

$$\textit{Failure time (t)} = cR^aT^b = 10^IR^aT^b = 10^{3.1}R^{-0.73}(2\text{-}T)^{-0.51}$$

FIGURE 5.4

EXAMPLE OF REGRESSION METHOD ON LOG/LOG CHART
EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
KILFROST TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/97

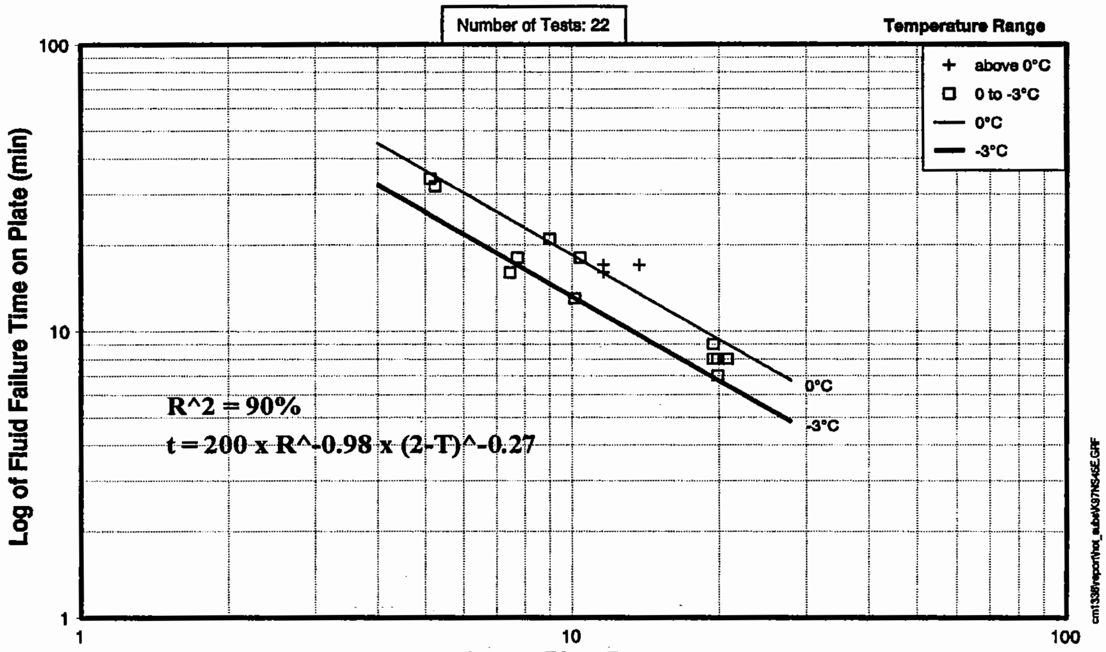


FIGURE 5.5

EXAMPLE OF REGRESSION METHOD ON STANDARD CHART
EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
KILFROST TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/97

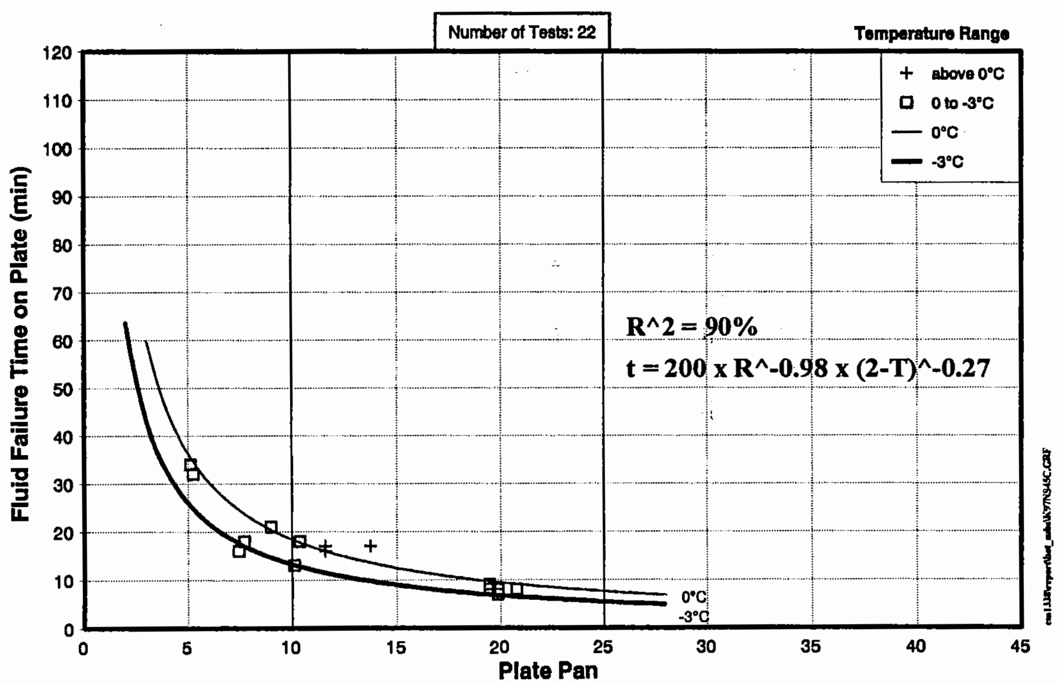


TABLE 5.2

SAMPLE OUTPUT OF NATURAL SNOW TESTS

fld dilution	fluid name	fluid code	fld type	fail time [min.]	AVG PAN RATE g/dm²/hr	temp [C]	wind [kph]	wind dir [°]	log_fail	log_rate	log_tem_C
neat	OCTAGON	C-108	4	90	10.3	-8.2	12.2	48	1.95	1.01	1.01
neat	OCTAGON	C-108	4	91	10.2	-8.2	12.2	48	1.96	1.01	1.01
neat	OCTAGON	C-108	4	76	8.4	-8.2	13.1	44	1.88	0.92	1.01
neat	OCTAGON	C-108	4	76	8.4	-8.2	13.1	44	1.88	0.92	1.01
neat	OCTAGON	C-108	4	99	4.9	-8.3	12.9	45	2.00	0.69	1.01
neat	OCTAGON	C-108	4	99	4.9	-8.3	12.9	45	2.00	0.69	1.01
neat	OCTAGON	C-108	4	26	27.3	-9.8	13.7	63	1.41	1.44	1.07
neat	OCTAGON	C-108	4	25	27.4	-9.8	13.6	63	1.40	1.44	1.07
neat	OCTAGON	C-108	4	55	15.9	-9.7	12.5	63	1.74	1.20	1.07
neat	OCTAGON	C-108	4	58	15.9	-9.7	12.5	63	1.76	1.20	1.07
neat	OCTAGON	C-108	4	62	14.8	-9.6	11.3	57	1.79	1.17	1.06
neat	OCTAGON	C-108	4	67	14.8	-9.5	11.3	56	1.83	1.17	1.06
neat	OCTAGON	C-108	4	74	11.0	-8.7	11.4	53	1.87	1.04	1.03
neat	OCTAGON	C-108	4	73	11.0	-8.7	11.4	53	1.86	1.04	1.03
neat	OCTAGON	C-108	4	47	13.9	-7.8	12.1	53	1.67	1.14	0.99
neat	OCTAGON	C-108	4	47	13.9	-7.8	12.1	53	1.67	1.14	0.99
neat	OCTAGON	C-108	4	40	17.8	-7.7	13.6	39	1.60	1.25	0.99
neat	OCTAGON	C-108	4	39	17.8	-7.7	13.6	39	1.59	1.25	0.99
neat	OCTAGON	C-108	4	105	9.1	-6.0	10.5	45	2.02	0.96	0.90
neat	OCTAGON	C-108	4	105	9.1	-6.0	10.5	45	2.02	0.96	0.90
neat	OCTAGON	C-108	4	58	8.7	-4.9	10.8	37	1.76	0.94	0.84
neat	OCTAGON	C-108	4	63	8.6	-4.9	10.9	37	1.80	0.94	0.84
neat	OCTAGON	C-108	4	20	44.9	-5.8	7.6	78	1.30	1.65	0.89
neat	OCTAGON	C-108	4	19	44.9	-5.8	7.6	77	1.28	1.65	0.89
neat	OCTAGON	C-108	4	18	71.3	-5.3	12.7	121	1.26	1.85	0.86
neat	OCTAGON	C-108	4	18	71.3	-5.3	12.7	121	1.26	1.85	0.86
neat	OCTAGON	C-108	4	32	29.3	-4.6	9.3	120	1.51	1.47	0.82
neat	OCTAGON	C-108	4	33	29.2	-4.6	9.4	119	1.52	1.47	0.82
neat	OCTAGON	C-108	4	50	21.2	-4.4	8.9	104	1.70	1.33	0.81
neat	OCTAGON	C-108	4	50	21.2	-4.4	8.9	104	1.70	1.33	0.81
neat	OCTAGON	C-108	4	106	8.8	-4.1	7.0	96	2.03	0.95	0.78
neat	OCTAGON	C-108	4	106	8.8	-4.1	7.0	96	2.03	0.95	0.78
neat	OCTAGON	C-108	4	127	7.7	-2.9	14.4	117	2.10	0.88	0.69
neat	OCTAGON	C-108	4	126	7.7	-2.9	14.4	117	2.10	0.88	0.69
neat	OCTAGON	C-108	4	32	14.2	-15.9	11.8	57	1.51	1.15	1.25
neat	OCTAGON	C-108	4	32	14.2	-15.9	11.8	57	1.51	1.15	1.25
neat	OCTAGON	C-108	4	33	16.0	-15.1	12.0	49	1.52	1.20	1.23
neat	OCTAGON	C-108	4	35	16.1	-15.1	12.1	49	1.54	1.21	1.23
neat	OCTAGON	C-108	4	50	15.3	-12.3	10.5	45	1.70	1.19	1.15
neat	OCTAGON	C-108	4	51	15.3	-12.3	10.5	45	1.71	1.18	1.15
neat	OCTAGON	C-108	4	72	11.7	-4.7	11.6	157	1.86	1.07	0.83
neat	OCTAGON	C-108	4	71	11.8	-4.7	11.6	157	1.85	1.07	0.83
neat	OCTAGON	C-108	4	82	9.5	-4.4	11.0	159	1.91	0.98	0.81
neat	OCTAGON	C-108	4	77	9.6	-4.5	11.0	158	1.89	0.98	0.81
neat	OCTAGON	C-108	4	68	16.7	-3.8	11.1	169	1.83	1.22	0.76
neat	OCTAGON	C-108	4	66	16.7	-3.8	11.1	169	1.82	1.22	0.77
neat	OCTAGON	C-108	4	75	9.3	-3.1	10.5	174	1.88	0.97	0.71
neat	OCTAGON	C-108	4	75	9.3	-3.1	10.5	174	1.88	0.97	0.71
neat	OCTAGON	C-108	4	70	14.1	-2.3	9.2	193	1.85	1.15	0.63
neat	OCTAGON	C-108	4	59	12.8	-2.3	9.6	189	1.77	1.11	0.64

TABLE 5.3

MULTI-VARIABLE REGRESSION OUTPUT

NATURAL SNOW CONDITIONS

OCTAGON TYPE IV NEAT (#7)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.8913
R Square	0.7944
Adjusted R Square	0.7885
Standard Error	0.0914
Observations	72

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.2289	1.1144	133.3177	1.9854E-24
Residual	69	0.5768	0.0084		
Total	71	2.8057			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	3.0573	0.0834	36.6761	5.4934E-47	2.8910	3.2236	2.8910	3.2236
log_rate	-0.7256	0.0469	-15.4707	4.0068E-24	-0.8192	-0.6320	-0.8192	-0.6320
log_tem_C	-0.5146	0.0549	-9.3704	6.3483E-14	-0.6241	-0.4050	-0.6241	-0.4050

Appendix G lists all the regression analyses performed, the corresponding equations with their associated coefficients, and the output summaries for each analysis.

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 wing. Each group was subject to a slightly modified version of the general equation given above, as described in the following sections.

5.4.3.1 Natural snow

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

$$t \quad = \quad 10^{I} R^{a} (2-T)^{b}.$$

- *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 outside 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 rate limits, respectively.

An illustration of the effect of fluid brand on holdover time is given by the regression curves shown in Figure 5.6. Note that the data and *best-fit* curve for Octagon exhibits superior protection relative to the other fluids tested under these conditions.

5.4.3.2 Simulated freezing drizzle and light freezing rain

The modified equation used to treat the data in this and the remaining groups of data is given by the expression below. The temperature variable is negative to prevent taking the log of a negative number.

$$t \quad = \quad 10^{I} R^{a} (-T)^{b}.$$

- For freezing drizzle and light freezing rain, the *best-fit* curves for data corresponding to a given cell in the holdover time table were also obtained by using the most restrictive (lowest) cell range temperature.

FIGURE 5.6
REGRESSION METHOD EXAMPLE
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 50/50 (0 to -3°C)
NATURAL SNOW CONDITIONS
1996/97

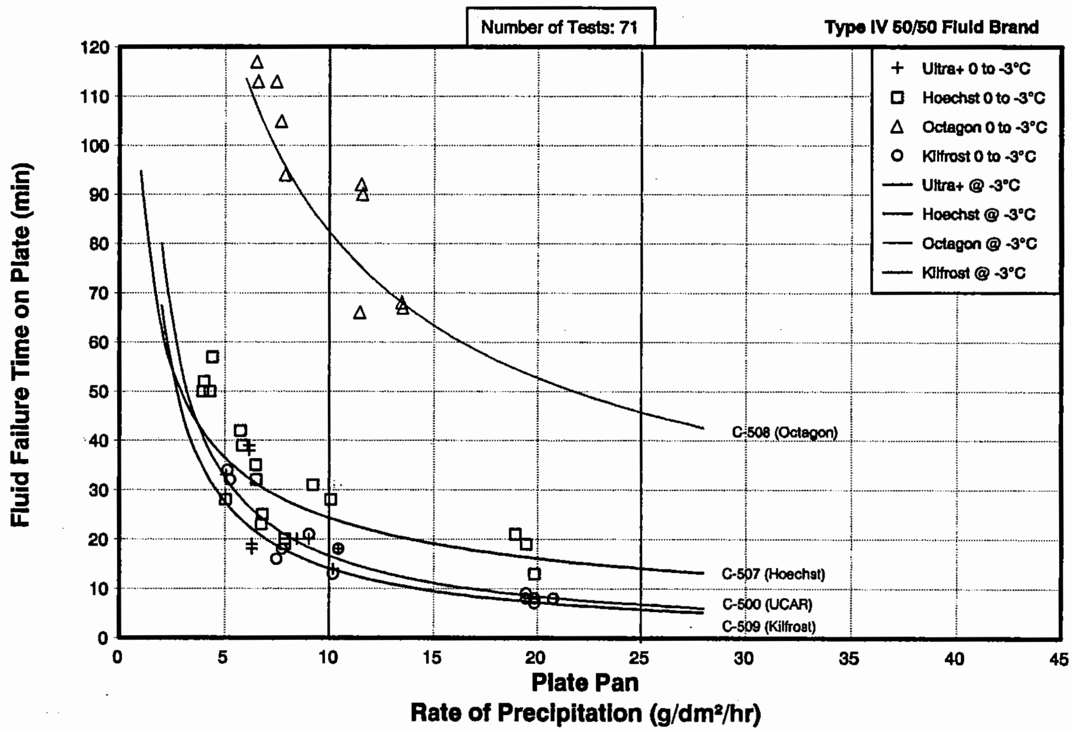
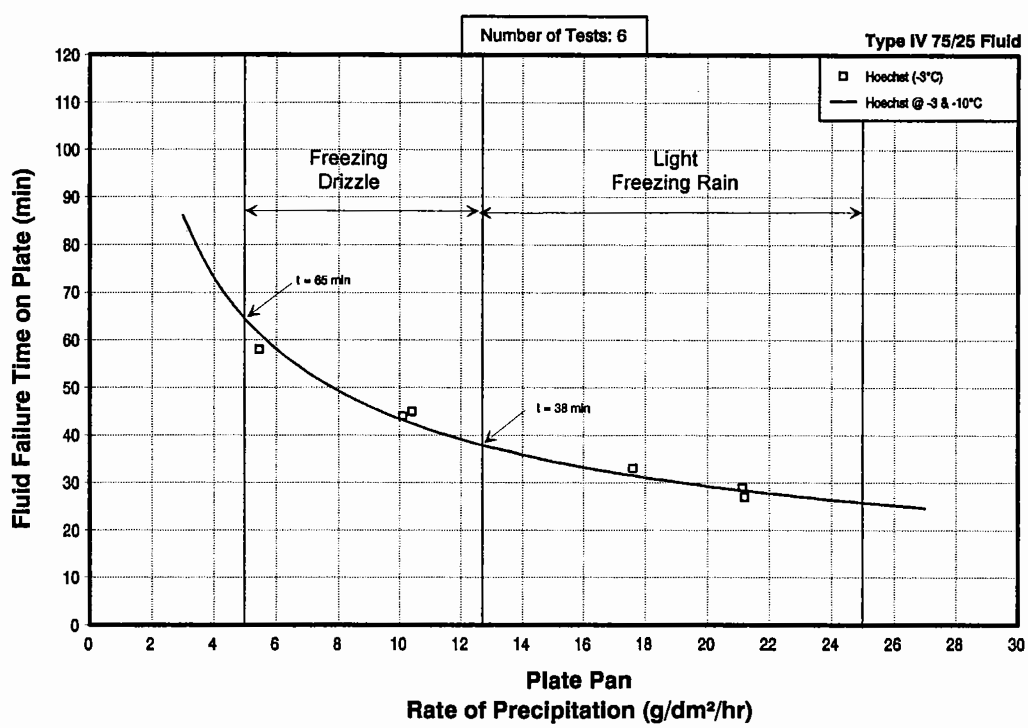


FIGURE 5.7
REGRESSION METHOD EXAMPLE
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
HOECHST TYPE IV 75/25
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/96 & 1996/97



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- 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 in an artificial environment at temperatures above 0°C and the equation could not be calculated at the most restrictive temperature of 0°C. Therefore, the holdover times for this range were obtained by using the same values calculated at -3°C.

An example of the data and *best-fit* curve for freezing drizzle and light freezing rain is given in Figure 5.7.

5.4.3.3 Simulated freezing fog

The same method was used for the freezing fog treatment with the exception that only one holdover time (not a range) was determined representing a deposition rate set at 5 g/dm²/hr. An example of the data and *best-fit* curve for freezing fog is given in Figure 5.8.

5.4.3.4 Rain on a cold-soaked wing (ROCSW)

The same method for the evaluation of holdover times was used for this category of precipitation with the following exceptions:

- An average skin temperature of -7°C was used in the fitting procedure. This was based upon an initial box temperature of -10°C used during most of the tests;
- Holdover times are based on the use of a cold-soaked box with a depth of 7.5 cm even though cold-soaked boxes with depths of 2.5 and 15 cm were used in the data collection;
- A *dummy* variable approach was used to evaluate whether box depth would significantly effect the outcome of the fit; and
- The range of times represent conditions of heavy drizzle, light freezing rain and moderate rain.

An example of the data and *best-fit* curve for rain on a cold-soaked wing is given in Figure 5.9.

FIGURE 5.8
EFFECT OF FLUID BRAND AND TEMPERATURE ON FAILURE TIME
TYPE IV NEAT
SIMULATED FREEZING FOG
1996/97

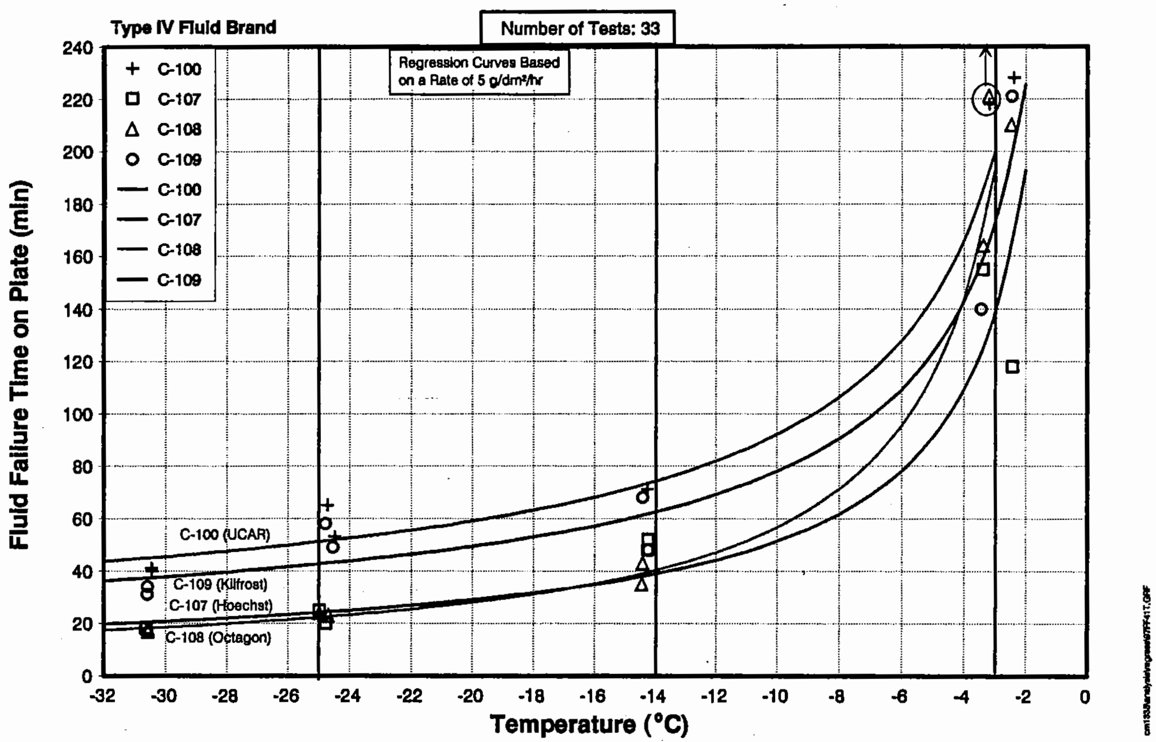
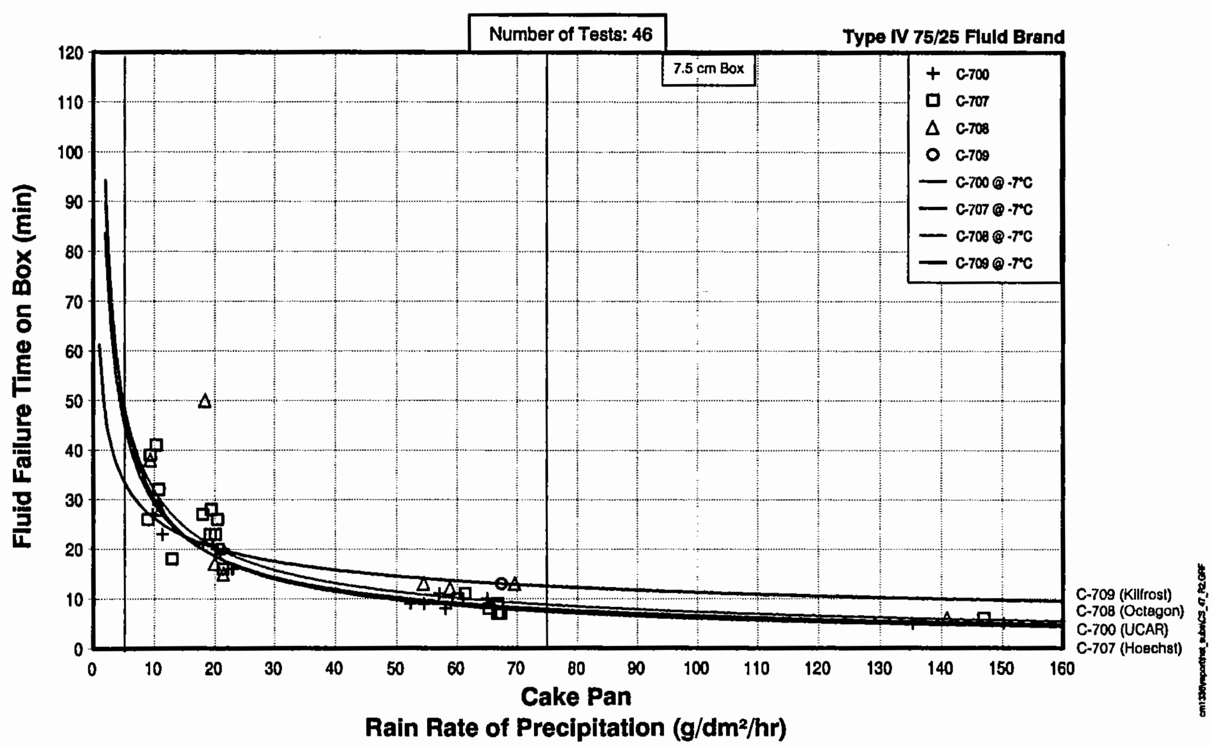


FIGURE 5.9
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25
RAIN ON COLD-SOAKED SURFACE
1995/96 & 1996/97



cm1338\report\hot_subs\FIG5_8-9.GRF

5.5 Upper Limit of Holdover Times

In order to avoid excessively long holdover times, which could not account for variations in intensity and type of precipitation, the upper holdover time for any given cell in the table was capped at 120 minutes, except in the case of freezing fog; freezing fog upper holdover times were capped at 240 minutes.

5.6 *Worst Case* Regression Table

From the procedure outlined in Subsection 5.4.3, plots similar to that given in Figure 5.6 were assembled from the Type IV fluid data. These plots were then compared on a cell-by-cell basis to determine the worst possible holdover time values. The result was the generation of a *worst case* regression method holdover time table (shown in Table 5.4) which was presented to the SAE G-12 Holdover Time Subcommittee at the Chicago meeting. Following this meeting, the values in this table were rounded and modified slightly based on the discussions at the meeting. The revised table appears in Section 6. The SAE G-12 Holdover Time Subcommittee's response to the regression approach was a positive one. This *Worst Case* Table subsequently became the SAE Type IV generic Holdover Time Table.

Although no single *worst case* fluid exists, the concept of a *worst case* fluid possessing performance characteristics that reflect the *worst case* holdover times is useful for the purpose of discussion. The term *worst case or generic fluid* is used in the remainder of the report and refers to a hypothetical fluid that exhibits *worst case* holdover time performance.

TABLE 5.4

SAE TYPE IV CURRENT/PROPOSED HOLDOVER TIMES

Regression Method - Not Rounded

"*Worst Case*" Fluid by Cell

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	DRIZZLE OR LIGHT RAIN ON COLD SOAKED WING
above 0°	above 32°	100/0	18:00	2:00-3:00 **138**	0:55-1:40 47-87	0:45-1:50 **40-60**	0:30-1:00 **37-57**	0:20-0:40 22-**51**
		75/25	6:00	0:40-2:00 **66**	0:20-1:00 **22-42**	0:20-1:00 **29-61**	0:15-0:30 **17-29**	0:10-0:25 16-**34**
		50/50	4:00	0:15-0:45 **21**	0:05-0:25 7-18	0:07-0:15 **12-18**	0:05-0:10 **8-12**	
0 to -3	32 to 27	100/0	12:00	2:00-3:00 **138**	0:45-1:40 33-61	0:45-1:50 40-60	0:30-1:00 37-**57**	
		75/25	5:00	0:40-2:00 **66**	0:15-1:00 **19**-36	0:20-1:00 **29**-61	0:15-0:30 17-29	
		50/50	3:00	0:15-0:45 21	0:05-0:20 6-14	0:07-0:15 12-18	0:05-0:10 8-12	
below -3 to -14	below 27 to 7	100/0	12:00	2:00-3:00 39	0:35-1:15 21-39	**0:45-1:50 28-60	**0:30-0:55 28-43	
		75/25	5:00	0:40-2:00 36	0:15-1:00 *15-29	**0:20-1:00 29-**61**	**0:10-0:25 17-29	
below -14 to -25	below 7 to -13	100/0	12:00	1:00-2:00 22	0:30-1:10 **17-32**			
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.					

* Insufficient data for fluid C-702, used fluid C-707/C-700

Legend:

0:35-1:15	- Holdover time in use for 1996/97.
21-39	- Proposed holdover time based on regression method (not rounded).

Firm

Insufficient Data

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5.7 Comparison of Results from Straight Line and Regression *Protocols*

Bar Charts were prepared from the data to illustrate the differences in fluid performance characteristics as determined from the two *protocols* outlined above. In addition, the comparison was extended to include holdover times from last year's table (Holdover Time Tables for 1996/97 season given in Section 1) for Type IV fluids as well as the proposed Type II fluid holdover times (described in Subsection 6.4). Each bar chart represents one cell in the holdover time tables.

The charts (shown in Figures 5.10 to 5.14) provide holdover time ranges of individual fluids (blackened bars portions) for all fluid brands most recently tested (H = Hoechst, K = Kilfrost, O = Octagon, U = Union Carbide), *worst case* results (WCl = straight line approach, WCr = regression approach), and Type II (TIIC = current, TIIP = proposed). The horizontal bars extending from end-to-end of each chart are the 1996/97 season holdover times for each cell. The exception to this scheme is Figure 5.13 for freezing fog which shows blackened bars only for Type II current and proposed holdover time limits. This is due to the fact that a range (prior to the Chicago meeting) was not determined for tests carried out under these conditions.

Consider the Type IV holdover time 75/25 Snow, -3°C cell bar chart in the middle of Figure 5.12. The upper and lower holdover time limits from the current Type IV holdover time table are approximately indicated by horizontal bars at 60 and 15 minutes, respectively. The Type II current and proposed upper and lower holdover time limits are the two blackened bars at the far right of the chart. Immediately to the left are the two *worst case* holdover time limits from the treatments as discussed in Subsections 5.4.2 and 5.4.3. The remaining bars show the upper and lower limits of the holdover times for the individual fluids as determined from the most recent series of tests.

From this presentation format it is evident that at certain concentrations, some fluids exhibit failure protection vastly superior to other fluids. In most cases regarding individual fluids, the *regression* approach yields longer upper and lower holdover time limits than does the straight line approach.

Inspection of the data in this format also emphasizes the widely varying performance characteristics of these fluids, each of which has been qualified yet has its particular *Achilles Heel*, as stated by Transport Canada in Appendix E.

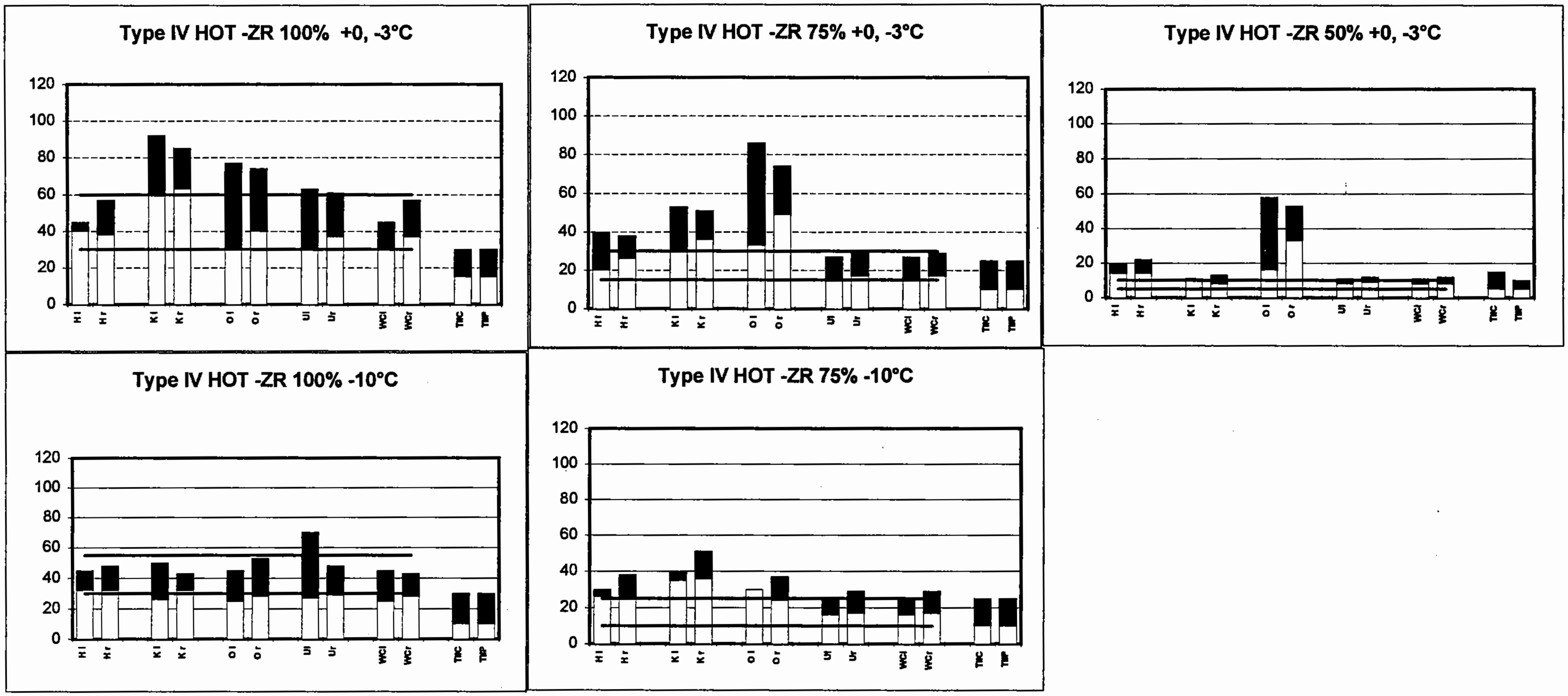
After seeing the evidence presented by APS and Transport Canada, the SAE G-12 Holdover Time Subcommittee accepted the regression approach to the determination of the holdover time ranges on the following grounds:

FIGURE 5.10

COMPARISON OF HOLDOVER TIMES

STRAIGHT LINE VERSUS CURVED REGRESSION METHOD

LIGHT FREEZING RAIN



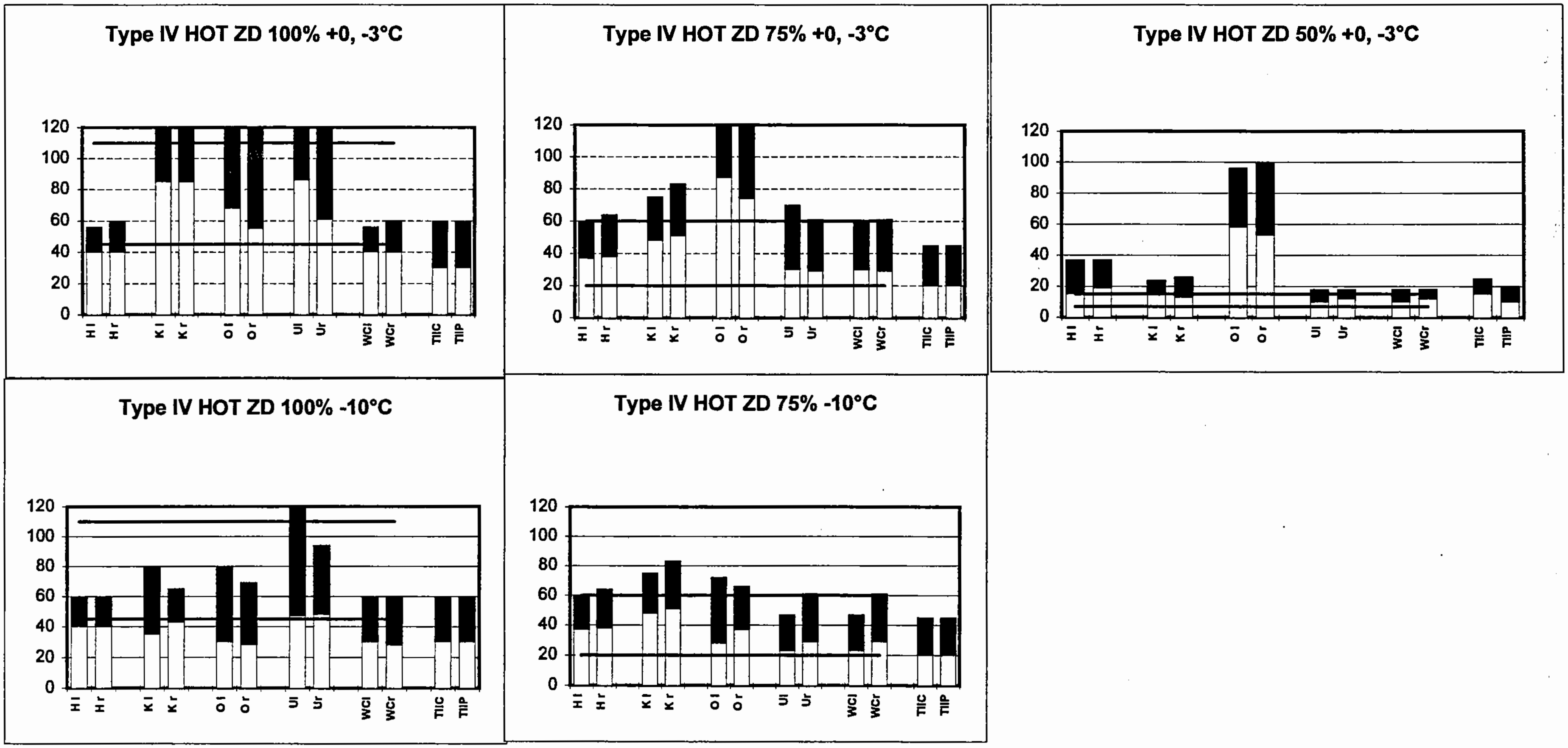
Note: Type IV values not rounded or adjusted.

FIGURE 5.11

COMPARISON OF HOLDOVER TIMES

STRAIGHT LINE VERSUS CURVED REGRESSION METHOD

FREEZING DRIZZLE



Note: Type IV values not rounded or adjusted.

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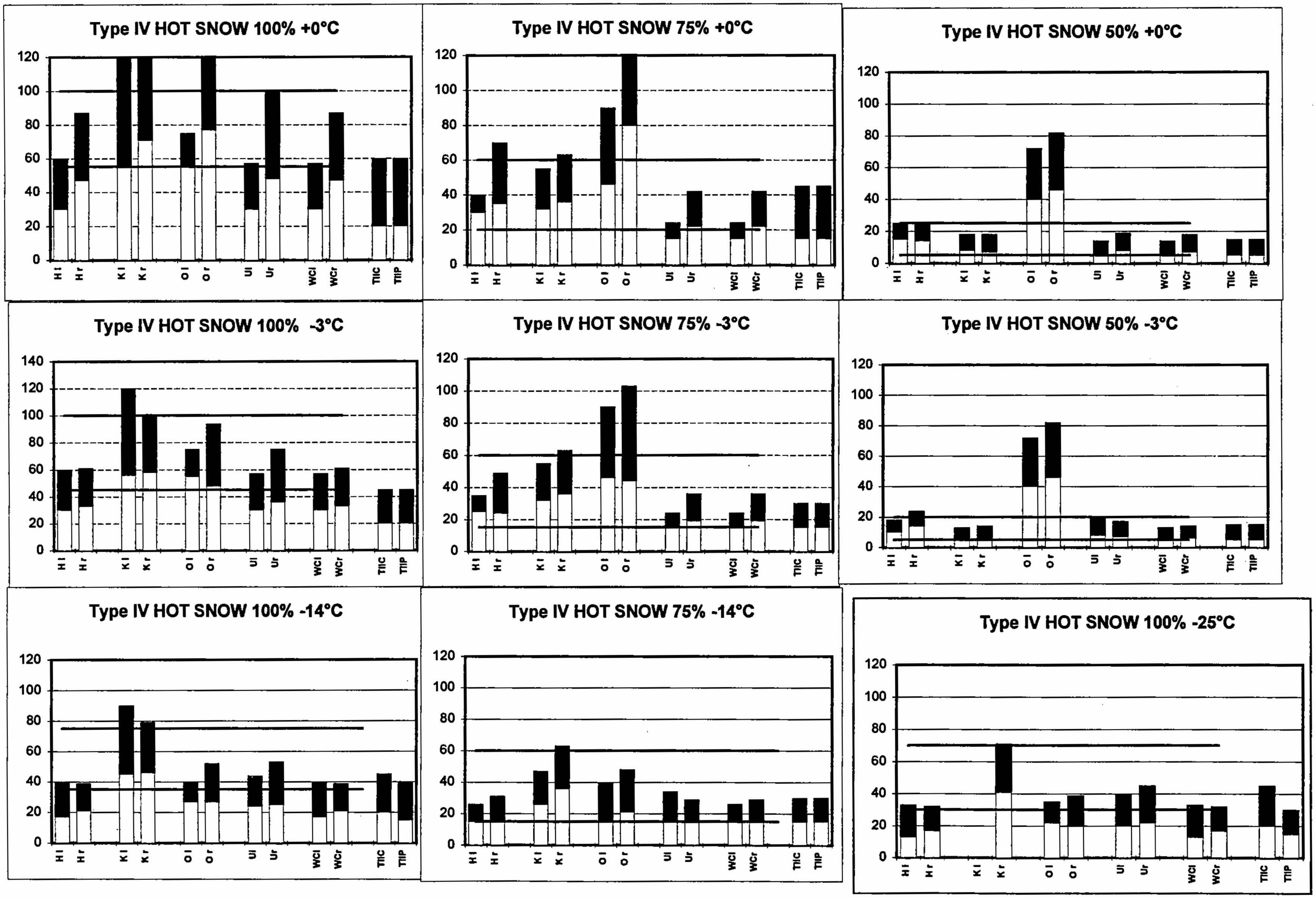
FIGURE 5.12

COMPARISON OF HOLDOVER TIMES

STRAIGHT LINE VERSUS CURVED REGRESSION METHOD

SNOW



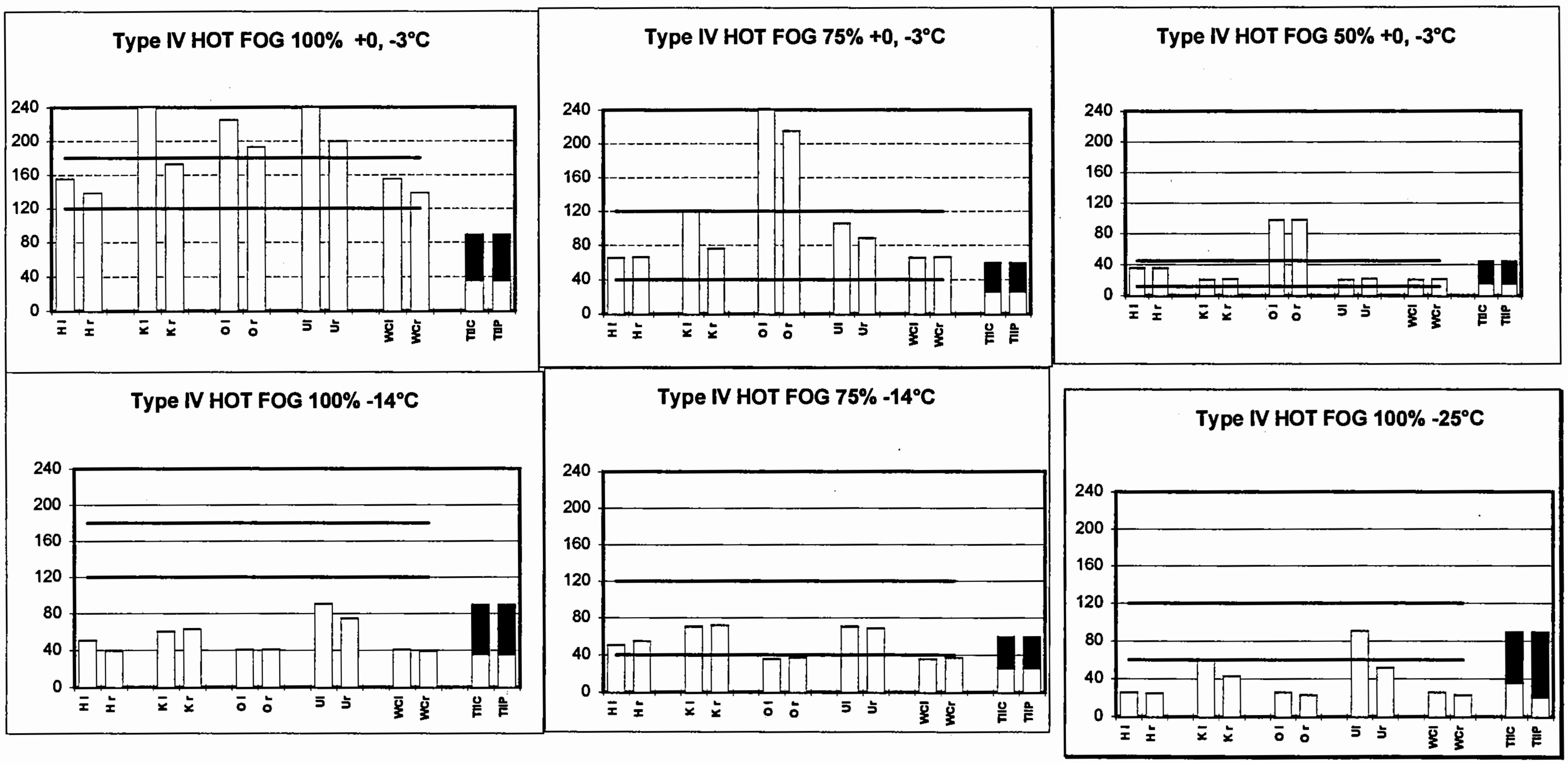
Note: Type IV values not rounded or adjusted.

FIGURE 5.13

COMPARISON OF HOLDOVER TIMES

STRAIGHT LINE VERSUS CURVED REGRESSION METHOD

FREEZING FOG



Note: - Type IV values not rounded or adjusted.

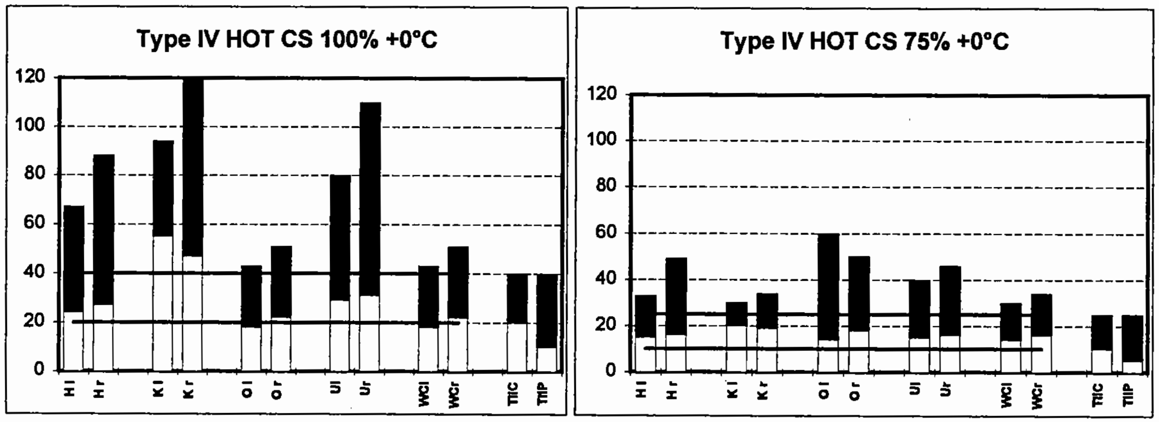
- Only lower limit values are provided in this chart, because this is what was presented at the Chicago SAE meeting.

FIGURE 5.14

COMPARISON OF HOLDOVER TIMES

STRAIGHT LINE VERSUS CURVED REGRESSION METHOD

COLD-SOAKED WING



Note: - Type IV values not rounded or adjusted.

- The lower limit values for both straight line and regression method considered data up to 25 g/dm²/hr, because this is what was presented at the Chicago SAE meeting.

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- The model appears to be consistent with the physics of these fluid types; that is there is a power law dependence on temperature and precipitation rate;

- The results so obtained are reproducible; a viable *protocol* has been developed;

- Interpolation and/or extrapolation is consistent;

- The regression approach allows holdover time values to be computed for the most restrictive temperature in a cell; and

- Holdover time values can easily be changed using new data from newly-developed fluids.

5.8 *Fluid-Specific* Holdover Time Tables

Fluid-specific holdover time table development was prompted by the fact that certain fluid brands were observed to significantly out-perform other fluids under conditions corresponding to specific cells in the holdover time tables. In general, any one fluid brand does not globally out-perform the other brands, but rather does so at a specific dilution, temperature range, and/or category of precipitation.

The **intent** of Transport Canada, the Federal Aviation Administration and APS was to develop modified versions of the *worst case* (generic) SAE table to reflect holdover time values that provide the benefits of a given fluid **where it exhibits significantly superior performance relative to a hypothetical *worst case* fluid.**

For each cell in the holdover time tables, a comparison was made between the *fluid-specific* holdover times and the *worst case* holdover times. If the *fluid-specific* holdover time cell values (average of lower limit and upper limit) were found to be 50% greater than that of the *worst case* fluid holdover time, credit for that fluid was to be given, **provided that there was sufficient data to warrant it.** Appendix L contains material related to the 50% factor which was proposed at the Chicago meeting.

At the Chicago meeting, most members of the SAE G-12 Holdover Time Subcommittee did not favour *fluid-specific* tables. However, significant reductions to holdover times for the cells corresponding to the most common Type IV fluid usage convinced the committee of the need to consider the *fluid-specific* tables over the *worst case* (generic) table. Furthermore, some members wanted to take advantage of the significant benefits exhibited by some fluids in certain conditions.

Of the 324 holdover time values for Type IV determined by the regression method, about 25% of the holdover times would have been affected by the proposed changes recommended by APS and Transport Canada. After considerable discussion, it was decided that the numbers, as they were determined by the regression method, would be used in the *fluid-specific* holdover time tables, provided there is sufficient supporting data.

These *fluid-specific* holdover times were adopted for the three most commonly occurring precipitation categories in the holdover time tables: freezing drizzle, light freezing rain, and snow. For the other categories of precipitation (freezing fog and rain on a cold-soaked wing), holdover times from the *worst case* (generic) table generated from the regression analysis were adopted. This outlines the procedure used as criterion for the acceptance of *fluid-specific* holdover times by the SAE G-12 Holdover Time Subcommittee. An example of one *fluid-specific* holdover time chart is shown in Table 5.5. The SAE does not publish data for brand name products; therefore *fluid-specific* tables were endorsed by the Federal Aviation Administration and Transport Canada.

TABLE 5.5

SAE TYPE IV CURRENT/PROPOSED HOLDOVER TIMES

Regression Method - Rounded

KILFROST ABC-S

OAT		Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
°C	°F		*FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	*DRIZZLE OR LIGHT* RAIN ON COLD SOAKED WING
above 0°	above 32°	100/0	18:00	~~2:00-3:00~~ *2:20-3:00*	~~0:55-1:40~~ *1:10-2:00*	~~0:45-1:50~~ *1:20-1:50*	~~0:30-1:00~~ *1:00-1:25*	~~0:20-0:40~~ *0:10-0:50*
		75/25	6:00	~~0:40-2:00~~ *1:05-2:00*	~~0:20-1:00~~ *0:35-1:05*	~~0:20-1:00~~ *0:50-1:25*	~~0:15-0:30~~ *0:35-0:50*	~~0:10-0:25~~ *0:05-0:35*
		50/50	4:00	~~0:15-0:45~~ *0:20-0:45*	~~0:05-0:25~~ *0:05-0:20*	~~0:07-0:15~~ *0:15-0:25*	~~0:05-0:10~~ *0:10-0:15*	
0 to -3	32 to 27	100/0	12:00	~~2:00-3:00~~ *2:20-3:00*	~~0:45-1:40~~ *1:00-1:40*	~~0:45-1:50~~ *1:20-1:50*	~~0:30-1:00~~ *1:00-1:25*	
		75/25	5:00	~~0:40-2:00~~ *1:05-2:00*	~~0:15-1:00~~ *0:35-1:05*	~~0:20-1:00~~ *0:50-1:25*	~~0:15-0:30~~ *0:35-0:50*	
		50/50	3:00	~~0:15-0:45~~ *0:20-0:45*	~~0:05-0:20~~ *0:05-0:15*	~~0:07-0:15~~ *0:15-0:25*	~~0:05-0:10~~ *0:10-0:15*	
below -3 to -14	below 27 to 7	100/0	12:00	~~2:00-3:00~~ *0:40-3:00*	~~0:35-1:15~~ *0:45-1:20*	**~~0:45-1:50~~ *0:35-1:00*	**~~0:30-0:55~~ *0:30-0:45*	
		75/25	5:00	~~0:40-2:00~~ *0:35-2:00*	~~0:15-1:00~~ *0:35-1:05*	**~~0:20-1:00~~ *0:50-1:25*	**~~0:10-0:25~~ *0:35-0:50*	
below -14 to -25	below 7 to -13	100/0	12:00	~~1:00-2:00~~ *0:20-2:00*	~~0:30-1:10~~ *0:40-1:10*			
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.

<u>Legend:</u>

0:35-1:15	- Holdover time in use for 1996/97.
0:45-1:20	- Proposed holdover time based on regression method (rounded).

(Because all cells for the three categories receiving benefits from the regression analyses have been accepted by the SAE G-12 Holdover Time Subcommittee, further testing is recommended to verify the integrity of the data at precipitation rate limits.)

It should also be mentioned that Table 5.5 has been modified; holdover times have been adjusted through SAE G-12 Holdover Time Subcommittee discussions. The values have been rounded with careful consideration being given to the raw data. The resultant *fluid-specific* tables are located in Section 6 where they are discussed in more detail.

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6. HOLDOVER TIME TABLES, RESULTS, AND DISCUSSIONS

The sequence of events and the methods used to treat the test data have been reviewed in Section 5. In this section, the officially accepted holdover time tables are presented, and important findings are discussed. Beginning with Type IV fluids in Subsection 6.1, the different categories of precipitation are presented one at a time, in a cell-by-cell fashion. Comments and discussions follow. This presentation format is repeated for Type III in Subsection 6.2, Type I in Subsection 6.3, and Type II in Subsection 6.4.

Subsection 6.5 presents all holdover time tables including the SAE *worst case* (generic) holdover time table described in Subsection 5.6. These are the tables proposed for worldwide use during the 1997/98 winter season.

At the Chicago SAE G-12 Holdover Time Subcommittee meeting, the Airline Pilot Association requested that a new caution statement be added to the bottom of all holdover time tables. The statement reads as follows:

> ***SAE Type I (or II or III or IV) fluid used during ground deicing/anti-icing is not intended for and does not provide protection during flight.***

6.1 Type IV Fluids

Fluids from four different manufacturers were tested during winter 1996/97. Another Type IV fluid (SPCA - AD-404) was tested the previous year, 1995/96, and added to the data set for analysis. At the Pittsburgh meeting, APS was notified that this fluid met all current qualifying criteria; however, at the Chicago meeting, the consensus was that a *fluid-specific* holdover time table for SPCA AD-404 would not be developed at the time due to insufficient data at many of the test conditions, and due to the uncertainty of the fluid satisfying future qualifying criteria. Subsequently, only the remaining fluids manufactured by Kilfrost (ABC-S), Octagon (Maxflight), Union Carbide (Ultra+), and Hoechst (MPIV 1957) were used to develop the holdover time tables.

6.1.1 Natural Snow

The natural snow holdover time data originated from two sources. The primary source was the APS test team operating at Dorval airport. The second source was the National Centre for Atmospheric Research group in Denver, Colorado. Fifty holdover time tests were conducted by the National Centre for Atmospheric Research in natural snow conditions using Hoechst and Union Carbide Ultra+ fluids in their neat and 75/25 forms. These tests amount to less than 10% of the total number of snow tests conducted by APS. The National Centre for Atmospheric Research recorded failure times and precipitation rate measurements in flat plate tests similar to those carried out by APS. A certain amount of variation in the data might be due to differences in meteorological conditions between the test site locations as well as some small differences in failure calls between the two groups. The National Centre for Atmospheric Research data are provided in Appendix I. The fluid failure time versus precipitation rate data from both sources have been combined and plotted either as a function of temperature (Figures on Pages F-16 to F-30 in Appendix F), or as a function of fluid brand (Figures on Pages F-31 to F-39 in Appendix F). 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 of the numbers obtained from the regression analyses. The plots have been reproduced in this section to facilitate the comparison and discussion of results. Because of this plot format it occasionally appears that the regression curves were generated despite a lack of data points. Inspection of the figures in Appendix F shows that each of the curves appearing on Pages F-31 to F-39 are taken from a family of curves at different temperatures for that same fluid and concentration. These families of curves are shown in the figures on Pages F-16 to F-30.

The following section contains comparisons of the 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 high to low temperature.

6.1.1.1 Changes to Type IV fluid holdover times for snow

The tables below are formatted to show columns containing the 1996/97 SAE (current), 1997/98 SAE, and the four *fluid-specific* holdover times for each cell in the holdover time tables. The underlined holdover time values in each of the tables indicate the fluids responsible for the *worst case* 1997/98 SAE holdover time.

i) Neat fluid, above 0°C, snow (Figure 6.1)

96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
0:55-1:40	0:45-1:25	1:10-2:00	1:15-2:00	0:50-1:40	0:45-1:25

From the tabulation above and from Figure 6.1, both Kilfrost and Octagon fluids outperform the others under these conditions. Note that the 1997/98 SAE value is below the 1996/97 SAE (current) value and is identical to the result achieved by the Hoechst fluid.

ii) 75/25 fluid, above 0°C, snow (Figure 6.2)

96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
0:20-1:00	00:20-0:40	0:35-1:05	1:20-2:00	0:20-0:40	0:35-1:10

At this concentration, the Octagon fluid is the top performer, even outperforming the Octagon neat fluid at this temperature. The 1997/98 SAE value is identical to the Ultra+ fluid. This result is also shown in Figure 6.2.

iii) 50/50 fluid, above 0°C, snow (Figure 6.3)

96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
0:05-0:25	0:05-0:20	0:05-0:20	0:40-1:20	0:05-0:20	0:15-0:25

Octagon fluid still displays the highest performance. At this concentration, Kilfrost performance parallels that of Ultra+ and the 1997/98 SAE fluid. The lower limit for Kilfrost and Ultra+ (5 minutes) was rounded down from the regression values of 8 minutes due to sparse data and the short duration of protection. The regression time range for Octagon fluid, 46 to 82 minutes, was also rounded down.

iv) Neat fluid, 0 to -3°C, snow (Figure 6.4)

96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
0:45-1:40	0:35-1:00	1:00-1:40	0:50-1:35	0:35-1:15	0:35-1:00

FIGURE 6.1
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT (Above 0°C)
NATURAL SNOW CONDITIONS

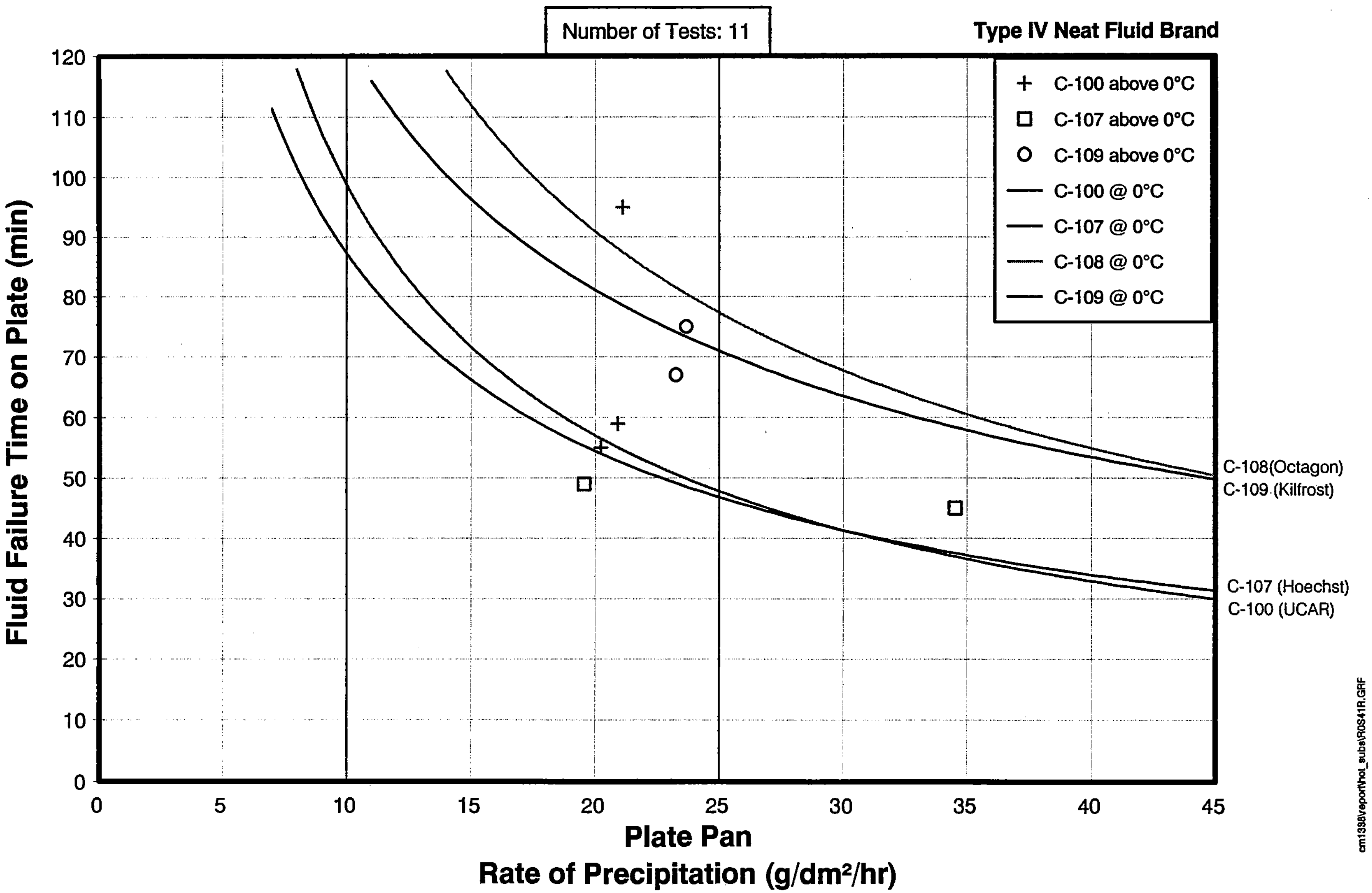


FIGURE 6.2

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25 (Above 0°C)

NATURAL SNOW CONDITIONS

(APS & NCAR)

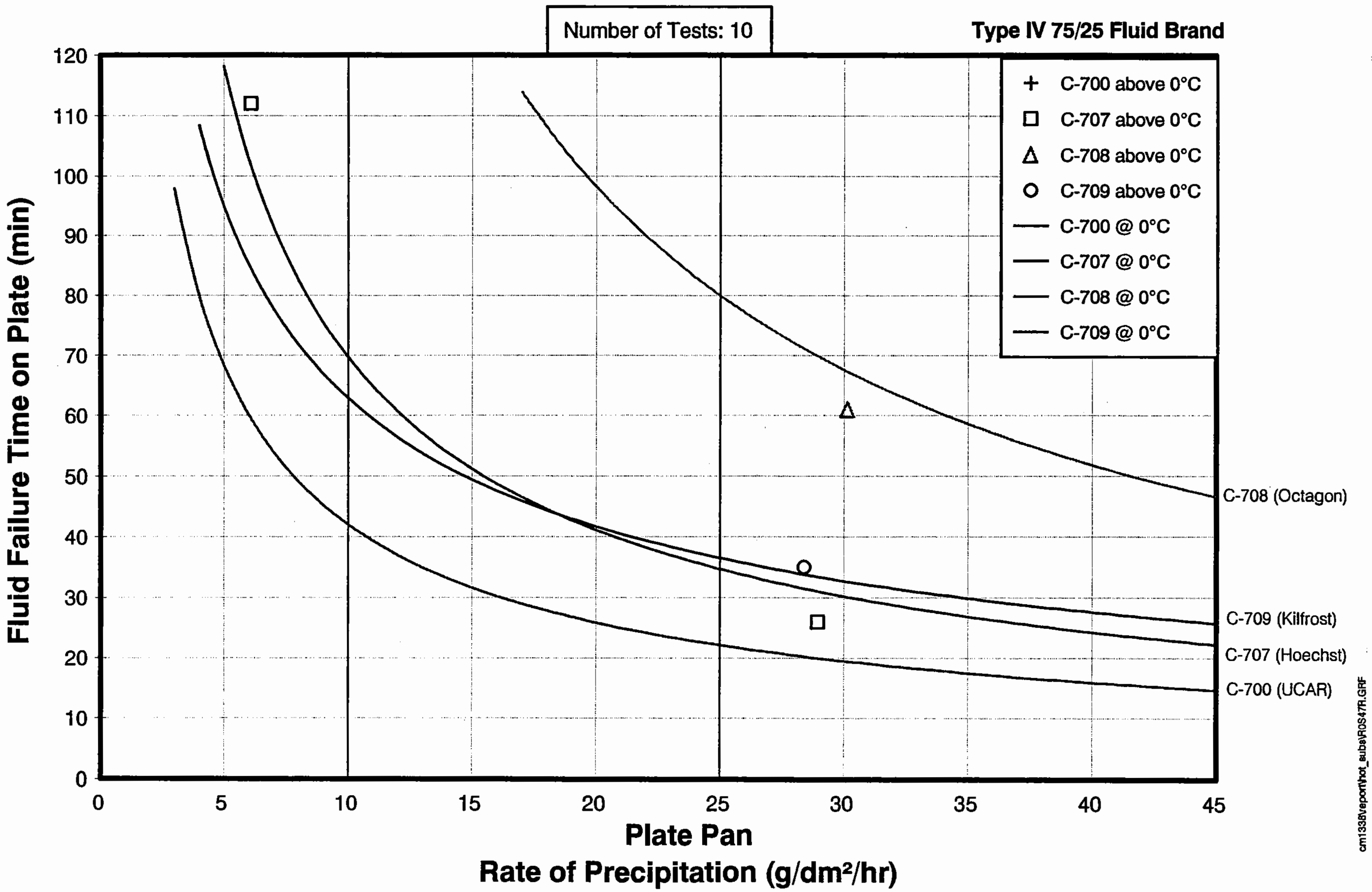


FIGURE 6.3

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50 (Above 0°C)

NATURAL SNOW CONDITIONS

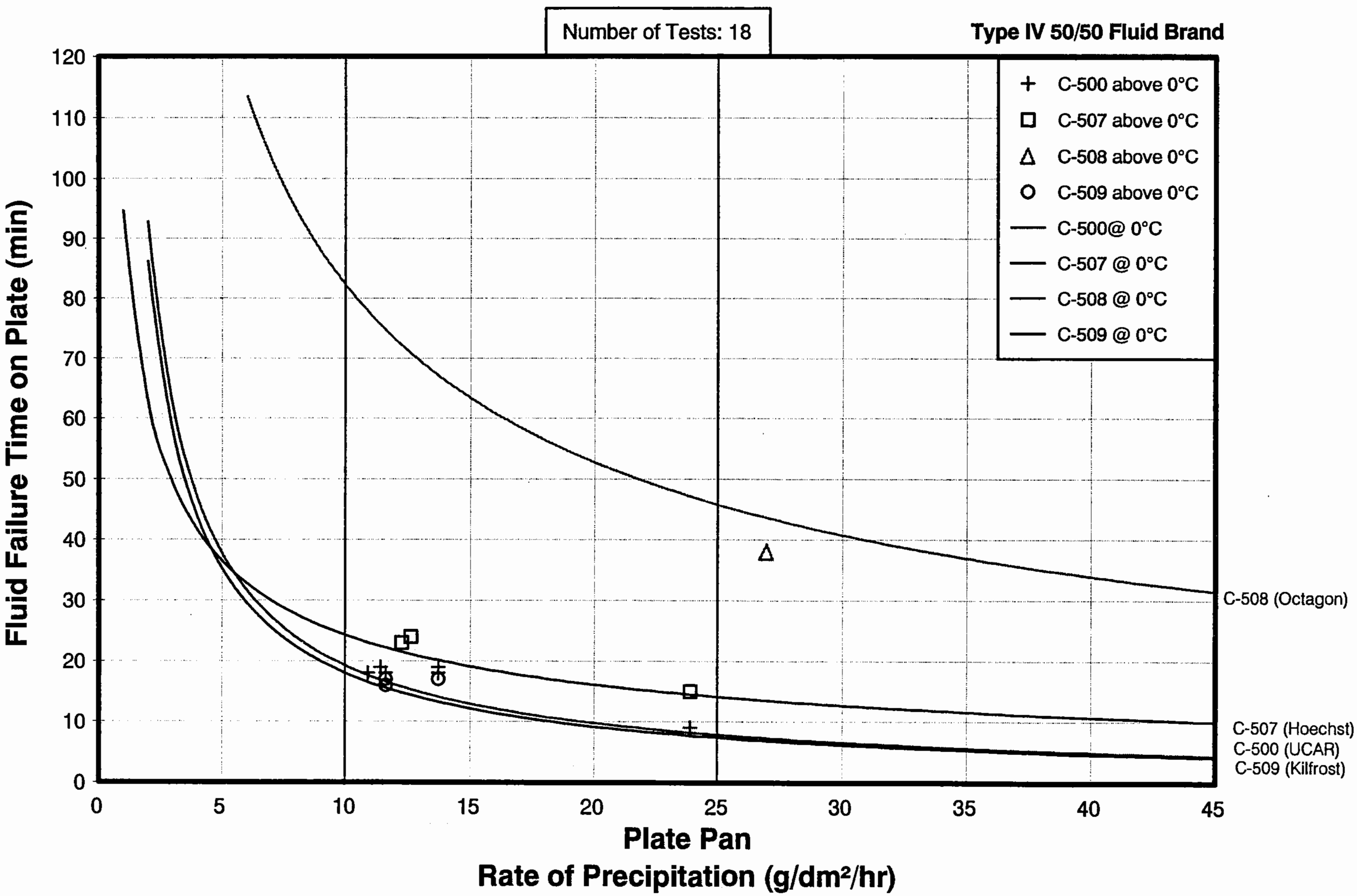
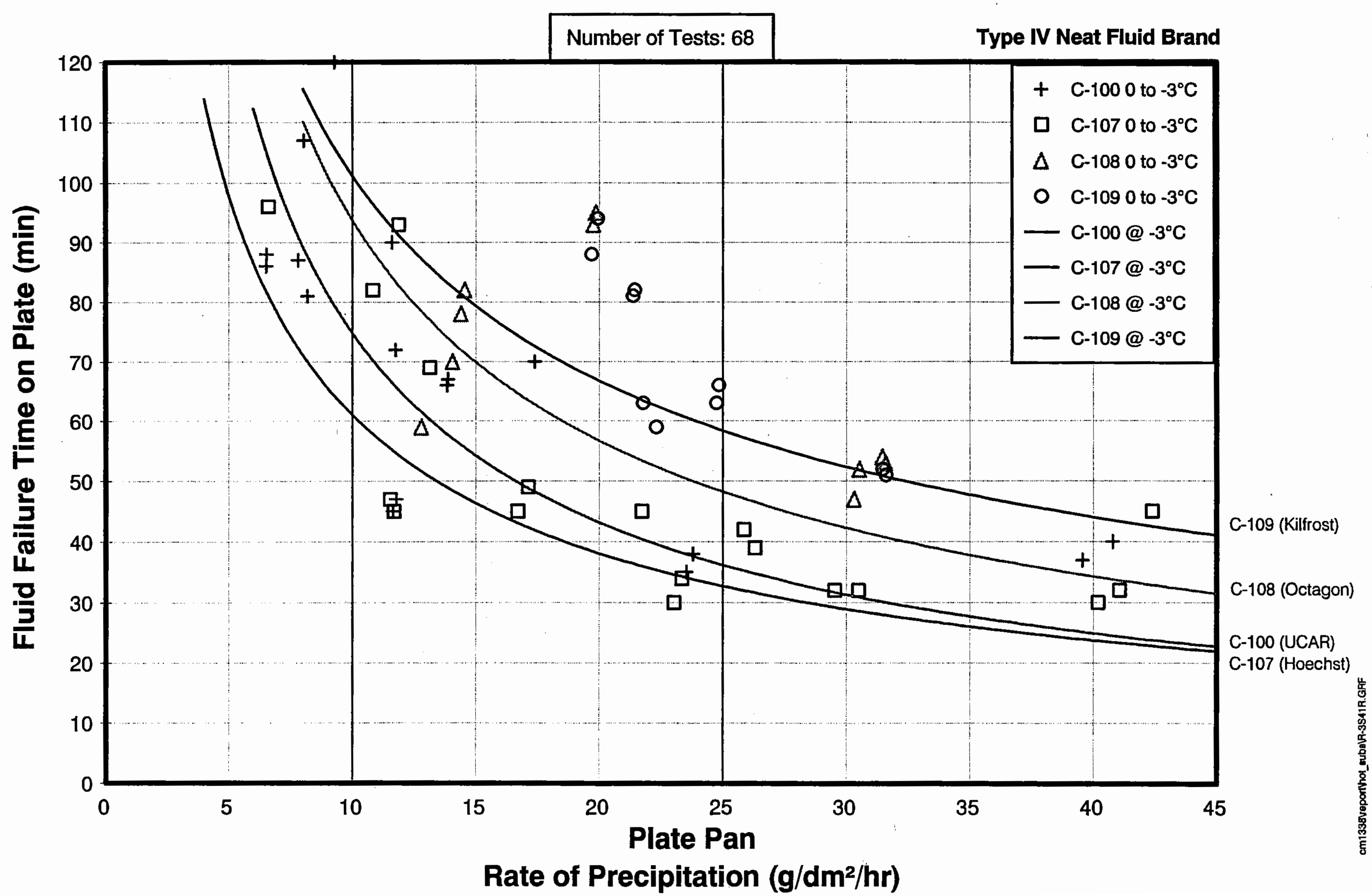


FIGURE 6.4

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT (0 to -3°C)

NATURAL SNOW CONDITIONS



At this temperature and concentration, the highest performance is achieved by the Kilfrost fluid. This is shown in Figure 6.4. The 1997/98 SAE *worst case* fluid is identical with Hoechst fluid under these conditions. The Ultra+ fluid also is responsible for the lower 1997/98 SAE holdover time. This result cannot be ignored. It is well supported by the four data points at 23 g/dm²/hr. This is the most frequently utilized cell in the holdover time table. The replacement of the 1996/97 SAE holdover time by the 1997/98 SAE holdover time was a driving element behind the adoption of *fluid-specific* tables.

v) 75/25 fluid, 0 to -3°C, snow (Figure 6.5)

96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
0:15-1:00	0:20-0:35	0:35-1:05	0:45-1:45	0:20-0:35	0:25-0:50

At this dilution, the performance gap between Octagon and the other fluids is substantial, especially at lower precipitation rates. The 1997/98 SAE fluid here is Ultra+. It should be noted, however, that the 1997/98 SAE lower limit holdover time has increased by five minutes over the 1996/97 SAE lower limit holdover time.

vi) 50/50 fluid, 0 to -3°C, snow (Figure 6.6)

96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
0:05-0:20	0:05-0:15	0:05-0:15	0:40-1:20	0:05-0:15	0:15-0:25

At this dilution the Kilfrost fluid performance properties are significantly diminished and it is equivalent to the 1997/98 SAE fluid. This result might have been predicted by observations from the thickness trials on flat plates described in Section 4, where Kilfrost 50/50 fluid thickness was substantially reduced from thickness values for neat and 75/25 fluid.

In this instance, the 1997/98 SAE times are generated by both Kilfrost and Ultra fluids.

The regression curve indicates that the Octagon fluid is far superior in this condition; however, more tests at higher precipitation rates would be useful. The lower holdover time, determined from the regression analysis was 46 minutes. Due to lack of data points for this fluid at the 25 g/dm²/hr precipitation rate limit, the regression value was rounded down to 40 minutes.

FIGURE 6.5

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25 (0 to -3°C)

NATURAL SNOW CONDITIONS

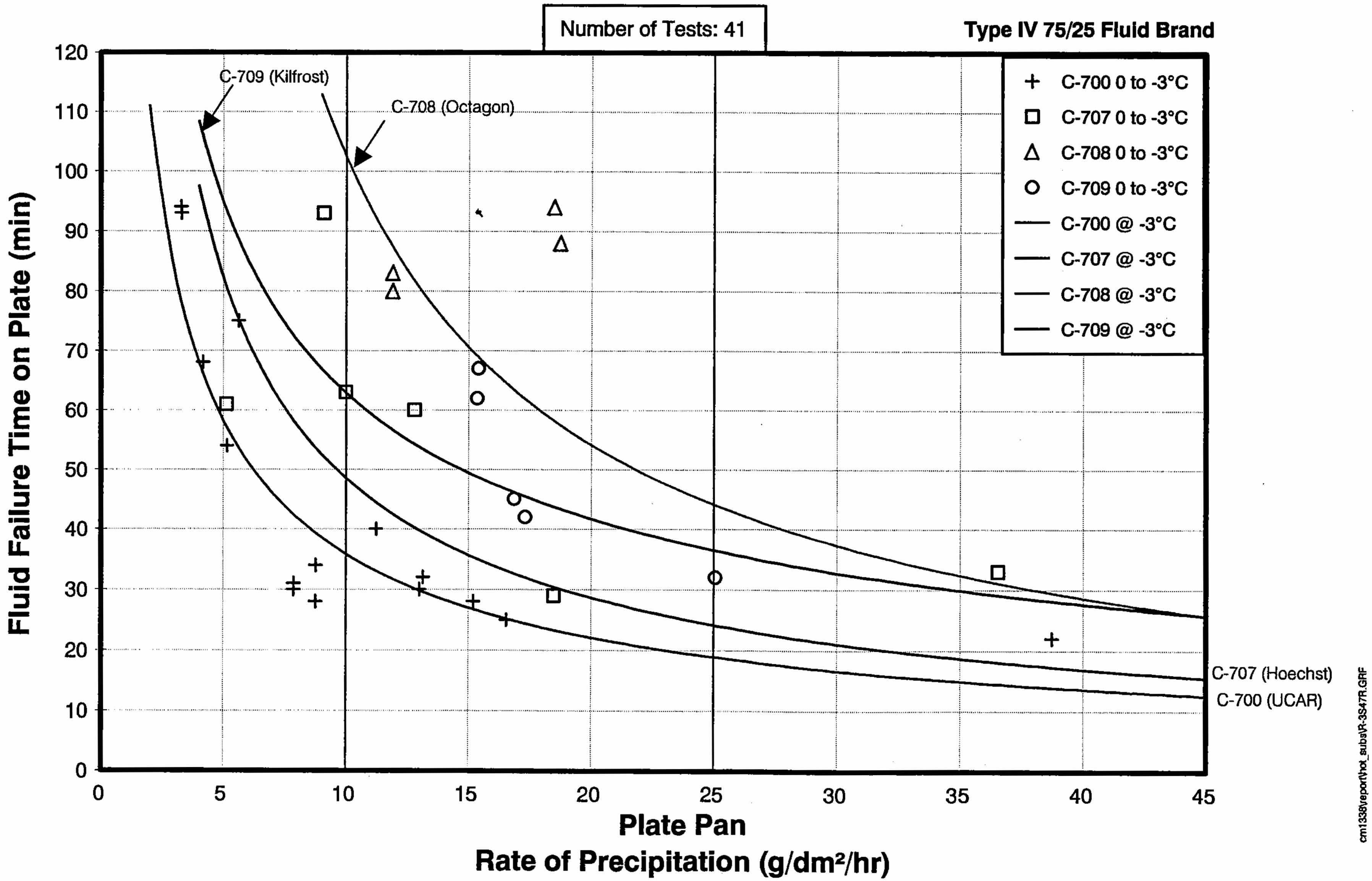


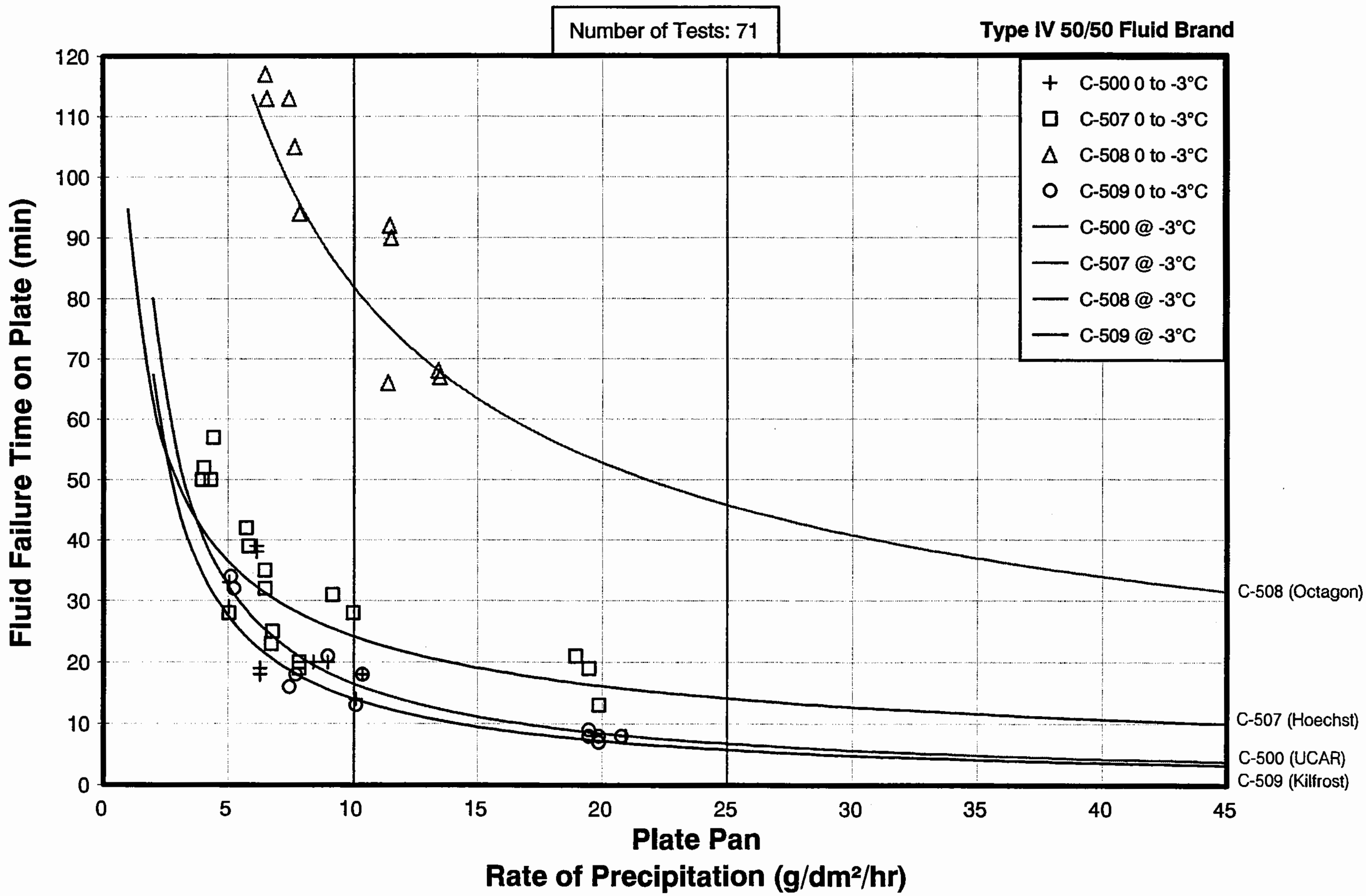
FIGURE 6.6

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50 (0 to -3°C)

NATURAL SNOW CONDITIONS

1996/97



vii) Neat fluid, below -3 to -14°C, snow (Figure 6.7)

96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
0:35-1:15	0:20-0:40	0:45-1:20	0:25-0:50	0:25-0:55	0:20-0:40

There is a major reduction in the holdover time range for this cell. One significant factor contributing to the reduction of holdover times is the poor performance of the Hoechst fluid. A second factor behind this reduction is due to the generation of regression curves using the most restrictive temperature (-14°C), which may not be representative of actual meteorological conditions. The probability of precipitation rates greater than 25 g/dm²/hr occurring at temperatures at or below -14°C is small. This subject is recommended for further study. For this range, Kilfrost is found to be the top performing fluid. This is evident from the plot shown in Figure 6.7.

viii) 75/25 fluid, below -3 to -14°C, snow (Figure 6.8)

96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
0:15-1:00	0:15-0:30	0:35-1:05	0:20-0:50	0:15-0:30	0:15-0:30

Union Carbide and Hoechst exhibit similar behaviour, and both are responsible for the 1997/98 SAE fluid. Despite a reduction in the upper limit holdover time, the 1997/98 SAE lower limit has remained identical to the 1996/97 SAE lower limit holdover time. Figure 6.8 reflects the trend.

ix) Neat fluid, below -14 to -25°C, snow (Figure 6.9)

96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
0:30-1:10	0:15-0:30	0:40-1:10	0:20-0:40	0:20-0:45	0:15-0:30

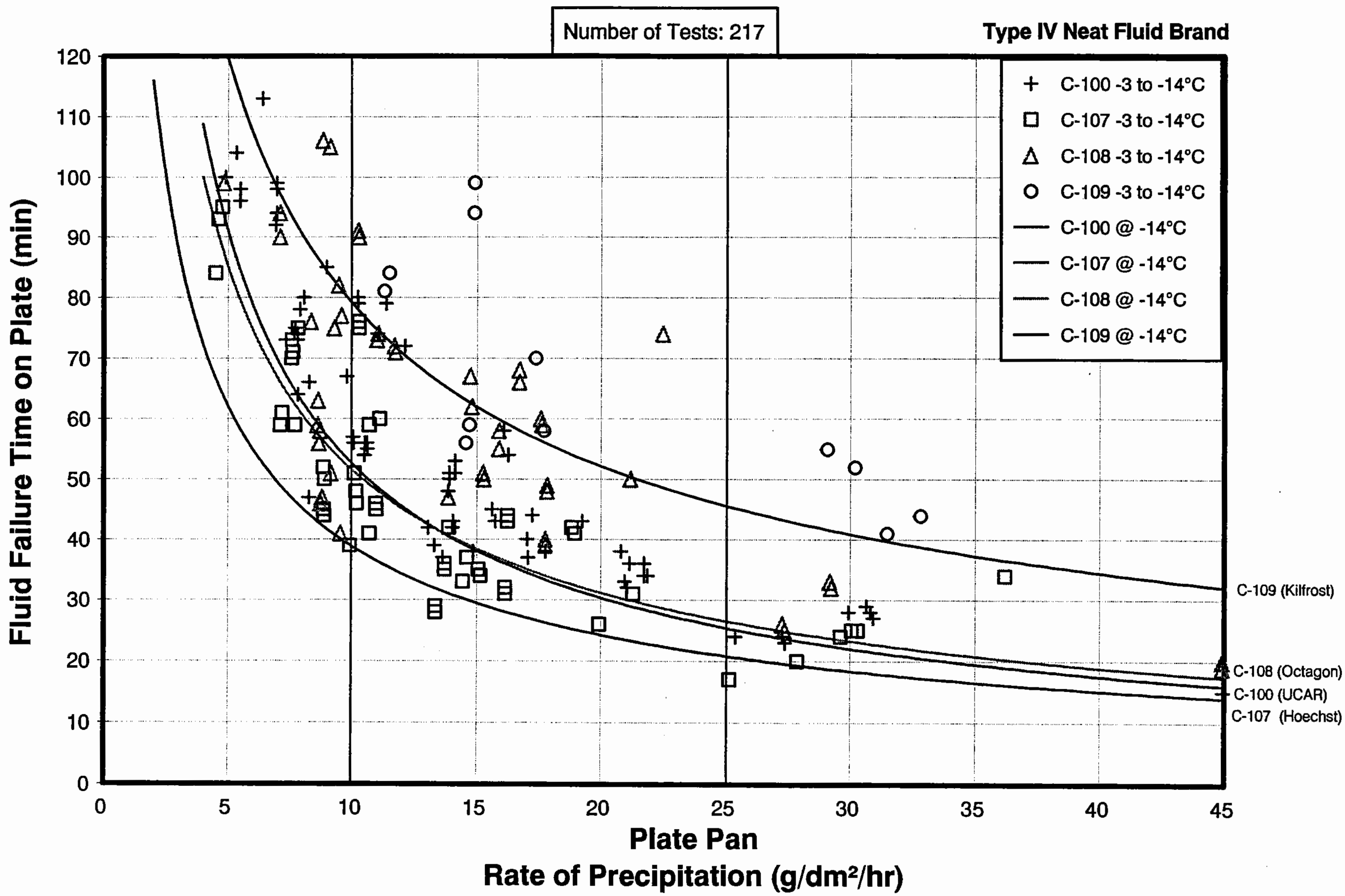
One fluid manufacturer is the top performer, while the other three fluids behave in a similar way, exhibiting poorer performance. The plot in Figure 6.9 shows the results. The 1997/98 SAE fluid is identical to Hoechst fluid. There is a major reduction to the holdover times in this cell. This is due primarily to the performance of neat Hoechst fluid in this low temperature range. It is also attributable to the regression curves that were generated using the most restrictive temperature in this range (-25°C). There is a low probability of the occurrence of high precipitation rates at temperatures approaching -25°C. In fact, the temperature range for the 16 data points shown in Figure 6.9 was from -14 and -16°C.

FIGURE 6.7

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT (-3 to -14°C)

NATURAL SNOW CONDITIONS



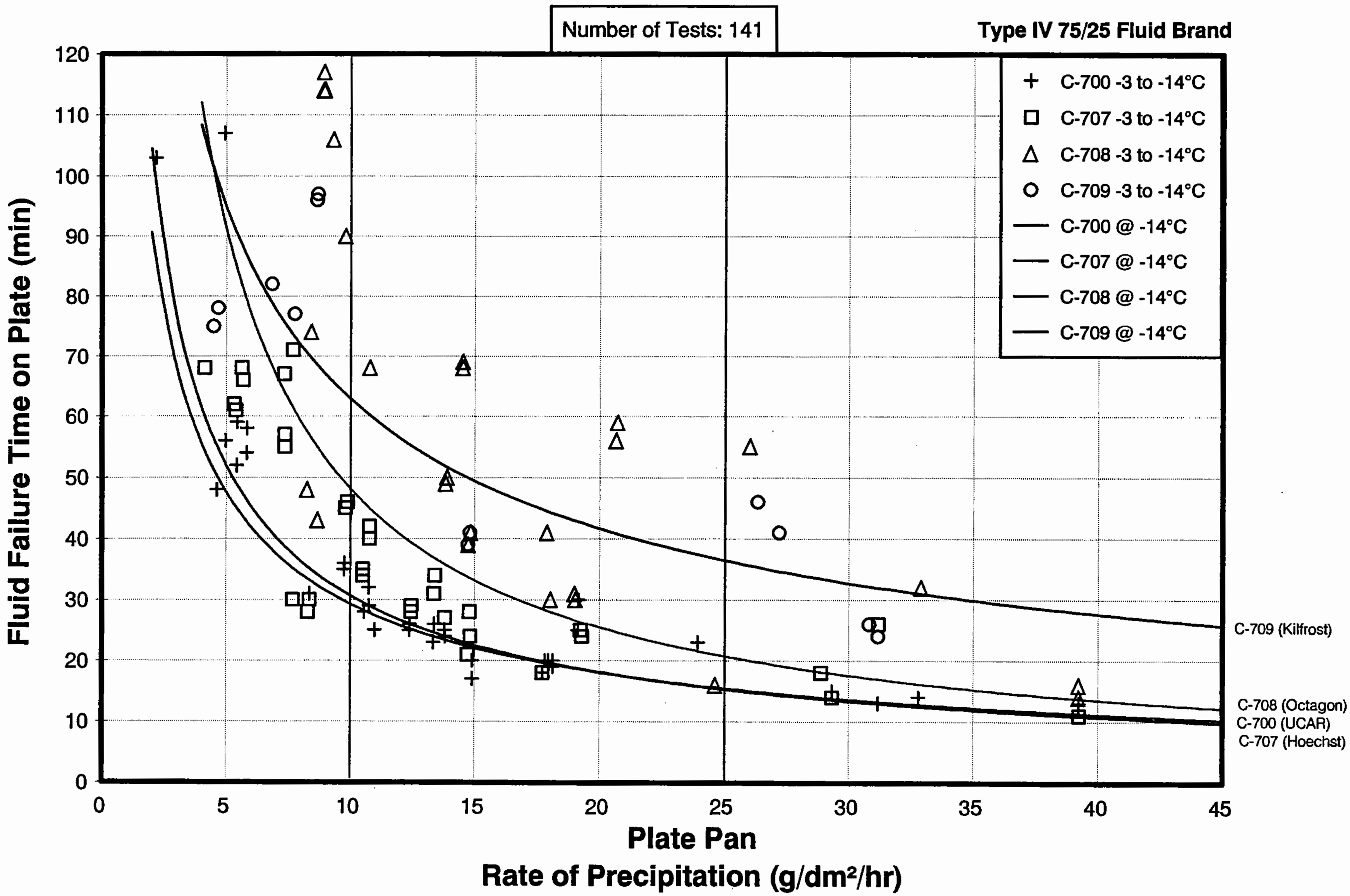
cm1338\report\hot_subs\R-14S41R.GRF

FIGURE 6.8

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25 (-3 to -14°C)

NATURAL SNOW CONDITIONS



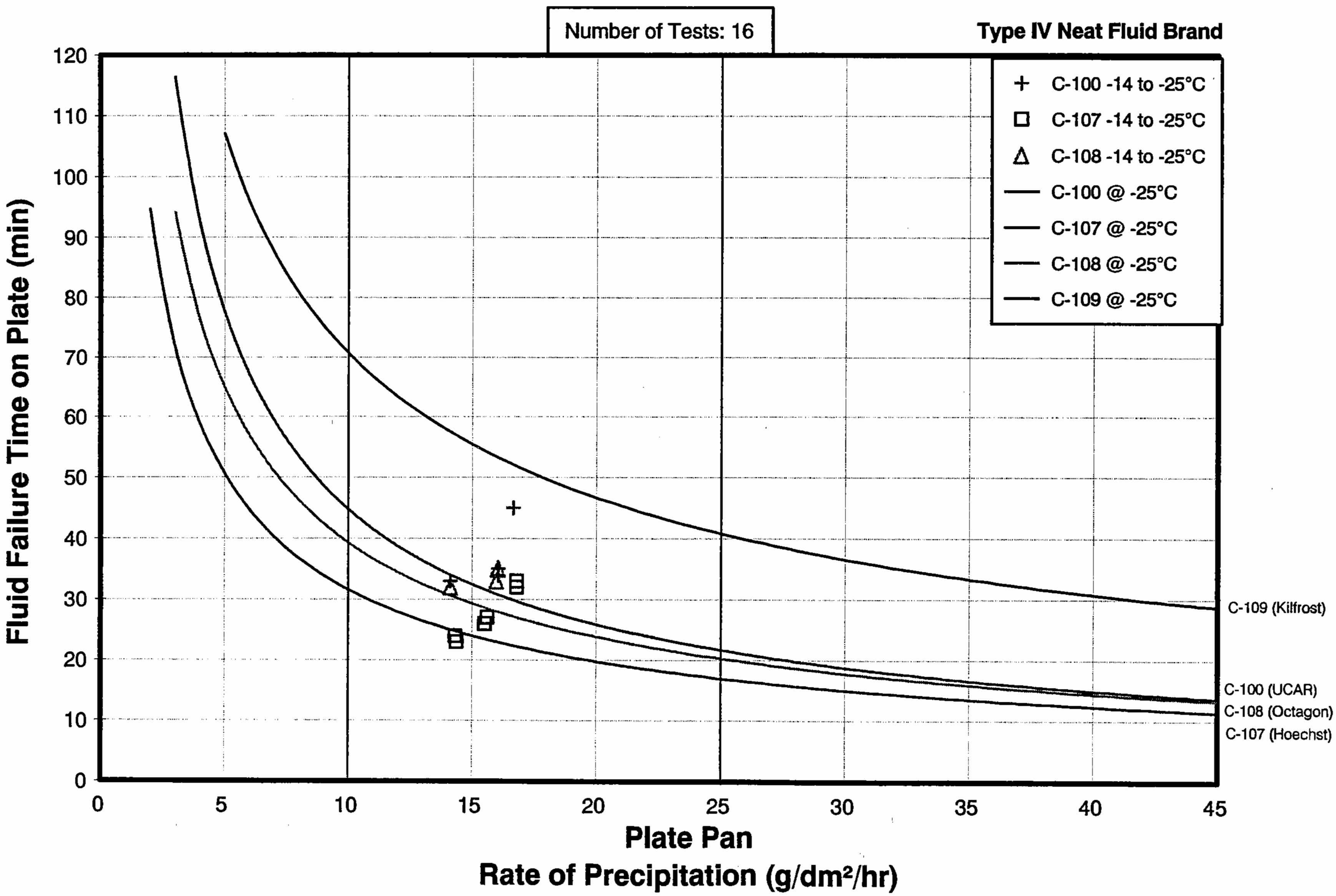
cm1338\report\hot_subs\R-14s47R.GRF

FIGURE 6.9

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT (-14 to -25°C)

NATURAL SNOW CONDITIONS



6.1.1.2 Overall perspective on snow results

There is scant data available for the snow category at temperatures above 0°C and below -14°C, due to the rarity of snow occurrences at these temperatures.

Large enhancements are obtained in the *fluid-specific* tables for the temperature ranges spanning 0 to -14°C. This also corresponds to the cells for which the *worst case* (generic) table most poorly compared with the current results taken from the tables in Section 1. These data are plotted in Figures 6.4 to 6.8 and represent the range of conditions most frequently occurring in the snow category. This emphasizes further the need for *fluid-specific* holdover time tables.

6.1.2 Freezing Drizzle and Light Freezing Rain

The following is a cell-by-cell summary of the holdover time performance of the fluid brands tested under simulated freezing drizzle and light freezing rain conditions. The results are arranged in table form and follow the sequence of temperature ranges (from top-to-bottom) as they appear in the corresponding columns of the holdover time tables. Because the holdover time results of these two categories of precipitation in the temperature range above 0°C are identical to those in the range from 0 to -3°C, there are only five tables.

Each table shows columns containing the 1996/97 SAE (current), the 1997/98 SAE, and the four *fluid-specific* holdover times. In this subsection, the tables for each temperature range contain two rows. The top row lists holdover times for freezing drizzle (ZD); the bottom row lists holdover times for light freezing rain (-ZR).

The fluid failure time versus precipitation rate data for these two categories of precipitation are plotted either as a function of temperature or as a function of brand (figures on Pages F-1 to F-15 in Appendix F). The plots as a function of fluid brand are used to help present discussions regarding changes to holdover times (figures on Pages F-1, F-2, F-8, F-9 and F-15 in Appendix F) and appear in the body of the text as Figures 6.10 to 6.14.

Each table is associated with one of the mentioned figures showing the data and the regression curves for each fluid brand. For some fluids, the regression curves are discontinuous. This is due to the regression analysis which made use of a *dummy* variable procedure to establish whether the data indicated the curve should be separated or not. If the curves are continuous, it is either because the data for both categories are fairly continuous along the precipitation rate range, or there was insufficient data to separate the two categories.

6.1.2.1 Changes to Type IV fluid HOTs for freezing drizzle and light freezing rain

i) Neat fluid, above 0 and 0 to -3°C, freezing drizzle and light freezing rain (Figure 6.10)

	96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
ZD	0:45-1:50	0:40-1:00	1:20-1:50	0:55-2:00	1:00-2:00	0:40-1:00
-ZR	0:30-1:00	0:35-0:55	1:00-1:25	0:40-1:15	0:35-1:00	0:40-0:55

The data for this range are shown in the plots on Figure 6.10. The differences between the holdover times for the 1996/97 SAE and 1997/98 SAE tables are somewhat significant, particularly in the category of freezing drizzle. For freezing drizzle, Hoechst fluid is identical to the 1997/98 SAE fluid. In the case of Kilfrost fluid, the regression-generated holdover times were determined to be 85-120 minutes but were reduced to 80-110 minutes due to sparsity of data. For light freezing rain, the lower holdover time in the 1997/98 SAE range comes from Ultra+ fluid while the upper holdover time for the 1997/98 SAE range comes from Hoechst fluid. Again, due to the sparsity of Kilfrost data, the holdover time regression results were conservatively rounded from 63-85 minutes to 60-85 minutes. There is a need to enlarge the database for these categories of precipitation in this temperature range.

ii) 75/25 fluid, above 0 and 0 to -3°C, freezing drizzle and light freezing rain (Figure 6.11)

	96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
ZD	0:20-1:00	0:30-1:00	0:50-1:25	1:15-2:00	0:30-1:00	0:40-1:05
-ZR	0:15-0:30	0:15-0:30	0:35-0:50	0:50-1:15	0:15-0:30	0:25-0:40

The data for this range are shown in the plots on Figure 6.11. Differences between 1997/98 SAE and 1996/97 SAE holdover times are considerably improved in the category of freezing drizzle, but nonexistent for light freezing rain. The dilution has deteriorated the Ultra+ fluid's performance much more than it has for the other fluids. The Ultra+ fluid is identical to the 1997/98 SAE fluid. The figure shows the performance of individual fluids to be more evenly separated for this dilution than for the neat fluid. The sparsity of data for each fluid in this range is a factor in the inability to separate the data between the two precipitation categories and the curves plotted for each fluid are continuous.

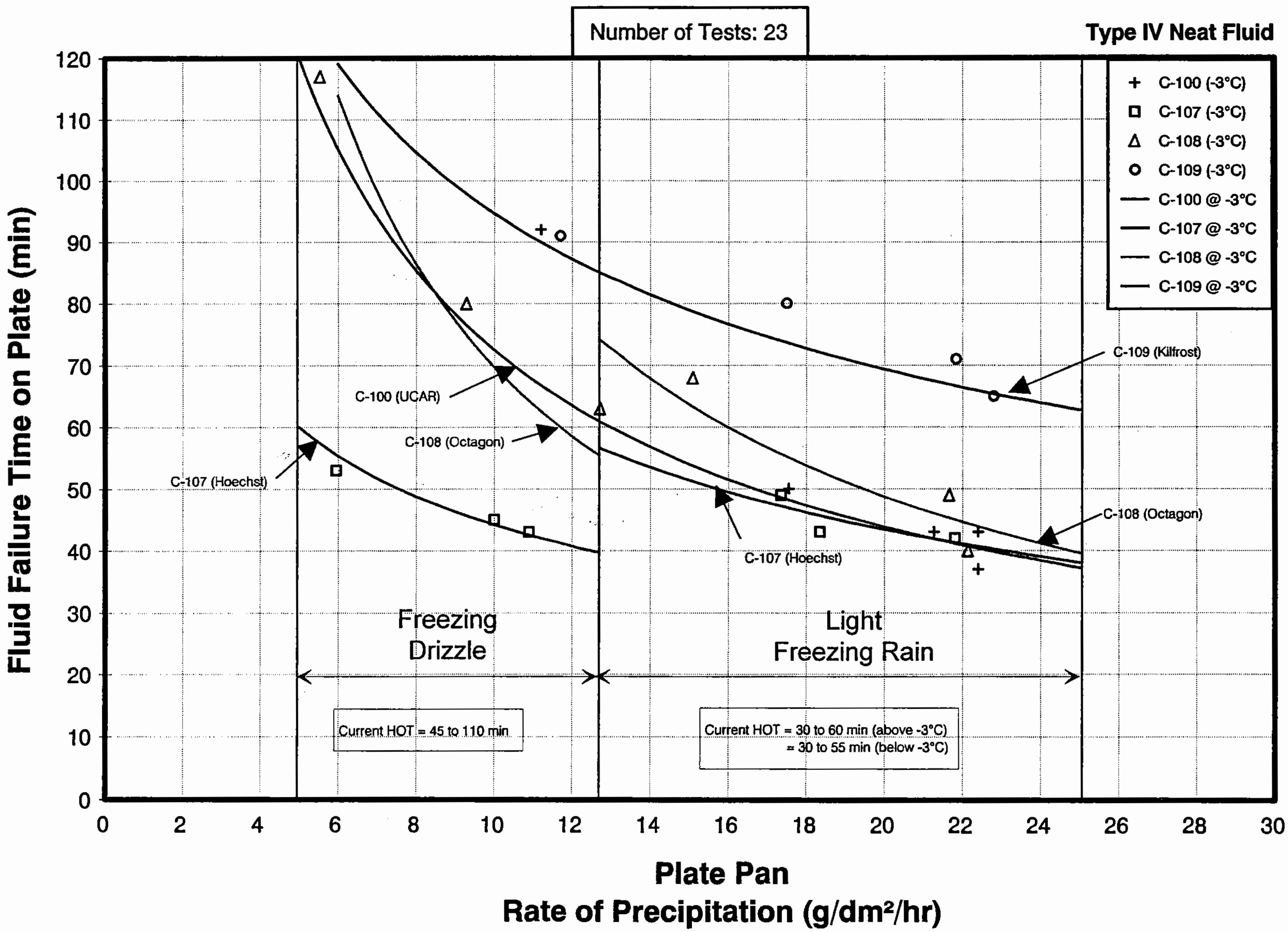
FIGURE 6.10

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT AT -3°C

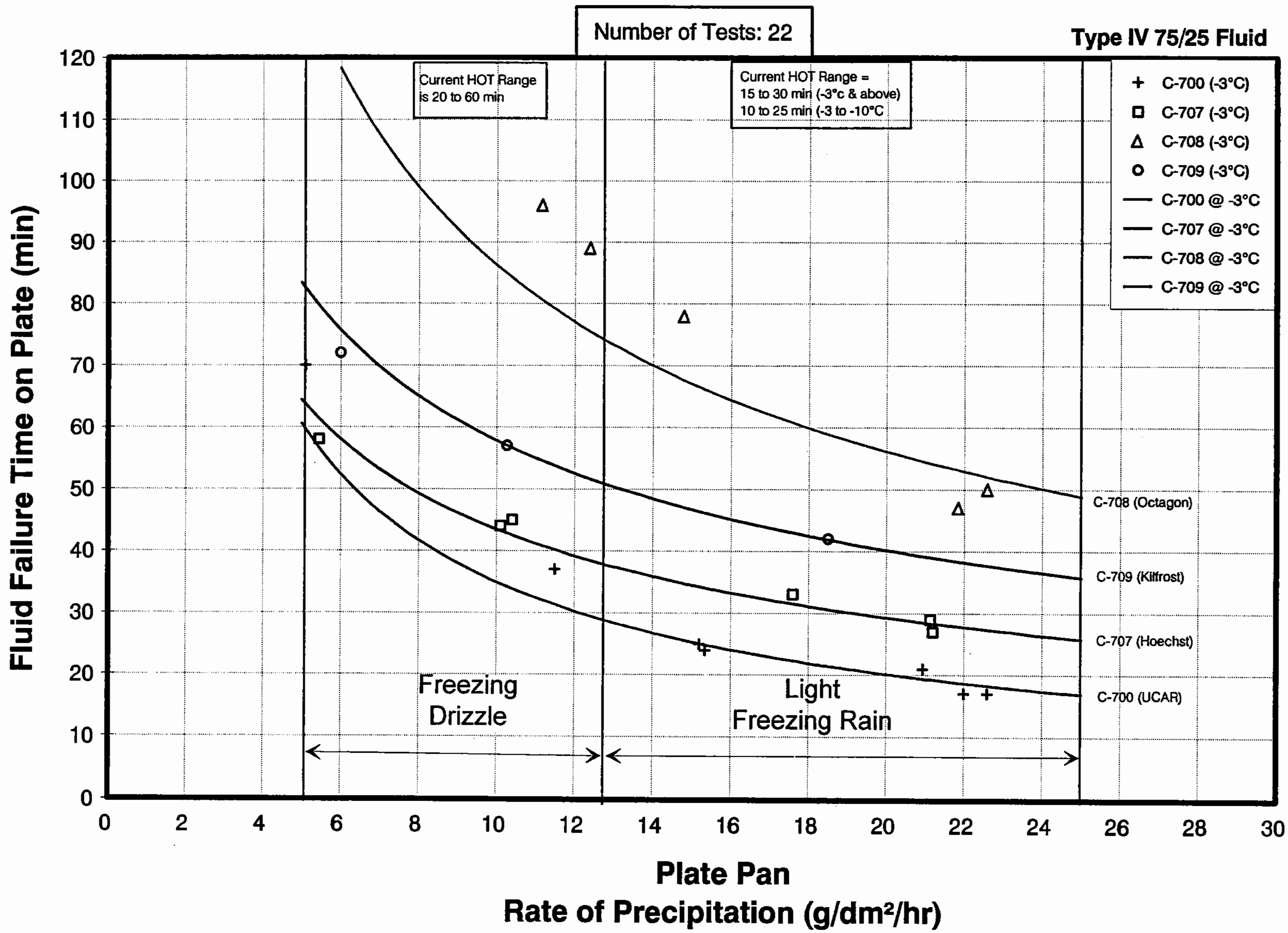
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1995/96 & 1996/97



cm1338\report\hot_subs\972R41R3.GRF

FIGURE 6.11
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25 AT -3°C
FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/96 & 1996/97



cm1338\report\hot_subs\97ZR47R3.grf

iii) 50/50 fluid, above 0 and 0 to -3°C, freezing drizzle and light freezing rain (Figure 6.12)

	96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra +	Hoechst
ZD	0:07-0:15	0:10-0:20	0:15-0:25	0:55-1:40	0:10-0:20	0:20-0:35
-ZR	0:05-0:10	0:05-0:10	0:10-0:15	0:30-0:55	0:05-0:10	0:15-0:20

The data for this range are shown in the plots on Figure 6.12. Slight increases are observed in the holdover times of the 1997/98 SAE fluid in freezing drizzle. The figure indicates Octagon fluid to be far superior to the other fluids at this dilution. The regression-generated lower holdover time for Octagon in freezing drizzle was determined to be 63 minutes, but was rounded down to 55 minutes due the sparsity of data. Ultra+ fluid is identical to the 1997/98 SAE fluid. Note that Kilfrost fluid performance is significantly reduced at this concentration. Although Ultra+ fluid is well represented by the data in both categories of precipitation, and the regression-generated lower holdover time for light freezing rain was determined to be 9 minutes. The value was rounded down to 5 minutes as a precaution due to the short absolute duration of this holdover time.

iv) Neat fluid, below -3 to -10°C, freezing drizzle and light freezing rain (Figure 6.13)

	96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra +	Hoechst
ZD	0:45-1:50	0:30-1:00	0:35-1:00	0:30-1:10	0:50-1:35	0:40-1:00
-ZR	0:30-0:55	0:30-0:45	0:30-0:45	0:30-0:55	0:30-0:50	0:30-0:50

The data for this range are shown in the plots on Figure 6.13. Differences between 1997/98 SAE and 1996/97 SAE holdover times are considerable, especially in the case of freezing drizzle. Both categories suffer reductions when compared to the current holdover time values. The figure indicates the data for individual fluid performance to be tightly grouped in this temperature range and more so in the light freezing rain category. The lower holdover time values for each fluid in light freezing rain are 30 minutes. Note that for freezing drizzle in this temperature range, the 1997/98 SAE fluid is identical to Octagon fluid for the lower holdover time and identical to Kilfrost and Hoechst fluids in the upper holdover time. Note that the regression-generated holdover time range for Kilfrost fluid in freezing drizzle was determined to be 43-65 minutes. These numbers were conservatively rounded to 35-60 minutes in light of the sparse data available for this fluid under these conditions.

FIGURE 6.12

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50 AT -3°C

FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1995/96 & 1996/97

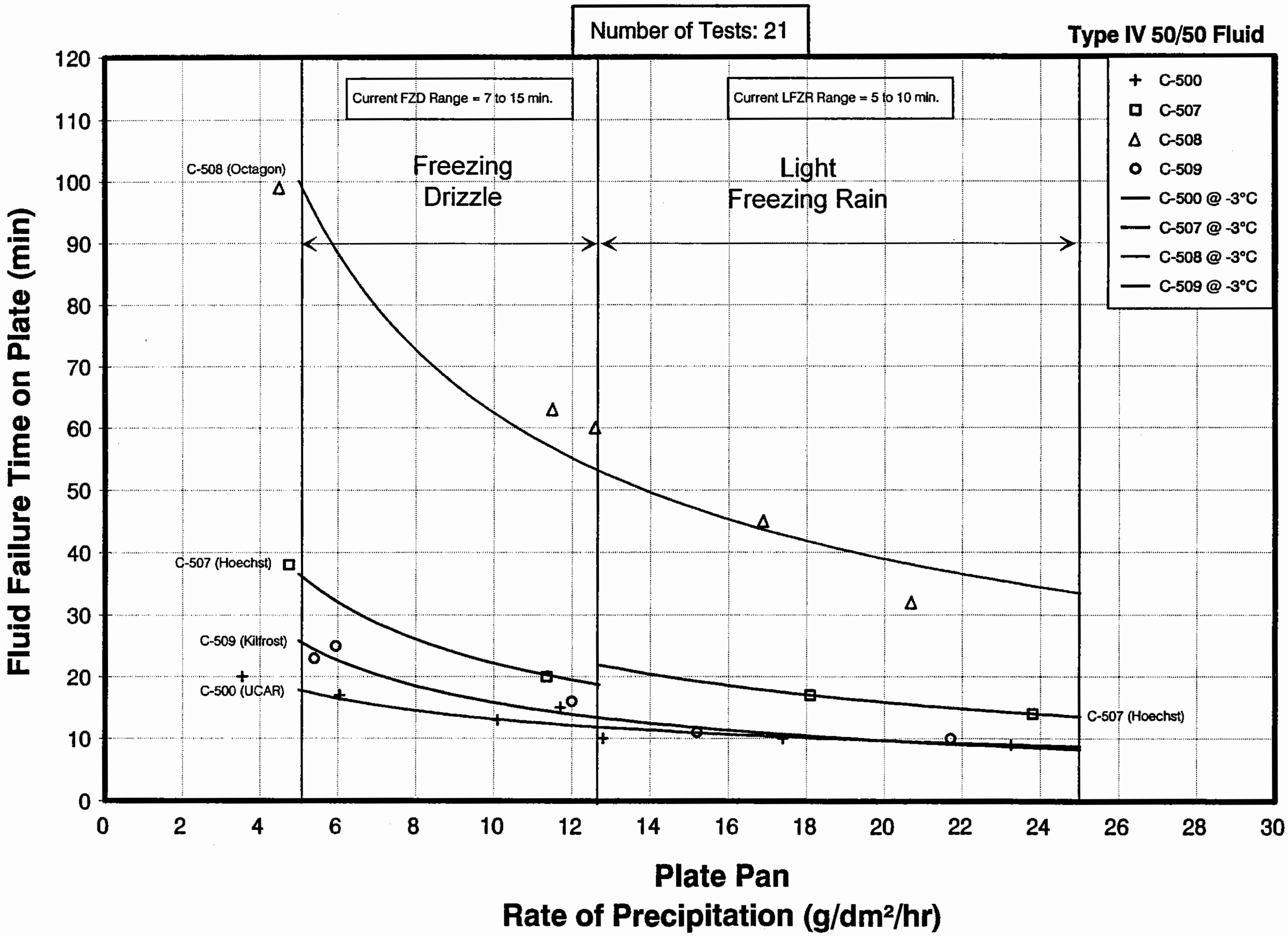


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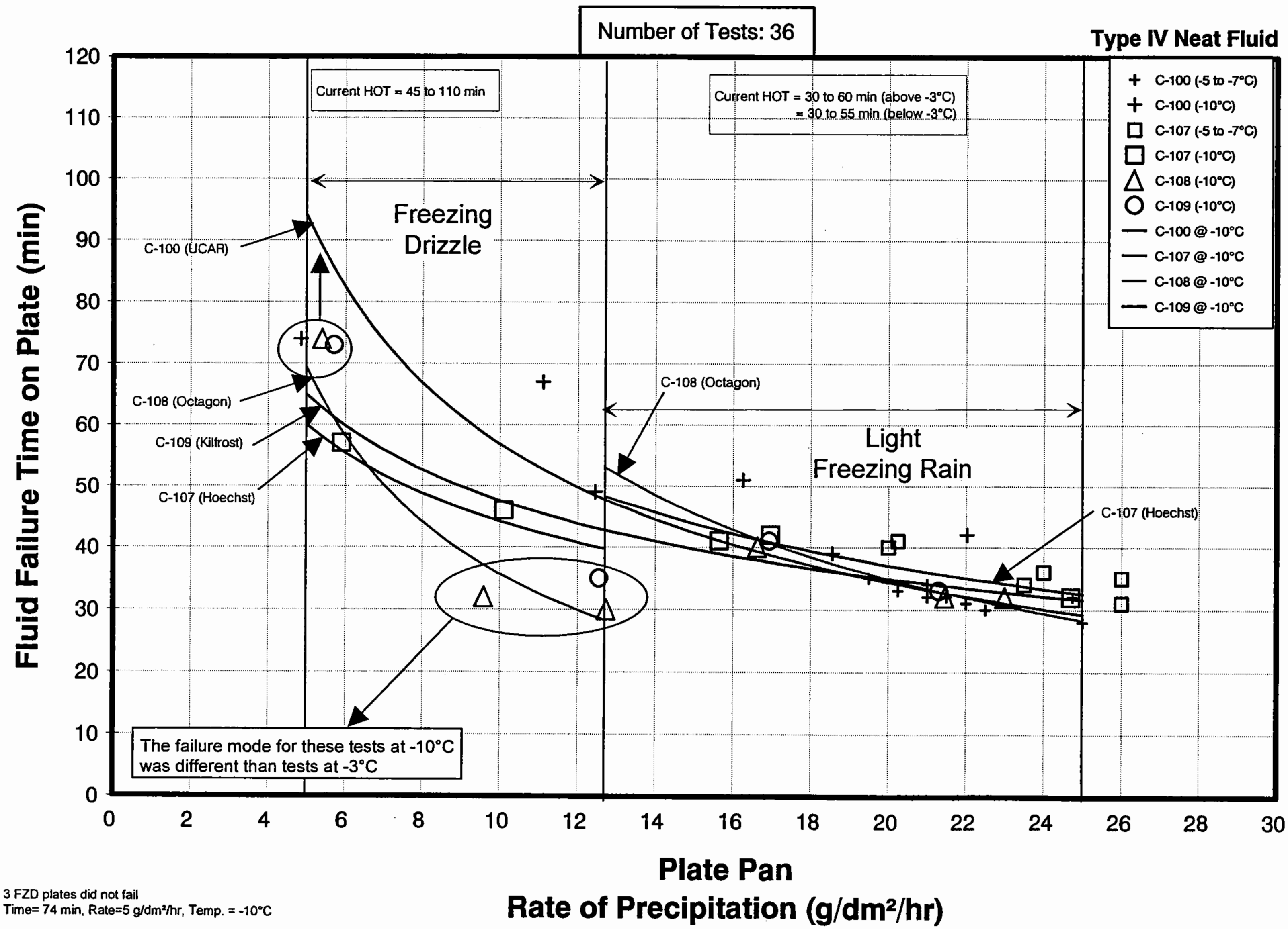
FIGURE 6.13

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT AT -10°C

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1995/96 & 1996/97



3 FZD plates did not fail
Time= 74 min, Rate=5 g/dm²/hr, Temp. = -10°C

cm1338/report/hot_subs\97ZR41R1.GRF

v) 75/25 fluid, below -3 to -10°C, freezing drizzle and light freezing rain (Figure 6.14)

	96/97 SAE	97/98 SAE	Kilfrost	Octagon	Ultra+	Hoechst
ZD	0:20-1:00	0:30-1:00	0:50-1:25	0:30-1:05	0:30-1:00	0:40-1:05
-ZR	0:10-0:25	0:15-0:30	0:35-0:50	0:25-0:35	0:15-0:30	0:25-0:40

The data for this range are shown in the plots on Figure 6.14. Differences between 1997/98 SAE and 1996/97 SAE holdover times are significant under these conditions and the differences are positive. Anomalous behaviour is noted for Kilfrost fluid when holdover times from Neat and 75/25 fluids are compared. The 75/25 Kilfrost fluid exhibit far superior performance in this temperature range than it does in its neat form. This is attributed to the neat fluid's failure mechanism at low temperatures. The Ultra+ fluid is identical to the 1997/98 SAE fluid in this temperature range.

6.1.2.2 Overall perspective on freezing drizzle and light freezing rain results

The plots in Figures 6.10 to 6.14 show that the largest disparities or discontinuities between freezing drizzle and light freezing rain data occur for the neat fluids. This is reflected in the discontinuities that appear at the precipitation rate limit of 12.7 g/dm²/hr separating the two categories. These disparities also appear in the case of 50/50 fluids, but the discontinuities are less pronounced. One possible reason is that under artificial precipitation conditions, the variation in droplet size and droplet density in the progression from drizzle to light rain is abrupt. Whether this occurs naturally is not known for certain, but is less likely than under simulated conditions. A larger data set for each fluid in each of the temperature ranges might shed some light on this situation. In the 75/25 dilutions, the data is more continuous from one category to the other, and the regression process does not indicate a need to perform separate treatments. It may be due to the absence of sufficient data for the fitting routine to indicate this. (The recommendations in Section 9 include a statement that the two categories should be studied and treated separately in future work.)

Differences in fluid formulations in relation to failure mechanisms at lower temperatures are manifested primarily in neat fluid behaviour. Consider that the Octagon and Kilfrost fluids tend to exhibit outstanding performance in tests conducted at higher temperatures. At lower temperatures, the property providing exceptional higher temperature performance seems to be hampering the low temperature performance. It was found during the process of testing that two behaviour extremes occur in the dilution mechanisms of these fluids. One extreme is exhibited by Ultra+ fluid, which tended to be diluted in a more homogeneous fashion through the fluid profile.

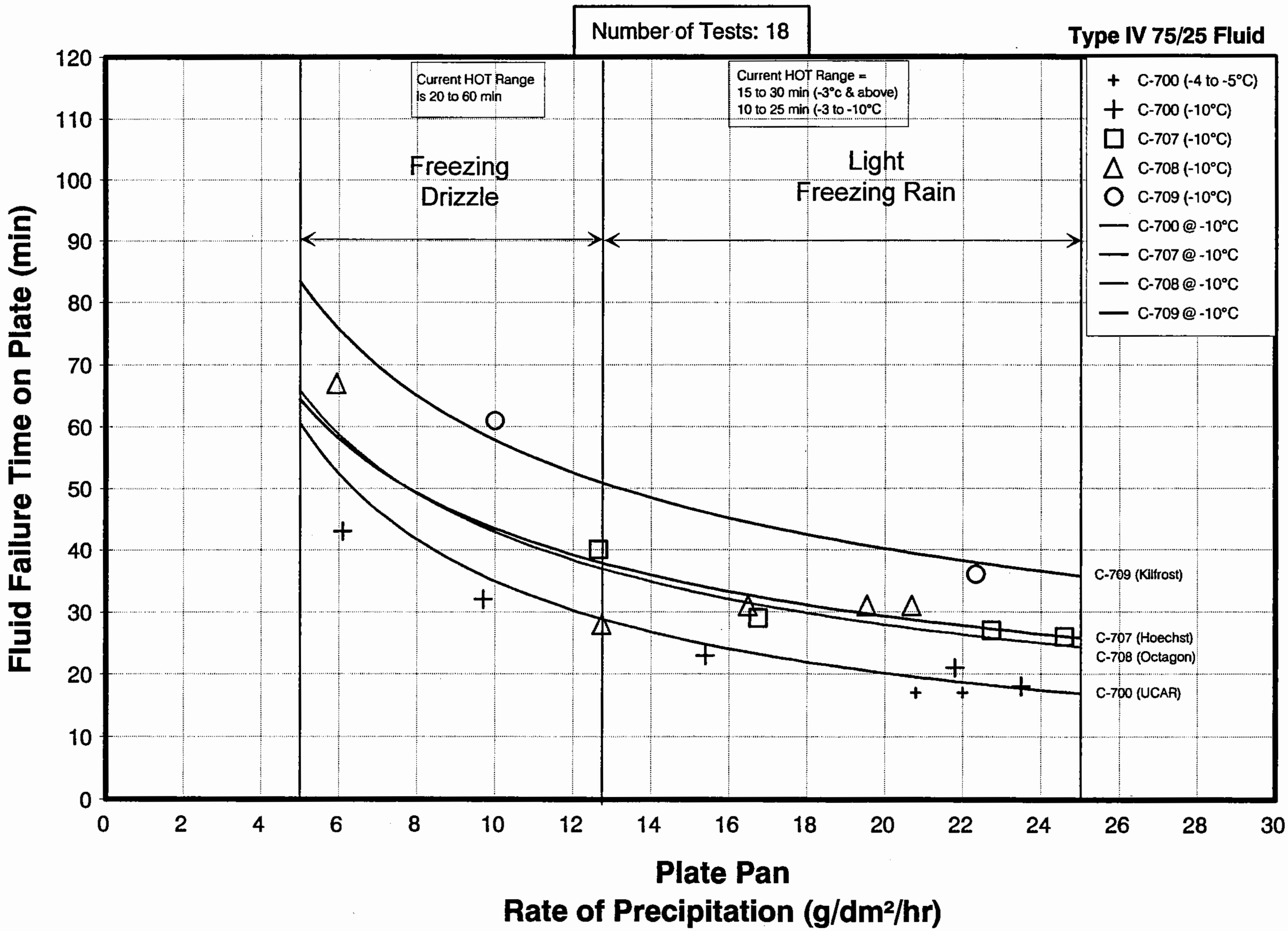
FIGURE 6.14

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25 AT -10°C

FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1995/96 & 1996/97



cm1338\report\hot_subs\97ZR47R1.grf

The other extreme is exhibited by the Octagon and Kilfrost fluids, which resisted dilution by maintaining the precipitation at the top of the fluid profile.

The diagram in Figure 6.15 helps to visualize this difference in behaviour during a freezing drizzle test at -10°C. The Ultra+ fluid failure mechanism is described as follows: initial exposure causes the fluid to absorb precipitation into its upper layers. This causes the fluid to swell. Continued dilution enhances the fluid's ability to flow. The diluted fluid runs off the surface, and its thickness is diminished until failure occurs. Typical failure is characterized by a thin layer of solidified precipitation. Kilfrost and Octagon fluids fail by accumulation of precipitation in the upper fluid layers. Although swelling initially occurs, these fluids resist dilution (especially at these lower temperatures). The upper layers can flow but *damming* of the failed surface layer occurs, trapping the failures in place. This situation is interpreted as a failure by an observer because the fluid has developed a layer of solid ice even though considerable *unfailed* fluid lies below the upper failed surface. This may be considered to be an extra measure of protection, but presents another potential difficulty in that the fluid so *failed* may not easily shear off the wing upon take-off. It might be worthwhile investigating this aspect of fluid behaviour in greater detail.

Another manifestation of what appears to be formulation-related anomalous behaviour is noted for Kilfrost 50/50 fluid at -3°C. At this concentration, the Kilfrost fluid integrity is severely compromised, a possible indication that the component responsible for some of this fluid's performance is rendered ineffective at a degree of dilution between the 75/25 and 50/50 concentrations.

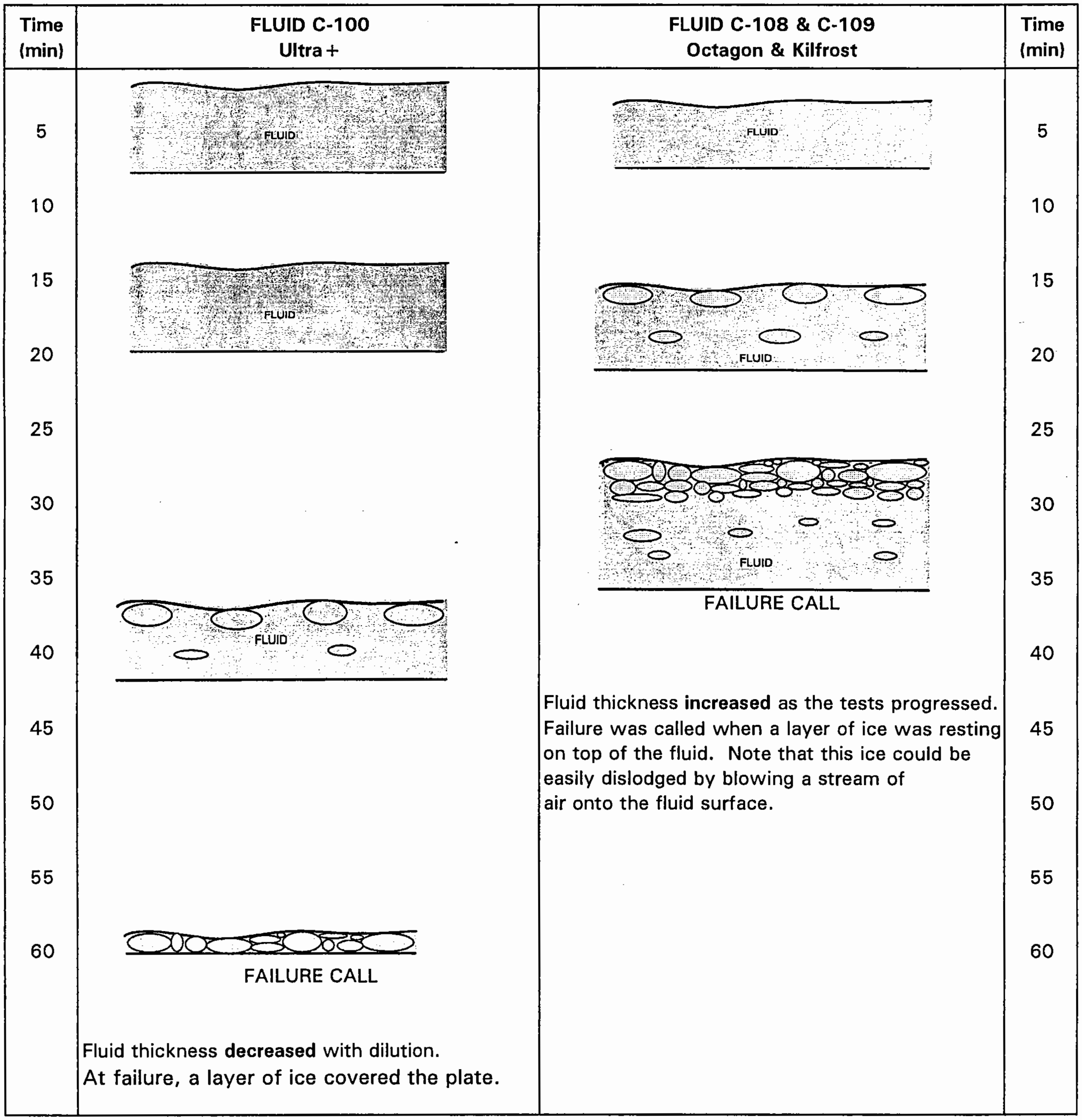
6.1.3 Freezing Fog

Freezing fog data originates from APS studies only. The freezing fog category is divided into nine cells. The data was collected under precipitation rates of 2 to 10 g/dm²/hr. From these data, lower holdover times for each cell were determined at 5 g/dm²/hr. The upper holdover times, which correspond to a lower precipitation rate limit of approximately 2 g/dm²/hr, were adopted from last year's holdover time tables, which are given in Section 1. The data from this year's work are presented in three figures, one at each of three dilutions. Figure 6.16 shows a plot of the fog data for all neat Type IV fluids. Figure 6.17 shows the data for 75/25 fluids, and Figure 6.18 shows the plots for the 50/50 fluids.

FIGURE 6.15

SCHEMATIC OF FAILURE MECHANISM

FREEZING DRIZZLE (-10°C)



g:\cm1338\report\hot_subs\Fail_sch

FIGURE 6.16

EFFECT OF FLUID BRAND AND TEMPERATURE ON FAILURE TIME

TYPE IV NEAT

SIMULATED FREEZING FOG

1996/97

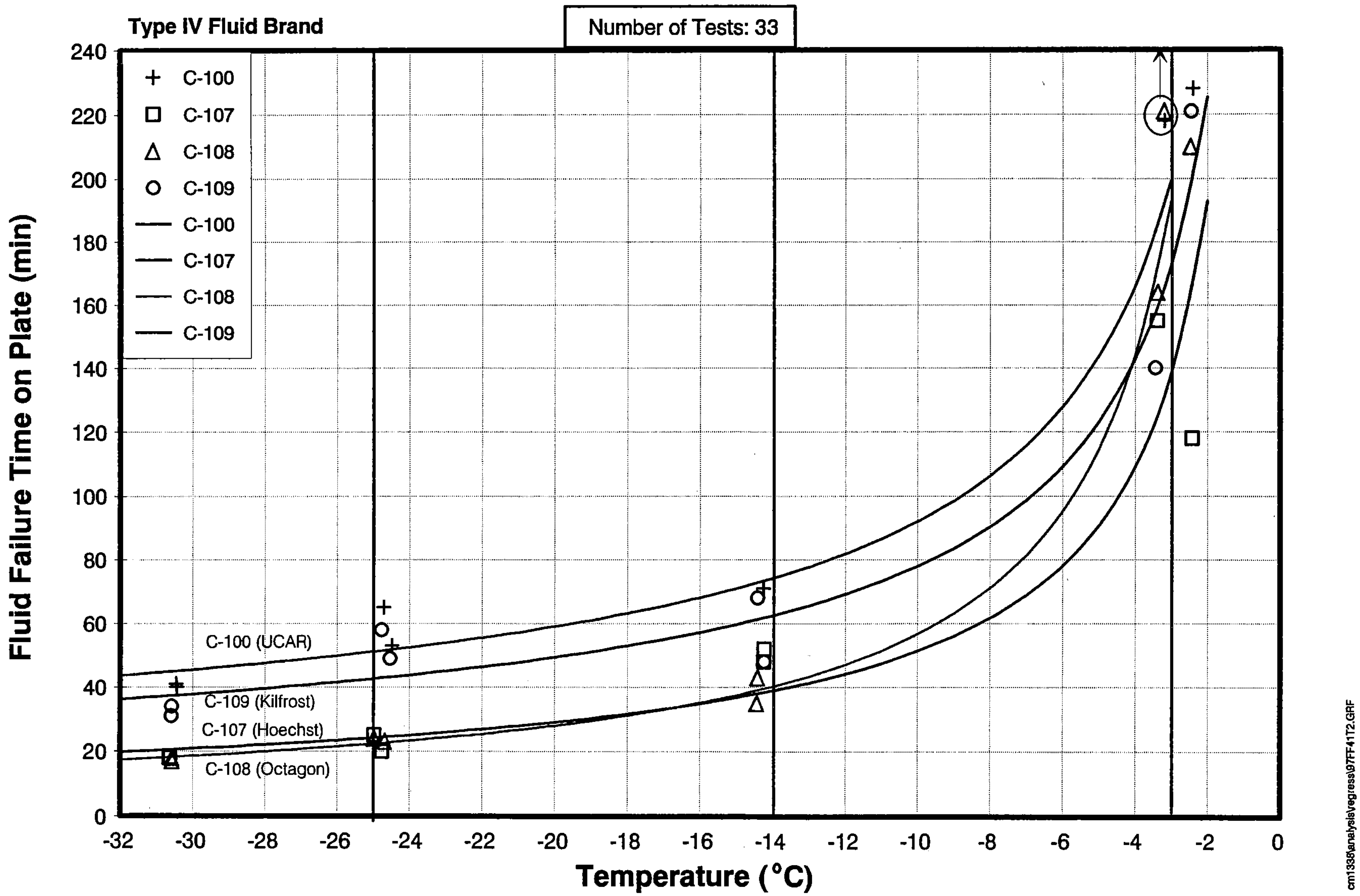


FIGURE 6.17

EFFECT OF FLUID BRAND AND TEMPERATURE ON FAILURE TIME

TYPE IV 75/25

SIMULATED FREEZING FOG

1996/97

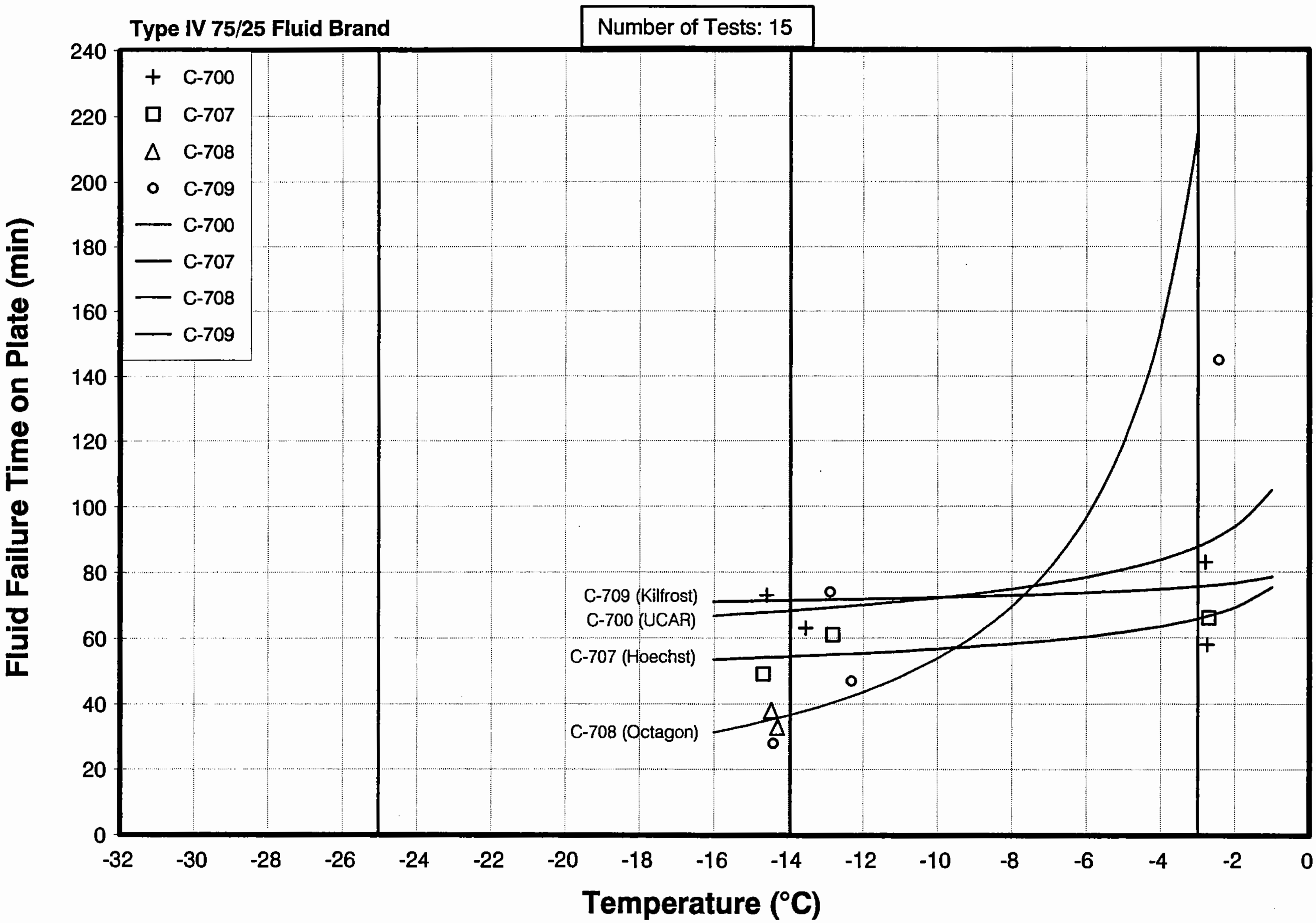


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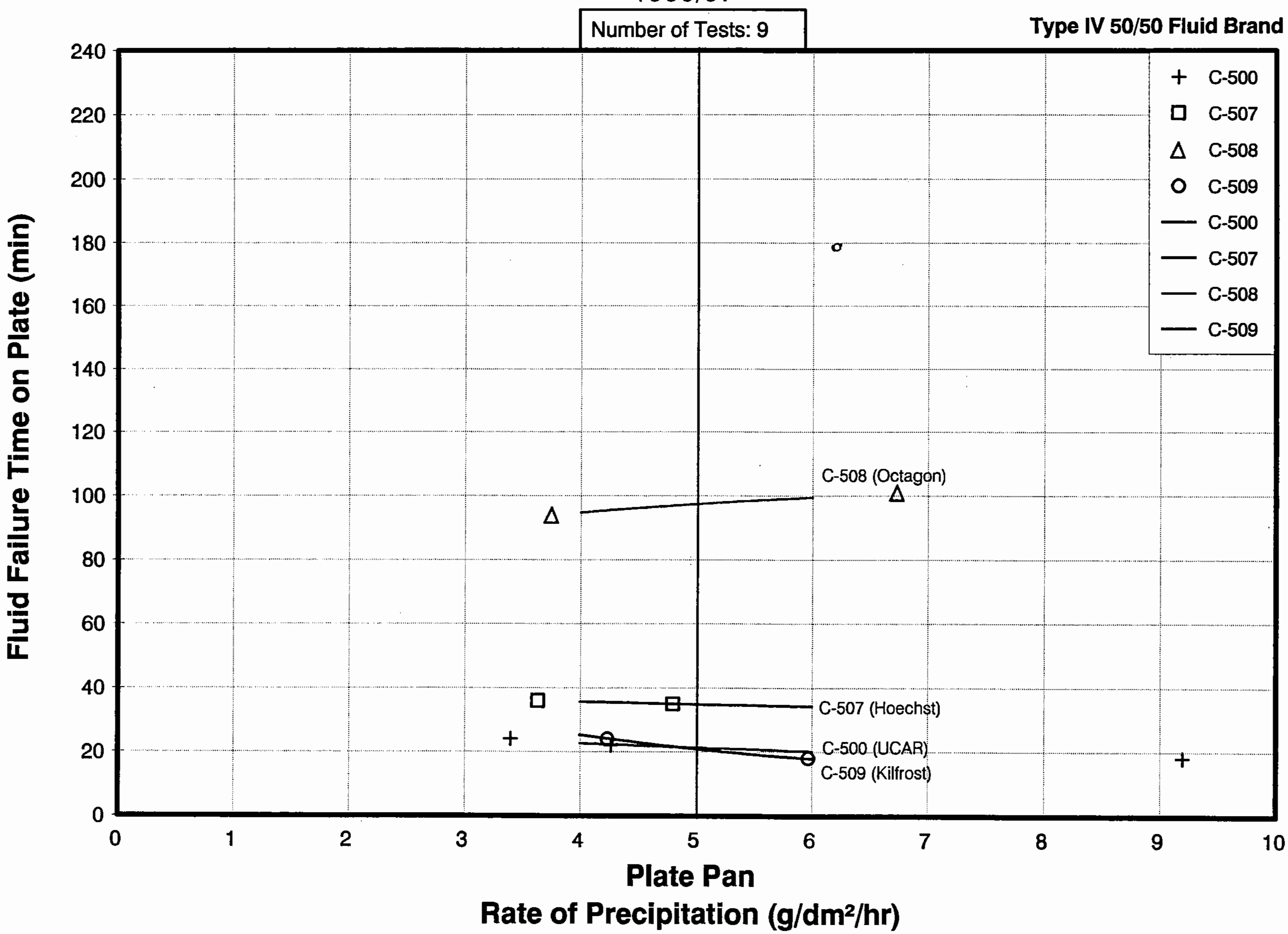
FIGURE 6.18

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50 AT -3C

SIMULATED FREEZING FOG

1996/97



cm1338\report\hot_subs\97FF45R.GRF

The plots in Figures 6.16 and 6.17 differ from the presentation format used for the categories already discussed in this section. The curves are plotted in the format of failure time versus temperature. This is due to the very narrow range of precipitation rates (centred around 5 g/dm²/hr) and the large temperature range over which the fog data was collected. The data represented in Figures 6.16 and 6.17, plotted as a function of precipitation rate, can be inspected in Appendix E, Pages E-8 to E-38.

The largest variation in the failure times recorded were due to temperature; therefore, the temperature was selected as the independent variable to plot failure times against. This is also confirmed by the regression analysis which indicated that precipitation rate was not significant for this data set. Failure times were measured at three different temperatures, -3, -14, and -25°C, which are demarcated as vertical lines on the figures. Due to the inability to produce freezing fog at temperatures approaching 0°C, the holdover times for the temperature range above 0°C are identical to those in the range from 0 to -3°C.

In the tests on neat fluids, some tests were also conducted at temperature below -30°C.

Recall that this category of precipitation is one for which *fluid-specific* values were not adopted by the SAE G-12 Holdover Time Subcommittee. Therefore, holdover times have been tabulated to read the same as the *worst case* (generic) holdover times.

6.1.3.1 Changes to Type IV fluid holdover times for freezing fog

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

i) Neat fluid, above 0°C and 0 to -3°C, freezing fog (Figure 6.16)

96/97 SAE	97/98 SAE
2:00-3:00	2:20-3:00

The 1997/98 SAE lower holdover time in the table is 2 hours and 20 minutes. The data for Hoechst fluid is driving the 1997/98 SAE holdover time. From Figure 6.16, the scatter at -3°C is wide. This suggests more tests are desirable.

ii) 75/25 fluid, above 0°C and 0 to -3°C, freezing fog (Figure 6.17)

96/97 SAE	97/98 SAE
0:40-2:00	1:05-2:00

Referring to Figure 6.17, the data driving the 1997/98 SAE lower holdover time value are for the Hoechst fluid. The regression line runs right through the data point at -3°C, and is positioned mid-way between the two points straddling -14°C. Although there are only three data points for this fluid, the confidence in the regression line is satisfactory.

iii) 50/50 fluid, above 0°C and 0 to -3°C, freezing fog (Figure 6.18)

96/97 SAE	97/98 SAE
0:15-0:4	0:20-0:45

The lowest holdover time for 50/50 fluids is driven by data for Ultra+ and Kilfrost fluids. Both regression lines run through the data points over the narrow precipitation rate range, and this lends a degree of confidence to the lower holdover time values. However, the need to collect more data at precipitation rates of 2 g/dm²/hr remains.

iv) Neat fluid, below -3 to -14°C, freezing fog (Figure 6.16)

96/97 SAE	97/98 SAE
2:00-3:00	0:40-3:00

The 1997/98 SAE lower limit holdover time at -14°C is 40 minutes. This represents an 80 minute decrease from the current lower limit holdover time. Two fluids drive the lower holdover time, Hoechst and Octagon. The regression lines for both fluids converge at about -17°C. There are two closely spaced Octagon data points one above and one below the regression line, boosting confidence in the lower holdover time. The need to collect more data particularly at 2 g/dm²/hr remains.

v) 75/25 fluid, below -3 to -14°C, freezing fog (Figure 6.17)

96/97 SAE	97/98 SAE
0:40-2:00	0:35-2:00

For Type IV 75/25 fluid at -14°C, the 1997/98 SAE fluid is Octagon. Two data points for this fluid straddle the lowest regression line in Figure 6.17. Because the times for this fluid are significantly below the other fluids, it may be useful to collect more data. The other data points lying close to this line are due to Kilfrost's fluid. The Kilfrost data, plotted as a function of precipitation rate, appear in the figure on Page E-37 of Appendix E. It shows three data points at -14°C covering the precipitation rate range of 4.8 to 8.9 g/dm²/hr. The point at 4.8 g/dm²/hr gives a fluid failure time of approximately 75 minutes; however, the other two points at 7.2 and

8.9 g/dm²/hr show failure times of 48 and 29 minutes, respectively. These two points are the small circles lying close to the Octagon fluid regression line in Figure 6.17. The lower holdover time values stem from the higher precipitation rates.

The Octagon fluid regression-generated line at -14°C is responsible for the 1997/98 SAE lower holdover time. This is evident in Figure 6.17. On Page E-36 of Appendix E, the Octagon fluid failure data is presented as a function of precipitation rate for two temperatures, -3°C and -14°C. The two -14°C data points straddle the 5 g/dm²/hr line, and the regression-generated curve crosses this line at 38 minutes. The value is rounded to the nearest 5 minute interval. The odd curvature of the Octagon line is due to the extreme variation in Octagon fluid performance as a function of temperature.

Figure 6.17 shows a sparsity of data at -3°C, and more data should be collected for all fluids at the higher temperature.

vi) Neat fluid, below -14 to -25°C, freezing fog (Figure 6.16)

96/97 SAE	97/98 SAE
1:00-2:00	0:20-2:00

At -25°C, Hoechst and Octagon fluids drive the lower holdover time of 20 minutes. The severe reduction in lower holdover time is ascribed to fluid differences and a more severe failure call at these temperatures. Under these test conditions, failures are difficult to call; to ensure a good safety margin, the most conservative lower holdover time was adopted for all fluids.

6.1.3.2 Overall perspective on freezing fog results

The upper holdover times were adopted from last year's SAE Type IV fluid table (Table 1.5, Section 1). The most recent Type IV fluids released by the manufacturers should be evaluated to determine upper holdover times at the lower end of the precipitation rate scale (2 g/dm²/hr). Comparison of the lower holdover times from both tables shows that:

- For the two highest temperature ranges, the values in this year's table have increased for all three fluid concentrations;
- For the -3 to -14°C range, the values in this year's table are reduced for both the neat and 75/25 dilutions; and
- For the -14 to -25°C range, there is a reduction in the lower holdover time in this year's table.

The differences in the lower holdover times are mostly due to differences between last year's and this year's fluids.

6.1.3.3 Determination of failure during freezing fog at cold temperatures

On March 24, 1997, simulated freezing fog holdover time tests were performed at the Climatic Engineering Facility. The purpose of these tests was to help eliminate inconsistencies in calling failure during freezing fog conditions at extremely cold temperatures. Representatives from APS Aviation, Transport Canada, Université du Québec à Chicoutimi, RVSI and the National Research Council were present for these tests.

APS Aviation's method of calling failures in freezing fog conditions below -25°C is shown in Photo 6.1 at the end of Section 6 of this report. Failures were called when areas consisting of ***hardened slush*** were present on the test surface. A loss of fluid gloss could be noted in the failed areas (recall the dilution of failure in Subsection 2.5). The dark shadows on the plate in the photograph represent the failed areas.

Another item to consider is that during tests conducted in freezing fog at these low temperatures, it was observed that when a stream of air was directed onto test surfaces coated with the apparently failed fluids (which by this time, possessed the consistency of a thick slush), the fluid mass could be easily moved by the stream. This suggests that the fluid does not adhere to the surface in this apparently failed state.

For the past several years, both AlliedSignals' C/FIMS surface ice detection sensors and RVSI's ice detection video system have been tested by APS to evaluate the performance of these units and, to complement flat plate and full-scale test data. Details and descriptions of these instruments appear in the 1994/95 winter holdover time report, TP 12654E (4). Figure 6.19 shows the C/FIMS sensor trace of the experiment depicted in Photo 6.2. The trace shows a slight discontinuity at about 12:13, at which point APS observers noted a thin layer of mobile freezing slush forming on the surface of the fluid, but not a sufficient accumulation to call a failure.

Photo 6.2 shows the bright (B) and dim (D) video graphs of RVSI's ice detection system from the same freezing fog experiment. The light response from several pixels, selected to cover an area just beside the C/FIMS sensor (on the central plate to the left of the observer in the videograph), was isolated from the video record. The signal outputs for these pixels in each videograph (B and D) as a function of time (response curves) are shown in Figure 6.20. The thin trace resulted from the response of the bright channel

FIGURE 6.19

C/FIMS SENSOR TRACE

SIMULATED FREEZING FOG

OCTAGON TYPE IV NEAT

March 24, 1997, Form 1, Plate V - T = -29°C

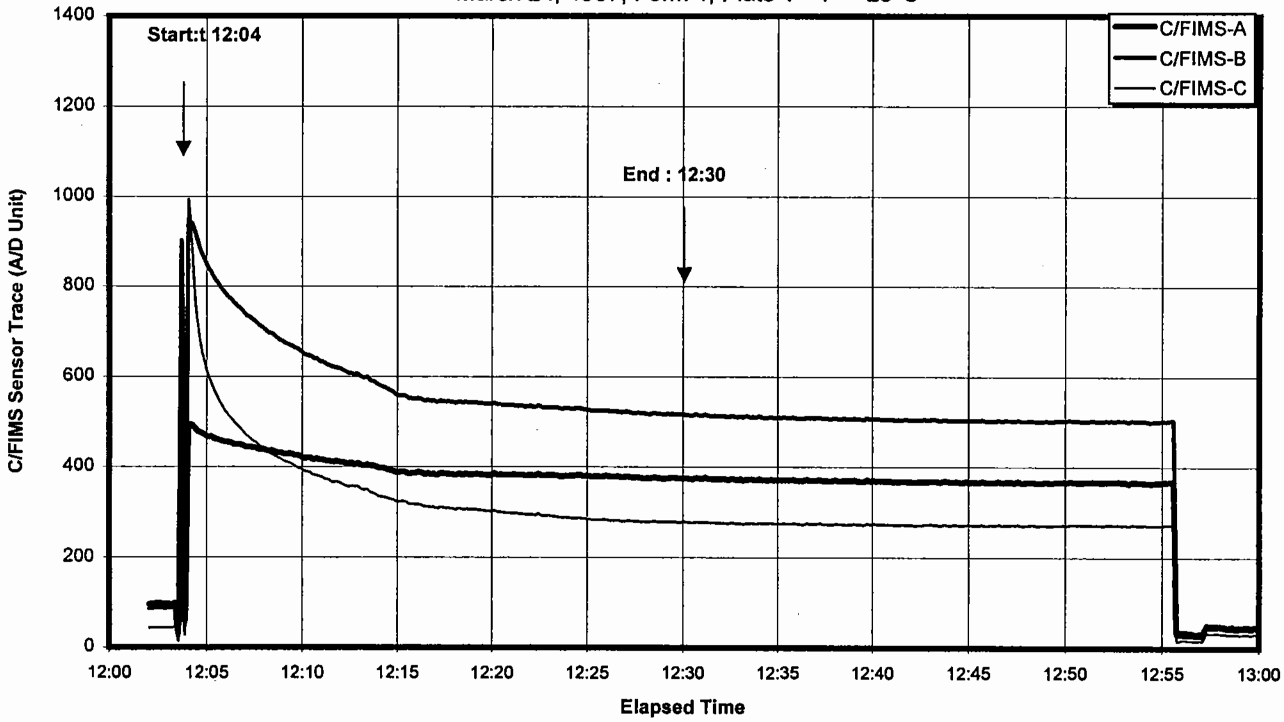


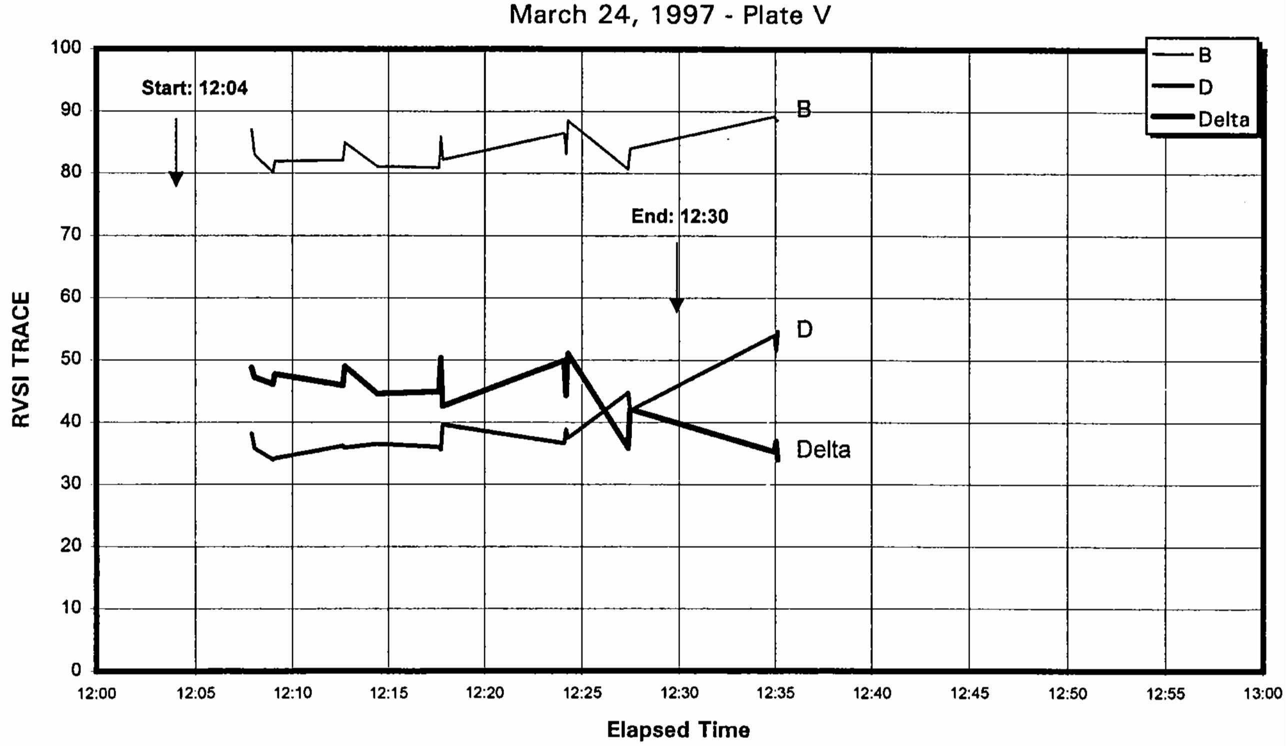
FIGURE 6.20

RVSI ICE SENSOR TRACE

SIMULATED FREEZING FOG

OCTAGON TYPE IV NEAT

March 24, 1997 - Plate V



and the medium thickness trace resulted from the response of the dim channel. The thickest trace in Figure 6.20 represents the difference between the two channels (delta). When this trace proceeds in the lower direction, it is due to a relative difference in response of the bright and dim channels. In Figure 6.20, aside from noise and several glitches in the response curve (possibly due to an observer crossing the camera's optical path), a steady downward trend is noted in the difference curve at about 12:27.

This corresponds to the visual failure call made by APS during the experiment. The C/FIMS trace shows hardly, if any, response at this time.

It was determined following discussion that APS Aviation's current method of calling failures under these conditions would be upheld. It should also be noted that failure mechanisms changed at different temperatures. Furthermore, different brands of fluid exhibited different modes of failure. To assist in the determination of failure, samples of the fluid should be taken.

6.1.4 Rain on a Cold-Soaked Wing (ROCSW)

The data used to evaluate the holdover times for this category of precipitation covered precipitation rates ranging from 5 g/dm²/hr to 76 g/dm²/hr. This encompasses heavy drizzle (5 to 12.7 g/dm²/hr), light rain (12.7 to 25 g/dm²/hr), and moderate rain (25 to 76 g/dm²/hr). The cold-soaked test boxes were of various depths. Dimensional details are described in Section 2. Recall that for the generation of regression curves, a cold-soaked box depth of 7.5 cm and a temperature of -7°C was used in the regression equation. Initial box temperatures of -10°C were employed during the testing unless otherwise specified.

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. Therefore all individual fluid holdover times are equal to 1997/98 SAE holdover times and have not been included.

6.1.4.1 Changes to Type IV fluid HOTs for rain on a cold-soaked wing

i) Neat fluid, above 0°C, rain on a cold-soaked wing (Figure 6.21)

96/97 SAE	97/98 SAE
0:20-0:40	0:10-0:50

The regression curves generated from the neat fluid data plotted in Figure 6.21 suggest the fluid driving the lower 1997/98 SAE holdover time (at 76 g/dm²/hr) is Kilfrost. The Kilfrost data for this fluid concentration is sparse. The tight grouping and convergence of the regression lines for all fluids at this precipitation rate, however, lends confidence to the holdover time value adopted for use in the tables. The upper 1997/98 SAE holdover time is seen to driven by the Octagon regression curve. The Octagon curve intersects the 5 g/dm²/hr precipitation rate limit at 50 minutes. Note that there is a ten minute reduction in lower holdover time from the 1996/97 SAE value to the 1997/98 SAE fluid value. This is due to the upper precipitation rate limit being extended to 76 g/dm²/hr (includes moderate rain).

ii) 75/25 fluid, above 0°C, rain on a cold-soaked wing (Figure 6.22)

96/97 SAE	97/98 SAE
0:10-0:25	0:05-0:35

For this concentration, the regression curves obtained from the data plotted in Figure 6.22 are tightly grouped at the 76 g/dm²/hr precipitation rate limit. The exception to this grouping is exhibited by the Kilfrost fluid for which the data is again sparse. The lower 1997/98 SAE holdover time is driven by the Hoechst regression curve. The upper 1997/98 SAE holdover time is driven by the Kilfrost regression curve which intersects the 5 g/dm²/hr at about 35 minutes. There is a five minute reduction in lower holdover time from the 1996/97 SAE value to the 1997/98 SAE fluid value. This is due to the extension of the precipitation rate range to 76 g/dm²/hr.

6.1.4.2 Overall perspective on a cold-soaked wing results

The data plotted in both Figures 6.21 and 6.22 show a tight grouping of regression curves at the upper precipitation rate range, and provide confidence particularly for the lower holdover time values adopted in each cell of this category. The situation is not so clear cut for the upper holdover times, particularly for the neat fluids. Considerable variation exists in the data in the vicinity of this precipitation rate limit and is the major factor driving the need for additional tests.

FIGURE 6.21

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT

RAIN ON COLD-SOAKED SURFACE
1995/96 & 1996/97

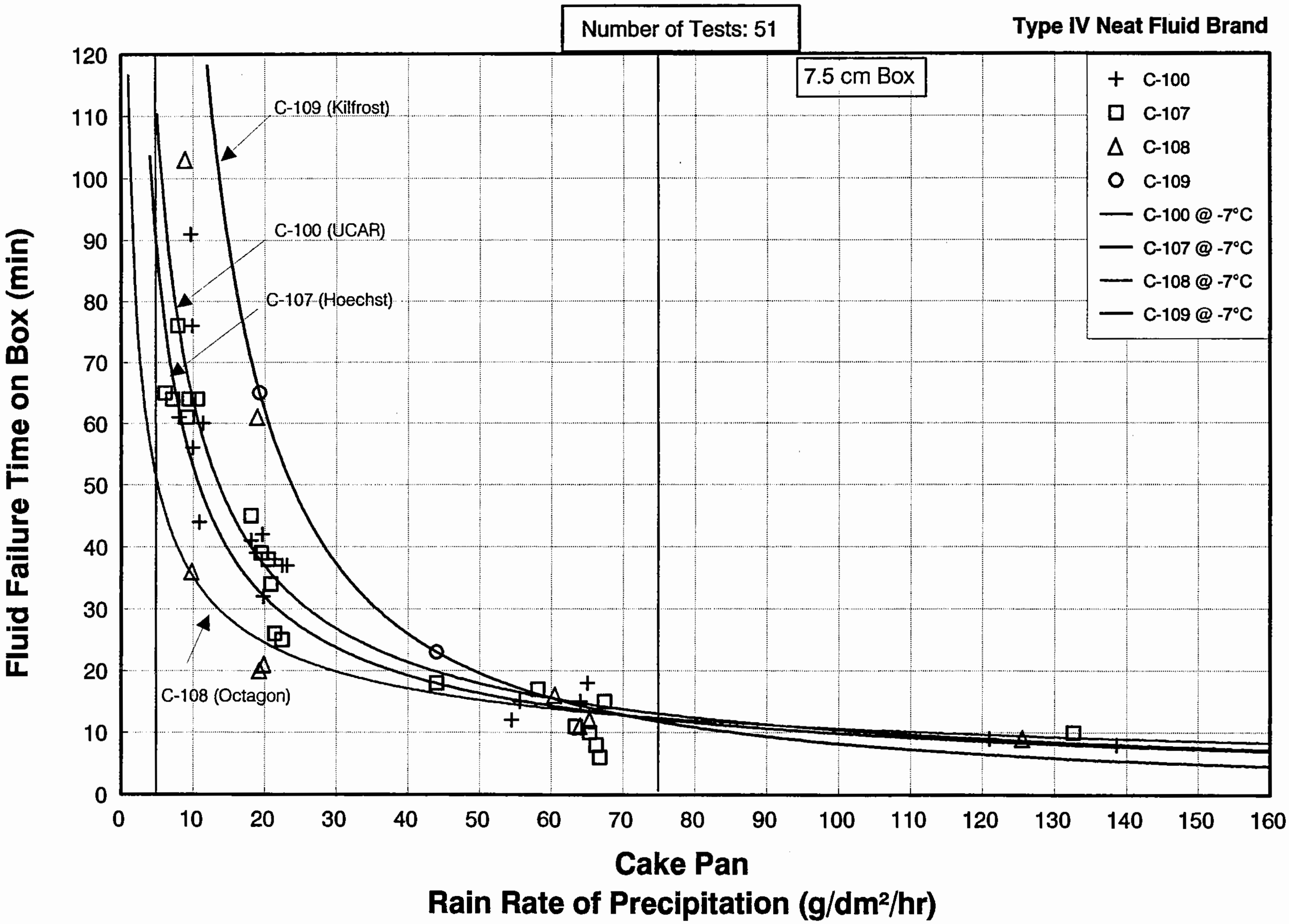


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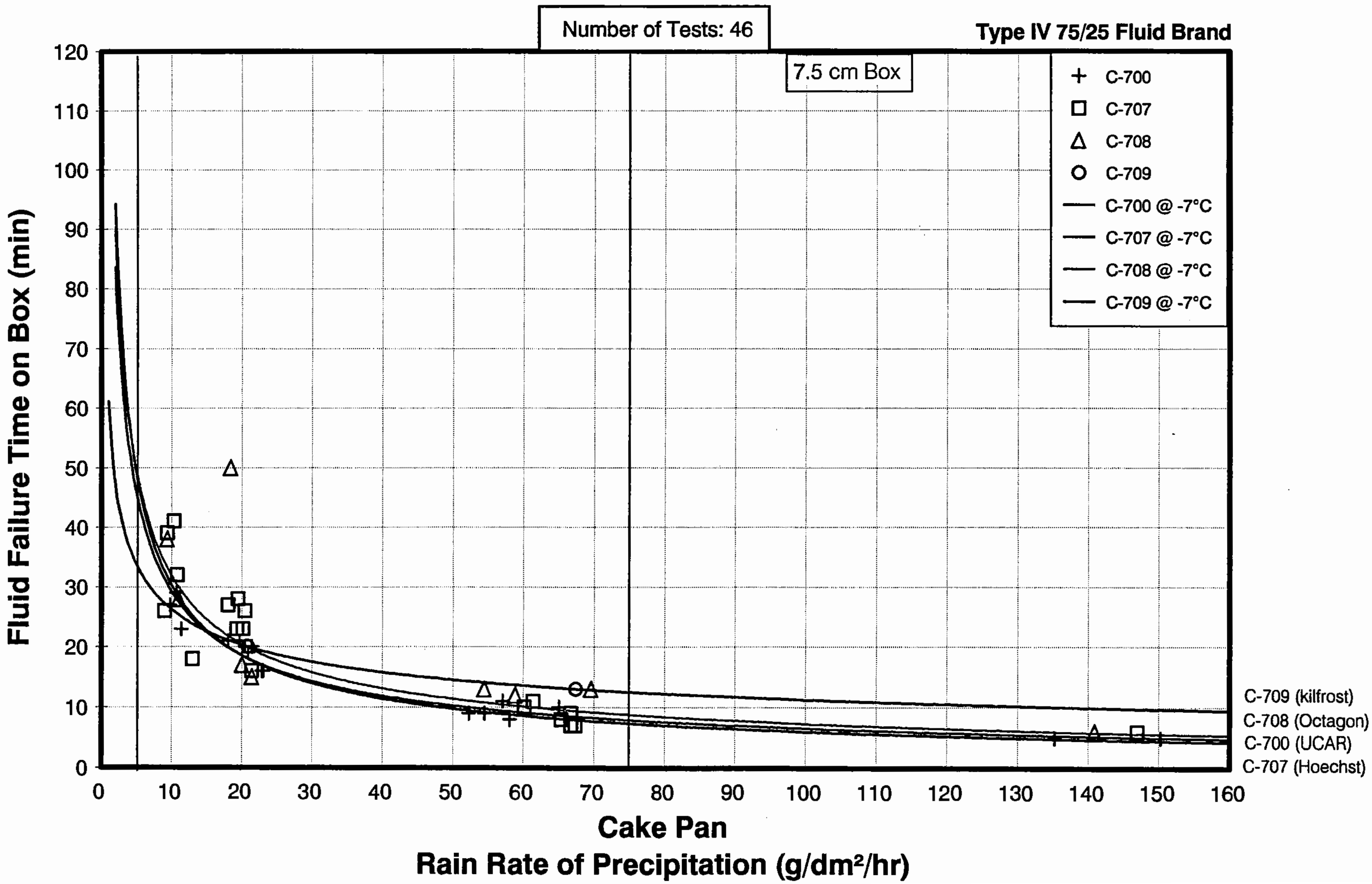
FIGURE 6.22

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25

RAIN ON COLD-SOAKED SURFACE

1995/96 & 1996/97



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6.1.5 Overall Perspective of Type IV Fluid Performance Characteristics

This section contains tables and comments on differences and similarities in performance of the Type IV fluids for the three categories of precipitation affected by *fluid-specific* considerations: snow, freezing drizzle and light freezing rain. A ranking scheme was developed based on *fluid-specific* holdover time ranges and applied to grade the overall performance of the four Type IV fluid brands relative to one another.

i) Snow

The results of the overall ranking for the snow category gave two of the four fluids high marks. The two groups were separated by a wide difference in rank. In Table 6.1, the fluids are ranked by cell. It shows performance trends as a function of temperature in the vertical sense and as a function of concentration in the horizontal sense. In each cell, the best to worst fluid brand performance is listed from top to bottom. In the case where two fluids were ranked the same, they appear next to one another. Each fluid is designated by an initial: Octagon's Maxflight fluid = O, Kilfrost's ABC-S fluid = K, Union Carbide's Ultra+ fluid = U, and Hoechst's MPIV 1957 fluid = H.

In the column for neat fluids, from top to bottom of the temperature range: two of the four fluids perform best, except at the lowest temperature range where the performance of one of those fluids slips a notch; the performance of one fluid increases relative to the other fluids as the temperature decreases; and one other fluid exhibits the poorest performance over the entire temperature range.

At higher temperatures and concentrations, both Octagon and Kilfrost fluids are the top performing fluids. Octagon fluid maintains its performance relative to the other fluids as concentration is reduced. However, Kilfrost fluid integrity is diminished at a concentration somewhere between the 75/25 and 50/50 dilutions. These observations are consistent with the results of fluid thickness tests presented in Section 4.

It is possible that the fluid component responsible for maintaining the Kilfrost fluid integrity at low temperatures is the same factor responsible for its lowered performance at the lowest (50/50) concentration. The converse can be said for the Octagon fluid, which retains its high performance at the lowest concentration but loses performance at the lowest temperatures.

TABLE 6.1
RANKING OF HOLDOVER TIMES OF TYPE IV FLUIDS BY CELL (SNOW)

TEMP/CONC	NEAT	75/25	50/50
Above 0°C	O	O	O
	K	K, H	H
	H, U	U	K, U
0 to -3°C	K	O	O
	O	K	H
	U	H	K, U
	H	U	
-3 to -14°C	K	K	
	O, U	O	
	H	H, U	
-14 to -25°C	K		
	U		
	O		
	H		

Note: K = Kilfrost
U = Union Carbide
O = Octagon
H = Hoechst

Best performer is on top; worst is on bottom.

In the two higher temperature ranges, the Hoechst fluid performance increases relative to the other fluids as its concentration is reduced.

ii) Freezing drizzle

The results of the overall ranking yielded the same order of fluid performance as that for snow; however, the grouping was different.

The temperature and concentration dependent extension to the overall performance ranking in freezing drizzle is tabulated in Table 6.2, which is arranged in the same way as is Table 6.1. Note that only two temperature ranges are presented. These ranges correspond to those for which distinct holdover times appear in the tables.

Union Carbide Ultra+ fluid is seen to exhibit its best performance in the neat fluid column. At the lower temperature range, it outperforms all fluids. Upon dilution, its relative performance drops.

Neat Kilfrost fluid performance (top rank at the higher temperature range) is reduced relative to the other fluids in the lower temperature range. At higher temperatures, it drops steadily in relative performance as it is diluted, but this behaviour is reversed at lower temperatures.

Neat Octagon fluid does not fare as well and also suffers a relative performance decrease in the lower temperature range. In the 75/25 column, its performance is seen to be reduced at lower temperatures relative to the other fluids. The performance of 50/50 Octagon fluid is superior to the other fluids.

Hoechst fluid performance at higher temperatures is enhanced relative to the other fluids as it is diluted, but at lower temperatures, its relative performance upon dilution remains constant.

It is interesting to note that in the freezing drizzle category of the holdover time tables, Octagon fluid exhibits longer upper and lower holdover times in its 75/25 dilution (at above -3°C) than it does in its neat form. The same is true for the upper holdover time for Hoechst fluid. These are due to the physical properties of each fluid coupling with the particular test conditions to exhibit more desirable performance properties in the diluted state.

TABLE 6.2
RANKING OF HOLDOVER TIMES OF TYPE IV FLUIDS BY CELL (FREEZING DRIZZLE)

TEMP/CONC	NEAT	75/25	50/50
Above 0°C, and 0 to -3°C	K	O	O
	U	K	H
	O	H	K
	H	U	U
-3 to -10°C	U	K	
	H	H	
	K	O	
	O	U	

TABLE 6.3
RANKING OF HOLDOVER TIMES OF TYPE IV FLUIDS BY CELL (LIGHT FREEZING RAIN)

TEMP/CONC	NEAT	75/25	50/50
Above 0°C, and 0 to -3°C	K	O	O
	O	K	H
	H	H	K
	U	U	U
-3 to -10°C	O	K	
	U, H	H	
	K	O	
		U	

Note: K = Kilfrost
U = Union Carbide
O = Octagon
H = Hoechst

Best performer is on top; worst is on bottom.

iii) Light freezing rain

The temperature and concentration-dependent extension to the overall performance ranking in light freezing rain is given in Table 6.3.

Neat Kilfrost fluid relative performance is observed to go from best to worst as one proceeds from the upper to the lower temperature range. This fluid also exhibits a steady drop in relative performance upon each successive dilution at higher temperatures. At low temperatures, its relative performance upon dilution goes from worst to best.

Octagon fluid performance improves relative to the other fluids upon dilution at higher temperatures, but decreases upon dilution at lower temperatures.

Figure 6.13 shows that in freezing rain conditions, the data for all neat fluid brands at the colder temperatures tend to converge onto a common performance curve within the limits of experimental error.

iv) Comparison of elements in freezing drizzle and light freezing rain

This exercise points out the differences and similarities between Tables 6.2 and 6.3, as they represent the relative results of two categories of similar precipitation whose holdover times were determined simultaneously by the regression procedure developed.

- The ranking of neat Union Carbide Ultra+ fluid performance varies considerably from freezing drizzle to light freezing rain.
- Kilfrost fluid performance is almost the same for both types of precipitation.
- The largest similarities to note are for the two diluted fluid columns (75/25 and 50/50) which are identical in each of Tables 6.2 and 6.3.

6.2 Type III Fluid Holdover Time Tests

Union Carbide's Type III fluid is a thickened anti-icing fluid that exhibits shear, flow, and anti-icing properties that lie between 75/25 and 50/50 Ultra+ fluids. This fluid was specifically designed for use on aircraft with lower rotation speeds like the DeHavilland Dash 8. At the time of writing this report, Union Carbide issued a warning which stated that diluted forms of Ultra+ fluid are not recommended for operational use due to performance deficiencies noted in qualifying tests.

The earliest holdover time tests were carried out during the 1991/92 test season primarily with Union Carbide 250-3 fluid (see Transport Canada report, TP 11454E (5). The next series of Type III fluid tests are documented in Transport Canada report TP 11836E (6) (Appendix G). This data is somewhat obsolete as the Union Carbide 250-3 fluid 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 last year's holdover time report (Transport Canada report, TP 12896E) and is presented as Table 1.4 in Section 1 of this report. Note that all cells in Table 1.4 bear the not substantiated (NS) designation.

The latest Type III fluid test data were acquired during the 1996/97 test season using Union Carbide's 67/33 Ultra+ Type IV fluid. 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 times are presented in Table 6.6 in Subsection 6.5. The values appearing in this table have been rounded to the nearest five minute time interval as they were in the Type IV fluid holdover time tables.

The Type III fluid holdover table was developed for temperatures extending down to -14°C. The table can be used below -14°C only so long as the aerodynamic acceptance criteria and 7°C buffer are respected.

6.2.1 Natural Snow

The snow data originated from tests performed outdoors at the APS Dorval test site. These data, plotted in failure time versus precipitation rate format, are presented in Figure 6.23. The data for all temperature ranges appear in the figure as do the regression curves generated for each temperature from the fitting procedure. Recall that the curves are produced using the most restrictive temperature in each of the ranges.

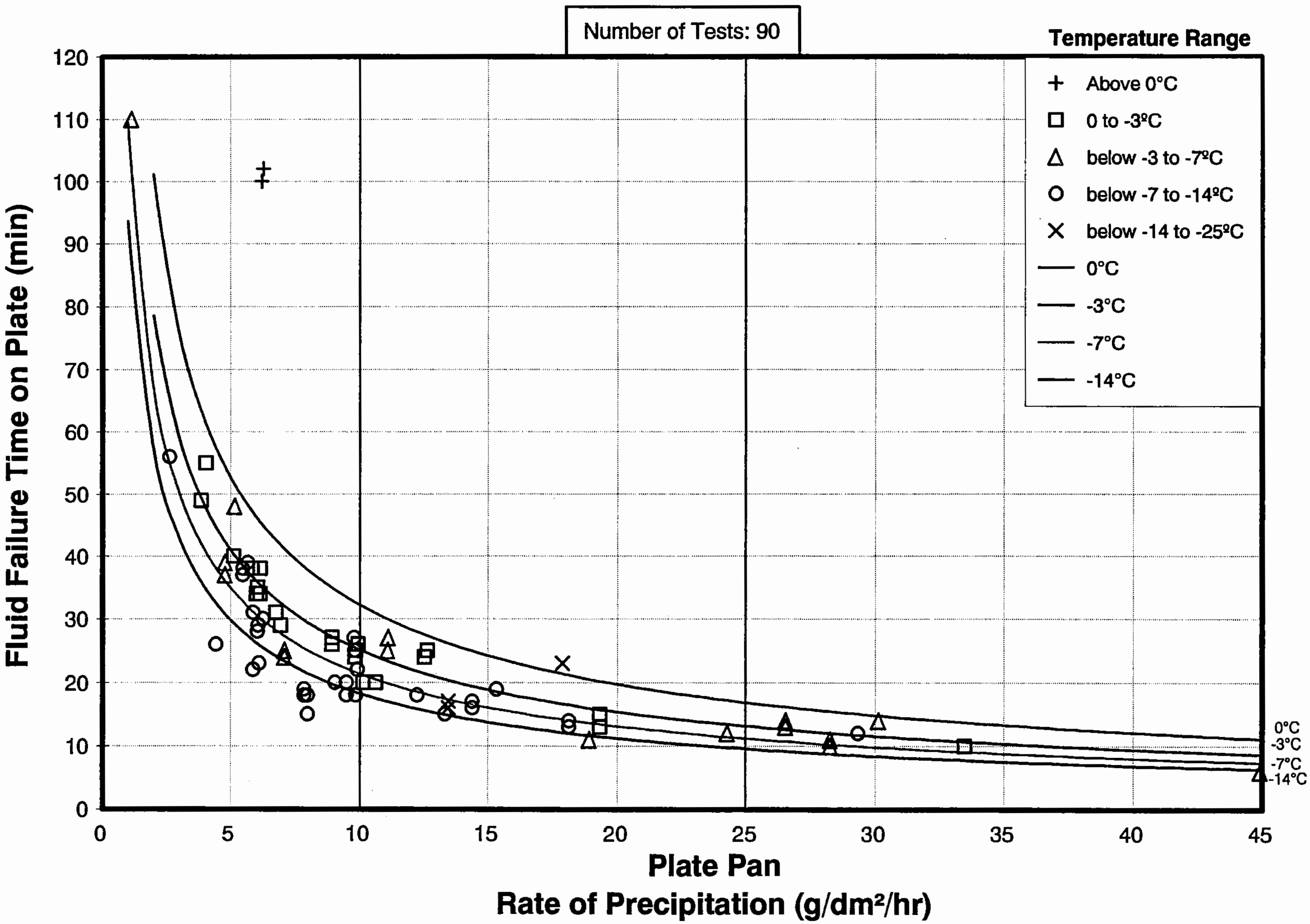
FIGURE 6.23

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE III

NATURAL SNOW CONDITIONS

1996/97



Holdover times were evaluated at the 10 and 25 g/dm²/hr precipitation rate limits which are demarcated by vertical lines in Figure 6.23. These limits were defined in Subsection 5.3 and are the same limits used to evaluate holdover times for Type IV fluids in snow. The snow holdover times for Type III fluids are as follows:

i)	above 0°C	00:15 - 00:30
ii)	0 to -3°C	00:15 - 00:25
iii)	below -3 to -14°C	00:10 - 00:20

The first noteworthy observation to be made is the tight grouping of the regression curves as a function of temperature. This is a property of the Ultra+ fluid in general, as can be seen by inspection of the figures on Pages F-16, F-17, and F-18 in Appendix F (for the Neat, 75/25, and 50/50 Type IV Ultra+ fluids, respectively). Also note that the Type III fluid family of regression curves lies between those of the 75/25 and 50/50 Ultra+ fluid curve sets, demonstrating a consistent and very predictable behaviour pattern for this brand of fluid.

The second observation worthy of mention relates to the holdover times of the new Type III table as compared to those from the previously proposed Type III table (Table 1.4). All upper holdover times are considerably reduced in the new table. The previously proposed upper holdover times for Type III fluids were not based on a significant body of data and were arrived at more intuitively in light of previous Type II and Type IV upper holdover time values. More importantly, the lower holdover times are identical in both tables except for the value at the lowest temperature range, which has been reduced by five minutes.

6.2.2 Freezing Drizzle and Light Freezing Rain

The data for freezing drizzle and light freezing rain were obtained from tests performed by APS and conducted indoors at the Climatic Engineering Facility of the National Research Council in Ottawa. These data, presented in failure time versus precipitation rate format, are shown in Figure 6.24. The data for both temperature ranges appear in the figure as does the regression curve generated from the fitting procedure. The figure shows that only one curve was generated from all the data. Recall that data could not be produced for these categories of precipitation above 0°C, and the data at the two lower temperature ranges were not sufficiently separated to generate two separate curves.

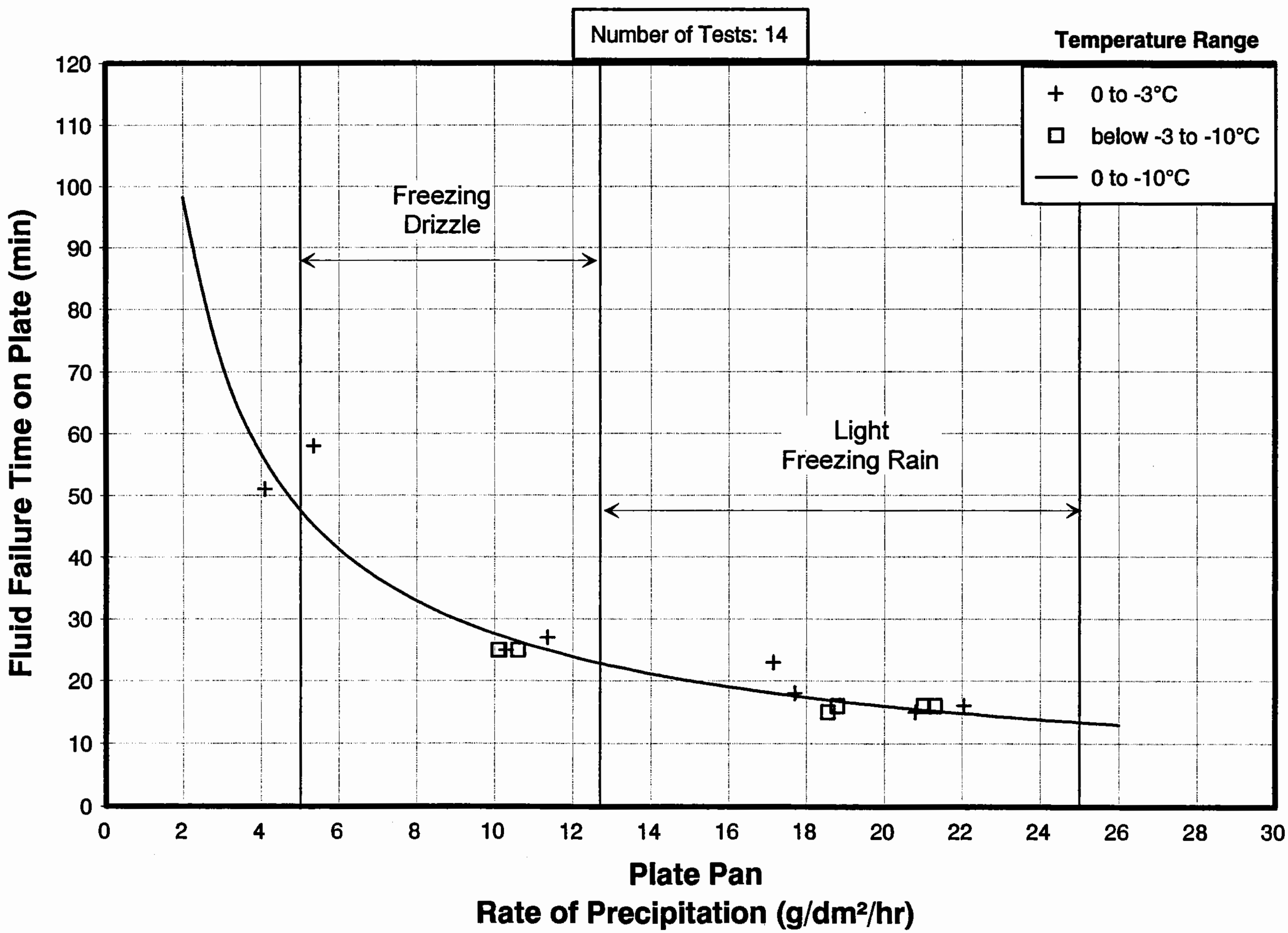
FIGURE 6.24

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE III

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1996/97



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Comparison of the curve generated from these data with those for the 75/25 and 50/50 Type IV Ultra+ fluid (presented in Appendix F, Pages F-10 and F-15, respectively) shows the Type III fluid performance to be consistent with the diluted Type IV Ultra+ fluids. This comparison again illustrates the predictable performance character of the Ultra+ fluid as a function of concentration. The holdover times are tabulated below. The numbers have been rounded from the values determined from the regression analysis to the nearest 5 minute interval.

Temperature	ZD	-ZR
i) above 0°C	00:25 - 00:50	00:15 - 00:25
ii) 0 to -3°C	00:25 - 00:50	00:15 - 00:25
iii) below -3 to -10°C	00:25 - 00:50	00:15 - 00:25

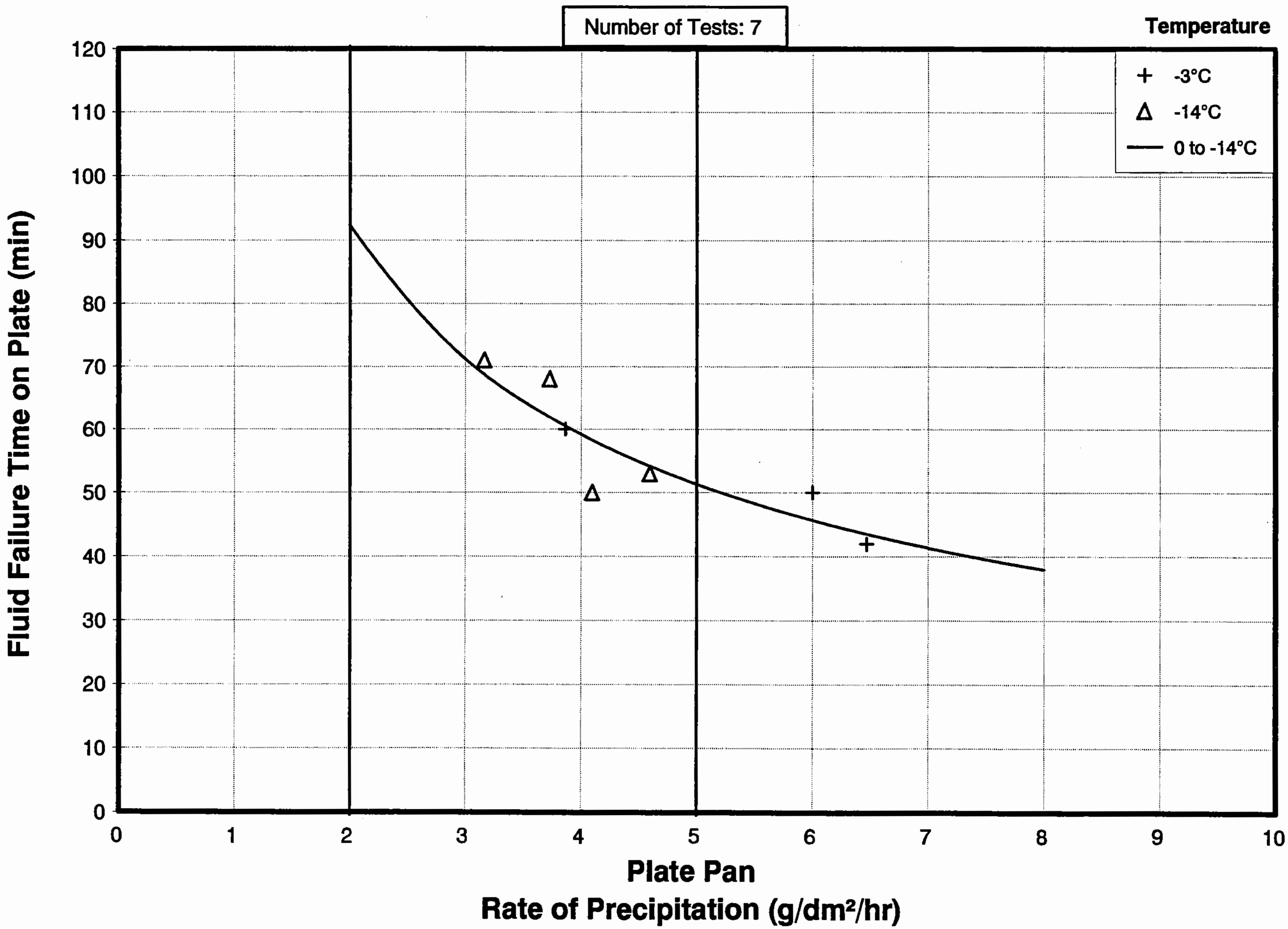
Comparison of these values to those contained in the previously proposed Type III fluid table (Table 1.4 in Section 1) show the lower values in the freezing drizzle category to be increased by 10 minutes and the upper values in the same category to be reduced by 10 minutes. For the light freezing rain category, the lower values remain the same, except for the lowest temperature range which has enjoyed a five minute increase. The upper values have suffered a five minute decrease except at the lowest temperature range in which the values remain the same.

6.2.3 Freezing Fog

The data for freezing fog were obtained from tests performed by APS and conducted indoors at the Climatic Engineering Facility of the National Research Council in Ottawa. These data, presented in failure time versus precipitation rate format, are shown in Figure 6.25. The data for both temperature ranges appear in the figure as does the regression curve generated from the fitting procedure. The figure shows that only one curve was generated because the data show little or no variation with temperature.

Recall that the lower Type IV fluid holdover times for this category of precipitation were determined at one precipitation rate only (5 g/dm²/hr) and the upper values correspond to the precipitation rate of 2 g/dm²/hr originating from the previous year's upper Type IV fluid holdover times. This is not the case for the Type III fluids. In this case, data were collected over the precipitation rate range of approximately 3 to 6.5 g/dm²/hr. The upper Type III fluid holdover time was determined by extrapolating the regression curve to the 2 g/dm²/hr precipitation rate and taking the value assumed by the curve rounded to the nearest five minute interval. The fact that the upper holdover time was determined at a point where the regression line was extrapolated indicates that supplemental data should be collected at the lower precipitation rate limit.

FIGURE 6.25
EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE III
SIMULATED FREEZING FOG
1996/97



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The holdover time range has been determined to be 50 to 90 minutes for each of the three temperature ranges in the holdover time table.

6.2.4 Rain on a Cold-Soaked Wing

The data for rain on a cold-soaked wing were obtained from tests performed by APS and conducted indoors at the Climatic Engineering Facility of the National Research Council in Ottawa. These data, presented in failure time versus precipitation rate format, are shown in Figure 6.26. The data for all average skin temperatures appear in the figure as does the regression curve generated from the fitting procedure.

Comparison of the holdover times determined for Type III fluid with the 75/25 Type IV fluid holdover times presented in Subsection 6.1.4 shows that the results are reasonable. Comparison to the previously proposed holdover time table presented in Section 1 of this report shows the lower holdover time in this year's Type III fluid table is reduced and reflects the newly defined upper precipitation rate limit of 76 $g/dm^2/hr$ which includes moderate rain.

The holdover time range for the single cell in the table is 5 to 35 minutes.

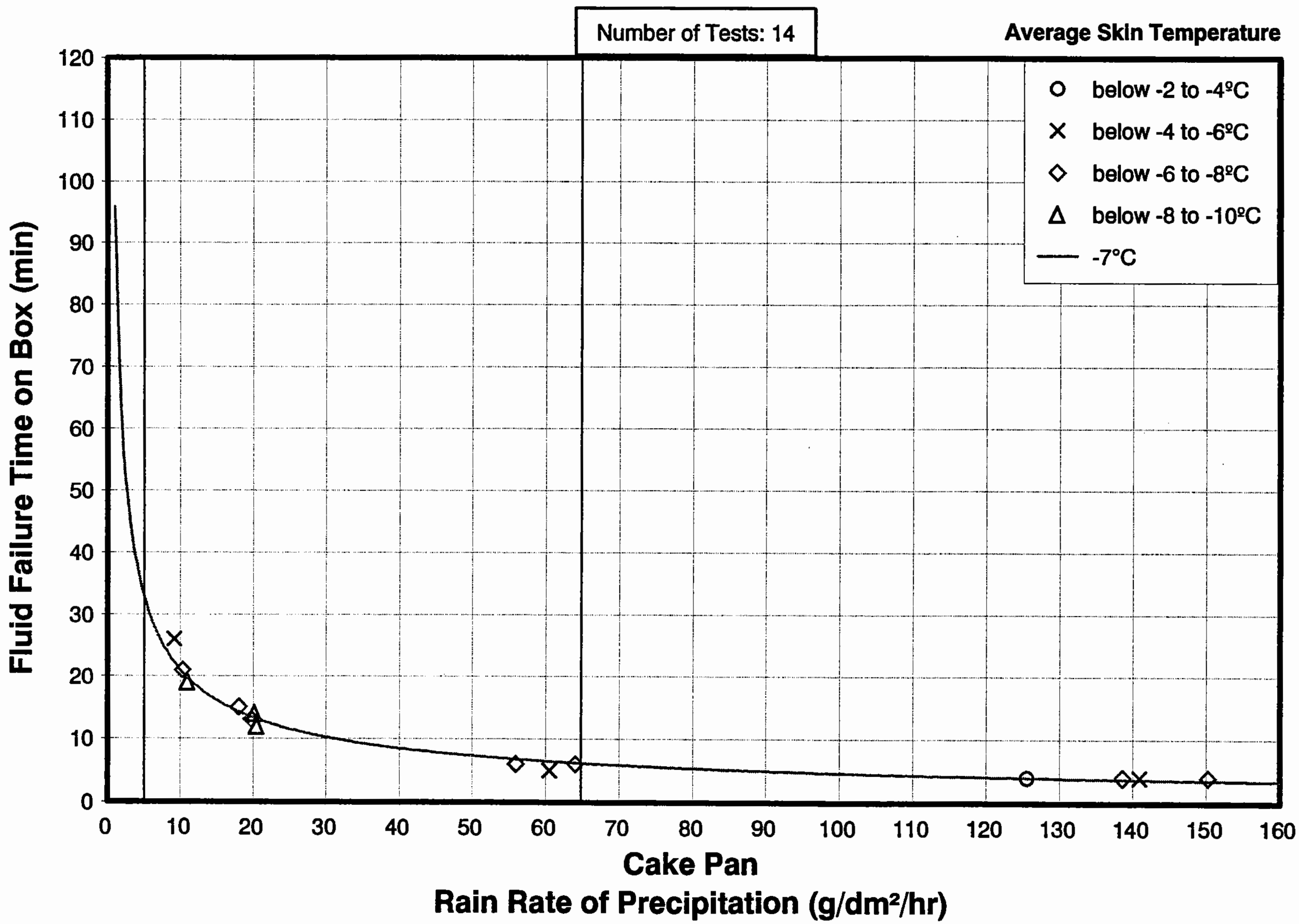
FIGURE 6.26

EFFECT OF SKIN TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE III

RAIN ON COLD-SOAKED SURFACE

1996/97



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6.3 Type I Fluid

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, so depending on weather conditions, anticipated taxi times, or other pre take-off delays, an operator can choose to extend the time of fluid protection by application of Type II or Type IV fluid on top of the Type I fluid.

The following Type I fluid tests were conducted during the 1996/97 test season: snow, 8 tests; freezing drizzle, 7 tests; light freezing rain, 3 tests; freezing fog, 15 tests; and rain on a cold-soaked wing, 1 test.

The larger number of tests conducted for the freezing fog category stem from holdover time reductions and difficulties in determining failures of Type IV fluids. These Type I tests were performed to substantiate Type I fluid holdover times. The raw data and results are listed in Appendix D. A review of the freezing fog data listed on Pages D-20 to D-21 in Appendix D shows that none of the data for the new fog tests lies below the holdover time ranges determined from previous tests. The Type I fluid holdover times determined from tests conducted during the 1995/96 winter season are included in Section 1 (Table 1.2) of this report. Two cells were designated as being not substantiated (NS). These two cells correspond to freezing fog above 0°C and rain on a cold-soaked wing above 0°C.

Last year's holdover time report included the recommendation to reduce the holdover time range in the freezing fog cell (above 0°C) from 12-30 minutes to 6-15 minutes. Due to the more pressing Type IV fluid considerations, this item was not reviewed by the SAE G-12 Holdover Time Subcommittee.

The second cell bearing the NS designation is for rain on a cold-soaked wing. The data were available for review at the SAE G-12 Holdover Time Subcommittee meetings, but the topic was not covered for reasons already cited. The data for standard (undiluted) Type I fluids and diluted Type I fluids have been plotted in fluid failure time versus precipitation rate format and both data sets have been subject to the newly developed regression *protocol*. Plots of the data for standard and diluted concentrations are shown in Figures 6.27 and 6.28, respectively. Comparison of the holdover times evaluated using the regression method to the currently accepted holdover times (2-5 minutes) indicates no change and, therefore, the rain on a cold-soaked wing holdover time cell can now be considered to be substantiated. Note, however, that it is not recommended that diluted Type I fluid be used for rain on a cold-soaked wing. The new Type I holdover time table is given in the summary in Subsection 6.5. The regression approach was implemented only for the rain on a cold-soaked wing data. All the currently available Type I data should be subject to this procedure in the future, (this is noted in the recommendations listed in Section 9).

FIGURE 6.27

EFFECT OF SKIN TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

RAIN ON COLD-SOAKED SURFACE

1994/95 to 1996/97

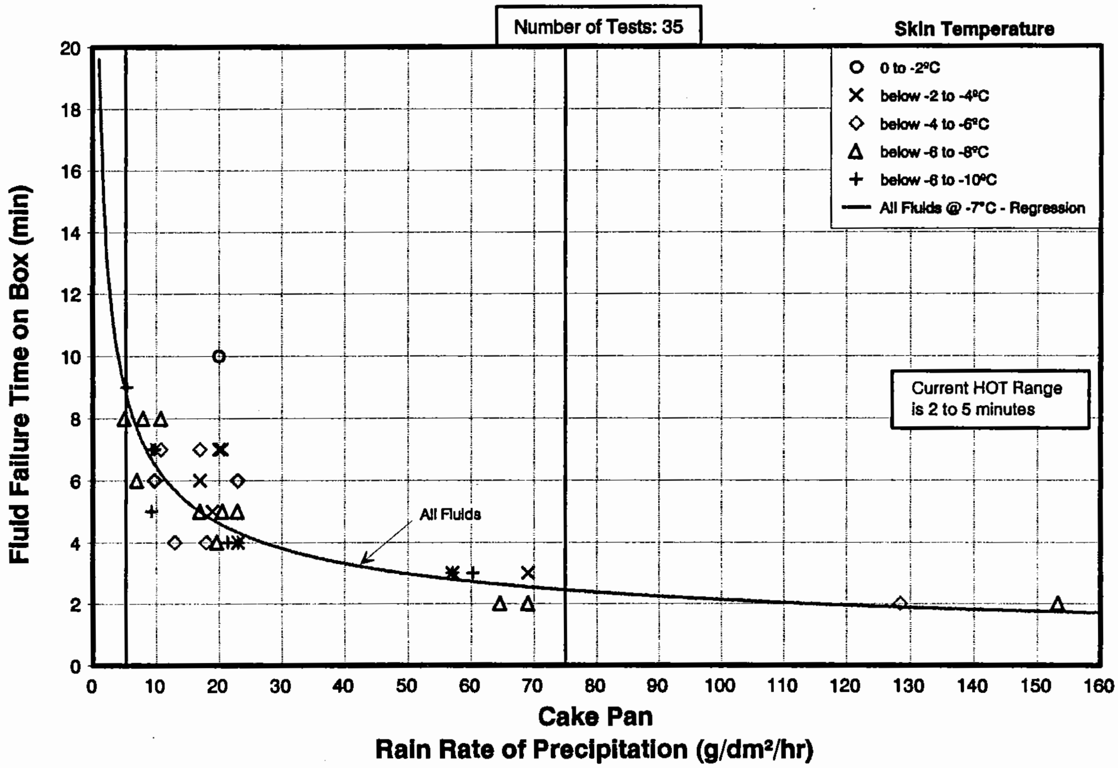


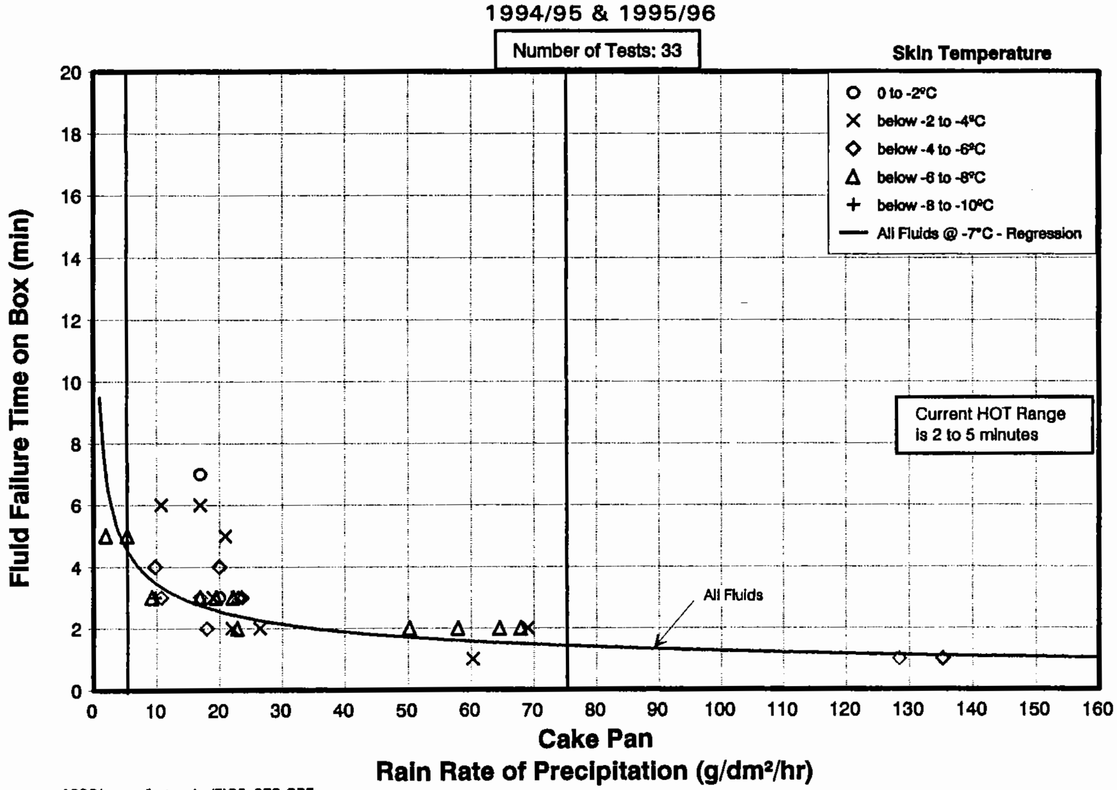
FIGURE 6.28

EFFECT OF SKIN TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

DILUTED (TO 10°C BUFFER) TYPE I

RAIN ON COLD-SOAKED SURFACE

1994/95 & 1995/96



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6.4 Type II Fluid

The Type II fluid holdover time table, accepted for use in 1996/97, is shown in Table 1.3 (Section 1). Subsequent changes were made to this table using Type II data collected during the past year. The new Type II holdover time table, which has been accepted for use in 1997/98 by the SAE G-12 Holdover Time Subcommittee, is shown in Table 6.5 (Subsection 6.5). The changes made to the previous Type II holdover time table will be discussed in this section.

6.4.1 Summary of Tests Conducted

APS Aviation conducted 55 Type II tests in 1996/97. Of this total, 29 tests were performed in freezing fog at the National Research Council. The remaining 26 tests were conducted in natural snow at Dorval.

i) Freezing Fog

The freezing fog data collected in this year's tests were acquired for comparison with previous Type II fluid data, particularly at cold temperatures. The raw data and results are listed in Appendix D. A review of the freezing fog data listed on Pages D-20 and D-21 shows that none of the data for the new fog tests lie outside the newly accepted holdover time ranges.

The complete set of Type II fluid holdover time data for freezing fog comprises the following:

- 59 data points logged during the 1992/93 to 1994/95 test seasons and which appear in Figure 3.65 of a consolidated fluid report, Transport Canada report, TP 12676E;
- In the 1995/96 test season, 17 data points were logged but 11 were considered unusable due to uncertain failure calls at low temperatures. The remaining six data points were incorporated into Appendix E (Page E-21) of last year's holdover time report, Transport Canada report, TP 12896E;
- The 11 data points put aside from the 17 collected in 1995/96 which were reexamined this year and found to be usable;
- 16 data points were logged in March 1997; 14 were retained and two were discarded due to loss of control in the precipitation rate; and
- 15 neat Type II fluid tests were conducted in April 1997 (all 15 data points were retained).

The data from the last three items listed (40 points) are plotted in Figure 6.29.

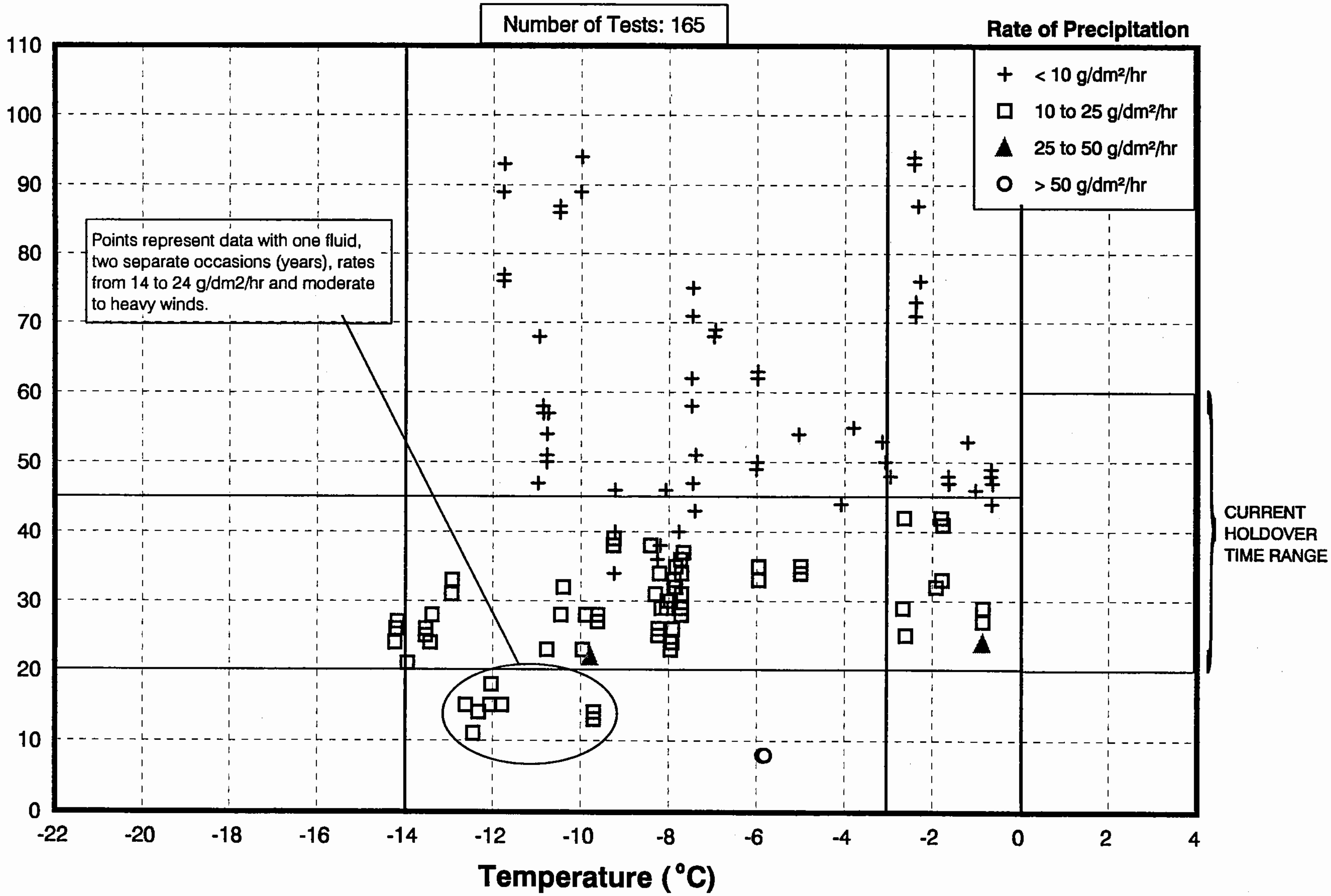
FIGURE 6.29

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II NEAT

NATURAL SNOW CONDITIONS

1995/96 & 1996/97



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ii) Natural Snow
Twenty-six usable Type II tests were conducted in natural snow in the past year. Results from these tests are listed in Appendix D, Pages D-3 to D-6.

The combined natural snow data for Type II fluids from the 1995/96 and 1996/97 test seasons (165 tests) are plotted in failure time versus temperature format and shown in Figure 6.30. The data represented by squares and positioned between the 10 and 20 minute failure time markers correspond to tests conducted on two separate occasions (two different years) using Hoechst Type II fluid in moderate to heavy wind and in precipitation rates from 14 to 24 $g/dm^2/hr$. The Hoechst Type II fluid exhibited the lowest holdover time performance of all the Type II fluids tested in snow. The tight grouping of the data for these two test sessions is a good indicator that the tests are reproducible and that the criteria for the calling of failures has not changed from year to year.

6.4.2 Changes to the Type II Holdover Time Tables

i) Changes Based on Data
The lower limit holdover time in one cell (-3°C to -14°C, Type II Neat, snow) of the new holdover time table for Type II fluid (Table 6.5 in the next subsection) was reduced to 15 minutes based on the results of snow tests that were discussed in Subsection 6.4.1.

ii) Changes Based on Type IV Fluid Holdover Time Constraint
It has been stipulated through discussion by the SAE G-12 Holdover Time Subcommittee that the holdover times for any cell in the Type II fluid table not exceed the holdover times for that same cell in the Type IV fluid tables. 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. This consideration has resulted in proposing lower holdover times for several Type II fluid holdover time table cells. The imposing of holdover time reductions based on this consideration is referred to as *Type IV fluid holdover time constraint.* The cells affected on this basis only and the specific holdover time changes contained therein are tabulated below:

Category	Range (°C)	Dilution	Old Holdover Time (Min)	New Holdover Time (Min)
Z Fog	Above 0	50/50	35-90	20-45
Z Fog	-14 to -25	Neat	35-90	20-90
ZD	Above 0	50/50	15-25	10-20
ZD	0 to -3	50/50	15-25	10-20

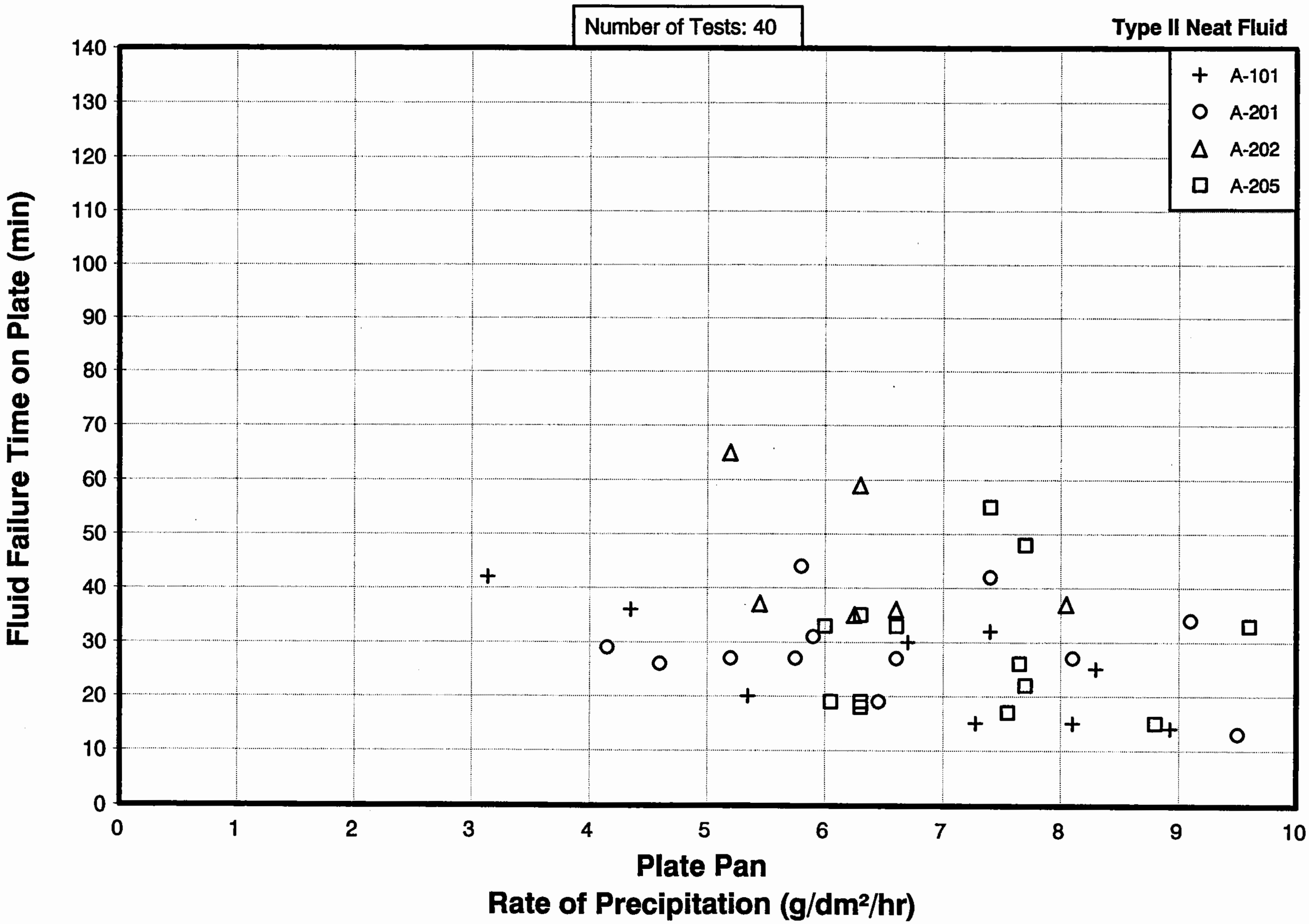
FIGURE 6.30

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

SIMULATED FREEZING FOG

1995/96 & 1996/97



cm1338/report/hot_subs/96FFT21.GRF

-ZR	Above 0	50/50	05-15	05-10
-ZR	0 to -3	50/50	05-15	05-10
ROCSW	Above 0	NEAT	20-40	10-40
ROCSW	Above 0	75/25	10-25	05-25
Snow	Above 0	75/25	14-45	15-40
Snow	-14 to -25	NEAT	20-45	15-30

iii) Non-Substantiated Cells in the Type II Holdover Time Table

Table 1.3 contains eight cells bearing the not substantiated (NS) designation. These include two cells for frost, four cells for freezing fog and two cells for rain on a cold-soaked wing. Each cell is described below:

- *Frost*: two cells in Table 1.3 are not substantiated for frost (-14°C to -25°C, below -25°C). The numbers in Table 6.5 are based on high humidity tests conducted by UQAC. The SAE G-12 Holdover Time Subcommittee is satisfied with the values in the table;

- *Freezing Fog*: four cells for freezing fog in Table 1.3 bear the not substantiated designation (Neat, 75/25, 50/50 above 0°C and Neat below -25°C). The three cells above 0°C were recommended for change in 1995/96, but due to time constraints at the SAE G-12 Holdover Time Subcommittee meeting, this recommendation was never presented. It is recommended once again that these values be changed to match the values in the 0°C to -3°C temperature range. The one cell in freezing fog below -25°C was previously not substantiated. Data points for tests conducted in this temperature range are located within the holdover time range of 20 to 90 minutes. A regression analysis of Type II data (using the newly defined precipitation rate range of 2 to 5 $g/dm^2/hr$) would likely indicate that these data points are within the holdover time limits; and

- *Rain on a cold-soaked wing*: the two cells for rain on a cold-soaked wing in Table 1.3 were not substantiated. The lower limit holdover time values for both Type II cells in Table 1.3 were reduced due to the Type IV fluid holdover time constraint. The data for neat and 75/25 fluids, plotted in failure time versus precipitation rate format, along with the corresponding regression-generated curves shown in Figures 6.31 and 6.32, support the lower limit reductions. The regression curves also suggest that the upper holdover time for both cells could be slightly increased to match the Type IV upper limits.

FIGURE 6.31
EFFECT OF SKIN TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE II NEAT
RAIN ON COLD-SOAKED SURFACE
1994/95 & 1995/96

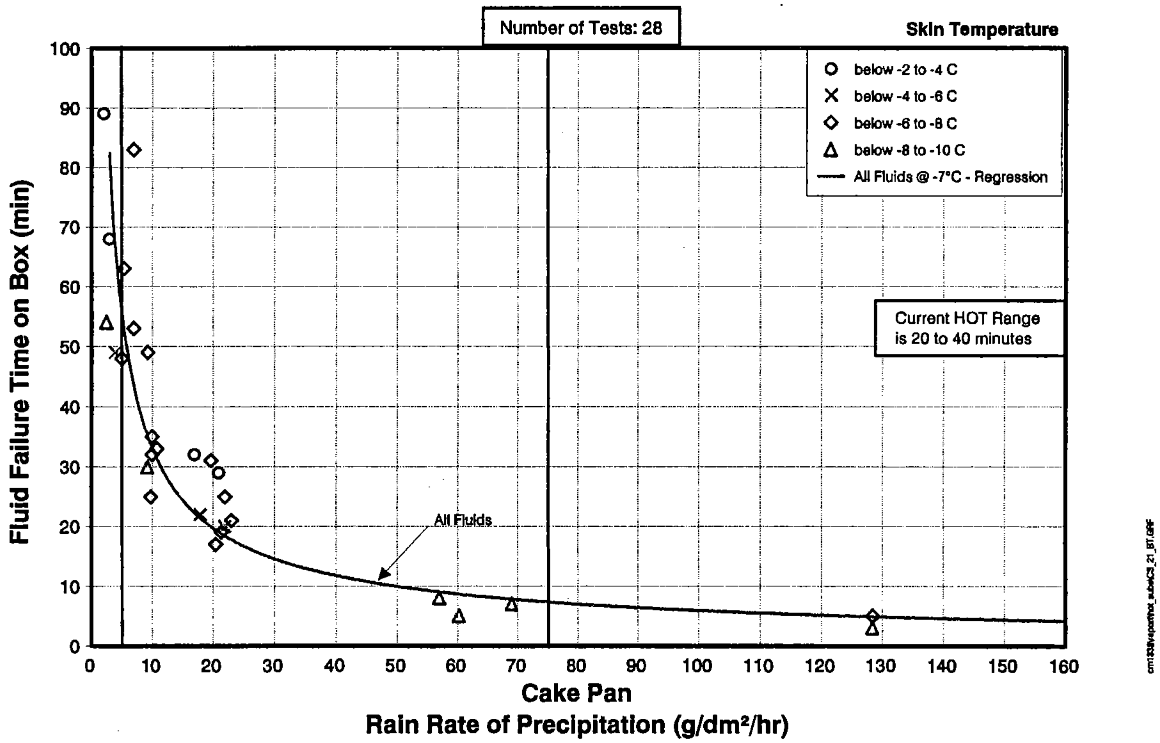
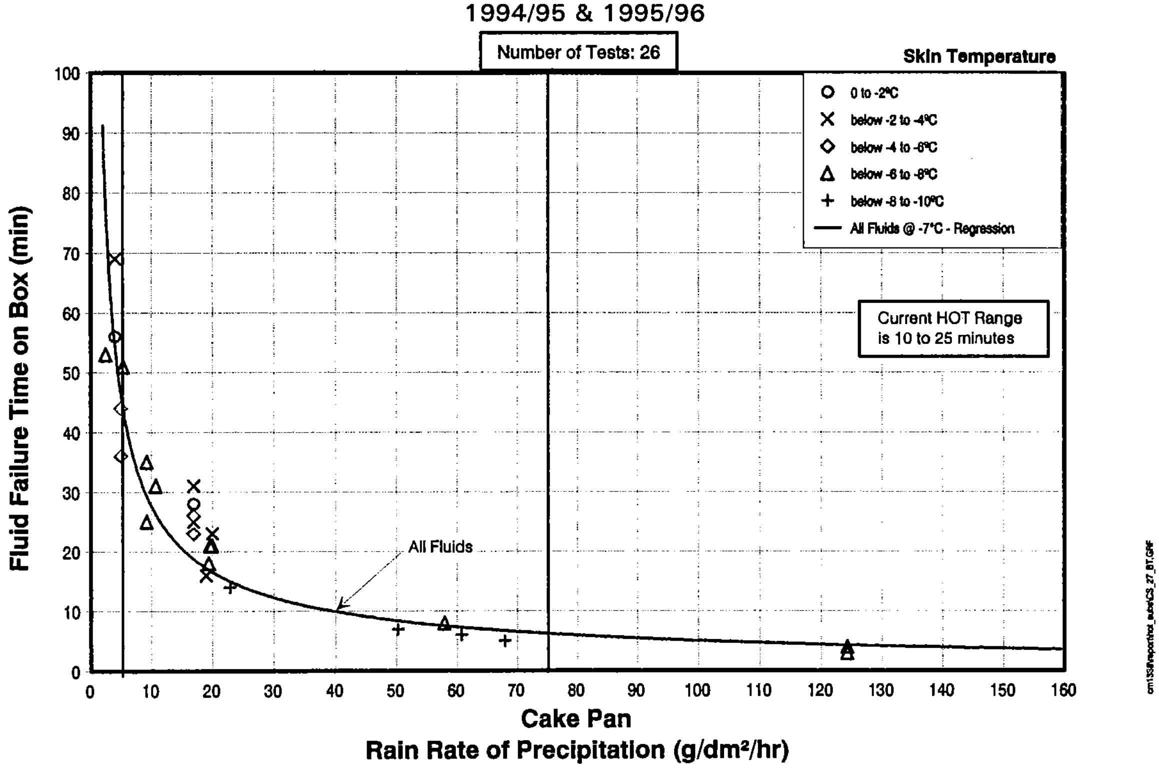


FIGURE 6.32
EFFECT OF SKIN TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE II 75/25
RAIN ON COLD-SOAKED SURFACE
1994/95 & 1995/96



cm1338/report/hot_subs/FIG6-312.GRF

6.5 Official and Proposed Holdover Time Tables for 1997/98

The SAE officially accepted holdover time tables for Type I, Type II, Type III and Type IV fluids are presented here. In the past, cells in the tables for which holdover times were not substantiated were designated by NS. Considerable effort has been spent this year in eradicating these designations from all holdover time tables. These tables are proposed for worldwide use during the 1997/98 winter season.

Table 6.4 is the proposed and accepted holdover time table for Type I fluids. It is the result of material presented in Subsection 6.3.

Table 6.5 is the proposed and accepted holdover time table for Type II fluids. It is the result of material presented in Subsection 6.4.

Table 6.6 is the proposed and accepted holdover time table for Type III fluids. It is the result of material presented in Subsection 6.2.

There are five Type IV fluid holdover time tables. The first, Table 6.7, is the SAE Type IV holdover time table and is identified as the *(worst case)* 1997/98 SAE holdover time table, described in Subsection 5.6. The Tables 6.8 to 6.11 are the *fluid-specific* Type IV fluid holdover time tables and correspond to Kilfrost ABC-S, Octagon Maxflight, Union Carbide Ultra+, and Hoechst MPIV 1957 fluids, respectively. These tables result from the material presented in Subsection 6.1.

The Transport Canada and Federal Aviation Administration versions of the SAE holdover time tables are found in Appendix H. This section includes the same tables but in a format which 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 6.4	SAE Type I holdover time table
Table 6.5	SAE Type II holdover time table
Table 6.6	SAE Type III holdover time table
Table 6.7	SAE Type IV holdover time table
Table 6.8	Kilfrost ABC-S holdover time table
Table 6.9	Octagon Maxflight holdover time table
Table 6.10	Union Carbide Ultra+ holdover time table
Table 6.11	Hoechst MPIV 1957 holdover time table

TABLE 6.4

SAE TYPE I HOLDOVER TIMES

OAT °C	OAT °F	Approximate Holdover Times Under Various Weather Conditions (hours:minutes) *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 6.5

SAE TYPE II HOLDOVER TIMES

OAT °C	OAT °F	SAE Type II Fluid Concentration Neat-Fluid/Water (Vol%/Vol%)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes) *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 -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.					

* 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 6.6

SAE TYPE III HOLDOVER TIMES

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.

<u>Note:</u> At the time of writing this report, 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 6.7

SAE TYPE IV HOLDOVER TIMES

OAT		Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Approximate Holdover Times Anticipated 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	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 6.8

"*FLUID-SPECIFIC*" TYPE IV HOLDOVER TIMES

KILFROST ABC-S

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 0°	above 32°	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 -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 6.9

"*FLUID-SPECIFIC*" TYPE IV HOLDOVER TIMES

OCTAGON MAXFLIGHT

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	*FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING
			Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
above 0°	above 32°	**100/0**	18:00	*2:20-3:00*	*1:15-2:00*	*0:55-2:00*	*0:40-1:15*	*0:10-0:50*
		75/25	6:00	*1:05-2:00*	*1:20-2:00*	*1:15-2:00*	*0:50-1:15*	*0:05-0:35*
		50/50	4:00	*0:20-0:45*	*0:40-1:20*	*0:55-1:40*	*0:30-0:55*	
0 to -3	32 to 27	**100/0**	12:00	*2:20-3:00*	*0:50-1:35*	*0:55-2:00*	*0:40-1:15*	
		75/25	5:00	*1:05-2:00*	*0:45-1:45*	*1:15-2:00*	*0:50-1:15*	
		50/50	3:00	*0:20-0:45*	*0:40-1:20*	*0:55-1:40*	*0:30-0:55*	
below -3 to -14	below 27 to 7	**100/0**	12:00	*0:40-3:00*	*0:25-0:50*	***0:30-1:10*	***0:30-0:55*	
		75/25	5:00	*0:35-2:00*	*0:20-0:50*	***0:30-1:05*	***0:25-0:35*	
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 -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.

cm1338\report\hot_subs\P_tbls
At:OCTAGON
Printed: 1:48 AM, 11/13/97

TABLE 6.10

"*FLUID-SPECIFIC*" TYPE IV HOLDOVER TIMES

UNION CARBIDE ULTRA+

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	*FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING
			Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
above 0°	above 32°	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 -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.

(1) At the time of writing this report, 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 6.11

"*FLUID-SPECIFIC*" TYPE IV HOLDOVER TIMES

HOECHST MPIV 1957

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 0°	above 32°	100/0	18:00	*2:20-3:00*	*0:45-1:25*	*0:40-1:00*	*0:40-0:55*	*0:10-0:50*
		75/25	6:00	*1:05-2:00*	*0:35-1:10*	*0:40-1:05*	*0:25-0:40*	*0:05-0:35*
		50/50	4:00	*0:20-0:45*	*0:15-0:25*	*0:20-0:35*	*0:15-0:20*	
0 to -3	32 to 27	100/0	12:00	*2:20-3:00*	*0:35-1:00*	*0:40-1:00*	*0:40-0:55*	
		75/25	5:00	*1:05-2:00*	*0:25-0:50*	*0:40-1:05*	*0:25-0:40*	
		50/50	3:00	*0:20-0:45*	*0:15-0:25*	*0:20-0:35*	*0:15-0:20*	
below -3 to -14	below 27 to 7	100/0	12:00	*0:40-3:00*	*0:20-0:40*	***0:40-1:00*	***0:30-0:50*	
		75/25	5:00	*0:35-2:00*	*0:15-0:30*	***0:40-1:05*	***0:25-0:40*	
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.					

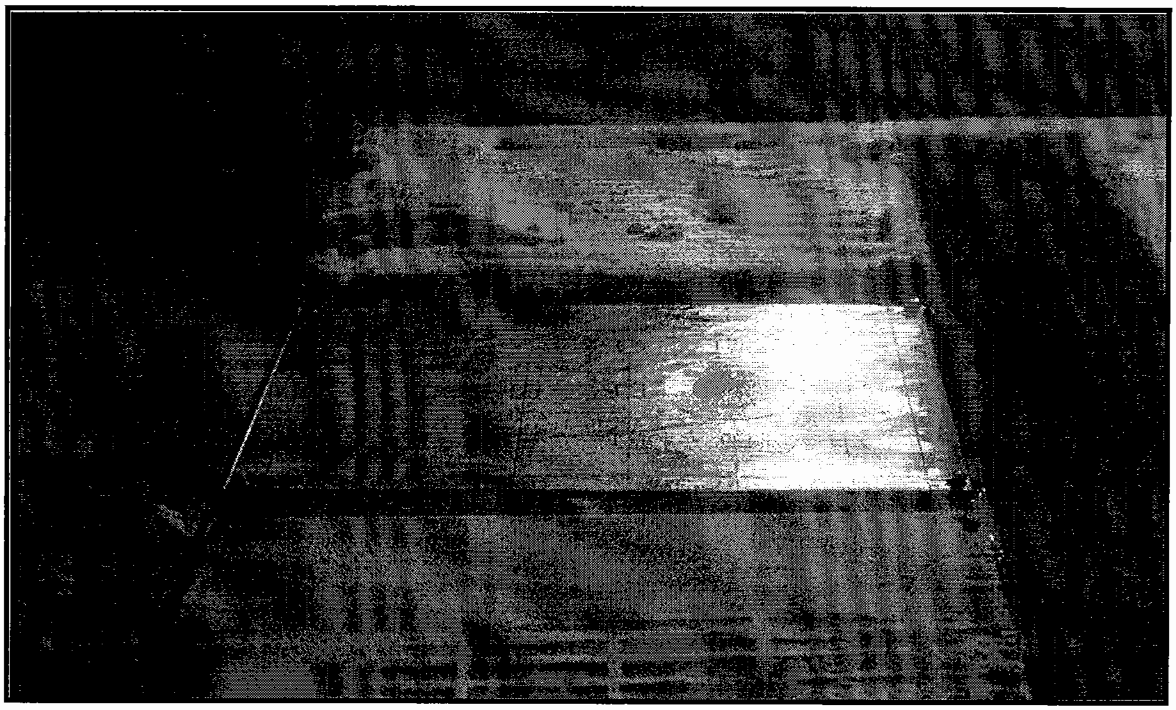
* During conditions that apply to aircraft protection for ACTIVE FROST.

** 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.

PHOTO 6.1
DOCUMENTATION OF NATURE OF FLUID FAILURE

Test Condition: Freezing Fog | Temperature: -10°C | Test Fluid: Ultra+ Neat



First Failure (Dark Shadow at Top of Plate) - Appearance with Light Shining Toward Camera

Photo 6.2
VIDEOGRAPH OF RVSI ICE DETECTION
Bright Output

Dim Output

7. SUPPLEMENTARY TESTS

Supplementary tests other than ones specifically intended to determine holdover times for qualified fluids were conducted during the 1996/97 test season. These supplementary tests are now presented.

Natural freezing precipitation holdover time tests in conditions other than snow were carried out whenever possible. In some cases, these involved tests in conditions resembling and easily mistaken for snow. These conditions include snow grains, ice pellets, mixtures of snow and ice, and also blowing snow. Tests in other conditions such as freezing drizzle and freezing rain were also tested outdoors to complement indoor tests. In some cases, weather changes during test sessions cause transformations from one type of precipitation into another. So long as fluids continued to fail, data acquisition was sustained. Details of these tests are given in Subsection 7.1.

The remaining large body of tests were performed to investigate certain fluid properties and fluid behaviour characteristics. Recycled fluid tests were performed indoors alongside the standard fluid holdover time tests. The remaining tests were not, or could not be carried out with the holdover time tests due to their nature and/or requirements. In the order of presentation, these tests are listed below:

- The evaluation of the holdover time performance of recycled (*Type O*) fluids, considered in Subsection 7.2;

- Investigation of concentration gradients developed in different fluids upon contamination by precipitation as a function of time, in Subsection 7.3;

- The evaluation of fluid performance applied to cold-soaked boxes during natural snow events, Subsection 7.4;

- Video recording of snowfall (different types of snowflakes) on fluid-covered test surfaces to observe the interaction or wetting mechanism by fluids upon contact, Subsection 7.5;

- Evaporation tests to investigate extent of volatility that the water component of dilute fluids exhibit, both as a function of initial concentration and as a function of ambient temperature and/or initial fluid temperature. These tests are considered in Subsection 7.6; and

- Dry-out tests to examine a procedure to determine fluid dry-out characteristics are considered in Subsection 7.7.

7.1 Natural Freezing Precipitation Tests Excluding Snow

Holdover time fluid tests in natural freezing precipitation excluding snow were carried out at the APS Dorval airport test site during the 1996/97 winter season. The data from these tests are presented in Figures 7.1 to 7.4 for all precipitation types in failure time versus precipitation rate format. Figures 7.1 to 7.3 contain Type IV fluid data plotted for three concentrations: neat, 75/25, and 50/50, respectively. Figure 7.4 contains the neat Type III fluid data plotted in the same format.

The precipitation types appearing in the figures are represented by the symbols:

- SG = snow grains;
- ZR = freezing rain;
- ZD = freezing drizzle;
- IP = ice pellets;
- IC = ice crystals;
- S = snow (included because it occurred with other precipitation types); and
- BS = blowing snow included because observers reported that snow from the ground was blown onto the fluids being tested.

Comparison between the fluid failure times recorded in these freezing precipitation events with the *worst case* (generic) SAE holdover time table (Figure 6.7, Subsection 6.5) shows that the lowest failure time data points represented by BS, SG, IP and S/IC lying approximately between 10 and 25 g/dm²/hr are covered by the *worst case* holdover times for the snow category. A few of the lowest failure time data points for tests in natural freezing rain and drizzle are below the *worst case* holdover times.

In Figure 7.1, the lowest failure time data are attributed to ice crystals and snow (IC/S, represented by triangles), blowing snow (BS, represented by +) and freezing rain/drizzle (represented by squares). The IC/S data points were recorded at -9°C and the BS data points were recorded at -4°C. The IC/S and BS points all fall within the *worst case* (generic) holdover time range for neat Type IV fluids in snow from -3 to -14°C (20 to 40 minutes). Since the above-mentioned conditions might be mistaken for snow by pilots using the holdover time tables, it is appropriate that the data points for these tests fall within the *worst case* holdover time ranges for snow. The low failure time ZD/ZR data points were recorded at -1°C and are not within the *worst case* (generic) holdover time range for freezing rain (the lowest holdover time range of the two categories at 0 to -3°C being 35 to 55 minutes). The three points were located just slightly below the lower limit of 35 minutes.

Figure 7.2 shows the same type of data, but for 75/25 Type IV fluid. The low failure time data points in this figure, with rates between 10 and 25 g/dm²/hr, are due to blowing snow. These data were collected at -4°C and are covered by the *worst case* (generic) holdover time range for 75/25 fluids in snow for the temperature range from -3 to -14°C (15 to 30 minutes).

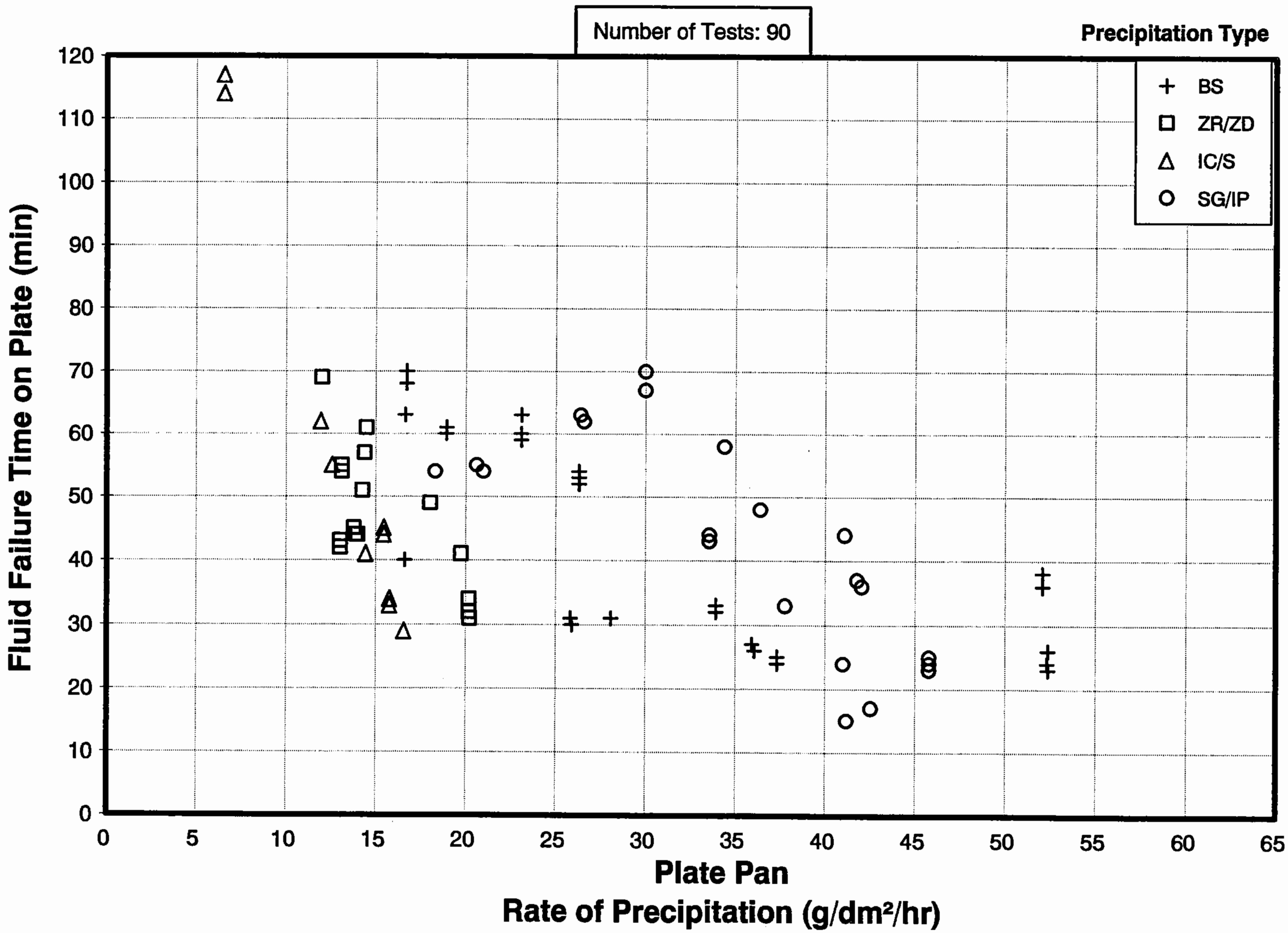
FIGURE 7.1

EFFECT OF PRECIPITATION TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT

NATURAL PRECIPITATION

APS Data - 1996/97



cm1338\analysis\dorval\charts\DIF_P_4.GRF

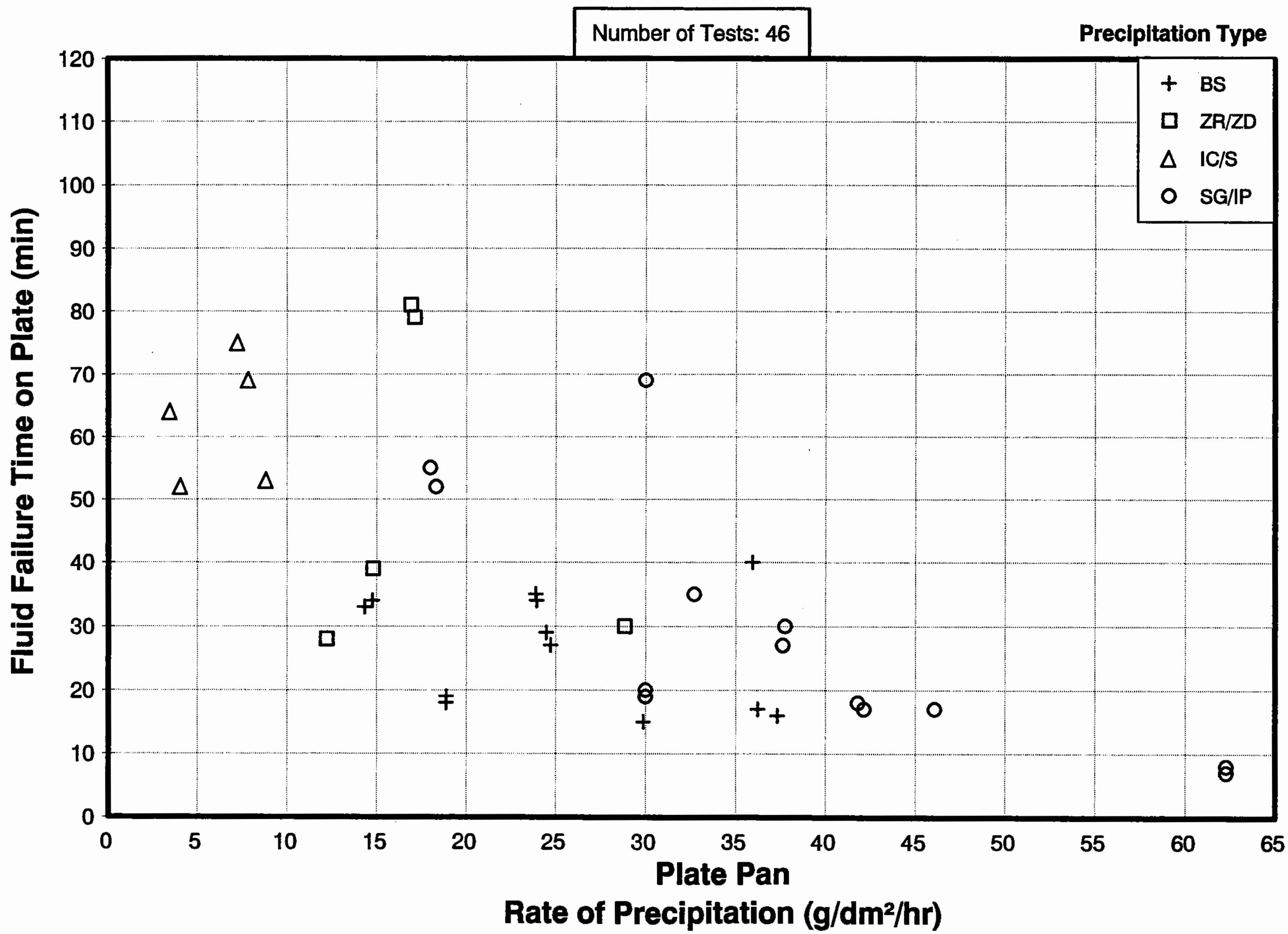
FIGURE 7.2

EFFECT OF PRECIPITATION TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25

NATURAL PRECIPITATION

APS Data - 1996/97



cm1335\analysis\dorval\charts\DIF_P_4B.GRF

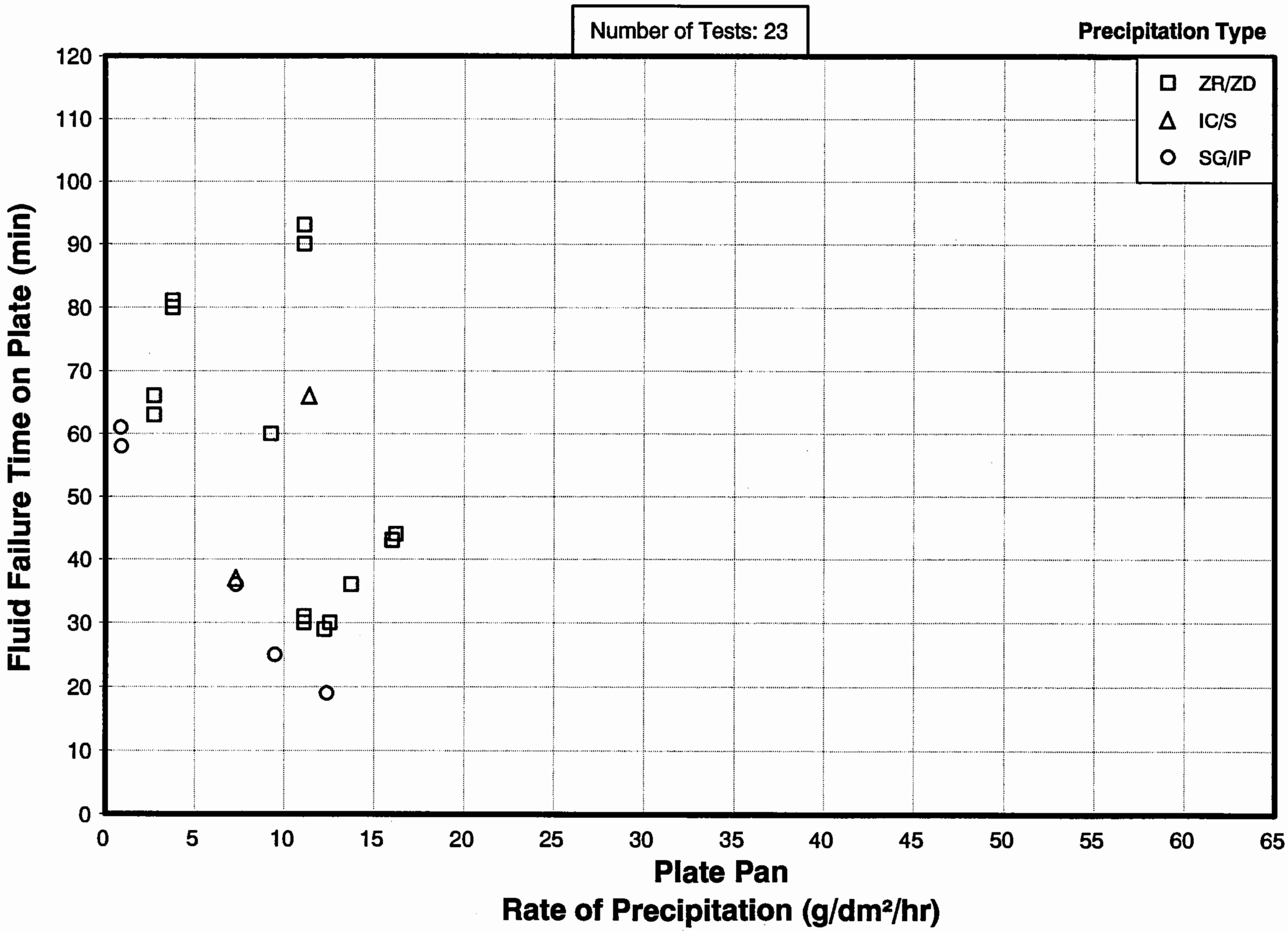
FIGURE 7.3

EFFECT OF PRECIPITATION TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50

NATURAL PRECIPITATION

APS Data - 1996/97



cm1338\analysis\dorval\charts\DIF_P_4A.GRF

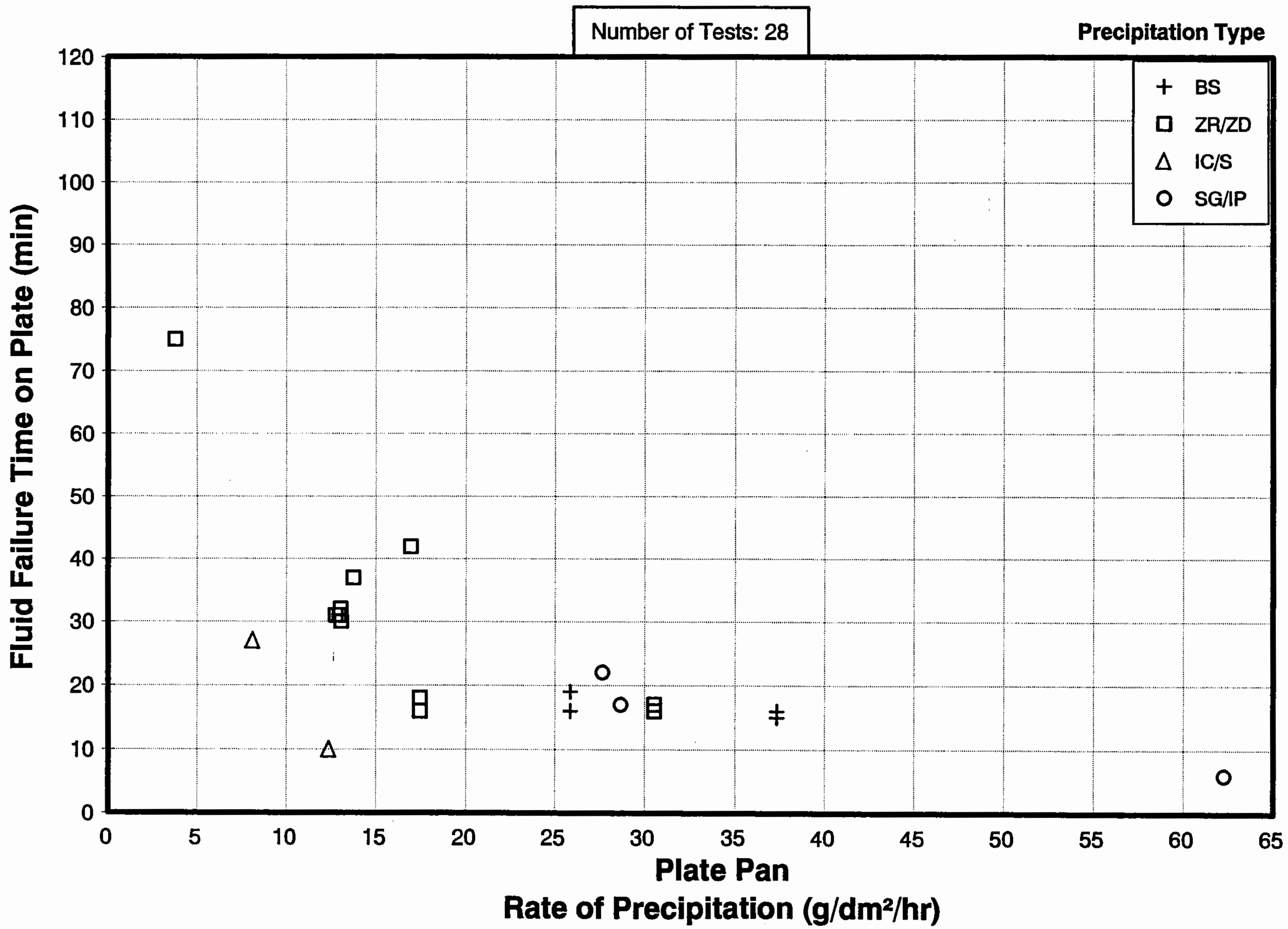
FIGURE 7.4

EFFECT OF PRECIPITATION TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE III

NATURAL PRECIPITATION

APS Data - 1996/97



cm1338/analysis/dorval/charts/DIF_P_3.GRF

Figure 7.3, shows the same type of data, but for 50/50 Type IV fluid. These data points all lie above the 5 to 15 minute *worst case* (generic) holdover time range for 50/50 Type IV fluids in snow at the lowest temperatures that it can be used.

Figure 7.4 shows outdoor data for Type III fluids. The lowest failure times in this figure are freezing rain and snow/ice crystal data points. The freezing rain data were collected at -6°C and are covered by the Type III fluid holdover time range of 15 to 25 minutes at this temperature. The snow/ice crystal data point was recorded at -9°C and also falls within the holdover time range for snow.

Figures 7.5 to 7.8 contain the data for natural and simulated freezing drizzle and light freezing rain for the 1995/96 and 1996/97 test seasons for the same fluid types and dilutions as presented in Figures 7.1 to 7.4. As discussed earlier, three Type IV neat data points fell below the *worst case* (generic) holdover time ranges. Other than these points, holdover times of natural and simulated freezing rain/drizzle tests are similar.

In general, holdover times for snow/ice crystals, ice pellets, snow grains and blowing snowfall within the *worst case* (generic) holdover time ranges for snow. Several freezing rain/drizzle data points fall just below the holdover time ranges. It should be noted that these tests conducted in natural conditions were not included in the regression analyses to determine holdover times.

The data corresponding to similar tests carried out from 1991 to 1995 are compiled in Appendix F of last year's holdover time report, Transport Canada report, TP 12896E.

Due to difficulties related to calling failures in several of the more uncommon precipitation conditions, failure times cited in this data may exhibit wide variations.

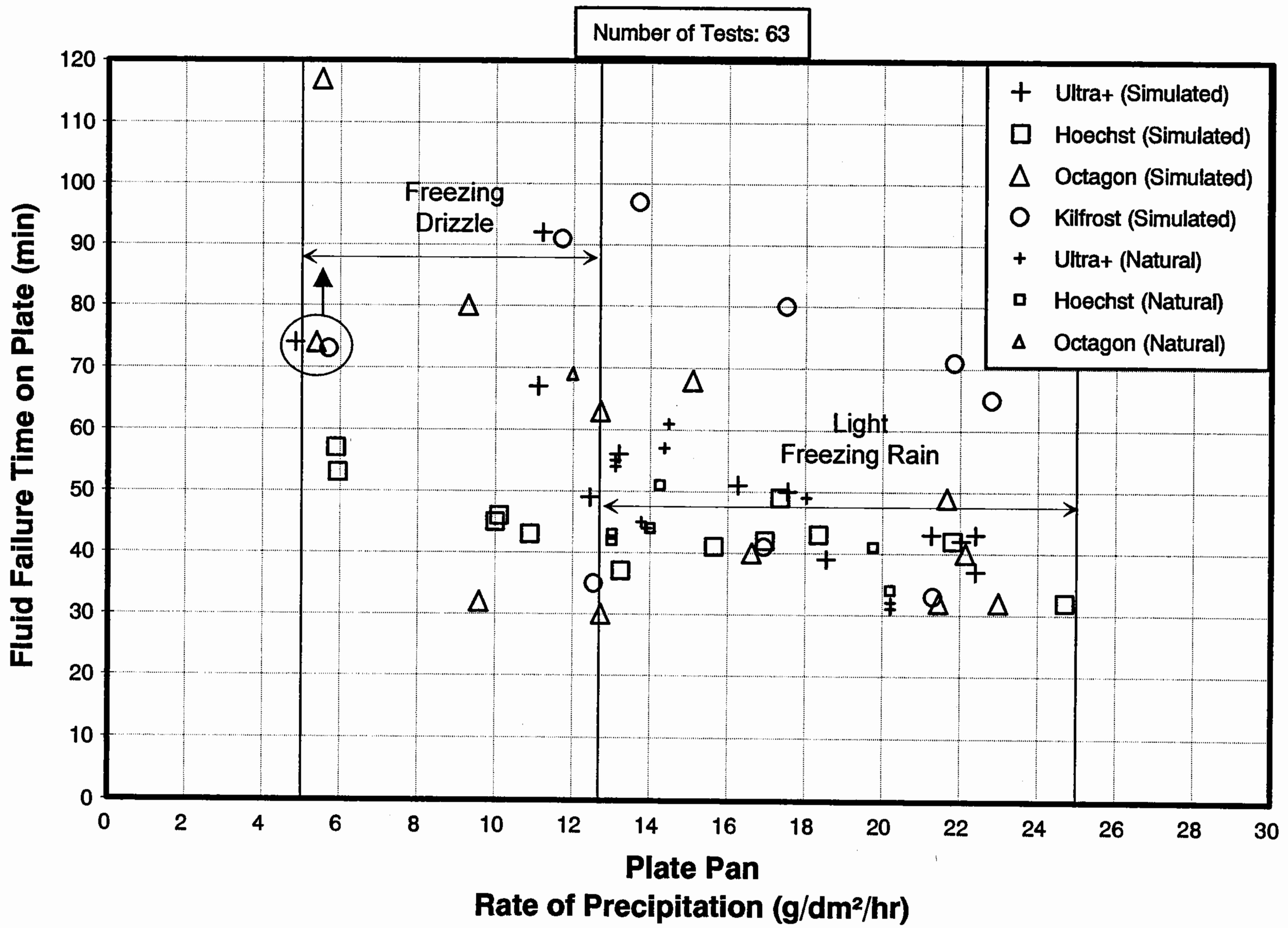
FIGURE 7.5

EFFECT OF PRECIPITATION TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT

NATURAL & SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1996/97



cm1338\report\hot_subs\FZR_T4.GRF

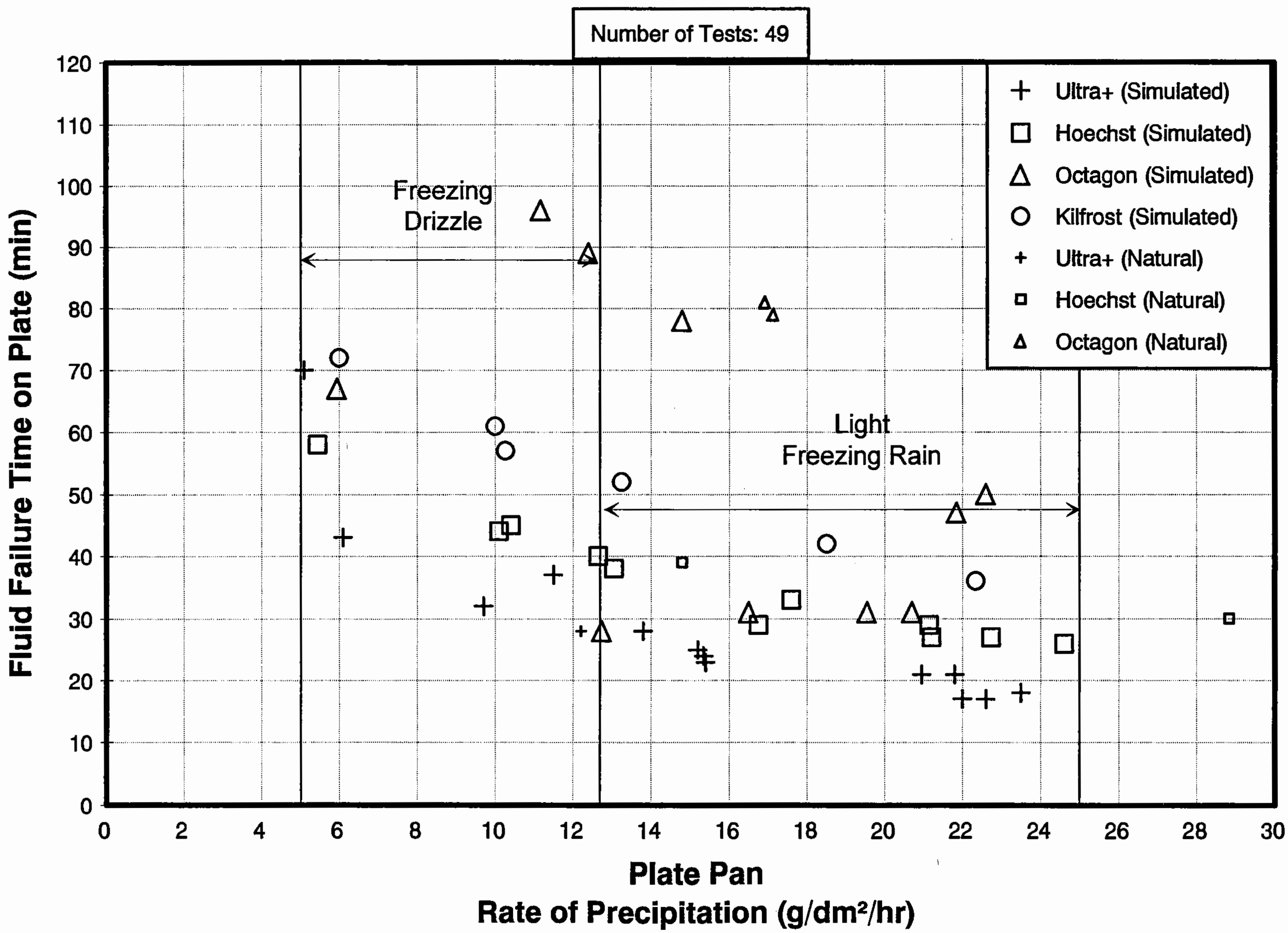
FIGURE 7.6

EFFECT OF PRECIPITATION TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25

NATURAL & SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1996/97



cm1338vaport\vol_subs\FZR_T4b.GRF

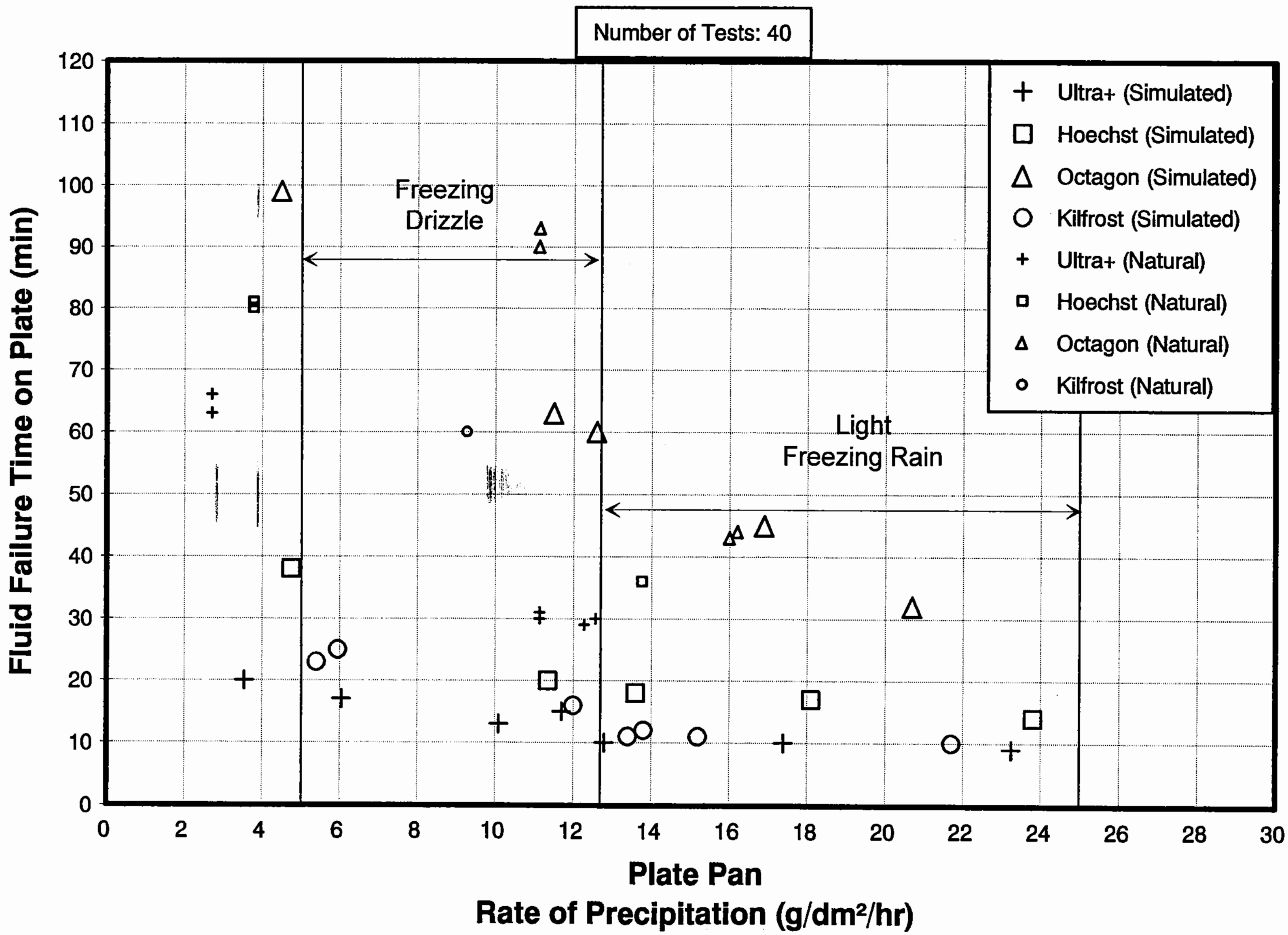
FIGURE 7.7

EFFECT OF PRECIPITATION TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50

NATURAL & SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1996/97



cm1338\report\vol_subs\FZR_T4a.GRF

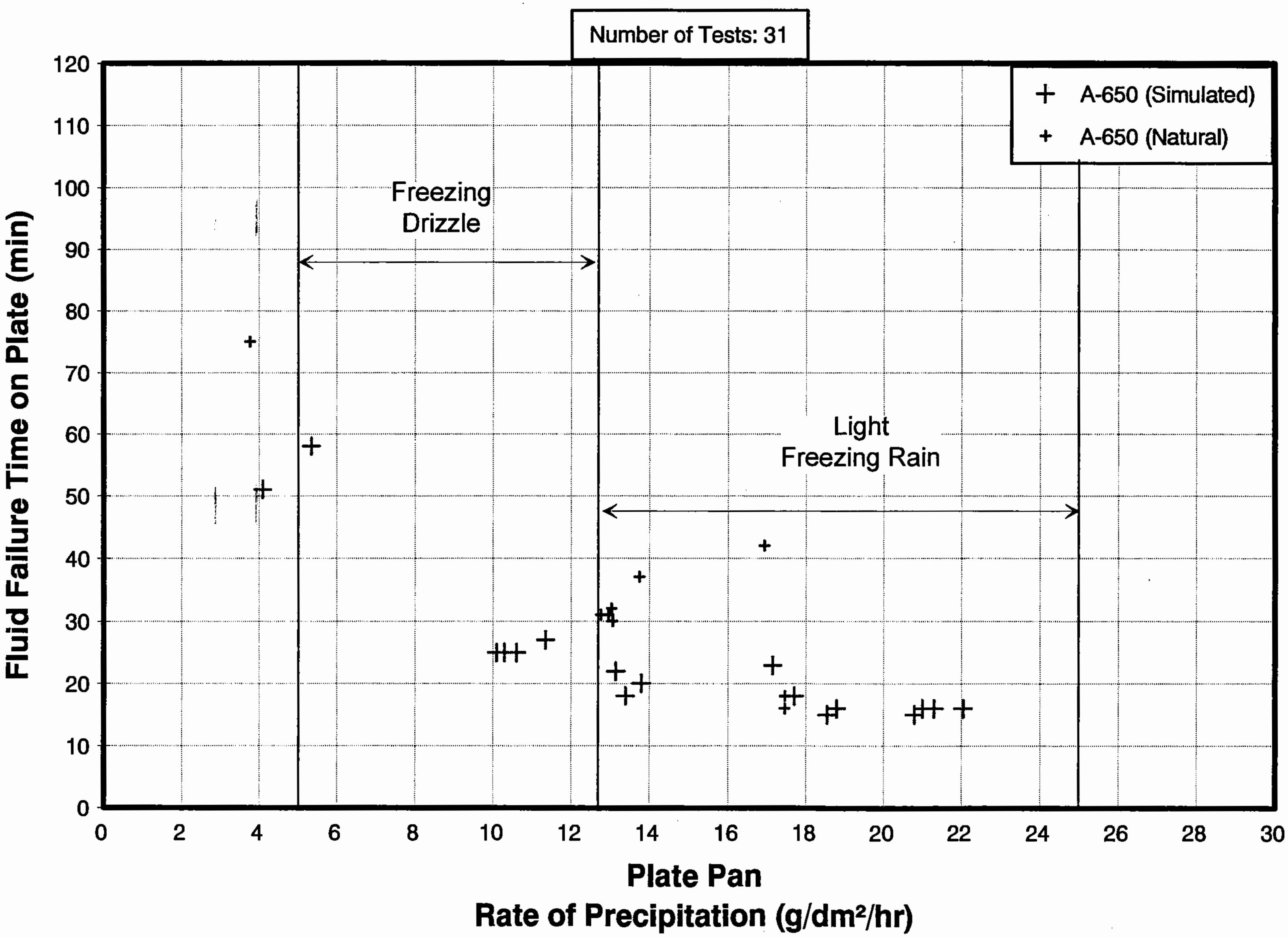
FIGURE 7.8

EFFECT OF PRECIPITATION TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE III

NATURAL & SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1996/97



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7.2 Preliminary Evaluation of Recycled Fluids

At the request of Inland Technologies Inc., APS Aviation was asked to evaluate the holdover time and fluid compatibility performance of a recycled fluid produced by Inland. Tests were conducted with one batch of fluid at the National Research Council's Climatic Engineering Facility in April 1997.

The fluid is being marketed as a deicing (or *washdown*) fluid to be applied on aircraft in the first step of the Two-Step operation. Because the fluid would not have a holdover time, *Type 0* may be an appropriate name for this recycled fluid, and it will be used for this report. To gain acceptance for use of the fluid on aircraft, Inland is also conducting corrosion tests with SMI and WSET tests with UQAC.

Figures 7.9 to 7.11 show the results of the holdover time and fluid compatibility tests conducted at the Climatic Engineering Facility in simulated freezing drizzle and freezing rain conditions. Inland's *Type 0* results were compared to another manufacturer's Type I fluid results. The failure time for each test is shown along with the rate of precipitation, temperature and run number.

Ten Inland *Type 0* holdover time tests were run in freezing rain and drizzle at the Climatic Engineering Facility. These plates were compared to ten plates of standard Type I fluid. Holdover times for the *Type 0* plates were slightly higher than the Type I plates.

Seven compatibility tests were run using various combinations of a neat ethylene glycol-based Type IV fluid, an ethylene glycol-based Type I fluid and Inland *Type 0*. The results show that *Type 0* is compatible with both the Type I and the Type IV fluids. Holdover times for Type IV over *Type 0*, and Type IV over Type I, were also comparable. Type IV over the Type I degrades the Type IV slightly. The same is true for Type IV over the *Type 0*.

One cold-soaked box test using *Type 0* fluid was conducted in drizzle and the results were compared to a box treated with Type I fluid. The boxes had identical failure times.

Figures 7.12 and 7.13 show the *Type 0* and Type I fluid data points from April 1997 plotted against the holdover time ranges for standard Type I fluid in simulated freezing drizzle and light freezing rain conditions. Every *Type 0* data point is within or above the different holdover time ranges.

Hot fluid evaporation tests using *Type 0* fluid were compared to similar Type I fluid tests. The *Type 0* fluid appeared to evaporate more than the Type I fluid. The refractive index of the fluids was similar.

FIGURE 7.9

COMPARISON WITH TYPE I HOLDOVER TIMES

FREEZING DRIZZLE

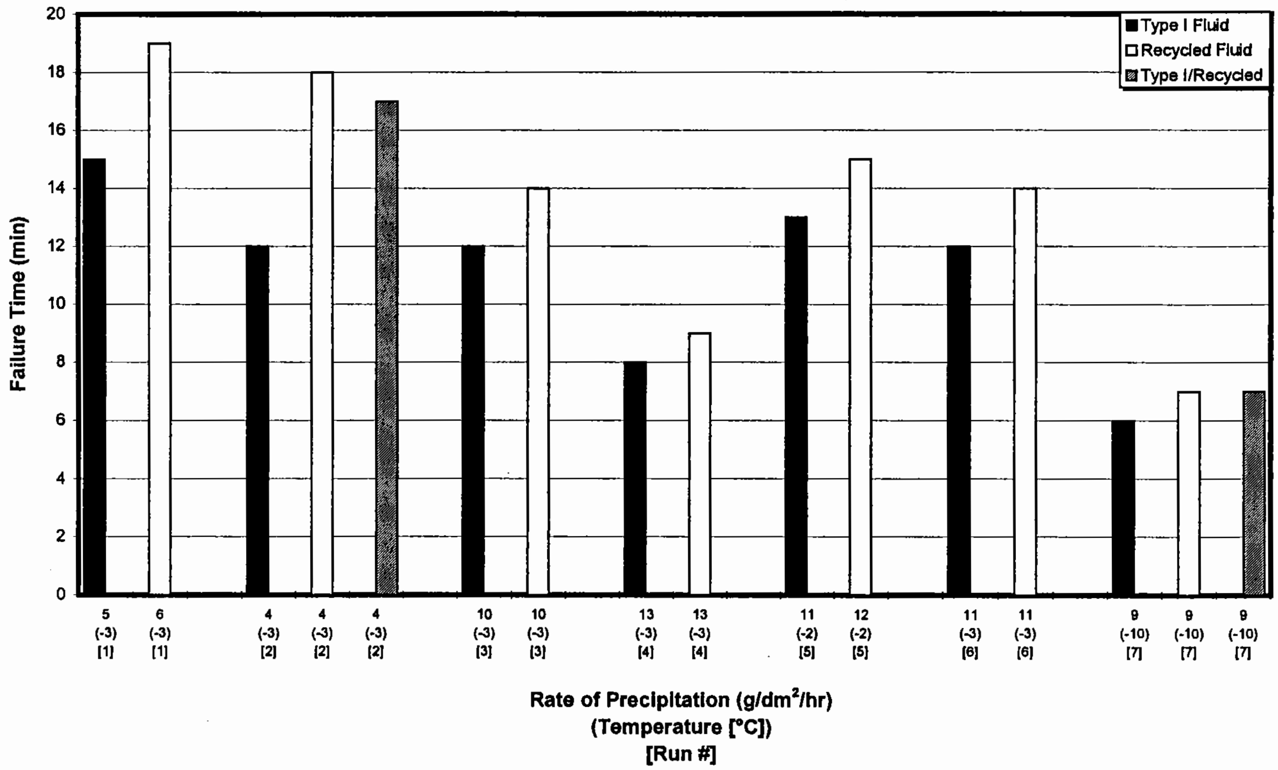

FIGURE 7.10

COMPARISON WITH TYPE I HOLDOVER TIMES

FREEZING RAIN

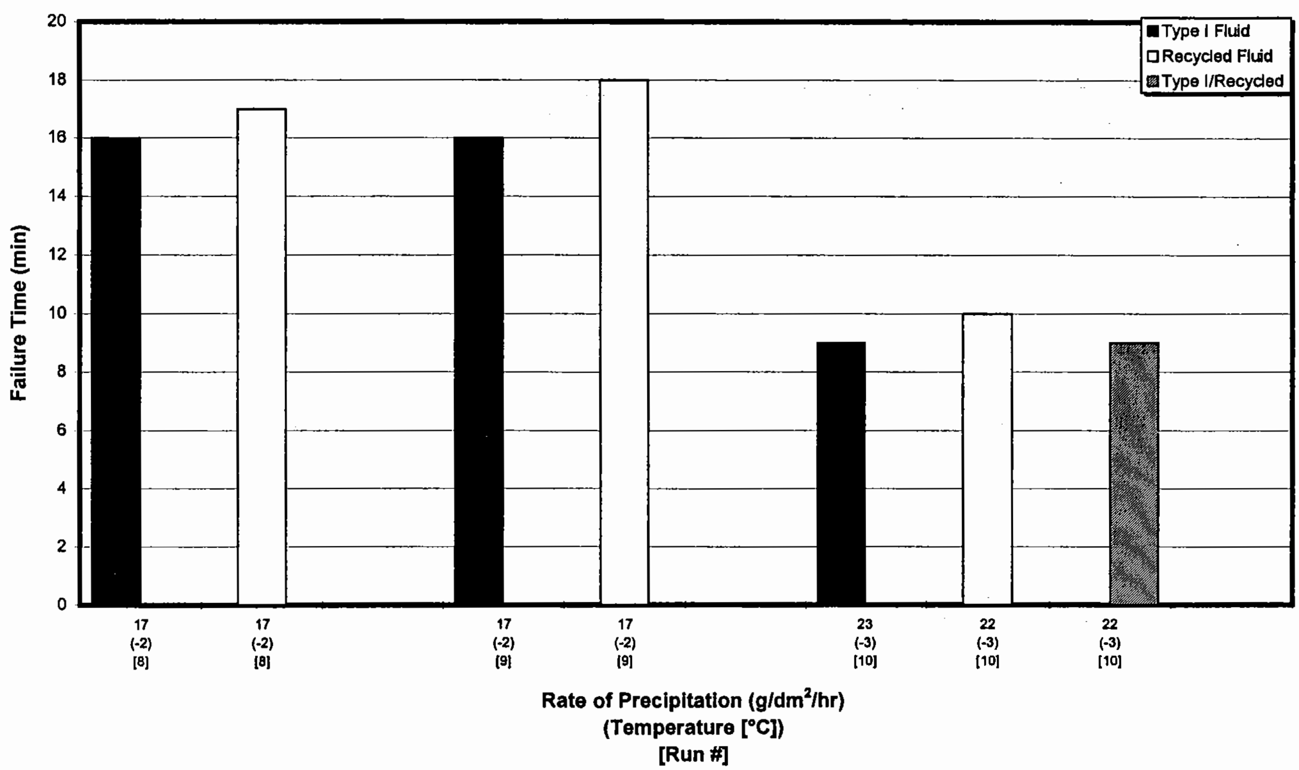

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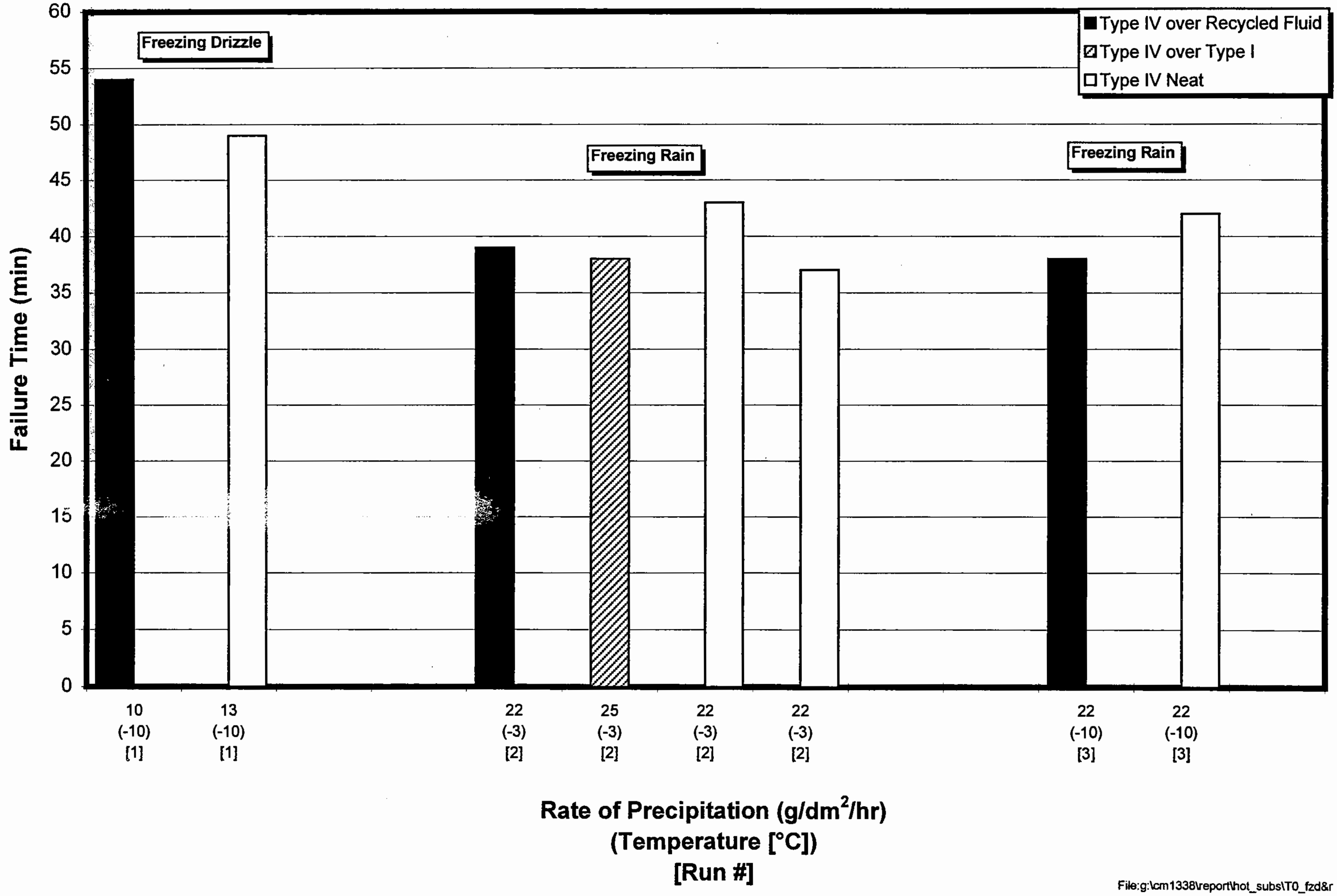
FIGURE 7.11

COMPATIBILITY WITH TYPE IV FLUID



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At: FZD & FZR
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FIGURE 7.12

HOLDOVER TIME VERSUS TEMPERATURE - TYPE I (STANDARD) AND RECYCLED FLUID

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1996/97 & 1995/96

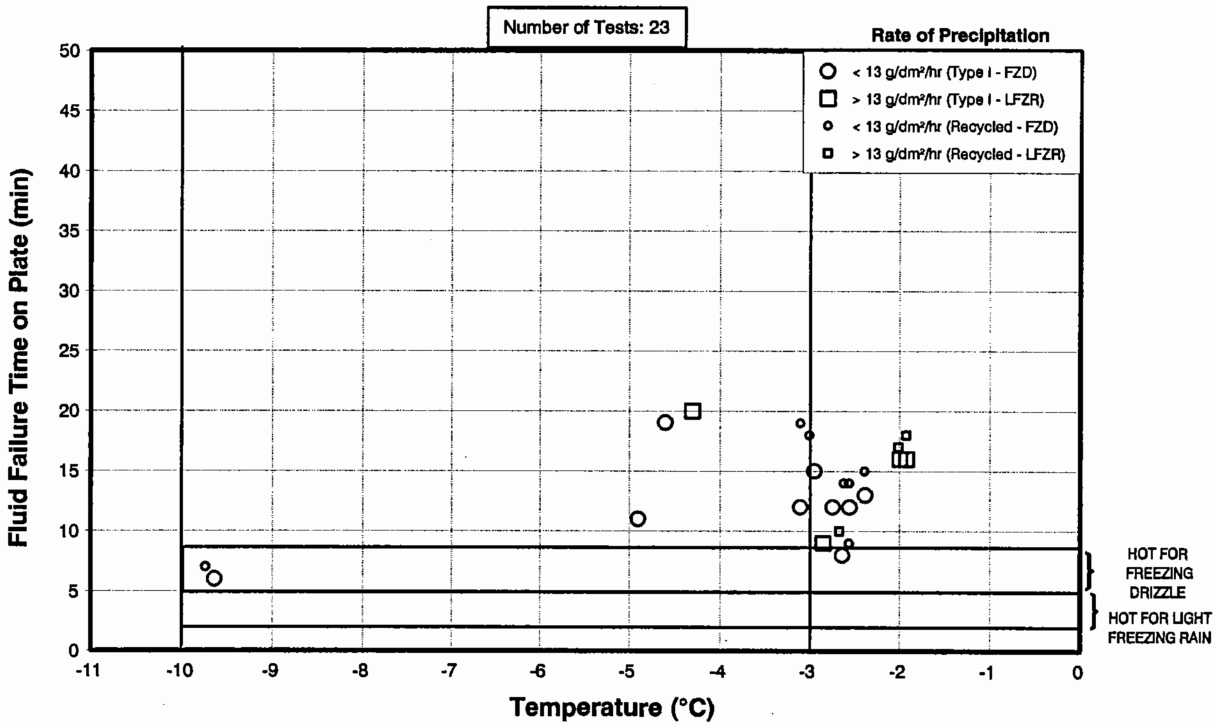
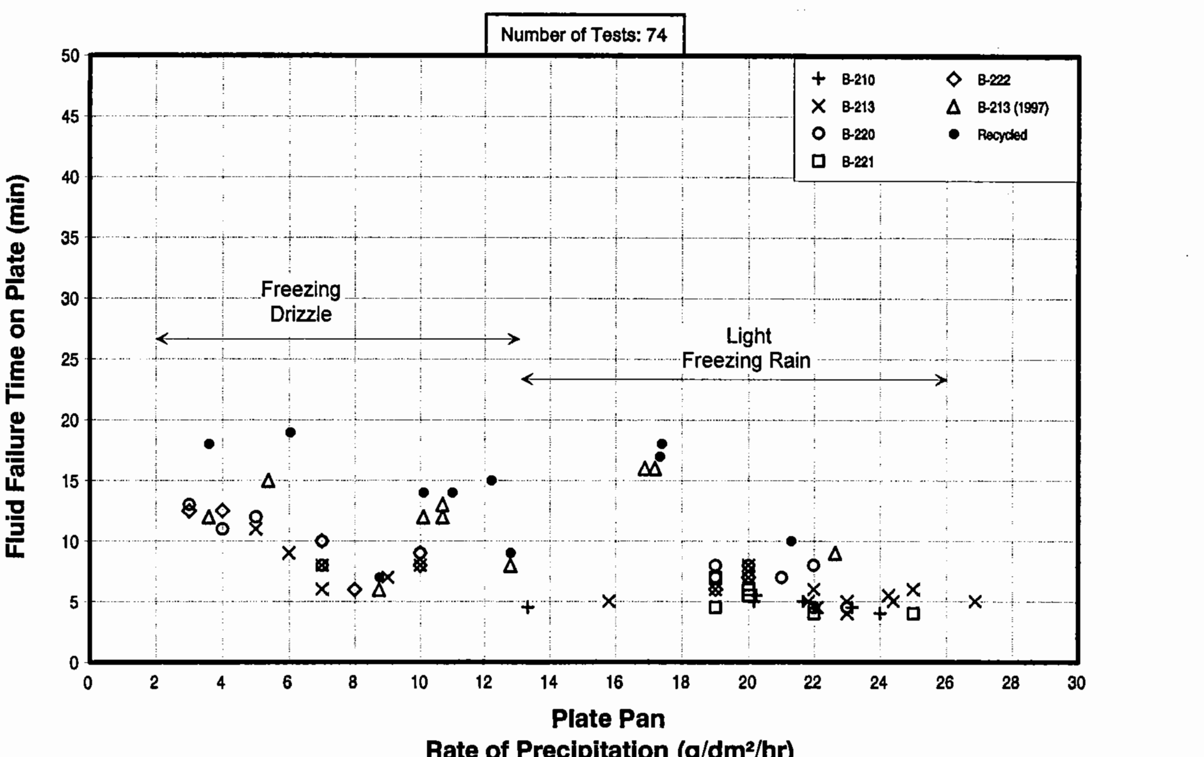


FIGURE 7.13

HOLDOVER TIME VERSUS RATE - TYPE I (STANDARD) AND RECYCLED FLUID

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



cm1338\report\hot_subs\FIG7_123.GRF

Type 0 and Type I fluid thickness tests were also performed. The stabilized thicknesses of a Type IV fluid over Type I and *Type 0* were identical. The stabilized thicknesses of *Type 0* alone, Type I alone, and Type I over *Type 0* were also identical.

Overall, preliminary results show that Inland *Type 0* performs as well as the Type I fluid used and was compatible with ethylene glycol-based Type I and Type IV fluids.

Ten holdover time tests were conducted with *Type 0* fluid in simulated freezing rain and freezing drizzle conditions. Further testing in these conditions is suggested. Holdover time tests particularily in natural snow and freezing fog would also be required, since no tests in these conditions were done. All holdover time tests need to be performed in various temperature ranges with varying rates of precipitation. Since only one cold-soaked box test was performed, more testing in this condition is recommended. Also, due to the fact that all compatibility tests were performed with ethylene fluid from one manufacturer, future compatibility tests should be done using ethylene and propylene products from various manufacturers. All tests from April 1997 were conducted using the same batch of fluid. In future tests, several batches of fluid should be made available.

7.3 Concentration Gradient

During the course of full-scale tests conducted in 1996/97, APS Aviation collected fluid samples at several predetermined points on aircraft wings. Fluid samples were collected with a spatula and consisted of a mixture of the top and bottom of the fluid present at each sample location. As a result of these tests, APS Aviation conducted a series of supplemental tests on flat plates aimed at determining whether a gradient exists between the fluid top (fluid to air interface) and fluid bottom (plate to fluid interface) freeze points of a Type IV fluid.

Twelve concentration gradient tests were performed on four different occasions using Ultra+ Type IV fluid. Fluids were poured on flat plates fitted with C/FIMS sensors during natural snow conditions. Samples at the top and bottom of the fluid were taken using a syringe (see Photo 7.1 at end of this section) at five minute intervals on a plate crosshair adjacent to the C/FIMS. Refractive index (Brix) values for each sample were obtained using a hand-held refractometer. A copy of the data form used for the sampling is included at the end of Appendix B. A preliminary analysis of the top and bottom Brix values was performed. Contrary to expectations, fluid bottom Brix values were consistently lower than fluid top Brix values. A review of sample collection procedures revealed a flaw. Fluid appeared to funnel up from the bottom of the plate when samples were taken from the top using a syringe. Likewise, fluid seemed to funnel down from the top when samples were taken from the bottom using a syringe (see Figure 7.14).

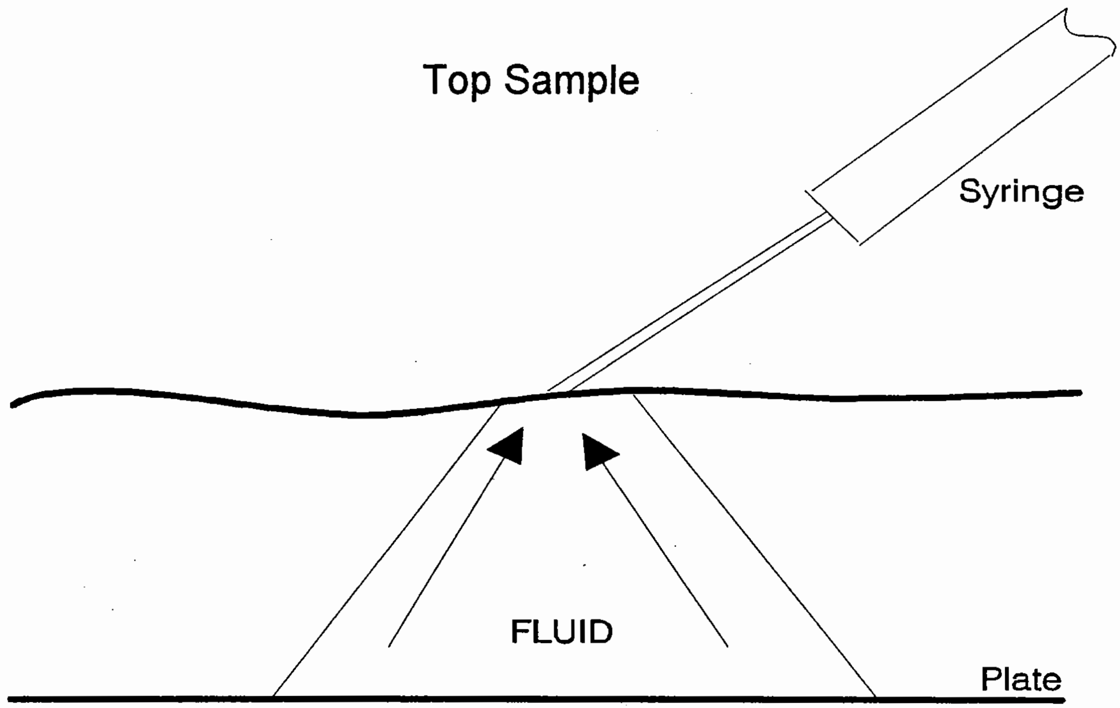
Procedures for fluid sample collection were updated. Top samples were obtained by resting a piece of plastic film on the surface of the fluid (see Photo 7.2). Bottom samples were taken with a syringe (see Photo 7.3) by drawing small amounts of fluid at several points near the sample location.

Calibration checks were conducted to determine the effect of the method of sample collection on the refractive index of the gathered sample. Trials were performed at the Dorval test site with no precipitation using Type IV fluids from two manufacturers. Fluids were poured on flat plates and samples were gathered using a plastic spoon and by resting a piece of plastic film on the fluid. Fluids were also poured straight from the containers onto the refractometer. In all cases, the refractive indexes of the samples collected were identical. Four tests were conducted using the new methods on two separate occasions. The fluid used in all tests was Ultra+ Type IV. Test temperatures were -1°C and -10°C. Tests were performed in natural snow and snow grain/ice pellet conditions.

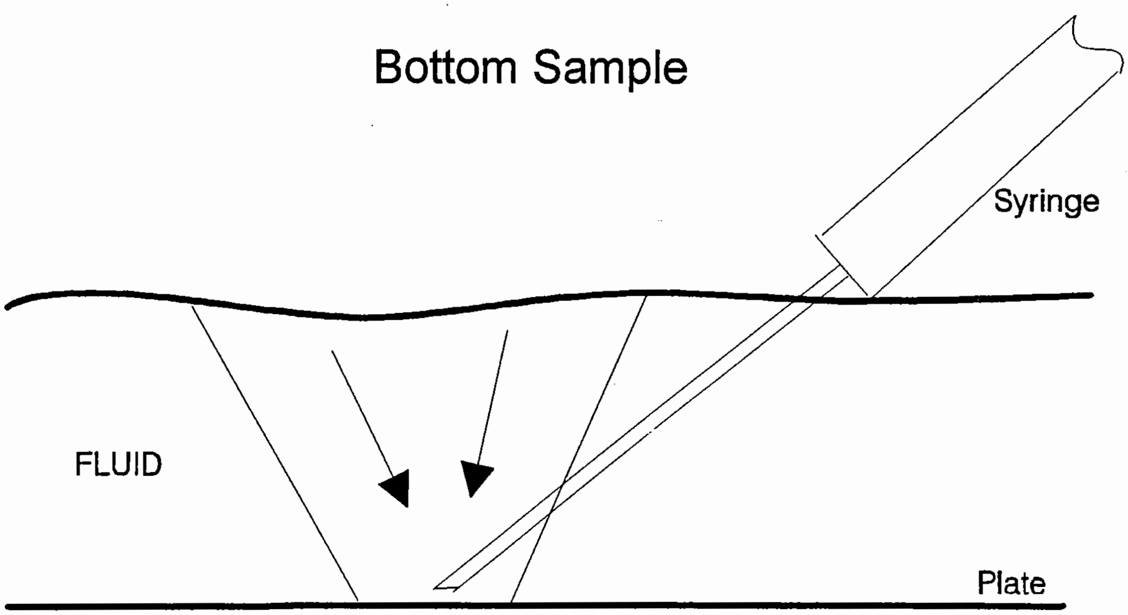
Figure 7.15 shows the results of two of the tests plotted versus the C/FIMS sensor traces. The three C/FIMS lines in each chart indicate the electrical impedance values for different levels within the fluid. Pans 1 and 2 are the

FIGURE 7.14

SCHEMATIC OF ORIGINAL SAMPLE COLLECTION PROCEDURE



- When fluid sample was taken from the top using a syringe, fluid appeared to funnel up from the bottom.



- When fluid sample was taken from the bottom using a syringe, fluid appeared to funnel down from the top.

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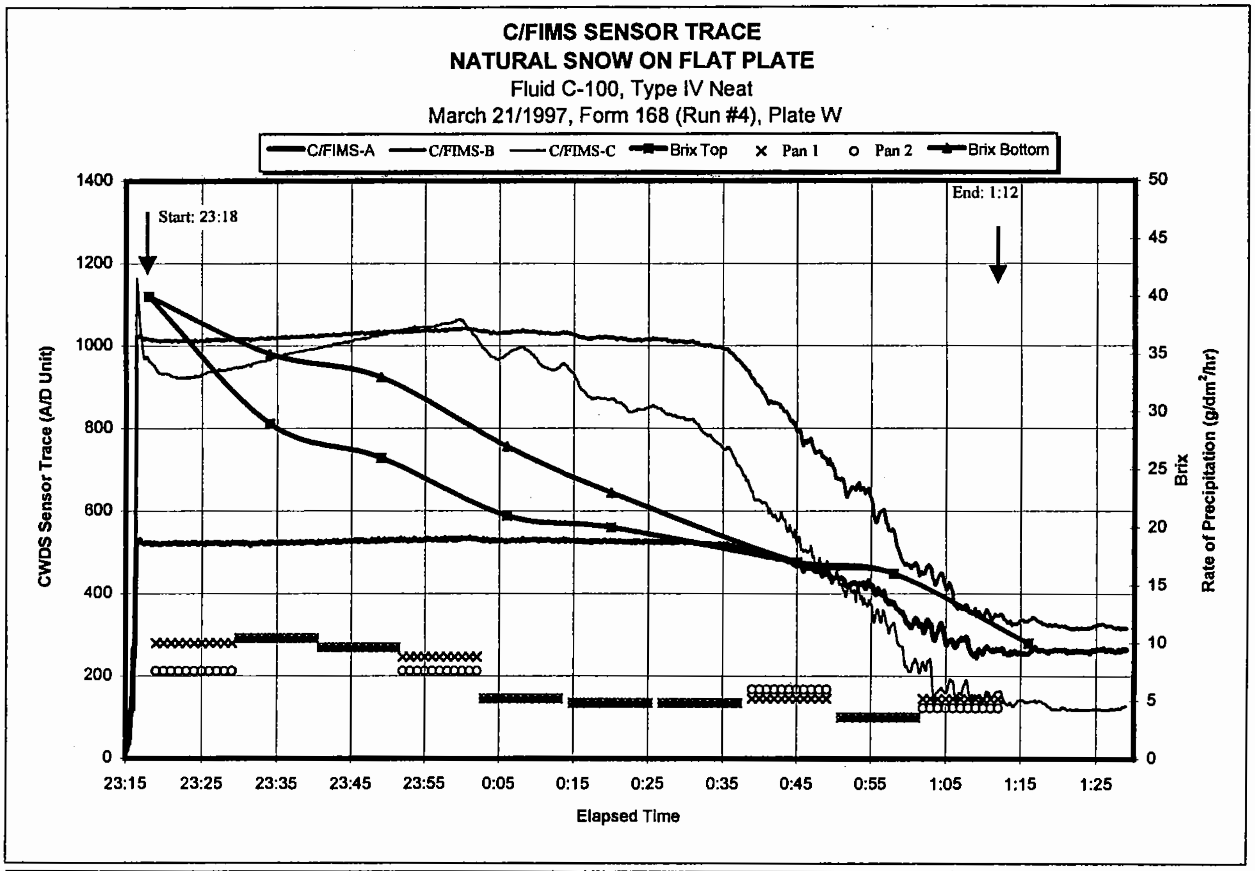
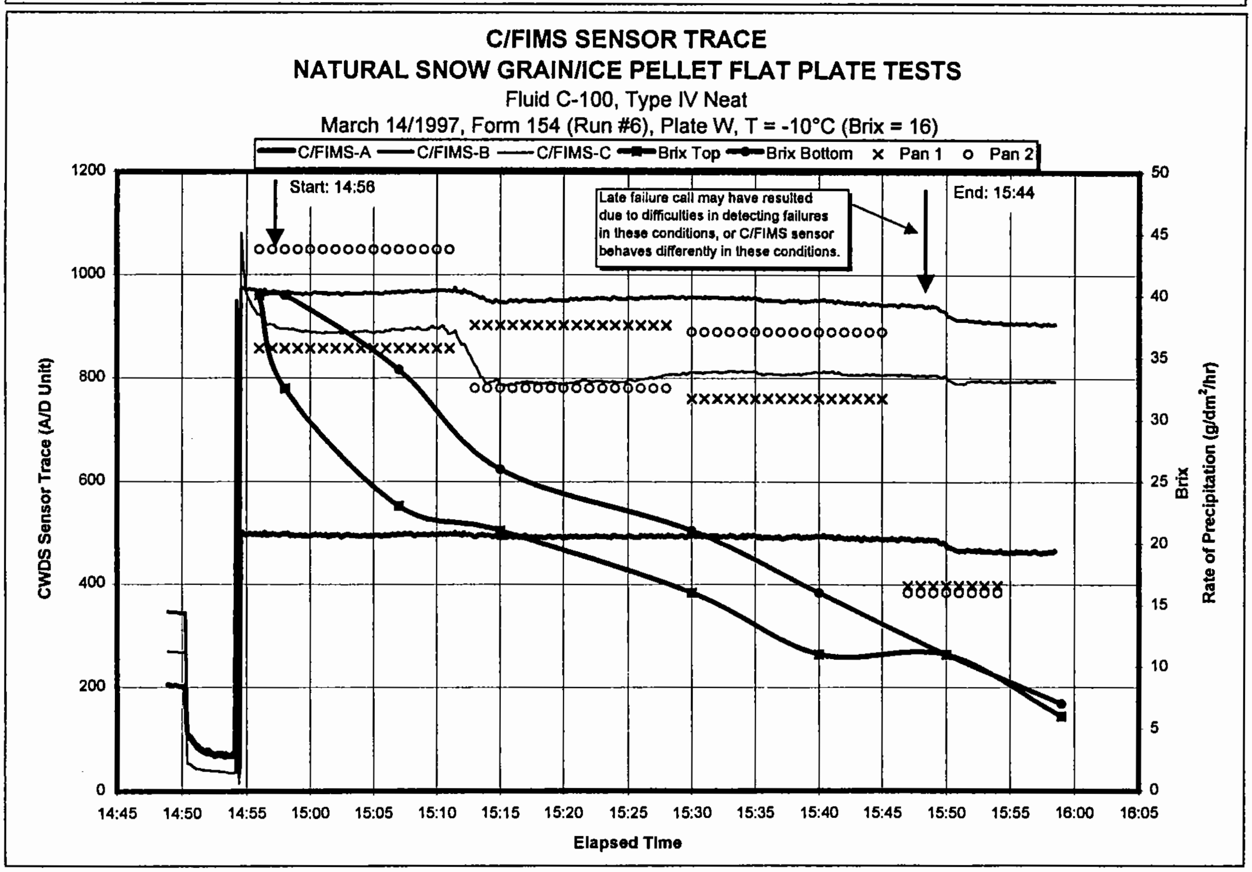
FIGURE 7.15

FLUID CONCENTRATION TESTS





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computed rates of precipitation (g/dm²/hr) at different intervals throughout the test period. The Brix top and Brix bottom lines show the measured Brix values. The test start and end times are also included. It can be observed from these charts that the Brix values at the bottom of the fluid layer are substantially higher than at the top of the fluid layer during the initial contamination phase.

During the failure phase, the fluid thins and the Brix values of the top and bottom are almost equal.

The results from these tests indicate that glycol concentrations are higher on the bottom layer of the fluid than the top. This might suggest an additional margin of safety after contamination occurs on the wing since a layer of fluid with acceptable glycol concentration might exist under a contaminated top layer.

7.4 Evaluation of Cold-Soaked Boxes in Natural Snow Conditions

In order to compare the fluid holdover time results of tests on a surface cooled below the ambient temperature (cold-soaked box) with those on a surface which is at the ambient temperature (flat plates) under natural snow conditions, a series of supplemental tests were conducted by APS Aviation during the course of the 1996/97 test season (see Photo 7.4). Cold-soaked boxes previously had only been tested in simulated rain conditions at the National Research Council's Climatic Engineering Facility.

Thirty-four cold-soaked box tests were performed by APS Aviation on eight different occasions during the course of the 1996/97 test season. Cold-soaked boxes used in the tests were 7.5 cm deep. The boxes were insulated from ambient air, except for the top plate surface, and filled with glycol. The boxes were placed in a freezer at the APS test site sufficiently long before each test in order to reach colder than ambient temperatures. At test time, the boxes were removed from the freezer and placed on the test stand next to the two flat plates and were allowed to stabilize prior to testing. Before fluid application, the box temperature was taken using a hand-held temperature probe. The same fluid was applied to two flat plates and the cold-soaked box as per the standard test procedure. Failures were called on the box and plates after five crosshairs had failed. Box temperature was again measured immediately following box failure. A copy of the cold-soaked box test procedure has been included (Figure 7.16).

The box start temperatures for test ID numbers 1 to 4 (see Figure 7.17) were not predetermined and large differences existed between the average box temperature (average between the start and end temperatures) and the ambient temperature. The procedure for determining box start temperature for subsequent tests (test ID numbers 5 to 21) followed the test envelope guidelines established by Scandinavian Airlines (Transport Canada Report TP 12899E, Page 70). Tests using this method were commenced when the box temperatures were inside the test envelope. It was discovered, however, that the difference between the average box and the ambient temperatures for several tests using this method was small. The procedure was again revised for test ID numbers 22 to 34. Tests were started prior to the suggested test envelope temperatures so that the average box temperatures fell inside the test envelope and the difference between the average box and ambient temperature was large.

Results of the cold-soaked tests are shown in Figure 7.17. The graph shows that 91% of the cold-soaked boxes failed prior to the flat plates. Box failure occurred 20% sooner on average than plate failure. It should be noted that the three boxes that failed following plate failure had similar average box and ambient temperatures. In fact, cold-soaked box tests where the difference between box

FIGURE 7.16
COLD-SOAKED BOX TEST PROCEDURE

OBJECTIVE: To compare the results of tests on a surface cooled below ambient temperature (cold-soaked box) with those on a surface which is at ambient temperature (flat plates).

Note: An extra person is required in addition to the camera man, meteo tester and stand observer.

PROCEDURE:

1) Remove cold-soaked box from freezer and place on stand reasonably close to the two flat plates.

2) Wait approximately five minutes for cold-soaked box to stabilize in temperature then cover until ready to begin testing. Refer to SAS sheet for start temperature.

3) Before the application of fluid, uncover the cold-soaked box and remove condensation with an ice scraper.

4) Immediately after this, use the hand held temperature probe to measure the temperature in the upper left hand quadrant of the crosshair on the 9" line, 1st Column. Allow enough time for the probe to stabilize then confirm the reading by quickly checking the other three quadrants. Round result off to nearest whole degree.

5) Apply the same fluid to the two (2) flat plates and the cold-soaked box as per standard test procedure.

6) Failure calls must be confirmed by the stand observer for consistency.

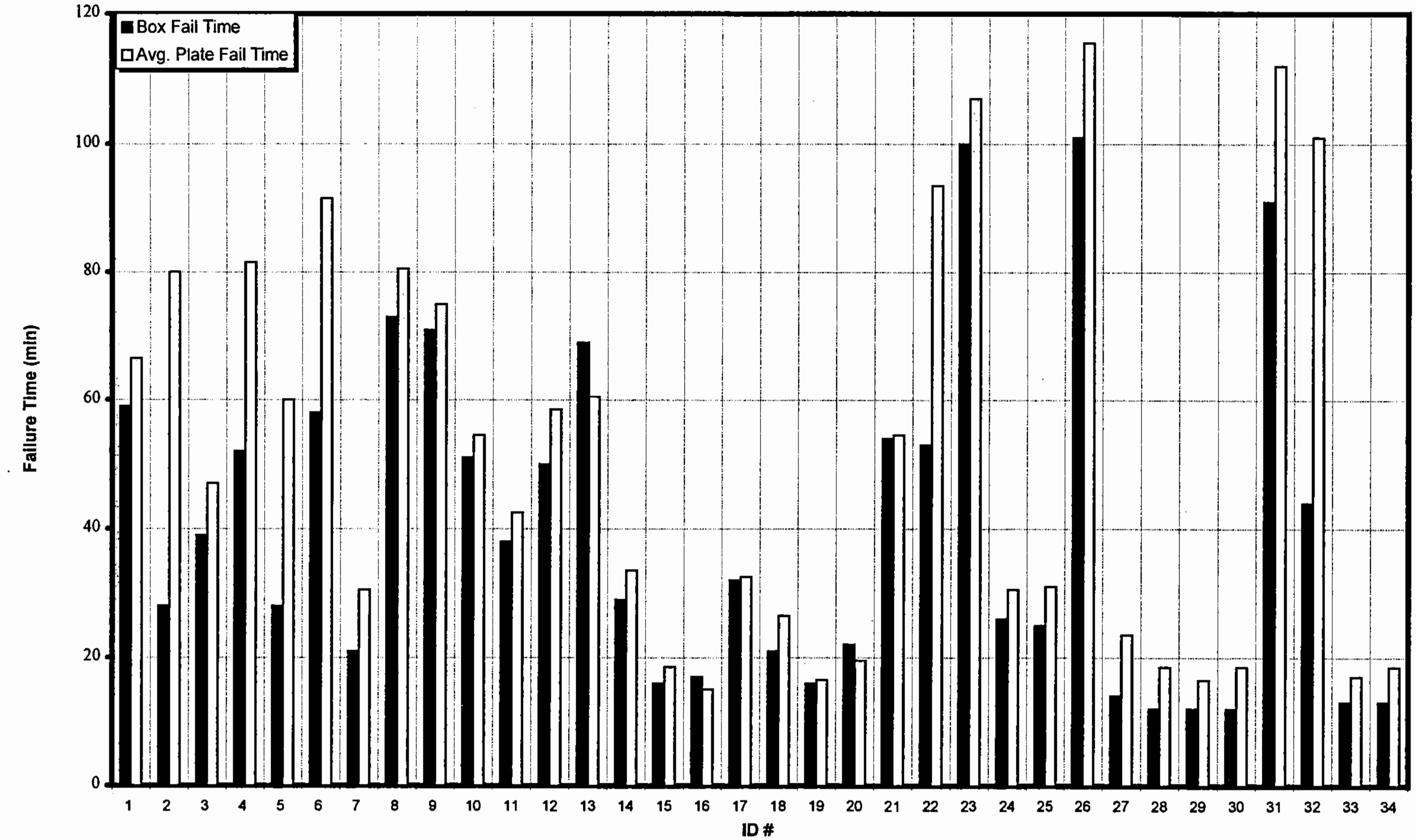
7) After five crosshairs have failed, take another temperature measurement as in step 4.

Note: Do not remove failed fluid before temperature probe.

Note: Refer to De/Anti-Icing Data form for Cold-Soaked Box in Attachment II. Take special care with the temperature probe and keep it warm between temperature readings.

FIGURE 7.17

FAILURE TIME COMPARISON BETWEEN COLD-SOAKED BOXES AND PLATES
NATURAL SNOW - APS SITE



ID#	1	2	3	4	5	6	7	8	9*	10	11	12	13	14	15	16	17
Box Rate g/dm²/hr	14	15	17	21	9	11	11	4	4	13	13	6	19	15	19	30	34
**ΔTemp.(°C)	17	16	11	10	6	5	7	5	4	3	6	4	4	4	1	1	2
Fluid	U+	O	H	K	K	O	U+	H	U+	U+	H	U+	U+	U+	U+	U+	U+
Dilution (%)	100	100	100	100	50	50	50	50	67	100	100	75	100	75	75	75	100

ID#	18	19	20	21	22	23	24	25	26	27*	28*	29*	30*	31*	32*	33*	34*
Box Rate g/dm²/hr	36	37	30	21	3	8	8	9	7	15	15	12	12	6	6	14	14
**ΔTemp.(°C)	3	1	2	2	7	8	9	7	7	10	11	7	7	9	5	10	5
Fluid	U+	U+	U+	U+	U+	U+	U+	U+	U+	H	U+	K	U+	H	U+	K	U+
Dilution (%)	100	75	75	100	75	100	75	75	100	50	50	50	50	75	67	50	50

* Tests were conducted with ambient temperature at or above 0°C.
** ΔTemp = difference between OAT and average box temperature.

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and ambient air temperatures was 5°C or more, showed box failure prior to plate failure in 100% of the cases. Box failure occurred 29% sooner than plate failure for these tests.

Nine cold-soaked box tests were conducted in natural snow conditions while the outside air temperature was just above 0°C. Box failure preceded plate failure in 100% of the tests. Box failure time was on average 33% shorter than plate failure time. Cold-soaked box tests conducted at or above 0°C are indicated with a * next to the test ID numbers in Figure 7.17.

The cold-soaked box tests were conducted using four different Type IV fluids: Ultra+, Octagon, Kilfrost and Hoechst. Ultra+ Type III was also used. Octagon had the largest difference between box and plate failure times (boxes failed 51% sooner than plates), followed by Kilfrost (35%) and Hoechst (19%). Ultra+ was the least affected by cold-soaking. Cold-soaked boxes covered with this fluid failed on average 15% earlier than corresponding flat plates.

Results from these tests show that cold-soaked wings reduce the holdover times of fluids in natural snow conditions. In cases where the variation between wing and ambient temperatures is significant, the holdover time reduction could be substantial. The results also show that certain fluids are more adversely affected by cold-soaking than others.

7.5 Video Recording of Snowflake Absorption

The purpose of this series of supplementary tests was to explore a potential alternative method of determining fluid failure times during snowfall. The primary objective was to test a procedure for capturing video footage of snowflake being absorbed into the fluid.

This approach is based on the assumption that the more dilute the protective fluid becomes as a result of absorbing ongoing precipitation, the longer it will take for snowflakes to be absorbed into the protective fluid. If the actual time to absorb snowflakes at any point in time could be determined, the rate of deterioration of fluid could be estimated. This can be represented in chart form as in Figure 7.18.

The procedure followed to evaluate this method was to video tape natural snowflakes as they settled and were absorbed into the protective fluid.

The test setup was as follows. Tests were conducted outdoors during natural snowfall at the APS test site. The test surface was a standard flat plate on a plate stand as used for holdover time tests. The plate was equipped with a C/FIMS sensor.

A video camera mounted on a tripod was focussed on a small area of the plate. The viewed area included a single crosshair at the 15 cm (6") line (same line as the C/FIMS sensor location). Fluid was applied to the plate and the camera was run continuously, capturing ongoing views of snowflakes settling and being absorbed into the fluid until fluid failure occurred. Photos 7.5 and 7.6 show the test setup with the video camera wrapped to protect it from the elements, focussed on the test plate.

Data gathered included progressive values for precipitation rates, fluid Brix values, ambient temperature, wind speed and direction, and C/FIMS sensor data.

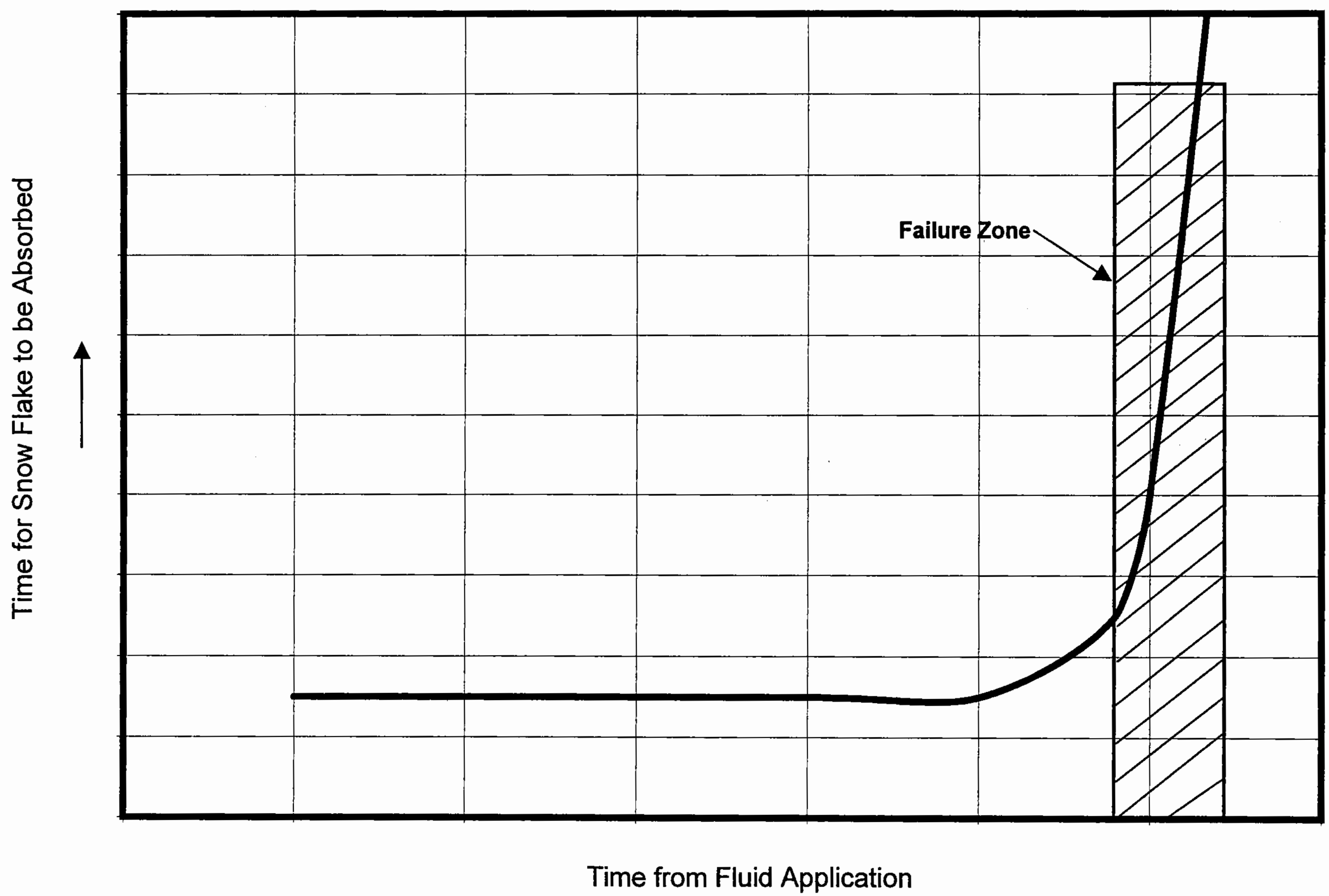
Preliminary trials were conducted on two occasions, March 21 and March 25, 1997. The video footage developed for these trials successfully captured images of snowflakes being absorbed into the fluid on the plates.

Insufficient runs were conducted to warrant an analysis of data and time for flakes to be absorbed. In addition, the fluid flow patterns on the top surface of the fluid/water mixture were clearly visible.

It was concluded from these trials that a video record of natural snowflakes settling on and being absorbed into fluid could be developed that would provide an adequate basis for evaluating absorption time of snowflakes.

FIGURE 7.18

TIME FOR SNOWFLAKE ABSORPTION



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8/3/98 M

7.6 Summary of Evaporation Tests

A full description of these tests is presented in Appendix M.

This series of tests was conducted to explore the feasibility of removing contamination following the end of a storm with a very low concentrate deicing fluid (below the buffer limits), and without an overspray of anti-icing fluid. As precipitation has ceased, a holdover time would not be required.

To understand the implications of this approach, trials were conducted on flat plates to examine the end result of application of a heated deicing fluid over a range of concentrations. Does the fluid film evaporate or freeze? Is the result a bare, dry surface? What is the impact of evaporation on the concentration of any fluid residue that is left behind?

The objectives of this series of trials were as follows:

- To determine whether a bare dry surface resulted from application of a heated deicing fluid at low concentration; and

- To determine the effect of evaporation on the concentration of any fluid remaining on the plate surface.

Variables considered in the trials were as follows:

- Fluid concentration;
- Ambient air temperature;
- Condition of plate surface;
- Quantity of fluid applied;
- Slope of test surface;
- Impact of snow on test surface; and
- Use of cold-soaked boxes to evaluate heat sink effect.

These tests were conducted at the APS test site at Dorval Airport and at the National Research Council Climatic Engineering Facility at Ottawa.

Fluids tested were Union Carbide ADF at concentrations of 2%, 10% and standard strength XL54. Water was used in one test. All fluids were heated to 80°C prior to pouring on plates.

7.6.1 Observations from Tests

The following observations were noted:

- Application of heated fluids, at low concentration, resulted in large areas of the surface being left bare and dry. Hot water and hot 2% fluid produced the largest area of the surface in a bare dry condition (95%);

- Colder ambient temperatures appeared to result in an increase in the area of the surface that was left bare and dry;

- In all cases, the freeze point of the applied fluid was depressed as a result of evaporation. This was most apparent where the final fluid existed as a thin film on the plate surface, and also occurred in the bead of fluid that formed on the surface lower edge;

- The condition of the test surface influenced results. A polished plate lost fluid more rapidly and the area left bare was greater than in standard tests;

- Application of XL54 on a surface previously treated with Ice EX (an ice phobic fluid) resulted in a large area left bare and dry, equivalent to results achieved by 2% fluid and hot water. Fluid films remaining on the plate exhibited a freeze point reduction equivalent to that observed in the standard tests;

- Increasing the quantity of fluid applied to the surface did not produce any notable difference in total surface area left bare, or in final Brix values;

- A decrease in the slope of the surface resulted in a reduced amount of surface left bare;

- Snow on the test surface did not diminish the amount of surface left bare or the Brix value of the remaining fluid film; and

- Cold-soaked boxes are inherent heat sinks. This factor reduces the quantity of heat available for the evaporation of fluid and is responsible for a reduced rise of Brix value when compared to the results of flat plate evaporation tests.

7.7 Summary of Dry-Out Tests

A full description of these tests is presented in Appendix K.

These tests addressed a potential issue that some amount of anti-icing fluid might remain on aircraft surfaces following take-off in quiet areas such as flap recesses. The concern is that the fluid might dry-out to a sticky residue that could impede free movement of moving or mating parts.

The objective of the study was to establish a procedure to investigate the characteristics of films of anti-icing fluid exposed to flight conditions.

The tests were conducted at the Centre de Recherche Industriel du Québec (CRIQ) whose facilities included a large depressurization chamber capable of simulating flight altitude and temperature conditions. Some preliminary trials to observe the nature of various fluids as they dried out were also conducted at APS facilities in Montreal.

The trials involved exposing small amounts of test fluids to typical flight profiles in the altitude chamber, represented by altitude, temperature and time. A series of five tests were conducted in the altitude chamber in which conditions included:

- Time to climb: 20 minutes
- Cruise time: 0, 20, 135 minutes
  altitude: 10 000 and 11 667 m (30 000 and 35 000 ft)
  temperature: -25, -40, -60°C
- Time to descend: 20 minutes

Relative humidity was not controllable but was measured with a probe installed in the chamber. Fluids tested in the altitude chamber trials were as follows:

- Hoechst MPII 1906 Type IV;
- Kilfrost ABC-S Type IV;
- Octagon Maxflight Type IV;
- Hoechst Safewing MPIV 1957 Type IV; and
- Union Carbide Ultra+ Type IV.

Fluid weights and concentrations were measured before and after each test. In one test, fluids were exposed to ambient laboratory conditions.

Very little fluid loss was experienced at temperatures of -40 and -60°C. Some loss was observed at -25°C, but that test was flawed by a longer start up following placement of fluid in the chamber.

The relative humidity in the altitude chamber changed markedly each time the cooling system cycled, in some tests ranging between 15 and 60%. During the very cold test at -60°C, when the cooling system ran continuously, the relative humidity was more stable, ranging between 18 to 27%. During this test, no fluid loss was measured. Although the inability to control humidity may have had some effect on the results, observations during the very cold test when the relative humidity was relatively stable and of low value indicate that the degree of influence was minor.

Fluids exposed to laboratory conditions did lose content. Over a five-hour period, four of the five fluids (all being propylene glycol-based) lost about 25% by weight. The fifth (ethylene glycol-based) lost about 15% by weight.

Long exposure tests of three fluids at the APS facilities resulted in two fluids becoming very thin and watery after three days of exposure. This characteristic would tend to indicate negligible residue(s) remain on flight surfaces due to dilution by atmospheric humidity. The third fluid became thick and jellied which would further prevent any residues of that fluid from running off the aircraft. This fluid is no longer in use as it failed to meet fluid specifications.

Photo 7.1
Ultra-Fine Syringe to Extract Fluid
29 Gauge, 12.5 mm Needle

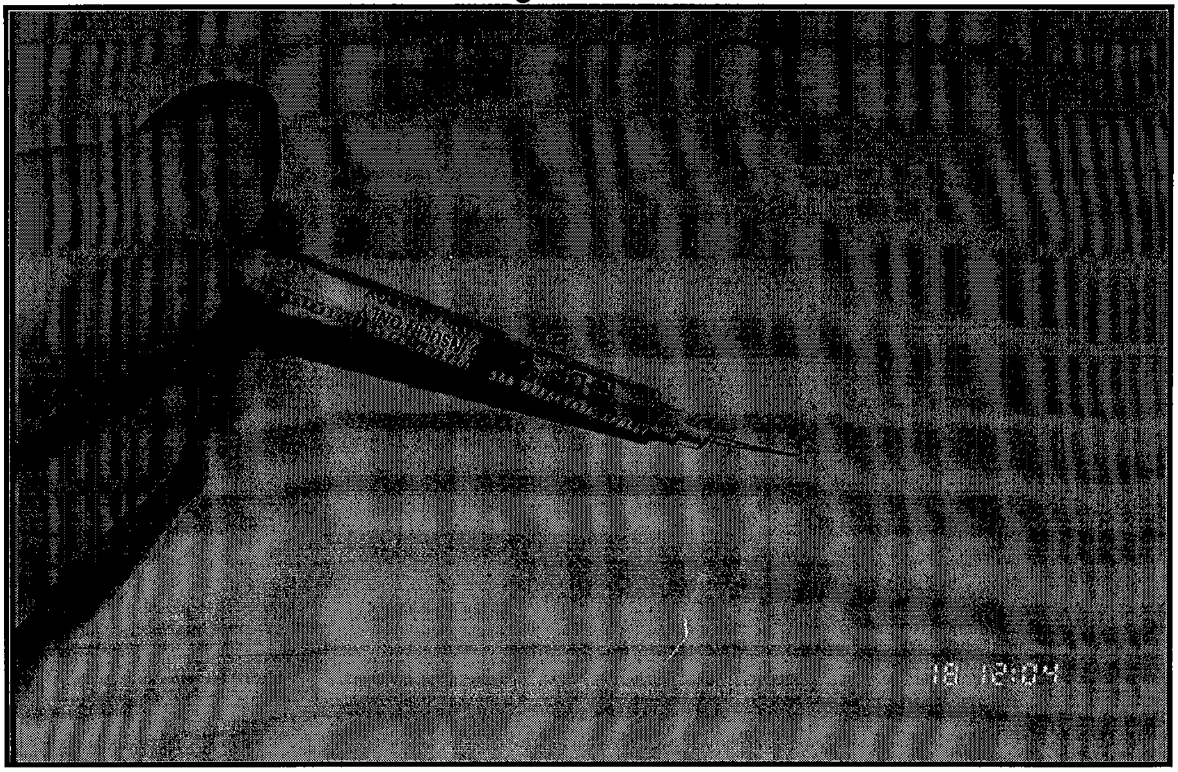

Photo 7.2
Collection of Sample from Top Surface

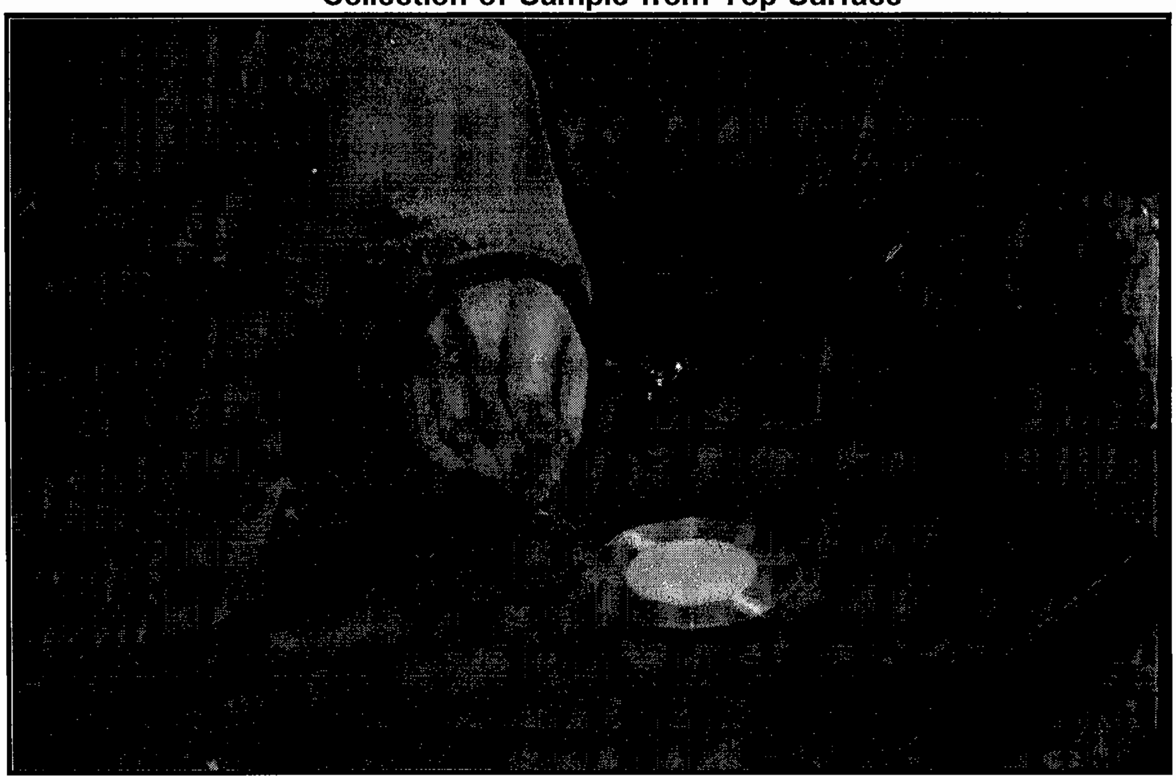

Photo 7.3
Sample of Fluid Extraction from Bottom Layer

Photo 7.4
Natural Snow Test on a Cold-Soaked Box and Flat Plate

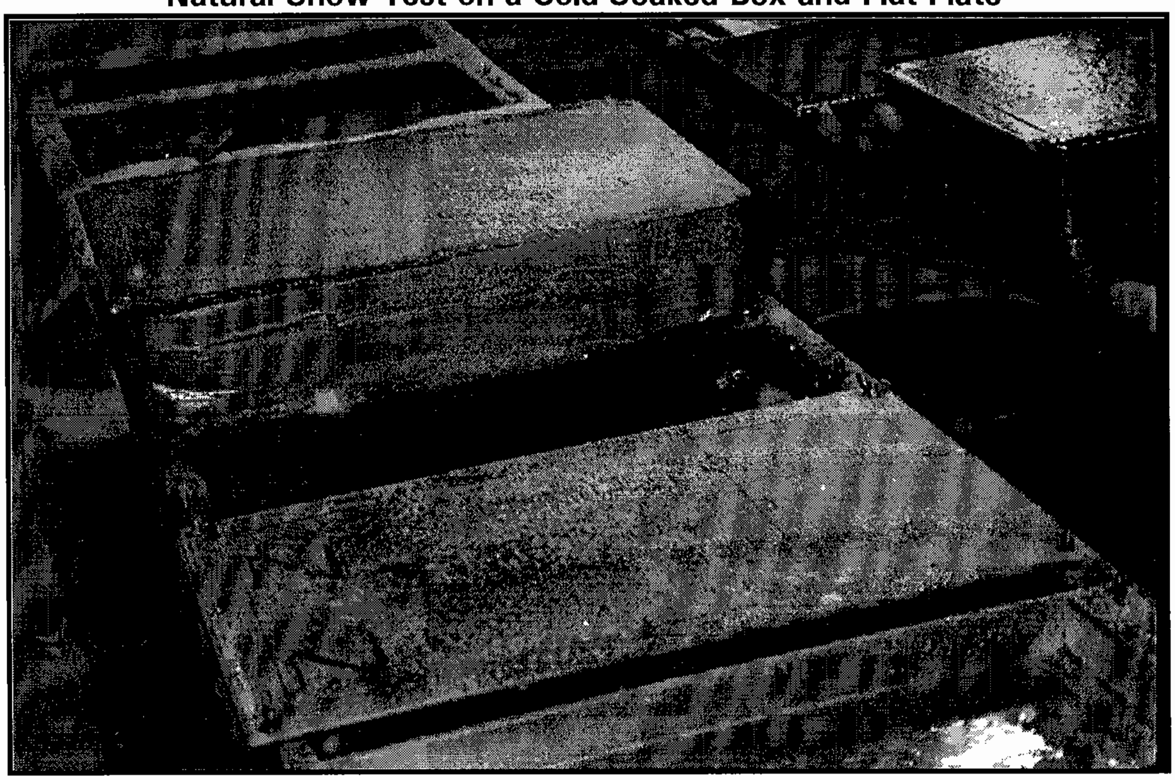

Photo 7.5
Test Setup

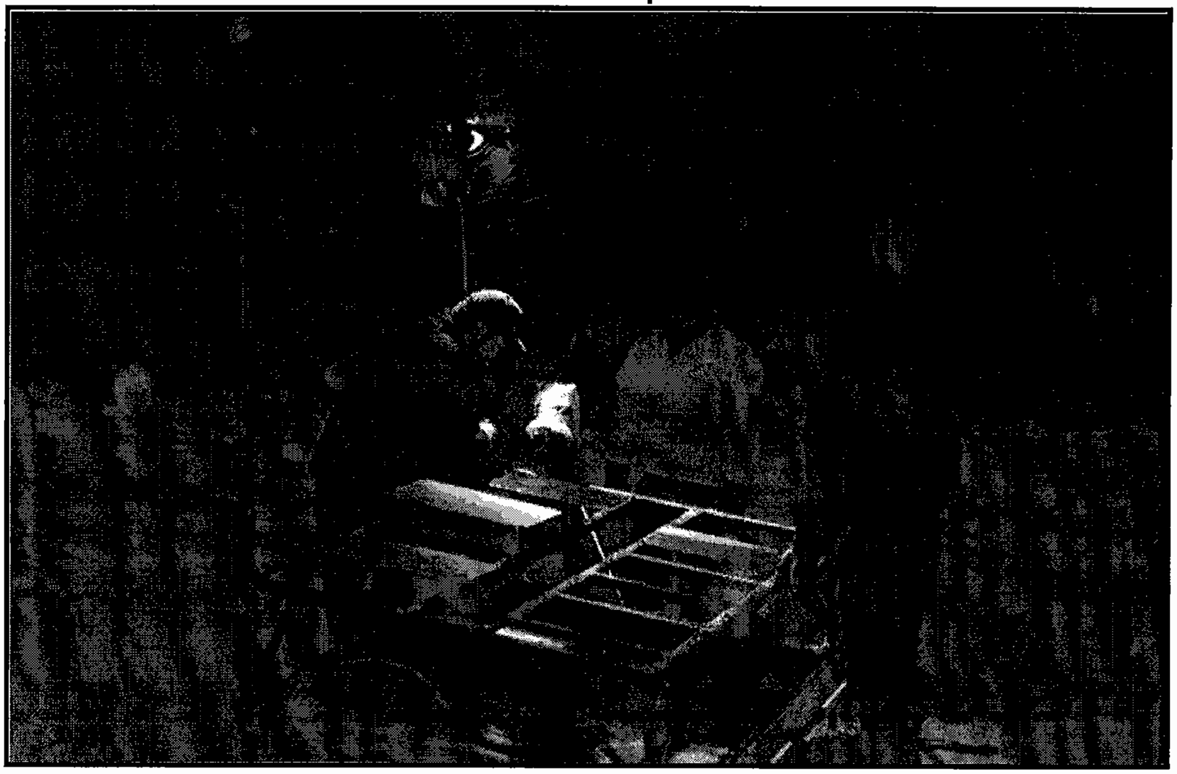

Photo 7.6
Wrapped Camera Focussed on Test Plate

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8. CONCLUSIONS

The 1996/97 winter season holdover time test program concentrated upon the determination of holdover times for Type IV fluids. All Type IV fluid brands tested were the latest formulations released by leading manufacturers. The results of these tests revealed a wide variation in performance properties among the different fluid brands. A new *protocol* for the determination of holdover times was developed. The data for each fluid and cell of the holdover time tables were subjected to a multi-variable regression analysis. From the results of the analyses, a generic Type IV fluid holdover time table was devised wherein each cell in the table contains the holdover times from the poorest performing fluid brand(s). This table was adopted as the SAE Type IV Table, and was sometimes known as the generic Type IV Table. The widely varying Type IV fluid performance observed from one fluid brand to another prompted the development of four Type IV *fluid-specific* holdover time tables. A total of 786 tests were conducted with Type IV fluids to determine 288 holdover times.

One Type III fluid was tested over the entire range of weather conditions and temperatures. The data from these tests were also subjected to the regression analysis and resulted in the generation of a Type III fluid holdover time table which was approved by the SAE G-12 Holdover Time Subcommittee.

All work was completed to substantiate the Type I and Type II holdover time tables, and recommendations are made in Section 9.

Fluid film thickness tests and an array of other supplementary tests were also carried out as part of the program. These tests were devised either to complement the holdover time tests or to investigate various fluid failure mechanisms that could not be carried out while standard flat plate tests were in progress.

The conclusions are presented as they pertain to fluid thickness tests, method of analysis, holdover time determination, supplementary tests, and finally, procedures and equipment.

8.1 Thickness Tests

The results of fluid film thickness tests of the new Type IV fluid formulations presented in Section 4 show a marked difference from previous years. The difference between the stabilized film thickness measurements of the Octagon and the Kilfrost fluids is notable. Although the performance of these two fluids was found to be exceptionally good under most of the test conditions, the mechanisms of failure protection operating for each fluid are quite dissimilar:

- The Kilfrost fluid assumes a thick film profile in its neat form but loses its ability to provide protection at lower concentrations due to pronounced thinning; and

- The neat Octagon fluid assumes a thinner film profile which thickens as it is diluted. Its holdover time performance increases relative to other fluids at less severe temperatures and lower concentrations.

Fluid thickness has been expected to play an important role in establishing holdover time. The conclusion drawn from the observations listed above is that the stabilized neat fluid film thickness does not always indicate how well a given fluid will perform at different temperatures and/or concentrations.

When Type IV, at ambient temperature, was applied over a hot Type I fluid, the combined film thickness was about 10% less than that for Type IV applied to a bare surface.

Tests conducted with both Type I and Type IV fluids heated to 80°C demonstrated that the stabilized film thickness was significantly reduced relative to tests using ambient temperature Type IV fluids only. This effect is probably the result of a reduction in Type IV fluid viscosity at elevated temperatures.

Although heated Type I fluid has little effect on fluid film thickness in a Two-Step fluid application, unintentionally heated Type IV fluid considerably effects combined fluid film thickness. As a consequence, there may be a reduction in holdover time.

8.2 Method of Analysis of Holdover Time Test Data

The precipitation rate range limits for each category of precipitation were adopted in an SAE G-12 Holdover Time Subcommittee meeting. These new limits are:

Freezing Fog	:	2	to	5	g/dm²/hr
Snow	:	10	to	25	g/dm²/hr
Freezing Drizzle	:	5	to	12.7	g/dm²/hr
Light Freezing Rain	:	12.7	to	25	g/dm²/hr
ROCSW	:	5	to	76	g/dm²/hr

A multi-variable regression *protocol* was developed to normalize the treatment of the raw Type IV fluid failure data. This way, all data were analysed using the same *protocol*, and the data for every fluid brand could be plotted separately for each and every cell in the holdover time table. As a consequence, a method now exists for the standard treatment of all holdover time data.

The test procedure for fluid failure in laboratory conditions may safely be simplified by collection of data only at the most restrictive temperature for each cell and at the precipitation limits set for a given category of precipitation. Holdover time data collected in this manner on new fluids will at once be in a form that allows convenient and confident comparison with previously collected data and with current fluid holdover times. This is the first year that a comprehensive, systematic, and reproducible method of data analysis has been implemented in the determination of holdover times.

8.3 Holdover Time Determination

8.3.1 Type IV Fluids

The Type IV fluid holdover time data were sorted by fluid brand and subjected to the regression analysis. The results for each fluid brand were compared on a cell-by-cell basis. From this exercise, a generic (SAE) Type IV fluid holdover time table has been assembled, wherein each cell contains the holdover times corresponding to the worst performing fluid brand(s). This table is more restrictive than last year's Type IV fluid holdover time table. Because this table implies a reduction in holdover times, where as the individual fluids generally had improved holdover times, it was concluded that the development of *fluid-specific* holdover time tables was imperative. The *fluid-specific* tables are less restrictive than last year's 1996/97 SAE holdover time table. Only the precipitation categories of snow, freezing drizzle, and light freezing rain were permitted to take advantage of enhanced holdover times for individual fluids. The holdover times in the remaining categories of precipitation assume cell values identical to those contained in the generic SAE table developed for the 1997/98 winter season.

Some general conclusions regarding the relative performance of Type IV fluids can be made. The holdover time performance of a Type IV fluid normally varies relative to the other Type IV fluids based on the precipitation type, temperature, and fluid dilution. Two fluids exhibit the best overall fluid performance. The performance of one of these fluids, however, is diminished at lower temperatures, while the performance of the second fluid is compromised relative to the other fluids at lower concentrations. One of the lesser performing fluids exhibits its best performance relative to the other fluids when diluted. The fourth fluid exhibits the top performance of any fluid in low temperature freezing drizzle and, in general, is a well-suited fluid for cold weather conditions.

At the time of writing this report, Union Carbide issued a statement advising that dilutions of its Ultra+ fluid are not be used due to unsatisfactory qualifying test performance.

i) Snow

Comparison of last year's 1996/97 SAE Type IV fluid holdover times in snow to those appearing in the 1997/98 SAE table shows that the lower holdover times for neat fluid and all the upper holdover times are reduced. The lower holdover times for the 75/25 and 50/50 dilutions are about the same as last year's results.

The cells in the 1997/98 SAE table for which the lower holdover times were reduced correspond to the snow conditions most commonly occurring in North American winters. They are consequently the cells most frequently referred to in pre-flight snow conditions. This important finding was one of the principal factors influencing the decision to adopt *fluid-specific* tables. The performance of one fluid in snow at the 75/25 and 50/50 dilutions was superior to the performance of the other fluid brands at these concentrations.

ii) Freezing Drizzle and Light Freezing Rain

Freezing drizzle and light freezing rain data were simultaneously subject to the regression method of analysis. The largest discontinuities in the data between these two categories of precipitation are found for the neat fluid. It is concluded that these two types of precipitation should be treated separately in future tests.

Comparison with last year's Type IV fluid holdover times in the freezing drizzle category shows that both lower and upper holdover times for neat fluids are reduced in the 1997/98 SAE table. The holdover times for 75/25 and 50/50 dilutions are higher than last year's values.

The same comparison for light freezing rain shows holdover times to be essentially unchanged for all concentrations. At most, five minute differences appear in either upper or lower holdover times. For the two lower concentrations, the performance of one fluid was superior to that of the other fluids.

iii) Freezing Fog

Only SAE generic holdover time values are approved for Type IV fluid tables for freezing fog. The lower holdover times were determined from the regression analysis using a precipitation rate of 5 $g/dm^2/hr$. Because data was not collected at the lower precipitation rate limit of 2 $g/dm^2/hr$, the upper holdover times were adopted from last year's 1996/97 SAE Type IV fluid table.

A comparison of both tables shows that the lower holdover times in this year's table have increased relative to last year's table for the two highest temperature ranges. For the lower temperature ranges, the lower holdover times are reduced relative to last year's table.

iv) Rain on a Cold-Soaked Wing

Extension of precipitation rate limits to include moderate rain (up to 76 g/dm²/hr) is the primary reason for the reductions to the lower holdover time values in this category. The upper holdover times for both cells are increased by ten minutes.

v) Final Note on Type IV Fluids

The conclusions relating to the need for more Type IV fluid data stem from the fact that the regression method of analysis was devised after the termination of the test period. Only after data were sorted by fluid type and subject to the newly devised analysis *protocol* did deficiencies in the Type IV fluid database become apparent.

The holdover times in the *fluid-specific* tables presented in Subsection 6.5 are enhanced (on average) to the following extent over last year's SAE table values.

The holdover times for Octagon, Kilfrost, Hoechst, and Union Carbide Ultra+ are respectively, 150%, 60%, 40%, and 15% higher than last year's values.

8.3.2 Type III Fluids

Type III fluid data were obtained from flat plate tests and were analysed using the newly-developed regression method. The Type III fluid test program was concluded with the generation of a fully substantiated Type III fluid holdover time table which was accepted by the SAE and fully endorsed for use during the 1997/98 winter season.

Comparison of last year's preliminary Type III fluid holdover time table (Table 1.5) to this year's Type III fluid table (Table 6.6) shows a considerable number of changes have been made to the holdover times in all conditions. In particular, the upper holdover time limits have been reduced in every cell except for rain on a cold-soaked wing. As well, the lower limit holdover times for freezing fog and freezing drizzle have increased over last year's numbers.

8.3.3 Type I Fluids

Type I fluid holdover times were unchanged from tables used during the 1996/97 winter.

8.3.4 Type II Fluids

Several changes were made to the Type II fluid holdover time table. Most of these changes are reductions to holdover times based upon a difference between Type II and Type IV fluid specifications as defined by the SAE. Type IV fluids meet all Type II fluid specifications, but the converse is not the case. This is discussed in some detail in Section 6.4.2, and the changes are listed therein.

8.4 Supplementary Tests

8.4.1 Natural Freezing Precipitation Tests Excluding Snow

Holdover times measured during natural freezing precipitation events excluding snow were examined. All snow grain, ice pellet, ice crystal and blowing snow data points fell within the holdover time ranges for snow. Three natural freezing rain points fell slightly below the holdover time range for freezing rain.

8.4.2 Recycled Fluids

Limited tests on a recycled fluid showed it to exhibit performance equivalent to a Type I fluid. It is compatible with a Type I and Type IV fluid overspray where it is intended for use as the first fluid in Two-Step fluid applications.

8.4.3 Concentration Gradient

A sampling method for establishing the existence of a glycol concentration gradient was devised.

Fluids undergoing failure tests were periodically sampled at the top and bottom of the fluid film. It was found that a concentration gradient (maximum dilution at the surface) is established early in the test and is diminished (due to thinning of the fluid) by the time failures begin to occur.

8.4.4 Cold-Soaked Boxes

Cold-soaked boxes fail more rapidly than flat plates in natural snow conditions. In cases where the variation between box and ambient temperatures was significant, the holdover time reduction could be substantial. Certain fluid brands are more adversely affected by cold-soaking than others.

8.4.5 Video Recording of Snowflake Absorption

Video recordings of precipitation impinging on fluid covered surfaces illustrate the ability to collect visual records of failure progression. They can also provide clues as to the failure mechanisms of different fluids, in different rates and categories of precipitation, and at different temperatures.

8.4.6 Evaporation Tests

The number of runs conducted in this series of tests was not sufficient to establish high confidence in results; however some trends appeared to be sufficiently strong to support the following tentative conclusions:

- Application of heated fluids, at low concentration, results in large areas of the surface being left bare and dry; and

- The freeze point of the applied fluid remaining on the surface was depressed as a result of evaporation. This is most evident where the final remaining fluid exists as a thin film on the plate surface, and also occurs in the bead of fluid that remains on its lower edge.

8.4.7 Dry-Out Tests

Based on tests in an altitude chamber, simulating an aircraft's climb to altitude and its subsequent descent, evaporation of anti-icing fluids at typical jet flight altitudes and temperatures appears to be a very slow process. Fluid loss during ground time appears to proceed much faster and aircraft ground time may be the principal influence on the time required to reach fluid dry-out.

Long exposure of fluids to ambient temperatures at ground level showed that two fluids became very thin and watery which would promote their draining from the aircraft. The third became thick and jellied which would prevent it from draining.

Use of an altitude chamber to test fluid dry-out properties does not appear to be necessary, and any future tests should consider using only a humidity control chamber.

8.5 Weather Data to Determine Boundary Conditions

Data on rates of precipitation for natural snowfall versus outside air temperature were collected to support establishing extreme weather conditions likely to be encountered. Particularly for snowfall during very low temperatures, further data are required to fully satisfy the need to establish these boundary conditions.

8.6 Procedures and Equipment

Comparison of meteorological data collected from the test site with READAC data shows a very close correlation between both sources. It is concluded that elimination of the APS meteorological apparatus and exclusive reliance upon READAC would be a cost-effective step without sacrificing the integrity of the outdoor holdover time test results. Plate pan measurements of precipitation rates should, however, be continued as this method affords the most reliable and accurate precipitation rate data.

9. RECOMMENDATIONS

The following subsections present recommendations in the areas relating to data analysis, holdover time testing, and procedures and equipment.

9.1 Analysis of Data

- The method of data analysis itself deserves further consideration. The newly-devised multiple regression *protocol* for the determination of holdover times should be applied to any new outdoor data collected. Tests in simulated conditions should be conducted at the adopted precipitation rate limits to determine the lower and upper holdover times. The holdover time data should be treated using established sampling and processing techniques. Several manufacturers will be releasing new Type IV fluid formulations which will require performance evaluation.

- The analysis of data from future freezing drizzle and light freezing rain experiments should be analysed separately due to droplet size differences in the simulation of each of the two categories.

- The rounding of all holdover times determined in future tests should be made to the most conservative five-minute interval rather than to the closest five-minute interval. This is recommended particularly for fluids exhibiting failure times shorter than fifteen minutes.

- The test data used to generate Type I and Type II holdover time tables should be subject to the new standard multiple regression methodology.

9.2 Holdover Time Tests

Recall that the method of analysis was devised after the data collection for which the results appear in this report. For this reason, there are some conditions for which a sparsity of data points persist.

It is recommended that:

- Any shortcomings in test data to satisfy the new analysis methodology be identified and corrected through conduct of further tests as needed;

- Further tests be conducted in freezing fog in particular to determine upper holdover times at the lower precipitation rate limit (2 g/dm²/hr) for which no recent fluid data are available;

- Further tests be conducted on new Type IV fluids anticipated for release during the 1997/98 winter season. These fluids will require evaluation over the entire range of conditions of the holdover time tables. In addition, a fluid from Aeroflot has been received and should be subjected to testing; and

- Tests be conducted with a new formulation of Ultra+ and with a new formulation of Type III when the fluid is available (Union Carbide has withdrawn the use of diluted forms of Ultra+ for operations during winter 1997/98).

9.3 Specifications for New Fluids

Specifications should be developed for new fluids which constrain their behaviour to within a reasonable performance envelope. The present wide variation in performance observed among the different brands of Type IV fluids results from the loose set of specifications now in existence for these fluids. In order to control this situation, it will be necessary to impose tighter specifications on new fluids. Consideration should be given to the data ranges adopted and the temperature ranges in the holdover time tables to assist in drawing up guidelines for new specifications. This will promote manufacturers to produce fluids with more competitive performance profiles and will likely eliminate the need for *fluid-specific* holdover time tables.

9.4 Test Procedures and Equipment

9.4.1 Procedures

- Increase the precipitation rate measurement frequency from 15 minutes to 10 minutes for outdoor tests on fluids with short failure times (50/50 Type IV and Type I fluids).

- Collect fluid samples on each plate subsequent to failure to evaluate the freeze point of the fluid.

- Evaluate the newly-developed visibility versus snowfall intensity table while conducting full-scale tests in natural snow at Dorval airport.

9.4.2 Equipment

- Phase out the redundancy in meteorological data acquisition. APS has relied on two sources for meteorological data up to this time: READAC, and its own set of instruments.

- 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.

9.5 Thickness Tests

Supplementary flat plate tests are required:

- To measure film thickness profiles of new fluids on flat plates; and

- To investigate further the extent to which heated Type IV fluids reduce holdover times.

9.6 Supplementary Tests

9.6.1 Evaporation Tests

It is recommended that further tests be conducted to determine operational limits for use of a diluted fluid in conditions not requiring a holdover time. Trials at various fluid concentrations and environmental conditions would be entailed. The end result of this activity would be the development of a *Deicing Only* table.

9.6.2 Dry-Out Tests

Any future trials to examine the nature of fluids as they dry-out should consider the use of a humidity control chamber. Simulation of the impact of flight conditions on the progress of dry-out does not appear to be necessary.

9.6.3 Recycled Fluids

- Recycled fluids should be subjected to a series of tests to determine holdover time in various weather conditions, and to determine compatibility with other fluids when applied as an overspray.

- It is recommended that recycled fluids be tested to determine their performance as a *Deicing Only* fluid, and their ability to produce a dry bare surface in different temperature and wind conditions.

9.6.4 Weather Data to Determine Boundary Conditions

Further data on precipitation rates needs to be gathered and analysed to refine specific precipitation boundary limits for future holdover time tests.

REFERENCES

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

2. Dawson, P., D'Avirro, J., *Validation of Methodology for Simulating a Cold-Soaked Wing*, APS Aviation Inc., Montreal, October 1996, Transportation Development Centre, TP 12899E, 92.

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

4. D'Avirro, J., Boutanios, Z., *Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1994-1995 Winter*, APS Aviation Inc., Montreal, December 1996, Transportation Development Centre, TP 12654E, 180.

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

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

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APPENDIX A

TERMS OF REFERENCE - WORK STATEMENT

TRANSPORTATION DEVELOPMENT CENTRE

WORK STATEMENT

AIRCRAFT AND FLUID HOLDOVER TIME TESTS FOR WINTER 96/97
(Short Title: Winter Tests 96/97)
(November 1996)

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 To complete the substantiation of holdover time tables and evaluate those parameters that may reduce holdover times for currently available and properly qualified, SAE deicing and anti-icing fluids (Types I,II,III and IV).

4.2 To collect weather data on winter storms at airports and to assess the precipitation, wind and temperature values that bound the holdover time ranges given in the tables.

4.3 To develop a procedure for evaluating fluid dry out characteristics and to determine the dry-out characteristics of fluids.

4.4 To determine the influence of fluid type, precipitation and wind on location and time to fluid failure initiation, and also failure progression on service aircraft .

5. DETAILED STATEMENT OF WORK

5.1 Planning and Preparation

5.1.1 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 and delivered to the TDC project officer for approval within one week of effective start date.

5.1.2 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) under no-precipitation conditions; and conduct of tests.

5.1.3 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 OSHA standards, Quebec CSST standards and applicable sections of the Canadian and Quebec 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.

5.2 Substantiation of HoldOver Time Tables

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 Completion of substantiation of existing Type I and Type II SAE holdover time tables at very low temperatures.

Conduct flat plate tests under conditions of natural snow precipitation to substantiate the existing Type I holdover time table at temperatures below -10^{0}C. Tests shall be conducted at temperatures as low as possible. Tests shall be conducted with at least two different manufacturers fluids, one propylene glycol and one ethylene glycol.
Conduct flat plate tests under conditions of natural snow precipitation to confirm the existing Type II holdover time table at temperatures between -14^{0}C and -25^{0}C, and to substantiate the existing Type II holdover time table at temperatures below -25^{0}C. Tests shall be conducted down to the lowest temperatures experienced in the field consistent with maintenance of a 7^{0}C buffer for each fluid tested. Tests shall be conducted with at least three different manufacturers fluids.
Planning shall be based on conduct of tests at Dorval Airport, Montreal. consideration shall be given to conduct of alternate test sites where the required test conditions may occur more frequently.

5.2.3 Evaluation of HoldOver Time performance of qualified Type III fluids; and Creation of a generic Type III Holdover time table.

Conduct flat plate tests under conditions of natural precipitation and in the laboratory to establish the holdover time performance of qualified Type III fluids.
Create a generic Type III HoldOver Time table in consultation with TDC.

5.2.4 Substantiation of Type IV fluids.

Conduct flat plate tests under conditions of natural precipitation and in the laboratory to substantiate the performance of new Type IV fluids over the full range of Holdover time characteristic conditions. Four new Type IV fluids are presently anticipated.

5.2.5 Review of 'Buffer' Temperatures

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

Review, from an operations standpoint, the components which contribute to these requirements including the effects of imprecise initial fluid mixture strength, discrepancies between nominal ambient temperature and actual temperature at the aircraft, discrepancies between ambient temperature and wing temperature, and possible precipitation accumulation where applicable. An independent reviewer will conduct a separate review of 'Buffer' temperatures oriented towards an evaluation of the properties of de/ant-icing fluids.

Prepare recommendations in cooperation with the independent reviewer and with TDC for possible revisions to the buffer temperatures for frost removal, for aircraft protection at very low temperatures, and to the 'lowest operational use temperature'.

5.2.6 Preparation of HoldOver Time Tables

Prepare draft revised Holdover Time tables for discussion at SAE Holdover Sub-committee meetings. Prepare presentation material for dissemination at SAE G-12 Committee meetings.

5.2.7 Presentation of findings

Participate at the SAE meeting to be held in Pittsburgh in June 1997, and present the results of the HoldOver Test work conducted during the winter season 1996/97.

5.3 Assembly of Weather Data

Assemble weather data from READAC, field measurements, and other data sources taken over several seasons for winter storms at airports for assessment of the precipitation, wind and temperature values that correspond to the limiting values given in the holdover time tables.

Data shall be assembled in a coherent electronic format, for use by others, to establish the combinations of precipitation, wind and temperature values that delimit holdover times.

5.4 Fluid Dry-Out Characteristics

5.4.1 Development of a Potential Test Procedure

Identify a potential procedure for testing the dry out characteristics of fluids using a simulated winter climb-to-altitude environment.

Base the procedure on use of a de-pressurization chamber such as that available at the Centre de Recherche Industriel du Quebec (CRIQ), or equivalent.

The procedure shall take into account action to be taken in the event that pressure and temperature cannot both correspond to a typical aircraft ascent path.

5.4.2 Characteristics of Fluids

Describe the dry-out characteristics of sample qualified Type II fluids to provide a benchmark for comparative evaluation of new fluids.

Determine the dry out characteristics of Type II and Type IV fluids.

Photographic coverage shall be provided where appropriate.

5.4.3 Acceptance Criteria

Review with aircraft operators the effects of contamination (e.g. residual grease, dirt, and ice) in 'aerodynamically quiet areas' on aircraft critical surfaces such as flap tracks, etc. Report on the significance of such contamination as it affects equipment operation, and as it affects maintenance.

Develop a tentative fluid dry-out acceptance criteria in conjunction with TDC.

5.4.4 Review and Coordination Meetings

Participate in review and coordination meetings with TDC and with the Université du Québec à Chicoutimi, Anti-icing Materials International Laboratory (AMIL) where similar work is being undertaken.

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 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 Dorval International Airport, Montreal and Pearson International Airport, Toronto 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.

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 of first point of fluid failure on the wing, and 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.

Develop a procedure for concurrent comparison testing of fluids under conditions of natural freezing precipitation on flat plates and on aircraft.
Present plans for review and approval by the TDC project officer.
Present the approved program to the airline 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 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 airline 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. Where possible fluids shall be supplied by the original fluid manufacturer to the operators on a replacement basis either directly or through intermediaries.
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
Fokker F-100	American	Dorval	West	American
Canadair RJ	Comair	Dorval	West or East	Delta
Boeing 737	Canadian	Dorval	South or East	Canadian
ATR 42	Cdn. Regl.	Dorval	East	-
D-H DASH-8	Cdn. Regl.	Toronto (or Ottawa)	N/A	-

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 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 the following conditions:

Aircraft orientations:	Headwind, Crosswind, Tailwind
Precipitation:	Snow, Freezing drizzle (If possible)
Fluids:	Type I (Predominantly), Type IV
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
Fokker F-100	1	T, C, H	Dry Run
Fokker F-100	2	T, C, H	Test F-100 & RJ in
Canadair RJ	2	T, C, H	common if possible
Boeing 737	2	T, C, H	
ATR 42	1	T, C, H	Engines running
D-H DASH-8	1	T, C, H	Engines running
Total Tests	8 + 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.

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 made through 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 Turbo-Prop Aircraft.

True functional tests with Turbo-prop aircraft; DeHavilland Dash 8 and ATR-42, 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.

Only one test series, each, shall be conducted with these aircraft, and 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.

5.5.13 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.

5.5.14 '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.

5.5.15 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.

5.5.16 Remote sensor records

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

5.5.17 Videotape Records

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

5.5.18 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.

5.5.19 Assembly and analysis of results

Assemble and analyze all results.

5.6 Fluids Physical Properties Measurements

In concert with the testing of fluids on flat plates undertaken in task 5.2 and the testing of fluids on aircraft undertaken in task 5.5, an independent researcher will conduct tests to determine the physical properties of the pertinent fluids.
Participate in a meeting with the researcher, to be called by TDC, to clarify roles and responsibilities and to establish priorities.

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. Make this plate available to the independent researcher for dedicated tests upon request. Make additional plates available for dedicated tests as requested by TDC.

5.7 Coordination with NRC
TDC will arrange with NRC to make the CEF cold chamber facility available for controlled environment testing as given in "Detailed statement of work". Co-ordinate with NRC for conduct of tests.

5.8 Presentations of test program results

5.8.1 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.

5.8.2 SAE G-12 Committee
Prepare and present, in conjunction with Transport Canada personnel, winter test program results at the SAE G-12 Committee meeting in Pittsburgh in June 1997.

5.8.3 Test Program Data
All data from tests shall be assembled in electronic format; a backup of all data files will be stored on a dedicated PC and presented to TDC. The data files will be updated on an ongoing basis throughout the test period. Graphic presentation material shall be supplied to facilitate data display.

5.9 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

Agreements as and when needed will be made by Transport Canada with the following airlines: Air Canada, American Airlines, Comair, Canadian Airlines International Ltd., 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.

APPENDIX B

APS TEST PROCEDURES
FOR DORVAL NATURAL PRECIPITATION
FLAT PLATE TESTING

CM1338.001

EXPERIMENTAL PROGRAM
FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING
1996 - 1997

APS Aviation Inc.

November 27, 1996
Version 3.0

EXPERIMENTAL PROGRAM
FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING
1996 - 1997

This document provides the detailed procedures and equipment required for the conduct of natural precipitation flat plate tests at Dorval for the 1996/97 winter season.

1. OBJECTIVE

To conduct of tests on standard flat plates as follows:

- Completion of substantiation of executing Type I and Type II SAE holdover time tables at very low temperatures;
- Evaluation of holdover time performance of qualified Type III fluids;
- Substantiation of Type IV 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 AES. 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 SAE working group. This equipment is listed in Attachment II.

4. PERSONNEL (See Attachment II)

The following personnel are required for the conduct of tests. The responsibility for each tester is provided in Attachment III.

<u>For one stand</u>

1 x Test site Leader/video
1 x End condition tester
1 x Meteo tester

<u>For two stands</u>

1 x Test site leader
2 x End condition tester
1 x Video
1 x Meteo

5. PROCEDURE

The modified test procedure is included in Attachment 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 V contains a brief summary of the steps required to conduct a test.

6. DATA FORM

The data forms are included with Attachment II. One data form was developed for the end-condition tester (Table 1) and one data form for the Meteo/video tester (Table 2).

ATTACHMENT I

NATURAL SNOW PRECIPITATION TEST PLAN / PRIORITIES

Temperature Range	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
>°C	NO	NO	NO	NO	NO	YES (1)	YES (3)	YES (4)	YES (2)
0 to -3°C	NO	NO	NO	NO	NO	YES (1)	YES (3)	YES (4)	YES (2)
-3 to -14°C	NO	NO	NO	NO		YES (1)	YES (3)		YES (2)
-14 to -25°C	YES (5)	YES (4)	YES (3)			YES (1)			YES (2)*
below -25°C	YES (4)	YES (3)	YES (2)			YES (1)			

<u>Legend:</u> NO = no tests required; YES = tests required = no tests required

* Insure 7°C buffer is maintained - for Ultra+ Type III, lowest temperature should be -22°C (29 - 7°C)

NB: Numbers given in each cell designate priority of testing for the given temperature range

For Example, if the temperature is -8°C, the first priority is to test type IV Neat fluids from different fluid manufacturers, and the second priority is to test Type III fluids.

File:g:\cm1338\procedur\nat_snow\TEST_PLN.XLS
Printed: 27/11/96 10:01 AM

ATTACHMENT II
FLAT PLATE FIELD TEST EQUIPMENT AND PROCEDURE
1996 - 1997 (Version 7.0)

This field test procedure has been developed by the Holdover Time Working Group of the SAE G-12 Committee 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 (FPD) 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 (FPD) 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 0)

A large low cakepan (6"x 6"x 2" minimum) may be used to collect and weigh snow. A plate pan (the same area as a flat plate and 4 cm deep) may be preferable since it lies like the flat plates at a 10° incline. A schematic of the plate pan is provided as Figure 0.

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 5 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 (0.01 inch) 0.25 mm 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 degrees C (1 degree 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 OAT.

2.3 Test Stand

A typical test stand is illustrated in Figure 1; 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 1 and 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 30 x 50 x 0.32 cm, for a working area of 25 x 40 cm. 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 from the panel top edge, with fifteen cross-hair points and with vertical lines

2.5 cm from each side; this marks off a working area of 25 x 45 cm on each panel. All marks shall be made using a 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 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 NRC, about 1 litre of fluid per panel is sufficient.

2.6 Film Thickness Gauge

Film thickness at the six inch 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

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.

2.9 Wind Vane

Model 2020 Qualimetrics or equivalent. To be mounted at 3 metres.

2.10 Relative Humidity Meter

Cole Parmer RH/Temperature Indicator P/N N-032321-00 with remote probe P/N N-03321030 temperature average or equivalent. Temperature limits -30 to 60°C RH range 20 to 100% accuracy ± 7% (20-30%); = -5% (30-100%); or equivalent. Available from Cole Parmer Instrument Company Chicago Illinois. The temperature gauge should be mounted at a height of 2 metres.

2.11 Ice Detection Sensors

Where feasible surface or remotely mounted ice detection sensors should be used during the tests.

2.12 Additional Equipment

- Squeegee
- Extension power cords
- Stopwatch
- Flood lights (2 x 500 watts)
- Pressurized space pens, pencils or "China Markers"
- Water repellent paper
- PC to record meteorological data

2.13 Integration of Equipment

Attachment IV provides a description of the equipment and how it is integrated.

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 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 University of Quebec at Chicoutimi (UQAC).

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

For dilution of Type I fluids, refer to the 1995/96 test procedure.

4. PROCEDURE

Attachment 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 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 Precipitation Gauge

Place the Precipitation Gauge as close as possible to the test fixture. Ensure that the interior 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 Manual Cake Pan or Plate Pan Method

Add ¼ inch 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 1.a). 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.

Use of more than one cake or plate pan is recommended to provide multiple readings through the course of the test period; mounting the pans on the test stand at the same orientation of the plates is recommended.

When using plate pans to measure precipitation rate, two plate pans shall be used. 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 placed outside (cold-soaked to ambient temperature conditions) at the start of the evening session.

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 0).

4.5 Holdover Time Testing

4.5.1 Commence recording 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

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. Record these measurements on the Form (Table 2) at the following times:

- at the start of the test;
- every 15 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.

4.8 Meteorological Observations

Meteorological observations must be recorded at the same times as in 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 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 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 5 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

Manual visibility measurements should be taken during daylight conditions. The markers to designate distance are those used by Environment Canada when these observations were being made manually.

4.9 Video Organization

The video equipment cassettes should be marked sequentially for the panning camera and the Hi 8 cameras. These #'s 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.

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.

Under conditions of moderate to heavy snow or hail, coverage may be very uneven; over about one-third of the panel should be recorded.

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 & OBSERVATIONS

Calculate and record test data, observations and comments in the format of Tables 1 and 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 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 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 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 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 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 IV

ICE SENSORS SYSTEM MANAGEMENT AND PROCEDURES

(see Test Site or Transport Canada Holdover Report Appendix B for 1995/96 winter for details)

ATTACHMENT 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 1 and 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 5th 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 VI

CHECKLIST FOR SITE LEADER FOR END OF TESTING

ITEM	ENTER DATE														
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 COMPUTER 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															

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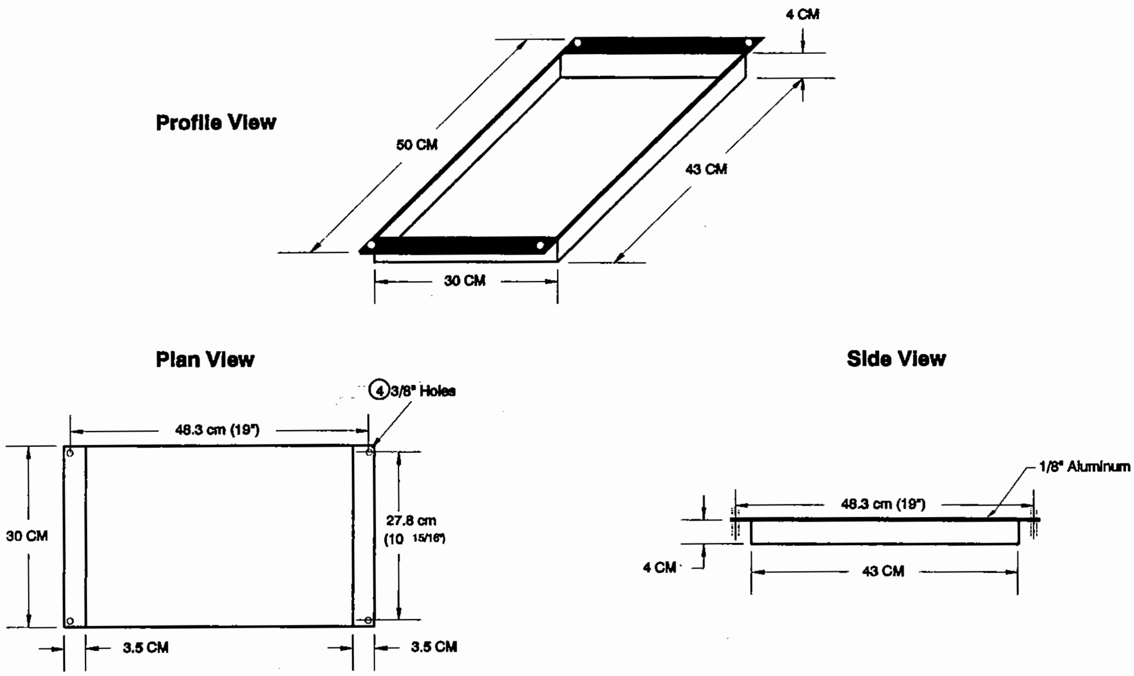
Printed: 27/11/96

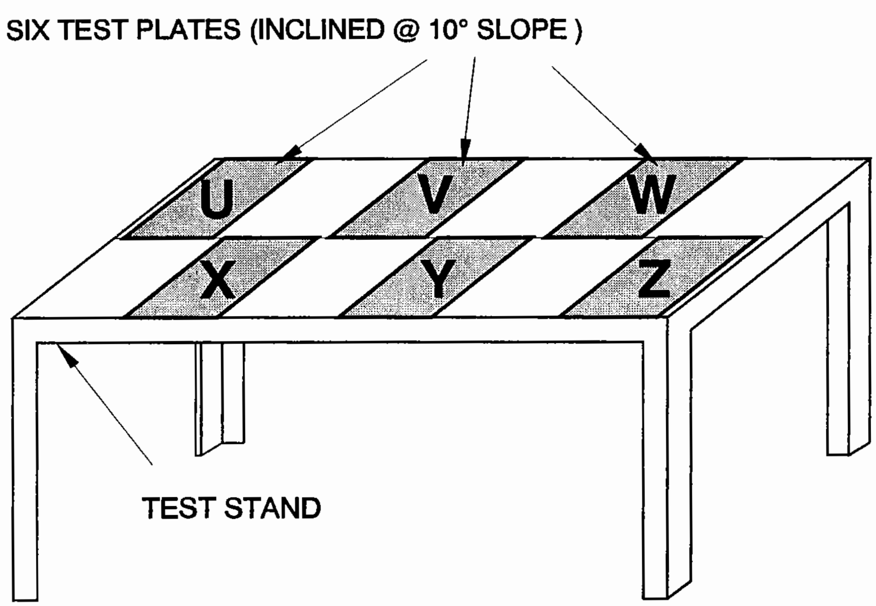
FIGURE 0

SCHEMATICS OF PLATE PAN AND TEST STAND

PLATE PAN

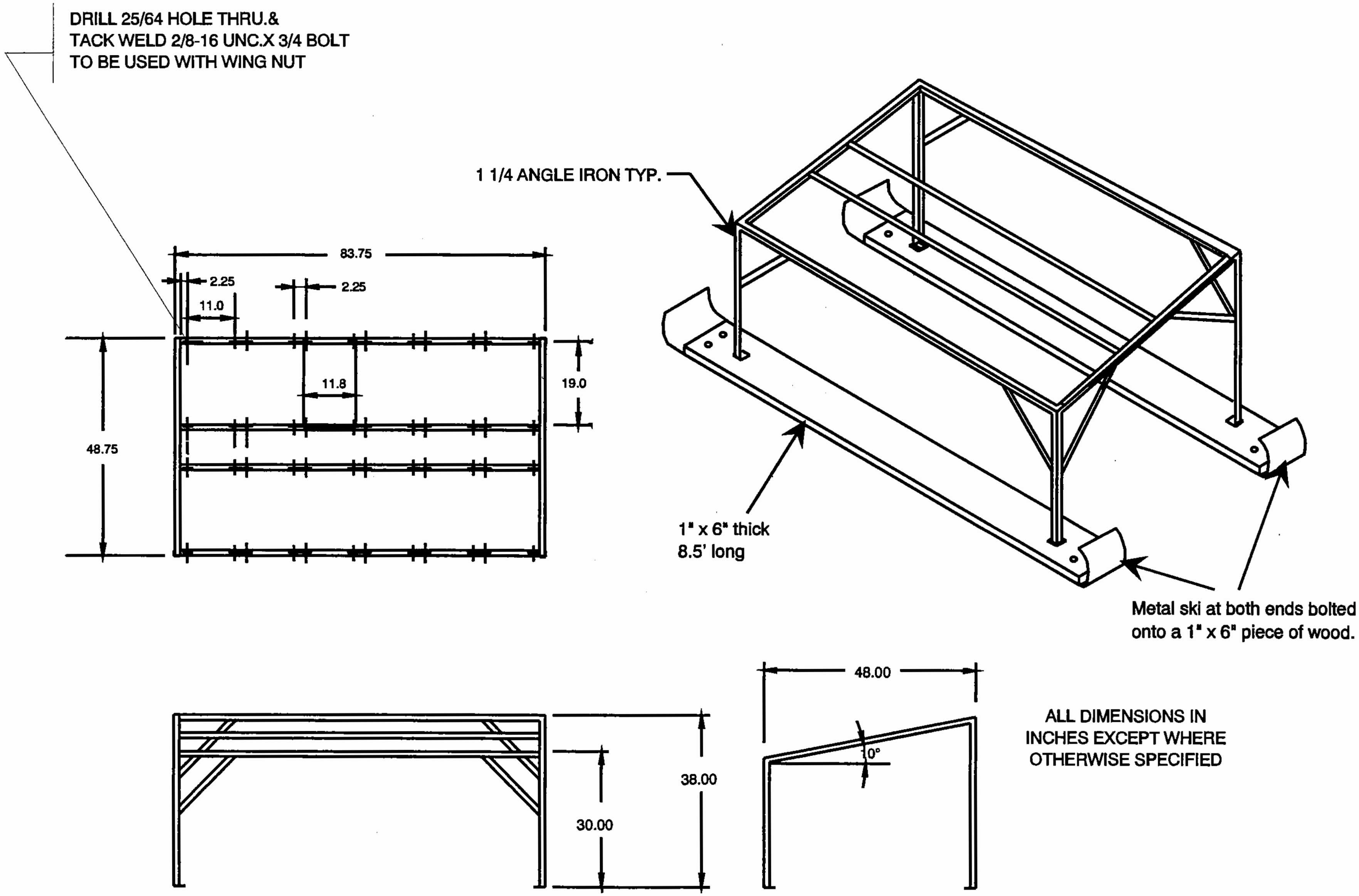


TEST STAND



cm1338\procedur\nat_snow\pan&stnd.drw

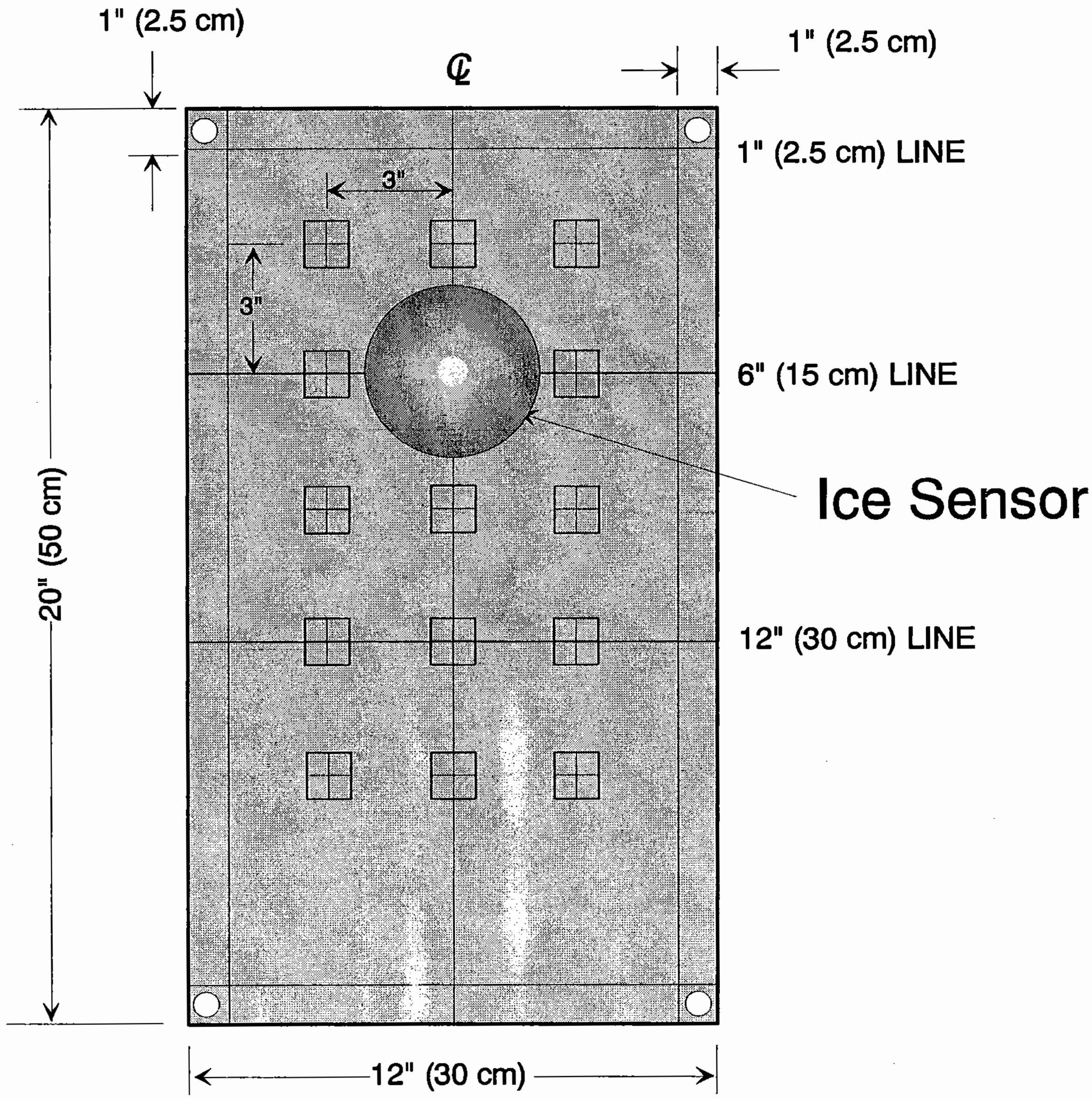
FIGURE 1
TEST STAND



cm1338\procedur\nat_snowrack_r2.drw

FIGURE 2

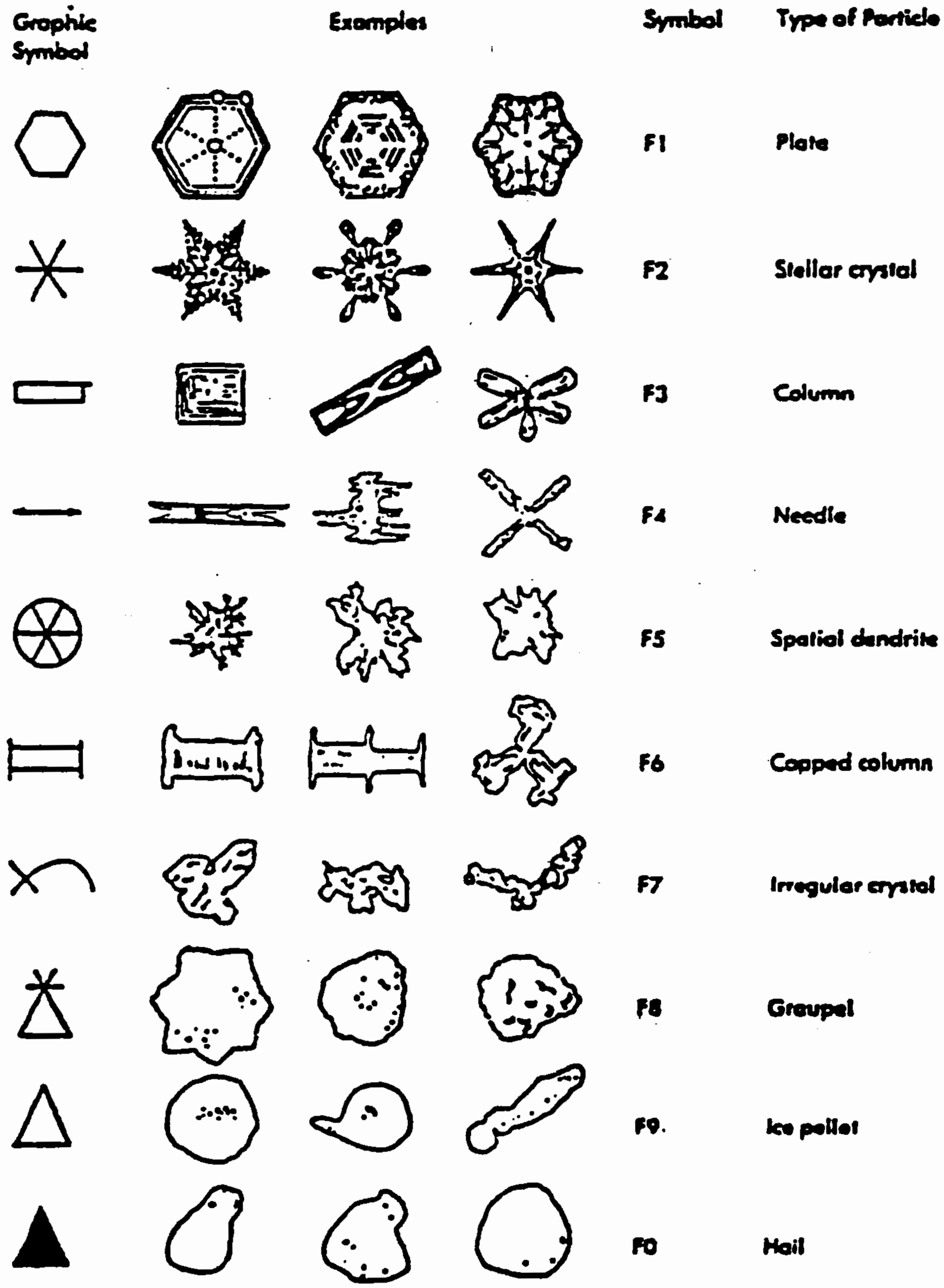
TYPICAL ICE SENSOR FLAT PLATE MARKINGS



cm1338\procedur\nat_snow\plate.drw

FIGURE 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 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 1

END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

VERSION 4.0 Winter 96/97

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 WRITTEN BY :		
TEST SITE LEADER :		

***TIME (After Fluid Application) TO FAILURE FOR INDIVIDUAL CROSSHAIRS (hr:min)**

Time of Fluid Application: ______ hr:min (U & X) ______ hr:min (V & Y) ______ hr:min (W & Z)

	Plate U			Plate V			Plate W		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									

	Plate X			Plate Y			Plate Z		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
CALCULATED FAILURE TIME (MINUTES)									

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At: Data Form Printed: 09/01/97

TABLE 2

METEO/PLATE PAN DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

VERSION 4.0 Winter 96/97

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 (Δ w*4/Δ t) (g/dm^2/h)

*measurements every 15 min. and at failure time of each test panel.

METEO OBSERVATIONS **

TIME (hr:min)	TYPE (Fig. 4) ZR, ZL,S, SG IP, IC, BS, SP	CLASSIF. (See Fig. 3)	Visibility (day only)	If SNOW, WET or DRY

**observations at beginning, end, and every 15 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 :	____________	____________

Fileg:\cm1338\procedur\nat_snow\PFORM4.XLS At:Meteo & Pan

SAMPLE OF READAC INFORMATION

LEGEND OF READAC INFORMATION

YUL 020200 11SCT22OVC58OVC/9.+/C/M/-12.0/-20.9/26110G20/037//21010/42 9+/10255/-132-120/27011G020264241//3596-1/

3596 -1	PCPN totale dans la dernière heure (0.1 mm)
3596	Quantité PCPN dans la collecteur (359.6 mm)
//	Données de verglas (intmt Z/./Z intmt/,/Z/ ou rien)
1	Unités de la moyenne de vent de deux minutes
26424	Direction et vitesse du plus haut vent de la dernière heure
G020	Rafale durant les 10 dernières minutes
27011	Direction et vitesse des vents (Moyenne 10 minutes)
-132 -120	Température Min et Max de la dernière heure
10255	Pression de la station (1025.5 mb)
42 9+	Visibilté Min et Max des 10 dernières minutes
21010	Opacité cumulative pour chaque couche de nuages (20% pour la première couche) (100% pour les deux premières couches) (100% pour les trois premières couches)
037	Calage Altimétrique (30.37)
26110G20	Direction et vitesse des vents (Moyenne de 2 minutes)
-20.9	Point de Rosée
-12.0	Température
M	Pression MSL (Toujours manquant)
C	PCPN détectée par la POSS (Type (Valeurs possibles: C,L,R,S,A et P) + intensité)
9.+	Visibilité
11SCT22OVC58OVC	Couches de Nuages
020200	Date et heure d'observation
YUL	Identification

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SAMPLE OF READAC INFORMATION

RA/ZUL/SA/062137/AUTO/19OVC/9.+/S-/M/-3.8/-9.2/18403/979//10/509+/10047/-43-37/19004G00000000//3864-0/

RA/ZUL/SA/062138/AUTO/19OVC/9.+/S-/M/-3.7/-9.1/18503/979//10/809+/10047/-43-37/19004G00000000//3864-0/

RA/ZUL/SA/062139/AUTO/19OVC/9.+/S-/M/-3.8/-9.1/18503/979//10/709+/10047/-43-37/19004G00000000//3864-0/

RA/ZUL/SA/062141/AUTO/19OVC/9.+/S-/M/-3.8/-9.2/19303/979//10/709+/10047/-43-37/19004G00000000//3864-0/

RA/ZUL/SA/062142/AUTO/19OVC36OVC/9.+/S-/M/-3.8/-9.1/20002/979//1010/609+/10047/-43-37/19004G00000000//
O

RA/ZUL/SP/062143/AUTO/19OVC37OVC/9.+/S--/M/-3.7/-9.1/20502/980//1010/609+/10048/-43-37/19003G00000000/
g

RA/ZUL/SA/062144/AUTO/19OVC/9.+/S--/M/-3.8/-9.0/00000/980//10/609+/10048/-42-37/19003G00000000//3863-0/
5

RA/ZUL/SA/062145/AUTO/19OVC/9.+/S--/M/-3.7/-9.0/00000/980//10/609+/10048/-42-37/19002G00000000//3865-0/

RA/ZUL/SA/062146/AUTO/19OVC/9.0/S--/M/-3.7/-8.8/00000/980//10/609+/10048/-42-37/19002G00000000//3863-0/

RA/ZUL/SP/062147/AUTO/19OVC/9.0/S-/M/-3.7/-8.8/22002/980//10/509+/10049/-42-37/20002G00000000//3865-0/

RA/ZUL/SA/062149/AUTO/20OVC/9.0/S-/M/-3.6/-8.9/22003/980//10/509+/10050/-42-36/21002G00000000//3865-0/

RA/ZUL/SA/062150/AUTO/20OVC/9.0/S-/M/-3.6/-8.8/22503/980//10/509+/10050/-41-36/22002G00000000//3863-0/

RA/ZUL/SA/062152/AUTO/20OVC/8.0/S-/M/-3.6/-8.9/22104/980//10/409+/10051/-41-36/22002G00000000//3863-0/

RA/ZUL/SA/062153/AUTO/21OVC/8.0/S-/M/-3.5/-8.9/22003/980//10/409+/10051/-41-35/22002G00000000//3865-0/

RA/ZUL/SA/062154/AUTO/20OVC/8.0/S-/M/-3.5/-8.8/22904/981//10/409+/10051/-40-35/22003G00000000//3863-0/

RA/ZUL/SA/062156/AUTO/20OVC/8.0/S-/M/-3.6/-8.8/24304/981//10/409+/10051/-40-35/23003G00000000//3863-0/

RA/ZUL/SA/062159/AUTO/17OVC/5.0/S-/M/-3.6/-8.8/23904/980//10/159+/10051/-39-35/23004G00000000//3864-0/

RA/ZUL/SA/062200/AUTO/17OVC/5.0/S-/M/-3.6/-8.8/24804/981//10/159+/10051/-39-35/24004G00000000//3864-0/

RA/ZUL/SA/062201/AUTO/11SCT17OVC/4.0/S-/M/-3.6/-8.9/24804/981//010/159+/10052/-39-35/24004G00000000//3
p

RA/ZUL/SA/062202/AUTO/11SCT17OVC/3.5/S-/M/-3.7/-8.9/25004/981//110/159+/10052/-39-35/24004G00000000//3

RA/ZUL/SP/062203/AUTO/11OVC/2.9V/S-/M/-3.7/-8.8/24704/981//10/15V9+/10052/-39-35/24004G00000000//3864-0

RA/ZUL/SA/062204/AUTO/11OVC/2.7V/S-/M/-3.7/-8.7/24705/981//10/15V9+/10053/-39-35/25004G00000000//3864-

RA/ZUL/SA/062205/AUTO/11OVC/2.5V/S-/M/-3.7/-8.7/25006/981//10/15V80/10053/-39-35/25005G00000000//3864-0

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PROCEDURE FOR SAMPLING FLUID TO DETERMINE CONCENTRATION GRADIENT

0) Measure Brix of Ultra + fluid.
1) Apply Ultra + fluid on plate with C/FIMS.
2) Measure Brix at 5 minutes interval on xhair adjacent to C/FIMS (C1 or C3). Take a sample at top of fluid (fluid to air interface) and at bottom of fluid (plate to fluid interface). Use a syringe for collection of sample.
3) Ensure that location for measurement is offset from one measurement to another.
4) Comment of condition (difference) of sample location as componed to C/FIMS sensor head.
5) Ensure the end condition for each xhair is determined by a trained observer (use standard flat plate form).
6) Continue testing until all xhairs have reached the end condition.

Location: ______________________ C/FIMS #: ______________________

Date: ______________________ Plate: ______________________

Run #: ______________________ Time of fluid application: ____________

Sample location: ______________

Time	**Brix Top**	**Brix Bottom**

Comments: ____

____

____

____

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APPENDIX C

DETAILED PLAN OF THE NATIONAL RESEARCH COUNCIL COLD CHAMBER TESTING

DETAILED PLAN OF NRC COLD CHAMBER TESTING 1996 - 1997

- Freezing Fog
- Freezing Drizzle and Light Freezing Rain
- Rain on a Cold-Soaked Surface

APS Aviation Inc.

April 1997
Version 4.1

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 III or 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 15 working days, including set-up time. Fluid failure will be determined by visual observation and supported by any instruments as these are made available.

It is anticipated that freesing fog tests will be conducted on the week of March 24, 1997, and freezing drizzle, light freezing rain and rain on cold-soaked surface tests will be conducted from April 14 to 25, 1997.

2. PERSONNEL

Four (4) testers will be required for the CEF testing at all times. Duties will be shared as follows:

Pan/Fluid/Video/Boxes

Tester 1/1A:
- Coordinate all equipment
- Record pan rates
- Assist end condition tester when failure times occur quickly
- Assist Team Leader
- Ensure power cables and lighting is in place
- Pour fluids
- Operate Cooling unit
- General setup
- Prepare plates, boxes and pans for each experiment
- Perform experiments
- Prepare fluids and ensure fluids are at correct temperatures
- Take video (hand-held) as required
- Ensure video equipment (tilt and pan) is operational

End Condition
Tester 2:

- Located by test stand
- Make observations and call conditions on test stand A
- Knowledge of procedures for test stands
- Setup lights and stand and cables
- Setting up, C/FIMS and video equipment
- Calling end conditions
- General setup
- Assist Tester 1 as required

Leader
Tester 3:

- Knowledge of test procedures and conditions
- Responsible for area and people
- Coordinate actions of APS team and NRC personnel
- Ensure test site is safe, functional and operational at all times.
- Supervise site personnel during the conduct of tests.
- Report to project manager on site activities on daily basis.
- Review data forms upon completion of test for completeness and correctness (sign).
- Ensure all clocks are synchronized at all times.
- Ensure fluids are available and verify fluids being used for test are correct.
- Ensure electronic data is being collected for all tests.
- Ensure proper documentation of tapes, diskettes, cassettes.
- Ensure all materials are available (pens, paper, batteries, etc.)
- Ensure all equipment is on

3. PROCEDURES

The procedures for most tests are the same as per the Flat Plate Test Procedure document. 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) Run numbers followed by a, b or c (sub-run) refer to tests conducted within a primary run.

b) Freezing fog tests will use two stands. Each stand should be started 30 minutes after the other or after the first sub-run is complete, and rates are being measured.

c) Rates will be measured before and after each run and sub-run at all tested locations. For the sub-runs, rates for only the concerned plates should be measured.

d) The sealed boxes for cold-soaked testing should be prepared in advance by T1 who will also run the cooling unit. T1A will participate in this effort.

e) Any special event should be video recorded by T1 using a hand held camera.

f) Refer to Attachment IX for the thermistor mounting procedure.

4. TEST PLAN AND EQUIPMENT LIST

Attachment VII provides the equipment list. Attachment VI provides a day by day test schedule, while Attachment V provides the more general test plan.

5. Data Form

The data forms are as follows:

- De/anti-icing data form for freezing precipitation, Attachment I
- De/anti-icing data form for cold-soak box, Attachment II
- Precipitation rate measurement, Attachment III
- Detailed precipitation rate measurement form, Attachment IIIa
- Continuous precipitation measurement form, Attachment IIIb
- Cold-soak precipitation rate measurement, Attachment IV

ATTACHMENT I

DE/ANTI-ICING DATA FORM FOR FREEZING PRECIPITATION

REMEMBER TO SYNCHRONIZE TIME — VERSION 4.0 — 1996/97

LOCATION: CEF (Ottawa)	DATE:	RUN NUMBER:	STAND # :
		am / pm	RVSI SENSOR Series #:

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

	Plate U	Plate UU	Plate V	Plate VV	Plate W	Plate WW
Time of Fluid Application: (real time)						
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						
FLUID TEMPERATURE						

	Plate XX	Plate X	Plate YY	Plate Y	Plate ZZ	Plate Z
Time of Fluid Application: (real time)						
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						
FLUO TEMPERATURE						

PRECIP: ZF , ZD , ZR, MOD — AMBIENT TEMPERATURE: ________ °C

COMMENTS: ______________________________

FAILURES CALLED BY : ______________

HAND WRITTTEN BY : ______________ LEADER: ______________

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ATTACHMENT II
DE/ANTI-ICING DATA FORM FOR COLD SOAK BOX

REMEMBER TO SYNCHRONIZE TIME — VERSION 3.0

LOCATION:	CEF (Ottawa)	DATE:	RUN NUMBER:	STAND # :	1
				am / pm	

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

Time of Fluid Application ________ ________ ________ ________

7.5 cm Box Depth

	Box A			Box B			Box C			Box D		
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												

BOX	A	B	C	D
Start T (°C)				
Final T (°C)				

Time of Fluid Application ________ ________ ________ ________

7.5 cm Box Depth

	Box E			Box F			Box G			Box H		
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												

BOX	E	F	G	H
Start T (°C)				
Final T (°C)				

AMBIENT TEMPERATURE: ________ °C

COMMENTS: ________________________________

FAILURES CALLED BY : ________

HAND WRITTTEN BY : ________

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ATTACHMENT III

PRECIPITATION RATE MEASUREMENT @ CEF IN OTTAWA

Date: ____________ Needles used: ____________

Start Time: ____________ am/pm Flow Rate of Water: ____________

Run # : ____________ Line Air Pressure: ____________

Stand: ____________ Line Air Temperature: ____________

Precip Type: ____________ (FZD, FZR, FZF, S) Line Water Pressure: ____________

Line Water Temperature: ____________

Pan Location:

U	UU	V	VV	W	WW
XX	X	YY	Y	ZZ	Z

Collection Pan:

Pan/ Cup #	Area of Pan (dm^2)	Location	Weight of Pan (g) Before	After	Collection Time (min) Start	End	Rate
		U =					
		UU =					
		V =					
		VV =					
		W =					
		WW =					
		XX =					
		X =					
		YY =					
		Y =					
		ZZ =					
		Z =					

Comments: ____________

Handwritten by: ____________

Measured by: ____________

Precipitation Rate = Δg/area (dm^2)/hr

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Printed:20/03/97

ATTACHMENT IIIA

DETAILED PRECIPITATION RATE MEASUREMENT @ CEF IN OTTAWA

Date: ______________________

Start Time: ______________________ am/pm

Run # : ______________________

Stand: ______________________

Precip Type: ______________________ (FZD, FZR, FZF, S, CS)

PLATE

1	2	3
4	5	6
7	8	9

Pan Location (Circle):

U	UU	V	VV	W	WW
XX	X	YY	Y	ZZ	Z

Collection Pan:

Pan/ Cup #	Area of Pan (dm²)	Weight of Pan (g) Before	After	Collection Time (min) Start	End	Rate
1						
2						
3						
4						
5						
6						
7						
8						
9						

Comments: ______________________

Handwritten by: ______________________

Measured by: ______________________

Precipitation Rate = Δg/area (dm²)/hr

File:g:/cm1338/procedur/cef/RATE_DET.XLS
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ATTACHMENT IIIB

CONTINUOUS PRECIPITATION RATE MEASUREMENT @ CEF IN OTTAWA

Date: ____________________

Start Time: ____________________ am/pm

Run # : ____________________

Stand: ____________________

Precip Type: ____________________ (FZD, FZR, FZF, S, CS)

Pan Location:

U	UU	V	VV	W	WW
XX	X	YY	Y	ZZ	Z

Collection Pan:

Pan/ Cup #	Area of Pan (dm²)	Location	Weight of Pan (g) Before	After	Collection Time Start	End	Rate
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: ____________________

Precipitation Rate = Δg/area (dm^2)/hr

File:g:/cm1338/procedur/cef/RATE_CON.XLS
Printed:18/03/97

ATTACHMENT IV

COLD SOAK PRECIPITATION RATE MEASUREMENT @ CEF IN OTTAWA

Date: ______________________

Start Time: ______________________ am/pm

Run # : ______________________

Precip Type: ______________________ (Drizzle, Light Rain, Moderate Rain, Heavy Rain)

Pan Location:

1	A	B	C	D
2	E	F	G	H

Collection Pan:

Pan/ Cup #	Area of Pan (dm^2)	Location		Weight of Pan (g) Before	After	Collection Time (min) Start	End	RATE
		A	=					
		B	=					
		C	=					
		D	=					
		E	=					
		F	=					
		G	=					
		H	=					

Comments: ______________________

Handwritten by: ______________________

Measured by: ______________________

Precipitation Rate = $\Delta g/\text{area } (dm^2)/hr$

File:g:\cm1338\procedur\cef\RATE_BX2.XLS
Printed:10/03/97

ATTACHMENT V

TESTS PLANNED AT CEF 1997

FREEZING FOG

Variables:

	*** Temperature:**	Above -3 °C, above -14 °C, above -25 °C, above -30 °C
	*** Fluid Type:**	STD T1, DIL T1, II 100, II 75, II 50, IV 100, IV 75, IV 50, III
	*** Fluid mfg:**	4 different ones (eg. UCAR, OCT, KILF, HOECHST)
	*** Rate of Precipitation:**	5, 8 $g/dm^2/hr$

	NUMBER OF TESTS								
TEMP. (°C)	**Type I DILUTED**	**Type I STD**	**Type II NEAT**	**Type II 75/25**	**Type II 50/50**	**Type IV NEAT**	**Type IV 75/25**	**Type IV 50/50**	**Type III std**
Above -3	S	S	S	S	S	8	8	8	2
Above -14	S	S	S	S	NA	8	8	NA	2*
Above -25	S	S	S	NA	NA	8	NA	NA	NA
Above -30	2	2	6	NA	NA	8	NA	NA	NA

S = Substantiated, no test required

NA = Not Applicable

Shaded cells = Absolutely required

* Should also include 2 extra tests at the lowest use temperature of -11°C (with 7°C buffer)

File:g/cm1338/procedur/cef/TESTS.XLS
Date: 10/03/97

ATTACHMENT V (cont'd)

TESTS PLANNED AT CEF 1997

FREEZING DRIZZLE

Variables:

- **Temperature:** Above -3 °C, above -10 °C
- **Fluid Type:** STD T1, DIL T1, II 100, II 75, IV 100, IV 75, IV 50, III
- **Fluid mfg:** 4 different ones (eg. UCAR, OCT, KILF, HOECHST)
- **Rate of Precipitation:** 4, 7, 12 $g/dm^2/hr$

	NUMBER OF TESTS								
TEMP. (°C)	**Type I DILUTED**	**Type I STD**	**Type II NEAT**	**Type II 75/25**	**Type II 50/50**	**Type IV NEAT**	**Type IV 75/25**	**Type IV 50/50**	**Type III std**
Above -3	S	S	S	S	NA	12	12	12	3
Above -10	S	S	S	S	NA	12	12	NA	3

LIGHT FREEZING RAIN

Variables:

- **Temperature:** Above -3 °C, above -10 °C
- **Fluid Type:** STD T1, DIL T1, II 100, II 75, II 50, IV 100, IV 75, IV 50, III
- **Fluid mfg:** 4 different ones (eg. UCAR, OCT, KILF, HOECHST)
- **Rate of Precipitation:** 14, 18, 25 $g/dm^2/hr$

	NUMBER OF TESTS								
TEMP. (°C)	**Type I DILUTED**	**Type I STD**	**Type II NEAT**	**Type II 75/25**	**Type II 50/50**	**Type IV NEAT**	**Type IV 75/25**	**Type IV 50/50**	**Type III std**
Above -3	S	S	S	S	NA	12	12	12	3
Above -10	S	S	S	S	NA	12	12	NA	3

S = Substantiated, no test required

NA = Not Applicable

Shaded cells = Absolutely required

File:g/cm1338/procedur/cef/TESTS.XLS
Date:10/03/97

ATTACHMENT V (cont'd)

TESTS PLANNED AT CEF 1997
COLD SOAKED BOXES

DRIZZLE

Variables:

* **OAT:**	+2 °C
* **Skin Temperature:**	-10 °C (get 1)
* **Fluid Type:**	STD T1, DIL T1, II 100, II 75, II 50, IV 100, IV 75, IV 50, III
* **Fluid mfg:**	4 different ones for Type IV (eg. UCAR, OCT, KILF, HOECHST)
* **Rate of Precipitation:**	12 g/dm²/hr
* **Box Size (Height):**	2.5, 7.5, 15 cm.

	NUMBER OF TESTS								
BOX SIZE	**Type I DILUTED**	**Type I STD**	**Type II NEAT**	**Type II 75/25**	**Type II 50/50**	**Type IV NEAT**	**Type IV 75/25**	**Type IV 50/50**	**Type III std**
2.5 cm	S	S	S	S	N/A	4	4	N/A	1
7.5 cm	S	S	S	S	N/A	4	4	N/A	1
15 cm	S	S	S	S	N/A	4	4	N/A	1

LIGHT RAIN

Variables:

* **OAT:**	+2 °C
* **Skin Temperature:**	-10 °C (get 1)
* **Fluid Type:**	STD T1, DIL T1, II 100, II 75, II 50, IV 100, IV 75, IV 50, III
* **Fluid mfg:**	4 different ones for Type IV (eg. UCAR, OCT, KILF, HOECHST)
* **Rate of Precipitation:**	25 g/dm²/hr
* **Box Size (Height):**	2.5, 7.5, 15 cm.

	NUMBER OF TESTS								
BOX SIZE	**Type I DILUTED**	**Type I STD**	**Type II NEAT**	**Type II 75/25**	**Type II 50/50**	**Type IV NEAT**	**Type IV 75/25**	**Type IV 50/50**	**Type III std**
2.5 cm	S	S	S	S	N/A	4	4	N/A	1
7.5 cm	S	S	S	S	N/A	4	4	N/A	1
15 cm	S	S	S	S	N/A	4	4	N/A	1

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Date:10/03/97

TESTS PLANNED AT CEF 1997
COLD SOAKED BOXES

MODERATE RAIN

Variables:

*** OAT:**	+2 °C
*** Skin Temperature:**	-10 °C (get 1)
*** Fluid Type:**	STD T1, DIL T1, II 100, II 75, II 50, IV 100, IV 75, IV 50, III
*** Fluid mfg:**	4 different ones for Type IV (eg. UCAR, OCT, KILF, HOECHST)
*** Rate of Precipitation:**	75 g/dm²/hr
*** Box Size (Height):**	2.5, 7.5, 15 cm.

	NUMBER OF TESTS								
BOX SIZE	**Type I DILUTED**	**Type I STD**	**Type II NEAT**	**Type II 75/25**	**Type II 50/50**	**Type IV NEAT**	**Type IV 75/25**	**Type IV 50/50**	**Type III std**
2.5 cm	S	S	S	S	N/A	4	4	N/A	1
7.5 cm	S	S	S	S	N/A	4	4	N/A	1
15 cm	S	S	S	S	N/A	4	4	N/A	1

HEAVY RAIN

Variables:

*** OAT:**	+2 °C
*** Skin Temperature:**	-10 °C (get 1)
*** Fluid Type:**	STD T1, DIL T1, II 100, II 75, II 50, IV 100, IV 75, IV 50, III
*** Fluid mfg:**	4 different ones for Type IV
*** Rate of Precipitation:**	(eg. UCAR, OCT, KILF, HOECHST)
*** Box Size (Height):**	>75 g/dm²/hr
	2.5, 7.5, 15 cm.

	NUMBER OF TESTS								
BOX SIZE	**Type I DILUTED**	**Type I STD**	**Type II NEAT**	**Type II 75/25**	**Type II 50/50**	**Type IV NEAT**	**Type IV 75/25**	**Type IV 50/50**	**Type III std**
2.5 cm	S	S	S	S	N/A	1	1	N/A	1
7.5 cm	S	S	S	S	N/A	1	1	N/A	1
15 cm	S	S	S	S	N/A	1	1	N/A	1

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Date:10/03/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

FREEZING FOG

RUN # :	1	**DAY :**	**1**
TEMP :	>-30 ° C	ETC :	130 min
PRECIP.:	ZF	STAND :	1

	RATE	U+/IV/100 (C/FIMS)	O/II/100 (C/FIMS)	XL54/STD (C/FIMS)	
					RATE

Day 1: - Setup and Calibration of chamber

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ATTACHMENT VI

CEF DETAILED TEST PLAN

FREEZING FOG

RUN # :	1	**DAY :**	**2**
TEMP :	>-30 ° C	ETC :	130 min
PRECIP.:	ZF	STAND :	1

RATE	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	XL54/STD
XL54/STD	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	**RATE**

RUN # :	2	**DAY :**	**2**
TEMP :	>-30 ° C	ETC :	100 min
PRECIP.:	ZF	STAND :	2

RATE	H/II/100	S/II/100	O/II/100	XL54/DIL	
	H/II/100	S/II/100	O/II/100	XL54/DIL	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

FREEZING FOG

RUN # :	3	**DAY :**	**2**
TEMP :	>-25 ° C	ETC :	160 min
PRECIP.:	ZF	STAND :	1

RATE	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	
	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

FREEZING FOG

RUN # :	4	**DAY :**	**3**
TEMP :	>-14 ° C	ETC :	180 min
PRECIP.:	ZF	STAND :	1

RATE	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	
	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	**RATE**

RUN # :	5	**DAY :**	**3**
TEMP :	>-14 ° C	ETC :	130 min
PRECIP.:	ZF	STAND :	2

RATE	K/IV/75/25	U+/IV/75/25	H/IV/75/25	O/IV/75/25	U+/III/STD
U+/III/STD	K/IV/75/25	U+/IV/75/25	H/IV/75/25	O/IV/75/25	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

FREEZING FOG

RUN # :	6	**DAY :**	**4**
TEMP :	>-3 ° C	ETC :	240 min
PRECIP.:	ZF	STAND :	1

RATE	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	U+/III/STD
U+/III/STD	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	**RATE**

RUN # :	7	**DAY :**	**4**
TEMP :	>-3 ° C	ETC :	240 min
PRECIP.:	ZF	STAND :	2

RATE	K/IV/75/25 K/IV/50/50	U+/IV/75/25 U+/IV/50/50	H/IV/75/25 H/IV/50/50	O/IV/75/25	O/IV/50/50
O/IV/50/50	K/IV/75/25 K/IV/50/50	U+/IV/75/25 U+/IV/50/50	H/IV/75/25 H/IV/50/50	O/IV/75/25	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

FREEZING DRIZZLE

RUN # :	1	**DAY :**	**April 14, 1997**
TEMP :	**>-3 ° C**	ETC :	240 min
PRECIP.:	ZD	STAND :	1

RATE	K/IV/100	U+/IV/100	H/IV/100 H/IV/50	O/IV/100	U+/III U+/IV/50
U+/III K/IV/50	K/IV/100	U+/IV/100	H/IV/100 H/IV/50	O/IV/100	**RATE**

RUN # :	2	**DAY :**	**April 14, 1997**
TEMP :	**>-3 ° C**	ETC :	120 min
PRECIP.:	ZD	STAND :	1

RATE	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	K/IV/75
U+/IV/75	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

FREEZING DRIZZLE

RUN # :	3	**DAY :**	**April 15, 1997**
TEMP :	>-3 ° C	ETC :	240 min
PRECIP.:	ZD	STAND :	1

RATE	U+/IV/100	K/IV/100	H/IV/100	O/IV/100	U+/III H/IV/75
O/IV/75	U+/IV/50 U+/IV/50	K/IV/50 K/IV/50	H/IV/50 O/IV/50	O/IV/50 O/IV/50	**RATE**

RUN # :	4	**DAY :**	**April 15, 1997**
TEMP :	>-10 ° C	ETC :	120 min
PRECIP.:	ZD	STAND :	1

RATE	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	U+/III
U+/III	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

FREEZING DRIZZLE

RUN # :	5	**DAY :**	**April 16, 1997**
TEMP :	>-10 °C	ETC :	120 min
PRECIP.:	ZD	STAND :	1

RATE	U+/IV/100	K/IV/100	H/IV/100	O/IV/100	U+/III
	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	**RATE**

RUN # :	6	**DAY :**	**April 16, 1997**
TEMP :	>-10 °C	ETC :	90 min
PRECIP.:	ZD	STAND :	1

RATE	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	
	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

LIGHT FREEZING RAIN

RUN # :	7	**DAY :**	**April 16, 1997**
TEMP :	>-10 ° C	ETC :	90 min
PRECIP.:	LZR	STAND :	1

RATE	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	U+/III
U+/III	K/IV/100	U+/IV/100	H/IV/100	O/IV/100	**RATE**

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ATTACHMENT VI
CEF DETAILED TEST PLAN
LIGHT FREEZING RAIN

RUN # :	8	**DAY :**	**April 17, 1997**
TEMP :	>-10 °C	ETC :	90 min
PRECIP.:	LZR	STAND :	1

RATE	U+/IV/100	K/IV/100	H/IV/100	O/IV/100	U+/III
	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	**RATE**

RUN # :	9	**DAY :**	**April 17, 1997**
TEMP :	>-10 °C	ETC :	90 min
PRECIP.:	LZR	STAND :	1

RATE	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	
	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

LIGHT FREEZING RAIN

RUN # :	10	**DAY :**	**April 17, 1997**
TEMP :	>-3 ° C	ETC :	120 MIN
PRECIP.:	LZR	STAND :	1

RATE	K/IV/100	U+/IV/100	H/IV/100 H/IV/50	O/IV/100	U+/III U+/IV/50
U+/III K/IV/50	K/IV/100	U+/IV/100	H/IV/100 H/IV/50	O/IV/100	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

LIGHT FREEZING RAIN

RUN # :	12	**DAY :**	**April 18, 1997**
TEMP :	>-3 ° C	ETC :	90 MIN
PRECIP.:	LZR	STAND :	1

RATE	U+/IV/100	K/IV/100	H/IV/100	O/IV/100	U+/III H/IV/75
O/IV/75	U+/IV/50 U+/IV/50	K/IV/50 K/IV/50	H/IV/50 O/IV/50	O/IV/50 O/IV/50	**RATE**

RUN # :	13	**DAY :**	**April 18, 1997**
TEMP :	>-3 ° C	ETC :	60 MIN
PRECIP.:	LZR	STAND :	1

RATE	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	K/IV/75
U+/IV/75	U+/IV/75	K/IV/75	H/IV/75	O/IV/75	**RATE**

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ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # :	1	DAY:	April 21, 1997
TEMP.:	+2°C	Estim. HOT:	120 min.
PRECIP	**FZD**		

	Box A	***Box B***	***Box C***	
RATE	ULTRA+ Type IV Neat (2.5 CM)	OCTAGON Type IV Neat (7.5 CM)	KILFROST Type IV Neat (15 CM)	
	Box D	***Box E***	***Box F***	
	OCTAGON Type IV Neat (2.5 CM)	HOECHST Type IV Neat (7.5 CM)	OCTAGON Type IV Neat (15 CM)	**RATE**

RUN # :	2	DAY:	April 21, 1997
TEMP.:	+2°C	Estim. HOT:	120 min.
PRECIP	**FZD**		

	Box A	***Box B***	***Box C***	
RATE	HOECHST Type IV Neat (2.5 CM)	ULTRA+ Type IV Neat (7.5 CM)	ULTRA+ Type IV Neat (15 CM)	
	Box D	***Box E***	***Box F***	
	KILFROST Type IV Neat (2.5 CM)	KILFROST Type IV Neat (7.5 CM)	HOECHST Type IV Neat (15 CM)	**RATE**

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At: COLDSOAK, 08/04/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # :	3	DAY:	April 21, 1997
TEMP.:	+2°C	Estim. HOT:	90 min.
PRECIP	**FZD**		

	Box A	***Box B***	***Box C***	
RATE	OCTAGON Type IV 75/25 (2.5 CM)	ULTRA+ Type IV 75/25 (7.5 CM)	ULTRA+ Type IV 75/25 (15 CM)	
	Box D	***Box E***	***Box F***	
	KILFROST Type IV 75/25 (2.5 CM)	HOECHST Type IV 75/25 (7.5 CM)	HOECHST Type IV 75/25 (15 CM)	**RATE**

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At: COLDSOAK, 08/04/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # :	4	DAY:	April 22, 1997
TEMP.:	+2°C	Estim. HOT:	90 min.
PRECIP	**FZD**		

	Box A	***Box B***	***Box C***	
RATE	HOECHST Type IV 75/25 (2.5 CM)	OCTAGON Type IV 75/25 (7.5 CM)	KILFROST Type IV 75/25 (15 CM)	
	Box D	***Box E***	***Box F***	
	ULTRA+ Type IV 75/25 (2.5 CM)	KILFROST Type IV 75/25 (7.5 CM)	OCTAGON Type IV 75/25 (15 CM)	**RATE**

RUN # :	5	DAY:	April 22, 1997
TEMP.:	+2°C	Estim. HOT:	90 min.
PRECIP	**FZD**		

	Box A	***Box B***	***Box C***	
RATE	ULTRA+ Type III Std (2.5 CM)	ULTRA+ Type III Std (7.5 CM)	ULTRA+ Type III Std (15 CM)	
				RATE

File:g:\cm1338\procedur\cef\CS_PLAN.XLS
At: COLDSOAK, 08/04/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # :	6	DAY:	April 22, 1997
TEMP.:	+2°C	Estim. HOT:	90 min.
PRECIP	**LFZR**		

	Box A	***Box B***	***Box C***	
RATE	ULTRA+ Type IV Neat (2.5 CM)	OCTAGON Type IV Neat (7.5 CM)	KILFROST Type IV Neat (15 CM)	
	Box D	***Box E***	***Box F***	
	OCTAGON Type IV Neat (2.5 CM)	HOECHST Type IV Neat (7.5 CM)	OCTAGON Type IV Neat (15 CM)	**RATE**

RUN # :	7	DAY:	April 22, 1997
TEMP.:	+2°C	Estim. HOT:	90 min.
PRECIP	**LFZR**		

	Box A	***Box B***	***Box C***	
RATE	HOECHST Type IV Neat (2.5 CM)	ULTRA+ Type IV Neat (7.5 CM)	ULTRA+ Type IV Neat (15 CM)	
	Box D	***Box E***	***Box F***	
	KILFROST Type IV Neat (2.5 CM)	KILFROST Type IV Neat (7.5 CM)	HOECHST Type IV Neat (15 CM)	**RATE**

File:g:\cm1338\procedur\cef\CS_PLAN.XLS
At: COLDSOAK, 08/04/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # :	8	DAY:	April 22, 1997
TEMP.:	+2°C	Estim. HOT:	60 min.
PRECIP	**LFZR**		

	Box A	***Box B***	***Box C***	
RATE	OCTAGON Type IV 75/25 (2.5 CM)	ULTRA+ Type IV 75/25 (7.5 CM)	ULTRA+ Type IV 75/25 (15 CM)	
	Box D	***Box E***	***Box F***	
	KILFROST Type IV 75/25 (2.5 CM)	HOECHST Type IV 75/25 (7.5 CM)	HOECHST Type IV 75/25 (15 CM)	**RATE**

File:g:\cm1338\procedur\cef\CS_PLAN.XLS
At: COLDSOAK, 08/04/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # :	9	DAY:	April 23, 1997
TEMP.:	+2°C	Estim. HOT:	90 min.
PRECIP	**LFZR**		

	Box A	***Box B***	***Box C***	
RATE	HOECHST Type IV 75/25 (2.5 CM)	OCTAGON Type IV 75/25 (7.5 CM)	KILFROST Type IV 75/25 (15 CM)	
	Box D	***Box E***	***Box F***	
	ULTRA+ Type IV 75/25 (2.5 CM)	KILFROST Type IV 75/25 (7.5 CM)	OCTAGON Type IV 75/25 (15 CM)	**RATE**

RUN # :	10	DAY:	April 23, 1997
TEMP.:	+2°C	Estim. HOT:	75 min.
PRECIP	**LFZR**		

	Box A	***Box B***	***Box C***	
RATE	ULTRA+ Type III Std (2.5 CM)	ULTRA+ Type III Std (7.5 CM)	ULTRA+ Type III Std (15 CM)	
				RATE

File:g:\cm1338\procedur\cef\CS_PLAN.XLS
At: COLDSOAK, 08/04/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # :	11	DAY:	April 24, 1997
TEMP.:	+2°C	Estim. HOT:	30 min.
PRECIP	**MOD. RAIN**		

	Box A	***Box B***	***Box C***	
RATE	ULTRA+ Type IV Neat (2.5 CM)	OCTAGON Type IV Neat (7.5 CM)	KILFROST Type IV Neat (15 CM)	
	Box D	***Box E***	***Box F***	
	OCTAGON Type IV Neat (2.5 CM)	HOECHST Type IV Neat (7.5 CM)	OCTAGON Type IV Neat (15 CM)	**RATE**

RUN # :	12	DAY:	April 24, 1997
TEMP.:	+2°C	Estim. HOT:	30 min.
PRECIP	**MOD. RAIN**		

	Box A	***Box B***	***Box C***	
RATE	HOECHST Type IV Neat (2.5 CM)	ULTRA+ Type IV Neat (7.5 CM)	ULTRA+ Type IV Neat (15 CM)	
	Box D	***Box E***	***Box F***	
	KILFROST Type IV Neat (2.5 CM)	KILFROST Type IV Neat (7.5 CM)	HOECHST Type IV Neat (15 CM)	**RATE**

File:g:\cm1338\procedur\cef\CS_PLAN.XLS
At: COLDSOAK, 08/04/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # :	13	DAY:	April 24, 1997
TEMP.:	+2°C	Estim. HOT:	30 min.
PRECIP	**MOD. RAIN**		

	Box A	***Box B***	***Box C***	
RATE	OCTAGON Type IV 75/25 (2.5 CM)	ULTRA+ Type IV 75/25 (7.5 CM)	ULTRA+ Type IV 75/25 (15 CM)	
	Box D	***Box E***	***Box F***	
	KILFROST Type IV 75/25 (2.5 CM)	HOECHST Type IV 75/25 (7.5 CM)	HOECHST Type IV 75/25 (15 CM)	**RATE**

RUN # :	14	DAY:	April 24, 1997
TEMP.:	+2°C	Estim. HOT:	30 min.
PRECIP	**MOD. RAIN**		

	Box A	***Box B***	***Box C***	
RATE	HOECHST Type IV 75/25 (2.5 CM)	OCTAGON Type IV 75/25 (7.5 CM)	KILFROST Type IV 75/25 (15 CM)	
	Box D	***Box E***	***Box F***	
	ULTRA+ Type IV 75/25 (2.5 CM)	KILFROST Type IV 75/25 (7.5 CM)	OCTAGON Type IV 75/25 (15 CM)	**RATE**

File:g:\cm1338\procedur\cef\CS_PLAN.XLS
At: COLDSOAK, 08/04/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # : 15
TEMP.: +2°C
PRECIP **MOD. RAIN**

DAY: April 24, 1997
Estim. HOT: 30 min.

	Box A	***Box B***	***Box C***	
RATE	ULTRA+ Type III Std (2.5 CM)	ULTRA+ Type III Std (7.5 CM)	ULTRA+ Type III Std (15 CM)	
				RATE

File:g:\cm1338\procedur\cef\CS_PLAN.XLS
At: COLDSOAK, 08/04/97

ATTACHMENT VI

CEF DETAILED TEST PLAN

COLDSOAK HOT TESTS

RUN # : 16   DAY: April 25, 1997
TEMP.: +2°C   Estim. HOT: 30 min.
PRECIP **HEAVY RAIN**

	Box A	***Box B***	***Box C***	
RATE	ULTRA+ Type IV Neat (2.5 CM)	OCTAGON Type IV Neat (7.5 CM)	KILFROST Type IV Neat (15 CM)	
	Box D	***Box E***	***Box F***	
	HOECHST Type IV 75/25 (2.5 CM)	ULTRA+ Type IV 75/25 (7.5 CM)	OCTAGON Type IV 75/25 (15 CM)	**RATE**

RUN # : 17   DAY: April 25, 1997
TEMP.: +2°C   Estim. HOT: 30 min.
PRECIP **HEAVY RAIN**

	Box A	***Box B***	***Box C***	
RATE	ULTRA+ Type III Std (2.5 CM)	ULTRA+ Type III Std (7.5 CM)	ULTRA+ Type III Std (15 CM)	
				RATE

File:g:\cm1338\procedur\cef\CS_PLAN.XLS
At: COLDSOAK, 08/04/97

ATTACHMENT VII

NRC COLD CHAMBER TESTS MARCH 1997

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, ...)		
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		
Precipitation rate Data Forms		
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		
Thermometers		
Refractometer		
Tie wraps		
Funnels		
Temperture Probes		
Thickness Gauges		
Fluid Sampling Kit		
Scrapers		
VHF radios		

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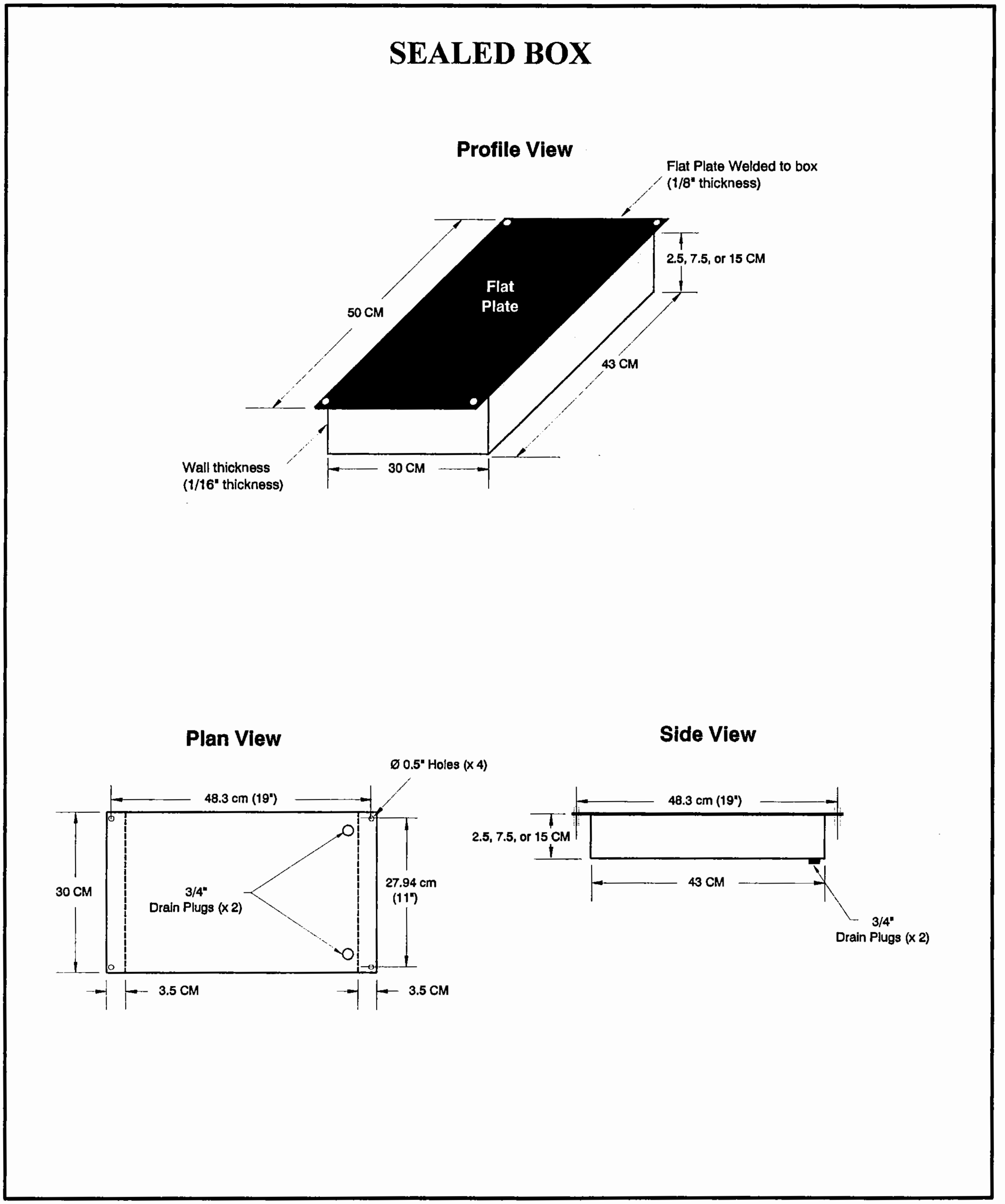
Printed: 18/03/97

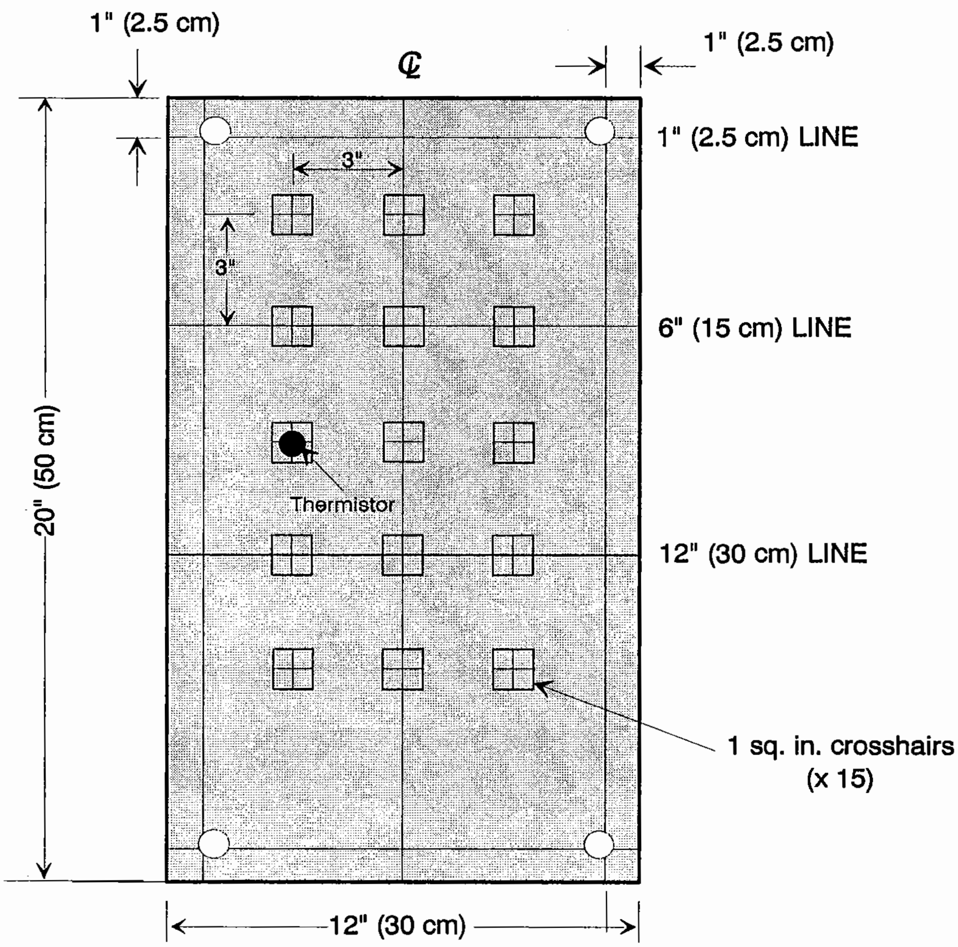
ATTACHMENT VIII

SCHEMATICS OF SEALED BOX



ATTACHMENT IX

THERMISTOR MOUNTING PROCEDURE
TYPICAL BOX



- Ensure that there are ten operational thermistors (one for each box). Each thermistor must have a clear marking relating it to the boxes (A to J) and the data logger software.
- Mount thermistors on crosshair C1 of the 9" line immediately before pouring fluid and after failure of the box is declared failed.
- Prior to mounting the thermistor, warm it up with you finger. This will provide an indication (marker) on the data logger that this sensor is being activated.
- Keep the thermistor on the plate for about 15 seconds before pouring at least three minutes after failure.

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APPENDIX D

LISTING OF FLAT PLATE TESTS CONDUCTED DURING 1996/97

NATURAL SNOW TESTS @ DORVAL 1996/97

Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data	
							temp [C]	wind [kph]
1	Dec-19-96	std	A-650	3	55	4.0	-2.7	8.6
2	Dec-19-96	std	A-650	3	49	3.9	-2.7	8.6
3	Dec-19-96	50%	C-508	4a	123	4.0	-2.6	8.5
4	Dec-19-96	50%	C-508	4a	130	6.6	-2.6	8.5
5	Dec-19-96	50%	C-507	4a	52	4.0	-2.7	8.5
6	Dec-19-96	50%	C-507	4a	57	4.4	-2.7	8.5
7	Dec-19-96	std	A-650	3	38	5.8	-2.7	8.6
8	Dec-19-96	std	A-650	3	38	5.8	-2.7	8.6
9	Dec-19-96	50%	C-507	4a	39	5.8	-2.7	8.6
10	Dec-19-96	50%	C-507	4a	42	5.7	-2.7	8.6
11	Dec-19-96	50%	C-500	4a	19	6.3	-2.7	8.5
12	Dec-19-96	50%	C-500	4a	18	6.3	-2.7	8.5
13	Dec-19-96	50%	C-508	4a	113	6.6	-2.6	8.7
14	Dec-19-96	50%	C-508	4a	117	6.5	-2.6	8.7
15	Dec-19-96	std	A-650	3	31	6.8	-2.6	8.2
16	Dec-19-96	std	A-650	3	29	7.0	-2.6	8.2
17	Dec-19-96	50%	C-507	4a	32	6.5	-2.6	8.3
18	Dec-19-96	50%	C-507	4a	35	6.5	-2.6	8.4
19	Dec-19-96	neat	C-100	4	124	6.0	-2.7	9.5
20	Dec-20-96	75%	C-707	4b	139	3.5	-3.0	11.8
21	Dec-20-96	75%	C-700	4b	75	5.6	-2.9	11.7
22	Dec-20-96	75%	C-700	4b	68	4.2	-2.9	11.8
23	Dec-20-96	std	A-650	3	48	5.2	-3.1	10.8
24	Dec-20-96	std	A-650	3	40	5.1	-3.0	10.8
25	Dec-26-96	std	A-650	3	38	6.2	-3.2	4.8
26	Dec-26-96	std	A-650	3	34	6.2	-3.2	4.8
27	Dec-26-96	50%	C-507	4a	20	7.9	-3.2	4.8
28	Dec-26-96	50%	C-507	4a	19	7.9	-3.2	4.8
29	Dec-26-96	50%	C-500	4a	39	6.2	-3.2	4.8
30	Dec-26-96	50%	C-500	4a	38	6.2	-3.2	4.8
31	Dec-26-96	50%	C-508	4a	94	5.2	-3.2	4.8
32	Dec-26-96	50%	C-508	4a	96	5.2	-3.2	4.8
33	Dec-26-96	75%	C-700	4b	56	5.0	-3.2	4.8
34	Dec-26-96	75%	C-700	4b	107	4.9	-3.2	4.8
35	Dec-26-96	75%	C-707	4b	121	5.0	-3.2	4.8
36	Dec-26-96	75%	C-707	4b	123	5.0	-3.2	4.8
37	Dec-27-96	50%	C-507	4a	23	5.7	-3.1	4.6
38	Dec-27-96	50%	C-507	4a	24	6.0	-3.1	4.7
39	Dec-27-96	50%	C-500	4a	34	6.0	-3.0	4.5
40	Dec-27-96	50%	C-500	4a	37	6.1	-3.0	4.5
41	Dec-27-96	std	A-650	3	34	6.0	-3.0	4.5
42	Dec-27-96	std	A-650	3	35	6.1	-3.0	4.5
43	Jan-02-97	std	A-650	3	29	6.1	-8.5	7.3
44	Jan-02-97	std	A-650	3	28	6.1	-8.5	7.3
45	Jan-02-97	75%	C-707	4b	66	5.7	-8.5	8.1
46	Jan-02-97	75%	C-707	4b	68	5.6	-8.5	8.2
47	Jan-02-97	75%	C-700	4b	54	5.8	-8.5	7.9
48	Jan-02-97	75%	C-700	4b	54	5.8	-8.5	7.9
49	Jan-02-97	std	A-650	3	30	6.3	-8.5	7.3
50	Jan-02-97	std	A-650	3	26	4.4	-8.5	7.2
51	Jan-02-97	75%	C-707	4b	62	5.3	-8.5	8.1
52	Jan-02-97	75%	C-707	4b	61	5.4	-8.5	8.1
53	Jan-02-97	75%	C-708	4b	142	4.7	-8.5	9.1
54	Jan-02-97	75%	C-708	4b	143	4.7	-8.5	9.1
55	Jan-02-97	neat	C-100	4	129	4.4	-8.5	9.4
56	Jan-03-97	neat	C-107	4	95	4.8	-8.3	10.3
57	Jan-03-97	neat	C-107	4	93	4.6	-8.3	10.4

File:g:\cm1338\report\hot_subs\967_SNOW.XLS
At: DRVL_LOG
Printed: 97-8-6, 4:02 PM

NATURAL SNOW TESTS @ DORVAL 1996/97

Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	APS Data wind [kph]
58	Jan-03-97	std	A-650	3	56	2.6	-8.4	9.8
59	Jan-03-97	neat	C-100	4	113	6.4	-8.3	10.5
60	Jan-03-97	neat	C-100	4	104	5.3	-8.3	10.5
61	Jan-03-97	std	A-650	3	56	2.6	-8.4	9.8
62	Jan-03-97	neat	C-108	4	90	10.3	-8.2	12.2
63	Jan-03-97	neat	C-108	4	91	10.2	-8.2	12.2
64	Jan-03-97	neat	C-100	4	79	10.2	-8.2	12.2
65	Jan-03-97	neat	C-100	4	80	10.2	-8.2	12.1
66	Jan-03-97	neat	C-107	4	76	10.3	-8.1	12.3
67	Jan-03-97	neat	C-107	4	75	10.3	-8.1	12.2
68	Jan-03-97	neat	C-100	4	85	9.0	-8.2	13.1
69	Jan-03-97	75%	C-708	4b	74	8.4	-8.2	13.3
70	Jan-03-97	75%	C-708	4b	74	8.4	-8.2	13.3
71	Jan-03-97	std	A-650	3	18	9.5	-8.2	13.2
72	Jan-03-97	std	A-650	3	18	9.5	-8.2	13.2
73	Jan-03-97	neat	C-108	4	76	8.4	-8.2	13.1
74	Jan-03-97	neat	C-108	4	76	8.4	-8.2	13.1
75	Jan-03-97	75%	C-707	4b	46	9.9	-8.2	14.0
76	Jan-03-97	std	A-650	3	25	9.8	-8.3	14.0
77	Jan-03-97	75%	C-700	4b	36	9.8	-8.2	13.6
78	Jan-03-97	75%	C-707	4b	45	9.8	-8.2	14.0
79	Jan-03-97	std	A-650	3	27	9.8	-8.3	13.9
80	Jan-03-97	75%	C-700	4b	35	9.8	-8.2	13.6
81	Jan-03-97	neat	C-107	4	84	4.5	-8.3	12.7
82	Jan-03-97	neat	C-107	4	84	4.5	-8.3	12.7
83	Jan-03-97	neat	C-108	4	99	4.9	-8.3	12.9
84	Jan-03-97	neat	C-108	4	99	4.9	-8.3	12.9
85	Jan-03-97	neat	C-100	4	100	4.9	-8.3	12.9
86	Jan-03-97	neat	C-100	4	100	4.9	-8.3	12.9
87	Jan-03-97	std	A-650	3	38	5.5	-8.3	12.0
88	Jan-03-97	std	A-650	3	37	5.5	-8.3	12.0
89	Jan-03-97	neat	C-100	4	96	5.5	-8.2	13.0
90	Jan-03-97	neat	C-100	4	98	5.5	-8.2	13.0
91	Jan-09-97	std	A-650	3	18	8.0	-9.2	10.0
92	Jan-09-97	std	A-650	3	15	8.0	-9.1	10.0
93	Jan-09-97	75%	C-700	4b	31	8.4	-9.2	10.0
94	Jan-09-97	75%	C-700	4b	31	8.4	-9.2	10.0
95	Jan-09-97	75%	C-707	4b	28	8.3	-9.2	10.0
96	Jan-09-97	75%	C-707	4b	30	8.4	-9.2	10.0
97	Jan-09-97	std	A-650	3	18	7.9	-9.3	10.0
98	Jan-09-97	std	A-650	3	19	7.9	-9.3	10.0
99	Jan-09-97	75%	C-708	4b	43	8.7	-9.3	14.0
100	Jan-09-97	75%	C-708	4b	43	8.7	-9.3	14.0
101	Jan-09-97	75%	C-707	4b	30	7.7	-9.3	12.6
102	Jan-09-97	75%	C-707	4b	30	7.7	-9.3	12.6
103	Jan-09-97	75%	C-707	4b	18	17.7	-9.5	14.4
104	Jan-09-97	75%	C-707	4b	18	17.7	-9.5	14.4
105	Jan-09-97	75%	C-708	4b	30	18.1	-9.6	14.5
106	Jan-09-97	75%	C-708	4b	30	18.1	-9.6	14.5
107	Jan-09-97	75%	C-700	4b	20	17.8	-9.6	14.5
108	Jan-09-97	75%	C-700	4b	18	17.7	-9.5	14.6
109	Jan-09-97	neat	C-107	4	17	25.2	-9.8	14.9
110	Jan-09-97	neat	C-107	4	17	25.2	-9.8	14.9
111	Jan-09-97	neat	C-100	4	24	25.4	-9.8	14.7
112	Jan-09-97	neat	C-100	4	24	25.4	-9.8	14.7
113	Jan-09-97	75%	C-708	4b	16	24.7	-9.8	15.2
114	Jan-09-97	75%	C-708	4b	16	24.7	-9.8	15.2

NATURAL SNOW TESTS @ DORVAL 1996/97

Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]
115	Jan-09-97	neat	C-108	4	26	27.3	-9.8	13.7
116	Jan-09-97	neat	C-108	4	25	27.4	-9.8	13.6
117	Jan-09-97	neat	C-107	4	20	27.9	-9.8	13.6
118	Jan-09-97	neat	C-107	4	20	27.9	-9.8	13.6
119	Jan-09-97	neat	C-100	4	24	27.3	-9.8	13.8
120	Jan-09-97	neat	C-100	4	23	27.4	-9.8	13.8
121	Jan-09-97	std	A-650	3	12	29.3	-9.8	14.2
122	Jan-09-97	std	A-650	3	12	29.3	-9.8	14.2
123	Jan-09-97	75%	C-707	4b	14	29.3	-9.8	13.9
124	Jan-09-97	75%	C-707	4b	14	29.3	-9.8	13.9
125	Jan-09-97	75%	C-700	4b	15	29.3	-9.8	14.3
126	Jan-09-97	75%	C-700	4b	15	29.3	-9.8	14.3
127	Jan-09-97	neat	A-101	2	13	23.5	-9.7	13.0
128	Jan-09-97	neat	A-101	2	14	23.5	-9.7	13.0
129	Jan-09-97	neat	C-100	4	37	17.1	-9.7	12.9
130	Jan-09-97	neat	C-100	4	37	17.1	-9.7	12.9
131	Jan-09-97	neat	C-108	4	55	15.9	-9.7	12.5
132	Jan-09-97	neat	C-108	4	58	15.9	-9.7	12.5
133	Jan-10-97	neat	A-101	2	27	14.2	-9.6	11.2
134	Jan-10-97	neat	A-101	2	28	14.3	-9.6	11.2
135	Jan-10-97	neat	C-108	4	62	14.8	-9.6	11.3
136	Jan-10-97	neat	C-108	4	67	14.8	-9.5	11.3
137	Jan-10-97	neat	C-107	4	33	14.4	-9.6	11.0
138	Jan-10-97	neat	C-107	4	37	14.6	-9.6	11.1
139	Jan-10-97	std	A-650	3	18	12.3	-9.2	11.2
140	Jan-10-97	std	A-650	3	18	12.3	-9.2	11.2
141	Jan-10-97	75%	C-700	4b	25	12.4	-9.2	11.3
142	Jan-10-97	75%	C-700	4b	26	12.4	-9.2	11.3
143	Jan-10-97	75%	C-707	4b	29	12.5	-9.1	11.3
144	Jan-10-97	75%	C-707	4b	28	12.5	-9.1	11.3
145	Jan-10-97	std	A-650	3	17	14.4	-9.1	11.2
146	Jan-10-97	std	A-650	3	16	14.4	-9.1	11.2
147	Jan-10-97	75%	C-708	4b	69	14.5	-9.0	12.0
148	Jan-10-97	75%	C-708	4b	68	14.5	-9.0	12.1
149	Jan-10-97	neat	C-107	4	41	18.9	-9.1	11.8
150	Jan-10-97	neat	C-107	4	42	18.8	-9.1	11.8
151	Jan-10-97	neat	C-108	4	74	11.0	-8.7	11.4
152	Jan-10-97	neat	C-108	4	73	11.0	-8.7	11.4
153	Jan-10-97	75%	C-708	4b	68	10.8	-8.7	11.5
154	Jan-10-97	75%	C-708	4b	68	10.8	-8.7	11.5
155	Jan-10-97	neat	C-100	4	56	10.6	-8.7	11.7
156	Jan-10-97	neat	C-100	4	54	10.5	-8.8	11.8
157	Jan-10-97	neat	C-107	4	36	13.7	-8.5	10.1
158	Jan-10-97	neat	C-107	4	35	13.7	-8.5	10.1
159	Jan-10-97	75%	C-707	4b	27	13.8	-8.5	9.9
160	Jan-10-97	75%	C-707	4b	27	13.8	-8.5	9.9
161	Jan-10-97	75%	C-700	4b	25	13.8	-8.5	9.9
162	Jan-10-97	75%	C-700	4b	24	13.8	-8.5	10.0
163	Jan-10-97	neat	A-101	2	26	10.2	-8.2	10.5
164	Jan-10-97	neat	A-101	2	25	10.2	-8.2	10.6
165	Jan-10-97	std	A-650	3	20	9.1	-8.2	10.6
166	Jan-10-97	std	A-650	3	18	9.9	-8.2	10.5
167	Jan-10-97	neat	C-100	4	72	12.1	-8.1	11.3
168	Jan-10-97	neat	C-100	4	51	14.1	-7.8	12.3
169	Jan-10-97	neat	C-100	4	53	14.1	-7.8	12.4
170	Jan-10-97	neat	C-108	4	47	13.9	-7.8	12.1
171	Jan-10-97	neat	C-108	4	47	13.9	-7.8	12.1

NATURAL SNOW TESTS @ DORVAL 1996/97

Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]
172	Jan-10-97	neat	C-107	4	42	13.9	-7.9	12.1
173	Jan-10-97	neat	C-107	4	42	13.9	-7.9	12.1
174	Jan-10-97	neat	A-205	2	32	11.0	-7.9	12.0
175	Jan-10-97	neat	A-205	2	33	11.2	-7.9	12.0
176	Jan-10-97	neat	A-101	2	24	10.1	-7.9	11.6
177	Jan-10-97	neat	A-101	2	26	10.4	-7.9	11.8
178	Jan-10-97	std	A-650	3	22	9.9	-7.9	11.6
179	Jan-10-97	std	A-650	3	20	9.5	-7.9	11.4
180	Jan-10-97	neat	C-108	4	40	17.8	-7.7	13.6
181	Jan-10-97	neat	C-108	4	39	17.8	-7.7	13.6
182	Jan-10-97	neat	C-107	4	26	19.9	-7.6	14.6
183	Jan-10-97	neat	C-107	4	26	19.9	-7.6	14.6
184	Jan-10-97	neat	C-100	4	40	17.0	-7.7	13.1
185	Jan-10-97	neat	C-100	4	38	17.8	-7.7	13.3
186	Jan-10-97	neat	A-205	2	36	17.8	-7.7	10.7
187	Jan-10-97	neat	A-205	2	36	17.8	-7.7	10.7
188	Jan-10-97	std	A-650	3	19	15.3	-7.9	10.1
189	Jan-10-97	std	A-650	3	19	15.3	-7.9	10.1
190	Jan-10-97	neat	A-101	2	37	12.8	-7.7	10.7
191	Jan-10-97	neat	A-101	2	37	12.8	-7.7	10.7
192	Jan-10-97	75%	C-708	4b	90	9.8	-6.5	10.9
193	Jan-10-97	75%	C-708	4b	90	9.8	-6.5	10.9
194	Jan-10-97	75%	C-707	4b	40	10.8	-6.9	10.7
195	Jan-10-97	75%	C-707	4b	42	10.8	-6.9	10.6
196	Jan-10-97	75%	C-700	4b	32	10.8	-7.0	10.9
197	Jan-10-97	75%	C-700	4b	29	10.8	-7.1	10.8
198	Jan-10-97	neat	C-108	4	105	9.1	-6.0	10.5
199	Jan-10-97	neat	C-108	4	105	9.1	-6.0	10.5
200	Jan-10-97	neat	C-107	4	51	10.1	-6.3	11.0
201	Jan-10-97	neat	C-107	4	51	10.1	-6.3	11.0
202	Jan-10-97	neat	C-100	4	67	9.8	-6.2	10.9
203	Jan-10-97	neat	C-100	4	67	9.8	-6.2	10.9
204	Jan-10-97	neat	C-107	4	52	8.8	-4.9	10.3
205	Jan-10-97	neat	C-107	4	50	8.9	-4.9	10.2
206	Jan-10-97	neat	C-108	4	58	8.7	-4.9	10.8
207	Jan-10-97	neat	C-108	4	63	8.6	-4.9	10.9
208	Jan-10-97	neat	C-100	4	126	8.0	-4.7	10.7
209	Jan-10-97	neat	C-100	4	125	8.0	-4.8	10.7
210	Jan-20-97	57%	B-213	1	29	5.1	-7.4	21.6
211	Jan-20-97	57%	B-213	1	28	5.1	-7.4	21.7
212	Jan-20-97	neat	A-101	2	71	4.9	-7.5	18.3
213	Jan-20-97	neat	A-101	2	75	5.2	-7.5	18.1
214	Jan-20-97	neat	A-205	2	62	5.0	-7.5	18.7
215	Jan-20-97	neat	A-205	2	58	5.1	-7.5	18.9
216	Jan-20-97	75%	C-700	4b	103	2.2	-6.8	16.5
217	Jan-20-97	75%	C-700	4b	103	2.2	-6.8	16.5
218	Jan-20-97	std	A-650	3	123	1.2	-3.9	7.6
219	Jan-20-97	std	A-650	3	110	1.1	-4.0	7.3
220	Jan-20-97	75%	C-700	4b	155	1.2	-3.7	8.6
221	Jan-22-97	neat	C-107	4	41	10.7	-8.4	9.8
222	Jan-22-97	neat	C-107	4	39	9.9	-8.3	9.8
223	Jan-22-97	neat	C-100	4	50	13.9	-8.4	9.9
224	Jan-22-97	neat	C-100	4	51	13.9	-8.4	9.9
225	Jan-22-97	75%	C-708	4b	50	13.9	-8.4	9.9
226	Jan-22-97	75%	C-708	4b	50	13.9	-8.4	9.9
227	Jan-24-97	std	A-650	3	22	5.9	-7.7	9.1
228	Jan-24-97	std	A-650	3	23	6.1	-7.7	9.0

NATURAL SNOW TESTS @ DORVAL 1996/97

Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]
229	Jan-24-97	75%	C-708	4b	48	8.3	-7.4	8.9
230	Jan-24-97	75%	C-708	4b	49	13.9	-7.4	8.8
231	Jan-24-97	neat	C-100	4	48	13.9	-7.4	8.9
232	Jan-24-97	neat	C-100	4	47	8.3	-7.4	8.9
233	Jan-24-97	75%	C-708	4b	14	39.2	-7.2	6.9
234	Jan-24-97	75%	C-708	4b	16	39.2	-7.2	7.1
235	Jan-24-97	75%	C-707	4b	11	39.2	-7.4	6.9
236	Jan-24-97	75%	C-707	4b	11	39.2	-7.4	6.9
237	Jan-24-97	75%	C-700	4b	12	39.2	-7.3	6.5
238	Jan-24-97	75%	C-700	4b	13	39.2	-7.3	6.6
239	Jan-24-97	std	A-650	3	6	44.9	-6.4	9.4
240	Jan-24-97	std	A-650	3	6	44.9	-6.4	9.4
241	Jan-24-97	neat	C-108	4	20	44.9	-5.8	7.6
242	Jan-24-97	neat	C-108	4	19	44.9	-5.8	7.6
243	Jan-24-97	neat	C-100	4	15	44.9	-5.7	7.4
244	Jan-24-97	neat	C-100	4	15	44.9	-5.7	7.4
245	Jan-24-97	std	A-650	3	6	66.2	-5.9	7.0
246	Jan-24-97	std	A-650	3	6	66.2	-5.9	7.0
247	Jan-24-97	neat	A-101	2	8	66.2	-5.9	6.7
248	Jan-24-97	neat	A-101	2	8	66.2	-5.9	6.7
249	Jan-24-97	neat	A-205	2	8	66.2	-5.8	7.7
250	Jan-24-97	neat	A-205	2	8	66.2	-5.8	7.7
251	Jan-24-97	neat	C-108	4	18	71.3	-5.3	12.7
252	Jan-24-97	neat	C-108	4	18	71.3	-5.3	12.7
253	Jan-24-97	neat	C-100	4	15	71.3	-5.3	12.9
254	Jan-24-97	neat	C-100	4	15	71.3	-5.3	12.9
255	Jan-24-97	neat	C-107	4	13	71.3	-5.2	13.1
256	Jan-24-97	neat	C-107	4	13	71.3	-5.2	13.1
257	Jan-24-97	neat	C-100	4	28	29.9	-4.6	10.3
258	Jan-24-97	neat	C-100	4	28	29.9	-4.6	10.3
259	Jan-24-97	neat	C-107	4	25	30.1	-4.5	9.8
260	Jan-24-97	neat	C-107	4	25	30.1	-4.5	9.8
261	Jan-24-97	neat	C-108	4	32	29.3	-4.6	9.3
262	Jan-24-97	neat	C-108	4	33	29.2	-4.6	9.4
263	Jan-24-97	neat	C-108	4	50	21.2	-4.4	8.9
264	Jan-24-97	neat	C-108	4	50	21.2	-4.4	8.9
265	Jan-24-97	neat	C-107	4	31	21.3	-4.4	9.3
266	Jan-24-97	neat	C-107	4	31	21.3	-4.4	9.3
267	Jan-24-97	neat	C-100	4	33	21.0	-4.5	9.4
268	Jan-24-97	neat	C-100	4	32	21.1	-4.5	9.3
269	Jan-24-97	std	A-650	3	10	28.3	-4.4	7.8
270	Jan-24-97	std	A-650	3	11	28.3	-4.5	7.8
271	Jan-24-97	75%	C-708	4b	32	32.9	-4.5	8.5
272	Jan-24-97	75%	C-708	4b	32	32.9	-4.5	8.5
273	Jan-24-97	75%	C-707	4b	18	28.9	-4.4	8.3
274	Jan-24-97	75%	C-707	4b	18	28.9	-4.4	8.3
275	Jan-24-97	std	A-650	3	11	18.9	-4.2	6.8
276	Jan-24-97	std	A-650	3	11	18.9	-4.2	6.8
277	Jan-24-97	75%	C-707	4b	28	14.8	-4.1	8.0
278	Jan-24-97	75%	C-707	4b	28	14.8	-4.1	8.0
279	Jan-25-97	75%	C-700	4b	20	18.0	-4.1	7.4
280	Jan-25-97	75%	C-700	4b	20	18.0	-4.1	7.4
281	Jan-25-97	neat	C-108	4	106	8.8	-3.4	12.1
282	Jan-25-97	neat	C-108	4	106	8.8	-3.4	12.1
283	Jan-25-97	neat	C-100	4	80	8.1	-3.5	11.3
284	Jan-25-97	neat	C-100	4	78	7.9	-3.6	11.3
285	Jan-25-97	neat	C-107	4	75	7.8	-3.6	11.3

NATURAL SNOW TESTS @ DORVAL 1996/97

Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]
286	Jan-25-97	neat	C-107	4	75	7.8	-3.6	11.3
287	Jan-25-97	neat	C-100	4	75	7.7	-3.5	11.7
288	Jan-25-97	neat	C-100	4	74	7.7	-3.4	12.3
289	Jan-25-97	neat	C-107	4	70	7.6	-3.4	12.4
290	Jan-25-97	neat	C-107	4	71	7.6	-3.4	12.4
291	Jan-25-97	neat	C-108	4	127	7.7	-2.9	14.5
292	Jan-25-97	neat	C-108	4	126	7.7	-2.9	14.5
293	Jan-27-97	neat	C-108	4	32	14.2	-15.9	11.8
294	Jan-27-97	neat	C-108	4	32	14.2	-15.9	11.8
295	Jan-27-97	neat	C-100	4	33	14.1	-15.9	11.9
296	Jan-27-97	neat	C-100	4	33	14.1	-15.9	11.9
297	Jan-27-97	neat	C-107	4	24	14.3	-15.9	11.8
298	Jan-27-97	neat	C-107	4	23	14.4	-15.9	11.8
299	Jan-27-97	std	A-650	3	17	13.5	-15.6	12.1
300	Jan-27-97	std	A-650	3	16	13.5	-15.6	12.2
301	Jan-27-97	neat	A-101	2	24	13.5	-15.6	12.5
302	Jan-27-97	neat	A-101	2	26	13.5	-15.6	12.6
303	Jan-27-97	neat	A-101	2	27	13.5	-15.5	12.6
304	Jan-27-97	neat	A-101	2	26	13.5	-15.6	12.6
305	Jan-27-97	neat	C-108	4	33	16.0	-15.1	12.0
306	Jan-27-97	neat	C-108	4	35	16.1	-15.1	12.1
307	Jan-27-97	neat	C-107	4	26	15.5	-15.1	12.1
308	Jan-27-97	neat	C-107	4	27	15.6	-15.1	12.0
309	Jan-27-97	neat	C-100	4	35	16.1	-15.0	11.8
310	Jan-27-97	neat	C-100	4	34	16.1	-15.0	11.8
311	Jan-27-97	neat	C-100	4	45	16.7	-14.2	10.5
312	Jan-27-97	neat	C-100	4	45	16.7	-14.2	10.5
313	Jan-27-97	neat	C-107	4	33	16.8	-14.2	10.8
314	Jan-27-97	neat	C-107	4	32	16.8	-14.2	10.8
315	Jan-27-97	std	A-650	3	23	17.9	-14.3	10.9
316	Jan-27-97	std	A-650	3	23	17.9	-14.3	10.9
317	Jan-27-97	75%	C-708	4b	31	19.0	-13.1	8.8
318	Jan-27-97	75%	C-708	4b	30	19.1	-13.1	8.8
319	Jan-27-97	75%	C-707	4b	24	19.3	-13.2	8.9
320	Jan-27-97	75%	C-707	4b	25	19.2	-13.2	8.9
321	Jan-27-97	75%	C-700	4b	25	19.1	-13.1	8.8
322	Jan-27-97	75%	C-700	4b	25	19.1	-13.1	8.8
323	Jan-27-97	neat	C-107	4	31	16.1	-12.3	10.5
324	Jan-27-97	neat	C-107	4	32	16.1	-12.3	10.5
325	Jan-27-97	neat	C-100	4	43	15.8	-12.3	10.5
326	Jan-27-97	neat	C-100	4	45	15.6	-12.3	10.5
327	Jan-27-97	neat	C-108	4	50	15.3	-12.3	10.5
328	Jan-27-97	neat	C-108	4	51	15.3	-12.3	10.5
329	Jan-28-97	75%	C-708	4b	41	17.9	-7.3	8.1
330	Jan-28-97	75%	C-708	4b	41	17.9	-7.3	8.1
331	Jan-28-97	75%	C-700	4b	19	18.1	-8.9	5.6
332	Jan-28-97	75%	C-700	4b	20	18.1	-8.8	5.8
333	Jan-28-97	std	A-650	3	13	18.1	-9.3	4.9
334	Jan-28-97	std	A-650	3	14	18.1	-9.1	4.9
335	Jan-28-97	neat	C-107	4	35	15.1	-4.9	11.8
336	Jan-28-97	neat	C-107	4	34	15.1	-4.9	11.8
337	Jan-28-97	neat	C-108	4	72	11.7	-4.7	11.6
338	Jan-28-97	neat	C-108	4	71	11.8	-4.7	11.6
339	Jan-28-97	neat	C-100	4	42	14.0	-4.9	11.6
340	Jan-28-97	neat	C-100	4	38	14.9	-4.9	11.6
341	Jan-28-97	neat	C-108	4	82	9.5	-4.5	11.0
342	Jan-28-97	neat	C-108	4	77	9.6	-4.5	11.0

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NATURAL SNOW TESTS @ DORVAL 1996/97

Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	APS Data wind [kph]
343	Jan-28-97	neat	C-100	4	56	10.5	-4.6	11.3
344	Jan-28-97	neat	C-100	4	55	10.6	-4.6	11.3
345	Jan-28-97	neat	C-107	4	46	10.9	-4.6	11.5
346	Jan-28-97	neat	C-107	4	45	11.0	-4.7	11.5
347	Jan-28-97	std	A-650	3	12	24.3	-4.0	11.8
348	Jan-28-97	std	A-650	3	12	24.3	-4.0	11.8
349	Jan-28-97	neat	C-108	4	68	16.7	-3.9	11.1
350	Jan-28-97	neat	C-108	4	66	16.7	-3.9	11.1
351	Jan-28-97	neat	C-100	4	34	21.9	-4.0	11.6
352	Jan-28-97	neat	C-100	4	36	21.2	-4.0	11.5
353	Jan-28-97	75%	C-700	4b	20	14.9	-4.0	11.6
354	Jan-28-97	75%	C-700	4b	17	14.9	-4.0	11.6
355	Jan-28-97	75%	C-708	4b	106	9.3	-3.6	10.6
356	Jan-28-97	75%	C-708	4b	114	9.0	-3.5	10.6
357	Jan-28-97	75%	C-707	4b	34	13.4	-3.9	11.4
358	Jan-28-97	75%	C-707	4b	31	13.4	-3.9	11.3
359	Jan-28-97	neat	C-108	4	75	9.3	-3.1	10.5
360	Jan-28-97	neat	C-108	4	75	9.3	-3.1	10.5
361	Jan-28-97	neat	C-100	4	66	8.3	-3.1	10.4
362	Jan-28-97	neat	C-100	4	64	7.8	-3.2	10.4
363	Jan-28-97	neat	C-107	4	59	7.7	-3.2	10.3
364	Jan-28-97	neat	C-107	4	59	7.7	-3.2	10.3
365	Jan-28-97	neat	C-107	4	45	11.7	-2.4	10.1
366	Jan-28-97	neat	C-107	4	47	11.5	-2.4	10.1
367	Jan-28-97	neat	C-108	4	70	14.1	-2.3	9.2
368	Jan-28-97	neat	C-108	4	59	12.8	-2.3	9.6
369	Jan-28-97	neat	C-100	4	47	11.8	-2.4	10.0
370	Jan-28-97	neat	C-100	4	45	11.7	-2.4	10.0
371	Jan-28-97	neat	C-100	4	44	17.2	-5.0	7.8
372	Jan-28-97	neat	C-100	4	44	17.2	-5.0	7.8
373	Jan-28-97	neat	C-108	4	48	17.8	-5.3	8.1
374	Jan-28-97	neat	C-108	4	49	17.8	-5.4	8.2
375	Jan-31-97	75%	C-700	4b	28	10.6	-6.2	9.0
376	Jan-31-97	75%	C-700	4b	25	11.0	-6.2	8.9
377	Jan-31-97	neat	C-100	4	57	10.0	-6.3	9.3
378	Jan-31-97	neat	C-100	4	56	10.1	-6.3	9.3
379	Jan-31-97	neat	C-107	4	48	10.1	-6.2	9.2
380	Jan-31-97	neat	C-107	4	46	10.2	-6.2	9.2
381	Jan-31-97	57%	B-213	1	9	6.8	-6.6	9.5
382	Jan-31-97	57%	B-213	1	9	6.8	-6.6	9.5
383	Jan-31-97	75%	C-707	4b	55	7.4	-6.2	9.3
384	Jan-31-97	75%	C-707	4b	57	7.4	-6.6	10.7
385	Jan-31-97	neat	C-108	4	94	7.1	-6.5	11.1
386	Jan-31-97	neat	C-108	4	90	7.1	-6.5	11.1
387	Jan-31-97	57%	B-213	1	12	7.1	-6.7	11.1
388	Jan-31-97	57%	B-213	1	11	7.1	-6.7	11.0
389	Jan-31-97	std	A-650	3	25	7.1	-6.4	12.4
390	Jan-31-97	std	A-650	3	24	7.1	-6.4	12.3
391	Jan-31-97	neat	C-100	4	73	7.3	-6.5	11.1
392	Feb-04-97	neat	C-109	4	58	17.7	-3.5	7.1
393	Feb-04-97	neat	C-109	4	70	17.4	-3.4	6.9
394	Feb-04-97	neat	C-108	4	59	17.6	-3.5	7.2
395	Feb-04-97	neat	C-108	4	60	17.6	-3.5	7.2
396	Feb-04-97	neat	C-100	4	43	19.3	-3.6	6.9
397	Feb-04-97	neat	C-100	4	38	20.8	-3.6	6.8
398	Feb-04-97	neat	C-100	4	54	16.3	-3.4	7.1
399	Feb-04-97	neat	C-100	4	58	16.1	-3.4	7.1

NATURAL SNOW TESTS @ DORVAL 1996/97

Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data	
							temp [C]	wind [kph]
400	Feb-04-97	neat	C-109	4	94	14.9	-3.3	7.0
401	Feb-04-97	neat	C-109	4	99	14.9	-3.3	7.1
402	Feb-04-97	neat	C-107	4	44	16.2	-3.5	7.0
403	Feb-04-97	neat	C-107	4	43	16.2	-3.5	6.9
404	Feb-04-97	std	A-650	3	20	10.6	-3.0	7.7
405	Feb-04-97	std	A-650	3	20	10.6	-3.0	7.7
406	Feb-04-97	75%	C-708	4b	80	11.9	-1.6	8.5
407	Feb-04-97	75%	C-708	4b	83	11.9	-1.6	8.5
408	Feb-04-97	75%	C-707	4b	35	10.5	-3.0	7.3
409	Feb-04-97	75%	C-707	4b	34	10.5	-3.0	7.3
410	Feb-04-97	75%	C-709	4b	62	15.4	-1.5	8.5
411	Feb-04-97	75%	C-709	4b	67	15.4	-1.5	8.5
412	Feb-04-97	75%	C-700	4b	32	13.2	-1.5	8.5
413	Feb-04-97	75%	C-700	4b	30	13.0	-3.0	6.7
414	Feb-04-97	std	A-650	3	24	12.5	-3.0	6.9
415	Feb-04-97	std	A-650	3	25	12.6	-3.0	6.8
416	Feb-05-97	neat	C-109	4	59	22.3	-2.5	14.3
417	Feb-05-97	neat	C-109	4	63	21.8	-2.5	13.3
418	Feb-05-97	75%	C-709	4b	32	25.1	-2.6	13.8
419	Feb-05-97	75%	C-709	4b	32	25.1	-2.6	13.8
420	Feb-05-97	75%	C-708	4b	94	18.5	-2.4	11.5
421	Feb-05-97	75%	C-708	4b	88	18.8	-2.4	9.0
422	Feb-05-97	neat	C-108	4	95	19.9	-2.4	11.5
423	Feb-05-97	neat	C-108	4	93	19.8	-2.4	11.6
424	Feb-05-97	neat	C-107	4	42	25.8	-2.5	6.1
425	Feb-05-97	neat	C-107	4	39	26.3	-2.5	6.1
426	Feb-05-97	neat	C-109	4	88	19.7	-2.4	9.0
427	Feb-05-97	neat	C-109	4	94	19.9	-2.3	8.9
428	Feb-05-97	50%	C-508	4a	68	13.4	-1.9	10.5
429	Feb-05-97	50%	C-508	4a	67	13.5	-1.9	10.5
430	Feb-05-97	50%	C-509	4a	7	19.9	-2.0	5.6
431	Feb-05-97	50%	C-509	4a	8	19.9	-2.0	5.6
432	Feb-05-97	50%	C-507	4a	13	19.9	-2.0	6.2
433	Feb-05-97	50%	C-507	4a	13	19.9	-2.0	6.2
434	Feb-05-97	neat	C-100	4	67	13.9	-1.8	10.9
435	Feb-05-97	neat	C-100	4	66	13.8	-1.8	10.9
436	Feb-05-97	neat	C-108	4	82	14.6	-1.8	10.5
437	Feb-05-97	neat	C-108	4	78	14.4	-1.8	10.7
438	Feb-05-97	std	A-650	3	13	19.3	-1.6	8.2
439	Feb-05-97	std	A-650	3	15	19.3	-1.6	8.1
440	Feb-05-97	75%	C-709	4b	42	17.3	-1.5	8.5
441	Feb-05-97	75%	C-709	4b	45	16.9	-1.5	8.5
442	Feb-05-97	75%	C-707	4b	29	18.5	-1.5	8.4
443	Feb-05-97	75%	C-707	4b	29	18.5	-1.5	8.4
444	Feb-05-97	neat	C-107	4	45	16.7	-1.4	9.4
445	Feb-05-97	neat	C-107	4	49	17.1	-1.4	9.5
446	Feb-05-97	neat	C-109	4	81	21.4	-1.3	9.0
447	Feb-05-97	neat	C-109	4	82	21.4	-1.3	9.0
448	Feb-05-97	50%	C-509	4a	8	20.8	-1.1	7.2
449	Feb-05-97	50%	C-509	4a	8	20.8	-1.1	7.2
450	Feb-05-97	50%	C-500	4a	8	20.9	-1.1	6.6
451	Feb-05-97	50%	C-500	4a	8	20.9	-1.1	6.6
452	Feb-05-97	neat	C-107	4	30	23.0	-1.3	10.3
453	Feb-05-97	neat	C-107	4	34	23.3	-1.3	10.1
454	Feb-05-97	neat	C-109	4	66	24.8	-1.1	8.4
455	Feb-05-97	neat	C-109	4	63	24.7	-1.1	8.6
456	Feb-05-97	neat	C-100	4	38	23.8	-1.2	9.6

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Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]
457	Feb-05-97	neat	C-100	4	35	23.5	-1.3	10.6
458	Feb-05-97	neat	C-108	4	52	30.5	-0.7	4.8
459	Feb-05-97	neat	C-108	4	47	30.3	-0.7	4.8
460	Feb-05-97	neat	C-107	4	32	30.5	-0.7	5.0
461	Feb-05-97	neat	C-107	4	32	29.5	-0.7	5.0
462	Feb-05-97	neat	C-100	4	40	30.2	-0.7	4.7
463	Feb-05-97	neat	C-100	4	38	30.0	-0.7	4.8
464	Feb-05-97	neat	C-108	4	53	31.6	-0.6	5.1
465	Feb-05-97	neat	C-108	4	54	31.5	-0.6	5.1
466	Feb-05-97	neat	C-109	4	52	31.5	-0.6	5.1
467	Feb-05-97	neat	C-109	4	51	31.6	-0.6	5.1
468	Feb-05-97	std	A-650	3	10	33.5	-0.6	5.2
469	Feb-05-97	std	A-650	3	10	33.5	-0.6	5.2
470	Feb-05-97	50%	C-509	4a	8	19.5	-0.5	6.7
471	Feb-05-97	50%	C-509	4a	9	19.5	-0.5	6.7
472	Feb-05-97	50%	C-507	4a	19	19.5	-0.5	6.2
473	Feb-05-97	50%	C-507	4a	21	18.9	-0.5	6.1
474	Feb-05-97	50%	C-508	4a	90	11.6	-0.7	8.2
475	Feb-05-97	50%	C-508	4a	92	11.5	-0.7	8.1
476	Feb-05-97	50%	C-508	4a	66	11.4	-0.8	9.0
477	Feb-05-97	std	A-650	3	27	9.0	-0.8	6.3
478	Feb-05-97	std	A-650	3	26	9.0	-0.8	6.4
479	Feb-05-97	50%	C-509	4a	18	7.7	-0.8	6.6
480	Feb-05-97	50%	C-509	4a	18	7.7	-0.8	6.6
481	Feb-05-97	50%	C-500	4a	20	8.4	-0.8	6.5
482	Feb-05-97	50%	C-500	4a	20	8.4	-0.8	6.5
483	Feb-05-97	75%	C-707	4b	61	5.1	-1.0	7.5
484	Feb-05-97	75%	C-700	4b	54	5.2	-0.9	7.3
485	Feb-05-97	75%	C-700	4b	54	5.2	-0.9	7.3
486	Feb-14-97	neat	C-100	4	42	13.1	-12.9	11.0
487	Feb-14-97	neat	C-100	4	39	13.3	-12.9	10.9
488	Feb-14-97	std	A-650	3	15	13.3	-13.1	10.8
489	Feb-14-97	std	A-650	3	15	13.3	-13.1	10.8
490	Feb-14-97	neat	C-107	4	28	13.3	-12.9	10.9
491	Feb-14-97	neat	C-107	4	29	13.3	-12.9	10.9
492	Feb-14-97	neat	C-108	4	41	9.5	-12.5	13.4
493	Feb-14-97	neat	C-108	4	51	9.2	-12.4	13.4
494	Feb-14-97	neat	C-100	4	73	7.8	-12.2	13.1
495	Feb-14-97	neat	C-100	4	74	7.8	-12.2	13.1
496	Feb-14-97	neat	C-109	4	81	11.3	-11.6	12.0
497	Feb-14-97	neat	C-109	4	84	11.5	-11.6	12.0
498	Feb-14-97	neat	C-108	4	46	8.7	-11.9	12.5
499	Feb-14-97	neat	C-108	4	47	8.8	-11.9	12.5
500	Feb-14-97	neat	C-100	4	79	11.4	-11.6	12.0
501	Feb-14-97	neat	C-100	4	74	11.0	-11.6	12.1
502	Feb-14-97	75%	C-709	4b	39	14.7	-10.7	10.3
503	Feb-14-97	75%	C-709	4b	41	14.8	-10.6	10.2
504	Feb-14-97	75%	C-708	4b	39	14.8	-10.6	10.2
505	Feb-14-97	75%	C-708	4b	41	14.9	-10.6	10.2
506	Feb-14-97	75%	C-707	4b	24	14.8	-10.9	10.8
507	Feb-14-97	75%	C-707	4b	21	14.7	-10.9	10.9
508	Feb-14-97	neat	C-109	4	56	14.6	-10.2	11.1
509	Feb-14-97	neat	C-109	4	59	14.7	-10.2	11.1
510	Feb-14-97	neat	C-100	4	37	13.6	-10.3	11.4
511	Feb-14-97	neat	C-100	4	43	14.1	-10.2	11.3
512	Feb-14-97	75%	C-700	4b	23	13.4	-10.3	12.2
513	Feb-14-97	75%	C-700	4b	26	13.4	-10.3	12.2

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Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]
514	Feb-14-97	neat	C-107	4	45	8.9	-10.0	10.2
515	Feb-14-97	neat	C-107	4	44	8.9	-10.0	10.2
516	Feb-14-97	neat	C-108	4	59	8.6	-9.9	10.1
517	Feb-14-97	neat	C-108	4	56	8.7	-9.9	10.1
518	Feb-14-97	57%	B-213	1	5	9.9	-10.0	9.8
519	Feb-14-97	57%	B-213	1	5	9.9	-10.0	9.8
520	Feb-14-97	std	A-650	3	31	5.9	-9.7	9.0
521	Feb-14-97	std	A-650	3	39	5.7	-9.7	9.0
522	Mar-04-97	neat	C-107	4	59	7.1	-4.4	10.9
523	Mar-04-97	neat	C-107	4	61	7.2	-4.4	10.8
524	Mar-04-97	75%	C-708	4b	114	8.9	-4.3	10.0
525	Mar-04-97	75%	C-708	4b	117	9.0	-4.3	10.0
526	Mar-04-97	75%	C-709	4b	97	8.7	-4.3	10.1
527	Mar-04-97	75%	C-709	4b	96	8.7	-4.3	10.1
528	Mar-04-97	neat	C-107	4	60	11.1	-4.4	10.0
529	Mar-04-97	neat	C-107	4	59	10.7	-4.4	10.0
530	Mar-04-97	std	A-650	3	27	11.1	-4.5	11.1
531	Mar-04-97	std	A-650	3	25	11.1	-4.5	11.2
532	Mar-04-97	neat	C-100	4	98	7.0	-4.2	8.3
533	Mar-04-97	neat	C-100	4	99	7.0	-4.2	8.3
534	Mar-04-97	neat	C-109	4	132	6.3	-4.2	7.9
535	Mar-04-97	neat	C-109	4	132	6.3	-4.2	7.9
536	Mar-04-97	75%	C-700	4b	58	5.8	-4.1	9.2
537	Mar-04-97	75%	C-700	4b	59	5.4	-4.1	9.2
538	Mar-04-97	std	A-650	3	37	4.8	-4.2	8.0
539	Mar-04-97	std	A-650	3	39	4.8	-4.2	8.0
540	Mar-04-97	neat	C-100	4	124	4.1	-4.1	7.9
541	Mar-04-97	neat	C-100	4	140	4.0	-4.1	8.0
542	Mar-04-97	neat	C-109	4	148	4.2	-4.1	8.2
543	Mar-04-97	neat	C-109	4	140	4.1	-4.1	8.0
544	Mar-06-97	std	A-650	3	24	9.8	-2.8	13.1
545	Mar-06-97	std	A-650	3	20	10.1	-2.8	13.1
546	Mar-06-97	50%	C-500	4a	14	10.1	-2.7	13.3
547	Mar-06-97	50%	C-500	4a	14	10.1	-2.7	13.3
548	Mar-06-97	50%	C-509	4a	13	10.1	-2.7	13.5
549	Mar-06-97	50%	C-509	4a	13	10.1	-2.7	13.5
550	Mar-06-97	neat	C-100	4	94	7.0	-3.1	14.1
551	Mar-06-97	neat	C-100	4	92	6.9	-3.1	14.1
552	Mar-06-97	50%	C-507	4a	23	6.7	-2.9	12.3
553	Mar-06-97	50%	C-507	4a	25	6.8	-2.9	12.3
554	Mar-06-97	75%	C-709	4b	82	6.8	-3.4	15.0
555	Mar-06-97	75%	C-709	4b	77	7.8	-3.3	15.2
556	Mar-06-97	75%	C-707	4b	71	7.7	-3.3	15.3
557	Mar-06-97	75%	C-707	4b	71	7.7	-3.3	15.3
558	Mar-06-97	75%	C-707	4b	68	4.1	-3.2	14.7
559	Mar-06-97	75%	C-707	4b	68	4.1	-3.2	14.7
560	Mar-06-97	75%	C-708	4b	132	5.9	-3.5	15.5
561	Mar-06-97	75%	C-708	4b	135	5.9	-3.5	15.7
562	Mar-06-97	75%	C-709	4b	78	4.7	-3.2	14.9
563	Mar-06-97	75%	C-709	4b	75	4.5	-3.2	14.8
564	Mar-10-97	75%	C-708	4b	55	26.1	-3.7	18.9
565	Mar-10-97	75%	C-708	4b	55	26.1	-3.7	18.9
566	Mar-10-97	75%	C-707	4b	26	31.2	-3.7	18.3
567	Mar-10-97	75%	C-707	4b	26	31.2	-3.7	18.3
568	Mar-10-97	75%	C-709	4b	41	27.2	-3.7	18.3
569	Mar-10-97	75%	C-709	4b	46	26.3	-3.7	18.4
570	Mar-10-97	neat	C-100	4	28	30.8	-3.7	18.6

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Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]
571	Mar-10-97	neat	C-100	4	29	30.7	-3.7	18.5
572	Mar-10-97	75%	C-709	4b	24	31.2	-3.7	18.9
573	Mar-10-97	75%	C-709	4b	26	30.8	-3.7	18.6
574	Mar-10-97	75%	C-700	4b	13	31.2	-3.6	20.2
575	Mar-10-97	75%	C-700	4b	14	32.8	-3.6	20.1
576	Mar-10-97	neat	C-100	4	27	30.9	-3.8	19.5
577	Mar-10-97	neat	C-100	4	27	30.9	-3.8	19.5
578	Mar-10-97	neat	C-107	4	24	29.6	-3.8	19.4
579	Mar-10-97	neat	C-107	4	25	30.3	-3.8	19.4
580	Mar-10-97	neat	C-109	4	41	31.5	-3.7	20.2
581	Mar-10-97	neat	C-109	4	44	32.8	-3.7	20.2
582	Mar-10-97	neat	C-108	4	74	22.5	-3.5	20.7
583	Mar-10-97	neat	C-108	4	74	22.5	-3.5	20.7
584	Mar-10-97	neat	C-109	4	55	29.1	-3.6	21.0
585	Mar-10-97	neat	C-109	4	52	30.2	-3.6	21.0
586	Mar-10-97	neat	C-107	4	34	36.2	-3.7	20.6
587	Mar-10-97	neat	C-107	4	34	36.2	-3.7	20.6
588	Mar-10-97	neat	C-100	4	36	21.7	-3.5	21.4
589	Mar-10-97	neat	C-100	4	34	21.7	-3.5	21.5
590	Mar-10-97	std	A-650	3	14	26.5	-3.6	21.5
591	Mar-10-97	std	A-650	3	13	26.5	-3.6	21.2
592	Mar-10-97	75%	C-708	4b	56	20.7	-3.4	20.7
593	Mar-10-97	75%	C-708	4b	59	20.7	-3.4	20.6
594	Mar-10-97	std	A-650	3	14	30.1	-3.1	17.4
595	Mar-10-97	std	A-650	3	14	30.1	-3.1	17.4
596	Mar-10-97	75%	C-707	4b	63	10.0	-2.9	15.6
597	Mar-10-97	75%	C-707	4b	63	10.0	-2.9	15.6
598	Mar-10-97	75%	C-700	4b	30	19.2	-3.1	16.2
599	Mar-10-97	75%	C-700	4b	23	24.0	-3.1	16.7
600	Mar-10-97	neat	C-100	4	86	6.5	-2.7	14.7
601	Mar-10-97	neat	C-100	4	88	6.5	-2.6	14.6
602	Mar-10-97	neat	C-107	4	96	6.6	-2.6	14.2
603	Mar-10-97	neat	C-107	4	96	6.6	-2.6	14.2
604	Mar-10-97	50%	C-500	4a	29	5.0	-2.2	12.9
605	Mar-10-97	50%	C-500	4a	29	5.0	-2.2	12.9
606	Mar-10-97	50%	C-507	4a	28	5.0	-2.2	12.8
607	Mar-10-97	50%	C-507	4a	28	5.0	-2.2	12.8
608	Mar-17-97	50%	C-509	4a	34	5.1	-1.9	6.3
609	Mar-17-97	50%	C-509	4a	32	5.2	-1.9	6.2
610	Mar-17-97	50%	C-500	4a	33	5.1	-1.8	6.5
611	Mar-17-97	50%	C-500	4a	33	5.1	-1.8	6.5
612	Mar-17-97	50%	C-507	4a	50	4.0	-1.5	8.5
613	Mar-17-97	50%	C-507	4a	50	4.3	-1.5	8.5
614	Mar-17-97	75%	C-700	4b	93	3.3	-0.9	12.7
615	Mar-17-97	75%	C-700	4b	94	3.3	-0.9	12.7
616	Mar-21-97	50%	C-508	4a	94	7.9	-1.3	3.1
617	Mar-21-97	50%	C-508	4a	105	7.7	-1.3	3.0
618	Mar-21-97	50%	C-500	4a	18	10.4	-1.1	2.8
619	Mar-21-97	50%	C-500	4a	18	10.4	-1.1	2.8
620	Mar-21-97	50%	C-509	4a	18	10.4	-1.1	3.0
621	Mar-21-97	50%	C-509	4a	18	10.4	-1.1	3.0
622	Mar-21-97	50%	C-500	4a	20	9.0	-1.5	3.0
623	Mar-21-97	50%	C-500	4a	20	9.0	-1.5	2.8
624	Mar-21-97	50%	C-509	4a	21	9.0	-1.5	2.7
625	Mar-21-97	50%	C-509	4a	21	9.0	-1.5	2.7
626	Mar-21-97	neat	C-100	4	81	8.2	-1.4	3.2
627	Mar-21-97	neat	C-100	4	87	7.8	-1.4	3.2

NATURAL SNOW TESTS @ DORVAL 1996/97

Test No.	Date	Fluid Dilution	Fluid code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]
628	Mar-21-97	neat	C-100	4	107	8.0	-1.3	2.3
629	Mar-21-97	75%	C-700	4b	31	7.9	-1.3	2.0
630	Mar-21-97	75%	C-700	4b	30	7.9	-1.3	2.0
631	Mar-21-97	75%	C-700	4b	28	8.8	-1.4	3.4
632	Mar-21-97	75%	C-700	4b	34	8.8	-1.4	3.7
633	Mar-21-97	50%	C-508	4a	113	7.5	-1.3	3.0
634	Mar-21-97	50%	C-508	4a	127	7.1	-1.3	3.0
635	Mar-21-97	50%	C-507	4a	28	10.0	-1.3	1.9
636	Mar-21-97	50%	C-507	4a	28	10.0	-1.3	1.9
637	Mar-21-97	std	A-650	3	26	10.0	-1.3	1.9
638	Mar-21-97	std	A-650	3	25	9.9	-1.3	2.0
639	Mar-21-97	50%	C-509	4a	16	7.5	-1.4	3.1
640	Mar-21-97	50%	C-509	4a	16	7.5	-1.4	3.1
641	Mar-21-97	50%	C-507	4a	31	9.2	-1.4	3.4
642	Mar-21-97	50%	C-507	4a	31	9.2	-1.4	3.4
643	Mar-25-97	50%	C-508	4a	38	26.9	0.4	13.6
644	Mar-25-97	50%	C-508	4a	38	26.9	0.4	13.6
645	Mar-25-97	50%	C-500	4a	9	23.9	0.5	12.6
646	Mar-25-97	50%	C-500	4a	9	23.9	0.5	12.6
647	Mar-25-97	50%	C-507	4a	15	23.9	0.4	12.7
648	Mar-25-97	50%	C-507	4a	15	23.9	0.4	12.7
649	Mar-25-97	75%	C-709	4b	35	28.4	0.3	16.5
650	Mar-25-97	75%	C-709	4b	35	28.4	0.3	16.5
651	Mar-25-97	75%	C-708	4b	61	30.1	0.3	16.6
652	Mar-25-97	75%	C-708	4b	61	30.1	0.3	16.6
653	Mar-25-97	75%	C-707	4b	26	28.9	0.3	16.4
654	Mar-25-97	75%	C-707	4b	26	28.9	0.3	16.4
655	Mar-25-97	neat	C-100	4	55	20.2	0.3	17.9
656	Mar-25-97	neat	C-100	4	59	20.9	0.4	17.4
657	Mar-25-97	neat	C-100	4	59	20.9	0.4	17.4
658	Mar-25-97	neat	C-109	4	67	23.2	0.4	17.3
659	Mar-25-97	neat	C-109	4	75	23.7	0.3	17.3
660	Mar-25-97	neat	C-107	4	49	19.6	0.4	17.5
661	Mar-25-97	neat	C-107	4	49	19.6	0.4	17.5
662	Apr-12-97	50%	C-507	4a	24	12.6	1.3	5.0
663	Apr-12-97	50%	C-507	4a	23	12.2	1.3	4.9
664	Apr-12-97	50%	C-500	4a	19	11.4	1.4	5.0
665	Apr-12-97	50%	C-500	4a	18	10.9	1.3	5.0
666	Apr-12-97	50%	C-509	4a	17	11.6	0.8	5.7
667	Apr-12-97	50%	C-509	4a	16	11.6	0.8	5.8
668	Apr-12-97	50%	C-500	4a	18	11.6	0.8	5.9
669	Apr-12-97	50%	C-500	4a	18	11.6	0.8	5.9
670	Apr-12-97	75%	C-707	4b	112	6.1	1.1	8.0
671	Apr-12-97	75%	C-707	4b	112	6.1	1.1	8.0
672	Apr-12-97	std	A-650	3	102	6.3	1.1	8.0
673	Apr-12-97	std	A-650	3	100	6.2	1.1	8.0
674	Apr-12-97	50%	C-509	4a	17	13.7	0.9	8.5
675	Apr-12-97	50%	C-509	4a	17	13.7	0.9	8.5
676	Apr-12-97	50%	C-500	4a	19	13.7	0.9	8.6
677	Apr-12-97	50%	C-500	4a	18	13.7	0.9	8.6

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NATURAL SNOW TESTS AT DORVAL 1996/97 (DIFFERENT PRECIPITATION)

Test No.	Date	Fluid Dilution	Fluid Code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]	Precip Type
1	Dec-28-96	50%	C-500	4a	63	2.7	-1.2	8.1	FZD
2	Dec-28-96	50%	C-500	4a	66	2.7	-1.1	8.1	FZD
3	Jan-04-97	50%	C-500	4a	29	12.3	-1.9	17.8	FZR
4	Jan-04-97	50%	C-500	4a	30	12.6	-1.9	17.8	FZR
5	Jan-04-97	50%	C-507	4a	36	13.8	-1.9	17.8	FZR
6	Jan-04-97	50%	C-507	4a	36	13.8	-1.9	17.8	FZR
7	Jan-04-97	std	A-650	3	37	13.8	-1.9	17.8	FZR
8	Jan-04-97	std	A-650	3	37	13.8	-1.9	17.8	FZR
9	Jan-04-97	std	A-650	3	31	12.8	-1.8	17.9	FZR
10	Jan-04-97	std	A-650	3	32	13.0	-2.0	17.9	FZR
11	Jan-04-97	75%	C-707	4b	39	14.8	-1.9	17.5	FZR
12	Jan-04-97	75%	C-707	4b	39	14.8	-1.9	17.5	FZR
13	Jan-04-97	50%	C-508	4a	43	16.0	-1.8	17.3	FZR
14	Jan-04-97	50%	C-508	4a	44	16.2	-1.8	17.3	FZR
15	Jan-04-97	std	A-650	3	16	30.5	-1.2	14.5	FZR
16	Jan-04-97	std	A-650	3	17	30.5	-1.2	14.4	FZR
17	Jan-04-97	75%	C-707	4b	30	28.8	-1.2	9.7	FZR
18	Jan-04-97	75%	C-707	4b	30	28.8	-1.2	9.7	FZR
19	Jan-04-97	75%	C-708	4b	79	17.1	-1.2	5.5	FZR
20	Jan-04-97	75%	C-708	4b	81	16.9	-1.2	5.5	FZR
21	Jan-05-97	neat	C-100	4	31	20.2	-1.2	6.2	FZR
22	Jan-05-97	neat	C-100	4	32	20.2	-1.2	6.1	FZR
23	Jan-05-97	neat	C-107	4	34	20.2	-1.3	5.3	FZR
24	Jan-05-97	neat	C-107	4	41	19.8	-1.2	4.7	FZR
25	Jan-05-97	neat	C-100	4	49	18.0	-1.2	3.4	FZR
26	Jan-05-97	std	A-650	3	42	16.9	0.0	6.8	FZR
27	Jan-05-97	std	A-650	3	42	16.9	0.0	6.8	FZR
28	Jan-22-97	std	A-650	3	16	17.5	-6.0	4.3	ZR/R
29	Jan-22-97	std	A-650	3	18	17.5	-5.9	4.0	ZR/R
30	Jan-22-97	neat	C-100	4	44	13.9	-3.8	5.0	ZR/R
31	Jan-22-97	neat	C-100	4	45	13.8	-3.7	5.0	ZR/R
32	Jan-22-97	neat	C-108	4	69	12.0	-3.2	4.6	ZR/R
33	Jan-24-97	std	A-650	3	10	12.4	-9.3	7.1	IC
34	Jan-24-97	std	A-650	3	10	12.4	-9.3	7.1	IC
35	Jan-24-97	neat	C-107	4	33	15.8	-8.7	8.0	IC
36	Jan-24-97	neat	C-107	4	34	15.8	-8.7	7.9	IC
37	Jan-24-97	neat	C-108	4	44	15.5	-8.5	7.9	IC
38	Jan-24-97	neat	C-108	4	45	15.5	-8.5	8.0	IC
39	Jan-24-97	neat	C-107	4	29	16.6	-8.2	8.2	IC/S
40	Jan-24-97	neat	C-107	4	29	16.6	-8.2	8.2	IC/S
41	Jan-24-97	neat	C-108	4	41	14.5	-8.1	8.6	IC/S
42	Jan-24-97	neat	C-108	4	41	14.5	-8.1	8.6	IC/S
43	Jan-24-97	neat	C-100	4	55	12.6	-7.9	8.8	IC/S
44	Jan-24-97	neat	C-100	4	62	12.0	-7.9	8.9	IC/S
45	Feb-05-97	50%	C-507	4a	37	7.3	-0.6	11.7	IC
46	Feb-05-97	50%	C-508	4a	66	11.4	-0.8	9.0	IC
47	Feb-05-97	50%	C-500	4a	19	12.4	-0.5	4.8	IP
48	Feb-05-97	50%	C-500	4a	25	9.5	-0.5	14.7	IP
49	Feb-05-97	50%	C-507	4a	36	7.3	-0.6	11.8	IP
50	Feb-27-97	50%	C-500	4a	30	11.1	0.8	13.8	FZR
51	Feb-27-97	50%	C-500	4a	31	11.1	0.8	13.8	FZR
52	Feb-27-97	50%	C-509	4a	60	9.3	1.4	12.7	FZR
53	Feb-27-97	50%	C-509	4a	60	9.3	1.4	12.7	FZR
54	Feb-27-97	50%	C-508	4a	90	11.1	1.2	12.8	FZR

NATURAL SNOW TESTS AT DORVAL 1996/97 (DIFFERENT PRECIPITATION)

Test No.	Date	Fluid Dilution	Fluid Code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]	Precip Type
55	Feb-27-97	50%	C-508	4a	93	11.1	1.2	12.9	FZR
56	Feb-27-97	50%	C-507	4a	80	3.8	-0.1	4.2	ZD
57	Feb-27-97	50%	C-507	4a	81	3.8	-0.1	4.1	ZD
58	Feb-27-97	std	A-650	3	75	3.8	0.0	4.2	ZR
59	Feb-27-97	std	A-650	3	75	3.8	0.0	4.2	ZR
60	Feb-27-97	neat	C-107	4	42	13.0	-1.6	0.0	ZR
61	Feb-27-97	neat	C-107	4	43	13.0	-1.6	0.0	ZR
62	Feb-27-97	neat	C-100	4	54	13.1	-1.6	0.0	ZR
63	Feb-27-97	neat	C-100	4	55	13.1	-1.6	0.0	ZR
64	Feb-27-97	75%	C-700	4b	28	12.2	-1.4	0.0	ZR
65	Feb-27-97	75%	C-700	4b	28	12.2	-1.4	0.0	ZR
66	Feb-27-97	neat	C-107	4	44	14.0	-1.5	0.0	ZR
67	Feb-27-97	neat	C-107	4	51	14.2	-1.6	0.0	ZR
68	Feb-27-97	neat	C-100	4	57	14.4	-1.6	0.0	ZR
69	Feb-27-97	neat	C-100	4	61	14.5	-1.6	0.0	ZR
70	Feb-27-97	50%	C-509	4a	58	0.9	-2.2	16.4	SG
71	Feb-27-97	50%	C-509	4a	61	0.8	-2.2	16.5	SG
72	Mar-06-97	75%	C-700	4b	18	18.9	-4.1	20.0	BS
73	Mar-06-97	75%	C-700	4b	19	18.9	-4.1	19.9	BS
74	Mar-06-97	75%	C-700	4b	33	14.3	-3.9	19.3	BS
75	Mar-06-97	75%	C-700	4b	34	14.8	-3.9	19.3	BS
76	Mar-06-97	neat	C-100	4	60	18.9	-3.9	19.6	BS
77	Mar-06-97	neat	C-100	4	61	19.0	-4.0	19.6	BS
78	Mar-06-97	neat	C-107	4	40	16.6	-4.2	19.8	BS
79	Mar-06-97	neat	C-107	4	40	16.6	-4.2	19.8	BS
80	Mar-06-97	neat	C-108	4	63	16.7	-4.4	19.7	BS
81	Mar-06-97	neat	C-109	4	68	16.7	-4.4	19.8	BS
82	Mar-06-97	neat	C-108	4	70	16.7	-4.4	19.8	BS
83	Mar-06-97	neat	C-109	4	70	16.7	-4.4	19.9	BS
84	Mar-06-97	75%	C-700	4b	15	29.9	-5.0	19.7	BS
85	Mar-06-97	75%	C-700	4b	15	29.9	-5.0	19.7	BS
86	Mar-06-97	neat	C-100	4	32	33.9	-4.8	20.1	BS
87	Mar-06-97	neat	C-100	4	33	33.9	-4.8	20.1	BS
88	Mar-06-97	std	A-650	3	15	37.3	-4.4	20.8	BS
89	Mar-06-97	std	A-650	3	16	37.3	-4.4	20.6	BS
90	Mar-06-97	neat	C-100	4	24	37.3	-4.4	20.4	BS
91	Mar-06-97	neat	C-100	4	25	37.3	-4.4	20.7	BS
92	Mar-06-97	75%	C-708	4b	40	35.9	-4.4	20.6	BS
93	Mar-06-97	75%	C-708	4b	40	35.9	-4.4	20.6	BS
94	Mar-06-97	neat	C-107	4	23	52.4	-4.5	20.7	BS
95	Mar-06-97	neat	C-107	4	24	52.3	-4.5	20.7	BS
96	Mar-06-97	neat	C-100	4	26	52.4	-4.5	20.5	BS
97	Mar-06-97	neat	C-100	4	26	52.4	-4.5	20.5	BS
98	Mar-06-97	neat	C-109	4	36	52.1	-4.4	20.4	BS
99	Mar-06-97	neat	C-109	4	38	52.1	-4.4	20.3	BS
100	Mar-06-97	neat	C-107	4	31	28.1	-4.3	19.3	BS
101	Mar-06-97	neat	C-107	4	31	28.1	-4.3	19.3	BS
102	Mar-06-97	neat	C-108	4	59	23.1	-4.1	19.5	BS
103	Mar-06-97	neat	C-108	4	60	23.1	-4.1	19.5	BS
104	Mar-06-97	neat	C-109	4	63	23.1	-4.1	19.5	BS
105	Mar-06-97	neat	C-109	4	63	23.1	-4.1	19.5	BS
106	Mar-06-97	75%	C-700	4b	16	37.3	-4.2	18.7	BS
107	Mar-06-97	75%	C-700	4b	17	36.2	-4.2	18.8	BS
108	Mar-06-97	neat	C-100	4	26	36.1	-4.2	18.7	BS

NATURAL SNOW TESTS AT DORVAL 1996/97 (DIFFERENT PRECIPITATION)

Test No.	Date	Fluid Dilution	Fluid Code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]	Precip Type
109	Mar-06-97	neat	C-100	4	27	35.9	-4.2	18.7	BS
110	Mar-06-97	std	A-650	3	16	25.9	-3.9	20.9	BS
111	Mar-06-97	std	A-650	3	19	25.9	-3.9	21.2	BS
112	Mar-06-97	75%	C-707	4b	27	24.7	-4.0	22.0	BS
113	Mar-06-97	75%	C-707	4b	29	24.5	-4.0	22.0	BS
114	Mar-06-97	75%	C-709	4b	34	24.0	-4.0	22.7	BS
115	Mar-06-97	75%	C-709	4b	35	23.9	-4.0	22.7	BS
116	Mar-06-97	neat	C-107	4	30	25.9	-4.0	25.4	BS
117	Mar-06-97	neat	C-107	4	31	25.8	-4.0	25.6	BS
118	Mar-06-97	neat	C-108	4	52	26.3	-4.1	26.3	BS
119	Mar-06-97	neat	C-109	4	53	26.3	-4.1	26.1	BS
120	Mar-06-97	neat	C-108	4	53	26.3	-4.1	26.3	BS
121	Mar-06-97	neat	C-109	4	54	26.3	-4.1	26.2	BS
122	Mar-14-97	neat	C-107	4	15	41.2	-12.3	13.9	SG
123	Mar-14-97	neat	C-107	4	15	41.2	-12.3	13.9	SG
124	Mar-14-97	neat	C-109	4	23	45.8	-12.3	13.3	SG
125	Mar-14-97	neat	C-109	4	23	45.8	-12.3	13.3	SG
126	Mar-14-97	neat	C-100	4	24	45.8	-12.3	13.2	SG
127	Mar-14-97	neat	C-100	4	25	45.8	-12.3	13.1	SG
128	Mar-14-97	std	A-650	3	6	62.3	-12.4	12.3	SG
129	Mar-14-97	std	A-650	3	6	62.3	-12.4	12.3	SG
130	Mar-14-97	75%	C-707	4b	7	62.3	-12.4	12.3	SG
131	Mar-14-97	75%	C-707	4b	8	62.3	-12.4	12.4	SG
132	Mar-14-97	neat	C-107	4	17	42.5	-12.2	12.5	SG
133	Mar-14-97	neat	C-107	4	17	42.5	-12.2	12.5	SG
134	Mar-14-97	75%	C-708	4b	17	42.1	-12.2	12.1	SG
135	Mar-14-97	75%	C-708	4b	18	41.8	-12.2	12.0	SG
136	Mar-14-97	neat	C-109	4	24	41.0	-12.2	12.4	SG
137	Mar-14-97	neat	C-109	4	24	41.0	-12.2	12.4	SG
138	Mar-14-97	75%	C-708	4b	27	37.6	-12.2	13.8	SG
139	Mar-14-97	75%	C-708	4b	27	37.6	-12.2	13.8	SG
140	Mar-14-97	75%	C-709	4b	30	37.7	-11.8	13.4	SG
141	Mar-14-97	75%	C-709	4b	30	37.7	-11.8	13.4	SG
142	Mar-14-97	neat	C-100	4	33	37.8	-11.9	13.6	SG
143	Mar-14-97	neat	C-100	4	33	37.8	-11.9	13.6	SG
144	Mar-14-97	75%	C-707	4b	17	46.1	-12.2	13.5	SG
145	Mar-14-97	75%	C-707	4b	17	46.1	-12.2	13.5	SG
146	Mar-14-97	neat	C-100	4	36	42.0	-11.7	14.2	SG
147	Mar-14-97	neat	C-100	4	37	41.8	-11.7	14.2	SG
148	Mar-14-97	neat	C-109	4	44	41.1	-11.8	14.2	SG
149	Mar-14-97	neat	C-109	4	44	41.1	-11.8	14.2	SG
150	Mar-14-97	neat	C-100	4	48	36.4	-11.2	12.4	SG
151	Mar-14-97	neat	C-100	4	48	36.4	-11.2	12.4	SG
152	Mar-14-97	neat	C-109	4	58	34.4	-11.2	12.4	SG
153	Mar-14-97	neat	C-109	4	58	34.4	-11.2	12.4	SG
154	Mar-14-97	75%	C-707	4b	35	32.7	-11.1	12.1	SG
155	Mar-14-97	75%	C-707	4b	35	32.7	-11.1	12.1	SG
156	Mar-14-97	neat	C-100	4	43	33.6	-11.1	12.2	SG
157	Mar-14-97	neat	C-100	4	44	33.6	-11.1	12.2	SG
158	Mar-14-97	std	A-650	3	22	27.7	-10.4	12.3	SG/IP
159	Mar-14-97	std	A-650	3	22	27.7	-10.4	12.3	SG/IP
160	Mar-14-97	neat	C-100	4	67	30.0	-9.2	13.3	SG/IP
161	Mar-14-97	75%	C-709	4b	69	30.0	-9.3	13.3	SG/IP
162	Mar-14-97	75%	C-709	4b	69	30.0	-9.3	13.3	SG/IP

NATURAL SNOW TESTS AT DORVAL 1996/97 (DIFFERENT PRECIPITATION)

Test No.	Date	Fluid Dilution	Fluid Code	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	APS Data temp [C]	wind [kph]	Precip Type
163	Mar-14-97	neat	C-100	4	70	30.0	-9.2	13.2	SG/IP
164	Mar-14-97	std	A-650	3	17	28.7	-10.4	12.3	SG/IP
165	Mar-14-97	std	A-650	3	17	28.7	-10.4	12.3	SG/IP
166	Mar-14-97	neat	C-100	4	62	26.6	-9.2	13.4	SG/IP
167	Mar-14-97	neat	C-100	4	63	26.4	-9.2	13.3	SG/IP
168	Mar-14-97	75%	C-708	4b	52	18.3	-8.1	10.1	SG/IP/ZD
169	Mar-14-97	neat	C-107	4	54	18.3	-8.1	10.1	SG/IP/ZD
170	Mar-14-97	neat	C-107	4	54	18.3	-8.1	10.1	SG/IP/ZD
171	Mar-14-97	75%	C-708	4b	55	18.0	-8.1	10.1	SG/IP/ZD
172	Mar-14-97	75%	C-700	4b	19	30.0	-8.4	10.2	SG/IP
173	Mar-14-97	75%	C-700	4b	20	30.0	-8.4	10.3	SG/IP
174	Mar-14-97	neat	C-100	4	54	21.0	-8.1	10.1	SG/IP
175	Mar-14-97	neat	C-100	4	55	20.6	-8.1	10.1	SG/IP
176	Mar-21-97	neat	C-100	4	114	6.6	-1.8	7.9	S/IC
177	Mar-21-97	neat	C-100	4	117	6.6	-1.8	7.9	S/IC
178	Mar-21-97	std	A-650	3	27	8.1	-1.7	6.8	S/IC
179	Mar-21-97	std	A-650	3	27	8.1	-1.7	6.8	S/IC
180	Mar-21-97	75%	C-707	4b	53	8.8	-1.8	7.5	S/IC
181	Mar-21-97	75%	C-707	4b	53	8.8	-1.8	7.5	S/IC
182	Mar-21-97	75%	C-709	4b	69	7.9	-1.8	7.7	S/IC
183	Mar-21-97	75%	C-709	4b	75	7.3	-1.8	7.7	S/IC
184	Mar-22-97	75%	C-700	4b	52	4.0	-1.8	8.8	S/IC
185	Mar-22-97	75%	C-700	4b	64	3.5	-1.8	9.1	S/IC
186	Jan-22-97	std	A-650	3	30	13.1	-2.2	5.0	ZR/R
187	Jan-22-97	std	A-650	3	31	13.0	-2.2	4.9	ZR/R

SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN @ CEF FOR 1996/97

Test Season	Test No.	Date	Fluid code	Fluid Dilution	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	Ambient Temp [C]	Precip Type
1997	1	Apr-14-97	C-107	neat	4	53	6.0	-2.8	frz_drz
1997	2	Apr-14-97	C-109	neat	4	132	4.2	-2.9	frz_drz
1997	3	Apr-14-97	C-108	neat	4	117	5.6	-2.9	frz_drz
1997	4	Apr-14-97	C-100	neat	4	123	4.9	-2.8	frz_drz
1997	5	Apr-14-97	C-707	75%	4b	58	5.5	-2.8	frz_drz
1997	6	Apr-14-97	C-708	75%	4b	131	4.6	-2.9	frz_drz
1997	7	Apr-14-97	C-709	75%	4b	72	6.0	-2.9	frz_drz
1997	8	Apr-14-97	A-650	std	3	51	4.1	-3.1	frz_drz
1997	9	Apr-14-97	A-650	std	3	58	5.4	-3.0	frz_drz
1997	10	Apr-14-97	C-508	50%	4a	99	4.5	-3.0	frz_drz
1997	11	Apr-14-97	C-700	75%	4b	70	5.1	-2.9	frz_drz
1997	12	Apr-14-97	C-500	50%	4a	20	3.6	-3.0	frz_drz
1997	13	Apr-14-97	C-509	50%	4a	25	6.0	-3.0	frz_drz
1997	14	Apr-14-97	C-507	50%	4a	38	4.8	-3.0	frz_drz
1997	15	Apr-14-97	C-509	50%	4a	23	5.4	-2.8	frz_drz
1997	16	Apr-14-97	B-213	57%	1	12	3.6	-3.1	frz_drz
1997	17	Apr-14-97	C-500	50%	4a	17	6.1	-3.1	frz_drz
1997	18	Apr-14-97	B-213	57%	1	15	5.4	-2.9	frz_drz
1997	19	Apr-15-97	C-107	neat	4	43	10.9	-2.7	frz_drz
1997	20	Apr-15-97	C-108	neat	4	63	12.7	-2.7	frz_drz
1997	21	Apr-15-97	C-100	neat	4	92	11.2	-2.7	frz_drz
1997	22	Apr-15-97	C-109	neat	4	97	13.7	-2.7	frz_drz
1997	23	Apr-15-97	C-709	75%	4b	57	10.3	-2.7	frz_drz
1997	24	Apr-15-97	C-708	75%	4b	96	11.2	-2.7	frz_drz
1997	25	Apr-15-97	C-700	75%	4b	37	11.5	-2.7	frz_drz
1997	26	Apr-15-97	A-650	std	3	22	13.2	-2.8	frz_drz
1997	27	Apr-15-97	C-707	75%	4b	45	10.4	-2.7	frz_drz
1997	28	Apr-15-97	C-508	50%	4a	60	12.6	-2.8	frz_drz
1997	29	Apr-15-97	C-509	50%	4a	11	13.4	-2.7	frz_drz
1997	30	Apr-15-97	C-500	50%	4a	15	11.7	-2.7	frz_drz
1997	31	Apr-15-97	C-507	50%	4a	18	13.6	-2.7	frz_drz
1997	32	Apr-15-97	B-213	57%	1	12	10.1	-2.7	frz_drz
1997	33	Apr-15-97	A-650	std	3	25	10.3	-2.7	frz_drz
1997	34	Apr-15-97	C-107	neat	4	37	13.3	-2.8	frz_drz
1997	35	Apr-15-97	C-109	neat	4	91	11.7	-2.7	frz_drz
1997	36	Apr-15-97	C-100	neat	4	56	13.2	-2.7	frz_drz
1997	37	Apr-15-97	C-108	neat	4	80	9.3	-2.7	frz_drz
1997	38	Apr-15-97	C-708	75%	4b	89	12.4	-2.7	frz_drz
1997	39	Apr-15-97	C-709	75%	4b	52	13.3	-2.6	frz_drz
1997	40	Apr-15-97	A-650	std	3	27	11.4	-2.8	frz_drz
1997	41	Apr-15-97	C-700	75%	4b	28	13.8	-2.6	frz_drz
1997	42	Apr-15-97	C-107	neat	4	45	10.0	-2.7	frz_drz
1997	43	Apr-15-97	C-509	50%	4a	12	13.8	-2.6	frz_drz
1997	44	Apr-15-97	C-500	50%	4a	13	10.1	-2.6	frz_drz
1997	45	Apr-15-97	C-509	50%	4a	16	12.0	-2.6	frz_drz
1997	46	Apr-15-97	C-500	50%	4a	10	12.8	-2.9	frz_drz
1997	47	Apr-15-97	C-507	50%	4a	20	11.4	-2.6	frz_drz
1997	48	Apr-15-97	A-650	std	3	20	13.8	-2.8	frz_drz
1997	49	Apr-15-97	C-707	75%	4b	44	10.1	-2.7	frz_drz
1997	50	Apr-15-97	C-508	50%	4a	63	11.5	-2.7	frz_drz
1997	51	Apr-15-97	B-213	57%	1	8	12.8	-2.6	frz_drz
1997	52	Apr-15-97	B-213	57%	1	12	10.7	-2.6	frz_drz
1997	53	Apr-15-97	B-213	57%	1	13	10.7	-2.4	frz_drz
1997	54	Apr-16-97	C-108	neat	4	49	21.7	-3.3	frz_rain
1997	55	Apr-16-97	C-709	75%	4b	42	18.5	-3.3	frz_rain
1997	56	Apr-16-97	C-100	neat	4	43	21.3	-3.3	frz_rain
1997	57	Apr-16-97	C-707	75%	4b	29	21.1	-3.4	frz_rain
1997	58	Apr-16-97	C-109	neat	4	71	21.8	-3.1	frz_rain

SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN @ CEF FOR 1996/97

Test Season	Test No.	Date	Fluid code	Fluid Dilution	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	Ambient Temp [C]	Precip Type
1997	59	Apr-16-97	C-700	75%	4b	17	22.0	-4.1	frz_rain
1997	60	Apr-16-97	C-107	neat	4	42	21.8	-3.3	frz_rain
1997	61	Apr-16-97	C-708	75%	4b	50	22.6	-3.2	frz_rain
1997	62	Apr-16-97	C-109	neat	4	65	22.8	-2.8	frz_rain
1997	63	Apr-16-97	C-107	neat	4	43	18.4	-2.8	frz_rain
1997	64	Apr-16-97	C-708	75%	4b	47	21.9	-2.8	frz_rain
1997	65	Apr-16-97	C-707	75%	4b	27	21.2	-2.8	frz_rain
1997	66	Apr-16-97	C-500	50%	4a	9	23.3	-2.7	frz_rain
1997	67	Apr-16-97	C-108	neat	4	40	22.2	-2.8	frz_rain
1997	68	Apr-16-97	C-100	neat	4	43	22.4	-2.8	frz_rain
1997	69	Apr-16-97	C-700	75%	4b	17	22.6	-2.9	frz_rain
1997	70	Apr-16-97	C-700	75%	4b	21	21.0	-2.9	frz_rain
1997	71	Apr-16-97	C-508	50%	4a	32	20.7	-2.9	frz_rain
1997	72	Apr-16-97	A-650	std	3	16	22.1	-2.8	frz_rain
1997	73	Apr-16-97	A-650	std	3	15	20.8	-2.8	frz_rain
1997	74	Apr-16-97	C-507	50%	4a	14	23.8	-2.8	frz_rain
1997	75	Apr-16-97	B-213	57%	1	9	22.7	-2.8	frz_rain
1997	76	Apr-16-97	C-509	50%	4a	10	21.7	-2.8	frz_rain
1997	77	Apr-16-97	C-100	neat	4	37	22.4	-2.8	frz_rain
1997	78	Apr-16-97	C-108	neat	4	68	15.1	-2.5	frz_rain
1997	79	Apr-16-97	C-707	75%	4b	33	17.6	-2.7	frz_rain
1997	80	Apr-16-97	C-109	neat	4	80	17.5	-2.5	frz_rain
1997	81	Apr-16-97	C-100	neat	4	50	17.6	-2.7	frz_rain
1997	82	Apr-16-97	C-107	neat	4	49	17.4	-2.7	frz_rain
1997	83	Apr-16-97	C-708	75%	4b	78	14.8	-2.5	frz_rain
1997	84	Apr-16-97	C-700	75%	4b	24	15.4	-2.7	frz_rain
1997	85	Apr-16-97	C-508	50%	4a	45	16.9	-2.0	frz_rain
1997	86	Apr-16-97	A-650	std	3	18	17.7	-2.1	frz_rain
1997	87	Apr-16-97	C-500	50%	4a	10	17.4	-2.2	frz_rain
1997	88	Apr-16-97	A-650	std	3	23	17.2	-2.0	frz_rain
1997	89	Apr-16-97	C-700	75%	4b	25	15.2	-2.2	frz_rain
1997	90	Apr-16-97	C-507	50%	4a	17	18.1	-2.0	frz_rain
1997	91	Apr-16-97	B-213	57%	1	16	17.2	-1.9	frz_rain
1997	92	Apr-16-97	C-509	50%	4a	11	15.2	-2.1	frz_rain
1997	93	Apr-16-97	B-213	57%	1	16	16.9	-2.0	frz_rain
1997	94	Apr-17-97	C-708	75%	4b	31	20.7	-9.9	frz_rain
1997	95	Apr-17-97	C-108	neat	4	40	16.6	-9.9	frz_rain
1997	96	Apr-17-97	C-700	75%	4b	21	21.8	-9.9	frz_rain
1997	97	Apr-17-97	C-109	neat	4	41	16.9	-9.9	frz_rain
1997	98	Apr-17-97	C-709	75%	4b	36	22.3	-9.9	frz_rain
1997	99	Apr-17-97	C-100	neat	4	51	16.3	-9.9	frz_rain
1997	100	Apr-17-97	C-707	75%	4b	27	22.7	-9.9	frz_rain
1997	101	Apr-17-97	C-107	neat	4	42	17.0	-9.9	frz_rain
1997	102	Apr-17-97	C-108	neat	4	32	21.5	-9.9	frz_rain
1997	103	Apr-17-97	C-100	neat	4	42	22.0	-9.9	frz_rain
1997	104	Apr-17-97	A-650	std	3	16	21.0	-9.9	frz_rain
1997	105	Apr-17-97	C-107	neat	4	41	15.7	-9.9	frz_rain
1997	106	Apr-17-97	C-708	75%	4b	31	16.5	-9.9	frz_rain
1997	107	Apr-17-97	C-700	75%	4b	23	15.4	-9.9	frz_rain
1997	108	Apr-17-97	C-707	75%	4b	29	16.8	-9.9	frz_rain
1997	109	Apr-17-97	A-650	std	3	16	21.3	-9.9	frz_rain
1997	110	Apr-17-97	C-100	neat	4	39	18.6	-10.0	frz_rain
1997	111	Apr-17-97	C-109	neat	4	33	21.3	-10.0	frz_rain
1997	112	Apr-17-97	A-650	std	3	16	18.8	-10.0	frz_rain
1997	113	Apr-17-97	C-108	neat	4	32	23.0	-10.0	frz_rain
1997	114	Apr-17-97	C-708	75%	4b	31	19.6	-9.9	frz_rain
1997	115	Apr-17-97	C-700	75%	4b	18	23.5	-10.0	frz_rain
1997	116	Apr-17-97	A-650	std	3	15	18.6	-10.0	frz_rain

SIMULATED FREEZING DRIZZLE AND LIGHT FRZ RAIN @ CEF FOR 1996/97

Test Season	Test No.	Date	Fluid code	Fluid Dilution	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	Ambient Temp [C]	Precip Type
1997	117	Apr-17-97	C-707	75%	4b	26	24.6	-9.9	frz_rain
1997	118	Apr-17-97	C-107	neat	4	32	24.7	-10.0	frz_rain
1997	119	Apr-18-97	C-100	neat	4	N/F	4.9	-9.7	frz_drz
1997	120	Apr-18-97	C-107	neat	4	57	5.9	-9.7	frz_drz
1997	121	Apr-18-97	C-108	neat	4	N/F	5.4	-9.7	frz_drz
1997	122	Apr-18-97	C-700	75%	4b	43	6.1	-9.8	frz_drz
1997	123	Apr-18-97	C-109	neat	4	N/F	5.7	-9.7	frz_drz
1997	124	Apr-18-97	C-708	75%	4b	67	6.0	-9.7	frz_drz
1997	125	Apr-21-97	C-108	neat	4	32	9.6	-9.7	frz_drz
1997	126	Apr-21-97	C-107	neat	4	46	10.1	-9.7	frz_drz
1997	127	Apr-21-97	C-100	neat	4	49	12.5	-9.7	frz_drz
1997	128	Apr-21-97	C-109	neat	4	35	12.6	-9.7	frz_drz
1997	129	Apr-21-97	B-213	57%	1	6	8.8	-9.6	frz_drz
1997	130	Apr-21-97	C-709	75%	4b	61	10.0	-9.7	frz_drz
1997	131	Apr-21-97	C-100	neat	4	67	11.1	-9.7	frz_drz
1997	132	Apr-21-97	C-108	neat	4	27	13.5	-9.7	frz_drz
1997	133	Apr-21-97	C-700	75%	4b	32	9.7	-9.7	frz_drz
1997	134	Apr-21-97	A-650	std	3	18	13.4	-9.7	frz_drz
1997	135	Apr-21-97	C-108	neat	4	30	12.8	-9.7	frz_drz
1997	136	Apr-21-97	A-650	std	3	25	10.6	-9.7	frz_drz
1997	137	Apr-21-97	C-707	75%	4b	40	12.7	-9.7	frz_drz
1997	138	Apr-21-97	C-707	75%	4b	38	13.1	-9.7	frz_drz
1997	139	Apr-21-97	A-650	std	3	25	10.1	-9.7	frz_drz
1997	140	Apr-21-97	C-708	75%	4b	28	12.8	-9.7	frz_drz

SIMULATED FREEZING FOG @ CEF FOR 1996/97

Test Season	Test No.	Date	Fluid code	Fluid Dilution	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	Ambient Temp [C]	Precip Type
1997	1	25-Mar-97	B-213	57%	1	7	5.9	-30.6	frz_fog
1997	2	25-Mar-97	C-109	neat	4	34	5.9	-30.6	frz_fog
1997	3	25-Mar-97	C-109	neat	4	31	6.7	-30.6	frz_fog
1997	4	25-Mar-97	C-100	neat	4	41	6.1	-30.4	frz_fog
1997	5	25-Mar-97	C-100	neat	4	40	6.8	-30.4	frz_fog
1997	6	25-Mar-97	C-107	neat	4	18	6.3	-30.6	frz_fog
1997	7	25-Mar-97	C-107	neat	4	18	7.1	-30.6	frz_fog
1997	8	25-Mar-97	C-108	neat	4	18	6.4	-30.6	frz_fog
1997	9	25-Mar-97	C-108	neat	4	17	7.4	-30.6	frz_fog
1997	10	25-Mar-97	B-213	57%	1	6	6.4	-30.5	frz_fog
1997	11	25-Mar-97	A-101	neat	2	15	7.3	-30.3	frz_fog
1997	12	25-Mar-97	A-101	neat	2	14	8.9	-30.3	frz_fog
1997	13	25-Mar-97	A-201	neat	2	13	9.5	-30.2	frz_fog
1997	15	25-Mar-97	A-205	neat	2	15	8.8	-30.0	frz_fog
1997	17	25-Mar-97	B-213	57%	1	6	9.3	-30.0	frz_fog
1997	19	25-Mar-97	A-205	neat	2	19	6.1	-28.5	frz_fog
1997	20	25-Mar-97	A-205	neat	2	18	6.3	-28.5	frz_fog
1997	21	25-Mar-97	A-201	neat	2	19	6.5	-28.5	frz_fog
1997	22	25-Mar-97	C-109	neat	4	58	5.8	-24.8	frz_fog
1997	23	25-Mar-97	C-107	neat	4	25	5.9	-25.0	frz_fog
1997	24	25-Mar-97	C-100	neat	4	65	6.2	-24.7	frz_fog
1997	25	25-Mar-97	C-108	neat	4	24	6.9	-25.0	frz_fog
1997	26	25-Mar-97	A-201	neat	2	27	5.2	-24.4	frz_fog
1997	27	25-Mar-97	A-101	neat	2	20	5.4	-24.4	frz_fog
1997	28	25-Mar-97	C-107	neat	4	20	6.3	-24.8	frz_fog
1997	29	25-Mar-97	C-108	neat	4	23	6.5	-24.7	frz_fog
1997	30	25-Mar-97	C-109	neat	4	49	5.8	-24.5	frz_fog
1997	31	25-Mar-97	C-100	neat	4	53	6.7	-24.5	frz_fog
1997	32	25-Mar-97	A-205	neat	2	17	7.6	-26.0	frz_fog
1997	33	25-Mar-97	A-101	neat	2	15	8.1	-25.9	frz_fog
1997	34	25-Mar-97	B-213	57%	1	6	5.7	-24.3	frz_fog
1997	35	25-Mar-97	A-201	neat	2	26	4.6	-24.3	frz_fog
1997	36	25-Mar-97	A-205	neat	2	19	6.3	-24.4	frz_fog
1997	37	26-Mar-97	C-708	75%	4b	33	3.9	-14.3	frz_fog
1997	38	26-Mar-97	C-109	neat	4	48	5.4	-14.2	frz_fog
1997	39	26-Mar-97	C-107	neat	4	52	3.7	-14.2	frz_fog
1997	40	26-Mar-97	C-100	neat	4	71	5.6	-14.3	frz_fog
1997	41	26-Mar-97	C-107	neat	4	48	9.3	-14.2	frz_fog
1997	43	26-Mar-97	C-700	75%	4b	73	4.1	-14.6	frz_fog
1997	44	26-Mar-97	C-108	neat	4	43	4.8	-14.4	frz_fog
1997	45	26-Mar-97	C-109	neat	4	68	5.7	-14.4	frz_fog
1997	46	26-Mar-97	C-108	neat	4	35	5.8	-14.4	frz_fog
1997	47	26-Mar-97	C-708	75%	4b	38	6.2	-14.5	frz_fog
1997	48	26-Mar-97	C-709	75%	4b	28	8.9	-14.4	frz_fog
1997	49	26-Mar-97	C-709	75%	4b	74	4.8	-12.9	frz_fog
1997	50	26-Mar-97	A-650	std	3	53	4.6	-14.7	frz_fog
1997	51	26-Mar-97	A-650	std	3	50	4.1	-14.0	frz_fog
1997	52	26-Mar-97	C-707	75%	4b	49	5.2	-14.7	frz_fog
1997	53	26-Mar-97	C-700	75%	4b	63	6.2	-13.5	frz_fog
1997	54	26-Mar-97	C-707	75%	4b	61	5.0	-12.8	frz_fog
1997	55	26-Mar-97	A-205	neat	2	33	6.0	-12.7	frz_fog
1997	56	26-Mar-97	B-213	57%	1	7	6.3	-12.7	frz_fog
1997	57	26-Mar-97	C-709	75%	4b	47	7.2	-12.3	frz_fog
1997	58	26-Mar-97	A-650	std	3	71	3.2	-12.7	frz_fog
1997	59	26-Mar-97	A-650	std	3	68	3.7	-12.6	frz_fog
1997	60	27-Mar-97	C-507	50%	4a	36	3.6	-2.8	frz_fog
1997	61	27-Mar-97	A-650	std	3	60	3.9	-2.7	frz_fog

SIMULATED FREEZING FOG @ CEF FOR 1996/97

Test Season	Test No.	Date	Fluid code	Fluid Dilution	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	Ambient Temp [C]	Precip Type
1997	62	27-Mar-97	C-500	50%	4a	22	4.3	-2.8	frz_fog
1997	63	27-Mar-97	C-509	50%	4a	24	4.2	-2.8	frz_fog
1997	64	27-Mar-97	C-508	50%	4a	94	3.8	-2.7	frz_fog
1997	65	27-Mar-97	C-507	50%	4a	35	4.8	-2.8	frz_fog
1997	66	27-Mar-97	C-509	50%	4a	18	6.0	-2.8	frz_fog
1997	67	27-Mar-97	C-508	50%	4a	101	6.7	-2.7	frz_fog
1997	68	27-Mar-97	A-650	std	3	42	6.5	-2.8	frz_fog
1997	69	27-Mar-97	C-500	50%	4a	18	9.2	-2.8	frz_fog
1997	70	27-Mar-97	C-700	75%	4b	83	6.5	-2.8	frz_fog
1997	71	27-Mar-97	C-500	50%	4a	24	3.4	-2.7	frz_fog
1997	73	27-Mar-97	C-707	75%	4b	66	7.1	-2.7	frz_fog
1997	74	27-Mar-97	C-700	75%	4b	58	8.1	-2.7	frz_fog
1997	76	27-Mar-97	C-708	75%	4b	N/F	2.8	-2.4	frz_fog
1997	77	27-Mar-97	C-708	75%	4b	N/F	3.0	-2.4	frz_fog
1997	78	27-Mar-97	C-709	75%	4b	145	3.2	-2.4	frz_fog
1997	79	27-Mar-97	C-107	neat	4	118	4.1	-2.4	frz_fog
1997	80	27-Mar-97	C-109	neat	4	221	5.3	-2.4	frz_fog
1997	81	27-Mar-97	C-108	neat	4	N/F	5.1	-2.5	frz_fog
1997	82	27-Mar-97	C-108	neat	4	210	5.5	-2.5	frz_fog
1997	83	27-Mar-97	C-100	neat	4	228	7.2	-2.4	frz_fog
1997	84	16-Apr-97	C-108	neat	4	N/F	3.3	-3.2	frz_fog
1997	85	16-Apr-97	A-650	std	3	50	6.0	-2.9	frz_fog
1997	86	16-Apr-97	C-109	neat	4	140	6.5	-3.4	frz_fog
1997	87	16-Apr-97	C-107	neat	4	155	7.0	-3.4	frz_fog
1997	88	16-Apr-97	C-108	neat	4	164	7.0	-3.4	frz_fog
1997	89	16-Apr-97	C-100	neat	4	N/F	5.7	-3.2	frz_fog
1997	90	17-Apr-97	A-202	neat	2	36	6.6	-21.2	frz_fog
1997	91	17-Apr-97	A-205	neat	2	26	7.7	-21.2	frz_fog
1997	92	17-Apr-97	A-201	neat	2	27	6.6	-21.3	frz_fog
1997	93	17-Apr-97	A-205	neat	2	33	6.6	-21.1	frz_fog
1997	94	17-Apr-97	A-101	neat	2	25	8.3	-21.2	frz_fog
1997	95	17-Apr-97	A-101	neat	2	30	6.7	-21.1	frz_fog
1997	96	17-Apr-97	A-202	neat	2	35	6.3	-21.2	frz_fog
1997	97	17-Apr-97	B-221	61%	1	8	8.5	-21.2	frz_fog
1997	98	17-Apr-97	A-201	neat	2	31	5.9	-21.2	frz_fog
1997	99	17-Apr-97	B-214	71%	1	8	8.6	-21.2	frz_fog
1997	100	17-Apr-97	B-231	75%	1	11	4.2	-20.9	frz_fog
1997	101	17-Apr-97	B-231	75%	1	7	5.4	-20.8	frz_fog
1997	102	17-Apr-97	B-211	68%	1	12	4.9	-20.9	frz_fog
1997	103	17-Apr-97	B-211	68%	1	13	5.1	-20.9	frz_fog
1997	104	17-Apr-97	B-213	57%	1	10	5.1	-21.0	frz_fog
1997	105	17-Apr-97	B-213	57%	1	10	5.9	-21.0	frz_fog
1997	106	17-Apr-97	B-221	61%	1	11	5.4	-21.0	frz_fog
1997	107	17-Apr-97	B-214	71%	1	11	5.7	-21.0	frz_fog
1997	108	17-Apr-97	A-202	neat	2	65	5.2	-14.8	frz_fog
1997	109	17-Apr-97	A-202	neat	2	59	6.3	-14.8	frz_fog
1997	110	17-Apr-97	A-201	neat	2	44	5.8	-14.7	frz_fog
1997	111	17-Apr-97	A-201	neat	2	42	7.4	-14.7	frz_fog
1997	112	17-Apr-97	A-205	neat	2	55	7.4	-14.8	frz_fog
1997	113	17-Apr-97	A-205	neat	2	48	7.7	-14.8	frz_fog
1997	114	17-Apr-97	A-201	neat	2	34	9.1	-14.9	frz_fog

SIMULATED FREEZING FOG @ CEF FOR 1996/97 (NOT USABLE)

Test Season	Test No.	Date	Fluid code	Fluid Dilution	Fluid Type	Fail Time [min.]	Rate of Precep. [g/dm*2/hr]	Ambient Temp [C]	Precip Type
1997	1	25-Mar-97	A-201	neat	2	13	10.0	-30.2	frz_fog
1997	2	25-Mar-97	A-205	neat	2	14	10.4	-30.0	frz_fog
1997	3	25-Mar-97	B-213	57%	1	6	10.8	-30.0	frz_fog
1997	4	26-Mar-97	C-100	neat	4	47	11.2	-14.2	frz_fog
1997	5	27-Mar-97	C-709	75%	4b	84	10.2	-2.8	frz_fog
1997	6	27-Mar-97	C-707	75%	4b	63	12.6	-2.8	frz_fog

COLD SOAK DATA @ CEF FOR 1996/97 TEST SEASON

Test Season	Test No.	Date	Fluid code	Fluid Dilution	Fluid Type	Box Size (cm)	BOX fail time [min.]	Rate of Precep. [g/dm*2/hr]	Precip. Type	Average Skin Temp [C]	Ambient Temp [C]
1997	1	Apr-22-97	C-107	neat	4	2.5	76	7.9	drizzle	-3.8	1.9
1997	2	Apr-22-97	C-108	neat	4	2.5	103	8.9	drizzle	-4.3	1.9
1997	3	Apr-22-97	C-100	neat	4	15	61	8.1	drizzle	-8.5	1.9
1997	4	Apr-22-97	A-650	std	3	2.5	26	9.2	drizzle	-5.0	1.9
1997	5	Apr-22-97	C-707	75%	4b	2.5	41	10.4	drizzle	-5.5	1.9
1997	6	Apr-22-97	C-100	neat	4	7.5	56	10.0	drizzle	-6.5	1.9
1997	7	Apr-22-97	C-700	75%	4b	7.5	29	10.7	drizzle	-8.0	1.9
1997	8	Apr-22-97	C-707	75%	4b	15	26	9.0	drizzle	-9.0	1.9
1997	9	Apr-22-97	C-708	75%	4b	15	28	11.1	drizzle	-7.0	1.9
1997	10	Apr-22-97	C-708	75%	4b	7.5	38	9.5	drizzle	-6.8	1.9
1997	11	Apr-22-97	A-650	std	3	7.5	21	10.4	drizzle	-7.5	1.9
1997	12	Apr-22-97	C-107	neat	4	15	64	7.2	drizzle	-7.0	1.9
1997	13	Apr-22-97	A-650	std	3	15	19	11.0	drizzle	-9.3	1.9
1997	14	Apr-22-97	C-108	neat	4	7.5	36	9.9	drizzle	-7.0	1.7
1997	15	Apr-22-97	B-213	std	1	15	4	10.1	drizzle	-4.8	6.0
1997	16	Apr-22-97	C-707	75%	4b	7.5	18	13.0	drizzle	-8.9	2.5
1997	17	Apr-22-97	C-100	neat	4	2.5	60	11.4	drizzle	-4.7	2.6
1997	18	Apr-22-97	C-107	neat	4	7.5	65	6.1	drizzle	-6.8	2.5
1997	19	Apr-22-97	C-700	75%	4b	2.5	23	11.4	drizzle	-8.1	2.4
1997	20	Apr-23-97	C-700	75%	4b	2.5	21	18.1	light rain	-8.0	1.8
1997	21	Apr-23-97	C-100	neat	4	2.5	41	18.2	light rain	-6.0	1.8
1997	22	Apr-23-97	C-108	neat	4	15	20	19.3	light rain	-8.5	1.5
1997	23	Apr-23-97	C-100	neat	4	7.5	39	18.9	light rain	-8.0	1.7
1997	24	Apr-23-97	C-108	neat	4	7.5	21	20.0	light rain	-8.5	1.4
1997	25	Apr-23-97	C-707	75%	4b	15	23	19.3	light rain	-7.2	2.1
1997	26	Apr-23-97	C-708	75%	4b	15	15	21.5	light rain	-7.5	2.0
1997	27	Apr-23-97	A-650	std	3	2.5	15	18.1	light rain	-6.8	1.8
1997	28	Apr-23-97	C-700	75%	4b	2.5	19	21.0	light rain	-5.5	1.9
1997	29	Apr-23-97	A-650	std	3	15	13	19.8	light rain	-7.8	1.9
1997	30	Apr-23-97	C-107	neat	4	15	25	22.5	light rain	-9.5	1.9
1997	31	Apr-23-97	C-109	neat	4	7.5	65	19.3	light rain	-7.0	1.9
1997	32	Apr-23-97	C-707	75%	4b	2.5	27	18.1	light rain	-5.8	1.9
1997	33	Apr-23-97	C-708	75%	4b	2.5	50	18.5	light rain	-5.0	2.0
1997	34	Apr-23-97	C-100	neat	4	15	32	19.8	light rain	-7.9	2.0
1997	35	Apr-23-97	C-100	neat	4	15	37	22.5	light rain	-7.0	1.9
1997	36	Apr-23-97	C-709	75%	4b	7.5	20	20.9	light rain	-8.3	1.9
1997	37	Apr-23-97	C-107	neat	4	2.5	45	18.1	light rain	-5.5	1.9
1997	38	Apr-23-97	C-700	75%	4b	7.5	20	20.5	light rain	-8.9	1.9
1997	39	Apr-23-97	C-107	neat	4	7.5	34	20.9	light rain	-8.5	1.9
1997	40	Apr-23-97	A-650	std	3	7.5	14	20.2	light rain	-9.0	2.0
1997	41	Apr-23-97	C-108	neat	4	2.5	61	19.0	light rain	-5.2	1.9
1997	42	Apr-23-97	C-700	75%	4b	15	20	21.5	light rain	-8.0	1.9
1997	43	Apr-23-97	C-708	75%	4b	7.5	17	20.1	light rain	-8.9	2.0
1997	44	Apr-23-97	C-707	75%	4b	7.5	23	20.2	light rain	-7.0	1.9
1997	45	Apr-23-97	A-650	std	3	2.5	12	20.5	light rain	-8.2	1.9
1997	46	Apr-23-97	C-707	75%	4b	2.5	6	147.0	heavy rain	-6.0	2.0
1997	47	Apr-23-97	A-650	std	3	7.5	4	125.6	heavy rain	-3.8	2.0
1997	48	Apr-23-97	A-650	std	3	2.5	4	138.6	heavy rain	-7.9	1.8
1997	49	Apr-23-97	A-650	std	3	7.5	4	150.2	heavy rain	-6.5	2.1
1997	50	Apr-23-97	A-650	std	3	15	4	141.0	heavy rain	-5.5	2.0
1997	51	Apr-23-97	C-108	neat	4	7.5	9	125.6	heavy rain	-6.5	1.9
1997	52	Apr-23-97	C-100	neat	4	2.5	8	138.6	heavy rain	-6.3	2.0
1997	53	Apr-23-97	C-107	neat	4	15	10	132.6	heavy rain	-6.2	1.9
1997	54	Apr-23-97	C-700	75%	4b	7.5	5	150.2	heavy rain	-6.0	2.0
1997	55	Apr-23-97	C-708	75%	4b	15	6	141.0	heavy rain	-5.5	1.9
1997	56	Apr-24-97	A-650	std	3	2.5	5	60.6	mod. rain	-6.0	1.7
1997	57	Apr-24-97	C-100	neat	4	2.5	15	55.7	mod. rain	-6.5	1.8
1997	58	Apr-24-97	C-108	neat	4	7.5	11	64.1	mod. rain	-8.8	1.8
1997	59	Apr-24-97	C-700	75%	4b	7.5	8	58.1	mod. rain	-8.5	1.8
1997	60	Apr-24-97	C-100	neat	4	15	12	54.5	mod. rain	-8.5	1.8
1997	61	Apr-24-97	C-107	neat	4	15	10	65.4	mod. rain	-9.3	1.8
1997	62	Apr-24-97	C-100	neat	4	7.5	15	64.1	mod. rain	-8.3	1.9
1997	63	Apr-24-97	C-708	75%	4b	15	13	54.5	mod. rain	-7.8	1.8

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COLD SOAK DATA @ CEF FOR 1996/97 TEST SEASON

Test Season	Test No.	Date	Fluid code	Fluid Dilution	Fluid Type	Box Size (cm)	BOX fail time [min.]	Rate of Precep. [g/dm*2/hr]	Precip. Type	Average Skin Temp [C]	Ambient Temp [C]
1997	64	Apr-24-97	C-108	neat	4	15	12	65.4	mod. rain	-8.7	1.9
1997	65	Apr-24-97	C-108	neat	4	7.5	16	60.6	mod. rain	-6.8	1.8
1997	66	Apr-24-97	C-107	neat	4	2.5	17	58.2	mod. rain	-7.4	1.9
1997	67	Apr-24-97	A-650	std	3	7.5	6	64.1	mod. rain	-7.3	1.8
1997	68	Apr-24-97	C-700	75%	4b	15	9	54.5	mod. rain	-8.0	1.8
1997	69	Apr-24-97	C-707	75%	4b	15	8	65.4	mod. rain	-7.7	1.9
1997	70	Apr-24-97	C-709	75%	4b	7.5	13	67.5	mod. rain	-7.5	1.9
1997	71	Apr-24-97	C-109	neat	4	7.5	23	44.0	mod. rain	-7.2	1.9
1997	72	Apr-24-97	A-650	std	3	15	6	56.0	mod. rain	-6.8	1.9
1997	73	Apr-24-97	C-707	75%	4b	2.5	11	61.4	mod. rain	-6.5	1.9
1997	74	Apr-24-97	C-107	neat	4	7.5	18	44.0	mod. rain	-7.5	1.9
1997	75	Apr-24-97	C-708	75%	4b	2.5	13	69.7	mod. rain	-5.5	1.8
1997	76	Apr-24-97	C-708	75%	4b	7.5	12	58.9	mod. rain	-6.3	1.9
1997	77	Apr-24-97	C-707	75%	4b	7.5	10	60.2	mod. rain	-8.0	1.9
1997	78	Apr-24-97	C-700	75%	4b	2.5	9	52.3	mod. rain	-7.0	1.8

COLD SOAK DATA @ CEF FOR 1996/97 TEST SEASON (NOT USABLE)

Test Season	Test No.	Date	Fluid code	Fluid Dilution	Fluid Type	Box Size (cm)	BOX fail time [min.]	Rate of Precep. [g/dm*2/hr]	Precip. Type	Average Skin Temp [C]	Ambient Temp [C]
1997	1	Apr-22-97	C-109	neat	4	7.5	23	10.4	drizzle	-8.5	1.9
1997	2	Apr-22-97	C-708	75%	4b	7.5	19	9.3	drizzle	-10.5	1.9
1997	3	Apr-22-97	C-108	neat	4	15	27	10.2	drizzle	-9.5	1.9
1997	4	Apr-22-97	C-700	75%	4b	15	23	10.1	drizzle	-8.0	1.5

APPENDIX E

EVALUATION OF TYPE IV TEST DATA USING LINEAR METHOD FOR WINTER 1996/97

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June 27,1997

SUBJECT: Type IV Holdover times as per Linear Protocol

Dear HOT Sub-Committee Member,

Attached hereto is the Type IV holdover time table generated using the Transport Canada test data prepared for the SAE 1997 Deicing Conference at Pittsburgh (See Attachment A). In accordance with the decision taken there at the June 10 meeting of the Holdover Time subcommittee, Transport Canada has, in conjunction with APS, revised the data analysis in accordance with the "linear protocol" procedure laid out in Attachment B, which involves straight line fits to the data of the worst fluid to be accommodated in each table cell. The resulting table has many values that are substantially lower than the current Type IV holdover time table and will therefore require much discussion; for this reason it will not be ballotted as originally proposed but will be reviewed at Chicago on 22 and 23 July, 1997.

The low values obtained for the new Type IV table are not due solely to one fluid, but result from all the manufacturers new fluids as tested last winter. In developing the Type I and Type II tables, all the fluids were similar with the differences in performance being obscured by experimental variations. The low values in the new table occur because the various manufacturers have produced widely differing Type IV fluids, each of which has been qualified yet has its particular "Achilles Heel". In producing the SAE Type IV table, the worst feature of each qualified fluid must be accomodated to ensure safe use of the Type IV fluid on a universal basis; that means for any brand, any dilution, any temperature and any weather the holdover time of the worst performing fluid must lie within the range of times quoted .

The data used to generate the precise time ranges in the Attachment A Table are contained in Attachment C along with the straight line relationships used to interpolate or extrapolate to the determining precipitation/ temperature conditions. Freezing fog was only given a single time value rather than a range.

We are currently pursuing a second approach which will be discussed in Chicago. This approach uses a regression analysis that provides a power law relationship between failure time and precipitation, similar to that derived from the UQAC laboratory tests, and therefore leads to a curved fit to the data in Attachment C. This less restrictive approach gives higher values than in Attachment A, but still does not do justice to the improvements available in the new fluids.

In addition, separate HOT tables are being prepared for each fluid, partially based on the regression approach (where the data are sufficient) and partially on a conservative evaluation of the available data, the latter subject to review as further data are generated. These tables will also be discussed at Chicago.

The North American regulatory authorities are considering publishing these holdover time tables for each qualified Type IV fluid to accompany their publication of the SAE Table. The tables will be referred to as "Fluid-Manufacturer-Specific HOT Guidelines" and would be modified versions of the SAE Table containing values that would provide the benefits of each fluid where it was significantly superior to the worst fluid. These tables would be usable in those conditions where the pilots and ground crew know what fluid is being used (this would require a change to the FLIGHT CREW INFORMATION reporting protocol in ARP 4737A).

Should you have any comments on the above or the attachments you may contact the undersigned

Yours truly

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Barry Myers

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Fax 514-283-7158
Email myersbb@tc.gc.ca

ATTACHMENT A

SAE TYPE IV CURRENT HOT'S

LINEAR

*Worst Case Fluid by Cell

TIVWF

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	*FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	*DRIZZLE or LIGHT* RAIN ON COLD SOAKED WING
			Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
above 0°	above 32°	100/0	18:00	2:00-3:00 *155 H*	0:55-1:40 *30-57*	0:45-1:50 *40-56 H*	0:30-1:00 *30-45*	0:20-0:40 *18-43 O*
		75/25	6:00	0:40-2:00 *65 H*	0:20-1:00 *15-24 U*	0:20-1:00 *30-60 UH*	0:15-0:30 *16-27 U*	0:10-0:25 *14-33 O-KH*
		50/50 *CORRECTION MADE AFTER MATERIAL FAXED*	4:00	0:15-0:45 *20 KU*	0:05-0:25 *5-18*	0:07-0:15 *10-18 U*	0:05-0:10 *8-11 U*	
0 to -3	32 to 27	100/0	12:00	2:00-3:00 *155 H*	0:45-1:40 *30-57*	0:45-1:50 *40-56 H*	0:30-1:00 *30-45*	
		75/25	5:00	0:40-2:00 *65 H*	0:15-1:00 *15-24 U*	0:20-1:00 *30-60 UH*	0:15-0:30 *16-27 U*	
		50/50	3:00	0:15-0:45 *20 KU*	0:05-0:20 *5-13 K*	0:07-0:15 *10-18 U*	0:05-0:10 *8-11 U*	
below -3 to -14	below 27 to 7	100/0	12:00	2:00-3:00 *40 O*	0:35-1:15 *17-40 H*	**0:45-1:50 *30-60*	**0:30-0:55 *25-45 O*	
		75/25	5:00	0:40-2:00 *35 O*	0:15-1:00 *15-26 H*	**0:20-1:00 *23-47*	**0:10-0:25 *16-25*	
below -14 to -25	below 7 to -13	100/0	12:00	1:00-2:00 *25 H*	0:30-1:10 *13-33 H*			
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.					

[redacted]

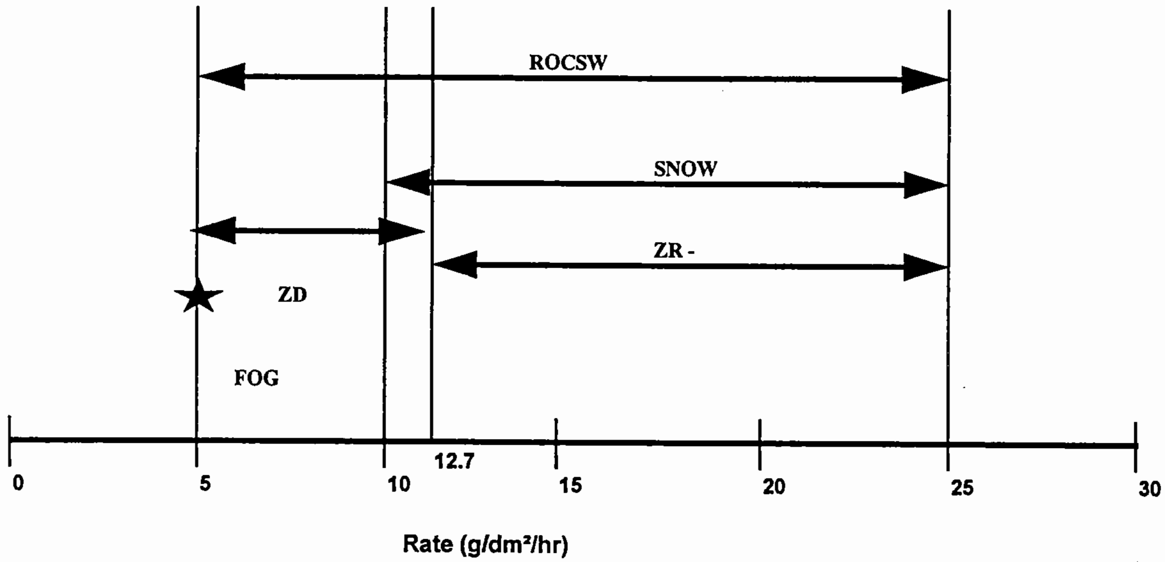
○ FIRM
□ CONSERVATIVE
△ CONSERVATIVE & INSIGNIFICANT
◇ INSUFFICIENT DATA

** Adjusted based upon coding*
→ insufficient data - not used as criteria.

cm1283\report\hot_sub\HO4_NUM.XLS
At:Type IV 97-6-19

DATA RANGE USED FOR EVALUATION OF HOT LIMITS

ATTACHMENT B



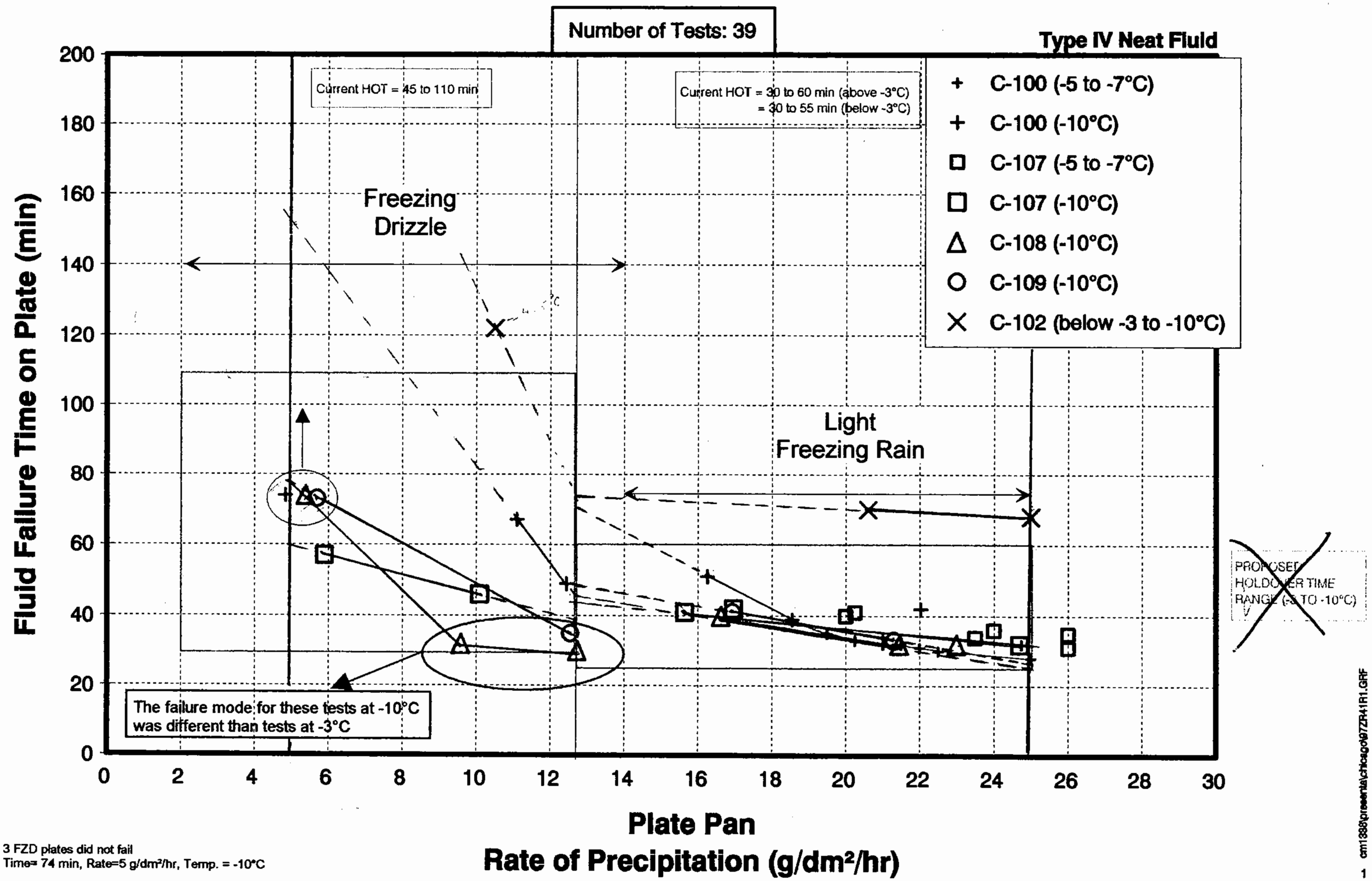
HOT LIMITS FOR EACH FLUID

1. Draw straight line between lowest data points, for each cell (see detailed charts in Attachment C).
2. Extrapolate, if necessary, to limits in chart above.
3. Based on physical properties of fluids, we reduced the gradient of the high precipitation rates and increased the gradient at the lower precipitation rates when data points allowed (see charts).
4. Read off corresponding time values for Lower Limit and Upper Limit (capped at 120 minutes except fog at 240 minutes).

DETERMINATION OF HOT TABLE VALUES

1. Select the lowest Lower Limit and lowest Upper Limit by inspection of the values of each fluid.
2. Evaluate reliability of data and adjust as required.

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT @ -3 to -10C
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997



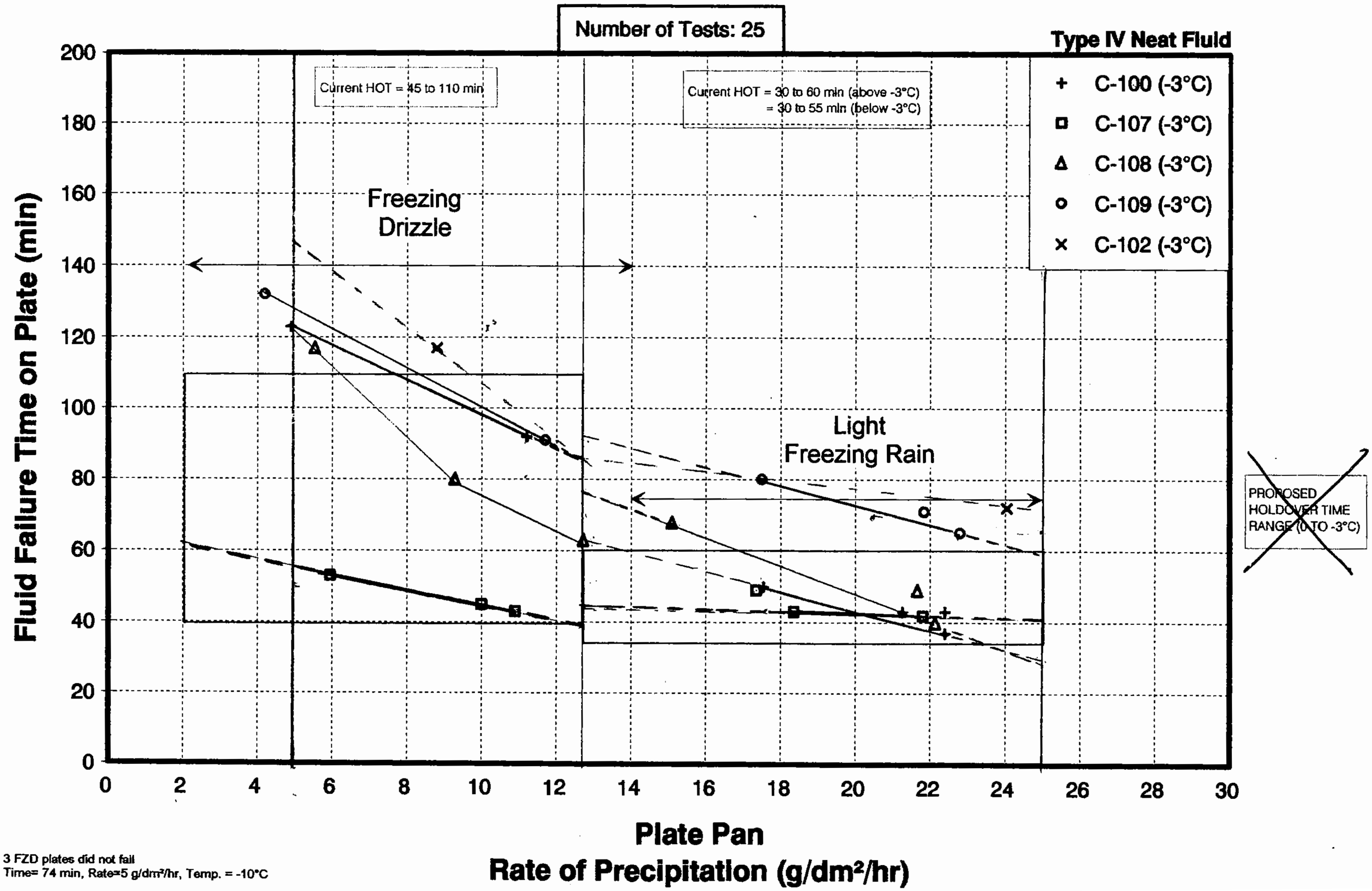
3 FZD plates did not fail
Time= 74 min, Rate=5 g/dm²/hr, Temp. = -10°C

cm1338\presenta\chicago\97ZR41R1.GRF
1

C-2

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT @ -3°C
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997

E-7



3 FZD plates did not fail
Time= 74 min, Rate=5 g/dm²/hr, Temp. = -10°C

cm1338/presenta/chicago/97ZR41R3.GRF

1

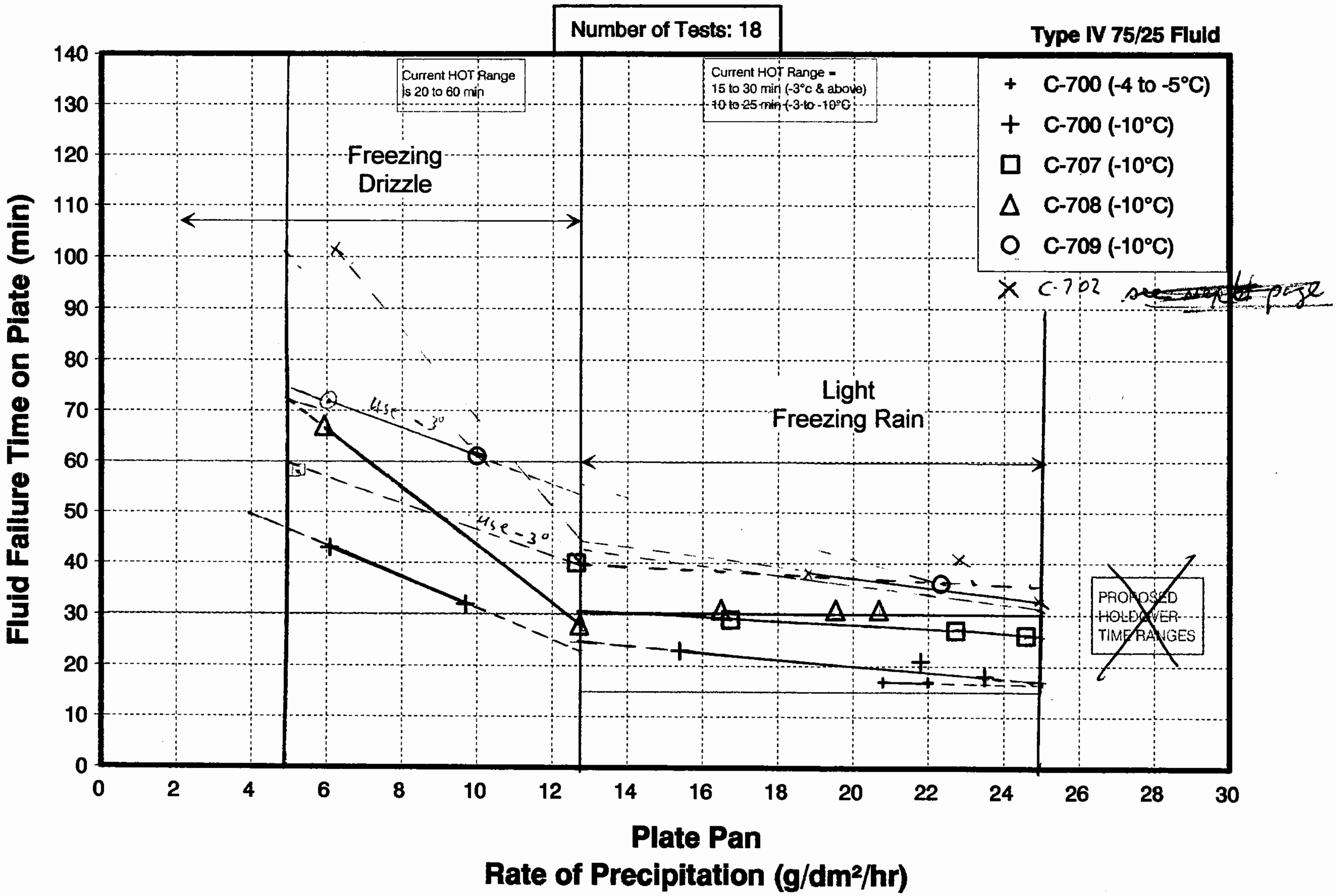
C-3

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25 @ -10°C to -3°C

FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1995/96 & 1996/97



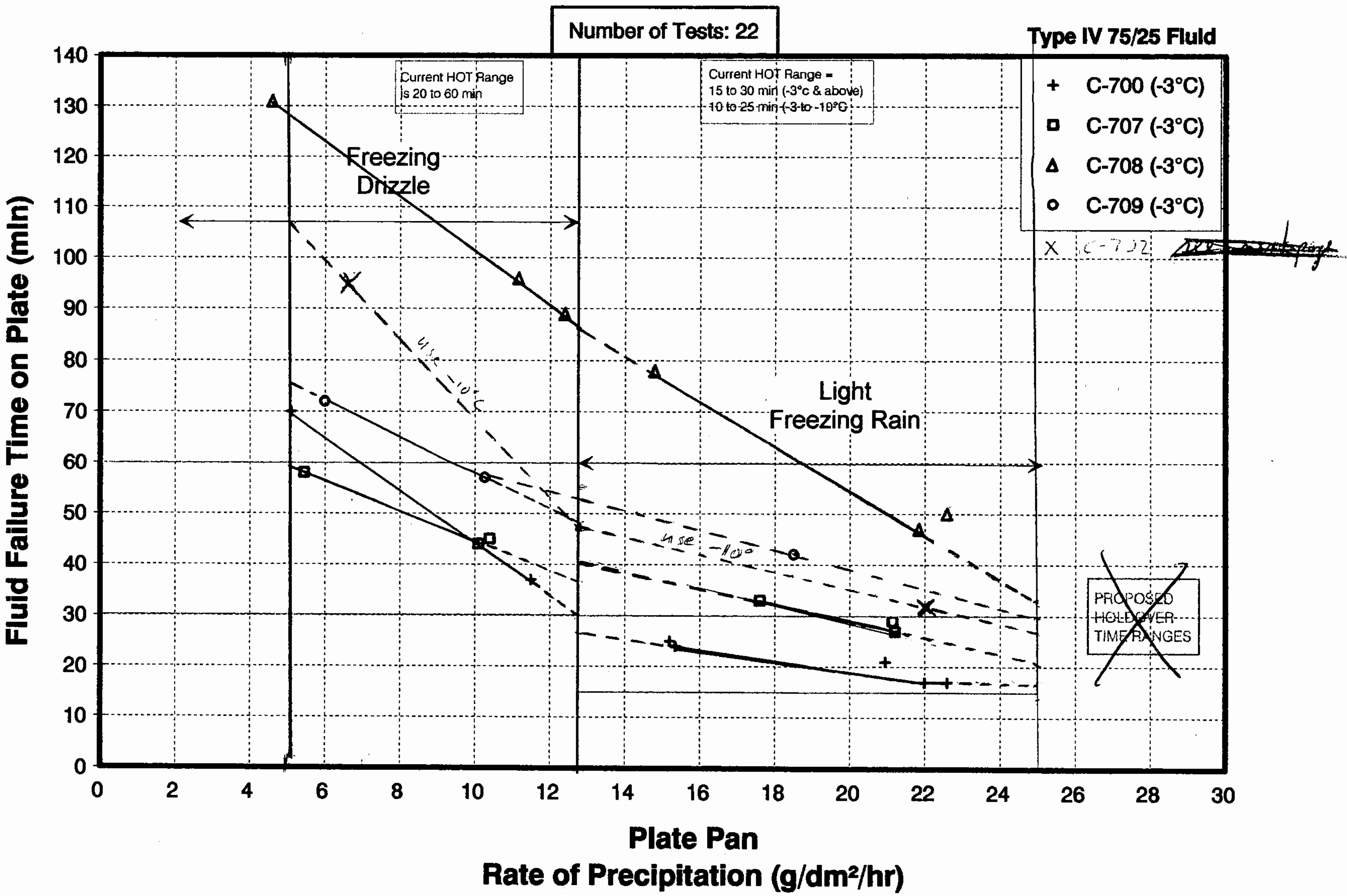
E-8

cm1338\presenta\pittsbur\97ZR47R1.grf

2

C-4

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25 @ -3° C
FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/96 & 1996/97



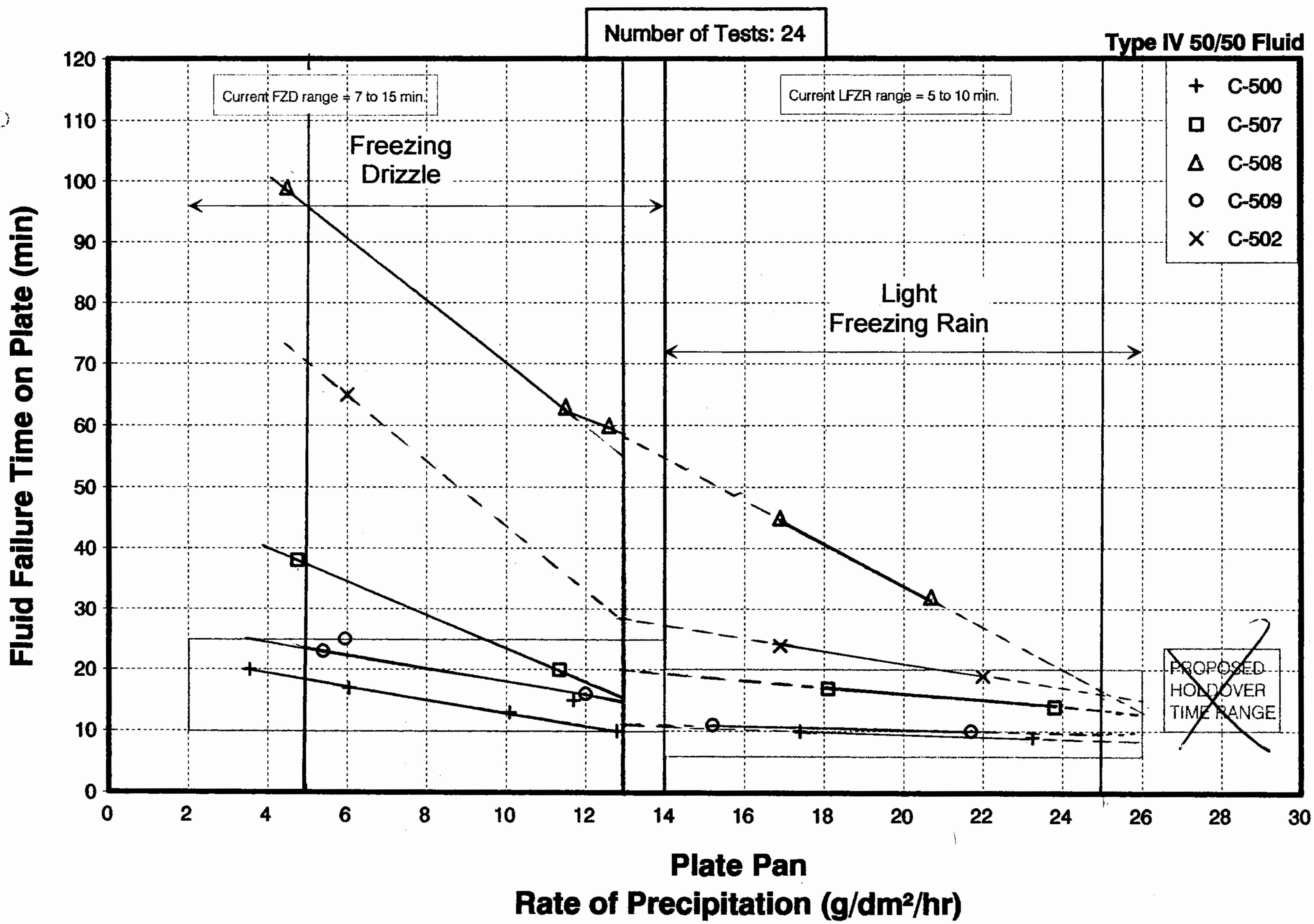
E-9

cm1338\presents\chicago\97Z R4 7R3.grf

2

C-5

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 50/50 @ -3°C
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997

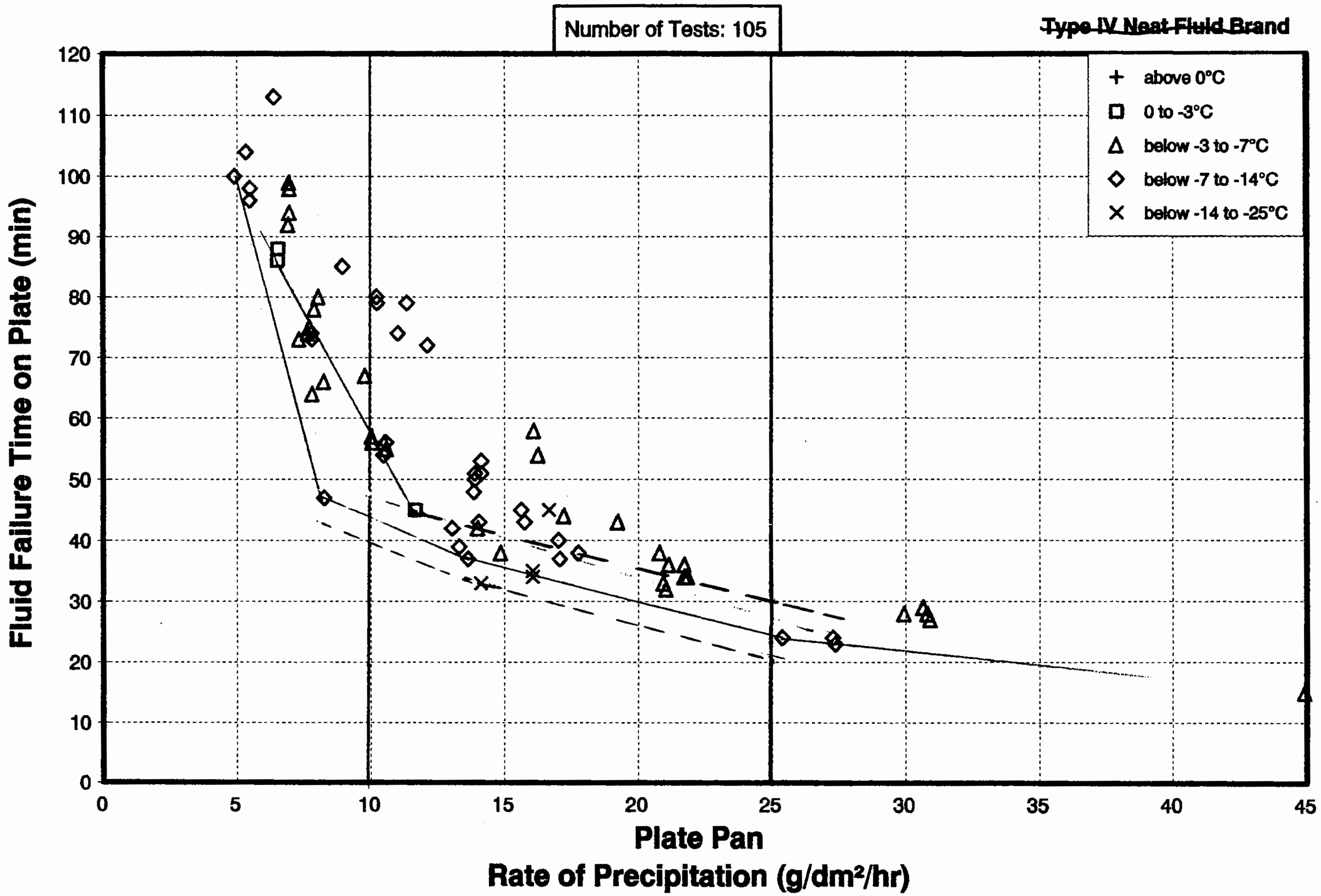


E-10

cm1338/present/pittsburh97FZR45R.GRF

C-6

EFFECT OF ~~FLUID BRAND~~ TEMP AND RATE OF PRECIPITATION ON FAILURE TIME
C-100 [redacted] TYPE IV NEAT
NATURAL SNOW CONDITIONS
1996/1997



E-11

cm1338\presents\chicago\U97NS41R.GRF

4b

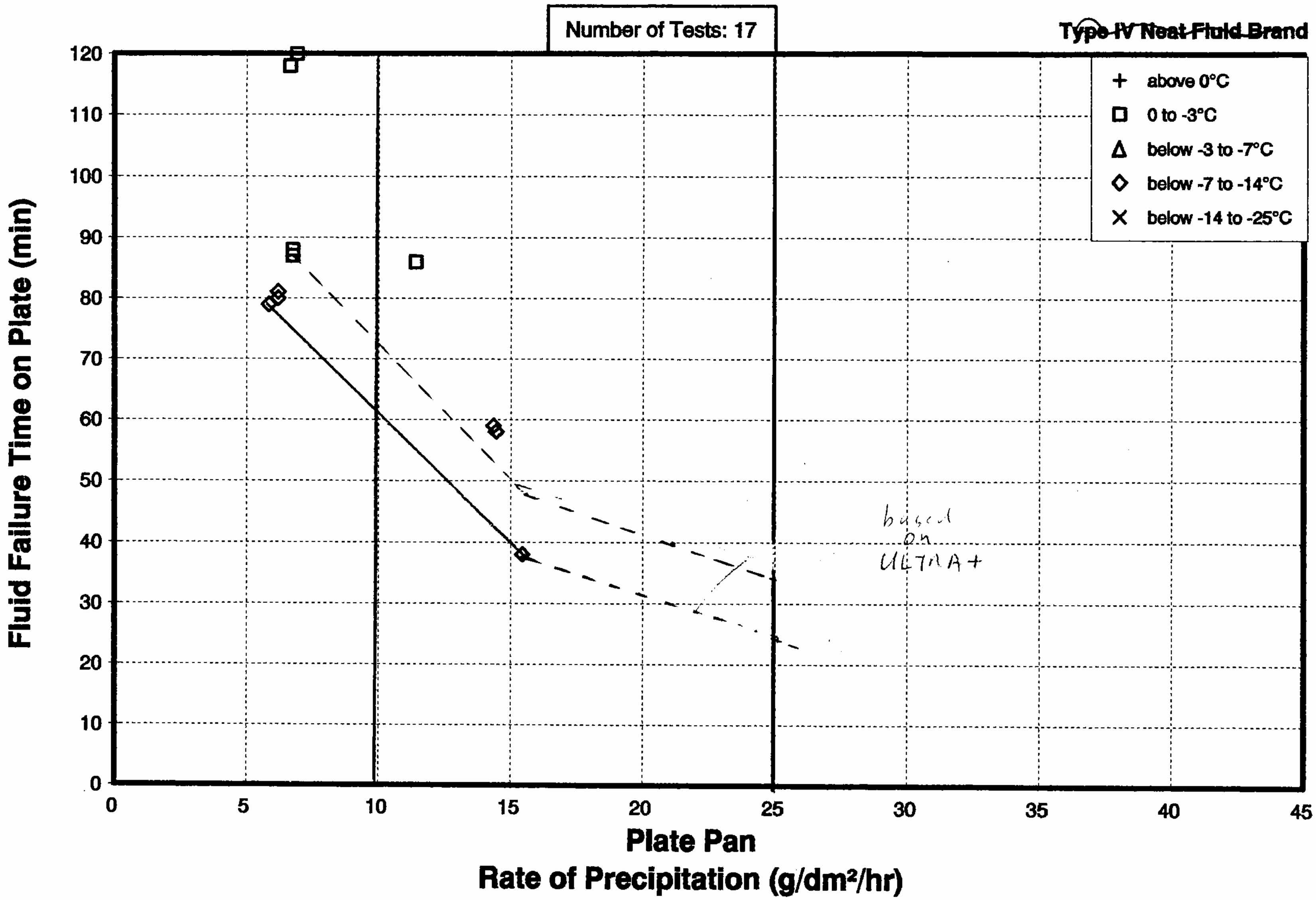
C-7

EFFECT OF ~~FLUID BRAND~~ [TEMP.] AND RATE OF PRECIPITATION ON FAILURE TIME

C-102 [redacted] TYPE IV NEAT

NATURAL SNOW CONDITIONS

1995/1996



cm1338\presenta\chicago\S97N841R.GRF

4b

C-8

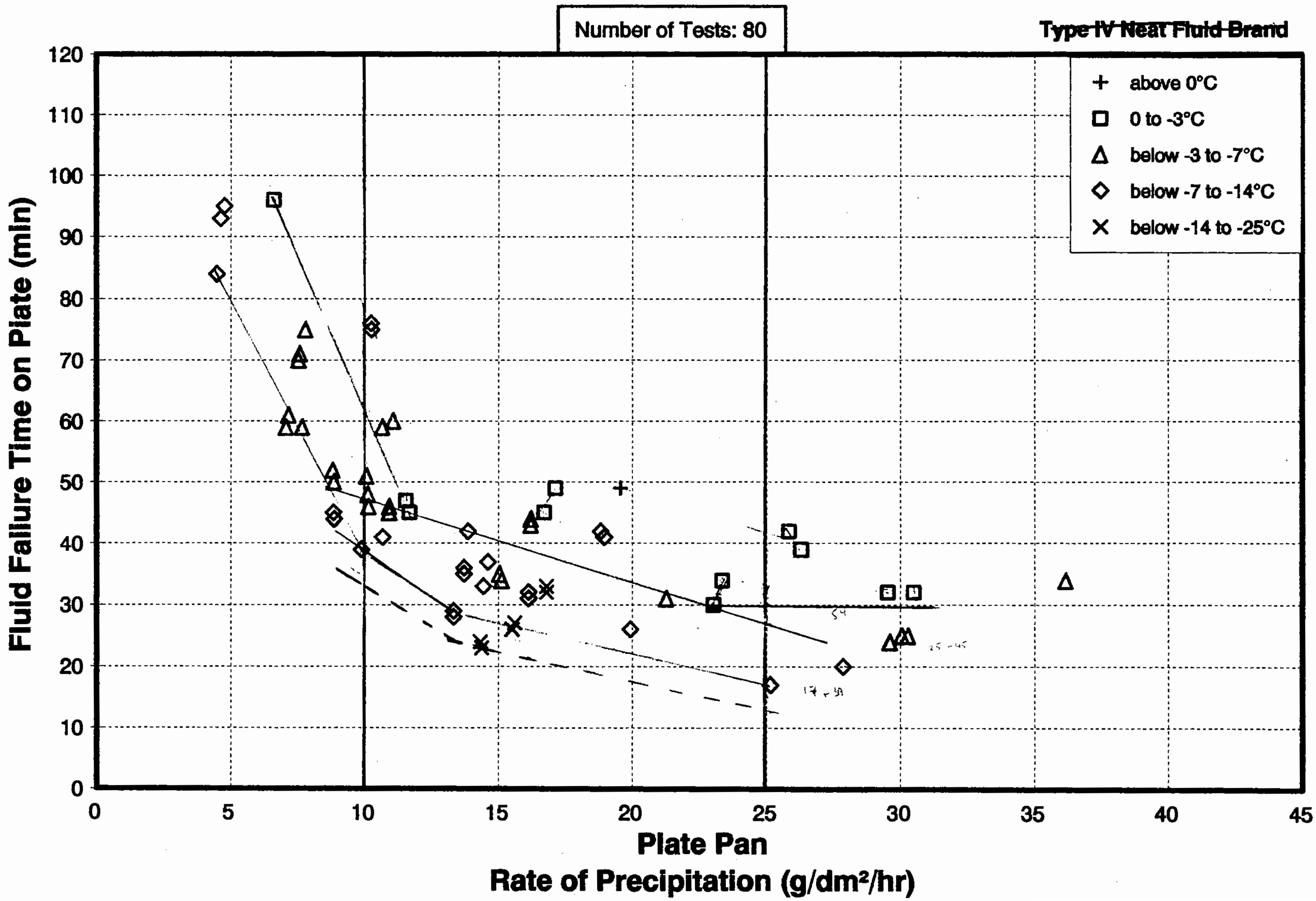
Temp

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

C-107 [redacted] TYPE IV NEAT

NATURAL SNOW CONDITIONS

1996/1997



E-13

cm1338\presenta\pittsburi\967NS41R.GRF

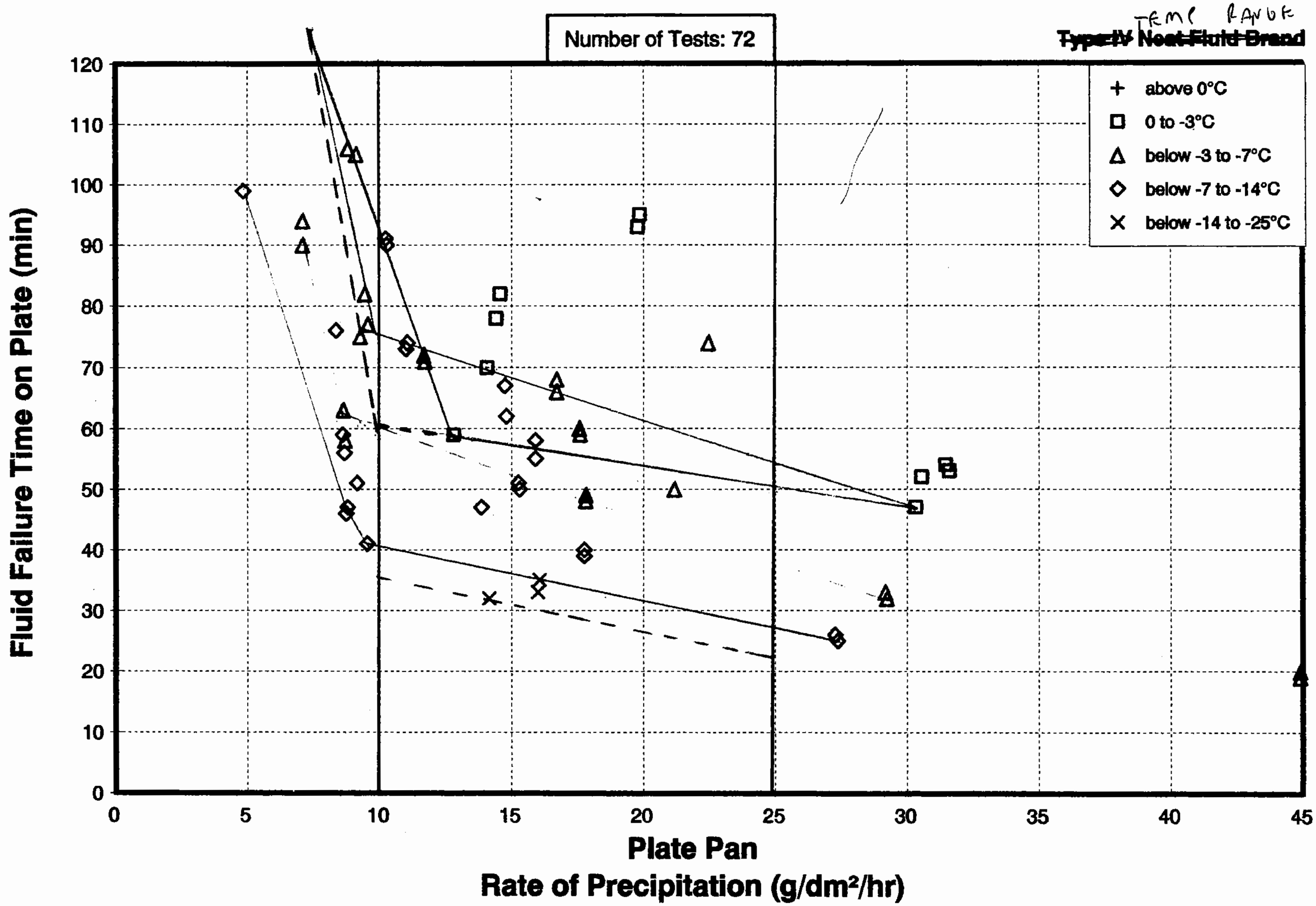
C-9

EFFECT OF ~~FLUID BRAND~~ TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-108 [redacted] TYPE IV NEAT

NATURAL SNOW CONDITIONS

1996/1997



4b

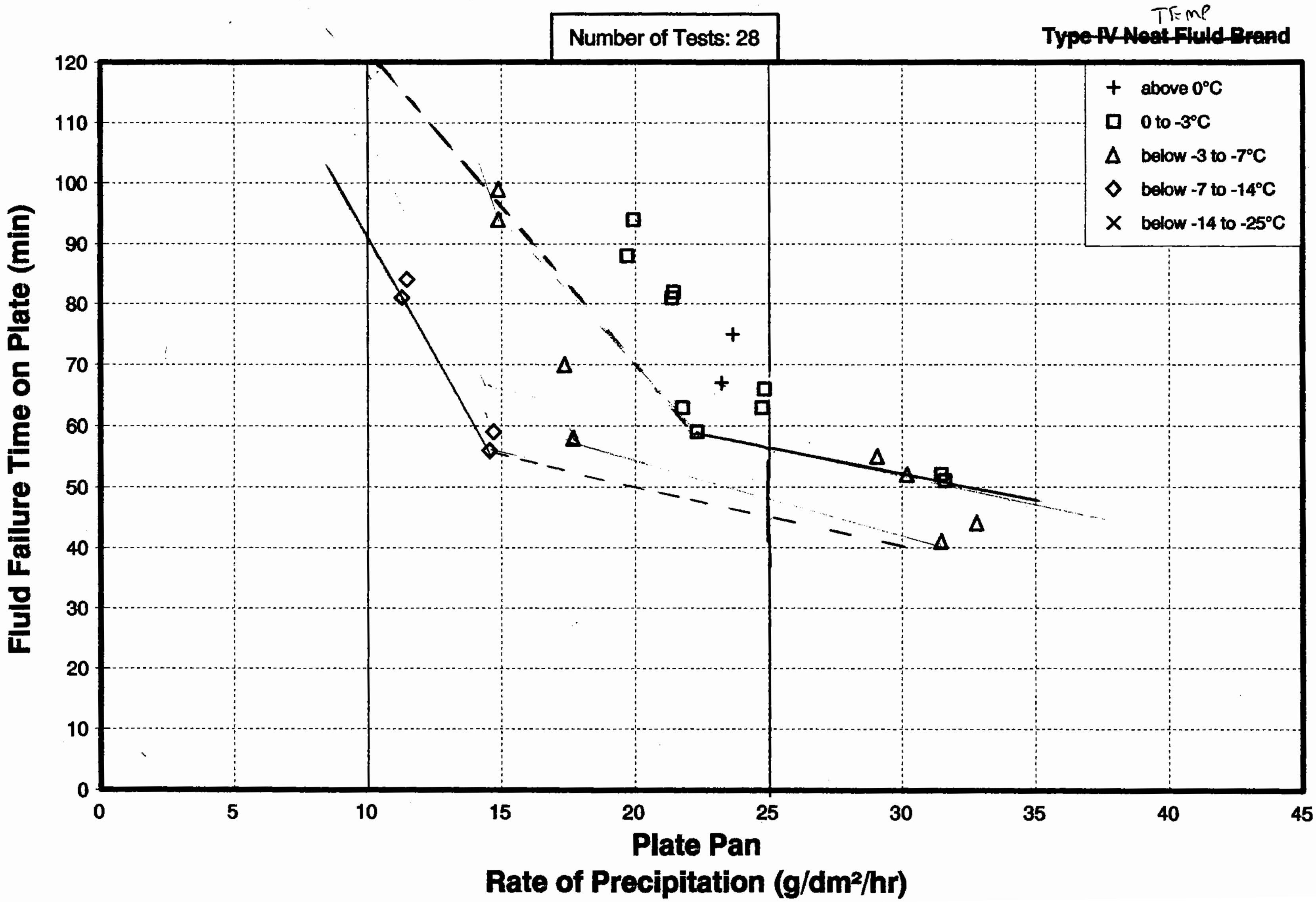
C-70

EFFECT OF ~~FLUID BRA~~ND [TEMP'] AND RATE OF PRECIPITATION ON FAILURE TIME

C-109 [redacted] TYPE IV NEAT

NATURAL SNOW CONDITIONS

1996/1997



E-15

cm1338\presents\chicago\V87NS41R.GRF

4b

C-11

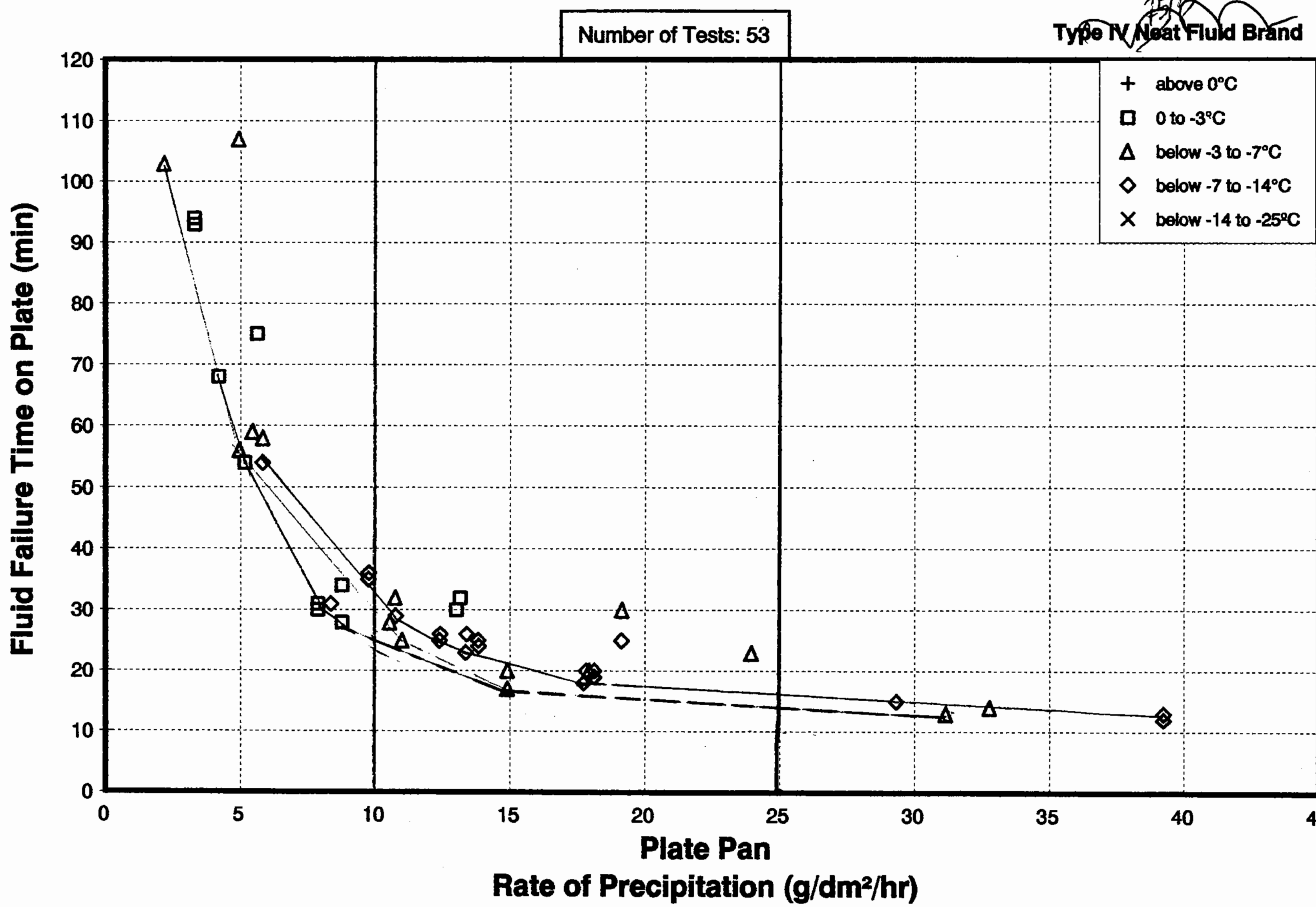
EFFECT OF ~~FLUID BRA~~ND AND RATE OF PRECIPITATION ON FAILURE TIME

Temp

C-700 [redacted] TYPE IV 75/25

NATURAL SNOW CONDITIONS

1996/1997



E-16

4b

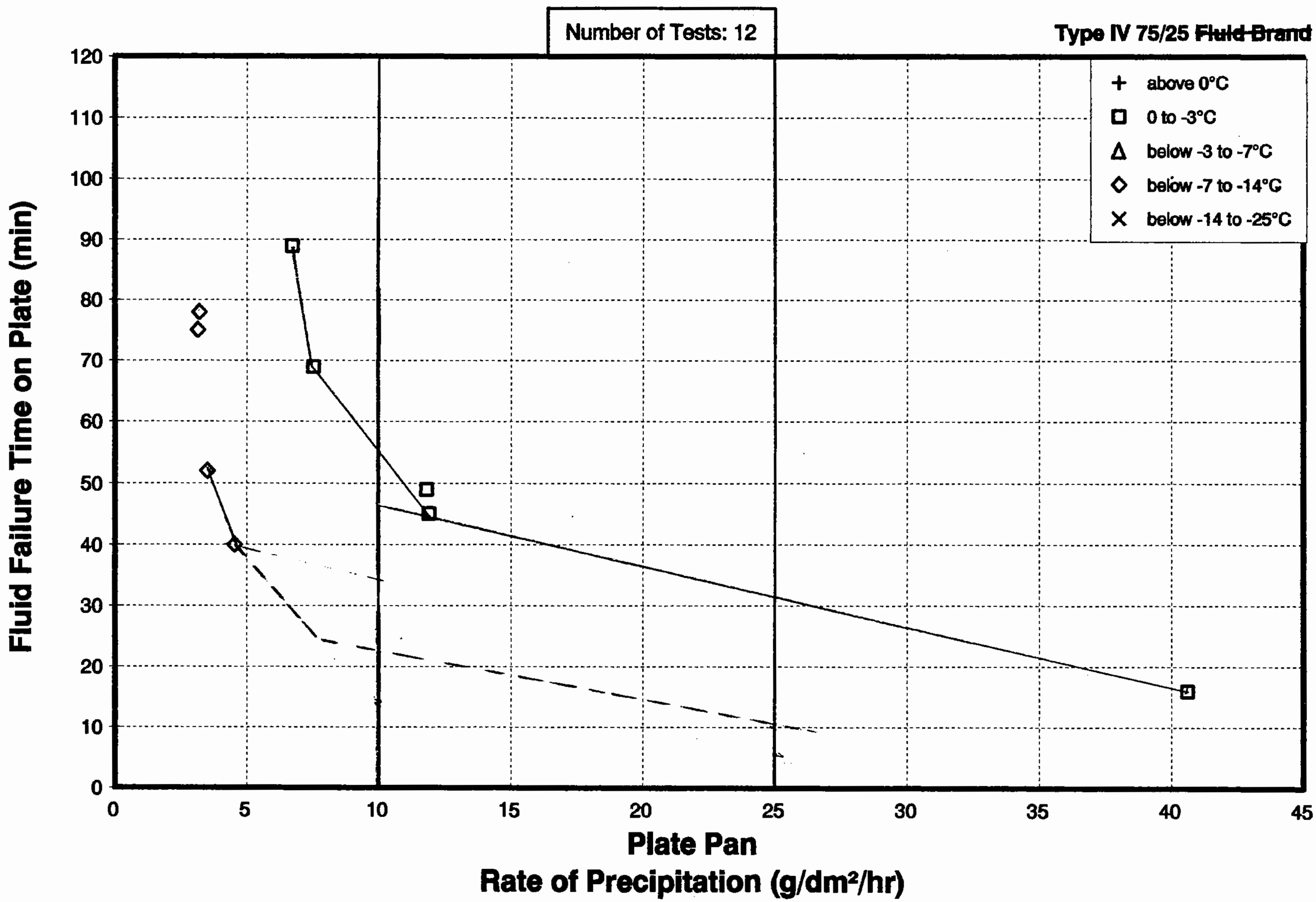
C-12

EFFECT OF ~~FLUID BRAND~~ TEMP. AND RATE OF PRECIPITATION ON FAILURE TIME

C-702 [redacted] TYPE 75/25

NATURAL SNOW CONDITIONS

1995/1996



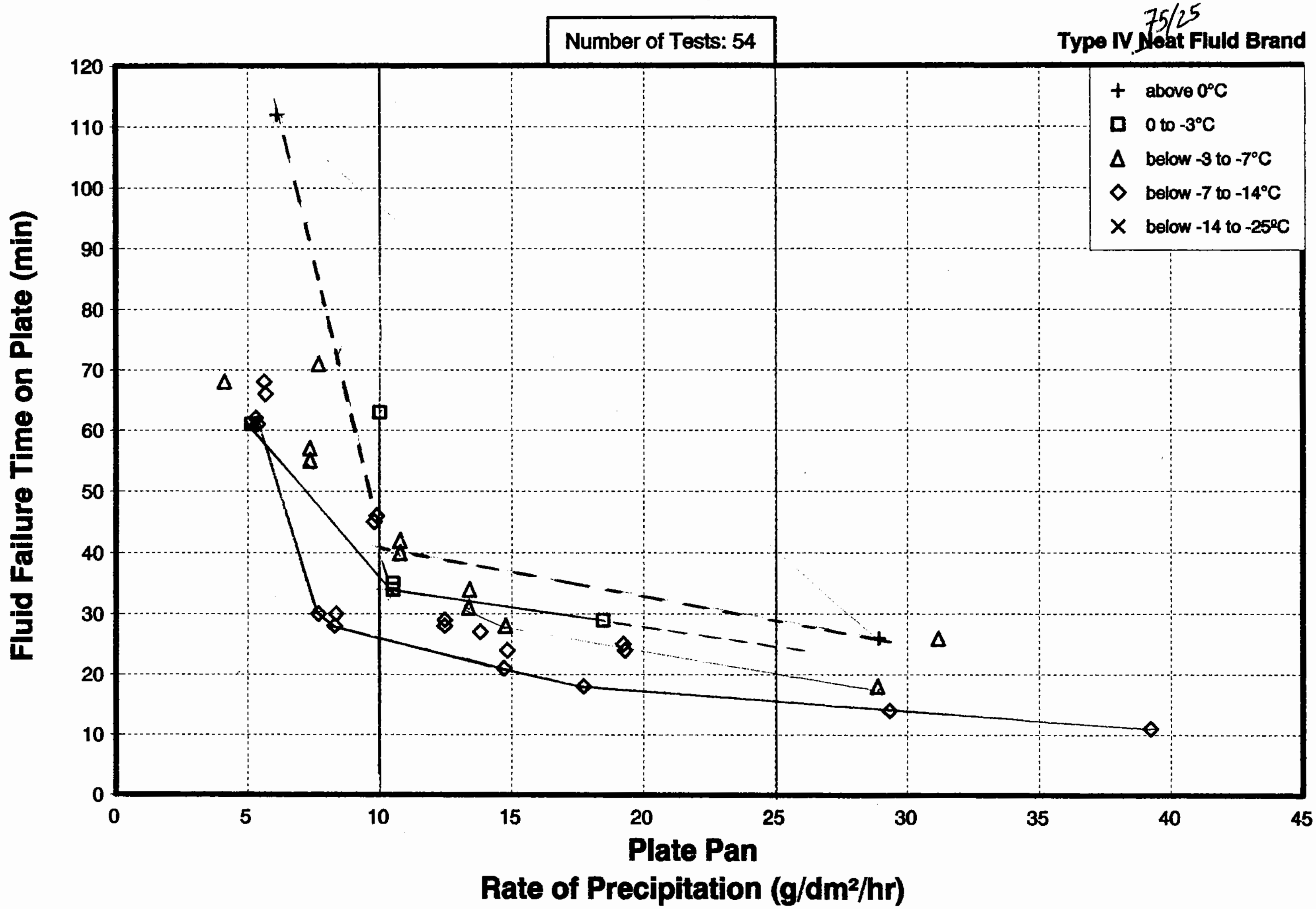
4b

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

[redacted] TYPE IV 75/25

NATURAL SNOW CONDITIONS

1996/1997



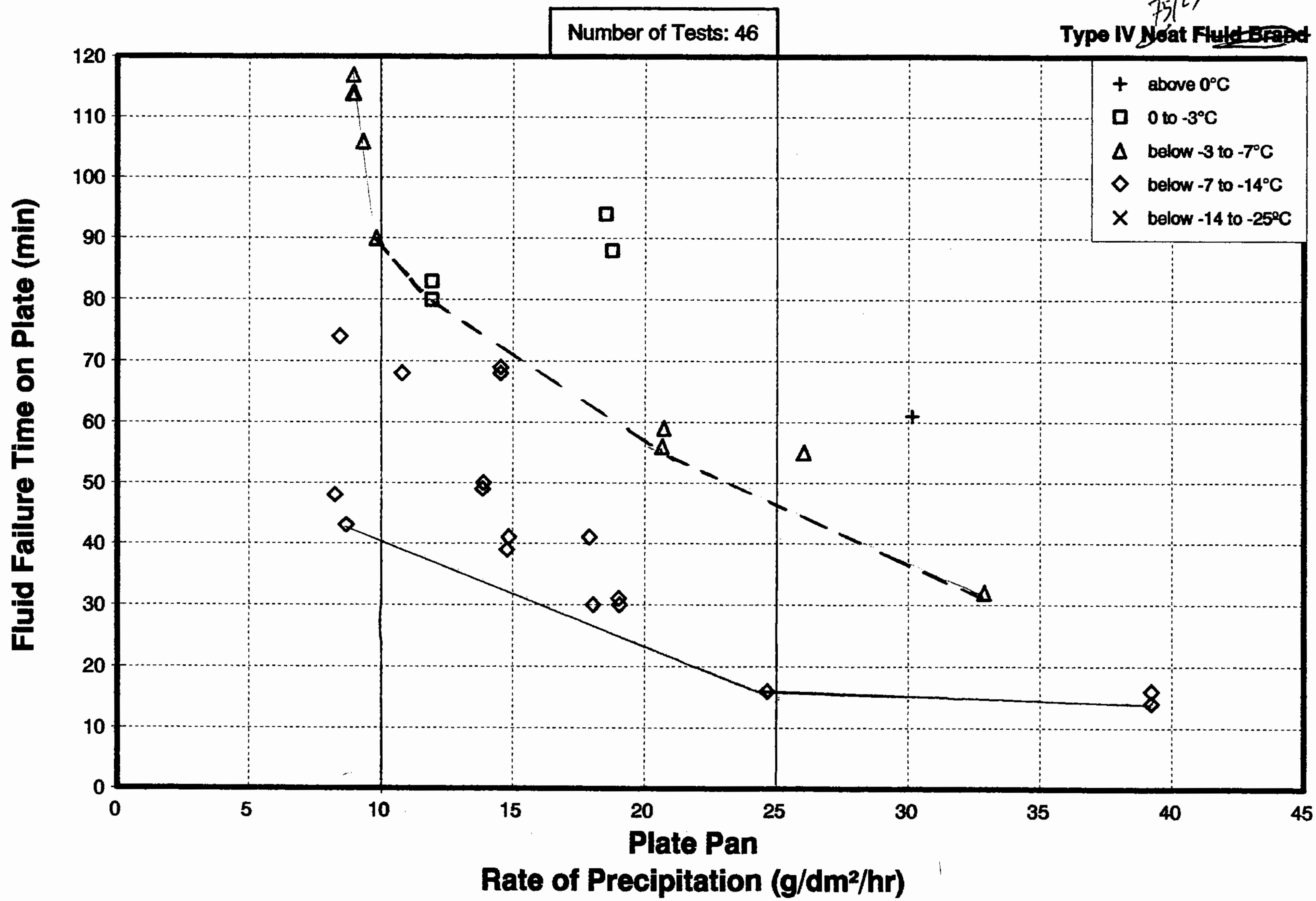
C-14

EFFECT OF ~~FLUID BRAND~~ TEMP. AND RATE OF PRECIPITATION ON FAILURE TIME

C-708 [redacted] TYPE IV 75/25

NATURAL SNOW CONDITIONS

1996/1997



E-19

cm1338\present\chicago\O97N547R.GRF

4b

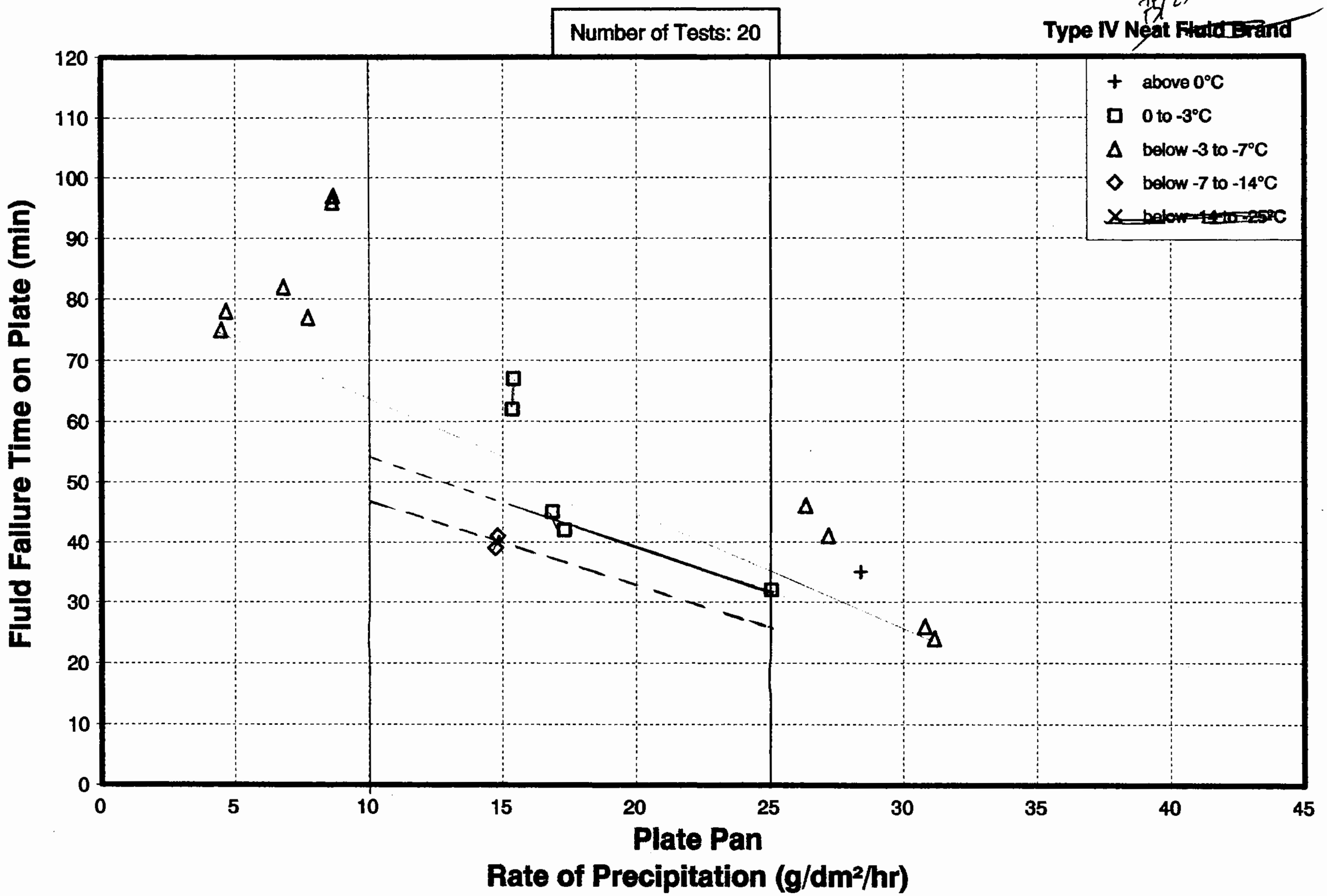
C-15

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME

C-709 [redacted] TYPE IV 75/25

NATURAL SNOW CONDITIONS

1996/1997



E-20

cm1338\presents\chicago\V97NS47R.GRF

4b

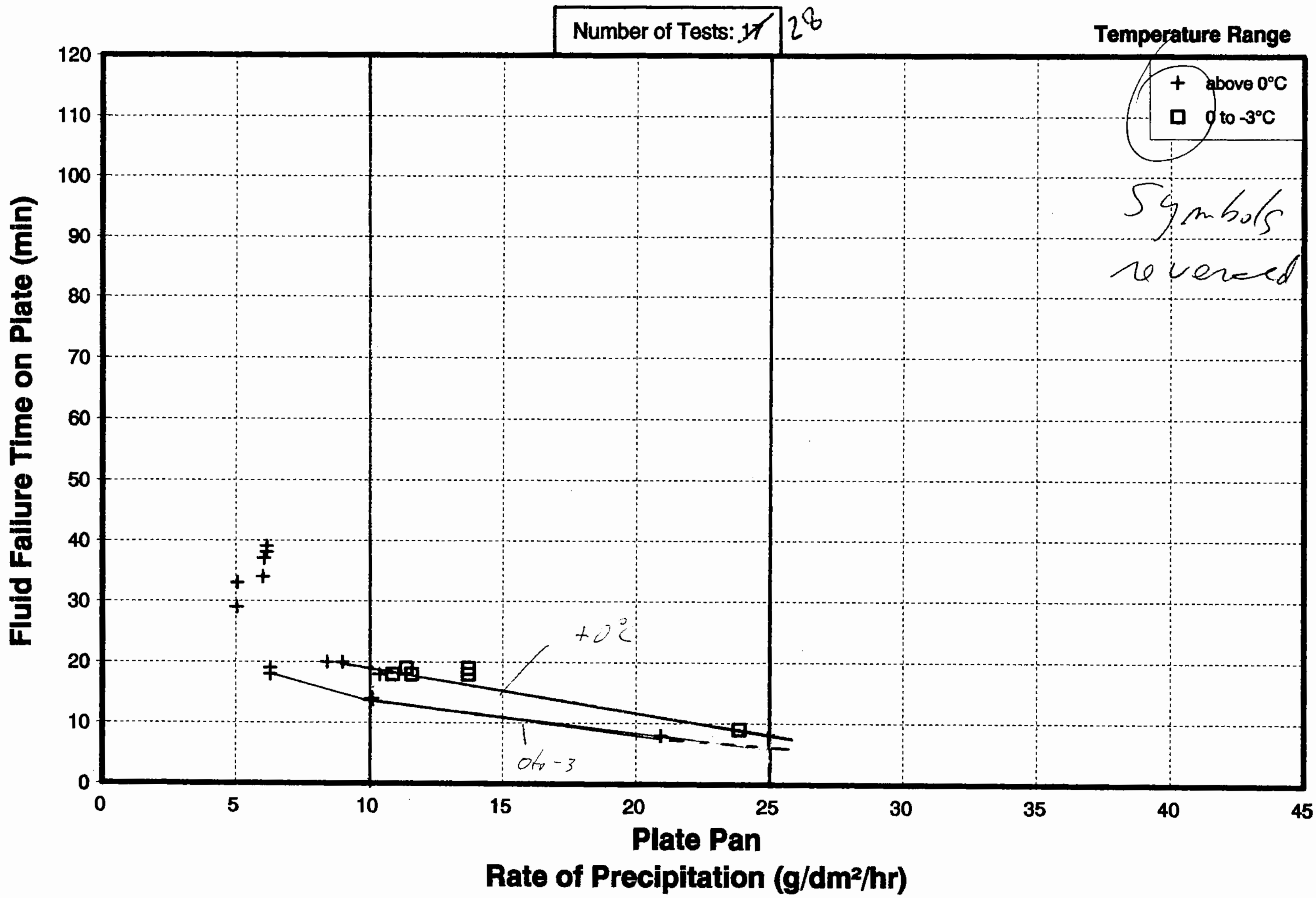
C-16

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-500 [redacted] TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/1997



E-21

om1338\presenta\chicago\U97N845o.GRF

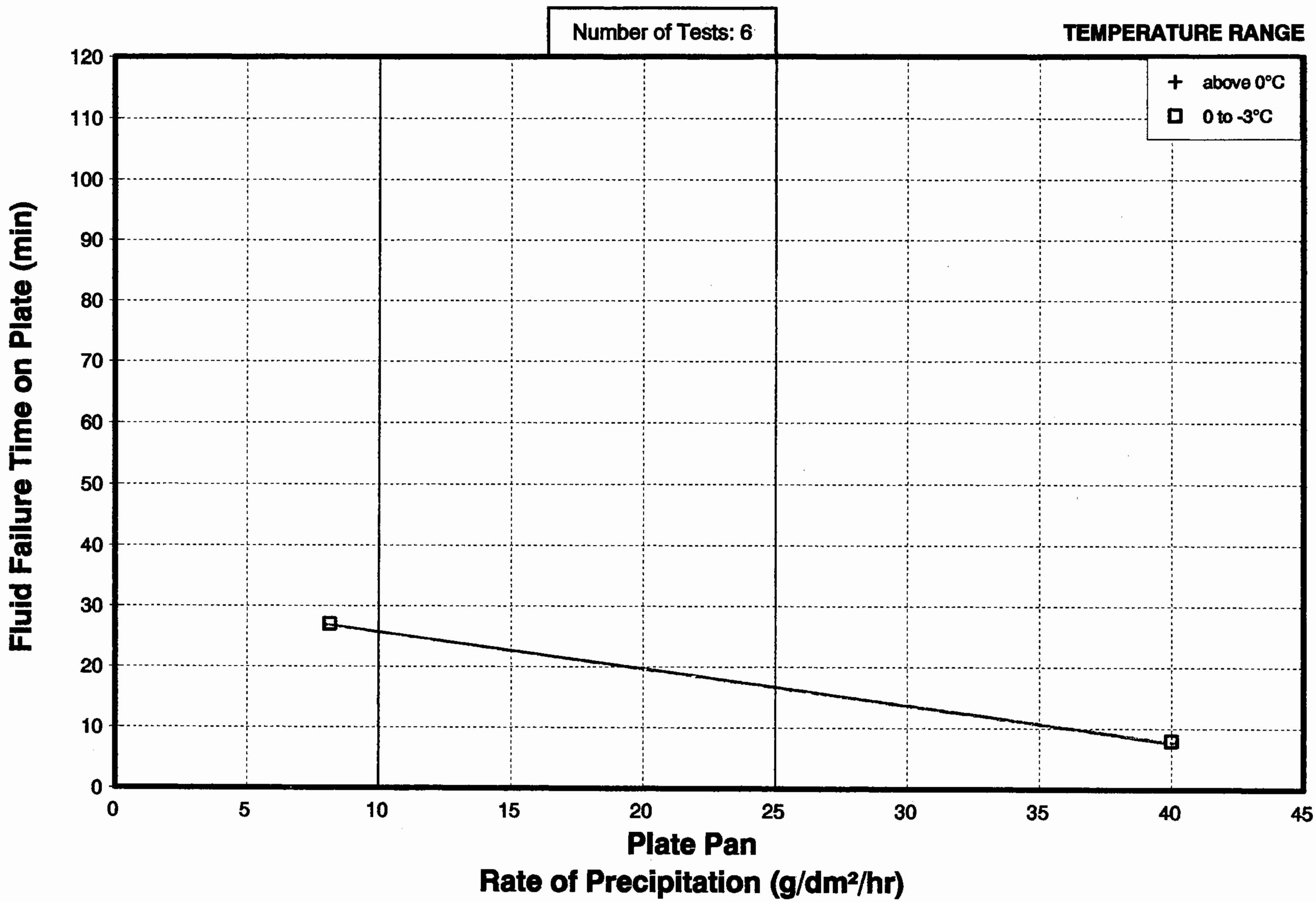
4b

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-502 [redacted] TYPE 50/50

NATURAL SNOW CONDITIONS

1995/1996



4b

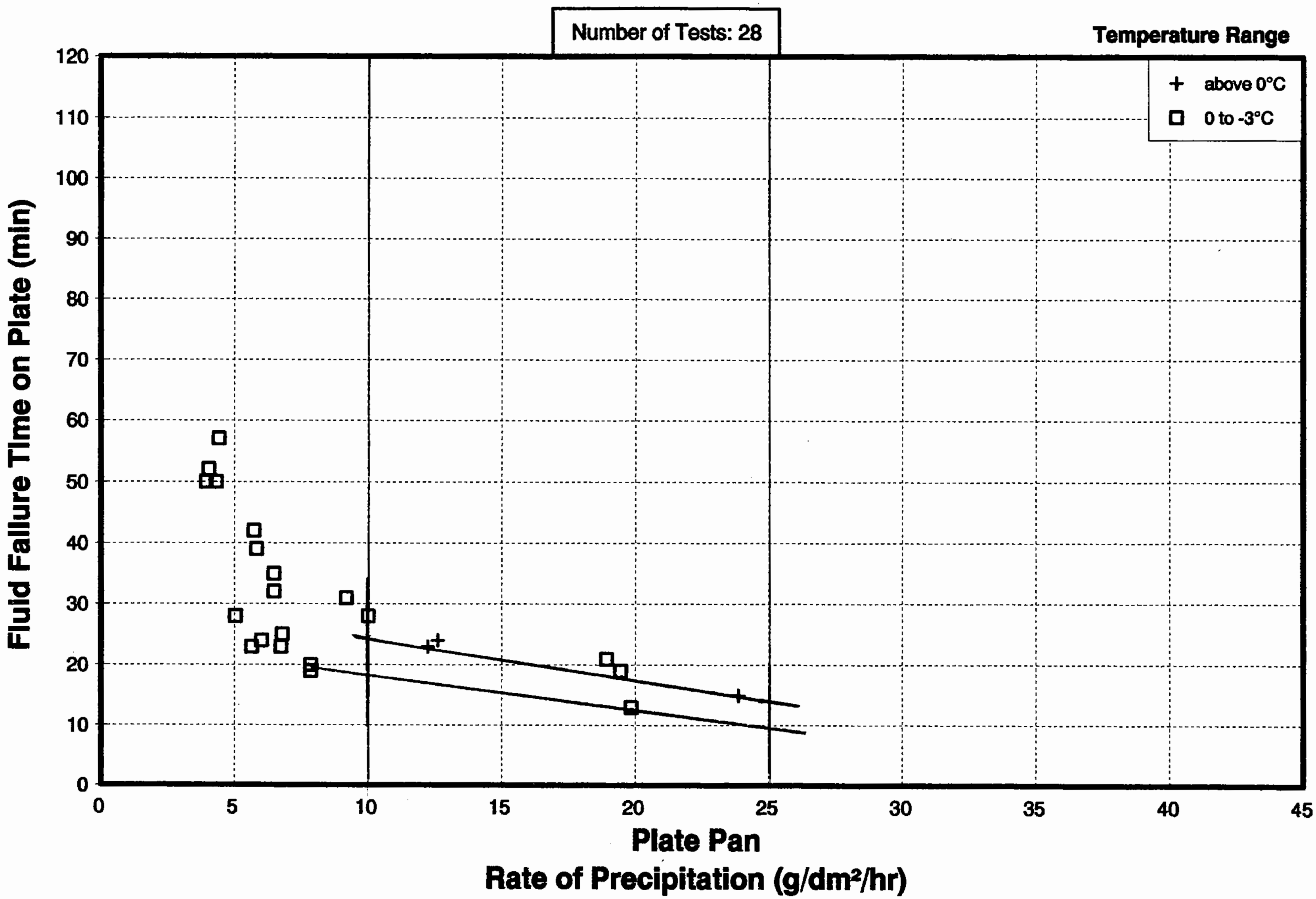
C-18

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-507 [redacted] TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/1997



E-23

4b

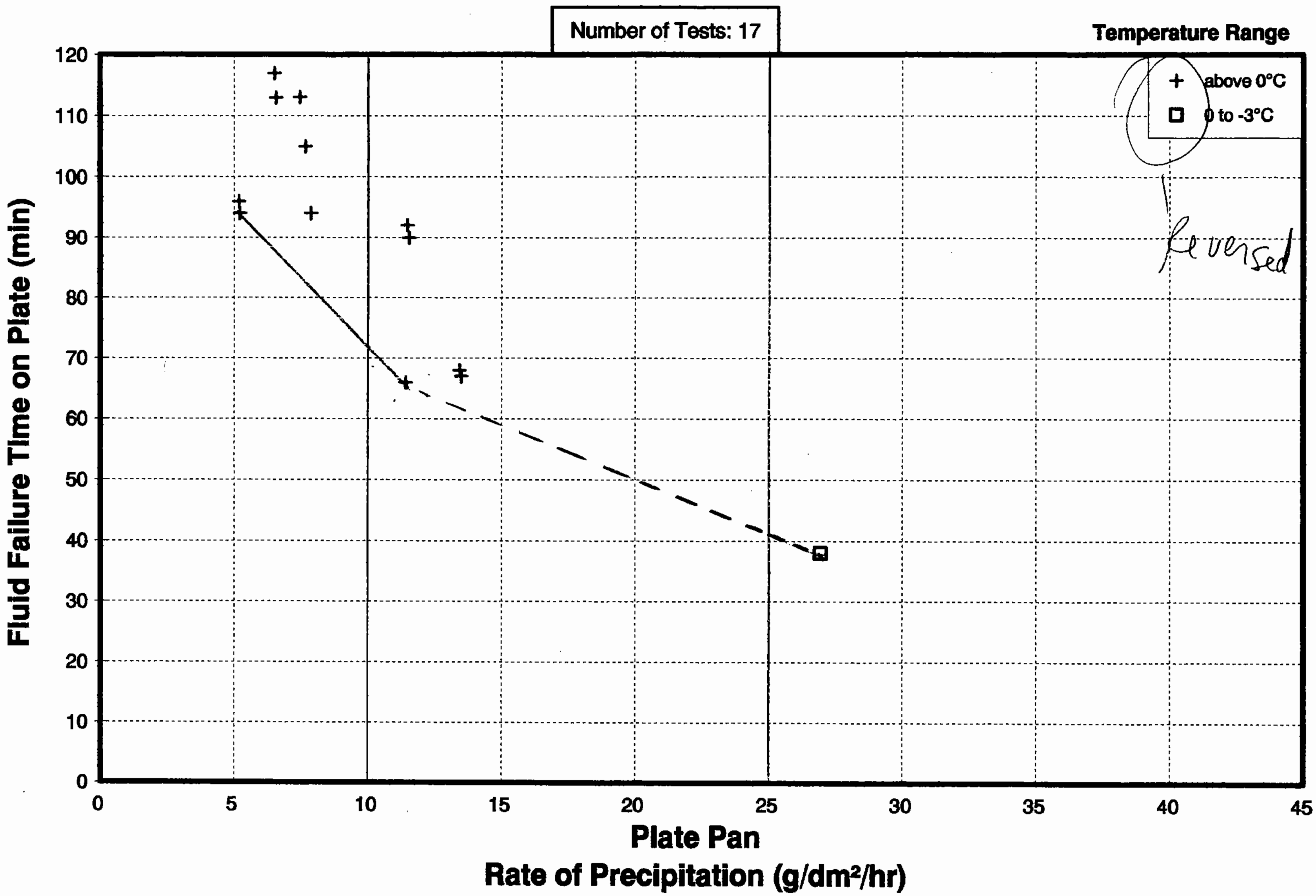
C-19

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-508 [redacted] TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/1997



E-24

cm1338\presenta\chicago\O97N845c.GRF

4b

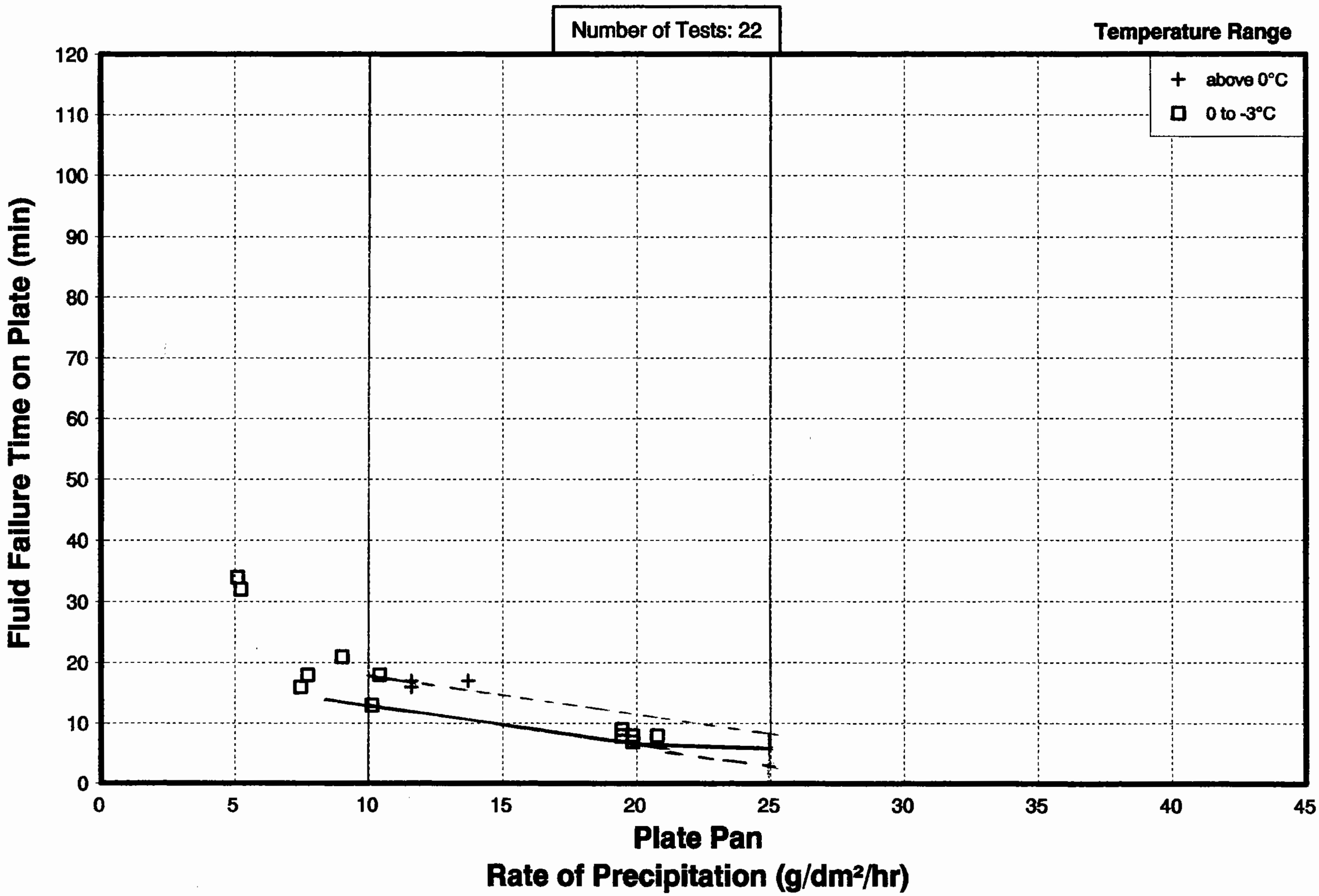
C-18
20

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-509 [redacted] TYPE IV 50/50

NATURAL SNOW CONDITIONS

1996/1997

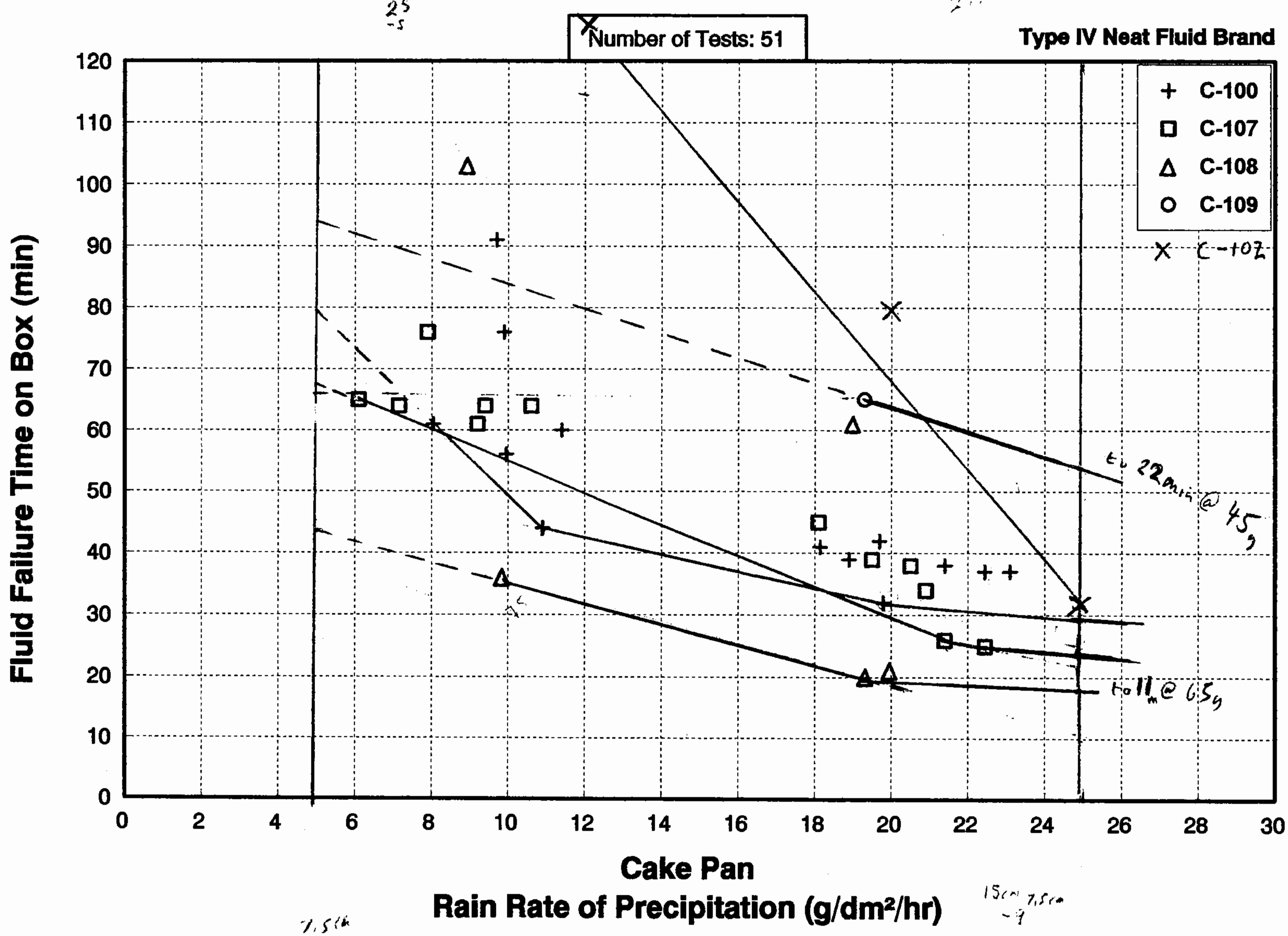


cm1338\presenta\chicago\K97N845c.GRF

4b

C-21

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT
RAIN ON COLD-SOAKED SURFACE
1995/1996 & 1996/1997



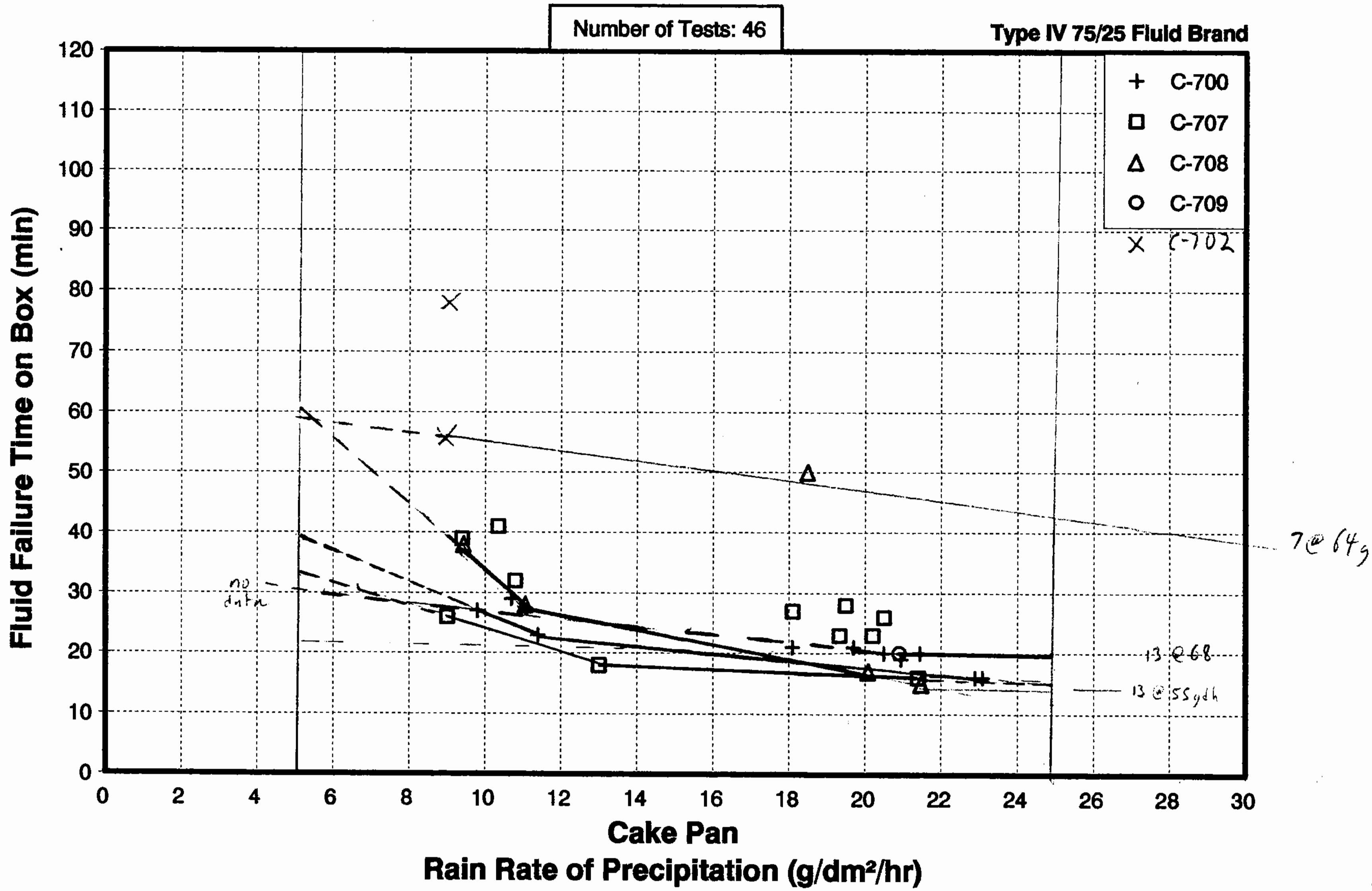
E-26

cm1338\presents\pittsburC3_41_R.GRF

10a

C-22

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25
RAIN ON COLD-SOAKED SURFACE
1995/1996 & 1996/1997



E-27

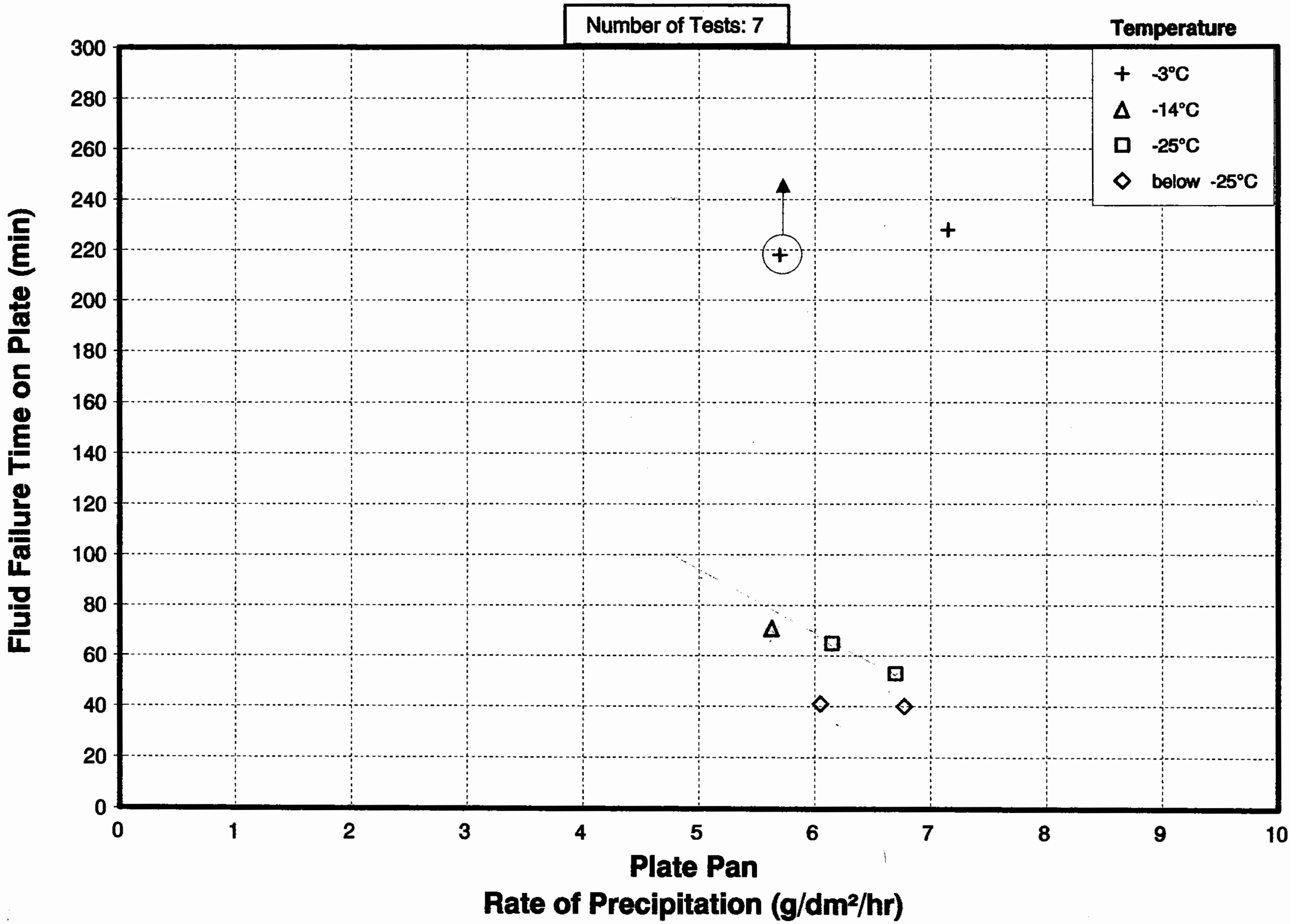
cm1338/present/pittsburi/CS_47_R.GRF

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-100 [redacted] TYPE IV NEAT

SIMULATED FREEZING FOG

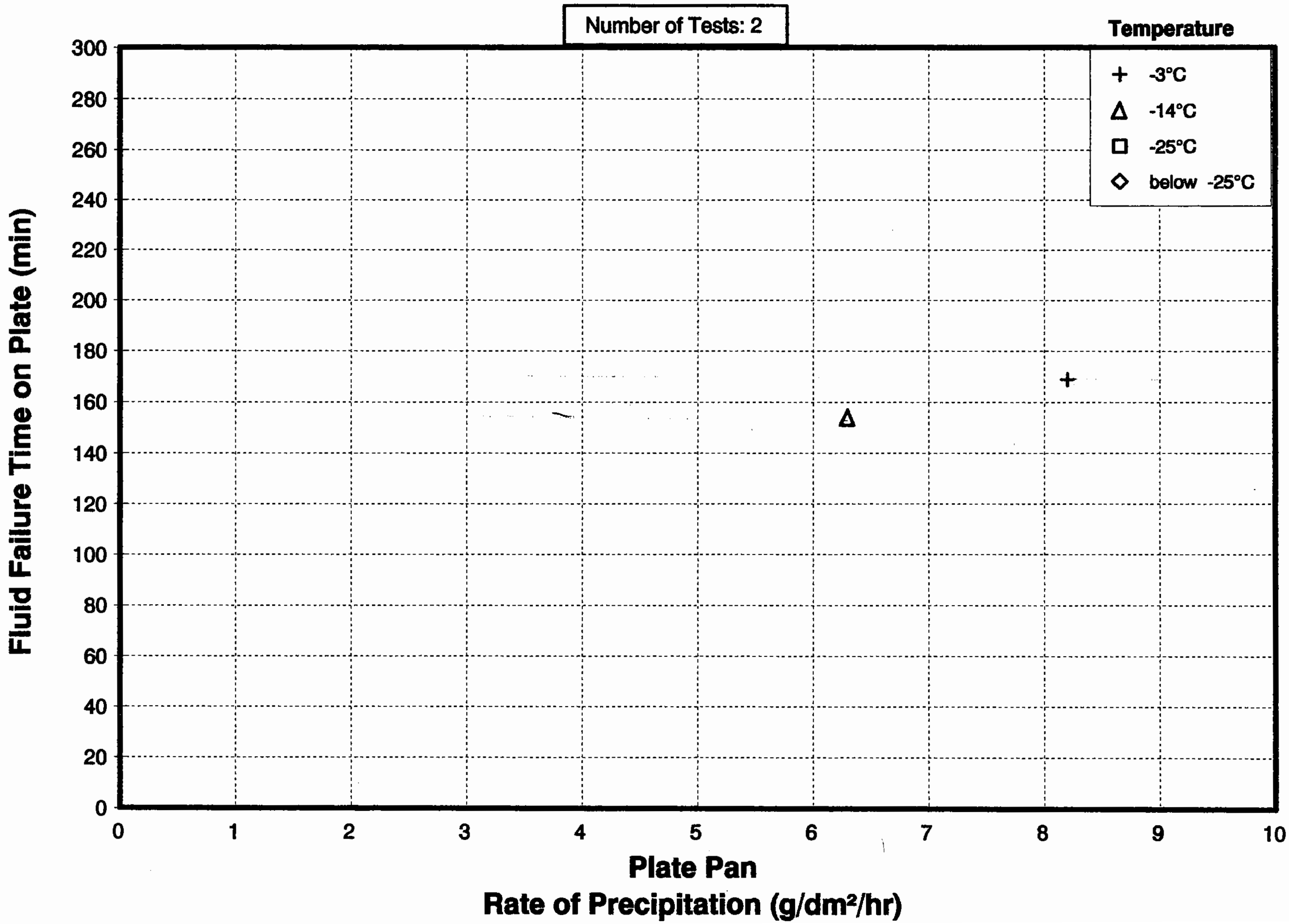
1996/1997



7b

C-24

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-102 [redacted] TYPE IV NEAT
SIMULATED FREEZING FOG
1995/1996



E-29

cm1338\presenta\chicago\S97FF41C.GRF

7b

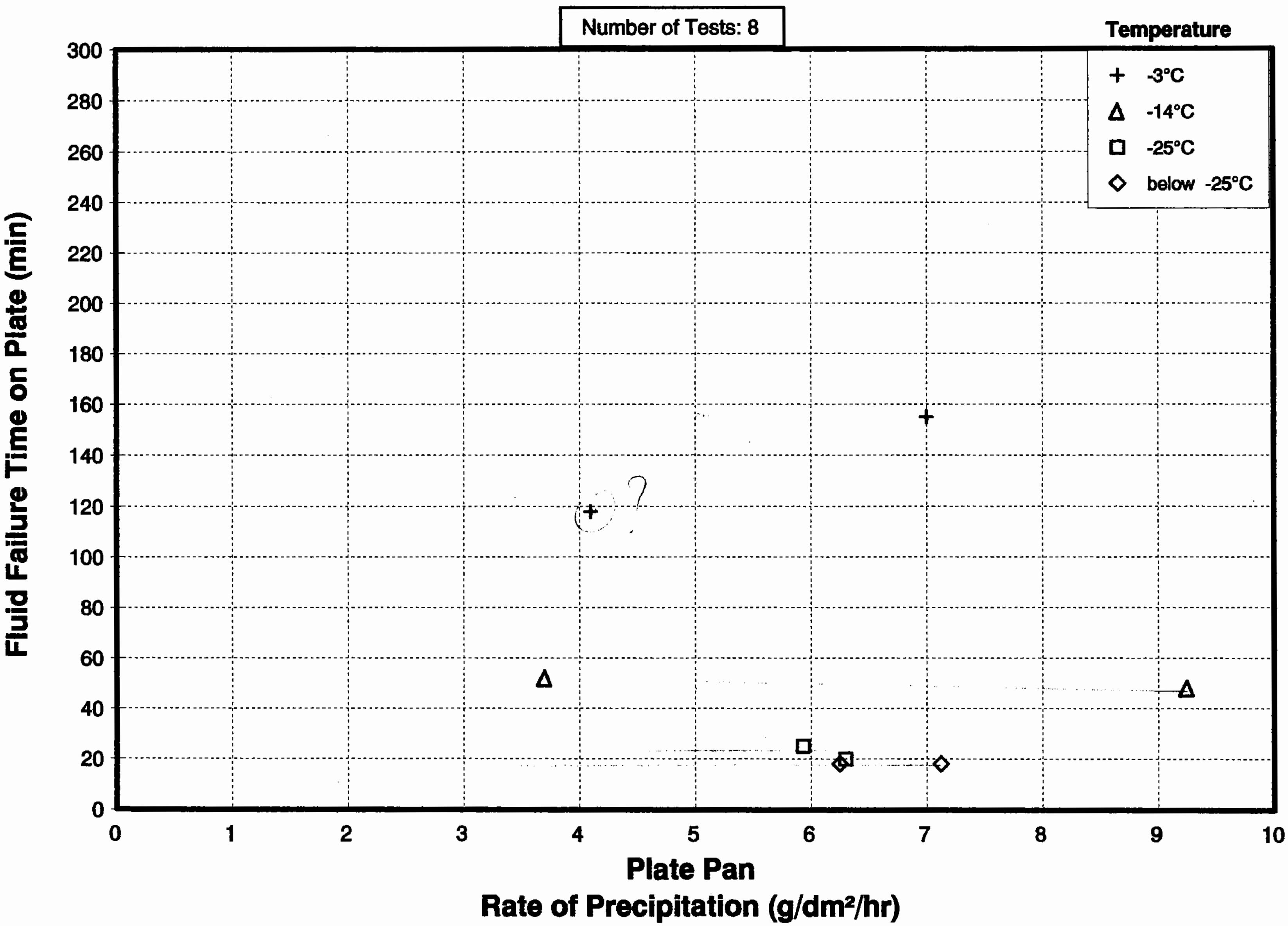
C-25

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-107 [redacted] TYPE IV NEAT

SIMULATED FREEZING FOG

1996/1997



E-30

cm1338\presents\chicago\H97FF41C.GRF

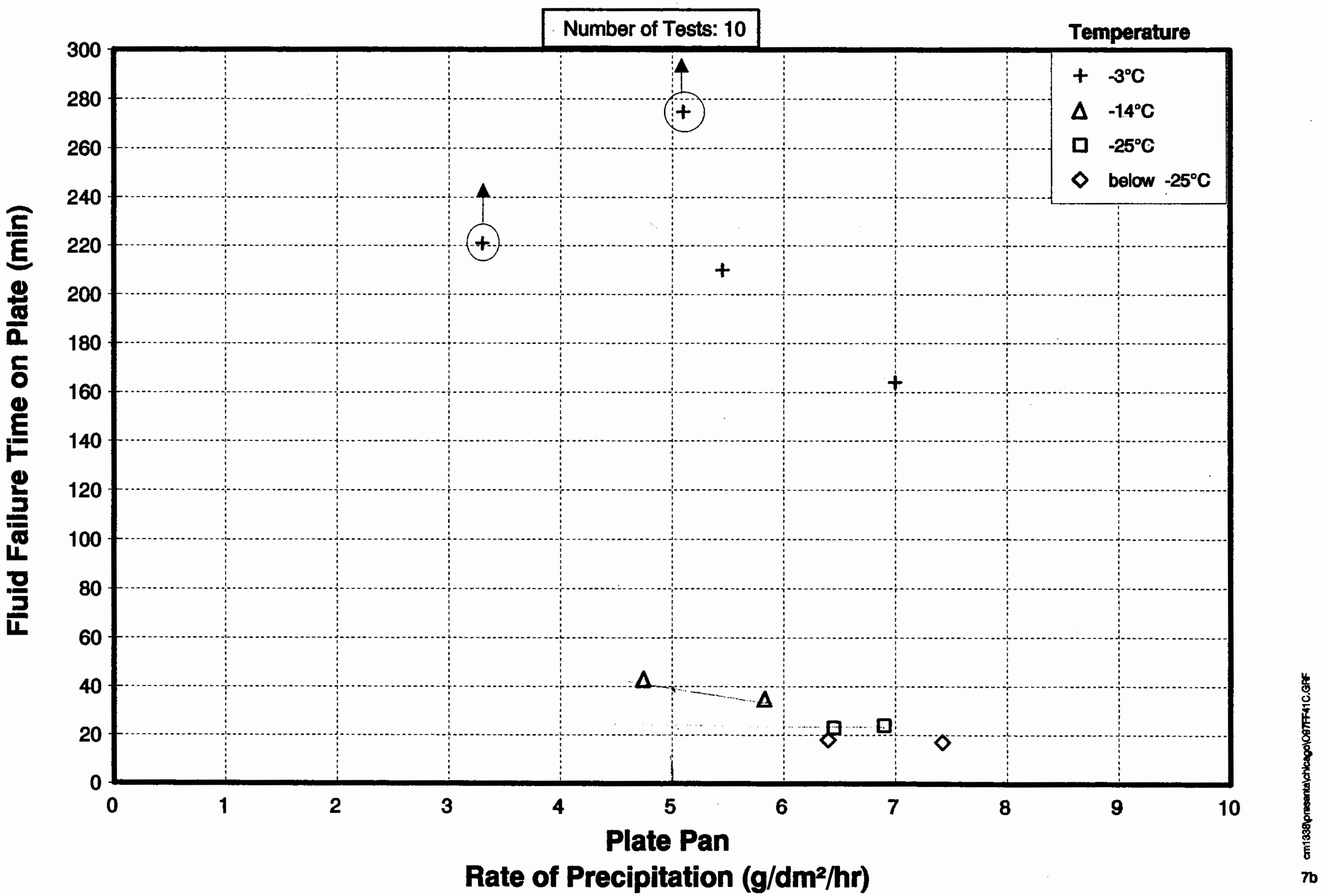
7b

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-108 [redacted] TYPE IV NEAT

SIMULATED FREEZING FOG

1996/1997



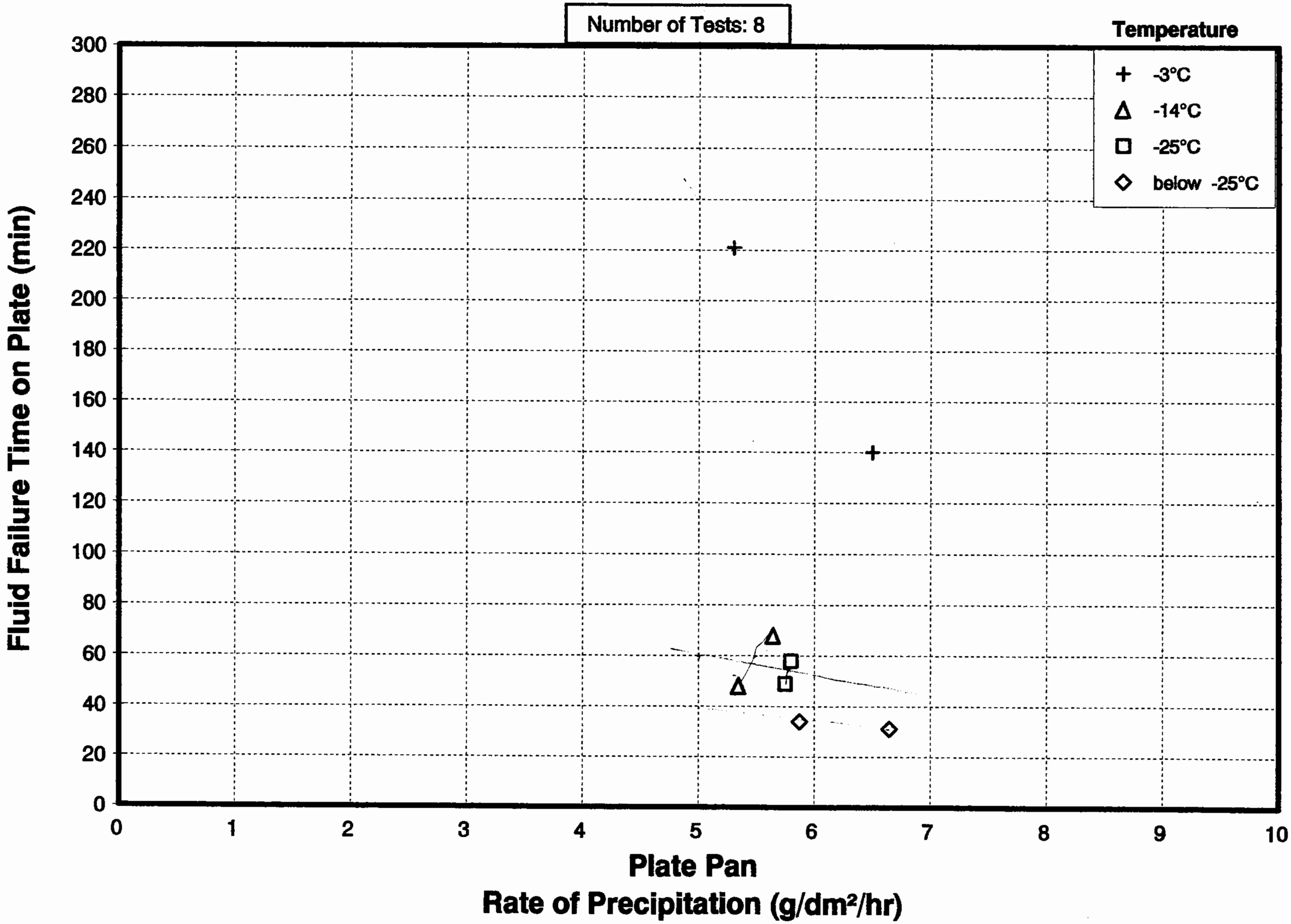
C-27

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C - 109 [redacted] TYPE IV NEAT

SIMULATED FREEZING FOG

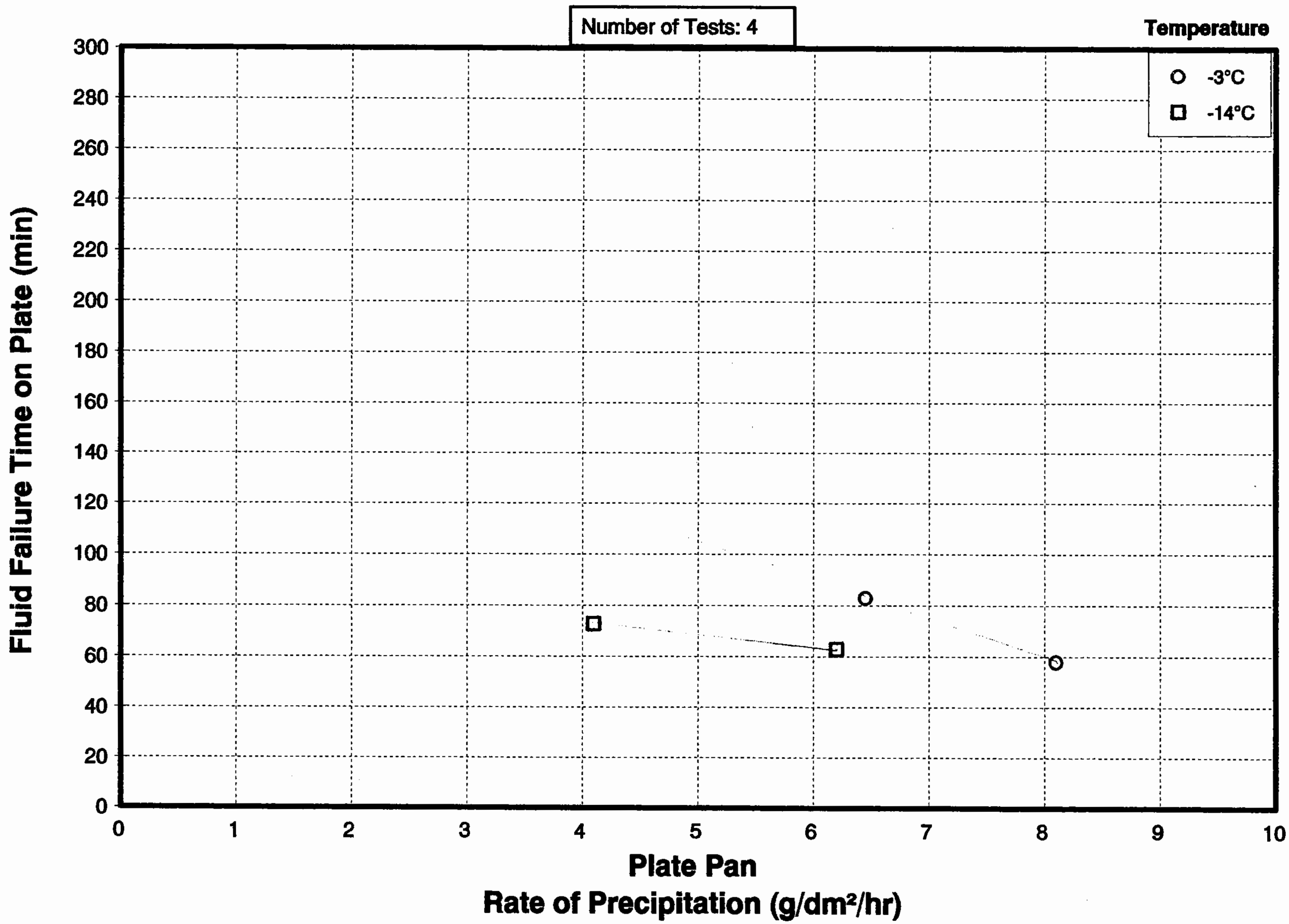
1996/1997



7b

C-28

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-700 [redacted] TYPE IV 75/25
SIMULATED FREEZING FOG
1996/1997



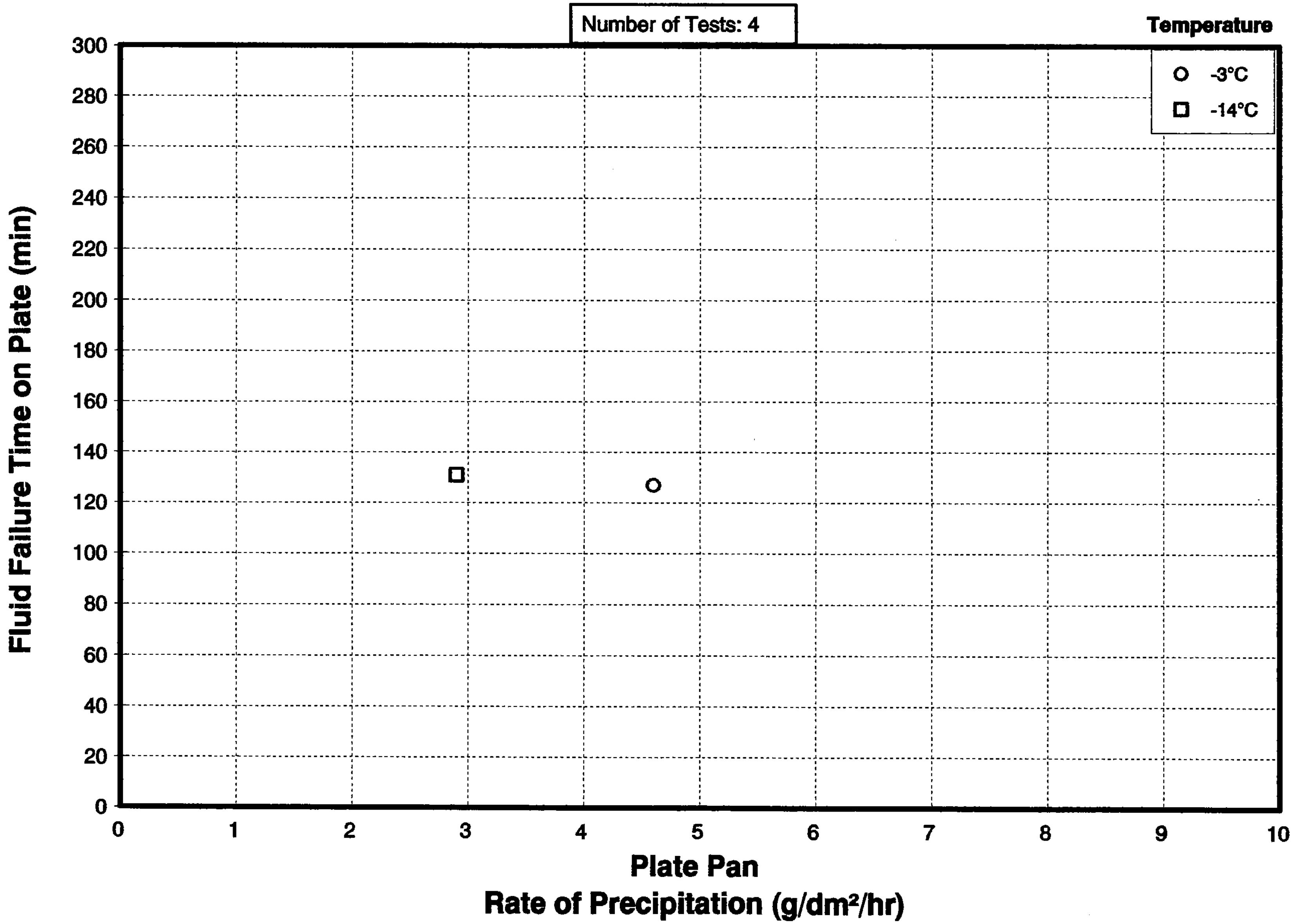
8b

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-702 [redacted] TYPE IV 75/25

SIMULATED FREEZING FOG

1995/1996



E-34

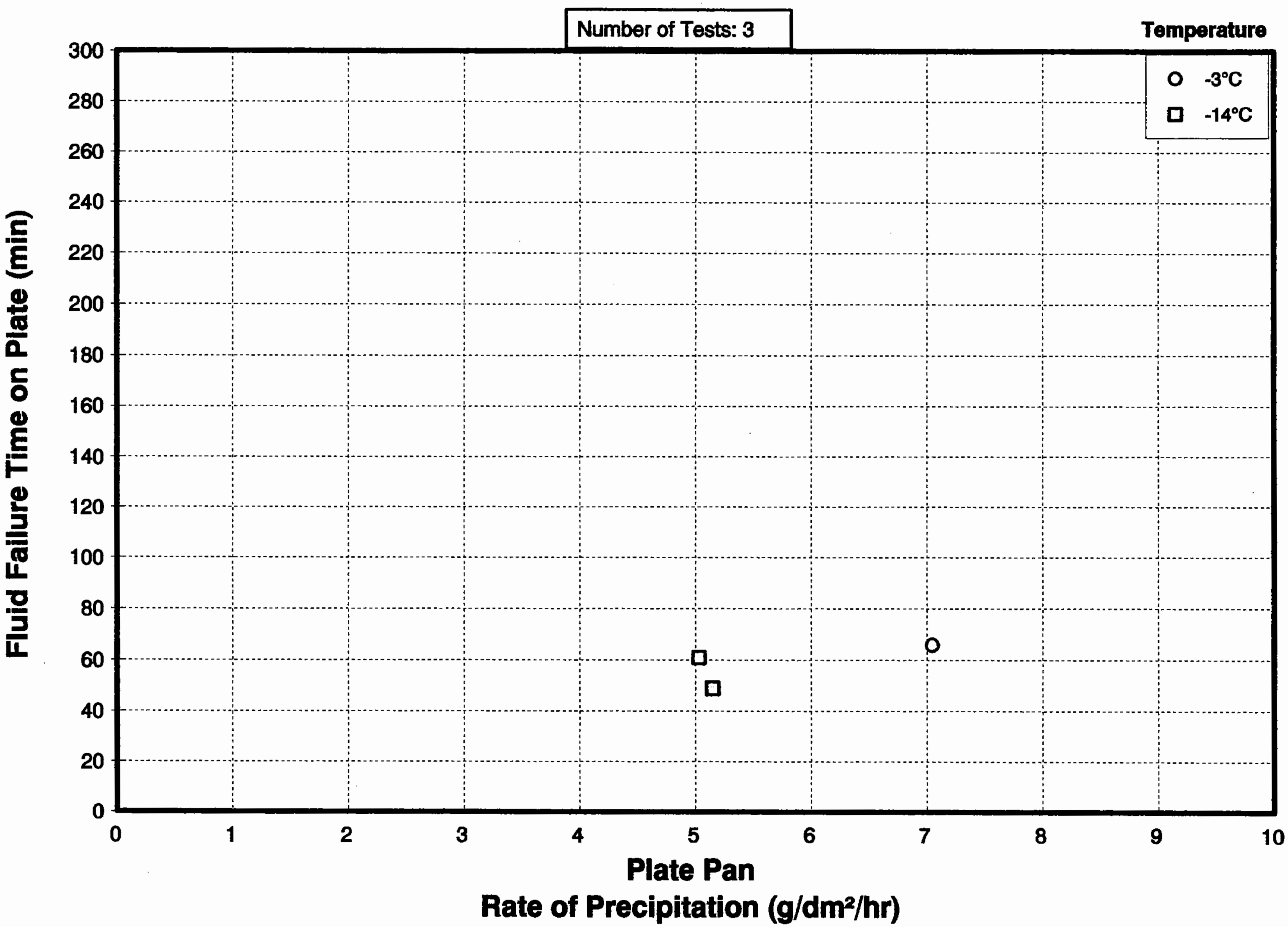
cm1335\presenta\chicago\S97FF47C.GRF

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-707 [redacted] TYPE IV 75/25

SIMULATED FREEZING FOG

1996/1997



cm1338\presenta\chicago\h97FF47C.GRF

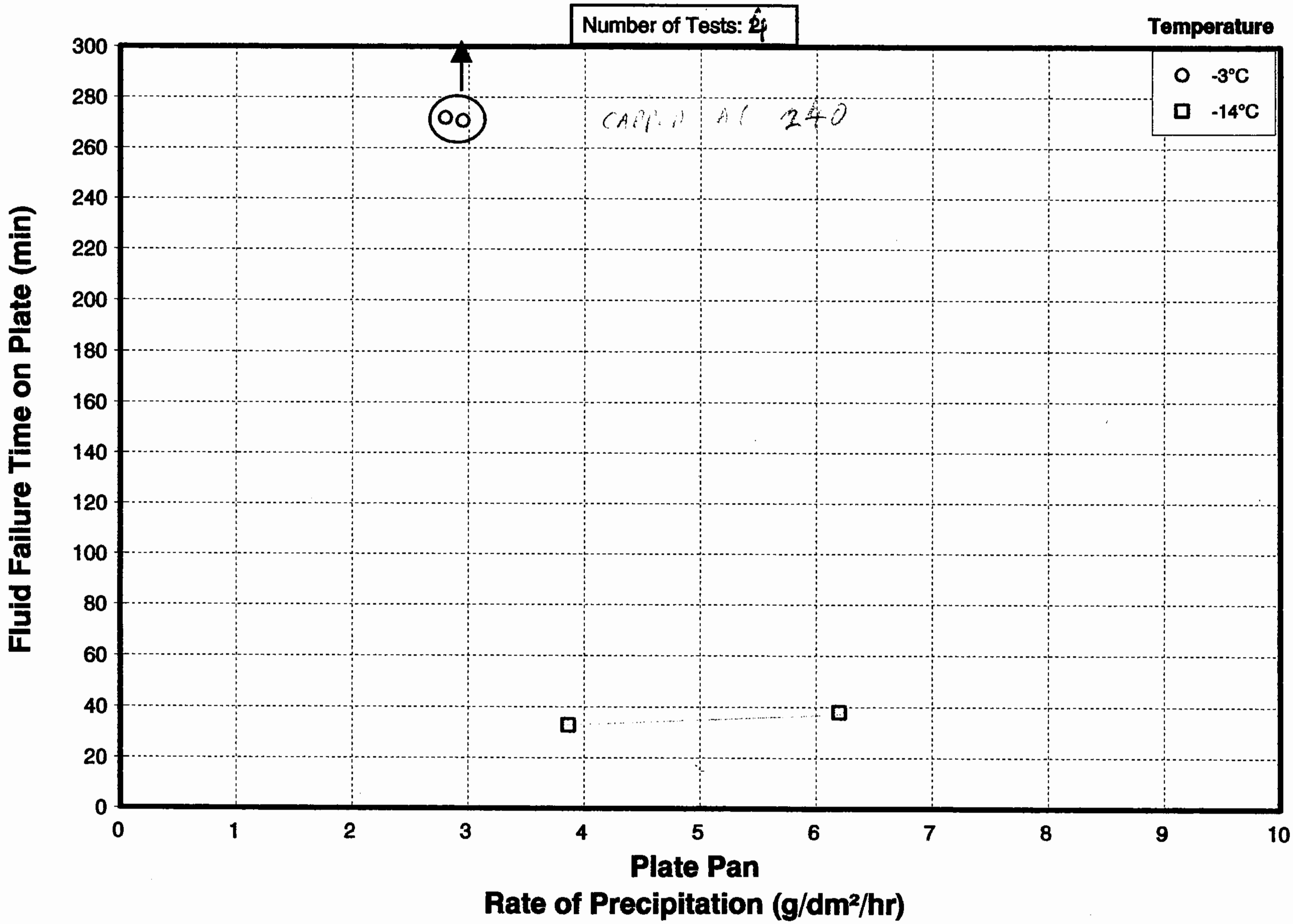
8b

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-708 [redacted] TYPE IV 75/25

SIMULATED FREEZING FOG

1996/1997



E-36

cm1338\presenta\chicago\O97FF47C.GRF

8b

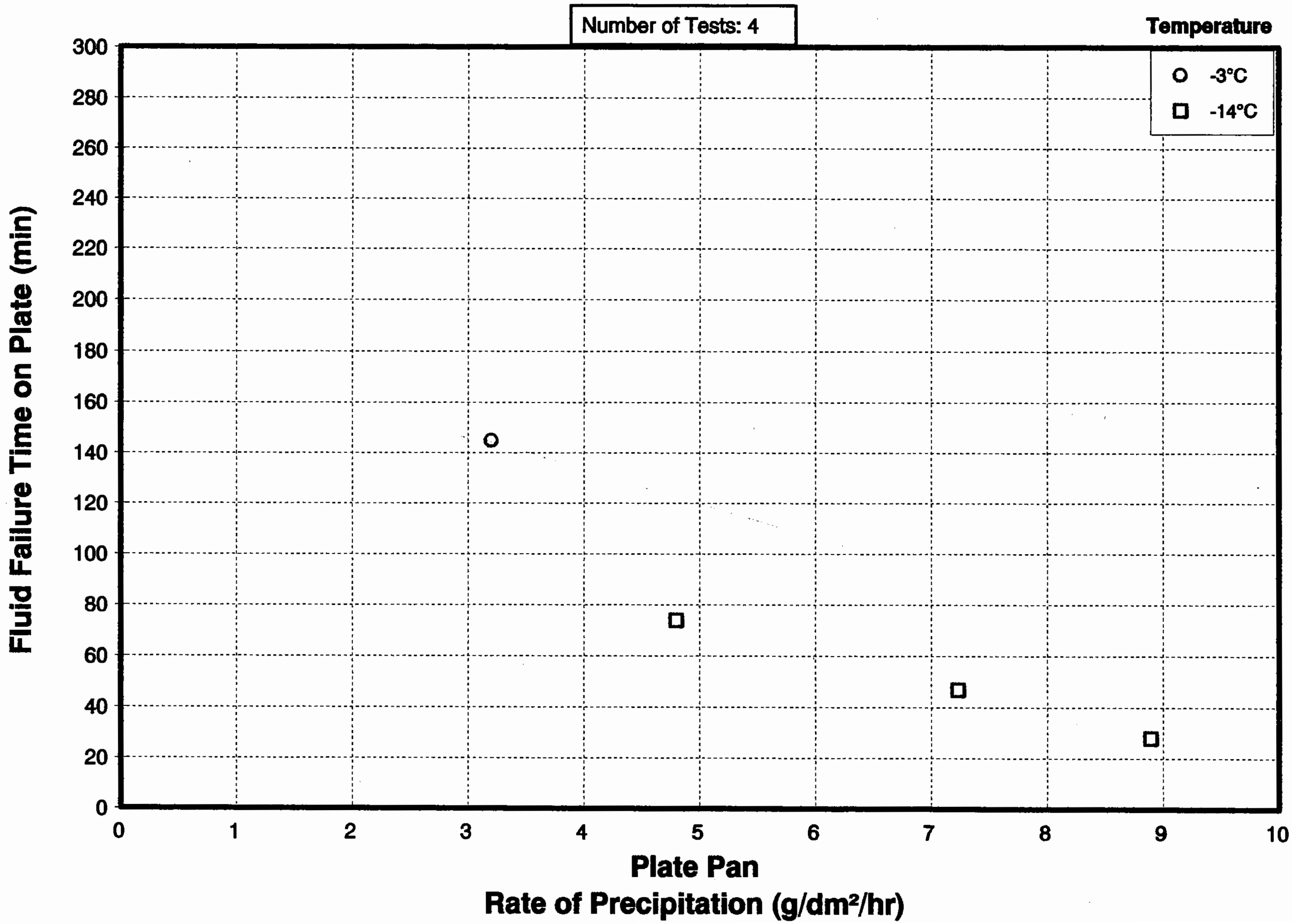
C-32

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-709 [redacted] TYPE IV 75/25

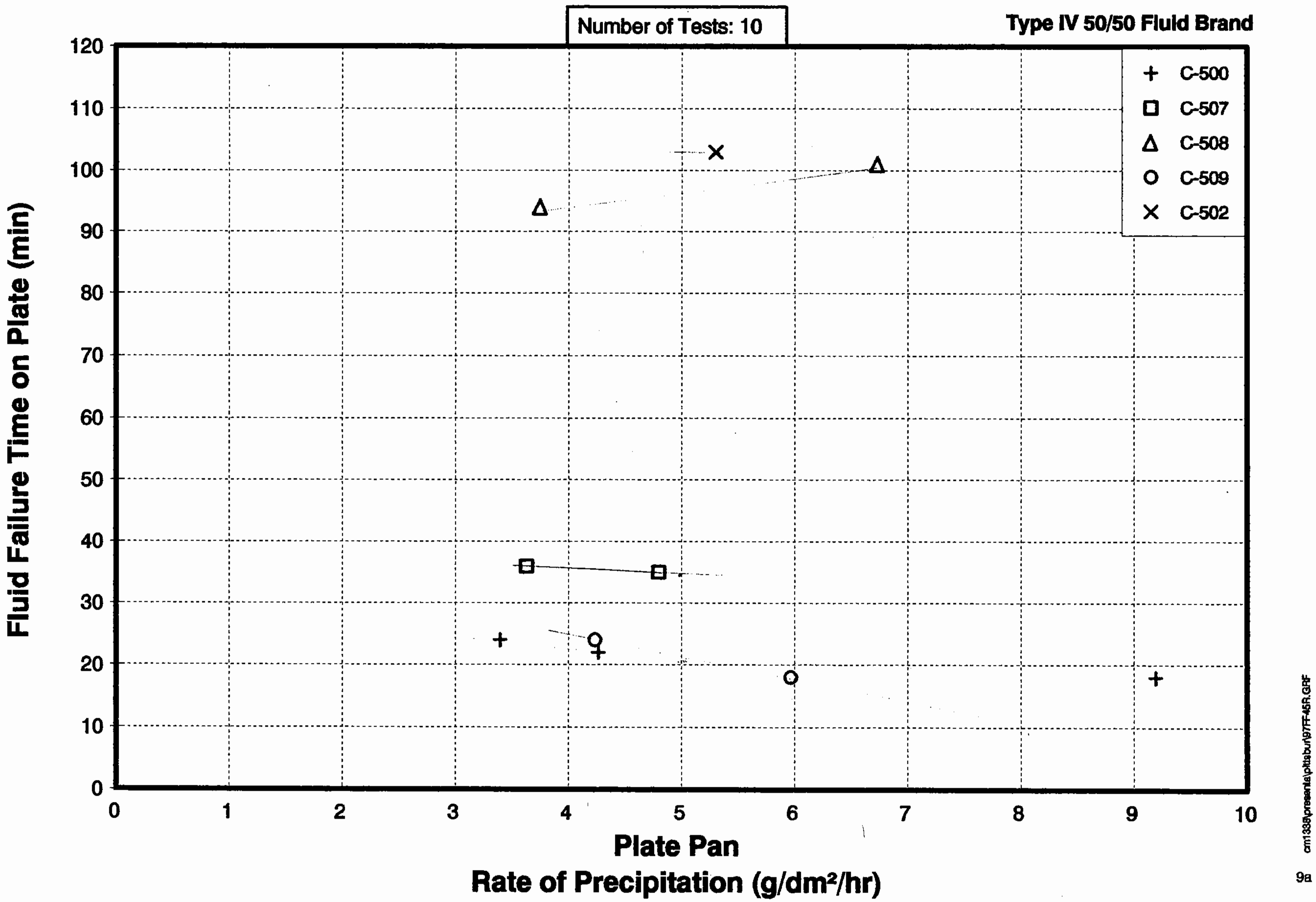
SIMULATED FREEZING FOG

1996/1997



8b

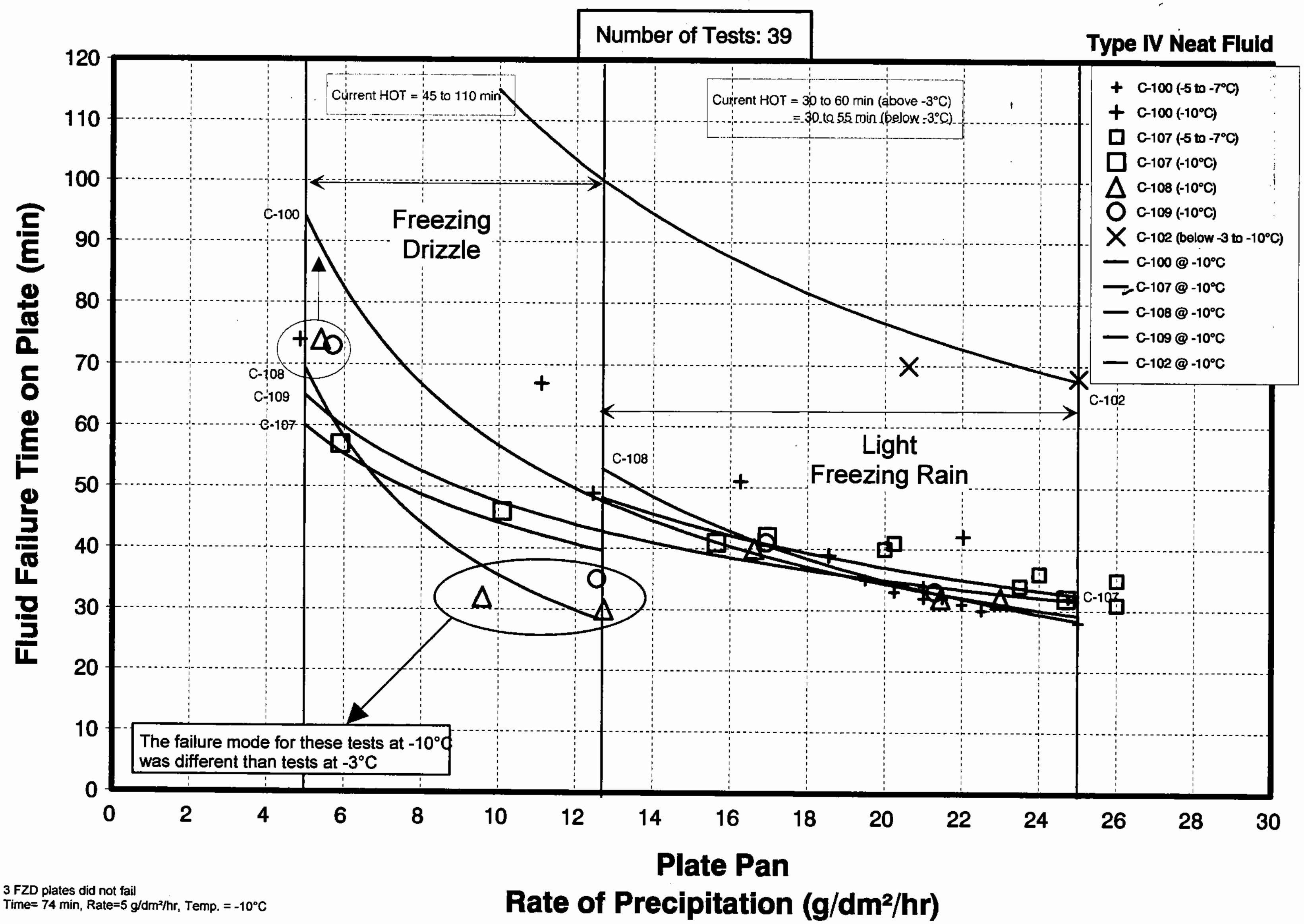
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 50/50 @ -3°C
SIMULATED FREEZING FOG
1996/1997



APPENDIX F

EVALUATION OF TYPE IV TEST DATA USING REGRESSION METHOD FOR WINTER 1996/97

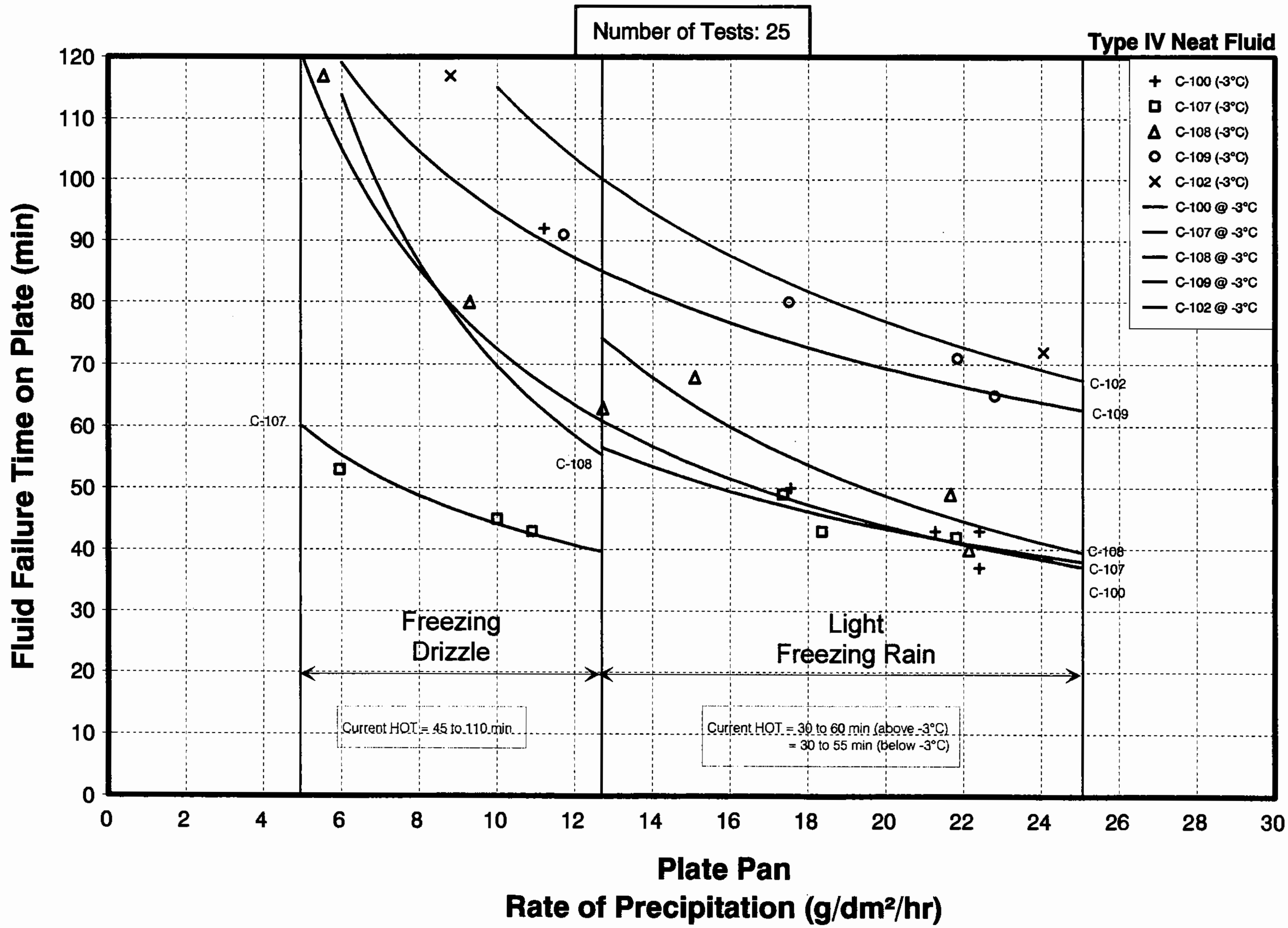
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT @ -10°C
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997



3 FZD plates did not fail
Time= 74 min, Rate=5 g/dm²/hr, Temp. = -10°C

cm1338\analy\regress\97ZR41R1.GRF 1

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT @ -3°C
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997



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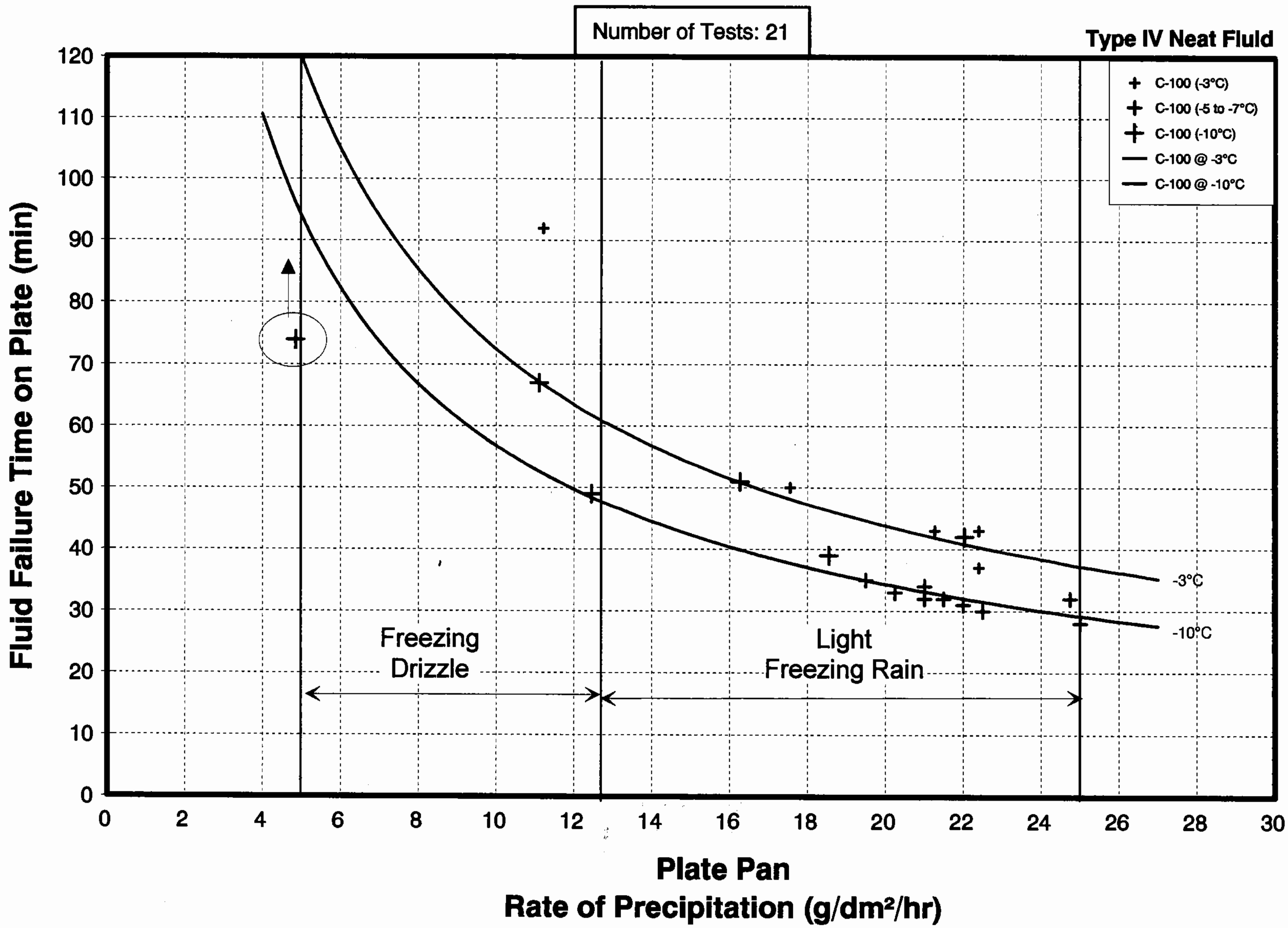
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-100 TYPE IV NEAT
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997

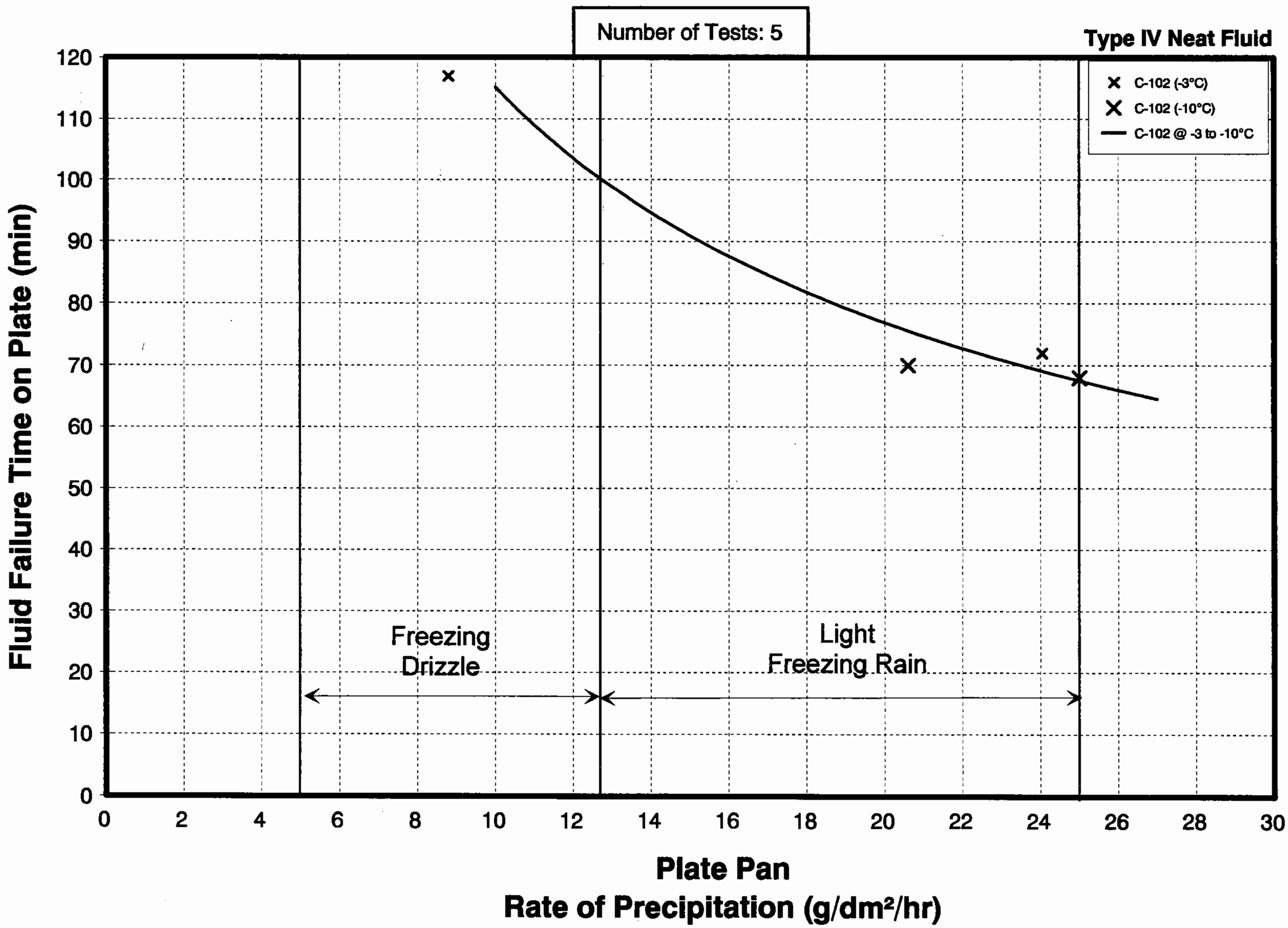


F-3

cm1338\analy\regress\U_FZR_41.GRF

1

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-102 TYPE IV NEAT
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996



F-4

cm1338\analy\regress\S_FZR_41.GRF
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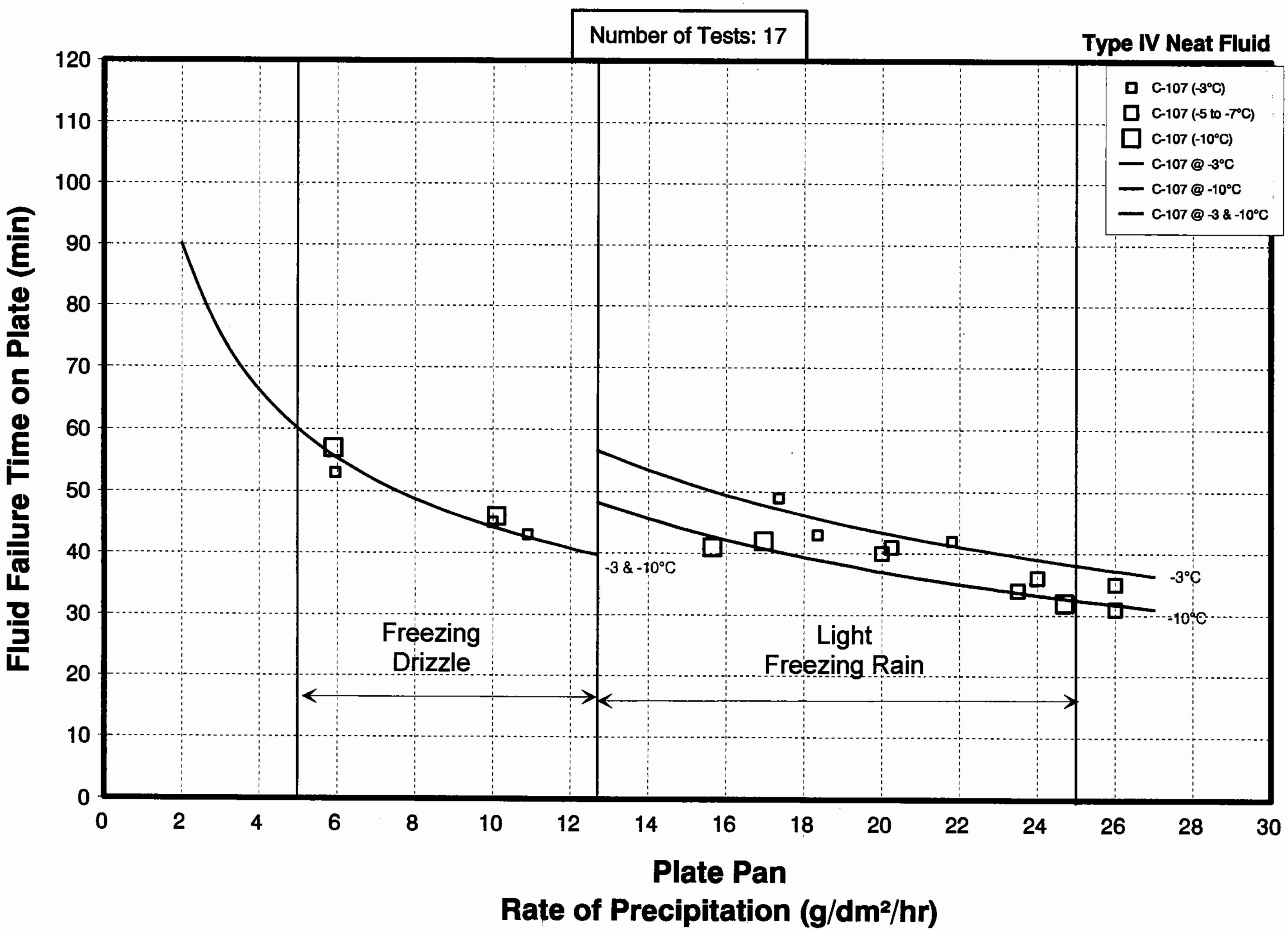
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-107 TYPE IV NEAT
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997



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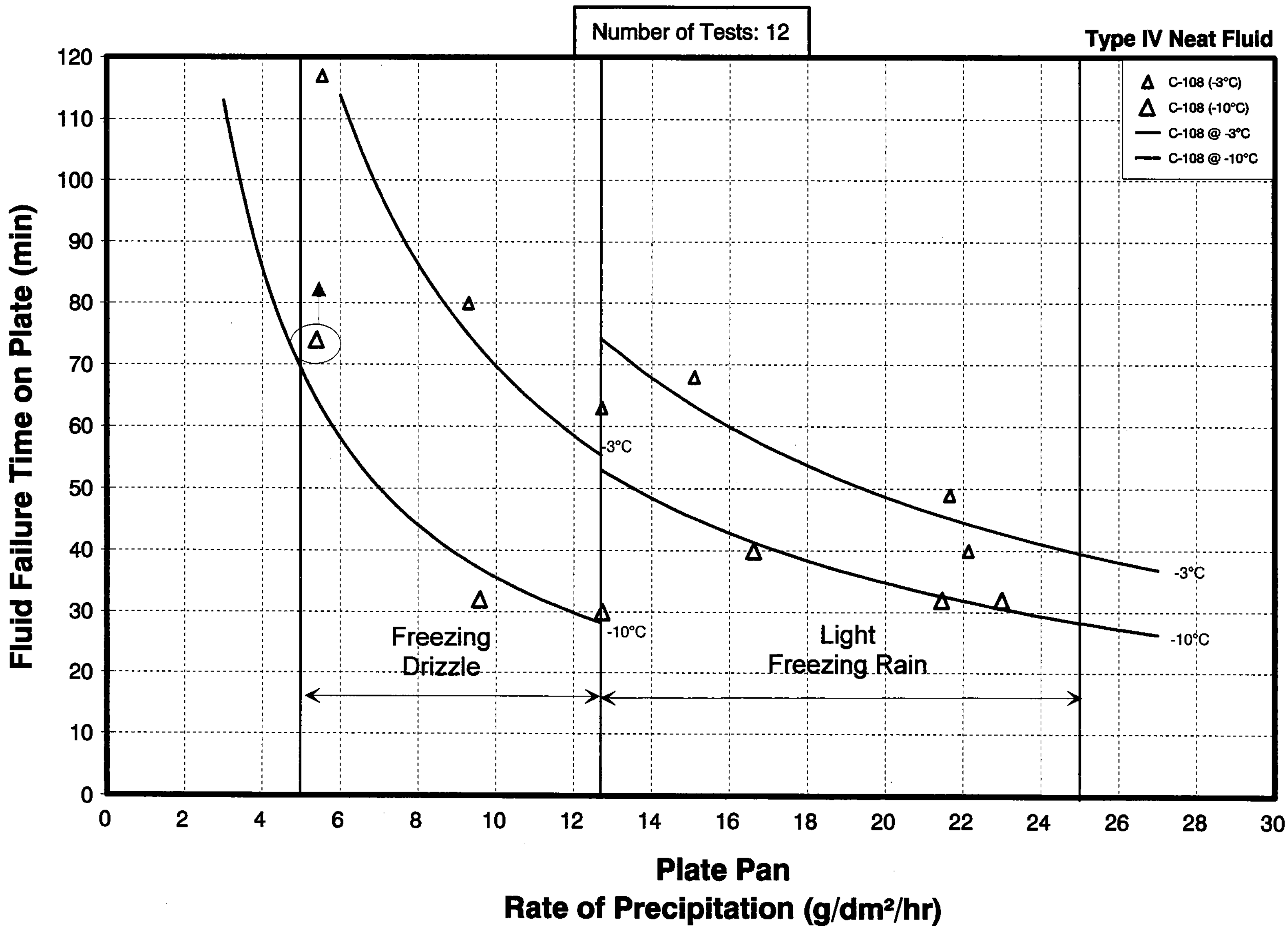
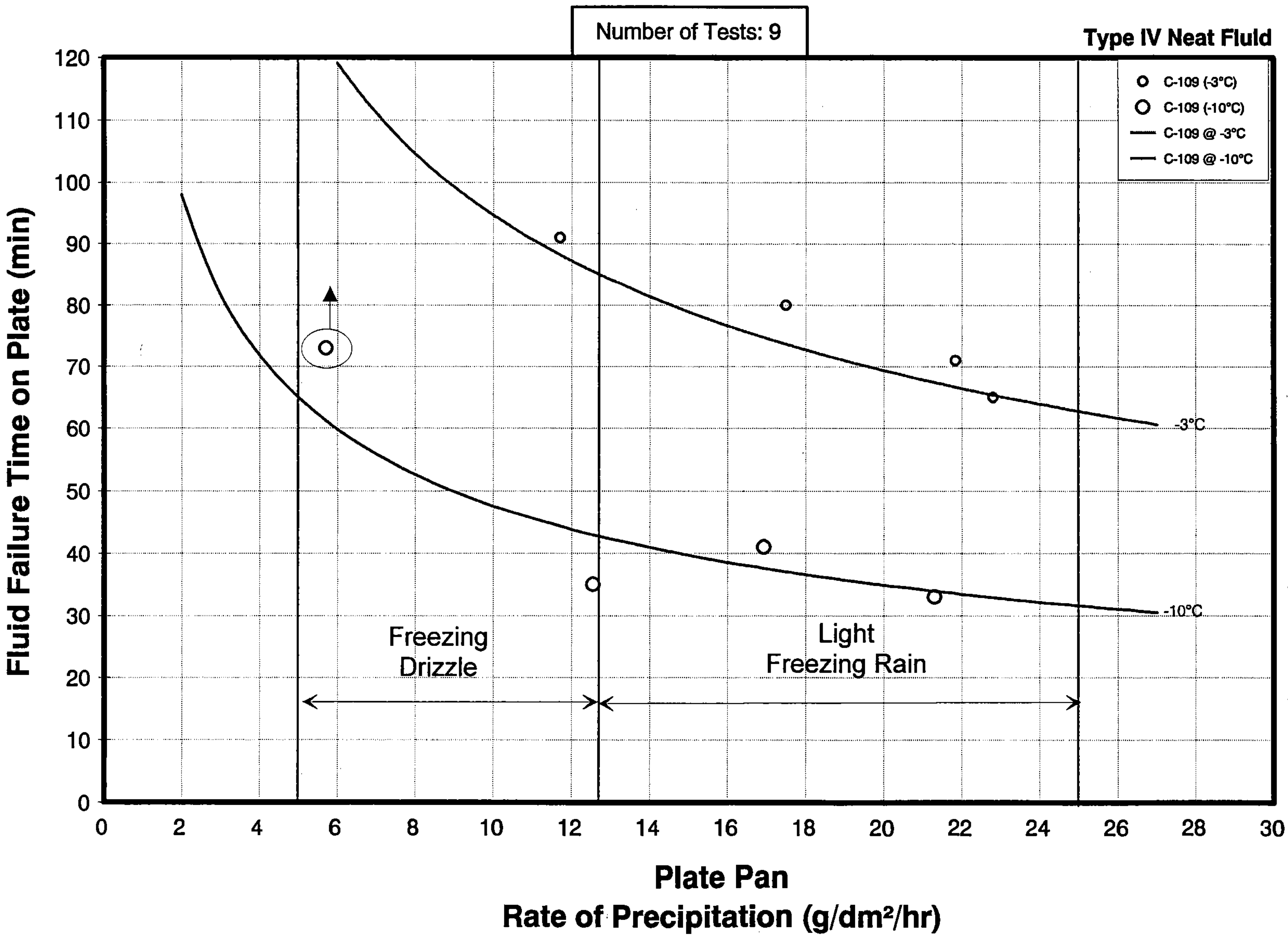
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-108 TYPE IV NEAT
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1996/1997



EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-109 TYPE IV NEAT
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1996/1997



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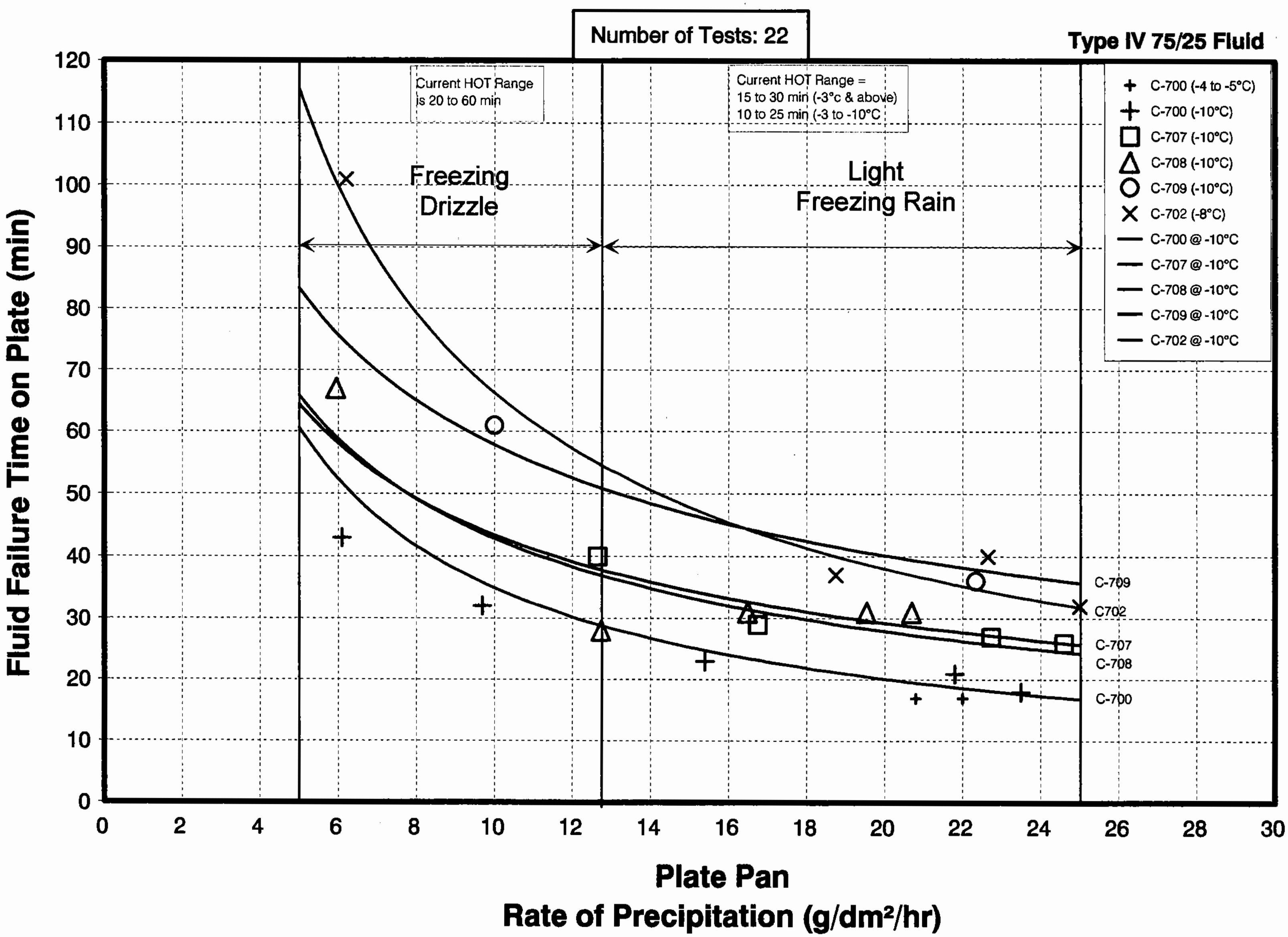
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25 @ -10°C
FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/96 & 1996/97



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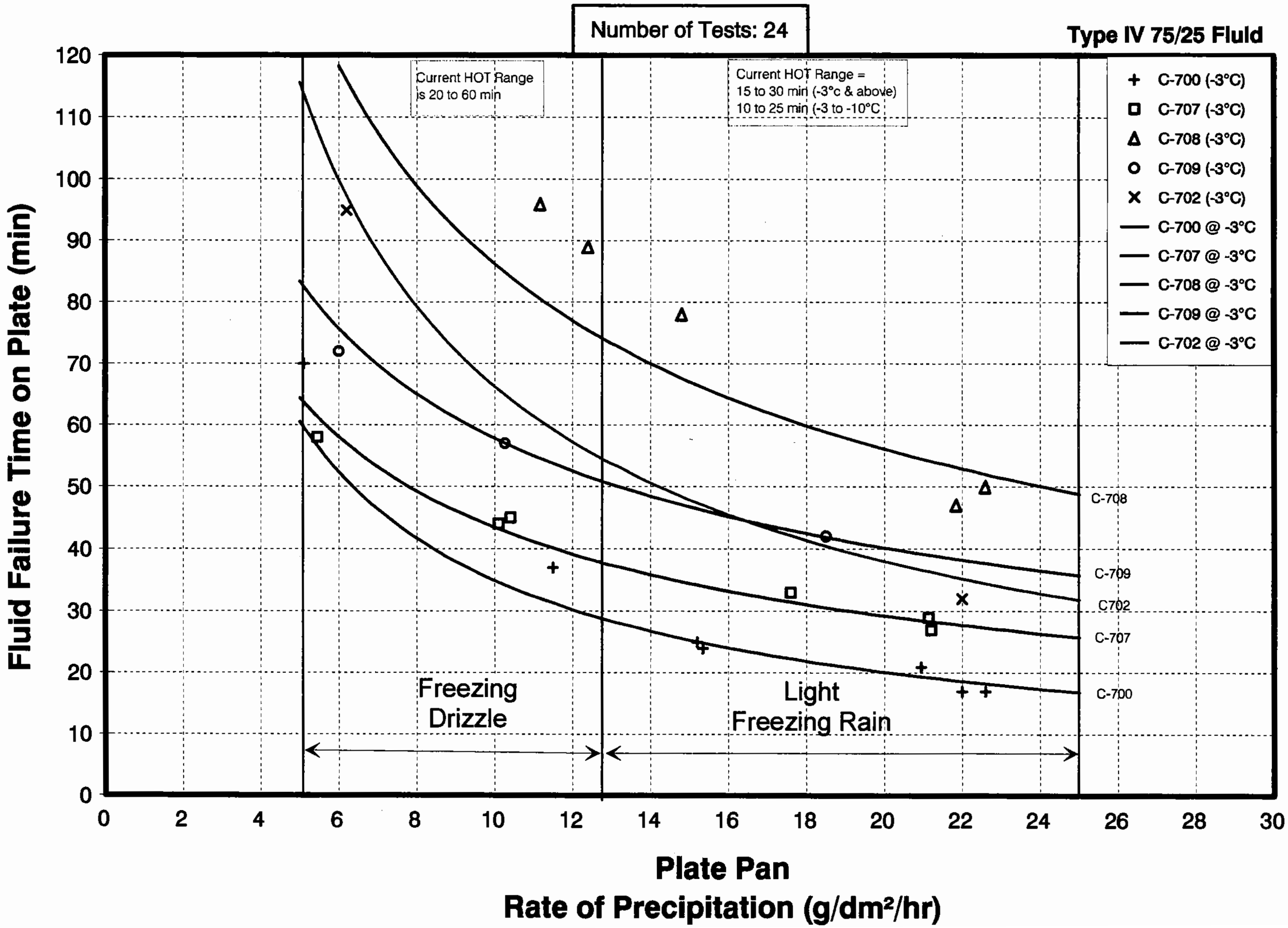
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25 @ -3°C
FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/96 & 1996/97

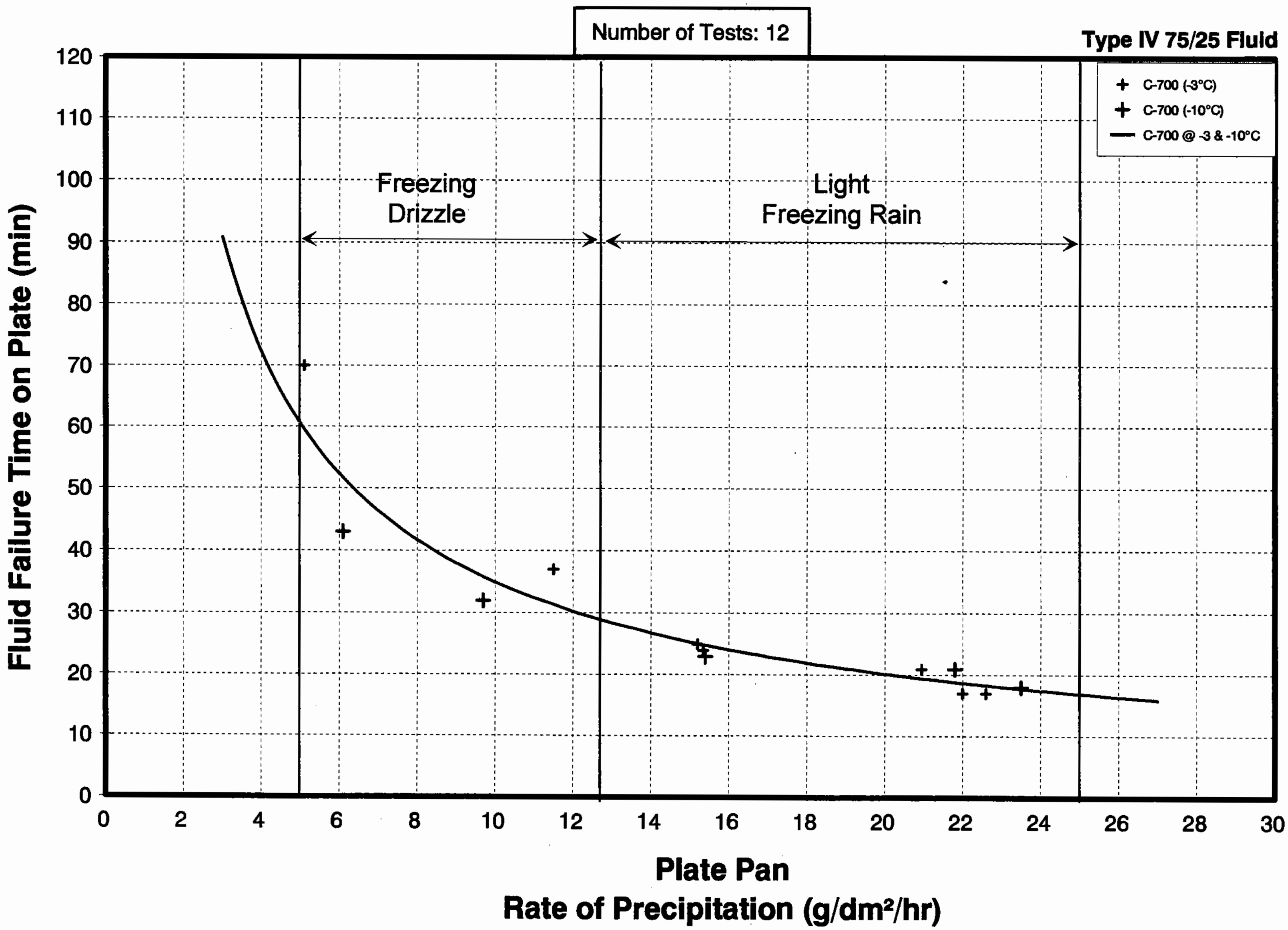


F-9

cm1338\analys\regress\97ZR47R3.grf

2

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-700 TYPE IV 75/25
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997



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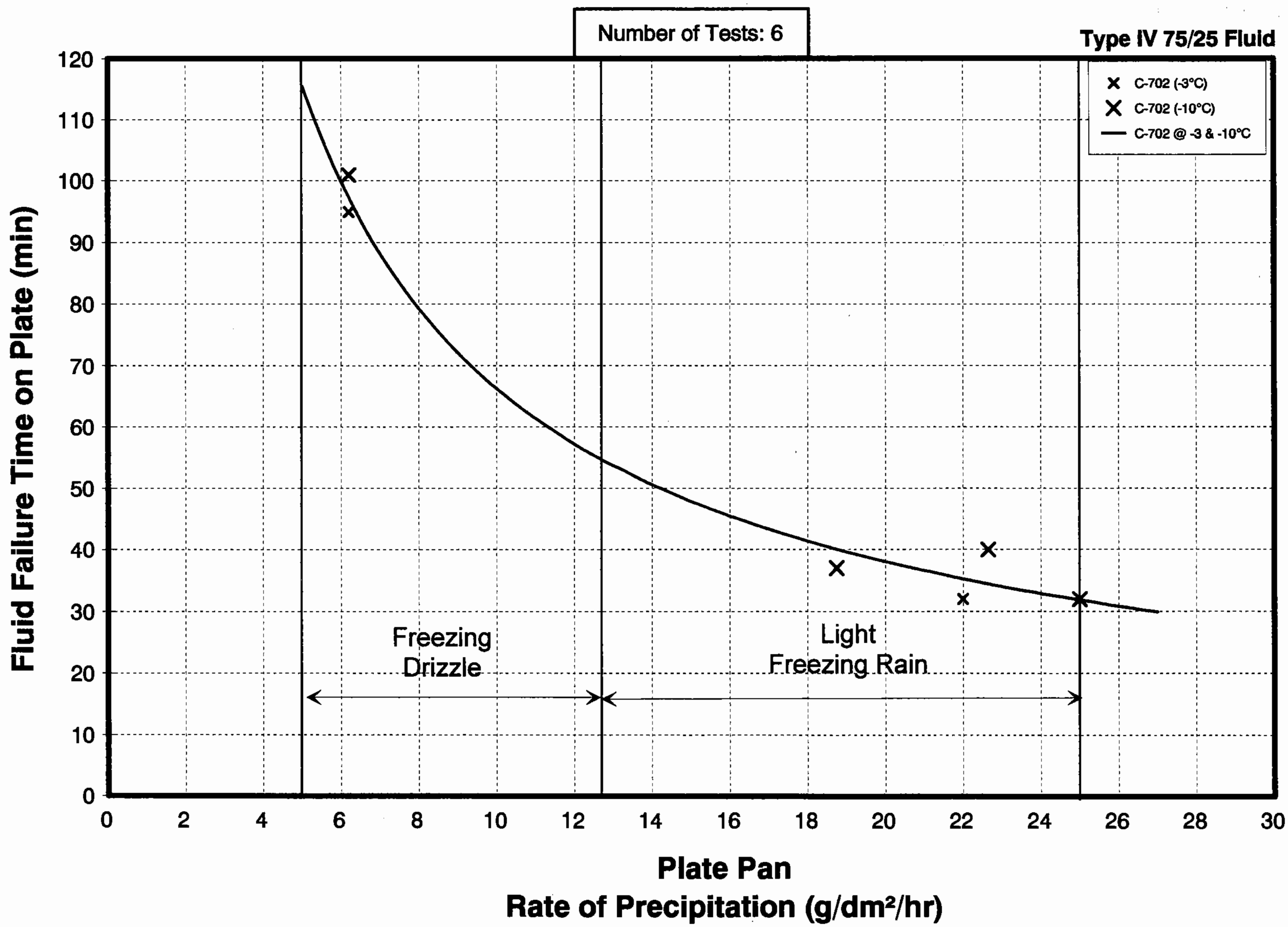
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-702 TYPE IV 75/25
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996



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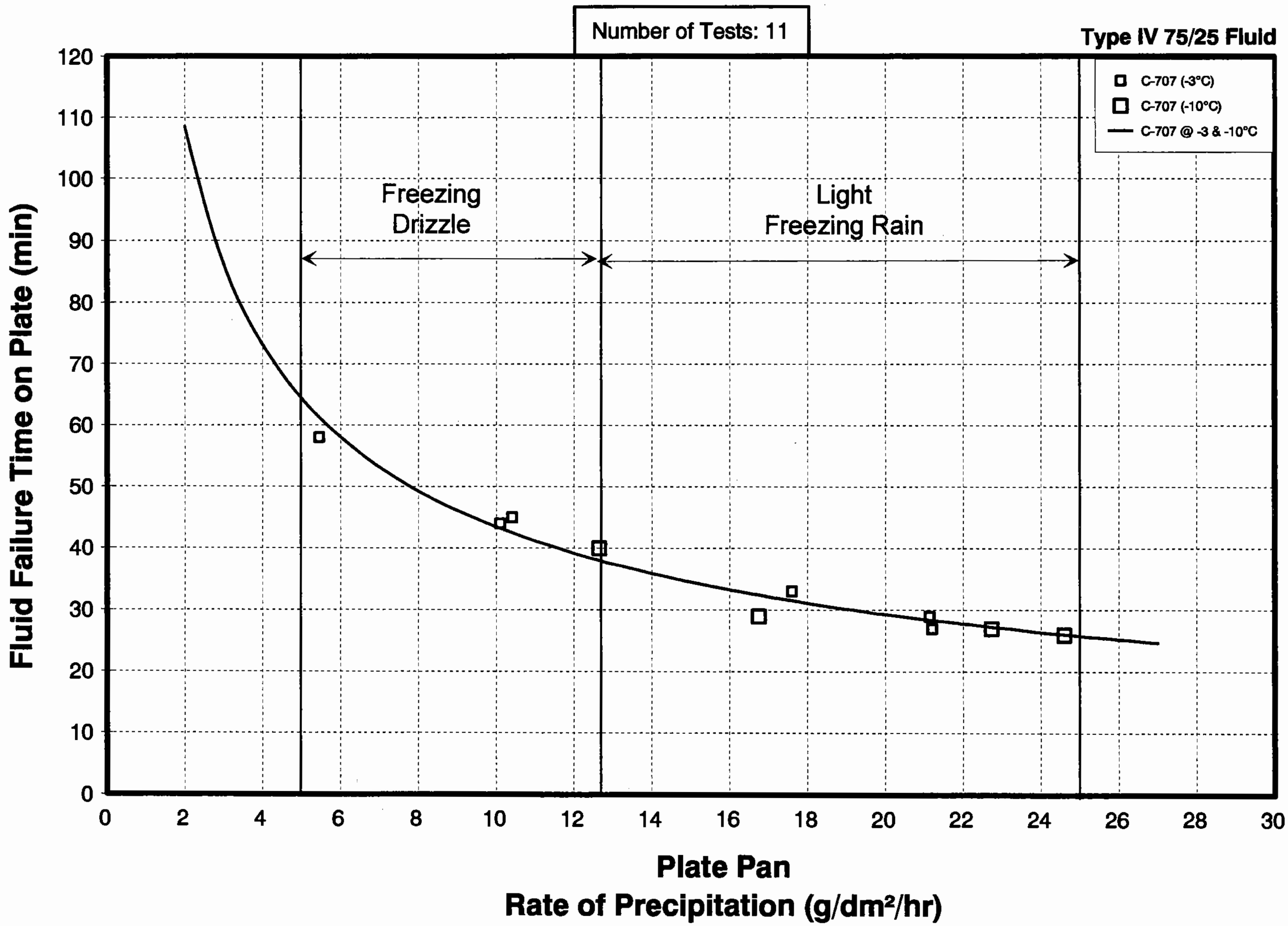
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-707 TYPE IV 75/25
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997



cm1338\analysis\regress\H_FZR_47.GRF
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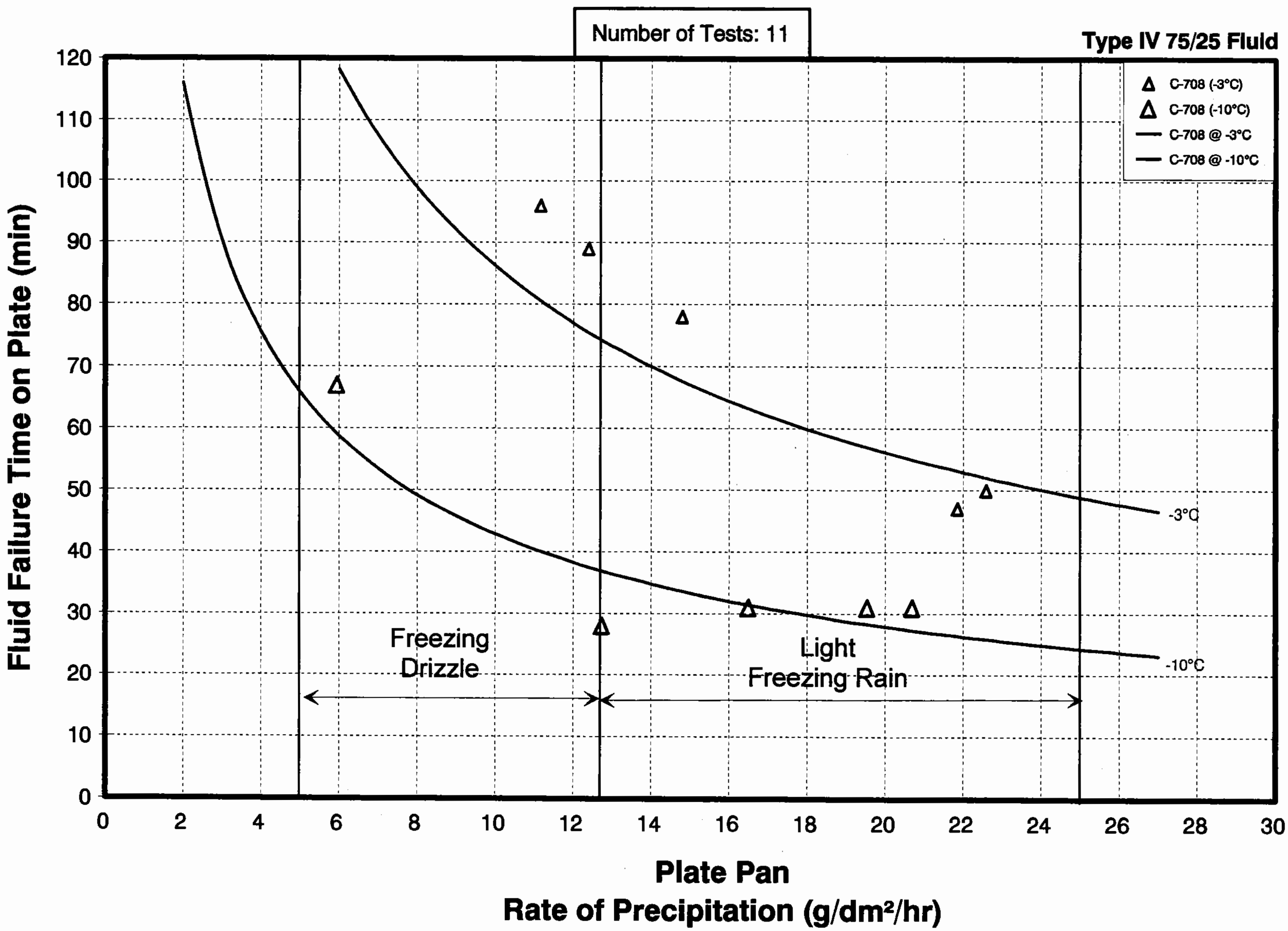
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-708 TYPE IV 75/25
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1996/1997



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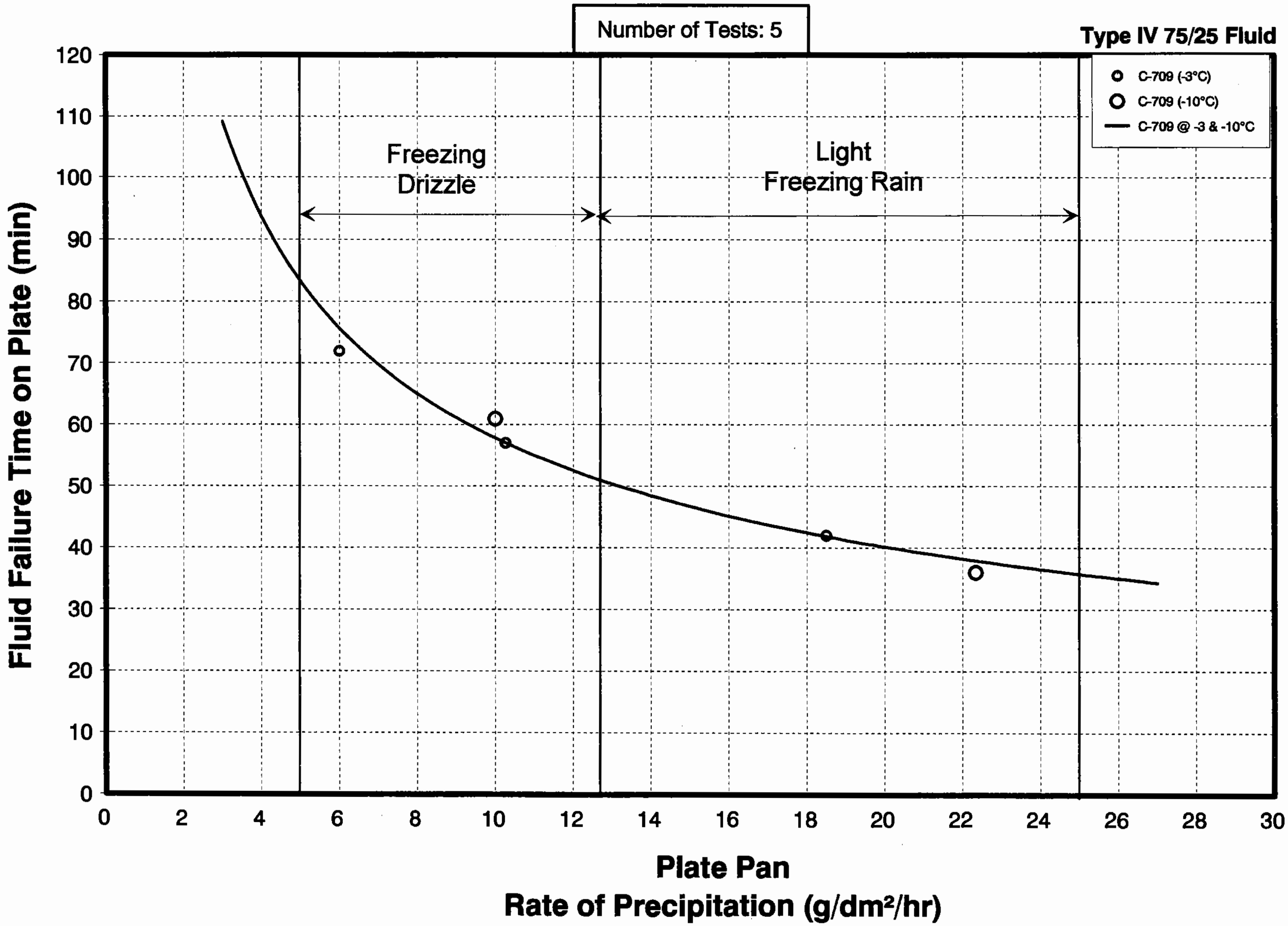
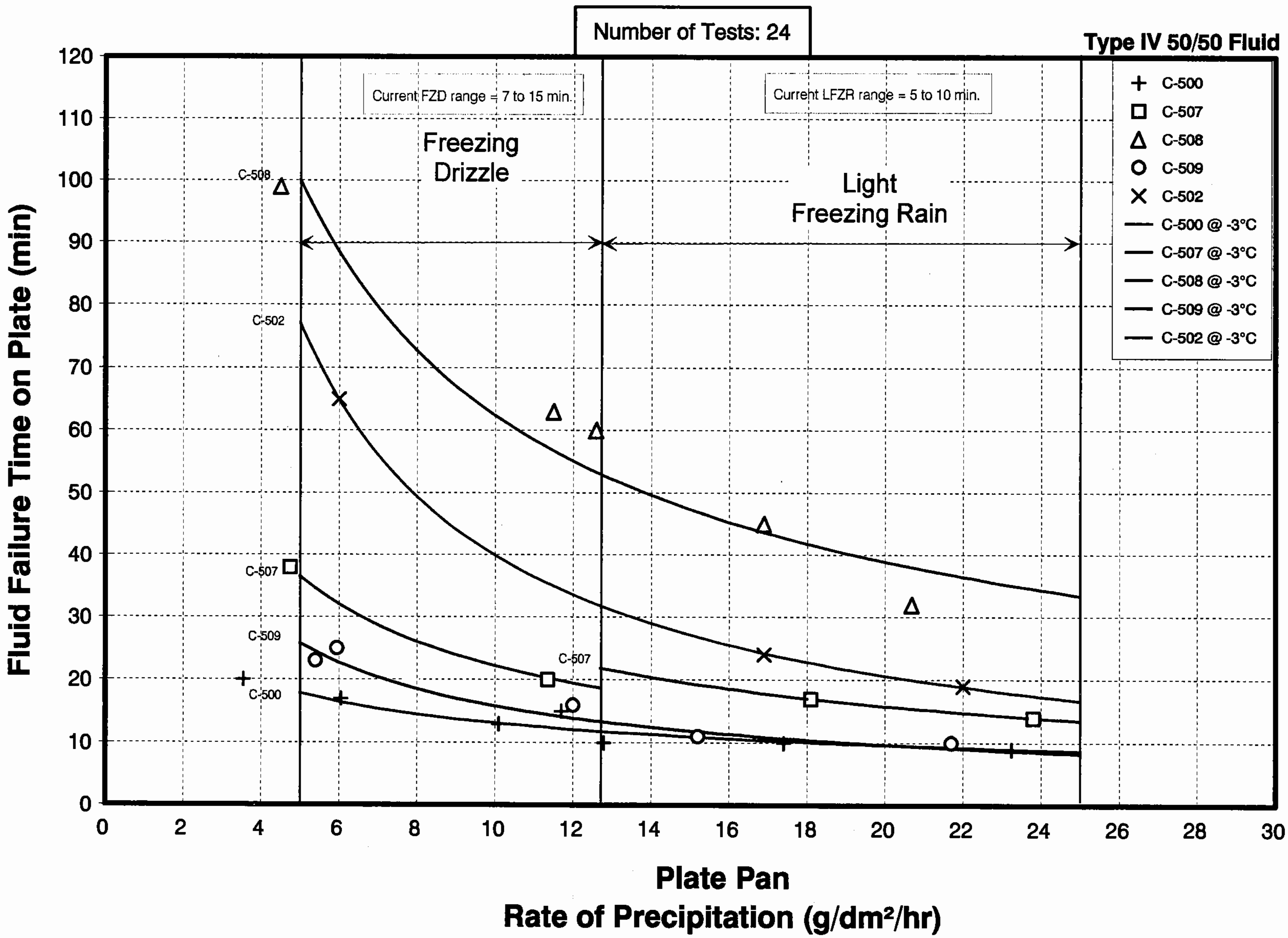
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
C-709 TYPE IV 75/25
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1996/1997



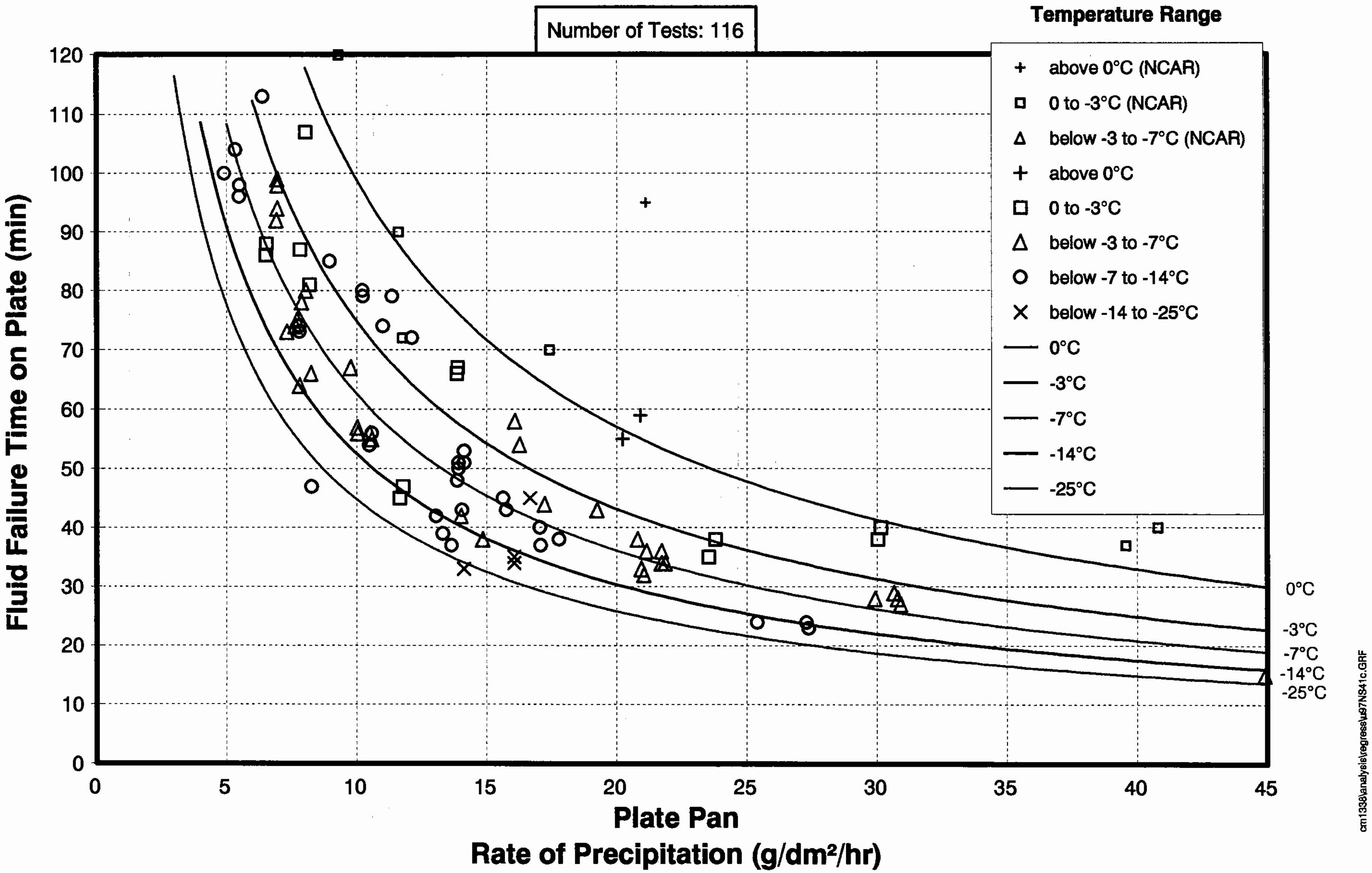
cm1338analysis\regress\IV_FZR_47.GRF
1

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 50/50 @ -3°C
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN
1995/1996 & 1996/1997

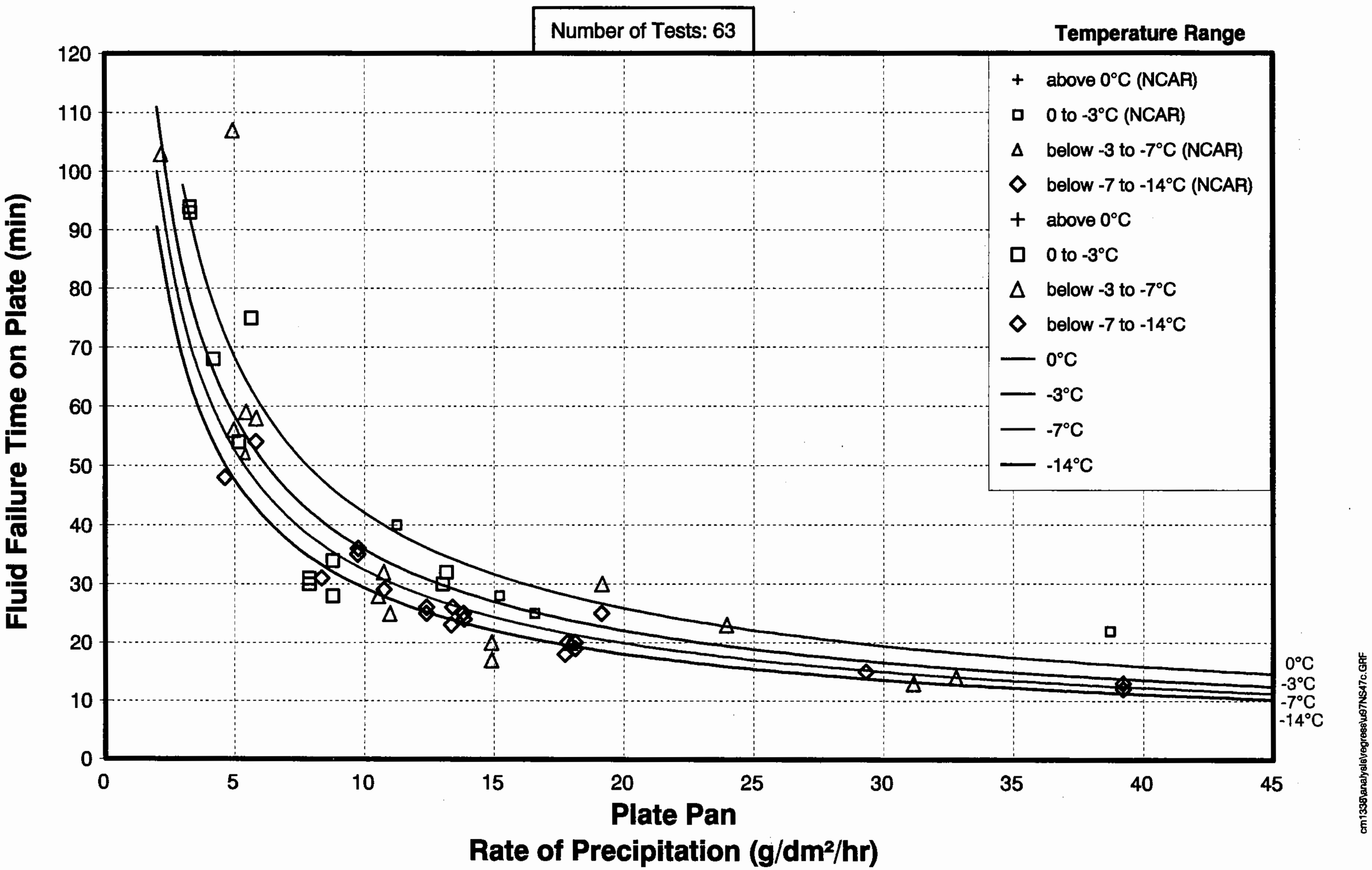


cm1338\analyvegress97FZR45R.GRF

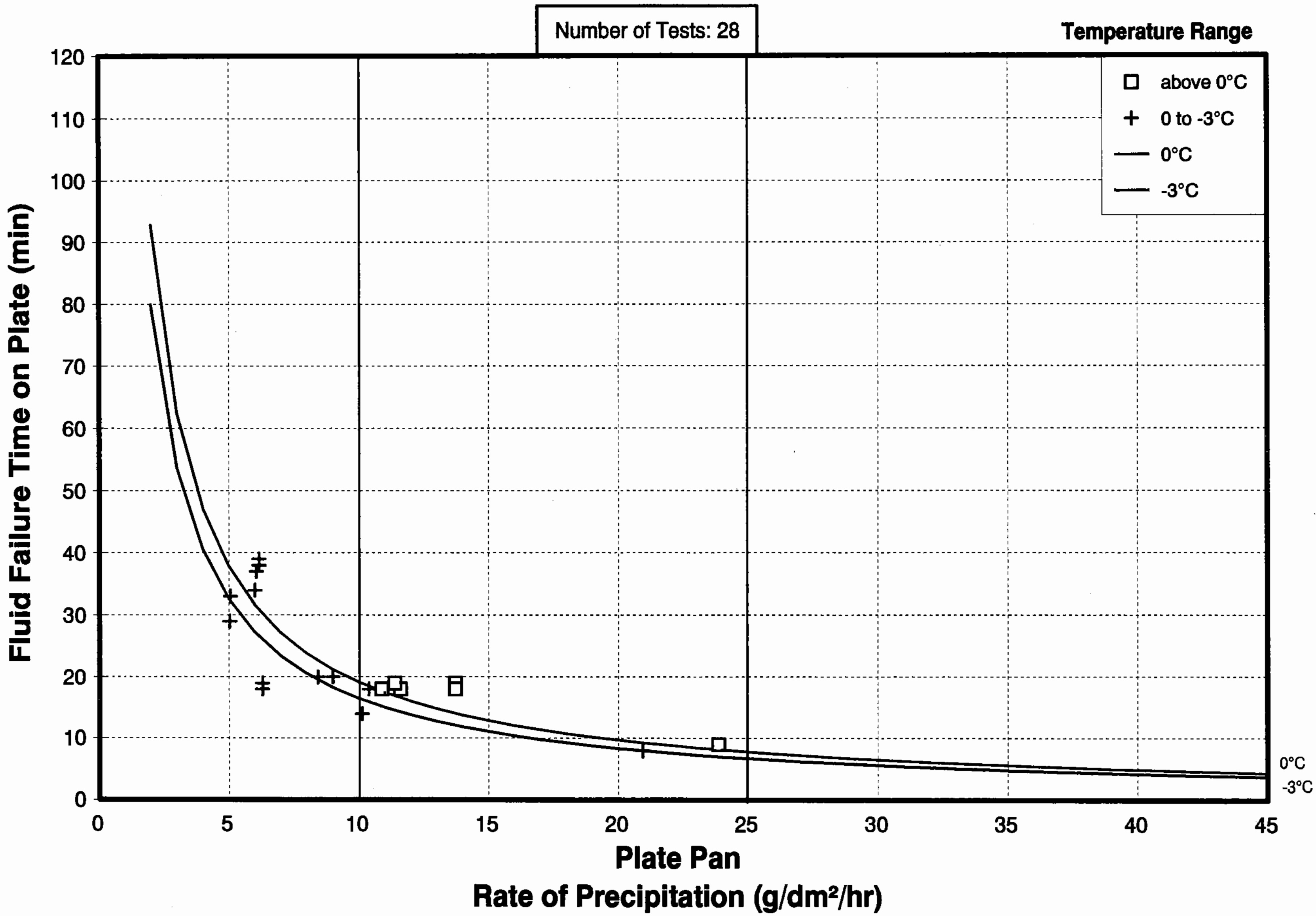
EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-100 TYPE IV NEAT
NATURAL SNOW CONDITIONS
1996/1997 (APS & NCAR)



EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-700 TYPE IV 75/25
NATURAL SNOW CONDITIONS
1996/1997 (APS & NCAR)



EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-500 TYPE IV 50/50
NATURAL SNOW CONDITIONS
1996/1997



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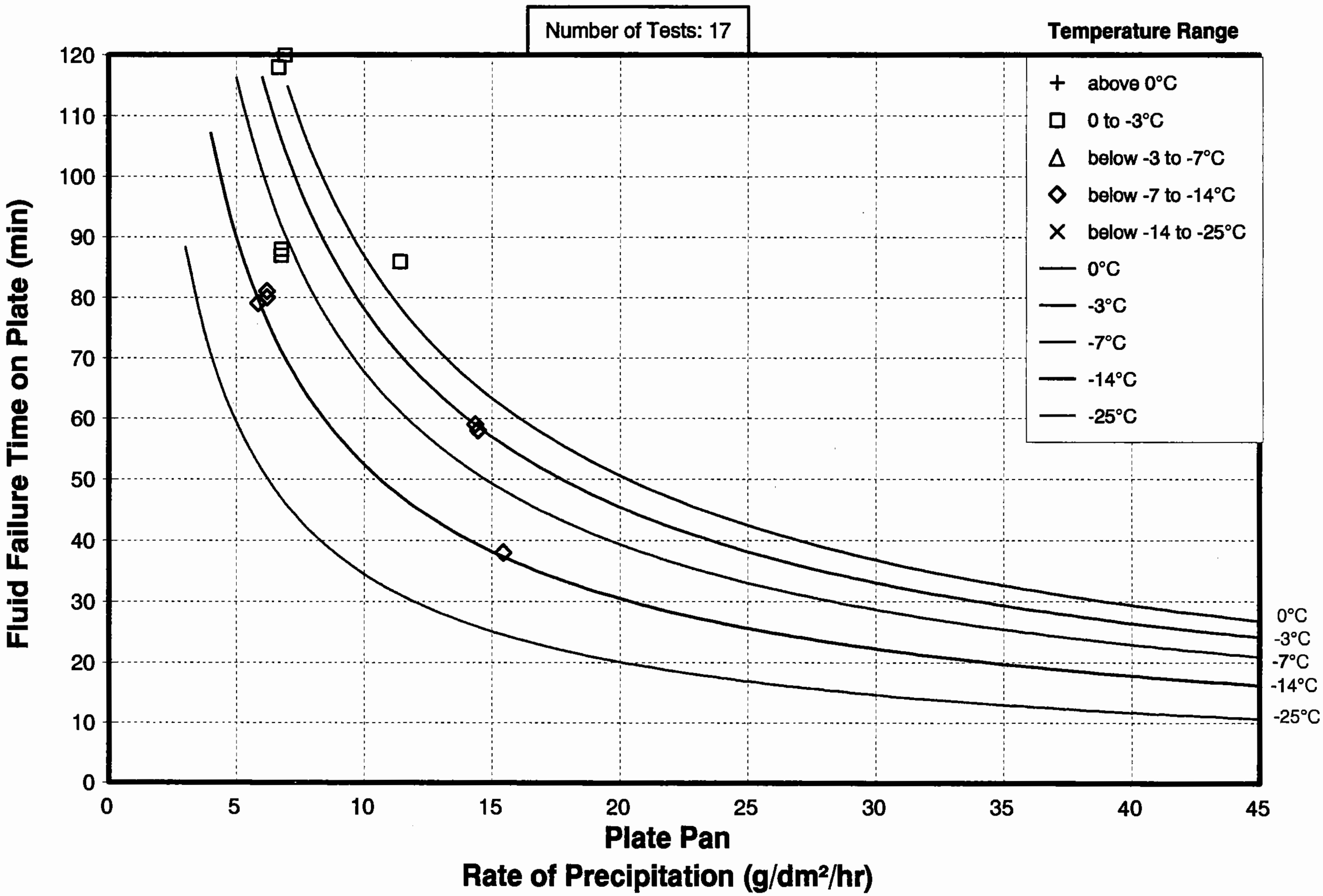
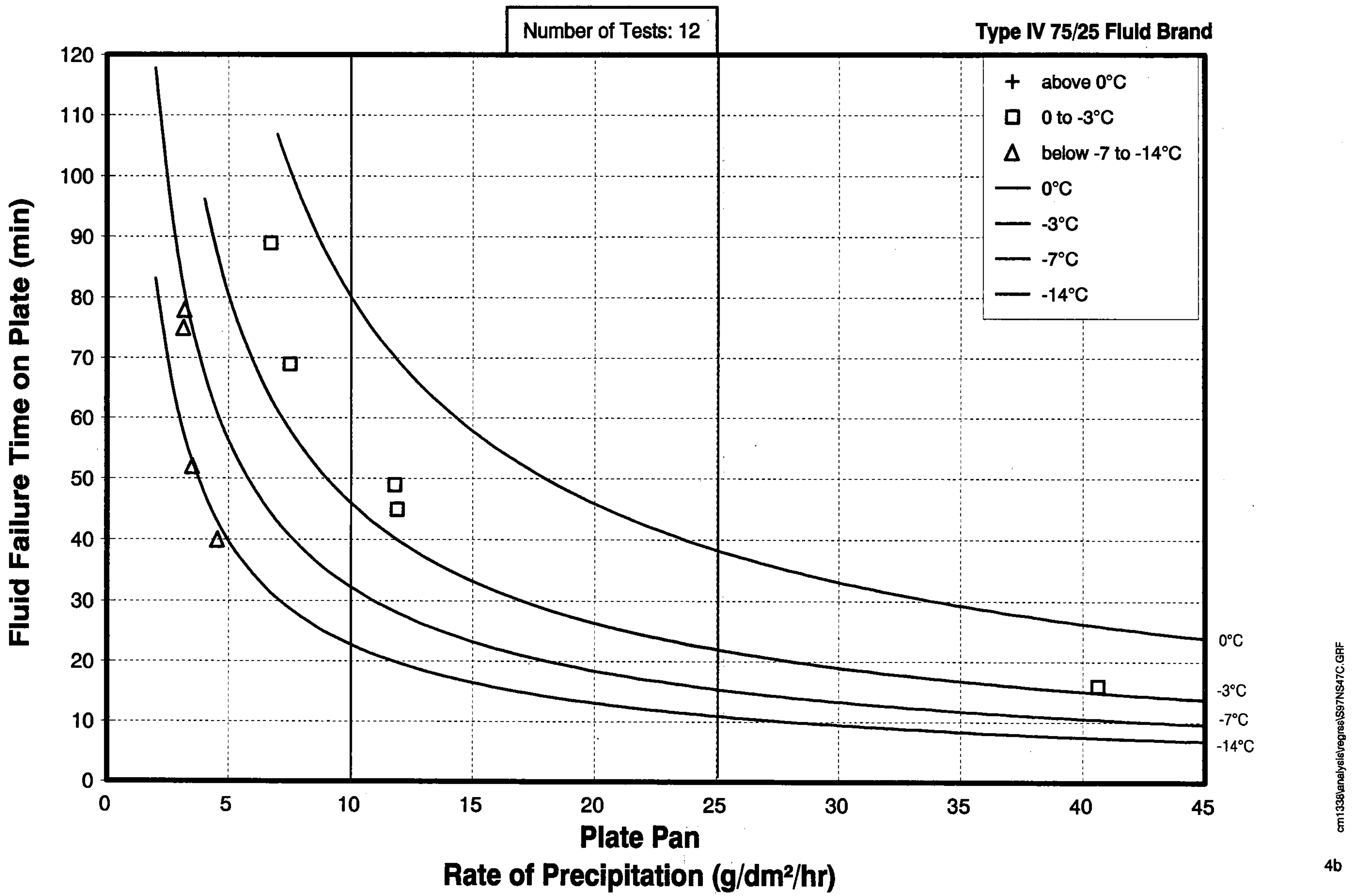
F-18

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-102 TYPE IV NEAT
NATURAL SNOW CONDITIONS
1995/1996



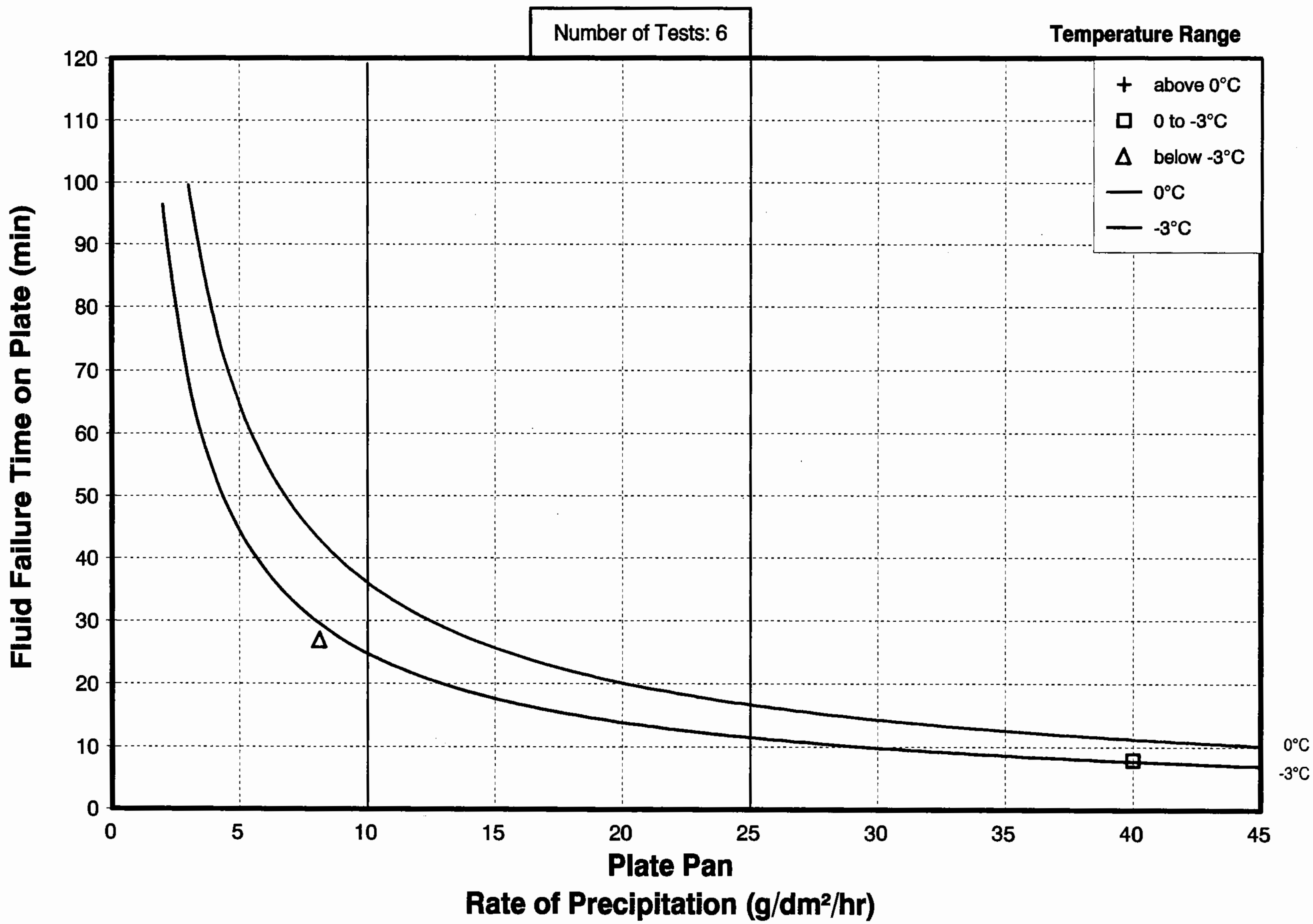
cm1338\anal\regress\S97NS41C

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-702 TYPE 75/25
NATURAL SNOW CONDITIONS
1995/1996



4b

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-502 TYPE IV 50/50
NATURAL SNOW CONDITIONS
1995/1996



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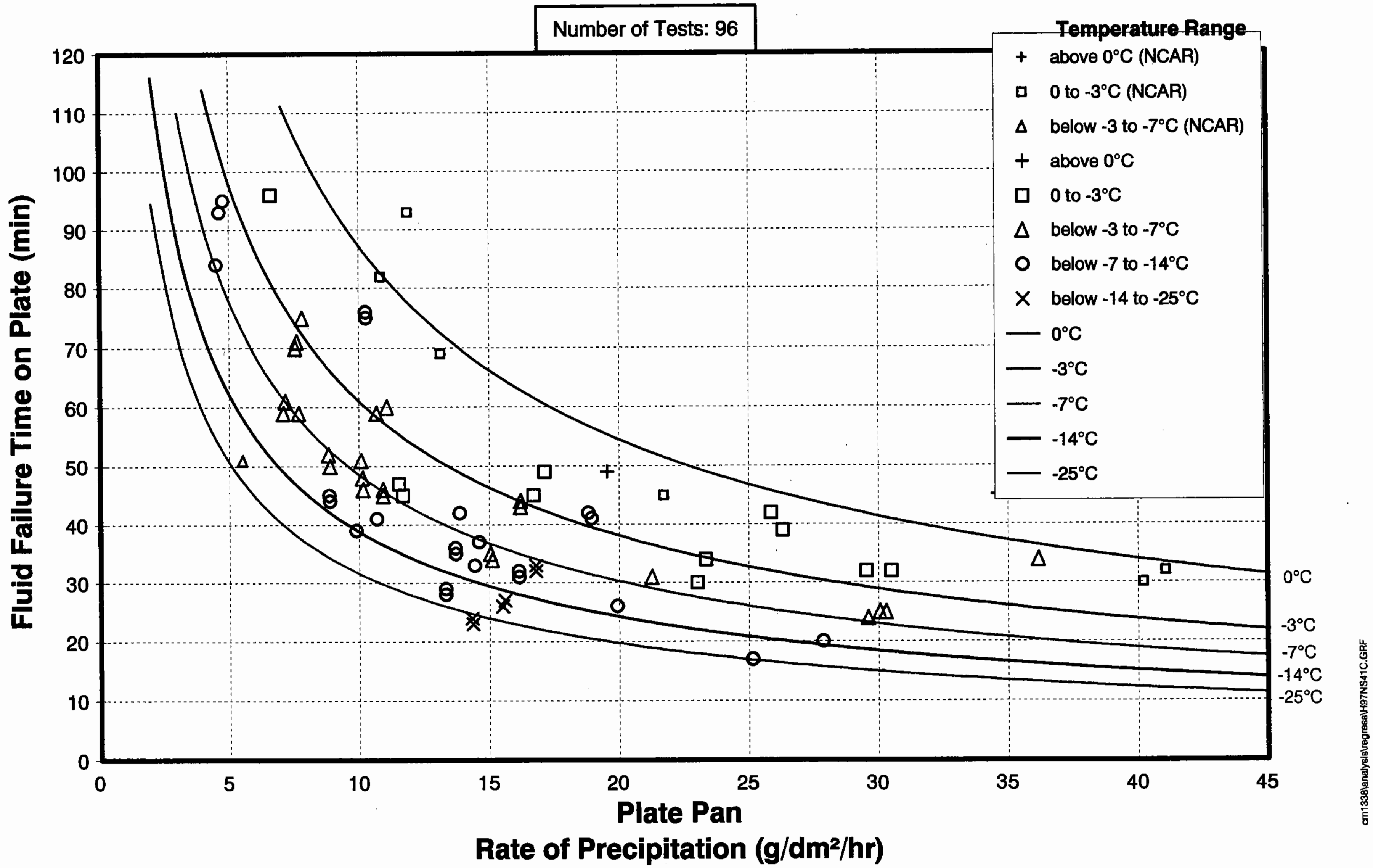
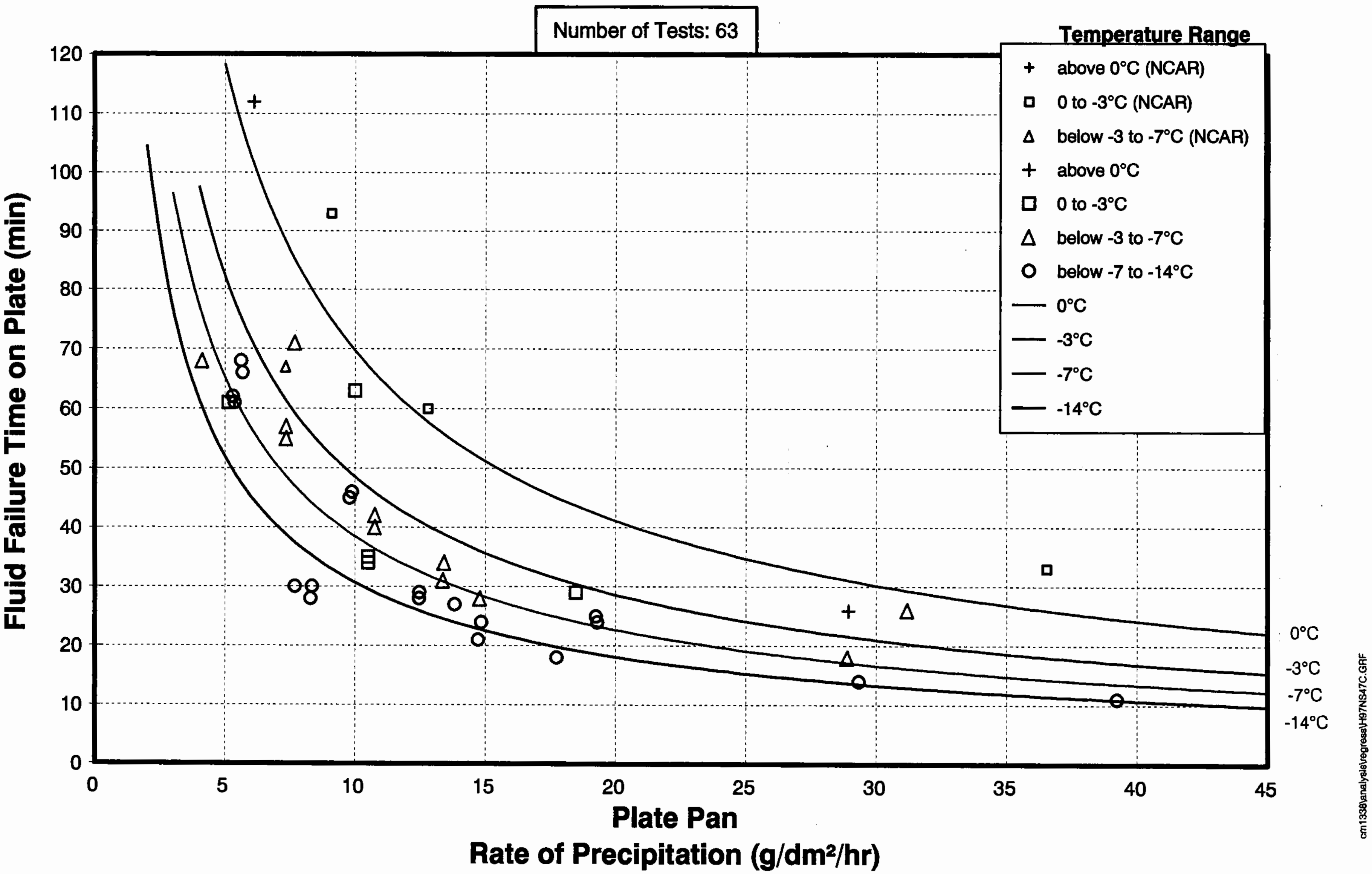
4b

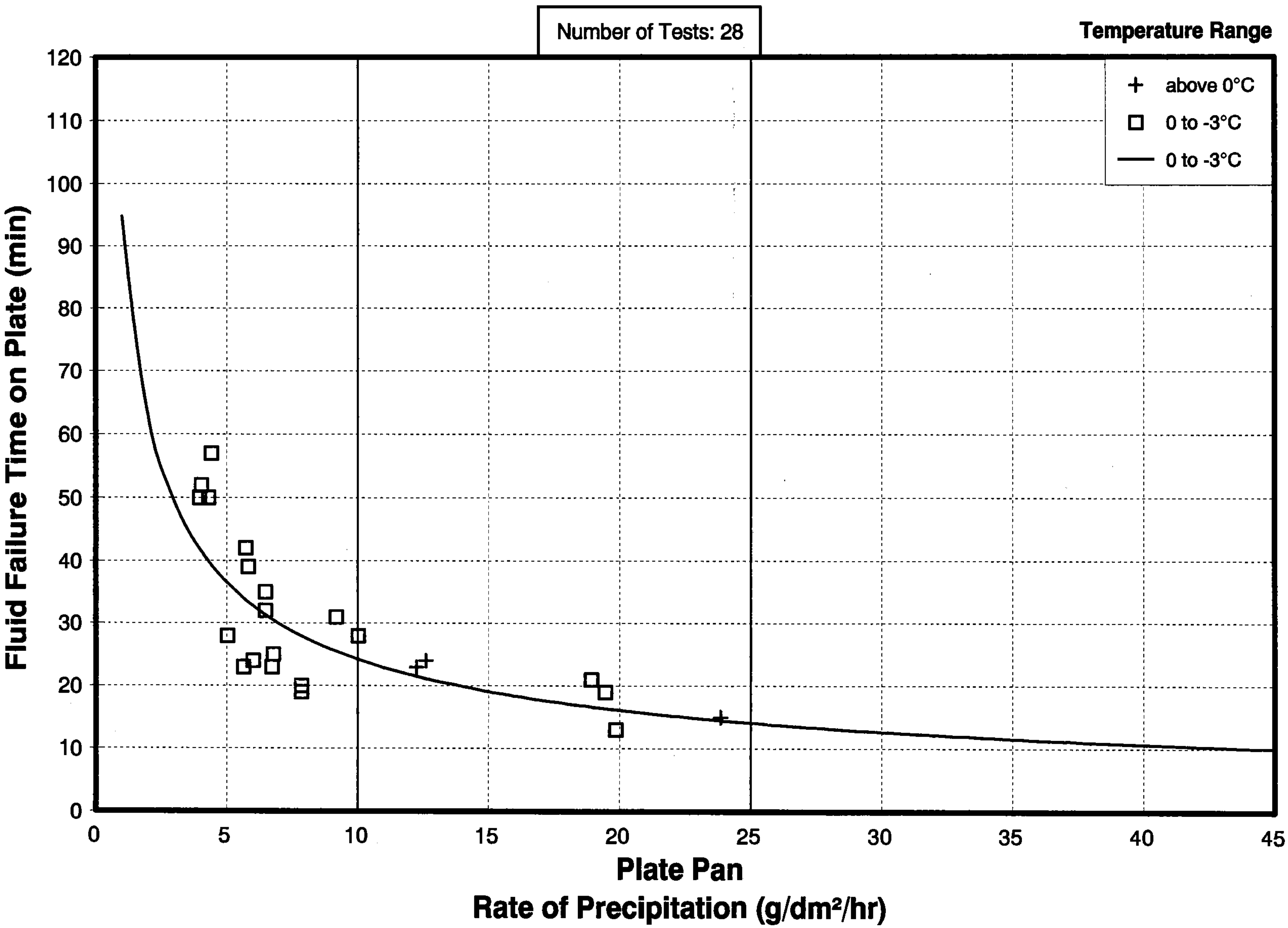
EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-107 TYPE IV NEAT
NATURAL SNOW CONDITIONS
1996/1997 (APS & NCAR)



EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-707 TYPE IV NEAT
NATURAL SNOW CONDITIONS
1996/1997 (APS & NCAR)



EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-507 TYPE IV 50/50
NATURAL SNOW CONDITIONS
1996/1997



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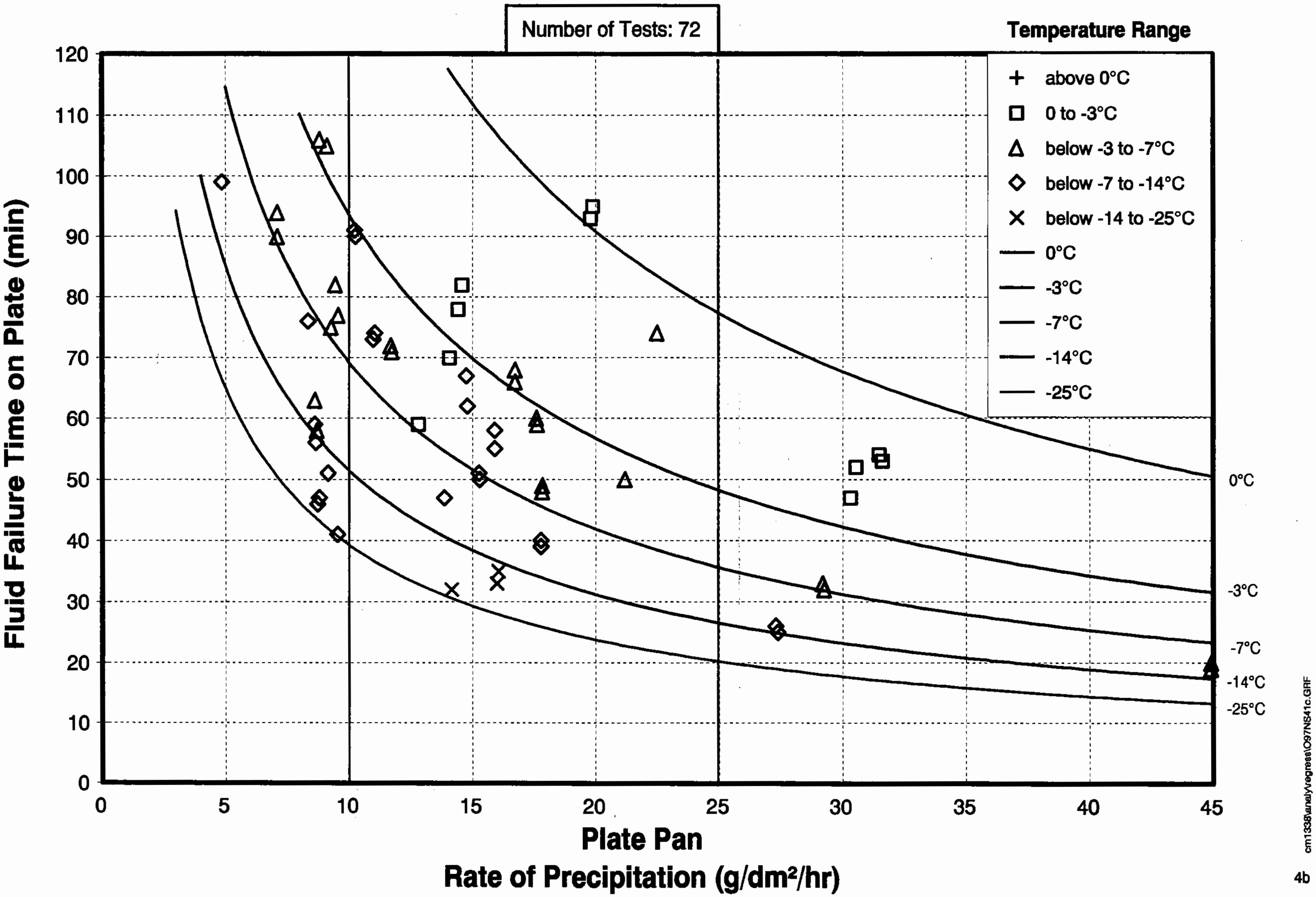
4b

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-108 TYPE IV NEAT

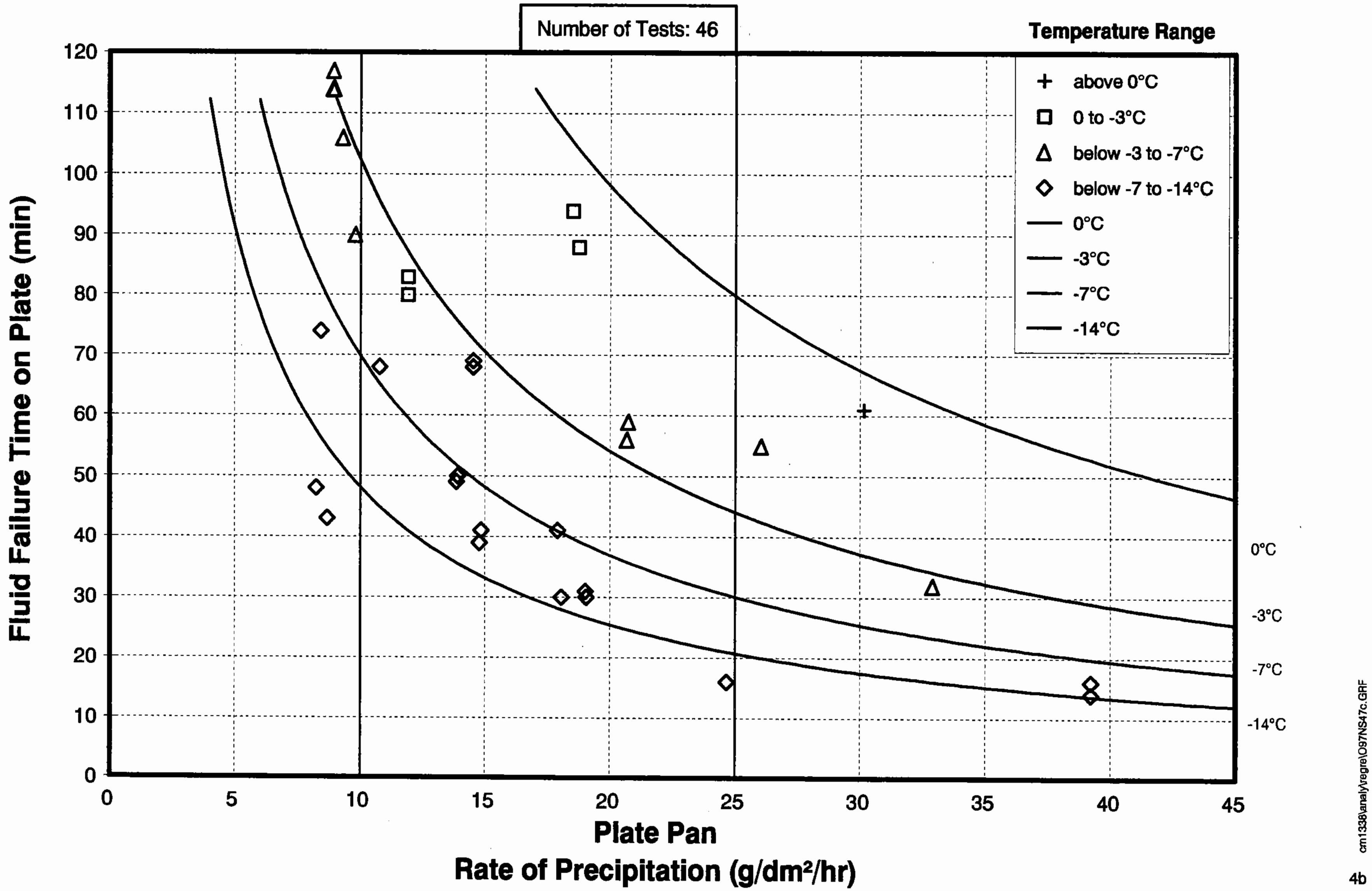
NATURAL SNOW CONDITIONS

1996/1997

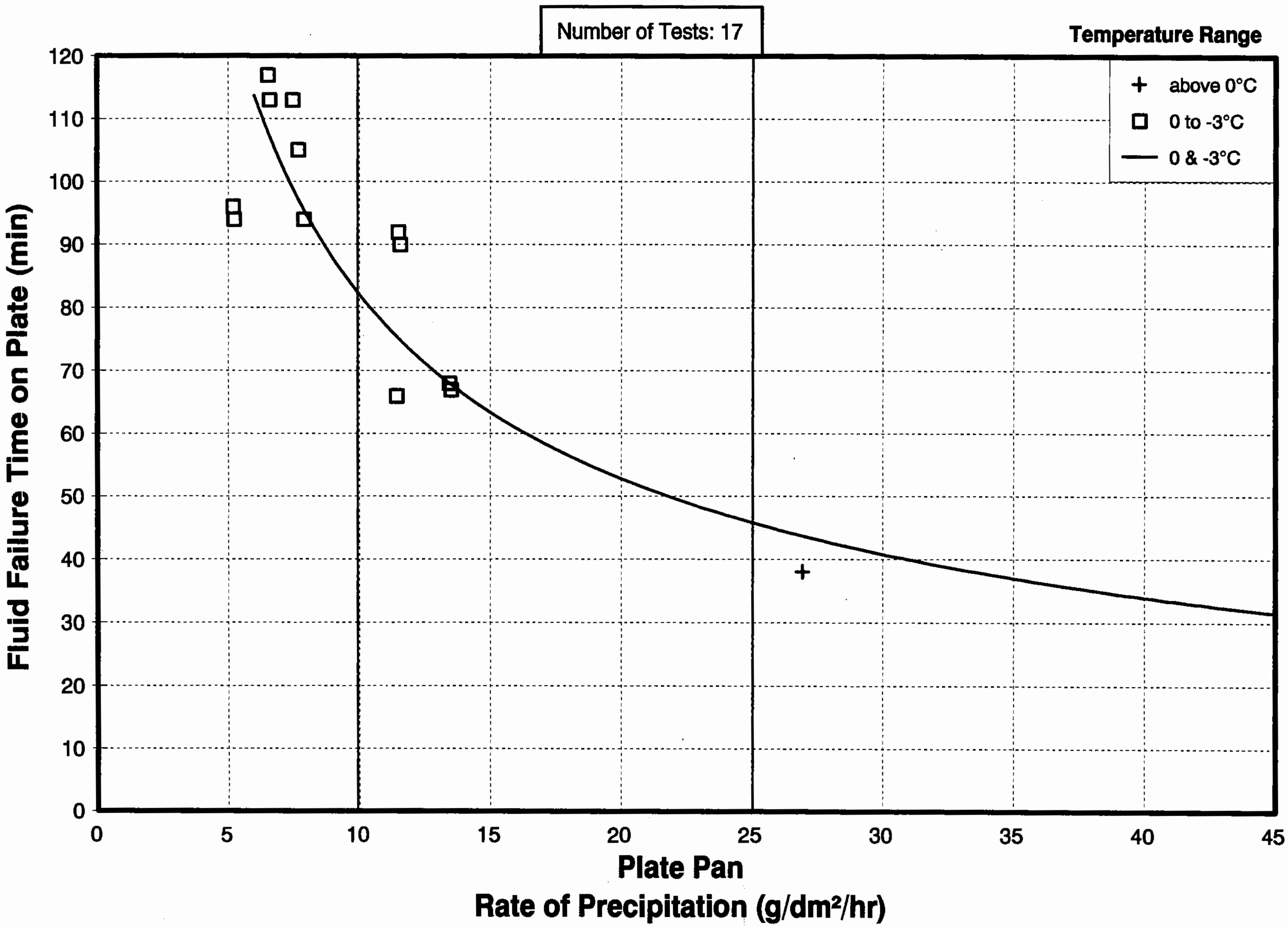


4b

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-708 TYPE IV 75/25
NATURAL SNOW CONDITIONS
1996/1997



EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-508 TYPE IV 50/50
NATURAL SNOW CONDITIONS
1996/1997



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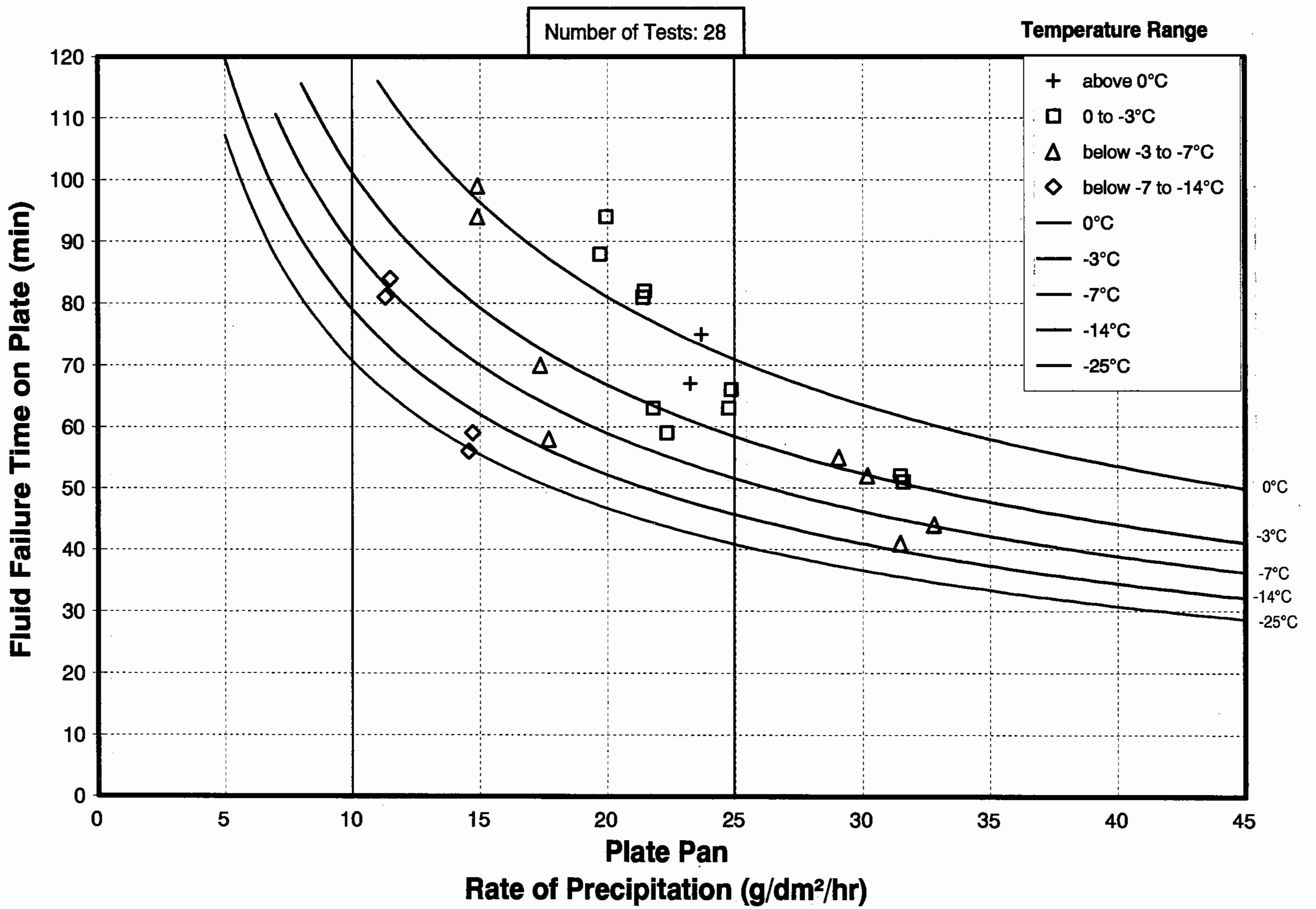
4b

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-109 TYPE IV NEAT
NATURAL SNOW CONDITIONS
1996/1997



cm1338\analysis\regress\K97NS41C.GRF

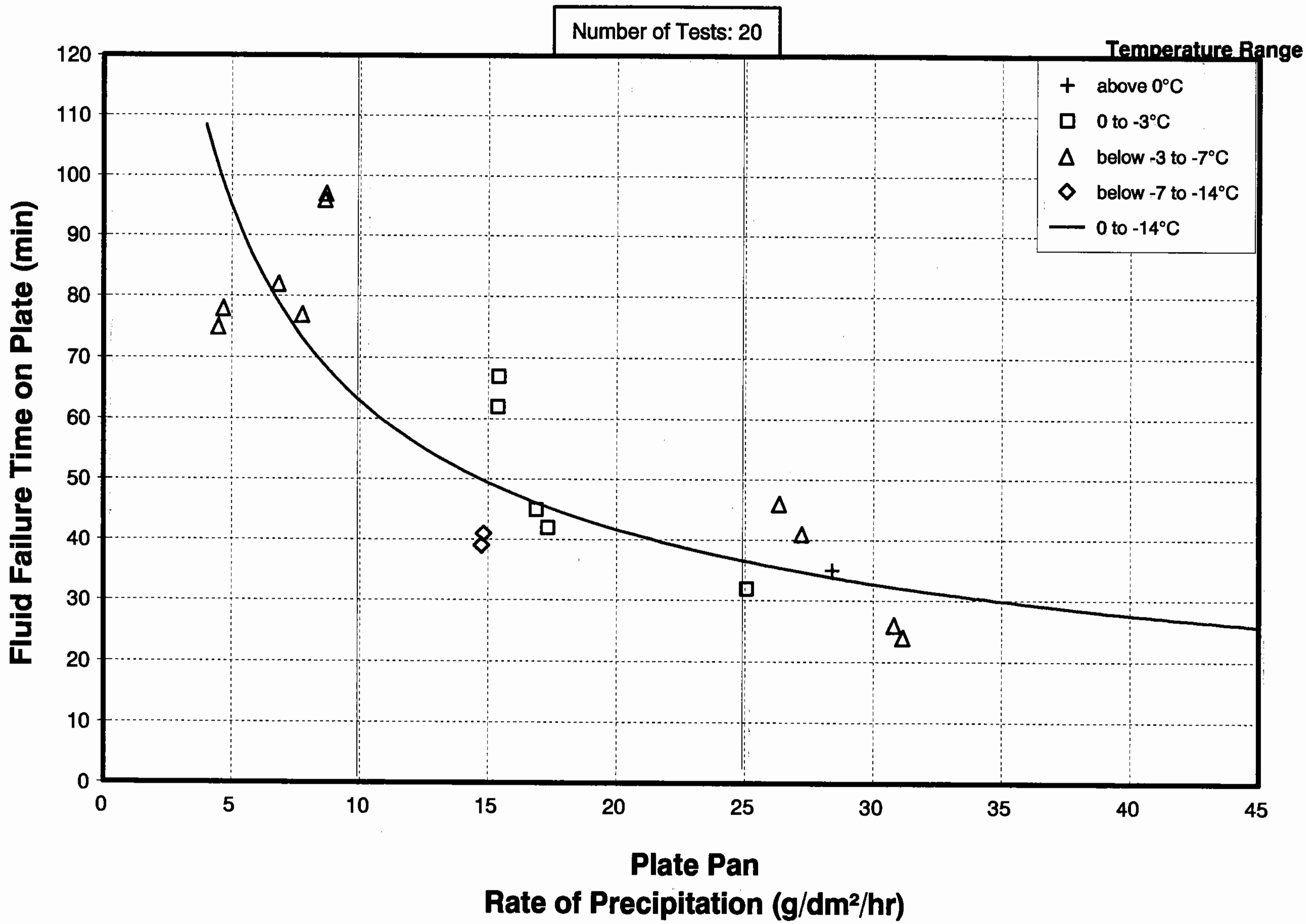
4b

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME

C-709 TYPE IV 75/25

NATURAL SNOW CONDITIONS

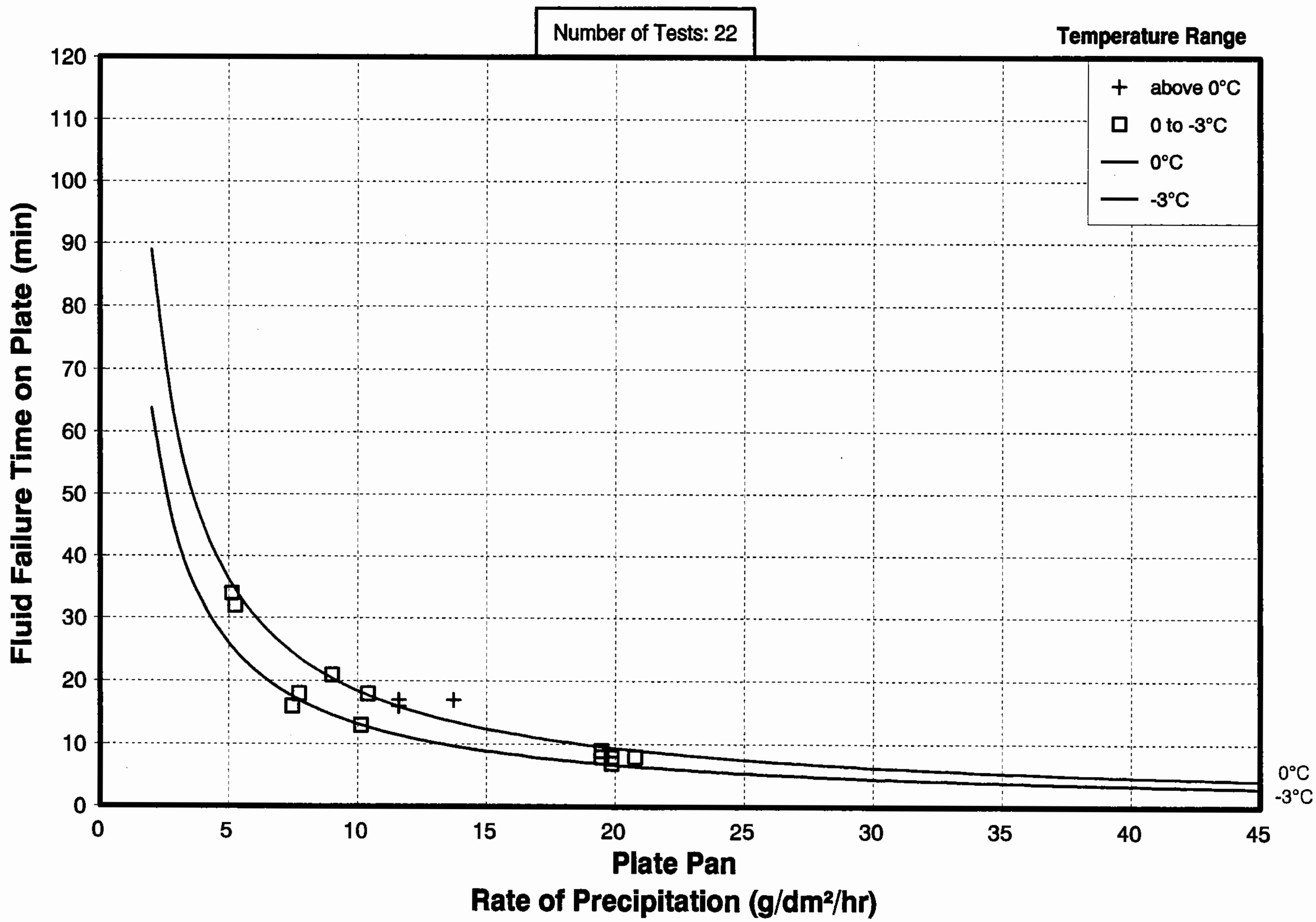
1996/1997



cm1338\analysis\regress\K97NS47C.GRF

4b

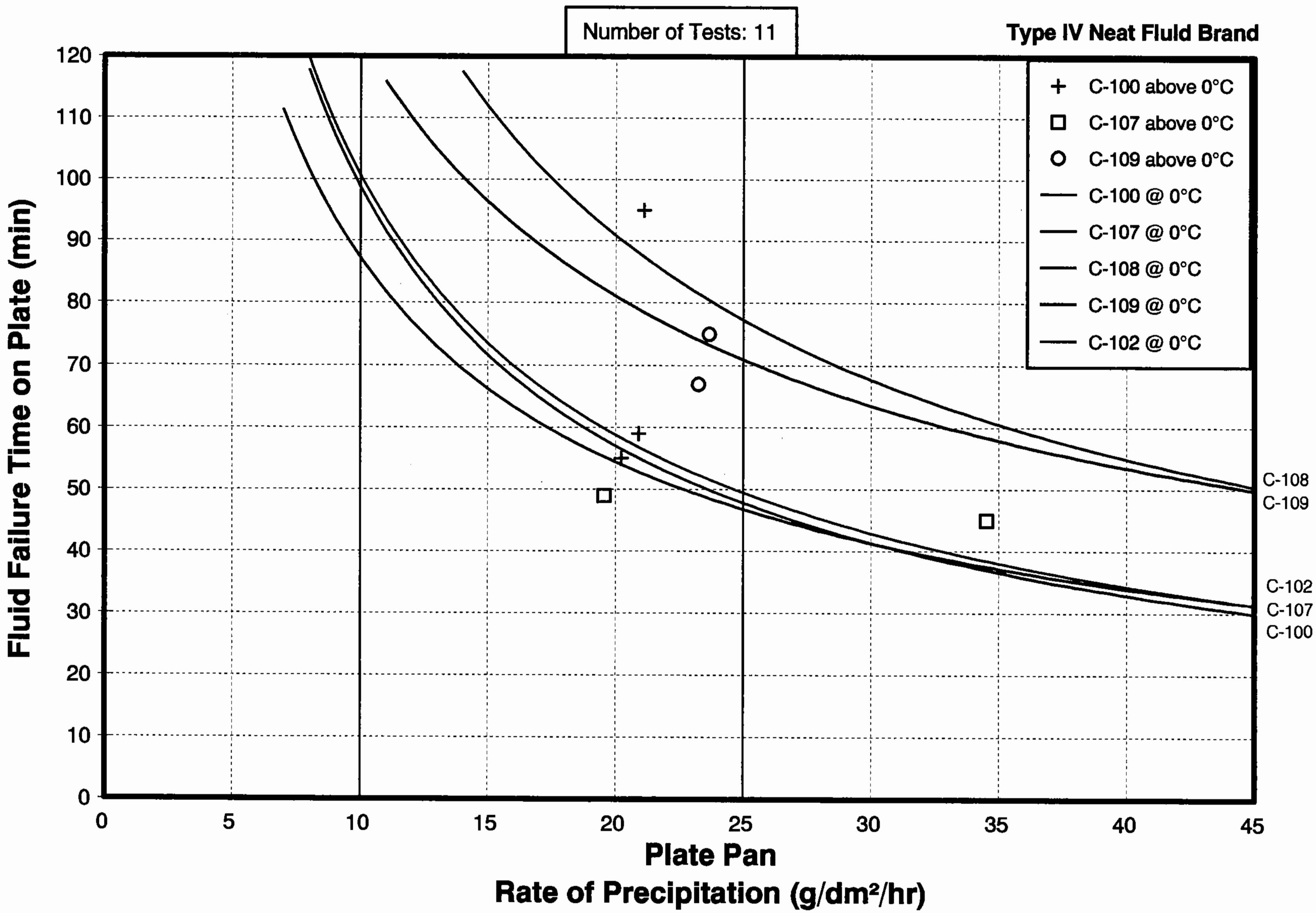
EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
C-509 TYPE IV 50/50
NATURAL SNOW CONDITIONS
1996/1997



cm1338\analysis\K97NS45c.GRF

4b

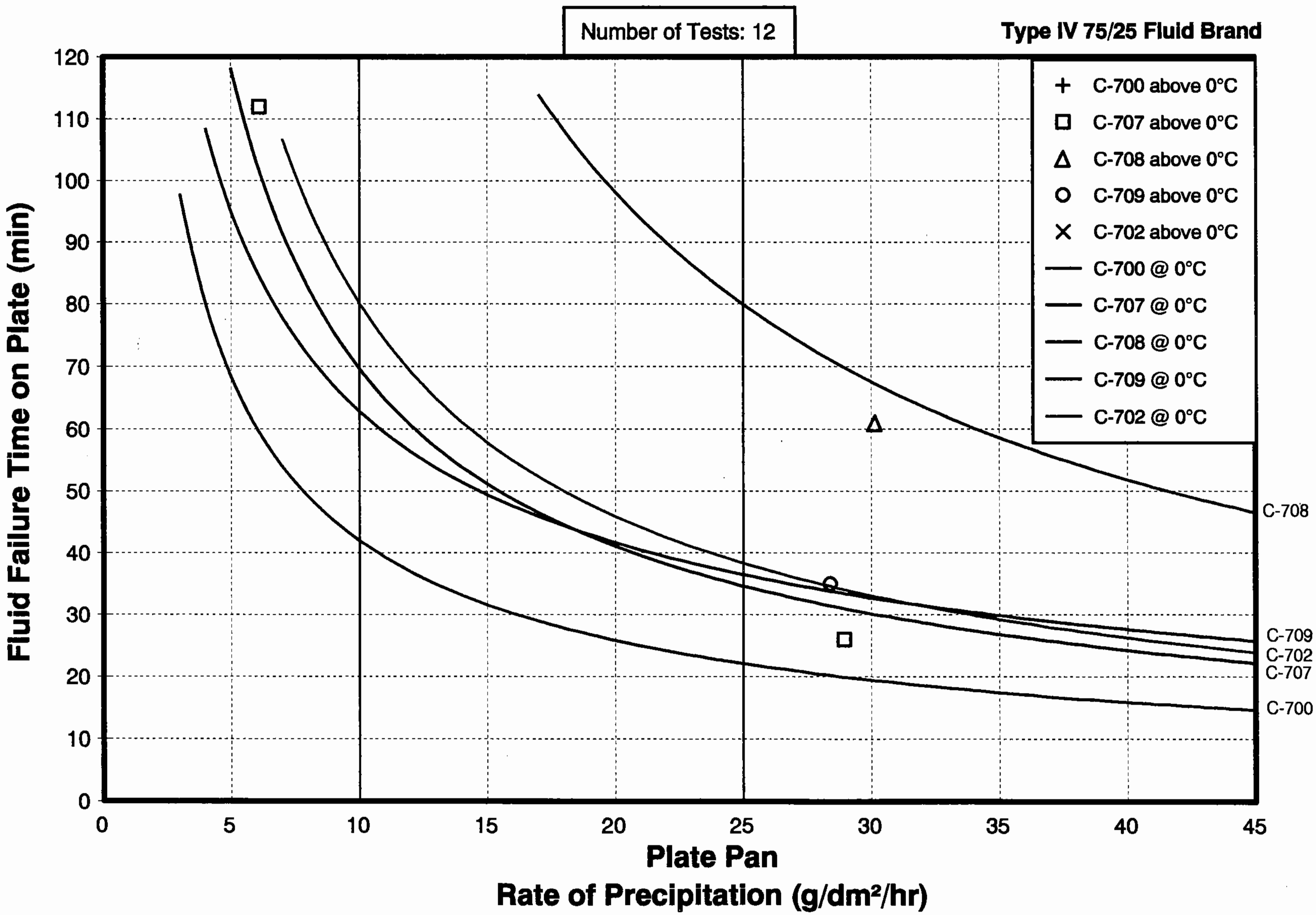
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT (above 0°C)
NATURAL SNOW CONDITIONS



cm1338\analysis\regress\R0S41R.GRF

4b

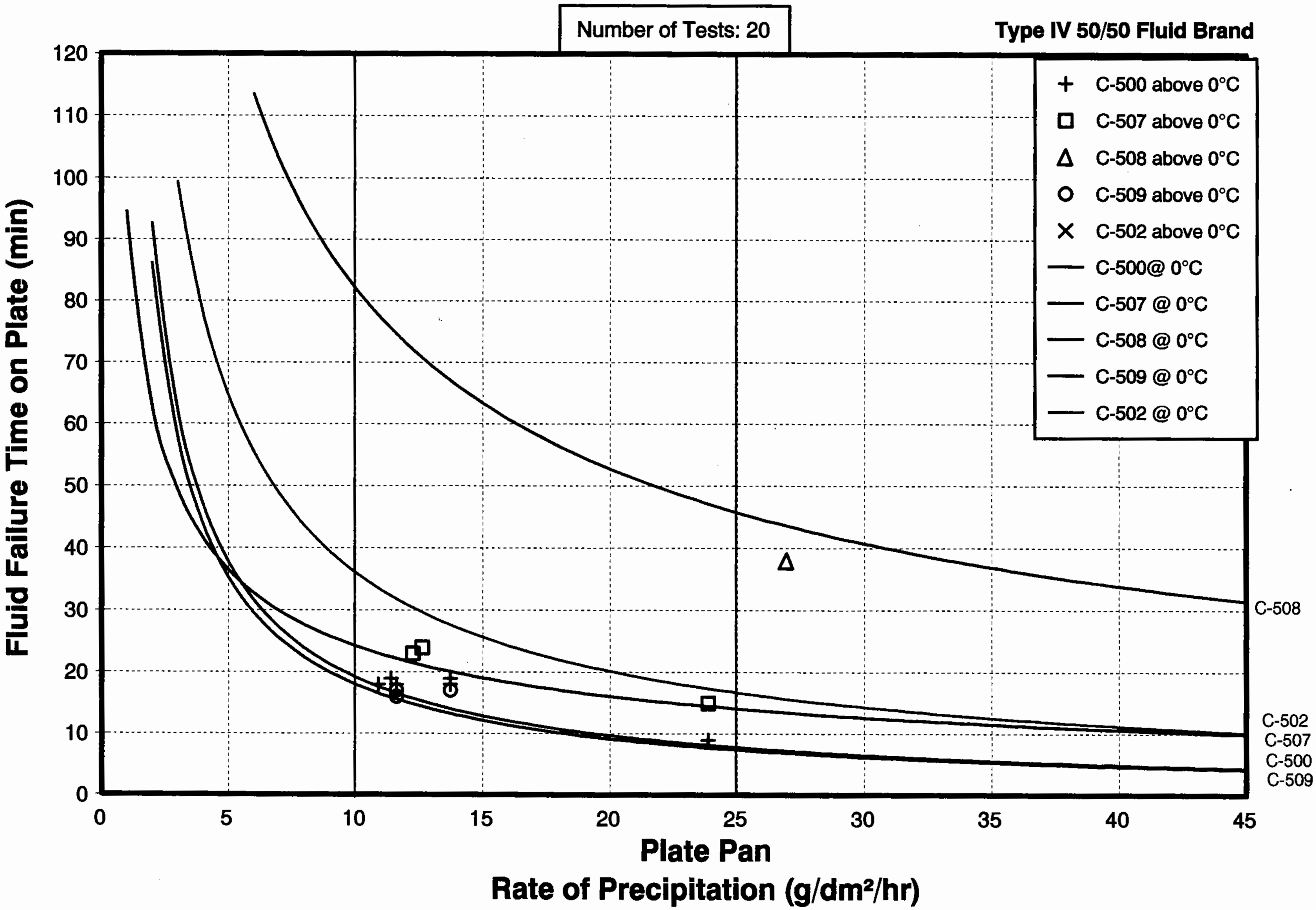
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25 (Above 0°C)
NATURAL SNOW CONDITIONS



cm1338\analysis\regress\v0S47R.GRF

4b

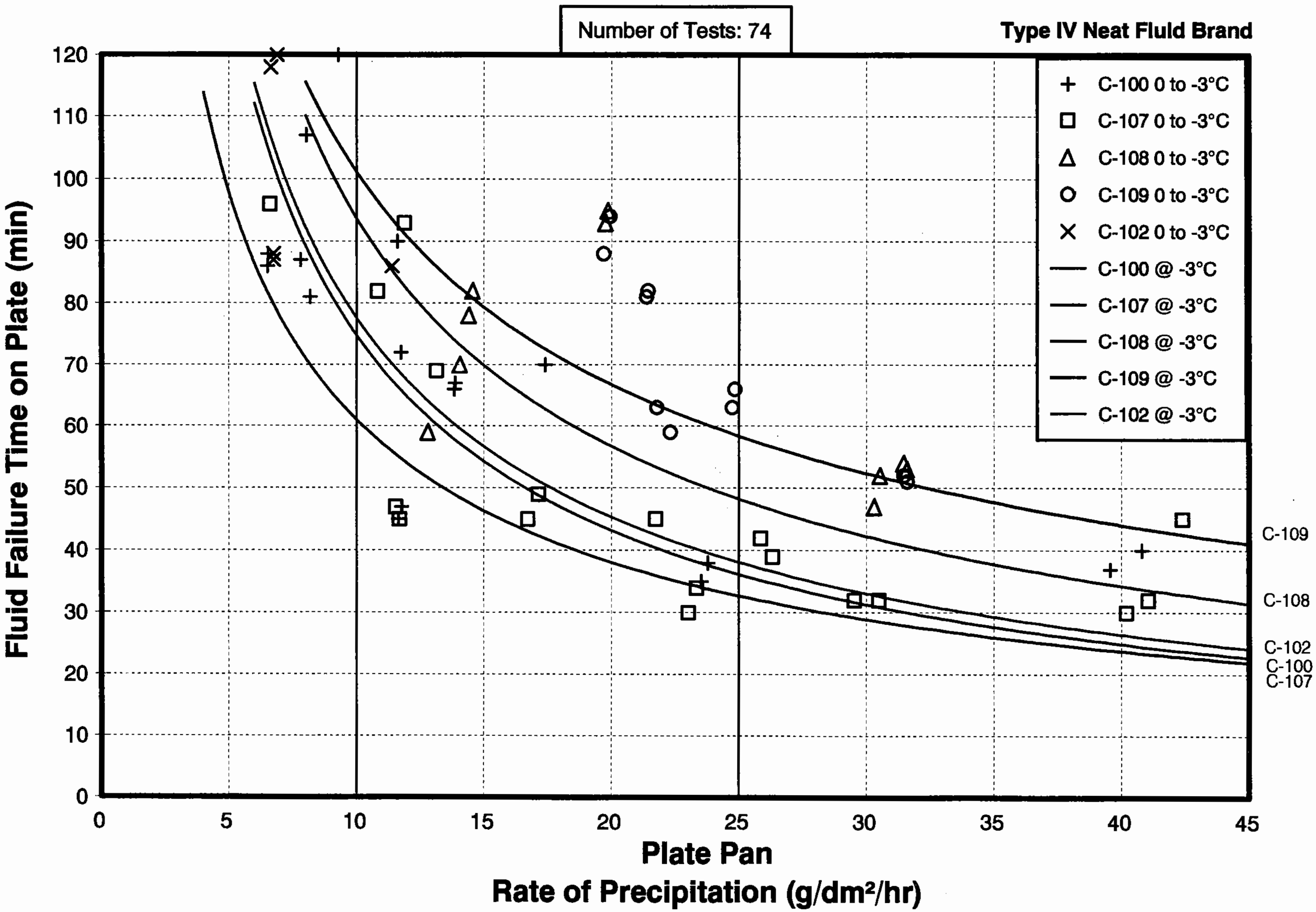
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 50/50 (Above 0°C)
NATURAL SNOW CONDITIONS



cm1338\analysis\regress\0S45R.GRF

4b

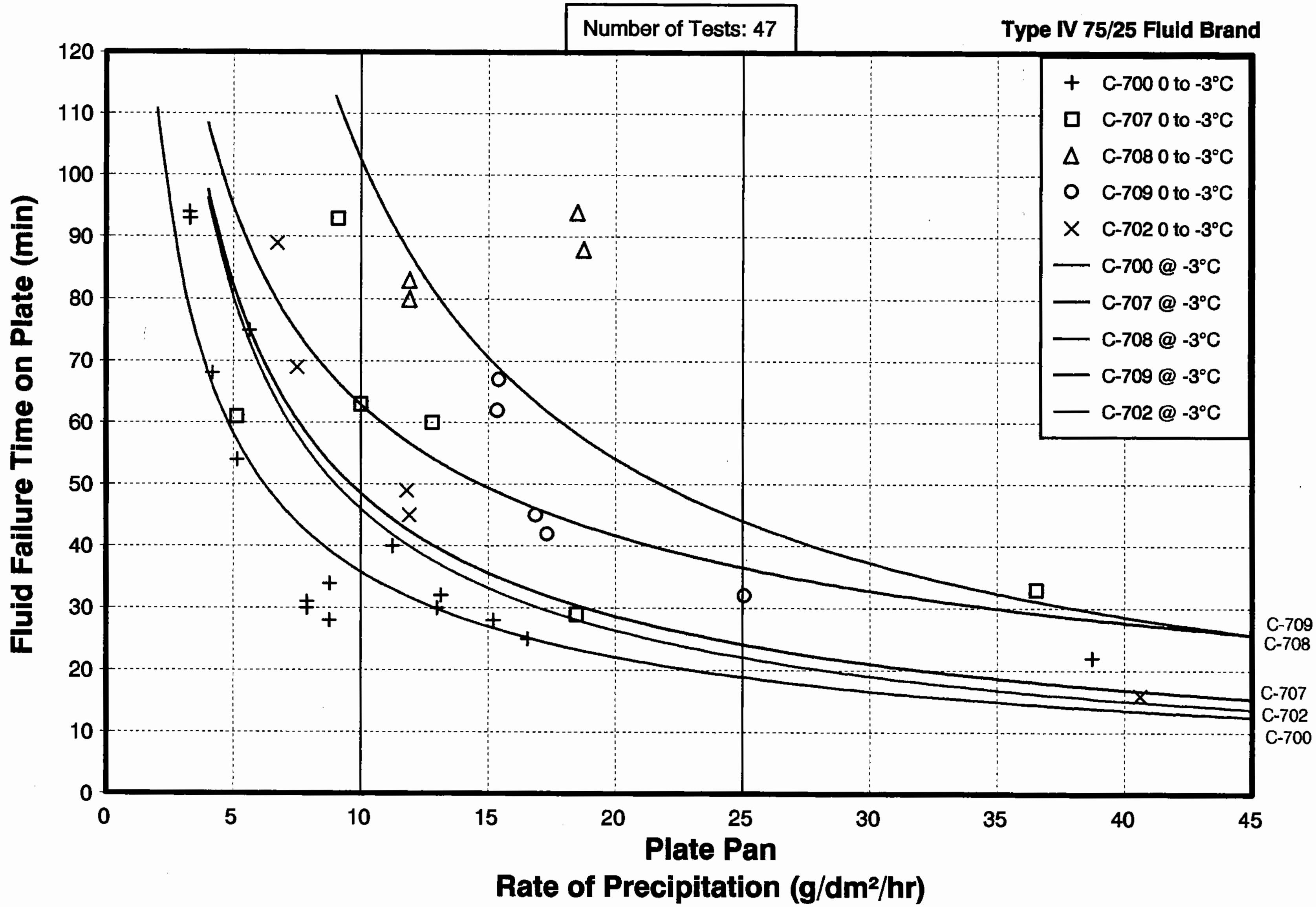
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT (0 to -3°C)
NATURAL SNOW CONDITIONS



cm1338\analysis\regress\-3S41R.GRF

4b

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25 (0 to -3°C)
NATURAL SNOW CONDITIONS

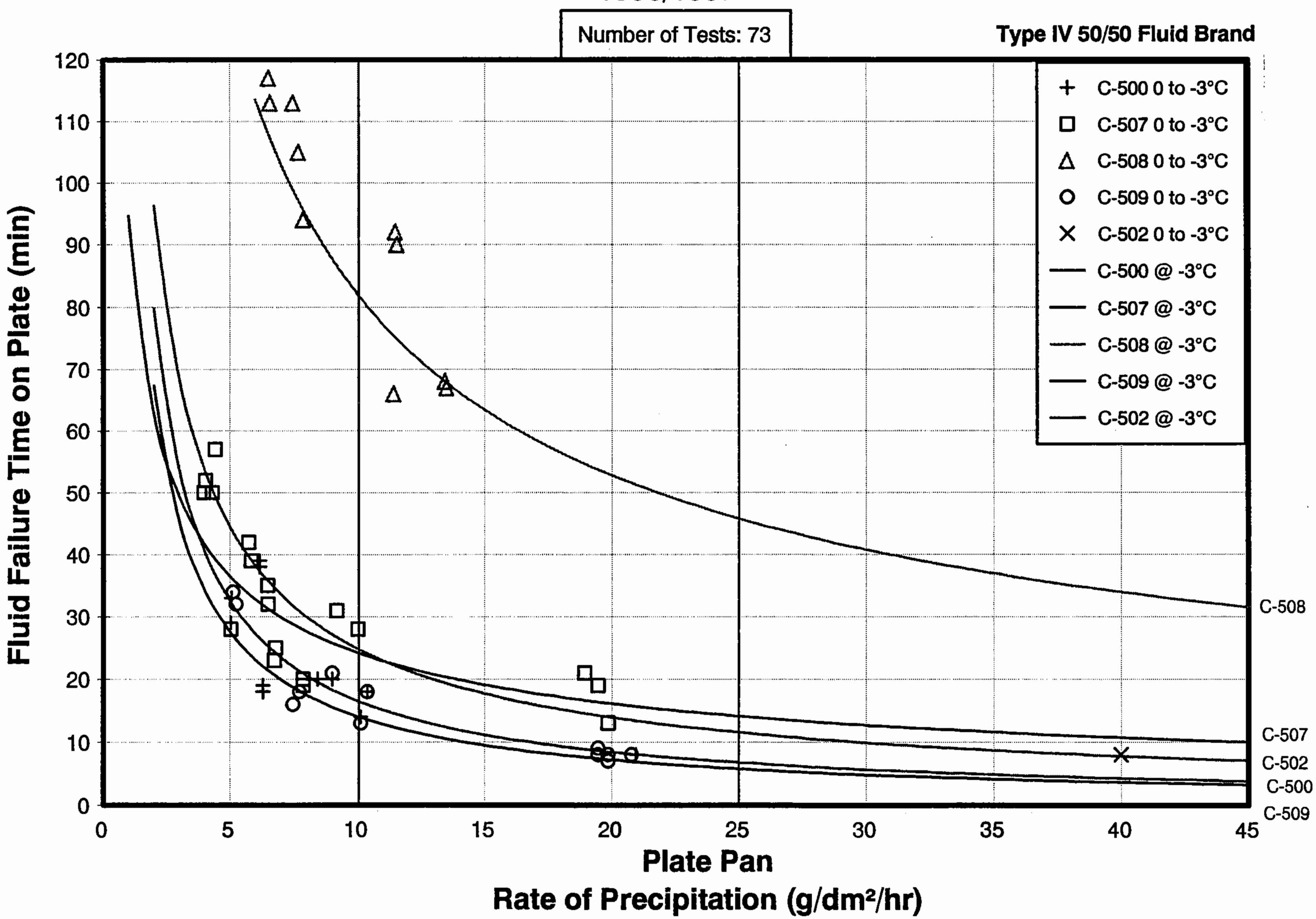


F-35

cm1338\analysis\regress\r-3S47R.GRF

4b

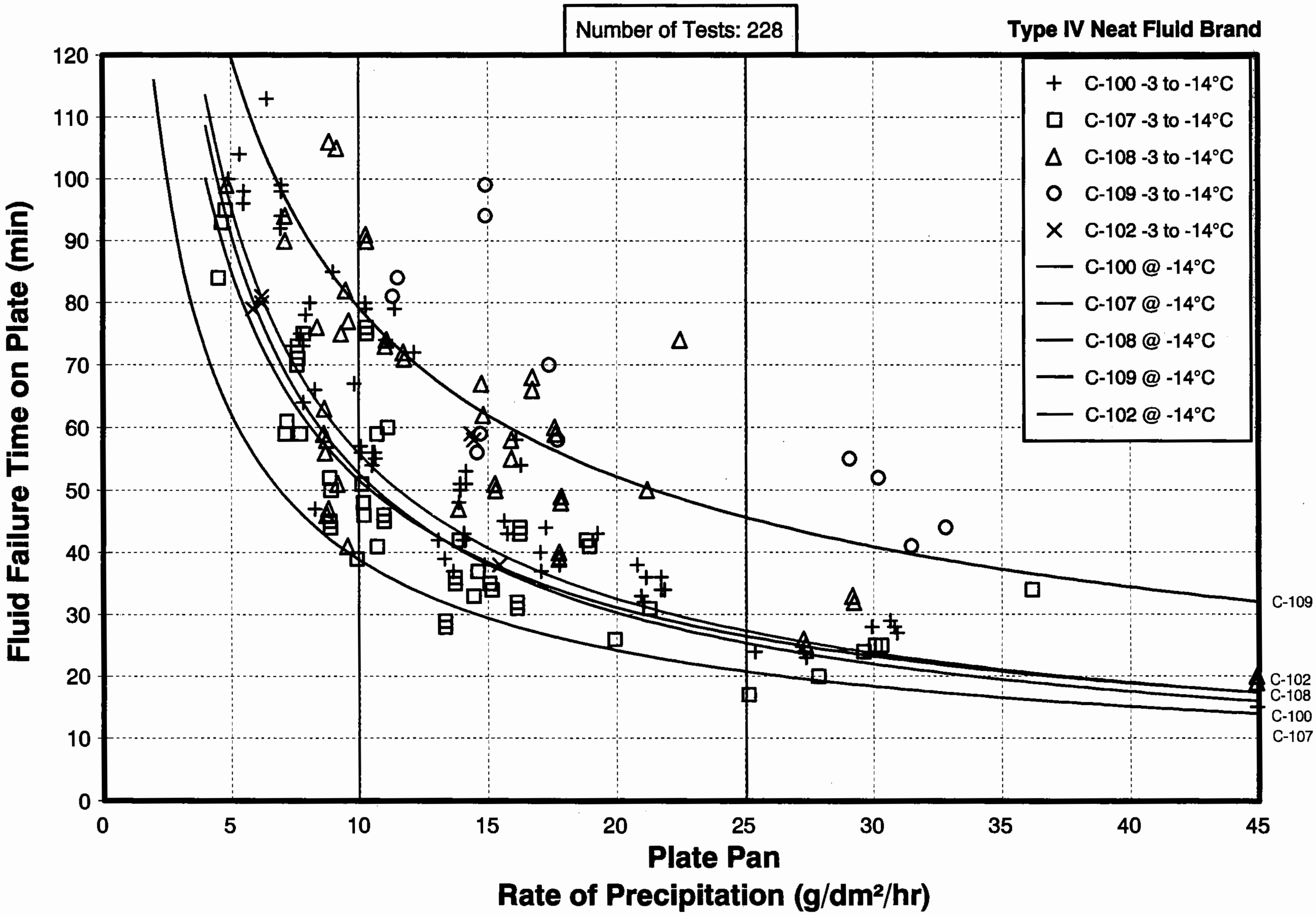
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 50/50 (0 to -3°C)
NATURAL SNOW CONDITIONS
1996/1997



cm1338\analysis\regress\-3S45R.GRF

4b

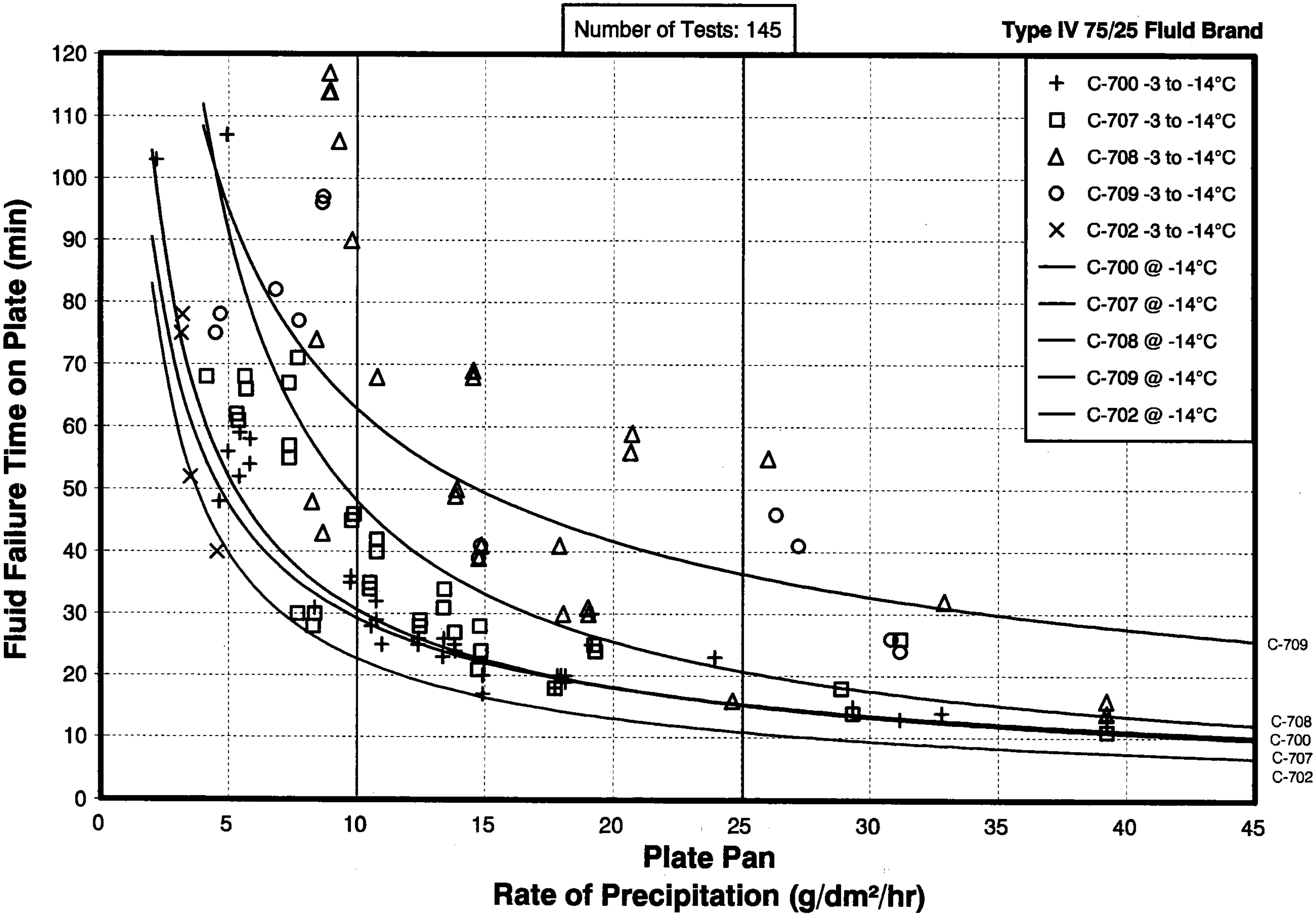
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT (-3 to -14°C)
NATURAL SNOW CONDITIONS



cm1338\analysis\regress\R-14541R.GRF

4b

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25 (-3 to -14°C)
NATURAL SNOW CONDITIONS



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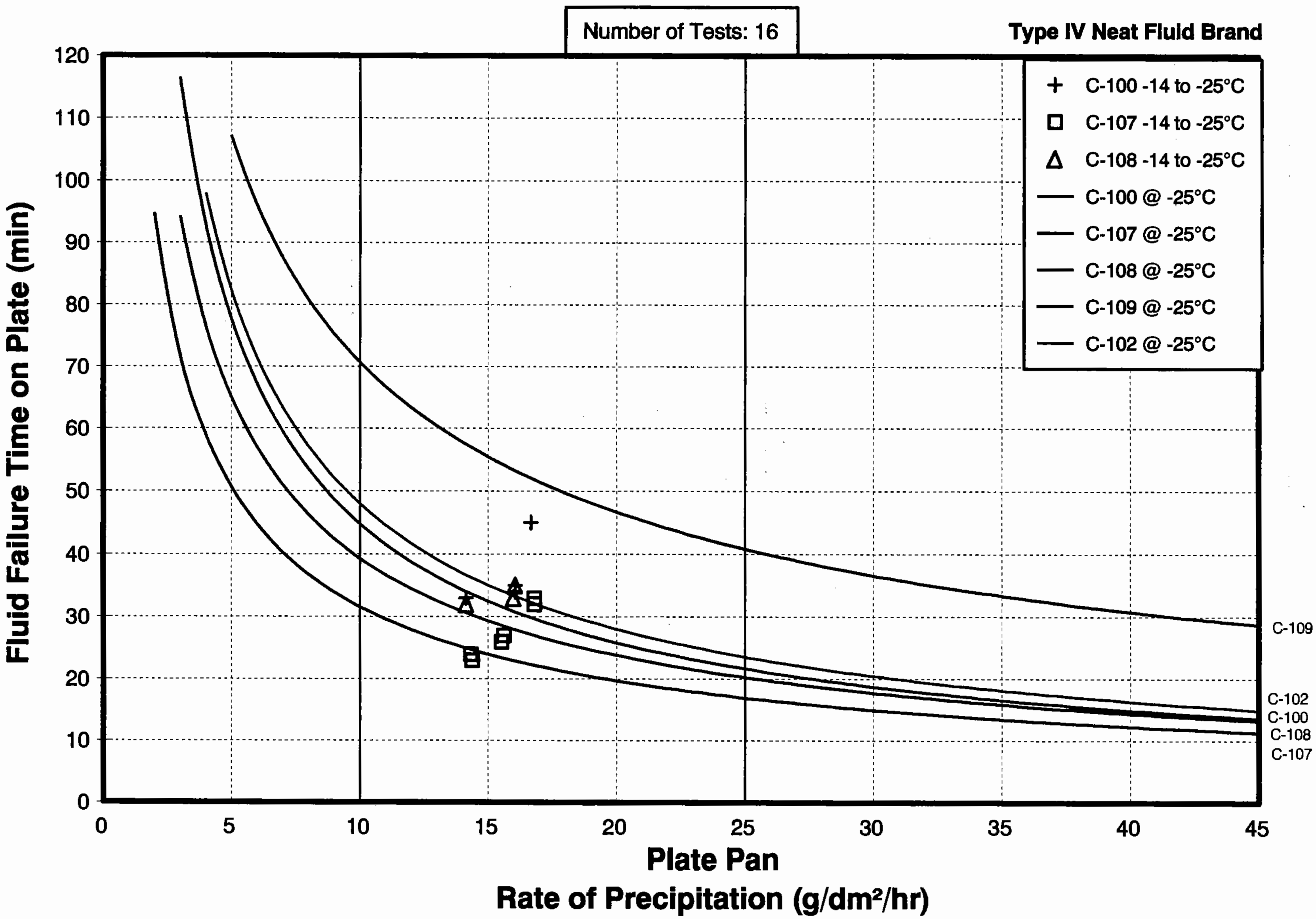
4b

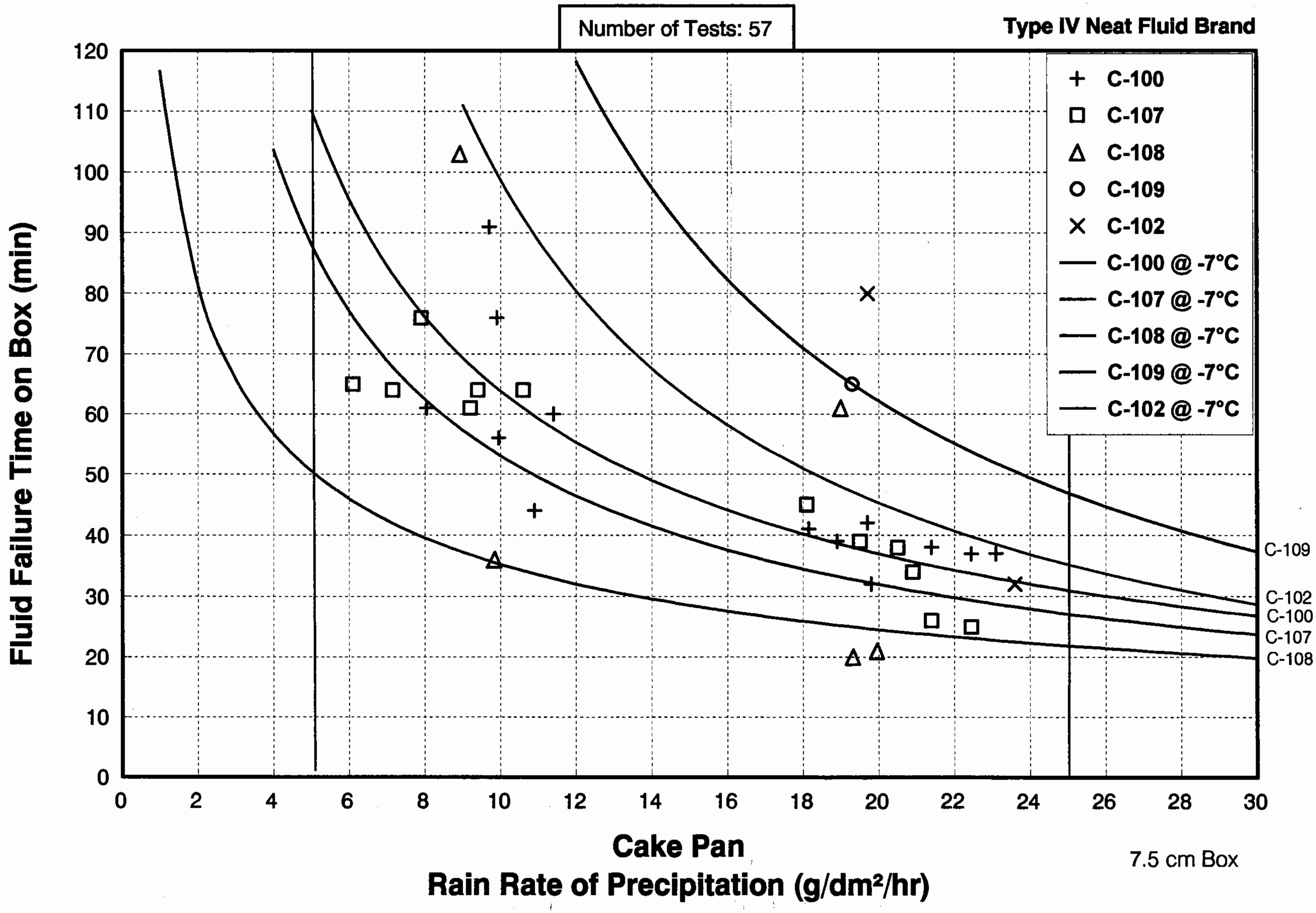
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT (-14 to -25°C)
NATURAL SNOW CONDITIONS



cm1338\analysis\regress\R-25S41R.GRF

4b

EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT
RAIN ON COLD-SOAKED SURFACE
1995/1996 & 1996/1997



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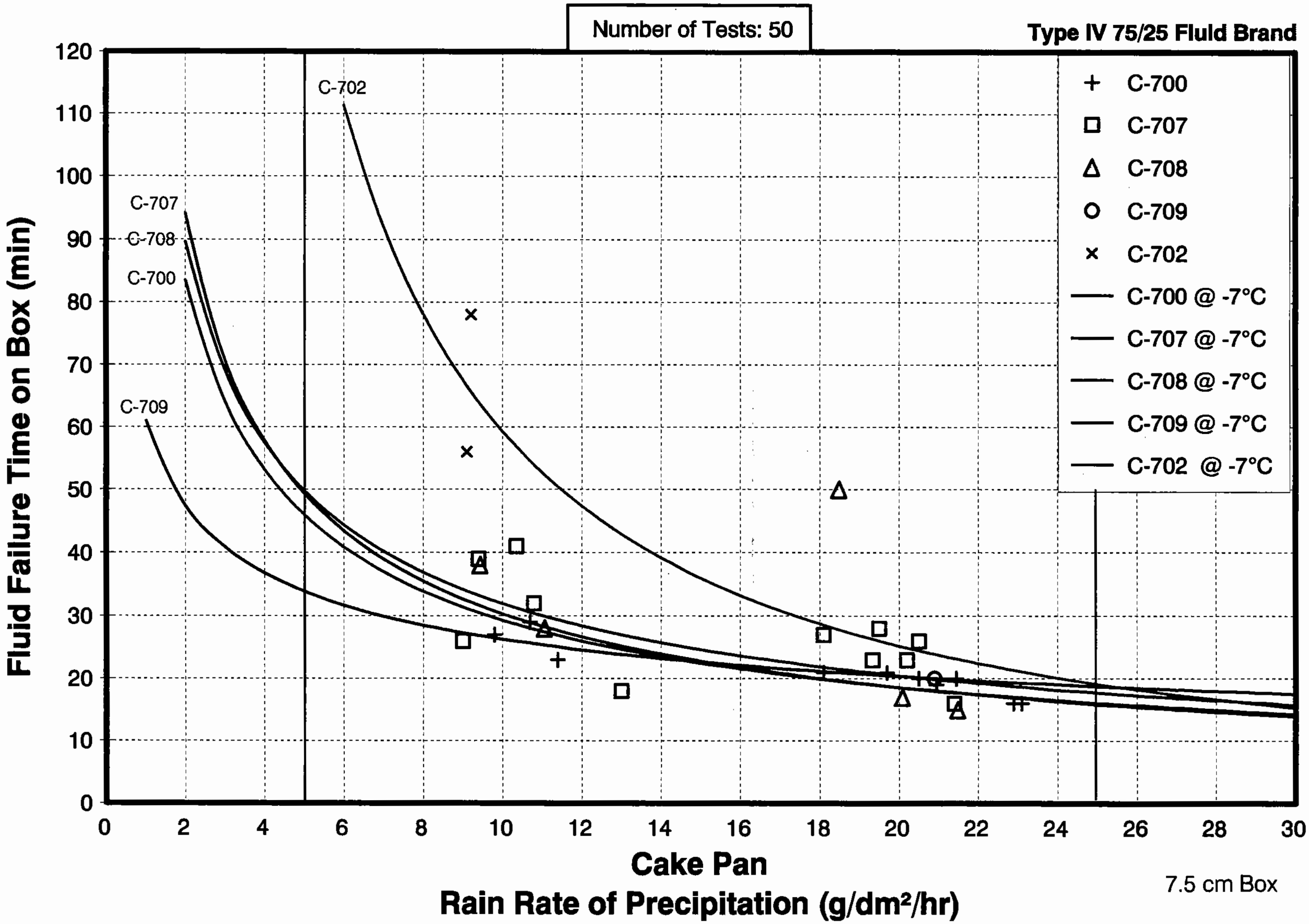
10a

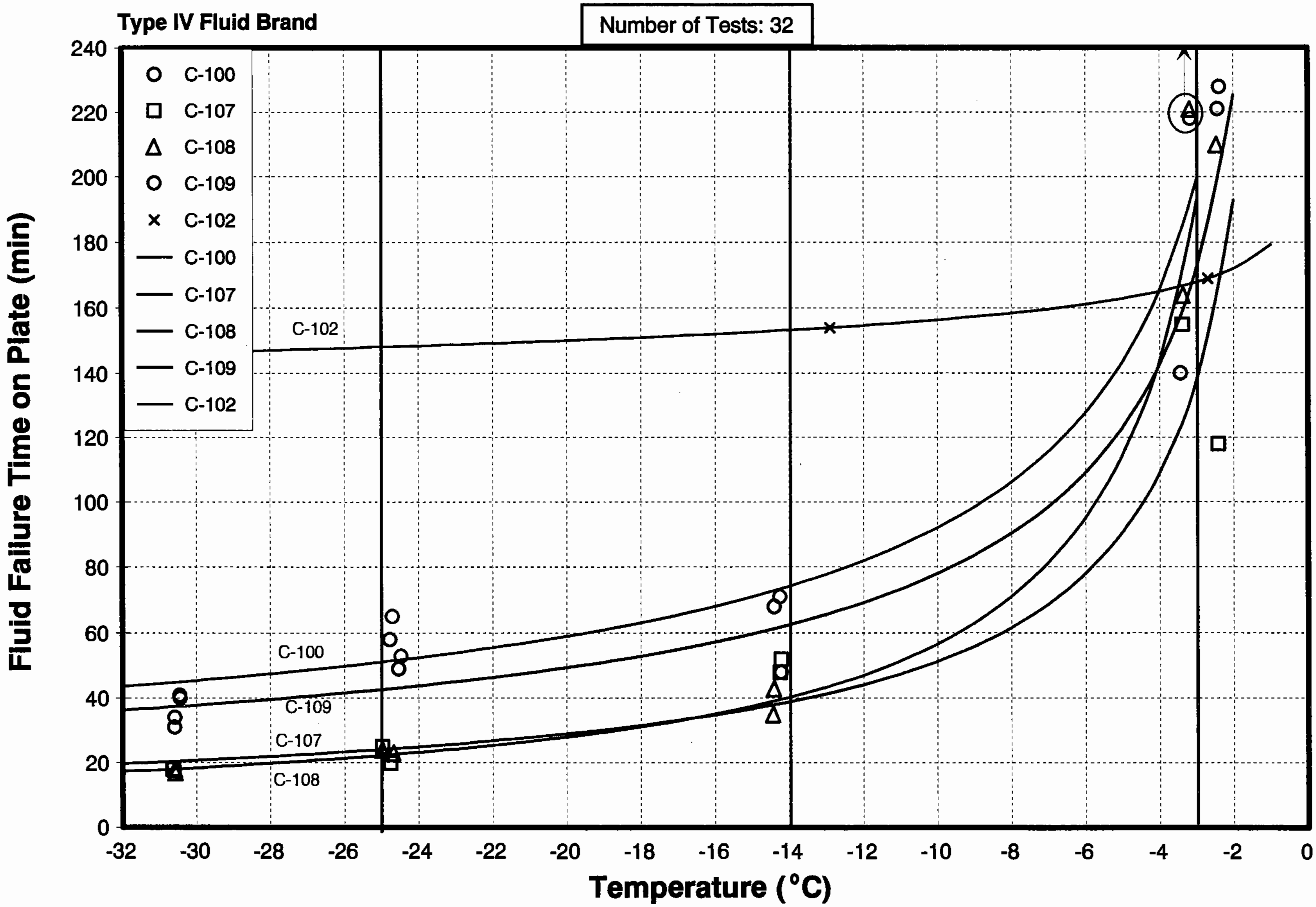
EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25
RAIN ON COLD-SOAKED SURFACE
1995/1996 & 1996/1997



cm1338\analysis\regress\CS_47_R.GRF

11a

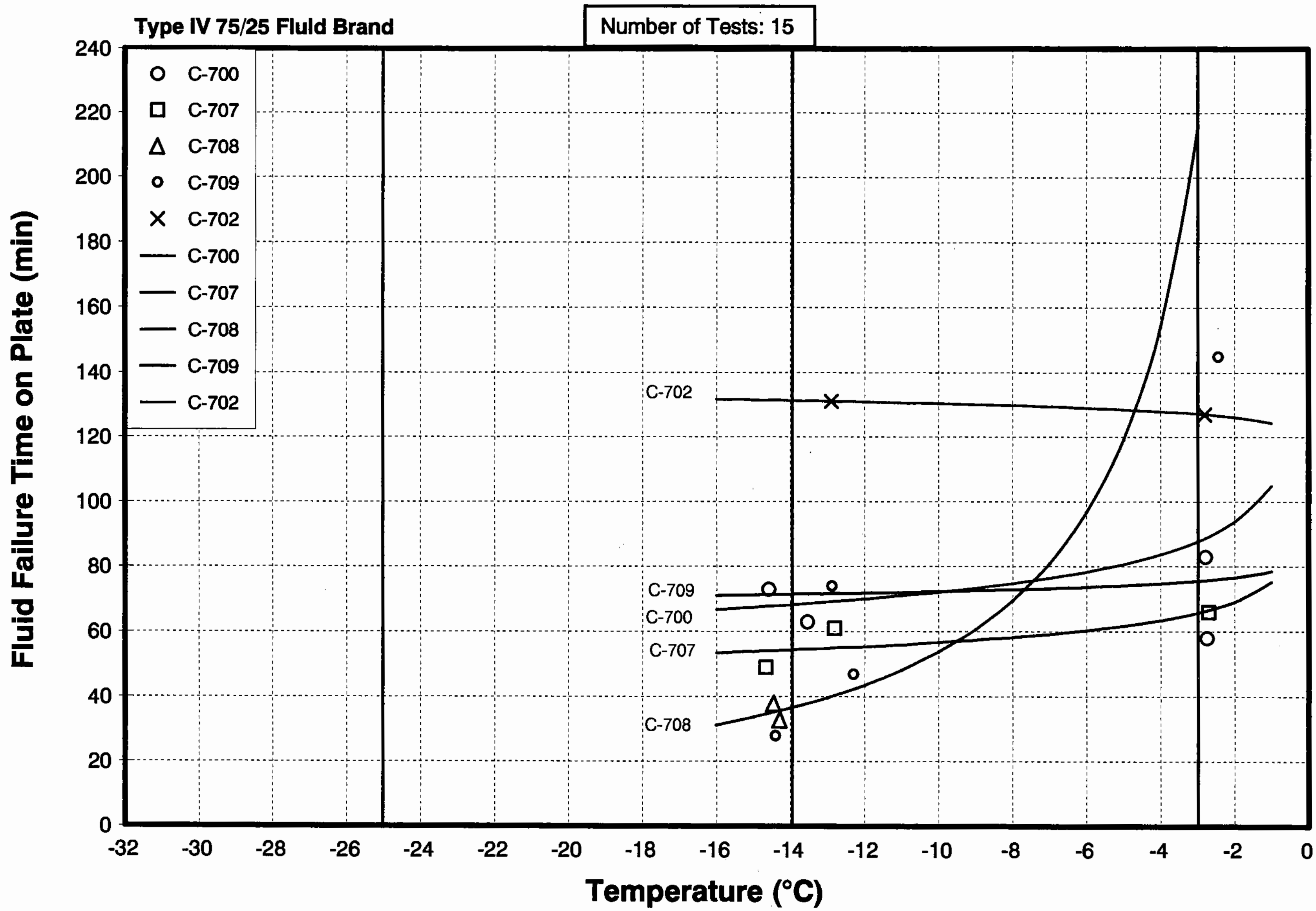
EFFECT OF FLUID BRAND AND TEMPERATURE ON FAILURE TIME
TYPE IV NEAT
SIMULATED FREEZING FOG
1996/1997



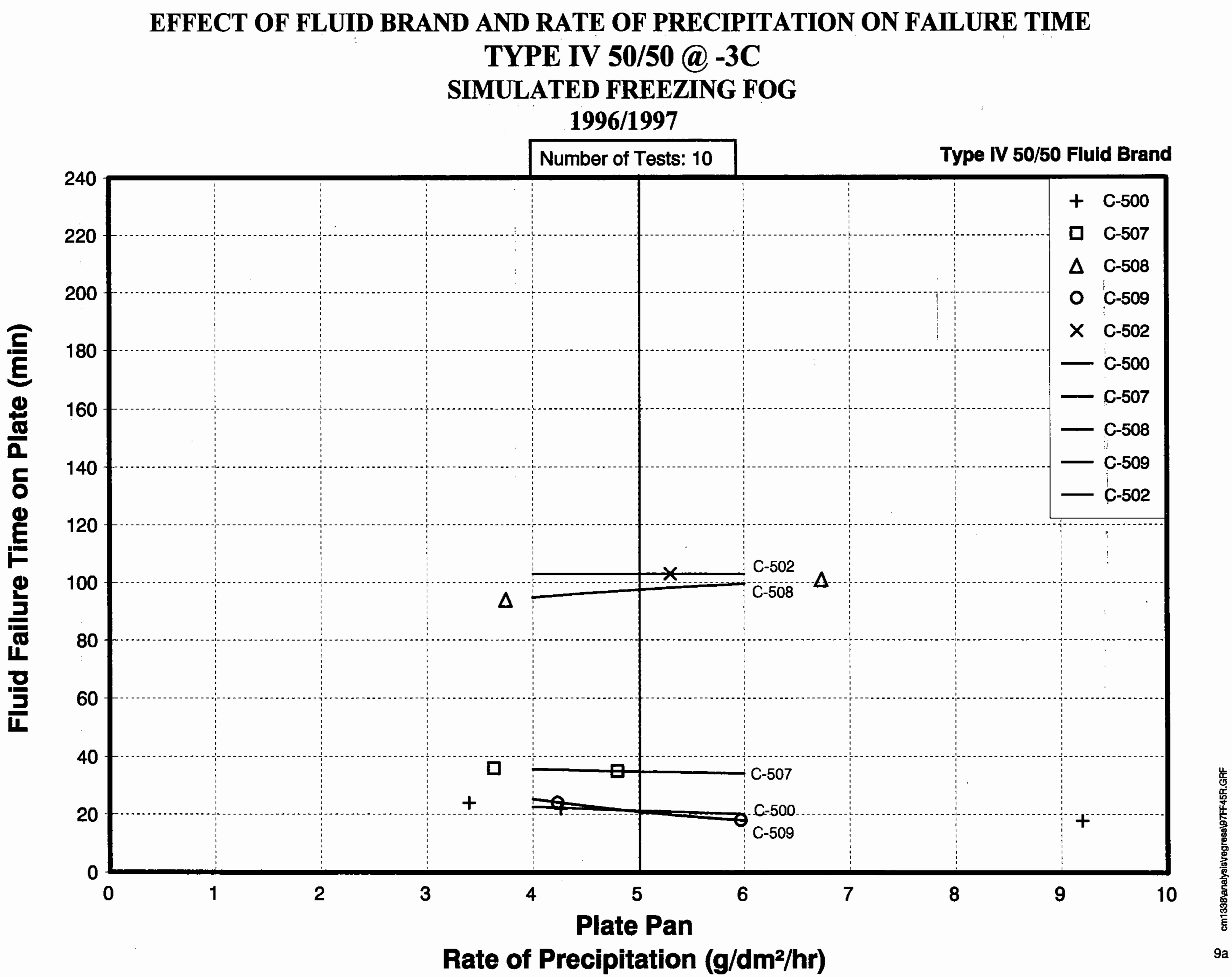
F-42

cm1338\analysis\regress\97FF41T.GRF

EFFECT OF FLUID BRAND AND TEMPERATURE ON FAILURE TIME
TYPE IV 75/25
SIMULATED FREEZING FOG
1996/1997



cm1338\analysis\regress\97FF47T.GRF


EFFECT OF FLUID BRAND AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 50/50 @ -3C
SIMULATED FREEZING FOG
1996/1997
Number of Tests: 10
Type IV 50/50 Fluid Brand
C-500
C-507
C-508
C-509
C-502
C-500
C-507
C-508
C-509
C-502
Fluid Failure Time on Plate (min)
240
220
200
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
C-502
C-508
C-507
C-500
C-509
Plate Pan
Rate of Precipitation (g/dm²/hr)
cm1338\analysis\vegress\97\TF45R.GRF

9a

APPENDIX G

STATISTICAL MULTI-VARIABLE REGRESSION ANALYSIS

TABLE G.1

MULTI-VARIABLE REGRESSION ANALYSIS RESULTS
TYPE IV FLUIDS IN NATURAL SNOW CONDITIONS

Dorval Tests 1996/97

EQUATION #	FLUID BRAND	DILUTION	NO. OF TESTS	EQUATION	R^2
1	HOECHST	Neat	96	$t = 10^{2.7} R^{-0.68} (2-T)^{-0.39}$	84%
2	HOECHST	75%	63	$t = 10^{2.7} R^{-0.76} (2-T)^{-0.40}$	86%
3	HOECHST	50%	28	$t = 10^{2.0} R^{-0.59}$	68%
4	KILFROST	Neat	28	$t = 10^{2.8} R^{-0.60} (2-T)^{-0.21}$	84%
5	KILFROST	75%	20	$t = 10^{2.4} R^{-0.60}$	75%
6	KILFROST	50%	22	$t = 10^{2.3} R^{-0.98} (2-T)^{-0.27}$	90%
7	OCTAGON	Neat	72	$t = 10^{3.1} R^{-0.73} (2-T)^{-0.51}$	79%
8	OCTAGON	75%	46	$t = 10^{3.4} R^{-0.92} (2-T)^{-0.65}$	82%
9	OCTAGON	50%	17	$t = 10^{2.6} R^{-0.64}$	81%
10	SPCA AD-404	Neat	17	$t = 10^{2.9} R^{-0.78} (2-T)^{-0.28}$	88%
11	SPCA AD-404	75%	12	$t = 10^{2.9} R^{-0.81} (2-T)^{-0.61}$	94%
12	SPCA AD-404	50%	6	$t = 10^{2.5} R^{-0.84} (2-T)^{-0.41}$	100%
13	ULTRA+	Neat	116	$t = 10^{2.9} R^{-0.79} (2-T)^{-0.30}$	88%
14	ULTRA+	75%	63	$t = 10^{2.4} R^{-0.70} (2-T)^{-0.17}$	91%
15	ULTRA+	50%	28	$t = 10^{2.3} R^{-0.98} (2-T)^{-0.16}$	84%

t = failure time (min.)
T = Degrees Celcius
R = Rate of precipitatioin ($g/dm^2/hr$)

General Equation $t = 10^{I} R^{A} (2-T)^{B}$

MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
HOECHST TYPE IV NEAT (#1)

G-2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.917895056
R Square	0.842531335
Adjusted R Square	0.839144912
Standard Error	0.083573586
Observations	96

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.475465156	1.73773258	248.7968445	4.67227E-38
Residual	93	0.649562618	0.00698454		
Total	95	4.125027775			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.740057532	0.052722674	51.9711408	1.61681E-70	2.635360855	2.84475421	2.635360855	2.84475421
log_rate	-0.681480811	0.031547199	-21.601944	5.14808E-38	-0.744127233	-0.61883439	-0.744127233	-0.618834389
log_tem_C	-0.390227426	0.033056598	-11.804827	3.41213E-20	-0.455871211	-0.32458364	-0.455871211	-0.32458364

MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
HOECHST TYPE IV 75/25 (#2)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.928202841
R Square	0.861560515
Adjusted R Square	0.856945865
Standard Error	0.106575277
Observations	63

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.241212178	2.12060609	186.7011814	1.72902E-26
Residual	60	0.681497377	0.01135829		
Total	62	4.922709555			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.725016419	0.061847029	44.0605873	2.10082E-47	2.601303982	2.84872886	2.601303982	2.848728856
log_rate	-0.762638172	0.043416382	-17.565678	2.49934E-25	-0.849483838	-0.67579251	-0.849483838	-0.675792506
log_tem_C	-0.395077912	0.046840316	-8.4345697	8.92122E-12	-0.488772465	-0.30138336	-0.488772465	-0.30138336

MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
HOECHST TYPE IV 50/50 (#3)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.823894899
R Square	0.678802805
Adjusted R Square	0.666449067
Standard Error	0.102196178
Observations	28

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.573871347	0.57387135	54.94715767	7.16748E-08
Residual	26	0.27154553	0.01044406		
Total	27	0.845416877			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	1.976691911	0.076848592	25.7219013	5.0956E-20	1.818727263	2.13465656	1.818727263	2.134656559
log_rate	-0.592402389	0.079917922	-7.412635	7.16748E-08	-0.756676139	-0.42812864	-0.756676139	-0.428128639

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
KILFROST TYPE IV NEAT (#4)

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 95.000%*	*Upper 95.000%*
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

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
KILFROST TYPE IV 75/25 (#5)

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 95.000%*	*Upper 95.000%*
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

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
KILFROST TYPE IV 50/50 (#6)

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 95.000%*	*Upper 95.000%*
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

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
OCTAGON TYPE IV NEAT (#7)

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 95.000%*	*Upper 95.000%*
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

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
OCTAGON TYPE IV 75/25 (#8)

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 95.000%*	*Upper 95.000%*
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

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
OCTAGON TYPE IV 50/50 (#9)

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 95.000%*	*Upper 95.000%*
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

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
SPCA AD-404 TYPE IV NEAT (#10)

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SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.939499536
R Square	0.882659379
Adjusted R Square	0.865896433
Standard Error	0.074819858
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.589530873	0.29476544	52.65538547	3.06294E-07
Residual	14	0.078372156	0.00559801		
Total	16	0.667903029			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.86632547	0.11820695	24.2483666	7.7875E-13	2.612796551	3.11985439	2.612796551	3.119854389
log_rate	-0.777268326	0.075742999	-10.261916	6.77521E-08	-0.939721046	-0.61481561	-0.939721046	-0.614815606
log_tem_C	-0.284564571	0.088425151	-3.2181406	0.006193015	-0.474217826	-0.09491132	-0.474217826	-0.094911316

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
SPCA AD-404 TYPE IV 75/25 (#11)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9670295
R Square	0.935146053
Adjusted R Square	0.920734065
Standard Error	0.093198496
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.127206144	0.56360307	64.88667897	4.5052E-06
Residual	9	0.078173636	0.00868596		
Total	11	1.205379781			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.891539909	0.105474624	27.4145554	5.54484E-10	2.652939552	3.13014027	2.652939552	3.130140266
log_rate	-0.805024535	0.075675968	-10.637783	2.1339E-06	-0.976215599	-0.63383347	-0.976215599	-0.633833472
log_tem_C	-0.605777673	0.086649847	-6.9910991	6.38722E-05	-0.801793395	-0.40976195	-0.801793395	-0.409761951

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
SPCA AD-404 TYPE IV 50/50 (#12)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	1
Standard Error	2.82035E-15
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.532297208	0.7661486	9.63182E+28	6.14574E-44
Residual	3	2.3863E-29	7.9543E-30		
Total	5	1.532297208			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.522755427	2.61902E-15	9.6324E+14	2.46752E-45	2.522755427	2.52275543	2.522755427	2.522755427
log_rate	-0.842328164	3.31309E-15	-2.542E+14	1.34192E-43	-0.842328164	-0.84232816	-0.842328164	-0.842328164
log_tem_C	-0.407791184	5.25868E-15	-7.755E+13	4.72921E-42	-0.407791184	-0.40779118	-0.407791184	-0.407791184

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
ULTRA+ TYPE IV NEAT (#13)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.937812859
R Square	0.879492959
Adjusted R Square	0.877360091
Standard Error	0.080076305
Observations	116

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	5.288182553	2.64409128	412.3522734	1.19454E-52
Residual	113	0.724580252	0.00641221		
Total	115	6.012762806			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.880352748	0.044986979	64.026365	1.23992E-90	2.791225463	2.96948003	2.791225463	2.969480033
log_rate	-0.793862433	0.027975912	-28.376641	3.12248E-53	-0.84928774	-0.73843713	-0.84928774	-0.738437126
log_tem_C	-0.303930527	0.030597391	-9.9332171	4.31792E-17	-0.364549453	-0.2433116	-0.364549453	-0.243311601

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
ULTRA+ TYPE IV 75/25 (#14)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.952316789
R Square	0.906907267
Adjusted R Square	0.903804176
Standard Error	0.08470479
Observations	63

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.193863498	2.09693175	292.2593107	1.16808E-31
Residual	60	0.430494086	0.0071749		
Total	62	4.624357584			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.377804238	0.04659978	51.0260828	3.94466E-51	2.28459083	2.47101765	2.28459083	2.471017646
log_rate	-0.70182347	0.02991018	-23.464368	6.38395E-32	-0.761652719	-0.64199422	-0.761652719	-0.641994221
log_tem_C	-0.173667941	0.04430696	-3.9196538	0.000230134	-0.262295028	-0.08504086	-0.262295028	-0.085040855

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MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
ULTRA+ TYPE IV 50/50 (#15)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.917445019
R Square	0.841705362
Adjusted R Square	0.829041791
Standard Error	0.081524805
Observations	28

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.88351401	0.44175701	66.46666732	9.84754E-11
Residual	25	0.166157347	0.00664629		
Total	27	1.049671357			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.311619312	0.109557811	21.0995391	1.9073E-17	2.085980935	2.53725769	2.085980935	2.537257689
log_rate	-0.979888014	0.091860268	-10.667158	8.57287E-11	-1.169077644	-0.79069838	-1.169077644	-0.790698383
log_tem_C	-0.162445711	0.067763169	-2.3972567	0.024313002	-0.302006473	-0.02288495	-0.302006473	-0.02288495

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TABLE G.2

MULTI-VARIABLE REGRESSION ANALYSIS RESULTS
TYPE IV FLUIDS IN SIMULATED FREEZING FOG

NRC Cold Chamber Tests 1996/97

EQUATION #	FLUID BRAND	DILUTION	NO. OF TESTS	EQUATION	R^2
1	HOECHST	Neat	8	$t = 10^{2.5} (-T)^{-0.82}$	93%
2	HOECHST	75%	3	$t = 10^{1.9} (-T)^{-0.12}$	57%
3	HOECHST	50%	2	$t = 10^{1.6} \quad R^{-0.10}$	100%
4	KILFROST	Neat	8	$t = 10^{2.6} (-T)^{-0.66}$	92%
5	KILFROST	75%	4	$t = 10^{2.9} (-T)^{-0.04} R^{-1.47}$	98%
6	KILFROST	50%	2	$t = 10^{1.9} \quad R^{-0.84}$	100%
7	OCTAGON	Neat	9	$t = 10^{2.8} (-T)^{-1.02}$	99%
8	OCTAGON	75%	4	$t = 10^{2.9} (-T)^{-1.15}$	100%
9	OCTAGON	50%	2	$t = 10^{1.9} \quad R^{0.12}$	100%
10	SPCA AD-404	Neat	2	$t = 10^{2.3} (-T)^{-0.06}$	100%
11	SPCA AD-404	75%	2	$t = 10^{2.1} (-T)^{0.02}$	100%
12	SPCA AD-404	50%		Not enough data for equation	
13	ULTRA+	Neat	6	$t = 10^{2.6} (-T)^{-0.64}$	96%
14	ULTRA+	75%	4	$t = 10^{2.5} (-T)^{-0.16} R^{-0.67}$	62%
15	ULTRA+	50%	3	$t = 10^{1.5} \quad R^{-0.28}$	99%

t = failure time (min.)
T = Degrees Celcius
R = Rate of precipitatioin ($g/dm^2/hr$)

General Equation $t = 10^{I} (-T)^{B} R^{A}$

MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
HOECHST TYPE IV NEAT (#1)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.962771412
R Square	0.926928792
Adjusted R Square	0.914750257
Standard Error	0.108042904
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.888472173	0.88847217	76.11168454	0.000125419
Residual	6	0.070039614	0.01167327		
Total	7	0.958511788			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.533045883	0.112636013	22.4887743	5.05897E-07	2.257435286	2.80865648	2.257435286	2.808656481
log_tem_c	-0.823103353	0.094347132	-8.7242011	0.000125419	-1.053962638	-0.59224407	-1.053962638	-0.592244068

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
HOECHST TYPE IV 75/25 (#2)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.753902111
R Square	0.568368393
Adjusted R Square	0.136736786
Standard Error	0.062271699
Observations	3

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.005106203	0.0051062	1.316790484	0.456338543
Residual	1	0.003877765	0.00387776		
Total	2	0.008983968			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.876550647	0.103626976	18.108708	0.03511978	0.559850719	3.19325057	0.559850719	3.193250575
log_tem_c	-0.123681918	0.107782405	-1.1475149	0.456338543	-1.493181356	1.24581752	-1.493181356	1.245817521

G-19

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
HOECHST TYPE IV 50/50 (#3)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	65535
Standard Error	0
Observations	2

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	7.4841E-05	7.4841E-05	0	#NUM!
Residual	0	2.46519E-30	65535		
Total	1	7.4841E-05			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.612985626	0	65535	#NUM!	1.612985626	1.61298563	1.612985626	1.612985626
log_rate	-0.101164724	0	65535	#NUM!	-0.101164724	-0.10116472	-0.101164724	-0.101164724

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
KILFROST TYPE IV NEAT (#4)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.96038867
R Square	0.922346398
Adjusted R Square	0.909404131
Standard Error	0.088944954
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.563801627	0.56380163	71.26621585	0.000150802
Residual	6	0.047467229	0.0079112		
Total	7	0.611268856			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.551386761	0.093272076	27.3542401	1.57779E-07	2.323158046	2.77961548	2.323158046	2.779615476
log_tem_c	-0.659679527	0.078143194	-8.441932	0.000150802	-0.850889174	-0.46846988	-0.850889174	-0.468469881

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
KILFROST TYPE IV 75/25 (#5)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.992134394
R Square	0.984330657
Adjusted R Square	0.95299197
Standard Error	0.065715988
Observations	4

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.271289071	0.13564454	31.40944185	0.125177248
Residual	1	0.004318591	0.00431859		
Total	3	0.275607662			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.921333638	0.155472458	18.7900396	0.033848771	0.94587722	4.89679006	0.94587722	4.896790055
log_rate	-1.46869537	0.361548227	-4.0622392	0.153661164	-6.062581478	3.12519074	-6.062581478	3.125190737
log_tem_c	-0.03646715	0.193621861	-0.1883421	0.881486012	-2.496655614	2.42372131	-2.496655614	2.423721314

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
KILFROST TYPE IV 50/50 (#6)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	65535
Standard Error	0
Observations	2

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.007804844	0.00780484	0	#NUM!
Residual	0	3.9443E-31	65535		
Total	1	0.007804844			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.905520051	0	65535	#NUM!	1.905520051	1.90552005	1.905520051	1.905520051
log_rate	-0.838237605	0	65535	#NUM!	-0.838237605	-0.8382376	-0.838237605	-0.838237605

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
OCTAGON TYPE IV NEAT (#7)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.996443197
R Square	0.992899045
Adjusted R Square	0.991884623
Standard Error	0.043458486
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.848568569	1.84856857	978.782912	8.80529E-09
Residual	7	0.01322048	0.00188864		
Total	8	1.861789049			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.771177148	0.036910468	75.0783526	1.95657E-11	2.683897822	2.85845647	2.683897822	2.858456474
log_tem_c	-1.018403764	0.032551935	-31.285506	8.80529E-09	-1.095376803	-0.94143072	-1.095376803	-0.941430725

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
OCTAGON TYPE IV 75/25 (#8)

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SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.998559315
R Square	0.997120705
Adjusted R Square	0.995681058
Standard Error	0.033605128
Observations	4

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.782172782	0.78217278	692.6145113	0.001440685
Residual	2	0.002258609	0.0011293		
Total	3	0.784431392			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.880643346	0.037734185	76.3404159	0.000171545	2.71828614	3.04300055	2.71828614	3.043000551
log_tem_c	-1.150389903	0.043711858	-26.31757	0.001440685	-1.338466979	-0.96231283	-1.338466979	-0.962312826

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
OCTAGON TYPE IV 50/50 (#9)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	65535
Standard Error	0
Observations	2

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000486518	0.00048652	0	#NUM!
Residual	0	4.19082E-30	65535		
Total	1	0.000486518			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.902686716	0	65535	#NUM!	1.902686716	1.90268672	1.902686716	1.902686716
log_rate	0.122713067	0	65535	#NUM!	0.122713067	0.12271307	0.122713067	0.122713067

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
SPCA AD-404 TYPE IV NEAT (#10)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	65535
Standard Error	0
Observations	2

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000814706	0.00081471	0	#NUM!
Residual	0	1.97215E-31	65535		
Total	1	0.000814706			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.25352239	0	65535	#NUM!	2.25352239	2.25352239	2.25352239	2.25352239
log_tem_c	-0.05942939	0	65535	#NUM!	-0.05942939	-0.05942939	-0.05942939	-0.05942939

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
SPCA AD-404 TYPE IV 75 (#11)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	65535
Standard Error	0
Observations	2

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	9.06878E-05	9.0688E-05	0	#NUM!
Residual	0	7.88861E-31	65535		
Total	1	9.06878E-05			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.094726472	0	65535	#NUM!	2.094726472	2.09472647	2.094726472	2.094726472
log_tem_c	0.020299867	0	65535	#NUM!	0.020299867	0.02029987	0.020299867	0.020299867

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
ULTRA+ TYPE IV NEAT (#13)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.980739662
R Square	0.961850285
Adjusted R Square	0.952312856
Standard Error	0.060966402
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.374849815	0.37484981	100.8500615	0.000552869
Residual	4	0.014867609	0.0037169		
Total	5	0.389717423			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.606038599	0.081482097	31.9829596	5.69707E-06	2.379807562	2.83226964	2.379807562	2.832269635
log_tem_c	-0.642079228	0.063936747	-10.042413	0.000552869	-0.819596464	-0.46456199	-0.819596464	-0.464561992

MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
ULTRA+ TYPE IV 75/25 (#14)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.788410468
R Square	0.621591066
Adjusted R Square	-0.135226803
Standard Error	0.07345508
Observations	4

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.008863129	0.00443156	0.821321868	0.615149522
Residual	1	0.005395649	0.00539565		
Total	3	0.014258778			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.489493611	0.512608995	4.85651566	0.129278838	-4.023793318	9.00278054	-4.023793318	9.002780541
log_rate	-0.670230479	0.524708015	-1.2773399	0.422850825	-7.337249382	5.99678842	-7.337249382	5.996788424
log_tem_c	-0.163472026	0.158296215	-1.032697	0.489760521	-2.174807529	1.84786348	-2.174807529	1.847863478

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
ULTRA+ TYPE IV 50/50 (#15)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.996805651
R Square	0.993621505
Adjusted R Square	0.98724301
Standard Error	0.007236949
Observations	3

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.008158565	0.00815857	155.7767958	0.050898151
Residual	1	5.23734E-05	5.2373E-05		
Total	2	0.008210939			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.525689772	0.016538424	92.2512206	0.006900666	1.315550075	1.73582947	1.315550075	1.735829469
log_rate	-0.281911849	0.022587177	-12.481057	0.050898151	-0.56890791	0.00508421	-0.56890791	0.005084211

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TABLE G.3

MULTI-VARIABLE REGRESSION ANALYSIS RESULTS
TYPE IV FLUIDS ON COLD-SOAKED BOXES

NRC Cold Chamber Tests 1996/97

EQUATION #	FLUID BRAND	DILUTION	NO. OF TESTS	EQUATION	R^2
1	HOECHST	Neat	20	$t = 10^{3.1} R^{-0.73} (-T)^{-0.74}$	93%
2	HOECHST	75%	18	$t = 10^{2.2} R^{-0.70}$	93%
3	KILFROST	Neat	2	$t = 10^{3.4} R^{-1.26}$	100%
4	KILFROST	75%	2	$t = 10^{1.8} R^{-0.37}$	100%
5	OCTAGON	Neat	9	$t = 10^{2.7} R^{-0.52} (-T)^{-0.78}$	99%
6	OCTAGON	75%	9	$t = 10^{2.1} R^{-0.64}$	91%
7	SPCA AD-404	Neat	6	$t = 10^{4.3} R^{-1.13} (-T)^{-1.39}$	99%
8	SPCA AD-404	75%	4	$t = 10^{3.0} R^{-1.23}$	98%
9	ULTRA+	Neat	20	$t = 10^{2.6} R^{-0.79}$	95%
10	ULTRA+	75%	17	$t = 10^{2.1} R^{-0.65}$	97%

t = failure time (min.)
T = Degrees Celcius
R = Rate of precipitatioin (g/dm²/hr)

General Equation $t = 10^{I} R^{A} (-T)^{B}$

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
HOECHST TYPE IV NEAT (#1)

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SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.963471225
R Square	0.928276802
Adjusted R Square	0.919838779
Standard Error	0.099941696
Observations	20

ANOVA

	df	SS	MS	F	Significance F
Regression	2	2.197658503	1.098829252	110.0111689	1.87546E-10
Residual	17	0.169801825	0.009988343		
Total	19	2.367460328			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.000%	Upper 95.000%
Intercept	3.078662755	0.201794908	15.25639465	2.36533E-11	2.65291212	3.50441339	2.65291212	3.50441339
log_rate	-0.732535652	0.067480284	-10.8555508	4.58803E-09	-0.874906806	-0.590164499	-0.874906806	-0.590164499
temp_c	-0.735302961	0.273571325	-2.68779252	0.015566501	-1.312488809	-0.158117112	-1.312488809	-0.158117112

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
HOECHST TYPE IV 75/25 (#2)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.963014301
R Square	0.927396543
Adjusted R Square	0.917716082
Standard Error	0.079778612
Observations	18

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.219473534	0.609736767	95.80086641	2.86536E-09
Residual	15	0.095469403	0.006364627		
Total	17	1.314942937			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.186271946	0.077943172	28.04956348	2.24158E-14	2.020139905	2.352403986	2.020139905	2.352403986
log_rate	-0.704866091	0.051685774	-13.63752596	7.38702E-10	-0.815031779	-0.594700402	-0.815031779	-0.594700402
box_2.5	0.108814751	0.037868245	2.873509223	0.011601084	0.028100448	0.189529053	0.028100448	0.189529053

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
KILFROST TYPE IV NEAT (#3)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	65535
Standard Error	0
Observations	2

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.101784187	0.101784187	0	#NUM!
Residual	0	9.95937E-30	65535		
Total	1	0.101784187			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	3.433568153	0	65535	#NUM!	3.433568153	3.433568153	3.433568153	3.433568153
log_rate	-1.260663204	0	65535	#NUM!	-1.260663204	-1.260663204	-1.260663204	-1.260663204

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
KILFROST TYPE IV 75/25 (#4)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Square	65535
Standard Error	0
Observations	2

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.017500706	0.017500706	0	#NUM!
Residual	0	5.57133E-30	65535		
Total	1	0.017500706			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	1.786416051	0	65535	#NUM!	1.786416051	1.786416051	1.786416051	1.786416051
log_rate	-0.367675961	0	65535	#NUM!	-0.367675961	-0.367675961	-0.367675961	-0.367675961

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MULTI-VARIABLE REGRESSION OUTPUT

COLD-SOAKED BOXES

OCTAGON TYPE IV NEAT (#5)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.996671757
R Square	0.993354591
Adjusted R Square	0.989367345
Standard Error	0.036816052
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1.013041009	0.337680336	249.1330424	7.31646E-06
Residual	5	0.006777109	0.001355422		
Total	8	1.019818118			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.723650025	0.226792519	12.00943504	7.06249E-05	2.140662247	3.306637802	2.140662247	3.306637802
log_rate	-0.521018996	0.037306004	-13.96608951	3.38349E-05	-0.616916976	-0.425121015	-0.616916976	-0.425121015
log_k	-0.776251322	0.240827139	-3.22327179	0.023380279	-1.395316178	-0.157186466	-1.395316178	-0.157186466
box_2.5	0.278102163	0.063614289	4.371693342	0.00721059	0.114576695	0.441627631	0.114576695	0.441627631

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
OCTAGON TYPE IV 75/25 (#6)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.953261116
R Square	0.908706756
Adjusted R Square	0.878275675
Standard Error	0.098971582
Observations	9

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.58500206	0.29250103	29.86113924	0.00076088
Residual	6	0.058772245	0.009795374		
Total	8	0.643774304			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.145871705	0.135116299	15.88166436	3.95474E-06	1.815253791	2.47648962	1.815253791	2.47648962
log_rate	-0.641696197	0.088145576	-7.279959207	0.000342056	-0.857380809	-0.426011585	-0.857380809	-0.426011585
box_2.5	0.258452349	0.079683003	3.243506625	0.017609207	0.063474922	0.453429777	0.063474922	0.453429777

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
SPCA AD-404 TYPE IV NEAT (#7)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.995761749
R Square	0.991541461
Adjusted R Square	0.985902436
Standard Error	0.070260335
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.73603003	0.868015015	175.835598	0.000777934
Residual	3	0.014809544	0.004936515		
Total	5	1.750839574			

G-39

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	4.294916448	0.214845554	19.99071599	0.000273582	3.611181368	4.978651529	3.611181368	4.978651529
log_rate	-1.1254624	0.070811412	-15.89379972	0.000541543	-1.350816127	-0.900108672	-1.350816127	-0.900108672
log_k	-1.390427758	0.255194403	-5.448504115	0.012143079	-2.202571006	-0.578284509	-2.202571006	-0.578284509

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
HOECHST TYPE IV 75/25 (#8)

G-40

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.991623492
R Square	0.98331715
Adjusted R Square	0.974975724
Standard Error	0.09663709
Observations	4

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.100882695	1.100882695	117.8835906	0.008376508
Residual	2	0.018677454	0.009338727		
Total	3	1.11956015			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	3.006684649	0.16479376	18.24513653	0.002990571	2.297633834	3.715735464	2.297633834	3.715735464
log_rate	-1.233655784	0.11362328	-10.85742099	0.008376508	-1.722537639	-0.744773928	-1.722537639	-0.744773928

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
ULTAR+ TYPE IV NEAT (#9)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.975125037
R Square	0.950868837
Adjusted R Square	0.948139328
Standard Error	0.074359066
Observations	20

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.926211295	1.926211295	348.3662531	3.16455E-13
Residual	18	0.099526871	0.005529271		
Total	19	2.025738166			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.594423216	0.062646915	41.41342349	2.62071E-19	2.46280683	2.726039602	2.46280683	2.726039602
log_rate	-0.789405253	0.042294313	-18.66457214	3.16455E-13	-0.878262376	-0.70054813	-0.878262376	-0.70054813

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
ULTRA+ TYPE IV 75/25 (#10)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.982576746
R Square	0.965457061
Adjusted R Square	0.963154199
Standard Error	0.046203551
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.894984768	0.894984768	419.2421508	2.24429E-12
Residual	15	0.032021521	0.002134768		
Total	16	0.92700629			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.118231788	0.048905061	43.31314032	3.57797E-17	2.013993053	2.222470523	2.013993053	2.222470523
log_rate	-0.651983604	0.031842283	-20.47540356	2.24429E-12	-0.719853867	-0.584113342	-0.719853867	-0.584113342

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TABLE G.4

MULTI-VARIABLE REGRESSION ANALYSIS RESULTS
TYPE IV FLUIDS IN SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN

NRC Cold Chamber Tests 1996/97

PRECIPITATION	EQUATION #	FLUID BRAND	DILUTION	NO. OF TESTS	EQUATION	R^2
LZR	1	HOECHST	Neat	12	$t = 10^{2.5} R^{-0.59} (-T)^{-0.13}$	89%
FZD	2	HOECHST	Neat	6	$t = 10^{2.1} R^{-0.44}$	93%
FZD & LZR	3	HOECHST	75%	11	$t = 10^{2.2} R^{-0.57}$	96%
LZR	4	HOECHST	50%	2	$t = 10^{2.1} R^{-0.71}$	100%
FZD	5	HOECHST	50%	3	$t = 10^{2.1} R^{-0.72}$	100%
FZD & LZR	6	KILFROST	Neat	10	$t = 10^{2.7} R^{-0.45} (-T)^{-0.57}$	94%
FZD & LZR	7	KILFROST	75%	6	$t = 10^{2.3} R^{-0.53}$	97%
FZD & LZR	8	KILFROST	50%	7	$t = 10^{1.9} R^{-0.71}$	92%
LZR	9	OCTAGON	Neat	6	$t = 10^{3.0} R^{-0.93} (-T)^{-0.28}$	93%
FZD	10	OCTAGON	Neat	7	$t = 10^{3.1} R^{-0.96} (-T)^{-0.56}$	97%
FZD & LZR	11	OCTAGON	75%	11	$t = 10^{2.8} R^{-0.62} (-T)^{-0.58}$	94%
FZD & LZR	12	OCTAGON	50%	5	$t = 10^{2.5} R^{-0.68}$	91%
FZD & LZR	13	SPCA AD-404	Neat	5	$t = 10^{2.6} R^{-0.58}$	95%
FZD & LZR	14	SPCA AD-404	75%	6	$t = 10^{2.6} R^{-0.80}$	97%
FZD & LZR	15	SPCA AD-404	50%	3	$t = 10^{2.6} R^{-0.95}$	100%
FZD & LZR	16	ULTRA+	Neat	22	$t = 10^{2.7} R^{-0.73} (-T)^{-0.20}$	86%
FZD & LZR	17	ULTRA+	75%	13	$t = 10^{2.3} R^{-0.79}$	93%
FZD & LZR	18	ULTRA+	50%	7	$t = 10^{1.6} R^{-0.45}$	87%

t = failure time (min.)
T = Degrees Celcius
R = Rate of precipitatioin (g/dm²/hr)

General Equation $t = 10^{I} R^{A} (-T)^{B}$

MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED LIGHT FREEZING RAIN
HOECHST TYPE IV NEAT (#1)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.942077004
R Square	0.887509081
Adjusted R Square	0.862511099
Standard Error	0.021987983
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.034329591	0.0171648	35.5032292	5.37067E-05
Residual	9	0.004351243	0.00048347		
Total	11	0.038680834			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.463507057	0.115125748	21.3984022	4.99864E-09	2.203074324	2.72393979	2.203074324	2.72393979
log_rate	-0.586482803	0.088030121	-6.6622969	9.2429E-05	-0.785620922	-0.38734468	-0.785620922	-0.387344684
log_temp	-0.132219388	0.03288989	-4.0200617	0.003017781	-0.206621546	-0.05781723	-0.206621546	-0.05781723

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE
HOECHST TYPE IV NEAT (#2)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.965604258
R Square	0.932391582
Adjusted R Square	0.915489478
Standard Error	0.019401227
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.020764237	0.02076424	55.1642305	0.001754254
Residual	4	0.001505631	0.00037641		
Total	5	0.022269868			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.088195187	0.057353333	36.4093083	3.3972E-06	1.928956476	2.2474339	1.928956476	2.247433898
log_rate	-0.443375783	0.059695719	-7.4272627	0.001754254	-0.609118013	-0.27763355	-0.609118013	-0.277633554

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
HOECHST TYPE IV 75/25 (#3)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.980290843
R Square	0.960970137
Adjusted R Square	0.956633485
Standard Error	0.023795455
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.125471009	0.12547101	221.5926609	1.20537E-07
Residual	9	0.005096013	0.00056622		
Total	10	0.130567022			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.206844992	0.045229349	48.7923226	3.19892E-12	2.104529018	2.30916097	2.104529018	2.309160965
log_rate	-0.569325335	0.038245718	-14.885989	1.20537E-07	-0.655843227	-0.48280744	-0.655843227	-0.482807443

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED LIGHT FREEZING RAIN
HOECHST TYPE IV 50/50 (#4)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	1
R Square	1
Adjusted R Squar	65535
Standard Error	0
Observations	2

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	1	0.003555006	0.003555	0	#NUM!
Residual	0	8.92399E-30	65535		
Total	1	0.003555006			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.000*	*Upper 95.000%*
Intercept	2.12237503	0	65535	#NUM!	2.12237503	2.122375	2.12237503	2.12237503
log_rate	-0.7091845	0	65535	#NUM!	-0.70918447	-0.7091845	-0.709184466	-0.709184466

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE
HOECHST TYPE IV 50/50 (#5)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999524232
R Square	0.99904869
Adjusted R Square	0.99809738
Standard Error	0.007661419
Observations	3

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.061642891	0.06164289	1050.182109	0.019638577
Residual	1	5.86973E-05	5.8697E-05		
Total	2	0.061701589			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.065139403	0.021639201	95.435104	0.006670465	1.790188462	2.34009034	1.790188462	2.340090343
log_rate	-0.718732275	0.022178636	-32.406513	0.019638577	-1.000537361	-0.43692719	-1.000537361	-0.436927188

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
KILFROST TYPE IV NEAT (#6)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.970081008
R Square	0.941057162
Adjusted R Square	0.924216351
Standard Error	0.054842548
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.336138491	0.16806925	55.87956322	4.97174E-05
Residual	7	0.021053935	0.00300771		
Total	9	0.357192426			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.697857158	0.095848385	28.1471322	1.8359E-08	2.471211905	2.92450241	2.471211905	2.924502411
log_rate	-0.449178193	0.073513534	-6.1101428	0.0004862	-0.623009954	-0.27534643	-0.623009954	-0.275346432
log_temp	-0.571448428	0.06420362	-8.900564	4.5851E-05	-0.723265756	-0.4196311	-0.723265756	-0.419631099

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MULTI-VARIABLE REGRESSION OUTPUT

SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
KILFROST TYPE IV 75/25 (#7)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.984767464
R Square	0.969766959
Adjusted R Square	0.962208698
Standard Error	0.021379898
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.058648483	0.05864848	128.3055782	0.000346278
Residual	4	0.0018284	0.0004571		
Total	5	0.060476884			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.28930705	0.051388033	44.5494196	1.51819E-06	2.146630701	2.4319834	2.146630701	2.431983398
log_rate	-0.527235167	0.046545918	-11.327205	0.000346278	-0.656467621	-0.39800271	-0.656467621	-0.398002713

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MULTI-VARIABLE REGRESSION OUTPUT

SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
KILFROST TYPE IV 50/50 (#8)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.957161728
R Square	0.916158573
Adjusted R Square	0.899390288
Standard Error	0.051718964
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.146144215	0.14614421	54.6363897	0.000712842
Residual	5	0.013374256	0.00267485		
Total	6	0.159518471			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	1.907069673	0.102833343	18.5452462	8.38891E-06	1.642728581	2.17141077	1.642728581	2.171410766
log_rate	-0.708650735	0.09587188	-7.3916432	0.000712842	-0.955096846	-0.46220462	-0.955096846	-0.462204624

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED LIGHT FREEZING RAIN
OCTAGON TYPE IV NEAT (#9)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.962543231
R Square	0.926489471
Adjusted R Square	0.877482451
Standard Error	0.043454846
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.071398422	0.03569921	18.90524012	0.019930781
Residual	3	0.005664971	0.00188832		
Total	5	0.077063393			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	3.029655411	0.332036973	9.12445197	0.002782166	1.972964583	4.08634624	1.972964583	4.086346239
log_rate	-0.929039982	0.260786744	-3.5624509	0.037754224	-1.75898057	-0.09909939	-1.75898057	-0.099099395
log_temp	-0.279253388	0.066639467	-4.1905105	0.024780021	-0.491330113	-0.06717666	-0.491330113	-0.067176663

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE
OCTAGON TYPE IV NEAT (#10)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.986077033
R Square	0.972347915
Adjusted R Square	0.958521873
Standard Error	0.050694737
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.361476064	0.18073803	70.32727743	0.000764638
Residual	4	0.010279825	0.00256996		
Total	6	0.371755889			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	3.069801788	0.126083398	24.347391	1.68839E-05	2.71973743	3.41986615	2.71973743	3.419866146
log_rate	-0.959840813	0.124181907	-7.7293129	0.00150874	-1.304625776	-0.61505585	-1.304625776	-0.61505585
log_temp	-0.558498251	0.071005784	-7.8655318	0.001411989	-0.75564232	-0.36135418	-0.75564232	-0.361354182

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
OCTAGON TYPE IV 75/25 (#11)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.969334979
R Square	0.939610301
Adjusted R Square	0.924512876
Standard Error	0.064571207
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.518982482	0.25949124	62.2364615	1.33E-05
Residual	8	0.033355526	0.00416944		
Total	10	0.552338009			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.832073754	0.11058633	25.6096189	5.79476E-09	2.577061056	3.08708645	2.577061056	3.087086453
log_rate	-0.61942492	0.09014072	-6.8717547	0.000128134	-0.827289927	-0.41155991	-0.827289927	-0.411559912
log_temp	-0.580893674	0.071149889	-8.1643651	3.77103E-05	-0.74496572	-0.41682163	-0.74496572	-0.416821629

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MULTI-VARIABLE REGRESSION OUTPUT

SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN

OCTAGON TYPE IV 50/50 (#12)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.954715265
R Square	0.911481237
Adjusted R Square	0.881974983
Standard Error	0.062600775
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.121057883	0.12105788	30.89111993	0.011489189
Residual	3	0.011756571	0.00391886		
Total	4	0.132814454			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.47733478	0.134475739	18.4221689	0.000349028	2.049372559	2.905297	2.049372559	2.905297
log_rate	-0.682174376	0.122737868	-5.557978	0.011489189	-1.072781417	-0.29156733	-1.072781417	-0.291567335

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
SPCA AD-404 TYPE IV NEAT (#13)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.972841354
R Square	0.9464203
Adjusted R Square	0.9285604
Standard Error	0.034130894
Observations	5

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.061730581	0.06173058	52.99135499	0.005350802
Residual	3	0.003494754	0.00116492		
Total	4	0.065225335			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.644514824	0.098262096	26.912868	0.000112574	2.331800685	2.95722896	2.331800685	2.957228962
log_rate	-0.583153255	0.080108794	-7.2795161	0.005350802	-0.838095429	-0.32821108	-0.838095429	-0.328211082

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
SPCA AD-404 TYPE IV 75/25 (#14)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.986012142
R Square	0.972219945
Adjusted R Square	0.965274931
Standard Error	0.043495473
Observations	6

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.264837524	0.26483752	139.9881947	0.000292122
Residual	4	0.007567425	0.00189186		
Total	5	0.272404948			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.624049909	0.080606679	32.5537528	5.30909E-06	2.400249426	2.84785039	2.400249426	2.847850392
log_rate	-0.802749859	0.067847607	-11.831661	0.000292122	-0.991125404	-0.61437431	-0.991125404	-0.614374314

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
SPCA AD-404 TYPE IV 50/50 (#15)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.999910069
R Square	0.999820147
Adjusted R Square	0.999640293
Standard Error	0.005380287
Observations	3

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.160921525	0.16092153	5559.084498	0.008537927
Residual	1	2.89475E-05	2.8947E-05		
Total	2	0.160950473			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.55210013	0.014571593	175.142155	0.003634835	2.366951284	2.73724898	2.366951284	2.737248975
log_rate	-0.951010789	0.012755098	-74.559268	0.008537927	-1.113078983	-0.78894259	-1.113078983	-0.788942594

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
ULTRA+ TYPE IV NEAT (#16)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.925367184
R Square	0.856304425
Adjusted R Square	0.841178574
Standard Error	0.067382734
Observations	22

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	0.514085848	0.25704292	56.61198688	9.90176E-09
Residual	19	0.086268224	0.00454043		
Total	21	0.600354072			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.683953215	0.100103864	26.8116844	1.45996E-16	2.474433354	2.89347308	2.474433354	2.893473076
log_rate	-0.727101262	0.073038622	-9.9550244	5.65913E-09	-0.879972901	-0.57422962	-0.879972901	-0.574229622
log_temp	-0.202433987	0.065963458	-3.0688808	0.006318106	-0.340497135	-0.06437084	-0.340497135	-0.06437084

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
ULTRA+ TYPE IV 75/25 (#17)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.964234809
R Square	0.929748767
Adjusted R Square	0.923362291
Standard Error	0.049243112
Observations	13

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.353016756	0.35301676	145.5808817	1.09978E-07
Residual	11	0.026673724	0.00242488		
Total	12	0.37969048			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.337275493	0.076992256	30.3572801	5.86127E-12	2.167816594	2.50673439	2.167816594	2.506734393
log_rate	-0.794295813	0.065830947	-12.06569	1.09978E-07	-0.939188823	-0.6494028	-0.939188823	-0.649402803

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
ULTRA+ TYPE IV 50/50 (#18)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.933179342
R Square	0.870823684
Adjusted R Square	0.84498842
Standard Error	0.051795031
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.090426043	0.09042604	33.70678574	0.002137984
Residual	5	0.013413626	0.00268273		
Total	6	0.103839669			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	1.563581965	0.080404294	19.4464984	6.63545E-06	1.356896486	1.77026744	1.356896486	1.770267444
log_rate	-0.445211861	0.076684582	-5.8057545	0.002137984	-0.642335533	-0.24808819	-0.642335533	-0.248088189

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TABLE G.5

MULTI-VARIABLE REGRESSION ANALYSIS RESULTS
TYPE III FLUID ULTRA+

Dorval & NRC Cold Chamber Tests 1996/97

PRECIPITATION	EQUATION #	FLUID BRAND	DILUTION	NO. OF TESTS	EQUATION	R^2
SNOW	1	ULTRA+	STANDARD (67%/33%)	90	$t = 10^{2.3} R^{-0.71} (2-T)^{-0.27}$	88%
FOG	2	ULTRA+	STANDARD (67%/33%)	7	$t = 10^{2.2} R^{-0.64}$	79%
COLD-SOAKED	3	ULTRA+	STANDARD (67%/33%)	14	$t = 10^{2.0} R^{-0.66}$	98%
FZD & LZR	4	ULTRA+	STANDARD (67%/33%)	17	$t = 10^{2.2} R^{-0.79}$	91%

t = failure time (min.)
T = Degrees Celcius
R = Rate of precipitatioin (g/dm²/hr)

MULTI-VARIABLE REGRESSION OUTPUT
NATURAL SNOW CONDITIONS
ULTRA+ TYPE III (#1)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.93759352
R Square	0.8790816
Adjusted R Squar	0.87630187
Standard Error	0.09262224
Observations	90

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	2	5.426085729	2.7130429	316.246744	1.2258E-40
Residual	87	0.74636256	0.0085789		
Total	89	6.17244829			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.000*	*Upper 95.000%*
Intercept	2.3011026	0.045702914	50.349143	3.9482E-66	2.21026304	2.3919422	2.21026304	2.391942154
log_rate	-0.7101357	0.029766395	-23.85696	6.1716E-40	-0.76929966	-0.6509717	-0.769299656	-0.650971704
log_temp	-0.2739398	0.040519907	-6.760622	1.5028E-09	-0.35447754	-0.193402	-0.35447754	-0.193402016

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING FOG
ULTRA+ TYPE III NEAT (#2)

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SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.890457863
R Square	0.792915207
Adjusted R Square	0.751498248
Standard Error	0.040462282
Observations	7

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.03134363	0.03134363	19.14469899	0.007185104
Residual	5	0.008185981	0.0016372		
Total	6	0.039529611			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.158963273	0.096083677	22.4696154	3.24454E-06	1.911972722	2.40595382	1.911972722	2.405953825
log_rate	-0.642152171	0.146762021	-4.3754656	0.007185104	-1.01941534	-0.264889	-1.01941534	-0.264889002

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MULTI-VARIABLE REGRESSION OUTPUT
COLD-SOAKED BOXES
ULTRA+ TYPE III (#3)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.98839211
R Square	0.976918964
Adjusted R Square	0.974995544
Standard Error	0.048073017
Observations	14

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1.173781429	1.173781429	507.9073327	3.44496E-11
Residual	12	0.027732179	0.002311015		
Total	13	1.201513608			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	1.981882761	0.047876148	41.39603647	2.55864E-14	1.877569597	2.086195924	1.877569597	2.086195924
log_rate	-0.65857644	0.02922227	-22.53679952	3.44496E-11	-0.722246296	-0.594906584	-0.722246296	-0.594906584

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MULTI-VARIABLE REGRESSION OUTPUT
SIMULATED FREEZING DRIZZLE & LIGHT FREEZING RAIN
ULTRA+ TYPE III NEAT (#4)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.954534197
R Square	0.911135534
Adjusted R Square	0.905211236
Standard Error	0.053145578
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.434390559	0.43439056	153.7963782	2.7534E-09
Residual	15	0.042366787	0.00282445		
Total	16	0.476757346			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.000%*	*Upper 95.000%*
Intercept	2.229879514	0.07290184	30.5874243	6.24367E-15	2.074492825	2.3852662	2.074492825	2.385266203
log_rate	-0.789475032	0.063659811	-12.401467	2.7534E-09	-0.925162791	-0.65378727	-0.925162791	-0.653787273

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APPENDIX H

OFFICIAL HOLDOVER TIME TABLES FOR USE DURING WINTER 1997/98

- Transport Canada
- Federal Aviation Administration

TRANSPORT CANADA

HOLDOVER TIME TABLES FOR 1997/98

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 Fahrenheit
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 TIMETABLE CELL.

FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT.

TRANSPORT CANADA, JULY 1997

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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	**0:30 - 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 -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 Fahrenheit
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, JULY 1997

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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 Fahrenheit
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 TIMETABLE CELL.

FLUIDS USED DURING GROUND DEICING ARE NOT INTENDED FOR AND DO NOT PROVIDE ICE PROTECTION DURING FLIGHT.

TRANSPORT CANADA, JULY 1997

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	2:20 - 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.					

°C = Degrees Celsius
°F = Degrees Fahrenheit
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, JULY 1997

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TABLE 4 H

HOECHST TYPE IV FLUID HOLDOVER TABLE

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	2:20 - 3:00	0:45 - 1:25	0:40 - 1:00	0:40 - 0:55	0:10 - 0:50
		75/25	6:00	1:05 - 2:00	0:35 - 1:10	0:40 - 1:05	0:25 - 0:40	0:05 - 0:35
		50/50	4:00	0:20 - 0:45	0:15 - 0:25	0:20 - 0:35	0:15 - 0:20	
0 to -3	32 to 27	100/0	12:00	2:20 - 3:00	0:35 - 1:00	0:40 - 1:00	0:40 - 0:55	
		75/25	5:00	1:05 - 2:00	0:25 - 0:50	0:40 - 1:05	0:25 - 0:40	
		50/50	3:00	0:20 - 0:45	0:15 - 0:25	0:20 - 0:35	0:15 - 0:20	
below -3 to -14	below 27 to 7	100/0	12:00	0:40 - 3:00	0:20 - 0:40	**0:40 - 1:00	**0:30 -0:50	
		75/25	5:00	0:35 - 2:00	0:15 - 0:30	**0:40 - 1:05	**0:25 - 0:40	
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 Fahrenheit
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, JULY 1997

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	2:20 - 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	0:10 - 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	**0:30 - 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	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 Fahrenheit
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, JULY 1997

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OCTAGON TYPE IV FLUID HOLDOVER TABLE

MAXFLIGHT

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	2:20 - 3:00	1:15 - 2:00	0:55 - 2:00	0:40 - 1:15	0:10 - 0:50
		75/25	6:00	1:05 - 2:00	1:20 - 2:00	1:15 - 2:00	0:50 - 1:15	0:05 - 0:35
		50/50	4:00	0:20 - 0:45	0:40 - 1:20	0:55 - 1:40	0:30 - 0:55	
0 to -3	32 to 27	100/0	12:00	2:20 - 3:00	0:50 - 1:35	0:55 - 2:00	0:40 - 1:15	
		75/25	5:00	1:05 - 2:00	0:45 - 1:45	1:15 - 2:00	0:50 - 1:15	
		50/50	3:00	0:20 - 0:45	0:40 - 1:20	0:55 - 1:40	0:30 - 0:55	
below -3 to -14	below 27 to 7	100/0	12:00	0:40 - 3:00	0:25 - 0:50	**0:30 - 1:10	**0:30 - 0:55	
		75/25	5:00	0:35 - 2:00	0:20 - 0:50	**0:30 - 1:05	**0:25 - 0:35	
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 Fahrenheit
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, JULY 1997

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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 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	2:20 - 3:00	0:50 - 1:40	1:00- -2:00	0:35 - 0:60	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 - 1:15	1:00- -2:00	0:35 - 0:60	
		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	0:25 - 0:55	**0:50 - 1:35	**0:30 - 0:50	
		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	0:20 - 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 Fahrenheit
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, JULY 1997

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FEDERAL AVIATION ADMINISTRATION

HOLDOVER TIME TABLES FOR 1997/98

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, 1997

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	**0:30-1:00	**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 -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 October 1, 1997

TABLE 3 - Guideline for Holdover Times Anticipated for SAE Type III 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	05:00	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	04:00	0:50-1:30	0:15-0:25	0:25-0:50	0:15-0:25	CAUTION: Clear ice may require touch for confirmation
below -3 to -14	below 27 to 7	04:00	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 Type III fluid cannot be used.					

°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 III 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 BE REDUCED WHEN AIRCRAFT SKIN TEMPERATURE IS LOWER THAN OAT.

CAUTION: SAE TYPE III FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective October 1, 1997

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	2:20-3:00	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	CAUTION: Clear ice may require touch for confirmation
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.					

°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 October 1, 1997

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	2:20-3:00	0:50-1:40	1:00-2:00	0:35-0:100	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	CAUTION: Clear ice may require touch for confirmation
0 to -3	32 to 27	100/0	12:00	2:20-3:00	0:35-1:15	1:00-2:00	0:35-0:100	
		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	0:25-0:55	**0:50-1:35	**0:30-0:50	
		75/25	5:00	0:35-2:00	0:15-0:30	**0:30-1:00	**0:15-0:30	
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 may be used below -24°C (-11°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 **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

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, 1997

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	2:20-3:00	1:15-2:00	0:55-2:00	0:40-1:15	0:10-0:50
		75/25	6:00	1:05-2:00	1:20-2:00	1:15-2:00	0:50-1:15	0:05-0:35
		50/50	4:00	0:20-0:45	0:40-1:20	0:55-1:40	0:30-0:55	CAUTION: Clear ice may require touch for confirmation
0 to -3	32 to 27	100/0	12:00	2:20-3:00	0:50-1:35	0:55-2:00	0:40-1:15	
		75/25	5:00	1:05-2:00	0:45-1:45	1:15-2:00	0:50-1:15	
		50/50	3:00	0:20-0:45	0:40-1:20	0:55-1:40	0:30-0:55	
below -3 to -14	below 27 to 7	100/0	12:00	0:40-3:00	0:25-0:50	**0:30-1:10	**0:30-0:55	
		75/25	5:00	0:35-2:00	0:20-0:50	**0:30-1:05	**0:25-0:35	
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, 1997

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	2:20-3:00	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	CAUTION: Clear ice may require touch for confirmation
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	**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, 1997

TABLE 4D - Guideline for Holdover Times Anticipated for SAFEWING® MP IV 1957-Green 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	2:20-3:00	0:45-1:25	0:40-1:00	0:40-0:55	0:10-0:50
		75/25	6:00	1:05-2:00	0:35-1:10	0:40-1:05	0:25-0:40	0:05-0:35
		50/50	4:00	0:20-0:45	0:15-0:25	0:20-0:35	0:15-0:20	CAUTION: Clear ice may require touch for confirmation
0 to -3	32 to 27	100/0	12:00	2:20-3:00	0:35-1:00	0:40-1:00	0:40-0:55	
		75/25	5:00	1:05-2:00	0:25-0:50	0:40-1:05	0:25-0:40	
		50/50	3:00	0:20-0:45	0:15-0:25	0:20-0:35	0:15-0:20	
below -3 to -14	below 27 to 7	100/0	12:00	0:40-3:00	0:20-0:40	**0:40-1:00	**0:30-0:50	
		75/25	5:00	0:35-2:00	0:15-0:30	**0:40-1:05	**0:25-0:40	
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	**SAFEWING® MP IV 1957-Green** 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-Green** 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: **SAFEWING® MP IV 1957-Green** TYPE IV FLUID USED DURING GROUND DEICING/ANTI-ICING IS NOT INTENDED FOR AND DOES NOT PROVIDE PROTECTION DURING FLIGHT.

Effective October 1, 1997

APPENDIX I

TESTING OF DE/ANTI-ICING FLUIDS FOR THE PURPOSE OF SUBSTANTIATING HOLDOVER TIME TABLES AT THE NATIONAL CENTRE FOR ATMOSPHERIC RESEARCH/MARSHALL WINTER TEST SITE

Testing of De/Anti-icing Fluids for the Purpose of Substantiating Holdover Time Tables at the NCAR/Marshall Winter Test Site; Boulder, CO, during the Winter of 1997

J. A. Cole, K. Knight, R.A. Rasmussen

Research Applications Program
National Center for Atmospheric Research*
P.O. Box 3000
Boulder, CO 80307-3000

OVERVIEW

The National Center for Atmospheric Research (NCAR) in Boulder, CO was funded by the Federal Aviation Administration Technical Center (FAATC) in Atlantic City, NJ to test aircraft anti-icing fluids during the winter of 1996 at the NCAR/Marshall Winter Test Site in Boulder, CO. This field test procedure has been developed by the Holdover Time Working Group of the SAE Committee 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 for freezing depressant (FDP) fluids know as de/anti-icing fluids.Holdover times will be determined as a function of fluid type and concentration, snowfall rate, temperature, humidity, and windspeed. The standardized testing method used establishes the time period for which freezing point depressant (FDP) fluids provide protection to test panels during inclement weather such as freezing rain or snow.

FLUID TEST SITE

The NCAR/Marshall Test Site is located in Boulder, CO at an elevation of 5,716 feet, with an annual snowfall of approximately 80 inches. Fluid testing began in January of 1997 and lasted through April 1997 (See Marshall Site Diagram and Event Summary List). The site was staffed during all winter precipitation events by one or two people. These observers performed de/anti-icing fluid tests and various weather observations.

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. The following fluids were tested at the Marshall Test Site:

1) Octagon Type II De/Anti-icing Fluid (100/0)
2) Union Carbide Ultra+ Type II/IV De/Anti-icing Fluid (100/0) - Ethylene Glycol/Clear
3) Union Carbide Ultra+ Type II/IV De/Anti-icing Fluid (100/0) - Ethylene Glycol/Green
4) Union Carbide Ultra+ Type II/IV De/Anti-icing Fluid (75/25) - Ethylene Glycol/Green
5) Hoechst Safewing Type II/IV De/Anti-icing Fluid (100/0) - Propylene Glycol
6) Hoechst Safewing Type II/IV De/Anti-icing Fluid (100/0) - Propylene Glycol

EQUIPMENT & TESTING

The following equipment was used at the NCAR/Marshall Test Site during the winter 1997 test season (See Instrumentation List and Precipitation Gauge Diagram)

Wind Shielded Precipitation Gauges (Automatic):

1)12" ETI NOAHII Precipitation Gauge with Wyoming Wind Shield
Sensor Type: Electronic weighing-type gauge
Collector orifice: 113.04 sq. in. (12 in diameter)
Capacity: Up to 12 inches of precipitation
Accuracy: + or - 0.01 inches (in calm or light wind conditions)
Sensitivity: 0.01 inches
Power Requirements: 12 VDC, 15 ma average current

2) 8" Belfort 3000 Precipitation Gauge with Wyoming Wind Shield
Sensor Type: Mechanical weighing-type gauge
Collector orifice: 50.24 sq. in. (8 in diameter)
Capacity: Up to 19.5 inches of precipitation
Accuracy: + or - 0.15 inches of precipitation span
Sensitivity: 0.025 inches
Power Requirements: 12 VDC, 15 ma average current

Meteorological Tower (1 minute averaged data):

a. Wind Speed & Direction - R.M. Young Wind Monitor @ 3 meters and 10 meters
b. Temperature & Relative Humidity - Vaisala HMP25C Temp/RH Probe @ 2 meters
c. Precipitation Detector - Vaisala DRD11A Precipitation Detector
d. Snow Depth Sensor - Campbell SR50 snow depth sensor

Manual Precipitation Measurements:

Manual measurements of precipitation were made at 15 minute intervals with a 30 cm Wide by 50 cm Long by 2.54 cm Deep aluminum pan that was coated with de-icing fluid to keep snow from blowing out of the shallow pan. The pan and precipitation were weighed every 15 minutes on a digital electronic scale and then recoated with fluid before replacing outside (See Snow Pan Measurement Log Sheet).

Fluid Test Stand:

A apparatus was designed and constructed by NCAR for testing fluids. It consisted of a rotational stand with 5-30x50 cm aluminum panels and a 30x50 cm snow pan. Each panel was marked with lines at 2.5 and 15 cm from the panel top edge, with fifteen cross-hair points. If there is any wind, the test panel was oriented such that the panels are facing into the wind at the beginning of the test. The test apparatus also includes an air temp/rh probe, panel temperature and windspeed sensor from which 1 min data is recorded. A video camera and halogen light are also mounted on the test apparatus for time-lapse imaging of the fluid tests (See diagram).

Fluid Application & Fluid Temperature:

The fluid was poured onto the plates from plastic one-quart bottles until the test panels are completely saturated. Store the fluids in containers at ambient outside air temperature (cold-soaked).

Videorecorder:

A Panasonic WV-BP314 CCD 570 line resoution B/W camera was used to record the fluid tests on a Panasonic AG6730 SVHS time-lapse VCR at 4 second intervals.

Holdover Time Testing:

Set the timer on as the first fluid application starts. Note the time when fluid application is completed. Commence recording the test with a video recorder at time zero (0) and then at one (1) and five (5) minute intervals fro freezing rain and snow respectively until the test reaches the END CONDITIONS. Record the elapsed time (holdover time) required for the precipitation to achieve the test END CONDITION. In heavy precipitation, continue the test until the precipitation reaches the bottom of the panel. Record the time for this event. See Ground Icing Log Sheet.

End Conditions:

The plate failure time is that time required for the end condition to be achieved. This occurs when the accumulating precipitation fails to be absorbed at any five of the crosshair marks on the panels. A crosshair is considered failed if:

1) There is visible accumulation of snow (not slush, e.g. white snow) on the fluid at the crosshair when viewed fro the front (i.e. perpendicular to the plate). The crosshair does NOT need to be obscured (as was the case in the 199001991 test season), you are looking for an indication that the fluid can no longer accommodate the precipitation at this point. OR.....

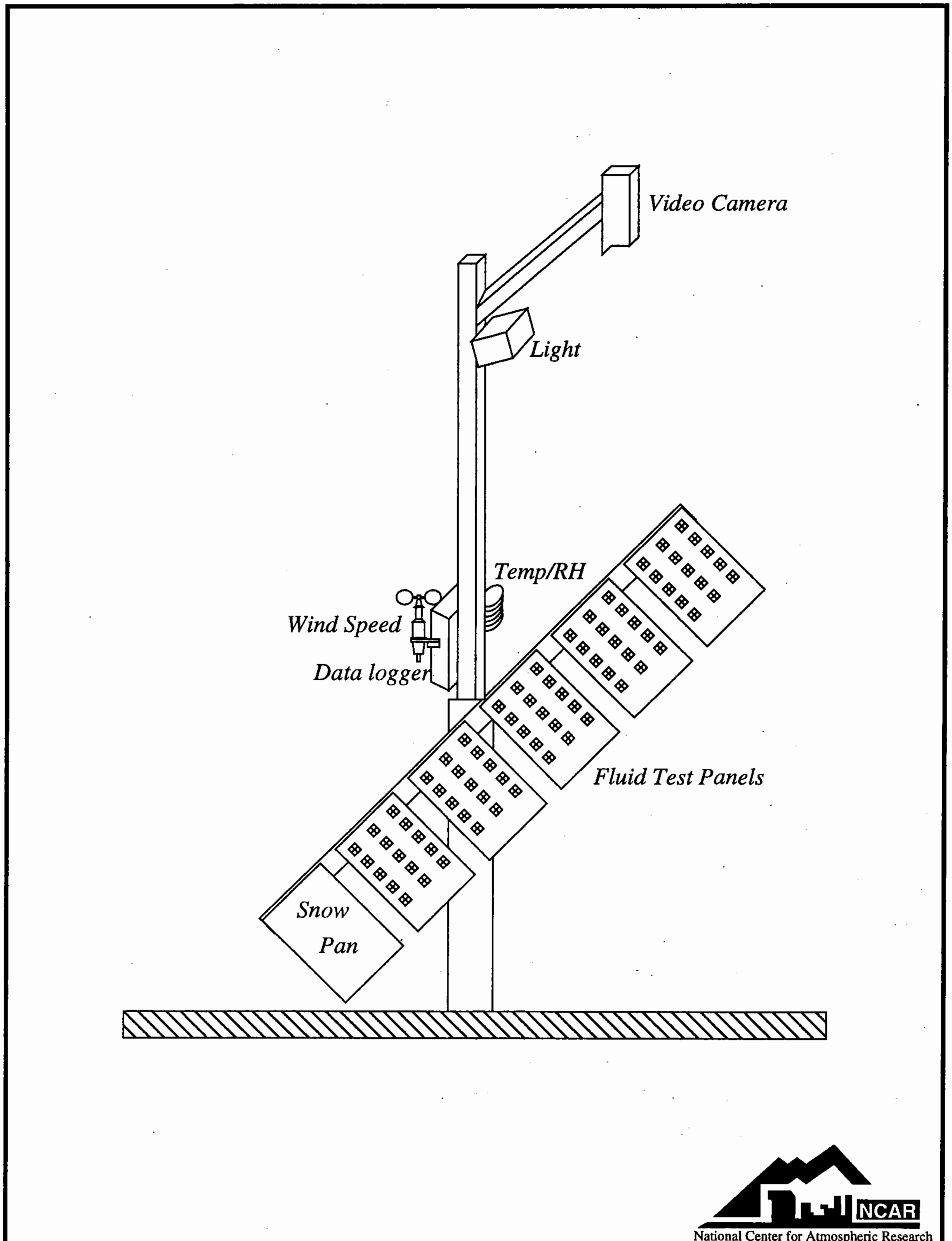
2) This condition is only applicable during freezing rain/drizzle, freezing fog or during a mixture of snow and freezing rain/drizzle. When precipitation or frosting produces a "loss of gloss" (i.e. a dulling of the surface reflectivity) or a change in color (dye) to grey or greyish appearance at any five crosshairs, or ice (or crusty snow) has formed on the crosshair (look for ice crystals).

As these determinations are subjective in nature, the following is very important: 1) Whenever possible, have the same individual make the determination that a crosshair has failed, 2) When making such determination, ensure consistency in the criteria used to call the end of a test, 3) Under light snow conditions, snow may sometimes build up on the fluid and then be absorbed later as the fluid accommodates for it. If this occurs, record the first time snow builds up and note (in the comments) that there was "un-failure" at a specific crosshair.

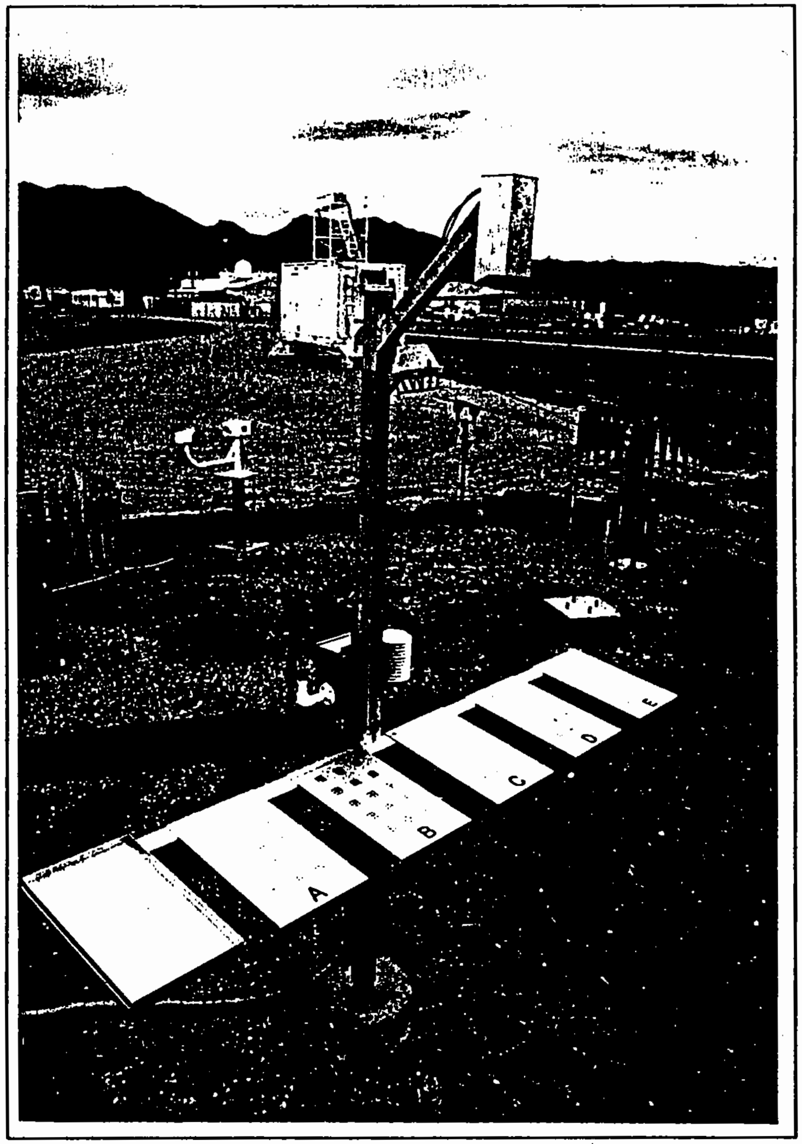
TEST RESULTS

The fluid test results for the tests performed by NCAR during the 1997 winter season are summarized in Chart 1, Chart 3, Chart 4 and in the table (Sheet 1).

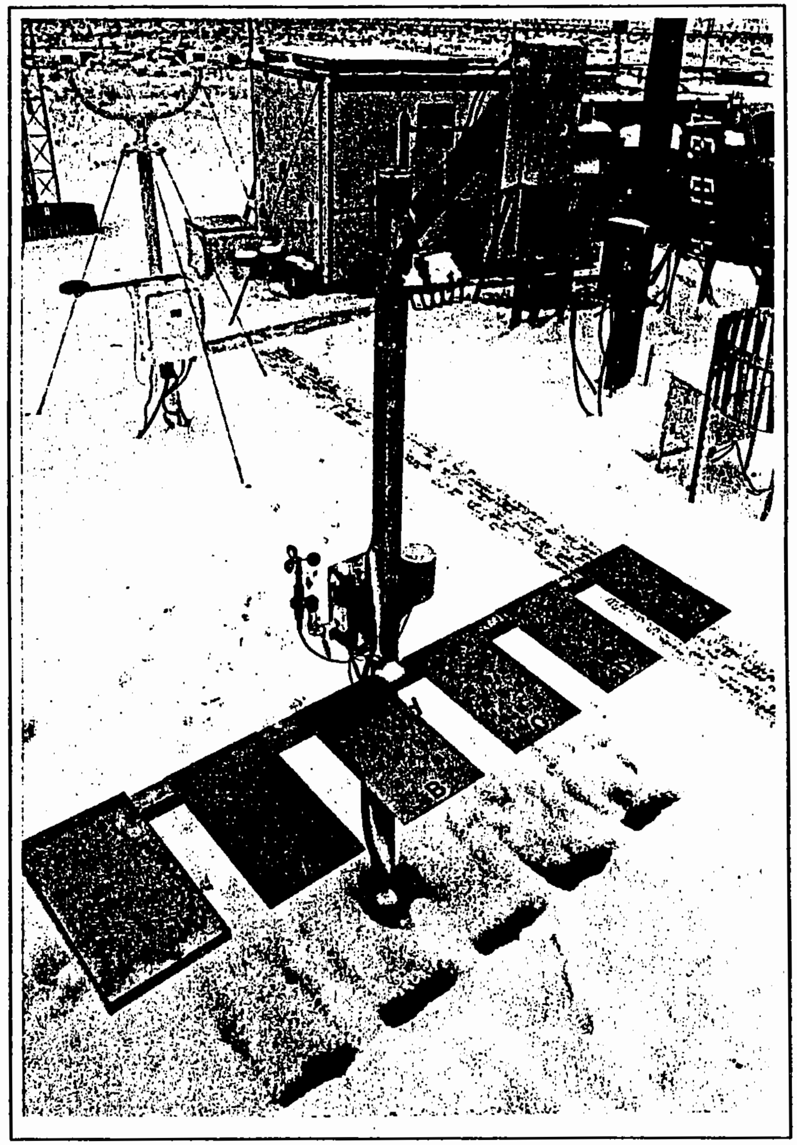
NCAR/Marshall Anti/De-Icing Fluid Test Apparatus



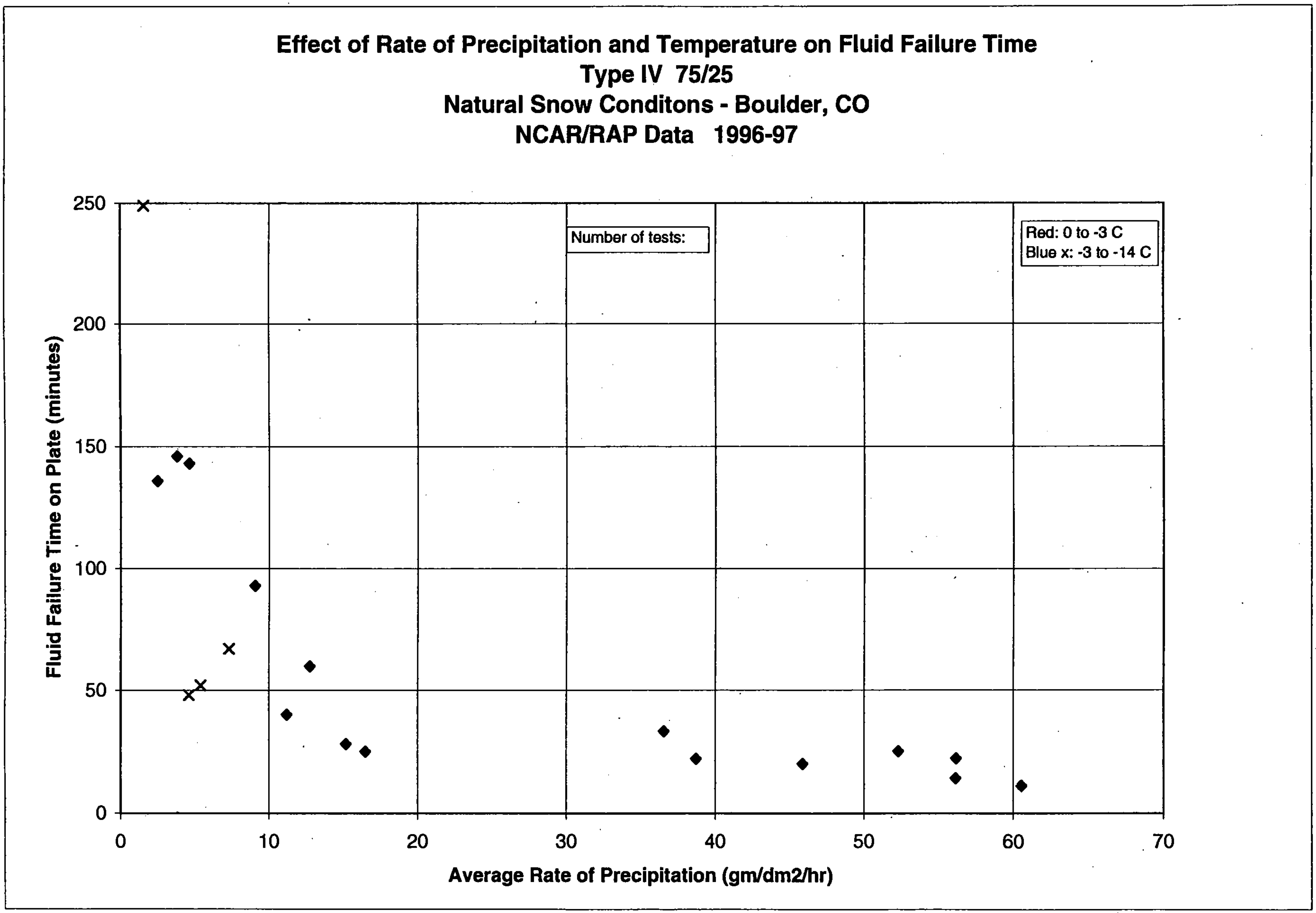
NCAR/RAP 05/30/97



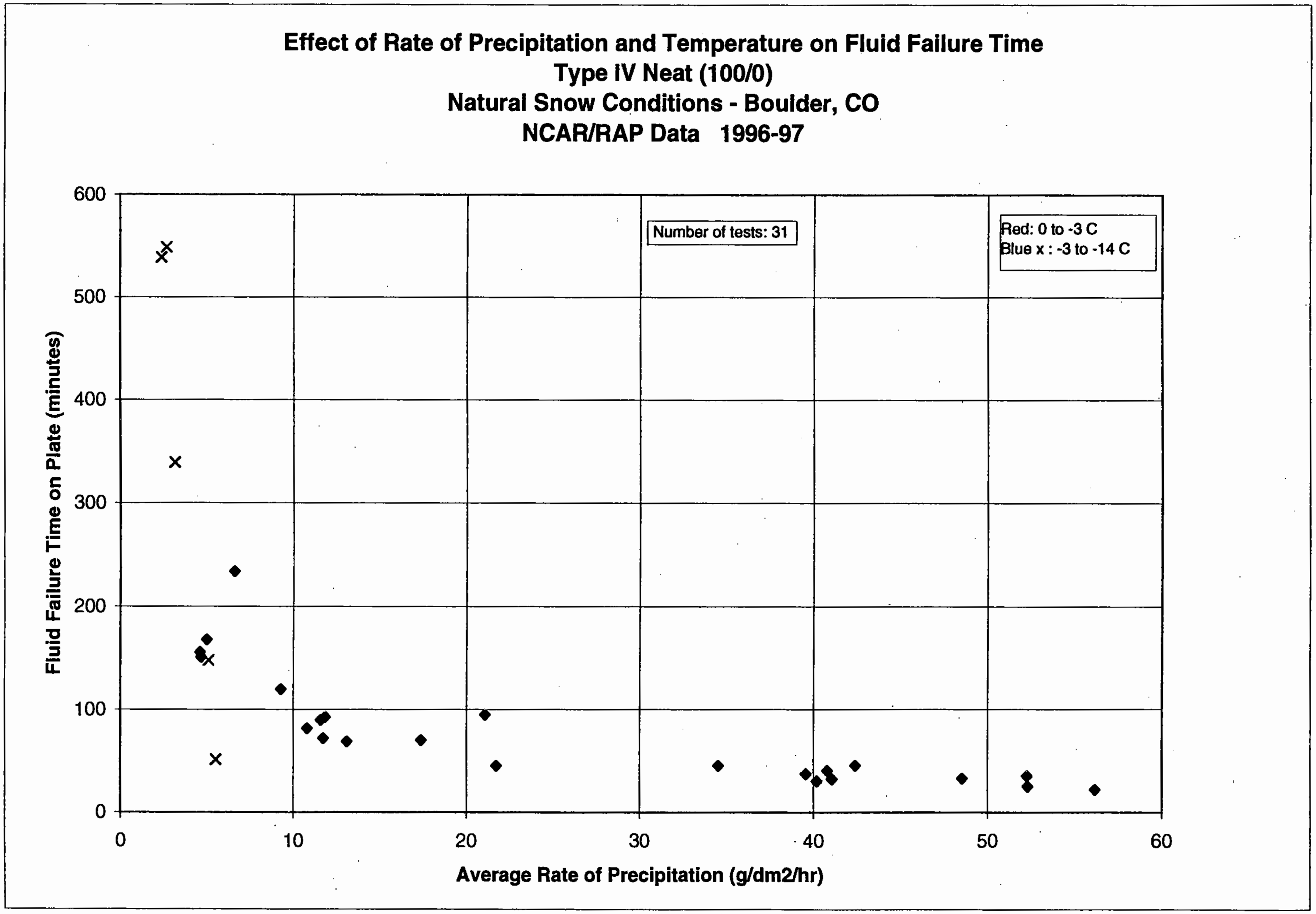
NCAR Fluid Test Apparatus



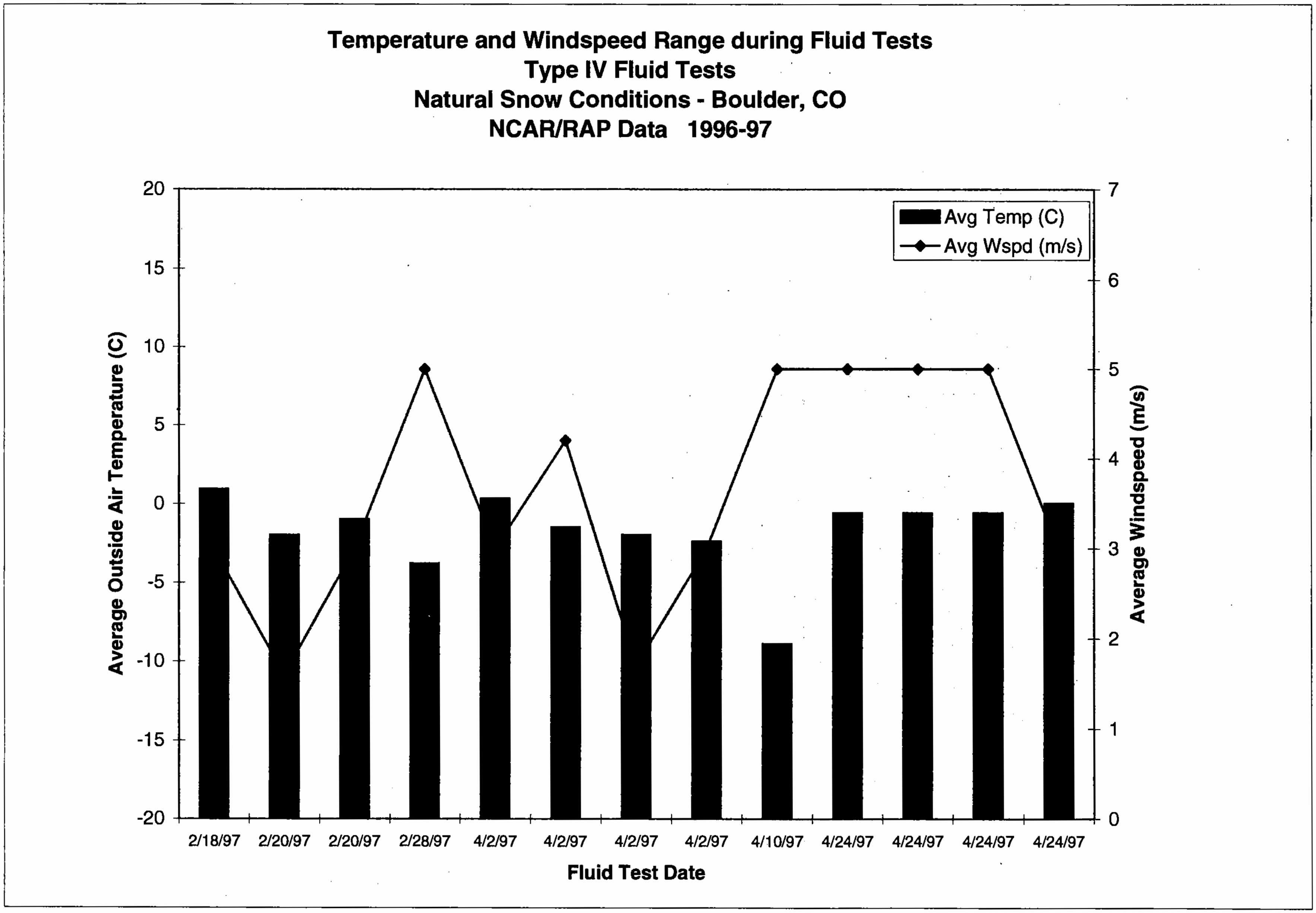
NCAR Fluid Test Apparatus - April 10, 1997 (Snow)

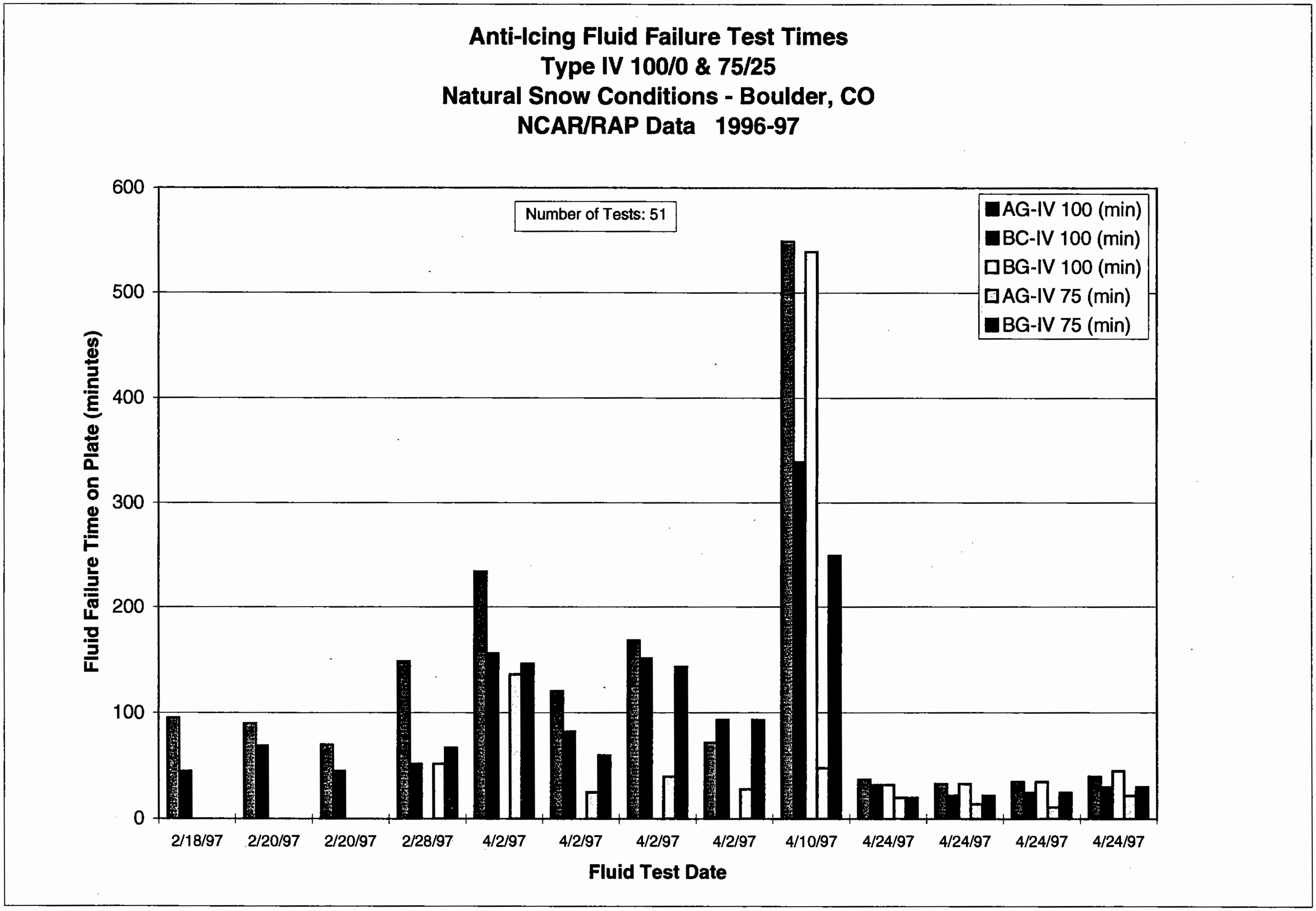

Effect of Rate of Precipitation and Temperature on Fluid Failure Time
Type IV 75/25
Natural Snow Conditons - Boulder, CO
NCAR/RAP Data 1996-97
Number of tests:
Red: 0 to -3 C
Blue x: -3 to -14 C
Fluid Failure Time on Plate (minutes)
Average Rate of Precipitation (gm/dm2/hr)
250
200
150
100
50
0
10
20
30
40
50
60
70

I-6


Effect of Rate of Precipitation and Temperature on Fluid Failure Time
Type IV Neat (100/0)
Natural Snow Conditions - Boulder, CO
NCAR/RAP Data 1996-97
Number of tests: 31
Red: 0 to -3 C
Blue x : -3 to -14 C
Fluid Failure Time on Plate (minutes)
Average Rate of Precipitation (g/dm2/hr)
0
100
200
300
400
500
600
0
10
20
30
40
50
60

I-7


Temperature and Windspeed Range during Fluid Tests
Type IV Fluid Tests
Natural Snow Conditions - Boulder, CO
NCAR/RAP Data 1996-97
Avg Temp (C)
Avg Wspd (m/s)
Average Outside Air Temperature (C)
Average Windspeed (m/s)
20
15
10
5
0
-5
-10
-15
-20
7
6
5
4
3
2
1
0
2/18/97
2/20/97
2/20/97
2/28/97
4/2/97
4/2/97
4/2/97
4/2/97
4/10/97
4/24/97
4/24/97
4/24/97
4/24/97
Fluid Test Date


Anti-Icing Fluid Failure Test Times
Type IV 100/0 & 75/25
Natural Snow Conditions - Boulder, CO
NCAR/RAP Data 1996-97
Number of Tests: 51
AG-IV 100 (min)
BC-IV 100 (min)
BG-IV 100 (min)
AG-IV 75 (min)
BG-IV 75 (min)
Fluid Failure Time on Plate (minutes)
0
100
200
300
400
500
600
2/18/97
2/20/97
2/20/97
2/28/97
4/2/97
4/2/97
4/2/97
4/2/97
4/10/97
4/24/97
4/24/97
4/24/97
4/24/97
Fluid Test Date

1996-97 Snow/Precip/Wind Events: NCAR/Marshall Winter Test Site

September 1996

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12 Rain(0.4in)	13	14
15	16	17	18 Rain(0.5in)	19 Rain(1.0in) Wind (G28kts)	20	21
22	23	24 Rain(0.5in)	25	26 Snow(1.0in)	27 Snow(2.0in)	28
29	30					

October 1996

Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16 Rain(0.5in)	17	18	19
20 Rain(0.5in)	21	22	23	24	25	26
27	28	29 Wind (Gust:95mph)	30	31		

November 1996

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1 Snow(2.0in)	2
3	4	5	6	7	8	9
10	11	12	13	14 Fog	15 Snow -->	16 Snow(6.0in)
17	18	19 Wind	20 Wind (Gust:59mph)	21 Fog	22	23 Snow(1.0in)
24	25	26 Snow -->	27 Snow(3.0in)	28	29 Snow -->	30 Snow(3.0in)

December 1996

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1 Wind (Gust:59mph)	2 Wind (Gust:61mph)	3 Wind (Gust:48mph)	4 Wind (Gust:48mph)	5 Wind (Gust:76mph)	6 Wind (Gust:36mph)	7 Wind (Gust:53mph)
8 Wind (Gust:52mph)	9 Wind (Gust:31mph)	10 Wind (Gust:49mph)	11 Wind (Gust:51mph)	12 Wind (Gust:50mph)	13 Wind (Gust:50mph)	14 Wind (Gust:63mph)
15 Wind (Gust:38mph)	16 Wind (Gust:44mph) Snow	17 Wind (Gust:24mph) Snow(3.5in)	18 Wind (Gust:25mph)	19 Wind (Gust:25mph)	20	21 Wind (Gust:55mph)
22 Wind (Gust:40mph)	23 Wind (Gust:37mph) Snow(0.5in)	24 Wind (Gust:57mph)	25 Wind (Gust:43mph)	26 Wind (Gust:48mph)	27 Wind (Gust:56mph)	28 Wind (Gust:52mph)
29 Wind (Gust:42mph)	30 Wind (Gust:43mph)	31				

January 1997

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			1 Wind (Gust:49mph)	2 Wind (Gust:33mph)	3	4
5	6 Snow(2.0in)	7	8	9	10 Arctic Air Snow	11 Snow -->
12 Snow(4.0in)	13	14	15	16 Arctic Air Snow(4.0in)	17	18
19	20	21 Wind (Gust:60mph)	22 Wind (Gust:61mph)	23 Wind (Gust 36mph)	24 Wind (Gust 30mph)	25 Wind (Gust 38mph)
26 Wind (Gust 64mph)	27 Snow(2.0in)	28 Wind (Gust 41mph)	29 Snow(1.5in)	30 Wind (Gust 39mph)	31 Wind (Gust 62mph)	

February 1997

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1 Wind (Gust 41mph)
2	3 Wind (Gust 51mph)	4 Wind (Gust 38mph)	5 Snow -->	6 Snow -->	7 Snow(3.0in)	8
9	10	11	12 Snow(1.0in)	13 Snow(3.0in)	14	15 Wind (Gust 49mph)
16 Wind (Gust 34mph)	17 Wind (Gust 34mph)	18 Rain(0.16in) Snow	19 Snow(2.0in)	20 Snow(4.0in)	21	22
23 Snow(3.0in)	24 Snow(1.0in)	25	26 Snow(4.0in)	27	28 Snow -->	

March 1997

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1 Snow(3.0in)
2	3 Wind (Gust 44mph)	4 Snow(1.0in)	5 Wind (Gust 35mph)	6	7 Wind (Gust 39mph)	8 Wind (Gust 34mph)
9 Wind (Gust 39mph)	10	11	12	13 Snow -->	14 Snow(4.0in)	15 Snow(1.0in)
16	17	18	19	20	21	22
23/30	24/31 Snow(1.0in)	25	26	27 Wind (Gust 43mph)	28 Wind (Gust 43mph)	29

April 1997

Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1 Snow -->	2 Snow(3.5in)	3	4 Rain-->	5 Snow(2.0in)
6	7	8	9	10 Snow -->	11 Snow(6.0in)	12 Snow(1.0in)
13	14	15	16 Rain(0.2in)	17	18	19
20	21	22	23 Rain(0.16in)	24 Rain/ Snow -->	25 Snow(15.0in)	26 Snow(1.0in)
27	28	29 Wind (Gust 58mph)	30 Wind (Gust 39mph)			

Marshall Snow Totals for Sep'96 thru Apr 1997 = 93.0" snow depth (Avg for Boulder = 80")

1996-97 Marshall Snowfall Event Summary

	Date	Liquid Equivalent	Snow Fall	Duration	Temp °F	Wind (dir/mph/gust)	Comments/Crystals
1.	1-2 Nov, 1996	0.13 in	2.0 in	1900-1500 Z (20 hrs)	32 to 15°F	3605G10	Freezing Drizzle, cold,dry snow
2.	15-16 Nov, 1996	0.62 in	5.5 in	1957-1900Z (23 hrs)	36 to 25°F	0804G15	Lgt-mod snow, rimed plates, needles,dendrites, irreg
3.	23-24 Nov, 1996	0.05 in	1.0 in	1600-0100Z (9 hrs)	32 to 25°F	1002G06	Light snow
4.	26-27 Nov, 1996	0.28 in	2.0 in	1515-0615 Z (15 hrs)	33 to 21°F	0904G8	Steady, light snow, irregs, graupel, dend, rimed (0.5-5mm)
5.	29-30 Nov, 1996	0.28 in	3.0 in	2155-1105 Z (13 hrs)	34 to 21°F	0904G15	Steady,light snow, irregs, dendrites, rimed, (0.5-4mm)
6.	16-17 Dec, 1996	0.25 in	3.5 in	1835-1535 Z (21 hrs)	29 to -6°F	0108G25	Arctic cold front, cold, dry snow
7.	6-7 Jan, 1997	0.10 in	1.7 in	1600-1500 Z (23 hrs)	20 to 14°F	3002G5	Mod snow, dry, cold, graupel then hvy rimed dendrites
8.	10-12 Jan, 1997	0.40 in	4.0 in	0339-2247Z (67 hrs)	18 to -9°F	0504G12	Arctic air mass, steady lgt snow, dendrites, lgt rime
9.	16 Jan, 1997	0.05 in	4.0 in	0715-1445Z (7.5 hrs)	19 to 7°F	1204G15	Arctic front, cold dry snow, hvy rimed dendrites
10.	27 Jan, 1997	0.05 in	2.0 in	1215-2030Z (8 hrs)	24 to 16°F	0608G15	Brief upslope, cold, dry snow, irregs, dendrites, lgt rime
11.	29 Jan, 1997	0.06 in	1.5 in	1100-1330 Z (2.5 hrs)	35 to 30°F	0410G8	Brief upslope, dendrites
12.	5-7 Feb, 1997	0.23 in	3.0 in	0222-1210 Z (58 hrs)	25 to 13°F	3605G15	Steady, light snow, cold northerly winds
13.	12 Feb, 1997	0.07 in	0.75 in	0015-1030 Z (11 hrs)	30 to 23°F	3603G8	Lgt snow, heavy rime
14.	13 Feb, 1997	0.24 in	2.5 in	0522-1054 Z (5 hrs)	28 to 25°F	3003G10	Lgt snow, heavy rime
15.	18-19 Feb, 1997	Rain: 0.16 in Snow: 0.14 in	1.5 in	2045-0115 Z (4.5 hrs)	46 to 31°F	368G16	FROPA @ 2015, rain @ 2045Z, wet snow @ 2310Z, 20 mm ags
16.	20-21 Feb, 1997	0.38 in	3.0 in	1730-0030 Z (5 hrs)	35 to 28°F	0905G10	Upslope snow event, heavy, wet snow, dendrites, irregs
17.	23-24 Feb, 1997	0.25 in	3.0 in 1.0 in	0445-0345Z 0920-1620Z	26 to 14°F	2806G10	Arctic front, cold,dry snow, dendrites, 10 mm aggs, lgt rime
18.	26 Feb, 1997	0.21 in	4.0 in	0900-1630 Z (7.5 hrs)	29 to 22°F	1202G8	Upslope snow, cold, dry snow, 1-5mm rimed dend, 10mm aggs
19.	28 Fb -1 Mr, 1997	0.18 in	3.0 in	1715-0515 Z (12 hrs)	26 to 18°F	0108G15	Cold, dry lgt snow, northerly winds, 1-5mm rimed dend & irregs
20.	4 Mar, 1997	0.06 in	1.0 in	0445-2100 Z (16 hrs)	32 to 25°F	0602G10	Light snow, 0.5mm irregs, northerly winds
21.	13-14 Mar, 1997	0.22 in	4.0 in	2100-1900 Z (22 hrs)	28 to 12°F	0305G15	SP, ZL,hvy rimed dend, then steady cold, dry lgt snow, dendrites
22.	15 Mar, 1997	0.05 in	1.0 in	0000-1200 Z (12 hrs)	19 to 12°F	0205G5	Light, cold, dry snow, 2-5mm dendrites
23.	24 Mar, 1997	0.20 in	1.5 in	1545-2245 Z (7 hrs)	38 to 28°F	3618G30	ZR,SP,S/S- w/ strong , driving N winds, 5mm aggs of dend/irreg

Revised: June 2, 1997

1996-97 Marshall Snowfall Event Summary

	Date	Liquid Equivalent	Snow Fall	Duration	Temp °F	Wind (dir/mph/gust)	Comments/Crystals
1.	2 Apr, 1997	0.45 in	3.5 in	0012-2200 Z (22 hrs)	41 to 27°F	3408G20	S /S-, N/NW winds, rimed dend, irreg, plates, need, 20 mm aggs
2.	4-5 Apr, 1997	0.56 in	2.0 in	1948-1250 Z (17 hrs)	42 to 27°F	3505G10	R-(1948-2140Z), R(2330-0153Z) then S-/S, irreg aggs(20mm)
3.	10-12 Apr, 1997	0.58 in	7.0 in	0000-1200 Z (60 hrs)	29 to 8°F	3502G10	S-/ S, cold, dry snow, 0.5-4mm dend/irreg, 20mm aggs
4.	16 Apr, 1997	0.20 in	Rain	0200-0630 Z (4.5 hrs)	47 to 38°F	0504G12	Light rain with N/NW winds
5.	23 Apr, 1997	0.16 in	Rain	0230-0730 Z (5 hrs)	44 to 35°F	0520G10	Light rain
6.	24-25 Apr, 1997	3.28 in	15.0 in	0120-1000 Z (33 hrs)	46 to 30°F	0834G10	Rain, then heavy, wet snow,mostly irregs & dend, some needlss
7.	26 Apr, 1997	0.18 in	1.0 in	1100-1500 Z (4 hrs)	31 to 33°F	0228G4	Short period of heavy, wet snow, large aggs
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
16.							
17.							
18.							
19.							
20.							
21.							
22.							
23.							

Revised: Apr 27, 1997

Instrumentation at Marshall Test Site (Winter 1996-97)

Instrument	November					December	January					February								March				April						
	Nov 1-2 (2 in)	Nov 15-16(6in)	Nov 23-24 (1 in)	Nov 26-27(3 in)	Nov 29-30 (3 in)	Dec16-17(3 in)	Jan 6-7 (4in)	Jan 10-12 (4in)	Jan 16 (4in)	Jan 27 (2in)	Jan 29 (1.5in)	Feb 5-7 (3.0in)	Feb 12 (1in)	Feb 13 (2.5in)	Feb 19 (2.0in)	Feb 20 (4.0in)	Feb 23-24 (4.0in)	Feb 26(4.0 in)	Feb 28(3.0 in)	Mar 4 (1.0 in)	Mar 13-14 (4.0 in)	Mar 15 (1.0 in)	Mar 24 (1.0 in)	Apr 2 (3.5 in)	Apr 4-5 (2.0 in)	Apr 10-12 (7.0 in)	Apr 16 (0.2 in)	Apr 23 (0.16 in)	Apr 24-25 (15 in)	Apr 26 (1.0 in)
12" ETI Precip Gage (10/10/96) (Wyoming Shield)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12" ETI Precip Gage (10/10/96) (Lexan Alter Shld + Teflon + Heat)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12" ETI Precip Gage (10/10/96) (Lexan Alter Shield + FF19R)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
12" ETI Precip Gage (10/10/96) (Double Lexan Alter Shield)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8" Belfort Precip Gage (9/9/96) (Alum Alter + Heat Tape + FF19R)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
6" Geonor Precip Gage (9/9/96) (Steel Alter + Heat + FF19R)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Campbell SR50 (9/9/96) (Snow Depth Sensor)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Vaisala DRD 11A (9/9/96) (Precipitation Indicator)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ScTI ORG-706B (10/18/96) (Optical Rain Gauge)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ScTI ORG-715 (11/1/95) (Optical Rain Gauge)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Li-Cor LI200S (9/30/95) (Silicon Pyranometer)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HSS VPF-730 (9/16/96) (Visibility/Present Wx Sensor)		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
AES POSS (9/16/96) (Precip Occurence Sensor Syst)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Vaisala FD12P (9/16/96) (Visibility/Present Wx Sensor)		X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Belfort Model 6210 (9/16/96) (Xenon Stobe Visibility Sensor)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
ScTI LEDWI (9/16/96) (Light Emitting Diode Wx Ind)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
ScTI Enhanced-LEDWI (12/02/96) (Light Emitting Diode Wx Ind)						X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Rosemount Frz Rain (???) (ZR Sensor)																								X	X	X	X		X	X

X = Instrument Data Available

Revised: June 2, 1997

Instrumentation at Marshall Test Site (Winter 1996-97)

Instrument	November					December	January					February								March				April						
	Nov 1-2 (2 in)	Nov 15-16(6in)	Nov 23-24(1in)	Nov 26-27(2in)	Nov 29-30 (3 in)	Dec16-17 (3 in)	Jan 6-7 (4in)	Jan 10-12 (4in)	Jan 16 (4in)	Jan 27 (2in)	Jan 29 (1.5in)	Feb 5-7 (3.0in)	Feb 12 (1in)	Feb 13 (2.5in)	Feb 19 (2.0in)	Feb 20 (4.0in)	Feb 23-24 (4.0in)	Feb 26(4.0 in)	Feb 28(3.0 in)	Mar 4 (1.0 in)	Mar 13-14 (4.0 in)	Mar 15 (1.0 in)	Mar 24 (1.0 in)	Apr 2 (3.5 in)	Apr 4-5 (2.0 in)	Apr 10-12 (7.0 in)	Apr 16(0.2 in)	Apr 23(0.16 in)	Apr 24-25(15 in)	Apr 26(1.0 in)
Snow Crystal Box (10/15/96) (Crystal Videotape)		X		X		X	X								X	X		X	X	X	X		X	X	X					
IAS Mobile 2D Van (11/26/96) (Video Distrometer)				X												X		X	X		X		X							
CLASS Sounding Syst (10/15/96) (Radiosonde Soundings)		X		X											X	X		X	X		X		X	X	X	X			X	
8" Hot-Plate Precip Sensor (w/ Alum Alter Shield)																			X	X	X		X	X	X	X	X		X	
Anti-Icing Fluid Tests (10/15/96) (Fluid Testing Apparatus)							X					X			X	X		X	X					X	X	X			X	
ETI NoahII All-Wx Guage (002) (ASOS Precip Gauge Test)															X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Belfort 3200 All-Wx Gauge (005) (ASOS Precip Gauge Test)																	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8" Universal Precip Gage (Steel Alter Shield)																														
Geonor Precip Gauge @ Betasso (Temp, Wind, LE Precip)										X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S-Pole Radar (Hxy 7 & I-25) (Doppar Radar)										X	X	X	X	X	X	X	X	X	X	X	X		X							
TE525 Tipping Bucket Gauge (w/ Snow Adaptor, No windshld)																		X	X	X	X	X	X	X	X	X	X	X	X	X

X = Instrument Data Available

Revised: June 2, 1997

NCAR/RAP Marshall Winter Testing Procedures

(1) Make sure Present Weather/Visibility Sensor PC's are operational, logging data, and PC clocks = GMT.

(2) Snow Pan measurements every 15 minutes using 30cm x 50cm aluminum pans and fill in snow log sheet:

a) 1-pan coated w/ Anti-icing Fluid outside on manual measurement stand
b) Weigh snow pan every 15 minutes and record pan weight (grams)
c) Measure Snow Depth inside SR50 Snow Depth Shield every 15 minutes (cm)

(3) Manual Visibility measurements every 15 minutes using utility pole markers.

(4) Snow Crystal observations every 15 minutes and videotape crystals using snow crystal box/video camera:

a) Note crystal type, size, riming, and aggregation size on log sheet
b) Make sure snow crystal video camera/VCR is working and crystal plate is cleaning off adequately

(5) Mobile CLASS sounding at beginning of storm and/or middle or end of event, as time permits.

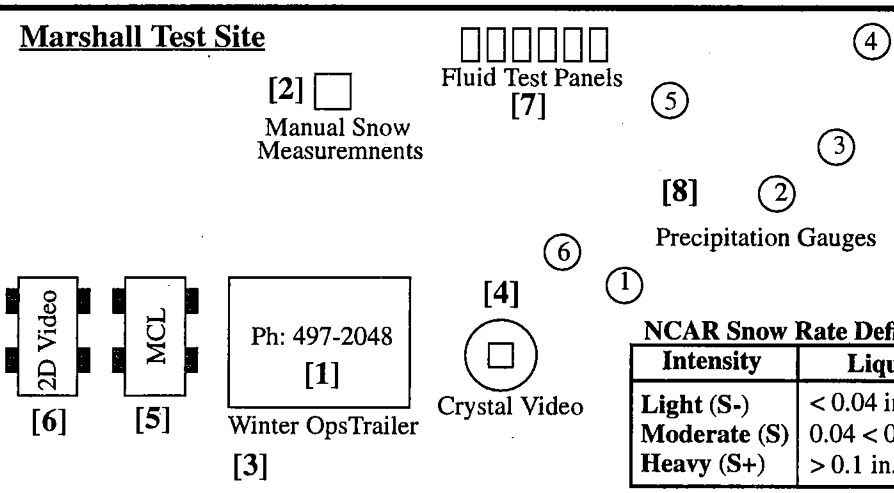
(6) Mobile 2-D Video Distrometer van - Turn on data system.

(7) Anti-icing fluid tests on aluminum test panels:

a) Apply fluids to panel A,B,C,D,E and put out 30cm x 50cm snowpan coated w/ Anti-icing fluid
b) Pour 1 quart of fluid on each aluminum test panel (simultaneously if possible)
c) Note start time and videotape progression of fluid failure every 5-15 minutes
d) Note 1" failure time and then 6" failure or 5 crosshairs obscured, which is complete failure
e) Weigh snowpan at failure time of each fluid type and fill in Ground Icing Log Sheet

(8) Video tape Precipitation Gauges every 60 minutes (Snow accumulation on gauges)

Marshall Test Site

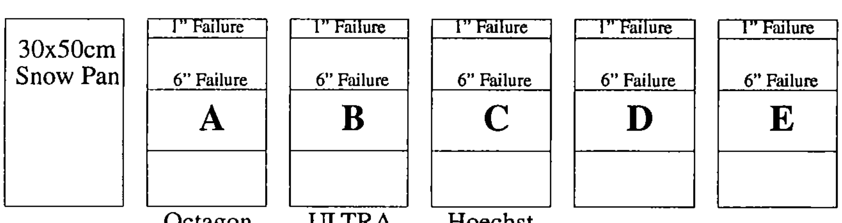


If you have:	Multiply by:	To get:
cm	0.3937	in
in	2.54	cm
m	3.281	ft
ft	0.3048	m
km	0.6214	mile
mile	1.609	km
m/s	2.237	mph
mph	0.45	m/s
oz	29.573	ml
oz	0.0625	lbs
ml	0.03382	oz
oz	1.805	in^3
°F	5/9(F-32)	°C
°C	9/5(C)+32	°F

NCAR Snow Rate Definitions:

Intensity	Liquid Equivalent (in/hr)	Approx Snow Depth
Light (S-)	< 0.04 in./hr (< 1.0 mm/hr)	0.4 in./hr
Moderate (S)	0.04 < 0.1 in./hr (1 < 2.5 mm/hr)	0.4 in. < 1.0 in./hr
Heavy (S+)	> 0.1 in./hr (> 2.5 mm/hr)	> 1.0 in./hr

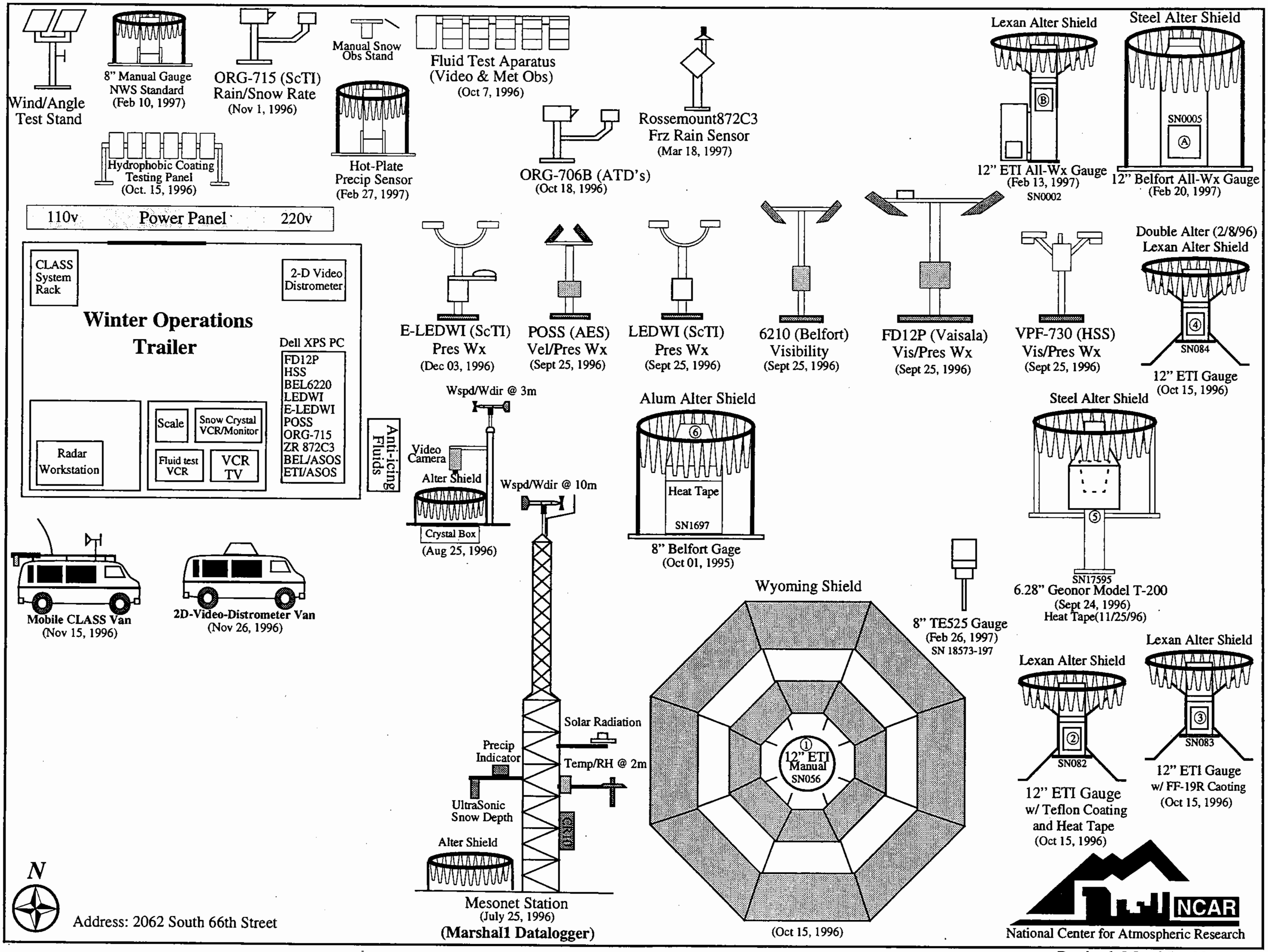
Fluid Testing Panels



Snow Intensity	NWS	NCAR	NCAR
		Temp <-1°C	Temp >-1°C
Light (-)	Vis > 1.0 km (> 5/8 mi)	Vis > 2.0 km (> 1.25 mi)	Vis > 3.2 km (> 2.0 mi)
Moderate	0.4 to 1.0 km (5/16 to <5/8 mi)	0.8 to 2.0 km (0.5 to <1.25 mi)	1.6 to 3.2 km (1.0 to <2.0)
Heavy (+)	Vis < 0.4 km (<5/16 mi)	Vis < 0.8 km (<0.5 mi)	Vis < 1.6 km (<1.0 mi)

Revised: Nov 27, 1996

NCAR/Marshall Field Test Site - Winter 1996-97

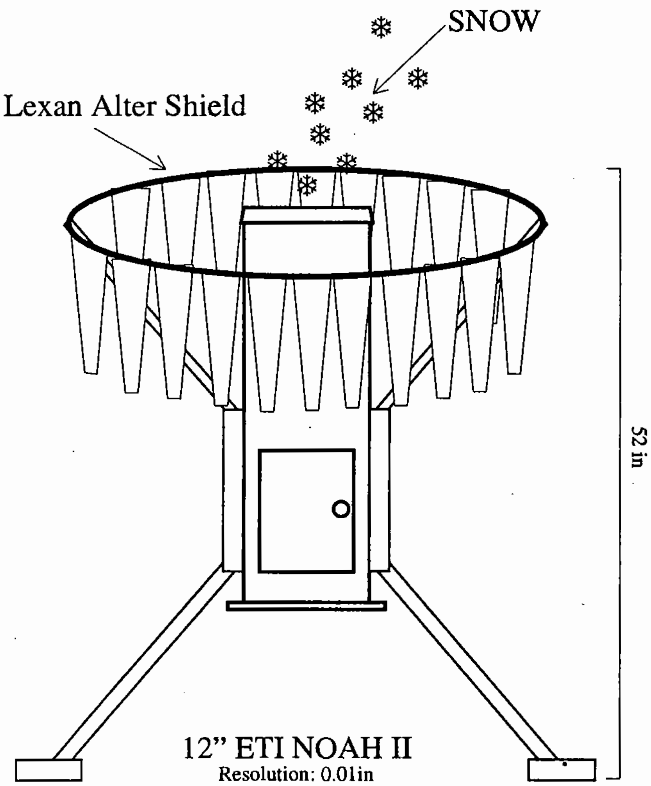


Lat: 39° 56.97' N Long: 105° 11.73' W Elev: 5716 ft (1742m) True North = 12.5° West of Mag North

Revised: Mar 25, 1997

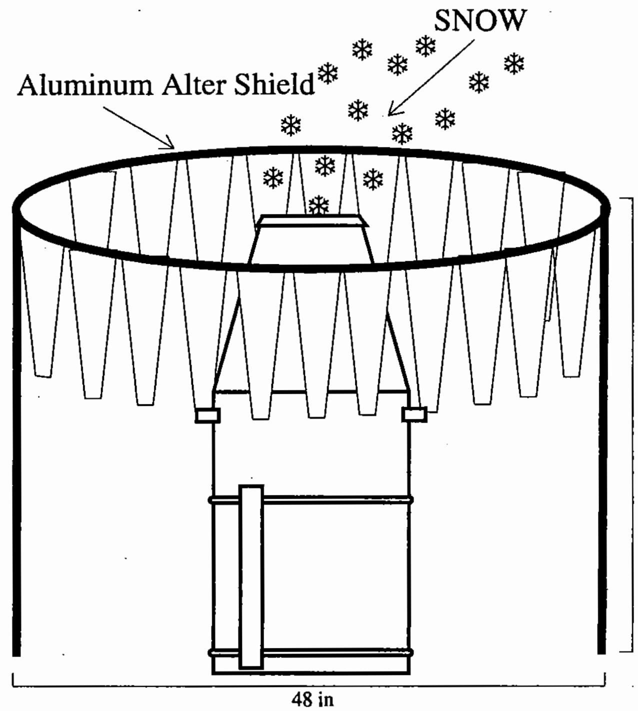
LIQUID EQUIVALENT PRECIPITATION GAUGES AND WIND SHIELDS

A. 12" Manual ETI Gauge w/ Lexan Alter Shield



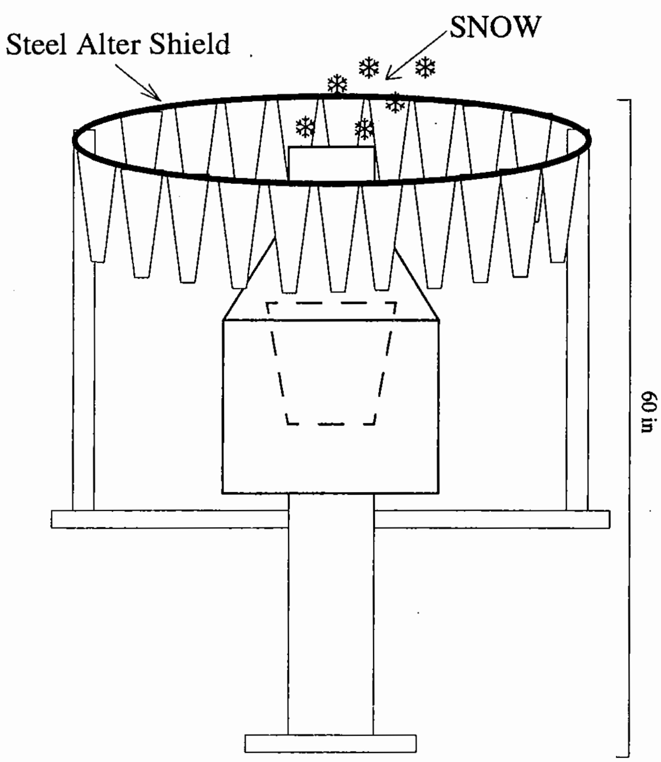
12" ETI NOAH II
Resolution: 0.01in

B. Belfort Gauge w/Aluminum Alter Shield



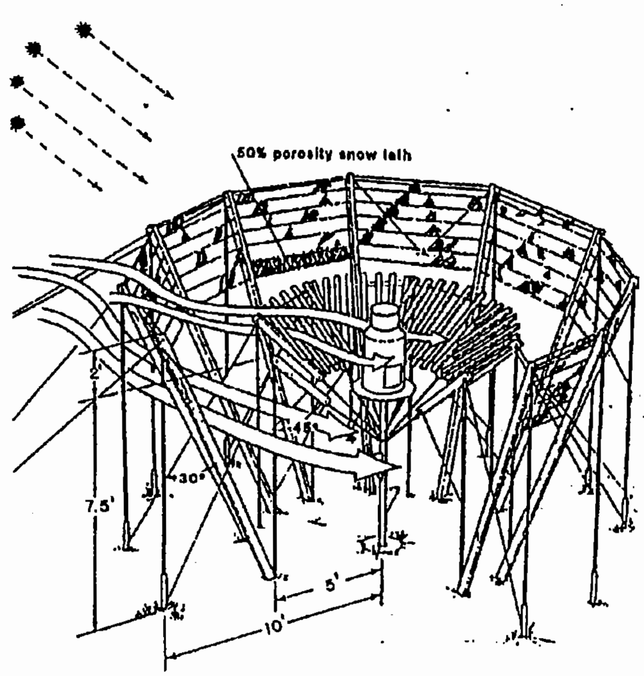
8 " BELFORT Model 3000
Resolution:.2mm(.007in)

C. Geonor Gauge w/ Steel Alter Shield



Geonor Model T-200
Resolution:.0.001in

D. Wyoming Shield w/ 8" Belfort Gauge



National Center for Atmospheric Research

NCAR/RAP 04/02/96

Manual Observations Log Sheet

Date(mmddyy):	
Test Site Name:	Marshall - Boulder, CO
Log Sheet #	of

Location of Snow Pan:	Manual Test Stand (N of Trailer)	
Slope of Snow Pan (deg):	0°	
Size of Snow Pan:	30 x 50 cm	Area = 1500cm^2

Manual Observers

	Time Start (GMT)	Time End (GMT)	1. Initial Mass of Pan (gm)	2. Final Mass of Pan (gm)	△Precip Mass (2-1) (gm or cm^3)	Liq Eqv (cm) [SM(cm^3)/1500cm2]	Crystal Observations Time(GMT)	Crystal Observations Crystal Type	Degree of Riming (None,Lgt,Hvy)	Min/Max Crystal Size (mm)	Size/Degree Aggregation (mm/%)	Wind Speed (m/s)	Wind Direc (deg)	OAT (°C)	Manual Visibility Measurements Time(GMT)	Manual Visibility Measurements Distance(km)	Precip Type/Int (R-,R,R+,S-,S,S+)
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
				Page Total		(cm) (in)											

Time(GMT)	Snow Depth (in) (On SR50 Board)	Time(GMT)	Observations/Comments:

Snow Intensity	NWS	NCAR Temp <-1°C	NCAR Temp >-1°C
Light (-)	Vis > 1.0 km (> 5/8 mi)	Vis > 2.0 km (> 1.25 mi)	Vis > 3.2 km (> 2.0 mi)
Moderate	0.4 to 1.0 km (5/16 to <5/8 mi)	0.8 to 2.0 km (0.5 to <1.25 mi)	1.6 to 3.2 km (1.0 to <2.0)
Heavy (+)	Vis < 0.4 km (<5/16 mi)	Vis < 0.8 km (<0.5 mi)	Vis < 1.6 km (<1.0 mi)

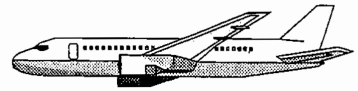
If you have:	Multiply by:	To get:
cm	0.3937	in
in	2.54	cm
m	3.281	ft
ft	0.3048	m
km	0.6214	mile
mile	1.609	km
m/s	2.237	mph
mph	0.45	m/s
oz	29.573	ml
oz	0.0625	lbs
ml	0.03382	oz
oz	1.805	in^3
°F	5/9(F-32)	°C
°C	9/5(C)+32	°F

Crystal Type	Name/Cloud Temp
	Columns (below 20°F) Plates (-20° to 0°F) Dendrites (0° to 20°F) Needles (20° to 32°F) Graupel Irregular

Revised: Apr 29, 1997

Ground Icing Log Sheet

(Anti-icing Fluid Test Panels)



Date(mmddyy):			
Location/Site:	NCAR/Marshall Test Site - Boulder, CO		
Lat/Long/Elev:	39° 56.75' N	105° 11.63' W	5716 ft
Test/Log Sheet #	of		

Panel Test Personnel

NWS Precip Intensity

	Snow or Drizzle
Light	VSBY 5/8 mile or more (≥3300ft)
Moderate	VSBY less than 5/8 to 5/16 mile
Heavy	VSBY less than 5/16 mile(<1650ft)

If you have:	Multiply by:	To get:
cm	0.3937	in
in	2.54	cm
m	3.281	ft
ft	0.3048	m
km	0.6214	mile
mile	1.609	km
m/s	2.237	mph
mph	0.45	m/s
oz	29.573	ml
oz	0.0625	lbs
ml	0.03382	oz
oz	1.805	in^3
°F	5/9(F-32)	°C
°C	9/5(C)+32	°F

Snow Pan Measurements

Location of Snow Pan:	**Fluid Test Apparatus**	
Slope of Snow Pan (deg):	**10° w/ slope facing into wind**	
Size of Snow Pan:	**30 x 50 cm**	**Area = $1500cm^2$**
Panel Direction (deg):		
Wind Spd/Dir at Start:	**Spd:**	**Dir:**

Note: Use Anti-icing fluid in Snowpan to avoid loss of blowing snow and rotate snowpan 180° every 5-15 min!

30x50cm Alum Precip Pan	A	B	C	D	E
	1" Failure	1" Failure	1" Failure	1" Failure	1" Failure
	6" Failure	6" Failure	6" Failure	6" Failure	6" Failure

Fluid Testing Panels

Precipitation Conversions

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

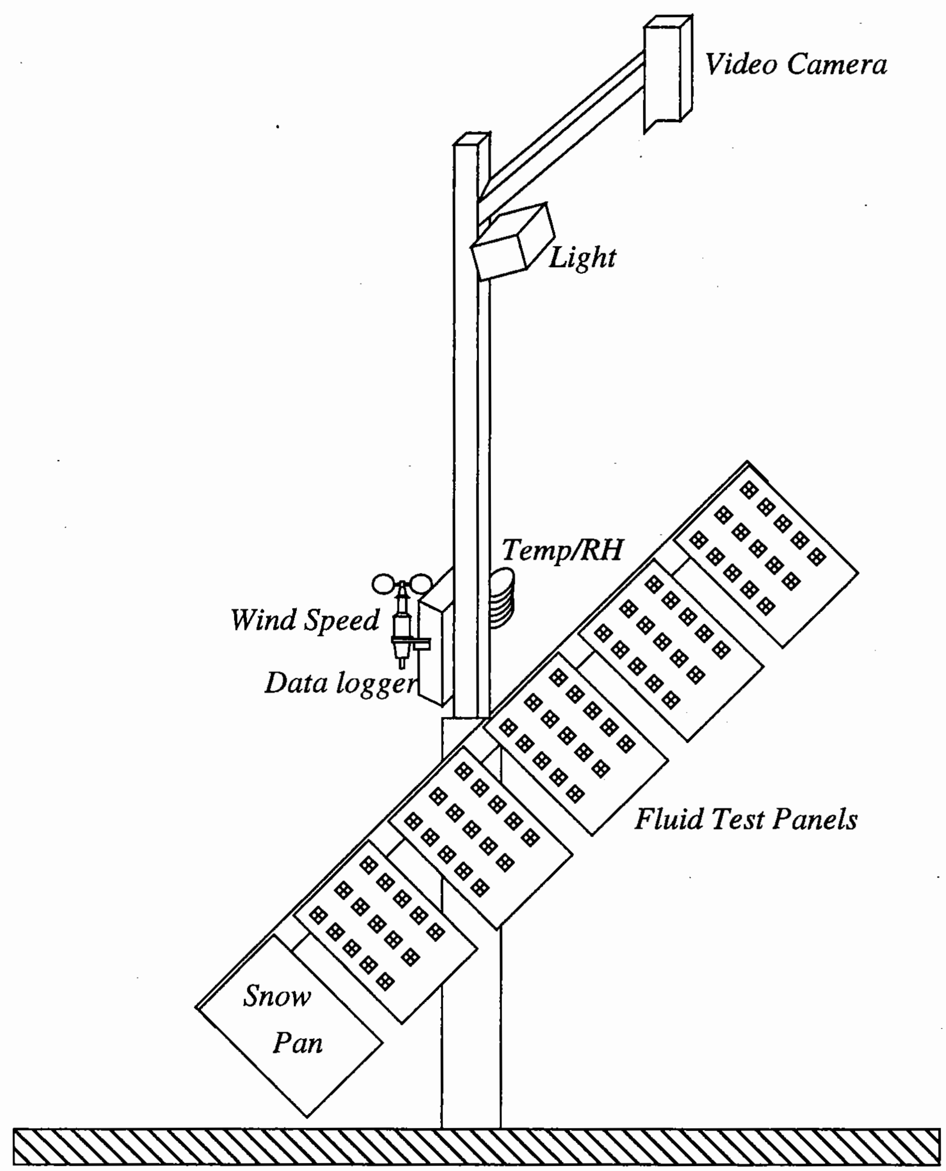
		Amt of Fluid applied (ml): Fluid Name/Type	Fluid Conc	Start Time (GMT)	OAT(°F) at Start Time	1 Initial Mass of Pan (gm)	6" Line Failure Time (GMT)	Fluid HOT (minutes)	OAT(°F) at Fluid Fail Time	2 Final Mass of Pan (gm)	Precip Mass [2-1] (gm or cm^3)	Liq Equiv(in) = $\left(\frac{\text{Precip Mass } cm^3}{1500cm2} \times 0.3937 \frac{in}{cm}\right)$	Liq Equiv (gm/dm^2) = [in. x 254]	Comments
Panel		Octagon Type II (Clear)	100/0											
Panel		Ultra+ II/IV (Green)	100/0											
Panel		Safewing II/IV (Clear)	100/0											
Panel		Ultra+ II/IV (Green)	75/25											
Panel		Safewing II/IV (Clear)	75/25											
Panel		Ultra+ II/IV (Green)	50/50											
Panel		Safewing II/IV (Clear)	50/50											
Panel		Safewing II/IV (Green)	100/0											
Panel														

Time(Z)	Crystal Type	Crystal Size(mm)	Wind Speed (km/w)	Wind Direction (deg)	**Obs/Comments:**

Crystal Type	Name/Cloud Temp
	Columns (below 20°F)
	Plates (-20° to 0°F)
	Dendrites (0° to 20°F)
	Needles (20° to 32°F)
	Graupel
	Irregular

NCAR/RAP Revised: Apr 29 ,1997

NCAR/Marshall Anti/De-Icing Fluid Test Apparatus



NCAR/RAP 05/30/97

APPENDIX J

PROPOSED HOLDOVER TIMES SUBMITTED TO SAE G-12 HOLDOVER TIME SUBCOMMITTEE FOR PITTSBURGH (JUNE 1997)

SAE TYPE IV HOTs *(DRAFT 97/98)*

OAT		SAE 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 FRZ RAIN	*DRIZZLE OR LIGHT RAIN ON COLD SOAKED WING*	*MODERATE OR HEAVY RAIN ON COLD SOAKED WING*
above 0°	above 32°	100/0	18:00	~~2:00~~-3:00 ***1:30*** (7)	~~0:55~~-1:40 ***0:50*** (4)	~~0:45~~-1:50 ***0:40*** (1)	~~0:30~~-1:00 ***0:35*** (1)	0:20-~~0:40~~ ***1:10*** (10)	***0:05-0:20*** (10)
		75/25	6:00	~~0:40~~-2:00 ***0:50*** (8)	0:20-1:00 (5)	~~0:20~~-1:00 ***0:25*** (2)	0:15-0:30 (2)	~~0:10-0:25~~ ***0:15-0:50*** (11)	***0:05-0:15*** (11)
		50/50	4:00	0:15-0:45 (9)	~~0:05~~-0:25 ***0:06*** (6)	~~0:07-0:15~~ (3) ***0:10-0:25***	~~0:05-0:10~~ (3) ***0:06-0:20***		
0 to -3	32 to 27	100/0	12:00	~~2:00~~-3:00 ***1:30*** (7)	~~0:45~~-1:40 ***0:30*** (4)	~~0:45~~-1:50 ***0:40*** (1)	~~0:30~~-1:00 ***0:35*** (1)		
		75/25	5:00	~~0:40~~-2:00 ***0:50*** (8)	~~0:15~~-1:00 ***0:20*** (5)	~~0:20~~-1:00 ***0:25*** (2)	0:15-0:30 (2)		
		50/50	3:00	0:15-0:45 (9)	~~0:05~~-0:20 ***0:06*** (6)	~~0:07-0:15~~ (3) ***0:10-0:25***	~~0:05-0:10~~ (3) ***0:06-0:20***		
below -3 to -14	below 27 to 7	100/0	12:00	~~2:00-3:00~~ (7) ***0:35-1:30***	~~0:35~~-1:15 ***0:30*** (4)	**~~0:45~~-1:50 ***0:25*** (1)	**~~0:30-0:55~~ (1) ***0:25-1:00***		
		75/25	5:00	~~0:40-2:00~~ (8) ***0:25-1:20***	0:15-1:00 (5)	**~~0:20~~-1:00 ***0:25*** (2)	**~~0:10-0:25~~ (2) ***0:15-0:30***		
below -14 to -25	below 7 to -13	100/0	12:00	~~1:00-2:00~~ **0:20-1:00** (7)	~~0:30~~-1:10 **0:20** (4)				
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.						

LEGEND	
~~0:45~~-1:40	Current HOT range.
0:30	Proposed HOT range.
(4)	Page location of data.

SAE TYPE II HOTs *(DRAFT 97/98)*

OAT °C	OAT °F	SAE Type II Fluid Concentration Neat-Fluid/Water (Vol%/Vol%)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes) *FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	*DRIZZLE OR LIGHT RAIN ON COLD SOAKED WING*	*MODERATE OR HEAVY RAIN ON COLD-SOAKED WING*
above 0°	above 32°	100/0	12:00	~~1:15-3:00~~ (22) *0:35-1:30*	0:20-1:00	0:30-1:00	0:15-0:30	~~0:20-0:40~~ (19) *0:15-0:45*	(19) *0:05-0:15*
		75/25	6:00	~~0:50-2:00~~ (22) *0:25-1:00*	0:15-0:45	0:20-0:45	0:10-0:25	0:10-~~0:25~~ *0:35* (20)	*0:03-0:10* (20)
		50/50	4:00	~~0:35-1:30~~ (22) *0:15-0:45*	0:05-0:15	~~0:15~~-0:25 *0:10* (21)	0:05-0:15		
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	~~0:15~~-0:25 *0:10* (21)	0:05-0:15		
below -3 to -14	below 27 to 7	100/0	8:00	0:35-1:30	~~0:20~~-0:45 *0:10* (16)	**0:30-1:00	**0:10-0:30		
		75/25	5:00	0:25-1:00	~~0:15~~-0:30 *0:10* (23)	**0:20-0:45	**0:10-0:25		
below -14 to -25	below 7 to -13	100/0	8:00	~~0:35-1:30~~ *0:15-1:00* (18)	~~0:20~~-0:45 *0:10* (16)				
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.						

LEGEND	
~~0:45~~-1:40	Current HOT range.
0:30	Proposed HOT range.
(4)	Page location of data.

SAE TYPE I HOTs *(DRAFT 97/98)*

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
°C	°F	*FROST	FREEZING FOG	SNOW	**FREEZING DRIZZLE	LIGHT FRZ RAIN	*DRIZZLE OR LIGHT* RAIN ON COLD SOAKED WING	*MODERATE OR HEAVY RAIN ON COLD-SOAKED WING*
above 0°	above 32°	0:45	(24) ~~0:12-0:30~~ ***0:06-0:15***	0:06-0:15	0:05-0:08	0:02-0:05	(17) 0:02-0:05	(17) ***0:01-0:02***
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				

LEGEND	
~~0:45~~ 1:4	Current HOT range.
0:30	Proposed HOT range.
(4)	Page location of data.

Tranport Canada (Aug. '96)

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At:TYPE I 97-5-22

NEW SAE TYPE III HOTs *(DRAFT 97/98)*

OAT		Approximate Holdover Times Under Various Weather Conditions (hours:minutes)						
°C	°F	*FROST	FREEZING FOG	SNOW	*** FREEZING DRIZZLE	LIGHT FRZ RAIN	DRIZZLE OR LIGHT RAIN ON COLD SOAKED WING	MODERATE OR HEAVY RAIN ON COLD-SOAKED WING
above 0°	above 32°	5:00	(15) 0:40 to 2:00	(14) 0:15 to 1:00	(12) 0:20 to 1:00	(12) 0:15 to 0:25	(13) 0:12 to 0:25	(13) 0:04 to 0:12
0 to -3	32 to 27	4:00	(15) 0:40 to 2:00	(14) 0:15 to 1:00	(12) 0:20 to 1:00	(12) 0:15 to 0:25		
below -3 to *-14*	below 27 to 7	4:00	(15) 0:40 to 2:00	(14) 0:12 to 1:00	(12) **0:18 to 0:45	(12) **0:15 to 0:20		
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 4°C (7°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.						

LEGEND	
~~0:45~~ 1:40	Current HOT range.
0:30	Proposed HOT range.
(4)	Page location of data.

Transport Canada (Aug. '96)

REVISION I
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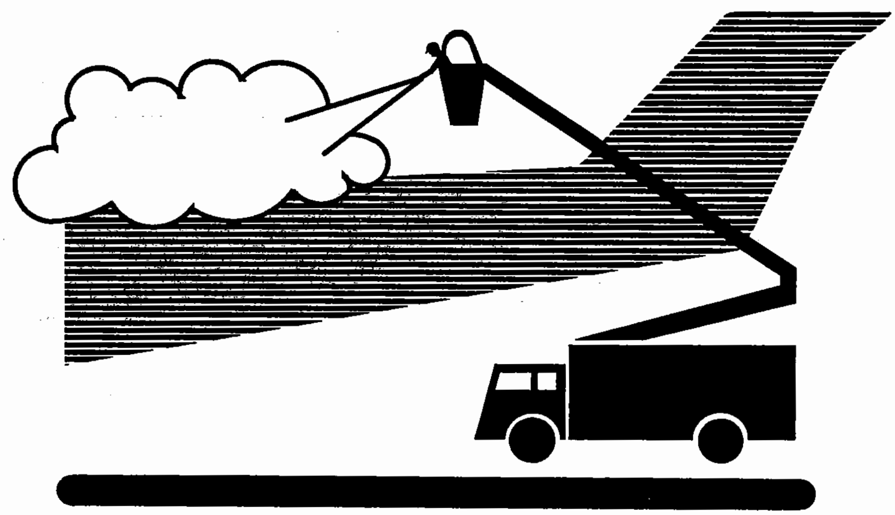
TYPE III 97-5-22

APPENDIX K

FLUID DRY-OUT

Appendix K

Fluid Dry-out



Prepared for

Transportation Development Centre
on behalf of
Civil Aviation

Safety and Security
Transport Canada

by

APS AVIATION INC.

October 1997

1. INTRODUCTION

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. undertook a study to determine a potential test procedure for determining the dry-out characteristics of anti-icing fluids during flight, and to apply that procedure to a sample of fluids to determine their dry-out characteristics. The statement of work for this study is included in Appendix A.

A potential issue has been raised by operators that some amount of anti-icing fluid may stay on the aircraft during take-off, in quiet areas such as flap recesses. The concern is that any such fluid will eventually dry-out leaving behind a residue. If the fluid dries out to a sticky residue in an area where there are moving or mating surfaces, the stickiness might restrict free movement.

The objective of this study was to establish a procedure to investigate the characteristics of a film of anti-icing fluid exposed to flight conditions, to determine the nature of the residue and how it changes with time. It was proposed that use of a depressurization chamber enabling simulation of altitude and temperature conditions of typical flight profiles could form the basis for such a procedure.

2. METHODOLOGY

This section describes test sites, equipment, test procedures and data forms, fluids used, personnel and participants, and analysis methodology.

2.1 Test Sites

The study was conducted at the Centre de Recherche Industriel du Québec (CRIQ), with some preliminary investigation performed at APS premises.

The CRIQ facilities include a large depressurization chamber which enabled simulation of flight altitude and temperature profiles which was rented for these trials.

Some preliminary trials to observe the nature of various fluids as they dried-out, were conducted at APS offices in Montreal.

2.2 Test Plan

The test plan is shown in Table 2.1. Each of the tests included a climb, cruise and descent phase. In one test (Run # 6), pans of fluid were exposed to ambient laboratory conditions to serve as a reference for observations from chamber tests.

2.3 Equipment

The decompression chamber was the principal equipment used in this study. This was a Thermotron *walk-in* chamber, model W-195-CHMA-25-25, serial number 4837. Photo 2.1 (photos are included at the end of this section) shows the chamber with the door partially opened. Chamber instrumentation included pen tracking devices to record pressure and temperature versus time, mercury column, and a monitor to display planned and current test parameters (Photo 2.2).

Because the chamber was not designed to control humidity, an instrument capable of measuring relative humidity at the cold temperatures planned (-40°C) was purchased. This was a Vaisala HMP 233 (Photo 2.3). This instrument design allowed installation of the relative humidity sensor remotely from the primary instrument and gauge, inside the altitude chamber. Photo 2.4 shows the cable from the instrument through a port in the chamber wall, and Photo 2.5 shows the cable emerging from the port inside the chamber, and the sensor head-mounted behind the table on which the test plates are situated.

TABLE 2.1
TEST PLAN FOR FLUID DRY-OUT

	Climb	Cruise			Descend	Comments
Run	**Time min.**	**Time hc: min.**	**Temp. °C**	**Alt 1000'**	**Time min.**	
1	0:20	0:20	-25	30	0:20	
2	0:25	2:15	-40	35	0:20	
3	0:20	0:20	-40	30	0:20	
4	0:20	0:20	-60	30	0:20	
5	0:20	0:20	-60	30	0:20	Test on water only
6		5:00	ambient	ambient		Ambient laboratory conditions
7	0:20	0	-25	30	0:15	

Additional equipment included a scale, sample jars and Brixometer (Photo 2.6).

2.4 Test Procedures

2.4.1 Altitude Chamber Procedures

The trials involved exposing small amounts of test fluids in pans to typical flight profiles represented by altitude, temperature and time.

For each test, the chamber was controlled to simulate a climb to altitude over a typical time period, cruise at altitude for a defined period and then descent over a typical period of time. Total flight durations planned were: one hour, three hours and five hours. Chamber temperatures and pressures were controlled and recorded over each of the flight stages. The relative humidity in the chamber was not controllable but was measured with a probe installed inside the chamber.

Sufficient sets of fluids were planned to enable examination of the effect on fluids after flights of each duration as well as the cumulative effect following a number of consecutive flights. A thin film (about 1.25 mm) of each fluid was tested in disposable aluminum baking pans.

The initial test plan was to include examination of the influence on fluid loss due to air movement as provided by a fan, however it was found that the chamber design provided air movement over the plates equivalent to that intended to be provided by an additional fan, and this was accepted as a standard condition for all tests.

Figure 2.1 presents the initial test procedure. This procedure was altered somewhat during the conduct of trials in response to trial results.

2.4.2 Investigative Procedures at APS Premises

These trials were conducted as a preliminary investigation to learn more about the characteristics of fluids as they progress through the dry-out process.

Small amounts of anti-icing fluids were poured into aluminum and plastic pans and exposed to ambient conditions in the APS premises. The fluids were weighed and fluid concentration measured initially and at intervals over a number of days. The nature of each fluid was observed as it progressively decreased in volume, and observations of fluid residue appearance and fluidity were recorded.

FIGURE 2.1
DRY-OUT TEST PROCEDURE

PROCEDURE

1) Video and photograph the test set-up and results of the test.

2) Place the table and lighting in the chamber.

3) Install the relative humidity meter and place the fan in the chamber.

4) Weigh the pans when empty to establish the tare weight.

5) Pour 35 ml of fluid into the pans and weigh again, then calculate the actual fluid weight. A variance of ± 10% is acceptable.

6) Measure the Brix of the fluid before and after its test period.

7) Set up the trays and the relative humidity meter so they are visible from the viewing window.

8) Record the relative humidity at the beginning of the test.

9) For the 1 hour duration step up to 30 000 ft over 20 minutes.
For the 3 hours duration step up to 35 000 ft over 25 minutes.
For the 5 hours duration step up to 35 000 ft over 30 minutes.

10) When the chamber reaches its goal elevation record the relative humidity. If the relative humidity changes while at this altitude, then record changes every 30 minutes.

11) Step down to the ambient elevation in the same manner as in step 8).

12) At the end of each test remove and add trays as outlined on the *Test Plan* sheet.

13) Weight the pans again after each duration (this should be done in the chamber to avoid condensation error). Calculate the final fluid weight.

14) Examine any remaining residue and describe it in terms of quantity, stickiness and adherence. Keep samples of any pans that have dry residue firmly adhered in powder, scale or other form.

15) Take samples of any remaining fluid and label.

2.5 Data Forms

Figure 2.2 presents the form used to collect data on each fluid as it progressed through dry-out. This form was used both for the trials at the altitude chamber and for the preliminary trials at APS premises.

The altitude chamber instrumentation produced pen traces for both altitude and temperature and samples are shown in Figures 2.3 and 2.4.

2.6 Fluids

Fluids tested in the altitude chamber trials were:
- Hoechst MPII 1906 Type II;
- Kilfrost ABC-S Type IV;
- Octagon Maxflight Type IV;
- Hoechst Safewing MPIV 1957 Type IV; and
- Union Carbide Ultra+ Type IV.

Fluids tested in the investigations at APS facilities were:
- SPCA AD-404 Type IV;
- Hoechst Safewing MPIV 1957 Type IV; and
- Union Carbide Ultra+ Type IV.

2.7 Personnel

Tests were conducted by APS personnel. Operation of the altitude chamber was programmed and conducted by CRIQ staff.

2.8 Analysis Methodology

Fluid weight and concentration were measured before and after exposure to the simulated flight profile. Changes in fluid quantity and concentration were calculated to quantify the dry-out effect.

Any changes in fluid appearance or fluidity were recorded.

FIGURE 2.2
FLUID DRY OUT TESTS
DATA FORM

Date: **Altitude:**

Location: **Chamber Temperature:**

		Start of test				Relative Humidity			Final				
Run #	Fluid Type	Time Poured	Pan Weight	Pan + Fluid Weight	Brix	Time/%	Time/%	Time/%	Time	Pan + Fluid Weight	Viscosity	Brix	Notes on Final Residue

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FIGURE 2.3
ALTITUDE TRACE

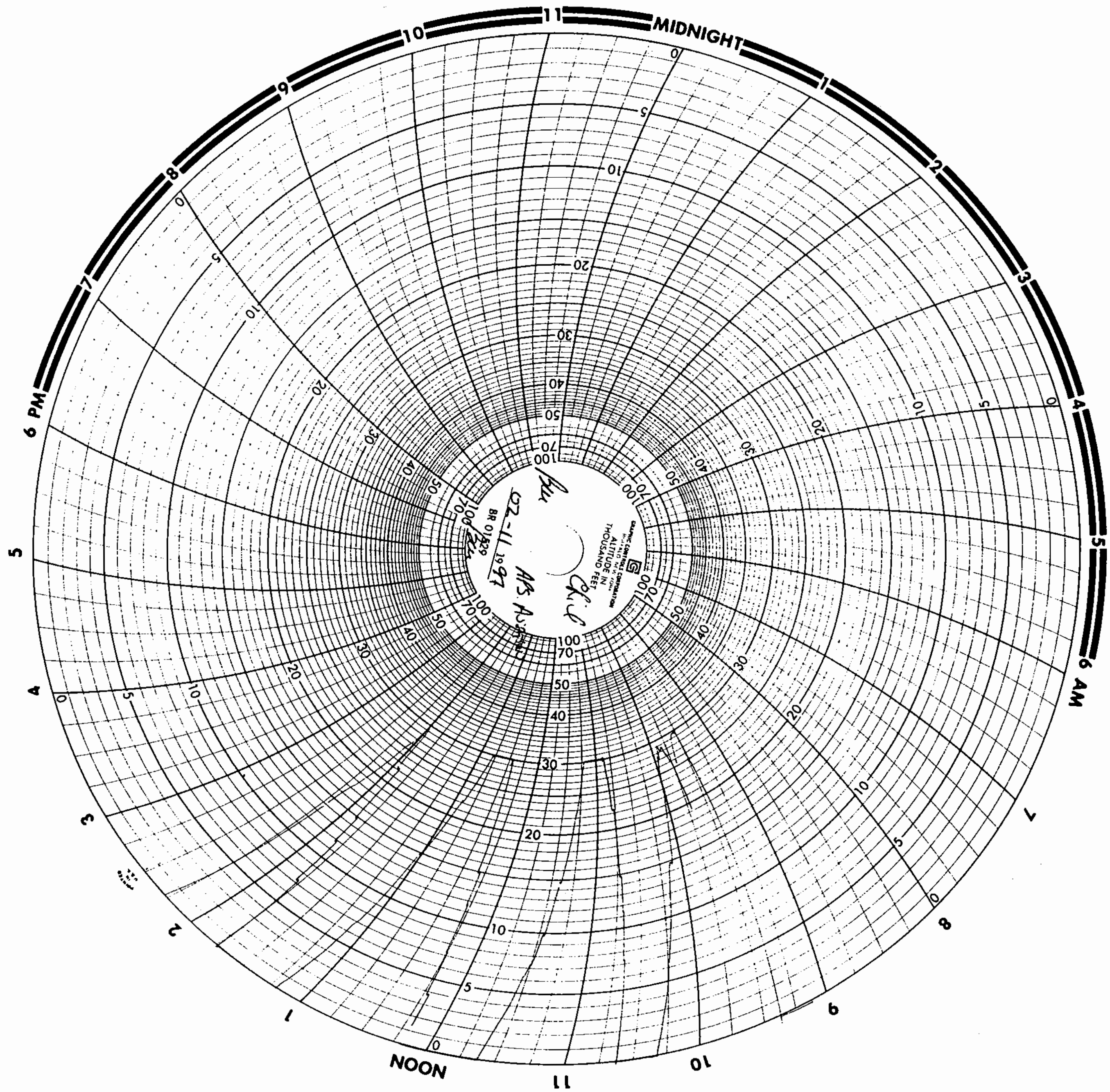


FIGURE 2.4
TEMPERATURE TRACE

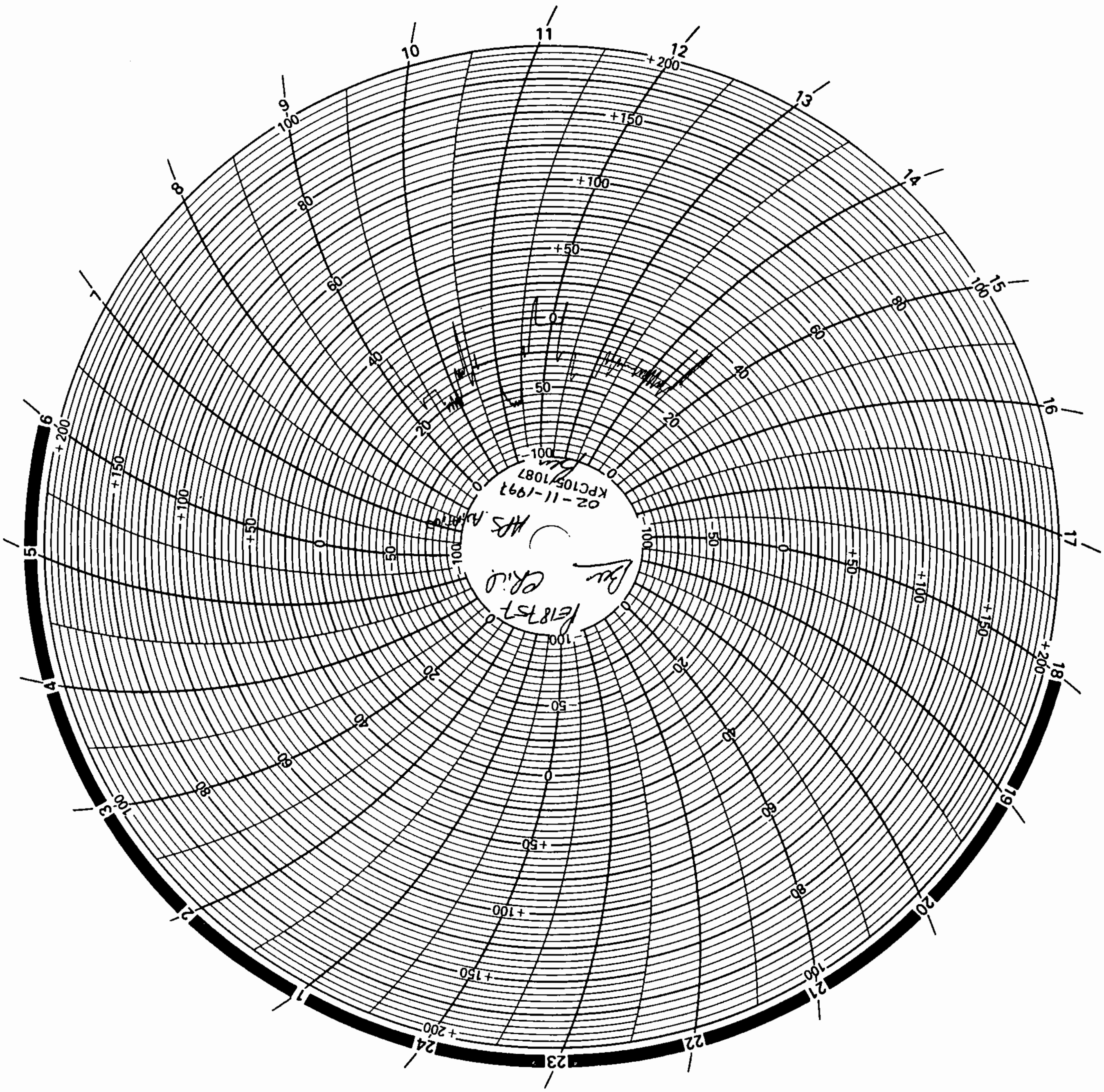


Photo 2.1
Decompression Chamber

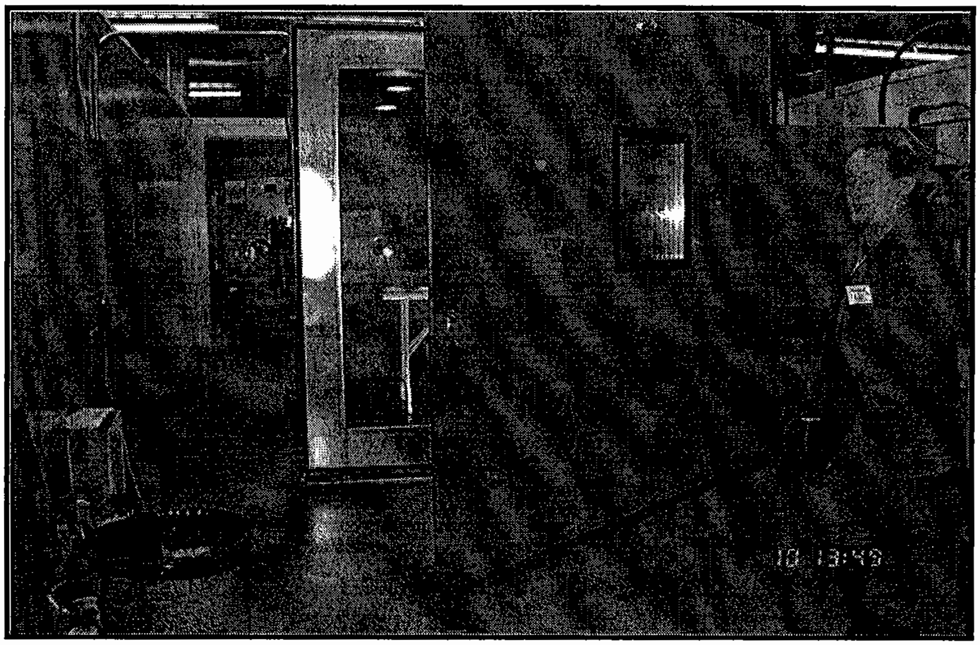


Photo 2.2
Decompression Chamber Instrumentation

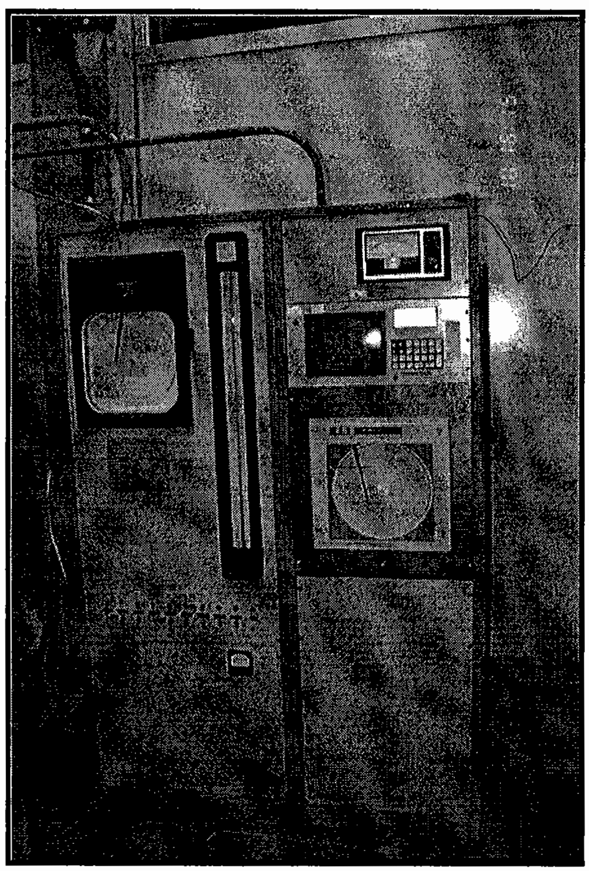


Photo 2.3
Vaisala Humidity Sensor

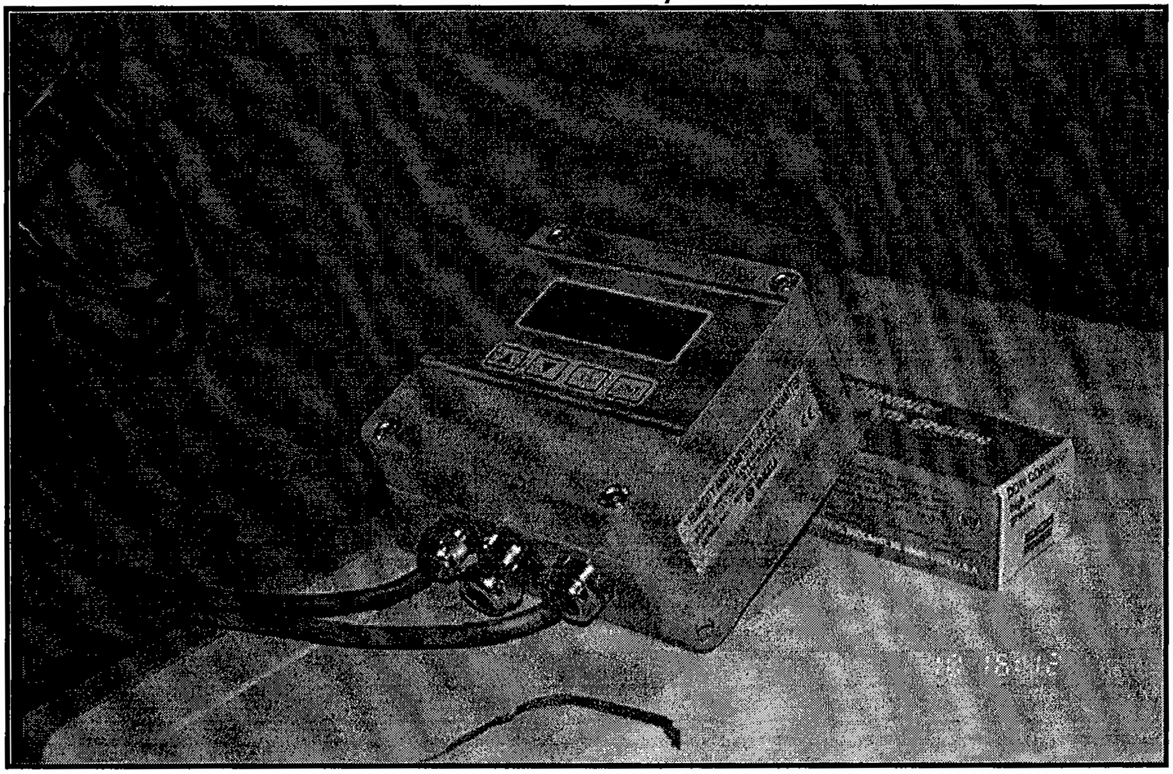


Photo 2.4
Humidity Sensor Installation

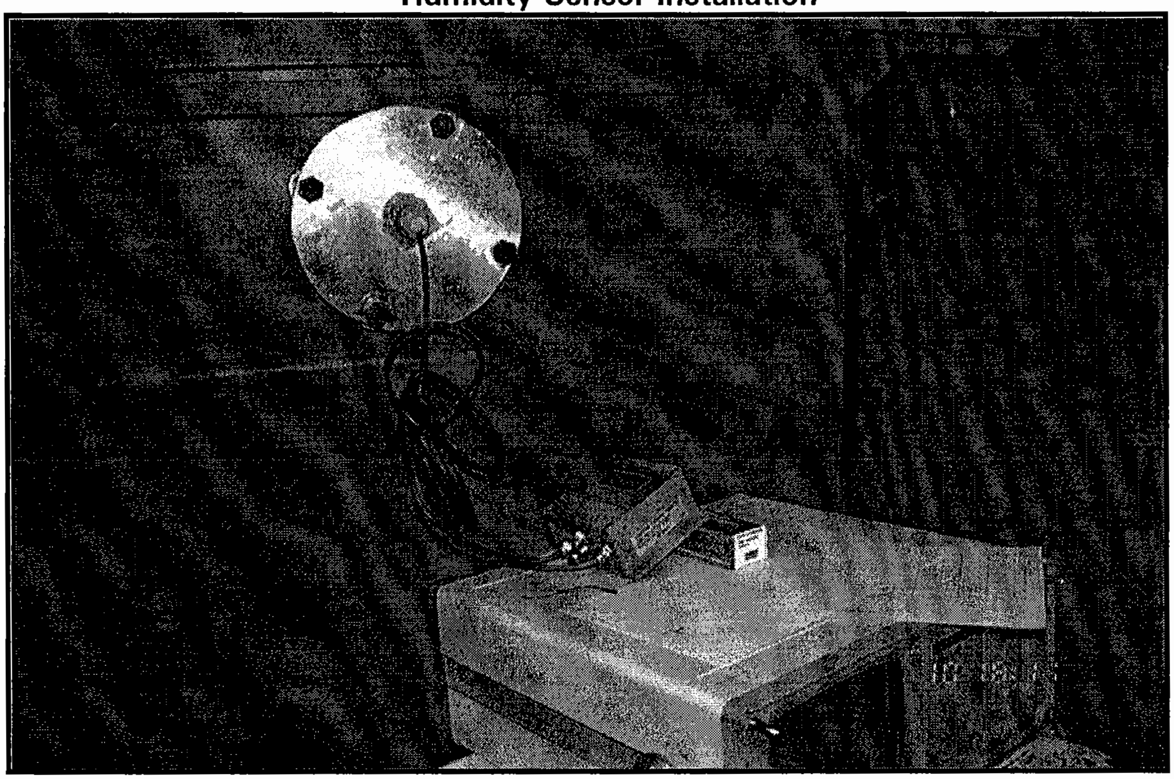
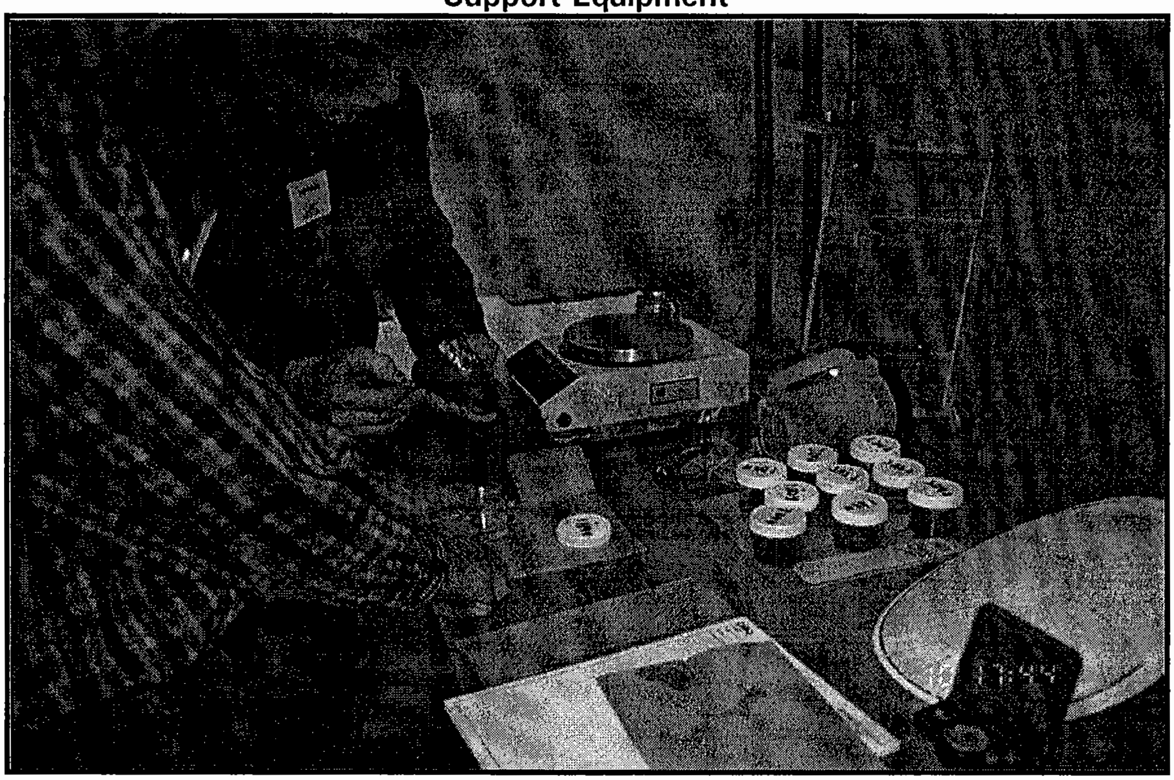


Photo 2.5
Setup in Chamber Showing Relative Humidity Sensor Head

Photo 2.6
Support Equipment



3. TEST DESCRIPTION, DATA AND OBSERVATIONS

3.1 Trials at CRIQ Altitude Chamber

3.1.1 Run # 1

Flight condition simulated;
- climb for 20 minutes
- cruise @ 9 100 m (30 000 ft) for 20 minutes
- descend 20 minutes
- temperature throughout @ -25°C

In this initial run, a delay of about 20 minutes was experienced following pouring of fluids into pans and placing in the chamber until decompression was initiated. During this period, the chamber temperature was lowered to -25°C.

Fluid weight after the flight showed a decrease ranging from 4% to 12%. Because some or all of the decrease could have occurred during the initial delay, the results of this test are not reliable. A subsequent test (Run # 6) was conducted to determine loss in fluids exposed to ambient laboratory conditions which measured fluid loss in the laboratory environment in the range from 15% to 25% in a 5 hour period.

Relative humidity in the chamber varied in cycles between 60% down to 15%. It was eventually determined that the cause of this variation was the intermittent operation of the chamber refrigeration equipment. Each time the cooling system turned on, frost formed on the cooling coils and relative humidity dropped, only to rise again when the cooling system turned off.

When the test was completed and the chamber door opened, it was noted that the walls and floor of the chamber were frosted.

3.1.2 Run # 2

Flight condition simulated;
- climb for 25 minutes @ -25°C
- cruise @ 10 700 m (35 000 ft) for 2 hours 15 minutes @ -40°C
- descend 20 minutes @ -25°C
- total flight time of 3 hours

In this run, new sets of fluids as well as fluid sets exposed to Run # 1 were tested.

Fluid weights decreased only 0.5 to 5.5% in this run, a lesser amount than in Run # 1 despite the longer duration. This was assumed to be due to the colder temperatures during the cruise phase.

Based on this result, the plan to conduct tests of five-hour flight duration was abandoned, and instead, tests of shorter duration but colder temperatures were planned.

3.1.3 Run # 3

Flight condition simulated;

climb for 20 minutes at -25°C
cruise at 9 100 m (30 000 ft) for 20 minutes at -40°C
descend 20 minutes at -25°C
total flight time of 1 hour

The same five fluid types were tested in this run.

Fluid weights following the run showed a slight increase for four of the fluids and a slight decrease for the fifth.

Relative humidity varied during the run, with the largest swings observed during the climb and descent phases. During the cruise phase, relative humidity varied from 45 to 29% .

3.1.4 Run # 4

Flight condition simulated;

climb for 20 minutes at -25°C
cruise at 9 100 m (30 000 ft) for 20 minutes at -60°C
descend 20 minutes at -25°C
total flight time of one hour

The same five fluid types were tested.

Again fluid weights following the run showed negligible change from start point.

3.1.5 Run # 5

This was a test to determine loss of pure tap water under similar altitude and temperature conditions. Water was placed in a pan, sufficient to cover the entire bottom surface. Because of the greater surface tension of the water, about 140 ml of water was tested.

Flight condition simulated;
climb for 20 minutes @ -25°C
cruise @ 9 100 m (30 000 ft) for 20 minutes @ -60°C
descend 20 minutes @ -25°C
total flight time of 1 hour

Weight loss during the test was approximately 4%. Crystals of frost were observed on top of the cake of ice in the pan.

3.1.6 Run # 6

This was a test of fluid loss in the ambient laboratory condition.

30 ml of each fluid type was poured in individual pans and exposed to the ambient laboratory condition. Pans were weighed several times to establish rate of fluid loss.

Over a five hour period, about 25% of the fluid was lost, except for Ultra+ which lost about 15%.

3.1.7 Run # 7

The purpose of this test was to measure fluid loss during the climb stage, eliminating the cruise stage.

Flight condition to be simulated;
climb for 20 minutes @ -25°C followed by immediate drop to sea level.

In fact due to chamber limitations the flight followed a profile as follows;
climb for 15 minutes @ -25°C
descend 15 minutes @ -25°C.

At the end of this run, fluid weight showed negligible change.

Table 3.1 presents a summary of these test results along with the test profile.

3.2 Preliminary Investigation at APS Premises

These preliminary trials were conducted for the sole purpose of providing an indication of the characteristics of each fluid as it progressively dried-out when exposed to ambient air. The ambient temperature was about 20°C during these trials.

TABLE 3.1

SUMMARY OF FLUID DRY-OUT TESTS RESULTS

Run		1	2	3	4	6	7
Climb	Time (min.)	20	25	20	20		20
Cruise	Time (min.)	20	135	20	20	(1) 5 hrs	0
	Altitude (1000 ft)	30	35	30	30	lab.	30
	Temp. (°C)	-25	-40	-40	-60	22	-25
Descent	Time (min.)	20	20	20	20		20

Fluid	Type	Initial brix	% wt loss/final Brix					
Kilfrost	IV	35.5	8.4/39.5	0.8/36.0	Nil/35.5	Nil/36.0	26.9/45.0	1.0
Hoechst	II	34.0	5.9/36.5	1.4/35.0	Nil/34.0	Nil/34.0	24.7/45.0	0.8
Octagon	IV	36.0	11.7/39	5.7/37.0	Nil/36.0	Nil/36.5	25.2/44.0	1.4
Hoechst	IV	34.5	3.9/36	0.5/34.5	Nil/34.5	Nil/35.0	24.5/44.0	0.1
Ultra+	IV	39.5	7.4/42.5	2.4/41.0	Nil/39.5	Nil/40.0	14.9/45.0	0.2
Water	(Run 5)					Nil/3.9		

(1) Relative Humidity in the laboratory was 29 to 32%.

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3.2.1 Hoechst MPIV 1957 Type IV

After three days of exposure, the consistency of this fluid had changed, appearing to have separated into two components; one being watery and loss viscous than the other. Within the fluid, white flakes at the bottom surface had formed. These were scattered where the fluid was thinnest, but joined to form a solid layer where fluid was thicker.

When the fluid eventually dried-out completely, the residue consisted of white rubbery skin or flakes. The flakes had the appearance of a salt-like substance, but when rubbed in the fingers, felt soft and rubbery. The residue was easily peeled off from the surface of the pan. This fluid was the first of the three types tested.

3.2.2 SPCA 404 Type IV

After three days of exposure, this fluid had become very thick and jellied. The fluid appeared viscous and a skin had formed on the top of the fluid.

This fluid remained viscous and gluey over the period until it finally dried-out.

When the fluid had dried-out completely, the residue consisted of a rubbery skin, which was easily peeled away from the surface.

3.2.3 Union Carbide Ultra+ Type IV

After three days of exposure, this fluid had become thin and watery throughout. The fluid remained in a state of watery consistency while progressing toward dry-out.

In a separate test of a larger amount of fluid, after an extended period of some months, an oily substance still remained. This residue was not sticky but felt like a heavy oil lubricant.

For all fluids, the Brix values progressively increased as the fluid volume decreased during dry-out.

4. DISCUSSION

4.1 Results of Trials at CRIQ Altitude Chamber

4.1.1 Loss of Fluid during Climb/Descent Stage

The test limited to climb and descent (Run # 7; climb to 9 100 m (30 000 ft) and descend; total 40 minutes) showed no net loss of fluid.

4.1.2 Loss of Fluid during Cruise Stage - Effect of Temperature

Runs # 1, 3 and 4 had identical climb/descent times, altitude and cruise times. A different temperature at altitude was established for each test (-25°C, -40°C, -60°C).

Tests conducted at -40°C and -60°C exhibited no loss of fluid. Fluid loss was observed in the test conducted at -25°C, but due to the delay in starting the experiment, this result can not be considered to be reliable.

4.1.3 Loss of Fluid during Cruise Stage - Effect of Time and Altitude

Results of Run # 2 can be compared to Run # 3. Cruise time for Run # 2 was 135 minutes versus 20 minutes for Run # 3, and altitude was 10 700 m (35 000 ft) versus 9 100 m (30 000 ft). Temperature was -40°C in both runs.

Fluid loss in Run # 2 ranged from 0.5% to 6% whereas no fluid loss was measured in Run # 3.

4.1.4 Loss of Fluid during Ground Stage

Fluid loss during exposure of fluids to ambient ground level laboratory conditions showed fluid loss for four of the fluids tested at about 25% over a five hour period. It is interesting to note that these fluids were all based on propylene glycol. The fifth fluid (which was based on ethylene glycol) experienced a 15% loss of fluid weight over the same period.

These rates of loss were considerably higher than those experienced at altitude (Run # 2).

4.2 Validity of Experiment

4.2.1 Altitude Chamber

The relative humidity in the chamber changed markedly each time the refrigerating unit cycled on, in some tests ranging between 15 and 60%. During the tests at -60°C the refrigeration unit operated almost continuously and relative humidity then experienced a smaller excursion between 18 to 27%.

The high relative humidity values seen in the chamber on a cycle basis reflect the properties of air at altitude where a very small amount of moisture is sufficient to saturate the air. In this experiment, the air in the surrounding laboratory and in the chamber prior to evacuation and cooling contained an absolute amount of humidity sufficient to produce a relative humidity reading (at sea level) of 30%. It is conjectured that when the chamber was sealed, evacuated and cooled, the initial amount of humidity in the air could no longer be supported, the air became saturated and water content was deposited as frost on chamber walls and on the cooling coils. Fogging of the air in the chamber did not occur. Any leakage of air from the laboratory environment into the evacuation chamber would have tended to renew and maintain the high relative humidity levels.

The degree of influence on results would depend on how faithfully the relative humidity value experienced in the altitude chamber during test reflected real relative humidity values of air at flight altitudes and temperatures. As noted, during the very cold test (-60°C) the cooling unit ran almost continuously producing values of relative humidity in the range between 18 to 27% , which may be typical of real conditions. In that event, the extent of fluid loss experienced during that test (which was too low to be measurable) would be a valid reflection of an actual flight.

4.2.2 Aircraft Ground Time versus Air Time

The approach taken in these tests addressed fluid dry-out during flight. In real operations, an aircraft may spend a significant portion of each day on the ground during scheduled turn-around, over-night parking, and other down time. Fluid residues on the wing would continue to dry-out during these periods, as evidenced in tests in which fluids were exposed to ambient ground level conditions.

Evaluation of fluid dry-out during ground time should be considered in any future testing.

4.3 Results of Investigations at APS Facilities

The consistency of two of the Type IV fluids observed during these preliminary trials (Hoechst and Ultra+) became fluid and watery after three days of exposure. Although the fluids were observed for a period beyond this phase, it is believed that the thin consistency of these fluids would have resulted in any fluid residues running off the aircraft prior to reaching the condition of complete dry-out. In that event, the reported nature of these two fluids at complete dry-out is irrelevant.

On the contrary, the third fluid (SPCA AD-404) became very thick and jellied. If this result was a reliable indicator of the nature of this fluid, then any residue of this fluid remaining on an aircraft might persist until complete dry-out was reached. At complete dry-out, the residue consisted of a rubber like skin which was easily peeled from the pan surface.

5. CONCLUSIONS

Evaporation of fluid during flight at typical jet flight altitudes and temperatures appears to be a very slow process. Fluid loss during ground time proceeds at a faster rate and aircraft time on ground may be the principal influence on time for fluid residues to dry-out.

The altitude chamber used in these trials was not designed to control humidity, and relative humidity in the chamber experienced wide variations during the tests. Although the inability to control humidity may have had some effect on the results, observations during the very cold test when the relative humidity was relatively stable and of low value indicate that the degree of influence was minor.

Observations of the nature of three fluids as they progressed toward dry-out in a ground level environment showed that two fluids quickly become thin and watery, which would promote draining of any fluid residues from the aircraft. The third fluid became thick and viscous, which would discourage it from draining from the aircraft.

Any further tests of fluid dry-out should consider the use of humidity/temperature control chambers to observe what actually happens to the fluid as it progresses toward dry-out. While observing dry-out in a humidity chamber would promote an understanding of the nature of the fluid, it would not provide a complete understanding of the fluid life on aircraft surfaces in operation, and the time to reach full dry-out. In real operations, periodic exposure of fluid residue on aircraft surfaces to precipitation would also impact the dry-out process.

6. RECOMMENDATIONS

Future trials to examine the nature of fluids as they progress toward dry-out should consider the use of a humidity/temperature control chamber as simulation of the impact of flight conditions does not appear necessary.

APPENDIX L

COMPARISON OF SPECIFIC FLUIDS TO THE *WORST CASE* FLUID

COMPARISON OF SPECIFIC FLUIDS TO THE *WORST CASE* FLUID

The following figures (Figures L.1 to L.5) are of the same form as Figures 5.10 to 5.14 except that they indicate the percent enhancement the individual fluids exhibit relative to the *worst case* table on a cell-by-cell basis. Each figure shows all cells for a particular type of precipitation.

As an example, consider the centre cell of Figure L.2, which compares the percent enhancements of individual Type IV 75/25 fluid in the snow category (in the temperature range of 0 to -3°C) relative to the *worst case* holdover times for these same conditions. Only two of the five individual fluids exhibit average holdover times greater than 50%, relative to the *worst case* table cell. According to the intended proposal, only these two fluids should receive credit for increased protection. Figures L.6 to L.10 show the *fluid-specific* tables generated from these considerations. The holdover times in these tables which have been credited with increased protection appear in large print and can be compared with identical cell values from the *worst case* table shown in Table 5.4.

FIGURE L.1

COMPARISON OF SPECIFIC FLUIDS TO WORST CASE FLUID (%)

REGRESSION METHOD

FREEZING FOG

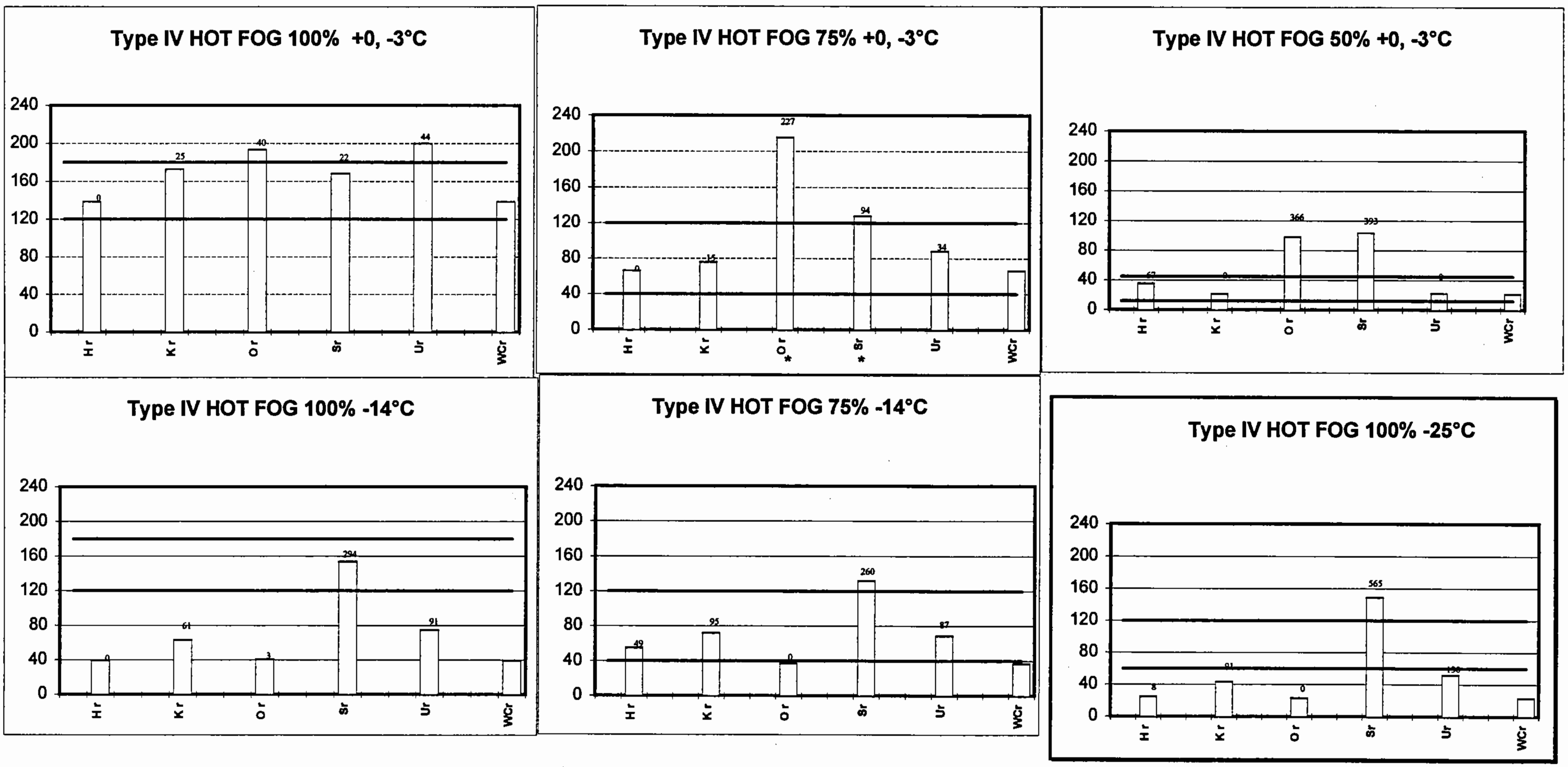

FIGURE L.2

COMPARISON OF SPECIFIC FLUIDS TO WORST CASE FLUID (%)

REGRESSION METHOD

SNOW

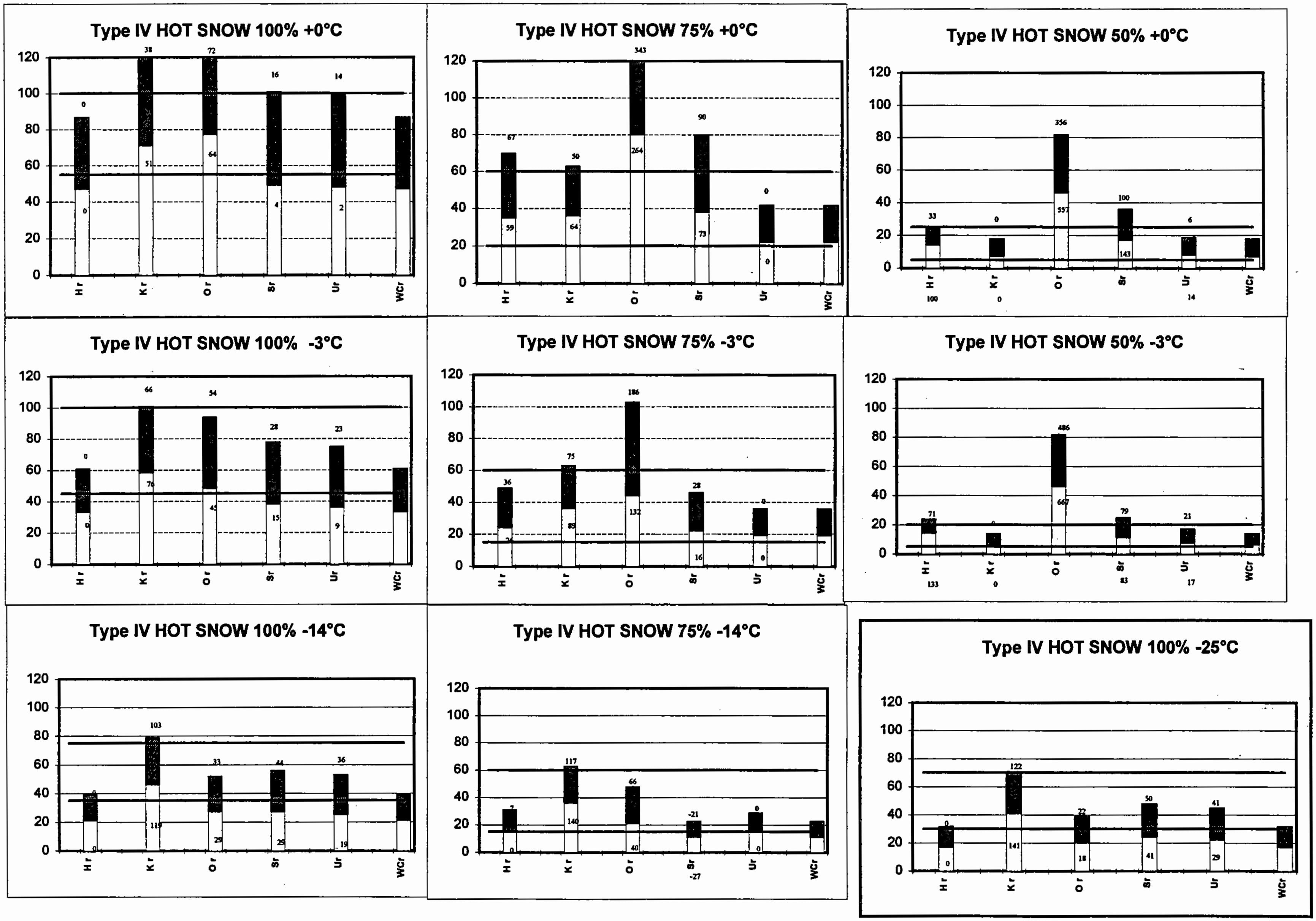

FIGURE L.3

COMPARISON OF SPECIFIC FLUIDS TO WORST CASE FLUID (%)

REGRESSION METHOD

FREEZING DRIZZLE

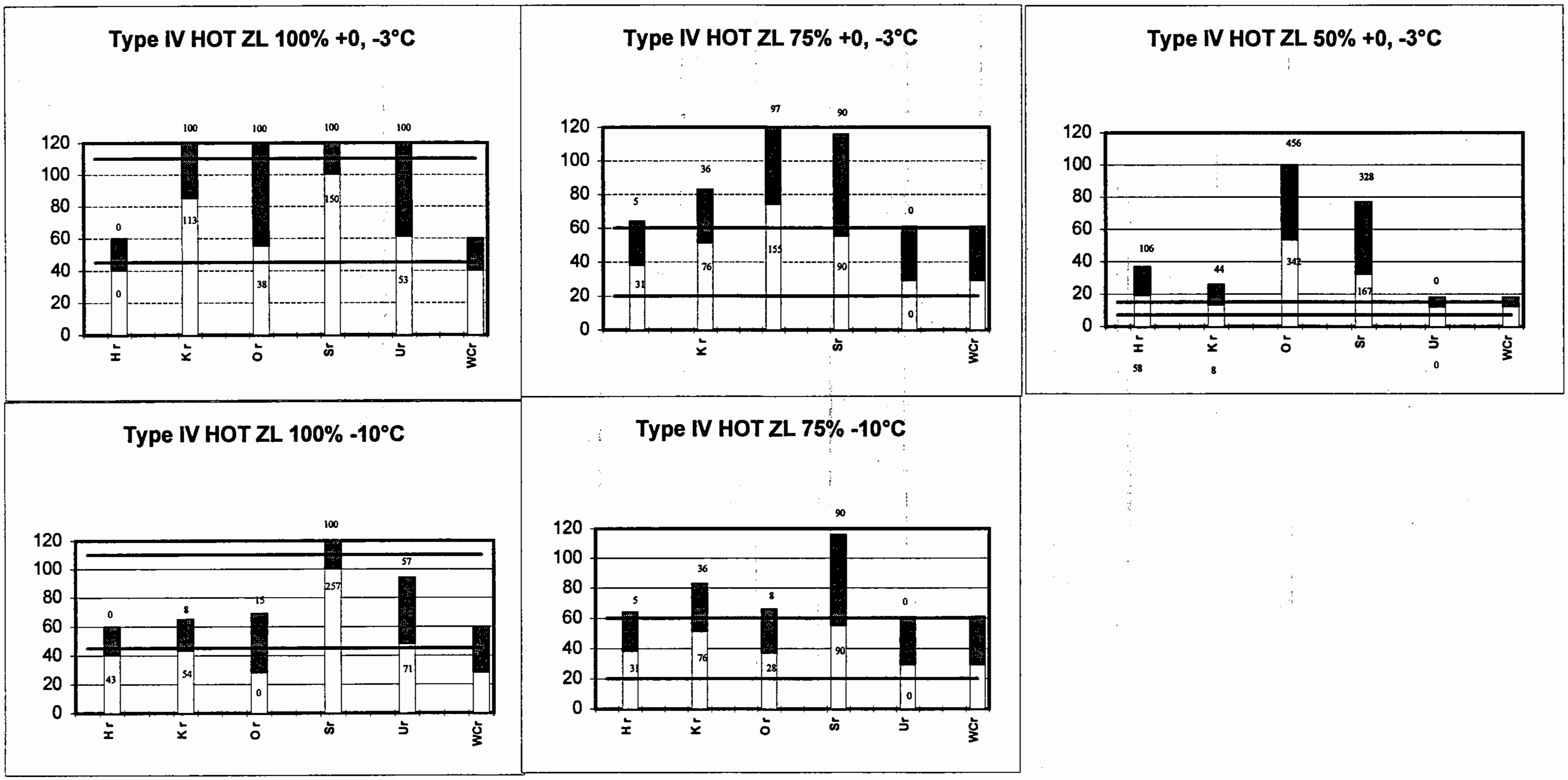

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FIGURE L.4

COMPARISON OF SPECIFIC FLUIDS TO WORST CASE FLUID (%)

REGRESSION METHOD

LIGHT FREEZING RAIN

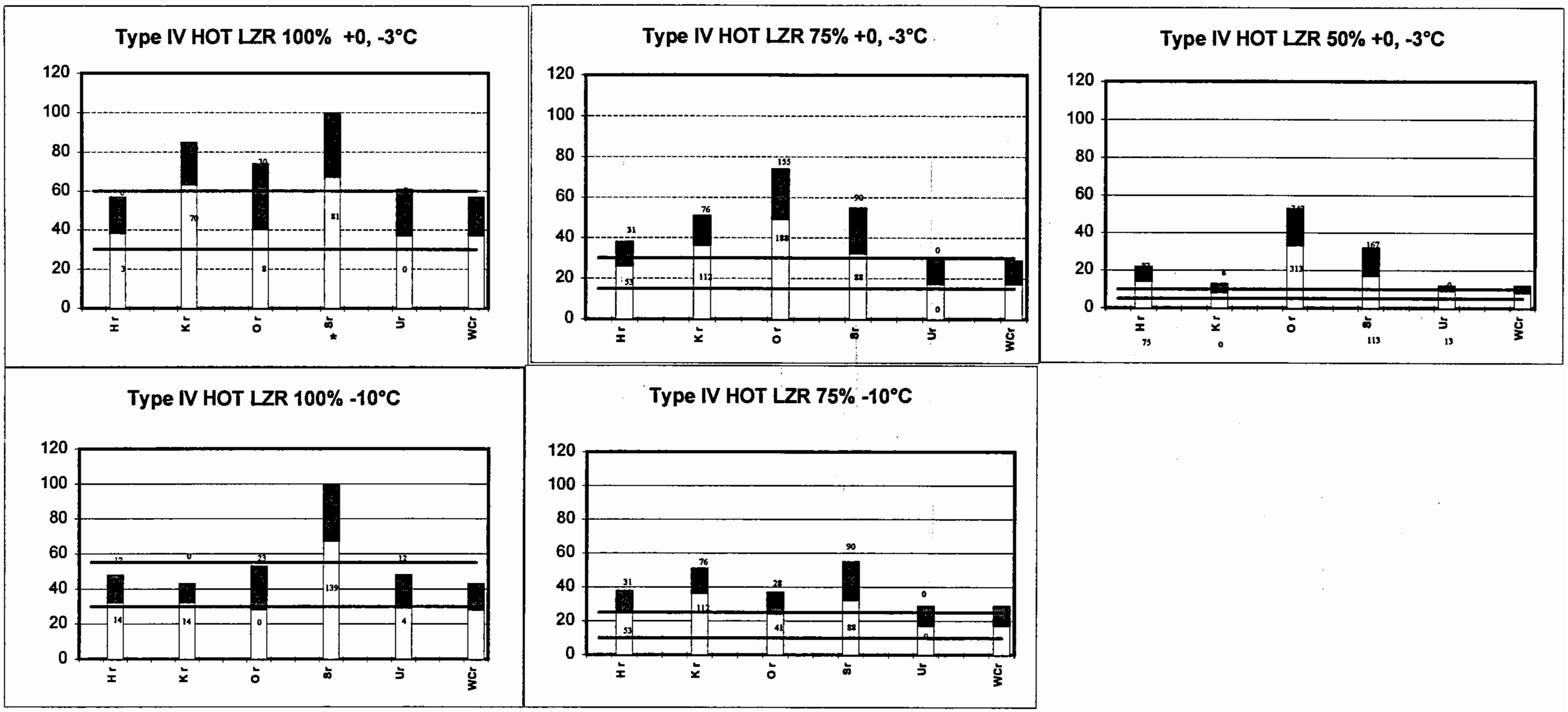

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FIGURE L.5

COMPARISON OF SPECIFIC FLUIDS TO WORST CASE FLUID (%)

REGRESSION METHOD

COLD-SOAKED WING

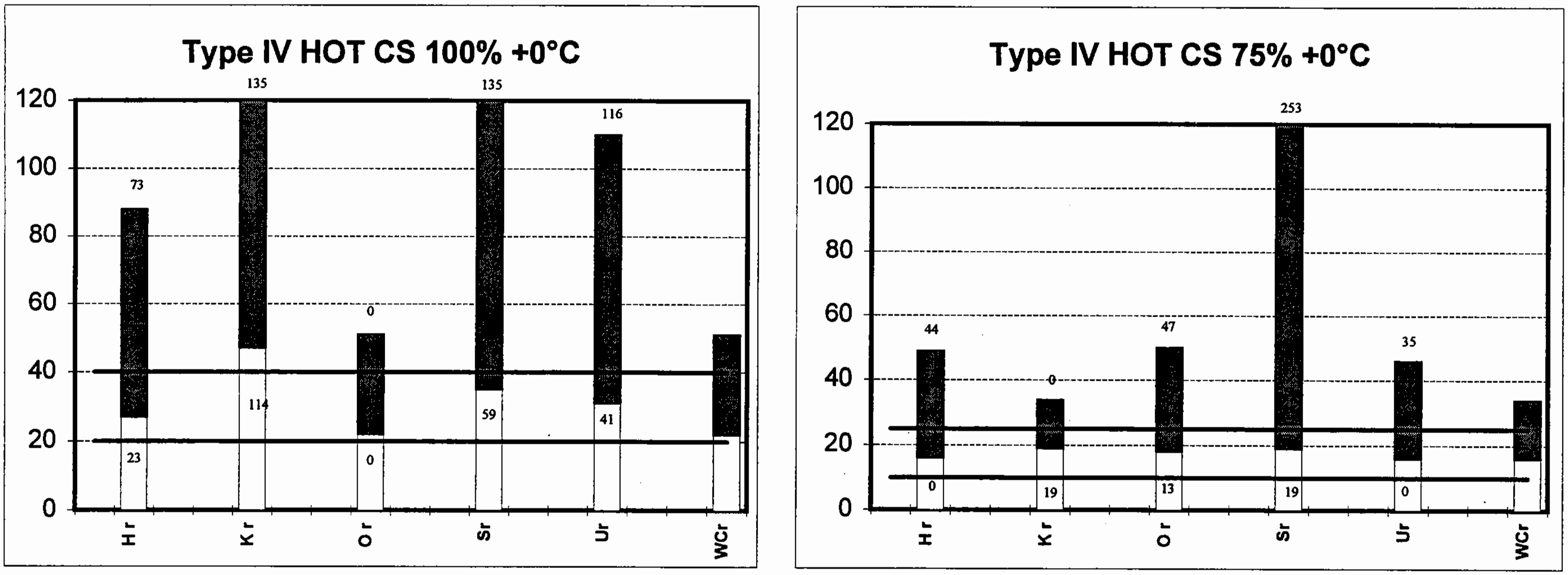

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FIGURE L.6

SAE TYPE IV CURRENT/PROPOSED HOT'S

Regression Method

FLUID C-?00 SPECIFIC HOT TABLE

Based on > = 50% Superior Performance

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	*FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	DRIZZLE OR LIGHT RAIN ON COLD SOAKED WING
			Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
above 0°	above 32°	100/0	18:00	2:00-3:00 138	0:55-1:40 47-87	0:45-1:50 40-60	0:30-1:00 37-57	0:20-0:40 31-110
		75/25	06:00	0:40-2:00 66	0:20-1:00 22-42	0:20-1:00 29-61	0:15-0:30 17-29	0:10-0:25 16-34
		50/50	04:00	0:15-0:45 21	0:05-0:25 7-18	0:07-0:15 12-18	0:05-0:10 8-12	
0 to -3	32 to 27	100/0	12:00	2:00-3:00 138	0:45-1:40 33-61	0:45-1:50 40-60	0:30-1:00 37-57	
		75/25	05:00	0:40-2:00 66	0:15-1:00 19-36	0:20-1:00 29-61	0:15-0:30 17-29	
		50/50	03:00	0:15-0:45 21	0:05-0:20 6-14	0:07-0:15 12-18	0:05-0:10 8-12	
below -3 to -14	below 27 to 7	100/0	12:00	2:00-3:00 74	0:35-1:15 21-39	**0:45-1:50 48-94	**0:30-0:55 28-43	
		75/25	05:00	0:40-2:00 68	0:15-1:00 *15-29	**0:20-1:00 29-61	**0:10-0:25 17-29	
below -14 to -25	below 7 to -13	100/0	12:00	1:00-2:00 51	0:30-1:10 17-32			
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.					

* Insufficient data for fluid C-702, used fluid C-707/C-700

Firm

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FIGURE L.7

SAE TYPE IV CURRENT/PROPOSED HOT'S

Regression Method

FLUID C-?02 SPECIFIC HOT TABLE

Based on > = 50% Superior Performance

OAT		Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
°C	°F		*FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	DRIZZLE OR LIGHT RAIN ON COLD SOAKED WING
above 0°	above 32°	100/0	18:00	2:00-3:00 138	0:55-1:40 47-87	0:45-1:50 40-60	0:30-1:00 37-57	0:20-0:40 22-51
		75/25	06:00	0:40-2:00 66	0:20-1:00 22-42	0:20-1:00 29-61	0:15-0:30 32-55	0:10-0:25 16-34
		50/50	04:00	0:15-0:45 21	0:05-0:25 7-18	0:07-0:15 32-77	0:05-0:10 17-32	
0 to -3	32 to 27	100/0	12:00	2:00-3:00 138	0:45-1:40 33-61	0:45-1:50 40-60	0:30-1:00 37-57	
		75/25	05:00	0:40-2:00 66	0:15-1:00 19-36	0:20-1:00 29-61	0:15-0:30 32-55	
		50/50	03:00	0:15-0:45 21	0:05-0:20 6-14	0:07-0:15 32-77	0:05-0:10 17-32	
below -3 to -14	below 27 to 7	100/0	12:00	2:00-3:00 39	0:35-1:15 21-39	**0:45-1:50 28-60	**0:30-0:55 28-43	
		75/25	05:00	0:40-2:00 36	0:15-1:00 *15-29	**0:20-1:00 29-61	**0:10-0:25 32-55	
below -14 to -25	below 7 to -13	100/0	12:00	1:00-2:00 22	0:30-1:10 17-32			
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.					

* Insufficient data for fluid C-702, used fluid C-707/C-700

Firm

Change Based on Firm Number from Colder Condition

Increased Because Lower Limit was Increased

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FIGURE L.8

SAE TYPE IV CURRENT/PROPOSED HOT'S

Regression Method

FLUID C-?07 SPECIFIC HOT TABLE

Based on > = 50% Superior Performance

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	DRIZZLE OR LIGHT RAIN ON COLD SOAKED WING
above 0°	above 32°	100/0	18:00	2:00-3:00 138	0:55-1:40 47-87	0:45-1:50 40-60	0:30-1:00 37-57	0:20-0:40 22-51
		75/25	06:00	0:40-2:00 66	0:20-1:00 22-42	0:20-1:00 29-61	0:15-0:30 17-29	0:10-0:25 16-34
		50/50	04:00	0:15-0:45 35	0:05-0:25 14-24	0:07-0:15 18-36	0:05-0:10 14-22	
0 to -3	32 to 27	100/0	12:00	2:00-3:00 138	0:45-1:40 33-61	0:45-1:50 40-60	0:30-1:00 37-57	
		75/25	05:00	0:40-2:00 66	0:15-1:00 19-36	0:20-1:00 29-61	0:15-0:30 17-29	
		50/50	03:00	0:15-0:45 35	0:05-0:20 14-24	0:07-0:15 18-36	0:05-0:10 14-22	
below -3 to -14	below 27 to 7	100/0	12:00	2:00-3:00 39	0:35-1:15 21-39	**0:45-1:50 28-60	**0:30-0:55 28-43	
		75/25	05:00	0:40-2:00 54	0:15-1:00 *15-29	**0:20-1:00 29-61	**0:10-0:25 17-29	
below -14 to -25	below 7 to -13	100/0	12:00	1:00-2:00 22	0:30-1:10 17-32			
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.					

* Insufficient data for fluid C-702, used fluid C-707/C-700

Firm

<u>Change Based on Firm Number from Colder Condition</u>

FIGURE L.9

SAE TYPE IV CURRENT/PROPOSED HOT'S

Regression Method

FLUID C-?08 SPECIFIC HOT TABLE

Large #'s Based on > = 50% Superior Performance

OAT		Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
°C	°F		*FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	DRIZZLE OR LIGHT RAIN ON COLD SOAKED WING
above 0°	above 32°	100/0	18:00	2:00-3:00 138	0:55-1:40 47-87	0:45-1:50 55-120	0:30-1:00 37-57	0:20-0:40 22-51
		75/25	06:00	0:40-2:00 66	0:20-1:00 22-103	0:20-1:00 74-120	0:15-0:30 49-74	0:10-0:25 16-34
		50/50	04:00	0:15-0:45 97	0:05-0:25 7-82	0:07-0:15 53-100	0:05-0:10 33-53	
0 to -3	32 to 27	100/0	12:00	2:00-3:00 138	0:45-1:40 48-94	0:45-1:50 55-120	0:30-1:00 37-57	
		75/25	05:00	0:40-2:00 66	0:15-1:00 19-103	0:20-1:00 74-120	0:15-0:30 49-74	
		50/50	03:00	0:15-0:45 97	0:05-0:20 6-82	0:07-0:15 53-100	0:05-0:10 33-53	
below -3 to -14	below 27 to 7	100/0	12:00	2:00-3:00 39	0:35-1:15 21-39	**0:45-1:50 28-60	**0:30-0:55 28-43	
		75/25	05:00	0:40-2:00 36	0:15-1:00 21-48	**0:20-1:00 29-61	**0:10-0:25 17-29	
below -14 to -25	below 7 to -13	100/0	12:00	1:00-2:00 22	0:30-1:10 17-32			
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.					

Firm

Change Based on Firm Number from Colder Condition

FIGURE L.10

SAE TYPE IV CURRENT/PROPOSED HOT'S

Regression Method

FLUID C-?09 SPECIFIC HOT TABLE

Based on > = 50% Superior Performance

OAT °C	OAT °F	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	*FROST	FREEZING FOG	SNOW	***FREEZING DRIZZLE	LIGHT FRZ RAIN	DRIZZLE OR LIGHT RAIN ON COLD SOAKED WING
			Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
above 0°	above 32°	100/0	18:00	2:00-3:00 138	0:55-1:40 *71-120*	0:45-1:50 *85-120*	0:30-1:00 *63-85*	0:20-0:40 22-51
		75/25	06:00	0:40-2:00 66	0:20-1:00 36-63	0:20-1:00 51-83	0:15-0:30 17-29	0:10-0:25 16-34
		50/50	04:00	0:15-0:45 21	0:05-0:25 7-18	0:07-0:15 12-18	0:05-0:10 8-12	
0 to -3	32 to 27	100/0	12:00	2:00-3:00 138	0:45-1:40 58-79	0:45-1:50 *85-120*	0:30-1:00 *63-85*	
		75/25	05:00	0:40-2:00 66	0:15-1:00 36-63	0:20-1:00 51-83	0:15-0:30 17-29	
		50/50	03:00	0:15-0:45 21	0:05-0:20 6-14	0:07-0:15 12-18	0:05-0:10 8-12	
below -3 to -14	below 27 to 7	100/0	12:00	2:00-3:00 62	0:35-1:15 46-79	**0:45-1:50 28-60	**0:30-0:55 28-43	
		75/25	05:00	0:40-2:00 36	0:15-1:00 36-63	**0:20-1:00 29-61	**0:10-0:25 17-29	
below -14 to -25	below 7 to -13	100/0	12:00	1:00-2:00 43	0:30-1:10 17-32			
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.					

Firm

<u>Change Based on Firm Number from Colder Condition</u>

Increased Because Lower Limit was Increased

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APPENDIX M

DEICING FLUID EVAPORATION TRIALS

1. BACKGROUND

This supplemental series of tests was conducted following discussions with a North American carrier. This operator was very interested in the possibility of installing a procedure for removing contamination following the end of a storm with a very low concentrate deicing fluid, and without an overspray of anti-icing fluid. A typical operating situation would be instances when overnight snow has ceased prior to morning start-up, and aircraft wings require deicing prior to first flight. As snow fall has ceased, there is no operational requirement for a holdover time. The objective of achieving maximum economic benefits would be met only if the concentration level of the deicing fluid was not limited by the current freeze point buffer of 10°C as specified in SAE ARP4737.

To better understand the implications of this approach and any potential risks associated with it, it was decided to conduct trials on flat plates to determine what happens when a heated deicing fluid of a range of concentrations is applied without a subsequent overspray of anti-icing fluid. Does the fluid film evaporate or freeze? Is the result a bare, dry surface? What is the impact of evaporation on the concentration of any fluid residue that is left behind?

2. OBJECTIVES

The objectives of this series of trials were:

- To determine whether a bare dry surface resulted from application of a heated deicing fluid at low concentration; and

- To determine the effect of evaporation on the concentration of any fluid remaining on the plate surface.

Variables considered in the trials were:
- Fluid concentration;
- Ambient air temperature;
- Condition of plate surface;
- Quantity of fluid applied;
- Slope of test surface;
- Impact of snow on test surface; and
- Use of cold-soaked boxes.

3. PROCEDURES

3.1 Test Sites

These tests were conducted at the APS test site at Dorval Airport and in the National Research Council Climatic Engineering Facility at Ottawa.

To eliminate influence of wind on results, tests at the APS site were conducted inside the site trailer. Photo 3.1 (photos are included at the end of this section) shows a test set-up inside the trailer, with a cold-soaked box mounted on a plate stand. Initial tests were conducted at the APS site at ambient temperatures in the range of -5°C or higher. Later tests were conducted at the National Research Council Climatic Engineering Facility in colder temperatures near -10°C. In one test, natural snow was carried from outdoors and scattered on the test plate.

3.2 Equipment

Principal equipment included in these trials was;

- Flat plates on test stand, mounted at 10° and 2° to the horizontal;
- Cold-soaked boxes, 2.5 and 7.5 cm (1 and 3") deep;
- Thermistor sensors, temperature loggers and software;
- Brixometer;
- Temperature probe;
- Thickness gauges;
- Kettles for heating fluids; and
- Still and video cameras.

The flat test plates were buffed with Scotchbrite pads prior to test.

In one test, a new plate with a smooth polished surface was used. In one test, the test plate was treated with BFGoodrich Ice EX water repellent.

Photo 3.2 shows plates with thermistor sensors installed, mounted on the test stands.

3.3 Test Procedures and Data Forms

A test plan (Table 3.1) was structured to conduct trials at different temperatures and fluid concentrations. Other variables were included on a one time basis.

The parameters for standard trials were:

- Flat plate used in holdover time trials, but with surface cleaned with Scotchbrite pads;

- Plate slope at 10°;
- Fluid heated to 80°C;
- Fluid concentration at 2%, 10%, and standard; and
- Ambient temperature in range 0 to -5°C and -8 to -13°C.

In preparation for test, thermistors (two) were mounted on the flat plates at the 15 cm (6") line. Plates were mounted on the stand at the desired slope. The standard slope for these tests was 10°. In one run, a 2° slope was tested to assess impact of different slopes.

For each run, the desired concentration of fluid was prepared, and then heated in a kettle to 80°C. The fluid was poured on the plate and results were observed. The pattern and extent of surface coverage was noted and sketched at 5, 10, 15, and 20 minutes following pouring of fluid. Photo 3.3 shows a typical fluid/bare surface pattern on a plate. Photo 3.4 is another view of the streaking on the surface as it dries out. In this view, the bead of fluid at the bottom edge can be seen.

Fluid initial Brix values were measured prior to heating, and final values for any fluid residue on plates were measured (Photo 3.5). Some tests were rerun to allow measurement of fluid thickness without disturbing other test parameters (Photos 3.6 & 3.7).

Cold-soaked boxes with depths of 2.5 and 7.5 cm (1 and 3") were used on two test occasions to examine the impact of their heat sink properties. The box temperatures were the same as ambient temperature (not cold-soaked) for these runs.

Data were recorded on Hot Fluid Test Form shown in Figure 3.1.

3.4 Fluids

Fluids tested were Union Carbide ADF at concentrations of 2%, 10% and standard strength XL54. Water was used in one test. All fluids were heated to 80°C prior to pouring on plates.

3.5 Personnel and Participation

APS Aviation staff prepared and performed the tests, and gathered and analysed the data.

TABLE 3.1

TEST PLAN FOR FLUID EVAPORATION TESTS

TEST #	FLUID #	SURFACE TYPE	FLUID QUANTITY Litres	SLOPE	COMMENTS
1	XL54	STD	50%	10°	STD Base Case
2	XL54	STD	50%	10°	Duplicate # 1
3	XL54	STD	50%	10°	Brix Curve
4	XL54	STD	50%	10°	Dye Test for Video
5	10%	STD	50%	10°	Concentration Effect
6	2%	STD	50%	10°	Concentration Effect
7	Water	STD	50%	10°	Concentration Effect
8	XL54	STD	150%	10°	Quantity Effect
9	XL54	2.5 cm BOX	50%	10°	Heat Sink Effect
10	XL54	7.5 cm BOX	50%	10°	Heat Sink Effect
11	XL54	New plate	50%	10°	Surface Condition
12	XL54	STD	50%	2°	Slope Effect
13	XL54	STD	50%	10°	Temperature Effect
14	2%	STD	50%	10°	Brix Effect
15	2%	STD	50%	10°	Duplicate # 11
16	2%	STD	50%	10°	Duplicate # 2

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FIGURE 3.1

HOT FLUID TEST FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

VERSION 4.0

LOCATION:	DATE:	TEST # :	TIME OF FLUID APPLICATION:

AIR TEMPERATURE: ____ °C BOX SIZE: 2.5 / 7.5 cm

FLUID TEMP.: ______ °C SURFACE TYPE: STD / CLADDED

PLATE ANGLE: _______ ° FLUID: WATER / XL54 / 2% / 10%

WIND SPEED _______ kph FLUID QUANTITY: 0.5 L / 1.5 L

THERMISTOR #'s: _______

BRIX BEFORE POURING: _______

BRIX OF FLUID LEFT ON PLATE AFTER 20 MINUTES: _______

____

____

THICKNESS OF FLUID AFTER 20 MINUTES: _______

____

OTHER COMMENTS (Fluid Batch, etc):

____

____

____

____

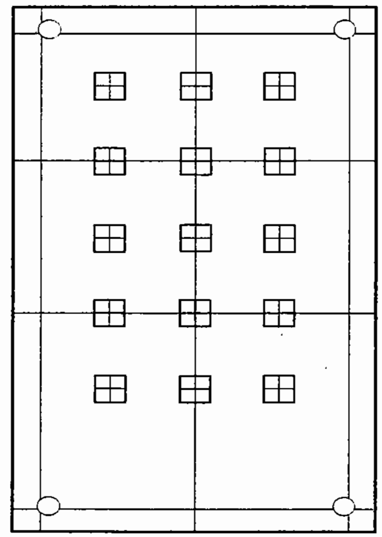
____

____

	PRINT	SIGN
OBSERVATIONS BY :		
HAND WRITTTEN BY :		
TEST SITE LEADER :		

TIME ____________

% Dry: 0-5 / 5-25 / 25-50 / 50-75 / 75-95 / 95-100%



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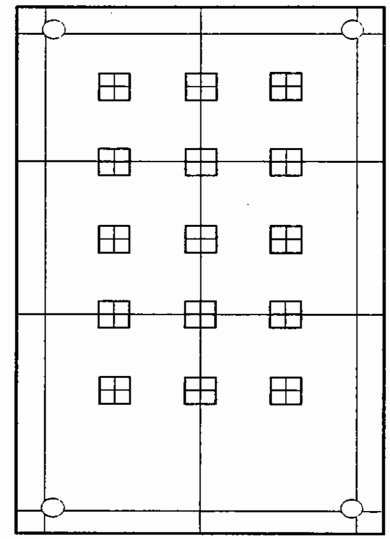
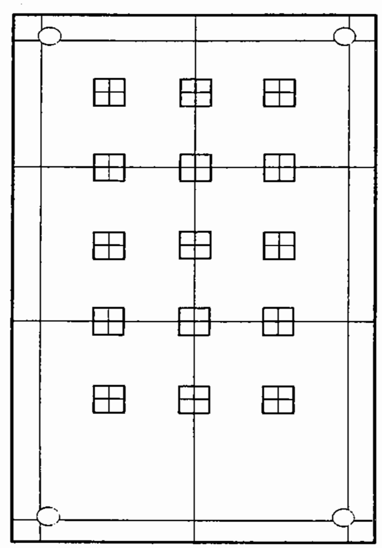
% Dry: 0-5 / 5-25 / 25-50 / 50-75 / 75-95 / 95-100%



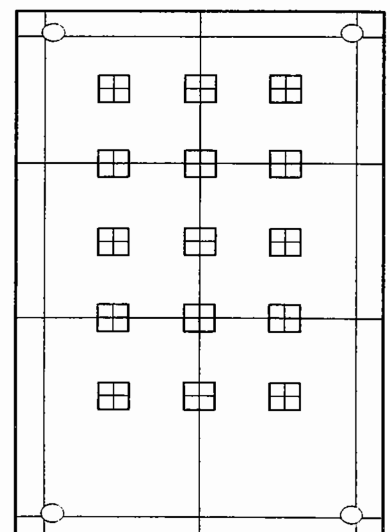
TIME ____________

% Dry: 0-5 / 5-25 / 25-50 / 50-75 / 75-95 / 95-100%



____

% Dry: 0-5 / 5-25 / 25-50 / 50-75 / 75-95 / 95-100%



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3.6 Analysis Methodology

Test data was entered on a Microsoft Excel spreadsheet for analysis. Processed data was presented in the form of bar charts to enable comparison of results of different test parameters.

Photo 3.1
Test Setup

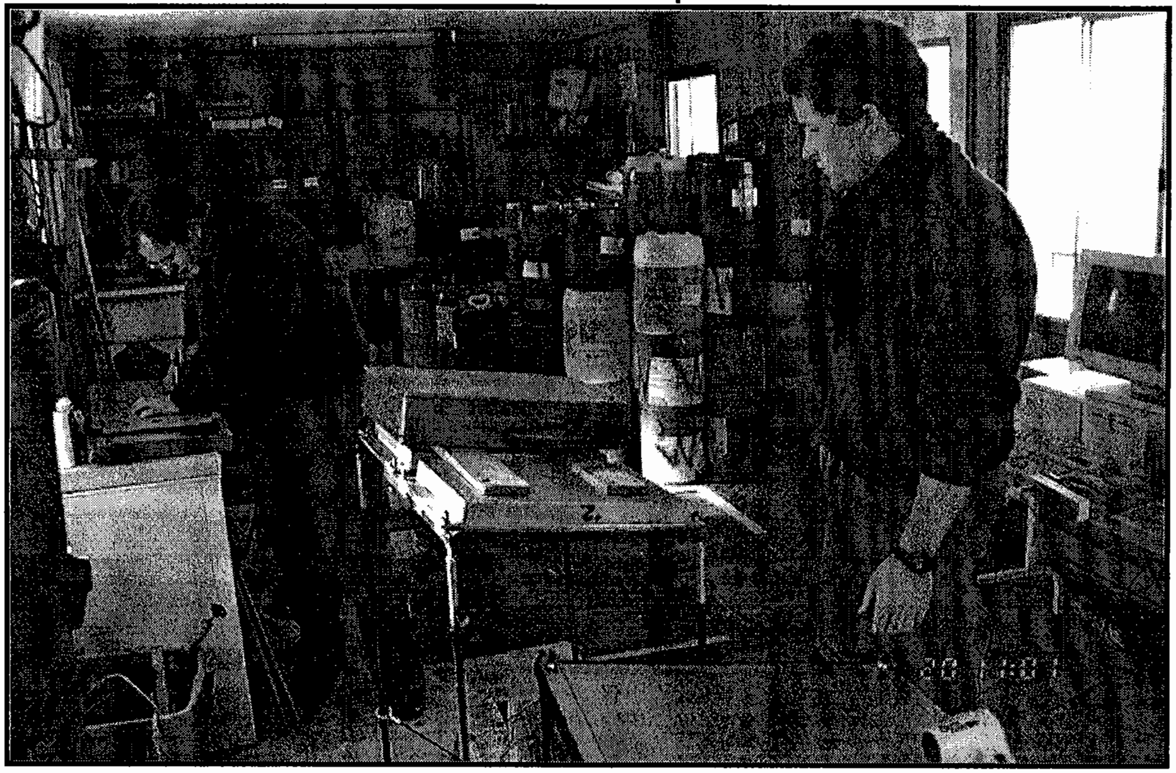


Photo 3.2
Test Plate with Thermistor Sensors

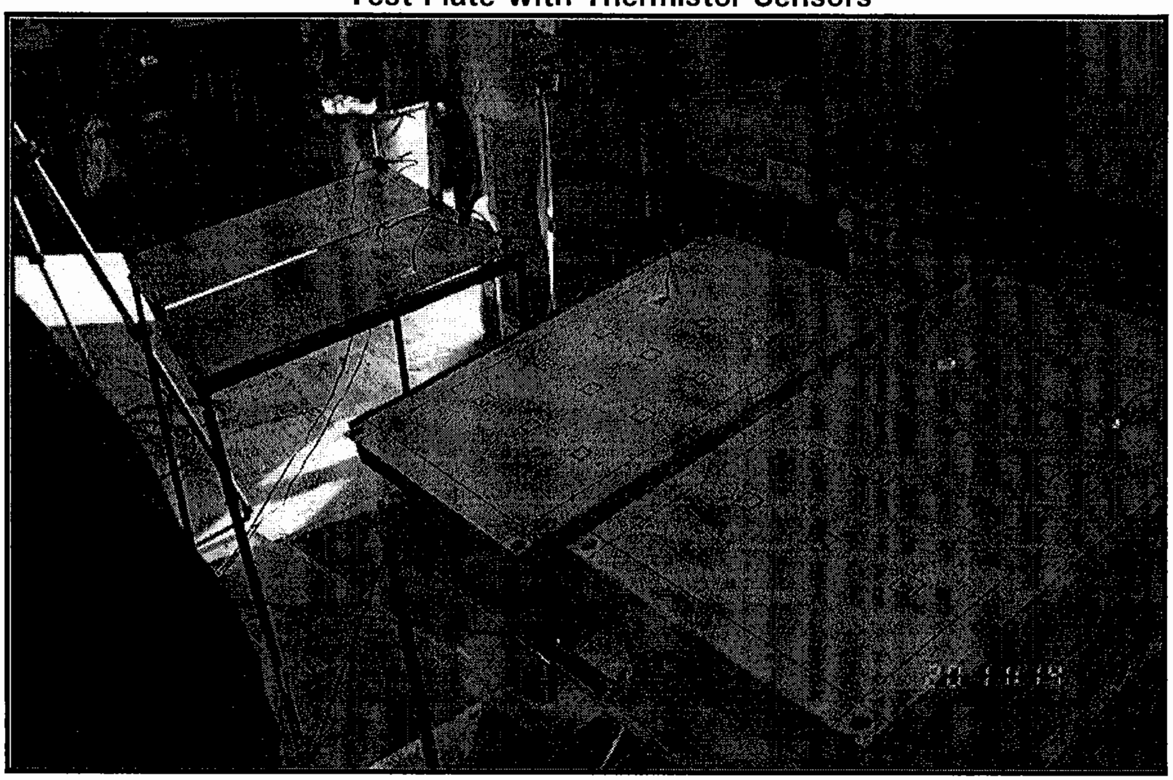


Photo 3.3
Surface Dry-Out Pattern

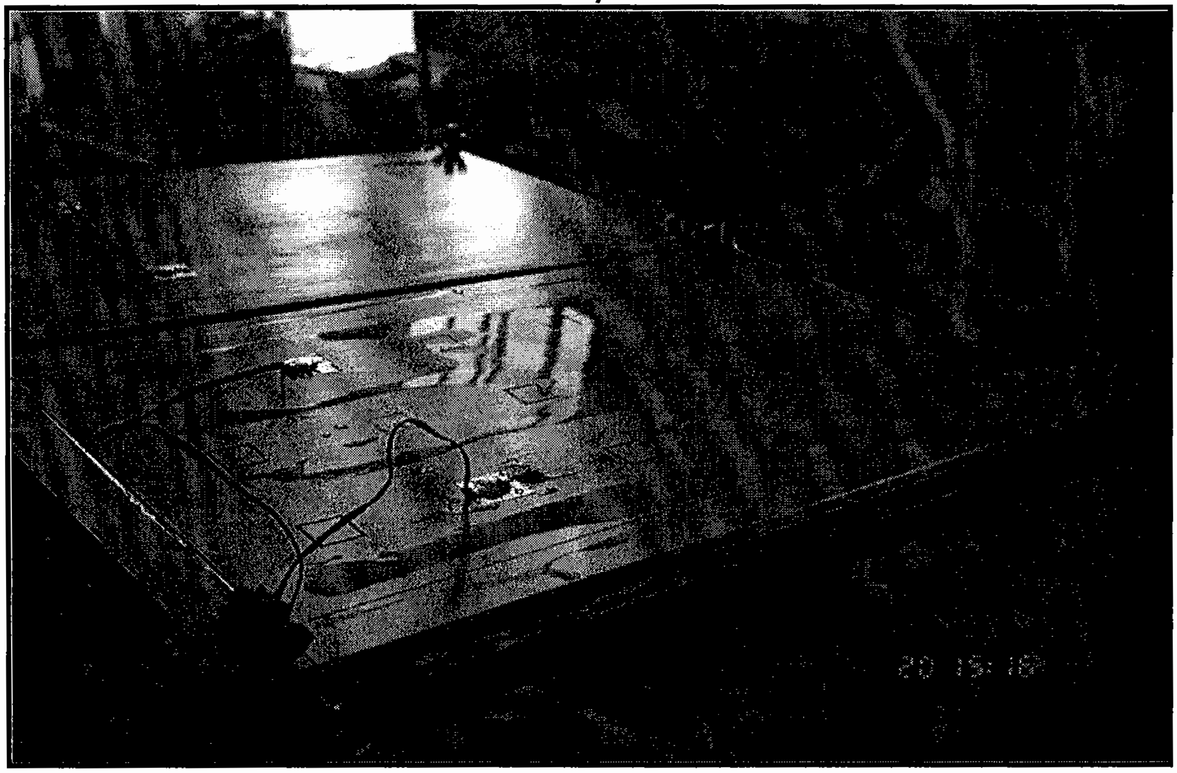


Photo 3.4
Surface Streaking

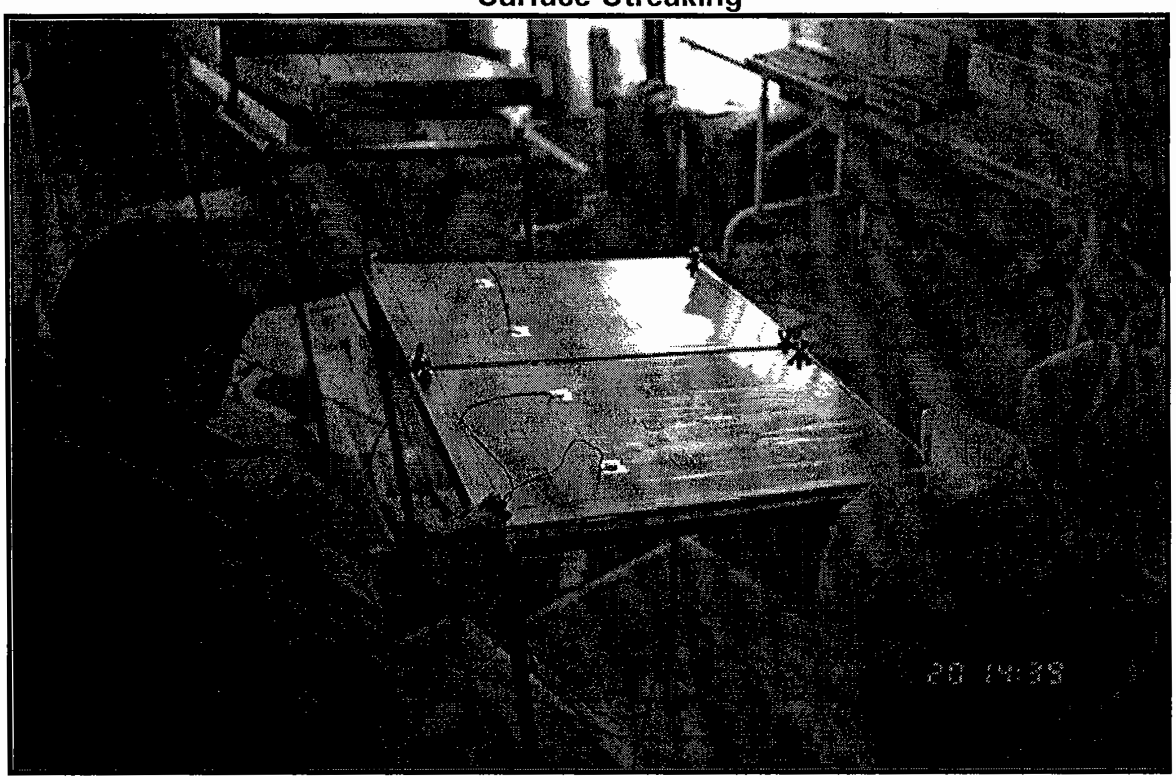


Photo 3.5
Surface Measuring Refractive Index

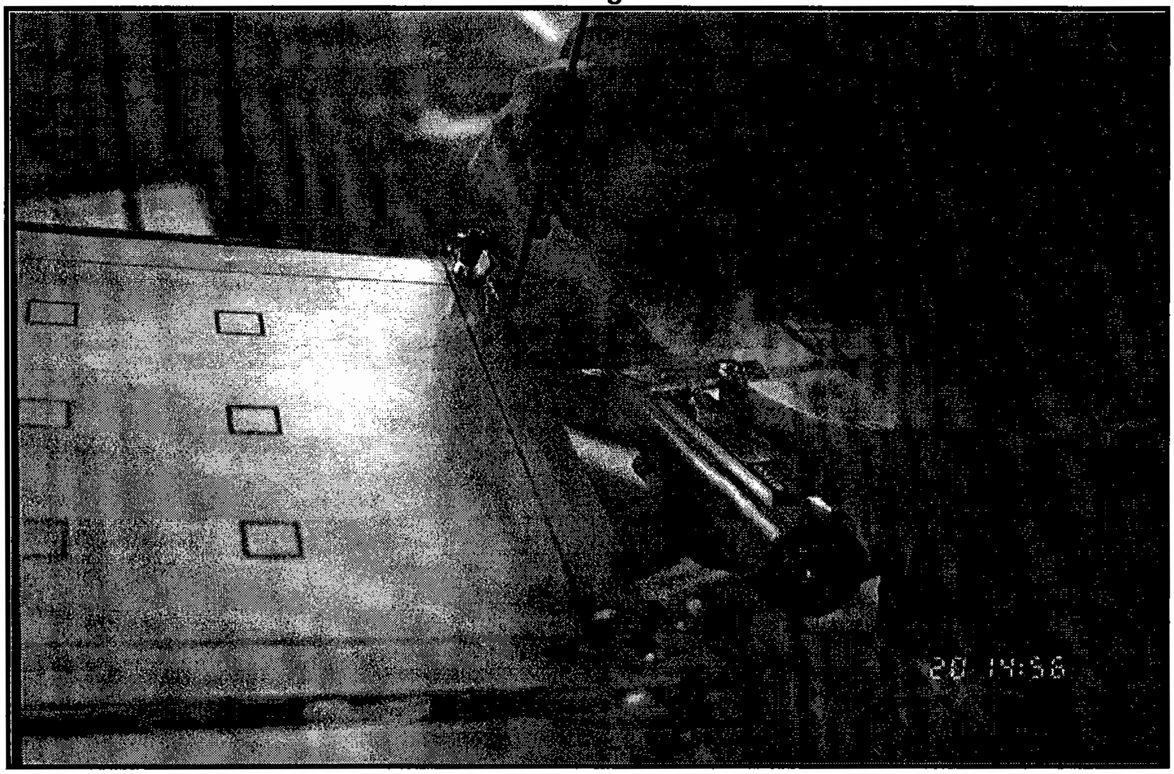


Photo 3.6
Measuring Thickness of Fluid Residue

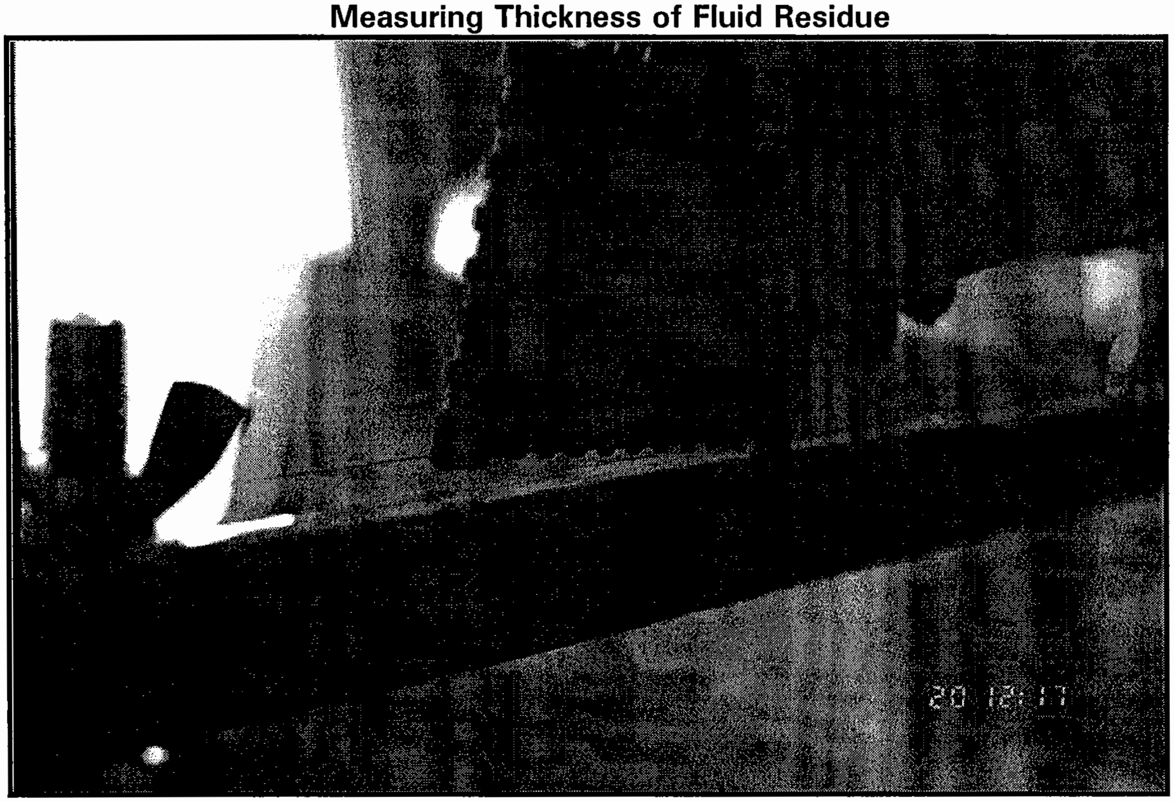
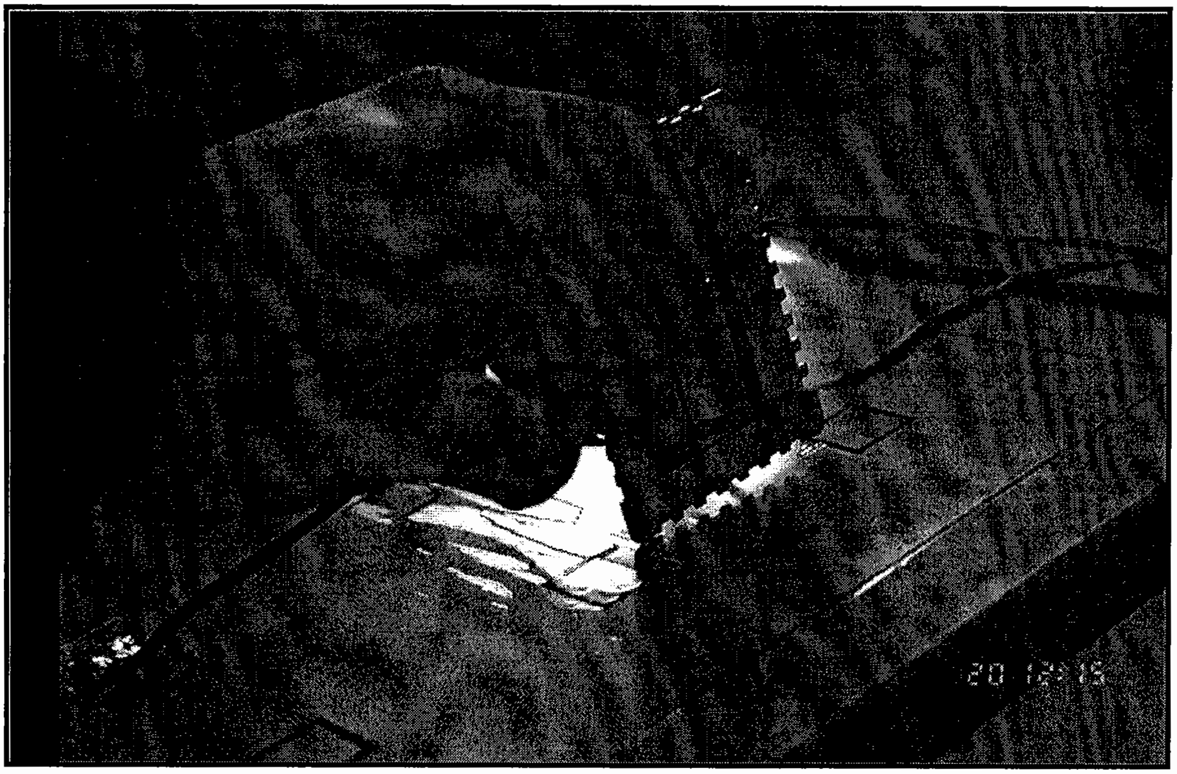


Photo 3.7
Surface Measuring Refractive Index



4. DESCRIPTION OF DATA AND OBSERVATIONS

4.1 Trial Results

Table 4.1 presents a log of all successful tests conducted. The log provides information on the parameters tested, (temperature, fluid concentration, plate slope and condition) as well as observed and measured results (Brix values, area of plate left bare, fluid thickness).

Table 4.2 presents a schematic view of trials conducted, giving the parameter under test and the test temperature condition.

The extent of the test plate left bare of fluid was estimated subsequent to the tests, based on sketched drawings of fluid coverage. The accuracy of both the sketching process and the subsequent estimate of coverage were dependent on the individual testers ability in performing these tasks. Any further trials should examine this requirement and explore alternative approaches. Some scatter in results may have been introduced by the use of plates in different tests whose surface condition was not exactly the same. Test personnel were changed for different test occasions which may have contributed to scatter in data values, particularly for estimates of percentages of plate left bare and dry.

The initial fluid Brix values showed some variance between tests. This is thought to be a result of the fluid heating procedure when some fluids may have been held at a high temperature prior to pouring, longer than others. A greater degree of evaporation would result, with related higher Brix values.

TABLE 4.1

FLUID EVAPORATION TESTS LOG

Test #	Date (1997)	Ambient Air Temp.	Fluid Type	Fluid Concentration	Surface Type	Fluid Quantity	Fluid Temp.(°C)	Slope of Plate	Evaporation of Fluid Over Time				Initial Brix	Brix After 20 minutes at			Thickness (mm) After 20 minutes at			Objectives and Comments
									5 min	10 min	15 min	20 min		6" line	15" line	"Low Edge"	6" line	15" line	"Low Edge"	
1	20-Feb-97	0°C	UCAR ADF	XL54	std	0.5 L	80	10°	4%	5%	6%	7%	35.5	47	47	45	0.04	0.04	0.38	We established a standard case to be used as a guideline.
2	20-Feb-97	0°C	UCAR ADF	XL54	std	0.5 L	80	10°	3%	5%	6%	6%	35.5	47	47	45	0.06	0.06	0.38	Duplicate of test#1, to verify method consistency.
3	20-Feb-97	0°C	UCAR ADF	XL54	std	0.5 L	80	10°	N/A	N/A	N/A	N/A	35.0	47.5	47	43.5	N/A	N/A	N/A	Test done for Brix values only.
4	20-Feb-97	0°C	UCAR ADF	XL54	std	0.5 L	80	10°	N/A	N/A	N/A	N/A	35.0	N/A	N/A	47	N/A	N/A	N/A	Fluid dyed before pouring for video purposes.
5	20-Feb-97	0°C	UCAR ADF	10%	std	0.5 L	80	10°	20%	25%	30%	35%	5.0	*	*	10	dry	0.04	0.27	Concentration: dilution effect.
6	20-Feb-97	0°C	UCAR ADF	2%	std	0.5 L	80	10°	75%	85%	90%	95%	1.3	dry	dry	dry	dry	dry	0.11	Concentration: dilution effect.
7	20-Feb-97	1.3°C	WATER	WATER	std	0.5 L	80	10°	95%	95%	97%	97%	0.0	dry	dry	dry	dry	dry	0.14	Water Baseline, to compare with low concentration fluids.
8	23-Feb-97	-2.5°C	UCAR ADF	XL54	std	1.5 L	80	10°	3%	5%	5%	6%	35.5	47.5	47.25	47	0.04	0.06	0.06	Volume of fluid applied effect.
9	23-Feb-97	-1.5°C	UCAR ADF	XL54	2.5 cm box	0.5 L	80	10°	2%	3%	4%	4%	36.3	46.75	43.75	41.75	0.04	0.09	0.09	Wing heat sink effect.
10	23-Feb-97	-1.5°C	UCAR ADF	XL54	7.5 cm box	0.5 L	80	10°	2%	3%	5%	5%	36.3	43	39	39	0.04	0.06	0.09	Wing heat sink effect.
11	23-Feb-97	-1.2°C	UCAR ADF	XL54	cladded plate	0.5 L	80	10°	4%	5%	10%	14%	39.8	47	45	43.25	0.04	0.04	0.04	Smoother surface condition effect.
12	23-Feb-97	-1.5°C	UCAR ADF	XL54	std	0.5 L	80	2°	1%	2%	3%	3%	40.3	46.5	43	41.75	0.09	0.09	0.11	Effect of plate slope
13	13-Mar-97	-13°C	UCAR ADF	2%	std	0.5 L	80	10°	75%	85%	95%	98%	1.5	dry	dry	9	dry	dry	ice	Lower ambient temperature effect on fluid freezing.
14	23-Feb-97	-3.5°C	UCAR ADF	2%	std	0.5 L	80	10°	N/A	N/A	N/A	N/A	1.0	N/A	N/A	N/A	N/A	N/A	N/A	Test done to gather more Brix values at different times.
15	23-Feb-97	-3.5°C	UCAR ADF	2%	std	0.5 L	80	10°	N/A	N/A	N/A	N/A	1.0	N/A	N/A	N/A	N/A	N/A	N/A	Test done to gather more Brix values at different times.
16	23-Feb-97	-3.5°C	UCAR ADF	2%	std	0.5 L	80	10°	N/A	N/A	N/A	N/A	1.8	N/A	N/A	2.75	N/A	N/A	0.14	Test done to gather more Brix values at different times.
18	18-Apr-97	-8	UCAR ADF	10%	std	0.5	80	10°	55%	65%	75%	75%	7.0	45.5	43.5	9	0.11	0.11	1.34	Observe low temp. solution of ADF
19	15-Apr-97	-3	UCAR ADF	XL54	std	1.5	80	10°	3%	4%	5%	8%	36.0	41.75	43.25	44.25	0.04	0.06	0.83	Retest of #8
20	15-Apr-97	-3	UCAR ADF	XL54	ICEX	0.5	80	10°	98%	98%	98%	98%	32.3	N/A	46.25	42	N/A	N/A	1.33	Surface treated with ICEX
21	15-Apr-97	-3	UCAR ADF	XL54	SNOW std	0.5	80	10°	5%	7%	12%	14%	33.0	47.75	45.5	42.25	0.06	0.06	0.64	Simulate de-icing of a snow-covered wing
24	18-Apr-97	-8	UCAR ADF	2%	std	0.5	80	10°	55%	75%	75%	80%	1.0	N/A	4	3	dry	0.04	ice	Observe low temp. solution of ADF
25	17-Apr-97	-10	UCAR ADF	XL%$	std	0.5	80	10°	45%	50%	60%	60%	33.0	45.5	44.5	39.5	0.06	0.06	1.09	Obsrerve low temp. XL54

Notes: - Test 17 discarded due to incorrect fluid concentration.
- Tests 22 and 23 conducted on Type)0 fluid.

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TABLE 4.2

OUTLINE OF TEST CONDITIONS

	Temperature		
	-10°C	-5°C	0°C
H2O			7
2%	13, 24		6
5%			
10%	18		5
XL54	25		1, 2
1.5L XL54		19	8
Boxes			9, 10
Clad Plate			11
Ice-Ex		20	
Snow		21	
Type 0			22, 23
Slope			12

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5. ANALYSIS AND DISCUSSION

This section discusses and compares test results of varied test parameters. To assist in this analysis, test results were charted in various formats.

Figure 5.1 presents information on extent of plate left bare at noted times following pouring of fluid.

Figure 5.2 presents information on Brix values measured for the initial heated test fluid and at selected points on the plate at 20 minutes following pouring of fluid.

Figure 5.3 presents information on fluid thickness at the 15 and 38 cm (6 and 15") lines and at the lower edge of the plate, at 20 minutes following pouring of fluid.

The presentation of each of these charts enables a comparison of results based on different fluid concentrations and well as based on different ambient temperatures.

5.1 Influence of Fluid Concentration

5.1.1 Area of Plate Surface Left Bare

In the temperature range from 0°C to -5°C, the percentage of plate left bare and dry increases markedly as the concentration of the fluid is decreased. From Figure 5.1, the results at this temperature range are:

Standard mix	7% bare	10% mix	35% bare
2% mix	95% bare	water	97% bare

The tests on full strength fluid always resulted in a film of fluid at the 15 cm and 38 cm (6 and 15") lines, as well as a bead at the bottom plate edge.

The tests on 10% fluid had no fluid film on the plates at the 15 cm and 38 cm (6 and 15") lines at 0°C. At -8°C, a film existed at both the 15 cm and 38 cm (6 and 15") line. A bead of fluid existed at the plate bottom edge at both temperatures.

5.1.2 Brix Value of Remaining Fluid

In all tests, the final Brix value for any fluid residue on the plates was greater than the initial value for the test fluid. The final Brix values for these thin films were remarkably consistent across all tests regardless of the initial Brix value of the fluid.

FIGURE 5.1

PERCENTAGE OF PLATE AREA BARE

HEATED WATER & TYPE I FLUID SOLUTIONS

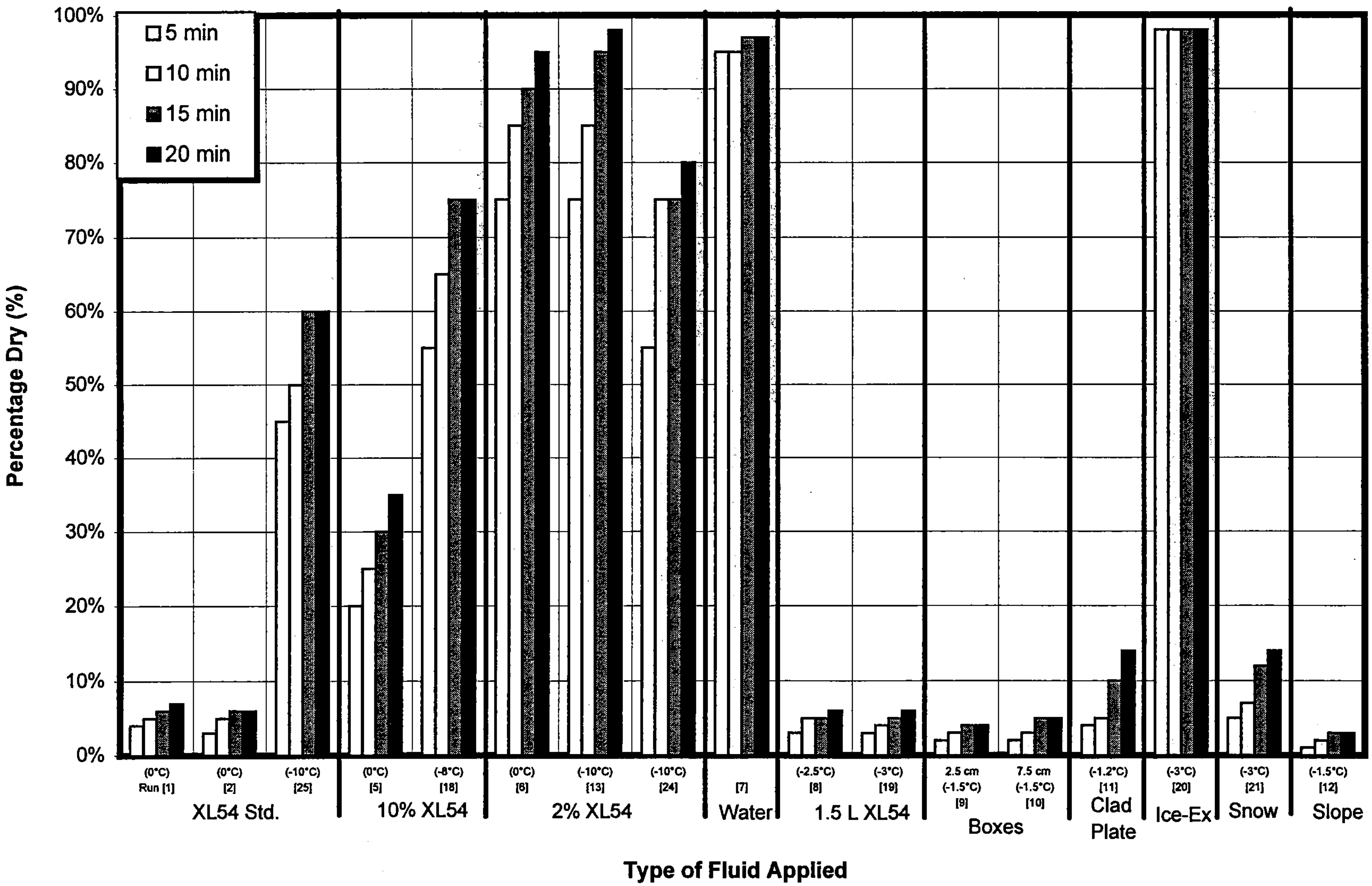

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FIGURE 5.2

BRIX VALUES OF FLUIDS RESIDUES AFTER 20 MINUTES

HEATED WATER & TYPE I FLUID SOLUTIONS

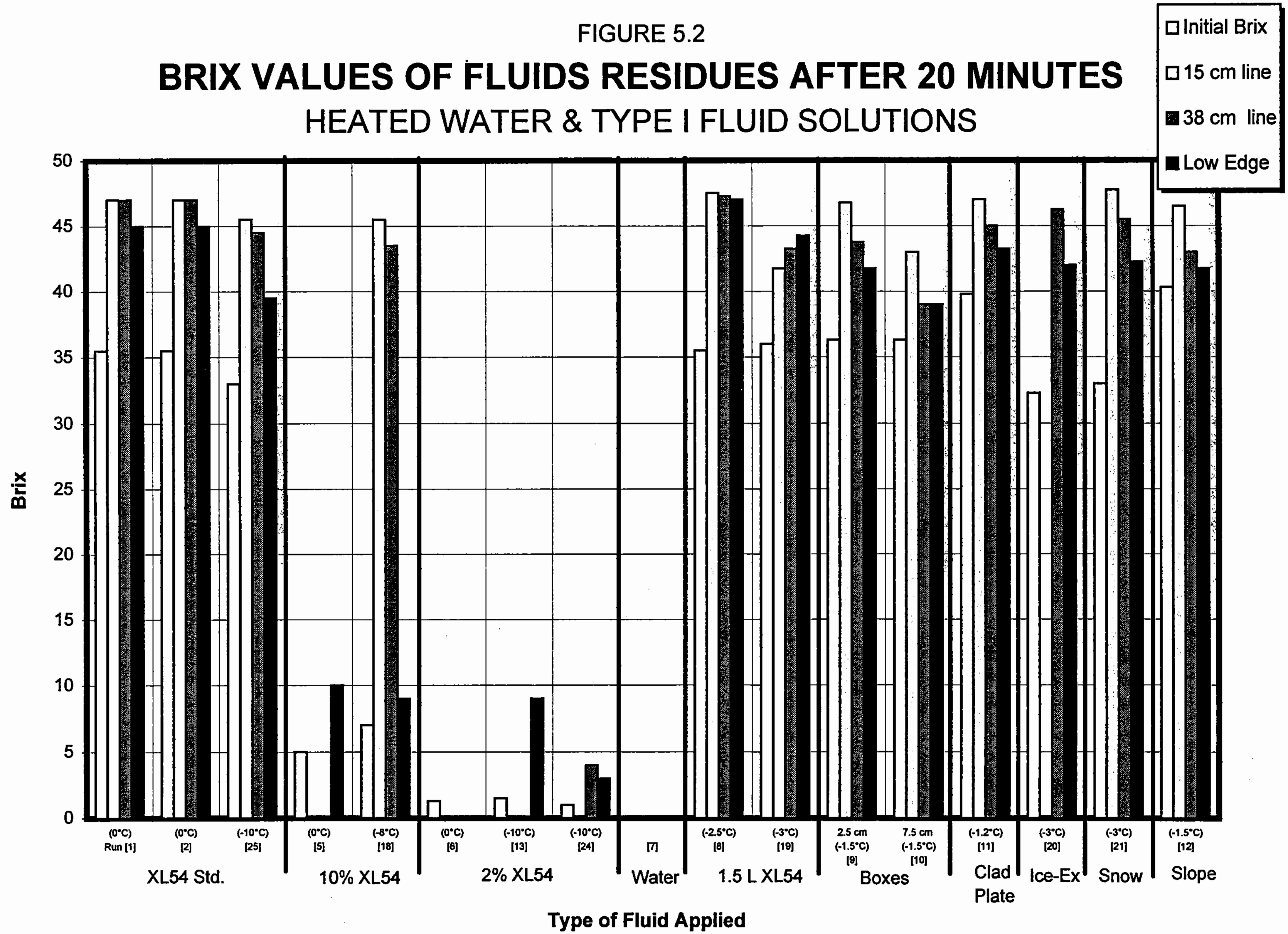

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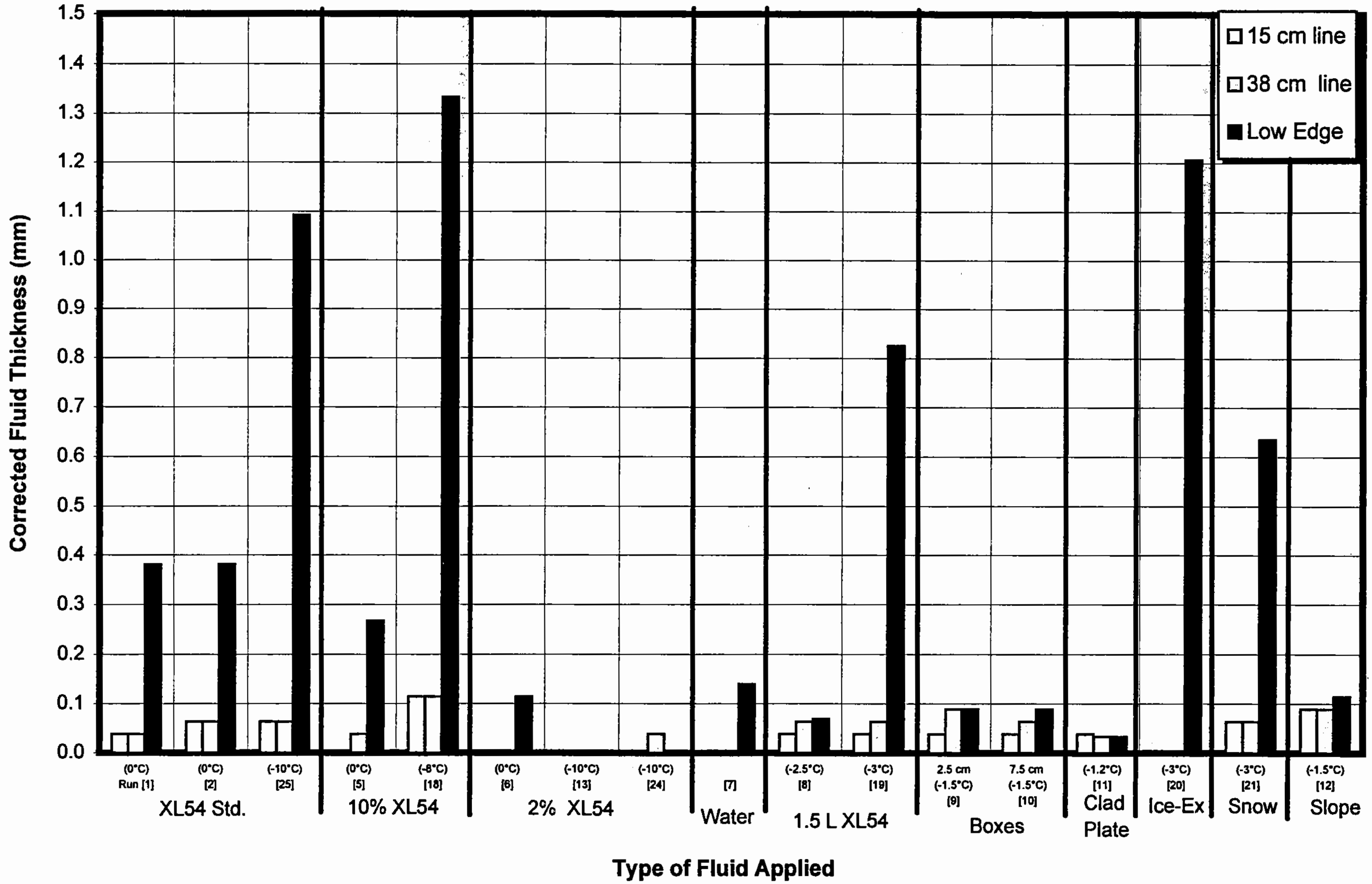
FIGURE 5.3

FILM THICKNESS OF FLUIDS RESIDUES AFTER 20 MINUTES

HEATED WATER & TYPE I FLUID SOLUTIONS



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The greatest increase in Brix values occurred on the areas of the plate where a very thin film resulted (at the 15 cm and 38 cm (6 and 15") line). Where the fluid formed a bead at the bottom edge of the plate due to fluid surface tension, the fluid was thicker and the increase in Brix values was generally less than elsewhere, but still apparent.

The full strength XL54 fluid showed an increase of 10 to 12 points on the Brix scale, about 30% in relative value.

The test on the 10% mix at -10°C resulted in some fluid still remaining on the plate at the 15 cm and 38 cm (6 and 15") lines. This fluid had reached a Brix value of 44 and 45, the same as that reached by full strength fluid at that temperature.

For the 10% mix, the average Brix value (over 2 tests) for the fluid in the bead on the lower edge increased by about 3 points, or about 50% in relative value. The fluid freeze point for this fluid was lowered by about 2°C, from -4 to -6°C.

For the 2% mix, the average Brix value (over 2 tests) for the fluid in the bead on the lower edge increased by about 4 points, or about 200% in relative value. The fluid freeze point for this fluid was lowered by about 2°C, from -1 to -3°C.

5.1.3 Fluid Thickness

At 0°C, the bead of fluid at the lower plate edge decreased as fluid concentration decreased.

5.2 Influence of Ambient Temperature

5.2.1 Area of Plate Surface Left Bare

The results for variable temperatures for the three concentrations of deicing fluids are:

Ambient Temp.	0 to -5°C	-8 to -13°C
Standard mix	7% bare	60% bare
10% mix	35% bare	75% bare
2% mix	95% bare	98 & 80% bare

The standard mix and the 10% mix show a strong direct relationship between percent of area left bare and decrease in ambient temperature.

The 2% mix had variable results at colder temperatures preventing any conclusion from being drawn.

5.2.2 Brix Value of Remaining Fluid

The data are insufficient to determine any relationship.

5.2.3 Fluid Thickness

For standard XL54 and the 10% mix, film thickness in the bead at the bottom edge of the plate increased markedly with lower ambient temperatures.

Thickness data for tests of the 2% mix are inconsistent with the tester ability to sample fluid for Brix values.

5.3 Influence of Condition of Plate Surface

Two tests were conducted to examine the impact of the condition of the plate surface. In one test, a new plate with a shiny polished surface was used. In one test, the plate surface was treated with Ice EX, a water repellent fluid used by some operators to discourage the formation of ice on the wing during flight.

5.3.1 Area of Plate Surface Left Bare

Compared to the standard XL54 fluid test, the area left bare on the new polished plate was 100% greater (14% vs 7%).

On the plate treated with Ice EX, nearly the entire plate was left bare at 5 minutes into the test. It is believed that the fluid immediately ran off the plate at time of pouring. This test confirmed observations made during full-scale tests on a DHC Dash 8 aircraft where the wing had been treated with Ice EX some time previously. In that test, sprayed deicing fluid quickly ran off the wing, with the only remaining fluid existing as beads, similar to water beading on a waxed surface.

5.3.2 Brix Value of Remaining Fluid

The final Brix values of any fluid film remaining on the plate surface were somewhat lower than those of the standard tests. This may be due to a lower heat transfer (and resultant less evaporation) to the plate in these tests due to rapid runoff of the poured fluid.

5.3.3 Fluid Thickness

The film thickness on the surface of the polished plate was about 25.4 μm (1 mil), somewhat less than thickness for the standard tests.

Thickness of the bead at the bottom edge of the plate was also about 25.4 μm (1 mil), the lowest value seen in this series of tests. This compares to a thickness of 357 μm (14 mil) for standard tests.

5.4 Influence of Amount of Fluid Applied

In two tests, the quantity of heated fluid applied was increased to 1.5 litres from the standard of 0.5 litres to examine the impact of a greater amount of fluid applied.

5.4.1 Area of Plate Surface Left Bare

In tests where 1.5 litres of fluid were applied, there was no difference in results compared to standard tests using 0.5 litres of fluid.

5.4.2 Brix Value of Remaining Fluid

Brix values were consistent with values measured in the standard tests.

5.4.3 Fluid Thickness

Film thickness values of any remaining fluid film on the surface of the plate were consistent with the standard tests. Thickness values for the fluid bead at the plate lower edge were inconsistent between the two tests.

5.5 Influence of Slope

In one test, the plate was mounted at 2° slope to examine the effect.

5.5.1 Area of Plate Surface Left Bare

For the plate tested at a slope of 2°, the area of the plate left dry and bare was about half of that for the standard plate tested at 10°, 3% versus 7%.

5.5.2 Brix Value of Remaining Fluid

The average Brix value for the plate at 2° was about 43, versus 46 for the standard test.

5.5.3 Fluid Thickness

Film thickness at the 15 and 38 cm (6 and 15") lines was about twice that of the standard tests, 0.08 mm versus 0.04 mm. The bead at the bottom edge was less thick than the standard test, about 0.1 mm compared to 0.4 mm.

5.6 Effect of Snow on Plate

Natural snow was carried in from outdoors and scattered on the plate to simulate a snow contamination condition.

5.6.1 Area of Plate Surface Left Bare

The area of plate left bare was greater than the standard test, about 14% versus 7%.

5.6.2 Brix Value of Remaining Fluid

The Brix values for any fluid film remaining on the plate surface were the same as the standard test. The Brix value for the fluid bead at the lower edge was somewhat less than the standard.

5.6.3 Fluid Thickness

Film thickness was the same as the standard test, with the exception that the bead at the lower edge may have been thicker than standard.

5.7 Cold-Soaked Boxes

Two cold-soaked boxes (of depths 2.5 and 7.5 cm (1 and 3")) were tested to examine the impact of their heat sink properties on evaporation. Box temperatures were the same as ambient.

5.7.1 Area of Plate Surface Left Bare

Results of tests on both sizes of box showed slightly less bare surface than the standard tests.

5.7.2 Brix Value of Remaining Fluid

Elevation in final Brix values from initial values were less than in the standard tests. Brix values on the 7.5 cm (3") box elevated to a lesser degree than on the 2.5 cm (1") box.

5.7.3 Fluid Thickness

Thickness of any fluid film an the surface of both box sizes was about the same as the standard test. Thickness of the bead at the bottom edge was less than in the standard tests.

6. SUMMARY OF OBSERVATIONS, AND CONCLUSIONS

The numbers of runs conducted in this series of tests were not sufficient to confirm repeatability of results, however some trends appeared to be sufficiently strong to allow tentative conclusions to be drawn.

Principal observations were:

- Application of heated fluids at low concentration results in large areas of the surface left bare and dry. Hot water and hot 2% fluid produced the largest area of the surface in a bare dry condition (95%);
- Colder ambient temperatures appeared to result in an increase in the area of the surface that is left bare and dry; and
- The freeze point of the applied fluid is depressed as a result of evaporation. This is most apparent where the final fluid exists as a thin film on the plate surface, but also occurs in the bead of fluid that forms on the surface lower edge. For heated Type I fluids this phenomenon serves to provide an inherent freeze point safety buffer in addition to the currently regulated buffer of 10°C.

Other observations were:

- The condition of the test surface influenced results. The polished plate lost fluid more rapidly through runoff than the standard plate. The area left bare was greater than in standard tests but the freeze point depression was less;
- Treatment of the surface with Ice EX resulted in a large area left bare and dry, equivalent to results achieved by 2% fluid and hot water. Fluid films remaining on the wing experienced freeze point lowering equivalent to the standard tests;
- Increasing the quantity of fluid applied to the surface did not produce any notable difference in area left bare or in final Brix values;
- A decrease in the slope of the surface resulted in a reduced amount of surface left bare;
- Snow on the test surface did not diminish the amount of surface left bare or the Brix value of the remaining fluid film; and
- The heat sink property of the cold-soaked boxes had the effect of diminishing the area of the surface left bare, and reducing the rise in Brix values.

From the foregoing, it can be tentatively concluded that:

i) The foregoing tentative conclusions indicate that the proposed procedure for deicing aircraft with a heated low concentrate fluid (having less than a 10°C buffer) without an anti-icing overspray in conditions following the end of precipitation may be a reasonable and safe approach; and

ii) It is possible that use of Ice EX in conjunction with a Type I deicing fluid may provide improved protection for the wing, as compared to the use of Type I fluid alone. It is generally accepted that Type I holdover times are given support from the heat transferred to the surface and that the fluids themselves have limited anti-icing effectiveness. The combination of the heated wing surface and the water repellent nature of this material may result in snow or freezing precipitation sliding off the wing without adhering.

7. RECOMMENDATIONS

It is recommended that:

i) Further tests be conducted, on aircraft as well as on plates, to substantiate the tentative conclusions. The real objective of these trials would be to prove or disprove the viability of the proposed procedure.

The Spar/Cox camera should be used for these trials to provide an objective and repeatable indication of condition of the test surface.

The test should give attention to plate condition, and be designed to use the same plates to eliminate that variability.

ii) Trials in snow and freezing precipitation conditions be conducted to evaluate the implication of use of Ice EX together with heated Type I fluid. Fluids mixed to low concentration should be included in these trials.

The combination of the heated wing surface and the water repellent nature of this material may result in snow or freezing precipitation sliding off the wing without adhering, and offering a holdover time greater than Type I alone.

As the Ice EX treatment lasts for some time, this approach would not be valid for operators who use a Type II, II, or IV anti-icing fluid, as it is expected that those fluids would also quickly run off the wing, destroying their expected holdover capacities.