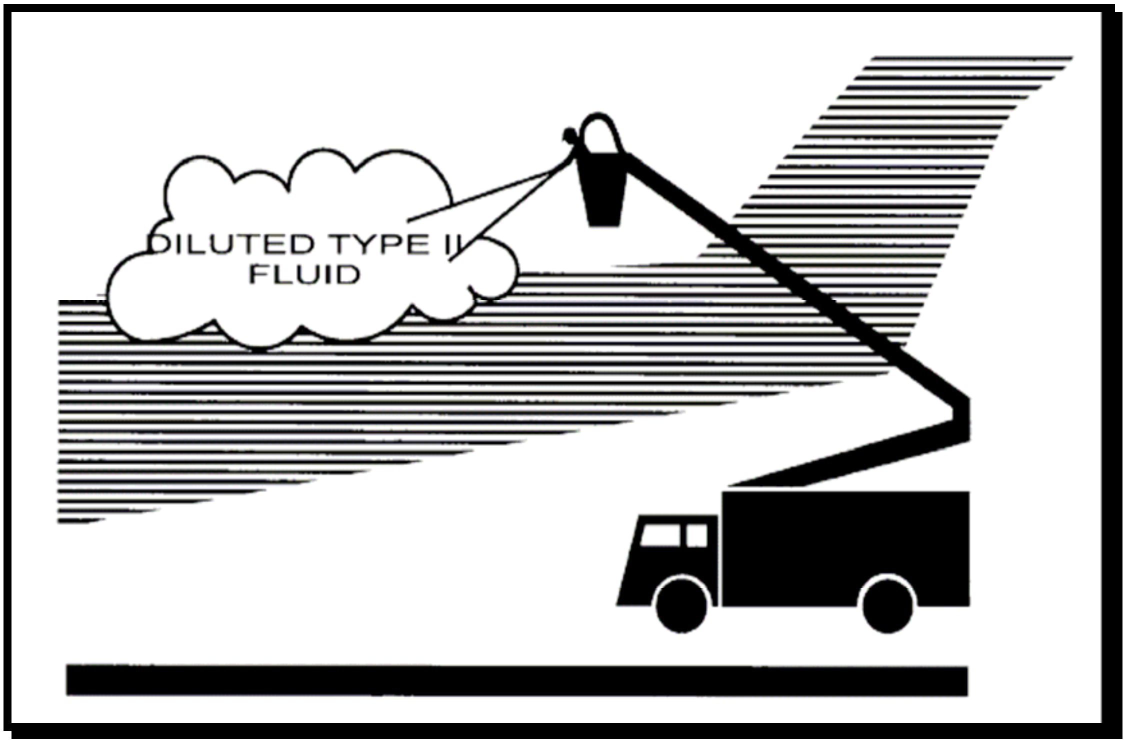
TP 12915E

Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1993-94 Winter

TEST RESULTS SUMMARY



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by
APS Aviation Inc.

September 1994

TP 12915E

Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1993-94 Winter

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by

John D’Avirro
APS Aviation Inc.

September 1994

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16. Abstract

Testing of commercially produced de/anti-icing fluids during the 1993-94 winter included natural snow tests at Dorval International Airport in Montreal, freezing drizzle and rain tests at the National Research Council Canada (NRC) Climatic Engineering Facility in Ottawa, freezing fog tests at NRC’s Helicopter Icing Facility, full-scale aircraft tests at Somiper Aviation at Dorval International Airport, and instrumentation tests with Instrumar's Clean Wing Detection System (CWDS) and RVSI’s ID-1. The fluids tested for the 1993-94 winter season were primarily diluted Type II fluids.

Conclusions

- Higher rates of precipitation and colder temperatures tend to reduce failure times.
- Fluids from different fluid manufacturers, but within the same type category, generally have different failure times.
- Based on the few Type II 75/25 and 50/50 cold soaked tests at Dorval, it appears that the SAE lower limit requires a reduction.
- The RVSI and Instrumar ice detectors seem to correlate well with the observed failure time.

It should be noted that, as a result of budgetary constraints, only a reduced analysis could be conducted, and that the final report was replaced by this test results summary.

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Aircraft, ground, anti-icing, deicing, fluid, holdover, time, test, precipitation, wing, plate, data

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Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1992-1993 Winter (TP 11836E)

16. Résumé

Les essais de durée d'efficacité de liquides de dégivrage/antigivre commerciaux réalisés au cours de l'hiver 1993-1994 comportaient des essais sous neige naturelle à l'Aéroport international de Dorval à Montréal, des essais sous bruine et sous pluie verglaçante à l'Installation de génie climatique du Conseil national de recherches du Canada à Ottawa (CNRC), des essais sous brouillard verglaçant au Laboratoire des essais de givrage sur hélicoptères du CNRC, des essais en vraie grandeur chez Somiper Aviation, à l'Aéroport international de Dorval, et des essais d'instruments de détection du givre, soit le CWDS (pour Clean Wing Detection System) d'Instrumar et le ID-1 de RVSI. Les essais de 1993-1994 ont surtout porté sur des liquides de type II dilués.

Conclusions

- Des taux de précipitation élevés et de faibles températures ont tendance à accélérer la perte d'efficacité des liquides.
- Dans l'ensemble, les liquides d'un même type mais de fabricants différents n'ont pas la même durée d'efficacité.
- Selon les quelques essais sur aile sur-refroidie menés à Dorval à l'aide de liquides de type II dilués dans des proportions 75/25 et 50/50, il semble que la limite inférieure des tableaux de la SAE doive être abaissée.
- Les détecteurs de givre de RVSI et d'Instrumar semblent appuyer les observations visuelles de la perte d'efficacité.

Il convient de noter que, en raison de restrictions financières, la portée de l'analyse a dû être réduite et le rapport final a été remplacé par le présent sommaire des résultats.

17. Mots clés Aéronef, sol, antigivre, dégivrage, liquide, efficacité, durée, essai, précipitation, aile, plaque, données	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 Dryden Commission Implementation Project (DCIP) of Transport Canada, APS Aviation Inc. undertook a study to manage, conduct and analyze holdover time tests used to assess the time effectiveness of the commercially produced de/anti-icing fluids.

The need for field-testing of the fluids was identified over five years ago and has been addressed through various programs with varying levels of success. Following a series of meetings on holdover time, Air Canada and Transport Canada's Transportation Development Centre (TDC) developed a small field test program for the 1989-90 winter season to determine fluid effectiveness under real precipitation conditions. The results were unsatisfactory for a number of reasons, which were subsequently addressed at a TDC-sponsored meeting of the SAE Ad Hoc Committee Working Group (Aircraft Ground Deicing Tests) in Montreal. Agreement was reached on standardized test equipment, procedures and the scope of the data to be collected during the 1990-91 winter. The results of the 1990-91 worldwide testing program, which concentrated on Type II fluids, were published in Transport Canada report TP 11206E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1990-1991 Winter*.

Testing during the 1991-92 winter was on a smaller scale. Type III fluids were the only fluids tested, with particular attention to a locally manufactured fluid. The intention was not to carry out extensive tests of all Type III fluids, but rather to gain a better understanding of the variances between fluids and, most importantly, to improve test methods, to gain better insight into the real-world modes of fluid failure, and to gain some understanding of the precipitation conditions that rapidly compromise the fluids. The results of the 1991-92 test program, which concentrated on Type III fluids, were published in Transport Canada report TP 11454E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1991-1992 Winter*.

Testing during the 1992-93 winter included natural snow tests at Dorval International Airport in Montreal, as well as freezing drizzle tests at the National Research Council Canada (NRC) indoor Climatic Engineering Facility (CEF) in Ottawa, and freezing fog tests at NRC's outdoor Helicopter Icing Facility. Three fluid types were tested, with an emphasis on Type I.

Testing during the 1993-94 winter included natural snow tests at Dorval International Airport, freezing drizzle and rain tests at NRC's CEF, freezing fog tests at NRC's Helicopter Icing Facility, full-scale aircraft tests at Somiper Aviation at Dorval International Airport, and instrumentation tests with Instrumar's Clean Wing Detection System (CWDS) and RVSI's ID-1. The fluids tested for the 1993-94 winter season were primarily diluted Type II fluids.

Generally, the testing consisted of pouring de/anti-icing fluids onto clean test sections (which were exposed to various winter precipitation conditions) and recording the elapsed times before the test sections reached the end condition. Test sections included flat aluminum plates inclined at 10º, a sealed box/plate section used for simulation of cold-soaking, and an airfoil section. Full-scale tests were conducted at Somiper Aviation with a Cessna Citation II and a Fairchild Metroliner.

EXECUTIVE SUMMARY

The ice sensors included a modified IM 101, three FM 202's, and three CWDS sensors from Instrumar Ltd. of St. John's, Newfoundland. One external optical area sensor was provided by RVSI of New York.

Type I and II fluids, provided by Union Carbide, Kilfrost, Octagon and Hoechst, were tested. The majority of tests were with 75/25 and 50/50 diluted Type II fluids. Type I fluids were requested at standard dilutions.

Before all the collected data was analyzed, the raw data underwent some manipulation and verification, specifically to correct or remove any obvious errors from the meteorological data. It should be noted that, as a result of budgetary constraints, only a reduced analysis could be conducted, and that the final report was replaced by this test results summary.

The conclusions from this year's testing and analysis are as follows:

- Plate pan rates of precipitation correlate well with the Fisher and Porter rates.
- Test panels within the Wyoming Shield, where there are lower winds, tend to fail faster.
- Higher rates of precipitation and colder temperatures tend to reduce failure times.
- Fluids from different fluid manufacturers, but within the same type category, generally have different failure times.
- During full scale tests at Somiper Aviation, the end condition resulted first on the leading edge of the aircraft, second on the 10^o flat plate, and last on the airfoil. Based on the few Type II 75/25 and 50/50 cold soaked tests at Dorval, it appears that the SAE lower limit requires a reduction.
- The two (RVSI and Instrumar) ice detectors used seem to correlate well with the observed failure time.

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À la demande du Groupe de travail chargé de la mise en oeuvre de la Commission Dryden de Transports Canada, APS Aviation Inc. a entrepris une étude qui a consisté à organiser et mener des essais de durée d’efficacité et à en analyser les résultats afin de déterminer pendant combien de temps les liquides de dégivrage/antigivre offerts sur le marché demeurent efficaces.

Il y a plus de cinq ans, la nécessité se faisait sentir d’étudier sur le terrain la performance des liquides de dégivrage/antigivre. Les divers programmes mis sur pied à cette fin ont connu divers degrés de succès. Au terme de plusieurs rencontres sur la durée d’efficacité des liquides, Air Canada et le Centre de développement des transports (CDT) de Transports Canada ont mis au point un programme limité d’essais sur le terrain qui avait pour but de déterminer l’efficacité des liquides sous des précipitations naturelles. Les résultats de ces essais, menés au cours de l’hiver 1989-1990, ont été décevants, pour plusieurs raisons. Ces raisons ont été examinées par le groupe de travail spécial de la SAE (essais de dégivrage au sol), au cours d’une réunion tenue à Montréal sous l’égide du CDT. Cette réunion a aussi permis d’établir un consensus sur un matériel et un protocole d’essai standard, et sur les données à recueillir au cours de l’hiver 1990-1991. Les résultats de la campagne d’essais 1990-1991, de portée mondiale et axée principalement sur les liquides de type II, sont l’objet du rapport TP 11206E de Transports Canada, intitulé *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1990-1991 Winter*.

Les essais de l’hiver 1991-1992 ont été plus limités. Les liquides de type III ont été les seuls testés, et une attention particulière a été portée à un liquide fabriqué localement. Le but n’était pas tant de faire des essais complets de tous les liquides de type III, que de mieux cerner les différences entre les liquides et, encore plus important, d’améliorer les méthodes d’essai, d’avoir une meilleure idée de la progression vers la perte d’efficacité en situation réelle, et de mieux comprendre les conditions de précipitations qui rendent les liquides rapidement inefficaces. Les résultats du programme d’essais de 1991-1992, qui a porté exclusivement sur les liquides de type III, figurent dans le rapport TP 11454E de Transports Canada, intitulé *Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1991-1992 Winter*.

Les essais de l’hiver 1992-1993 comportaient des essais sous neige naturelle à l’Aéroport international de Dorval à Montréal, de même que des essais sous bruine verglaçante à l’Installation de génie climatique (IGC) du Conseil national de recherches du Canada (CNRC) à Ottawa et des essais sous brouillard verglaçant au Laboratoire des essais de givrage sur hélicoptères du CNRC. Trois types de liquides ont été essayés, mais l’accent était surtout mis sur les liquides de type I.

La campagne de l’hiver 1993-1994 a comporté des essais sous neige naturelle à l’Aéroport international de Dorval, des essais sous bruine et sous pluie verglaçante à l’IGC du CNRC, des essais sous brouillard verglaçant au Laboratoire des essais de givrage sur hélicoptères du CNRC, des essais en vraie grandeur chez Somiper Aviation à l’Aéroport international de Dorval et des essais d’instruments de détection du givre, soit le CWDS (pour *Clean Wing Detection System*) d’Instrumar et le ID-1 de RVSI. Ces essais ont surtout porté sur des liquides de type II dilués.

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Les essais consistaient généralement à verser les liquides de dégivrage/antigivre sur des surfaces d'essai propres (exposées à diverses conditions de précipitations hivernales) et à mesurer le temps écoulé jusqu'à ce que les surfaces atteignent un état final prédéfini. Les surfaces d'essai étaient constituées de plaques planes en aluminium inclinées à 10º, d'une boîte métallique fermée recouverte d'une plaque, simulant une aile sur-refroidie, et d'une section de voilure. Les essais en vraie grandeur ont été menés chez Somiper Aviation, avec un avion Cessna Citation II et un Fairchild Metroliner.

Les détecteurs de givre étudiés comprenaient un IM 101 modifié, trois FM 202, et trois détecteurs CWDS d'Instrumar Ltd. de St. John's, Terre-Neuve. De plus, un détecteur optique à distance a été fourni par RVSI de New York.

Les liquides de type I et de type II mis à l'essai étaient des liquides de Union Carbide, de Kilfrost, d'Octagon et d'Hoechst. La plupart des liquides de type II étaient dilués dans des proportions 75/25 et 50/50. Les liquides de type I étaient livrés dilués dans des proportions standard.

Avant d'être analysées, les données brutes ont été l'objet de certaines manipulations et vérifications, qui visaient à corriger ou supprimer les données météorologiques manifestement erronées. Il convient de noter que, en raison de restrictions financières, la portée de l'analyse a dû être réduite et le rapport final a été remplacé par le présent sommaire des résultats.

Voici les conclusions des essais et des analyses de cette année :

- les taux de précipitation mesurés à l'aide des bacs coïncident généralement avec ceux mesurés à l'aide du pluviomètre Fisher et Porter;
- sur les plaques d'essai protégées du vent par l'écran Wyoming, les liquides ont tendance à perdre plus rapidement leur efficacité;
- des taux de précipitation élevés et de faibles températures ont tendance à accélérer la perte d'efficacité des liquides;
- dans l'ensemble, les liquides d'un même type mais de fabricants différents n'ont pas la même durée d'efficacité;
- au cours des essais en vraie grandeur menés chez Somiper Aviation, l'état dit final apparaissait d'abord sur le bord d'attaque de l'aile d'avion, ensuite sur la plaque plane inclinée à 10°, et finalement sur la section de voilure. Selon les résultats des quelques essais de liquides de type II (mélanges 75/25 et 50/50) menés sur une aile sur-refroidie à Dorval, il semble que la limite inférieure des tableaux de la SAE doive être abaissée.
- Les deux détecteurs de givre étudiés (RVSI et Instrumar) semblent appuyer les observations visuelles de la perte d'efficacité.

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1. INTRODUCTION

At the request of the Dryden Commission Implementation Project (DCIP) of Transport Canada, APS Aviation Inc. undertook a study to manage, conduct and analyze holdover time tests used to assess the time effectiveness of the commercially produced de/anti-icing fluids.

The need for field testing of the fluids was identified over five years ago and has been addressed through various programs with varying levels of success. Following a series of meetings on holdover time, held in 1988-1989 under SAE auspices with many major airlines and de/anti-icing fluid manufacturers, Air Canada and the Transportation Development Centre (TDC) took the initiative to develop a small field test program for the 1989-1990 winter season to determine fluid effectiveness under real precipitation conditions. The results were unsatisfactory for a number of reasons that were subsequently addressed at a TDC-sponsored meeting of the SAE Ad Hoc Committee Working Group (Aircraft Ground Deicing Tests), June 6th, 1990, in Montreal. Agreement was reached on standardized test equipment, procedures and the scope of the data to be collected during the 1990-1991 winter. The results of the 1990-1991 worldwide testing program, which concentrated on Type II fluids, were published by Aviation Planning Services (APS) Ltd. in the Transport Canada report TP 11206E, **Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1990-1991 Winter**.

Testing during the 1991-1992 winter was on a smaller scale and had a slightly redirected focus. Type III fluids were the only fluids tested, with particular attention to a locally manufactured fluid. The intention was not to carry out extensive tests of all Type III fluids, but rather to gain a better understanding of the variances between fluids and, most importantly, to improve test methods, gain better insight into the real-world modes of fluid failure and to gain some understanding of the precipitation conditions that rapidly compromise the fluids. The results of the 1991-1992 test program, which concentrated on Type III fluids, were published by APS in the Transport Canada report TP 11454E, **Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1991-1992 Winter**.

Testing during the 1992-1993 winter included not only testing of snow at Dorval, but also testing of freezing drizzle at NRC's indoor Climatic Engineering Facility (CEF) and testing of freezing fog at NRC's outdoor Helicopter Icing Facility. Three fluid types were tested, from various fluid manufacturers, with an emphasis on Type I. The test site was changed from Air Canada's Dorval hangar roof-top location to a site on airport grounds located adjacent to Atmospheric Environment Services (AES), Environment Canada's meteorological station.

Testing during the 1993/94 winter included natural snow tests at Dorval, freezing drizzle and rain tests at NRC's CEF, testing of freezing fog at NRC's Helicopter Icing Facility, full scale aircraft tests at Somiper Aviation and instrumentation tests with Instrumar's CWDS and RVSI's ID-1. The fluids tested for the 1993/94 winter season were primarily diluted Type II fluids.

It should be noted that as a result of budgetary constraints, the analysis was limited to a reduced analysis, and the draft and final reports were replaced by this test results summary. Therefore, this document contains only the results based upon the reduced analysis.

2. METHODOLOGY

The methodology description is sub-divided into sections dealing with testing sites; test procedures and data forms, equipment, fluids, personnel and participants, and analysis methodology.

2.1 Test Sites

In-situ natural snow testing for the 1993/94 winter was performed at Montreal's Dorval airport, adjacent to AES' weather observation station. The location of the site at Dorval is shown on the plan view of the airport in Figure 2.1.

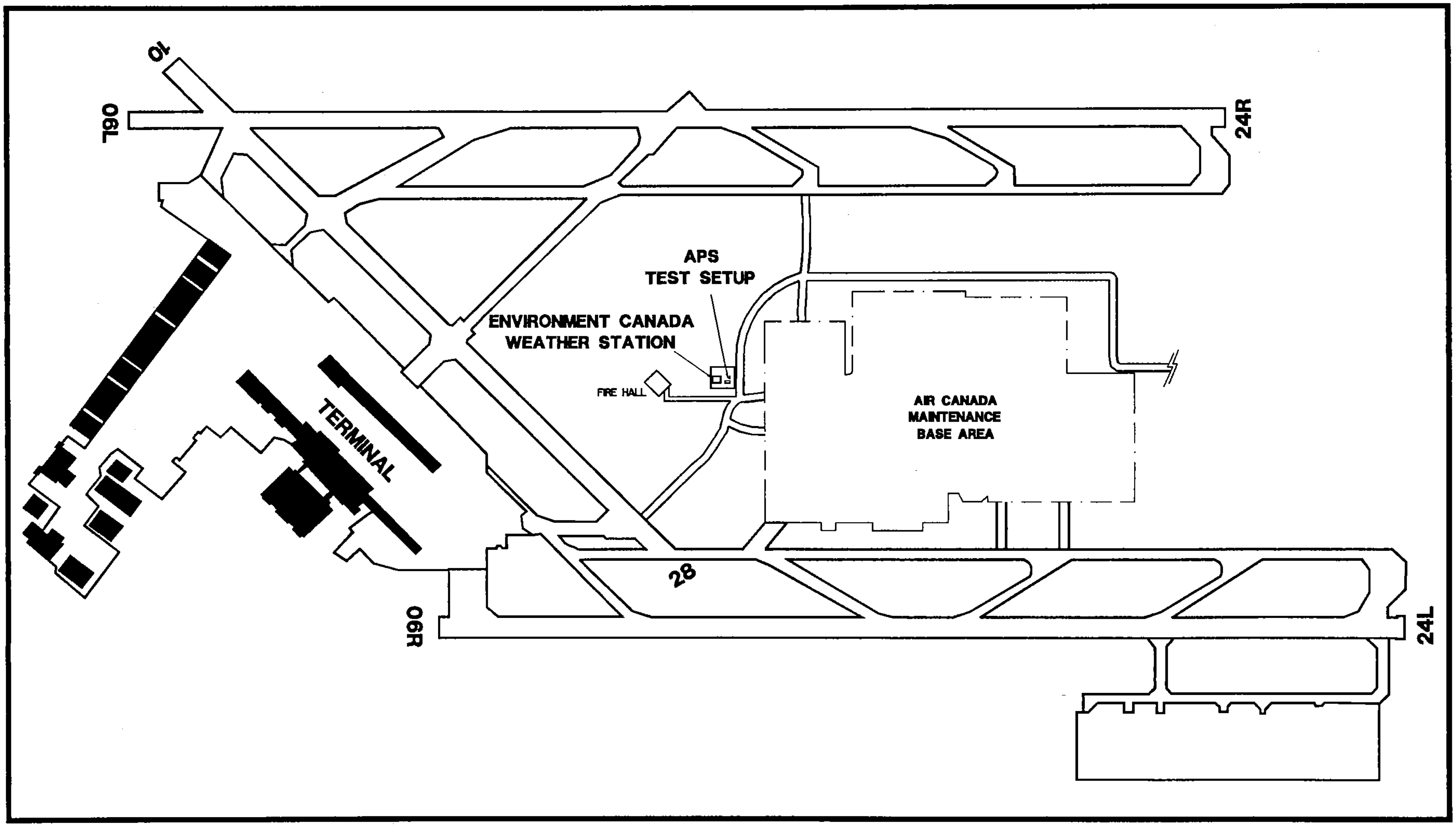
In-situ testing was also carried out by the NRC in Ottawa, while limited and other specialized testing was conducted by NCAR on behalf of United Airlines at Denver. The results from these tests were not incorporated as part of this report.

Testing for simulated freezing fog and freezing drizzle/rain was carried out at NRC's outdoor Helicopter Icing Facility and NRC's indoor Climatic Engineering Facility, respectively. The characteristics of the facilities and the simulated precipitation are described below.

- NRC Helicopter Icing Facility (freezing fog) Characteristics:
    - Nozzle array: 23 m (75 ft) wide x 5 m (16 ft) high
    - Spray nozzles: 161 steam-atomized water nozzles
    - Natural wind speeds
    - Natural air temperatures

- Freezing Fog Characteristics:
    - Droplet median volume diameter: 30 µm
    - Liquid Water Content: 0.2 to 0.6 g m^{-3}

FIGURE 2.1
TEST SITE AT DORVAL AIRPORT



- NRC Climatic Engineering Facility (Freezing Drizzle/rain) Characteristics:
    - Chamber size: 29.7 m (97 ft) long x 5.4 m (18 ft) wide x 5.8 m (19 ft) high
    - Air temperature: 0 to -10°C
    - Two spray nozzles, with three degrees of freedom

- Freezing Drizzle Characteristics:
    - Droplet median volume diameter: 600 um
    - Precipitation Rate: less than 13 $g/dm^2/hr$
    - Droplets produced with #24 hyperdermic needle

- Freezing Rain Characteristics:
    - Droplet median volume diameter: 1500 um
    - Precipitation Rate: 13 to 28 $g/dm^2/hr$
    - Droplets produced with #20 hyperdermic needle

Testing during natural snow conditions on full-scale aircraft took place at Somiper Aviation at Dorval airport.

2.2 Test Procedures and Data Forms

Generally, the testing consisted of pouring de/anti-icing fluids onto clean test sections (which are exposed to various winter precipitation conditions) and recording the elapsed times before the test sections reached the end condition. Test sections included flat aluminum plates inclined at 10°, a sealed box/plate section used for simulation of cold-soaking and an airfoil section with the following characteristics:

Section:	NACA 0012 (upper surface)
Chord:	2 m
Span:	0.8 m
Stand:	Upper surface 1.0 m above ground Airfoil incidence - 0°

- CWDS: Flush mounted
  Adjustable installation to permit angles up to 15°

Figure 2.2 shows the collection (plate) pan which is of the same size as a standard plate and used for measuring precipitation. Also shown is the sealed box which was used for simulating cold-soaked tests. Full-scale tests were conducted at Somiper Aviation with a Cessna Citation II and a Fairchild Metroliner.

Complete details of the actual test procedures are provided in Appendix A. Also included in Appendix A is the procedure used for testing of the airfoil and the procedure used to conduct the cold-soaking tests.

The end condition (see Appendix A) is still subjective in nature, although perhaps less so than in the past. It was still possible for different individuals to make different determinations as to the time the end condition was reached.

2.3 Equipment

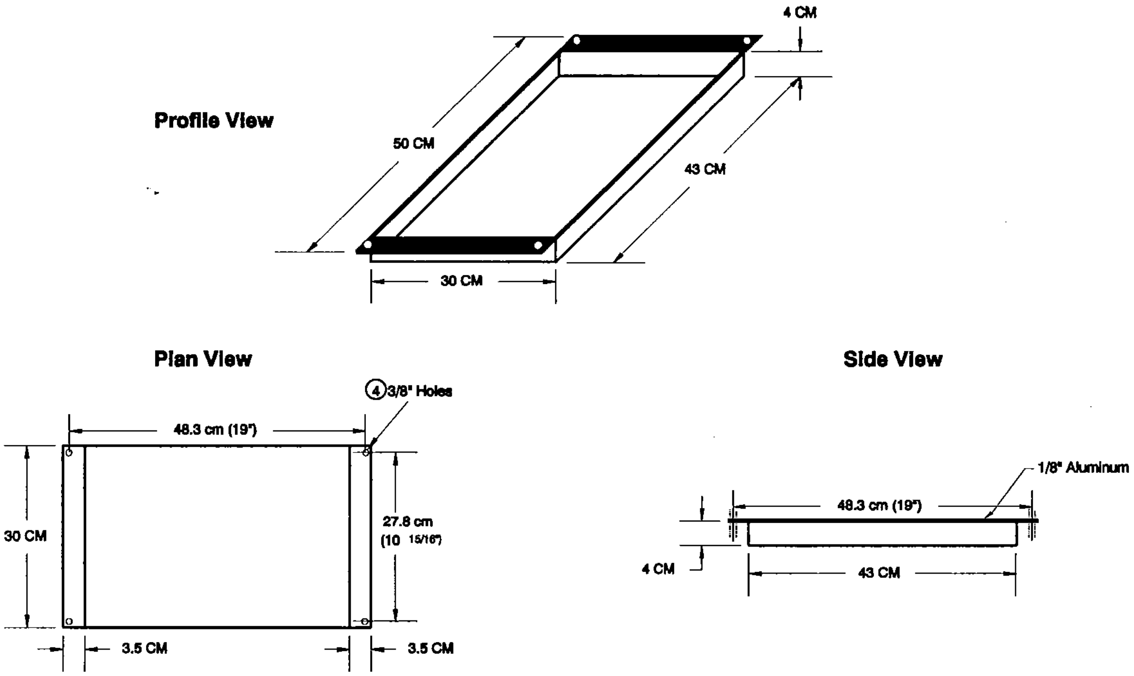
The equipment list and specifications are included in Appendix A. Equipment was required to record precipitation, temperature, wind speed and direction, and relative humidity.

The European ombrometer, which was shielded in the 1993-94 winter, and plate pans were used to measure precipitation from tests at Dorval. Data was also acquired from Meteoglobe Canada Inc., a firm which collects precipitation data on behalf of the City of Montreal. This data was collected at three locations in Montreal using Fisher and Porter precipitation gauges. The three sites are situated near the following streets: d'Agençon and Grand Trunk; Poincarré and

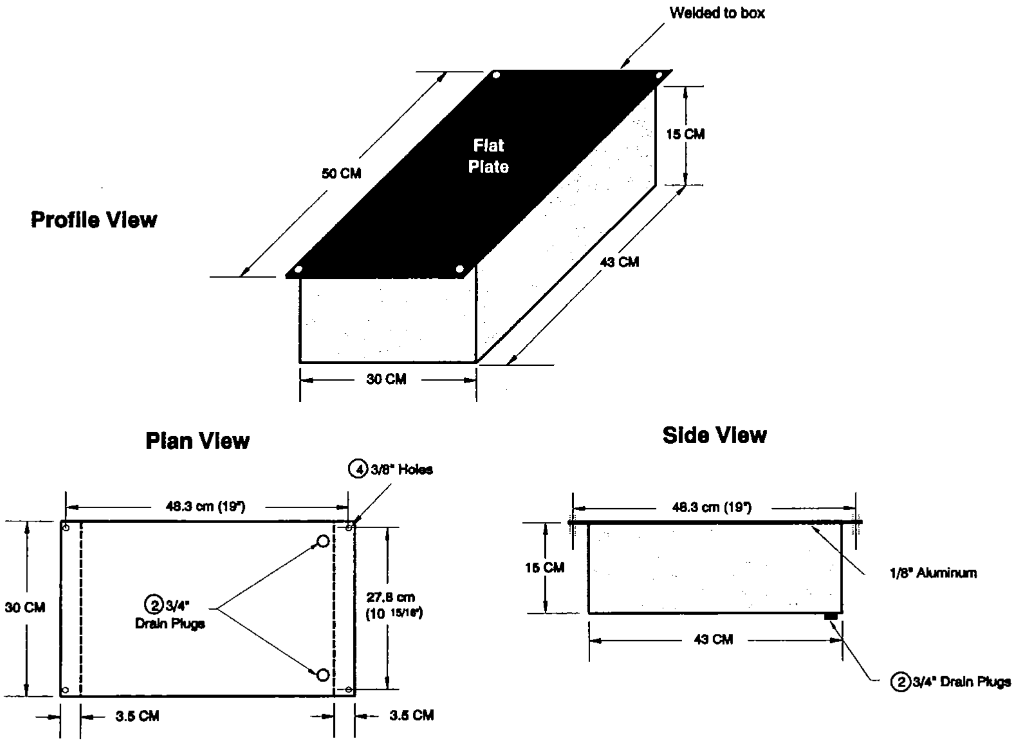
FIGURE 2.2

SCHEMATICS OF PLATE PAN AND SEALED BOX

PLATE PAN



SEALED BOX



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McDuff; and Laurier and 15th Avenue. This meteorological data was compared with the ombrometer and the plate pan data. The results of this comparison are shown in Section 4.1.

The ice sensors used in the 1993/94 season included a modified IM 101, three FM 202, and three CWDS sensors from Instrumar Ltd. of St. John's, Newfoundland. One external optical area sensor was provided by RVSI of New York.

The rate of precipitation for freezing fog, freezing rain and freezing drizzle, as simulated at the NRC test sites, were measured using plate pans.

2.4 Fluids

Type I and II fluids were teste and these were provided by Union Carbide, Kilfrost, Octagon and Hoechst. The majority of tests conducted by APS were with 75/25 and 50/50 diluted Type II fluids. Type I fluids were requested at standard dilutions.

2.5 Personnel and Participants

The site at Dorval was staffed mainly by university students and supervised by the APS staff. This APS involvement was critical in giving the analysts a thorough understanding of the intricacies and potential problems with the data collection process.

2.6 Analysis Methodology

Before all the collected data was analyzed, the raw data underwent some manipulation and verification, specifically to correct or remove any obvious errors from the meteorological data. The individual data parameters and the units used in the final analysis are listed below.

- Precipitation rate - ($g/dm^2/hr$) averaged over test
- Total precipitation - (g/dm^2)
- Air temperature - (°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)
- Time to failure of each crosshair - (minutes)

The analysis was performed in different stages, which were driven by various deadlines. These deadlines resulted from the requirement of presentation of the results to the SAE G-12 committee in Atlantic City, Denver and Toronto as well as presentation of the results to the Canadian Ground De-icing R&D task group members in Montreal.

3. DESCRIPTION OF DATA

This section provides a description of the data collected. Breakdowns will be provided for the quantity of data received, by fluid type, distributions of the basic weather parameters such as temperature, precipitation, wind speed and direction, and humidity over the range of the tests collected. This will be presented for the natural snow tests conducted at Dorval, freezing rain and drizzle tests carried out in Ottawa, and freezing fog tests conducted in Ottawa. Table 3.1 shows a summary of the number of Type II fluid tests conducted by APS from 1990 to 1994 as a function of outside air temperature, fluid concentration and type of precipitation. Similarly, Tables 3.2 and 3.3 show the number of Type I and Type III tests conducted from 1990 to 1994.

3.1 Dorval Natural Snow Tests

3.1.1 Usable Data

During the 1993/94 test season, APS collected test data from 85 forms (usable) for the two stands located at Dorval. Each form contained data for up to six test plates. As shown in Figure 3.1, these data forms contained a total of 447 usable test points. The 447 tests occurred during natural snow conditions - 52 points were removed from this group because freezing precipitation was mixed with snow. This data with the 52 points is available. Of the 447 usable tests, a total of 36 tests were of Type I, 34 were of Type II neat, 234 were of Type II 50/50 and 143 were of Type II 75/25 fluids. The number of usable tests performed during this test season at Dorval was the greatest of all tests seasons.

TABLE 3.1

Number of Type II Fluid Tests Conducted From 1990 to 1994

Sep-02-94

OAT °C	Type II Fluid Concentration Neat-Fluid/Water (% by volume)	Various Weather Conditions											
		Snow				Freezing Fog*				Freezing Drizzle/Rain			
		1990/91****	1991/92	1992/93	1993/94	1990/91	1991/92	1992/93	1993/94	1990/91**	1991/92	1992/93*	1993/94***
	TYPE	S1	S2	S3	S4	F1	F2	F3	F4	D1	D2	D3	D4
0°C and Above	100/0	66	-	3	-	-	-	-	-	0	-	-	-
	75/25	-	-	-	14	-	-	-	-	0	-	-	-
	50/50	-	-	-	18	-	-	-	-	0	-	-	-
0 to -7	100/0	231	-	70	2	-	-	-	7	81	-	71	21
	75/25	-	-	-	18	-	-	-	32	0	-	16	32
	50/50	-	-	-	12	-	-	-	24	0	-	16	56
-7 to -14	100/0	57	-	18	32	-	-	10	18	0	-	16	23
	75/25	-	-	-	71	-	-	-	18	0	-	-	53
	50/50	-	-	-	103	-	-	-	27	0	-	-	41
-14 to -25	100/0	30	-	4	-	-	-	-	-	4	-	-	-
	75/25	-	-	-	40	-	-	-	-	0	-	-	-
	50/50	-	-	-	101	-	-	-	-	0	-	-	-
Total		384	0	95	411	0	0	10	126	85	0	119	226

* Simulated

** Natural Freezing Precipitation

*** Simulated, but includes a few points under natural freezing precipitation

**** 1990/91 data includes Chicago and Denver data which United Airlines provided for the inclusion in the Appendix of the in 1992/93 APS report

▨ Designates that SAE/ISO holdover times do not exist

TABLE 3.2

Number of Type I Fluid Tests Conducted From 1990 to 1994

Sep-02-94

OAT °C	Various Weather Conditions											
	Snow				Freezing Fog*				Freezing Drizzle/Rain			
	1990/91	1991/92	1992/93	1993/94	1990/91	1991/92	1992/93	1993/94	1990/91**	1991/92	1992/93*	1993/94***
0 and above	8	-	10	4	-	-	-	-	-	-	-	-
0 to -7	48	-	110	-	-	-	21	-	1	-	99	2
Below -7	9	-	31	32	-	-	23	-	▨ -	▨ -	▨ 22	▨ 12
Total	**65**	**0**	**151**	**36**	**0**	**0**	**44**	**0**	**1**	**0**	**121**	**14**

* Simulated

** Natural Freezing Precipitation

*** Simulated, but includes a few points under natural freezing precipitation

▨ Designates that SAE/ISO holdover times do not exist

TABLE 3.3

Number of Type III Fluid Tests Conducted From 1990 to 1994

Aug-08-94

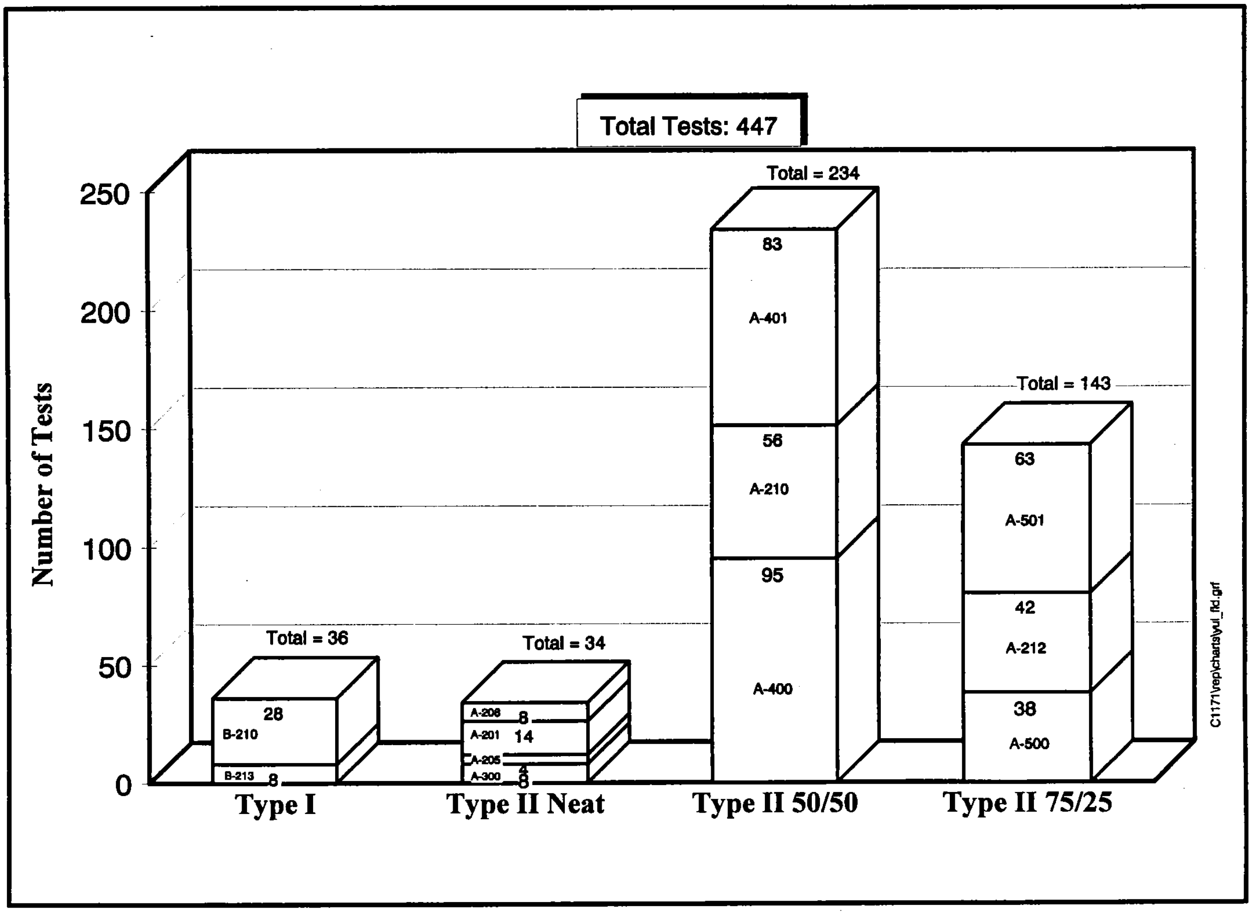
OAT °C	Various Weather Conditions											
	Snow				Freezing Fog*				Freezing Drizzle/Rain			
	1990/91	1991/92	1992/93	1993/94	1990/91	1991/92	1992/93	1993/94	1990/91**	1991/92**	1992/93*	1993/94***
0°C and Above	12	17	2	-	-	-	-	-	-	3	-	-
0 to -7	43	85	24	-	-	-	-	10	15	17	52	-
-7 to -14	24	81	4	-	-	-	4	2	-	-	10	12
-14 to -25	11	-	-	-	-	-	-	-	2	-	-	-
Total	**89**	**183**	**30**	**0**	**0**	**0**	**4**	**12**	**17**	**20**	**62**	**12**

* Simulated
** Natural Freezing Precipitation
*** Simulated, but includes a few points under natural freezing precipitation

FIGURE 3.1

NUMBER OF NATURAL SNOW TESTS

1993-1994 TEST SEASON AT DORVAL



3.1.2 Fluids Tested and Test Location

As mentioned earlier, all of the 447 usable tests were carried out at Dorval. Independent tests were conducted by United Airlines in Denver and by the NRC in Ottawa, and the results are not included here. Tests were conducted with fluids from Octagon, Union Carbide, Hoechst and Kilfrost (represented by ARCO).

3.1.3 Frequency of Average Precipitation Rates

Figure 3.2 shows the distribution of average precipitation rates measured at Dorval with plate pans. The average rates were calculated by dividing, the total precipitation recorded from start of test to time of failure, by the failure time.

3.1.4 Frequency of Other Meteorological Conditions

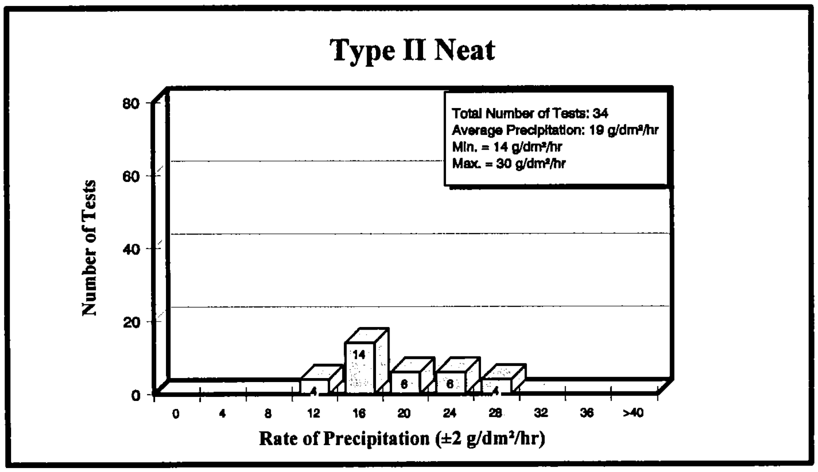
The distribution of meteorological parameters such as temperature, relative humidity, wind speed and wind direction is presented in Figures 3.3, 3.4, 3.5, and 3.6, respectively.

FIGURE 3.2

DISTRIBUTION OF PRECIPITATION RATE

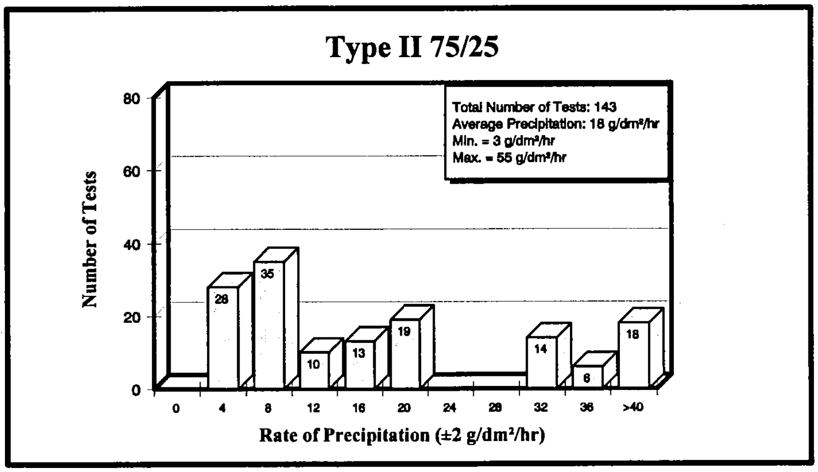
Natural Snow Tests

1993-1994



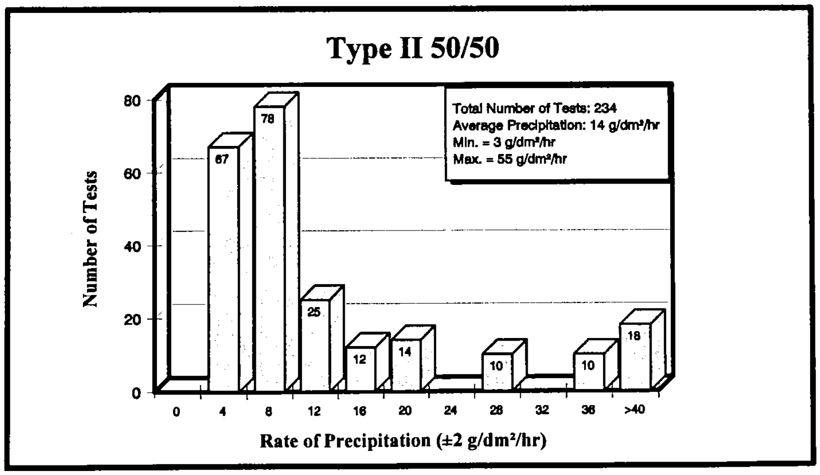
Type II Neat

Total Number of Tests: 34
Average Precipitation: 19 $g/dm^2/hr$
Min. = 14 $g/dm^2/hr$
Max. = 30 $g/dm^2/hr$



Type II 75/25

Total Number of Tests: 143
Average Precipitation: 18 $g/dm^2/hr$
Min. = 3 $g/dm^2/hr$
Max. = 55 $g/dm^2/hr$



Type II 50/50

Total Number of Tests: 234
Average Precipitation: 14 $g/dm^2/hr$
Min. = 3 $g/dm^2/hr$
Max. = 55 $g/dm^2/hr$

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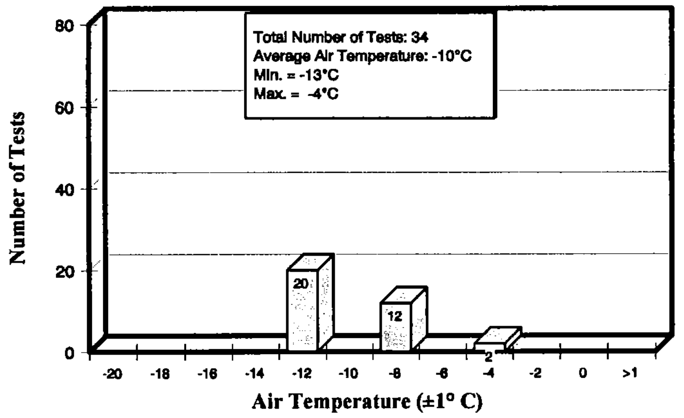
FIGURE 3.3

DISTRIBUTION OF AIR TEMPERATURE

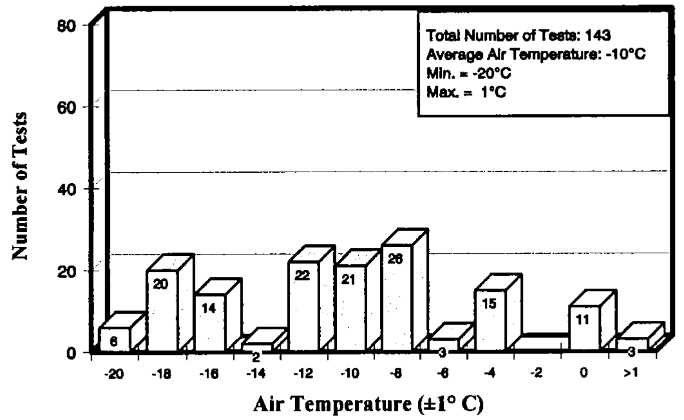
Natural Snow Tests

1993-1994

Type II Neat



Type II 75/25



Type II 50/50

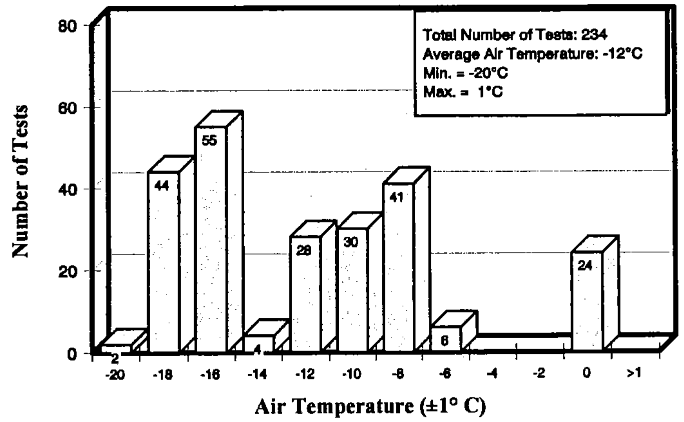


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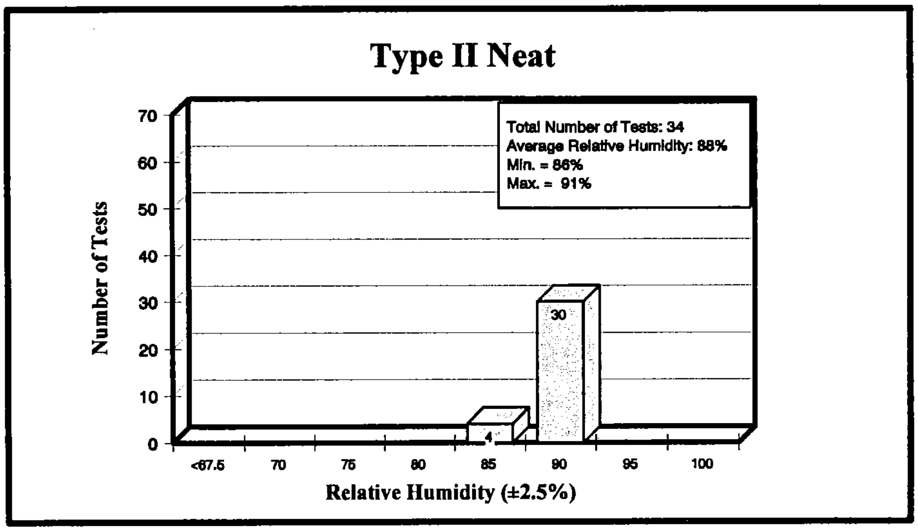
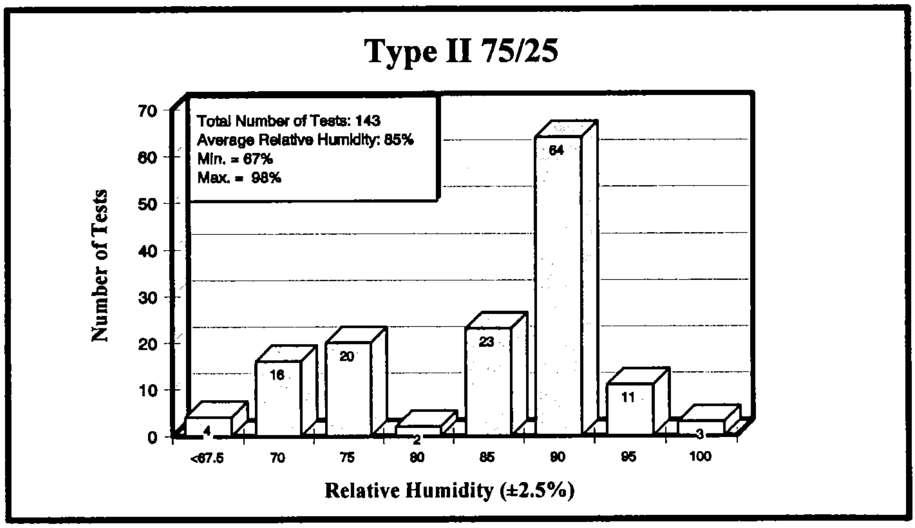
FIGURE 3.4

DISTRIBUTION OF AES RELATIVE HUMIDITY

Natural Snow Tests

1993-1994


Type II Neat


Type II 75/25

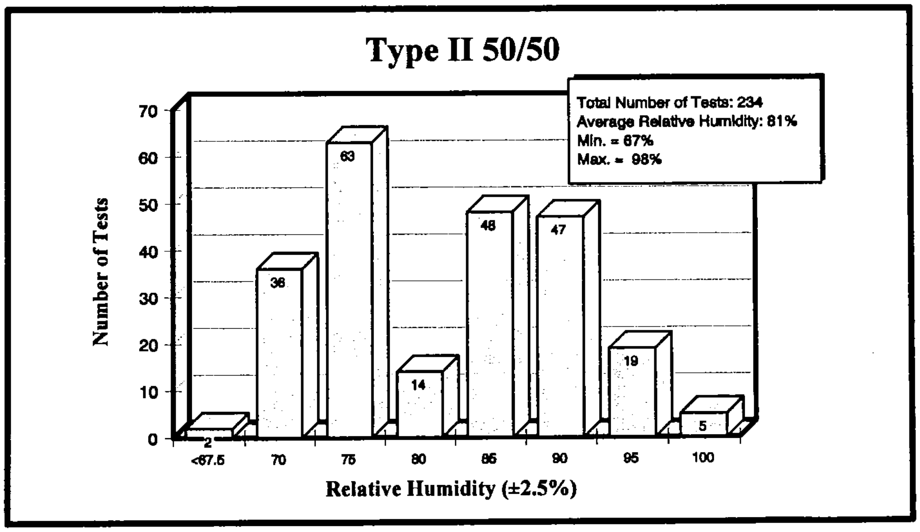

Type II 50/50

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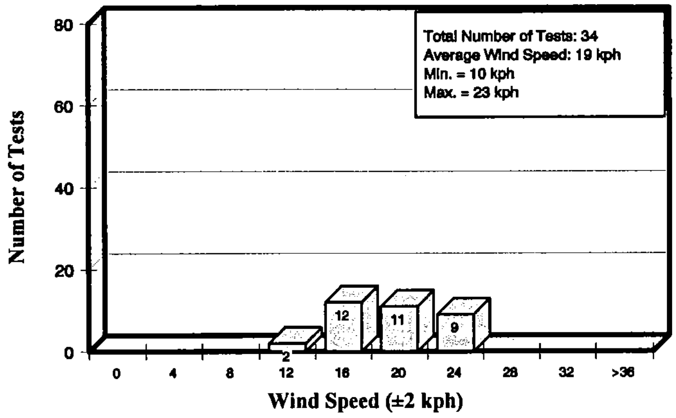
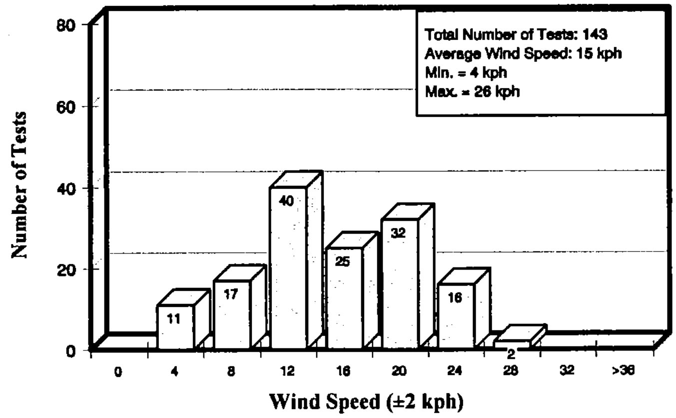
FIGURE 3.5
DISTRIBUTION OF WIND SPEED
Natural Snow Tests
1993-1994

Type II Neat



Type II 75/25



Type II 50/50

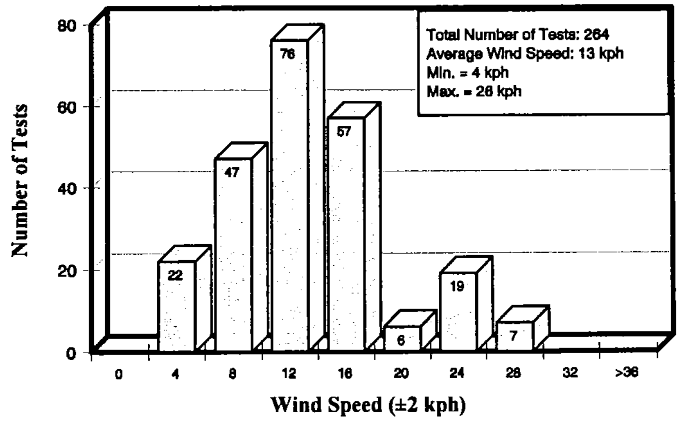


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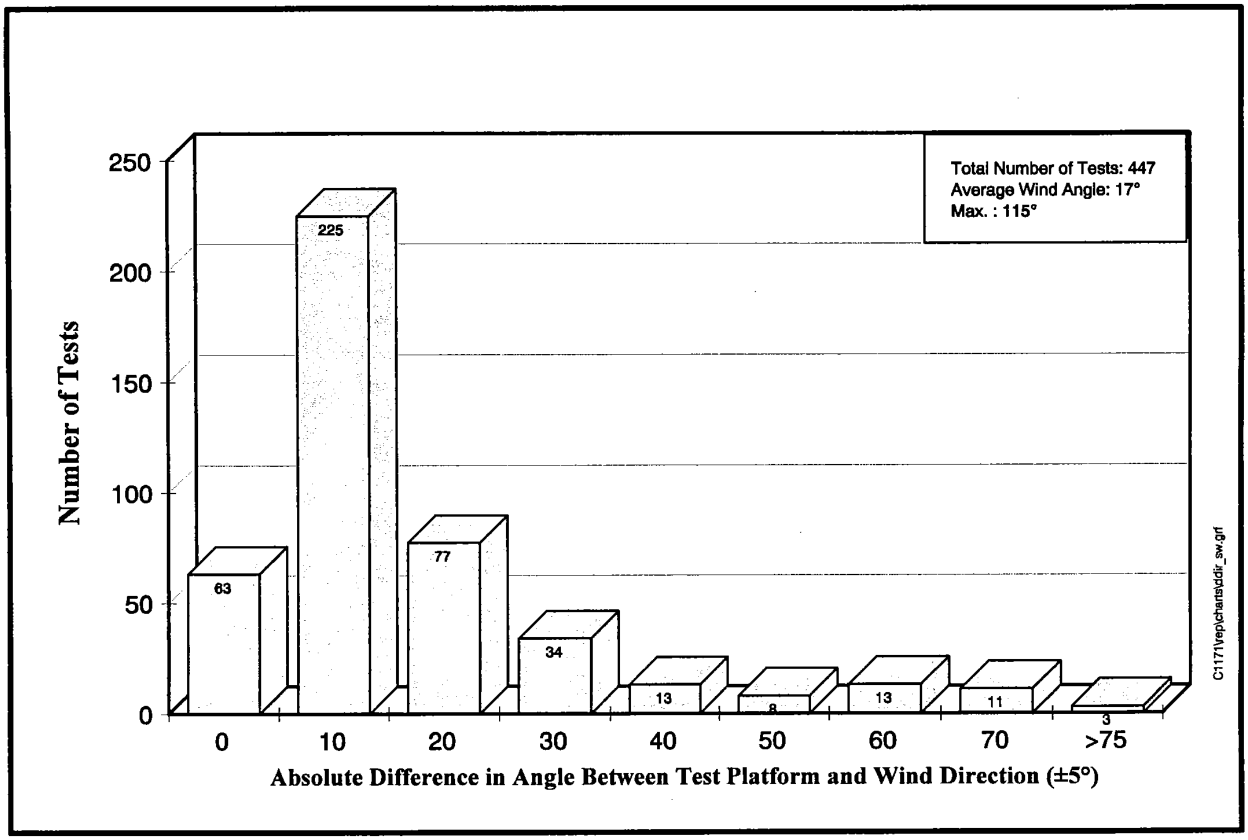
FIGURE 3.6

DISTRIBUTION OF WIND DIRECTION

Natural Snow Tests

1993-1994



3.2 Simulated Freezing Drizzle and Light Freezing Rain

3.2.1 Usable Data

During the period of May 30 to June 3, 1994, APS collected test data from 34 forms for the simulated freezing drizzle and light freezing rain tests in Ottawa. Almost every form contained data for six test plates. As shown in Figure 3.7, these data forms contained a total of 200 usable test points, of which 52 points were during drizzle conditions and 148 were during freezing rain.

3.2.2 Fluids Tested and Test Location

All of the 200 usable tests were carried out at NRC's climatic engineering facility in Ottawa. As with natural snow, the fluids used were from Union Carbide, Octagon, Hoescht, and Kilfrost.

3.2.3 Frequency of Average Precipitation Rates

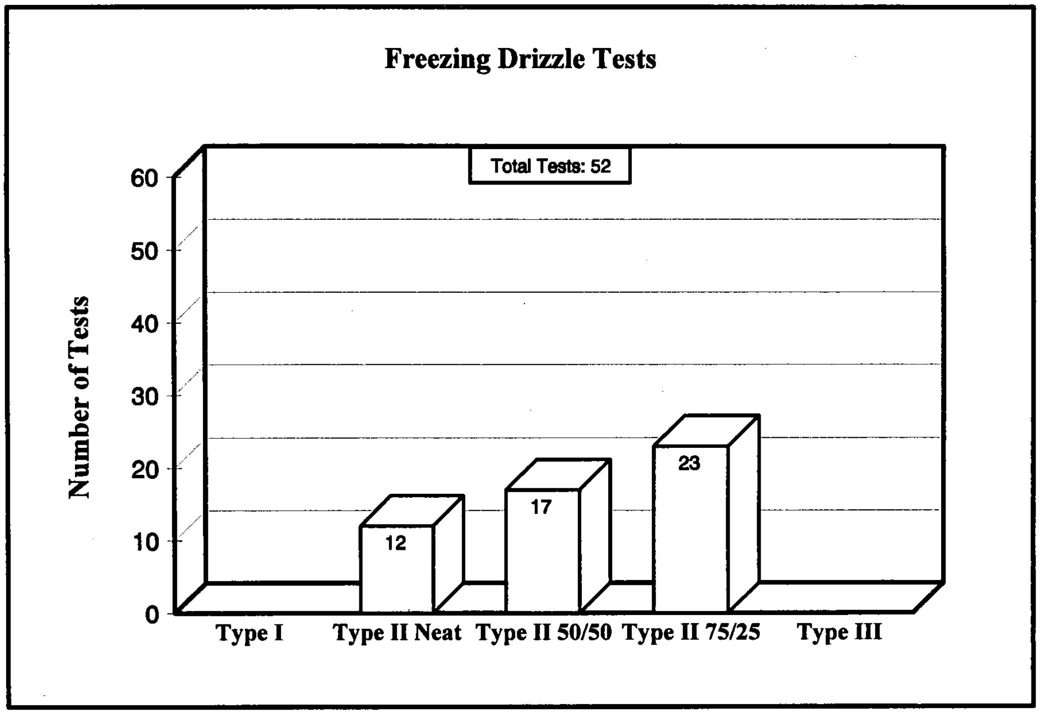
Figure 3.8 shows the distribution of average precipitation rates recorded at the NRC facilities. As described in Section 2, the average precipitation rates for freezing drizzle and rain were computed from weight measurements taken with the plate pans.

It can be seen in Figure 3.8 that simulated freezing drizzle was produced with rates less than 13 g/dm^2/hr, while light freezing rain was produced with rates greater than 13 g/dm^2/hr.

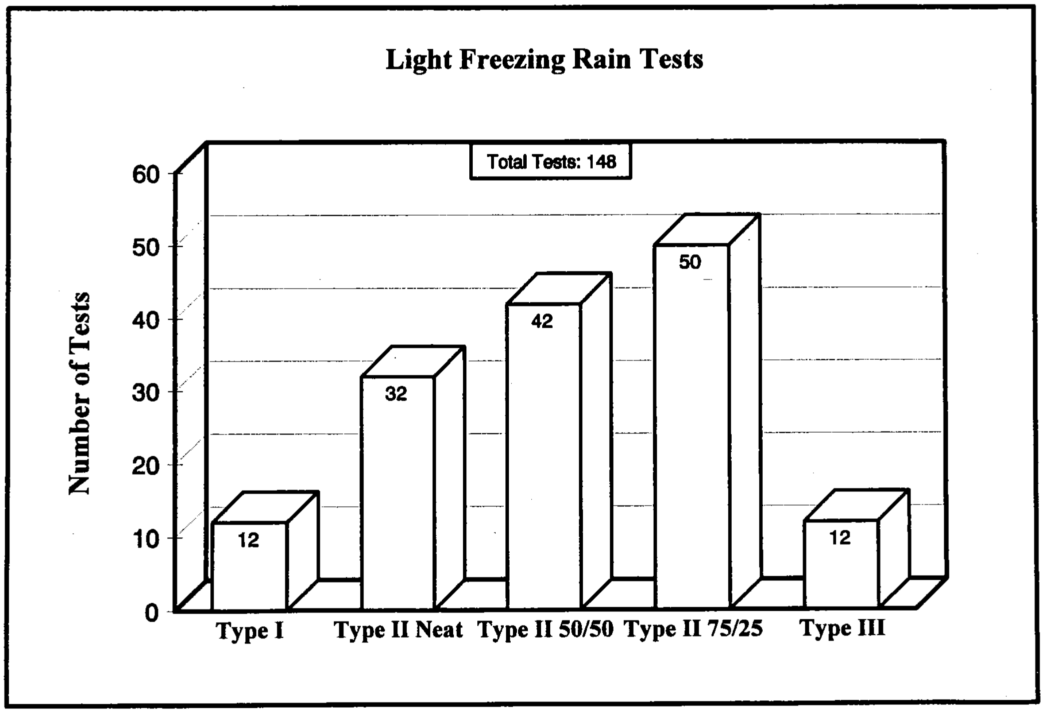
FIGURE 3.7

NUMBER OF SIMULATED FREEZING DRIZZLE/RAIN TESTS

1993-1994 TEST SEASON



Freezing Drizzle Tests



Light Freezing Rain Tests

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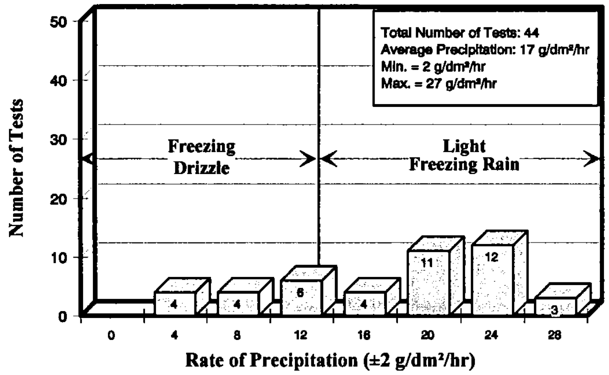
FIGURE 3.8

DISTRIBUTION OF PRECIPITATION RATE

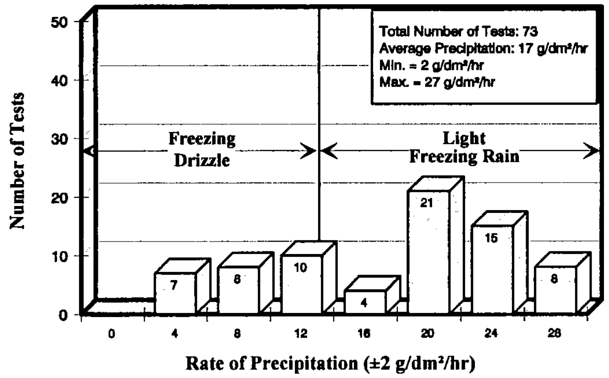
Simulated Freezing Drizzle/Rain Tests

1993-1994

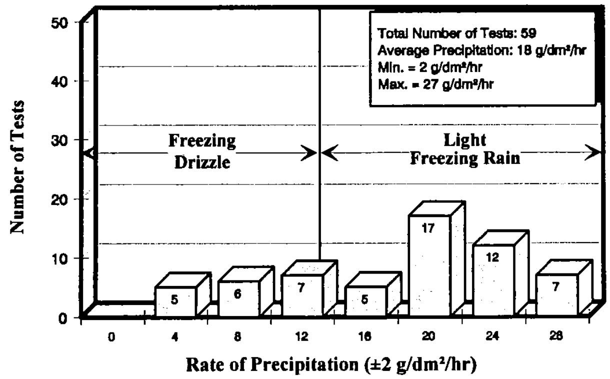
Type II Neat



Type II 75/25



Type II 50/50



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3.2.4 Frequency of Other Meteorological Conditions

The only meteorological factor which was varied during the freezing drizzle and rain tests was air temperature. The distribution of the air temperatures is presented in Figure 3.9, which shows that the majority of the tests were conducted with air temperatures from -6°C to -9°C.

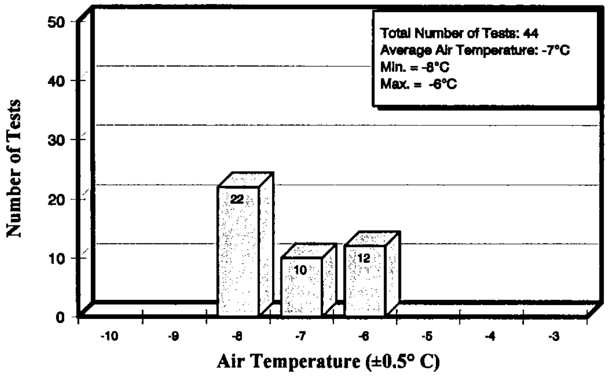
FIGURE 3.9

DISTRIBUTION OF AIR TEMPERATURE

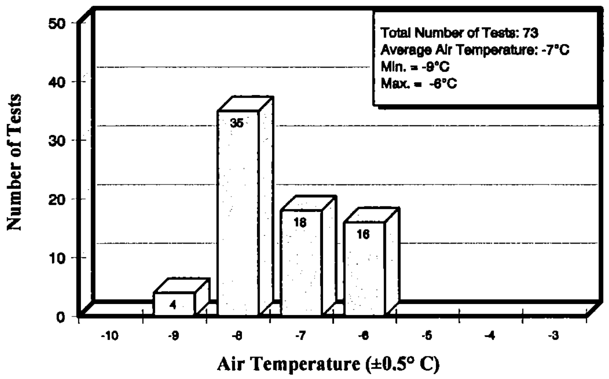
Simulated Freezing Drizzle/Rain Tests

1993-1994

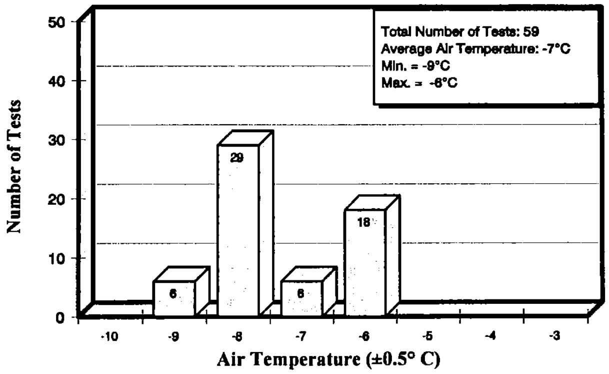
Type II Neat



Type II 75/25



Type II 50/50



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3.3 Simulated Freezing Fog Tests

3.3.1 Usable Data

APS collected test data on 25 usable forms from the outdoor freezing fog tests in Ottawa. These data forms contained a total of 138 usable test points. Of the usable tests, a total of 25 tests were of Type II, 50 were of Type II 75/25, 51 were of Type II 50/50, and 12 were of Type III fluids. This is shown in Figure 3.10.

3.3.2 Fluids Tested and Test Location

As mentioned earlier, all of the 138 tests were carried out at NRC's outdoor helicopter icing facility in Ottawa. As for the freezing rain/drizzle tests and the natural snow tests, the fluids tested were from Union Carbide, Octagon, Kilfrost and Hoechst.

3.3.3 Frequency of Average Precipitation Rates

Figure 3.11 provides the distribution of average precipitation rates recorded at the icing facility. As previously mentioned, these rates were measured with the plate pan. It can be seen that the rates vary from about 2 to 9 g/dm^2/hr.

FIGURE 3.10

NUMBER OF SIMULATED FREEZING FOG TESTS

1993-1994 TEST SEASON

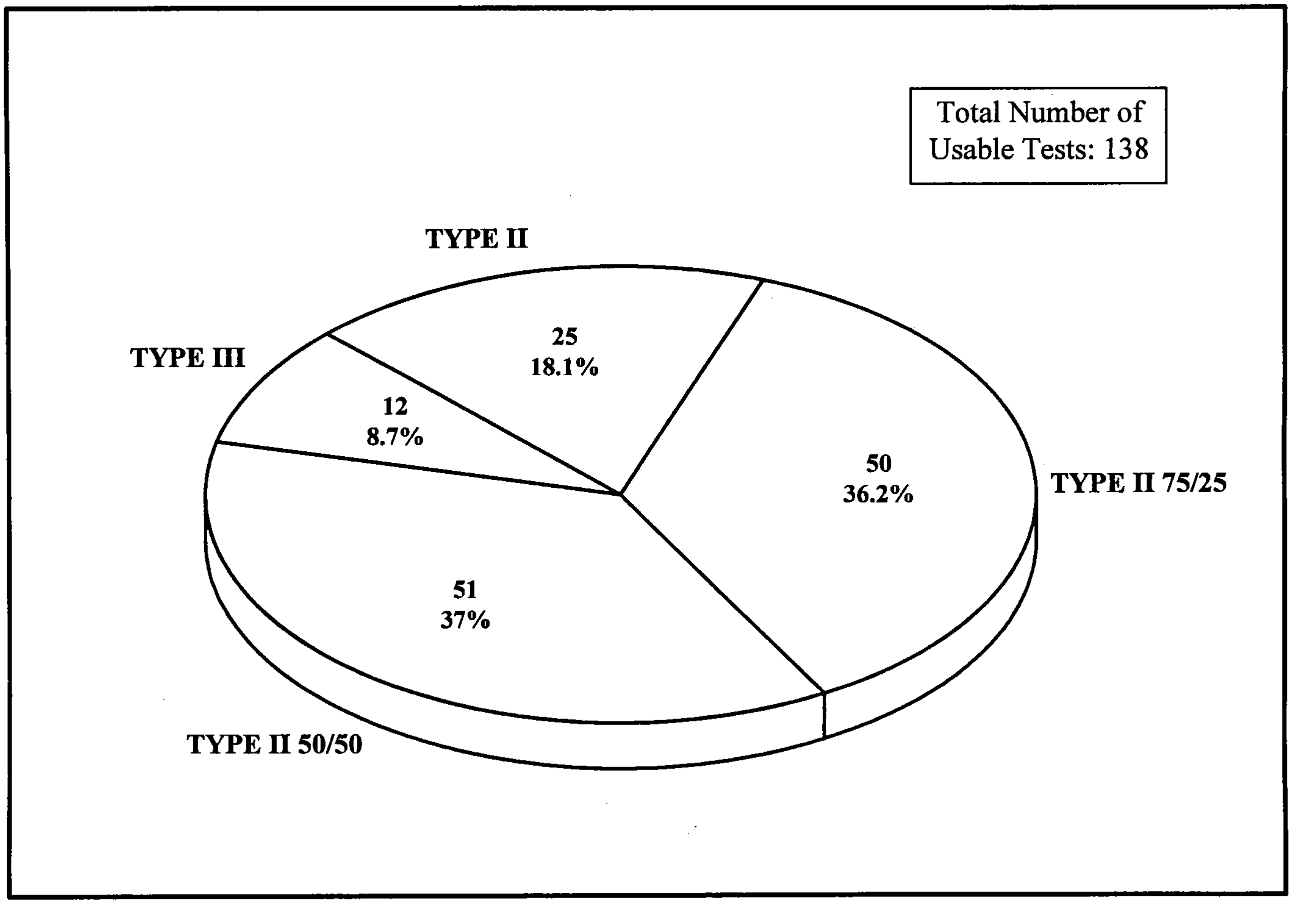
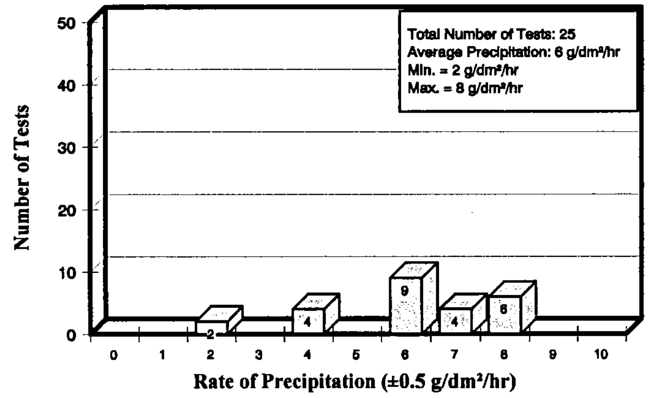


FIGURE 3.11

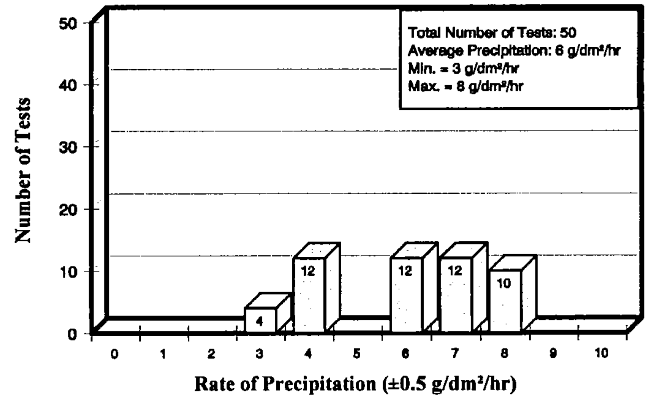
DISTRIBUTION OF PRECIPITATION RATE

Simulated Freezing Fog Tests

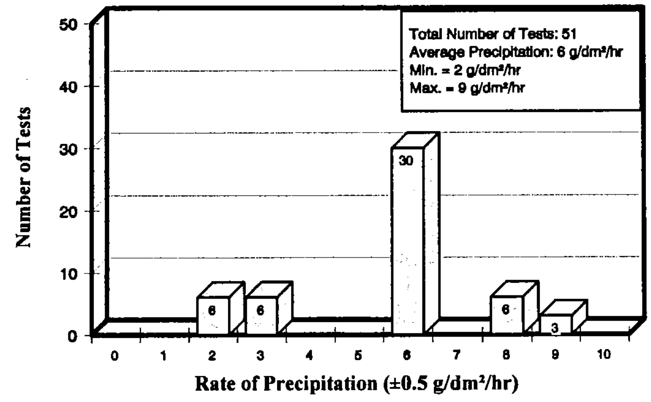
1993-1994



Type II Neat



Type II 75/25



Type II 50/50

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3.3.4 Frequency of Other Meteorological Conditions

The only meteorological factor which varied substantially during the freezing fog tests is temperature. The distribution of temperatures is presented in Figure 3.12, which shows that the test temperatures varied from about -5°C to -11°C. Wind conditions measured from an NRC meteorological set-up, were recorded, however these were not plotted.

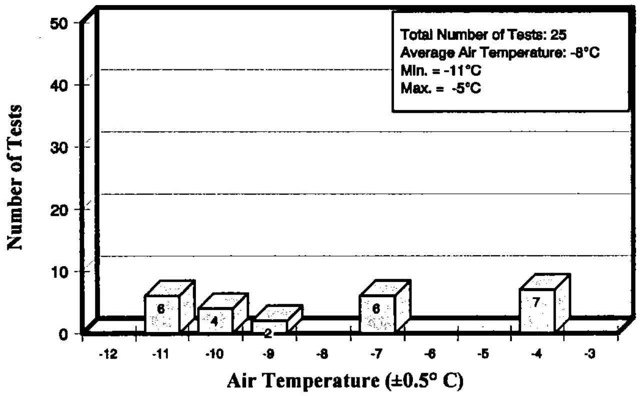
FIGRE 3.12

DISTRIBUTION OF AIR TEMPERATURE

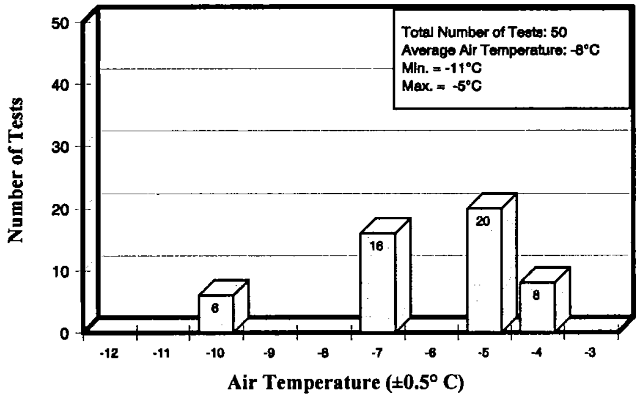
Simulated Freezing Fog Tests

1993-1994

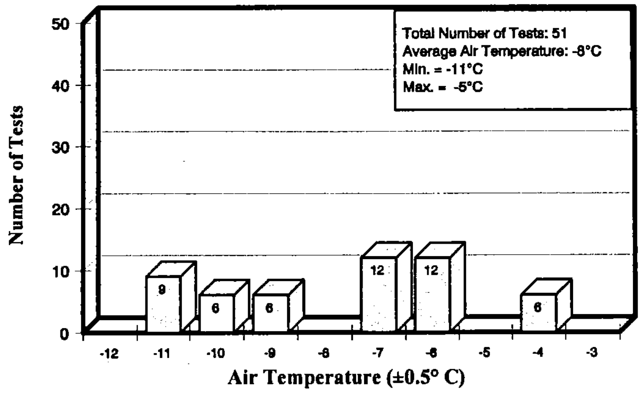
Type II Neat



Type II 75/25



Type II 50/50



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4. METEOROLOGICAL ANALYSIS

The following subsections take an in depth look at precipitation collection devices, and provide a comparison of the Dorval site equipment with that from AES.

4.1 Comparison of Precipitation Collection Devices at Dorval

For the snow tests at Dorval, two methods were used to record precipitation rate: the European ombrometer (shielded) which measures the precipitation in increments of 0.05 g/dm^2, and one or two plate pans on the stand (two pans were used only at the end of the test season). The plate pan, which is pre-wetted and pre-weighed, is used to record total precipitation from the beginning to the end of the test. The pan is installed on the stand, beside the flat plates, at a 10° incline. Figure 4.1 shows that while the European ombrometer was shielded, a large scatter between the two devices still exists.

Precipitation data was also acquired from Meteoglobe Canada Inc. who are under contract to the City of Montreal to provide precipitation data. The total precipitation was measured with Fisher and Porter gauge protected against wind by Nipher shields. Three gauges were available and located in Montreal at 9, 13 and 16 km from the APS test site. Figure 4.2 shows a comparison of the rate of precipitation of the plate pans with the two closest Fisher and Porter gauges. The chart shows a reasonable correlation between these instruments, and as a result, the plate pan precipitation data was used for the analysis. Any future testing should probably be conducted with plate pans as well as a shielded Fisher and Porter gauge located adjacent to the site.

FIGURE 4.1

COMPARISON OF RATE OF PRECIPITATION OF EUROPEAN OMBROMETER vs PLATE PAN

DORVAL TESTING 1993-1994

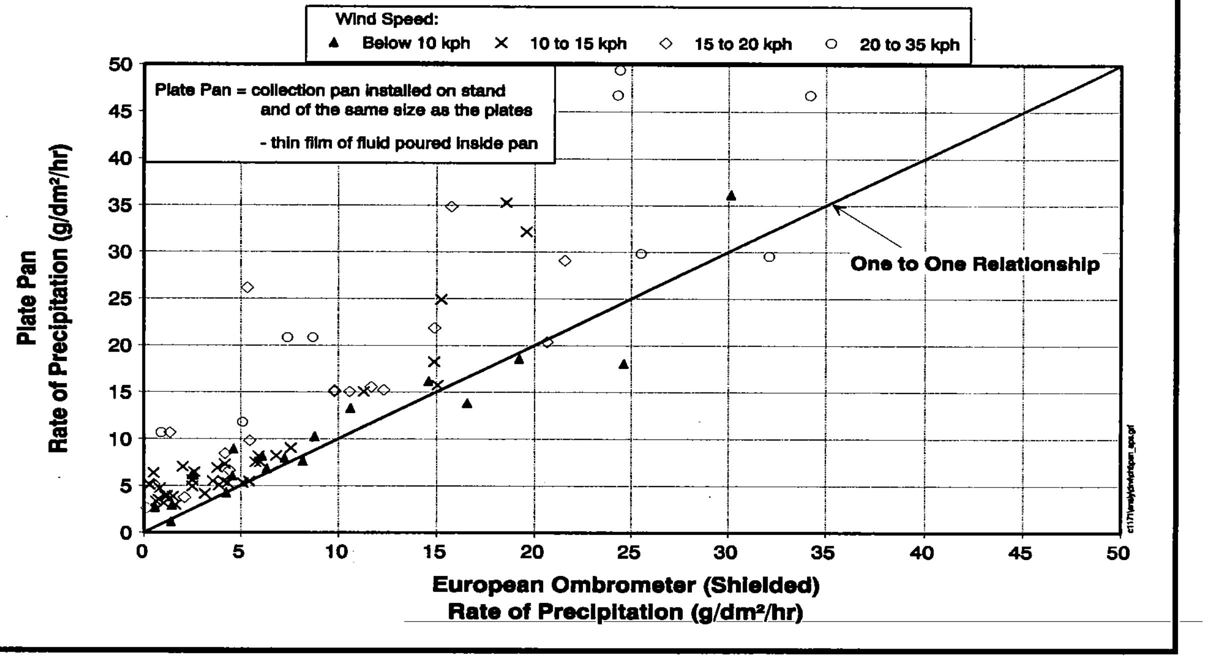
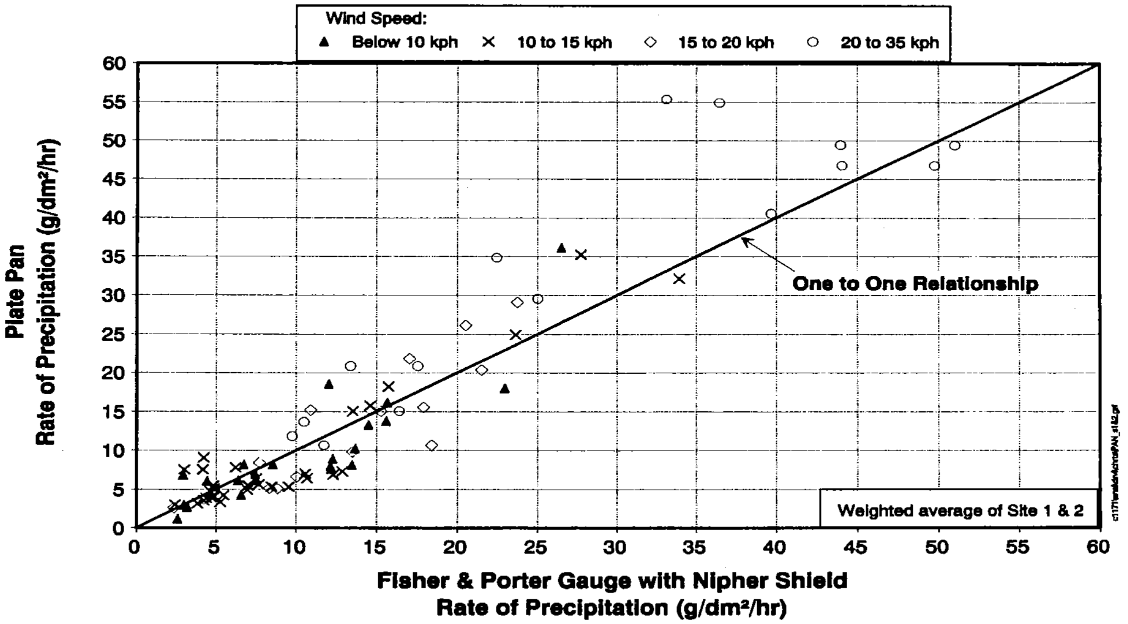


FIGURE 4.2

COMPARISON OF RATE OF PRECIPITATION OF FISHER & PORTER vs PLATE PAN

DORVAL TESTING 1993-1994



4.2 Visibility vs Rate of Precipitation

Figure 4.3 illustrates relationships between visibility in miles for various rates of precipitation, as a function of temperature. The visibility data was obtained from observations by Environment Canada at Dorval airport. The data points represent the plate pan precipitation rates, for all 1993/94 snow tests versus the average visibility during the time of testing. Visibility data from last winter recorded by the three transmissometers at Dorval should be acquired and compared to the observed values. This data is maintained by AES for a one year period only. Any future testing should consider usage of automated equipment to measure visibility.

4.3 Comparison of Meteorological Measurements

Figure 4.4 presents test site wind speed measurements versus Environment Canada's wind speed measurements. The test site measurements were consistently in the range of about 56 % of those from AES.

Temperature, relative humidity and wind direction were also compared for this winters' test season. While both temperature and wind direction data between APS' equipment and that of Environment Canada compared as expected, relative humidity did not (the instrument requires repair). Therefore, relative humidity data from Environment Canada was used for the analysis.

FIGURE 4.3
VISIBILITY vs PRECIPITATION

DORVAL TESTING 1993-1994

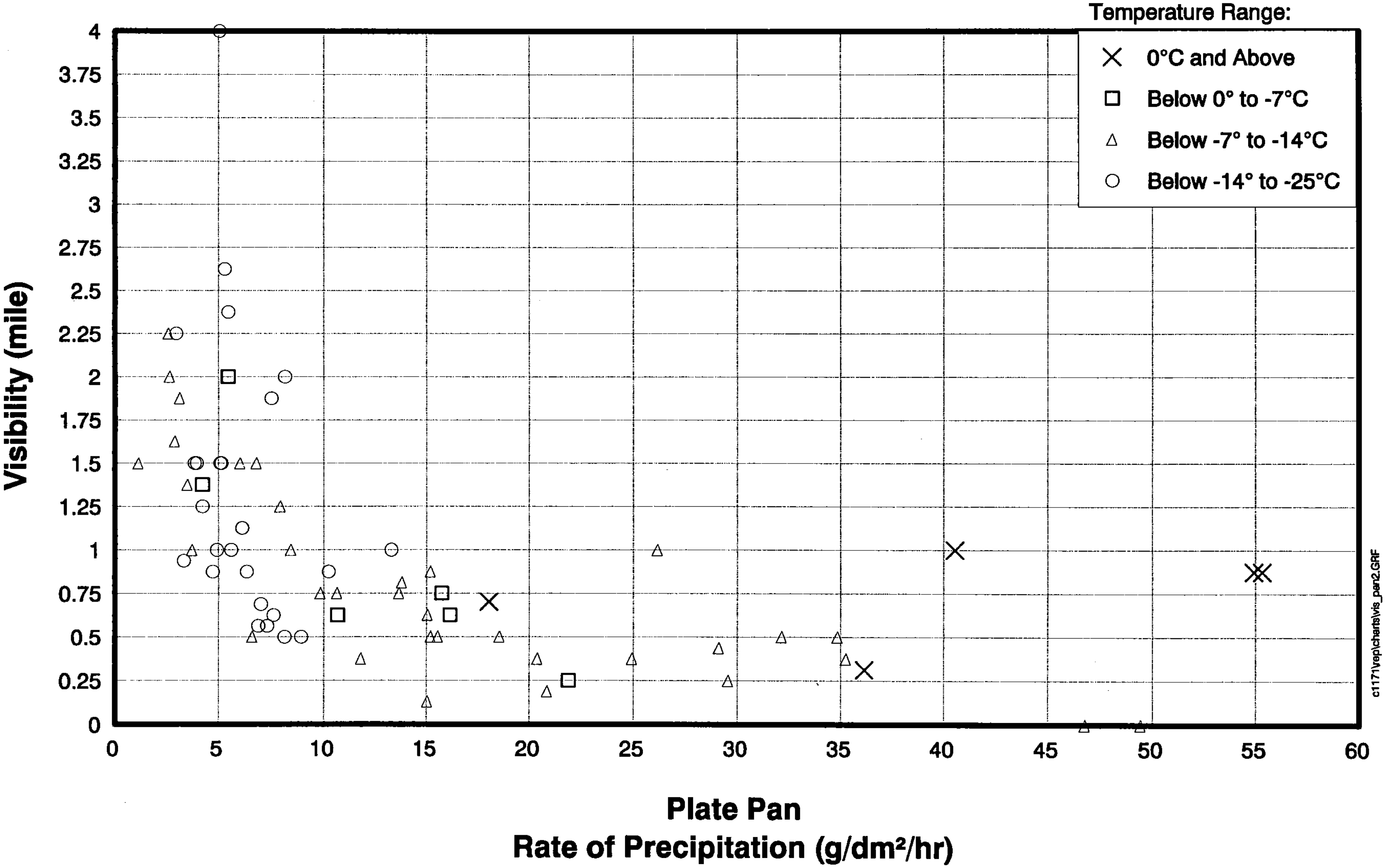
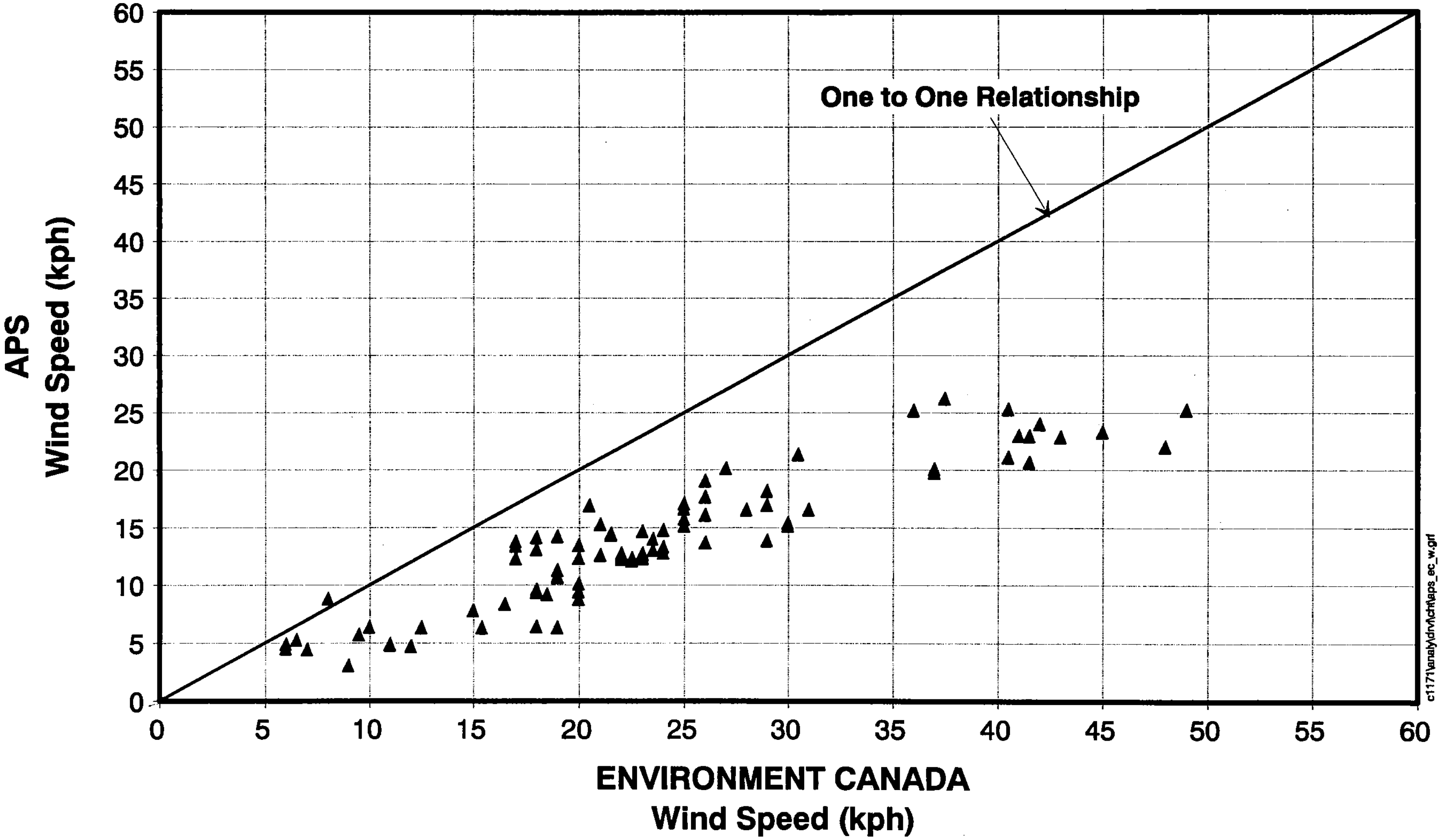


FIGURE 4.4

COMPARISON OF WIND SPEED
ENVIRONMENT CANADA vs APS

Dorval Testing 1993-1994



5. ANALYSIS

The results are sub-divided into three main sections, namely flat plate tests, ice sensor tests and aircraft surface tests, which are discussed separately in their respective sections.

5.1 Flat Plate Tests

The objectives of the flat plate tests were:

a) to verify the currently used SAE holdover times;

b) to identify the important (environmental) parameters which influence the fluid failure time and develop correlation equations where possible;

c) to develop recommendations and changes to test procedures for future testing.

Flat plate tests were conducted under four general categories of conditions, namely natural snow, freezing rain and drizzle, freezing fog, and rain on a cold-soaked surface. Throughout the discussions, it is presumed that a one to one relationship exists between fluid failure times on the flat plate and on an aircraft surface.

5.1.1 Natural Snow Conditions

In general, for a given fluid, the failure time under snow conditions is governed by the following measured parameters: rate of precipitation, wind speed and air temperature.

A multi-variable regression analysis was performed to determine the existence of a relationship between fluid failure time and the measured parameters. The results of the regression analysis for the set of snow data is summarized in Table 5.1.

As was shown in Section 3, natural snow tests at Dorval during 1993/94 were carried out primarily with diluted Type II fluids, and the results of these tests are provided in the next few sections.

5.1.1.1 Type II 75/25 Fluids in Natural Snow

Figure 5.1 shows a plot of the effect of fluid type and rate of precipitation on Type II 75/25 fluid failure time in natural snow conditions. The chart shows that fluids from different manufacturers, but of the same type, generally have different failure times. The tests conducted with fluid A-500 generally lasted longer, while those with fluid A-212 and A-501 had approximately the same endurance.

Figure 5.2 shows the effect of temperature and rate of precipitation on failure time for only one of the three fluids shown in Figure 5.1. The chart demonstrates that the few test points designated by "Xs" resulted in longer failure times from warm temperature tests, while the test points with reduced failure times in the encircled area on the bottom left resulted from very cold temperature tests. Figure 5.2 further illustrates that both temperature and rate of precipitation have a strong influence on fluid failure time.

TABLE 5.1

MULTI-VARIABLE REGRESSION ANALYSIS RESULTS FOR TYPE II DILUTED FLUIDS IN NATURAL SNOW CONDITIONS

Dorval Test 1993-1994

Equation #	Fluid Type	No. of Tests	Equation	R²
1	All Type II 75/25	143	$t = 10^{(-31 - 0.138(A\text{-}501) - 0.129(A\text{-}212) + 0(A\text{-}500))} (Tk)^{13.55} (W)^{0.35} (R)^{-0.66}$	81%
1a	A-501	63	$t = 10^{-35.95} (Tk)^{15.44} (W)^{0.69} (R)^{-0.67}$	89%
1b	A-212	42	$t = 10^{-31.41} (Tk)^{13.83} (W)^{0.18} (R)^{-0.73}$	88%
1c	A-500	38	$t = 10^{-19.1} (Tk)^{8.74} (W)^{0.33} (R)^{-0.72}$	82%
2	All Type II 50/50	234	$t = 10^{(-61.35 - 0.098(A\text{-}401) - 0(A\text{-}210) + 0(A\text{-}400))} (Tk)^{26.03} (W)^{0.18} (R)^{-0.58}$	77%
2a	A-401	83	$t = 10^{-64.09} (Tk)^{26.98} (W)^{0.43} (R)^{-0.55}$	82%
2b	A-210	56	$t = 10^{-76.35} (Tk)^{32.34} (R)^{-0.67}$	90%
2c	A-400	95	$t = 10^{-52.99} (Tk)^{22.60} (W)^{0.15} (R)^{-0.62}$	68%

Tk = kelvin (°C + 273.2)

W = wind speed (kph)

R = precipitation rate (g/dm²/hr)

t = failure time (min)

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FIGURE 5.1

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON TYPE II 75/25 FLUID FAILURE TIME IN NATURAL SNOW CONDITIONS

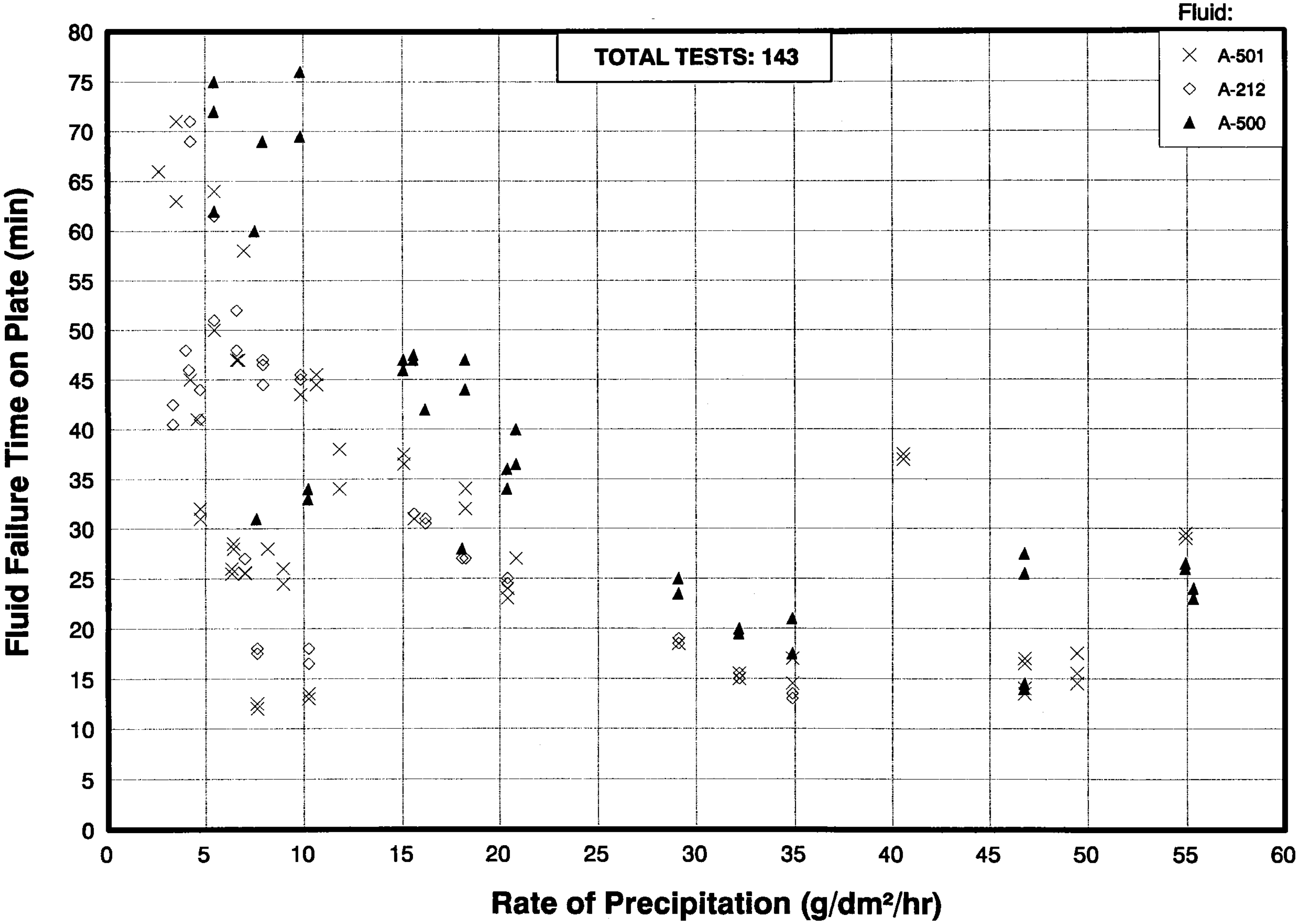

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FIGURE 5.2

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON TYPE II 75/25 A-501 FLUID FAILURE TIME IN NATURAL SNOW CONDITIONS

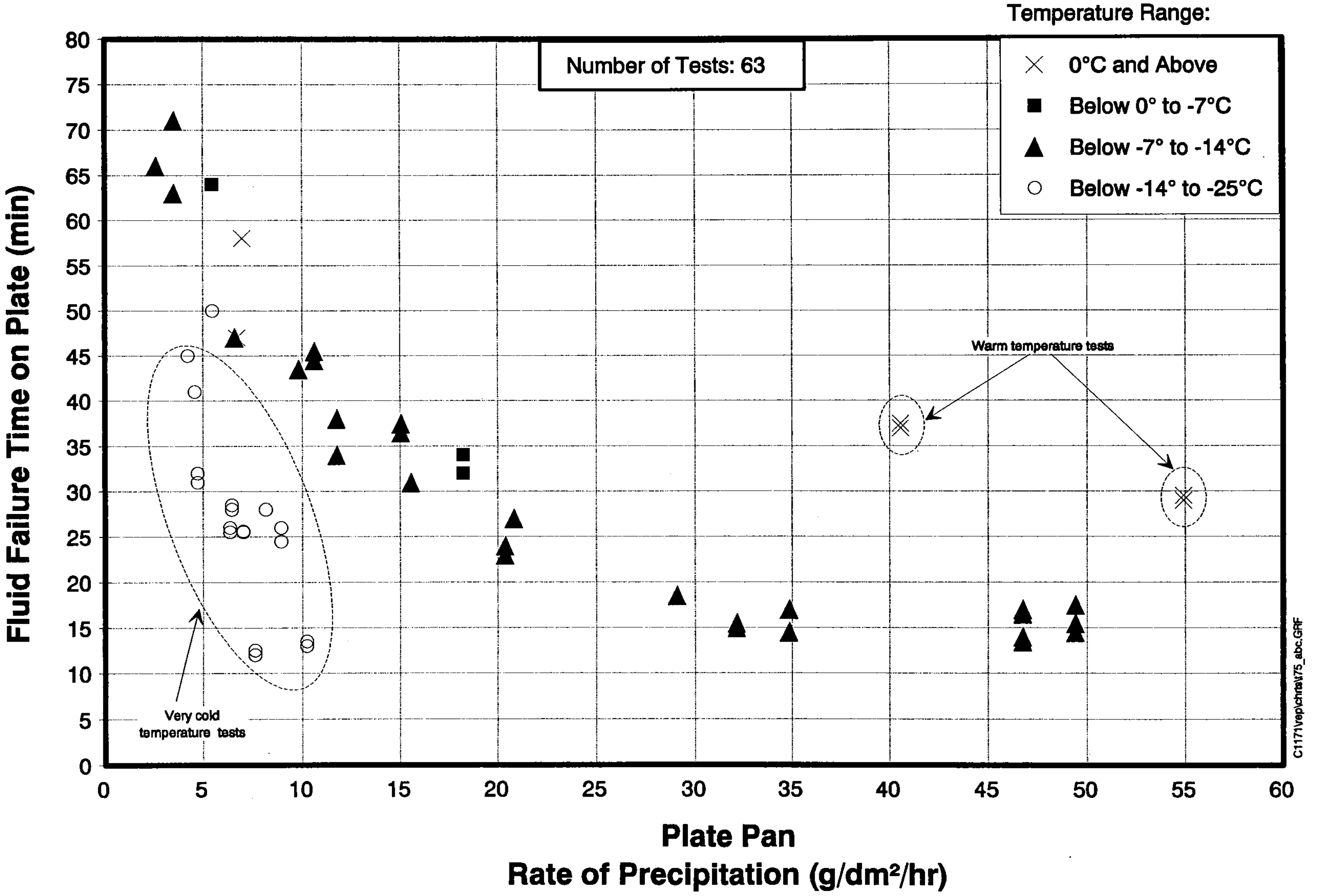

Figure 5.3 shows the effect of wind speed on fluid failure time. It can be seen from the chart that test points with high winds generally tend to last longer, while tests conducted during calm wind conditions generally tend to fail faster.

Figure 5.4 also shows the results of the 75/25 tests, but with temperature on the abscissa and with the rate of precipitation sub-divided as indicated in the legend. Also shown on the chart is the present SAE/ISO holdover time range for air temperatures down to -14°C. Based upon the test data collected at Dorval, the following observations can be stated:

- For temperatures of 0°C and above, all 14 test end condition times exceeded the HOT lower limit.

- For temperatures below 0°C to -7°C, all 18 test end condition times exceeded the HOT lower limit. Figure 5.4 shows that none of the 18 test points occurred during precipitation rates exceeding 25 g/dm^2/hr.

- For temperatures below -7°C to -14°C , all test points with rates of precipitation below 25 g/dm^2/hr exceeded the lower limit. The lower limit should be reduced to include the points with higher rates of precipitation.

The multi-variable regression analysis, shown in Table 5.1, provided support to the statements made earlier. Equation 1 shows that an increasing rate of precipitation and cold temperatures tend to decrease failure time, while higher winds

FIGURE 5.3

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON TYPE II 75/25 FLUID FAILURE TIME IN NATURAL SNOW CONDITIONS

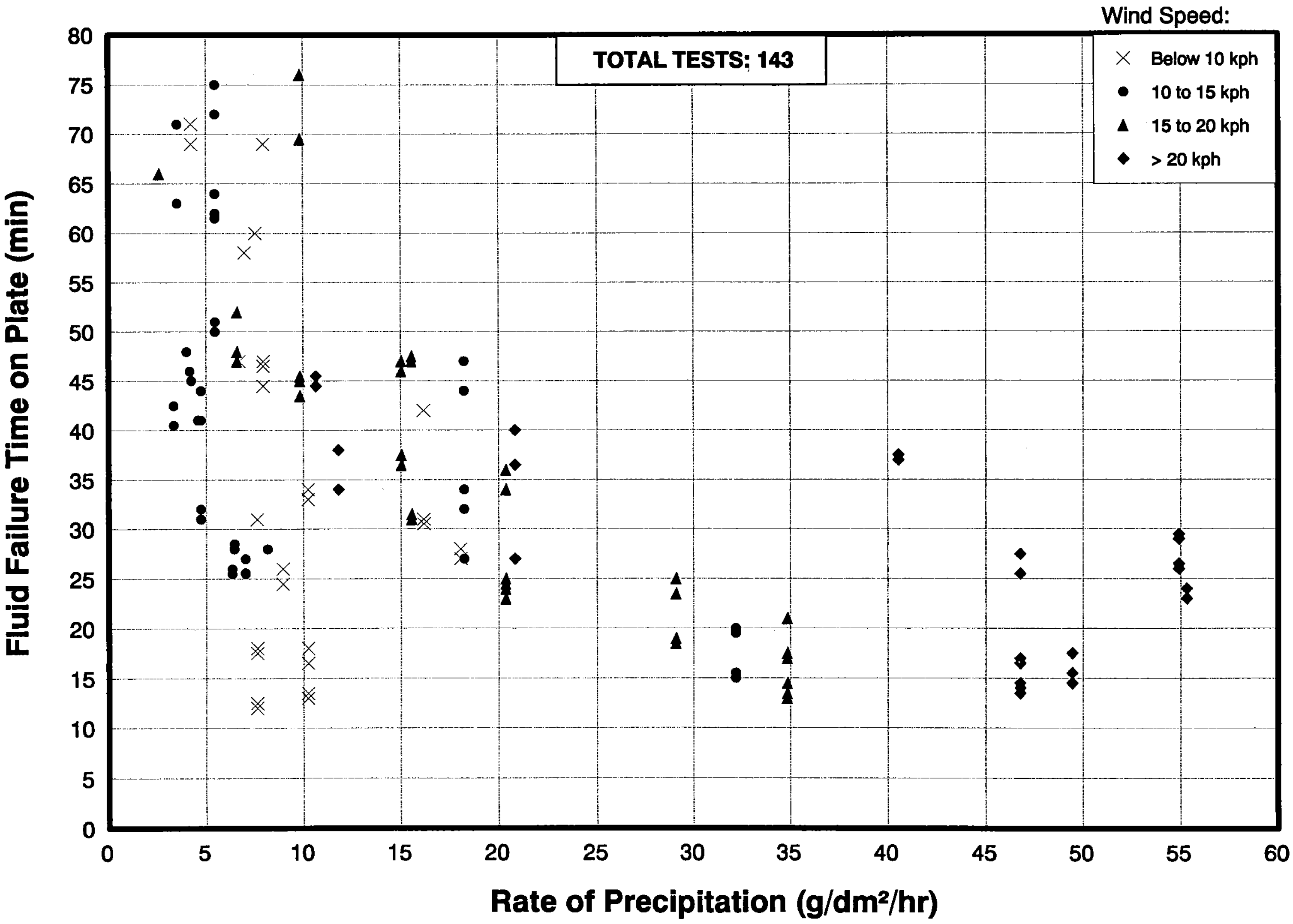

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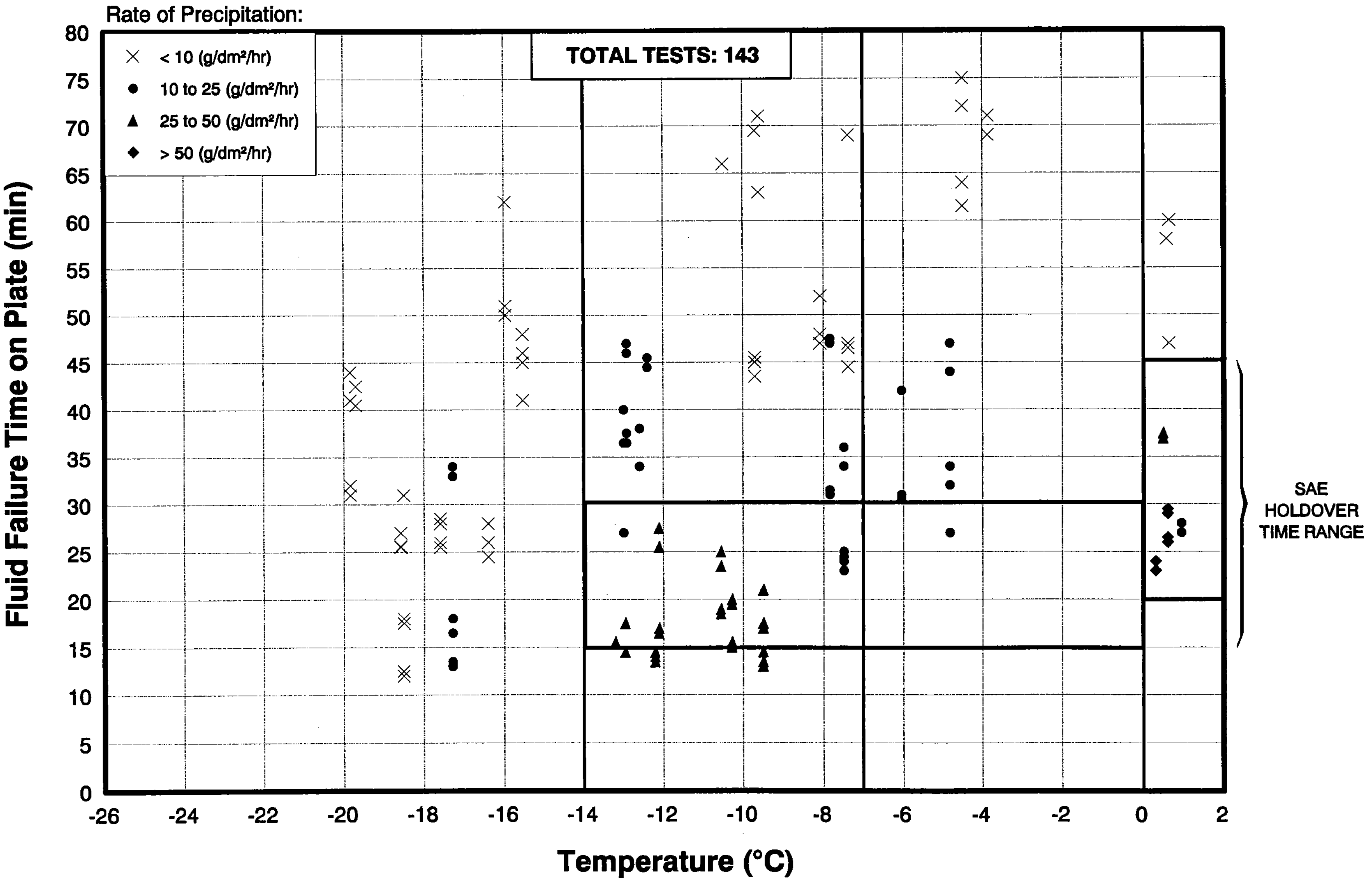
FIGURE 5.4

RESULTS OF TYPE II 75/25 NATURAL SNOW TESTS AS A FUNCTION OF TEMPERATURE AND RATE OF PRECIPITATION



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tend to prolong failure times. The equation also distinguishes from one fluid type to another, particularly A-500 which is a superior fluid.

5.1.1.2 Type II 50/50 Fluids in Natural Snow

Figure 5.5 shows a plot of the effect of temperature and rate of precipitation on Type II 50/50 fluid failure time in natural snow conditions. The chart shows that temperature has a strong influence on failure time - cold temperatures tend to reduce failure times and warmer temperatures tend to prolong failure times.

Figure 5.6 shows the effect of temperature and rate of precipitation on one of the three fluids shown on the previous chart. The chart further demonstrates that both temperature and rate of precipitation have a strong influence on fluid failure time. The points designated by square symbols on the upper left of the chart are tests which were conducted during warm temperatures and high winds. These conditions tend to increase failure times. The test points circled at the bottom left of the chart occurred during very cold temperatures. These conditions tend to reduce plate failure times.

Figure 5.7 shows the effect of wind speed on plate failure time. A similar physical phenomena as was experienced in Type II 75/25 fluids is seen for 50/50 fluids. Winds forces in the upstream direction of the plates tend to increase plate failure time.

FIGURE 5.5

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON TYPE II 50/50 FLUID FAILURE TIME IN NATURAL SNOW CONDITIONS

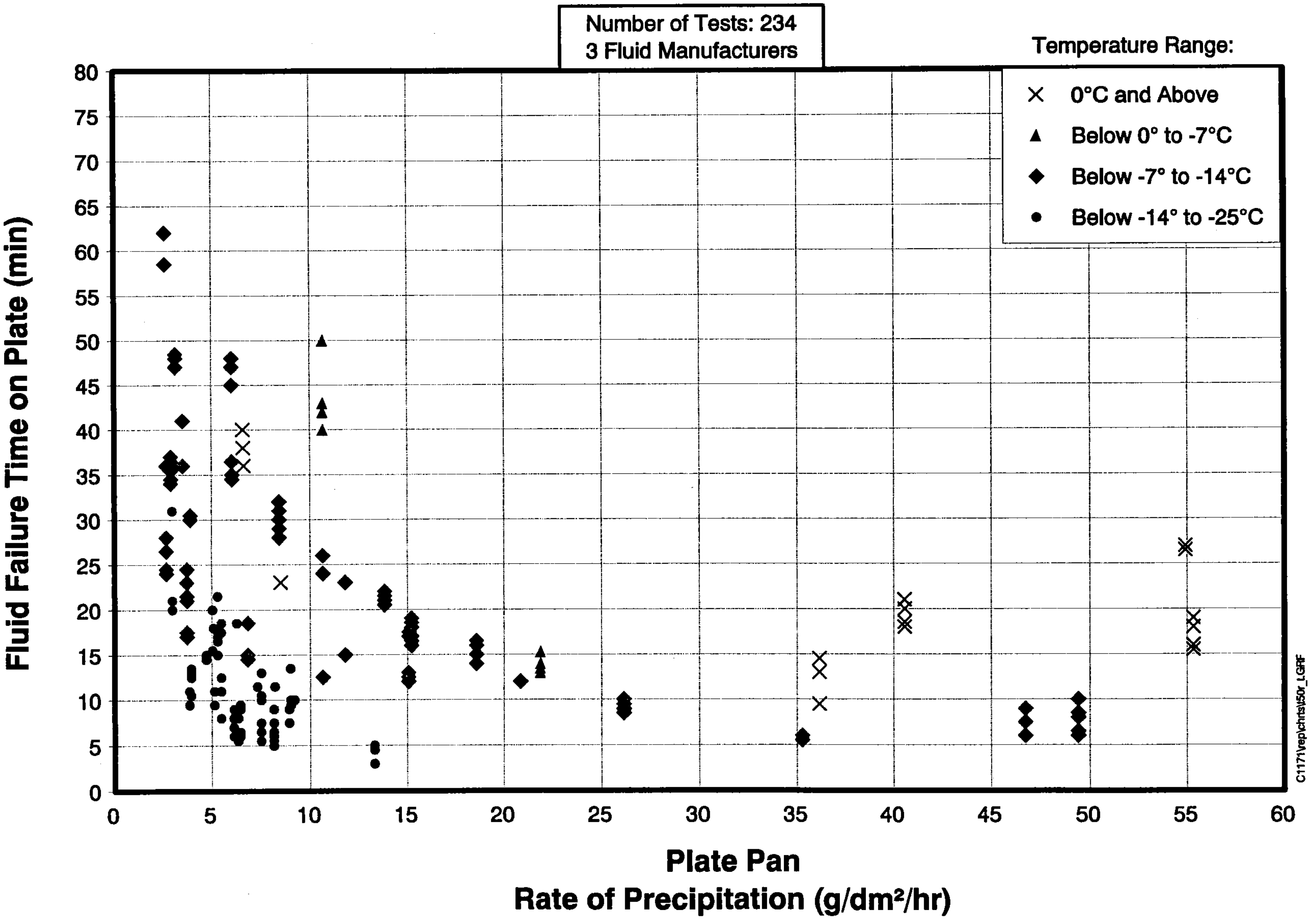


FIGURE 5.6

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON TYPE II 50/50 A-210 FLUID FAILURE TIME IN NATURAL SNOW CONDITIONS

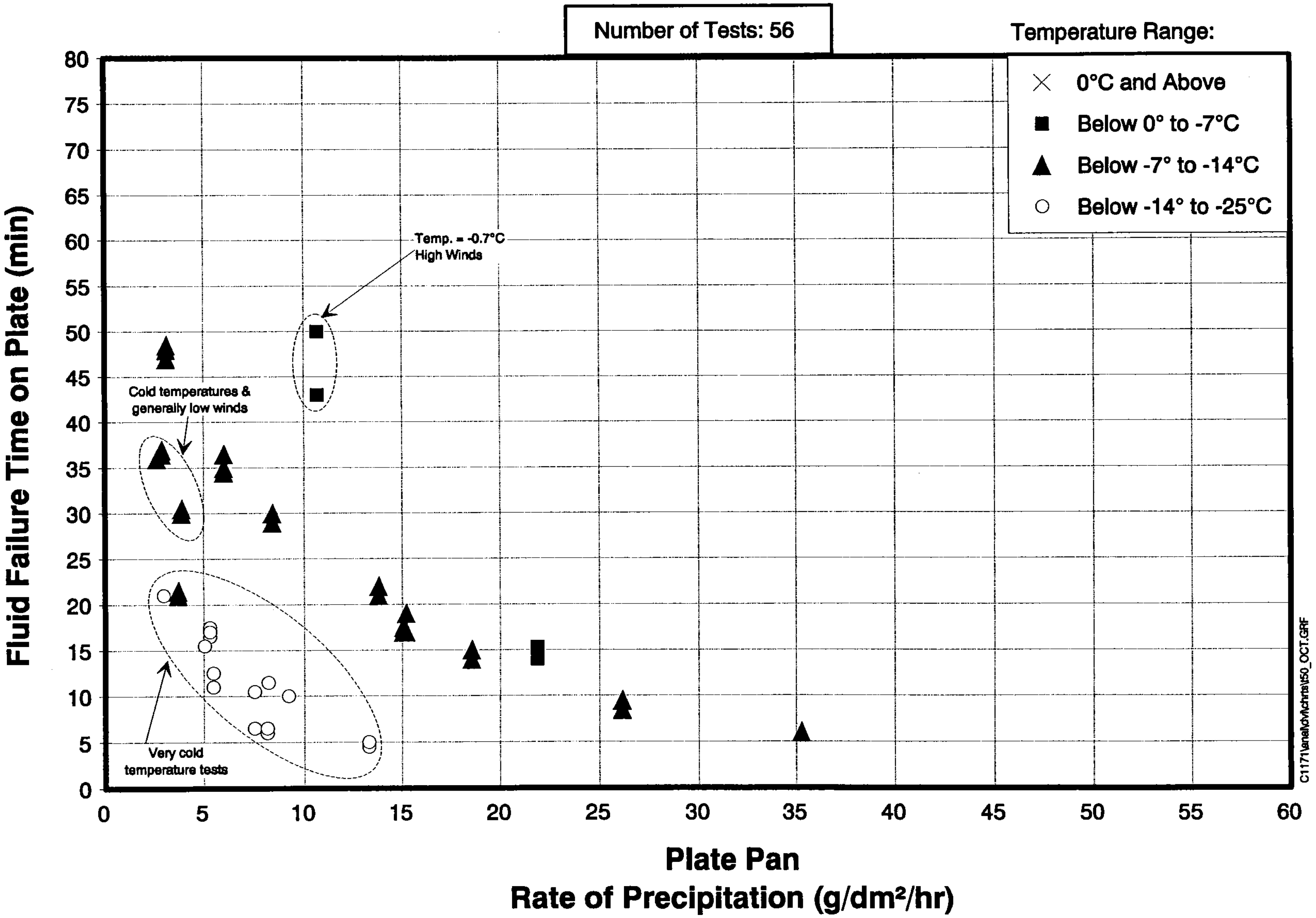


FIGURE 5.7

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON TYPE II 50/50 FLUID FAILURE TIME IN NATURAL SNOW CONDITIONS

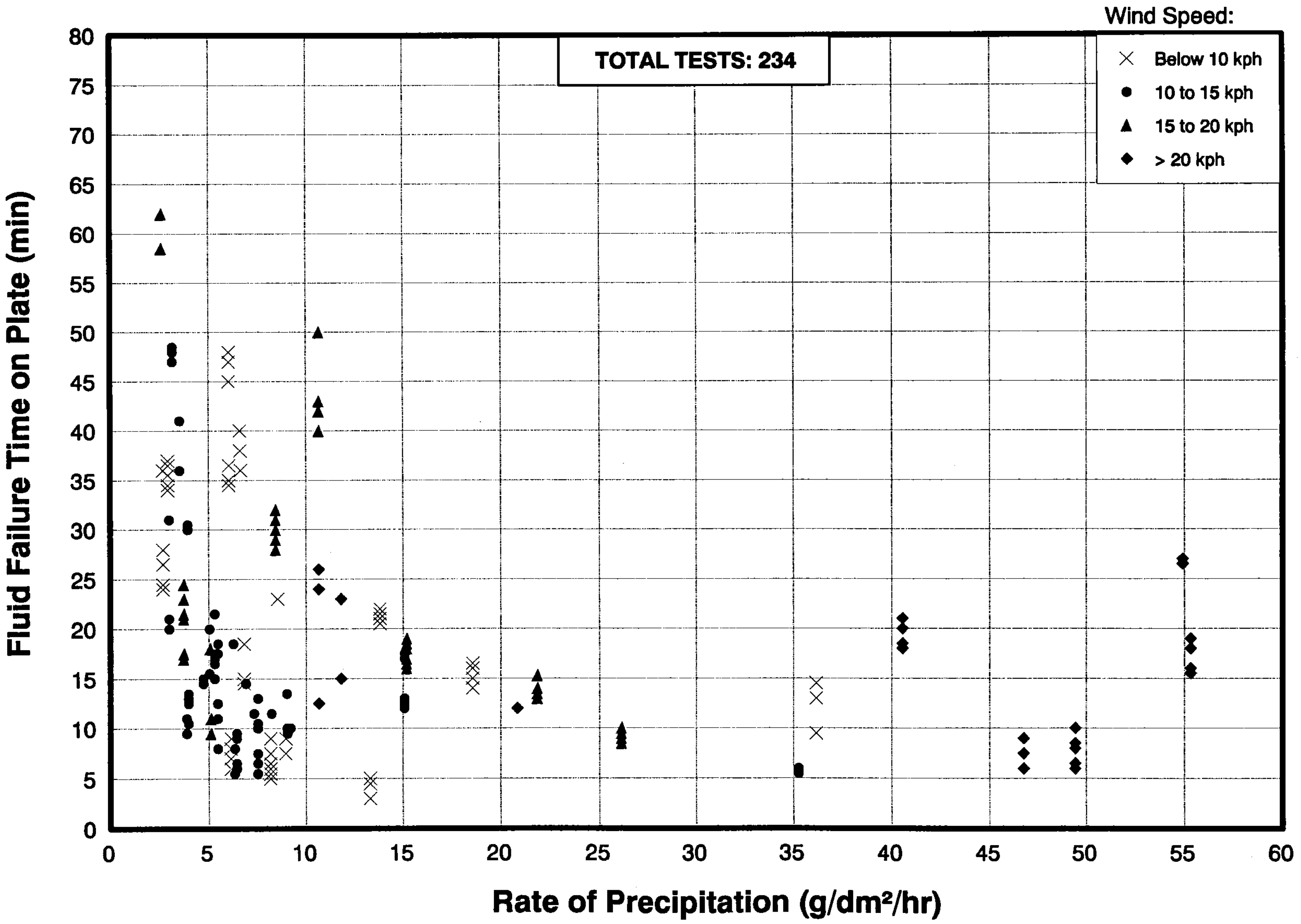


Figure 5.8 shows the results of the Type II 50/50 tests as a function of temperature, and further sub-divided into precipitation rate groups. Also shown on the chart is the SAE/ISO holdover time range for temperatures down to -7°C. The following observations can be made from Figure 5.8:

- For temperatures of 0°C and above, the HOT lower limit requires a reduction to include the high rates of precipitation.

- For temperatures below 0°C to -7°C, the HOT lower limit of five minutes is satisfactory, based on the data at colder temperatures.

The multi-variable regression analysis, shown in Table 5.1, provides further support to the observations stated above. With respect to fluid type, Equation 2 shows that two of the three fluids tested were equivalent while fluid A401 was slightly inferior.

5.1.1.3 Type II Neat Fluids in Natural Snow

Figure 5.9 presents a plot of the undiluted Type II fluids tested during natural snow conditions at Dorval in the two last winter seasons. The chart shows that the few tests conducted in the 93/94 winter season are generally in agreement with those from the previous winter, with the exception of a few points, which had higher than expected failure times. These test values occurred with a new advanced anti-icing fluid, which has far

FIGURE 5.8

RESULTS OF TYPE II 50/50 NATURAL SNOW TESTS AS A FUNCTION OF TEMPERATURE AND RATE OF PRECIPITATION

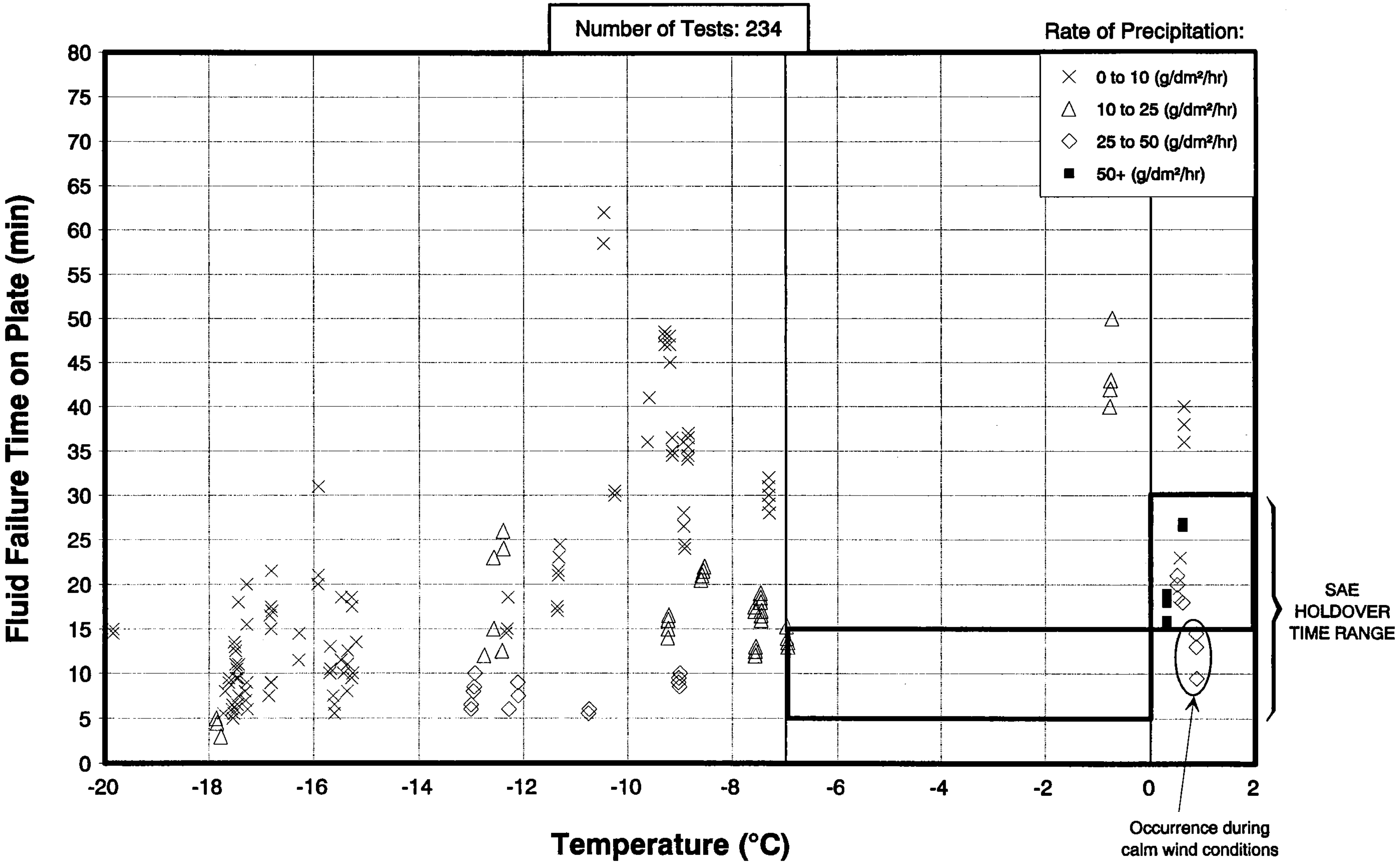
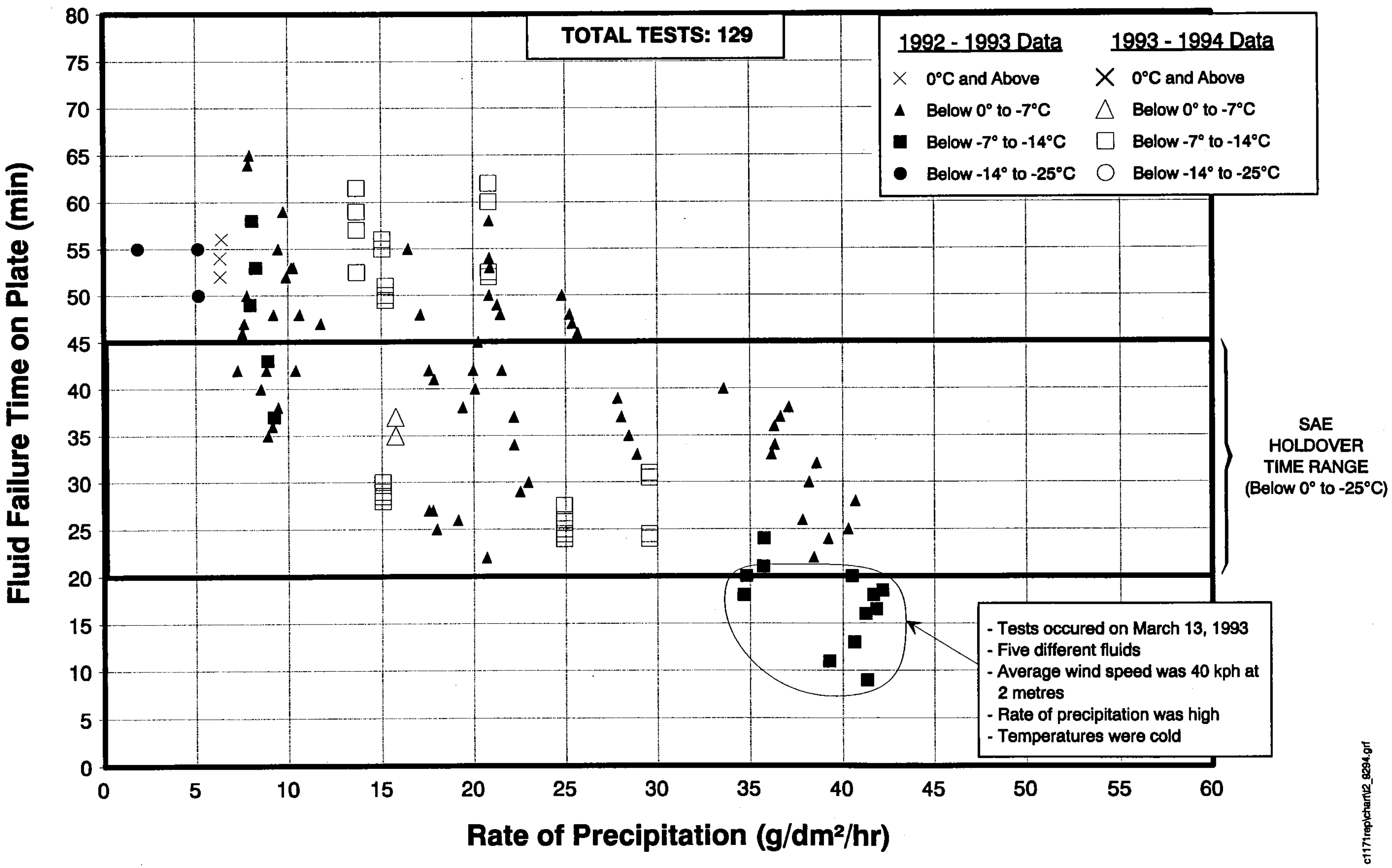


FIGURE 5.9

EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON TYPE II FLUID FAILURE TIME IN NATURAL SNOW CONDITIONS

1992 - 1994



- Tests occured on March 13, 1993
- Five different fluids
- Average wind speed was 40 kph at 2 metres
- Rate of precipitation was high
- Temperatures were cold

superior protection times than the minimum required by SAE/AEA/ISO on WSET and HHET tests. Once again shown on the illustration, is the SAE/ISO Type II holdover time range for temperatures ranging from 0°C to -25°C. A few points with high rates of precipitation and low temperatures had plate failure times below the SAE/ISO HOT lower limit. These occurred on the same day that many of the North Eastern U.S. airports were closed.

5.1.1.4 Wyoming Shield Tests

Figure 5.10 shows the comparison of fluid failure times for plates in the Wyoming Shield versus plates mounted on the standard test stand, as a function of wind speed. A total of 16 tests were conducted simultaneously with the same fluid. The chart shows that test panels within the Wyoming Shield, where there are lower winds, have a tendency to fail faster. Insufficient data is available from the tests to quantify the effect of the wind. Additional tests in the Wyoming Shield should be carried out to increase the database.

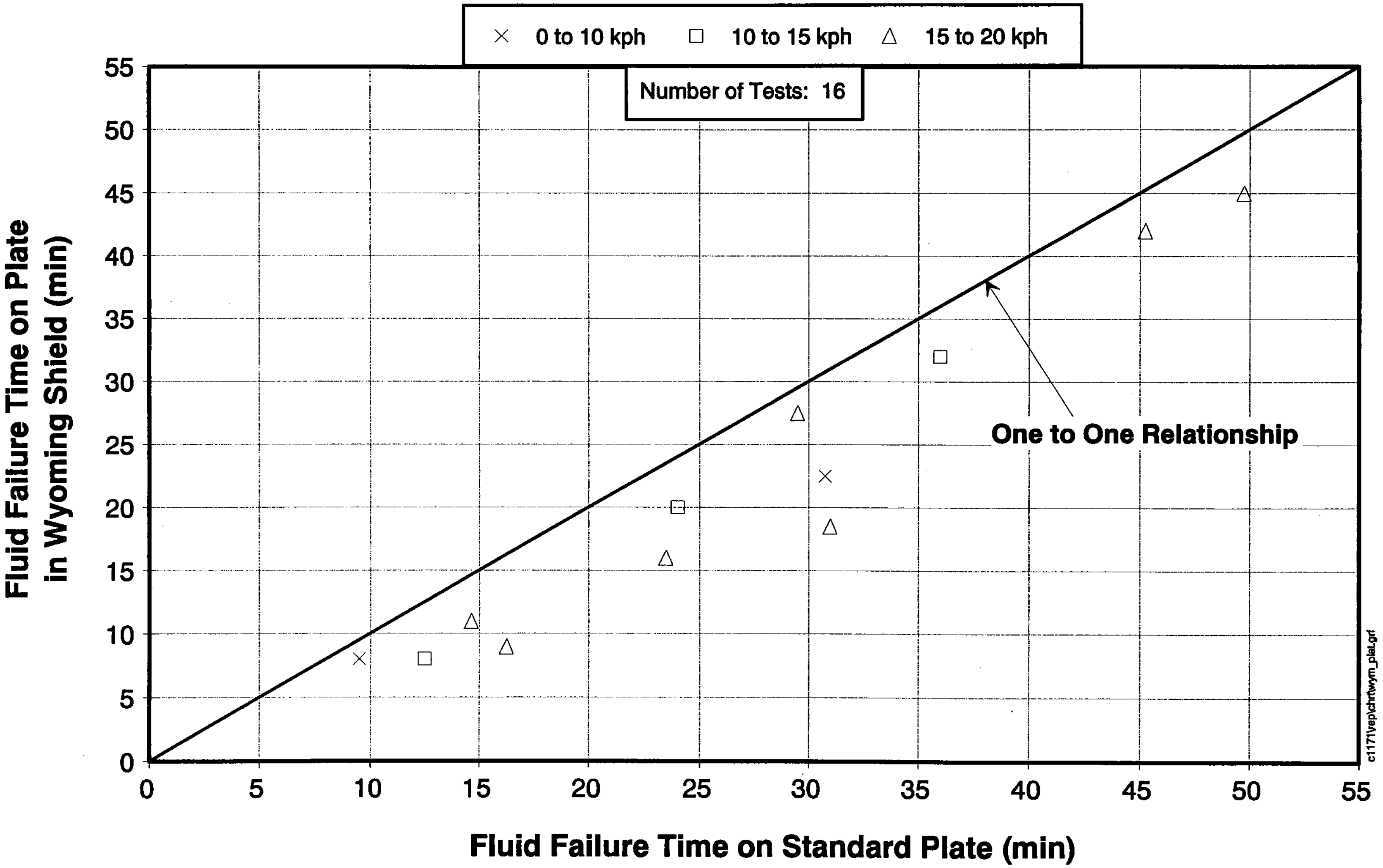
5.1.2 Simulated Freezing Drizzle and Light Freezing Rain Conditions

In general, for a given fluid, failure times under the simulated light freezing rain and drizzle conditions are governed by the rate of precipitation and temperature.

Simulated freezing drizzle tests for the 92/93 test season were conducted, however these should not be used since according to MANOBS, the rates

FIGURE 5.10

COMPARISON OF FLUID FAILURE TIMES FOR PLATES IN WYOMING SHIELD vs PLATES ON STANDARD TEST STAND



produced were classified as heavy drizzle, a condition not usually experienced in the real world.

The effect of fluid type and rate of precipitation on fluid failure time in simulated freezing rain and freezing drizzle conditions is shown in the figures listed below:

Figure 5.11	Type I
Figure 5.12	Type II Neat
Figure 5.13	Type II 75/25
Figure 5.14	Type II 50/50

The results in each of the graphs generally show that both rate of precipitation and fluid type have the strongest effect on plate failure time, with droplet size and temperature having smaller impacts on the outcome.

Each of the charts show the present SAE/ISO holdover time range for air temperatures below 0°C to -7°C under the freezing rain column heading. The four charts show all test cases resulted in failure times above the SAE/ISO lower limit for both the simulated freezing drizzle and simulated light freezing rain. In fact, based on the test data, it can be seen that the SAE/ISO lower limits can be increased for freezing drizzle and light freezing rain conditions. It would be useful to have three column headings in the HOT table: freezing drizzle, light freezing rain, and moderate or heavy freezing rain conditions. During moderate or heavy freezing rain conditions, aircraft departures should not be attempted. In order to verify the results, it would be useful to superimpose the results from UQAC's WSET tests over the results from

FIGURE 5.11

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON TYPE I FLUID FAILURE TIME IN SIMULATED FREEZING RAIN CONDITIONS

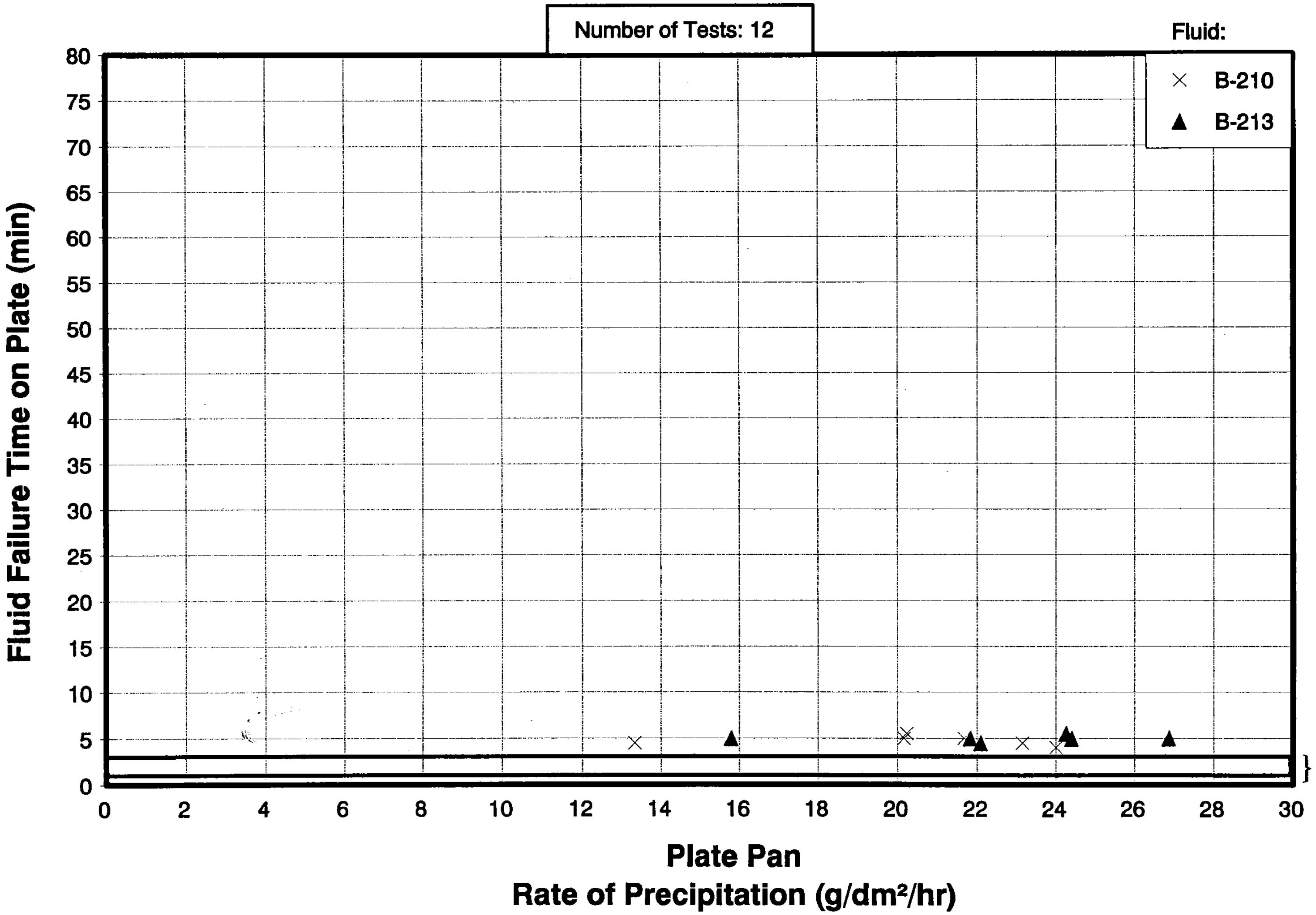


FIGURE 5.12

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON TYPE II NEAT FLUID FAILURE TIME IN SIMULATED FREEZING DRIZZLE/RAIN CONDITIONS

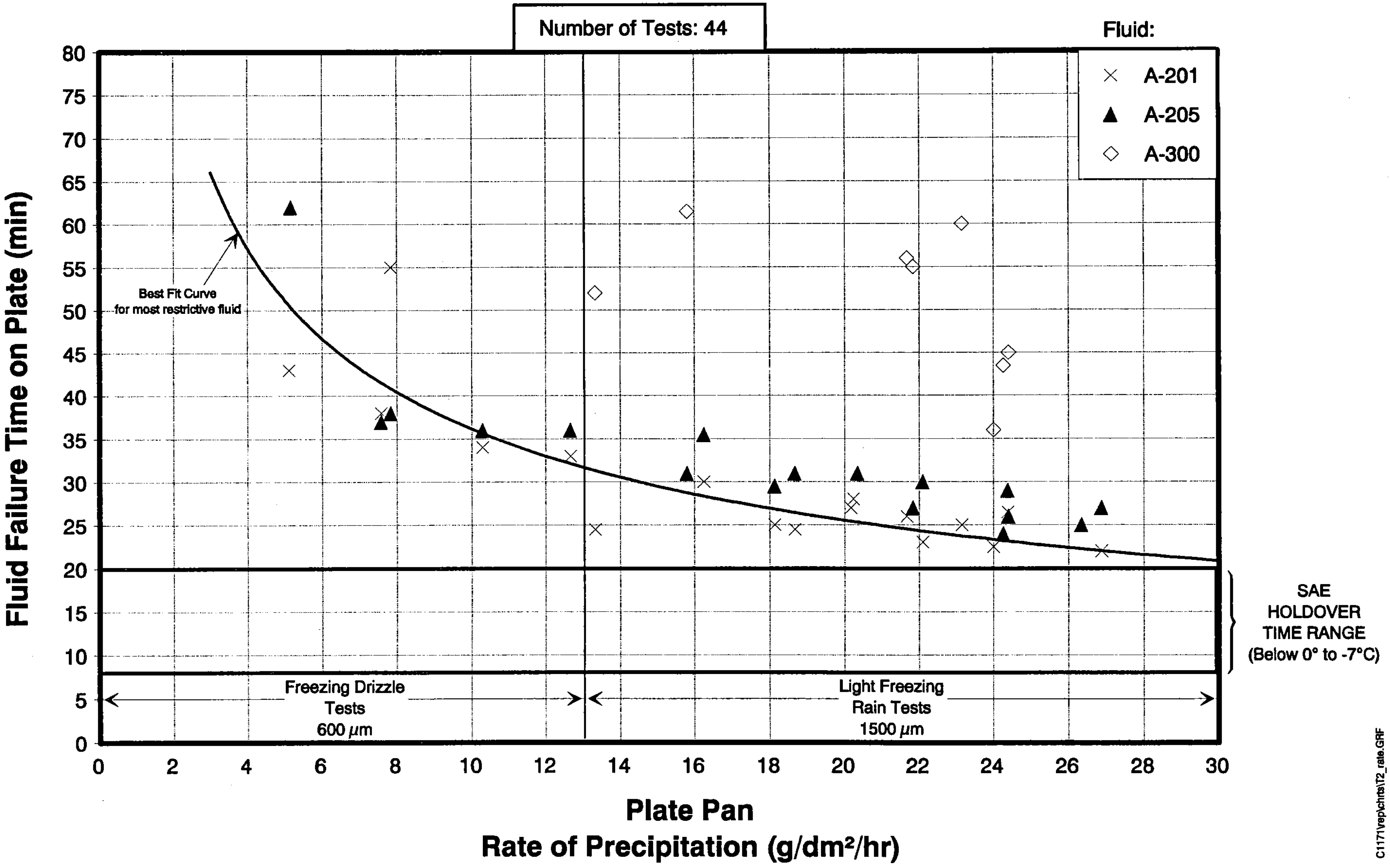


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FIGURE 5.13

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON TYPE II 75/25 FLUID FAILURE TIME IN SIMULATED FREEZING DRIZZLE/RAIN CONDITIONS

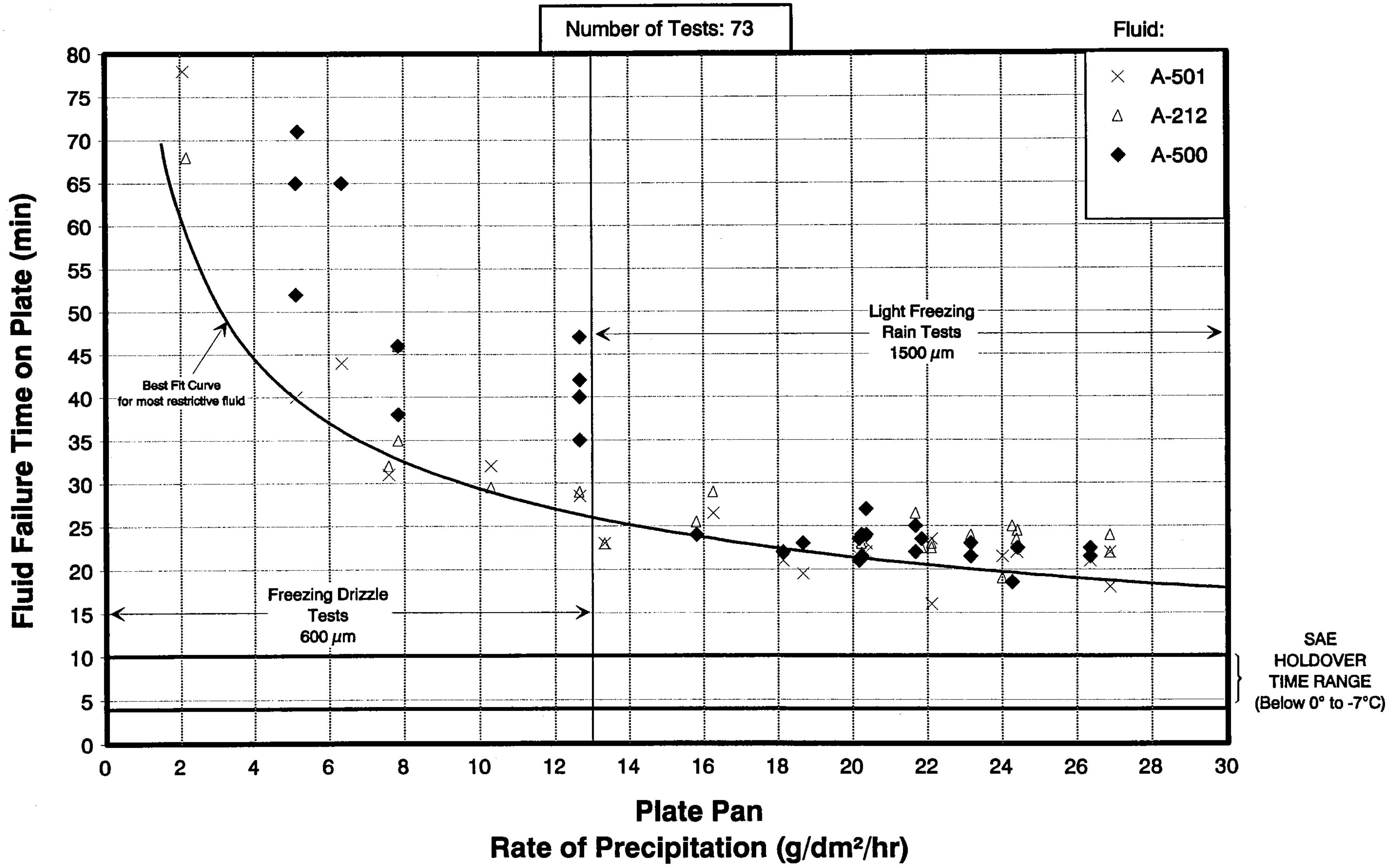
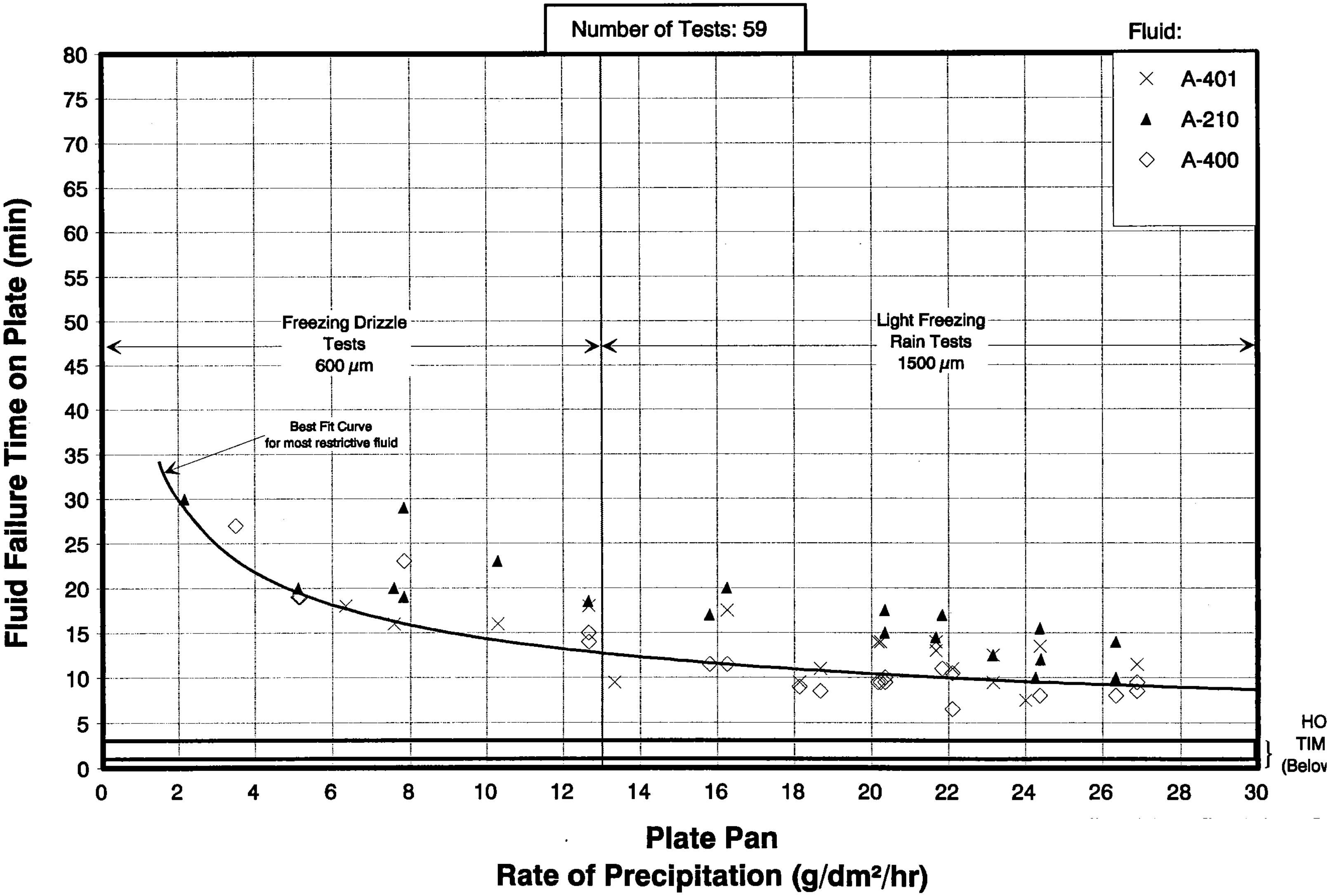


FIGURE 5.14

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON TYPE II 50/50 FLUID FAILURE TIME IN SIMULATED FREEZING DRIZZLE/RAIN CONDITIONS



these tests..

5.1.3 Simulated Freezing Fog Conditions

Given a fluid type, the main parameter affecting the failure time in simulated freezing fog tests at the NRC, is the rate of precipitation. Although the fog generated at the test site ranges from about 2 to 10 g/dm^2/hr, freezing fog in natural conditions typically results in deposition rates at the lower end of this range. This is based on discussions held at SAE meetings.

The results from the Type I freezing fog tests were provided in last year's report (TP 11836E), while the results from this years testing are shown in the figures described below:

Figure 5.15	Type II Neat
Figure 5.16	Type II 75/25
Figure 5.17	Type II 50/50

The three figures show that the current SAE/ISO HOT lower limits are satisfactory, with the exception of the Type II 50/50 tests. A few of the tests with high rates of precipitation had plate failure times below the current lower limit. For Type II neat and Type II 75/25 fluids test data is lacking at temperatures ranging from -13°C to -25°C and -12°C to -14°C, respectively.

5.1.4 Combined Tests

Figure 5.18 shows the effect of type of precipitation and rate of

FIGURE 5.15
RESULTS OF TYPE II NEAT SIMULATED FREEZING FOG TESTS FOR TEMPERATURES BETWEEN 0° AND -12°C

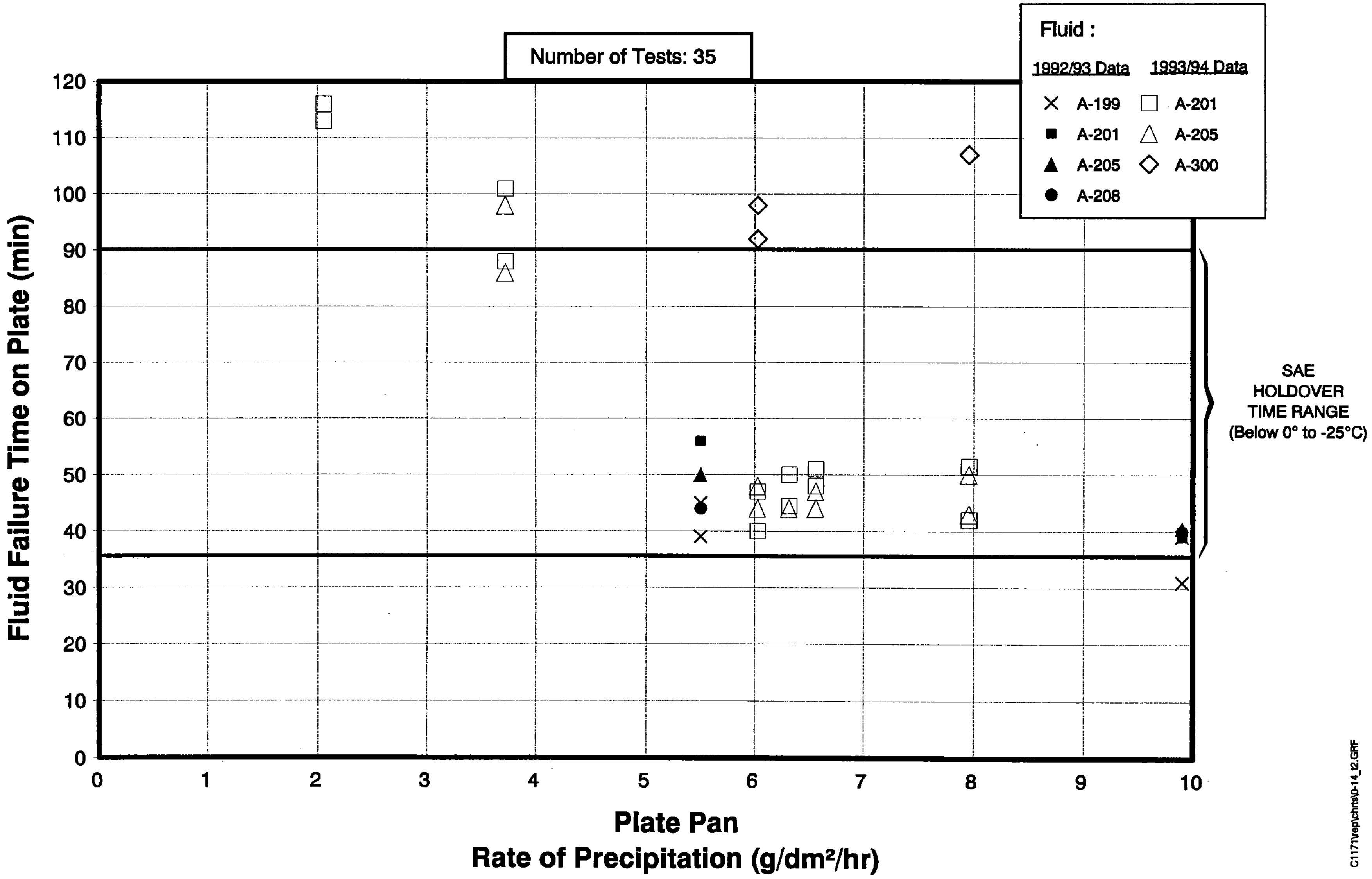


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FIGURE 5.16

RESULTS OF TYPE II 75/25 SIMULATED FREEZING FOG TESTS FOR TEMPERATURES BETWEEN 0° AND -11°C

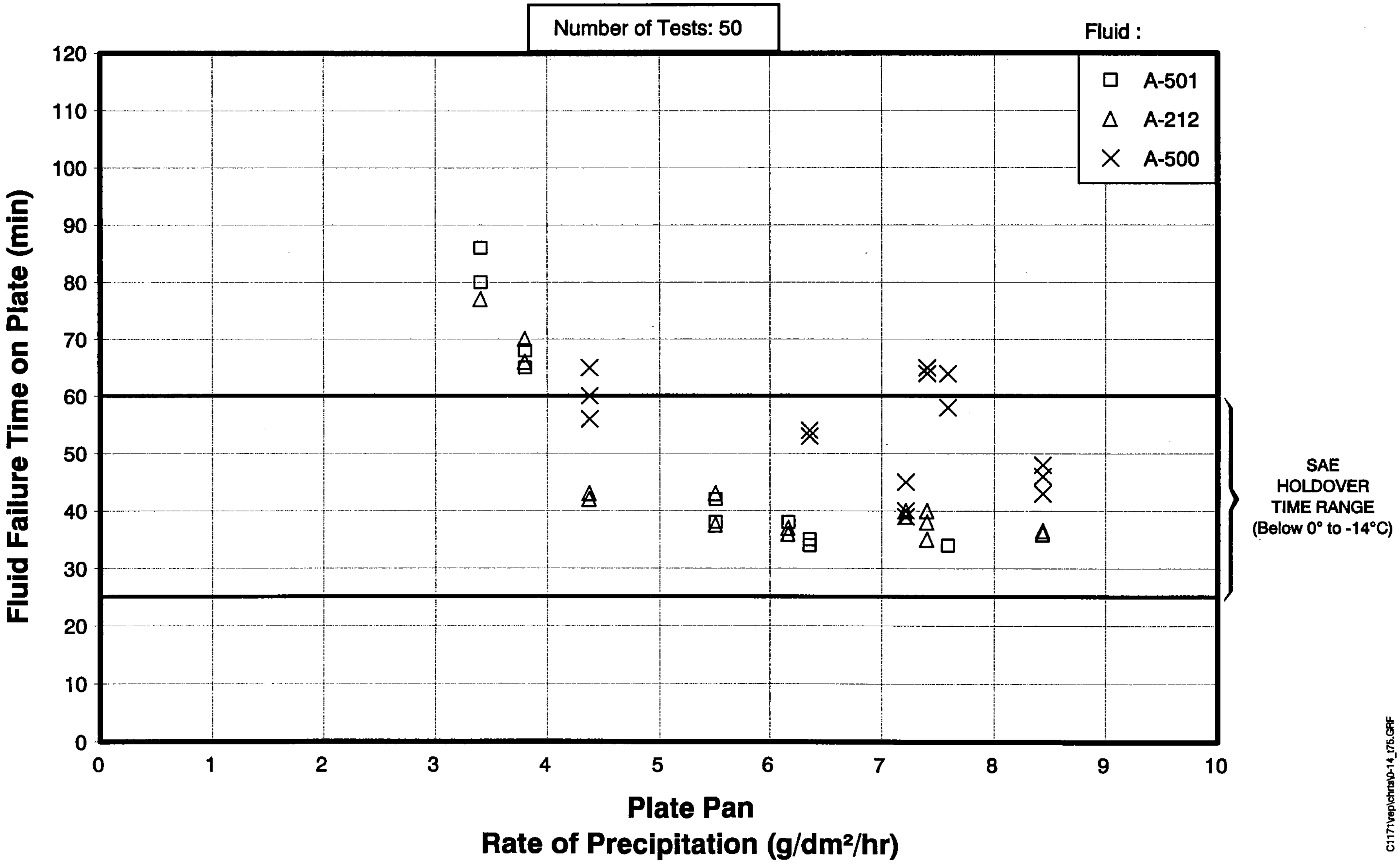

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FIGURE 5.17

RESULTS OF TYPE II 50/50 SIMULATED FREEZING FOG TESTS FOR TEMPERATURES BETWEEN 0° AND -11°C

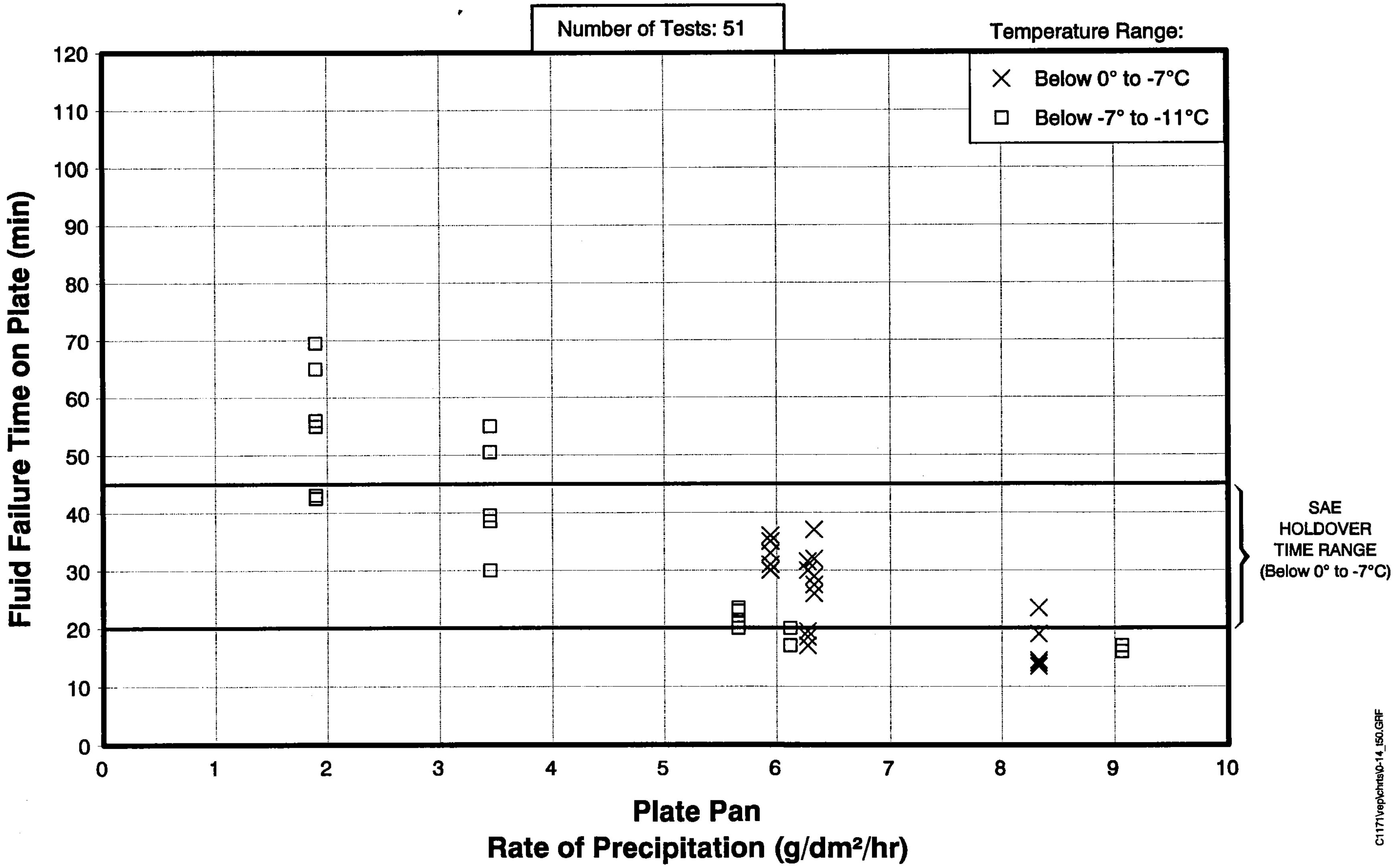

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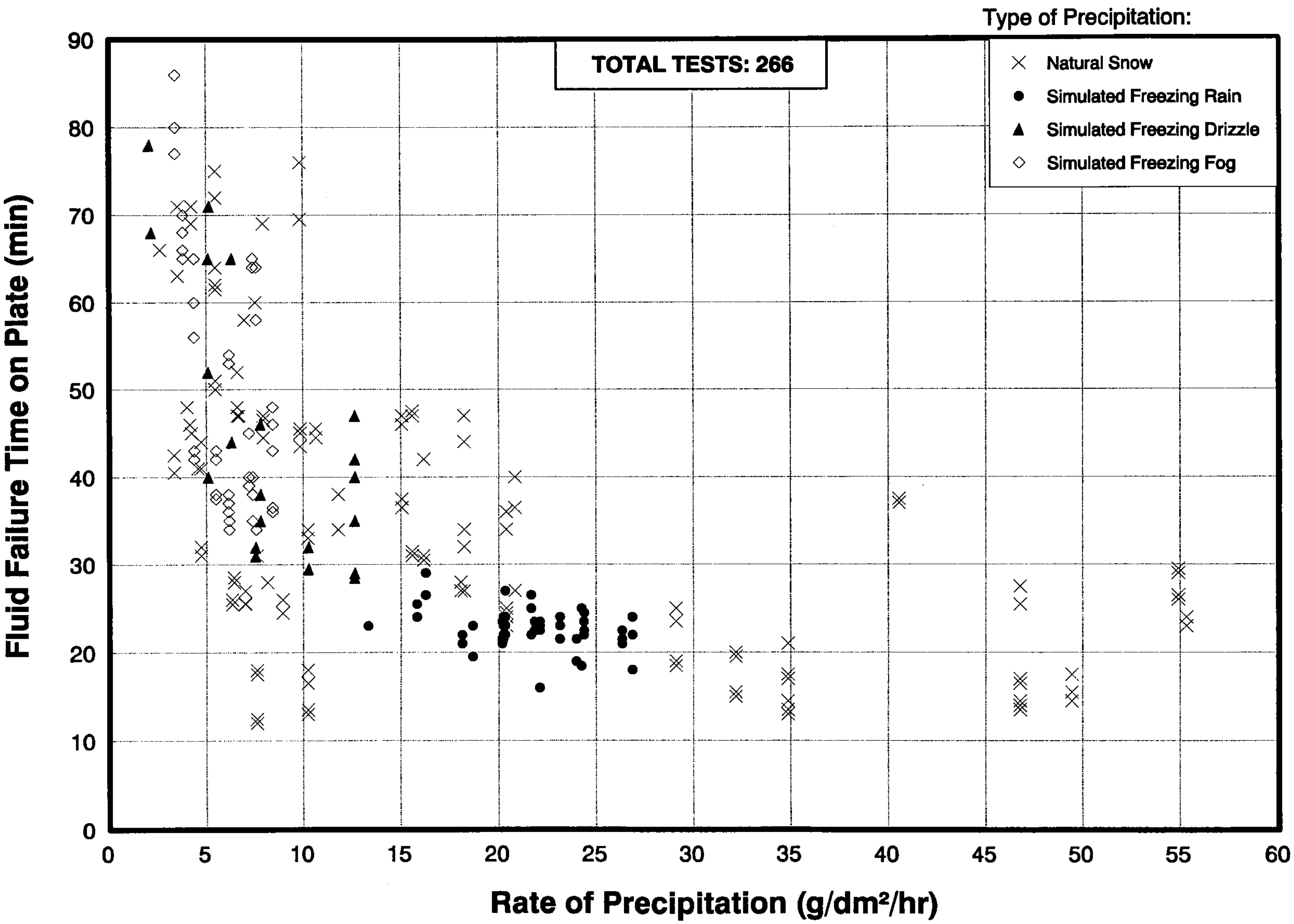
FIGURE 5.18

EFFECT OF TYPE OF PRECIPITATION AND RATE OF PRECIPITATION ON TYPE II 75/25 FLUID FAILURE TIME



precipitation on Type II 75/25 fluid failure time. The following observations were made:

- rate of precipitation has a strong influence on failure time;
- temperature, wind speed and fluid type have an effect on failure time;
- type of precipitation is not as influential, however based on the same rate of precipitation and same conditions it appears that fluid subjected to fog fails before fluids subjected to light freezing rain, freezing drizzle or natural snow.

As a result of budgetary limitations, results for the other fluid types are not available.

5.1.5 No Precipitation Conditions

A number of flat plate tests were conducted in the absence of any precipitation to study the thickness distribution over the plate as a function of time. Hence, the objective of these tests was to study the thickness distribution primarily for diluted Type II fluids. Due to budgetary constraints, this data was not analyzed.

5.1.6 Rain on a Cold-Soaked Surface

The objective of the cold-soaked flat plate tests was to investigate the effect of rain on a cold-soaked surface such as the wing skin of an aircraft with cold fuel. These experiments were conducted under rain at ambient air temperatures above 0°C. The test procedure consisted of pouring the test fluid on the top face of an aluminum box, which was filled with a Type II fluid and cooled in a freezer.

Figure 5.19 shows the effect of skin temperature and the rain rate of precipitation on Type II 75/25 fluid failure time during cold-soaked tests. Six tests with fluids from two manufacturers were conducted at the test site in Dorval. The ambient temperature ranged between 3 and 9°C, while plate temperatures, measured at the 23 cm (9 inch) line and averaged (to limit the disturbance of the fluid at the 15 cm (6 inch) line over the test, ranged from about 0 to -10°C. Figure 5.19 shows that test plates with colder skin temperatures subjected to higher precipitation rates tend to fail faster.

Figure 5.20 shows the results from six tests conducted with 50/50 fluid. Once again, these tests show that colder skin temperatures coupled with high rates of precipitation results in a reduction of fluid endurance time. Figure 5.20 also shows the current SAE/ISO holdover time range for rain on cold-soaked wing. Three of the six test points had end condition times below the 12 minute lower limit, and the three others fell within the current range of 12 to 30 minutes.

These results indicated that the cold-soaked phenomenon observed on aircraft can be simulated in tests and should be pursued in future testing programs.

FIGURE 5.19

EFFECT OF SKIN TEMPERATURE AND RAIN RATE OF PRECIPITATION ON TYPE II 75/25 FLUID FAILURE TIME IN COLD SOAK CONDITIONS

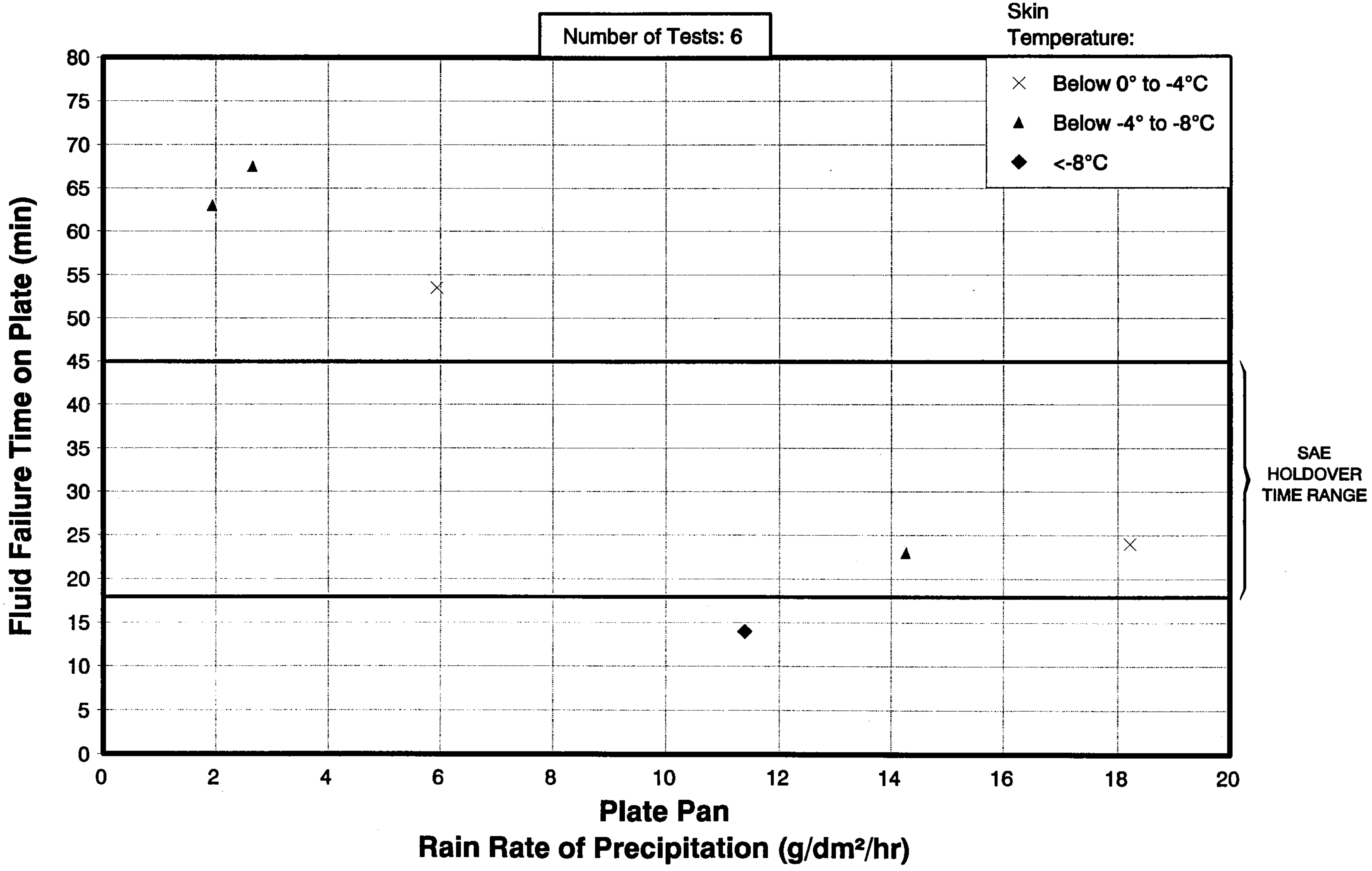


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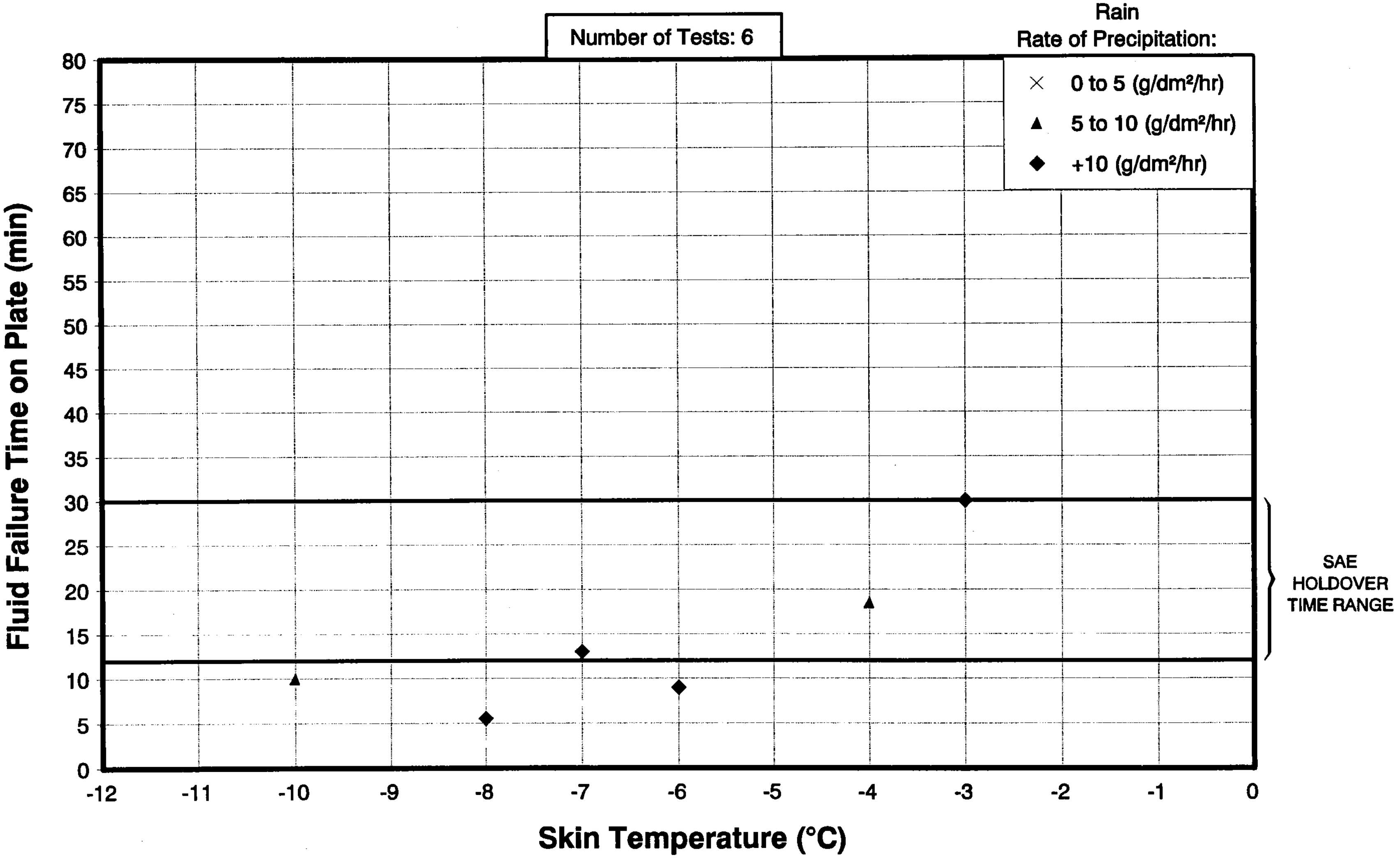
FIGURE 5.20

EFFECT OF RAIN RATE OF PRECIPITATION AND SKIN TEMPERATURE ON TYPE II 50/50 FLUID FAILURE TIME IN COLD SOAK CONDITIONS



5.2 Aircraft Surface Tests

The objective of the tests was to compare endurance times between aircraft wing surfaces, 10° flat plates and the airfoil. Five tests took place at Somiper Aviation, an FBO at Dorval airport, on March 10, 1994 during natural precipitation conditions. A Cessna Citation II or a Fairchild Metroliner was used for these tests. The test conditions were as follows:

- The snow was light to moderate;
- The temperature was -5°C;
- The winds were 10 to 15 kph at a height of 2 metres;
- The aircraft and the airfoil were facing into wind, and;
- The rate of precipitation was measured with plate pans and ranged from about 5 to 20 $g/dm^2/hr$.

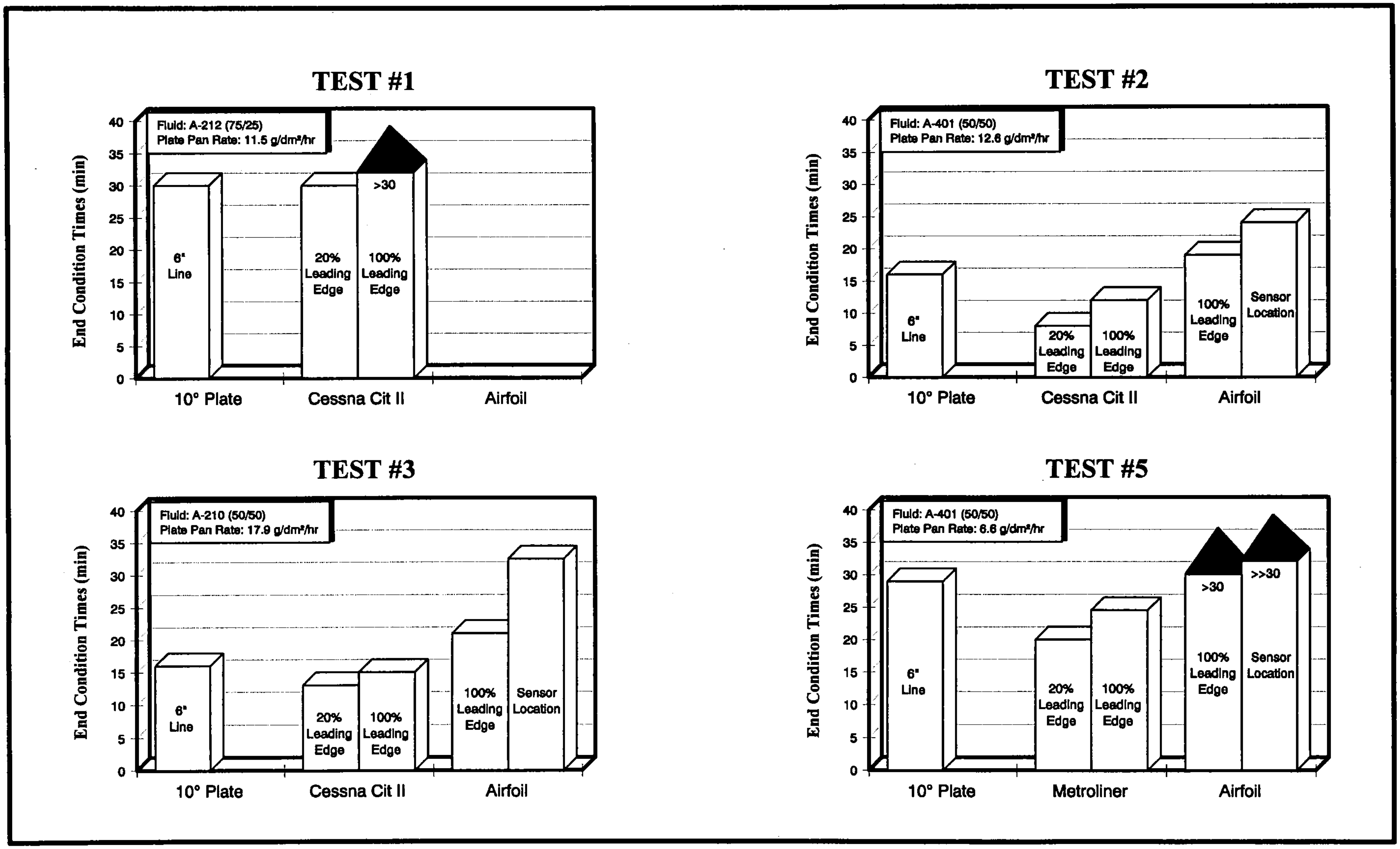
For each test, the following times were determined:

- when the end condition occurred on the 10° flat plate;
- when 20% and 100% of the leading edge of the test aircraft reached the end condition, and
- when 100% of the leading edge of the airfoil reached the end condition, and when the end condition occurred on the sensor head.

These results are shown in Figure 5.21 for four of the five tests. It can be seen that the end condition resulted first on a substantial portion of the aircraft and last on the airfoil. These results negate those which were obtained by United Airlines in Denver and are a cause for concern. It should be noted that fluid near discontinuities on the aircraft reached the end condition long before the six inch line of the 10° flat plate.

FIGURE 5.21

RESULTS OF 4 AIRCRAFT AND AIRFOIL TESTS



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To better understand why the end condition happened first on the aircraft leading edge, a series of fluid thickness tests were conducted on the Fairchild Metroliner. These tests were also used to understand the progression of the failures on the aircraft surface. Thickness decay curves at various locations on the aircraft and the 10° flat plate were plotted over time in Figure 5.22. The locations are shown in the legend provided in Figure 5.22. It can be seen that the fluid on the leading edge of the aircraft is generally thinner than on the 10° flat plate. Due to budgetary constraints, data from the other thickness tests with other fluids was not analysed.

Figure 5.23 provides a comparison of fluid failure times on a standard plate and the airfoil at the sensor location. Figure 5.23 shows that failure on the airfoil at the sensor location is substantially longer than on the flat plate.

The following observations can be made:

- Fluid Flow-"Feeding"- on the surface (3-D surface fluid flow on a full scale aircraft vs 2-D surface flow on the airfoil) during precipitation is a major factor in the determination of fluid failure times. Due to the wing's dihedral angle, the highest point (wing tip leading ledge) failed first.

- The wind speed and orientation of the wing surface have a significant impact on fluid endurance times.

- One needs to determine if the same end condition should be used for aircraft testing as is currently used for flat plates. If so, then where on surface and how much coverage? It may very well be that the end condition (degree of contamination) must be determined by aerodynamic

FIGURE 5.22

THICKNESS DECAY AT VARIOUS LOCATIONS ON AIRCRAFT AND 10° FLAT PLATE

Type II 75/25 Fluid
(A-500)

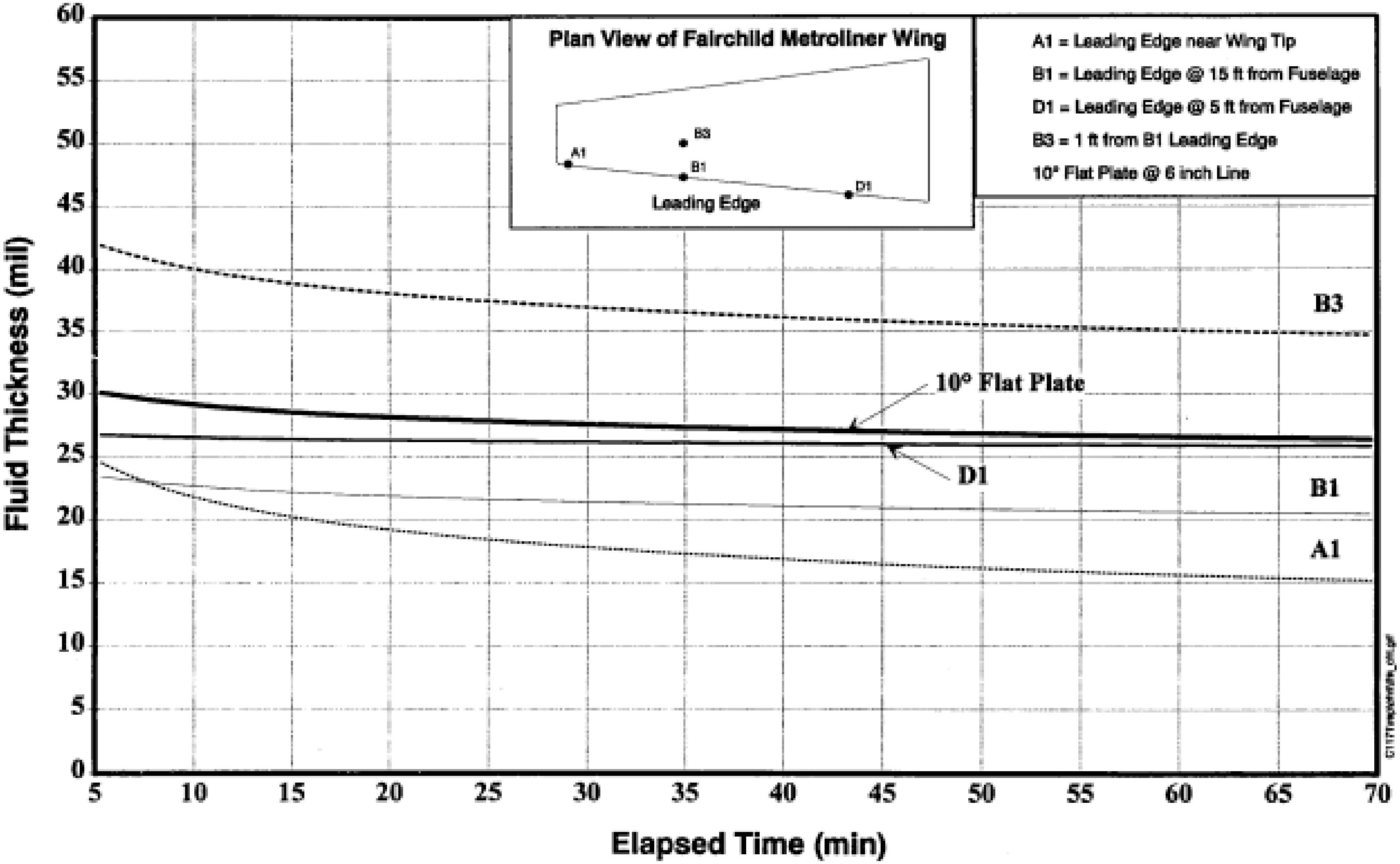
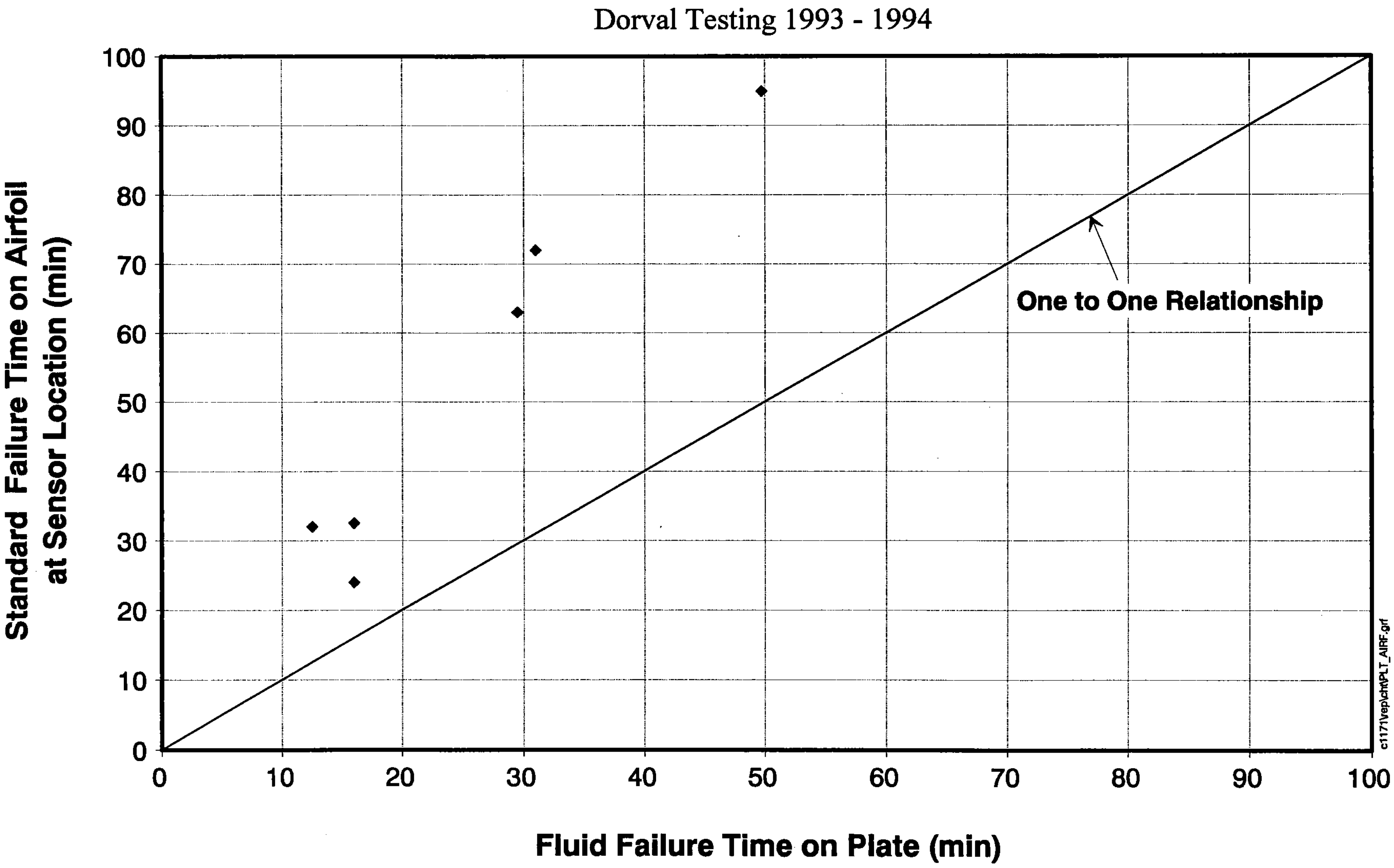


FIGURE 5.23

COMPARISON OF FAILURE TIMES ON A STANDARD PLATE vs AIRFOIL AT THE SENSOR LOCATION



testing at UQAC.

5.3 Ice Sensor Tests

The objectives of the ice sensor tests were:

a) to evaluate their usefulness in future de/anti-icing tests, particularly in the determination of the fluid failure time under all forms of precipitation;
b) to compare responses of the Instrumar CWDS and the RVSI ID-1 during the same test, and to see how these correspond to the visual end condition time.

The ice sensor tests are primarily flat plate tests with Instrumar's IM101, FM202 and CWDS ice sensors, and RVSI's ID-1 ice sensor. Instrumar's sensors are basically point sensors mounted on the flat plate at the 6 inch line, where failure is normally reported. RVSI's sensor can view the area of a large surface. For this winter's testing the sensor was mounted for viewing an area of (1.2 x 2.4 metres) 4 x 8 feet.

In most of the 92/93 tests with Instrumar's FM202 Sensor, a good correlation between sensor reading and observed failures was obtained for Type II and III fluids. The results are contained in report TP11836E. Three new CWDS ice sensors were provided by Instrumar for 93/94 testing. Two were mounted on 10° plates: one was operational after the first half of the test season and the second was delivered at the end of the winter season. The last sensor was provided in the middle of the test season and was mounted on the airfoil.

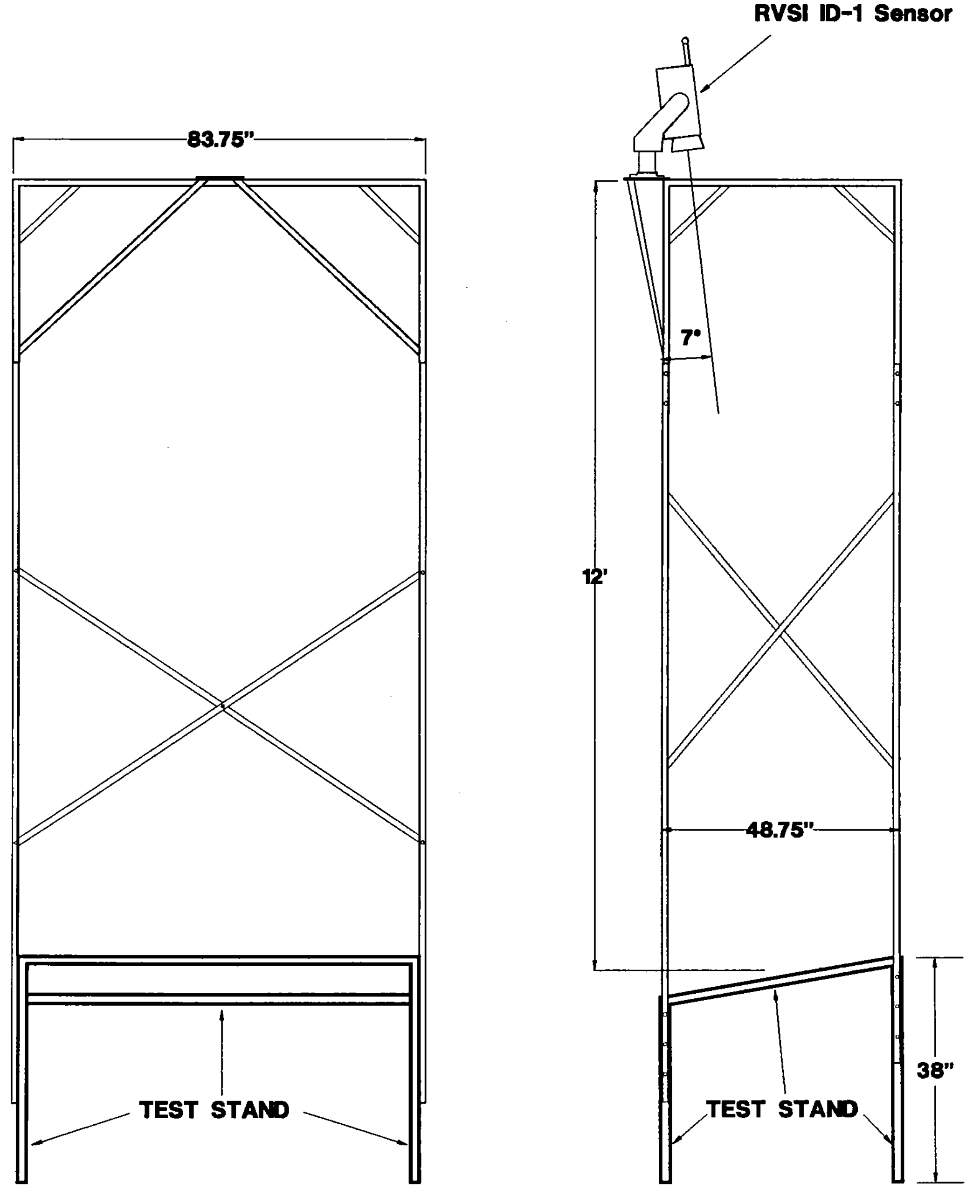
Just under 30 tests were conducted with the CWDS instruments at Dorval, and almost 80 tests were conducted at NRC's cold chamber in Ottawa. The CWDS data files for 93/94 testing were sent to Instrumar for analysis.

The ID-1 external ice detection sensor was provided in Mid-March by RVSI for testing at Dorval, and as a result it was only used for testing on two or three occasions. RVSI's technology detects ice by electro-optical means and can help verify the safe condition of entire aircraft surfaces in a short time. It is claimed that the technology can be adapted to both ground-based and airborne ice detection systems and is expected to have significant safety, economic, and environmental benefits. The ID-1 was designed with the intent to provide inspection of critical surfaces in adverse winter conditions on large commercial jets or small commuters.

The ID-1 test unit at Dorval is mounted on the test stand as shown in Figure 5.24, and because it is a visual system with video display capabilities, it has the capability to show results of the scanned image on a computer monitor instantaneously. For the analysis, the results can be replayed with up to eight colour resolutions showing differing ice contamination intensities (or ice confidence levels).

20 plate tests were conducted at Dorval during natural snow conditions with the ID-1. Additional tests were conducted during cold soak tests in Montreal and freezing drizzle and rain tests at NRC in Ottawa.

FIGURE 5.24
RVSI ID-1 SENSOR MOUNTING



5.3.2 ID-1 Ice Intensity Level Analysis

The ID-1 at Dorval can provide a display showing up to eight *ice intensity levels*, in the shaded mode, for each of the 200 x 300 pixels in its image. This works out to between 5 and 10 pixels per square inch (or per cross-hair) on the standard 10° flat plate. In the binary mode, only two levels are available. A schematic showing a comparison of the two modes is provided below.

Binary Mode

Green	White

← clear surface → | ← contaminated → surface

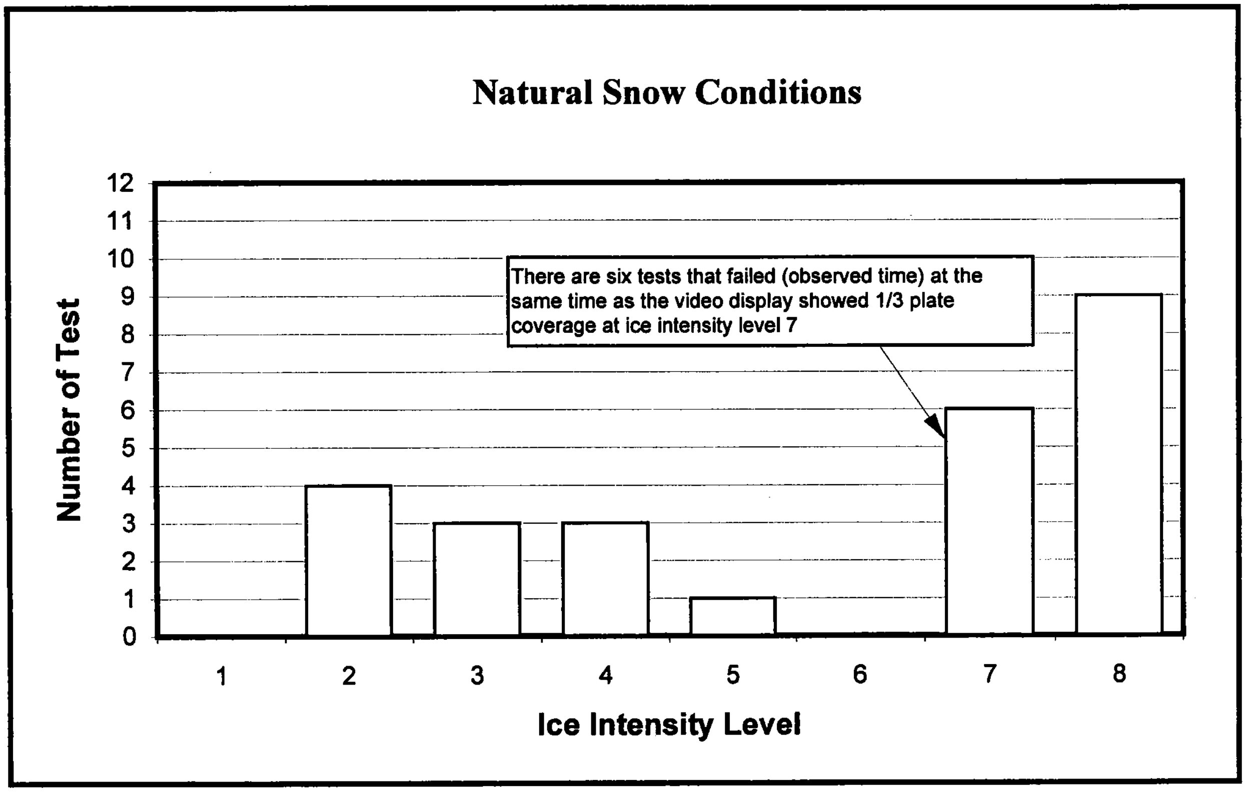
Shaded Mode ← ice intensity level →

1 Gr	2	3	4	5	6	7	8 Wh

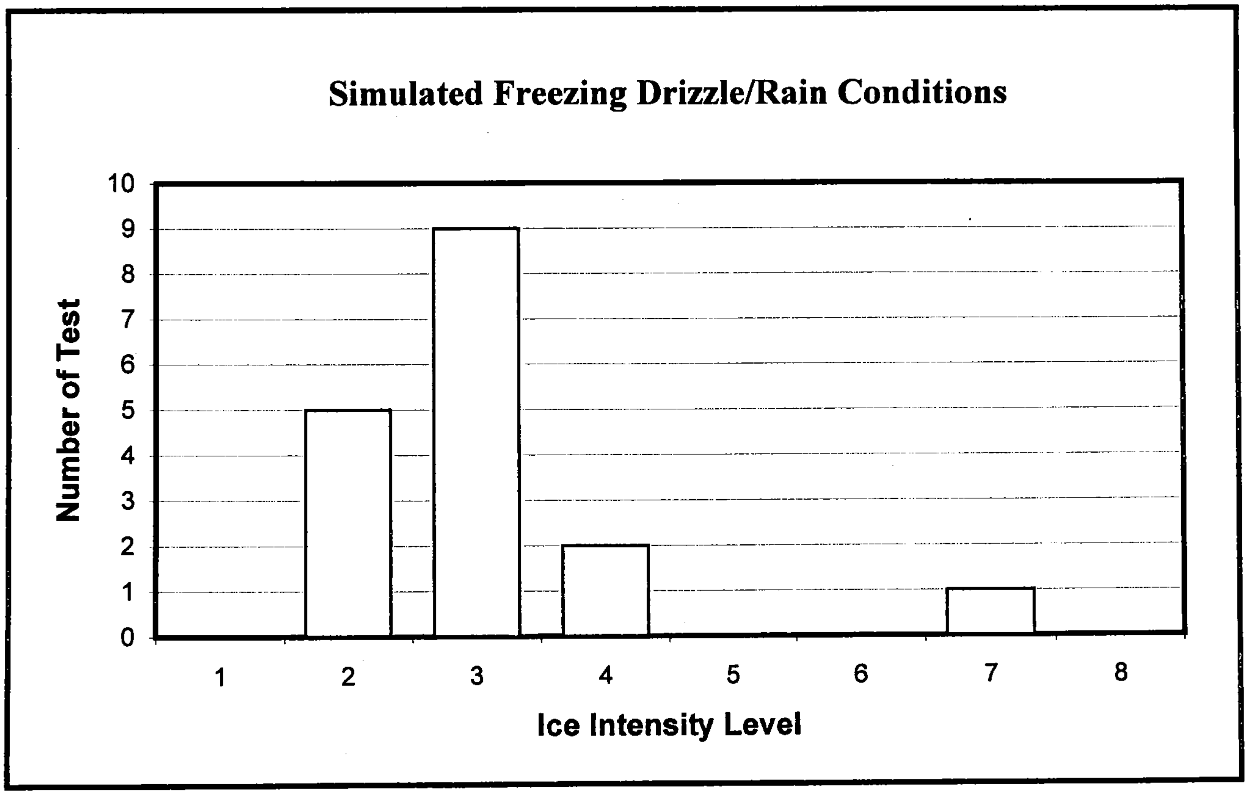
For each test, the observed end condition time (⅓ of the plate) coincided with an ice intensity level when ⅓ of the plate was covered. Figure 5.25 shows a tally of these occurrences for all tests conducted at Dorval during natural snow conditions and from a few of the tests conducted at NRC's cold chamber. For example, the natural snow chart shows that there were six tests that failed (observed time) at the same time as the video display showed ⅓ plate coverage at ice intensity level 7.

FIGURE 5.25

FREQUENCY OF ICE INTENSITY LEVEL WITH RVSI ID-1 SENSOR



There are six tests that failed (observed time) at the same time as the video display showed 1/3 plate coverage at ice intensity level 7



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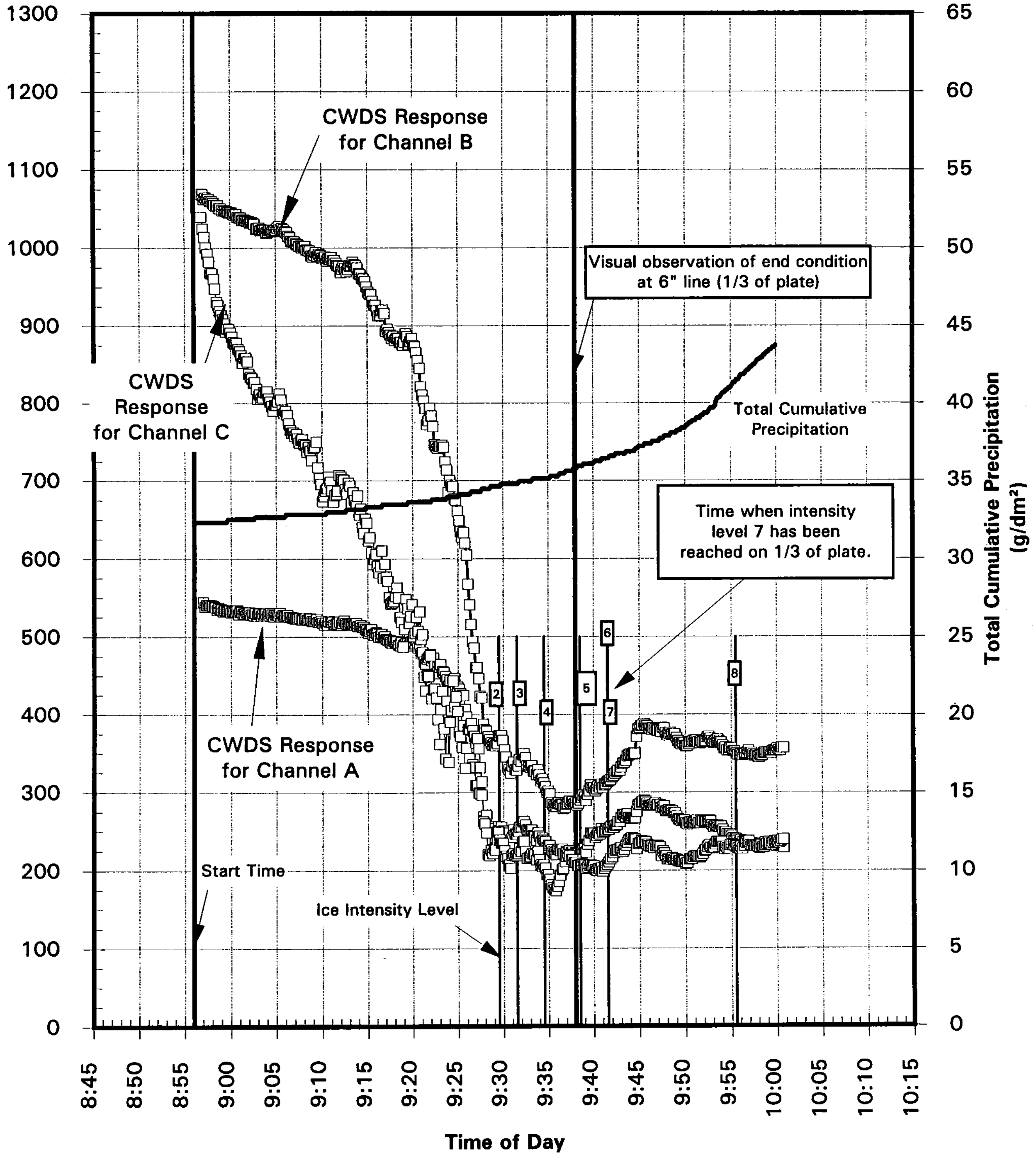
The following observations can be made:

- most of the natural snow end condition times occurred at ice intensity levels 7 and 8, which is not surprising considering the end condition for snow is defined as the "fluid no longer being able to absorb the snow";
- more testing and/or more detailed analysis is required to explain the occurrences at the lower levels;
- most of the freezing drizzle and rain end condition times occurred at lower levels. The earlier failure call during these conditions is also consistent with the end condition definition - *loss of gloss*;
- the end condition call is more consistent during freezing drizzle/rain tests, and is supported by the histogram;
- the visually observed end condition always occurred within the ice intensity bands.

5.3.2 Ice Sensor Comparisons

Figure 5.26 shows the comparison of the visually observed end condition time at the 6 inch line (⅓ of the plate) with Instrumar's CWDS responses and RVSI's ice intensity levels. This test was conducted on April 7, 1994 during natural snow conditions with ABC-3 Type II 50/50 fluid, and the average rate of precipitation was 11 $g/dm^2/hr$. Instrumar's CWDS signatures consist of three responses. Channel A is closest to the

FIGURE 5.26
COMPARISON OF THE VISUALLY OBSERVED END CONDITION WITH INSTRUMAR's CWDS RESPONSE AND RVSI's ID-1 ICE INTENSITY LEVEL
Natural Snow, Apr. 7, 1994, Form 116, Plate U, A-401



sensor head, while Channel C is furthest. The chart also shows the cumulative precipitation over the test period. Other tests which were conducted simultaneously with Instrumar's CWDS were plotted. Figure 5.26 illustrates that the bottom of the CWDS response (levelling point after the steep drop off) generally coincides with ice intensity level 2 of the ID-1, plus or minus five minutes; this was also observed on a number of other test results.

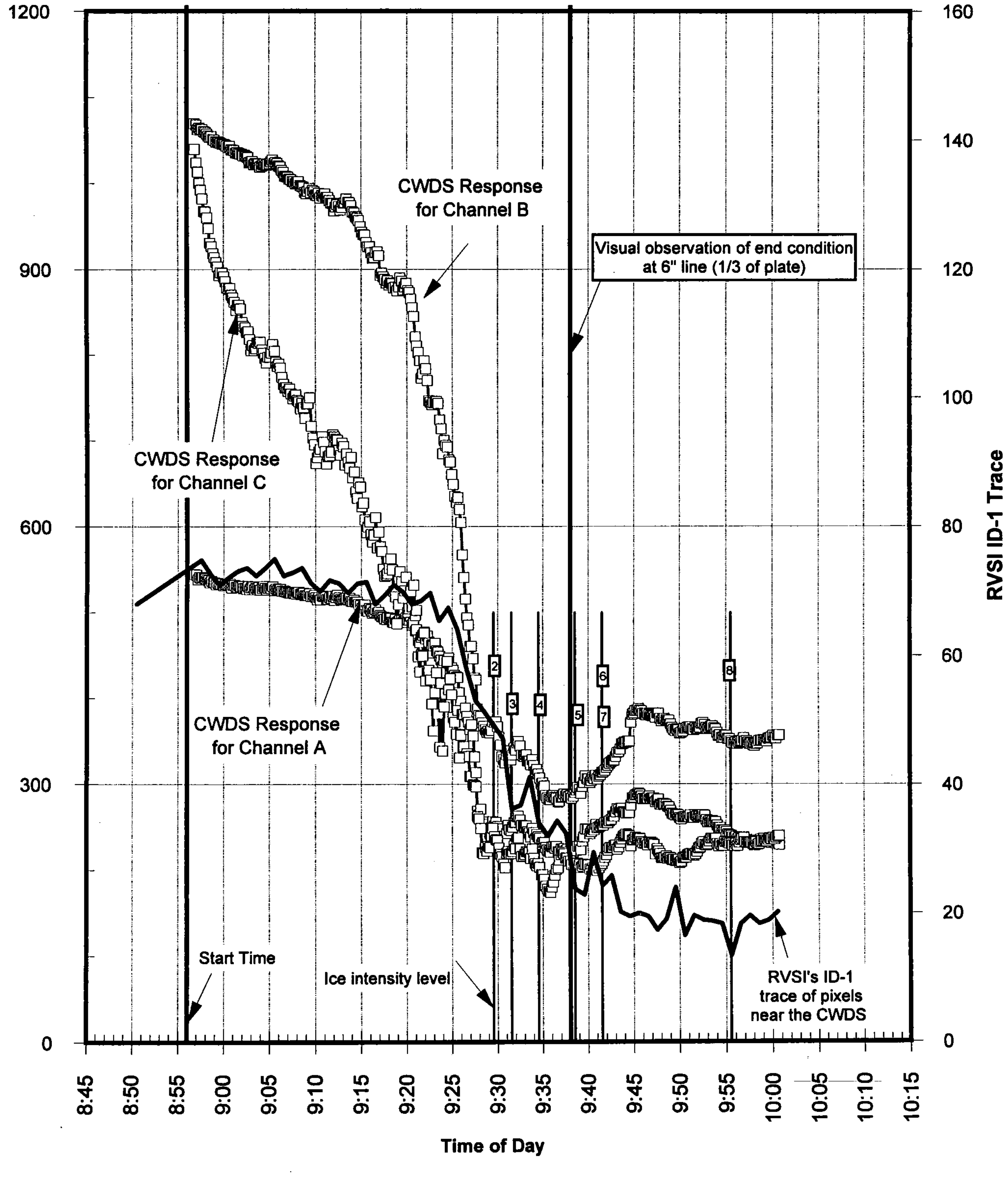
The observed end condition generally happened shortly after this levelling point (or ice intensity level 2). It appears, based on only a few tests, that ice intensity level 2 could therefore be used for future testing to provide an early indicator of imminent failure. More tests are required to acquire a better understanding and develop an improved correlation.

Figure 5.27 shows the same information provided on Figure 5.26, but with RVSI's ID-1 responses of a small region superimposed. The region is on the 15 cm (6 inch) line adjacent to the CWDS. It is interesting to note that the CWDS (channel A) and the ID-1 traces generally follow the same pattern for this test. Figure 5.28 provides a similar plot to Figure 5.27 but during freezing drizzle tests. This type of analysis should be carried out for the tests done at NRC CEF. Furthermore, additional tests, particularly during natural snow, are required in order to carry out an improved analysis of these types of curves.

5.3.3 Operational Considerations - RVSI's ID-1

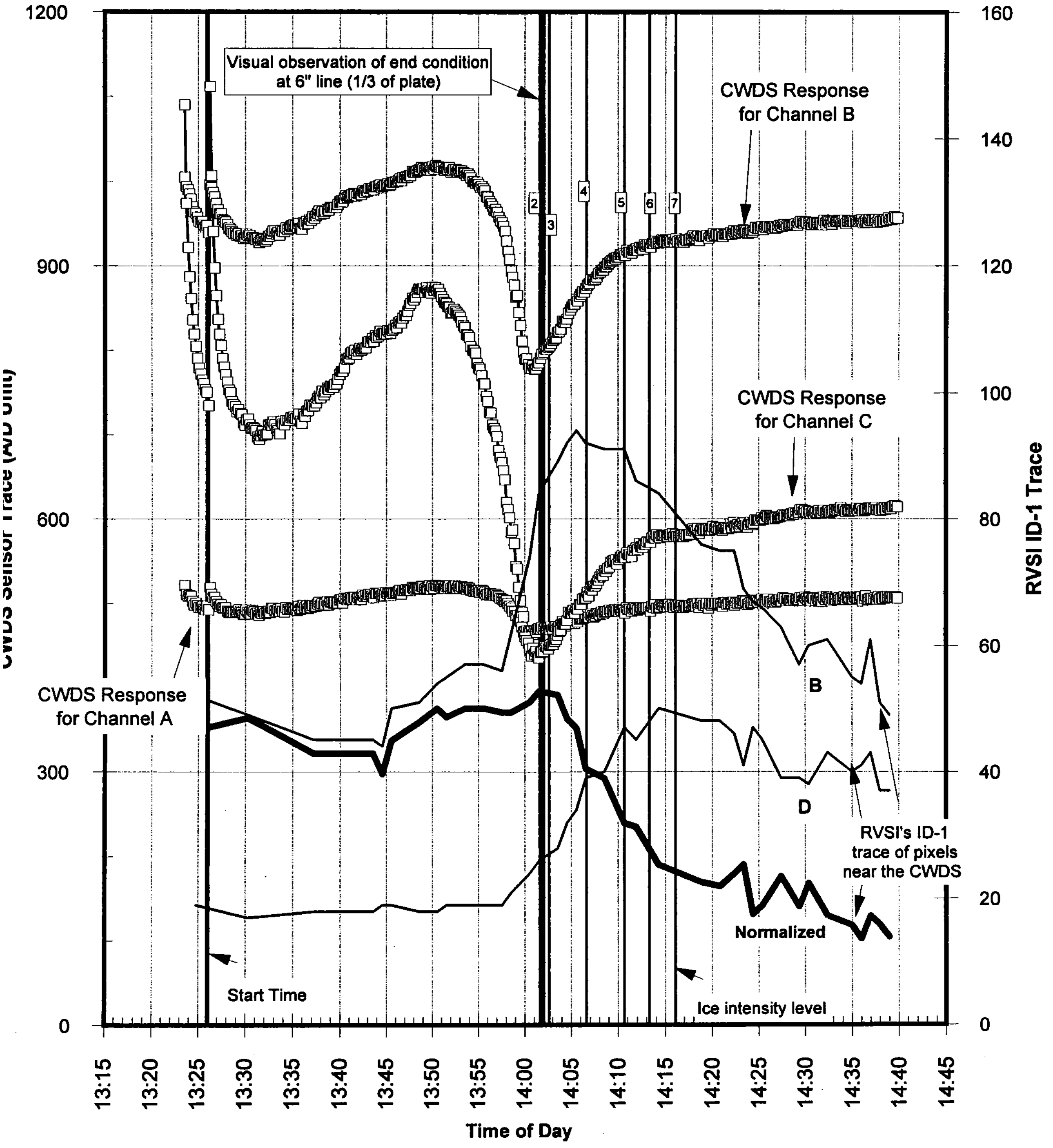
It was mentioned in previous sections that the RVSI ID-1 unit was mounted for testing at the APS test site, 3.7 metres (12 feet) above the test stand at a fixed position. As was demonstrated in the previous

FIGURE 5.27
COMPARISON OF ICE DETECTION SENSOR TRACES
Natural Snow, Apr. 7, 1994, Form 116 Plate U, A-401



anal\rvsi\F5_27.XLC

FIGURE 5.28
COMPARISON OF ICE DETECTION SENSOR TRACES
Simulated Freezing Drizzle, June 02, 1994, Plate V, A-205



F5_28.XLC

sections, based on the limited number of tests, the ice detectors seem to correlate well with the observed end condition time. It is recommended that operational testing of the RVSI unit be carried out to determine its effectiveness when viewing from an angle at variable distances. For example, a phased operational test program should be developed and may include the following activities:

- Testing of effectiveness on wing surfaces (paints, composites, rubber boots, etc.);
- Laboratory testing at NRC's cold chamber during freezing rain or drizzle simulations;
- Testing on smaller General Aviation aircraft at Dorval during natural snow;
- Testing on larger commercial aircraft at Dorval during natural snow, either after de-icing at the gate, de-icing pad, or prior to departure.

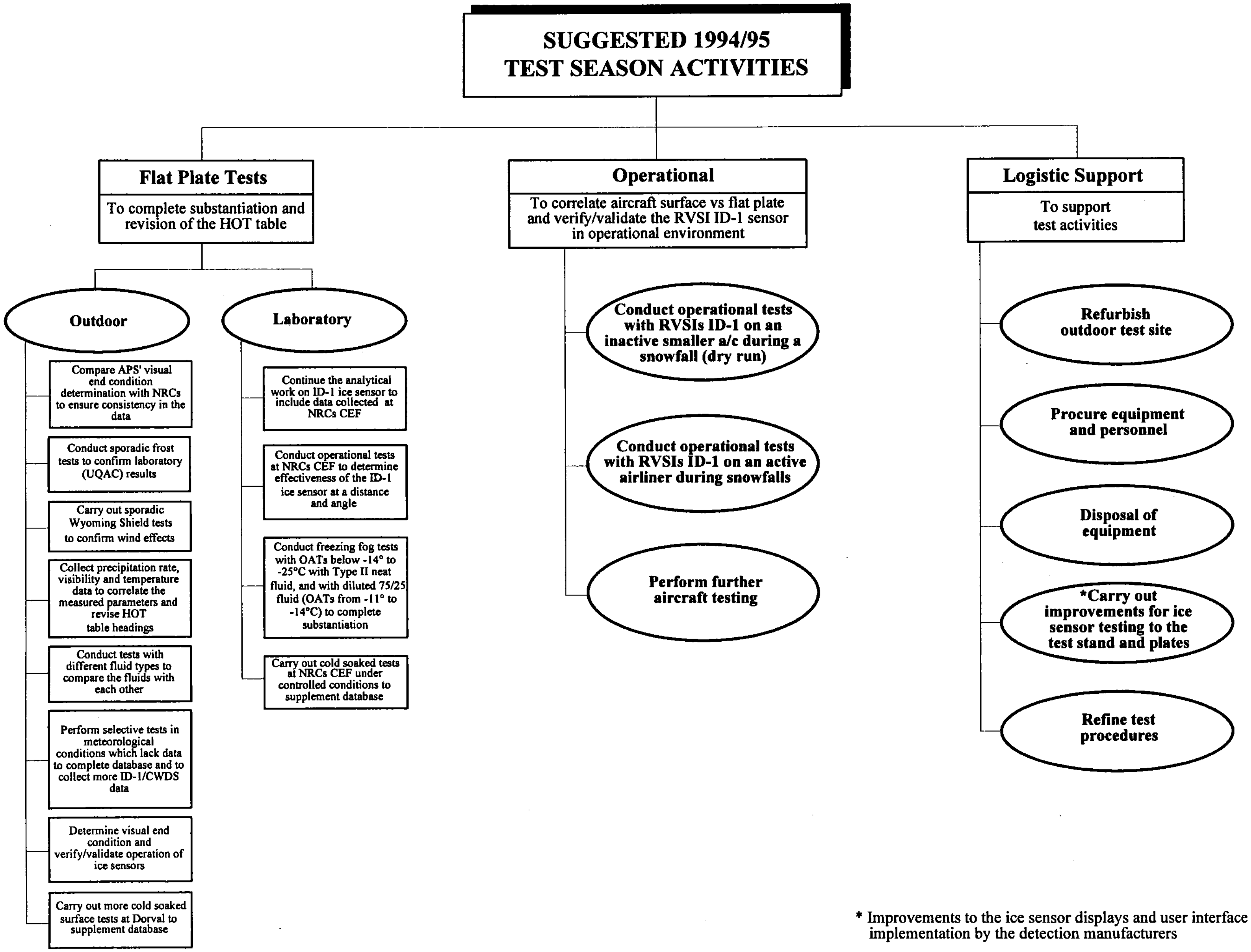
6. CONCLUSIONS AND RECOMMENDATIONS ON FUTURE TESTING

The conclusions from this years' testing and analysis are presented in point form:

- plate pan rates of precipitation correlated well with the Fisher and Porter rates
- test panels within the Wyoming Shield, where there are lower winds, tend to fail faster
- higher rates of precipitation and colder temperatures tend to reduce failure times
- fluids from different fluid manufacturers, but within the same type category, generally have different failure times
- during full scale tests at Somiper Aviation, the end condition resulted first on the leading edge of the aircraft, second on the 10° flat plate, and last on the airfoil.
- based on the few Type II 75/25 and 50/50 cold soaked tests at Dorval, it appears that the SAE lower limit requires a reduction
- the two (RVSI and Instrumar) ice detectors used seem to correlate well with the observed failure time

Figure 6.1 provides a depiction of the recommended test program for the 1994/95 winter season.

FIGURE 6.1



* Improvements to the ice sensor displays and user interface need implementation by the detection manufacturers

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APPENDIX A

TEST PROCEDURES
AND
EQUIPMENT LIST

FIELD TESTING OF DE/ANTI-ICING FLUID FOR THE PURPOSE OF SUBSTANTIATING HOLDOVER TIME TABLES

Version 4.0
Winter 1993 - 1994

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 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

2.1 Rain/Snow Gauge

The following equipment or equivalent are recommended:

2.1.1 Tipping Bucket

2.1.1.1 Electrically Heated Gauge - Weathertronics Model 6021-B

collector orifice	200 mm diameter
sensitivity	1 tip/0.1 mm accuracy 0.5% @ 13 mm/hr
output	0.1 sec switch closure
voltage	115 v (model -D 230 v)
switch	A reed mercury wetted

2.1.1.2 Electromechanical Event Counter Option

Event counter (112 V DC # 115 V AC) Weathertronics Model 6422

2.1.1.3 Digital Display Option

(A) Event Accumulator - Weathertronics Model 1600
range 0-1000 counts

linearity 0.05%

(B) Power Supply and Enclosure	- Weathertronics Model 1020
(C) LCD Digital Display	- Weathertronics Model 1991

2.1.1.4 Ombrometer

Thies Model 5.4031.11.000, resolution 0.005 mm, maximum rate 2 mm/min (24 V DC). To be used with associated wind protection element.

2.1.1.5 PC Interface Option

(A) Event Accumulator	- Weathertronics Model 1600
(B) Power Supply and Enclosure	- Weathertronics Model 1025
(C) PC Interface module	- Weathertronics Model 1799

2.1.2 Manual Gauge

A manual standard rain and snow gauge can be used provided that the diameter of the gauge be as close as possible to 208 mm. This may not be possible in Europe therefore the diameter of the gauge must be reported with all tests results.

2.1.3 Cake Pan or Plate Pan

A large low cakepan (6"x6"x2" 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.

Note: When this method is used the bottom and sides of the pan MUST BE WETTED (before each pre-test weighing) with de/anti-icing fluid to prevent the blowing snow from escaping the pan.

2.2 Temperature Gauge

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).

2.2.1 Cole Parmer P/N N-08110-25, probe P/N N-08500-55 available from Cole Parmer Instrument Company, Chicago Illinois.

2.2.2 Omega 450AKT Thermocouple thermometer available from Omega Engineering Stamford Connecticut.

2.2.3 or thermocouple thermometer equivalent to 2.2.1 or 2.2.2.

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 polished standard roll mill finish 30x50x0.32 cm, for a working area of 25x40 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 cm from each side; this marks off a working area of 2 26 x 50 cm on each panel. All marks shall be made using a 1/8" thick black marker, 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.

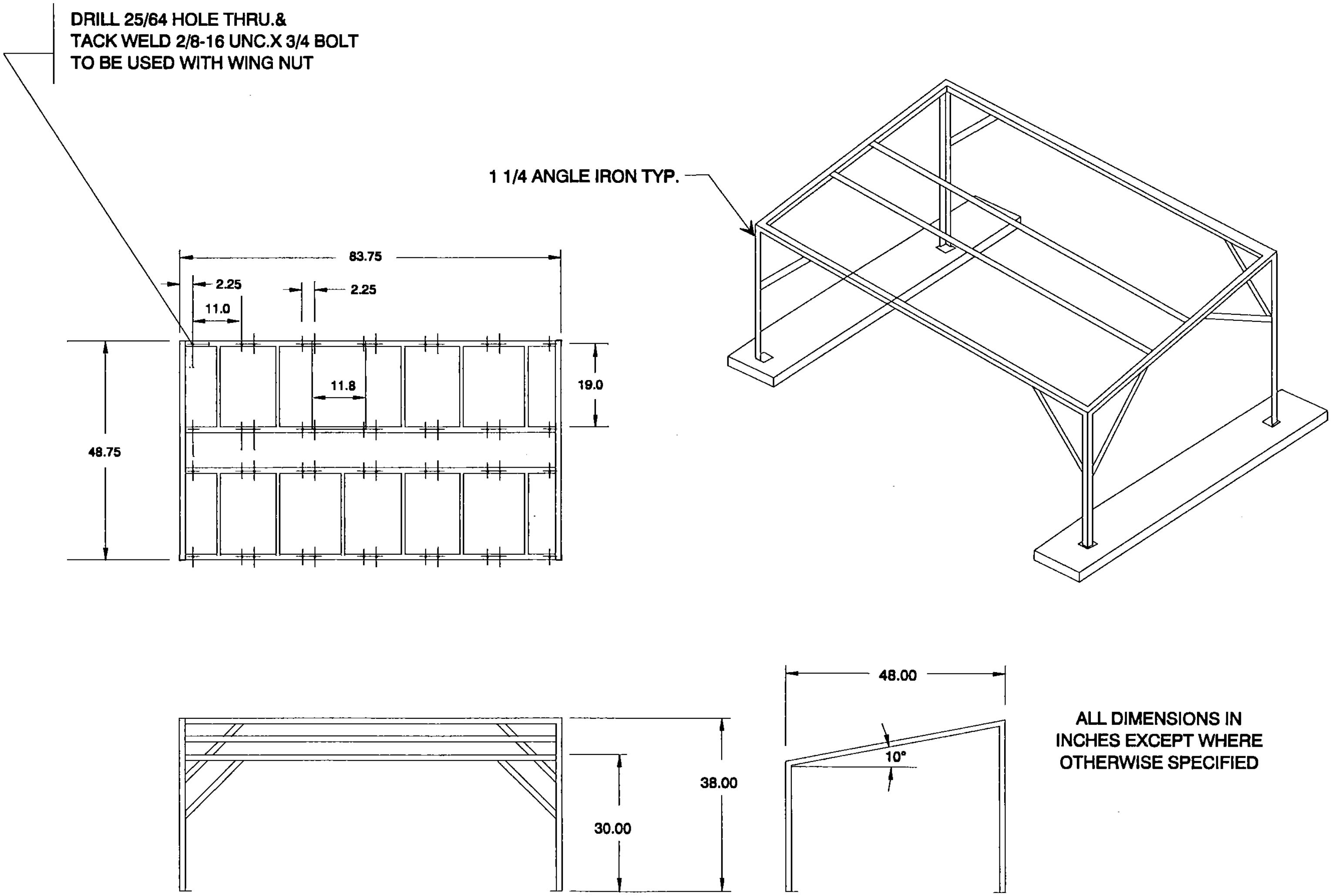
2.4.3 Attachment

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. Supports may be needed under the panels to avoid sagging under heavy loads.

2.5 Fluid Application

The fluid should be poured onto the plates from a beaker or a bottle, until the entire test section surface is saturated.

FIGURE 1
TEST STAND



ALL DIMENSIONS IN
INCHES EXCEPT WHERE
OTHERWISE SPECIFIED

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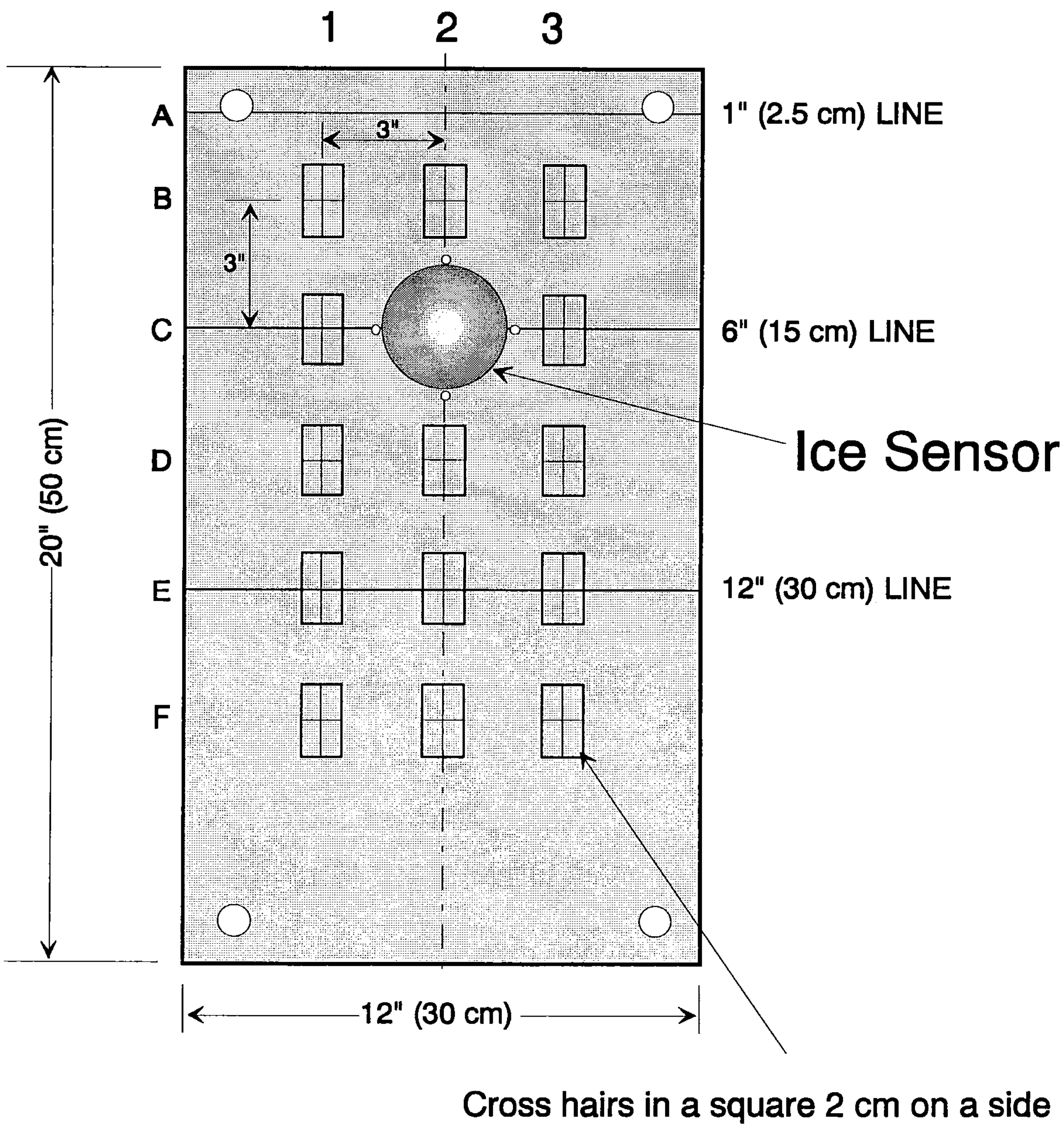
FIGURE 2
FLAT PLATE MARKINGS

TYPICAL PLATE



rep\fig\plate.drw

Alternatively, the fluid may be sprayed on with a low pressure garden sprayer equipped with a ¼ P3510 Flatjet Nozzle (35 degree angle). The Flatjet Nozzle is available from Spraying Systems Company USA.

2.6 Film Thickness Gauge

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 Videorecorder

Where feasible a videocamera should be mounted to record salient events during testing. 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.

2.9 Wind Vane

Model 2020 Qualimetrics

2.10 Relative Humidity Meter

Cole Parmer RH/Temperature Indicator P/N N-032321-00 with remote probe P/N N-03321030. 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.

2.11 Signal Conditioning Modules

Qualimetrics:

- Enclosure/Power Supply Model 1020 (115 V AC)
- Ombrometer Module Model 1600
- Anemometer Module Model 1202
- Temperature Module Model 1419-A
- Relative Humidity Module Model 1500
- Wind Vane Module

2.12 Computer Interface

Qualimetrics Model 1799-A, RS-232, 1 to 10 channels, 10 sec. to 1 hr. sampling rate.

2.13 Additional Equipment

- Squeegee
- Extension power cords
- Stopwatch
- Flood lights (2 x 500 watts)
- Pressurized space pens and water repellent paper
- PC to record meteorological data

3. DE/ANTI-ICING FLUIDS (INCLUDES INSTRUCTIONS FOR FLUID SUPPLIERS)

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 will 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.

4. PROCEDURE

4.1 Setup

4.1.1 Panel Test Stand

If there is any wind, orient the test fixture such that the aluminum holdover test panels top surfaces are facing into the wind direction at the beginning of the test such that 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.

4.1.2 Rain Gauge

Place the Rain/Gauge on one side of the test fixture at a distance between 1 and 2 meters from the fixture.
Ensure that the interior level is used to indicate that the bucket is level. Ensure that the gauge is not shadowed by an object which would interfere with the collection for the snow or the freezing rain.

If there is drifting snow if maybe necessary to raise the snow gauge above the drift level but no higher than the test panel.
It may be preferable to use a rain gauge snow fence such as the Weathertronics wind screen Model 6410.

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.

4.1.3 Manual Cake Pan or Plate Pan Method

Add ¼ inch de/anti-icing fluid 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 milligram. Weigh again after test completion to determine the true water content reading of the snow.

Use of more than one cake or plate pan is recommended to provide multiple readings through the course of the test period; mounting one pan on the test stand along side the plates at the same orientation and one horizontally off the stand is recommended.

4.2 Test Panel Preparation

4.2.1 Before the start of each day's testing, wash the panels with a solvent such as isopropyl alcohol followed by a wash with an alkali detergent. Rinse thoroughly with water and dry.

Between tests wash the panels with pure glycol (NOT type I fluid) and wipe dry.

4.2.2 Place the panels on the fixture and attach to the frame screws with flat bolts (wing nuts will make attaching and removal easier in poor weather)

4.2.3 Allow the panels to cool to outside air temperature.

4.3 Fluid Preparation and Application

4.3.1 Fluid Temperature

Store fluids in containers at room temperature between 20-24 C. Except for Type I fluids, all fluids should be kept outside (cold-soaked to ambient temperature conditions) before tests start.

4.3.2 Cleaning Panels

Before applying test fluid to a panel, squeegee the surface to remove any precipitation or moisture.

4.3.3 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 sane fluid, load the second test fluid on panel V followed by panel Y; use location W as the bare test panel and location Z for a precipitation measuring device such as a cake pan.

4.3.4 Thickness Measurement

Between the 3-5 minutes interval following test commencement time measure the fluid thickness at the centre of the 15 cm line (C in figure 2).

4.4 Holdover Time Testing

4.4.1 Set the timer on as the first fluid application starts. Note the time when fluid application is completed.

4.4.2 Commence recording the test with a video recorder or take pictures at time 0 and then at one (1) and five (5) minute intervals for freezing rain and snow respectively until the test reaches the END CONDITIONS.

4.4.3 Record the elapsed time (holdover time) required for the precipitation to achieve the test END CONDITION.

4.4.4 Also record the elapsed time when five of the crosshairs are covered with slush so that correlation with the ice sensors can be attempted.

4.4.5 In heavy precipitation, continue the test until the precipitation reaches the bottom of the panel. Record the time for this event.

5. END CONDITIONS

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, e.g. white snow) on the fluid at the crosshair when viewed from the front (i.e. perpendicular to the plate). The crosshair does **NOT** need to be obscured (as was the case in the 1990-1991 test season), you are looking for an indication that the fluid can no longer accommodate the precipitation at this point.

OR

- 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 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).

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, 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 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; this measure should indicate failure over about one-third of the panel.

For end conditions on airfoil sections, see Attachment I.

6. END OF TEST

At the end of the test as the plate is being cleaned record for each plate any of the following occurrences:

1) There are some frozen patches on the plate itself;
2) A sheet of ice (not necessarily covering a large area) has formed on the fluid itself but has not reached the plate;
3) Any case where the fluid is difficult to remove not covered by cases 1 or 2, e.g. the fluid/snow mixture has a paste-like consistency.

Record the type and extent of contamination on the control plate. For example note if the plate is covered in a light fluffy snow, or light ice, or any other distinguishing features of the contamination.

Once the test has ended, wipe the plates and cleanse with isopropyl alcohol and/or pure glycol. Restart the testing procedure and continue as long as the weather conditions warrant.

7. REPORTING AND OBSERVATIONS

Calculate and record test data, observations and comments in the format of Table 1. Each test must be conducted in duplicate. Detailed definitions and descriptions of meteorological phenomena are available in the Manual of Surface Weather Observation (MANOBS).

TABLE 1

REMEMBER TO SYNCHRONIZE TIME

DE/ANTI-ICING DATA FORM

VERSION 2.0 Winter 93/94

LOCATION: **DATE:** **RUN NUMBER:** **STAND # :** **CIRCLE SENSOR PLATE: u v w x y z**

Time Before Fluid Application: am / pm **Time After Fluid Application:** am / pm **SENSOR NAME:**

Fluid Film Thickness Time (After Fluid Application): ____________ min : sec

		PLATE U	PLATE V	PLATE W
THICKNESS	15 cm LINE	________ mils	________ mils	________ mils
		PLATE X	PLATE Y	PLATE Z
THICKNESS	15 cm LINE	________ mils	________ mils	________ mils

COLLECTION PAN:	PAN # ________		PAN # ________	
	Before	After	Before	After
Computer Precip. (g/dm²)	________	________		
Weight of Pan (g)	________	________	________	________
Collection Time (min)	________	________	________	________

DIRECTION OF STAND:

CONTROL PLATE COMMENTS:

SNOW/RAIN CATEGORIES (use velvet & classification):

OTHER COMMENTS:

PERFORMED BY: **ASSISTED BY:**

TIME (After Fluid Application) TO FAILURE FOR INDIVIDUAL CROSSHAIRS (MINUTES)

	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 CONTAMINATION									
	1st	½	Full	1st	½	Full	1st	½	Full
TIME OF SLUSH FORMATION ON SENSOR HEAD									
TIME OF SLUSH AT 6" LINE									

	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 CONTAMINATION									
	1st	½	Full	1st	½	Full	1st	½	Full
TIME OF SLUSH FORMATION ON SENSOR HEAD									
TIME OF SLUSH AT 6" LINE									

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ATTACHMENT I

End Conditions for Airfoil

Winter 1993/94

The following procedure must be followed for determination of contamination and end condition times for airfoil sections.

1) Proceed in the same manner as the flat plate tests by measuring fluid thickness and direction of the airfoil, as per the data form (Table 1a).

2) Ensure that airfoil tests are conducted simultaneously with flat plate tests and with the same fluid.

3) On the two scaled diagrams in Table 1a (one for "slush formation" and one for "loss of absorption capability") draw the following:
   a) time and location of first signs of slush and loss of absorption
   b) observe the airfoil at **5 minutes intervals** (1) after fluid application and draw "equi-time" lines (time contours) on the attached diagrams showing "slush formation" and "loss of absorption". Ensure that the "equi-time" lines have the appropriate time labels.

4) The airfoil tests should be carried out for at least one hour or until the CWDS has received substantial contamination.

5) General observations during airfoil testing are important and therefore should be noted on the data form.

6) For freezing fog/drizzle tests, use the "loss of gloss" end condition in lieu of "loss of absorption capability".

(1) The interval may be increased to 10 minutes if the changes on the airfoil are not significant (eg. due to light snow or Type II neat fluid).

TABLE 1a

AIRFOIL DE/ANTI-ICING DATA FORM

REMEMBER TO SYNCHRONIZE TIME

VERSION 1.2 Winter 93/94

LOCATION: **DATE:** **RUN # (Same as Plate Tests):** **FLUID TYPE:**

Time After Fluid Application: am / pm

Fluid Film Thickness Time

(Time After Fluid Application): ________ min : sec

	SLUSH	**FAILURE**
1st Contamination Time :	________ min	________ min
Time on Centre of Sensor Head :	________ min	________ min

DIRECTION OF AIRFOIL: ________

OTHER COMMENTS: ________

____

____

____

____

____

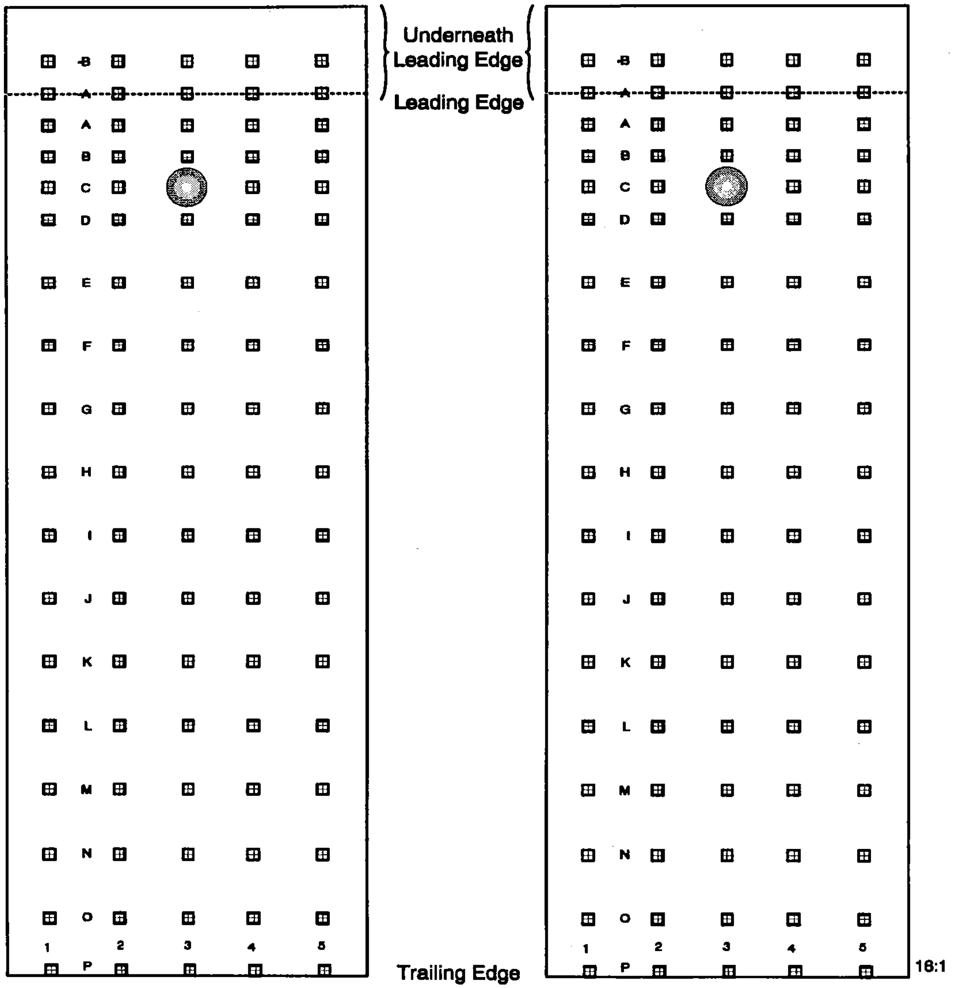
PERFORMED BY: ________

ASSISTED BY: ________

TIME CONTOURS (min)*

SLUSH FORMATION **LOSS OF ABSORPTION CAPABILITY****

(Standard Failure)



* Inspect airfoil at 5 minute intervals (After Fluid Application) and draw time contours.

** For freezing fog/drizzle, use "Loss of Gloss" end condition.

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ATTACHMENT II

PROCEDURE FOR COLD SOAK TESTS (Table 1b)

Winter 1993/94

1) Ensure that Box #1 and Box #2 is filled with Type II fluid (neat), and has been cold soaked for several hours and the insulating jacket is attached. When ready to start the first test, remove boxes from freezer and leave in the trailer for about 20 minutes in order to have the temperature stabilize on the plate.

2) Conduct tests during cold (0° to 5°C) rainy days.

3) Place Box #1, Box #2, and two flat plates on the test stand.

4) Ensure that the main computer, video camera and RVSI unit is functional.

5) Proceed in the same manner as the flat plate tests (place stand into wind).

6) When ready to proceed with tests, pour the same test fluid on Box #1 and one plate only (see data form).

7) Measure plate temperatures at times indicated on the data form.

8) When ice formation (loss of gloss) forms over a cross hair, note the time on the data form. It is expected that the "loss of gloss" type of failure will result for this type of test.

TABLE 1b

REMEMBER TO SYNCHRONIZE TIME

DATA FORM FOR COLD SOAK TESTS

VERSION 2.1 Winter 93/94

LOCATION: **DATE:** **RUN NUMBER:** **Direction of Stand:** **Ambient Start Temp. (°C):**

Circle Rain Type: Light , Mod , Heavy , Mitg Snow **Time After Fluid Application:** am / pm **Fluid Name:**

Temperature (°C)

Location	Before fluid poured 0 min	After fluid poured 0 min	5 min	10 min	20 min	30 min	45 min	60 min	End
B#1-6"	___								___
B#1-9"	___	___	___	___	___	___	___	___	___
B#1-12"	___								___
P#1-6"	___								___
P#2-6"	___								___
B#2-6"	___								___
B#2-9"	___	___	___	___	___	___	___	___	___
B#2-12"	___								___

COLLECTION PAN:

	PAN #1 Start	PAN #1 End	PAN #2 Start	PAN #2 End
Weight of Pan (g)	___	___	___	___
Collection Time (min)	___	___	___	___

OTHER COMMENTS:

* TIME (After Fluid Application) TO FAILURE FOR INDIVIDUAL CROSSHAIRS (MINUTES)

LOCATION ON STAND: ___ ___

	COLD SOAKED Box #1 POUR FLUID EXTERNALLY			Plate #1 POUR FLUID EXTERNALLY		
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE CONTAMINATION						

SENSOR NAME: ___

LOCATION ON STAND: ___ ___

	Plate #2 DO NOT POUR FLUID EXTERNALLY			COLD SOAKED Box #2 DO NOT POUR FLUID EXTERNALLY		
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE CONTAMINATION						

SENSOR NAME: ___

procedu\cbox_fm.drw

* Look for "Loss of Gloss"

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PERFORMED BY: