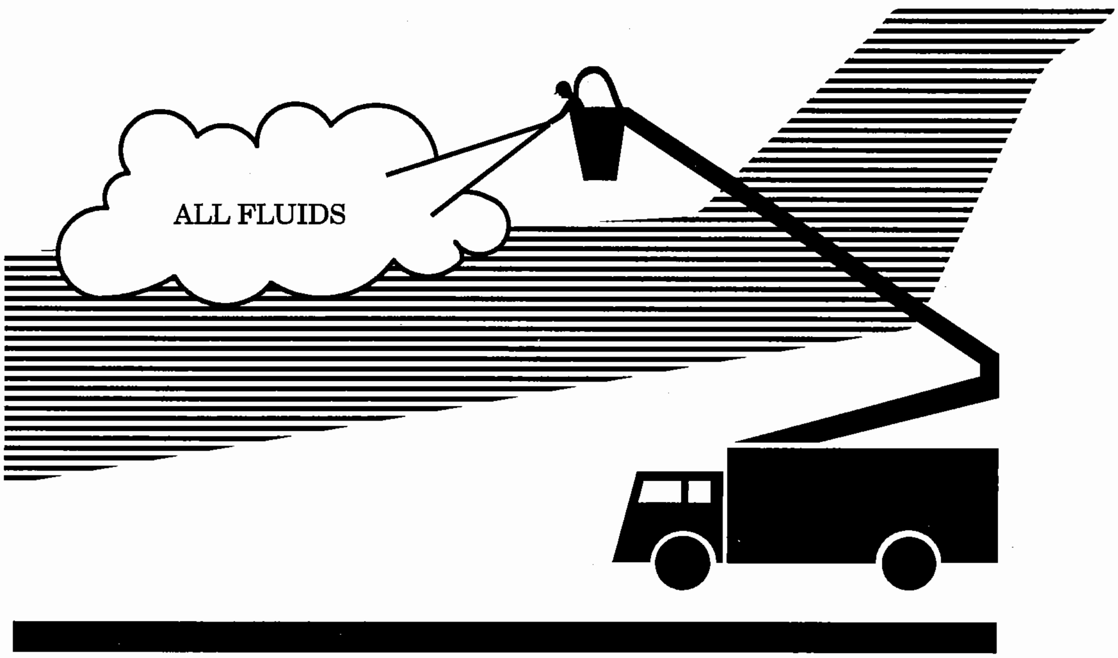
TP 12676E

Consolidated Fluid Holdover Time Field Test Data



Prepared for

Dryden Commission Implementation Project
Transport Canada

by

APS AVIATION INC.

December 1995

TP 12676E
CM1222.001

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John D'Avirro

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The contents of this report reflect the views of APS Aviation Inc. and not necessarily the official view or opinions of the Dryden Commission Implementation Project of Transport Canada.

Un sommaire en français de ce rapport est inclus.

PREFACE

At the request of the Dryden Commission Implementation Program of Transport Canada, APS Aviation Inc. has undertaken a research program to further advance aircraft ground de-icing/anti-icing technology. Specific objectives of the program were:

- Substantiation of SAE/ISO Holdover Time Tables that define a de-icing fluid's ability to delay ice formation by conducting tests on flat plates under conditions of natural snow, simulated freezing drizzle, simulated light freezing rain, and simulated freezing fog for a range of fluid dilutions and temperature conditions;

- Development of data for the "cold-soaked" wing conditions using cooled flat plates to simulate the conditions;

- Correlation of flat plate test data with the performance of various fluids on service aircraft by concurrent testing;

- Evaluation of the suitability of hot blown air equipment to remove frost at extreme low temperatures;

- Evaluation of the suitability of equipment which blows air to remove snow;

- Determination of the environmental limits for use of hot water as a de-icing fluid;

- Evaluation of a remote sensor to detect contamination on wing surfaces;

- Determination of the pattern of fluid run-off from the wing during take-off; and

- Determination of wing temperature profiles during and after the de-icing operation.

The research activities of the program conducted on behalf of Transport Canada during the 1994/95 winter season are documented in four separate reports. The titles of these reports are as follows:

- TP 12595E Aircraft Full-Scale Test Program for the 1994/95 Winter;
- TP 12653E Hot Water De-Icing Trials for the 1994/95 Winter;
- TP 12654E Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1994/95 Winter; and
- TP 12655E Forced Air De-Icing Trials for the 1994/95 Winter.

Three additional reports were produced as a part of this research program. The titles of these reports are as follows:

- TP 12676E Consolidated Fluid Holdover Time Test Data;
- TP 12677E Consolidated Research and Development Report; and
- TP 12678E Methodology for Simulating a Cold-Soaked Wing.

The present report provides the consolidated data from each test year (1990 to 1995) relating to the substantiation of the SAE/ISO Holdover Time Tables.

The completion of this program could not have occurred without the assistance of many individuals and organizations. APS would therefore like to thank the Dryden Commission Implementation Project, Transportation Development Centre, the Federal Aviation Administration, the National Research Council, Atmospheric Environment Services, Transport Canada and the fluid manufacturers for their contribution and assistance in the project. Special thanks are extended to Aeromag 2000, Aerotech International Incorporated, Air Atlantic, Air Canada, Calm Air, Canadian Airlines International, CanAir Cargo, and United Airlines for their cooperation, personnel and facilities.

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See abstract

16. Abstract

Research reports produced on behalf of Transport Canada for testing during previous winters are available as follows: TP 11206E 1990/91; TP 11454E 1991/92; TP 11836E 1992/93; and 1993/94 Summary Report submitted to DCIP. Seven reports (including this report) were produced as part of the 1994/95 research program: TP 12595E Full-Scale Tests; TP 12653E Hot Water; TP 12655E Forced Air; TP 12654E Holdover Time Substantiation; TP 12676E Consolidated Holdover Time Data; TP 12678E Methodology for Simulating a Cold-Soaked Wing; and TP 12677E Consolidated Research and Development.

At the request of the Dryden Commission Implementation Program (DCIP) of Transport Canada (TC), APS Aviation Inc. (APS) has undertaken a research program to further advance aircraft ground de-icing/anti-icing technology. While a number of objectives of the test program are covered by related reports, this report provides the consolidated data associated with the substantiation of SAE/ISO Holdover Time Tables. The need for testing was identified in the late 1980s. Following numerous SAE Committee meetings, Air Canada, TDC and APS developed a test program. A series of tests were conducted starting in the winter of 1990. The objective was to substantiate the AEA/ISO holdover times that were being used in Europe. These holdover times were derived by the AEA/ISO from long-term European operational experience.

More than 2500 tests have been conducted by APS, NRC, United Airlines and NCAR. The data is sub-divided as a function of precipitation condition type: natural snow; simulated freezing drizzle and light freezing rain; simulated freezing fog; and rain on cold-soaked surfaces. The majority of these tests were completed under natural snow conditions. Types I, II, III and the new Type IV fluids were provided by more than ten manufacturers. This report contains a record of all the data collected over the years. Charts were developed for each precipitation condition type in an attempt to illustrate the important variables such as precipitation rate, temperature and windspeed as a function of fluid failure time.

The flat plate tests have shown that the pre-1991 AEA/ISO Holdover Time values required a reduction to satisfactorily cover operational conditions in North America. This research has demonstrated the need for improved holdover times which in turn fostered the development of *Ultra* (Type IV). When using *Ultra*, the Neat Type II holdover times can be increased by 50%. For natural snow conditions, Types I and II tests have shown that the current SAE/ISO holdover times are substantiated. The holdover time ranges for Types I and II fluids are mostly applicable to moderate snow conditions – during heavy snow conditions the holdover times must be reduced. For freezing fog conditions, test results have shown that the holdover times are substantiated. The "freezing rain" column has been changed and sub-divided into two new columns, "freezing drizzle and light freezing rain". Holdover time ranges were developed for these new categories.

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Voir résumé

16. Résumé

Transports Canada a fait produire les rapports de recherche suivants sur les essais menés durant les hivers précédents : TP 11206E pour 1990-1991; TP 11454E pour 1991-1992; TP 11836E pour 1992-1993 et le rapport sommaire pour l'année 1993-1994 présenté au Comité de mise en oeuvre de la Commission Dryden. Concernant le programme de recherche mené durant l'hiver de 1994-1995, les sept rapports suivants (y compris le présent) ont été produits : TP 12595E Full-Scale Tests; TP 12653E Hot Water; TP 12655E Forced Air; TP 12654E Holdover Time Substantiation; TP 12676E Consolidated Holdover Time Data; TP 12678E Methodology for Simulating a Cold-Soaked Wing et, enfin, TP 12677E Consolidated Research and Development.

À la demande du Comité de mise en oeuvre de la Commission Dryden mis sur pied par Transports Canada, APS Aviation Inc. (APS) a lancé un programme de recherches visant à faire progresser la technologie de dégivrage/antigivrage des aéronefs au sol. Certains des objectifs fixés à ce programme sont décrits dans plusieurs rapports connexes. Le présent rapport montre les données consolidées qui ont servi à la vérification des tables de durée d'efficacité selon SAE/ISO. C'est vers la fin des années 1980 que l'on a compris la nécessité de procéder à des essais normalisés. À l'issue des nombreuses réunions du comité compétent mis sur pied par la SAE, Air Canada, APS et le Centre de développement des transports (CDT) ont mis au point un programme d'essais. Le but fixé à la batterie d'essais menés dès l'hiver de 1990 était de vérifier le bien-fondé des tables de durée d'efficacité ACENA/ISO utilisées en Europe. ACENA/ISO avaient déterminé les durées d'efficacité à la lumière de la longue expérience acquise par les compagnies européennes de navigation aérienne.

Plus de 2 500 tests ont été menés par APS, le Conseil national de recherches (CNR), United Airlines et le National Centre for Atmospheric Research des États-Unis. Les valeurs de durée sont présentées sous forme tabulaire, selon le type de précipitation : neige naturelle, bruine ou pluie légère verglaçantes simulées, brouillard verglaçant simulé ou pluie sur surfaces sur-refroidies. La plupart des essais décrits ont eu lieu avec de la neige naturelle. Plus de dix fabricants ont fourni les liquides antigivre de type I, II, III ainsi que le nouveau liquide de type IV. Le rapport donne les résultats obtenus depuis le début des essais. À l'égard de chaque forme de précipitation, des courbes ont été élaborées, montrant la correspondance entre, d'une part, des variables dominantes telles que taux de précipitation, température et vitesse du vent et les durées d'efficacité, d'autre part.

Les essais sur plaques planes ont montré que les valeurs indiquées dans les tables normalisées ACENA/ISO et remontant aux années avant 1991 doivent être abaissées afin de mieux refléter la réalité des conditions d'exploitation en Amérique du Nord. Le programme de recherche a encouragé Union Carbide à se lancer dans la fabrication d'un nouveau liquide «longue durée» appelé *Ultra* ou de type IV. Il a été constaté que le liquide *Ultra* avait une durée d'efficacité de 50 p. 100 supérieure à celle des liquides de type II non dilués. Dans le cas de neige naturelle, les essais avec les liquides de type I et II ont confirmé le bien-fondé des valeurs courantes, normalisées ACENA/ISO. Les plages de durée d'efficacité pour les liquides de type I et II sont valides lorsque la précipitation neigeuse est d'intensité moyenne. Mais lorsqu'elle est de forte intensité, les valeurs de durée doivent être abaissées. Les résultats ont également confirmé le bien-fondé des valeurs courantes en cas de brouillard verglaçant. Pour ce qui est de la pluie verglaçante, on distingue maintenant deux catégories : bruine verglaçante et pluie légère verglaçante, pour lesquelles des plages de durée d'efficacité ont été définies.

17. Mots clés Aéronefs, neige, brouillard, bruine, pluie, antigivrage, liquide, durée d'efficacité, précipitations, aile, plaque, données, dégivrage, glace, capteur, sur-refroidissement	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 Program (DCIP) of Transport Canada (TC), APS Aviation Inc. (APS) undertook a research program to further advance aircraft ground de-icing/anti-icing technology. While a number of objectives of the test program are covered by related reports, this report provides the consolidated data associated with the substantiation of the SAE/ISO Holdover Time Tables.

The need for testing was identified in the late 1980s. Following numerous Society of Automotive Engineers (SAE) Committee meetings, Air Canada, the Transportation Development Centre (TDC) and APS developed a field test program. A series of tests were conducted starting in the winter of 1990. The objective of these tests was to substantiate the AEA/ISO holdover times that were being used in Europe. Holdover time is characterised as the time a test fluid can delay ice formation. These holdover times are provided as a function of weather condition, fluid mixture and outside air temperature. Only one number representing holdover time is recommended in each of the table categories. These holdover times was derived by the AEA/ISO from long-term European operational experience.

Most of the natural snow tests were conducted outdoors at a site located at Dorval Airport in Montreal, Quebec. Testing of simulated freezing fog, freezing drizzle, light freezing rain and rain on cold-soaked surfaces were carried out at National Research Council (NRC) facilities in Ottawa, Canada.

More than 2500 tests have been completed since 1990 by APS, NRC, United Airlines and the National Centre for Atmospheric Research (NCAR). The data is sub-divided as a function of precipitation condition: natural snow; simulated freezing drizzle and light freezing rain; simulated freezing fog; and rain on cold-soaked surfaces. This report includes the results from all tests conducted since 1990 with the exception of frost tests conducted by UQAC, which are reported elsewhere. The majority of these tests were completed under natural snow conditions. Types I, II, III and the proposed new Type IV fluids were provided by more than ten manufacturers.

Charts were developed for each precipitation condition type to illustrate the important variables such as precipitation rate, temperature and windspeed as a function of fluid failure time. While a large part of the spread in the test data results can be attributed to these variables, other variables have also affected the results.

The flat plate tests have shown that the pre-1991 AEA/ISO Holdover Time Tables require a reduction to satisfactorily cover operational conditions in North America. This research promoted the development by Union Carbide of *Ultra*, a new "long life" fluid, and of a pertinent new Type IV holdover time table. When using *Ultra*, the Neat Type II holdover times were increased by 50%. For natural snow conditions, Types I and II fluid tests have substantiated the current SAE/ISO holdover times. The holdover time ranges for Types I and II fluids are applicable for moderate snow conditions – during heavy snow conditions the holdover times must be reduced. For freezing fog conditions, test results have substantiated the holdover times. "Freezing rain" has been redefined as two categories: "freezing drizzle" and "light freezing rain". Holdover time ranges were developed for these new categories.

SOMMAIRE

À la demande du Comité de mise en oeuvre de la Commission Dryden mis sur pied par Transports Canada, APS Aviation Inc. (APS) a lancé un programme de recherches visant à faire progresser la technologie de dégivrage/antigivrage des aéronefs au sol. Certains des objectifs fixés à ce programme sont décrits dans plusieurs rapports connexes. Le présent rapport montre les données consolidées qui ont servi à la vérification des tables de durée d'efficacité SAE/ISO.

C'est vers la fin des années 1980 que l'on a compris la nécessité de procéder à des essais normalisés. À l'issue des nombreuses réunions du comité compétent mis sur pied par la SAE, Air Canada, APS et le Centre de développement des transports (CDT) ont mis au point un programme d'essais. Le but fixé à la batterie d'essais menés dès l'hiver de 1990 était de vérifier le bien-fondé des tables de durée d'efficacité ACENA/ISO utilisées en Europe. La durée d'efficacité est le temps durant lequel le liquide sous essai parvient à retarder la formation de givre. Les durées d'efficacité indiquées dans les tables sont données en fonction des conditions météorologiques, du degré de dilution du liquide et de la température de l'air à l'extérieur. Dans chacune de ces catégories, une seule valeur de durée est préconisée. L'ACENA/ISO avaient déterminé les durées d'efficacité à la lumière de la longue expérience acquise par les compagnies européennes de navigation aérienne.

Les essais sous neige naturelle menés à l'extérieur ont eu lieu à l'aéroport de Dorval à Montréal (Québec), alors que les essais par simulation de brouillard verglaçant, de bruine verglaçante, de pluie légère verglaçante et enfin de pluie sur des surfaces sur-refroidies ont été menés dans les installations du Conseil national de recherches (CNR) à Ottawa.

Depuis 1990, plus de 2 500 tests ont été menés par APS, le CNR, United Airlines et le National Centre for Atmospheric Research des États-Unis. Les valeurs de durée sont présentées sous forme tabulaire, selon le type de précipitation : neige naturelle, bruine ou pluie légère verglaçantes simulées, brouillard verglaçant simulé ou pluie sur surfaces sur-refroidies. Le rapport donne les résultats obtenus des tests menés depuis 1990, à l'exception des essais de givrage menés par l'Université du Québec à Chicoutimi, dont les résultats figurent dans un autre rapport. La plupart des essais décrits ont eu lieu sous neige naturelle. Plus de dix fabricants ont fourni les liquides essayés, de type I, II, III ainsi que le nouveau liquide de type IV.

À l'égard de chaque forme de précipitation, des courbes ont été élaborées, montrant la correspondance entre, d'une part, des variables dominantes telles que taux de précipitation, température et

vitesse du vent et les durées d'efficacité, d'autre part. La dispersion des résultats peut, dans de nombreux cas, être attribuée aux variables précitées, mais elles ne sont toutefois pas les seules en cause.

Les essais sur plaques planes ont montré que les valeurs indiquées dans les tables normalisées ACENA/ISO et remontant aux années avant 1991 doivent être abaissées afin de mieux refléter la réalité des conditions d'exploitation en Amérique du Nord. Le programme de recherche a encouragé Union Carbide à se lancer dans la fabrication d'un nouveau liquide «longue durée» appelé *Ultra* ou de type IV et dans l'établissement d'une table de durées d'efficacité correspondante. Il a été constaté que le liquide *Ultra* avait une durée d'efficacité de 50 p. 100 supérieure à celle des liquides de type II non dilués. Dans le cas de neige naturelle, les essais avec les liquides de type I et II ont confirmé le bien-fondé des valeurs courantes ACENA/ISO. Les plages de durée d'efficacité pour les liquides de type I et II sont valides lorsque la précipitation neigeuse est d'intensité moyenne. Mais lorsqu'elle est de forte intensité, les valeurs de durée doivent être abaissées. Les résultats ont également confirmé le bien-fondé des valeurs courantes en cas de brouillard verglaçant. Pour ce qui est de la pluie verglaçante, on distingue maintenant deux catégories : bruine verglaçante et pluie légère verglaçante, pour lesquelles des plages de durée d'efficacité ont été définies.

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1. INTRODUCTION

1. INTRODUCTION

The need for testing of de/anti-icing fluids for aircraft was identified in the late 1980's. Following a series of Society of Automotive Engineers (SAE) meetings on holdover times, Air Canada, Transport Canada (TC), the Transportation Development Centre (TDC) and APS Aviation Inc. (APS) developed a field test program to determine the fluid effectiveness on standardized flat plates under a variety of precipitation conditions. A series of tests were conducted starting in 1990. The objective of these tests was to substantiate the Association of European Airlines/International Standards Organization (AEA/ISO) holdover times which were being used in Europe. These holdover times were determined by the AEA/ISO based mostly on operational experience in Europe over a number of years.

This report provides the consolidated data relating to the substantiation of the holdover time tables by the conduct of tests on standard flat plates under conditions of natural snow, simulated freezing drizzle, simulated light freezing rain, simulated freezing fog and rain on cold-soaked surfaces for a range of fluid dilutions and temperature conditions. The test data from all winters starting in 1990 is included in this report.

Aircraft are de-iced using Type I de-icing fluids, which are sometimes diluted. While excellent for removing ice and snow which has already accumulated on the wings of aircraft, Type I fluids provide only limited protection against further ice build up. The Type II fluids, being significantly more viscous, provide this kind of protection. Type III fluid (previously called Type 1.5) is a thickened fluid which has properties that lie between Types I and II. Its shearing and flow off characteristics are designed for aircraft with lower take-off speeds. Newer, longer lasting fluids are also in development. One such fluid which is commercially available is Union Carbide's (UCAR's) Ultra Type II anti-icing fluid (possibly becoming Type IV in the future).

Table 1.1 shows the Type II AEA/ISO holdover times which were used in 1990. Holdover time is characterized as the time a test fluid can delay ice formation. The holdover times are provided as a function of weather condition, fluid mixture and outside air temperature. Only one number was being used in each box. This represents the upper time given in the current (SAE/ISO) holdover time tables.

TABLE 1.1

TYPE II ISO/AEA HOT TABLE USED IN 1990

OAT (deg C)	ISO TYPE II FLUID MIXTURE CONCENTRATION NEAT-FLUID/WATER (VOL % / VOL %)	WEATHER CONDITIONS				
		FROST	FREEZING FOG	STEADY SNOW	FREEZING RAIN	RAIN ON COLD SOAKED WING
+0	100/0	12h	3h	1h	20min	1h
and	75/25	6h	2h	45min	10min	45min
above	50/50	4h	1.5h	30min	5min	30min
-0	100/0	8h	1.5h	45min	20min	
to	75/25	5h	1h	30min	10min	
-7	50/50	3h	45min	15min	3min	
-8	100/0	8h	1.5h	45min		
to	75/25	5h	1h	30min		
-14	50/50					
-15	100/0	8h	1.5h	45min		
to	75/25					
-25	50/50					

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The upper limits given in the current (SAE/ISO) holdover time tables were originally established by the AEA/ISO. The lower limits of the holdover time ranges (a fraction of the higher times) were determined by the SAE G-12 Committee based upon test data from the 1990/91 winter. The extensive testing conducted by APS has been to determine the performance of fluids on standard flat plates to substantiate the holdover times, or if warranted, to recommend changes. The results of the 1990/91 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 1990/91 Winter"**. The results of the 1991/92 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 1991/92 Winter"**. Testing during the 1992/93 winter included not only testing of snow at Dorval, but also testing of freezing drizzle and freezing fog at NRC. The results of the 1992/93 test program, which focused on Type I fluids, were published by APS Aviation in the Transport Canada report TP 11836E, **"Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1992/93 Winter"**. The results of the 1993/94 test program, which focused on diluted Type II's, were published by APS Aviation in the report entitled, **"Aircraft Ground De/Anti-Icing Fluid Holdover Time Field Testing Program for the 1993/94 Winter"**. Testing during the 1994/95 winter included natural snow tests at Dorval, freezing drizzle, rain, fog and rain on cold-soaked surface tests conducted at the NRC Cold Chamber. The fluids tested for the 1994/95 winter season were primarily diluted Type I fluids and the new "next generation" Ultra Type II fluid.

The subsequent sections of this report describe the data which was collected and contain the charts illustrating the data. The final section provides the principal conclusions from the testing.

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2. DESCRIPTION OF DATA

2.1 Researchers

2.2 Fluids

2.3 Test Data Summary

2.4 Format of Electronic Data

2. DESCRIPTION OF DATA

A detailed description of the methodology and test procedures can be found in the previous related Transport Canada reports prepared by APS. This section provides a description of the data collected. Tables 2.1 through 2.4 show a summary of the number of tests conducted from 1990 to 1995 as a function of outside air temperature (OAT), fluid concentration and type of precipitation. Table 2.1 provides the data for Type I fluids, Table 2.2 for Type II, Table 2.3 for Type III, and Table 2.4 for Type IV fluids.

2.1 Researchers

The primary research organizations for the testing include APS, National Research Council (NRC), United Airlines (UA) and National Centre for Atmospheric Research (NCAR). APS has conducted the majority of the testing over all of the winters starting in 1990/91. Some of the old test data from the early years was collected by other research organizations such as Rutgers University, Japan Airlines, etc. This data is shown in Section 3 on selected charts. Table 2.5 provides a summary of the tests conducted by United Airlines, NRC, and NCAR.

Tests under frost conditions have been conducted by the University of Quebec at Chicoutimi (UQAC), however this data is not included as part of this report.

TABLE 2.1

Number of Type I Fluid Tests Conducted From 1990 to 1995

TEMP[1] °C	Various Weather Conditions																			
	Snow						Freezing Fog						Freezing Drizzle/Light Freezing Rain						Cold-Soaked	
	1990/91*	1991/92	1992/93	1993/94	1994/95		1990/91	1991/92	1992/93	1993/94	1994/95		1990/91**	1991/92	1992/93	1993/94	1994/95		1994/95	
					Standard	Diluted					Standard	Diluted					Standard	Diluted	Standard	Diluted
0 and above	8	-	10	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Below 0 to -7	48	-	110	-	55	48	-	-	21	-	-	-	1	-	99	-	10	4	10	10
Below -7	9	-	31	32	57	51	-	-	23	-	28	31	-	-	22	12	32	38	12	12
Total	**65**	**0**	**151**	**36**	**112**	**99**	**0**	**0**	**44**	**0**	**28**	**31**	**1**	**0**	**121**	**12**	**42**	**42**	**22**	**22**

[1] For cold-soaked tests this column designates skin temperature.

* 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.

** Natural Freezing Precipitation

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Type I, 16/01/96

TABLE 2.2

Number of Type II Fluid Tests Conducted From 1990 to 1995

TEMP[1] °C	Type II Fluid Concentration Neat-Fluid/Water (% by volume)	Various Weather Conditions															
		Snow					Freezing Fog					Freezing Drizzle/Light Freezing Rain					Cold-Soaked
		1990/91*	1991/92	1992/93	1993/94	1994/95	1990/91	1991/92	1992/93	1993/94	1994/95	1990/91**	1991/92	1992/93	1993/94	1994/95	1994/95
0 and Above	100/0	66	-	3	-	2	-	-	-	-	-	-	-	-	-	-	-
	75/25	-	-	-	8	2	-	-	-	-	-	-	-	-	-	-	-
	50/50	-	-	-	10	2	-	-	-	-	-	-	-	-	-	-	-
below 0 to -7	100/0	231	-	70	-	56	-	-	-	7	-	81	-	71	20	10	12
	75/25	-	-	-	13	12	-	-	-	22	-	-	-	16	8	6	12
	50/50	-	-	-	8	8	-	-	-	15	-	-	-	16	12	2	9
below -7 to -14	100/0	57	-	18	26	38	-	-	10	14	3	-	-	16	16	28	6
	75/25	-	-	-	50	20	-	-	-	10	3	-	-	-	36	28	1
	50/50	-	-	-	65	-	-	-	-	13	8	-	-	-	25	2	6
below -14 to -25	100/0	30	-	4	-	2	-	-	-	-	32	4	-	-	-	-	-
	75/25	-	-	-	34	-	-	-	-	-	5	-	-	-	-	-	-
	50/50	-	-	-	56	-	-	-	-	-	-	-	-	-	-	-	-
below -25	100/0	-	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-
	75/25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	50/50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total		384	0	95	270	142	0	0	10	81	61	85	0	119	117	76	46

[1] For cold-soaked tests this column designates skin temperature.

* 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.

** Natural Freezing Precipitation

cm1222\cons_hot\#TEST_R2.XLS
Type II, 16/01/96

TABLE 2.3

Number of Type III Fluid Tests Conducted From 1990 to 1994

APS Data

OAT °C	Various Weather Conditions											
	Snow				Freezing Fog				Freezing Drizzle/Light Freezing 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	-	-
below 0 to -7	43	85	24	-	-	-	-	10	15	17	52	-
below -7 to -14	24	81	4	-	-	-	4	2	-	-	10	12
below -14 to -25	11	-	-	-	-	-	-	-	2	-	-	-
Total	**90**	**183**	**30**	**0**	**0**	**0**	**4**	**12**	**17**	**20**	**62**	**12**

* Natural Freezing Precipitation

cm1222\cons_hot\HO_TYP3.XLS
16/01/96

TABLE 2.4

Number of Type IV Fluid Tests Conducted From 1993 to 1995

APS Data

TEMP[1] °C	Type IV Fluid Concentration Neat-Fluid/Water (% by volume)	Various Weather Conditions						
		Snow		Freezing Fog		Freezing Drizzle/Light Freezing Rain		Cold-Soaked
		1993/94*	1994/95	1993/94*	1994/95	1993/94*	1994/95	1994/95
0 and Above	100/0	-	1	-	-	-	-	-
	75/25	6	-	-	-	-	-	-
	50/50	8	-	-	-	-	-	-
below 0 to -7	100/0	2	17	-	-	1	12	9
	75/25	5	14	10	-	12	2	11
	50/50	4	16	9	-	6	-	10
below -7 to -14	100/0	6	12	4	-	7	14	5
	75/25	21	10	8	-	17	16	2
	50/50	38	2	14	4	16	2	4
below -14 to -25	100/0	-	-	-	13	-	-	-
	75/25	6	-	-	3	-	-	-
	50/50	45	-	-	-	-	-	-
below -25	100/0	-	-	-	10	-	-	-
	75/25	-	-	-	-	-	-	-
	50/50	-	-	-	-	-	-	-
Total		**141**	**72**	**45**	**30**	**59**	**46**	**41**

[1] For cold-soaked tests this column designates skin temperature.

* Tests performed in 1993/94 with ULTRA fluid. This was considered a Type II at the time.

cm1222\cons_hot\#TEST_R2.XLS
Type IV, 16/01/96

TABLE 2.5

TESTS CONDUCTED BY NCAR, UA, & NRC

NCAR tests (Natural Snow) - winter 1994/95

Temp. (°C)	II neat	IV neat	Total
0 and above	7	7	14
below 0 to -7	10	10	20
below -7 to -14	1	1	2
Total:	18	18	36

United Airlines tests (Natural Snow) - 1990/91 to 1992/93

Fluid Type:	I (40/60)	I (50/50)	II neat	Total
winter 1990/91[1]				
No. of tests:	0	21	51[2]	75
winter 1991/92				
No. of tests:	7	7	8	22
winter 1992/93				
No. of tests:	0	15	9	24
Total:	7	43	68	121

NRC tests (Natural Snow) - winter 1993/94

Fluid Type:	I std	II (50/50)	II (75/25)	II neat	III neat	Total
No. of tests:[3]	22	19	41	83	26	191

[1] These tests are also included in the totals of Tables 2.1 and 2.2.

[2] Three tests were not included due to freezing rain and hail.

[3] Type II fluids include 14 ULTRA Neat, 11 ULTRA 75/25 and 4 ULTRA 50/50.

2.2 Fluids

Figure 2.1 provides a list of the fluids which have been used over the winters. Type I, II, III and IV fluids were provided by more than ten manufacturers, the most recent being Union Carbide (UCAR), Octagon, SPCA, Hoechst, Kilfrost, and Arco. Fluids marked with an asterisk in Figure 2.1 are no longer commercially available. UCAR's Ultra fluid is listed as a Type II fluid in Figure 2.1, however Ultra tests were plotted on Type IV charts in Section 3.

This report contains charts for two varieties of Type I fluids, standard and diluted. The volumetric concentrations for the Type I fluids as a function of freeze point were provided by the fluid manufacturers and are as follows:

Standard Type I Fluid Concentration (% glycol to % water):

- Fluid B-222 was 50/50;
- Fluid B-213 was 57/43; and
- Fluid B-220 and Fluid B-221 were 63/37.

Diluted Type I Fluid:

Fluid concentrations for diluted Type I fluids were determined based upon the outside air temperature such that a 10°C buffer from the fluid freeze point (FP) was maintained.

Even though Type III fluids were tested, the data for this fluid type is not included as part of the report since the fluid is not commercially available. A summary of the most recent data for Type III fluids is available in Appendix G of Transport Canada's Report TP 11836E.

Figure 2.1

FLUID LIST

TYPE I

DOW 146AR
*OCTAGON ADF
*FG 1000
*U.C. ADF/2D
BASF AEREX
HOECHST 1732
KILFROST DF1D
*TEXACO WD20
U.C. XL54
ARCO +
OCTAGON (94/95)
HOECHST (94/95) (1898 MPI)

TYPE I (DILUTED)

ARCO +
OCTAGON (94/95)
HOECHST (94/95)
U.C. XL54

TYPE II

*U.C. 5.1
KILFROST ABC-3
SPCA AD104 (new formulation)
*DOW FG 2000
OCTAGON 40 Below
*HOECHST 1704
*TEXACO
*ULTRA (93/94) - Type IV
ULTRA (94/95) - Type IV

TYPE III

*U.C. 250-3
*UCAR Ultra (93/94)

TYPE II (50/50 DILUTED)

OCTAGON 40 Below
*U.C. 5.1
*ULTRA (93/94) - Type IV
KILFROST ABC-3
*HOECHST 1704
ULTRA (94/95) - Type IV

TYPE II (75/25 DILUTED)

OCTAGON 40 Below
*U.C. 5.1
*ULTRA (93/94) - Type IV
KILFROST ABC-3
*HOECHST 1704
ULTRA (94/95) - Type IV

* Fluid not commercially available

cm1222\cons_hot\fld_cod2.txt

2.3 Test Data Summary

In summary, the following was the general sequence of events with regard to the types of fluids tested and the organization which conducted the tests.

1990/91 Test Program: Outdoor tests were conducted on a world-wide basis using predominantly Neat Type II fluids, many of which are no longer commercially available. The majority of tests were conducted by APS at Dorval Airport in Montreal, Canada (Transport Canada's Report TP 11206E).

1991/92 Test Program: Outdoor tests using Type III fluids were conducted at Dorval by APS (Transport Canada's Report TP 11454E). United Airlines also conducted a few Type I and II tests at Denver and Chicago.

1992/93 Test Program: The 1992/93 test program included the following.

- Mostly Type I fluids were tested.
- Outdoor tests were conducted largely by APS at Dorval, as well as on a small scale by the NRC in Ottawa, however this data was not provided to APS.
- There were significant changes to the test procedure. One such change was to not wait five minutes after fluid application before the start of test.
- Freezing drizzle tests were completed indoors at the NRC Climatic Engineering Facility in Ottawa.
- Freezing fog test were conducted outdoors at NRC's Helicopter Icing Facility in Ottawa.
- Tests were carried out by United Airlines at Denver and Chicago using Type I and II fluids.
- Transport Canada's Report TP 11836E contains the results of the 1992/93 test program.

1993/94 Test Program: The 1993/94 test program included the following.

- Mostly diluted Type II fluids were tested.
- Outdoor tests were conducted largely by APS at Dorval, as well as on a small scale by the NRC in Ottawa.
- Freezing drizzle and light freezing rain tests were completed indoors at the NRC Climatic Engineering Facility in Ottawa.
- Freezing fog test were conducted outdoors at NRC's Helicopter Icing Facility in Ottawa.
- A summary report was submitted to Transport Canada.

1994/95 Test Program: Testing during the 1994/95 winter included natural snow tests at Dorval, freezing drizzle and light freezing rain, and fog tests at the NRC Cold Chamber, as well as rain on cold-soaked surface tests also conducted at the NRC Chamber. The fluids tested during the 1994/95 winter season were primarily diluted Type I fluids and the new "next generation" Ultra Type II fluid.

Figure 2.2 shows the number of tests conducted since 1990 as a function of precipitation type and the eight fluid types. The majority of tests were completed under natural snow conditions, with predominantly Standard Type I and Neat Type II fluids.

2.4 Format of Electronic Data

Table 2.6 shows the matrix of electronic files which are available for each precipitation condition and winter season. These files are ready for use with Microsoft's Excel Software. The file name for the test data collected by NCAR, NRC and United Airlines is also included in the matrix.

FIGURE 2.2

NUMBER OF TESTS FOR ALL CONDITIONS

APS Data from 1990/91 to 1994/95

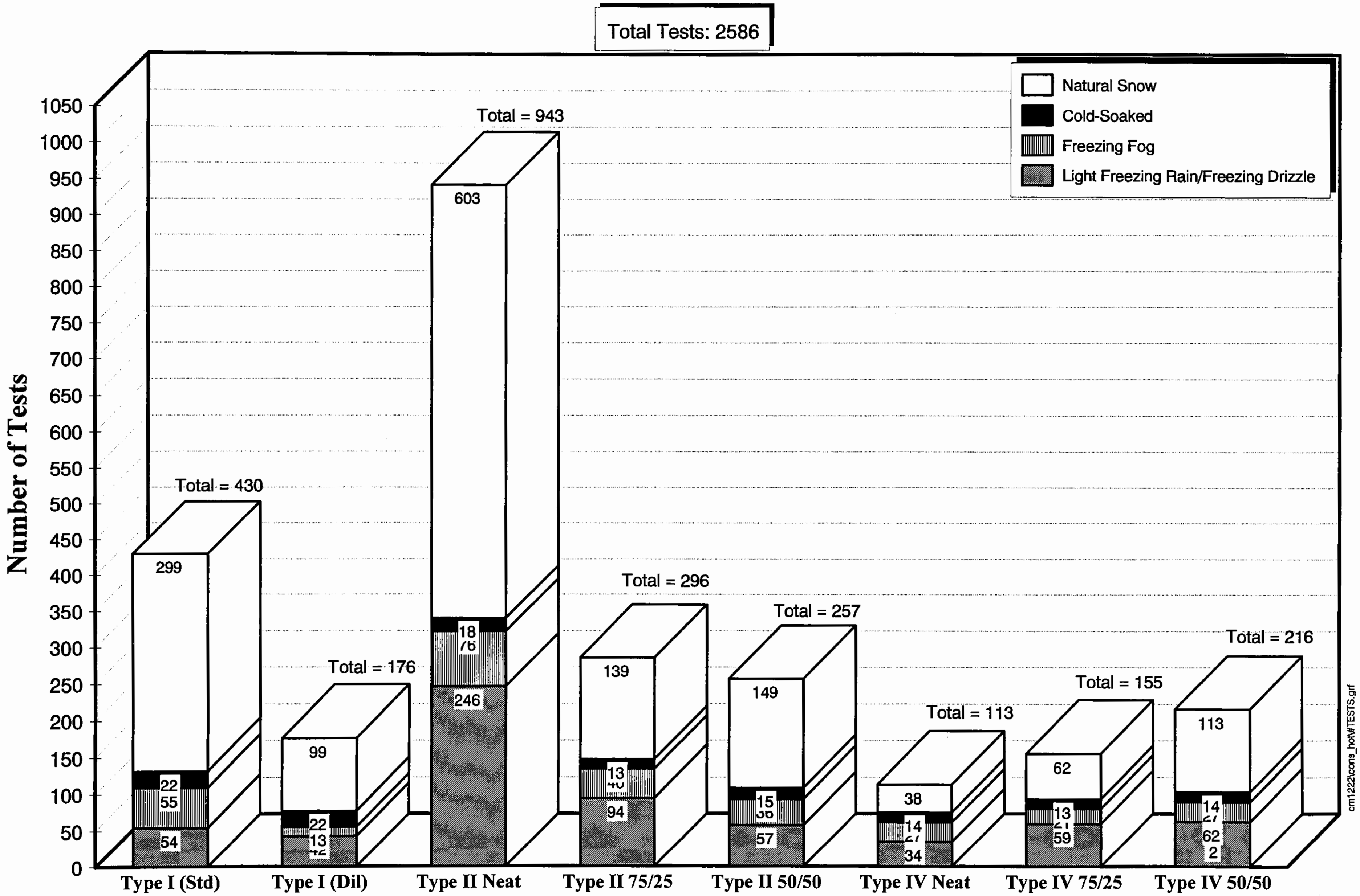


TABLE 2.6
MATRIX OF DATA LOGS

CONDITION	LOGS 90/91	LOGS 91/92	LOGS 92/93	LOGS 93/94	LOGS 94/95
Natural Snow (APS)	90&91_NS.XLS	91&92_NS.XLS	92&93_NS.XLS	93&94_NS.XLS	94&95_NS.XLS
Natural Snow (NCAR)	N/A	N/A	N/A	N/A	NCAR9495.XLS
Natural Snow (United Airlines)	UANS9093.XLS	UANS9093.XLS	UANS9093.XLS	N/A	N/A
Natural Snow (NRC)	N/A	N/A	(1)	NRC_NS93.XLS	N/A
Simulated Light Freezing Rain/Freezing Drizzle	90&91DRZ.XLS *	N/A	(2)	93&94DRZ.XLS	94&95DRZ.XLS
Simulated Freezing Fog	N/A	N/A	92&93FOG.XLS	93&94FOG.XLS	94&95FOG.XLS
Simulated Cold-Soaked	N/A	N/A	N/A	(3)	94&95_CS.XLS
Frost	(4)	(4)	(4)	(4)	(4)

(1) Tests conducted by NRC but not provided to APS

(2) Tests conducted but not used due to invalid precipitation rates and droplet sizes

(3) Preliminary tests conducted outdoors with very large boxes

(4) Tests conducted by UQAC and not included as part of this report

N/A = Not Applicable

* Natural freezing precipitation

Note: All files can be found in CM1222\CONS_HOT\LOGS

CM1222\CONS_HOT\MATRIX.XLS
Logs, 15/01/96

3. ANALYSIS

3.1 Evolution and Development of SAE/ISO Holdover Time Range

3.2 Natural Snow

3.3 Freezing Drizzle and Light Freezing Rain

3.4 Freezing Fog

3.5 Rain on Cold-Soaked Surface

3. ANALYSIS

The main objective of the fluid holdover time test program was to conduct flat plate tests in order to acquire data which could be evaluated against the holdover times. If the data fell within or above the holdover time range, than the holdover times were considered to be substantiated. This evaluation process was conducted by the members of the SAE G-12 HOT Sub-Committee during working group sessions.

The main purpose of this report was to collate all the data from previous APS winter tests and document this information in graphical form. These graphs also contain the data from tests conducted by NCAR, NRC and United Airlines.

This report contains only a summary of the results from testing conducted since 1990. Complete detailed descriptions can be found in the reports described in Sections 1 and 2. The intent of this document is to provide the data in a consolidated format for reference purposes, and to facilitate entry of new data from future testing.

Table 3.1 shows that 109 graphs have been produced. These graphs provide the test results for each precipitation condition as a function of rate of precipitation, fluid type, windspeed, and temperature. For the cold-soaked tests, two other variables were found to affect the failure time, these were skin temperature and box size. Charts were produced for each fluid type (I, II, and IV) including the diluted variations of these types: Type I standard; Type I diluted; Type II 100%; Type II 75/25; Type II 50/50; Type IV 100%; Type IV 75/25; Type IV 50/50. The charts are included at the end of this section.

The remainder of this section provides a summary of the data by precipitation condition: natural snow; freezing drizzle and light freezing rain; freezing fog; and rain on cold-soaked surface.

TABLE 3.1

MATRIX OF CHARTS SHOWING VARIABLES PLOTTED

(Figure number's given below)

		CHARTS			
CONDITION	**FLUID TYPE**	**t vs R vs Researcher**	**t vs R vs FM**	**t vs T vs R**	**t vs R vs WS**
NS	I STD	1	2	4	6
NS[2]	I STD	-	3	5	7
NS	I DIL	-	8	9	10
NS[3]	II 100/0	-	11*	12	-
NS	II 100/0	13	14	15	16
NS[2]	II 100/0	-	17	18	19
NS	II 75/25	20	21	22	23
NS	II 50/50	24	25	26	27
NS	IV 100/0	28[1,4]	29	30	31
NS	IV 75/25	32[4]	33	34	35
NS	IV 50/50	36[4]	37	38	39
LFZR/FZD	I STD	-	40	41	-
LFZR/FZD	I DIL	-	42	43	-
LFZR/FZD	II 100/0	-	44	45	-
LFZR/FZD	II 75/25	-	46	47	-
LFZR/FZD	II 50/50	-	48	49	-
LFZR/FZD	IV 100/0	-	50	51	-
LFZR/FZD	IV 75/25	-	52	53	-
LFZR/FZD	IV 50/50	-	54	55	-
CONDITION	**FLUID TYPE**	**t vs R vs FM**	**t vs R vs FM**	**t vs T vs R**	**t vs R vs WS**
FZF	I STD	56	57	58	59
FZF	I DIL	60	61	62	63
FZF	II 100/0	64	65	66	67
FZF	II 75/25	68	69	70	71
FZF	II 50/50	-	72	73	74
FZF	IV 100/0	75	76	77	78
FZF	IV 75/25	79	80	81	82
FZF	IV 50/50	-	83	84	85
CONDITION	**FLUID TYPE**	**t vs R vs FT**	**t vs R vs FM**	**t vs ST vs R**	**t vs R vs BS**
CS	I STD	-	86	87	88
CS	I DIL	-	89	90	91
CS	II 100/0	-	92	93	94
CS	II 75/25	-	95	96	97
CS	II 50/50	-	98	99	100
CS	IV 100/0	-	101	102	103
CS	IV 75/25	-	104	105	106
CS	IV 50/50	-	107	108	109
CONDITION	**FLUID TYPE**		**t vs R vs ALL**	**t vs R vs T**	**t vs R vs WS**
ALL	I STD	-	110	111	112
ALL	I DIL	-	113	114	115
ALL	II 100/0	-	116	117	118
ALL	II 75/25	-	119	120	121
ALL	II 50/50	-	122	123	124

t : TIME   FM : FLUID MANUFACTURER   WS : WIND SPEED   ST : SKIN TEMPERATURE

R : RATE   T : TEMPERATURE   BS : BOX SIZE

* t vs R vs T   1 Includes NCAR 2 APS data only

3 All data 90/91 to 94/95   4 Includes ULTRA Data from 93/94

see shaded box: Example: Figure 3.25 (designated by 25) is a graph of the failure time of the Type II 50/50 fluid tests plotted as a function of precipitation rate and fluid manufacturer under natural snow condition

3.1 Evolution and Development of SAE/ISO Holdover Time Range

The 1990 Type II AEA/ISO table (Table 1.1) shows that the holdover time for temperatures below 0°C under "steady snow" conditions when using a Neat fluid is 45 minutes. A survey of precipitation rate patterns in Europe by the Atmospheric Environment Service (AES) has indicated that the term "steady snow", referred to snow falling at low precipitation rates typically less than 10 $g/dm^2/hr$ (equivalent to 1 cm/hr[1] of snow). It is commonly accepted by members of the SAE G-12 HOT Sub-Committee that low precipitation rates less than 10 $g/dm^2/hr$ and light snow can be reasonably interchanged. This is consistent with the 1990/91 APS test data which included European data and showed that 45 minutes was applicable for the low precipitation rates experienced in Europe. Figure 3.11 includes tests conducted in Europe by Swissair, Lufthansa and British Airways during the 1990/91 winter. Of the 58 European test points (Type I and II), 7 test points were reported with rates of precipitation ranging from 5 to 10 $g/dm^2/hr$, while the remaining 51 test points were reported with rates less than 5 $g/dm^2/hr$.

The APS test data showed that a reduction of the holdover times was necessary to encompass all the data including that at higher rates of precipitation which are typically experienced in North America. The lower value was determined from this test data in association with the SAE G-12 HOT Sub-Committee. A value of 40% of the AEA/ISO Holdover Time Table was considered representative for the lower limit of the recommended ranges. This 40% factor was applied to all the values (except frost) of the AEA/ISO Holdover Time Tables. This led to the adoption and acceptance of these tables by the SAE for the 1991/92 winter.

1 This assumes a 10 to 1 water to snow equivalent.

3.2 Natural Snow

The following comments are in reference to the natural snow charts.

- Natural snow tests were conducted by many organizations including United Airlines (UA) at Denver and Chicago, NCAR at Denver, NRC at Ottawa, and APS at Dorval Airport (Montreal) and other Canadian sites. Some tests were also conducted by airlines in Europe and the Far East. These tests, conducted in 1990/91, are included in this report as part of APS' data.
- The test data for natural snow should be analyzed with the intention of developing new holdover times to provide more useful data for the pilot (eg., light, moderate, and heavy snow based on either visibility or wet versus dry snow).

3.2.1. Natural Snow - Standard Type I Fluid

- Figure 3.1 shows the effect of rate of precipitation on failure time as a function of the researcher (APS, NRC or UA). The data in the chart includes all tests carried out from 1992/93 and all of United Airline's tests. Figure 3.2 provides a plot of the same points as a function of fluid manufacturer, while Figure 3.3 is a sub-set of Figure 3.2 and contains only the APS data.
- Figures 3.4 and 3.5 also show a plot of the same data with temperature on the horizontal axis and the SAE holdover time range indicated. The SAE Committee considered these SAE/ISO holdover time ranges substantiated. The few points below the lower limit were found to occur during extreme weather conditions or with fluids which are no longer commercially available (See Appendix A).

- Figure 3.6 and 3.7 show the same data plotted as a function of windspeed.
- This Type I data confirms the necessary reduction of the AEA/ISO pre-1991 holdover time 6 minutes (40% of 15 minutes).

3.2.2 Natural Snow - Diluted Type I Fluid

- Diluted Type I tests were conducted by APS at Dorval in 1994/95.
- Figures 3.8, 3.9, and 3.10 show the diluted Type I data plotted as a function of rate of precipitation, temperature and windspeed.
- The data supports the conclusion that the Type I holdover time range of 6 to 15 minutes is substantiated (Figure 3.9).

3.2.3 Natural Snow - Type II Fluid (100%)

- Figures 3.11 through 3.19 contain the data for the Neat Type II fluid tests. The first two charts show all the data from all the organizations who participated in the tests since 1990. Figures 3.13 through 3.16 show the same data excluding the 1990/91 data, but including United Airline's data, while Figures 3.17, 3.18 and 3.19 show only APS' data from 1992/93 to 1994/95.
- Based on this data, the SAE/ISO holdover time range was considered substantiated by the SAE G-12 HOT Committee. At a meeting in Toronto in September 1994, the points below the holdover time ranges were examined in more detail. Those points were found to occur under extreme weather conditions or with fluids which are no longer commercially available. (See Appendix A).

3.2.4 Natural Snow - Type II Fluid (75/25 and 50/50 dilutions)

- Diluted Type II tests were conducted by APS and NRC.
- The results of these tests are provided on Figures 3.20 through 3.27 as a function of the researcher, fluid manufacturer, rate of precipitation and windspeed.
- Figures 3.22 and 3.26 show that the SAE/ISO holdover time ranges have been substantiated for the Type II 75/25 and Type II 50/50 fluids.

3.2.5 Natural Snow - Type IV Fluid

- Type IV tests were carried out by APS at Dorval and NCAR at Denver.
- Figure 3.28 (Neat) shows results from NCAR and APS tests and includes tests with the older 1993/94 Ultra fluid. Figures 3.32 (75/25) and 3.36 (50/50) also include 1993/94 Ultra test results. The remaining charts (Figures 3.29 through 3.39) provide results from 1994/95 tests conducted by APS.
- Figure 3.30 shows the new proposed Neat Type II (Type IV) SAE holdover times when using Ultra.

3.3 Freezing Drizzle and Light Freezing Rain

The SAE G-12 Sub-Committee decided that the current freezing rain column in the holdover time tables should be changed and expanded to two columns, freezing drizzle and light freezing rain, and the new holdover times should reflect the testing conducted by APS.

The following comments pertain to the freezing drizzle and light freezing rain charts.

- All the freezing drizzle and light freezing rain tests were conducted by APS at the NRC Climatic Engineering Facility in Ottawa. The data from 59 Ultra tests (8 Neat, 29 75/25 and 22 50/50) completed in 1993/94 has not been included because Ultra fluid used in that winter is no longer commercially available.
- Eight graphs (one for each fluid type) describing the failure time versus the rate of precipitation as a function of fluid manufacturer were produced (T vs R vs FM).
- Eight graphs (one for each fluid type) describing the failure time versus the temperature as a function of rate of precipitation were produced.
- Each chart provides an indication of whether the data point represents freezing drizzle (< 13 $g/dm^2/hr$) or light freezing rain (13 $g/dm^2/hr$ to 25 $g/dm^2/hr$).
- The freezing drizzle and light freezing rain tests (represented in the 16 charts) were conducted in 1993/94 and 1994/95. Tests were also conducted indoors at the NRC Climatic Engineering Facility in 1992/93, however these were not considered appropriate for a number of reasons, and this data was not included in the charts. Inappropriate droplet size, high rates of precipitation, and the inconsistency in the precipitation rate were factors which contributed to the invalidity of this data, and this has led to improvements at the NRC Climatic Engineering Facility.
- Discussions within the SAE G-12 Holdover Time Sub-Committee provided insight into the appropriate droplet size ranges and precipitation rates required for simulation of freezing drizzle and light freezing rain.
- The methodology used by the SAE Sub-Committee in determining the new range of HOT's in each cell of the tables was as follows:
  - **Lower number:** Selecting either the lowest data point (failure time) or a more conservative time obtained by inspection. Consideration

was given to the values consistent with the adjacent cells of the holdover time table.

- **<u>Upper number:</u>** Selecting the time when most or all of the data points fall below this number. (Based on the above, it is important that the operators and training personnel express ***caution*** to the pilots in the utilization of the upper number.)

- The new holdover time ranges were determined based on the NRC Climatic Engineering Facility flat plate tests for all fluid types. These new holdover time ranges are applicable for temperatures down to -10°C for all fluid types except Type II 50/50. For Type II 50/50, the new holdover time range is applicable down to -7°C. For Ultra, the Neat Type II SAE holdover times were increased by 50%.

3.4 Freezing Fog

The following comments pertain to the freezing fog graphs.

- All the freezing fog tests were conducted by APS at NRC facilities. The data from the Ultra tests carried out in 1993/94 was included with the Type II charts.
- Six graphs (one for each fluid type excluding Type II and IV 50/50) have been produced. Each graph describes the failure time versus the rate of precipitation as a function of fluid manufacturer (Figures 3.56, 3.60, 3.64, 3.68, 3.75 and 3.79). These charts show all the data points collected including the 1994/95 test points with rates of precipitation above 8 g/dm^2/hr. These tests were conducted with four sets of nozzles while experimenting with the Climatic Engineering Facility set-up. The conditions produced by this set-up are not representative of actual operating conditions, therefore these test points were excluded from the resulting charts. The charts with these points removed are provided as

the second series of charts.

- Eight charts (one for each fluid type) describing the failure time versus the temperature as a function of rate of precipitation were produced.
- Eight additional charts (one for each fluid type) describing the failure time versus the rate of precipitation as a function of windspeed were produced.
- The freezing fog tests were tests conducted outdoors at NRC's Helicopter Icing Facility in 1992/93 and 1993/94. Additional tests were conducted indoors at NRC's Climatic Engineering Facility in 1994/95. Due to an incident at the outdoor facility, the test rig is no longer functional. When comparing the results from the indoor and outdoor facilities, it was found that the two facilities produced similar results. The first series of charts (T vs R vs FM) show whether the tests were done indoors or outdoors.
- Based on the APS test data, the Type I and II SAE/ISO holdover time ranges for freezing fog have been substantiated in all but one case. For Type II 50/50 fluids, the holdover time lower limit was reduced to 15 minutes.
- For Type I and II fluids, the holdover ranges above 0°C can not be substantiated because freezing fog can not be simulated at these temperatures. Since this condition would not likely occur operationally, the lower holdover time ranges below 0°C should be adopted.
- The SAE Committee indicated that freezing fog could occur at temperatures below -25°C. The limited tests conducted at these low temperatures indicate that the holdover time ranges are adequate for Type I and II fluids.
- Figure 3.76 shows that the Neat Type II fluid holdover time range can be increased by 50% when using Ultra (Type IV).

3.5 Rain on Cold-Soaked Surface

The following comments apply to the rain on cold-soaked surface tests.

- All the cold-soaked surface tests with rain were conducted by APS at the NRC Climatic Engineering Facility during 1994/95. Some exploratory tests were conducted outdoors at Dorval during earlier winters.
- Two sealed boxes filled with fluid, 15 cm and 7.5 cm deep, were used for the simulation of rain on a cold-soaked wing. These boxes were used in the scaling of the test results from the boxes to a full-scale wing.
- A total of 24 graphs were produced for these tests. Eight charts (one for each fluid type) describing the failure time versus the rate of precipitation as a function of fluid manufacturer, eight charts depicting the time versus the skin temperature as a function of rate of precipitation, with the final eight charts providing the failure time versus rate of precipitation as a function of box size.
- Based upon the heat transfer analysis (see associated Transport Canada Report TP 12678E), a scale factor of 2.5 was applied to the test results of the small box to get the projected full-scale wing results.
- The precipitation was produced with two types of nozzles which provided droplet sizes representing drizzle and light rain. The associated rate of precipitation for drizzle was < 13 g/dm^2/hr, while the rate of precipitation for light rain was between 13 and 25 g/dm^2/hr. The rates of precipitation were measured using cake pans. Testing under moderate or heavy rain was not carried out.
- The Type IV charts show that a few tests were completed with fluid from only one manufacturer.

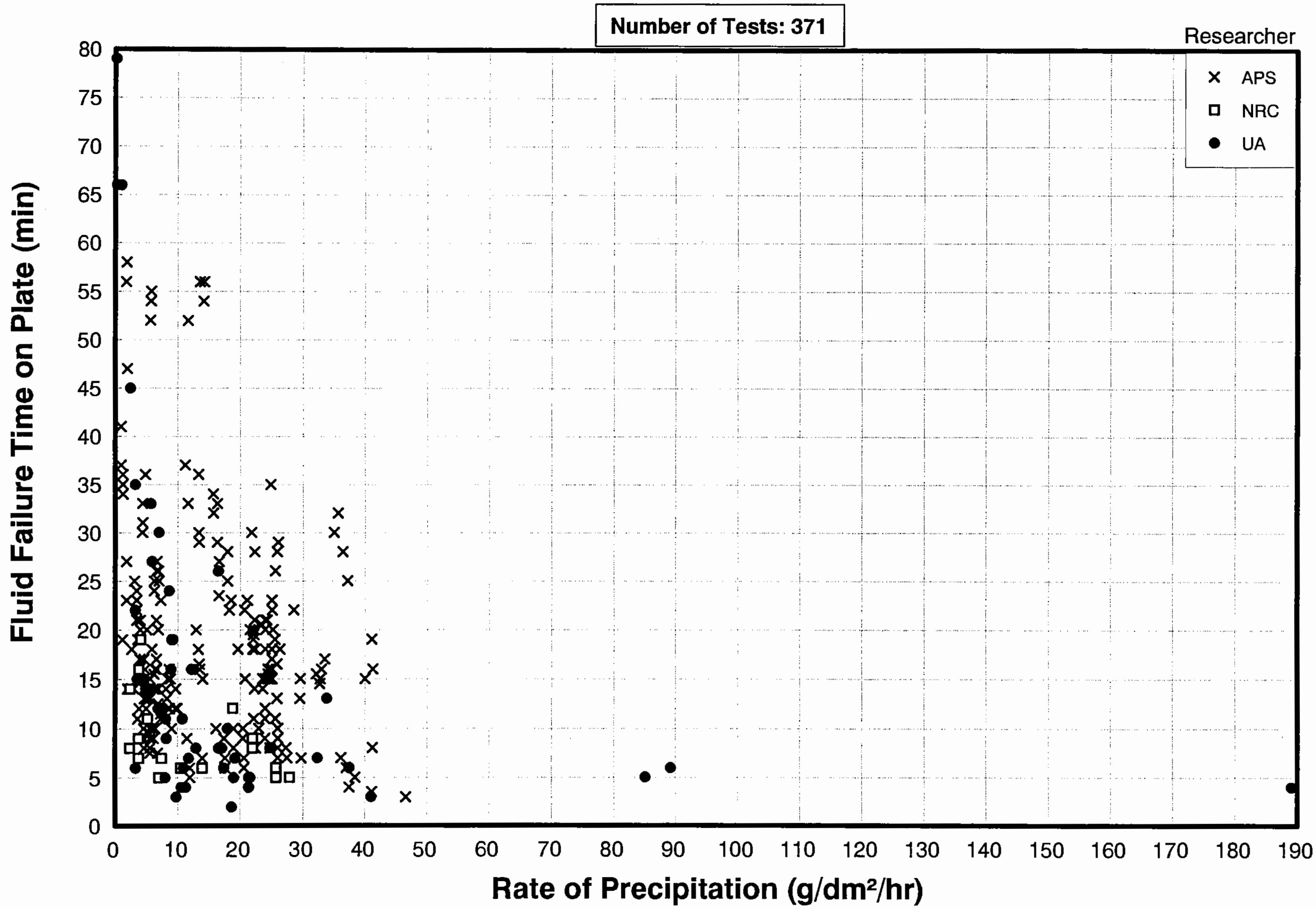
FIGURE 3.1

EFFECT OF RESEARCHER AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

NATURAL SNOW CONDITIONS

All data from APS, NRC, & UA except 90/91 APS



cm1222\cons_hot\nat_snow\NS1S_1.GRF

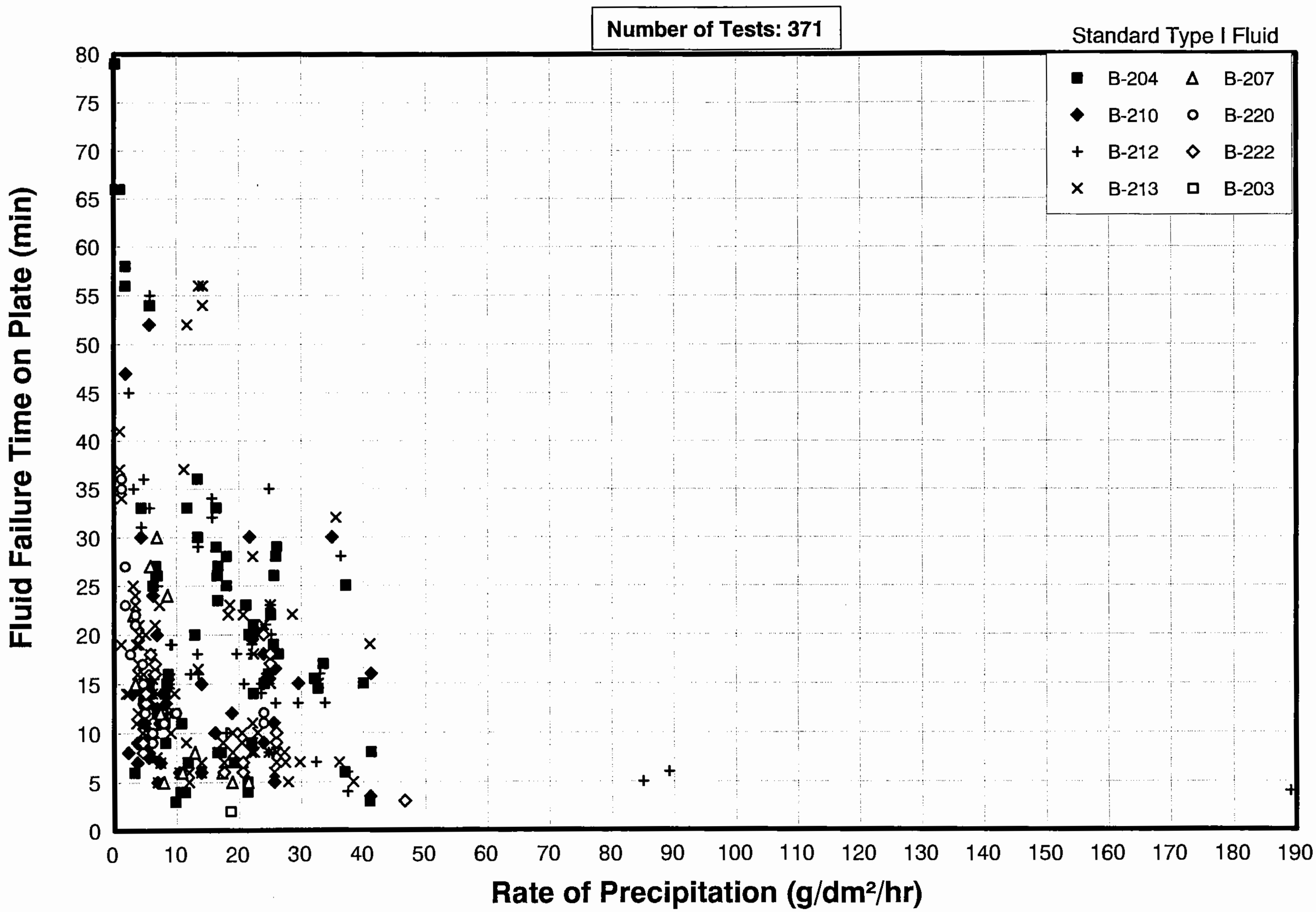
FIGURE 3.2

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

NATURAL SNOW CONDITIONS

All data from APS, NRC, & UA except 90/91 APS



cm1222\cons_hot\nat_snow\NS1S_2.GRF

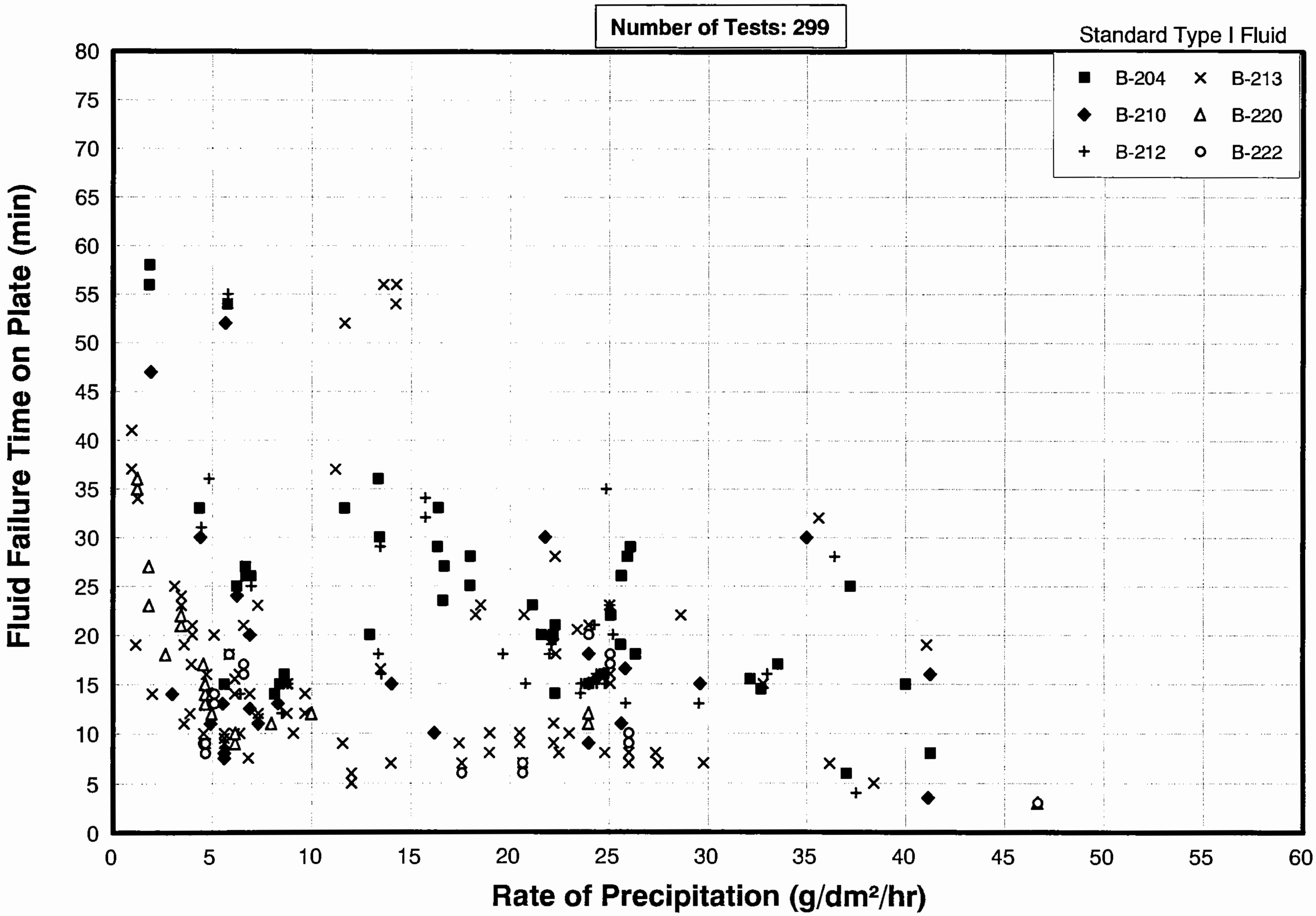
FIGURE 3.3

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

NATURAL SNOW CONDITIONS

APS Data - 92/93 to 94/95



m1222\cons_hot\nat_snow\NS1S_3.GRF

FIGURE 3.4

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

STANDARD TYPE I

NATURAL SNOW CONDITIONS

All data from APS, NRC, & UA except 90/91 APS

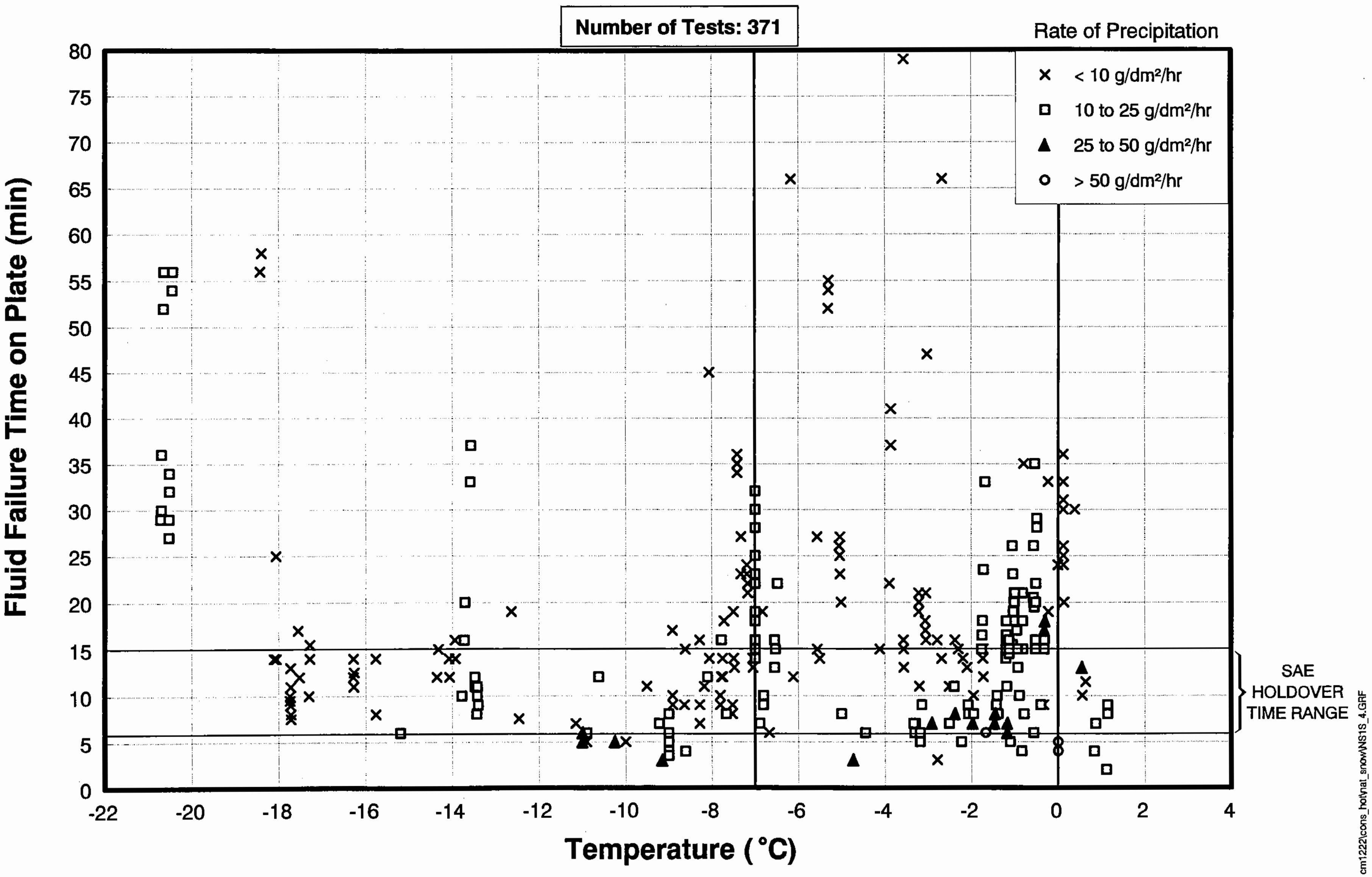


FIGURE 3.5

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

STANDARD TYPE I

NATURAL SNOW CONDITIONS

APS Data - 92/93 to 94/95

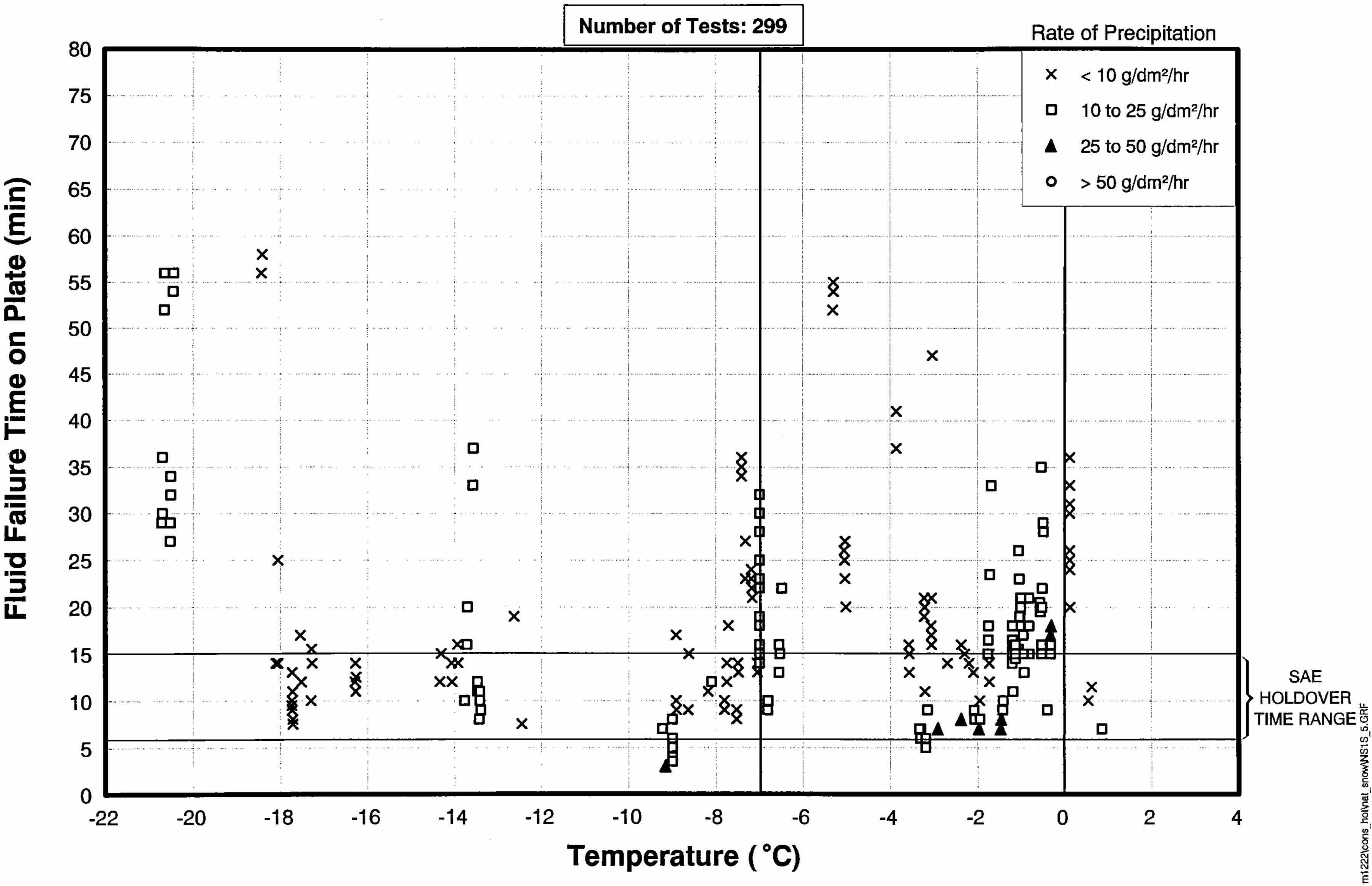


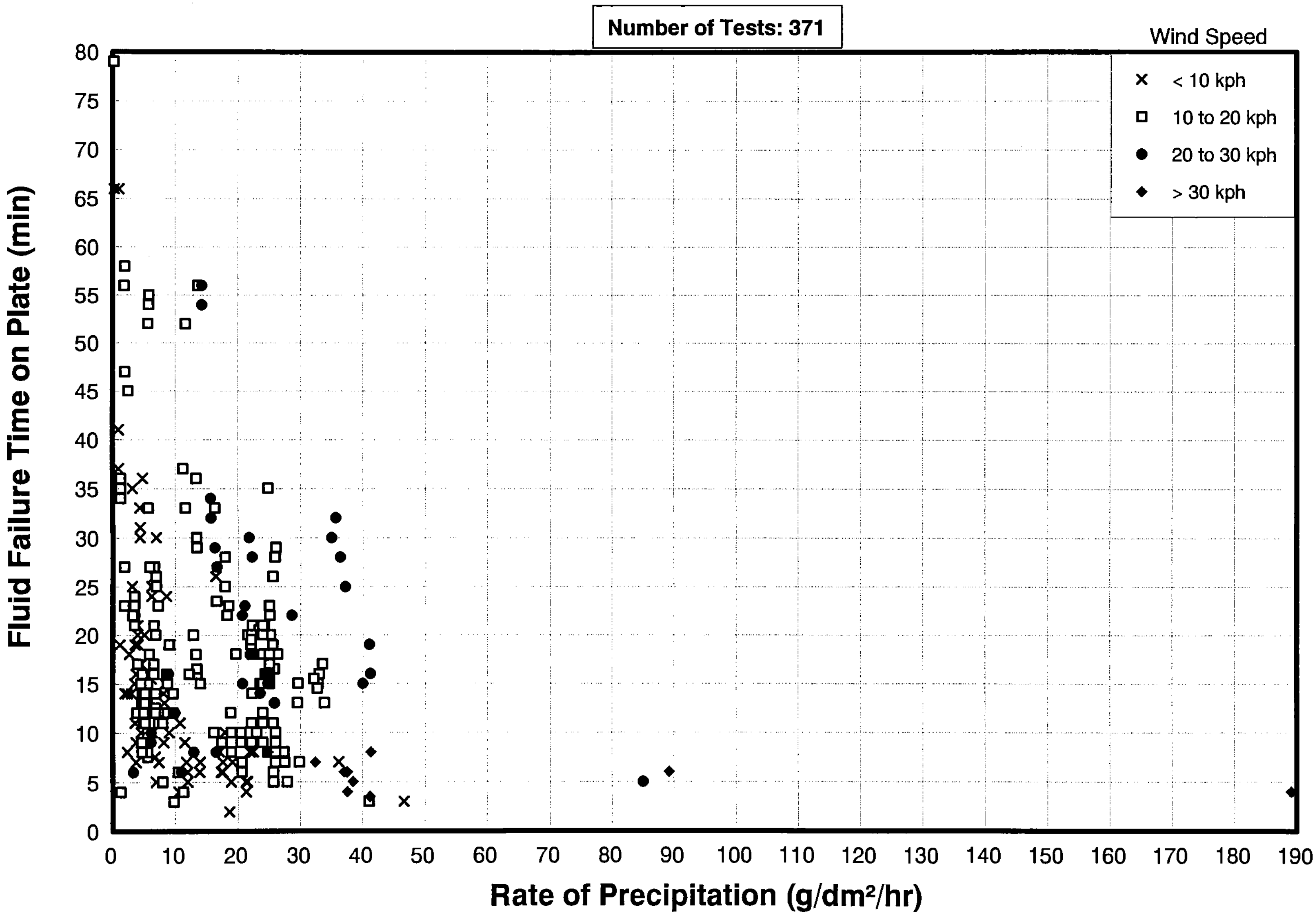
FIGURE 3.6

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

NATURAL SNOW CONDITIONS

All data from APS, NRC, & UA except 90/91 APS



cm1222\cons_hot\nat_snow\NS1S_6.GRF

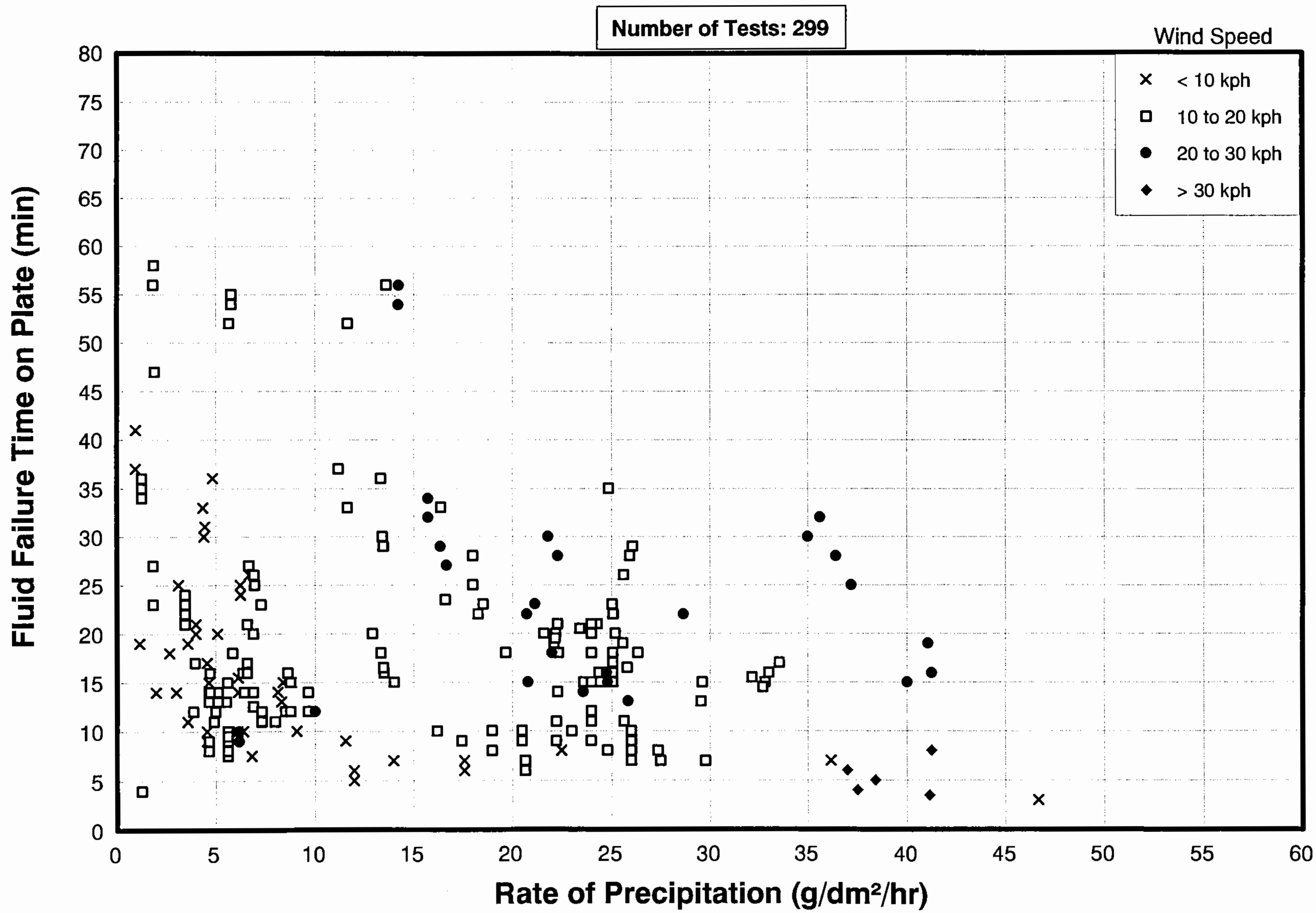
FIGURE 3.7

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

NATURAL SNOW CONDITIONS

APS Data - 92/93 to 94/95



cm1222\cons_hot\nat_snow\NS1S_7.GRF

FIGURE 3.8
EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME
DILUTED TYPE I
NATURAL SNOW CONDITIONS
APS Data

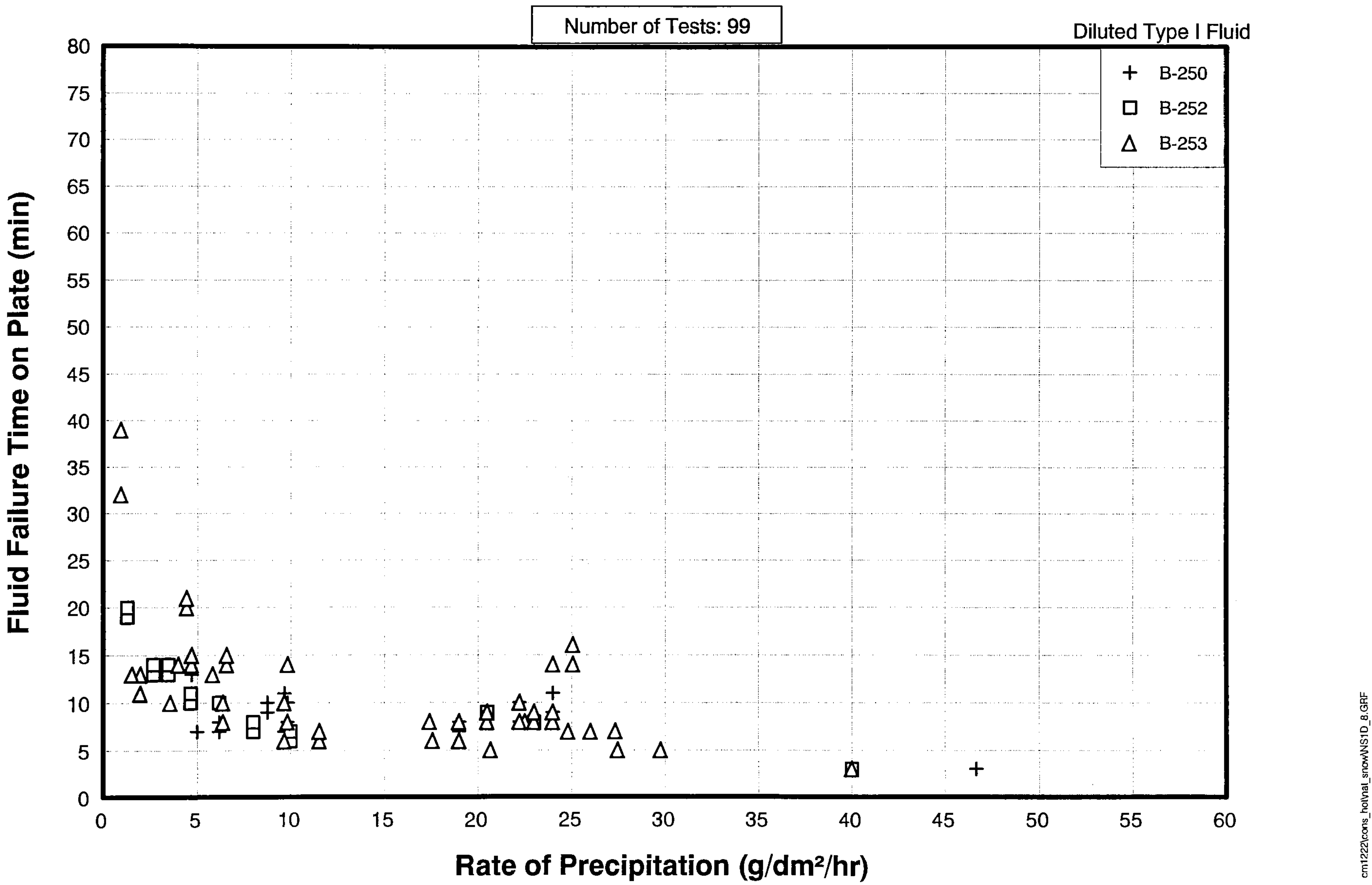


FIGURE 3.9

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

DILUTED TYPE I

NATURAL SNOW CONDITIONS

APS Data

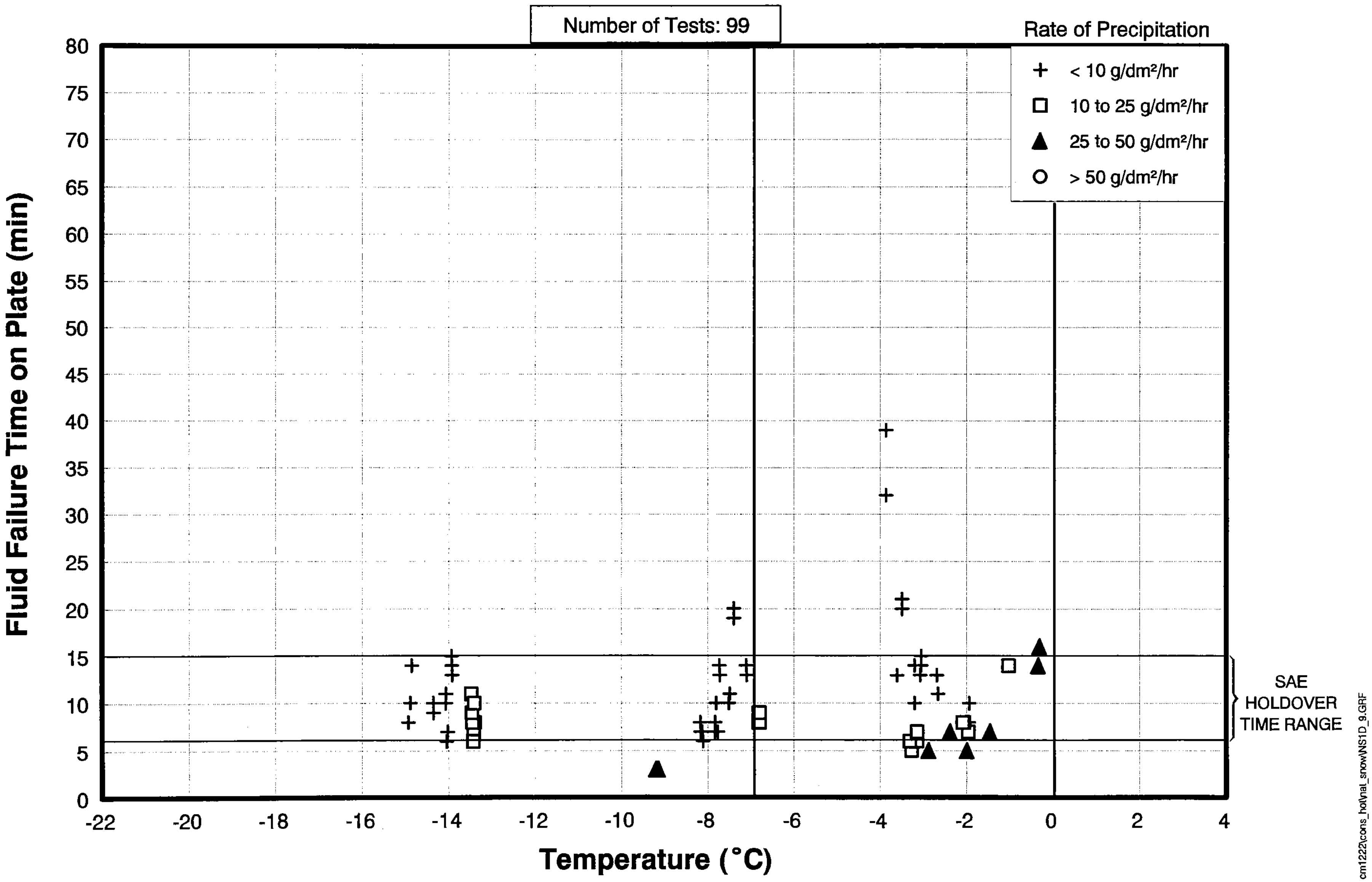


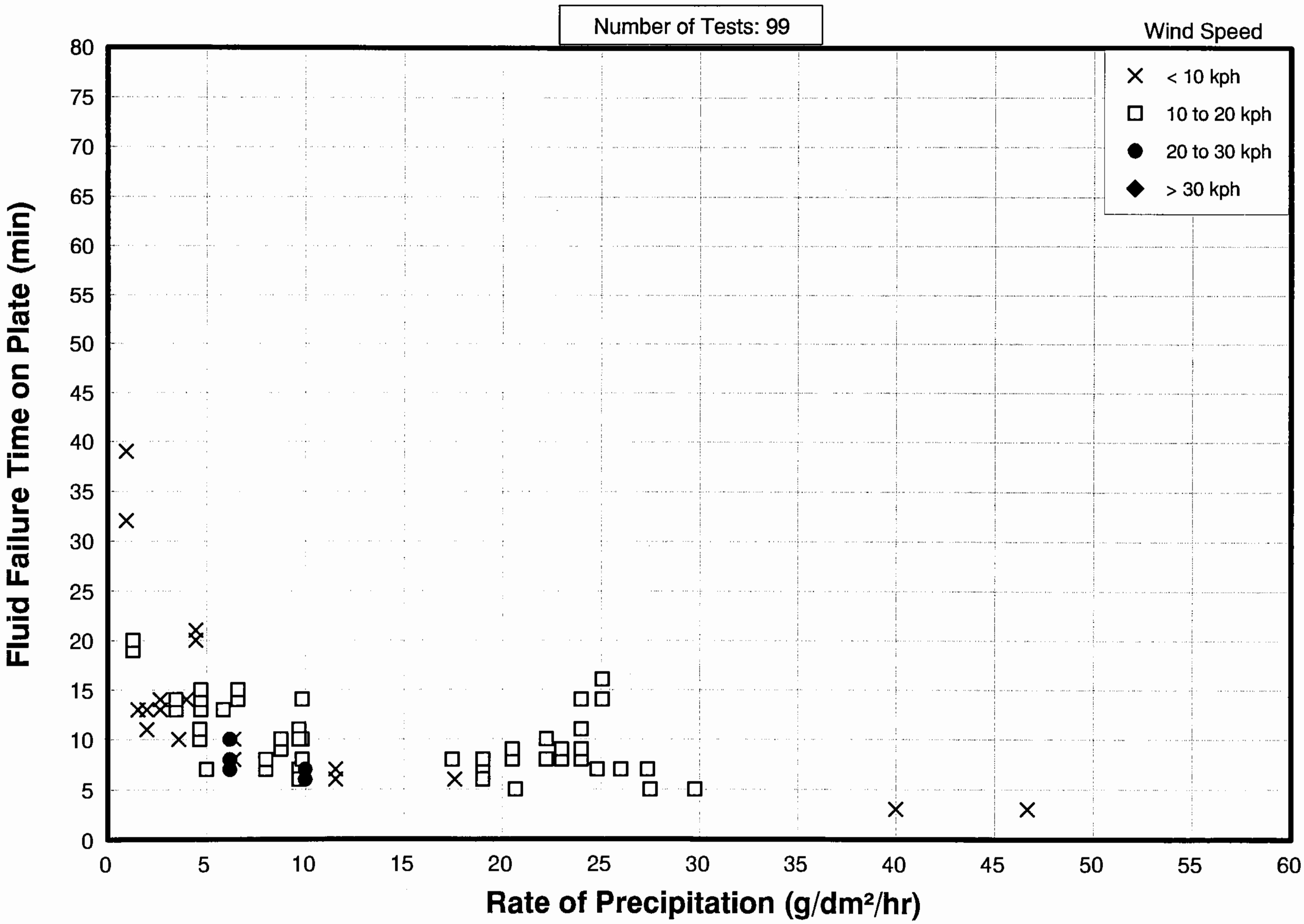
FIGURE 3.10

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

DILUTED TYPE I

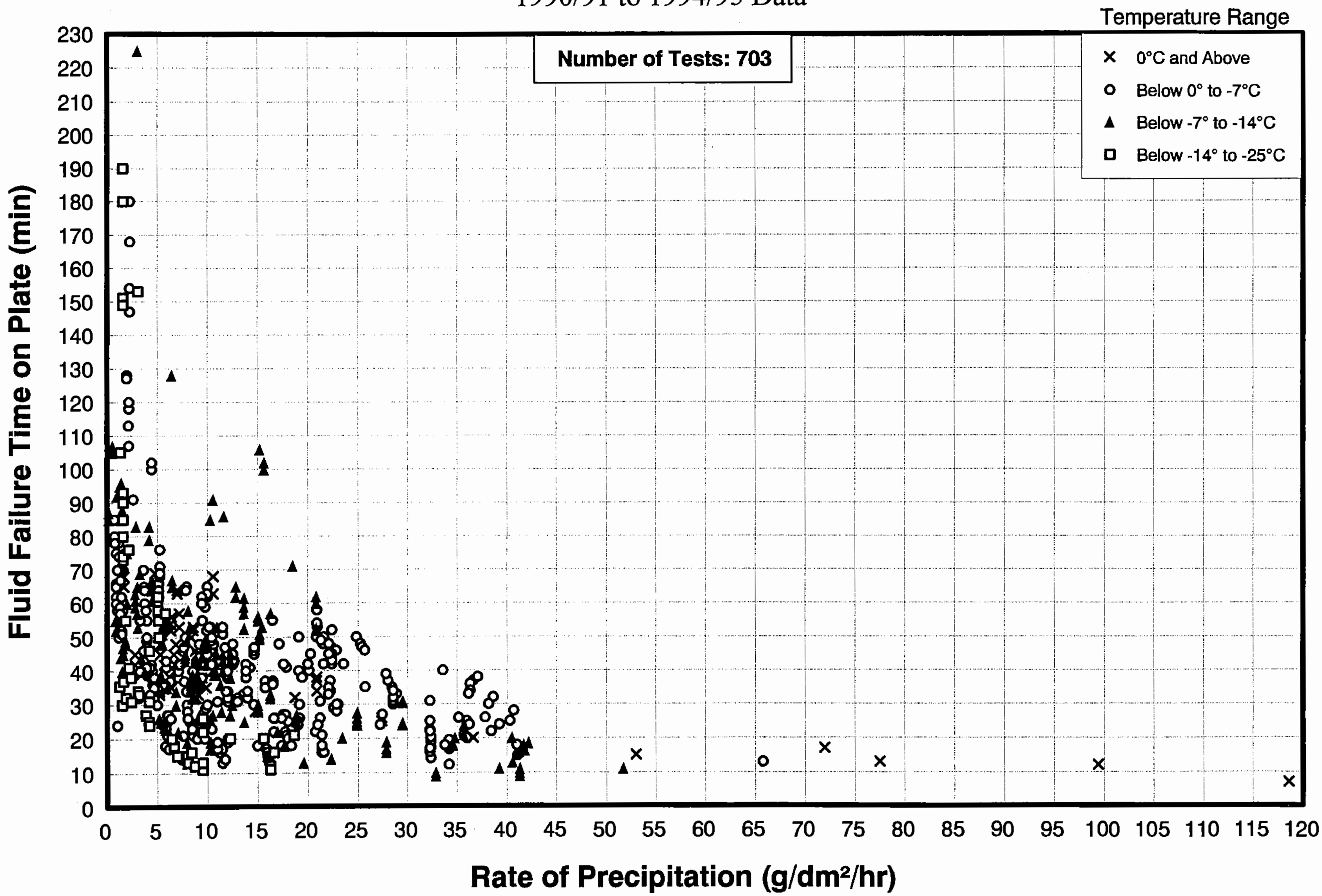
NATURAL SNOW CONDITIONS

APS Data



cm1222\cons_hot\nat_snow\NS1D_10.GRF

FIGURE 3.11
EFFECT OF TEMPERATURE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE II NEAT
NATURAL SNOW CONDITIONS
APS, NRC and United Airlines
1990/91 to 1994/95 Data



cm1222cons_hot\nat_snow\NS21_11.GRF

FIGURE 3.12

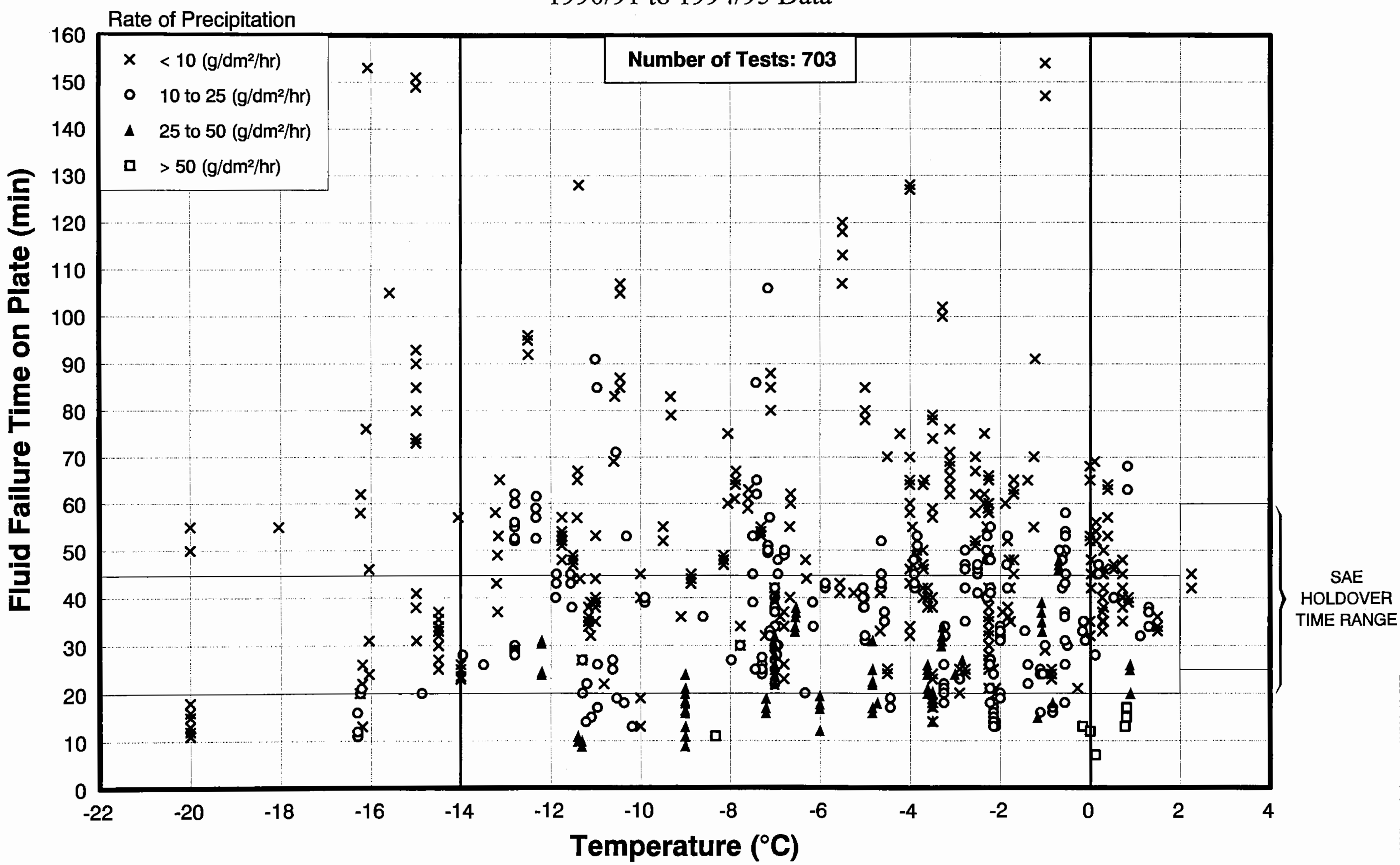
EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II NEAT

NATURAL SNOW CONDITIONS

APS, NRC and United Airlines

1990/91 to 1994/95 Data



cm1222\cons_hot\nat_snow\NS21_12.GRF

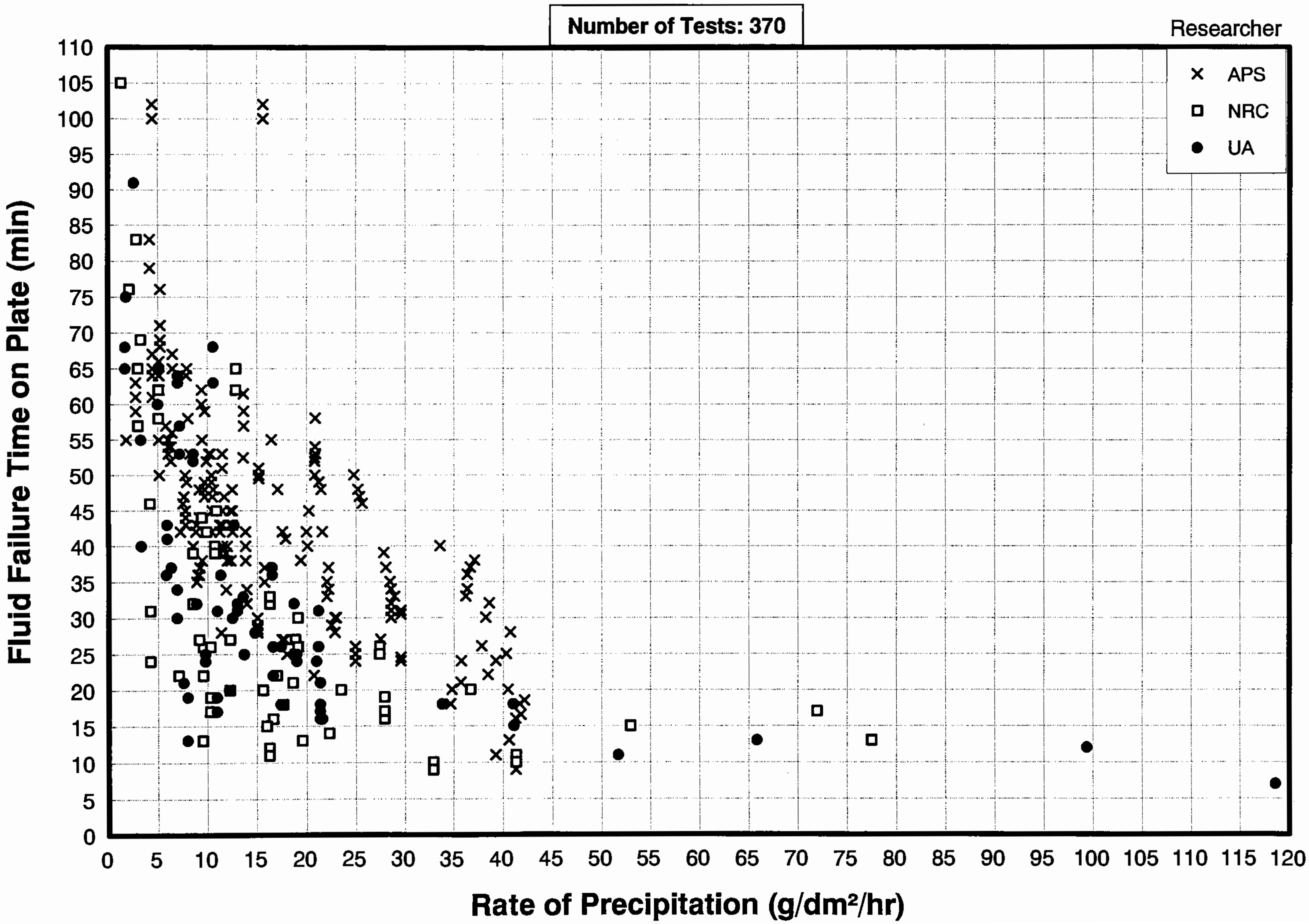
FIGURE 3.13

EFFECT OF RESEARCHER AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

NATURAL SNOW CONDITIONS

All data from APS, NRC, & UA except 90/91 APS



cm1222\cons_hol\nat_snow\NS21_13.grf

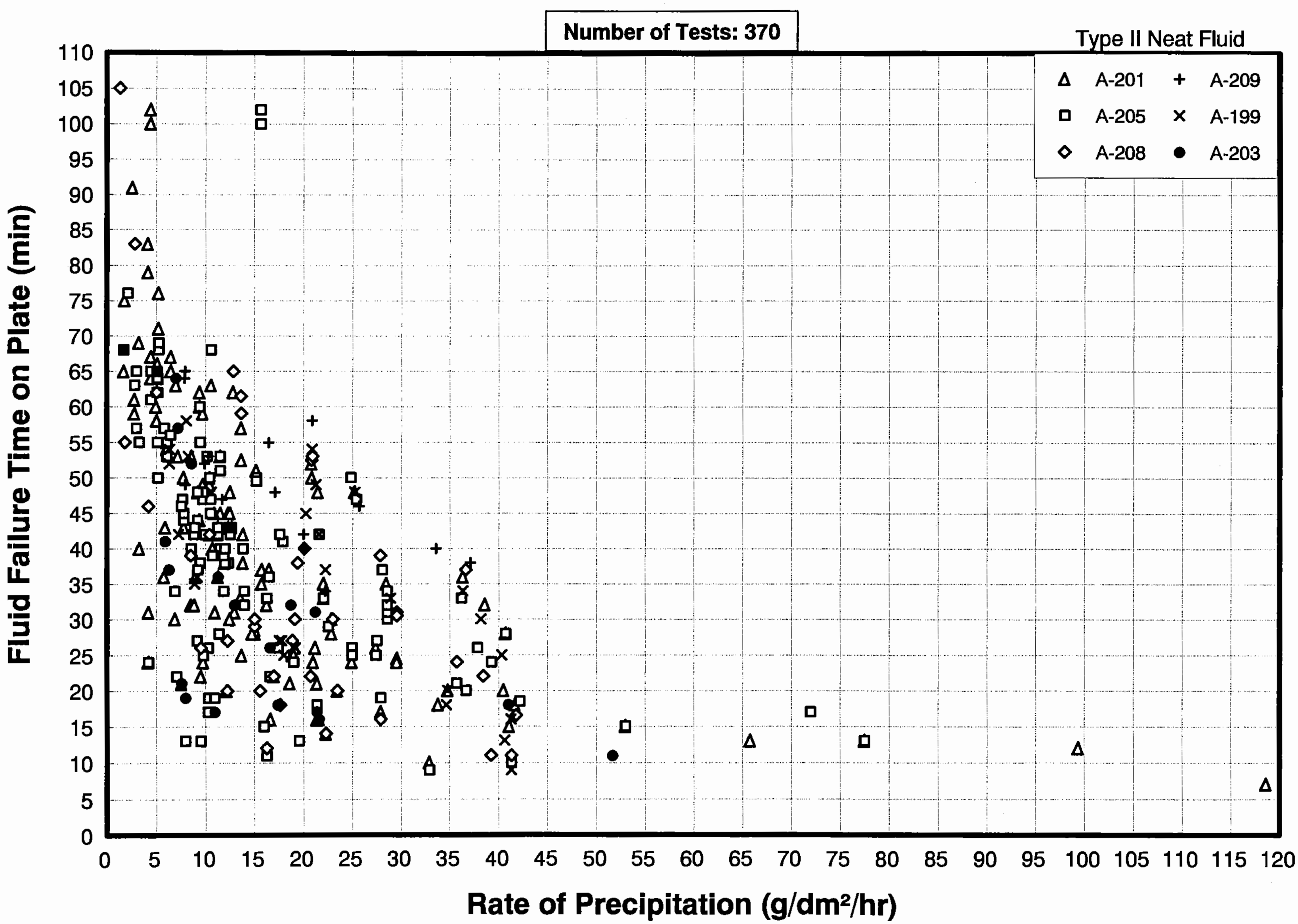
FIGURE 3.14

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

NATURAL SNOW CONDITIONS

All data from APS, NRC, & UA except 90/91 APS



cm1222\cons_hot\nat_snow\NS21_14.grf

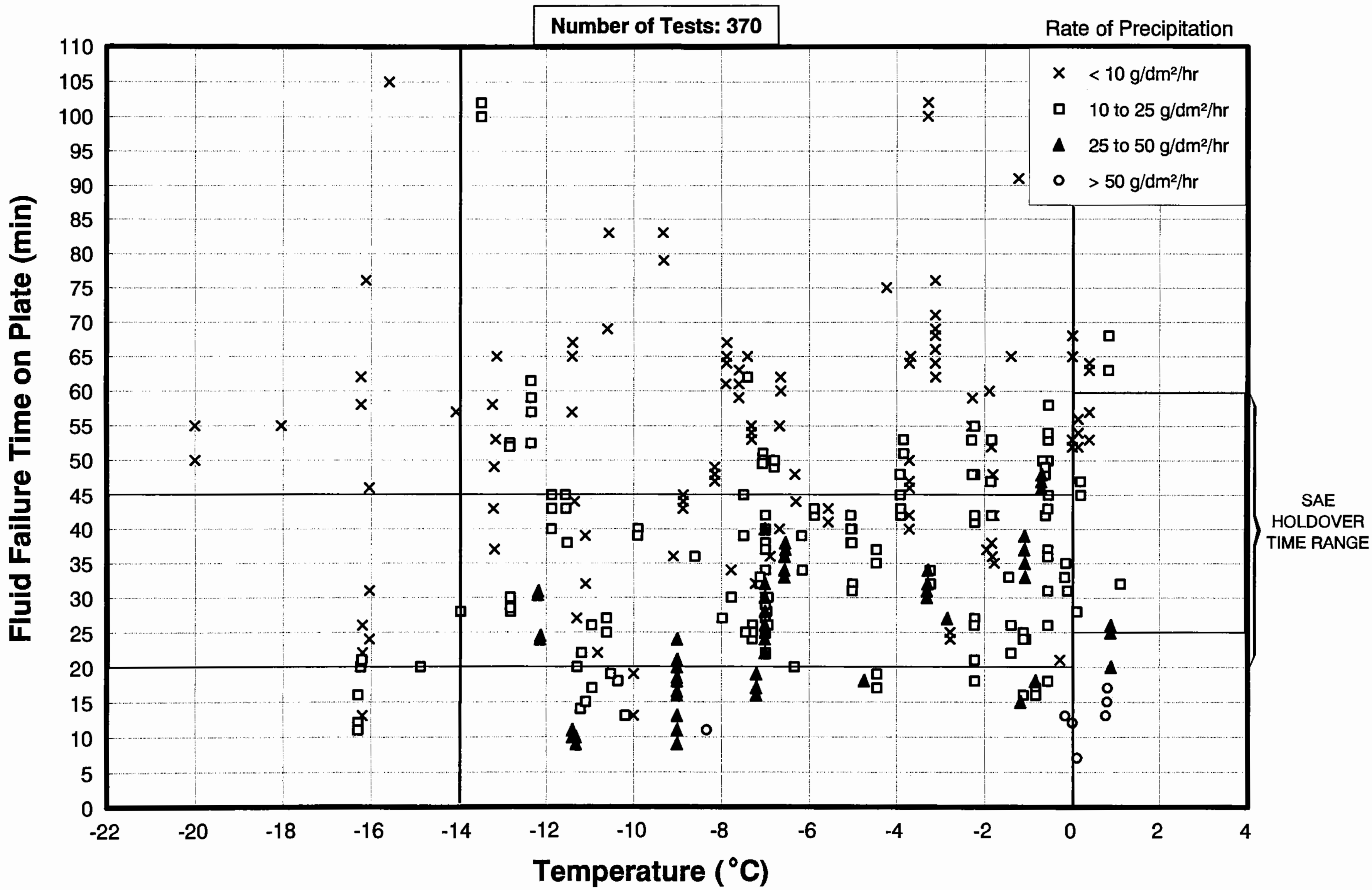
FIGURE 3.15

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II NEAT

NATURAL SNOW CONDITIONS

All data from APS, NRC, & UA except 90/91 APS



cm1222cons_hot\nat_snow\NS21_15.grf

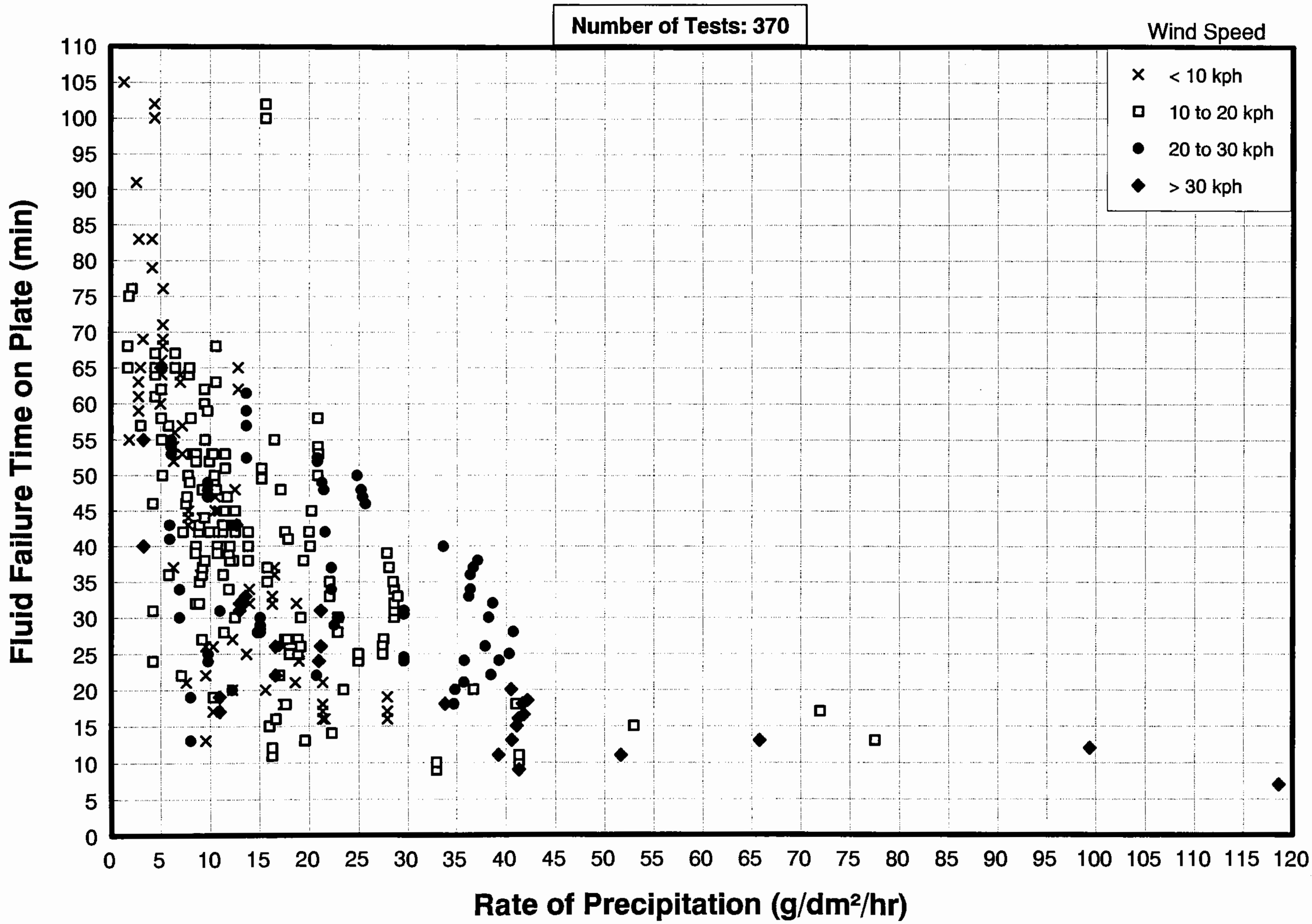
FIGURE 3.16

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

NATURAL SNOW CONDITIONS

All data from APS, NRC, & UA except 90/91 APS



cm1222\cons_hot\nat_snow\NS21_16.grf

FIGURE 3.17

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

NATURAL SNOW CONDITIONS

APS Data - 92/93 to 94/95

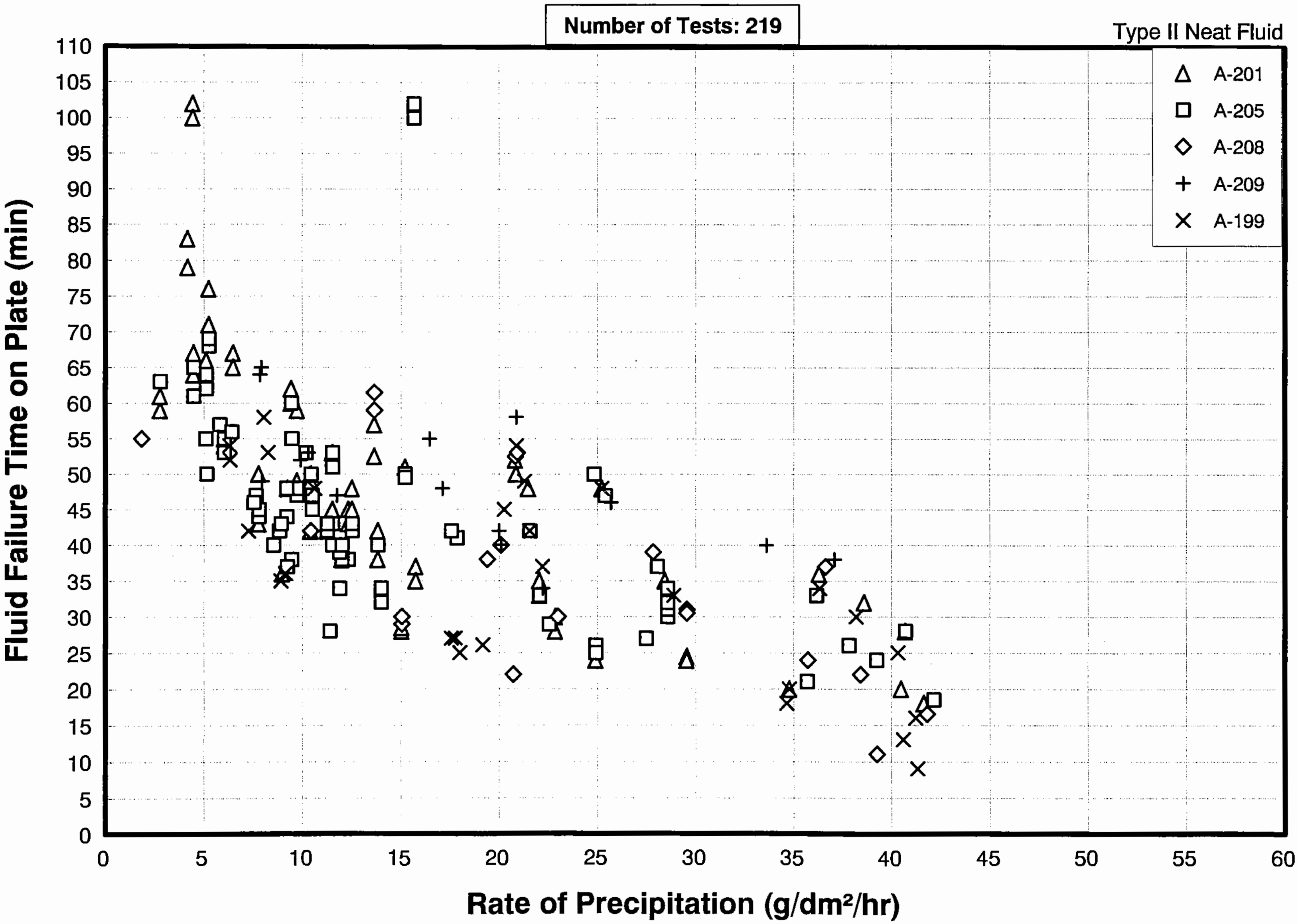


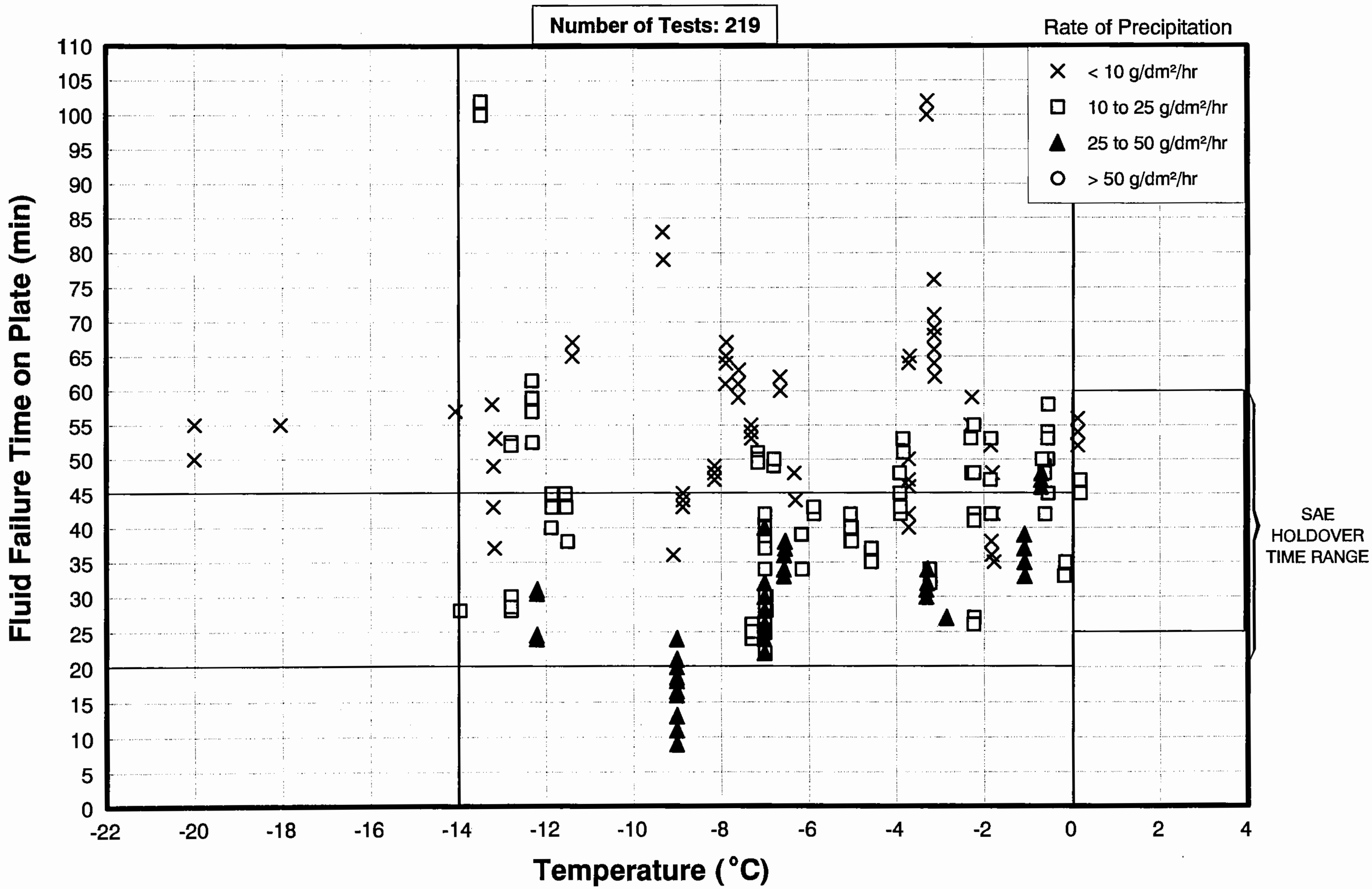
FIGURE 3.18

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II NEAT

NATURAL SNOW CONDITIONS

APS Data - 92/93 to 94/95



cm1222\cons_hot\nat_snow\NS21_18.grf

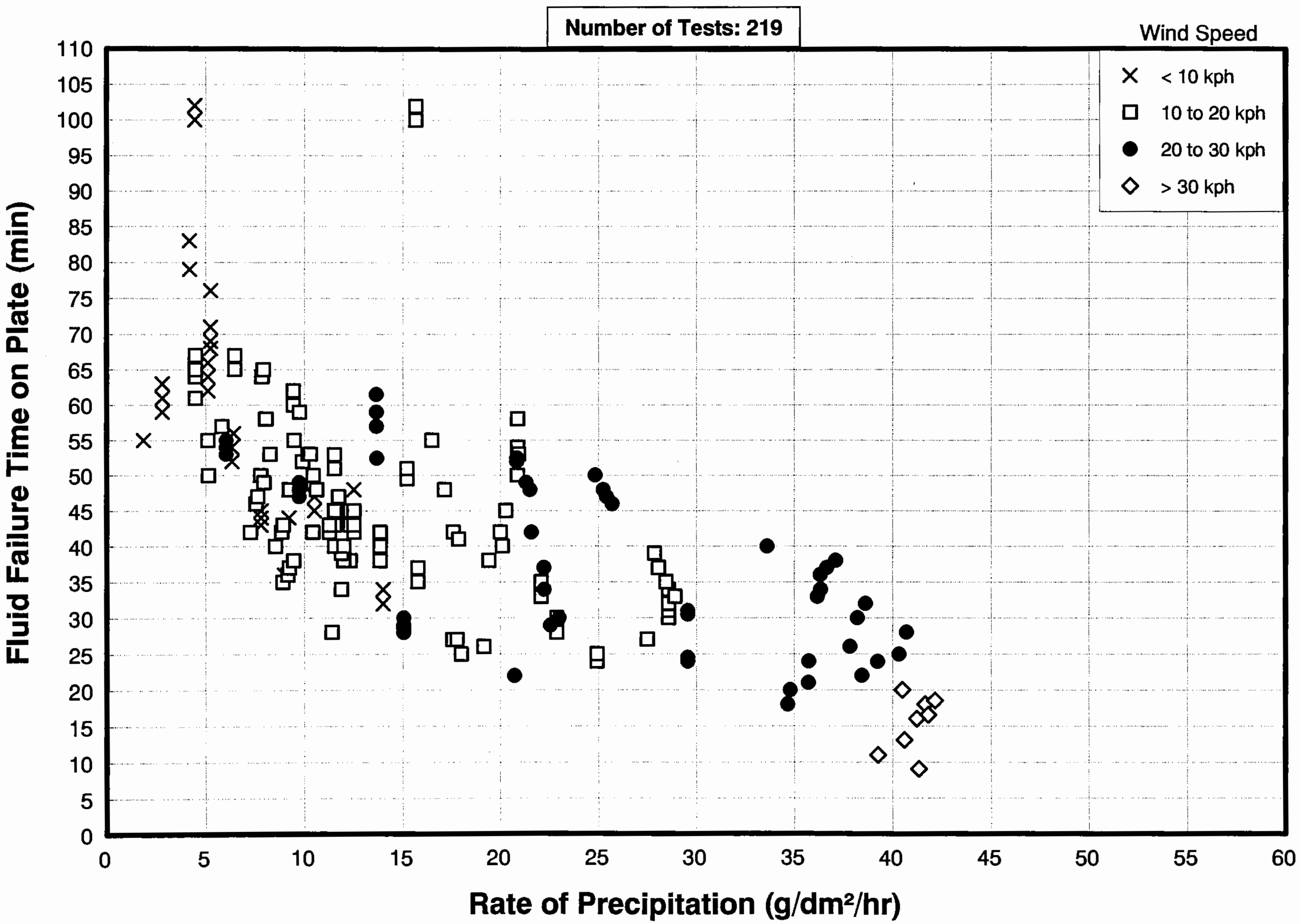
FIGURE 3.19

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

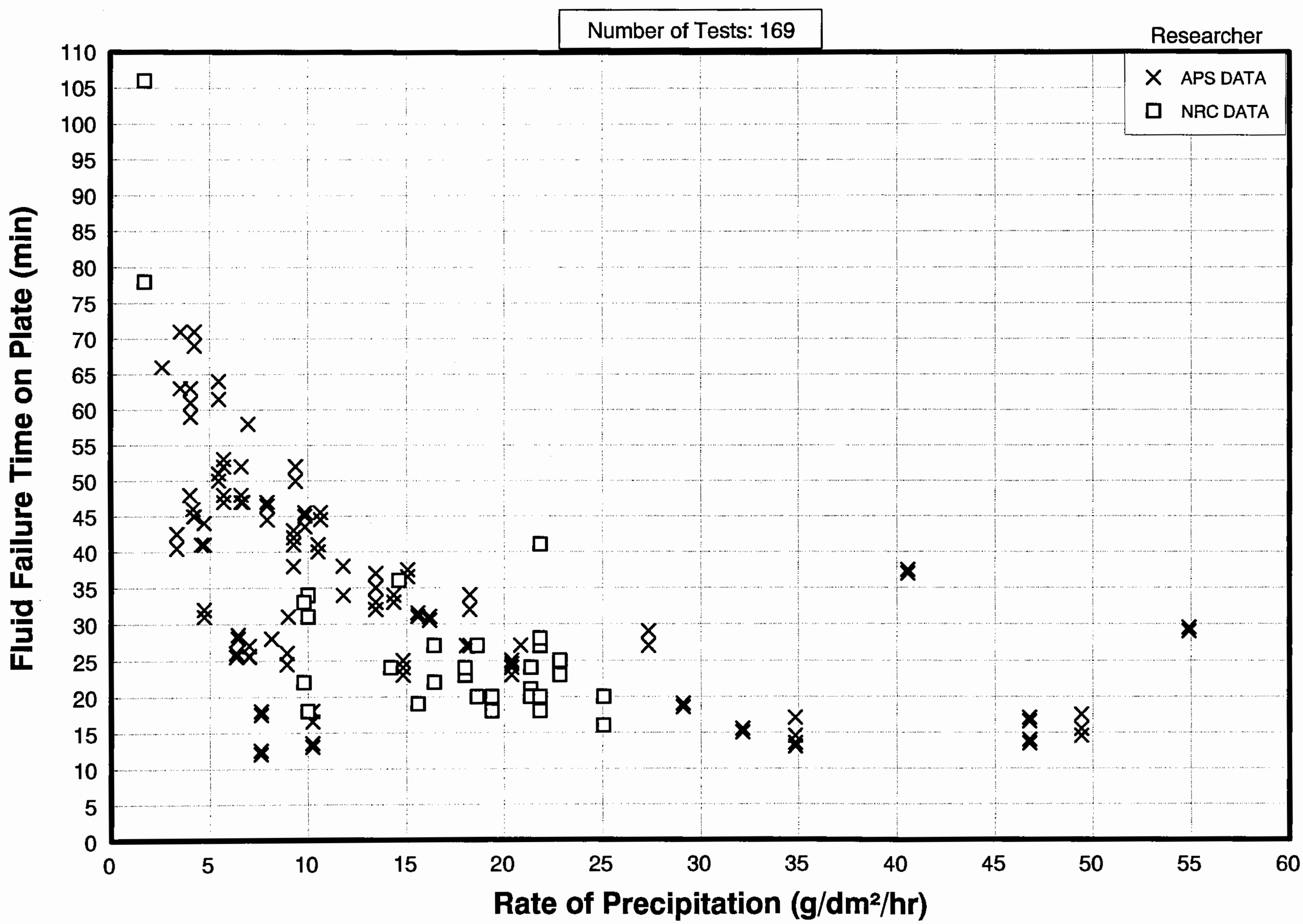
NATURAL SNOW CONDITIONS

APS Data - 92/93 to 94/95



:m1222\cons_hot\nat_snow\NS21_19.grf

FIGURE 3.20
EFFECT OF RESEARCHER AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE II 75/25
NATURAL SNOW CONDITIONS
APS and NRC Data



cm1222\cons_hot\nat_snow\NS27_20.GRF

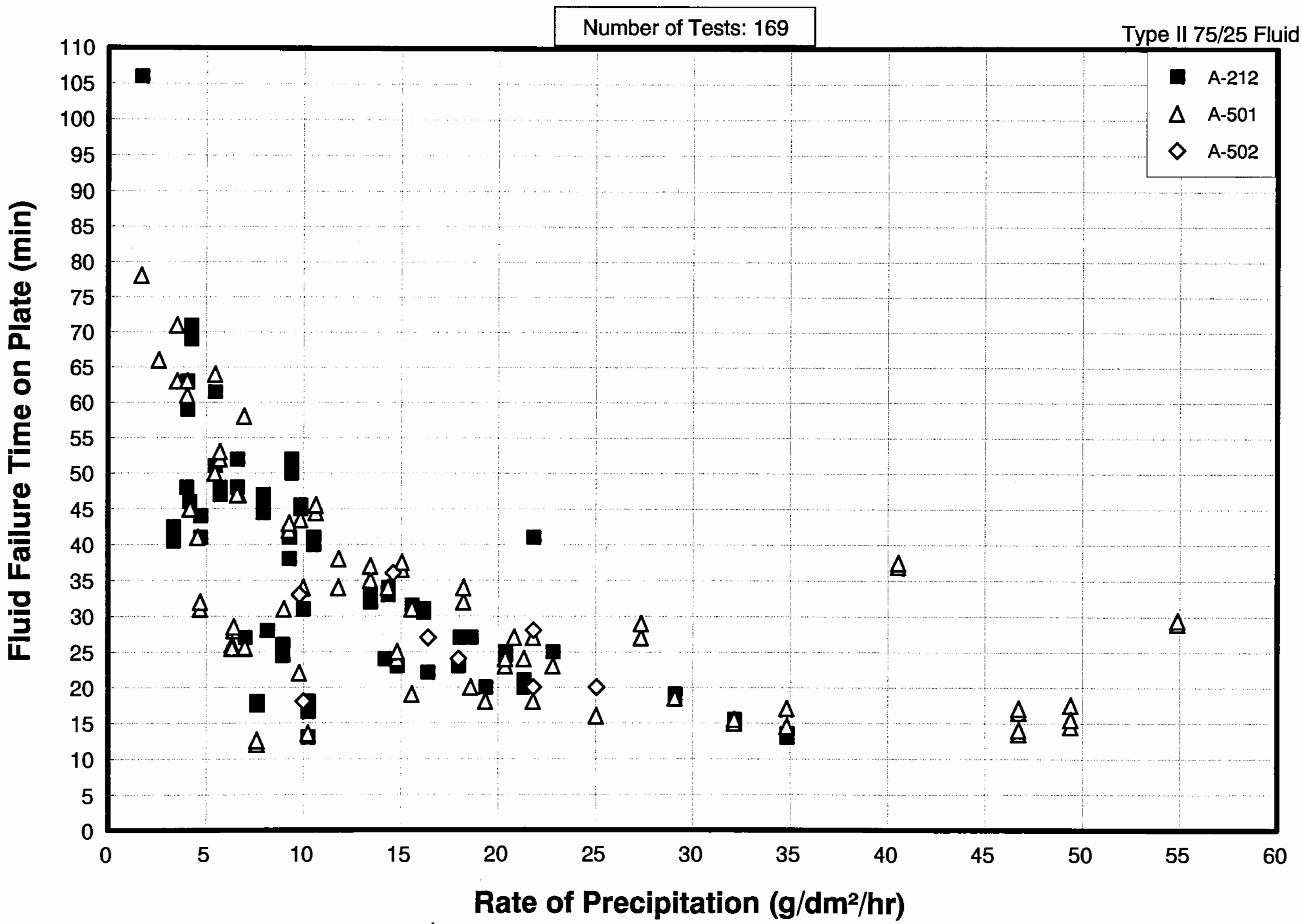
FIGURE 3.21

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 75/25

NATURAL SNOW CONDITIONS

APS and NRC Data



cm1222\cons_hot\nat_snow\NS27_21.GRF

FIGURE 3.22

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II 75/25

NATURAL SNOW CONDITIONS

APS and NRC Data

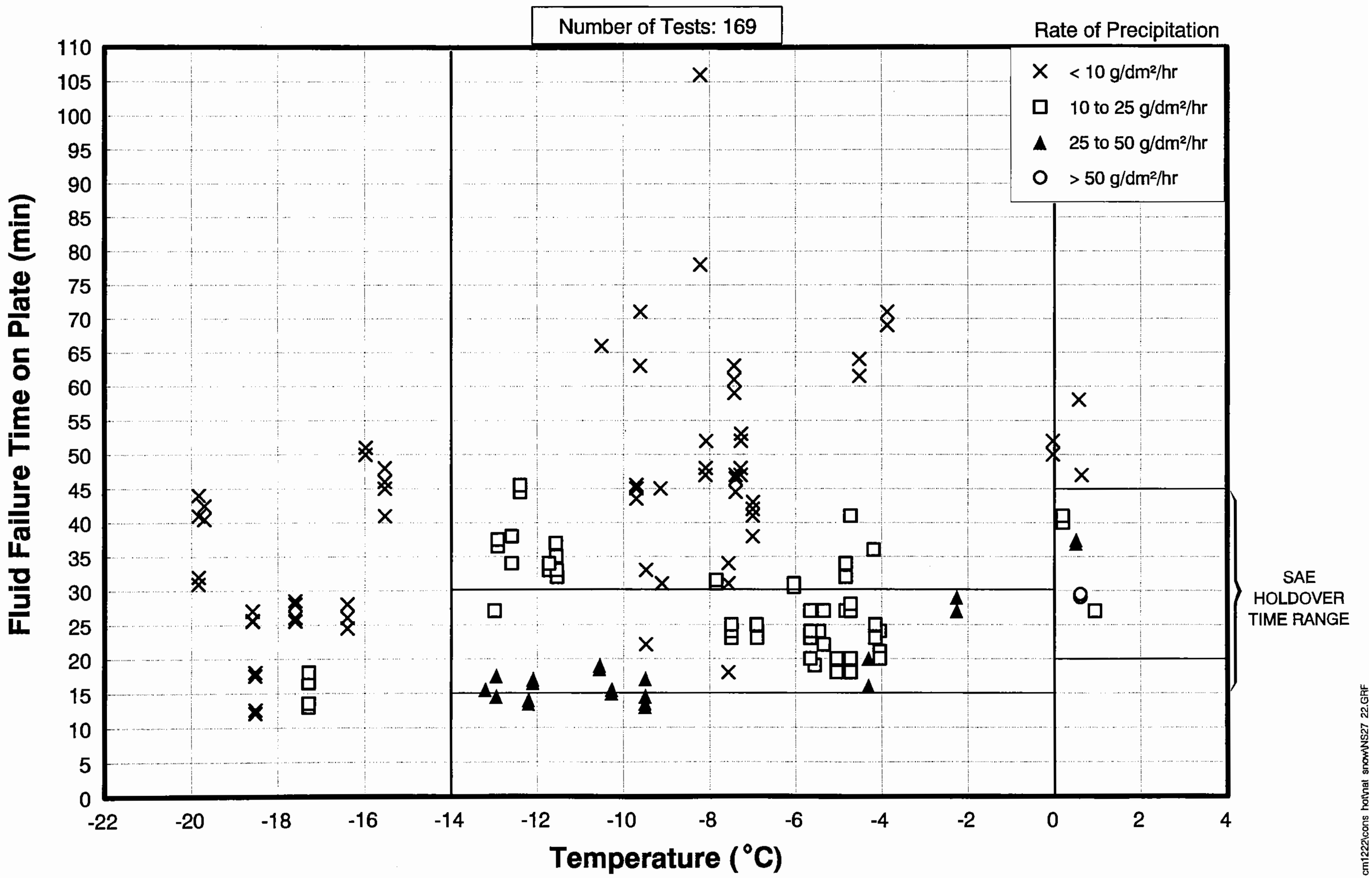


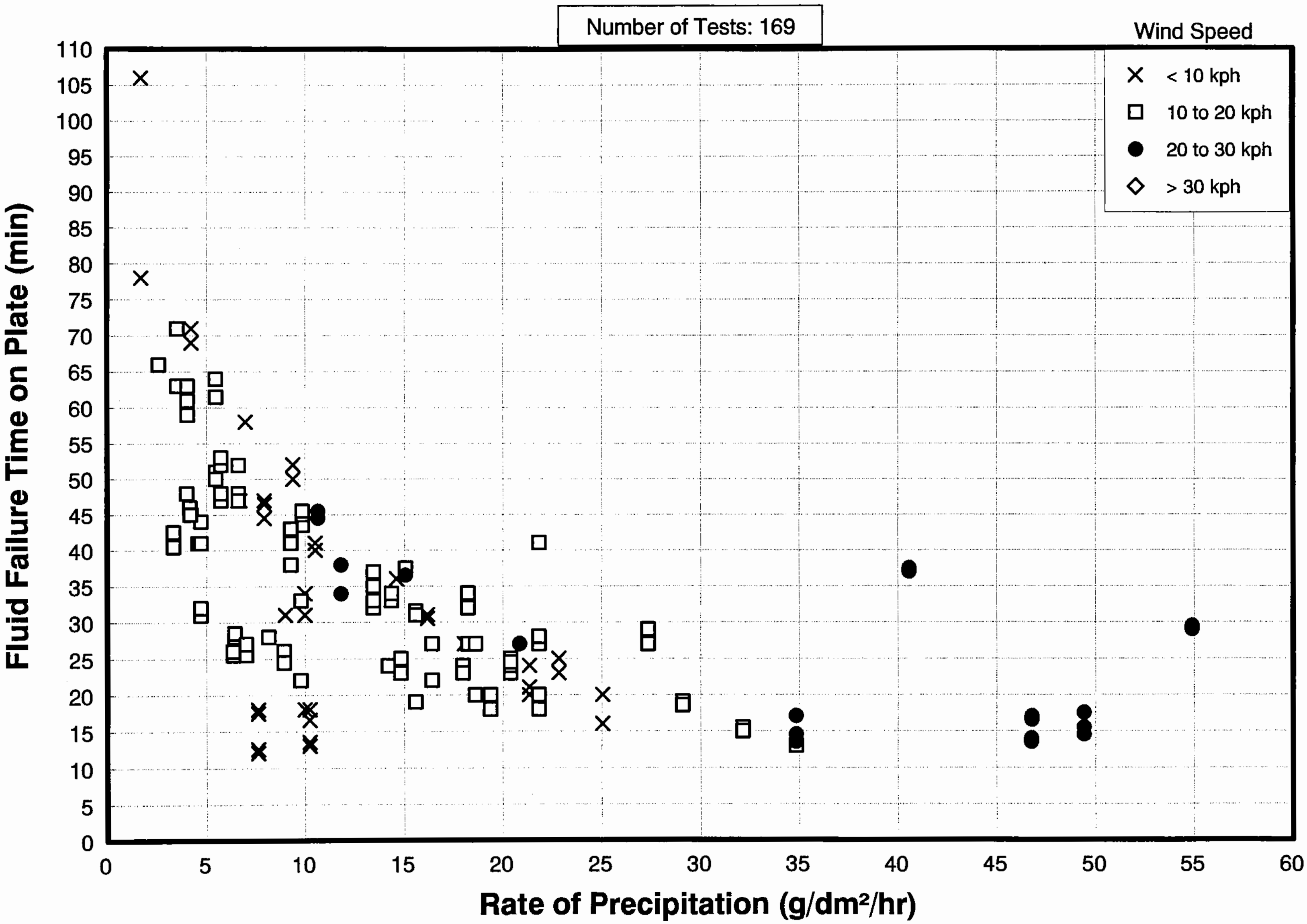
FIGURE 3.23

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 75/25

NATURAL SNOW CONDITIONS

APS and NRC Data



cm1222\cons_hot\nat_snow\NS27_23.GRF

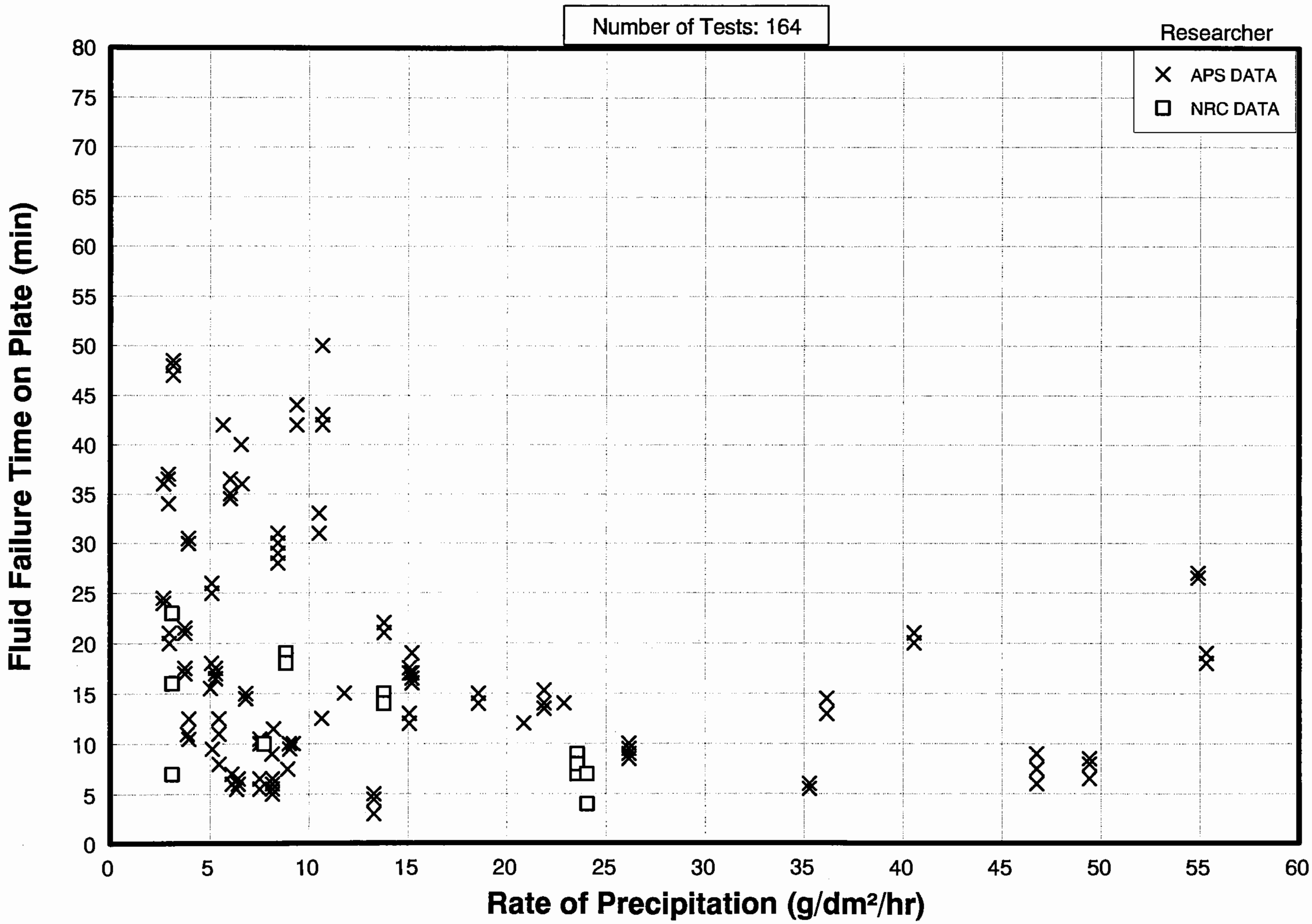
FIGURE 3.24

EFFECT OF RESEARCHER AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 50/50

NATURAL SNOW CONDITIONS

APS and NRC Data



cm1222\cons_hot\nat_snow\NS25_24.GRF

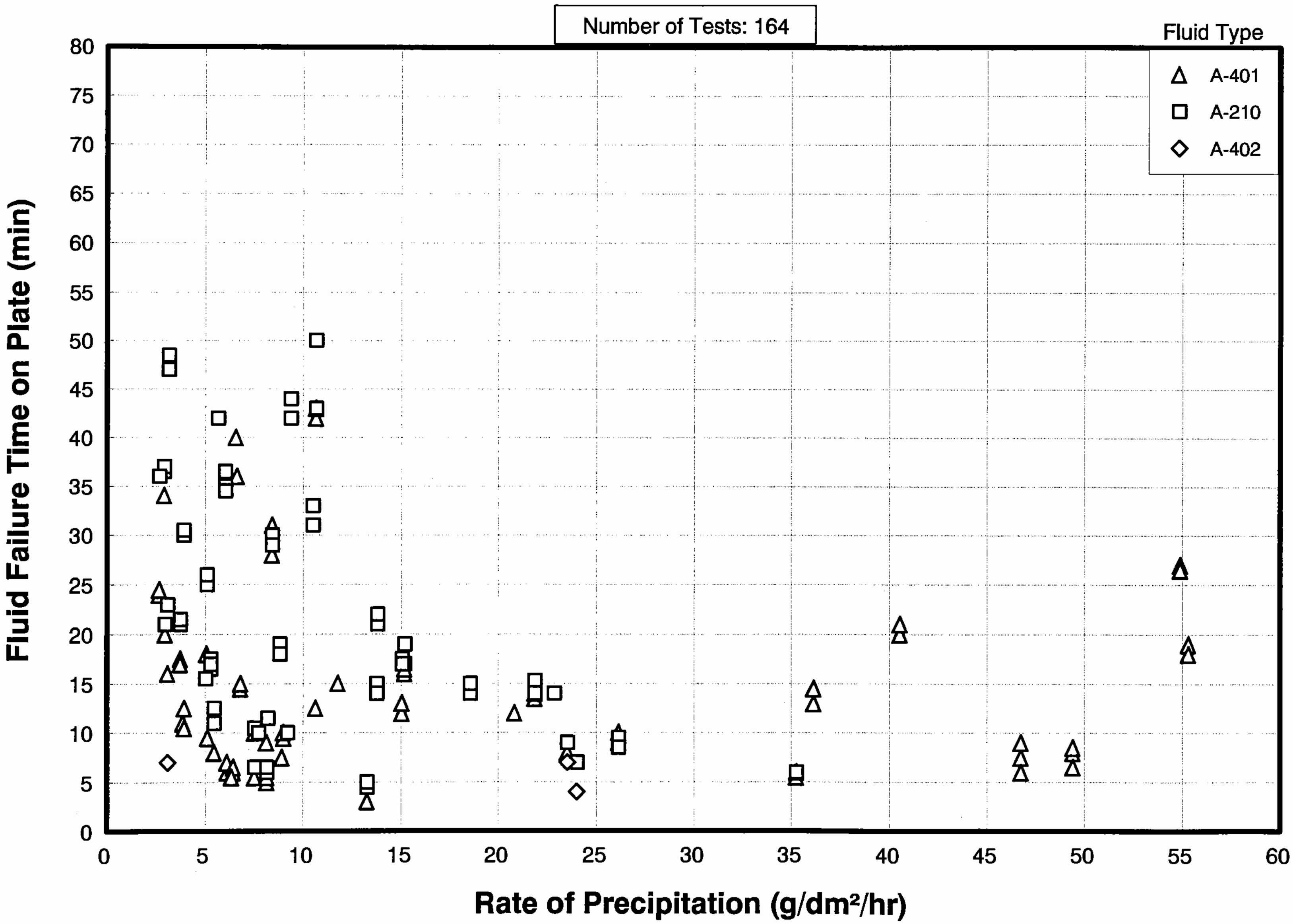
FIGURE 3.25

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 50/50

NATURAL SNOW CONDITIONS

APS and NRC Data



cm1222\cons_hot\nat_snow\NS25_25.GRF

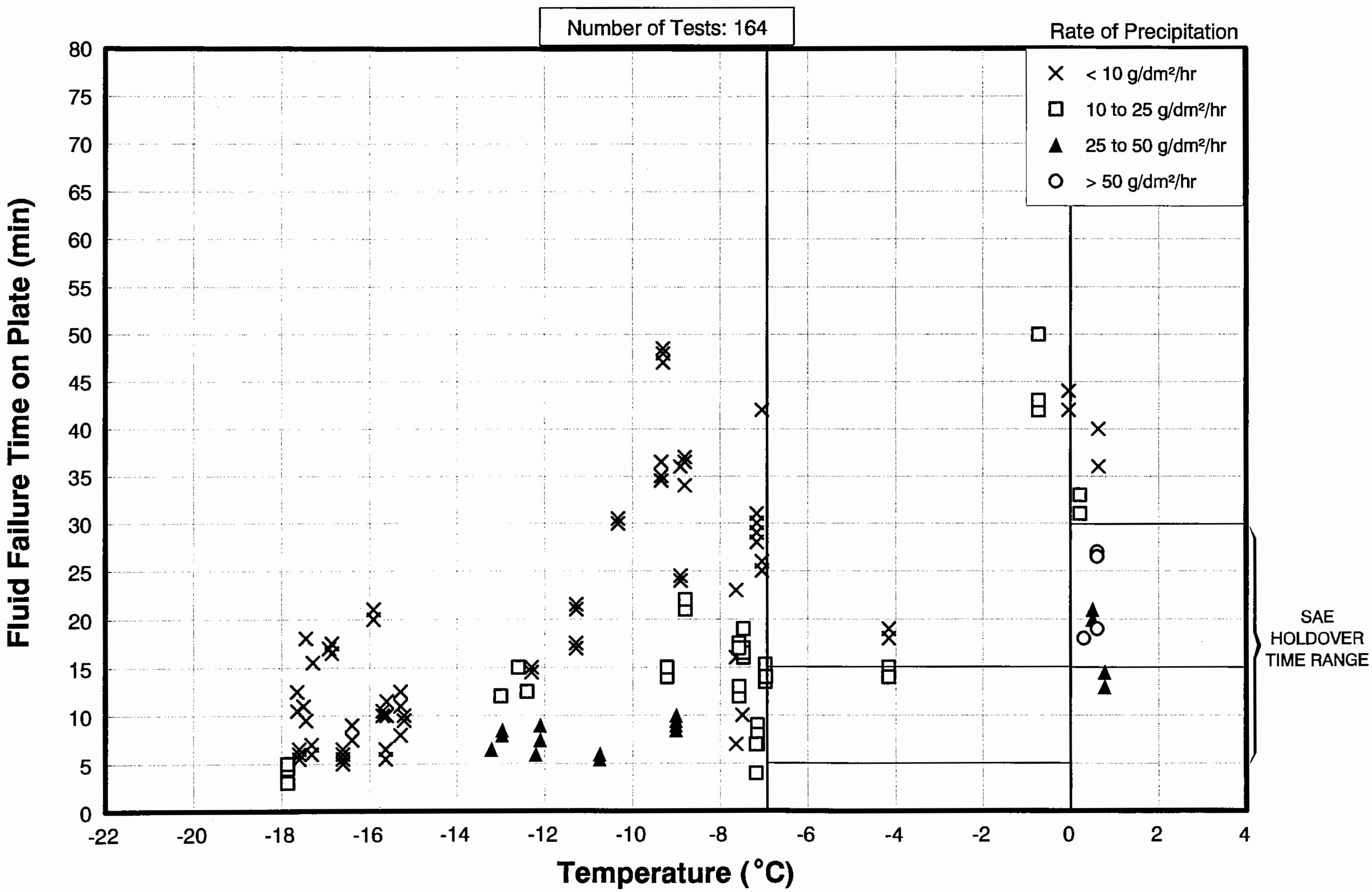
FIGURE 3.26

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II 50/50

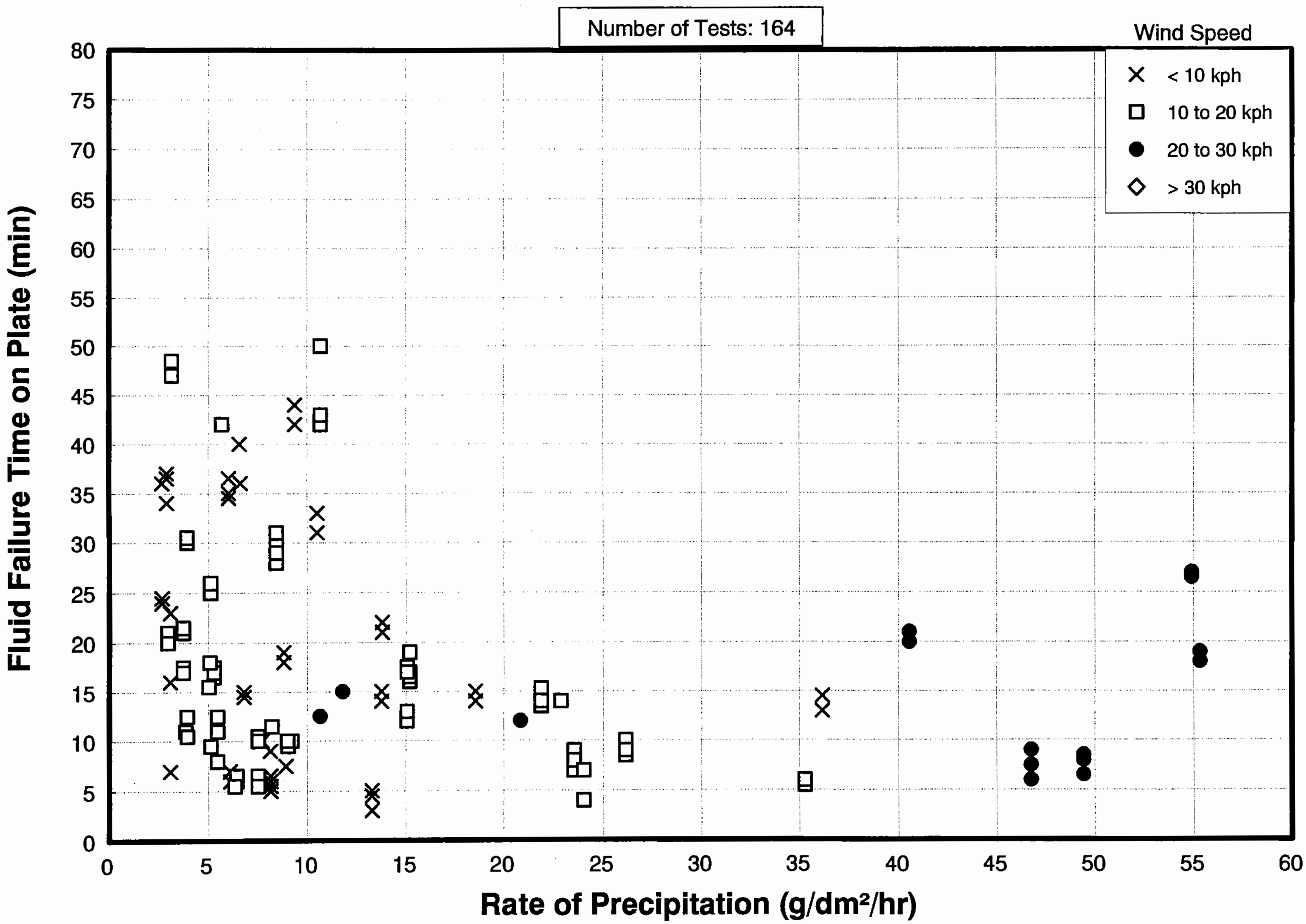
NATURAL SNOW CONDITIONS

APS and NRC Data



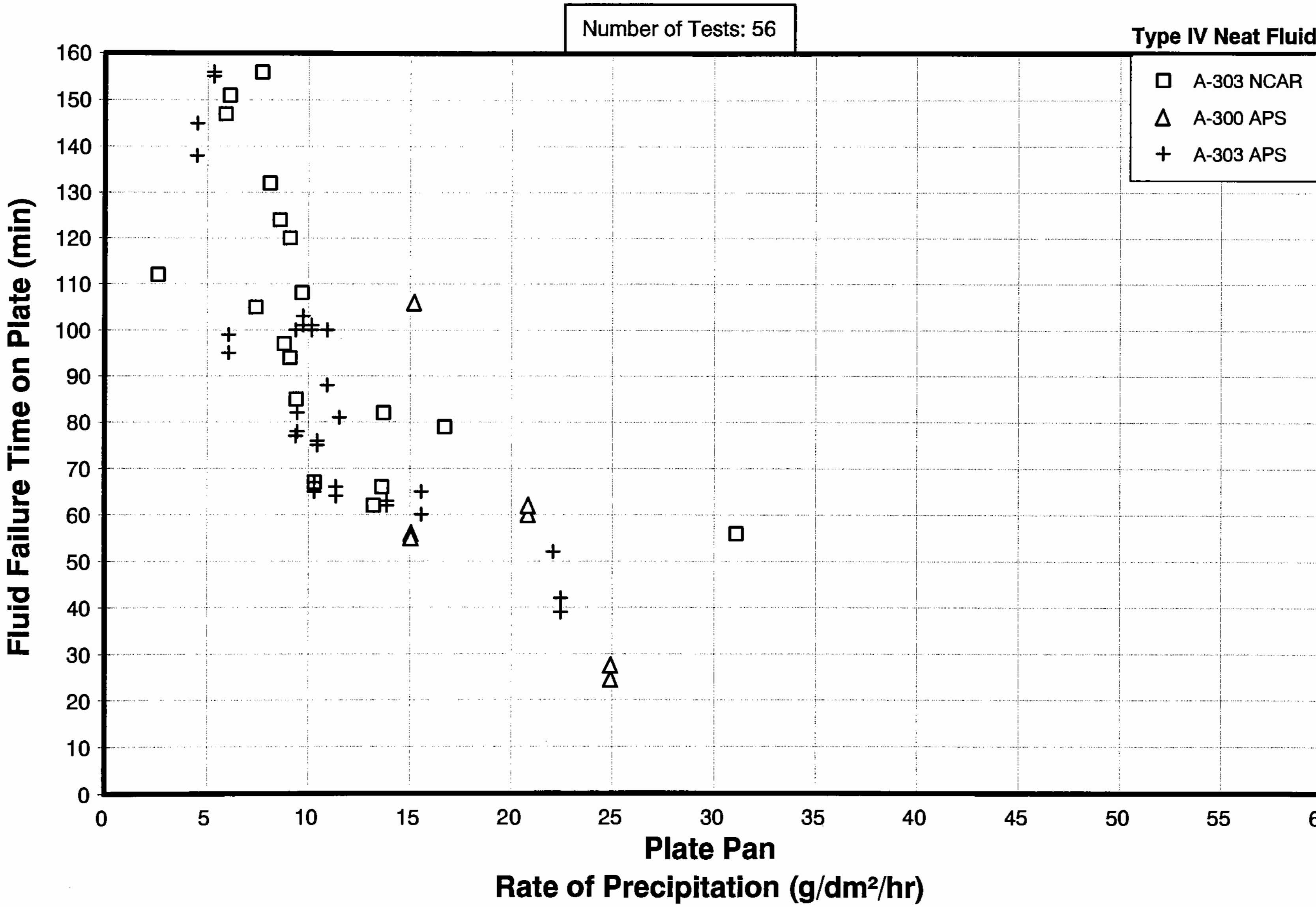
cm1221cons_hot\nat_snow\NS25_26.GRF

FIGURE 3.27
EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE II 50/50
NATURAL SNOW CONDITIONS
APS and NRC Data



cm1222\cons_hot\nat_snow\NS25_27.GRF

FIGURE 3.28
EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT
NATURAL SNOW CONDITIONS
NCAR and APS Data Combined



cm1222\cons_hol\nat_snow\NS41_28.GRF

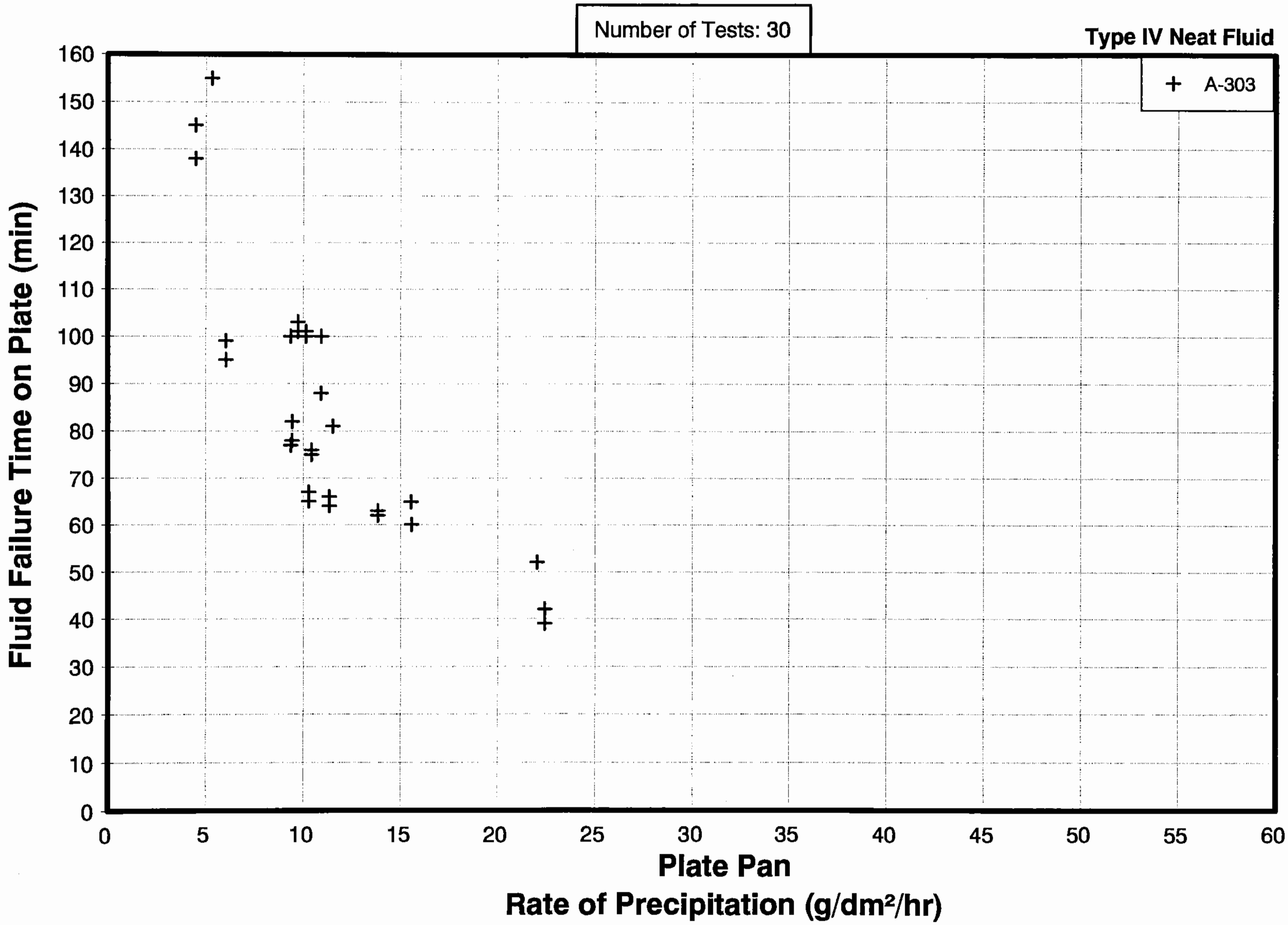
FIGURE 3.29

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT

NATURAL SNOW CONDITIONS

APS Data



cm1222\cons_hot\nat_snow\NS41_29.GRF

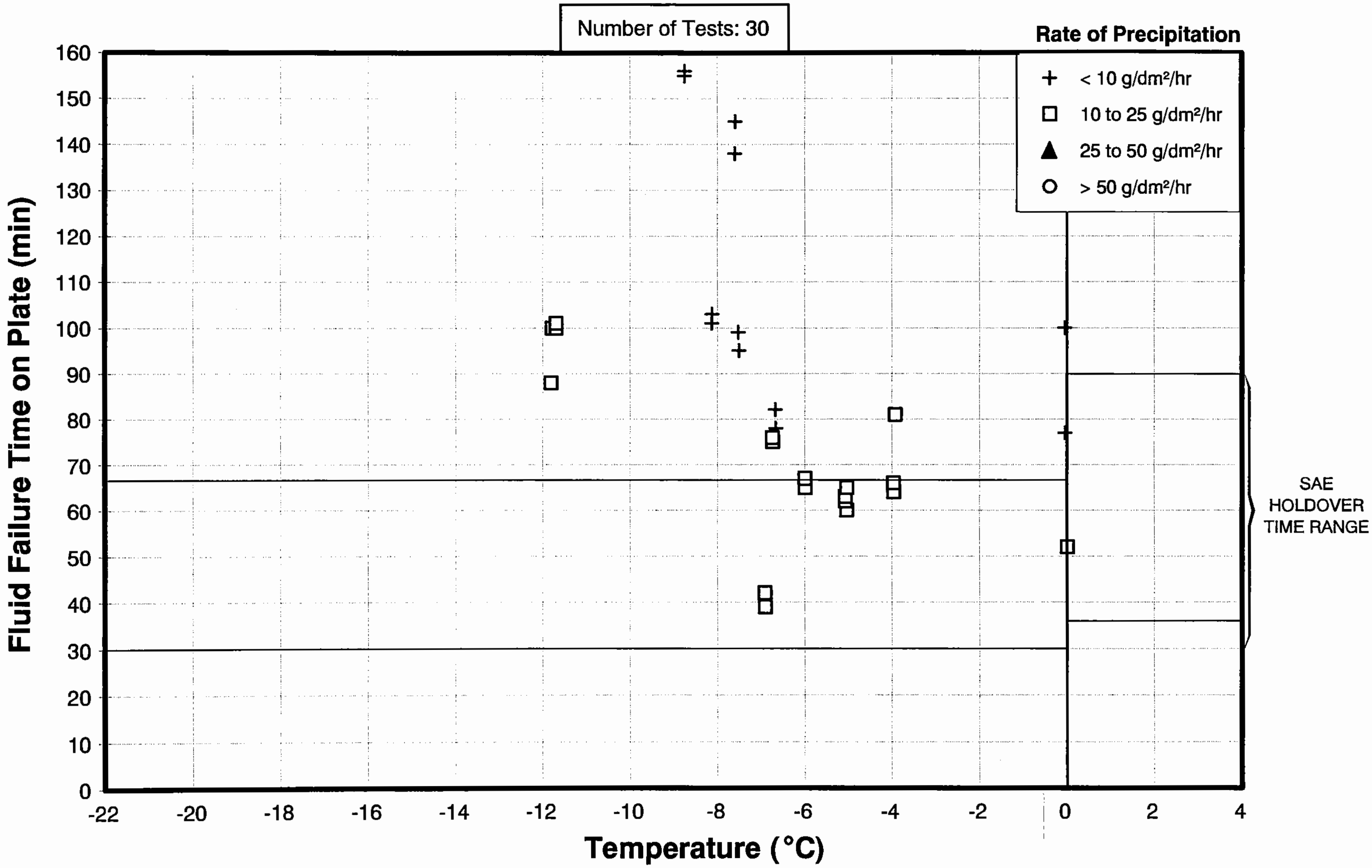
FIGURE 3.30

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE IV NEAT

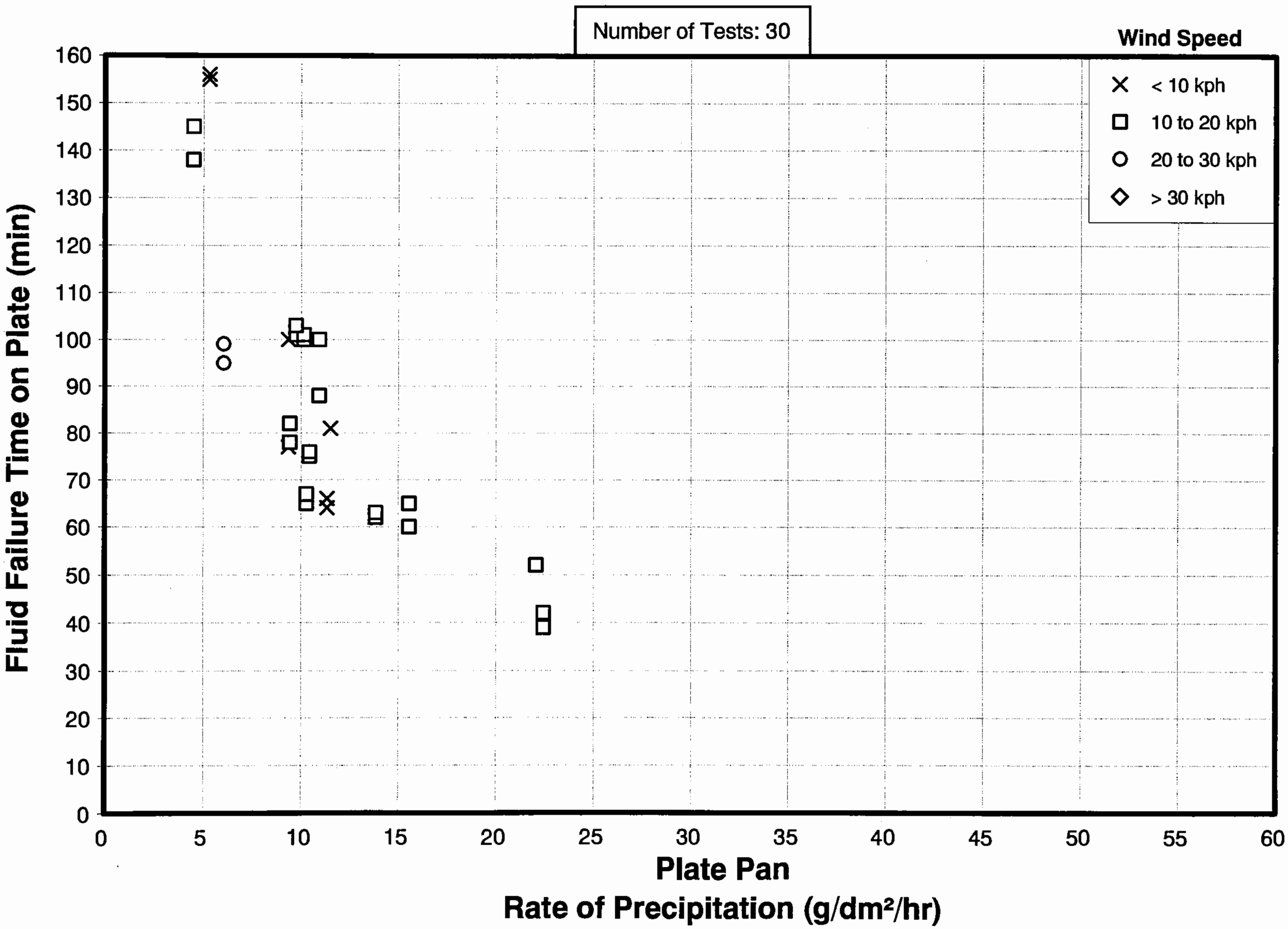
NATURAL SNOW CONDITIONS

APS Data



cm1222\cons_hot\nat_snow\NS41_30.GRF

FIGURE 3.31
EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV NEAT
NATURAL SNOW CONDITIONS
APS Data



cm1222\cons_hol\nat_snow\NS41_31.GRF

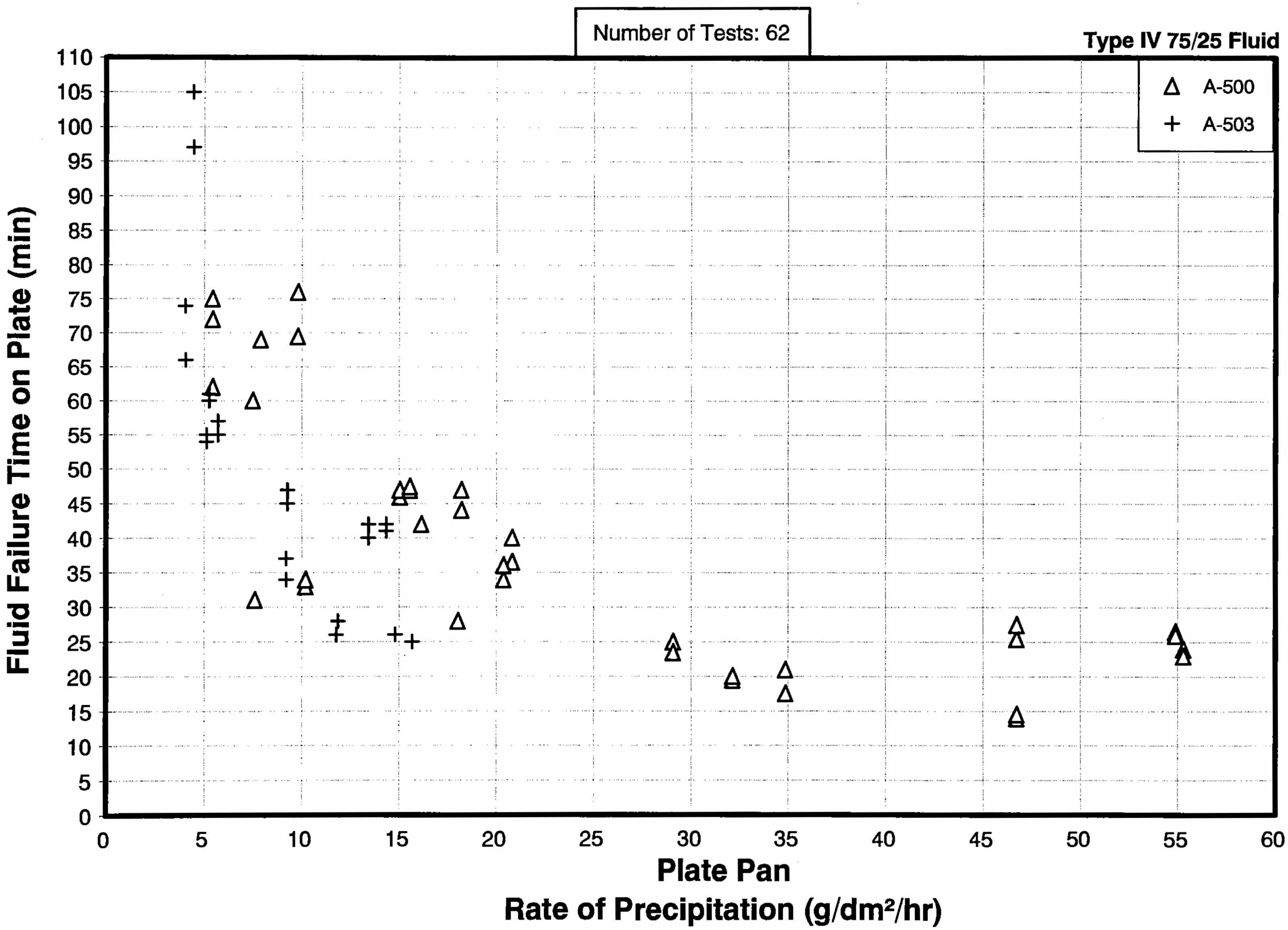
FIGURE 3.32

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25

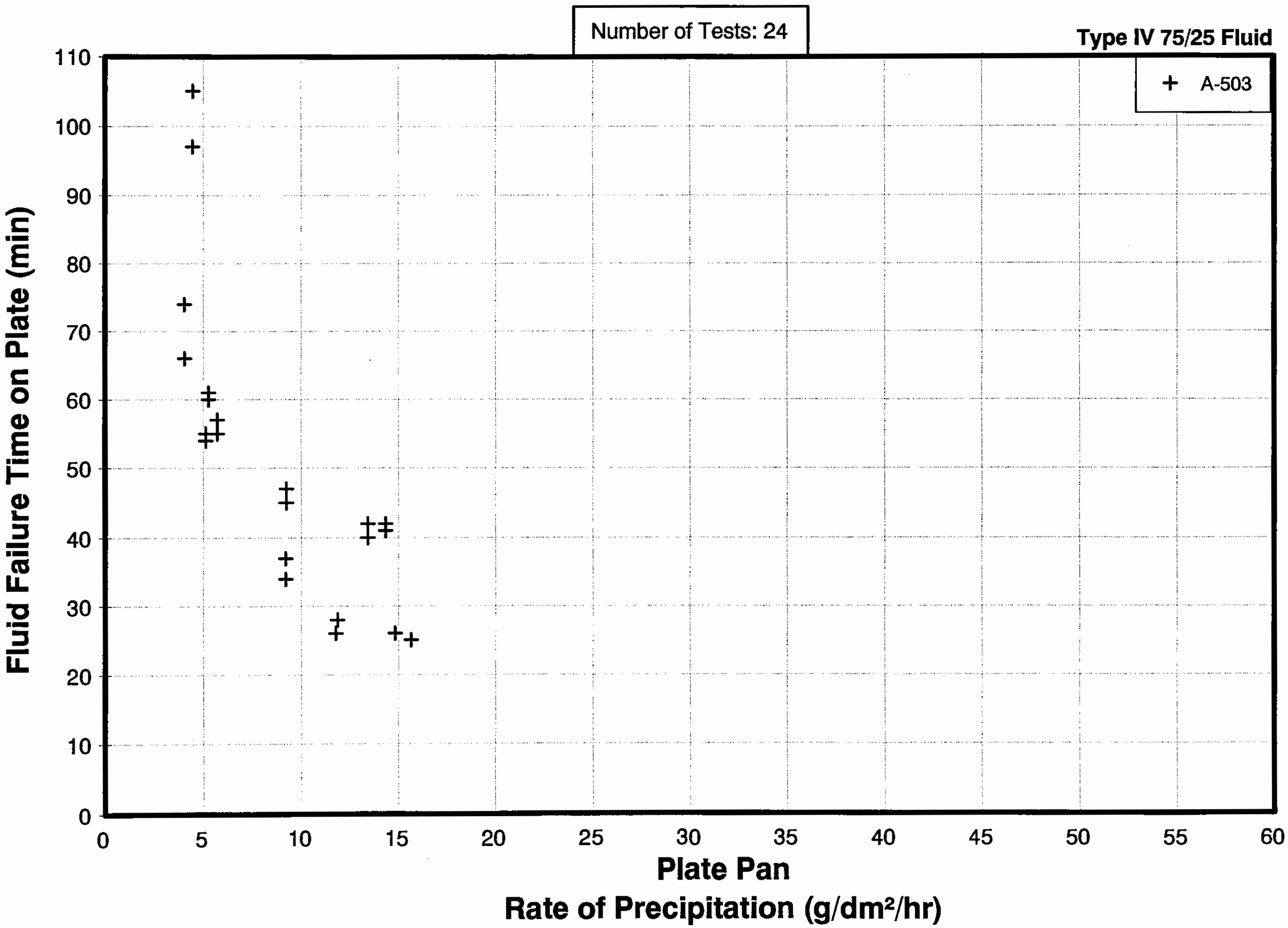
NATURAL SNOW CONDITIONS

APS Data



cm1222\cons_hot\nal_snow\NS47_32.GRF

FIGURE 3.33
EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25
NATURAL SNOW CONDITIONS
APS Data



cm1222\cons_hol\nat_snow\NS47_33.GRF

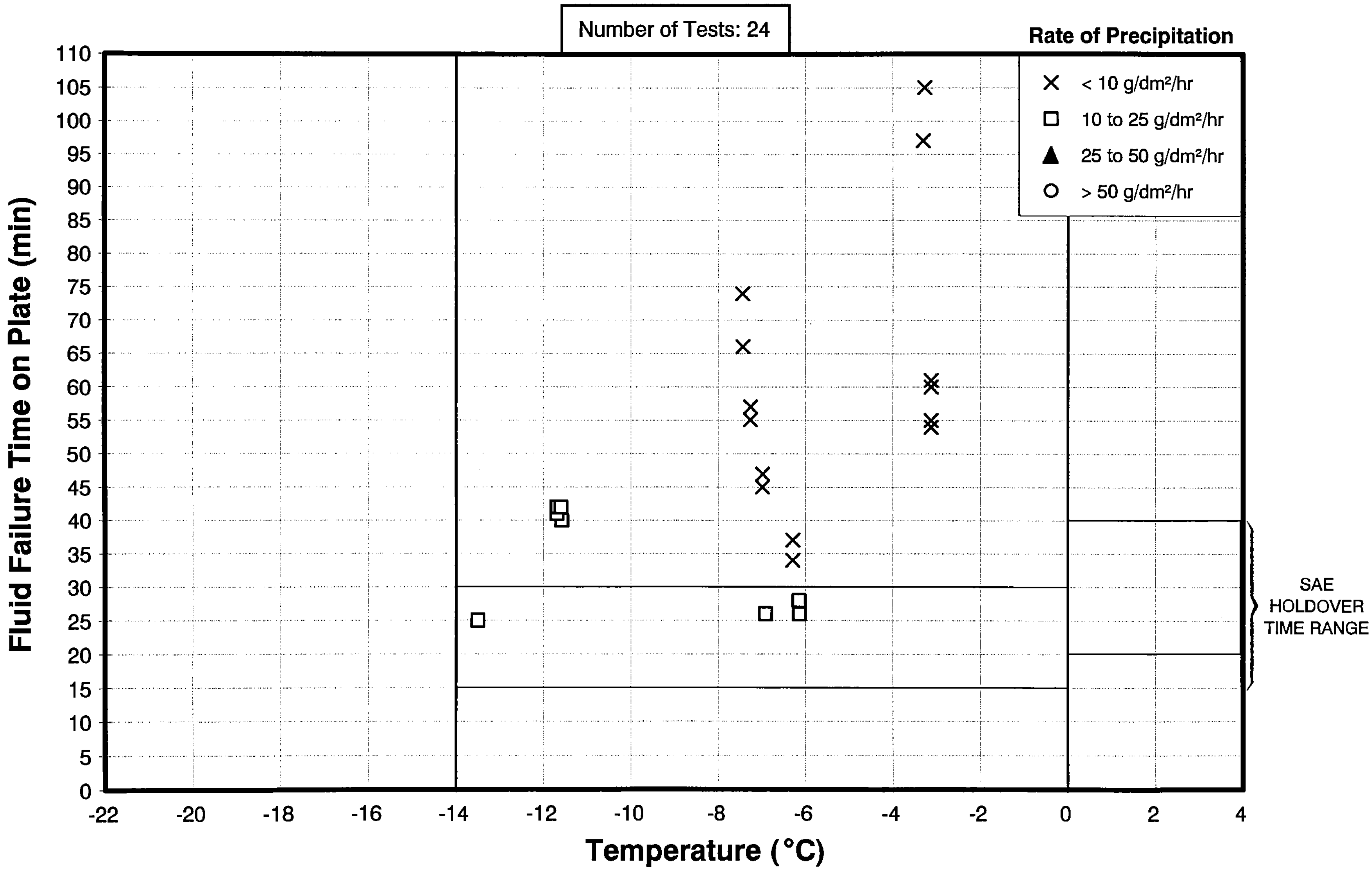
FIGURE 3.34

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE IV 75/25

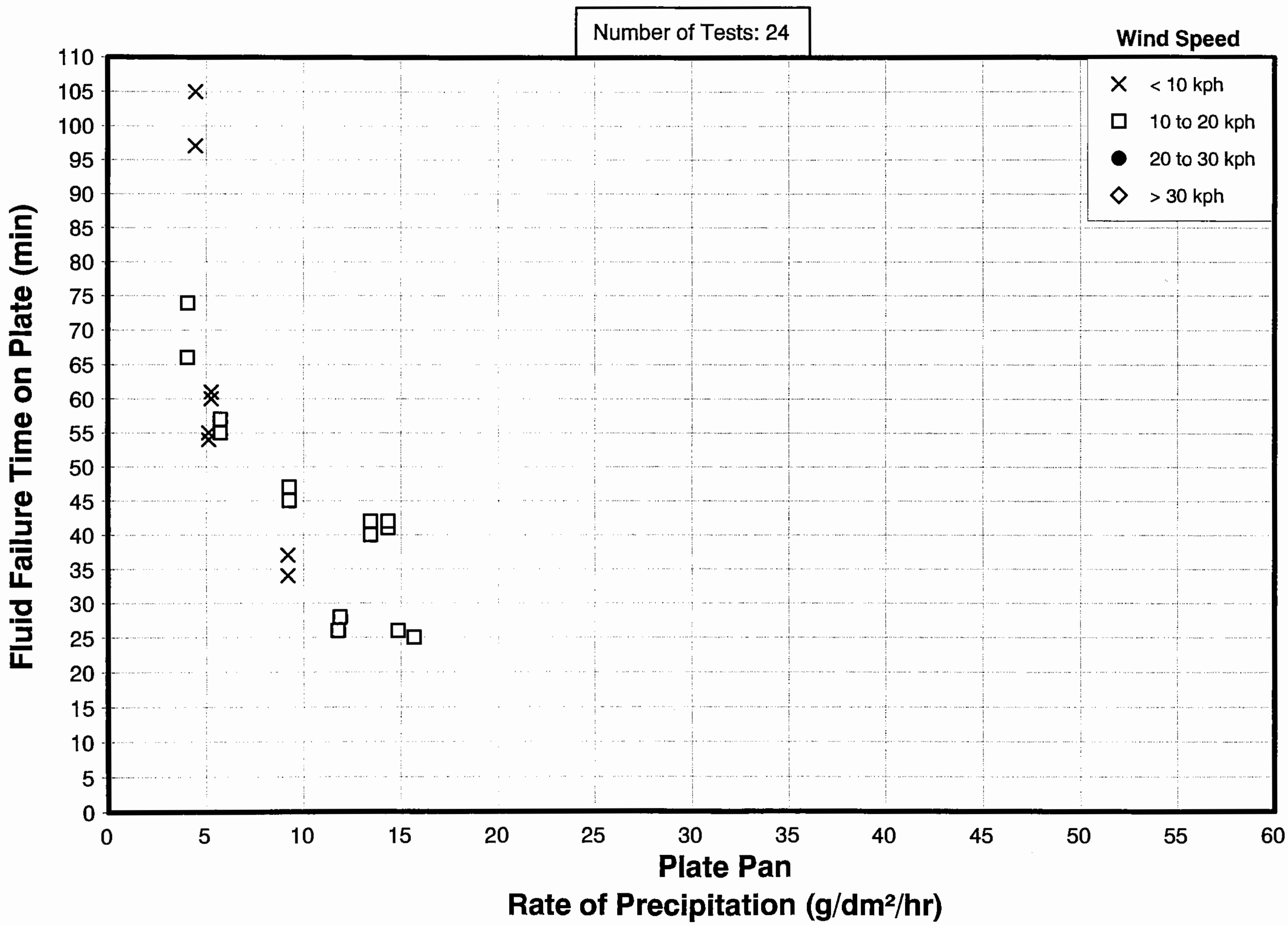
NATURAL SNOW CONDITIONS

APS Data



cm1222\cons_hot\nat_snow\NS47_34.GRF

FIGURE 3.35
EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25
NATURAL SNOW CONDITIONS
APS Data



cm1222\cons_hot\nat_snow\NS47_35.GRF

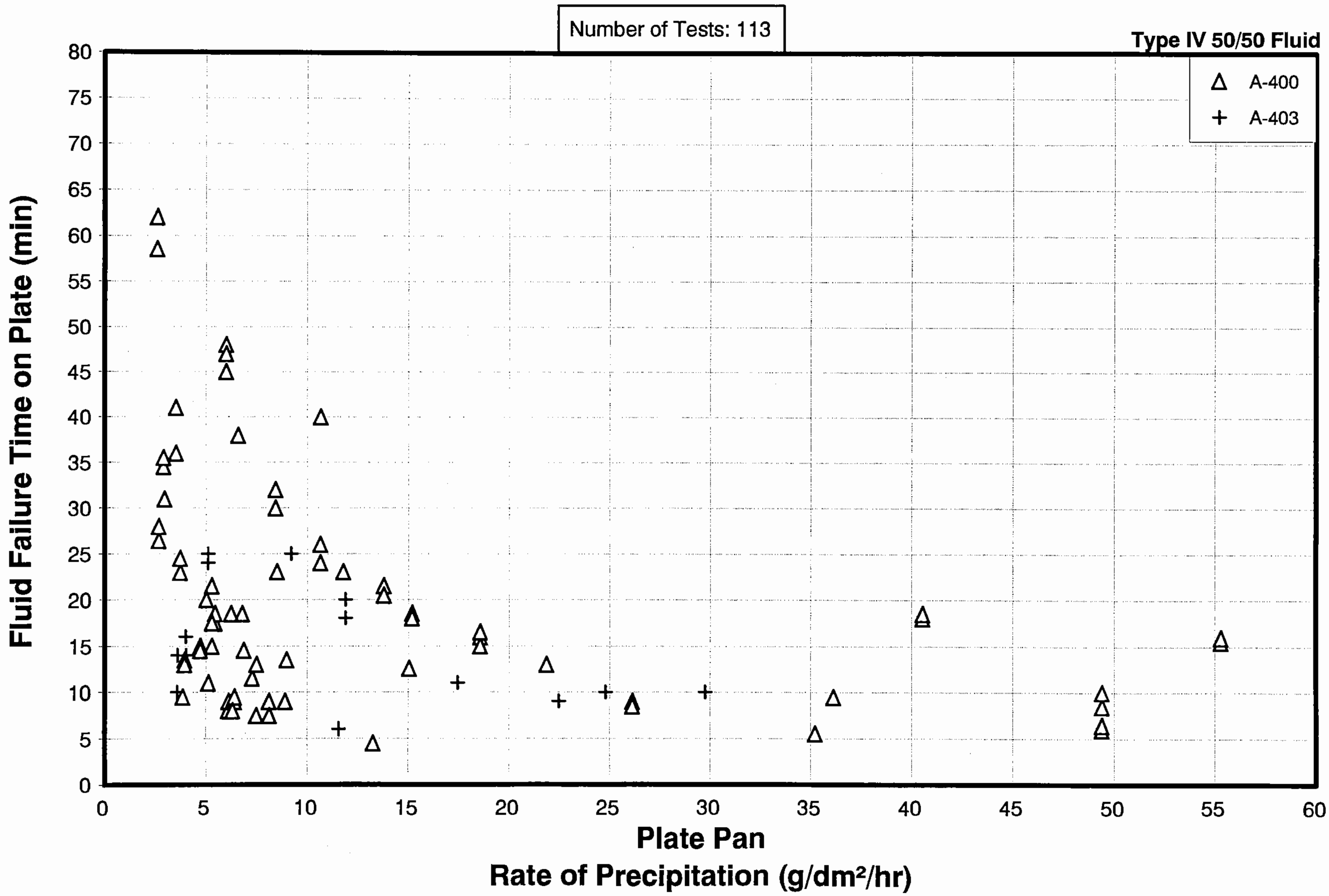
FIGURE 3.36

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50

NATURAL SNOW CONDITIONS

APS Data



cm1222\cons_hot\nat_snow\NS45_36.GRF

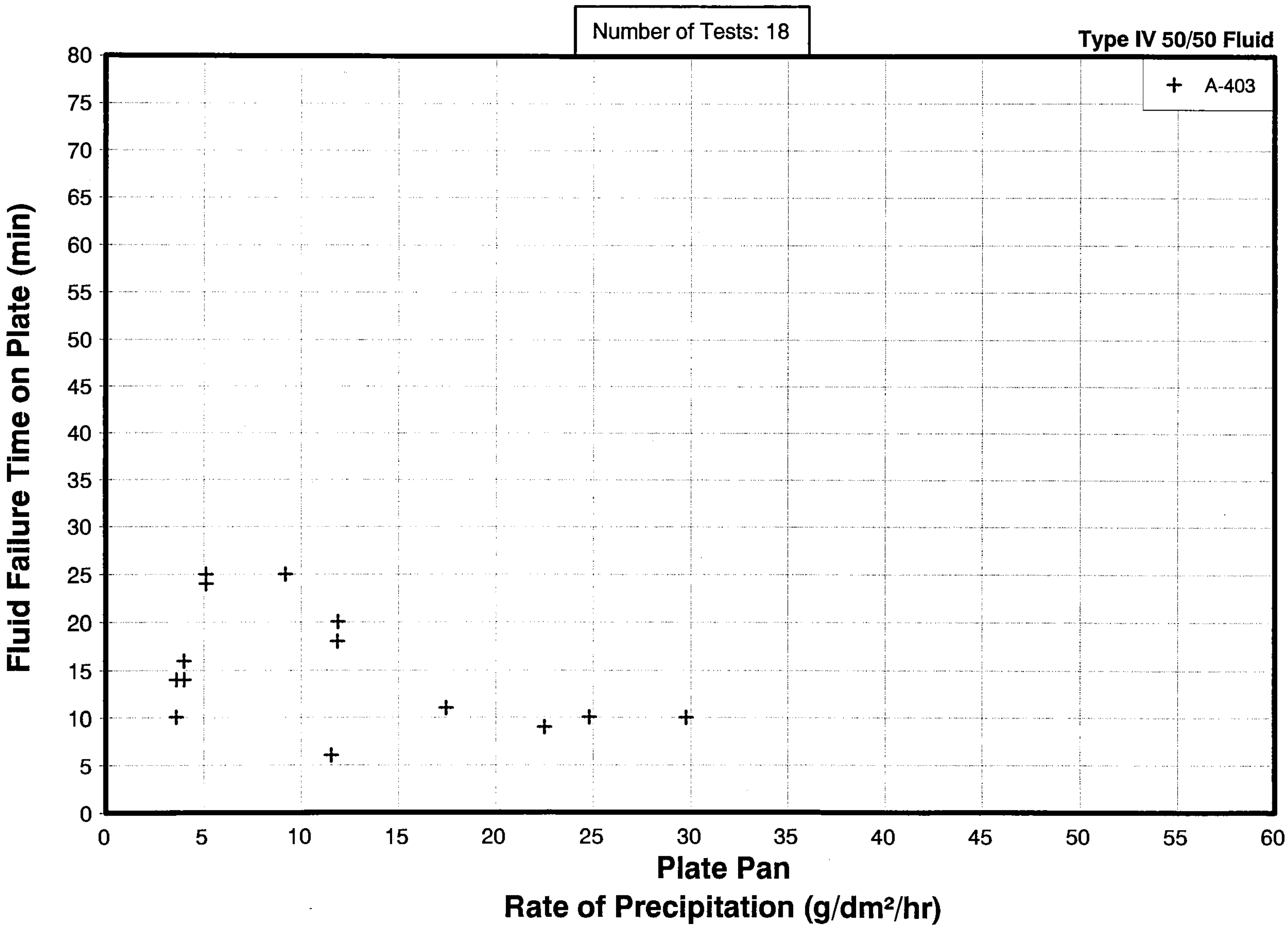
FIGURE 3.37

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50

NATURAL SNOW CONDITIONS

APS Data



cm1222\cons_holval_snow\NS45_37.GRF

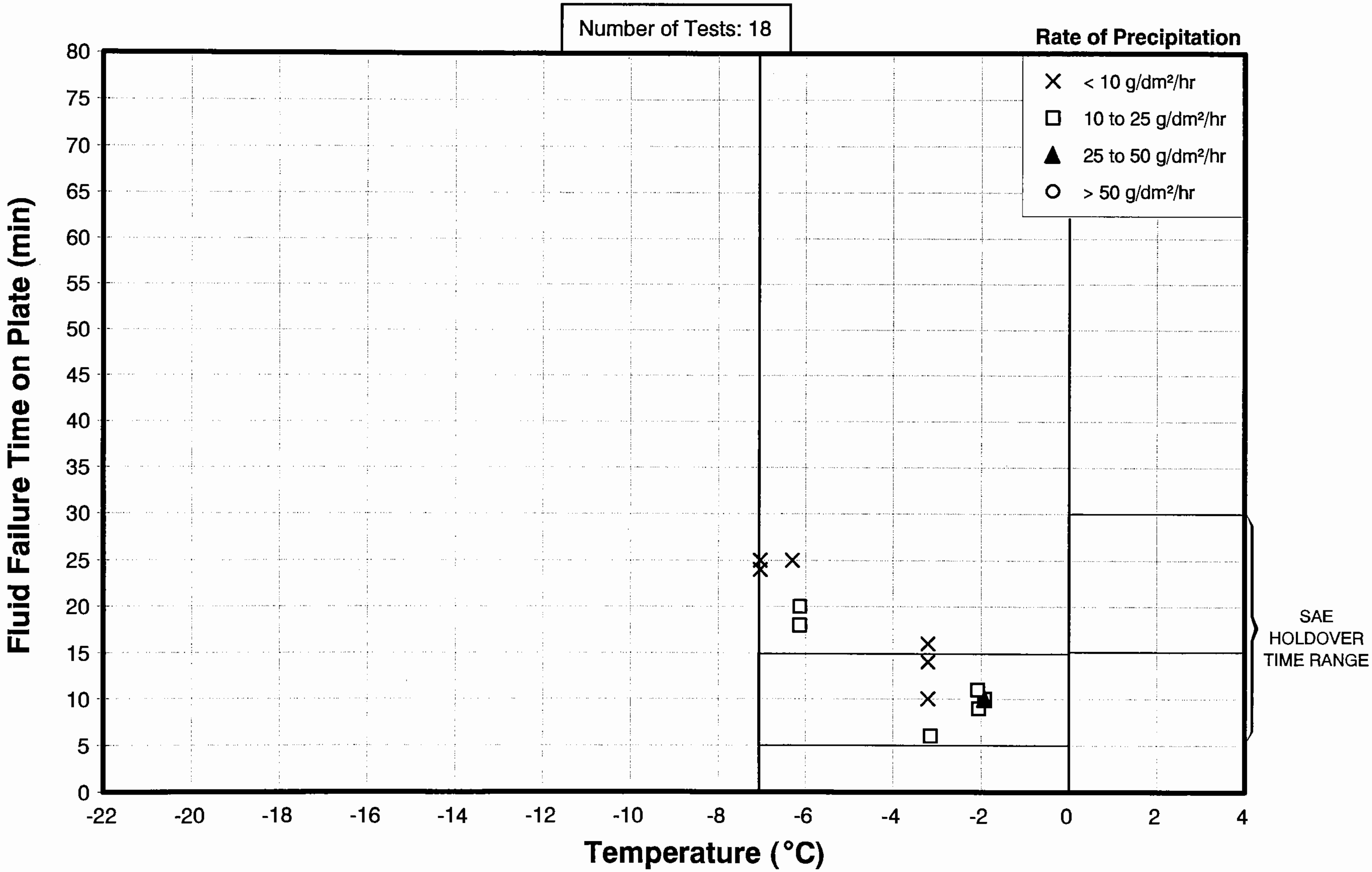
FIGURE 3.38

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE IV 50/50

NATURAL SNOW CONDITIONS

APS Data



cm1221\cons_hol\nat_snow\NS45_38.GRF

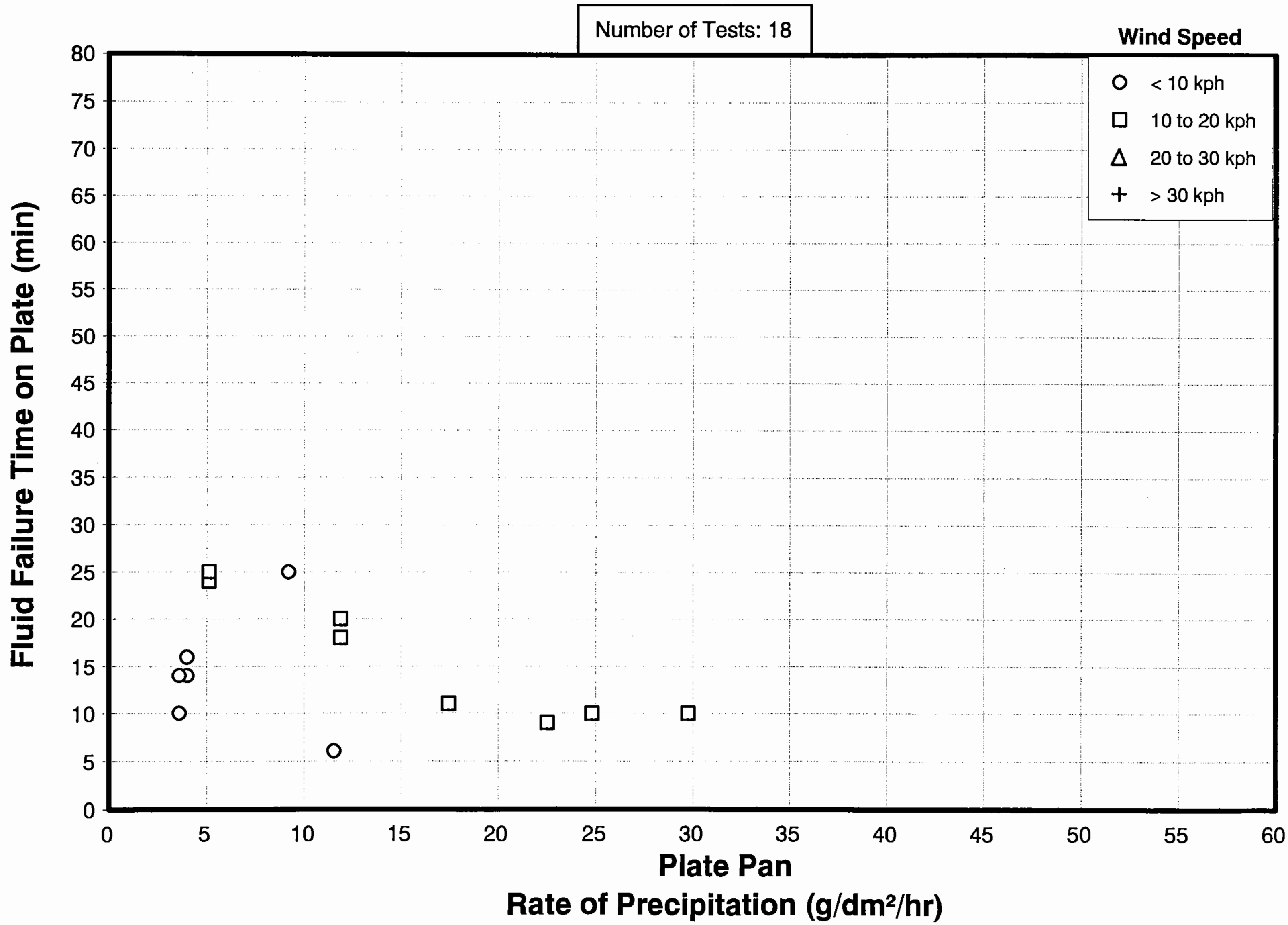
FIGURE 3.39

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50

NATURAL SNOW CONDITIONS

APS Data



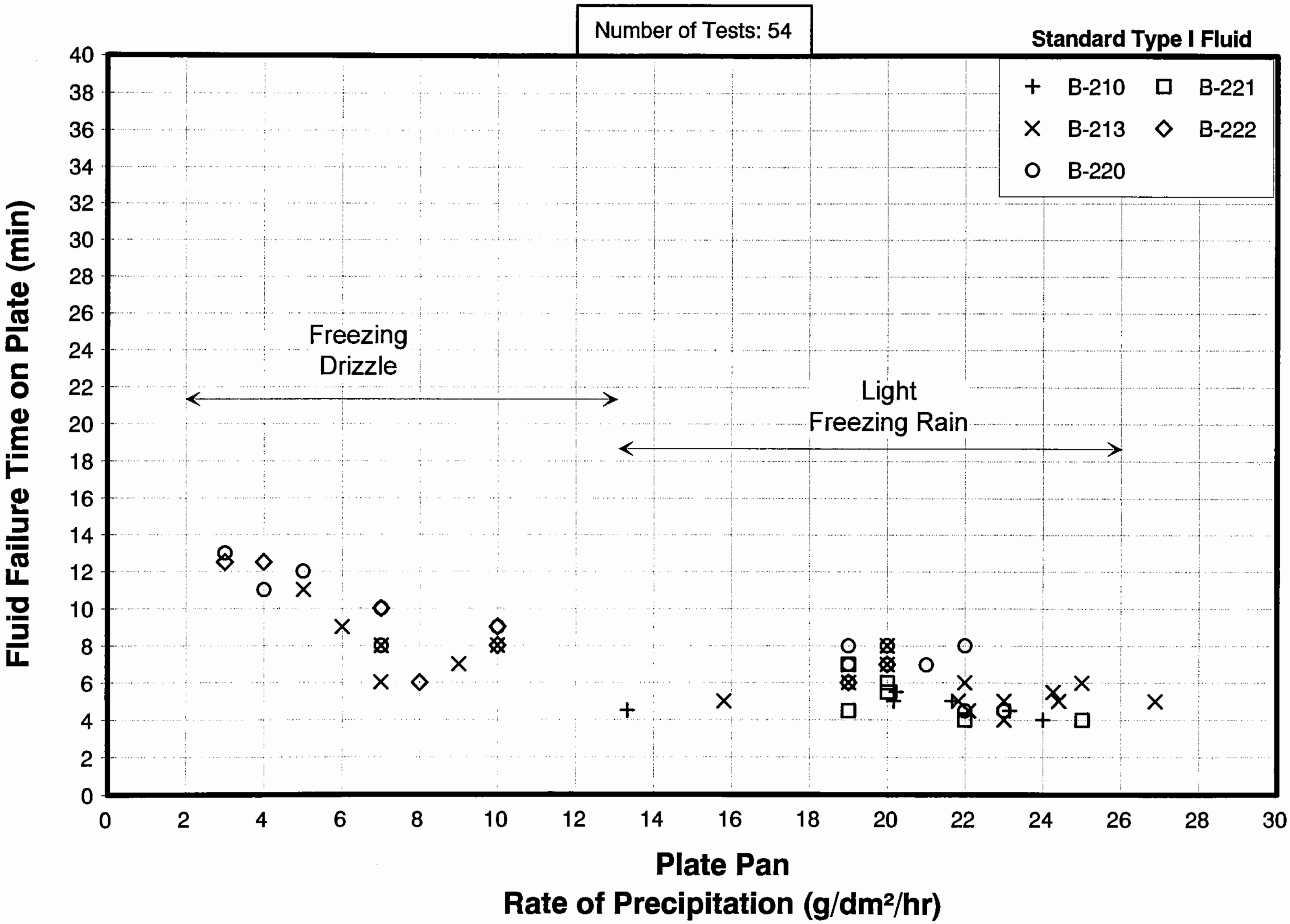
cm1222\cons_hot\nat_snow\NS45_39.GRF

FIGURE 3.40

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



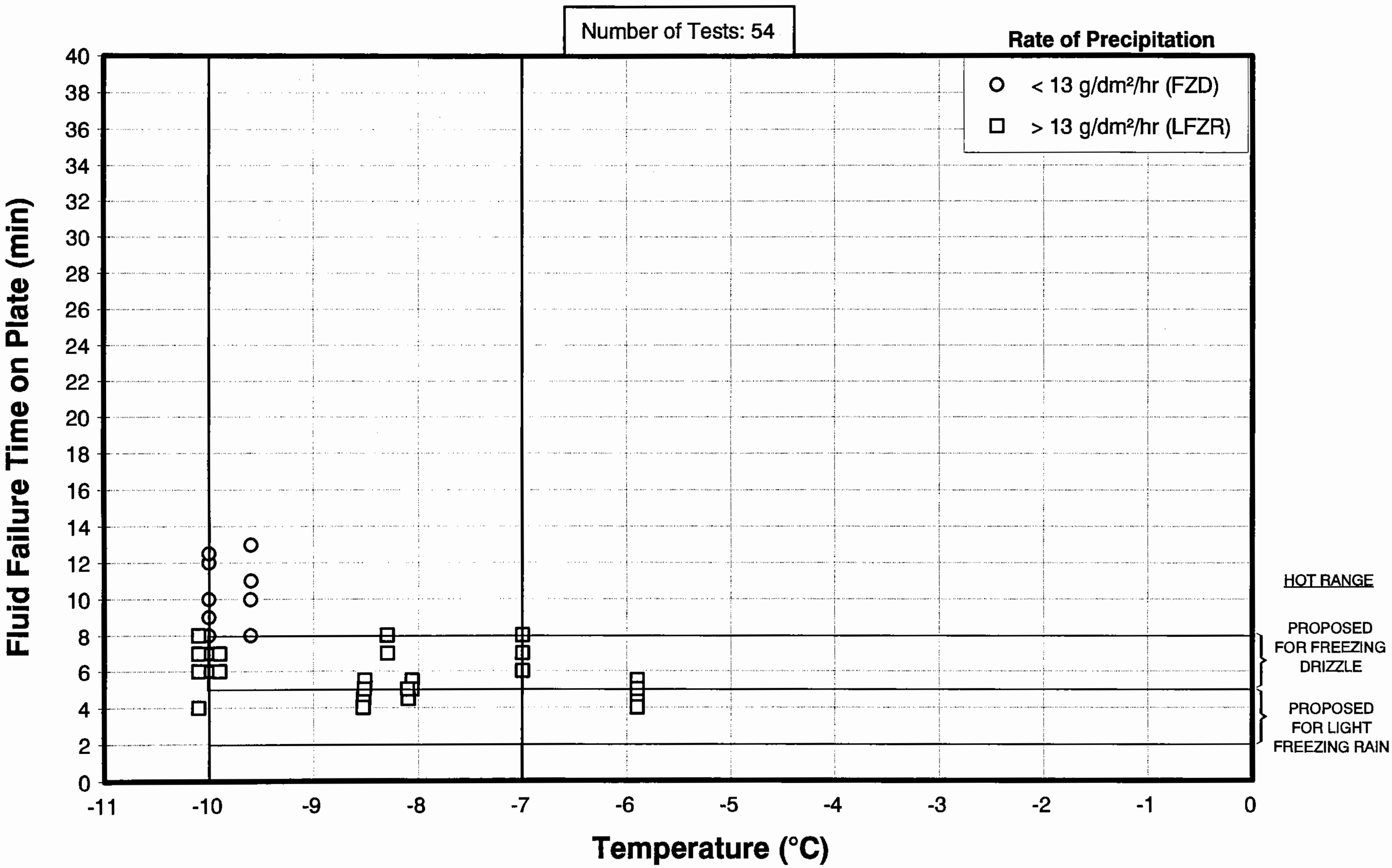
cm1222\cons_hot\llzr&fzd\LFZR1S40.GRF

FIGURE 3.41

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

STANDARD TYPE I

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



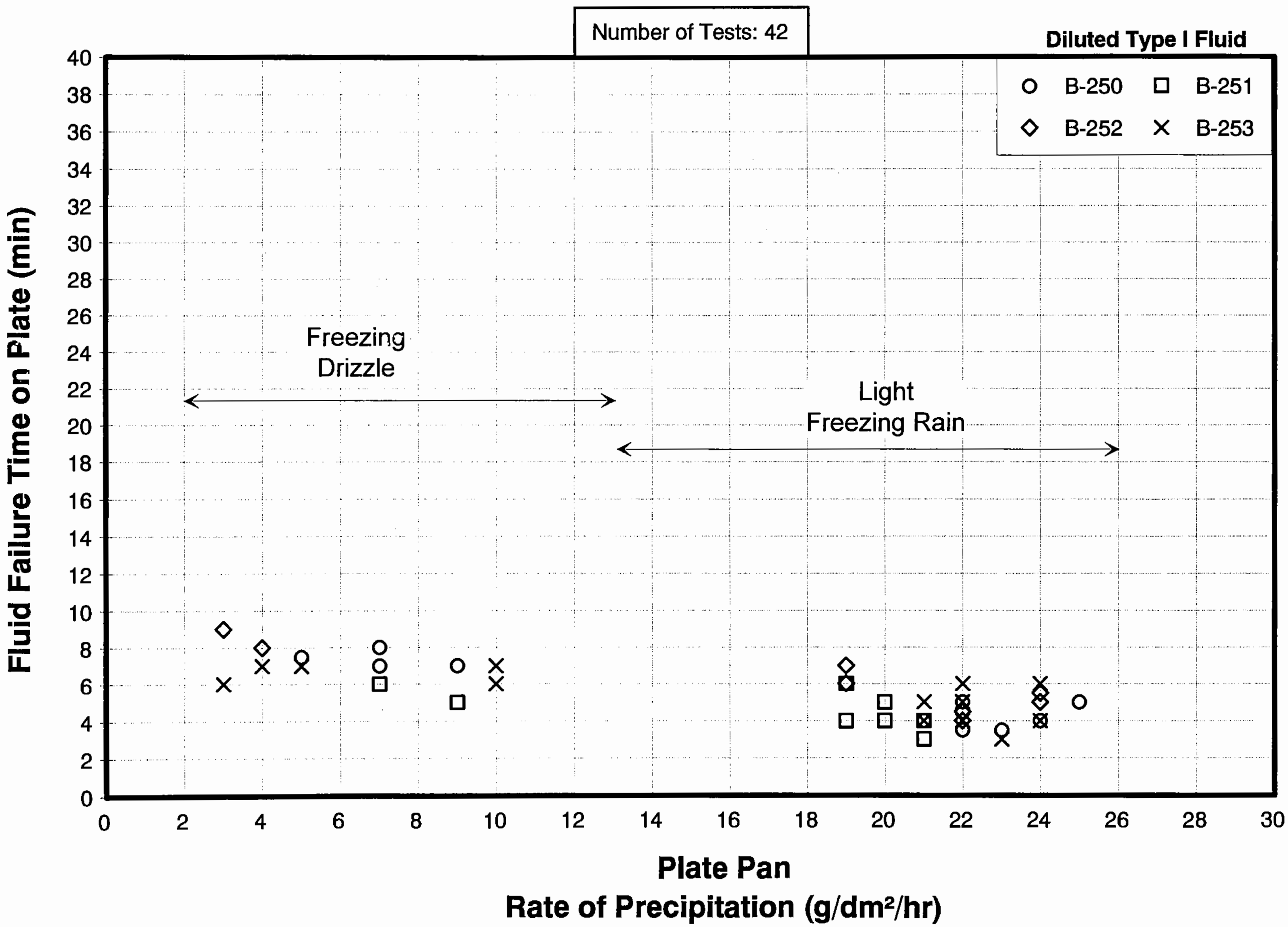
cm1222\cons_hot\fzr&fzd\LFZR1S41.GRF

FIGURE 3.42

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

DILUTED TYPE I

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



cm1222\corrs_hot\fzr&fzd\LFZR1D42.GRF

FIGURE 3.43

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

DILUTED TYPE I

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

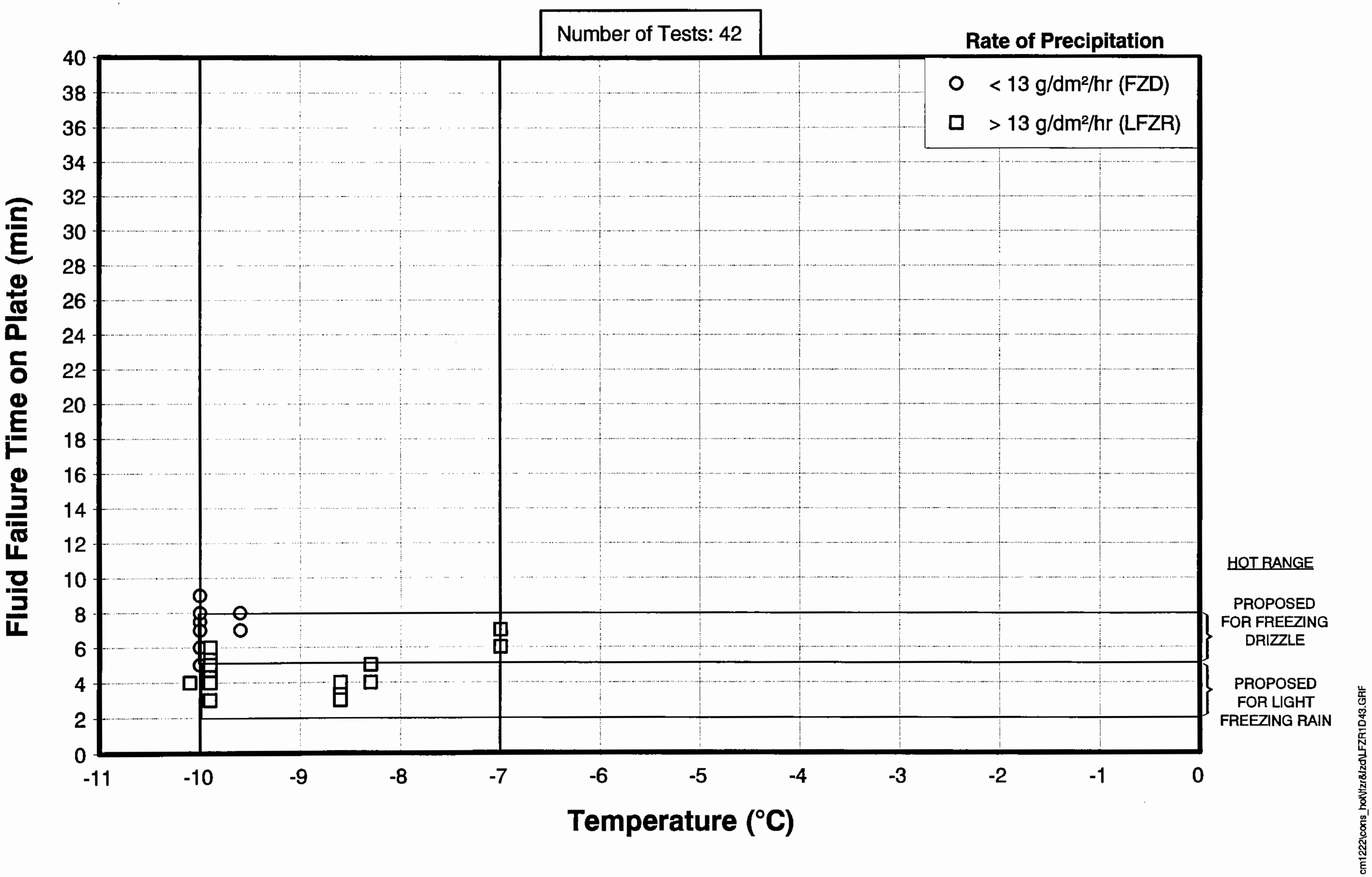
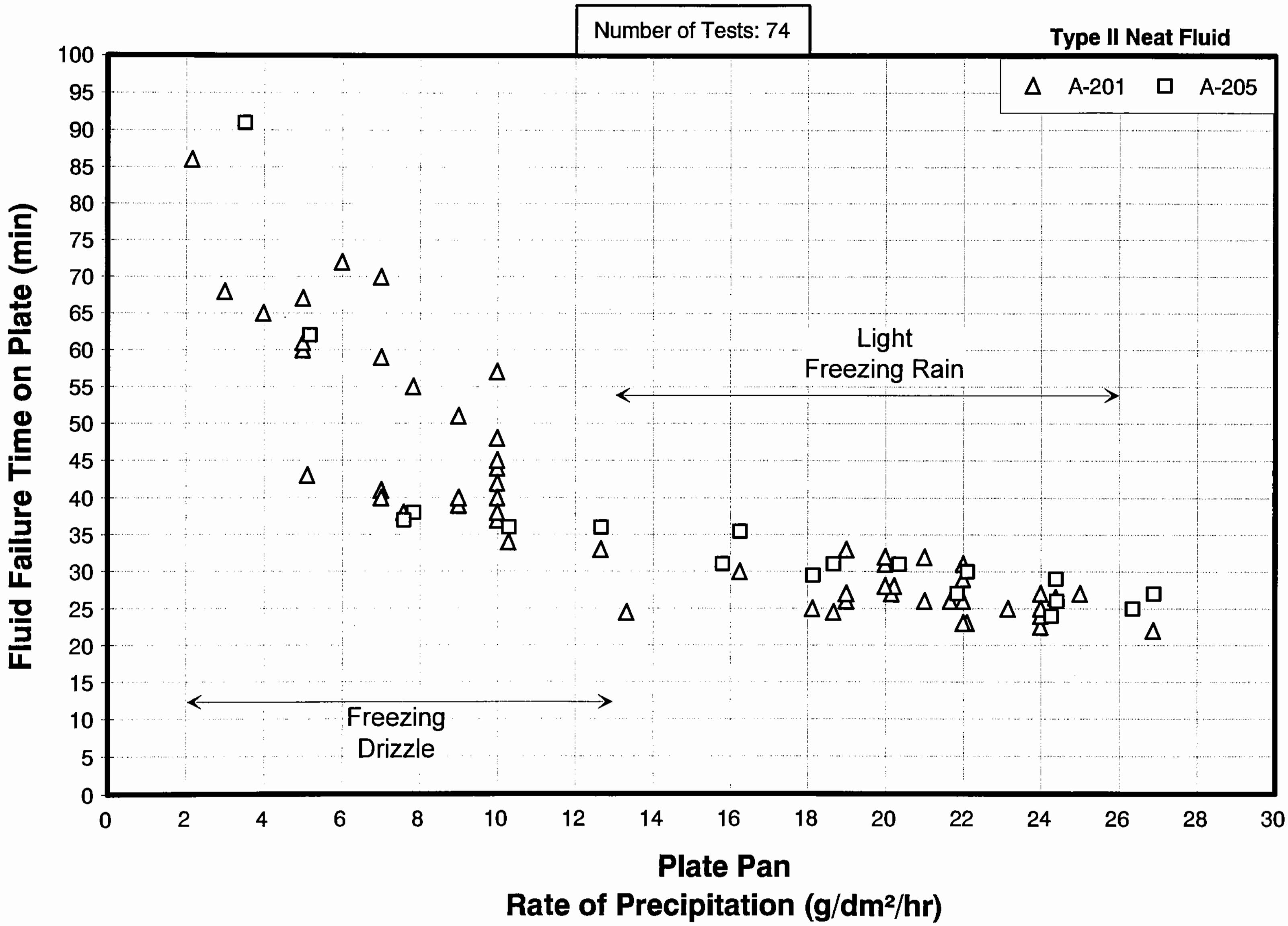


FIGURE 3.44

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



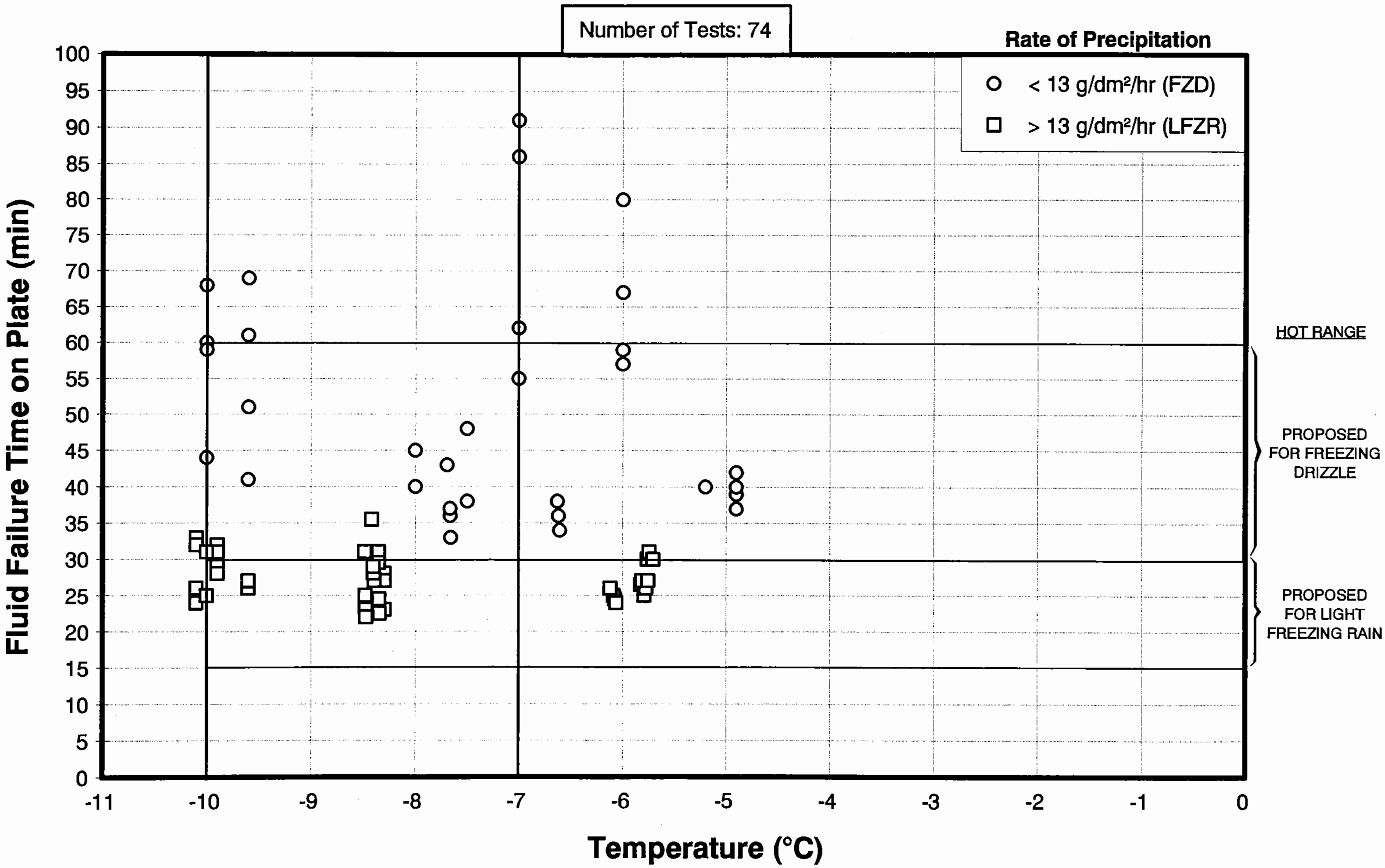
cm1222\cons_hot\fzr&lzd\LFZR2144.GRF

FIGURE 3.45

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II NEAT

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



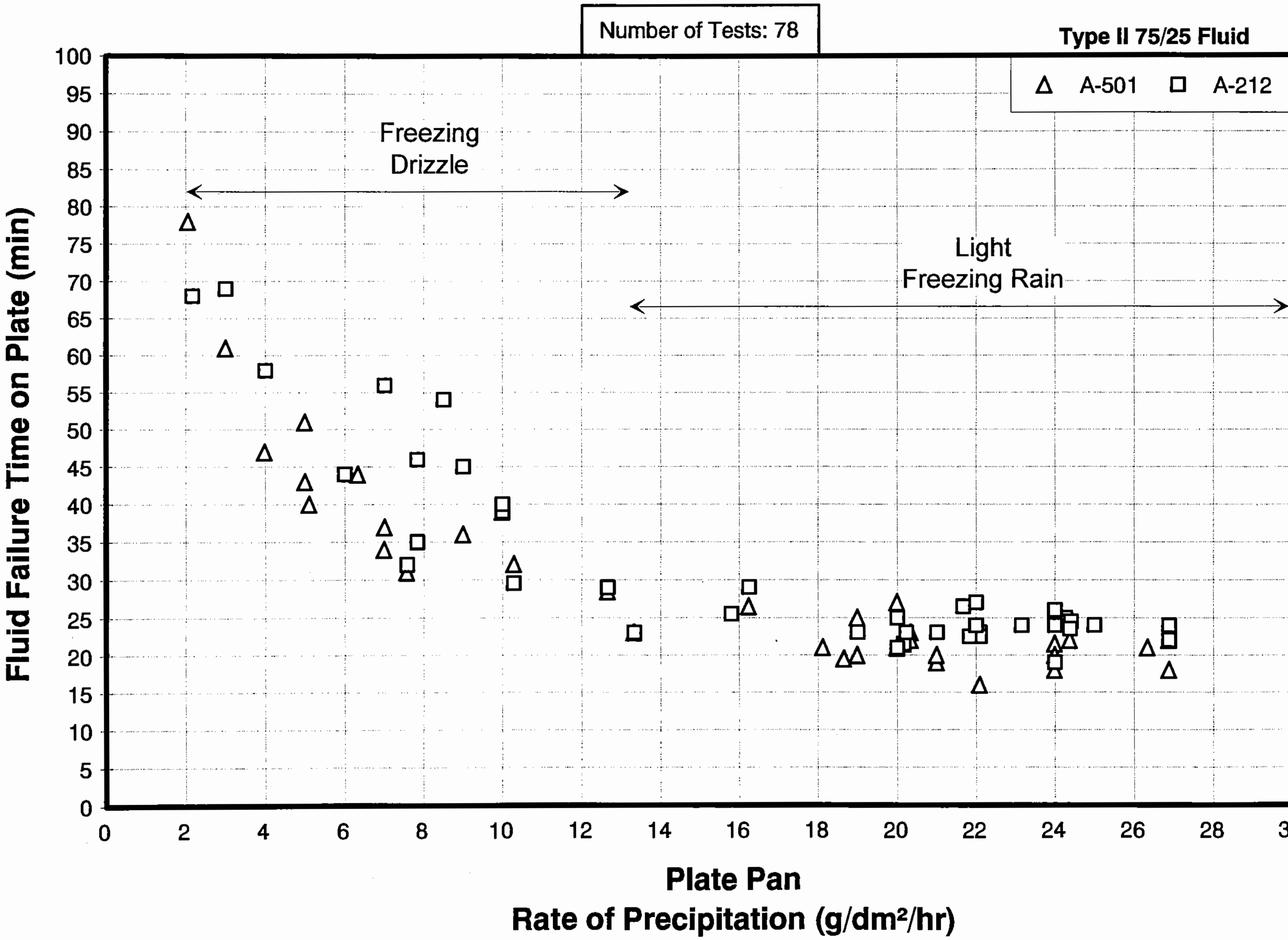
cm1222\cons_hot\lfzr&fzd\LFZR2145.GRF

FIGURE 3.46

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 75/25

FREEZING DRIZZLE AND LIGHT FREEZING RAIN



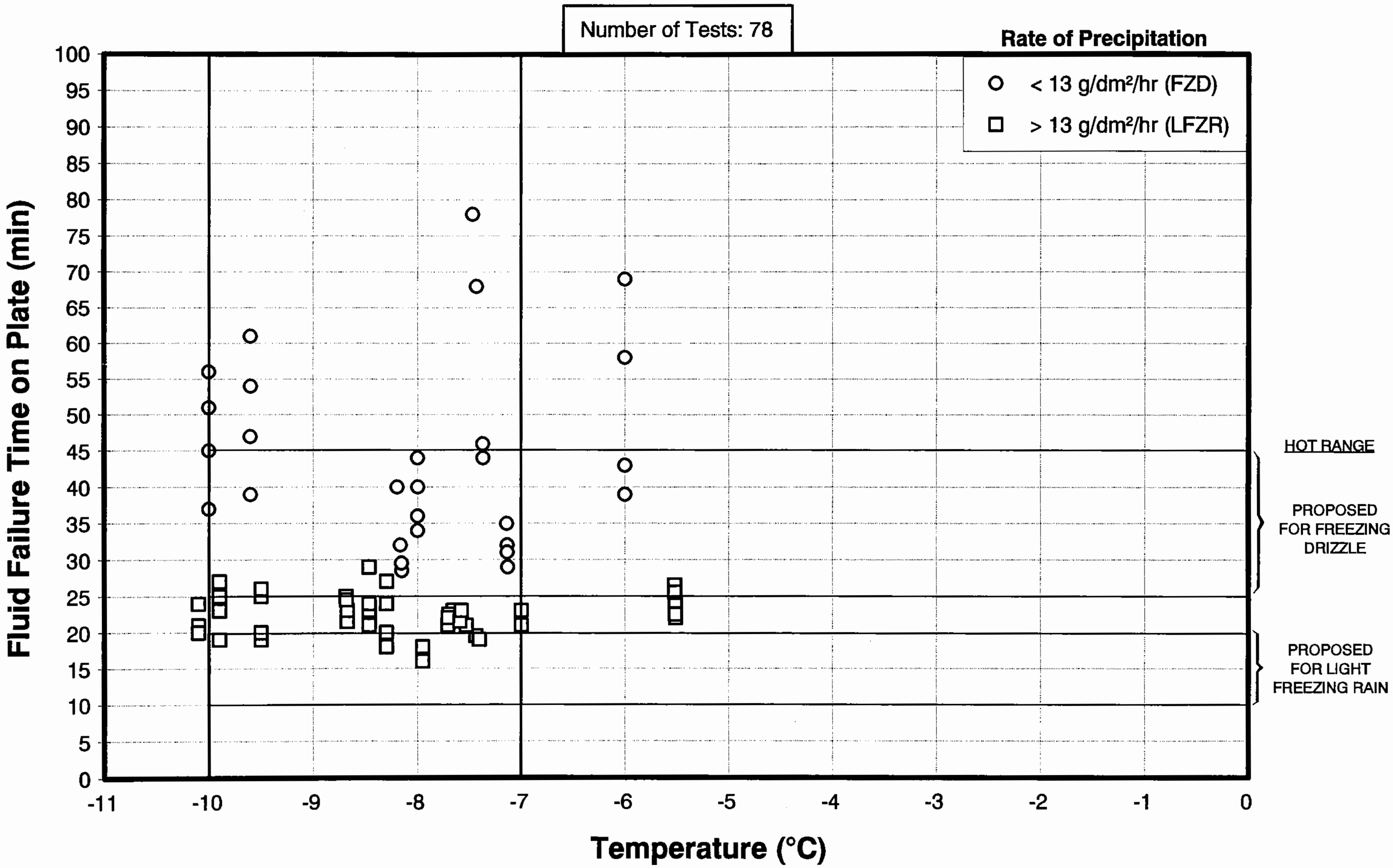
cm1222\cons_hot\fzr&fzd\LFZR2746.grf

FIGURE 3.47

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II 75/25

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



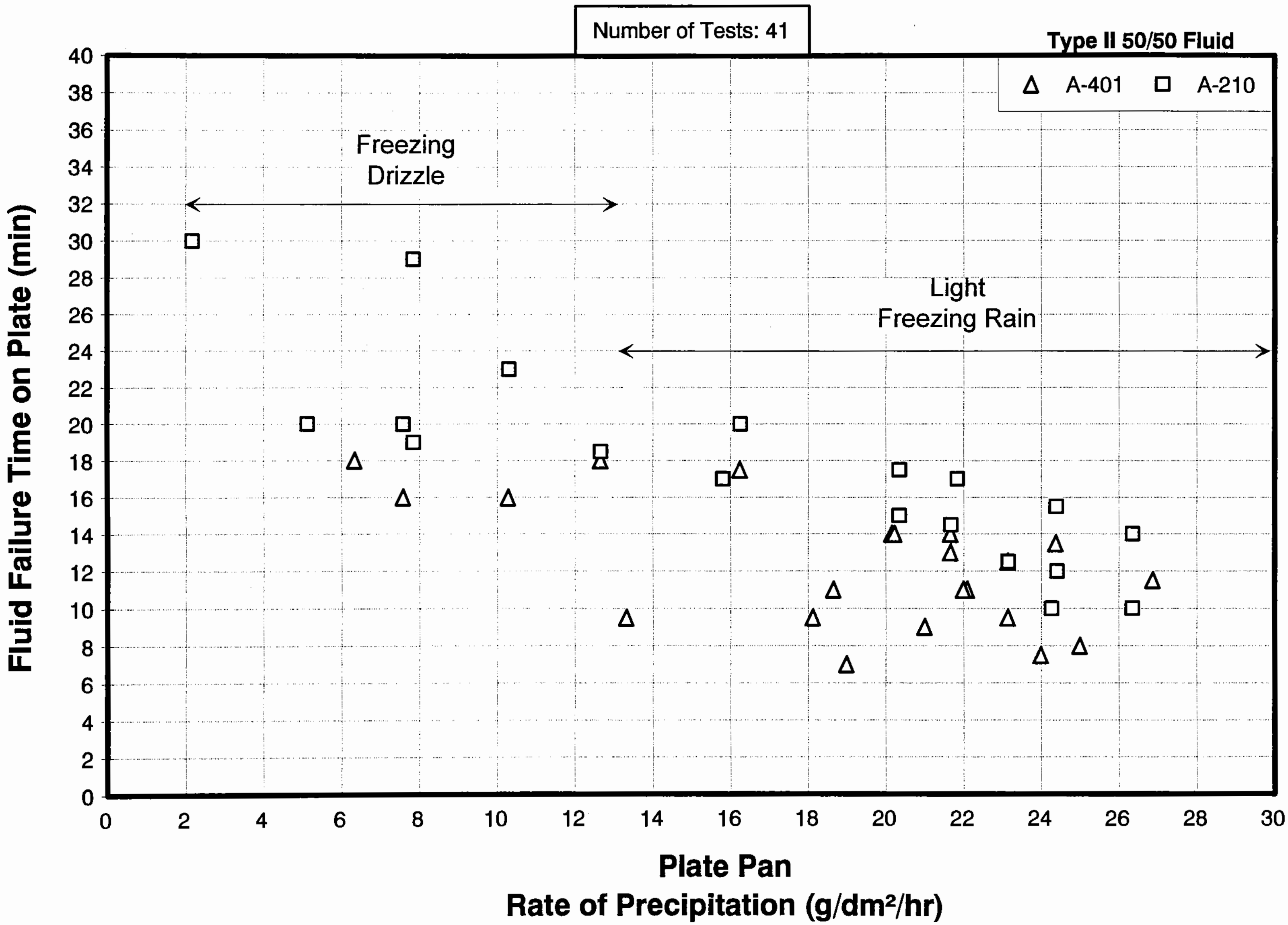
cm1222\cons_hot\fzr&fzd\LFZR2747.GRF

FIGURE 3.48

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 50/50

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



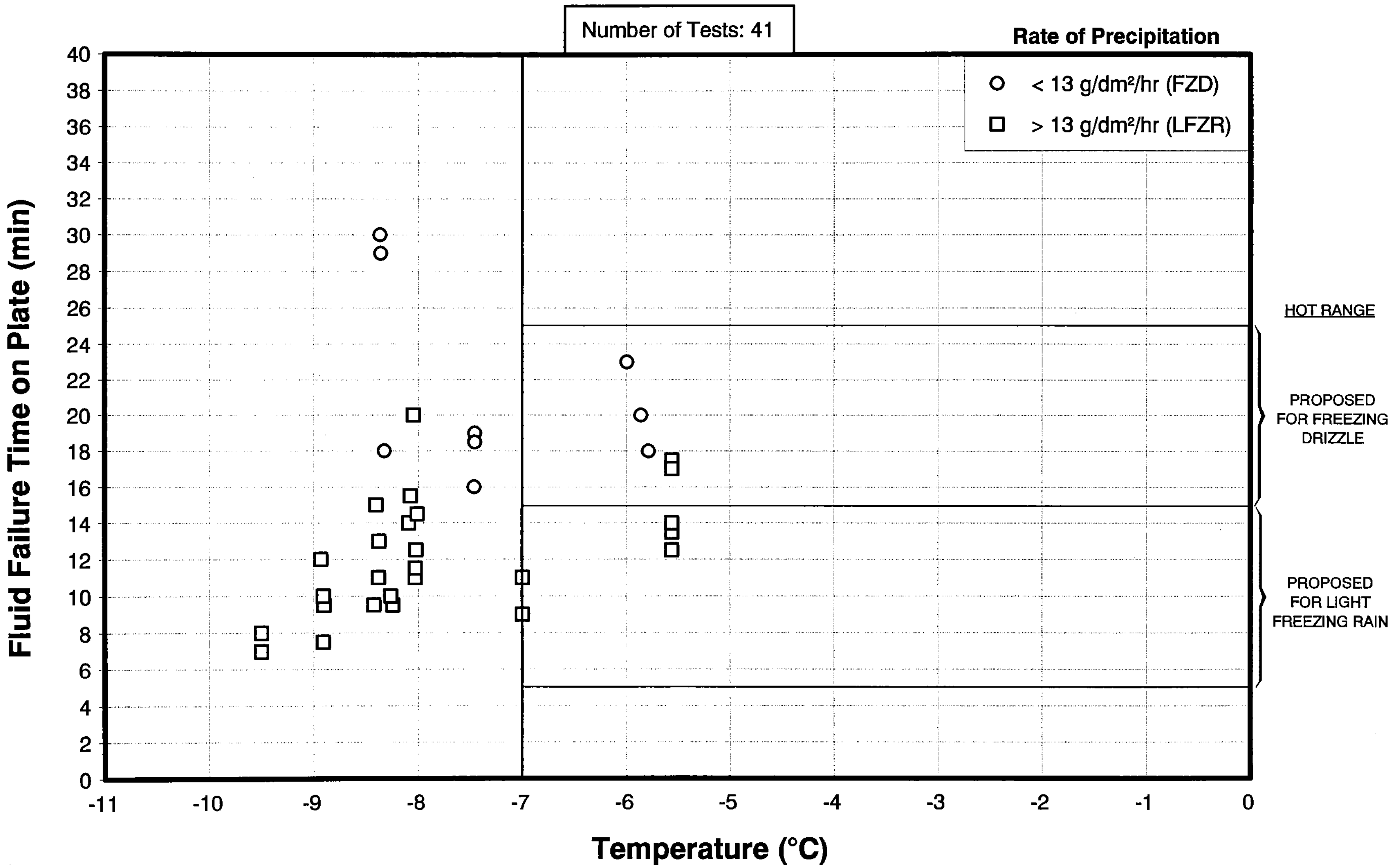
cm1222\cons_hot\fzr&fzd\LFZR2548.GRF

FIGURE 3.49

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II 50/50

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



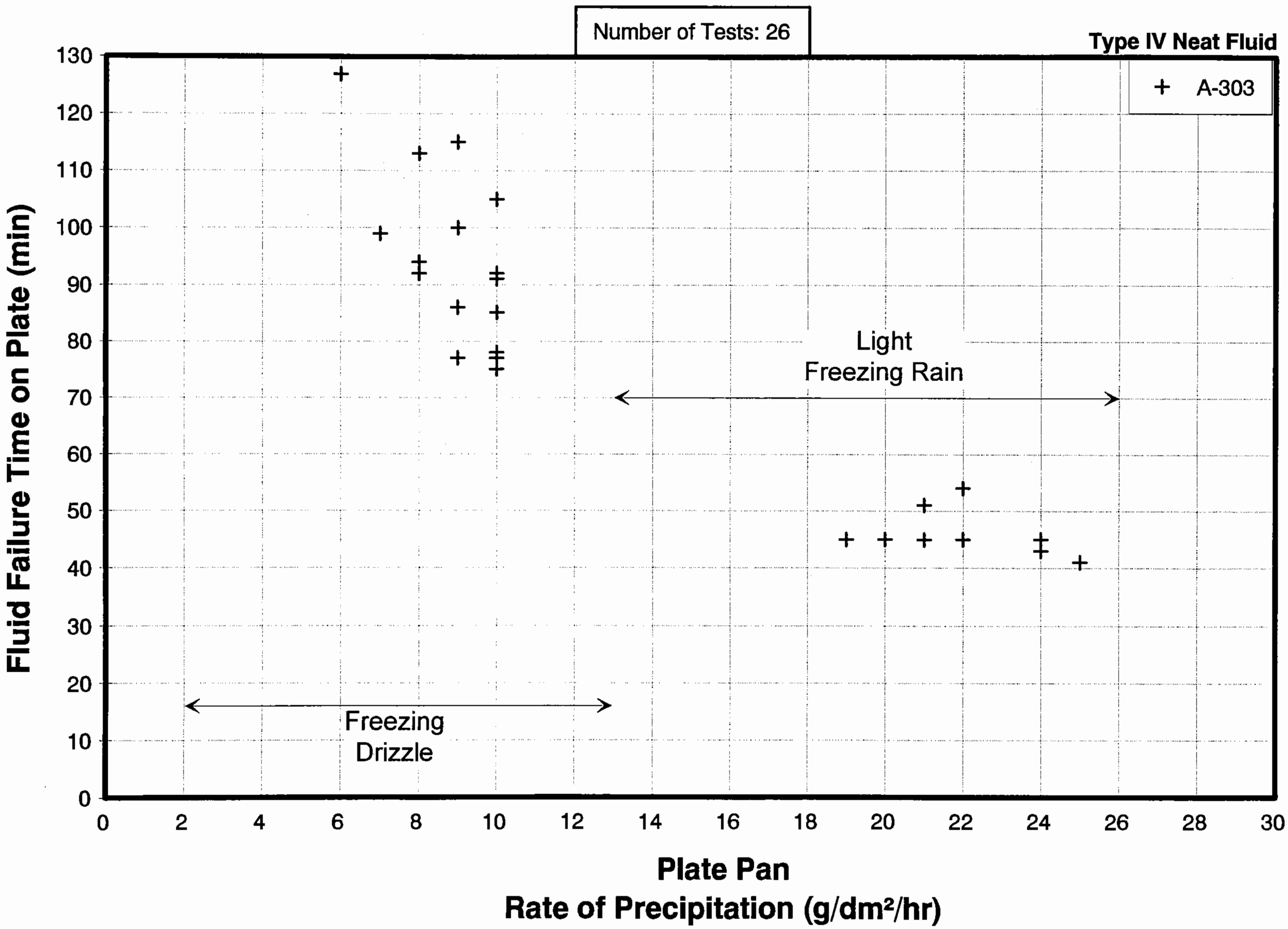
cm1222\cons_hot\lzr&fzd\LFZR2549.GRF

FIGURE 3.50

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

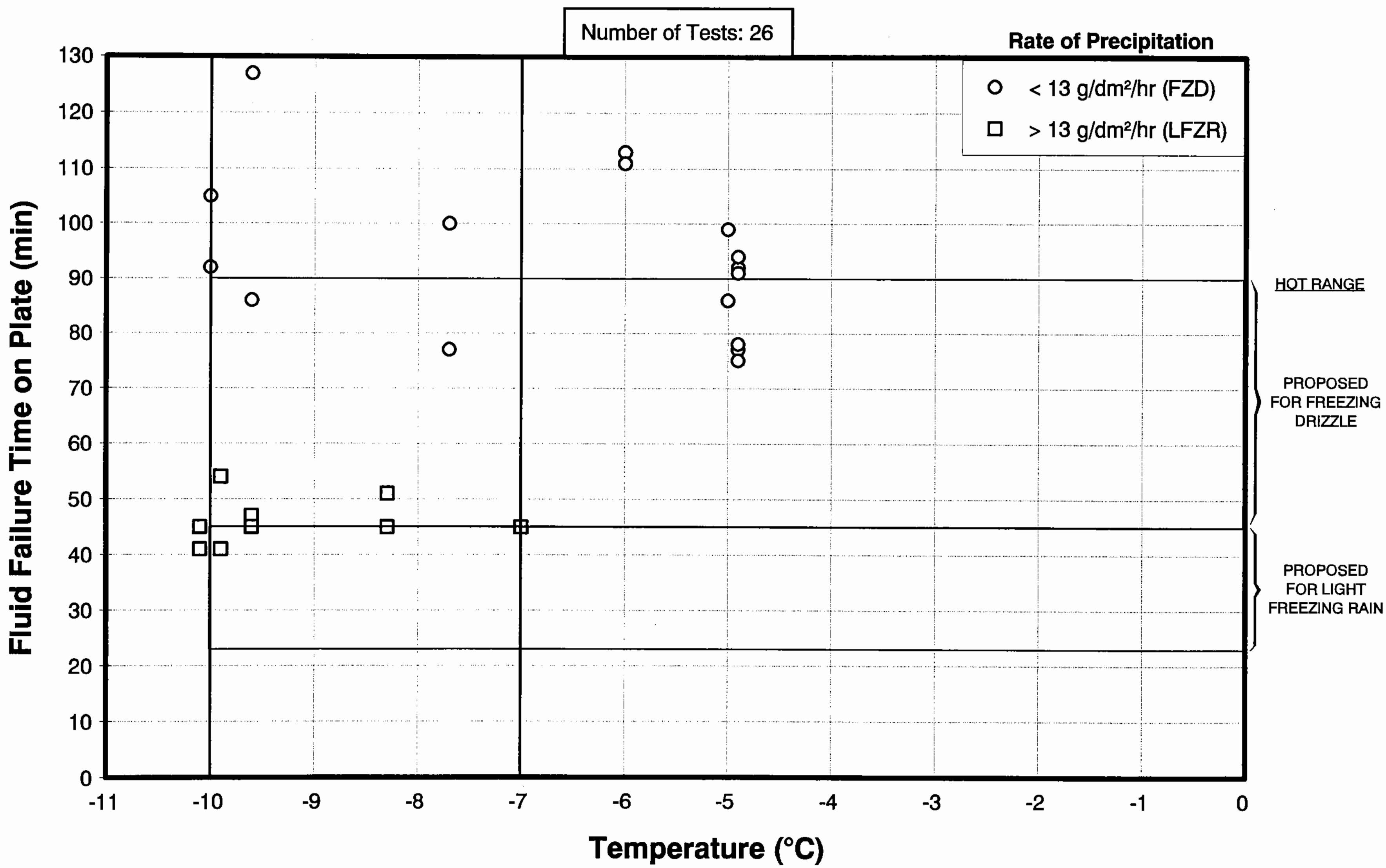
TYPE IV NEAT

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



cm1222\cons_hot\fzr&zd\LFZR4150.GRF

FIGURE 3.51
EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME
TYPE IV NEAT
SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



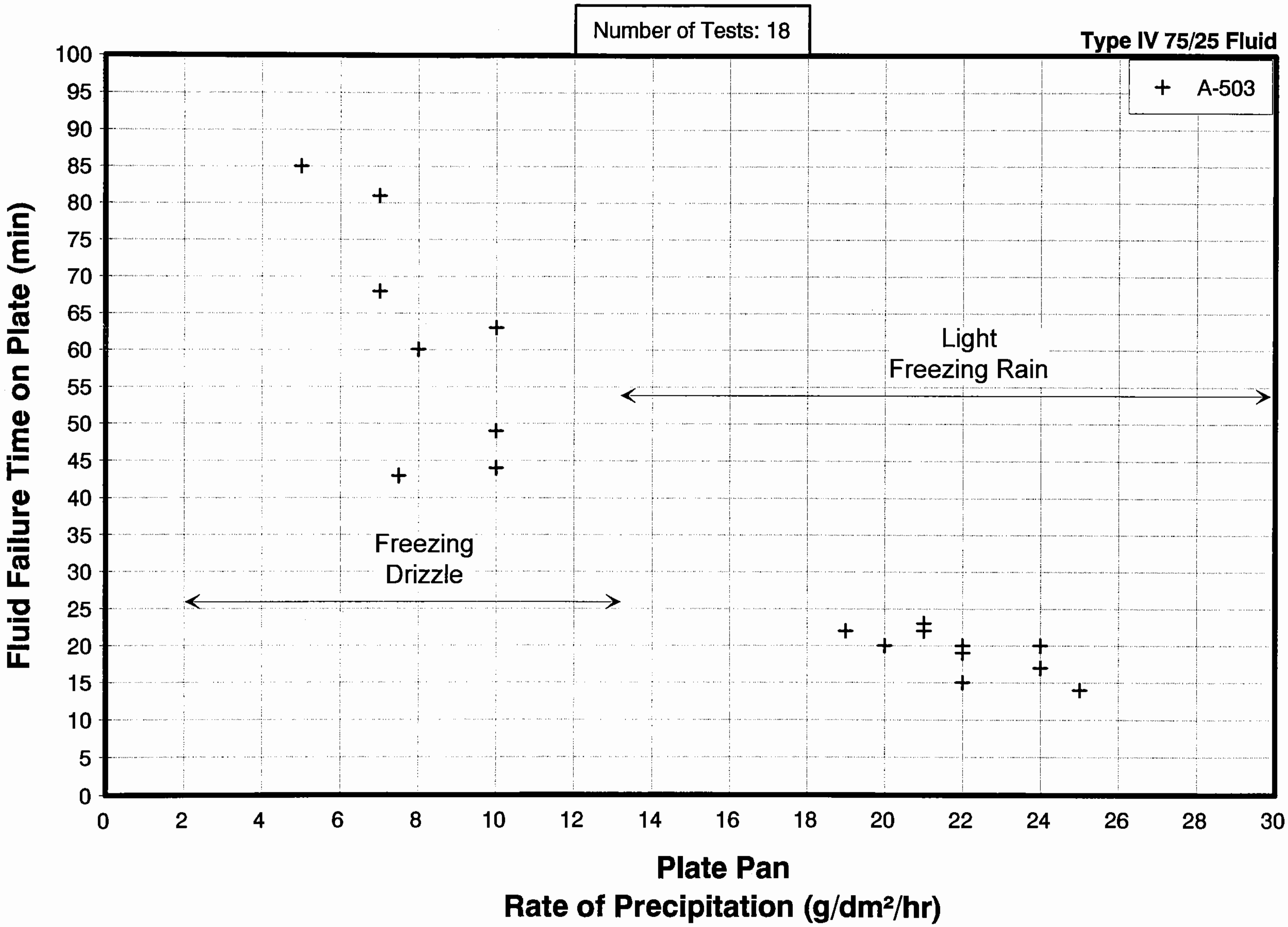
cm1222\cons_hot\lfzr&fzd\LFZR4151.GRF

FIGURE 3.52

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25

FREEZING DRIZZLE AND LIGHT FREEZING RAIN



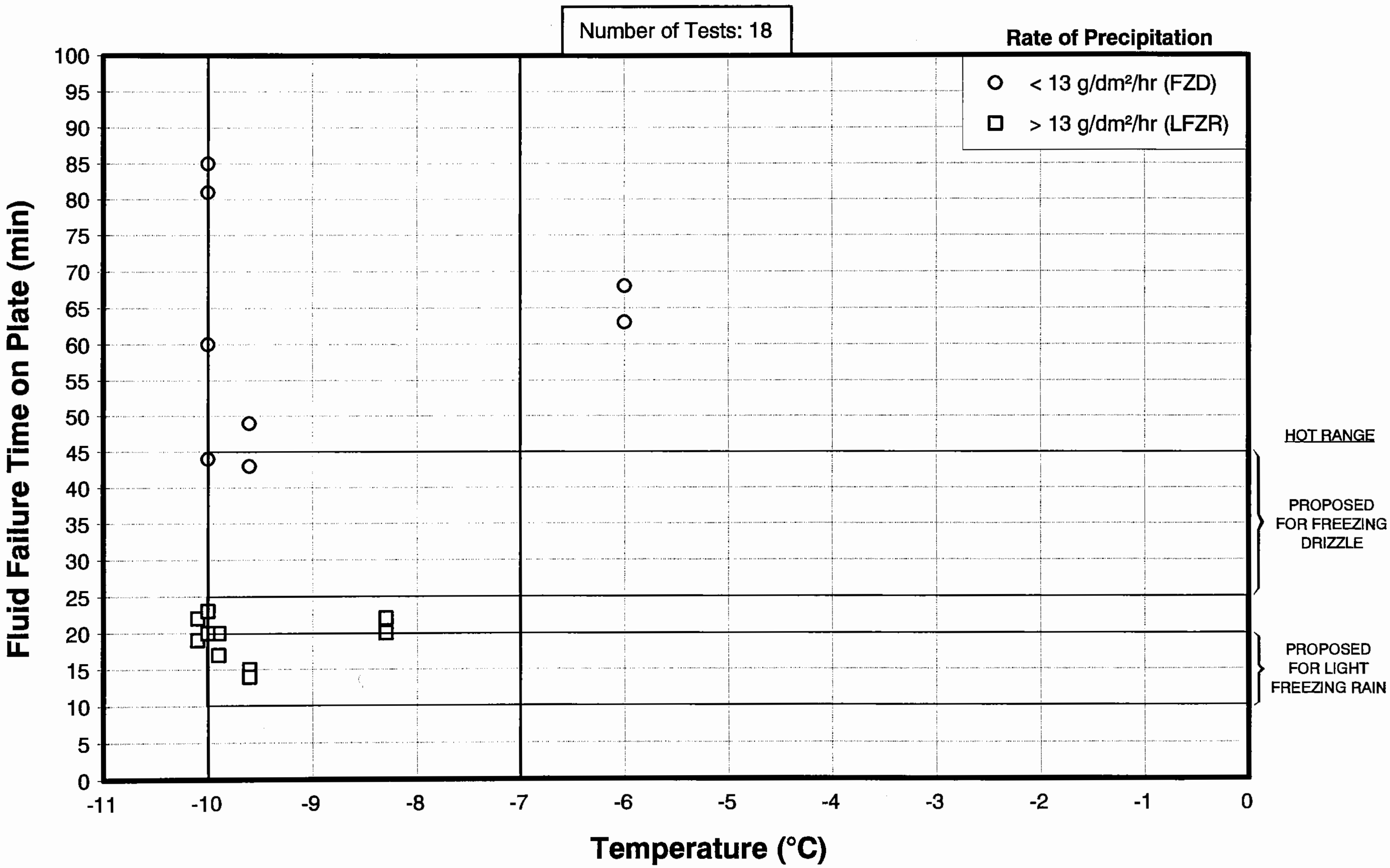
cm1222\cons_hot\fzr&fzd\LFZR4752.grf

FIGURE 3.53

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE IV 75/25

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



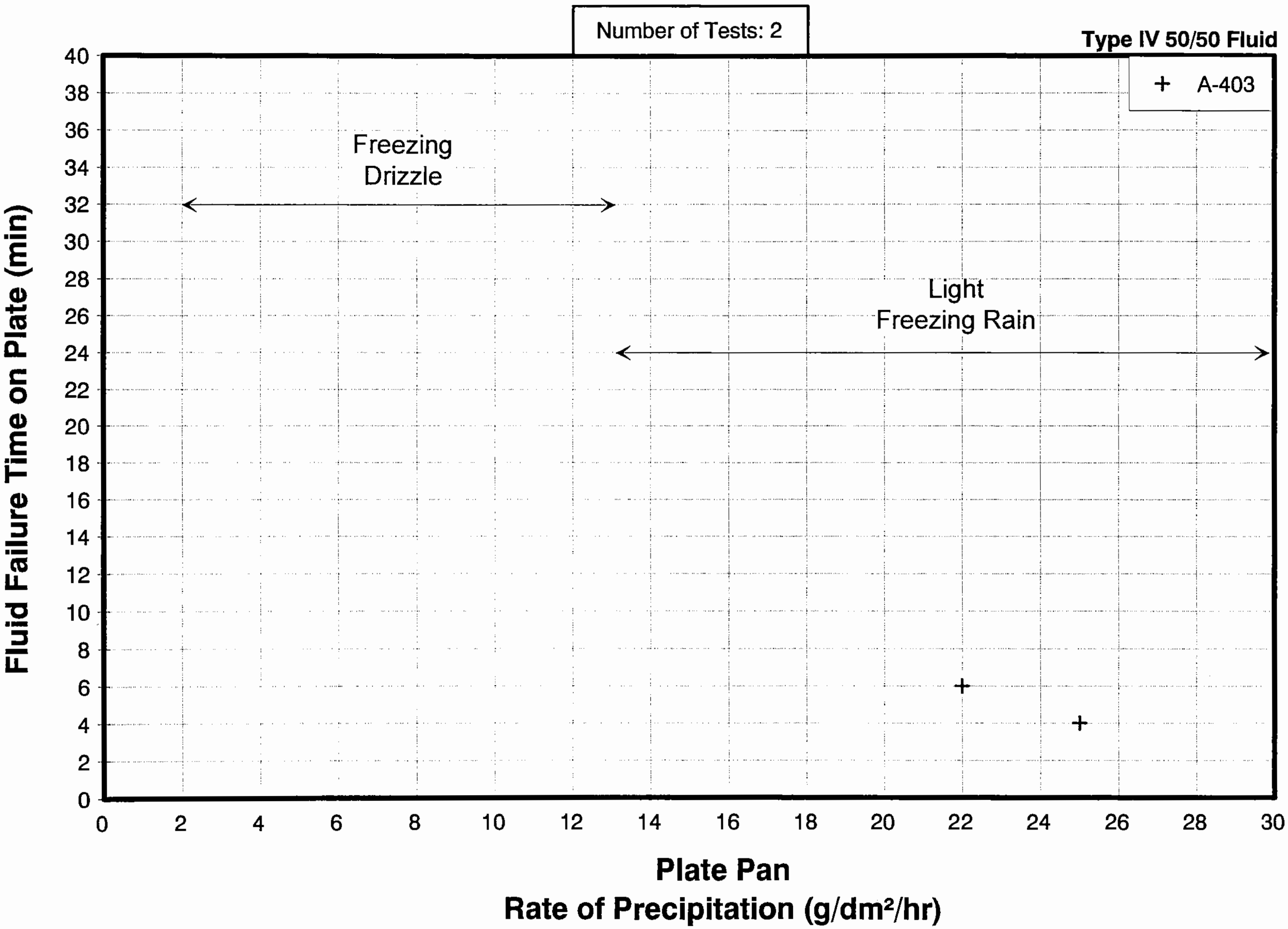
cm1222\cons_hot\fzr&fzd\LFZR4753.GRF

FIGURE 3.54

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



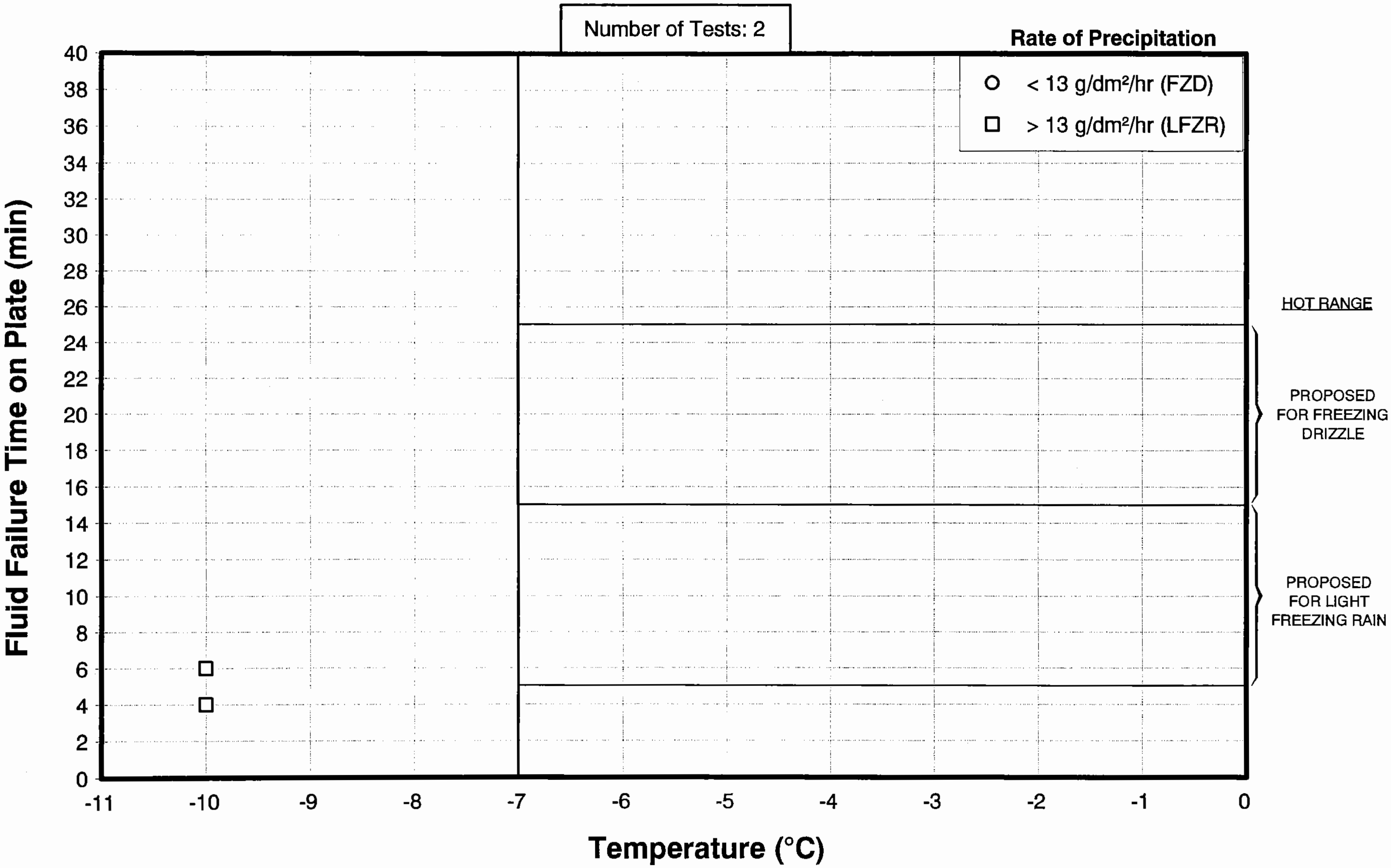
cm1222\cons_hol\lzr&fzd\LFZR4554.GRF

FIGURE 3.55

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE IV 50/50

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN



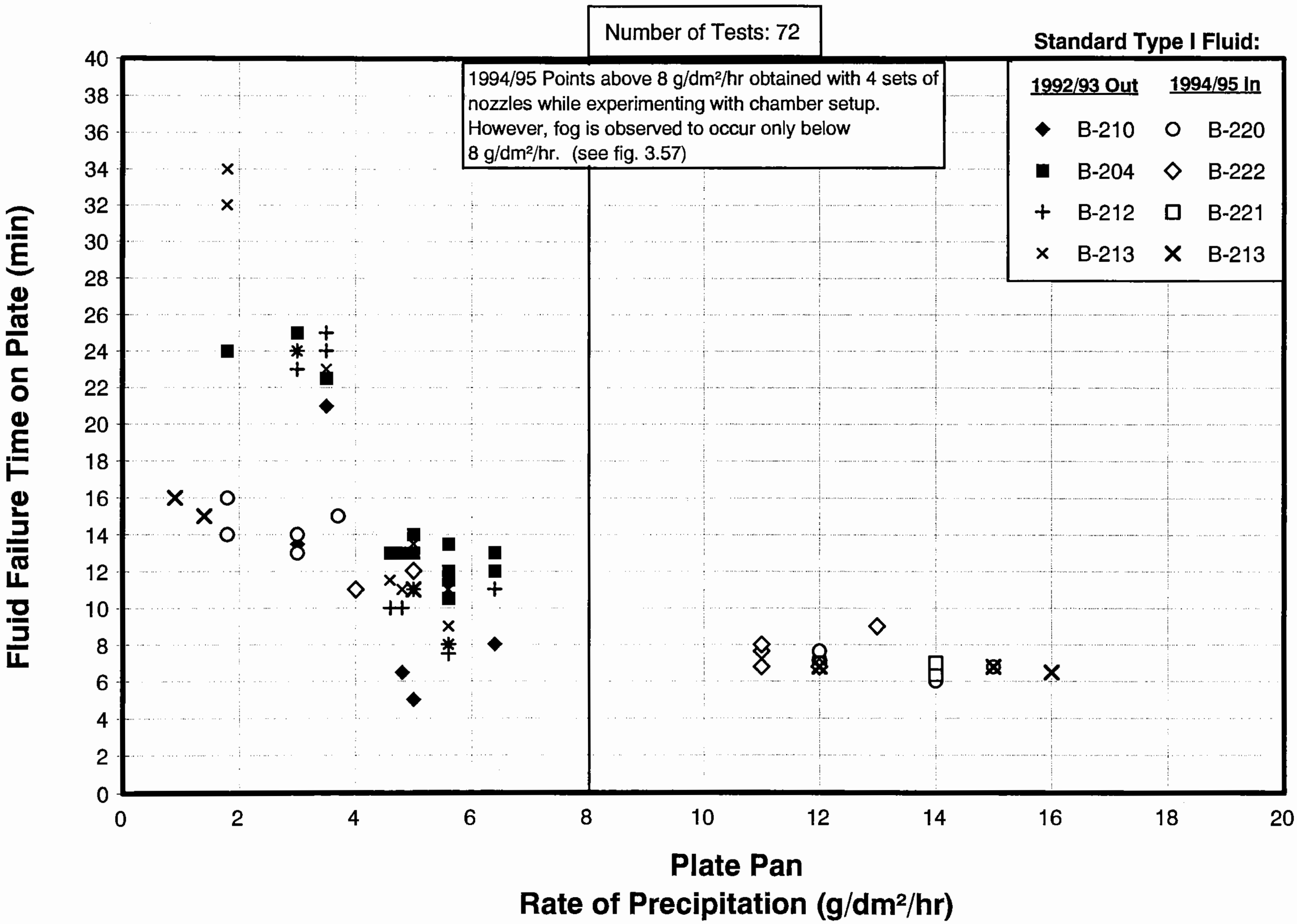
cm1222\cons_hot\lfzr&fzd\LFZR4555.GRF

FIGURE 3.56

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

SIMULATED FREEZING FOG



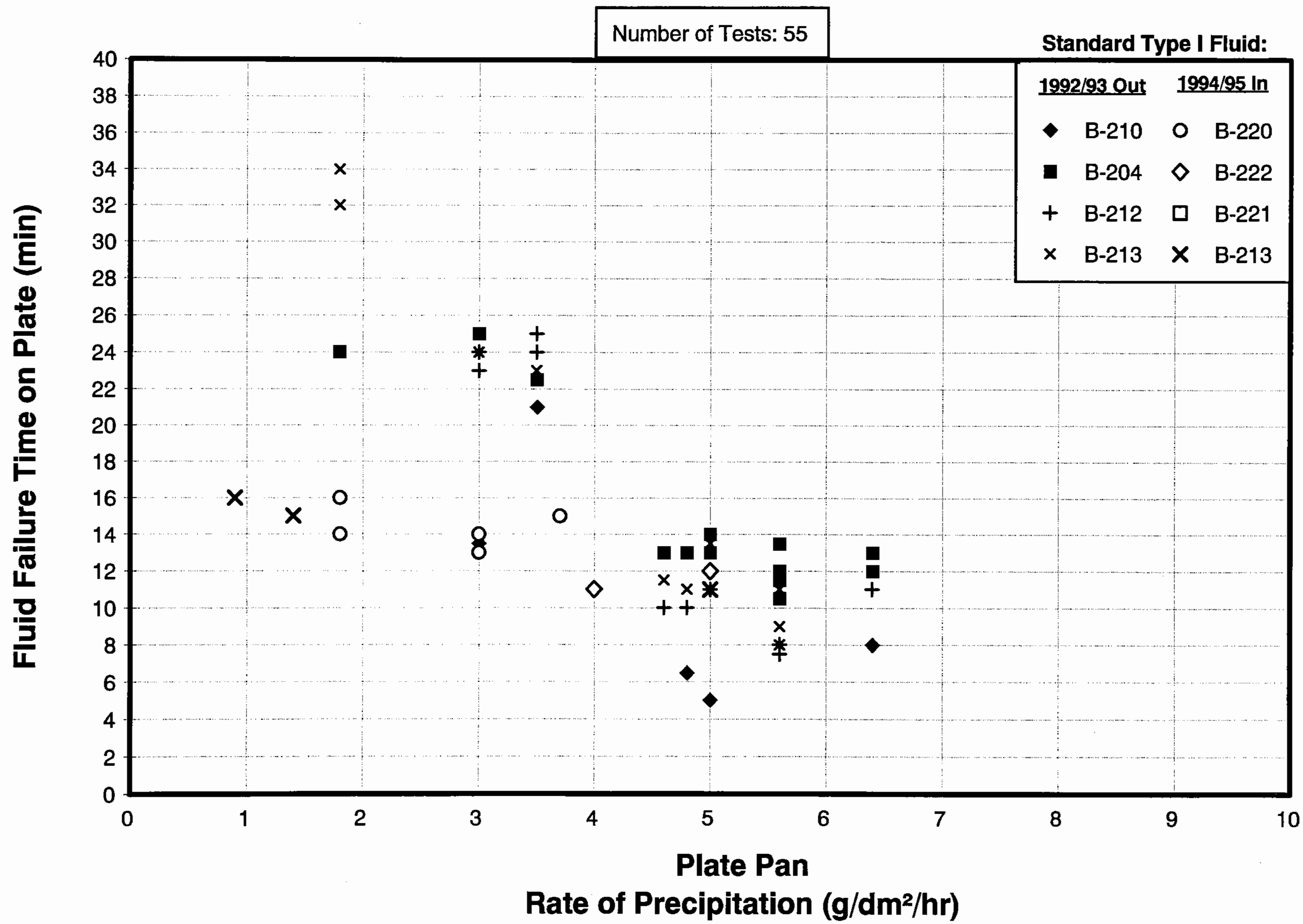
cm1222\cons_hot\fzfog\FZF1S_56.GRF

FIGURE 3.57

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

SIMULATED FREEZING FOG



cm1222\cons_hot\zfog\FZF1S_57.GRF

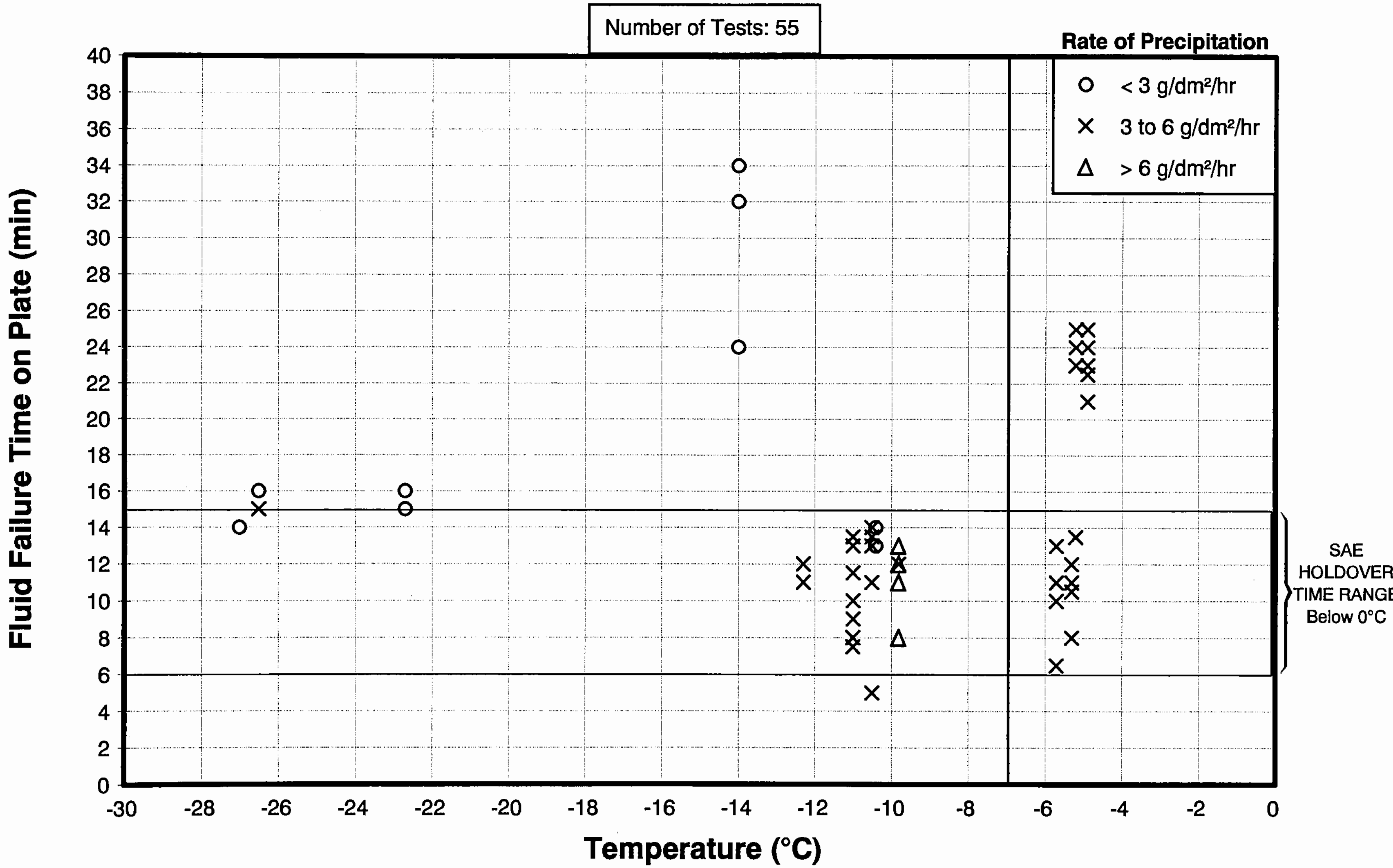
FIGURE 3.58

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

STANDARD TYPE I

SIMULATED FREEZING FOG

1992/93 & 1994/95 TEST SEASON



cm1222\cons_hot\fzfog\FZF1S_58.GRF

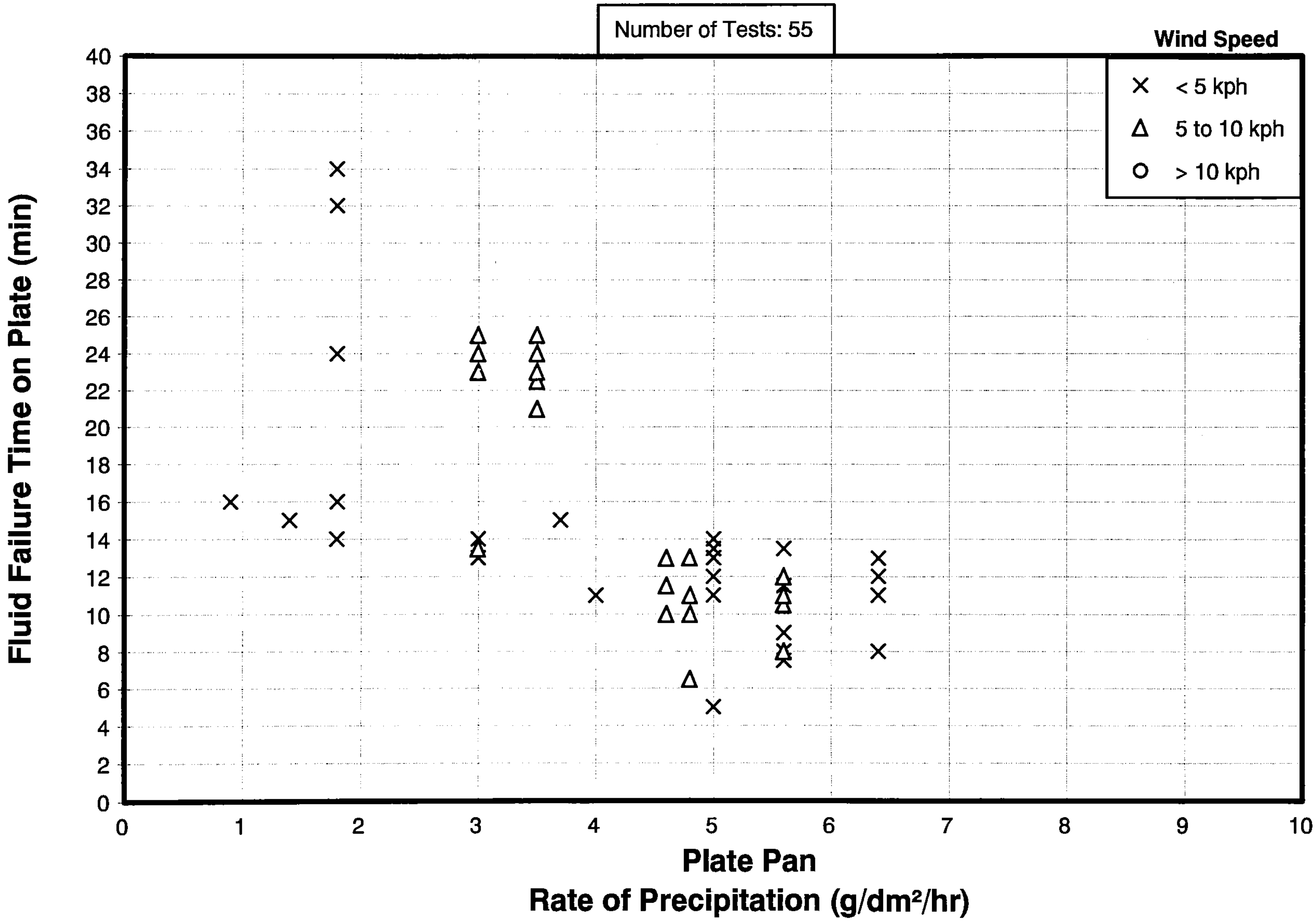
FIGURE 3.59

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

STANDARD TYPE I

SIMULATED FREEZING FOG

1992/93 & 1994/95 TEST SEASON



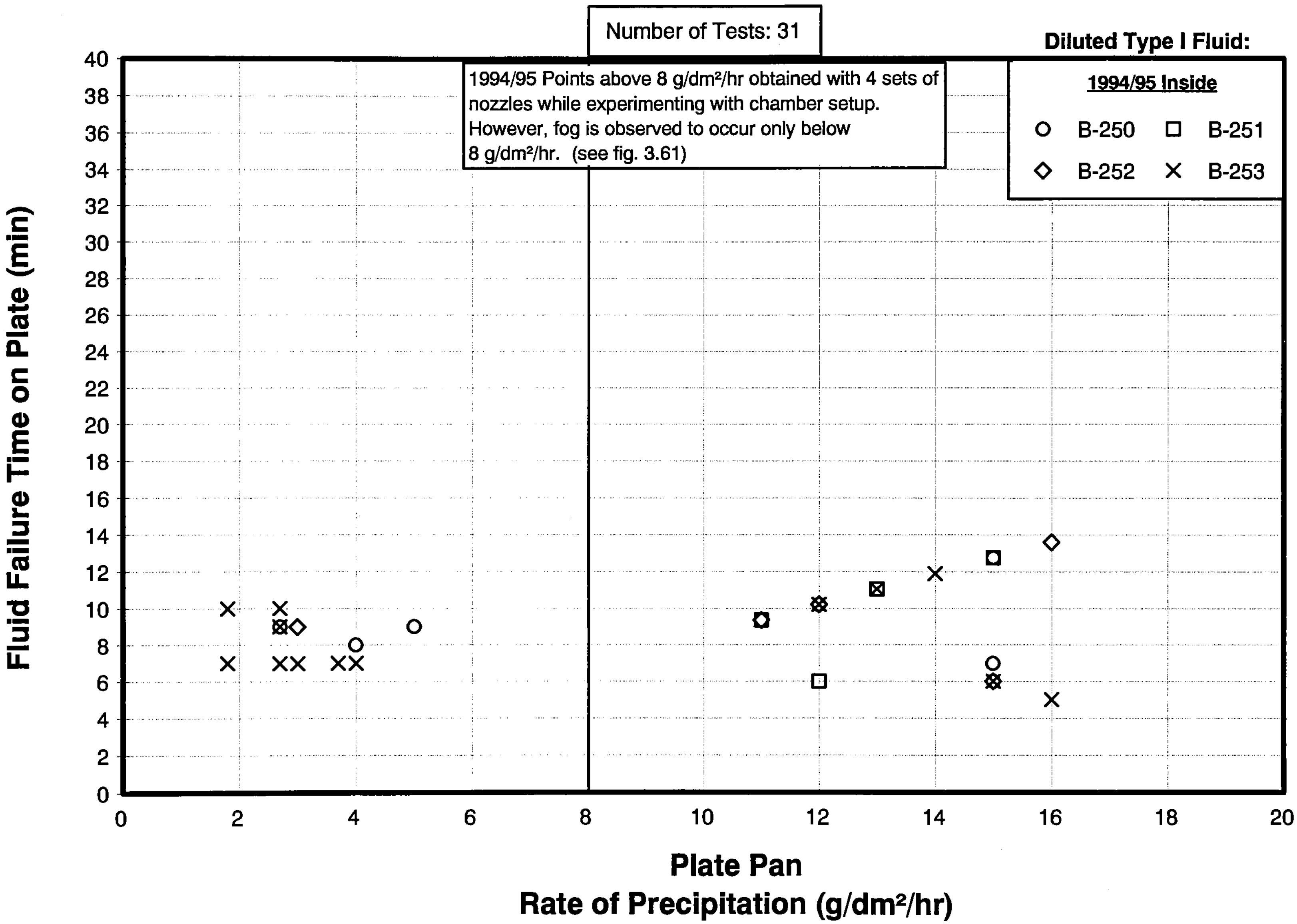
cm1222\cons_hot\zfog\FZF1S_59.GRF

FIGURE 3.60

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

DILUTED TYPE I

SIMULATED FREEZING FOG



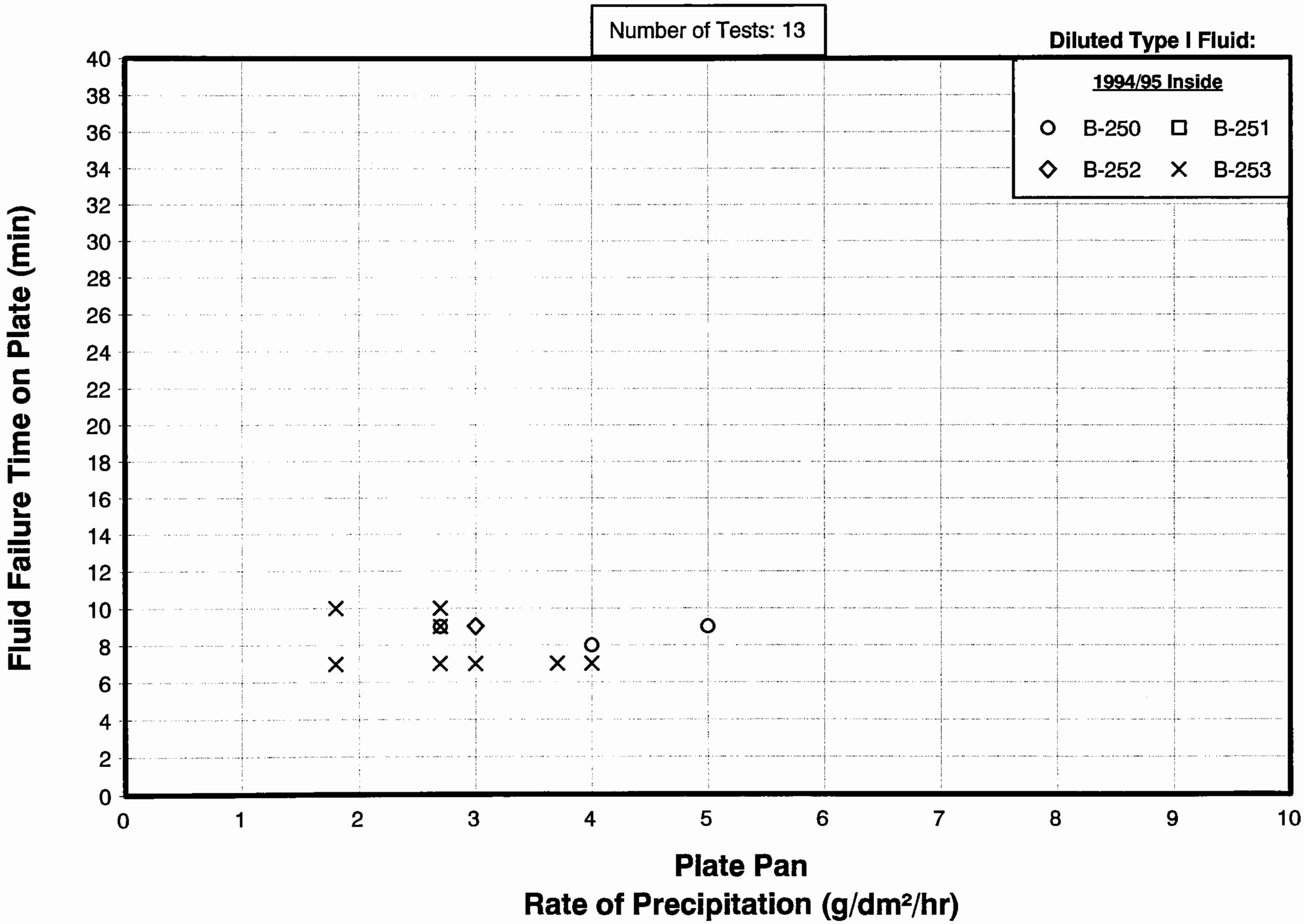
cm1222\cons_hot\fzfog\FZF1D_60.GRF

FIGURE 3.61

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

DILUTED TYPE I

SIMULATED FREEZING FOG



cm1222\cons_hot\fog\FZF1D_61.GRF

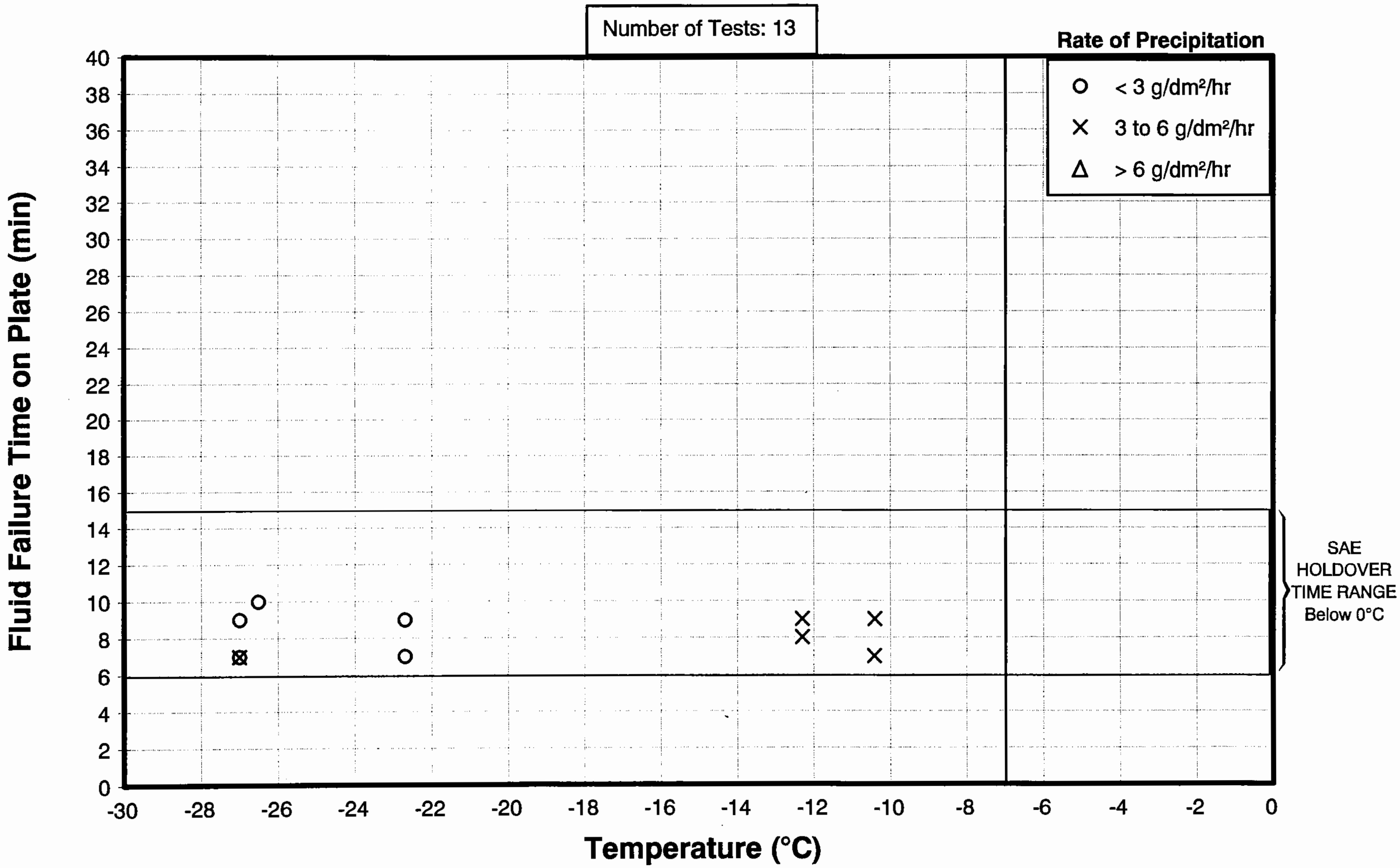
FIGURE 3.62

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

DILUTED TYPE I

SIMULATED FREEZING FOG

1994/95 TEST SEASON



cm1222\cons hot\fzfog\FZF1D_62.GRF

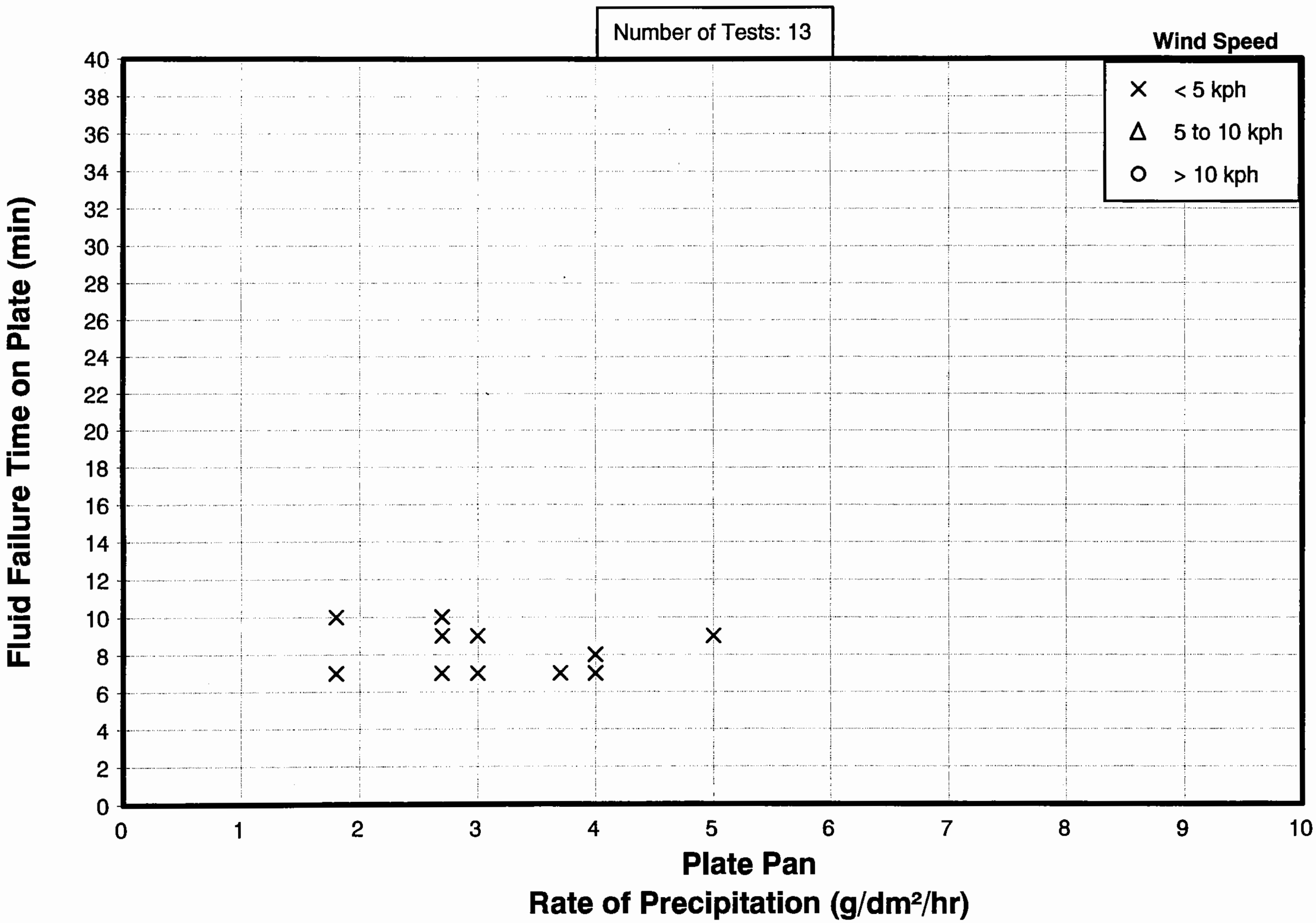
FIGURE 3.63

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

DILUTED TYPE I

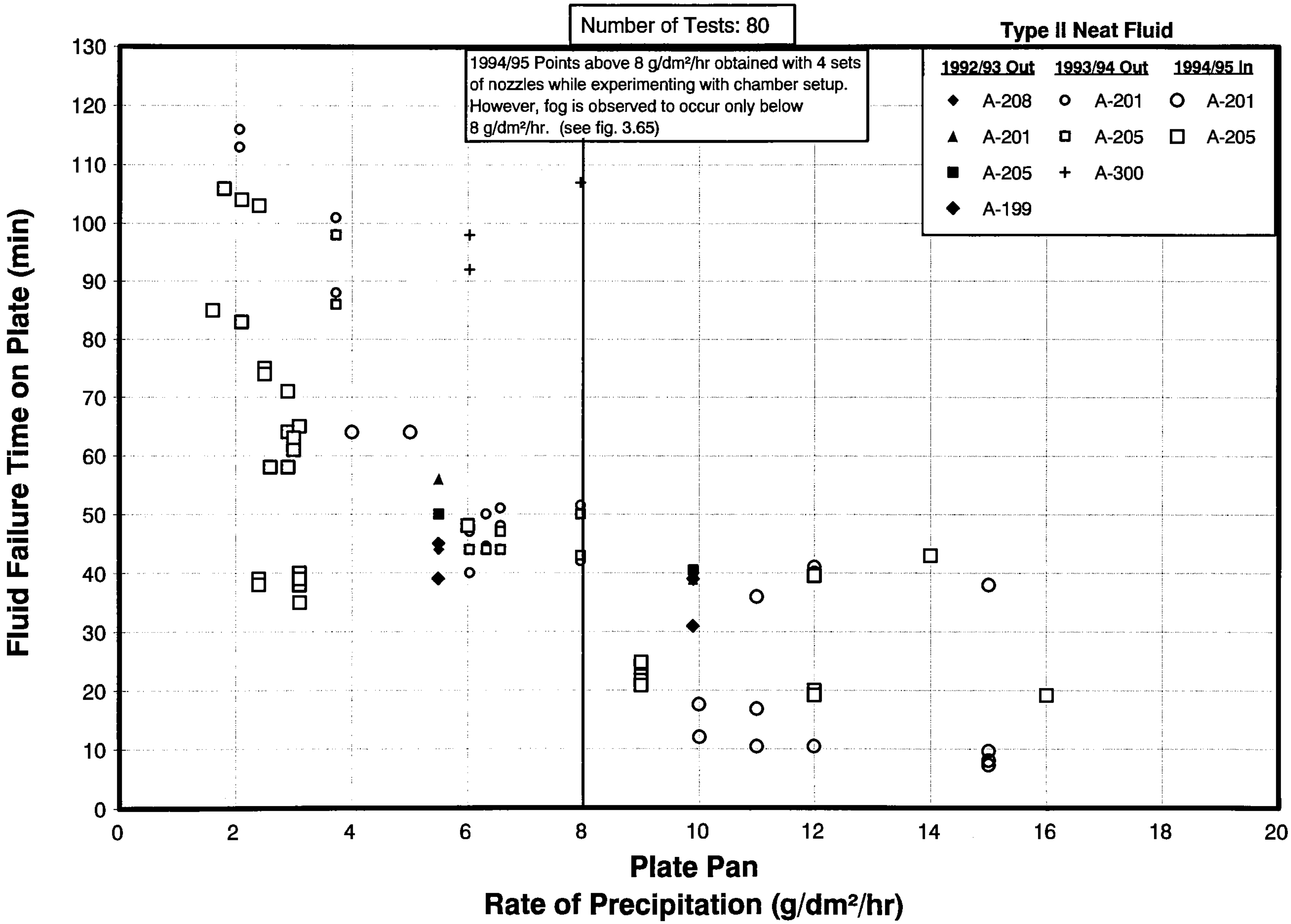
SIMULATED FREEZING FOG

1994/95 TEST SEASON



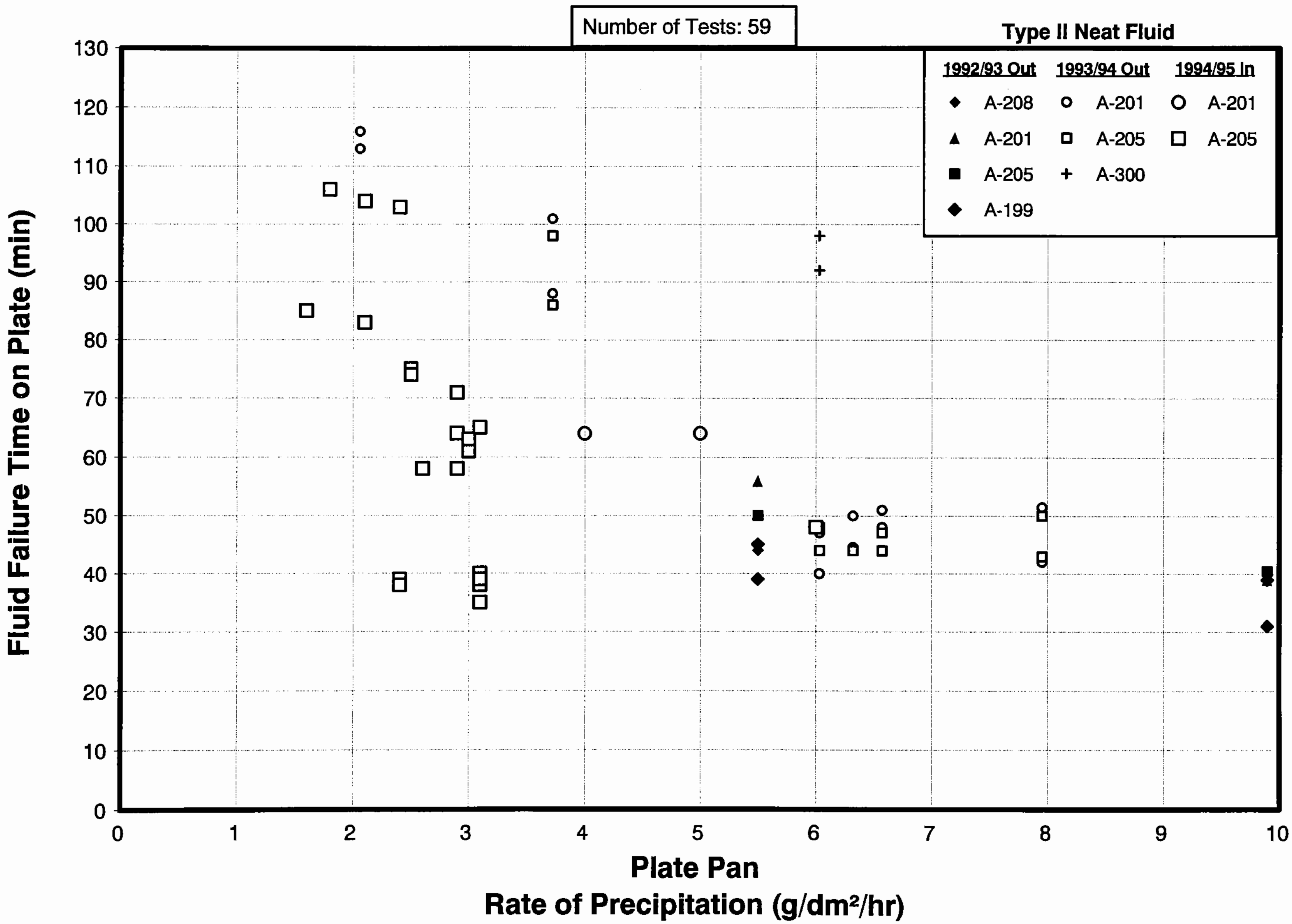
cm1222\cons_hot\fzfog\FZF1D_63.GRF

FIGURE 3.64
EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE II NEAT
SIMULATED FREEZING FOG



cm1222\cons_hot\zfog\FZF21_64.GRF

FIGURE 3.65
EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE II NEAT
SIMULATED FREEZING FOG



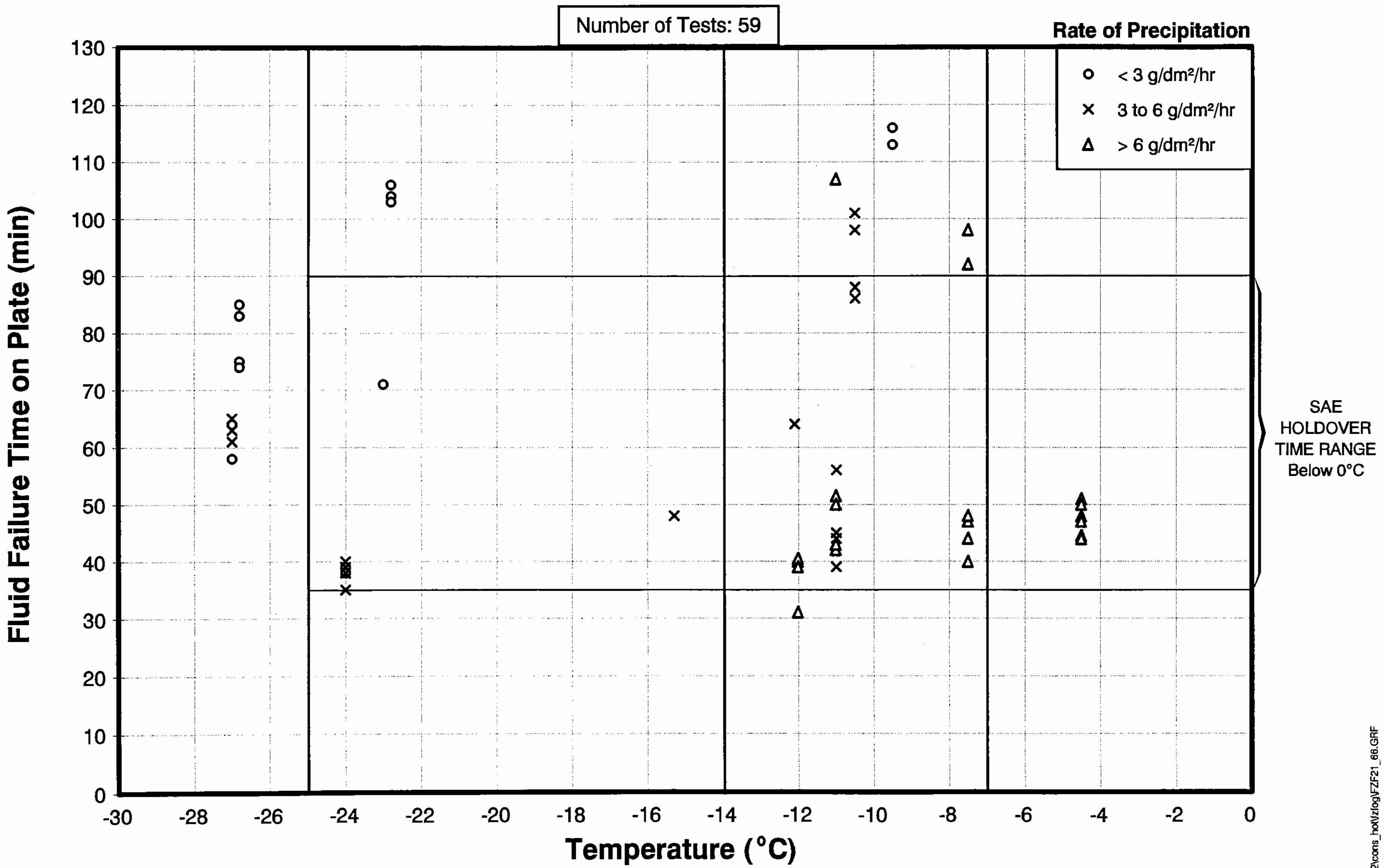
cm1222\cons_hot\fzfog\FZF21_65.GRF

FIGURE 3.66

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II NEAT

SIMULATED FREEZING FOG



cm1222\cons_hot\fzlog\FZF21_66.GRF

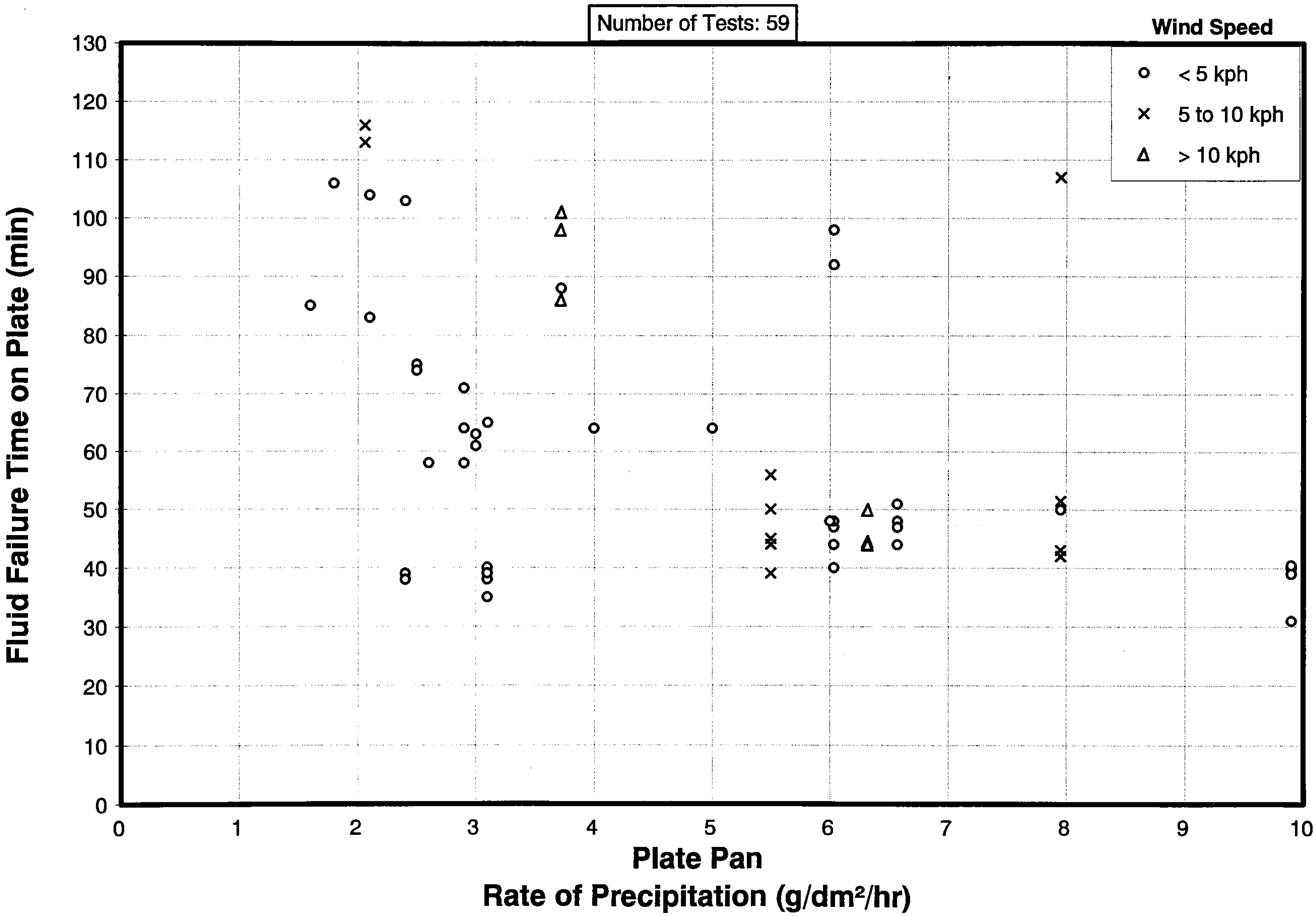
FIGURE 3.67

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

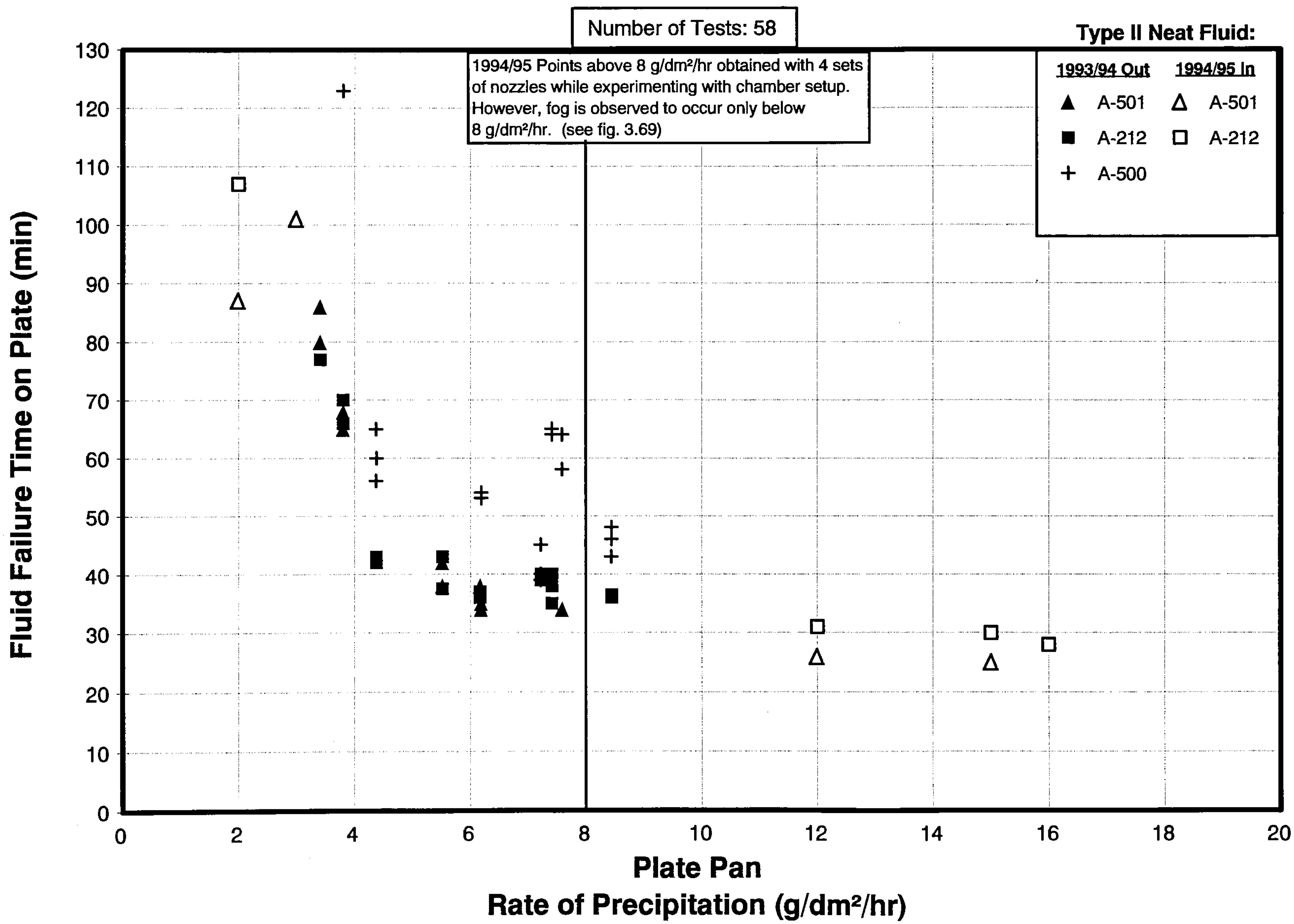
SIMULATED FREEZING FOG

1992 to 1995 TEST SEASON



cm1222\cons_hot\zfog\FZF21_67.GRF

FIGURE 3.68
EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE II 75/25
SIMULATED FREEZING FOG



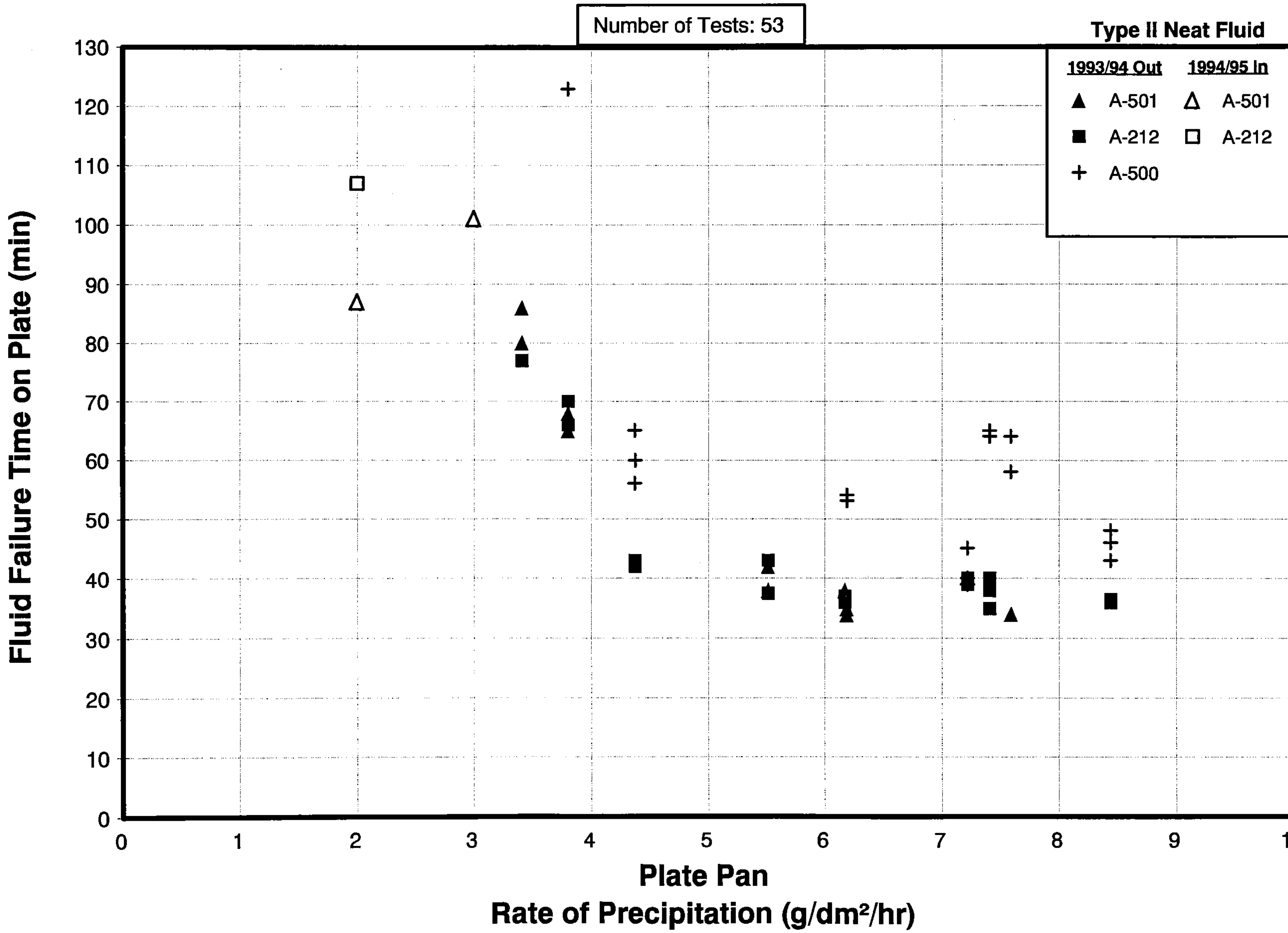
cm1222\cons_hot\zlog\FZF27_68.GRF

FIGURE 3.69

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 75/25

SIMULATED FREEZING FOG



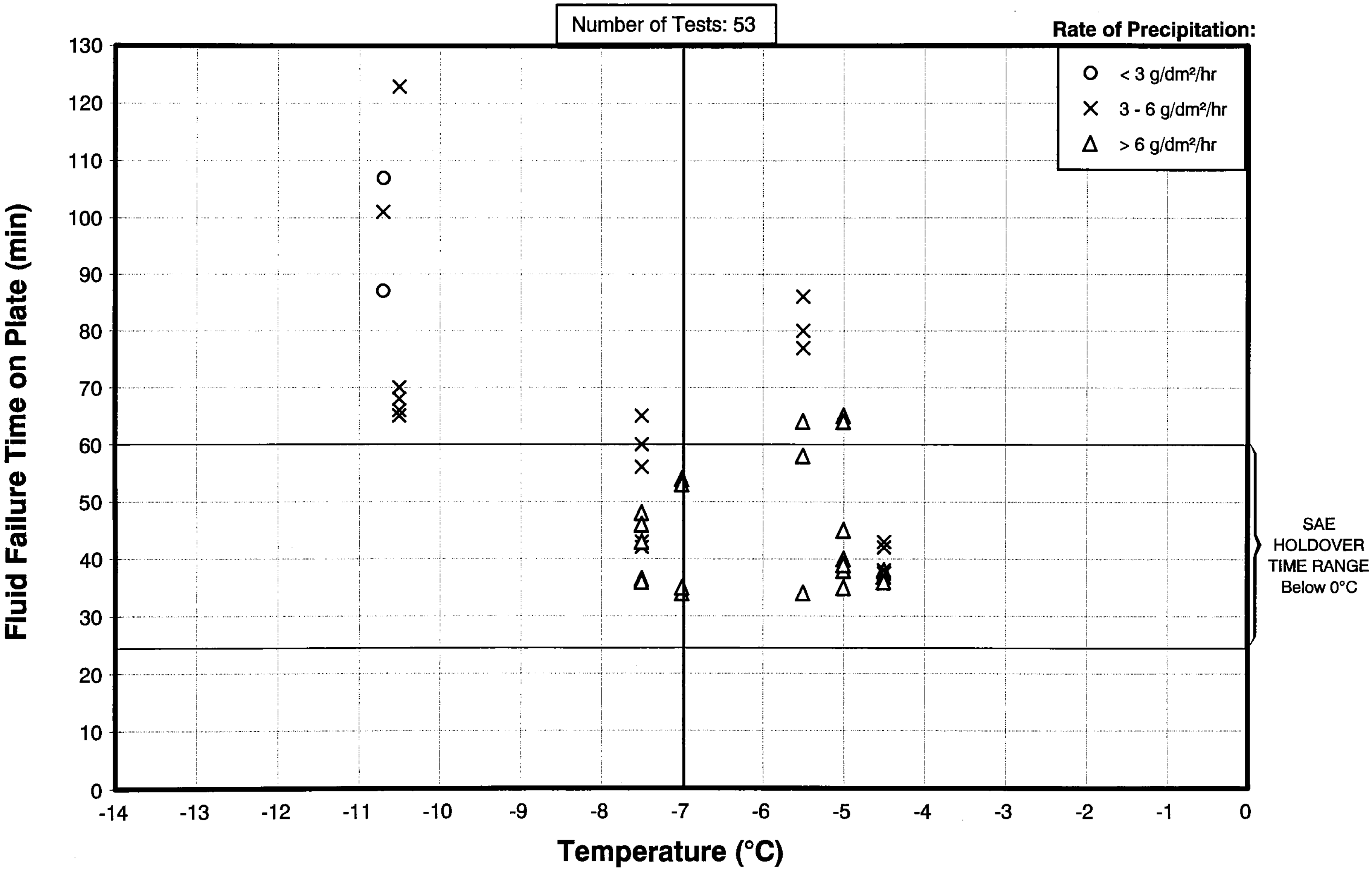
cm1222\cons_hot\fzfog\FZF27_69.GRF

FIGURE 3.70

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II 75/25

SIMULATED FREEZING FOG



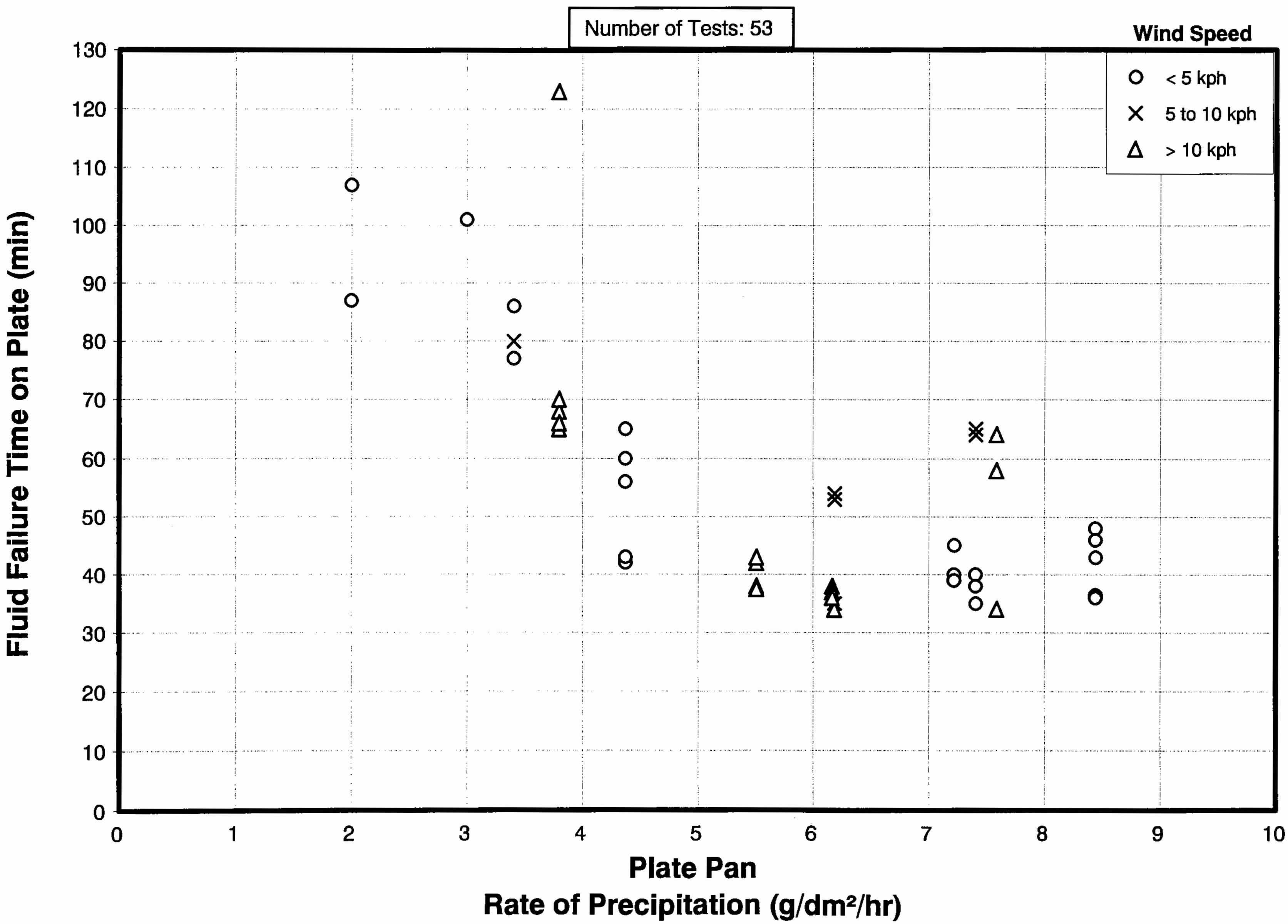
cm1222\cons_hot\zfog\FZF27_70.GRF

FIGURE 3.71

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 75/25

SIMULATED FREEZING FOG



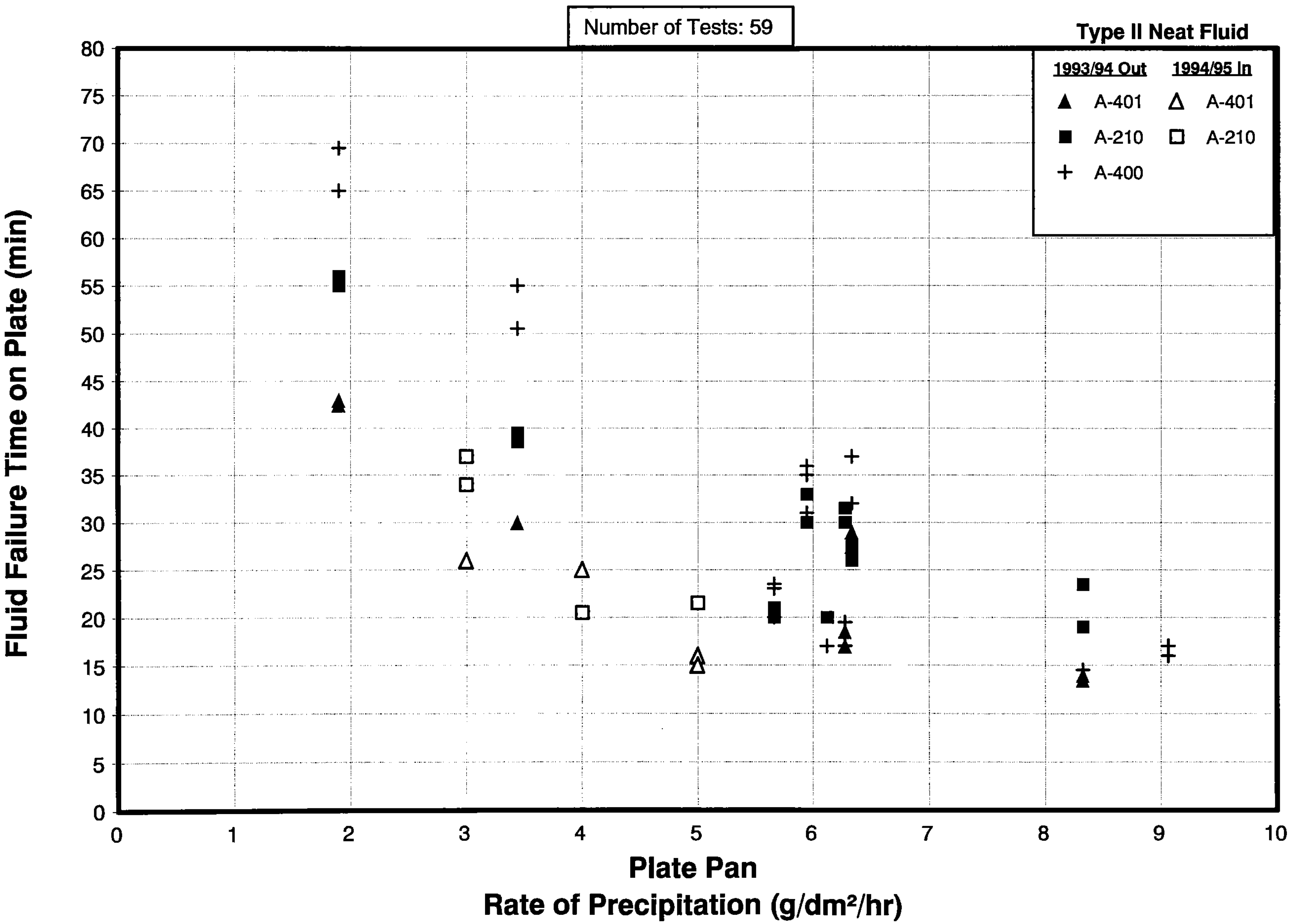
cm1222\cons_hot\zdog\FZF27_71.GRF

FIGURE 3.72

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 50/50

SIMULATED FREEZING FOG



cm1222\cons_hot\zfog\FZF25_72.GRF

FIGURE 3.73

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE II 50/50

SIMULATED FREEZING FOG

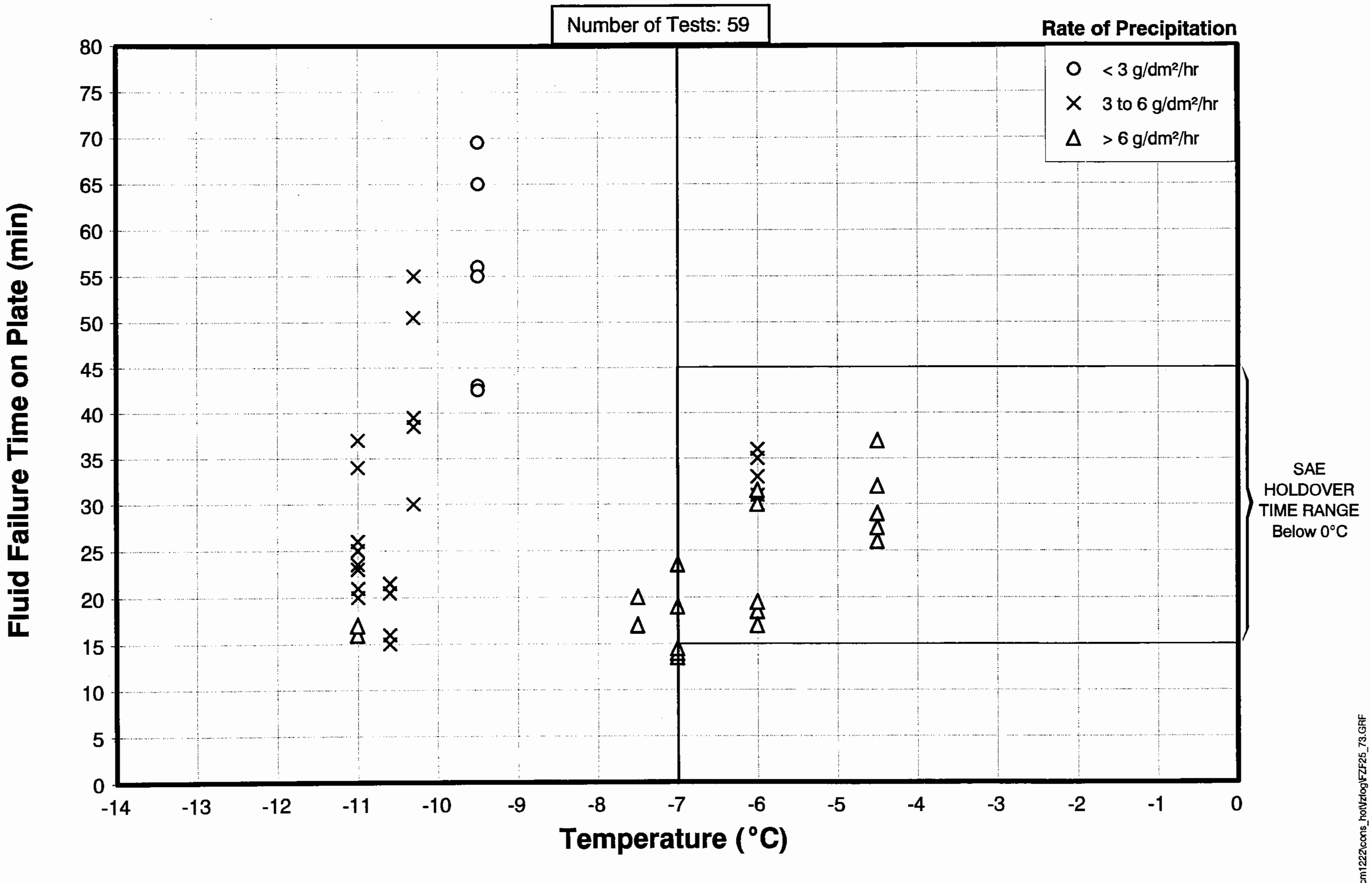
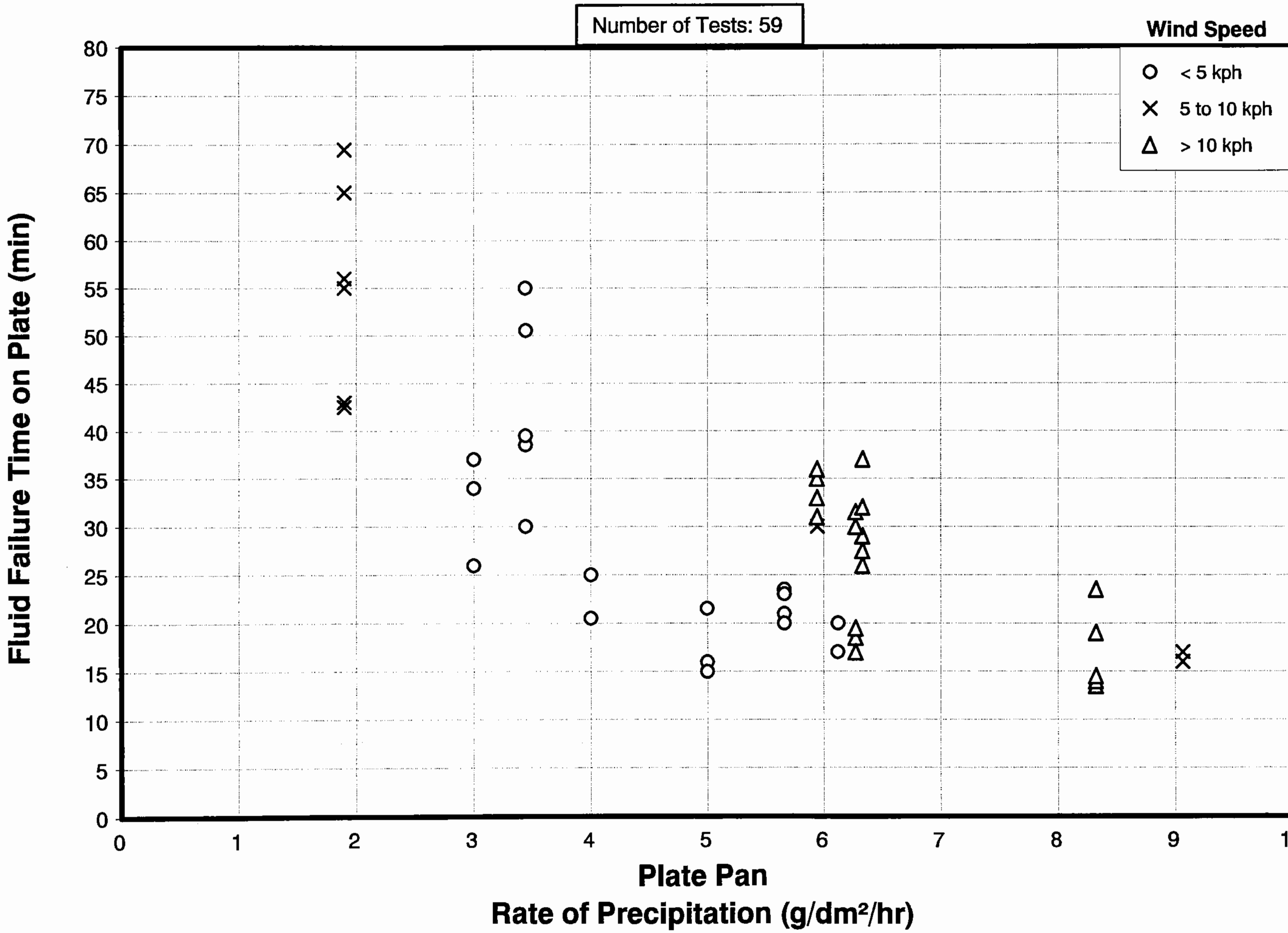


FIGURE 3.74

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 50/50

SIMULATED FREEZING FOG



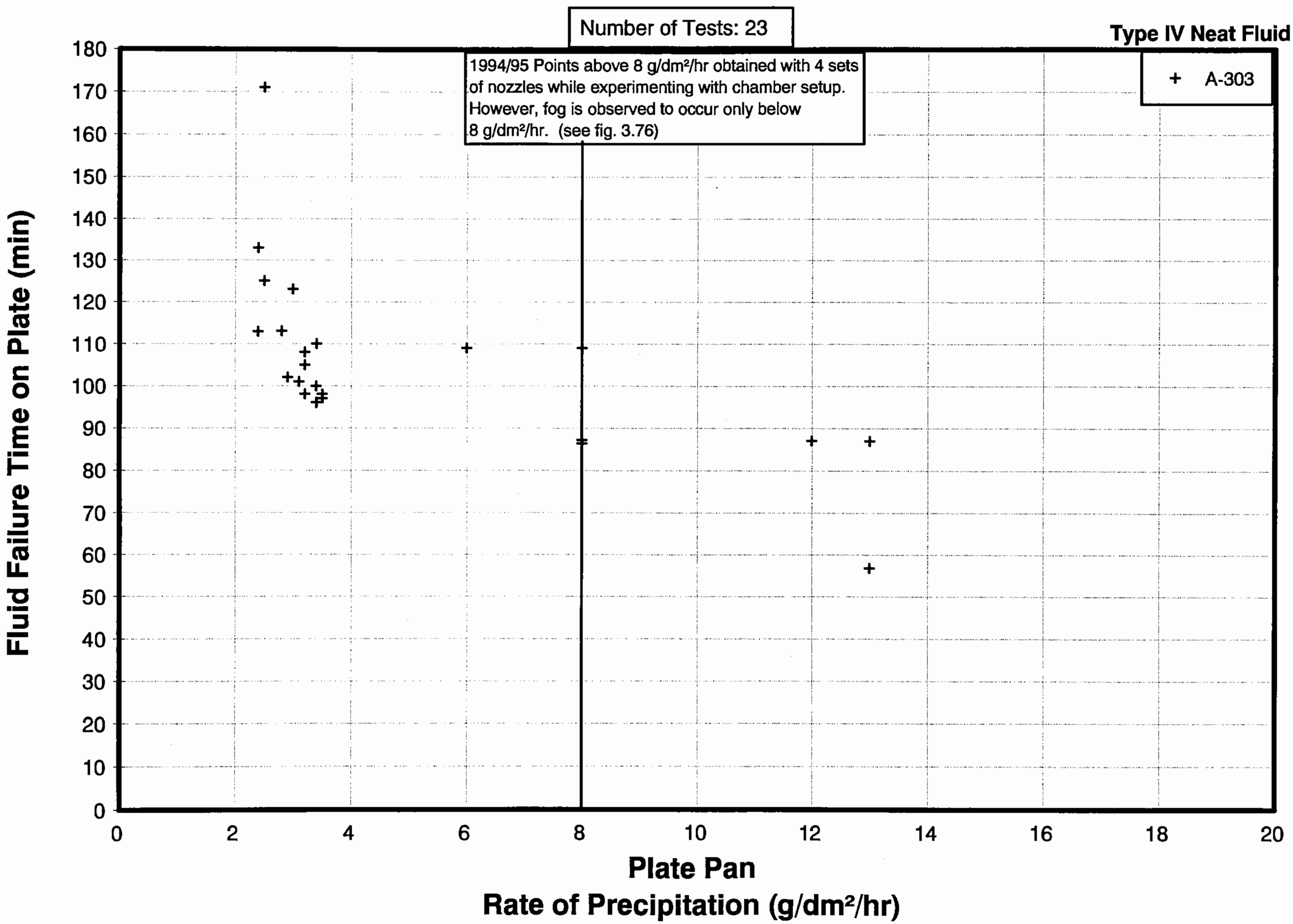
cm1222\cons_hot\fzfog\FZF25_74.GRF

FIGURE 3.75

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT

SIMULATED FREEZING FOG



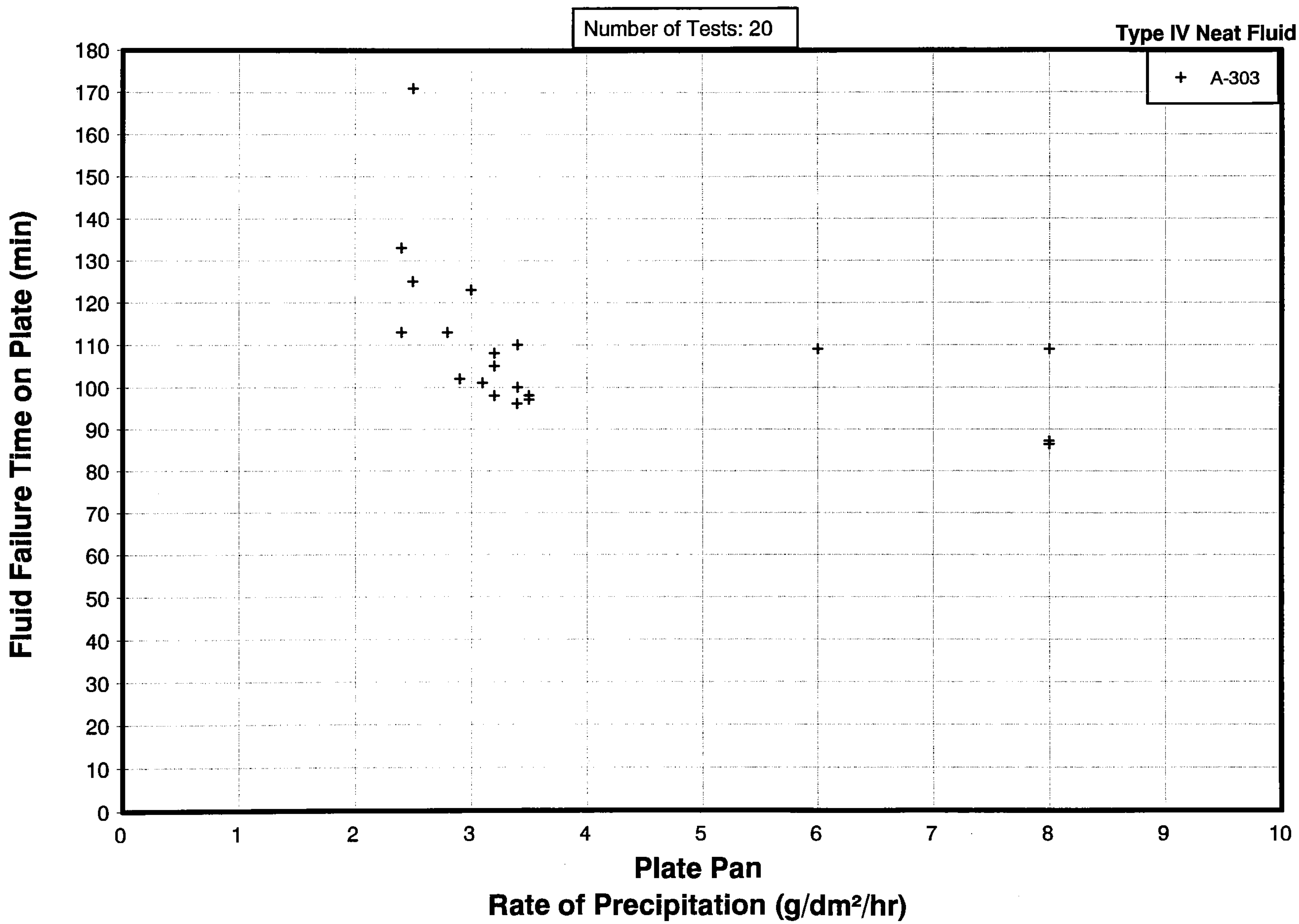
cm1222\cons_hot\zfog\FZF41_75.GRF

FIGURE 3.76

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT

SIMULATED FREEZING FOG



cm1222\cons_hot\fzfog\FZF41_76.GRF

FIGURE 3.77

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE IV NEAT

SIMULATED FREEZING FOG

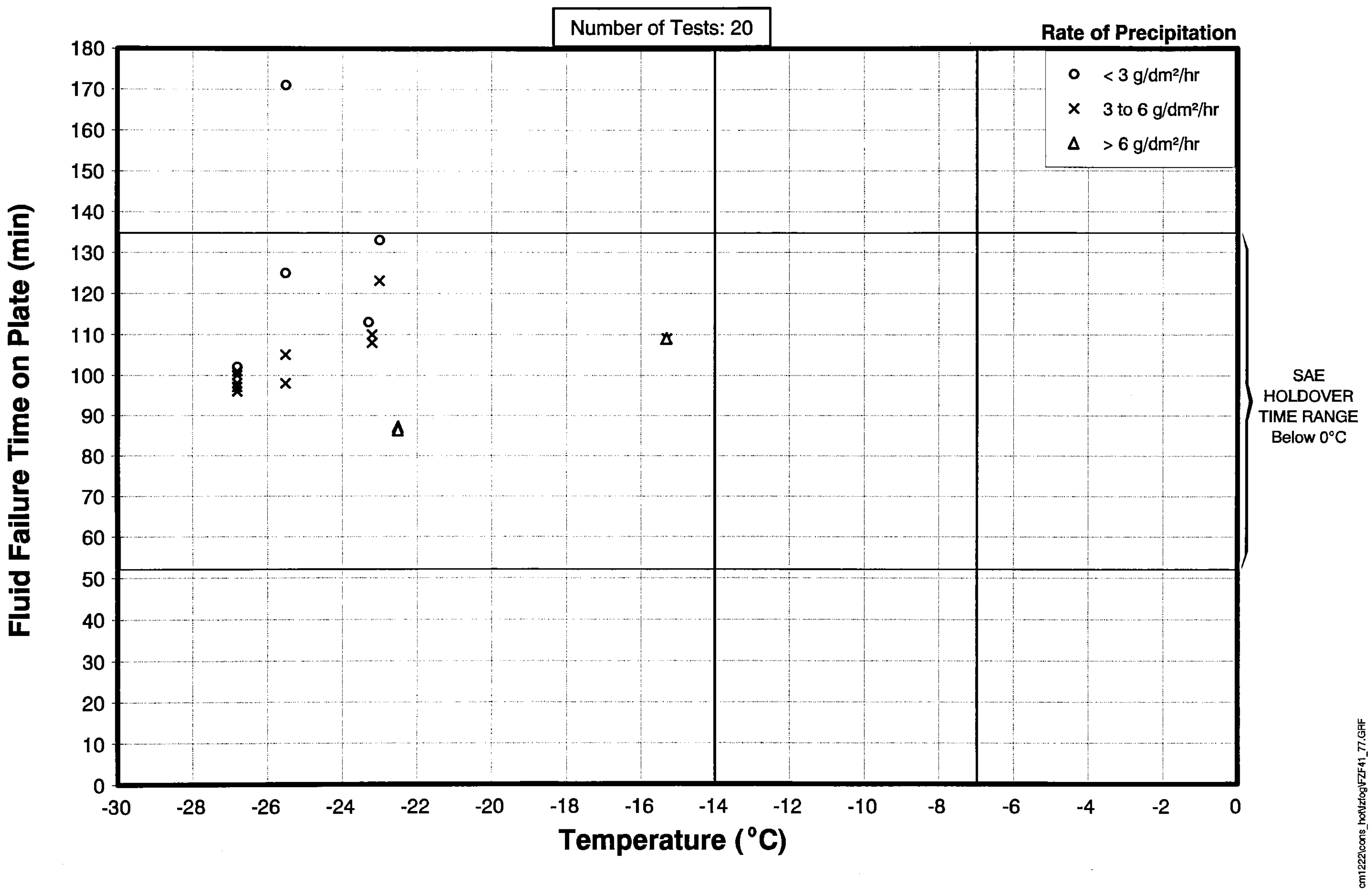


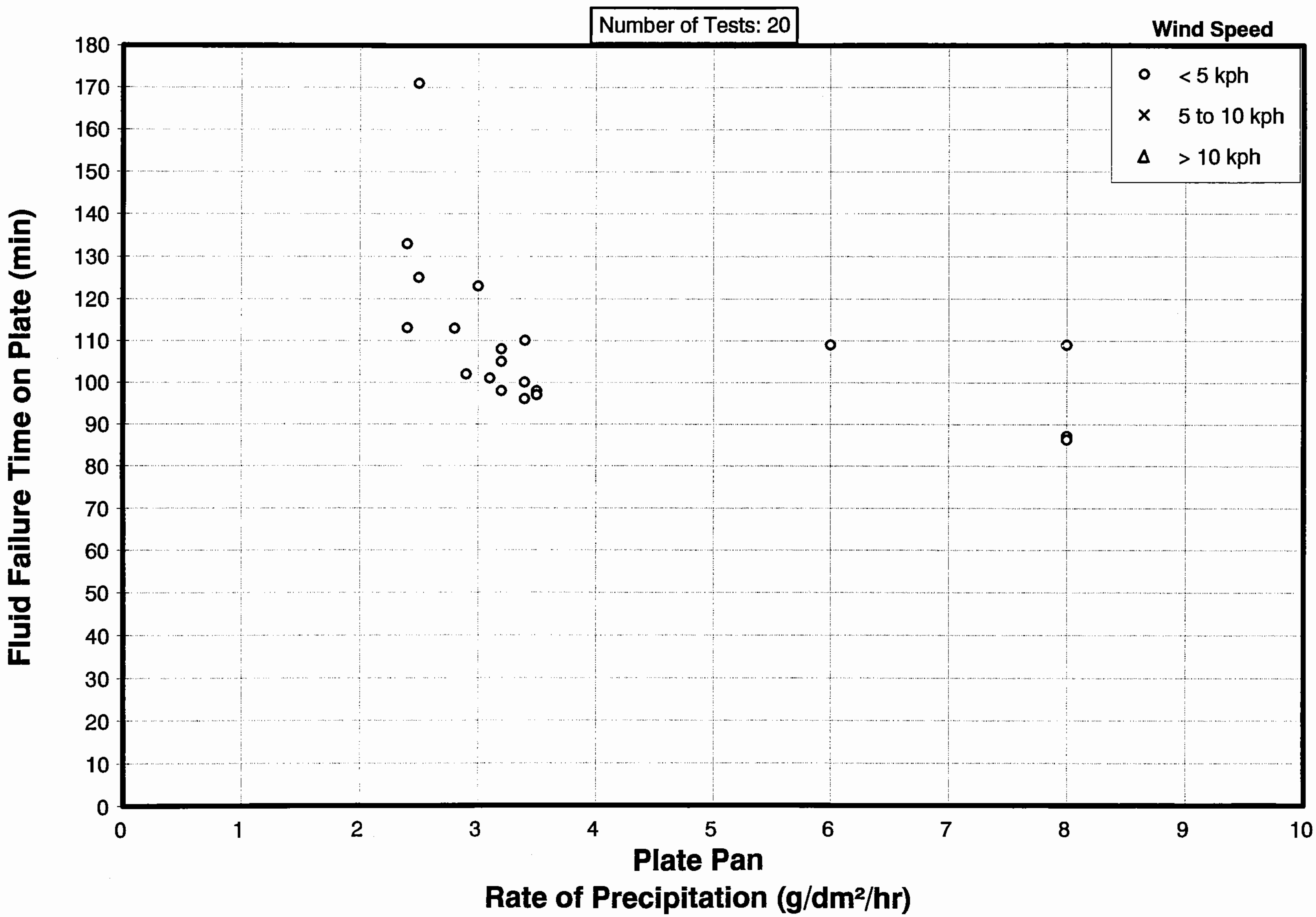
FIGURE 3.78

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT

SIMULATED FREEZING FOG

1992 to 1995 TEST SEASON



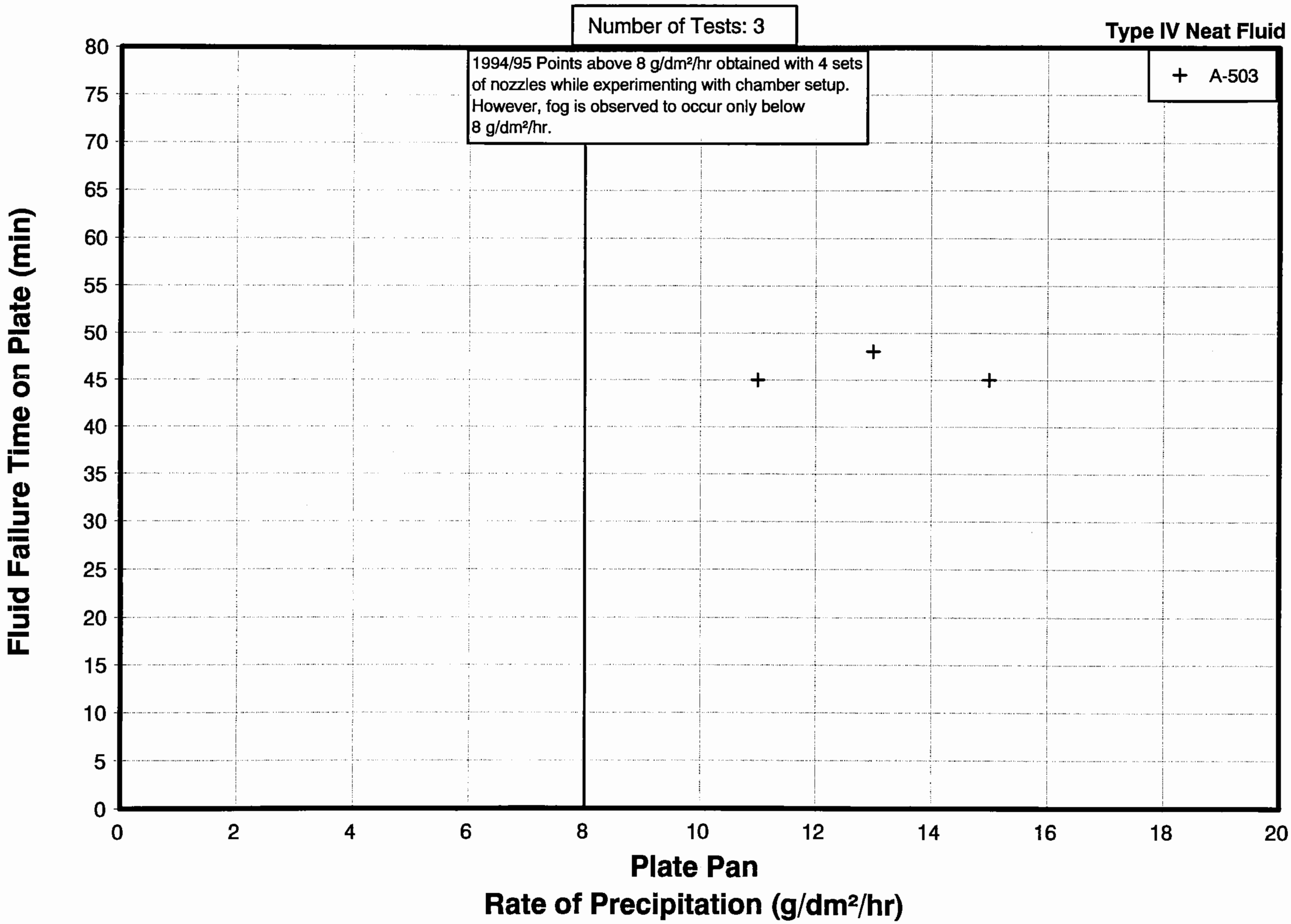
cm1222\cons_hot\fzfog\FZF41_78.GRF

FIGURE 3.79

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

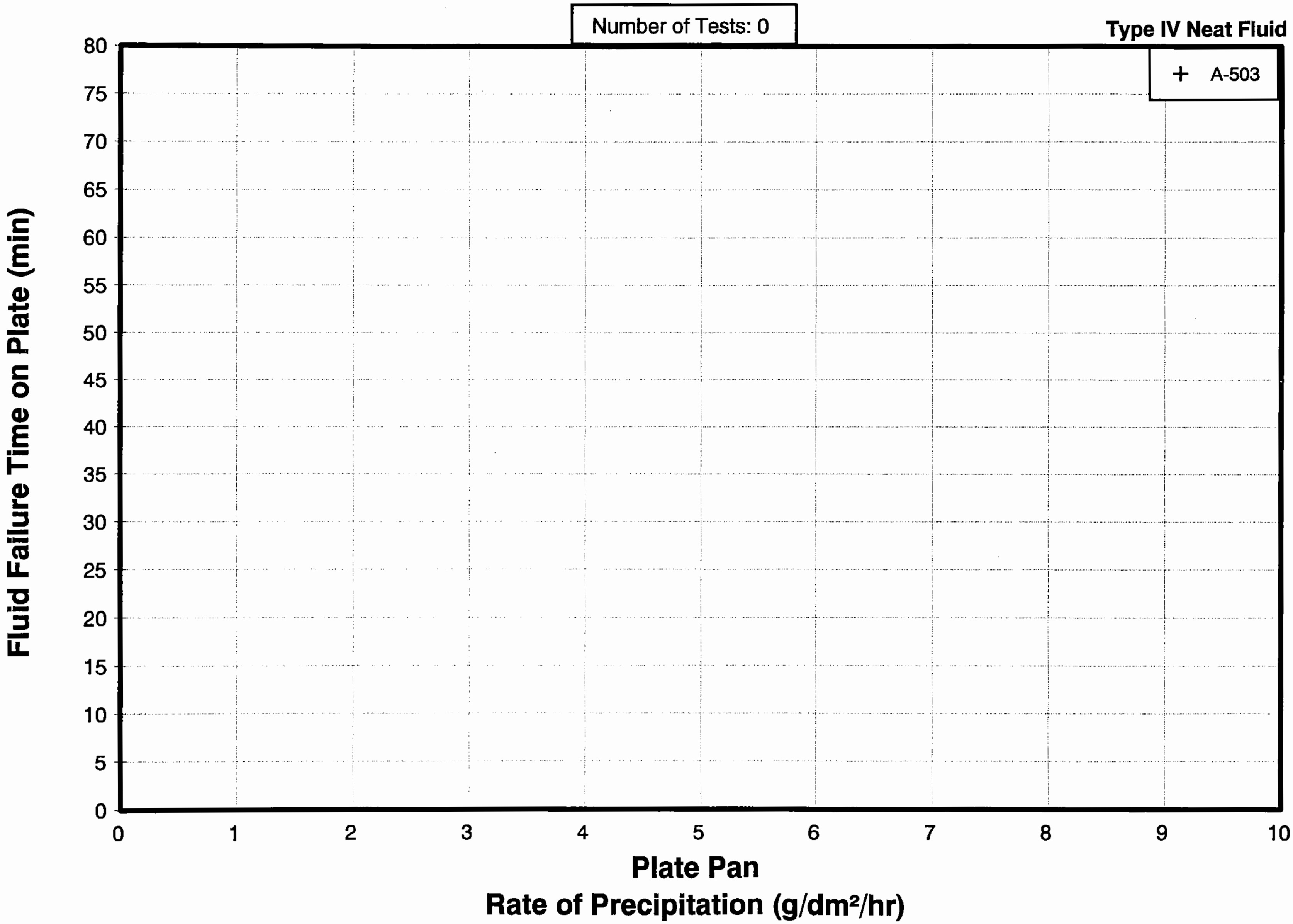
TYPE IV 75/25

SIMULATED FREEZING FOG



cm1222\cons_hot\zdog\FZF47_79.GRF

FIGURE 3.80
EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25
SIMULATED FREEZING FOG



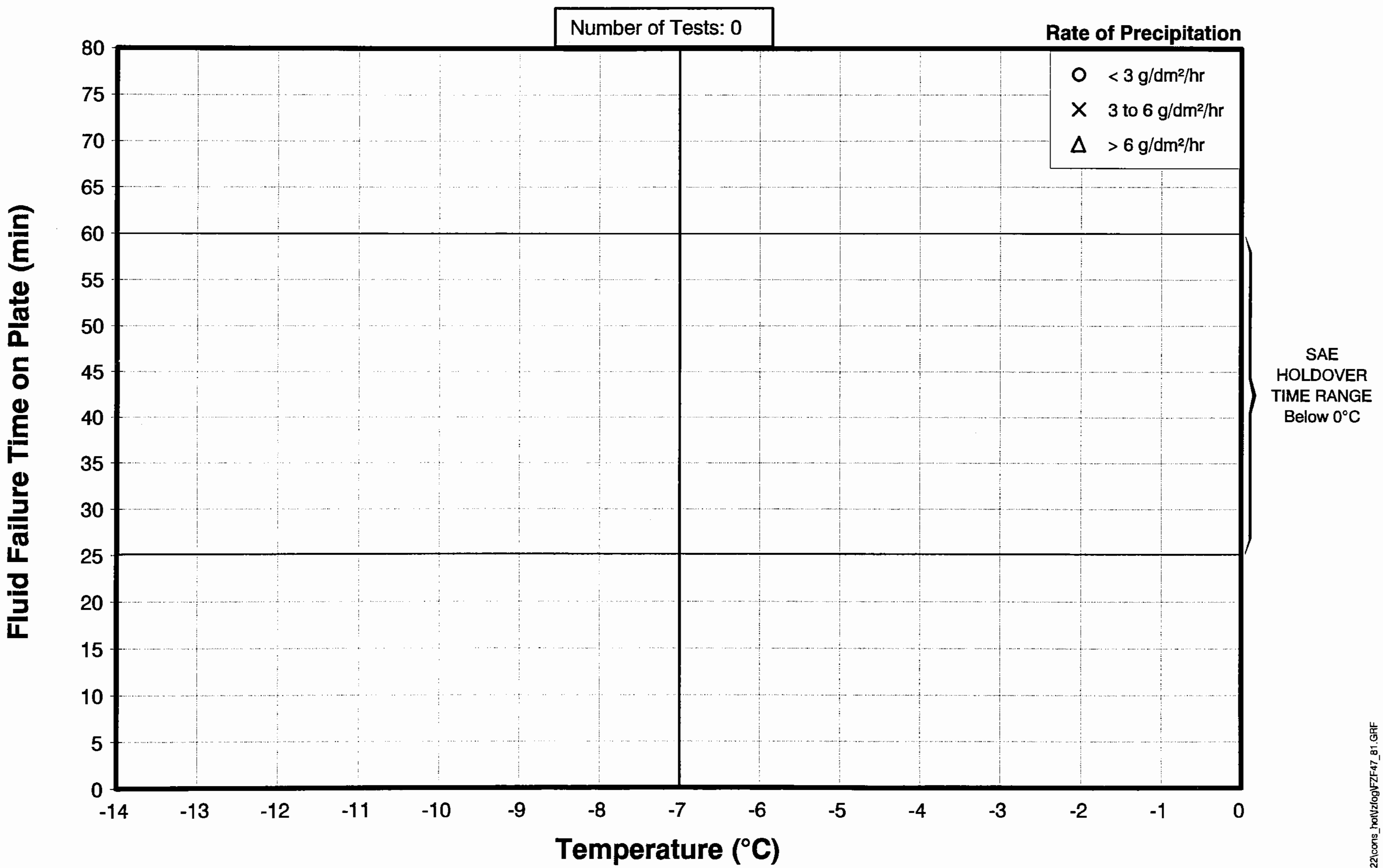
cm1222\cons_hot\zfog\FZF47_80.GRF

FIGURE 3.81

EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME

TYPE IV 75/25

SIMULATED FREEZING FOG



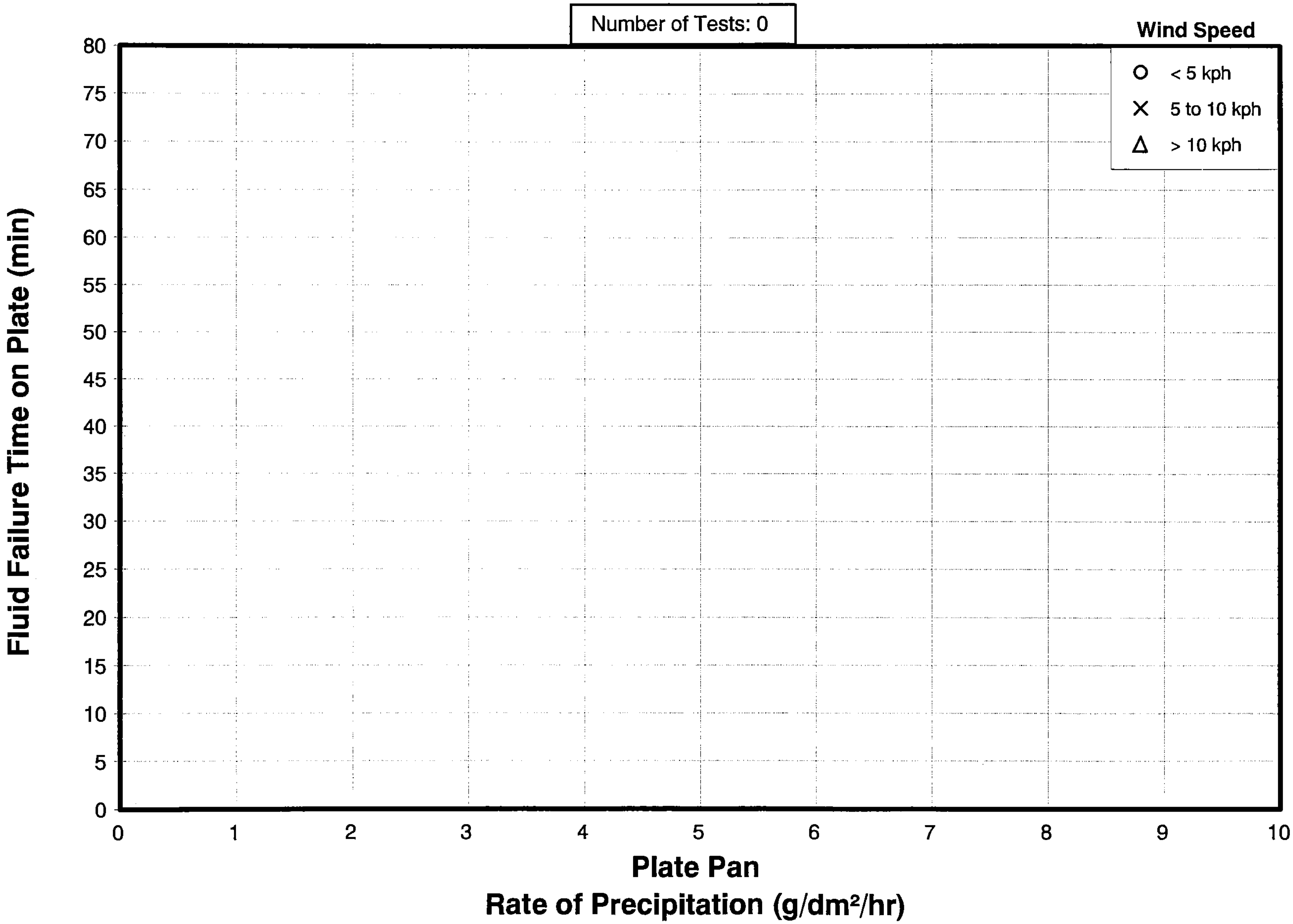
cm1222\cons_hot\zfog\FZF47_81.GRF

FIGURE 3.82

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25

SIMULATED FREEZING FOG



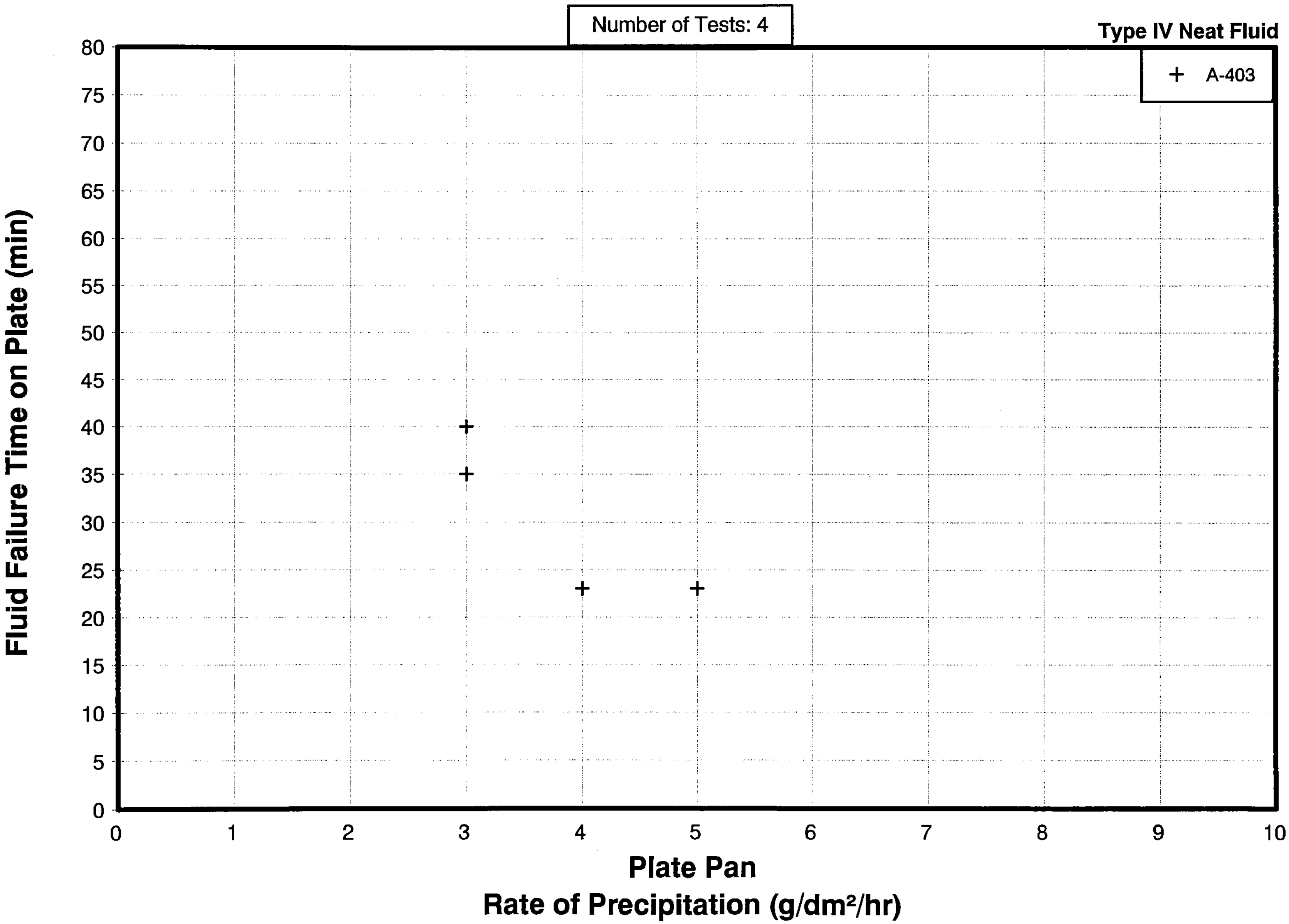
cm1222\cons_hot\fzfog\FZF47_82.GRF

FIGURE 3.83

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50

SIMULATED FREEZING FOG



cm1222\cons_hot\zlog\FZF45_83.GRF

FIGURE 3.84
EFFECT OF RATE OF PRECIPITATION AND TEMPERATURE ON FAILURE TIME
TYPE IV 50/50
SIMULATED FREEZING FOG

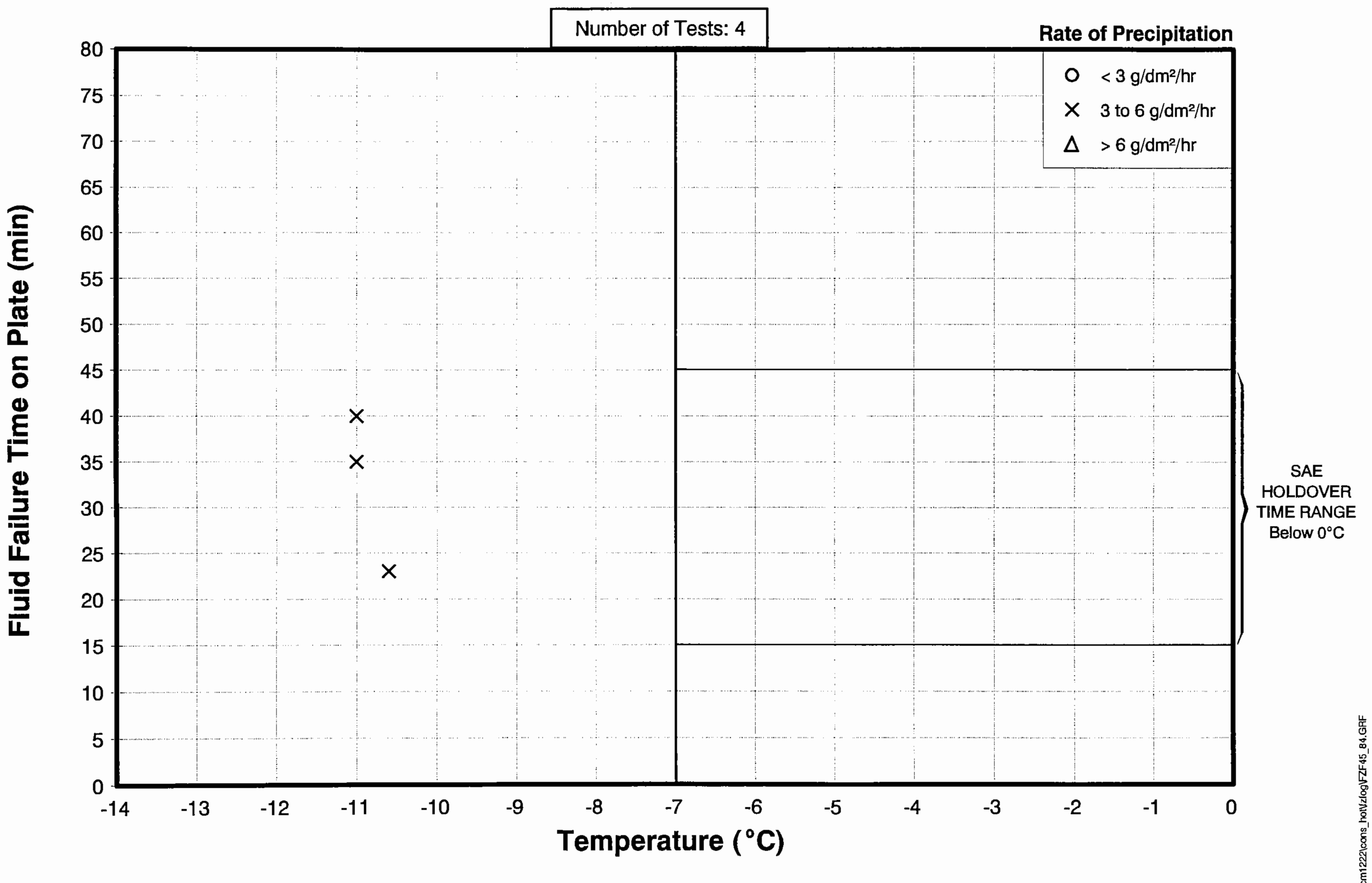
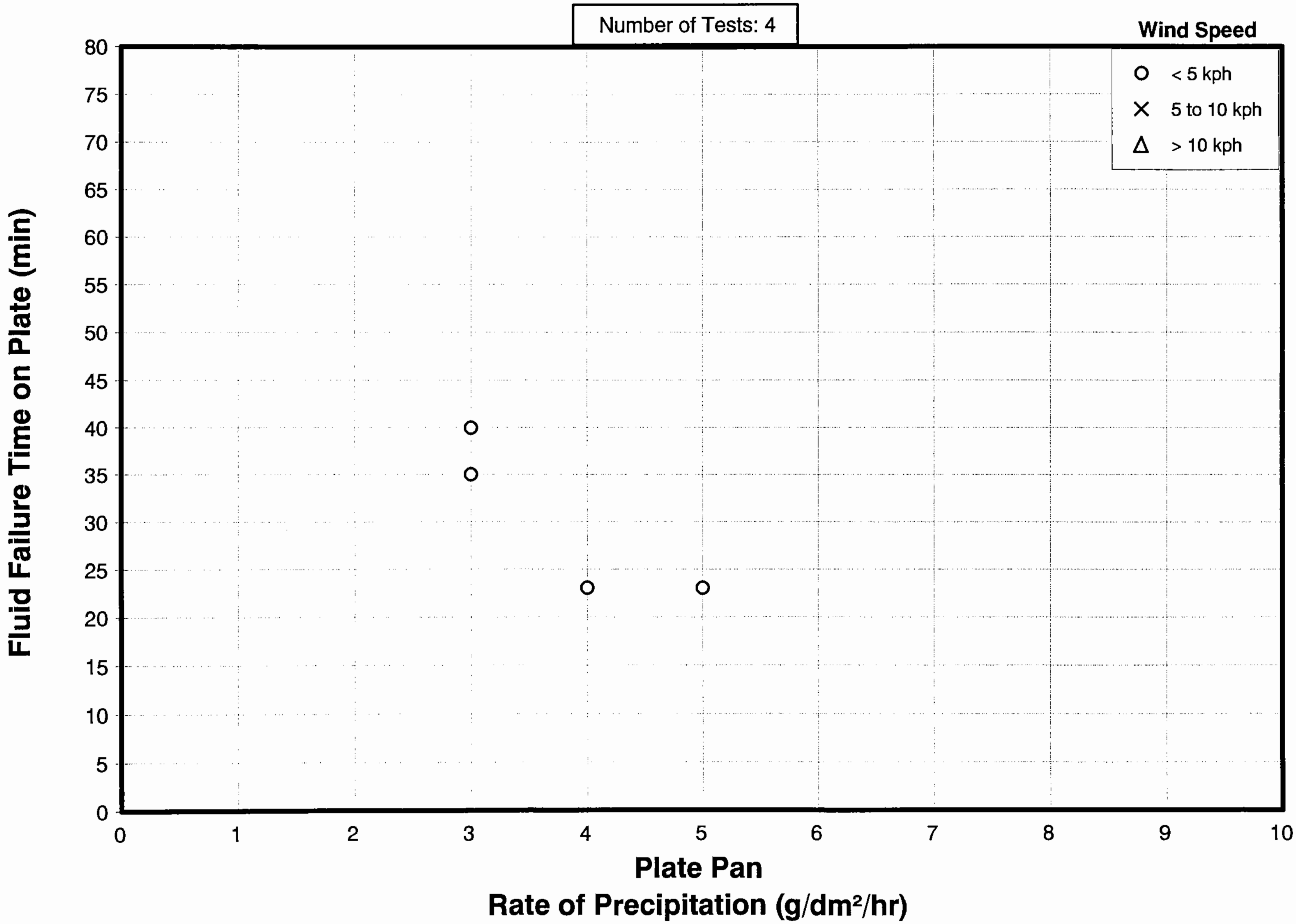


FIGURE 3.85

EFFECT OF WIND SPEED AND RATE OF PRECIPITATION ON FAILURE TIME

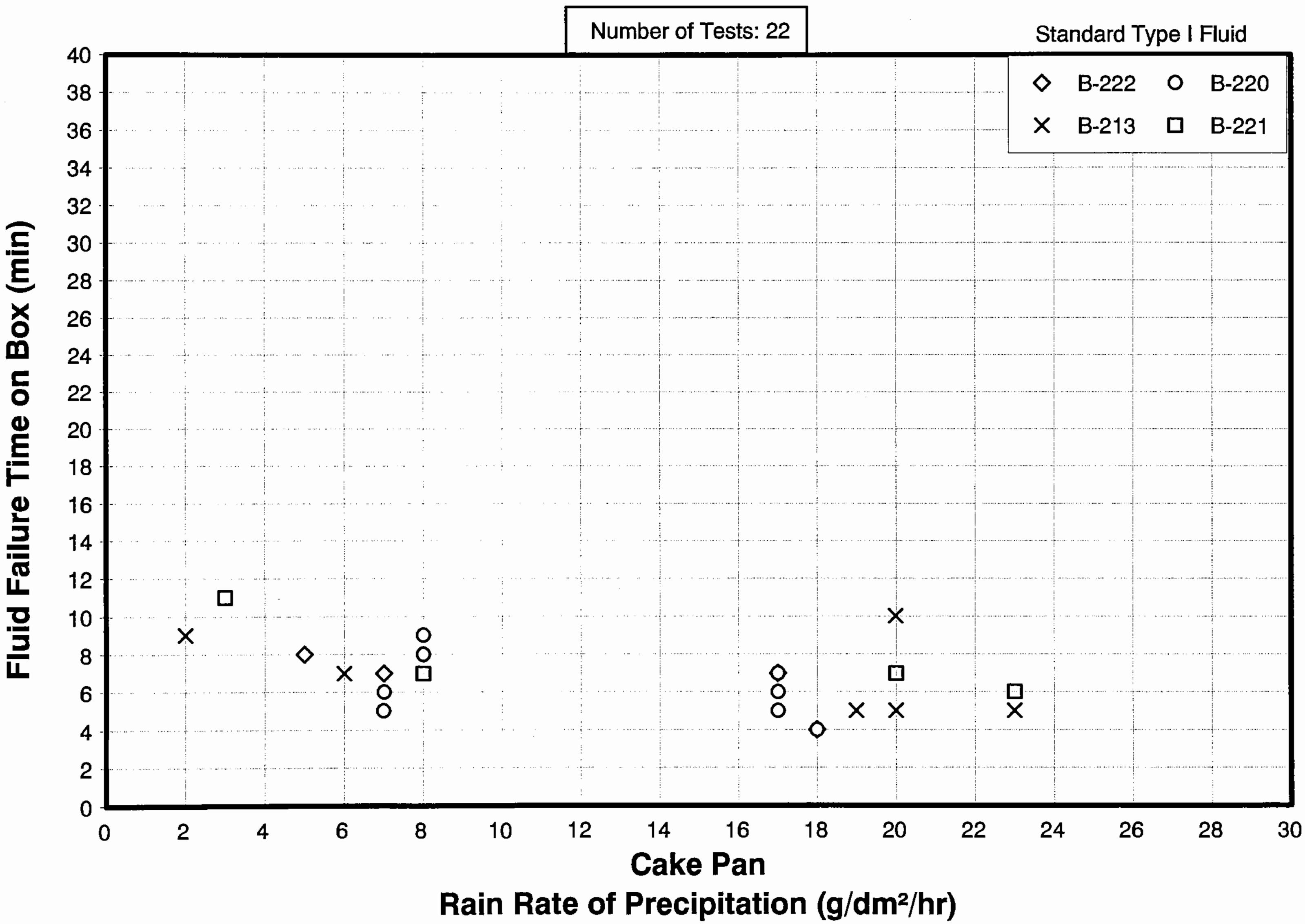
TYPE IV 50/50

SIMULATED FREEZING FOG



cm1222\cons_hot\fzlog\FZF45_85.GRF

FIGURE 3.86
EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME
STANDARD TYPE I
RAIN ON COLD-SOAKED SURFACE



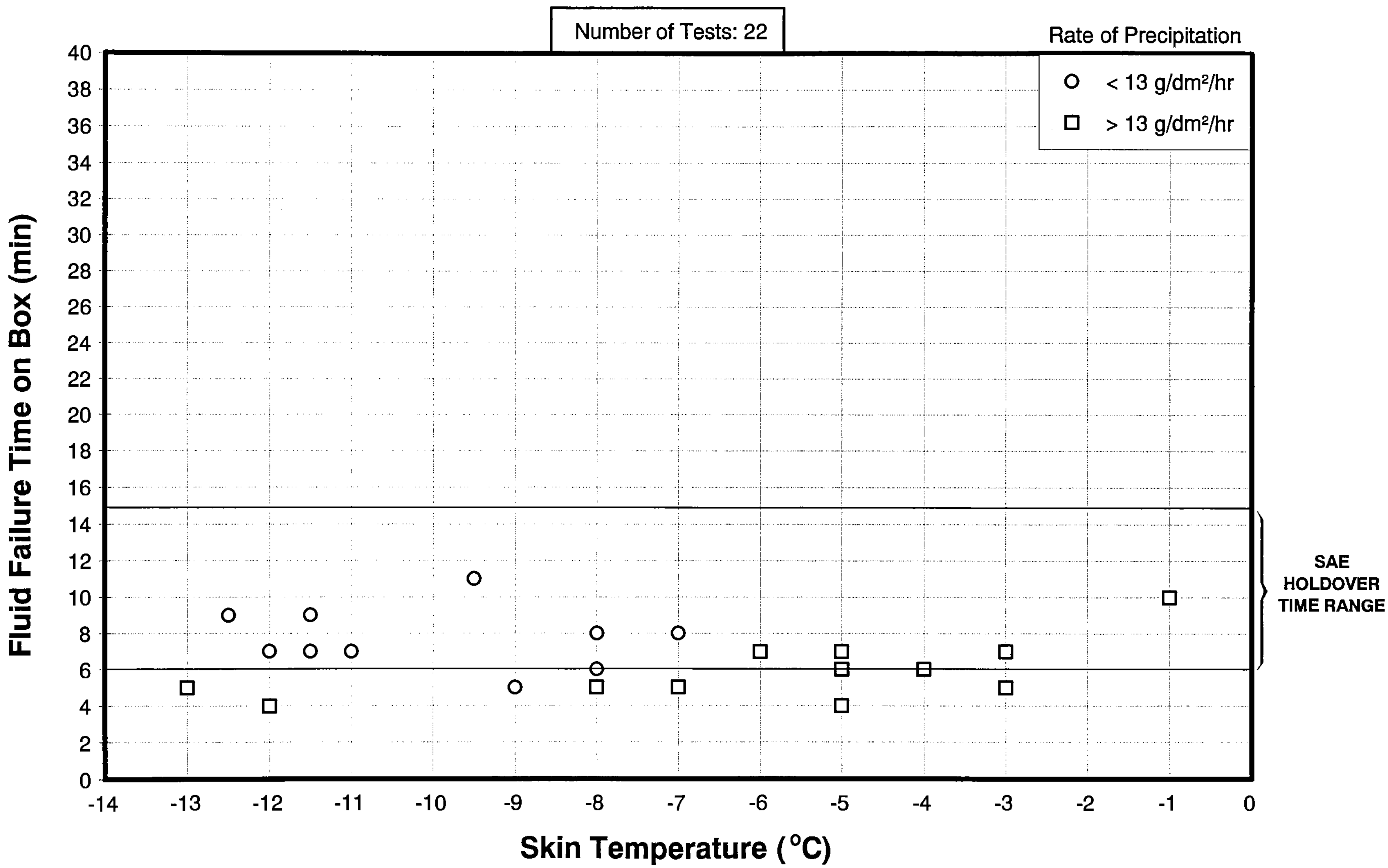
C1222\cons_hot\coldsoak\CS1S_86.GRF

FIGURE 3.87

EFFECT OF RATE OF PRECIPITATION AND SKIN TEMPERATURE ON FAILURE TIME

STANDARD TYPE I

RAIN ON COLD-SOAKED SURFACE



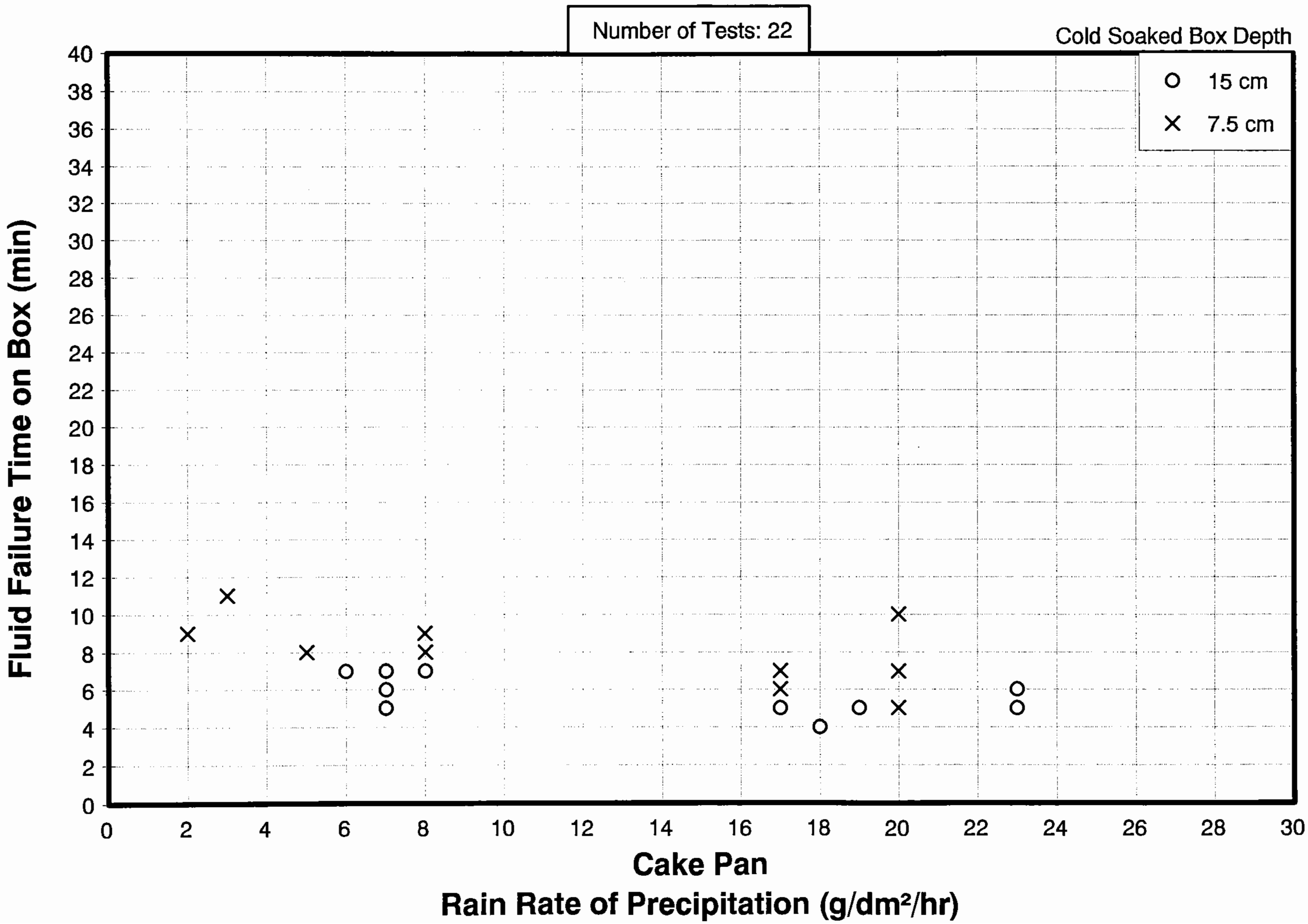
c1222\cons_hot\coldsoak\CS1S_87.GRF

FIGURE 3.88

EFFECT OF BOX SIZE AND RATE OF PRECIPITATION ON FAILURE TIME

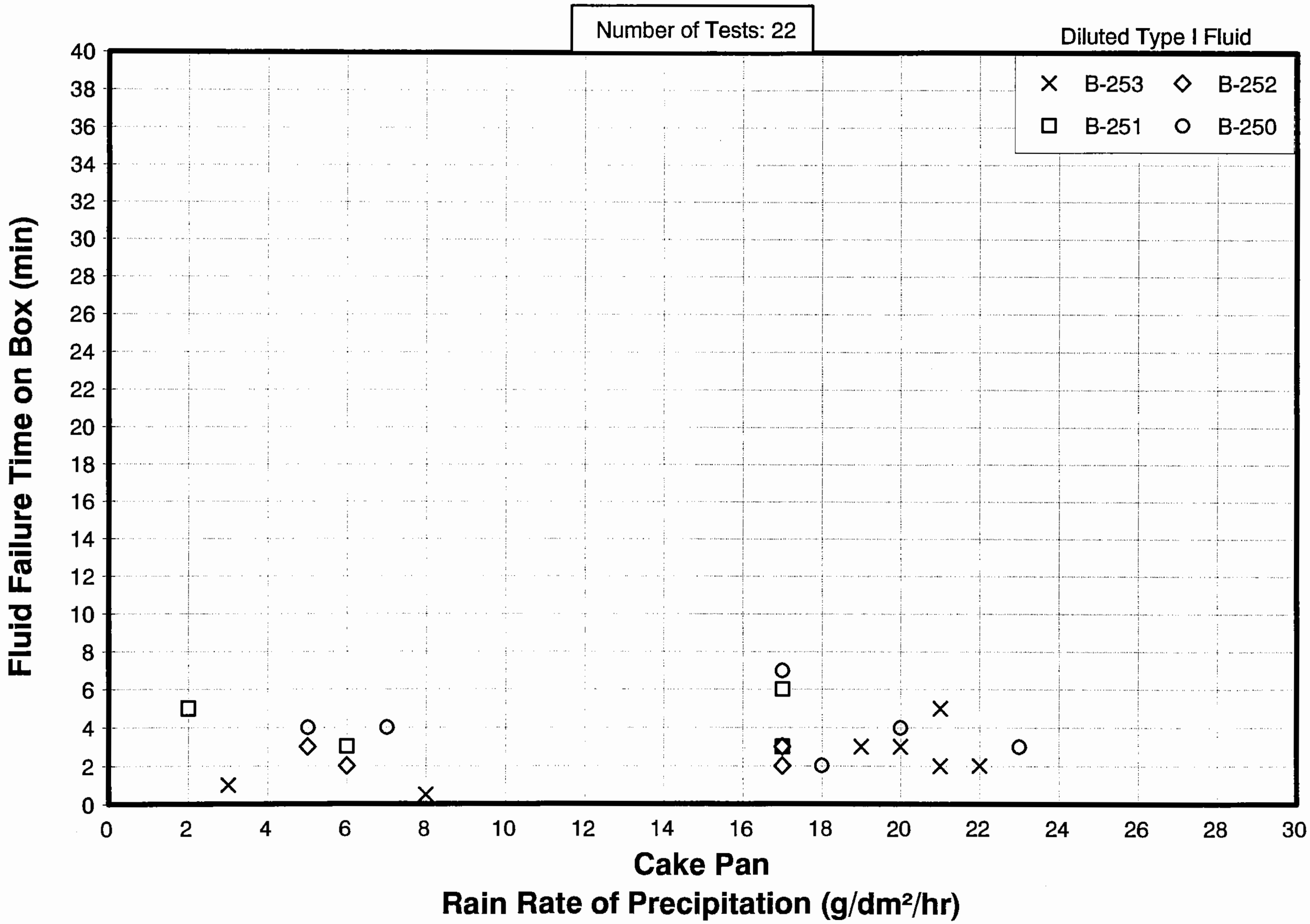
STANDARD TYPE I

RAIN ON COLD-SOAKED SURFACE



C1222\cons_hot\coldsoak\CS1S_88.GRF

FIGURE 3.89
EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME
DILUTED TYPE I
RAIN ON COLD-SOAKED SURFACE



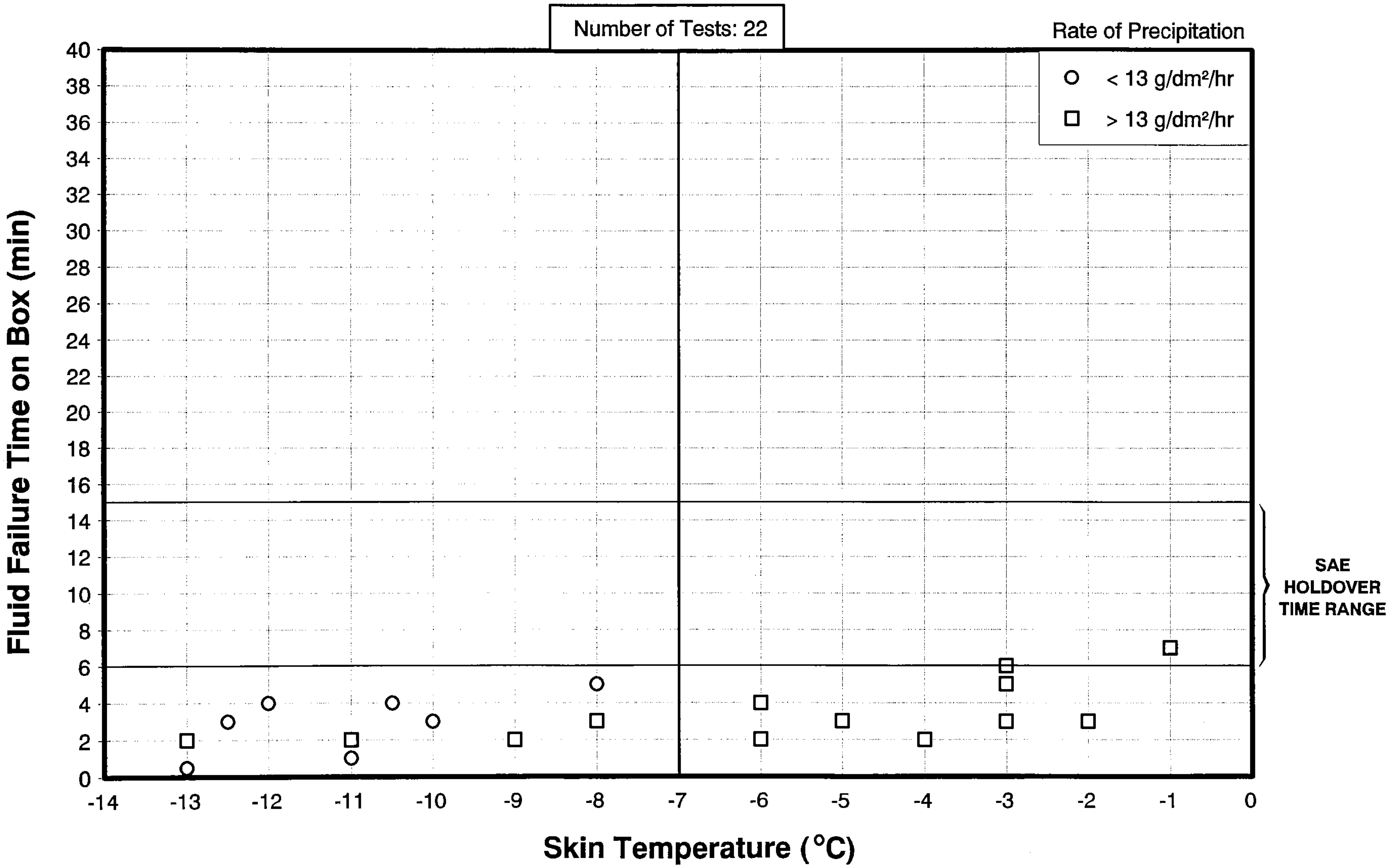
cm1222\cons_hot\coldsoak\CS1D_89.GRF

FIGURE 3.90

EFFECT OF RATE OF PRECIPITATION AND SKIN TEMPERATURE ON FAILURE TIME

DILUTED TYPE I

RAIN ON COLD-SOAKED SURFACE



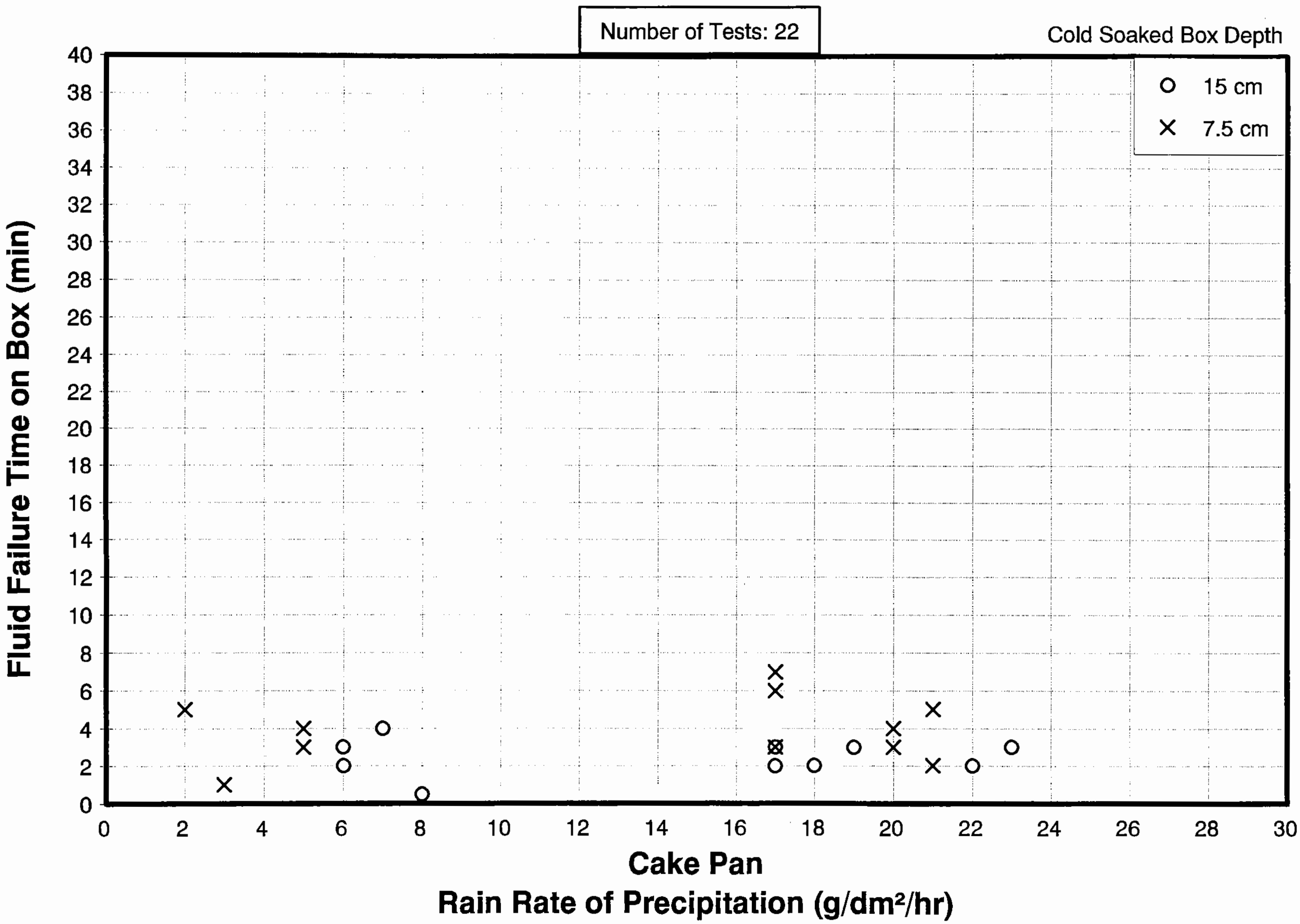
cm1222\cons_hot\coldsoak\CS1D_90.GRF

FIGURE 3.91

EFFECT OF BOX SIZE AND RATE OF PRECIPITATION ON FAILURE TIME

DILUTED TYPE I

RAIN ON COLD-SOAKED SURFACE



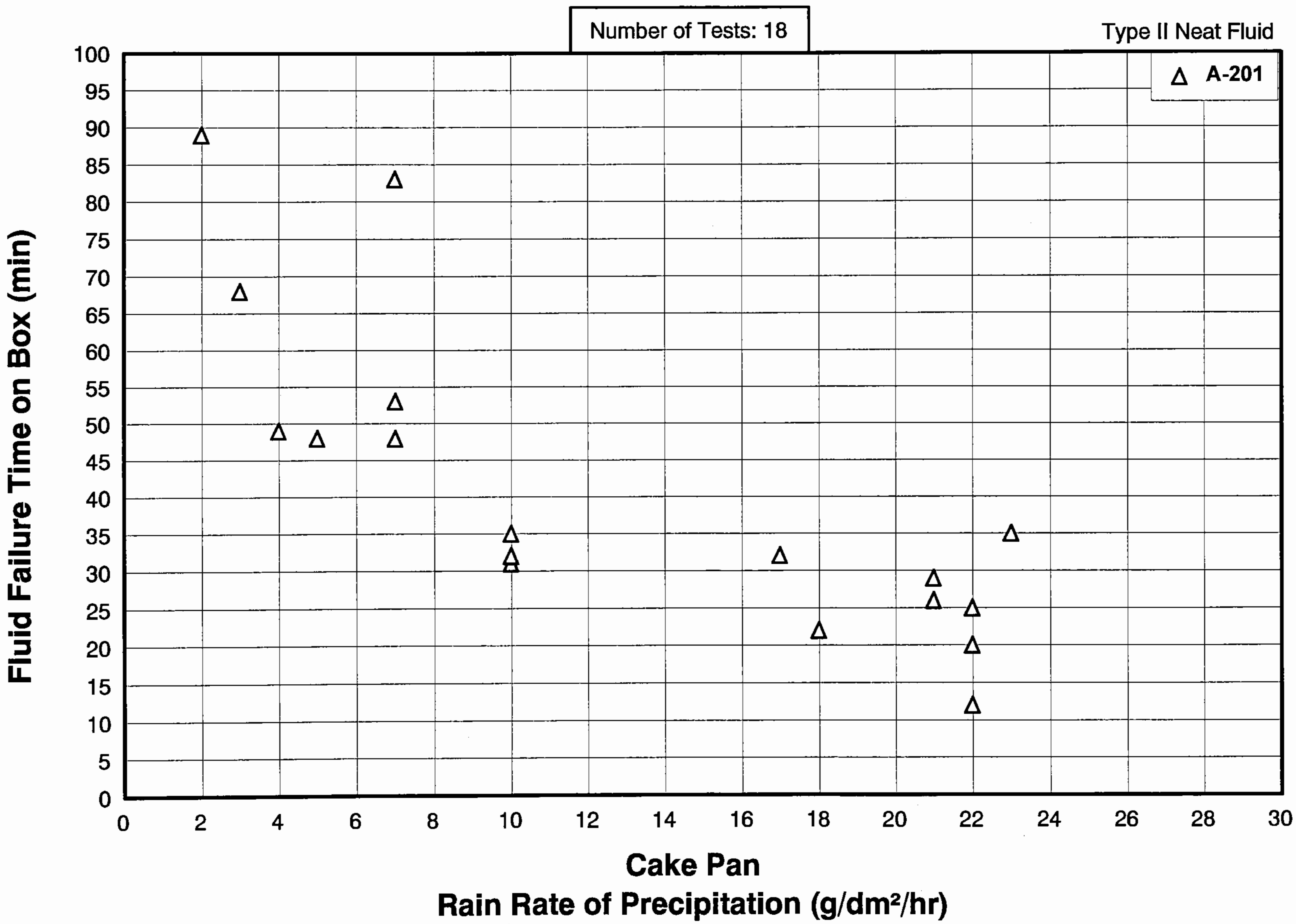
cm1222\cons_hot\coldsoak\CS1D_91.GRF

FIGURE 3.92

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

RAIN ON COLD-SOAKED SURFACE



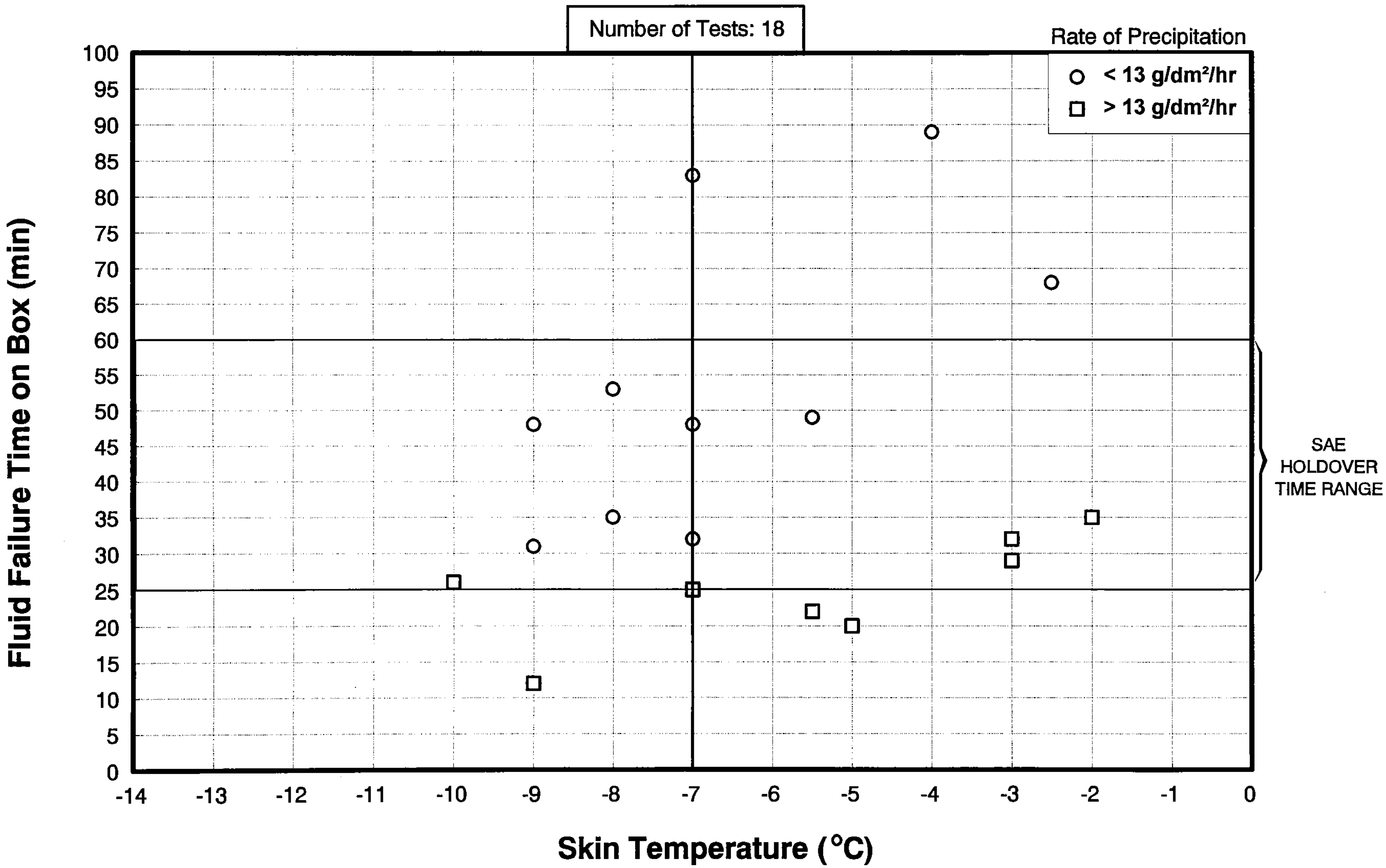
cm1222\cons_hot\coldsoak\CS21_92.GRF

FIGURE 3.93

EFFECT OF RATE OF PRECIPITATION SKIN TEMPERATURE ON FAILURE TIME

TYPE II NEAT

RAIN ON COLD-SOAKED SURFACE



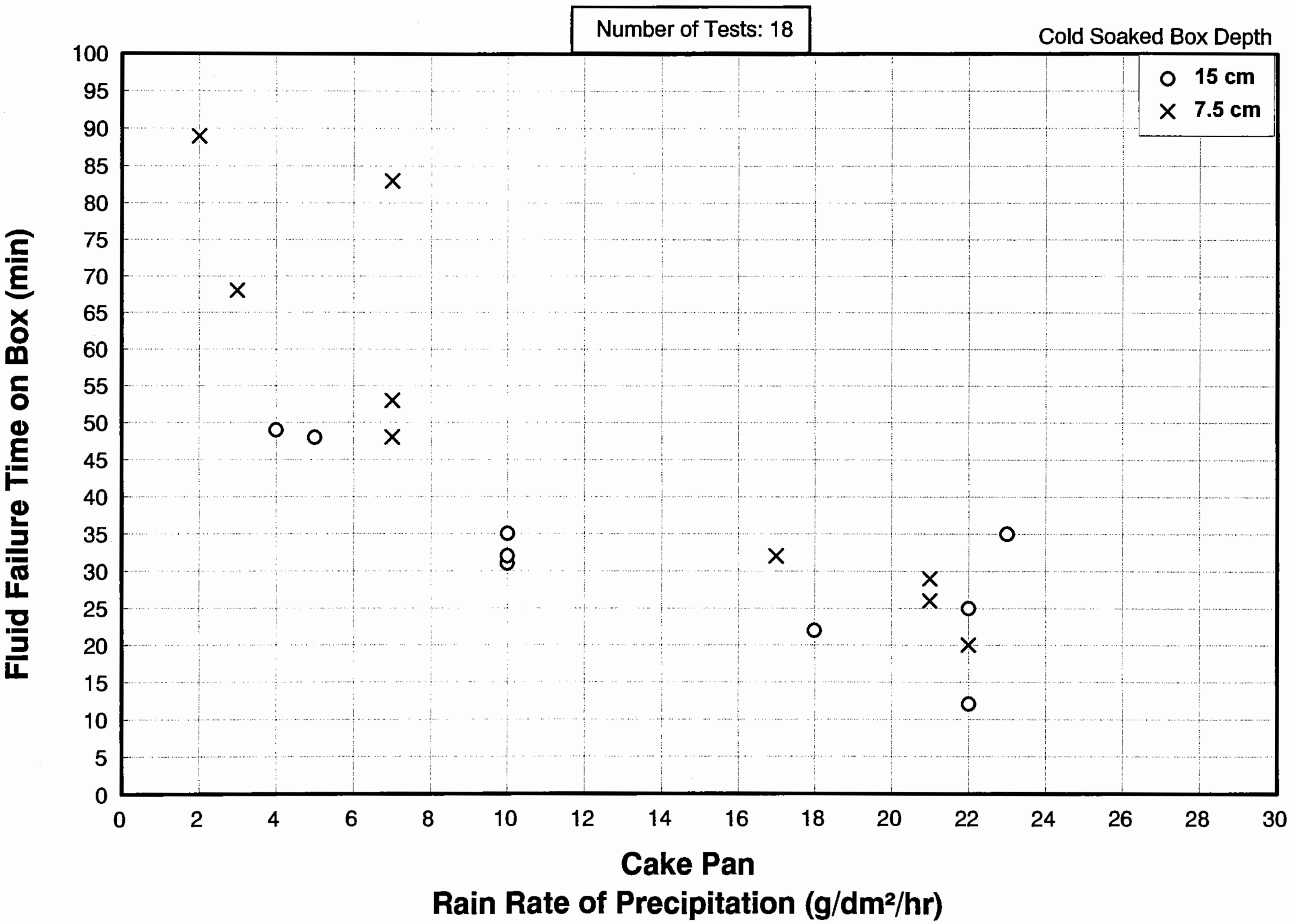
cm1222\cons_hot\coldsoak\CS21_93.GRF

FIGURE 3.94

EFFECT OF BOX SIZE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II NEAT

RAIN ON COLD-SOAKED SURFACE



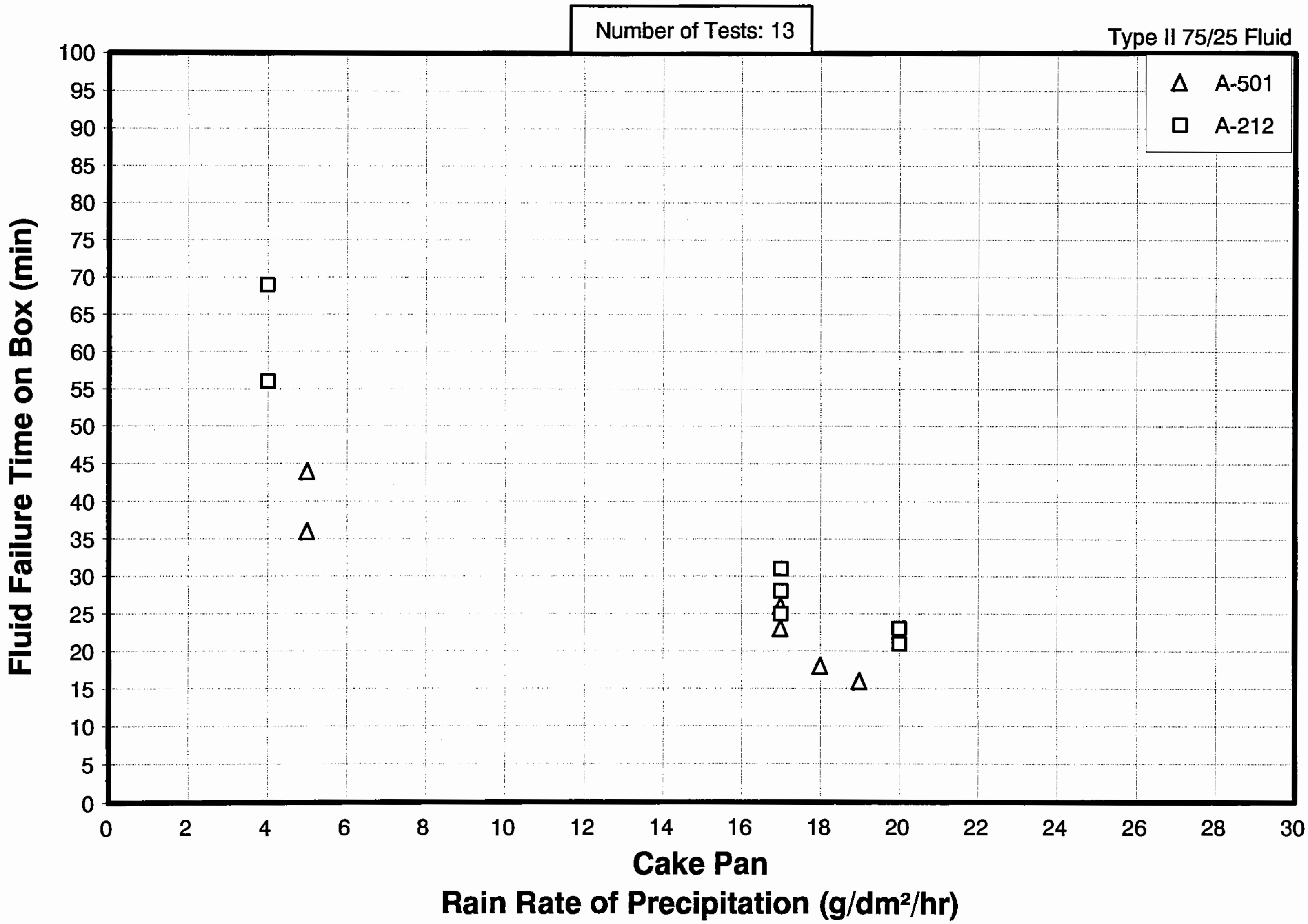
cm1222\cons_hot\coldsoak\CS21_94.GRF

FIGURE 3.95

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 75/25

RAIN ON COLD-SOAKED SURFACE



cm1222\cons_hol\coldsoak\CS27_95.GRF

FIGURE 3.96
EFFECT OF RATE OF PRECIPITATION SKIN TEMPERATURE ON FAILURE TIME
TYPE II 75/25
RAIN ON COLD-SOAKED SURFACE

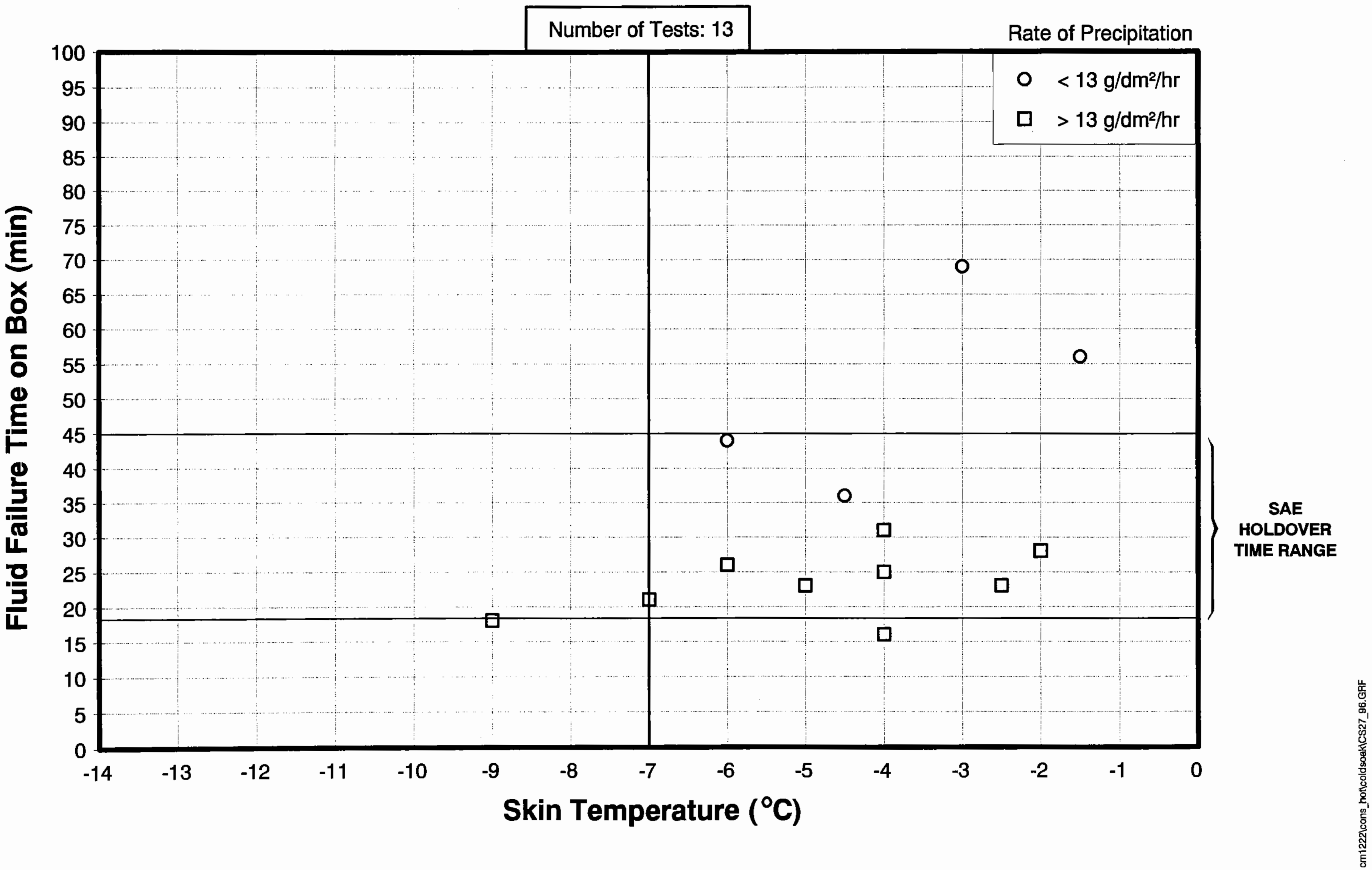
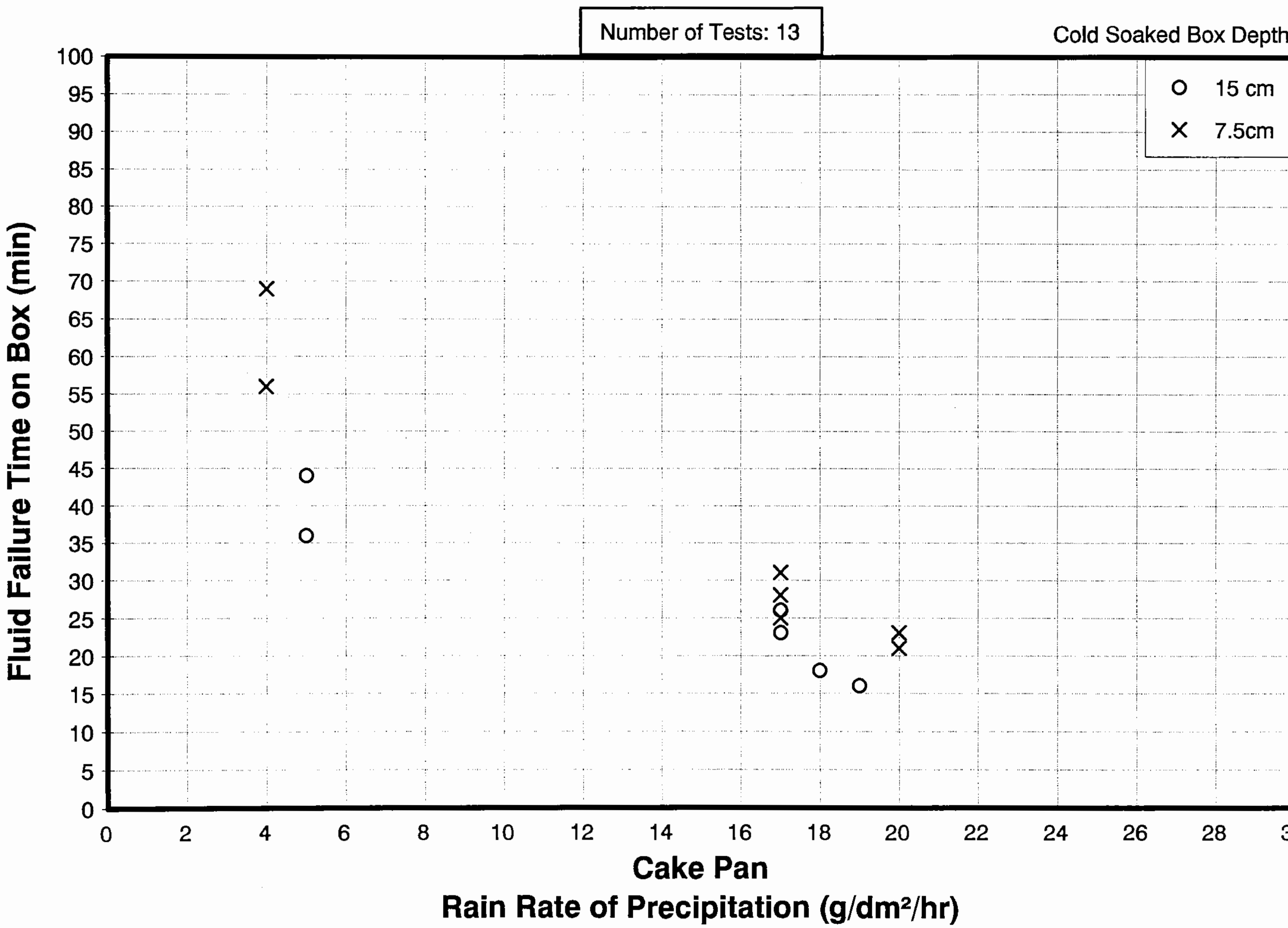


FIGURE 3.97

EFFECT OF BOX SIZE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 75/25

RAIN ON COLD-SOAKED SURFACE



cm1222\cons_hot\coldsoak\CS27_97.GRF

FIGURE 3.98

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 50/50

RAIN ON COLD-SOAKED SURFACE

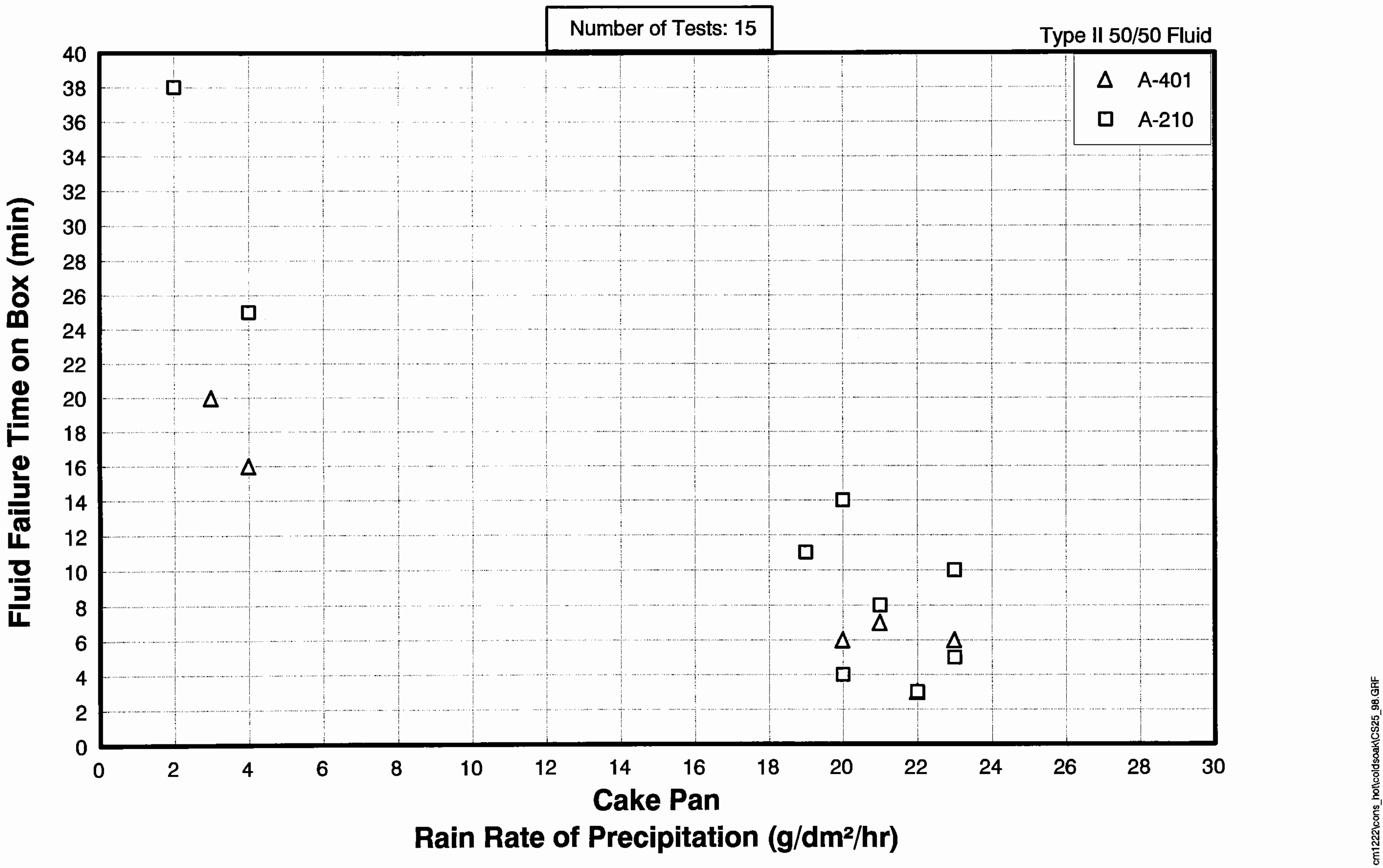


FIGURE 3.99

EFFECT OF RATE OF PRECIPITATION AND SKIN TEMPERATURE ON FAILURE TIME

TYPE II 50/50

RAIN ON COLD-SOAKED SURFACE

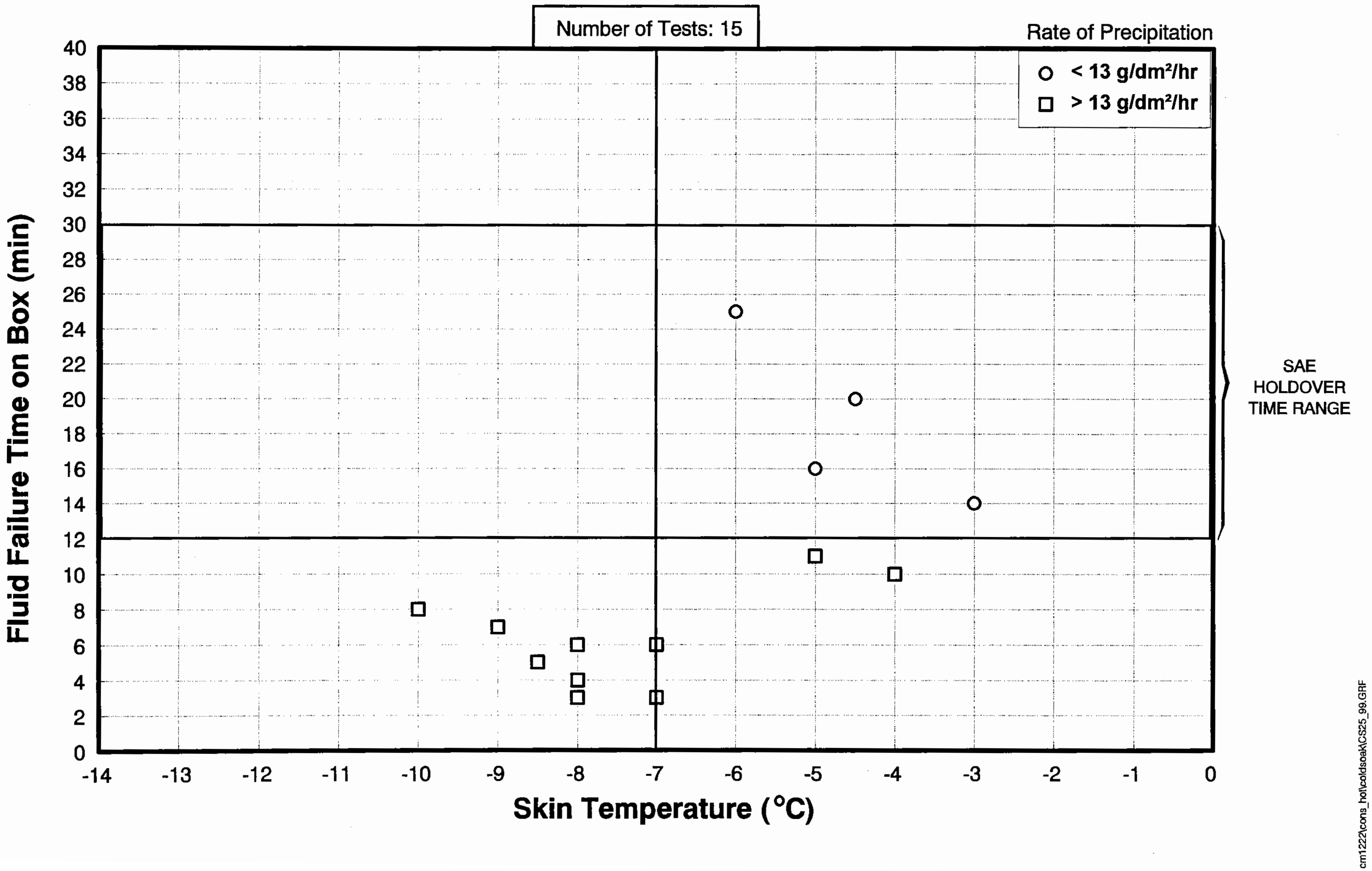
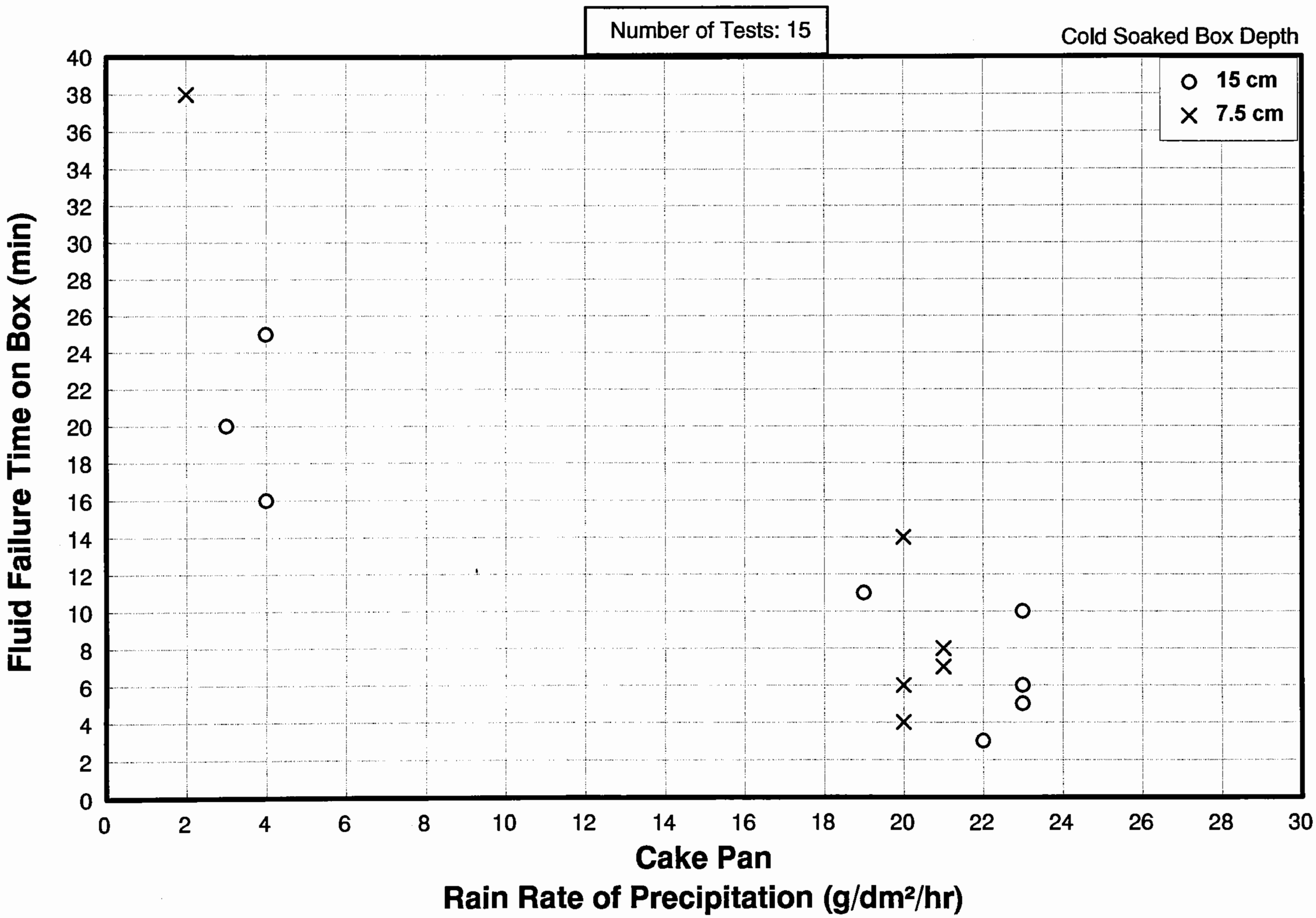


FIGURE 3.100

EFFECT OF BOX SIZE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE II 50/50

RAIN ON COLD-SOAKED SURFACE



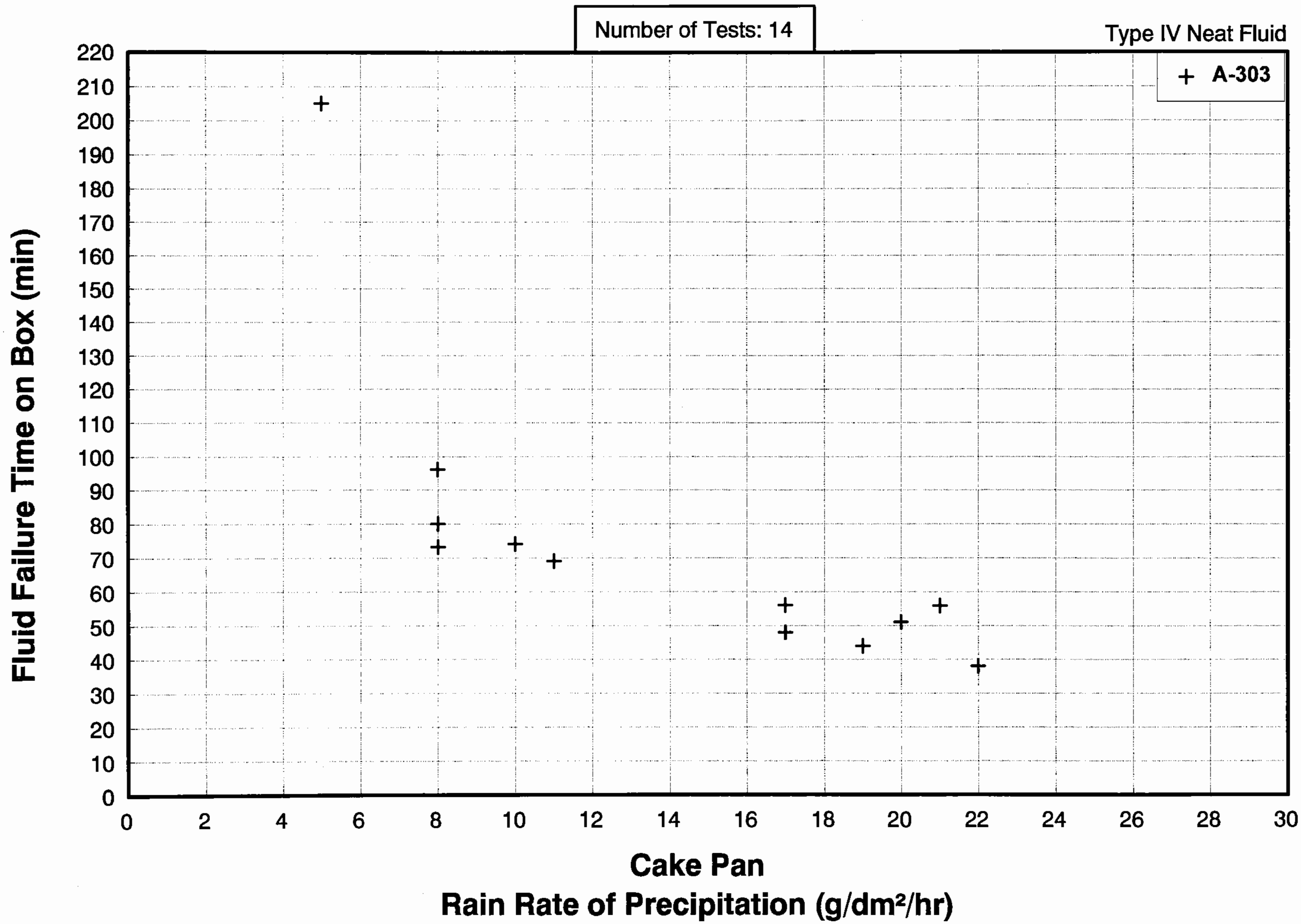
cm1222\cons_hot\coldsoak\CS25_100.GRF

FIGURE 3.101

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT

RAIN ON COLD-SOAKED SURFACE



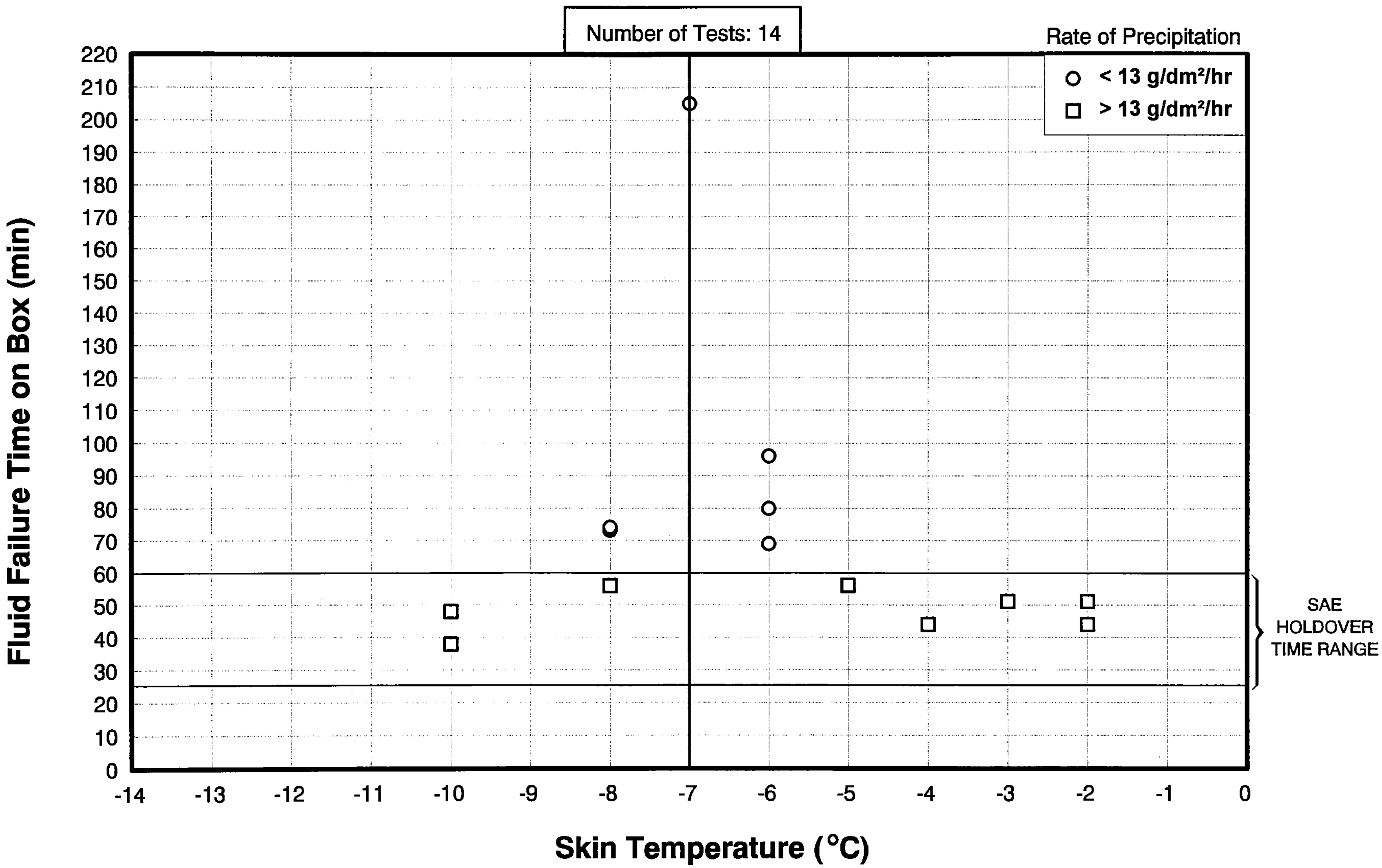
cm1222\cons_hot\coldsoak\CS41_101.GRF

FIGURE 3.102

EFFECT OF RATE OF PRECIPITATION AND SKIN TEMPERATURE ON FAILURE TIME

TYPE IV NEAT

RAIN ON COLD-SOAKED SURFACE



cm1222\cons_hot\coldsoak\CS41_102.GRF

FIGURE 3.103

EFFECT OF BOX SIZE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT

RAIN ON COLD-SOAKED SURFACE

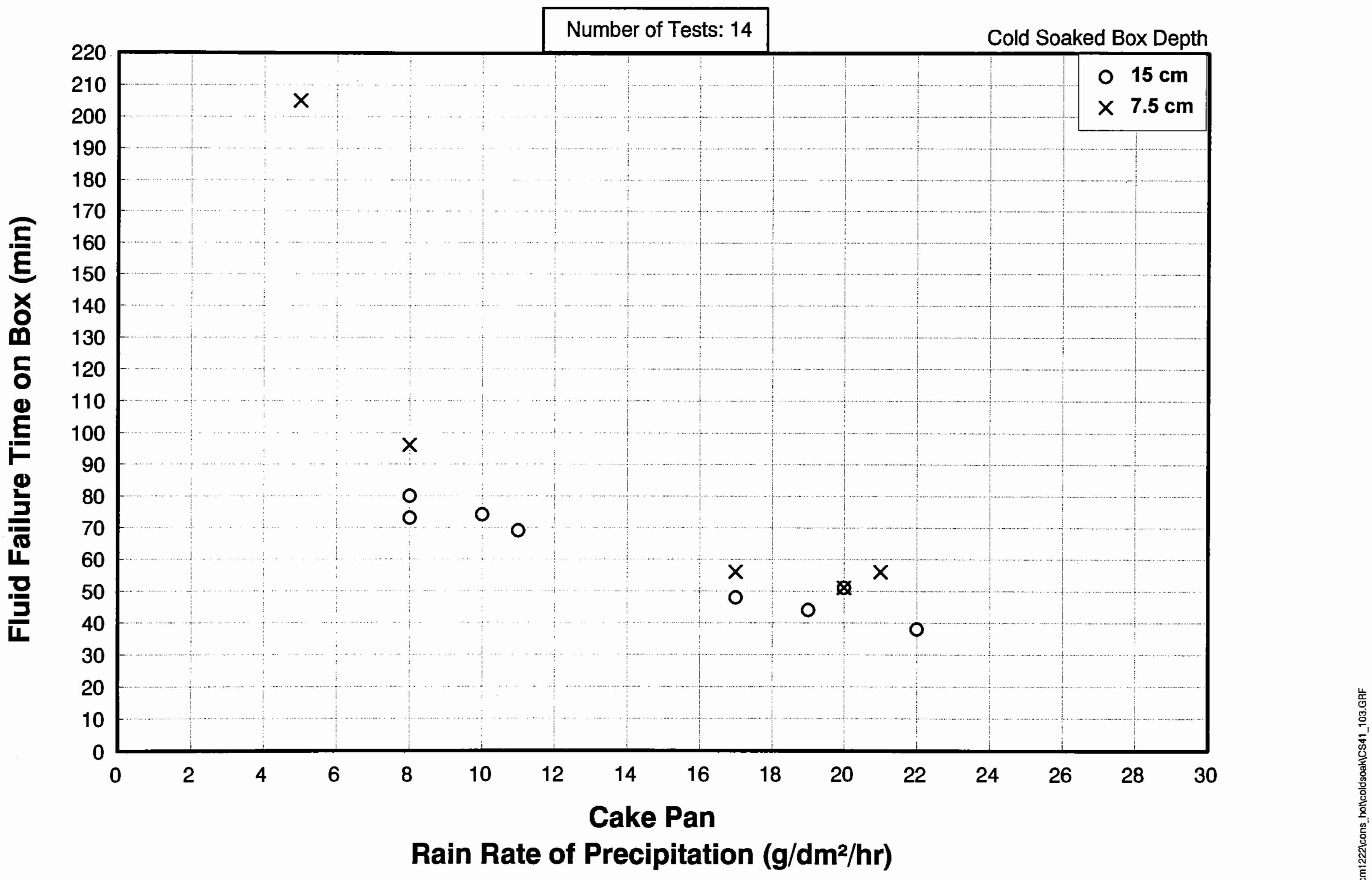
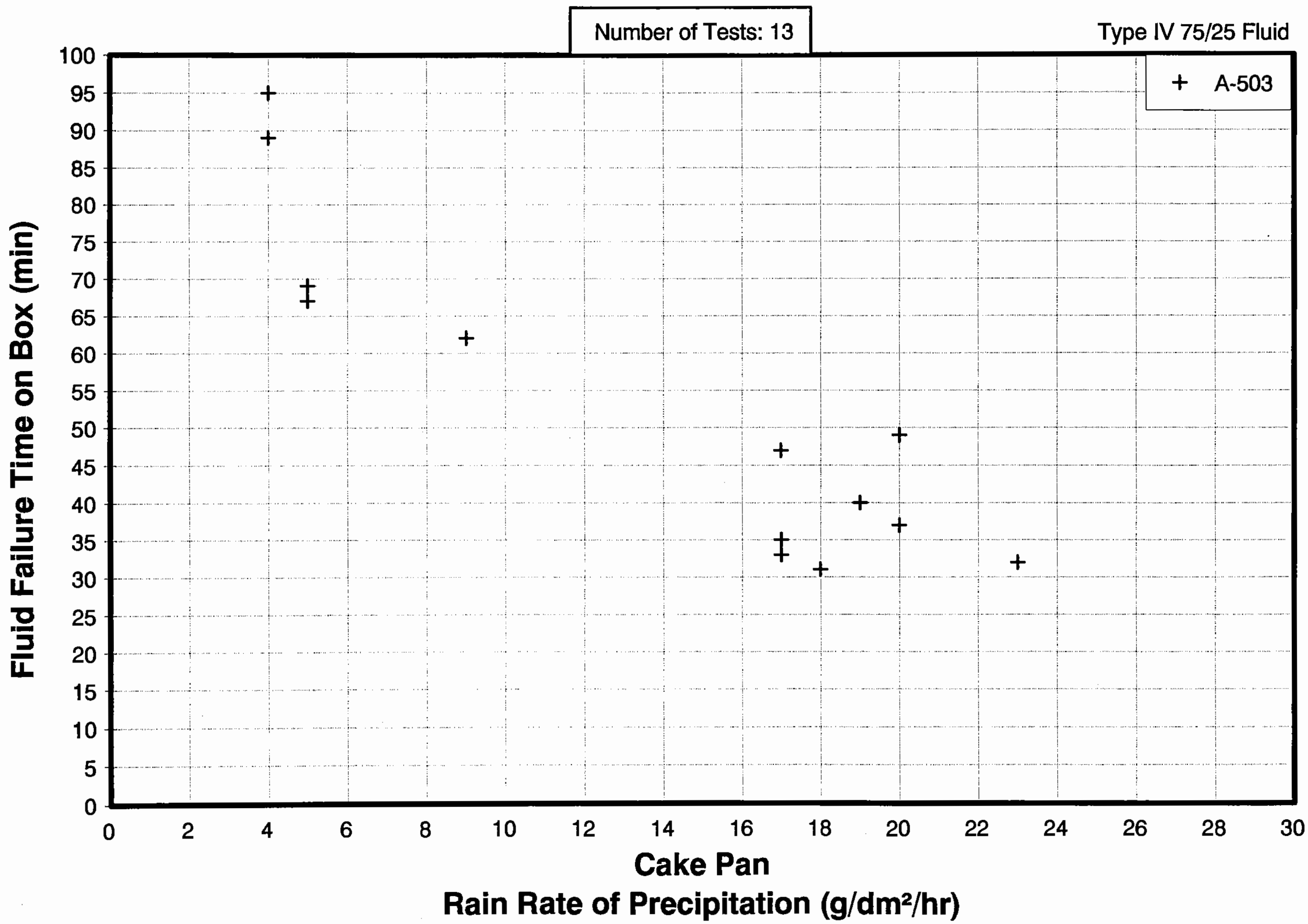


FIGURE 3.104

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 75/25

RAIN ON COLD-SOAKED SURFACE



cm1222\cons_hot\coldsoak\CS47_104.GRF

FIGURE 3.105

EFFECT OF RATE OF PRECIPITATION AND SKIN TEMPERATURE ON FAILURE TIME

TYPE IV 75/25

RAIN ON COLD-SOAKED SURFACE

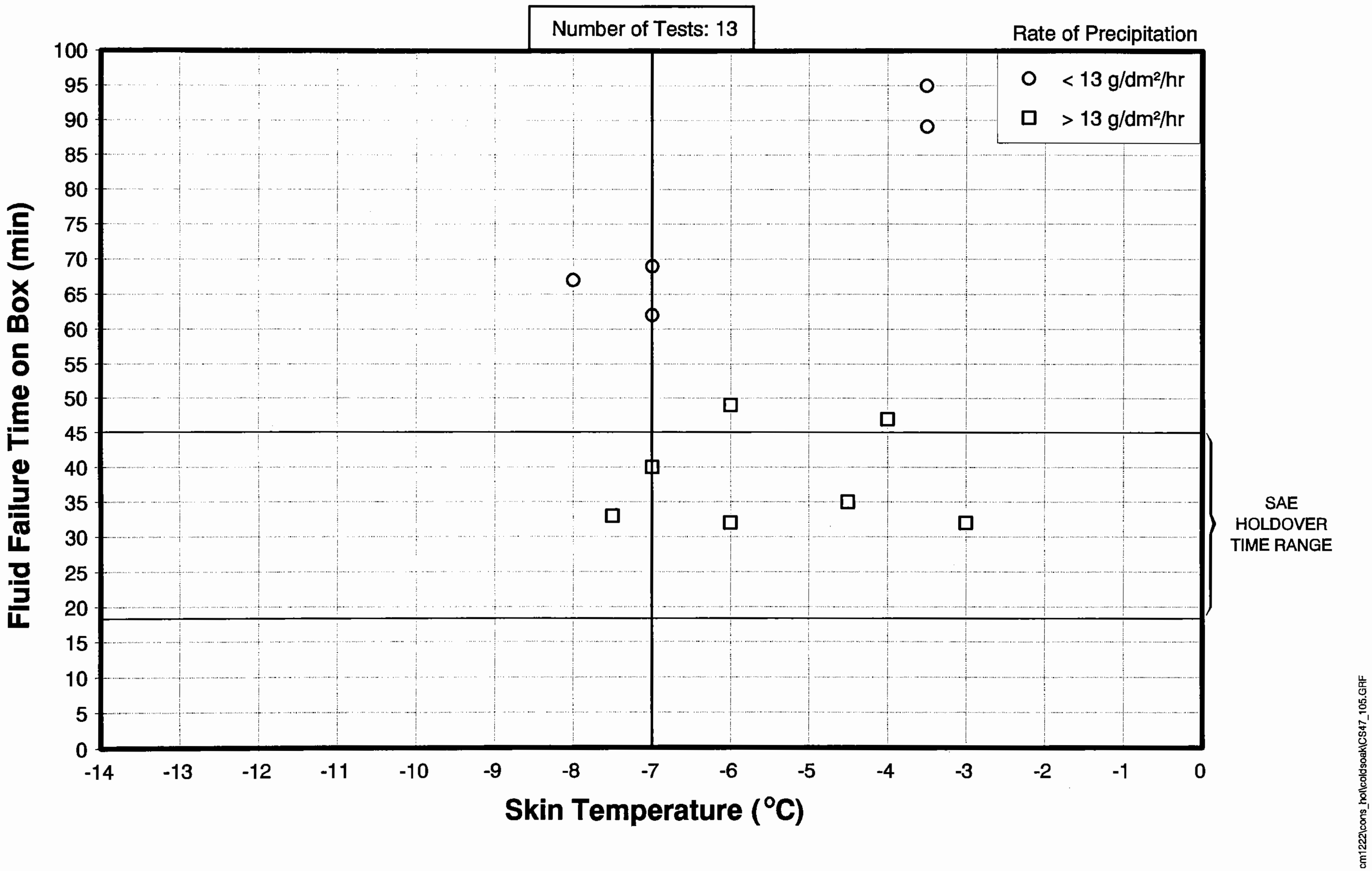
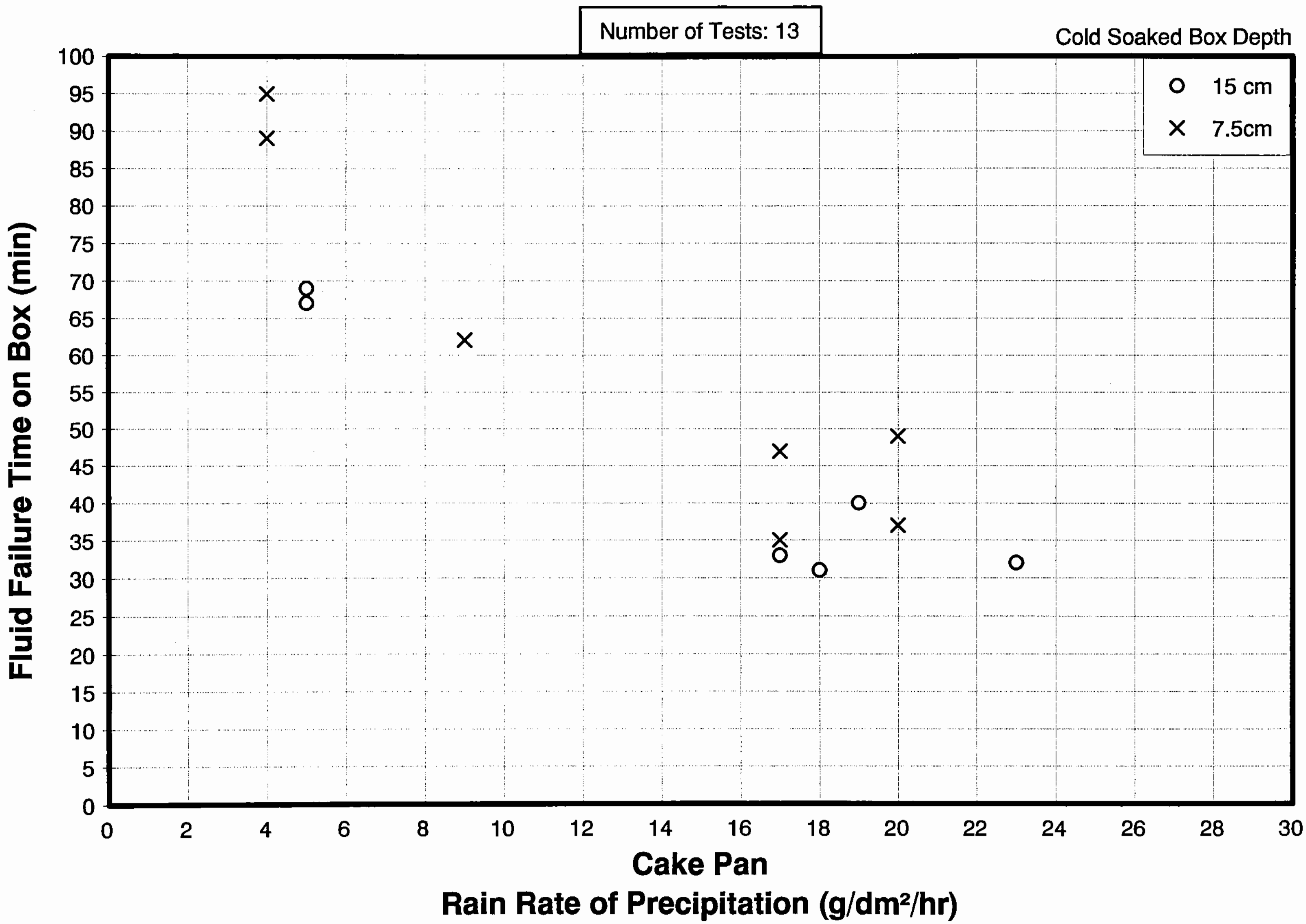


FIGURE 3.106
EFFECT OF BOX SIZE AND RATE OF PRECIPITATION ON FAILURE TIME
TYPE IV 75/25
RAIN ON COLD-SOAKED SURFACE



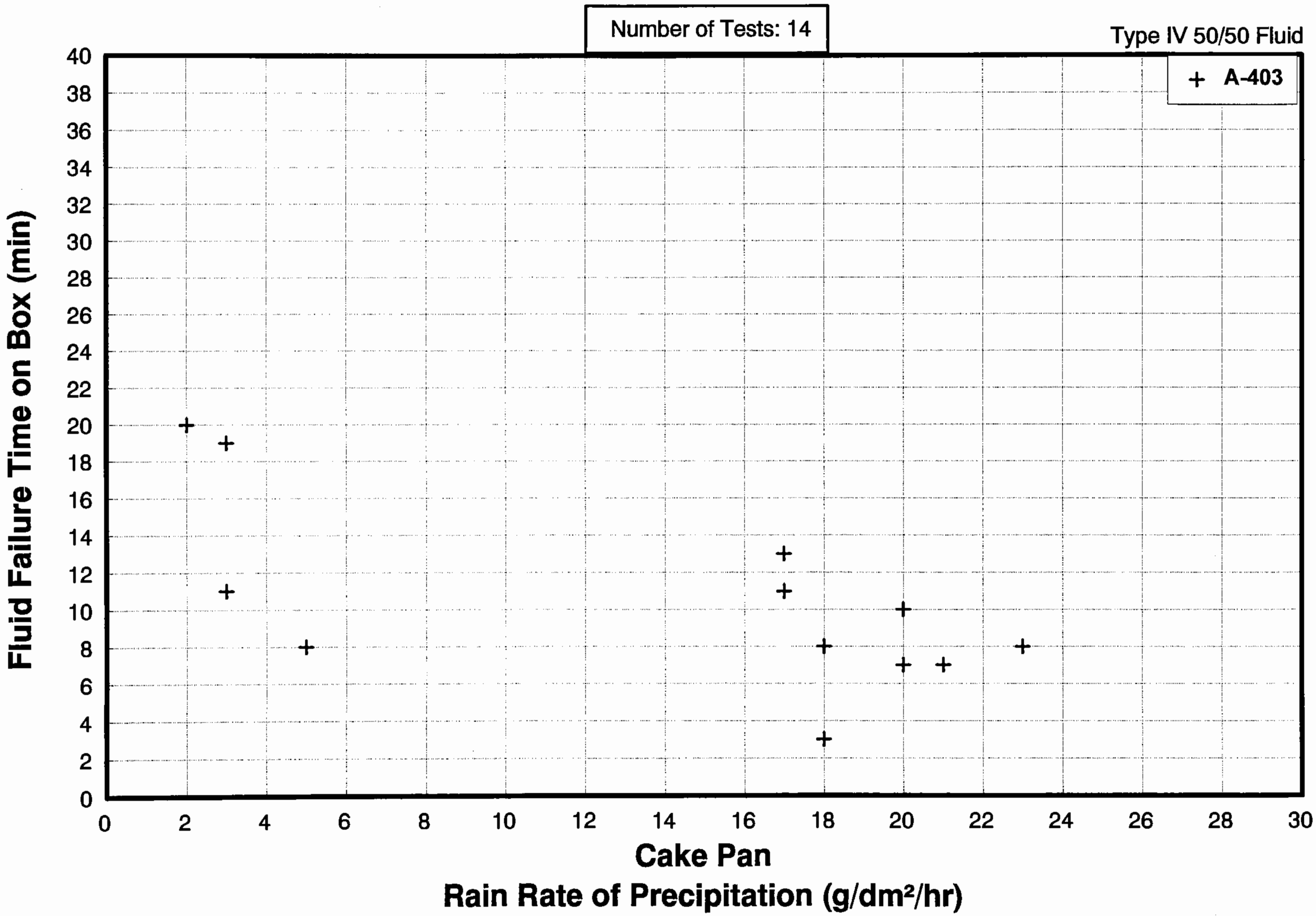
cm1222\cons_hot\coldsoak\CS47_108.GRF

FIGURE 3.107

EFFECT OF FLUID TYPE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50

RAIN ON COLD-SOAKED SURFACE



cm1222\cons_hot\coldsoak\CS45_107.GRF

FIGURE 3.108

EFFECT OF RATE OF PRECIPITATION AND SKIN TEMPERATURE ON FAILURE TIME

TYPE IV 50/50

RAIN ON COLD-SOAKED SURFACE

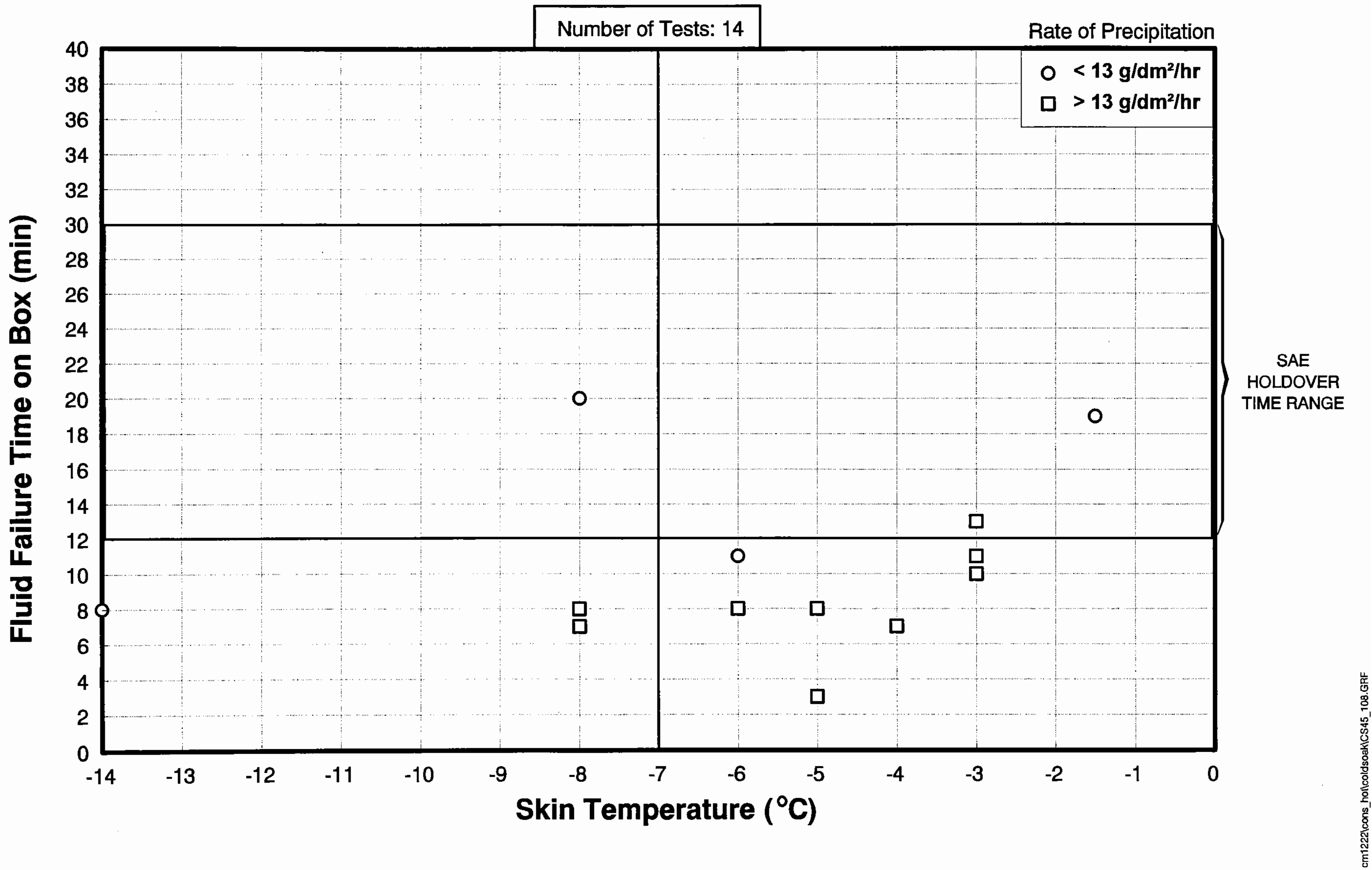
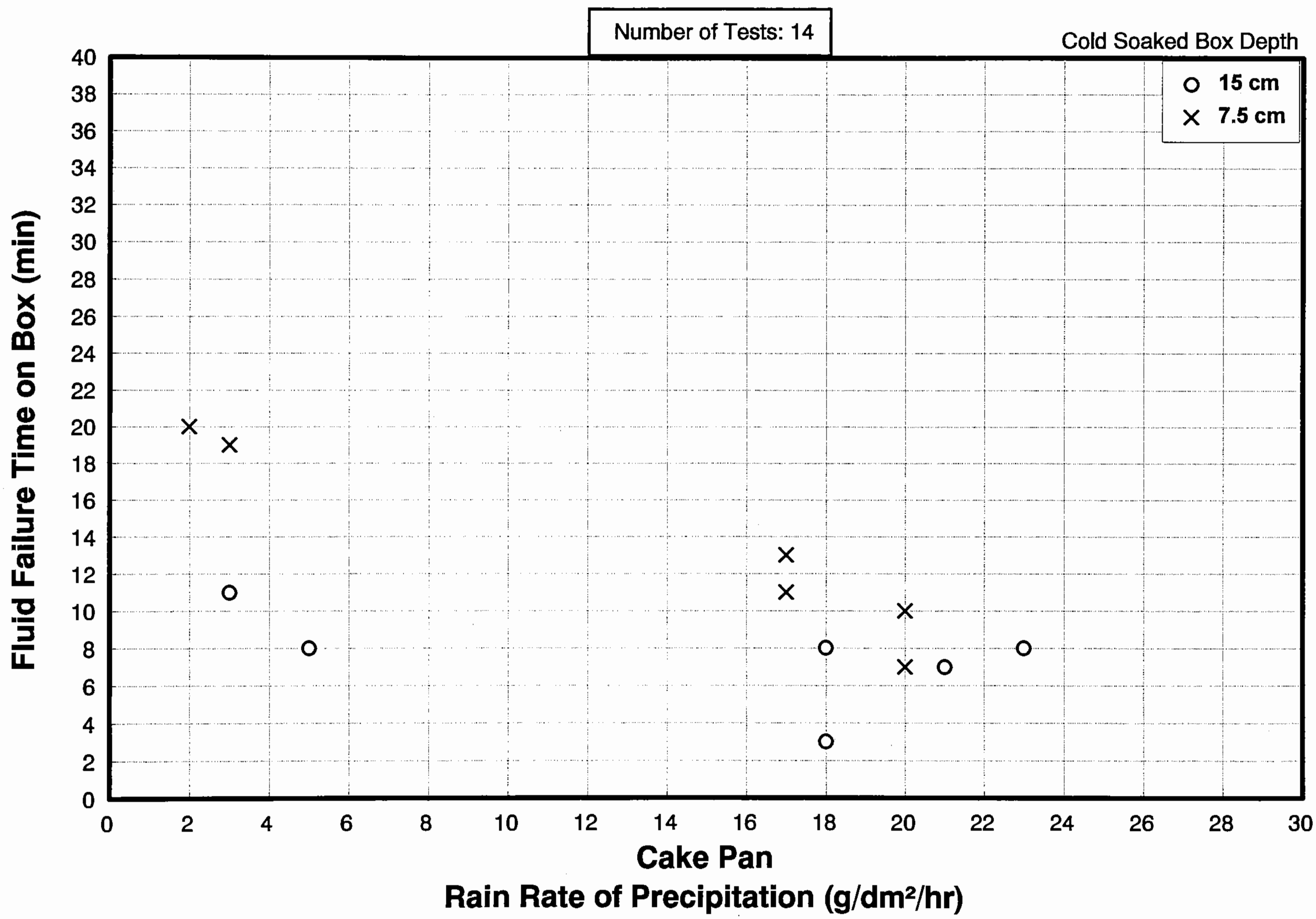


FIGURE 3.109

EFFECT OF BOX SIZE AND RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV 50/50

RAIN ON COLD-SOAKED SURFACE



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4. CONCLUSIONS

4. CONCLUSIONS

A comparison made of the analysis contained in recent reports with that included in earlier reports, showed that relationships between the failure times of the de/anti-icing fluids and the meteorological parameters were more evident than was the case in 1990. Improvements in meteorological data collection contributed greatly to this result.

The list below shows the most significant variables that influence the fluid failure times on the flat plates:

- Rate and type of precipitation;
- Ambient air temperatures;
- Fluid temperature;
- Wind velocity;
- Plate orientation with respect to the wind direction;
- Subjectivity of visual determination of the end condition;
- Fluid application quantity; and
- Fluid characteristics (type, dilution, and manufacturer).

The flat plate tests were conducted under a variety of precipitation conditions. Tables 4.1, 4.2 and 4.3 provide the current status of the SAE/ISO holdover time tables as they have been proposed by the SAE G-12 Committee for use in Canada and the United States during the 1995/96 winter season. Table 4.1 is for Type I, Table 4.2 is for Type II and Table 4.3 is for the new Union Carbide "Ultra" fluid. Every block in each table is labelled with an indicator to provide the current status. "S" designates that the times for the specific condition and fluid are substantiated, while "NS" indicates that they are not yet substantiated.

TABLE 4.1

CURRENT SAE/ISO HOLDOVER TIME TABLE FOR TYPE I FLUIDS TO BE USED IN 1995/96

TABLE 2. Guidelines for Holdover Times Anticipated by SAE Type I and ISO Type I Fluid Mixtures as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY AND IT SHOULD BE USED IN CONJUNCTION WITH PRETAKEOFF CHECK PROCEDURES.

TYPE I

Freezing Point of Type I Fluid Mixture used must be at least 10°C (18°F) below OAT.

OAT		Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
					PROPOSED		
°C	°F	FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING
0 & above	32 & above	0:18-0:45 **S**	0:12-0:30 **NS**	0:06-0:15 **S**	0:05-0:08 **S**	0:02-0:05 **S**	0:06-0:15 **NS**
below 0 to -7	below 32 to 19	0:18-0:45 **S**	0:06-0:15 **S**	0:06-0:15 **S**	0:05-0:08 **S**	0:02-0:05 **S**	CAUTION! clear ice may require touch for confirmation
below -7	below 19	0:12-0:30 **S**	0:06-0:15 **S**	0:06-0:15 **S**	** **S**	*** **S**	

This table does not apply to other than SAE or ISO Type I FPD fluids.

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

** Approximate Holdover Time for Freezing Drizzle is between 5 to 8 min below -7°C to -10°C.

*** Approximate Holdover Time for Light Freezing Rain is between 2 to 5 min below -7°C to -10°C.

S = Substantiated
NS = Not substantiated

TABLE 4.2

CURRENT SAE/ISO HOLDOVER TIME TABLE FOR TYPE II FLUIDS TO BE USED IN 1995/96

TABLE 1. Guidelines for Holdover Times Anticipated by SAE Type II and ISO Type II Fluid Mixtures as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY AND IT SHOULD BE USED IN CONJUNCTION WITH PRETAKEOFF CHECK PROCEDURES.

TYPE II

OAT °C	OAT °F	Type II Fluid Concentration Neat-Fluid/Water (% by volume)	FROST	FREEZING FOG	SNOW	PROPOSED FREEZING DRIZZLE	PROPOSED LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING
			Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
0 and above	32 and above	100/0	12:00 S	1:15-3:00 NS	0:25-1:00 S	0:30-1:00 S	0:15-0:30 S	0:24-1:00 NS
		75/25	06:00 S	0:50-2:00 NS	0:20-0:45 S	0:20-0:45 S	0:10-0:25 S	0:18-0:45 NS
		50/50	04:00 S	0:35-1:30 NS	0:15-0:30 S	0:15-0:25 S	0:05-0:15 S	0:12-0:30 NS
below 0 to -7	below 32 to 19	100/0	08:00 S	0:35-1:30 S	0:20-0:45 S	0:30-1:00 S	0:15-0:30 S	CAUTION! clear ice may require touch for confirmation
		75/25	05:00 S	0:25-1:00 S	0:15-0:30 S	0:20-0:45 S	0:10-0:25 S	
		50/50	03:00 S	0:15-0:45 S	0:05-0:15 S	0:15-0:25 S	0:05-0:15 S	
below -7 to -14	below 19 to 7	100/0	08:00 S	0:35-1:30 S	0:20-0:45 S	A S	C S	
		75/25	05:00 S	0:25-1:00 S	0:15-0:30 S	B S	D S	
below -14 to -25	below 7 to -13	100/0	08:00 NS	0:35-1:30 S	0:20-0:45 S			
below -25	below -13	100/0 if 7°C (13°F) Buffer is maintained	NS	NS	A buffer of at least 7°C (13°F) must be maintained for Type II used for anti-icing at OAT below -25°C (-13°F). Consider use of Type I fluids where SAE or ISO Type II cannot be used.			

This table does not apply to other than SAE or ISO Type II FPD fluids.

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

A - Approximate Holdover Time for Type II Neat in Freezing Drizzle is between 30 to 60 min below -7°C to -10°C.

B - Approximate Holdover Time for Type II 75/25 in Freezing Drizzle is between 20 to 45 min below -7°C to -10°C.

C - Approximate Holdover Time for Type II Neat in Light Freezing Rain is between 15 to 30 min below -7°C to -10°C.

D - Approximate Holdover Time for Type II 75/25 in Light Freezing Rain is between 10 to 25 min below -7°C to -10°C.

S = Substantiated

NS = Not substiantiated

TABLE 4.3

CURRENT HOLDOVER TIME TABLE FOR ULTRA FLUID TO BE USED IN 1995/96

TABLE 1. Guidelines for Holdover Times Anticipated by SAE Type II and ISO Type II Fluid Mixtures as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR USE IN DEPARTURE PLANNING ONLY AND IT SHOULD BE USED IN CONJUNCTION WITH PRETAKEOFF CHECK PROCEDURES.

ULTRA

OAT		Ultra Fluid Concentration Neat-Fluid/Water (% by volume)	Approximate Holdover Times Anticipated Under Various Weather Conditions (hours:minutes)					
						PROPOSED		
°C	°F		FROST	FREEZING FOG	SNOW	FREEZING DRIZZLE	LIGHT FRZ RAIN	RAIN ON COLD SOAKED WING
0 and above	32 and above	100/0	18:00 S	1:52-4:30 NS	0:37-1:30 S	0:45-1:30 S	0:22-0:45 S	0:24-1:00 NS
		75/25	06:00 NS	0:50-2:00 NS	0:20-0:45 NS	0:20-0:45 NS	0:10-0:25 NS	0:18-0:45 NS
		50/50	04:00 NS	0:35-1:30 NS	0:15-0:30 NS	0:15-0:25 NS	0:05-0:15 NS	0:12-0:30 NS
below 0 to -7	below 32 to 19	100/0	12:00 S	0:52-2:15 S	0:30-1:07 S	0:45-1:30 S	0:22-0:45 S	CAUTION! clear ice may require touch for confirmation
		75/25	05:00 NS	0:25-1:00 NS	0:15-0:30 NS	0:20-0:45 NS	0:10-0:25 NS	
		50/50	03:00 NS	0:15-0:45 NS	0:05-0:15 NS	0:15-0:25 NS	0:05-0:15 NS	
below -7 to -14	below 19 to 7	100/0	12:00 S	0:52-2:15 S	0:30-1:07 S	A S	C S	
		75/25	05:00 NS	0:25-1:00 NS	0:15-0:30 NS	B NS	D NS	
bel** -14 to -30	bel** 7 to -22	100/0	12:00 S	0:52-2:15 S	0:30-1:07 S			

This table does not apply to other than Ultra FPD fluids.

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

A - Approximate Holdover Time for Ultra Neat in Freezing Drizzle is between 45 to 90 min below -7°C to -10°C.

B - Approximate Holdover Time for Ultra 75/25 in Freezing Drizzle is between 20 to 45 min below -7°C to -10°C.

C - Approximate Holdover Time for Ultra Neat in Light Freezing Rain is between 22 to 45 min below -7°C to -10°C.

D - Approximate Holdover Time for Ultra 75/25 in Light Freezing Rain is between 10 to 25 min below -7°C to -10°C.

**** - Below -30°C, consider use of Type I fluid.**

Based on the Ultra Flat Plate test results, the Type II neat HOT's were increased by 50% in all conditions except rain on cold-soaked wing.

S = Substantiated

NS = Not substantiated

The major conclusions from the tests conducted over the last few years are presented in point form below. The first three points are general conclusions which have evolved over the years. The basis for these conclusions is provided in the pertinent detailed reports.

4.1 General Conclusions

1) Higher winds generally tend to produce longer times to fluid failure. This is believed to occur since the fluid is being kept on the plate longer due to the wind blowing up the test plate.

2) Higher rates of precipitation and colder temperatures tend to reduce failure times for both indoor and outdoor testing.

3) Fluids from different manufacturers, but within the same type category, generally have different failure times.

4.2 Specific Conclusions

1) The flat plate tests have shown that the pre-1991 European AEA/ISO holdover times required a reduction to satisfactorily cover operational conditions experienced in North America. A factor of 40% was applied to these holdover times to arrive at the range which was subsequently adopted by the SAE.

2) Research conducted primarily by APS on behalf of Transport Canada demonstrated the need for improved holdover times, and provided an opportunity to test newly discovered long lasting fluids, which in turn

fostered the development of a new longer life class of fluid. This promoted the on-going development of a Type IV holdover time table.

3) When using Ultra, the Neat Type II holdover times were increased by 50% for all precipitation conditions except "rain on cold-soaked wings".

4) For natural snow conditions, Type I and II fluid tests have substantiated the current SAE/ISO holdover times. The holdover time ranges for Type I and II fluids are applicable during moderate conditions. During conditions of heavy precipitation the holdover times must be reduced.

5) For freezing fog conditions, tests results have substantiated the current holdover times.

6) The freezing rain column in the SAE/ISO holdover time tables was eliminated and replaced with two new columns: freezing drizzle and light freezing rain. These two precipitation types were differentiated because their respective holdover times were notably different.

7) New holdover time ranges were developed for freezing drizzle and light freezing rain based on the NRC Climatic Engineering Facility flat plate tests for all fluid types. These new holdover time ranges are applicable for temperatures down to -10°C for all fluid types except Type II 50/50. For Type II 50/50 fluid, the new holdover time range is applicable down to -7°C.

8) For rain on cold-soaked wings, preliminary results have shown that the SAE/ISO holdover time ranges may be adequate for Neat Type II and Type II 75/25 fluids. For Type II 50/50 and diluted Type I fluids, the SAE/ISO holdover time ranges may require a reduction.

APPENDIX A

NATURAL SNOW

DATA PRESENTED TO SAE

TORONTO 1994

RESULTS OF TYPE I FLUID FAILURE BELOW SAE HOLDOVER TIME IN NATURAL SNOW TESTS

APS, NRC and United Airlines

1992/93 & 1993/94 Data

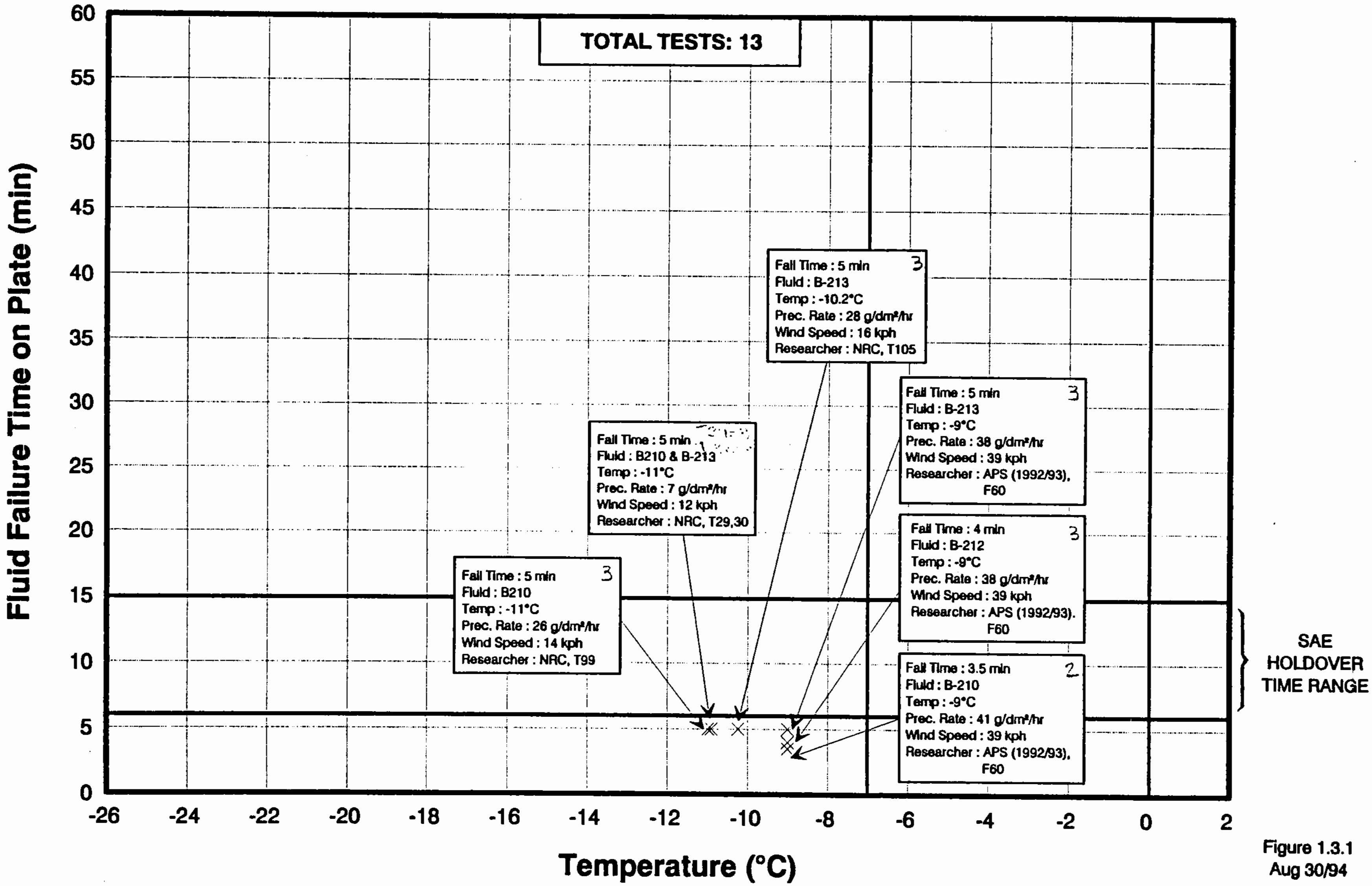

Figure 1.3.1
Aug 30/94

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RESULTS OF TYPE II NEAT FLUID FAILURE BELOW SAE HOLDOVER TIME IN NATURAL SNOW TESTS

APS, NRC and United Airlines

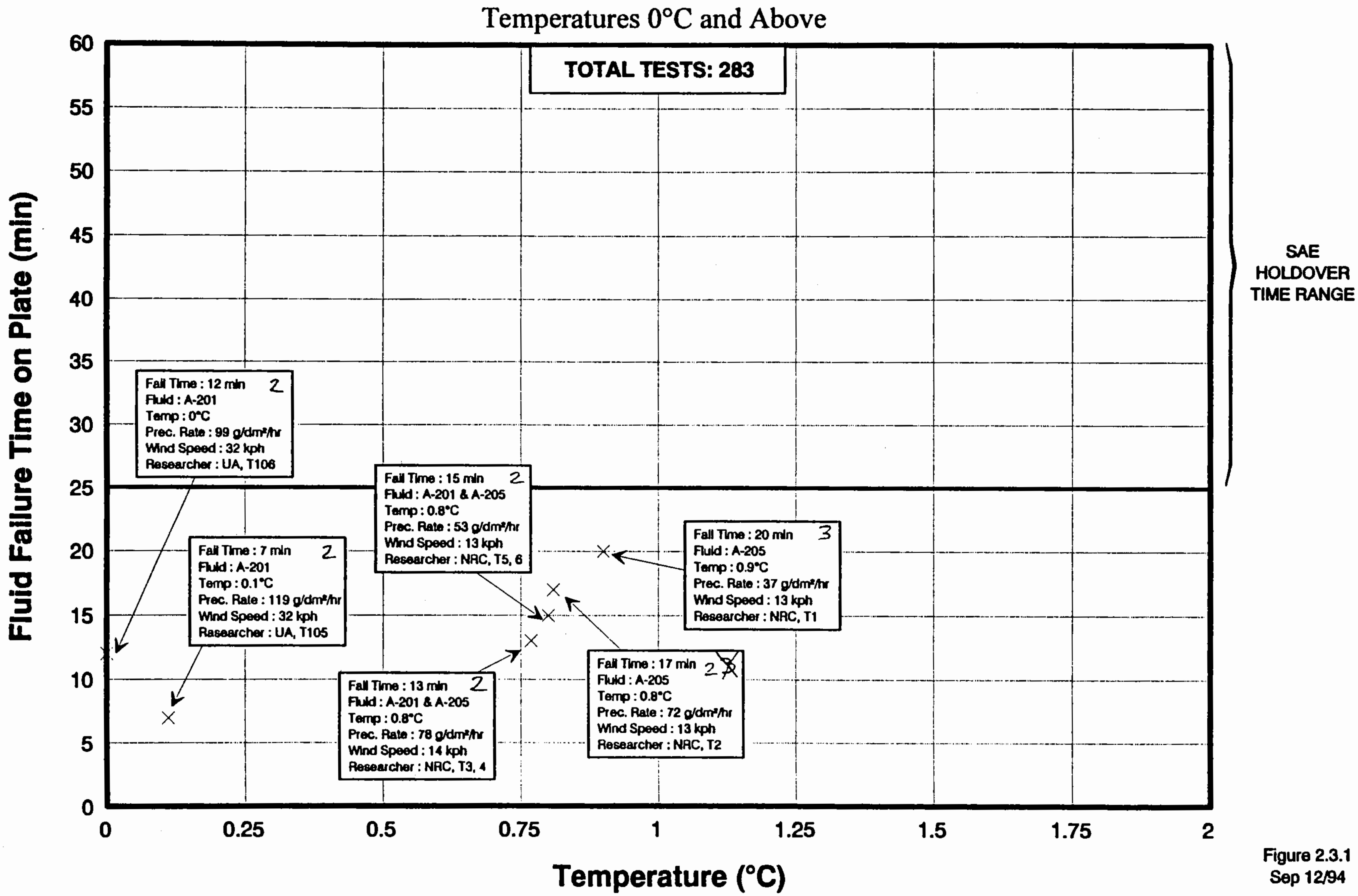

Figure 2.3.1
Sep 12/94

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RESULTS OF TYPE II NEAT FLUID FAILURE BELOW SAE HOLDOVER TIME IN NATURAL SNOW TESTS

APS, NRC and United Airlines

TRANSPORT CANADA
DCIP

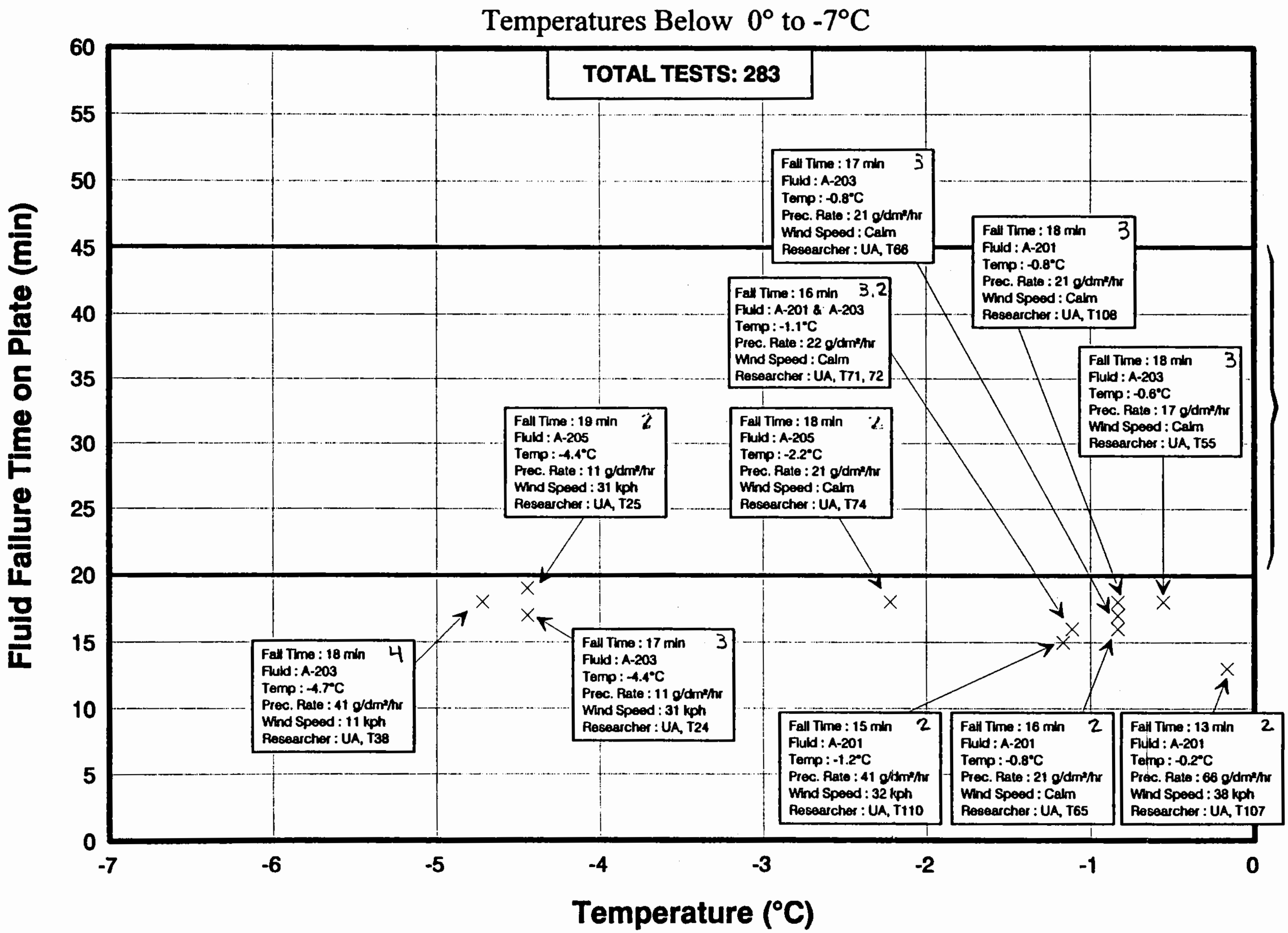

Figure 2.3.2
Sep 12/94

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RESULTS OF TYPE II NEAT FLUID FAILURE BELOW SAE HOLDOVER TIME IN NATURAL SNOW TESTS

APS, NRC and United Airlines

TRANSPORT CANADA
DCIP

Temperatures Below -7° to -14°C

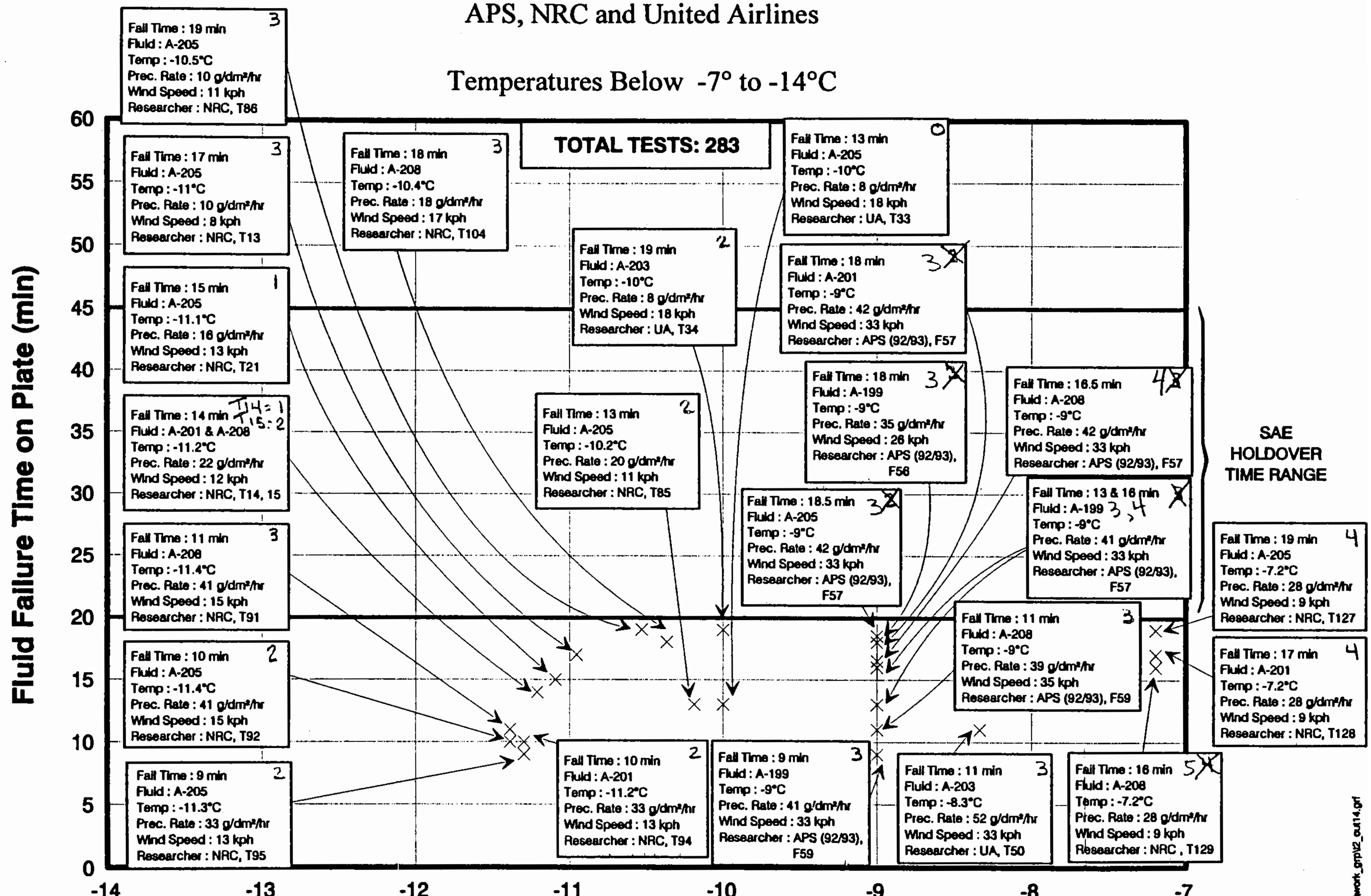

Figure 2.3.3
Sep 12/94

RESULTS OF TYPE II NEAT FLUID FAILURE BELOW SAE HOLDOVER TIME IN NATURAL SNOW TESTS

APS, NRC and United Airlines

TRANSPORT CANADA
DCIP

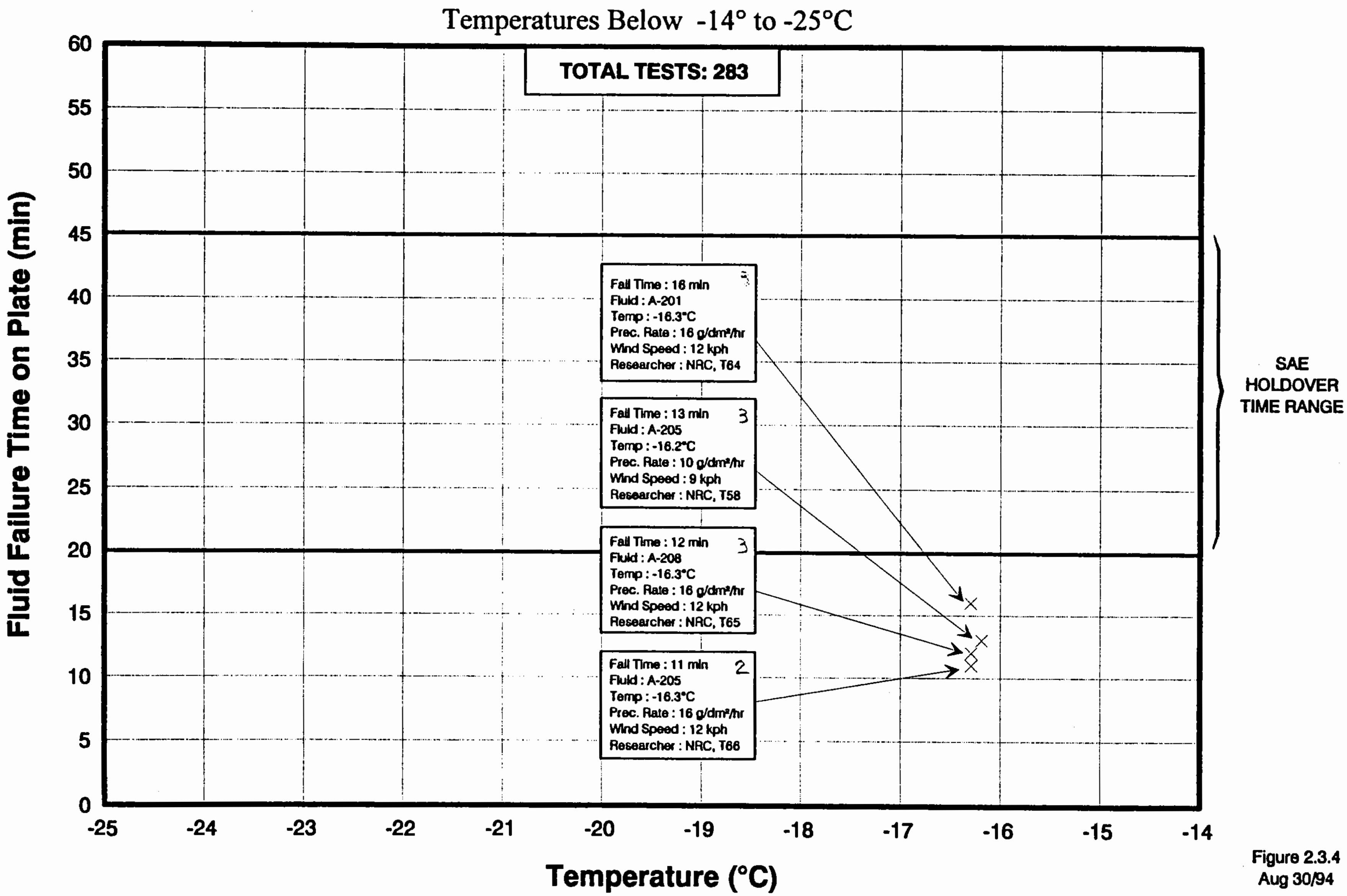

Figure 2.3.4
Aug 30/94

RESULTS OF TYPE II 75/25 FLUID FAILURE BELOW SAE HOLDOVER TIME IN NATURAL SNOW TESTS

APS and NRC

TRANSPORT CANADA
DCIP

All Temperatures

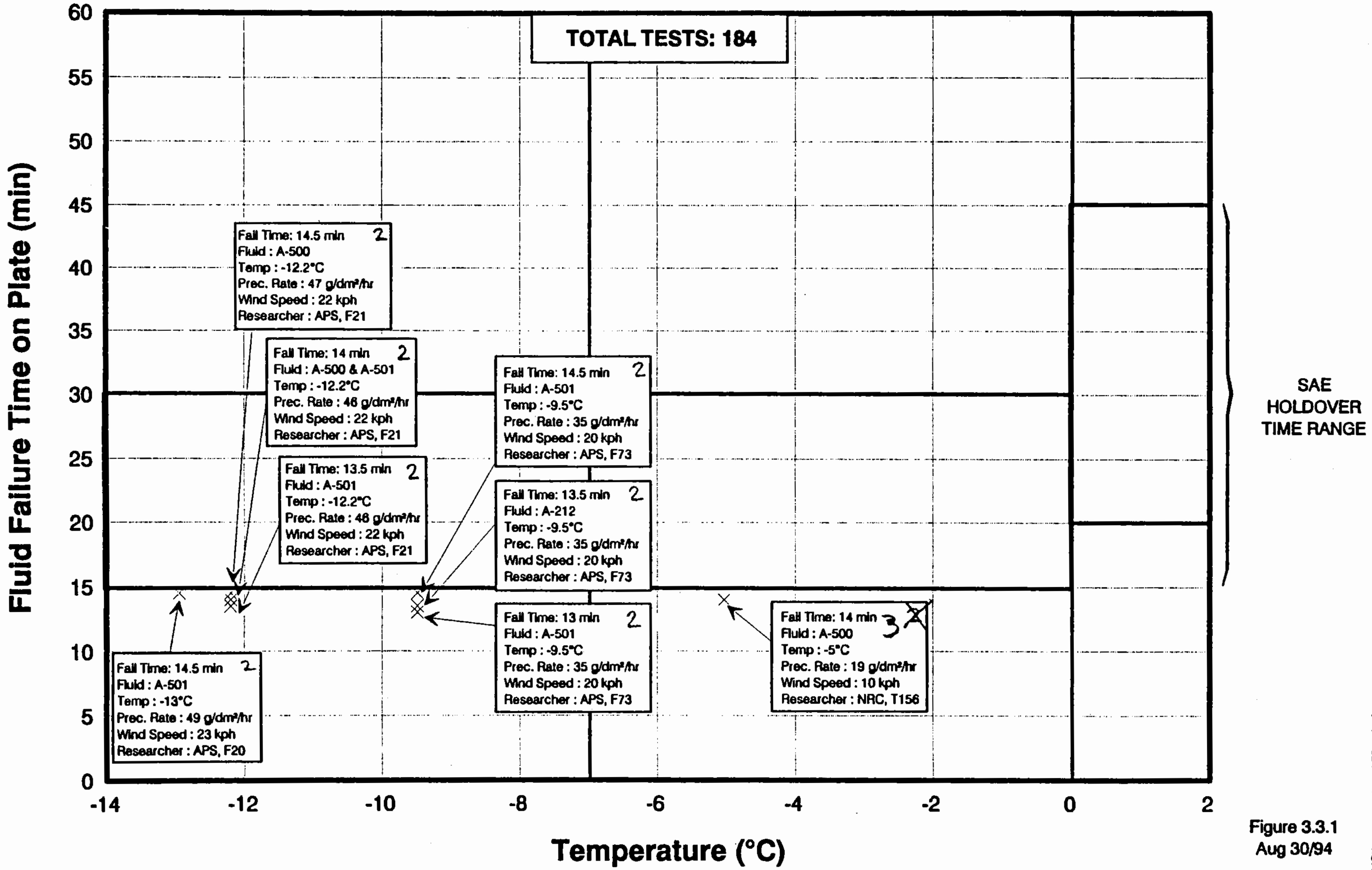

Figure 3.3.1
Aug 30/94

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TRANSPORT CANADA
DCIP

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

APS and NRC

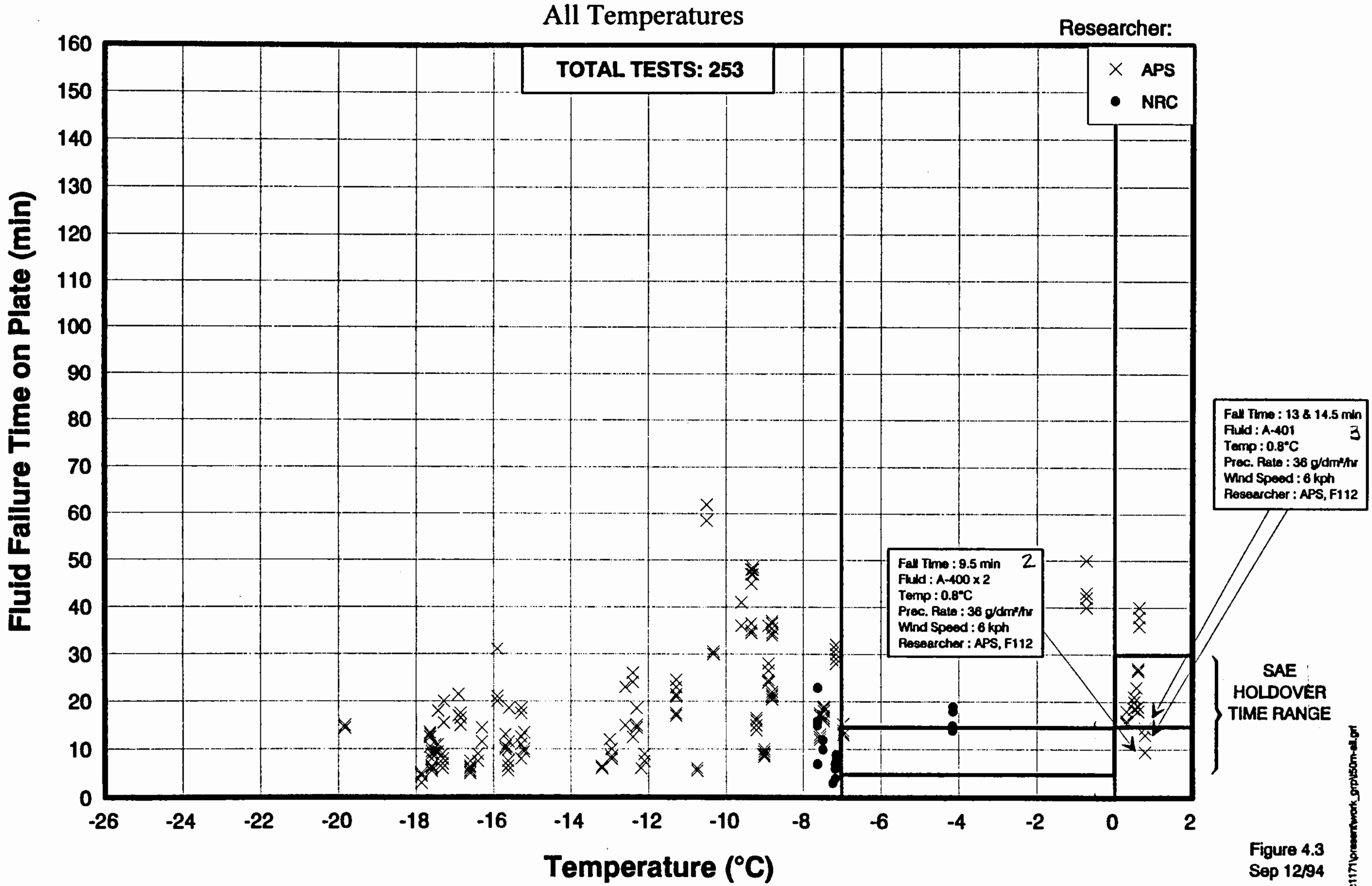

Figure 4.3
Sep 12/94

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POSSIBLE VARIABLES CAUSING FLUID FAILURE

Variable	Score		Criterion used
	1	0	
Failure Time (subjective)	Close to HOT LL	Far from HOT LL	80% of LL
Fluid	No longer available	Commercially available	
Air Temperature	Cold	Warm	-14°C
Rate of Precipitation	High	Low	25 g/dm/hr
Wind @ 2 metres	Low & Hi	Moderate	L<12 H>30
Researcher	NRC	APS, UA	

Score of 6 designates that all six variables may have had an influence on Failure
Score of 0 designates none of these variables had an influence on Failure

APPENDIX B
FLAT PLATE TEST PROCEDURE

CM1222.001

EXPERIMENTAL PROGRAM
FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING
1994 - 1995

APS Aviation Inc.

January 31, 1995
Version 1.2

EXPERIMENTAL PROGRAM
FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING
1994 - 1995

This document provides the detailed procedures and equipment required for the conduct of natural precipitation flat plate tests at Dorval for the 1994/95 winter season.

1. OBJECTIVE

To complete the substantiation of the existing SAE Holdover Time Tables and proposed table extensions by conduct of tests on standard flat plates as follows:

- Type I and Type II fluids under conditions of natural snow at the lowest temperature ranges.
- Type I fluids at dilutions for which a buffer of approximately 10°C from the fluid freeze point is maintained.
- At least two samples of a new family of "long-life" fluids will be tested to establish the holdover times over the full range of HOT Table conditions for this potential new fluids category.

2. TEST REQUIREMENTS (PLAN)

Attachment I provides the list (not in any order) of tests to be conducted at the Dorval test site located adjacent to AES. These tests shall be conducted during natural precipitation conditions.

3. EQUIPMENT

Test equipment required for the flat plate tests was determined in the last four years in association with the SAE working group. This equipment is listed in Attachment II.

4. PERSONNEL

One test site supervisor and at least two testers per stand are required to conduct a test.

5. PROCEDURE

The modified test procedure is also included in Attachment II. This procedure was developed more than four years ago and was modified over the years to incorporate discussions at the SAE working group meetings.

6. DATA FORM

A data form is included with Attachment II.

ATTACHMENT I

NATURAL PRECIPITATION TEST PLAN

RUN #	TEMP DEG C	NUMBER OF PLATES TESTED	TYPE 1* (De-Icing)						TYPE II (Anti-Icing)											
			HOECHST		ARCO PLUS		UCAR		OCT			OCT-NEW			KIL ABC-3/ARCO ABC-3			UCAR-ULTRA		
			50/50	DIL	63/37	DIL	XL54	DIL	NEAT	75/25	50/50	NEAT	75/25	50/50	NEAT	75/25	50/50	NEAT	75/25	50/50
1	>0	6				2	2	2												
2	>0	6			2		2	2												
3	>0	6			2	2		2												
4	>0	6	2	2				2												
5	>0	6				2		2			2									
6	>0	6											2	2					2	
7	>0	6									2			2						2
8	>0	6											2	2					2	
9	>0	6								2					2	2				
10	>0	6							2	2					2					
11	>0	6										2			2			2		
12	>0	6							2			2						2		
13	>0	6										2			2			2		
14	>0	6										2			2			2		
15	>0	6								2				2						2
16	0 TO -7	6								2				2						2
17	0 TO -7	6											2	2					2	
18	0 TO -7	6									2			2						2
19	0 TO -7	6											2	2					2	
20	0 TO -7	6				2	2	2												
21	0 TO -7	6			2		2	2												
22	0 TO -7	6			2	2		2												
23	0 TO -7	6	2	2				2												
24	0 TO -7	6		2		2		2												
25	0 TO -7	6							2			2						2		
26	0 TO -7	6							2			2						2		
27	0 TO -7	6										2			2			2		
28	0 TO -7	6										2			2			2		
29	0 TO -7	6									2	2						2		
30	-7 TO -14	6				2	2	2												
31	-7 TO -14	6			2		2	2												
32	-7 TO -14	6			2	2		2												
33	-7 TO -14	6	2	2				2												
34	-7 TO -14	6		2		2		2												
35	-7 TO -14	6											2			2			2	
36	-7 TO -14	6									2		2						2	
37	-7 TO -14	6							2			2						2		
38	-7 TO -14	6							2			2						2		
39	-7 TO -14	6										2			2			2		
40	-7 TO -14	6										2			2			2		
41	-7 TO -14	6							2			2						2		
42	-14 TO -25	6				2	2	2												
43	-14 TO -25	6			2		2	2												
44	-14 TO -25	6			2	2		2												
45	-14 TO -25	6	2	2				2												
46	-14 TO -25	6							2			2			2					
47	-14 TO -25	6							2			2			2					
48	-14 TO -25	6										2			2			2		
49	-14 TO -25	6							2						2			2		
50	-14 TO -25	6							2						2			2		
51	<-25	6				2	2	2												
52	<-25	6			2		2	2												
53	<-25	6			2	2		2												
54	<-25	6	2	2				2												
55	<-25	6							2			2			2					
56	<-25	6							2			2			2					
57	<-25	6										2			2			2		
58	<-25	6							2						2			2		
59	<-25	6							2						2			2		
TOTAL		354	10	14	20	26	20	46	30	8	10	40	12	16	38	4	0	40	12	8

* The dilutions should be based upon Table 2. XL54 (57% - 43%) and ARCO PLUS (63% - 37%) are commonly used in Canada.

Note: Type I fluid should be applied at Indoor Temperatures, while Type II fluids should be at Outside Air Temperatures.

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ATTACHMENT II
FLAT PLATE FIELD TEST EQUIPMENT AND PROCEDURE
1994 - 1995

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 range 0-1000 counts linearity 0.05%	- Weathertronics Model 1600
(B) Power Supply & 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 & Enclosure	- Weathertronics Model 1025
(C) PC Interface module	- Weathertronics Model 1799

2.1.1.6 Fisher and Porter with Nipher Shield

This model, used at many Canadian airports, has a resolution of 0.1mm.

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. A schematic of the plate pan is provided as Figure 0.

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

2.3 Test Stand

A typical test stand is illustrated in Figure 1; it may be altered to suit the location and facilities, but the angle for the panels, their arrangement and markings must all conform to Figures 1 and 2.

There shall be no flanges or obstructions close to the edges of the panels that could interfere with the airflow over the panels.

2.4 Test Panels

2.4.1 Material and Dimensions

Alclad Aluminum 2024-T6 or 5052-H32 polished standard roll mill finish 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 2.5 cm from each side; this marks off a working area of 25 x 45 cm on each panel. All marks shall be made using a 1/8" thick black marker or silk screen process, which does not come off with application of the test fluids or any of the cleaning agents. Remarking of the plates will be required as the markings fade because of the cleaning actions.

2.4.3 Attachment

For attachment to the test stand, at least four holes shall be made, spaced along the two sides of each panel; the holes shall be within 2 cm from the panel edge.

2.5 Fluid Application

The fluid should be poured onto the plates from a manageable container, until the entire test section surface is saturated.

2.6 Film Thickness Gauge

Film thickness at the six inch line can be measured (this is optional). Painter's wet paint film thickness gauge. 1-08 mil gauge or equivalent is available from Paul N. Gardner Company Inc. Pompano Beach Florida.

2.7 Video recording

Where feasible a video recorder 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 or equivalent

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

3. DE/ANTI-ICING FLUIDS

3.1 Test Fluids

Only fluids that have been certified will be included in tests. Fluid suppliers shall submit to the test coordinating organization proof of certification for the fluids they provide.

3.2 Certification

Type II fluids shall be sheared by each manufacturer to that viscosity which would have been obtained by subjecting their fluids to the shear Stability Test found in the AEA Material specification revision C (October 1, 1988) paragraph 4.2.8.2.2.

Each manufacturer shall provide samples and a certificate of compliance showing the viscosity of their test sample of fluid before and after the Shear Stabile Test. Test verifications of each fluid may be made at the University of Quebec at Chicoutimi (UQAC).

3.3 Dye

Fluids will be supplied for certification and for testing in the form to be used on aircraft.

3.4 Dilution of Type I Fluids

Type I fluids must be diluted as a function of outside air temperature according to Table 2. These concentrations were determined based upon information provided by the fluid manufacturers for which a buffer of 10°C from the fluid freeze point is maintained. When preparing the mixtures, verify with a refractometer that the percentage concentrations are accurate. Union Carbide products are based on Ethylene Glycol, while the Octagon and Arco products are composed of Propylene Glycol.

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 as close as possible to the test 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 it may be necessary to raise the snow gauge above the drift level but no higher than the test panel. The snow gauge measurements should be started as early as feasible and continue throughout the duration of all tests to provide a continuous record of precipitation.

4.1.3 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 gram. 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 the pans on the test stand at the same orientation of the plates is recommended.

When using plate pans to measure precipitation rate, ensure that two plate pans are used. Care must be taken to ensure that snow or ice does not fall into the pans when transporting them into the trailer.

4.2 Test Panel Preparation

4.2.1 Before the start of each day's testing, ensure the panels are clean.

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

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 same fluid, load the second test fluid on panel V followed by panel Y, etc. (see Figure 0).

4.4 Holdover Time Testing

4.4.1 Set the **timer on** as the first fluid application (plate u and x) is completed. Note the time when fluid application is completed on the remaining panels.

4.4.2 Commence recording the test with a video recorder until the test reaches the END CONDITION (see Section 5).

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

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

5. <u>END CONDITIONS</u>

The plate failure time is that time required for the end conditions to be achieved.

This occurs when the accumulating precipitation fails to be absorbed at any five of the crosshair marks on the panels.

A crosshair is considered failed if:

- There is a visible accumulation of snow (not slush, but white snow) on the fluid at the crosshair when viewed from the front (i.e. perpendicular to the plate). You are looking for an indication that the fluid can no longer accommodate or absorb the precipitation at this point.

OR

- This condition is <u>only</u> applicable during freezing rain/drizzle ice pellets, freezing fog or during a mixture of snow and freezing rain/drizzle and ice pellets. 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 <u>**very important**</u>:

- 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 (absorbs) 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.

6. END OF TEST

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. Record the type of snow according to the classification in Figure 3.

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.

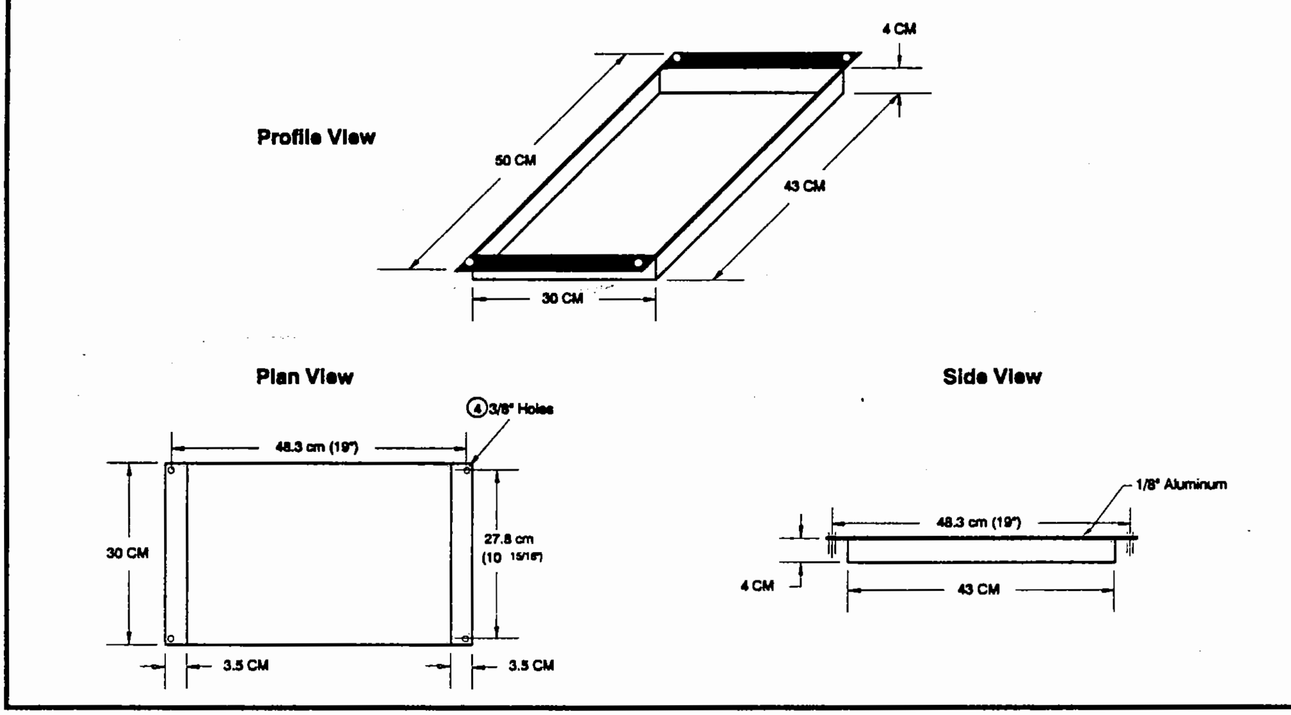
7. REPORTING & OBSERVATIONS

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).

FIGURE 0

SCHEMATICS OF PLATE PAN AND TEST STAND

PLATE PAN



TEST STAND

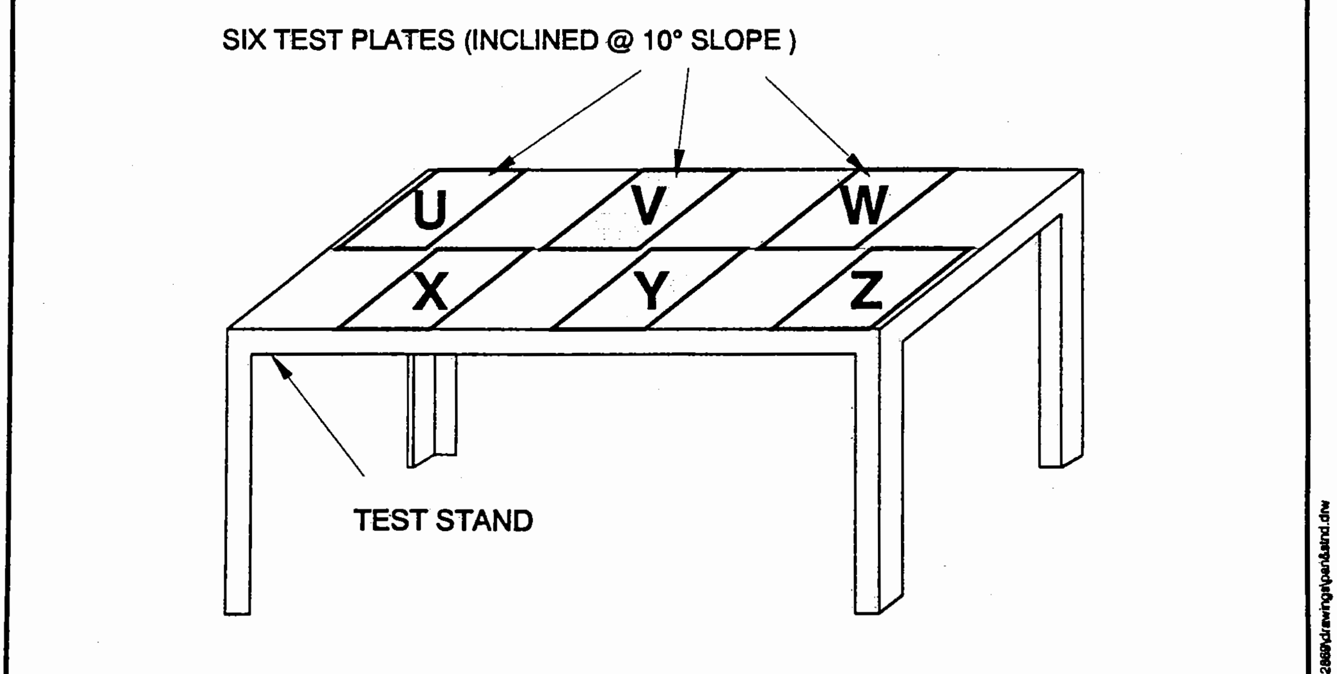


FIGURE 1
TEST STAND

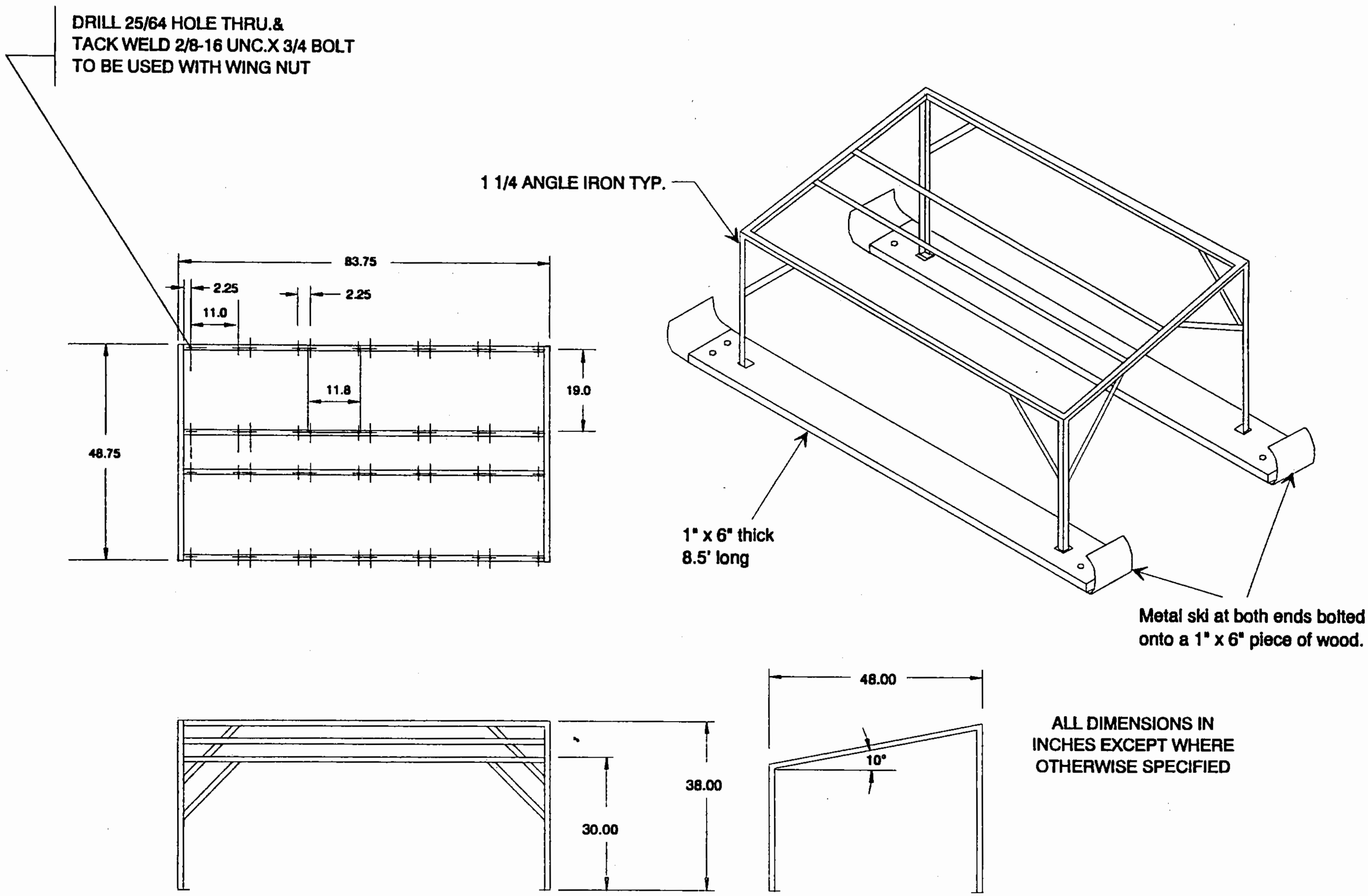


FIGURE 2
FLAT PLATE MARKINGS

TYPICAL PLATE

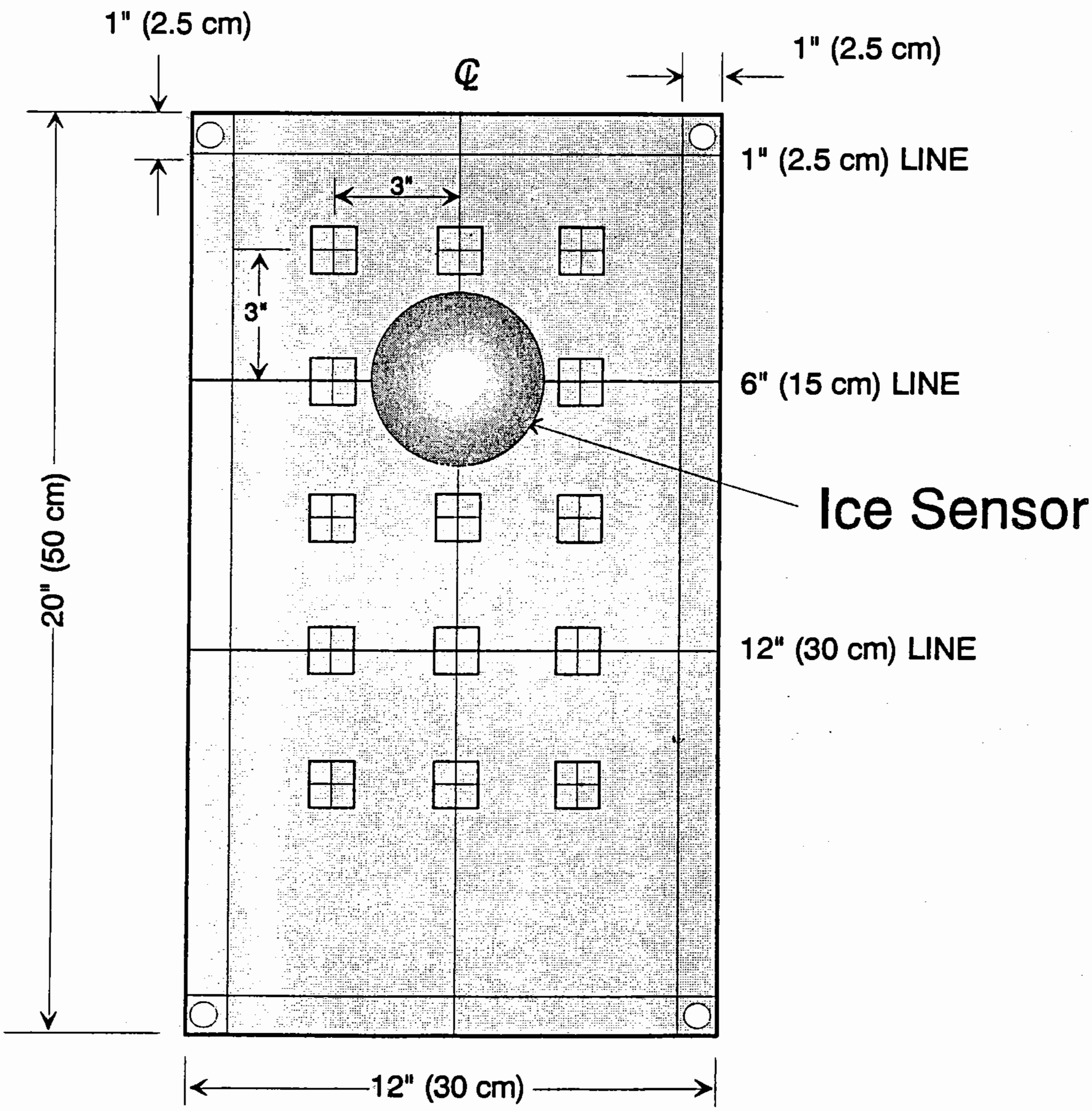


TABLE I

DE/ANTI-ICING DATA FORM

REMEMBER TO SYNCHRONIZE TIME

VERSION 2.2 Winter 94/95

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

Time After Fluid Applied to Plates U and X: am / pm SENSOR NAME:

RVSI Series # : ____________ Frame # : ____________

COLLECTION PAN: PAN # ________ PAN # ________

	Before	After	Before	After
Weight of Pan (g)				
Collection Time (min)				

DIRECTION OF STAND:

CONTROL PLATE COMMENTS:

PRECIP: ZR ZL S SW IP IC BS SP ++ + - --

SNOW/RAIN CATEGORIES (use velvet & classification):

OTHER COMMENTS (Fluid Batch, etc):

FAILURES CALLED BY :

HAND WRITTTEN BY :

ASSISTED BY:

* To Compare to previous years of testing, subtract "Time of Fluid Aplication".

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

Time of Fluid Application: → ________ mins (V & Y) ________ mins (W & Z)

	Plate U			Plate V			Plate W		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
TIME OF SLUSH FORMATION ON SENSOR HEAD	1st	½	Full	1st	½	Full	1st	½	Full

	Plate X			Plate Y			Plate Z		
FLUID NAME									
B1 B2 B3									
C1 C2 C3									
D1 D2 D3									
E1 E2 E3									
F1 F2 F3									
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA									
TIME OF SLUSH FORMATION ON SENSOR HEAD	1st	½	Full	1st	½	Full	1st	½	Full

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TABLE 2

PERCENTAGE OF GLYCOL MIXTURE WITH WATER (%) AS A FUNCTION OF OAT USED FOR DILUTED TYPE I TESTS TO ACHIEVE A 10°C BUFFER

Outside Air Test Temperature (°C) OAT	Fluid Freeze Point (°C)	B-250* (Dilution) (% Glycol in water mix)	B-251* (Dilution) (% Glycol in water mix)	B252* (Dilution) (% Glycol in water mix)	B-253* (Dilution) (% Glycol in water mix)	B-253* (Brix)
0 °C	-10 °C	28%	28%	31%	23%	14
-2 °C	-12 °C	31%	31%	35%	26%	16
-4 °C	-14 °C	35%	34%	39%	29%	18
-6 °C	-16 °C	37%	37%	42%	31%	19.7
-8 °C	-18 °C	40%	40%	45%	34%	21.2
-10 °C	-20 °C	42%	42%	48%	36%	22.5
-14 °C	-24 °C			50%**		24.8
-15 °C	-25 °C	47%	48%	53%	41%	25.5
-20 °C	-30 °C	52%	52%	58%	46%	27.9
-25 °C	-35 °C	56%	57%	63%	50%	30
-30 °C	-40 °C	60%	TBD	67%	54%	32
-33 °C	-43 °C		TBD		57%**	33
-35 °C	-45 °C	63%**	63%**			33.7

* Based on a 10°C buffer. If Based on a 10°C buffer. If verifying the glycol concentration/freeze point with a refractometer, note that the freeze point will be 10°C lower.

** Brix for UCAR Ultra is 37 (Brix for UCAR Ultra is 37 (min: 35, max: 38)

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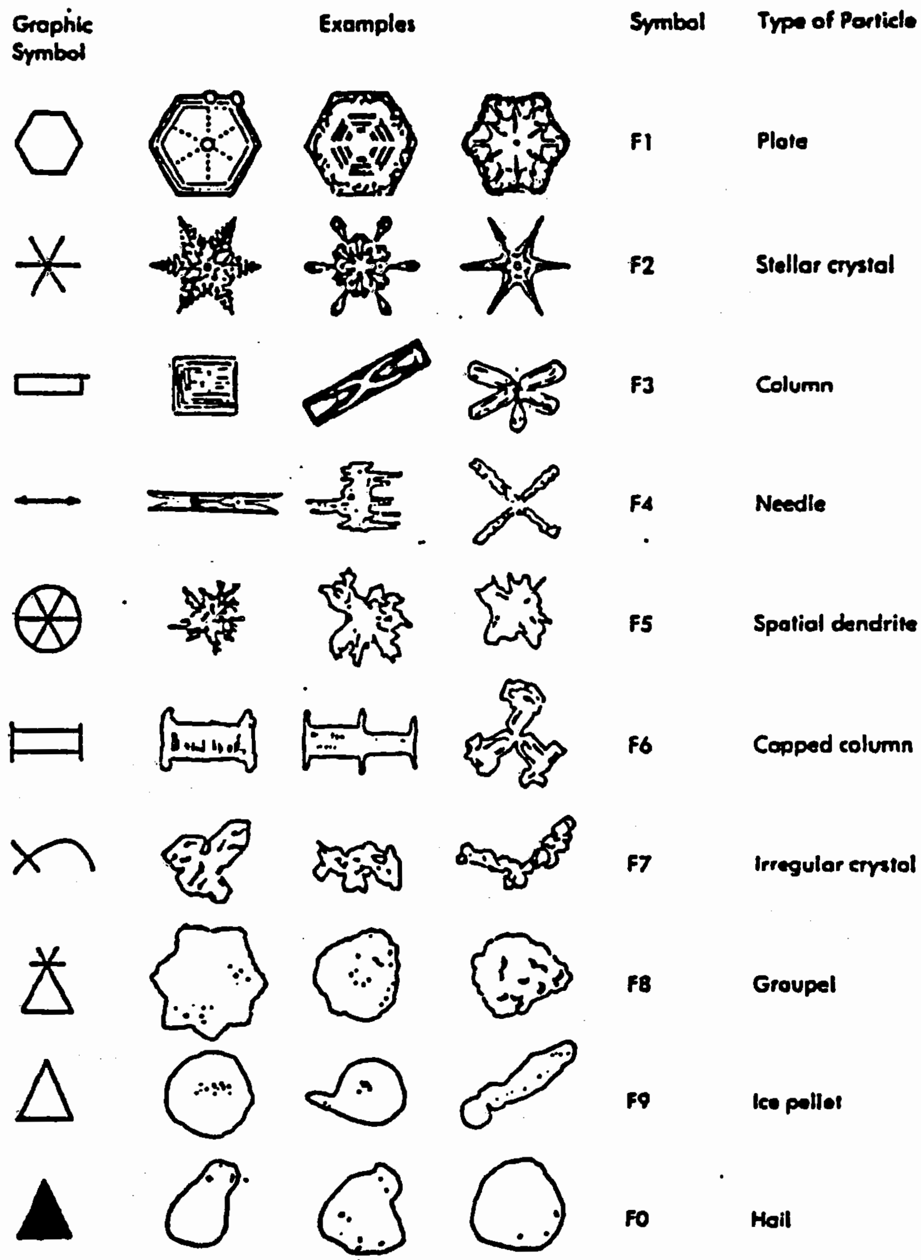
INTERNATIONAL CLASSIFICATION FOR SOLID PRECIPITATION



4. A pictorial summary of the International Snow Classification for solid precipitation. This classification applies to falling snow.

Source: *International Commission on Snow and Ice, 1951*