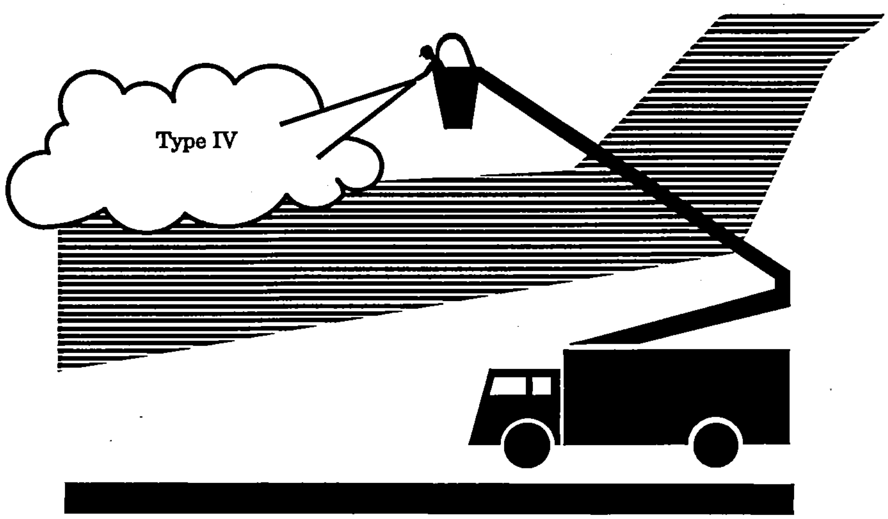
TP 12901E

Aircraft Full-Scale Test Program for the 1995-1996 Winter



Prepared for

Transportation Development Centre
on behalf of
Civil Aviation

Safety and Security
Transport Canada

by

APS AVIATION INC.

October 1996

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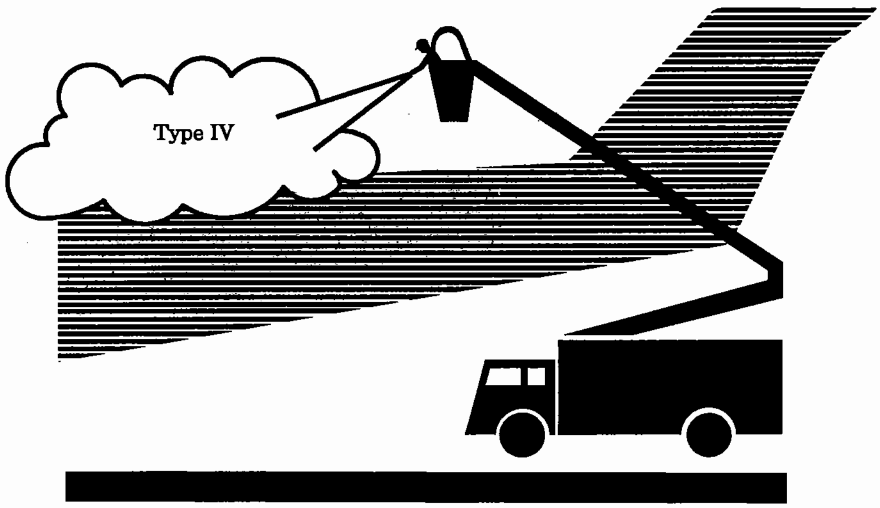

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Prepared by:	John D'Avirro Program Manager	Date: Feb 13, 97
Reviewed by:	Gilles Bourret, Eng. Director of Programs	Date: Feb. 13, 97
Approved by:	R.V. Potter, Ph.D. Vice-President Programs & QA	Date: Feb. 13, 97

Un sommaire français se trouve avant la table des matières.

PREFACE

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

- To complete the substantiation of the existing Type I and Type II fluid SAE/ISO holdover time tables by conducting cold-soak tests at very low temperature tests;
- To determine the holdover time performance of the proposed Type IV fluids over the range of characteristic conditions and develop a generic Type IV holdover time table;
- To establish the precipitation, wind and temperature values that delimit the holdover times given in the tables;
- To validate that test data on Type IV fluid performance on flat plates used to establish the SAE holdover time tables is representative of Type IV fluid performance on service aircraft under conditions of natural freezing precipitation;
- To document the characteristics of frost deposits occurring naturally during very cold temperatures;
- To validate that fluid performance on cold-soaked boxes used for establishing holdover times is representative of fluid performance on a cold-soaked wing;
- To identify potential means of enhancing the visibility of failed wing surfaces from inside the aircraft; and
- To identify optimum wing locations to be used as representative surfaces by measuring the wet film thickness profiles of fluid application to aircraft wing surfaces.

The research activities of the program conducted on behalf of Transport Canada during the 1995/96 winter season are documented in six separate reports. The titles of these reports are as follows:

- TP 12896E Aircraft Ground De/Anti-icing Fluid Holdover Time Field Testing Program for the 1995/96 Winter;
- TP 12897E Evaluation of Frost Formations at Very Cold Temperatures;
- TP 12898E Feasibility of Enhancing Visibility of Contamination on a Wing;
- TP 12899E Validation of Methodology for Simulating a Cold-Soaked Wing;
- TP 12900E Evaluation of Fluid Thickness to Locate Representative Surfaces; and
- TP 12901E Aircraft Full-Scale Test Program for the 1995/96 Winter.

This report TP 12901E addresses the objective to verify that flat plate test data used to establish the SAE Type IV holdover time tables is representative of Type IV fluid performance on service aircraft.

Funding for the research has come from the Civil Aviation Group, Transport Canada, with support from the Federal Aviation Administration. This program of research could not have been accomplished without the assistance of many organizations. APS would therefore like to thank the 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 Air Canada for provision of personnel and facilities and for their cooperation on the test program. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data leading to the preparation of this document.

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Research reports produced on behalf of Transport Canada for testing during previous winters are available from TDC. Six reports (including this report) were produced as part of this winter's research program. The subject matter of these reports is provided in the preface. Funding for this project was provided by the Civil Aviation Group, Transport Canada and, in part, by the FAA.

16. Abstract

The main objectives of this study were to compare behaviour of Type IV fluids on flat plates as employed in standard test procedures with the performance on real aircraft wings, and to establish the validity of the flat plate as a wing representation. The secondary objective was an examination of various aspects of fluid failure on the aircraft.

Two simultaneous tests were conducted employing standard flat plates along with an actual aircraft, in natural light freezing rain conditions. Union Carbide Ultra Type IV fluid was employed for the tests using Air Canada de-icing facilities and spray vehicles at Dorval Airport. For the first run, first failure occured at the leading edge of the DC-9 aircraft. After 72 minutes, when the Type IV fluid on the standard flat plates reached failure, areas totalling less than 10% of the entire wing had failed fluid. Similar results were observed during the second test.

Further tests were not possible due to the lack of suitable weather conditions when aircraft were available.

The results of the two 1995/96 winter tests showed that flat plates are a satisfactory representation of the fluid behaviour on aircraft wing surfaces. Type IV fluid application technique must ensure that care is taken to obtain a complete and consistent coverage over the entire wing surface to ensure that design holdover times are achieved. The trailing edge and the leading edge appear to be the most failure sensitive regions.

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Transports Canada a fait produire des rapports de recherche sur les essais menés durant les hivers précédents et ils sont disponibles auprès du CDT. Concernant le programme de recherche mené durant l'hiver de 1994-1995, six rapports (y compris le présent) ont été produits. Le principal sujet de ces rapports est donné dans la préface. Le financement de ce projet a été assuré par le Groupe Aviation civile, Transports Canada et en partie, par la FAA.

16. Résumé

Le but premier de cette étude était de comparer le comportement des liquides de type IV sur plaques planes avec le comportement de ces mêmes agents sur les surfaces portantes d'avions réels, et de déterminer dans quelle mesure le comportement sur plaques planes est représentatif du comportement de ces agents dans des conditions réelles de service. La détermination des différents autres effets constatés une fois que ces liquides cessaient d'être efficaces figurait parmi les objectifs secondaires fixés à la recherche.

Deux essais ont été menés simultanément sur des plaques planes et sur les ailes d'un avion, sous une pluie fine verglaçante. Le liquide de type IV dit *Ultra*, fabriqué par Union Carbide, a servi à l'arrosage, par un véhicule et dans les installations de dégivrage des avions d'Air Canada à Dorval. Au cours du premier essai, la première perte d'efficacité s'est produite sur les bords d'attaque des ailes d'un DC-9. Au bout de 72 minutes, lorsque le liquide a cessé d'être efficace sur les plaques planes, les mesures faites sur les ailes du DC-9 montraient que le liquide avait perdu son efficacité sur moins de 10 p. 100 de l'aile au complet. Des résultats comparables ont été obtenus au second arrosage.

Il a été impossible de réaliser des essais plus élaborés, en raison de conditions météorologiques inadéquates lorsque les avions étaient disponibles.

Les résultats des deux essais en 1995-1996 montrent que les durées d'efficacité sur plaques planes sont représentatives dans une bonne mesure des durées d'efficacité des liquides de type IV sur une aile d'avion. Cependant, des précautions doivent être prises pour s'assurer que l'aile au complet soit recouverte d'une couche uniforme du liquide, et que la conception pour la durée d'efficacité soit atteinte. Il a été constaté que les parties de l'aile les plus vulnérables sont les bords d'attaque et de fuite.

17. Mots clés: Avion, neige, bruine, pluie, antigivrage, agent, durée d'efficacité, test, précipitation, aile, plaque, dégivrage, glace, capteur, température, épaisseur	18. Diffusion: Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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Introduction

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. (APS) undertook a study to develop a test program, conduct tests, and analyse results in order to compare the test data for the performance of fluids on flat plates which has been used to substantiate the SAE/ISO holdover time tables with the performance of fluids on service aircraft.

Aircraft ground de-icing has been the subject of concentrated industry attention over the past decade as a result of a number of fatal aircraft accidents. Investigation into aircraft ground de-icing and anti-icing holdover times has led to the establishment of holdover time tables and the development of new fluids designed specifically to extend holdover times. Test procedures to establish fluid holdover times have been adopted based on use of a standard flat plate.

The standard flat plate test has been adopted as the basis for the generation of freezing point depressant fluid holdover times. However, previous tests conducted by APS using Type IV fluid indicated failure on aircraft wing surfaces prior to failure on standard flat plates. The prime objective of this study was to investigate this discrepancy, to identify possible causes, and to determine the validity of the flat plate test as being representative of Type IV fluid performance on service aircraft.

Data Collection

A set of trials was designed involving simultaneous application of Type IV fluid on standard flat plates and aircraft wings in natural precipitation conditions. Standard flat plate test procedures as used in holdover time trials were followed, and the aircraft was tested in a static position. Measurements of Type I and Type IV fluid wet film thickness profiles were also carried out and reported under a separate document (TP 12900E).

The tests were conducted at Montreal's Dorval Airport employing Air Canada's de-icing facility, vehicles and DC-9 aircraft, and Union Carbide's Type I XL54 and Type IV Ultra fluid.

Results and Conclusions

During the 1994/95 winter, test results with Type I fluid showed that flat plate holdover times (which are based on 33% of plate failure) are equivalent to the time when 10% of the entire wing had failed. It was concluded that flat plates offer a reasonable representation of aircraft wing surfaces in holdover time trials for Type I fluids (see TP 12595E).

Tests in 1994/95 performed with Type IV fluid showed fluid failure on aircraft wings earlier than on flat plates. A number of potential causes associated with application procedures were believed to have contributed to this early failure. These concerns were investigated with the airline operator and the fluid manufacturer. It was concluded that care in application must be taken with the new, more viscous Type IV fluids to ensure complete and consistent coverage over the entire wing surface.

Only two tests were possible during winter 1995/96 due to the absence of suitable weather conditions when aircraft were available. These two tests, conducted with Ultra Type IV fluid showed similar patterns of results to those conducted with Type I fluids. The flat plate holdover times are equivalent to the failure of about 10% or less of the entire wing area, and flat plates offer a satisfactory representation of aircraft wing surfaces in holdover time trials for Type IV fluids. These results are based on only two tests under one type of precipitation (light freezing rain).

Observations of failure progression on the wing indicate that the trailing edge and the leading edge are the most failure sensitive regions, due to the presence of flight control surfaces and the fluid thinning effect of surface discontinuities. Film thickness measurements (ref. TP 12900E) on the DC-9 and other aircraft support this.

Observations during the two tests showed that ice formation on the Type IV fluid resulting from light freezing rain precipitation was not difficult to identify visually, once the failures started. Both photographic and video records show the very distinct difference between the failed (matte) sections and the non-failed (glossy) areas. This is not the case when ice accumulates on an unprotected surface or once the fluid on the entire wing surface has lost its protection capabilities.

The freezing points of fluid samples taken from potential ice detection sensor locations (shortly after first failure) during holdover time tests on a DC-9 were significantly lower than the ambient air temperature. Algorithms in development for surface mounted ice detection sensors must consider film thickness profiles over a wing chord.

Recommendations

Further activities are recommended to determine the optimal placement of surface mounted sensors, and to compare the performance of Type IV fluid on other aircraft wing surfaces with flat plates during natural snow conditions.

Introduction

À la demande du Centre de développement des transports, Transports Canada, les Services de planification en aviation Inc. (APS) ont lancé une série d'études visant à mettre au point et à mener un programme d'essais, à en analyser les résultats et à établir des comparaisons entre le comportement de différents liquides de dégivrage/antigivrage sur plaques planes (ceux-ci ayant servi à la vérification des tables de durée d'efficacité selon SAE/ISO) et le comportement de ces mêmes liquides sur les surfaces portantes d'avions réels.

La question du dégivrage des avions au sol a fait l'objet de nombreuses études au cours de la dernière décennie, en raison des nombreux accidents d'avions avec tués reliés à ce facteur. Les recherches visant à déterminer les durées d'efficacité des divers liquides de dégivrage/antigivrage ont mené à l'élaboration de tables de durées d'efficacité, d'une part, et à la mise au point de nouveaux liquides permettant de prolonger ces durées, d'autre part. Les procédures adoptées pour la détermination des durées d'efficacité ont été fondées sur celles qui avaient été étudiées à l'égard des durées d'efficacité sur plaques planes.

La méthode d'essai sur plaques planes est devenue la méthode standard pour la détermination des durées d'efficacité des liquides abaisseurs du point de congélation. Cependant, des essais antérieurs faits par APS avaient montré que les durées d'efficacité du liquide de type IV sur aile d'avion étaient moindres que sur plaques planes. La présente recherche avait donc pour objet de déterminer la cause de cet écart et de confirmer que le comportement du liquide de type IV sur plaques planes est représentatif du comportement de ce liquide sur des ailes d'avions.

Saisie de données

Une série d'essais a été préparée, pour lesquels il fallait déposer simultanément un liquide de type IV sur des plaques planes standard et sur les ailes d'un avion dans des conditions de précipitation naturelle. À l'égard des plaques planes, les procédures utilisées ont été les mêmes que les procédures normalisées pour la détermination des durées d'efficacité. À l'égard des avions, la durée d'efficacité a été déterminée dans des conditions statiques (voir le rapport *Evaluation of* *fluid thickness to locate representative surfaces* TP 12900E, sur l'effet de l'épaisseur des couches déposées).

Les observations ont eu lieu à l'aéroport international de Dorval à Montréal, dans les installations d'Air Canada et utilisant des véhicules et un avion (DC-9) de cette société. Les liquides testés étaient de type I (XL54) et IV (*Ultra)* de Union Carbide.

Résultats et conclusions

Pour les essais de l'hiver 1994-1995, les résultats montrent qu'avec les liquides de type I, les durées d'efficacité sur plaques planes (qui sont les valeurs retenues lorsque le liquide cesse d'être efficace pour 33 p. 100 de la surface de chaque plaque) correspondent aux durées d'efficacité lorsque le liquide cesse d'être efficace pour 10 p. 100 d'une aile au complet. On peut en conclure que les durées d'efficacité sur plaques planes sont représentatives dans une bonne mesure des durées d'efficacité des liquides de type I sur une aile d'avion (voir le rapport TP 12595E).

Les essais de l'hiver 1994-1995 avec le liquide de type IV ont révélé que sa durée d'efficacité sur une aile d'avion était moindre que sur plaques planes. Cet écart peut être attribué à un certain nombre de causes probables, liées à la méthode utilisée pour déposer le liquide sur l'aile. Cette constatation a fait l'objet de discussions avec la société aérienne et le fabricant du liquide, à l'issue desquelles il a été convenu que, avec un liquide aussi visqueux que le type IV, des précautions doivent être prises pour s'assurer que l'aile au complet soit recouverte d'une couche uniforme du liquide.

Seulement deux essais ont pu être effectués lors de l'hiver 1995-1996, en raison des conditions atmosphériques inadéquates lorsque les avions étaient disponibles. Ces deux essais menés avec le liquide de type IV ont donné des types de résultats identiques à ceux mettant en oeuvre des liquides de type I. Les durées d'efficacité sur plaques planes correspondent aux durées d'efficacité lorsque le liquide cesse d'être efficace pour 10 p. 100 ou moins d'une aile au complet. Quant aux durées d'efficacité sur plaques planes, elles sont représentatives dans une bonne mesure des durées d'efficacité des liquides de type IV sur une aile d'avion. Ces conclusions sont tirées de deux essais seulement et sous une seule forme de précipitation - pluie fine verglaçante.

Les observations concernant la propagation de la cessation d'efficacité montrent que les parties de l'aile les plus sensibles sont les bords d'attaque et de fuite, à cause de la présence des gouvernes et d'irrégularités géométriques qui causent des inégalités dans les épaisseurs de liquide déposé. Ces observations sont confirmées par les recherches sur l'épaisseur des couches (TP 12900E) déposées sur les ailes du DC-9 et d'autres avions.

Durant les deux essais de 1995-1996, il a été relativement facile d'observer visuellement, sous pluie fine verglaçante, la propagation de la cessation d'efficacité du liquide de type IV, une fois que le processus de formation de givre a commencé. Tant les photos prises que les enregistrements vidéo permettent de distinguer nettement entre les parties verglacées (aspect mat) et non verglacées (aspect brillant). Un tel contraste n'apparaît pas lorsque le givre se dépose sur une surface non protégée, ou lorsque le liquide antigivre déposé sur une aile au complet cesse d'être efficace.

Des échantillons de liquide ont été prélevés (à la première apparition de givre) en des endroits de l'aile du DC-9 où des détecteurs de givre pourront être éventuellement implantés, et ces échantillons ont été analysés pour en connaître le point de congélation. Il a été constaté que celui-ci était bien inférieur à la température ambiante de l'air. Il faudra que l'étude des algorithmes qui analyseront les signaux provenant des détecteurs de givre encastrés dans une aile d'avion tienne compte des variations d'épaisseur qui se produisent dans la couche déposée, entre le bord d'attaque et le bord de fuite.

Recommandations

Des recherches plus poussées seront nécessaires pour déterminer l'emplacement optimal des détecteurs de givre encastrés, et pour comparer le comportement du liquide de type IV sous neige naturelle, sur des plaques planes et sur les ailes d'autres avions.

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LIST OF ACRONYMS

APS	APS Aviation Inc.
C/FIMS	Contaminant/Fluid Integrity Monitoring System
FPD	Freezing Point Depressant
FZR	Freezing Rain
GPM	Gallons per Minute
HOT	Holdover Time
ISO	International Standards Organization
L	Leading Edge
M	Mid-Wing
NRC	National Research Council
SAE	Society of Automotive Engineers
T	Trailing Edge
TDC	Transportation Development Centre
UCAR	Union Carbide

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1. INTRODUCTION

At the request of the Transportation Development Centre (TDC) of Transport Canada (TC), APS Aviation undertook a research program to further advance aircraft ground de-icing/anti-icing technology. Objectives of the entire program and of the project described in this report were provided in the preface.

Aircraft ground de-icing has been the subject of concentrated industry attention over the past decade as a result of a number of fatal aircraft accidents. Much of this attention has been given to the abilities of anti-icing fluids to provide an extended duration of protection against further snow or ice buildup following initial de-icing. This has led to the development of fluid holdover time tables for use by aircraft operators and accepted by regulatory authorities. As well, new improved fluids have been developed with the specific objective of extending holdover times without affecting aerodynamic characteristics of the airfoil.

The process of developing and substantiating these holdover time tables for existing fluids and new fluids as they have become available, has taken the form of tests, both in the field during natural precipitation conditions and in laboratory situations, utilizing inclined flat plates. Test procedures to measure duration of fluid protection against ice have evolved to a standard approach that has been followed by APS and others at a number of different locations in previous years.

The result of intensive testing has been the acceptance of greatly increased holdover times for new generation Type IV anti-icing fluids, and general recognition of the holdover time limitations of the older Type I de-icing fluids. Although the flat plate test procedures have become quite sophisticated over the past few years, test results with the newer Type IV fluids have not yet been thoroughly correlated against results using full-scale aircraft wings, and the flat plate has not yet been fully validated as an adequate representation of the airfoil.

To determine correlation, a set of simultaneous trials was planned involving the standardized flat plate tests together with actual aircraft in natural precipitation conditions. A total of 39 simultaneous aircraft and flat plate tests were conducted during the 1994/95 winter at Dorval, St. John's and Toronto. Thirty-six tests were conducted with Type I de-icing fluid, and these tests showed that flat plates are a satisfactory representation of the fluid behaviour on aircraft wing surfaces. Three tests were conducted with Union Carbide's Ultra Type IV fluid (previously referred to as Type II). Failures on aircraft wings with Type IV fluid occurred much earlier than on flat plates. A number of factors contributed to these early failures, and many of these were operational. The results and description of these tests can be found in Transport Canada Report TP 12595E, "**Aircraft Full-Scale Test Program for the 1994-1995 Winter**." The present report provides the results of the tests conducted during the 1995/96 winter season. Corrections to the operational application procedures were implemented.

The primary objective of the study was to compare Type IV fluid failure times between flat plates and aircraft wing surfaces under conditions of natural freezing precipitation (see Appendix A for detailed statement of work).

For the 1995/96 winter, testing was limited to one occasion (enabling two runs) due to the lack of freezing precipitation after January and because the testing was limited to overnight hours. For this test occasion, Air Canada provided a DC-9 aircraft, de-icing personnel, de-icing equipment and facilities for storage of equipment. Type I and Type IV fluids were provided by Union Carbide.

This report is presented in five parts, with Section 1 being the general introduction. Section 2 outlines the test procedures and data collected, and Section 3 provides a discussion of the tests and results. Sections 4 and 5 present conclusions and recommendations.

2. METHODOLOGY AND DATA ACQUISITION

In the 1994/95 season, freezing point depressant (FPD) fluid failures recorded simultaneously on flat plates and aircraft wings indicated that:

- For Type I fluids, flat plates represented satisfactory model surfaces for the evaluation of fluid behaviour on aircraft wing surfaces; and

- For Type IV fluids, a significant disparity between the results of flat plate tests and fluid failures on wing surfaces indicated that additional Type IV fluid tests were required. The results of these tests demonstrated that fluid applied to the aircraft wing was failing before the fluid on the flat plates. To further elucidate possible mechanisms for this apparent anomaly, further Type IV fluid testing was carried out during the winter of 1995/96.

2.1 Test Site

The full-scale tests conducted in the 1995/96 winter evolved from collaborative efforts of APS, Transport Canada, Air Canada and Union Carbide (UCAR). Contrary to the 1994/95 winter when tests were conducted at Toronto, St. John's and Montreal, tests in 1995/96 were conducted only at Montreal's Dorval Airport, employing Air Canada aircraft.

2.2 Equipment

Three test sessions were planned for the 1995/96 winter season. Two were to be conducted on DC-9 aircraft and a third was to be conducted on a Canadair Regional Jet aircraft. The test procedures are detailed in Appendix C. Air Canada was committed to providing these aircraft for test purposes. Figure 2.1 shows the positioning of the major equipment and personnel with respect to the aircraft. Two test sessions were planned with the leading edge of the aircraft positioned into the wind and the third with the trailing edge into the wind. The test stands are positioned such that the wind is blowing up the plates, as per the standard flat plate test procedure (see Appendix B).

FIGURE 2.1

POSITION OF EQUIPMENT AND PERSONNEL

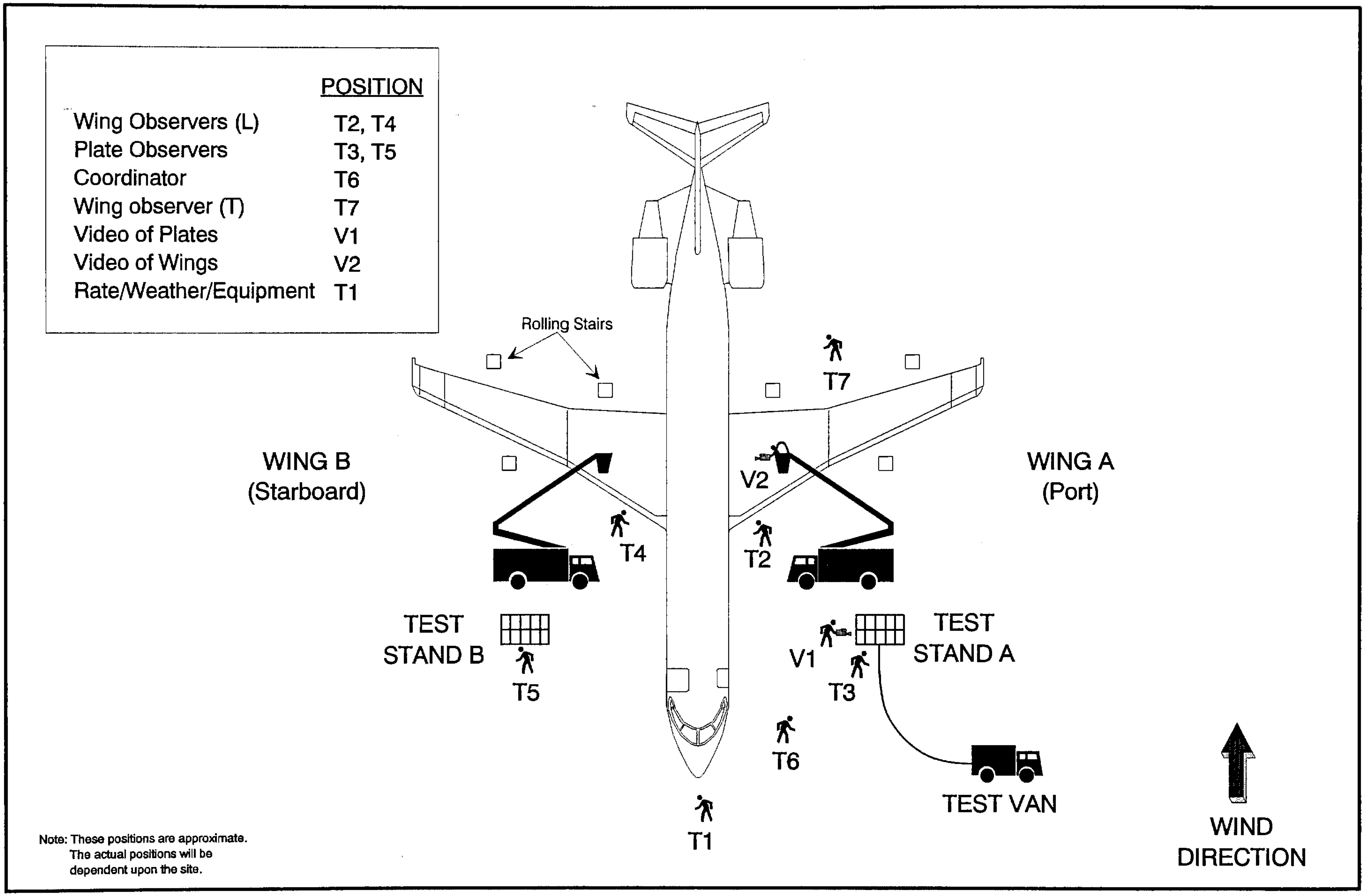

Figure 2.2 shows a schematic of the stand used for testing. Six test plates are mounted on the stand and these are inclined at a 10° slope. Figure 2.2 also depicts the size of a typical flat plate and cross hair markings on the flat plate.

The plates were marked with three parallel lines, 2.5 cm (1"), 15 cm (6") and 30 cm (12") from the top of the plate. The plates were also marked with 15 cross hairs. The cross hairs were to serve as criteria for the calling of failures on flat plate test surfaces (see Appendix B for definition).

To facilitate the viewing of contamination on the wing, six rolling stairs were positioned around the two wings of the aircraft. Other test equipment for the Dorval aircraft full-scale testing program is given in Appendix C Attachment II "Test Equipment Checklist." Photo 2.1 shows some of the equipment set-up at Dorval prior to a test. Test equipment was stored on-site at Air Canada's de-icing facility, Dorval International Airport.

Meteorological data including wind direction, wind speed, and temperature was obtained from Environment Canada's Dorval weather station. The rate of precipitation was measured using plate pans (see Appendix B) mounted on the test stand.

2.3 Procedures

The APS document "Experimental Program for Dorval Natural Precipitation Flat Plate Testing" and "Experimental Program for Simultaneous Aircraft vs Plate Testing" are provided in Appendices B and C, respectively. These describe the detailed procedures employed.

Figures 2.3 provides schematic descriptions of the simultaneous aircraft and flat plate two-step fluid application procedures for Type IV fluids (note that the appendices may still refer to these fluids as Type II fluids).

FIGURE 2.2

FLAT PLATE TEST SET-UP

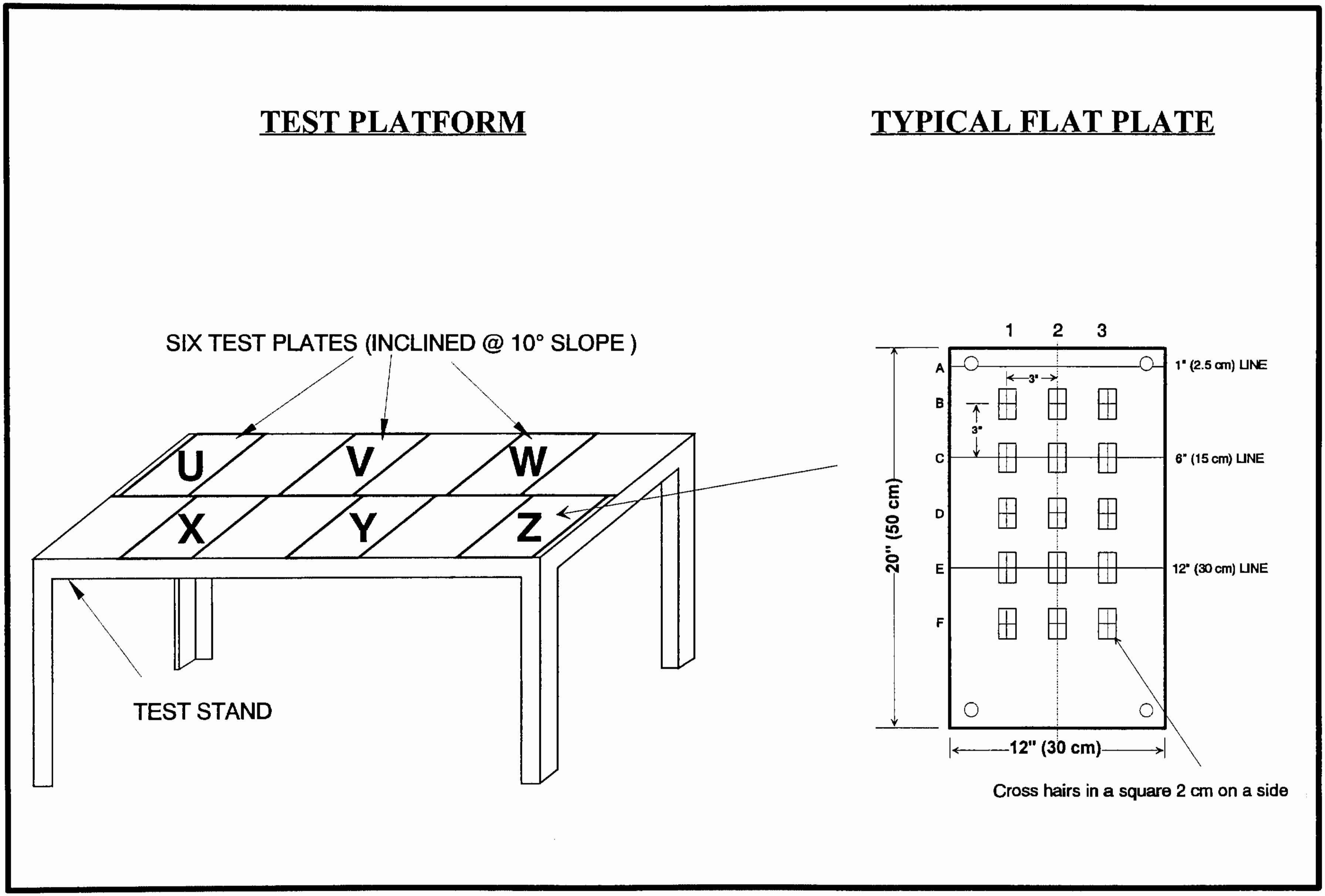

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PHOTO 2.1
GENERAL SET-UP OF EQUIPMENT AT DORVAL

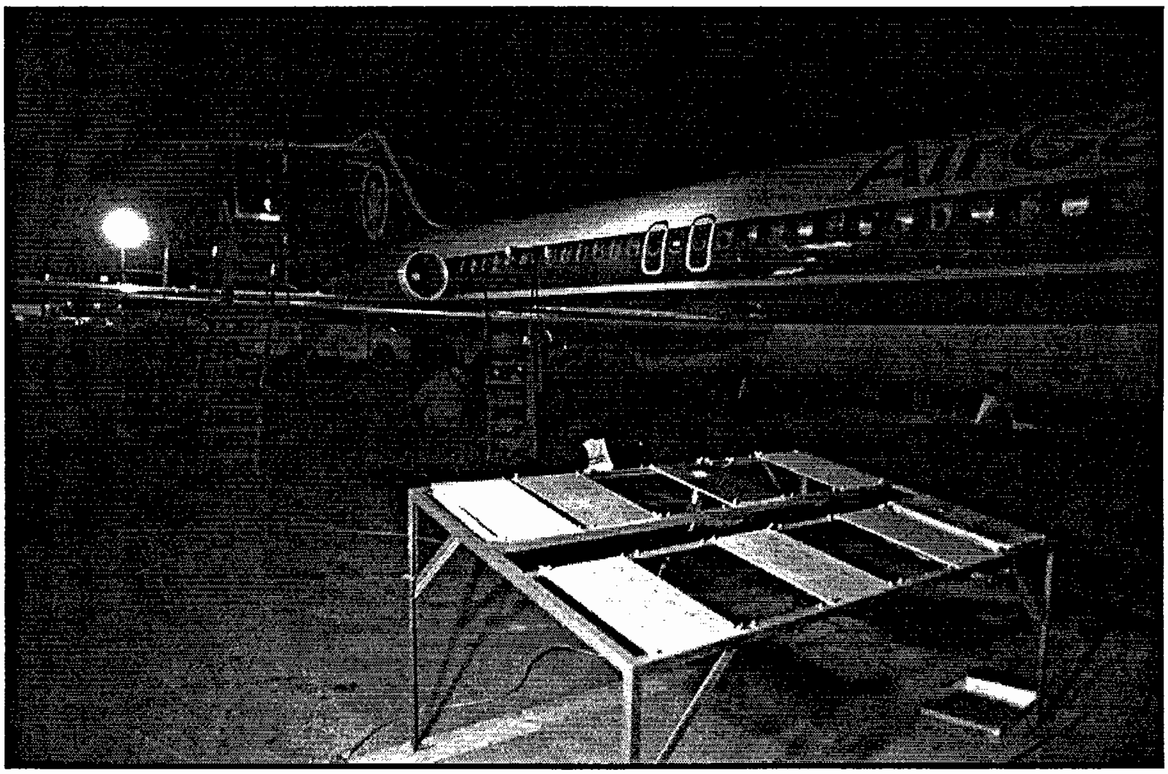


FIGURE 2.3

TWO-STEP FLUID APPLICATION PROCEDURE

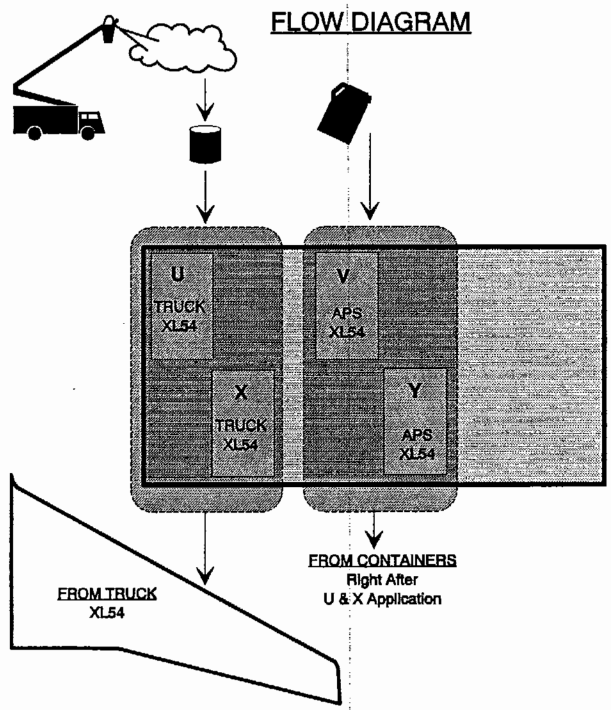
TYPE I FLUID APPLICATION (1st STEP)

1: Spray XL54 fluid from cherry picker into pail.

2: Apply XL54 onto plates U and X from the pail.

3: Apply XL54 onto the aircraft wing

4: Apply XL54 from gasoline containters on plates V and Y



TYPE IV FLUID APPLICATION (2nd STEP)

1: Follow 1 to 3 in Type I application.

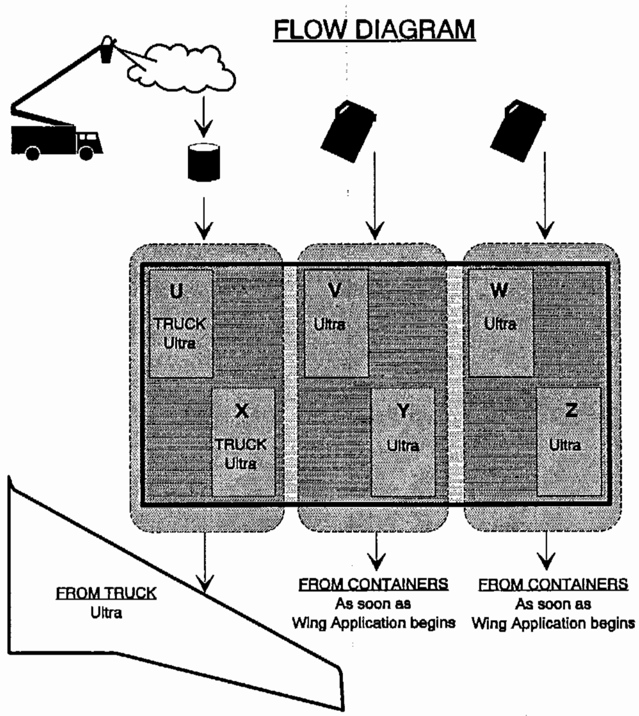
2: Apply Ultra Type IV onto plates U and X from the pail.

2a: Start stopwatch and record true time for beginning of tests.

3: Apply Type IV fluid onto the aircraft wing.

4: Apply Type IV fluid onto plates V and Y at the same time that the wing application has started. Use gasoline containers for this application. Then record time.

5: Apply Type IV fluid onto plates W and Z as soon as wing application has started. Use the same procedure as in 4. Then record time.



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The fluid to be applied to plates U and X on the test stand was obtained directly from the spray nozzle of the de-icing vehicle. The fluid sample was collected in a pail and poured onto the plates coincident with fluid application to the aircraft wing. Fluids applied on the other plates were taken from the APS Dorval test site fluid supplies. Type IV fluid for these tests was delivered in a condition corresponding to fluid pumped from a de-icing vehicle (referred to as "pre-sheared" condition). Fluid application procedures for plates W and Z adhered to the standard flat plate test procedures. Fluid application on these plates followed the application on plates U, V, X and Y and was concurrent with wing spraying. Fluid on plates U, X, V and Y followed a two-step (Type IV over Type I) application procedure. Fluid application start times for all plate pairs were recorded.

To simplify reference, the plate sets will hereafter be referred to as follows:

Plates U and X:	Truck fluid plates	(Type IV over Type I)
Plates V and Y:	Test site fluid plates	(Type IV over Type I)
Plates W and Z:	**Standard test site** fluid plates	(Type IV on bare plate)

The failure time is the time required for the end condition (see Flat Plate Test Procedure in Appendix B) to be achieved. On a plate, this occurs when precipitation fails to be absorbed at five of the fifteen cross hair marks on the panels.

2.4 Fluids

The Type I and Type IV fluids tested were provided by Union Carbide. Only fluids from Union Carbide were tested since these were the fluids available in Air Canada's de/anti-icing vehicles. Type I was applied in its standard concentration (XL54), and Ultra Type IV was applied in its neat (100%) concentration. Note that the initial plan was to test the newer Ultra Plus Type IV, however this fluid was not available in time for the tests.

2.5 Personnel

Nine test members were required to conduct each test at the Dorval Air Canada de-icing facility. Figure 2.1 provides a schematic description of the general test set-up as well as the location of the nine testers. It is worth noting that two of the testers were dedicated video personnel (V1 and V2) taking video records of the tests. For the 1994/95 winter season, position T1 was usually manned by a pilot, who also recorded video from inside the aircraft cabin. In tests conducted during the 1995/96 season, member T1 assumed the responsibilities of proper equipment function and acquisition of rates of precipitation. The latter task was accomplished by measuring the accumulation of precipitation in plate pans at 15 minute intervals for the duration of the tests. Appendix C Attachment III "Responsibilities/Duties of Test Personnel" contains more accurate descriptions of the testers' responsibilities, individual duties and positions.

2.6 Data Forms

Four data forms were used for these tests. The general data form (Figure 2.4) was completed by the coordinator (T6) and contains information such as type and quantity of fluid sprayed and the initial aircraft skin temperature measurements. The flat plate data form (see Appendix B, Table 1) was completed by the flat plate observer (T3 or T5) and contains information relating to fluid failure times on the flat plates. The meteo/plate pan data form (see Appendix B, Table 1a) was completed by observer T1 and contains information on the weather conditions.

The fourth data form is the aircraft wing form. Figure 2.5 shows the form used for a DC-9 wing. Forms for the Canadair Regional Jet and the A320 were also developed (see Appendix C). Observers T2, T4 and T7 assigned to the wing were required to identify fluid failures and to draw failure contours on the wing grid structure (see Section 2.6.1) shown on Figure 2.5.

FIGURE 2.4

GENERAL FORM

AIRPORT: YUL YYZ YYT

AIRCRAFT TYPE: A320 DC-9 B-737 RJ BAe 146

EXACT LOCATION OF TEST: ______________________

AIRLINE: ______________________

DATE: ______________________

FIN #: ______________________

RUN #: ______________________

FUEL LOAD: ______________________ **LB / KG**

LOCATION OF PILOT IN CABIN: ______________________

1st FLUID APPLICATION

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

Start of Fluid Gauge: ____________ **L / gal** **End of Fluid Gauge:** ____________ **L / gal**

Type of Fluid: ____________ **Truck #:** ____________

Fluid Temperature: ____________ **Fluid Nozzle Type:** ____________

2nd FLUID APPLICATION

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

Start of Fluid Gauge: ____________ **L / gal** **End of Fluid Gauge:** ____________ **L / gal**

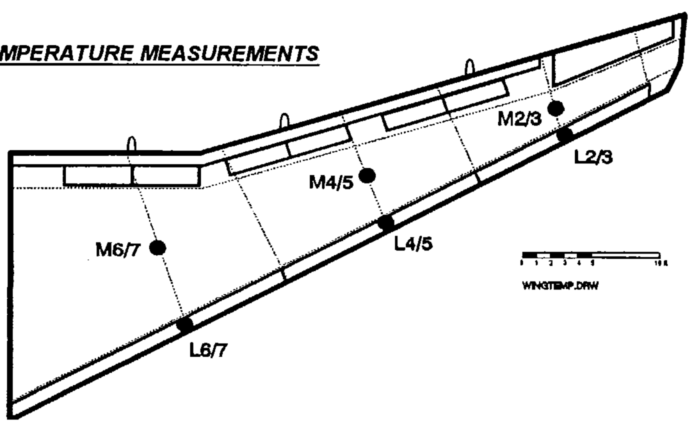
Type of Fluid: ____________ **Truck #:** ____________

Fluid Temperature: ____________ **Fluid Nozzle Type:** ____________

Time When Stopwatch is Started: ____________ **am/pm**

End of Test Time: ____________ **am/pm**

TEMPERATURE MEASUREMENTS



ENTER FLUID TYPE:						
TIME	**TEMPERATURE AT LOCATION (°C)**					
(min)	**L6/7**	**M6/7**	**L4/5**	**M4/5**	**L2/3**	**M2/3**
Before¹ ( )						

COMMENTS:

(1) Actual Time Before Fluid Application

*Time After Fluid Application.

MEASUREMENTS BY: ______________________

HAND WRITTEN BY: ______________________

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Version 2.2
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FIGURE 2.5

REMEMBER TO SYNCHRONIZE TIME

DE/ANTI-ICING FORM FOR AIRCRAFT WING

VERSION 2.3 Winter 94/95

LOCATION:	DATE:	RUN NUMBER:	WING # :	RVSI AVAILABLE: Y / N
Time After Fluid Applied to Plates U and X:	am / pm			C/FIMS SENSOR AVAILABLE: Y / N

TIME OF INITIAL FLUID APPLICATION: ____________ (hr:min:sec)
(Last step only)

TIME AFTER FLUID APPLICATION: ____________ (hr:min:sec)
(Last step only)

DIRECTION OF AIRCRAFT: ____________

FAILURES CALLED BY: ____________

DESCRIBE SENSORS/LOCATION: ____________

HANDWRITTEN BY: ____________

____

ASSISTED BY: ____________

COMMENTS: ____________

____

IMPORTANT EVENTS (min)

	L.Edge	Mid	T.Edge
1st Failure:			
10% :			
25% :			
75% :			
100% :			

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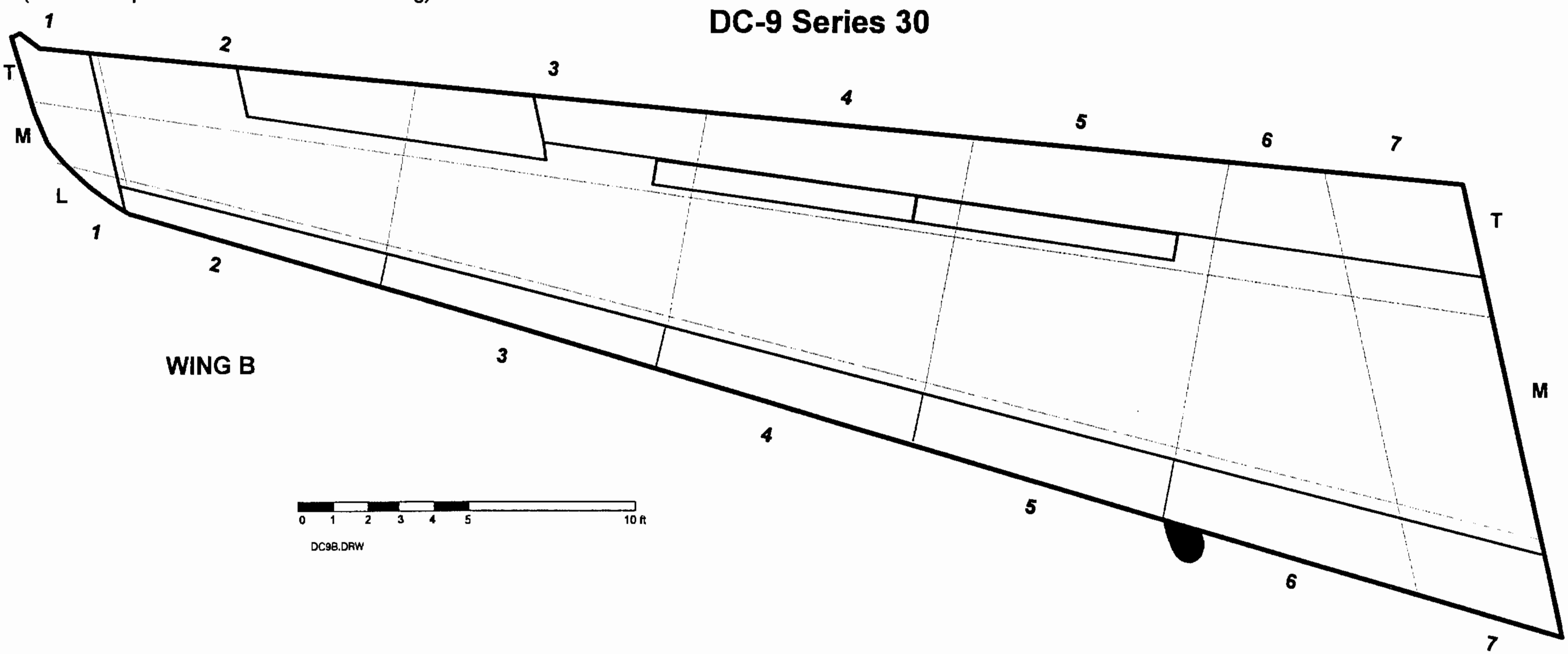
DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE
(Indicate Representative Surface on Drawing)

DC-9 Series 30



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

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Failure times in the box labelled "important events" in Figure 2.5 were also requested from the testers. For each of the three columns (leading edge, middle section, trailing edge), five fluid failure time entries which correspond to standard definitions of levels of failures were required:

1. First Failure: occurred when the test fluid within the wing region was first observed to have failed;
2. 10% failure: when approximately 10% of the wing region had failed test fluid;
3. 25% failure: when approximately 25% of the wing region had failed test fluid;
4. 75% fluid failure: when approximately 75% of the wing region had failed test fluid; and
5. 100% fluid failure: when 100% of the wing region had failed test fluid.

2.6.1 Wing Grid Structure

During the full-scale tests, observers T2, T4, and T7 were assigned to the wing section of the aircraft. They were required to identify freezing point depressant fluid failures in terms of location on the wing and to record the progress of the failures as a function of time. This involved mapping failure time contours onto the aircraft wing form (Figure 2.5). To facilitate this method of data recording, the following wing grid structure was adopted. Using the DC-9 wing as an example, each wing is partitioned into three major subsections:

1. Leading Edge (L);
2. Middle (M); and
3. Trailing Edge (T).

Referring to Figure 2.5, the trailing edge is defined as the area between the inner edge of the aileron and flap hinges and the trailing edge of the wing. This is easily identified visually on the actual wing surface. The boundary of the wing leading edge is also easily identified by a highly visible seam in the aluminum skin, located where the curvature of the upper wing surface begins to taper off and round out towards the under wing surface. The remaining surface makes up the middle wing subsection. The wing is also partitioned by six chords into seven subdivisions from tip to root (see Figure 2.5) defining the grid structure. The grid was used to define areas for which observers were responsible for data collection and provided identifiable features for the positioning of failure contours on the aircraft wing test form. Failure detection on representative surfaces was not a test concern for the 1995/96 season; however, some general observations are discussed regarding this item (see Section 3.6).

2.7 Data Collected

Only two full-scale tests were conducted in the 1995/96 winter at Dorval airport on February 28, 1996. This low number of tests was a result of lack of suitable weather conditions between 23:00 hrs and 5:00 hrs. A "dry run" was also conducted prior to this occasion to train the new personnel. The two tests were conducted under freezing rain precipitation. The conditions and average meteorological parameters for the two tests are as follows:

	RUN 1	RUN 2
Aircraft type	DC-9-30	DC-9-30
Fluid application - 1st step	Type I XL54	Type I XL54
Fluid application - 2nd step	Type IV Ultra Neat	Type IV Ultra Neat
Start of HOT test	2:23 am	4:03 am
Precipitation type (reported)	Light Freezing Rain with periods of moderate	Light Freezing Rain
Plate pan rate of precipitation	11 g/dm²/h	17 g/dm²/h
Outside air temperature	-1°C	-1°C
Wing skin temperature before test	-1°C	-1°C
Wind speed @ 10 m	13 kph	17 kph
Wind speed @ stand level (est.)	9 kph	11 kph
Wind direction	41°	26°
Aircraft direction (nose)	52°	52°
Stand direction	50°	50°

Key Data

Fluid failure time on standard plates	72 min.	53 min.
Fluid failure on aircraft (first)	50 min.	50 min.
Fluid failure on aircraft (10% of L, M or T)	67 min.	59 min.

Most of the meteorological data was acquired from Environment Canada's automated weather observation station. The above data indicates that the aircraft was oriented with the nose into the wind and that the winds were generally light.

The fuel on board the DC-9 was 6350 lb (2883 kg). This amounts to about one-third of the DC-9's fuel capacity. Surface temperature measurements of the wing prior to the start of the first test indicated that the wing was not in a cold-soaked condition.

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3. OBSERVATIONS AND DISCUSSION

This section of the report provides observations and discussion of the full-scale Type IV Ultra tests and how these compare to the laboratory flat plate tests, followed by illustrations of the progression of Type IV fluid failure on the wing surface. The last sub-section contains observations relating to samples of fluids taken on the aircraft wing during the full-scale tests. Only two full-scale aircraft tests were accomplished due to the lack of precipitation conditions on nights when aircraft and ground crews were available.

3.1 Background

The 1995/96 full-scale tests were undertaken in light of test results obtained during the 1994/95 season. The latter indicated that Type IV fluids failed on wing surfaces before failures were recorded on flat test plates. This called into question whether the flat test plate is a satisfactory representation of a wing surface for Type IV fluids. The full-scale report for the 1994/95 tests (reference TP 12595E) described several factors which could be used to explain these early fluid failures on wing surfaces. These factors were:

1) The de-icing vehicle operated from the rear of the wing with fluid applied from the trailing edge, perhaps giving poor coverage to the leading edge where many of the early failures occurred.

2) The de-icing vehicle was equipped with a spray nozzle normally used for Type I fluid, with a high pump pressure. Union Carbide, who developed and produced Ultra fluid, recommended the use of a fan nozzle with a low pressure setting to achieve optimum coverage over the entire wing surface.

3) The standard procedure in these and previous flat plate tests involved application of Ultra fluid onto the flat plates by pouring. This method of fluid application may produce surface coverage sufficiently different in nature from spray application coverage to significantly influence failure times. This difference arises due to low fluid shear in pouring as opposed to high fluid shear

achieved in spraying. High shear conditions affect fluid rheology and formation of foam. Both factors have the potential to create discrepancies in the pertinent fluid failure times. Both tend to negatively affect fluid failure times for wing surfaces (which are coated by spraying).

4) The rather lengthy time lapse between the start of Type I and Type IV applications in the tests, combined with moderate to high rates of precipitation may have contributed to early wing failures.

Prior to the 1995/96 winter tests, a meeting was held with Air Canada and Union Carbide to discuss the previous winter results and these operational concerns, particularly items 1 and 4. These two concerns were resolved. The Air Canada operators were requested to spray fluid from the front of the aircraft, and Air Canada was committed to using one vehicle with dual tanks to spray Type I and Type IV fluid. A discussion relating to the concerns of item 2 (spray nozzle) is provided in the next section, and a discussion regarding item 3 is provided in Section 3.3.

3.2 Spray Nozzle

To address item 2, Union Carbide provided Air Canada with a new spray nozzle for application of Ultra. Air Canada's engineering department modified one of their de-icing vehicles to adapt this new spray nozzle. The nozzle was manufactured by Task Force Tips Inc. The pressure is self regulating at 50 psi (3.5 kg/cm^2), and the nozzle can flow 10 to 60 GPM (38 to 228 l/min), but is ideal between 20 and 30 GPM (76 and 114 l/min).

The new nozzle installation was first utilized during initial runs of fluid thickness tests February 15, 1996, observed by representatives from Union Carbide and Transport Canada. The Type IV fluid applied on the wing was contaminated by Type I fluid. According to Air Canada this was caused by back pressure. An improved piping and fluid flow design in the truck was required to correct this problem, however this modification could not be executed before the end of the winter. Subsequent thickness tests were conducted that evening with another spray vehicle using Air Canada's Akron nozzle. With proper attention given to ensuring complete wing coverage, this nozzle did produce satisfactory results. This was confirmed by the Union Carbide representative, who participated in these tests. As a result, subsequent tests were conducted with the Akron nozzle and the operators were encouraged to ensure that sufficient fluid was applied to obtain complete wing coverage.

3.3 Testing of Plates Mounted on the Wing Surface

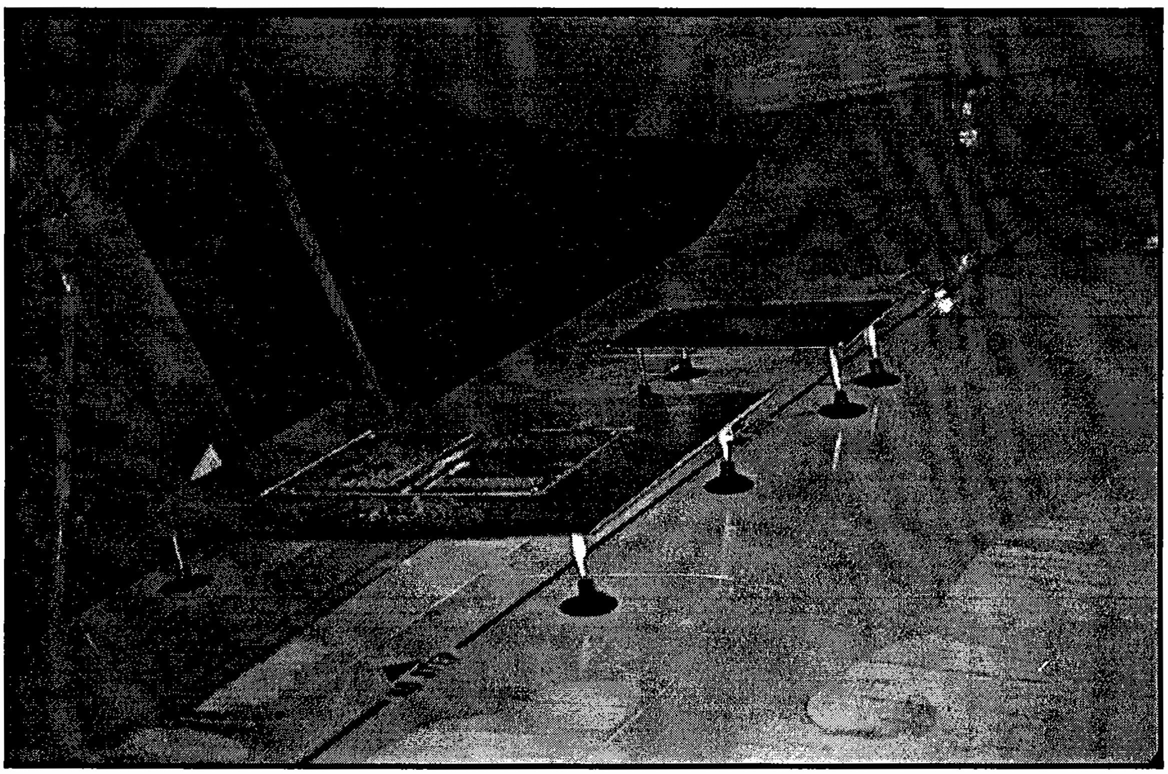
To address the concerns of item 3, two special plates were manufactured for mounting on the aircraft wing surface (see Photo 3.1).

The plate at the far end in Photo 3.1 was exactly the same as the standard flat plate, except that it was elevated above the wing surface. It was mounted on the trailing edge surface of the aircraft such that the angle of the plate with respect to the horizontal plane was 10°. Fluid was poured from a smaller container onto this plate in exactly the same manner as plates V and Y on the test stand (Type IV Ultra poured over Type I XL54). The procedure used for the testing of these special plates is included as Appendix D.

The second "skirted" plate on the left side of Photo 3.1 was also mounted on the trailing edge at 10°, however the fluid (Type IV over Type I) on this plate was applied by the Air Canada spray vehicle. An extension (skirt) was welded to the standard plate, giving an overall plate dimension of 90 cm x 70 cm. A gap of about 1 cm allowed excess fluid to flow off the plate in the same manner as it would on the standard flat plate. The skirt, however, provided a better simulation of fluid application on the wing, i.e. it provided a proper simulation of fluid splashing effects.

The HOT test results from the two special wing mounted plates provide an indication as to whether pouring or spray application has any influence upon fluid failure times (see next section).

PHOTO 3.1
PLATES MOUNTED ABOVE AIRCRAFT WING SURFACE



3.4 Analysis of Ultra Fluid Behaviour

This section of the report examines the relationship between time for Ultra fluid to fail on an aircraft wing versus time to fail on flat plates.

During winter (1994/95), three tests using Ultra fluid were conducted at Dorval during natural snow conditions. Data from the three tests indicated that failure times for all three failure criteria, first failure, 10% and 25% failure of leading edge/trailing edge/mid-wing area, were significantly shorter than failure times for the concurrent standard fluid test plates. In fact, the fluid test plate failure times appeared to have a stronger correlation with failure criteria of 100% of leading edge/trailing edge/mid-wing area, which would mean in effect that the entire wing surface could be in a failed condition within holdover times established based on plate failure times. This alone provided justification for continued testing to characterize Type IV fluid behaviour in the 1995/96 winter season.

Figure 3.1 shows the comparison of the fluid failure times of the DC-9 wing and the flat plates for Run 1 on February 28, 1996. Similarly, the results for Run 2 are shown in Figure 3.2. These two tests were conducted under natural freezing rain precipitation conditions.

The three first bars on the left side of Figure 3.1 illustrate the observed failure times of the fluid on the leading edge, mid-section and trailing edge of the DC-9 wing. For example, the first bar shows that the first failure on the leading edge was observed after 50 minutes, and fluid failure on 10% of the leading edge was observed after 67 minutes.

The next three bars in the middle of Figure 3.1 show the observed average failure times of the fluid on each of the three pairs of plates (U and X, V and Y and W and Z). The end condition on the plates was recorded when 5 of the 15 cross hairs were declared failed. For example, the fluids on plates W and Z which are a representation of the standard test procedure (Type IV Ultra on a bare plate) failed after 72 minutes. Recall from Section 2 that the fluid (Type IV over Type 1) on plates U and X was poured using fluid taken from the Air Canada

FIGURE 3.1

COMPARISON OF END CONDITION TIMES FROM THE DC-9 WING OBSERVER AND FLAT PLATE OBSERVER

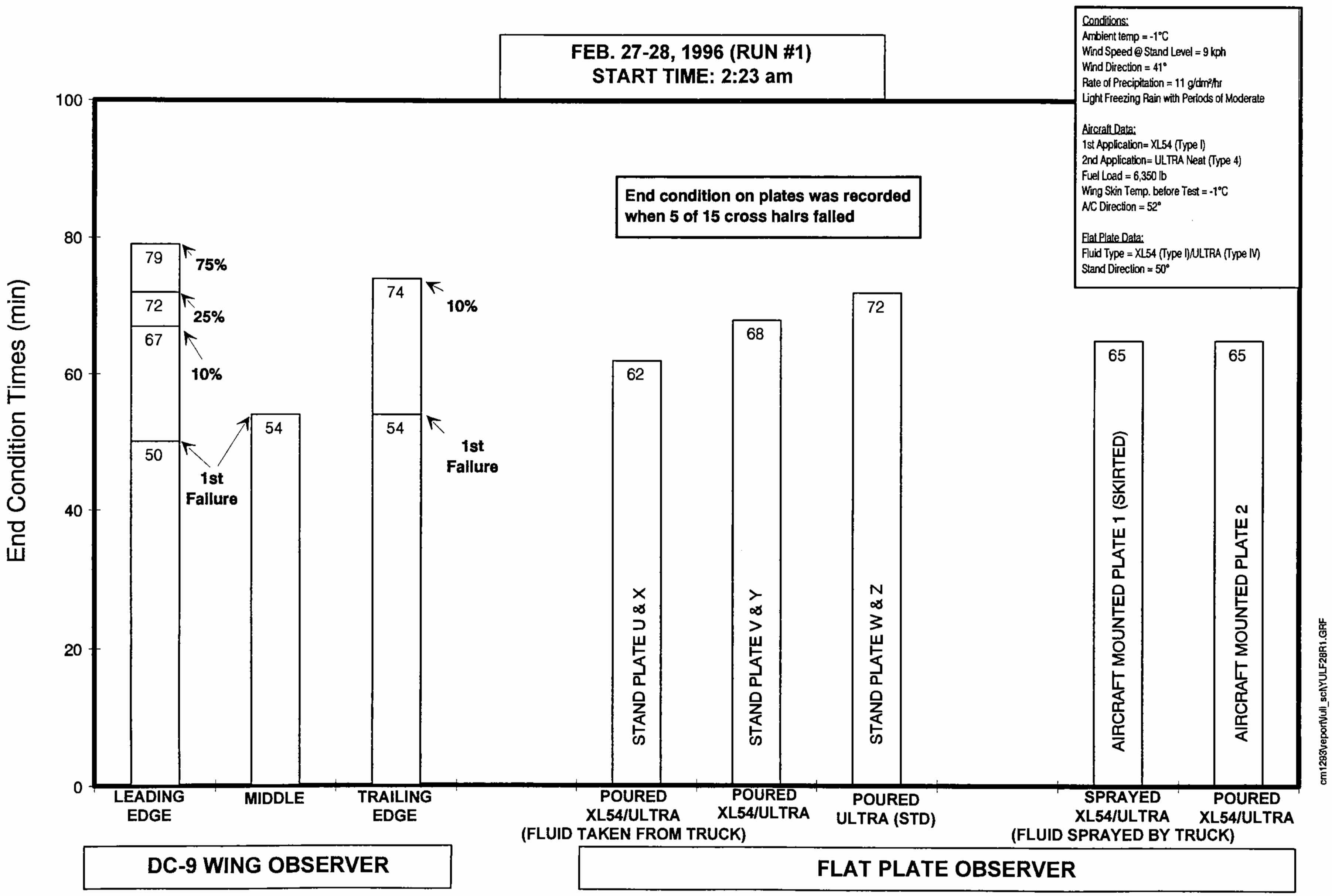
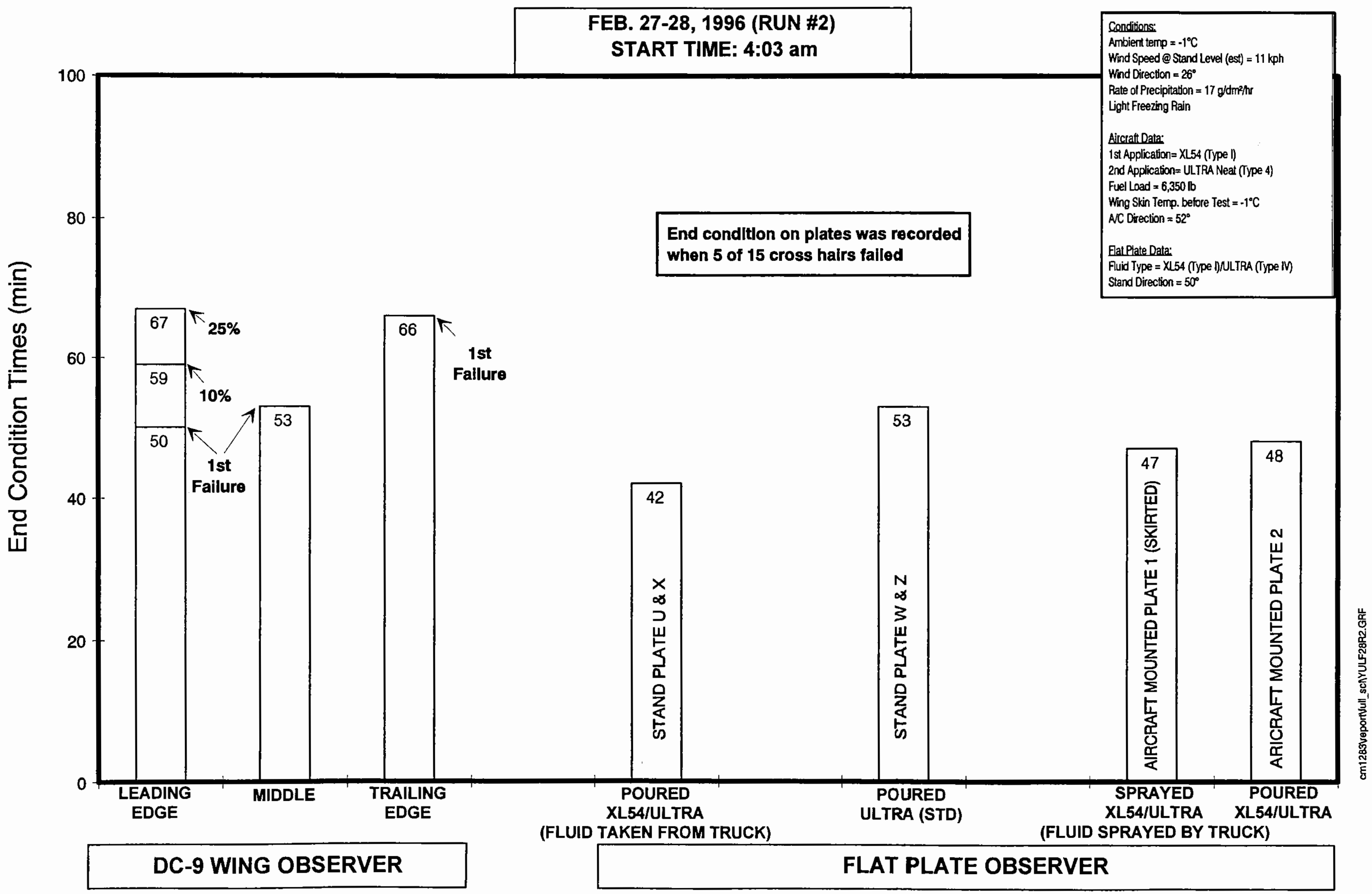


FIGURE 3.2

COMPARISON OF END CONDITION TIMES FROM THE DC-9 WING OBSERVER AND FLAT PLATE OBSERVER



truck. Fluid (Type IV over Type I) on plates V and Y was also poured, but using APS supplies from the test site. The Type I fluid on plates U and X was heated by the de-icing truck, while the Type I on plates V and Y was at room temperature.

The two bars on the right side of Figures 3.1 and 3.2 represent the failure times of the fluid (Type IV over Type I) on the plates mounted above the trailing edge (see Section 3.3) of the DC-9 wing.

The following observations can be made relating to Figure 3.1 and Figure 3.2.

1) In the first test, about 25% of the fluid on the leading edge, and less than 10% of the fluid on the trailing edge had failed when the fluid on the standard plates (W and Z) had failed. In the second test, less than 10% of the fluid on the leading edge had failed, and first fluid failures were just detected on the mid-section of the wing when the fluids on the standard plates (W and Z) had failed.

   These results seem to indicate similar results to those experienced in the previous winter with Type I fluids - flat plate holdover times are equivalent to the failure of about 10% or less of the entire wing area.

   The question as to whether up to 10% of the wing surface area represents an acceptable level of contamination needs to be addressed, since regulations preclude acceptance of any contamination at take-off. Pertinent questions address the minimum level of contamination which is detectable, the time to first failure vs. the hot table times and the degree of early failed fluid adhesion to the wing. An NRC project examining aerodynamic penalties caused by frozen precipitation on aircraft wings will address this question.

   Results of the APS tests are supported by results experienced by United Airlines in trials conducted at Denver Stapleton Airport. A total of forty-six individual tests was conducted to determine holdover times of Type I and Type II fluids on aircraft (B-727/B-737) surfaces. The conclusion drawn was that aircraft holdover times validated the SAE/ISO guidelines for the conditions measured, and that end of protection or holdover times on flat panels are similar to those observed on an aircraft wing.

It is believed that the most significant difference in the APS test results between winter 1995/96 and winter 1994/95 can be attributed to fluid application procedures. While operators are under pressure by management to reduce costs (apply less fluid), the properties of the more viscous, newer Type IV fluids are such that sufficient fluid must be applied to build up a layer thick enough (1 to 3 mm recommended by one fluid manufacturer) to provide the prolonged HOTs of Type IV fluids. A measure of this variability in fluid application can be seen in Figure 3.3. Figure 3.3 shows two Type IV fluid stabilized thickness (constant thickness after the fluid has settled) profiles over a chord located on the outboard wing section of an A320. The film thicknesses were measured on the same evening at two different times (Run 4 and Run 5). Although the spray time and amount of fluid applied during Run 5 was slightly greater than Run 4, the difference in measured film thickness for Run 5 was found to be as much **as 400% greater than Run 4 at some locations.**

2) Figures 3.1 and 3.2 indicate that initial failures of the fluid on the aircraft were detected on the leading edge. A discussion relating to the progression of fluid failure on the wing is provided in Section 3.6.

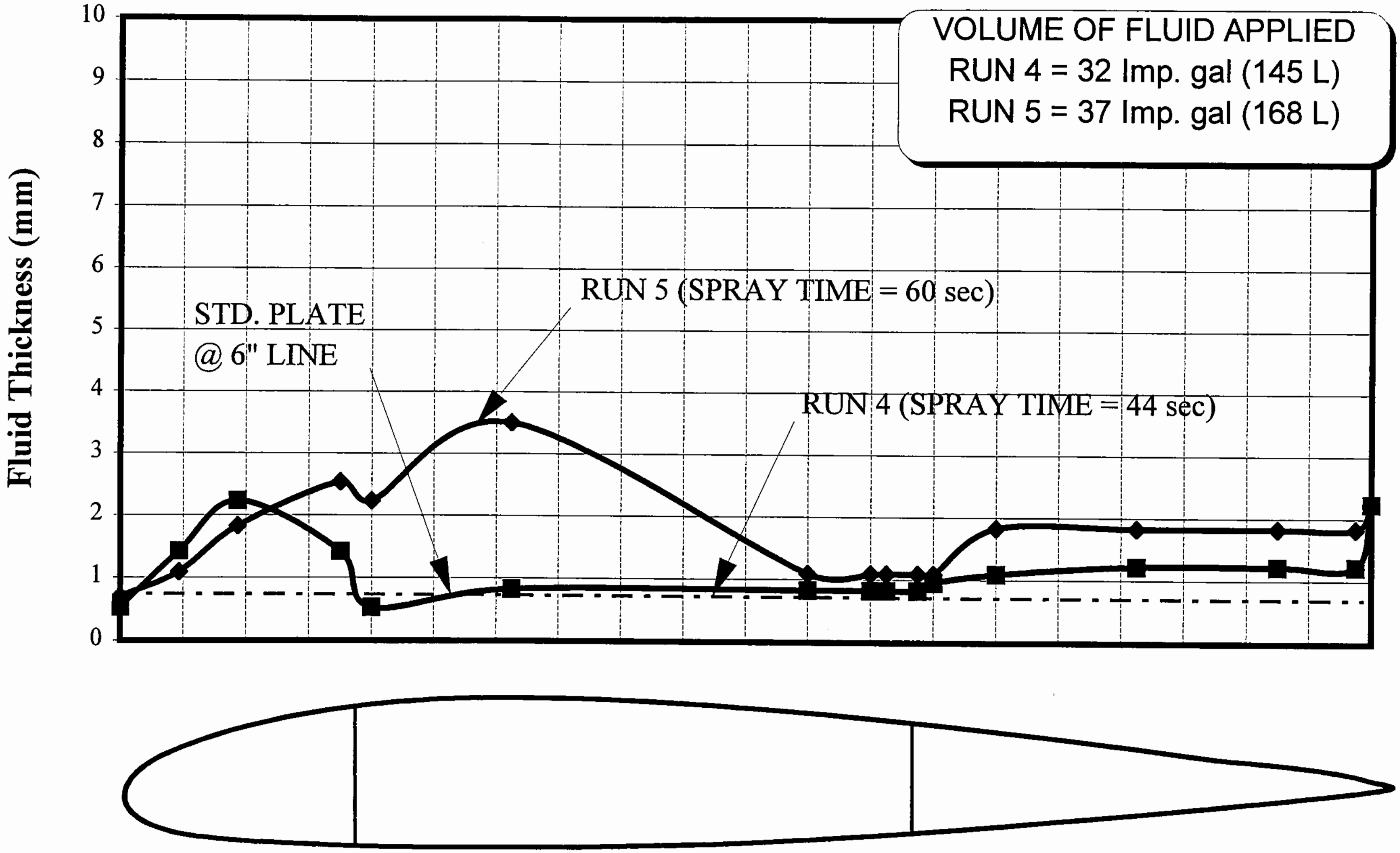
3) When comparing the three sets of plates mounted on the test stand, it was observed that the HOT when Ultra Type IV was applied over Type I is less than the HOT when Type IV is applied over a bare plate. It may be that the Type I acts as a lubricant such that the Type IV's shear strength at the boundary between the two fluids is reduced.

4) When comparing the plates mounted on the test stand with the plates mounted on the wing, no major differences were found.

5) There was a concern (see Section 3.1, item 3) that the fluid thickness and therefore the HOT of a fluid on a surface would not be the same if it was poured versus sprayed. The two special plates (sprayed versus poured) mounted on the wing's trailiing edge showed

FIGURE 3.3

TYPE IV FLUID THICKNESS (STABILIZED) PROFILE
AT CHORD 3 OF A320
MARCH 29, 1996 - ULTRA OVER XL54



File:g:\cm1283\report\full_scl\A320TPRF.XLS
At:RUN 5
Printed:23/01/97

no significant difference in failure time. This is true for both Run 1 and Run 2, as depicted in the two last bars on the right side of Figures 3.1 and 3.2.

3.5 Comparison with Laboratory Flat Plate Holdover Times

The data points resultant from the two tests were superimposed (Figure 3.4) on the flat plate results from the laboratory (NRC) simulations of freezing drizzle and light freezing rain with Type IV neat fluid. The proposed HOT ranges for these conditions are also shown. Figure 3.4 shows the failure times are well within the HOT ranges, showing consistency in procedures and results.

Also recall from Section 2 that "Light Freezing Rain" was reported by the weather station at Dorval for both these tests and therefore an aircraft operator would have been using the more conservative HOT range (30 to 60 minutes). Figures 3.1 and 3.2 showed that first failure of fluid on the wing was only detected by an observer after 50 minutes.

A separate report, TP 12900E, provides the results from fluid thickness measurements on DC-9, Canadair RJ, and A320 aircraft. It was found that the thickness of the fluid on the standard flat plate at the 6 " (15 cm) line was generally comparable to the fluid thickness on the trailing edge and some parts of the leading edge of the A320 and DC-9. In fact, thickness tests showed that the stabilized thickness of the fluid on much of the trailing edge and most of the leading edge lies between the fluid thickness at the 1" (2.5 cm) and 6" (15 cm) line of the standard flat plate (see Figure 3.10 in Section 3.7). These thickness tests have reinforced the initial hypothesis that flat plates are a satisfactory representation of fluid behaviour on an A320 and DC-9 aircraft wing.

It was however noted that for the Canadair RJ, the fluid thickness over the leading edge section was mostly below the thickness of the flat plate 1" (2.5 cm) line. The associated report, TP 12900E, describes the potential causes and recommends additional tests to investigate these concerns.

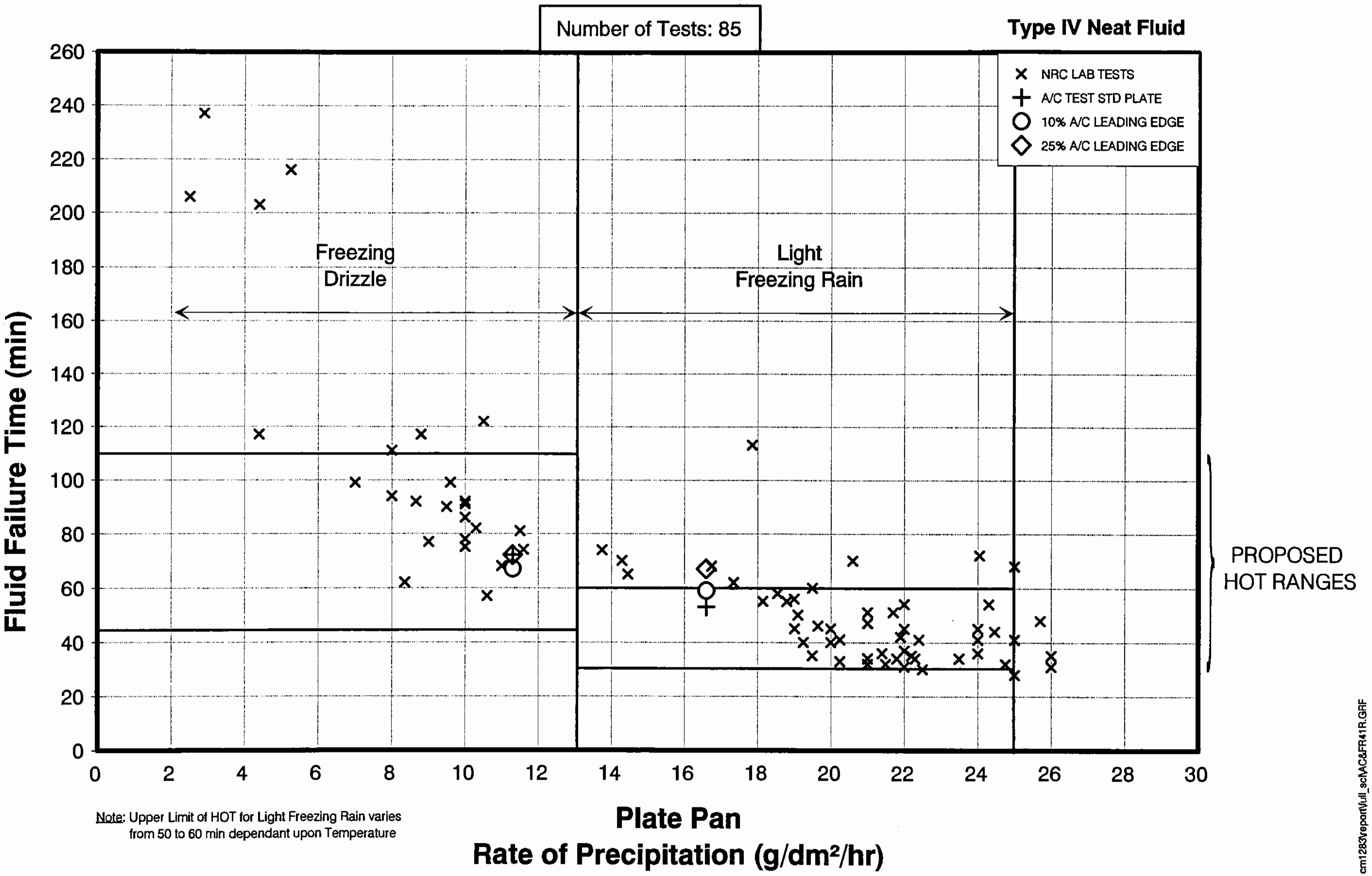
FIGURE 3.4

EFFECT OF RATE OF PRECIPITATION ON FAILURE TIME

TYPE IV NEAT

SIMULATED FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1994-1996



3.6 Failure Progression

This section of the report addresses the relationship between first failure and subsequent failures on the wing surface. Maps of failure progression on the DC-9 wing surface, developed from observations during Run 1 and Run 2, are shown in Figures 3.5 and 3.6. The first test was terminated just before 4:00 a.m. because the conditions were ideal for testing, and all efforts were being made to try to conduct a second test before the aircraft had to be returned to the gate (the aircraft was requested at 5:00 a.m.).

Figures 3.5 and 3.6 show that initial fluid failures during these light freezing rain tests originated at the leading edge.

Photos and videos of the fluid behaviour were taken during the tests. Photo 3.2 shows the condition of the fluid over the wing prior to failure. The green dye of the Ultra fluid provided confirmation at the start of the test that fluid was present.

As soon as contamination of the wing was observed, failures were easily identifiable, provided the viewing angle was optimal. Photo 3.3 clearly shows failure of the leading edge of the wing during one of the two tests. Initial failures of fluid on the leading edge were observed at seams which join two leading edge panels. The failures propagated from these joints. Fluid failures at these locations were simple to identify because the joint area was "matte" in contrast to the adjoining "glossy" part of the leading edge. Similarly, the contrast between the fluid on the middle of the wing and the failed leading edge, provided easy failure identification.

Photo 3.4 was taken on the opposite wing which was not protected with fluid. Ice on the wing surface occurred soon after the freezing rain started. The colour photo showed that detection of ice is not apparent, particularly if the fluid is not dyed. There is no contrast between any two areas of the wing surface. This could lead one to falsely believe that there is fluid on the wing, when viewing the surface from a distance.

The top of Photo 3.5 shows a close-up view of failure on the leading edge of the DC-9. The bottom portions of Photo 3.5 and Photo 3.6 show progression of fluid failure on a flat plate.

FIGURE 3.5

FAILURE TIME PROGRESSION FOR A TYPE IV TEST
RUN # 1

Test conditions were:
- February 28, 1996
- Wind speed was 9 kph
- DC-9 Series 30 was used
- Type of Precipitation was Light Freezing Rain with periods of moderate

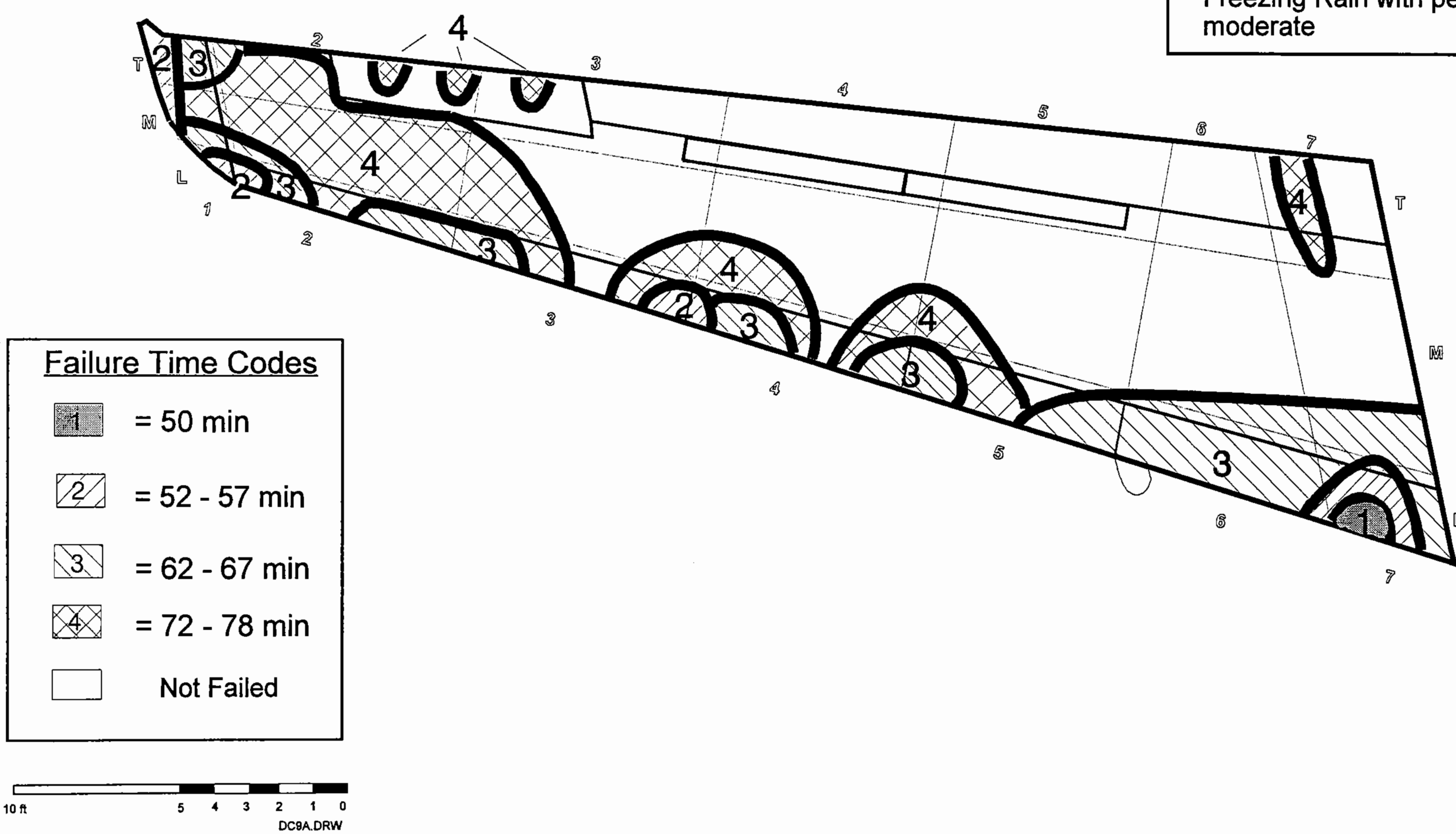


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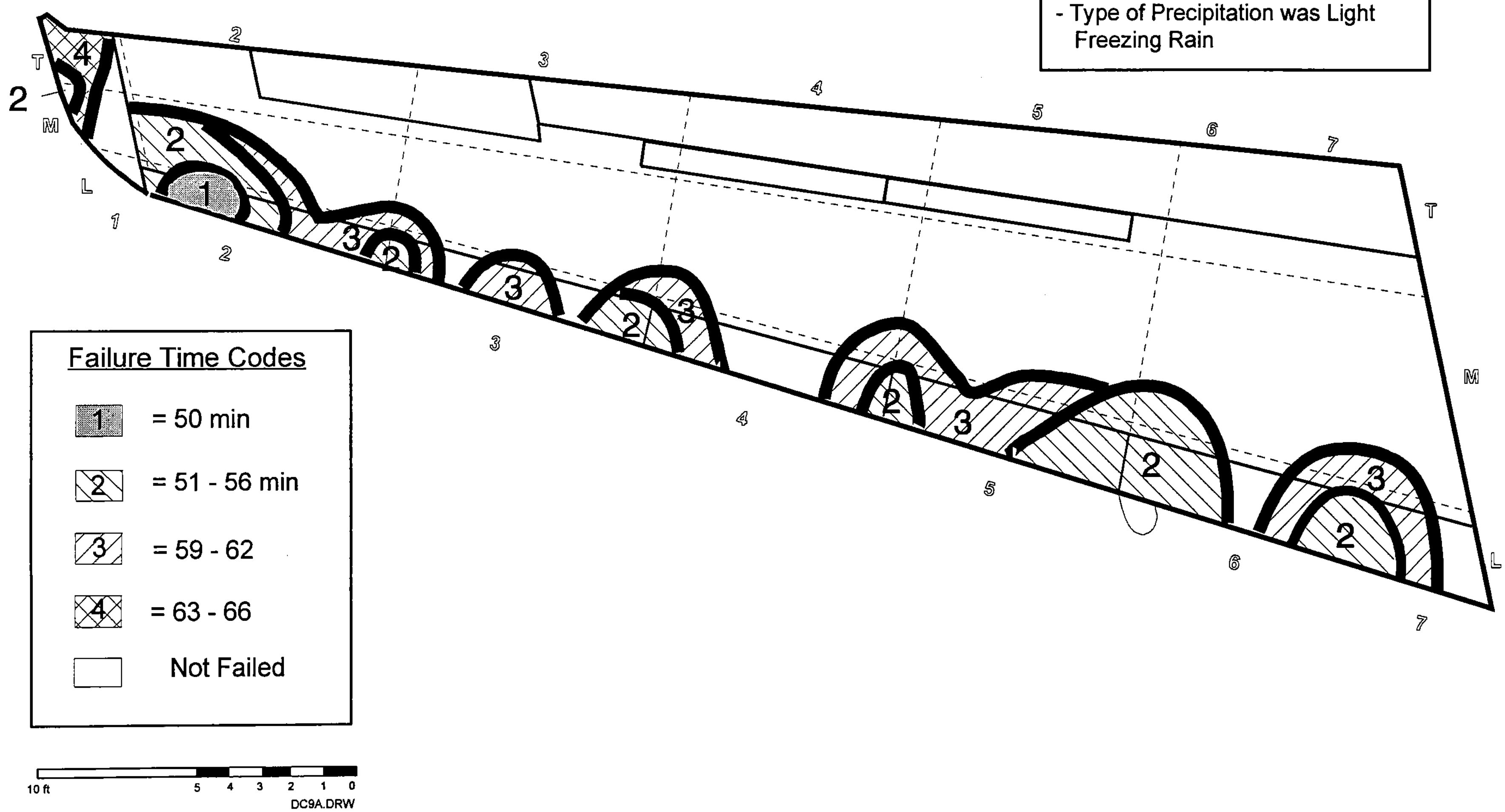
FIGURE 3.6

FAILURE TIME PROGRESSION FOR A TYPE IV TEST
RUN # 2

Test conditions were:

- February 28, 1996
- Wind speed was 11 kph
- DC-9 Series 30 was used
- Type of Precipitation was Light Freezing Rain



cm1283\report\full_scl\CNT2_DC9.DRW

PHOTO 3.2
DC-9 WING SURFACE DURING FREEZING RAIN TESTS AT DORVAL (Feb. 28, '96)

PRIOR TO FAILURE

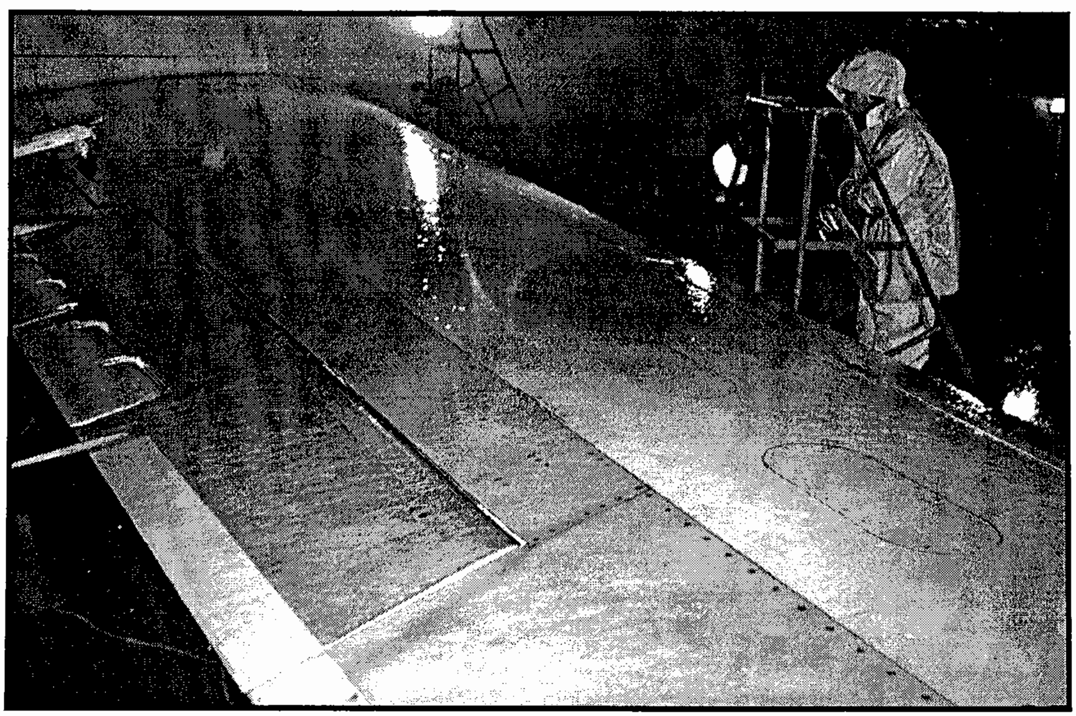
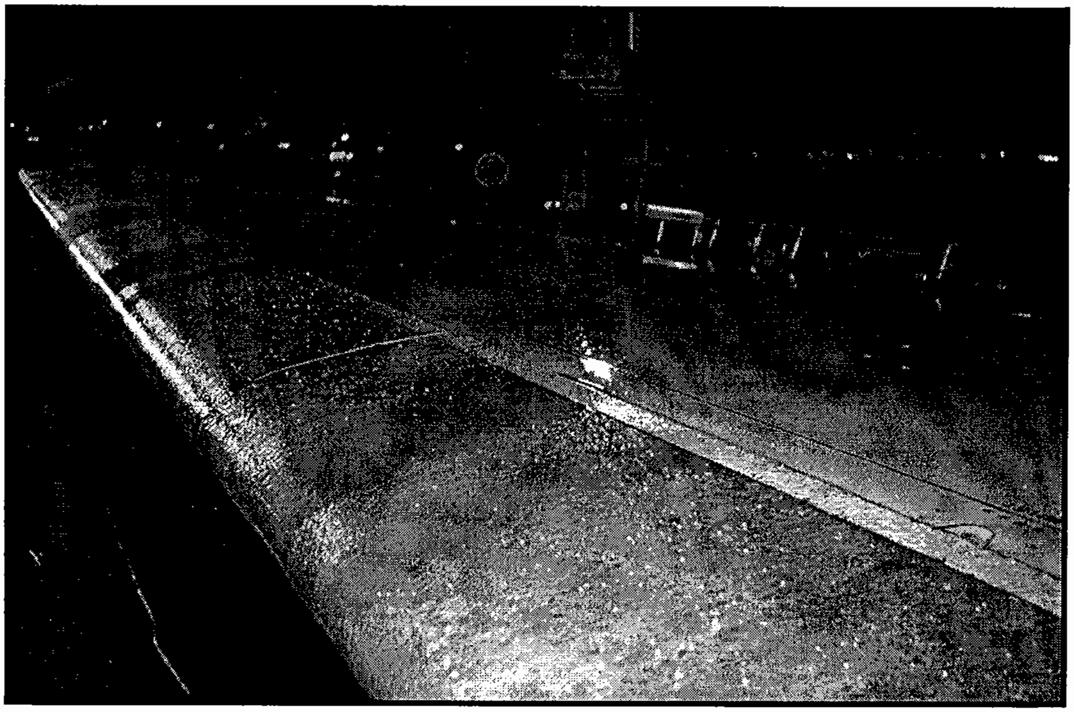


PHOTO 3.3
DC-9 WING SURFACE DURING FREEZING RAIN TESTS AT DORVAL (Feb. 28, '96)

DURING FAILURE



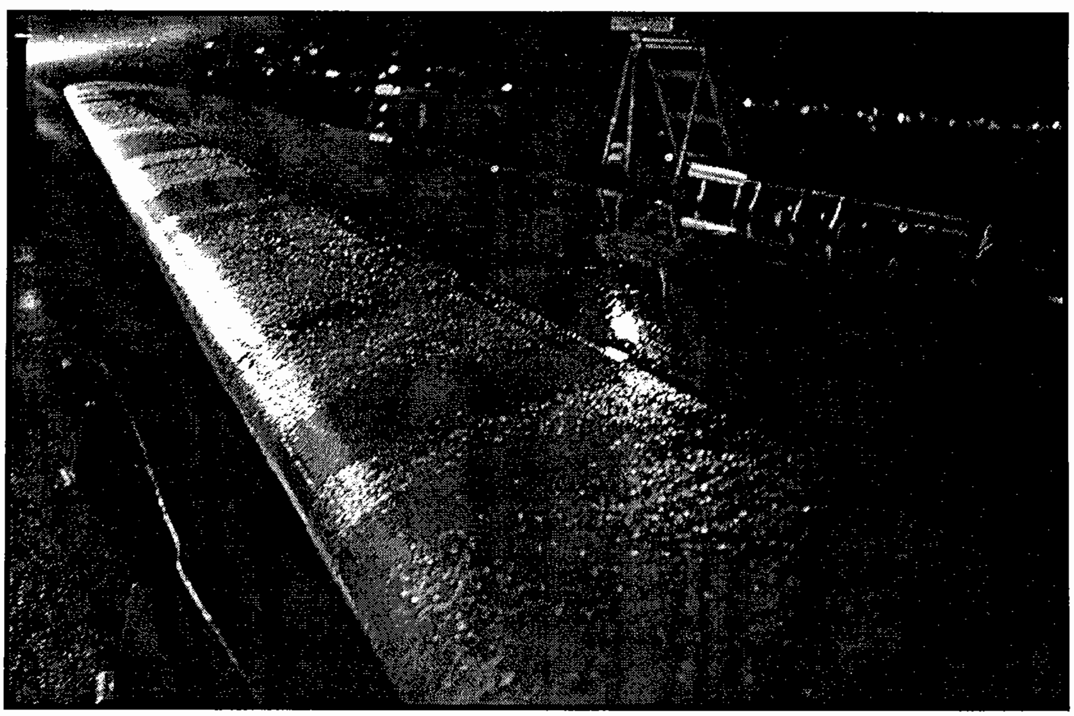
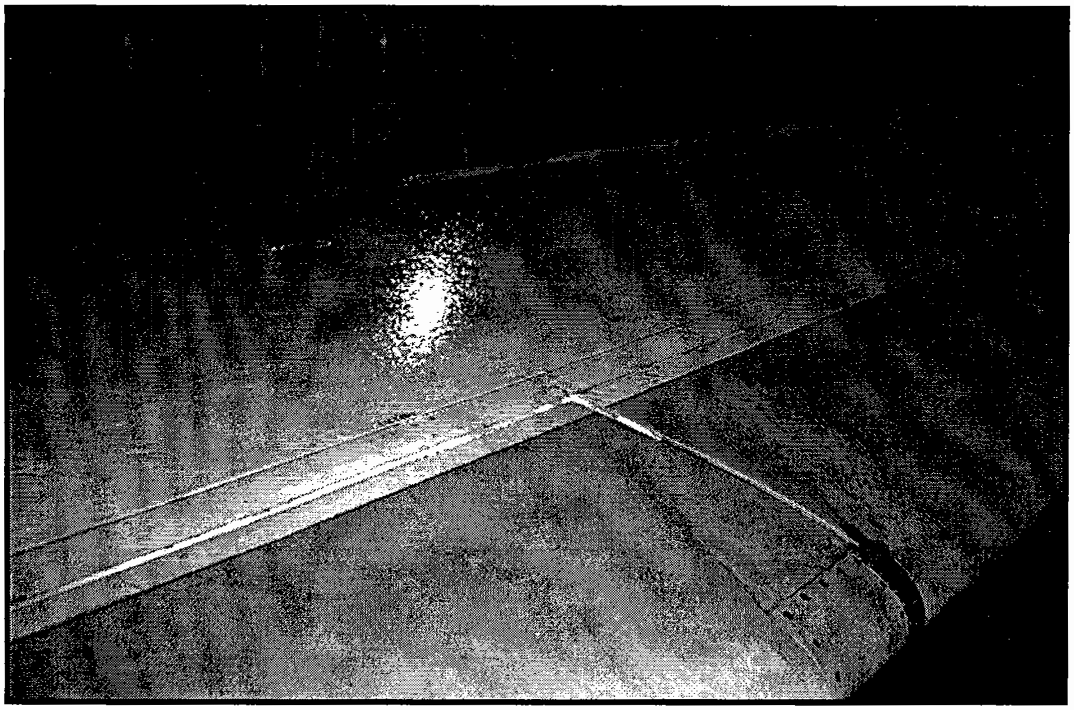


PHOTO 3.4
DC-9 WING SURFACE DURING FREEZING RAIN TESTS AT DORVAL (Feb. 28, '96)

AFTER FAILURE



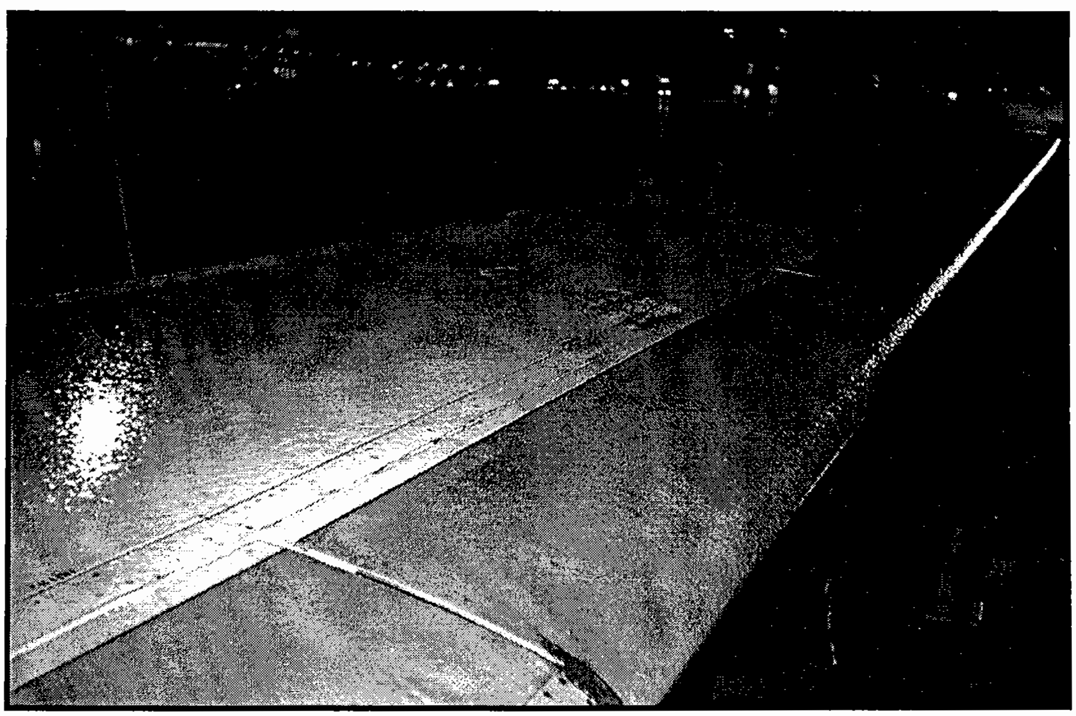
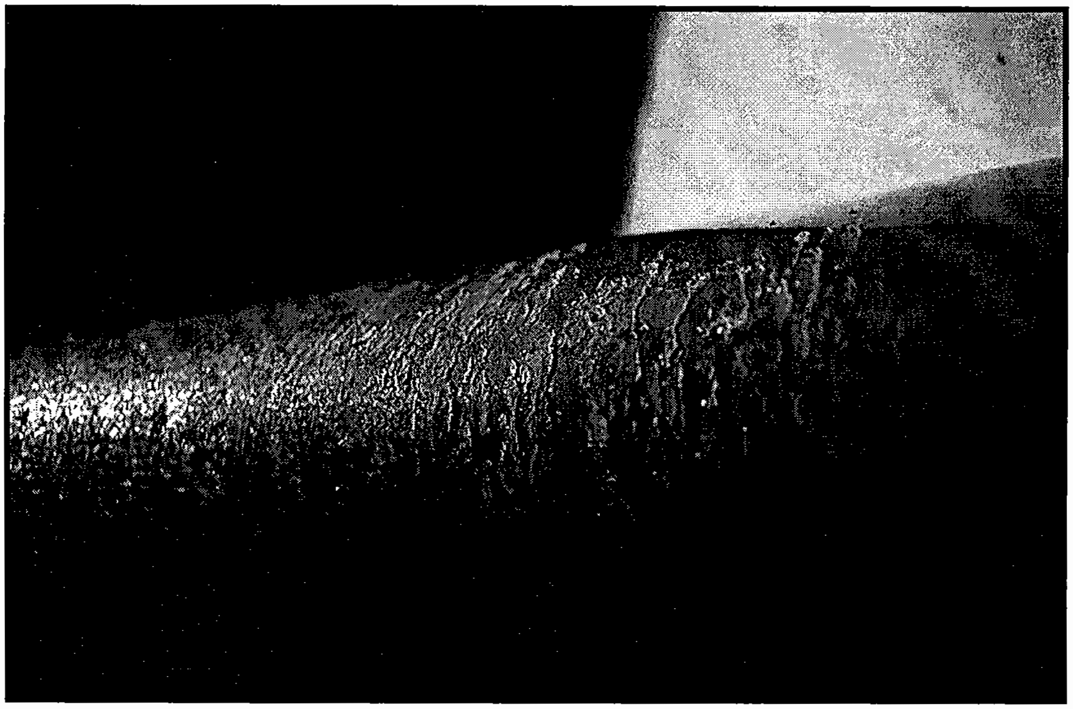


PHOTO 3.5

DC-9 WING SURFACE DURING FREEZING RAIN TESTS AT DORVAL (Feb. 28, '96)

CLOSE-UP OF FAILURE ON LEADING EDGE



FLAT PLATE DURING FREEZING RAIN TESTS AT DORVAL (Feb. 28, '96)

FAILURE PROGRESSION TO 3" LINE

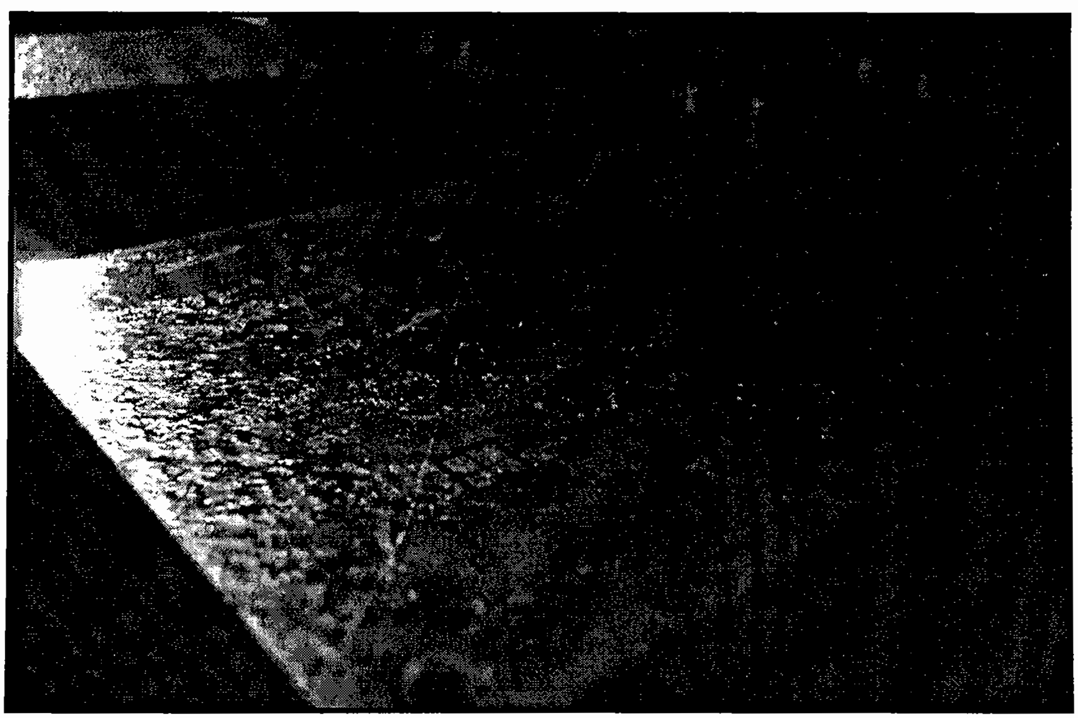
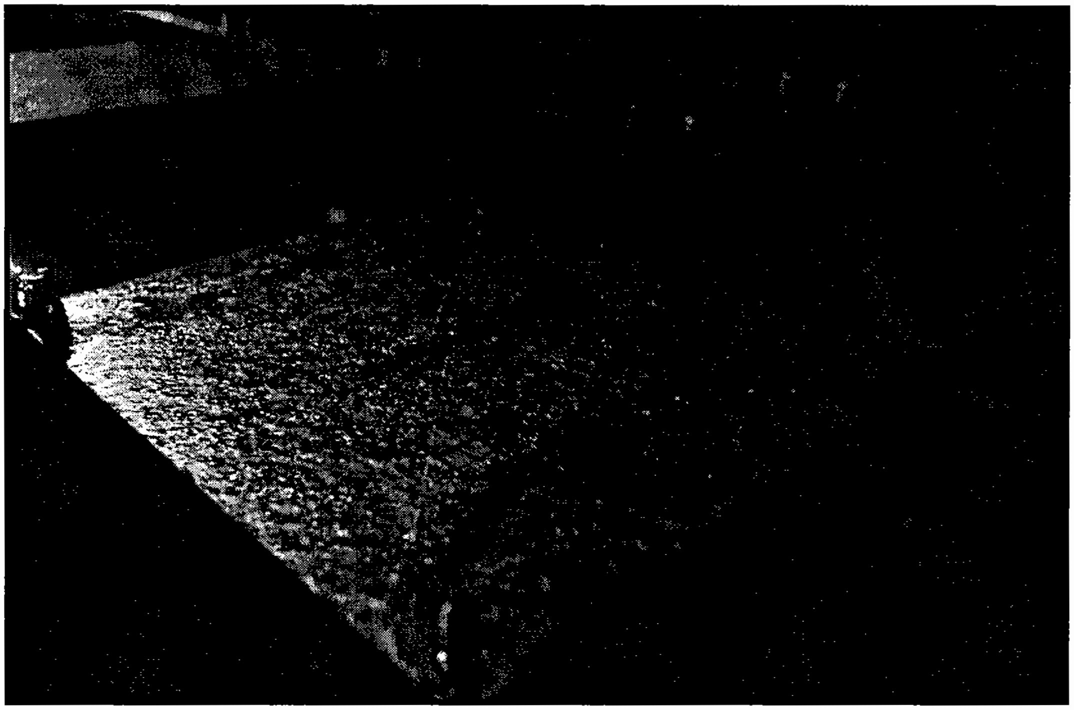
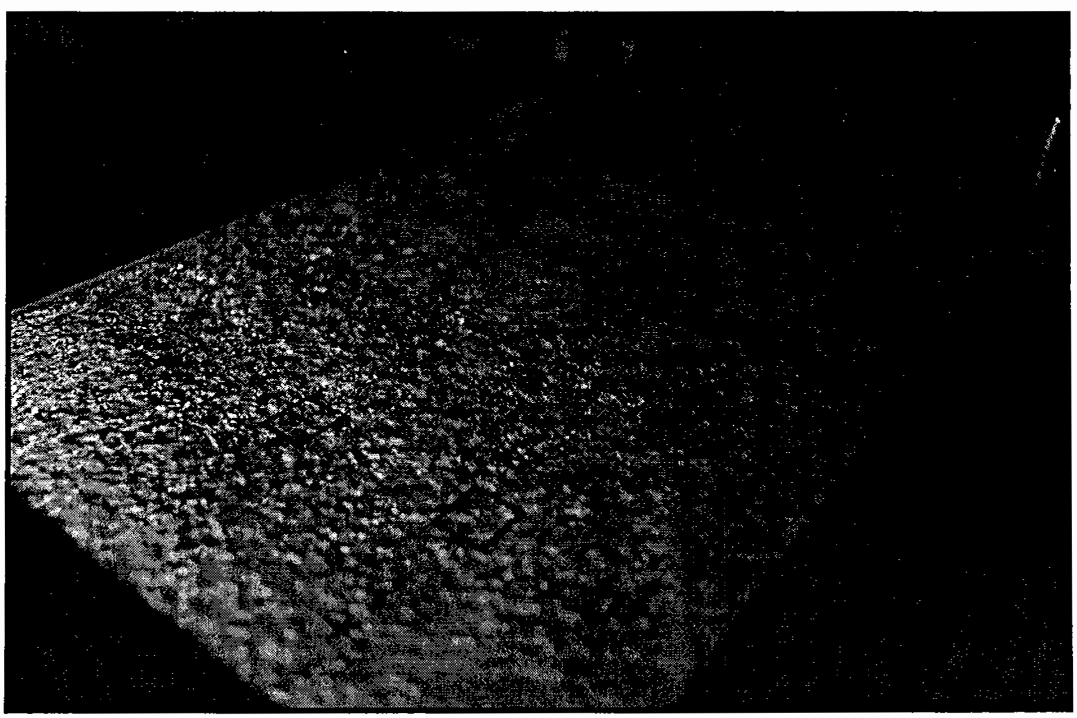


PHOTO 3.6
FLAT PLATE DURING FREEZING RAIN TESTS AT DORVAL (Feb. 28, '96)
MOST OF PLATE FAILED



ALL OF PLATE FAILED



It can be observed that failure of fluid is easily identifiable when ice progresses to the 3" (7.5 cm) line and becomes more difficult when the entire plate is iced.

One of the conclusions from the 1994/95 winter test program was that the representative surface was not a conclusive representation of the condition of the aircraft wing surface. The two tests conducted during the 1995/96 winter support this conclusion - the initial fluid failures were observed on the leading edge (see Figures 3.5 and 3.6) away from the DC-9 representative surface.

3.7 Sampling of Fluids

During the "dry run" test session, APS was requested by Transport Canada to collect samples of fluids on the wing surface as part of the full-scale test program. The intent was to measure the freeze point of samples of fluid taken on the wing surface and compare these to the outside air temperature. The samples were taken at six locations. The locations were roughly at ¼, ½ and ¾ of the wing span, near the leading and trailing edges, but on the main body of the wing. These points were selected to develop a measure of the contamination profiles on a wing and because it was felt that the installation of surface mounted sensors might be easier on the main section of the wing than on the leading or trailing edges.

The overall objective was to determine whether sensors mounted at these locations would provide a satisfactory representation of the condition of the entire wing.

Based on the discussions with Transport Canada, a test procedure for sampling of the fluid on the wing was developed. This data form and test procedure is shown in Table 3.1. The samples were to be taken at the first sign of failure anywhere on the wing and at every 15 minutes thereafter. The samples were raised with two small putty knives (see Photo 3.7) and placed in a covered ice cube maker. The refractive index (Brix) was measured using a Misco Refractometer (see Photo 3.8) which has automatic temperature compensation, and then converted to fluid freeze point using a chart provided by the fluid manufacturer.

TABLE 3.1

TEST PROCEDURE FOR SAMPLING OF FLUIDS

Sampling of applied fluid on aircraft wing (Brix tests)

1) Locate sampling points using a black marker. **Each wing has 6 sampling locations, roughly at $^1/_4$, $^2/_4$ and $^3/_4$ of the wing span, near the leading (L1, L2, L3) and trailing (T1, T2, T3) edges on the main body of the wing**, not the ailerons or flaps. Location 1 is close to the fuselage.

2) **At 1st sign of failure on the wing, take a sample at all 6 locations** on that wing, and every 15 minutes after (use sampling tool and ice cube maker). Cover container between each sampling. Record sampling time.

3) Leave samples inside for a few minutes allowing them to warm up. **Proceed with Brix readings** (use temperature compensated instrument).

4) Clean up containers before next test.

Date: Run #: OAT: °C

WING	BRIX	L1	L2	L3	T3	T2	T1
A (port)	Sampling Time						
	Reading						
A	Sampling Time						
	Reading						
A	Sampling Time						
	Reading						
A	Sampling Time						
	Reading						

Date: Run #: OAT: °C

WING	BRIX	L1	L2	L3	T3	T2	T1
B (strbrd)	Sampling Time						
	Reading						
B	Sampling Time						
	Reading						
B	Sampling Time						
	Reading						
B	Sampling Time						
	Reading						

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PHOTO 3.7
SCRAPERS USED TO COLLECT SAMPLES TO DETERMINE FREEZE POINT

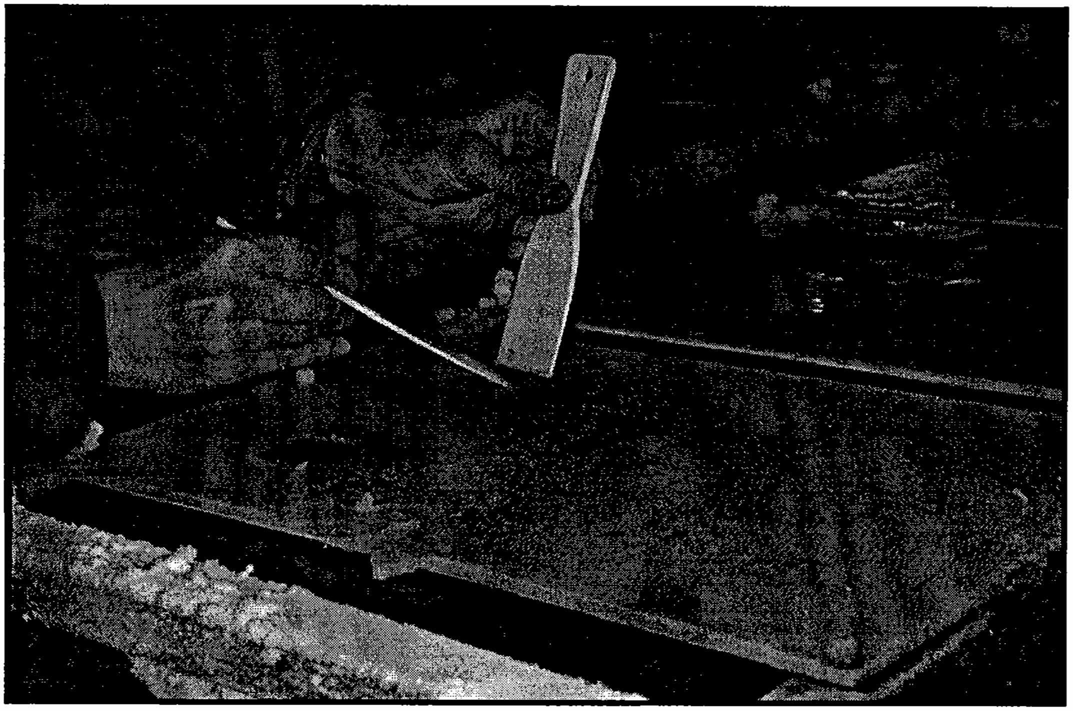

PHOTO 3.8
REFRACTROMETER TO MEASURE FLUID FREEZE POINT

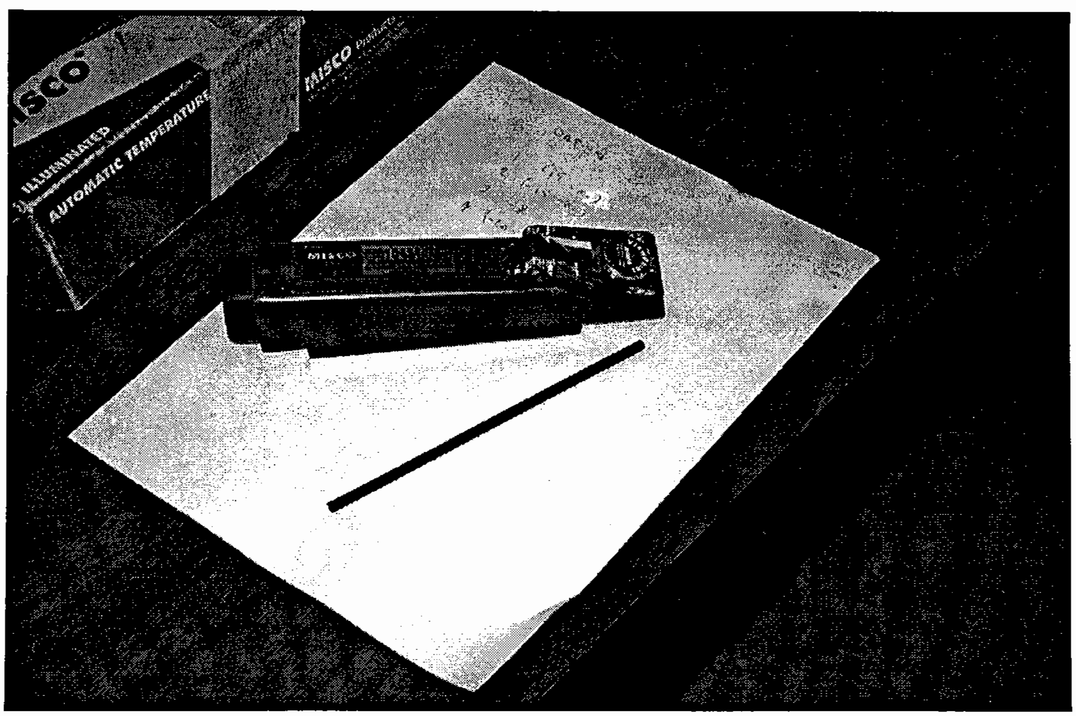

Figure 3.7 shows the freeze point of fluids sampled at four cross hairs on a plate. Failure of the fluid had progressed beyond the 6" (15 cm) line but before the 9" (22.5 cm) line. The samples were collected during a freezing drizzle test at NRC while the air temperature was -9.5°C. Ideally one would expect that the freeze point of fluid sampled at the "ice front" location should be equal to the ambient temperature. This appears to be the case in Figure 3.7.

Figure 3.8 and 3.9 show the locations used to sample fluids on the aircraft, as well as the freeze point results of the sampled fluid, for Run 1 and Run 2, respectively. The collected data is shown in an italics font. The samples of both tests were taken about 10 minutes after the first failure was observed. The outside air temperature was -1°C and the fluid freeze point in its undiluted form is -49°C. The two figures show that while the fluid freeze point rose as much as 39°C to -10°C at one point just aft of the leading edge, the same point on the other test still had 15°C to rise before it reached the outside air temperature of -1°C. This was at a time when much of the fluid at the leading edge had failed. Figure 3.10 shows the fluid thickness profile on the wing of a DC-9 during a test conducted on March 12, 1996. Figure 3.10 shows that the film thickness at the leading edge was much less than at the sample location and therefore supports the above observation. Samples of fluid from locations near the trailing edge had freeze points closer to -1°C than did samples on the leading edge. Figure 3.10 also shows that the thickness of the fluid at the trailing edge sampling location is less than at the leading edge sampling location.

Figure 3.11 shows "hypothetical" curves representing fluid concentration and fluid freeze point over a wing. The curves were developed based upon the fluid thickness curves from a test on March 12, 1996 and from the freeze points of the samples taken on February 28, 1996 during Run 1. The fluid concentration curve for Ultra was developed using the freeze points measured and the fluid freeze point/dilution curves from Union Carbide. The chart shows that the fluid concentration is highest at the middle of the wing. During moderate or heavy wind conditions, this curve could be distorted further. More precipitation would impinge on the leading edge and less on the mid-section and trailing edge.

FIGURE 3.7

FREEZE POINT OF SAMPLED FLUIDS ON FLAT PLATE

MARCH 14, 1996 @ CEF DURING FZD TEST
Ambient Temperature: -9.5°C

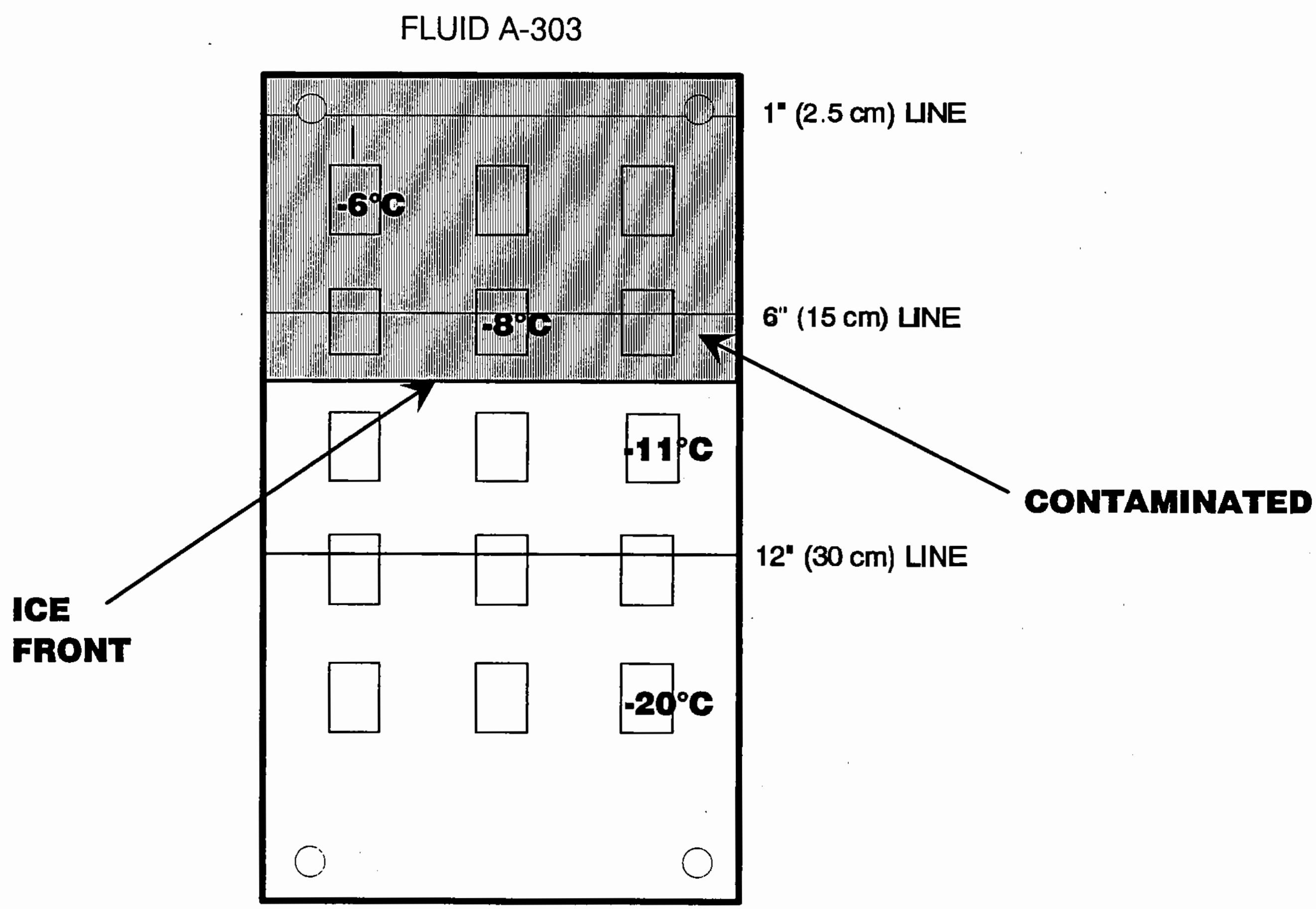

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FIGURE 3.8

REMEMBER TO SYNCHRONIZE TIME

DE/ANTI-ICING FORM FOR AIRCRAFT WING (RUN 1)

VERSION 2.3 Winter 94/95

LOCATION: *A/C DEICING BAY (YUL)* DATE: *FEB. 28, 1996* RUN NUMBER: *1* WING #: *B* RVSI AVAILABLE: Y / (N)

Time After Fluid Applied to Plates U and X: am / pm C/FIMS SENSOR AVAILABLE: Y / (N)

TIME OF INITIAL FLUID APPLICATION: *2:23:07* (hr:min:sec)
(Last step only)

TIME AFTER FLUID APPLICATION: *2:24:40* (hr:min:sec)
(Last step only)

DIRECTION OF AIRCRAFT: ____________

FAILURES CALLED BY: ____________

DESCRIBE SENSORS/LOCATION: ____________

HANDWRITTEN BY: ____________

ASSISTED BY: ____________

COMMENTS: *OAT: -1°C*

SAMPLING TIME: 3:24 AM

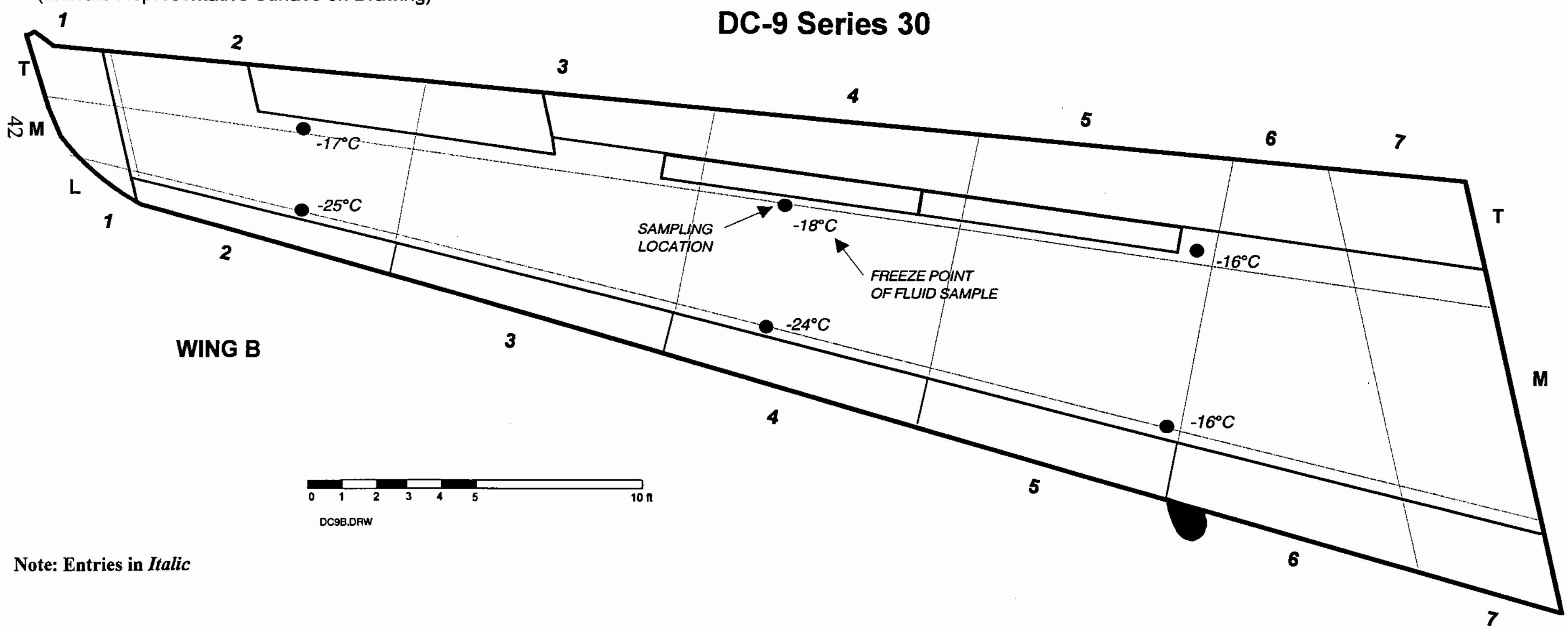
IMPORTANT EVENTS (min)

	L.Edge	Mid	T.Edge
1st Failure:	*3:13*	*3:17*	*3:17*
10% :	*3:30*		*3:37*
25% :	*3:33*		
75% :	*3:42*		
100% :			

File: Aform2-3.drw

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE
(Indicate Representative Surface on Drawing)

DC-9 Series 30



Note: Entries in *Italic*

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

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FIGURE 3.9

DE/ANTI-ICING FORM FOR AIRCRAFT WING (RUN 2)

REMEMBER TO SYNCHRONIZE TIME — VERSION 2.3 — Winter 94/95

LOCATION: *A/C DEICING BAY (YUL)* DATE: *FEB. 28, 1996* RUN NUMBER: *2* WING #: *B* RVSI AVAILABLE: Y / (N)

Time After Fluid Applied to Plates U and X: ______ am / pm C/FIMS SENSOR AVAILABLE: Y / (N)

TIME OF INITIAL FLUID APPLICATION: *4:03:02* (hr:min:sec)
(Last step only)

TIME AFTER FLUID APPLICATION: *4:04:31* (hr:min:sec)
(Last step only)

DIRECTION OF AIRCRAFT: ______

FAILURES CALLED BY: ______

DESCRIBE SENSORS/LOCATION: ______

HANDWRITTEN BY: ______

ASSISTED BY: ______

COMMENTS: *OAT: -1°C*

SAMPLING TIME: 5:04 AM

IMPORTANT EVENTS (min)

	L.Edge	Mid	T.Edge
1st Failure:	*4:53*	*5:06*	*5:09*
10% :	*5:02*		
25% :	*5:10*		
75% :			
100% :			

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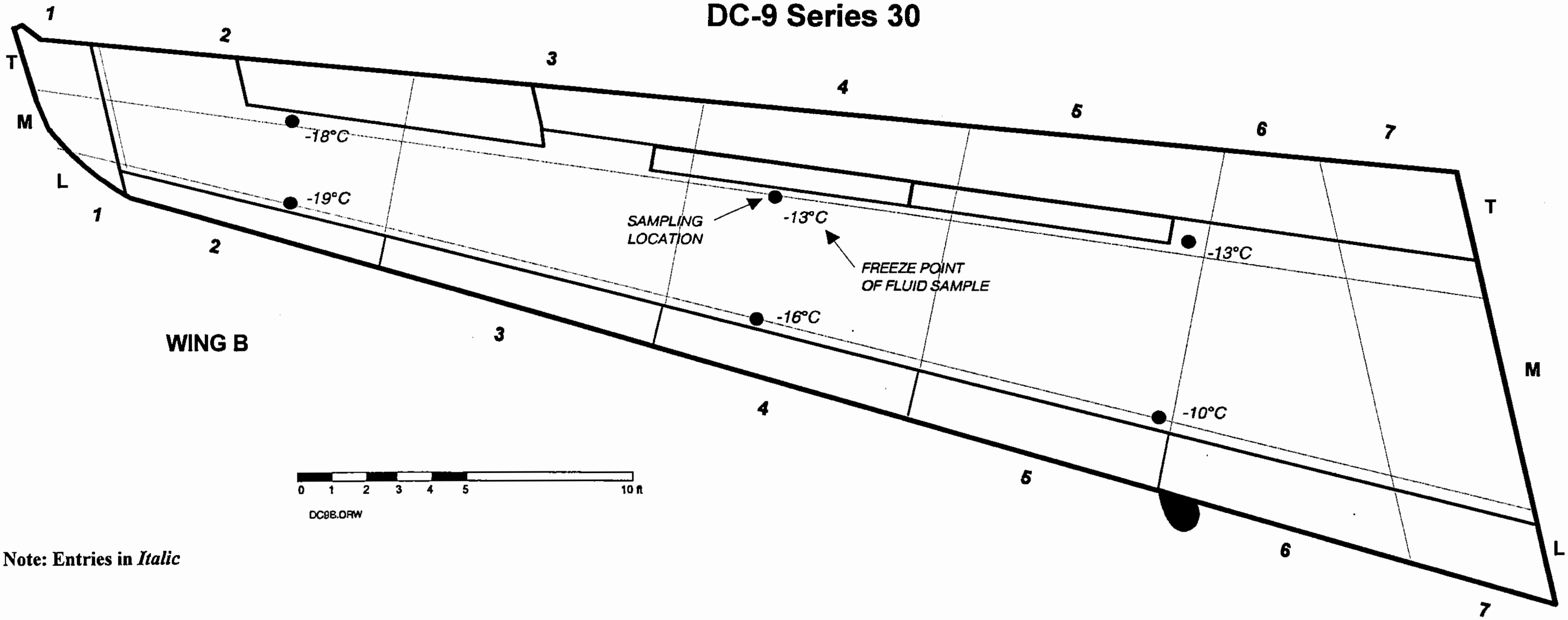
DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE
(Indicate Representative Surface on Drawing)

DC-9 Series 30



Note: Entries in *Italic*

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

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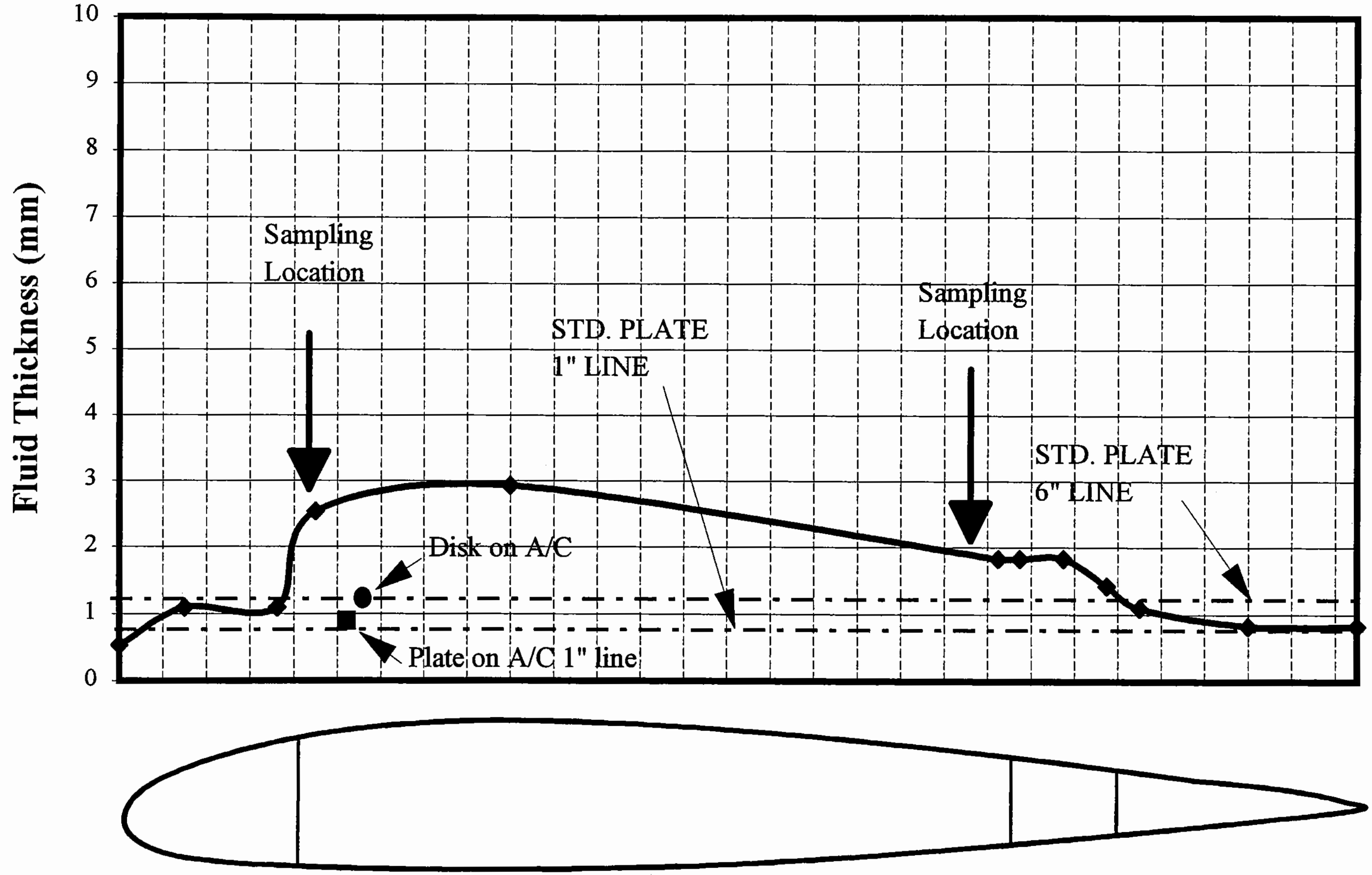
FIGURE 3.10

TYPE IV OVER TYPE I FLUID THICKNESS (STABILIZED) PROFILE AT CHORD 2 OF DC-9 MARCH 12, 1996, RUN 6 - XL54 + ULTRA



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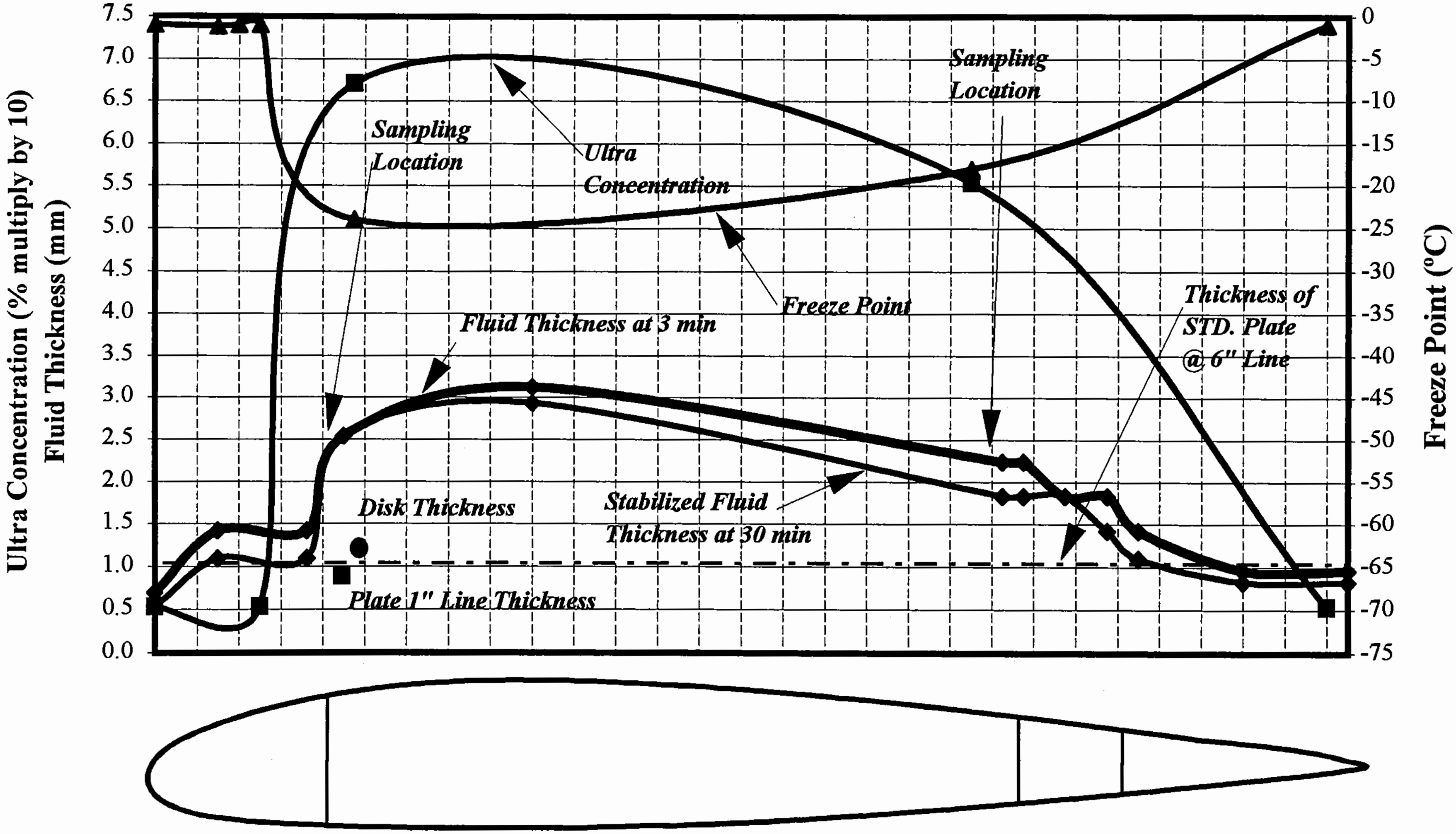
At:RUN 6
Printed:19/09/96

FIGURE 3.11

HYPOTHETICAL CURVES
TYPE IV OVER TYPE I FLUID THICKNESS (STABILIZED) PROFILE
AT CHORD 2 OF DC-9
MARCH 12, 1996, RUN 6 - XL54 + ULTRA

Samples Taken on Feb. 28, 1996, Run 1



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At:RUN 6 - HYP
Printed:24/09/96

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4. CONCLUSIONS

The conclusions are presented in point form below.

1. Results of the three tests performed with Ultra Type IV Neat fluid in winter 1994/95 did not confirm that flat plates offer a satisfactory wing representation possibly due to the method of fluid application to the wing. During the 1995/96 winter testing, one objective was to ensure that fluid was suitably applied. Together with the airline operator and the fluid manufacturer, an acceptable method was identified. The spray technique must ensure that care is taken to guarantee complete and consistent coverage over the entire wing surface.

   Experience from the tests points out the need for particular care in the application of Type IV fluid during normal winter operations. Attainment of the full potential of the fluid is highly dependent on the use of suitably equipped de/anti-icing vehicles and application by knowledgeable operators fully trained in spray techniques unique to the more viscous Type IV fluids.

2. For Type IV neat Ultra fluid applied to a DC-9, the winter 1995/96 trials showed that the flat plate holdover times are equivalent to the failure of about 10% or less of the entire wing area. The flat plates offer a reasonable representation of aircraft wing surfaces in holdover time trials for Type IV fluids. Similar results were obtained with Type I fluid.

   These results are based on only two experiments under one type of precipitation (light freezing rain). These tests support findings from United Airlines' trials at Denver Airport with Type II fluid on B-737 and B-727 aircraft.

   Film thickness tests showed that the flat plates offer an adequate representation of the leading and trailing edges of A320 and DC-9 aircraft, but not for the Canadair RJ wing. Further test work is needed.

3. Flight control systems such as ailerons, flaps, slats and spoilers are well defined sections of the aircraft wing. They contain abrupt surface discontinuities from which fluid can drain and where heat is more efficiently radiated, causing (potential) local fluid failures to initiate.

   The trailing edge and the leading edge are the most failure sensitive regions due to the presence of flight control surfaces and surface discontinuities. These conclusions are supported by the film thickness tests conducted on the DC-9, Canadair RJ and A320.

4. Observations during the two full-scale aircraft tests conducted under precipitation conditions showed that ice formation on the Type IV fluid was not difficult to identify visually, once the failures started. Both photograph and video records show the very distinct difference between the failed (matte) sections and the non-failed (glossy) areas. This is not the case when ice accumulates on an un-protected surface or once the fluid on the entire wing surface has lost its protection capabilities, in which case failures are less easy to identify from a distance.

5. The freeze point of samples of failed fluid taken on flat plates while conducting holdover time tests at NRC closely matched the ambient temperature.

6. The freeze point of fluid samples taken on an aircraft wing away from the leading and trailing edges after first failure, was significantly below the outside air temperature.

5. RECOMMENDATIONS FOR FUTURE TESTING

This section outlines the direction and scope for future testing.

1. For the two Type IV fluid tests conducted in winter 1995/96, it was found that approximately 10 % or less of the entire wing surface had failed when the flat plates were considered failed. The shortage of suitable weather conditions during the 1995/96 winter season test period prompts APS to recommend further testing and consequent data acquisition of Type IV fluid behaviour in order to build a credible database comparing flat plate test results with fluid failures on aircraft. It is recommended to test Type IV fluid under natural snow conditions. Film thickness tests suggest that these tests should be conducted with the Canadair RJ aircraft, with the leading edge facing the wind.

   The question of whether up to 10% of the wing surface area represents an acceptable level of contamination needs to be addressed and is the subject of an NRC project.

2. Develop a video or computer based training module to be made available to industry users, on application of Type IV fluids. Include a description of the unique characteristics of the fluid that require special application techniques, for the general education of hands-on de-icing operators as well as all those involved in de-icing throughout the industry.

3. Fluid testing (sampling) at locations where point sensors may be positioned on an aircraft wing should be carried out. In order to determine the relationship between failure progression and fluid contamination, it is recommended that the fluid be sampled at 15 minute intervals beginning at first failure. This could be quantified both as a function of time and as a function of dilution or fluid composition (i.e. the amount of precipitation). Additional tests relating to fluid contamination levels using surface mounted sensors under controlled laboratory conditions are recommended in related document TP 12900E.

4. Conduct tests during precipitation on flat plates to explore the relationship between the fluid freeze point (by sampling) and the trace of the C/FIMS sensor. Tests should be conducted for a variety of fluids under controlled laboratory conditions.

APPENDIX A

TERMS OF REFERENCE - WORK STATEMENT

TRANSPORTATION DEVELOPMENT CENTRE

WORK STATEMENT
(revised* November 96)

AIRCRAFT AND FLUID HOLDOVER TIME TESTS FOR WINTER 95/96
(Short Title: Winter Tests 95/96)

1 INTRODUCTION

In the last decade, a number of fatal aircraft accidents have occurred in the winter at take-off during periods of precipitation that could contaminate aerodynamic surfaces; in several of these accidents the effectiveness of aircraft ground anti-icing has been suspect. Of particular importance to Canada was the crash of an Air Ontario F-28 at Dryden, Ontario on 10th March 1989, which led to a Commission of Inquiry led by Justice Moshansky.

The deicing fluids used on aircraft were originally expected to provide protection for the surfaces during only brief taxi and take-off periods. As traffic demand has grown, operations under more extreme weather conditions have increased, and traffic congestion on the airports has introduced lengthy line-ups for take off with the accompanying longer anti-icing protection requirement. This led to the development of the Type II anti-icing fluids for the jet aircraft and the Type III fluids for turboprops, both of which provide longer protection time (known as Holdover Time) following application. The times given in the official Holdover Time Tables were originally established by the Association of European Airlines (AEA) based on assumptions of fluid properties, and anecdotal data all related to operations in the European environment. These tables are published by the AEA, the Society of Automotive Engineers (SAE) and the International Standards Organization (ISO).

In a series of meetings on holdover time sponsored by the SAE Committee on Aircraft Ground Anti-icing involving the major airlines, aircraft manufacturers and anti-icing fluid producers, a program for field testing Type II fluids to establish holdover times in representative weather conditions was proposed. TDC took the lead in accepting to coordinate these activities for the 90/91 winter season with the participation of a number of carriers, deicing fluid manufacturers, the University of Quebec at Chicoutimi (UQAC), the National Research Council (NRC), and the Federal Aviation Administration (FAA). TDC undertook to prepare the test procedures and analyze and distribute all test results.

During the 90/91 season the methods of testing were developed and Type II and Type III fluids were tested. The Type II fluid results indicated that the times in the holdover tables were excessively long under normal winter snow conditions in North America. This led to the introduction of a range of time values for each condition (except frost) in the AEA/SAE/ISO tables, the original AEA value being retained for the high time and a new lower time from the TDC tests for the "worst" conditions.

For the 91/92 winter season TDC tests were made on Type III fluids exclusively because of the importance of this fluid to commuter operators.

With the release of the recommendations of the Dryden Inquiry in March, 1992 and the setting up of the Dryden Commission Implementation Project Office (DCIP), even greater support for these holdover tests was generated in Canada. Almost simultaneously the La Guardia crash of a F-28, also in March 1992 spurred the FAA to introduce Holdover Time regulations and to request that the SAE Committee on Aircraft Ground Deicing spearhead work on establishing holdover guidelines. This led to the formation of the holdover time working group, co-chaired by DCIP and FAA/ARC. Building on the earlier work initiated by TDC for the 90/91 and 91/92 winter seasons, a major test program was initiated to substantiate the existing holdover time tables. DCIP undertook to coordinate the expanded test program as part of its fulfilment of the recommendations of the Dryden Commission.

The 92/93 series of outdoor winter tests were in Montreal and involved revision of the test protocol, tests in both natural and artificial snow on flat plates, on simulated wings and on wing leading edges, and used a sensor to confirm fluid failure criteria. Type I, Type II and Type III fluids were tested. Simulated frosting, freezing fog and freezing rain conditions were tested at the NRC facilities in Ottawa. As a result of these tests large parts of the Type I and Type II tables were substantiated

For the 93/94 testing season, efforts were aimed at continuing the substantiation of the holdover tables and mostly involved testing diluted Type II fluids. All natural snow tests were made at Dorval, freezing fog at the NRC Helicopter Icing Facility and Freezing drizzle and freezing rain at the NRC Cold Environment Facility (CEF). In addition to the Instrumar sensor the RVSI remote sensor was also used to assist in collecting data. UCAR provided a new long lasting Type II fluid for preliminary testing.

An important effort was made in the 94/95 season to verify that the flat plate data were representative of aircraft wings. Air Canada cooperated with DCIP by making aircraft and limited ground support staff available at night to facilitate the correlation testing of flat plates with performance of fluids on aircraft. The new UCAR ULTRA fluid was extensive tested and resulted in a new TC/FAA holdover table providing 50% longer holdover times for use during the 95/96 winter season. Additional testing was undertaken to evaluate the suitability of hot air for de-icing as an alternative to heated de-icing fluids at low (e.g. -30°C and below) ambient temperatures. wet snow. Tests were also performed to assess the potential for extending the use of hot water for de-icing from the current -3°C limitation down to -7°C or lower, where past experience has shown it feasible.

The winter 94/95 season testing was very restricted by the paucity of snow conditions and therefore much of the planned testing was not completed. Substantiation of the Type I and Type II tables needs certain special conditions hard to find in the field such as low temperatures with precipitation, and rain or other precipitation on cold soaked surfaces. The development of ULTRA by Union Carbide has stimulated all the manufacturers to produce new long lasting anti-icing fluids that will be defined as Type IV; all these fluids will contribute to the definition of the performance requirements for a generic Type IV. Although the Holdover tables are widely used in the industry as guides to operating aircraft in winter precipitation the significance of the range of time values given in each cell of the table is obscure; there is a clear need to improve the understanding of the limiting weather conditions to which these values relate. The few aircraft tests made to validate the flat plate tests were inconclusive and more such tests are needed. The testing with hot water and with hot air for special deicing conditions have not been completed. All these areas are the subjects for the further research that is planned for the 95/96 winter.

2 PROGRAM OBJECTIVE (MCR 16)

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

3 PROGRAM SUB-OBJECTIVES

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

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

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

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

4 PROJECT OBJECTIVES

4.1 To complete the substantiation of the existing Type I and Type II SAE holdover time Tables by conducting cold soak tests and very low temperature tests.

4.2 To determine the holdover time performance of the proposed Type IV fluids over the range of characteristic conditions and create a generic Type IV holdover time table.

4.3 To establish the precipitation, wind and temperature values that delimit the holdover times given in the tables.

4.4 To validate that flat plate test data used to establish the SAE Type IV holdover time tables is representative of Type IV performance on service aircraft. under conditions of natural freezing precipitation.

4.5 To evaluate hot air de-icing as an alternative to heated de-icing fluids for frost removal at low ambient temperatures.

4.6 To undertake special tests of Type IV fluids in comparison with a Type II fluid at high rates of precipitation.

5. DETAILED STATEMENT OF WORK

The work shall be broken down into the several distinct areas of activity consistent with the project objectives, together with activities for presentations and reporting at the completion of work. A detailed workplan, activity schedule, cash flow projection, project management control and documentation procedure shall be developed and delivered to the TDC project officer for approval within one week of effective start date.

5.1 Substantiation of Type I and Type II Tables

5.1A Laboratory "Cold soak" Test Program

Tests will be conducted at the Climatic Engineering Facility (CEF), of the National Research Council, Ottawa. APS will supply all necessary equipment and fluids for the conduct of the tests. Laboratory test should be performed after the field tests so that some temperatures can be chosen to match the field tests.

5.1.1 Develop an experimental plan to conduct tests, analyze results and prepare a report to provide values given for the SAE/ISO Holdover Time Tables for Type I. Type II and Type IV fluids using cold soaked boxes to simulate cold soaked wing conditions for a range of precipitation rates above and below freezing.

5.1.2 Include tests at +2°C and -7°C and at temperatures corresponding to selected field tests and cover a range of box temperatures from 0°C to -15°C and a range of precipitation rates, simulating rain, freezing drizzle and snow. These rates should be determined in consultation with personnel from AES and NRC. APS will use their own cold box designs.

5.1.3 Present the test plan to TDC Project Office for review Comment and approval.

5.1.4 Schedule tests with NRC and give advance notice of all intended tests to the TDC project officer.

5.1.5 Conduct tests in the NRC cold chamber using flat plates as benchmark

5.1.6 Analyze results from cold boxes and compare with the flat plate results

5.1B ***Field "Cold soak" Test Program***

Conduct full scale aircraft cold soak experiments with the cooperation of local airlines. Use thermistors to measure temperatures on cold soak box and aircraft wing.

5.1C **Low Temperature Test**

Test Type I and Type II fluids on flat plates to establish holdover times at the lowest temperatures encountered in the winter. These test will be similar to those in the program of Type IV testing and will run concurrently with the Type IV tests

5.2 Program of Type IV

This program will test new "long-life" Type IV fluids over the entire range of conditions covered by the HOT Tables and will include outside testing under conditions of natural precipitation, and laboratory testing in the NRC CEF for tests involving freezing fog, freezing drizzle and light freezing rain.

5.2.1 Develop a program to test samples of the new Type IV fluids to establish holdover times over the full range of HOT table conditions.

5.2.2 Obtain samples from producers of qualified Type IV fluids

5.2.3 Establish a test site for the conduct of outside tests at Montreal, Dorval Airport

5.2.4 Arrange for support services and appropriate facilities.

5.2.5 Recruit and train local personnel .

5.2.6 Repair and replace TDC supplied equipment used for testing in previous years as necessary.

5.2.7 In consultation with TDC, devise a method to evaluate the precipitation type in order to assess the effects of wet and dry snow on visibility in precipitation.

5.2.8 Install an ETI precipitation gauge at Dorval to study its correlation with the READAC gauge and the plate pans.

5.2.9 Acquire data from the READAC station at Dorval on a minute-by-minute basis.

5.2.10 Give advance notice of all intended tests to the TDC project officer.

5.2.11 Conduct tests during periods of freezing precipitation concurrent with HOT Table substantiation tests of conventional fluids. For Type I,II and IV fluids, frequent testing should be conducted under natural precipitation conditions when temperatures are below -14°C.

5.2.12 Coordinate scheduling of the indoor tests with the NRC.

5.2.13 Install Instrumar's C/FIMS on at least one plate, if available RVSI's and SPAR remote sensor will be set up to view the stand holding six standard test plates. All sensors will be used for both the chamber tests and all the field tests where feasible. Determine fluid failure by visual observation

5.2.14 Conduct tests with simulated freezing fog, freezing drizzle and light freezing rain in the NRC CEF facility, Ottawa, supplying the necessary materials and equipment for tests.

5.2.15 Conduct ancillary tests at Dorval and the NRC Chamber to study the effect of HOT's of successive application of new and conventional Type II fluids on clear and contaminated Type I's.

5.2.16 Collect visibility data during periods of freezing precipitation at Dorval and correlated with concurrent meteorological data, including precipitation rate, precipitation type, temperature, wind velocity and direction as appropriate.

5.2.17 Present program results and plans for completion for a "mid-term" review to be called by TDC.

5.2.18 Video tape the tests for archival purposes

5.2.19 Test results will be collected, analyzed and a report produced.

5.3 Weather

The significance of weather conditions in the holdover time tables needs to be defined the high time value represents "light"" conditions and the shortest time is the boundary for a "heavy" condition. Some evaluation of these terms shall be developed on the basis of existing and current data.

5.3.1 Review weather conditions for test data from all years and all sites for the cases where failure time lay outside the range in the tables for Type I and Type II fluids
5.3.2 Study extreme weather conditions during the 1995/96 winter tests at Dorval using a Type 1 fluid to evaluate "Light" conditions and a Type II to evaluate "heavy" conditions
5.3.3 Analyze the data with respect to the parameters of experimental site, weather conditions, fluid type and fluid manufacturer to establish relationships between weather parameters and holdover time values
5.3.4 Recommend caution statements to go into the holdover time tables
5.3.5 Recommend revisions to the fluid performance tests.

5.4 Performance of Ultra Fluids on Flat Plates Versus Aircraft Surfaces

This test program will be conducted at Dorval International Airport, using aircraft made available by an airline, and, subject to weather conditions, will include three (3) all night test sessions. In general, aircraft will be made available for testing outside regular service hours, i.e. available between 23:00 hrs. and 06:00 hrs. Tests will be conducted to verify that fluid failures on the flat plates used to develop HOT guidelines for the new fluid occurred before failure on the aircraft wings. Depending on the site selected for these tests, it is expected that Air Canada will be providing ancillary equipment and services as stipulated in their agreement with Transport Canada for the 1994/95 winter; this equipment will include lighting fixtures as necessary, observation platforms, vehicles, storage facilities, office facilities and personnel rest accommodation. Additional tests, if required, may be requested subject to agreement by all parties involved.

5.4.1 Develop an experimental program for concurrent comparison testing of fluids under conditions of natural freezing precipitation on flat plates and on aircraft.

5.4.2 ***Prepare the following test plan features, plans and procedures:***

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

b) A specific test plan, for review by all parties, which will include as a minimum:

- Schedule and sequence of activities;
- Detailed list of responsibilities;
- Complete equipment list;
- List of data, measurements and observations to be recorded; and
- Test procedures.

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

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

5.4.3 Present the experimental programs for review and approval by the TDC project officer.

5.4.4 Arrange (with the cooperation of TDC) for deicing equipment and aircraft representative of those in common use by airlines in Canada to be made available for the tests .

5.4.5 Present the approved program to the airline involved prior to the start of field tests.

5.4.6 Recruit and train local personnel who will conduct test work.

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

5.4.8 Arrange for the provision of fluids by UCAR for spraying an aircraft.

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

5.4.10 Schedule tests on the basis of forecast significant-duration night-time periods of freezing precipitation;

5.4.11 Provide advance notice to Air Canada of the desired test set-up, including aircraft orientation with respect to the forecast wind direction, sequence of fluid applications, and any additional services requested.

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

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

5.4.14 Orient the aircraft with leading edge into the wind on two occasions and trailing edge into the wind on the third occasion.

5.4.15 Conduct tests of Type II Ultra plus fluid on standard flat plates and aircraft, using Ultra on the plates as a benchmark fluid along with a standard Type II when available.

5.4.16 Record the progression of fluid failure on the wing over the series of tests conducted.

5.4.17 Videotape records of all tests will be made.

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

5.4.19 Assemble and analyze all results

5.5 Frost Removal

Frost alleviation and removal by "sweep and shine" and hot air shall be explored.

5.5.1 Sweep and Shine

Tests shall be conducted at very low temperatures to evaluate the efficacy of sweep and shine. Micromeasurements of frost shall be made prior to tests and following various amounts of sweeping. Numbers of crystals per area will be noted along with their height and shape to indicate roughness level

5.5.2 Hot Air

Successful application of hot air for frost removal is dependent on provision of a well designed air application tool; one that is user friendly and will provide speedy and effective results. provision will be made to evaluate prototype equipment in conjunction with an airline and a manufacturer.

5.6 Wing Surface Visibility Study

Examine various options to enhance visibility of failed wing surfaces from inside the cabin and flight deck and make recommendations.

5.7 Representative Surfaces Guidelines Study

5.7.1 Study the optimum locations for representative surfaces on specific test aircraft wings.

5.7.2 Develop generic guidelines for defining the optimum locations for representative surfaces on any aircraft and for installation of wing contamination sensors.

5.8 *Heavy Precipitation Type IV Tests*

Using the NRC CEF, test all qualified Type IV fluids at 100% concentration along with a standard Type II fluid as a benchmark at simulated high precipitation rates of 25gm/dm2/hr and at low temperatures close to -7C.

5.9 Presentations of test program results

5.9.1 Prepare and present preliminary findings of test programs involving field tests with aircraft to representatives of Transport Canada and the Airlines involved at end of the test season, but no later than April 30 1995.

5.9.2 Prepare and present, in conjunction with Transport Canada personnel, winter test program results at SAE G-12 Committee meetings in Chicago, and London, England.

5.10 Reporting

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

5.10.1 Substantiation of HoldOver Time Tables
A final report shall be prepared covering all winter testing sponsored by TDC and DCIP, including that from previous winters, conducted to substantiate the SAE HOT Tables.

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

APPENDIX B

APS TEST PROCEDURES
FOR DORVAL NATURAL PRECIPITATION
FLAT PLATE TESTING

BM2980.00

EXPERIMENTAL PROGRAM
FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING
1995 - 1996

APS Aviation Inc.

January 10, 1996
Version 2.3

EXPERIMENTAL PROGRAM
FOR DORVAL NATURAL PRECIPITATION FLAT PLATE TESTING
1995 - 1996

This document provides the detailed procedures and equipment required for the conduct of natural precipitation flat plate tests at Dorval for the 1995/96 winter season.

1. OBJECTIVE

To complete the substantiation of the existing SAE/ISO 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.
- All samples of Type IV 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 from previous winters in association with the SAE working group. This equipment is listed in Attachment II.

4. **PERSONNEL** (See Attachment II)

The following personnel are required for the conduct of tests. The responsibility for each tester is provided in Attachment III.

For one stand
1 x Test site Leader/video
1 x End condition tester
1 x Meteo tester

For two stands
1 x Test site leader
2 x End condition tester
1 x Video
1 x Meteo

5. **PROCEDURE**

The modified test procedure is included in Attachment II. This procedure was developed more than five years ago and was modified over the years to incorporate discussions at the SAE working group meetings. Attachment V contains a brief summary of the steps required to conduct a test.

6. **DATA FORM**

The data forms are included with Attachment II. One data form was developed for the end-condition tester (Table 1) and one data form for the Meteo/video tester (Table 1a).

TABLE 1
END CONDITION DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME — VERSION 3.0 — Winter 95/96

LOCATION: DATE: PLAN # (see Attachment I): RUN #: STAND #:
Real Time After Fluid Applied to Plates U and X: am / pm

RVSI Series # : ____________ Frame # : ____________

CIRCLE SENSOR PLATE: u v w x y z

SENSOR NAME: ____ ____ ____ ____ ____ ____

DIRECTION OF STAND: ______ °

OTHER COMMENTS (Fluid Batch, etc):

____

____

____

____

____

____

____

____

	PRINT	SIGN
FAILURES CALLED BY :		
HAND WRITTEN BY :		
TEST SITE LEADER :		

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

Time of Fluid Application: ——————→ ______ hr:min (V & Y) ______ hr:min (W & Z)

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

METEO/PLATE PAN DATA FORM

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME | VERSION 3.0 | Winter 95/96

LOCATION: **DATE:** **PLAN # (see Attachment I):** **RUN # :** **STAND # :**

RVSI VIDEO CASSETTE #: **Real Time After Fluid Applied to Plates U and X:** am / pm

VIDEO CAMERA (PANNING) CASSETTE #: **HAND HELD VIDEO CASSETTE #:**

PLATE PAN WEIGHT MEASUREMENTS *

PAN #	t TIME BEFORE (hr:min)	t TIME AFTER (hr:min)	w WEIGHT BEFORE (grams)	w WEIGHT AFTER (grams)	COMPUTE RATE ($\Delta w*4/\Delta t$) ($g/dm^2/h$)

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

METEO OBSERVATIONS **

TIME (hr:min)	TYPE (Fig. 4) ZR, ZL,S, SG IP, IC, BS, SP	AMOUNT + +, +, -, --	CLASSIF. (See Fig. 3)	Visibility (day only)	If SNOW, WET or DRY	TEMP °C	WIND SPEED	WIND DIR.

**observations at beginning, end, and every 15 min. intervals. Additional observations when there are significant changes.

COMMENTS : ____

	PRINT	SIGN
WRITTEN & PERFORMED BY :	____________	____________
VIDEO BY :	____________	____________
TEST SITE LEADER :	____________	____________

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Meteo & Pan

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)	Fluid Freeze Point (°C)	B-255* Propylene	B-251* Propylene	B-254* Propylene	B-253* Ethylene	B-256* Propylene	B-331* Propylene	B-330[1] Propylene + Ethylene
0 °C	-10 °C	28%	27%	31%	23%	30%	29%	30%
-2 °C	-12 °C	31%	29%	36%	26%	35%	33%	33%
-4 °C	-14 °C	35%	31%	39%	29%	39%	37%	38%
-6 °C	-16 °C	37%	34%	43%	31%	42%	40%	41%
-8 °C	-18 °C	40%	37%	45%	34%	45%	44%	43%
-10 °C	-20 °C	42%	40%	48%	36%	48%	47%	46%
-15 °C	-25 °C	47%	45%	54%	41%	54%	54%	52%
-20 °C	-30 °C	52%	50%	58%	46%	59%	61%	57%
-25 °C	-35 °C	56%	55%	63%	50%	63%	67%	62%
-30 °C	-40 °C	60%	59%	68%	54%	66%	72%	64%
-33 °C	-43 °C		61%**	71%**	57%**	68%**	75%**	66%**
-35 °C	-45 °C	63%**	63%			69%	77%	67%

* 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.

** Standard Type I mixtures

1 This fluid cannot be checked with the Refractometer

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ATTACHMENT I

NATURAL SNOW PRECIPITATION TEST PLAN

TYPE I (De-icing)

RU #	TEMP DEG °C	TESTS	ETHEL		PROPL		ETHEL/PROP		PROPL		PROPL		PROPL		PROPL	
GLYCOL BASE	FREEZING POINT (°C)		-43	*	-45	*	-43	*	-43	*	-45	*	-43	*	-43	*
			STD	DIL	STD	DIL	STD	DIL	STD	DIL	STD	DIL	STD	DIL	STD	DIL
			B-213	B-253	B-215	B-255	B-230	B-330	B-231	B-331	B-221	B-251	B-216	B-258	B-214	B-254
1	>0	6														
2	>0	6														
3	>0	6														
4	>0	6														
5	>0	6														
6	>0	6														
7	>0	6														
8	>0	6														
9	>0	6														
10	>0	6														
11	>0	6														
12	>0	6														
13	>0	6		2												
14	>0	6				2										
15	>0	6										2				
16	>0	6	2													
17	>0	6	2	2												
18	0 TO -3	6														
19	0 TO -3	6														
20	0 TO -3	6														
21	0 TO -3	6														
22	0 TO -3	6														
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30	0 TO -3	6		2												
31	0 TO -3	6				2										
32	0 TO -3	6										2				
33	0 TO -3	6	2													
34	0 TO -3	6	2	2												
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45	-3 TO -7	6														
46	-3 TO -7	6														
47	-3 TO -7	6		2												
48	-3 TO -7	6				2										
49	-3 TO -7	6										2				
50	-3 TO -7	6	2													
51	-3 TO -7	6	2	2												
52	-7 TO -1	6														
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60	-7 TO -1	6		2												
61	-7 TO -1	6				2										
62	-7 TO -1	6	2													
63	-7 TO -1	6	2	2												
64	-14 TO -2	6	2	2												
65	-14 TO -2	6	2			2										
66	-14 TO -2	6										2				
67	-14 TO -2	6														
68	-14 TO -2	6														
69	-14 TO -2	6														
70	-14 TO -2	6														
71	-14 TO -2	6														
72	<-25	6	2	2												
73	<-25	6	2			2										
74	<-25	6										2				
75	<-25	6														
76	<-25	6														
77	<-25	6														
78	<-25	6														
79	<-25	6														
TOTAL		474	24	20	0	12	0	0	0	0	0	10	0	0	0	0

TYPE II (Anti-icing)

RU #	TEMP DEG °C	TESTS	PROPL			PROPL			PROPL			PROPL		
GLYCOL BASE	FREEZING POINT (°C)		-45	-24	-12	-48	-30	-15	-36	-22	-10.5	-34	-20	-10
			100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50
			A-202	A-510	A-700	A-205	A-210	A-212	A-201	A-401	A-501	A-101	A-511	A-701
1	>0	6				2								
2	>0	6					2							
3	>0	6						2						
4	>0	6										2		
5	>0	6											2	
6	>0	6												2
7	>0	6				2								
8	>0	6					2							
9	>0	6						2						
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43	-3 TO -7	6						2						
44	-3 TO -7	6							2					
45	-3 TO -7	6								2				
46	-3 TO -7	6									2			
47	-3 TO -7	6												
48	-3 TO -7	6												
49	-3 TO -7	6												
50	-3 TO -7	6												
51	-3 TO -7	6												
52	-7 TO -1	6				2								
53	-7 TO -1	6					2							
54	-7 TO -1	6										2		
55	-7 TO -1	6											2	
56	-7 TO -1	6				2								
57	-7 TO -1	6					2							
58	-7 TO -1	6							2					
59	-7 TO -1	6								2				
60	-7 TO -1	6												
61	-7 TO -1	6												
62	-7 TO -1	6												
63	-7 TO -1	6												
64	-14 TO -2	6												
65	-14 TO -2	6												
66	-14 TO -2	6												
67	-14 TO -2	6				2								
68	-14 TO -2	6										2		
69	-14 TO -2	6				2								
70	-14 TO -2	6							2					
71	-14 TO -2	6				2			2			2		
72	<-25	6												
73	<-25	6												
74	<-25	6												
75	<-25	6				2								
76	<-25	6										2		
77	<-25	6				2								
78	<-25	6							2					
79	<-25	6				2			2			2		
TOTAL		474	0	0	0	28	16	12	16	8	8	16	8	8

TYPE IV (Anti-icing)

RU #	TEMP DEG °C	TESTS	ETHEL			ETHEL			PROPL			ETHEL			PROPL			PROPL			PROPL			PROPL		
GLYCOL BASE	FREEZING POINT (°C)		-49	-30	-15	-58	-38	-18	?	?	?	-47	-30	-17	-43	-25.5	-12	?	?	?	-38	-22	-10.5	-34	-20	-10
			100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50
			A-303	A-403	A-503	C-100	C-700	C-500	C-101	C-701	C-501	C-102	C-702	C502	C-103	C-703	C-503	C-104	C-704	C-504	C-105	C-705	C-505	C-108	C-706	C-506
1	>0	6	2																					2		
2	>0	6		2																					2	
3	>0	6			2																					2
4	>0	6	2			2																				
5	>0	6		2			2																			
6	>0	6			2																					
7	>0	6				2						2														
8	>0	6					2						2													
9	>0	6						2						2												
10	>0	6										2												2		
11	>0	6											2												2	
12	>0	6												2												2
13	>0	6						2																		2
14	>0	6						2						2												
15	>0	6												2												2
16	>0	6						2																		2
17	>0	6						2																		
18	0 TO -3	6	2																					2		
19	0 TO -3	6		2																					2	
20	0 TO -3	6			2																					2
21	0 TO -3	6	2			2																				
22	0 TO -3	6		2			2																			
23	0 TO -3	6			2			2																		
24	0 TO -3	6				2						2														
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26	0 TO -3	6						2						2												
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28	0 TO -3	6											2												2	
29	0 TO -3	6												2												2
30	0 TO -3	6						2																		2
31	0 TO -3	6						2						2												
32	0 TO -3	6												2												2
33	0 TO -3	6						2																		2
34	0 TO -3	6						2																		
35	-3 TO -7	6	2																					2		
36	-3 TO -7	6		2																					2	
37	-3 TO -7	6			2																					2
38	-3 TO -7	6	2			2																				
39	-3 TO -7	6		2			2																			
40	-3 TO -7	6			2			2																		
41	-3 TO -7	6				2						2														
42	-3 TO -7	6					2						2													
43	-3 TO -7	6						2						2												
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56	-7 TO -1	6				2						2														
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62	-7 TO -1	6						2																		2
63	-7 TO -1	6						2																		
64	-14 TO -2	6					2																			
65	-14 TO -2	6					2																			
66	-14 TO -2	6					2																		2	
67	-14 TO -2	6	2																					2		
68	-14 TO -2	6	2			2																				
69	-14 TO -2	6				2						2														
70	-14 TO -2	6										2												2		
71	-14 TO -2	6																								
72	<-25	6					2																			
73	<-25	6					2																			
74	<-25	6					2																		2	
75	<-25	6	2																					2		
76	<-25	6	2			2																				
77	<-25	6				2						2														
78	<-25	6										2												2		
79	<-25	6																								
TOTAL		474	24	16	12	24	28	44	0	0	0	24	16	12	0	0	0	0	0	0	0	0	0	24	20	34

ATTACHMENT II
FLAT PLATE FIELD TEST EQUIPMENT AND PROCEDURE
1995 - 1996 (Version 6.2)

This field test procedure has been developed by the Holdover Time Working Group of the SAE G-12 Committee on Aircraft Ground De/Anti-icing as part of an overall testing program that includes laboratory tests, field tests and full-scale aircraft tests, which is aimed at substantiating the holdover time table entries for freezing point depressant (FPD) fluids known as de/anti-icing fluids. This procedure will also be utilized for the development of new tables for the "next generation" fluids.

1. SCOPE

This procedure describes the equipment and generalized steps to follow in order to standardize the method to be used to establish the time period for which freezing point depressant (FPD) fluids provide protection to test panels during inclement weather such as freezing rain or snow.

2. EQUIPMENT

Environment Canada's READAC (Automated Weather Station) is located within 50 metres of the Dorval test stands. Data from this station will be required on a one minute basis. Temperature, total precipitation, visibility, wind speed and direction are among a few of the parameters measured.

2.1 Rain/Snow Gauge

The following equipment or equivalent are recommended:

2.1.1 Cake Pan or Plate Pan (see Figure 0)

A large low cakepan (6"x 6"x 2" minimum) may be used to collect and weigh snow. A plate pan (the same area as a flat plate and 4 cm deep) may be preferable since it lies like the flat plates at a 10° incline. A schematic of the plate pan is provided as Figure 0.

Note: When this method is used the bottom and sides of the pan MUST BE WETTED (before each pre-test weighing) with Type IV anti-icing fluid to prevent blowing snow from escaping the pan. The plate pans should be carefully rotated every 10 minutes to prevent accumulating snow from blowing away. The time of rotation should be reduced to 5 minutes during heavy precipitation or high wind conditions.

2.1.2 Tipping Bucket

2.1.2.1 ETI Snow Gauge

Electronic simulation of a Tipping bucket with a (0.01 inch) 0.25 mm accuracy. The instrument is not heated (anti freeze used to melt precipitation).

2.2 Temperature Gauge for Panels (optional)

T or K type thermocouple thermometer capable of measuring outside air and panel temperatures to an accuracy of 0.5 degrees C (1 degree F) over the range +10 to -30 C (+50 to -20 F). This gauge is optional and should be used to verify that the panel temperatures are cold-soaked to the OAT.

2.3 Test Stand

A typical test stand is illustrated in Figure 1; it may be altered to suit the location and facilities, but the angle for the panels, their arrangement and markings must all conform to Figures 1 and 2. There shall be no flanges or obstructions close to the edges of the panels that could interfere with the airflow over the panels.

2.4 Test Panels

2.4.1 Material and Dimensions

Alclad Aluminum 2024-T6 or 5052-H32 polished standard roll mill finish 30 x 50 x 0.32 cm, for a working area of 25 x 40 cm. Thicker aluminum stock may be needed when an instrument is mounted on the plate.

2.4.2 Markings

Each panel shall be marked as shown in Figure 2 with lines at 2.5 and 15 cm from the panel top edge, with fifteen cross-hair points and with vertical lines 2.5 cm from each side; this marks off a working area of 25 x 45 cm on each panel. All marks shall be made using a 1/8" thick black marker or silk screen process, which does not come off with application of the test fluids or any of the cleaning agents. Remarking of the plates will be required as the markings fade because of the cleaning actions.

2.4.3 Attachment

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

2.5 Fluid Application

The fluid should be poured onto the plates from a manageable container, until the entire test section surface is saturated. Up to two litres of fluid should be applied to each panel. This amount is dependant upon the amount of ice/snow on the panels prior to the start of the test. Strong wind conditions will require greater amounts of fluid. For indoor tests at the NRC, about 1 litre of fluid per panel is sufficient.

2.6 Film Thickness Gauge

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

2.7 Video recording

A panning video camera 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.

Tests must also be recorded with a hand-held video camera, in particular at the start of the test and when failures are being called.

2.8 Anemometer

Wind Minder Anemometer Model 2615 or equivalent. Available from Qualimetrics Inc. Princeton New Jersey. To be mounted at 3 metres.

2.9 Wind Vane

Model 2020 Qualimetrics or equivalent. To be mounted at 3 metres.

2.10 Relative Humidity Meter

Cole Parmer RH/Temperature Indicator P/N N-032321-00 with remote probe P/N N-03321030 temperature average or equivalent. Temperature limits -30 to 60°C RH range 20 to 100% accuracy ± 7% (20-30%); = -5% (30-100%); or equivalent. Available from Cole Parmer Instrument Company Chicago Illinois. The temperature gauge should be mounted at a height of 2 metres.

2.11 Ice Detection Sensors

Where feasible surface or remotely mounted ice detection sensors should be used during the tests.

2.12 Additional Equipment

- Squeegee
- Extension power cords
- Stopwatch
- Flood lights (2 x 500 watts)
- Pressurized space pens, pencils or "China Markers"
- Water repellent paper
- PC to record meteorological data

2.13 Integration of Equipment

Attachment IV provides a description of the equipment and how it is integrated.

3. DE/ANTI-ICING FLUIDS

3.1 Test Fluids

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

3.2 Certification

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

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

3.3 Dye

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

3.4 Dilution of Type I Fluids

Diluted Type I fluids must be mixed by the testers 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, Hoechst and Arco products are Propylene Glycol based.

Some tests are also planned with Standard Type I fluids and the concentrations of these are shown in Table 2. The dilution of these fluids is based upon the standard mixes used by many North American operators.

4. PROCEDURE

Attachment V contains a summary of the major steps required for the conduct of flat plate tests. This should be mounted on the wall in the trailer at the site.

4.1 Start-up and Close-up

Attachment IV provides a reference to enable tester to open the equipment at the start of a test session. This attachment also provides reference on what should be closed at the end of a session.

4.2 Set-up

4.2.1 Panel Test Stand

If there is any wind, orient the test fixture so that the test panels are facing into the wind direction at the beginning of the test and the wind is blowing up the panels,

i.e. ----> /
wind panel

If the wind shifts during the test do not move the fixture; simply note it on the data sheet.

4.2.2 Precipitation Gauge

Place the Precipitation Gauge as close as possible to the test fixture. Ensure that the interior level is used to indicate that the gauge is level. Ensure that the gauge is not shadowed by an object which would interfere with the collection of precipitation. If there is drifting snow it may be necessary to raise the snow gauge above the drift level but no higher than the test panel. The snow gauge measurements should be started as early as feasible and continue throughout the duration of all tests to provide a continuous record of precipitation.

4.2.3 Manual Cake Pan or Plate Pan Method

Add ¼ inch anti-icing fluid (Type IV) to the bottom of the pan as well as wetting the inner sides of the pan. Weigh the wetted pan prior to testing to the nearest gram. Weigh the pan at 15 minute intervals over the course of the test (see Table 1.a). Replace the pans on the test stand as long as the duration of the last test panel. Do not remove the contents of the pan until the test is complete. Weigh again after test completion of each panel to determine the true water content reading of the precipitation.

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

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

4.3 Test Panel Preparation

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

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

4.3.3 Allow the panels to cool to outside air temperature.

4.4 Fluid Preparation and Application

4.4.1 Fluid Temperature

Except for Type I fluids, all fluids should be placed outside (cold-soaked to ambient temperature conditions) at the start of the evening session.

4.4.2 Cleaning Panels

Before applying test fluid to a panel, squeegee the surface to remove any precipitation or moisture. Fluid being used for the test could be used to help remove snow or ice from the test panel.

4.4.3 Order of Application

Apply the fluid to the panels, commencing at the upper edge of the test panel and working downwards to the lower edge. Ensure complete coverage by applying the fluid in a flooding manner. Start with the top left panel U, then cover panel X in the second row with the same fluid, then flood the second test fluid on panel V followed by panel Y, etc. (see Figure 0).

4.4.4 Testing New Fluids

When testing the new Type IV fluids, two panels with standard Type II fluids should be tested at the same time on the same stand. When the end condition occurs on the standard Type II fluids, a new test with the same Type II fluids should be started immediately. A new form should be used for this and the test # and Run # should be the same, but with an "a" (eg. Test # 7a, Run # 23a). At the start of this new test, the plate pans should be weighed again. The test should be continued until these new panels have reached the end condition.

Similarly, when testing Type IV 50/50 fluids with Type I fluids, new tests should be started with Type I fluids if these fail much before the Type IV 50/50.

4.5 Holdover Time Testing

4.5.1 Set the **timer on** (for video) as the first fluid application (plate U and X) is completed. This designates the start of the test (time = zero). Note the time when fluid application is completed on the remaining panels.

4.5.2 Commence recording the test with a video recorder until the test reaches the END CONDITION. See Section 5 for definition of end condition.

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

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

4.6 Video Recording

The panning camera should be positioned and functional for every test. It must capture the 1", 3" and 6" line of the top plates (u, v, w). A suggested position is to center the camera motor laterally and position it 8' from the back of the stand at the same height as the top plates.

Video record each test with a hand-held camera in the following sequences:

1) General outdoor condition prior to test (get good view of snow falling).

2) Video record the data forms.

3) Video record pouring. Ensure that name of fluids are captured, testers faces, your voice, name and stand # (ensure date and time are available and synchronized).

4) Record pans being weighed and brought out.

5) Record timer/clock (at beginning of run and during the run).

6) Record establishing shot of test stand (all the plates).

7) Record establishing shot of each plate, followed by a close-up of the plate (scan the plate slowly), then returning to wide shot of the plate. Repeat this with each plate in sequence, beginning from left to right, top to bottom. Always follow the same sequence. Ensure that each plate has a tag marked with the type of fluid used on the plate and that the plate itself is marked with its corresponding letter (X, Y, Z...). Record the clock/timer often.

8) For each failure, record an overview of the plates, followed by a wide shot of the plate, zooming in into a close-up of the failure. Return to the establishing shot at the end of the procedure. Repeat this procedure for each failure.

9) Ensure that the lighting is appropriate for video purposes.

10) Ensure that the video camera is in fact recording. At the end of a test, rewind a few seconds and check that the test was recorded.

4.7 Plate Pan Measurements

Measure the quantity (rate) of precipitation using at least two plate pans mounted on the test stand. Record these measurements on the Form (Table 1.a) at the following times:

- at the start of the test;
- every 15 minutes;
- when there is a significant change in the rate (intensity) for more than one minute;
- after failure of each panel (measure only once if two panels fail at almost the same time); and
- at the end of the test.

4.8 Meteorological Observations

Meteorological observations must be recorded at the same times as in 4.7, and when there are changes in the type and category of precipitation. Significant changes in wind speed and direction should also be noted.

4.8.1 Type of Precipitation

Note the type of precipitation (refer to Figure 4 for the codes). This is a subjective determination. If two or three forms of precipitation co-exist, then note all of these.

4.8.2 Amount of Precipitation

This is a subjective determination by the tester. Normally, this is determined by a trained meteo observer using visibility as a guideline. The symbols are as follows: ++ is heavy; + is moderate; - is light; -- is very light.

4.8.3 Classification of Precipitation

While many different classifications are available, a simple classification of ten forms of solid precipitation is shown in Figure 3. Use of black velvet to collect the snow and inspect it, will facilitate the identification.

4.8.4 Determination of Wet or Dry Snow

While this is usually temperature and humidity level dependant, determination of wet or dry snow could be determined by collecting snow in a dry plate pan on a stand not being used. If in the course of a test, the snow in the pan can be combined and formed into a "snow-ball", then this will be identified as wet snow. If the snow does not form into a "snow-ball" or if the snow does not even accumulate, then this is considered dry snow. Note that the time to form a "snow-ball", when collecting with gloves, should be less then 5 seconds. One other method to determine whether the snow is wet or dry would be to measure the depth of the snow in the pan and compare it to the liquid equivalent depth. If the ratio is > 10, then it would be wet snow.

4.8.5 Temperature and Wind Measurements

These can be read and recorded from the computer monitor at the site.

4.8.6 Visibility

Manual visibility measurements should be taken during daylight conditions. The markers to designate distance are those used by Environment Canada when these observations were being made manually.

4.9 Video Organization

The video equipment cassettes should be marked sequentially for the panning camera and the Hi 8 cameras. These #'s should be recorded on the data form at the time of testing. When these are full, then they should be marked as full.

5. END CONDITION

The plate failure time is that time required for the end conditions to be achieved. This occurs when the accumulating precipitation fails to be absorbed at any five of the crosshair marks on the panels.

A crosshair is considered failed if:

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

OR

- When precipitation or frosting produces a "loss of gloss" (i.e. a dulling of the surface reflectivity) or a change in colour (dye) to grey or greyish appearance at any five crosshairs, or ice (or crusty snow) has formed on the crosshair (look for ice crystals). This condition is only applicable during freezing rain/drizzle, ice pellets, freezing fog or during a mixture of snow and freezing rain/drizzle and ice pellets.

As these determinations are subjective in nature, the following is **very important**:

- Whenever possible, have the same individual make the determination that a crosshair has failed.
- When making such a determination, ensure consistency in the criteria used to call the end of a test.
- Under light snow conditions or when the precipitation rate decreases, snow may sometimes build up on the fluid and then be absorbed later as the fluid accommodates (absorbs) it. If this occurs, record the first time snow builds up and note (in the comments sections) that there was an "un-failure" at a specific crosshair.

Under conditions of moderate to heavy snow or hail, coverage may be very uneven; over about one-third of the panel should be recorded.

6. END OF TEST

Run test at least 10% longer than the time to reach the end condition on the last panel. This will allow the sensor traces to be longer for analysis. Once the test has ended, restart the testing procedure and continue as long as the weather conditions warrant.

7. REPORTING & OBSERVATIONS

Calculate and record test data, observations and comments in the format of Tables 1 and 1a. Each test must be conducted in duplicate. Detailed definitions and descriptions of meteorological phenomena are available in the Manual of Surface Weather Observation (MANOBS) - a copy is available at APS offices.

ATTACHMENT III
PERSONNEL RESPONSIBILITY

Test Site Leader

- Call personnel to conduct tests.
- Ensure test site is safe, functional and operational at all times.
- Supervise site personnel during the conduct of tests.
- Ensure site is opened and closed properly.
- Monitor weather forecasts on a daily basis.
- Report to project manager on site activities on daily basis.
- Review data forms upon completion of test for completeness and correctness (sign).
- Decide what fluids should be tested.
- Ensure results are reasonable.
- Ensure all clocks are synchronized at all times.
- Monitor weather forecasts during test period.
- Ensure fluids are available and verify fluids being used for test are correct.
- Get samples of all fluids.
- Ensure computers are all operational.
- Ensure electronic data is being collected for all tests.
- Ensure proper documentation of tapes, diskettes, cassettes.
- Verify test procedure is correct (eg. stand into wind).
- Ensure all materials are available (pens, paper, batteries, etc.)
- Ensure all equipment is on (tilt and pan video etc.).
- Fill in end of testing checklist for every session (see Attachment VI).

End Condition Tester

- Monitor the progression of failures on the plates.
- Record end condition times for each crosshair.
- Communicate to video operator the end condition times.
- Apply fluids onto test panels.
- Complete and sign Data Form (Table 1).
- Prepare fluids for each test.
- Prepare name tags for each test.

Meteo Tester

- Record meteo for both stands
- Rotate and measure plate pan weights.
- Squeegee plates prior the fluid application.
- Complete and sign Data Form (Table 1a).
- Assist end condition tester when failure times occur quickly.
- Place stop-watch and start stop-watch on test stand.

Video Tester

- Sign and fill in cassette #'s, etc. in data form (Table 1a)
- Video all tests (see procedure)
- Verify all equipment is on (tilt and pan video etc.).
- Document and mark all cassettes used for all electronic equipment.
- Ensure camera batteries are recharged and available.
- Ensure lighting is appropriate.

ATTACHMENT IV

SYSTEM MANAGEMENT AND PROCEDURES

Table of Contents:

Objective..
References..
Introduction..
Overall Hardware Diagram..
MET Computer...
Table of Commands..
MET Computer procedures..
RVSI..
Table of Menu Options...
RVSI example screen...
RVSI procedures..
Accessing the File Manager in the RVSI..
CFIMS...
CFIMS procedures...
Example of 7 screens...
Video Camera...
Getting Started..
End of Test..
End of Night..

System management and procedures

OBJECTIVE:

The object of this report is to provide written procedures to follow for each test session at the APS trailer site. These procedures are intended for normal operations during testing but will offer guidelines in the case of abnormalities such as computer breakdown.

An introductory section will describe the general aspects of the computer systems as well as the peripheral components involved in their functioning and test operations.

Procedures will be placed in a black binder that will determine procedures for anti icing and computer operations.

Introduction

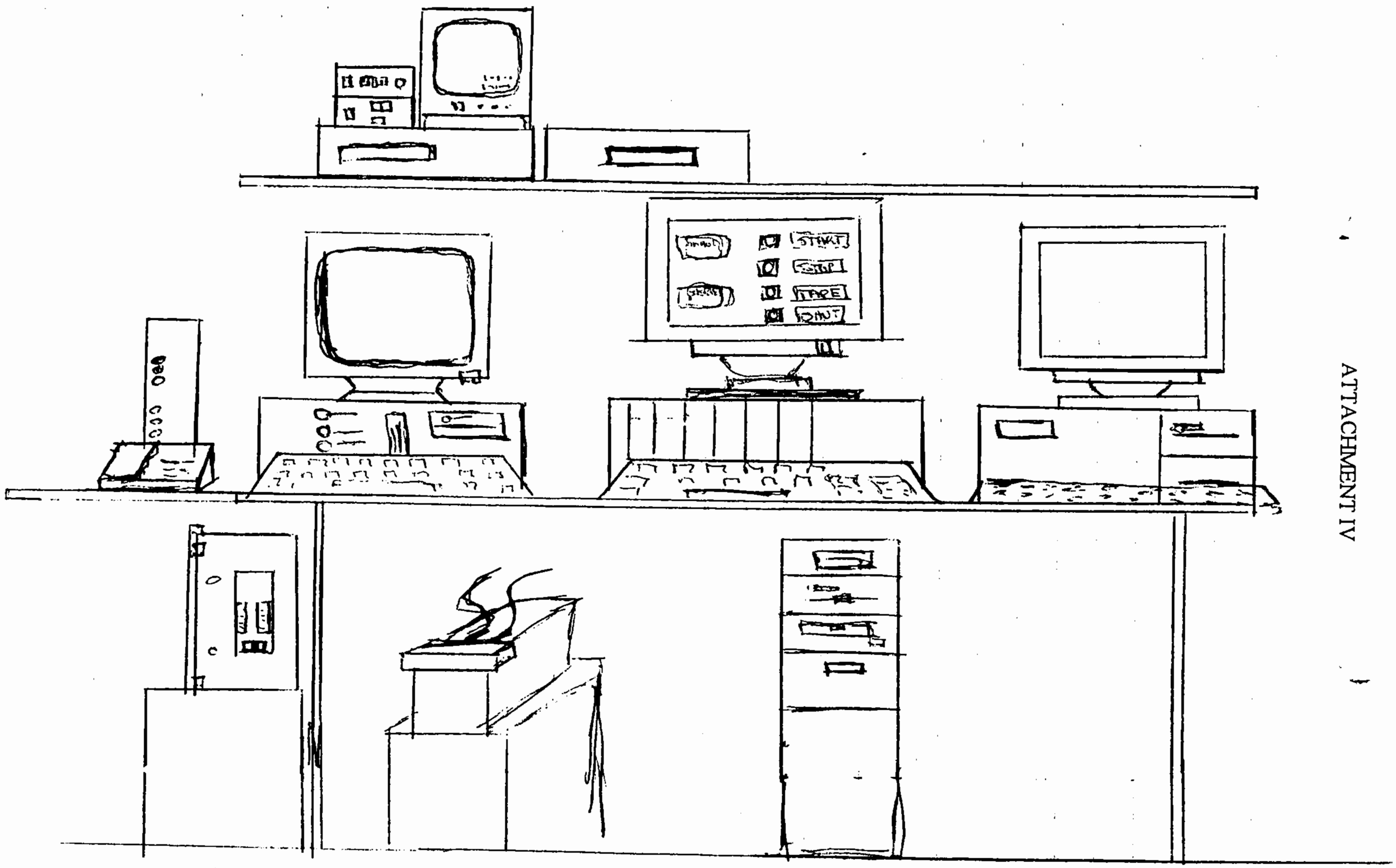
There are three computer systems running at the same time to ensure proper data collection at the APS site. The primary functions of these computers are to provide meteorological data as well as sensor data. The three computer systems are called:

1. MET computer;
2. RVSI;
3. CFIMS (or CWDS).

Along with these systems are the video recording equipment, as well as various power unit boxes that assure a proper power supply .

(Feb 4 '95)

APS TRAILER SITE SYSTEM SETUP FOR SYSTEMS MANAGEMENT REPORT.



- DC Power Source.

ATTACHMENT IV

MET COMPUTER

MET is the chosen abbreviation for meteorological computer. The computer may also be referred to as the WX station, for weather station. This computer is hooked up to a series of reading instruments located on the outside that provide necessary information such as ambient temperature, wind speed, etc.. The information is obtained through a program called GET-DATA. It is vital to set proper time and date on this computer before the start of any experiment.

The computer is equipped with a 5¼ floppy drive and is running in the DOS 5.0 environment. Usually the computer is running on a 24 hr. basis.

Table of commands for the **MET** Computer:

COMMANDS	DESCRIPTION
Alt-X or Ctrl-Esc	to exit the program GET-DATA and go into DOS. You may go back to the program by typing GET-DATA. When turning on the computer, a window will pop up asking if the user wishes to append the unsaved data or overwrite onto the file.
F5	to start a new test file. A test file is started at the beginning of the session when testing starts.
F6	to close a test file. A test file is closed when all testing is completed for the night.
Alt-F10	to escape to DOS temporarily (10 to 15 min.) also called shelling to DOS.
Alt-H	for HELP
DIAGNOSTIC / MAINTENANCE FUNCTIONS ** Warning. Data collection will be interrupted with these.	
Ctrl-F2	Debug / Diagnostic Mode ON/OFF
F4	DOS / Module Time Toggle
Alt-F4	Read in new DEFAULTS/ PARAMETERS
F8	Sync. time
Ctrl-F8	Sync. time now

The accumulated data is going to be stored in files (located in directory **c:\1100\DATA)** that are labeled under three categories:

i) **S** for scan 24 hr. data (backup), extension .CVS (Direct read excel)
ii) **L** for log, running log that keeps track of events on computer, extension .LOG
iii) **T** for test file, actual experiment.

These files are saved according to their category followed by the date sequence **YYMMDD**. Note that all files are denoted by date in this form as presented in the following example:

ex: S941201.CVS
L940302.LOG

Once the files are saved, they are compressed through a ZIP program.

MET COMPUTER PROCEDURES

1) Turn on the screen (bottom right hand side, on the side), the terminal itself is usually running 24 hrs.
2) Call **FSS**: 633-3345, to get a time check to set the computer:
note:
UTC time = Zulu time, i.e. you must subtract 5 hrs. to get E.S.T.
for example: 18:15 Zulu time → 13:15 E.S.T.
or request EST time (i.e. Local time check)

3) Enter the new time in the computer:
- **Alt-F10** to DOS
- set the time
- type in **exit** then press **enter**
- press **F7** and confirm **yes** to reset the data module

4) Open the test file: press **F5**
-you'll see that in the running log the test file is open
(remember to close the test file at the end of the night : press **F6**).

RVSI

This system is named after the developers, *Robotics Vision Systems Inc.*. This system is hooked up to the testing stand, and includes a photo-scanner that relays information back to the computer to display on screen the state of the aluminum plates. The software runs in the OS/2 environment. The computer runs in conjunction with a gray power supply box located under the desk.

This gray power unit also supplies power to heat the RVSI or the scaffolding at the test stand.

While the RVSI is running, a main menu is displayed on screen featuring options to proceed with the tests. The menu options are presented in the following table.

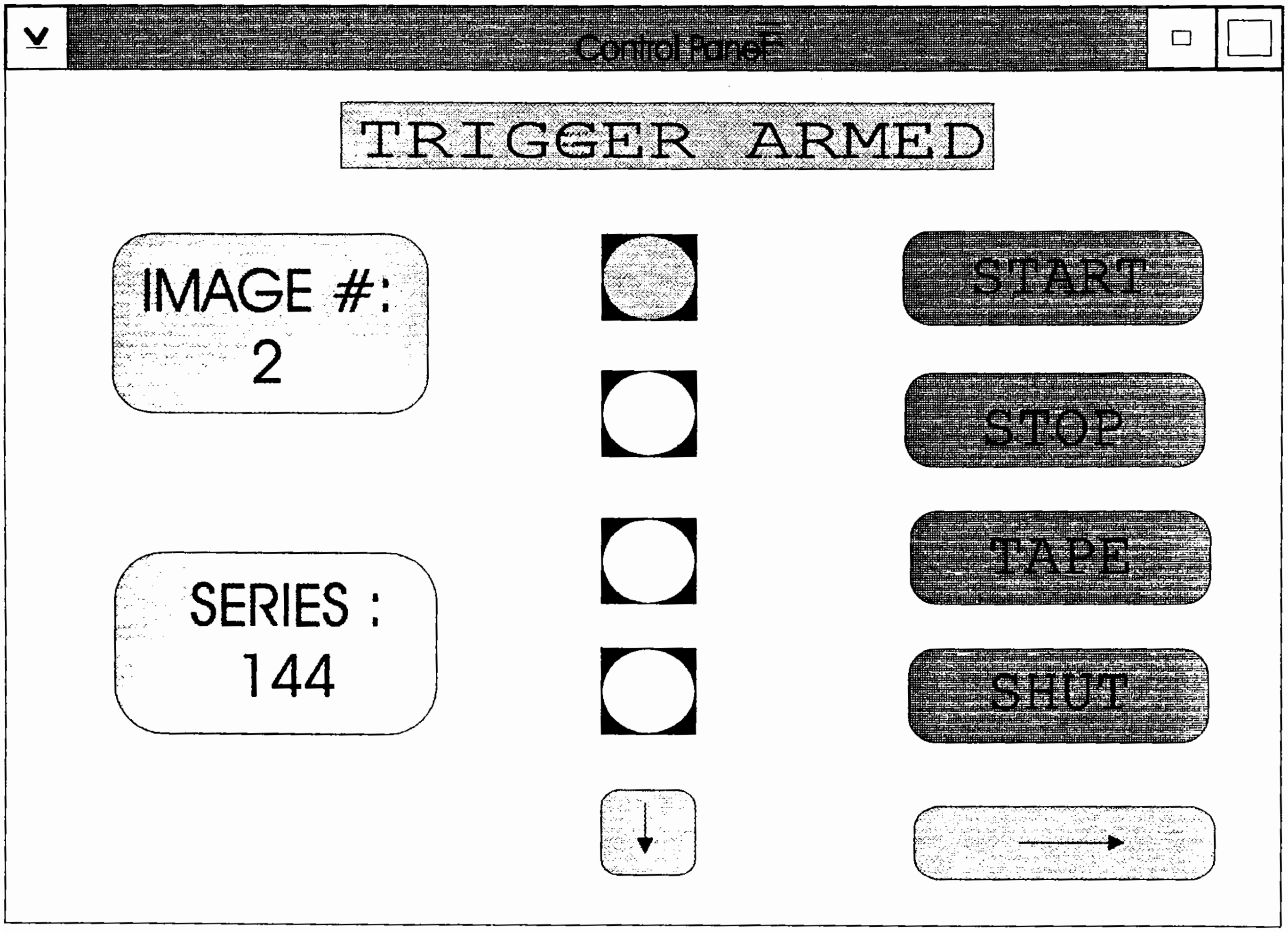
Table of menu options for the RVSI:

MENU	DESCRIPTION
RUN	commence scanning and reads data
STOP	displays " Compressing the image sequence. Please wait..." - after a scanning sequence was run, you have to go to STOP to compress the data. Once that has occurred, the program takes you back to the main menu and stores the data on the hard drive.
TAPE	to transfer the data to a tape backup, this option temporarily takes you into a yellow screen.
SHUT	goes through the proper shut down sequence to exit the program. When you shut down the application, the computer displays some difficulty in terminating the shut down sequence where after a certain delay, when not registering any hard drive activity, it is safe to turn off the computer.

Operating keys to select an item on the MENU are as follows:

- ↓ down arrow to scroll through the menu;
- → right arrow to select an option;
- ← the left arrow will give you an instantaneous scanning and also exits back to the menu (in control panel) if you are in scan mode already.

RVSI SCREEN


Control Panel
TRIGGER ARMED
IMAGE #:
2
SERIES :
144
START
STOP
TAPE
SHUT

RVSI PROCEDURES

1) Turn on the RVSI monitor (bottom right on the face) & CPU (slim gray button on tower).
2) Turn on the gray power supply box in order to have the "result" screen (do not touch the heater power switch, the heater remains on at all times).
3) Set the time on the RVSI
   - click the upper left hand corner with the mouse and go into "window list"
   - select DATETIME.CMD icon to change the date and time, once the date and time have been entered the screen disappears and takes you back to the main menu.
   - If it doesn't exist then select the STARTUP menu, then select DATETIME.CMD icon.
   - Exit the DATETIME.CMD application by selecting the corner of the STATRTUP menu and then selecting close.
4) When the "control panel" menu appears (and the test is ready to start), select RUN this will take you into a "result" screen.
5) At the end of the experiment, press left arrow to exit the "result" screen
6) Then select STOP, in order to save the data (after each test run go to STOP to compress the images).
7) At the end of the night select SHUT
   - if a screen prompts you that there is another application, select YES to shut it down.
8) Shut the gray power supply box as well to save on energy.

Accessing the FILE MANAGER in the RVSI computer:

To view the directories and files in a global manner and perhaps copy them to diskette, it is easier to work through the File Manager in OS/2 Windows. To access the File Manager through complex maze of windows, you might use the following procedure:

1) Starting from the RVSI menu screen, go to the upper right hand corner and click on the small box (the box on the left).
(there may be a delayed response, avoid the temptation of repeatedly clicking)
2) The DATETIME.CMD screen appears, click on the small box of that screen.
3) The Monitor Window appears (with a list of commands), press on the small box of that screen.
4) Then you'll find yourself in a light blue screen: double click on the OS/2 System icon which is on the bottom left hand corner.
5) That will take you to a black screen called OS/2 System-Icon View: double click on the folder located on the bottom left (first in the second row).
6) That takes you to a white screen called Windows Programs-Icon View, double click on the Program Manager icon
7) When the Program Manager screen pops up, select the File Manager (double click or press enter).
8) View the files, copy etc.
9) When finished, go to the top left box of the Program Manager Screen & select close
10) press OK to end WIN-OS/2 session
11) go to top left corner of Windows Programs-Icon View screen and click on the gray file on the top left corner, and select close
12) Go to top left corner of OS/2 System-Icon View screen and click on gray circle, and select close.
13) Go to the top left corner and double click on the start up file
14) Start up screen appears with DATETIME.CMD and Ice Detection icons
15) Double click on the Ice Detection icon and you'll be back to the RVSI screen.

CFIMS

The CFIMS is hooked up to a data logger called the LRU which in turn is connected to the ice sensors. This computer runs on a software called FLUIDSTY that analyses the temperature on the ice sensors.

The FLUIDSTY program is located in the **c:\fluidsty** directory. Usually when the computer is powered on, the program is run automatically. Should the user have exited the program, he needs to type in **fluisty** and press **enter** in order to have it run again.

When running the FLUISTY program, the user will encounter five typical screens, not including error messages. These screens guide the user to select or enter the data pertinent to the test such as: the number of sensors used, the snow type, the fluid name, the mounting as well as comments.

Before each test conducted on the test stand #1, it is important to repower the LRU (turn it off then back on). Otherwise an error message will be pop up. (the LRU is the gray box with the switch on the right hand side next to the power cord). On the LRU test panel (the gray box), the Fault light that is not lit, or off, indicates that the sensor is connected correctly. A fault light that is lit, or on, indicates that a sensor is either not connected or not connected correctly.

CFIM PROCEDURE

1) Power on the screen, the computer and the LRU
2) "doskey installed" will pop up, press any key to continue.
3) It will automatically prompt you to set the time and date, use the FSS time.
4) Press **Esc** to accept and continue.
5) On the bottom of the screen it indicates to "Repower LRU", it means to reset the LRU test panel (turn it off then on)
6) When the LRU is reset, you are ready to start sampling.
7) Select "S" to start sampling.
8) Enter the necessary information in each field.
9) Press Esc to accept the configured data.
10) A data collecting screen will appear during the length of the test.
11) At the end of the test, press Ctrl-Q to stop sampling.
12) Enter the test comments to conclude the experiment.
13) Press Esc to accept, and we go back to the first screen.
14) At the end of the night select Q to quit, then it will save all the data.

Fluid Study Software

Enter Test Configuration :

Number of CWDS Sensors [1 or 2]: 2

Use TAB or ENTER to skip between fields. Press ESC to accept.

- First screen that pops up after the time & date were entered.
- Press ESC to accept.

Fluid Study Software

Select a Command

S - Start Sampling

C - Change Setup

Q - Quit

Repower LRU test panel before sampling data

* Repower LRU
* ~~[illegible]~~ press enter to Start Sampling.

· Be sure to start video tape recording also.

Fluid Study Software

Enter Test Description

Initial Precipitation Type: ①

Sensor 1

Fluid Name: ②

Mounting: ③

Sensor 2

Fluid Name: ④

Mounting: ⑤

Comment: ⑥

Use TAB or Enter to skip between fields. Press ESC to accept.

① type of snow or precipitation ex: F1 - F2.
The reference to the categories of snow are listed on the appendix C chart pasted on the wall next to the door.

②,④ manufacturer / commercial name (fluid name) / type of fluid
ex: UCAR / ULTRA / type 2
or UCAR / XL54 / 23% / Type 1

③,⑤ select 10° incline

⑥ comments like FSS weather data, other.

Fluid Study Software 02/08/95 23:02:18

CWDS Sensor 1	CWDS Sensor 2
206	193
29	12
191	167
-12	-19
107	89
-5	-10
-12.524C	-12.622C

Sampling data. Press Ctrl+Q to stop sampling.

Fluid Study Software
Enter End-of-Test Comment Comment:
Enter comment. Press ESC to accept.

- ESC to accept - remember* to repower LRU
  * turn off VCR - stop recording.

Fluid Study Software

The last instance of this application was terminated for the following reason: RS422/4-- waiting for data ready, timeout period exceeded. The last test data set contains sensor data. Do you wish to have the last test data set deleted?

NO

YES

Repower LRU test panel before sampling data

* select no to save data & proceed to screen one

Fluid Study Software
The following error was encountered: RS422/4 -- waiting for data ready, timeout period exceeded. Repower LRU test panel & try again. Terminating the application. Press any key to exit.
Repower LRU test panel before sampling data

* when going ahead without repowering.

VIDEO CAMERA

The video monitor is observing the test stand #1. It is hooked up with a time lapse VCR. The VCR must be turned on in order to receive a picture. There are also two black scan control boxes next to the monitor that permit panning and zooming with the camera. During a test, the scan control will be on the automatic mode in order to pan continuously on the three panels. Behind the RVSI power source is a small DC power source that must be on to power the VCR. The scan control must be set up to focus on the top three plates, on the top third of the plates, i.e. from the top to the 6" line. Then, in order to record the test, it is important to press **play-record** (ensure there is a tape inside) at the beginning of each test and **stop** at the end of each test.

GETTING STARTED:

1A) Call FSS, get TIME & WEATHER check
- synchronize all computers and watches
- type in the FSS weather data in the CFIM comment box

1) Met Computer ON
- F5 to start new test
- Alt-F10, set time, exit
- F7 to reset data module

2) RVSI computer ON
- set the time
- make sure the screen is right
- note down the image # and the series #

3) CFIM computer ON
- set the time

4) Press left arrow to start sampling RVSI
Press "S" to start sampling CFIM , enter data and Esc to accept
VCR ON, press Play-Record

5) START TEST

END OF TEST:

1) Down Arrow to STOP, Right Arrow to select STOP on RVSI
2) STOP VCR
3) Ctrl-Q to end CFIM data collection, Repower LRU

END OF NIGHT:

1) F6 on MET
2) SHUT on RVSI
3) Quit on CFIM
4) Turn off all monitors, CFIM and RVSI computers, VCR and gray power supply box

ATTACHMENT V
SUMMARY OF STEPS TO CONDUCT TESTS

The following are the major steps required to conduct flat plate tests at Dorval.

Upon Entering Trailer

1) Turn on lights (outside and inside) and sign-in
2) Determine tests to be conducted and fluids (Type II, IV to be placed outdoors).
3) Remove snow and clear access to stands.
4) Turn on RVSI computer, C/FIMS computers, and video camera equipment.
5) Synchronize all clocks on all equipment in 4) and stop watches.

For Each Test

1) Fill in general material on Table 1 and 1.a, and prepare plate pans for start of test.
2) Place fluids and tags by stand.
3) Ensure stand is into wind.
4) Start logging of following computers: C/FIMS and RVSI, and apply fluids on panels.
5) Start timer on stand (t = 0) after application on plates U and X.
6) Record end condition times of all panels **(care to be taken for the 5th crosshair of each panel)**.
7) Measure plate pan weights over the course of the test.
8) Video record start of test, progression of failures, and when the end condition (5 of 15 crosshairs) is being called on each panel.
9) Ensure forms are properly completed and signed.
10) Save C/FIMS and RVSI data.
11) Start a new test.

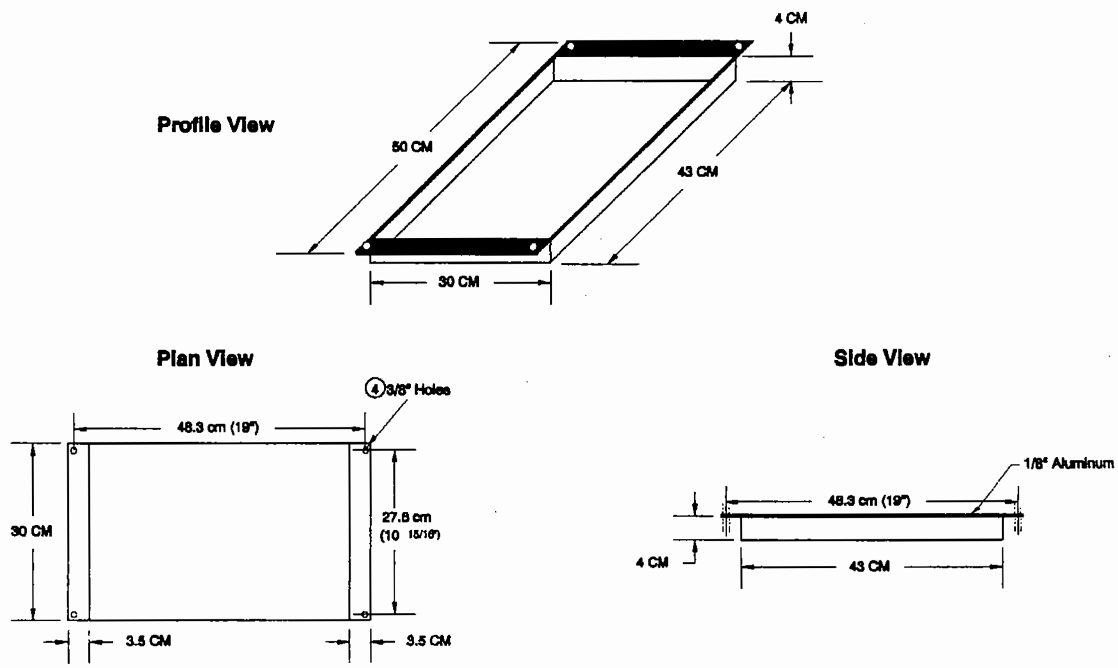
To Close Trailer

1) Replenish fluids.
2) Log and document date, times, test #'s, etc. on all media
3) After major events (more than 10 tests), start new tapes for next occasion.
4) Place all media and test forms in large envelope for delivery to office.
5) Shut off the following equipment RVSI; video camera; and C/FIMS; bring in timers.
6) Clean trailer and all garbage.
7) Ensure outdoor is left clean and presentable.
8) Close lights and sign-out.

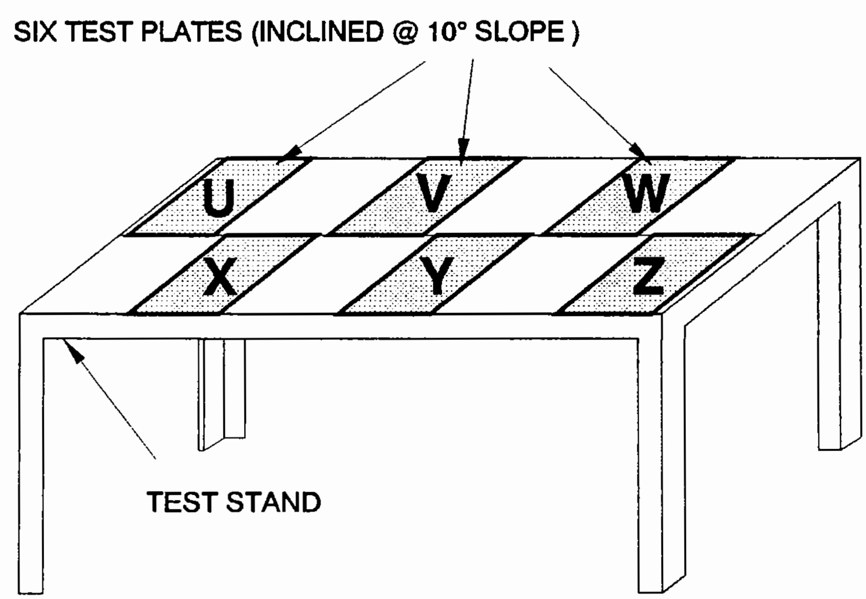
FIGURE 0

SCHEMATICS OF PLATE PAN AND TEST STAND

PLATE PAN



TEST STAND



bm2980\procedur\nat_snow\pan&stnd.drw

FIGURE 1
TEST STAND

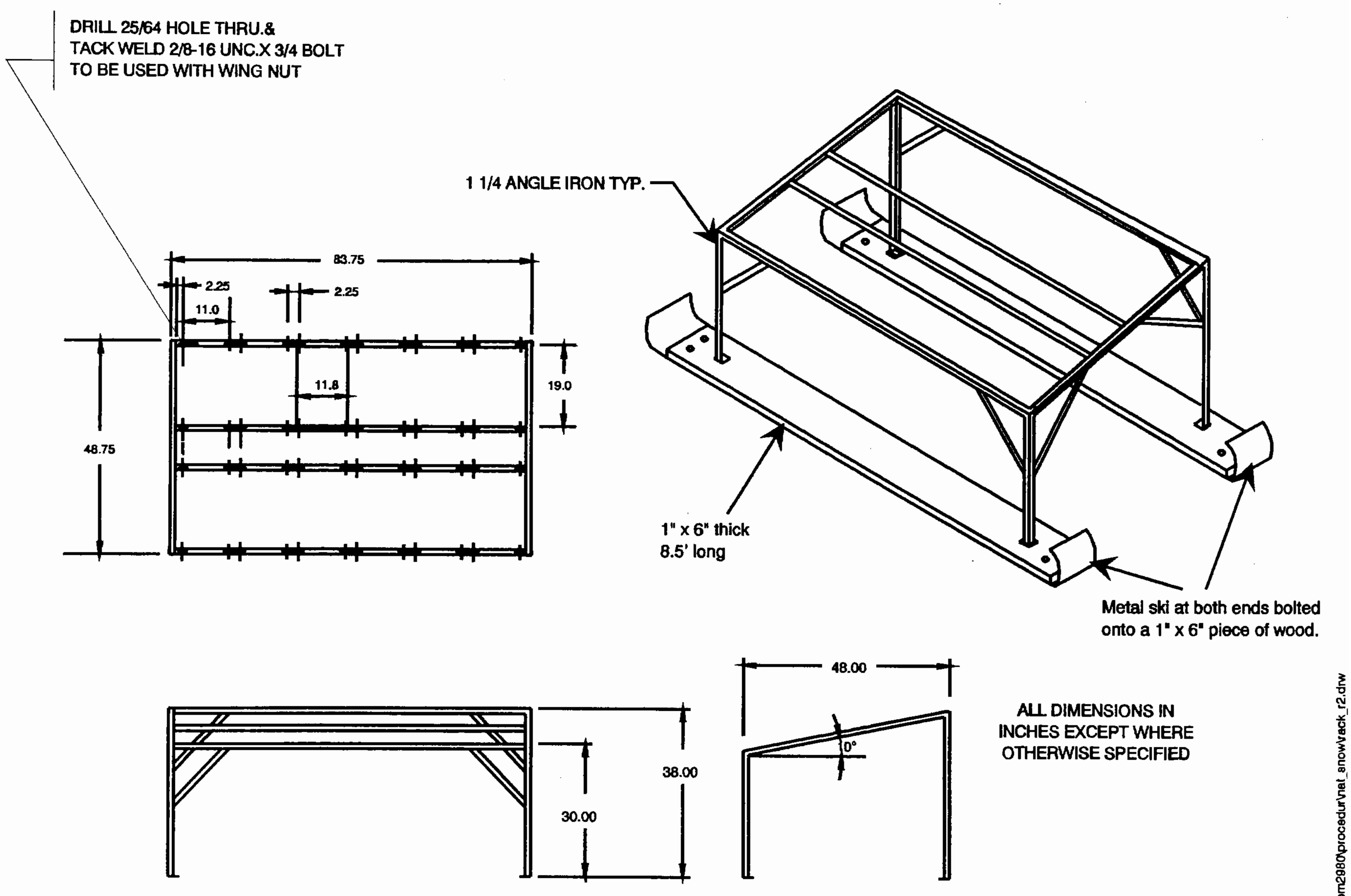
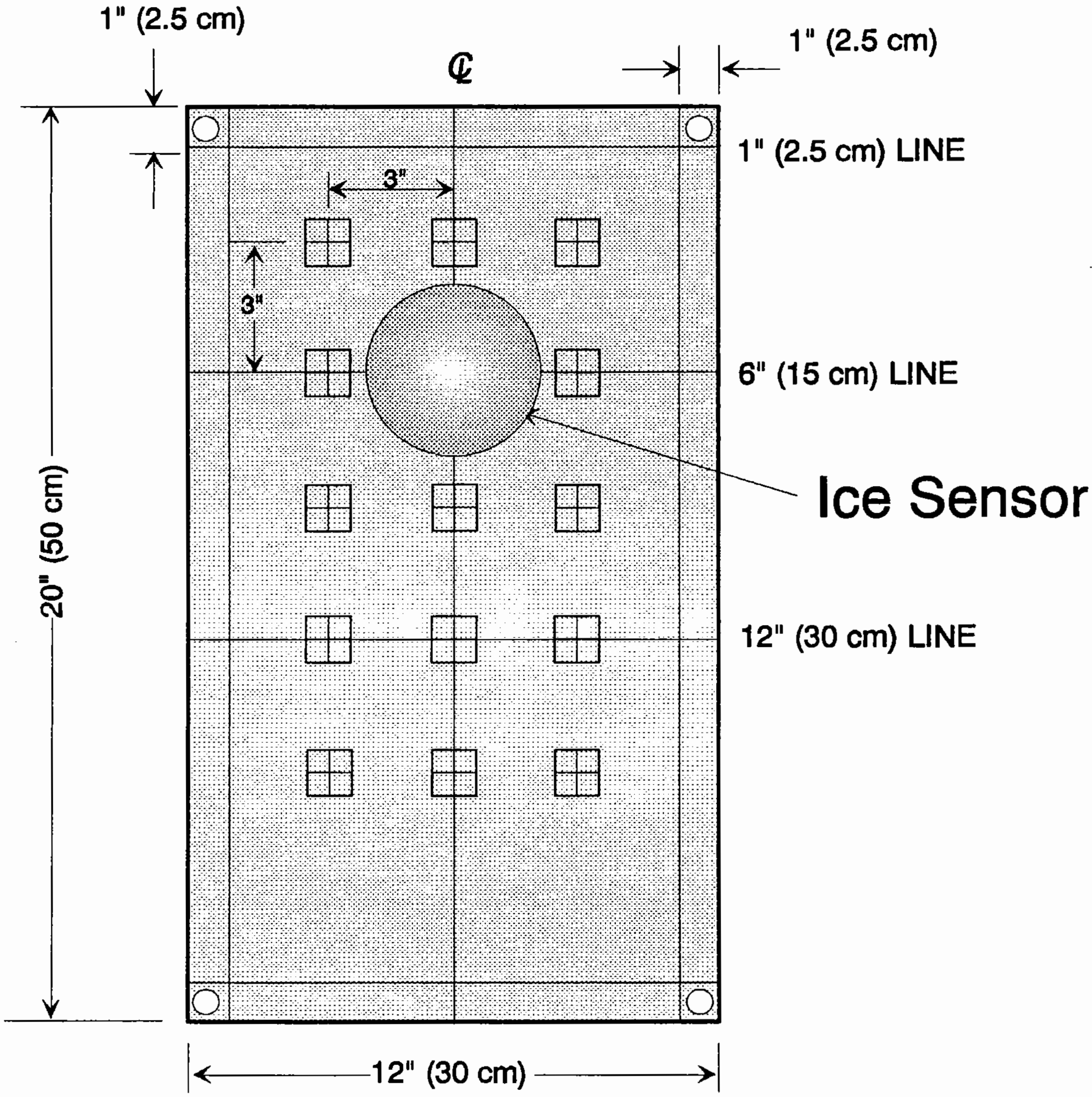


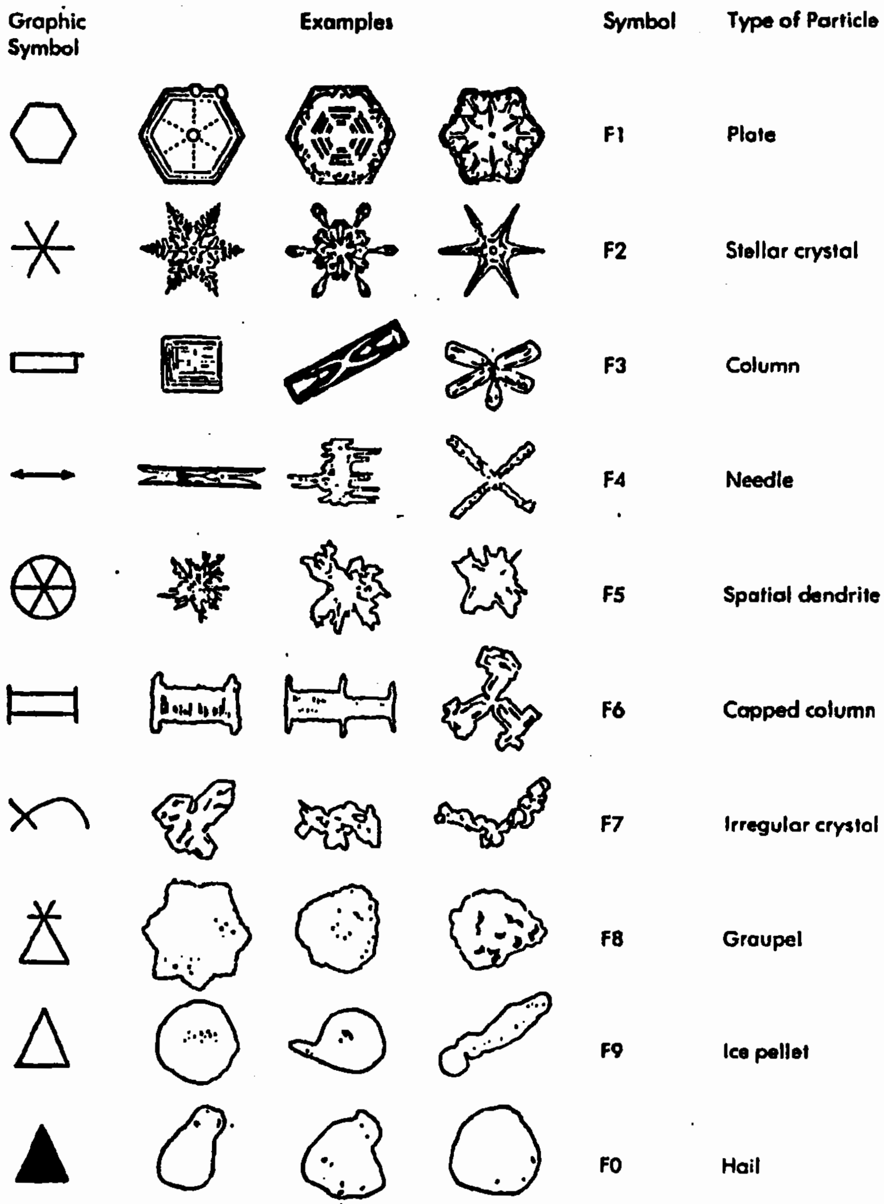
FIGURE 2
TYPICAL ICE SENSOR FLAT PLATE MARKINGS



bm2980\procedur\nat_snow\plate.drw

FIGURE 3

INTERNATIONAL CLASSIFICATION FOR SOLID PRECIPITATION



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

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

FIGURE 4

WEATHER PHENOMENA AND SYMBOLS

General Category	Specific Phenomena	Symbol
Tornadoes and Thunderstorms	Tornado	Tornado
	Waterspout	Waterspout
	Funnel Cloud	Funnel Cloud
	Thunderstorm	T, T+
Precipitation	Rain	R--, R-, R, R+
	Rain Showers	RW--, RW-, RW, RW+
	Drizzle	L--, L-, L, L+
	Freezing Rain	ZR--, ZR-, ZR, ZR+
	Freezing Drizzle	ZL--, ZL-, ZL, ZL+
	Snow	S--, S-, S, S+
	Snow Grains	SG--, SG-, SG, SG+
	Ice Crystals	IC
	Ice Pellets	IP--, IP-, IP, IP+
	Ice Pellet Showers	IPW--, IPW-, IPW, IPW+
	Snow Showers	SW--, SW-, SW, SW+
	Snow Pellets	SP--, SP-, SP, SP+
	Hail	A--, A-, A, A+
Obstructions to Vision (visibility 6 miles or less)	Fog	F
	Ice Fog	IF
	Haze	H
	Smoke	K
	Blowing Snow	BS
	Blowing Sand	BN
	Blowing Dust	BD
	Dust Haze	D

ATTACHMENT VI

CHECKLIST FOR END OF TESTING

[illegible]	[illegible]	[illegible]
ALL FLUIDS BROUGHT IN		
ALL FLUIDS REPLENISHED		
STAND TIMERS BROUGHT IN		
FLUID TAGS BROUGHT IN		
WASTE FLUIDS BROUGHT IN		
HANDHELD CAMERAS BROUGHT IN		
OUTDOOR AND STAND LIGHTS TURNED OFF		
PANNING VIDEO CAMERA TURNED OFF		
C/FIMS COMPUTER TURNED OFF		
MET FILE CLOSED AND NEW FILE OPENED (MET COMPUTER KEPT ON)		
RVSI FILES COMPRESSED AND SAVED TO TAPE		
RVSI COMPUTER AND HEATER TURNED OFF		
WRIST WATCHES HANDED IN		
ALL TEST MEDIA PROPERLY LABELED (VCR, SUPER 8, RVSI, C/FIMS)		
DATA FORMS CHECKED AND SIGNED		
ALL PERSONNEL SIGNED OUT		
TRAILER CLEANED UP		
TRAILER HEATER KEPT AT +17C		
C/FIMS		
TRIPOD		

BM2980\SETUP\CHEKLIST.XLS
10/01/96 10:21 AM

Attachment VII

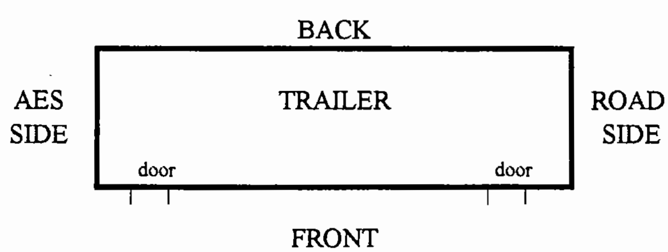
MARKERS FOR DETERMINATION OF VISIBILTY

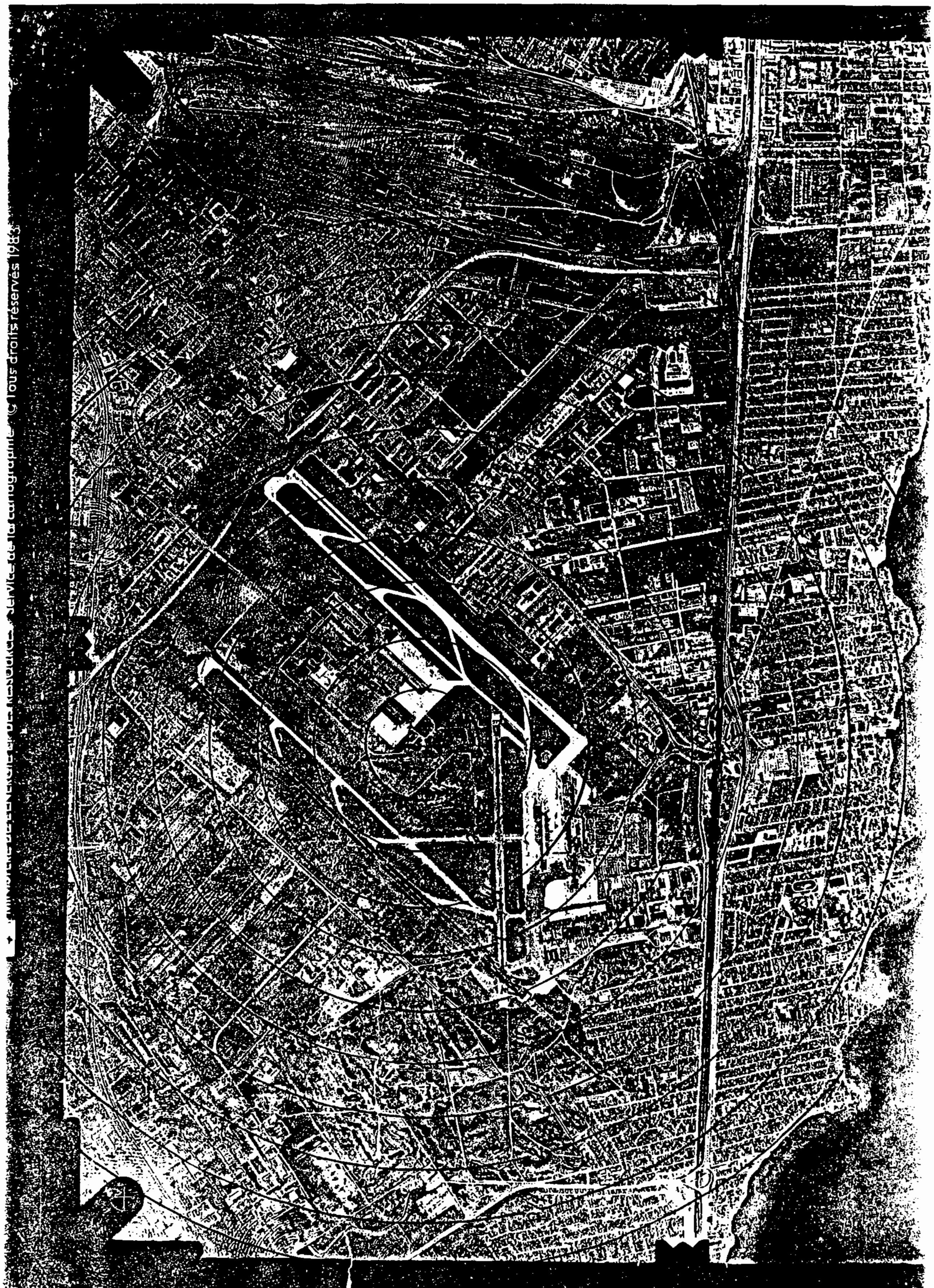
(Refer to Visibilty Map of the AES Site, Dorval)

1) Visibility should by measured only during the daylight.
2) To determine visibilty, search for the furthest visible marker and enter the distance of this marker on the data form.

DISTANCE (miles)	LANDMARK	LOCATION FROM TRAILER
1/8	Top of Air Canada garage, Road Side of trailer	N/E
1/4	Air Canada lights (top of Garage), Road Side of trailer	E
3/8	(Judgment call)	??
1/2	Building in Road Side of trailer	N/E
5/8	Air Canada De-Icing trailer (next to runway), front side of trailer	S/W
3/4	Blue Building, between Back & Road Side of trailer	N
7/8	Small Blue Building, Front of trailer	S/E
1.0	Building, Front of trailer	S/E
1.5	Brown Buildings, AES Side of trailer	S/W
2.0	Group of three (3) Buildings, between Back and AES Side	W

ORIENTATION




Service de la cartographie © Tous droits réservés 1983

APPENDIX C

APS TEST PROCEDURES
FOR
SIMULTANEOUS AIRCRAFT VS PLATE TESTING

BM2980.00

EXPERIMENTAL PROGRAM
FOR SIMULTANEOUS AIRCRAFT VS PLATE TESTING
1995 - 1996

APS Aviation Inc.

February 6, 1996
Version 2.1

EXPERIMENTAL PROGRAM FOR SIMULTANEOUS AIRCRAFT VS PLATE TESTING 1995 - 1996

This document provides the detailed procedures and equipment required for the conduct of simultaneous aircraft vs plate testing for the 1995/96 winter season. The document is a revision to the document used for testing during the 1994/95 winter.

1. OBJECTIVE

To **correlate the flat plate** test data used to substantiate the SAE Holdover Time Tables with the **performance of fluids on service aircraft**, by concurrently testing the new Ultra, or Ultra + Type II (IV) anti-icing fluid on standard flat plates and service aircraft under conditions of natural freezing precipitation during the 95/96 winter season.

Aircraft will be made available for testing outside regular service hours, between 23:00 hrs. and 06:00 hrs. Aircraft types to be used will be representative of those in use by major airlines in Canada. Tests will be conducted at Dorval Airport, using aircraft made available by Air Canada. Availability of aircraft will be negotiated by TDC.

2. TEST REQUIREMENTS (PLAN)

Attachment Ia provides the list of tests to be conducted at Dorval during natural snow conditions. It is anticipated that two sessions will be with leading edge into the wind and one with trailing edge. Two sessions will be conducted with a DC-9 and one with an RJ if this is available.

3. EQUIPMENT

Test equipment required for the simultaneous aircraft vs flat plate tests is provided in Attachment II. Details and specifications for some of the equipment is provided in the experimental plan developed for Dorval's flat plate testing "Experimental Program for Dorval Natural Precipitation Testing 1995/96" (*FPTP*).

4. PERSONNEL

Up to nine personnel are required to conduct tests for each occasion. A description of the responsibilities and duties of each of the personnel is provided as guidelines in Attachment III. Depending upon the weather forecast at the site, the number of personnel will be reduced or increased, but it will not exceed ten. Figure 1 shows a schematic of the positioning of the test personnel. Ground support personnel from the airlines will be available to apply fluids, position the aircraft and facilitate the inspection of the critical aircraft surfaces.

5. PROCEDURE

The test procedure is included in Attachment IV.

6. DATA FORMS

The data forms are listed below:

- Figure 3 General Data Form
- Figure 4 Aircraft Data Form
- Table 1 and 1a from the *FPTP*

ATTACHMENT Ia

TEST PLAN FOR
SIMULTANEOUS AIRCRAFT vs PLATE TESTS AT YUL

NATURAL SNOW CONDITIONS

RUN #	OCCASION #	NUMBER OF PLATES TESTED	PLATES			WING
			ULTRA+ FROM TRUCK/PAIL	ULTRA+ FROM CONT PRIOR	ULTRA+ FROM CONT AFTER	ULTRA+ FROM TRUCK
1	1	6	2	2	2	1
2	1	6	2	2	2	1
3	1	6	2	2	2	1
4	1	6	2	2	2	1
5	2	6	2	2	2	1
6	2	6	2	2	2	1
7	2	6	2	2	2	1
8	2	6	2	2	2	1
9	3	6	2	2	2	1
10	3	6	2	2	2	1
11	3	6	2	2	2	1
12	3	6	2	2	2	1
TOTAL		**72**	**24**	**24**	**24**	**12**

ATTACHMENT II

SIMULTANEOUS AIRCRAFT vs PLATE TESTS

TEST EQUIPMENT CHECKLIST

TASK	*Montreal*	
	Resp.	Status
[illegible]		
Passes		
Rent Van		
Call Personnel (JM, DB, ER, AP, GT, MH, CL, ZB, ML)		
Advise Airlines (Personnel, A/C Orientation, Equip)		
Monitor Forecast		
Test Equipment		
Stand X 2 Blue detached ones		
Tape Recorder with Mic.(voice) x 2		
Weigh Scale x 1		
Video Cameras X 3 + 15 batteries + 2 chargers		
Thickness Gauges - Optional		
Reg. Plates (wing nuts) X 12		
Data Forms for plates and general		
Aircraft Wing Forms		
XL 54 Fluid for plates (10L of conc.)		
Ultra Fluid for plates x4 red containers		
Plate Pan X 4		
Compass		
Tape measure		
Clipboards X 5		
Space pens and pencils X 6		
Paper Towels (buy 1 more box)		
Rubber squeegees x 2		
Plastic Refills for Fluids and funnels		
Electrical Extension Chords x 8 minimum		
Lighting x 6 single black & 3 double yellow poles		
Tools		
Water containers for dilution x 1 red container		
Stop watches (buy 5 more)		
Pylons		
Laser Pointers x 3		
Storage bins for small equipment (buy small ones)		
Temperature Probe x 2		
Thermometer (digital hand held)		
VHF radios (rentx4)		
Pails for Fluid from Truck x 2		
Protective clothing x 9 (pants + coats)		
Refractometer + brixometer		
Tie wraps (buy)		
Tags (Labels) for Fluid designation on stand (buy)		
Scrapers (buy) x 2		
Whistle x 2		
Rolling Stairs		
[illegible]		
XL 54 Fluids for wings (UCAR)		
Ultra Fluids for wings (UCAR)		
Spray vehicle for XL54 x1 (A/L)		
Spray vehicle for Ultra x1 (A/L)		
Test Aircraft		
Storage Facilities (A/L)		
Fluid Collection Facilities		
Electrical Power (A/L)		
Airline Personnel		

(1) To be provided by others

File:g/bm2980/procedur/full_scl/CHKLS_AC.XLS
Printed: 13/02/96

ATTACHMENT III
Simultaneous Aircraft vs Plate Tests
Responsibilities/Duties of Test Personnel

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

Video 1 (V1)
- Located on ground (Refer to FPTP)
- Video a/c test site
- Concentrate on test stands A & B - plate failures
- Must be mobile
- Picture to be steady and well lit
- Knowledge of test procedures and end conditions
- Video application of fluid and placement of plate pans

Video 2 (V2)
- Good knowledge of test procedures
- To video wing before and after fluid application, to concentrate on fluid contamination and failure
- Need high quality photo, steady and well lit
- To be located in "cherry picker" side A, then side B after failure of side A wing

Meteo/Equipment Tester (T1)
- Coordinate all equipment
- Record meteo for both stands
- Rotate and measure plate pan weights
- Complete and sign Data Form (Table 1a)
- Assist end condition tester when failure times occur quickly
- Measure wing temperatures
- Assist Team Leader
- Ensure power cables and lighting is in place
- Prepare plate pans

Wing Observers (T2/T7)
- Located on ground (rolling stairs) or in cherry picker
- Communicate with V2
- Make observations of wing A and/or B
- Knowledgeable in procedures and conditions
- T2 on LE, T7 on TE or both wings
- Set up rolling stairs and lights and cables

End Condition Tester (T3)
- Apply fluids to Stand A
- Located by Test Stand A
- Make observations and call conditions on test stand A
- Knowledge of procedures for test stands
- To aid T5 on stand B, if needed
- Set up lights and stand and cables
- Bring fluid samples and squeegee on A + pour on B
- Place and start stop watch on stand A

Wing Observer (T4)
- Located in cherry picker B or on scaffold (rolling stairs)
- To observe application of fluid to wing B
- Take notes
- Knowledgeable in test procedures and conditions
- Call conditions e.g. failures
- Communicate with T2

End Condition Tester (T5)
- Located on ground by test stand B
- Apply fluid to test stand B
- Observe and note conditions
- Call failures
- Knowledgeable of test procedures and conditions
- Set up lights and stand and cables
- Bring fluid samples + squeegee on B and pour on A
- Place and start stop watch on stand B

Leader (T6)

- Team Leader
- Knowledge of test procedures and conditions
- Responsible for area and people
- To aid any personnel on side A or B
- Coordinate actions of APS team and Air Canada personnel
- Responsible for weather condition observations and forecast, advise tester team
- Ensure that the end conditions on the plates and on the aircraft are called in the same manner.
- Ensure that there are no objects on the ground which may cause FOD at end of session.
- Call personnel to conduct tests.
- Ensure test site is safe, functional and operational at all times.
- Supervise site personnel during the conduct of tests.
- Report to project manager on site activities on daily basis.
- Review data forms upon completion of test for completeness and correctness (sign).
- Ensure all clocks are synchronized at all times.
- Monitor weather forecasts during test period.
- Ensure fluids are available and verify fluids being used for test are correct.
- Ensure electronic data is being collected for all tests.
- Ensure proper documentation of tapes, diskettes, cassettes.
- Verify test procedure is correct (eg. stand into wind).
- Ensure all materials are available (pens, paper, batteries, etc.)
- Ensure all equipment is on

ATTACHMENT IV
TEST PROCEDURE

1. Training

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

2. Pre-Test Set-Up

Figure 1 should be consulted in reference to the responsibilities.

1. Arrange favourable aircraft orientation (**leading or trailing edge into the wind**) and place pylons below wings to delineate sections (T6).
2. Intentionally left blank.
3. Set up power cords and generator (optional) (T3/T5).
4. Turn on aircraft wing lights (optional) (T6).
5. Ensure temperature probes and weigh scale are functional (T6).
6. Position flat plate test stand into the wind as per the *FPTP*. Note that this orientation may be different than that of the aircraft (T3/T5).
7. Position pre-filled test fluid containers, squeegees, and scrapers accordingly. (Type I fluids are stored inside at 20°C; Type II fluids are applied at ambient temperature) (T3/T5).
8. Check cameras and recording devices for proper function (V1/V2).
9. Ensure proper illumination of test areas (T3/T5/V1/V2).
10. Establish communication between team members and coordinator (T6).
11. Camera and test personnel ensure ability to identify laser light signature (T2/T3/V1/V2).
12. Synchronize all timepieces including video cameras to the instrument computer (T6).
13. Ensure airline personnel are aware and knowledgeable of test procedures (T6).

14. Data forms to be used are: general data form (Figure 3) by the test site leader (T6); standard plate data form from the *FPTP* by T3 or T5; and the aircraft data form by T1 and T2 or T4.

3. Initialization of Fluid Test

1. Ensure all aircraft de/anti-icing systems are off (T6).
2. Measure and record fuel load in wing to be tested (T1/T6).
3. Measure wing skin temperature at predetermined locations before fluid application (see Figure 3) (T1).
4. Record all necessary data from fluid delivery vehicle (cherry picker). (Temperature, nozzle-type, quantity of fluid, dilution of fluid, etc.) (T6).
5. Record all general measurements and general information in the three data forms (T6). Attach clips with fluid name and type to stand (T3/T5).
6. Ensure all fluids are prepared to the appropriate concentrations (T3/T5).
7. Intentionally left blank.

4. Execution of Fluid Test

1. **Type II Fluid Application** (T3/T5) - the following subsection refers to Figure 2b
   - 1.1 Type I fluid application (see Figure 2a).
     - 1.1.1 Spray Type I fluid from cherry picker into pail.
     - 1.1.2 Apply fluid onto test plates U and X from pail.
     - 1.1.3 Cherry Picker vehicle proceeds to apply heated Type I fluid to wing surface.
     - 1.1.4 Apply Type I fluid from containers onto test plates V and Y.
   - 1.2 Apply Ultra Type II onto plates U and X from the pail after sprayed into pail from cherry picker. (**Start all stop watches and record true time for the beginning of the test**). A whistle is suggested to designate this event.
   - 1.3 Apply Type II fluid onto the wing.
   - 1.4 Type II fluid is applied manually to plates V and Y as wing application commences.
   - 1.5 Type II fluid is applied manually to plates W and Z as wing application commences.
2. Put two plate pans on test stand and note time and initial weights (refer to *FPTP*) (T3/T5).
3. Continue Holdover Time Testing until the end conditions are called for all six flat plates. (See Section 7 below).
4. Final plate pan measurements are taken (T3/T5).

5. Holdover Time (end condition) Testing

Holdover time testing will consist of: A) Video recording of all procedures and fluid failures; and B) Visual monitoring and manual recording of failure data.

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

1. Record the complete fluid application from a distance.
2. Record the conditions of the flat plate set-up and the wing at time = 0.
3. (i) For Type I fluids, record conditions of wing and flat plates every 2 minutes.
   (ii) For Type II fluids, record conditions of wing and test plates every 5 minutes.
4. Once the first failure on the wing or on the one inch line is called, monitor (record) continuously until the end of the test.
5. Record the "important events" as described in the form (Figure 4)
6. Record condition of the wing and representative surface continuously from the aircraft cabin.

B. Visual Recording
1. For the plates, refer to *FPTP* for determination of the end condition (T3/T5).
2. For the wing, three (3) ways to record visual observations have been devised (T2/T4).

   (i) Manual recording of failure contours on preprinted data form (Figure 4). This is to be performed by person making the observations, and/or
   (ii) Observer may talk to a voice recorder, and/or
   (iii) Observer may talk directly to the video camera microphone.

   In any case, the methods would utilize the Wing Section Data Form (Figure 4), and these are complementary to the video recording.

3. Intentionally left blank.

4. When the first flat plate failure is reported at the six-inch line (⅓ of plate), the visual data recorder (T2/T4) must acquire contours every 2 to 5 minutes, thereafter. Time increment is dependent upon weather. Process is

continued until all six flat plates have failed according to the end condition defined in the *FPTP* (T2/T4).

5. If wing fails before first flat plate fails, continue data collection for wing via contour drawing and/or voice communication until all flat plates fail (T2/T4).
6. Team coordinator (T6) must confirm initial end condition calls on flat plate tests. Once the first flat plate fails at the six inch line (⅓ of plate), the coordinator is notified and makes inspection of the wing contour drawing to confirm the accuracy of the wing data and instructs video camera operator to make a record of the area. The area should be located using a laser pointer. If the wing start to fail first, the coordinator must confirm this and simultaneously note areas of failure on the flat plates using the laser pointer.
7. Measure as many wing skin temperatures at the start of the evening. If the wing is cold-soaked, then continue monitoring the temperatures.

6. End condition

Refer to the *FPTP* for this definition.

7. End of test

Team coordinator (T6) must confirm the end of test. This occurs when all six plates have reached the end condition (under heavy snow conditions, continue testing until nine crosshairs have failed) and when a substantial part of the aircraft wings leading/trailing edge has reached the end condition. Most or all of the "important events" in the aircraft wing data from (Figure 4) must be completed by T2/T4. Ensure all data collection is completed including plate pan measurements (T1).

FIGURE 1
POSITION OF EQUIPMENT AND PERSONNEL

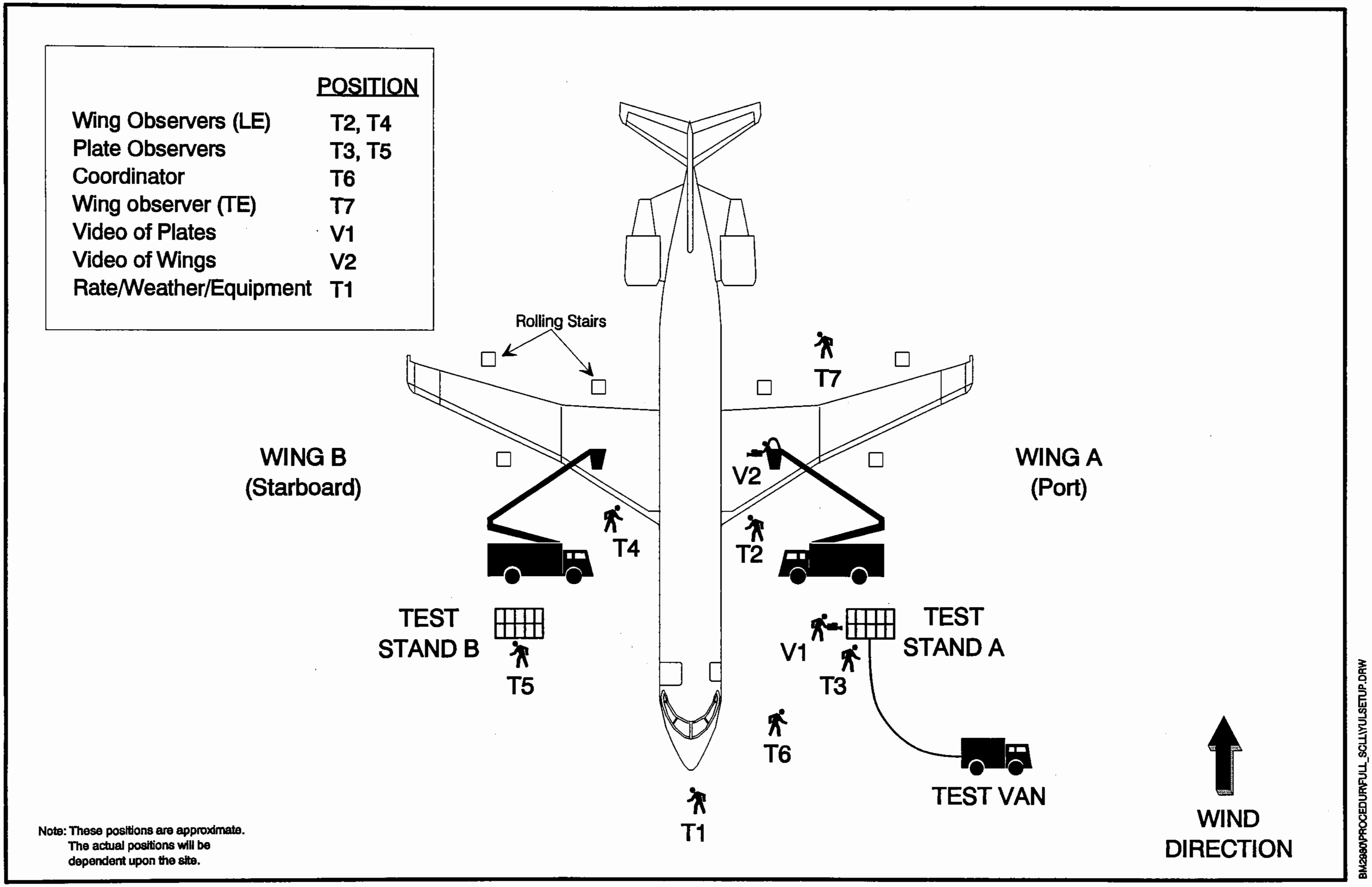


FIGURE 2a

TYPE I FLUID APPLICATION

Step 1: Spray XL54 fluid from cherry picker into pail.

Step 2: Apply XL54 onto plates U and X from the pail.

Step 3: Apply XL54 onto the aircraft wing

Step 4: Apply XL54 from gasoline containters on plates V and Y

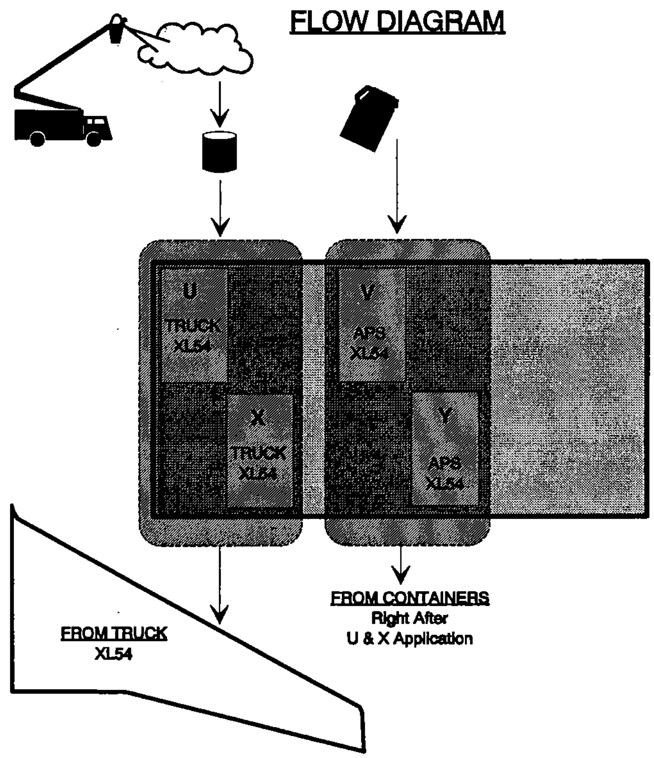


FIGURE 2b

TYPE II FLUID APPLICATION

Step 1: Follow Step 1 to 3 in Type I application.

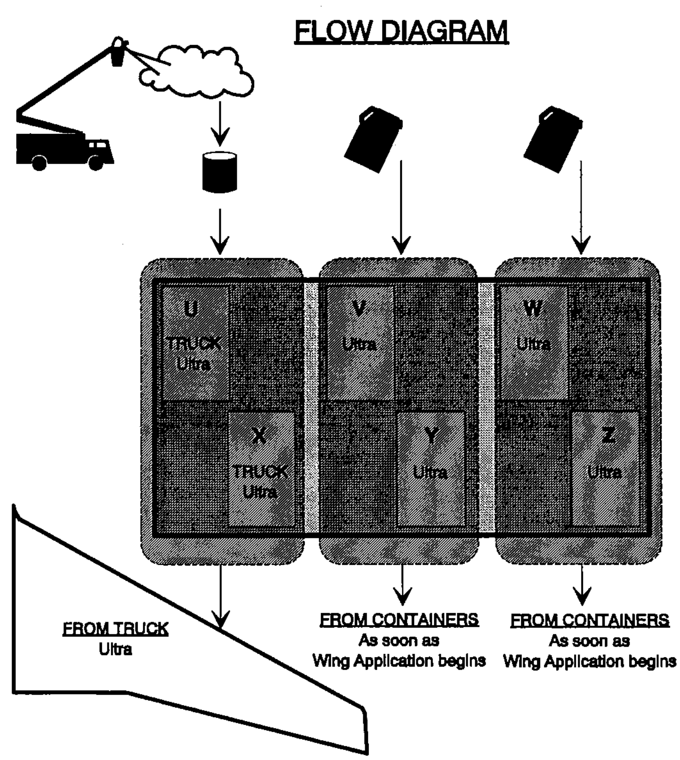
Step 2: Apply Ultra Type II onto plates U and X from the pail.

Step 2a: Start stop watch and record true time for beginning of tests.

Step 3: Apply Type II fluid onto the aircraft wing.

Step 4: Apply Type II fluid onto plates V and Y at the same time that the wing application has started. Use gasoline containers for this application. Then record time.

Step 5: Apply Type II fluid onto plates W and Z as soon as wing application has started. Use the same procedure as in Step 4. Then record time.



BM2980\PROCEDUR\FULL_SCL\FLD_APPL.DRW

FIGURE 3

GENERAL FORM

AIRPORT: YUL

AIRCRAFT TYPE: A320 DC-9 B-737 RJ BAe 146

EXACT LOCATION OF TEST: ______________________

AIRLINE: ______________________

DATE: ______________________

FIN #: ______________________

RUN #: ______________________

FUEL LOAD: ______________________ LB / KG

LOCATION OF PILOT IN CABIN: ______________________

1st FLUID APPLICATION

Actual Start Time: ____________ am / pm

Actual End Time: ____________ am / pm

Start of Fluid Gauge: ____________ L / gal

End of Fluid Gauge: ____________ L / gal

Type of Fluid: ____________

Truck #: ____________

Fluid Temperature: ____________

Fluid Nozzle Type: ____________

2nd FLUID APPLICATION

Actual Start Time: ____________ am / pm

Actual End Time: ____________ am / pm

Start of Fluid Gauge: ____________ L / gal

End of Fluid Gauge: ____________ L / gal

Type of Fluid: ____________

Truck #: ____________

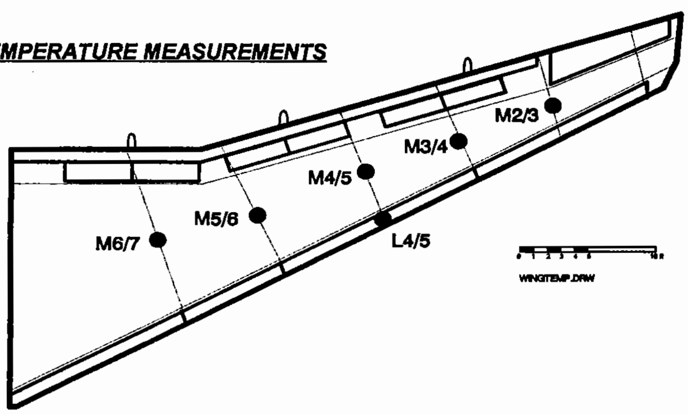
Fluid Temperature: ____________

Fluid Nozzle Type: ____________

Time When Stop Watch is Started: ____________ am/pm

End of Test Time: ____________ am/pm

TEMPERATURE MEASUREMENTS



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

COMMENTS: ______________________

(1) Actual Time Before Fluid Application

MEASUREMENTS BY: ______________________

HAND WRITTEN BY: ______________________

Printed: 26/01/96
Version 2.2
File: GFORM2-2.XLS

FIGURE 4

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 2.2 Winter 95/96

LOCATION:	DATE:	RUN NUMBER:	WING #:	RVSI AVAILABLE: Y / N
Time After Fluid Applied to Plates U and X:	am / pm			C/FIMS SENSOR AVAILABLE: Y / N

TIME OF INITIAL FLUID APPLICATION: ____________ (hr:min)
(Last step only)

TIME AFTER FLUID APPLICATION: ____________ (hr:min)
(Last step only)

DIRECTION OF AIRCRAFT: ____________

FAILURES CALLED BY: ____________

DESCRIBE SENSORS/LOCATION: ____________

____

HANDWRITTEN BY: ____________

ASSISTED BY: ____________

COMMENTS: ____________

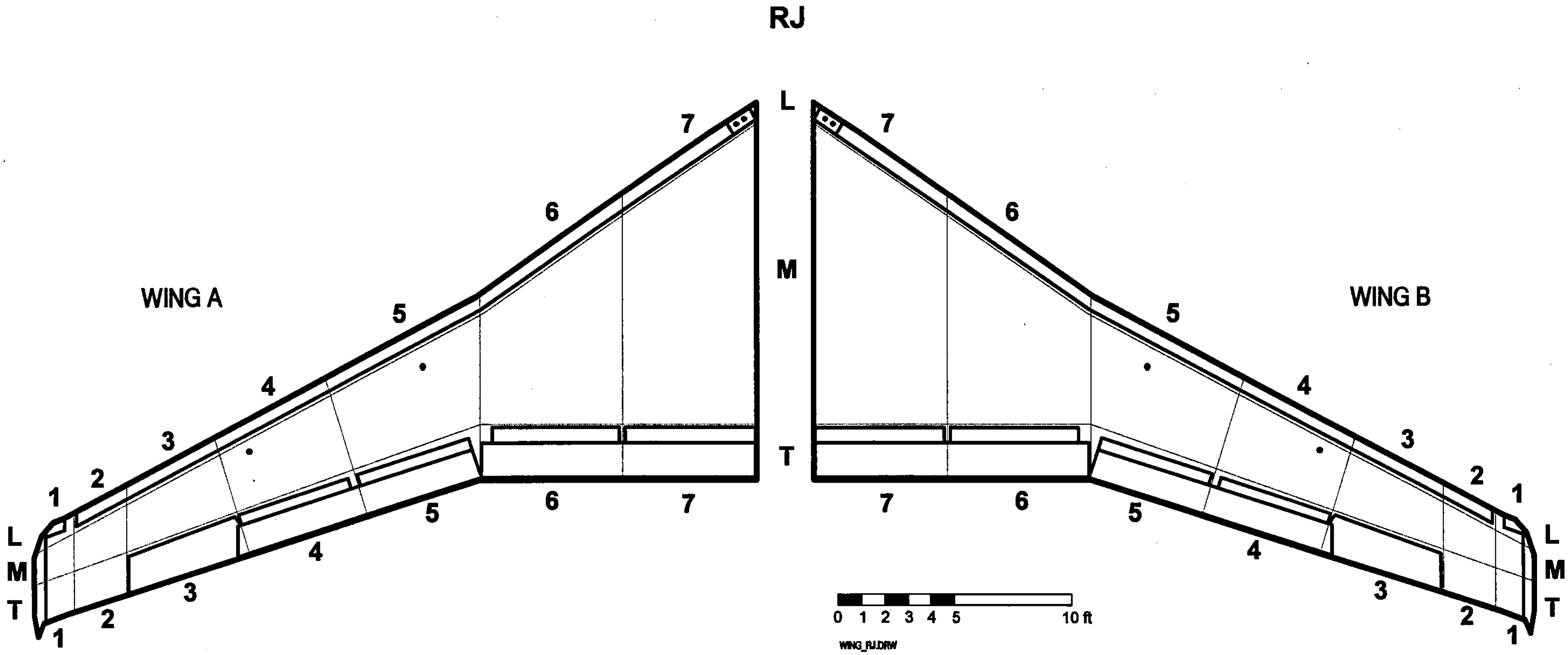
____

IMPORTANT EVENTS

	TIME (min)	LOCATION
1st Failure:		
10% of LE/TE:		
25% of LE/TE:		
75% of LE/TE:		
100% of LE/TE:		

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE
(Indicate Representative Surface on Drawing)

File: Aform2-2.drw



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

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FIGURE 4

DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 2.2 Winter 95/96

LOCATION:	DATE:	RUN NUMBER:	WING # :	RVSI AVAILABLE: Y / N
Time After Fluid Applied to Plates U and X:	am / pm			C/FIMS SENSOR AVAILABLE: Y / N

TIME OF INITIAL FLUID APPLICATION: ____________ **(hr:min)**
(Last step only)

DIRECTION OF AIRCRAFT: ____________

DESCRIBE SENSORS/LOCATION: ____________

____

COMMENTS: ____________

____

TIME AFTER FLUID APPLICATION: ____________ **(hr:min)**
(Last step only)

FAILURES CALLED BY: ____________

HANDWRITTEN BY: ____________

ASSISTED BY: ____________

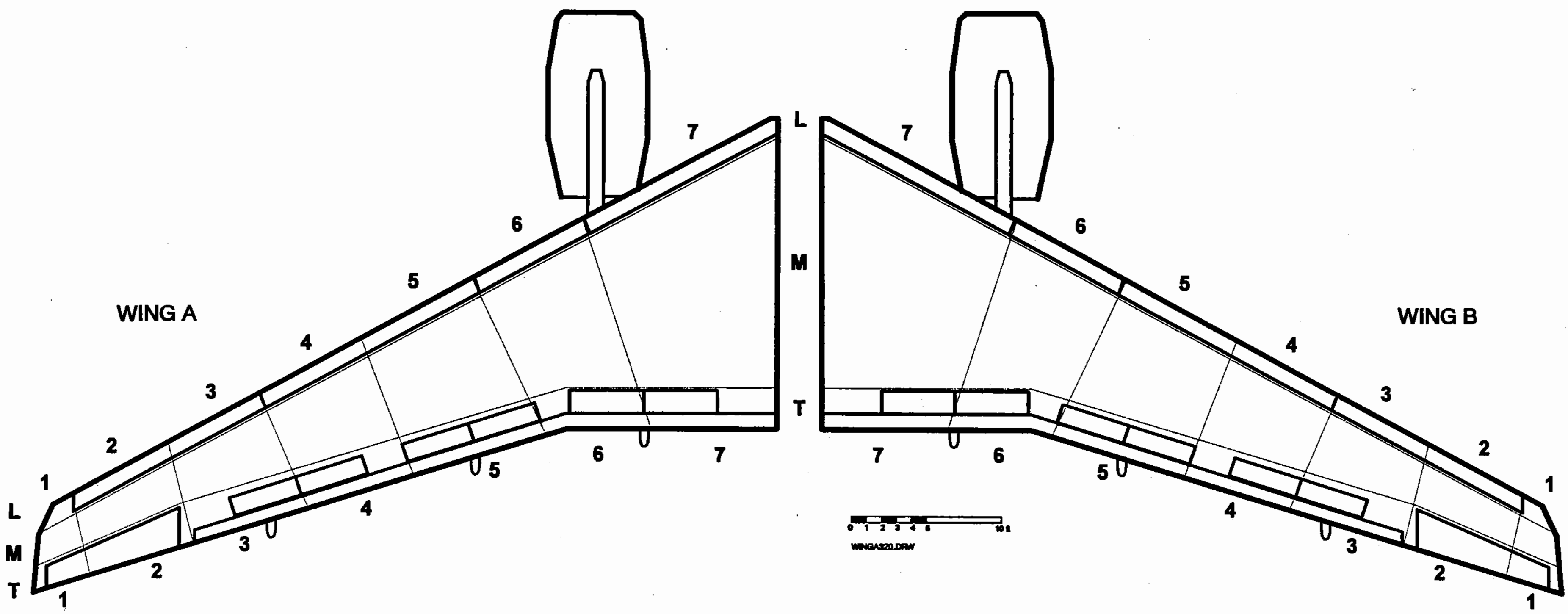
IMPORTANT EVENTS

	TIME (min)	LOCATION
1st Failure:	______	______
10% of LE/TE:	______	______
25% of LE/TE:	______	______
75% of LE/TE:	______	______
100% of LE/TE:	______	______

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE
(Indicate Representative Surface on Drawing)

File: Aform2-2.drw

A320



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

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FIGURE 4
DE/ANTI-ICING FORM FOR AIRCRAFT WING

REMEMBER TO SYNCHRONIZE TIME

VERSION 2.3 Winter 95/96

LOCATION: DATE: RUN NUMBER: WING # : RVSI AVAILABLE: Y / N

Time After Fluid Applied to Plates U and X: am / pm C/FIMS SENSOR AVAILABLE: Y / N

TIME OF INITIAL FLUID APPLICATION: ____________ (hr:min)
(Last step only)

TIME AFTER FLUID APPLICATION: ____________ (hr:min)
(Last step only)

DIRECTION OF AIRCRAFT: ____________

FAILURES CALLED BY: ____________

DESCRIBE SENSORS/LOCATION: ____________

____

HANDWRITTEN BY: ____________

ASSISTED BY: ____________

COMMENTS: ____________

____

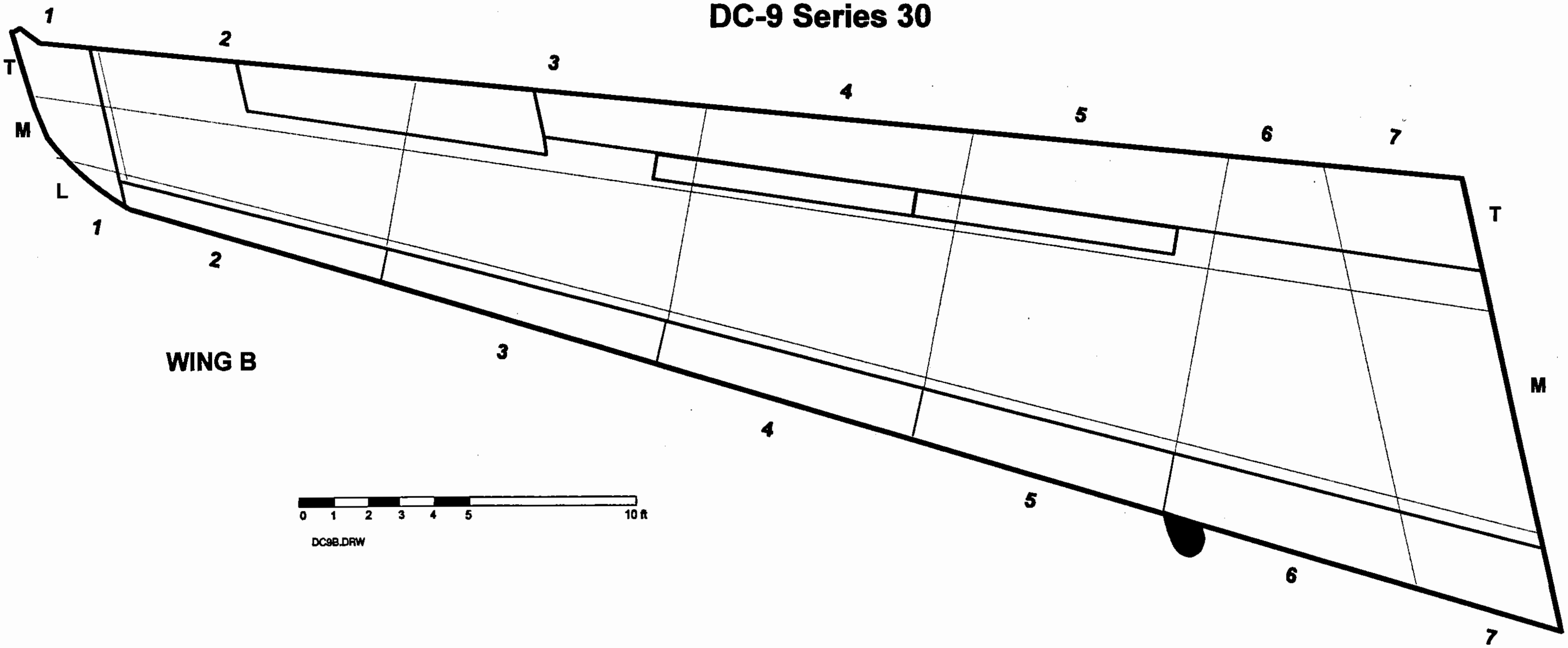
IMPORTANT EVENTS (hr:min)

	L.Edge	Mid	T.Edge
1st Failure:			
10% :			
25% :			
75% :			
100% :			

File: Aform2-3.drw

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE
(Indicate Representative Surface on Drawing)

DC-9 Series 30



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

File:V2-3_DC9.XLS Printed:26/01/96

REMEMBER TO SYNCHRONIZE TIME

FIGURE 4
DE/ANTI-ICING FORM FOR AIRCRAFT WING

VERSION 2.3 Winter 95/96

LOCATION: DATE: RUN NUMBER: WING # : RVSI AVAILABLE: Y / N

Time After Fluid Applied to Plates U and X: am / pm C/FIMS SENSOR AVAILABLE: Y / N

TIME OF INITIAL FLUID APPLICATION: ________ (hr:min)
(Last step only)

TIME AFTER FLUID APPLICATION: ________ (hr:min)
(Last step only)

DIRECTION OF AIRCRAFT: ________

FAILURES CALLED BY: ________

DESCRIBE SENSORS/LOCATION: ________

____

HANDWRITTEN BY: ________

ASSISTED BY: ________

COMMENTS: ________

____

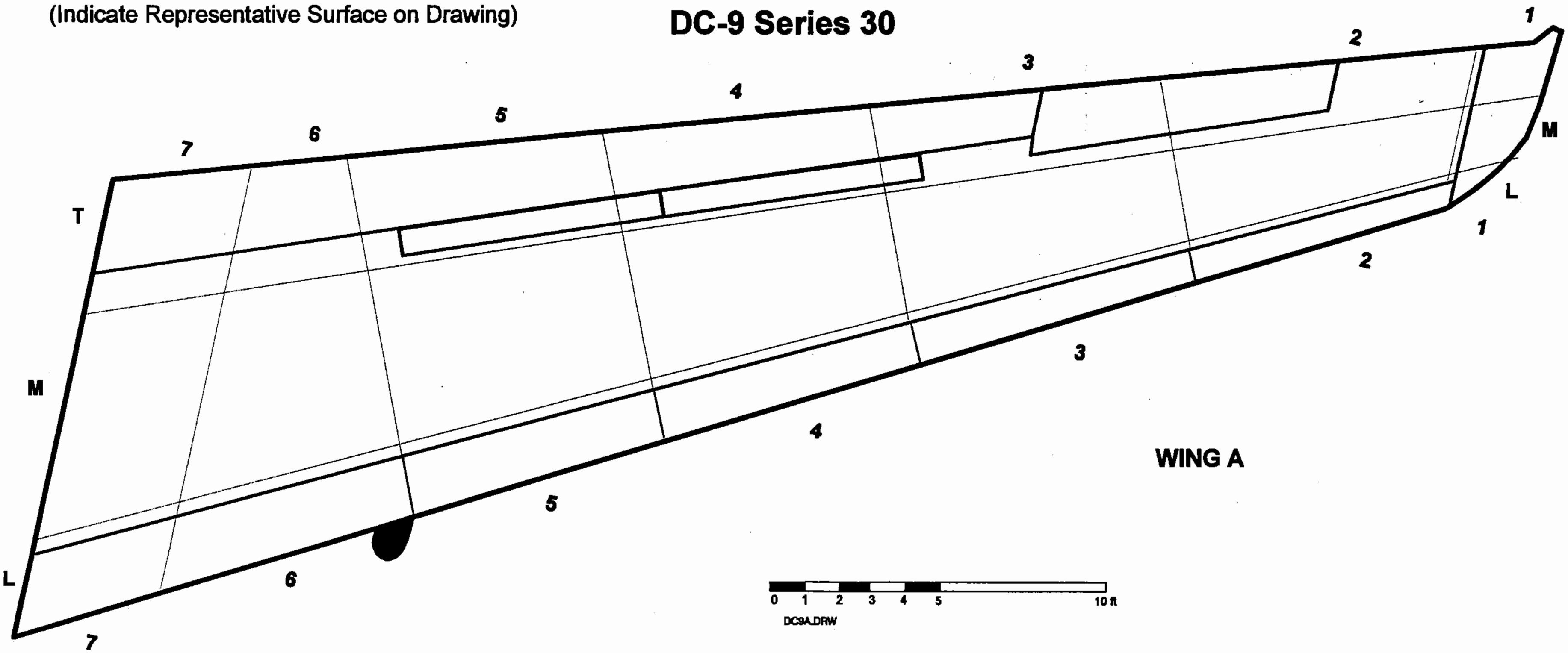
IMPORTANT EVENTS (hr:min)

	L.Edge	Mid	T.Edge
1st Failure:			
10% :			
25% :			
75% :			
100% :			

File: Aform2-3.drw

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE
(Indicate Representative Surface on Drawing)

DC-9 Series 30



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

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APPENDIX D

SIMULTANEOUS AIRCRAFT VS PLATE TESTING PROCEDURE FOR SPECIAL PLATES

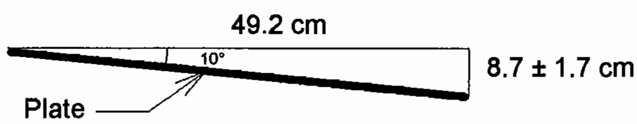
APPENDIX D

SIMULTANEOUS AIRCRAFT VS PLATE TESTING PROCEDURE FOR SPECIAL PLATES

- The skirted and non skirted plates and the plate pan should be located near the middle of the wing span, close to the trailing edge and about 30 cm apart.

- Measure initial plate pan weight before installation.

- The plates should be installed at an angle of 10 ± 2° (8.7 ± 1.7 cm over 49.2 cm). Use the torpedo level over the full length of the plate to adjust.



- The plates should be fixed to the wing by firmly pressing on the suction cups. Clean area on wing with paper towel first.

- Fluid XL54 (or U1STD) should be kept at room temperature.

- Fluid ULTRA (or UIV100) should be kept outside.

- After fluid application by truck, squeegee non skirted plate only.

- Pour same fluid(s) as poured onto plates V and Y. Record time of application (minutes and seconds). Video tape the fluid application and all other important events.

- Use same data forms as in the flat plate test procedure (End Condition Data Form and Meteo/Plate Pan Data Form). It is not necessary to record the meteo observations.

- Record time of installation of the plate pan and measure plate pan weight every 15 minutes thereafter. To remove the plate pan from the wing, use a pen cap to release the succion cups. Be careful not to spill any fluid from the pan.

- Make observations and call end conditions (T3 and/or T5).

- After completion of test, squeegee all plates.

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