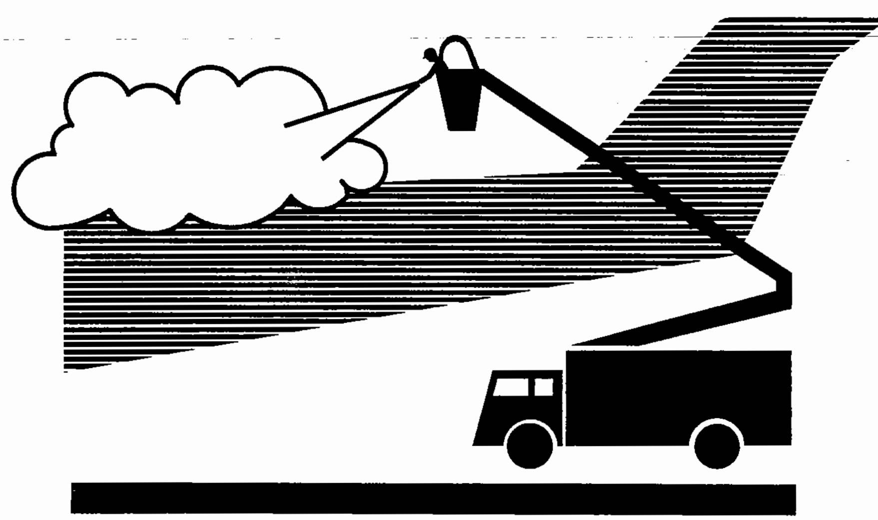
TP 12900E

Evaluation of Fluid Thickness to Locate Representative Surfaces



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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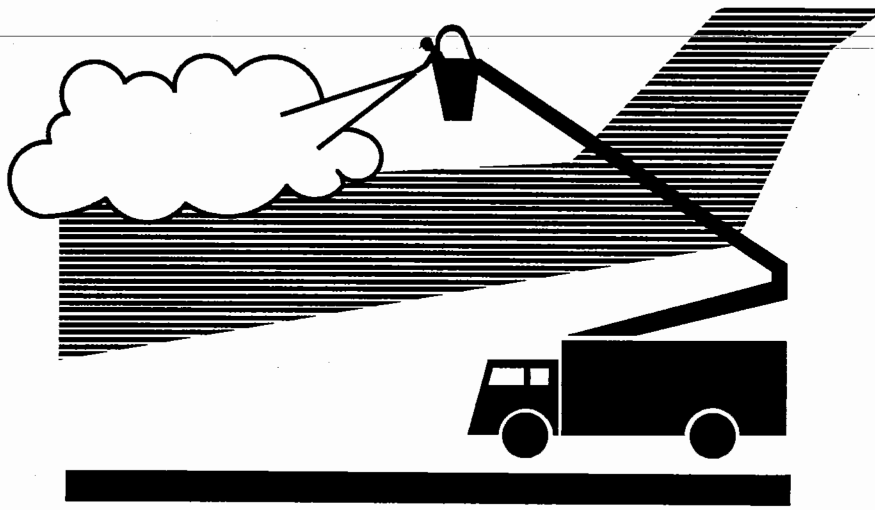

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Un sommaire français se trouve avant la table des matières.

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 and 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 solutions to enhance 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 on 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 12900E addresses the objective of determining optimum locations for representative surfaces through establishing fluid thickness profiles on wing surfaces.

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 use of a representative surface on an aircraft wing to serve as an indicator of the condition of non-observable critical wing surfaces is a common and approved practice. Field de-icing tests on aircraft during winter precipitation conditions have shown that the concept is not fully effective, as earlier failures frequently occur elsewhere on the wing. Field observations indicate that the flow-thinning action of applied films of de-icing or anti-icing fluid with time has a primary influence on the onset of fluid failure.

This project set out to measure fluid thickness profiles over the wing to assist in the determination of optimum representative surface locations. Trials were conducted using DC-9, A320 and Canadair RJ aircraft. It was found that effective locations should include a section of the wing leading edge and of flight control surfaces at the trailing edge, and any irregularities or discontinuities on the wing which precipitate early fluid thinning. Selection of wing areas to serve as representative surfaces should follow a process of examining and testing each aircraft type.

Examination of other aspects of fluid thickness behaviour using aircraft wings, standard test flat plates and specially designed plates indicated that: **1)** The fluid film thickness decreases steadily to that of a dilute aqueous solution as it is contaminated with precipitation; **2)** Type IV fluid applied over Type I fluid (normal two-step process) results in thinner films than Type IV fluid alone applied directly to the bare surface; **3)** Type IV fluid thickness stabilizes at a value approaching 40 times that of Type I fluid and twice that of Type II fluid; **4)** To gain full benefits of Type IV fluids requires skilled and knowledgeable operators using appropriate fluid delivery equipment (especially spray nozzles) to achieve the required depth and consistency in fluid film thickness; **5)** The fluid film thickness on the leading edge of the DC-9 and A320 wings is typical of wet film thickness measurements taken during fluid holdover time trials on flat plates. However, the fluid film thickness on the leading edge of the RJ is somewhat below those of the flat plate measurements; and **6)** The design of fluid contamination heads for point sensors as (and potentially visible) raised surfaces on aircraft wings in order to simulate conditions at more critical (and possibly less visible) wing areas may have merit.

Recommendations based on study findings are included.

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Les rapports sur les recherches effectuées au cours des hivers précédents pour le compte de Transports Canada sont disponibles au CDT. Six rapports, dont le présent, ont été produits dans le cadre des recherches menées cet hiver. L'objet de ces recherches figure dans l'avant-propos. Les recherches ont été financées principalement par le Groupe Aviation civile, Transports Canada et en partie par la FAA.

16. Résumé

Le recours à une surface représentative sur la voilure d'un avion pour indiquer l'état dans lequel se trouvent les parties de celle-ci qui ne sont pas observables est une pratique approuvée et courante. Mais, les tests de dégivrage menés sous des précipitations hivernales ont montré que cette pratique n'est pas infaillible, puisqu'il arrive souvent que l'efficacité d'un liquide peut cesser ailleurs, avant que cela ne paraisse sur la surface représentative. Les observations expérimentales ont montré que l'amincissement des couches de liquide antigivrage ou dégivrant est le principal facteur de la perte d'efficacité de ces liquides.

La recherche avait pour objet de mesurer les profils d'épaisseur de liquide sur une aile d'aéronef dans le but de déterminer l'emplacement optimal des surfaces dites représentatives. Les tests ont été menés sur un DC-9, un A320 et un Regional Jet de Canadair. Pour être représentative, une surface doit comprendre une partie du bord d'attaque et des gouvernes dans le bord de fuite et toutes les irrégularités à la surface de la voilure de nature à provoquer un amincissement prématuré des couches de liquide. La sélection doit se faire selon un processus rigoureux d'examen des voilures individuelles et de tests séparés.

Les autres tests menés sur des voilures d'avions, des plaques planes standard et des plaques planes autres que standard ont permis de constater que : **1)** les épaisseurs de liquide s'amincissent de façon constante pour ne constituer qu'une solution aqueuse diluée à mesure qu'ils deviennent de plus en plus contaminés par les précipitations; **2)** les liquides de type IV déposés sur un liquide de type I (procédure 2 étapes) donnent une épaisseur stabilisée plus mince que lorsqu'ils sont déposés sur une surface dégivrée; **3)** les épaisseurs stabilisées d'un liquide de type IV sont environ 40 fois supérieures à celle d'un liquide de type I et deux fois celle d'un liquide de type II pur; **4)** pour tirer le plein parti des liquides de type IV, il faut mettre en oeuvre une main-d'oeuvre compétente utilisant l'équipement approprié (de préférence des buses d'arrosage) de manière à réaliser des profils uniformes ayant l'épaisseur voulue; **5)** dans la plupart des endroits sélectionnés sur les bords d'attaque et de fuite du DC-9 et du A320, les épaisseurs stabilisées mesurées sont égales ou supérieures à l'épaisseur caractéristique observée pour les plaques planes standard, dans des conditions identiques, mais que, dans le cas du RJ de Canadair, l'épaisseur sur le bord d'attaque est inférieure à l'épaisseur observable sur une plaque plane; et **6)** le recours à des capteurs dont la tête ferait saillie au-dessus de la voilure afin de reproduire en cet endroit les profils d'épaisseur caractéristiques des bords d'attaque (endroit difficilement observable) semble prometteur.

Le rapport se termine par des recommandations formulées à partir des résultats obtenus.

17. Mots clés
Avion, neige, bruine, pluie, antigivrage, liquide, durée d'efficacité, test, précipitation, aile, plaque, dégivrage, glace, capteur, température, épaisseur

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EXECUTIVE SUMMARY

At the request of the Transportation Development Centre (TDC) of Transport Canada, APS Aviation Inc. undertook a study to survey the thickness of de-icing and anti-icing fluid films on aircraft wings, to determine stabilized film thickness profiles as well as the rate of fluid film thinning.

The primary objective was to provide data on fluid thickness profiles on aircraft wings to support development of guidelines for defining locations best suited as representative surfaces. A representative aircraft surface is a portion of the aircraft which can be readily and clearly observed by flight crew from inside the aircraft to judge whether or not the surface has become contaminated.

As a primary influence on the onset of fluid failure is the thinning of the protective fluid layer, it has been suggested that effective locations for representative surfaces would be at those areas on the wings that experience early thinning during de-icing operations, and that are visible from the aircraft cabin.

Supplementary objectives were included to provide an improved understanding of the behaviour of de-icing and anti-icing fluid films on wings. These included:

- Comparison of fluid thickness on the aircraft wing with the thickness profile on a standard flat plate used for holdover time trials;
- Examination of thickness of Type IV fluid applied over Type I fluid versus application directly on a bare surface;
- Measurement of film thickness of Type IV fluid on a standard flat plate;
- Examination of the impact on thickness of the method of application (fluid sprayed from a garden sprayer or de-icing vehicle versus poured from a container);
- Examination of fluid thickness as the fluid becomes increasingly contaminated from precipitation and reaches the point of failure; and

- Exploring the viability of installing on the wing a surface with a profile designed to emulate the thickness of fluid experienced at early failure locations such as the leading edge. Such a surface could be used as a visual representative surface, or as a contaminant sensor head surface to enable data to be produced that is representative of fluid condition at the leading edge.

A test program to satisfy the study objectives was defined, and trials were conducted at the Air Canada de-icing centre at Dorval Airport in Montreal, employing aircraft made available by Air Canada. In conjunction with aircraft tests at Dorval Airport, further supplemental trials on flat plates were conducted in the National Research Council (NRC) Climatic Engineering Facility (CEF) cold chamber in Ottawa.

Data Collection

Trials were conducted on overnighting Air Canada aircraft (DC-9, A320, Canadair RJ) at the Air Canada de-icing centre at Dorval Airport.

Type I or Type IV fluid was applied by Air Canada de-icing personnel and fluid thickness was measured using wet film thickness gauges at a number of pre-selected points along three chords of the test wing. Fluid thickness measurements were initiated as soon as possible following spray application and continued until the thickness stabilized.

To address supplementary objectives, special test plates were fabricated and installed directly on the wing. Furthermore, tests were conducted at the NRC cold chamber on standard flat plates.

Results

Type I fluid thinned rapidly to a very thin film in about 4 to 6 minutes. The final film thickness was not sufficient to influence decisions on representative surface location.

Type IV fluid applied on a bare surface stabilized in about 12 to 14 minutes. Final film thickness was influenced by thickness of initial application (within the bounds of normal application) together with the slope of the wing surface and existence of gaps in the wing surface.

Type IV applied over Type I on aircraft wings indicated thinner final thickness as compared to Type IV on a bare wing. Variance in fluid application prevented firm conclusions, and tests on flat plates with controlled application were conducted to further investigate this question.

As expected, fluid film profiles over the entire wing chord demonstrated that the leading edge is the most critical area with a typical profile showing thin values of fluid film as the slope of the curvature becomes more steep. This effect can be magnified by escape of fluid under the rear edge of the leading edge slat as fluid flows forward from the main wing. The rear of the wing is the next most critical area with fluid film thicknesses progressively thinning from the high point of the wing to the trailing edge.

Distinctive areas unique to each aircraft were seen to demonstrate thinner fluid film than surrounding areas. The process for identifying representative areas for each aircraft type should entail a visual examination of an actual wing surface with a view to identifying and including any such irregularities.

Test surfaces designed to artificially induce film thinning experienced the same effect as the integral surfaces described in the previous paragraph, showing thinner final film values than the surrounding areas. This approach could be useful in the design of heads for fluid contamination sensors, providing an area with artificially induced fluid thinning that is truly representative of film thickness at the critical leading edge area.

The stabilized fluid thicknesses at most locations on the leading and trailing edge of the DC-9 and A320 aircraft wing were found to be between or greater than the fluid thickness ranging the 2.5 cm and 15 cm line of the standard flat plate subjected to the same conditions. For the Canadair RJ, the film thickness on the leading edge was found to be less than that of the flat plate at the 2.5 cm line.

The stabilized film thickness at the 15 cm line of the standard flat plate ranged from about 1.2 to 1.6 mm for five Type IV neat fluids tested at -9°C. This is approximately 40 times the thickness of Type I fluid and twice the thickness of Type II neat fluid.

When comparing Type IV film thickness in tests where the initial amount was tightly controlled, examining a one-step fluid application (on a bare plate) versus a two-step application (over Type I), the two-step method gave a thinner stabilized thickness. The potential impact on holdover time is discussed in related report TP 12896E.

Fluid shearing effects resulting from a sprayer application onto a standard plate were found to significantly degrade (reduce fluid thickness) some Type IV fluids.

Recommendations

- Key criteria to be included in guidelines for selecting an area to serve as a Representative Surface (for low wing aircraft) were documented and may be implemented. A satisfactory representative surface would include an area of the leading edge, the flight control surfaces at the rear of the wing, and any irregularities or discontinuities on the surface which may precipitate premature fluid thinning.

- Investigate the impact on holdover time of the two-step application of Type IV over heated Type I, using service aircraft and airline spray vehicles for tests.

- Conduct holdover time tests on Canadair RJ aircraft to ensure that standard flat plate test results apply.

- An information circular to operators is recommended to alert them to meet fluid manufacturers' recommendations for fluid application in order to obtain full holdover time benefits. An Air Carrier Advisory Circular to this effect is being issued by Transport Canada.

- Operator procedures should recognize the potential impact on fluid thinning and exposure of unprotected surfaces that may result from extension of leading edge slats and other flight control surfaces.

- It is recommended that a thorough investigation be made of the benefits and implications of designing contamination sensors with sensor head raised above the surrounding wing surface to emulate fluid condition experienced on the critical leading edge.

SOMMAIRE

À la demande du Centre de développement des transports (CDT), Transports Canada, les Services de planification en aviation Inc. (APS) ont lancé une étude visant à mesurer les profils d'épaisseur des liquides antigivrage et dégivrants sur une aile d'aéronef et à déterminer le profil d'épaisseur après qu'il se soit stabilisé ainsi que le taux d'amincissement des profils d'épaisseur de ces liquides.

Le but premier de la recherche était de déterminer les profils d'épaisseur sur une aile d'aéronef dans le but d'élaborer des lignes directrices concernant l'emplacement optimal des surfaces d'aile dites représentatives. Une surface est dite représentative lorsqu'elle est facilement et directement observable à partir du poste de pilotage de manière à pouvoir déterminer si cette surface est contaminée ou non.

Étant donné que le facteur premier dans la cessation de l'efficacité d'un liquide dégivrant est l'amincissement de la couche protectrice, il est proposé de situer les surfaces représentatives aux endroits de la voilure où l'amincissement commence à se manifester, une fois l'opération de dégivrage terminée, et en des endroits directement observables du poste de pilotage.

La recherche avait pour objectifs secondaires d'approfondir les connaissances concernant le comportement des liquides antigivrage et dégivrants sur une aile d'aéronef, c'est-à-dire :

- comparaison des profils d'épaisseur sur une aile d'aéronef et sur les plaques planes utilisées pour la détermination des durées d'efficacité;
- comparaison des profils d'épaisseur d'un liquide de type IV lorsqu'il est déposé sur un liquide de type I, et lorsqu'il est déposé directement sur une surface dégivrée;
- mesure des profils d'épaisseur d'un liquide de type IV déposé sur une plaque plane;
- effet sur le profil d'épaisseur de la méthode d'arrosage utilisée, à savoir pulvérisation avec une buse d'arrosage ou à partir d'un véhicule de dégivrage, par rapport à la méthode qui consiste à verser directement du récipient;

- détermination des profils d'épaisseur à mesure que la contamination augmente et lorsque le point de cessation de l'efficacité est atteint;

- étudier l'utilité éventuelle du procédé suivant : placer sur la voilure un profil permettant de reproduire fidèlement les profils d'épaisseur caractéristiques d'un bord d'attaque, lieu où la cessation de l'efficacité commence généralement. Ce profil expérimental pourrait être considéré comme une surface représentative observable visuellement, ou bien comme le lieu d'implantation de capteurs sur lesquels se reproduiront fidèlement les profils d'épaisseur caractéristiques d'un bord d'attaque.

Un programme d'essai a été défini et des tests ont été menés dans les installations de dégivrage d'Air Canada à l'aéroport de Dorval (Montréal), sur des avions mis à disposition par cette société. Parallèlement, des tests complémentaires sur plaques planes ont été menés dans le laboratoire de recherches climatiques du Conseil national de recherches à Ottawa.

Saisie de données

Les tests ont été menés durant la nuit sur des avions DC-9, A320 et Regional Jet de Canadair dans les installations de dégivrage d'Air Canada à l'aéroport de Dorval.

Réalisés par le personnel d'Air Canada, les tests ont consisté à déposer un liquide de type I ou IV et à mesurer à l'aide de jauges les profils d'épaisseur en certains endroits sélectionnés d'avance, situés sur trois cordes des voilures. Le mesurage des profils a commencé le plus tôt possible après la fin de l'opération d'arrosage et il s'est poursuivi jusqu'à ce que le stade de stabilisation ait été atteint.

Pour les besoins des tests complémentaires, des plaques spéciales avaient été fabriquées exprès et placées directement sur la voilure. Des tests ont été menés par ailleurs sur plaques planes dans la chambre froide du Conseil national de recherches.

Résultats

Il n'a fallu que de 4 à 6 minutes pour que le liquide de type I devienne une couche très fine, le profil final n'étant pas probant au point de permettre une détermination concernant l'emplacement éventuel des surfaces représentatives.

Le liquide de type IV sur surface dégivrée s'est stabilisé au bout de 12 à 14 minutes. Le profil final a été conditionné par l'épaisseur initiale (dans les limites normales prévues), par l'angle d'incurvation de la voilure et par l'existence ou non de fentes dans celle-ci (bec de sécurité).

Dans le cas d'un liquide de type IV déposé sur un de type I, les profils d'épaisseur finals sur la voilure ont été plus minces que lorsque le type IV est déposé sur une voilure dégivrée. Les différences dues aux méthodes d'arrosage n'ont pas permis de tirer des conclusions définitives et il a fallu mener des tests sur plaques planes dans des conditions contrôlées afin d'élucider cet aspect de la recherche.

Comme il avait été prévu, les profils d'épaisseur stabilisés sur le bord d'attaque correspondant à une corde de voilure donnée sont de plus en plus minces à mesure que s'accentue l'incurvation de la voilure, faisant du bord d'attaque l'endroit le plus critique, de ce point de vue. De plus, il a été observé que cet état de choses est aggravé par la présence d'une fente dans la voilure (bec de sécurité), dans laquelle s'écoule le liquide provenant de la partie plus épaisse de la voilure. Après le bord d'attaque, le bord de fuite constitue l'autre endroit critique, la couche de liquide devenant de plus en plus mince à mesure qu'il s'écoule du point où la voilure est la plus épaisse, vers les points où elle l'est moins.

Des zones précises, distinctes d'un type d'avion à l'autre, ont la particularité de présenter un profil d'épaisseur plus mince qu'ailleurs. Il faudra donc procéder à un examen attentif de la voilure de chaque type d'avion afin de reconnaître et de repérer les irrégularités qui peuvent s'y présenter et de la sorte bien situer les endroits où les surfaces représentatives pourraient être implantées.

Des surfaces ont été créées, ayant la particularité décrite dans le paragraphe précédent, c'est-à-dire de présenter un profil d'épaisseur plus mince qu'ailleurs. En créant sur une voilure une surface sur lesquelles se reproduisent les profils d'épaisseur caractéristiques d'un bord d'attaque, les chercheurs pourront étudier des capteurs susceptibles de servir d'indicateurs de l'état de contamination atteint en cet endroit.

Dans la plupart des endroits sélectionnés sur les bords d'attaque et de fuite du DC-9 et du A320, les profils d'épaisseur stabilisés mesurés ont été égaux ou supérieurs à l'épaisseur caractéristique de la plage séparant la ligne 2,5 cm de la ligne 15 cm sur une plaque plane standard, lorsque les conditions sont identiques. Dans le cas du RJ de Canadair, le profil d'épaisseur au bord d'attaque a été inférieur à l'épaisseur observable à la ligne 2,5 cm d'une plaque plane.

À -9 °C, et pour les cinq liquides de type IV utilisés purs, les profils d'épaisseur stabilisés à la ligne 15 cm d'une plaque plane standard ont varié de 1,2 à 1,6 mm, soit environ 40 fois l'épaisseur d'un liquide de type I et deux fois celle d'un liquide de type II pur.

Dans les tests où les épaisseurs initiales du liquide de type IV déposé avaient été rigoureusement vérifiées, il a été constaté que le liquide déposé sur une surface déjà dégivrée (procédure une étape) donnait une épaisseur stabilisée plus mince que lorsqu'il était déposé sur un liquide de type I (procédure 2 étapes). L'effet possible de ces procédures sur les durées d'efficacité est examiné dans un rapport connexe (TP 12896E).

Il a été constaté aussi que la méthode consistant à pulvériser les liquides de type IV sur une plaque plane standard produisait des forces de cisaillement qui détérioraient de façon significative les durées d'efficacité de ces liquides, en amincissant les couches déposées.

Recommandations

- Les critères sur la base desquels pourra se faire la sélection des surfaces représentatives (dans le cas des avions à voilure basse) ont été étudiés et seraient sur le point d'être adoptés. Pour être représentative, une surface doit comprendre une partie du bord d'attaque, les gouvernes dans le bord de fuite et toutes les irrégularités à la surface de la voilure de nature à provoquer un amincissement prématuré des couches de liquide.

- Examiner l'effet sur les durées d'efficacité de la procédure dite à 2 étapes par rapport à celle à 1 étape, utilisant pour cela des avions et les véhicules d'arrosage en service.

- Mener des tests de durées d'efficacité sur le Regional Jet de Canadair pour vérifier la validité des résultats tirés des tests sur plaques planes standard.

- Publier une circulaire recommandant aux exploitants de suivre les recommandations des fabricants de liquides quant à la méthode de leur application, afin d'en tirer tout le parti possible. Transports Canada s'apprête à lancer une circulaire à cet effet, destinée aux transporteurs aériens.

- Reconnaître dans les procédures mises en oeuvre l'amincissement possible des liquides et le risque de givrage qui peut s'ensuivre, lorsque le bec de sécurité est sorti et les autres gouvernes sont actionnées.

- Mener une étude approfondie sur les avantages et les contraintes découlant de la mise en oeuvre de capteurs dont la tête ferait saillie au-dessus de la voilure afin de reproduire en cet endroit les profils d'épaisseur caractéristiques des bords d'attaque.

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FIGURE NUMBER		PAGE NUMBER

PHOTOS NUMBER **PAGE NUMBER**

TABLES NUMBER **PAGE NUMBER**

LIST OF ACRONYMS

ACAC	Air Carrier Advisory Circular
AES	Atmospheric Environment Services (Canada)
APS	APS Aviation Inc.
CEF	Climatic Engineering Facility
C/FIMS	Contaminant/Fluid Integrity Monitoring System
ISO	International Standards Organization
L	Leading Edge
NRC	National Research Council
SAE	Society of Automotive Engineers
T	Trailing Edge
TDC	Transportation Development Centre
WSET	Water Spray Endurance Test

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1. INTRODUCTION

At the request of the Transportation Development Centre (TDC) of Transport Canada, APS Aviation Inc. undertook a study to survey the thickness of de-icing and anti-icing fluid films on aircraft wings to determine stabilized film thickness profiles as well as the rate of fluid film thinning. Appendix D presents the detailed statement of work for this project and the entire program.

The primary objective and initial intent of the study was to provide data on fluid thickness profiles on aircraft wings to support development of guidelines for defining best locations for representative surfaces. A limited activity to determine the thickness decay rate of fluids on aircraft wings was conducted and reported during the 1993/94 Winter test program(1)* to determine fluid holdover times. Appendix B illustrates typical results from that activity.

As preparation for the study progressed, it was recognized that an improved understanding of the thickness behaviour of de-icing and anti-icing fluid films on wings would be useful in deliberations on several related issues. Consequently, supplementary objectives and test activities were included in the test plan.

A representative aircraft surface is a portion of the aircraft wing which can be readily and clearly observed by flight crew from inside the aircraft in order to judge whether or not the surface has become contaminated. By determining the state of the representative surface, it can then be reasonably expected that other critical surfaces are in the same (or better) condition.

The concept of representative surfaces as an indication of wing contamination has been approved by authorities for use by air carriers in their aircraft operations. Surfaces selected by the air carrier as being representative are submitted to appropriate authorities for approval.

* Number in brackets denotes reference given at the end of the report.

During the 1994/95 Winter field tests on aircraft[2] (which were designed to validate fluid failure times determined in tests utilizing flat plates), it was observed that the representative surface concept was not fully effective as earlier failure frequently occurred elsewhere on the wing. That study recommended further investigation of the concept of representative surfaces.

Observations of initial fluid failure location and failure progression indicate that critical wing areas are the leading and trailing edges, and flight control surfaces that are shielded from fluid flowdown by gaps in the wing surface at their forward edges. Fluid thinning in these areas is believed to be the major contributor to early local fluid failure, with failure then progressively extending from these points.

Because the thinning of the protective fluid layer is a primary factor influencing the onset of failure, it has been suggested that effective locations for representative surfaces be wing areas exhibiting early film thinning during de-icing operations and that are visible from the aircraft cabin.

The objective of this study was to measure the thickness of stabilized fluid on aircraft wings, to identify potential locations for representative surfaces on test wings based on early thinning of fluid, and then to develop generic criteria for locating representative surfaces for all aircraft. The study examines the pattern of fluid thickness established over the surface of the wing in the absence of normal de-icing conditions such as precipitation and wind. While these factors would influence fluid thickness, conclusions drawn from the base case should still be valid.

Supplementary objectives to provide improved understanding of de-icing and anti-icing fluid film thickness behaviour on wings included:

1. The comparison of fluid thickness on the aircraft wing with the thickness profile on a standard flat plate used for holdover time trials;

2. The comparison of thickness of Type IV fluid applied over Type I fluid with the thickness of Type IV fluid applied directly to a surface;

3. Measurement of film thickness of Type IV fluid on standard flat plates;

4. Establishing how the method of application (pouring vs backpack sprayer vs de-icing vehicle) affects the thickness of the fluid layer;

5. An examination of the decrease in fluid thickness upon dilution or contamination from natural or artificial precipitation (to the point of failure); and

6. Exploring the viability of installing a small test surface on the airplane wing which emulates the surface conditions on wing areas subject to early thinning of fluid. Such a surface could be used as a visual representative surface, or as a surface for mounting a contaminant sensor head to enable continuous instrument monitoring of critical wing surface conditions.

A test program to satisfy the study objectives was defined, and trials were conducted at the Air Canada de-icing centre at Dorval Airport (Montreal) employing aircraft made available by Air Canada. Further supplemental trials on flat plates were conducted in the National Research Council (NRC) Climatic Engineering Facility (CEF) cold chamber in Ottawa, and in conjunction with aircraft tests at Dorval Airport.

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2. METHODOLOGY

The methodology description is presented in six sections which deal with test sites, equipment, test procedures and data forms, fluids, personnel and participants, and analysis methodology.

2.1 Test Sites

Field aircraft trials were conducted at the Air Canada de-icing centre at Dorval Airport (Montreal). This enabled access to overnighting aircraft and de-icing facilities as employed by Air Canada. Test aircraft included DC-9, A320 and Canadair RJ aircraft.

APS Aviation coordinated the tests seeking test weather conditions with an ambient outside air temperature in the range of -10°C to 0°C, calm winds, overcast or night skies, and no precipitation. Meteorological data was made available from Environment Canada's automated weather station situated at a site in close proximity to the de-icing centre.

Supplementary laboratory tests on flat plates were conducted in the National Research Council (NRC) Climatic Engineering Facility (CEF) cold chamber at Ottawa, taking advantage of periods when the facility was in use for fluid holdover time trials. The cold chamber facility enabled control of temperature, wind, and type and rate of precipitation.

Trials at the NRC were conducted:

- to determine the thickness profile of the new Type IV fluids on flat plates;
- to determine the effect of temperature on the fluid;
- to determine the effect of Type IV fluid applied over Type I; and
- to study the effects of using a sprayer for fluid application.

2.2 Equipment

Test aircraft were provided by Air Canada and included Canadair RJ, DC-9 and A320 aircraft.

The most significant instrument in this study was the gauge used to measure fluid thickness. A review of various types of wet film thickness measuring instruments eventually settled on a simple thickness gauge based on a standard painter's gauge design. The Octagon wet film thickness gauge (Figure 2.1) manufactured by Gardco was chosen for the task as it provided a range of thicknesses suitable for the fluids being tested (0.4 mil to 400 mil or 0.01 mm to 10.2 mm). The procedure for reading this type of gauge involves identifying the last tooth that is wetted, and recording that tooth depth. The actual fluid thickness is then calculated as the midpoint of the depth of that tooth and that of the next unwetted tooth. Fluid thickness measured in "mils" was converted to "mm" in the report.

To enable measurement of positions over the centre of the wing, the Octagon gauge was mounted at the end of a handle. Two different handle lengths were used, 18 inches (45 cm) and 60 inches (150 cm). Photo 2.1 gives an illustration of this set-up. Test observers also used the gauge without handle when measuring points within reach near the edge of the wing.

The Octagon gauge provided acceptable results. Experience showed that the gauge had to be handled and stored with care as the measuring teeth were easily bent. Lengths of PVC pipe were taped to the observer's stairs to serve as a holder for those gauges fitted with handles.

The second rectangular wet film gauge shown in Figure 2.1 was used to supplement the Octagon gauge during the initial test, as it offered a finer detail of film thickness in lower ranges. The rectangular gauge usually provided a range sufficient for the

FIGURE 2.1

WET FILM THICKNESS GAUGES

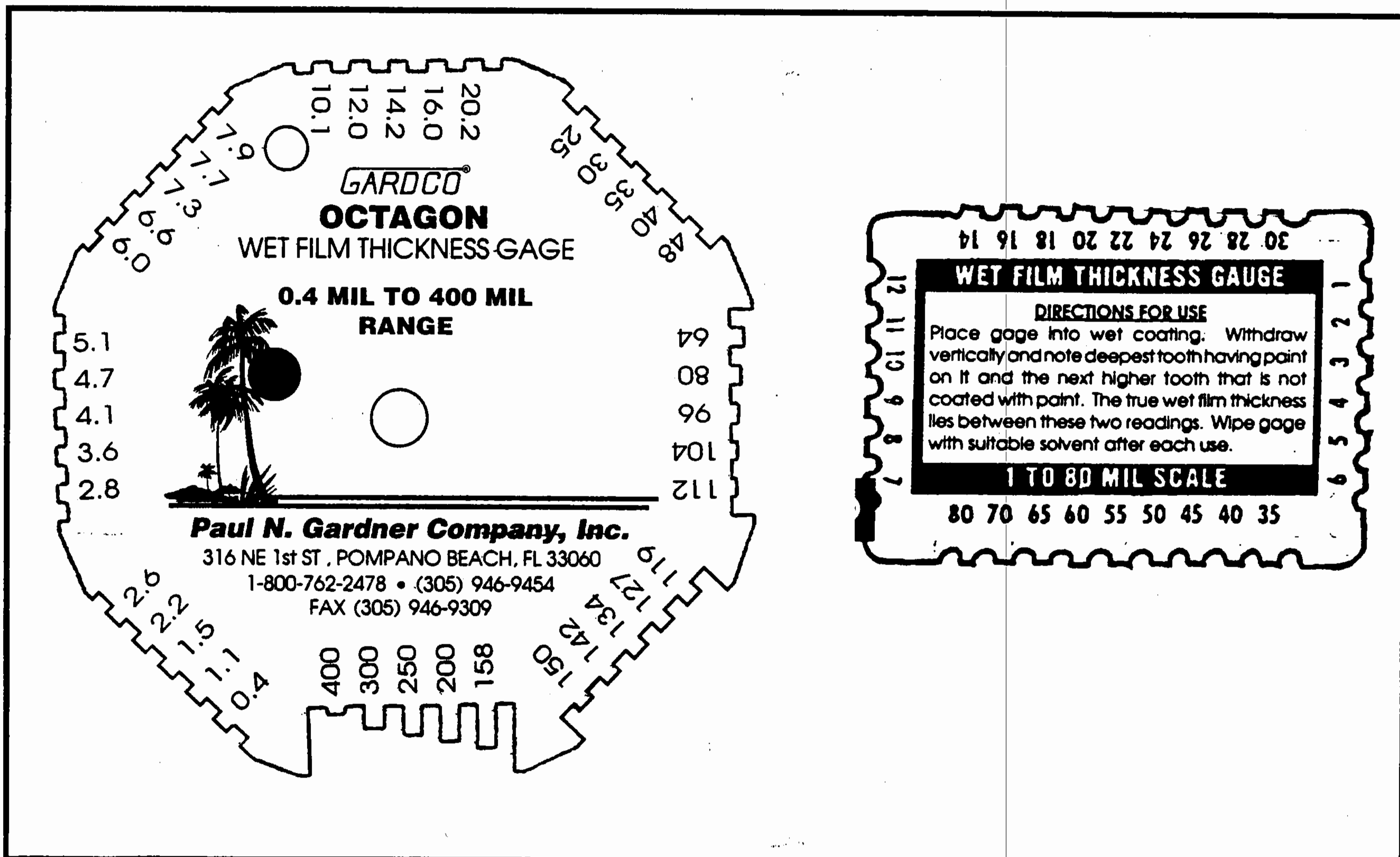

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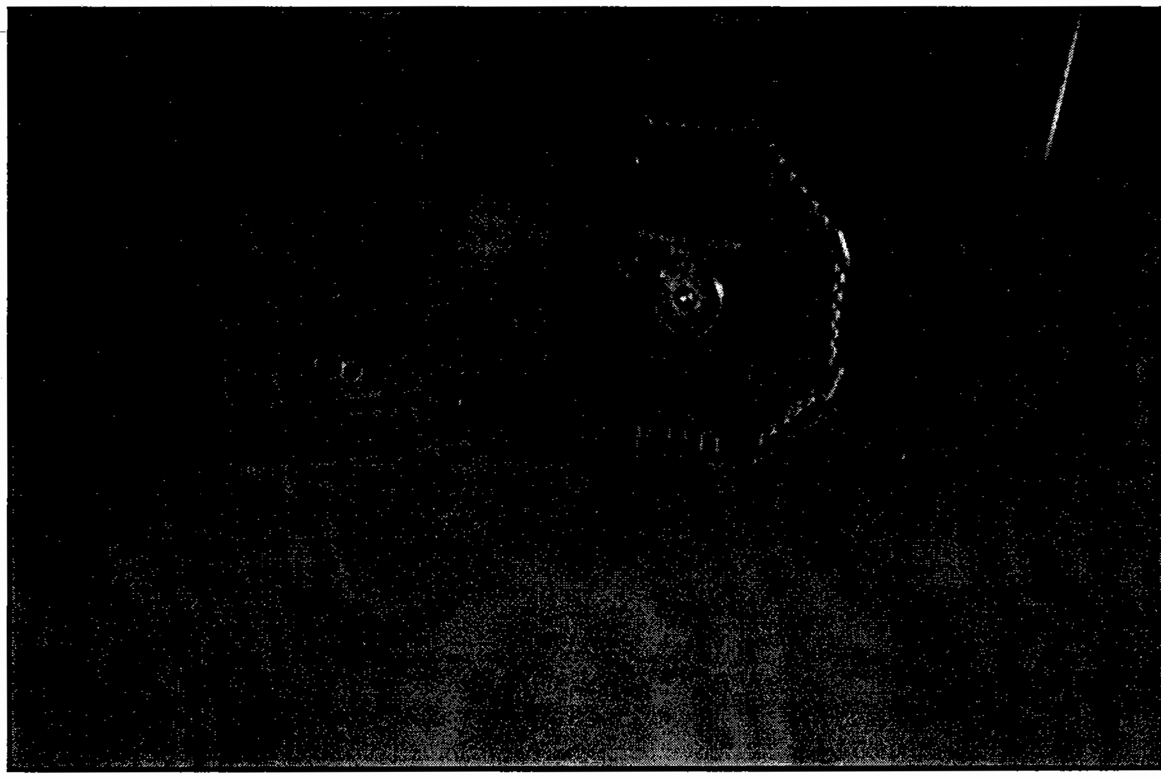
PHOTO 2.1

FLUID THICKNESS GAUGES ILLUSTRATING OCTAGON GAUGE FITTED WITH EXTENSION HANDLE



measurement of fluid thickness on flat plates, and was used for plate measurements after the initial test. Its use was discontinued for the aircraft measurements due to the complication of handling two gauges with the associated handles and subsequently reconciling data gathered from two different instruments.

Because tests were conducted at night it was necessary to provide observers with a supplemental individual source of light to enable identification of which teeth were wetted on the test gauge. Head mounted flashlights (head lamps) were acquired, which allowed the light beam to be directed on the gauge by movement of the head.

Voice recorders were used to record data, freeing the observer from the problem of handling paper forms and clipboards. A wipe cloth with a clip for attaching to the observers outer wear was part of each observers equipment. Photos 2.2, 2.3 and 2.4 depict the equipment in use during the trials.

Air Canada de-icing trucks were used to spray fluid for the trials. A nozzle recommended for use with Union Carbide's Ultra fluid (Appendix C, Task Force Tips® Anti-Icing Nozzle) had been installed on one de-icing vehicle prior to commencing these tests. Initial trials using this truck/nozzle combination during tests on the Canadair RJ aircraft (February 15, 1996), resulted in spray delivery of a Ultra fluid contaminated with Type I. Because the problem could not be quickly resolved, a different truck, equipped with an Akron nozzle, was substituted after the first two runs and fluid was applied in all subsequent tests using the Akron nozzle.

To address supplementary objectives of the study, special test plates were fabricated. The first set of special plates were designed to be mounted directly on the aircraft wing, and were intended to stimulate fluid thinning to represent fluid thicknesses at early failure points such as the leading edge. Two shapes of plates were fabricated; circular disks of 2" (5 cm) radius, 1/4" (0.64 cm) thick, with bevelled edges, and rectangular plates 9" x 12" x 1/4" (23 x 30 x 0.64 cm) with bevelled edges. These plates are illustrated in Photo 2.5 and Figure 2.2 . These plates were mounted at

PHOTO 2.2
MEASURING FLUID THICKNESS USING OCTAGON GAUGE WITH EXTENSION HANDLE AND HEADLAMP

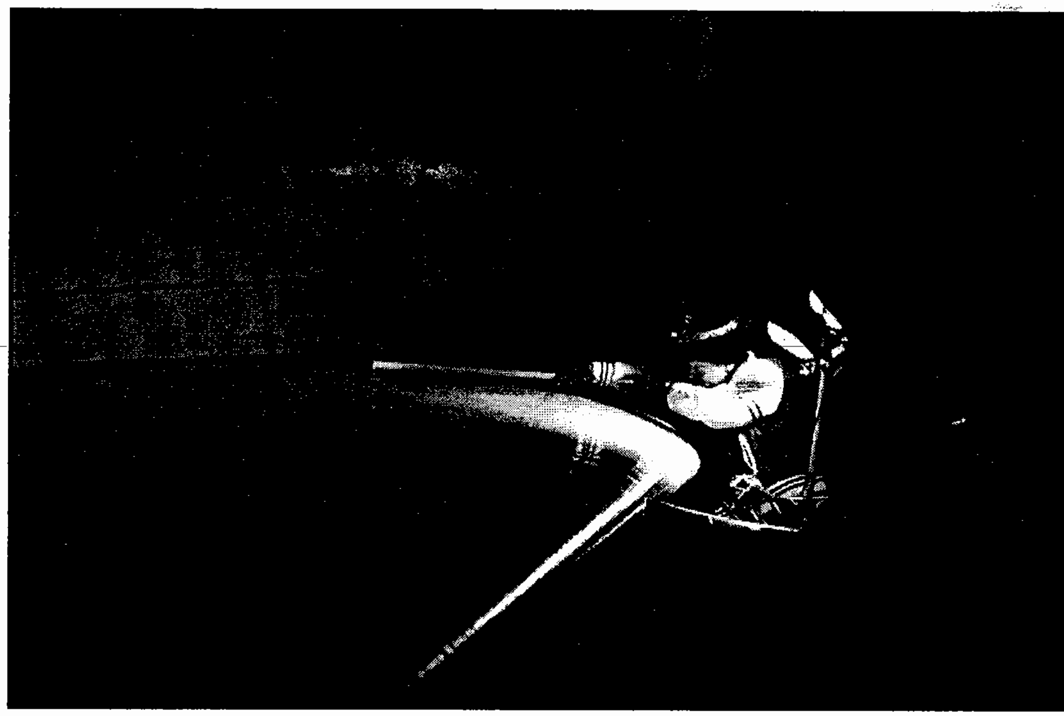


PHOTO 2.3
MEASURING FLUID THICKNESS USING OCTAGON GAUGE WITHOUT EXTENSION AND HEADLAMP

PHOTO 2.4
MEASURING FLUID THICKNESS ON FLAT PLATE

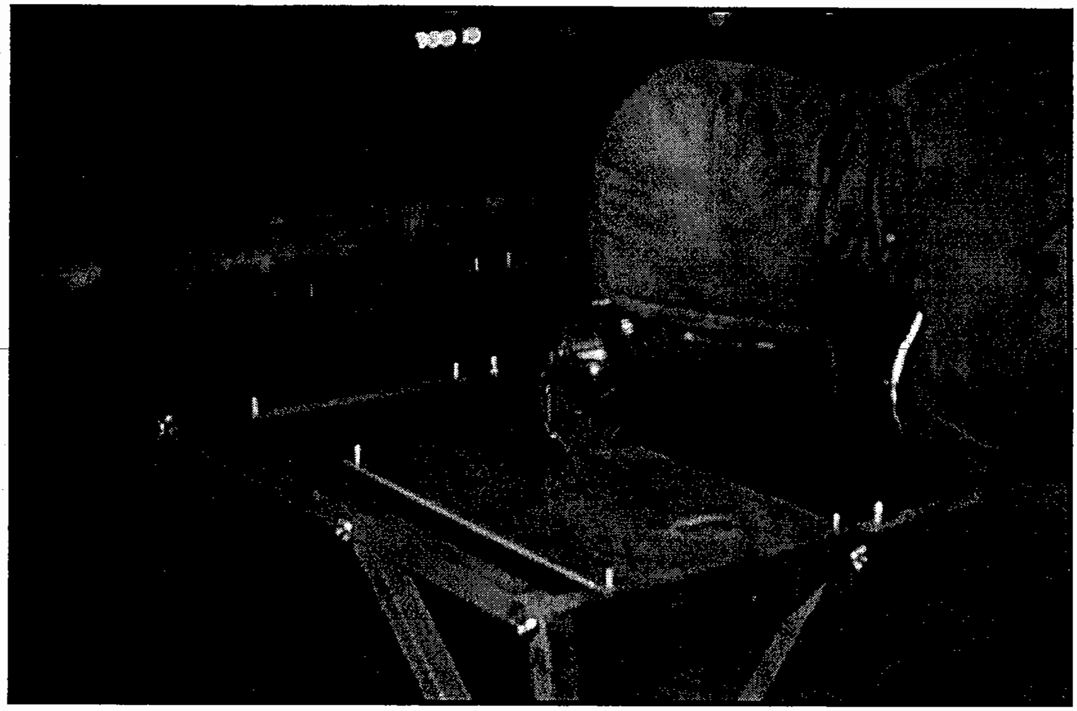


PHOTO 2.5
SPECIAL PLATES TO STIMULATE FLUID THINNING

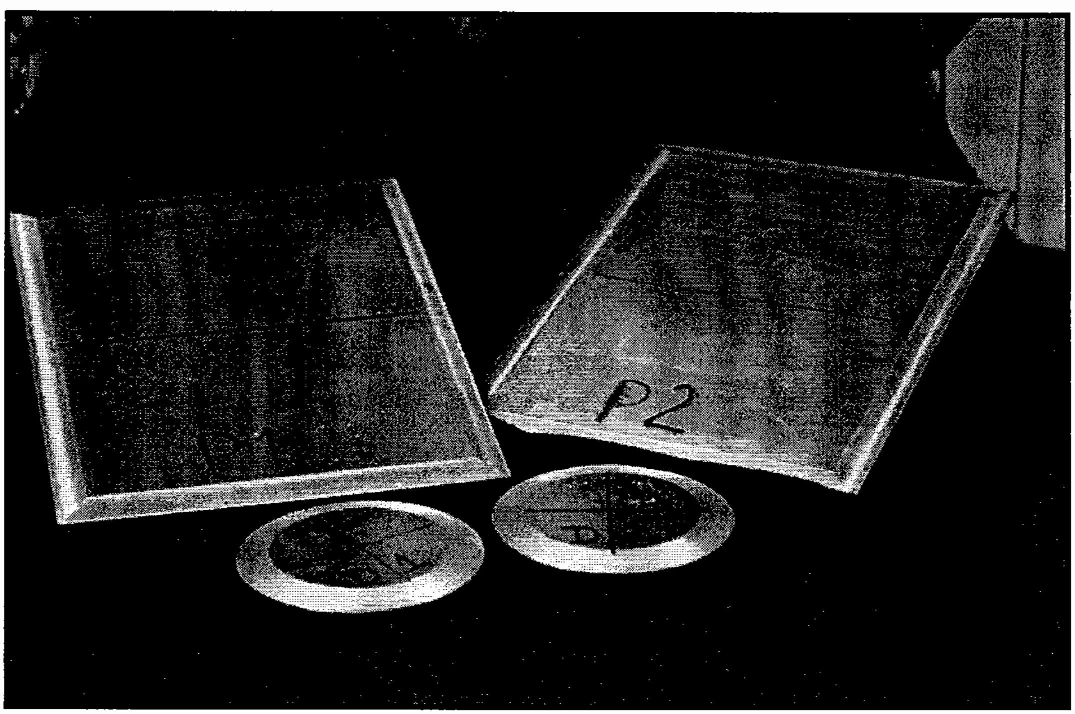
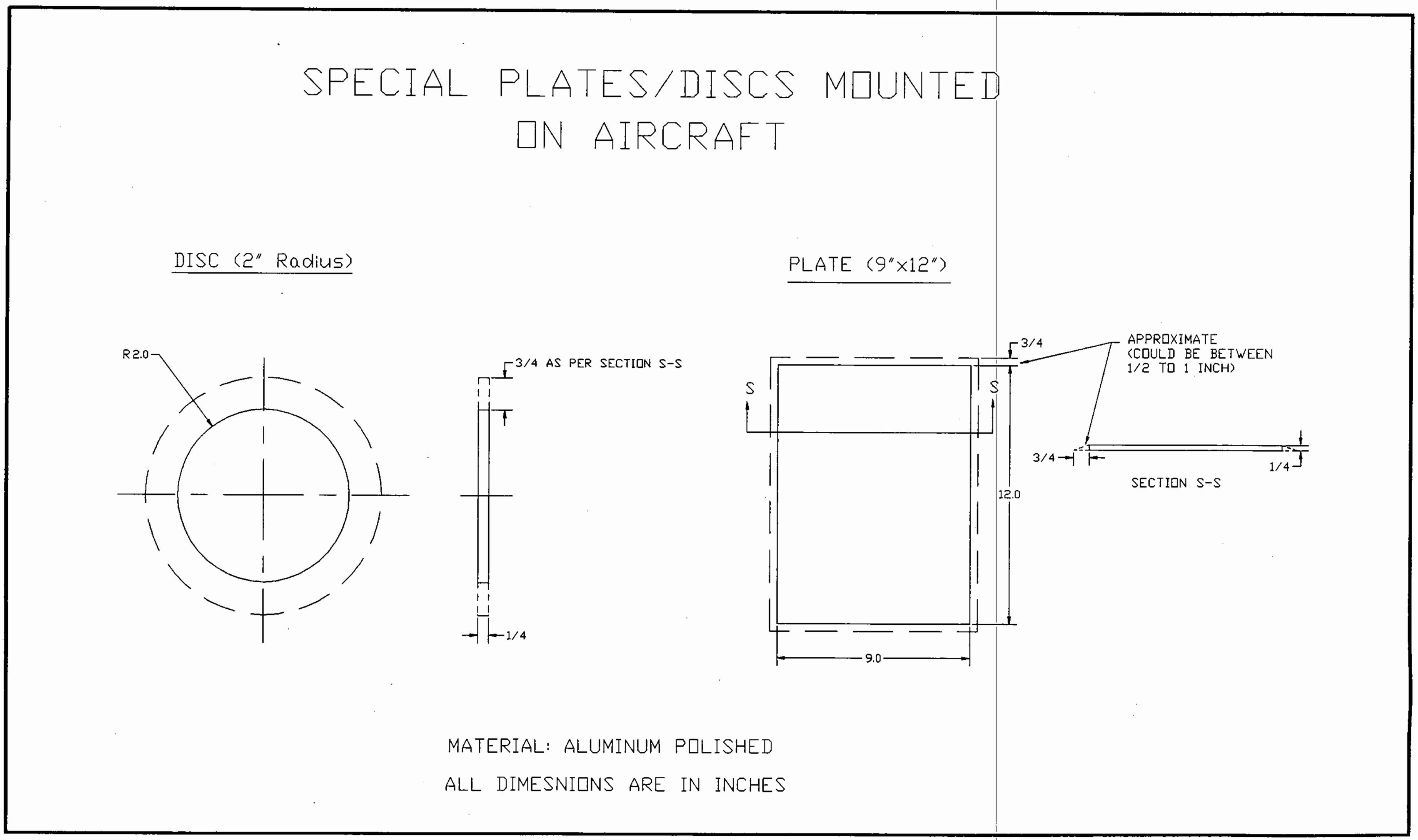


FIGURE 2.2



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selected locations directly on the aircraft wing using aluminum speed tape. Fluid thickness was measured at the centre of the circular disc, and at the 1" (2.5 cm) and 6" (15 cm) line of the plate.

The second set of special plates was intended to enable a comparison of thickness of fluid as sprayed by the de-icing truck to that applied by pouring (standard fluid holdover time flat plate test procedure). These plates were comprised of flat plates used in holdover time trials modified by the addition of adjustable length legs fitted with suction cups to enable installation on the wing surface. The plate which was to be subjected to de-icing truck spray was designed with a surrounding skirt to simulate distribution of fluid by splashing as is experienced on a real wing surface during spraying. The second plate (on which fluid was applied by pouring) did not have a surrounding skirt. Installation of the plates included adjustment of slope to reflect plate attitude when installed on flat plate test stands. Photos 2.6, 2.7, 2.8 and 2.9 illustrate these plates in position on the wing. These plates performed satisfactorily for the intended purpose, with the suction cup feet providing adequate grip to the wing skin.

Standard flat plate stands from fluid holdover time trials were used to measure film thickness on flat plates (Photo 2.4). Section 2.3.2 describes the procedures used for measuring fluid thickness on a standard flat plate.

A complete equipment list for fluid thickness tests on aircraft is included in Appendix A (Experimental Program to Establish Film Thickness Profiles for De-icing and Anti-icing Fluids on Aircraft Wings). For the flat plates, a similar list of equipment to the one contained in Appendix A is included in Appendix G (Experimental Program to Establish Film Thickness Profiles for De-icing and Anti-icing Fluids on Flat Plates).

PHOTO 2.6
MOUNTING SPECIAL FLAT PLATE ON WING

PHOTO 2.7
LEVELLING PLATE TO CONFORM TO TEST STAND INSTALLATION

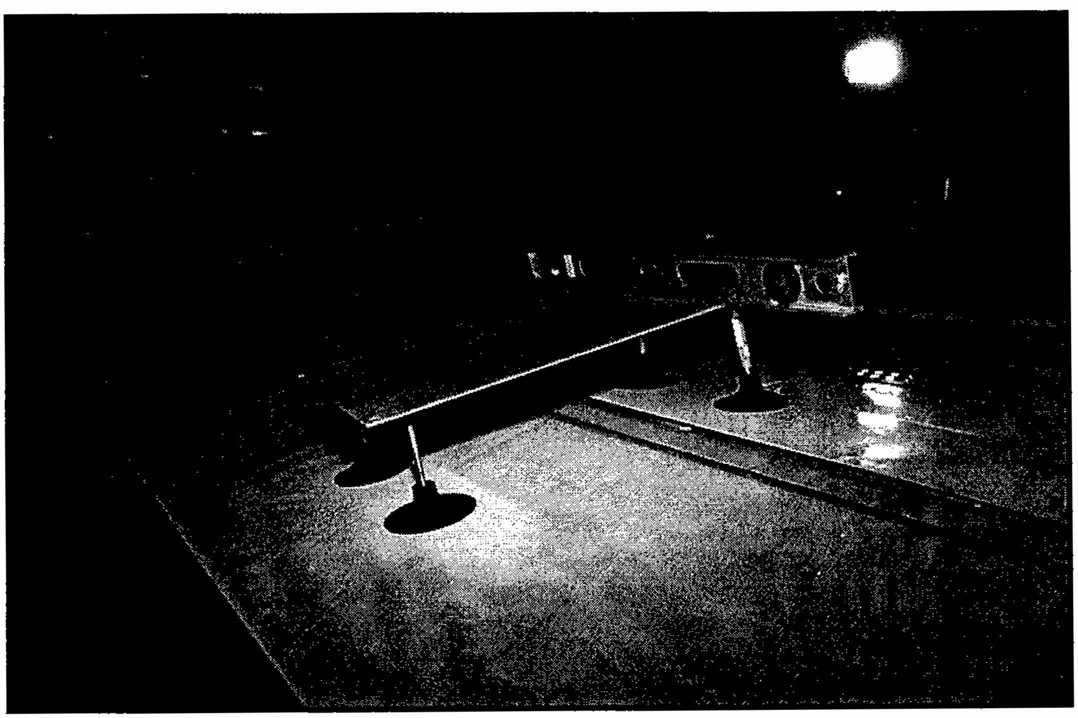


PHOTO 2.8
TWO TYPES OF PLATES - ONE WITH SURROUNDING SKIRT AND ONE WITHOUT

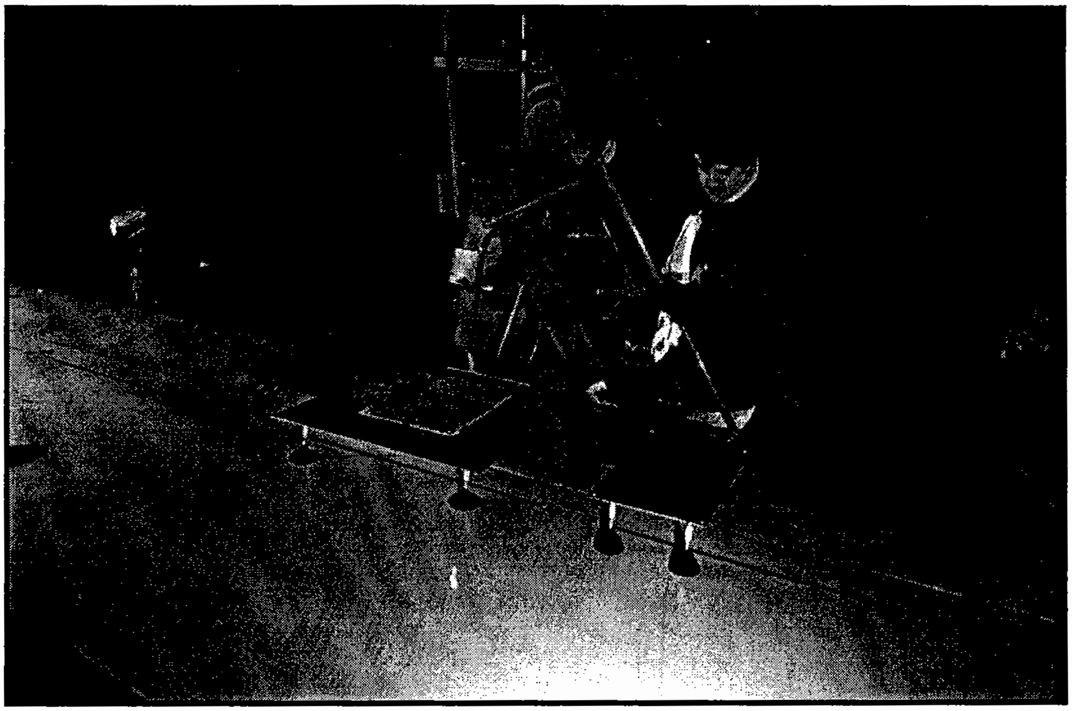
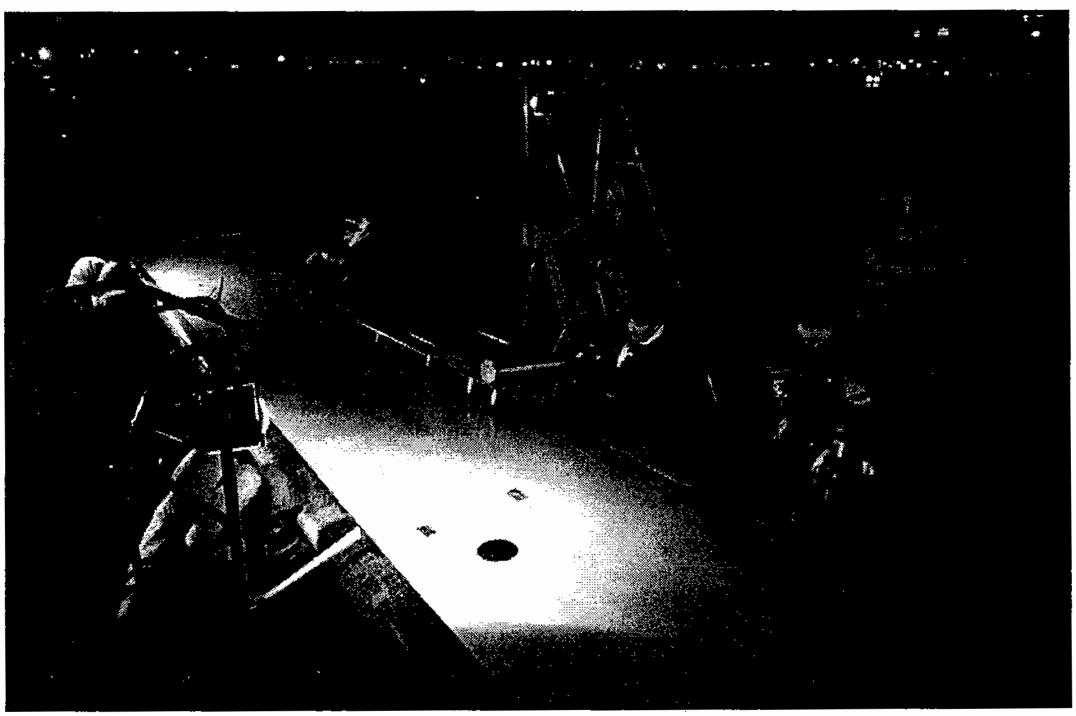


PHOTO 2.9
MEASURING FLUID THICKNESS ON SPECIAL PLATES INSTALLED ON WING



2.3 Test Procedures and Data Forms

2.3.1 Aircraft Trials

Weather forecasts were monitored and tests initiated in conditions of outside air temperature of -10°C to 0°C, calm winds, overcast or night skies, and no precipitation.

The test plan (Figure 2.3) specified three fluid types (Ultra on Bare Wing, Ultra over Type I, Type I) with two test runs for each fluid type. Application of fluids was performed by Air Canada personnel using Air Canada de-icing vehicles.

2.3.1.1 Locations on the wing for measuring thickness

Locations for measuring thickness were predefined and illustrated on a wing plan form (Figures 2.4 to 2.6). Locations were selected to reflect fluid thickness at specific areas of interest such as the leading edge (where several points were identified), the top of the wing, the trailing edge, and at gaps in the wing surface where flight control panels were located. At these gaps, measures were taken both upstream and downstream from the gap to identify any fluid escape via the gap, and any consequent fluid thinning downstream of the gap. Specifically, these measurement points were located at 1" and 6" (2.5 and 15 cm) distances from the gap to enable comparison with corresponding lines on standard flat plates. Additionally at observer location T3 (trailing edge of chord 3) further measurement points were identified to provide greater detail. Detail A in Figure 2.4 provides an illustration of this detail for position T3, and shows that points on the edge of gaps were included.

On the leading edge, points selected were on the nose (where the tangent to the curvature is 90° to the horizontal), 1" (2.5 cm) forward of the juncture of the leading edge with the wing structure, and at one or more points on the curve of

FIGURE 2.3

FLUID THICKNESS PROFILE TESTS
TEST PLAN

RUN #	OCCASION #	FLUID Type	A/C Type
1	1	ULTRA on Bare Wing	DC-9
2	1	ULTRA on Bare Wing	
3	1	ULTRA over Type I	
4	1	ULTRA over Type I	
5	1	Type I	
6	1	Type I	
7	2	ULTRA on Bare Wing	RJ
8	2	ULTRA on Bare Wing	
9	2	ULTRA over Type I	
10	2	ULTRA over Type I	
11	2	Type I	
12	2	Type I	
13	3	ULTRA on Bare Wing	A320
14	3	ULTRA on Bare Wing	
15	3	ULTRA over Type I	
16	3	ULTRA over Type I	
17	3	Type I	
18	3	Type I	

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FIGURE 2.4

DC-9 SERIES 30 AIRCRAFT WING PLAN
LOCATIONS FOR FLUID THICKNESS MEASUREMENTS
LOCATIONS FOR MOUNTING OF SPECIAL PLATES/DISCS

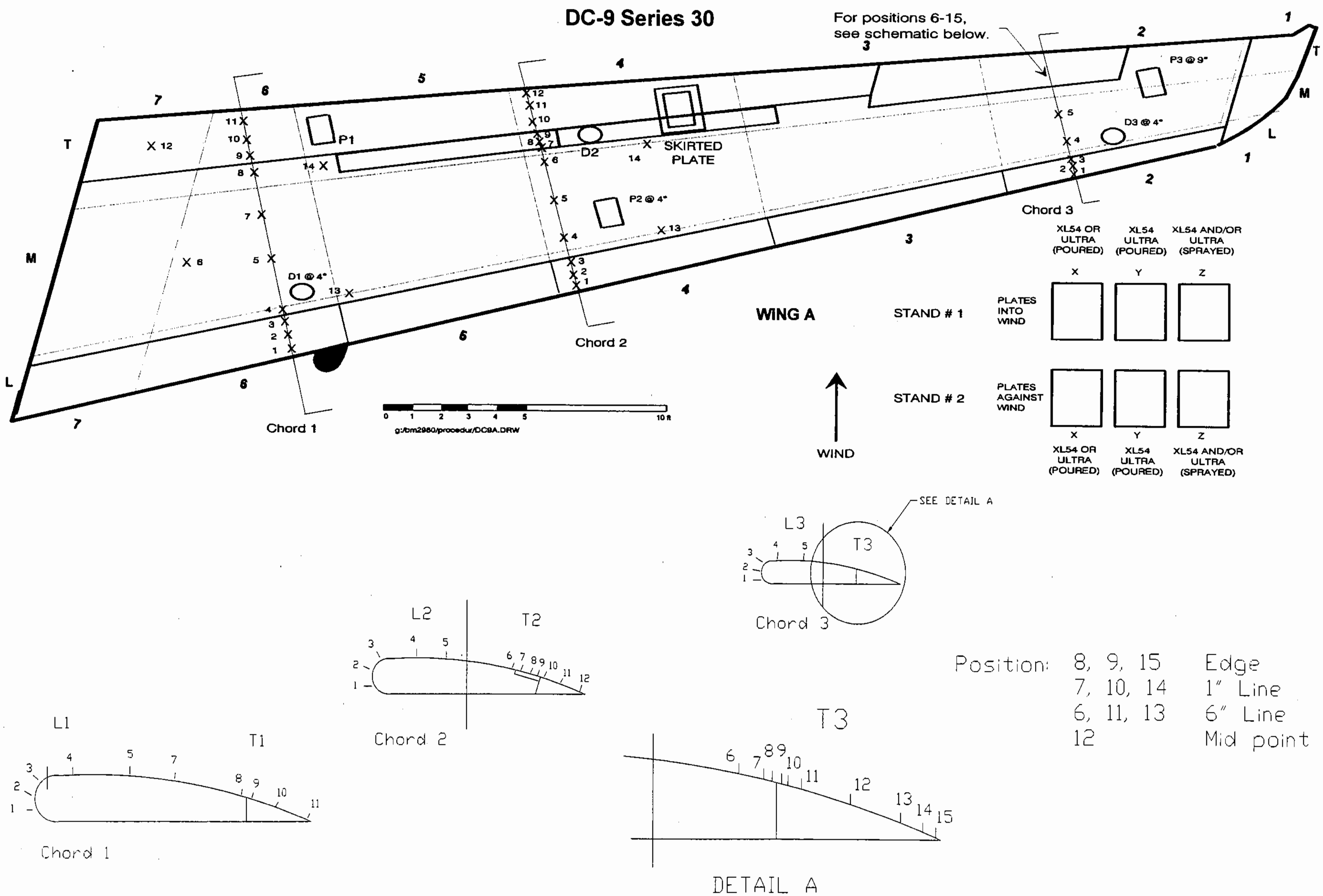

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FIGURE 2.5

A320 AIRCRAFT WING PLAN

LOCATIONS FOR FLUID THICKNESS MEASUREMENTS

A320

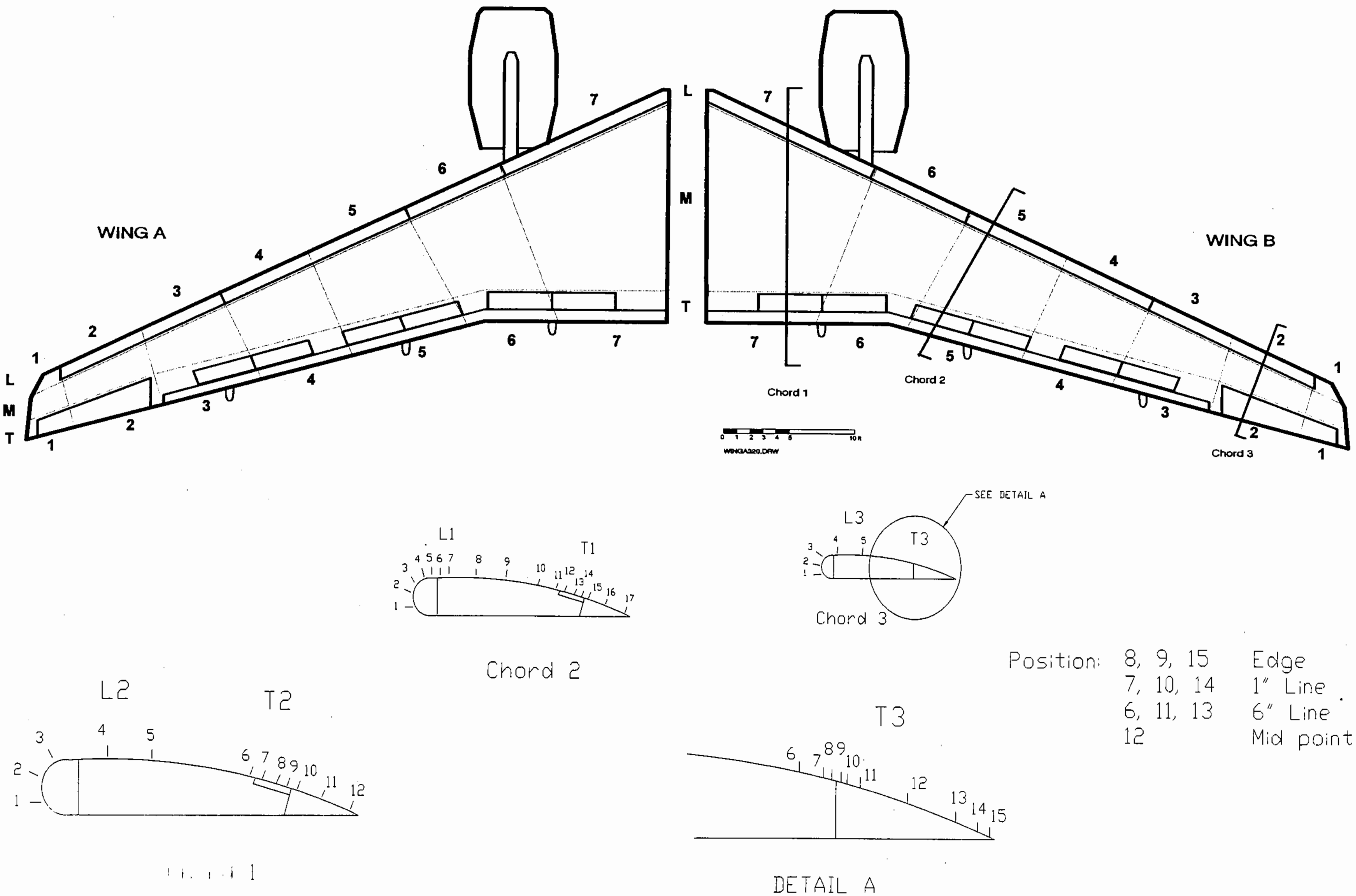

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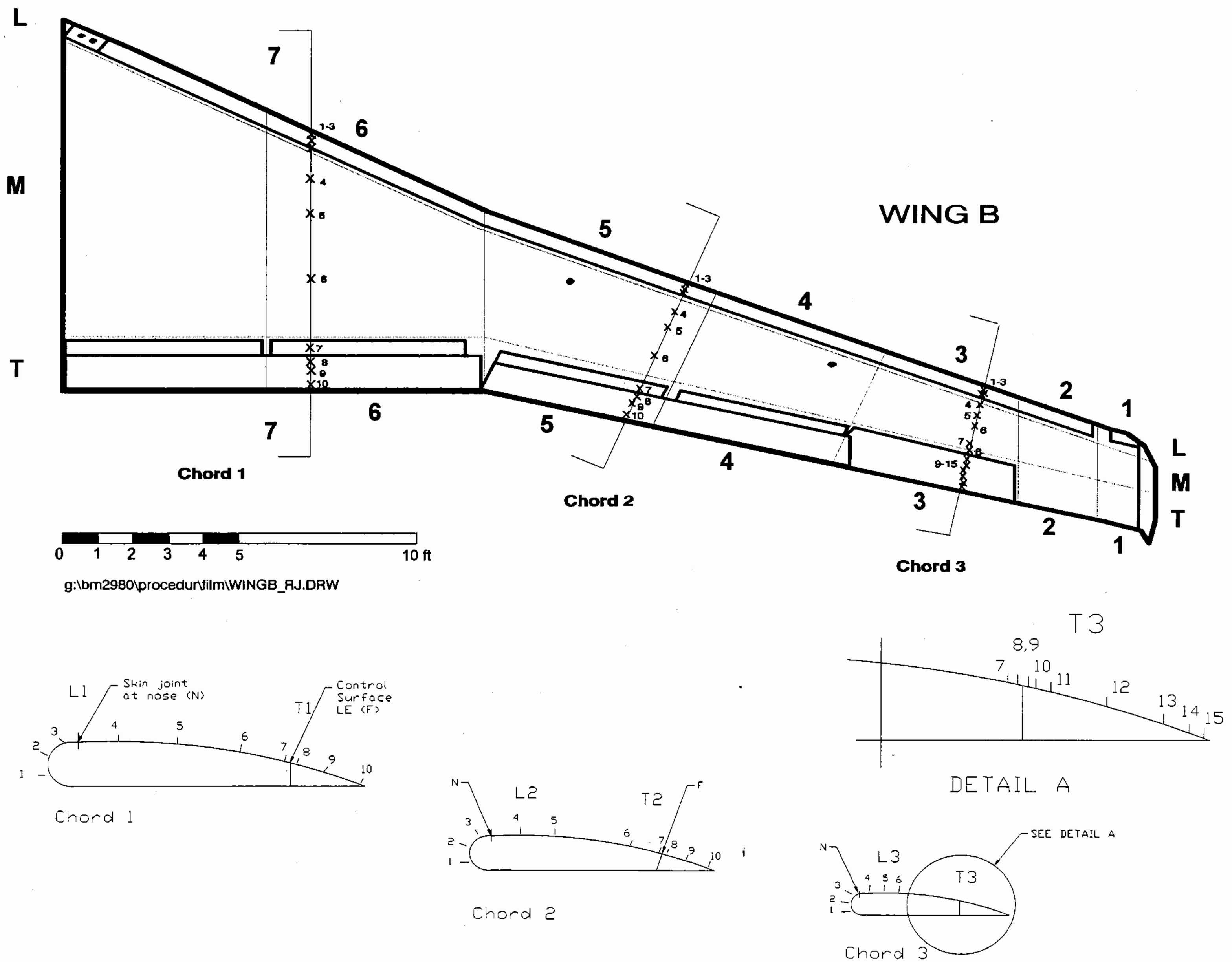
FIGURE 2.6

CANADAIR RJ AIRCRAFT WING PLAN
LOCATIONS FOR FLUID THICKNESS MEASUREMENTS



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the leading edge with the wing structure, and at one or more points on the curve of the leading edge in between these two points. In preparation for tests, on each test occasion small segments of aluminum tape were applied to the aircraft wing at each measurement location, with the reference index for that location noted on the tape. The location of each fluid thickness measurement point was measured and identified in relation to noted aircraft structural reference points.

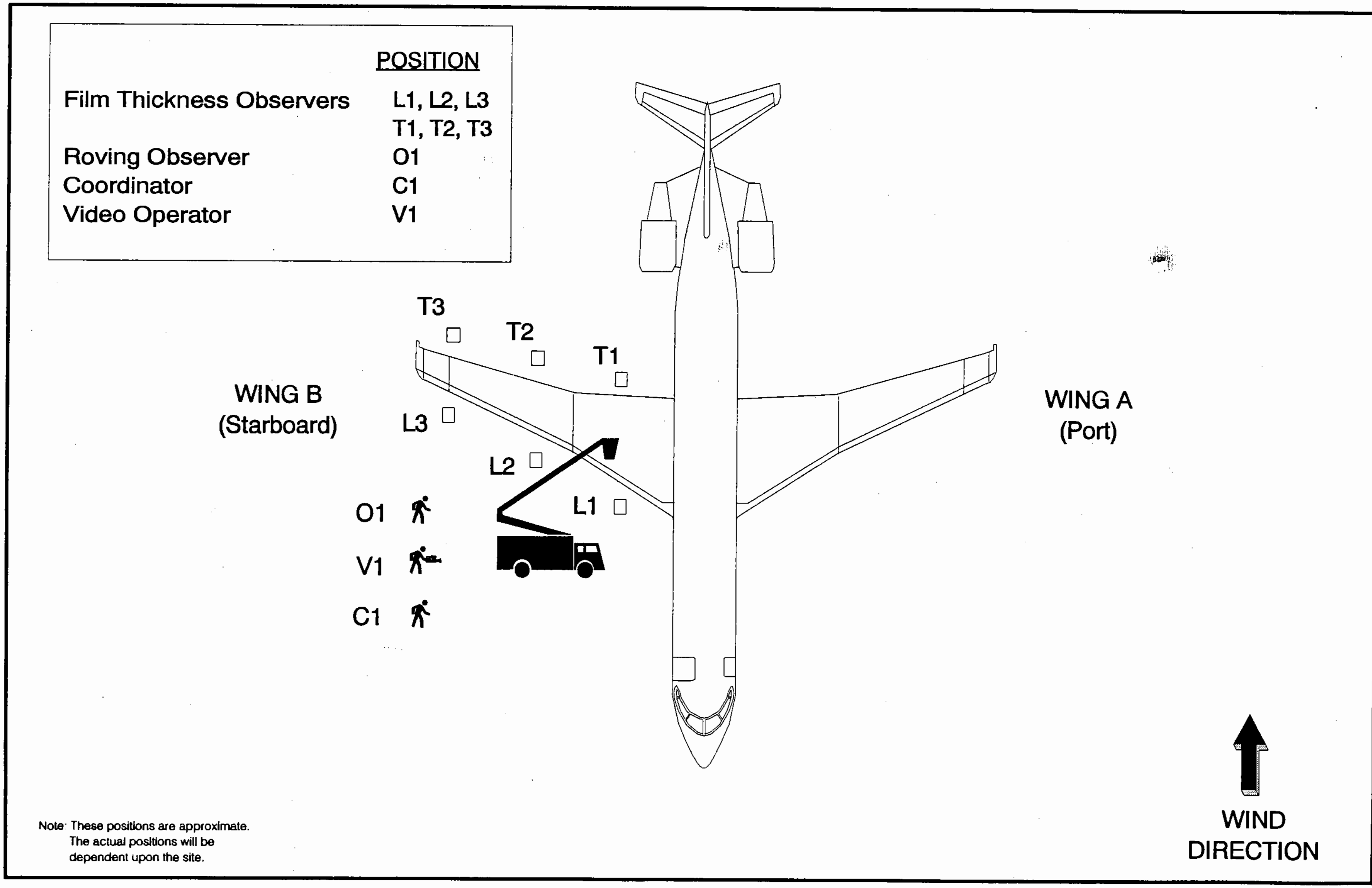
Fluid thickness measurement locations for the DC-9 and Canadair RJ aircraft were planned along three chords of the test wing, with locations on each chord selected to give attention to critical areas where rapid thinning was expected, such as the leading edge, and the forward area of flight control panels. Measurement on the A320 wing was limited to two chords due to the need for taller access stands capable of reaching its higher wing. The Canadair RJ aircraft, in contrast, did not require stairs to reach measurement points. Prior to commencing the tests, the test wing was examined to identify any apparent raised surfaces or peculiarities that might experience faster than normal thinning, and these were included in the measurement procedure. Temperature of the wing surface was measured to identify any cold-soak wing condition (none of the test aircraft had cold-soaked wings).

2.3.1.2 Procedure for measuring thickness

Observers responsible for recording fluid thickness measurements were positioned on stairs at the wing leading and trailing edge at each planned chord, as illustrated in Figure 2.7. Each observer was assigned a specific set of measurement locations which were monitored on a continuous basis until thickness was judged to have stabilized. Trials were terminated when observers reported that thickness values were no longer decreasing.

FIGURE 2.7

POSITION OF EQUIPMENT AND PERSONNEL FLUID THICKNESS PROFILE TESTS



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Attention was given to obtaining initial fluid thickness data immediately following spray application. As soon as the final spray application had passed each chord, the observers assigned to that chord quickly moved their stairs to the wing edge and commenced data acquisition.

Data readings were recorded on voice recorders following a set pattern; first stating the reference location index, then the time, then the thickness gauge reading. Data from tapes was subsequently transcribed to data sheets (Figure 2.8) arranged in the same format, and then entered in a spreadsheet for analysis.

As a precaution against loss of the entire data in the event of malfunction of any individual observer's recorder, observers at the leading and trailing edge of each chord were switched for the final reading just prior to the end of each test run. A final redundancy of writing results was opted for by some test personnel to prevent loss of data from equipment malfunction.

2.3.1.3 Measuring thickness on special plates

Prior to commencing trials on each test occasion, the special plates were installed on the wing. Location and angle of the plates were measured and recorded. Figure 2.4 illustrates the locations of the special plates. In certain tests, plates were located near test chords to enable thickness measurement by chord observers, while in other tests dedicated observers were assigned to measure fluid thickness on wing mounted plates and on flat plates mounted on flat plate stands.

Recall that these special plates mounted on the wing were sprayed from the de-icing truck. For the small disks and plates, fluid was applied exactly like the wing. For the larger skirted and non-skirted plates, fluid was applied using the procedure developed in Figure 2.9.

FIGURE 2.8

FLUID THICKNESS TEST DATA SHEETS

TEST DATE: ____________

RUN NUMBER: ____________

POSITION/CHORD: ____________

LOCATION: YUL

OBSERVER'S NAME: ____________

TRANSCRIBER'S NAME: ____________

POSITION:		POSITION:		POSITION:		POSITION:		POSITION:		POSITION:		POSITION:		POSITION:		POSITION:		POSITION:	
TIME (hh:mm:ss)	GA. (MIL)	TIME (hh:mm:ss)	GA. (MIL)	TIME (hh:mm:ss)	GA. (MIL)	TIME (hh:mm:ss)	GA. (MIL)	TIME (hh:mm:ss)	GA. (MIL)	TIME (hh:mm:ss)	GA. (MIL)	TIME (hh:mm:ss)	GA. (MIL)	TIME (hh:mm:ss)	GA. (MIL)	TIME (hh:mm:ss)	GA. (MIL)	TIME (hh:mm:ss)	GA. (MIL)

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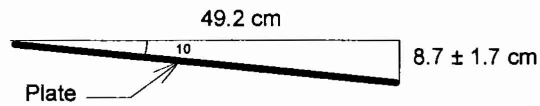
FIGURE 2.9

FLUID APPLICATION PROCEDURE

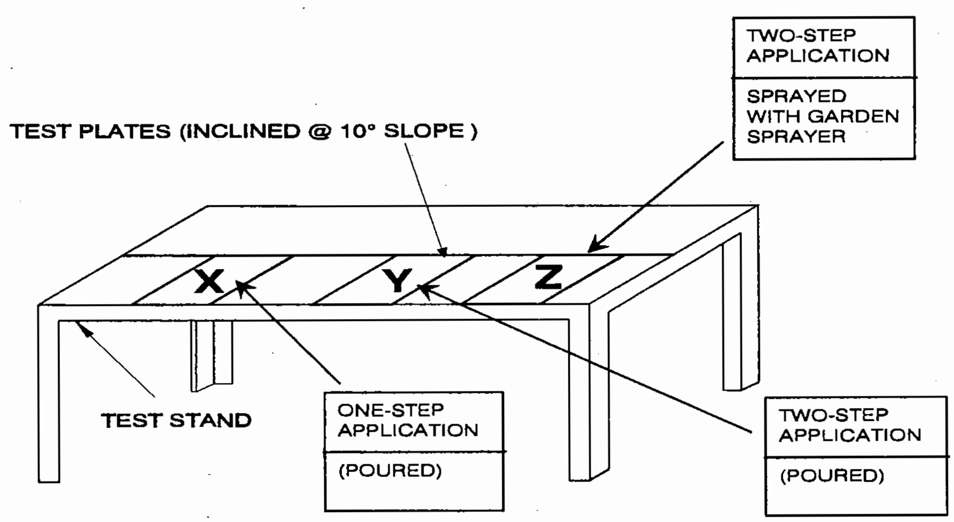
PROCEDURE FOR SPECIAL PLATES ON WING

- The skirted and non skirted plates should be located near the middle of the wing span, close to the trailing edge and about 30 cm apart.
- 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.
- The stand (with one plate mounted) should be oriented facing into the wind.
- 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 <u>only</u>.
- Pour same fluid(s) as sprayed by truck (ULTRA only, XL54 only or ULTRA over XL54). Record time of application (minutes and seconds).
- Go to the stand, squeegee the plate and pour ULTRA only. Record time of application.
- Measure and record fluid thicknesses (2.5 cm, 15 cm and 30 cm lines) with associated time (minutes and seconds) on all 3 plates immediately following fluid application and subsequently as many times as practical.
- After completion of test, squeegee all plates.

PROCEDURE FOR PLATES ON TEST PLATFORM



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Film thickness measurements were also taken on standard flat plates mounted on a test stand. Fluid on these plates was applied using the standard test procedure (see bottom of Figure 2.9). For Type I tests, warm (room temperature) XL54 was applied from a container, and for Type IV tests, Ultra was applied on the bare plate. For some Type IV tests, thickness was measured for fluid sprayed onto plates using a backpack (garden) sprayer (see Photo 2.10) with a pressure of 3.5 kg/cm^2 to 4.2 kg/cm^2 (50 to 60 psi). Fluid was also applied onto plates positioned on a second stand such that the wind flow was from the top of the plate to the bottom.

2.3.1.4 General

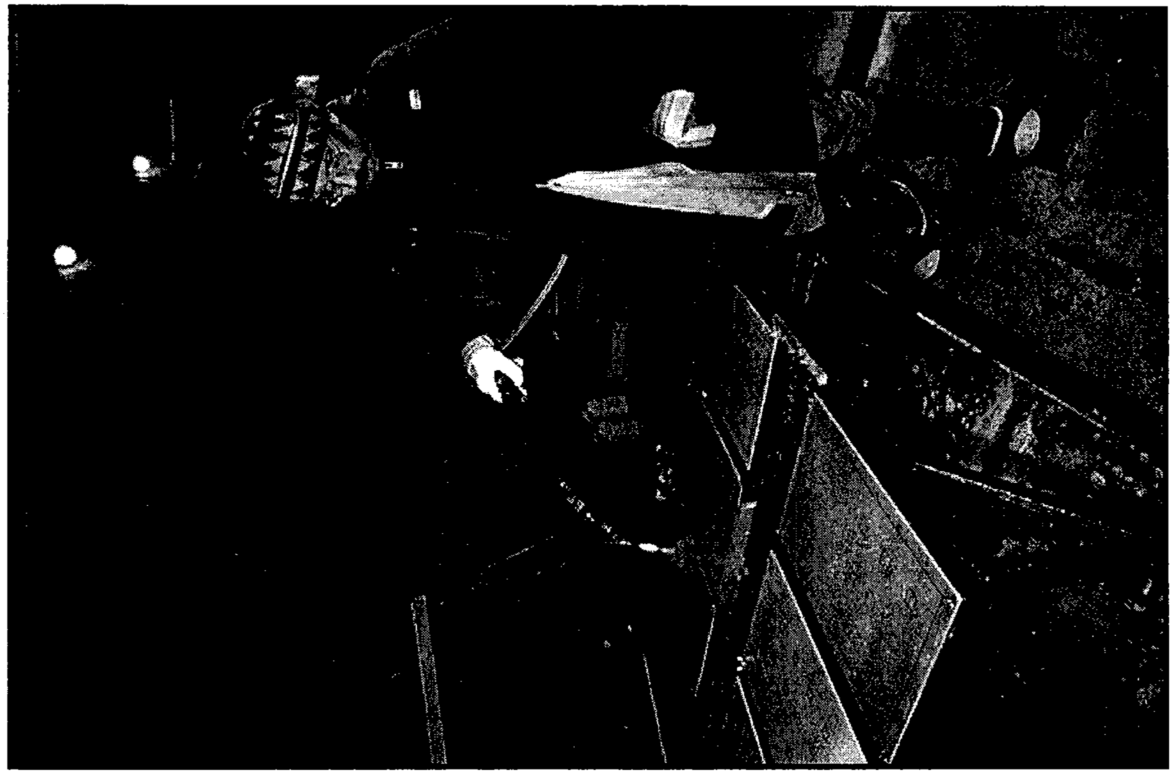
Wings were cleaned between consecutive tests by spraying with Type I fluid, following removal of the major part of Ultra fluid using squeegees. Fluid samples (see Figure 2.10) for collection procedure from the de/anti-icing truck were collected for subsequent analysis on each test occasion to ensure that the fluid was acceptable. General data forms (Figure 2.11) were used to record general test data including amounts of fluids applied. Meteorological data was retrieved from Environment Canada's weather station located in close proximity to the Air Canada de-icing centre.

Complete details of test procedures with data forms are presented in Appendix A.

2.3.2 Trials on Flat Plates at NRC

Thicknesses were measured for both de-icing and anti-icing fluids on flat plates at NRC's Climatic Engineering Facility in Ottawa. A few preliminary measurements were also taken outdoors at the Dorval (Montreal) test site. Tests were conducted to establish fluid thickness profiles for a number of fluids in both neat and diluted forms. To minimize the project costs, thickness tests were conducted in the chamber

PHOTO 2.10
SPRAYER USED FOR APPLICATION OF FLUIDS ON FLAT PLATES
PRESSURE 50 TO 60 PSI



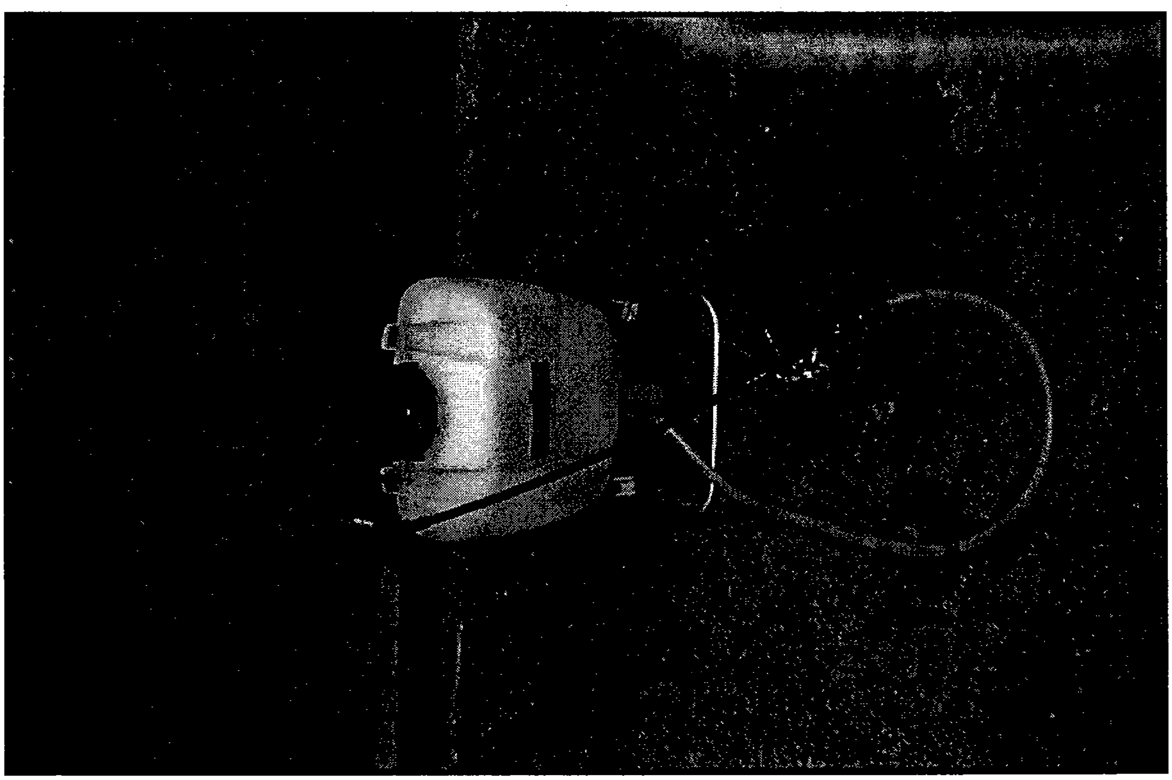


FIGURE 2.10

SAMPLING OF FLUID FROM TRUCK

- Place a clean plastic pan on the ground.
- Spray a few litres into the pan.
- Label bottle properly (Date, Time, Fluid Type, Run No.).
- Pour fluid into sampling bottle (0.5 litre).
- Enter data below.

Date: ____________	Run No.: ____________	Airline: ____________
Time: ____________	Nozzle Type: ____________	Airport: ____________
Bottle No.: ____________	Truck No.: ____________	Brix Reading: ____________
Fluid Type: ____________	Sampled by: ____________	

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FIGURE 2.11

GENERAL FORM
FLUID THICKNESS TESTS

AIRPORT: YUL

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

EXACT LOCATION OF TEST: ______________________

AIRLINE: ______________________

DATE: ______________________

FIN #: ______________________

RUN #: ______________________

FUEL LOAD: ______________________ LB / KG

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

Test Started	Chord 1 Sprayed	Chord 2 Sprayed	Chord 3 Sprayed	Test Ended

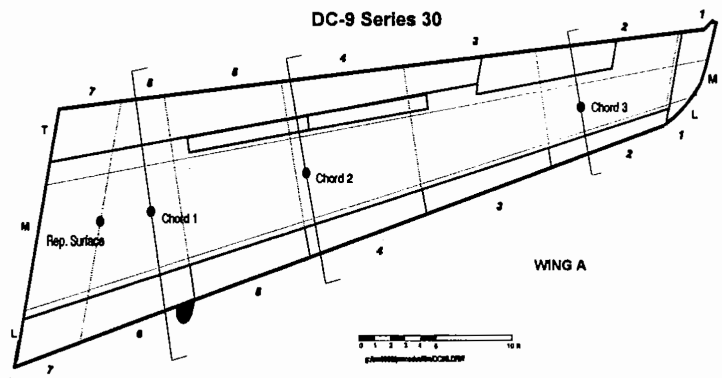
TIME (min)	TEMPERATURE AT LOCATION (°C)			
	Rep. Surf	Chord 1	Chord 2	Chord 3
Before[1] ( )				

Weather Conditions

OAT ________ ° C Relative Humidity ________ %

Wind Speed ________ km/h Wind Direction ________ degrees

DC-9 Series 30



Team Assignments

L1 ______________________

L2 ______________________

L3 ______________________

O1 ______________________ T1 ______________________

V1 ______________________ T2 ______________________

C1 ______________________ T3 ______________________

Airline Team

______________________ ______________________

______________________ ______________________

Observers

______________________ ______________________

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at the same time as the holdover time tests, but away from the precipitation on a second test stand.

Thickness of the fluid film on the plates was measured and recorded at a number of pre-defined locations (see Figure 2.12). Fluid thickness measurements were taken on a frequent basis (particularly at the beginning) and the clock time for each measurement was recorded. Other data recorded includes ambient meteorological conditions.

To minimize errors resulting from deformations in the fluid caused by the thickness gauge, measurement locations from one time to the next were staggered (offset) slightly. Measurements at the 6" (15 cm) line were repeated to ensure accuracy.

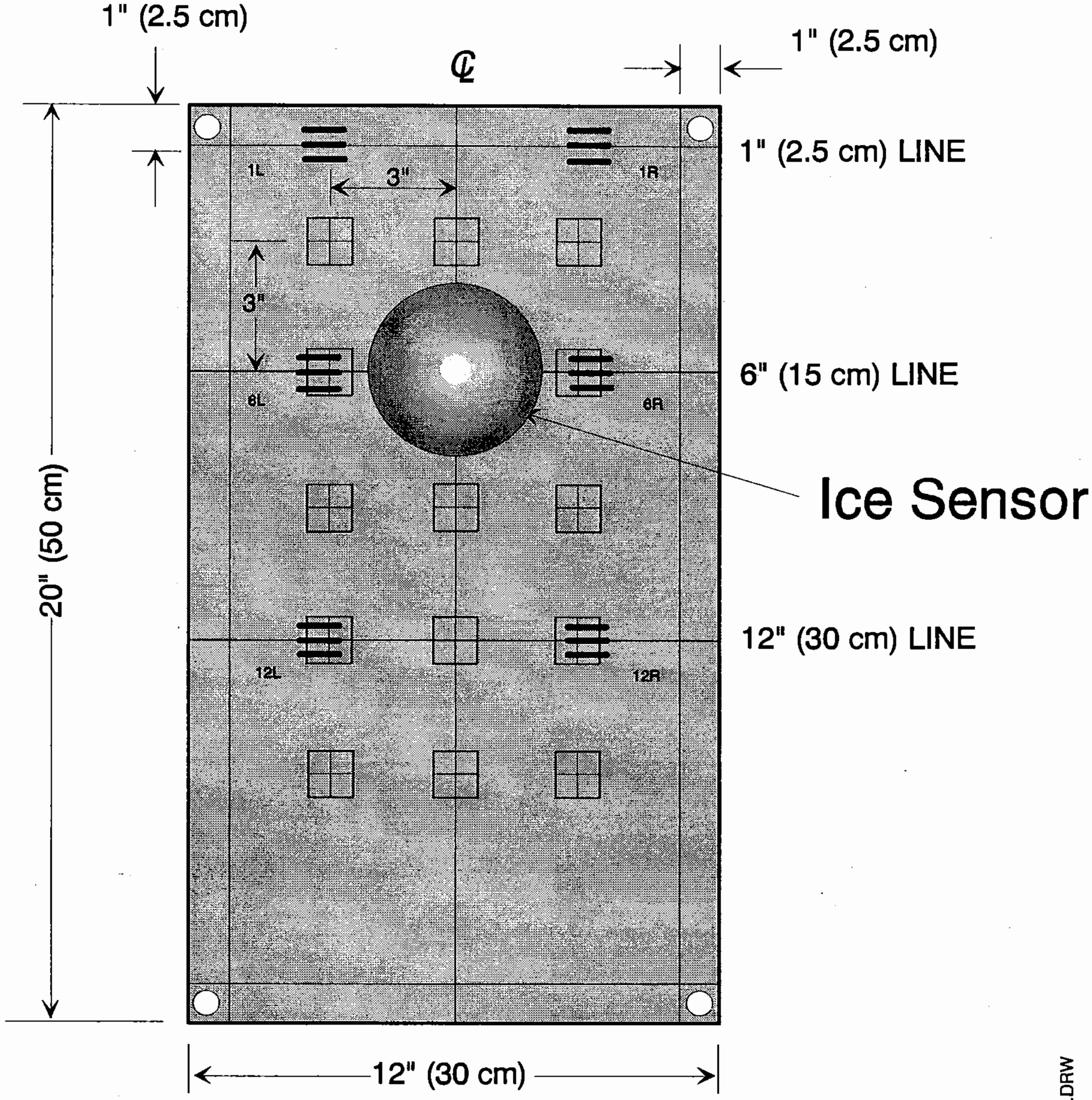
For the tests using a two-step fluid application procedure, the second fluid was applied immediately following the application of the first fluid and the quantity of fluid applied was 1.5 litres. For the one-step application, the procedure was to flood the plates with fluid. This is the standard test procedure and the amount of fluid normally used in holdover time tests, with no wind, is approximately 1.5 litres. In the case of the sprayer application, fluid was applied for one minute.

2.4 Fluids

Aircraft are de-iced using Type I de-icing fluids, which are sometimes diluted. While excellent for removing ice and snow which has already accumulated on the wings of aircraft, Type I fluids provide limited protection against further ice build-up. The Type II anti-icing fluids, being significantly more viscous, provide this kind of protection. Newer, longer lasting Type IV fluids are also in development. One such fluid which is commercially available is Union Carbide's (UCAR) Ultra Type IV anti-icing fluid.

FIGURE 2.12

THICKNESS MEASUREMENT LOCATIONS ON STANDARD PLATE



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2.4.1 Aircraft Trials

Type I fluid (UCAR XL 54) heated in the de-icing vehicle to 71°C (160°F) and unheated Type IV fluid (UCAR Ultra) were used as test fluids. It may be noted that in the vehicles used for the trials, the heated Type I fluid tank was separated from the Type IV fluid tank by a common metal wall, and consequently some heat was transferred to the Type IV fluid. It is believed that this situation is common among de-icing fleet vehicles.

The test plan in Appendix A shows that out of the six tests planned per session, two tests were planned with Type I fluid, two tests with Type IV fluid over a bare wing, and two tests with Type IV over Type I. For the special plates mounted on the aircraft, the same fluids were used except that fluid was sprayed by the truck on the skirted plate, and poured on the non-skirted plate. For the plates mounted on the stand, fluid was applied using the standard test procedure, unless otherwise noted.

2.4.2 Trials on Flat Plates at NRC

The fluids used for the thickness tests conducted at NRC's cold chamber are listed below.

Type IV (Neat and Diluted 75/25, 50/50)

UCAR Ultra
UCAR Ultra Plus
Kilfrost ABC 4
Hoechst MPIV 1934
SPCA AD-404
SPCA AD-460

Type I (standard concentration)

Octagon
UCAR

These fluids when tested were applied in the same manner as they would be during the standard holdover time tests (see Appendix H). The temperature of the Type IV fluids were at chamber temperatures, and the Type I fluids were at room temperature (15°C to 20°C).

2.5 Personnel and Participation

Air Canada staff operated the airline de-icing vehicles and followed airline standard spraying procedures for these tests. The tests were coordinated by APS Aviation personnel based on forecasted weather conditions. Test data was gathered and analysed by APS Aviation.

Individual task assignments are shown in Appendix A for the aircraft trials and Appendix G for the flat plate tests.

2.6 Analysis Methodology

Data from voice recorders was transcribed to data sheets (Figure 2.8) and subsequently entered on a Microsoft Excel spreadsheet. The processed data was presented in several formats to provide a visual representation of the fluid film on the wing as an aid to analysis.

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3. DESCRIPTION OF DATA AND OBSERVATIONS

3.1 Aircraft Trials

Tests were conducted on Canadair RJ, DC-9 and A320 aircraft (Table 3.1), to develop data representing fluid thickness at time intervals after application along selected chords of test wings.

The points identified for measurement on each chord were selected to enable construction of a profile of fluid thickness across the full wing chord. Attention was given to gaps in the wing surface at flight control surfaces where fluid could drain away, potentially resulting in fluid thickness on the surfaces just downstream of such gaps deteriorating more rapidly than elsewhere as fluid flowed down slope on that surface and was not replaced by upstream fluid.

Other points identified for measurement were irregularities on the wing surface that might experience rapid fluid thinning, such as a raised surface inboard on the DC-9 wing, and areas where early fluid failure was observed during full-scale aircraft fluid holdover tests[2] during the Winter 1994/1995 season.

Each trial ran until it was determined that fluid thickness had stabilized. For trials with Ultra fluid this resulted in durations up to 25 minutes, while Type I fluid trials needed about 10 minutes. With six observers continually measuring thickness, large data sets (of the order of 400 data points) were generated for each run.

Sources of data errors include instrument and human observer errors. Calculation of film thickness as the midpoint between the last wetted tooth and the next unwetted tooth generated potential reading errors ranging from ± 3% to ± 14%.

Failing to hold the gauge perpendicular to the substrate surface was a potential source of

TABLE 3.1

FLUID THICKNESS TRIALS ON AIRCRAFT

Aircraft	Run #	Date	Fluid	Temp. (°C)	Wind* (kph)	Notes
Canadair RJ	1	14-15 Feb. 1996	Ultra	-16	7	Contaminated Fluid, Tips nozzle
	2	14-15 Feb. 1996	Ultra	-17	5	Contaminated Fluid, Tips nozzle
	3	14-15 Feb. 1996	Ultra	-18	7	Akron nozzle
	4	14-15 Feb. 1996	Ultra/XL54	-18	7	Akron nozzle
DC-9	1	11-12 Mar. 1996	Ultra	-4	9	Akron nozzle
	2	11-12 Mar. 1996	Ultra	-5	8	Akron nozzle
	3	11-12 Mar. 1996	XL54	-4	10	Akron nozzle
	4	11-12 Mar. 1996	XL54	-4	10	Akron nozzle
	5	11-12 Mar. 1996	Ultra/XL54	-5	6	Akron nozzle
	6	11-12 Mar. 1996	Ultra/XL54	-6	5	Akron nozzle
A320	1	28-29 Mar. 1996	Ultra	-1	7	Contaminated Fluid, Akron nozzle
	2	28-29 Mar. 1996	Ultra	-2	10	Akron nozzle
	3	28-29 Mar. 1996	XL54	-3	13	Akron nozzle
	4	28-29 Mar. 1996	Ultra/XL54	-3	13	Akron nozzle
	5	28-29 Mar. 1996	Ultra/XL54	-4	13	Akron nozzle

* Wind Speed was measured by AES with an instrument 10 metres above the ground.

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error; an additional error of +3.5 % may be generated by a 15° tilt. Use of the gauge mounted at the end of a handle provided some degree of protection against inadvertent tilting. Incorrect identification of the last wetted tooth was a further potential source of error, guarded against by equipping each observer with a head-mounted flashlight to aid visibility.

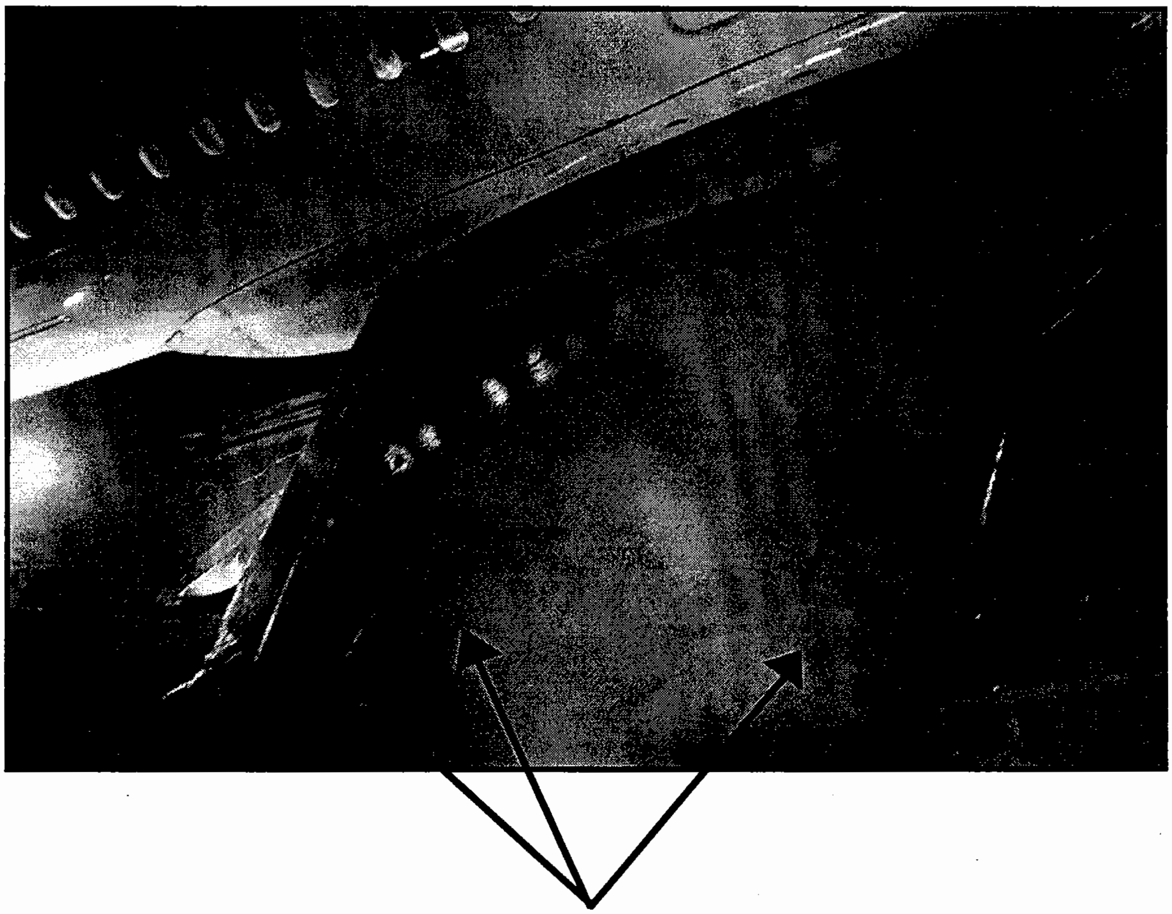
The measurement procedure involved offsetting the gauge for subsequent readings at each reference point, to avoid influence of depressions remaining on the fluid surface as a result of the previous gauge placement. At some locations, such as the leading edge where there was a high initial rate of fluid flow, thickness measurements were inconsistent as fluid of different depths flowed by the point of measurement. Offsetting the gauge placement for subsequent readings occasionally resulted in inconsistent readings particularly when the fluid application had produced irregularities in depth.

Inconsistencies in depth of applied fluid could be observed by the naked eye in some trials. Ridges of thicker fluid can be discerned on close examination of Photo 3.1. In certain instances, the trials were repeated with particular care taken by the spray operator to produce consistent coverage.

The voice recorders generally were reliable, but did contribute to loss of data on different occasions. The procedure finally settled on operating the recorders on continuous recording as opposed to voice activated recording, thereby eliminating some problems. Background noise in some instances required careful deciphering of data values. Switching of observers between the leading and trailing edges of each chord for the last set of readings of each trial was useful and in two separate cases provided the sole data for the run when a voice recorder had stopped, unknown to the user. Some observers (test personnel) elected to also record written data logs in the event of equipment malfunction or other factors which would result in the loss of data.

PHOTO 3.1

EXAMPLE OF INCONSISTENT FLUID DEPTH



Ridges of Deeper Fluid

The lag time between spray application and first observation was minimized by applying the final fluid spray from the fuselage outwards, and moving the observer stairs to the wing position as soon as spraying at each chord was completed. A delay in taking first measurements (in the order of one minute) resulted.

Voice data was first transcribed onto data forms and then entered on a PC spreadsheet for analysis. Film thickness was calculated as the mid-point between the values of the last wetted tooth wetted and the next unwetted tooth. A conversion table (Table 3.2) was constructed to aid this procedure. Analysis of film thicknesses included presentation of data in several chart formats which are presented and discussed in the next section.

Thickness data gathered from special plates mounted on the wing and plates on the flat plate stand were treated in a like manner.

Samples of fluids were taken from de-icing vehicles on each test occasion and forwarded to Union Carbide for analysis. Data on ambient weather conditions was retrieved from Environment Canada's Atmospheric Environment Services (AES) weather station at their Dorval Airport site.

3.1.1 Flat Plate and Disk Data During Aircraft Trials

For each of the three aircraft test sessions, film thickness was measured on flat plates and/or disks as described below. Table 3.3 provides a summary of the fluid application methods and which plates/disks were used for the tests.

A detailed description is provided here because these were non-standard tests and were not anticipated during the development of the initial test plan. Tests on these surfaces were conceived and developed during the course of the testing based upon results from previous tests and discussions with Transport Canada.

TABLE 3.2

FILM THICKNESS CONVERSION TABLE

RECTANGULAR GAUGE			OCTAGON GAUGE		
Reading* (mil)	Calculated Thickness (mil)	Calculated Thickness (mm)	Reading* (mil)	Calculated Thickness (mil)	Calculated Thickness (mm)
			0.4	0.8	0.0
1.0	1.5	0.0	1.1	1.3	0.0
			1.5	1.9	0.0
2.0	2.5	0.1	2.2	2.4	0.1
			2.6	2.7	0.1
3.0	3.5	0.1	2.8	3.2	0.1
			3.6	3.9	0.1
4.0	4.5	0.1	4.1	4.4	0.1
			4.7	4.9	0.1
5.0	5.5	0.1	5.1	5.6	0.1
6.0	6.4	0.2	6.0	6.4	0.2
			6.6	7.0	0.2
7.0	7.5	0.2	7.3	7.5	0.2
8.0	8.5	0.2	7.7	7.8	0.2
9.0	9.5	0.2	7.9	9.0	0.2
10	11	0.3	10	11	0.3
11	12	0.3			
12	13	0.3	12	13	0.3
14	15	0.4	14	15	0.4
16	18	0.4	16	18	0.4
18	19	0.5			
20	21	0.5	20	23	0.6
22	23	0.6			
24	25	0.6	25	28	0.7
26	27	0.7			
28	29	0.7			
30	33	0.8	30	33	0.8
35	38	1.0	35	38	1.0
40	43	1.1	40	43	1.1
45	48	1.2			
50	53	1.3	48	56	1.4
55	58	1.5			
60	63	1.6			
65	68	1.7	64	72	1.8
70	73	1.8			
75	78	2.0			
80	88	2.2	80	88	2.2
			96	100	2.5
			104	108	2.7
			112	116	2.9
			119	123	3.1
			127	131	3.3
			134	138	3.5
			142	146	3.7
			150	154	3.9
			158	179	4.5
			200	225	5.7
			250	275	7.0
			300	350	8.9
			400	400	10.2

* Reading of last wetted tooth.

TABLE 3.3

FLUID APPLICATION METHODS AND THICKNESS MEASUREMENTS ON PLATES AND DISKS DURING AIRCRAFT TESTS

		Raised Above Wing		On Wing Surface						On Stand							
				Plates			Disks			Into Wind			Against Wind				
Aircraft	Run #	Skirted Plate (TE)	Standard Plate (TE)	P1 (TE)	P2 (LE)	P3 (TE)	D1 (LE)	D2 (TE)	D3 (LE)	STD X	Y	Z	X	Y	Z	Fluid	Notes
Canadair** RJ	1	✓	✓							✓						Ultra	Contaminated Fluid, Tips nozzle
	2	✓	✓							✓						Ultra	Contaminated Fluid, Tips nozzle
	3	✓	✓							✓						Ultra	Akron nozzle
	4	✓	✓							✓						Ultra/XL54	Akron nozzle
DC-9	1	✓		-	✓	✓	✓	✓	✓	✓	-	✓	✓	-	✓	Ultra	Akron nozzle
	2	✓		✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-	✓	Ultra	Akron nozzle
	3	✓		✓	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	XL54	Akron nozzle
	4	✓		✓	✓	✓	✓	✓	✓	✓	-	-	✓	-	-	XL54	Akron nozzle
	5	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Ultra/XL54	Akron nozzle
	6	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Ultra/XL54	Akron nozzle
A320	1						✓*	✓	✓	✓*	-		✓	-		Ultra	Contaminated Fluid, Akron nozzle
	2						✓*	✓	✓	✓	-		✓	-		Ultra	Akron nozzle
	3						✓*	✓	✓	✓	-		✓	-		XL54	Akron nozzle
	4						✓*	✓	✓	-	✓		-	✓		Ultra/XL54	Akron nozzle
	5						✓*	✓	✓	-	-		-	-		Ultra/XL54	Akron nozzle
Location of Measurement		6"	6"	6"	6"	6"	2"	2"	2"	6"	6"	6"	6"	6"	6"		
Slope (Estimate)		10°	10°	9°	4°	9°	4°	9°	4°	10°	10°	10°	10°	10°	10°		

Fluid Application

	Skirted Plate (TE)	Standard Plate (TE)	P1 (TE)	P2 (LE)	P3 (TE)	D1 (LE)	D2 (TE)	D3 (LE)	Into Wind STD X	Into Wind Y	Into Wind Z	Against Wind X	Against Wind Y	Against Wind Z
Pour from Container		✓							✓	✓		✓	✓	
Spray from Truck	✓		✓	✓	✓	✓	✓	✓						
Spray from Garden Sprayer											✓			✓
Truck Fluid	✓		✓	✓	✓	✓	✓	✓						
Site Fluid		✓							✓	✓	✓	✓	✓	✓
One-Step (XL54 or Ultra)	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓
Two-Step (XL54 + Ultra)	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓

* Placed near Trailing Edge for this test.

** For the RJ session, only the Octagon thickness gauge was used to measure film thickness on plates.

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During the first session (Canadair RJ):

- Film thickness was measured with the Octagon gauge only;

- To have a "bench mark" with the holdover time tests, measurements were made on standard plate (X) mounted on a test stand at a 10° slope. The stand was positioned such that the direction of wind flow was up the plate. Fluid on this plate was poured as per the standard procedure used for the holdover time tests; and

- Two other plates (skirted and standard) were mounted above the aircraft wing surface at a 10° slope, near the trailing edge. The application of fluid on the skirted plate was rendered in the same manner as for the aircraft. Application on the standard raised plate used the same fluid steps as for the aircraft, however fluid was poured from a container using fluid samples provided to APS by the fluid manufacturer.

For the second session (DC-9):

- The standard raised plate on the aircraft was not used because the results from the first test showed that it compared well with the standard plate on the test stand, and because application of the fluid from a container was difficult, particularly on the higher DC-9 wing;

- Three small rectangular plates and three disks were mounted on or near the leading and trailing edge surfaces. Figure 2.4 shows the positions of these on the wing surface. The mountings on the trailing edge sat at approximately a 9° slope, and those on the leading edge were at a 4° slope. The fluid application for these plates and disks was the same as for the aircraft wing; and

- Six standard plates were mounted on stands, three into the wind and three against the wind (see Figure 2.4). For plate X, fluid was poured from a container using the standard one-step holdover time procedure. For plate Y, a two-step (Type IV over Type I) application procedure was used, and the fluid was poured. For plate Z, fluid was sprayed for one minute using a garden sprayer.

For the third session (A320):

- Only three disks were mounted on the wing of the A320, because of the difficulty in attaining access to the higher wing; and

- Film thickness was measured on standard flat plates mounted on the test stand. (Runs 4 and 5 had a voice recorder malfunction.)

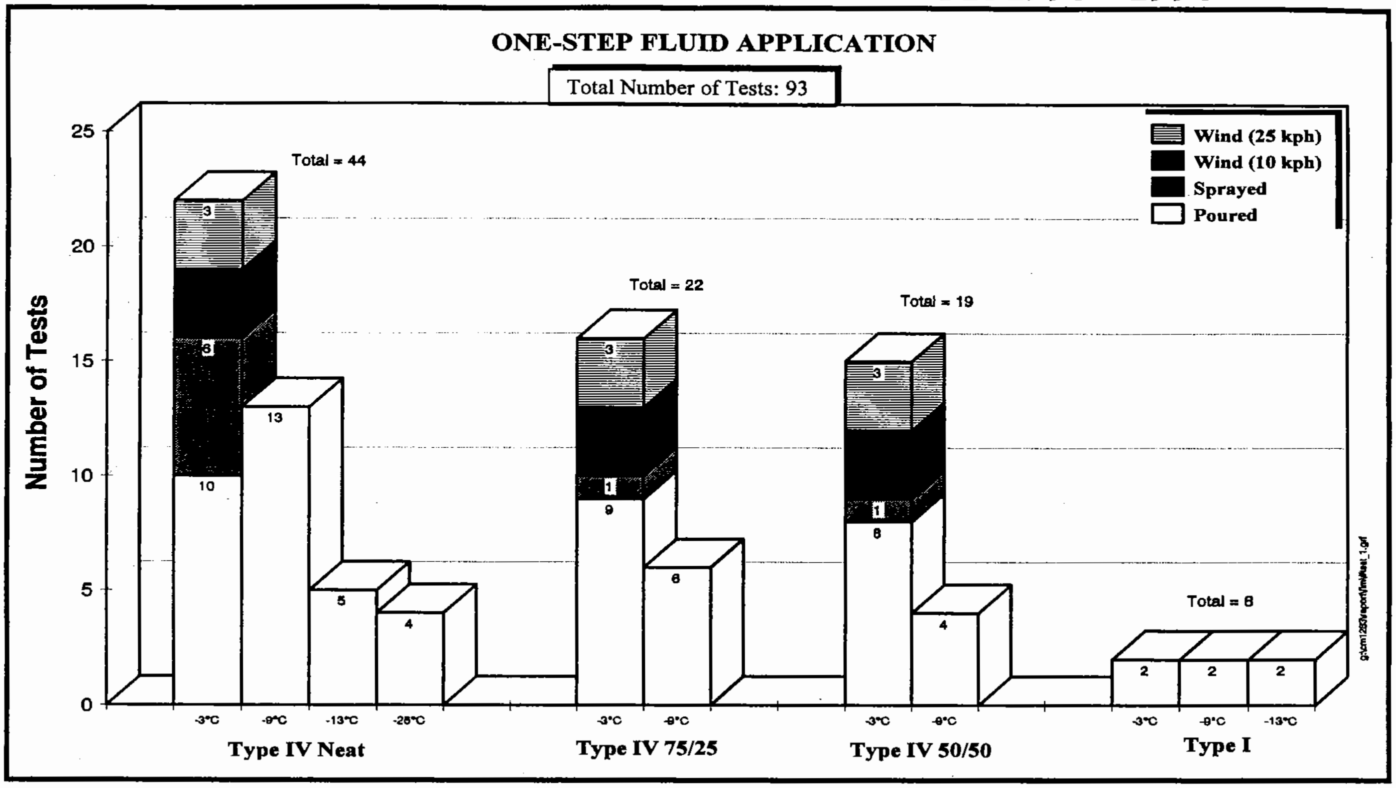
3.2 Flat Plate Trials at NRC

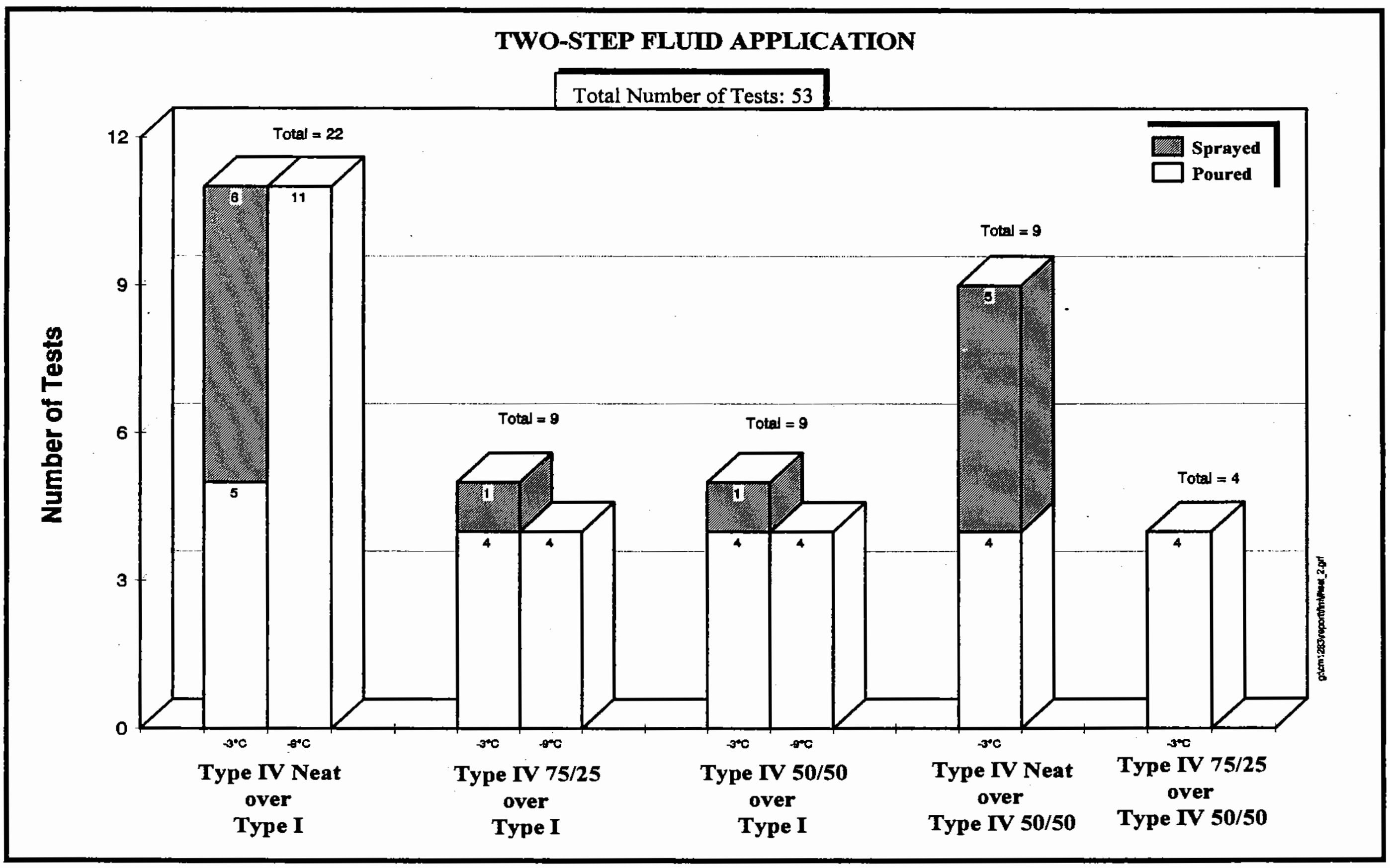
Over the 1995/96 winter season, 146 flat plate tests were conducted in the absence of precipitation to measure the thickness of fluids on the plate as a function of time. Contrary to previous years when tests were performed outdoors, these tests were done indoors at NRC's Climatic Engineering Facility in Ottawa, concurrent with the holdover time tests. Although previous tests have already been done and reported for Type I, Type II and Type III fluids, very few thickness tests had been carried out for Type IV fluids.

Figure 3.1 shows the breakdown of thickness tests conducted at NRC's cold chamber. The upper part of the chart shows the breakdown by dilution for fluids applied in a one-step procedure (on a bare plate), and the lower part of the chart shows the number of tests conducted using a two-step fluid application procedure. The majority of the tests were conducted using Type IV fluids in both neat and diluted forms (see Section 2.4.2) at temperatures of -3°C and -9°C. A small percentage of tests were done with Type I fluids and at temperatures of -13°C and -25°C. A few tests were also done using a garden sprayer to apply fluid and a fan to simulate wind.

FIGURE 3.1

NUMBER OF THICKNESS TESTS FOR 1995 - 1996





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Out of the 146 tests conducted, 17 tests were with Type IV Hoechst fluid (MPIV 1934). These tests were removed from subsequent analysis because APS was informed that this fluid did not satisfy the proposed water spray endurance test requirements.

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4. ANALYSIS AND DISCUSSION

This section presents an analysis and discussion of the study data collected during aircraft tests at Dorval Airport, and during supplemental tests at the NRC cold chamber, Ottawa.

Test data was organized in three main formats for visual presentation and analysis.

i) **Rate of Thinning:** Fluid thickness data for each measurement point plotted against time.

Figures 4.1 to 4.4 are examples of charts showing best fit exponential decay curves of fluid thickness values plotted versus time from start of test. These curves, developed for each measured position for all test runs, provide initial, interim and stabilized values and illustrate progressive thinning of the fluid over time. Locations of measured positions along the wing chord are provided. Complete sets of these charts are provided in Appendix E.

The title block of Figure 4.1 indicates the specifics of the test condition (date, aircraft type, fluid) and the observer location involved (location L1 - leading edge of chord 1). The wing plan in Figure 4.1 illustrates the chords measured and the inset indicates measurement points along the chord. Measured thickness values are plotted for each point, and a best fit curve is drawn for the set of values for each point.

In Figure 4.1 which reports thickness values for Ultra Type IV application, the resultant curves are easily distinguished. Figures 4.3 and 4.4 reporting on XL54 Type I fluid show thickness decay lines closely grouped and overlaid on one another, reflecting the rapid thinning and small stabilized thickness values for Type I fluid. The curve representing thickness values for position 8 in Figure 4.3 is an anomaly caused by fluid surface tension, and is described in Section 4.1 (Type I fluid).

FIGURE 4.1

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 3 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L1

1st FLUID: ULTRA TYPE IV / 73 LITRES

2nd FLUID: NIL

Temperature: -17.6°C | Wind Speed: 7.3 kph | Nozzle Type: AKRON

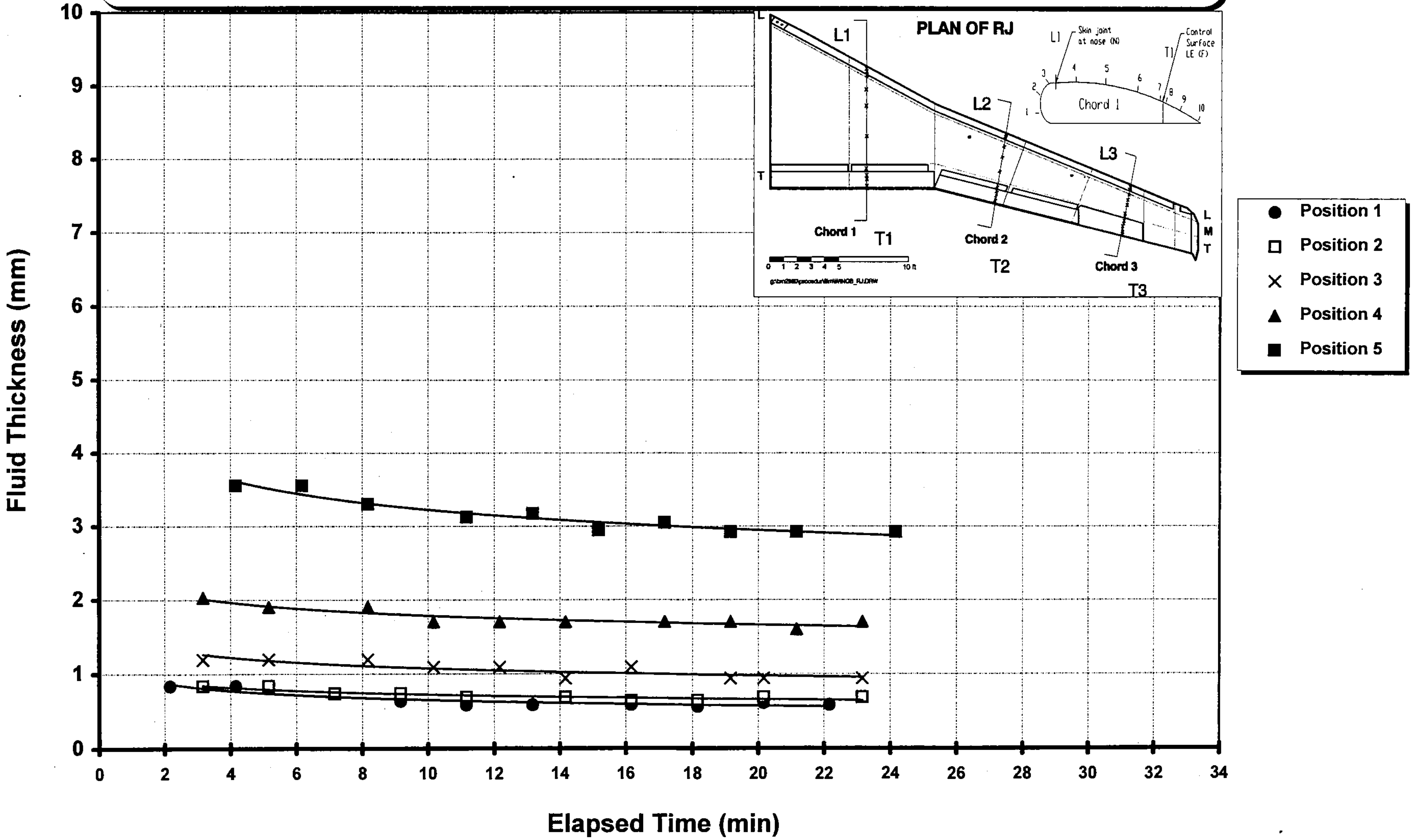

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FIGURE 4.2

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 3 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T3

1st FLUID: ULTRA TYPE IV / 73 LITRES

2nd FLUID: NIL

Temperature: -17.6°C | Wind Speed: 7.3 kph | Nozzle Type: AKRON

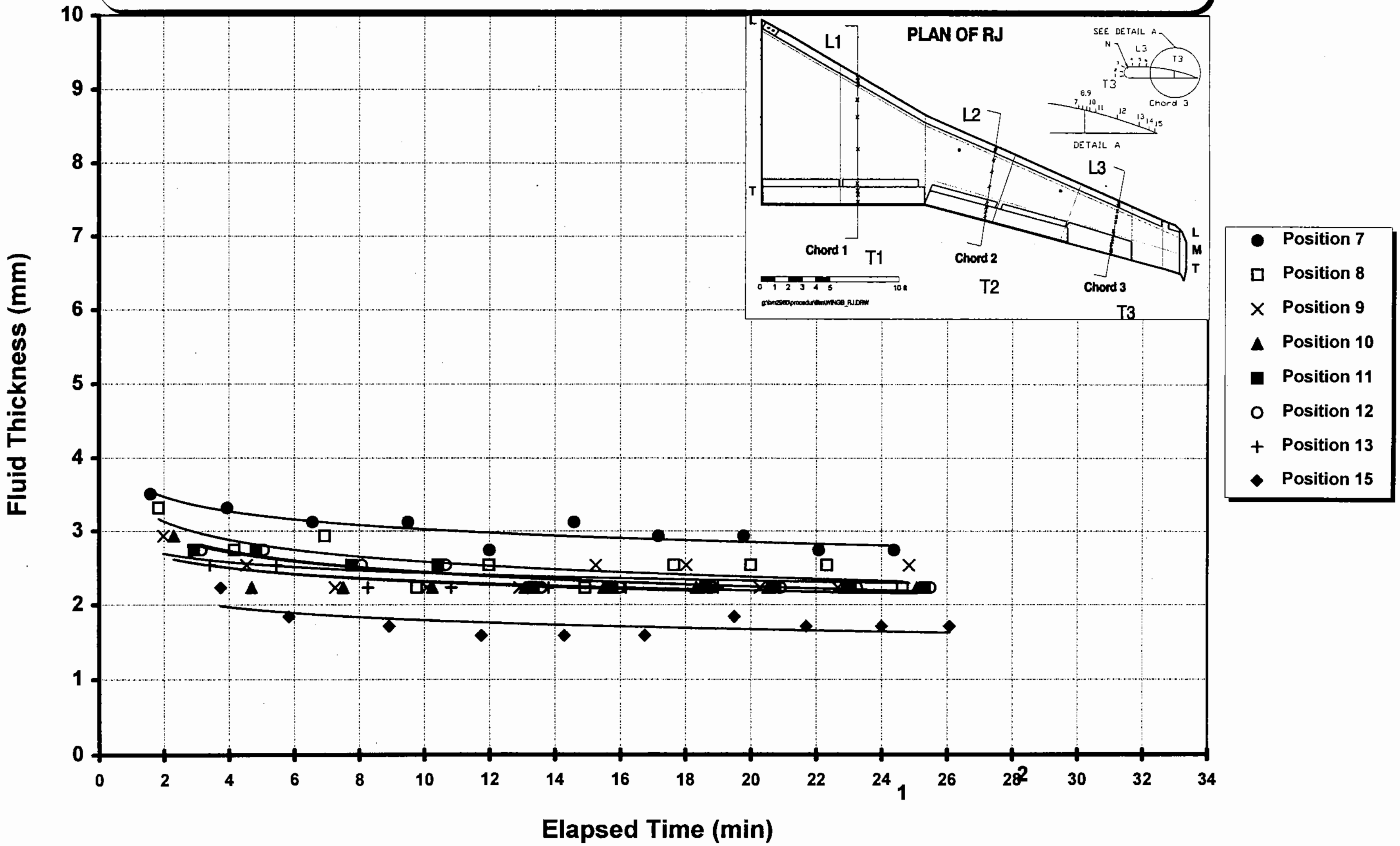

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FIGURE 4.3

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 3 - MARCH 12, 1996

DC-9 - LOCATION T3

1st FLUID: XL54 TYPE I / 318 LITRES

2nd FLUID: NIL

Temperature: -3.6°C | Wind Speed: 10.0 kph | Nozzle Type: AKRON

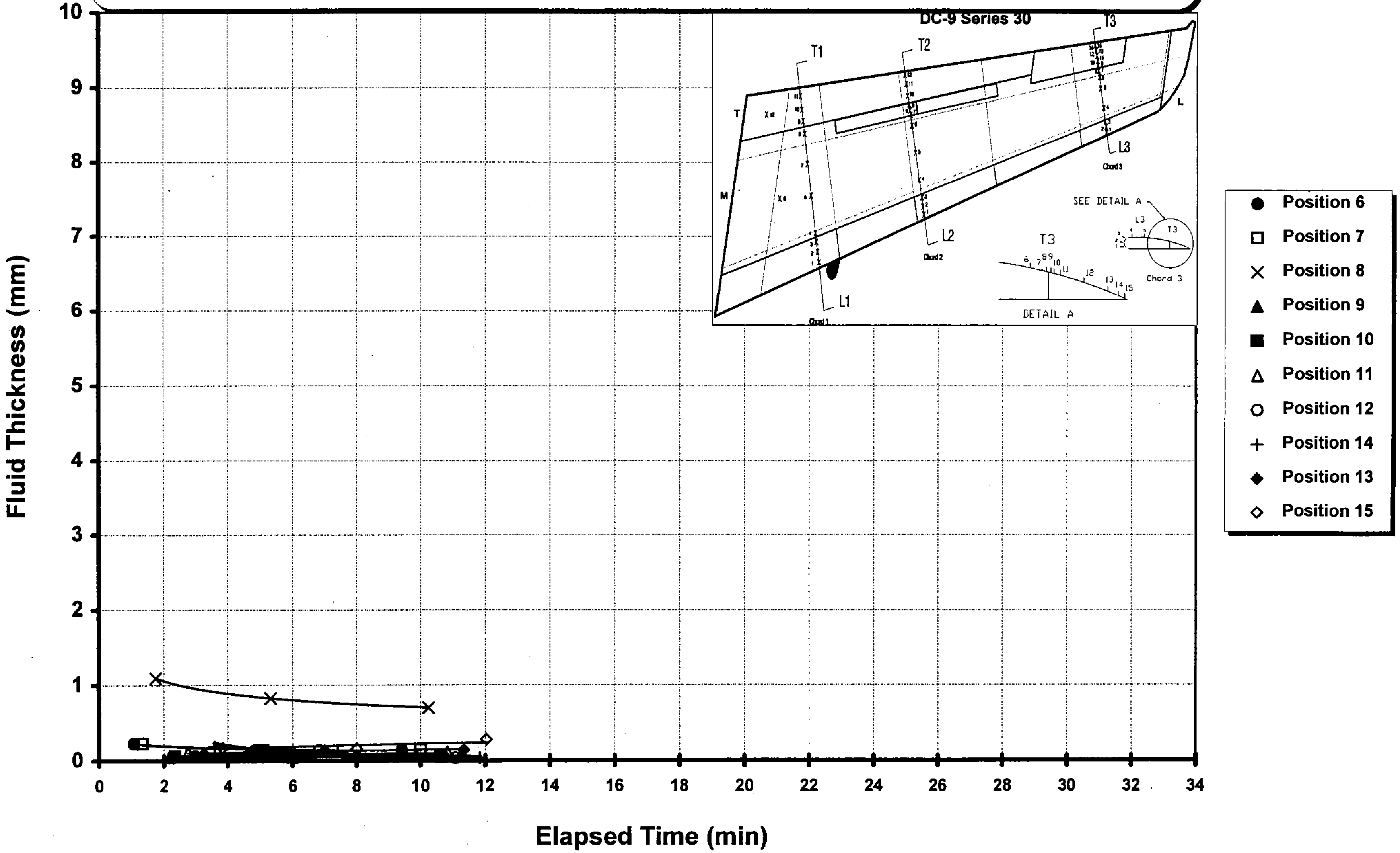

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FIGURE 4.4

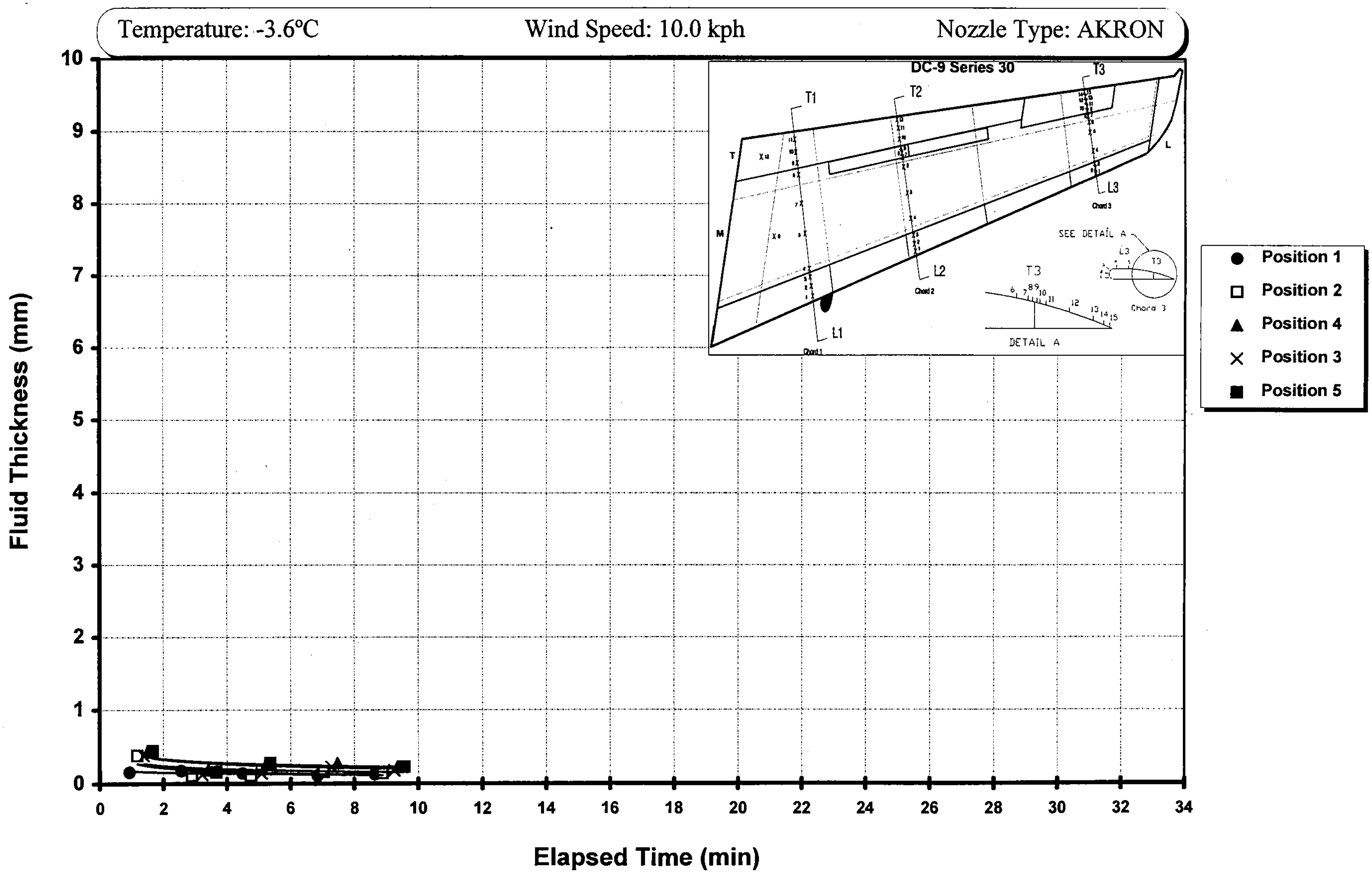
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 3 - MARCH 12, 1996

DC-9 - LOCATION L3

1st FLUID: XL54 TYPE I / 318 LITRES

2nd FLUID: NIL



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ii) **Wing Profile:** Profile of stabilized fluid thickness across the full wing chord.

These profiles provided as Figures 4.5 to 4.12 illustrate stabilized thickness of fluid at measured points along the wing chord. Figure 4.13 portrays film thickness profiles for all test aircraft for comparison. A discussion of film profiles across the wing chord is presented in Section 4.4.

iii) **Wing Plan:** Stabilized fluid thickness on the wing plan.

Fluid thickness values were plotted on the wing plan to assist in examination of data from additional plates used on flat plate stands. Figures 4.14 to 4.19 show stabilized values of film thickness at each measurement point along wing chords, and on special plates. A full set of these charts is included in Appendix F.

These presentations of study data support the following observations.

4.1 Type I Fluid

- Type I fluid thickness stabilized in about 4 to 6 minutes to a very thin film.

- Values for stabilized thickness of Type I fluid varied among positions on the surface. At points where there existed any degree of slope, the resultant film generally became too thin to allow measurement. At points on relatively flat surfaces, such as the top of the wing, thicknesses in the order of 0.25 to 0.5 mm were measured at 6 to 8 minutes following spray. As well, some results (e.g. Figure 4.17 chord 3 and Figure 4.3 position 8) show the effect of fluid surface tension causing a bead of fluid to form at the wing edge. Some of the variability in the data collected for Type I fluid resulted from the fluid bubbles (foam) caused by the spray gun application.

FIGURE 4.5

TYPE IV FLUID THICKNESS (STABILIZED) PROFILE AT CHORD 3 OF CANADAIR RJ

MARCH 12, 1996, RUN 3 - ULTRA

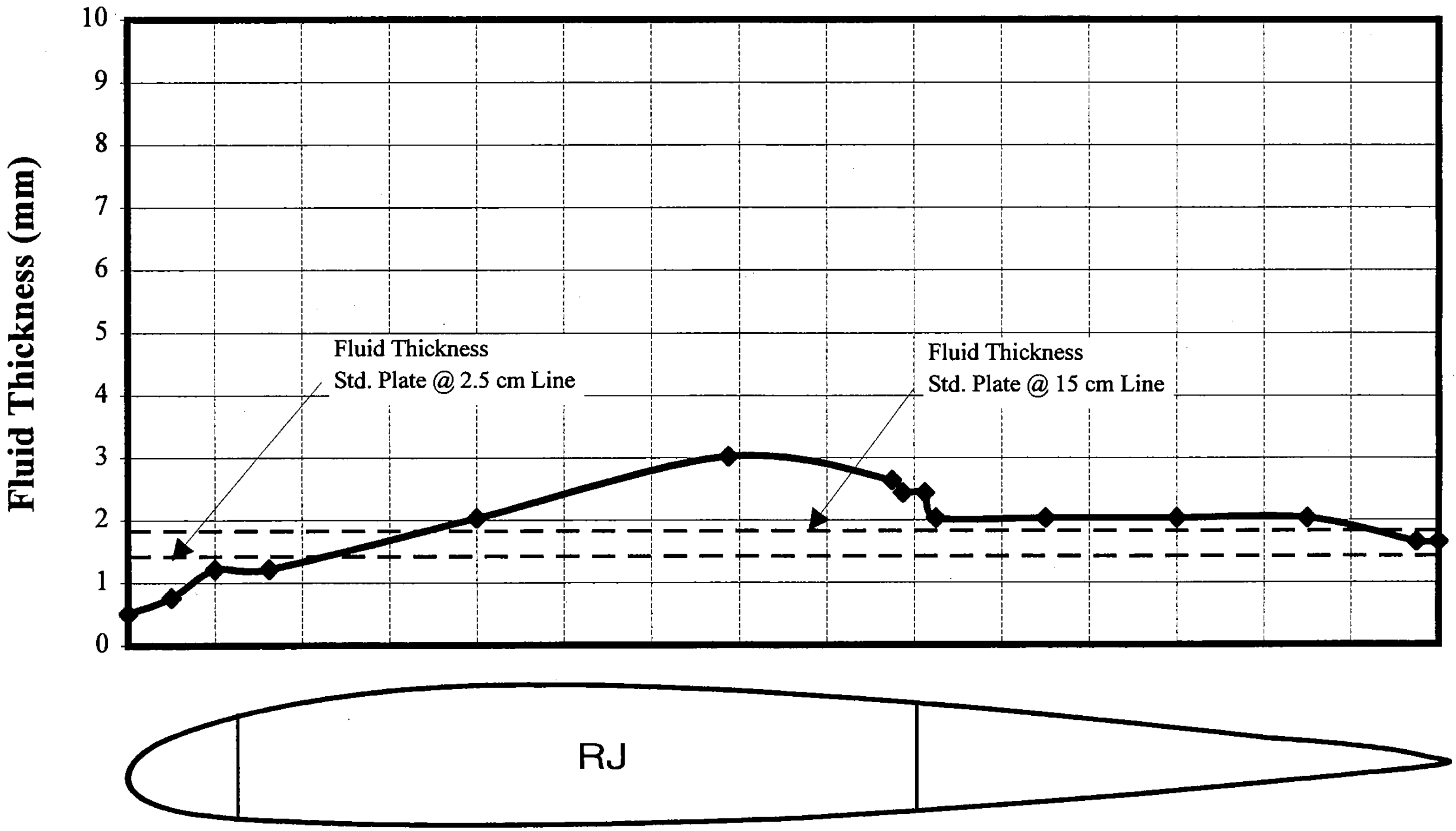

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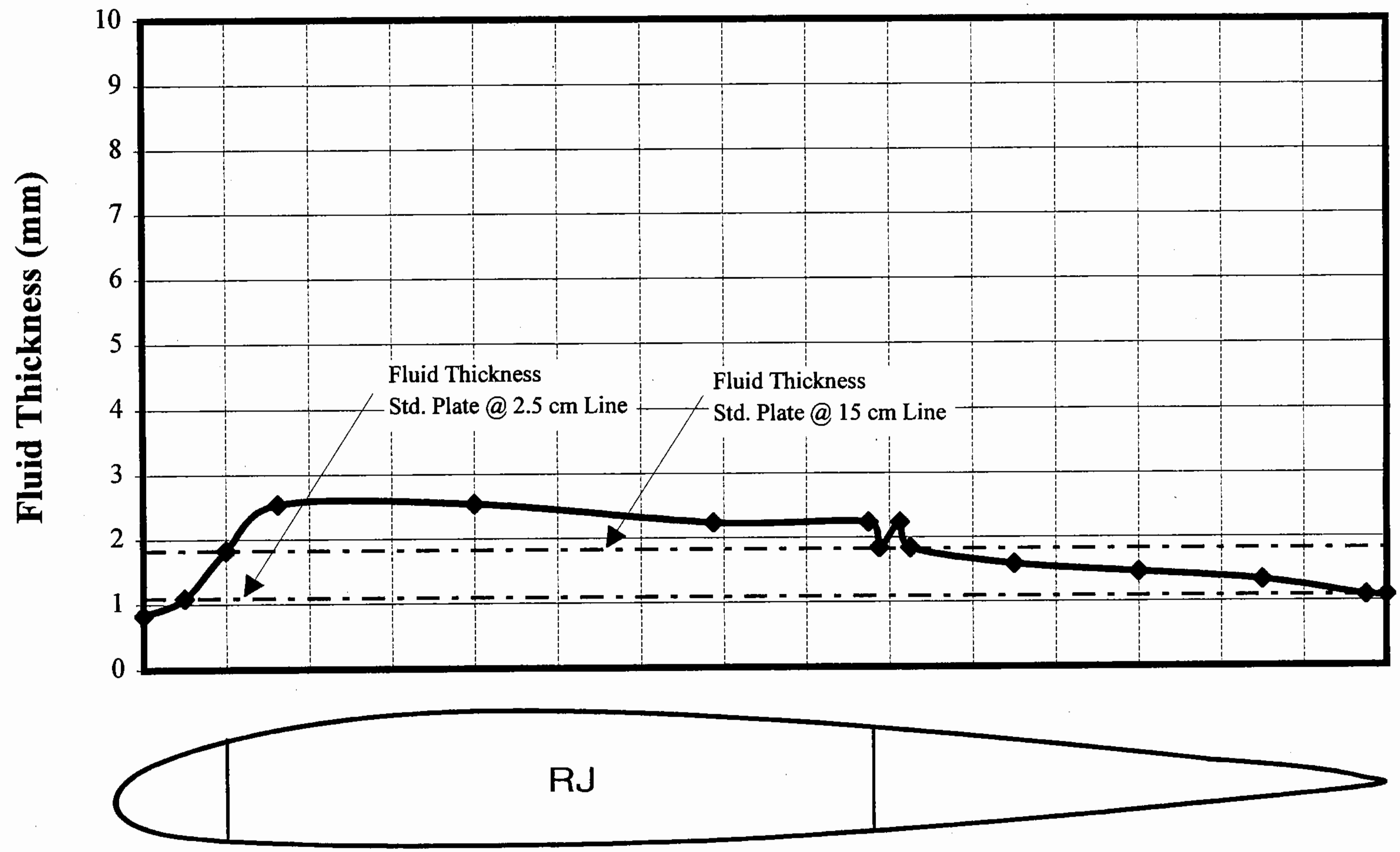
FIGURE 4.6

TYPE IV FLUID THICKNESS (STABILIZED) PROFILE AT CHORD 3 OF CANADAIR RJ

MARCH 12, 1996, RUN 4 - ULTRA OVER XL54



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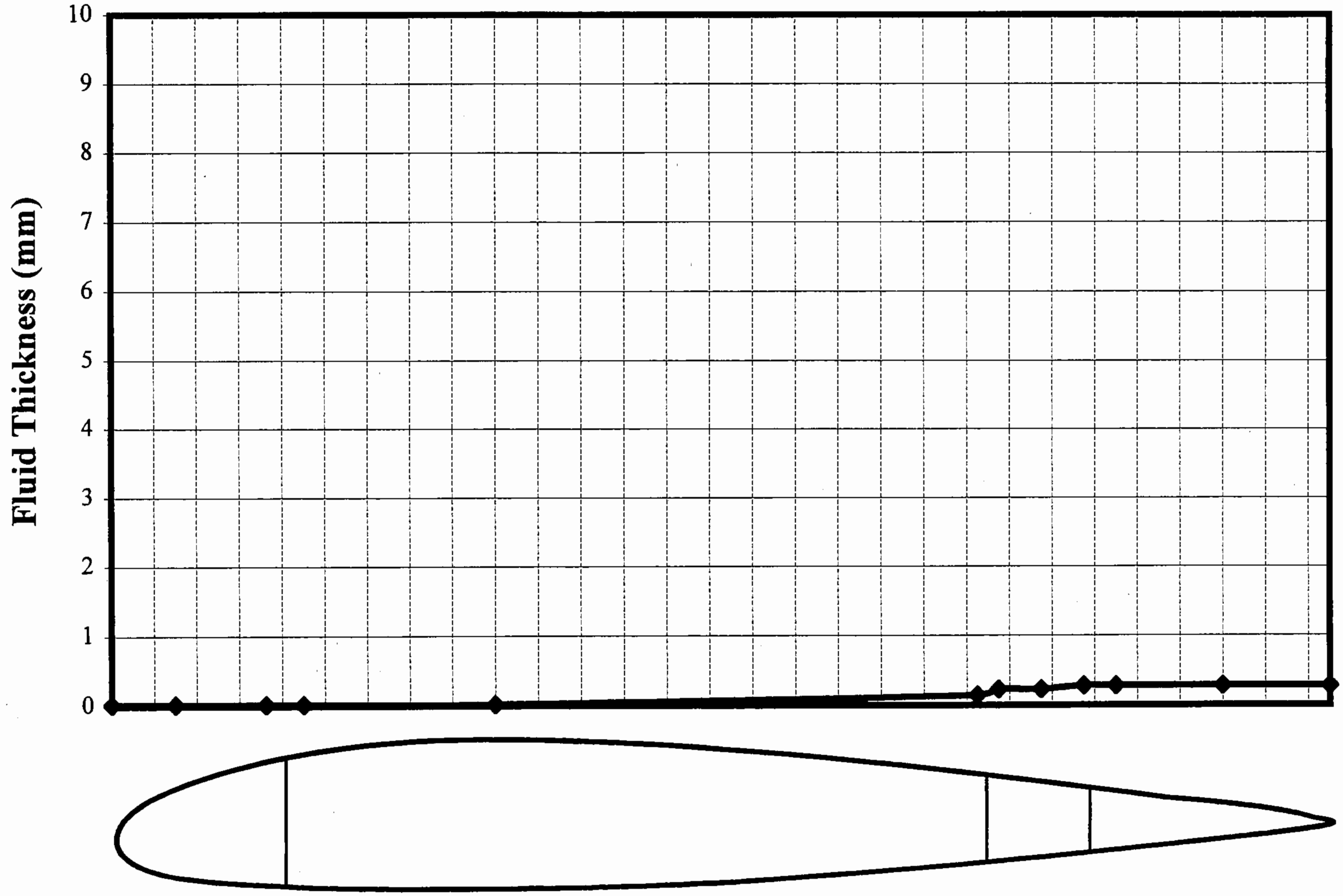
At:RJ RUN 4
Printed:30/09/96

FIGURE 4.7

TYPE I FLUID THICKNESS (STABILIZED) PROFILE AT CHORD 2 OF DC- 9

MARCH 12, 1996, RUN 4 - XL54

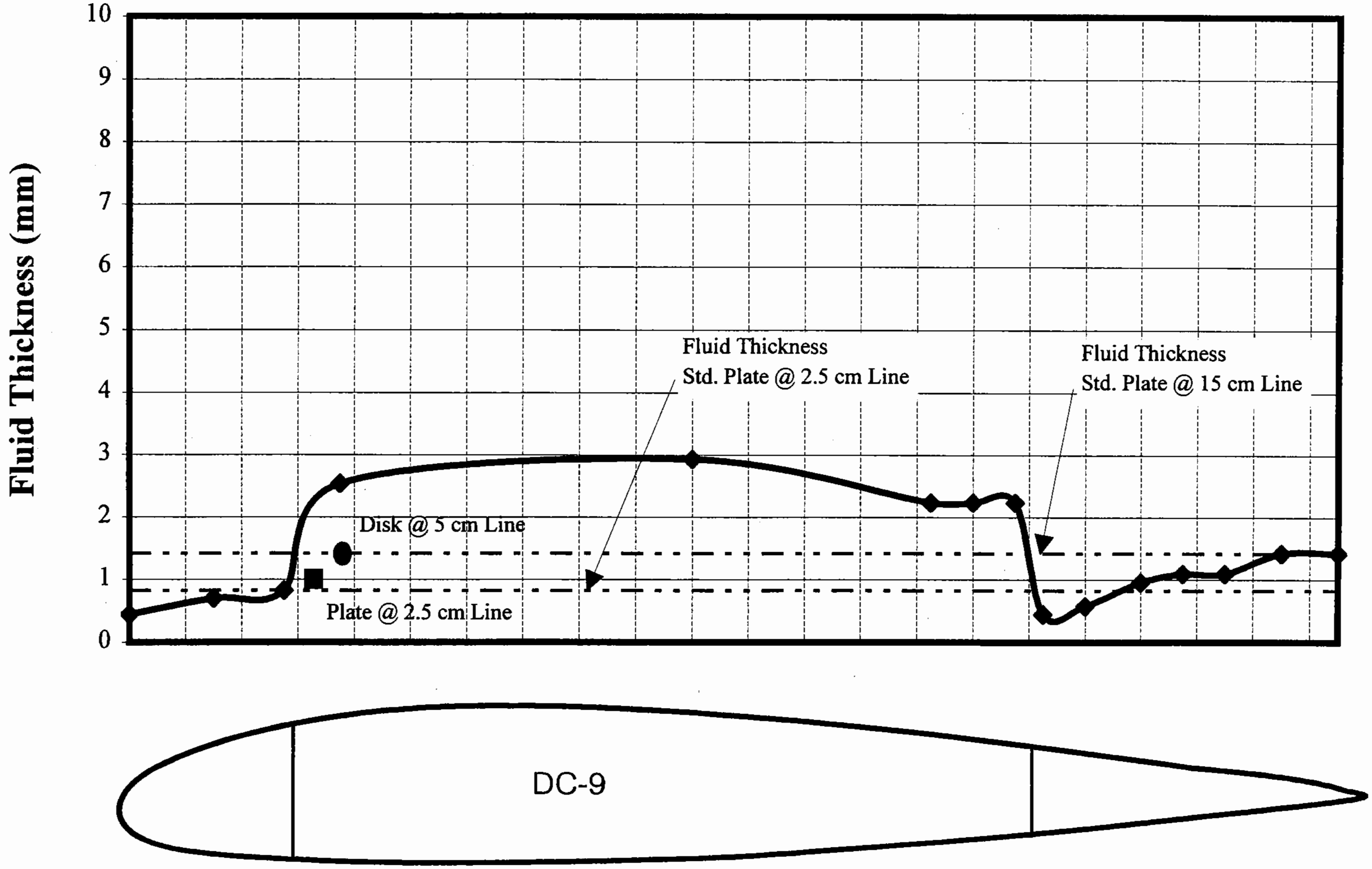


File:g:\cm1283\report\film\DC9_TPRF.XLS
At:RUN 4
Printed:26/09/96

FIGURE 4.8

TYPE IV FLUID THICKNESS (STABILIZED) PROFILE AT CHORD 3 OF DC-9

MARCH 12, 1996, RUN 1 - ULTRA

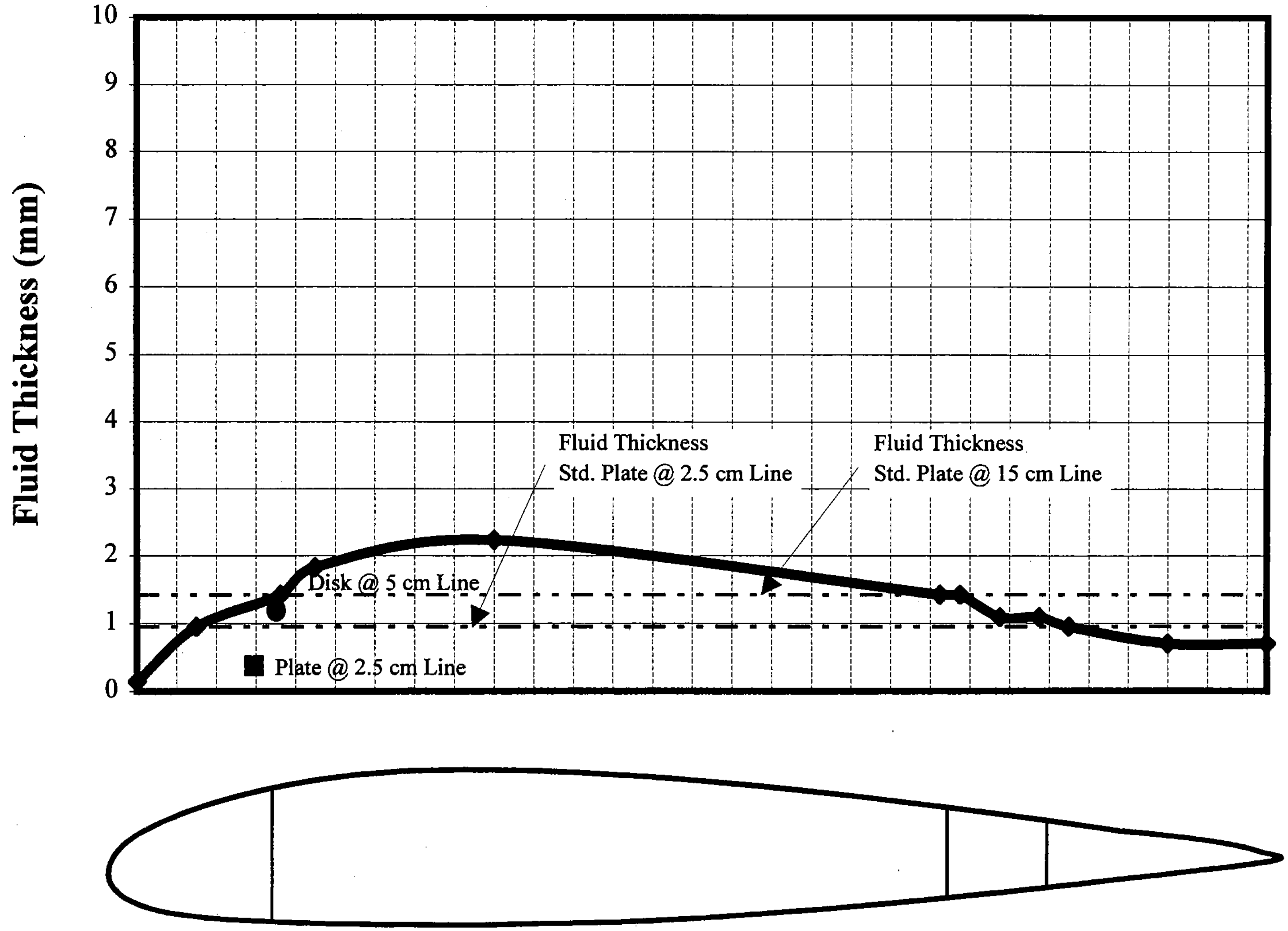


File:g:\cm1283\report\film\DC9_TPRF.XLS
At:DC9 RUN 1
Printed:30/09/96

FIGURE 4.9

TYPE IV OVER TYPE I FLUID THICKNESS (STABLIZED) PROFILE AT CHORD 2 OF DC- 9

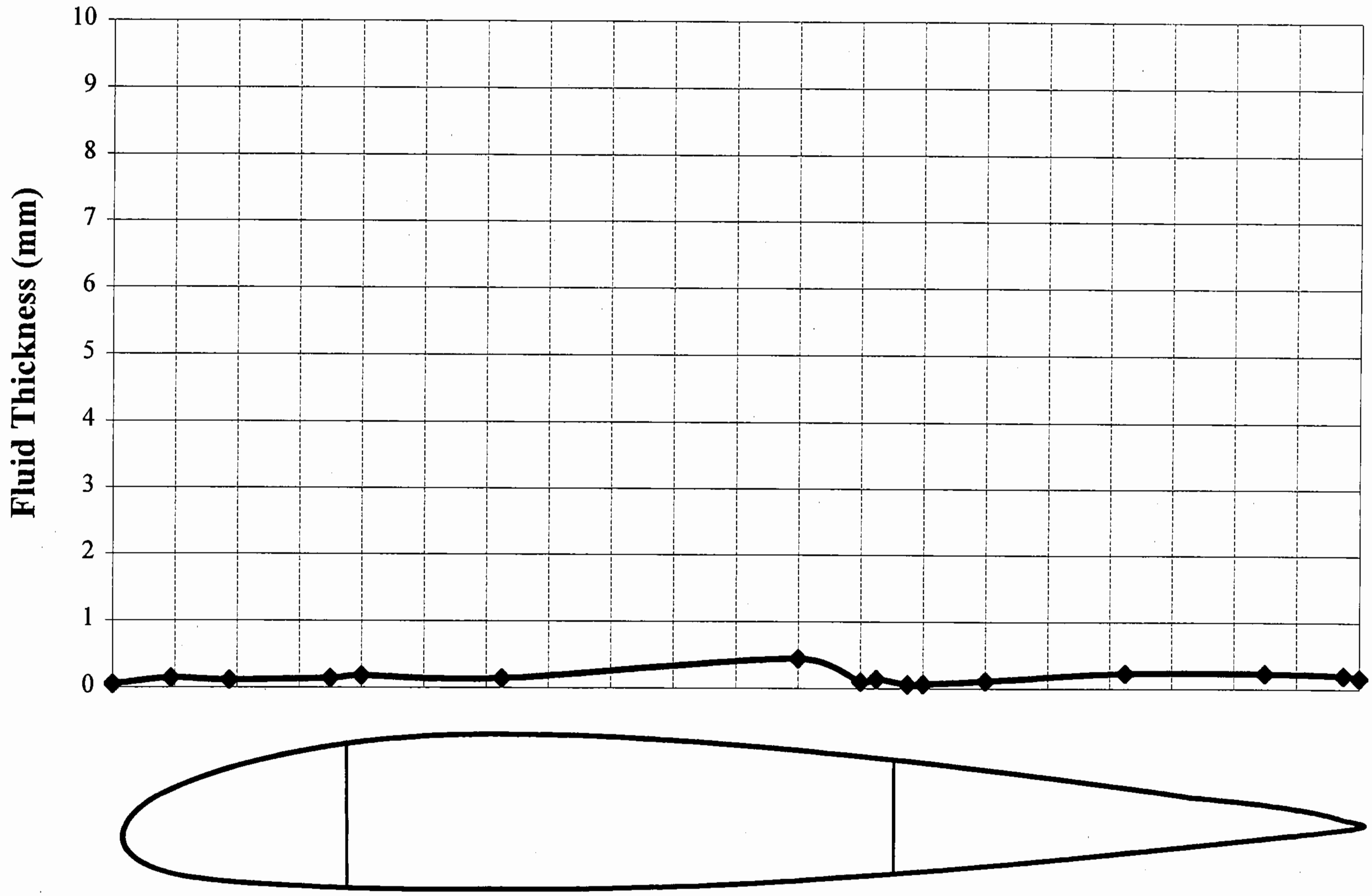
MARCH 12, 1996, RUN 5 - XL54 + ULTRA



File:g:\cm1283\report\film\DC9_TPRF.XLS
At:RUN 5
Printed:30/09/96

FIGURE 4.10

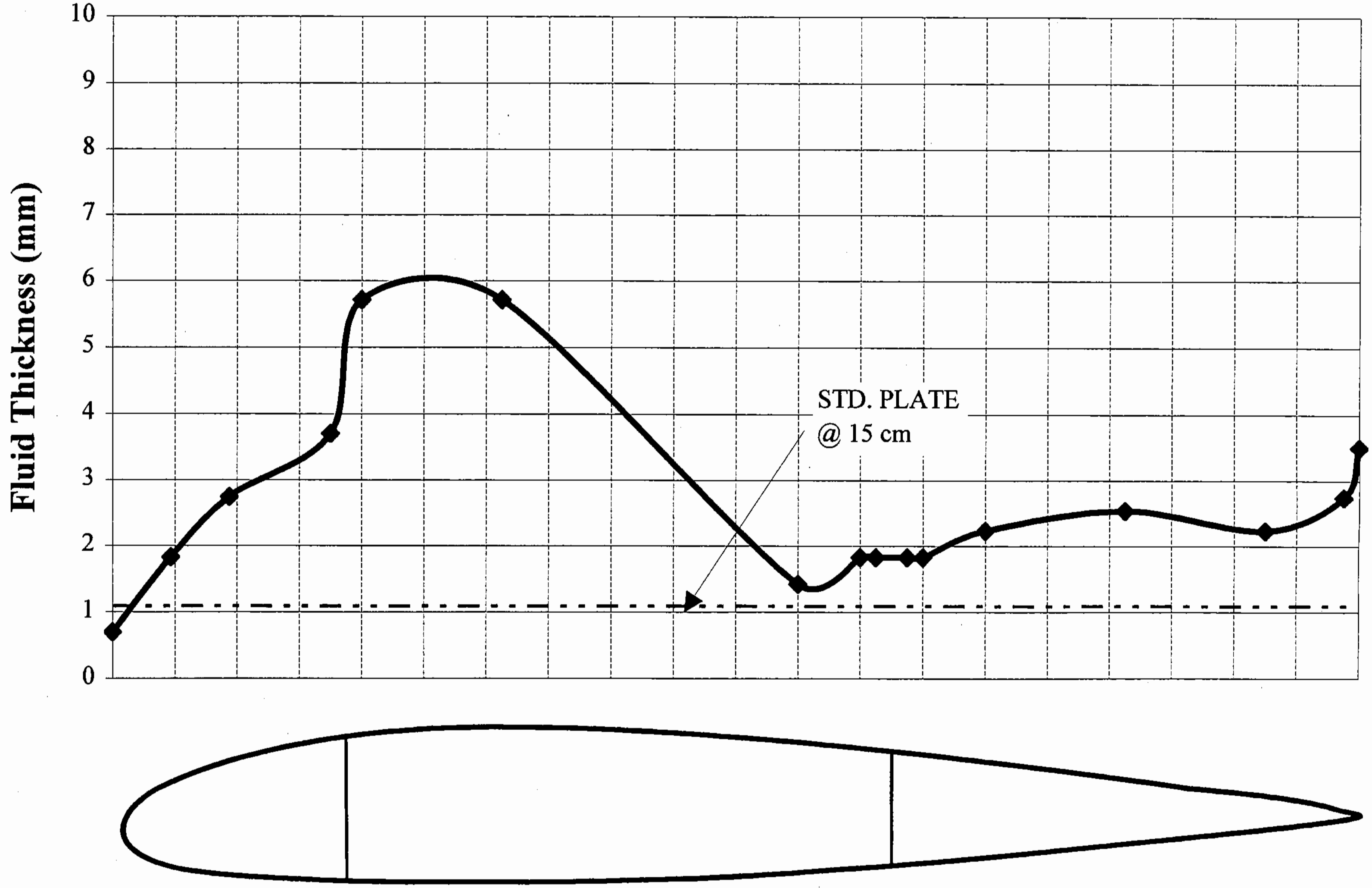
TYPE IV FLUID THICKNESS (STABILIZED) PROFILE AT CHORD 3 OF A-320 MARCH 29, 1996, RUN 3 - XL54



File:g:\cm1283\report\film\A320TPRF.XLS
At:RUN 3
Printed:23/08/96

FIGURE 4.11

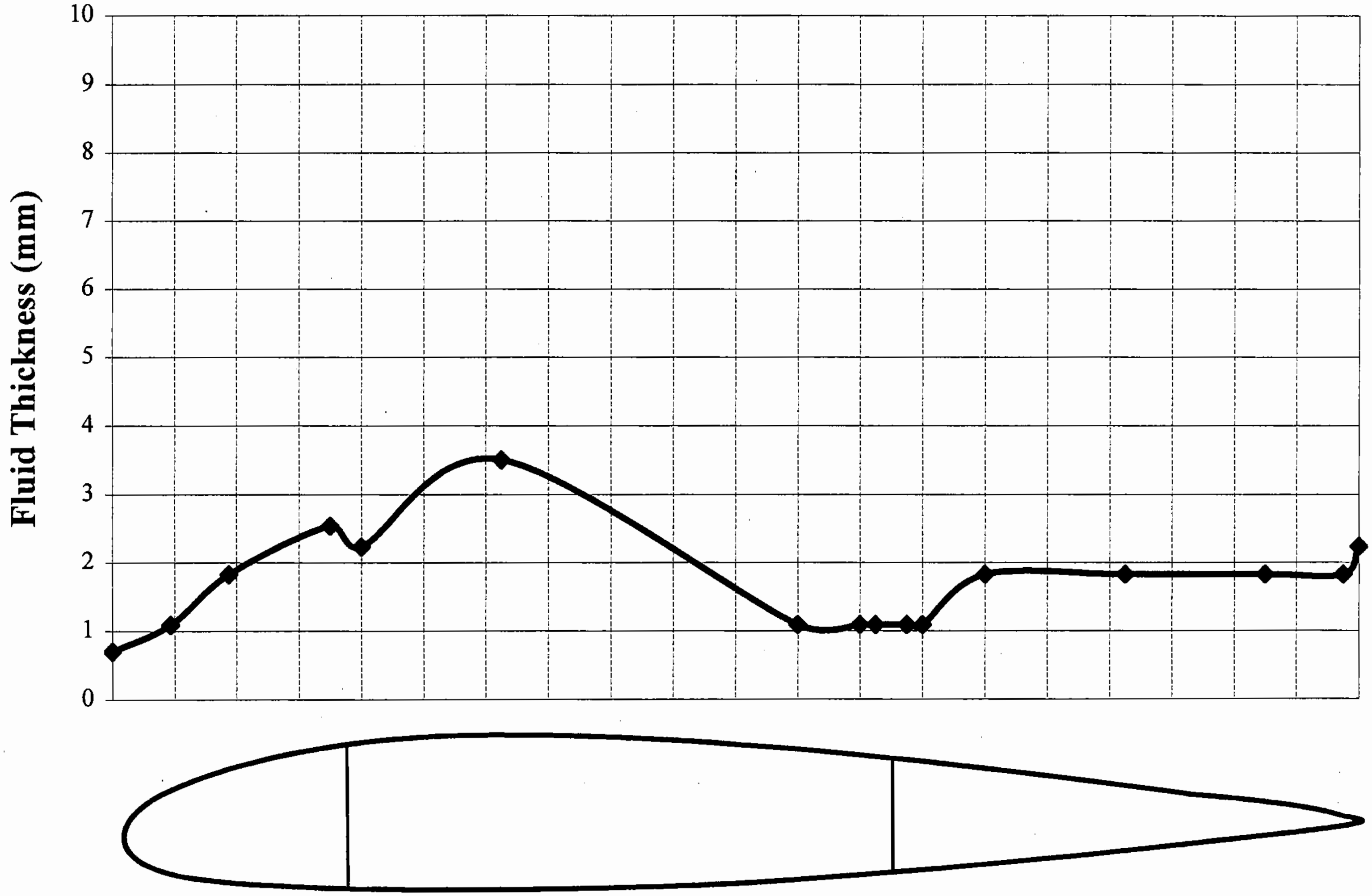
TYPE IV FLUID THICKNESS (STABILIZED) PROFILE AT CHORD 3 OF A-320 MARCH 29, 1996, RUN 2 - ULTRA



File:g:\cm1283\report\film\A320TPRF.XLS
At:RUN 2
Printed:28/08/96

FIGURE 4.12

TYPE IV FLUID THICKNESS (STABILIZED) PROFILE AT CHORD 3 OF A-320, RUN 5 MARCH 29, 1996 - ULTRA OVER XL54

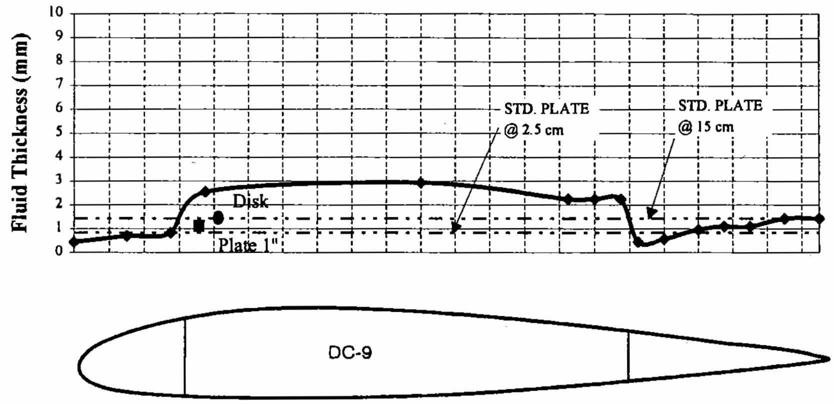


File:g:\cm1283\report\film\A320TPRF.XLS
At:RUN 5
Printed:28/08/96

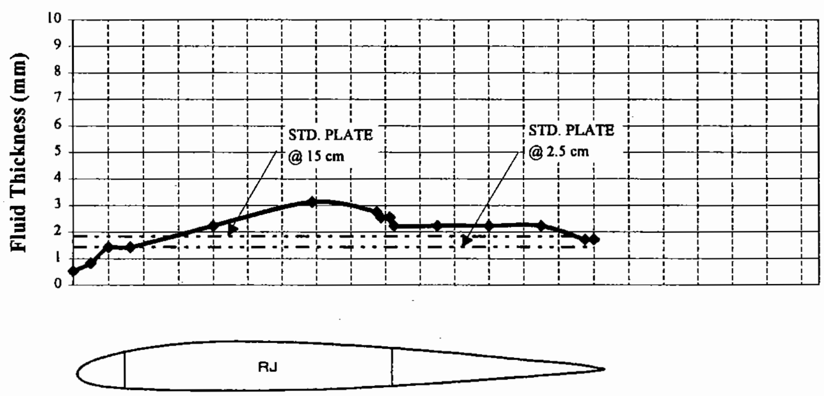
FIGURE 4.13

TYPE IV FLUID THICKNESS (STABILIZED) PROFILE AT CHORD 3 OF DC-9, RJ AND A320

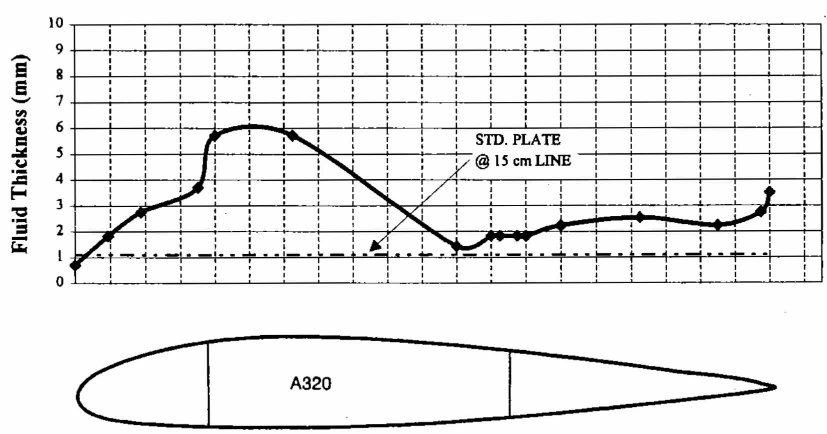
MARCH 12, 1996, RUN 1 - DC-9



MARCH 12, 1996, RUN 3 - CANADAIR RJ



MARCH 29, 1996, RUN 2 - A320



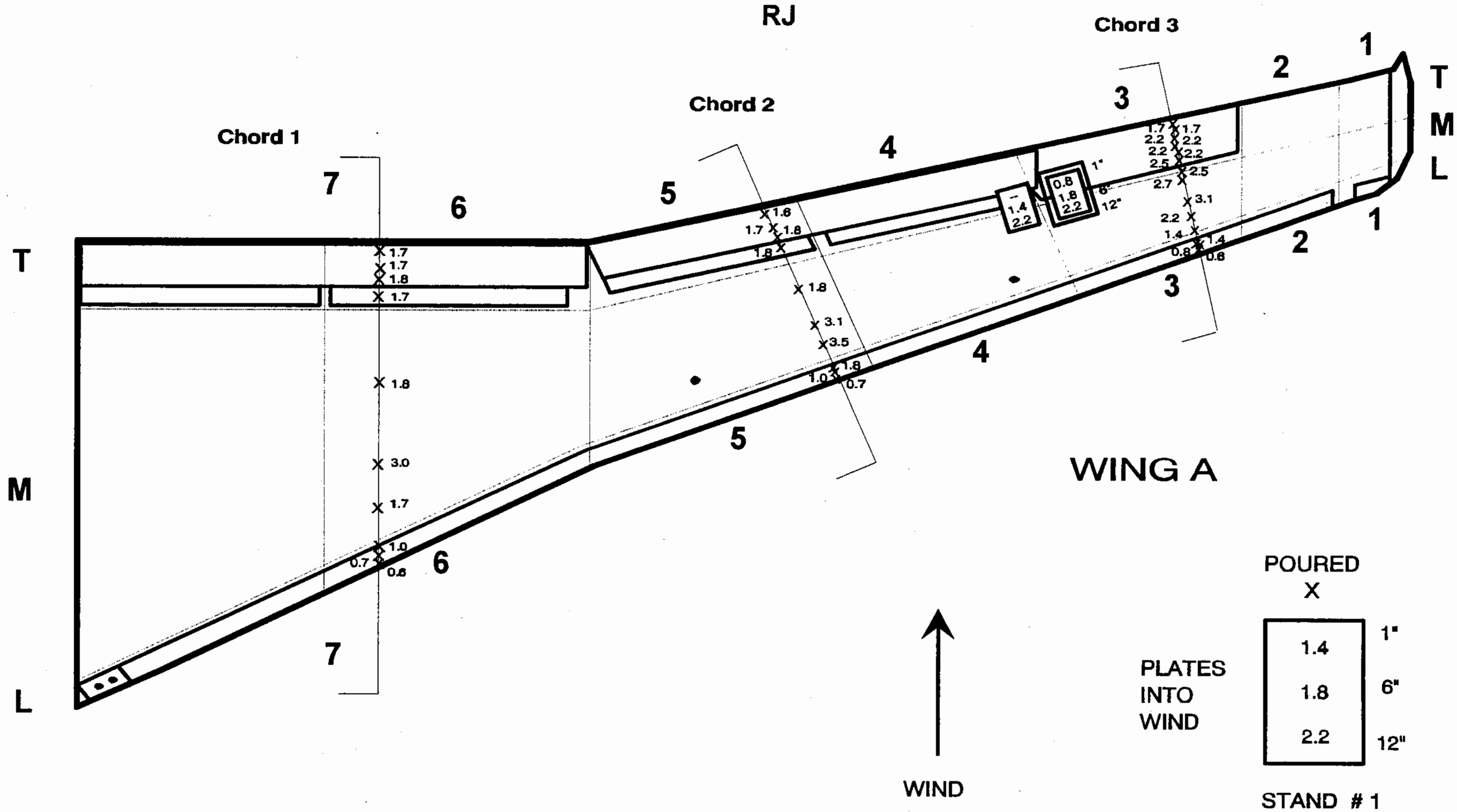
File:g:\cm1283\report\film\A320TPRF.XLS
At:A320-RJ-DC9
Printed:17/09/96

FIGURE 4.14

CANADAIR RJ STABILIZED THICKNESS ON WING PLAN

Run 3 - Feburary 15, 1996, Ultra

(mm)



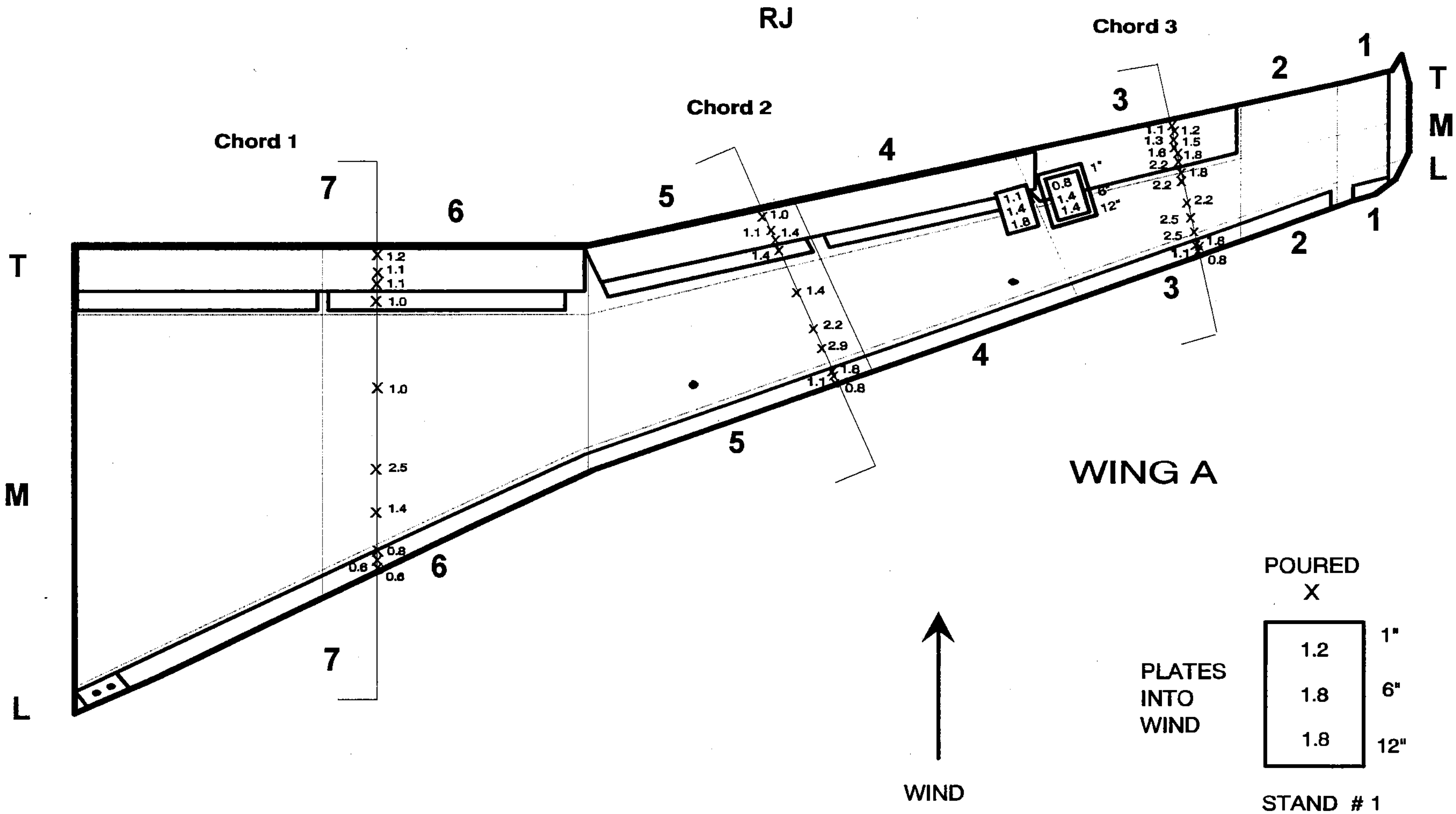
File:g/cm1283/report/film/RJ-AFR3.XLS
Date:30/09/96

FIGURE 4.15

CANADAIR RJ STABILIZED THICKNESS ON WING PLAN

Run 4 - Feburary 15, 1996, XL54 + Ultra

(mm)



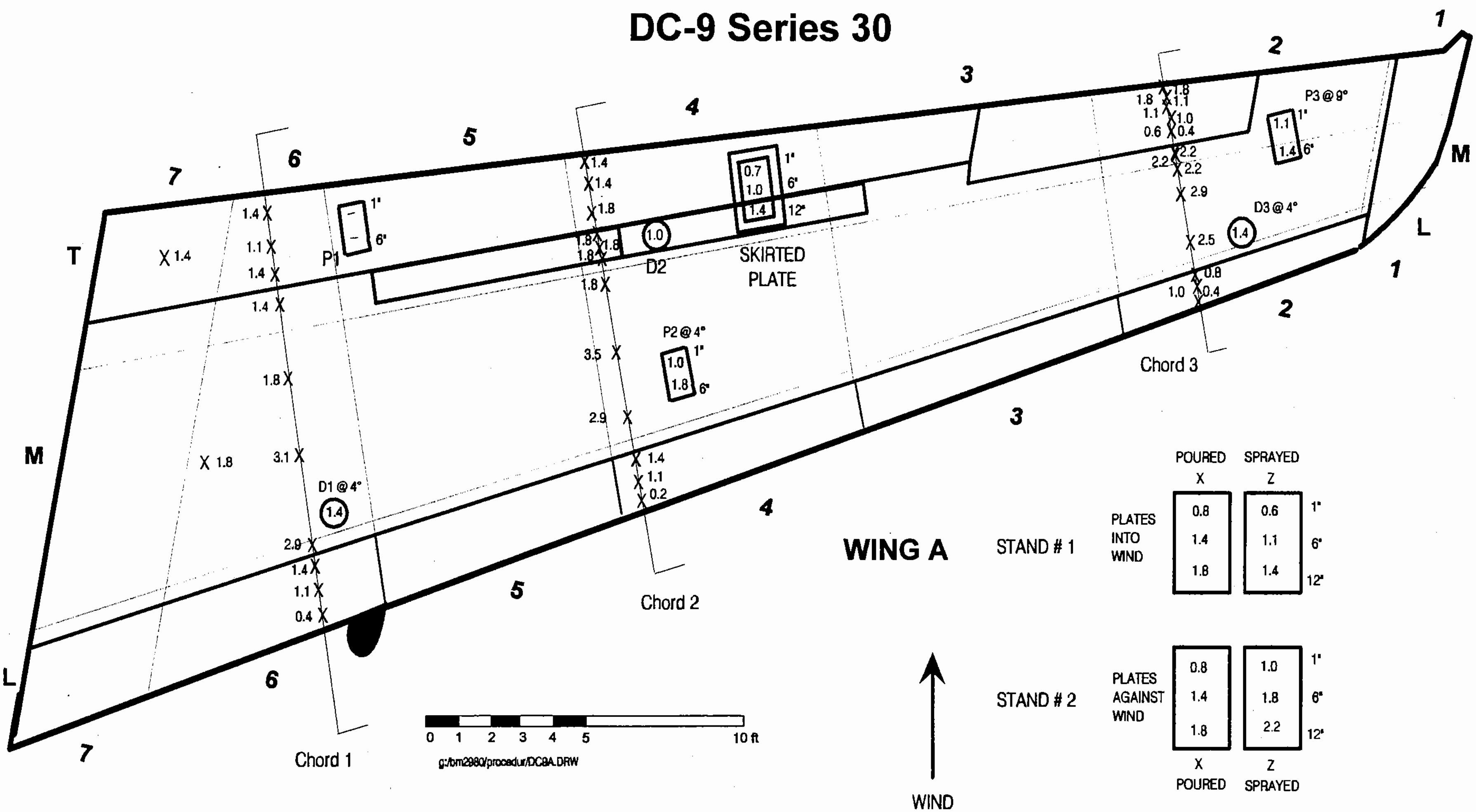
File:g/cm1283/reportr/film/RJ-AFR4.XLS
Date:30/09/96

FIGURE 4.16

DC-9 STABILIZED FLUID THICKNESS ON WING PLAN

Run 1 - March 12, 1996, Ultra

(mm)



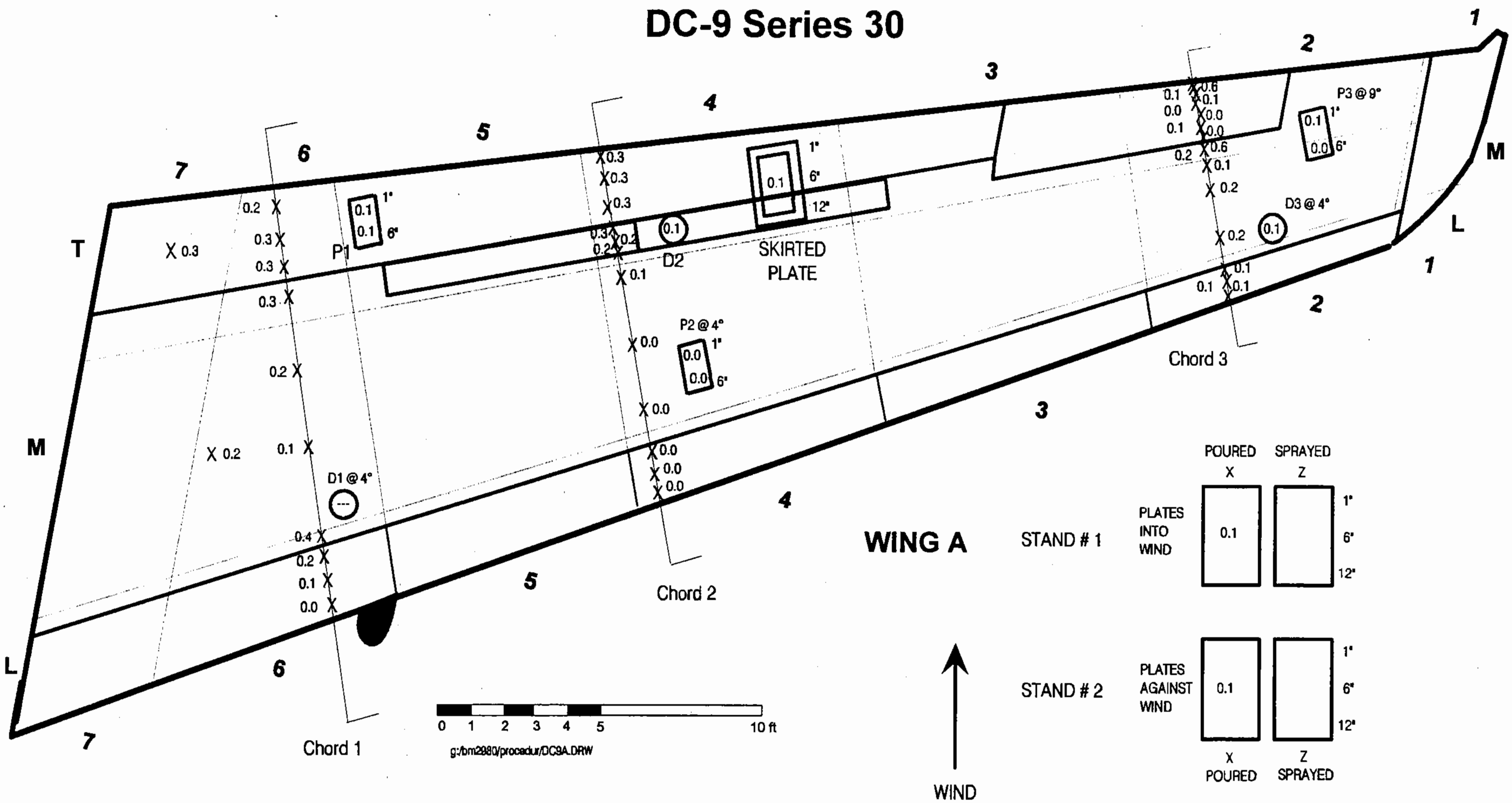
File:g/cm1283/report/film/DC9_RUN1.XLS
Printed: 30/09/96

FIGURE 4.17

DC-9 STABILIZED FLUID THICKNESS ON WING PLAN

Run 4 - March 12, 1996, XL54

(mm)



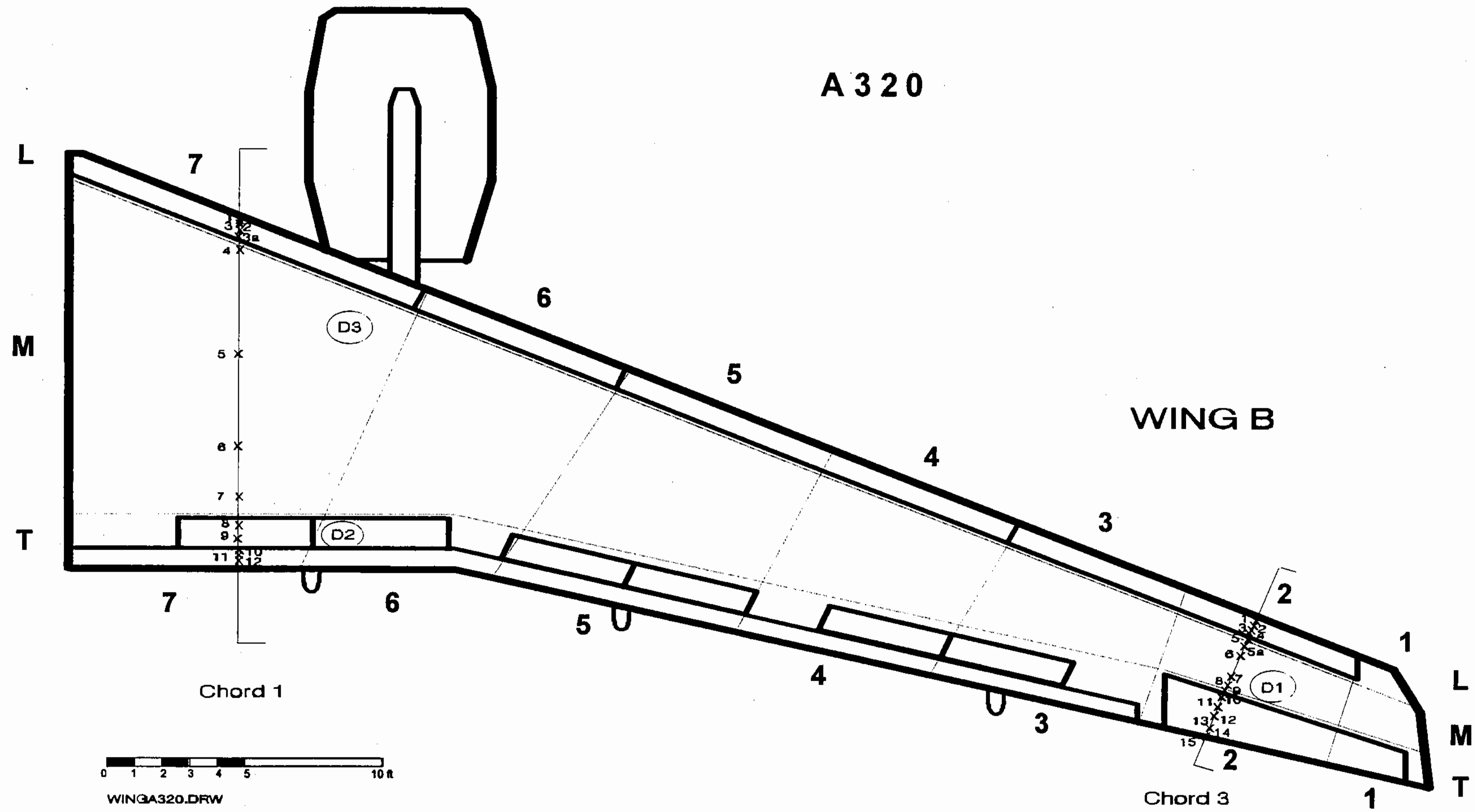
File:g/cm1283/report/film/DC9_RUN4.XLS
Printed: 30/09/96

FIGURE 4.18

A320 STABILIZED THICKNESS ON WING PLAN

Run 2 - March 29, 1996, Ultra

(mm)



STABILIZED THICKNESS (mm)																	
Location	1	2	3	3a	4	5	6	7	8	9	10	11	12	Disk 2	Disk 3		
Chord 1	0.7	1.4	2.2	4.5	4.5	5.7	1.8	2.2	2.2	1.8	2.2	1.8	1.8	1.8	2.5		
Location	1	2	3	4	5	5a	6	7	8	9	10	11	12	13	14	15	Disk 1
Chord 3	0.7	1.8	2.7	3.7	5.7	5.7	1.4	1.8	1.8	1.8	1.8	2.2	2.5	2.2	2.7	3.5	2.2

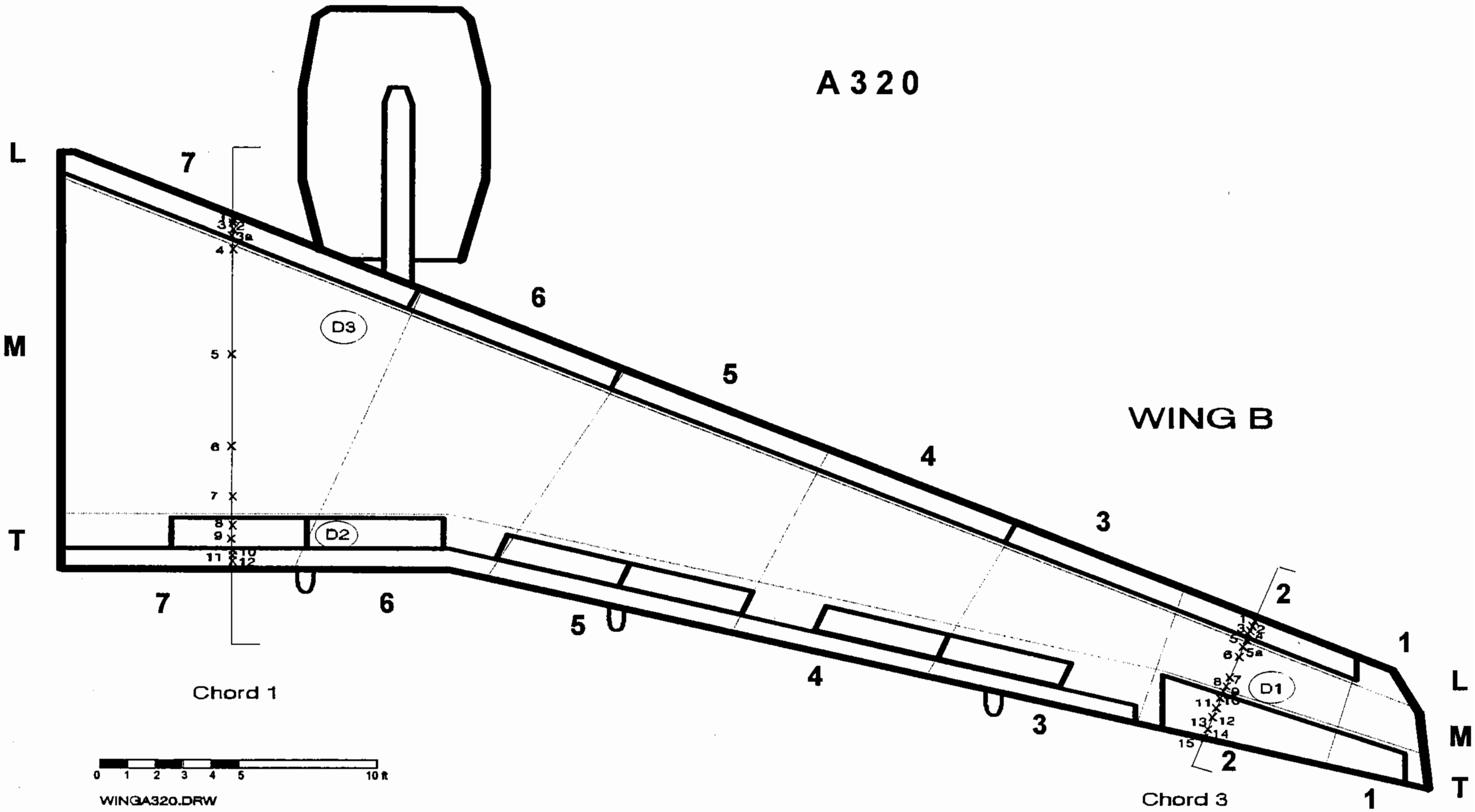
File:g/cm1283/report/film/A320_R2.XLS
Date:30/09/96

FIGURE 4.19

A320 STABILIZED THICKNESS ON WING PLAN

Run 5 - March 29, 1996, XL54 + Ultra

(mm)



STABILIZED THICKNESS (mm)																
Location	1	2	3	3a	4	5	6	7	8	9	10	11	12	Disk 2	Disk 3	
Chord 1	0.4	0.8	1.8	2.2	2.7	3.3	1.1	1.0	0.8	1.0	0.8	0.8	0.7	0.7	1.1	
Location	1	2	3	4	5	5a	6	7	8	9	10	11	12	13	14	15	Disk 1
Chord 3	0.7	1.1	1.8	2.5	2.2	3.5	1.1	1.1	1.1	1.1	1.1	1.8	1.8	1.8	1.8	2.2	1.8

File:g/cm1283/report/film/A320_R5.XLS
Date:30/09/96

- Measured values of final fluid thickness would be expected to have limited capability to support holdover time. Experienced holdover times longer than supportable by measured fluid thicknesses must be attributed to heat transfer from the heated Type I fluid to the wing surface.

- Although there is some variation in film thickness at different points along the wing chord, the difference is not significant enough to support conclusions for locating representative surfaces. Use of fluid thickness as the sole criteria would indicate that current representative surface locations on the top surface of the wing should be as satisfactory as any other location, however observations during Aircraft Full-Scale tests showed that other areas on the wing, especially the leading and trailing edge surfaces, failed before representative surfaces. Observations from "Hot Water De-Icing Trials for the 1994-1995 Winter"(3) may offer an explanation for this. Those trials demonstrated that after application of hot water, the most rapid drop in temperature and earliest freeze-up occurred on thinner surface panels such as flight control surfaces. The same would be expected to be true following application of heated Type I de-icing fluid.

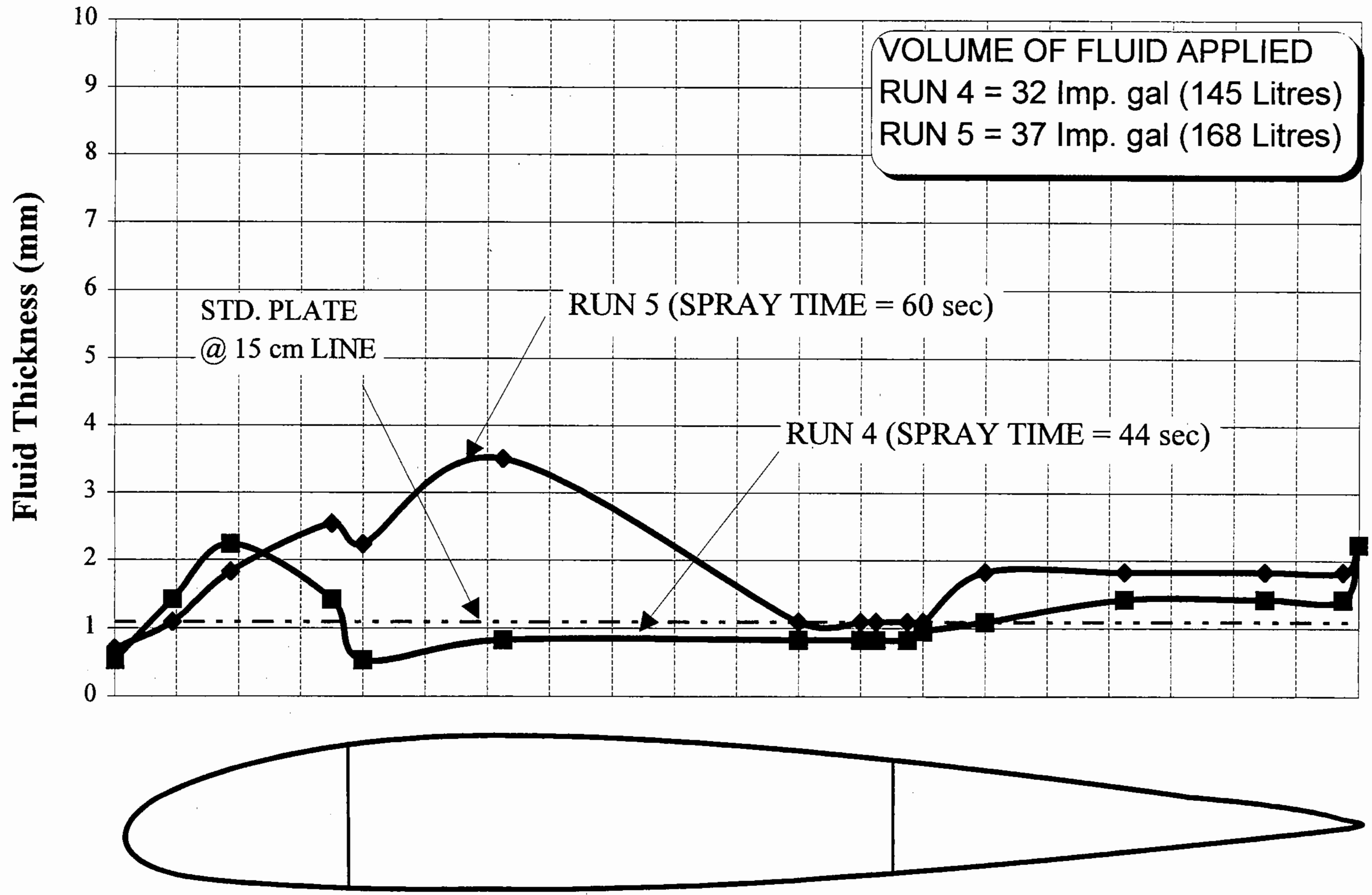
4.2 Type IV Fluid

- Type IV fluid, whether applied on a bare surface or over Type I generally stabilized in about 12 to 14 minutes.

- Stabilized thickness was dependent on the thickness of the initial application (within the bounds of normal application quantities), on the existence of gaps in the wing surface (as at edges of flight control surfaces) where fluid could drain away, and on the slope of the surface at each data point location. The results from Run 4 and 5 on March 29, 1996 for Type IV Ultra fluid over Type I XL54 fluid (Figure 4.20) illustrate the influence of application technique on fluid thickness. In Run 5, the spray operator was asked to give particular attention (note longer spray time) to building

FIGURE 4.20

TYPE IV FLUID THICKNESS (STABILIZED) PROFILE
AT CHORD 3 OF A-320
MARCH 29, 1996 - ULTRA OVER XL54



File:g:\cm1283\report\film\A320TPRF.XLS
At:RUN 4&5
Printed:28/08/96

up a thick and consistent layer of fluid over the entire wing. Fluid thickness after stabilizing reflected the much thicker initial application. Charts illustrating the fluid thickness profile along the wing chord (Figures 4.5 to 4.12) all show how fluid becomes thinner where surface slopes increase. The leading edge offers the best example of this effect.

- Some scatter of film thickness data resulted on some runs when spray application produced inconsistent film thickness. As these runs progressed, fluid film of varying thicknesses were observed to flow by the measurement locations. An example of inconsistent film thickness is illustrated in previously referred Photo 3.1. Figure 4.21 presents another perspective of the mechanics of inconsistent fluid film thickness. In this chart, a thin initial film at position 5 after spray application is seen to progressively increase in thickness as fluid flows down from position 4, providing a final film of adequate thickness.

4.3 Type IV Fluid Over Type I Fluid

- In general, Ultra Type IV fluid applied over XL54 Type I fluid stabilized within a time frame similar to Ultra on a bare plate.

- Data indicated that film thicknesses resultant from the two-step operation were almost always less than those from Ultra applied directly on a bare wing. For the RJ aircraft, values on the high point of the wing where fluid thickness was greatest produced values of 3.8 mm for Ultra on bare wing versus 2.5 mm for Ultra over Type I. Related values for the DC-9 aircraft were 3.1 versus 3.0 mm.

  For the DC-9 aircraft, on the leading edge just forward of the main wing, values for Ultra on bare wing ranged from 1.0 to 2.0 mm versus 0.8 to 1.4 for the two-step application. For the A320 aircraft, related values were 2.5 versus 2.0 mm. Results observed on special disks mounted on the wing surface (Section 4.7) supported this

FIGURE 4.21

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

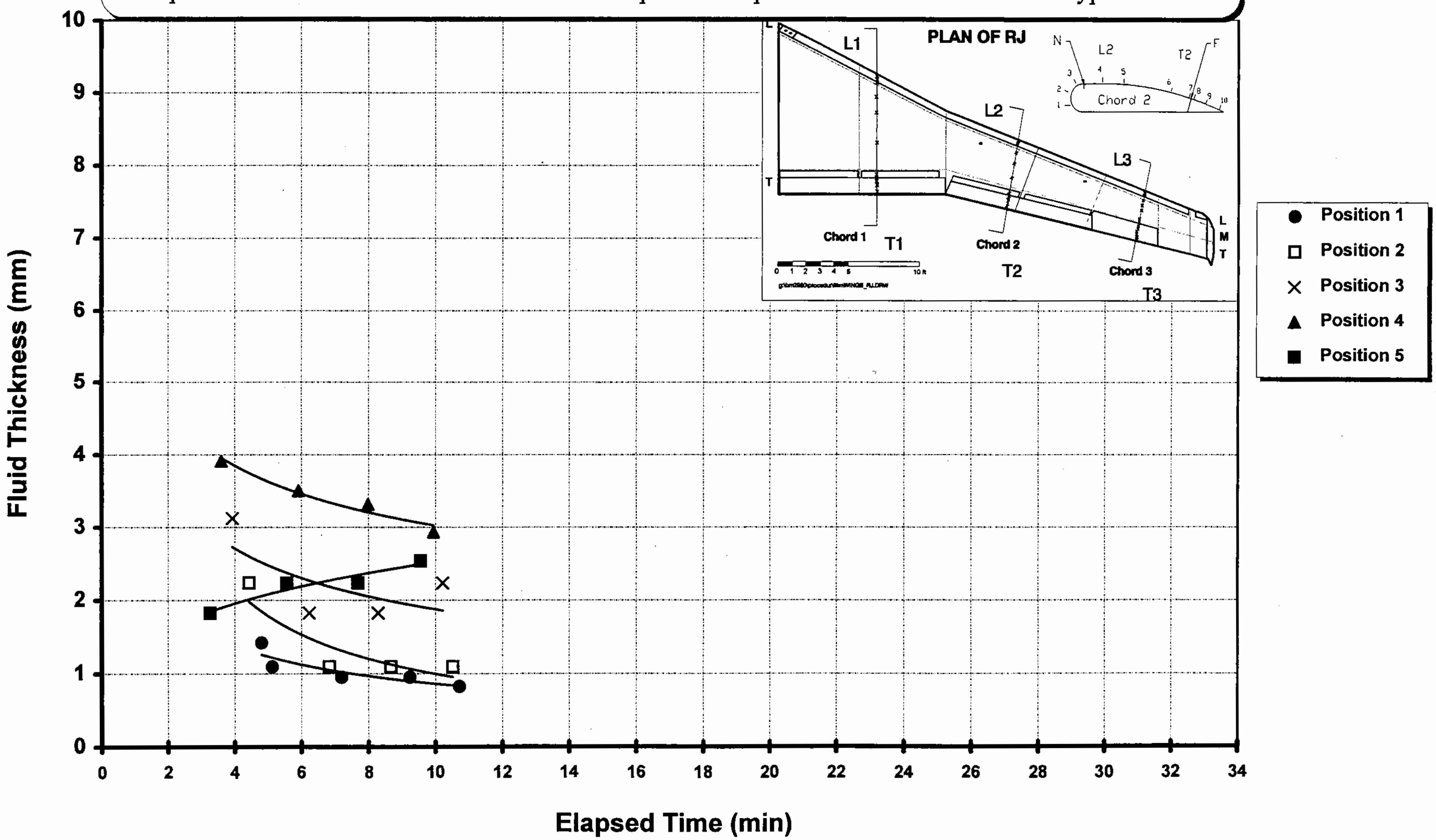
RUN 4 - FEBURARY 15, 1996

CANADAIR RJ - LOCATION L2

1st FLUID: XL54 TYPE I / 109 LITRES

2nd FLUID: ULTRA TYPE IV / 109 LITRES

Temperature: -17.9°C | Wind Speed: 6.7 kph | Nozzle Type: AKRON



File:g:\cm1283\report\film\FEB15_R4.XLS
At: L2_CHT
Printed:09/12/96

observation and also indicated that the thinning effect of Ultra over Type I may be more pronounced as the surface slope increases. While these observations appear to have validity, variance in initial film thickness from run to run prevented firm conclusions from being drawn, and tests with flat plates (Section 4.9.3) were conducted to investigate this further.

4.4 Fluid Film Profiles Across the Wing Chord

For Type IV, and for Type IV over Type I, fluid thickness profiles followed a standard pattern across the chord.

- The greatest film thickness was found on the top of the wing curvature, where the slope is least. Stabilized thickness values in the order of 3 mm (120 mil) were commonly seen with some values up to 5 mm (200 mil) occurring.

- Film thickness progressively decreased as the slope of the wing surface increased, moving away from the high point of the wing. Just forward of the wing juncture on the leading edge, film thickness dropped to values of 1 to 2 mm (40 to 80 mil) rapidly decreasing to 0.5 mm (20 mil) on the nose of the leading edge. Here, fluid existed only while being fed from above.

- Fluid progressively thinned moving from the high point of the wing toward the trailing edge. On flight control surfaces at the rear of the wing, fluid thickness varied from 1.5 mm on the surface to 0.5 mm on the trailing edge.

- Examination of the results of the different chords on each wing did not produce any trends. The critical leading edge demonstrated consistent fluid thickness values along its entire length. The wing dihedral did not offer any observable impact on fluid thickness.

- Comparisons of results from one aircraft to another similarly produced no observable trends, with comparison restricted by the limited number of runs and inconsistency in application between runs and sessions.

- The DC-9 aircraft experienced loss of fluid at gaps in the wing surface, such as the juncture of wing and leading edge slat (Figure 4.22) and at the forward edges of flight control surfaces. This resulted in further reduction in film thickness downstream from these gaps as the fluid drained away and was not replaced by fluid from higher elevations. This process was not so pronounced at flight control surfaces on the A320 and Canadair RJ aircraft where fluid drainage was limited by seals incorporated between the wing and mating flight control surfaces (Photo 4.1). (As the tests were conducted without hydraulic pressure on the aircraft, a concern was raised as to whether the slats were completely retracted during the test. A test was repeated with hydraulic pressure on, in which Type IV fluid was applied over a portion of the wing and leading edge slat and fluid thickness measured. The results were consistent with those reported previously).

- Extension of leading edge slats for take-off configuration would result in increased slope of the leading edge surface (Figure 4.22) and consequently, more pronounced thinning of fluid at that phase of the operation. Additionally, leading edge slat extension exposes an unprotected area to precipitation.

- Type I fluid thinned rapidly at all points along the chord, producing a stabilized thickness profile that was nearly flat.

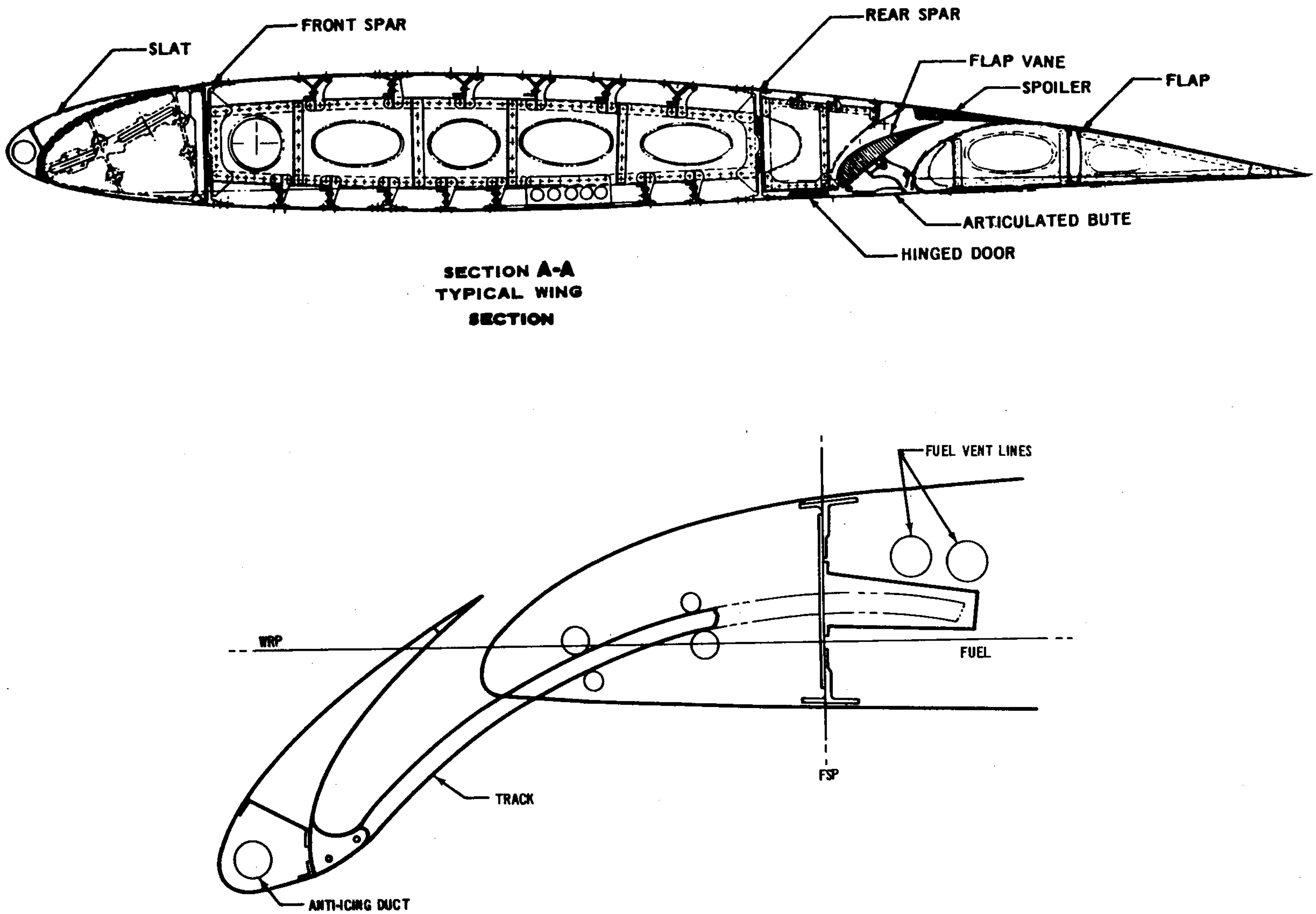
Figure 4.13 provides a comparison of film profiles for all three aircraft tested.

4.5 Areas Demonstrating Faster than Normal Fluid Thinning

- As reported in previous studies[(2)], the DC-9 aircraft has a raised surface area on the

FIGURE 4.22

DC-9 WING CROSS SECTION AND LEADING EDGE EXTENDED



Reference: DC-9 Douglas Jet Transport - Detail Type Specification OTS-3850
McDonnell Douglas Corporation, Revised 1 July 1969

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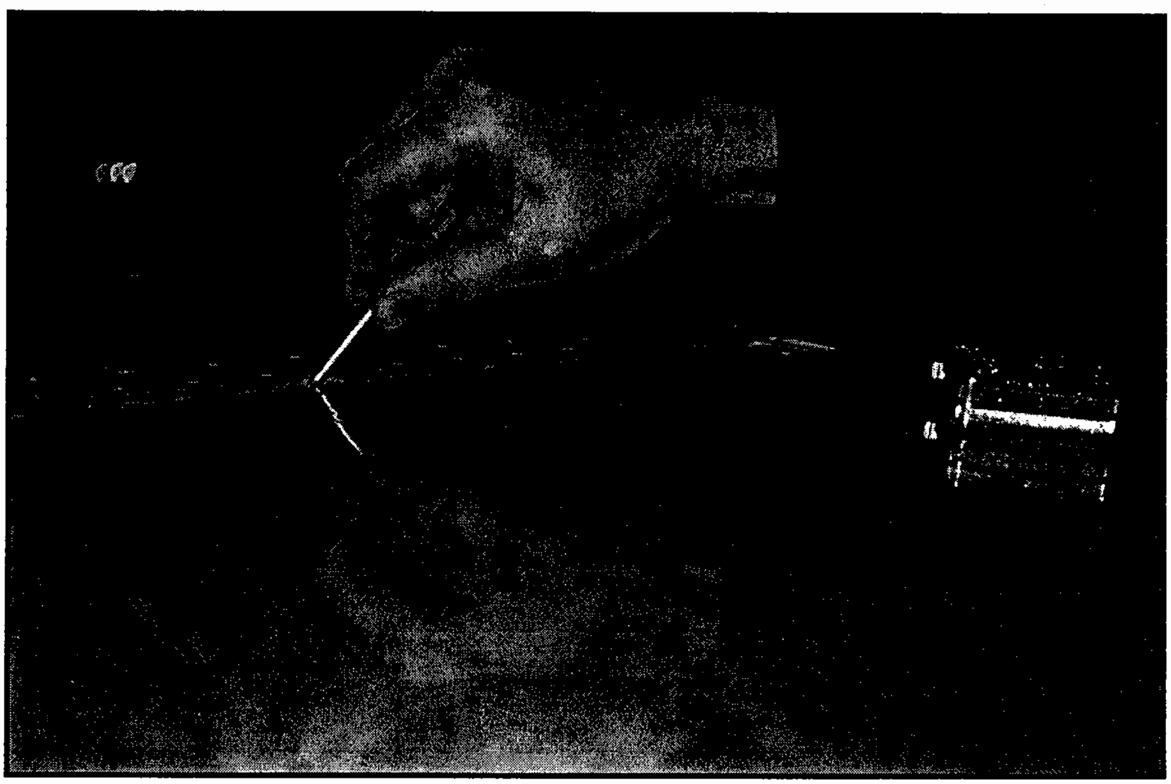
PHOTO 4.1

SEAL AT JUNCTION OF MAIN WING AND FLIGHT CONTROL SURFACE

CANADAIR RJ



inner wing. This was identified as location L1 position 6 in this study. While film thickness results from run # 2 (Ultra fluid) indicated that film thickness at this location is equivalent to position 2 or 3 on the leading edge, this finding was not supported by all runs.

- The A320 aircraft experienced fluid film thinning more rapidly than expected at Chord 3 on a surface of the main wing immediately forward of the outboard aileron.

4.6 Comparison of Film Thickness on Wing and Flat Plate

Film thicknesses on the leading edge of the A320 and DC-9 aircraft fall within the range of thicknesses measured at the 1" (2.5 cm) and 6" (15 cm) lines on standard test plates. This supports conclusions in the "Aircraft Full-Scale Test Program for the 1994-1995 Winter"(2) study that the flat plate is a satisfactory representation of the aircraft wing. Film thickness test results on the Canadair RJ aircraft differed in that the leading edge film thickness was most often less than that measured at the 1" (2.5 cm) line on the test plate, and was found to be up to 50% less than the film thickness on the flat plate at the 6" (15 cm) line. These observations are of concern because this aircraft has a supercritical wing and, the leading edge does not have slats. Some possible causes of this result may be:

- The leading edge curvature may be greater over a larger section than on the other tested aircraft. This may result in greater slopes on the leading edge over a greater distance;

- The leading edge is manufactured from an aluminum alloy, polished and buffed to a very smooth finish. It is inspected in service to ensure that it is maintained in a very clean state; and

- The Type IV fluid applied on the wing may have been warmer than the fluid on the plates. If the fluid was warmer than -14°C (ambient temperature) fluid viscosity would have been reduced and may have resulted in a thinner film.

The concerns on the RJ leading edge must be investigated further.

4.7 Special Disks and Plates Mounted Directly on the Wing Surface

- The effect of slope on Ultra fluid film thickness was demonstrated in results observed on disks and plates installed on the DC-9 aircraft (Figures F-5 and F-6 in Appendix F and Table 4.1). Disk D2 with an installed slope of 9 degrees showed film thickness of about 75% that of film on disks D1 and D3 having installed slopes of 4 degrees. This observation was also true with plates P1 and P3 (at slope of 9 degrees) versus plate P2 (at slope of 4 degrees).

- Comparison of results from the same disks when treated with Ultra fluid applied over Type I (Figures F-9 and F-10 in Appendix F) showed film thickness on disk D2 (at slope 9 degrees) at about 50% that of disks D1 and D3 (with slopes of 4 degrees), indicating that this combination of fluids may thin more rapidly with increasing slope than does Ultra applied on a bare surface.

4.7.1 Artificial Surface for Sensor Location

- Still on results from the DC-9 test, film thickness on disks D1 and D3 (mounted on the top of the wing) reflect film thicknesses experienced at position 3 on the leading edge. Film thickness on plate 2 measured at the 1" (2.5 cm) line also tends to reflect film thickness experienced on the leading edge. This indicates that the concept of artificial surfaces designed to simulate fluid condition on wing critical areas which are not clearly visible to flight crew, or not adaptable to installation of contamination sensors, is a

TABLE 4.1

STABILIZED THICKNESS ON PLATES AND DISKS DURING AIRCRAFT TESTS

(mm)

Aircraft	Run #	Raised Above Wing		On Wing Surface						On Stand						Fluid	Temp. (°C)	Wind (kph)	Notes
				Plates			Disks			Into Wind			Against Wind						
		Skirted Plate (TE)	Standard Plate (TE)	P1 (TE)	P2 (LE)	P3 (TE)	D1 (LE)	D2 (TE)	D3 (LE)	STD X	Y	Z	X	Y	Z				
Canadair** RJ	1	0.4	1.4							1.8						Ultra	-16	7	Contaminated Fluid, Tips nozzle
	2	1.4	1.8							1.8						Ultra	-17	5	Contaminated Fluid, Tips nozzle
	3	1.4	1.8							1.8						Ultra	-18	7	Akron nozzle
	4	1.4	1.4							1.8						Ultra/XL54	-18	7	Akron nozzle
DC-9	1	1.0		-	1.8	1.4	1.4	1.0	1.4	1.4	-	1.1	1.4	-	1.8	Ultra	-4	9	Akron nozzle
	2	1.0		1.4	1.8	1.4	1.4	1.0	1.4	1.8	-	1.4	1.4	-	1.4	Ultra	-5	8	Akron nozzle
	3	0.1		0.1	0.0	0.1	-	0.1	0.0	0.1	-	-	0.0	-	-	XL54	-4	10	Akron nozzle
	4	0.1		0.1	0.0	0.0	-	0.1	0.1	0.1	-	-	0.1	-	-	XL54	-4	10	Akron nozzle
	5	0.8		0.7	1.1	1.4	1.1	0.6	1.4	1.4	1.1	1.4	1.4	1.4	1.1	Ultra/XL54	-5	6	Akron nozzle
	6	0.8		0.8	1.8	1.4	1.1	0.7	1.8	1.4	1.4	1.1	1.4	1.4	1.1	Ultra/XL54	-6	5	Akron nozzle
A320	1						0.7*	0.8	0.5	1.0*	-		1.0	-		Ultra	-1	7	Contaminated Fluid, Akron nozzle
	2						1.8*	1.8	2.2	1.1	-		1.1	-		Ultra	-2	10	Akron nozzle
	3						0.1*	0.4	0.1	0.0	-		0.0	-		XL54	-3	13	Akron nozzle
	4						1.4*	0.2	0.3	-	1.0		-	1.0		Ultra/XL54	-3	13	Akron nozzle
	5						1.8*	0.7	1.1	-	-		-	-		Ultra/XL54	-4	13	Akron nozzle
Location of Measurement		6"	6"	6"	6"	6"	2"	2"	2"	6"	6"	6"	6"	6"	6"				
Slope (Estimate)		10°	10°	9°	4°	9°	4°	9°	4°	10°	10°	10°	10°	10°	10°				

Fluid Application

	Skirted Plate (TE)	Standard Plate (TE)	P1	P2	P3	D1	D2	D3	STD X	Y	Z	X	Y	Z
One-Step (XL54 or Ultra)	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓
Two-Step (XL54 + Ultra)	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓
Pour from Container		✓							✓	✓		✓	✓	
Spray from Truck	✓		✓	✓	✓	✓	✓	✓						
Spray from Garden Sprayer											✓			✓
Truck Fluid	✓		✓	✓	✓	✓	✓	✓						
Site Fluid		✓							✓	✓	✓	✓	✓	✓

* Placed near Trailing Edge for this test.

** For the RJ session, only the Octagon thickness gauge was used to measure film thickness on plates.

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Printed: 18/09/96

possible solution. In this approach the sensor head would be designed to induce fluid thinning that is representative of film thickness on the leading edge.

4.7.2 Predicting Fluid Condition Using Fixed Point Sensors

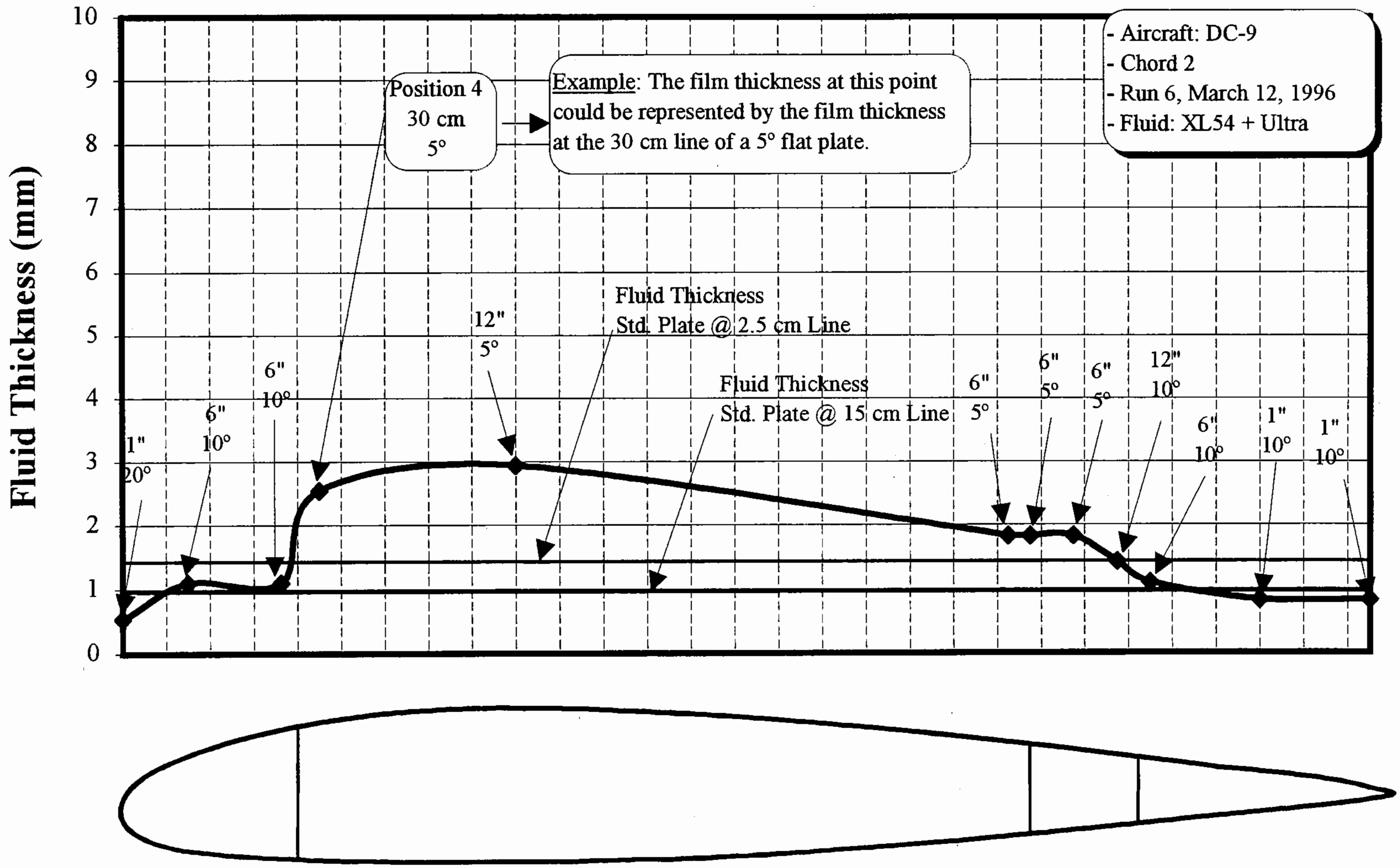
One premise regarding point sensors has been that they must predict ice formation at any location of the wing, with high confidence if not with certainty. The difficulty with surface mounted sensors is that they can only view a point or a small area of the wing. One other problem is that the installation of these devices requires a clean, "dry" space underneath the top surface of the wing for hardware and wiring. Installation within the critical leading or trailing edge could be difficult, depending upon the aircraft. The film thickness profiles which were developed for the A320, Canadair RJ, and DC-9 show that a point sensor mounted within the main section of the wing would not likely provide a good indication of the condition of the fluid on the leading or trailing edge. During precipitating conditions with the leading edge into the wind, the condition of the fluid above a point sensor on the middle of the wing, compared to that on the leading edge, could be further distorted.

An alternative to the potential solution posed in Section 4.7.1 involves the development of algorithms for surface mounted sensors to identify the presence of ice formation at any location on the wing. Film thickness profiles along the chord of a wing must be considered. Laboratory tests under controlled conditions during precipitation could be designed to accelerate the development of algorithms. Figure 4.23 shows hypothetical representations of fluid thickness along chord 2 of a DC-9 by equivalent thickness of fluid on flat plates. Fluid thickness for each position measured on the wing could be represented by fluid on flat plates or curved sections at different positions or different slope angles. For example, fluid at position 4 of the wing chord could be hypothetically simulated by fluid at the 12" (30 cm) line of a flat plate with a 5° slope. If a point sensor was installed at position 4, then the sensor signal response at this position (4) could be

FIGURE 4.23

HYPOTHETICAL REPRESENTATION OF FLUID THICKNESS BY FLAT PLATE

TYPE IV OVER TYPE I FLUID THICKNESS (STABILIZED) PROFILE



File:g:\cm1283\report\film\DC9_HYP.XLS
At:RUN 6
Printed:22/10/96

compared with the sensor response at position 2 (15 cm line of a 10° flat plate). The results could then be integrated into the development of an algorithm.

4.8 Observations of Film Thickness on Plates During Aircraft Tests

Table 4.1 contains the stabilized thickness values for each run from all three test sessions for all the plates. All values were derived from measurements at the 6" (15 cm) line, except for the disks where the measurements were taken at the 2" (5 cm) line. Recall that only one fluid is poured on the standard plate (designated X) which is mounted on the test stand. The following observations are derived from the values in Table 4.1. The previous Section 4.7 contained comments relating to the flush mounted plates and disks.

Canadair RJ Test Session

The fluid thickness on standard plate X on the test stand was in all cases equal to or slightly greater than the thicknesses on the raised wing plates. This is not surprising considering that standard plate X is subjected to head winds and the raised plates are subjected to tail winds. For Run 4, the two-step fluid application method on the raised wing plates may have contributed to the lower thickness.

The differences in Run 2, 3 and 4 may not be as large as they appear because of the self induced error in the thickness gauge. For the Octagon gauge, the teeth representing the values of 1.4 and 1.8 mm are adjacent to one another (see Table 3.2).

The Type IV fluid in the spray vehicle was warmer than the outside air temperature. This was caused by the Type IV tank situated in close proximity to the heated Type I tank. The warmer Type IV fluid has a lower viscosity resulting in increased flow and lower thickness.

In summary, lower values on the skirted plate could be attributed to one or more of the following:

- Poor operator application technique (this was the first run only).
- Contaminated fluid (Type I entering the Type IV tank for Run 1 and 2).
- Type IV over Type I effects.
- Fluid shear effects.
- Heated Type IV fluid in truck.
- Wind effects.

DC-9 Test Session

As with the Canadair RJ tests, the thickness of fluid on the skirted plate was lower than the thickness on the standard plate X for all Type IV tests. Sprayed fluid on the stand plates was generally thinner than poured, suggesting that fluid shear effects may be significant.

A320 Test Session

Film thickness on the standard test plates during the A320 session was generally lower than on the DC-9 and RJ sessions. The temperature during this test session was higher than during the other sessions.

4.9 Type IV Film Thickness on Plates at NRC

Type IV film thickness measurements were taken on flat plates without precipitation at NRC's cold chamber. Film thickness was measured over time for five different Type IV fluids for each standard fluid concentration (Neat, 75/25 and 50/50). Table 1 and Table 2 in Appendix I show the stabilized thickness results at the 15 cm line of the 129 tests conducted at NRC. Table 1 in Appendix I shows results from thickness tests using a one-step fluid application procedure, and Table 2 contains the two-step results.

Figure 4.24 illustrates typical thickness decays of Type I, II, III and IV fluids at the 15 cm line of the 10° flat plate. A best fit exponential decay curve was drawn in for every fluid type. The Type II and III data shown is from previous winter studies and the tests were conducted outdoors. As expected, the stabilized film thickness (after approximately 30 minutes) is greatest for the new more viscous Type IV fluid and smallest for the less viscous Type I fluids. The stabilized film thicknesses for these tests were determined to be:

Fluid Type	**Thickness (mm) @ 10 minutes**	**Thickness (mm) @ 30 minutes**
Type I	0.05	0.03
Type II	0.7	0.6
Type III	0.4	0.3
Type IV 50/50	0.15	0.1
Type IV 75/25	1.15	0.8
Type IV neat	1.35	1.2

These measurements show that the Type IV neat fluid is 40 times thicker than the Type I fluid and twice as thick as the Type II neat fluid. The Type IV 50/50 is 12 times thinner than the Type IV neat, but more than three times thicker than Type I. When comparing the Type IV neat to the 75/25 and 50/50 mixes, the table shows that the thickness quickly decreases once the fluid gets diluted more than the 75/25 mix.

Figure 4.25 shows thickness decay curves for the five Type IV neat fluids available at the time of testing. These tests were conducted while the chamber was at -9°C. For four of the five fluids, the film thins to about 1.5 mm at the 15 cm line after 30 minutes. The other fluid (A-303) thins to about 1.2 mm.

FIGURE 4.24

THICKNESS DECAY FOR VARIOUS FLUID TYPES

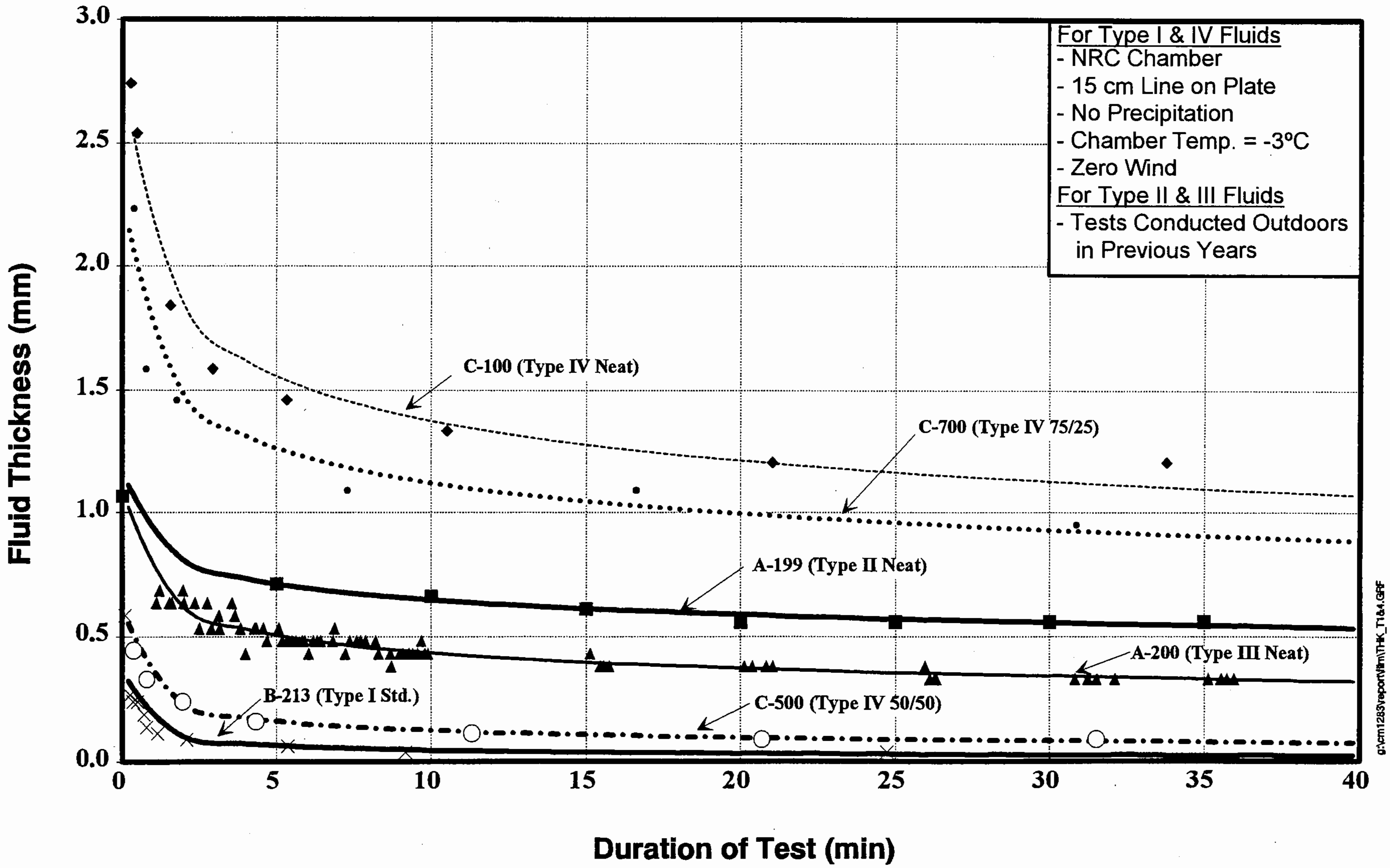
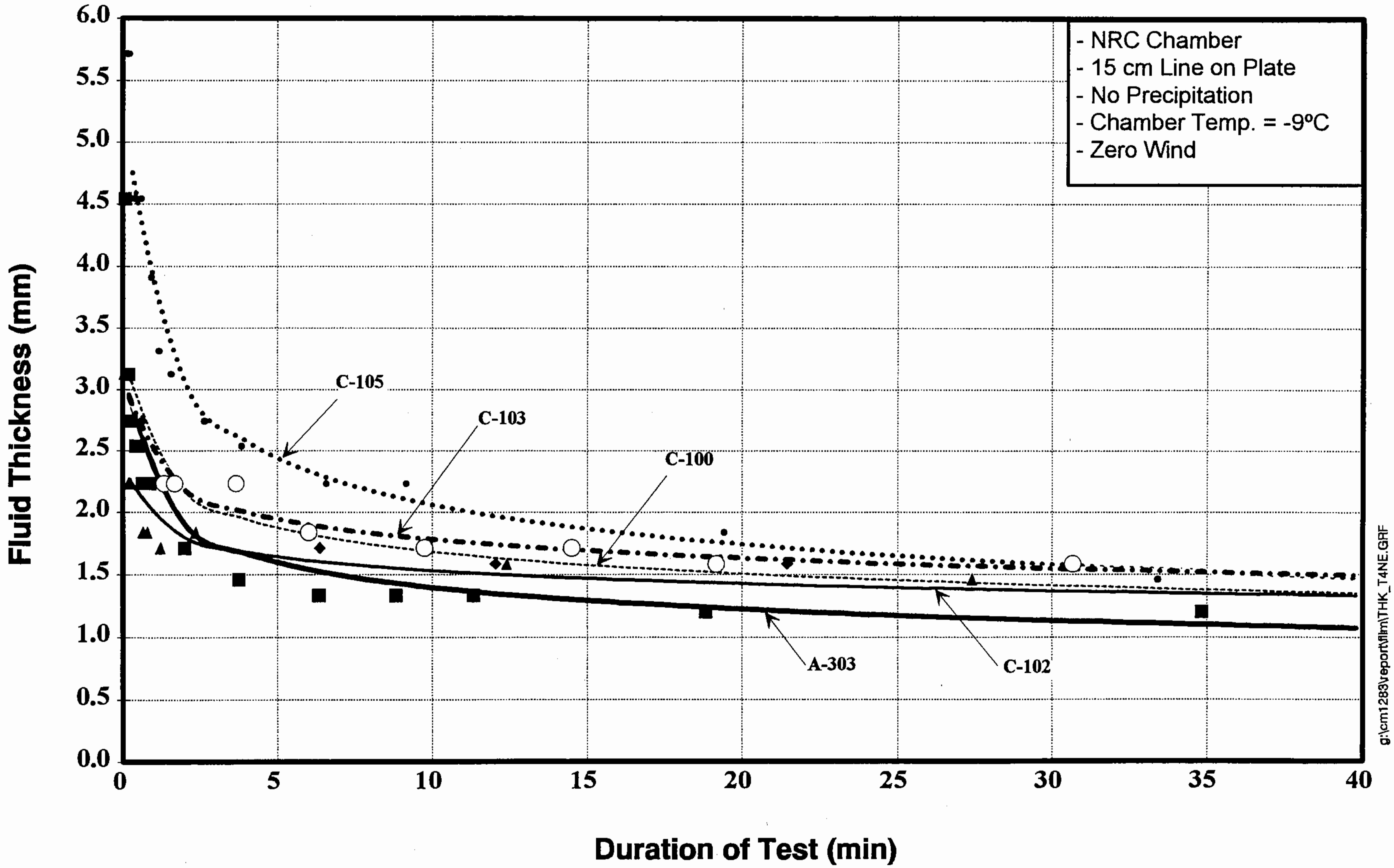


FIGURE 4.25

THICKNESS DECAY FOR VARIOUS TYPE IV NEAT FLUIDS



4.9.1 Influence of Ambient Temperature on Film Thickness

Examination of the results in Table 1 and Table 2 of Appendix I lead to the following observations regarding the influence of temperature on film thickness.

- For Type IV neat fluids (except fluid A-303), about a 10% increase in film thickness was observed when the chamber temperature was decreased from -3°C to -9°C. Similar increases were observed on tests with diluted Type IV fluids.

- For the two Type IV neat fluids (A-303 and C-105), a greater increase (about 45%) in stabilized film thickness was observed at -25°C.

The tests confirm the general observation that the viscosity of the fluid increases with decreasing temperatures, resulting in an increase in film thickness.

4.9.2 Influence on Film Thickness of Applying Fluid by Spraying Versus Pouring

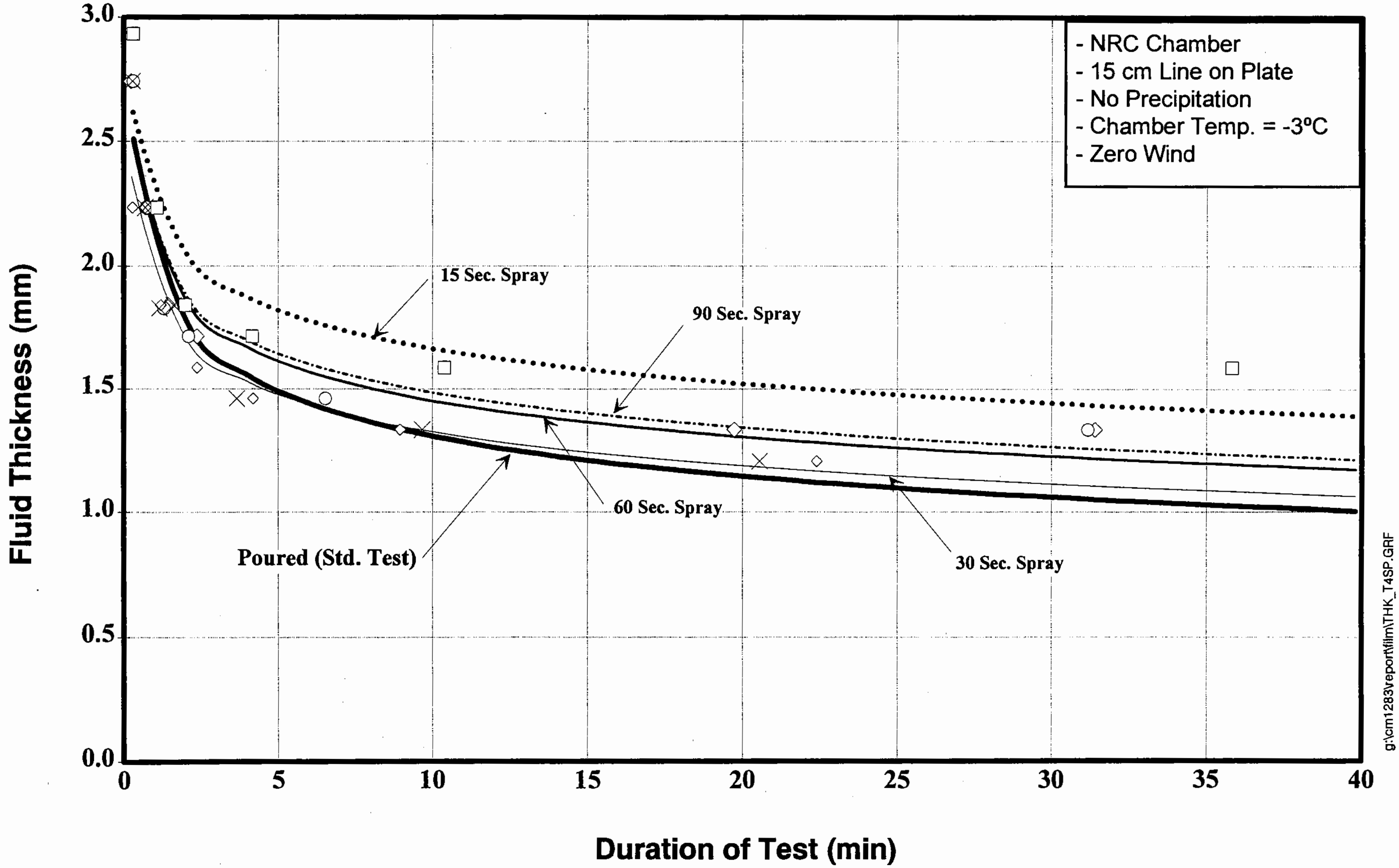
Recall (Section 2) that a garden sprayer was used for the conduct of some tests to study the influence on film thickness of spraying rather than pouring fluid. Figure 4.26 illustrates the film thickness decay of Type IV fluid A-303 applied on bare plates by pouring, and also by spraying for 15 seconds, 30 seconds, 60 seconds and 90 seconds. These measurements were taken while the chamber was at -3°C with no precipitation.

The measurements and observations made during the tests show that there was no significant difference in thickness when spraying for more than 60 seconds, and 30 seconds may not have been long enough to ensure consistent coverage from test to test. Subsequent tests with the sprayer were done with a 60 second application.

Figure 4.26 also shows that the shorter 15 second application on a bare plate resulted in

FIGURE 4.26

THICKNESS DECAY FOR TYPE IV NEAT FLUID A-303
POURED vs SPRAYED



an unanticipated thicker film. This may be analogous to the Type IV over Type I phenomenon as compared to Type IV on a bare plate. Perhaps when the plate is saturated, the fluid flows and drains quicker because the upstream fluid has an easier path to follow. This effect, while producing thicker or apparent films, may suffer from earlier failure due to the lack of sufficient fluid. This phenomenon should be investigated further.

For fluid A-303, the sprayer gave a thicker coat (1.3 mm vs 1.2 mm) than when the fluid was poured (see Figure 4.26 and Table 1 in Appendix I). For the other Type IV neat fluids, the sprayer provided a slightly thinner film of fluid than when the fluid was poured. This may be related to fluid shearing effects causing the fluid to flow off the plate more readily than when the application is by pouring, or maybe effects similar to those described in the previous paragraph.

4.9.3 Film Thickness for Two-Step Fluid Application

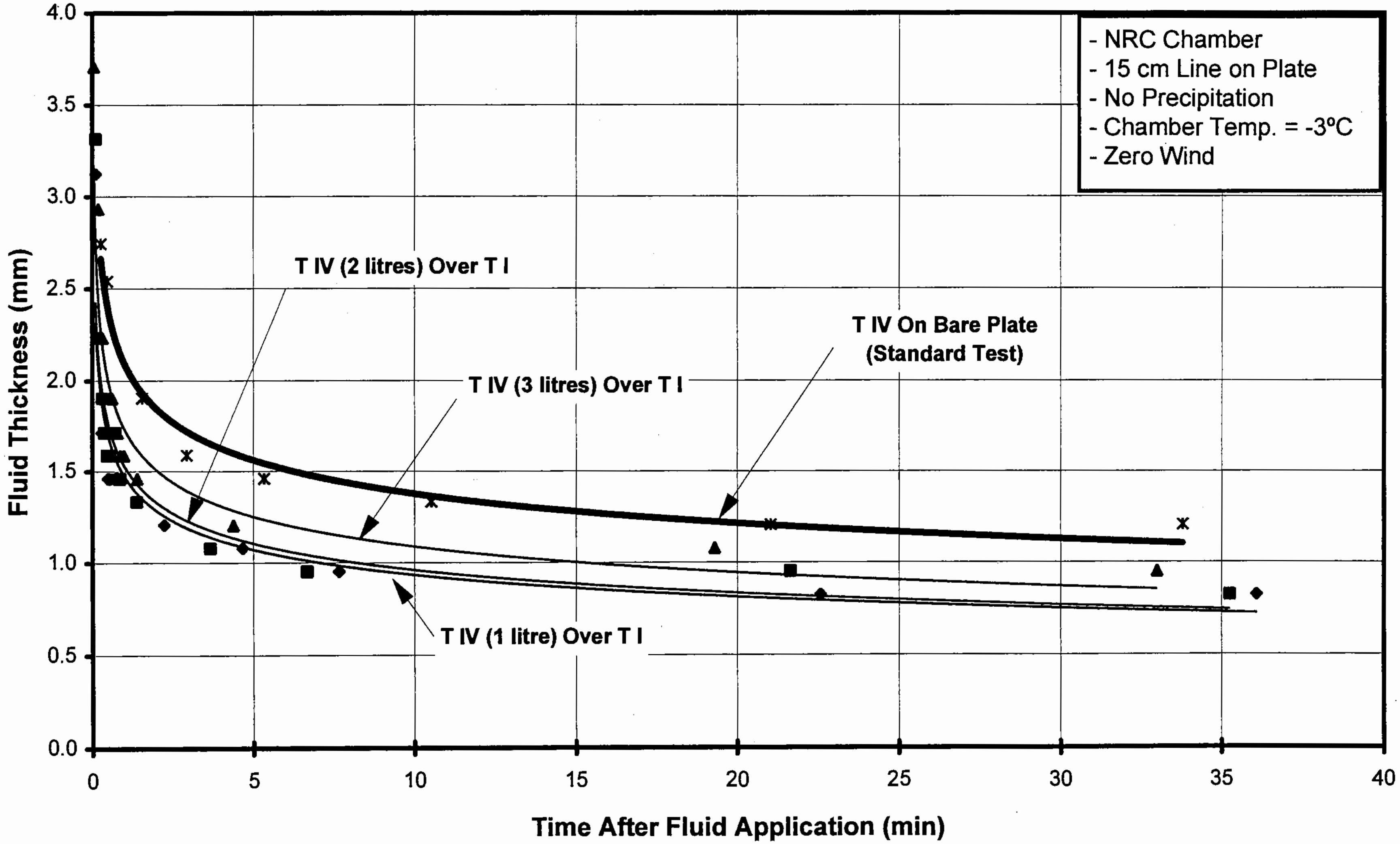
This section provides an investigation of the rate of thinning of Type IV fluid applied over Type I or Type IV 50/50, as compared to Type IV on a bare surface. The application of the second fluid was started as soon as the application of the first fluid was completed. When using a two-step process, the two fluids used in the trials were from the same manufacturer. One fluid manufacturer provided two Type IV fluids (one ethylene, one propylene) and two Type I fluids (one ethylene/propylene, one propylene). In this case, the propylene Type IV product was applied over the propylene Type I, and the ethylene Type IV product was applied over the ethylene/propylene Type I.

Figure 4.27 shows the results of three thickness decay tests conducted using a two-step fluid application procedure. For each of the three tests, Type IV neat fluid (A-303) was applied over the standard Type I fluid as follows:

- Plate 1 1 litre of Type IV over Type I

FIGURE 4.27

FLUID THICKNESS DECAY ON FLAT PLATES (TWO-STEP APPLICATION)
EFFECT OF QUANTITY OF FLUID APPLIED
Type IV Fluid = A-303, Type I Fluid = B-253



File:g:\cm1283\report\film\T4_T4&T1.XLS
At: T4 OVER T1
Printed: 17/09/96

- Plate 2 2 litres of Type IV over Type I
- Plate 3 3 litres of Type IV over Type I

The chart shows that the two-step fluids thin out more rapidly and to a lower stabilized thickness than the standard test plate (Type IV on a bare surface). Recall that approximately 1.5 litres is applied on the standard test plate to ensure complete and consistent coverage over the entire surface. However, when applying the second fluid over the Type I fluid, complete coverage of the entire surface was obtained by applying much less than 1.5 litres (the Type IV fluid slides more readily over Type I than on a bare surface). Subsequent two-step thickness tests were conducted with a measured (1.5 litre) amount of fluid.

Two other fluid tests were plotted (Figure 4.28 and Figure 4.29) and show the comparison of one-step and two-step fluid application. These plots also illustrate that the fluid in the two-step process is thinner. For Type IV fluid C-103 (Figure 4.29) the thickness after 30 minutes of the fluid using a two-step application is less than ½ that of the fluid poured on a plate.

Figure 4.30 shows a bar chart plot of the stabilized thickness of fluid at the 15 cm line for one-step and two-step application procedures, using neat Type IV fluids at temperatures of -3°C and -9°C. Figure 4.30 was derived using the data from Table 1 and Table 2 of Appendix I. For each test conducted, the stabilized thickness was plotted. The figure shows that the thickness of Type IV fluid applied over Type I was generally found to be thinner than when applied on a bare surface.

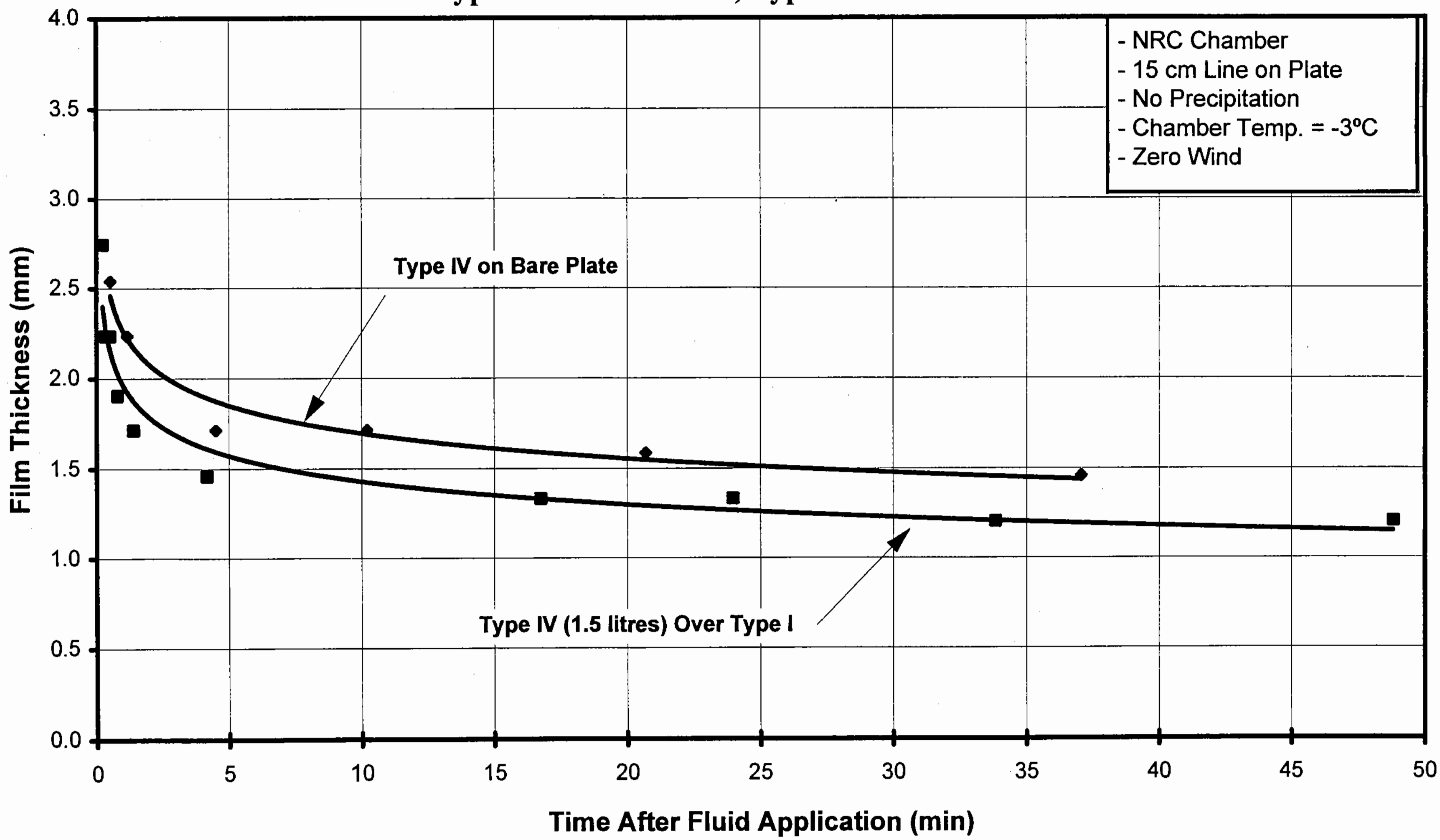
For the diluted Type IV fluids (50/50 and 75/25), similar effects were observed for the two-step application compared to the one-step application. The results are provided in Table 1 and Table 2 of Appendix I. The results were not as severe when Type IV neat or Type IV 75/25 was applied over Type IV 50/50, probably caused by the improved compatibility of the two fluids under this scenario.

FIGURE 4.28

FILM THICKNESS DECAY ON FLAT PLATES

Type IV Neat on Bare Plate VS Type IV Neat over Type I (std)

Type IV Fluid = C-100, Type I Fluid = B-253



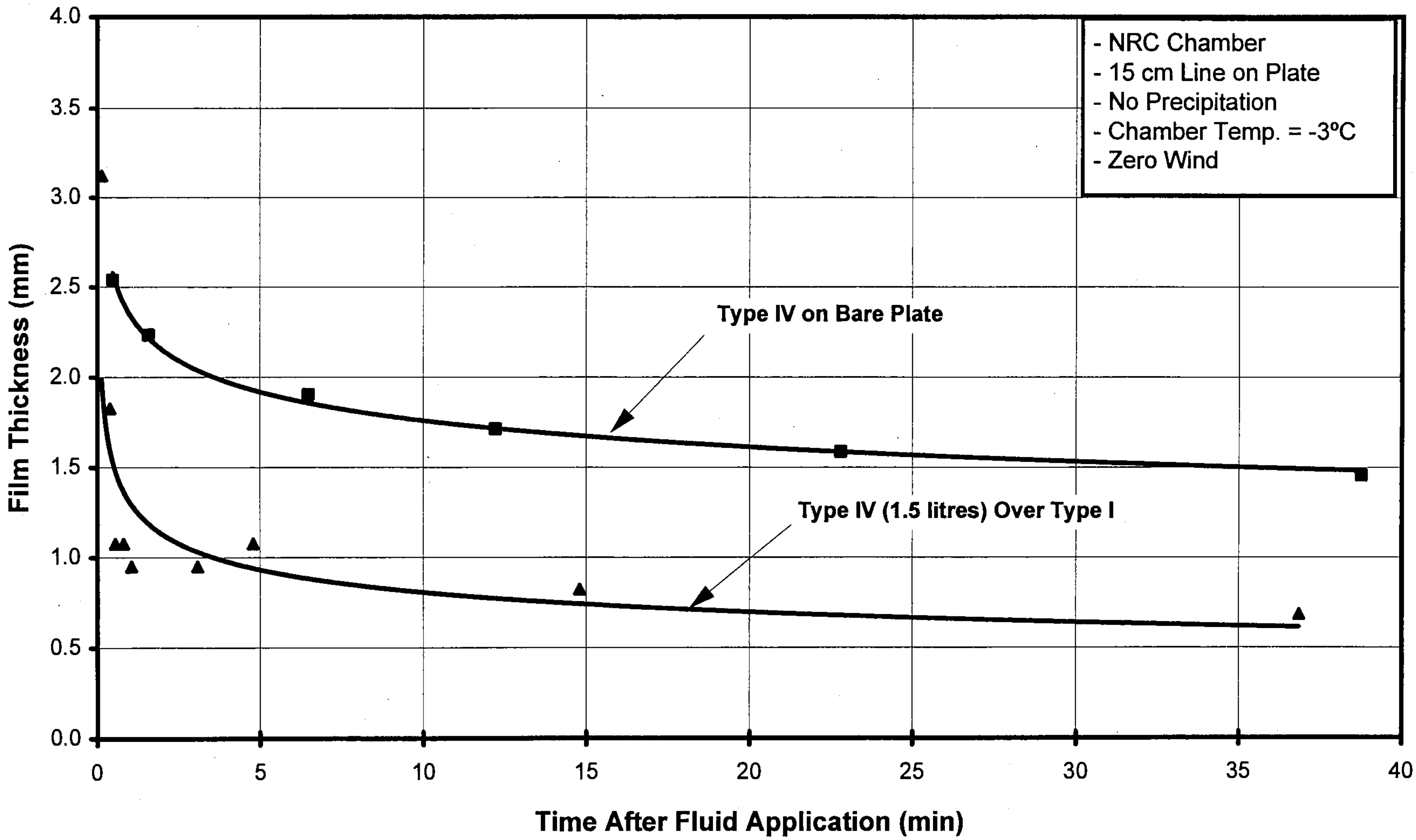
File:g:\cm1283\report\film\T4_T4&T1.XLS
At: Ultra over XL54
Printed: 22/08/96

FIGURE 4.29

FILM THICKNESS DECAY ON FLAT PLATES

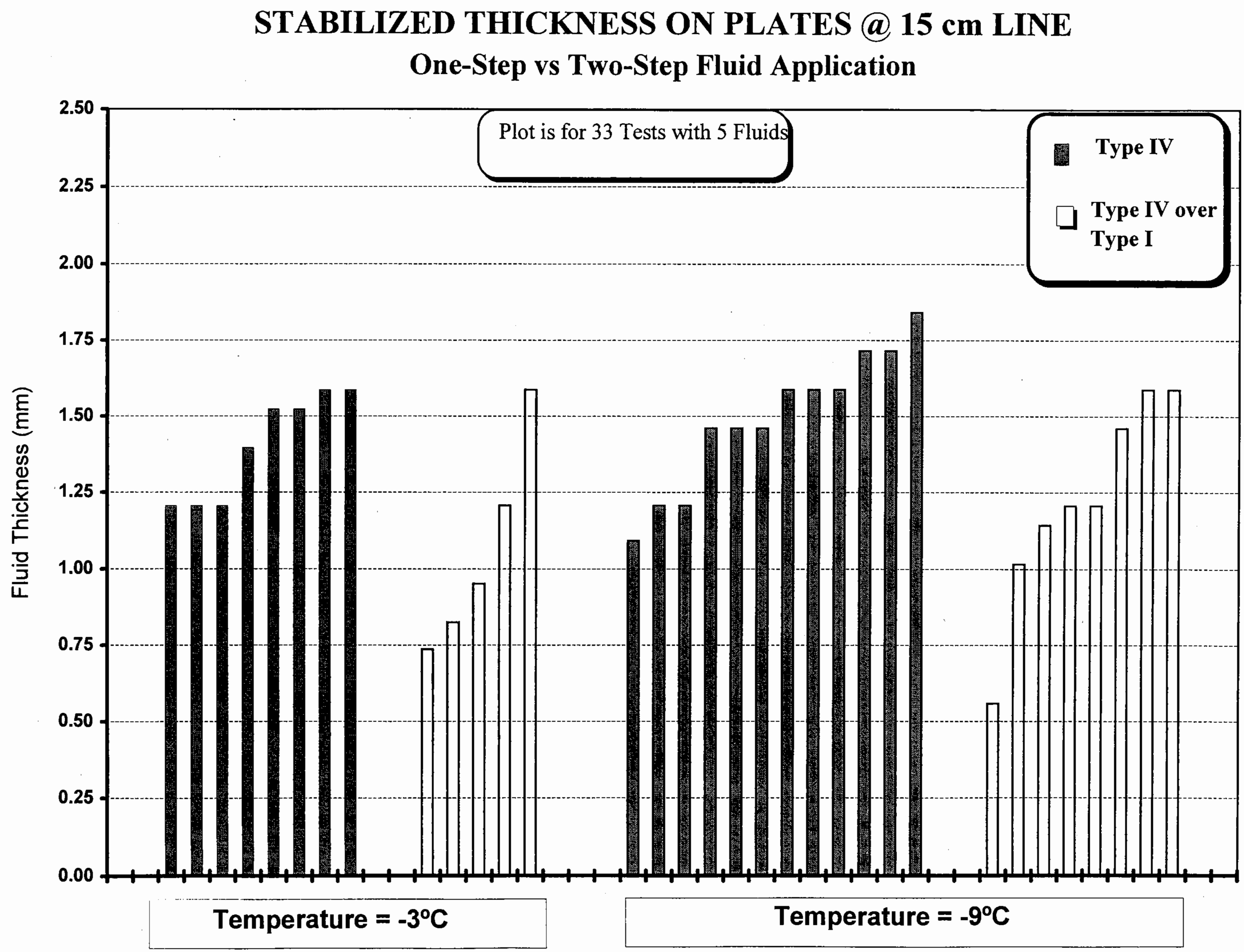
Type IV Neat on Bare Plate VS Type IV Neat over Type I (std)

Type IV Fluid = C-103, Type I Fluid = B-231



File:g:\cm1283\report\film\T4_T4&T1.XLS
At: SPCA460 over T1
Printed: 22/08/96

FIGURE 4.30



File:g:\cm1283\presenta\denver\T4_ANAL2.XLS
At: CHART 1
Printed:23/08/96

4.10 Fluid Thickness Decay During Precipitation

A series of thickness measurements were made while holdover time tests were in progress at NRC's cold chamber. These measurements were requested by Transport Canada while representatives were witnessing the holdover time tests (a test plan was not developed). The test procedure and conditions were as follows:

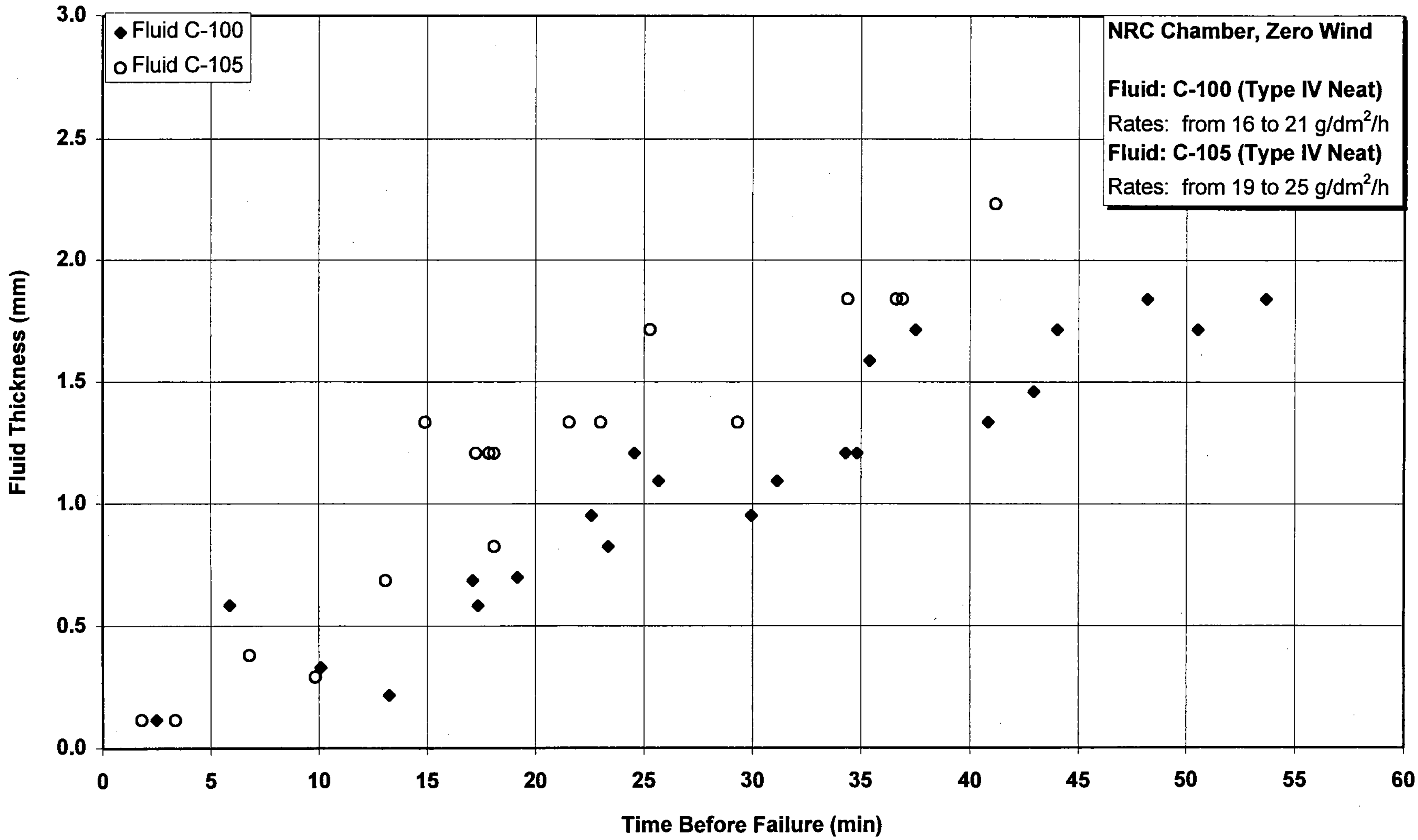
- Thickness measurements were made at the 15 cm line of the flat plates;
- Measurements were made during the conduct of holdover time tests;
- Two Type IV neat fluids were tested (C-100 and C-105);
- Temperature in the chamber was -3°C;
- Precipitation being simulated was light freezing rain;
- Eight different application techniques were used for the holdover time tests. Four plates were sprayed with fluid and four were poured. Each of the four plates were applied differently (e.g. over Type I, on a bare plate, etc.). The application procedure is not relevant to this discussion and will not be elaborated upon here; and
- The rate of precipitation on each plate was slightly different and varied from 19 to 25 g/dm^2/hr for Type IV fluid C-105, and 16 to 21 g/dm^2/hr for Type IV fluid C-100.

The results of these thickness measurements are summarized in Figure 4.31. The following observations are made:

- The thickness of fluid at the 15 cm line tends to zero as the fluid approaches failure. This applies to both test fluids and only to these test conditions. Different failure phenomenon were observed under different test conditions;
- The thickness decreases faster for the faster failing fluid (C-105), mostly due to the higher precipitation rate. Some of the variability in the data within each fluid is explained by the different precipitation rates;
- Some variability in Figure 4.31 could be caused by the fluid's absorption capabilities. At the start of the test, the fluid does not necessarily start thinning. In fact, sensors

FIGURE 4.31

FLUID THICKNESS BEFORE PLATE FAILURE DURING HOT TESTS
Type IV Neat - Light Freezing Rain at -3°C
Thickness Measured @ 15 cm Line



cm1283\report\film\SPC_PLT1.XLS
At: C-100&105
Printed: 17/09/96

have shown that some fluids often becomes thicker shortly after the application;

- Thickness measurements became more difficult and more inconsistent as ice started forming at and around the 15 cm line; and
- The plate is declared failed when the 5th crosshair has failed. Failures did not necessarily occur at the 15 cm line where thickness was measured, adding to the scatter in the data.

4.11 General Observations

- Type IV fluid contaminated with Type I was encountered on two aircraft test occasions. The problem was reported to the operator for attention, and the tests were continued with a different de-icing truck. Subsequent analysis of the fluid determined that the Brix reading was not affected by the contamination, but the viscosity and WSET (water spray endurance test) values were significantly reduced. Appendix F contains the fluid test results which were obtained from Union Carbide. The thickness data for the contaminated fluid is included in the report (Runs 1 and 2 on the RJ aircraft and Run 1 on the A320 aircraft).

- Application of Type IV fluid with the Akron nozzle (originally intended for use with Type I fluid) requires considerable operator attention to produce a consistent and adequately thick film over the complete wing. The potential impact on film thickness is illustrated in the comparison of the two runs in Figure 4.20. In one run, a film thickness of 3.5 mm (on the top of the wing) was achieved, while in the second only 0.8 mm resulted. The two runs used about the same quantities of fluid, but the more successful run involved a spray time of one minute versus 44 seconds in the other run, reflecting the additional attention given. Photo 3.1 illustrates inconsistent film thickness.

5. CONCLUSIONS

5.1 Results from Aircraft Trials

5.1.1 Type I Fluid

Type I fluid thins rapidly to a very thin film in about 4 to 6 minutes. Although there is some variance in film thickness at different points along the wing chord, the difference is not significant enough to support conclusions for locating representative surfaces. Use of fluid thickness as the sole criteria would indicate that current representative surface locations on the top surface of the wing should be as satisfactory as any other location, however observations during Aircraft Full Scale(2) tests showed that other areas on the wing, especially the leading and trailing edge surfaces, failed before representative surfaces. Observations from the "Hot Water De-Icing Trials for the 1994-1995 Winter"(3) may offer an explanation for this. Those trials demonstrated that after application of hot water, the most rapid drop in temperature and earliest freeze-up occurred on thinner surface panels such as flight control surfaces. The same would be expected to be true following the application of heated Type I de-icing fluid.

The extended holdover times experienced with Type I fluid in actual operations must be attributable in part to heat transfer from the heated fluid to the wing as the final values for film thicknesses would not appear to have the precipitation absorbing capacity to achieve those holdover times commonly experienced in actual practice.

5.1.2 Type IV Fluid

Type IV fluid applied on a bare surface stabilizes in about 12 to 14 minutes. Final film thickness is influenced by thickness of initial application (within the bounds of normal application) together with the slope of the wing surface and existence of gaps in the wing surface. Special disks mounted on the wing with a surface slope of 9 degrees resulted in a fluid film 75% as thick as a similar disk mounted at 4 degrees of slope.

Type IV applied over Type I indicates thinner stabilized thickness values as compared to Type IV on a bare wing. Variance in fluid application prevented firm conclusions, and tests on standard flat plates with controlled fluid application were conducted to further investigate this observation.

5.1.3 Fluid Thickness Profiles

Fluid film profiles over the entire chord of a wing demonstrate those areas that are subject to rapid thinning of fluid. As expected, the leading edge is the most critical area on all aircraft types tested, with a typical profile showing rapid thinning of fluid film as the slope of the curvature becomes more steep. Film thicknesses on the leading and trailing edges of the DC-9 and A320 aircraft fall within the thickness ranges measured on standard test plates, and add support to conclusions of the Aircraft Full-Scale(2) study that the flat plate satisfactorily represents the aircraft wing.

Film thicknesses on the leading edge of the Canadair RJ aircraft were less than those at the 1" (2.5 cm) and 6" (15 cm) lines of the standard test plates. Some possible explanation may be the shape of the wing, the exceptionally polished and smooth surface on the leading edge, or the possibility that the fluid applied on the wing from the de-icing truck was warmer (and therefore of lower viscosity) than that applied on the test plate. These concerns on the RJ results must be further investigated.

On the DC-9 aircraft, fluid thinning on the leading edge is accelerated by escape of fluid under the rear edge of the leading edge slat as fluid flows forward from the main wing, and fluid loss on the slat surface is not replaced by fluid flowdown.

Extension of the leading edge slat on any aircraft will result in steeper slopes on its surface and will further hasten thinning of fluid film. The area of the main wing that is exposed when the leading edge slat is extended will be protected only by any fluid that has penetrated the gap at the rear edge. Operator procedures defining at what point in the departure sequence the leading edge slat (and other control surfaces) are to be extended should recognize this feature and attempt to reduce the exposure time of unprotected surfaces as well as the accelerated fluid run-off.

Flight control surfaces at the rear of the wing also exhibit stabilized values of fluid film thinner than the top of the wing, although not so severe as the leading edge.

Distinctive areas unique to each aircraft experience rapid rates of fluid film thinning. On the DC-9 aircraft a raised surface area on top of the inner wing has shown early fluid failure during field trials. This was corroborated by results from one run in this series of tests where Ultra fluid experienced early thinning, but was not observed during other runs. On the A320 aircraft, an area on the main wing just forward of the outer aileron displayed thinner fluid than other areas nearby. No similar area was observed on the Canadair RJ aircraft.

5.1.4 Artificial Surface on Wing to Simulate Leading Edge Fluid Condition

The trials included an examination of the feasibility of artificially inducing film thinning through installation of disks and plates directly on the wing surface. The test surfaces experienced the same effect as the integral surfaces described in the previous paragraph, showing thinner stabilized thickness values than the surrounding areas. This approach could be useful in design of heads for fluid contamination sensors, providing an area with artificially induced fluid thinning that is truly representative of film thickness at the critical leading edge area. An examination of potential aerodynamic impact of such a raised surface would be necessary.

5.1.5 Influence of Spray Application Technique

The trial runs exposed a degree of inconsistent coverage with Type IV fluid application. Application using the Akron nozzle required the attention of the operator in order to build up a film meeting the thickness specified by the fluid manufacturer. Variation in film thickness could be observed over the wing surface, generally identified by thicker ridges of fluid showing a deeper colour. The operator intends to install the Task Force Tips ® nozzle to be used for applying Type IV fluid in future seasons. Variation of fluid film thickness from one operator to another was noted. It is suspected that this is due to lack of experience as a result of infrequent use of Type IV fluids at Dorval Airport where the need for extended holdover times is very limited. De-icing operators require a sound understanding of application requirements of new fluids, and of the need to apply a film of depth sufficient to absorb precipitation.

5.1.6 Selection and Locations for Representative Surface

5.1.6.1 Considerations

Selection of representative areas for aircrew reference should reflect those surface areas that would be expected to fail earliest.

When using Type IV fluid, all tests showed that the leading edge experienced the lowest values of fluid film thickness. No other area of the wing experienced equivalent thinning of fluid, leading to the conclusion that any area selected to serve as representative must include the leading edge.

The flaps and ailerons were the next most critical area with respect to fluid thickness. As these surfaces may be more visible to an observer from inside the cabin, there is merit in their inclusion as a component of the representative area.

Specific areas on wings that entail surfaces raised above the surrounding wing area were observed to experience lower final fluid thickness values. The process for identifying representative areas for each aircraft type should entail a visual examination of an actual wing surface with a view to identifying and including any such irregularities.

5.1.6.2 Key guidelines for selecting an area to serve as a representative surfaces (for low wing aircraft)

- Include a segment of the leading edge ensuring satisfactory visibility from either the flight deck or from a cabin window.

- Include a segment of the flight control surfaces at the rear of the wing. These areas have demonstrated earlier fluid thinning and fluid failure than surrounding areas, and generally provide good visibility from the cabin.

- Examine the surface area of the wing to identify any irregularities on the surface which may precipitate premature fluid thinning. Edges of any raised areas will experience more rapid thinning of film thickness than nearby areas and will display a tendency for early fluid failure.

5.2 Comparison of Fluid Thickness on a Wing to a Standard Flat Plate

The stabilized thicknesses at most locations on the leading edge and trailing edge of the DC- 9 and A320 aircraft tested were found to be between the thickness at the 2.5 cm and 15 cm line of the standard flat plate. For the Canadair RJ aircraft tests, the thickness on the leading edge was below that of the 2.5 cm line of the standard plate.

5.3 Method of Fluid Application - Sprayed Versus Poured

The thickness of the poured fluid on the standard flat plate mounted on a test stand was found to be slightly thicker than the fluid sprayed by the airline operator onto the skirted plate mounted above the wing surface. Aside from errors in the gauge and from the tests when the application was not optimal, potential causes of the reduced thickness on the skirted plate include: contaminated fluid in the truck; fluid shear effects due to the spray nozzle; wind effects; effects of Type I underneath Type IV; and the warmer, less viscous Type IV fluid from the truck.

When comparing the film thickness from a backpack sprayer fluid application to the standard poured fluid, Type IV fluid A-303 when sprayed was slightly thicker than when it was poured. However, for the other Type IV fluids, the sprayer fluid was thinner than the poured fluid. The other fluids may be more susceptible to the influence of fluid shear.

5.4 Type IV Film Thickness on Flat Plates

After 5 minutes the thickness of Type IV fluid at the 15 cm line of a flat plate at -9°C varies from roughly 1.5 to 2.5 mm, dependent of the fluid. After 30 minutes with no precipitation, all five fluids stabilize to a thickness ranging from approximately 1.2 to 1.6 mm.

The stabilized thickness of Type IV neat fluid at the 15 cm line was found to be roughly 40 times the thickness of Type I, double that of Type II neat, and about four times the thickness of the Type III fluid from 1991/92. The above figures may vary dependent upon temperature and fluid manufacturer. For one fluid, Type IV neat was found to be more than 10 times thicker than Type IV 50/50, however only 50% thicker than Type IV 75/25.

The stabilized thicknesses of Type IV neat fluid on flat plates at temperatures of -9°C were found to be approximately 10% greater than at -3°C. Larger increases (approximately 45%) due to the higher viscosity were observed for some fluids at a temperature of -25°C.

5.5 One-step Versus Two-step Application

When comparing the thickness decay of Type IV fluid poured on a bare plate to the decay of the same fluid poured over a Type I fluid, it was found that the fluid for the one-step application was thicker than the two-step application. For one particular test, the two-step application provided a stabilized film thickness less than 50% that of the one-step application. Similar results were observed with the diluted (50/50 and 75/25) Type IV fluids.

5.6 Effect of Precipitation on Fluid Thickness

Given that there is variability in the measurement of film thickness under precipitation conditions, the thickness of fluid at the 15 cm line decreases towards zero as the fluid nears failure. This was found while testing two different Type IV neat fluids under simulated light freezing rain at -3°C. The precipitation has the effect of diluting the fluid, reducing its viscosity and causing it to flush off the 10° plate. This type of fluid film thickness reduction could be more severe than during snow conditions because freezing rain precipitation can form hard ice more quickly on the surface of the plate.

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6. RECOMMENDATIONS

This section outlines recommendations for establishing Representative Surface Areas and identifies other areas for further consideration:

- Modify current guidelines for selecting areas to serve as a Representative Surfaces (for low wing aircraft) with the following key criteria;

  - Include a segment of the leading edge ensuring satisfactory visibility from either the flight deck or from a cabin window;

  - Include a segment of the flight control surfaces at the rear of the wing. These areas demonstrate earlier fluid thinning and fluid failure than surrounding areas, and generally provide good visibility from the cabin; and

  - Examine the surface area of the wing to identify any irregularities on the surface which may precipitate premature fluid thinning. Edges of any raised areas will experience more rapid thinning of film thickness than nearby areas and will display a tendency for early fluid failure.

- Develop and recommend locations for representative surfaces for principal aircraft types in common service by a process of examining actual wings and confirming proposed locations by measuring stabilized fluid thickness profiles.

- Examine the sensitivity of fluid holdover times of Type IV fluid which has been heated to temperatures typical of de-icing vehicle fluid temperatures. This would include an examination of vehicle fluid temperatures experienced in normal operations.

- Conduct further testing to address the impact of application of Type IV fluid over heated Type I. These tests should be conducted on service aircraft using an airline spray vehicle.

- Examine the need to develop new test procedures for the determination of holdover times by using a two-step fluid application, and further elucidate the viscosity reduction of Type IV fluid when overspraying onto heated Type I fluid. Consider the use of a backpack spray unit to apply fluid.

- Conduct fluid holdover time trials on Canadair RJ aircraft to confirm that standard flat plate test results are applicable to this aircraft.

- Publish an information circular to operators to alert them of the need to meet fluid manufacturers recommendations for fluid application in order to obtain full holdover time benefits. An Air Carrier Advisory Circular (ACAC) to this effect is being issued by Transport Canada.

- Review the need to alert aircraft operators that premature extension of leading edge slats and other flight control surfaces may lead to early fluid failure due to accelerated fluid thinning on the control surface and exposed unprotected surfaces. Issue an Air Carrier Advisory Circular (ACAC) to this effect if appropriate.

- Give consideration to designing a contamination sensor with sensor head raised above the surrounding wing surface to artificially stimulate fluid thinning and thereby emulate fluid conditions actually observed on the critical leading edge. The impact on aerodynamic efficiency would require evaluation.

- To help develop algorithms for the surface mounted sensors, develop a plan to conduct holdover time tests on surfaces providing equivalent film thickness representing different positions on a typical chord of a wing. Ensure that sensors (eg. C/FIMS) are used for each surface. Design tests under controlled conditions to develop relationships between the sensor response due to precipitation over a thick fluid film (representing a section on the middle of the wing) and response over a thinner film (representing the critical leading edge).

- During tests on the A320 and DC-9 aircraft, most of the film thickness measurements fell between the thickness at the 2.5 and 15 cm lines of the simultaneously tested flat plates. Using data collected in the past, study the failure time relationship between the 2.5 and 15 cm lines during flat plate testing.

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2. D'Avirro, J., Boutanios, Z., Dawson, P., *Aircraft Full-Scale Test Program for the 1994-1995 Winter*, APS Aviation Inc., Montreal, December 1995, TP 12595E, 90.

3. Dawson, P., D'Avirro, J., *Hot Water De-icing Trials for the 1994-1995 Winter*, APS Aviation Inc., Montreal, December 1995, TP 12653E, 48.

APPENDIX A

EXPERIMENTAL PROGRAM
TO ESTABLISH
FILM THICKNESS PROFILES
FOR DE-ICING AND ANTI-ICING FLUIDS
ON AIRCRAFT WINGS

EXPERIMENTAL PROGRAM TO ESTABLISH FILM THICKNESS PROFILES FOR DE-ICING AND ANTI-ICING FLUIDS ON AIRCRAFT WINGS

Winter 1995/96
Version 1.2

1. OBJECTIVE

To develop generic guidelines for defining optimum locations for representative surfaces on aircraft wings by establishing film thickness profiles for anti-icing fluids on wings of test aircraft.

2. TEST REQUIREMENTS

APS will coordinate a series of trials at Dorval airport. Trials may be conducted in conjunction with tests being conducted for other purposes including simultaneous aircraft/flat plate fluid holdover time tests. In those tests the weather conditions will be predicated by the needs of those other tests, and fluid thickness tests will be conducted during any periods of no precipitation that may occur. At least one trial will be planned and coordinated specifically to establish fluid thickness profiles, in which test weather conditions will include an ambient outside air temperature of -10°C to -0°C, calm winds, overcast or night skies, and no precipitation.

Arrangements will be made with an airline for aircraft, staff, and de-icing equipment. It is desirable to test a different aircraft type on each test occasion, with priority given to the DC-9, the Canadair RJ, and the A320.

Current APS staff will be utilized during tests as necessary.

Type I and Ultra neat fluids, will be applied in separate trials. Ultra will be tested both on a bare wing and over an initial application of Type I fluid (see Attachment I).

Thickness of the fluid film on the test wing will be measured and recorded at a number of pre-defined locations along selected chords and at points where early failure has been experienced. Fluid thickness measures will be taken on a continuous basis to provide at least three data points per location, and the clock time for each measure will be recorded.

Data will be analyzed to develop a fluid film profile for each wing chord, indicating how the film thickness changes with time.

Selection of measurement locations on the wing be based on previous test experience and give attention to those areas where early fluid failures typically occurred.

Other data recorded will include ambient meteorological conditions, and temperature of wing skin surface at selected locations. Data on fluid sprayed will be recorded. Visual observations of the condition of the fluid will be noted in tests where precipitation occurs.

Conduct of the trial will be photographed and video taped to demonstrate the test set-up and procedures, and to highlight any aircraft discontinuities, protrusions, bumps, etc.

3. EQUIPMENT

Equipment to be employed is described in Attachment II.

4. PERSONNEL

Nine personnel are required for each test occasion. A description of the responsibilities and duties of each person is provided as guidelines in Attachment III.

5. PROCEDURE

The test procedure is included in Attachment IV.

6. DATA FORMS

The data forms are listed below:

- Figure 2 Aircraft Wing Plan Form
- Figure 3 General Data Form

ATTACHMENT I

FLUID THICKNESS PROFILE TESTS

TEST PLAN

RUN #	OCCASION #	FLUID Type	A/C Type
1	1	ULTRA on Bare Wing	DC 9
2	1	ULTRA on Bare Wing	
3	1	ULTRA over Type I	
4	1	ULTRA over Type I	
5	1	Type I	
6	1	Type I	
7	2	ULTRA on Bare Wing	RJ
8	2	ULTRA on Bare Wing	
9	2	ULTRA over Type I	
10	2	ULTRA over Type I	
11	2	Type I	
12	2	Type I	
13	3	ULTRA on Bare Wing	A320
14	3	ULTRA on Bare Wing	
15	3	ULTRA over Type I	
16	3	ULTRA over Type I	
17	3	Type I	
18	3	Type I	

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ATTACHMENT II

FLUID THICKNESS PROFILE TESTS

TEST EQUIPMENT CHECKLIST

TASK	*Montreal*	
	Resp.	Status
Logistics for Every Test		
Passes		
Call Personnel (JD, PD, ZB, GT, ML, MH, ER, JFB, JM)		
Advise Airlines (Personnel, A/C Orientation, Equip)		
Monitor Forecast		
Test Equipment		
Tape Recorder with Mic.(voice) x 7		
Supply of tapes for recorder		
Supply of AA cells		
Video Cameras X 2 + 15 batteries + 2 chargers		
Thickness Gauges - 8 hand held, 6 mounted on poles		
General Data Forms		
Aircraft Wing Forms		
Compass		
Tape measure		
Clipboards X 5		
Space pens and pencils X 6		
Paper Towels (buy 1 more box)		
Electrical Extension Chords x 8 minimum		
Lighting x 6 single black & 3 double yellow poles		
Tools		
Hands-free flashlights x 7		
Cloth wipers for gauges		
Speed tape and china marker to mark test points		
Cotton gloves (mechanics type)		
Stop watches x 7		
Pylons		
Laser Pointers x 3		
Storage bins for small equipment (buy small ones)		
Temperature Probe x 2		
Thermometer (digital hand held)		
Protective clothing x 9 (pants + coats)		
Refractometer + brixometer		
Tie wraps / duct tape		
Whistle x 2		
Still camera		
PVC tubes for extension sticks		
Rolling Stairs x 6		
OTHER TEST EQUIPMENT		
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

ATTACHMENT III
FLUID THICKNESS PROFILE TESTS
RESPONSIBILITIES/DUTIES OF TEST PERSONNEL

Refer to Figure 1 for position of equipment and personnel. Refer to the test procedure Attachment IV for more detail.

Observers
L1, L2, L3, T1, T2, T3

- Located on stairs at assigned position at leading or trailing edge of wing.
- Identify thickness measurement locations from wing plan form. With the team co-ordinator, measure distances to wing reference points for each thickness measurement location. Identify reference points and record distances on the wing plan form.
- Apply speed tape to indicate locations of measurement points. For reference purposes, indicate the number (based on the plan view) of each tape marker. For midwing measurement locations not reachable for tape application, identify and make a note of the kind of reach needed to enable readings to be taken, so that the same location can be repeated in subsequent cycles.
- Before each test run, voice record your name, your assigned position (L1, T2 etc.), date and time, and the run number.
- Progressively measure fluid thickness at assigned measurement locations:
    - Use the MIL scale on the gauge
    - Record the gauge of the tooth that is wetted
    - When measuring fluid thickness, follow offset routine to avoid inaccuracies related to depressions in fluid surface caused by previous gauge placement.
    - Measurements should be taken about 12" (laterally towards the fuselage) from the speed tape.
    - Ensure the thickness gauge is perpendicular to the surface of the wing.
    - Record time in seconds during the initial measurement cycle when the rate of fluid thinning is fastest. Time to the nearest minute is acceptable for subsequent recording.
    - Proceed as quickly as possible without sacrificing accuracy.
- For each measurement, record on voice tape recorder the measurement location index, the time, and the fluid thickness gauge reading.
  Example; Position 8, time 024238, gauge 55 mil.
  Always say the words preceding the data (position, time, gauge) to voice activate the tape.
  Speak clearly.
- Remove speed tape and any sticky residue at end of test session.
- Ensure all recorded voice tapes are properly tagged (date, observer, run #, etc.) and submitted to test coordinator.

Observers
L3, T1, T2, T3

- Setup rolling stairs, lights and cables.
- Replace the rolling stairs, lights and cables to storage locations at end of test session.

Observer O1

- Examine wing. Identify and record on wing plan form any specific areas that might be suitable for representative surface location.
- Note and record all times required on the general data form; test start and end times, and fluid spray times at each test chord.
- Progressively measure fluid thickness at selected locations.
- Assist team coordinator.

Observer L1

- Obtain following data and record on the General Data Form; fluid data, fuel load, weather conditions.
- Obtain fluid samples; measure and record brixometer readings.

Observer L2

- Measure and record on General Data Form the wing skin temperatures at indicated locations, prior to fluid application.

Video Operator

- Install PVC tubes on stairs with duct tape.
- Ensure proper lighting .
- Mobile.
- Understanding of test objectives and procedures.
- Video a/c test set-up including application of speed tape to indicate measurement locations. Video fluid application procedure.
- Video fluid thickness measurement process.
- Follow O1 and video miscellaneous measurements of potential representative surfaces.
- Take still photos showing instruments, setup, measurements, etc.

Test Coordinator

- Team leader.
- Responsible for test area and test team.
- Authority on test procedures and conditions.
- Coordinate activities of APS team and airline personnel.
- Responsible for deciding when tests will be conducted based on weather condition observations and forecasts. Coordinate with airline contact.
- Alert team personnel to conduct the tests.
- Assign tasks to team personnel. Provide briefings as needed.
- Co-ordinate observer activity to locate, record reference distances and apply tape for thickness measurement points.
- Review data forms at test completion for completeness and accuracy.
- Ensure all clocks and video are synchronized.
- Ensure functioning of voice recorders, in particular the voice activation function.
- Ensure proper documentation of voice and video tapes, and of fluid samples.
- Monitor test procedure in progress to ensure proper application.
- Call end of test based on fluid thinning reaching state of stability.
- Ensure that the site is returned to original condition. Final site inspection to ensure no objects left at the site that could cause FOD.

ATTACHMENT IV
FLUID THICKNESS PROFILE TESTS
TEST PROCEDURE

1. Preparation

Preparation will consist of briefing those involved on the objectives of the trials, the data and observations to be gathered, and the roles and tasks of each participant. Copies of the wing plan form indicating locations of measurement locations will be provided to each team member.

Instruct observers on equipment use; fluid measuring gauges, gauge wipers, hands free flashlights and voice recorders. Discuss the measurement and recording process.

Review fluid spray pattern with Air Canada to enable access to measurement locations immediately following spraying of that area. Arrange for the test fluid to be sprayed from the fuselage outwards, so that stairs can be positioned and measurement commenced as soon as the spray has moved beyond the test chord.

The video recording technician will be briefed on the type of detail desired.

2. Pre-Test Set-Up

Monitor weather forecasts seeking a period with temperatures in the range of -10 to 0°C with no precipitation.

Discuss with Air Canada 48 hours prior to intended test.

Advise all involved including F. Eyre and T. Manzo.

Locate aircraft at the de-icing centre.

Synchronize time on stopwatches, video camera.

Check video equipment for functioning.

Locate positions where fluid thickness readings will be taken, and define exact position by measuring and recording distances to wing surface reference points.
Apply speed tape on wing surface to indicate measurement location points.

3. Test Procedure

Record data on the General Test Data form reporting on weather conditions, fluid utilized, aircraft and fuel data and team member names.

Position stairs with lights at locations ready to be quickly moved to wing leading and trailing edge for each chord location selected for measurement.

Apply test fluid over the entire test wing from the de-icing truck. Ultra fluid will be tested in two forms of application; one being applied directly on a bare wing, and the other being applied following an initial application of Type I fluid.

Fixed observers located on stairs at the wing leading and trailing edges will measure and record fluid thickness at each assigned measurement location. Record the location index and the time corresponding to each measurement.

The roving observer will identify areas prone to early failure, and will record progress of fluid thickness at those points.

Fluid thickness measurement will be continued until the test coordinator signals test termination.

The entire process will be video taped.

4. End of Test

The test will be terminated when fluid thickness stabilizes.

Ensure all voice tapes are collected and properly identified.

Ensure data form is completed for end of test and other data.

5. Post test

For tests involving Ultra, spray wings with Type I fluid to remove all traces of test fluid.

Remove all tape used as measurement location indicators.

Restore test area to pre-test conditions.

FIGURE 1

POSITION OF EQUIPMENT AND PERSONNEL FLUID THICKNESS PROFILE TESTS

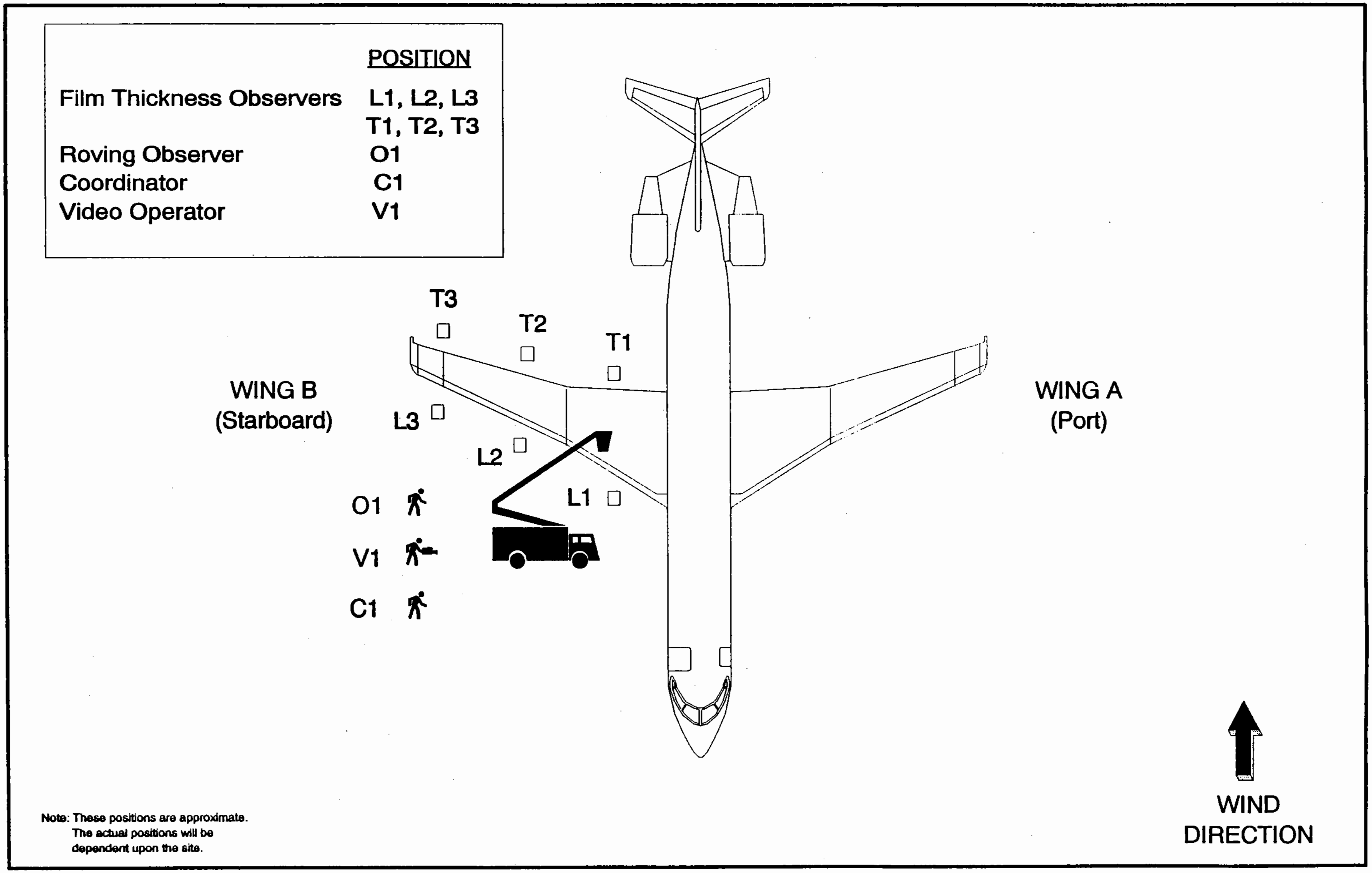

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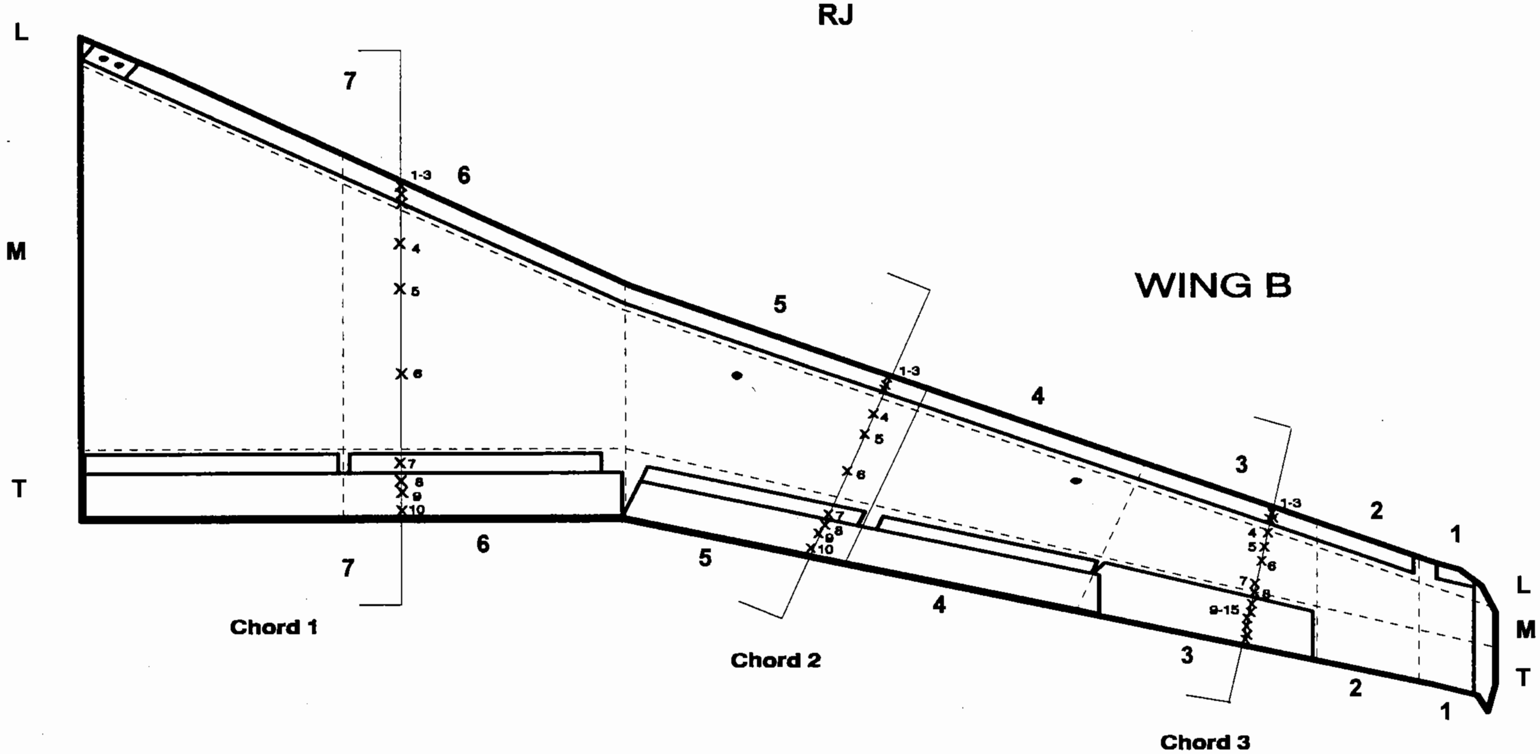
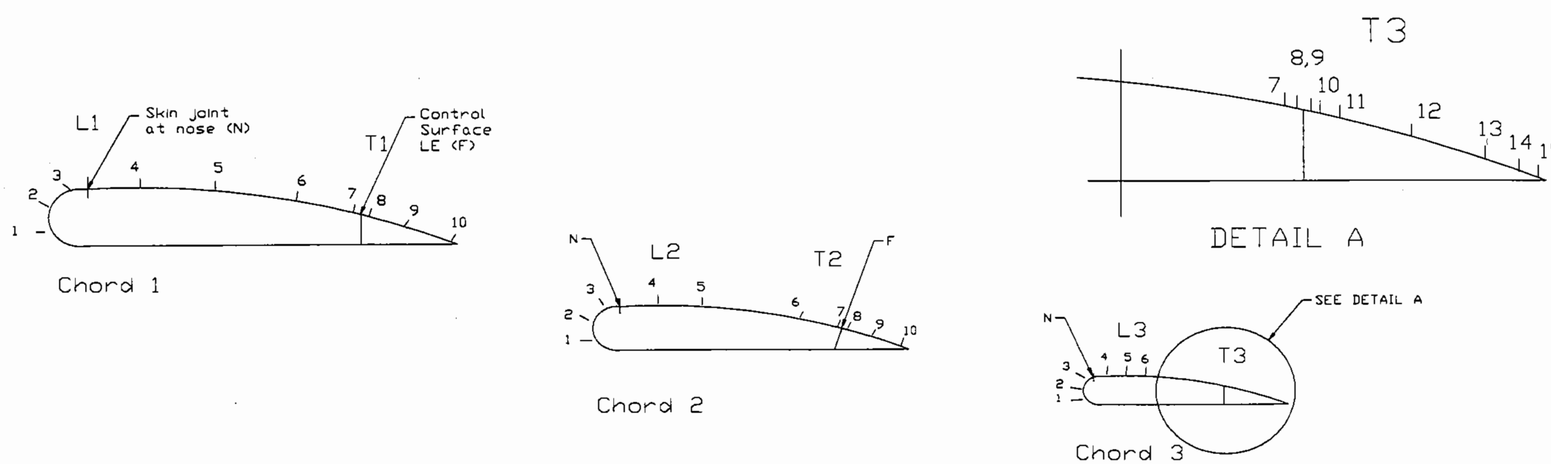
FIGURE 2
AIRCRAFT WING PLAN
LOCATIONS FOR FLUID THICKNESS MEASUREMENTS





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Date:1996-03-22

FIGURE 2
AIRCRAFT WING PLAN
LOCATIONS FOR FLUID THICKNESS MEASUREMENTS

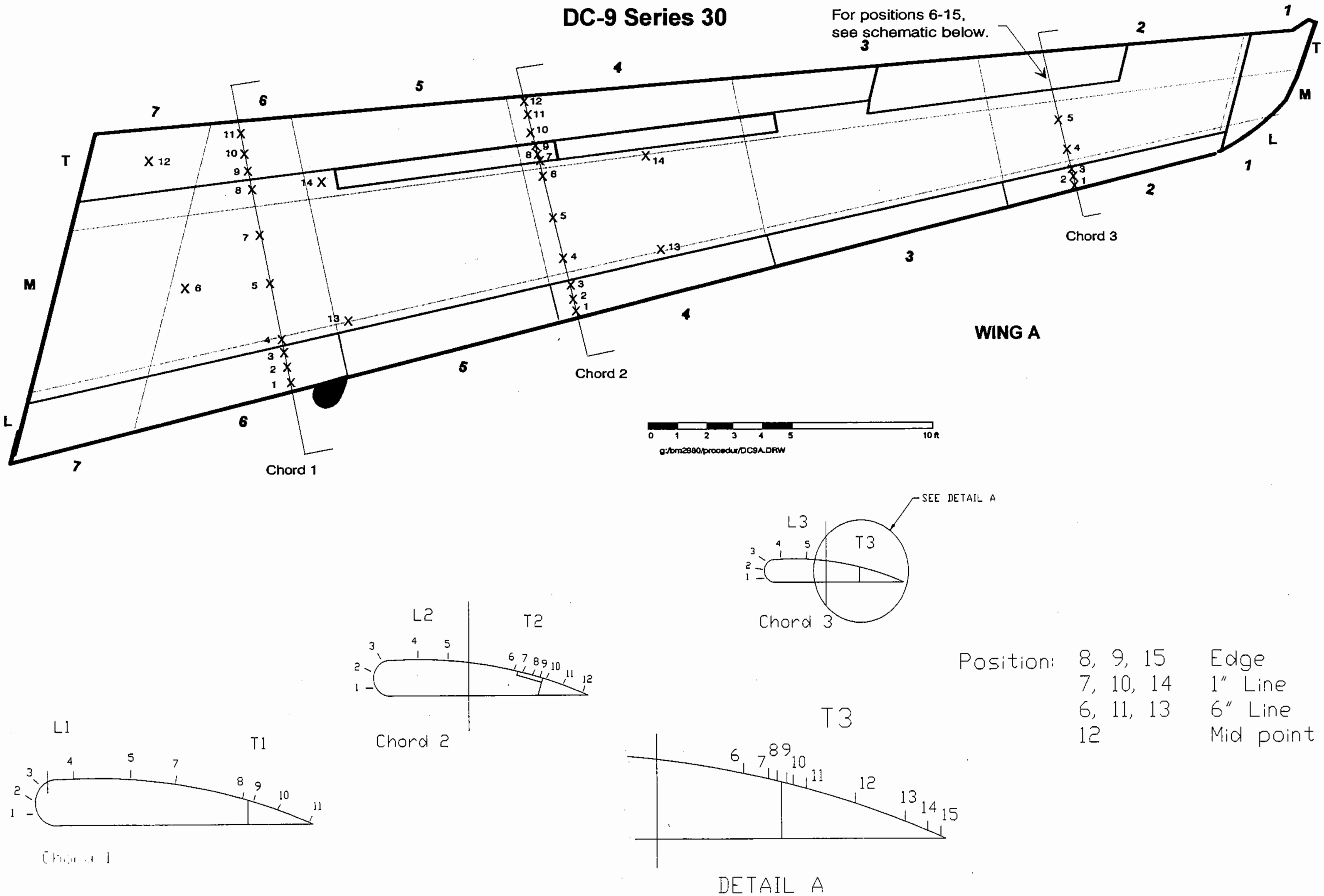

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FIGURE 2

AIRCRAFT WING PLAN

LOCATIONS FOR FLUID THICKNESS MEASUREMENTS

A320

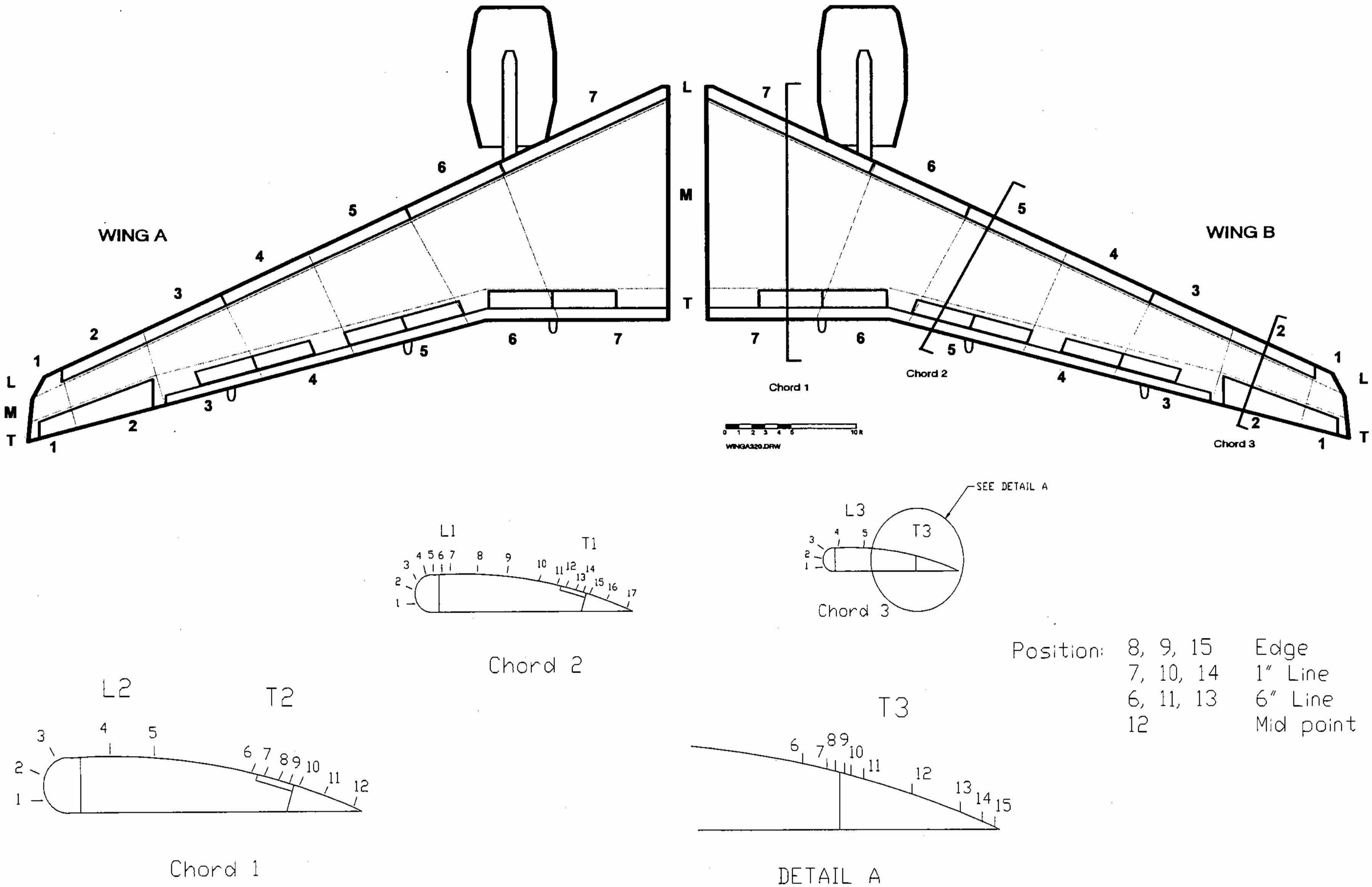

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FIGURE 5

GENERAL FORM
FLUID THICKNESS TESTS

AIRPORT: YUL

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

EXACT LOCATION OF TEST: ______________________

AIRLINE: ______________

DATE: ______________

FIN #: ______________

RUN #: ______________

FUEL LOAD: ______________ LB / KG

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

Test Started	Chord 1 Sprayed	Chord 2 Sprayed	Chord 3 Sprayed	Test Ended

TIME (min)	TEMPERATURE AT LOCATION (°C)			
	Rep. Surf	Chord 1	Chord 2	Chord 3
Before[1] ( )				

Weather Conditions

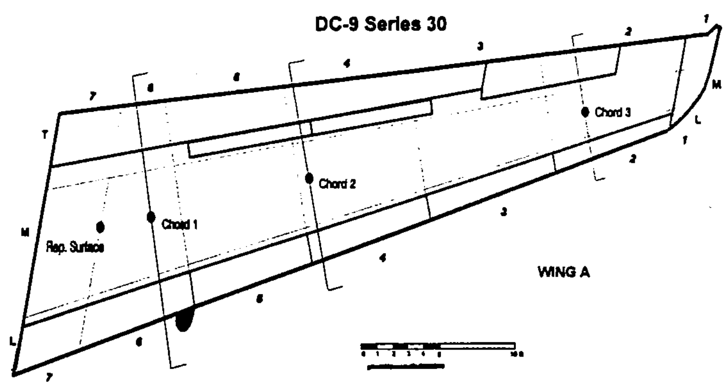
OAT ________ ° C

Relative Humidity ________ %

Wind Speed ________ km/h

Wind Direction ________ degrees

DC-9 Series 30



Team Assignments

L1 ______________________

L2 ______________________

L3 ______________________

O1 ______________________

T1 ______________________

V1 ______________________

T2 ______________________

C1 ______________________

T3 ______________________

Airline Team

______________________ ______________________

______________________ ______________________

Observers

______________________ ______________________

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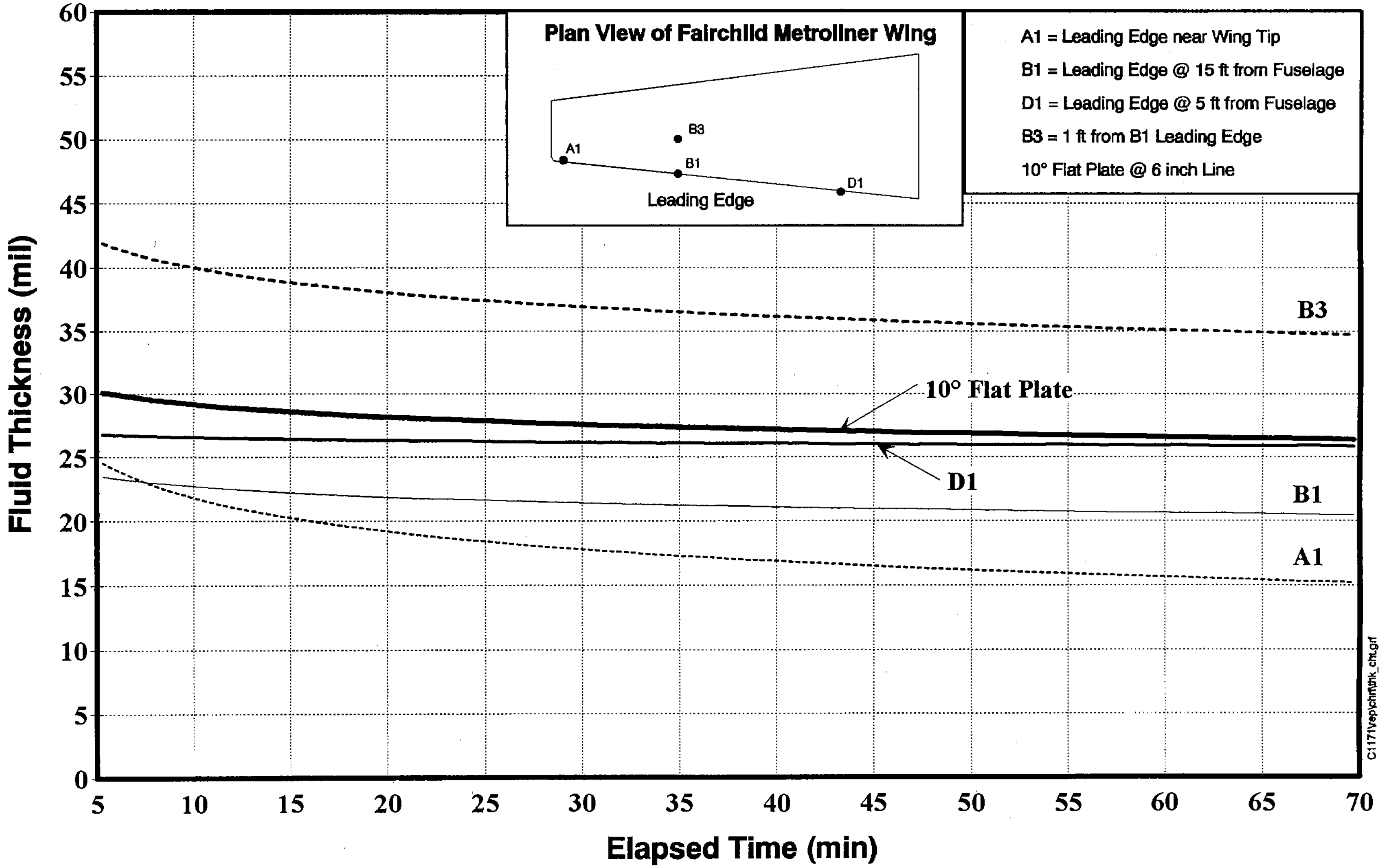
APPENDIX B

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

FIGURE 5.22

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

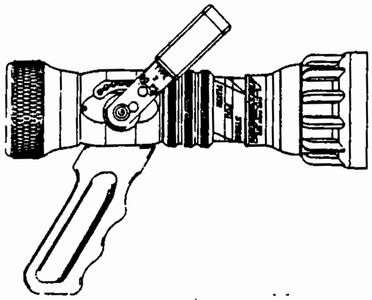
Type II 75/25 Fluid (A-500)



APPENDIX C

TASK FORCE TIPS®
AIRCRAFT ANTI-ICING NOZZLES
TECHNICAL INFORMATION

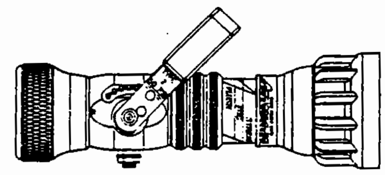
TASK FORCE TIPS
AIRCRAFT ANTI-ICING NOZZLES
TECHNICAL INFORMATION



MODEL# BGH-TYPE2
FLOW RANGE..... 10-60 GPM
LENGTH........................ 9-3/4"
WIDTH................................ 3"
WEIGHT.................. 3.25 LBS

TYPE-II

ANTI-ICING NOZZLES



MODEL# BH-TYPE2
FLOW RANGE ..... 10-60 GPM
LENGTH .... 9-3/4"
WIDTH................................ 3"
WEIGHT .... 2.62 LBS

GENERAL INFORMATION - The anti-icing nozzles from Task Force Tips® are modified for the application of Propylene Glycol Type II fluids based on testing and requests of major airlines. The proper use of these agents aids ground support professionals in their efforts to prevent ice and snow from forming on the wings of aircraft. This extends holdover times and helps to make air travel in cold weather conditions less hazardous.

The Type II nozzles come with either an insulated pistol grip which helps to protect the operator's hands from very low or high temperatures, (BGH-TYPE2), or without a pistol grip for use on rigid mount swivel guns, (BH-TYPE2). The Type II nozzles operate at the industry standard of 50 PSI at 20-30 GPM.

OPERATION - All anti-icing nozzles have been modified to perform under the following parameters:

1. Nozzles are self-regulating at 50 psi.
2. Nozzles can flow 10 to 60 GPM, and are ideal between 20-30 GPM.
3. Nozzles have a "toothless" bumper to reduce air turbulence.
4. For application of Type II Propylene Glycol "Neat" or with a water mixture.
5. Each shutoff is tested to withstand 800 PSI.
6. Nozzles use 1.5"-9 NH, female National Hose thread inlet.

NOTE: Alternate threads are available. Consult factory for special orders.

TASK FORCE TIPS, INC. **2800 EAST EVANS AVENUE, VALPARAISO, INDIANA 46383**
(800) 348-2686 (219) 462-6161 FAX (219) 464-0620

FEATURES - The following points make the Task Force Tips® Type II nozzle a better value for your anti-icing ground support activities:

Automatic Pressure Control - The anti-icing nozzle from TFT® incorporates a pressure regulating mechanism which means the fluid discharge velocity is always constant. With a constant nozzle discharge pressure, the anti-icing agent will have optimum reach at all flow settings, thereby reducing waste due to insufficient range of the stream. This will help insure that you will always achieve low degradation because the operator can't change the pressure to a higher setting by accident.

Slide-Type Valve - All anti-icing nozzles are constructed of heat treated hard anodized aluminum, and utilize a heat and leak resistant EPDM valve seat which conforms to our patented slide-type valve. This valve design controls the flow through the nozzle without creating turbulence that causes shear and degradation of the fluid. Because of this feature, the nozzle can be operated at any handle position, thereby allowing the operator to regulate the amount of agent being applied. This gives the operator the ability to conserve fluid and minimize waste without sacrificing reach or range of the stream. Unlike a ball valve, the stainless steel slide valve is not directly in the flow path, and will not tighten under high pressures, or bind with age. Therefore, it is always easy to operate.

Pattern Control - The nozzle features a "toothless" bumper to reduce air turbulence, and can be easily adjusted for any desired spray pattern by rotating the shaper between a straight stream or narrow fog position for application to sensitive areas of the aircraft.

WARRANTY - This anti-icing nozzle is a modified fire fighting nozzle. These modifications have been the result of requests from various airline and truck manufacturers. Task Force Tips® has NOT run any specific testing of this nozzle for its suitability as a Type II anti-icing nozzle. Type II fluids by their very nature are sensitive to turbulence in the entire delivery system. This nozzle constitutes only a small portion of the system. It is very important that every end user make sure that the system being used is not causing degradation of the Type II fluid. **TASK FORCE TIPS® MAKES NO WARRANTY OF FITNESS FOR THIS PARTICULAR PURPOSE.**

All TFT® nozzles carry a written Limited Warranty against defects in materials and workmanship. This Limited Warranty in part limits the purchaser's / user's remedy to repair or replacement of the nozzle and excludes consequential or incidental damages. The Limited Warranty accompanies each nozzle and a copy is also available upon request.

APPENDIX D

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^{0}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^{0}C limitation down to -7^{0}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 E

FLUID THICKNESS DECAY
OF VARIOUS WING POSITIONS

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

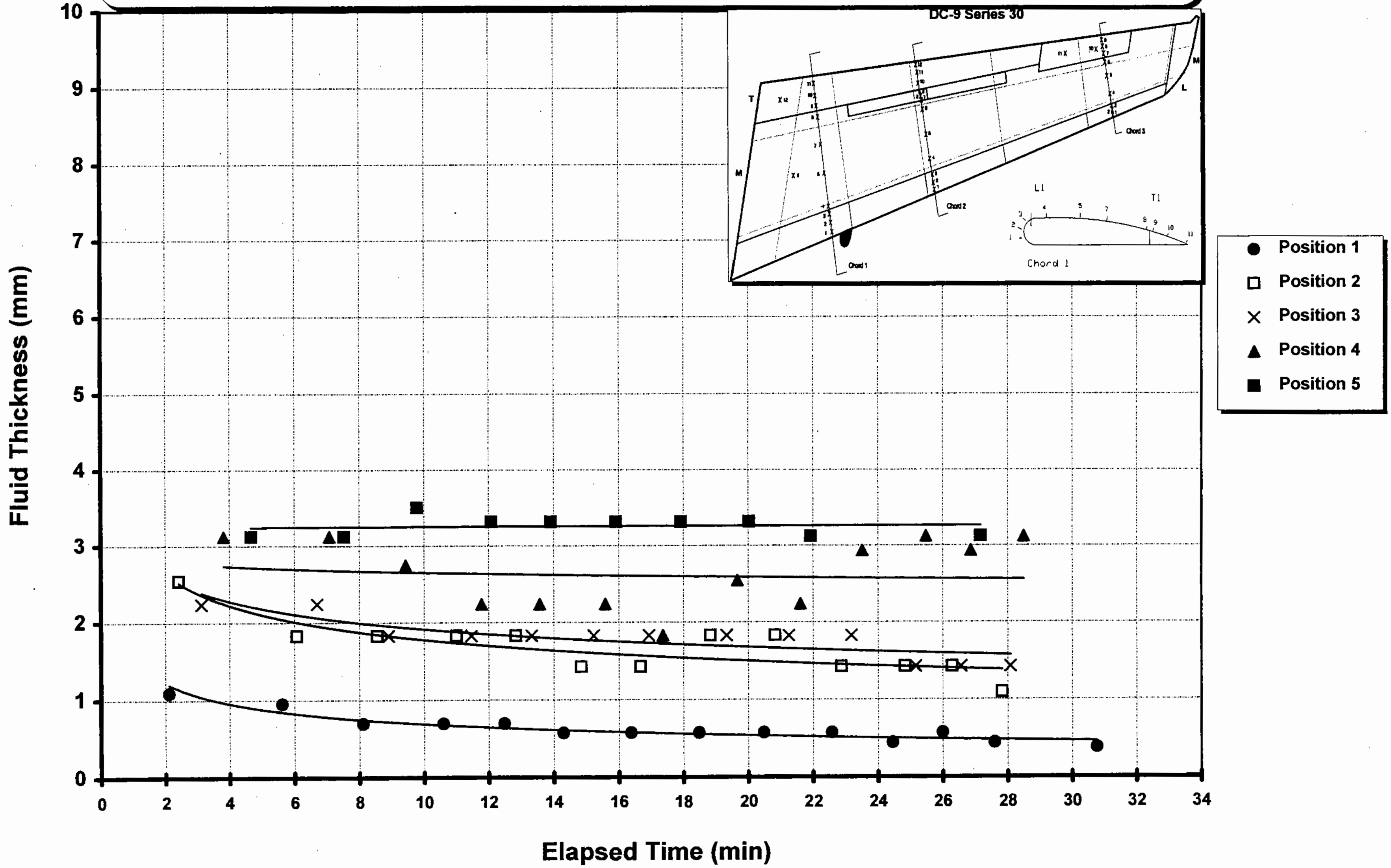
RUN 1 - MARCH 12, 1996

DC-9 - LOCATION L1

1st FLUID: ULTRA TYPE IV / 290 LITRES

2nd FLUID: NIL

Temperature: -4.4°C | Wind Speed: 9.0 kph | Nozzle Type: AKRON



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At: L1_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

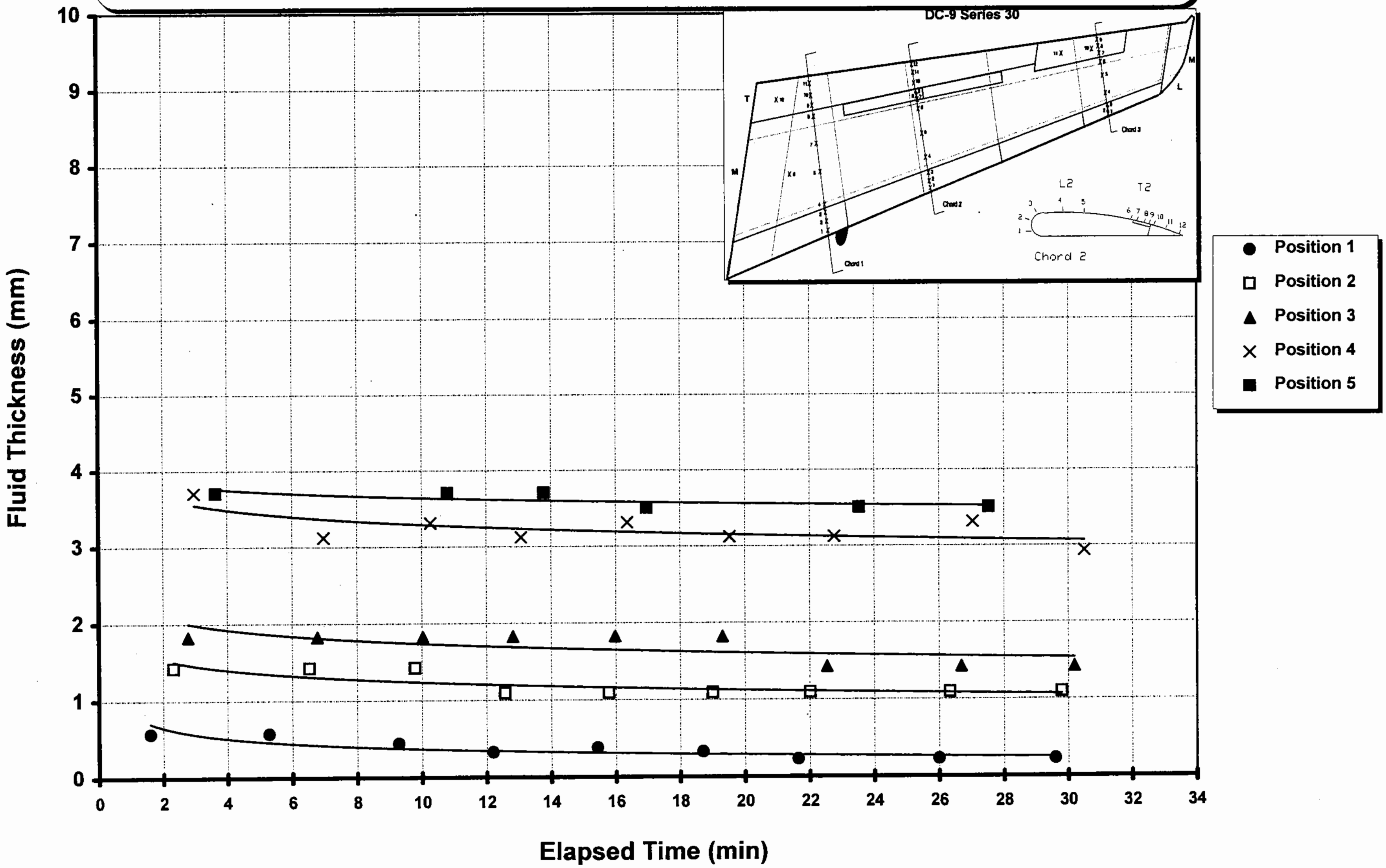
RUN 1 - MARCH 12, 1996

DC-9 - LOCATION L2

1st FLUID: ULTRA TYPE IV / 290 LITRES

2nd FLUID: NIL

Temperature: -4.4ºC | Wind Speed: 9.0 kph | Nozzle Type: AKRON



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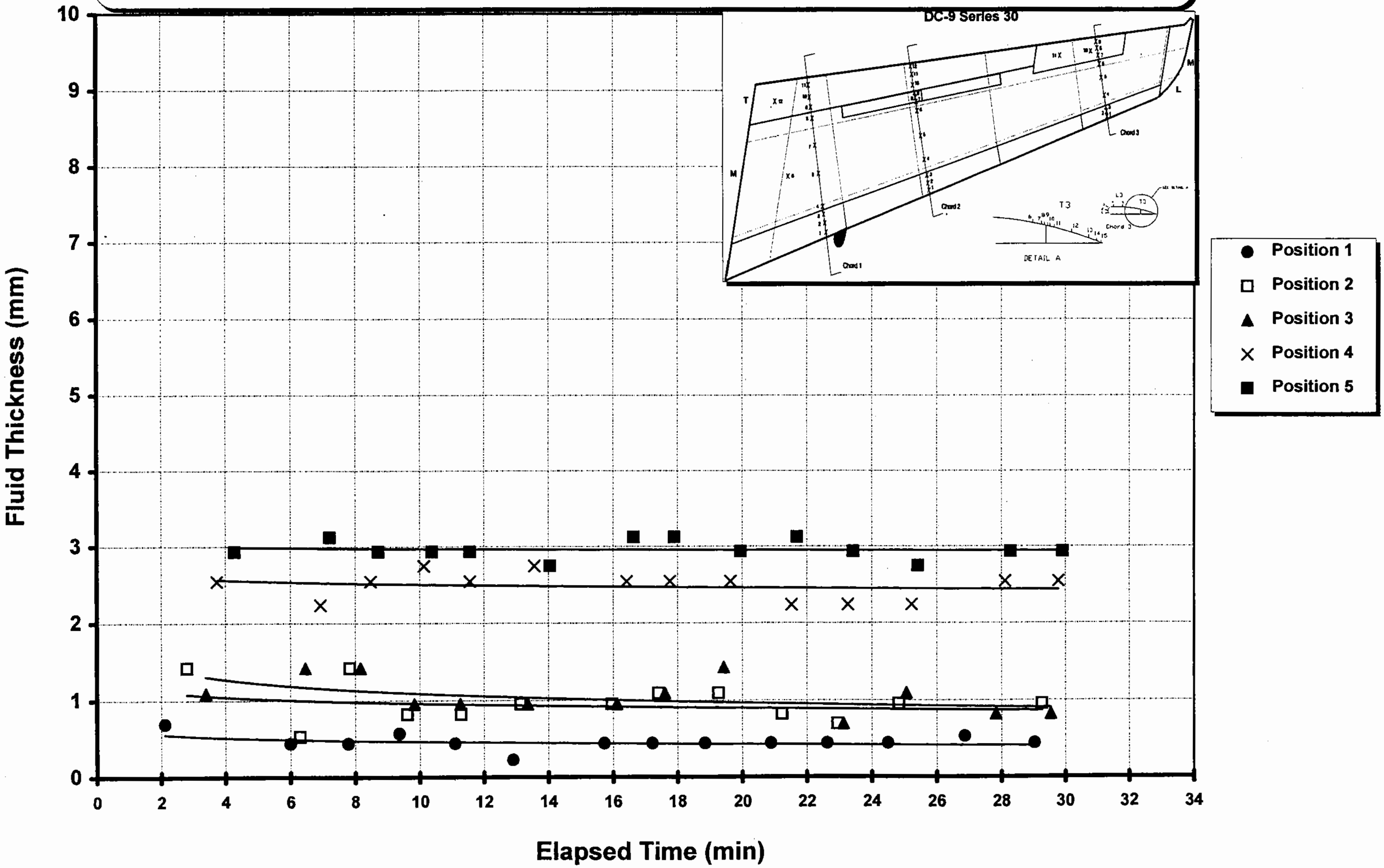
Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS
RUN 1 - MARCH 12, 1996
DC-9 - LOCATION L3
1st FLUID: ULTRA TYPE IV / 290 LITRES
2nd FLUID: NIL

Temperature: -4.4°C | Wind Speed: 9.0 kph | Nozzle Type: AKRON



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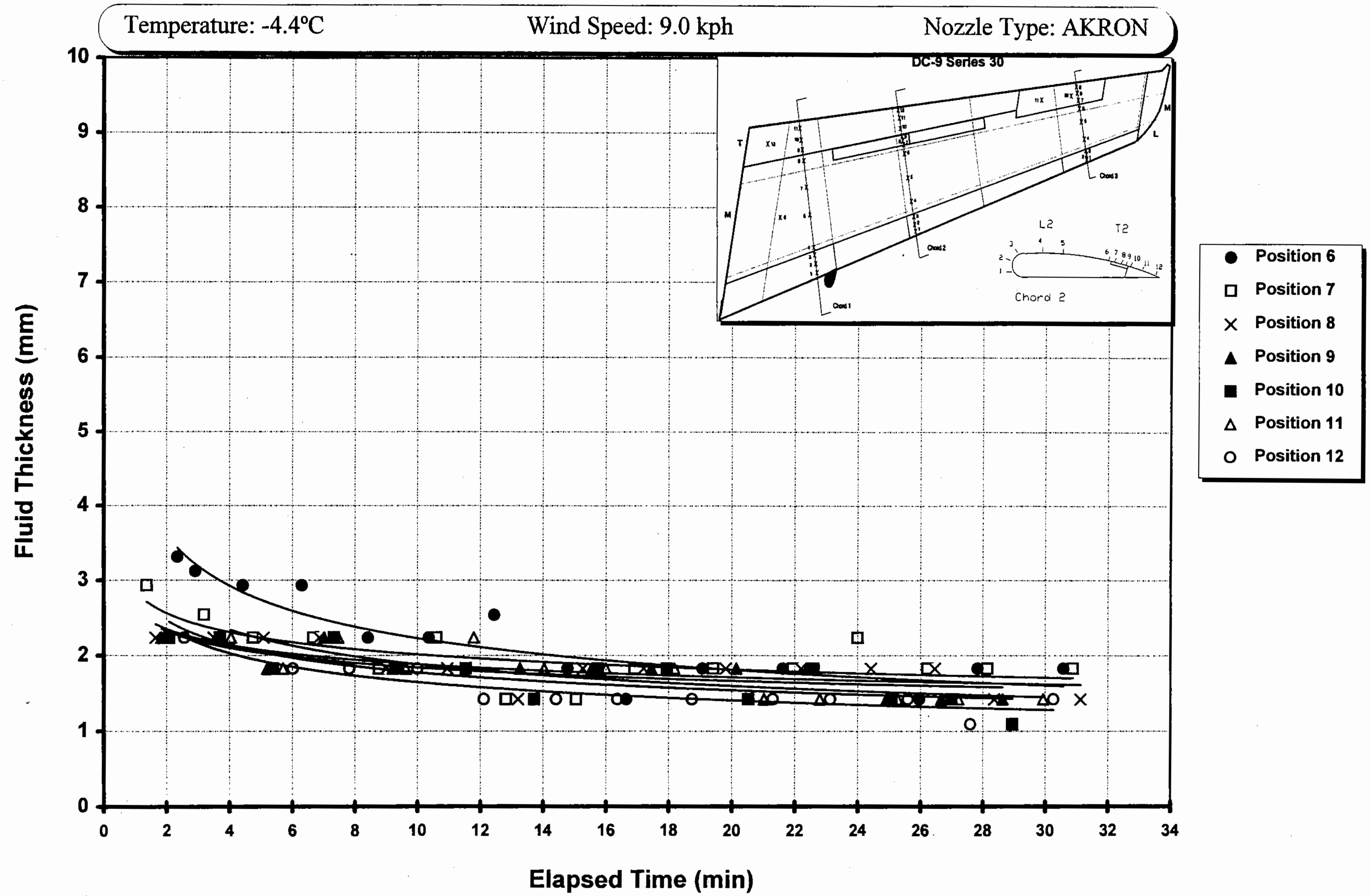
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 1 - MARCH 12, 1996

DC-9 - LOCATION T1

1st FLUID: ULTRA TYPE IV / 290 LITRES

2nd FLUID: NIL



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Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

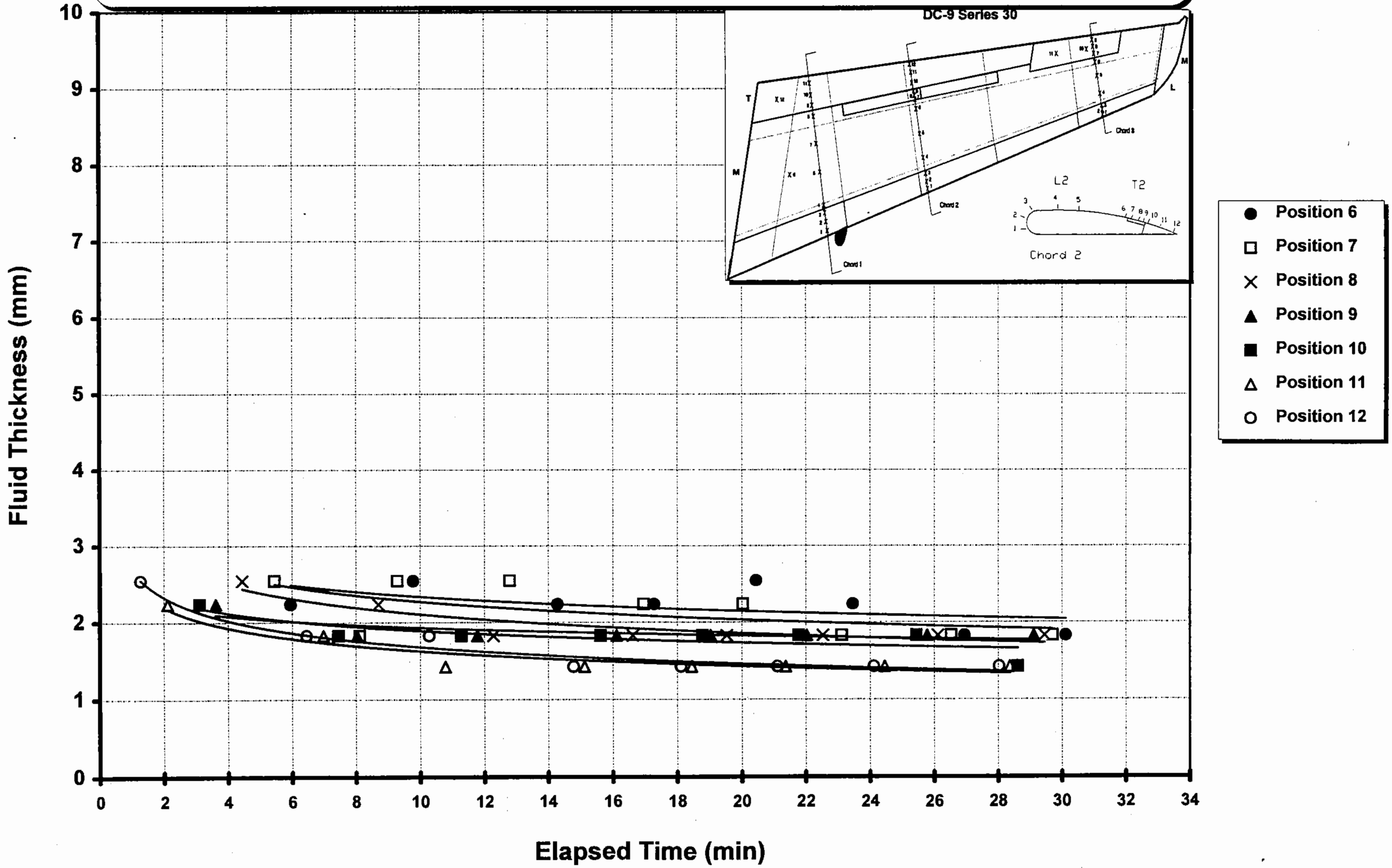
RUN 1 - MARCH 12, 1996

DC-9 - LOCATION T2

1st FLUID: ULTRA TYPE IV / 290 LITRES

2nd FLUID: NIL

Temperature: -4.4°C | Wind Speed: 9.0 kph | Nozzle Type: AKRON



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Printed 09/12/96

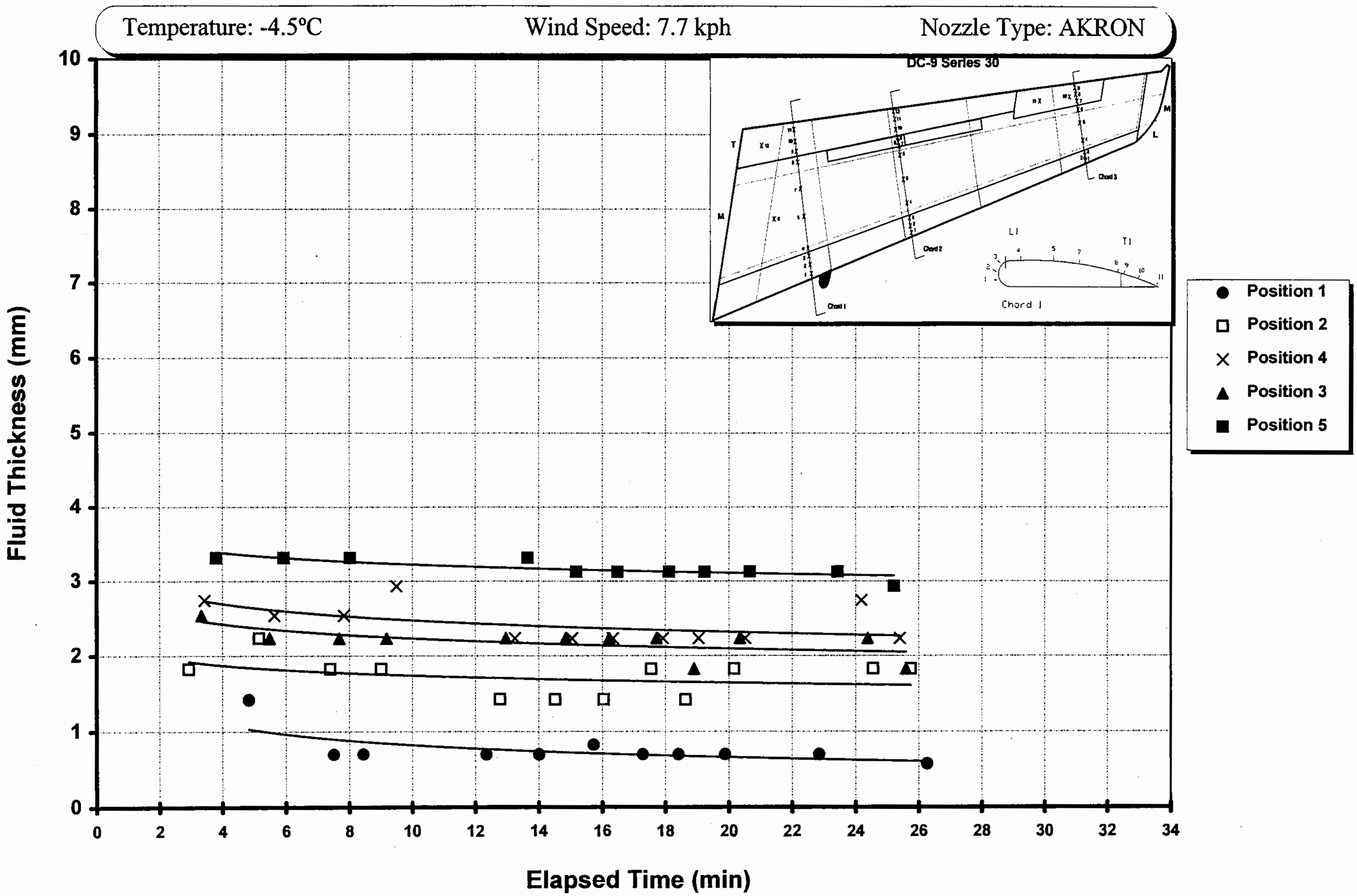
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 2 - MARCH 12, 1996

DC-9 - LOCATION L1

1st FLUID: ULTRA TYPE IV / 273 LITRES

2nd FLUID: NIL



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Printed:09/12/96

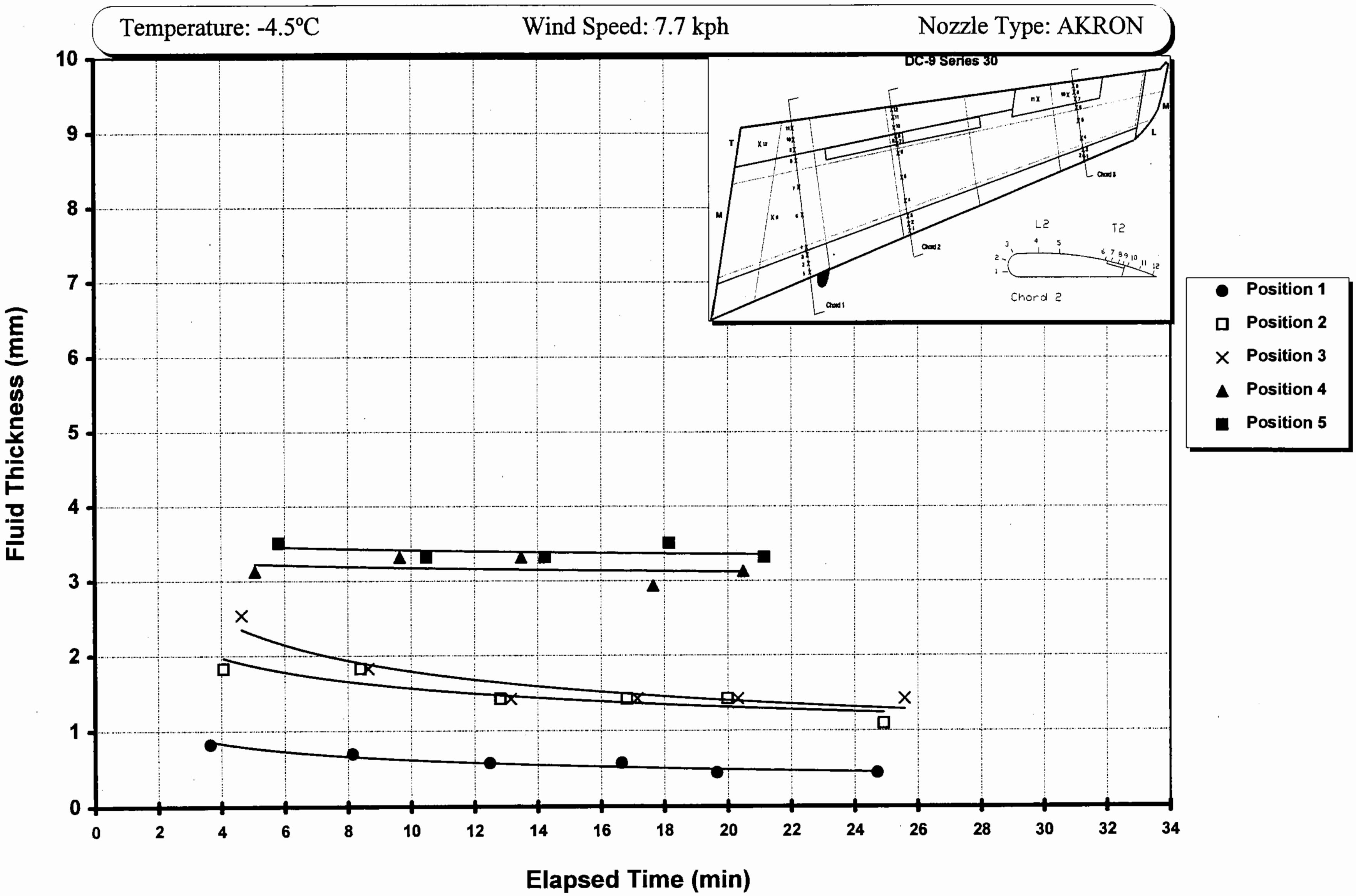
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 2 - MARCH 12, 1996

DC-9 - LOCATION L2

1st FLUID: ULTRA TYPE IV / 273 LITRES

2nd FLUID: NIL



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Printed:09/12/96

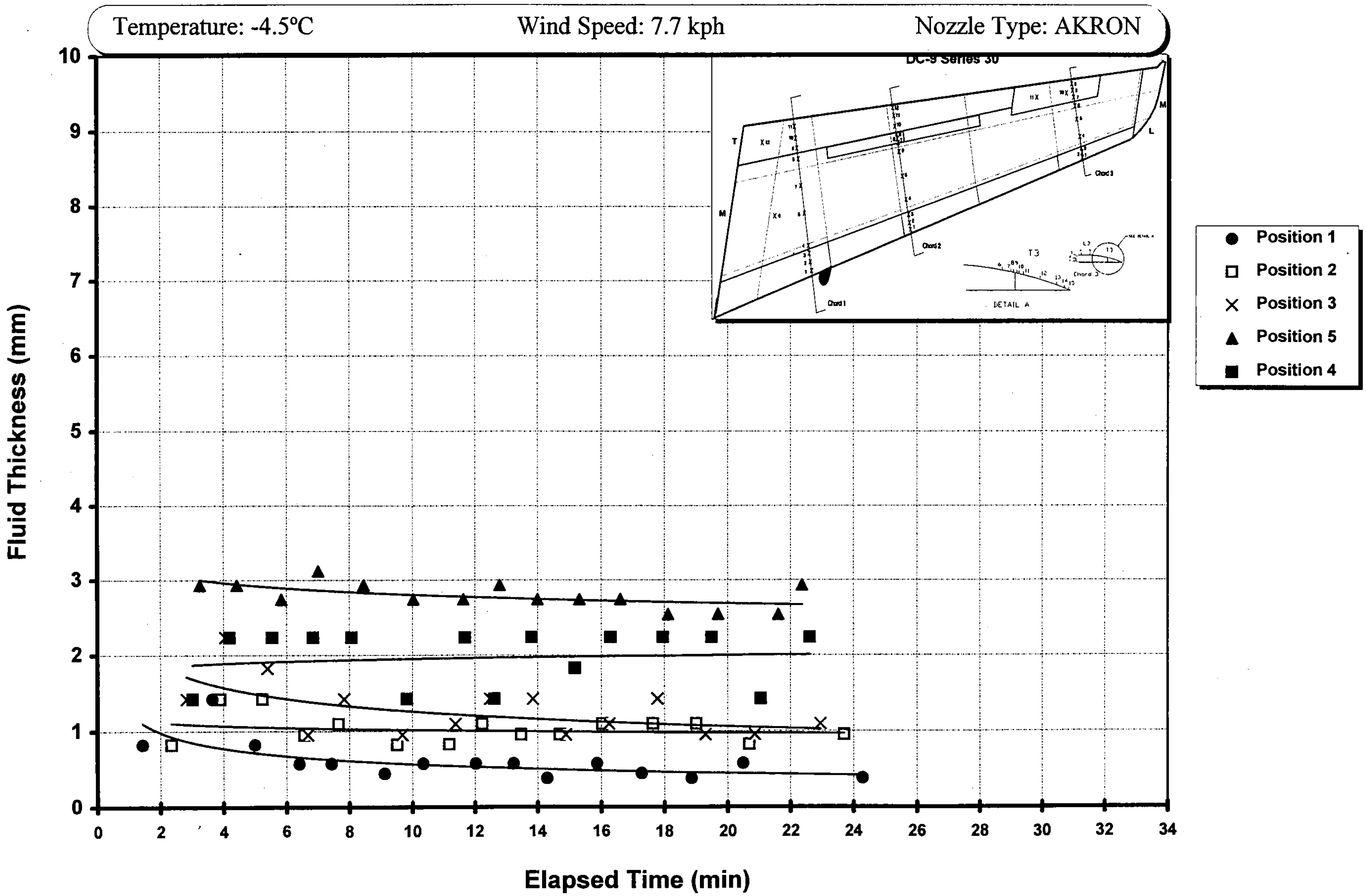
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 2 - MARCH 12, 1996

DC-9 - LOCATION L3

1st FLUID: ULTRA TYPE IV / 273 LITRES

2nd FLUID: NIL



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FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

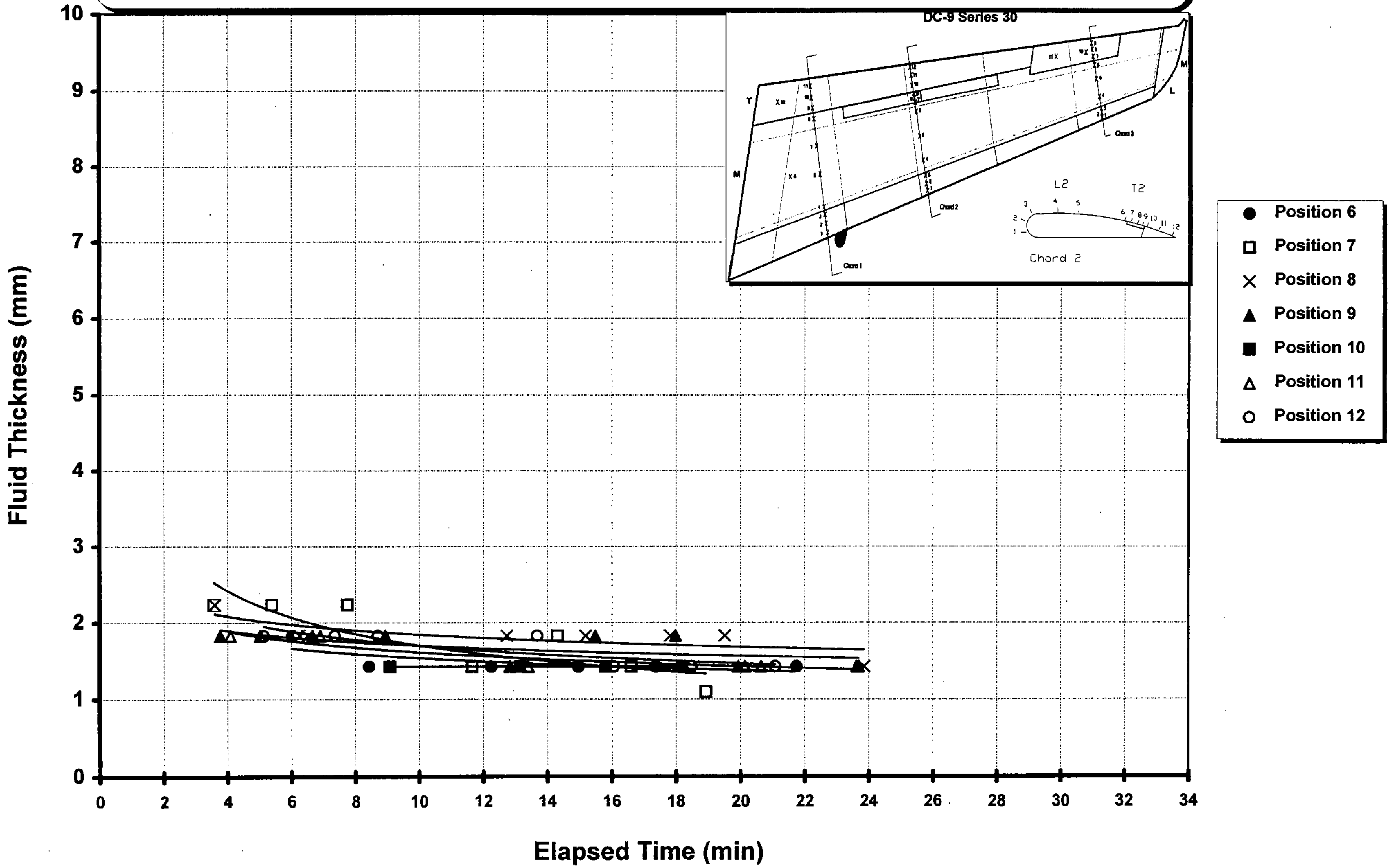
RUN 2 - MARCH 12, 1996

DC-9 - LOCATION T1

1st FLUID: ULTRA TYPE IV / 273 LITRES

2nd FLUID: NIL

Temperature: -4.5°C | Wind Speed: 7.7 kph | Nozzle Type: AKRON



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FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

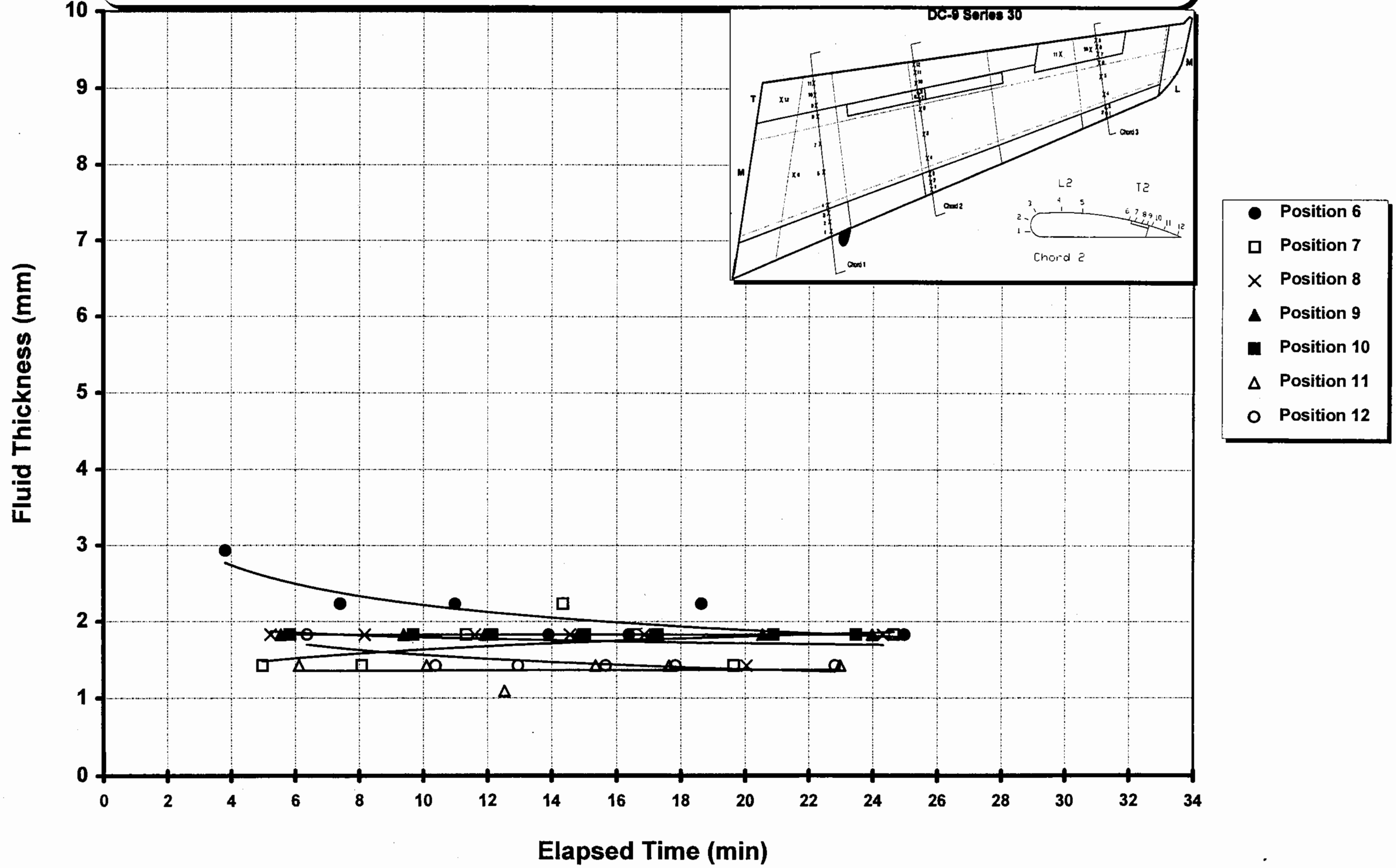
RUN 2 - MARCH 12, 1996

DC-9 - LOCATION T2

1st FLUID: ULTRA TYPE IV / 273 LITRES

2nd FLUID: NIL

Temperature: -4.5°C | Wind Speed: 7.7 kph | Nozzle Type: AKRON



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Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

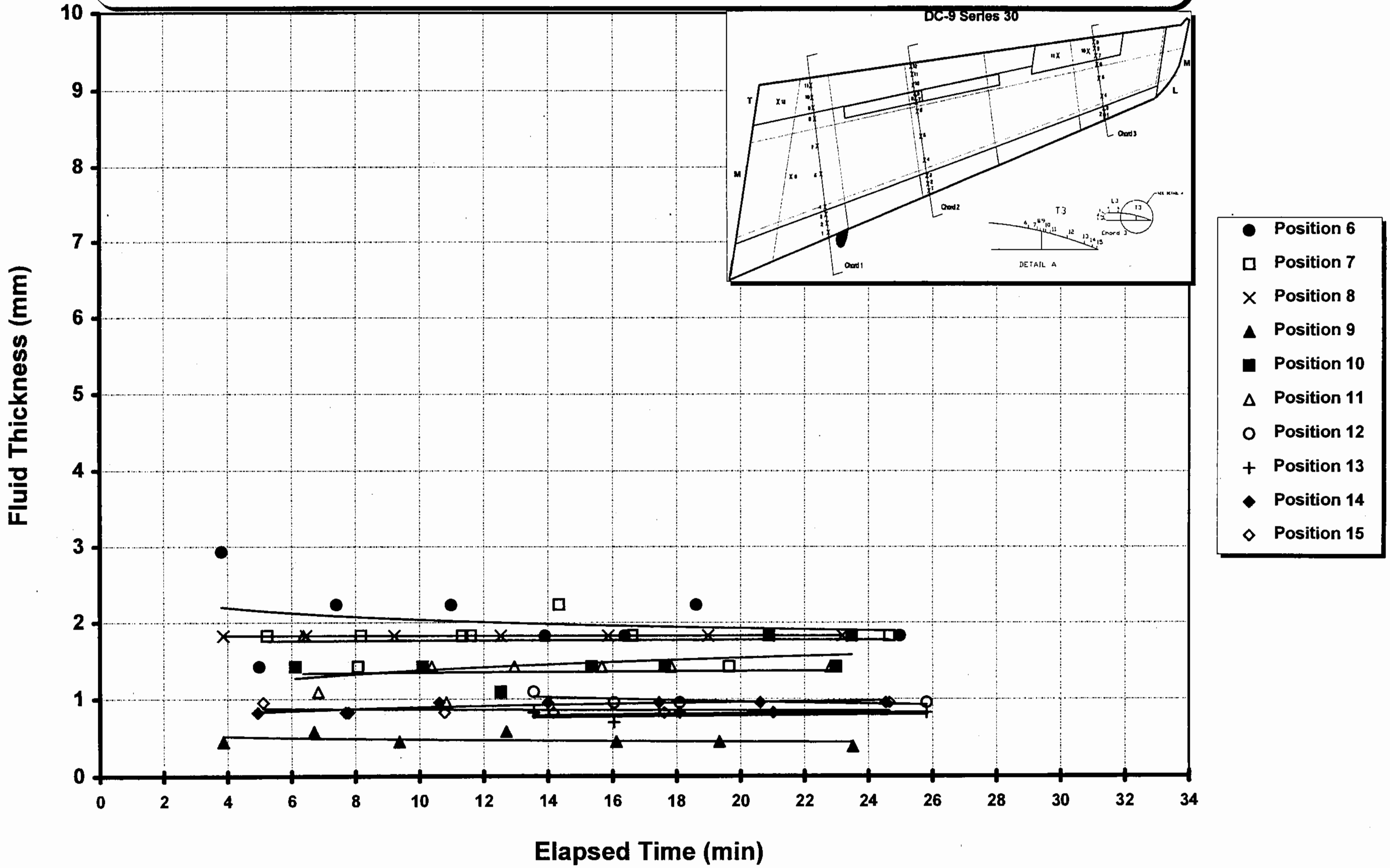
RUN 2 - MARCH 12, 1996

DC-9 - LOCATION T3

1st FLUID: ULTRA TYPE IV / 273 LITRES

2nd FLUID: NIL

Temperature: -4.5°C   Wind Speed: 7.7 kph   Nozzle Type: AKRON



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Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

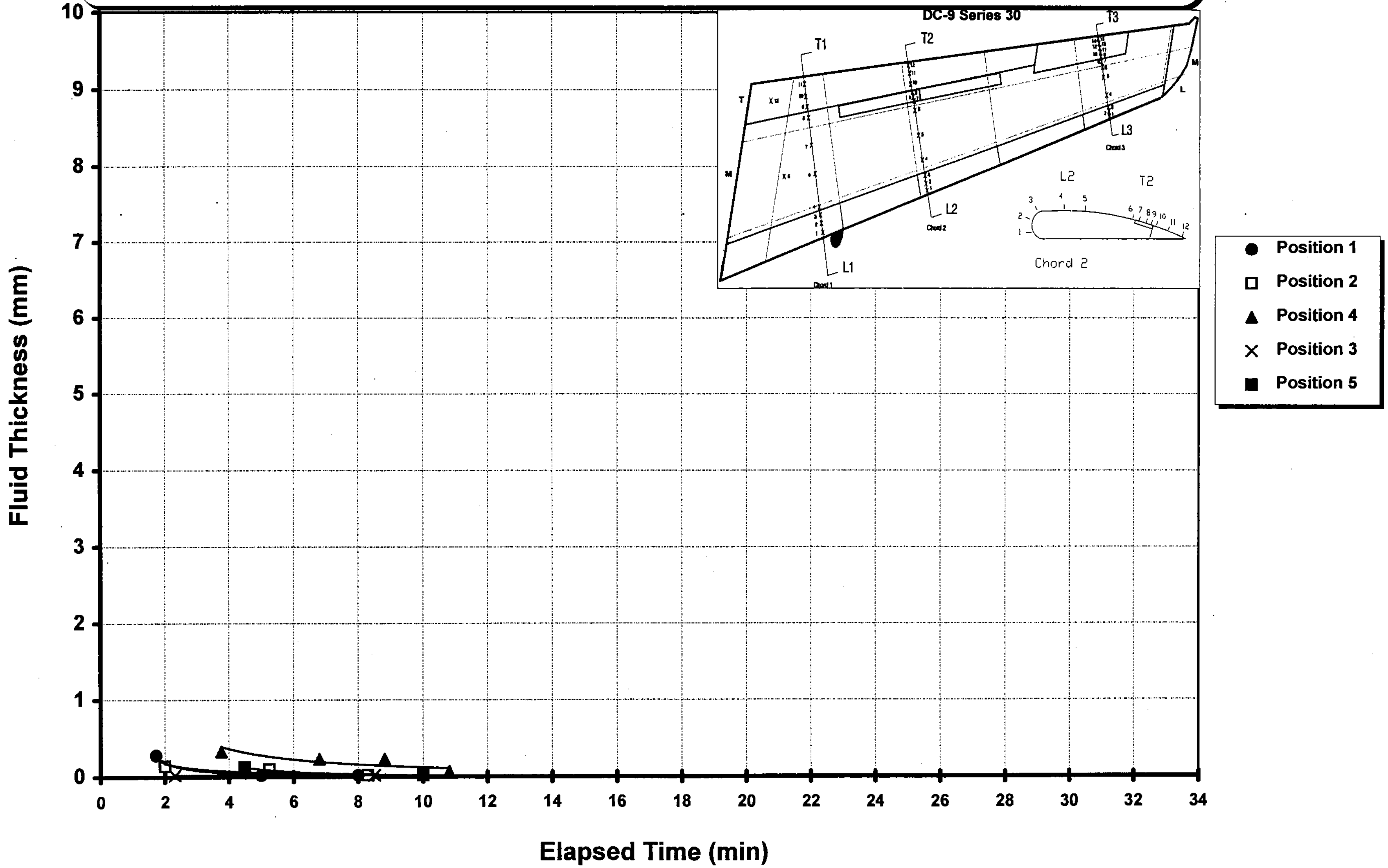
RUN 3 - MARCH 12, 1996

DC-9 - LOCATION L2

1st FLUID: XL54 TYPE I / 318 LITRES

2nd FLUID: NIL

Temperature: -3.6°C	Wind Speed: 10.0 kph	Nozzle Type: AKRON



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Printed:09/12/96

FIGURE 4.4

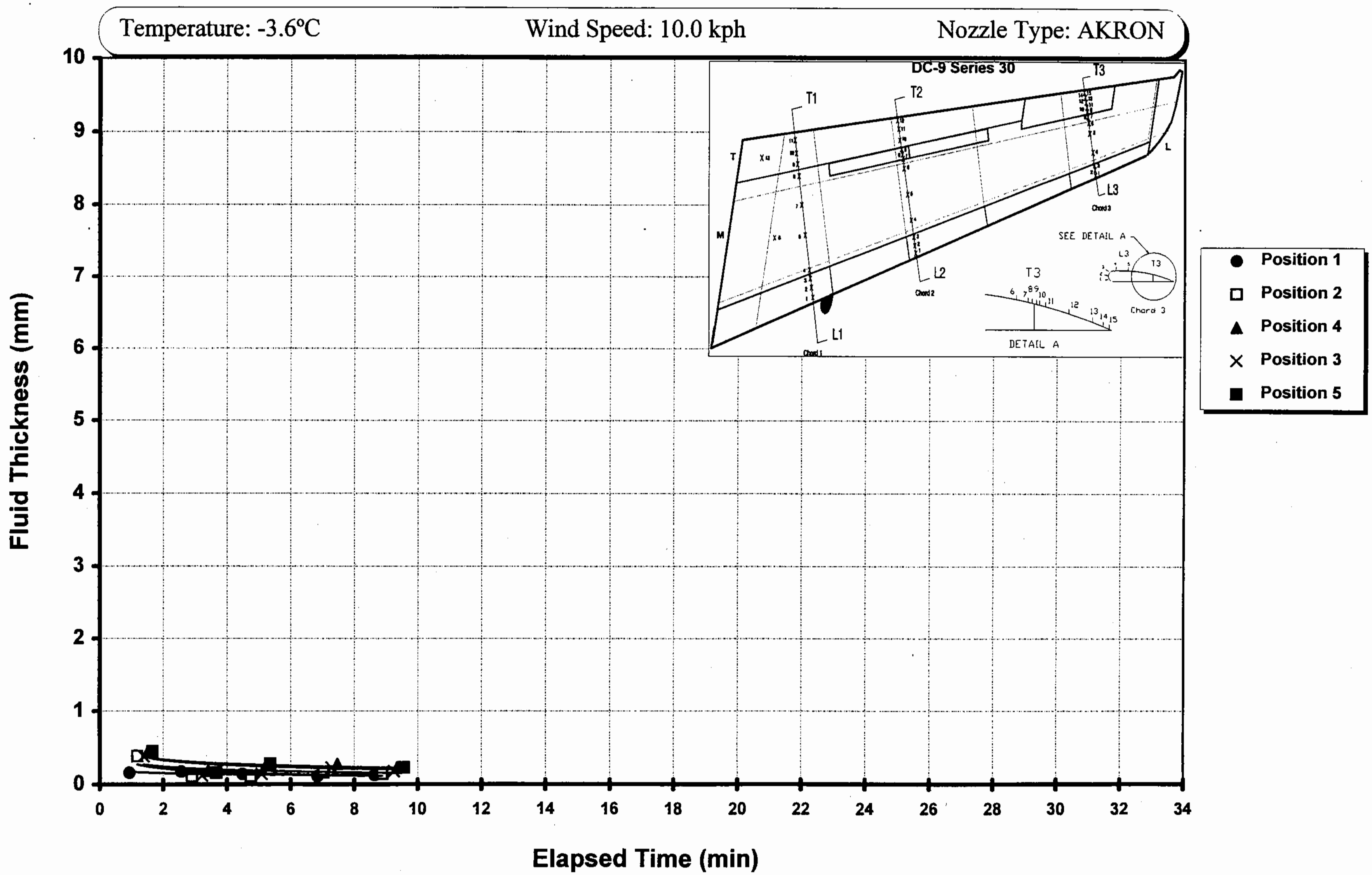
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 3 - MARCH 12, 1996

DC-9 - LOCATION L3

1st FLUID: XL54 TYPE I / 318 LITRES

2nd FLUID: NIL



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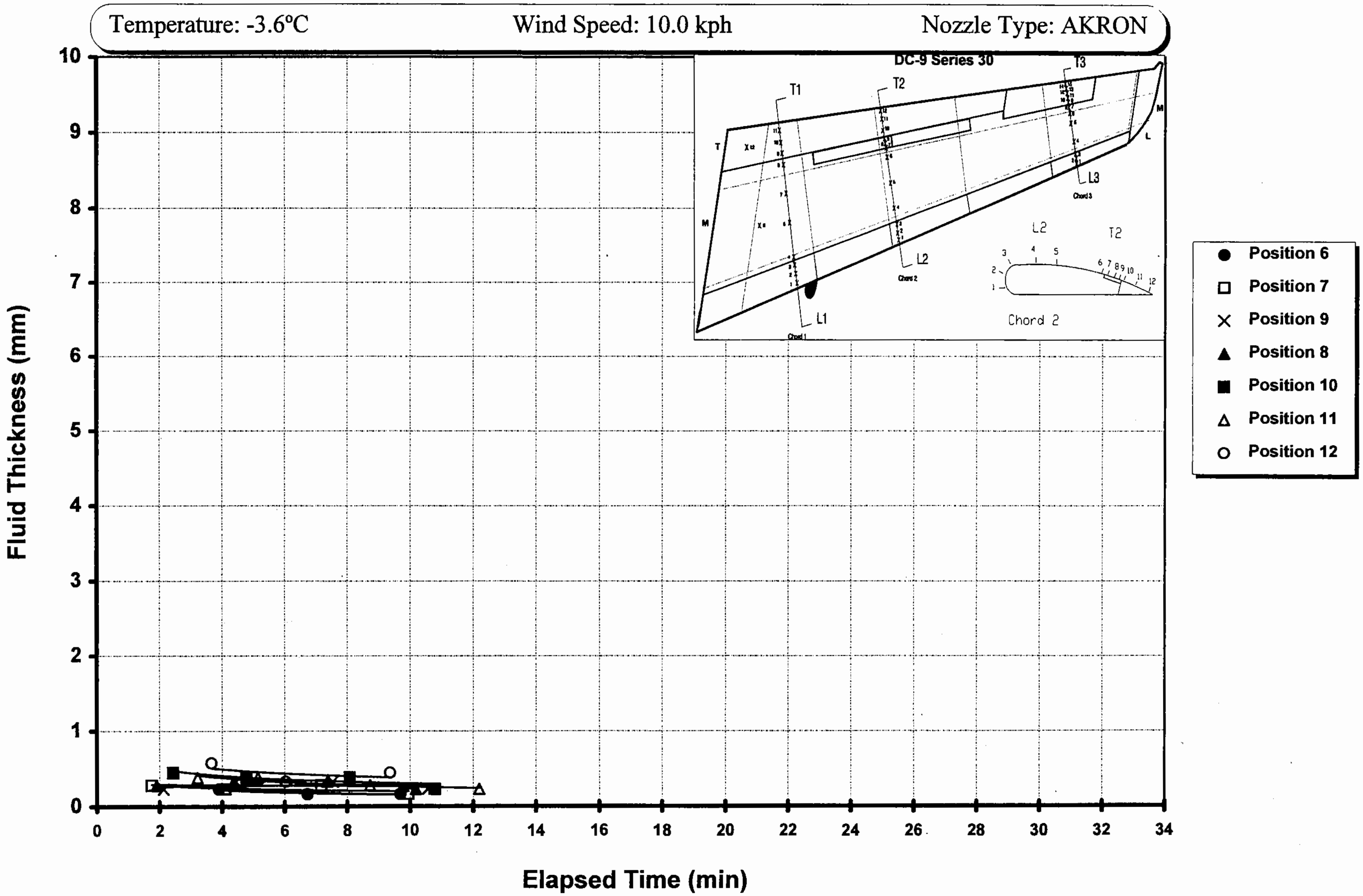
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 3 - MARCH 12, 1996

DC-9 - LOCATION T1

1st FLUID: XL54 TYPE I / 318 LITRES

2nd FLUID: NIL



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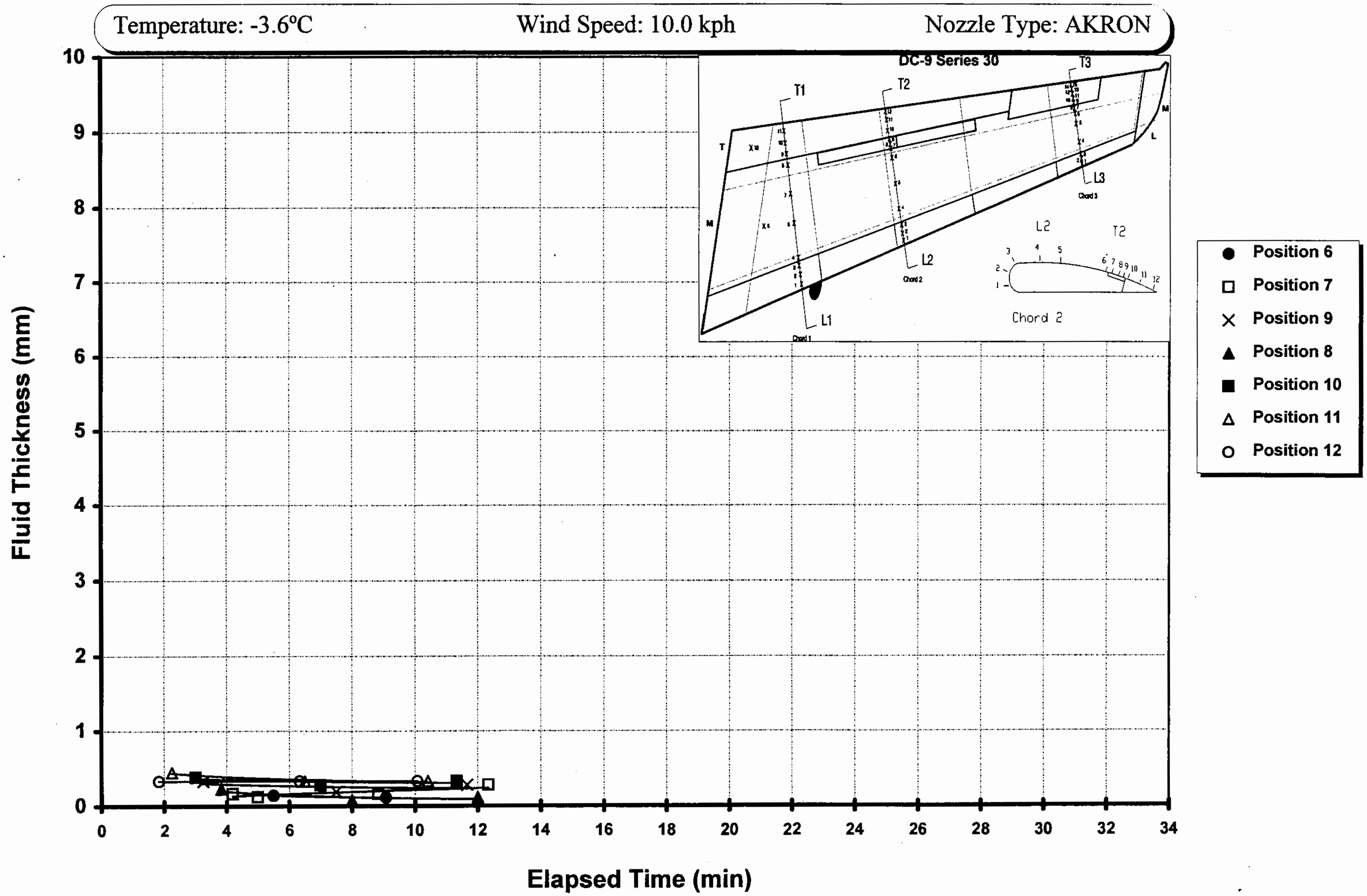
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 3 - MARCH 12, 1996

DC-9 - LOCATION T2

1st FLUID: XL54 TYPE I / 318 LITRES

2nd FLUID: NIL



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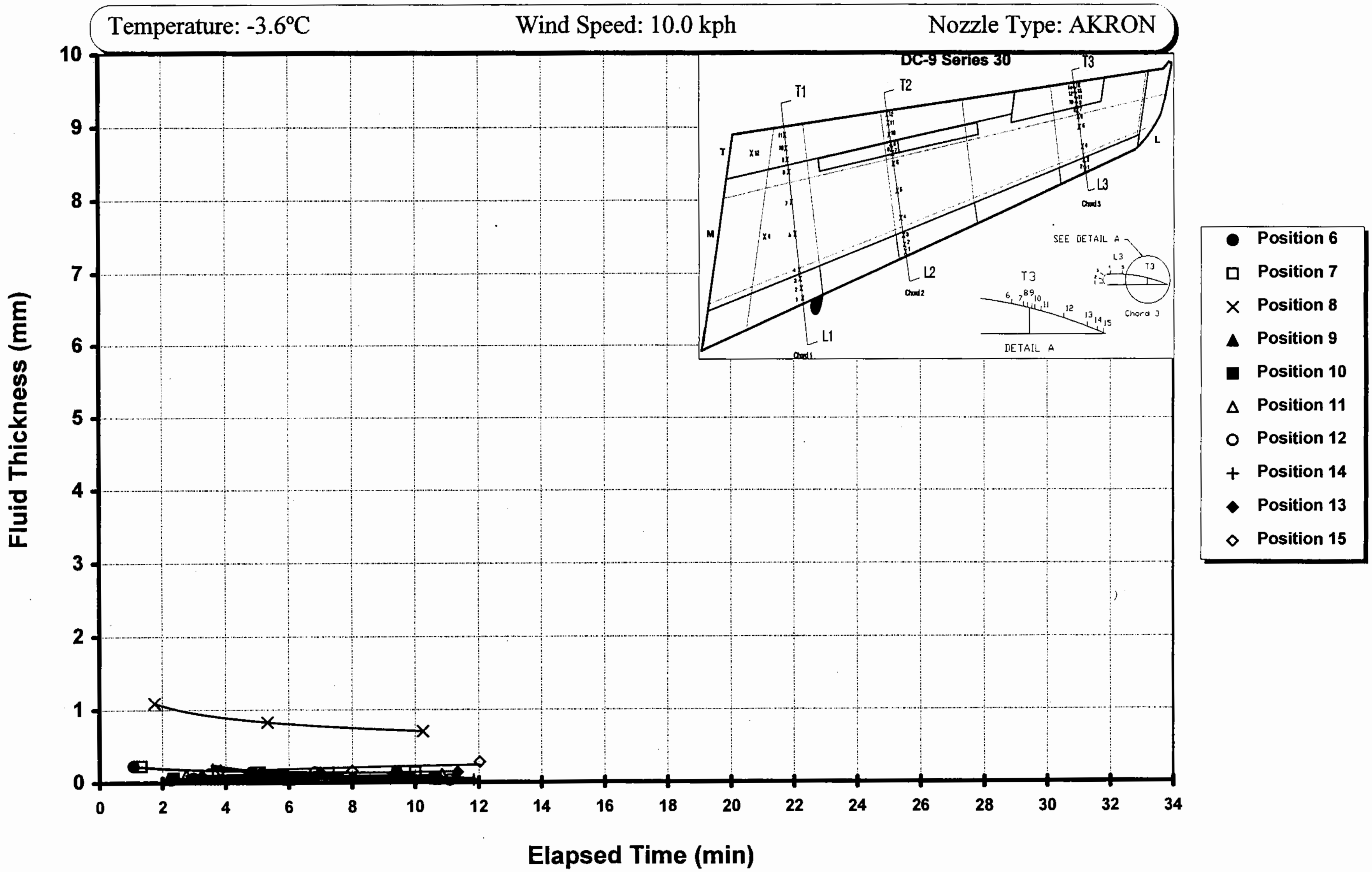
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 3 - MARCH 12, 1996

DC-9 - LOCATION T3

1st FLUID: XL54 TYPE I / 318 LITRES

2nd FLUID: NIL



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FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

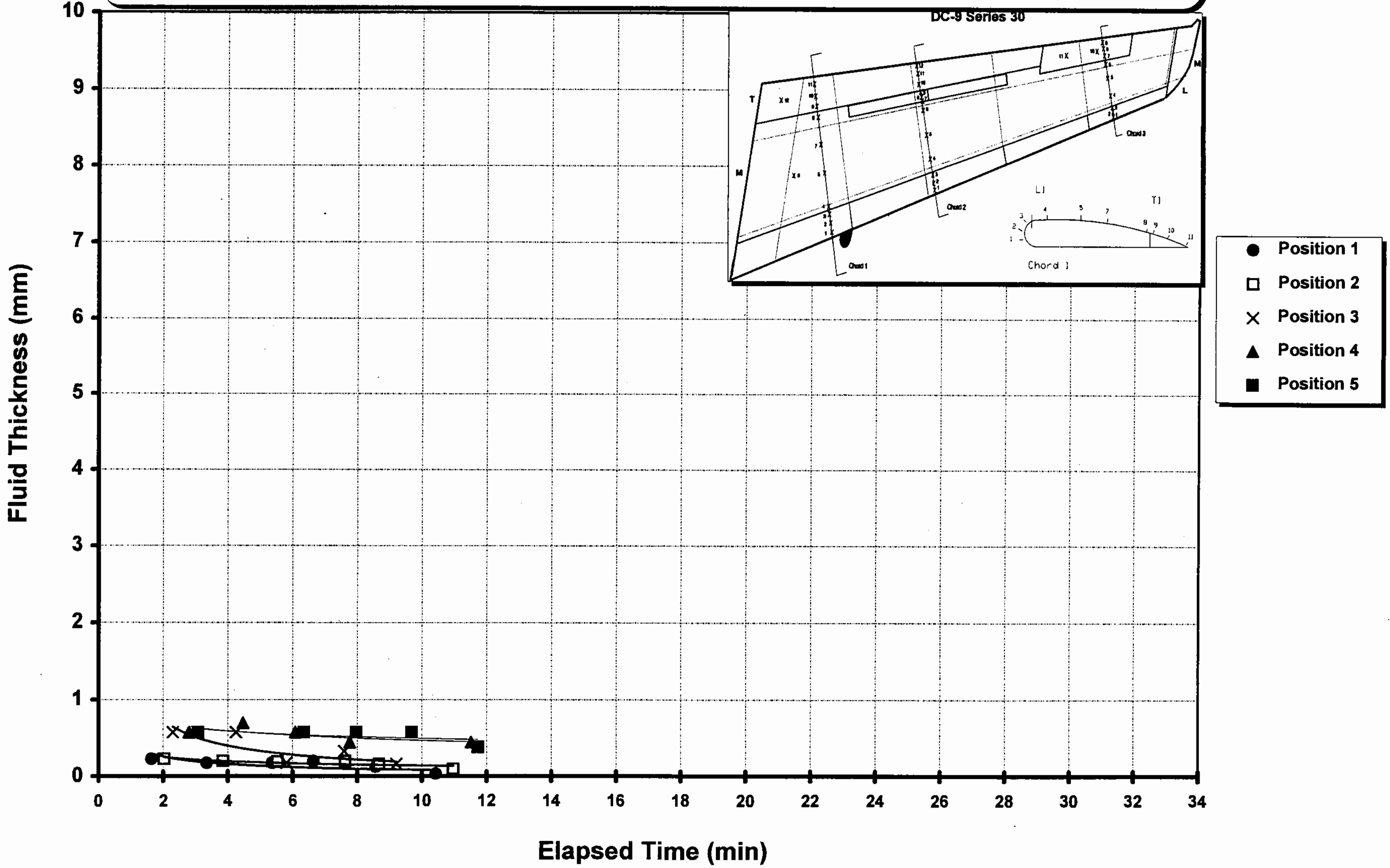
RUN 4 - MARCH 12, 1996

DC-9 - LOCATION L1

1st FLUID: XL54 TYPE I / 245 LITRES

2nd FLUID: NIL

Temperature: -4.2°C   Wind Speed: 10.1 kph   Nozzle Type: AKRON



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Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

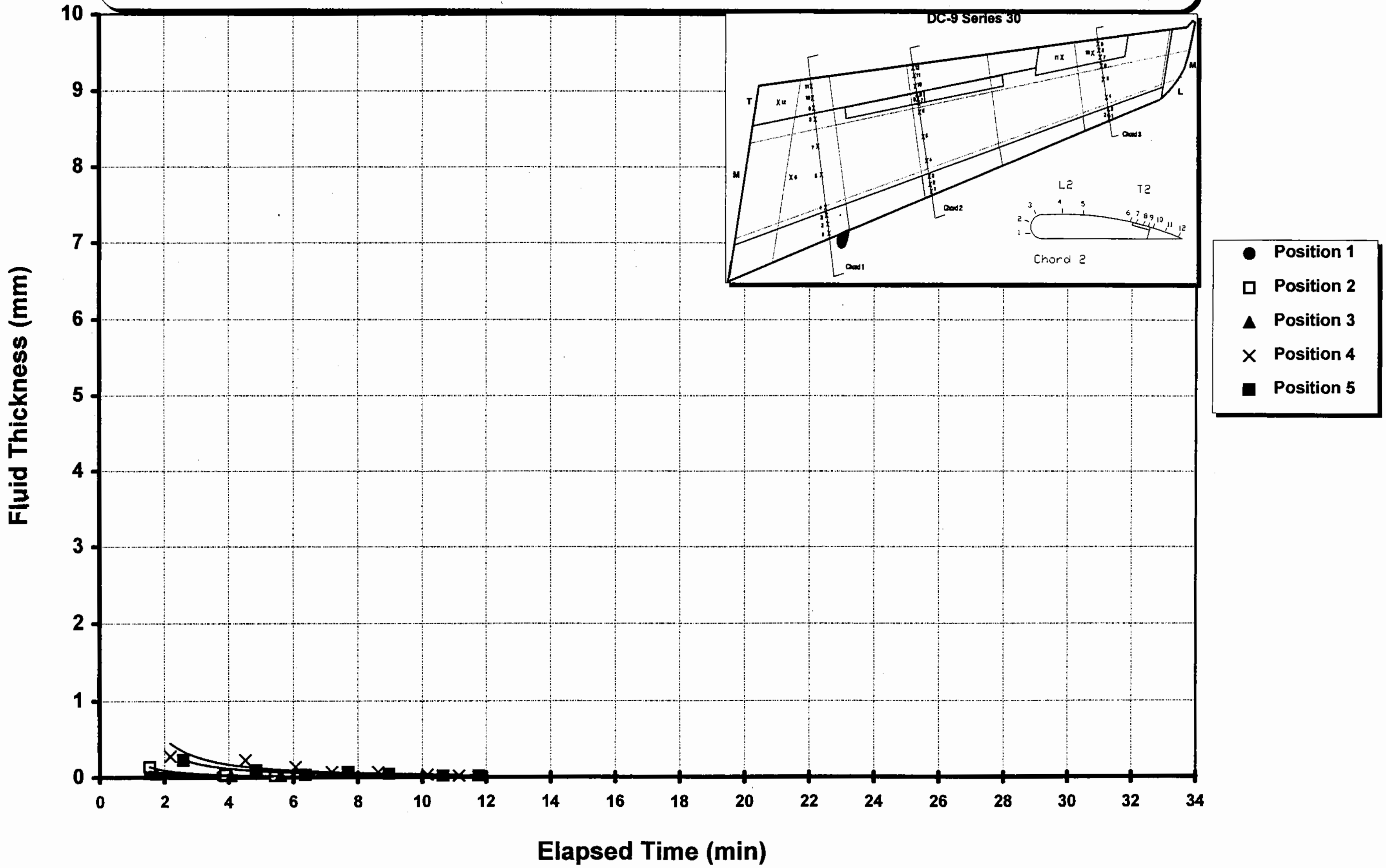
RUN 4 - MARCH 12, 1996

DC-9 - LOCATION L2

1st FLUID: XL54 TYPE I / 245 LITRES

2nd FLUID: NIL

Temperature: -4.2°C Wind Speed: 10.1 kph Nozzle Type: AKRON



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Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

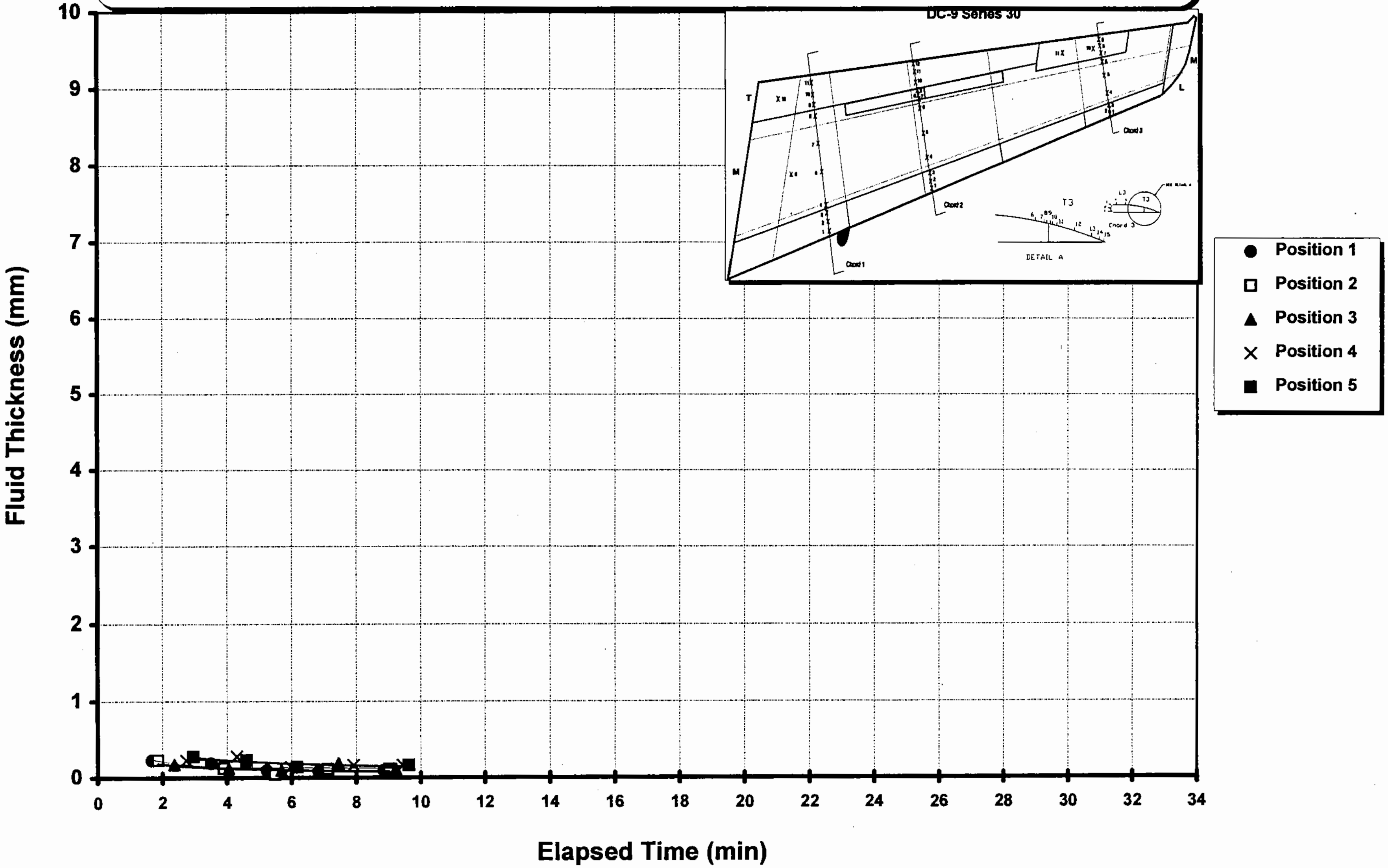
RUN 4 - MARCH 12, 1996

DC-9 - LOCATION L3

1st FLUID: XL54 TYPE I / 245 LITRES

2nd FLUID: NIL

Temperature: -4.2°C | Wind Speed: 10.1 kph | Nozzle Type: AKRON



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Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

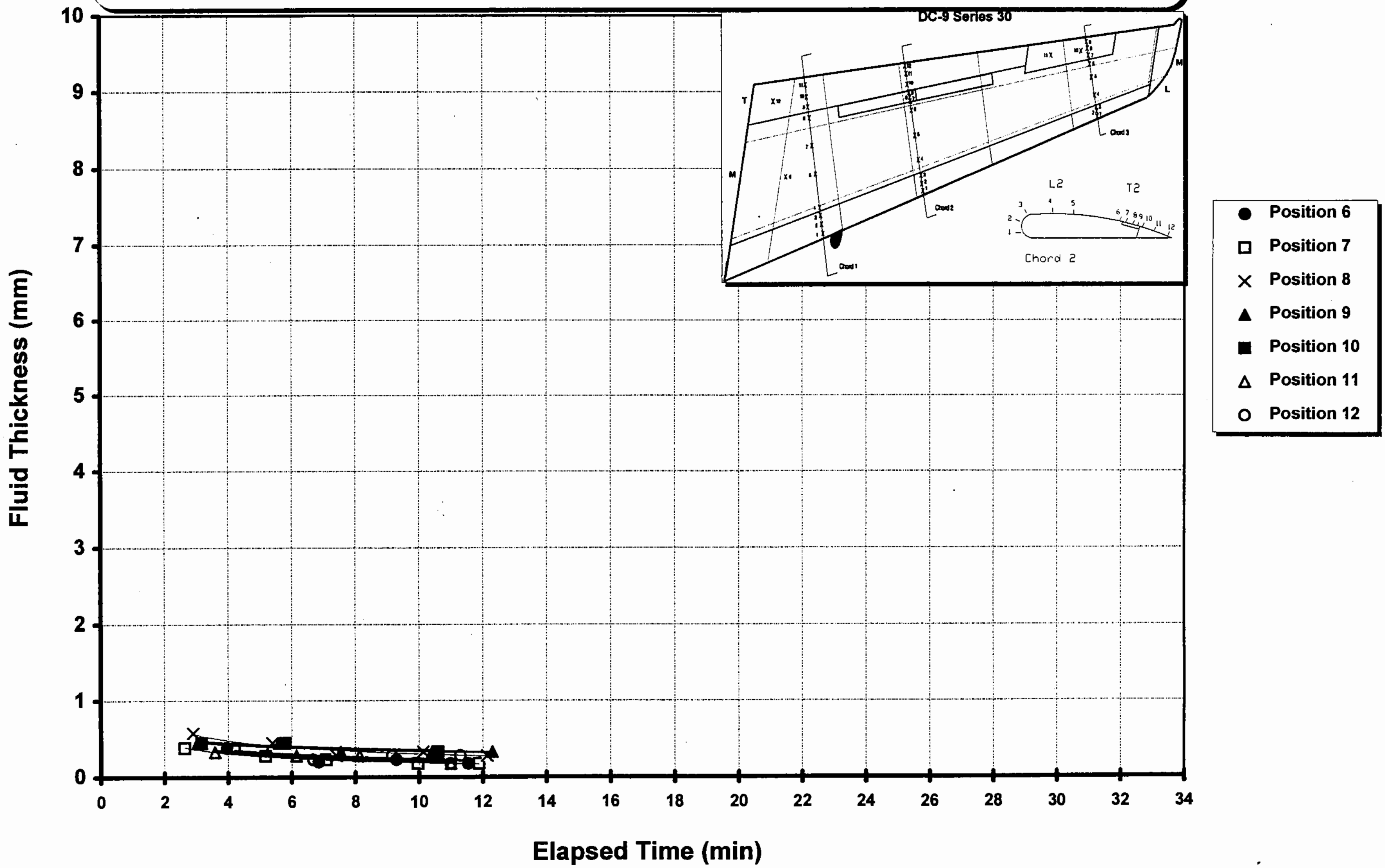
RUN 4 - MARCH 12, 1996

DC-9 - LOCATION T1

1st FLUID: XL54 TYPE I / 245 LITRES

2nd FLUID: NIL

Temperature: -4.2°C | Wind Speed: 10.1 kph | Nozzle Type: AKRON



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Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

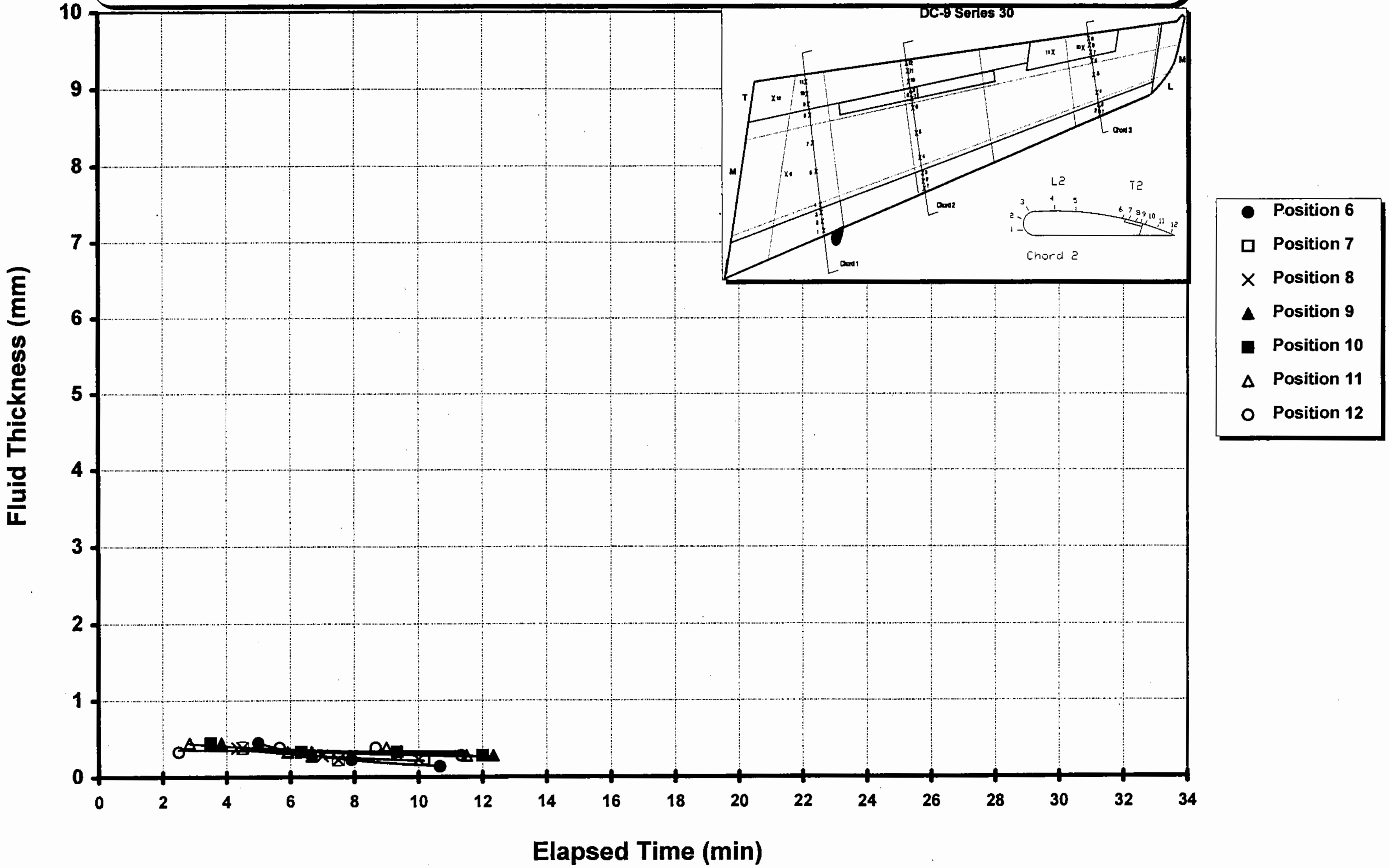
RUN 4 - MARCH 12, 1996

DC-9 - LOCATION T2

1st FLUID: XL54 TYPE I / 245 LITRES

2nd FLUID: NIL

Temperature: -4.2°C | Wind Speed: 10.1 kph | Nozzle Type: AKRON



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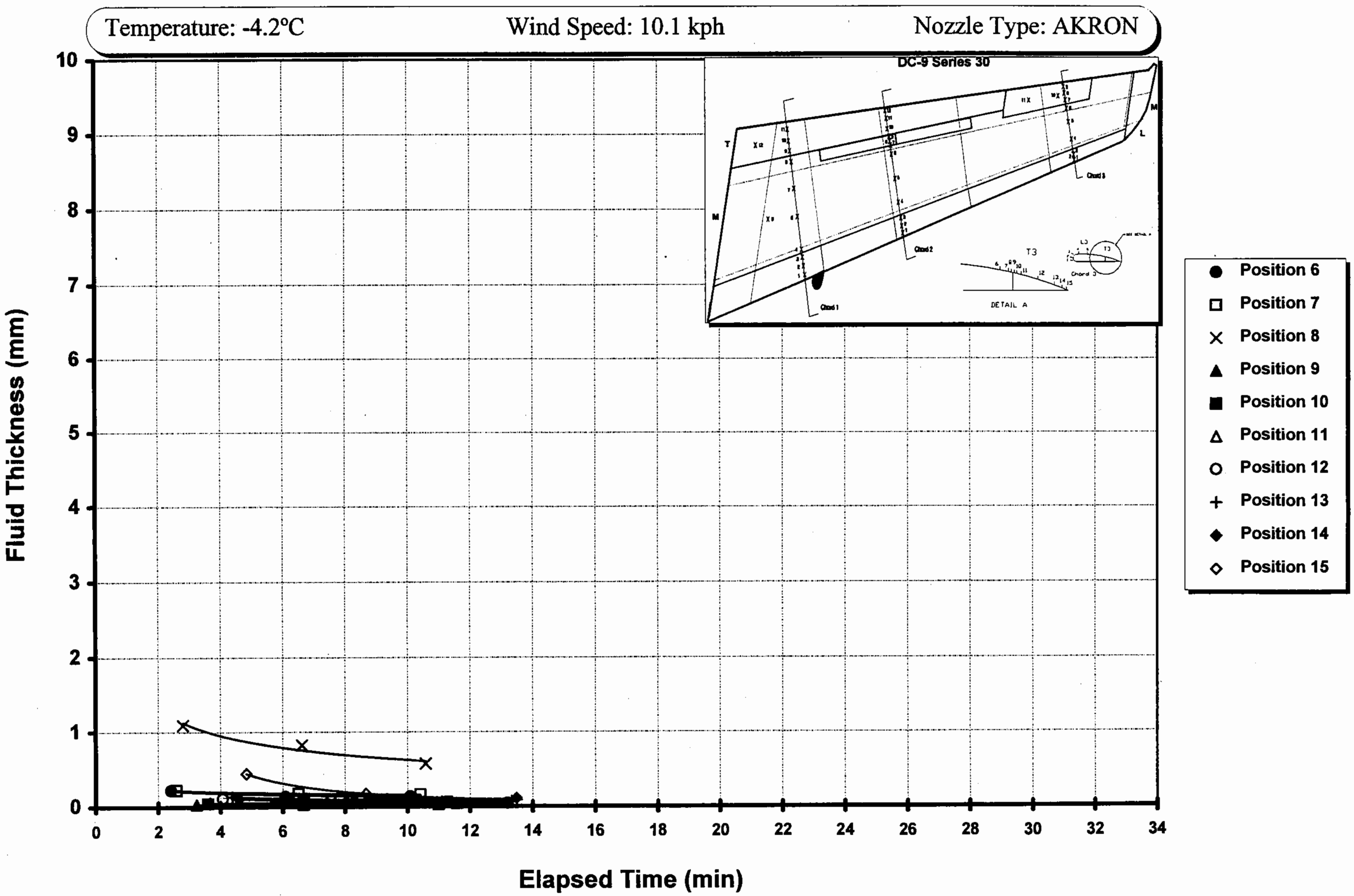
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 4 - MARCH 12, 1996

DC-9 - LOCATION T3

1st FLUID: XL54 TYPE I / 245 LITRES

2nd FLUID: NIL



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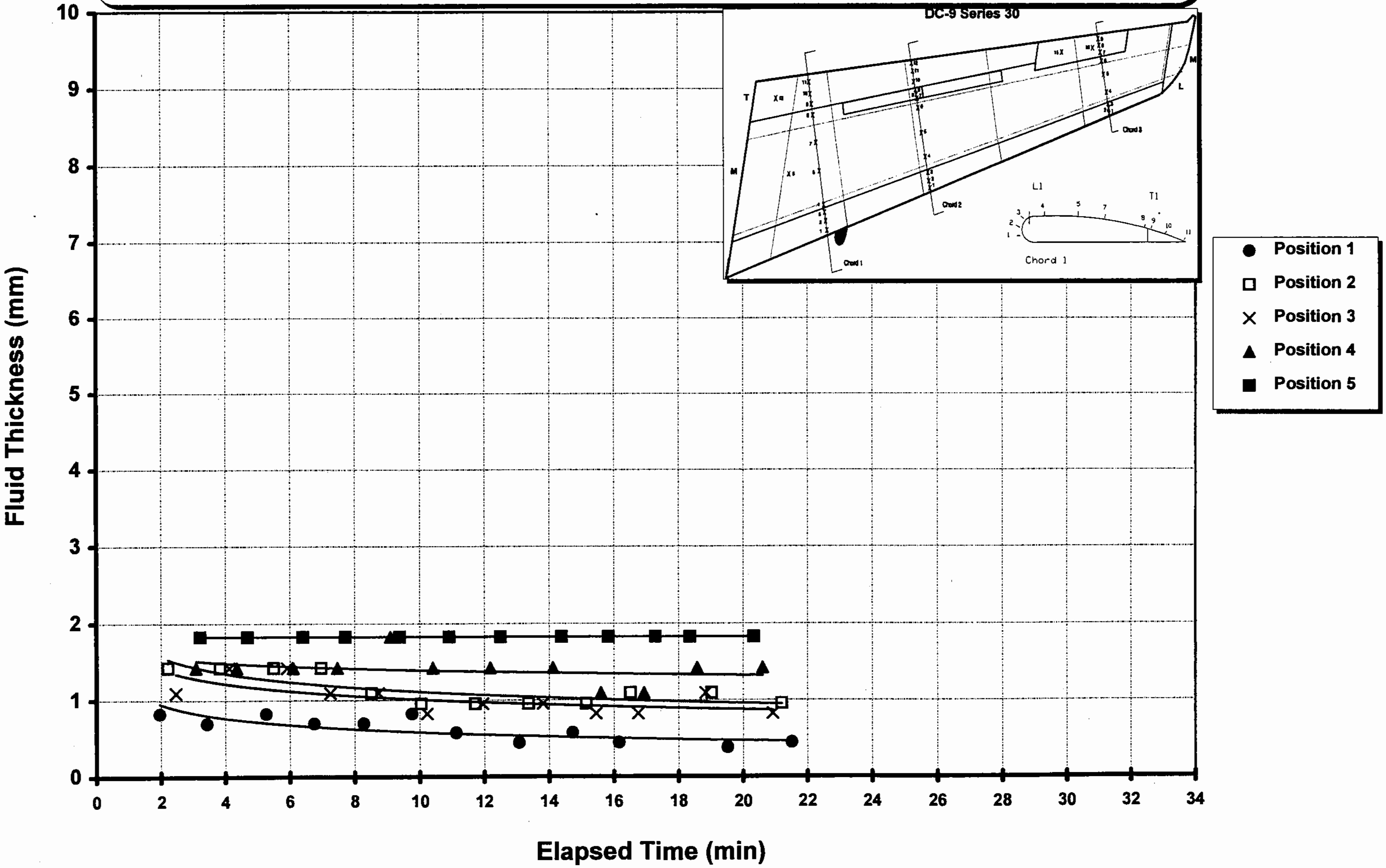
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS
RUN 5 - MARCH 12, 1996
DC-9 - LOCATION L1
1st FLUID: XL54 TYPE I / 155 LITRES
2nd FLUID: ULTRA TYPE IV / 245 LITRES

Temperature: -4.8°C | Wind Speed: 6.4 kph | Nozzle Type: AKRON



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Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

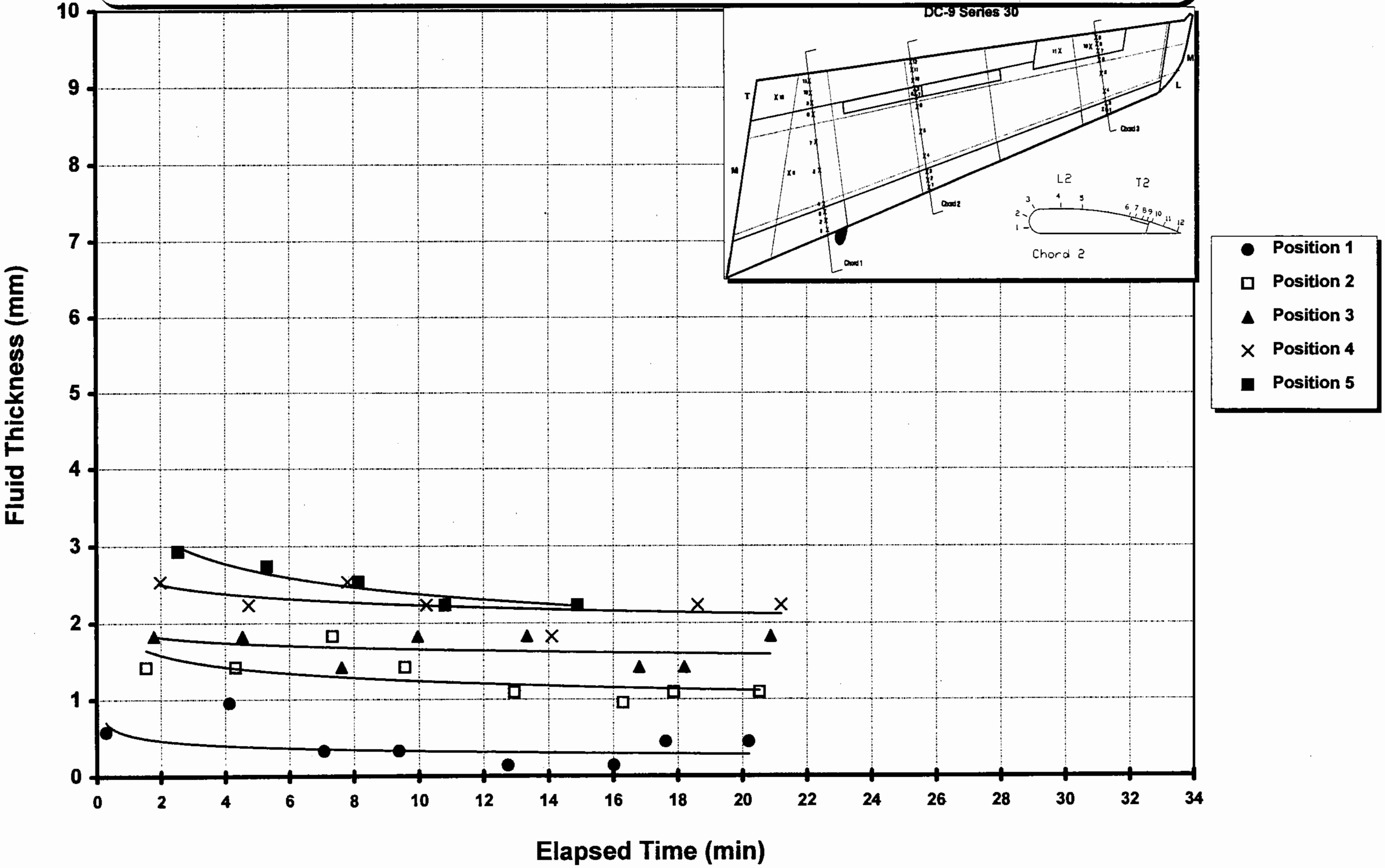
RUN 5 - MARCH 12, 1996

DC-9 - LOCATION L2

1st FLUID: XL54 TYPE I / 155 LITRES

2nd FLUID: ULTRA TYPE IV / 245 LITRES

Temperature: -4.8°C | Wind Speed: 6.4 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R5.XLS
At: L2_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

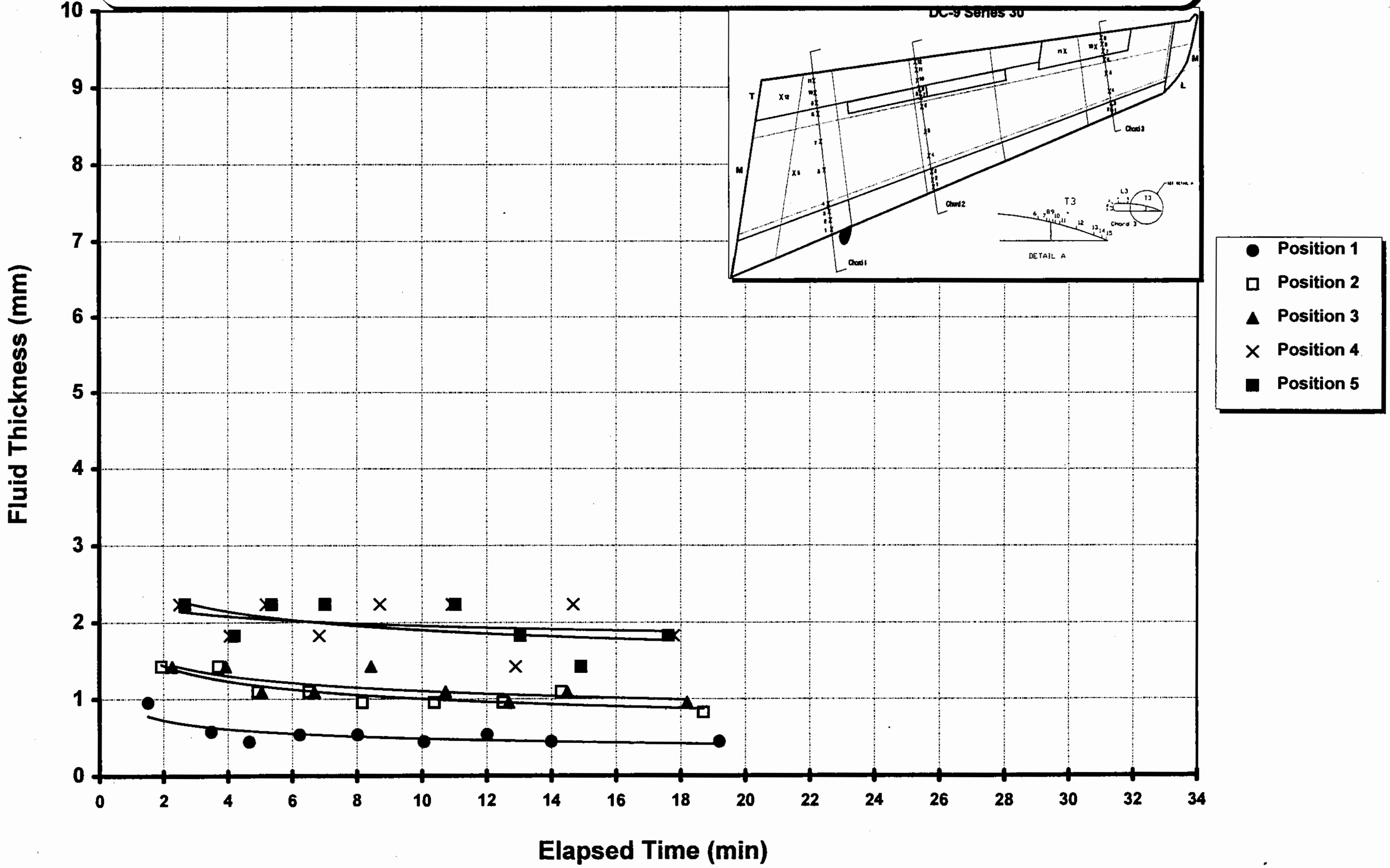
RUN 5 - MARCH 12, 1996

DC-9 - LOCATION L3

1st FLUID: XL54 TYPE I / 155 LITRES

2nd FLUID: ULTRA TYPE IV / 245 LITRES

Temperature: -4.8°C   Wind Speed: 6.4 kph   Nozzle Type: AKRON



E-25

File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R5.XLS
At: L3_CHT
Printed:09/12/96

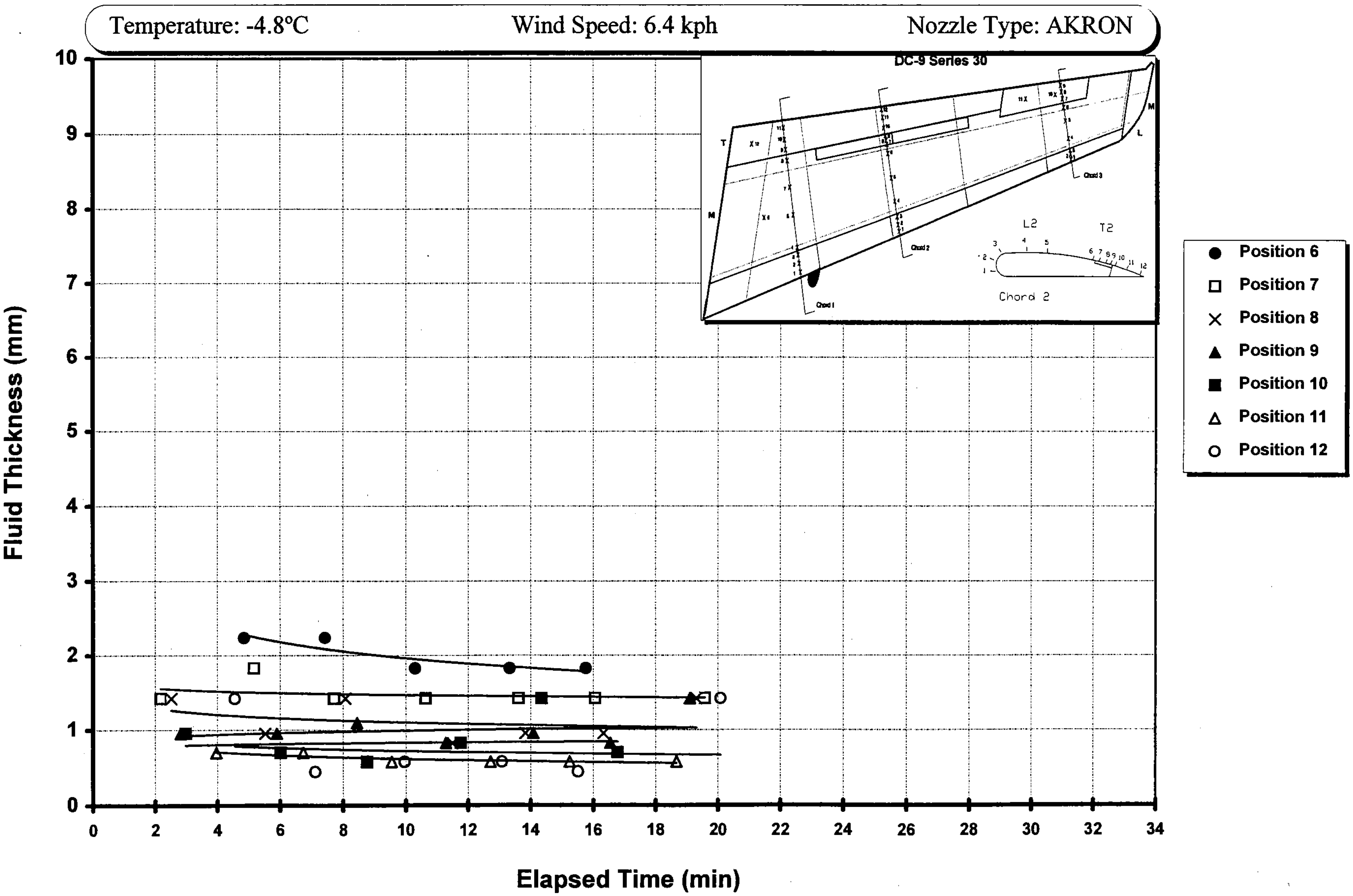
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 5 - MARCH 12, 1996

DC-9 - LOCATION T1

1st FLUID: XL54 TYPE I / 155 LITRES

2nd FLUID: ULTRA TYPE IV / 245 LITRES



File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R5.XLS
At: T1_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

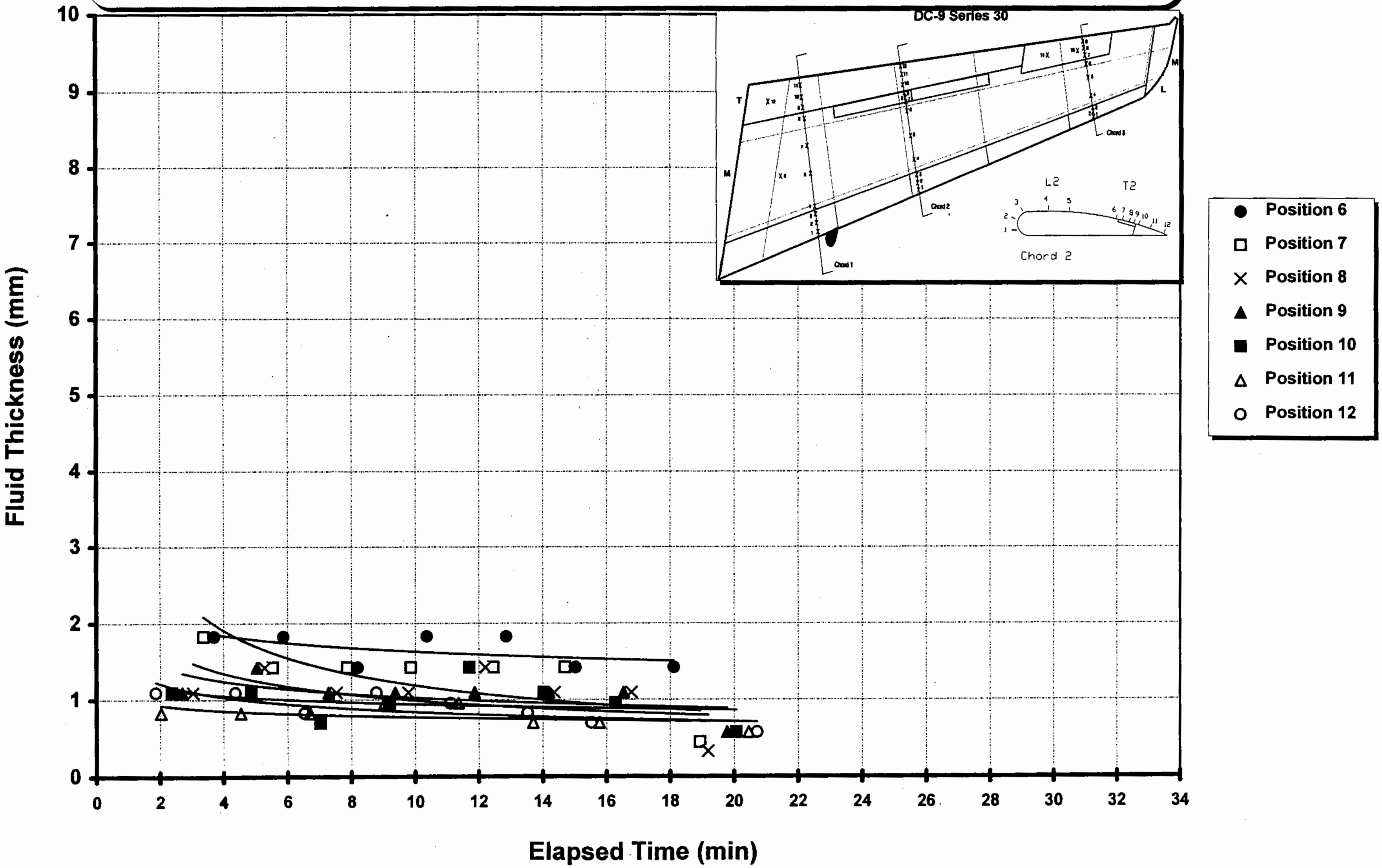
RUN 5 - MARCH 12, 1996

DC-9 - LOCATION T2

1st FLUID: XL54 TYPE I / 155 LITRES

2nd FLUID: ULTRA TYPE IV / 245 LITRES

Temperature: -4.8°C   Wind Speed: 6.4 kph   Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R5.XLS
At: T2 CHT

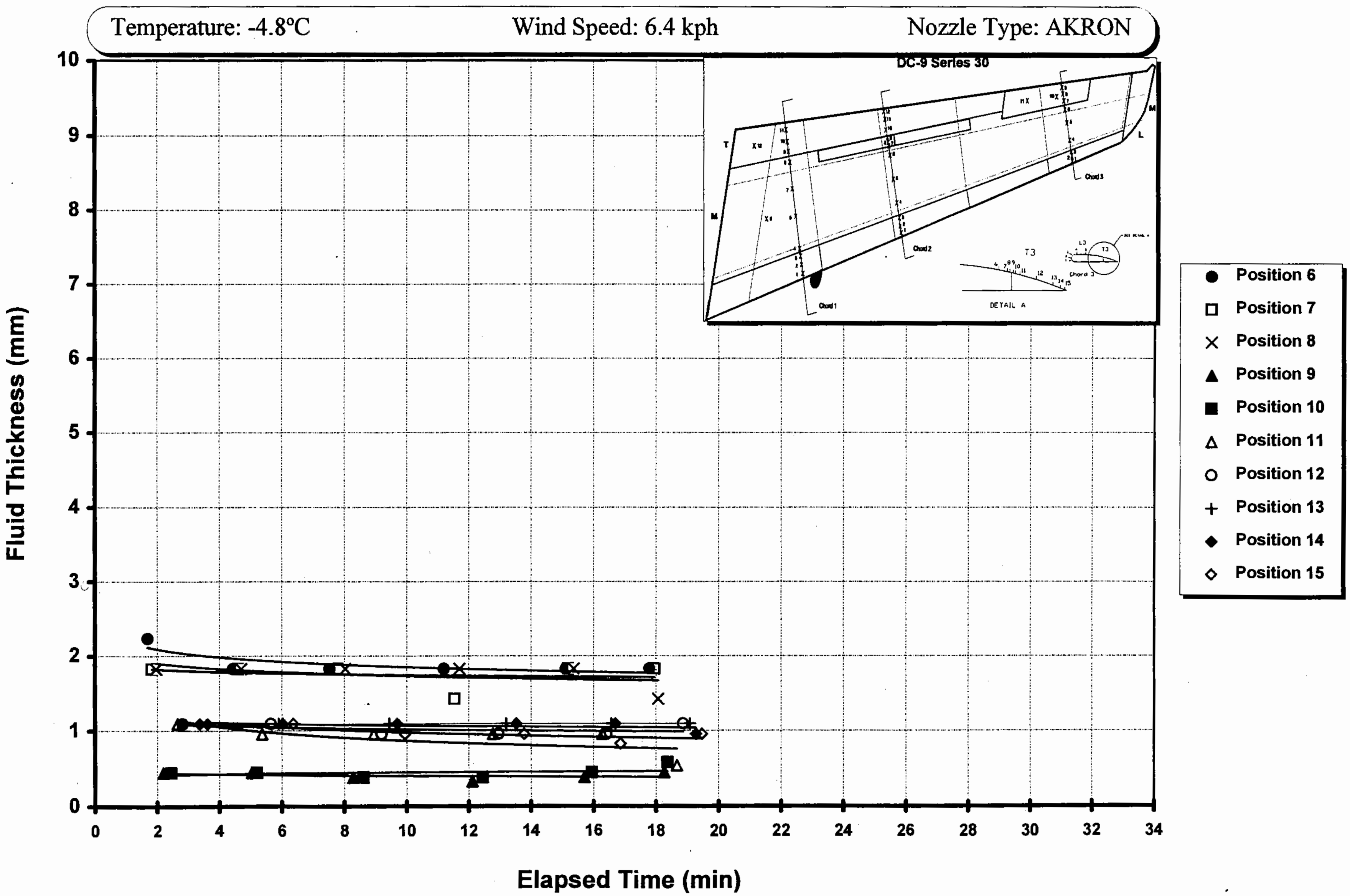
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 5 - MARCH 12, 1996

DC-9 - LOCATION T3

1st FLUID: XL54 TYPE I / 155 LITRES

2nd FLUID: ULTRA TYPE IV / 245 LITRES



File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R5.XLS
At: T3_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

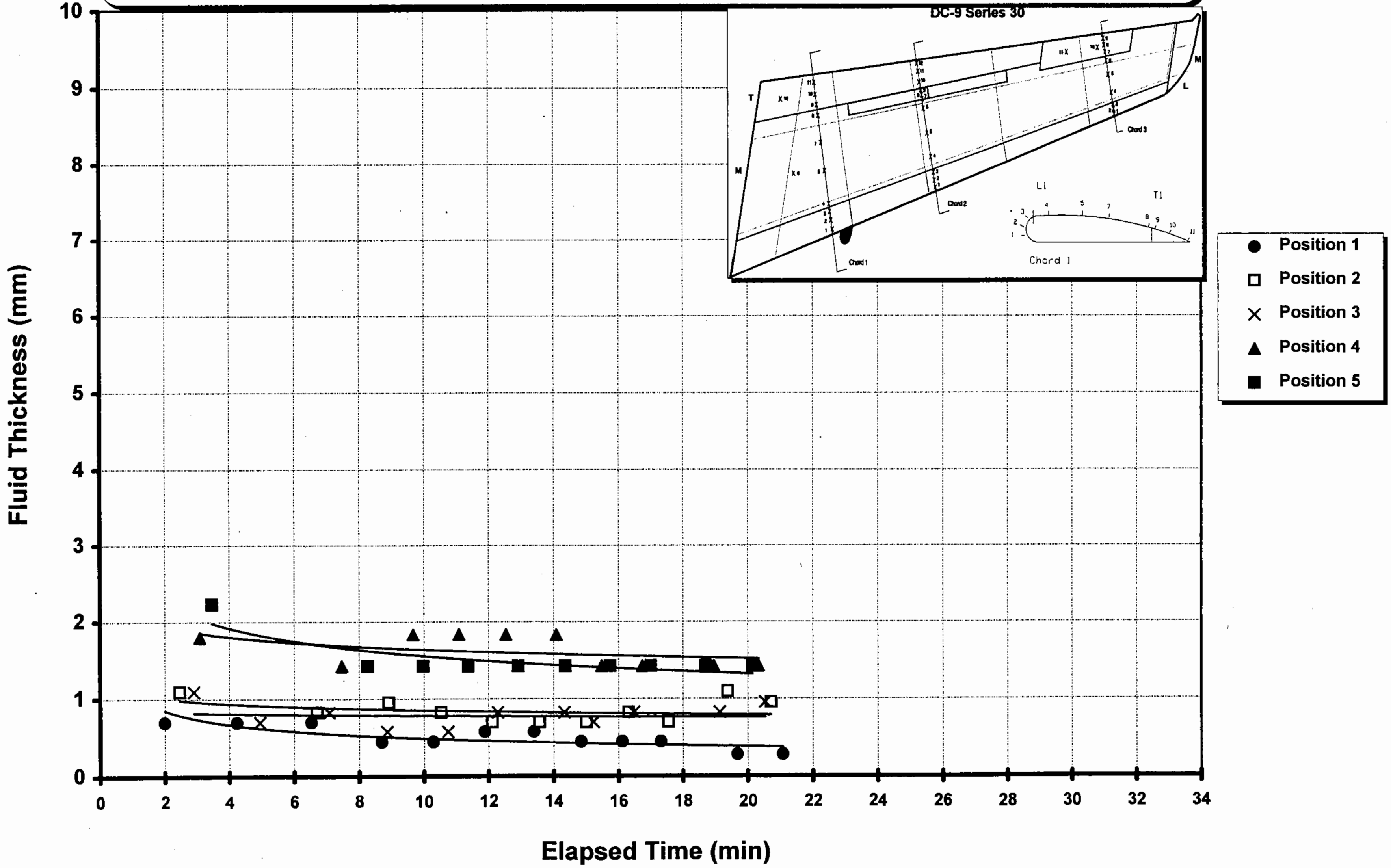
RUN 6 - MARCH 12, 1996

DC-9 - LOCATION L1

1st FLUID: XL54 TYPE I / 132 LITRES

2nd FLUID: ULTRA TYPE IV / 136 LITRES

Temperature: -5.5°C Wind Speed: 5.1 kph Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R6.XLS
At: L1_CHT
Printed:09/12/96

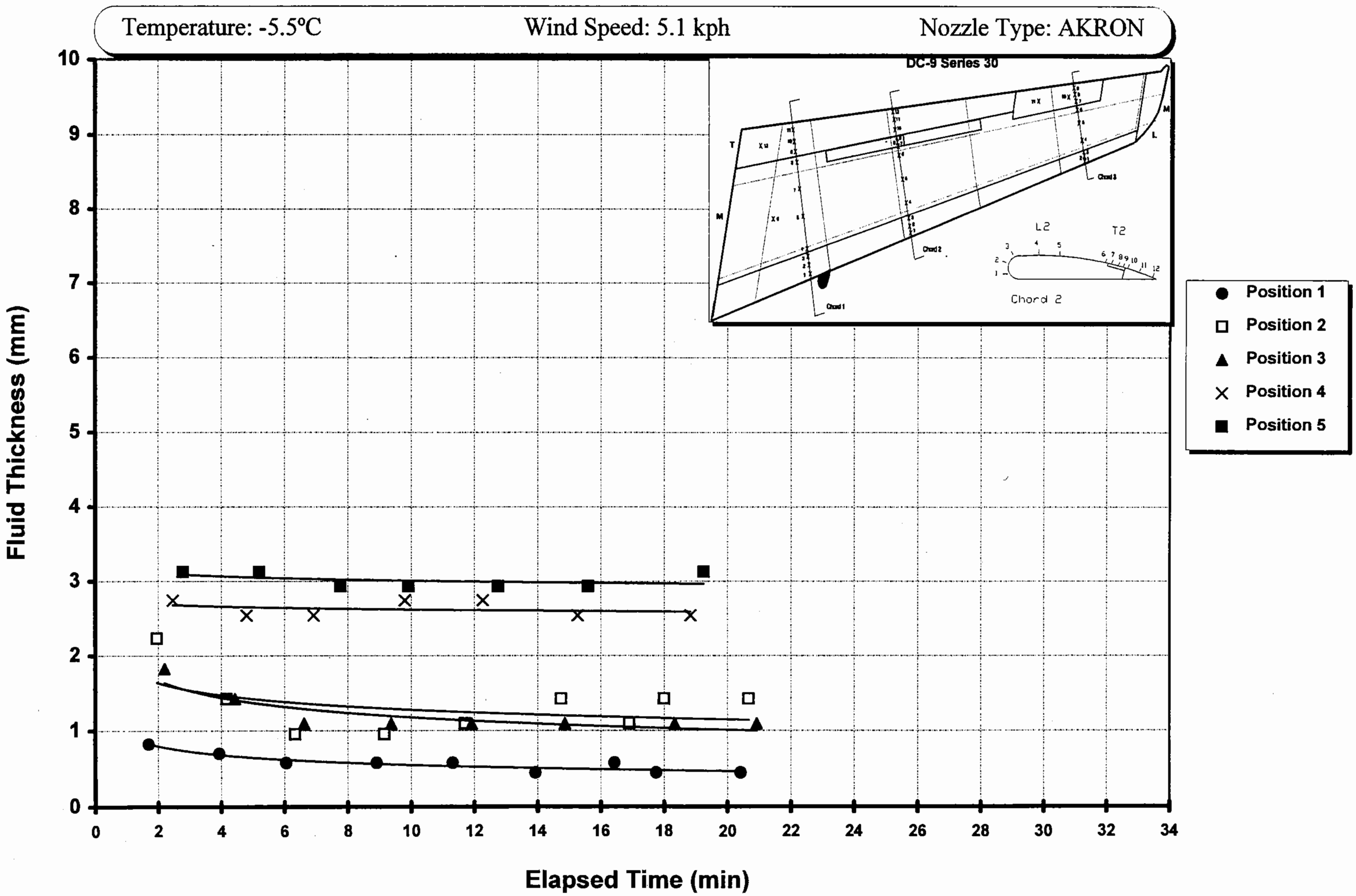
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 6 - MARCH 12, 1996

DC-9 - LOCATION L2

1st FLUID: XL54 TYPE I / 132 LITRES

2nd FLUID: ULTRA TYPE IV / 136 LITRES



File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R6.XLS
At: L2_CHT
Printed:09/12/96

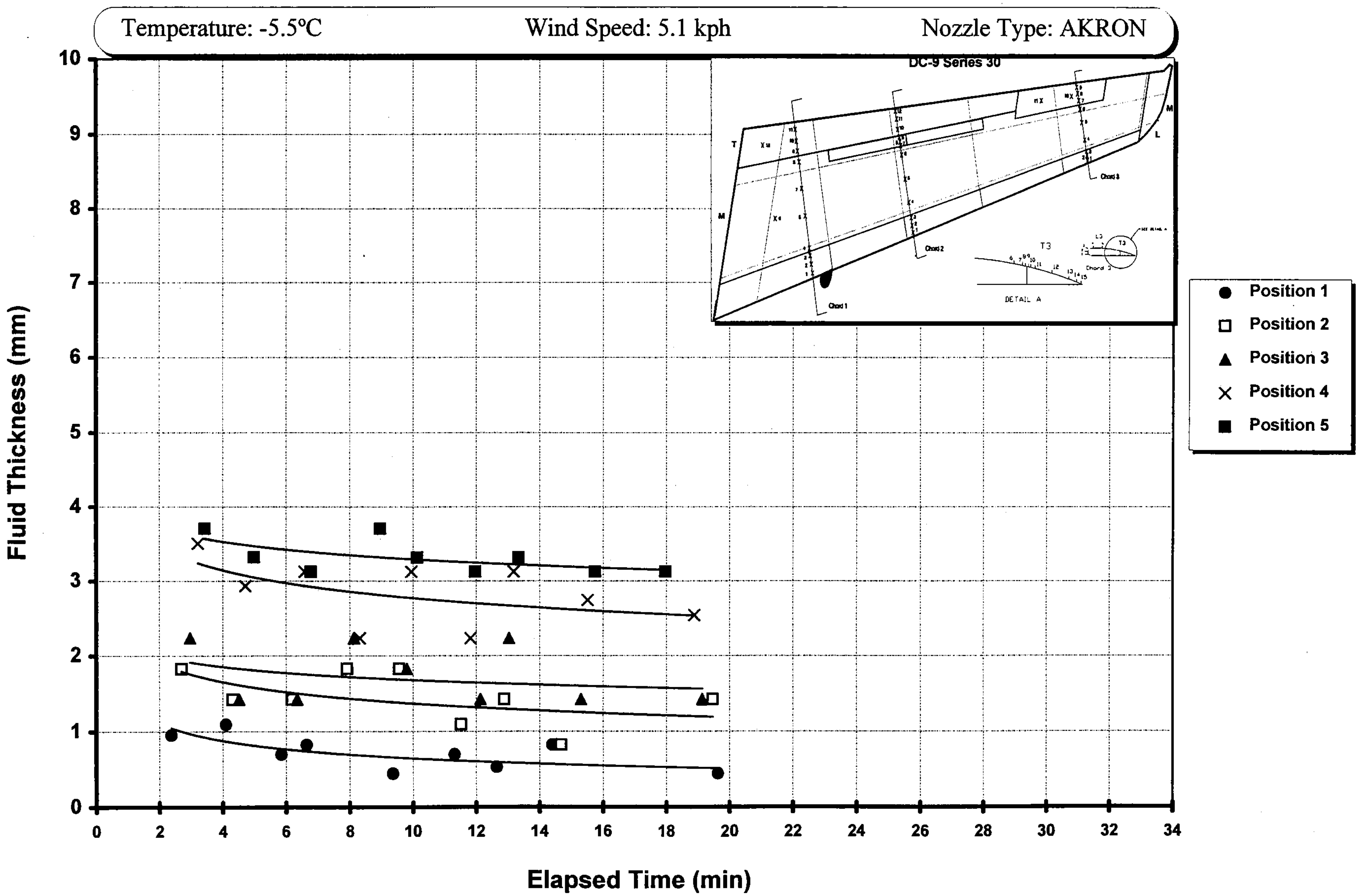
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 6 - MARCH 12, 1996

DC-9 - LOCATION L3

1st FLUID: XL54 TYPE I / 132 LITRES

2nd FLUID: ULTRA TYPE IV / 136 LITRES



File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R6.XLS
At: L3_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

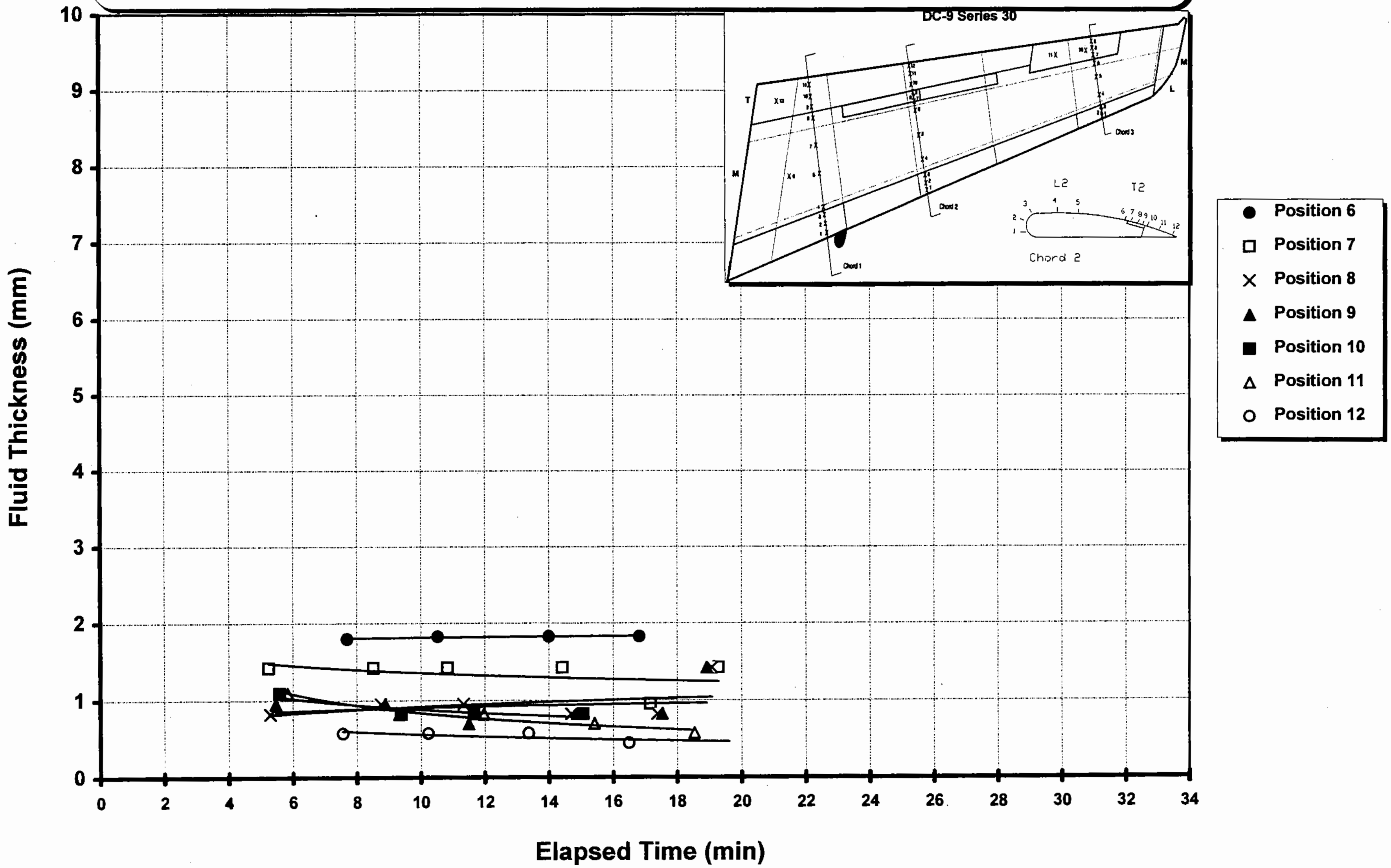
RUN 6 - MARCH 12, 1996

DC-9 - LOCATION T1

1st FLUID: XL54 TYPE I / 132 LITRES

2nd FLUID: ULTRA TYPE IV / 136 LITRES

Temperature: -5.5°C | Wind Speed: 5.1 kph | Nozzle Type: AKRON



E-32

File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R6.XLS
At: T1_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

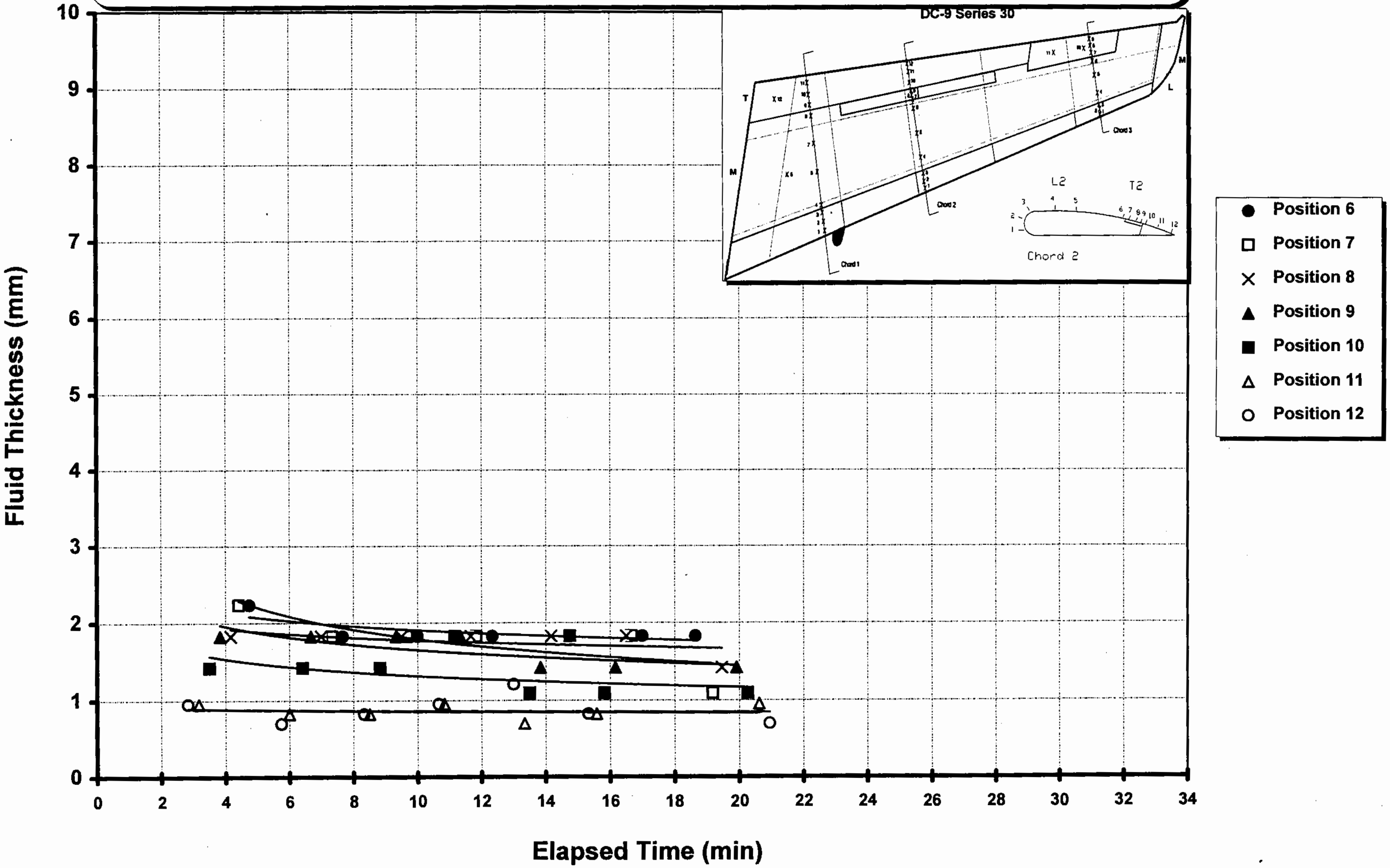
RUN 6 - MARCH 12, 1996

DC-9 - LOCATION T2

1st FLUID: XL54 TYPE I / 132 LITRES

2nd FLUID: ULTRA TYPE IV / 136 LITRES

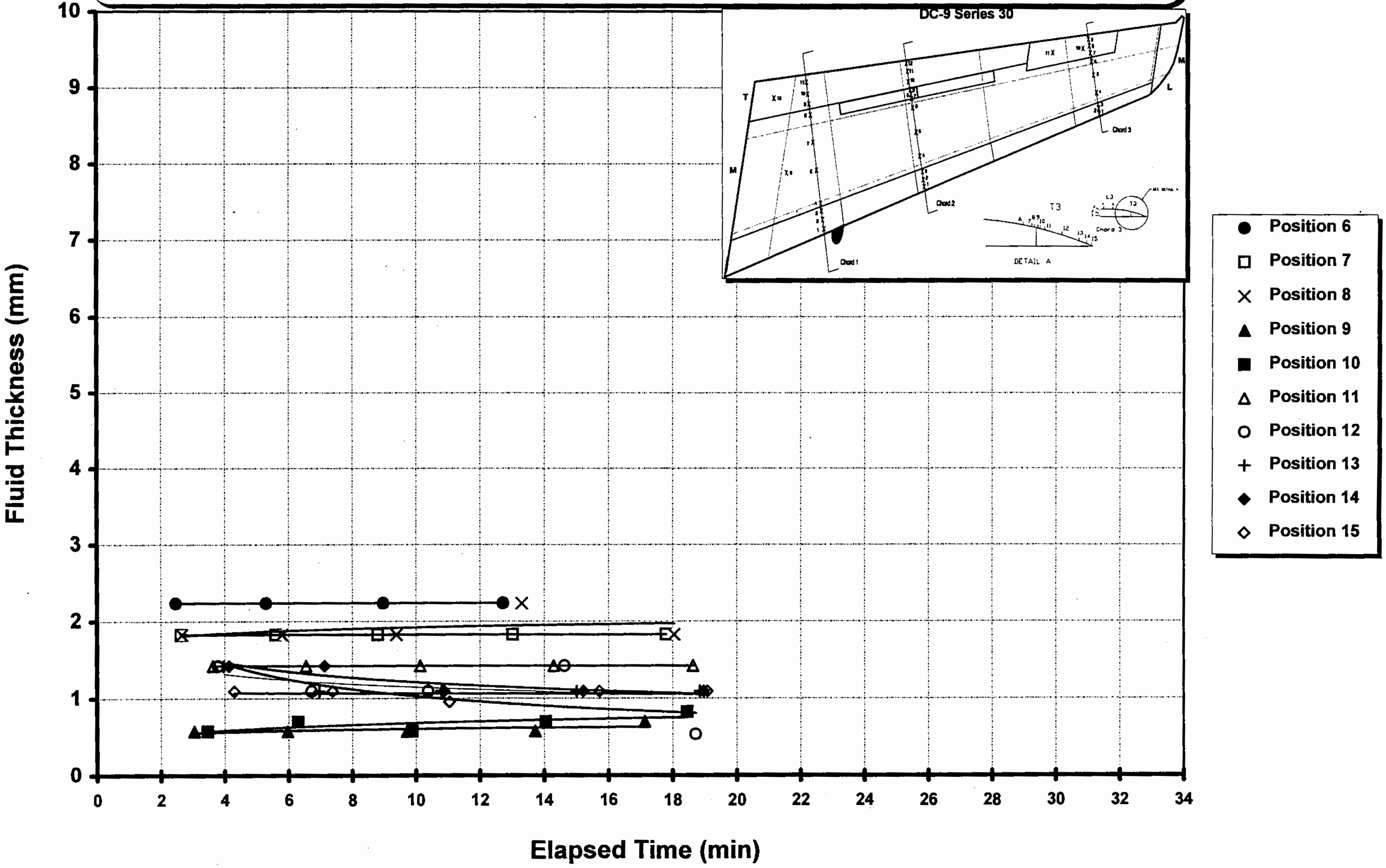
Temperature: -5.5°C | Wind Speed: 5.1 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R6.XLS
At: T2_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS
RUN 6 - MARCH 12, 1996
DC-9 - LOCATION T3
1st FLUID: XL54 TYPE I / 132 LITRES
2nd FLUID: ULTRA TYPE IV / 136 LITRES

Temperature: -5.5°C | Wind Speed: 5.1 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR12_R6.XLS
At: T3_CHT

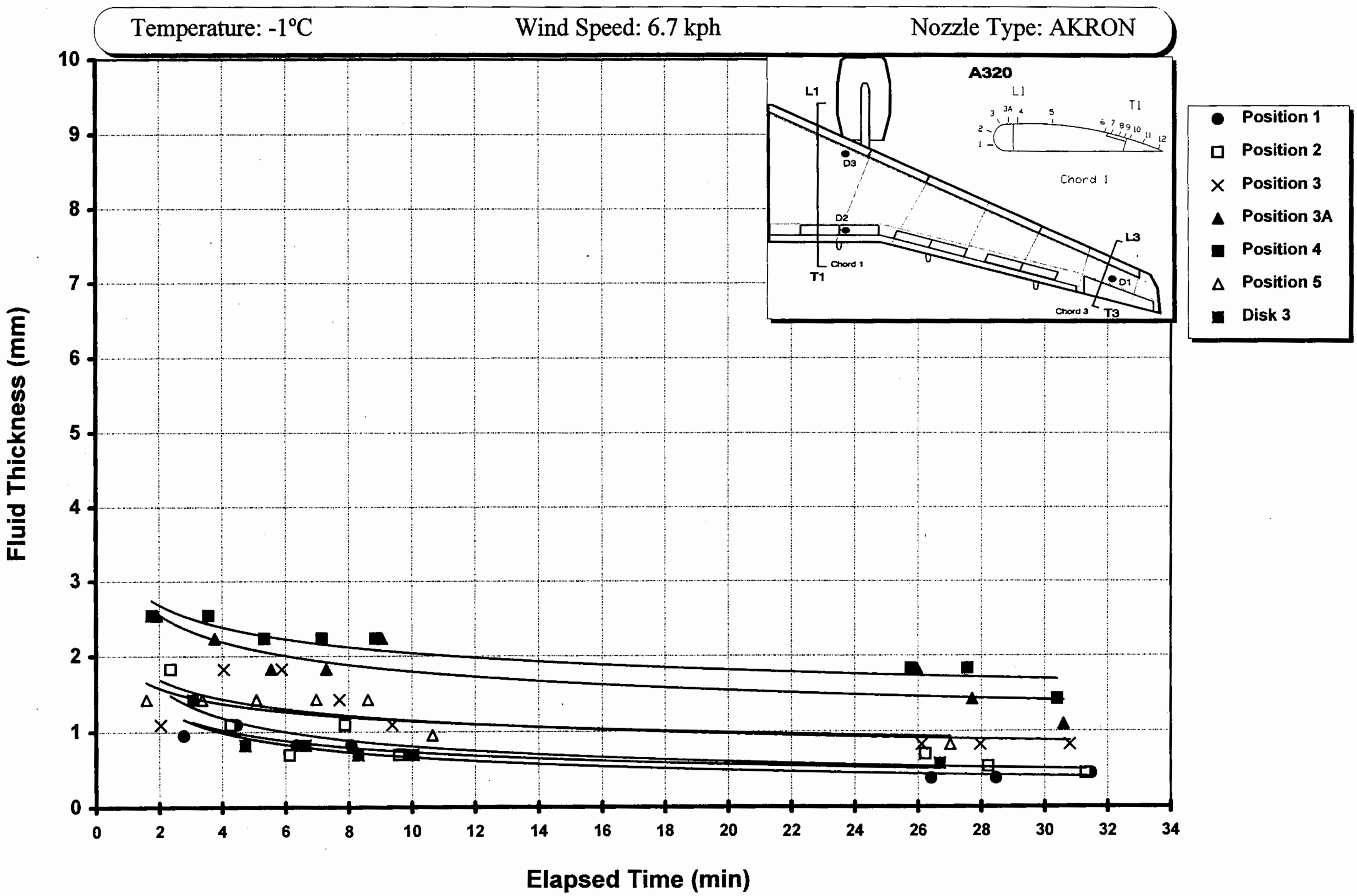
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 1 - MARCH 29, 1996

A320 - LOCATION L1

1st FLUID: ULTRA TYPE IV / 205 LITRES (Contaminated with Type I)

2nd FLUID: NIL



E-35

File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R1.XLS
At L1 CHT

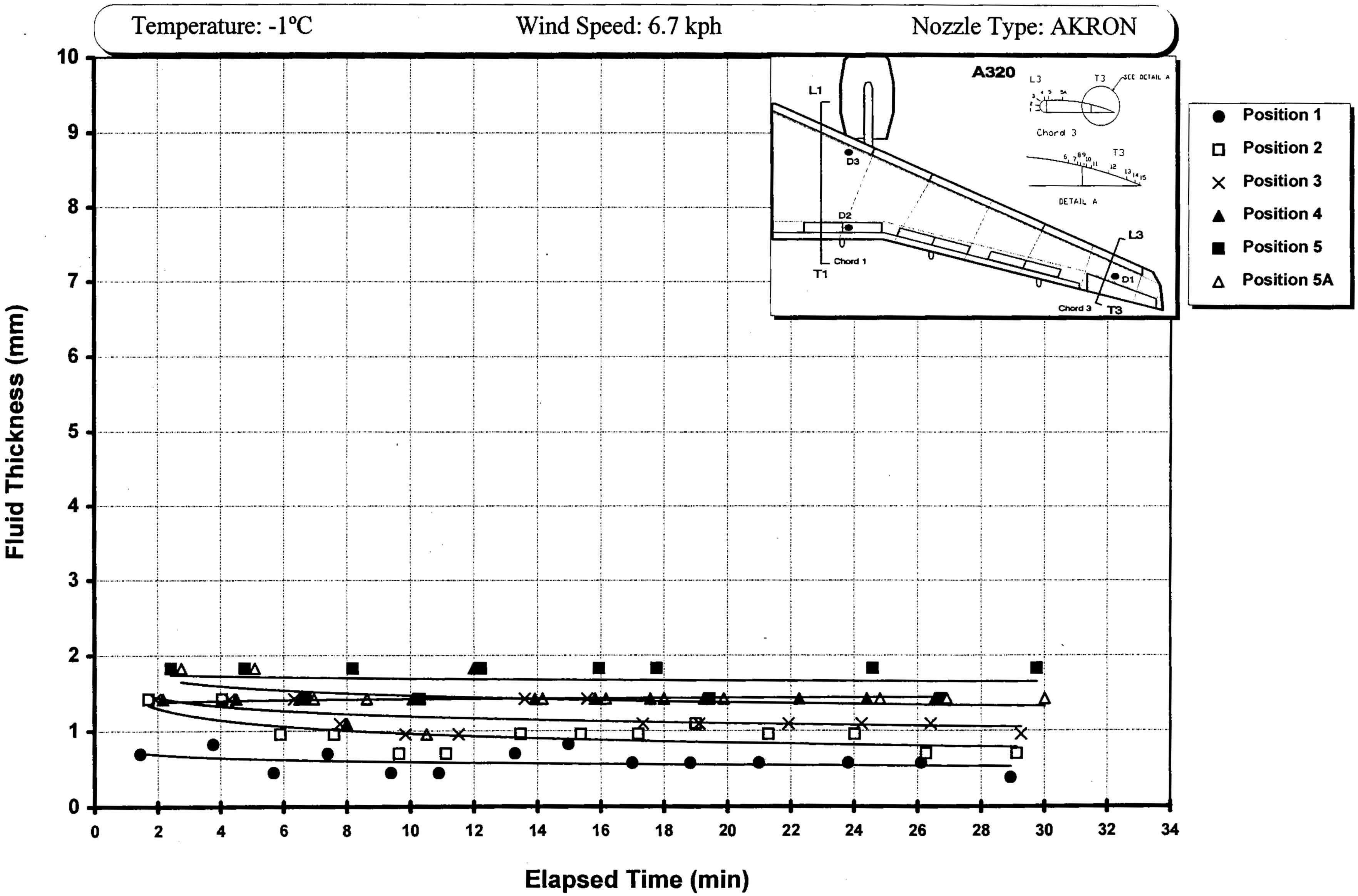
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 1 - MARCH 29, 1996

A320 - LOCATION L3

1st FLUID: ULTRA TYPE IV / 205 LITRES

2nd FLUID: NIL



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R1.XLS
At: L3 CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

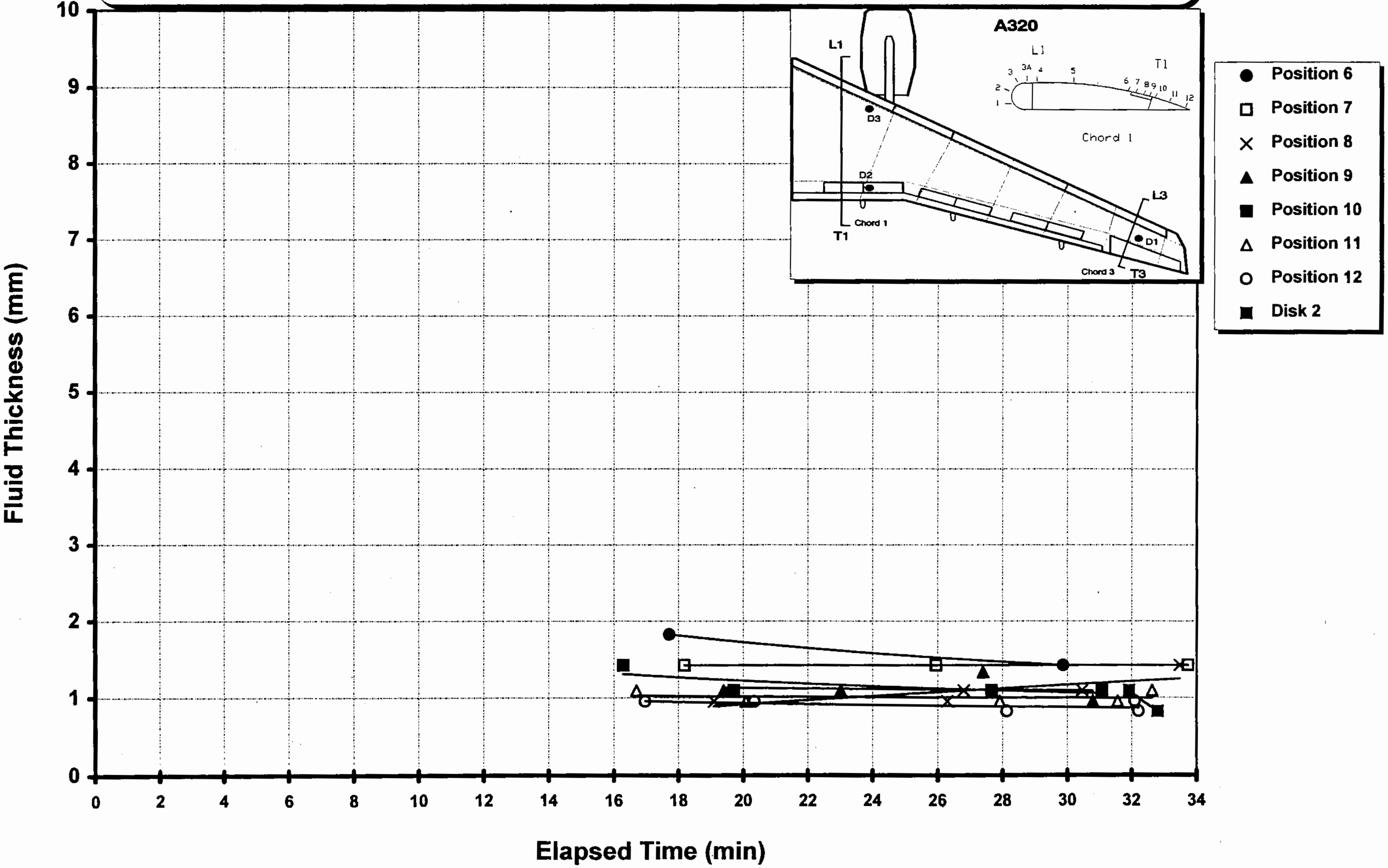
RUN 1 - MARCH 29, 1996

A320 - LOCATION T1

1st FLUID: ULTRA TYPE IV / 205 LITRES

2nd FLUID: NIL

Temperature: -1°C — Wind Speed: 6.7 kph — Nozzle Type: AKRON



E-37

File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R1.XLS
At: T1_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

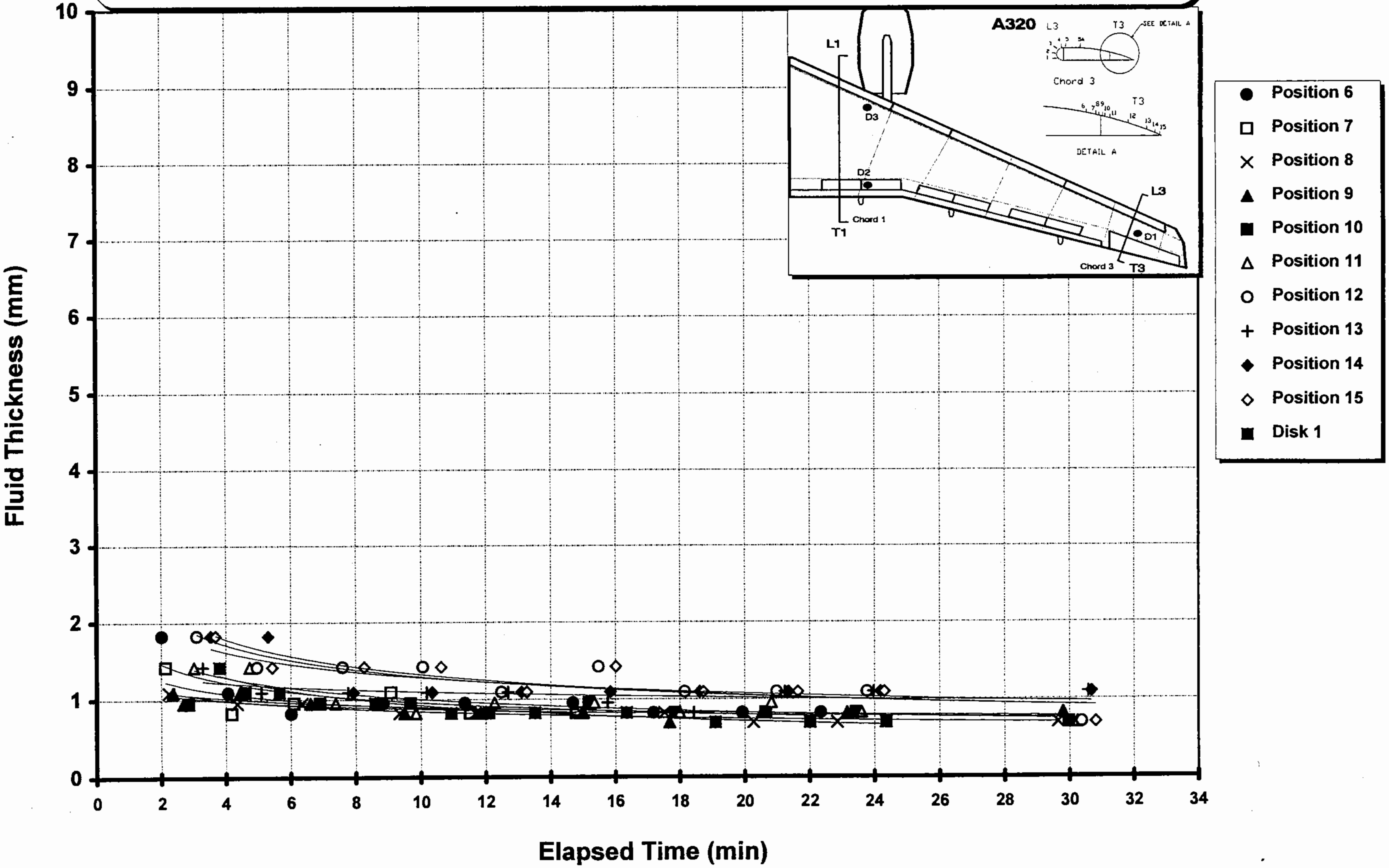
RUN 1 - MARCH 29, 1996

A320 - LOCATION T3

1st FLUID: ULTRA TYPE IV / 205 LITRES

2nd FLUID: NIL

Temperature: -1°C | Wind Speed: 6.7 kph | Nozzle Type: AKRON



E-38

File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R1.XLS
At: T3_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

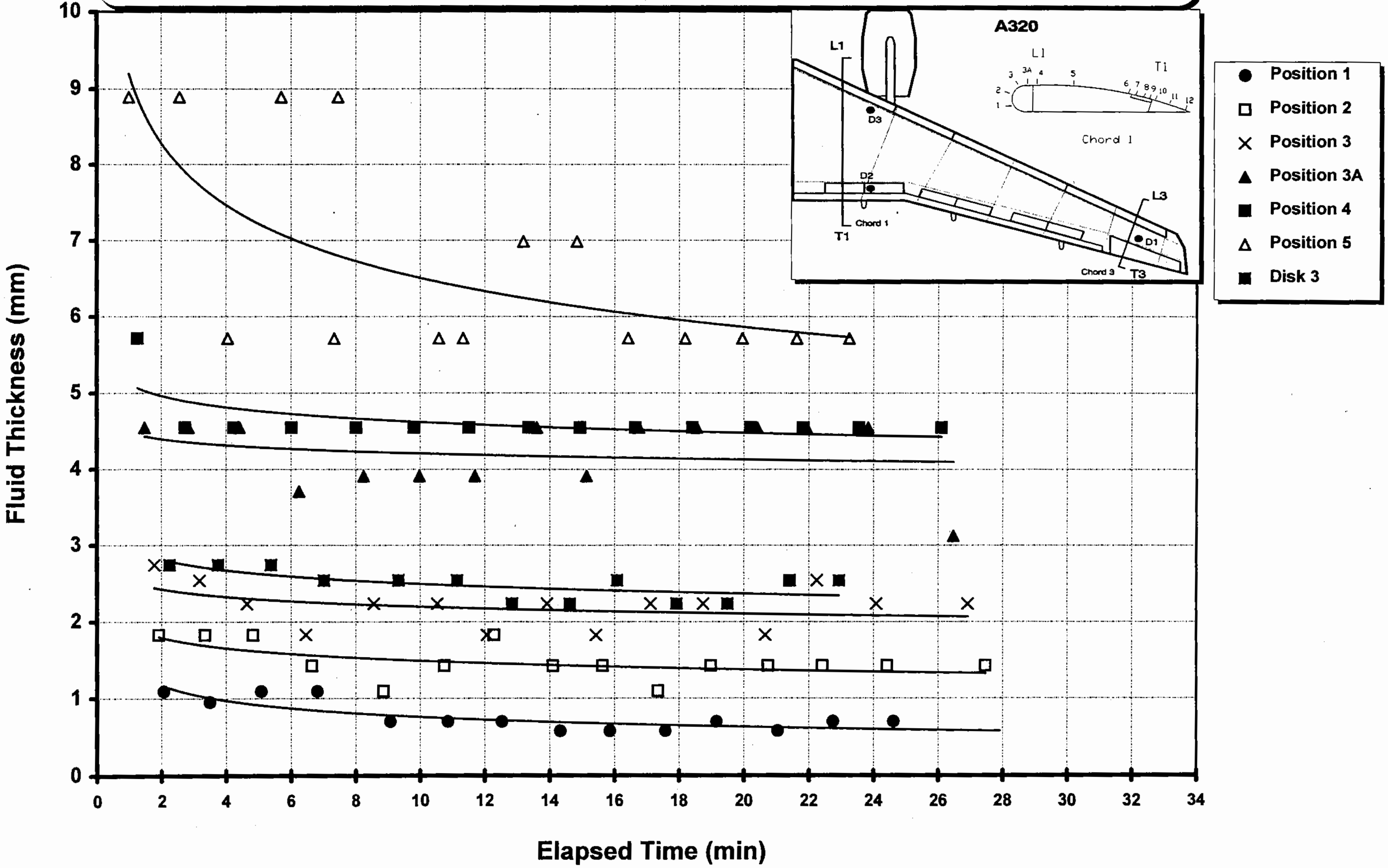
RUN 2 - MARCH 29, 1996

A320 - LOCATION L1

1st FLUID: ULTRA TYPE IV / 282 LITRES

2nd FLUID: NIL

Temperature: -1.7ºC | Wind Speed: 9.5 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R2.XLS
At: L1 CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

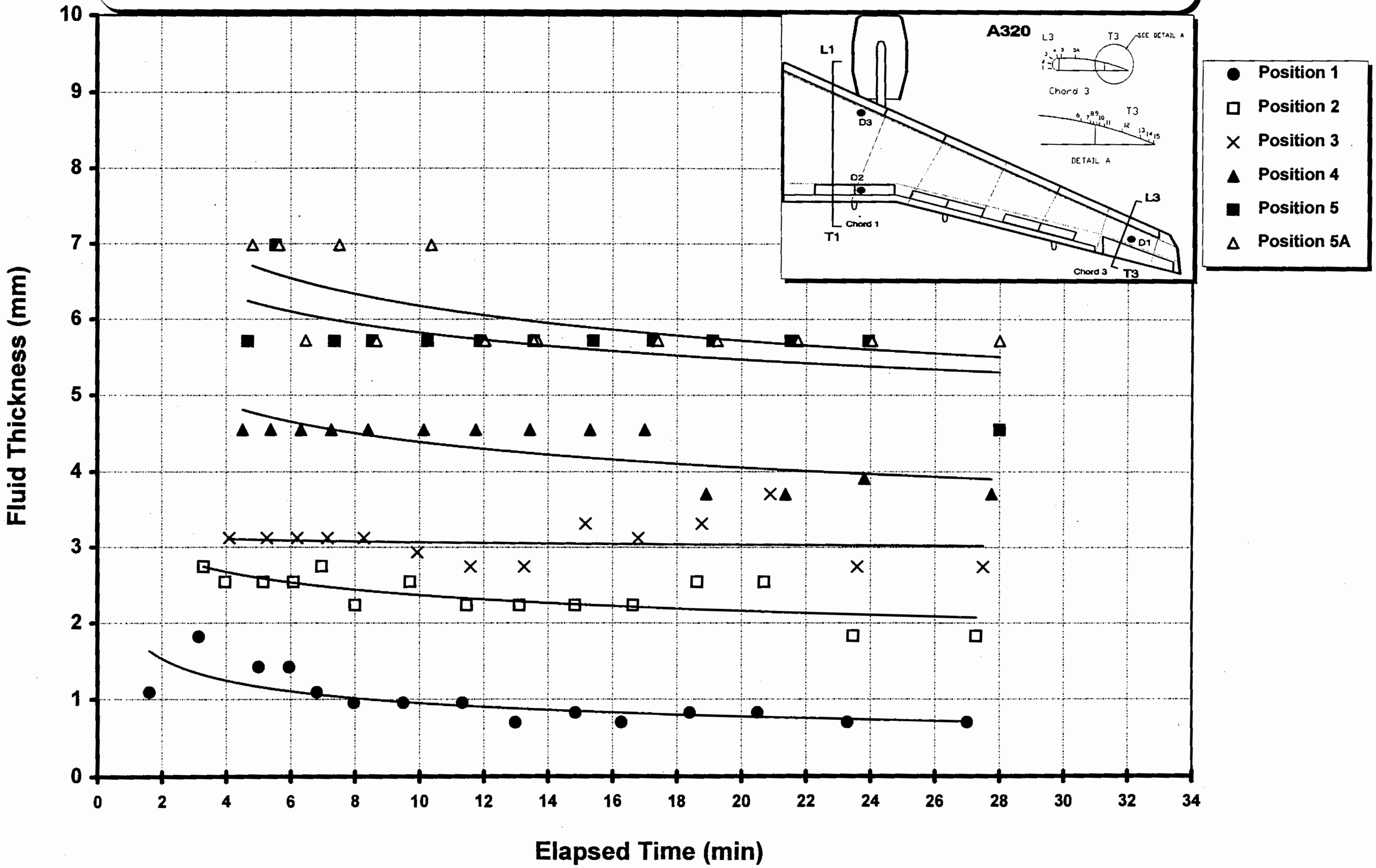
RUN 2 - MARCH 29, 1996

A320 - LOCATION L3

1st FLUID: ULTRA TYPE IV / 282 LITRES

2nd FLUID: NIL

Temperature: -1.7°C | Wind Speed: 9.5 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R2.XLS

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

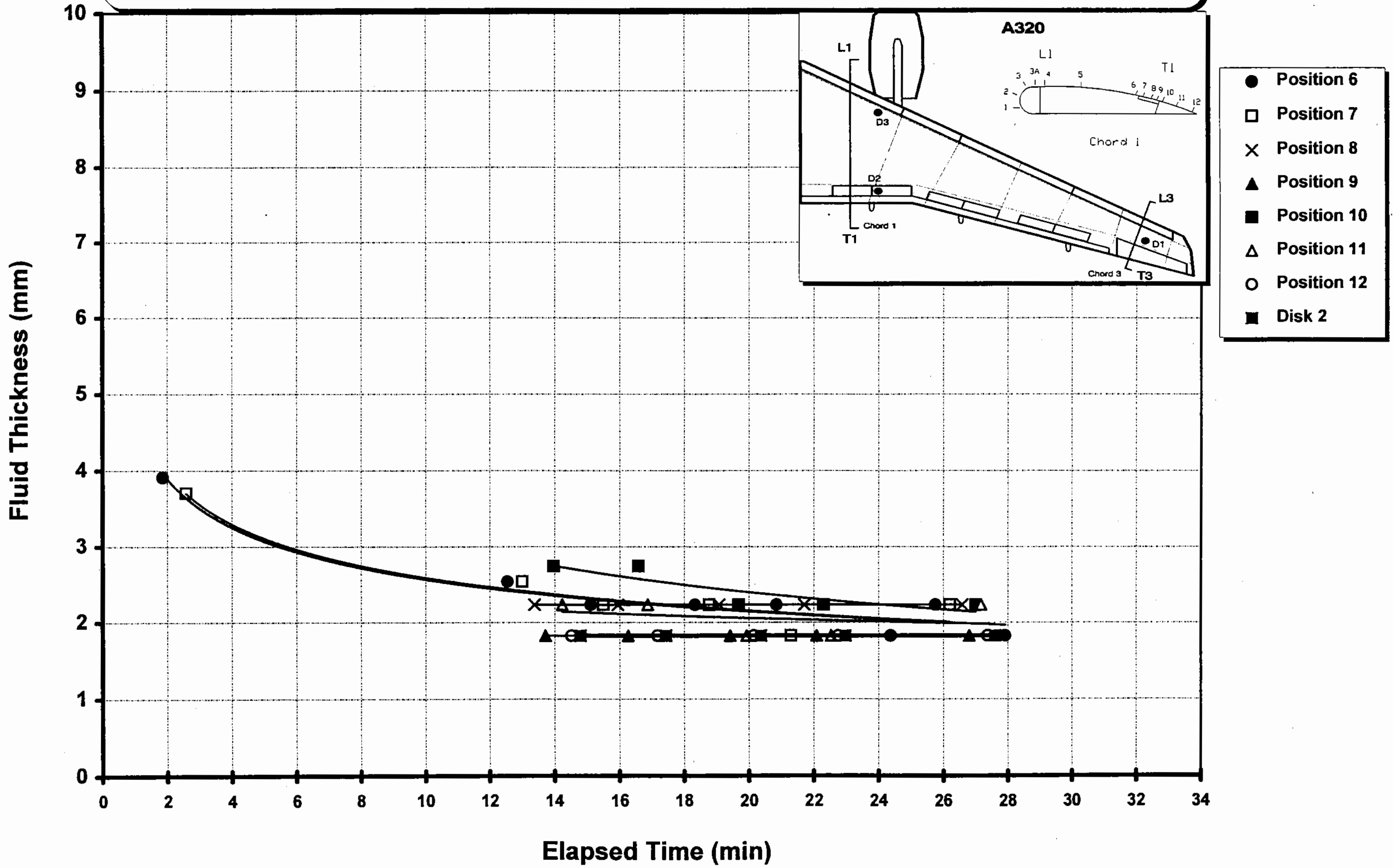
RUN 2 - MARCH 29, 1996

A320 - LOCATION T1

1st FLUID: ULTRA TYPE IV / 282 LITRES

2nd FLUID: NIL

Temperature: -1.7ºC | Wind Speed: 9.5 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R2.XLS
At: T1_CHT
Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

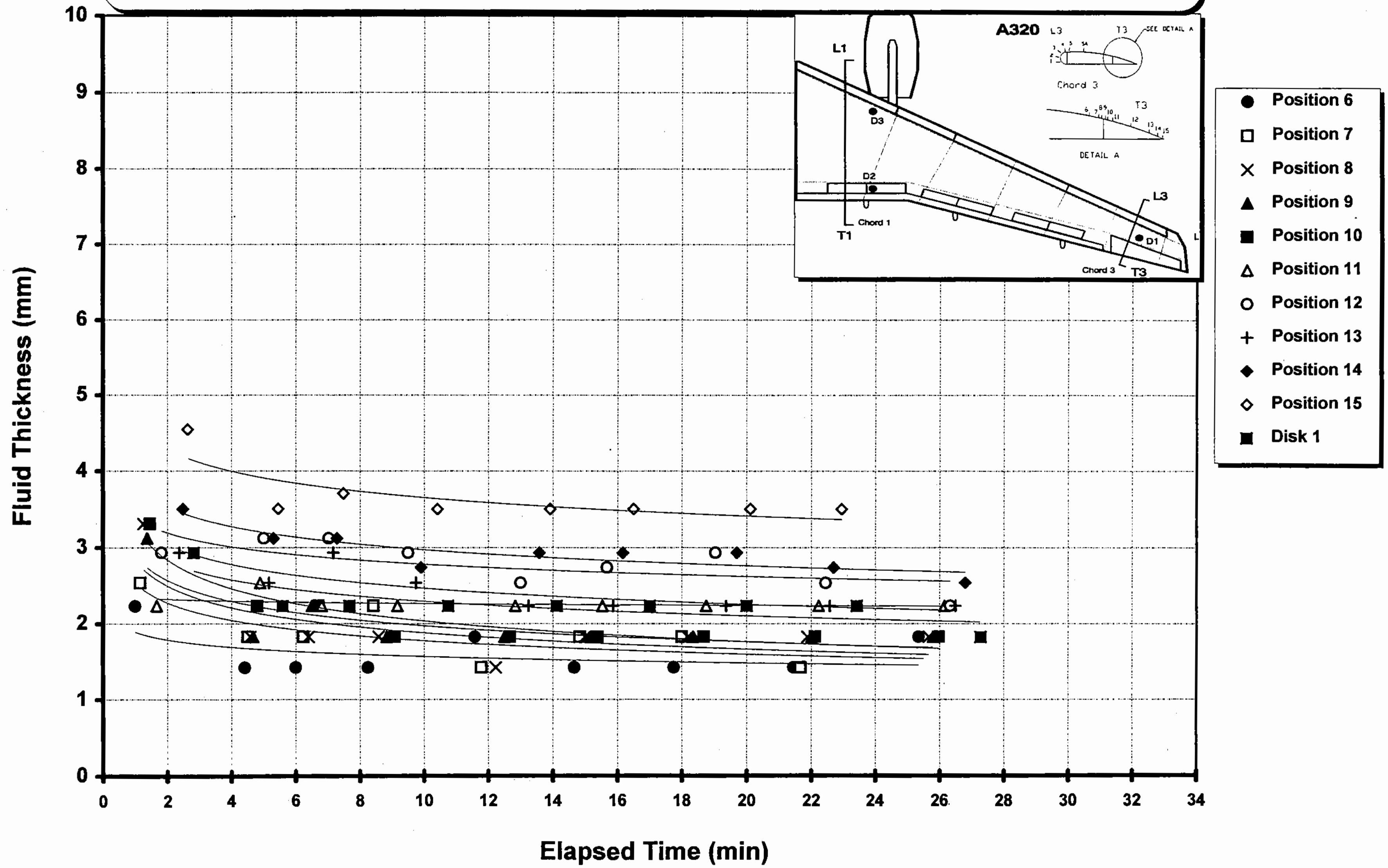
RUN 2 - MARCH 29, 1996

A320 - LOCATION T3

1st FLUID: ULTRA TYPE IV / 282 LITRES

2nd FLUID: NIL

Temperature: -1.7°C | Wind Speed: 9.5 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R2.XLS
At: T3_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

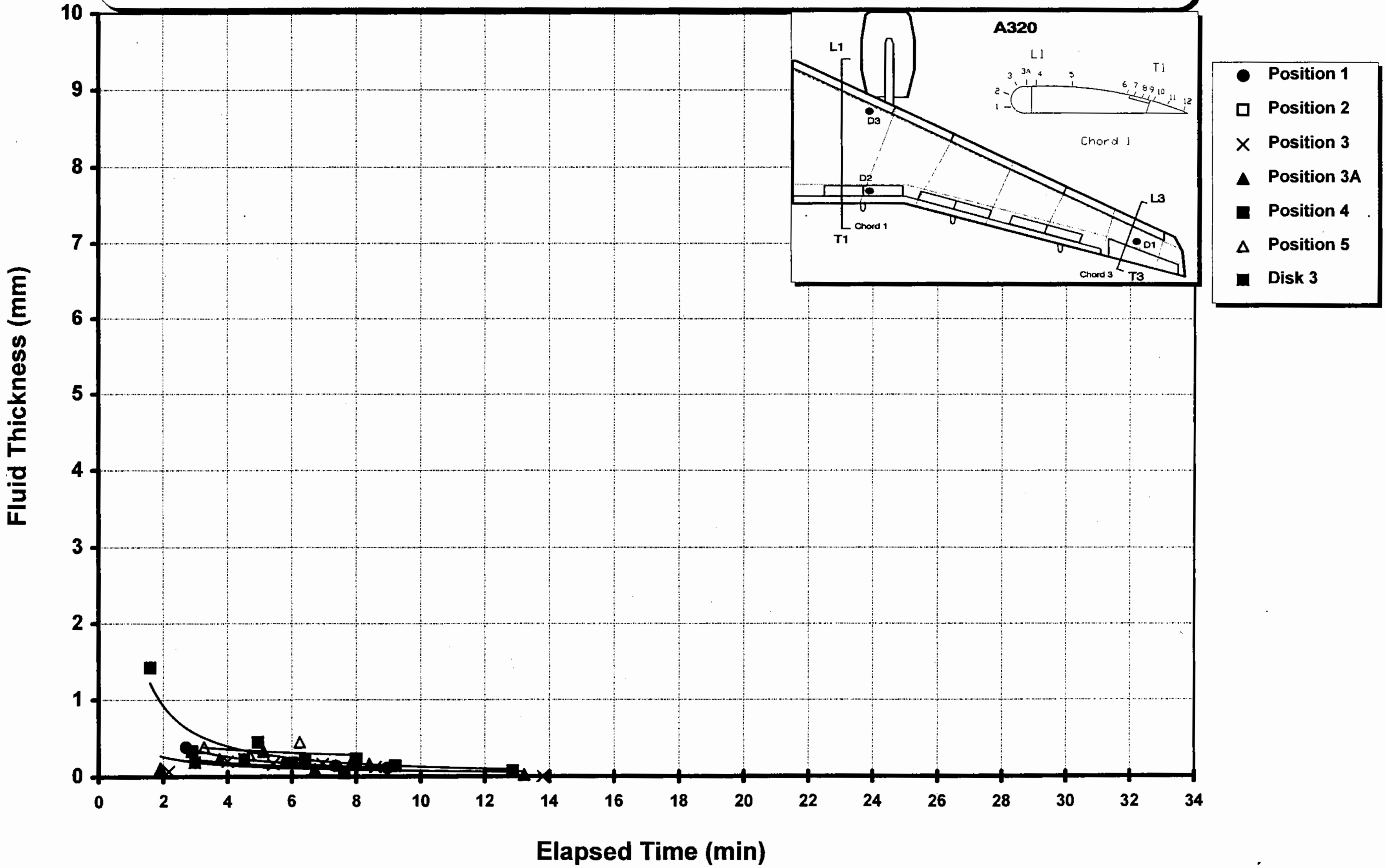
RUN 3 - MARCH 29, 1996

A320 - LOCATION L1

1st FLUID: XL54 TYPE I / 177 LITRES

2nd FLUID: NIL

Temperature: -3.2°C | Wind Speed: 12.5 kph | Nozzle Type: AKRON



E-43

File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R3.XLS
At: L1_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

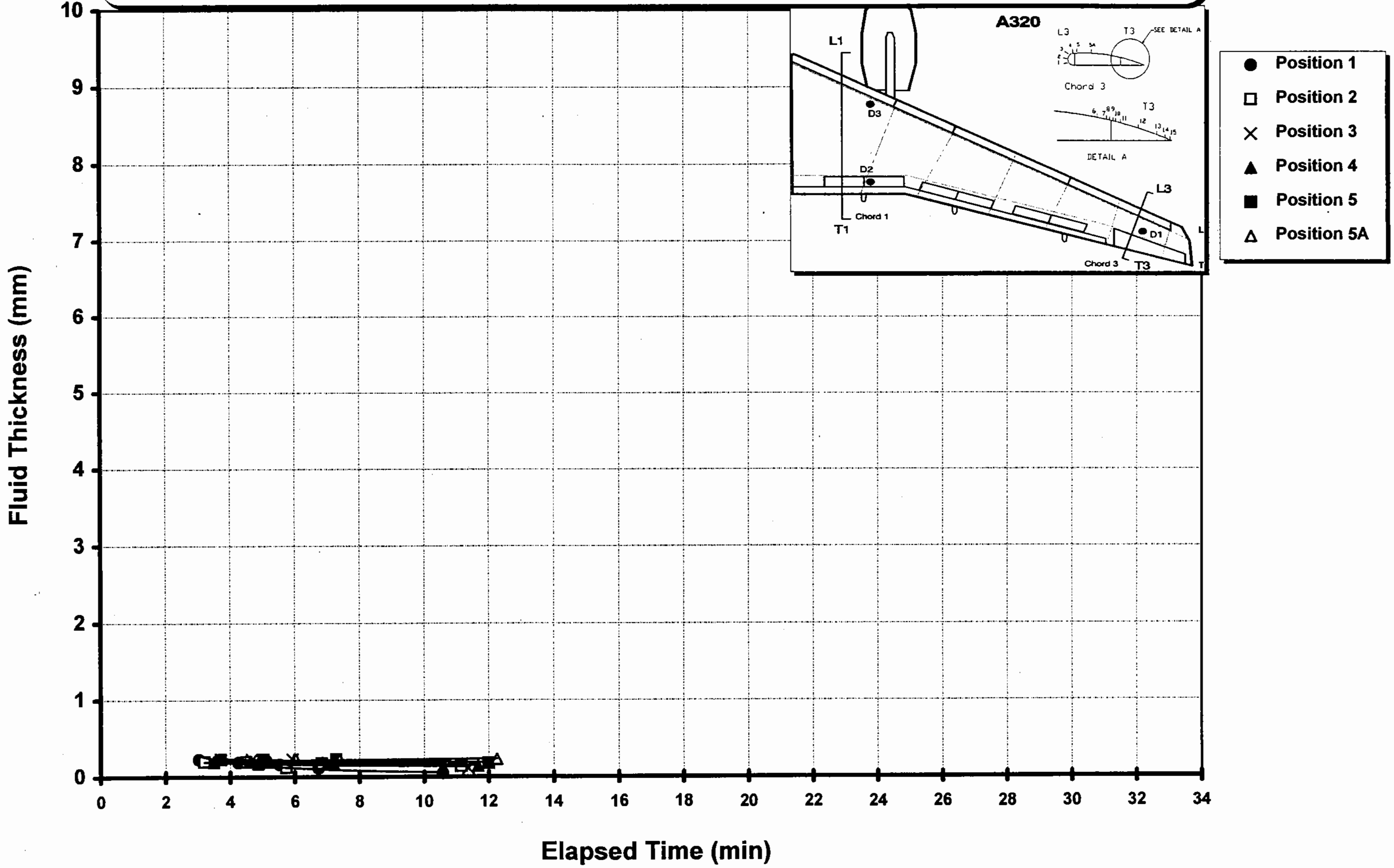
RUN 3 - MARCH 29, 1996

A320 - LOCATION L3

1st FLUID: XL54 TYPE I / 177 LITRES

2nd FLUID: NIL

Temperature: -3.2°C | Wind Speed: 12.5 kph | Nozzle Type: AKRON



E-44

File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R3.XLS
At: L3_CHT
Printed 09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

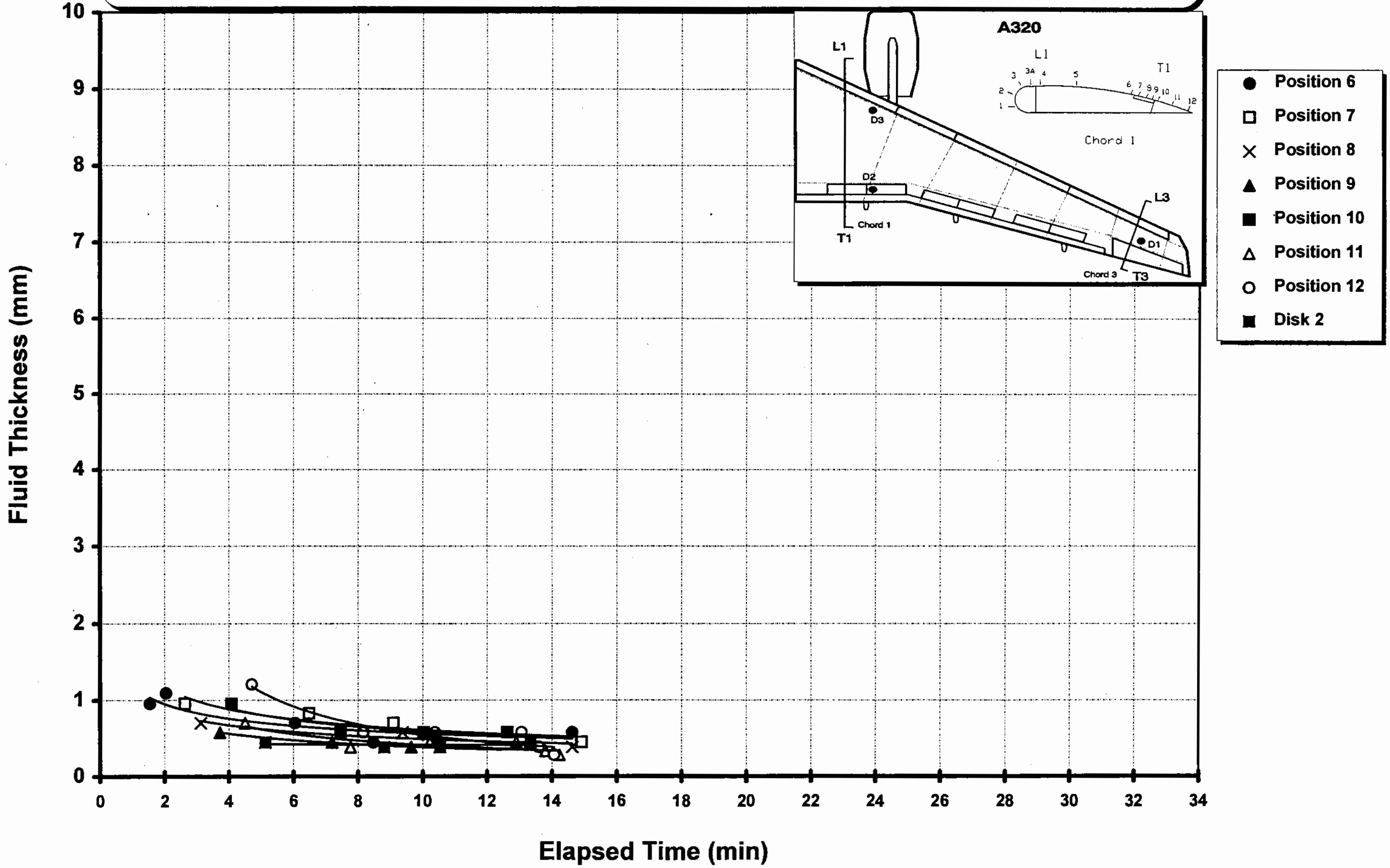
RUN 3 - MARCH 29, 1996

A320 - LOCATION T1

1st FLUID: XL54 TYPE IV / 177 LITRES

2nd FLUID: NIL

Temperature: -3.2°C | Wind Speed: 12.5 kph | Nozzle Type: AKRON



E-45

File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R3.XLS
At: T1_CHT
Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

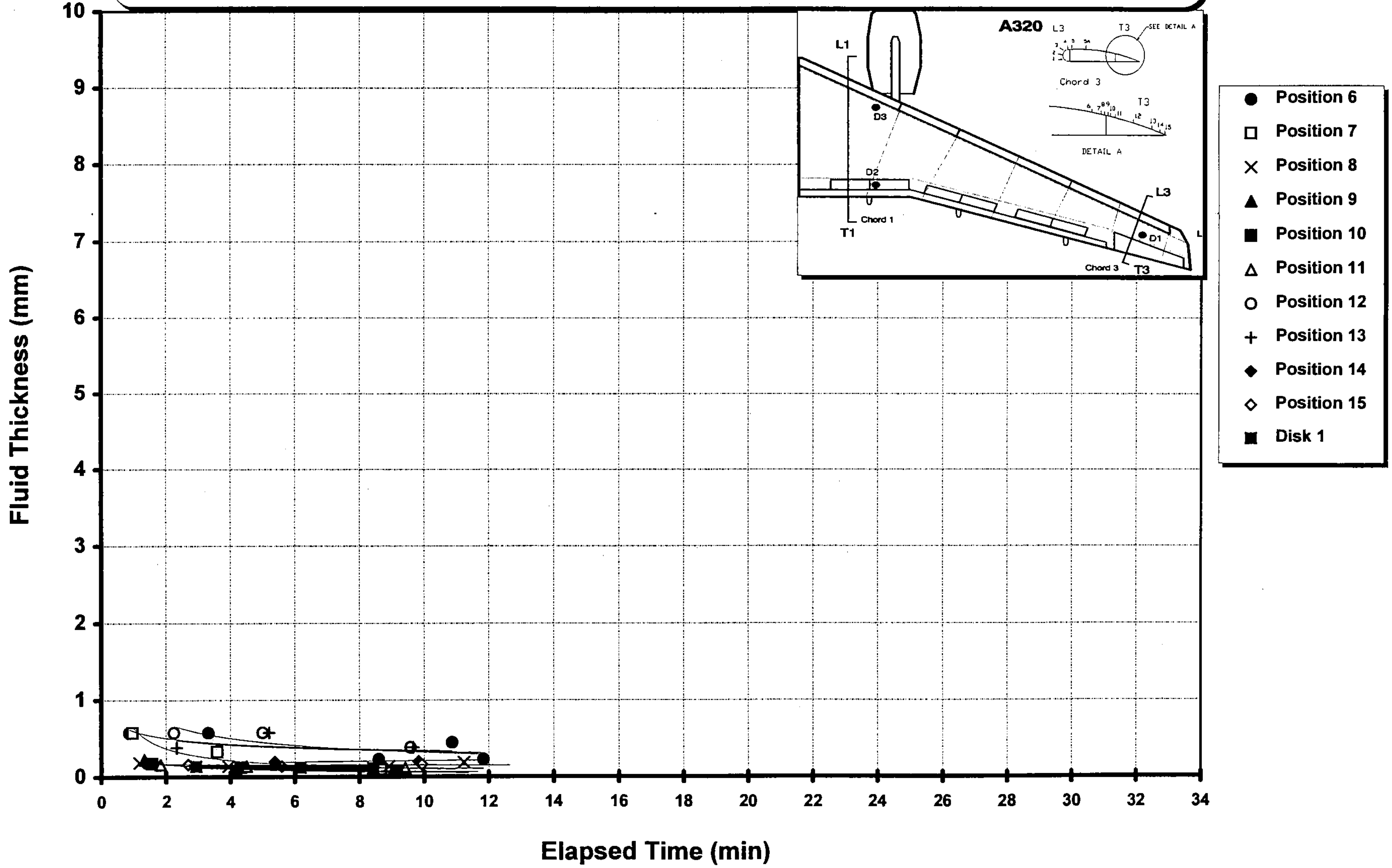
RUN 3 - MARCH 29, 1996

A320 - LOCATION T3

1st FLUID: XL54 TYPE IV / 177 LITRES

2nd FLUID: NIL

Temperature: -3.2°C | Wind Speed: 12.5 kph | Nozzle Type: AKRON



E-46

File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R3.XLS
At: T3_CHT
Printed:09/12/96

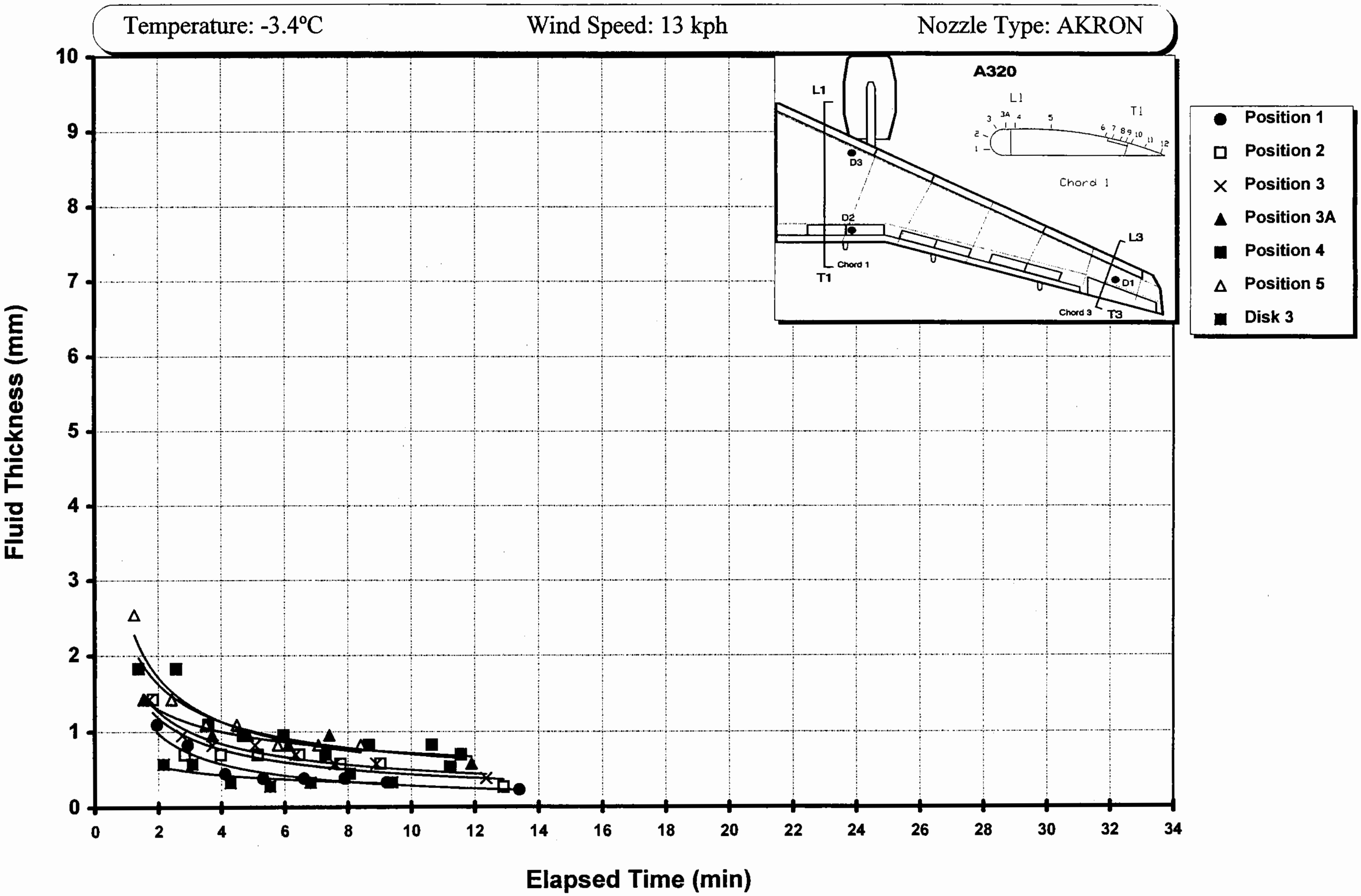
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 4 - MARCH 29, 1996

A320 - LOCATION L1

1st FLUID: XL54 TYPE I / 36 LITRES

2nd FLUID: ULTRA TYPE IV / 145 LITRES



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R4.XLS
At: L1_CHT
Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

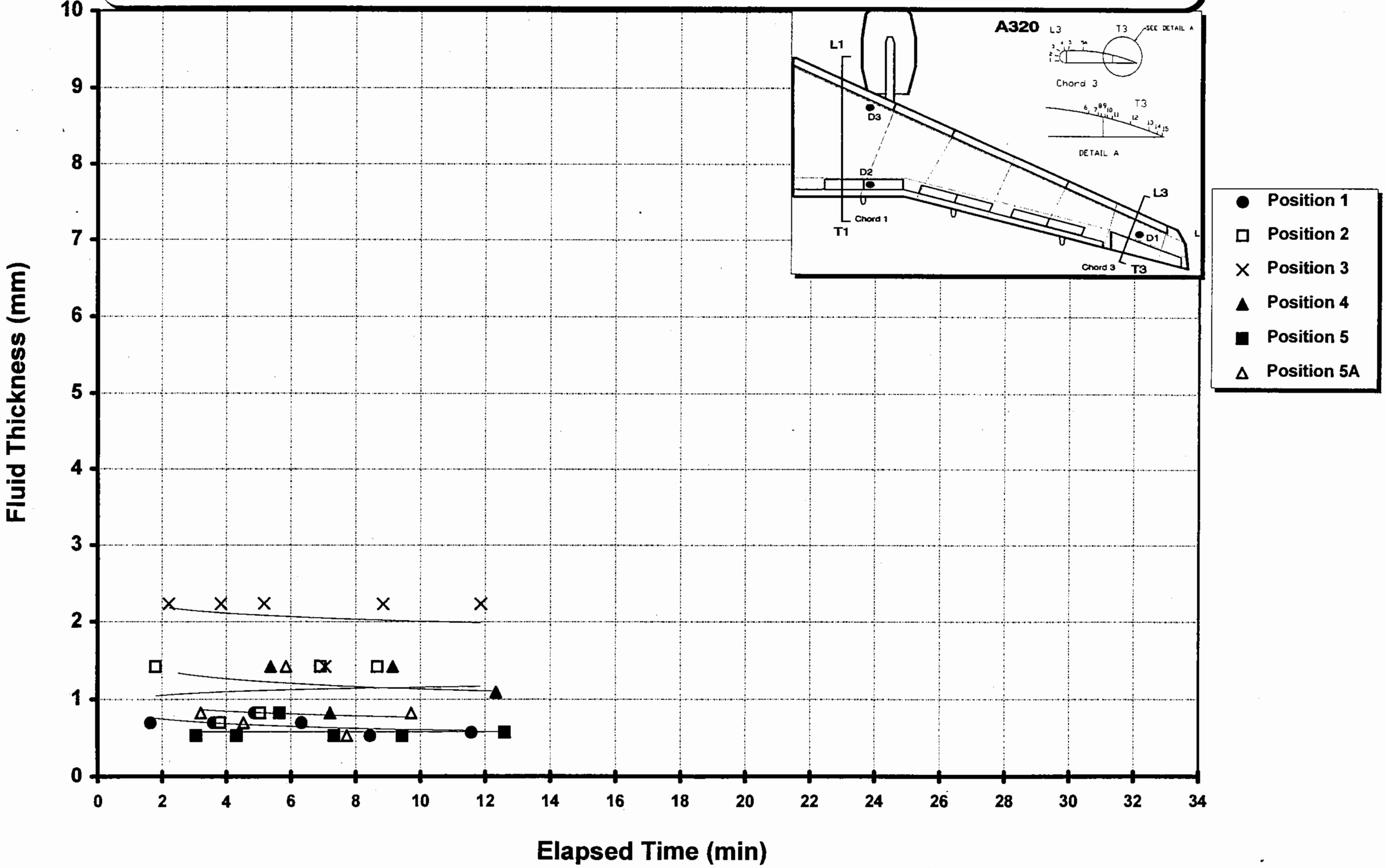
RUN 4 - MARCH 29, 1996

A320 - LOCATION L3

1st FLUID: XL54 TYPE I / 36 LITRES

2nd FLUID: ULTRA TYPE IV / 145 LITRES

Temperature: -3.4°C | Wind Speed: 13 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R4.XLS
At: L3_CHT
Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

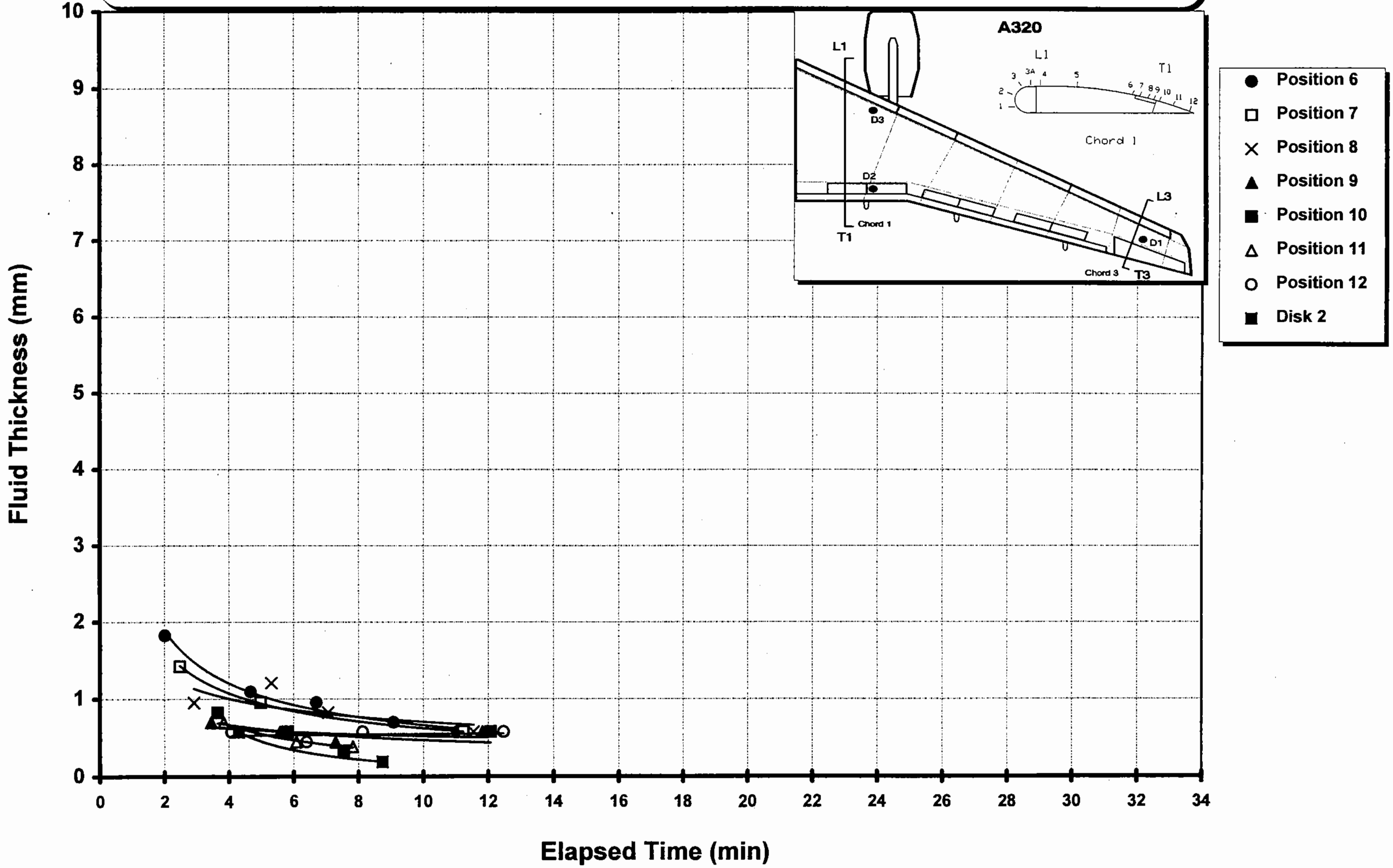
RUN 4 - MARCH 29, 1996

A320 - LOCATION T1

1st FLUID: XL54 TYPE I / 36 LITRES

2nd FLUID: ULTRA TYPE IV / 145 LITRES

Temperature: -3.4°C Wind Speed: 13 kph Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R4.XLS
At: T1_CHT
Printed:09/12/96

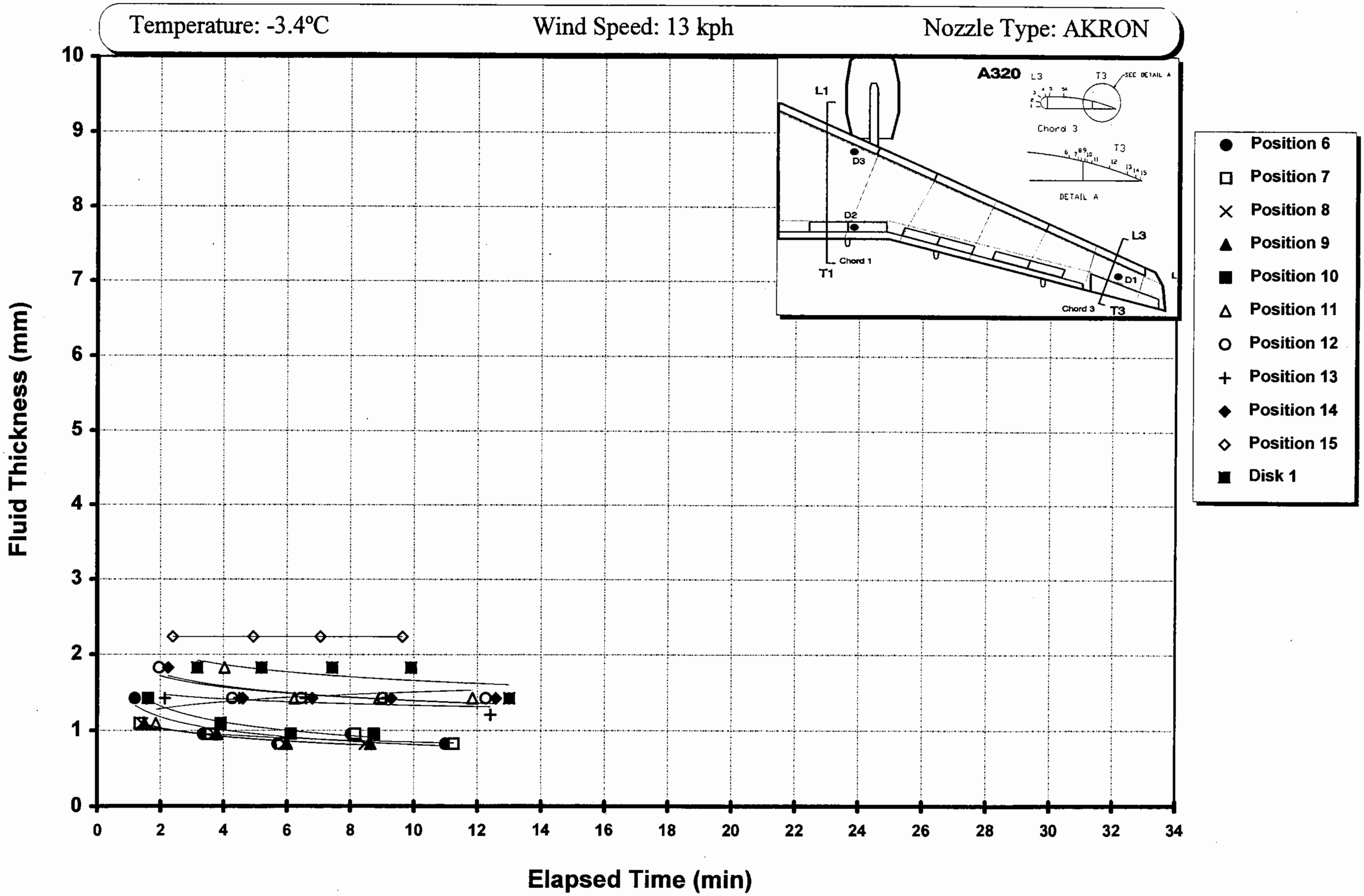
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 4 - MARCH 29, 1996

A320 - LOCATION T3

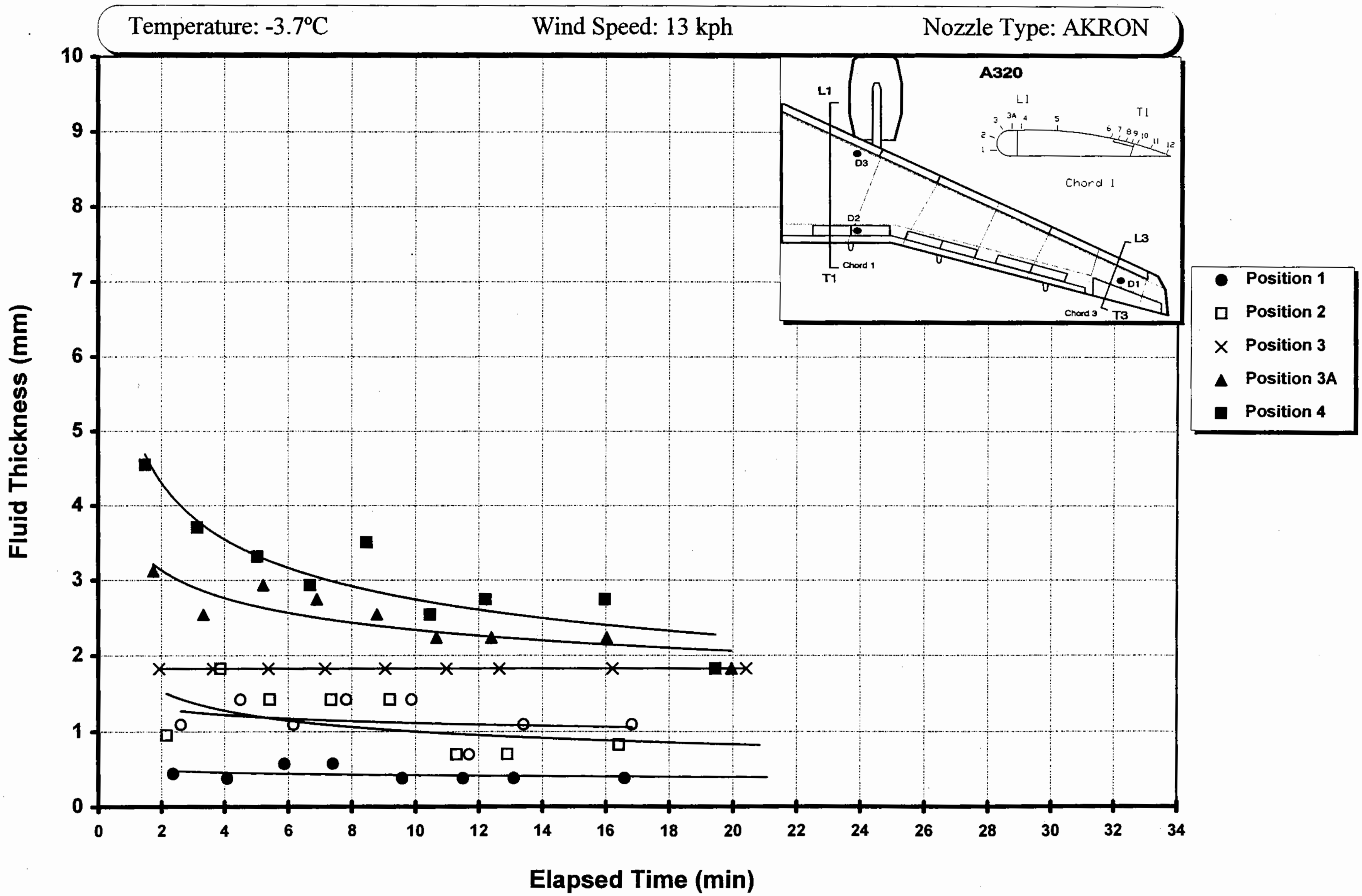
1st FLUID: XL54 TYPE I / 36 LITRES

2nd FLUID: ULTRA TYPE IV / 145 LITRES



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R4.XLS
At: T3_CHT
Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS
RUN 5 - MARCH 29, 1996
A320 - LOCATION L1
1st FLUID: XL54 TYPE I / 41 LITRES
2nd FLUID: ULTRA TYPE IV / 168 LITRES



E-51

File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R5.XLS
At: L1_CHT

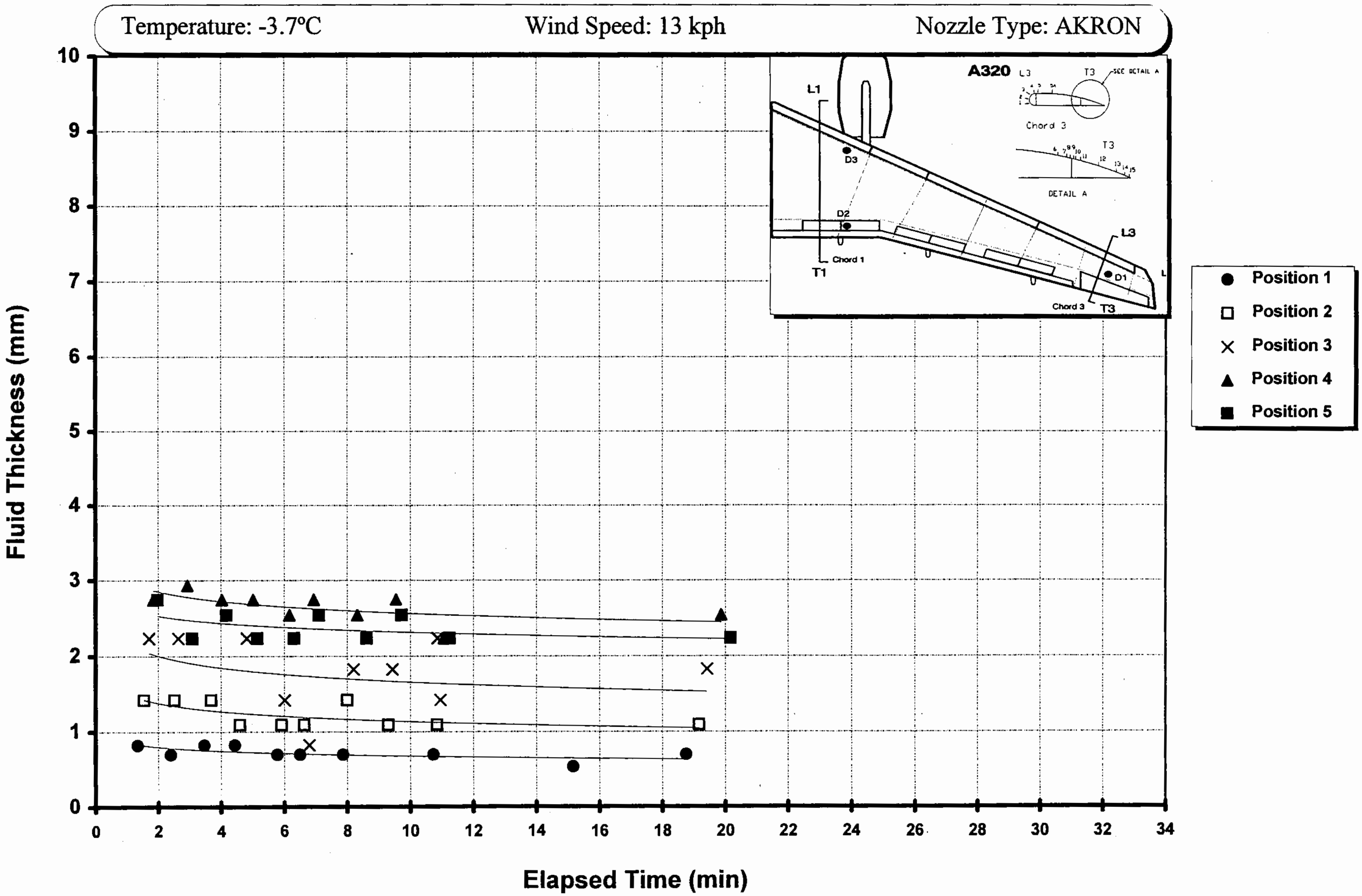
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 5 - MARCH 29, 1996

A320 - LOCATION L3

1st FLUID: XL54 TYPE I / 41 LITRES

2nd FLUID: ULTRA TYPE IV / 168 LITRES



E-52

File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R5.XLS
At: L3_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

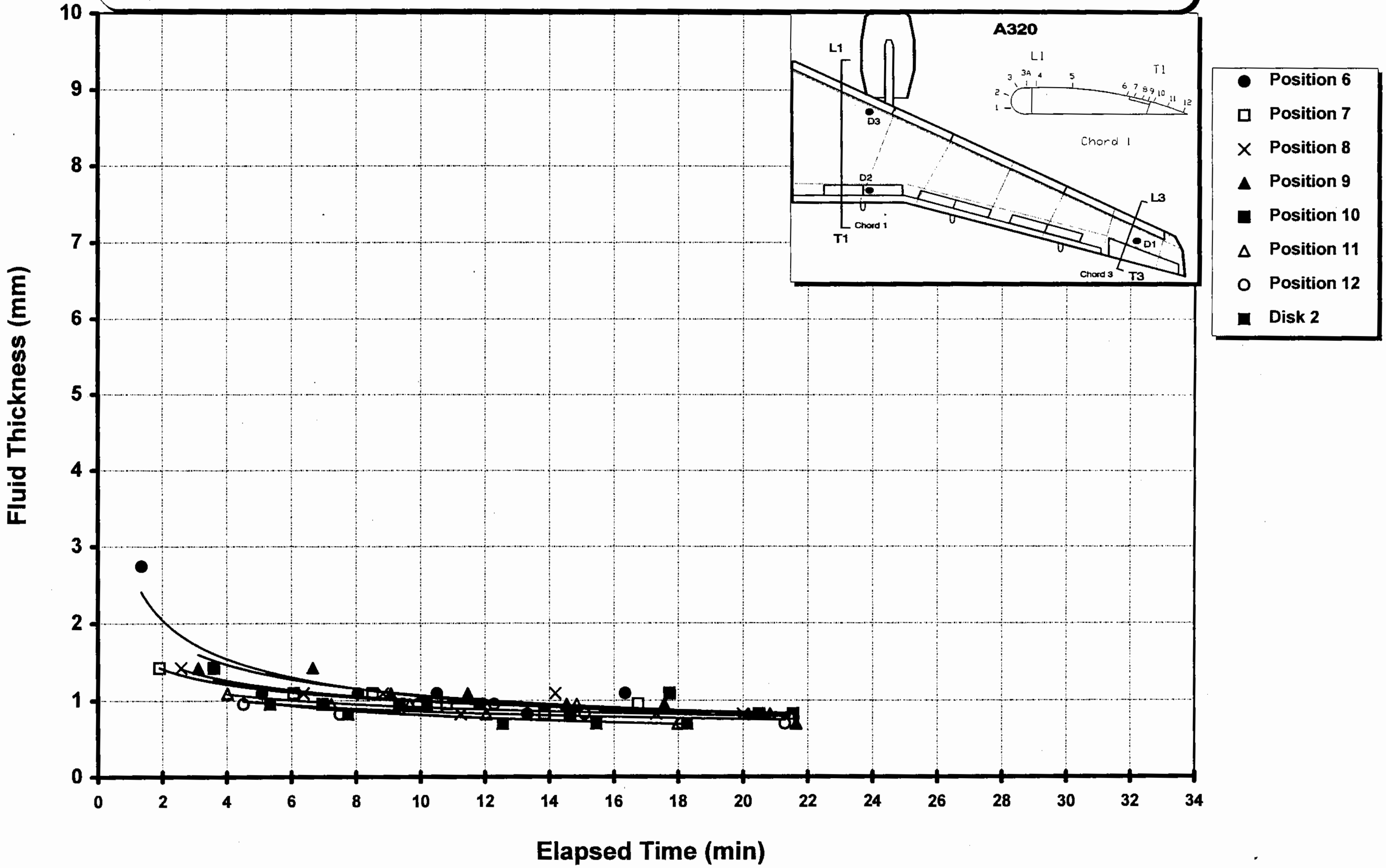
RUN 5 - MARCH 29, 1996

A320 - LOCATION T1

1st FLUID: XL54 TYPE I / 41 LITRES

2nd FLUID: ULTRA TYPE IV / 168 LITRES

Temperature: -3.7°C Wind Speed: 13 kph Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R5.XLS
At: T1 CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

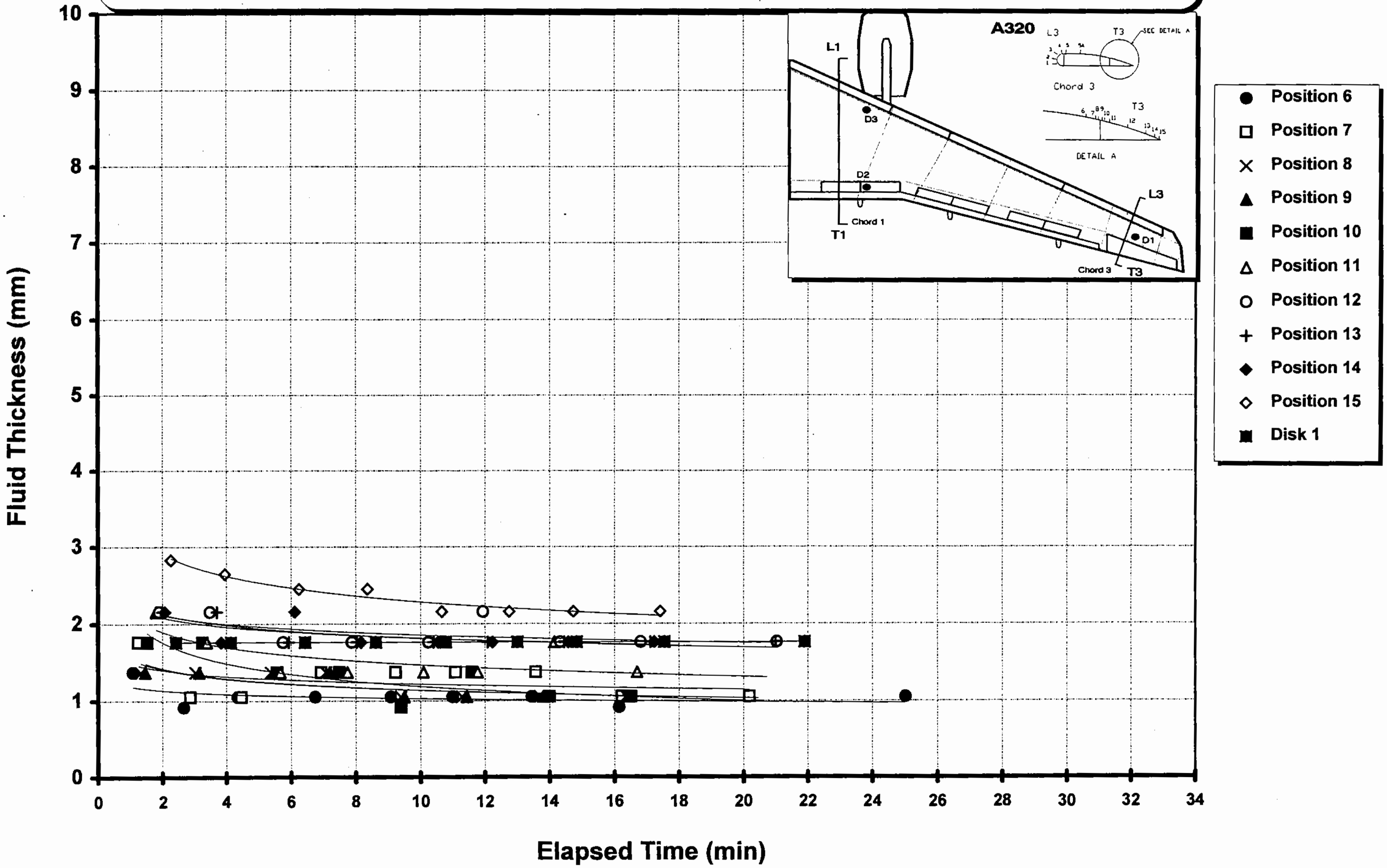
RUN 5 - MARCH 29, 1996

A320 - LOCATION T3

1st FLUID: XL54 TYPE I / 41 LITRES

2nd FLUID: ULTRA TYPE IV / 168 LITRES

Temperature: -3.7°C | Wind Speed: 13 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\MAR29_R5.XLS
At: T3 CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

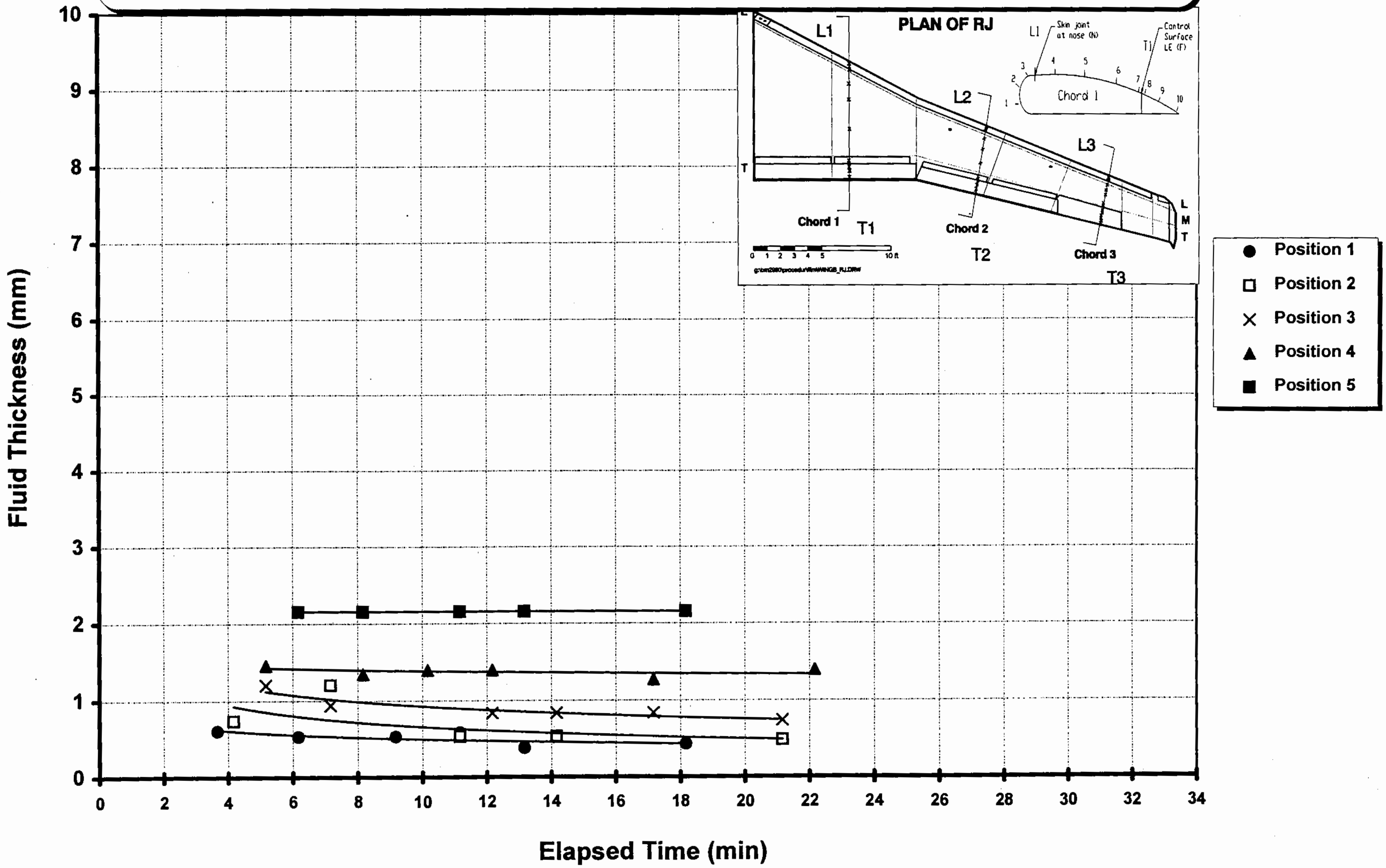
RUN 1 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L1

1st FLUID: ULTRA TYPE IV / 27 LITRES

2nd FLUID: NIL

Temperature: -16.4°C | Wind Speed: 6.8 kph | Nozzle Type: TIPS



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R1.XLS

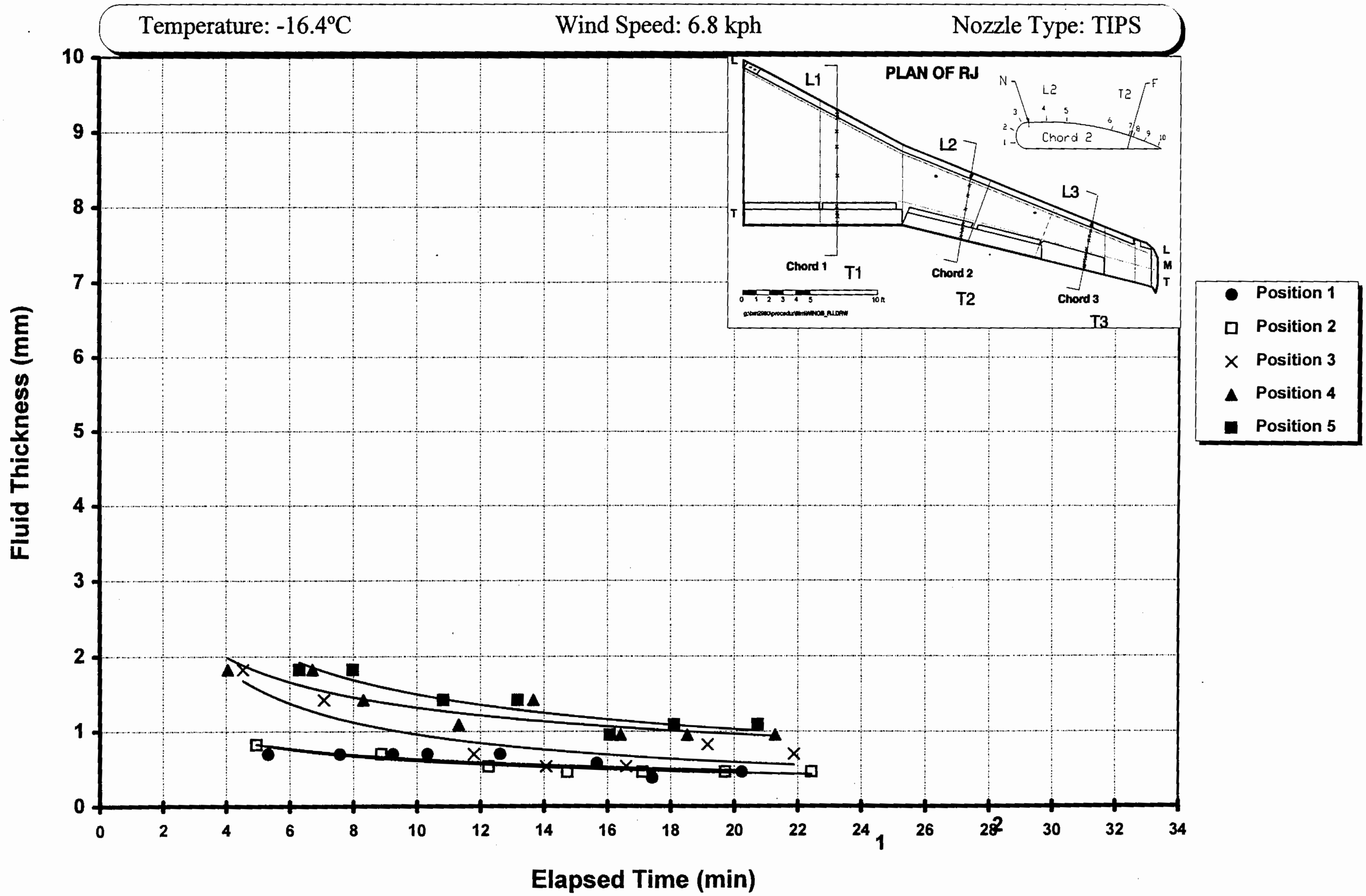
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 1 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L2

1st FLUID: ULTRA TYPE IV / 27 LITRES

2nd FLUID: NIL



FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

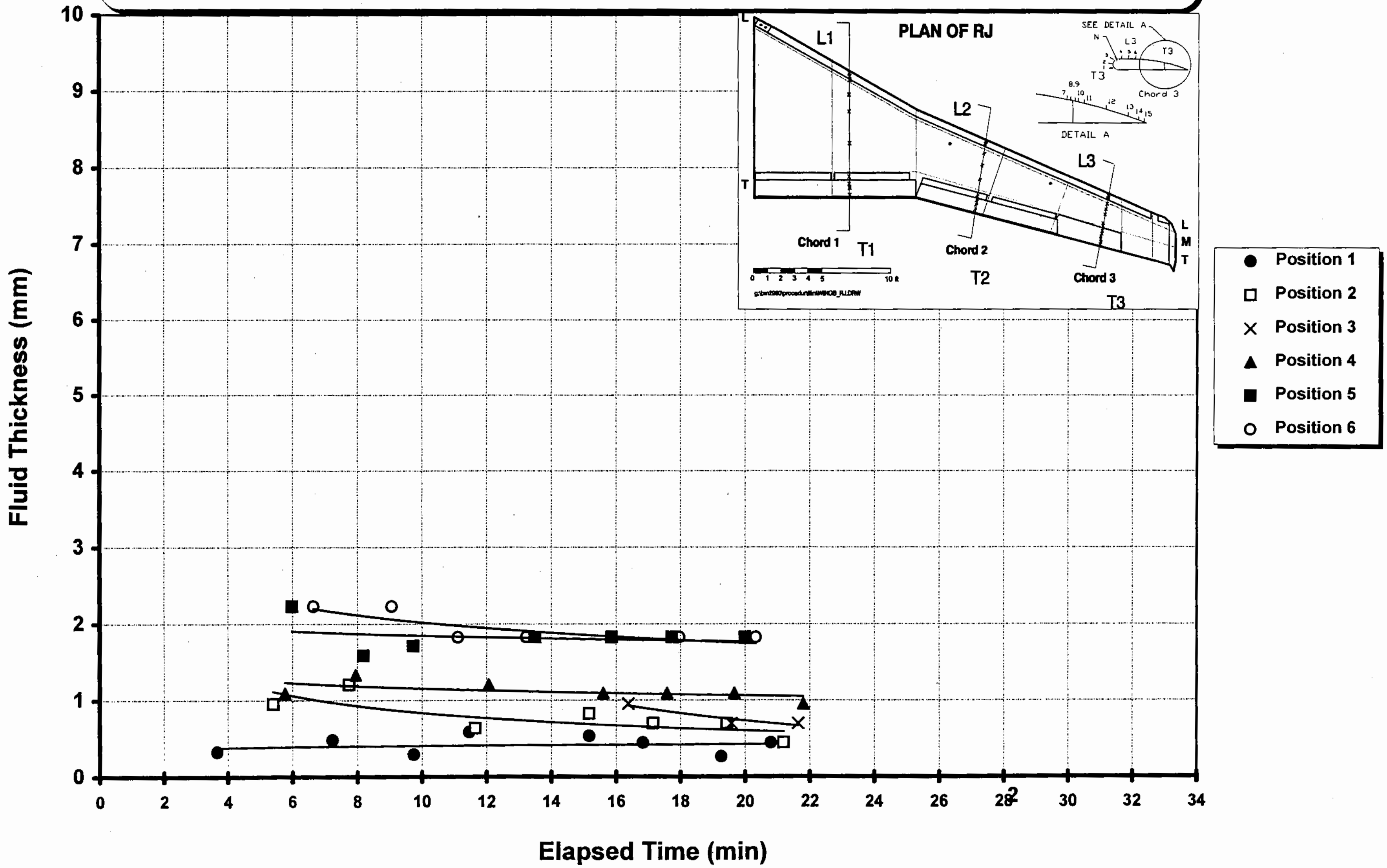
RUN 1 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L3

1st FLUID: ULTRA TYPE IV / 27 LITRES

2nd FLUID: NIL

Temperature: -16.4°C Wind Speed: 6.8 kph Nozzle Type: TIPS



E-57

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R1.XLS
At: L3 CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

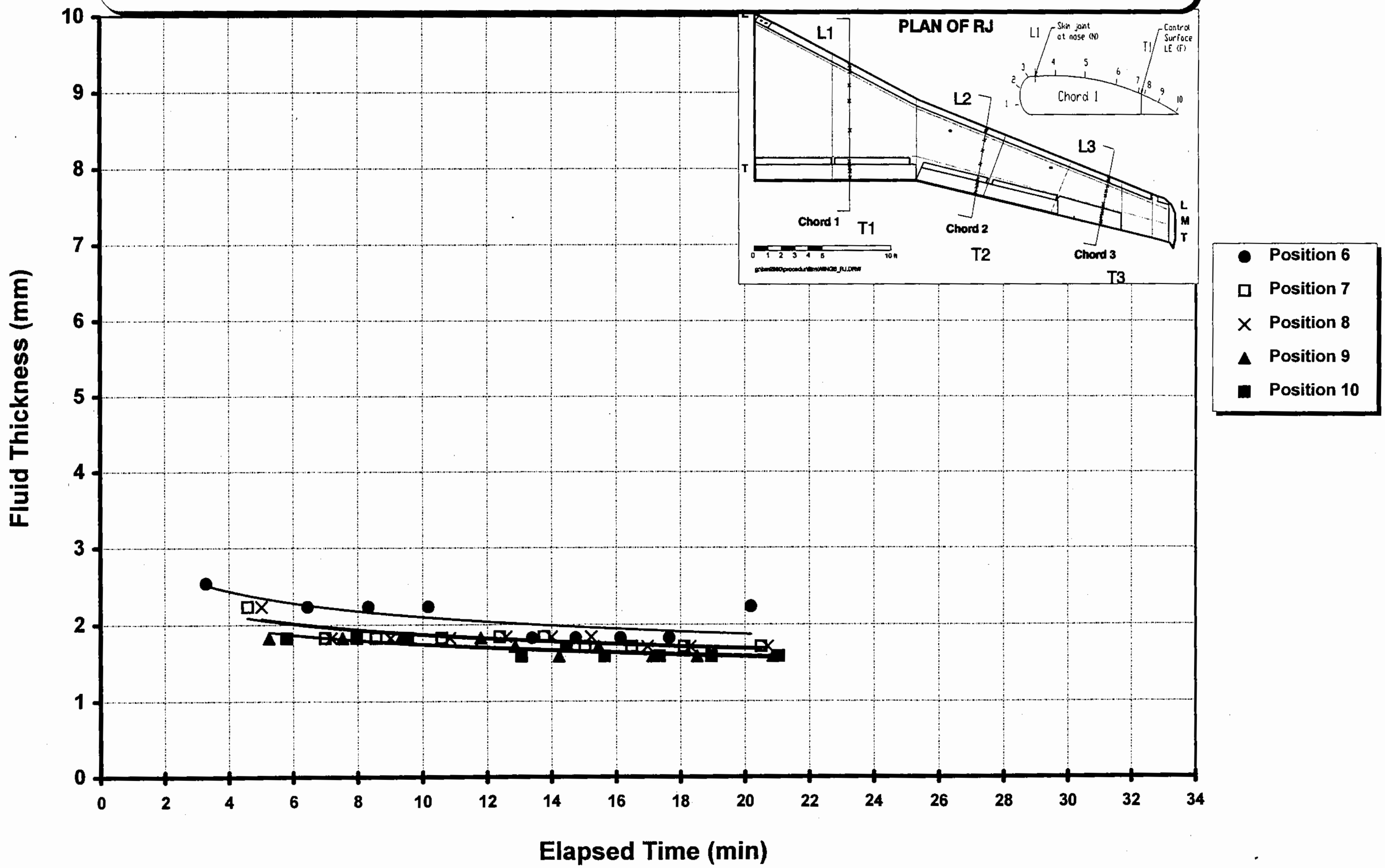
RUN 1 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T1

1st FLUID: ULTRA TYPE IV / 27 LITRES

2nd FLUID: NIL

Temperature: -16.4°C | Wind Speed: 6.8 kph | Nozzle Type: TIPS



E-58

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R1.XLS
At: T1_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

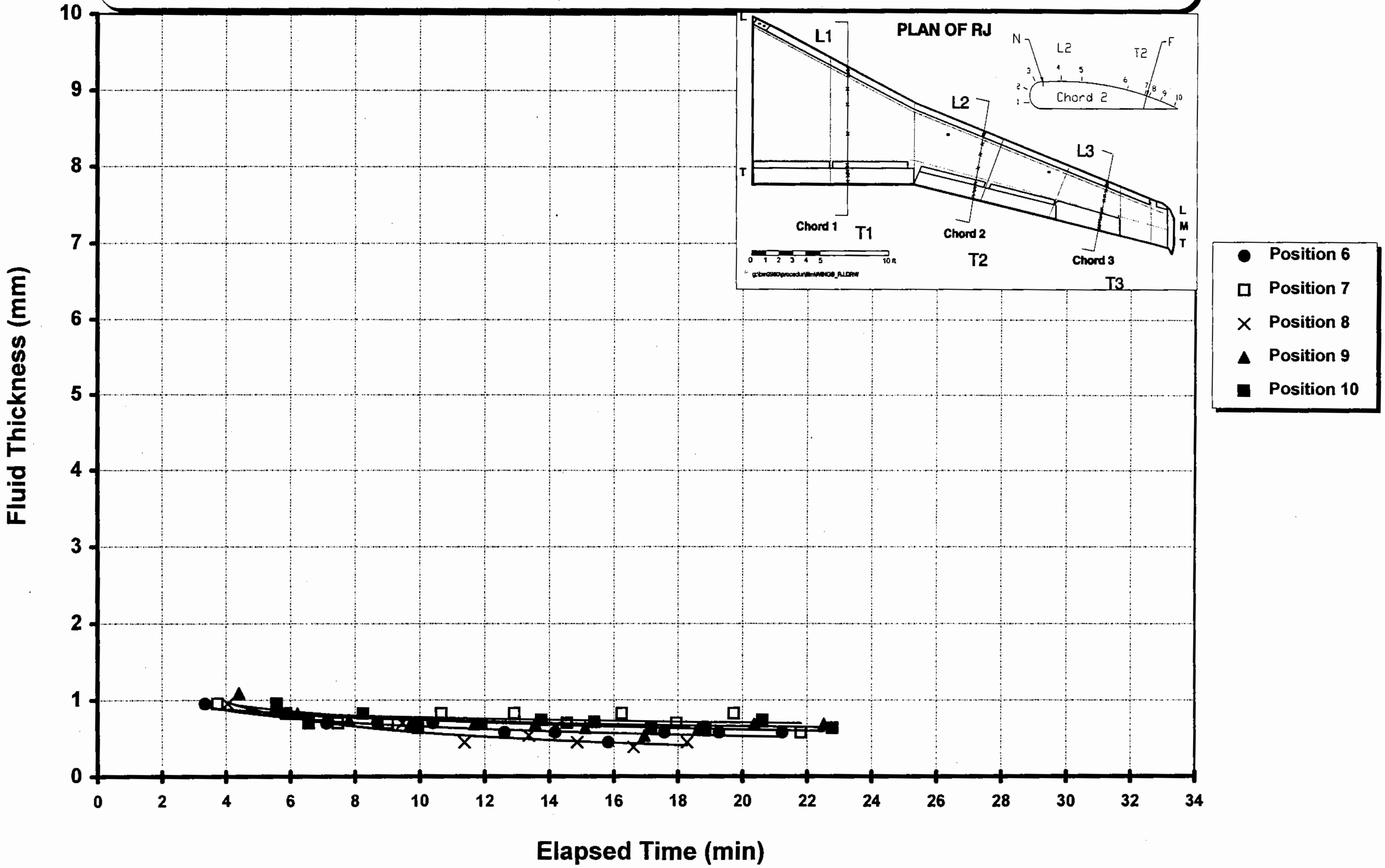
RUN 1 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T2

1st FLUID: ULTRA TYPE IV / 27 LITRES

2nd FLUID: NIL

Temperature: -16.4°C | Wind Speed: 6.8 kph | Nozzle Type: TIPS



E-59

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R1.XLS
At: T2_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

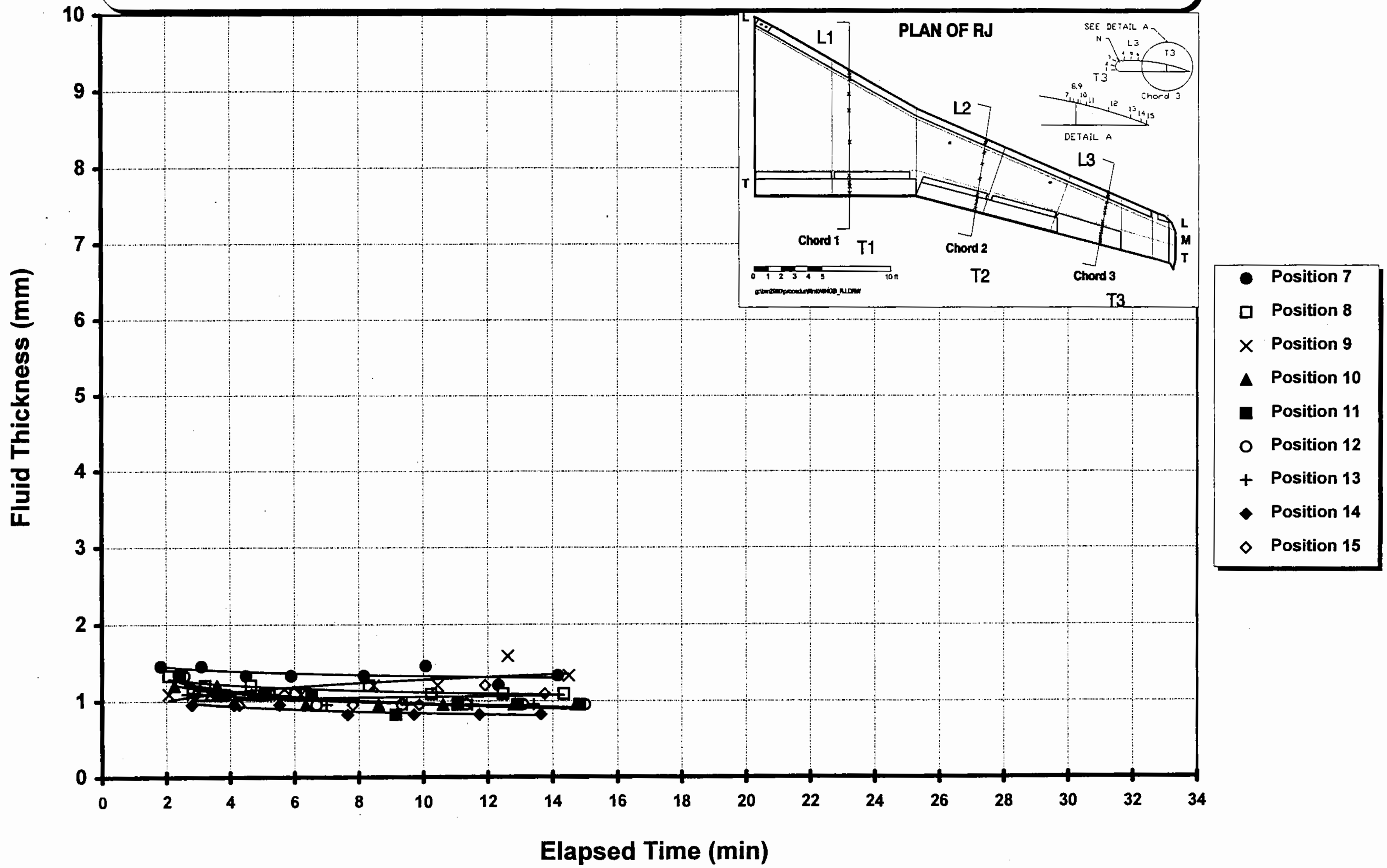
RUN 1 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T3

1st FLUID: ULTRA TYPE IV / 27 LITRES

2nd FLUID: NIL

Temperature: -16.4°C Wind Speed: 6.8 kph Nozzle Type: TIPS



E-60

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R1.XLS
At: T3_CHT

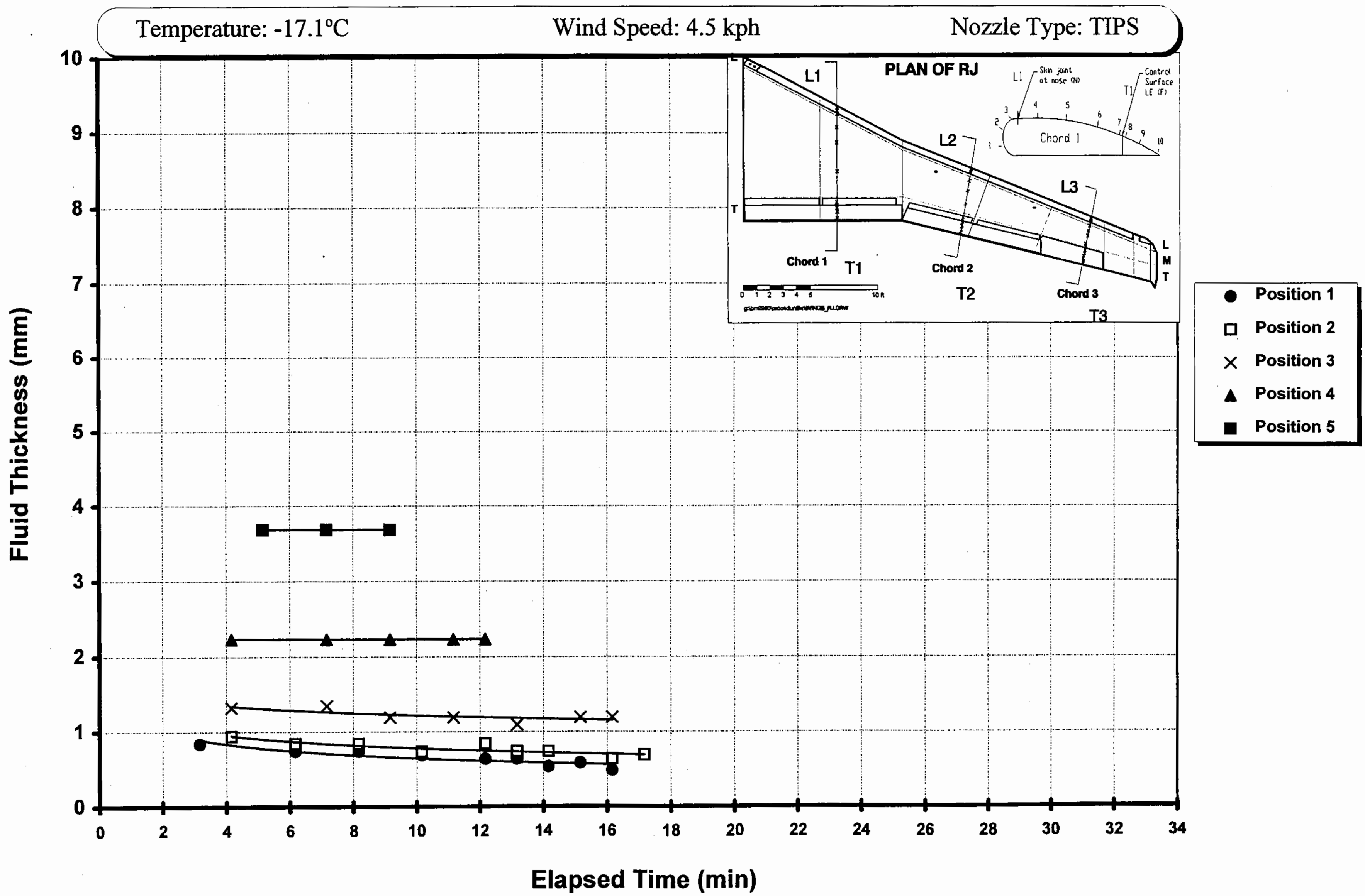
FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 2 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L1

1st FLUID: ULTRA TYPE IV / 150 LITRES

2nd FLUID: NIL



E-61

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R2.XLS
At: L1_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

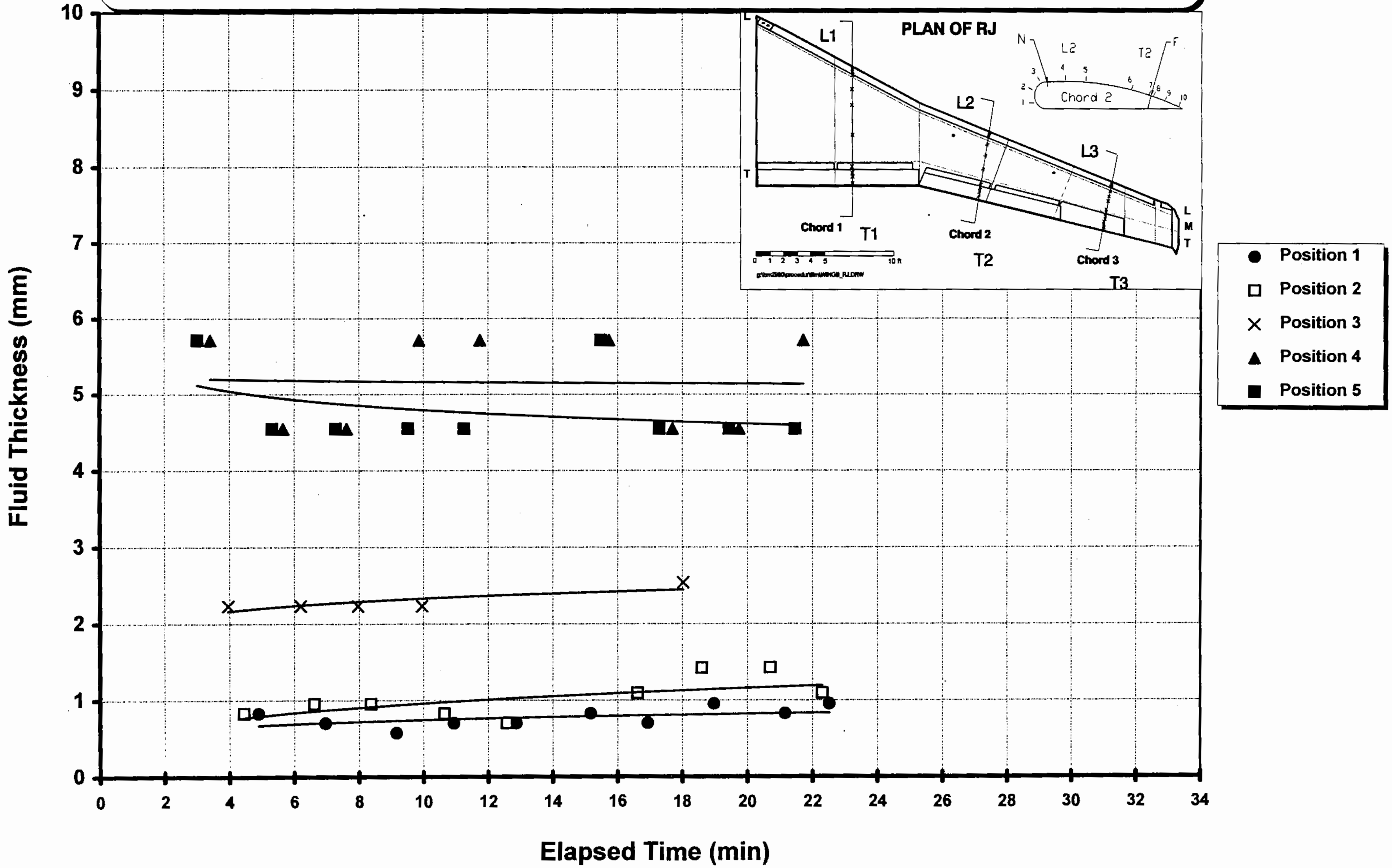
RUN 2 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L2

1st FLUID: ULTRA TYPE IV / 150 LITRES

2nd FLUID: NIL

Temperature: -17.1°C   Wind Speed: 4.5 kph   Nozzle Type: TIPS



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R2.XLS

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

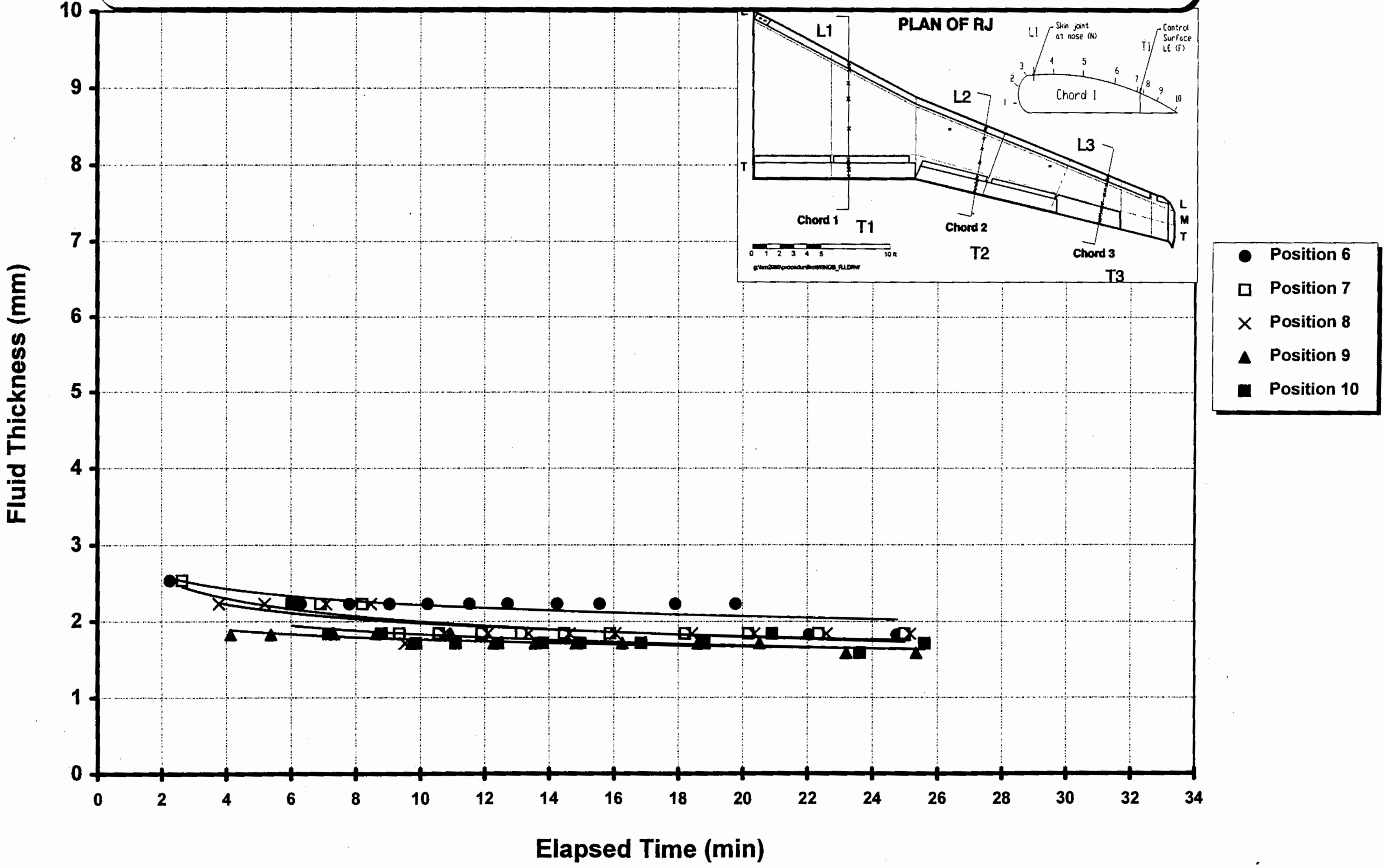
RUN 2 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T1

1st FLUID: ULTRA TYPE IV / 150 LITRES

2nd FLUID: NIL

Temperature: -17.1°C   Wind Speed: 4.5 kph   Nozzle Type: TIPS



E-63

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R2.XLS

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

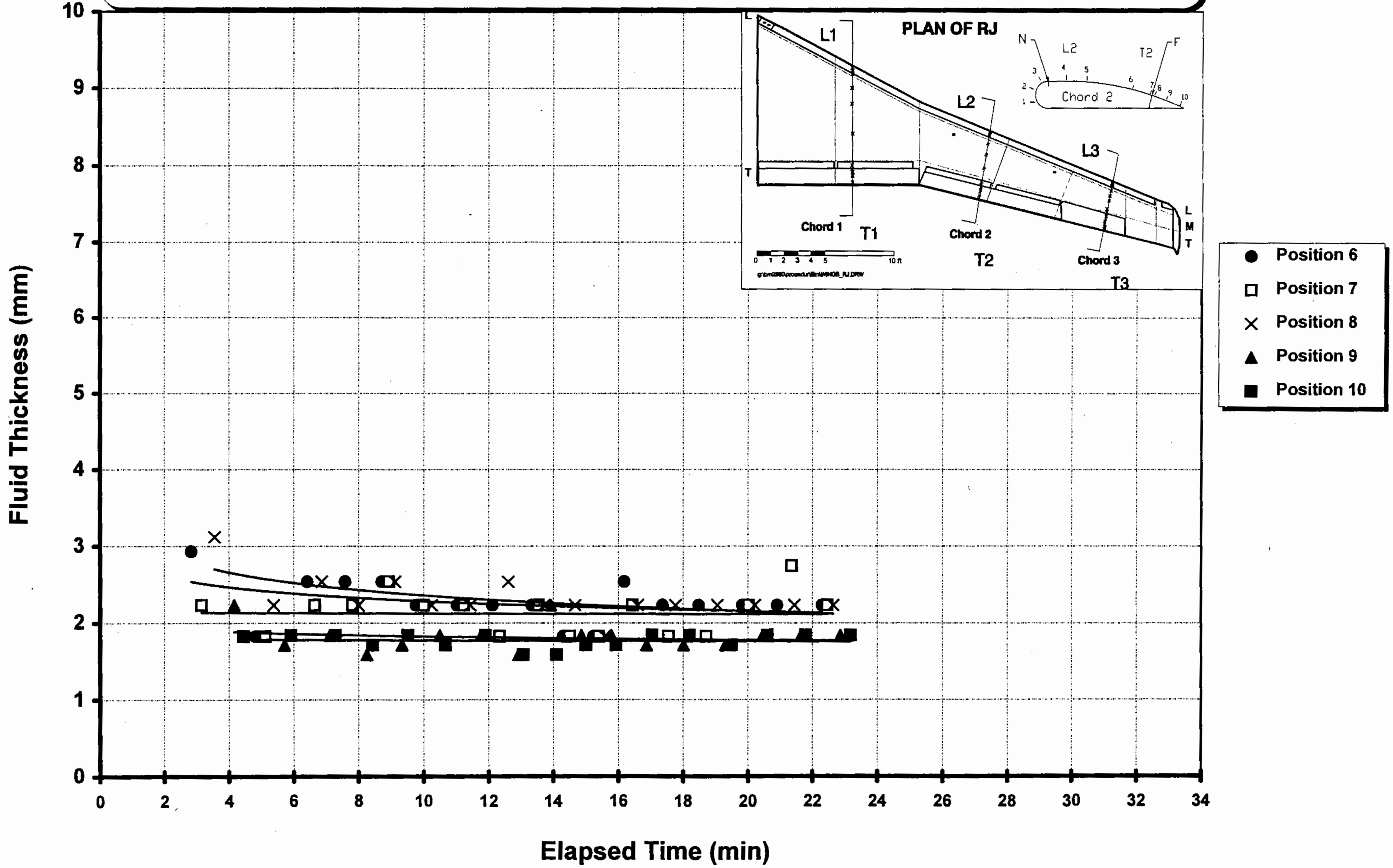
RUN 2 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T2

1st FLUID: ULTRA TYPE IV / 150 LITRES

2nd FLUID: NIL

Temperature: -17.1°C Wind Speed: 4.5 kph Nozzle Type: TIPS



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R2.XLS
At: T2 CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

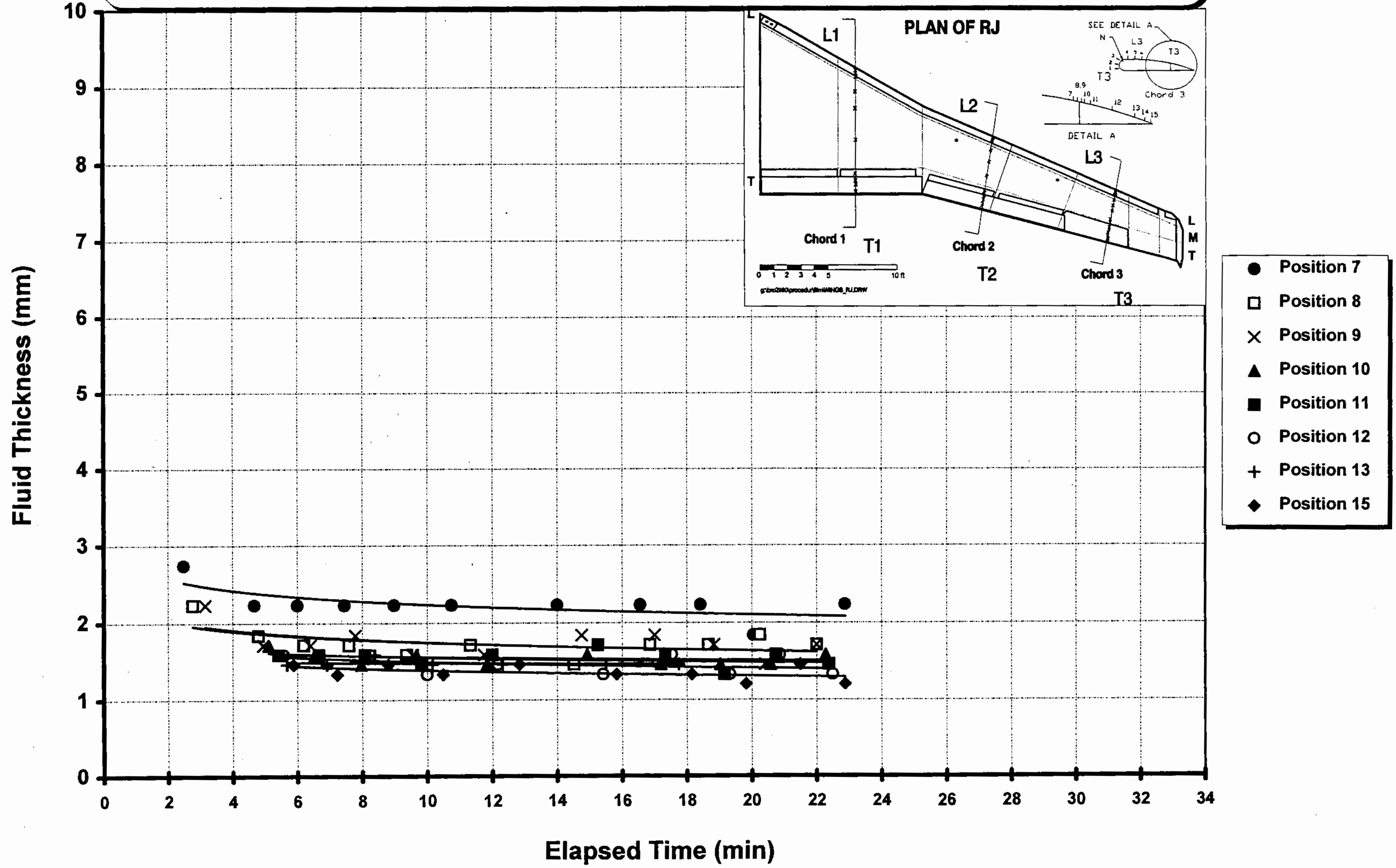
RUN 2 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T3

1st FLUID: ULTRA TYPE IV / 150 LITRES

2nd FLUID: NIL

Temperature: -17.1°C   Wind Speed: 4.5 kph   Nozzle Type: TIPS



E-65

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R2.XLS
At: T3 CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

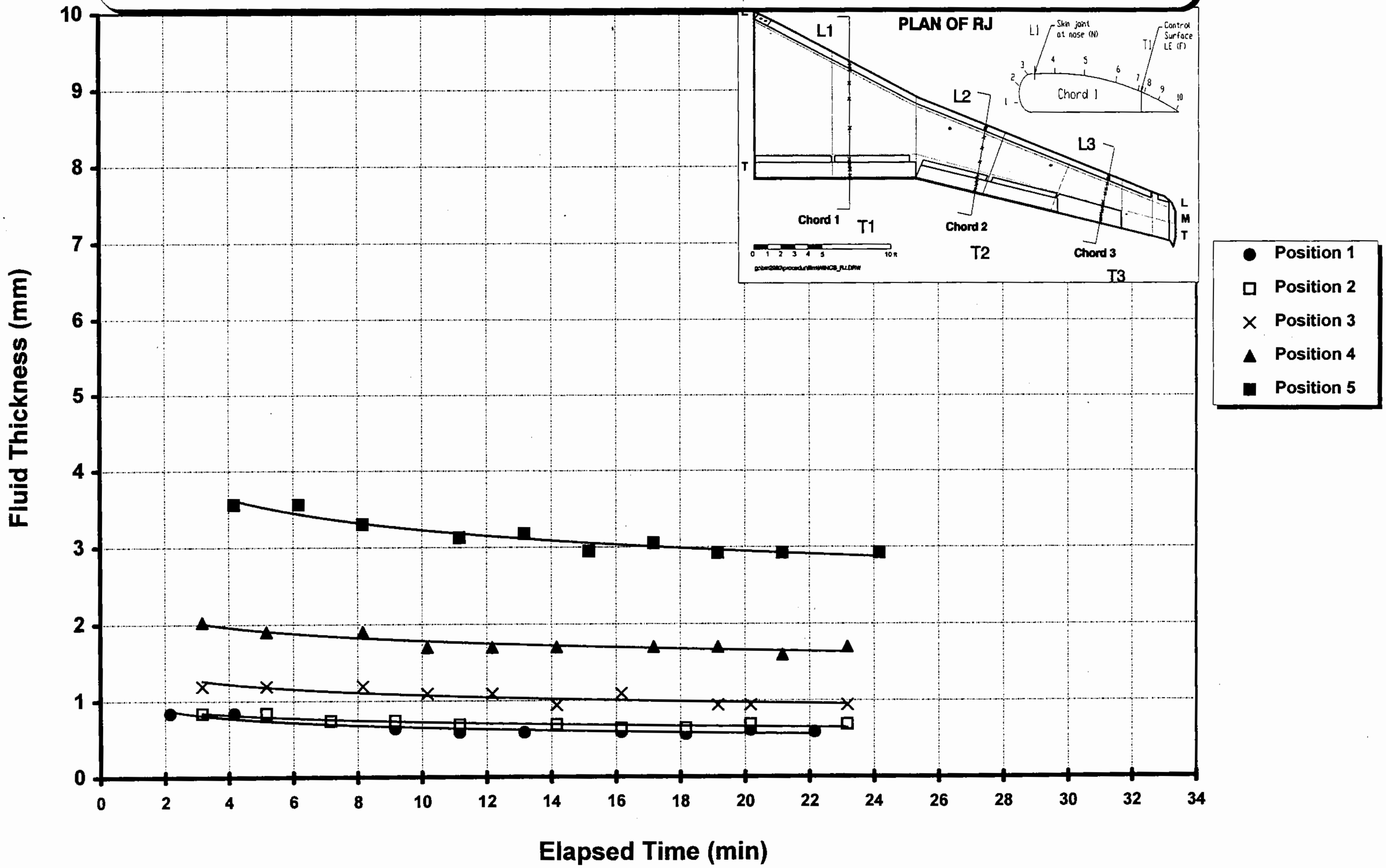
RUN 3 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L1

1st FLUID: ULTRA TYPE IV / 73 LITRES

2nd FLUID: NIL

Temperature: -17.6°C | Wind Speed: 7.3 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R3.XLS
At: L1 CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

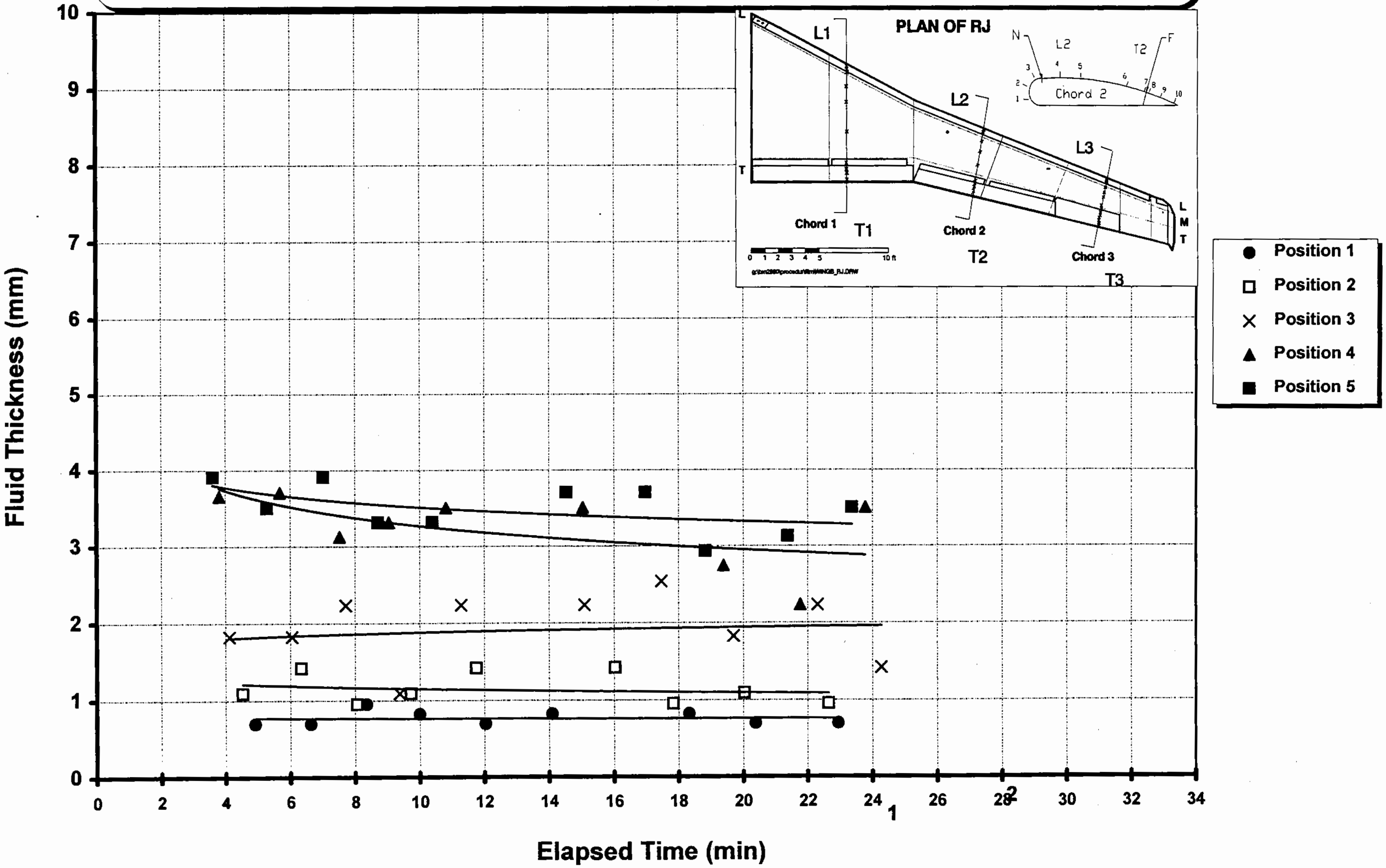
RUN 3 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L2

1st FLUID: ULTRA TYPE IV / 73 LITRES

2nd FLUID: NIL

Temperature: -17.6°C | Wind Speed: 7.3 kph | Nozzle Type: AKRON



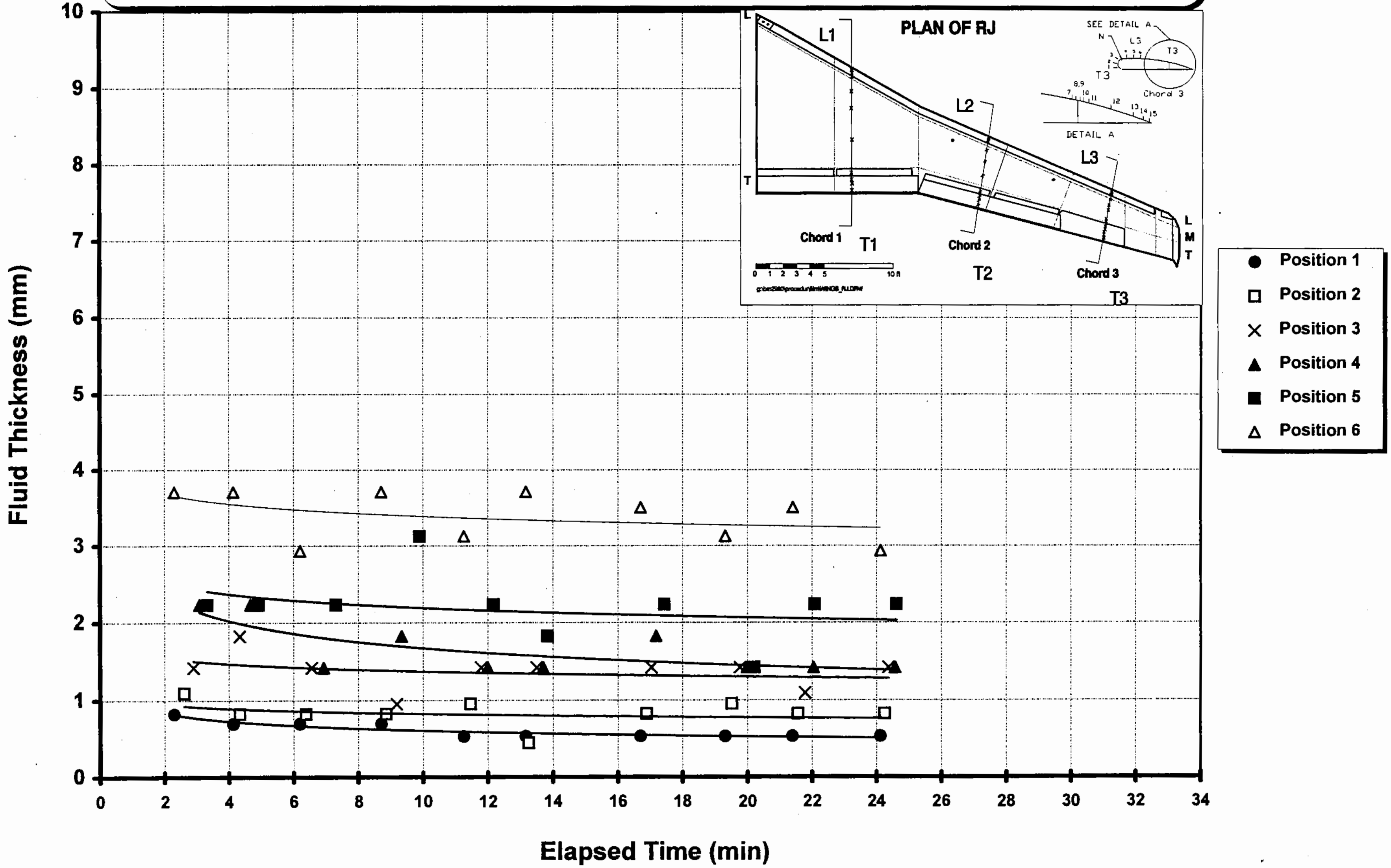
E-67

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R3.XLS
At: L2_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 3 - FEBRUARY 15, 1996
CANADAIR RJ - LOCATION L3
1st FLUID: ULTRA TYPE IV / 73 LITRES
2nd FLUID: NIL

Temperature: -17.6°C   Wind Speed: 7.3 kph   Nozzle Type: AKRON



E-68

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R3.XLS
At: L3_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

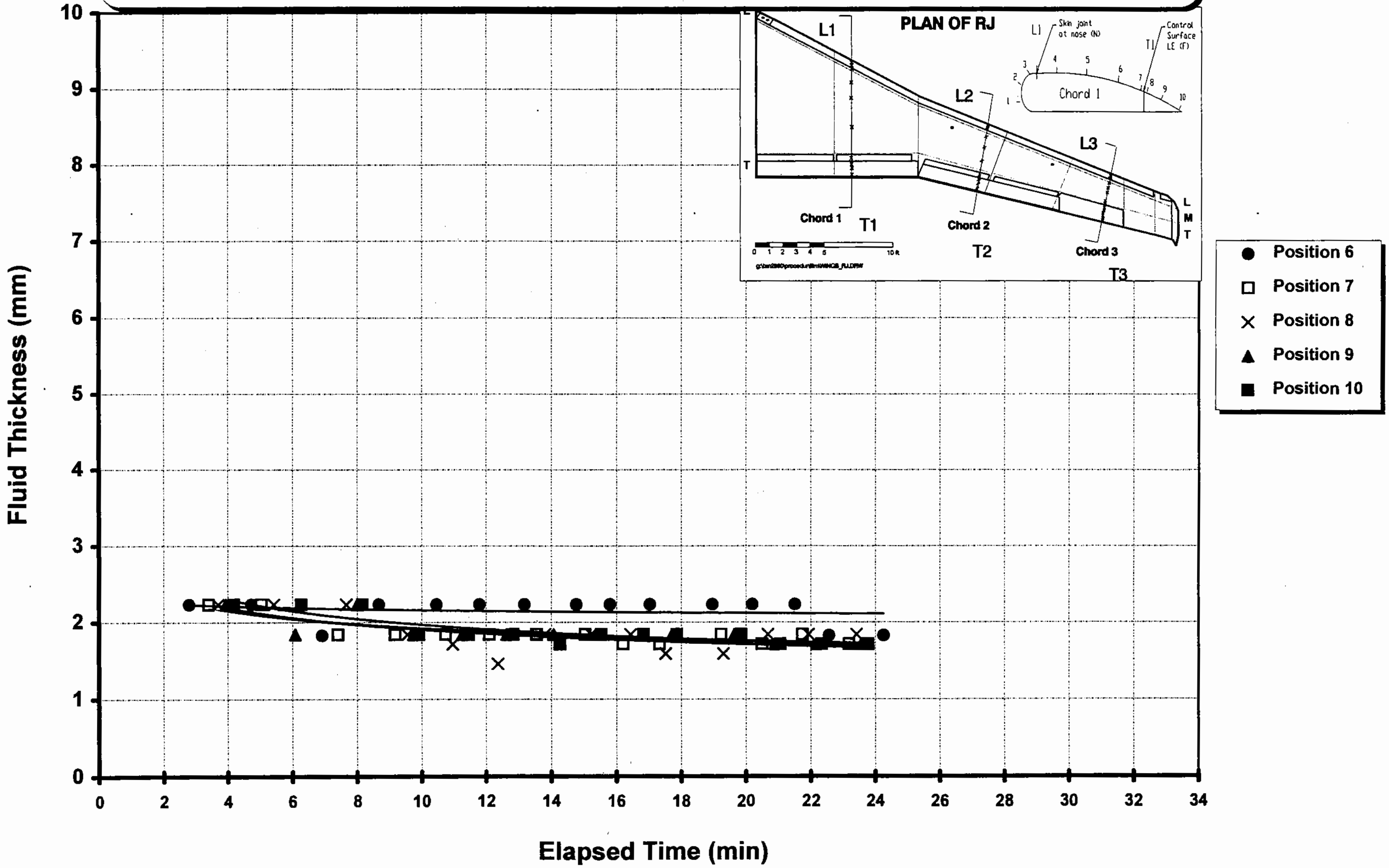
RUN 3 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T1

1st FLUID: ULTRA TYPE IV / 73 LITRES

2nd FLUID: NIL

Temperature: -17.6°C | Wind Speed: 7.3 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R3.XLS
At: T1_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

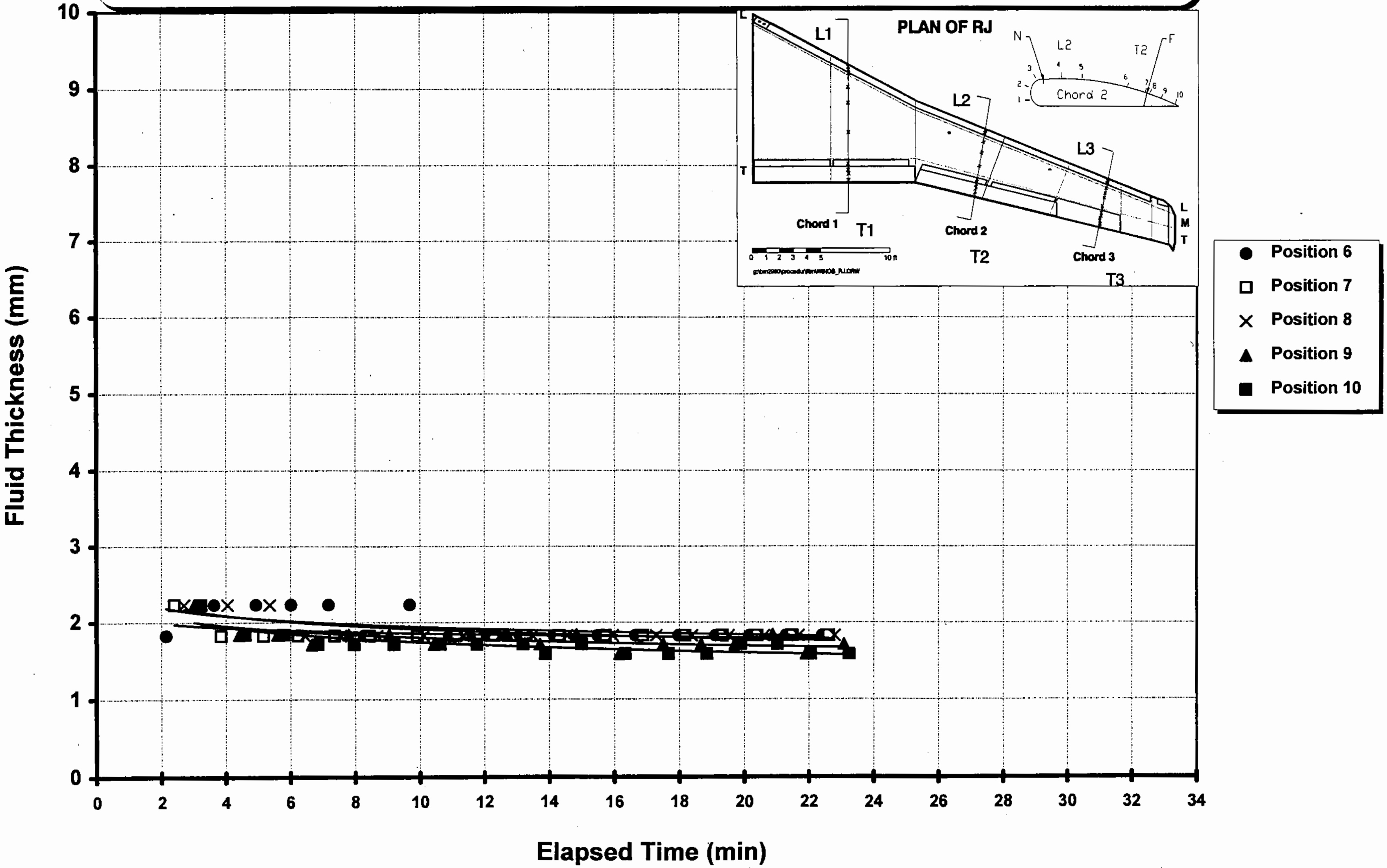
RUN 3 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T2

1st FLUID: ULTRA TYPE IV / 73 LITRES

2nd FLUID: NIL

Temperature: -17.6°C Wind Speed: 7.3 kph Nozzle Type: AKRON



E-70

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R3.XLS
At: T2_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

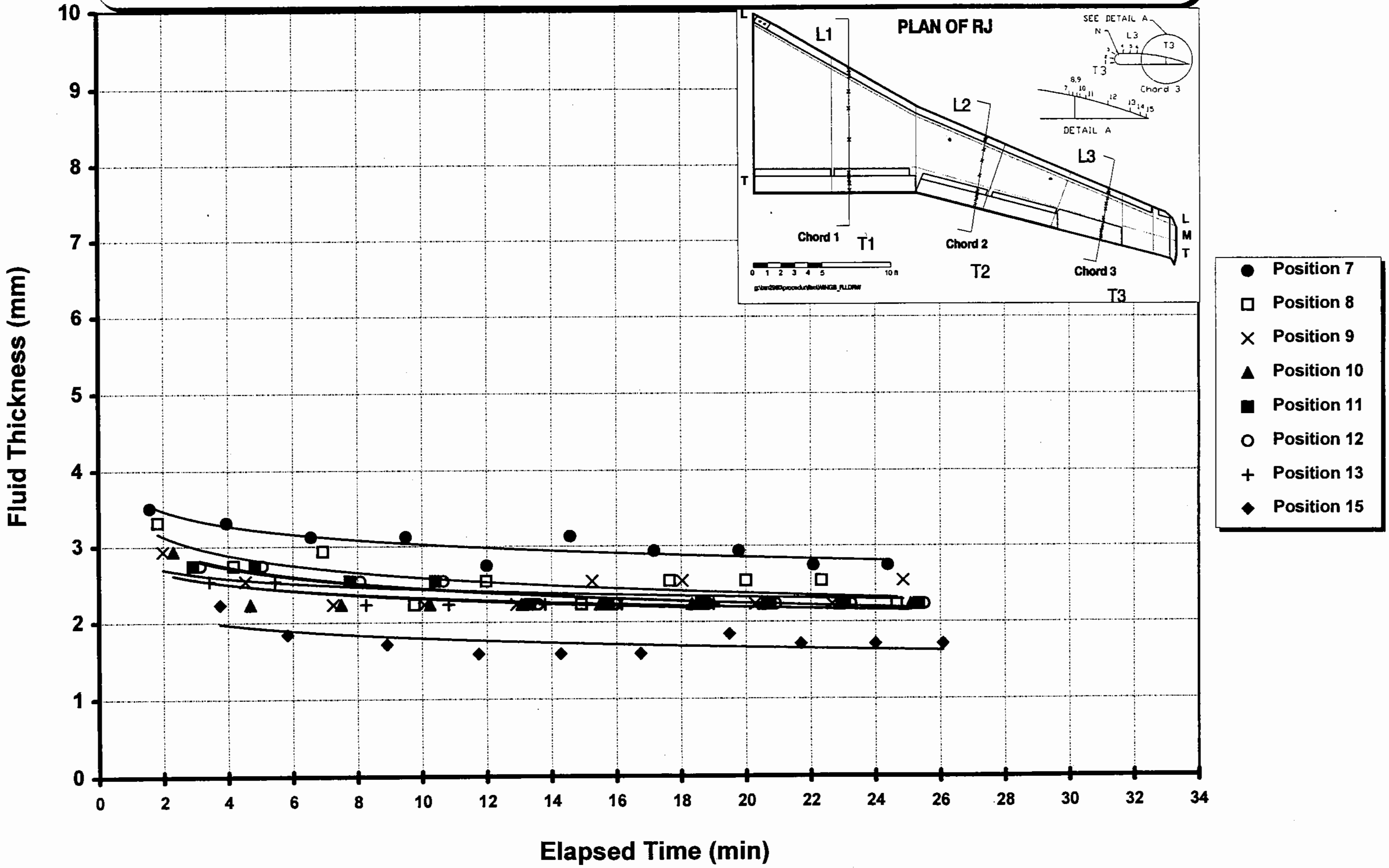
RUN 3 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T3

1st FLUID: ULTRA TYPE IV / 73 LITRES

2nd FLUID: NIL

Temperature: -17.6°C | Wind Speed: 7.3 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R3.XLS
At: T3_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

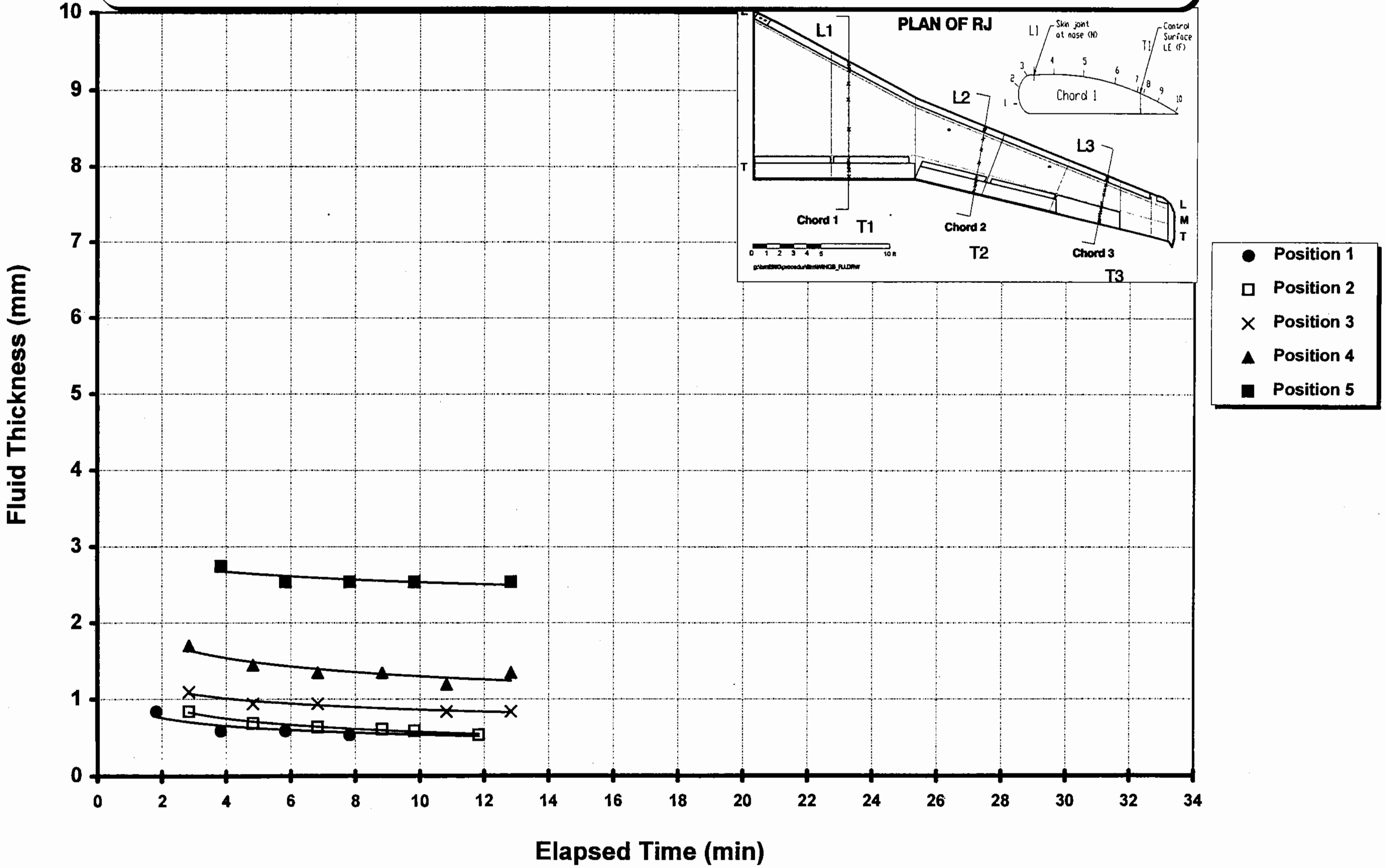
RUN 4 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L1

1st FLUID: XL54 TYPE I / 109 LITRES

2nd FLUID: ULTRA TYPE IV / 109 LITRES

Temperature: -17.9°C | Wind Speed: 6.7 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R4.XLS
At: L1_CHT

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

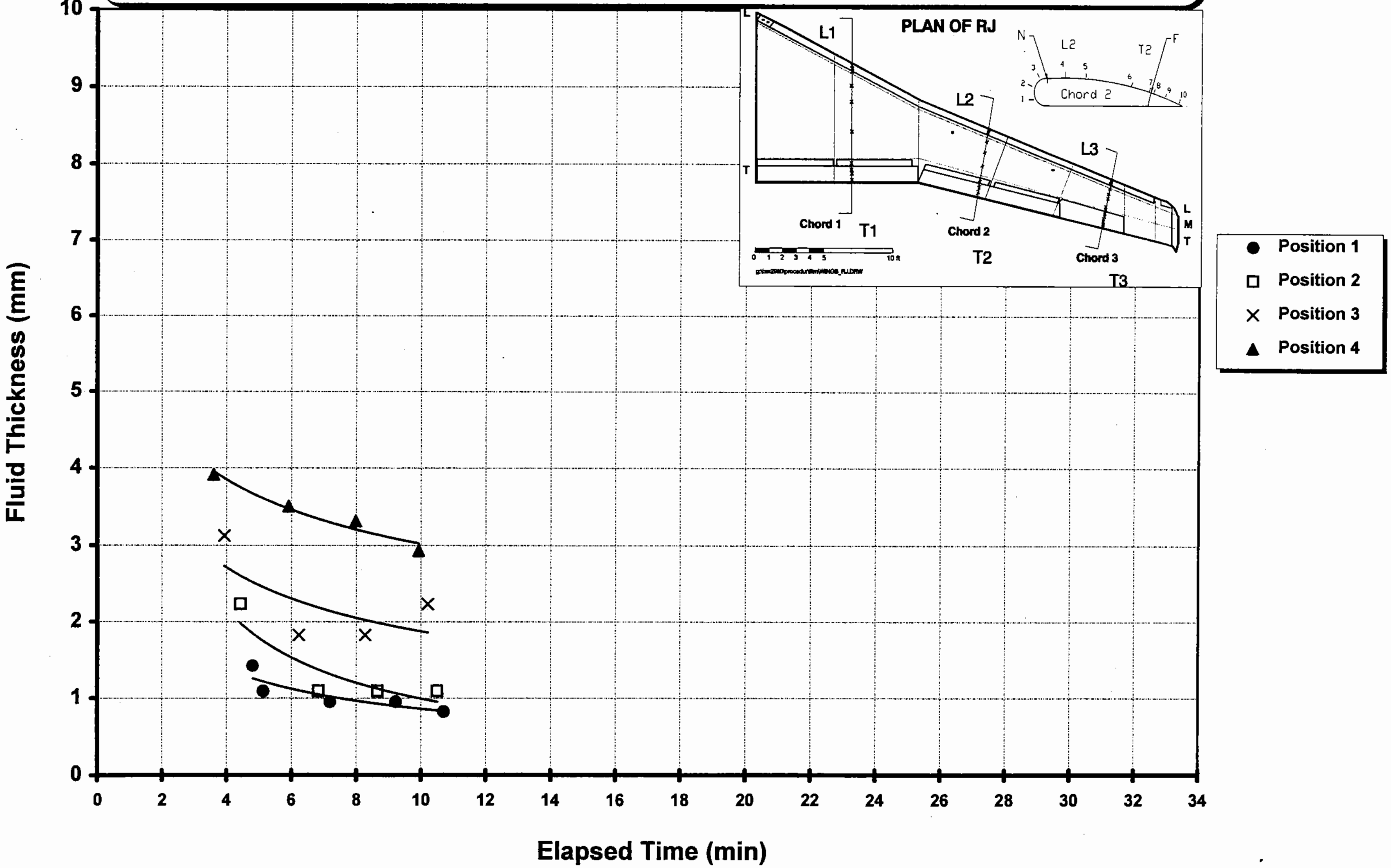
RUN 4 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L2

1st FLUID: XL54 TYPE I / 109 LITRES

2nd FLUID: ULTRA TYPE IV / 109 LITRES

Temperature: -17.9°C Wind Speed: 6.7 kph Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R4.XLS
At: L2_CHT
Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

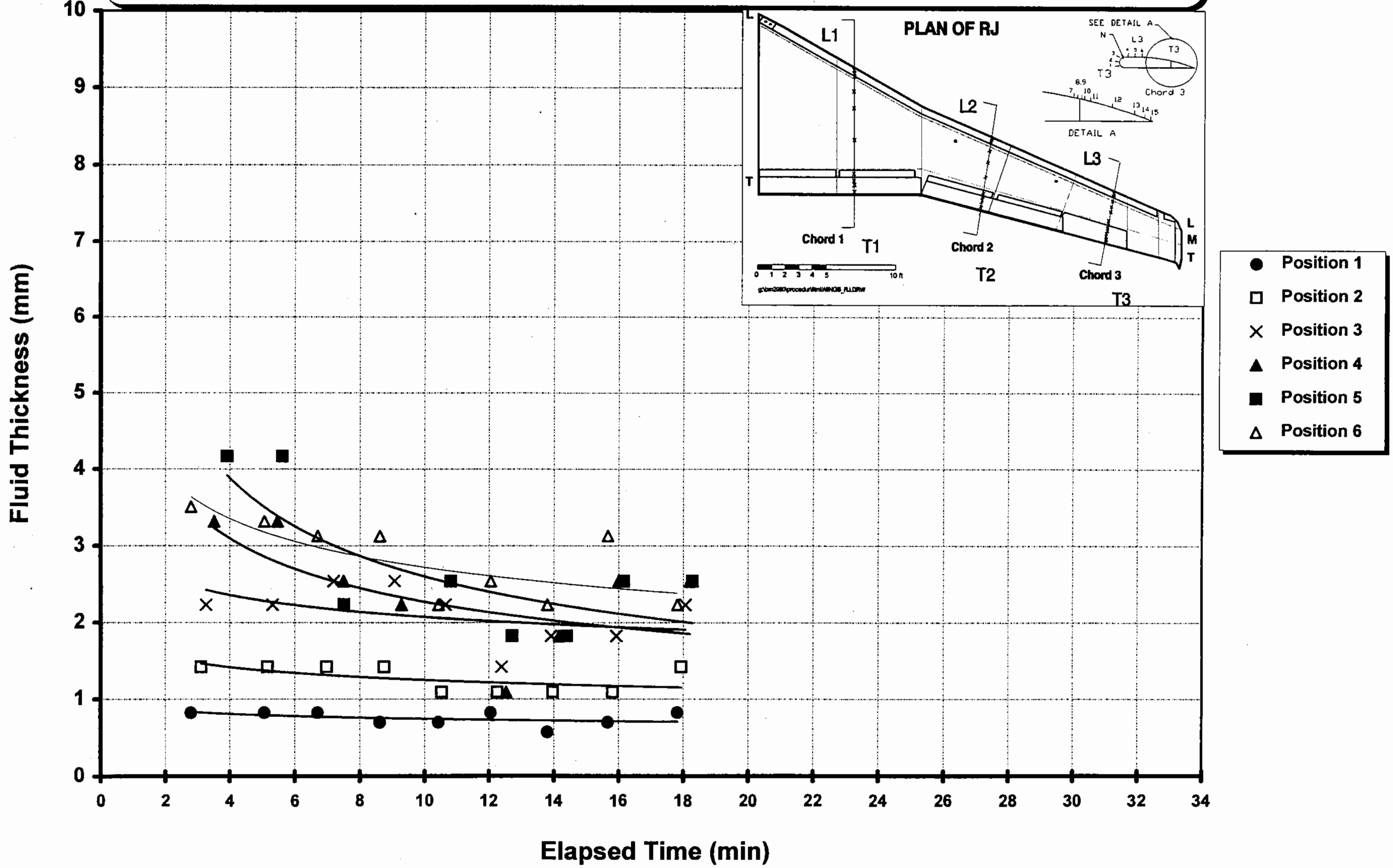
RUN 4 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION L3

1st FLUID: XL54 TYPE I / 109 LITRES

2nd FLUID: ULTRA TYPE IV / 109 LITRES

Temperature: -17.9°C | Wind Speed: 6.7 kph | Nozzle Type: AKRON

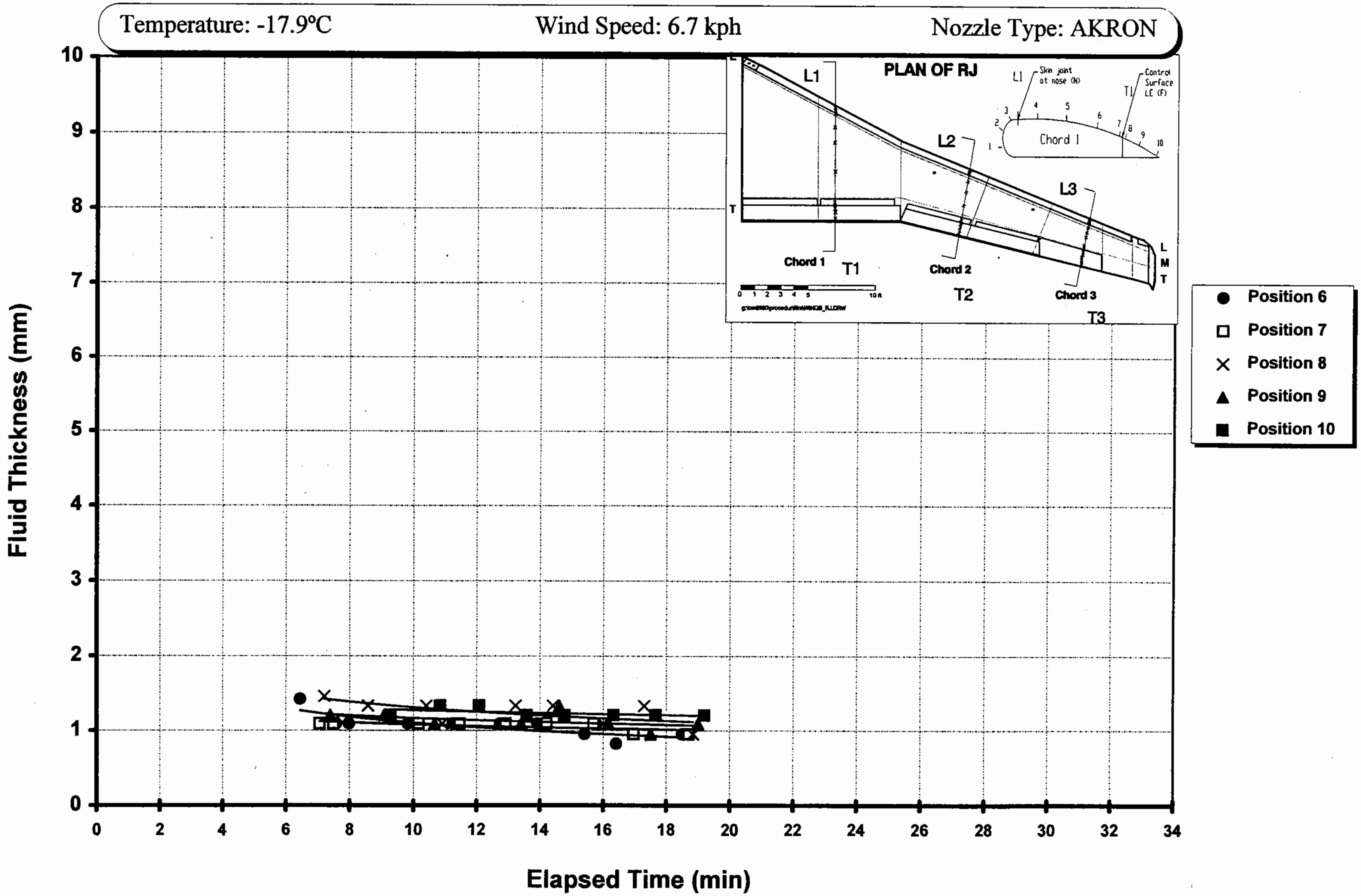


E-74

File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R4.XLS
At: L3_CHT
Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

RUN 4 - FEBRUARY 15, 1996
CANADAIR RJ - LOCATION T1
1st FLUID: XL54 TYPE I / 109 LITRES
2nd FLUID: ULTRA TYPE IV / 109 LITRES



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R4.XLS
At: T1_CHT
Printed:09/12/96

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

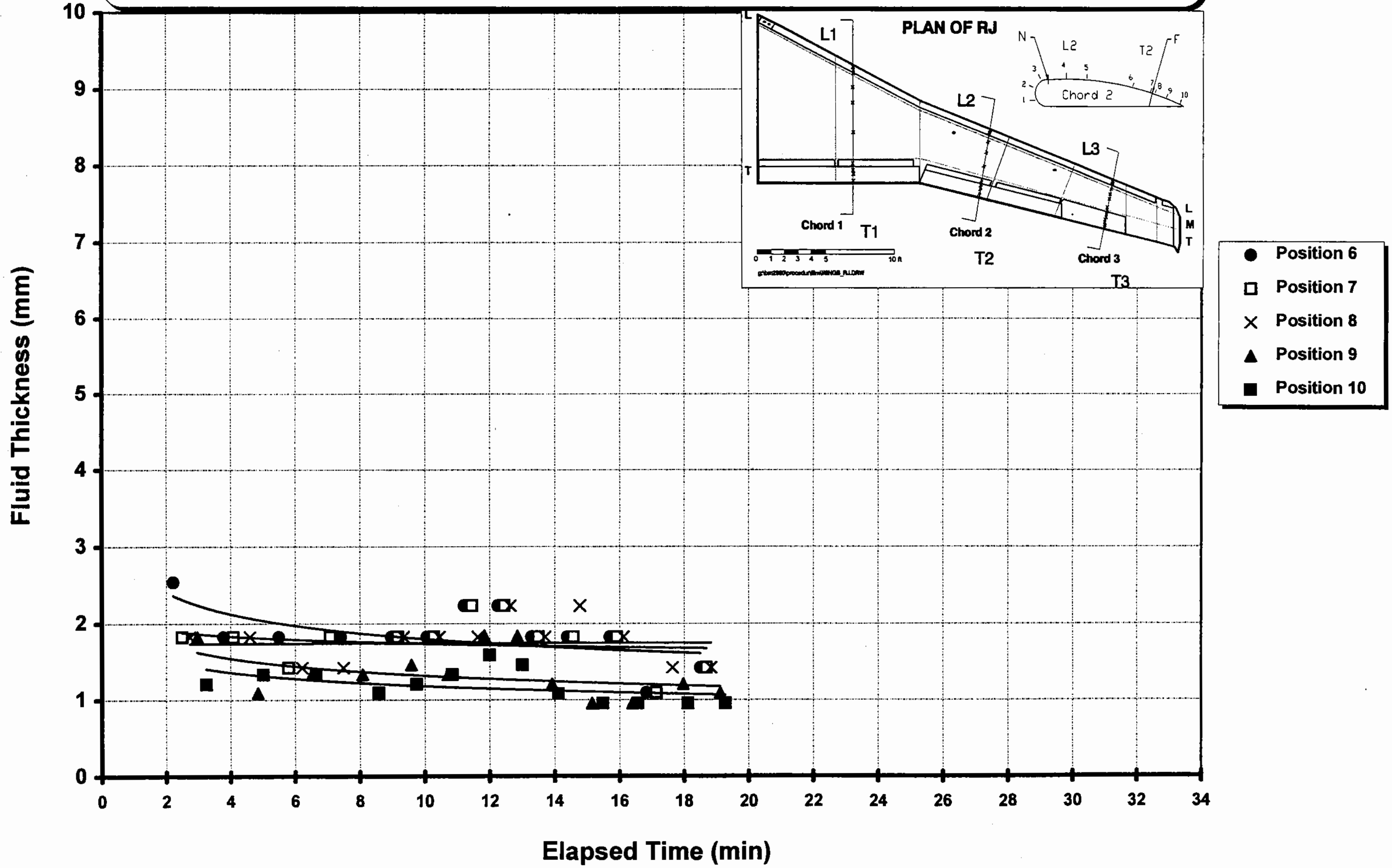
RUN 4 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T2

1st FLUID: XL54 TYPE I / 109 LITRES

2nd FLUID: ULTRA TYPE IV / 109 LITRES

Temperature: -17.9°C   Wind Speed: 6.7 kph   Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R4.XLS
At: T2_CHT
Printed:00/12/06

FLUID THICKNESS DECAY OF VARIOUS WING POSITIONS

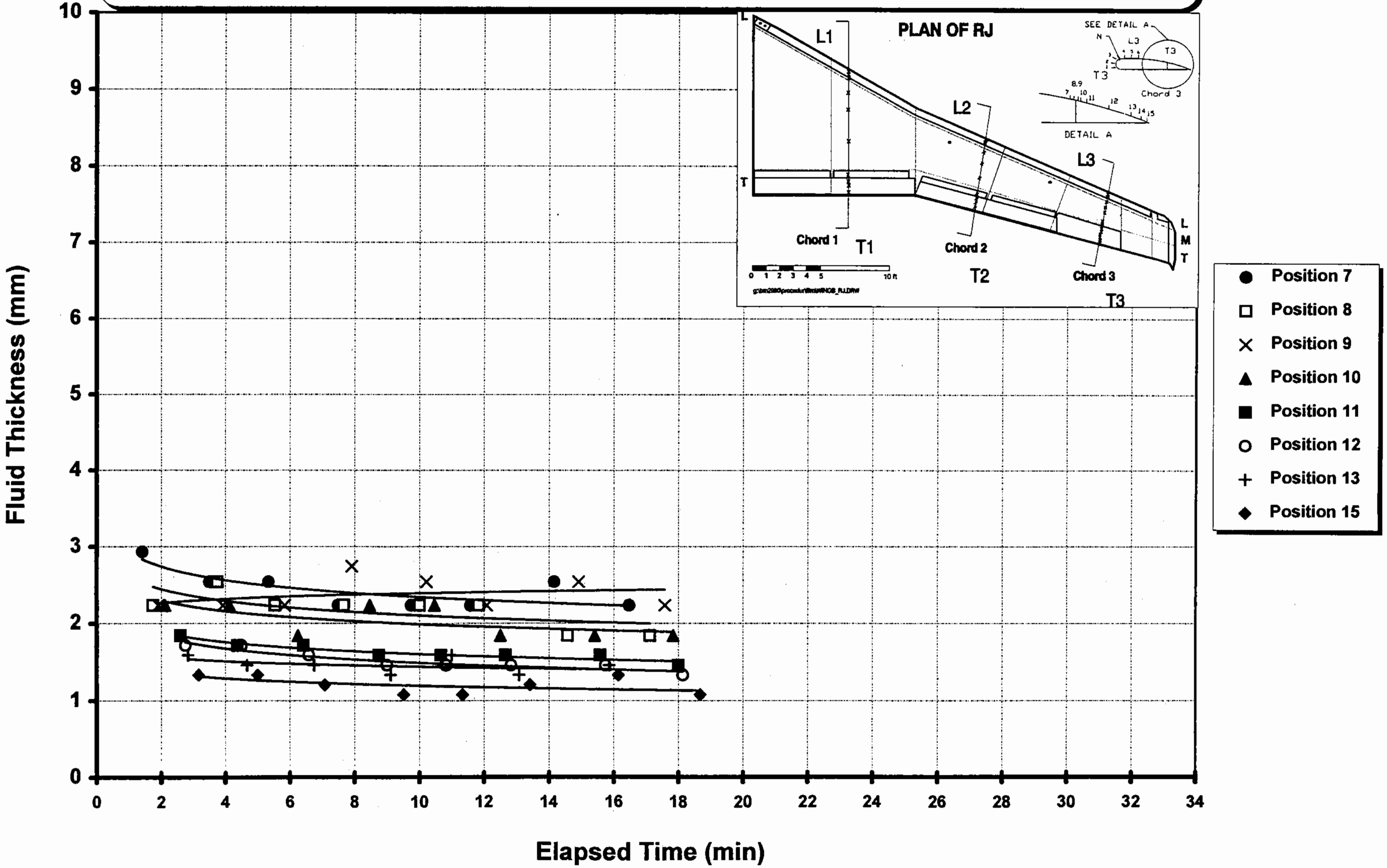
RUN 4 - FEBRUARY 15, 1996

CANADAIR RJ - LOCATION T3

1st FLUID: XL54 TYPE I / 109 LITRES

2nd FLUID: ULTRA TYPE IV / 109 LITRES

Temperature: -17.9°C | Wind Speed: 6.7 kph | Nozzle Type: AKRON



File:g:\cm1283\analysis\ac_tests\thk_test\FEB15_R4.XLS
At: T3_CHT
Printed:09/12/96

APPENDIX F

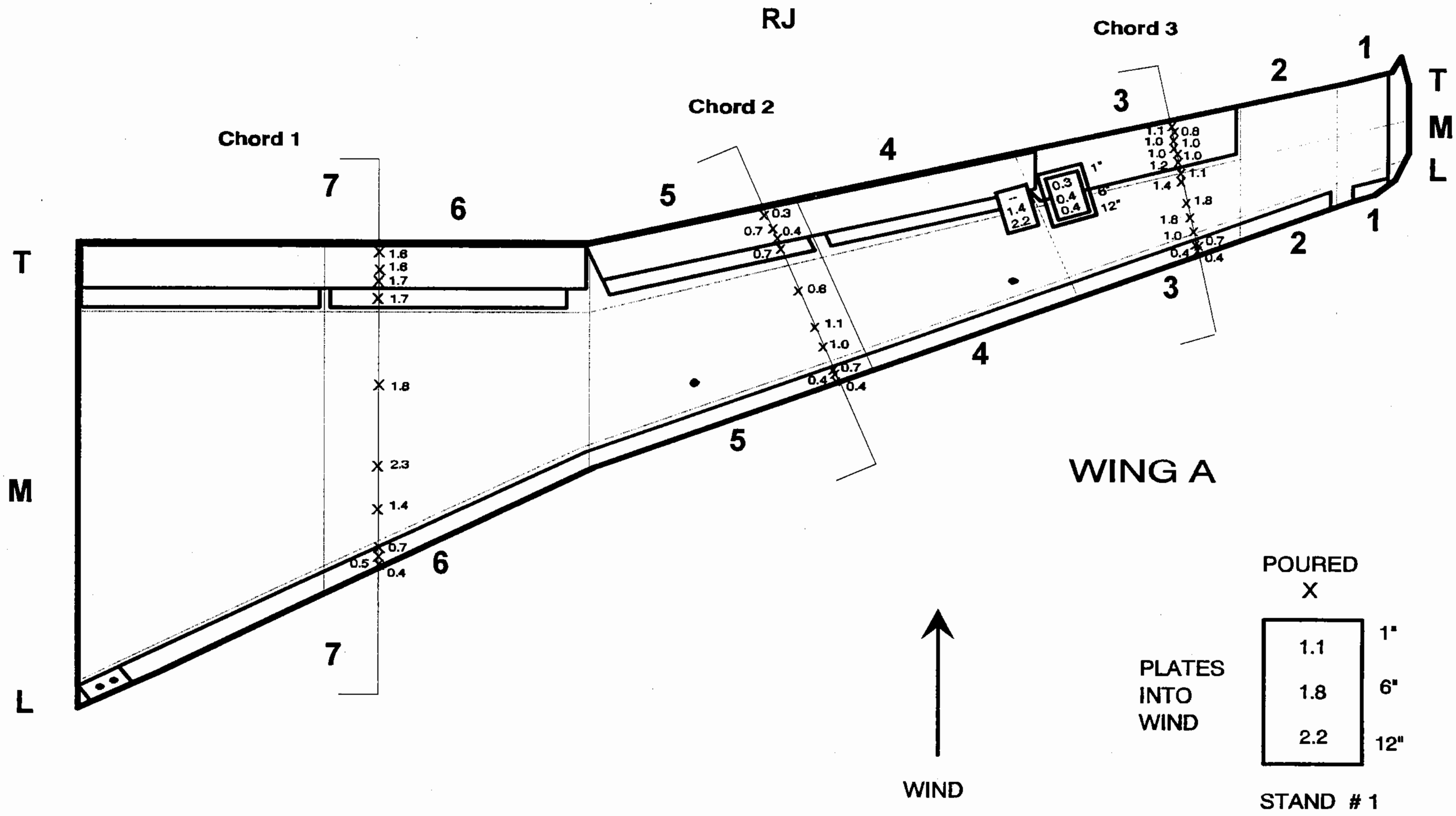
FLUID THICKNESS VALUES REPORTED ON WING PLANS

FIGURE F-1

CANADAIR RJ STABILIZED THICKNESS ON WING PLAN

Run 1 - Feburary 15, 1996, Ultra (Contaminated Tips Nozzle)

(mm)



File:g/cm1283/report/film/RJ-AFR1.XLS
Date:30/09/96

FIGURE F-2

CANADAIR RJ STABILIZED THICKNESS ON WING PLAN

Run 2 - Feburary 15, 1996, Ultra (Contaminated Tips Nozzle)

(mm)

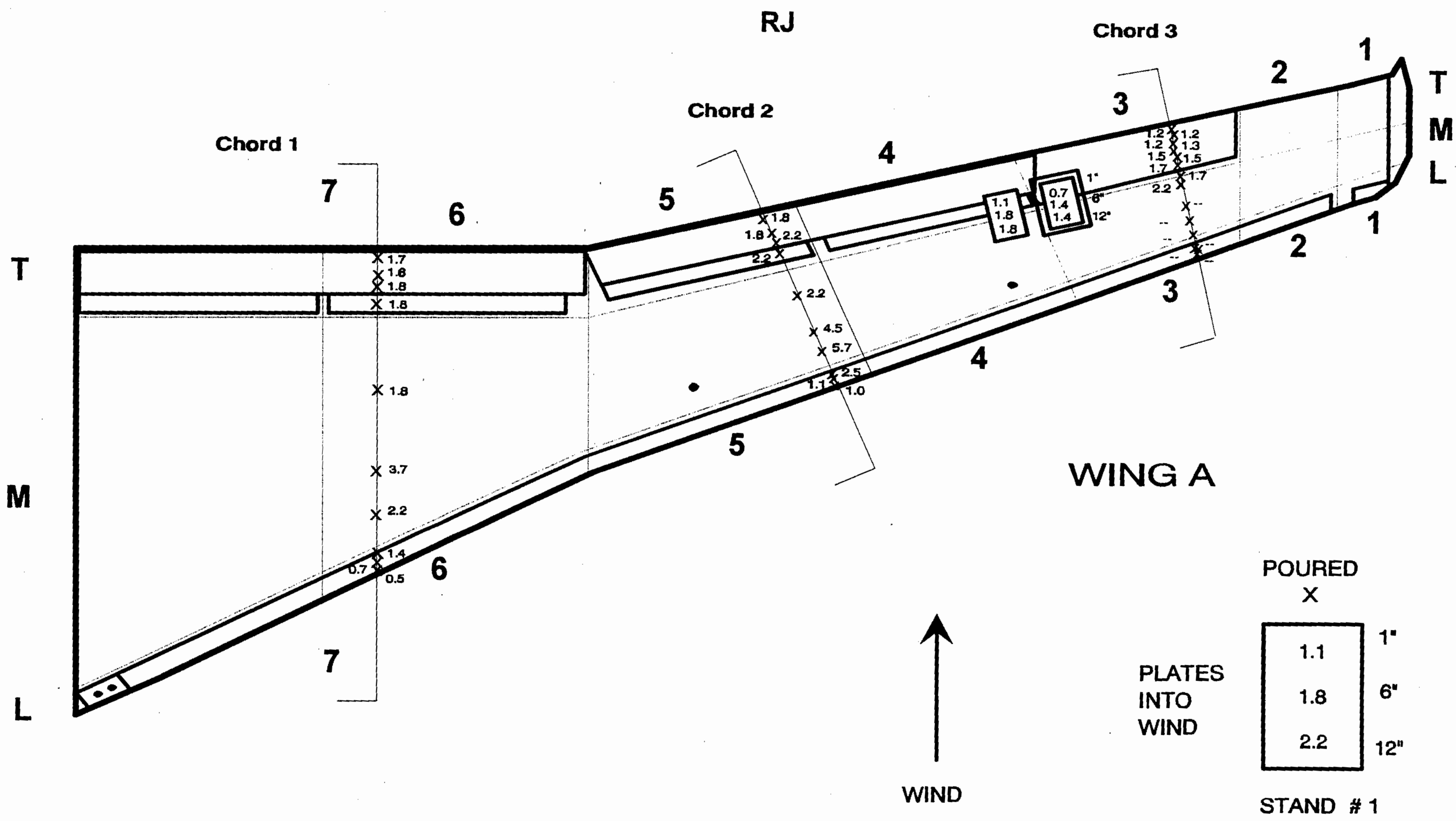
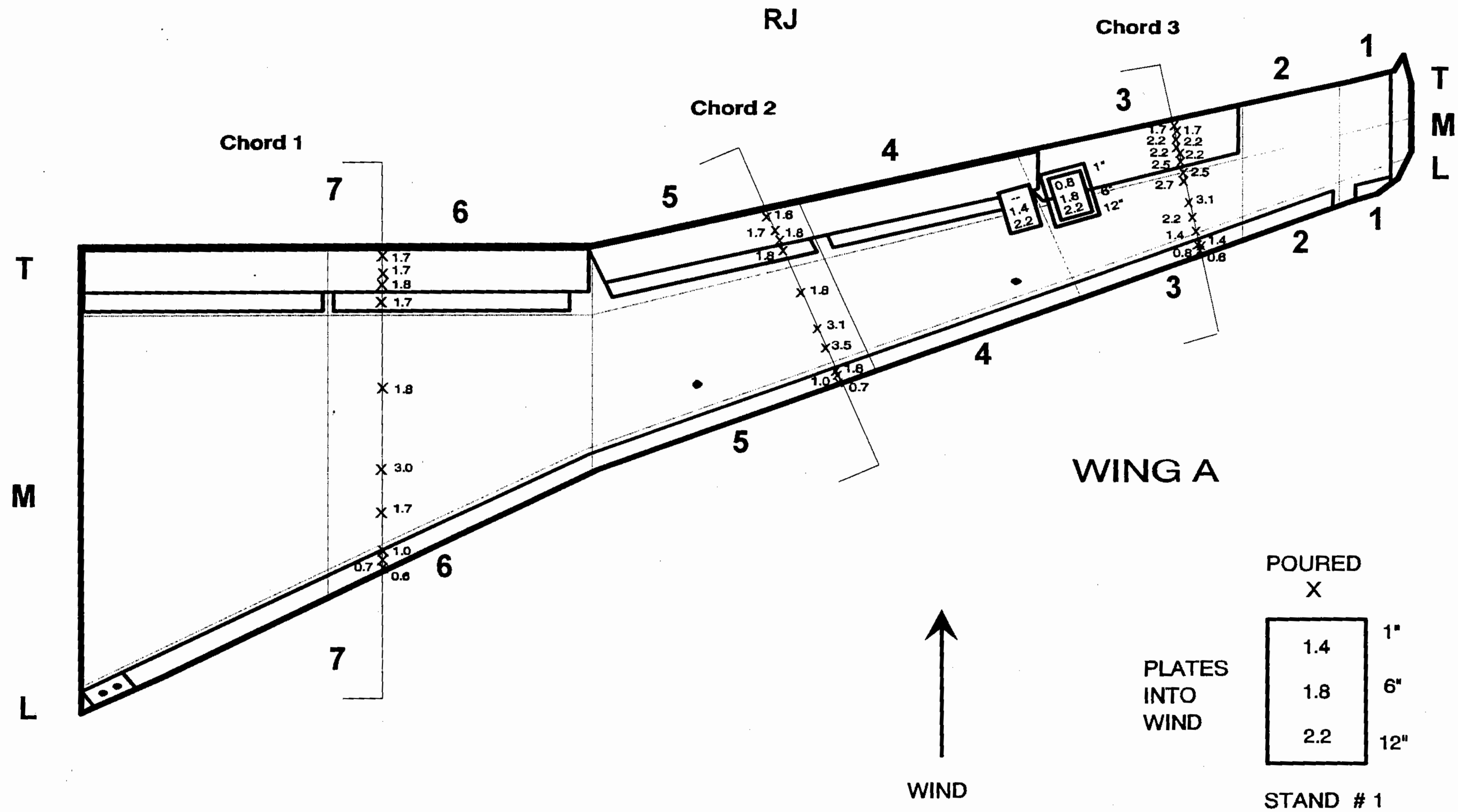


FIGURE F-3

CANADAIR RJ STABILIZED THICKNESS ON WING PLAN

Run 3 - Feburary 15, 1996, Ultra

(mm)



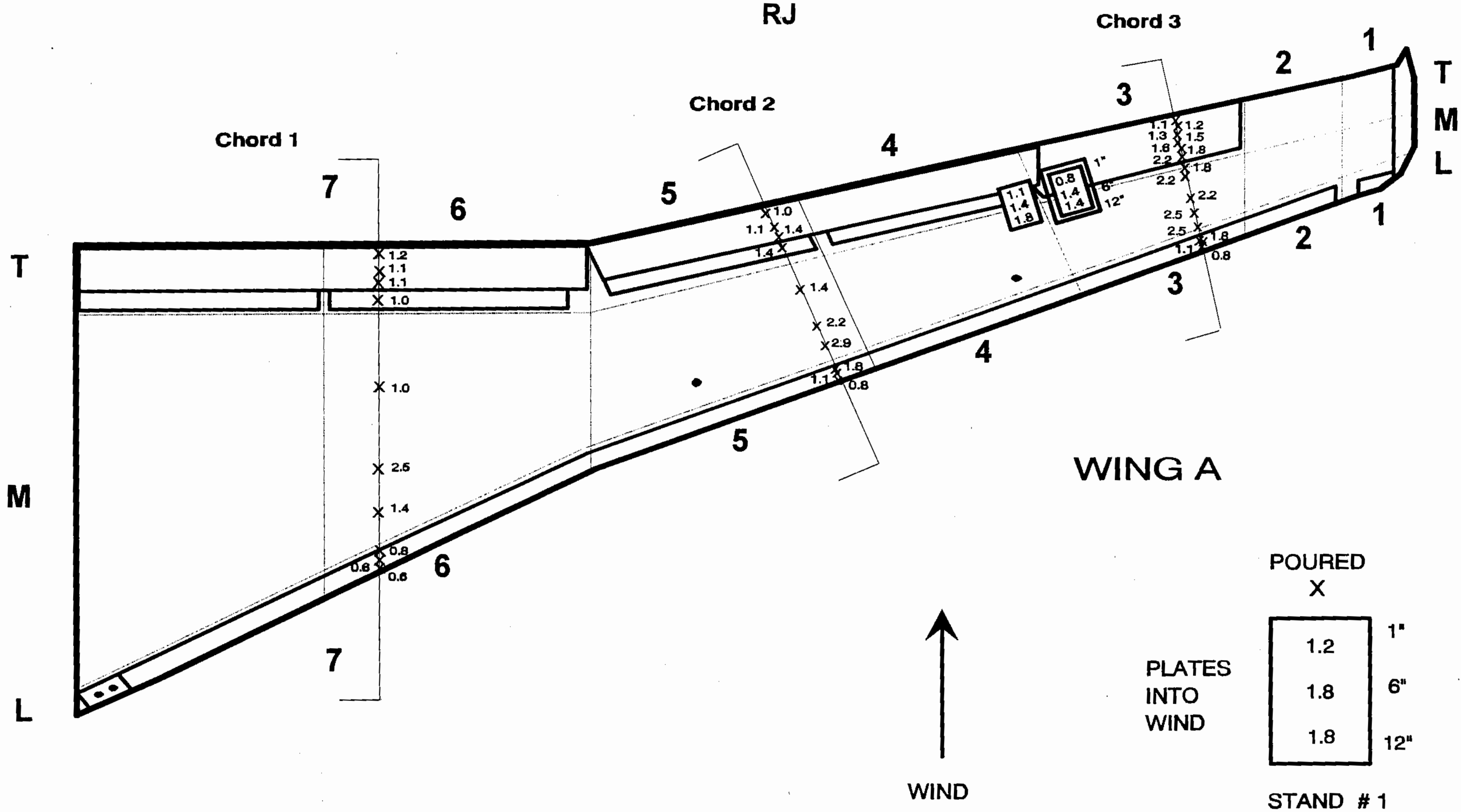
F-3

FIGURE F-4

CANADAIR RJ STABILIZED THICKNESS ON WING PLAN

Run 4 - Feburary 15, 1996, XL54 + Ultra

(mm)



File:g/cm1283/reportr/film/RJ-AFR4.XLS
Date:19/09/96

FIGURE F-5

DC-9 STABILIZED FLUID THICKNESS ON WING PLAN
Run 1 - March 12, 1996, Ultra
(mm)

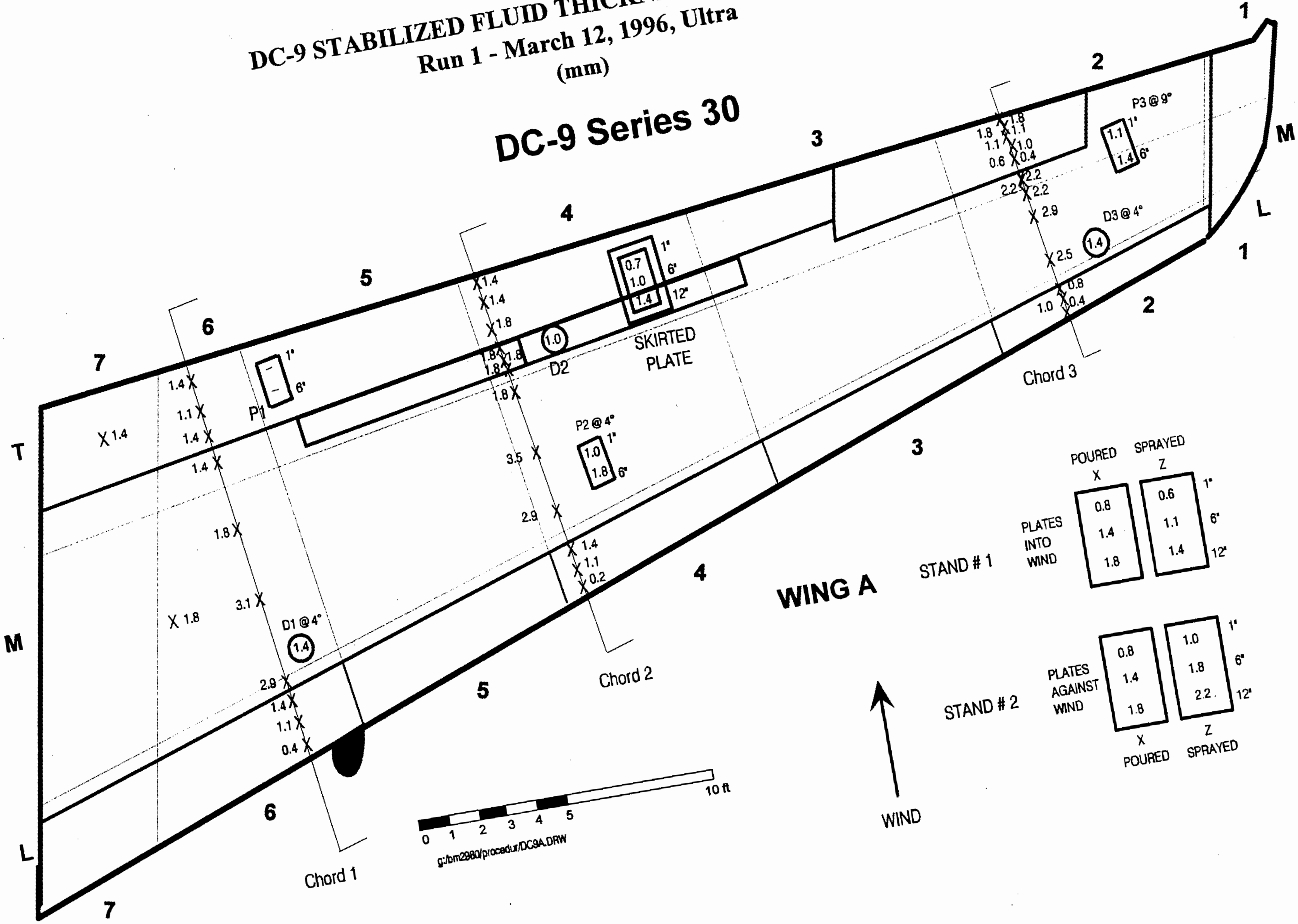


FIGURE F-6

DC-9 STABILIZED FLUID THICKNESS ON WING PLAN
Run 2 - March 12, 1996, Ultra
(mm)

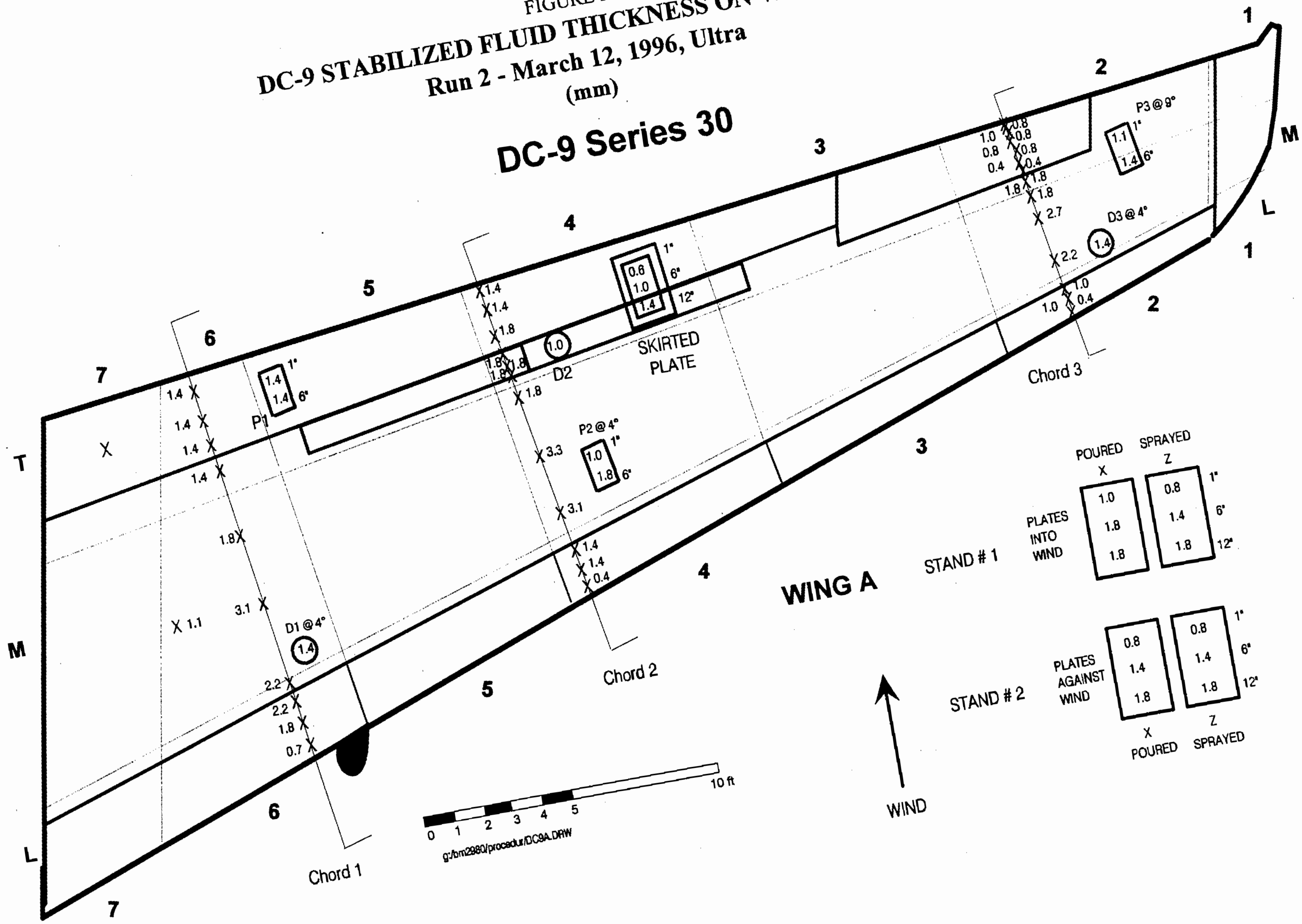
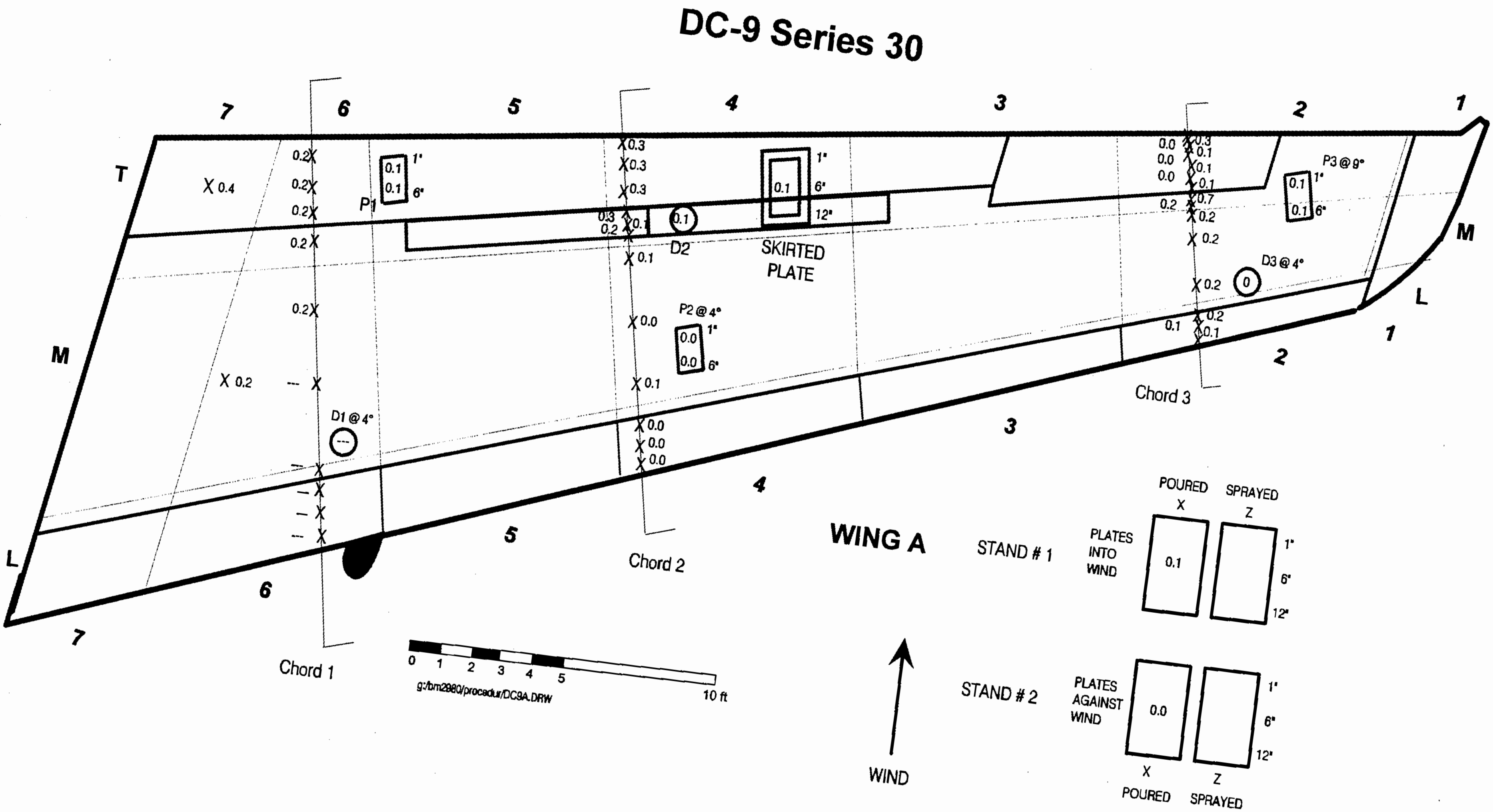


FIGURE F-7

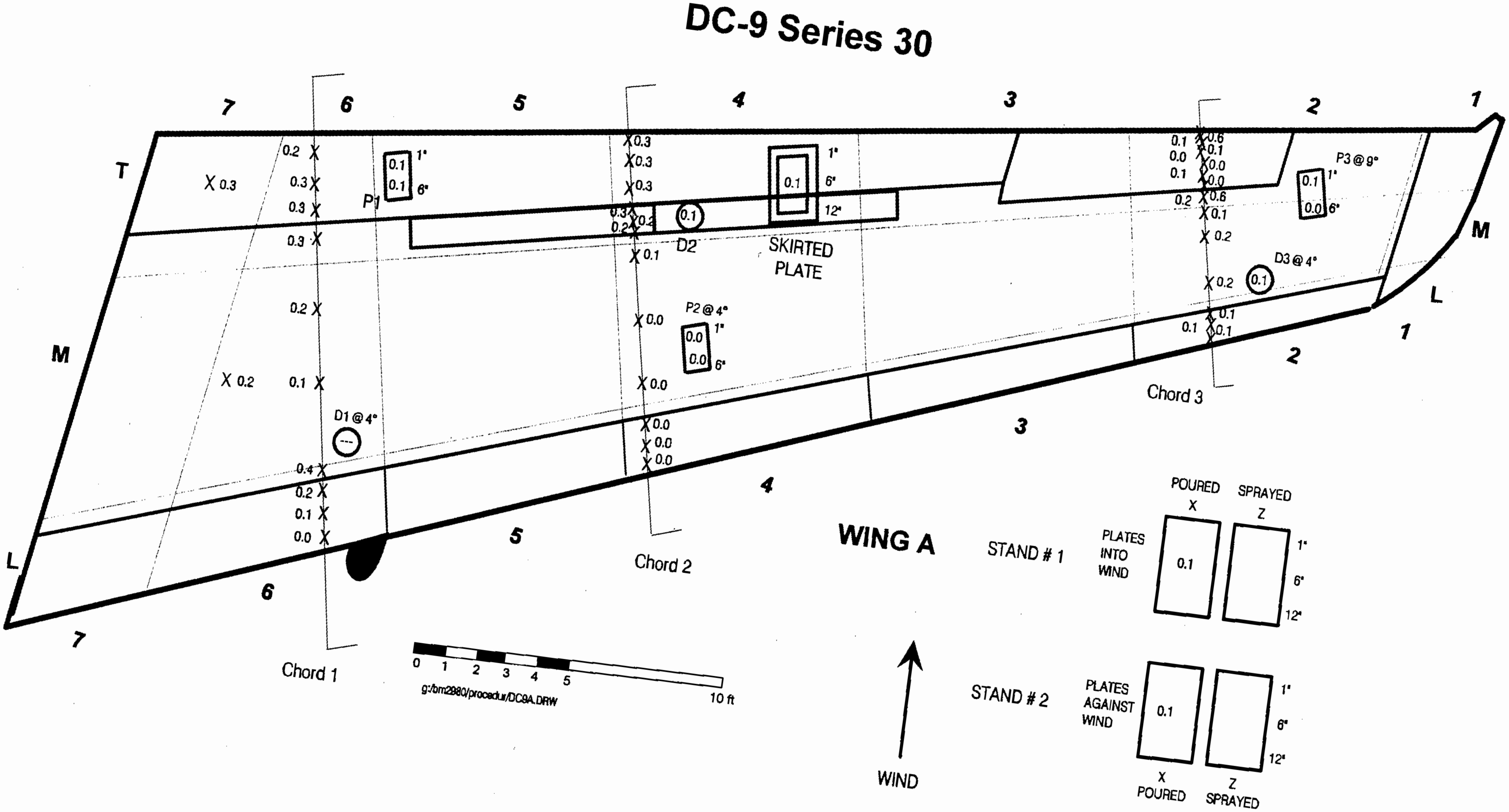
DC-9 STABILIZED FLUID THICKNESS ON WING PLAN
Run 3 - March 12, 1996, XL54
(mm)



F-7

FIGURE F-8

DC-9 STABILIZED FLUID THICKNESS ON WING PLAN
Run 4 - March 12, 1996, XL54
(mm)

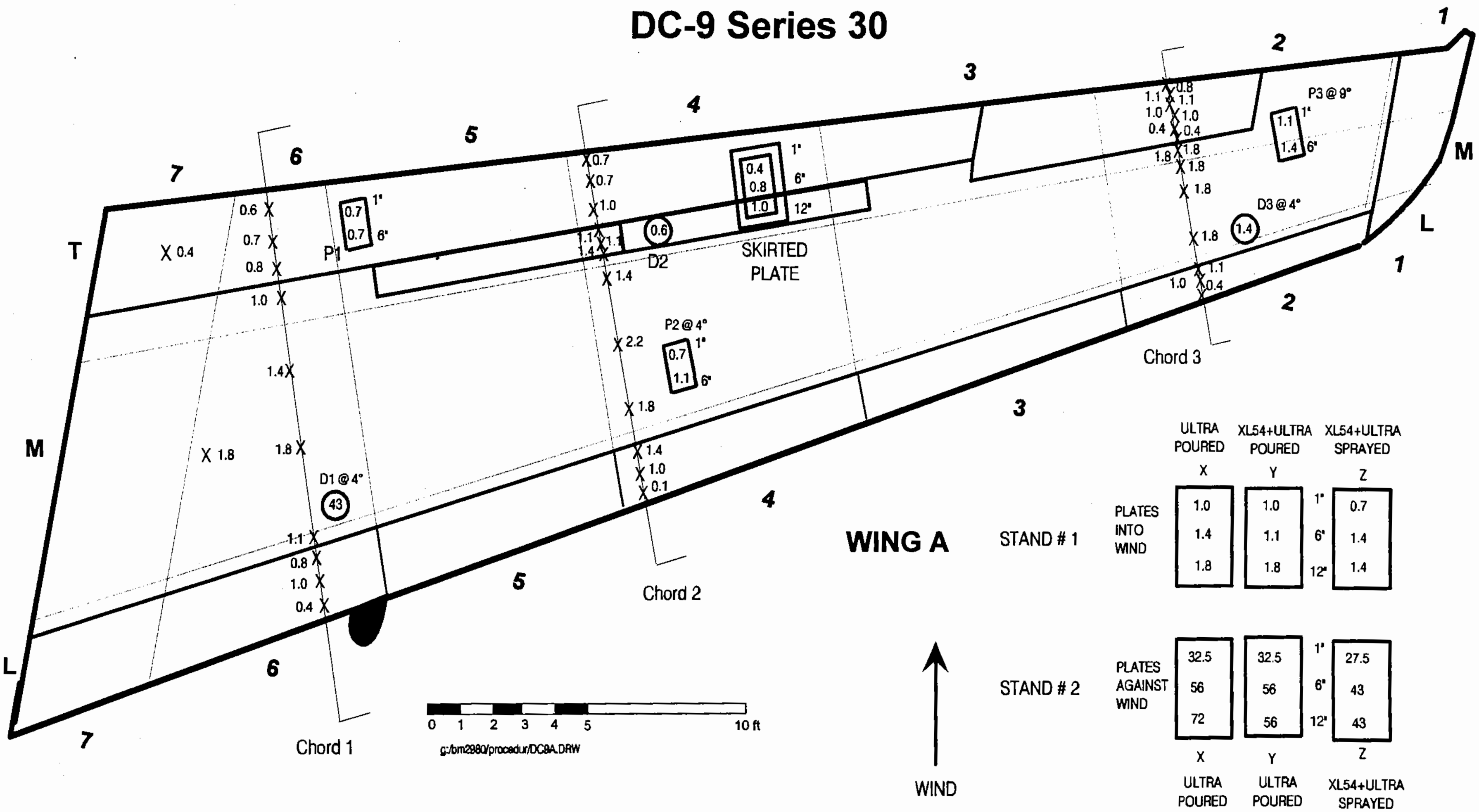


F-8

File:g/cm1283/report/film/DC9_AFR4.XLS
Printed: 19/09/96

FIGURE F-9

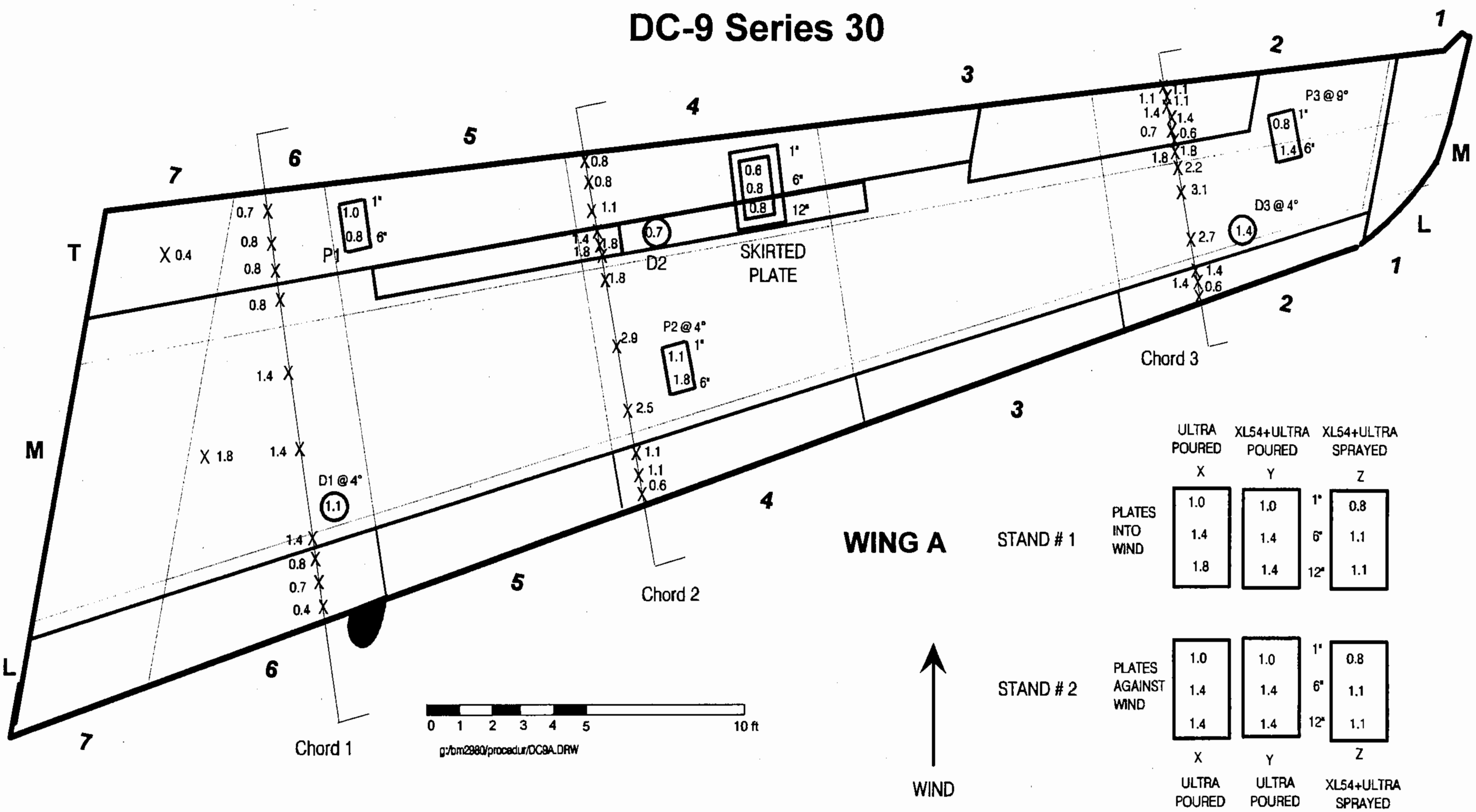
DC-9 STABILIZED FLUID THICKNESS ON WING PLAN
Run 5 - March 12, 1996, XL54 + Ultra
(mm)



File:g/cm1283/report/film/DC9_AFR5.XLS
Printed: 19/09/96

FIGURE F-10

DC-9 STABILIZED FLUID THICKNESS ON WING PLAN
Run 6 - March 12, 1996, XL54 + Ultra
(mm)



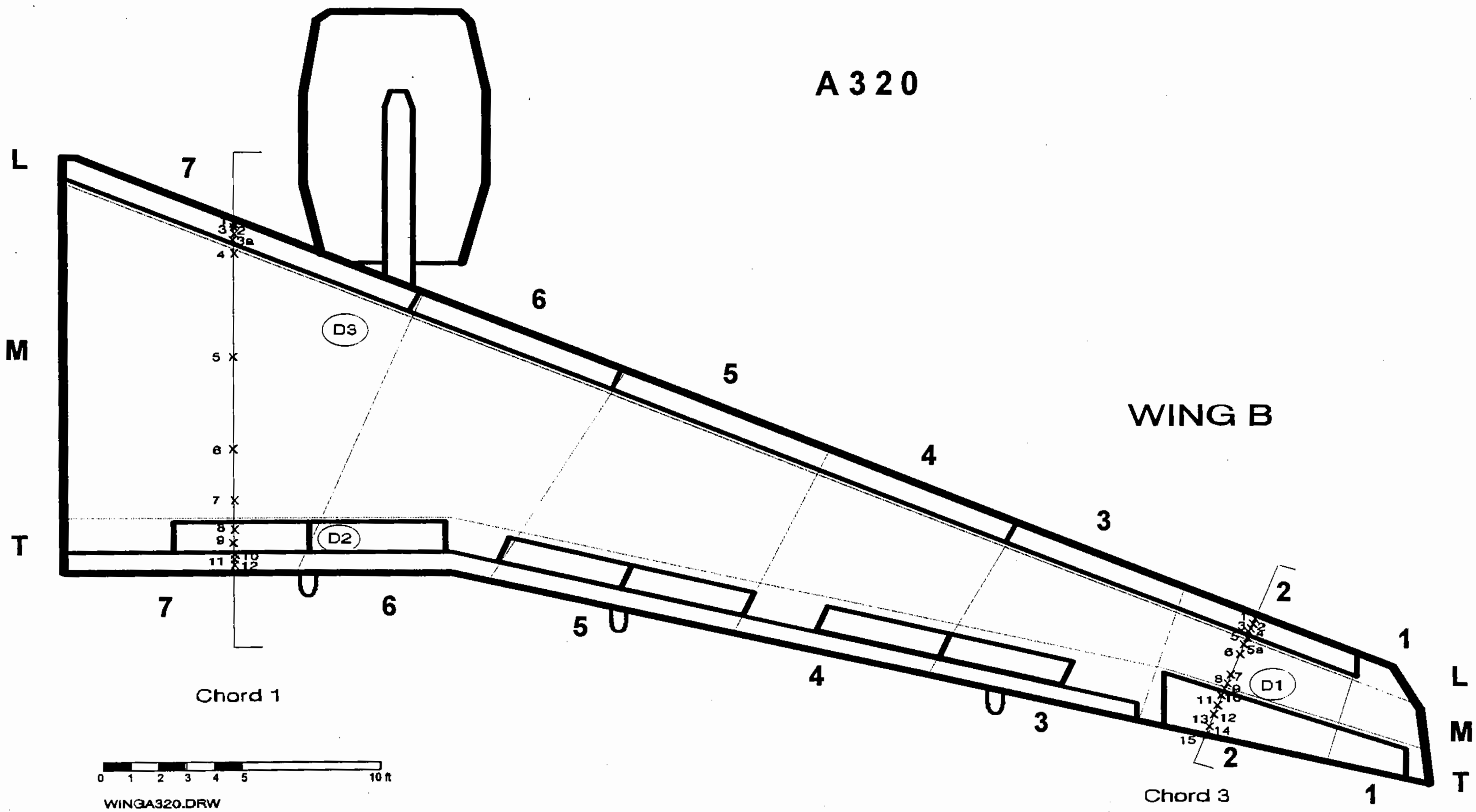
File:g/cm1283/report/film/DC9_AFR6.XLS
Printed: 19/09/96

FIGURE F-11

A320 STABILIZED THICKNESS ON WING PLAN

Run 1 - March 29, 1996, Ultra

(mm)



STABILIZED THICKNESS (mm)																
Location	1	2	3	3a	4	5	6	7	8	9	10	11	12	Disk 2	Disk 3	
Chord 1	0.4	0.5	0.8	1.4	1.8	1.0	1.4	1.1	1.1	1.0	1.1	1.0	0.8	0.6	1.0	
Location	1	2	3	4	5	5a	6	7	8	9	10	11	12	13	14	15	Disk 1
Chord 3	0.6	0.7	1.1	1.4	1.8	1.4	0.8	0.8	0.7	0.8	0.8	0.8	1.1	1.1	1.1	1.4	0.7

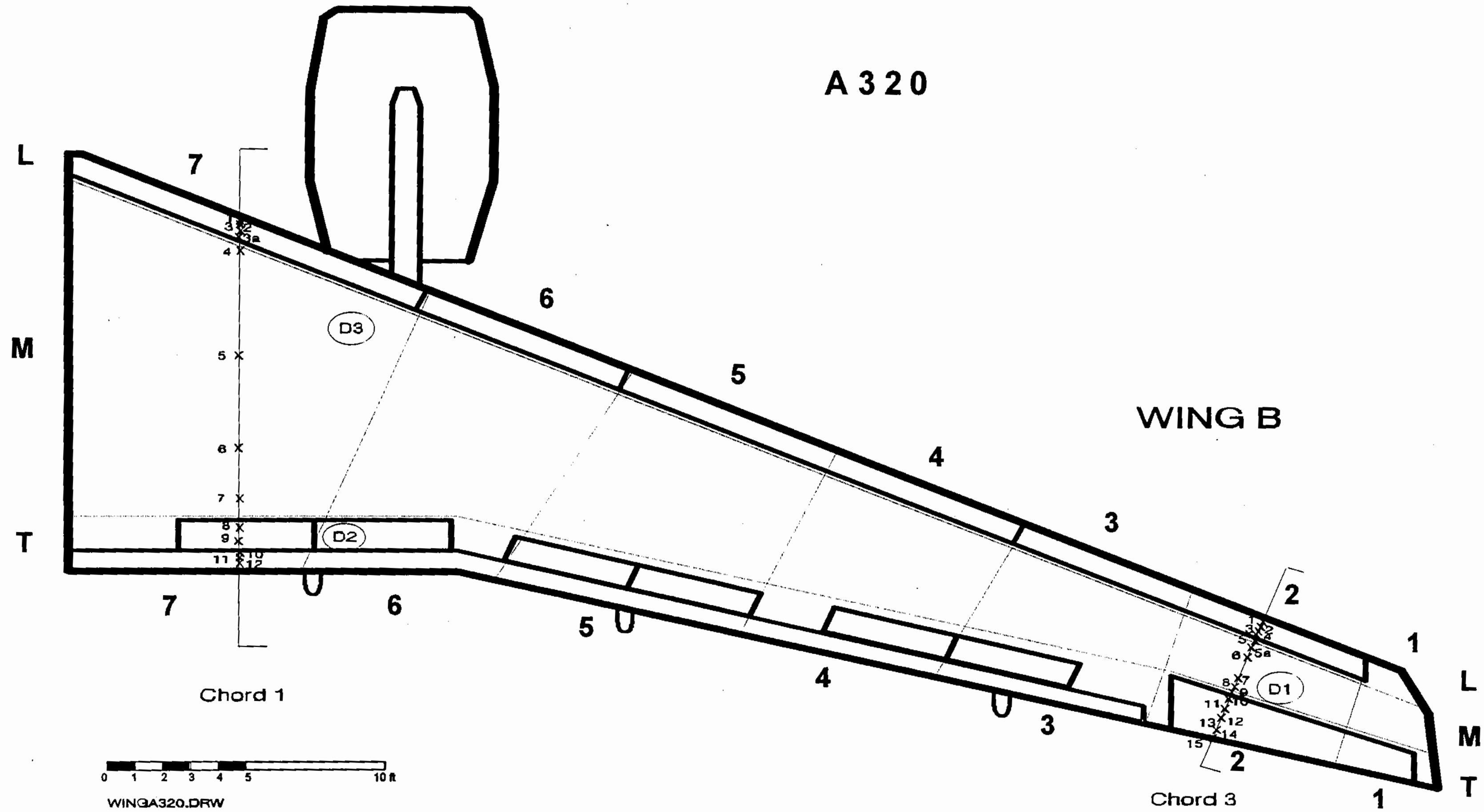
File:g/cm1283/report/film/A320_R1.XLS
Date:20/09/96

FIGURE F-12

A320 STABILIZED THICKNESS ON WING PLAN

Run 2 - March 29, 1996, Ultra

(mm)



STABILIZED THICKNESS (mm)																	
Location	1	2	3	3a	4	5	6	7	8	9	10	11	12	Disk 2	Disk 3		
Chord 1	0.7	1.4	2.2	4.5	4.5	5.7	1.8	2.2	2.2	1.8	2.2	1.8	1.8	1.8	2.5		
Location	1	2	3	4	5	5a	6	7	8	9	10	11	12	13	14	15	Disk 1
Chord 3	0.7	1.8	2.7	3.7	5.7	5.7	1.4	1.8	1.8	1.8	1.8	2.2	2.5	2.2	2.7	3.5	2.2

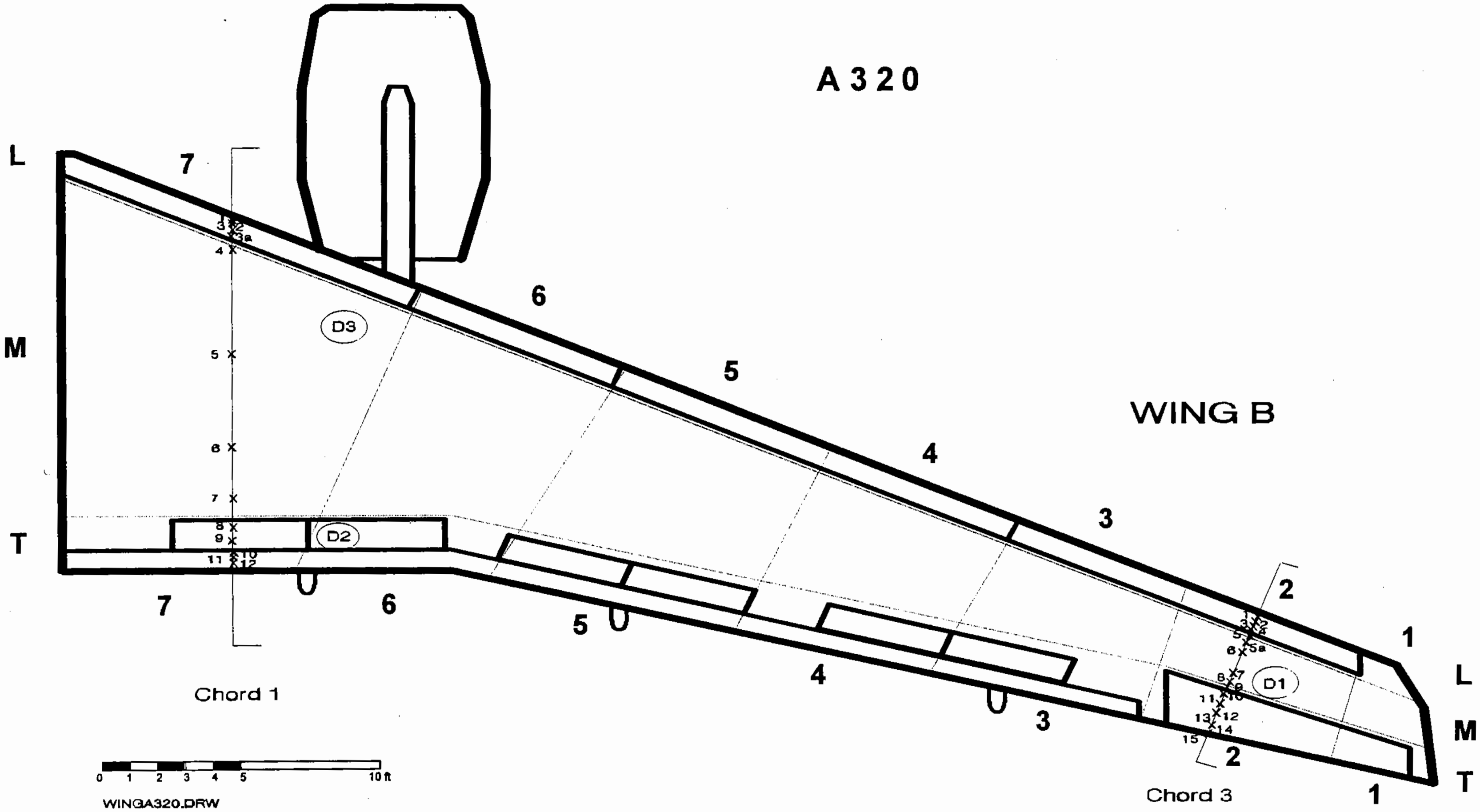
File:g/cm1283/report/film/A320_R2.XLS
Date:20/09/96

FIGURE F-13

A320 STABILIZED THICKNESS ON WING PLAN

Run 3 - March 29, 1996, XL54

(mm)



STABILIZED THICKNESS (mm)																
Location	1	2	3	3a	4	5	6	7	8	9	10	11	12	Disk 2	Disk 3	
Chord 1	0.1	0.1	0.1	0.2	0.2	0.2	0.6	0.7	0.6	0.4	0.6	0.4	0.6	0.4	0.1	
Location	1	2	3	4	5	5a	6	7	8	9	10	11	12	13	14	15	Disk 1
Chord 3	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.4	0.4	0.2	0.2	0.1

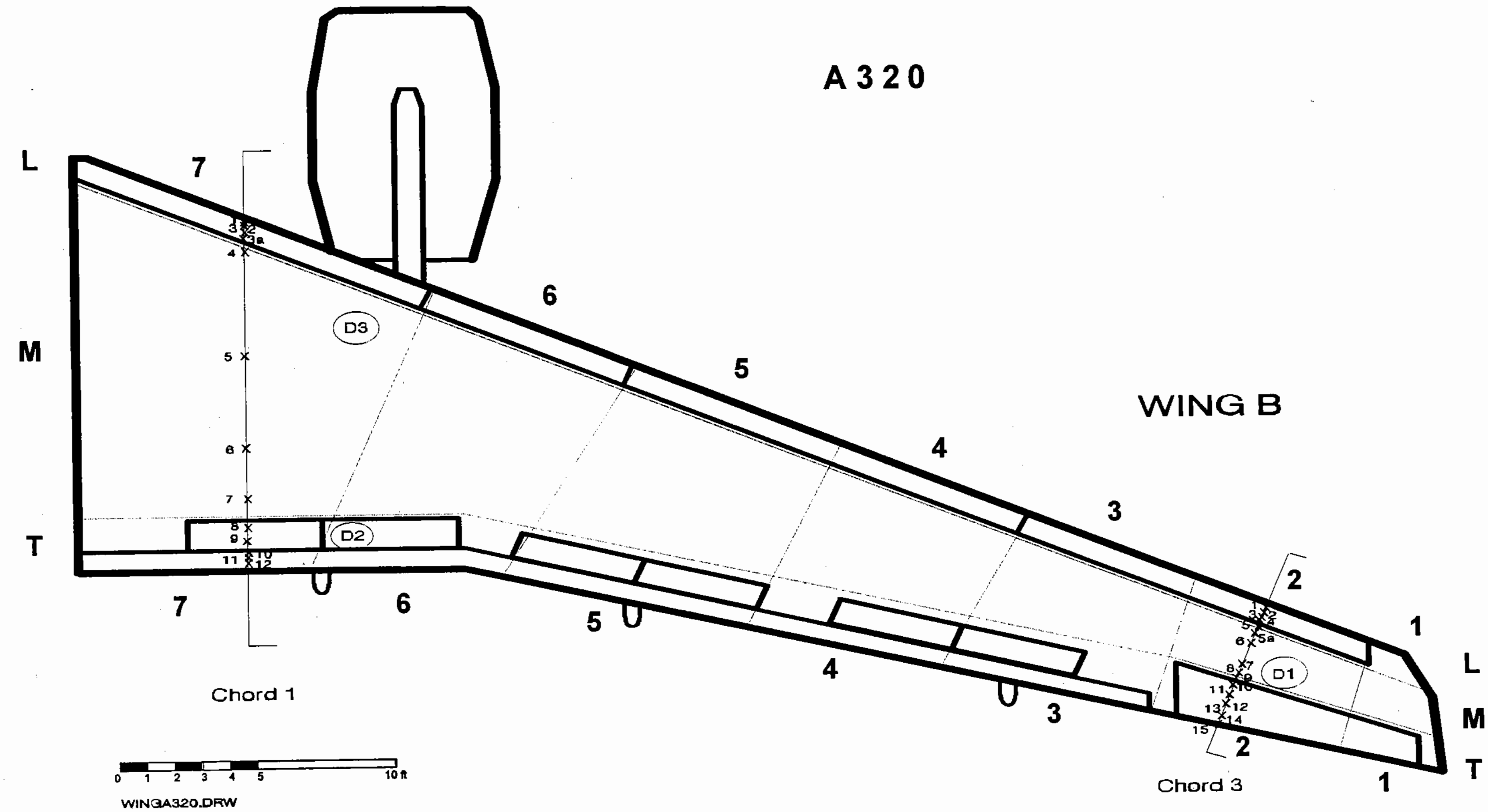
File:g/cm1283/report/film/A320_R3.XLS
Date:20/09/96

FIGURE F-14

A320 STABILIZED THICKNESS ON WING PLAN

Run 4 - March 29, 1996, XL54 + Ultra

(mm)



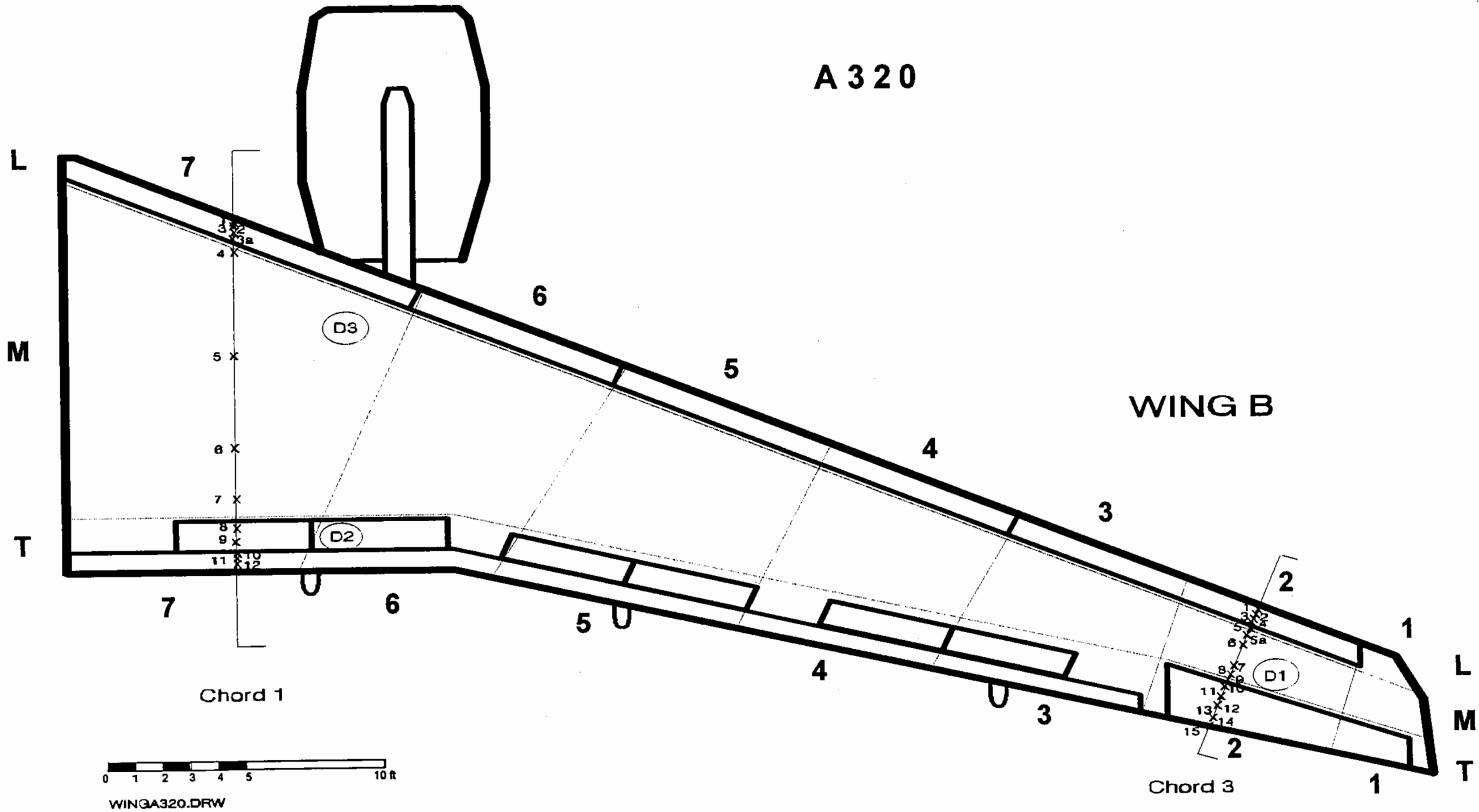
STABILIZED THICKNESS (mm)

Location	1	2	3	3a	4	5	6	7	8	9	10	11	12	Disk 2	Disk 3		
Chord 1	0.3	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.4	0.6	0.4	0.6	0.6	0.3		

Location	1	2	3	4	5	5a	6	7	8	9	10	11	12	13	14	15	Disk 1
Chord 3	0.5	1.4	2.2	1.4	0.5	0.8	0.8	0.8	0.8	0.8	1.0	1.1	1.4	1.4	1.4	2.2	1.8

File:g/cm1283/report/film/A320_R4.XLS
Date:20/09/96

FIGURE F-15
A320 STABILIZED THICKNESS ON WING PLAN
Run 5 - March 29, 1996, XL54 + Ultra
(mm)



STABILIZED THICKNESS (mm)																
Location	1	2	3	3a	4	5	6	7	8	9	10	11	12	Disk 2	Disk 3	
Chord 1	0.4	0.8	1.8	2.2	2.7	3.3	1.1	1.0	0.8	1.0	0.8	0.8	0.7	0.7	1.1	
Location	1	2	3	4	5	5a	6	7	8	9	10	11	12	13	14	15	Disk 1
Chord 3	0.7	1.1	1.8	2.5	2.2	3.5	1.1	1.1	1.1	1.1	1.1	1.8	1.8	1.8	1.8	2.2	1.8

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APPENDIX G

EXPERIMENTAL PROGRAM TO ESTABLISH FILM THICKNESS PROFILES FOR DE-ICING AND ANTI-ICING FLUIDS ON FLAT PLATES CLIMATIC ENGINEERING FACILITY

EXPERIMENTAL PROGRAM
TO ESTABLISH FILM THICKNESS PROFILES FOR DE-ICING AND ANTI-ICING FLUIDS ON FLAT PLATES
CLIMATIC ENGINEERING FACILITY

Winter 1995/96
Version 1.1

1. OBJECTIVE

Establish film thickness profiles for de-icing and anti-icing fluids on flat plates.

2. TEST REQUIREMENTS

APS will coordinate a series of trials (see Attachment I) at the NRC Climatic Engineering Facility in Ottawa. Tests will be planned and coordinated specifically to establish fluid thickness profiles, in which test weather conditions will include an air temperature of -15°C to -0°C, varying winds, and no precipitation.

Thickness of the fluid film on the plates will be measured and recorded at a number of pre-defined locations along selected cross-sections. Fluid thickness measures will be taken on a continuous basis and the clock time for each measure will be recorded. Other data recorded will include ambient meteorological conditions. Tests should be conducted on C/FIMS mounted plates if available, and the logging of this data must be started prior to fluid application.

3. EQUIPMENT

Equipment to be employed is described in Attachment II.

4. PERSONNEL

One or two persons are required for each occasion (see Attachment III).

5. PROCEDURE

The test procedure is included in Attachment IV.

6. DATA FORM

The data form for measuring thickness is included as Attachment VI.

ATTACHMENT 1

FLUID THICKNESS PROFILE TEST

TEST PLAN ON PLATES (COLD CHAMBER)

RUN #	FLUID Type	TEMP °C	WIND kph	OBJECTIVE
1	Type IV - Ultra 100	-3	0	BASELINE
2	Type IV - Kilfrost 100	-3	0	BASELINE
3	Type IV - Hoechst 100	-3	0	BASELINE
4	Type IV - Ultra 75/25	-3	0	BASELINE
5	Type IV - Kilfrost 75/25	-3	0	BASELINE
6	Type IV - Hoechst 75/25	-3	0	BASELINE
7	Type IV - Ultra 50/50	-3	0	BASELINE
8	Type IV - Kilfrost 50/50	-3	0	BASELINE
9	Type IV - Hoechst 50/50	-3	0	BASELINE
10	Type IV - Ultra 100	-3	0	REPEAT
11	Type IV - Kilfrost 100	-3	0	REPEAT
12	Type IV - Hoechst 100	-3	0	REPEAT
13	Type IV - Ultra 75/25	-3	0	REPEAT
14	Type IV - Kilfrost 75/25	-3	0	REPEAT
15	Type IV - Hoechst 75/25	-3	0	REPEAT
16	Type IV - Ultra 50/50	-3	0	REPEAT
17	Type IV - Kilfrost 50/50	-3	0	REPEAT
18	Type IV - Hoechst 50/50	-3	0	REPEAT
19	Type IV - Ultra 100	-10	0	TEMP EFFECT
20	Type IV - Kilfrost 100	-10	0	TEMP EFFECT
21	Type IV - Hoechst 100	-10	0	TEMP EFFECT
22	Type IV - Ultra 75/25	-10	0	TEMP EFFECT
23	Type IV - Kilfrost 75/25	-10	0	TEMP EFFECT
24	Type IV - Hoechst 75/25	-10	0	TEMP EFFECT
25	Type IV - Ultra 100	-14	0	TEMP EFFECT
26	Type IV - Kilfrost 100	-14	0	TEMP EFFECT
27	Type IV - Hoechst 100	-14	0	TEMP EFFECT
28	Type IV - Ultra 100	-30	0	TEMP EFFECT
29	Type IV - Kilfrost 100	-30	0	TEMP EFFECT
30	Type IV - Hoechst 100	-30	0	TEMP EFFECT
31	Type IV - Ultra 100	2	0	TEMP EFFECT
32	Type IV - Kilfrost 100	2	0	TEMP EFFECT
33	Type IV - Hoechst 100	2	0	TEMP EFFECT
34	Type IV - Ultra 75/25	2	0	TEMP EFFECT
35	Type IV - Kilfrost 75/25	2	0	TEMP EFFECT
36	Type IV - Hoechst 75/25	2	0	TEMP EFFECT
37	Type IV - Ultra 50/50	2	0	TEMP EFFECT
38	Type IV - Kilfrost 50/50	2	0	TEMP EFFECT
39	Type IV - Hoechst 50/50	2	0	TEMP EFFECT
40	Type IV - Ultra 100	-3	10	WIND EFFECT
41	Type IV - Kilfrost 100	-3	10	WIND EFFECT
42	Type IV - Hoechst 100	-3	10	WIND EFFECT
43	Type IV - Ultra 75/25	-3	10	WIND EFFECT
44	Type IV - Kilfrost 75/25	-3	10	WIND EFFECT
45	Type IV - Hoechst 75/25	-3	10	WIND EFFECT
46	Type IV - Ultra 50/50	-3	10	WIND EFFECT
47	Type IV - Kilfrost 50/50	-3	10	WIND EFFECT
48	Type IV - Hoechst 50/50	-3	10	WIND EFFECT
49	Type IV - Ultra 100	-3	25	WIND EFFECT
50	Type IV - Kilfrost 100	-3	25	WIND EFFECT
51	Type IV - Hoechst 100	-3	25	WIND EFFECT
52	Type IV - Ultra 75/25	-3	25	WIND EFFECT

ATTACHMENT 1 (continued)
FLUID THICKNESS PROFILE TEST
TEST PLAN ON PLATES (COLD CHAMBER)

RUN #	FLUID Type	TEMP	WIND	OBJECTIVE
53	Type IV - Kilfrost 75/25	-3	25	WIND EFFECT
54	Type IV - Hoechst 75/25	-3	25	WIND EFFECT
55	Type IV - Ultra 50/50	-3	25	WIND EFFECT
56	Type IV - Kilfrost 50/50	-3	25	WIND EFFECT
57	Type IV - Hoechst 50/50	-3	25	WIND EFFECT
58	Type IV - SPCA 404 100	-3	0	OTHER FLUID
59	Type IV - SPCA 460 100	-3	0	OTHER FLUID
60	Type IV - ULTRA + 100	-3	0	OTHER FLUID
61	Type IV - SPCA 404 75/25	-3	0	OTHER FLUID
62	Type IV - SPCA 460 75/25	-3	0	OTHER FLUID
63	Type IV - ULTRA + 75/25	-3	0	OTHER FLUID
64	Type IV - SPCA 404 50/50	-3	0	OTHER FLUID
65	Type IV - SPCA 460 50/50	-3	0	OTHER FLUID
66	Type IV - ULTRA + 50/50	-3	0	OTHER FLUID
67	Type IV - SPCA 404 100	-10	0	OTHER FLUID
68	Type IV - SPCA 460 100	-10	0	OTHER FLUID
69	Type IV - ULTRA + 100	-10	0	OTHER FLUID
70	Type IV - SPCA 404 75/25	-10	0	OTHER FLUID
71	Type IV - SPCA 460 75/25	-10	0	OTHER FLUID
72	Type IV - ULTRA + 75/25	-10	0	OTHER FLUID
73	Type IV - SPCA 404 50/50	-10	0	OTHER FLUID
74	Type IV - SPCA 460 50/50	-10	0	OTHER FLUID
75	Type IV - ULTRA + 50/50	-10	0	OTHER FLUID
76	XL 54 TYPE I	-3	0	TYP I FLUID
77	Octagon Type I	-3	0	TYP I FLUID
78	XL 54 TYPE I	-10	0	TYP I FLUID
79	Octagon Type I	-10	0	TYP I FLUID
80	XL 54 TYPE I	-14	0	TYP I FLUID
81	Octagon Type I	-14	0	TYP I FLUID
82	XL 54 TYPE I	-30	0	TYP I FLUID
83	Octagon Type I	-30	0	TYP I FLUID

Type IV over Type I

84	Ultra 100 over XL54	-3	0	BASELINE
85	Ultra + 100 over XL54	-3	0	BASELINE
86	Kilfrost Type IV-100 over Kilfrost Type I	-3	0	BASELINE
87	SPCA 404 Type IV-100 over SPCA 825 Type I	-3	0	BASELINE
88	SPCA 460 Type IV-100 over SPCA 910 Type I	-3	0	BASELINE
89	Ultra 75/25 over XL54	-3	0	BASELINE
90	Ultra + 75/25 over XL54	-3	0	BASELINE
91	Kilfrost Type IV-75 over Kilfrost Type I	-3	0	BASELINE
92	SPCA 404 Type IV-75/25 over SPCA 825 Type I	-3	0	BASELINE
93	SPCA 460 Type IV-75/25 over SPCA 910 Type I	-3	0	BASELINE
94	Ultra 50/50 over XL54	-3	0	BASELINE
95	Ultra + 50/50 over XL54	-3	0	BASELINE
96	Kilfrost Type IV-50 over Kilfrost Type I	-3	0	BASELINE
97	SPCA 404 Type IV-50/50 over SPCA 825 Type I	-3	0	BASELINE
98	SPCA 460 Type IV-50/50 over SPCA 910 Type I	-3	0	BASELINE
99	Ultra 100 over Ultra 50/50	-3	0	Verification Type IV 100 over 50
100	Ultra + 100 over Ultra + 50/50	-3	0	Verification Type IV 100 over 50
101	Kilfrost 100 over Kilfrost 50/50	-3	0	Verification Type IV 100 over 50
102	SPCA 404 100 over SPCA 404 50/50	-3	0	Verification Type IV 100 over 50

ATTACHMENT 1 (continued)

FLUID THICKNESS PROFILE TEST

TEST PLAN ON PLATES (COLD CHAMBER)

RUN #	FLUID Type	TEMP	WIND	OBJECTIVE
103	SPCA 460 100 over SPCA 460 50/50	-3	0	Verification Type IV 100 over 50
104	Ultra 75 /25 over Ultra 50/50	-3	0	Verification Type IV 75 over 50
105	Ultra + 75/25 over Ultra + 50/50	-3	0	Verification Type IV 75 over 50
106	Kilfrost 75/25 over Kilfrost 50/50	-3	0	Verification Type IV 75 over 50
107	SPCA 404 75/25 over SPCA 404 50/50	-3	0	Verification Type IV 75 over 50
108	SPCA 460 75/25 over SPCA 460 50/50	-3	0	Verification Type IV 75 over 50
109	Ultra 100 over XL54	-10	0	TEMP EFFECT
110	Ultra + 100 over XL54	-10	0	TEMP EFFECT
111	Kilfrost Type IV-100 over Kilfrost Type I	-10	0	TEMP EFFECT
112	SPCA 404 Type IV-100 over SPCA 825 Type I	-10	0	TEMP EFFECT
113	SPCA 460 Type IV-100 over SPCA 910 Type I	-10	0	TEMP EFFECT
114	Ultra 75/25 over XL54	-10	0	TEMP EFFECT
115	Ultra + 75/25 over XL54	-10	0	TEMP EFFECT
116	Kilfrost Type IV-75 over Kilfrost Type I	-10	0	TEMP EFFECT
117	SPCA 404 Type IV-75/25 over SPCA 825 Type I	-10	0	TEMP EFFECT
118	SPCA 460 Type IV-75/25 over SPCA 910 Type I	-10	0	TEMP EFFECT
119	Ultra 50/50 over XL54	-10	0	TEMP EFFECT
120	Ultra + 50/50 over XL54	-10	0	TEMP EFFECT
121	Kilfrost Type IV-50 over Kilfrost Type I	-10	0	TEMP EFFECT
122	SPCA 404 Type IV-50/50 over SPCA 825 Type I	-10	0	TEMP EFFECT
123	SPCA 460 Type IV-50/50 over SPCA 910 Type I	-10	0	TEMP EFFECT
124	Type IV - Ultra 100	-14	0	TEMP EFFECT
125	Type IV - Ultra 100 +	-14	0	TEMP EFFECT
126	Type IV - Kilfrost 100	-14	0	TEMP EFFECT
127	Type IV - SPCA 404 100	-14	0	TEMP EFFECT
128	Type IV - SPCA 460 100	-14	0	TEMP EFFECT
129	Type IV - Ultra 100	2	0	TEMP EFFECT
130	Type IV - Ultra 100 +	2	0	TEMP EFFECT
131	Type IV - Kilfrost 100	2	0	TEMP EFFECT
132	Type IV - SPCA 460 100	2	0	TEMP EFFECT
133	Type IV - SPCA 460 100	2	0	TEMP EFFECT
134	Type IV - Ultra 100	-3	0	SPRAYER EFFECT*
135	Type IV - Ultra 100 +	-3	0	SPRAYER EFFECT*
136	Type IV - Kilfrost 100	-3	0	SPRAYER EFFECT*
137	Type IV - SPCA 404 100	-3	0	SPRAYER EFFECT*
138	Type IV - SPCA 460 100	-3	0	SPRAYER EFFECT*
139	Ultra 100 over XL54	-3	0	SPRAYER EFFECT*
140	Ultra + 100 over XL54	-3	0	SPRAYER EFFECT*
141	Kilfrost Type IV-100 over Kilfrost Type I	-3	0	SPRAYER EFFECT*
142	SPCA 404 Type IV-100 over SPCA 825 Type I	-3	0	SPRAYER EFFECT*
143	SPCA 460 Type IV-100 over SPCA 910 Type I	-3	0	SPRAYER EFFECT*
144	Ultra 100 over Ultra 50/50	-3	0	SPRAYER EFFECT*
145	Ultra + 100 over Ultra + 50/50	-3	0	SPRAYER EFFECT*
146	Kilfrost 100 over Kilfrost 50/50	-3	0	SPRAYER EFFECT*
147	SPCA 404100 over SPCA 404 50/50	-3	0	SPRAYER EFFECT*
148	SPCA 460100 over SPCA 460 50/50	-3	0	SPRAYER EFFECT*
149	Ultra 75/25 over XL54	-3	0	SPRAYER EFFECT*
150	Ultra 50/50 over XL54	-3	0	SPRAYER EFFECT*
151	Type IV - Ultra 75/25	-3	0	SPRAYER EFFECT*
152	Type IV - Ultra 50/50	-3	0	SPRAYER EFFECT*

Note: * Spray Type IV fluids for 1 minute.

ATTACHMENT II

FLUID THICKNESS PROFILE TESTS

TEST EQUIPMENT CHECKLIST - PLATES @ NRC

TASK	*Montreal*	
	Resp.	**Status**
Test Equipment		
Tape Recorder with Mic.(voice) - Optional		
Supply of tapes for recorder		
Supply of AA cells		
Thickness Gauges - 8 hand held, 6 mounted on poles		
General Data Forms		
Compass		
Clipboard		
Space pens and pencils		
Lighting		
C/FIMS Sensors		
Hands-free flashlight		
Cloth wipers for gauges		
Cotton gloves (mechanics type)		
Stop watch		
Protective clothing		
Still camera		
Fluids		
Industrial Fan (from NRC)		
Hand Held Anemometer (from NRC)		
Garden Sprayer Equipment		

ATTACHMENT III
FLUID THICKNESS PROFILE TESTS
RESPONSIBILITIES/DUTIES OF TEST PERSONNEL

Refer to Attachment V for measurement position on plates. Refer to the test procedure Attachment IV for more detail.

Observer

- Ensure clocks are synchronized.
- Located by test stand.
- Before each test run, record your name, C/FIMS #, date and time, the run number, fluid type.
- Indicate time of fluid application.
- Progressively measure fluid thickness at assigned measurement locations:
  - Use the MIL scale on the gauge
  - Record the gauge of the tooth that is wetted
  - When measuring fluid thickness, follow offset routine (see Attachment V) to avoid inaccuracies related to depressions in fluid surface caused by previous gauge placement.
  - Ensure the thickness gauge is perpendicular to the surface of the wing.
  - Record time in seconds during the initial measurement cycle when the rate of fluid thinning is fastest. Time to the nearest minute is acceptable for subsequent recording.
  - Proceed as quickly as possible without sacrificing accuracy.
- For each measurement, record plate identification, the measurement location, the time, and the fluid thickness gauge reading.
  Example: Plate u, line six inch, time 024238, gauge 55 mil.
  Always say the words preceding the data (plate, line, time, gauge) to voice activate the tape recorder if this is being used. Speak clearly.
- Alternatively, measurements could be recorded directly on the data form.
- Ensure all recorded voice tapes are properly tagged (date, observer, run #, etc.) and submitted to the project manager.
- Review data forms at test completion for completeness and accuracy.
- Ensure functioning of voice recorders, in particular the voice activation function.
- Ensure proper documentation of voice and video tapes, and of fluid samples.
- Call end of test based on fluid thinning reaching state of stability.

If the data is being recorded directly onto the data form, then two observers would be required for the first 5 to 10 minutes.

ATTACHMENT IV
FLUID THICKNESS PROFILE TESTS
TEST PROCEDURE

1. Pre-Test Set-Up

Synchronize time on stopwatches.

Locate positions where fluid thickness readings will be taken.

Use up to six plates with C/FIMS mounted, if available.

Turn on C/FIMS computer for the fluids being tested.

2. Test Procedure

Ensure test stand is into the wind.

Apply test fluid over the test panels as per standard flat plate test procedure. Some tests will require a one minute spray application. Type IV should be at chamber temperatures and Type I at room temperature.

Some tests will be conducted with a two-step Type I initial application.

Observers will measure and record fluid thickness at each assigned measurement location. Record the location and the time corresponding to each measurement.

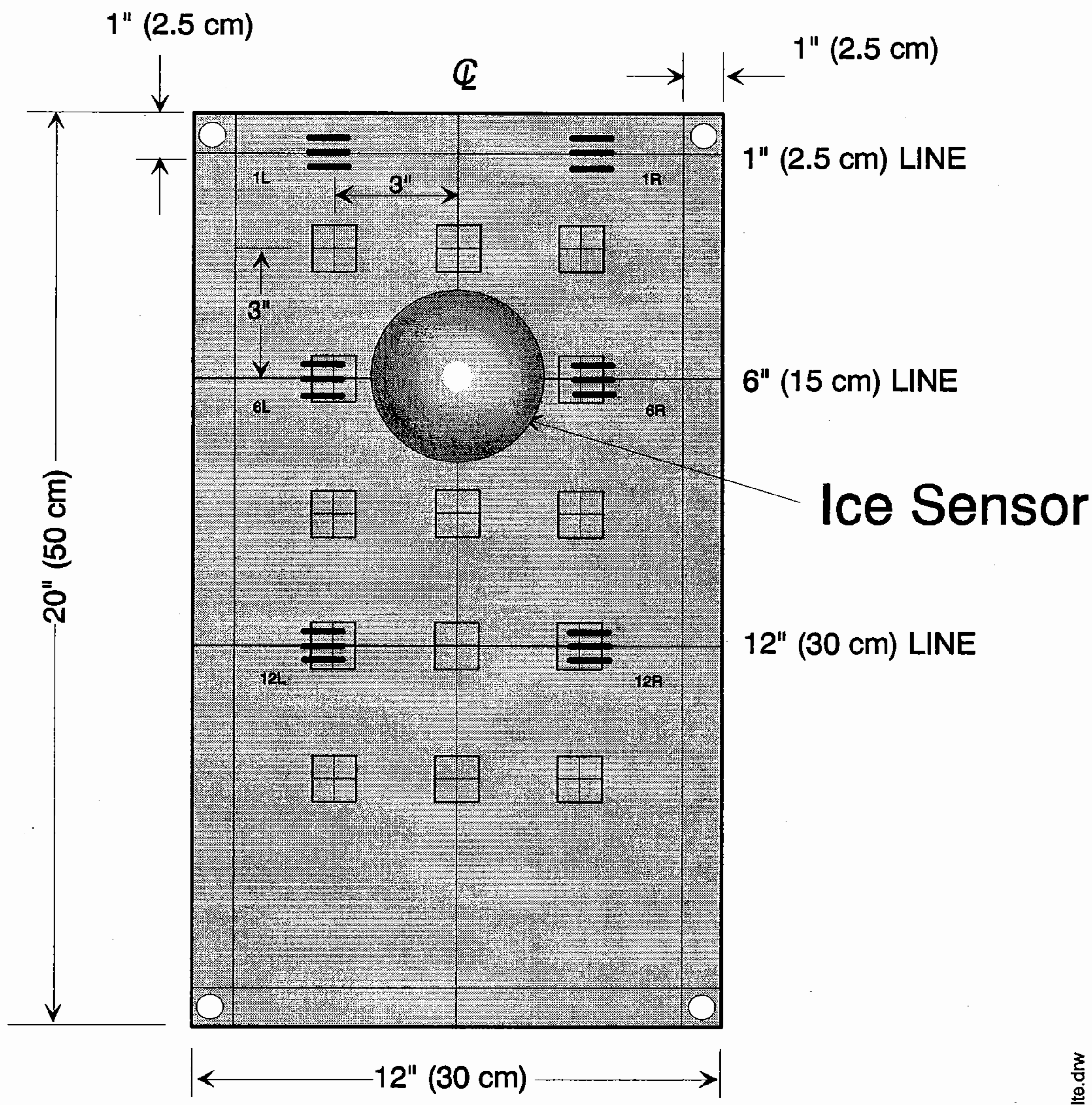
For the "baseline" tests (see Attachment I), record the thickness on the 1", 6", and 12" line, while for the other tests only record the 6" line. For the six inch line, ensure accuracy by measuring two times.

3. End of Test

The test will be terminated when fluid thickness stabilizes.

Ensure all voice tapes (if this is used) are properly identified and then transcribed onto paper.

ATTACHMENT V
THICKNESS MEASUREMENT LOCATIONS



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ATTACHMENT VI

FLUID THICKNESS TEST

DATE: ______________ OAT, °C (beg.): ______________

RUN NUMBERS: ______________ WIND SPEED, kph (beg.): ______________

STAND: ______________ PERFORMED BY: ______________

LOCATION: <u>CEF (NRC)</u> WRITTEN BY: ______________

THICKNESS (mil)							
Plate: Sensor: Fluid: Fluid Application Time:				Plate: Sensor: Fluid: Fluid Application Time:			
TIME	**1" LINE**	**6" LINE**	**12" LINE**	**TIME**	**1" LINE**	**6" LINE**	**12" LINE**

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ATTACHMENT VI

FLUID THICKNESS TEST

DATE: ________________ **TEMPERATURE °C (beg.):** ________________ **PERFORMED BY:** ________________

TEST #: ________ to ________ **WIND SPEED, kph (beg.):** ________________ **WRITTEN BY:** ________________

STAND: ________________ **LOCATION:** CEF (NRC)

THICKNESS (mil)											
Plate: **U** Run #: Fluid: Application Time:		Plate: **V** Run #: Fluid: Application Time:		Plate: **W** Run #: Fluid: Application Time:		Plate: **X** Run #: Fluid: Application Time:		Plate: **Y** Run #: Fluid: Application Time:		Plate: **Z** Run #: Fluid: Application Time:	
TIME	**6" LINE**	**TIME**	**6" LINE**	**TIME**	**6" LINE**	**TIME**	**6" LINE**	**TIME**	**6" LINE**	**TIME**	**6" LINE**

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Printed:28/03/96

THICKNESS TESTS DURING HOT TESTS @ CEF
FREEZING FOG

RUN # : TEMP.: DATE:

(Enter time and thickness)

U	UU	V	VV	W	WW
Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____
Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____
Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____
Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____
Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____
XX	X	YY	Y	ZZ	Z
Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____
Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____
Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____
Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____
Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____

Sub-Runs

U	UU	V	VV	W	WW
Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____
Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____
Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____
Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____
Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____
XX	X	YY	Y	ZZ	Z
Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____
Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____
Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____
Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____
Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____

Sub-Runs

U	UU	V	VV	W	WW
Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____
Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____
Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____
Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____
Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____
XX	X	YY	Y	ZZ	Z
Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____	Beg ____ ____
Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____	Pt 2 ____ ____
Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____	Pt 3 ____ ____
Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____	Pt 4 ____ ____
Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____	Fail ____ ____

NOTE: All readings at 6" line unless other location specified.

APPENDIX H

APPS 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 WRITTTEN 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

BM2980\WAT_SNOW\PFORM2-2.XLS Printed: 20/12/95

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 (Δw*4/ Δt) (g/dm²/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 :		

BM2980\NAT_SNOWPFROM2-2.XLS
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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At: CODED
Printed: 02/10/96

ATTACHMENT I

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ATTACHMENT I

NATURAL SNOW PRECIPITATION TEST PLAN

			TYPE I (De-icing)														TYPE II (Anti-icing)												TYPE IV (Anti-icing)																							
GLYCOL BASE			ETHEL		PROPL		ETHEL/PROP		PROPL		PROPL		PROPL		PROPL		PROPL			PROPL			PROPL			PROPL			ETHEL			ETHEL			PROPL			ETHEL			PROPL			PROPL			PROPL			PROPL		
FREEZING POINT (°C)			-43	*	-45	*	-43	*	-43	*	-45	*	-43	*	-43	*	-45	-24	-12	-46	-30	-15	-36	-22	-10.5	-34	-20	-10	-49	-30	-15	-59	-36	-18	?	?	?	-47	-30	-17	-43	-25.5	-12	?	?	?	-36	-22	-10.5	-34	-20	-10
RU	TEMP	TESTS	STD	DIL	STD	DIL	STD	DIL	STD	DIL	STD	DIL	STD	DIL	STD	DIL	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	100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50	100/0	75/25	50/50
#	DEG °C		B-213	B-253	B-215	B-255	B-230	B-330	B-231	B-331	B-221	B-251	B-218	B-256	B-214	B-254	A-202	A-510	A-700	A-205	A-210	A-212	A-201	A-401	A-501	A-101	A-511	A-701	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-106	C-706	C-506
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TOTAL		474	24	20	0	12	0	0	0	0	0	10	0	0	0	0	0	0	0	28	18	12	16	8	6	18	8	8	24	16	12	24	28	44	0	0	0	24	16	12	0	0	0	0	0	0	0	0	0	24	20	34

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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 <u>only</u> applicable during freezing rain/drizzle, ice pellets, freezing fog or during a mixture of snow and freezing rain/drizzle and ice pellets.

As these determinations are subjective in nature, the following is **<u>very important</u>**:

- Whenever possible, have the same individual make the determination that a crosshair has failed.

- When making such a determination, ensure consistency in the criteria used to call the end of a test.

- Under light snow conditions 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:

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

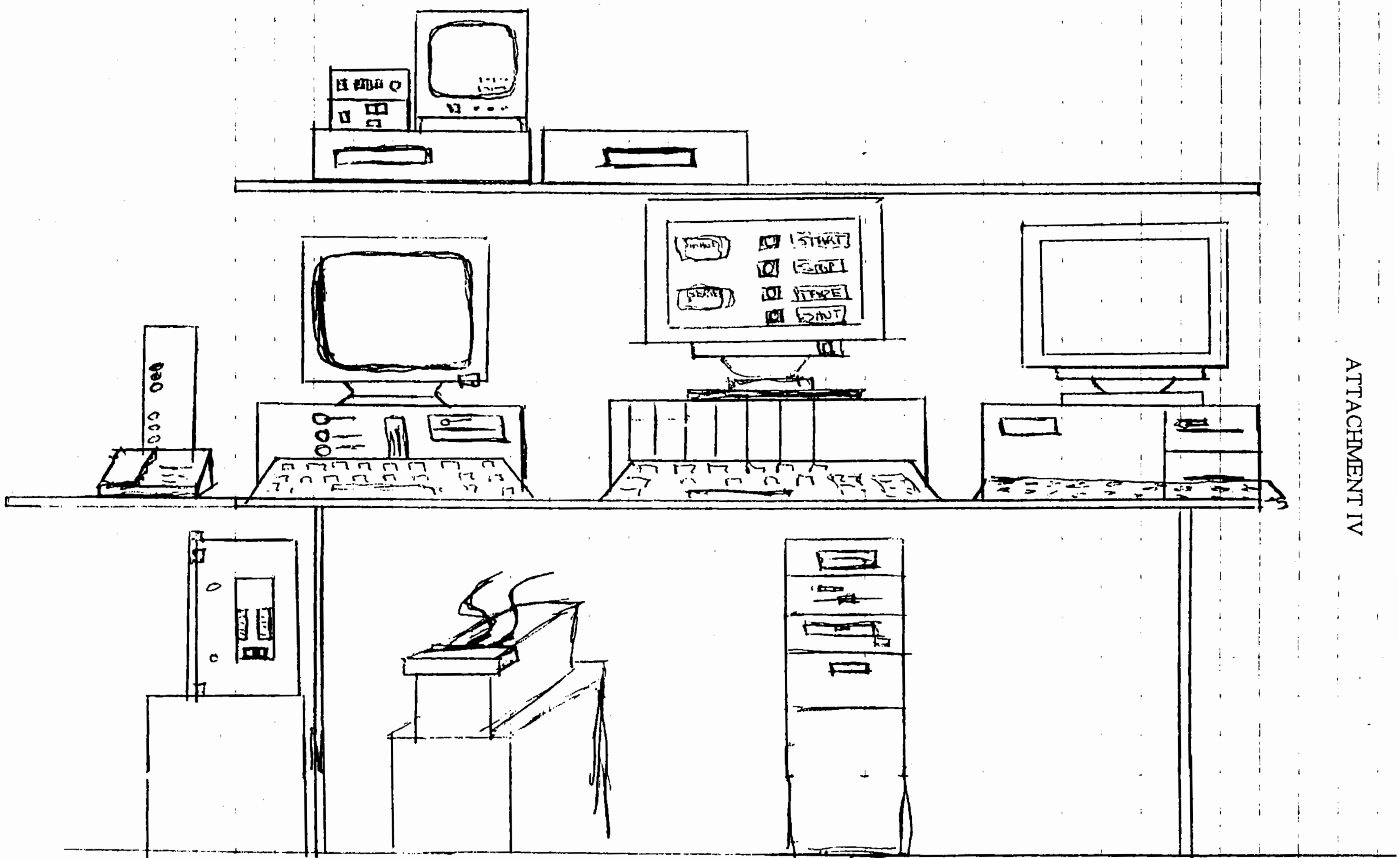
There are three computer systems running at the same time to ensure proper data collection at the APS site. The primary functions of these computers are to provide meteorological data as well as sensor data. The three computer systems are called:

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.

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 on 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.

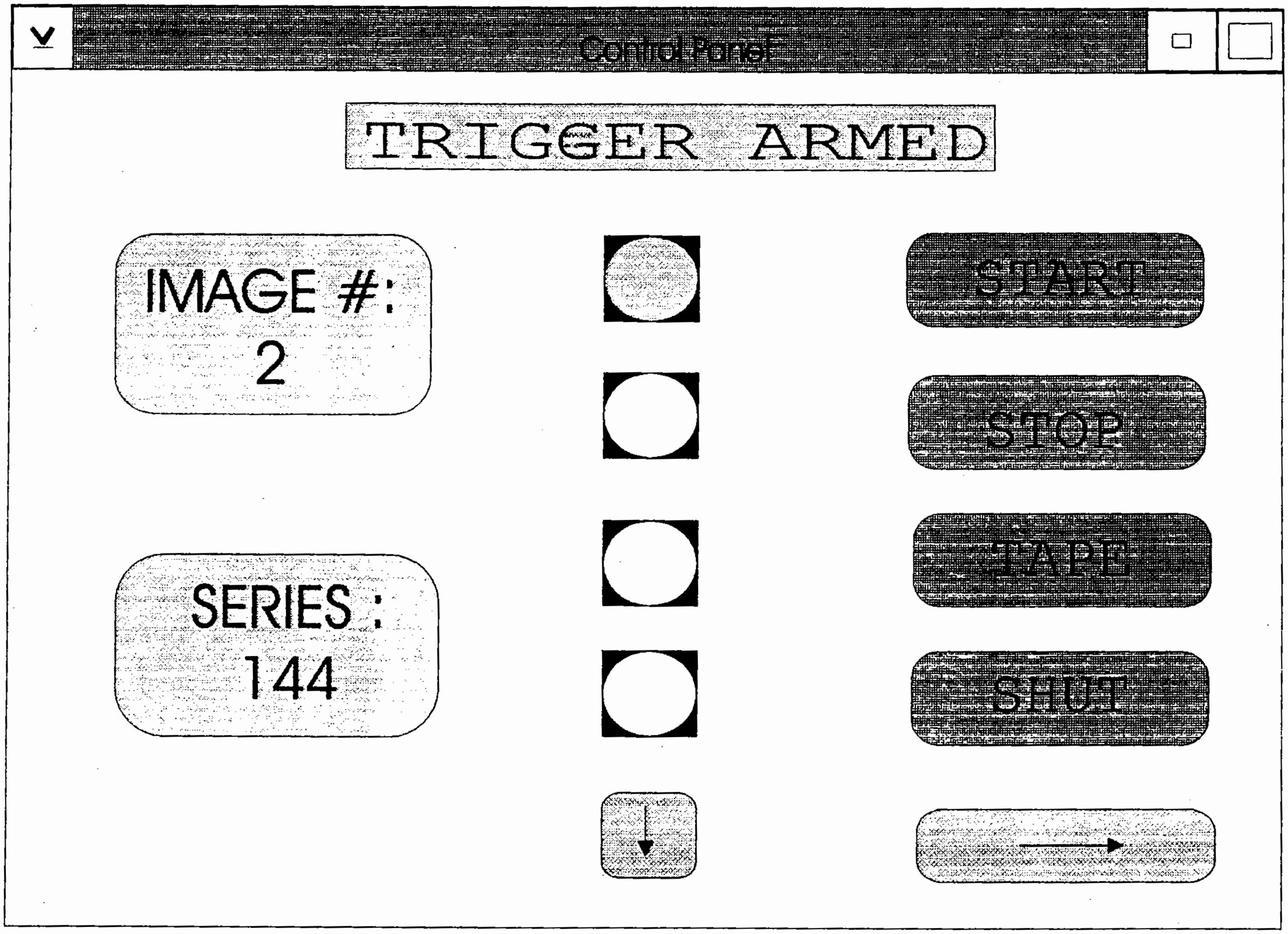
Table of menu options for the RVSI:

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.

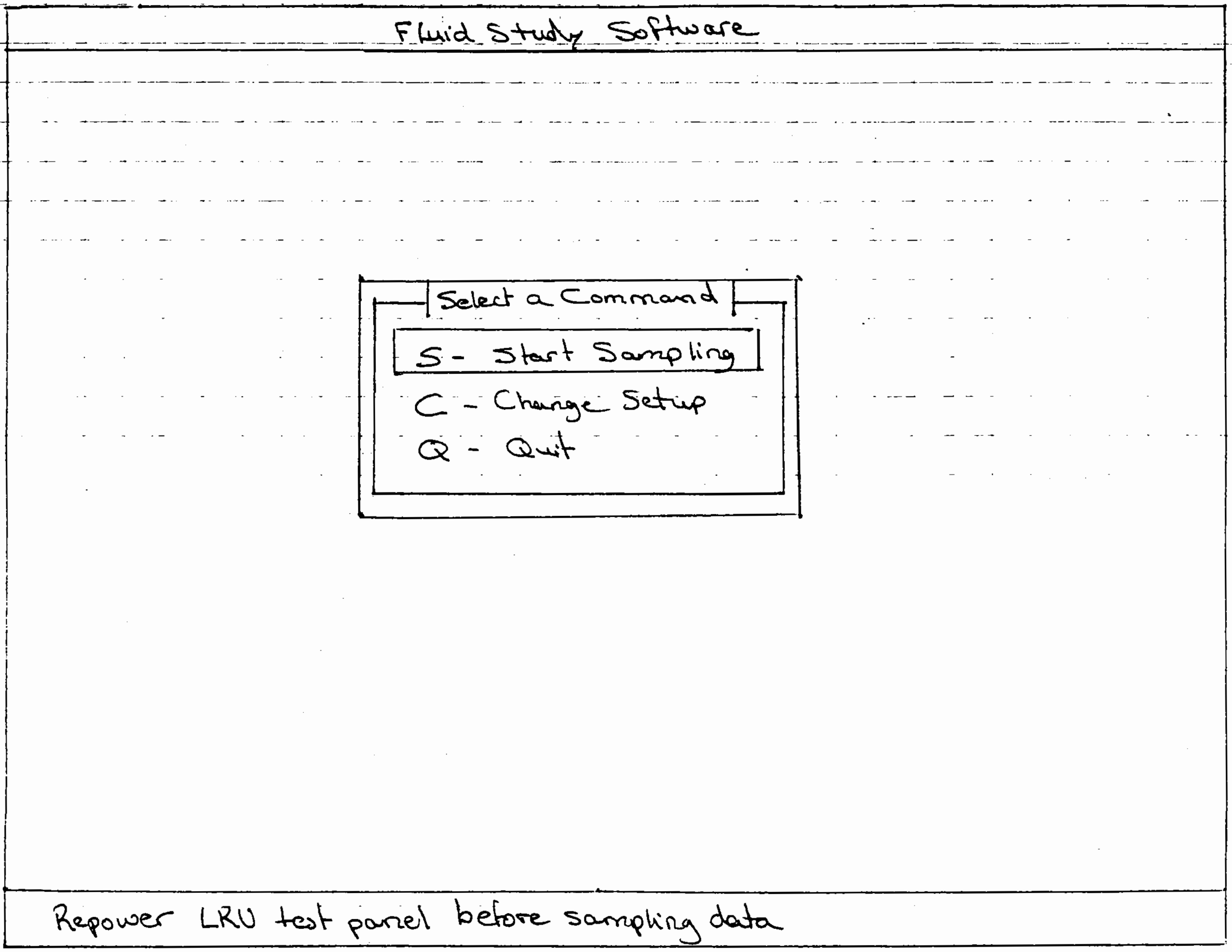
Fluid Study Software

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.



* 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~~ 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.

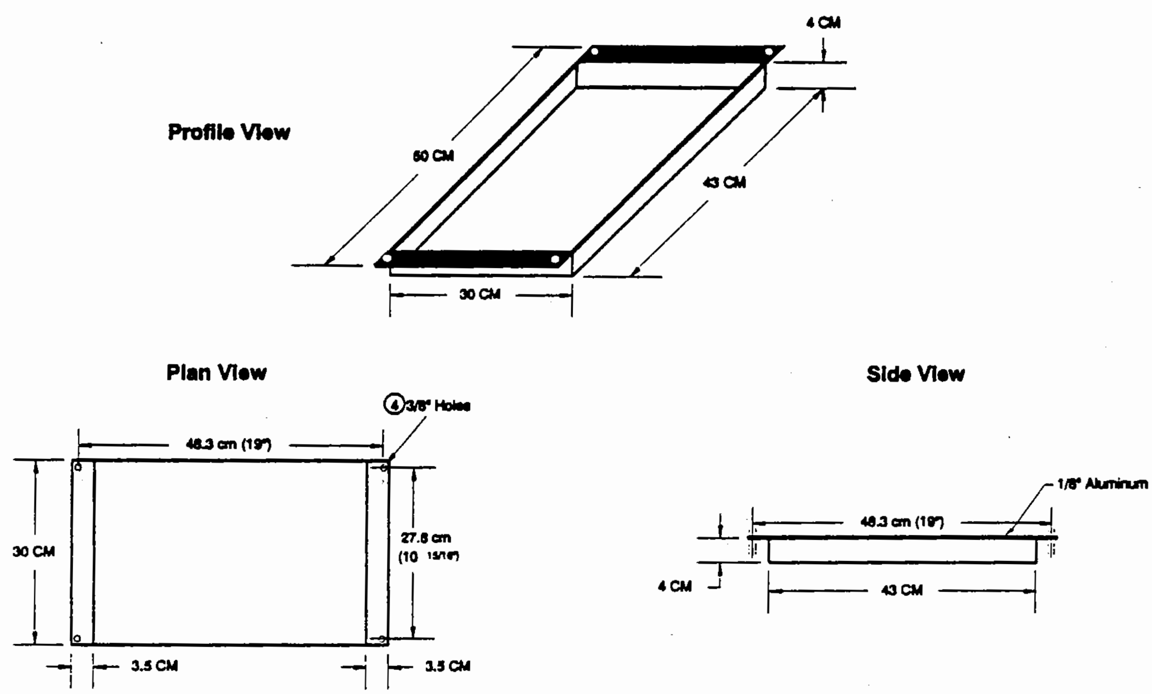
To Close Trailer

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.

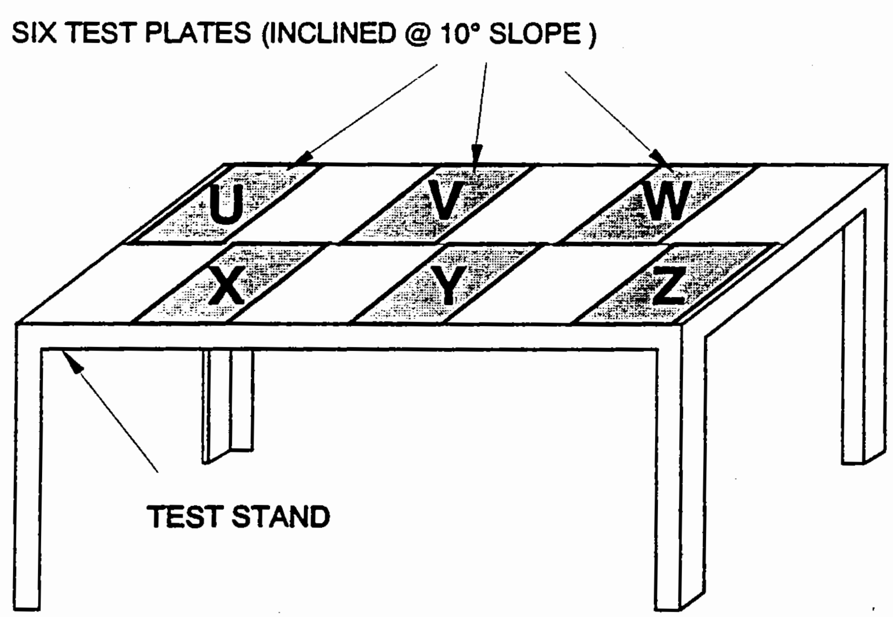
FIGURE 0

SCHEMATICS OF PLATE PAN AND TEST STAND

PLATE PAN



TEST STAND



bm2980\procedur\nat_snow\pan&stnd.drw

FIGURE 1
TEST STAND

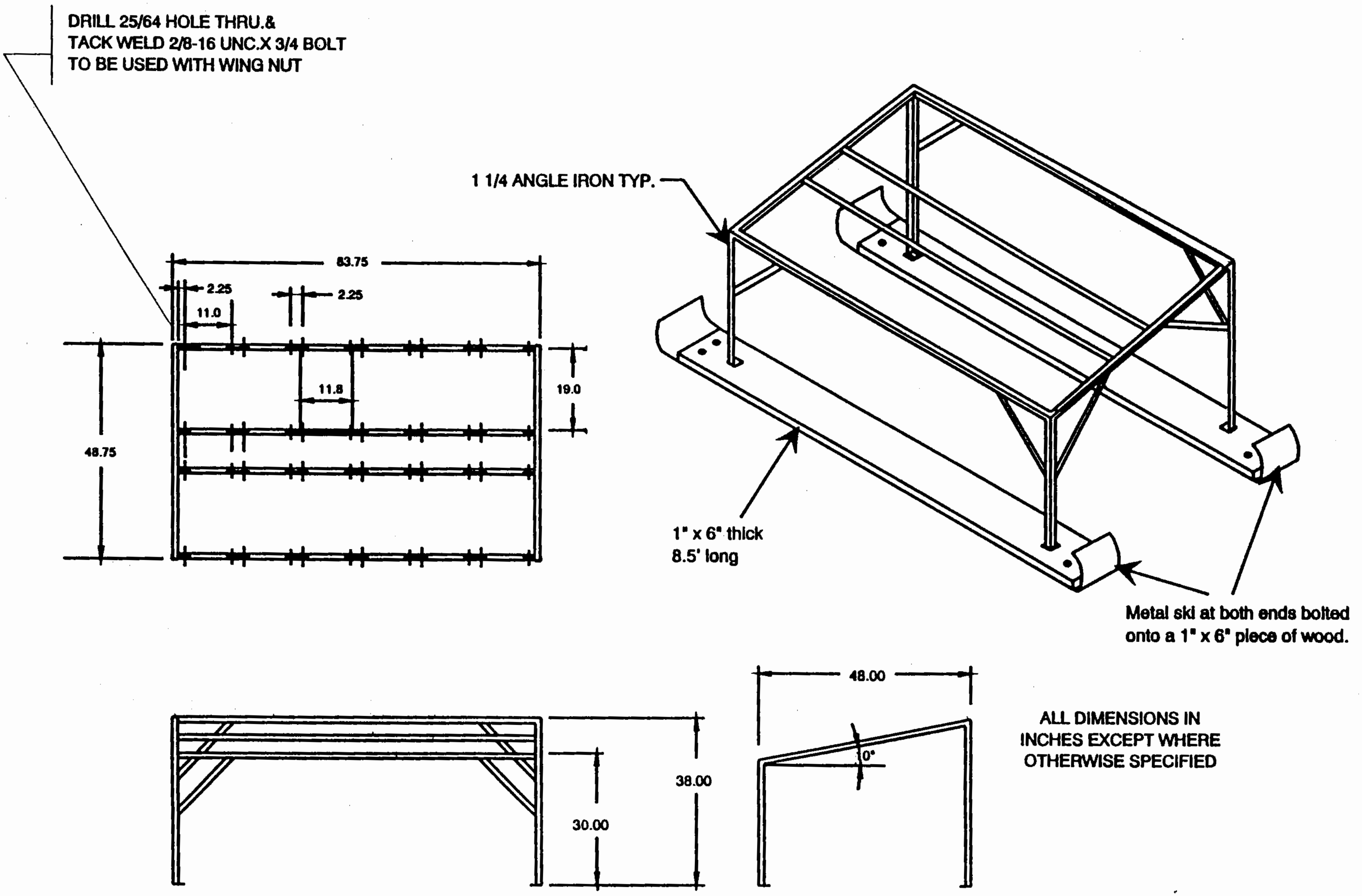
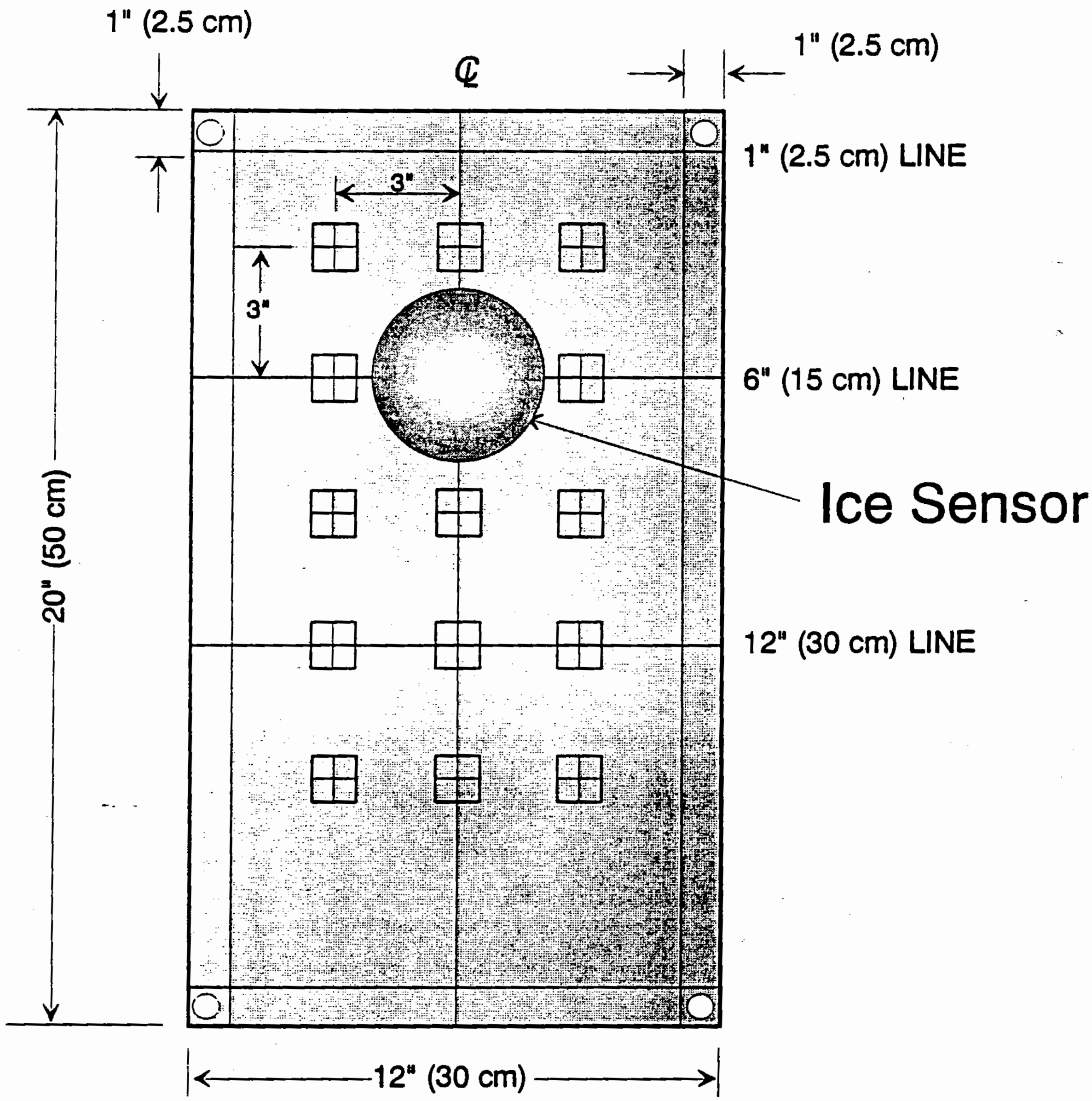


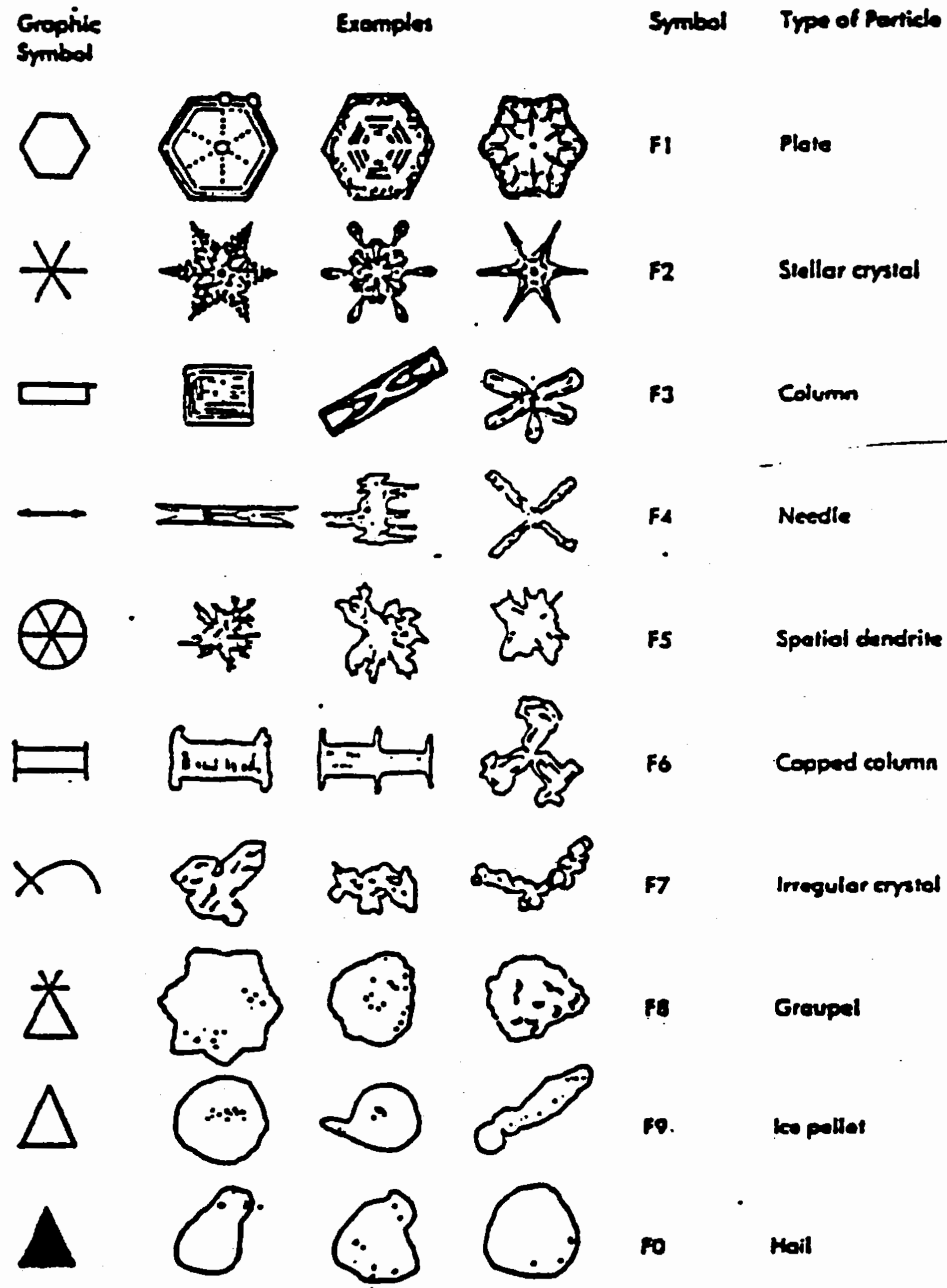
FIGURE 2
TYPICAL ICE SENSOR FLAT PLATE MARKINGS



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+
	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+
Precipitation	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+
	Fog	F
	Ice Fog	IF
	Haze	H
Obstructions to Vision (visibility 6 miles or less)	Smoke	K
	Blowing Snow	BS
	Blowing Sand	BN
	Blowing Dust	BD
	Dust Haze	D

ATTACHMENT VI

CHECKLIST FOR END OF TESTING

ITEM	CHECKED	NOTES
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		

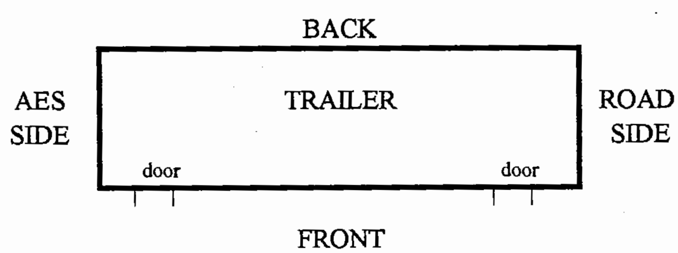
MARKERS FOR DETERMINATION OF VISIBILTY

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

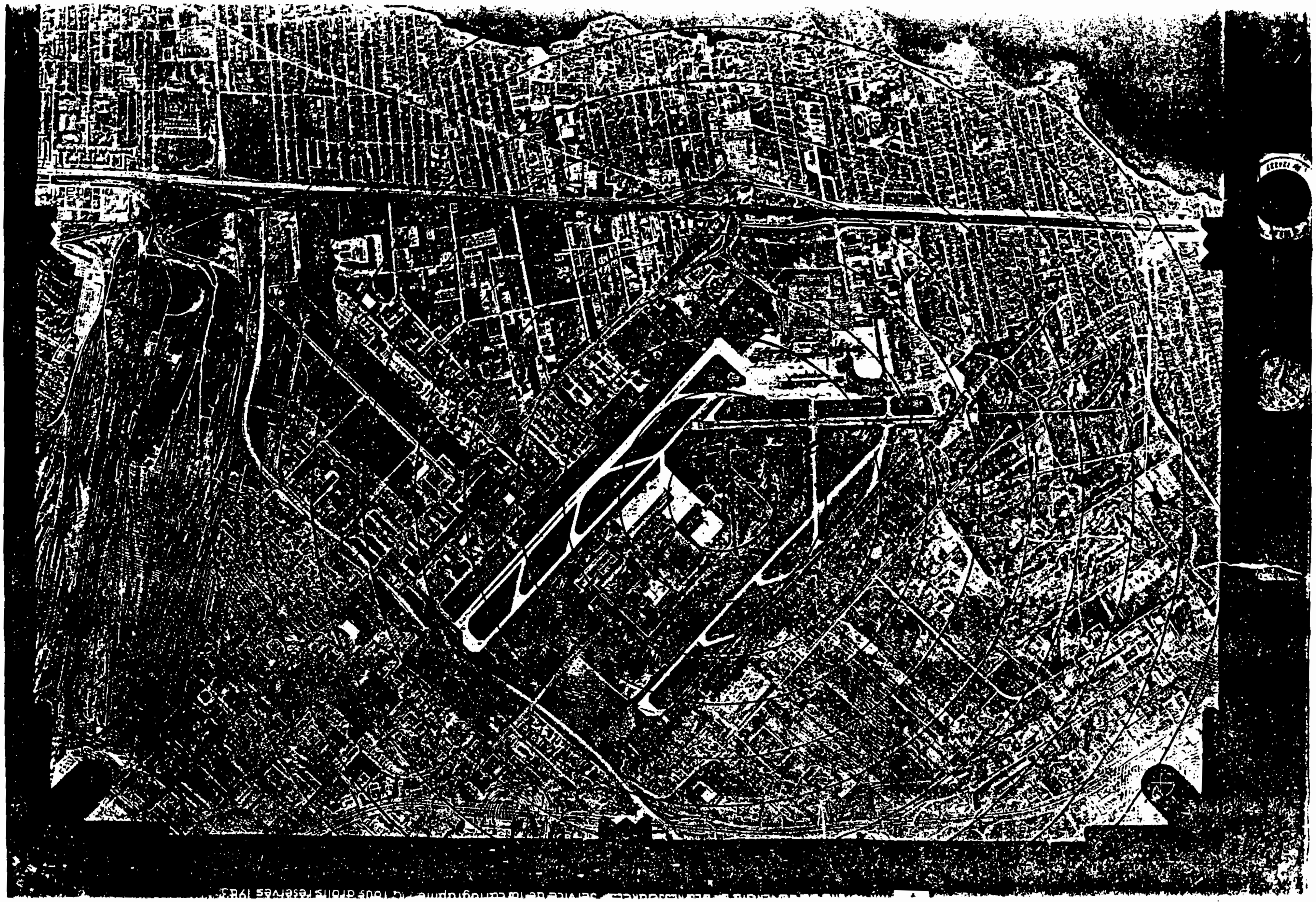
1) Visibility should by measured only during the daylight.
2) To determine visibilty, search for the furthest visible marker and enter the distance of this marker on the data form.

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



Attachment VII
Map to determine visibility at AES Site, Dorval
(concentric circle ¼ mile apart)



APPENDIX I

RESULTS OF FILM THICKNESS TESTS CONDUCTED AT NRC

TABLE 1

THICKNESS TESTS @ CEF (1996)

ONE-STEP FLUID APPLICATION

Stabilized Thickness at 15 cm Line (after ~30 min)

Application	Fluid Name	Temperature (°C)						
		-3	-9	-13	-25	-3 Sprayed	-3 10 kph	-3 25 kph
Type IV Neat	A-303	1.2, 1.2	1.1, 1.2 1.2	1.3	1.7	1.3, 1.3	1.1	1.2
	C-100	1.5	1.6			1.3-1.5		
	C-105	1.2, 1.6 1.6	1.8, 1.5 1.6, 1.7	1.8	2.2	1.2	1.8	1.6
	C-102	1.3-1.5	1.5, 1.5	1.5		1.3		
	C-103	1.5-1.6	1.6, 1.7	1.7		1.2		
Type IV 75/25	A-503	0.7, 1.0	0.7			0.4	0.4	0.5
	C-700	0.4	0.5					
	C-705	1.0, 1.0	1.3				1	1.1
	C-702	0.8	1.1					
	C-703	1	1.1					
Type IV 50/50	A-403	0.1	0.1			0.1	0.1	0.1
	C-500	0.1-0.2	0.1					
	C-505	0.1, 0.1					0.4	0.3
	C-502	0.3-0.4	0.5					
	C-503	0.5	0.4					
Type I	B-213	0	0.1 (12 min)	0	0.1			
	B-221	0	0.1 (12 min)	0.1	0.1			

Notes:

#1 - #2 designates one test where the final stabilized thickness varied between #1 and #2.

#3, #4 designates two tests with final stabilized thickness of #3 and #4.

TABLE 2

THICKNESS TESTS @ CEF (1996)

TWO-STEP FLUID APPLICATION

Stabilized Thickness at 15 cm Line (after ~30 min)

Application	Fluid Name	Temperature (°C)						
		-3	-9	-13	-25	-3 Sprayed	-3 10 kph	-3 25 kph
Type IV Neat over Type I	A-303/ B-213	1	1.2 1.0-1.1			0.4		
	C-100/ B-213	1.2	1.1-1.2			1		
	C-105/ B-211	0.8, 1.6	1.2, 1.5 1.6, 1.6			0.8-1.0 1		
	C-103/ B-231	0.7-0.8	0.5-0.6			1		
	C-102/ B-230		0.2, 0.3 0.4			1		
Type IV 75/25 over Type I	A-503/ B-213	0.5	0.6			0.3		
	C-700/ B-213	0.5	0.4					
	C-705/ B-211	1.1	1.3					
	C-703/ B-231	0.5	0.7					
Type IV 50/50 over Type I	A-403/ B-213	0.1	0.1			0.1		
	C-500/ B-213	0.1	0.1					
	C-505/ B-211	0.1	0.2					
	C-503/ B-231	0.2	0.2					
Type IV Neat over Type IV 50/50	A-303/ A-403	0.7				0.7		
	C-100/ C-500					1.2		
	C-105/ C-505	1.2				1		
	C-103/ C-502	1.3				1.3		
	C-102/ C-503	1.2				1.3		
Type IV 75/25 over Type IV 50/50	A-503/ A-403	0.6						
	C-705/ C-505	0.7						
	C-702/ C-502	1						
	C-703 C-503	0.8						

cm1283\report\film\THKN@CEF.XLS
At: MM
30/09/96

APPENDIX J

CERTIFICATE OF ANALYSIS AND PROCEDURES FOR SPECIAL TESTS

JFB
F6 CM1283

UNION CARBIDE

UNION CARBIDE CANADA INC.
7400 LES GALERIES D'ANJOU BLVD, SUITE 360
ANJOU, QUEBEC H1M 3M2

DATE: April 9, 96.

TO: Jean Francais
APS

FAX No: 861-6310

CC Bud Carder.

FROM : JACQUES LEROUX (Office 514-493-2606, home 514-466-8561)
(Office fax 514-493-2619, home fax 514-466-3961)

Jean Francais

Note CC2 is contaminated with UCAR
ADF XL 54.
CC4 is ok.

Number of pages including cover page: 2

UNION CARBIDE CHEMICALS AND PLASTICS COMPANY INC.
INDUSTRIAL CHEMICALS DIVISION
TECHNICAL CENTER, P.O. BOX 8361
SOUTH CHARLESTON, WV 25303

FACSIMILE

TO:	Jacques Leroux	# PAGES:	One (1)
FAX NO:	(514) 493 - 2619	DATE:	4-9-96
COMPANY:	UCC Canada Inc.		
TELE NO:		FROM:	C.H. (Bud) Carder D.R. Lorentz
cc:	Jacques Leroux		
FAX NO:	(514) 493-2619		
COMPANY:	Union Carbide Corporation Montreal, Canada	TELE NO:	(304) 747-7774 (304) 747-3703
TELE NO:	(514) 640-6400		

Facsimile sent from Fax No: (304) 747-4073. If transmittal problems occur, call Operator Ben Vance at Telephone No: (304) 747-4753.

CERTIFICATE OF ANALYSIS

PRODUCT:	UCAR® AAF ULTRA				
CUSTOMER:	Jacques Leroux				
LOCATION:					
UCC Reference #	Customer Identification	Viscosity, cP, @ 10 min, 0°C, #31spindle, 0.3rpm	pH, @25°C	Brix, @25°C	WSET in mins.
56-CHC-121-1	7 (73) CC2	*6899	8.63	37.3	26
56-CHC-121-2	7 (70) CC4	*33993	8.69	37.2	92

NOTE: * Fluid viscosities are below specification requiring at least 35000 cps..

UNION CARBIDE CORPORATION
Research & Development

SIMULTANEOUS AIRCRAFT VS PLATE TESTING
PROCEDURES FOR SPECIAL TESTS

Sampling of fluid from truck

- Place a clean plastic pan on the ground.
- Spray a few litres into the pan.
- Label bottle properly (Date, Time, Fluid Type, Run No.).
- Pour fluid into sampling bottle (0.5 litre).
- Enter data in Table A.

Table A

Date:	29.03.96	Run No.:	1	Airline:	A/C
Time:	–	Nozzle Type:	AKRON	Airport:	DORVAL
Bottle No.:	CC2	Truck No.:	13	Brix Reading:	37.5
Fluid Type:	ULTRA	Sampled by:	JD		

Date:	29.03.96	Run No.:	2	Airline:	A/C
Time:	–	Nozzle Type:	AKRON	Airport:	DORVAL
Bottle No.:	CC4	Truck No.:	10	Brix Reading:	37.5
Fluid Type:	ULTRA	Sampled by:	JD		

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01/04/96