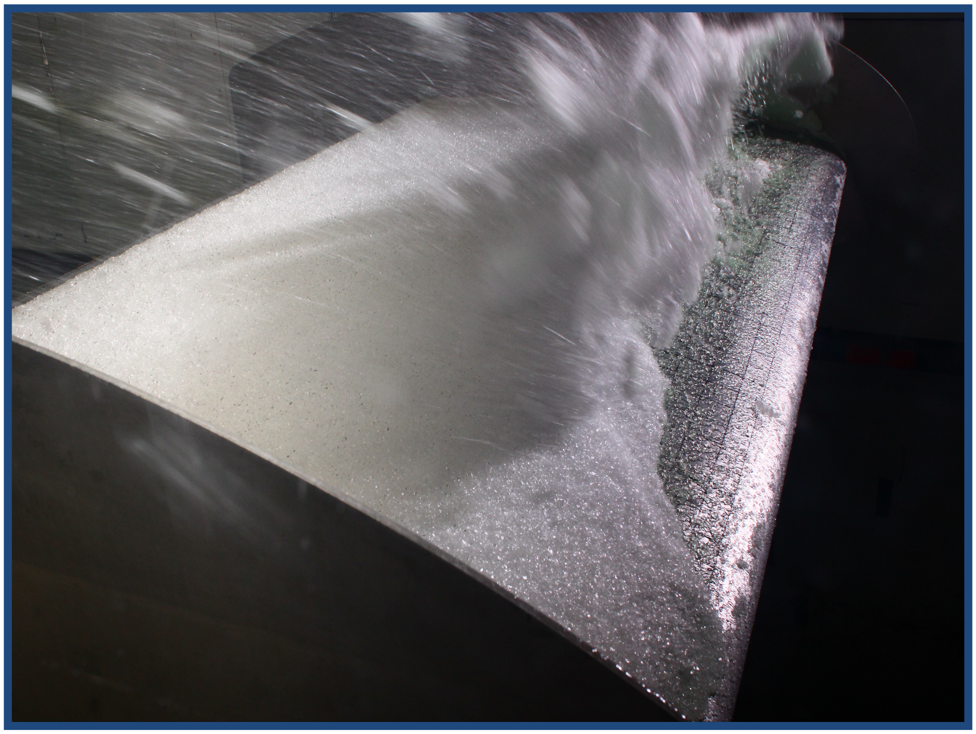
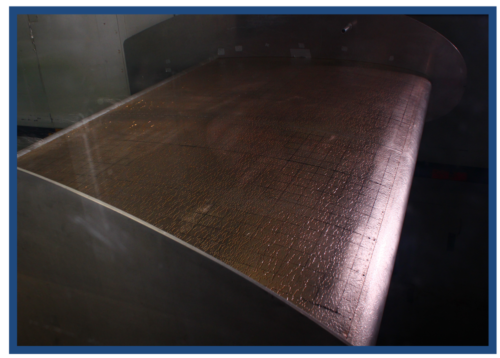
TP 15274E

EXPLORATORY WIND TUNNEL AERODYNAMIC RESEARCH EXAMINATION OF CONTAMINATED ANTI-ICING FLUID FLOW-OFF CHARACTERISTICS WINTER 2013-14





Prepared for
Transportation Development Centre

In cooperation with

Civil Aviation
Transport Canada

and

The Federal Aviation Administration
William J. Hughes Technical Center

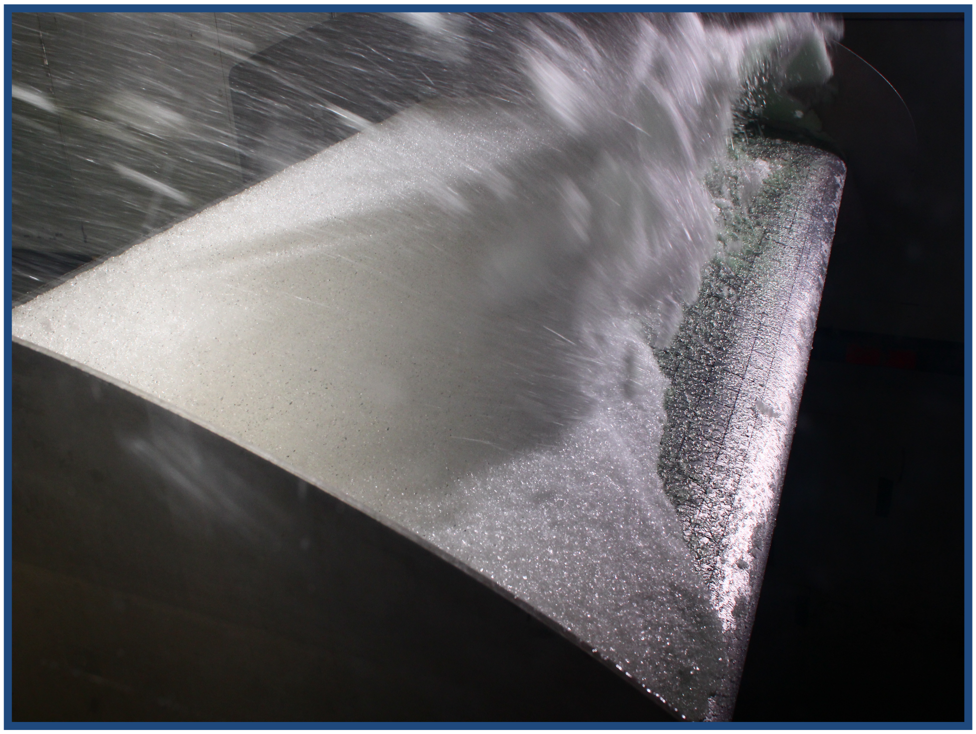
Prepared by:

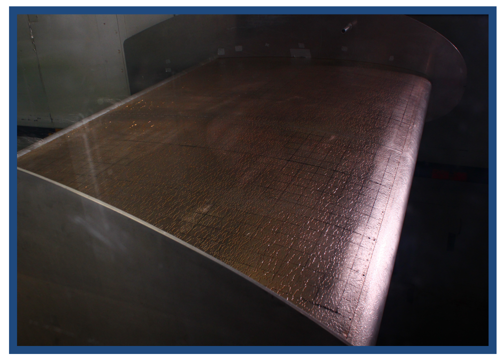
APS Aviation Inc.

June 2015
Final Version 1.0

TP 15274E

EXPLORATORY WIND TUNNEL AERODYNAMIC RESEARCH EXAMINATION OF CONTAMINATED ANTI-ICING FLUID FLOW-OFF CHARACTERISTICS WINTER 2013-14





by

Marco Ruggi

Prepared by:

APS Aviation Inc.

June 2015
Final Version 1.0

The contents of this report reflect the views of APS Aviation Inc. and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

DOCUMENT ORIGIN AND APPROVAL RECORD

Prepared by:

Aug 24, 2021

Marco Ruggi, Eng., M.B.A. — Date
Project Leader

Reviewed by:

Aug 24, 2021

John D'Avirro, Eng., PBDM — Date
Program Manager

Approved by: **

John Detombe — Date
Principal Engineer, Defence and Security
ADGA Group Consultant Inc.

Un sommaire français se trouve avant la table des matières.

This report was first provided to Transport Canada as Final Draft 1.0 in June 2015.
It has been published as Final Version 1.0 in August 2021.

***Final Draft 1.0 of this report was signed and provided to Transport Canada in June 2015. A Transport Canada technical and editorial review was subsequently completed and the report was finalized in August 2021; John Detombe was not available to participate in the final review or to sign the current version of the report.*

PREFACE

Under contract to the Transportation Development Centre of Transport Canada with support from the Federal Aviation Administration, APS Aviation Inc. has undertaken a research program to advance aircraft ground de/anti-icing technology. The specific objectives of the APS Aviation Inc. test program are the following:

- To develop holdover time data for all newly-qualified de/anti-icing fluids and update and maintain the website for the holdover time guidelines;
- To evaluate weather data from previous winters that can have an impact on the format of the holdover time guidelines;
- To conduct general and exploratory de/anti-icing research;
- To conduct tests to evaluate the effect of deployed flaps and slats prior to anti-icing;
- To conduct tests and research on surfaces treated with ice phobic products;
- To conduct tests with the snow machine to support ARP5485 changes;
- To conduct tests to evaluate holdover times in heavy snow conditions;
- To develop an SAE International Aerospace Information Report for the evaluation of aircraft coatings;
- To support the evaluation of the National Research Council Canada propulsion icing wind tunnel to determine its flow characteristics;
- To develop holdover time guidance for operation in ice crystal conditions;
- To continue research for development of ice detection capabilities for pre-deicing, engine deicing and departing aircraft at the runway threshold;
- To develop a performance specification for electronic holdover time applications;
- To investigate pre-takeoff contamination check 5-minute allowance;
- To conduct full-scale general aviation aircraft windshield washer fluid deicing testing to substantiate and support flat plate testing results;
- To develop training and fluid failure photos/videos for global archive;
- To update the regression coefficient report with the newly-qualified de/anti-icing fluids; and
- To develop guidelines on radiation cooling during taxi.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2013-14 are documented in eight reports. The titles of the reports are as follows:

- TP 15268E Winter Weather Impact on Holdover Time Table Format (1995-2014);
- TP 15269E Aircraft Ground Icing General Research Activities During the 2013-14 Winter;

- TP 15270E Regression Coefficients and Equations Used to Develop the Winter 2014-15 Aircraft Ground Deicing Holdover Time Tables;
- TP 15271E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2013-14 Winter;
- TP 15272E Cold Climate Technologies – Investigation of Sensor Technologies as an Alternative Means of Detecting Aircraft Icing (Year 3 of 3);
- TP 15273E Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2013-14;
- TP 15274E Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2013-14; and
- TP 15275E Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates.

In addition, the following interim report is being prepared:

- *Evaluation of Endurance Times on Extended Flaps and Slats.*

This report, TP 15274E, has the following objective:

- To support the evaluation of the National Research Council Canada Propulsion Icing Wind Tunnel to determine its flow characteristics.

This objective was met by conducting a series of full-scale tests using a supercritical wing section mounted in the National Research Council Canada open circuit wind tunnel to examine the flow-off properties of anti-icing fluids contaminated with various forms of simulated freezing precipitation to investigate several recent industry operational concerns. This work was completed in conjunction with the ice pellet research being conducted at the National Research Council Canada Propulsion Icing Wind Tunnel.

PROGRAM ACKNOWLEDGEMENTS

This multi-year research program has been funded by Transport Canada with support from the Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City, NJ. This program could not have been accomplished without the participation of many organizations. APS Aviation Inc. would therefore like to thank the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, National Research Council Canada, and several fluid manufacturers.

APS Aviation Inc. would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Yelyzaveta Asnytska, Brandon Auclair, Steven Baker, Stephanie Bendickson, John D'Avirro, Jesse Dybka, Ben Falvo, Benjamin Guthrie, Michael Hawdur, Eric Perocchio, Dany Posteraro, Marco Ruggi, Gordon Smith, James Smyth, David Youssef, Nondas Zoitakis, and Victoria Zoitakis.

Special thanks are extended to Howard Posluns, Yvan Chabot, Doug Ingold, Warren Underwood and Charles J. Enders, who on behalf of the Transportation Development Centre and the Federal Aviation Administration, have participated, contributed and provided guidance in the preparation of these documents.

REPORT ACKNOWLEDGEMENTS

The author would like to recognize the significant contributions of Elizabeth Asnytska, Brandon Auclair, Chloe Bernier, David Youssef, and Victoria Zoitakis at APS Aviation Inc. for their support in preparing this report.

This page intentionally left blank.

Transport Canada | Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.	2. Project No.	3. Recipient's Catalogue No.
TP 15274E	B14W	

4. Title and Subtitle

Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2013-14

5. Publication Date

June 2015

6. Performing Organization Document No.

CM2265.003

7. Author(s)

Marco Ruggi

8. Transport Canada File No.

2450-BP-14

9. Performing Organization Name and Address

APS Aviation Inc.
6700 Cote-de-Liesse Rd., Suite 105
Montreal, Quebec, H4T 2B5

10. PWGSC File No.

TOR-4-37170

11. PWGSC or Transport Canada Contract No.

T8156-140243/001/TOR

12. Sponsoring Agency Name and Address

Transportation Development Centre
Transport Canada
330 Sparks St., 26th Floor
Ottawa, Ontario, K1A 0N5

13. Type of Publication and Period Covered

Final

14. Project Officer

Antoine Lacroix for Howard Posluns

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Several research reports for testing of de/anti-icing technologies were produced for previous winters on behalf of Transport Canada. These are available from the Transportation Development Centre. Several reports were produced as part of this winter's research program. Their subject matter is outlined in the preface. This project was co-sponsored by the Federal Aviation Administration.

16. Abstract

This objective was met by conducting a series of full-scale tests using the National Research Council Canada (NRC) open circuit wind tunnel to examine the flow-off properties of anti-icing fluids contaminated with various forms of simulated freezing precipitation to investigate several recent industry operational concerns; this work was completed in conjunction with the ice pellet research being conducted at the NRC Propulsion Icing Wind Tunnel.

- EVALUATION OF AN AIRFOIL PERFORMANCE MONITOR (APM): The testing conducted provided Marinvent with a platform for evaluating the APM unit, the details of which remain internal to Marinvent. Initial observations saw fluid get into the pressure probes of the APM unit; however, the extent of the effects should be further investigated by the manufacturer. Future testing should be done with a wireless unit to minimize aerodynamic effects of passing wires over the wing.
- AERODYNAMIC TESTING OF ICE PHOBIC COATINGS: A test plan was developed and conducted during the winter of 2013-14 to gain new insight into the potential applications of these coatings for aircraft operations, and to continue the research to include newly developed coatings. As part of this test plan, it was recommended that testing continue to investigate the effects of these coatings on de/anti-icing fluids from both a holdover time and aerodynamic perspective.
- EFFECT OF COOLING SYSTEM ON TESTING PROCEDURES: In general, the concept has shown promise and with some effort to isolate the problematic areas of the system, the cooling system can become a critical tool for testing and will allow greater flexibility.

17. Key Words

Data Log, Airfoil Performance Monitor, Aerodynamic testing of Ice Phobic coatings, Type I Fluid, Ice Pellet dispensers, Cooling System, Heavy Contamination

18. Distribution Statement

Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
Unclassified	Unclassified	—	xviii, 78 apps	—

CDT/TDC 79-005
Rev. 96

Canada

Transports Canada | Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. Nº de la publication de Transports Canada
TP 15274E

2. Nº de l'étude
B14W

3. Nº de catalogue du destinataire

4. Titre et sous-titre
Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2013-14

5. Date de la publication
Juin 2015

6. Nº de document de l'organisme exécutant
CM2265.003

7. Auteur(s)
Marco Ruggi

8. Nº de dossier - Transports Canada
2450-BP-14

9. Nom et adresse de l'organisme exécutant
APS Aviation Inc.
6700, Chemin de la Côte-de-Liesse, Bureau 105
Montréal (Québec) H4T 2B5

10. Nº de dossier - TPSGC
TOR-4-37170

11. Nº de contrat - TPSGC ou Transports Canada
T8156-140243/001/TOR

12. Nom et adresse de l'organisme parrain
Centre de développement des transports
Transports Canada
330, rue Sparks, 26ième étage
Ottawa (Ontario) K1A 0N5

13. Genre de publication et période visée
Final

14. Agent de projet
Antoine Lacroix pour Howard Posluns

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)
Plusieurs rapports de recherche sur des essais de technologies de dégivrage et d'antigivrage ont été produits au cours des hivers précédents pour le compte de Transports Canada. Ils sont disponibles auprès du Centre de développement des transports. Plusieurs rapports ont été rédigés dans le cadre du programme de recherche de cet hiver. Leur objet apparaît à l'avant-propos. Ce projet était coparrainé par la Federal Aviation Administration.

16. Résumé

Cet objectif a été atteint en réalisant une série d'essais pleine grandeur dans la soufflerie à circuit ouvert du Conseil national de recherches Canada (CNRC) visant à examiner les propriétés de ruissellement de liquides d'antigivrage contaminés par diverses formes de précipitations givrantes simulées dans le but d'étudier de récentes préoccupations opérationnelles du secteur. Les travaux ont été réalisés en même temps que la recherche sur les granules de glace menée dans la soufflerie de givrage à propulsion du CNRC.

- ÉVALUATION D'UN MONITEUR DE PERFORMANCE DU PROFIL D'AILE (APM) : Les essais réalisés ont fourni à Marinvent une plateforme lui permettant d'évaluer l'APM, dont les détails ont été conservés à l'interne. Les premières observations ont révélé que du liquide s'introduisait dans les sondes de pression de l'APM ; la portée des effets devrait toutefois être étudiée davantage par le fabricant. D'autres essais devraient être réalisés avec un dispositif sans fil afin de réduire au minimum les effets aérodynamiques causés par les fils qui passent par-dessus les ailes.
- ESSAIS AÉRODYNAMIQUES SUR LES REVÊTEMENTS GLACIOPHOBES : Un plan d'essais a été conçu et mis en œuvre au cours de l'hiver 2013-2014 dans le but d'étudier d'autres facteurs et d'obtenir de nouveaux renseignements sur les possibles applications de ces revêtements pour la navigation aérienne, ainsi que pour continuer les recherches de façon à inclure les formulations de revêtement nouvellement développées. Dans le cadre de ce plan, il a été recommandé de poursuivre les essais afin d'étudier les effets de tels revêtements sur les liquides de dégivrage et d'antigivrage du point de vue des durées d'efficacité et de l'aérodynamisme.
- EFFET DU SYSTÈME DE REFROIDISSEMENT SUR LES PROCÉDURES D'ESSAI : En général, le concept s'est révélé prometteur et, en déployant quelques efforts pour isoler les zones problématiques, le système de refroidissement peut devenir un outil essentiel pour les essais, offrant une plus grande flexibilité.

17. Mots clés
Registre de données, moniteur de performance du profil d'aile, essais aérodynamiques sur les revêtements glaciophobes, liquide de type I, distributeurs de granules de glace, système de refroidissement, forte contamination

18. Diffusion
Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	—	xviii, 78 ann	—

CDT/TDC 79-005
Rev. 96

Canada

EXECUTIVE SUMMARY

BACKGROUND

Under contract to the Transportation Development Centre (TDC), with financial support from the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology. APS conducted a series of full-scale tests in the National Research Council Canada (NRC) 3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel (PIWT) to determine the flow-off characteristics of anti-icing fluid with and without simulated frozen precipitation contamination.

To benefit from economies of scale associated with the large fixed cost component, Transport Canada (TC) and the FAA opted to conduct a series of tests to investigate areas of research that are of interest to industry to address operational concerns. This work was completed in conjunction with the ice pellet research being conducted at the NRC PIWT. Details of the 2013-14 ice pellet allowance time related research as well as the wind tunnel and wing calibration and characterization can be found in the TC report, TP 15273E, *Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2013-14* (1).

Evaluation of an Airfoil Performance Monitor (APM)

The testing conducted provided Marinvent with a platform for evaluating the APM unit, the details of which remain internal to Marinvent. Similar to the 2012-13 testing, initial observations saw fluid enter the pressure probes of the APM unit; the effects of fluid intrusion should be further investigated by the manufacturer. This collaborative effort between TC/FAA and Marinvent has provided laboratory data generated in a controlled environment that can be used to further the development of this sensor and increase the likeliness of this technology being used in the field.

Aerodynamic Testing of Ice Phobic Coatings

A test plan was developed and conducted during the winter of 2013-14 to gain new insight into the potential applications of these coatings for aircraft operations, and to continue the research to include newly developed coatings. As part of this test plan, it was recommended that testing continue to investigate the effects of these coatings on de/anti-icing fluids from both a holdover time (HOT) and aerodynamic perspective. The work conducted in the wind tunnel during the winter of 2013-14 was done as part of a larger multi-year project, the details of which are included in the TC report, TP 15275E, *Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates* (Vol. 1) (2).

Type I Fluid for Very Low Speed Aircraft

The results from the PIWT and boundary layer displacement thickness (BLDT) testing indicated that lift loss and BLDT increase as temperature or speed decreases. Raising the fluid lowest operational use temperature (LOUT) (to warmer temperatures) could compensate for lower rotation speeds and provide some flexibility for aircraft with very low rotation speeds. Alternatively, using a fluid with a much lower LOUT could also provide additional flexibility at the lower temperatures with the lower speeds. It should be noted that these results are based on 2-dimensional modelling and some full-scale testing would likely be required in order for operational guidance changes to be issued.

Evaluation of New Generation Ice Pellet Dispensers

The results indicate that the differences in recorded lift losses were generally very small when comparing back-to-back tests with no bias towards one system or the other. In addition, the tests were visually evaluated to verify that the distribution of the ice pellets was similar, further supporting the similarity in aerodynamic results between the two dispenser systems. In general, the results further support the original distribution equivalency work conducted during the winter of 2012-13 and demonstrates that the new generation dispensers are suitable replacements for the older model dispensers.

Effect of Cooling System on Testing Procedures

In general, the concept has shown promise and with some effort to isolate the problematic areas of the system, the cooling system can become a critical tool for testing and will allow greater flexibility.

Heavy Contamination

In general, the results indicated that although a significant amount of frozen contamination was present prior to takeoff, the anti-icing fluid provided the protection required by allowing the shear forces to remove most of the ice prior to rotation. Although difficult to extrapolate such an extreme case in a two-dimensional model to a full-scale aircraft, it does provide information into the safety buffers inherently built into these fluids.

SOMMAIRE

CONTEXTE

Dans le cadre d'un contrat avec le Centre de développement des transports (CDT) et avec l'appui financier de la Federal Aviation Administration (FAA), APS Aviation Inc. (APS) a entrepris des activités de recherche visant à faire progresser les technologies associées au dégivrage et à l'antigivrage d'aéronefs au sol. APS a mené une série d'essais pleine grandeur dans la soufflerie de givrage à propulsion et à circuit ouvert de 3 m sur 6 m du Conseil national de recherches Canada (CNRC) afin de déterminer les caractéristiques de ruissellement du liquide d'antigivrage avec et sans contamination par des précipitations gelées simulées.

Afin de profiter des économies d'échelle associées au composant à coûts fixes élevés, Transports Canada (TC) et la FAA ont décidé de mener une série d'essais dans le but d'étudier des domaines de recherche revêtant un intérêt pour le secteur afin de répondre à des préoccupations opérationnelles. Ces essais ont été réalisés en même temps que la recherche sur les granules de glace menée dans la soufflerie de givrage à propulsion du CNRC. Les résultats des essais menés en 2013-2014 sur les marges de tolérance dans des conditions de granules de glace, de même que les résultats des essais menés en soufflerie et sur l'étalonnage et la caractérisation des ailes, se trouvent dans le rapport de TC, TP 15273E, *Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2013-14* (1).

<u>Évaluation d'un moniteur de performance du profil d'aile (APM)</u>

Les essais réalisés ont fourni à Marinvent une plateforme lui permettant d'évaluer l'APM, dont les détails ont été conservés à l'interne. Comme lors des essais menés en 2012-2013, les premières observations ont révélé que du liquide s'introduisait dans les sondes de pression de l'APM ; la portée des effets devrait toutefois être étudiée davantage par le fabricant. Cette collaboration entre TC, la FAA et Marinvent a permis de générer des données de laboratoire dans un environnement contrôlé pouvant être utilisées pour poursuivre le développement de ce capteur et accroître la possibilité que cette technologie soit utilisée sur le terrain.

<u>Essais aérodynamiques sur les revêtements glaciophobes</u>

Un plan d'essais a été conçu et mis en œuvre au cours de l'hiver 2013-2014 dans le but d'étudier d'autres facteurs et d'obtenir de nouveaux renseignements sur les possibles applications de ces revêtements pour la navigation aérienne, ainsi que pour continuer les recherches de façon à inclure les formulations de revêtement nouvellement développées. Dans le cadre de ce plan, il a été recommandé de poursuivre les essais afin d'étudier les effets de tels revêtements sur les liquides de dégivrage et d'antigivrage du point de vue des durées d'efficacité et de l'aérodynamisme. Les travaux réalisés dans la soufflerie au cours de l'hiver 2013-2014 s'inscrivaient dans un projet plus vaste de plusieurs années, dont les détails sont inclus dans le rapport de TC, TP 15275E, *Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates* (Vol. 1) (2).

Liquide de type I pour les aéronefs à très basse vitesse

Selon les résultats des essais en soufflerie et sur l'épaisseur de déplacement de la couche limite (EDCL), la perte de portance et l'EDCL augmentent à mesure que la température ou la vitesse diminuent. L'élévation de la température minimale d'utilisation opérationnelle (LOUT) du liquide pourrait compenser les vitesses de rotation plus basses et fournir une certaine flexibilité pour les aéronefs dont la vitesse de rotation est très basse. L'utilisation d'un liquide associé à une LOUT beaucoup plus basse pourrait aussi augmenter la flexibilité à des températures et à des vitesses plus basses. Il convient de noter que ces résultats ont été obtenus à partir d'un modèle bidimensionnel ; des essais en grandeur réelle seraient probablement requis pour apporter des changements aux directives opérationnelles.

Évaluation des distributeurs de granules de glace de nouvelle génération

Les résultats indiquent que les différences dans les pertes de portance enregistrées étaient généralement très faibles lorsque l'on compare les essais successifs sans parti pris pour un système ou un autre. En outre, les essais ont été évalués de façon visuelle afin de veiller à ce que la distribution des granules de glace soit semblable, ce qui vient confirmer la similarité des résultats aérodynamiques entre les deux distributeurs. En général, les résultats sont venus étayer les travaux d'équivalence de la distribution d'origine menés au cours de l'hiver 2012-2013 et démontrent que les distributeurs de nouvelle génération constituent des remplacements adéquats pour les anciens modèles.

Effet du système de refroidissement sur les procédures d'essai

En général, le concept s'est révélé prometteur et, en déployant quelques efforts pour isoler les zones problématiques, le système de refroidissement peut devenir un outil essentiel pour les essais, offrant une plus grande flexibilité.

Forte contamination

En général, les résultats ont indiqué que, même si une quantité importante de contaminants gelés était présente avant le décollage, le liquide d'antigivrage fournissait la protection requise en permettant à la force de cisaillement d'éliminer presque totalement la glace avant la rotation. Bien qu'il soit difficile d'extrapoler une situation si extrême d'un modèle bidimensionnel à un aéronef pleine grandeur, ces résultats fournissent de l'information sur les marges de sécurité inhérentes à ces liquides.

CONTENTS Page

LIST OF APPENDICES

LIST OF FIGURES Page

LIST OF TABLES Page

LIST OF PHOTOS Page

This page intentionally left blank.

GLOSSARY

APM	Airfoil Performance Monitor
APS	APS Aviation Inc.
BLDT	Boundary Layer Displacement Thickness
CEF	Climatic Engineering Facility
EG	Ethylene Glycol
FAA	Federal Aviation Administration
HOT	Holdover Time
LOUT	Lowest Operational Use Temperature
MSC	Meteorological Service of Canada
NRC	National Research Council Canada
OAT	Outside Air Temperature
PIWT	3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel
SAE	SAE International
TC	Transport Canada
TDC	Transportation Development Centre

This page intentionally left blank.

1. INTRODUCTION

Under winter precipitation conditions, aircraft are cleaned with a freezing point depressant fluid and protected against further accumulation by an additional application of such a fluid, possibly thickened to extend the protection time. Aircraft ground deicing had, until recently, never been researched and there is still an incomplete understanding of the hazard and of what can be done to reduce the risks posed by the operation of aircraft in winter precipitation conditions. This "winter operations contaminated aircraft – ground" program of research is aimed at overcoming this lack of knowledge.

Since the early 1990s, the Transportation Development Centre (TDC) of Transport Canada (TC) has managed and conducted de/anti-icing related tests at various sites in Canada; it has also coordinated worldwide testing and evaluation of evolving technologies related to de/anti-icing operations with the co-operation of the United States Federal Aviation Administration (FAA), the National Research Council Canada (NRC), the Meteorological Service of Canada (MSC), several major airlines, and deicing fluid manufacturers. The TDC is continuing its research, development, testing and evaluation program.

Under contract to the TDC, with financial support from the FAA, APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology.

As part of a larger research program examining de/anti-icing fluid flow-off during simulated aircraft takeoff, APS conducted a series of full-scale tests in the NRC 3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel (PIWT) using a super-critical wing model to determine the flow-off characteristics of anti-icing fluid with and without mixed precipitation conditions with ice pellets.

1.1 Background

The Ice Pellet Allowance Time research has helped further develop and improve the PIWT facility. As a result, a new medium is now available for aerodynamic testing of aircraft ground icing fluids with or without contamination in a full-scale format. Several other ground deicing projects have been ongoing as a result of industry requests and are expected to continue. The PIWT has evolved into a multidisciplinary facility; however, it continues to be the primary source for the development and further refinement of the ground deicing ice pellet allowance time guidance material.

To benefit from economies of scale associated with the large fixed cost component of running the PIWT, TC and the FAA opted to conduct a series of tests to investigate areas of research that are of interest to industry to address operational concerns. This work was completed in conjunction with the ice pellet research being conducted at the NRC PIWT. Details of the 2013-14 ice pellet allowance time related research, as well as the wind tunnel and wing calibration and characterization research, can be found in the TC report, TP 15273E, *Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2013-14* (1).

1.2 Previous Reports

Reports describing the research and development objectives conducted in previous years in the NRC wind tunnel have been compiled and are available. In 2008-09, 2009-10, 2010-11, and 2012-13, comprehensive reports describing the R&D objectives were compiled and can be referenced as:

- TC report, TP 14939E, *Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2008-09* (3);
- TC report, TP 15057E, *Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2009-10* (4);
- TC report, TP 15160E, *Exploratory Wind Tunnel Aerodynamic Research: Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2010-11* (5); and
- TC report, TP 15233E, *Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2012-13* (6).

In 2006-07, a feasibility report describing the potential for using the wind tunnel and Falcon 20 aircraft for R&D testing initiatives was compiled and can be referenced as TC report, TP 14778E, *Flow of Contaminated Fluid from Aircraft Wings: Feasibility Report* (7).

1.3 Program Objectives

Full-scale testing during the winter of 2013-14 was conducted using the NRC PIWT. The primary testing conducted aimed at validating the current allowance times for use with newer generation aircraft with thin high-performance wing designs, as well as completing the wind tunnel and wing calibration and characterization research.

As part of this larger research program, APS conducted some additional testing during the winter of 2013-14 to investigate several areas of research. Aerodynamic testing was conducted in conjunction with the ice pellet allowance time research program. Research was conducted to satisfy the following objectives:

- Evaluation of an airfoil performance monitor (APM);
- Evaluation of ice phobic coatings with and without fluid;
- Type I fluid use for very low-speed aircraft;
- Equivalency evaluation of a new ice pellet dispenser system;
- Evaluation of a cooling system for the wind tunnel test section; and
- Heavy contamination and aerodynamic effects.

The results from this work are reported in Sections 3 to 7 of this report. The work statement for these tests is provided in Appendix A.

1.4 Overview of 2013-14 Testing

Table 1.1 demonstrates the groupings for the global set of tests conducted at the wind tunnel during the winter of 2013-14. Only tests pertaining to Objectives #5, #6, #7, and #8 are described in this report.

Table 1.1: Summary of 2013-14 Wind Tunnel Tests by Objective

Objective #	Objective	# of Runs
1	Baseline	26
2	Type III Allowance Times	28
3	Ice Pellet Expansion	11
4	Ice Pellet Validation with New Temperatures & Fluids	10
5	Ice Phobic Coatings	257
6	Type I Very Low Speed	31
7	New Ice Pellet Dispenser System Validation	11
8	R&D (APM, Heavy Contamination, Cooling System)	9
	Total	**383**

1.5 General Methodology

To satisfy the program objective, simulated takeoff and climb-out tests were performed with the thin high-performance wing section, and different parameters, including fluid thickness, wing temperature, and fluid freezing point, were recorded at designated times during the tests. The thin high-performance wing section was constructed by the NRC specifically to conduct these tests following extensive consultations with an airframe manufacturer to ensure a representative thin high-performance design was used.

The typical procedure for each test was as follows:

a) The wing section was treated with anti-icing fluid, poured as a one-step operation;
b) In some tests, contamination, in the form of simulated ice pellets, freezing rain, and/or snow, was applied to the wing section. Test parameters were measured at the beginning and end of the exposure to contamination;
c) At the end of the contamination period (if applicable), the tunnel was cleared of all equipment and scaffolding;
d) The wind tunnel was subsequently operated through a simulated takeoff and climb-out test; and
e) The behaviour of the fluid during takeoff and climb-out was recorded with digital high-speed still cameras. In addition, windows overlooking the wing section allowed observers to document the fluid elimination performance in real-time.

The procedure for the wind tunnel tests is included in Appendix B. The procedure includes details regarding the test objectives, test plan, procedure and methodology, and pertinent information and documentation.

This general methodology was modified as necessary in order to satisfy the individual test objectives. Deviation from this methodology will be described in the individual test results sections.

1.6 General Analysis Methodology

A thorough and extensive analysis methodology has been developed and applied for the ice pellet allowance time testing. This is described in the TC report, TP 15232E, *Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics and to Support the Development of Ice Pellet Allowance Times, Winters 2009-10 to 2012-13* (8). This analysis methodology has been applied when applicable for analysing the tests described in this report.

Typically, each test is analysed in detail using the following objectives:

a) Test parameters;

b) Visual ratings at the start of the test;

c) Visual ratings at rotation;

d) 8° rotation lift loss; and

e) Overall test status.

The evaluation grades for each criterion were "good," "review," or "bad." These grades were determined based on whether the criteria satisfied each test objective requirement. Figure 1.1 shows a summary of each test objective and criteria. These evaluation criteria were applied as necessary to the analysis of the tests described in this report.

1. TEST PARAMETERS

2. VISUAL RATINGS AT START OF TEST

CRITERIA:	**LE / TE**	**≤ 3**
	Flap	**≤ 4**

≤ 3, 3, 4	GOOD
> 3, 3, 4 to 3.5, 3.5, 4.5	REVIEW
> 3.5, 3.5, 4.5	BAD

3. VISUAL RATINGS AT ROTATION

CRITERIA:	**LE**	**= 1**

1	GOOD
1 to 1.5	REVIEW
> 1.5	BAD

4. LIFT LOSS AT 8°

CRITERIA:

< -2 σ	< 5.4%	GOOD
-2 σ to 2σ	5.4% to 9.2%	REVIEW
> +2 σ	> 9.2%	BAD

OVERALL STATUS

IF ANY OF THE ABOVE CRITERIA ARE RED, TEST IS NOT ACCEPTABLE

THEREFORE WORST OF ABOVE 3 CRITERIA, ORDER IS:

GREEN
YELLOW
RED

Figure 1.1: Wind Tunnel Test Analysis Criteria

1.7 General Data

For documentation purposes, data that was collected during the wind tunnel tests has been included in this report regardless of whether or not the information was used for analysis. Completed wing temperature, fluid thickness, and fluid Brix data forms have been included in Appendix C. High-speed digital photography of each test, as well as video in some cases, was taken. However, due to the large amount of data available, photos of the individual tests have not been included in this report. Rather, the high-resolution photos are in electronic format and have been made available to the TDC and can be seen upon request.

1.8 Report Format

The following list provides short descriptions of subsequent sections of this report:

a) Section 2 contains the global test log for the 2013-14 wind tunnel testing campaign;

b) Section 3 describes the data, results, and observations for the evaluation of the APM;

c) Section 4 describes the data, results, and observations for the evaluation of ice phobic coatings with and without fluid;

d) Section 5 describes the data, results, and observations for the Type I fluid use for very low-speed aircraft;

e) Section 6 describes the data, results, and observations for the equivalency evaluation of a new ice pellet dispenser system;

f) Section 7 describes the data, results, and observations for the evaluation of a cooling system for the wind tunnel test section; and

g) Section 8 describes the data, results, and observations for the heavy contamination tests.

2. DATA LOG

2.1 Test Log

A detailed log of the tests conducted in the NRC PIWT is shown in Table 2.1. Data pertaining to all test objectives (ice pellet allowance time research objectives as well) is included in the log. Table 2.1 provides relevant information for each of the tests, as well as final values used for the data analysis. Each column contains data specific to one test. The following is a brief description of the column headings for Table 2.1.

Test #:	Exclusive number identifying each test.
Test Year:	The year in which the test was conducted.
Objective:	Main objective of the test.
Test Condition:	Description of the simulated conditions for the test.
Fluid Name:	Name of the aircraft anti-icing fluid used during the test.
Rotation Angle (º):	Maximum angle of rotation obtained during simulated takeoff run; began testing with a max 8º rotation angle and increased to 20º as testing progressed.
Flap Angle:	Positioning of the flap during the precipitation period; either 0º (retracted) or 20º (extended). *Note: Flap was always extended at 20º during the takeoff run.*
Date:	Date when the test was conducted.
OAT Before Test (ºC):	Outside air temperature recorded just before the start of the simulated takeoff test, measured in degrees Celsius. *Note: Not an important parameter as "Tunnel Temp. Before Test" was used as actual test temperature for analysis.*
Tunnel Temp. Before Test (ºC):	Static tunnel ambient temperature recorded just before the start of the simulated takeoff test, measured in degrees Celsius. *Note: This parameter was used as the actual test temperature for analysis.*

Precipitation Rate (g/dm²/h): Simulated freezing or frozen precipitation rate (or combination of different precipitation rates). "N/A" indicates that no precipitation was applied.

Exposure Time: Simulated precipitation period, recorded in minutes.

The visual contamination ratings are described below. Visual contamination ratings were typically reported as the average of the three observer ratings and rounded to the nearest decimal. The visual contamination ratings system is further described in Subsection 4.1.

Visual Contamination Rating Before Takeoff (LE, TE, Flap): Visual contamination rating determined before the start of the simulated takeoff:

1 - Contamination not very visible, fluid still clean.
2 - Contamination is visible, but lots of fluid still present.
3 - Contamination visible, spots of bridging contamination.
4 - Contamination visible, lots of dry bridging present.
5 - Contamination visible, adherence of contamination.

Visual Contamination Rating at Rotation (LE, TE, Flap): Visual contamination rating determined at the time of rotation:

1 - Contamination not very visible, fluid still clean.
2 - Contamination is visible, but lots of fluid still present.
3 - Contamination visible, spots of bridging contamination.
4 - Contamination visible, lots of dry bridging present.
5 - Contamination visible, adherence of contamination.

Visual Contamination Rating After Takeoff (LE, TE, Flap): Visual contamination rating determined at the end of the test:

1 - Contamination not very visible, fluid still clean.
2 - Contamination is visible, but lots of fluid still present.
3 - Contamination visible, spots of bridging contamination.
4 - Contamination visible, lots of dry bridging present.
5 - Contamination visible, adherence of contamination.

Corrected for 3D Effects C_L at 8º: Calculated lift coefficient at the 8º wing rotation angle position; data provided by the NRC.

Corrected for 3D Effects % Lift Loss on C_L vs. Dry C_L: Percentage lift loss calculated based on the comparison of the 8º lift coefficient during the test run versus the dry wing average lift coefficient.

Speed (kts): Maximum speed obtained during simulated takeoff run, recorded in knots.

Table 2.1: Wind Tunnel Test Log 2013-14

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
1	2013-14	Baseline	Dry Wing	none	22	20	8-Jan-14	-9.9	-9.3	-	-	-	-	-	1.460	0.38%	80
2	2013-14	Baseline	Dry Wing	none	8	20	8-Jan-14	-9.9	-9.3	-	-	-	-	-	1.473	-0.56%	100
3	2013-14	Baseline	Dry Wing	none	22	20	8-Jan-14	-10.1	-10.1	-	-	-	-	-	1.460	0.34%	80
4	2013-14	Baseline	Dry Wing	none	8	20	8-Jan-14	-10.1	-10.1	-	-	-	-	-	1.474	-0.60%	100
5	2013-14	R&D	EFFECT OF COOLING SYSTEM	EG106	8	20	8-Jan-14	-9.2	-5.2	-	-	-	-	-	1.439	1.78%	100
6	2013-14	R&D	EFFECT OF COOLING SYSTEM	EG106	8	20	8-Jan-14	n/a	n/a	-	-	-	-	-	n/a	-	100
7	2013-14	Baseline	Dry Wing	none	22	20	9-Jan-14	-11.5	-9.9	-	-	-	-	-	1.462	0.24%	80
8	2013-14	Baseline	Dry Wing	none	8	20	9-Jan-14	-10.1	-7.3	-	-	-	-	-	1.471	-0.41%	100
9	2013-14	IP Expansion	IP- / SN-	ABC-S Plus	8	20	9-Jan-14	-10.1	-7.3	IP=25 SN=10	10	2, 2, 2.5	1, 1.5, 1.75	1, 1, 1.1	1.370	6.47%	100
10	2013-14	IP Expansion	IP- / SN	ABC-S Plus	8	20	9-Jan-14	-9.6	-6.7	IP=25 SN=25	10	2, 2, 3	1, 1.5, 2.25	1, 1, 1.2	1.372	6.38%	100
11	2013-14	IP Expansion	IP- / SN	Launch	8	20	9-Jan-14	-9	-5.2	IP=25 SN=25	10	2, 1.75, 3.25	1, 1.35, 2.25	1, 1, 1.2	1.367	6.70%	100
12	2013-14	IP Expansion	IP- / SN	AD-49	8	20	9-Jan-14	-7.4	-3.3	IP=25 SN=25	10	2, 2, 3.5	1, 1.6, 2.25	1, 1.2, 1.4	1.381	5.75%	100
13	2013-14	Type III Allowance Times	IP- / SN	2031 - Cold	8	20	9-Jan-14	-7.4	-3.1	IP=25 SN=25	10	2.25, 1.9, 3.5	1, 1.5, 1.95	1, 1.15, 1.2	1.431	2.32%	100
14	2013-14	Type III Allowance Times	IP- / SN-	2031 - Cold	8	20	9-Jan-14	-7.2	-4.2	IP=25 SN=10	10	2, 2, 2.1	1, 1.05, 1.25	1, 1, 1	1.441	1.64%	100
15	2013-14	Type III Allowance Times	IP-	2031 - Cold	8	20	9-Jan-14	-7.1	-4.7	IP=25	10	2, 2, 2	1, 1, 1.15	1, 1, 1	1.434	2.14%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
16	2013-14	Type III Allowance Times	IP Mod	2031 - Cold	8	20	9-Jan-14	-7.3	-4.8	IP=75	5	2, 2, 2.15	1, 1.1, 1.4	1, 1, 1	1.441	1.63%	100
17	2013-14	Baseline	Dry Wing	none	22	20	10-Jan-14	-11.2	-4.8	-	-	-	-	-	1.465	0.00%	80
18	2013-14	Baseline	Dry Wing	none	8	20	10-Jan-14	-11.2	-4.8	-	-	-	-	-	1.462	0.22%	100
19	2013-14	Type III Allowance Times	IP- / ZR-	2031 - Cold	8	20	10-Jan-14	-9.2	-3.8	IP=25 ZR=25	7	2, 2, 2.15	1, 1, 1.5	1, 1, 1.35	1.442	1.57%	100
20	2013-14	Type III Allowance Times	IP- / ZR-	2031 - Hot	8	20	10-Jan-14	-8.5	-3.3	IP=25 ZR=25	7	1.25, 1.5, 1.45	1, 1, 1	1, 1, 1	1.439	1.77%	100
21	2013-14	Type III Allowance Times	IP-	2031 - Hot	8	20	10-Jan-14	-7.7	-5.2	IP=25	10	2, 2, 2.1	1, 5, 1	1, 5, 1	1.437	1.90%	100
22	2013-14	Type III Allowance Times	IP-	2031 - Hot	8	20	10-Jan-14	-7.2	-2.8	IP=25	7	1.9, 1.75, 1.25	1, 3, 1	1, 3, 1	1.441	1.64%	100
23	2013-14	Type III Allowance Times	IP-	2031 - Hot	8	20	10-Jan-14	-6.9	-2.9	IP=25	5	1.5, 1.25, 1.15	1, 1, 1	1, 1, 1	1.436	2.00%	100
24	2013-14	Type III Allowance Times	IP Mod	2031 - Hot	8	20	10-Jan-14	-6.7	-3	IP=75	5	2.25, 2, 2.25	1, 5, 1	1, 5, 1	1.444	1.46%	100
25	2013-14	Type III Allowance Times	IP- / SN	2031 - Hot	8	20	10-Jan-14	-6.1	-2.3	IP=25 SN=25	10	2.5, 2, 3.75	1, 3.25, 3.75	1, 5, 3.75	1.439	1.76%	100
26	2013-14	Baseline	Dry Wing	none	22	20	13-Jan-14	4.8	8.1	-	-	-	-	-	1.460	0.35%	80
27	2013-14	Baseline	Dry Wing	none	8	20	13-Jan-14	4.8	8.1	-	-	-	-	-	1.477	-0.81%	100
28	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.470	-0.29%	100
29	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.471	-0.37%	100
30	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.473	-0.56%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
31	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.481	-1.10%	100
32	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.482	-1.14%	100
33	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.482	-1.11%	100
34	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	5.5	5.7	-	-	-	-	-	n/a	-	80
35	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	5.5	5.7	-	-	-	-	-	n/a	-	80
36	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	5.5	5.7	-	-	-	-	-	n/a	-	80
37	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	5.5	5.7	-	-	-	-	-	n/a	-	100
38	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	5.5	5.7	-	-	-	-	-	n/a	-	100
39	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	5.5	5.7	-	-	-	-	-	n/a	-	100
40	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	5.5	5.7	-	-	-	-	-	n/a	-	115
41	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	5.5	5.7	-	-	-	-	-	n/a	-	115
42	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	5.5	5.7	-	-	-	-	-	n/a	-	115
43	2013-14	Ice Phobic R&D	Dry Wing	none	22	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.461	0.26%	80
44	2013-14	Ice Phobic R&D	Dry Wing	none	22	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.466	-0.03%	80
45	2013-14	Ice Phobic R&D	Dry Wing	none	22	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.466	-0.03%	80

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
46	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.474	-0.63%	100
47	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.469	-0.27%	100
48	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	13-Jan-14	5.5	5.7	-	-	-	-	-	1.469	-0.26%	100
49	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	40
50	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	40
51	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	40
52	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	60
53	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	60
54	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	60
55	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	80
56	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	80
57	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	80
58	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	100
59	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	100
60	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
61	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	max (120)
62	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	max (120)
63	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	13-Jan-14	6.1	6.4	-	-	-	-	-	n/a	-	max (120)
64	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	13-Jan-14	6.1	6.4	-	-	-	-	-	1.448	1.21%	80
65	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	13-Jan-14	6.1	6.4	-	-	-	-	-	1.464	0.09%	80
66	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	13-Jan-14	6.1	6.4	-	-	-	-	-	1.464	0.09%	80
67	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.466	-0.08%	100
68	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.459	0.44%	100
69	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.460	0.33%	100
70	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.471	-0.38%	100
71	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.470	-0.32%	100
72	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.470	-0.32%	100
73	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	80
74	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	80
75	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	80

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
76	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	100
77	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	100
78	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	100
79	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	115
80	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	115
81	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	115
82	2013-14	Ice Phobic R&D	Dry Wing	none	20	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.449	1.11%	80
83	2013-14	Ice Phobic R&D	Dry Wing	none	20	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.449	1.14%	80
84	2013-14	Ice Phobic R&D	Dry Wing	none	20	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.447	1.24%	80
85	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.458	0.46%	100
86	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.461	0.27%	100
87	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.462	0.20%	100
88	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.464	0.11%	100
89	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.465	0.04%	100
90	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.461	0.30%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
91	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.470	-0.31%	100
92	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.472	-0.44%	100
93	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.470	-0.33%	100
94	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	80
95	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	80
96	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	80
97	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	100
98	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	100
99	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	100
100	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	115
101	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	115
102	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.4	4.3	-	-	-	-	-	n/a	-	115
103	2013-14	Ice Phobic R&D	Dry Wing	none	20	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.445	1.37%	80
104	2013-14	Ice Phobic R&D	Dry Wing	none	20	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.444	1.44%	80
105	2013-14	Ice Phobic R&D	Dry Wing	none	20	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.451	0.97%	80

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
106	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.463	0.17%	100
107	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.460	0.36%	100
108	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.4	4.3	-	-	-	-	-	1.461	0.31%	100
109	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.460	0.33%	100
110	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.458	0.50%	100
111	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.462	0.25%	100
112	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.466	-0.02%	100
113	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.464	0.06%	100
114	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.466	-0.07%	100
115	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.3	4.4	-	-	-	-	-	n/a	-	80
116	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.3	4.4	-	-	-	-	-	n/a	-	80
117	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.3	4.4	-	-	-	-	-	n/a	-	80
118	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.3	4.4	-	-	-	-	-	n/a	-	100
119	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.3	4.4	-	-	-	-	-	n/a	-	100
120	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.3	4.4	-	-	-	-	-	n/a	-	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
121	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.3	4.4	-	-	-	-	-	n/a	-	115
122	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.3	4.4	-	-	-	-	-	n/a	-	115
123	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	14-Jan-14	4.3	4.4	-	-	-	-	-	n/a	-	115
124	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.444	1.43%	80
125	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.443	1.53%	80
126	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.446	1.30%	80
127	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.458	0.50%	100
128	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.454	0.76%	100
129	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	4.3	4.4	-	-	-	-	-	1.453	0.85%	100
130	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	14-Jan-14	-0.4	1.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.426	2.65%	100
131	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	14-Jan-14	-0.5	1.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.427	2.62%	100
132	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	14-Jan-14	-1.3	1.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.424	2.83%	100
133	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	-1.2	-0.3	-	-	-	-	-	1.444	1.45%	100
134	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	14-Jan-14	-1.2	-0.3	-	-	-	-	-	1.445	1.36%	100
135	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-1.1	1.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.426	2.71%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
136	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-1.5	-0.5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.425	2.74%	100
137	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-1.7	0.9	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.430	2.42%	100
138	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-1.5	0.4	-	-	-	-	-	1.456	0.65%	100
139	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-1.5	0.4	-	-	-	-	-	1.457	0.55%	100
140	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.454	0.76%	100
141	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.452	0.93%	100
142	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.462	0.20%	100
143	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.462	0.25%	100
144	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.461	0.29%	100
145	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	100
146	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	80
147	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	80
148	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	80
149	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	100
150	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
151	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	100
152	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	115
153	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	115
154	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	n/a	-	115
155	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.442	1.59%	80
156	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.443	1.49%	80
157	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.435	2.05%	80
158	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.453	0.82%	100
159	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.455	0.69%	100
160	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-2.3	-1.5	-	-	-	-	-	1.454	0.80%	100
161	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-2.9	-1.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.426	2.70%	100
162	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-3	-1.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.426	2.68%	100
163	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-3.3	-1.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.426	2.66%	100
164	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-4.3	0.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.436	1.99%	100
165	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-4.1	-2.9	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.437	1.95%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
166	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-4.3	0.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.436	2.00%	100
167	2013-14	Baseline	Dry Wing	none	8	20	15-Jan-14	-0.3	0.3	-	-	-	-	-	1.479	-0.96%	100
168	2013-14	Baseline	Dry Wing	none	22	20	15-Jan-14	-0.3	0.3	-	-	-	-	-	1.456	0.64%	80
169	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.459	0.45%	100
170	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.459	0.44%	100
171	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.457	0.56%	100
172	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.468	-0.20%	100
173	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.466	-0.07%	100
174	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.468	-0.20%	100
175	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-1.1	-1	-	-	-	-	-	n/a	-	80
176	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-1.1	-1	-	-	-	-	-	n/a	-	80
177	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-1.1	-1	-	-	-	-	-	n/a	-	80
178	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-1.1	-1	-	-	-	-	-	n/a	-	100
179	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-1.1	-1	-	-	-	-	-	n/a	-	100
180	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-1.1	-1	-	-	-	-	-	n/a	-	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
181	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-1.1	-1	-	-	-	-	-	n/a	-	115
182	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-1.1	-1	-	-	-	-	-	n/a	-	115
183	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	15-Jan-14	-1.1	-1	-	-	-	-	-	n/a	-	115
184	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.435	2.04%	80
185	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.445	1.35%	80
186	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.435	2.09%	80
187	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.453	0.81%	100
188	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.455	0.68%	100
189	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	15-Jan-14	-1.1	-1	-	-	-	-	-	1.457	0.54%	100
190	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-0.9	-0.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.429	2.46%	100
191	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-0.8	-0.5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.424	2.80%	100
192	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	15-Jan-14	-0.9	-0.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.430	2.40%	100
193	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-1.1	-0.3	-	-	-	-	-	1.462	0.25%	100
194	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-1.1	-0.3	-	-	-	-	-	1.456	0.62%	100
195	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.460	0.39%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
196	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.456	0.66%	100
197	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.453	0.86%	100
198	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.461	0.32%	100
199	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.462	0.25%	100
200	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.463	0.13%	100
201	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	n/a	-	100
202	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	n/a	-	100
203	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	n/a	-	100
204	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	n/a	-	80
205	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	n/a	-	80
206	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	n/a	-	80
207	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	n/a	-	115
208	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	n/a	-	115
209	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	n/a	-	115
210	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.439	1.78%	80

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
211	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.439	1.81%	80
212	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.442	1.60%	80
213	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.458	0.49%	100
214	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.455	0.70%	100
215	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-1.9	-2.3	-	-	-	-	-	1.456	0.66%	100
216	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	16-Jan-14	-2	-0.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.426	2.68%	100
217	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	16-Jan-14	-2.2	-1.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.424	2.84%	100
218	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	16-Jan-14	-2.5	-2.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.426	2.65%	100
219	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-2.6	-1.8	-	-	-	-	-	1.448	1.21%	100
220	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-2.6	-1.8	-	-	-	-	-	1.450	1.01%	100
221	2013-14	Ice Phobic R&D	ZR	none	8	20	16-Jan-14	-2.8	-1.8	ZR=100	2	-	-	-	1.427	2.59%	100
222	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.458	0.50%	100
223	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.455	0.71%	100
224	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.449	1.14%	100
225	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.461	0.29%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
226	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.458	0.50%	100
227	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	100
228	2013-14	Ice Phobic R&D	Dry Wing	none	n/a*	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	n/a*
229	2013-14	Ice Phobic R&D	Dry Wing	none	n/a*	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	n/a*
230	2013-14	Ice Phobic R&D	Dry Wing	none	n/a*	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	n/a*
231	2013-14	Ice Phobic R&D	Dry Wing	none	n/a*	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	n/a*
232	2013-14	Ice Phobic R&D	Dry Wing	none	n/a*	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	n/a*
233	2013-14	Ice Phobic R&D	Dry Wing	none	n/a*	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	n/a*
234	2013-14	Ice Phobic R&D	Dry Wing	none	n/a*	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	n/a*
235	2013-14	Ice Phobic R&D	Dry Wing	none	n/a*	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	n/a*
236	2013-14	Ice Phobic R&D	Dry Wing	none	n/a*	20	16-Jan-14	-3	-3.4	-	-	-	-	-	n/a	-	n/a*
237	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.435	2.09%	100
238	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.439	1.80%	100
239	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.434	2.10%	100
240	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.450	1.03%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
241	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.443	1.50%	100
242	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	16-Jan-14	-3	-3.4	-	-	-	-	-	1.449	1.12%	100
243	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	16-Jan-14	-3.5	-1.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.422	2.96%	100
244	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	16-Jan-14	-3.7	-3.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.422	2.94%	100
245	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	17-Jan-14	-3.8	-1.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.414	3.47%	100
246	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	17-Jan-14	-4.1	-1.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.420	3.07%	100
247	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	17-Jan-14	-4.2	-2.6	-	-	-	-	-	1.449	1.13%	100
248	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	17-Jan-14	-4.2	-2.6	-	-	-	-	-	n/a	-	100
249	2013-14	Ice Phobic R&D	ZR	none	8	20	17-Jan-14	-4.1	-1.5	-	5	-	-	-	1.446	1.34%	100
250	2013-14	Baseline	Dry Wing	none	22	20	17-Jan-14	-4.3	0	-	-	-	-	-	1.447	1.26%	80
251	2013-14	Baseline	Dry Wing	none	8	20	17-Jan-14	-4.3	0	-	-	-	-	-	1.463	0.17%	100
252	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	17-Jan-14	-4.3	-0.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.463	0.16%	100
253	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	17-Jan-14	-4.4	-1.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.434	2.11%	60
254	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	17-Jan-14	-4.5	-1.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.437	1.91%	55
255	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	17-Jan-14	-4.5	-0.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.440	1.71%	45

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
256	2013-14	Type I Low Speed	Baseline	none	8	20	17-Jan-14	-4.4	-0.2	-	-	-	-	-	1.466	-0.04%	45
257	2013-14	Type I Low Speed	Baseline	none	8	20	17-Jan-14	-4.4	-0.2	-	-	-	-	-	1.459	0.41%	55
258	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	17-Jan-14	-4.4	-0.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.422	2.95%	45
259	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	17-Jan-14	-4.5	-1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.430	2.44%	55
260	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.463	0.18%	100
261	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.455	0.68%	100
262	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.461	0.27%	100
263	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.468	-0.16%	100
264	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.468	-0.17%	100
265	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.469	-0.27%	100
266	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	n/a	-	80
267	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	n/a	-	80
268	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	n/a	-	80
269	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	n/a	-	100
270	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	n/a	-	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
271	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	n/a	-	100
272	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	n/a	-	115
273	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	n/a	-	115
274	2013-14	Ice Phobic R&D	Dry Wing	none	-2,0,+2	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	n/a	-	115
275	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.438	1.83%	80
276	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.442	1.59%	80
277	2013-14	Ice Phobic R&D	Dry Wing	none	23	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.439	1.77%	80
278	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.456	0.63%	100
279	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.456	0.62%	100
280	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	20-Jan-14	-8.1	-8.3	-	-	-	-	-	1.456	0.66%	100
281	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	20-Jan-14	-9	-8.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.425	2.75%	100
282	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	20-Jan-14	-9.4	-8.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.423	2.91%	100
283	2013-14	Ice Phobic R&D	Fluid Only	EG106	8	20	20-Jan-14	-10	-9.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.423	2.88%	100
284	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	20-Jan-14	-10.4	-10.1	-	-	-	-	-	1.461	0.26%	100
285	2013-14	Ice Phobic R&D	Dry Wing	none	8	20	20-Jan-14	-10.4	-10.1	-	-	-	-	-	1.458	0.52%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
286	2013-14	Ice Phobic R&D	ZR	none	8	20	20-Jan-14	-10.7	-10.3	-	6	-	-	-	1.429	2.47%	100
287	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	20-Jan-14	-11.8	-11.6	-	-	-	-	-	1.466	-0.08%	100
288	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	20-Jan-14	-11.8	-11.6	-	-	-	-	-	1.463	0.13%	100
289	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	20-Jan-14	-11.8	-11.6	-	-	-	-	-	1.464	0.10%	100
290	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	20-Jan-14	-13	-13	-	-	-	-	-	1.467	-0.10%	100
291	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	20-Jan-14	-13	-13	-	-	-	-	-	1.465	0.03%	100
292	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	20-Jan-14	-13	-13	-	-	-	-	-	1.465	-0.01%	100
293	2013-14	Baseline	Dry Wing	none	22	20	20-Jan-14	-20	-17.9	-	-	-	-	-	1.458	0.52%	80
294	2013-14	Baseline	Dry Wing	none	8	20	20-Jan-14	-20	-17.9	-	-	-	-	-	1.465	0.03%	100
295	2013-14	Type III Allowance Times	IP-	2031 - Cold	8	20	20-Jan-14	-20.4	-18.7	IP=25	10	2.2, 2.2, 2.7	1, 1.8, 2.1	1, 1, 1.2	1.384	5.55%	100
296	2013-14	Type III Allowance Times	IP Mod	2031 - Cold	8	20	21-Jan-14	-20.6	-17.7	IP=75	5	2.3, 2.3, 2.8	1, 1.8, 2.1	1, 1.1, 1.3	1.393	4.90%	100
297	2013-14	Type III Allowance Times	IP-	2031 - Hot	8	20	21-Jan-14	-21.1	-18.1	IP=25	10	2.2, 2.1, 2.7	2.3, 3.8, 1.6	2.3, 5, 1.2	1.395	4.79%	100
298	2013-14	Type III Allowance Times	IP Mod	2031 - Hot	8	20	21-Jan-14	-21.3	-19	IP=75	5	2.2, 2.5, 3.2	2.4, 5, 2	2.3, 5, 1.2	1.396	4.73%	100
299	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	21-Jan-14	-21.7	-18.5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.436	2.01%	100
300	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	21-Jan-14	-22	-20.5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.398	4.57%	60

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
301	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	21-Jan-14	-22.4	-20.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.401	4.41%	60
302	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	21-Jan-14	-22.4	-20.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.409	3.83%	55
303	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	21-Jan-14	-22.5	-17.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.404	4.21%	45
304	2013-14	IP Expansion	IP- / SN-	Polar Guard Advance	8	20	21-Jan-14	-23.5	-14.6	IP=25 SN=10	15	2.5, 2.7, 3.83	1.2, 1.9, 3.2	1.1, 1.1, 2.8	1.348	8.01%	115
305	2013-14	New Ice Pellet Dispenser Validation	IP- / SN-	Polar Guard Advance	8	20	21-Jan-14	-23.8	-11.4	IP=25 SN=10	15	2.5, 2.6, 3.8	1.2, 2, 3	1, 1.4, 2.9	1.351	7.80%	115
306	2013-14	New Ice Pellet Dispenser Validation	IP- / SN-	Polar Guard Advance	8	20	21-Jan-14	-24	-14.4	IP=25 SN=10	15	2.3, 2.3, 3.6	1.2, 1.8, 3	1, 1.5, 2.7	1.348	7.97%	115
307	2013-14	Baseline	Dry Wing	none	22	20	21-Jan-14	-22.6	-14	-	-	-	-	-	1.456	0.62%	80
308	2013-14	Baseline	Dry Wing	none	8	20	21-Jan-14	-22.6	-14	-	-	-	-	-	1.465	0.00%	100
309	2013-14	New Ice Pellet Dispenser Validation	IP- / SN-	Polar Guard Advance	8	20	21-Jan-14	-22.6	-9.6	IP=25 SN=10	15	2.8, 2.8, 4	1.1, 2, 3.3	1.1, 1.5, 3.2	1.349	7.94%	115
310	2013-14	IP Expansion	IP- / SN-	EG106	8	20	21-Jan-14	-23.1	-17.4	IP=25 SN=10	15	1.7, 1.7, 2.3	1, 1.3, 1.5	1, 1.1, 1.3	1.436	2.00%	115
311	2013-14	IP Expansion	IP- / SN-	EG106	8	20	21-Jan-14	-23.9	-18.1	IP=25 SN=10	15	1.9, 1.9, 2.3	1.1, 1.5, 1.7	1, 1.1, 1.2	1.406	4.06%	100
312	2013-14	IP Expansion	IP- / SN-	Launch	8	20	21-Jan-14	-24.3	-17.4	IP=25 SN=10	15	2.8, 2.7, 3.7	1.1, 1.9, 2.4	1, 1.6, 2.1	1.332	9.11%	115
313	2013-14	IP Expansion	IP- / SN-	Max-Flight	8	20	21-Jan-14	-24.5	-15.3	IP=25 SN=10	15	2.6, 2.5, 3.5	1.1, 1.8, 2.4	1, 1.1, 1.4	1.340	8.54%	115
314	2013-14	IP Expansion	IP- / SN-	AD-49	8	20	22-Jan-14	-24.8	-19.8	IP=25 SN=10	15	3, 2.4, 4	1.3, 2, 3.7	1.1, 1.8, 3.7	1.342	8.39%	115
315	2013-14	IP Expansion	IP- / SN-	AD-49	8	20	22-Jan-14	-25.1	-19.4	IP=25 SN=10	10	2.9, 2.8, 3.8	1.2, 1.9, 3	1.1, 1.9, 3	1.361	7.14%	115

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
316	2013-14	Type I Low Speed	Fluid Only	Dow ADF	8	20	22-Jan-14	-25.5	-23.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.449	1.11%	100
317	2013-14	Type I Low Speed	Fluid Only	Dow ADF	8	20	22-Jan-14	-25.6	-23.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.438	1.83%	60
318	2013-14	Type I Low Speed	Fluid Only	Dow ADF	8	20	22-Jan-14	-25.6	-24.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.434	2.11%	55
319	2013-14	Type I Low Speed	Fluid Only	Dow ADF	8	20	22-Jan-14	-25.7	-24.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.421	3.05%	45
320	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	22-Jan-14	-25.8	-24.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.409	3.84%	100
321	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	22-Jan-14	-25.9	-25	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.375	6.15%	60
322	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	22-Jan-14	-26	-25.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.353	7.65%	55
323	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	22-Jan-14	-26	-25.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.342	8.40%	45
324	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	22-Jan-14	-26.2	-24.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.406	4.06%	100
325	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	22-Jan-14	-26.3	-25.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.370	6.50%	60
326	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	22-Jan-14	-26.4	-25.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.346	8.14%	55
327	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	22-Jan-14	-26.5	-25.5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.340	8.55%	45
328	2013-14	Baseline	Dry Wing	none	22	20	22-Jan-14	-19.8	-16.1	-	-	-	-	-	1.465	0.00%	80
329	2013-14	Baseline	Dry Wing	none	8	20	22-Jan-14	-19.8	-16.1	-	-	-	-	-	1.472	-0.43%	100
330	2013-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	20	22-Jan-14	-20	-18.1	IP=75	10	2.5, 3, 3.6	1, 1.9, 2.4	1, 1, 1.6	1.353	7.67%	115

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
331	2013-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	20	22-Jan-14	-20.2	-16.3	IP=75	10	2.7, 2.8, 3.6	1.1, 2.1, 2.5	1, 1.4, 2	1.334	8.95%	115
332	2013-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	20	22-Jan-14	-20.6	-17	IP=75	10	2.9, 2.8, 3.8	1.1, 1.7, 2.5	1, 1.2, 1.5	1.330	9.25%	115
333	2013-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	20	22-Jan-14	-20.6	-16.4	IP=75	10	3, 2.8, 3.8	1.1, 1.9, 2.4	1, 1.2, 1.5	1.327	9.42%	115
334	2013-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	20	23-Jan-14	-20.9	-18.8	IP=75	10	2.9, 2.8, 3.8	1.1, 1.9, 2.3	1, 1.1, 1.4	1.307	10.82%	115
335	2013-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	20	22-Jan-14	-21	-20	IP=75	10	2.8, 2.8, 3.8	1.1, 1.9, 2.2	1, 1.3, 1.5	1.325	9.55%	115
336	2013-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	20	23-Jan-14	-21.4	-19.6	IP=75	10	3, 2.8, 3.8	1.1, 1.6, 2.2	1, 1.3, 1.5	1.328	9.35%	115
337	2013-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	20	23-Jan-14	-21.9	-20.6	IP=75	5	2.6, 2.5, 3.7	1.1, 1.8, 2.2	1, 1.1, 1.4	1.338	8.66%	115
338	2013-14	IP Validation with New Temps & Fluids	IP Mod	ABC-S Plus	8	20	23-Jan-14	-22.3	-20.6	IP=75	7	2.8, 2.7, 3.8	1, 1.7, 2.1	1, 1.1, 1.3	1.368	6.61%	115
339	2013-14	IP Validation with New Temps & Fluids	IP Mod	Max-Flight	8	20	23-Jan-14	-22.6	-21.5	IP=75	7	2.6, 2.6, 3.9	1, 1.7, 2.2	1, 1, 1.2	1.358	7.35%	115
340	2013-14	IP Validation with New Temps & Fluids	IP Mod	Polar Guard Advance	8	20	23-Jan-14	-22.8	-21.4	IP=75	10	2.7, 2.4, 3.8	1, 1.6, 2.2	1, 1, 1.2	1.372	6.37%	115
341	2013-14	Baseline	Dry Wing	none	22	20	27-Jan-14	-13.3	-9.3	-	-	-	-	-	1.468	-0.16%	80
342	2013-14	Baseline	Dry Wing	none	8	20	27-Jan-14	-13.3	-9.3	-	-	-	-	-	1.459	0.45%	100
343	2013-14	Type III Allowance Times	IP-	2031 - Cold	8	20	27-Jan-14	-11.6	-11.4	IP=25	10	2.5, 2.7, 2.8	1, 1, 1.3	1, 1, 1.1	1.439	1.76%	100
344	2013-14	Type III Allowance Times	IP-	2031 - Hot	8	20	27-Jan-14	-9.2	-9.1	IP=25	10	2.3, 2.4, 2.2	3, 5, 5	3, 5, 5	1.432	2.30%	100
345	2013-14	Type III Allowance Times	IP Mod	2031 - Cold	8	20	27-Jan-14	-7.8	-6.9	IP=75	5	2.5, 2.7, 2.8	1, 1.1, 1.2	1, 1, 1	1.435	2.04%	100

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
346	2013-14	Type III Allowance Times	IP Mod	2031 - Hot	8	20	27-Jan-14	-7.9	-6.4	IP=75	5	2.8, 2.4, 2.2	2.3, 4.7, 2.5	2.3, 4.8, 4.5	1.439	1.77%	100
347	2013-14	Type III Allowance Times	IP Mod	ABC-S Plus - Hot	8	20	27-Jan-14	-11.3	-9.4	IP=75	10	2.1, 2.4, 2.8	3, 5, 5	3, 5, 5	1.390	5.13%	100
348	2013-14	Type III Allowance Times	IP Mod	EG106 - Hot	8	20	27-Jan-14	-11.7	-10.6	IP=75	10	2.5, 2.3, 3	3, 5, 5	3, 5, 5	1.445	1.40%	100
349	2013-14	Type III Allowance Times	IP Mod	2031 - Hot	8	20	27-Jan-14	-12.4	-9.5	IP=75	5	2.7, 2.7, 2.5	3, 5, 5	3, 5, 5	1.412	3.61%	100
350	2013-14	Type III Allowance Times	IP- / ZR-	2031 - Cold	8	20	27-Jan-14	-12.2	-11.1	IP=25 ZR=25	5	2.5, 2.7, 2.9	1, 1.1, 1.5	1, 1, 1.1	1.426	2.68%	100
351	2013-14	Type III Allowance Times	IP- / ZR-	2031 - Hot	8	20	27-Jan-14	-12.9	-9.6	IP=25 ZR=25	5	2, 2, 2.3	5, 5, 5	5, 5, 5	1.434	2.15%	100
352	2013-14	Type III Allowance Times	IP- / SN-	2031 - Cold	8	20	27-Jan-14	-12.8	-11	IP=25 SN=10	10	2.5, 2.8, 3.3	1.1, 1.4, 1.8	1, 1.1, 1.3	1.410	3.75%	100
353	2013-14	Type III Allowance Times	IP- / SN	2031 - Cold	8	20	27-Jan-14	-13	-10.2	IP=25 SN=25	5	2.5, 2.7, 3.5	1.1, 1.4, 2	1, 1.1, 1.3	1.409	3.83%	100
354	2013-14	Baseline	Dry Wing	none	22	20	28-Jan-14	-19	-11.4	-	-	-	-	-	1.459	0.46%	80
355	2013-14	Baseline	Dry Wing	none	8	20	28-Jan-14	-19	-11.4	-	-	-	-	-	1.469	-0.26%	100
356	2013-14	IP Validation with New Temps & Fluids	IP Mod	AD-49	8	20	28-Jan-14	-18.7	-11.6	IP=75	7	2.7, 2.4, 3.5	1.2, 1.6, 2	1, 1.3, 1.5	1.368	6.66%	115
357	2013-14	IP Validation with New Temps & Fluids	IP Mod	AD-49	8	20	28-Jan-14	-17.9	-14	IP=75	10	3, 2.8, 3.8	1.2, 1.6, 2.2	1, 1.2, 1.6	1.360	7.16%	115
358	2013-14	IP Validation with New Temps & Fluids	IP Mod	ABC-S Plus	8	20	28-Jan-14	-16.9	-12.2	IP=75	10	2.5, 2.3, 3.8	1, 1.5, -	-, -, -	n/a	-	115
359	2013-14	IP Validation with New Temps & Fluids	IP Mod	ABC-S Plus	8	20	28-Jan-14	-14.1	-10.9	IP=75	10	2.4, 2.4, 3.8	1.1, 1.5, 1.9	1, 1.1, 1.2	1.358	7.31%	115

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
360	2013-14	IP Validation with New Temps & Fluids	IP Mod	Launch	8	20	28-Jan-14	-12.3	-12.1	IP=75	10	2.3, 2.3, 3.7	1.1, 1.3, 1.9	1, 1, 1.2	1.363	6.95%	115
361	2013-14	IP Validation with New Temps & Fluids	IP Mod	Max-Flight	8	20	28-Jan-14	-11	-10.9	IP=75	10	2.2, 2.3, 3.3	1, 1.2, 1.7	1, 1, 1.2	1.391	5.08%	115
362	2013-14	IP Validation with New Temps & Fluids	IP Mod	Polar Guard Advance	8	20	28-Jan-14	-10.9	-11	IP=75	10	2.3, 2.3, 3.3	1, 1.3, 1.7	1, 1, 1.2	1.377	6.01%	115
363	2013-14	Type III Allowance Times	IP Mod	ABC-S Plus	8	20	28-Jan-14	-10.6	-7.4	IP=75	10	2, 2, 2.8	1, 1.3, 1.7	1, 1, 1.2	1.337	8.72%	100
364	2013-14	Type III Allowance Times	IP Mod	EG106	8	20	28-Jan-14	-10.2	-7.1	IP=75	10	2.3, 2.3, 2.8	3, 5, 5	3, 5, 5	1.442	1.56%	100
365	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	28-Jan-14	-10.7	-10.4	-	-	-	-	-	1.463	0.13%	100
366	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	28-Jan-14	-10.7	-10.4	-	-	-	-	-	1.455	0.67%	100
367	2013-14	Ice Phobic R&D	Dry Wing	none	8 pitch pause	20	28-Jan-14	-10.7	-10.4	-	-	-	-	-	1.458	0.52%	100
368	2013-14	Baseline	Dry Wing	none	22	20	29-Jan-14	-14.1	-8.2	-	-	-	-	-	1.471	-0.41%	80
369	2013-14	Baseline	Dry Wing	none	8	20	29-Jan-14	-14.1	-8.2	-	-	-	-	-	1.465	-0.01%	100
370	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	29-Jan-14	-13.6	-13.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.442	1.57%	100
371	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	29-Jan-14	-13.3	-13.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.414	3.52%	60
372	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	29-Jan-14	-12.6	-13.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.400	4.47%	55
373	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	29-Jan-14	-12.5	-13	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.386	5.41%	45
374	2013-14	Type I Low Speed	Fluid Only	Polar Plus	8	20	29-Jan-14	-12.3	-12.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.366	6.79%	30

Table 2.1: Wind Tunnel Test Log 2013-14 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL At 8°	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Speed Kts
375	2013-14	Type I Low Speed	Fluid Only w/ Squeegee Lines	Polar Plus	8	20	29-Jan-14	-12.2	-12.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.420	3.06%	45
376	2013-14	Ice Phobic R&D	Fluid Only	2031	fixed angle 4deg	20	29-Jan-14	-12.3	-12.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	n/a	-	100
377	2013-14	R&D	HEAVY CONTAMINATION	ABC-S+	22	20	29-Jan-14	-11.2	-4.1	IP=375 ZR=50	26	-	-	-	1.279	12.73%	80
378	2013-14	R&D	APM Unit	None	23	20	29-Jan-14	-11.2	-1.8	-	-	-	-	-	1.442	1.57%	80
379	2013-14	R&D	APM Unit	None	23 PITCH PAUSE	20	29-Jan-14	-11.2	-11.3	-	-	-	-	-	1.459	0.41%	80
380	2013-14	R&D	APM Unit	ABC-S Plus	23	20	29-Jan-14	-11.1	-11.3	-	-	-	-	-	1.355	7.56%	80
381	2013-14	R&D	APM Unit	ABC-S Plus	23 PITCH PAUSE	20	29-Jan-14	-11.1	-11.6	-	-	-	-	-	1.431	2.33%	80
382	2013-14	R&D	APM Unit	ABC-S Plus (unit covered)	23	20	29-Jan-14	-11	-11.3	-	-	-	-	-	1.422	2.96%	80
383	2013-14	R&D	APM Unit	ABC-S Plus (unit covered)	23 PITCH PAUSE	20	29-Jan-14	-11	-11.3	-	-	-	-	-	1.436	2.02%	80

This page intentionally left blank.

3. EVALUATION OF AN AIRFOIL PERFORMANCE MONITOR

3.1 Background

APMs are being developed and can be installed on any airfoil on an aircraft, including the tail. An APM is designed to measure the airflow over the wing, which reveals how well the wing is performing. As a wing becomes contaminated, the APM should measure the changing or turbulent airflow and resulting lift generated by the wing. The APM is designed to alert the crew if the airflow degrades below a configurable threshold, giving the crew time to correct a potential stall before it happens. It was recommended that testing be conducted with a Canadian-developed APM to support the development of the technology. This research would aid in evaluating the potential for its use in ground icing operations and to investigate whether or not the use of fluids with the APM system would potentially obstruct the pressure ports that are critical to the systems' operation. The APM unit was provided by Marinvent and was the latest generation wireless system available. Previous testing with an earlier hard-wired version of the system was conducted in the winter of 2012-13.

3.2 Objective

To provide a testing platform to the manufacturer allowing them to evaluate the ability of the APM to properly identify stall with and without icing conditions during aircraft ground operations with de/anti-icing fluid applications.

3.3 General Methodology

The APM unit was mounted onto the trailing edge of the wing section using a screw and pre-existing threaded holes, along with aircraft speed-tape (Photo 3.1). The unit was connected wirelessly into the NRC data acquisition systems, and data was collected in real-time during each test.

The following is a brief summary of the methodology used for this testing; the general testing procedures were in-line with the typical wind tunnel testing procedures used at the NRC PIWT:

- Conduct dry wing baseline testing with and without the installation to understand any potential aerodynamic influences the sensor may have;
- With the sensor installed, conduct dry wing tests to stall;
- Repeat tests with fluid only to stall (with the sensor installed);

- Evaluate ability of the APM to measure stall, and compare to the stall observed through the aerodynamic data collected; and
- Evaluate the performance of the APM unit with fluids, and note any potential adverse effects.

3.4 Data Collected

Six tests were conducted, dry and with fluid. A summary of the test data is included in Table 3.1.

Table 3.1: Log of APM Unit Tests

Test #	Date	Test Condition	Fluid Name	Rotation Angle (°)	Speed Kts	Extra Run Information	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)
378	29-Jan-14	APM Unit	None	23	80		1.57%	-1.8	n/a	-11.2
379	29-Jan-14	APM Unit	None	23 PITCH PAUSE	80		0.41%	-11.3	n/a	-11.2
380	29-Jan-14	APM Unit	ABC-S Plus	23	80		7.56%	-11.3	16	-11.1
381	29-Jan-14	APM Unit	ABC-S Plus	23 PITCH PAUSE	80	re-run with the same fluid from #380	2.33%	-11.6	fluid from test 380	-11.1
382	29-Jan-14	APM Unit	ABC-S Plus (unit covered)	23	80	fluid remaining from Test 380/381, 6 inch strip of fluid added along the chord where sensor is located	2.96%	-11.3	fluid from test 381	-11
383	29-Jan-14	APM Unit	ABC-S Plus (unit covered)	23 PITCH PAUSE	80	fluid remaining from Test 380/381, 6 inch strip of fluid added along the chord where sensor is located and on sensor itself	2.02%	-11.3	fluid from test 382	-11

3.5 Summary of Test Results

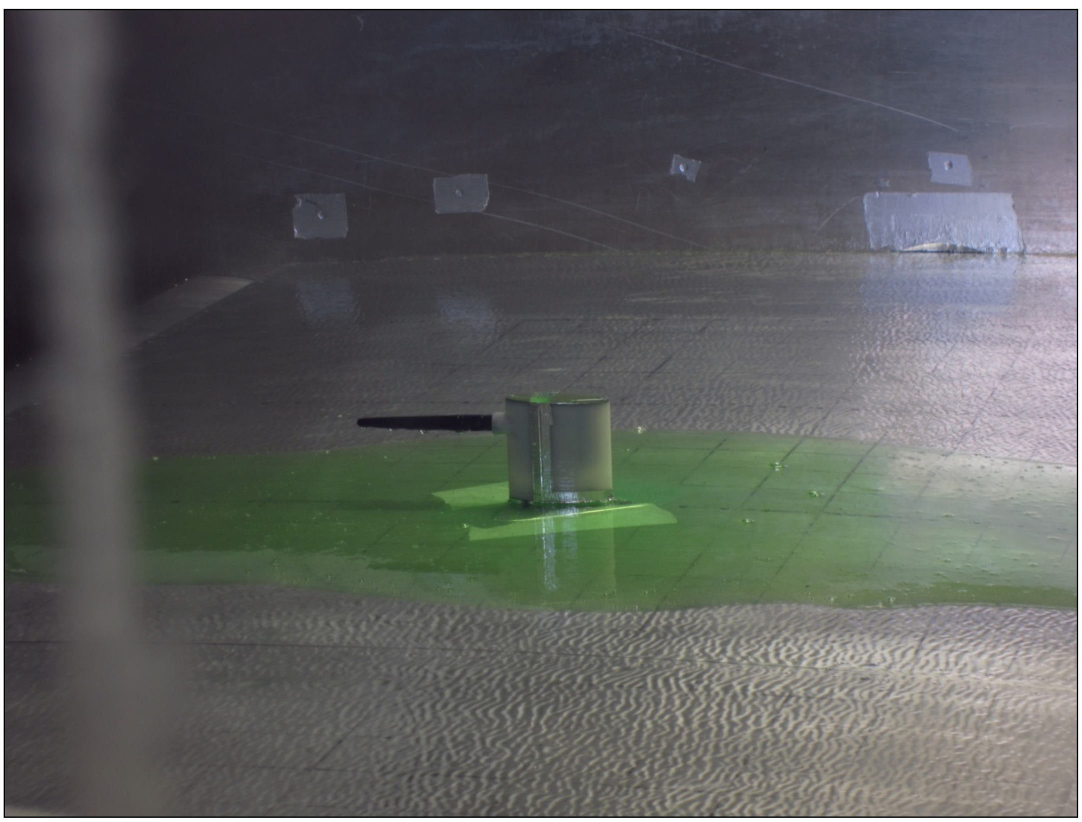
The testing conducted provided Marinvent with a platform for evaluating the APM unit, the details of which remain internal to Marinvent. Similar to the 2012-13 testing, initial observations saw fluid enter the pressure probes of the APM unit; however, the effects of fluid intrusion should be further investigated by the manufacturer. Test #383 had fluid applied directly onto the APM unit (Photo 3.2).

This collaborative effort between TC/FAA and Marinvent has provided laboratory data generated in a controlled environment that can be used to further develop this sensor and increase the potential of this technology to be used in the field.

This page intentionally left blank.

Photo 3.1: Installation of APM Unit with Speed-Tape to Wing

Photo 3.2: Test #383 With Fluid Applied Directly over APM Unit



This page intentionally left blank.

4. AERODYNAMIC TESTING OF ICE PHOBIC COATINGS

4.1 Background

Ice build-up on aircraft is a major safety concern for both on-ground and in-flight aircraft operations. In recent years, there has been significant industry interest in the use of coatings to protect aircraft critical surfaces. Early research conducted by APS on behalf of TC and the FAA tested ice phobic coatings and raised industry awareness about potential adverse effects of coatings on de/anti-icing fluid performance. These concerns applied to aircraft coatings in general, not only to ice phobic coatings (i.e., coatings for fuel savings, appearance enhancement). In November 2011, the SAE International (SAE) G-12 committee agreed to develop an SAE Aerospace Information Report (AIR) document with the purpose of evaluating the potential impact these coatings may have on aircraft de/anti-icing fluid performance.

From 2011 to 2014, a three-year project led by TC and the FAA with the support of APS was launched to assess the safety and effectiveness of ice phobic materials/coating and investigate the feasibility of employing ice phobic materials in the design of aircraft or specific aircraft sections that are more prone to icing. During this period, the work has been presented bi-annually to the SAE G-12 committee. As a result of this research and with industry participation, SAE AIR 6232 has now been developed and is available as a reference for the industry.

4.2 Summary of Results

A test plan was developed and conducted during the winter of 2013-14 to gain new insight into the potential applications of these coatings for aircraft operations and to continue the research to include newly developed coatings. As part of this test plan, it was recommended that testing continue to investigate the effects of these coatings on de/anti-icing fluids from both a holdover time (HOT) and aerodynamic perspective. The work conducted in the wind tunnel during the winter of 2013-14 was done as part of a larger multi-year project, the details of which are included in the TC report, TP 15275E, *Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates* (Vol. 1) (2).

This page intentionally left blank.

5. TYPE I FLUID FLOW-OFF FOR VERY LOW-SPEED AIRCRAFT

5.1 Background

The lowest operational use temperature (LOUT) for a fluid is determined based on the higher value of either the fluid freezing point plus a buffer, or the lowest temperature that passes the aerodynamic test (AS5900) for either the low-speed or high-speed ramp. Currently, the high-speed ramp is representative of aircraft rotating at 100 knots or higher, whereas the low-speed ramp is representative of aircraft rotating between 67 knots and 100 knots.

There currently does not exist any fluid qualification for aircraft rotating below 67 knots; however, several operators do have aircraft that rotate below 67 knots and that encounter ground icing conditions during winter months. Aerodynamic testing in the NRC wind tunnel, and possibly according to the AS5900 testing, can provide insight into alternatives for operating in such conditions (i.e., limit LOUT for lower rotation speeds, use diluted fluid, delay rotation beyond rotation speed, increase the rotation speed). These operators have requested that TC provide operational guidance when using Type I fluids on these aircraft. The aircraft in question is a Cessna 172 aircraft that typically rotates around 55 knots.

5.2 Objective

To evaluate the aerodynamic impact of using Type I fluid on aircraft with rotation speeds below 67 knots and the resulting effect on the LOUT.

5.3 General Methodology

The general methodology used for these tests was in accordance with the methodologies used for typical fluid with and without contamination tests conducted in the wind tunnel. The evaluation methodology was modified to allow a comparison of the rotation speed:

- Conduct a high-speed (100 knots) test with a propylene glycol (PG) Type I fluid to identify acceptable lift losses;
- Conduct comparative test runs with the same fluid at 60 knots, 55 knots, and 45 knots to determine likely increases in lift losses;

- When testing close to the PG Type I LOUT, conduct an additional set of tests with an ethylene glycol (EG) Type I fluid with a lower LOUT; and
- Compare results.

The fluids used were diluted to the standard mix as determined by the manufacturer, which can range in glycol concentration from about 50 percent to 75 percent of the mix (the balance being hard water).

5.4 Data Collected

In total, 31 tests were conducted for a total of six comparative test runs, as well as two additional tests (one at 30 knots and one with fluid streaks simulating fluid squeegeed off the wing following deicing). For each comparative set of tests, the ramp profile and rotation speed were varied to be able to evaluate the resulting effects on lift loss. A log is included in Table 5.1.

Table 5.1: Log of Type I Very Low Speed Tests

Test Year	Test #	Date	Test Condition	Fluid Name	Rotation Angle (°)	Speed Kts	Extra Run Information	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)
Winter 2013-14	**252**	17-Jan-14	Fluid Only	PG Type I	8	100	no wing tilt on Type I tests	0.16%	-0.3	7	-4.3
Winter 2013-14	**253**	17-Jan-14	Fluid Only	PG Type I	8	60	no wing tilt on Type I tests. Target 80 kts, rotated at 60, @ 70 by 8 deg	2.11%	-1.4	6	-4.4
Winter 2013-14	**254**	17-Jan-14	Fluid Only	PG Type I	8	55	no wing tilt on Type I tests. Target 75 kts, rotated at 55, @ 63 by 8 deg	1.91%	-1.6	6	-4.5
Winter 2013-14	**255**	17-Jan-14	Fluid Only	PG Type I	8	45	no wing tilt on Type I tests	1.71%	-0.6	6	-4.5
Winter 2013-14	**256**	17-Jan-14	Baseline	none	8	45		-0.04%	-0.2	n/a	-4.4
Winter 2013-14	**257**	17-Jan-14	Baseline	none	8	55		0.41%	-0.2	n/a	-4.4
Winter 2013-14	**258**	17-Jan-14	Fluid Only	PG Type I	8	45		2.95%	-0.7	6	-4.4
Winter 2013-14	**259**	17-Jan-14	Fluid Only	PG Type I	8	55		2.44%	-1	6	-4.5
Winter 2013-14	**299**	21-Jan-14	Fluid Only	PG Type I	8	100		2.01%	-18.5	8	-21.7
Winter 2013-14	**300**	21-Jan-14	Fluid Only	PG Type I	8	60	test not valid, ramp too slow	4.57%	-20.5	8	-22
Winter 2013-14	**301**	21-Jan-14	Fluid Only	PG Type I	8	60		4.41%	-20.2	8	-22.4
Winter 2013-14	**302**	21-Jan-14	Fluid Only	PG Type I	8	55		3.83%	-20.2	8	-22.4
Winter 2013-14	**303**	21-Jan-14	Fluid Only	PG Type I	8	45		4.21%	-17.6	11	-22.5
Winter 2013-14	**316**	22-Jan-14	Fluid Only	EG Type I	8	100		1.11%	-23.4	8	-25.5
Winter 2013-14	**317**	22-Jan-14	Fluid Only	EG Type I	8	60		1.83%	-23.6	8	-25.6

Table 5.1: Log of Type I Very Low Speed Tests (cont'd)

Test Year	Test #	Date	Test Condition	Fluid Name	Rotation Angle (°)	Speed Kts	Extra Run Information	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)
Winter 2013-14	**318**	22-Jan-14	Fluid Only	EG Type I	8	55		2.11%	-24.1	8	-25.6
Winter 2013-14	**319**	22-Jan-14	Fluid Only	EG Type I	8	45		3.05%	-24.3	8	-25.7
Winter 2013-14	**320**	22-Jan-14	Fluid Only	PG Type I	8	100		3.84%	-24.3	8	-25.8
Winter 2013-14	**321**	22-Jan-14	Fluid Only	PG Type I	8	60		6.15%	-25	8.5	-25.9
Winter 2013-14	**322**	22-Jan-14	Fluid Only	PG Type I	8	55		7.65%	-25.4	8	-26
Winter 2013-14	**323**	22-Jan-14	Fluid Only	PG Type I	8	45		8.40%	-25.1	8	-26
Winter 2013-14	**324**	22-Jan-14	Fluid Only	PG Type I	8	100		4.06%	-24.8	8	-26.2
Winter 2013-14	**325**	22-Jan-14	Fluid Only	PG Type I	8	60		6.50%	-25.6	8	-26.3
Winter 2013-14	**326**	22-Jan-14	Fluid Only	PG Type I	8	55		8.14%	-25.1	8	-26.4
Winter 2013-14	**327**	22-Jan-14	Fluid Only	PG Type I	8	45		8.55%	-25.5	8	-26.5
Winter 2013-14	**370**	29-Jan-14	Fluid Only	PG Type I	8	100		1.57%	-13.8	9	-13.6
Winter 2013-14	**371**	29-Jan-14	Fluid Only	PG Type I	8	60		3.52%	-13.4	9	-13.3
Winter 2013-14	**372**	29-Jan-14	Fluid Only	PG Type I	8	55		4.47%	-13.1	9	-12.6
Winter 2013-14	**373**	29-Jan-14	Fluid Only	PG Type I	8	45		5.41%	-13	9	-12.5
Winter 2013-14	**374**	29-Jan-14	Fluid Only	PG Type I	8	30		6.79%	-12.6	9	-12.3
Winter 2013-14	**375**	29-Jan-14	Fluid Only w/ Squeegee Lines	PG Type I	8	45		3.06%	-12.6	10	-12.2

5.5 Summary of Test Results

A summary of a selection of results from the wind tunnel tests is also included in Table 5.2. In this table, the start and end rotation speeds as well as the acceleration time are included. Due to the low speeds and due to the capability of the tunnel, the operator had to cut the throttle prior to the target speed and let the engine acceleration momentum increase the speed to the desired rotation speed; this was done to avoid overshooting the target speed.

Table 5.2: Summary of Test Results

Run #	Fluid	OAT	Start Rotation Speed (kts)	End Rotation Speed (kts)	Time 20 kts to Start Rotation	% Lift Loss @ 8 deg
252	PG Type I	0	100	100	21.5 (40 kts to rot)	**0.2**
253	PG Type I	-1	60	70	8.6	**2.1**
259	PG Type I	-1	55	68	7.2	**2.5**
258	PG Type I	-1	45	62	5.1	**3.0**
370	PG Type I	-14	100	100	20 (40 kts to rot)	1.6
371	PG Type I	-13	60	65	16	3.5
372	PG Type I	-13	55	65	13	4.5
373	PG Type I	-13	45	65	9	5.4
374	PG Type I	-13	30	65	4	6.8
299	PG Type I	-19	100	100	20 (40 kts to rot)	2.0
301	PG Type I	-20	60	65	17	4.4
302	PG Type I	-20	55	65	15	3.8
303	PG Type I	-18	45	65	8.01	4.2
316	EG Type I	-23	100	100	20 (40 kts to rot)	1.1
317	EG Type I	-24	60	65	21	1.8
318	EG Type I	-24	55	65	16	2.1
319	EG Type I	-24	45	65	8	3.1
320	PG Type I	-24	100	100	20 (40 kts to rot)	3.9
321	PG Type I	-25	60	65	18	6.2
322	PG Type I	-25	55	65	15	7.7
323	PG Type I	-25	45	65	8	8.4
324	PG Type I	-25	100	100	20 (40 kts to rot)	4.1
325	PG Type I	-26	60	65	18	6.5
326	PG Type I	-25	55	65	14	8.2
327	PG Type I	-26	45	65	8	8.6

The results obtained have been demonstrated in Figure 5.1 to Figure 5.4. The recorded lift loss measured at 8 degrees rotation was plotted against the test temperature at the start of the test. As expected, the lift losses increased as the test temperature decreased. Based on the PG Type I high-speed LOUT of -32ºC, and by extrapolating the 100 knots data set, the data indicates that the highest acceptable lift loss for this fluid would be about 6.8 percent (see Figure 5.1). Using the 6.8 percent lift loss as the cut-off, the 60 knots, 55 knots, and 45 knots speed profiles would have to be limited to temperatures of -27.5 ºC, -21.5 ºC, and -19 ºC to stay below the acceptable lift loss limit (see Figure 5.2). This indicates that increasing the fluid LOUT for lower speeds could potentially provide equivalent scenarios and allow for operations at these lower speeds. Alternatively, using a fluid with a much lower LOUT, such as the EG Type I fluid, could provide additional flexibility at the lower temperatures with the lower speeds; this is shown in Figure 5.3, where the data collected at colder temperatures has lower lift losses compared to the PG Type I fluid. Figure 5.4 shows all the data plotted together.

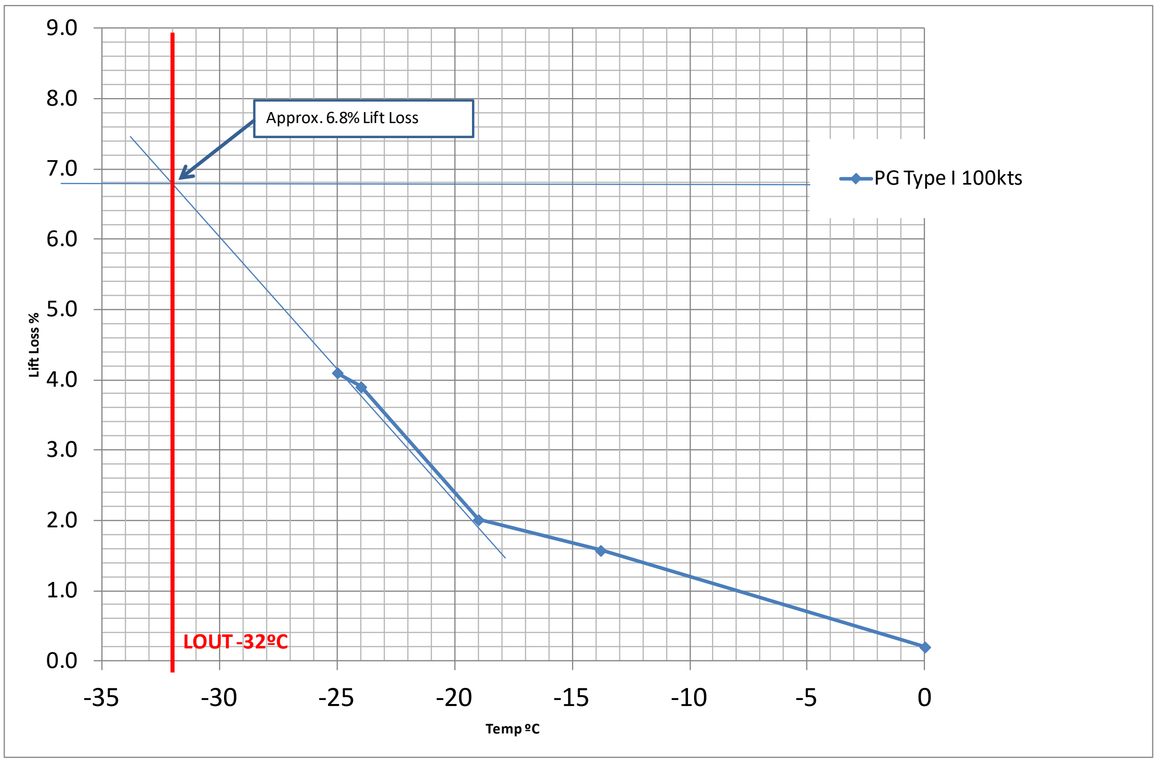


Figure 5.1: PG Type I Data at 100 Knots at Different Temperatures

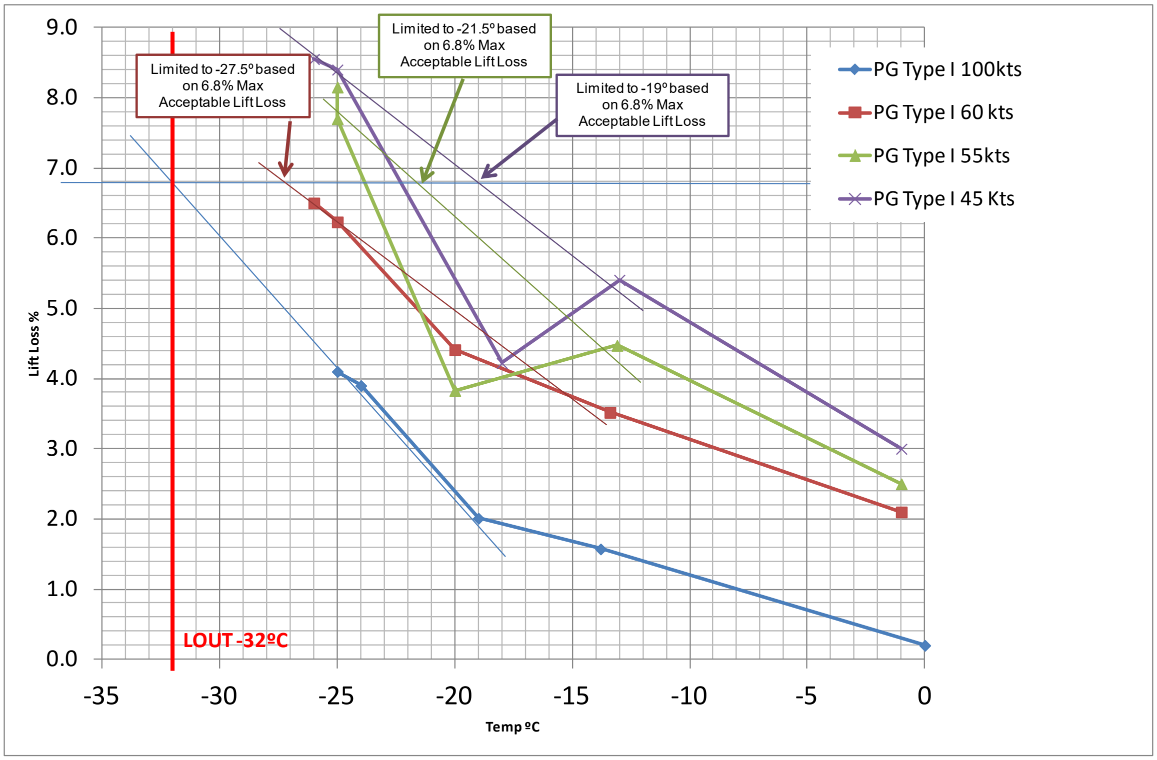


Figure 5.2: Type I PG Data at Different Temperatures and Rotation Speeds

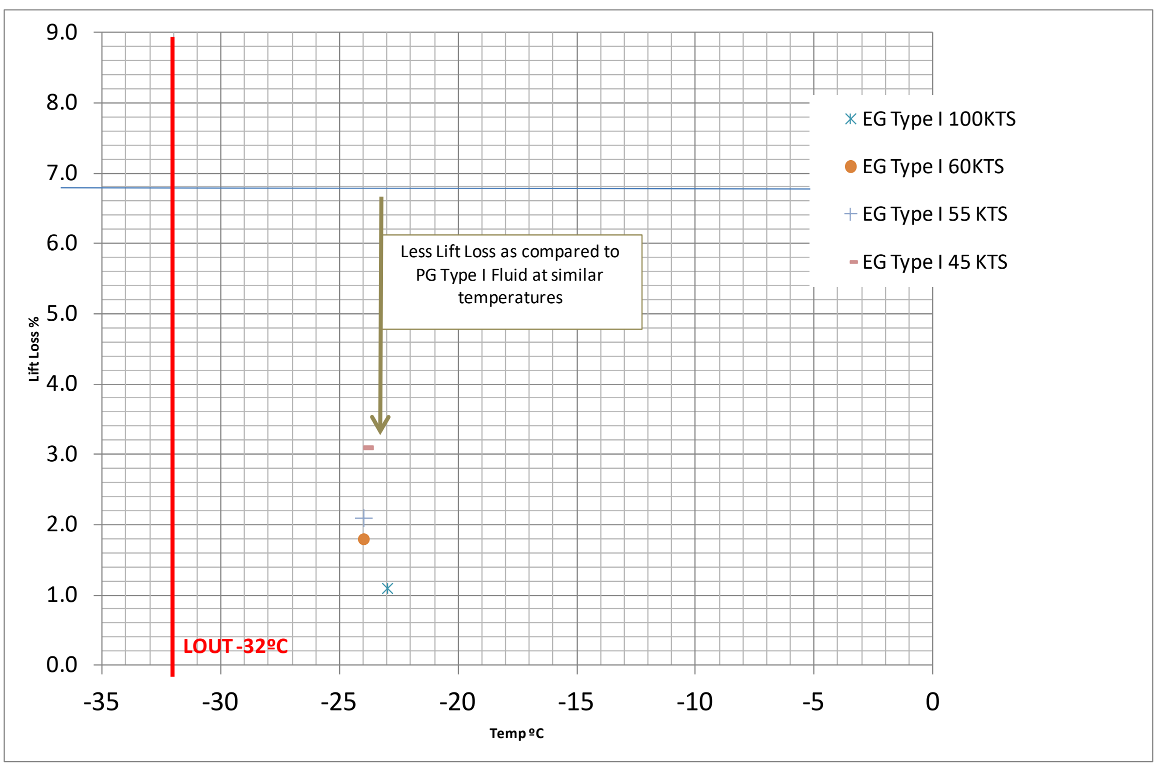


Figure 5.3: EG Type I Data at Different Rotation Speeds at Similar Temperatures

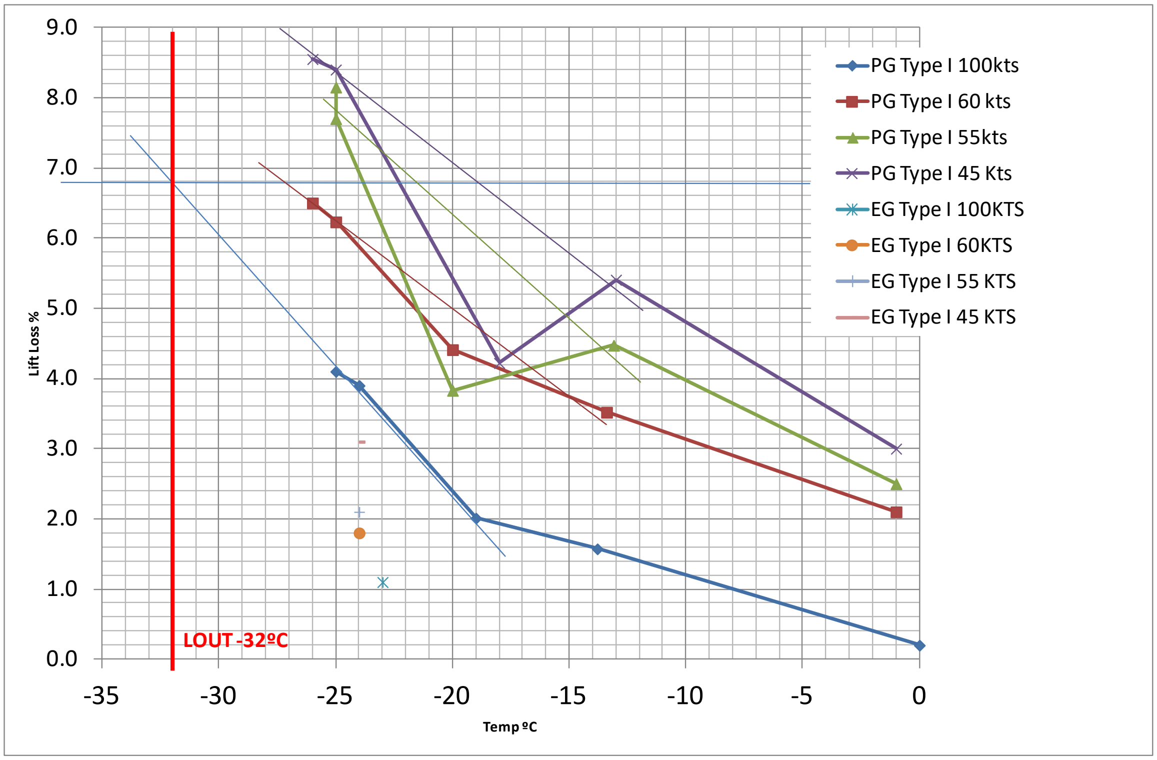


Figure 5.4: All PIWT EG and PG Type I Data Collected

An additional test (#374) was conducted at 30 knots and indicated that the lift losses further increased, as expected. A separate fluid application and squeegeeing simulation test (#375) was conducted, which indicated that if an operator wanted to deice the aircraft and then remove the fluid with a squeegee but did a poor job, this could still cause some lift losses, as demonstrated by the results.

Photo 5.1 to Photo 5.5 demonstrate the condition of the wing at the time of rotation for the five different takeoff profiles tested. The photos clearly indicate that the slower the speed, the more fluid is present at the time of rotation. Photo 5.6 also shows the condition of the wing during Test #375.

5.6 Additional BLDT Testing

The aerodynamic acceptance test for aircraft ground de/anti-icing fluids is based on the air and fluid boundary layer displacement thickness (BLDT) on a flat plate measured after experiencing the free stream velocity time history of a representative aircraft takeoff. Acceptability of the fluid is determined by comparing BLDT measurements of the candidate fluid with a datum established from the values of a reference fluid BLDT and the BLDT of the candidate fluid over the dry (clean) plate. Testing is carried out in the temperature range at which the fluid, undiluted and diluted, is to be used in airline service. This methodology is part of the fluid certification process and is described in detail in the SAE AS5900 document.

In addition to the wind tunnel testing conducted, fluid samples were retained and sent for BLDT testing using a methodology based on the AS5900 procedure; a testing methodology similar to that used in the NRC wind tunnel was used. The flat plate BLDT test compared the results of different wind speeds on the fluid BLDT; different ramp profiles were developed in order to perform this comparison. A separate report has been included in Appendix D that includes the details and parameters related to the BLDT testing.

Figure 5.5 shows a summary table of the results obtained, plotted, and analysed in a fashion similar to Figure 5.1 to Figure 5.4. The results support the data collected in the PIWT and indicate that reducing the LOUT for the lower speed tests could provide a solution for operating with Type I fluid at lower speeds. Based on these results, the 35 m/s, 32 m/s, and 26 m/s speed profiles, which correspond to the 60, 55, and 45 knot tests, respectively, would have to be limited to -25ºC, -21.5ºC, and -17.5ºC to stay below the acceptable lift loss limit; these results are very similar to those obtained in the wind tunnel. In addition, these results also showed that using a fluid with a lower LOUT (EG Type I) could provide more flexibility in this situation.

5.7 Summary of Test Results

The results from the PIWT and BLDT testing indicated that lift loss and BLDT increase as temperature or speed decreases. Increasing the fluid LOUT (to warmer temperatures) could compensate for lower rotation speeds and provide some flexibility for aircraft with very low rotation speeds. Alternatively, using a fluid with a much lower LOUT could also provide additional flexibility at the lower temperatures with the lower speeds. It should be noted that these results are based on 2D modelling, and some full-scale testing would likely be required in order for operational guidance changes to be issued.

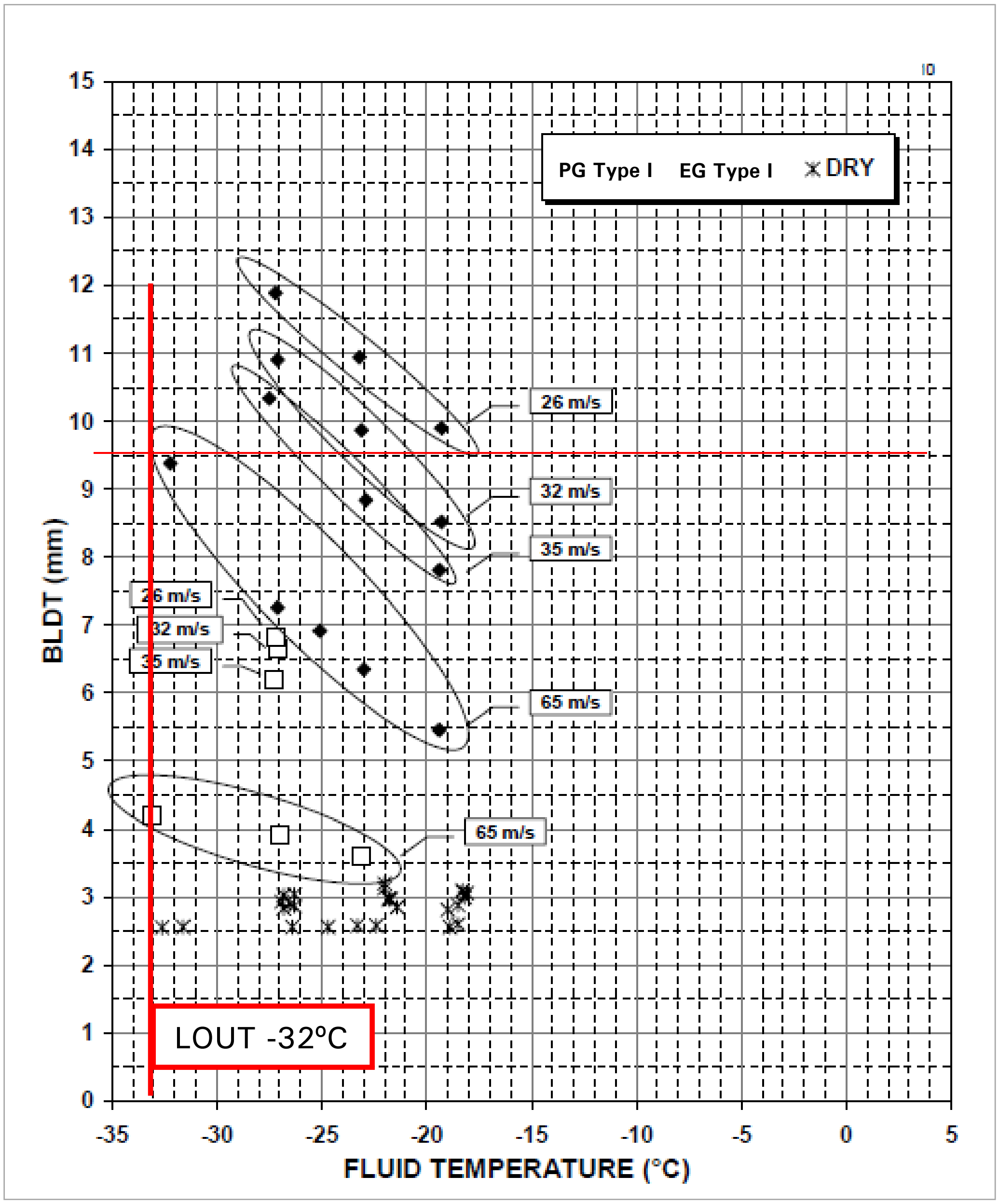


Figure 5.5: BLDT Data for Type I Very Low-Speed Rotation

Photo 5.1: Test #370 at Time of Rotation – 100 Knots, PG Type I

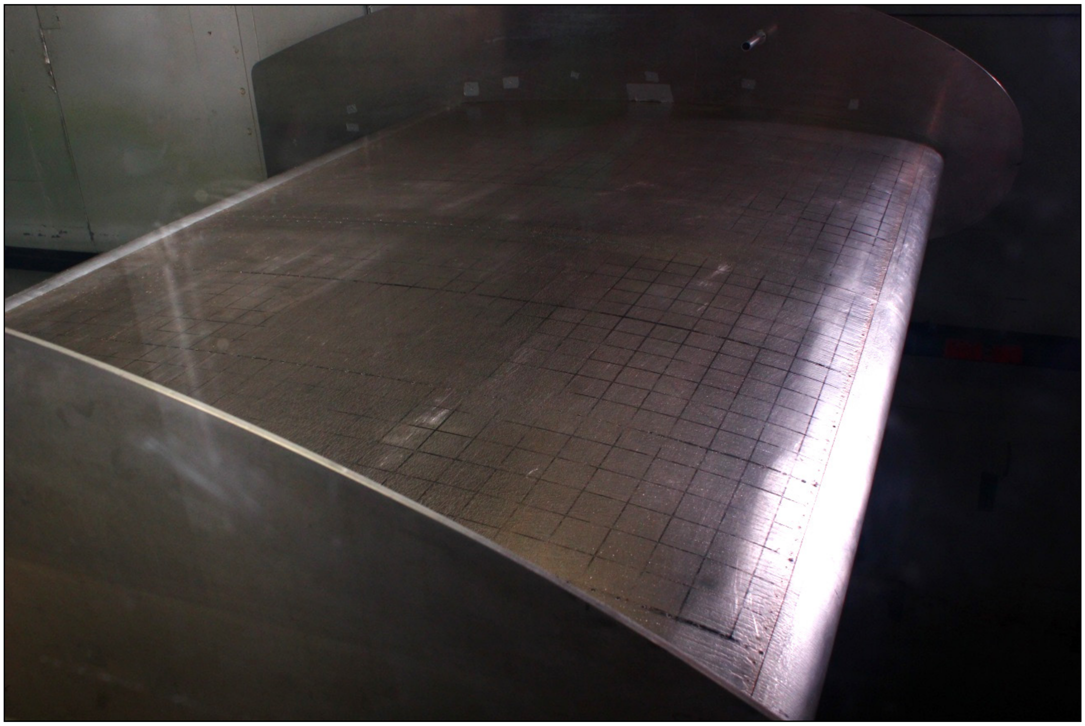


Photo 5.2: Test #371 at Time of Rotation – 60 Knots, PG Type I

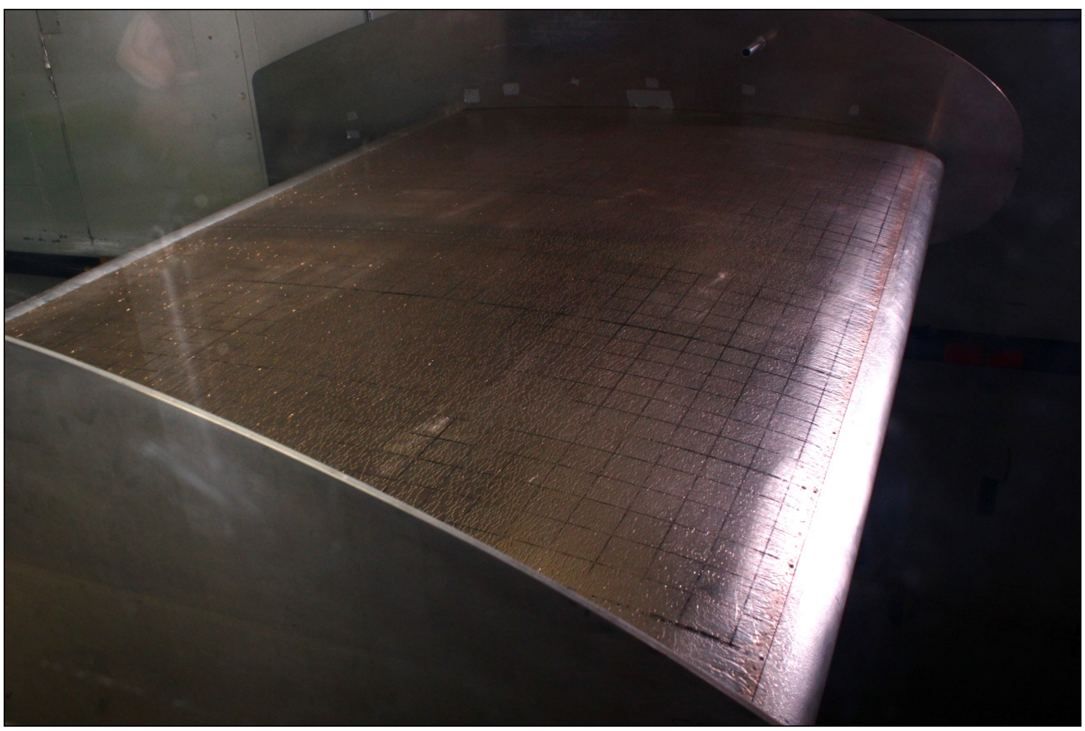


Photo 5.3: Test #372 at Time of Rotation – 55 Knots, PG Type I

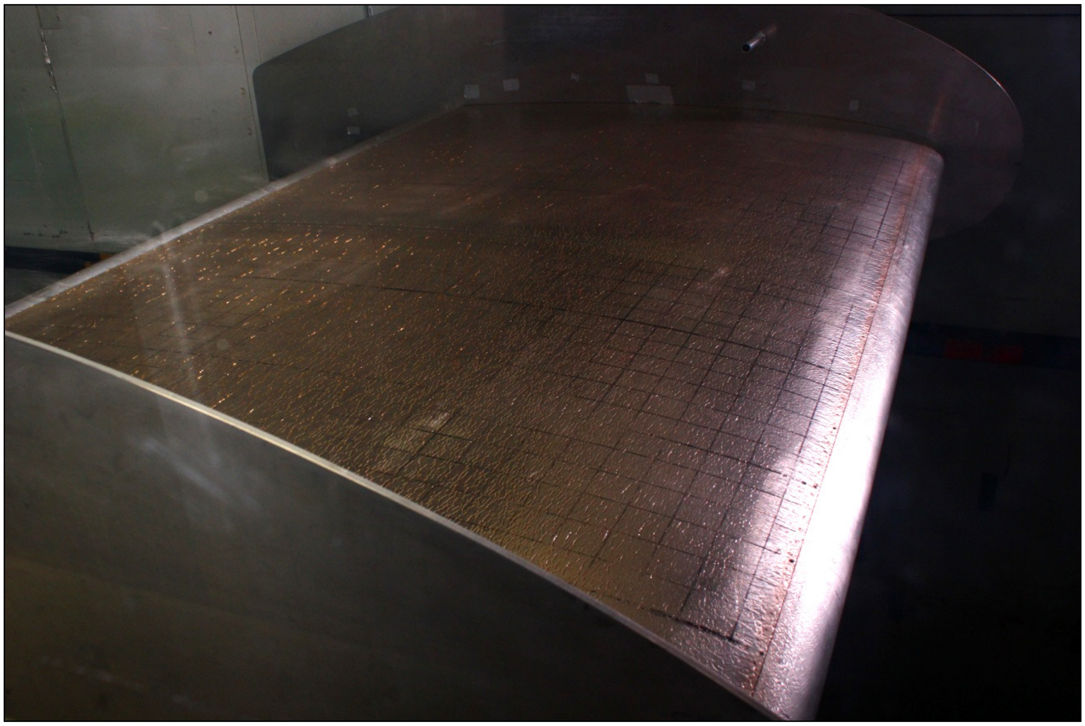


Photo 5.4: Test #373 at Time of Rotation – 45 Knots, PG Type I

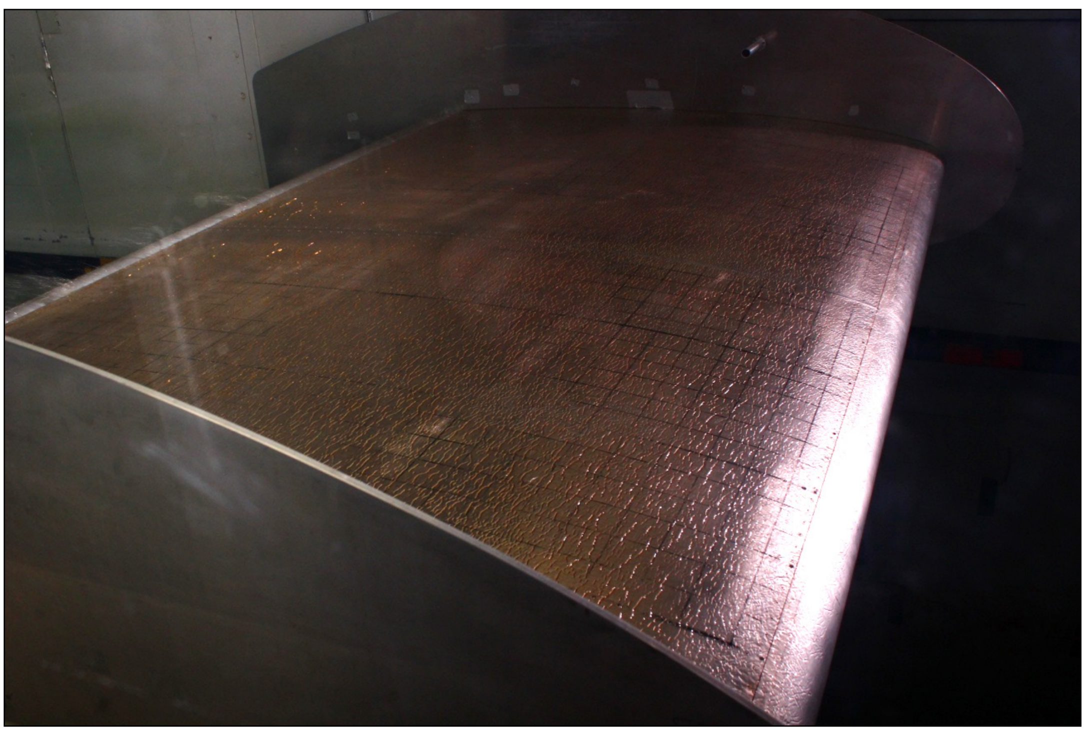


Photo 5.5: Test #374 at Time of Rotation – 30 Knots, PG Type I

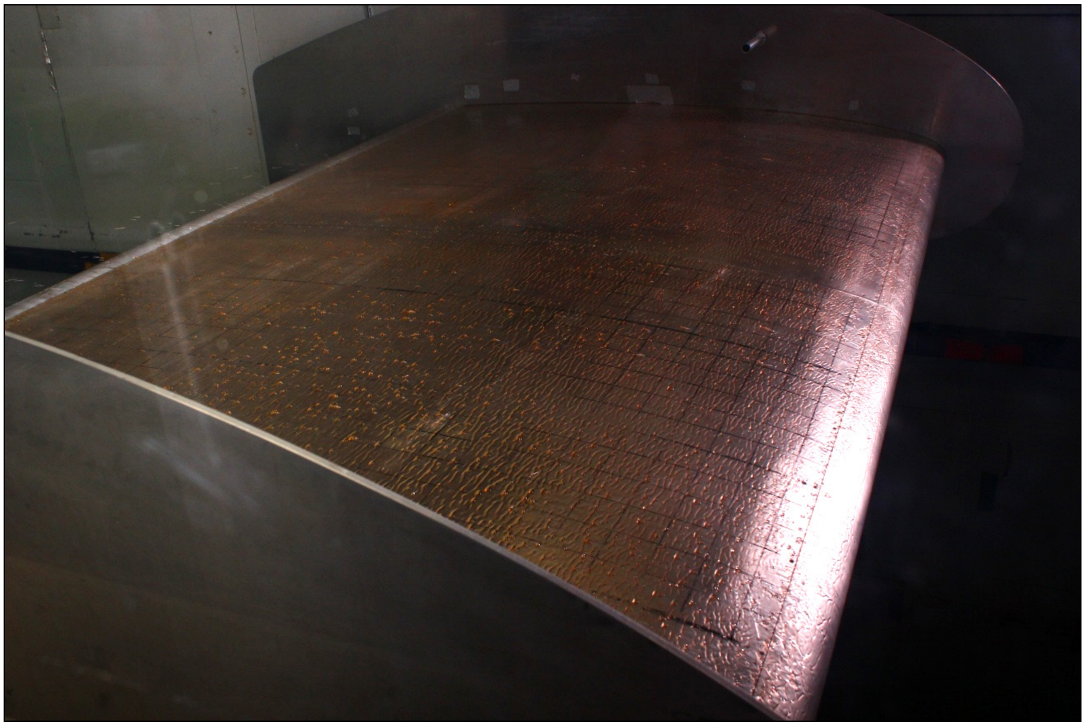
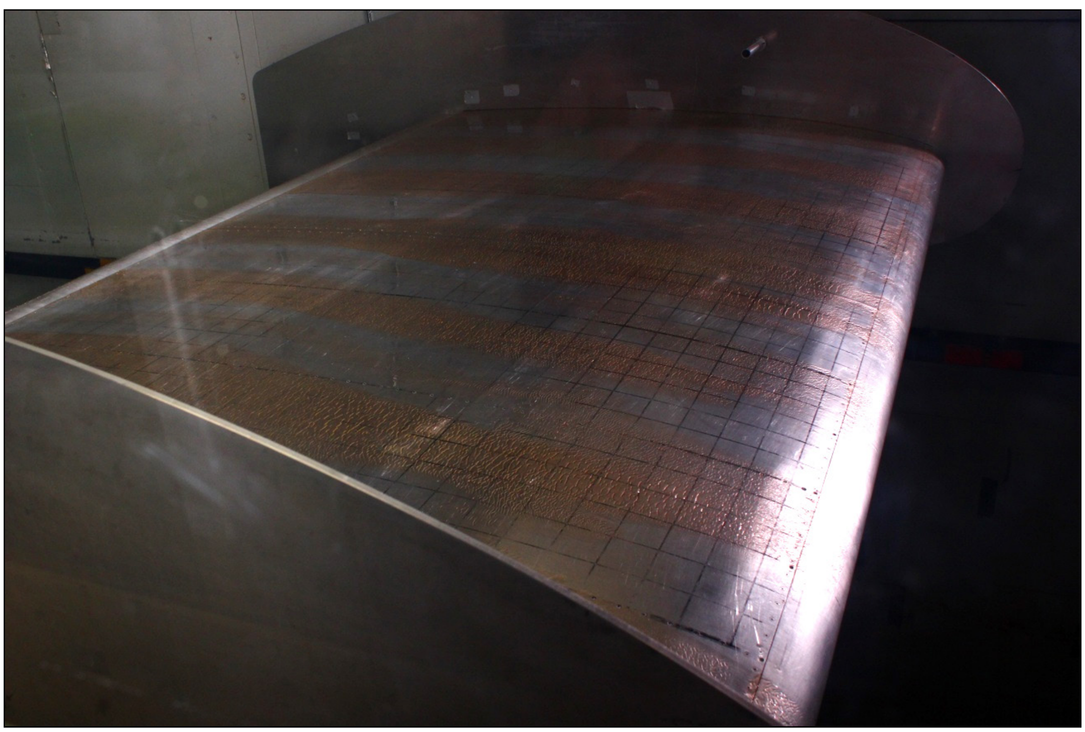


Photo 5.6: Test #375 at Time of Rotation – 45 Knots, PG Type I, with Squeegee Lines



This page intentionally left blank.

6. EVALUATION OF NEW GENERATION REPLACEMENT ICE PELLET DISPENSERS

6.1 Background

Simulated ice pellets are distributed over a test surface using an ice pellet pitcher. The original ice pellet pitcher was a modified hand-held fertilizer dispenser. The rate of precipitation was controlled with the speed of rotation of the motor, as well as the size of the opening of the dispenser reservoir drop feeder.

In the winter of 2012-13, seed spreaders historically modified and used for applying ice pellets during wind tunnel and flat plate testing were no longer available, as the manufacturer stopped production of the model. A new replacement seed spreader system was found that is similar (but not identical). Some calibration work was required to demonstrate an equivalency in the two systems; testing was conducted at the NRC Climatic Engineering Facility (CEF) prior to the wind tunnel testing to verify the distribution of the historical system versus the new replacement system, the details of which are included in the TC report, TP 15230E, *Aircraft Ground Icing General Research Activities During the 2012-13 Winter* (9). The data collected demonstrated that the new system is very similar to the old system. Some small variation was present in distribution within the footprint, but there was equivalent efficiency on the overall footprint. Based on this, it was concluded that, for ice pellets, the new system can be used as a direct replacement. For snow, the new system was more efficient; therefore, a reduction of 10 percent should be used for the snow mass requested. It was recommended that comparative wind tunnel testing be conducted to further validate the equivalency of the systems.

6.2 Objective

To evaluate the equivalency of the new and old generation dispenser systems through comparative wind tunnel testing.

6.3 General Methodology

The general methodology used for these tests was in accordance with the methodologies used for typical fluid with and without contamination tests conducted in the wind tunnel. The evaluation methodology was modified to allow a comparison of back-to-back tests done with the different sets of ice pellet dispensers: the old (Photo 6.1) and the new (Photo 6.2) systems. For each comparative test set, a test was conducted with the old dispenser system and immediately followed by a test with the same conditions but using the newer generation system, and the differences in lift loss during these tests were compared.

6.4 Data Collected

In total, 11 comparative tests were conducted. A summary of the test data is included in Table 6.1.

Table 6.1: Log of New vs. Old Dispenser Tests

Test #	Date	Objective	Test Condition	Fluid Name	Rotation Angle (°)	Speed Kts	Extra Run Information	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)
305	21-Jan-14	New Ice Pellet Dispenser Validation	IP-/SN-	Polar Guard Advance	8	115	old dispenser	7.80%	-11.4	11	-23.8
306	21-Jan-14	New Ice Pellet Dispenser Validation	IP-/SN-	Polar Guard Advance	8	115	new dispenser	7.97%	-14.4	11	-24
309	21-Jan-14	New Ice Pellet Dispenser Validation	IP-/SN-	Polar Guard Advance	8	115	new dispenser	7.94%	-9.6	11	-22.6
330	22-Jan-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	115	old dispenser	7.67%	-18.1	16	-20
331	22-Jan-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	115	new dispenser	8.95%	-16.3	16	-20.2
332	22-Jan-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	115	old dispenser	9.25%	-17	15.5	-20.6
333	22-Jan-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	115	new dispenser	9.42%	-16.4	15	-20.6
334	23-Jan-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	115	old dispenser	10.82%	-18.8	15.5	-20.9
335	22-Jan-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	115	new dispenser	9.55%	-20	15.5	-21
336	23-Jan-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	115	old dispenser	9.35%	-19.6	13	-21.4
337	23-Jan-14	New Ice Pellet Dispenser Validation	IP Mod	Launch	8	115	new dispenser	8.66%	-20.6	14	-21.9

6.5 Summary of Test Results

The comparative test results have been presented in an abbreviated table format in Table 6.2. The results indicate that the differences in recorded lift losses were generally very small (less than 1.3 percent) when comparing back-to-back tests with no bias towards one system or the other. The differences were even smaller when looking at the average of the four comparative sequential tests (Tests #330 to #337), which was 0.1 percent.

In addition, the tests were visually evaluated to verify that the distribution of the ice pellets was similar, further supporting the similarity in aerodynamic results between the two dispenser systems.

In general, the results further support the original distribution equivalency work conducted during the winter of 2012-13 and demonstrate that the new generation dispensers are suitable replacements for the older model dispensers.

Table 6.2: Comparison of New vs. Old Dispenser Test Results

OLD DISPENSER SYSTEM		NEW DISPENSER SYSTEM			
Test #	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL	Test #	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL	Absolute Difference in % (per row)	Absolute Difference in % (avg 330,332,334,336 vs. avg 331,333,335,337)
305	7.8%	**306**	8.0%	0.2%	n/a
305	7.8%	**309**	7.9%	0.1%	n/a
330	7.7%	**331**	9.0%	1.3%	0.1%
332	9.2%	**333**	9.4%	0.2%	
334	10.8%	**335**	9.5%	1.3%	
336	9.4%	**337**	8.7%	0.7%	

Photo 6.1: Old Ice Pellet Dispenser System

Photo 6.2: New Ice Pellet Dispenser System

This page intentionally left blank.

7. EFFECT OF COOLING SYSTEM ON TESTING PROCEDURES

7.1 Background

Recent wind tunnel research has been limited by the ambient temperature in the wind tunnel test section; in sunny conditions, the radiation will raise the temperature in the test section, making testing difficult. To mitigate this effect, testing is often conducted overnight. However, in some cases, even body heat from workers in the test area (specifically during long precipitation exposure tests) can affect the temperature. A new cooling system has been installed by the NRC to mitigate the effects of the solar radiation warming as well as from the heat generated by workers in the test section. It was recommended that testing be conducted to evaluate the effects of the new cooling system on the test results.

7.2 Objective

To evaluate the effect of the cooling system on the aerodynamic test results produced.

7.3 General Methodology

The general methodology used for these tests was in accordance with the methodologies used for typical fluid with and without contamination and fluid/contamination tests conducted in the wind tunnel. The evaluation methodology was modified to allow a comparison of tests with and without the aid of the cooling system.

7.4 Data Collected

In total, 2 tests were conducted: the baseline fluid test without the help of the cooling system (Photo 7.1 and Photo 7.2), followed by a test with the cooling system active. Details are included in Table 7.1. Due to the poor results, no further testing as part of the TC/FAA campaign was conducted.

Table 7.1: Log of Cooling System Tests

Test Year	Test #	Date	Objective	Test Condition	Fluid Name	Rotation Angle (°)	Speed Kts	Extra Run Information	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)
Winter 2013-14	5	8-Jan-14	R&D	EFFECT OF COOLING SYSTEM	EG106	8	100	front door of tunnel closed right after wing tilt cooling system was off during test front door closed due to windy day	1.78%	-5.2	18	-9.2
Winter 2013-14	**6**	8-Jan-14	R&D	EFFECT OF COOLING SYSTEM	EG106	8	100	Wind tunnel not run. When fan turned on it actually heated section. Testing stopped until issue could be resolved.	n/a	n/a	16	n/a

7.5 Summary of Test Results

It was determined immediately during the first test (#6) that the system was not functioning efficiently. During the start-up of the system, hot rather than cold air would be pumped into the test section and would have adverse effects on the tests. Throughout the test campaign, the NRC continued to attempt to rectify the issues with the system. Several independent tests were conducted by the NRC to evaluate the system; however, no additional tests as part of the TC/FAA campaign were conducted. At the end of the test campaign, the system was still not functioning correctly. However, a list of recommendations for improvement was compiled, and the NRC would attempt to rectify these issues during the down-season in preparation for the next year of testing.

In general, the concept has shown promise, and with some effort to isolate the problematic areas of the system, the cooling system can become a critical tool for testing and will allow greater flexibility.

This page intentionally left blank.

Photo 7.1: Cooling System (View from Outside Test Section)

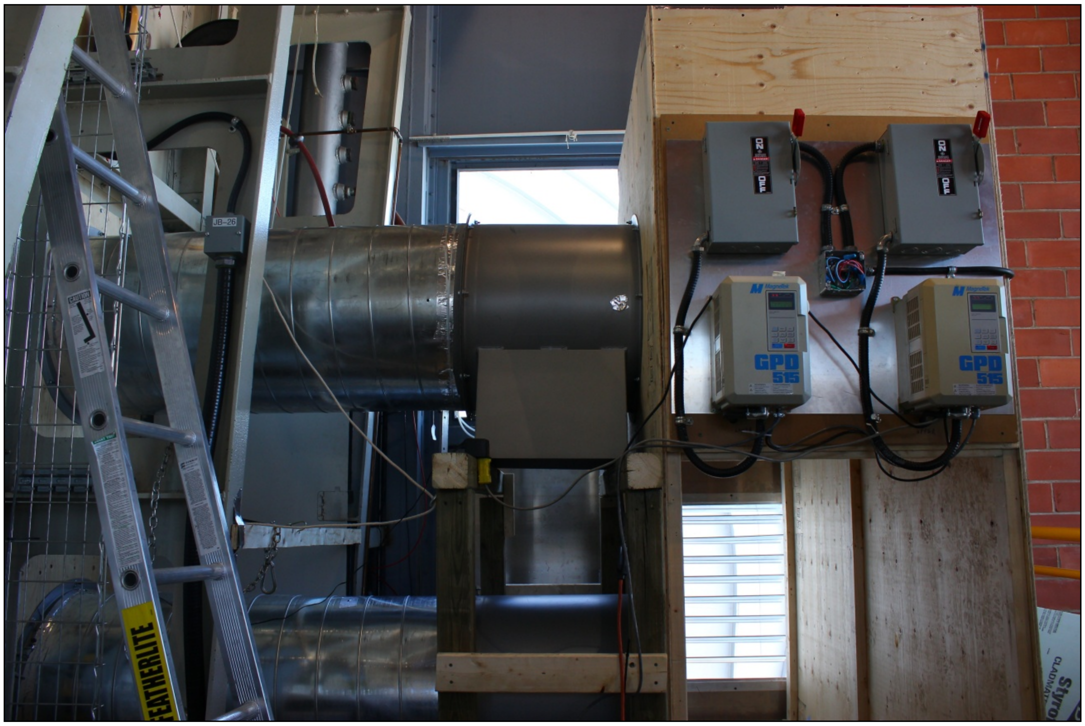
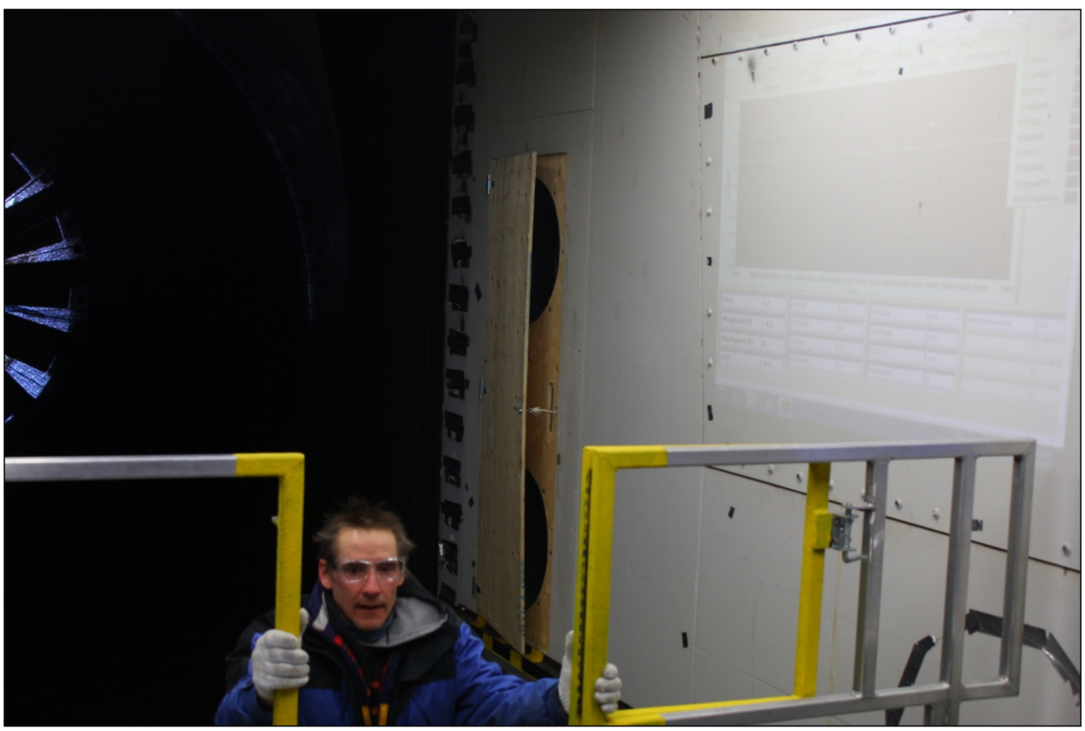


Photo 7.2: Cooling System Vents (View from Inside Test Section)



This page intentionally left blank.

8. HEAVY CONTAMINATION

8.1 Background

Previous testing in the wind tunnel demonstrated that even when very heavy ice pellet and/or snow contamination was applied to a fluid-covered wing section, the majority of the fluid and contamination was still eliminated by the time of rotation. The initial testing indicated that above a certain level of contamination, the dry, loose ice pellets or snow are no longer absorbed into the fluid to be easily shed off during the acceleration. The protection is due to a thin layer of fluid present underneath the contamination that prevents adherence. Questions concerning the point at which the lift losses become a safety issue have been raised.

8.2 Objective

To continue previous research investigating de/anti-icing fluids exposed to heavy contamination and the resulting aerodynamic effects.

8.3 General Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical ice pellet tests conducted in the wind tunnel. For a chosen fluid, conduct a test simulating ice pellets, snow, or freezing rain for an exposure time far exceeding the recommended HOT or allowance time. Record the lift data, visual observations, and manually collected data. Compare aerodynamic performance results to fluid with and without contamination tests at the same temperature.

8.4 Data Collected

Only 1 test was conducted at the end of the test campaign; the entire remaining inventory of ice pellets and snow was used to conduct this test (details are found in Table 8.1). An equivalent rate of 375 g/dm^2/h of ice pellets and 50 g/dm^2/h of freezing rain were applied for a period of 26 minutes.

Table 8.1: Log of Heavy Contamination Tests

Test Year	Test #	Date	Objective	Test Condition	Fluid Name	Rotation Angle (°)	Speed Kts	Extra Run Information	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL	Tunnel Temp. Before Test (°C)	Fluid Amount (L)	OAT Before Test (°C)
Winter 2013-14	**377**	29-Jan-14	R&D	HEAVY CONTAMINATION	ABC-S+	22	100	Used entire remaining inventory of ice pellets with added freezing rain	12.73%	-4.1	16	-11.2

8.5 Summary of Test Results

The test conducted demonstrated interesting results. Prior to the start of the test, the thickness of the contamination layer measured close to 40mm on top of the wing (Photo 8.1 and Photo 8.2). At the start of rotation (Photo 8.3), only a portion of the contamination was removed; most came off in large adhered sheets of ice and snow during the first few seconds of the rotation cycle (Photo 8.4). The wing section still had a good amount of fluid present on the wing at the end of rotation; the thick slushy fluid was not completely sheared off. The results showed a higher than usual lift loss of 12.73 percent. The wing entered a stall at 16 degrees angle of attack (the dry wing typically stalled at around 21-22 degrees).

In general, the results indicated that although a significant amount of frozen contamination was present prior to takeoff, the anti-icing fluid provided the protection required to allow the shear forces to remove most of the ice prior to rotation. Although difficult to extrapolate such an extreme case in a 2D model to a full-scale aircraft, it does provide information into the safety buffers inherently built into these fluids.

This page intentionally left blank.

Photo 8.1: Test #375 – Start of Test

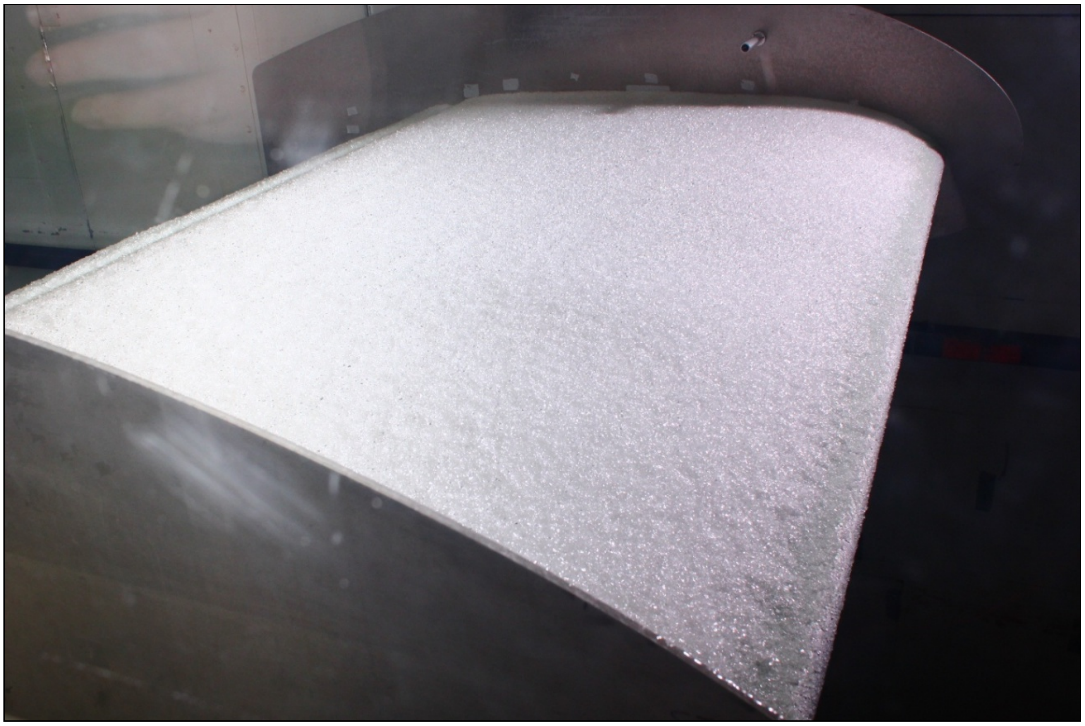


Photo 8.2: Measuring Thickness (about 40 mm) of Accumulated Ice on Top Middle Point of Wing

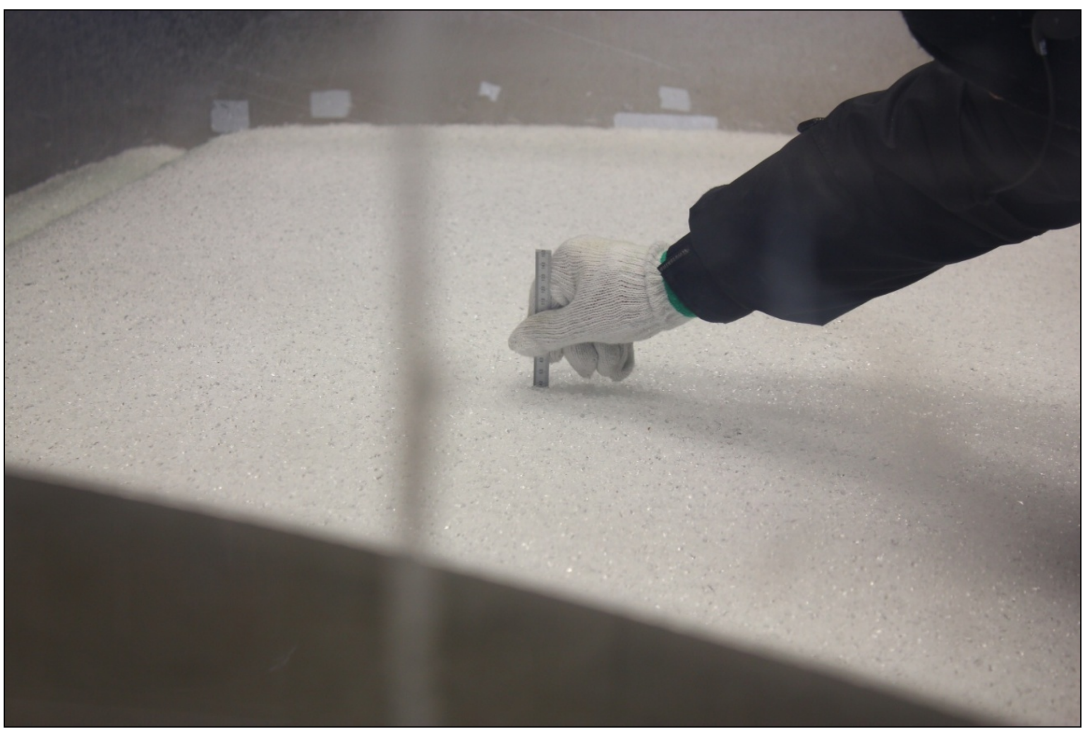


Photo 8.3: Test #375 – Start of Rotation

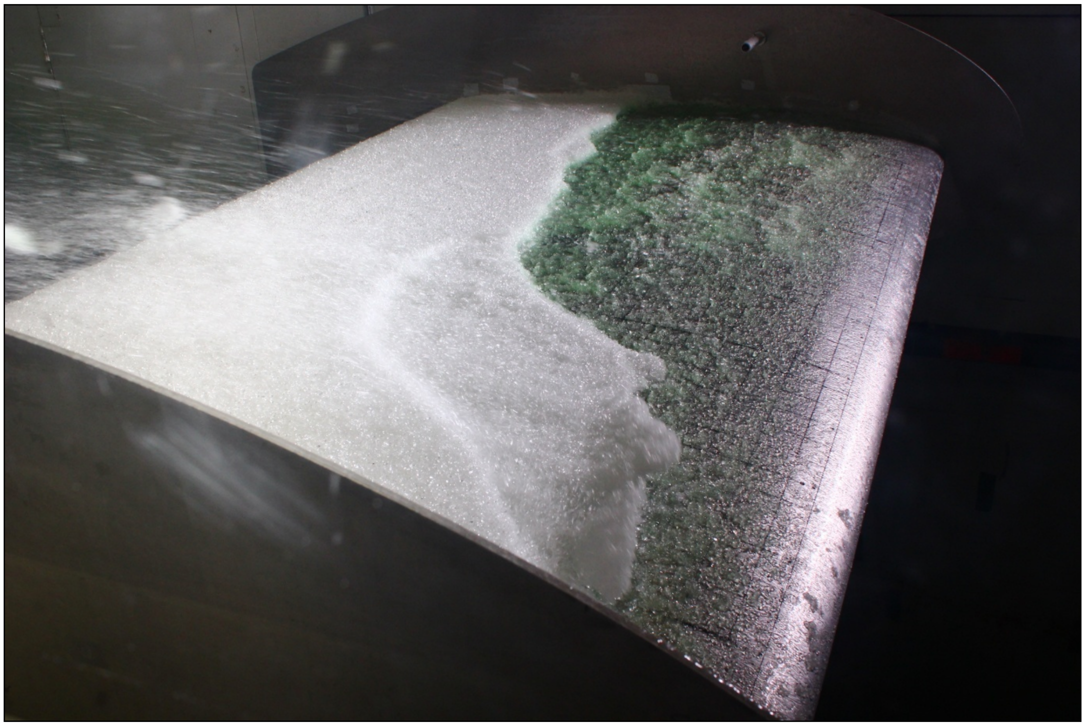
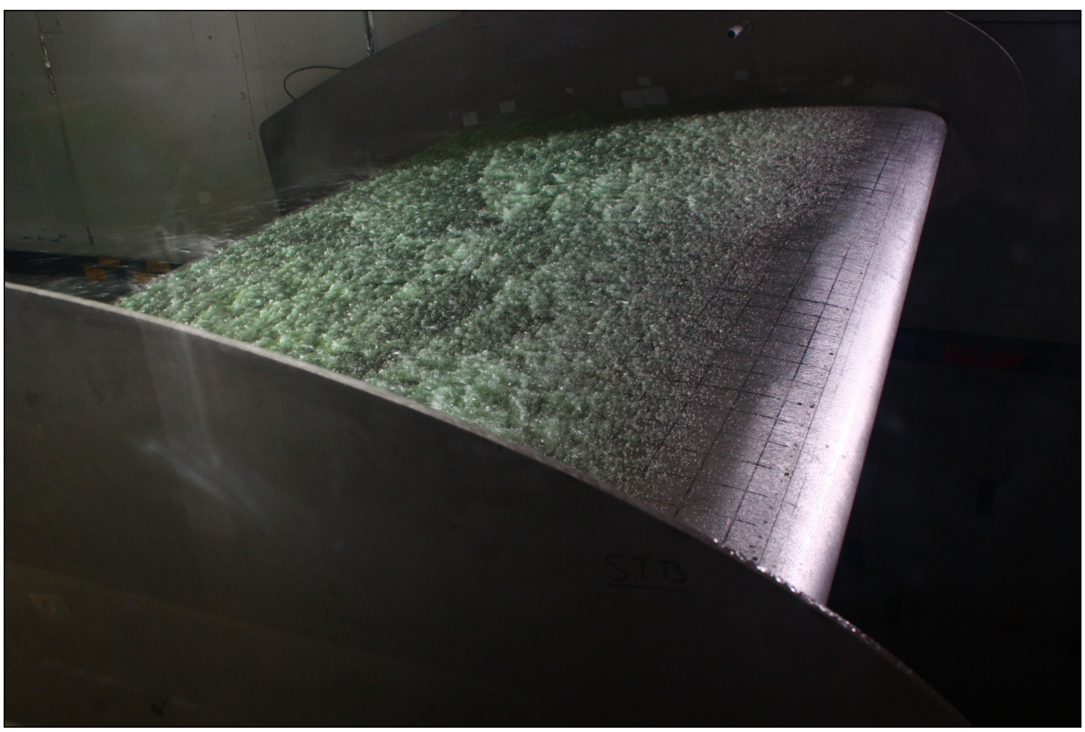


Photo 8.4: Test #375 – 3 Seconds After Start of Rotation (Approximately 8° AoA)



REFERENCES

1. Ruggi, M., *Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2013-14,* APS Aviation Inc., Transportation Development Centre, Montreal, February 2015, TP 15273E, 116.

2. Ruggi, M., *Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates*, APS Aviation Inc., Transportation Development Centre, Montreal, October 2014, TP 15275E, 264.

3. Ruggi, M., *Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2008-09*, APS Aviation Inc., Transportation Development Centre, Montreal, March 2010, TP 14939E, XX (to be published).

4. Ruggi, M., *Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2009-10*, APS Aviation Inc., Transportation Development Centre, Montreal, August 2011, TP 15057E, XX (to be published).

5. Ruggi, M., *Exploratory Wind Tunnel Aerodynamic Research: Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2010-11,* APS Aviation Inc., Transportation Development Centre, Montreal, March 2012, TP 15160E, XX (to be published).

6. Ruggi, M., *Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2012-13*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2013, TP 15233E, XX (to be published).

7. Balaban, G., *Flow of Contaminated Fluid from Aircraft Wings: Feasibility Report*, APS Aviation Inc., Transportation Development Centre, Montreal, January 2008, TP 14778E, XX (to be published).

8. Ruggi, M., *Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics and to Support the Development of Ice Pellet Allowance Times, Winters 2009-10 to 2012-13,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2013, TP 15232E, 1044.

9. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2012-13 Winter,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2013, TP 15230E, XX (to be published).

This page intentionally left blank.

APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2013-14

TRANSPORTATION DEVELOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2013-14

5.39.2 Testing to Support the Development of Aircraft Ground Deicing Related Procedures and Technologies (1 Week)

Testing will be done according to the procedures and methodologies used for “Testing to Further Refine Ice Pellet Allowance Times”.

a) Meet and discuss with NRC personnel as necessary for specific project related tasks (i.e. preparation of ice phobic wing skins);

NOTE: The NRC facility costs associated with testing at M46 are not included in this task and are dealt with directly with TC through a M.O.U. agreement with NRC;

b) Develop procedure for conducting wind tunnel testing in accordance with the existing ice pellet allowance time testing methodology;

c) Perform wind tunnel tests over a period of five (5) days to support the development of aircraft ground deicing related procedures and technologies; and

   i. Aircraft coating testing to evaluate lift, drag, and other dry wing properties for take-off, climb-out, and cruise flight portions;

   ii. Aircraft coating testing to evaluate fluid and fluid/contamination testing;

   iii. Aircraft coating testing to evaluate repeatability, and proof of methodology; and

   iv. Testing to address industry concerns and interests.

d) Analyze the data collected, Report the findings, and prepare presentation material for the SAE G-12 meetings.

5.39.3 Type I LOUT for Very Low Speed Aircraft (2 Days)

Testing will be done according to the procedures and methodologies used for “Testing to Further Refine Ice Pellet Allowance Times”.

a) Conduct a review of existing material from operators, regulators, and airframe manufacturers to develop a test plan;

b) Develop procedure for conducting full-scale wind tunnel testing simulating Type I anti-icing and deicing scenarios during active frost and post active frost conditions. Testing will be conducted according to the existing methodology using a thin high performance wing section, or alternatively, with a thicker low speed airfoil (LS-0417);

c) Conduct testing with the thin high performance wing section for 1-2 days in the NRC wind tunnel (a longer more detailed test plan is required if the LS-0417 section is selected). Testing should focus on identifying the limiting factors and possibly developing alternatives for operators;

d) Determine best practice alternatives;

e) Report the findings, and prepare presentation material for the SAE G-12 annual meeting; and

f) If appropriate publish guidance in the Transport Canada 2014-2015 HOT Guidelines and/or TP 14052.

APPENDIX B

PROCEDURE:
WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

CM2265.003

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

Winter 2013-14

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi and Victoria Zoitakis

Reviewed by: John D'Avirro

January 6, 2014
Final Version 1.0

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

1. BACKGROUND

Prior to the winter of 2006-07, Holdover Time (HOT) guidance material did not exist for ice pellet conditions, however aircraft could still depart during ice pellet conditions following aircraft deicing and a pre take off contamination check. This protocol was feasible for common air carrier aircraft that provided access to emergency exit windows overlooking the leading edge of the aircraft wings; however, it posed a significant problem for cargo aircraft that have limited visibility of the wings from the cabin.

On December 22, 2004, United Parcel Service (UPS) aircraft in Louisville were grounded for several hours due to extended ice pellet conditions. Due to cargo aircraft configuration, pre-take off contamination checks by the on-board crew were not possible. FedEx had been faced with similar problems in Memphis. Following this event, in October 2005, the FAA issued two notices restricting take offs in ice pellet conditions.

As a result of this costly incident, UPS set out to obtain experimental data to provide guidance and allow operations to continue in ice pellet conditions. During the winter of 2004-05, aerodynamic and endurance time testing were conducted in simulated ice pellet conditions. APS also conducted some preliminary flat plate research (see TP 14718E). Based on the preliminary data, an allowance of 20 minutes in light ice pellet conditions was proposed, however no changes to the HOT guidelines were made.

During the following winter of 2006-07, the FAA provided a 25 minute allowance as a preliminary guideline; TC issued a note indicating that no changes would be made to the HOT guidelines. This allowance was based on the previous research conducted during the winter of 2005-06, primarily as a result of Falcon 20 aerodynamic research (see TP 14716E); these results were presented at the Society of Automotive Engineers (SAE) meeting in Lisbon in May 2006. To address the option of a pre-take off contamination check, the 20 minute targeted allowance was extended to 25 minutes; pre-take off contamination checks would no longer apply. This allowance was followed by a list of conditions; one restriction was that operations would be limited to ice pellets alone (no mixed conditions).

Due to the high occurrence of ice pellets combined with freezing rain or snow, the industry requested additional guidance material for operations in mixed ice pellet conditions. Additional endurance time testing and aerodynamic research were conducted in simulated ice pellet conditions during the winter of 2006-07.

During the winter of 2007-08, the TC and FAA provided allowance time guidance material for operations in mixed conditions with ice pellets guideline. These allowance times were based on the research conducted during the winter of 2006-07 (see TP 14779E). The recommended allowance times were based on aerodynamic research conducted using the 3 m x 6 m Open Circuit Propulsion and Icing Wind Tunnel (PIWT) and the NRC Falcon 20 aircraft; these results were presented at the SAE meeting in San Diego in May 2007. These allowance time guidelines were followed by a list of restrictions based on the results obtained through the research conducted, and the lack of data in specific conditions.

During the winter of 2008-09, additional endurance time testing and aerodynamic research was conducted to support and further expand the ice pellet allowance times (see TP 14935E). Full-scale testing with the NRC PIWT was conducted in mixed conditions with ice pellets and in non precipitation conditions. Testing was geared towards validating the current ice pellet allowance times, and potentially expanding the guidance material to include different conditions, fluids, and acceleration profiles. A revised version of the ice pellet allowance times was published for the winter of 2009-10; changes were made to the high speed table allowance times only.

During the winter of 2009-10, additional aerodynamic research using a generic super-critical wing model was conducted at the NRC PIWT to support and further expand the ice pellet allowance times for use with newer generation aircraft. During the testing, fluid flow-off issues with the supercritical wing were observed with PG fluids at the lower temperatures; more specifically during light ice pellets and moderate ice pellet conditions below -10°C. In addition fluid failure issues with the supercritical wing were observed with PG fluids during moderate ice pellets above -5°C; the relatively flat surface of the wing had less fluid flow off during contamination and resulted in an earlier fluid failure for PG fluids. In general, higher lift losses were observed with the supercritical wing as compared to previous wings tested. A revised version of the ice pellet allowance times was published for the winter of 2009-10. Additional analysis paired with wind tunnel testing was recommended for the winter of 2010-11 to develop a correlation between the lift losses observed in the wind tunnel and those used as the basis of the aerodynamic acceptance tests for fluid certification.

Results from the 2010-11 testing demonstrated similar results to the 2009-10 testing in that the results indicated fluid flow-off issues with the supercritical wing when using PG fluids at the lower temperatures. The results indicated that the changes to the guidance material made the previous winter were still relevant and should remain in the allowance time table for the winter of 2011-12. However, a large part of the 2010-11 work was focused on developing a correlation between the PIWT and the aerodynamic acceptance test. Based on the work that was conducted by NASA and APS, it was determined that a maximum lift loss of 5.24% on the B737-200ADV airplane is equivalent to a lift loss of 7.29% on the PIWT model. Due to the scatter in the data, the standard error of the estimate resulted in a range of values which determined an upper limit of lift loss on the PIWT model of 9.2% and a lower limit of 5.4%. Currently the scatter in the "review" range is still large and causes complications when analyzing the data collected. It is anticipated that as future testing progresses, and as more data is collected, a single-value pass/fail cutoff maybe developed similar to the AAT and B737-200ADV airplane tests.

Due to industry concern with the validity of the results obtained, and the relevance of the test methods to operational aircraft, it was recommended that testing during the winter of 2011-12 focus on surveying and calibrating the wind tunnel to obtain a better sense of the repeatability of the results. With the support of NRC and under direction of NASA, a large series of test runs were conducted to better understand the performance characteristics of the wind tunnel and airfoil. The results indicated that the year-to-year equipment and facility upgrades have increased the integrity of the aerodynamic data produced, and the wind tunnel can closely simulate aircraft take-off profiles. The characterization of the current dry wing model with original endplates demonstrated appropriate aerodynamic behavior. The back-to-back fluid-only runs demonstrated excellent repeatability of test methods and this was reflected in the aerodynamic data collected. The repeatability of the testing was considered acceptable for this type of aerodynamic testing work and was not indicative of systematic errors in procedures or equipment.

FAA and TC were satisfied with calibration technical evaluation results, and therefore it was recommended that testing during the winter of 2012-13 revert back to the initial research and development objectives of further refining and substantiating the ice pellet allowance times. During the winter of 2012-13, the clean, dry wing aerodynamic repeatability was confirmed in comparison with previous data and the additional data collected in 2012-13 helped in substantiating these findings. The stalling characteristics of the wing with fluid (or fluid with contamination) appeared to be driven by secondary wave effects near the leading edge; these effects were difficult to interpret on the two-dimensional model relative to a fully three-dimensional wing and therefore should not be used in developing allowance times. Additional lift-loss scaling correlation data with different fluids at colder temperatures confirmed that previous lift loss limits were still valid. Forty ice pellet allowance time tests were conducted to validate and possibly expand the current guidance material. The data validated the current allowance times with new fluids and also indicated a potential to expand the allowance times for light ice pellets mixed with light snow and moderate snow.

For the Winter 2013-14, the primary focus of testing will be on the ice pellet allowance time validation and development and other R&D activities.

2. OBJECTIVES

The objective of this testing is to conduct aerodynamic testing with a super critical airfoil to:

- Ensure the repeatability of the dry wing performance;
- Expand the ice pellet allowance times for light ice pellets mixed with light or moderate snow conditions;
- Substantiate the current ice pellet allowance times with new fluids, fluids previously tested but with limited data, and temperatures close to the lowest operational use temperature (LOUT);
- Evaluate the equivalency of the new ice pellet/snow dispenser systems;
- Evaluate the effect of coatings on aerodynamics with and without fluids;
- Support the development of a Type III ice pellet allowance time table; and
- Evaluate Type I fluid flow-off performance for low speed rotation less than 80 knots.

Attachments I to VII provide additional information for performing some of these activities which may not use the typical wind tunnel testing methodology.

As lower priority objectives, testing may be conducted to investigate other objectives of high importance to industry which may include (and is described further in Section 6.11):

  - Evaluation of an airfoil performance monitor (APM) system;
  - Heavy snow;
  - Heavy contamination;
  - Effect of cooling system on testing repeatability;
  - Effect of fluid viscosity;
  - Fluid and contamination at LOUT;
  - Small hail;

- Frost simulation in the wind tunnel;
- Flaps/Slats testing to support YMX tests;
- Mixed HOT conditions;
- Snow on an un-protected wing;
- Feasibility of IP testing at higher speed (130-150kts);
- Windshield washer used as a Type I deicer;
- Effect of fluid seepage on dry wing performance; and
- Second wave of fluid at rotation.

To satisfy these objectives, a super-critical wing section (Figure 2.1) will be subjected to a series of tests in the NRC PIWT. The dimensions indicated are in inches. This wing section was constructed by NRC in 2009 specifically for the conduct of these tests following extensive consultations with an airframe manufacturer to ensure a representative super-critical design.

Fifteen days of testing have been scheduled for the conduct of these tests. The available testing days will be from January 8th to the 31st (see Figure 2.2). Testing will likely be conducted during overnight periods (i.e. 10 pm – 6 am), unless temperatures are suitable for day/evening testing. The weekends will be considered only if deemed necessary.

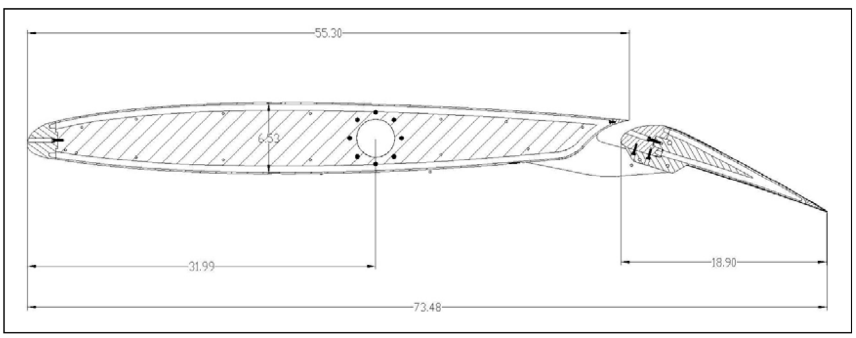


Figure 2.1: Super-Critical Wing Section

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLET PRECIPITATION CONDITIONS

CALENDAR JANUARY 2014

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2 NRC back from holidays	3 check forecast and ensure wx is good for the daytime testing (1st	4
5	6 Ice Pellet Manufacturing Start	7 Pack Truck and leave for YOW Ice Pellet Manufacturing Continue	8 ***TEST DAY 1*** -Set-up,calibration, training, briefing *TESTING ACTIVITY TBD** *day shift (8am-4pm)* *WT Task: TBD*	9 ***TEST DAY 2*** TESTING ACTIVITY TBD *day shift (8am-4pm)* *WT Task: TBD*	10 ***TEST DAY 3*** TESTING ACTIVITY TBD *day shift (8am-4pm)* *WT Task: TBD*	11
12	13 ***TEST DAY 4*** TESTING ACTIVITY TBD *WT Task: TBD*	14 ***TEST DAY 5*** TESTING ACTIVITY TBD *WT Task: TBD*	15 ***TEST DAY 6*** TESTING ACTIVITY TBD *WT Task: TBD*	16 ***TEST DAY 7*** TESTING ACTIVITY TBD *WT Task: TBD*	17 ***TEST DAY 8*** TESTING ACTIVITY TBD *WT Task: TBD*	18
19	20 ***TEST DAY 9*** TESTING ACTIVITY TBD *WT Task: TBD*	21 ***TEST DAY 10*** TESTING ACTIVITY TBD *WT Task: TBD*	22 ***TEST DAY 11*** TESTING ACTIVITY TBD *WT Task: TBD*	23 ***TEST DAY 12*** TESTING ACTIVITY TBD *WT Task: TBD*	24 ***TEST DAY 13*** TESTING ACTIVITY TBD *WT Task: TBD*	25
26	27 ***TEST DAY 14*** TESTING ACTIVITY TBD *WT Task: TBD*	28 ***TEST DAY 15*** TESTING ACTIVITY TBD *WT Task: TBD*	29 ***BACKUP DAY*** TESTING ACTIVITY TBD *WT Task: TBD*	30 ***BACKUP DAY*** TESTING ACTIVITY TBD *WT Task: TBD*	31 ***BACKUP DAY*** TESTING ACTIVITY TBD *WT Task: TBD*	FEB 1

NOTES

Anticipate Mon-Fri Testing, However, Weekend May be Needed Due to Temperature.
Test Day 1, 2, and 3 of testing to be conducted during daytime and the following will be overnights. This is dependent on the weather forecast and required temperature needed for testin
Testing will Likely be Conducted During Overnight Periods (i.e. 10PM - 6AM), Unless Temperatures are Suitable for Day, Evening Testing. Typical Test Day is 8hrs for APS Staff.
If extra days are required, or if runnng late on schedule due to equipement malfunction, or weather, consider 1-2 hours longer per day to make-up.
Testing team will be JD, MR, DY, VZ, BG & YOW x 4
Spare days are available (Jan 29-31) should it be needed.

* Consider running the effect of cooling system tests on Day 1.

TESTING ACTIVITIES

Above 0ºC						*n/a* **TYPE III ALLOWANCE TIMES (also some at above 0ºC)** ***WT Task: TIII***
0ºC to -5ºC	***#1*** **TYPE III ALLOWANCE TIMES (also some at above 0ºC)** ***WT Task: TIII***					
Below -5ºC	***#2*** **NEW ICE PELLET DISPENSER CALIBRATION** ***WT Task: IP***	***#3*** **Coatings: B14, B15** -Methodology Validation -Drag and Fuel Efficiency -Effect on Fluid Flow Off -Effect with Contamination ***WT TASK: R&D***	***#4*** **SNC (skin no coating), OW (Original Wing)** -Methodology Validation -Drag and Fuel Efficiency -Effect on Fluid Flow Off -Effect with Contamination ***WT TASK: R&D***	***#5*** **Coatings: E1, C3** -Methodology Validation -Drag and Fuel Efficiency -Effect on Fluid Flow Off -Effect with Contamination ***WT TASK: R&D***	***#6*** **Coatings: B12, B13, SNC** -Methodology Validation -Drag and Fuel Efficiency -Effect on Fluid Flow Off -Effect with Contamination -Installation Repeatability ***WT TASK: R&D***	***#7*** **R&D ACTIVITIES** **- APM UNIT** **- EFFECT OF COOLING** **- HEAVY SNOW** **- ETC** ***WT TASK: R&D / IP***
-5ºC to -10ºC	***#8*** **IP EXPANSION (IP/SN, IP/SN-) (also some at -10 to -30ºC)** ***WT Task: IP***	***#9*** **TYPE III ALLOWANCE TIMES** ***WT Task: TIII***				*n/a* **TYPE I FOR VERY LOW SPEED T/O (also some at -5 to -10º)** ***WT Task: TI <60kts***
-10ºC to -20ºC	***#10*** **TYPE III ALLOWANCE TIMES** ***WT Task: TIII***	***#11*** **TYPE I FOR VERY LOW SPEED T/O (also some at -5 to -10º)** ***WT Task: TI <60kts***				*n/a* **IP EXPANSION (IP/SN, IP/SN-) (also some at -10 to -30ºC)** ***WT Task: IP***
-20ºC to -30ºC	***#12*** **IP VALIDATION (NEW TEMPS & FLUIDS)** ***WT Task: IP***	***#13*** **IP VALIDATION (NEW TEMPS & FLUIDS)** ***WT Task: IP***	***#14*** **TYPE I FOR VERY LOW SPEED T/O (also some <-30ºC)** ***WT Task: TI <60kts***	***#15*** **TYPE III ALLOWANCE TIMES** ***WT Task: IP / R&D***		*n/a* **IP EXPANSION (IP/SN, IP/SN-) (also some at -10 to -30ºC)** ***WT Task: IP***
Below -30ºC						*n/a* **TYPE I FOR VERY LOW SPEED T/O (also some <-30ºC)** ***WT Task: TI <60kts***

Figure 10.1: Test Calendar

M:\Projects\PM2265.003 (TC Deicing 2013-14)\Procedures\Wind Tunnel\Final Version 1.0\Wind Tunnel Final Version 1.0.docx
Final Draft 1.0, January 14

Page 7 of 70

3. TEST PLAN

The NRC wind tunnel is an open circuit tunnel. The temperature inside the wind tunnel is dependent on the outside ambient temperature. Prior to testing, the weather should be monitored to ensure proper temperatures for testing.

Representative Type I/III/IV propylene and ethylene fluids in Neat form (standard mix for Type I) shall be evaluated against their uncontaminated performance; Attachments VIII to XIV present the generic holdover time guidelines for Type I and III as well as the fluid-specific holdover time guidelines for the representative Type IV fluids that will be tested. The current Ice Pellet Allowance Time table has been included in Attachment XV.

A preliminary list of test objectives is shown in Table 3.1. It should be noted that the order in which the tests will be carried out will be depend on weather conditions and TC/FAA directive. A detailed preliminary test matrix is shown in Table 3.2.

NOTE: The numbering of the test runs will be done in a sequential order starting with number 1.

A rating system has been developed for fluid and contamination tests, and will be filled out by the onsite experts when applicable. The overall rating will provide insight into the severity of the conditions observed. A test failure (failure to shed the fluid at time of rotation) shall be determined by the on-site experts based on residual contamination.

4. PRE-TESTING SETUP ACTIVITIES

The activities to be performed for planning and preparation, on the first day of testing, and prior to each testing day thereafter, have been detailed in a list included in Attachment XVI.

Table 4.1: Preliminary List of Testing Objectives for Winter 2012-13 Wind Tunnel Testing

Item #	Objective	Priority	Description	# of Days
1	Dry Wing Baseline Repeatability	1	Baseline test at beginning of each day. Ensure repeatability	-
2	IP Expansion (IP-/SN and IP-/SN-)	1	Expand IP Allowance Time Table for IP-/SN and IP-/SN-	1
3	IP Validation (New Temps & Fluids)	1	Substantiate current times with new fluids, fluids previously tested but with limited data, and temperatures close to LOUT	2
4	New Ice Pellet Dispenser Calibration	1	Evaluate the equivalency of the new ice pellet/snow dispenser systems	1
5	Ice Phobic Coating R&D	1	Evaluate the effect of coatings on aerodynamics with and without fluids	4
6	Type III IP Allowance Times	1	Support the development of a Type III high speed ice pellet allowance time table	4
7	Type I for Very Low Speed T/O	1	Evaluate Type I fluid flow-off performance for low speed rotation less than 80 knots	2
8	Other R&D Activites	1	To be selected from item # 8.1 to 8.16	1
8.1	Evaluation of an APM Sensor	2	Testing an airfoil performance monitor (APM) to evaluate potential for use in ground icing operations with and without fluids	-
8.2	Heavy Snow	2	Continue Heavy Snow Research comparing lift losses with Light/Moderate Snow vs. heavy Snow	-
8.3	Heavy Contamination (Aero vs. Visual Failure)	2	Continue work looking at aerodynamic failure vs. HOT defined failure, and effect of surface roughness on lift degredation	-
8.4	Tunnel Test Section Cooling System Evaluation	2	Evaluate effectiveness of new wind tunnel colling system and potential effects on data results	-
8.5	Effect of Viscosity on Fluid Aerodynamics	3	Evaluate effect of viscosity on aero flow-off to better understand year to year differences with same fluid (test high and low visc)	-
8.6	Fluid + Cont @ LOUT	3	Effect of contamination on fluid performance at LOUT with IP, SN, ZF, Frost etc.	-
8.7	Small Hail	3	Develop HOT Guidance for small hail. Requires consult with meteorologist for specific conditions	-
8.8	Simulate Frost in Wind Tunnel	3	Attempt to simulate frost conditions in wind tunnel.	-
8.9	Flaps/Slats to Support YMX	3	Conduct flaps failure research to support UPS/SWA trials, comparative fluid/cont. and possibly sandpaper tests	-
8.10	Mixed HOT Conditions	3	Develop HOT Guidance for mixed conditions i.e. ZR/SN, R/SN, ZD/SN	-
8.11	Snow on Un-protected Wing	3	Continue previous research	-
8.12	130-150 Knots IP Testing	3	Conduct IP testing at 130-150 knots or validate feasibility MAY NEED TO MODIFY TUNNEL	-
8.13	Windshield Washer Fluid Testing	3	Conduct aero testing to support full testing conducted at Rockliffe Flying Club in Ottawa	-
8.14	Effect of Fluid Seepage	3	Evaluate the effect of fluid seepage on dry wing performance and repeatability	-
8.15	2nd Wave of Fluid During Rotation	3	Investigate the aero effects of the 2nd wave of fluid created from fluid at the stagnation point which flows over the LE during rotation	-
8.16	Other	3	Any potential suggestions from industry	-

Total # of Days for Priority 1 Tests	**15**

Table 3.1: Proposed Test Plan

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (ºC)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time	Coating	Priority	COMMENT
P001	Baseline	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	-	1	to be conducted daily before start ot tests
P002	Baseline	1	Dry Wing	stall	100	any (target <-5ºC)	none	-	-	-	-	-	-	1	to be conducted daily before start ot tests
P003	Type I Low Speed	1	Fluid Only	8	100	below -30	Polar Plus	-	-	-	-	-	-	1	
P004	Type I Low Speed	1	Fluid Only	8	60	below -30	Polar Plus	-	-	-	-	-	-	1	
P005	Type I Low Speed	1	Fluid Only	8	55	below -30	Polar Plus	-	-	-	-	-	-	1	
P006	Type I Low Speed	1	Fluid Only	8	55+3 sec	below -30	Polar Plus	-	-	-	-	-	-	1	
P007	Type I Low Speed	1	Fluid Only	8	100	-20 to -30	Polar Plus	-	-	-	-	-	-	1	
P008	Type I Low Speed	1	Fluid Only	8	60	-20 to -30	Polar Plus	-	-	-	-	-	-	1	
P009	Type I Low Speed	1	Fluid Only	8	55	-20 to -30	Polar Plus	-	-	-	-	-	-	1	
P010	Type I Low Speed	1	Fluid Only	8	55+3 sec	-20 to -30	Polar Plus	-	-	-	-	-	-	1	
P011	Type I Low Speed	1	Fluid Only	8	100	-20 to -30	Polar Plus	-	-	-	-	-	-	2	
P012	Type I Low Speed	1	Fluid Only	8	60	-20 to -30	Polar Plus	-	-	-	-	-	-	2	
P013	Type I Low Speed	1	Fluid Only	8	55	-20 to -30	Polar Plus	-	-	-	-	-	-	2	
P014	Type I Low Speed	1	Fluid Only	8	55+3 sec	-20 to -30	Polar Plus	-	-	-	-	-	-	2	
P015	Type I Low Speed	1	Fluid Only	8	60	-20 to -30	Polar Plus	-	-	-	-	-	-	3	
P016	Type I Low Speed	1	Fluid Only	8	100	-20 to -30	Dow ADF	-	-	-	-	-	-	1	
P017	Type I Low Speed	1	Fluid Only	8	60	-20 to -30	Dow ADF	-	-	-	-	-	-	1	
P018	Type I Low Speed	1	Fluid Only	8	55	-20 to -30	Dow ADF	-	-	-	-	-	-	1	
P019	Type I Low Speed	1	Fluid Only	8	55+3 sec	-20 to -30	Dow ADF	-	-	-	-	-	-	1	
P020	Type I Low Speed	1	Fluid Only	8	100	-10 to -20	Polar Plus	-	-	-	-	-	-	1	
P021	Type I Low Speed	1	Fluid Only	8	60	-10 to -20	Polar Plus	-	-	-	-	-	-	1	
P022	Type I Low Speed	1	Fluid Only	8	55	-10 to -20	Polar Plus	-	-	-	-	-	-	1	
P023	Type I Low Speed	1	Fluid Only	8	55+3 sec	-10 to -20	Polar Plus	-	-	-	-	-	-	1	
P024	Type I Low Speed	1	Fluid Only	8	60	-10 to -20	Polar Plus	-	-	-	-	-	-	2	
P025	Type I Low Speed	1	Fluid Only	8	100	-5 to -10	Polar Plus	-	-	-	-	-	-	1	

Table 3.1: Proposed Test Plan (cont.)

P026	Type I Low Speed	1	Fluid Only	8	60	-5 to -10	Polar Plus	-	-	-	-	-	-	1	
P027	Type I Low Speed	1	Fluid Only	8	60	-5 to -10	Polar Plus	-	-	-	-	-	-	2	
P028	Type I Low Speed	1	Fluid Only	8	55	-5 to -10	Polar Plus	-	-	-	-	-	-	1	
P029	Type I Low Speed	1	Fluid Only	8	55+3 sec	-5 to -10	Polar Plus	-	-	-	-	-	-	1	
P030	Type III Allowance Times	1	IP-	8	100	-5 and above	2031 - Hot	25	-	-	-	10	-	1	
P031	Type III Allowance Times	1	IP Mod	8	100	-5 and above	2031 - Hot	75	-	-	-	5	-	1	
P032	Type III Allowance Times	1	IP- / ZR-	8	100	-5 and above	2031 - Hot	25	-	25	-	7	-	1	
P033	Type III Allowance Times	1	IP- / R	8	100	-5 and above	2031 - Hot	25	-	-	75	7	-	1	
P034	Type III Allowance Times	1	IP- / SN-	8	100	-5 and above	2031 - Hot	25	10	-	-	10	-	1	
P035	Type III Allowance Times	1	IP- / SN	8	100	-5 and above	2031 - Hot	25	25	-	-	10	-	1	
P036	Type III Allowance Times	1	IP-	8	100	-5 to -10	2031 - Hot	25	-	-	-	10	-	1	
P037	Type III Allowance Times	1	IP Mod	8	100	-5 to -10	2031 - Hot	75	-	-	-	5	-	1	
P038	Type III Allowance Times	1	IP- / ZR-	8	100	-5 to -10	2031 - Hot	25	-	25	-	5	-	1	
P039	Type III Allowance Times	1	IP- / SN-	8	100	-5 to -10	2031 - Hot	25	10	-	-	10	-	1	
P040	Type III Allowance Times	1	IP- / SN	8	100	-5 to -10	2031 - Hot	25	25	-	-	5	-	1	
P041	Type III Allowance Times	1	IP-	8	100	-10 to -20	2031 - Hot	25	-	-	-	10	-	1	
P042	Type III Allowance Times	1	IP Mod	8	100	-10 to -20	2031 - Hot	75	-	-	-	5	-	1	
P043	Type III Allowance Times	1	IP-	8	100	-20 to -30	2031 - Hot	25	-	-	-	10	-	1	
P044	Type III Allowance Times	1	IP Mod	8	100	-20 to -30	2031 - Hot	75	-	-	-	5	-	1	
P045	Type III Allowance Times	1	IP-	8	100	-5 and above	2031 - Cold	25	-	-	-	10	-	1	
P046	Type III Allowance Times	1	IP Mod	8	100	-5 and above	2031 - Cold	75	-	-	-	5	-	1	
P047	Type III Allowance Times	1	IP- / ZR-	8	100	-5 and above	2031 - Cold	25	-	25	-	7	-	1	
P048	Type III Allowance Times	1	IP- / SN-	8	100	-5 and above	2031 - Cold	25	10	-	-	10	-	1	
P049	Type III Allowance Times	1	IP- / SN	8	100	-5 and above	2031 - Cold	25	25	-	-	10	-	1	
P050	Type III Allowance Times	1	IP-	8	100	-5 and above	2031 - Cold	25	-	-	-	10	-	1	
P051	Type III Allowance Times	1	IP Mod	8	100	-5 to -10	2031 - Cold	75	-	-	-	5	-	1	
P052	Type III Allowance Times	1	IP- / ZR-	8	100	-5 to -10	2031 - Cold	25	-	25	-	5	-	1	

Table 3.1: Proposed Test Plan (cont.)

P053	Type III Allowance Times	1	IP- / R	8	100	-5 to -10	2031 - Cold	25	-	-	75	7	-	1	
P054	Type III Allowance Times	1	IP- / SN-	8	100	-5 to -10	2031 - Cold	25	10	-	-	10	-	1	
P055	Type III Allowance Times	1	IP- / SN	8	100	-5 to -10	2031 - Cold	25	25	-	-	5	-	1	
P056	Type III Allowance Times	1	IP-	8	100	-10 to -20	2031 - Cold	25	-	-	-	10	-	1	
P057	Type III Allowance Times	1	IP Mod	8	100	-10 to -20	2031 - Cold	75	-	-	-	5	-	1	
P058	Type III Allowance Times	1	IP-	8	100	-20 to -30	2031 - Cold	25	-	-	-	10	-	1	
P059	Type III Allowance Times	1	IP Mod	8	100	-20 to -30	2031 - Cold	75	-	-	-	5	-	1	
P060	IP Expansion	1	IP- / SN-	8	100	-10 to -20	ABC-S Plus	25	10	-	-	15		2	
P061	IP Expansion	1	IP- / SN-	8	100	-10 to -20	Launch	25	10	-	-	15		2	
P062	IP Expansion	1	IP- / SN-	8	100	-10 to -20	Max-Flight	25	10	-	-	15		2	
P063	IP Expansion	1	IP- / SN-	8	100	-10 to -20	AD-49	25	10	-	-	15		2	
P064	IP Expansion	1	IP- / SN-	8	100	-10 to -20	Polar Guard Advance	25	10	-	-	15		2	
P065	IP Expansion	1	IP- / SN-	8	100	-20 to -30	EG106	25	10	-	-	15		1	
P066	IP Expansion	1	IP- / SN-	8	100	-20 to -30	ABC-S Plus	25	10	-	-	15		1	
P067	IP Expansion	1	IP- / SN-	8	100	-20 to -30	Launch	25	10	-	-	15		1	
P068	IP Expansion	1	IP- / SN-	8	100	-20 to -30	Max-Flight	25	10	-	-	15		1	
P069	IP Expansion	1	IP- / SN-	8	100	-20 to -30	AD-49	25	10	-	-	15		1	
P070	IP Expansion	1	IP- / SN-	8	100	-20 to -30	Polar Guard Advance	25	10	-	-	15		1	
P071	IP Expansion	1	IP- / SN	8	100	-5 to -10	ABC-S Plus	25	10	-	-	10		1	
P072	IP Expansion	1	IP- / SN	8	100	-5 to -10	Launch	25	10	-	-	10		1	
P073	IP Expansion	1	IP- / SN	8	100	-5 to -10	AD-49	25	10	-	-	10		1	
P074	IP Expansion	1	IP- / SN	8	100	-5 to -10	Polar Guard Advance	25	10	-	-	10		1	failed in 2012-13 test
P075	IP Validation with New Temps & Fluids	1	IP-	8	115	-20 to -30	ABC-S Plus	25	-	-	-	50	-	1	run @ LOUT
P076	IP Validation with New Temps & Fluids	1	IP-	8	115	-20 to -30	EG106	25	-	-	-	50	-	1	run @ LOUT
P077	IP Validation with New Temps & Fluids	1	IP-	8	115	-20 to -30	Launch	25	-	-	-	50	-	1	run @ LOUT
P078	IP Validation with New Temps & Fluids	1	IP-	8	115	-20 to -30	Max-Flight	25	-	-	-	50	-	1	run @ LOUT
P079	IP Validation with New Temps & Fluids	1	IP-	8	115	-20 to -30	AD-49	25	-	-	-	50	-	1	run @ LOUT

Table 3.1: Proposed Test Plan (cont.)

P080	IP Validation with New Temps & Fluids	1	IP-	8	115	-20 to -30	Polar Guard Advance	25	-	-	-	50	-	1	run @ LOUT
P081	IP Validation with New Temps & Fluids	1	IP Mod	8	115	-20 to -30	ABC-S Plus	75	-	-	-	10	-	1	run @ LOUT
P082	IP Validation with New Temps & Fluids	1	IP Mod	8	115	-20 to -30	EG106	75	-	-	-	10	-	1	run @ LOUT
P083	IP Validation with New Temps & Fluids	1	IP Mod	8	115	-20 to -30	Launch	75	-	-	-	10	-	1	run @ LOUT
P084	IP Validation with New Temps & Fluids	1	IP Mod	8	115	-20 to -30	Max-Flight	75	-	-	-	10	-	1	run @ LOUT
P085	IP Validation with New Temps & Fluids	1	IP Mod	8	115	-20 to -30	AD-49	75	-	-	-	10	-	1	run @ LOUT
P086	IP Validation with New Temps & Fluids	1	IP Mod	8	115	-20 to -30	Polar Guard Advance	75	-	-	-	10	-	1	run @ LOUT
P087	IP Validation with New Temps & Fluids	1	Fluid Only	8	115	-20 to -30	ABC-S Plus	-	-	-	-	-	-	1	run @ LOUT
P088	IP Validation with New Temps & Fluids	1	Fluid Only	8	115	-20 to -30	EG106	-	-	-	-	-	-	1	run @ LOUT
P089	IP Validation with New Temps & Fluids	1	Fluid Only	8	115	-20 to -30	Launch	-	-	-	-	-	-	1	run @ LOUT
P090	IP Validation with New Temps & Fluids	1	Fluid Only	8	115	-20 to -30	Max-Flight	-	-	-	-	-	-	1	run @ LOUT
P091	IP Validation with New Temps & Fluids	1	Fluid Only	8	115	-20 to -30	AD-49	-	-	-	-	-	-	1	run @ LOUT
P092	IP Validation with New Temps & Fluids	1	Fluid Only	8	115	-20 to -30	Polar Guard Advance	-	-	-	-	-	-	1	run @ LOUT
P093	New Ice Pellet Dispenser Validation	1	IP Mod	8	100	below -5	Launch	75	-	-	-	10	-	1	new dispenser
P094	New Ice Pellet Dispenser Validation	1	IP Mod	8	100	below -5	Launch	75	-	-	-	10	-	1	new dispenser
P095	New Ice Pellet Dispenser Validation	1	IP Mod	8	100	below -5	Launch	75	-	-	-	10	-	2	new dispenser
P096	New Ice Pellet Dispenser Validation	1	IP Mod	8	100	below -5	Launch	75	-	-	-	10	-	1	old dispenser
P097	New Ice Pellet Dispenser Validation	1	IP Mod	8	100	below -5	Launch	75	-	-	-	10	-	1	old dispenser
P098	New Ice Pellet Dispenser Validation	1	IP Mod	8	100	below -5	Launch	75	-	-	-	10	-	2	old dispenser
P099	New Ice Pellet Dispenser Validation	1	IP-/SN-	8	100	below -5	Polar Guard Advance	25	25	-	-	15	-	1	new dispenser
P100	New Ice Pellet Dispenser Validation	1	IP-/SN-	8	100	below -5	Polar Guard Advance	25	25	-	-	15	-	1	new dispenser
P101	New Ice Pellet Dispenser Validation	1	IP-/SN-	8	100	below -5	Polar Guard Advance	25	25	-	-	15	-	1	old dispenser
P102	New Ice Pellet Dispenser Validation	1	IP-/SN-	8	100	below -5	Polar Guard Advance	25	25	-	-	15	-	1	old dispenser
P103	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B14	1	objective: baseline
P104	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B14	1	objective: baseline
P105	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B14	2	objective: baseline
P106	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B14	1	objective: baseline

Table 3.1: Proposed Test Plan (cont.)

P107	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B14	1	objective: baseline
P108	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B14	2	objective: baseline
P109	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B14	1	objective: drag and fuel efficiency * SCENARIO 1: climb or cruise to be simulated, i.e: 0 º for 30 sec
P110	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B14	2	objective: drag and fuel efficiency * SCENARIO 2: climb or cruise to be simulated, i.e: +2 º for 15 sec
P111	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B14	3	objective: drag and fuel efficiency * SCENARIO 3: climb or cruise to be simulated, i.e:-2 º for 10 sec
P112	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B14	1	objective: effect of coatings on fluid flow-off
P113	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B14	1	objective: effect of coatings on fluid flow-off
P114	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B14	2	objective: effect of coatings on fluid flow-off
P115	Ice Phobic R&D	1	ZR	8	100	below -5	none	-	-	25	-	20	B14	1	objective: effect of coatings with precip
P116	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B14	1	objective: baseline/ fluid seepage
P117	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B14	2	objective: baseline/ fluid seepage
P118	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B15	1	objective: baseline
P119	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B15	1	objective: baseline
P120	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B15	2	objective: baseline
P121	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B15	1	objective: baseline
P122	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B15	1	objective: baseline
P123	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B15	2	objective: baseline
P124	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B15	1	objective: drag and fuel efficiency * SCENARIO 1: climb or cruise to be simulated, i.e: 0 º for 30 sec
P125	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B15	2	objective: drag and fuel efficiency * SCENARIO 2: climb or cruise to be simulated, i.e: +2 º for 15 sec

Table 3.1: Proposed Test Plan (cont.)

P126	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B15	3	objective: drag and fuel efficiency * SCENARIO 3: climb or cruise to be simulated, i.e:-2 º for 10 sec
P127	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B15	1	objective: effect of coatings on fluid flow-off
P128	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B15	1	objective: effect of coatings on fluid flow-off
P129	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B15	2	objective: effect of coatings on fluid flow-off
P130	Ice Phobic R&D	1	ZR	8	100	below -5	none	-	-	25	-	20	B15	1	objective: effect of coatings with precip
P131	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B15	1	objective: baseline/ fluid seepage
P132	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B15	2	objective: baseline/ fluid seepage
P133	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	1	objective: baseline
P134	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	1	objective: baseline
P135	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	2	objective: baseline
P136	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	1	objective: baseline
P137	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	1	objective: baseline
P138	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	2	objective: baseline
P139	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	1	objective: drag and fuel efficiency * SCENARIO 1: climb or cruise to be simulated, i.e: 0 º for 30 sec
P140	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	2	objective: drag and fuel efficiency * SCENARIO 2: climb or cruise to be simulated, i.e: +2 º for 15 sec
P141	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	3	objective: drag and fuel efficiency * SCENARIO 3: climb or cruise to be simulated, i.e:-2 º for 10 sec
P142	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	skin no coating	1	objective: effect of coatings on fluid flow-off
P143	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	skin no coating	1	objective: effect of coatings on fluid flow-off
P144	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	skin no coating	2	objective: effect of coatings on fluid flow-off
P145	Ice Phobic R&D	1	ZR	8	100	below -5	none	-	-	25	-	20	skin no coating	1	objective: effect of coatings with precip
P146	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	1	objective: baseline/ fluid seepage

Table 3.1: Proposed Test Plan (cont.)

P147	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	2	objective: baseline/ fluid seepage
P148	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	original wing	1	objective: baseline
P149	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	original wing	1	objective: baseline
P150	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	original wing	2	objective: baseline
P151	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	original wing	1	objective: baseline
P152	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	original wing	1	objective: baseline
P153	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	original wing	2	objective: baseline
P154	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	original wing	1	objective: drag and fuel efficiency * SCENARIO 1: climb or cruise to be simulated, i.e: 0 º for 30 sec
P155	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	original wing	2	objective: drag and fuel efficiency * SCENARIO 2: climb or cruise to be simulated, i.e: +2 º for 15 sec
P156	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	original wing	3	objective: drag and fuel efficiency * SCENARIO 3: climb or cruise to be simulated, i.e:-2 º for 10 sec
P157	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	original wing	1	objective: effect of coatings on fluid flow-off
P158	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	original wing	1	objective: effect of coatings on fluid flow-off
P159	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	original wing	2	objective: effect of coatings on fluid flow-off
P160	Ice Phobic R&D	1	ZR	8	100	below -5	none	-	-	25	-	20	original wing	1	objective: effect of coatings with precip
P161	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	original wing	1	objective: baseline/ fluid seepage
P162	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	original wing	2	objective: baseline/ fluid seepage
P163	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	E1	1	objective: baseline
P164	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	E1	1	objective: baseline
P165	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	E1	2	objective: baseline
P166	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	E1	1	objective: baseline
P167	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	E1	1	objective: baseline

Table 3.1: Proposed Test Plan (cont.)

P168	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	E1	2	objective: baseline
P169	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	E1	1	objective: drag and fuel efficiency * SCENARIO 1: climb or cruise to be simulated, i.e: 0 º for 30 sec
P170	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	E1	2	objective: drag and fuel efficiency * SCENARIO 2: climb or cruise to be simulated, i.e: +2 º for 15 sec
P171	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	E1	3	objective: drag and fuel efficiency * SCENARIO 3: climb or cruise to be simulated, i.e:-2 º for 10 sec
P172	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	E1	1	objective: effect of coatings on fluid flow-off
P173	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	E1	1	objective: effect of coatings on fluid flow-off
P174	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	E1	2	objective: effect of coatings on fluid flow-off
P175	Ice Phobic R&D	1	ZR	8	100	below -5	none	-	-	25	-	20	E1	1	objective: effect of coatings with precip
P176	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	E1	1	objective: baseline/ fluid seepage
P177	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	E1	2	objective: baseline/ fluid seepage
P178	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	C3	1	objective: baseline
P179	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	C3	1	objective: baseline
P180	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	C3	2	objective: baseline
P181	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	C3	1	objective: baseline
P182	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	C3	1	objective: baseline
P183	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	C3	2	objective: baseline
P184	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	C3	1	objective: drag and fuel efficiency * SCENARIO 1: climb or cruise to be simulated, i.e: 0 º for 30 sec
P185	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	C3	2	objective: drag and fuel efficiency * SCENARIO 2: climb or cruise to be simulated, i.e: +2 º for 15 sec

Table 3.1: Proposed Test Plan (cont.)

P186	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	C3	3	objective: drag and fuel efficiency * SCENARIO 3: climb or cruise to be simulated, i.e:-2 º for 10 sec
P187	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	C3	1	objective: effect of coatings on fluid flow-off
P188	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	C3	1	objective: effect of coatings on fluid flow-off
P189	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	C3	2	objective: effect of coatings on fluid flow-off
P190	Ice Phobic R&D	1	ZR	8	100	below -5	none	-	-	25	-	20	C3	1	objective: effect of coatings with precip
P191	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	C3	1	objective: baseline/ fluid seepage
P192	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	C3	2	objective: baseline/ fluid seepage
P193	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B12	1	objective: baseline
P194	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B12	1	objective: baseline
P195	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B12	2	objective: baseline
P196	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B12	1	objective: baseline
P197	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B12	1	objective: baseline
P198	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B12	2	objective: baseline
P199	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B12	1	objective: drag and fuel efficiency * SCENARIO 1: climb or cruise to be simulated, i.e: 0 º for 30 sec
P200	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B12	2	objective: drag and fuel efficiency * SCENARIO 2: climb or cruise to be simulated, i.e: +2 º for 15 sec
P201	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B12	3	objective: drag and fuel efficiency * SCENARIO 3: climb or cruise to be simulated, i.e:-2 º for 10 sec
P202	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B12	1	objective: effect of coatings on fluid flow-off
P203	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B12	1	objective: effect of coatings on fluid flow-off
P204	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B12	2	objective: effect of coatings on fluid flow-off
P205	Ice Phobic R&D	1	ZR	8	100	below -5	none	-	-	25	-	20	B12	1	objective: effect of coatings with precip
P206	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B12	1	objective: baseline/ fluid seepage

Table 3.1: Proposed Test Plan (cont.)

P207	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B12	2	objective: baseline/ fluid seepage
P208	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B13	1	objective: baseline
P209	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B13	1	objective: baseline
P210	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B13	2	objective: baseline
P211	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B13	1	objective: baseline
P212	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B13	1	objective: baseline
P213	Ice Phobic R&D	1	Dry Wing	8 pitch pause	100	any (target <-5ºC)	none	-	-	-	-	-	B13	2	objective: baseline
P214	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B13	1	objective: drag and fuel efficiency * SCENARIO 1: climb or cruise to be simulated, i.e: 0 º for 30 sec
P215	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B13	2	objective: drag and fuel efficiency * SCENARIO 2: climb or cruise to be simulated, i.e: +2 º for 15 sec
P216	Ice Phobic R&D	1	Dry Wing	n/a*	n/a*	any (target <-5ºC)	none	-	-	-	-	-	B13	3	objective: drag and fuel efficiency * SCENARIO 3: climb or cruise to be simulated, i.e:-2 º for 10 sec
P217	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B13	1	objective: effect of coatings on fluid flow-off
P218	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B13	1	objective: effect of coatings on fluid flow-off
P219	Ice Phobic R&D	1	Fluid Only	8	100	below -5	EG106	-	-	-	-	-	B13	2	objective: effect of coatings on fluid flow-off
P220	Ice Phobic R&D	1	ZR	8	100	below -5	none	-	-	25	-	20	B13	1	objective: effect of coatings with precip
P221	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B13	1	objective: baseline/ fluid seepage
P222	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	B13	2	objective: baseline/ fluid seepage
P223	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	1	objective: baseline/installation repeatability
P224	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	1	objective: baseline/installation repeatability
P225	Ice Phobic R&D	1	Dry Wing	8	100	any (target <-5ºC)	none	-	-	-	-	-	skin no coating	2	objective: baseline/installation repeatability
P226	R&D	1	APM Unit	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	1	
P227	R&D	1	S+++	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	1	
P228	R&D	1	HEAVY CONTAMINATION	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	1	
P229	R&D	1	EFFECT OF COOLING SYSTEM	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	1	

Table 3.1: Proposed Test Plan (cont.)

P230	R&D	1	Effect of Viscosity	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P231	R&D	1	FLUID & CONT @ LOUT	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P232	R&D	1	SMALL HAIL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P233	R&D	1	FROST	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P234	R&D	1	FLAPS/SLATS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P235	R&D	1	MIXED CONDITIONS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P236	R&D	1	SNOW NO FLUID	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P237	R&D	1	IP TESTs @ 130-150 KTS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P238	R&D	1	WINDSHIELD WASHER FLUID	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P239	R&D	1	FLUID SEEPAGE	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	
P240	R&D	1	2ND WAVE	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	-	2	

5. DATA FORMS

The following data forms are required for the January 2014 wind tunnel tests:

- Attachment XVII – General Form;
- Attachment XVIII – Wing Temperature, Fluid Thickness and Fluid Brix Measurements and Condition of Wing and Plate Form;
- Attachment XIX, XX and XXI – Ice Pellet, Snow and Sifted Snow Dispensing Forms;
- Attachment XXII – Visual Evaluation Rating Form
- Attachment XXIII – Fluid Receipt Form (Generic form used by APS; will be used for this project as appropriate);
- Attachment XXIV – Log of Fluid Sample Bottles.

When and how the data forms will be used is described throughout Section 6.

6. PROCEDURE

The following sections describe the tasks to be performed during each test conducted. It should be noted that some sections (i.e. fluid application and contamination application) will be omitted depending on the objective of the test.

6.1 Initial Test Conditions Survey

- Record ambient conditions of the test (Attachment XVII); and
- Record wing temperature (Attachment XVIII).

6.2 Fluid Application (Pour)

- Hand pour 20L of anti-icing fluid over the test area (fluid can be poured directly out of pales or transferred into smaller 3L jugs);
- Record fluid application times (Attachment XVII);
- Record fluid application quantities (Attachment XVII);
- Let fluid settle for 5 minutes (as the wing section is relatively flat, last winter it required tilting the wing for 1-minute to enable fluid to be uniform);
- Measure fluid thickness at pre-determined locations on the wing (Attachment XVIII);
- Record wing temperature (Attachment XVIII).

- Measure fluid Brix value (Attachment XVIII); and
- Photograph and videotape the appearance of the fluid on the wing;
- Begin the time-lapse camera to gather photos of the precipitation application phase.

Note: At the request of TC/FAA, a standard aluminum test plate can be positioned on the wing in order to run a simultaneous endurance time test.

6.3 Application of Contamination

6.3.1 Ice Pellet/Snow Dispenser Calibration and Set-Up

Calibration work was performed during the winter of 2007-08 on the modified ice pellet/snow dispensers prior to testing with the Falcon 20. The purpose of this calibration work was to attain the dispenser's distribution footprint for both ice pellets and snow. A series of tests were performed in various conditions:

1. Ice Pellets, Low Winds (0 to 5 km/h);
2. Ice Pellets, Moderate Winds (10 km/h);
3. Snow, Low Wind (0 to 5 km/h); and
4. Snow, Moderate Wind (10 km/h).

These tests were conducted using 121 collection pans, each measuring 6 x 6 inches, over an area 11 x 11 feet. Pre-measured amounts of ice pellets/snow were dispersed over this area and the amount collected by each pan was recorded. A distribution footprint of the dispenser was attained and efficiency for the dispenser was computed.

6.3.2 Dispensing Ice Pellets/Snow for Wind Tunnel Tests

Using the results from these calibration tests, a decision was made to use two dispensers on each of the leading and trailing edges of wing; each of the four dispensers are moved to four different positions along each edge during the dispensing process. Attachments XIX and XX display the data sheets that will be used during testing in the wind tunnel. These data sheets will provide all the necessary information related to the amount of ice pellets/snow needed, effective rates and dispenser positions. During the winter of 2009-10, snow was also dispensed manually using sieves. This technique was used when higher rates of precipitation were required (for heavy snow) or when winds in the tunnel made dispensing difficult. The efficiency of this technique was estimated at 90% and a form to be used for this dispensing process along with dispensing instructions is included in Attachment XXI.

Note: Dispensing forms should be filled out and saved for each run and included and pertinent information shall be included in the general form (Attachment XVII). Any comments regarding dispensing activities should be documented directly on the form.

6.3.3 New Ice Pellets/Snow Dispensing Systems for 2014 Onwards

Yardworks seed spreaders were modified and used for applying ice pellets and snow during wind tunnel and flat plate testing. The spreaders are no longer available as the manufacturer has stopped production. A new replacement seed spreader system, Wolf Garten, was found which is similar (but not identical), and may be a suitable replacement (with necessary modifications). Some calibration work was required to demonstrate an equivalency in the two systems: the historical system versus the new replacement system. TC requested to evaluate the new system while at NRC Cold Chamber in September 2013.

The data collected demonstrates that the new system is very similar to old system. Some small variation is present in distribution within the footprint, but equivalent efficiency on the overall footprint. Based on this it was concluded that for ice pellets, the use of the new system can be made as a direct replacement. For snow, the new system is more efficient, therefore a reduction of 10% shall be used for the snow mass requested. The details of this calibration are described in TC report, TP 15230E*, Aircraft Ground Icing General Research Activities During the 2012-13 Winter.*

6.4 Prior to Engines-On Wind Tunnel Test

- Measure fluid thickness at the pre-determined locations on the wing (Attachment XVIII);
- Measure fluid Brix value (Attachment XVIII);
- Record wing temperatures (Attachment XVIII);
- Record start time of test (Attachment XVII); and
- Fill out visual evaluation rating form (Attachment XXII).

Note: In order to minimize the measurement time post precipitation, temperature should be measured 5 minutes before the end of precipitation, thickness measured 3 minutes before the end of precipitation, and Brix measured when the precipitation ends. Also consideration as been given to reducing the number of measures that are taken for this phase (i.e. locations 2 and 5 only).

6.5 During Wind Tunnel Test:

- Take still pictures and video the behavior of the fluid on the wing during the takeoff run, capturing any movement of fluid/contamination;
- Fill out visual evaluation rating form at the time of rotation (Attachment XXII); and
- Record wind tunnel operation start and stop times.

6.6 After the Wind Tunnel Test:

- Measure fluid thickness at the pre-determined locations on the wing (Attachment XVIII);
- Measure fluid Brix value (Attachment XVIII);
- Record wing temperatures (Attachment XVIII);
- Observe and record the status of the fluid/contamination (Attachment XVIII);
- Fill out visual evaluation rating form (Attachment XXII);
- Obtain lift data (excel file) from NRC; and
- Update APS test log with pertinent information.

6.7 Fluid Sample Collection for Viscosity Testing

Two litres of each fluid to be tested are to be collected on the first day of testing. The fluid receipt form (Attachment XXIII) should be completed indicating quantity of fluid and date received. Any samples extracted for viscosity purposes should be documented in the log of fluid samples data form (Attachment XXIV). A falling ball viscosity test should be performed on site to confirm that fluid viscosity is appropriate before testing.

6.8 At the End of Each Test Session

If required, APS personnel will collect the waste solution. At the end of the testing period, the glycol recovery service provider will be employed to safely dispose of the waste glycol fluid.

6.9 Camera Setup

It is anticipated that the camera setup will be similar to the setup used during the winter of 2011-12. Modifications may be necessary to account for the different airfoil. The flashes will be positioned on the control-room side of the tunnel, and the cameras will be positioned on the opposite side. The final positioning of the cameras and flashes should be documented to identify any deviation from the previous year's setup.

6.10 Demonstration of a Typical Wind Tunnel Test Sequence

Table 6.1 demonstrates a typical Wind Tunnel test sequence of activities, assuming the test starts at 08:00:00. Figure 6.1 demonstrates a typical wind tunnel run timeline.

Table 6.1: Typical Wind Tunnel Test

TIME	TASK
8:30:00	START OF TEST. ALL EQUIPMENT READY.
8:30:00	- Record test conditions.
8:35:00	- Prepare wing for fluid application (clean wing, etc).
8:45:00	- Measure wing temperature. - Ensure clean wing for fluid application
8:50:00	- Pour fluid over test area.
9:00:00	- Measure Brix, thickness, wing temperature. - Photograph test area.
9:05:00	- Apply contamination over test area. (i.e. 30 min)
9:35:00	- Measure Brix, thickness, wing temperature. - Photograph test area.
9:40:00	- Clear area and start wind tunnel
9:55:00	- Wind tunnel stopped
10:05:00	- Measure Brix, thickness, wing temperature. - Photograph test area. - Record test observations.
10:35:00	END OF TEST

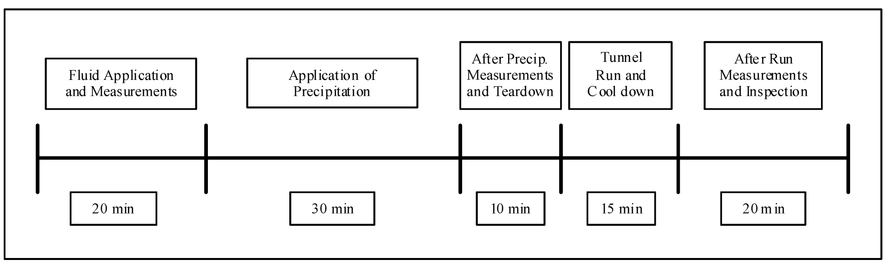


Figure 6.1: Typical Wind Tunnel Run Timeline

6.11 Procedures for R&D Activities

It is anticipated that testing will be conducted to support several research and development (R&D) activities. The objectives of these lower priority activities are as follows:

- Evaluation of an airfoil performance monitor (APM) system;
- Heavy snow;
- Heavy contamination;
- Effect of cooling system on testing repeatability;
- Effect of fluid viscosity;
- Fluid and contamination at LOUT;
- Small hail;
- Frost simulation in the wind tunnel;
- Flaps/Slats testing to support YMX tests;
- Mixed HOT conditions;
- Snow on an un-protected wing;
- Feasibility of IP testing at higher speed (130-150kts);
- Windshield washer used as a Type I deicer;
- Effect of fluid seepage on dry wing performance; and
- Second wave of fluid at rotation.

As these full-scale R&D activities have in general not been previously attempted, therefore brief summaries of the anticipated procedures have been prepared to provide guidance at the time of testing. These procedures are attached to this document as Attachments XXV to XXXIX. The procedures are preliminary and may change based on the quality of the results obtained in the wind tunnel.

7. EQUIPMENT

Equipment to be employed is shown in Table 7.1.

Table 7.1: Test Equipment Checklist

EQUIPMENT	STATUS	EQUIPMENT	STATUS
General Support and Testing Equipment		**Camera Equipment**	
20L containers x 12		AA Batteries x 48	
Adherence Probes Kit		C2032 Batteries x 4	
Barrel Opener (steel)		Digital still cameras x3 (two suitcases)	
Black Shelving Unit (or plastic)		Flashes and tripods (in APS storage)	
Blow Horns x 4		GoPro Camera	
Electrical tape x 5			
Envelopes and labels			
Exacto Knives x 2		**Ice Pellets Fabrication Equipment**	
Extension cords (power bars x 6 + reels x 4)		Blenders x 12 in good condition	
Falling Ball Viscometer		Folding tables (2 large, 1 small)	
Fluid pouring jugs x 60		Ice bags	
Fluids (ORDER and SHIP to Ottawa)		Ice bags storage freezer x 3	
Funnels(1big + 1 small)		Ice pellets sieves (base, 1.4 mm, 4 mm)	1 set in YOW
Gloves - black and yellow		Ice pellets Styrofoam containers x20	
Gloves - cotton (1 box)		Measuring cups (1L and smaller ones for dispensing)	
Gloves - latex (2 boxes)		NCAR Scale x 1	
Grid Section + Location docs		Refrigerated Truck	
Hard water chemicals x 3 premixes		Rubber Mats x all	
Horse and tap for fluid barrel x all		Wooden Spoons	
Hot Plate x 3 and Large Pots with rubber handles for Type III			
Ice pellet box supports for railing x4		**Freezing Rain Equipment**	
Ice Pellet control wires and boxes (all for new and old)		APS PC equipped with rate station software	
Ice pellets dispersers x 12 (6 new and 6 old)		NRC Freezing rain sprayer (NRC will provide)	
Inclinometer (yellow level) x 2		Rubber suction cup feet for wooden boards	
Isopropyl x 24		White plastic rate pans (1 to 8 x 2)	
Large and small tape measure		Wooden boards for rate pans (x8)	
Large Sharpies for Grid Section			
Long Ruler for marking wing x 2			
Marker for waste x 2		**Office Equipment**	
Paper towel x 48		Accordian Folder	
Protective clothing (all) and personel clothing		APS Laptops x 6	
Protective clothing (all) and personel clothing		Calculators x 3	
Sample bottles for viscosity measurement x 8		Clip boards x 8	
Sartorius Weigh Scale x 1		Dry eraser markers	
Scrapers x 5		Envelopes (9x12) x box	
Shop Vac		Hard drive with all TC Deicing Projects	
Speed tape x 1 small		Hard Drive x 2	
Squeegees (5 small + 3 large floor)		Mouse for Rate Station and keypad	
Stands for ice pellets dispensing devices x 6		Pencils + wing markers for sample locations	
Stop Watches x 4		Projector for laptop	
Temperature probes: immersion x 3		Scissors	
Temperature probes: surface x 3		Small 90º aluminum ruler for wing	
Temperature readers x 2 + spare batteries		Test Procedures x 8, data forms, printer paper	
Test Plate x 1		YOW employee contracts	
Thermometer for Reefer Truck			
Thickness Gauges (5 small, 5 big)			
Vise grip (large) + rubber opener for containers			
Walkie Talkies x 12			
Water (2 x 18L) for hard water			
Watmans Paper and conversion charts			

8. FLUIDS

Mid-viscosity samples of ethylene glycol and propylene glycol IV fluid will be used in the wind tunnel tests. Although the number of tests conducted will be determined based on the results obtained, the fluid quantities available are shown in Table 8.1 (quantities to be confirmed once fluid is received). Fluid application will be performed by pouring the fluid (rather than spraying) to reduce any shearing to the fluid.

Table 8.1: Fluid Available for Wind Tunnel Tests

FLUID	QUANTITY ORDERED	QUANTITY ALREADY IN STOCK	COMBINED TOTAL OF FLUID AVAILABLE	TOTAL QUANTITY RQ'D
Kilfrost ABC-S Plus	400	250	**650**	120
Dow FlightGuard AD-49	0	440	**440**	120
Dow EG106	0	600	**600**	560
Clariant MP III 2031 ECO	200	150	**350**	300
Clariant MP IV Launch	0	200	**200**	240
Clariant Max-Flight	0	160	**160**	100
Cryotech Polar Guard Advance	400	120	**520**	200
Cryotech Polar Plus	240	0	**240**	230
Dow Type I ADF	60	0	**60**	40

3600 L Ordered For 2009-10 Testing (18 Days)
3200 L Ordered For 2010-11 Testing (15 Days)
1800 L Ordered For 2011-12 Testing (7 of 15 days will be fluid testing)
4200 L Ordered for 2012-13 Testing (15 Days)

9. PERSONNEL

Four APS staff members are required for the tests at the NRC wind tunnel. Four additional persons (with one back-up) will be required from Ottawa for making and dispensing the ice pellets and snow. One additional person from

Ottawa will be required to photograph the testing. Table 9.1 demonstrates the personnel required and their associated tasks.

Fluid and ice pellets applications will be performed by APS/YOW personnel at the NRC wind tunnel. NRC personnel will operate the NRC wind tunnel and operate the freezing rain/drizzle sprayer (if requested).

Table 9.1: Personnel List

Wind Tunnel 11-12- Tentative	
Person	**Responsibility**
John	Overall Co-ordinator
Marco	Co-ordinator / General
Victoria	Forms & Data Collection Manager / IP Manager / YOW Pers. Manager / Camera Documentation
Dave	Data Collection / IP Support / Fluid Application / Fluid Manager
YOW Personnel	
Ben/Jesse	Photography
James	Fluids / IP / Dispensing / General Support
YOW 1	Fluids / IP / Dispensing
YOW 2	Fluids / IP / Dispensing
YOW 3	Fluids / IP / Dispensing
YOW 4	Back-up

NRC Institute of Aerospace Research Contacts

- Lucio Del Ciotto: (613) 913-9720
- Catherine Clark: (613) 998-6932

10. SAFETY

- A safety briefing will be done on the first day of testing;
- Personnel should be familiar with NRC emergency procedures i.e. DO NOT CALL 9-1-1, instead call the NRC Emergency Center as they will contact and direct the necessary services;
- All personnel must be familiar with the Material Safety Data Sheets (MSDS) for fluids;
- Prior to operating the wind tunnel, loose objects should be removed from the vicinity;
- When wind tunnel is operating, ensure that ear plugs are worn if necessary and personnel keep safe distances;

- When working on ladders, ensure equipment is stable;
- CSA approved footwear and appropriate clothing for frigid temperatures are to be worn by all personnel;
- Caution should be taken when walking in the test section due to slippery floors, and dripping fluid from the wing section;
- If fluid comes into contact with skin, rinse hands under running water; and
- If fluid comes into contact with eyes, flush with the portable eye wash station.

ATTACHMENT I – Procedure: Dry Wing Performance

Background

A significant amount of work has been done in conjunction with NASA and NRC in order to calibrate and characterize the wind tunnel and airfoil model during the last two winter seasons. This work has further increased the confidence in the data produced, however ongoing verification is necessary in order to identify potential changes in the system performance.

Objective

Verify that clean model aerodynamic data agree with the data acquired in previous years with the same model. Given the various issues with repeatability and angle of attack offsets in the past, this is an important step prior to fluids testing.

Methodology

- Ensure the wing is clean and dry;
- Conduct a dry wing test using the regular take-off profile;
- Conduct a dry wing test using a take-off profile with rotation to stall;
- Compare lift performance to historical data; and
- Address potential discrepancies accordingly.

Test Plan

This testing should be conducted at the start of each testing day.

ATTACHMENT II – Procedure: Allowance Times in Light Ice Pellets Mixed with Light or Moderate Snow Conditions

Background

Historical winter weather data has indicated that a significant portion of “light ice pellets mixed with light snow” precipitation occurs below -10°C and “light ice pellets mixed with moderate snow” precipitation occurs below -5 to -10°C where no allowance times currently exist. Some additional data has been collected in 2012-13 which supports a potential for guidance in these conditions, however testing is still required in order to substantiate any proposed changes to the allowance times.

Objective

To conduct testing in conditions of “light ice pellets mixed with light snow” below -10°C and “light ice pellets mixed with moderate snow” below -5 to -10°C to support potential changes to the allowance times table.

Methodology

- Analyze existing data;
- Identify data gaps (fluids, temperatures, etc);
- Conduct testing with appropriate conditions to address data gaps;
- Adjust testing plan accordingly based on aerodynamic data collected.

Test Plan

One day of testing is planned, however testing could be expanded to 3 days.

ATTACHMENT III – Procedure: Ice Pellet Allowance Time Substantiation with New Fluids, Fluids Previously Tested with Limited Data, and Temperatures Close to the LOUT

Background

Previous testing has shown that typically lift losses will significantly increase at the lower temperatures. Limited data is available at (or very near) the fluid Lowest Operational Use Temperature (LOUT). Additional testing is recommended to obtain data close to the fluid LOUT to determine the aerodynamic effects of ice pellet contamination at these colder temperatures.

Objective

To determine the aerodynamic effects of ice pellet contamination close to the fluid LOUT.

Methodology

- Analyze existing data;
- Identify data gaps (fluids, temperatures, etc);
- Conduct testing close to the fluid LOUT (-20 to -30ºC) with appropriate conditions to address data gaps;
- Adjust testing plan accordingly based on aerodynamic data collected.

Test Plan

Two days of testing are planned, however this testing is temperature critical and requires very low temperatures below -20ºC.

ATTACHMENT IV – Procedure: Equivalency of New IP/SN Dispenser Systems

Background

In the winter of 2012-13, seed spreaders historically modified and used for applying ice pellets during wind tunnel and flat plate testing, were no longer available as the manufacturer has stopped production of the model. A new replacement seed spreader system was found which is similar (but not identical). Some calibration work was required to demonstrate an equivalency in the two systems: testing was conducted to verify the distribution of the historical system versus the new replacement system. The data collected demonstrates that the new system is very similar to old system with some small variations. It is recommended comparative wind tunnel testing be conducted to validate the equivalency of the systems.

Objective

To evaluate the equivalency of the new and old generation dispenser systems through comparative wind tunnel testing.

Methodology

- Conduct 2-3 tests with the same fluid in an existing ice pellet only condition with the old dispenser systems;
- Conduct the same 2-3 tests with the new dispenser system;
- Compare the results and address discrepancies accordingly; and
- Repeat for snow conditions (consider doing 1-2 tests for each dispenser instead).

Test Plan

One day of testing is anticipated.

ATTACHMENT V – Procedure: Effect of Ice Phobic Coating on Aerodynamics With or Without Fluids

Background

In recent years, there has been significant industry interest in the use of coatings to protect aircraft critical surfaces. These coatings can sometimes designed and marketed as ice phobic coatings, but the behavior and performance of these coatings during ground icing operations has yet to be fully investigated Previous flat plate and wind tunnel work has been conducted since 2009-10 and has helped identify both strengths and weaknesses associated with these technologies. Additional aerodynamic testing was recommended to further develop the evaluation methodology and to investigate new product formulations.

Objective

To investigate the aerodynamic performance of ice phobic coatings with and without de/anti-icing fluids.

Methodology

Testing will be conducted using wing skins specifically manufactured to fit onto the existing thin high performance wing section and be secured by bolts. To cover the entire test wing, two individual wing skin halves are required.

Testing will consist of comparative test sets done with different sets of wing skins. The test set will consist of the following:

- Dry wing tests to 8degrees and to stall to understand effects of coatings and to evaluate the repeatability of the tests;
- Simulated climb-out or cruise runs to evaluate drag and fuel efficiency;
- Fluid only testing with a known fluid;
- Freezing rain with no fluid test to evaluate how contamination forms on the surface and the aerodynamic effects (beads of ice vs. smooth ice);
- Repeat dry wing tests to investigate fluid seepage issues associated with the wing skins and effect on repeatability;
- Un-install and re-install a wing skin to evaluate the repeatability of the installation process; and
- Compare the results with the coated wing skins to the un-coated wing skins. An additional comparison to the original wing is also useful.

Test Plan

Four days of testing are planned.

ATTACHMENT VI – Procedure: Development of a Type III Ice Pellet Allowance Time Table

Background

Several Canadian regional air operators (Porter & Skyregional) operating out of the Toronto Island airport, use Type III fluid for deicing and anti-icing of their turbo-prop aircraft. These operators were driven to use Type III fluids instead of Type IV fluids, due to aircraft performance penalties when using Type IV fluids. As this airport (and several other Canadian airports) is subject to ice pellet conditions, Porter has requested guidance from TC on the use of Type III fluids in ice pellet conditions. It is likely that other air operators will be requesting similar guidance in the near future, since both Skyregional and WestJet Encore also operate Dash 8-400 aircraft. Additional operational research is required by TC prior to providing operational guidance in this area due to the limited knowledge in using Type III fluids during ice pellet events.

Objective

To develop preliminary ice pellet allowance times for use with Type III fluids.

Methodology

- Conduct a thorough review of Type III data collected in previous years of ice pellet testing to determine information availability and requirements;
- Identify data requirements (fluids, temperatures, etc);
- Conduct testing with appropriate conditions to address data requirements. Both hot and cold fluid application data should be collected; and
- Adjust testing plan accordingly based on aerodynamic data collected to support the development of a Type III allowance time table.

Test Plan

Four days of testing are anticipated.

ATTACHMENT VII – Procedure: Evaluation of Type I Fluid Flow-off for Low Speed Rotation Less than 80 Knots

Background

The lowest operational use temperature (LOUT) for a fluid is determined based on the higher of the fluid freeze point plus a buffer, or the lowest temperature which passes the aerodynamic test (AS5900) for either the low speed or high speed ramp. Currently the high speed ramp is representative of aircraft rotating at 100 knots or higher, whereas the low speed ramp is representative of aircraft rotating between 67 knots and 100 knots.

There currently does not exist any fluid qualification for aircraft rotating below 67 knots, however several operators have aircraft that rotate below 67 knots that encounter ground icing conditions during winter months. Aerodynamic testing in the NRC wind tunnel, and possibly according to AS5900, can provide insight into alternatives for operating in such conditions; i.e. limit LOUT for lower rotation speeds, use diluted fluid, delay rotation when at Vr, increase the rotation speed etc. These operators have requested that TC provide operational guidance when using Type I fluids on these aircraft. Additional operational research is required by TC prior to providing operational guidance in this area.

Objective

To evaluate the aerodynamic impact of using Type I fluid on aircraft with rotation speeds below 67 knots and resulting effect on the LOUT.

Methodology

- Comparative test sets should be done at all temperatures below -5°C, but specifically data at or near the Polar Plus LOUT is especially useful;
- Conduct a high speed (100kts) test with Polar Plus Type I fluid to identify acceptable lift losses;
- Conduct comparative test runs with the same fluid at 60 kts, 55kts, and at 55kts with a 3 second delayed rotation to determine likely increases in lift losses;
- When testing close to the Polar Plus LOUT, conduct an additional set of test with a Type I EG fluid with a lower LOUT (i.e. Dow ADF).
- Analyze results and modify test plan accordingly.
-

Test Plan

Two days of testing are anticipated.

ATTACHMENT VIII – Generic Type I Holdover Time Table

Transport Canada Holdover Time Guidelines — Winter 2013-2014

TABLE 1-A

SAE TYPE I FLUID HOLDOVER GUIDELINES ON ALUMINUM WING SURFACES FOR WINTER 2013-2014[1]

This table applies to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Approximate Holdover Times Under Various Weather Conditions (minutes)								
Degrees Celsius	Degrees Fahrenheit	Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets: Very Light[3]	Snow, Snow Grains or Snow Pellets: Light[3]	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6		
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	5 – 9	7	4 – 7	2 – 4				

NOTES
1 Type I Fluid / Water Mixture must be selected so that the freezing point of the mixture is at least 10°C (18°F) below outside air temperature.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover time guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

Page 16 of 61 — August 2013

ATTACHMENT IX – Generic Type III Holdover Time Table

Transport Canada Holdover Time Guidelines **Winter 2013-2014**

TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2013-2014

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[1]		Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets: Very Light[2]	Snow, Snow Grains or Snow Pellets: Light[2]	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle[3]	Light Freezing Rain	Rain on Cold Soaked Wing[4]	Other[5]
-3 and above	27 and above	100/0	20 – 40	35	20 – 35	10 – 20	10 – 20	8 – 10	6 – 20	CAUTION: No holdover time guidelines exist
		75/25	15 – 30	25	15 – 25	8 – 15	8 – 15	6 – 10	2 – 10	
		50/50	10 – 20	15	8 – 15	4 – 8	5 – 9	4 – 6		
below -3 to -10	below 27 to 14	100/0	20 – 40	30	15 – 30	9 – 15	10 – 20	8 – 10		
		75/25	15 – 30[6]	25[6]	10 – 25[6]	7 – 10[6]	9 – 12[6]	6 – 9[6]		
below -10	below 14	100/0	20 – 40	30	15 – 30	8 – 15				

NOTES

1 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type III fluid cannot be used.
2 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
3 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4 No holdover guidelines exist for this condition for 0°C (32°F) and below.
5 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
6 For aircraft with a take-off profile conforming to the low speed aerodynamic test criterion (refer to Section 8.1.6.1 f) of TP 14052E), these holdover times only apply to outside air temperatures from below -3°C to -9°C (below 27°F to 15.8°F). If uncertain whether the aircraft performance conforms to this criterion, consult the aircraft manufacturer.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

ATTACHMENT X – Dow Chemical UCAR Endurance EG106 Type IV Holdover Time Table

TABLE 4-D-E106

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2013-2014[1]
UCAR™ ENDURANCE EG106

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets: Very Light[3]	Snow, Snow Grains or Snow Pellets: Light[3]	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:05 – 3:10	2:00	1:20 – 2:00	0:40 – 1:20	1:10 – 2:00	0:50 – 1:15	0:20 – 2:00	CAUTION: No holdover time guidelines exist
		75/25								
		50/50							CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	1:50 – 3:20	2:00	1:05 – 2:00	0:30 – 1:05	0:55 – 1:50[7]	0:45 – 1:10[7]		
		75/25								
below -14 to -27	below 7 to -16.6	100/0	0:30 – 1:05	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES
1. These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2. Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3. Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5. No holdover guidelines exist for this condition for 0°C (32°F) and below.
6. Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7. These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

ATTACHMENT XI – Kilfrost ABC-S Plus Type IV Holdover Time Table

TABLE 4-K-ABC-S+

KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2013-2014[1]
ABC-S PLUS

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets: Very Light[3]	Snow, Snow Grains or Snow Pellets: Light[3]	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:10 – 4:00	2:00	2:00 – 2:00	1:15 – 2:00	1:50 – 2:00	1:05 – 2:00	0:25 – 2:00	CAUTION: No holdover time guidelines exist
		75/25	1:25 – 2:40	2:00	1:15 – 2:00	0:45 – 1:15	1:00 – 1:20	0:30 – 0:50	0:10 – 1:20	
		50/50	0:30 – 0:55	1:00	0:30 – 1:00	0:15 – 0:30	0:15 – 0:40	0:15 – 0:20		
below -3 to -14	below 27 to 7	100/0	0:55 – 3:30	2:00	1:45 – 2:00	1:00 – 1:45	0:25 – 1:35[7]	0:20 – 0:30[7]		
		75/25	0:45 – 1:50	1:45	1:00 – 1:45	0:35 – 1:00	0:20 – 1:10[7]	0:15 – 0:25[7]		
below -14 to -28	below 7 to -18.4	100/0	0:40 – 1:00	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

ATTACHMENT XII – Clariant Safewing MP IV Launch Type IV Holdover Time Table

TABLE 4-C-LAUNCH

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2013-2014[1]
SAFEWING MP IV LAUNCH

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets: Very Light[3]	Snow, Snow Grains or Snow Pellets: Light[3]	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	4:00 – 4:00	2:00	1:45 – 2:00	1:05 – 1:45	1:30 – 2:00	1:00 – 1:40	0:15 – 1:40	CAUTION: No holdover time guidelines exist
		75/25	3:40 – 4:00	2:00	1:45 – 2:00	1:00 – 1:45	1:40 – 2:00	0:45 – 1:15	0:10 – 1:45	
		50/50	1:25 – 2:45	1:25	0:45 – 1:25	0:25 – 0:45	0:30 – 0:50	0:20 – 0:25		
below -3 to -14	below 27 to 7	100/0	1:00 – 1:55	2:00	1:20 – 2:00	0:50 – 1:20	0:35 – 1:40[7]	0:25 – 0:45[7]		
		75/25	0:40 – 1:20	2:00	1:25 – 2:00	0:45 – 1:25	0:25 – 1:10[7]	0:25 – 0:45[7]		
below -14 to -28.5	below 7 to -19.3	100/0	0:30 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES

1. These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2. Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3. Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5. No holdover guidelines exist for this condition for 0°C (32°F) and below.
6. Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7. These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

ATTACHMENT XIII – Cryotech Polar Guard Advance Type IV Holdover Time Table

TABLE 4-CR-PG-A

CRYOTECH TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2013-2014[1]
POLAR GUARD ADVANCE

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets: Very Light[3]	Snow, Snow Grains or Snow Pellets: Light[3]	Snow, Snow Grains or Snow Pellets: Moderate	Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
-3 and above	27 and above	100/0	2:50 – 4:00	2:00	1:50 – 2:00	1:20 – 1:50	1:35 – 2:00	1:15 – 1:30	0:15 – 2:00	CAUTION: No holdover time guidelines exist
		75/25	2:30 – 4:00	2:00	1:20 – 2:00	0:45 – 1:20	1:40 – 2:00	0:40 – 1:10	0:09 – 1:40	
		50/50	0:50 – 1:25	1:20	0:35 – 1:20	0:15 – 0:35	0:20 – 0:45	0:09 – 0:20		
below -3 to -14	below 27 to 7	100/0	0:55 – 2:30	1:45	1:15 – 1:45	0:55 – 1:15	0:35 – 1:35[7]	0:35 – 0:45[7]		
		75/25	0:40 – 1:30	1:45	1:00 – 1:45	0:35 – 1:00	0:25 – 1:05[7]	0:35 – 0:45[7]		
below -14 to -30.5	below 7 to -22.9	100/0	0:25 – 0:50	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

CAUTIONS
- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

ATTACHMENT XIV – ABAX ECOWING AD-49 Type IV Holdover Time Table

TABLE 4-D-AD-49

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2013-2014[1]
UCAR™ FLIGHTGUARD AD-49

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)							
Degrees Celsius	Degrees Fahrenheit		Freezing Fog or Ice Crystals	Snow, Snow Grains or Snow Pellets			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
				Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	100/0	3:20 – 4:00	2:00	1:50-2:00	1:10 – 1:50	1:25 – 2:00	1:00 – 1:25	0:10 – 1:55	
		75/25	2:25 – 4:00	2:00	1:40-2:00	1:20 – 1:40	1:55 – 2:00	0:50 – 1:30	0:10 – 1:40	
		50/50	0:25 – 0:50	0:40	0:25-0:40	0:15 – 0:25	0:15 – 0:30	0:10 – 0:15	CAUTION: No holdover time guidelines exist	
below -3 to -14	below 27 to 7	100/0	0:20 – 1:35	2:00	1:50-2:00	1:10 – 1:50	0:25 – 1:25[7]	0:20 – 0:25[7]		
		75/25	0:30 – 1:10	2:00	1:40-2:00	1:20 – 1:40	0:15 – 1:05[7]	0:15 – 0:25[7]		
below -14 to -26	below 7 to -14.8	100/0	0:25 – 0:40	0:40	0:30 – 0:40	0:15 – 0:30				

NOTES

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type IV fluid cannot be used.
3 Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 No holdover guidelines exist for this condition for 0°C (32°F) and below.
6 Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
7 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **The time of protection will be shortened in heavy weather conditions, heavy precipitation rates, or high moisture content.**
- **High wind velocity or jet blast may reduce holdover time.**
- **Holdover time may be reduced when aircraft skin temperature is lower than outside air temperature.**
- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

ATTACHMENT XV– Ice Pellet Allowance Time Table

TABLE 11

ICE PELLET ALLOWANCE TIMES FOR WINTER 2013-2014

This table is for use with SAE Type IV undiluted (100/0) fluids only.
All Type IV fluids are propylene glycol based with the exception of Dow Chemical EG106 which is ethylene glycol based.

THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C[1]
Light Ice Pellets	50 minutes	30 minutes	30 minutes[2]
Moderate Ice Pellets	25 minutes[3]	10 minutes	10 minutes[2]
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	25 minutes	10 minutes	**Caution: No allowance times currently exist**
Light Ice Pellets Mixed with Light Freezing Rain	25 minutes	10 minutes	
Light Ice Pellets Mixed with Light Rain	25 minutes[4]		
Light Ice Pellets Mixed with Moderate Rain	25 minutes[5]		
Light Ice Pellets Mixed with Light Snow	25 minutes	15 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes		

NOTES

1. Ensure that the lowest operational use temperature (LOUT) is respected.
2. No allowance times exist for propylene glycol (PG) fluids, when used on aircraft with rotation speeds less than 115 knots. (For these aircraft, if the fluid type is not known, assume zero allowance time).
3. Allowance time is 15 minutes for propylene glycol (PG) fluids or when the fluid type is unknown.
4. No allowance times exist in this condition for temperatures below 0°C; consider use of light ice pellets mixed with light freezing rain.
5. No allowance times exist in this condition for temperatures below 0°C.

CAUTIONS

- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**

ATTACHMENT XVI – Task List for Setup and Actual Tests

No.	Task	Person	Status
	Planning and Preparation		
1	Co-ordinate with NRC wind tunnel personnel	MR/JD	
2	Ensure fluid is received ny NRC and is stored outdoors	MR/JD	
3	Check with NRC the status of the testing site, tunnel etc	MR	
4	Arrange for hotel accommodations for APS personnel	VZ	
5	Arrange truck rental	VZ	
6	Arrange for ice and freezer delivery	DY	
7	Organize personnel travel to Ottawa;	VZ	
8	Hire YOW personnel	VZ	
9	Complete contract for YOW personnel	VZ	
10	Co-ordinate with APS photographer	MR	
11	Ensure availability of freezing rain sprayer equipment;	MR	
12	Prepare and Arrange Office Materials for YOW	VZ	
13	Prepare Data forms and procedure	VZ	
14	Back up hard drives with all TC projects	VZ	
15	Prepare Test Log and Merge Historical Logs for Reference	VZ	
16	Prepare weather forceast spreadsheet	VZ	
17	Prepare historical falling ball records spreadsheet	VZ	
18	Finalize and complete list of equipment/materials required	MR	
19	Prepare and Arrange Site Equipment for YOW	DY	
20	Ensure proper functioning of ice pellet dispenser equipment;	MR	
21	Review IP/ZR/SN dispersal techniques and location	VZ/MR	
22	Update IP Rate File (if necessary)	VZ/MR	
23	Check weather prior to finalizing test dates and Day vs. Night Shift,	MR/JD	
24	Arrange for pallets to lift up 1000L totes (if applicable)	MR	
25	Purchase new 20 L containers (as necessary)	DY	
26	Complete purchase list and shopping	VZ	
27	Pack and leave YUL for YOW on Monday Jan 7th for AM start on Jan	APS	
	Wednesday Jan 8		
28	Safety Briefing & Training (APS/YOW)	MR	
29	Unload Truck and organize equipement in lower, middle, or office area	APS	
30	Verify and Organize Fluid Recieved (labels and fluid receipt forms)	DY/JS	
31	Transfer Fluids from 1000 L Totes to 20 L containers	DY/JS	
32	Collect fluid samples for viscosity at APS office and for Falling Ball	DY/VZ	
33	Conduct falling ball verification	DY/VZ	
34	Confirm ice and freezer delivery	DY	
35	Setup general office and testing equipment	VZ	
36	Setup Projector	VZ	
37	Setup Printer	VZ	
38	Setup rate station (if necessary)	DY	
39	Setup IP/SN manufacturing material in reefer truck	JS	
40	Test and prepare IP dispensing equipment	JS	
41	Train IP making personnel (ongoing)	JS/YOW	
42	Co-ordinate fabrication of ice pellets/snow	VZ/JS	
43	IP/SN/ZR Calibration (if necessary)	DY/VZ/MR	
44	Start IP manufacturing	JS	
45	Mark wing (only if requested);	VZ	
46	Setup Still and Video Cameras same as 2010-11	BG/JsD	
47	Verify photo and video angles, resolution, etc, against 2010-11/11-12	BG/JsD/MR	
48	Document new final camera and flash locations	VZ/BG/JsD	
49	General safety briefing and update on testing	APS/NRC/YOW	
50	Dry Run of tests with APS and NRC (if necessary)	APS/NRC	
51	Start Testing (Dry wing tests may be possible while setup occurs)	APS/NRC	
	Each Testing Day		
52	Check with NRC the status of the testing site, tunnel, weather etc	MR	
53	Deicide personnel requirements for following day for 24hr notice	MR/WU	
54	Prepare equipment and fluid to be used for test	DY	
55	Manufacture ice pellets	JS/YOW	
56	Prepare photography equipment	BG	
57	Prepare data forms for test	VZ	
58	Conduct tests based on test plan	APS	
59	Modify test plan based on results obtained	WU/JD/MR	
60	Update ice pellet, snow, raw ice, and fluid Inventory (end of day)	VZ/JS	
61	Update Test Log and Test Plan (ongoing and end of day)	VZ	

ATTACHMENT XVII – General Form

Form 1

GENERAL FORM (EVERY TEST)

DATE: ____________ FLUID APPLIED: ____________ RUN # (Plan #): ____________

AIR TEMPERATURE (°C) BEFORE TEST: ____________ AIR TEMPERATURE (°C) AFTER TEST: ____________

TUNNEL TEMPERATURE (°C) BEFORE TEST: ____________ TUNNEL TEMPERATURE (°C) AFTER TEST: ____________

WIND TUNNEL START TIME: ____________ PROJECTED SPEED (S/KTS): ____________

ROTATION ANGLE: ____________ EXTRA RUN INFO: ____________

FLAP SETTING (20°, 0°): ____________

☐ Check if additional notes provided on a separate sheet

FLUID APPLICATION

Actual start time: ____________ Actual End Time: ____________

Fluid Brix: ____________ Amount of Fluid (L): ____________

Fluid Temperature (°C): ____________ Fluid Application Method: POUR

ICE PELLETS APPLICATION (if applicable)

Actual start time: ____________ Actual End Time: ____________

Rate of Ice Pellets Applied (g/dm²/h): ____________ Ice Pellets Size (mm): 1.4 - 4.0 mm

Exposure Time: ____________

Total IP Required per Dispenser: ____________

FREEZING RAIN/DRIZZLE APPLICATION (if applicable)

Actual start time: ____________ Actual End Time: ____________

Rate of Precipitation Applied (g/dm²/h): ____________ Droplet Size (mm): ____________

Exposure Time: ____________ Needle: ____________

Flow: ____________

Pressure ____________

SNOW APPLICATION (if applicable)

Actual start time: ____________ Actual End Time: ____________

Rate of Snow Applied (g/dm²/h): ____________ Snow Size (mm): <1.4 mm

Exposure Time: ____________ Method: ☐ Dispenser ☐ Sieve

Total SN Required per Dispenser: ____________

COMMENTS ____________

MEASUREMENTS BY: ____________ **HANDWRITTEN BY:** ____________

ATTACHMENT XVIII – Wing Temperature, Fluid Thickness and Fluid Brix Form

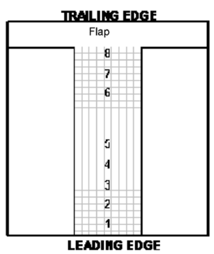
Date: ______________________ Run: ______________

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2				
T5				
TU				
Time:				

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2			
8			
Flap			
Time:			

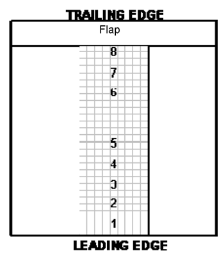
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2			
3			
4			
5			
6			
7			
8			
Flap			
Time:			

Wing and Plate Condition
After the Takeoff Run
Time: __________

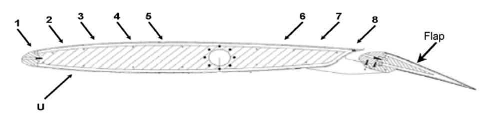


Comments:______________________

Wing and Plate Condition
Before the Takeoff Run
Time: __________



Comments:______________________



Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;

Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;

Wing Position 6: Approximately 30 cm from trailing edge;

Wing Position 7: Approximately 15 cm from trailing edge;

Wing Position 8: Approximately 2.5 cm from trailing edge; and

Wing Position 9: Midway up the flap

Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: ______________________

OBSERVER: ______________________

ASSISTED BY: ______________________

ATTACHMENT XIX – Example Ice Pellet Dispensing Form

WING TRAILING EDGE

8 ft = 24.4 dm

6 ft = 18.3 dm

DISPENSOR #3								DISPENSOR #4							
1 ←	1ft	→2 ←	1ft	→3 ←	1ft	→4		1 ←	1ft	→2 ←	1ft	→3 ←	1ft	→4	
14.9	16.5	18.2	17.4	18.5	17.6	18.5	17.6	18.5	17.6	18.5	17.6	17.2	17.2	16.3	13.3
20.3	24.1	26.2	26.4	27.3	26.9	27.5	26.9	27.5	26.9	27.5	26.9	26.9	25.8	24.2	18.6
20.3	25.4	27.4	28.7	29.0	29.4	29.0	29.4	29.0	29.4	29.0	29.3	28.3	27.7	24.4	19.3
19.1	23.8	25.6	25.6	29.2	29.6	29.3	29.6	29.3	29.6	29.3	29.5	28.6	27.4	24.3	19.2
18.8	23.5	27.2	27.9	29.4	28.8	29.5	28.8	29.5	28.8	29.5	28.8	28.7	26.8	24.1	18.5
18.4	24.0	26.9	28.7	29.0	29.6	29.1	29.6	29.1	29.6	29.1	29.4	28.4	27.2	23.5	18.5
18.5	23.5	27.2	28.4	29.4	29.1	29.6	29.1	29.6	29.1	29.6	29.0	28.7	26.9	24.0	18.4
18.5	24.1	26.8	28.7	28.8	29.5	28.8	29.5	28.8	29.5	28.8	29.4	27.9	27.2	23.5	18.8
19.2	24.3	27.4	28.6	29.5	29.3	29.6	29.3	29.6	29.3	29.6	29.2	25.6	25.6	23.8	19.1
19.3	24.4	27.7	28.3	29.3	29.0	29.4	29.0	29.4	29.0	29.4	29.0	28.7	27.4	25.4	20.3
18.6	24.2	25.8	26.9	26.9	27.5	26.9	27.5	26.9	27.5	26.9	27.3	26.4	26.2	24.1	20.3
13.3	16.3	17.2	17.2	17.6	18.5	17.6	18.5	17.6	18.5	17.6	18.5	17.4	18.2	16.5	14.9
	4 ←	1ft	→3 ←	1ft	→2 ←	1ft	→1		4 ←	1ft	→3 ←	1ft	→2 ←	1ft	→1
	DISPENSOR #2								DISPENSOR #1						

WING LEADING EDGE

Precipitation Type	IP	Date		Run #	

Field to be manipulated

Target Rate	**25**	**g/dm²/h**
Duration	**5**	**minutes**

Footprint Rate	25	g/dm²/h
Stdev of Rate (+/-)	5	g/dm²/h

IP needed per 5min

In each position	81	g
In each Dispensor	323	g

IP needed for entire test

Total amount of IP in Each Dispensor	323	g
Total Amount IP Needed for Entire Test	1291	g

1. Enter "Date" and "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of IP Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of IP in Each Dispensor" in grams. **(Each Dispensor must be emptied at 5-minute intervals.)**
6. Dictate amount of IP needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispensor 1-foot to the left.
8. Once a Dispensor has complested its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals). (e.g: Position #1 -> Pos #2 -> Pos #3 -> Pos #4 -> Pos #4 -> Pos #3 -> Pos #2 -> Pos #1 -> Pos #1...)

NOTE:

- Leading Edge (LE): Centre Pole of the Dispensor Stands must be 1-foot (12 inches) from the Leading Edge (LE)

-Trailing Edge (TE): Centre Pole of the Dispensor Stands must be 10-inches from the Trailing Edge (TE) Flap.

- Height of the Stand must be 4-feet from bottom of the dispensor

ATTACHMENT XX – Example Snow Dispensing Form

WING TRAILING EDGE

← 8 ft = 24.4 dm →

6 ft = 18.3 dm

DISPENSOR #3								DISPENSOR #4							
1	1ft	2	1ft	3	1ft	4		1	1ft	2	1ft	3	1ft	4	
23.1	24.8	27.2	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.4	26.6	19.7
27.1	35.5	34.9	36.7	35.1	36.7	35.1	36.7	35.1	36.7	35.1	36.7	35.0	36.3	33.9	29.8
24.6	39.4	36.4	41.4	36.8	41.5	36.8	41.5	36.8	41.5	36.8	41.5	36.7	41.1	35.5	35.2
14.4	26.3	25.3	28.6	25.7	28.7	25.7	28.7	25.7	28.7	25.7	28.7	25.6	28.4	24.7	24.3
8.8	15.2	16.4	17.4	17.0	17.6	17.2	17.6	17.2	17.6	17.2	17.6	17.0	17.2	15.9	14.2
6.1	9.4	10.6	11.2	11.1	11.4	11.2	11.4	11.2	11.4	11.2	11.3	11.0	10.9	9.8	7.9
7.9	9.8	10.9	11.0	11.3	11.2	11.4	11.2	11.4	11.2	11.4	11.1	11.2	10.6	9.4	6.1
14.2	15.9	17.2	17.0	17.6	17.2	17.6	17.2	17.6	17.2	17.6	17.0	17.4	16.4	15.2	8.8
24.3	24.7	28.4	25.6	28.7	25.7	28.7	25.7	28.7	25.7	28.7	25.7	28.6	25.3	26.3	14.4
35.2	35.5	41.1	36.7	41.5	36.8	41.5	36.8	41.5	36.8	41.5	36.8	41.4	36.4	39.4	24.6
29.8	33.9	36.3	35.0	36.7	35.1	36.7	35.1	36.7	35.1	36.7	35.1	36.7	34.9	35.5	27.1
19.7	26.6	25.4	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.4	25.5	27.2	24.8	23.1
	4	1ft	3	1ft	2	1ft	1		4	1ft	3	1ft	2	1ft	1
	DISPENSOR #2								DISPENSOR #1						

WING LEADING EDGE

Precipitation Type	Snow	Date		Run #	

* ***Field to be manipulated***

Target Rate	**25**	**g/dm²/h**
Duration	**5**	**minutes**

Footprint Rate	25	g/dm²/h
Stdev of Rate	10	g/dm²/h

Snow needed per 5 minutes

In each position	84	76	g
In each Dispensor	336	305	g

Snow needed for entire test

In each Dispensor	336	305	g
Total Amount Snow Needed for Entire Test	1344	1222	g

1. Enter "Date" and "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of Snow Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of Snow in Each Dispensor" in grams. **(Each Dispensor must be emptied at 5-minute intervals.)**
6. Dictate amount of Snow needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispensor 1-foot to the left.
8. Once a Dispensor has completested its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals).

(e.g: Position #1 -> Pos #2 -> Pos #3 -> Pos #4 -> Pos #4 -> Pos #3 -> Pos #2 -> Pos #1 -> Pos #1...)

NOTE:

- Leading Edge (LE): Centre Pole of the Dispensor Stands must be 1-foot (12 inches) from the Leading Edge (LE)

-Trailing Edge (TE): Centre Pole of the Dispensor Stands must be 10-inches from the Trailing Edge (TE) Flap. The use of Dispensor Stand Extention is needed.

- Height of the Stand must be 4-feet from bottom of the dispensor

ATTACHMENT XXI – Example Snow Dispensing Form

Precipitation Type	Sifted Snow

Date	

Run #	

* ***Field to be manipulated***

Target Rate	**25**	**g/dm²/h**
Duration	**5**	**minutes**

Footprint Rate	25	g/dm²/h
Stdev of Rate	10	g/dm²/h

Snow needed per 5 minutes

In each position	66
In each Dispensor	265

Snow needed for entire test

In each Dispensor	265
Total Amount Snow Needed for Entire Test	1062

1. Enter "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of Snow Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of Snow in Each Dispensor" in grams. **(Each Dispensor must be emptied at 5-minute intervals.)**
6. Dictate amount of Snow needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispensor 1-foot to the left.
8. Once a Dispensor has complested its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals). (e.g: Position #1 -> Pos #2 -> Pos #3 -> Pos #4 -> Pos #4 -> Pos #3 -> Pos #2 -> Pos #1 -> Pos #1...)

NOTE:

- Leading Edge (LE): Centre Pole of the Dispensor Stands must be 1-foot (12 inches) from the Leading Edge (LE)

-Trailing Edge (TE): Centre Pole of the Dispensor Stands must be 10-inches from the Trailing Edge (TE) Flap.

- Height of the Stand must be 4-feet from bottom of the dispensor

- Since dispensing is done using a sieve, the percentage of snow loss is reduced. This efficiency is estimated at 90%, as per visual analysis in 2009-10.

ATTACHMENT XXII – Visual Evaluation Rating Form

VISUAL EVALUATION RATING OF CONDITION OF WING

Date: ____________________ Run Number: _______

Ratings:
1 - Contamination not very visible, fluid still clean.
2 - Contamination is visible, but lots of fluid still present
3 - Contamination visible, spots of bridging contamination
4 - Contamination visible, lots of dry bridging present
5 - Contamiantion visible, adherence of contamination

Before Take-off Run

Area	Visual Severity Rating (1-5)
Leading Edge	
Trailing Edge	
Flap	

At Rotation

Area	Visual Severity Rating (1-5)
Leading Edge	
Trailing Edge	
Flap	

Expected Lift Loss (%)

After Take-off Run

Area	Visual Severity Rating (1-5)
Leading Edge	
Trailing Edge	
Flap	

Additional Observations:

OBSERVER: ________________________

ATTACHMENT XXIII – Fluid Receipt Form

(Consider using electronic auto-fill format)

SECTION A - SITE

☐ **HOT SAMPLE** ☐ **RESEARCH/OTHER SAMPLE**

Receiving Location: ____________ **Date of Receiving:** ____________

Manufacturer: ____________ **Fluid Name:** ____________ **Fluid Type:** ______

Date of Production: ____________ **Batch #:** ____________

Fluid Dilution:	______	______	______
Fluid Quantity:	___ x ___ L = _____ L	___ x ___ L = _____ L	___ x ___ L = _____ L
APS Measured BRIX:	______	______	______

Note any additional information included on fluid containers:

Received by: ____________
(PRINT NAME)
on: ____________
(DATE)

SECTION B - OFFICE

Fluid Code Assigned: 100/0 ______ 75/25 ______ 50/50 ______ Type I ______

Viscosity Information Received:[1] ☐ **Viscosity Measured:**[1] ☐

WSET Sample Sent to AMIL: ☐ **WSET Result Received:** ☐

FFP Curves Received:[2] ☐

[1] Type II/III/IV fluids only
[2] Type I fluids only

ATTACHMENT XXIV – Log of Fluid Sample Bottles

Date of Extraction	Fluid and Dilution	Batch #	Sample Source (i.e. drum)	Falling Ball Fluid Temp (°C)	Falling Ball Time (sec)	Comments

ATTACHMENT XXV – Procedure: Stall Warning Sensor

Background

Airfoil performance monitors (APM) are being developed and can be installed on any airfoil on an aircraft, including the tail. An APM is designed to measure the airflow over the wing, which reveals how well the wing is working. As a wing becomes contaminated, the APM should measure the changing or turbulent airflow and resulting lift generated by the wing. The APM is designed to alert the crew if the airflow degrades below a configurable threshold, giving the crew time to correct a potential stall before it happens. It was recommended that testing be conducted with a Canadian developed APM to support the development of the technology and aid in evaluating the potential for use in ground icing operations and to investigate whether or not the use of fluids with the systems would potentially obstruct the pressure ports which are critical to the systems operation.

Objective

To provide a testing platform to the manufacturer and allow them to evaluate the ability of the airfoil performance monitor to properly identify stall with and without icing conditions during aircraft ground operations with de/anti-icing fluid applications.

Methodology

- Conduct dry wing baseline testing with and without the installation to understand any potential aerodynamic influences the sensor may have;
- With the sensor installed, conduct dry wing tests to stall;
- Repeat tests with fluid only to stall;
- Evaluate ability of the APM to measure stall and compare to the stall observed through the aerodynamic data collected; and
- Evaluate the use of the APM unit with fluids.

Test Plan

Four tests are anticipated.

ATTACHMENT XXVI – Procedure: Heavy Snow

Background

As a direct result of the ice pellet research conducted, the use of HOTs for determining the protection time provided by anti-icing fluids was questioned. The focus has turned towards "aerodynamic failure" which can be defined as a significant lift loss resulting from contaminated anti-icing fluid. Heavy snow conditions have been selected for this study for two reasons. First, snow conditions account for the most significant portion of de-icing operations globally. Secondly, there has been a recent industry interest for holdover time for heavy snow conditions. Preliminary aerodynamic testing was conducted during the winters of 2006-07 and 2008-2011.

Objective

To investigate the fluid aerodynamic flow-off characteristics of anti-icing fluid contaminated with simulated heavy snow versus moderate snow.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical snow condition tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating moderate snow conditions (rate of 25 $g/dm^2/h$) for an exposure time derived from the HOT table based on the tunnel temperature at the time of the test
- Record lift data, visual observations, and manually collected data;
- Conduct two comparative tests simulating heavy snow conditions (rate of 50 $g/dm^2/h$ or higher) for the same exposure time used during the moderate snow test.
    - NOTE: previous testing has indicated that using half, to ¾ of the moderate snow HOT generates similar end conditions, whereas using the full moderate HOT for heavy snow conditions generates a more sever fluid failure which behaves worse aerodynamically. ;
- Record lift data, visual observations, and manually collected data;
- Compare the heavy snow results to the moderate snow results. If the heavy snow results are worse, repeat the heavy snow test with a reduced exposure time, if the results are better, repeat the heavy snow test with an increased exposure time.
- Repeat until similar lift data, and visual observations are achieved for both heavy snow and moderate snow; and
- Document the percentage of the moderate snow HOT that is acceptable for heavy snow conditions.

Test Plan

Two to four comparative tests are anticipated. See previous reports for suggested test plan.

ATTACHMENT XXVII– Procedure: Heavy Contamination

Background

Previous testing in the wind tunnel demonstrated that although very heavy ice pellet and/or snow contamination was applied to a fluid covered wing section, significant lift losses were not apparent. The initial testing indicated that after a certain level of contamination, the dry loose ice pellets or snow no longer absorb into the fluid and easily fly off during the acceleration. The protection is due to a thin layer of fluid present underneath the contamination that prevents adherence. Questions of which point the lift losses become detrimental have been raised.

Objective

To continue previous research investigating heavy contamination effects on fluid flow off.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical ice pellet tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating ice pellets, snow, or freezing rain, for an exposure time far exceeding the recommended HOT or allowance time;
- Record lift data, visual observations, and manually collected data;
- Compare aerodynamic performance results to fluid only or fluid and contamination tests at the same temperature.

Test Plan

One to four tests are anticipated. Previous work should be referenced to identify starting levels of heavy contamination.

ATTACHMENT XXVIII – Procedure: Wind Tunnel Test Section Cooling

Background

Recent wind tunnel research has been limited by the ambient temperature in wind tunnel test section; in sunny conditions, the radiation will raise the temperature in the test section making testing difficult. To mitigate this effect, testing is often conducted overnight, however in some cases, even body heat from people working in the test area (specifically during long precipitation exposure tests) can effect the temperature. A new cooling system has been installed by the NRC to mitigate the effects of the radiation warming as well as from the heat generated by the personnel working in the test section. It was recommended that testing be condutced to evaluate the effects of the new cooling system on the test results.

Objective

To evaluate the effect of the cooling system on the aerodynamic test results produced.

Methodology

- Conduct a fluid only test without the cooling system. Have personnel standing on scaffolding for 20-minutes following fluid application to generate extra heat prior to running the wind tunnel;
- Conduct a second comparative fluid only test with the cooling system. Have personnel standing on scaffolding for 20-minutes following fluid application to generate extra heat prior to running the wind tunnel;
- Conduct a third comparative test at a suitable ambient temperature where the expected test area temperature with the cooling system is equal to the test area temperature of the test conducted without the cooling system.
- Compare aerodynamic performance results.

EXAMPLE OF COMPARATIVE DATA TO BE COLLECTED

Test #	Cooling System Status	OAT ºC	Test Area Temp ºC	Lift Loss %
1	Off	-18	-14	6.3
2	On	-18	-17	7.5
3	On	-15*	-14	5.7

* to be selected based on efficiency of cooling system based on test #2

Test Plan

Three tests at a minimum are expected.

ATTACHMENT XXIX- Procedure: Effect of Fluid Viscosity

Background

Testing was previously conducted to evaluate the aerodynamic effects of fluid viscosity on flow-off. To do so, comparative testing was conducted with both mid-production fluid (used for ice pellet allowance time testing) and with lowest on-wing viscosity fluid (LOWV) (used for holdover time testing). Testing was conducted with the thin high performance airfoil in fluid only conditions. Additional testing was recommended to further substantiate the testing results.

Objective

To continue previous research evaluating the effect of fluid viscosity on aerodynamics.

Methodology

For each comparative test set, a baseline mid-production test should be conducted, and immediately followed by a lowest on-wing viscosity test of the same fluid type. Testing should be done with fluid only and fluid and contamination.

Test Plan

Two to four tests are anticipated.

ATTACHMENT XXX – Procedure: Fluid and Contamination at LOUT

Background

Recent changes to the frost HOT guidance material allowing fluids to be used to the LOUT have raised concerns about whether or not this is an appropriate practice. In frost the major concern was the effect of radiation cooling and how it could affect the LOUT, however the concern also includes contamination at LOUT. This issue was also raised from the AWG for the ice pellet testing which allows fluids to be used to LOUT: will the added ice pellet contamination at the LOUT not bust BLDT? It was recommended that some testing be conducted at the fluid LOUT to investigate how contamination can affect the aerodynamic performance of the fluid.

Objective

To investigate the fluid aerodynamic flow-off characteristics of anti-icing fluid with contamination at the LOUT.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical ice pellet tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating ice pellets, snow, freezing fog, or frost, for an exposure time derived from the HOT table at the fluid LOUT.
- Record lift data, visual observations, and manually collected data;
- Conduct a fluid only baseline test at the same temperature (at LOUT);
- Compare the aerodynamic performance.

Test Plan

Four or more tests are anticipated at a minimum. If LOUT temperatures for neat fluids are not likely to occur, investigate the possibility of using diluted fluids to obtain a higher LOUT.

ATTACHMENT XXXI – Procedure: Small Hail

Background

Reports from primarily Asian operators have indicated that small hail can occur frequently during winter operations. The small hail will generally occur above freezing conditions; however no guidance for operating in the conditions is currently available. Questions have been raised as to whether the ice pellet allowance times can be used due to similarity in precipitation type. Although this concern has only been raised by Asian operators, it can be assumed that similar conditions can be expected by North American operators. WMO defines small hail as snow pellets encapsulated by ice, a precipitation halfway between graupel and hail.

Objective

To investigate the fluid aerodynamic flow-off characteristics of anti-icing fluid with contamination with small hail and to compare the results to ice pellets.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical ice pellet tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating small hail for an exposure time derived from the current ice pellet allowance time table as a starting point;
- Record lift data, visual observations, and manually collected data;
- Conduct a fluid only baseline test at the same temperature;
- Compare the aerodynamic performance.

Test Plan

One to four tests are anticipated. A meteorologist should be consulted prior to the conduct to narrow down the exact conditions and temperatures at which small hail will occur, as well as to obtain the desired small hail diameter.

ATTACHMENT XXXII – Procedure: Frost Simulation in the Wind Tunnel

Background

Frost is an important consideration in aircraft deicing. The irregular and rough frost accretion patterns can result in a significant loss of lift on critical aircraft surfaces. This potential hazard is amplified by the frequent occurrence of frost accretion in winter operations. Frost is an area of research that has yet to be fully explored. Discussions regarding the aerodynamic effects of frost have been raised, and the possibility of doing wind tunnel testing has been considered. It was recommended that initial testing be performed to investigate whether it would be feasible to simulate frost conditions in the PIWT.

Objective

To investigate the feasibility of simulating frost conditions in the PIWT.

Methodology

This work is exploratory, so no exact procedure exists. It is recommended that the frost generating parameters be explored to try and stimulate frost accretion. This can be done by causing a negative temperature differential between the wing and the ambient air i.e. air is warmer than skin. A more specific methodology may be determined on site following a brain-storm with onsite technicians.

Test Plan

One or two tests is anticipated.

ATTACHMENT XXXIII – Procedure: Flaps/Slats Testing to Support YMX Tests

Background

Flaps/slats testing has been conducted with the support of UPS during the winter sof 2011-12 and 2012-13, and is scheduled to continue during the winter of 2013-14. The initial results have indicated that extended configurations can result in earlier fluid failure on the flap and slats as compared to the main section of the wing. It was recommended that testing in the wind tunnel be conducted to evaluate how significant the aerodynamic penalties would be from having failed fluid in these isolated areas.

Objective

To investigate the aerodynamic performance degradation associated with failed fluid on flaps and slats.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical snow condition tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating moderate snow conditions (rate of 25 g/dm²/h) for an exposure time derived from the HOT table based on the tunnel temperature at the time of the test;
- Simulate early fluid failure on the fixed leading edge by applying higher rates of contamination on this area (record additional amounts);
- The flap is a hinged flap, so will be subject to early failure by design;
- Record lift data, visual observations, and manually collected data;
- Conduct a fluid only baseline test at the same temperature;
- Compare the aerodynamic performance;
- Consideration should be given to conducting Type I tests.

Test Plan

Two to four comparative tests are anticipated.

ATTACHMENT XXXIV – Procedure: Mixed HOT Conditions

Background

As the accuracy of meteorological reporting continues to improve, there has been a need to provide improved guidance material during these transitional periods of mixed precipitation. During the winter of 2008-09, guidance material was developed for operations during light snow mixed with light rain conditions. As a result of this work, there was industry interest in guidance material for operations during light freezing rain and moderate snow conditions as well as other mixed conditions. The objective of these tests is to collect data to determine if the current HOT guidelines can be expanded to include other operational mixed conditions which may be of current interest to industry.

Objective

To investigate if the current HOT guidelines can be expanded to include mixed conditions i.e. light freezing rain and moderate snow conditions.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for precipitation tests conducted in the wind tunnel.

- For a chosen fluid, conduct a test simulating mixed conditions for an exposure time derived from the HOT table based on relative condition.
- Record lift data, visual observations, and manually collected data;
- Conduct a fluid only baseline test at the same temperature; or
- Conduct a test with an existing relative HOT condition to evaluate the severity of the condition;
- Compare the aerodynamic performance.
- If the mixed condition results are severe, repeat the test with a reduced exposure time, if the results are good, repeat the test with a increased exposure time.

Test Plan

Two to four comparative tests are anticipated.

ATTACHMENT XXXV – Procedure: Snow on an Un-Protected Wing

Background

In colder northern operations, it is common for aircraft to depart with "loose, dry, un-adhered snow" on present on their wing sections. Although it is assumed most or all of this contamination will be removed at the time of rotation, it is unknown whether a certain level of contamination will reduce aerodynamic performance. Preliminary testing has demonstrated fluid seepage from the airfoil can lead to snow diluting and adhering to the airfoil during rotation; this effect has yet to be substantiated will operational data. During the winter of 2011-12, a video was leaked on the internet of an eastern European aircraft taking off with significant amounts of snow on the wing. As a result, additional wind tunnel testing was conducted during the winter of 2011-12. It was recommended that additional testing investigate the aerodynamic performance of a wing section contaminated with dry, un-adhered snow versus wet or humid snow.

Objective

To investigate the aerodynamic performance of a wing section contaminated with dry, un-adhered snow versus wet or humid snow.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical snow condition tests conducted in the wind tunnel.

- Ensure the wing section and tunnel temperature are well below freezing (-5ºC and below);
- Ensure the wing section is clean, dry, and free of any forms of contamination;
- Apply loose, dry snow contamination to the wing section;
- Record lift data, visual observations, and manually collected data;
- Compare the results to baseline fluid only and dry wing test results;

Test Plan

One to four comparative tests are anticipated.

ATTACHMENT XXXVI – Procedure: Feasibility of Ice Pellet Testing at Higher Speeds

Background

Historically, the ice pellet allowance time testing conducted in the wind tunnel simulated typical aircraft rotation of 100 knots, and more recently some limited work at 115 knots. As a result of some of the higher lift losses observed at colder temperatures with PG fluids applied to a thin high performance airfoil, it was recommended that higher speed testing be conducted to verify if the limitations in the allowance times would need to be applied to commercial aircraft with rotation speeds well above 115 knots. It was recommended that 130-150 knots be targeted, however modifications to the wind tunnel may be required as those higher speeds may increase stress on the wind tunnel engine and other structural systems.

Objective

To investigate the feasibility of conducting ice pellet testing at higher speeds of 130-150 knots. .

Methodology

This work is exploratory, so no exact procedure exists. A more specific methodology may be determined on site following a brain-storm with onsite technicians. It is expected that a series of tests may be conducted to try and achieve speeds above 115 knots without rotating the wing model.

Test Plan

One or two tests are anticipated, however more tests may be required based on the results.

ATTACHMENT XXXVII – Procedure: Windshield Washer Used as Type I Deicer

Background

Based on recent industry reports, it has become apparent that in more remote airports or with general aviation aircraft with smaller operations, aircraft deicing is not being conducted with SAE aircraft ground deicing Type I fluid, but rather with off-the-shelf windshield washer fluid. Although the basic chemistry of the windshield washer fluid may be similar, questions regarding the fluid freeze point, holdover time, aerodynamics, and material compatibility have been raised. It was recommended that some preliminary testing be conducted to investigate fluid flow off in the wind tunnel with and without contamination. Limited test was conducted during the winter of 2011-12. It was recommended that testing should continue if necessary based on operational needs.

Objective

To evaluate the holdover time and aerodynamic effects windshield washer fluid when used a substitute for an aircraft ground deicing Type I fluid.

Methodology

- Purchase various formulations of windshield washer fluid with varying freeze points;
- Apply fluid heated to 20ºC using a garden sprayer;
- Expose to simulated freezing contamination (snow, freezing rain, or ice pellets). The exposure time is to be determined based on Type I fluid HOT's (45 minutes at a rate of 0.3 g/dm^2/h);
- Document condition of the wing;
- Run the wind tunnel and collect data; and
- Compare results to baseline uncontaminated windshield washer tests and potentially with standard Type I tests.

Test Plan

No testing is planned unless indicated otherwise by TC.

ATTACHMENT XXXVIII – Procedure: Effect of Fluid Seepage on Dry Wing Performance

Background

Preliminary observations have indicated that fluid seepage from the airfoil can lead to lift losses and other aerodynamic impacts. This is especially of concern after a long series of fluid tests followed by a baseline dry wing test. It was recommended that testing investigate the aerodynamic impacts of residual fluid seepage on the airfoil performance.

Objective

To investigate the aerodynamic impacts of residual fluid seepage on the airfoil performance.

Methodology

The general methodology to be used during these tests is in accordance with the methodologies used for typical tests conducted in the wind tunnel.

- To be conducted following a long series of fluid and/or contamination tests;
- Ensure the wing section is clean, dry, and free of any forms of contamination;
- Record lift data, visual observations, and manually collected data;
- Compare results to the first dry wing test of the season;
- Re-clean the wing using a wet-vac or other alternative method to try and remove any residual fluid;
- Record lift data, visual observations, and manually collected data;
- Compare the results;

Test Plan

One to three comparative tests are anticipated

ATTACHMENT XXXIX – Procedure: 2nd Wave of Fluid during Rotation

Background

Previous wind tunnel testing has shown that during a simulated take-off roll following de/anti-icing, fluid will shear off the wing section; however a small amount of fluid can remain trapped along the leading edge at the stagnation point. This "trapped" fluid begins to flow over the wing only once the wing is rotated; the stagnation point shifts below the leading edge, and the "trapped" fluid begins to shear off as a second wave. Previous testing was simulated in a static model using strips of speed tape and cork tape strategically located on the leading edge of the wing section (along the span where the separation bubble will typically occur). A separate set of dynamic tests simulated the second wave with actual anti-icing fluid; sheared fluid prior to rotation was left only in select areas either below or above the stagnation point and then the flow was observed during a typical rotation. The results showed the stalling characteristics of the wing with fluid (or fluid with contamination) appear to be driven by secondary wave effects near the leading edge; these effects are difficult to interpret on the two-dimensional model relative to a fully three-dimensional wing and should not be used in developing allowance times. Additional testing may be useful to better understand this effect.

Objective

To investigate the aerodynamic effects of the second wave of fluid flow during rotation.

Methodology

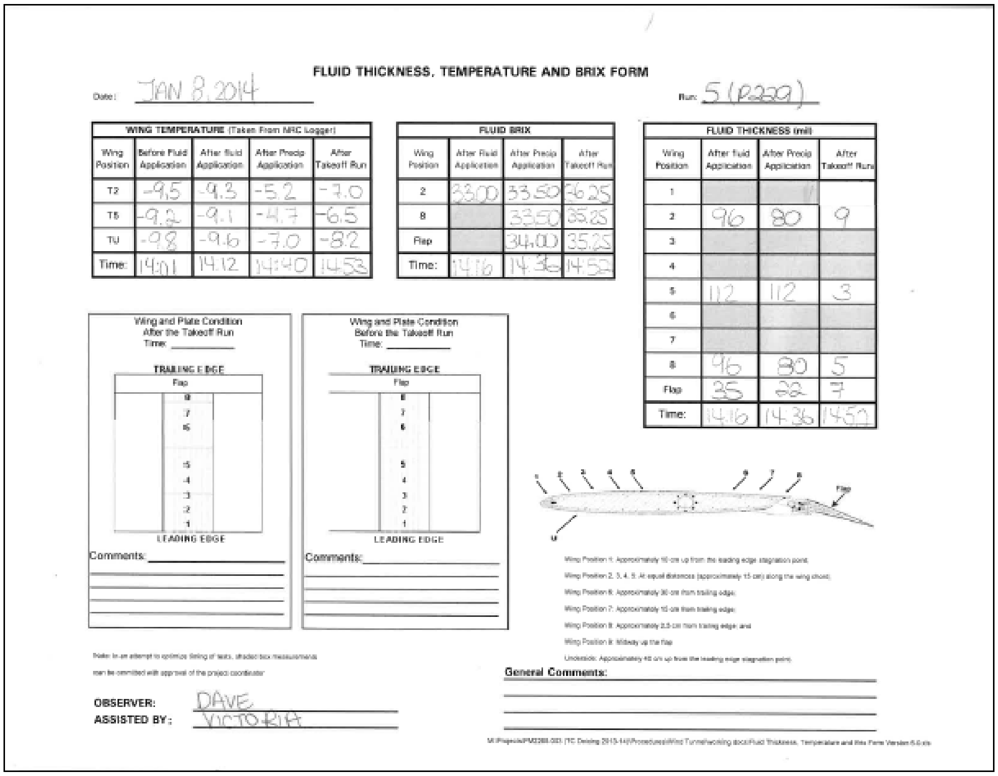
- Simulate the 2nd wave of fluid using strips of tape applied at specific areas at different thicknesses on the wing, or with fluid; and
- Compare the different results.

Test Plan

One to four tests are anticipated.

APPENDIX C

FLUID THICKNESS, TEMPERATURE, AND BRIX DATA FORMS



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 8, 2014

Run: 5 (P229)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-9.5	-9.3	-5.2	-7.0
T5	-9.2	-9.1	-4.7	-6.5
TU	-9.8	-9.6	-7.0	-8.2
Time:	14:01	14:12	14:40	14:53

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00	33.50	36.25
8		33.50	35.25
Flap		34.00	35.25
Time:	14:16	14:36	14:52

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	80	9
3			
4			
5	112	112	3
6			
7			
8	96	80	5
Flap	35	22	7
Time:	14:16	14:36	14:52

Wing and Plate Condition After the Takeoff Run
Time: ______

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE
Comments: ______

Wing and Plate Condition Before the Takeoff Run
Time: ______

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE
Comments: ______

Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

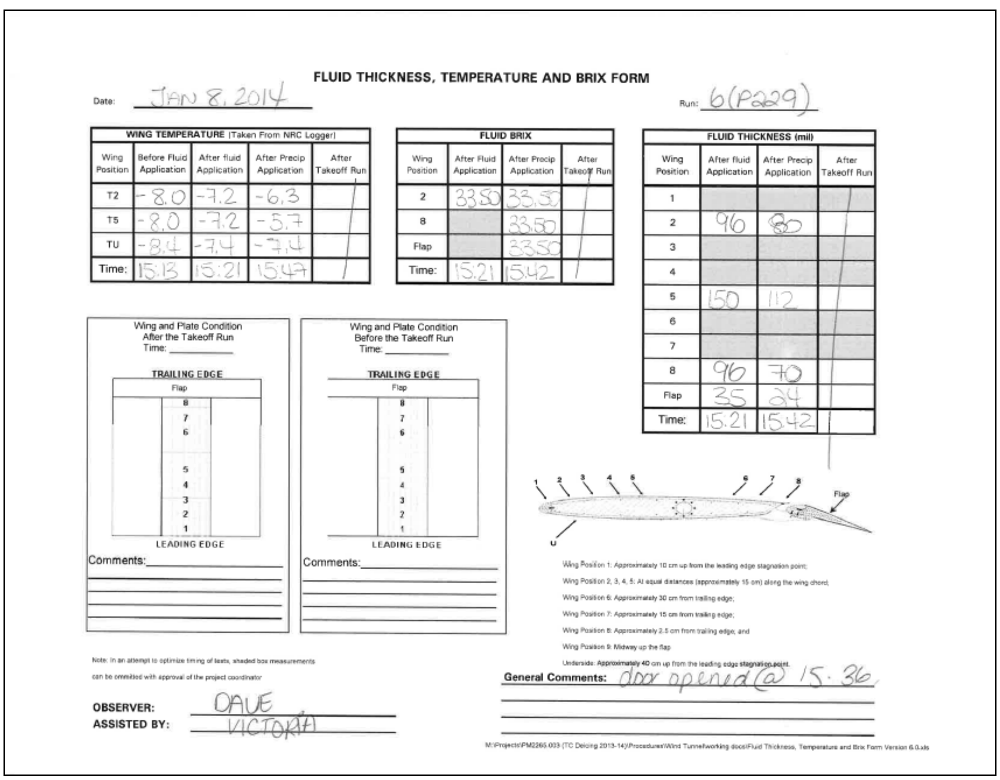
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: ______

OBSERVER: DAVE
ASSISTED BY: VICTORIA

M:\Projects\PM2265.003 (TC Deicing 2013-14)\Procedures\Wind Tunnel\working docs\Fluid Thickness, Temperature and Brix Form Version 6.0.xls

Figure C1: Test # 5



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 8, 2014

Run: 6(P229)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-8.0	-7.2	-6.3	
T5	-8.0	-7.2	-5.7	
TU	-8.4	-7.4	-7.4	
Time:	15:13	15:21	15:47	

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.50	33.50	
8		33.50	
Flap		33.50	
Time:	15:21	15:42	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	80	
3			
4			
5	150	112	
6			
7			
8	96	70	
Flap	35	24	
Time:	15:21	15:42	

Wing and Plate Condition After the Takeoff Run
Time: ______

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE
Comments: ______

Wing and Plate Condition Before the Takeoff Run
Time: ______

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE
Comments: ______

Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

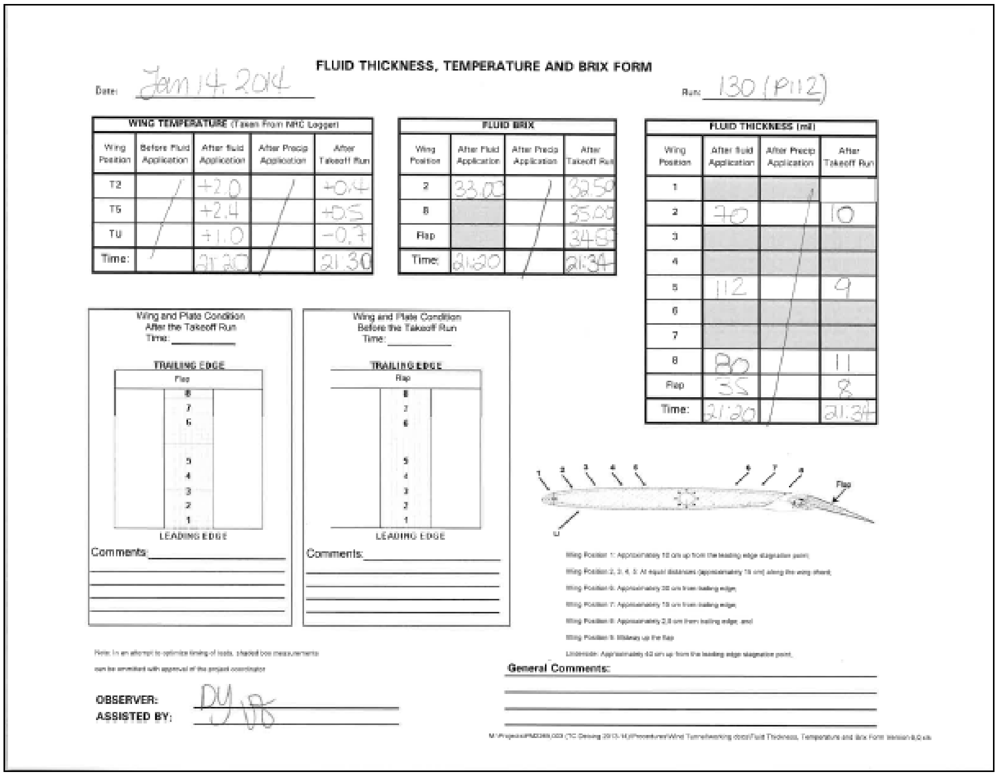
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: door opened @ 15:36

OBSERVER: DAVE
ASSISTED BY: VICTORIA

M:\Projects\PM2265.003 (TC Deicing 2013-14)\Procedures\Wind Tunnel\working docs\Fluid Thickness, Temperature and Brix Form Version 6.0.xls

Figure C2: Test # 6



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 14, 2014

Run: 130 (P112)

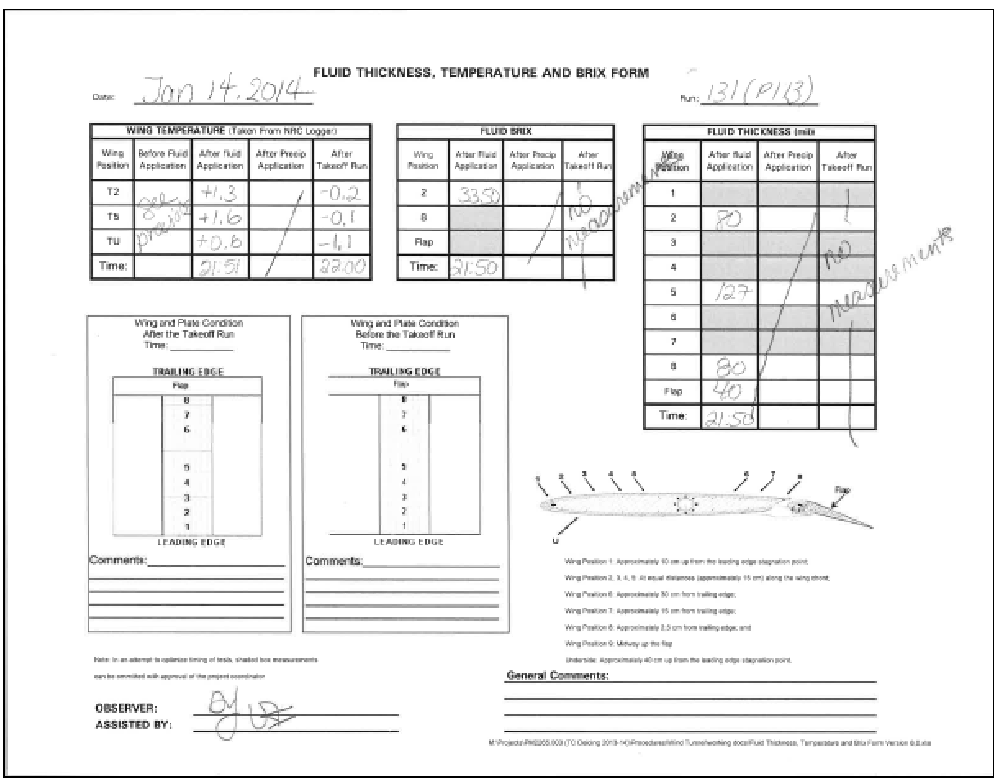
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	+2.0	/	+0.4
T5	/	+2.4	/	+0.5
TU	/	+1.0	/	-0.7
Time:	/	21:20	/	21:30

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00	/	32.50
8		/	35.00
Flap		/	34.80
Time:	21:20	/	21:34

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	70	/	10
3		/	
4		/	
5	112	/	9
6		/	
7		/	
8	80	/	11
Flap	35	/	8
Time:	21:20	/	21:34

OBSERVER: DY
ASSISTED BY: VB

Figure C3: Test # 130



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 14, 2014

Run: 131 (P113)

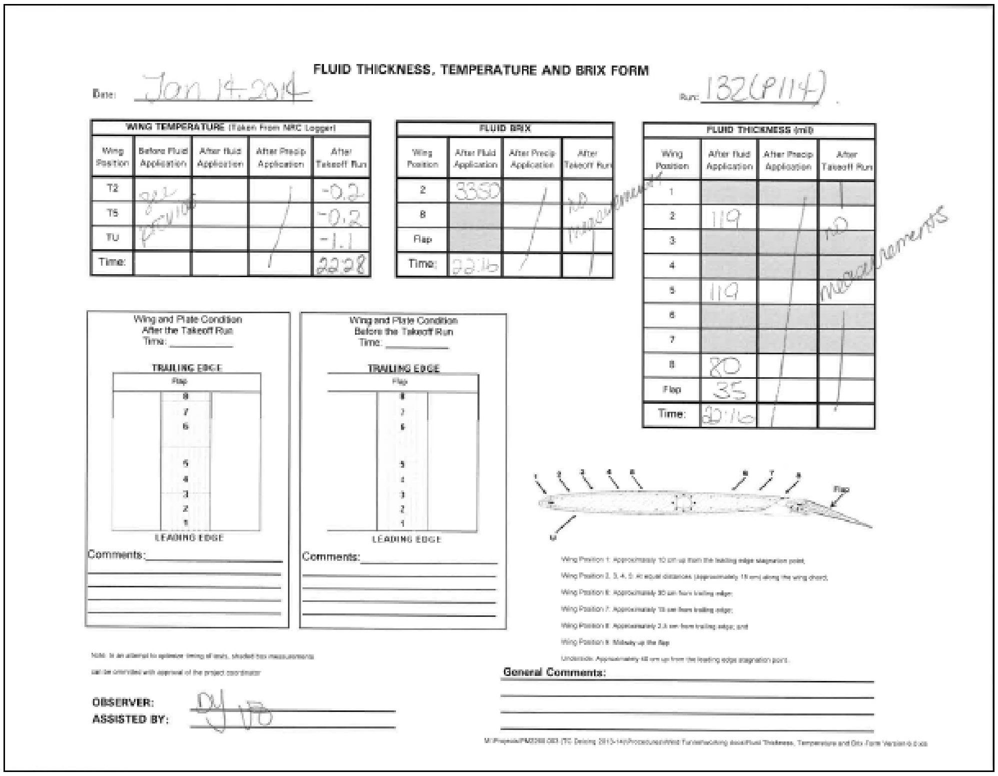
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	+1.3	/	-0.2
T5		+1.6	/	-0.1
TU		+0.6	/	-1.1
Time:		21:51	/	22:00

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.50	/	no measurement
8		/	
Flap		/	
Time:	21:50	/	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	no measurements
2	80	/	
3		/	
4		/	
5	127	/	
6		/	
7		/	
8	80	/	
Flap	40	/	
Time:	21:50	/	

OBSERVER: DY
ASSISTED BY: VB

Figure C4: Test # 131



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 14 2014 Run: 132(P114)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous		/	-0.2
T5			/	-0.2
TU			/	-1.1
Time:			/	2228

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	3350	/	no measurement
8		/	
Flap		/	
Time:	22:16	/	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	no measurements
2	119	/	
3		/	
4		/	
5	119	/	
6		/	
7		/	
8	80	/	
Flap	35	/	
Time:	22:16	/	

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / LEADING EDGE

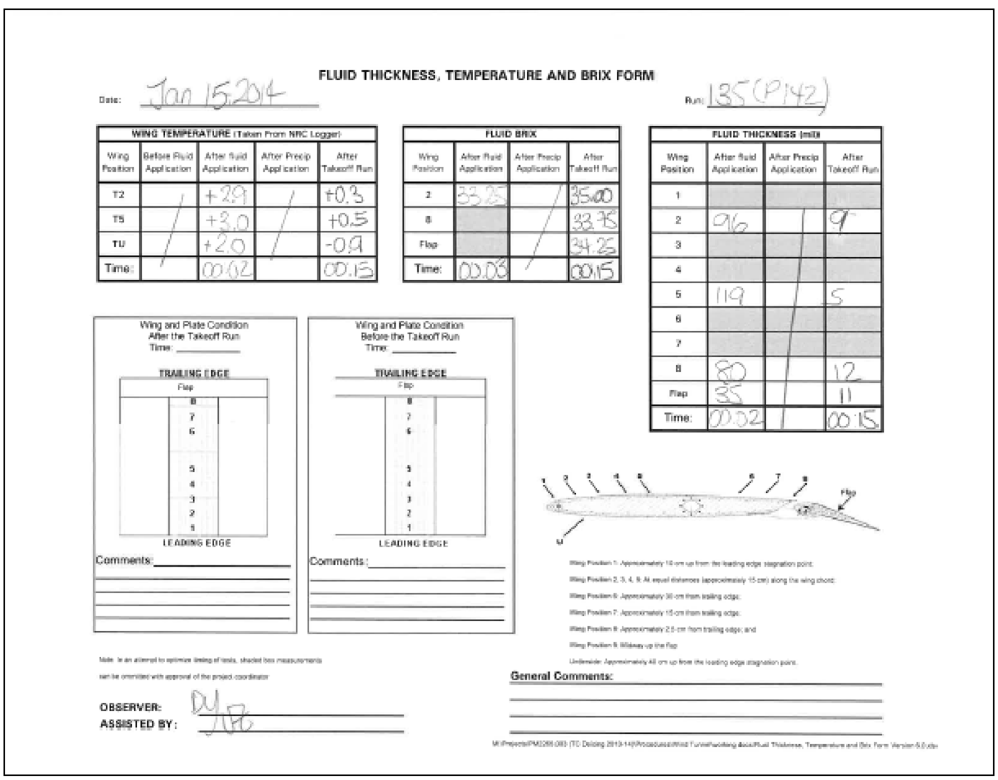
Comments:

General Comments:

OBSERVER: DY

ASSISTED BY: VB

Figure C5: Test # 132



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15 2014 Run: 135 (P142)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	+2.9	/	+0.3
T5	/	+3.0	/	+0.5
TU	/	+2.0	/	-0.9
Time:	/	00:02		00:15

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25	/	35.00
8		/	33.75
Flap		/	34.25
Time:	00:03	/	00:15

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	96	/	9
3		/	
4		/	
5	119	/	5
6		/	
7		/	
8	80	/	12
Flap	35	/	11
Time:	00:02	/	00:15

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / LEADING EDGE

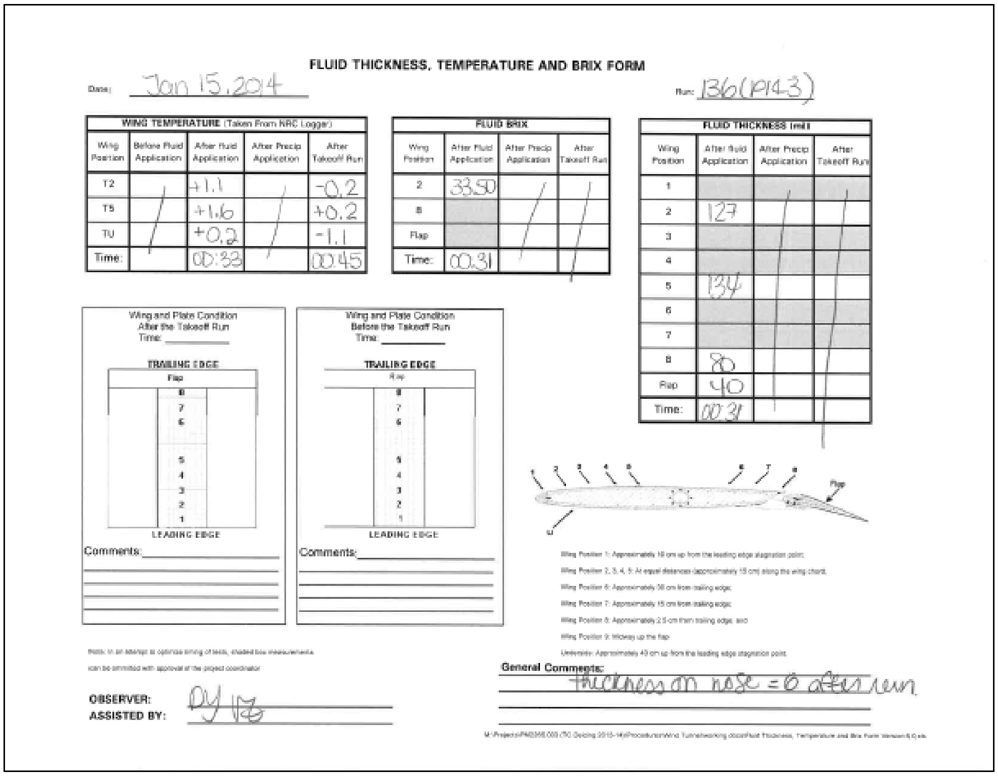
Comments:

General Comments:

OBSERVER: DY

ASSISTED BY: VB

Figure C6: Test #135



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014   Run: 136(P143)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Run
T2	/	+1.1	/	-0.2
T5	/	+1.6	/	+0.2
TU	/	+0.2	/	-1.1
Time:		00:33		00:45

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.50	/	/
8		/	/
Flap		/	/
Time:	00:31		

FLUID THICKNESS (mil)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1		/	/
2	127	/	/
3		/	/
4		/	/
5	134	/	/
6		/	/
7		/	/
8	80	/	/
Flap	40	/	/
Time:	00:31		

Wing and Plate Condition After the Takeoff Run
Time: ________
TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE
Comments: ________

Wing and Plate Condition Before the Takeoff Run
Time: ________
TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE
Comments: ________

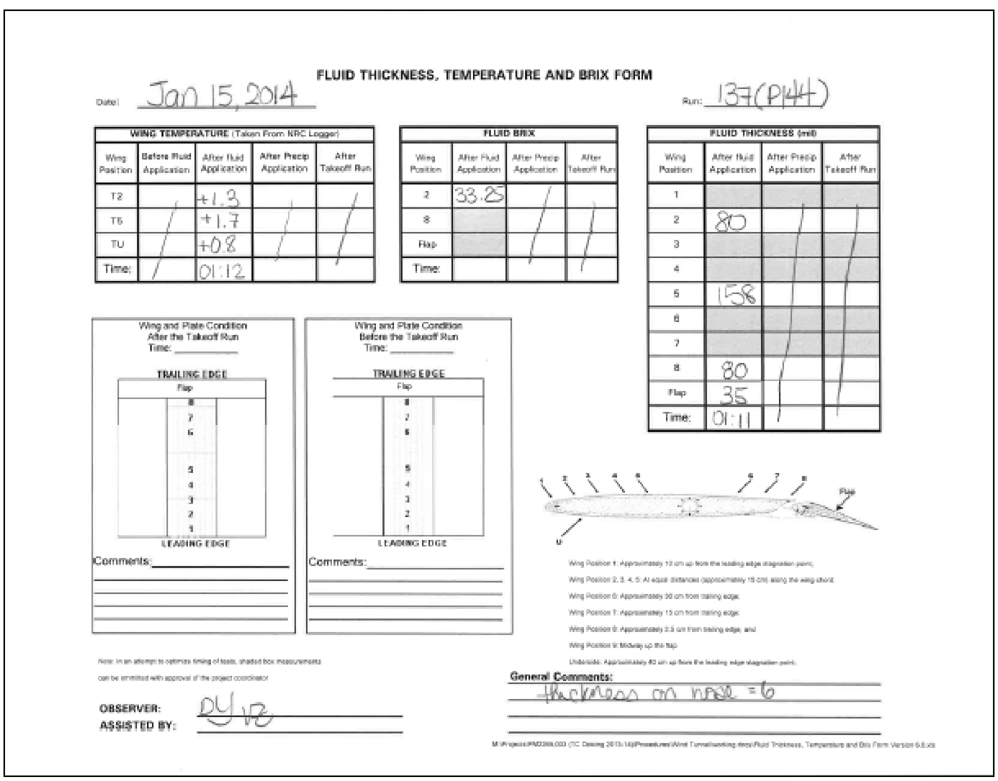
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap.
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: thickness on nose = 6 after run

OBSERVER: DY
ASSISTED BY: VB

Figure C7: Test # 136



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014   Run: 137(P144)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Run
T2	/	+1.3	/	/
T5	/	+1.7	/	/
TU	/	+0.8	/	/
Time:	/	01:12		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25	/	/
8		/	/
Flap		/	/
Time:			

FLUID THICKNESS (mil)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	/
3		/	/
4		/	/
5	158	/	/
6		/	/
7		/	/
8	80	/	/
Flap	35	/	/
Time:	01:11	/	

Wing and Plate Condition After the Takeoff Run
Time: ________
TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE
Comments: ________

Wing and Plate Condition Before the Takeoff Run
Time: ________
TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE
Comments: ________

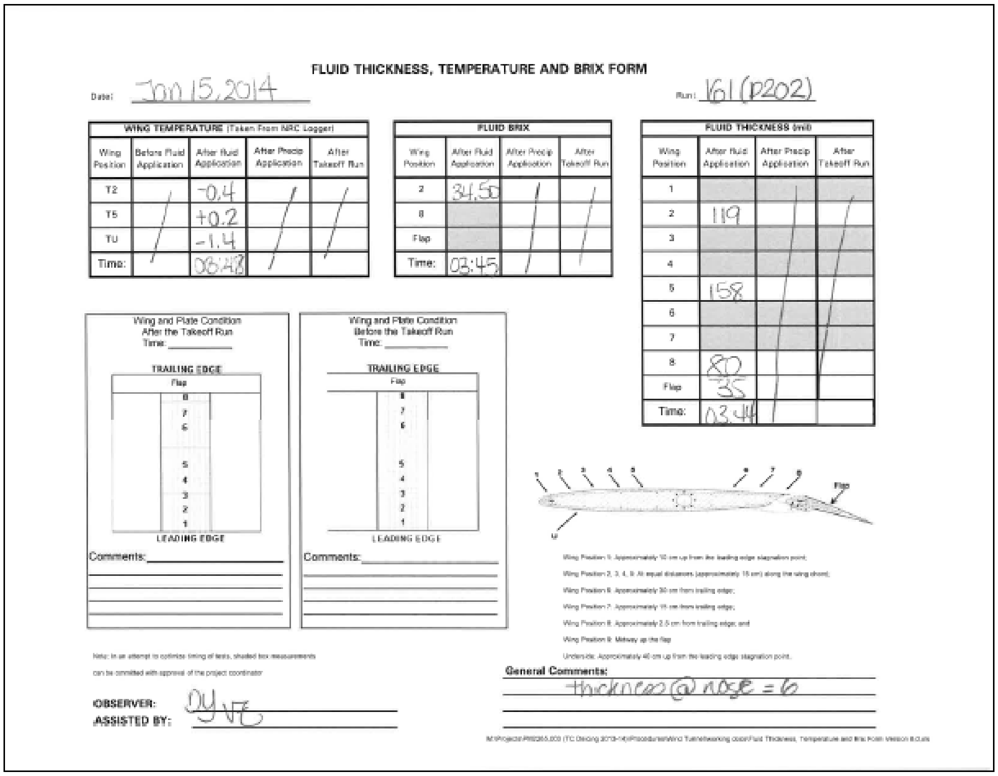
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap.
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: thickness on nose = 6

OBSERVER: DY
ASSISTED BY: VB

Figure C8: Test # 137



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014

Run: 161 (P202)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-0.4	/	/
T5	/	+0.2	/	/
TU	/	-1.4	/	/
Time:	/	03:48	/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.50	/	/
8		/	/
Flap		/	/
Time:	03:45	/	/

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	119	/	/
3		/	/
4		/	/
5	158	/	/
6		/	/
7		/	/
8	80	/	/
Flap	35	/	
Time:	03:44	/	

Wing and Plate Condition After the Takeoff Run Time: ____

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ____

Wing and Plate Condition Before the Takeoff Run Time: ____

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ____

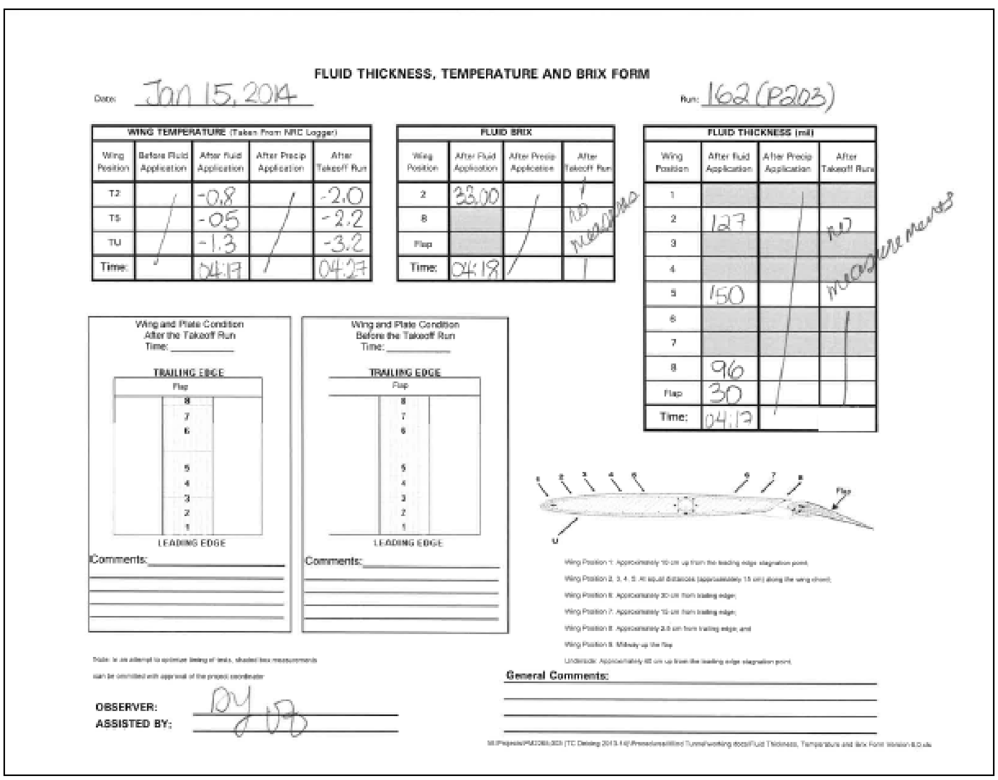
Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

OBSERVER: DY VF

ASSISTED BY:

General Comments: thickness @ nose = 6

Figure C9: Test # 161



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014

Run: 162 (P203)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-0.8	/	-2.0
T5	/	-05	/	-2.2
TU	/	-1.3	/	-3.2
Time:	/	04:17		04:27

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00	/	no measures
8		/	
Flap		/	
Time:	04:18	/	/

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	127	/	no measurements
3		/	
4		/	
5	150	/	
6		/	/
7		/	/
8	96	/	/
Flap	30	/	
Time:	04:17	/	

Wing and Plate Condition After the Takeoff Run Time: ____

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ____

Wing and Plate Condition Before the Takeoff Run Time: ____

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ____

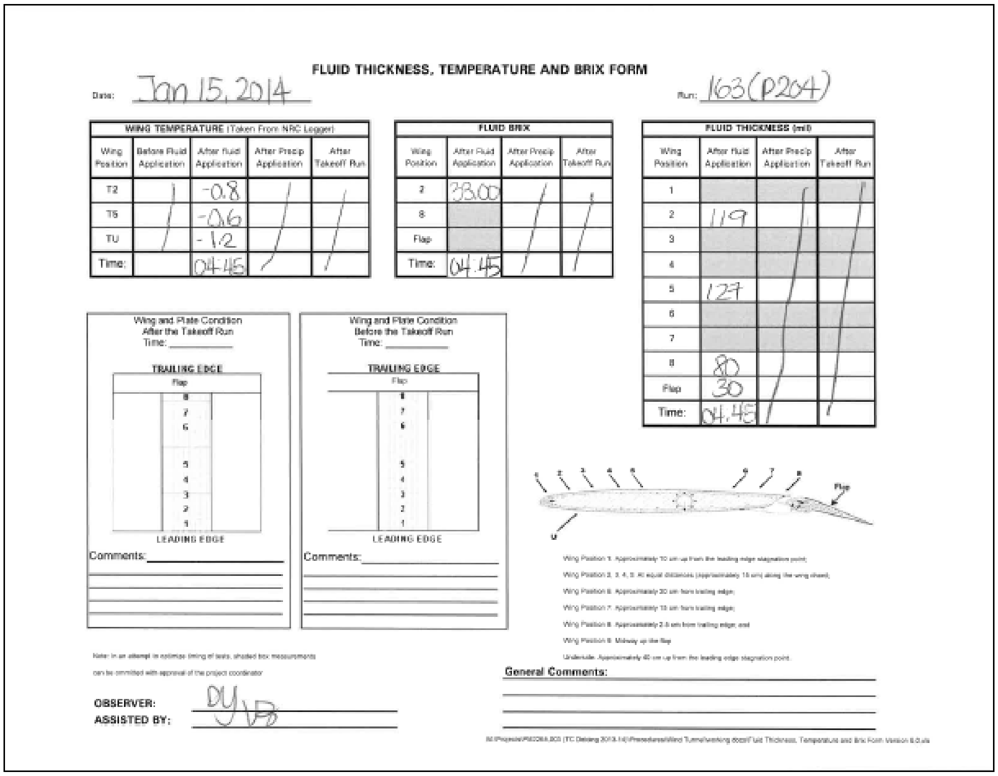
Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

OBSERVER: DY VB

ASSISTED BY:

General Comments:

Figure C10: Test # 162



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014

Run: 163 (P204)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2		-0.8		
T5		-0.6		
TU		-1.2		
Time:		04:45		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00		
8			
Flap			
Time:	04:45		

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	119		
3			
4			
5	127		
6			
7			
8	80		
Flap	30		
Time:	04.45		

Wing and Plate Condition After the Takeoff Run
Time: ________

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments:

Wing and Plate Condition Before the Takeoff Run
Time: ________

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

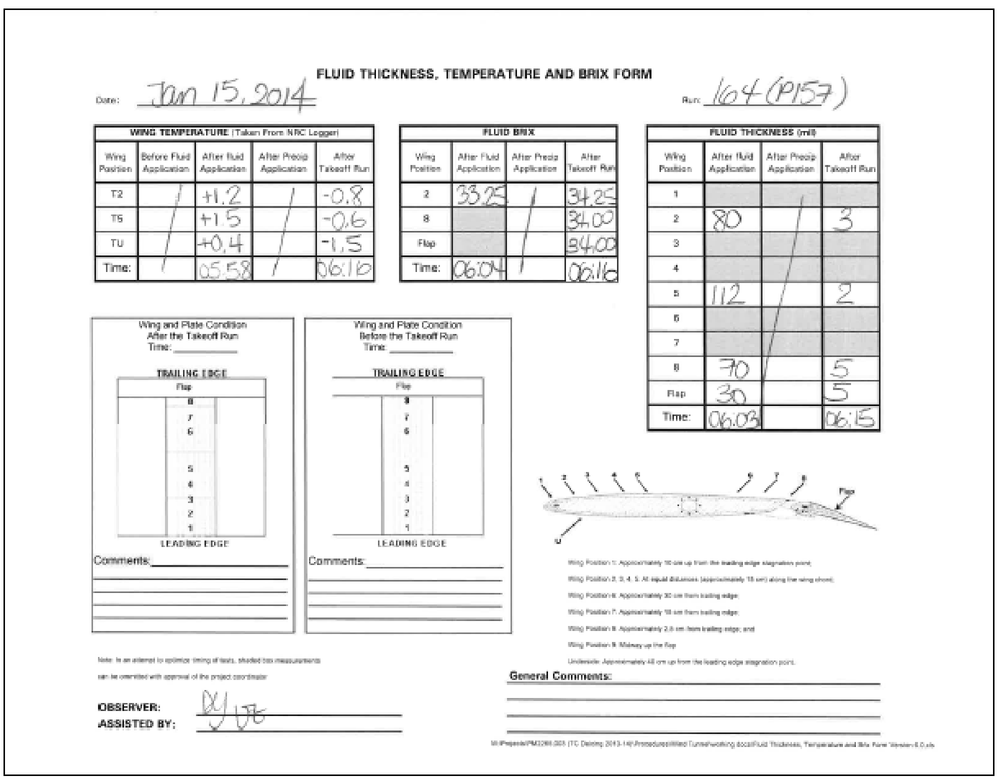
Comments:

1 2 3 4 5 6 7 8 Flap U

General Comments:

OBSERVER: DY
ASSISTED BY: VB

Figure C11: Test # 163



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014

Run: 164 (P157)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2		+1.2		-0.8
T5		+1.5		-0.6
TU		+0.4		-1.5
Time:		05:58		06:16

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25		34.25
8			34.00
Flap			34.00
Time:	06:04		06:16

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80		3
3			
4			
5	112		2
6			
7			
8	70		5
Flap	30		5
Time:	06:03		06:15

Wing and Plate Condition After the Takeoff Run
Time: ________

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments:

Wing and Plate Condition Before the Takeoff Run
Time: ________

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

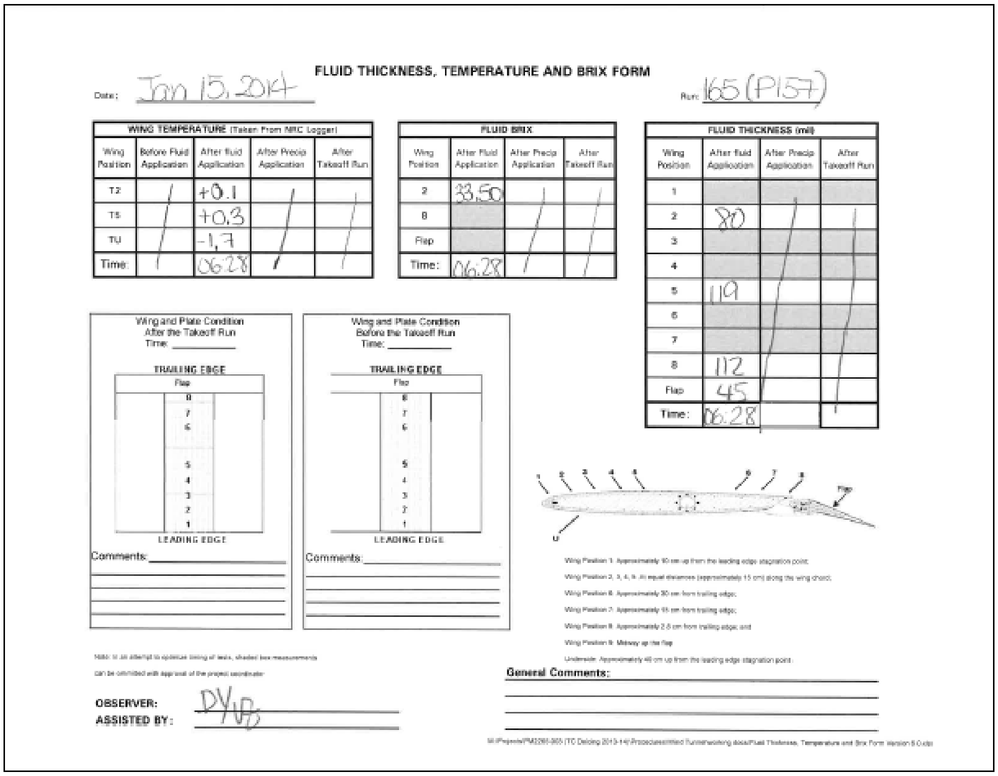
Comments:

1 2 3 4 5 6 7 8 Flap U

General Comments:

OBSERVER: DY
ASSISTED BY: VB

Figure C12: Test # 164



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014

Run: 165 (P157)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	+0.1	/	/
T5	/	+0.3	/	/
TU	/	-1.7	/	/
Time:	/	06:28	/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.50	/	/
8		/	/
Flap		/	/
Time:	06:28	/	/

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	/
3			
4			
5	119	/	/
6			
7			
8	112	/	/
Flap	45	/	/
Time:	06:28		

Wing and Plate Condition After the Takeoff Run Time: ______ — TRAILING EDGE, Flap, 8, 7, 6, 5, 4, 3, 2, 1, LEADING EDGE — Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______ — TRAILING EDGE, Flap, 8, 7, 6, 5, 4, 3, 2, 1, LEADING EDGE — Comments: ______

Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

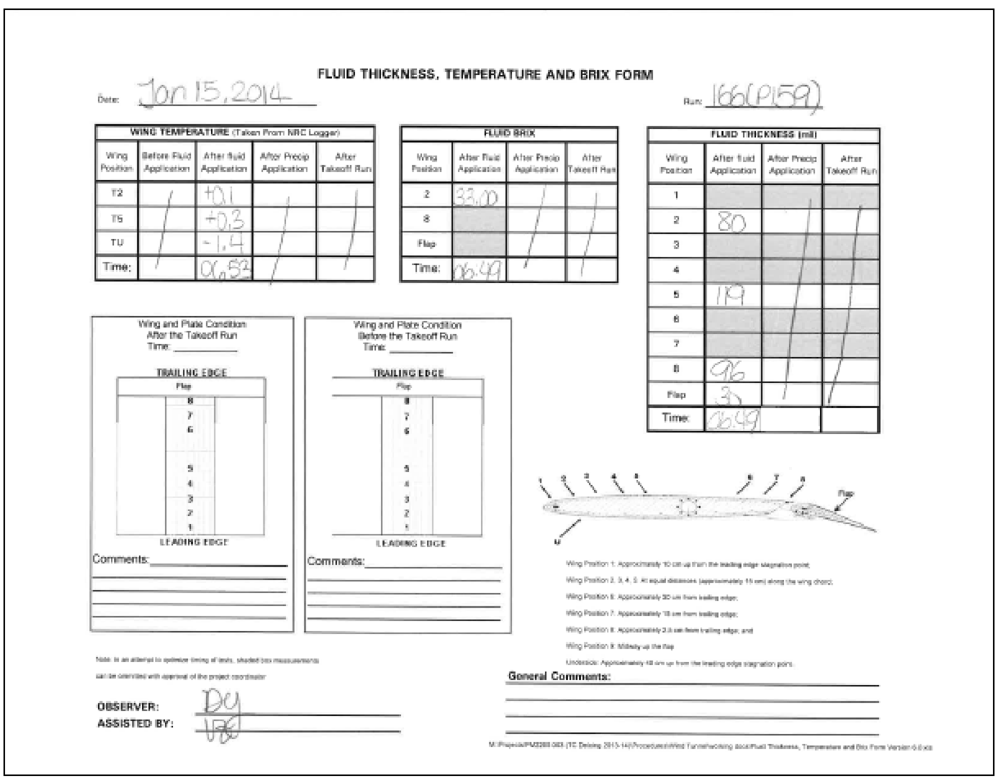
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: ______

OBSERVER: DY

ASSISTED BY: VB

Figure C13: Test # 165



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014

Run: 166 (P159)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	+0.1	/	/
T5	/	+0.3	/	/
TU	/	-1.4	/	/
Time:	/	06:53	/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00	/	/
8		/	/
Flap		/	/
Time:	06:49	/	/

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	/
3			
4			
5	119	/	/
6			
7			
8	96	/	/
Flap	31	/	/
Time:	06:49		

Wing and Plate Condition After the Takeoff Run Time: ______ — TRAILING EDGE, Flap, 8, 7, 6, 5, 4, 3, 2, 1, LEADING EDGE — Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______ — TRAILING EDGE, Flap, 8, 7, 6, 5, 4, 3, 2, 1, LEADING EDGE — Comments: ______

Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

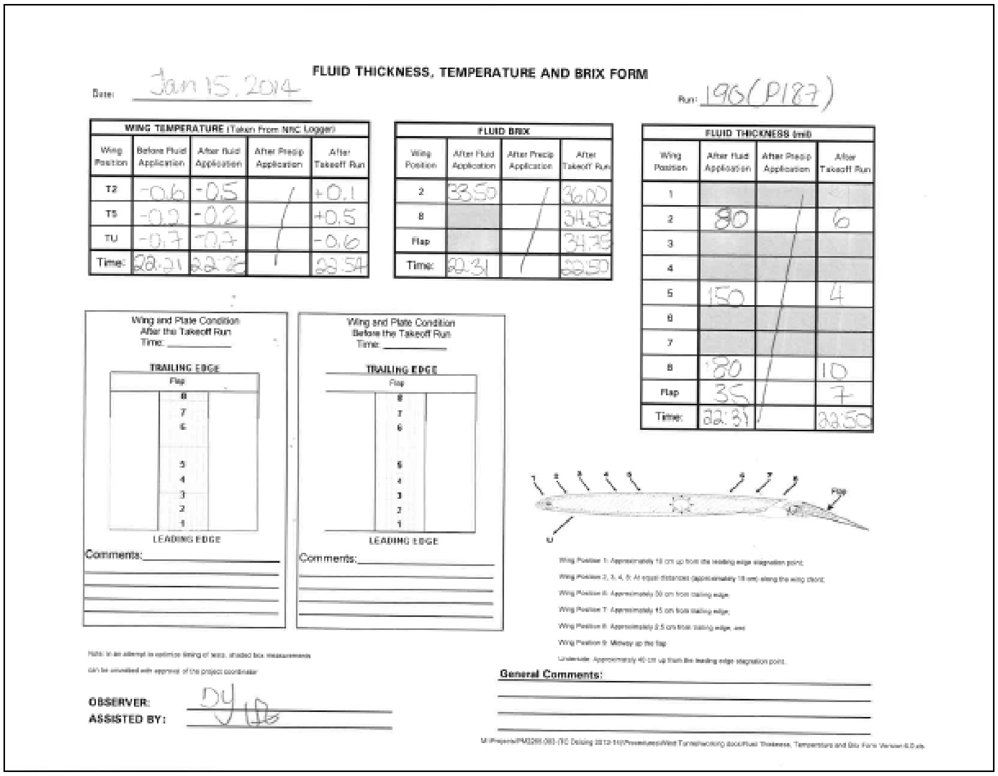
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: ______

OBSERVER: DY

ASSISTED BY: VB

Figure C14: Test # 166



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014

Run: 190(P187)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-0.6	-0.5	/	+0.1
T5	-0.2	-0.2	/	+0.5
TU	-0.7	-0.7	/	-0.6
Time:	22:21	22:26	/	22:54

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.50	/	36.00
8		/	34.50
Flap		/	34.75
Time:	22:31	/	22:50

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	80	/	6
3		/	
4		/	
5	150	/	4
6		/	
7		/	
8	80	/	10
Flap	35	/	7
Time:	22:31	/	22:50

Wing and Plate Condition After the Takeoff Run Time: ______ (TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE) Comments:

Wing and Plate Condition Before the Takeoff Run Time: ______ (TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE) Comments:

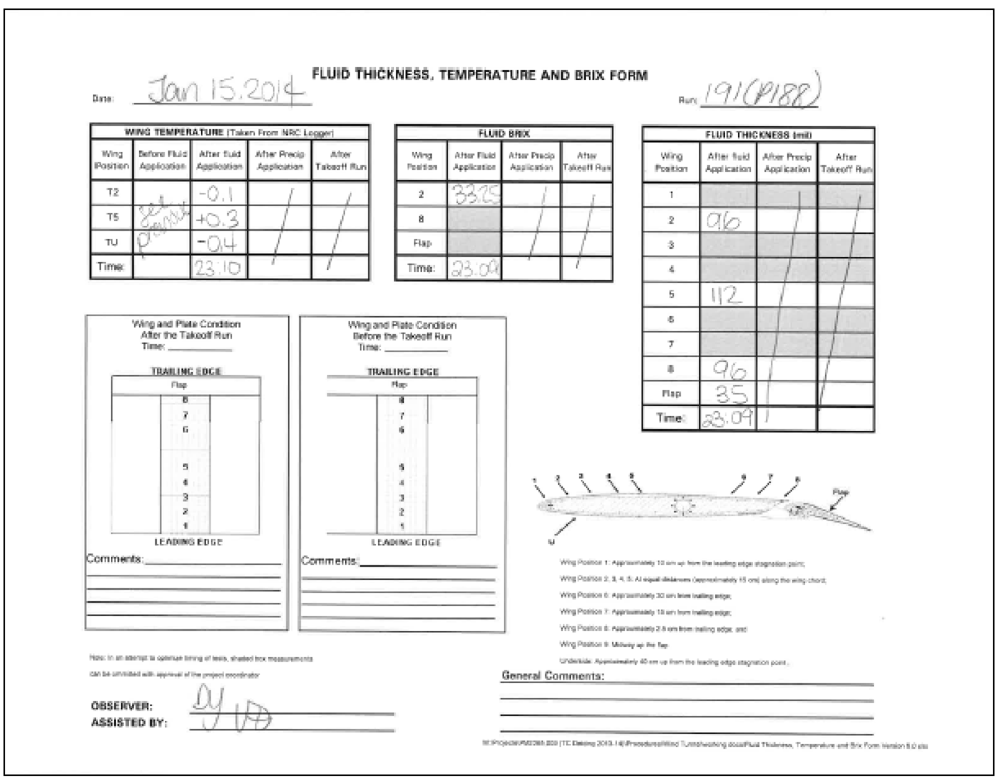
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

General Comments:

OBSERVER: DY
ASSISTED BY: JB

Figure C15: Test # 190



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014

Run: 191(P188)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	[illegible]	-0.1	/	/
T5	[illegible]	+0.3	/	/
TU	[illegible]	-0.4	/	/
Time:		23:10	/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25	/	/
8		/	/
Flap		/	/
Time:	23:09		/

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	/
2	96	/	/
3		/	/
4		/	/
5	112	/	/
6		/	/
7		/	/
8	96	/	/
Flap	35	/	/
Time:	23:09	/	

Wing and Plate Condition After the Takeoff Run Time: ______ (TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE) Comments:

Wing and Plate Condition Before the Takeoff Run Time: ______ (TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE) Comments:

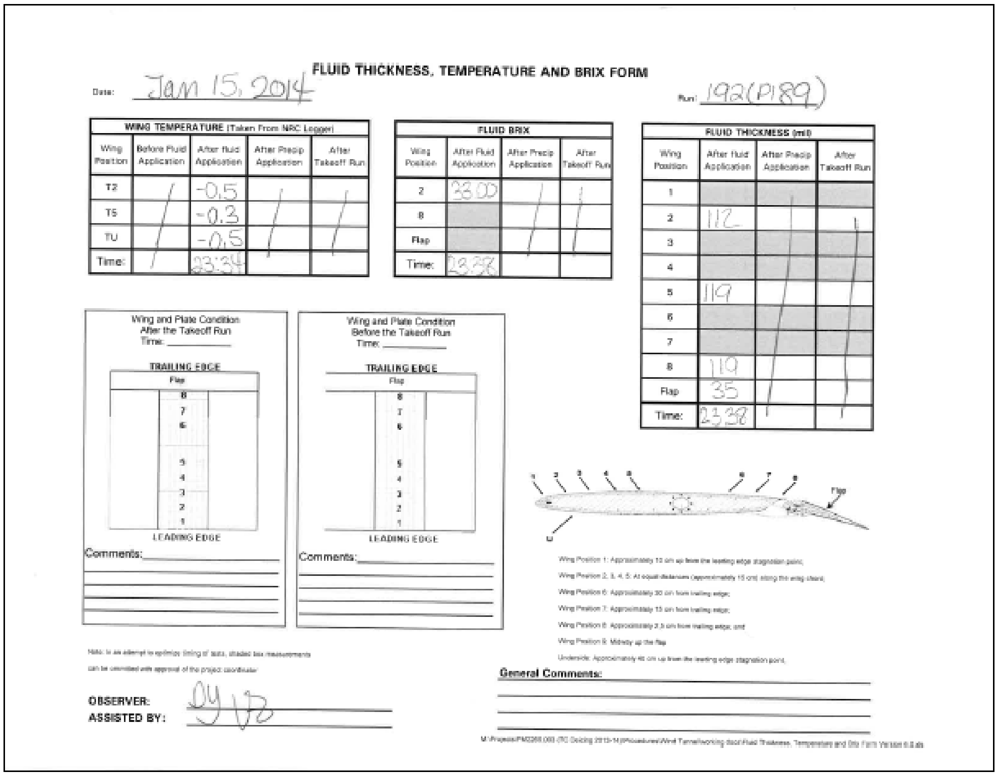
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

General Comments:

OBSERVER: DY
ASSISTED BY: JB

Figure C16: Test # 191



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15, 2014

Run: 192(P189)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-0.5	/	/
T5	/	-0.3	/	/
TU	/	-0.5	/	/
Time:	/	23:34		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00	/	/
8		/	/
Flap		/	/
Time:	23:38		

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	112	/	/
3		/	/
4		/	/
5	119	/	/
6		/	/
7		/	/
8	119	/	/
Flap	35	/	/
Time:	23:38	/	/

Wing and Plate Condition After the Takeoff Run Time:

Wing and Plate Condition Before the Takeoff Run Time:

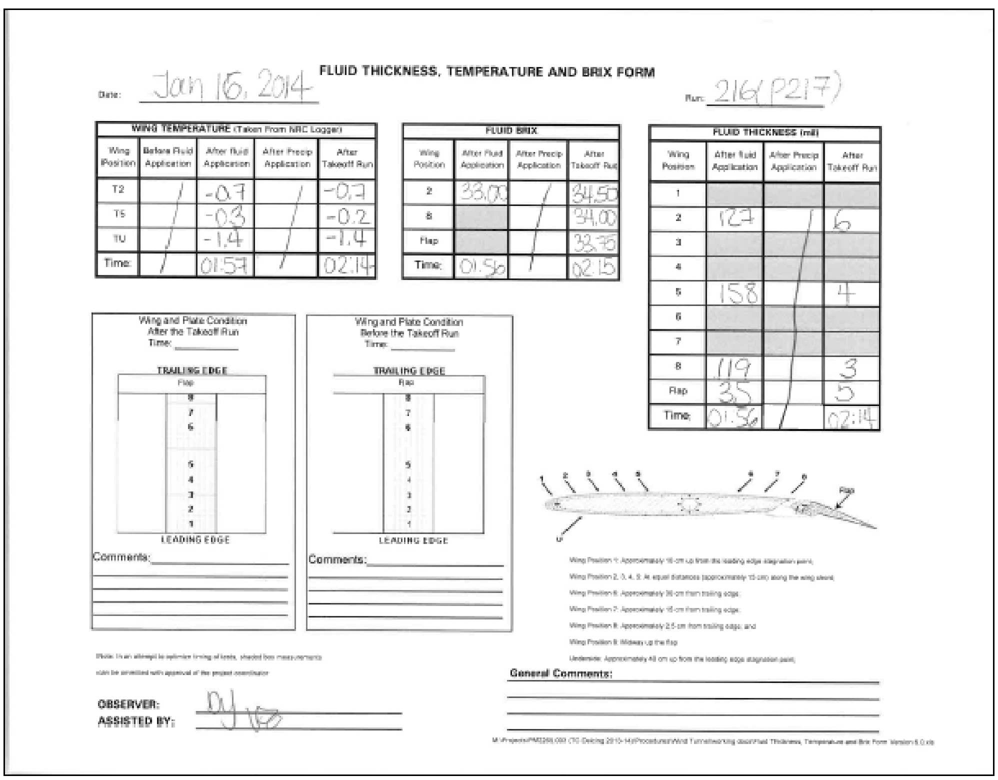
TRAILING EDGE / Flap / LEADING EDGE

Comments:

General Comments:

OBSERVER:
ASSISTED BY:

Figure C17: Test # 192



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 16, 2014

Run: 216(P217)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-0.7	/	-0.7
T5	/	-0.3	/	-0.2
TU	/	-1.4	/	-1.4
Time:	/	01:57	/	02:14

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00	/	34.50
8		/	34.00
Flap		/	33.75
Time:	01:56	/	02:15

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	127	/	6
3		/	
4		/	
5	158	/	4
6		/	
7		/	
8	119	/	3
Flap	35	/	5
Time:	01:56	/	02:14

Wing and Plate Condition After the Takeoff Run Time:

Wing and Plate Condition Before the Takeoff Run Time:

TRAILING EDGE / Flap / LEADING EDGE

Comments:

General Comments:

OBSERVER:
ASSISTED BY:

Figure C18: Test # 216

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 16, 2014

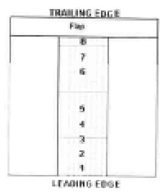
Run: 217 (P218)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-0.5	/	/
T5	/	-0.3	/	/
TU	/	-1.0	/	/
Time:	/	02:30	/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.50	/	/
8		/	/
Flap		/	/
Time:	02:31	/	/

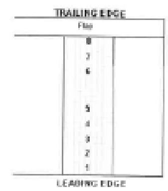
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	119		
3			
4			
5	127		
6			
7			
8	80		
Flap	30		
Time:	02:30		

Wing and Plate Condition
After the Takeoff Run
Time: ________

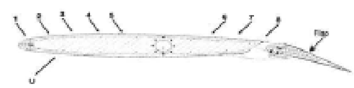


Comments: ________

Wing and Plate Condition
Before the Takeoff Run
Time: ________



Comments: ________



Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 10 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge, and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator.

General Comments:

OBSERVER:
ASSISTED BY:

M:\Projects\PM2265.003 (TC Deicing 2013-14)\Procedures\Wind Tunnel\working docs\Fluid Thickness, Temperature and Brix Form Version 6.0.xls

Figure C19: Test # 217

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 16, 2014

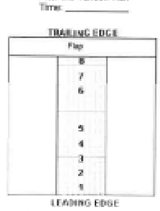
Run: 218 (P219)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-0.8	/	/
T5	/	-0.6	/	/
TU	/	-1.5	/	/
Time:	/	03:00	/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25	/	/
8		/	/
Flap		/	/
Time:	03:01	/	/

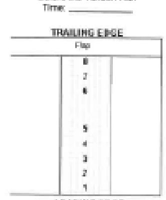
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	104		
3			
4			
5	150		
6			
7			
8	80		
Flap	30		
Time:	3.01		

Wing and Plate Condition
After the Takeoff Run
Time: ________

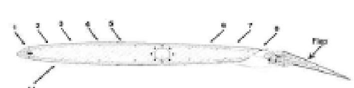


Comments: ________

Wing and Plate Condition
Before the Takeoff Run
Time: ________



Comments: ________



Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 10 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge, and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

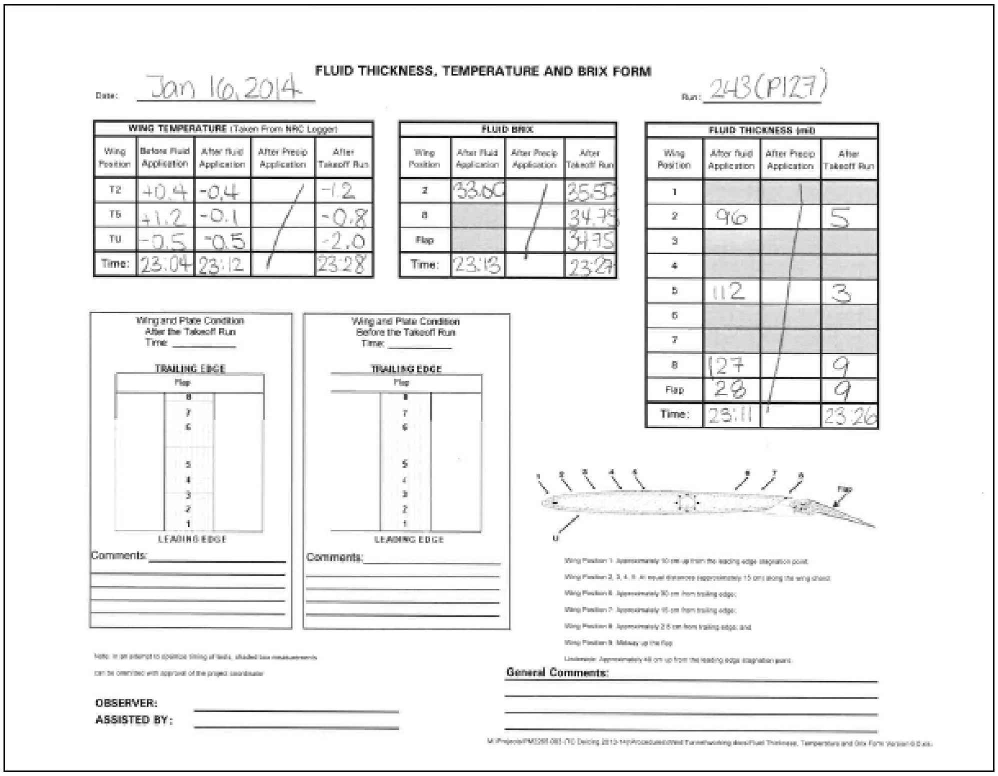
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator.

General Comments:

OBSERVER: DY
ASSISTED BY: JB

M:\Projects\PM2265.003 (TC Deicing 2013-14)\Procedures\Wind Tunnel\working docs\Fluid Thickness, Temperature and Brix Form Version 6.0.xls

Figure C20: Test # 218



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 16, 2014

Run: 243(P127)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	+0.4	-0.4		-1.2
T5	+1.2	-0.1		-0.8
TU	-0.5	-0.5		-2.0
Time:	23:04	23:12		23:28

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00		35.50
8			34.75
Flap			34.75
Time:	23:13		23:27

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96		5
3			
4			
5	112		3
6			
7			
8	127		9
Flap	28		9
Time:	23:11		23:26

Wing and Plate Condition After the Takeoff Run Time: ______

TRAILING EDGE / LEADING EDGE

Comments:

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / LEADING EDGE

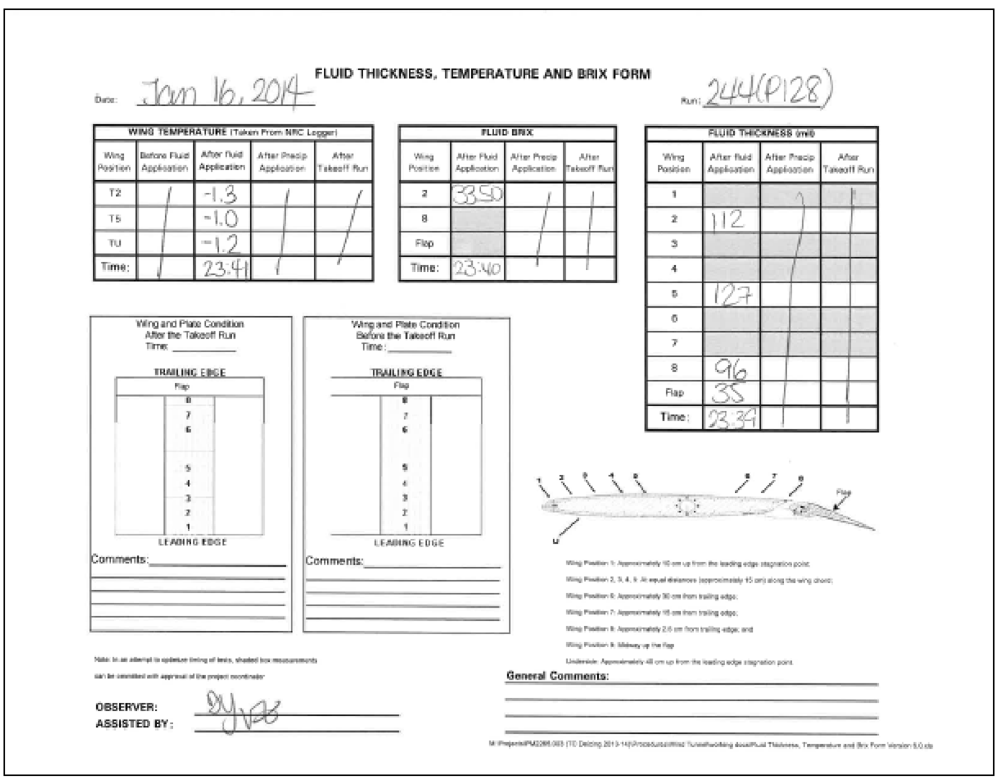
Comments:

General Comments:

OBSERVER:

ASSISTED BY:

Figure C21: Test # 243



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 16, 2014

Run: 244(P128)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2		-1.3		
T5		-1.0		
TU		-1.2		
Time:		23:41		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.50		
8			
Flap			
Time:	23:40		

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	112		
3			
4			
5	127		
6			
7			
8	96		
Flap	35		
Time:	23:39		

Wing and Plate Condition After the Takeoff Run Time: ______

TRAILING EDGE / LEADING EDGE

Comments:

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / LEADING EDGE

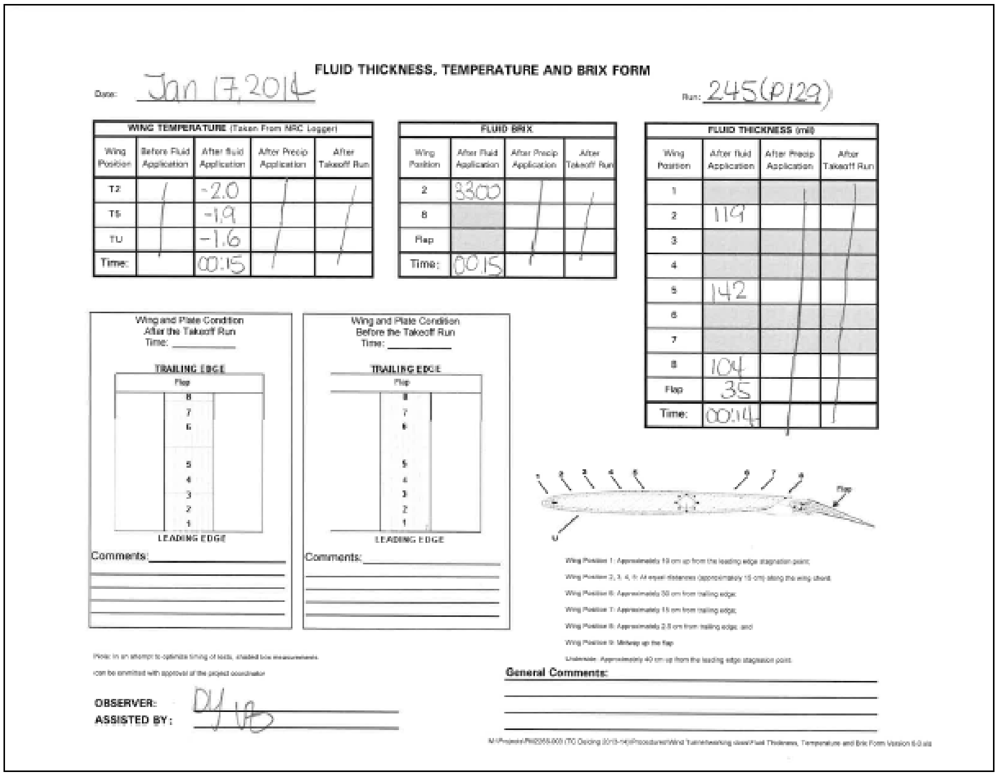
Comments:

General Comments:

OBSERVER:

ASSISTED BY:

Figure C22: Test # 244



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 17, 2014 Run: 245(P129)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2		-2.0		
T5		-1.9		
TU		-1.6		
Time:		00:15		

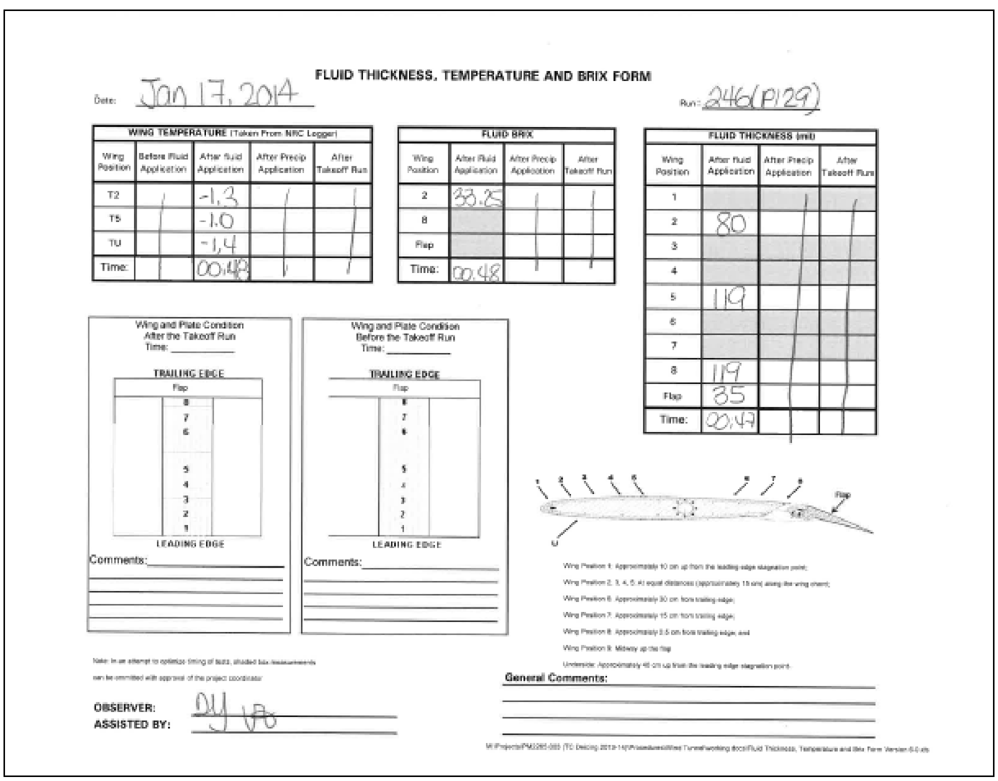
FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00		
8			
Flap			
Time:	00:15		

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	119		
3			
4			
5	142		
6			
7			
8	104		
Flap	35		
Time:	00:14		

Wing and Plate Condition After the Takeoff Run / Wing and Plate Condition Before the Takeoff Run

OBSERVER: DY
ASSISTED BY: VB

Figure C23: Test # 245



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 17, 2014 Run: 246(P129)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2		-1.3		
T5		-1.0		
TU		-1.4		
Time:		00:48		

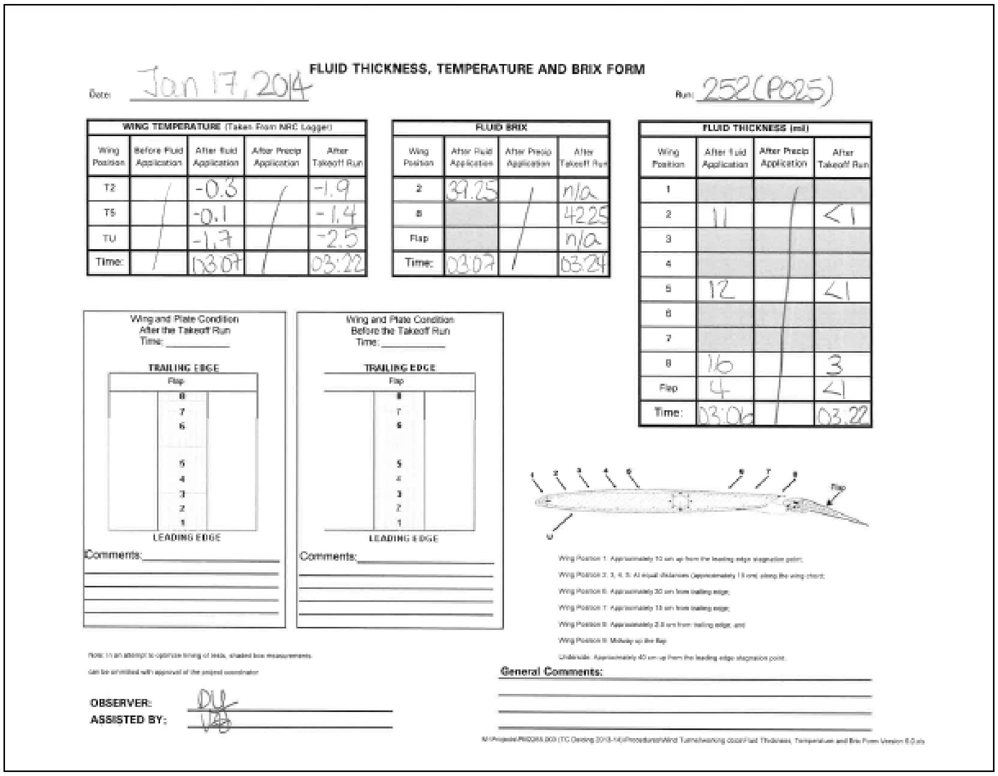
FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25		
8			
Flap			
Time:	00:48		

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80		
3			
4			
5	119		
6			
7			
8	119		
Flap	35		
Time:	00:47		

Wing and Plate Condition After the Takeoff Run / Wing and Plate Condition Before the Takeoff Run

OBSERVER: DY
ASSISTED BY: VB

Figure C24: Test # 246



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 17, 2014

Run: 252 (P025)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-0.3	/	-1.9
T5	/	-0.1	/	-1.4
TU	/	-1.7	/	-2.5
Time:	/	03:07	/	03:22

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	39.25	/	n/a
8		/	42.25
Flap		/	n/a
Time:	03:07	/	03:24

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	11	/	<1
3		/	
4		/	
5	12	/	<1
6		/	
7		/	
8	16	/	3
Flap	4	/	<1
Time:	03:06	/	03:22

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

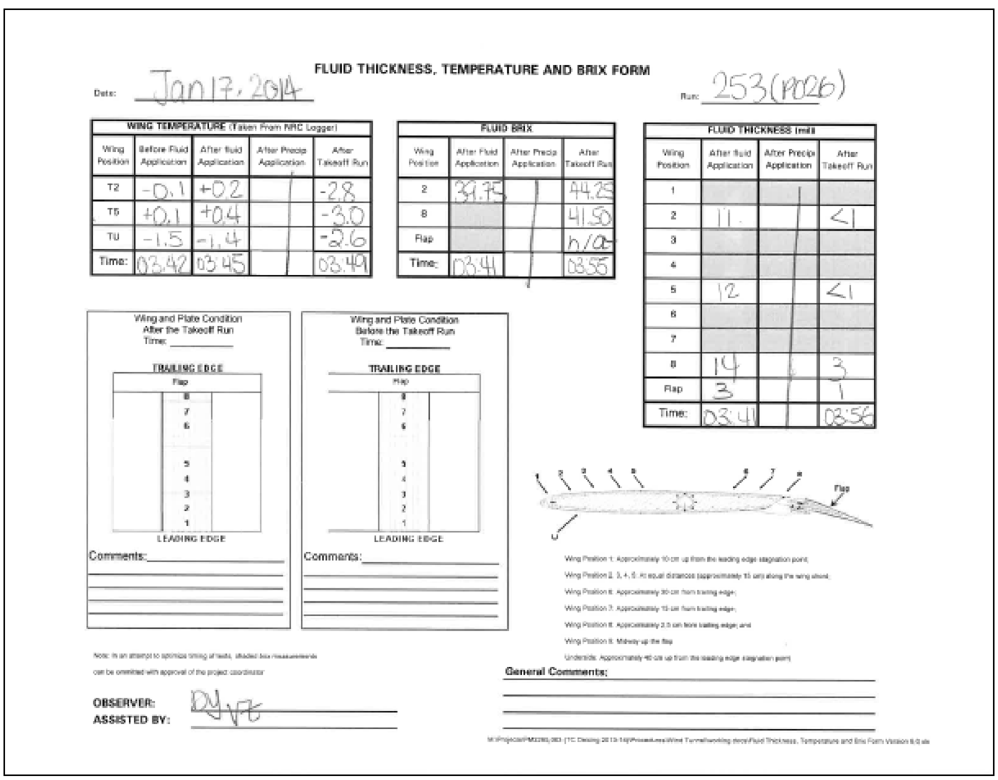
Comments: ______

General Comments: ______

OBSERVER: DY

ASSISTED BY: VB

Figure C25: Test # 252



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 17, 2014

Run: 253 (P026)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-0.1	+0.2	/	-2.8
T5	+0.1	+0.4	/	-3.0
TU	-1.5	-1.4	/	-2.6
Time:	03:42	03:45	/	03:49

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	39.75	/	44.25
8		/	41.50
Flap		/	n/a
Time:	03:41	/	03:55

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	11	/	<1
3		/	
4		/	
5	12	/	<1
6		/	
7		/	
8	14	/	3
Flap	3	/	1
Time:	03:41	/	03:56

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

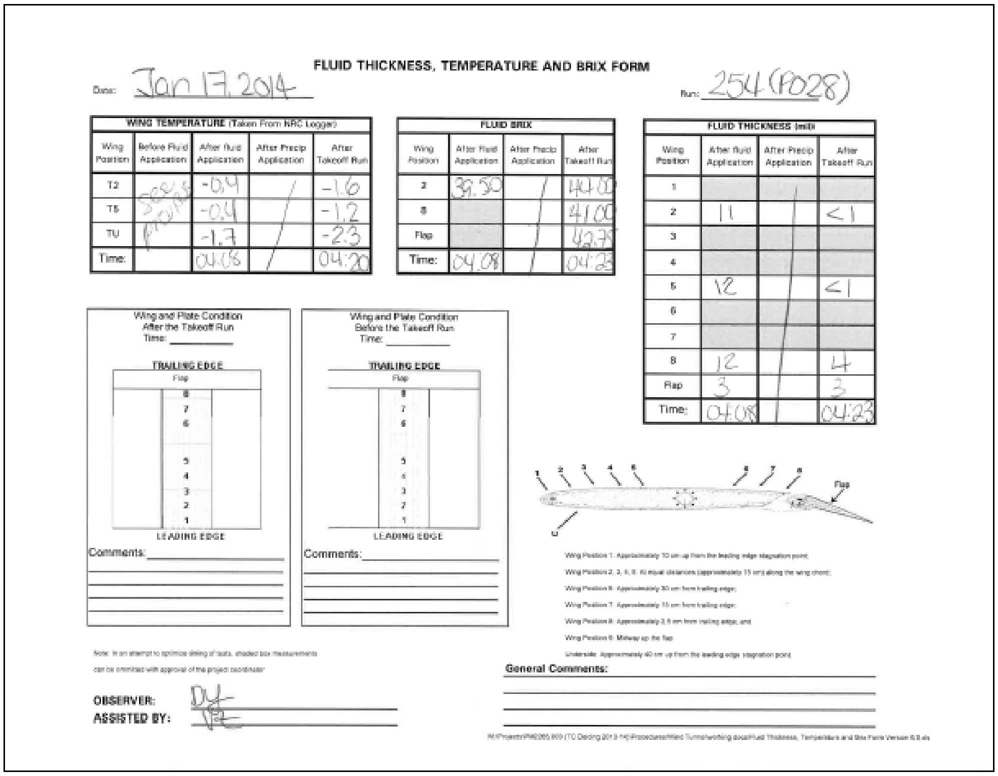
Comments: ______

General Comments: ______

OBSERVER: DY / VB

ASSISTED BY:

Figure C26: Test # 253



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 17, 2014

Run: 254 (P028)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-0.4	/	-1.6
T5		-0.4	/	-1.2
TU		-1.7	/	-2.3
Time:		04:08	/	04:20

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	39.50	/	44.00
8		/	41.00
Flap		/	42.75
Time:	04:08	/	04:23

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	11	/	<1
3		/	
4		/	
5	12	/	<1
6		/	
7		/	
8	12	/	4
Flap	3	/	3
Time:	04:08	/	04:23

Wing and Plate Condition After the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

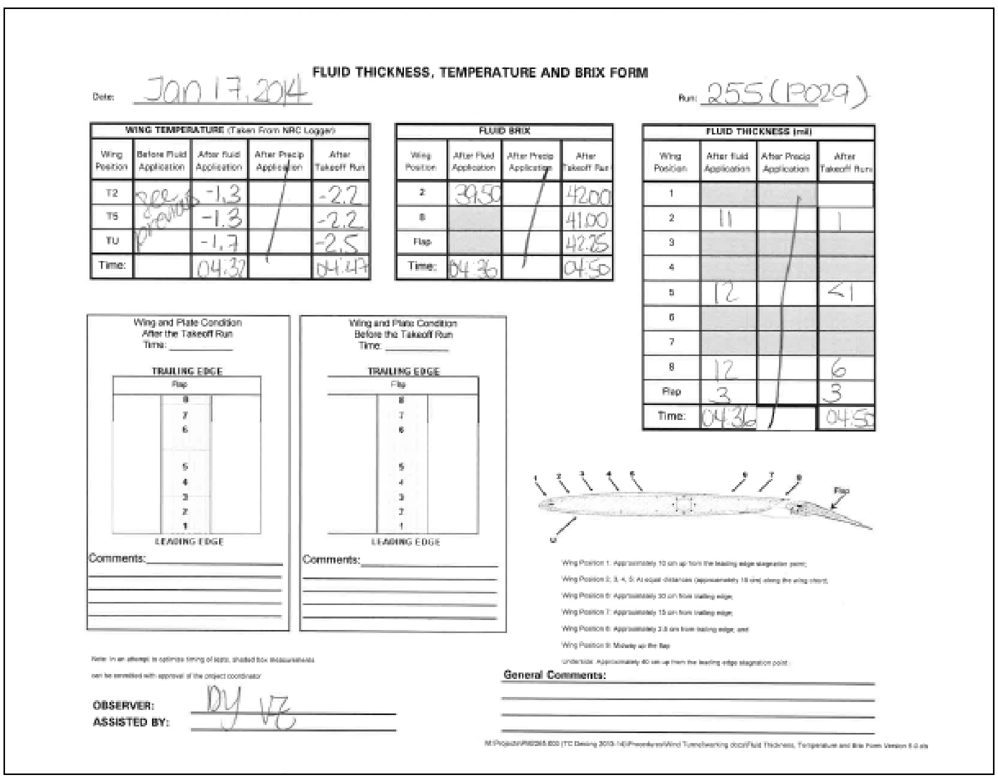
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommited with approval of the project coordinator

General Comments:

OBSERVER: DY
ASSISTED BY: VZ

Figure C27: Test # 254



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 17, 2014

Run: 255 (P029)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-1.3	/	-2.2
T5		-1.3	/	-2.2
TU		-1.7	/	-2.5
Time:		04:37	/	04:47

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	39.50	/	42.00
8		/	41.00
Flap		/	42.75
Time:	04:36	/	04:50

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	11	/	1
3		/	
4		/	
5	12	/	<1
6		/	
7		/	
8	12	/	6
Flap	3	/	3
Time:	04:36	/	04:55

Wing and Plate Condition After the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommited with approval of the project coordinator

General Comments:

OBSERVER: DY
ASSISTED BY: VZ

Figure C28: Test # 255

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 17, 2014

Run: 258 (P028)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-0.6	/	-1.7
T5	/	-0.5	/	-1.3
TU	/	-1.7	/	-2.3
Time:	/	05:36	/	05:47

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	40.00	/	44.00
8		/	40.75
Flap		/	41.25
Time:	05:35	/	05:48

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	12	/	1
3		/	
4		/	
5	12	/	<1
6		/	
7		/	
8	14	/	3
Flap	3	/	<1
Time:	05:35	/	05:47

Wing and Plate Condition After the Takeoff Run
Time: ________

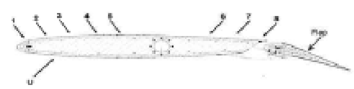
TRAILING EDGE
Flap
8
7
6
5
4
3
2
1
LEADING EDGE

Comments: ________

Wing and Plate Condition Before the Takeoff Run
Time: ________

TRAILING EDGE
Flap
8
7
6
5
4
3
2
1
LEADING EDGE

Comments: ________



Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

OBSERVER: DY
ASSISTED BY: JVB

General Comments: ________

M:\Projects\PM2265.003 (TC Deicing 2013-14)\Procedures\Wind Tunnel\working docs\Fluid Thickness, Temperature and Brix Form Version 6.0.xls

Figure C29: Test # 258

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 17, 2014

Run: 259 (P028)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-0.7	/	-3.0
T5	/	-0.7	/	-3.1
TU	/	-1.7	/	-2.7
Time:	/	05:56	/	06:04

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	39.25	/	43.50
8		/	41.25
Flap		/	43.00
Time:	05:58	/	06:09

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	11	/	1
3		/	
4		/	
5	12	/	<1
6		/	
7		/	
8	12	/	2
Flap	3	/	<1
Time:	05:57	/	06:08

Wing and Plate Condition After the Takeoff Run
Time: ________

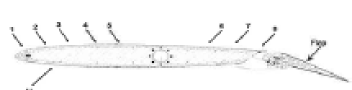
TRAILING EDGE
Flap
8
7
6
5
4
3
2
1
LEADING EDGE

Comments: ________

Wing and Plate Condition Before the Takeoff Run
Time: ________

TRAILING EDGE
Flap
8
7
6
5
4
3
2
1
LEADING EDGE

Comments: ________



Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

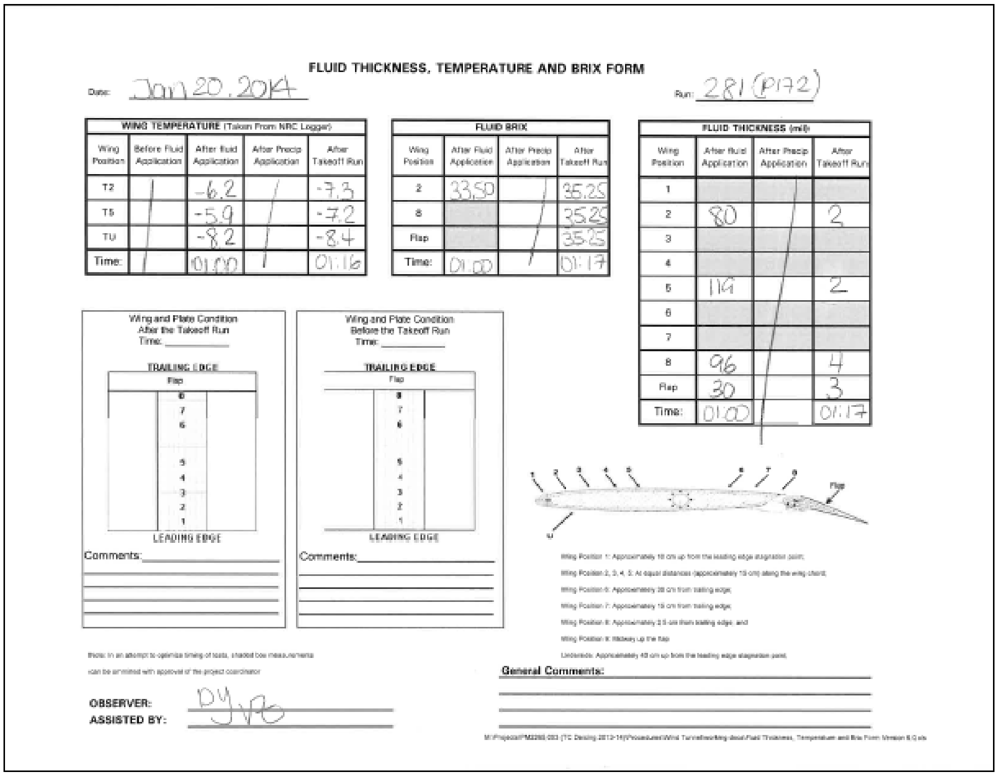
Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

OBSERVER: DY
ASSISTED BY: JVB

General Comments: ________

M:\Projects\PM2265.003 (TC Deicing 2013-14)\Procedures\Wind Tunnel\working docs\Fluid Thickness, Temperature and Brix Form Version 6.0.xls

Figure C30: Test # 259



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20, 2014

Run: 281 (P172)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-6.2	/	-7.3
T5	/	-5.9		-7.2
TU	/	-8.2		-8.4
Time:	/	01:00	/	01:16

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.50	/	35.25
8		/	35.25
Flap		/	35.25
Time:	01:00	/	01:17

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	80	/	2
3		/	
4		/	
5	119	/	2
6		/	
7		/	
8	96	/	4
Flap	30	/	3
Time:	01:00	/	01:17

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

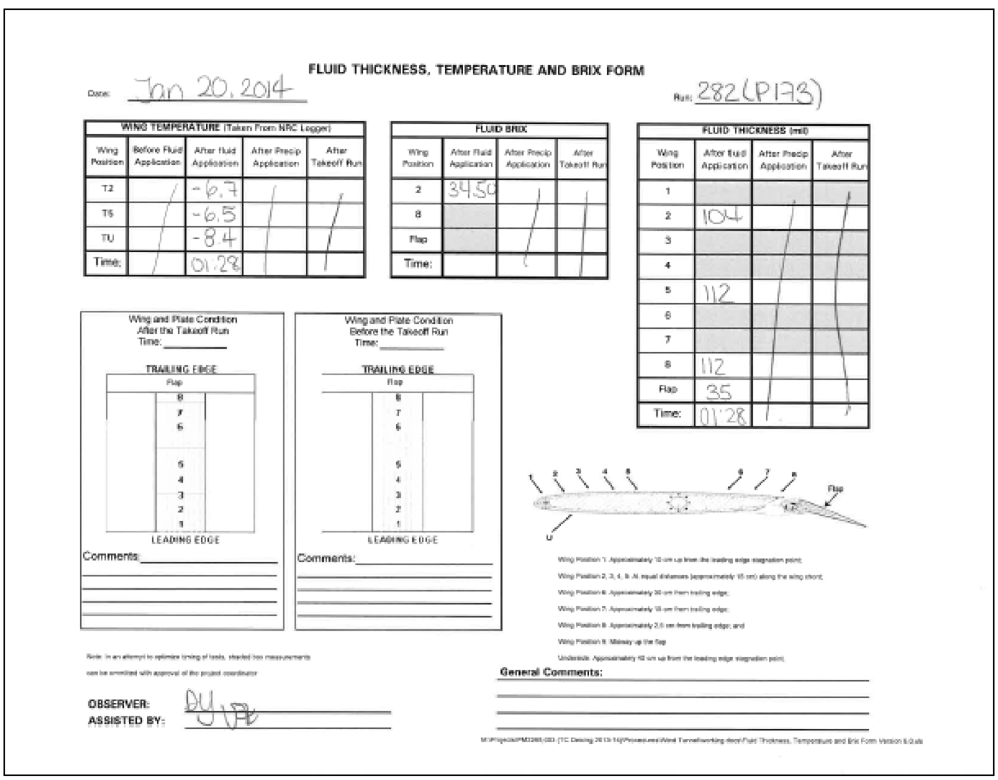
Comments: ______

OBSERVER: DY

ASSISTED BY:

General Comments: ______

Figure C31: Test # 281



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20, 2014

Run: 282 (P173)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-6.7		/
T5	/	-6.5	/	/
TU	/	-8.4		/
Time:	/	01:28		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.50	/	/
8		/	/
Flap		/	/
Time:		(	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	104	/	/
3		/	/
4		/	/
5	112	/	/
6		/	/
7		/	/
8	112	/	/
Flap	35	/	/
Time:	01:28	/	/

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

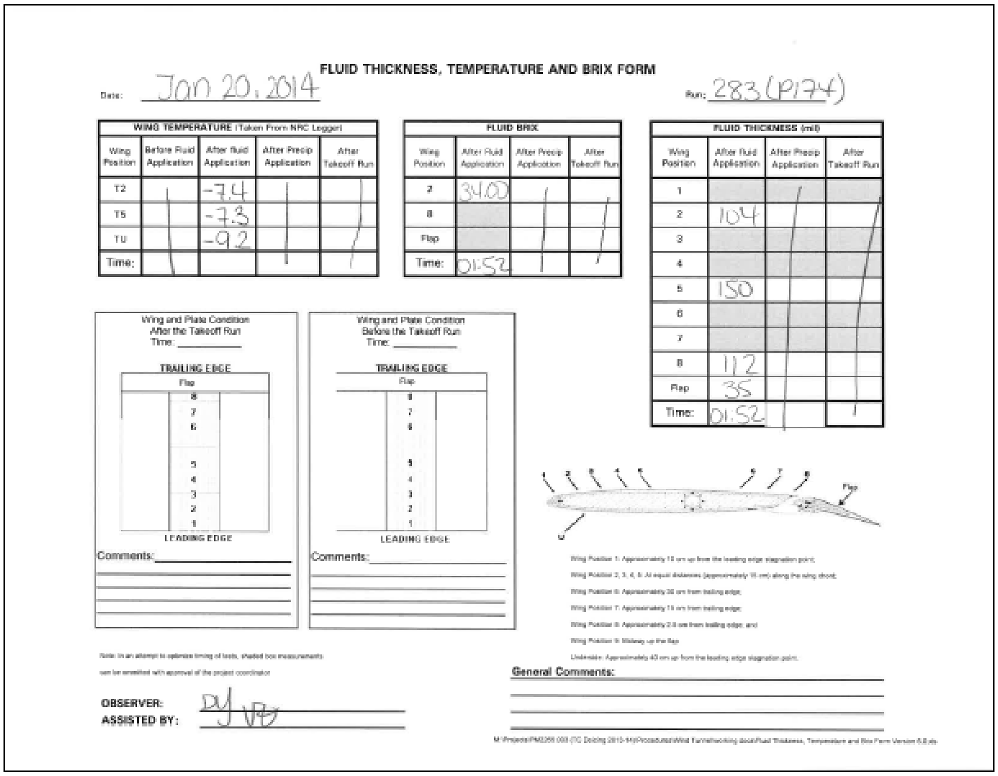
Comments: ______

OBSERVER: DY

ASSISTED BY:

General Comments: ______

Figure C32: Test # 282



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20, 2014

Run: 283 (P174)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-7.4	/	/
T5	/	-7.3	/	/
TU	/	-9.2	/	/
Time:	/		/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.00	/	/
8		/	/
Flap		/	/
Time:	01:52	/	/

FLUID THICKNESS (mil)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1		/	/
2	104	/	/
3		/	/
4		/	/
5	150	/	/
6		/	/
7		/	/
8	112	/	/
Flap	35	/	/
Time:	01:52	/	/

Wing and Plate Condition After the Takeoff Run Time: ______

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments: ______

1 2 3 4 5 6 7 8 Flap U

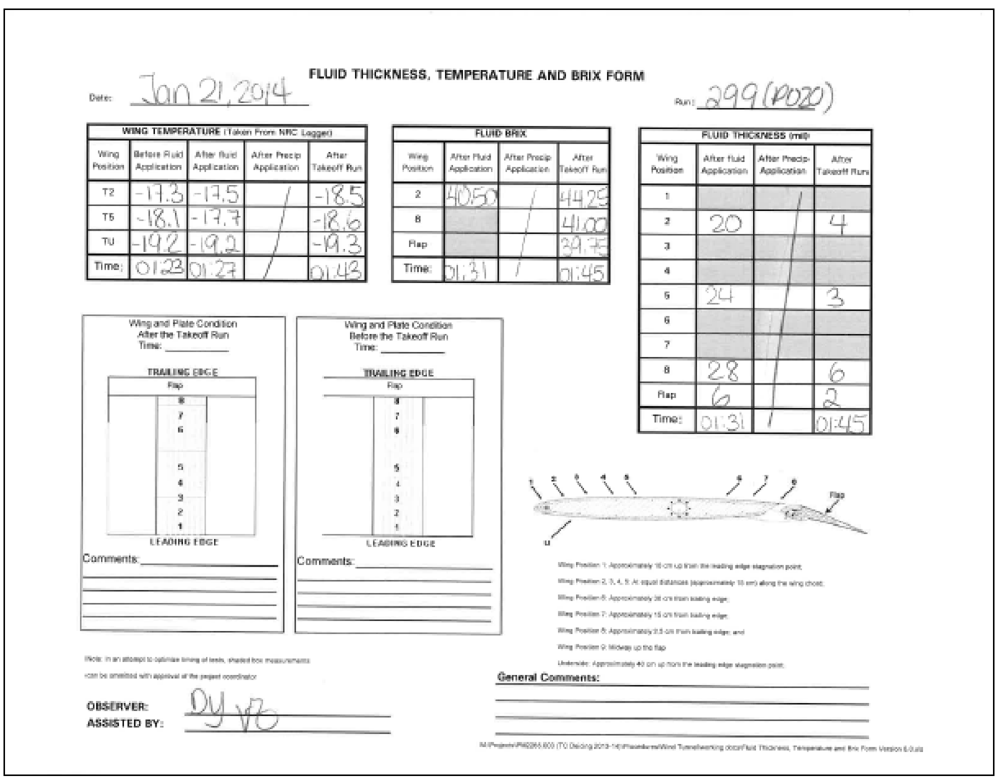
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

General Comments: ______

OBSERVER: DY
ASSISTED BY: VB

Figure C33: Test # 283



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 21, 2014

Run: 299 (P020)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-17.3	-17.5	/	-18.5
T5	-18.1	-17.7	/	-18.6
TU	-19.2	-19.2	/	-19.3
Time:	01:23	01:27	/	01:43

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	40.50	/	44.25
8		/	41.00
Flap		/	39.75
Time:	01:31	/	01:45

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	20	/	4
3		/	
4		/	
5	24	/	3
6		/	
7		/	
8	28	/	6
Flap	6	/	2
Time:	01:31	/	01:45

Wing and Plate Condition After the Takeoff Run Time: ______

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments: ______

1 2 3 4 5 6 7 8 Flap U

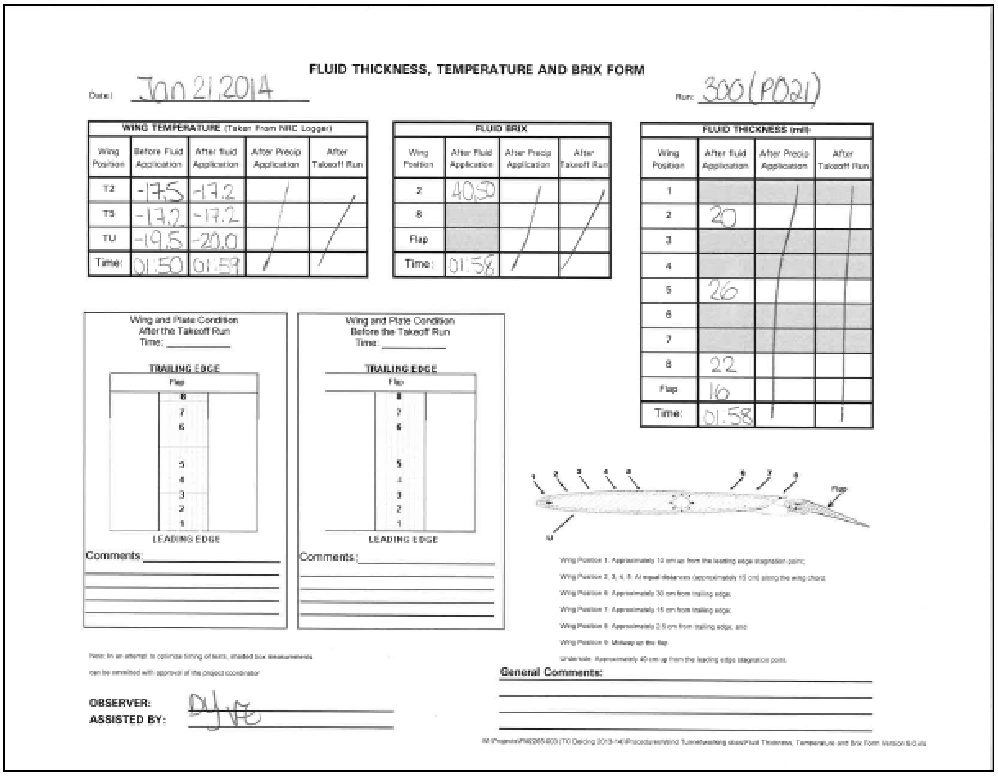
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

General Comments: ______

OBSERVER: DY
ASSISTED BY: VB

Figure C34: Test # 299



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 21, 2014 Run: 300 (P021)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-17.5	-17.2	/	/
T5	-17.2	-17.2	/	/
TU	-19.5	-20.0	/	/
Time:	01:50	01:58	/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	40.50	/	/
8		/	/
Flap		/	/
Time:	01:58	/	/

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	20		
3			
4			
5	26		
6			
7			
8	22		
Flap	16		
Time:	01:58		

Wing and Plate Condition After the Takeoff Run Time: ___

Wing and Plate Condition Before the Takeoff Run Time: ___

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

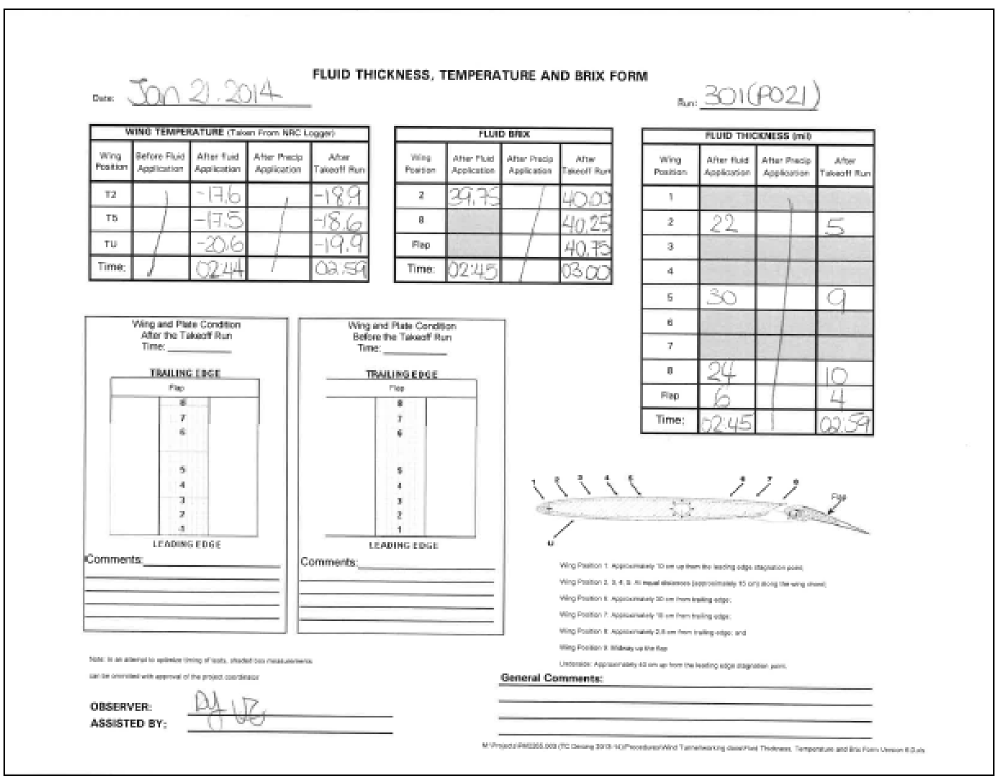
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap.
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be revisited with approval of the project coordinator

General Comments:

OBSERVER: DY
ASSISTED BY: VB

Figure C35: Test # 300



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 21, 2014 Run: 301 (P021)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-17.6	/	-18.9
T5	/	-17.5	/	-18.6
TU	/	-20.6	/	-19.9
Time:	/	02:44	/	02:59

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	39.75	/	40.00
8		/	40.25
Flap		/	40.75
Time:	02:45	/	03:00

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	22		5
3			
4			
5	30		9
6			
7			
8	24		10
Flap	6		4
Time:	02:45		02:59

Wing and Plate Condition After the Takeoff Run Time: ___

Wing and Plate Condition Before the Takeoff Run Time: ___

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

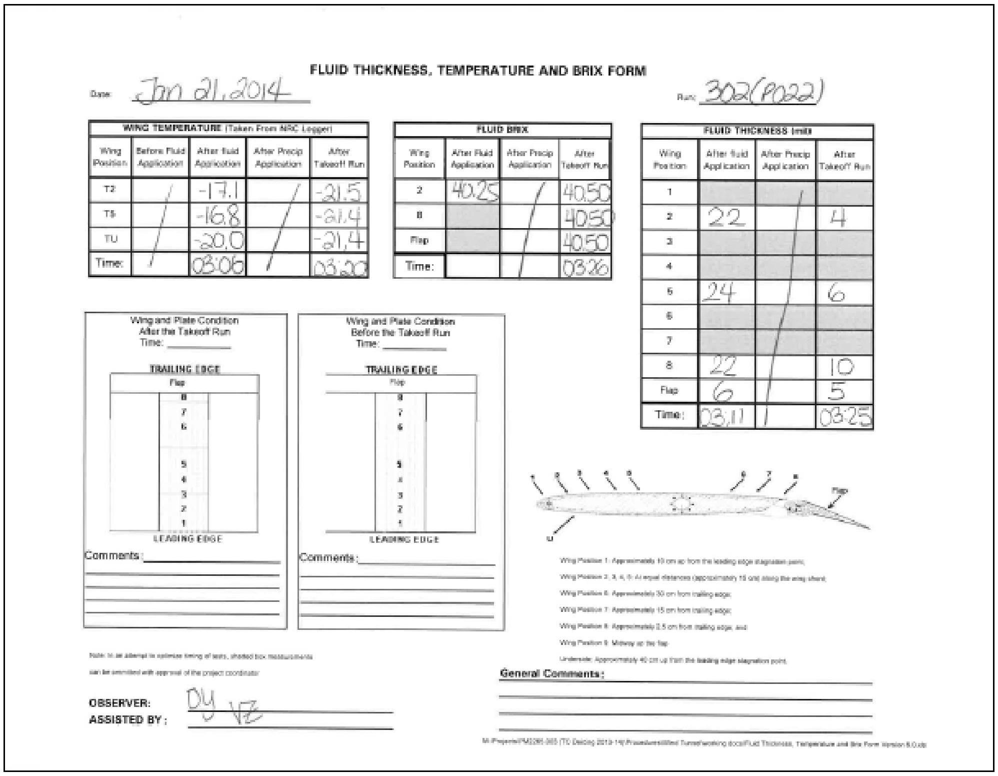
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap.
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be overridden with approval of the project coordinator

General Comments:

OBSERVER: DY
ASSISTED BY: VB

Figure C36: Test # 301



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 21, 2014

Run: 302(P022)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-17.1	/	-21.5
T5	/	-16.8	/	-21.4
TU	/	-20.0	/	-21.4
Time:	/	03:06	/	03:20

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	40.25	/	40.50
8		/	40.50
Flap		/	40.50
Time:		/	03:26

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	22	/	4
3			
4			
5	24	/	6
6			
7			
8	22	/	10
Flap	6	/	5
Time:	03:11	/	03:25

Wing and Plate Condition After the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ______

Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

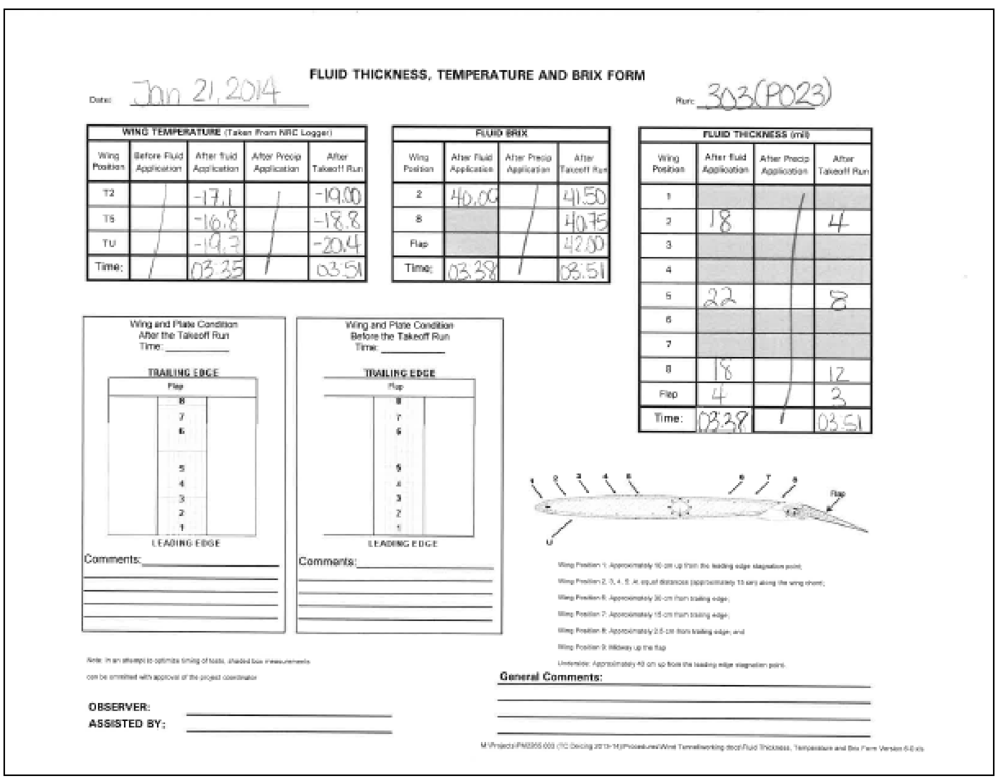
Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

General Comments: ______

OBSERVER: DY

ASSISTED BY: VZ

Figure C37: Test # 302



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 21, 2014

Run: 303(P023)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-17.1	/	-19.00
T5	/	-16.8	/	-18.8
TU	/	-19.3	/	-20.4
Time:	/	03:25	/	03:51

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	40.00	/	41.50
8		/	40.75
Flap		/	42.00
Time:	03:38	/	03:51

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	18	/	4
3			
4			
5	22	/	8
6			
7			
8	18	/	12
Flap	4	/	3
Time:	03:38	/	03:51

Wing and Plate Condition After the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ______

Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

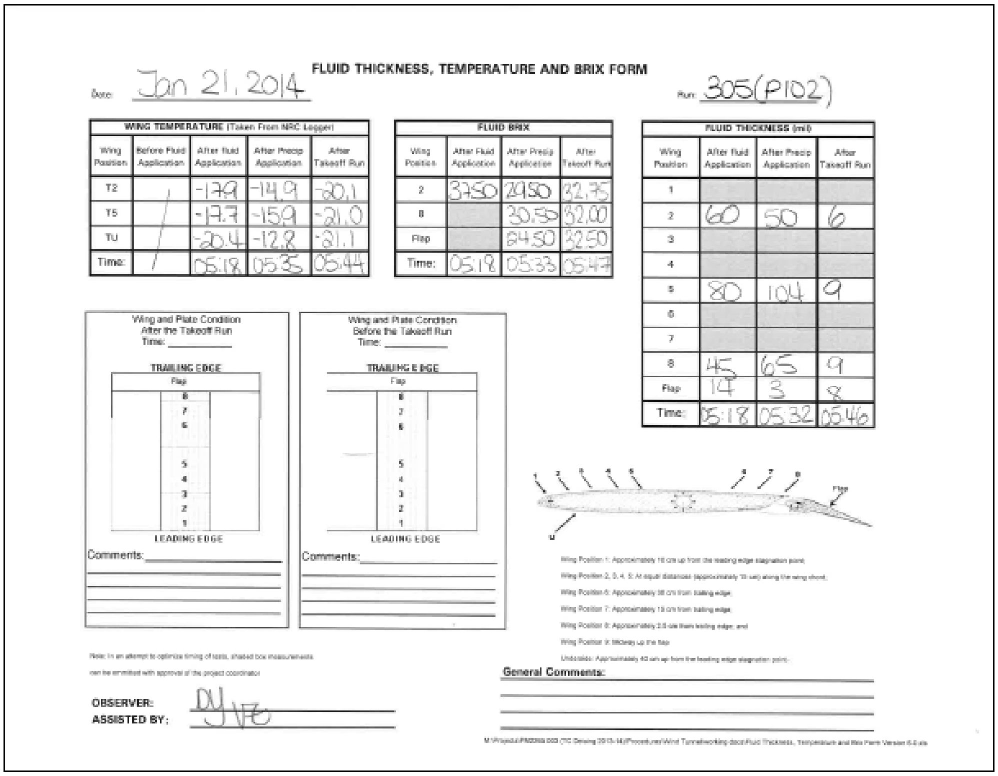
Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

General Comments: ______

OBSERVER: ______

ASSISTED BY: ______

Figure C38: Test # 303



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 21, 2014

Run: 305(P102)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-17.9	-14.9	-20.1
T5	/	-17.7	-15.9	-21.0
TU	/	-20.4	-12.8	-21.1
Time:	/	05:18	05:35	05:44

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	29.50	32.75
8		30.50	32.00
Flap		24.50	32.50
Time:	05:18	05:33	05:47

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	60	50	6
3			
4			
5	80	104	9
6			
7			
8	45	65	9
Flap	14	3	8
Time:	05:18	05:32	05:46

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

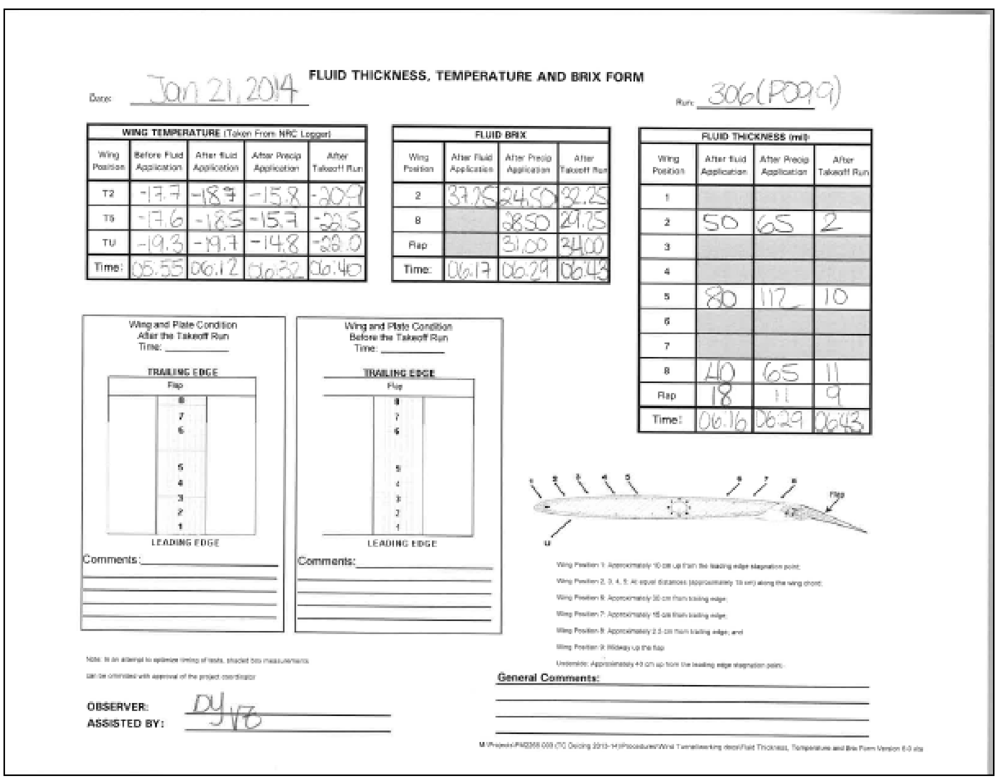
Comments:

General Comments:

OBSERVER: DY

ASSISTED BY: VB

Figure C39: Test # 305



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 21, 2014

Run: 306(P099)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-17.7	-18.7	-15.8	-20.9
T5	-17.6	-18.5	-15.7	-22.5
TU	-19.3	-19.7	-14.8	-23.0
Time:	05:55	06:12	06:32	06:40

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	24.50	32.25
8		28.50	29.75
Flap		31.00	34.00
Time:	06:17	06:29	06:43

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	50	65	2
3			
4			
5	80	117	10
6			
7			
8	40	65	11
Flap	18	11	9
Time:	06:16	06:29	06:43

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

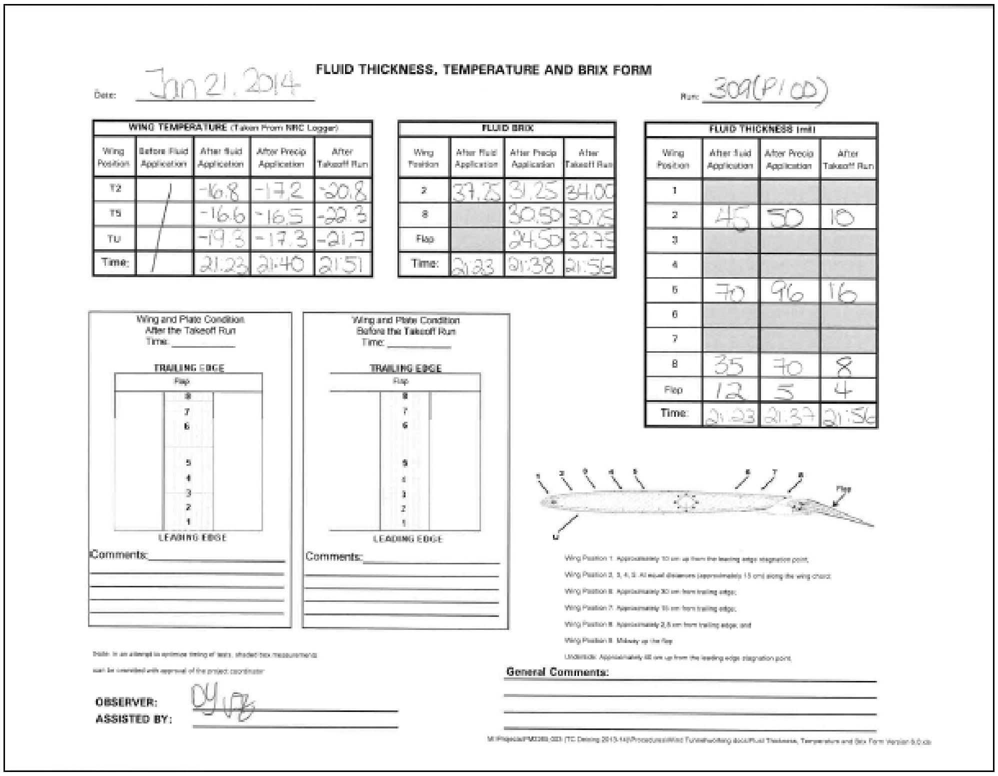
Comments:

General Comments:

OBSERVER: DY

ASSISTED BY: VB

Figure C40: Test # 306



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 21, 2014 Run: 309(P/OD)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-16.8	-17.2	-20.8
T5	/	-16.6	-16.5	-22.3
TU	/	-19.3	-17.3	-21.7
Time:	/	21:23	21:40	21:51

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	31.25	34.00
8		30.50	30.25
Flap		24.50	32.75
Time:	21:23	21:38	21:56

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	45	50	10
3			
4			
5	70	96	16
6			
7			
8	35	70	8
Flap	12	5	4
Time:	21:23	21:37	21:56

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / LEADING EDGE

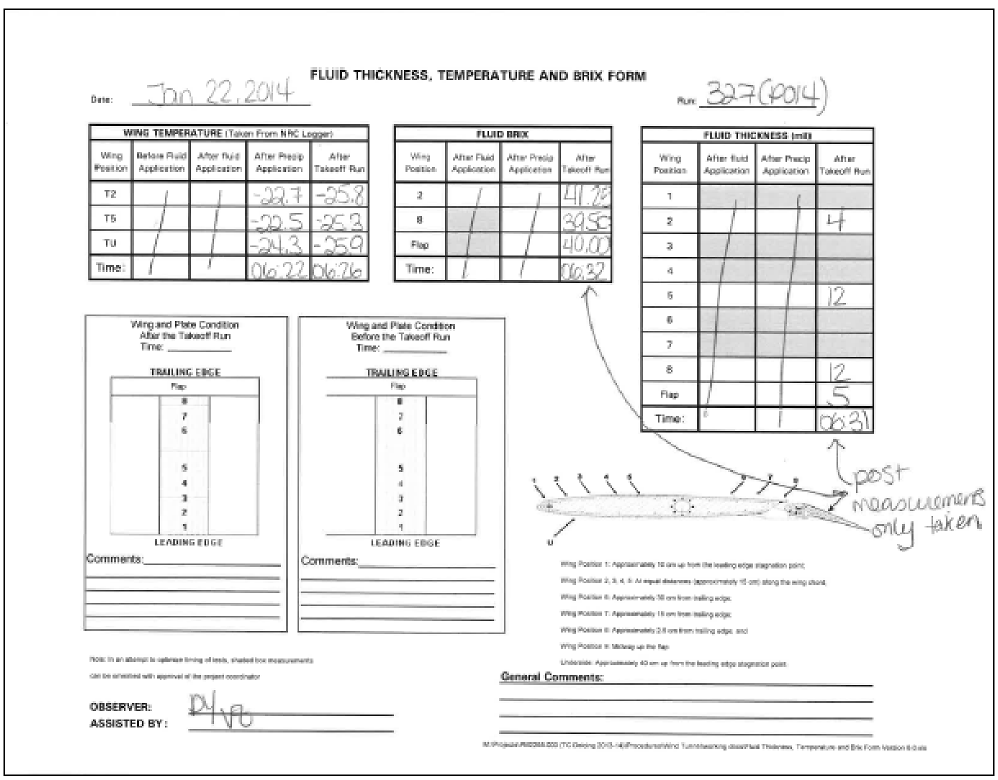
Comments:

General Comments:

OBSERVER: DY/VB

ASSISTED BY:

Figure C41: Test # 309



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2014 Run: 327(P014)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	/	-22.7	-25.8
T5	/	/	-22.5	-25.3
TU	/	/	-24.3	-25.9
Time:	/	/	06:22	06:26

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	/	/	41.25
8	/	/	39.50
Flap	/	/	40.00
Time:	/	/	06:32

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	/	/	
2	/	/	4
3	/	/	
4	/	/	
5	/	/	12
6	/	/	
7	/	/	
8	/	/	12
Flap	/	/	5
Time:	/	/	06:31

post measurements only taken

Wing and Plate Condition After the Takeoff Run Time: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / LEADING EDGE

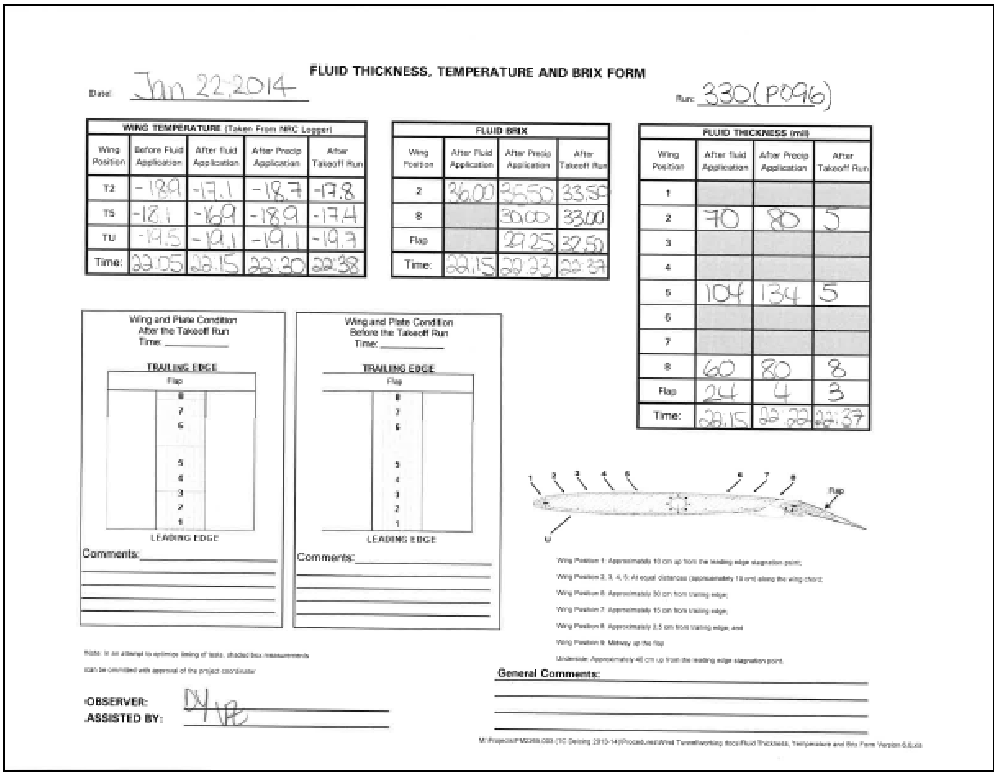
Comments:

General Comments:

OBSERVER: DY/VB

ASSISTED BY:

Figure C42: Test # 327



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2014

Run: 330 (P096)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Run
T2	-18.9	-17.1	-18.7	-17.8
T5	-18.1	-16.9	-18.9	-17.4
TU	-19.5	-19.1	-19.1	-19.7
Time:	22:05	22:15	22:30	22:38

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.00	35.50	33.50
8		30.00	33.00
Flap		29.25	32.50
Time:	22:15	22:23	22:37

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	80	5
3			
4			
5	104	134	5
6			
7			
8	60	80	8
Flap	24	4	3
Time:	22:15	22:22	22:37

Wing and Plate Condition After the Takeoff Run Time: ____

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

Wing and Plate Condition Before the Takeoff Run Time: ____

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

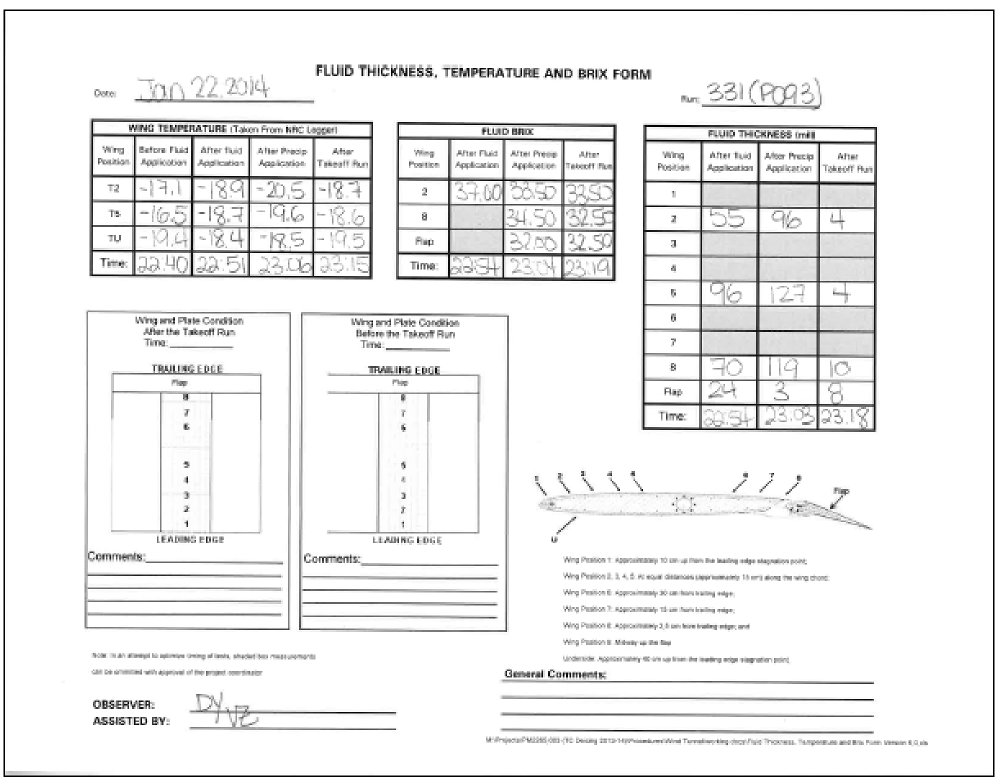
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

General Comments:

OBSERVER: DY
ASSISTED BY: VB

Figure C43: Test # 330



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2014

Run: 331 (P093)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Run
T2	-17.1	-18.9	-20.5	-18.7
T5	-16.5	-18.7	-19.6	-18.6
TU	-19.4	-18.4	-18.5	-19.5
Time:	22:40	22:51	23:06	23:15

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	33.50	33.50
8		34.50	32.50
Flap		32.00	32.50
Time:	22:54	23:04	23:19

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	55	96	4
3			
4			
5	96	127	4
6			
7			
8	70	119	10
Flap	24	3	8
Time:	22:54	23:03	23:18

Wing and Plate Condition After the Takeoff Run Time: ____

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

Wing and Plate Condition Before the Takeoff Run Time: ____

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be omitted with approval of the project coordinator

General Comments:

OBSERVER: DY
ASSISTED BY: VB

Figure C44: Test # 331

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2014

Run: 332(P097)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-16.5	-17.5	-19.1	-18.5
T5	-15.8	-17.6	-19.4	-18.3
TU	-18.4	-18.2	-18.2	-19.6
Time:	23:21	23:30	23:47	23:54

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.75	32.00	34.25
8		34.75	33.00
Flap		31.50	34.50
Time:	23:32	23:43	23:54

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	80	6
3			
4			
5	96	142	5
6			
7			
8	70	96	4
Flap	22	4	5
Time:	23:32	23:43	23:54

Wing and Plate Condition
After the Takeoff Run
Time: ________

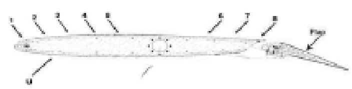
TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments:

Wing and Plate Condition
Before the Takeoff Run
Time: ________

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments:



Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;

Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;

Wing Position 6: Approximately 30 cm from trailing edge;

Wing Position 7: Approximately 15 cm from trailing edge;

Wing Position 8: Approximately 2.5 cm from trailing edge; and

Wing Position 9: Midway up the flap

Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: DY

ASSISTED BY: VF

Figure C45: Test # 332

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2014

Run: 333(P094)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-17.5	-17.5	-20.2	-19.1
T5	-17.1	-17.3	-19.3	-19.1
TU	-19.2	-18.5	-18.0	-19.7
Time:	23:57	00:08	00:20	00:29

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	n/a	33.00
8			31.75
Flap			32.75
Time:	00:08		00:33

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		n/a	
2	70		4
3			
4			
5	112		9
6			
7			
8	80		11
Flap	28		4
Time:	00:07		00:33

Wing and Plate Condition
After the Takeoff Run
Time: ________

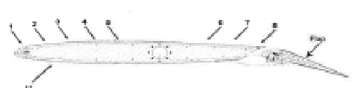
TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments:

Wing and Plate Condition
Before the Takeoff Run
Time: ________

TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

Comments:



Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;

Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;

Wing Position 6: Approximately 30 cm from trailing edge;

Wing Position 7: Approximately 15 cm from trailing edge;

Wing Position 8: Approximately 2.5 cm from trailing edge; and

Wing Position 9: Midway up the flap

Underside: Approximately 40 cm up from the leading edge stagnation point.

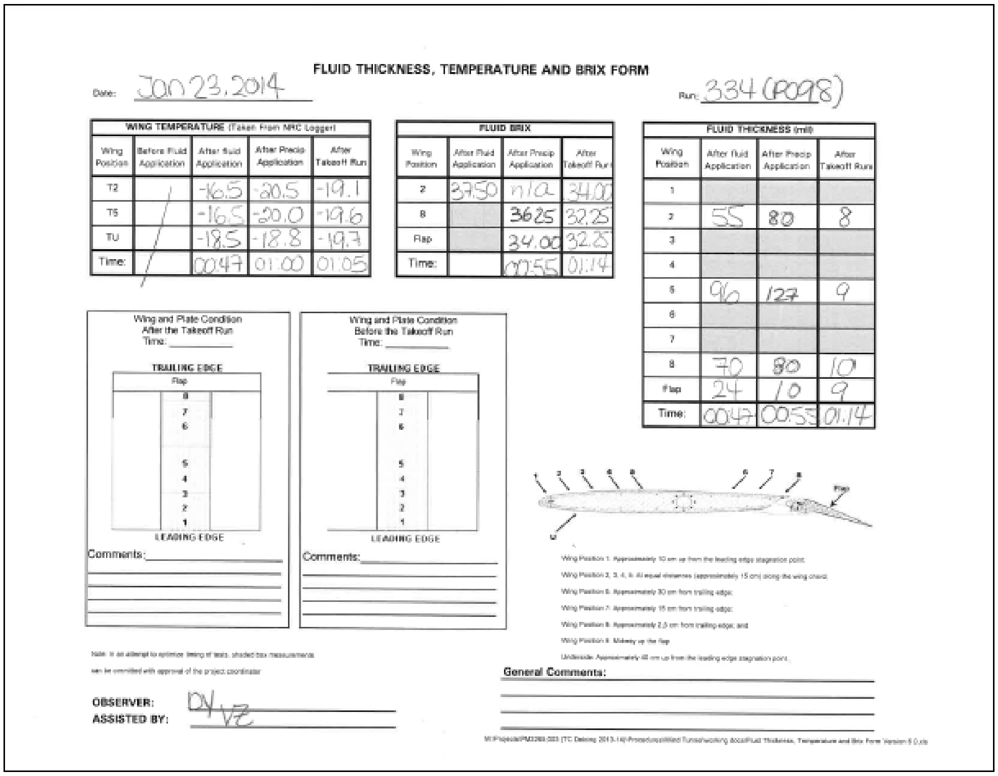
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: DY

ASSISTED BY: VF

Figure C46: Test # 333



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23, 2014   Run: 334 (P098)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-16.5	-20.5	-19.1
T5	/	-16.5	-20.0	-19.6
TU	/	-18.5	-18.8	-19.7
Time:	/	00:47	01:00	01:05

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	n/a	34.00
8		36.25	32.25
Flap		34.00	32.25
Time:		00:55	01:14

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	55	80	8
3			
4			
5	96	127	9
6			
7			
8	70	80	10
Flap	24	10	9
Time:	00:47	00:55	01:14

Wing and Plate Condition After the Takeoff Run Time: ______ TRAILING EDGE Flap 8 7 6 5 4 3 2 1 LEADING EDGE Comments:

Wing and Plate Condition Before the Takeoff Run Time: ______ TRAILING EDGE Flap 8 7 6 5 4 3 2 1 LEADING EDGE Comments:

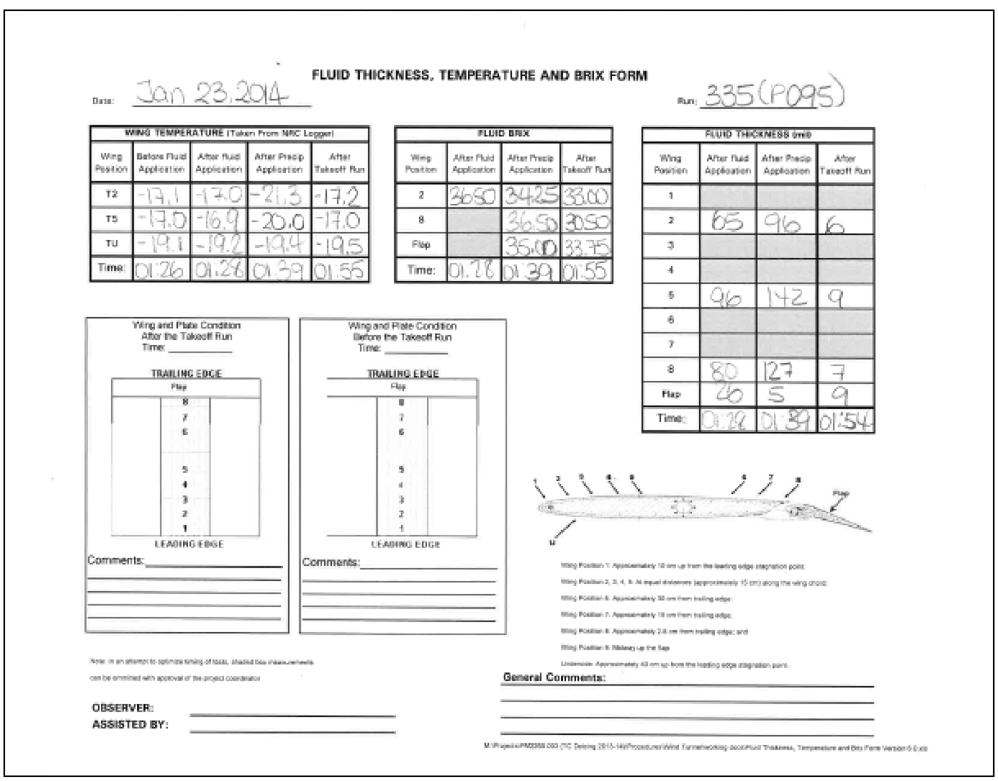
Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately 2.5 cm from trailing edge; and
Wing Position 9: Midway up the flap
Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER: DY
ASSISTED BY: VZ

Figure C47: Test # 334



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23, 2014   Run: 335 (P095)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-17.1	-17.0	-21.3	-17.2
T5	-17.0	-16.9	-20.0	-17.0
TU	-19.1	-19.2	-19.4	-19.5
Time:	01:26	01:28	01:39	01:55

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.50	34.25	33.00
8		36.50	30.50
Flap		35.00	33.75
Time:	01:28	01:39	01:55

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65	96	6
3			
4			
5	96	142	9
6			
7			
8	80	127	7
Flap	26	5	9
Time:	01:28	01:39	01:54

Wing and Plate Condition After the Takeoff Run Time: ______ TRAILING EDGE Flap 8 7 6 5 4 3 2 1 LEADING EDGE Comments:

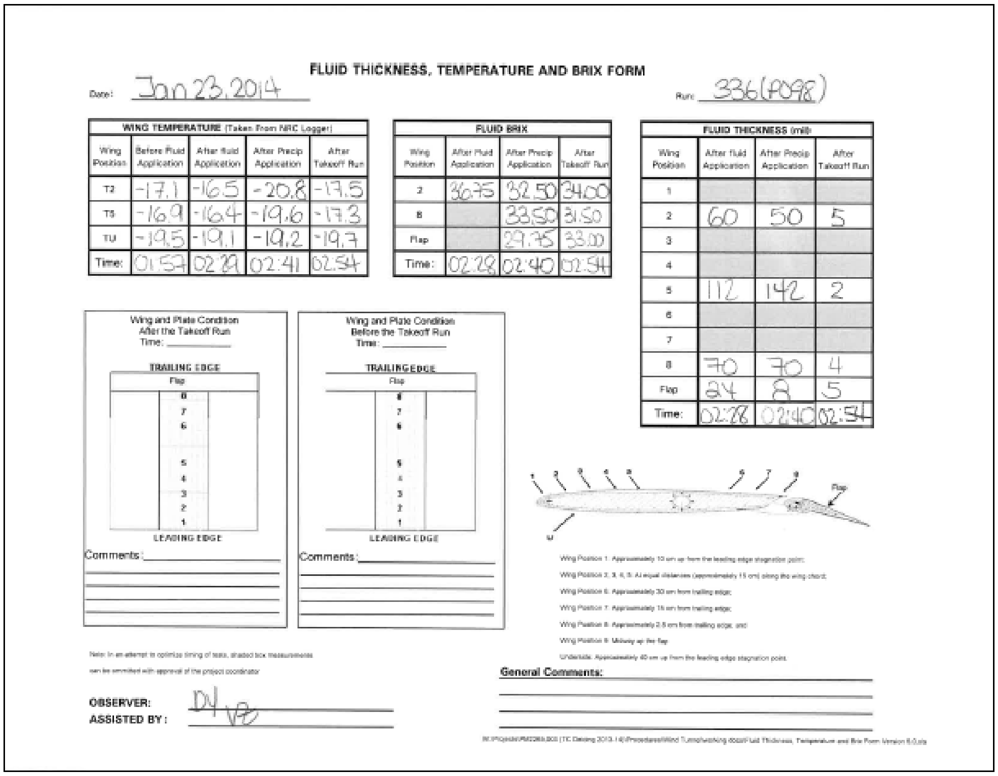
Wing and Plate Condition Before the Takeoff Run Time: ______ TRAILING EDGE Flap 8 7 6 5 4 3 2 1 LEADING EDGE Comments:

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments:

OBSERVER:
ASSISTED BY:

Figure C48: Test # 335



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23, 2014 Run: 336 (P098)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-17.1	-16.5	-20.8	-17.5
T5	-16.9	-16.4	-19.6	-17.3
TU	-19.5	-19.1	-19.2	-19.7
Time:	01:57	02:29	02:41	02:54

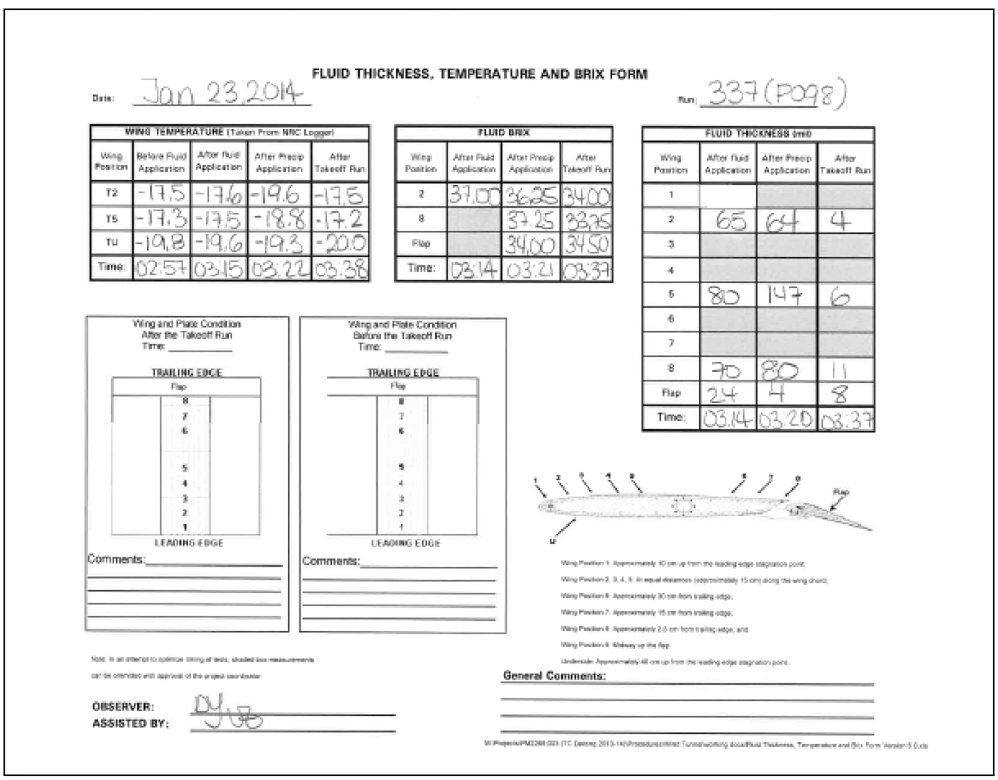
FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.75	32.50	34.00
8		33.50	31.50
Flap		29.75	33.00
Time:	02:28	02:40	02:54

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	60	50	5
3			
4			
5	112	142	2
6			
7			
8	70	70	4
Flap	24	8	5
Time:	02:28	02:40	02:54

Wing and Plate Condition After the Takeoff Run / Wing and Plate Condition Before the Takeoff Run

OBSERVER: DY
ASSISTED BY: VB

Figure C49: Test # 336



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23, 2014 Run: 337 (P098)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-17.5	-17.6	-19.6	-17.5
T5	-17.3	-17.5	-18.8	-17.2
TU	-19.8	-19.6	-19.3	-20.0
Time:	02:57	03:15	03:22	03:38

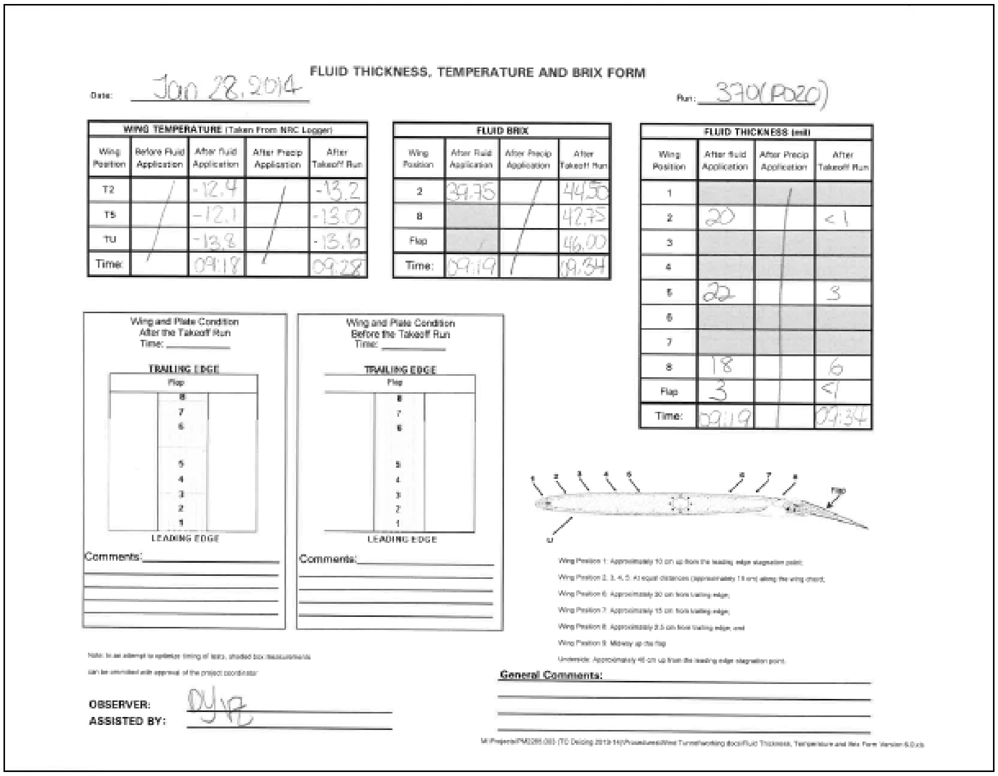
FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	36.25	34.00
8		37.25	33.75
Flap		34.00	34.50
Time:	03:14	03:21	03:37

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65	64	4
3			
4			
5	80	147	6
6			
7			
8	70	80	11
Flap	24	4	8
Time:	03:14	03:20	03:37

Wing and Plate Condition After the Takeoff Run / Wing and Plate Condition Before the Takeoff Run

OBSERVER: DY
ASSISTED BY: VB

Figure C50: Test # 337


FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 28, 2014

Run: 370(P020)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Run
T2		-12.4		-13.2
T5		-12.1		-13.0
TU		-13.8		-13.6
Time:		09:18		09:28

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	39.75		44.50
8			42.75
Flap			46.00
Time:	09:19		09:34

FLUID THICKNESS (mil)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1			
2	20		< 1
3			
4			
5	22		3
6			
7			
8	18		6
Flap	3		<1
Time:	09:19		09:34

Wing and Plate Condition After the Takeoff Run Time:

Wing and Plate Condition Before the Takeoff Run Time:

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

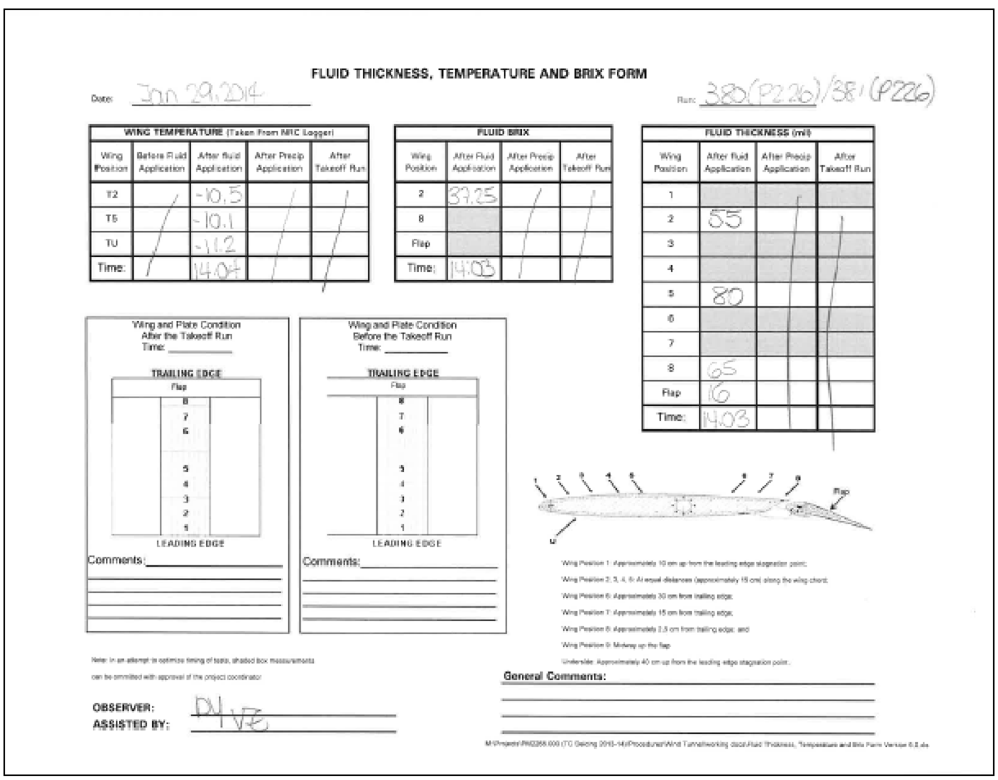
Comments:

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

OBSERVER: DY
ASSISTED BY: VB

General Comments:

Figure C51: Test # 370


FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 29, 2014

Run: 380(P226)/381(P226)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After Fluid Application	After Precip Application	After Takeoff Run
T2		-10.5		
T5		-10.1		
TU		-11.2		
Time:		14:04		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25		
8			
Flap			
Time:	14:03		

FLUID THICKNESS (mil)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1			
2	55		
3			
4			
5	80		
6			
7			
8	65		
Flap	16		
Time:	14:03		

Wing and Plate Condition After the Takeoff Run Time:

Wing and Plate Condition Before the Takeoff Run Time:

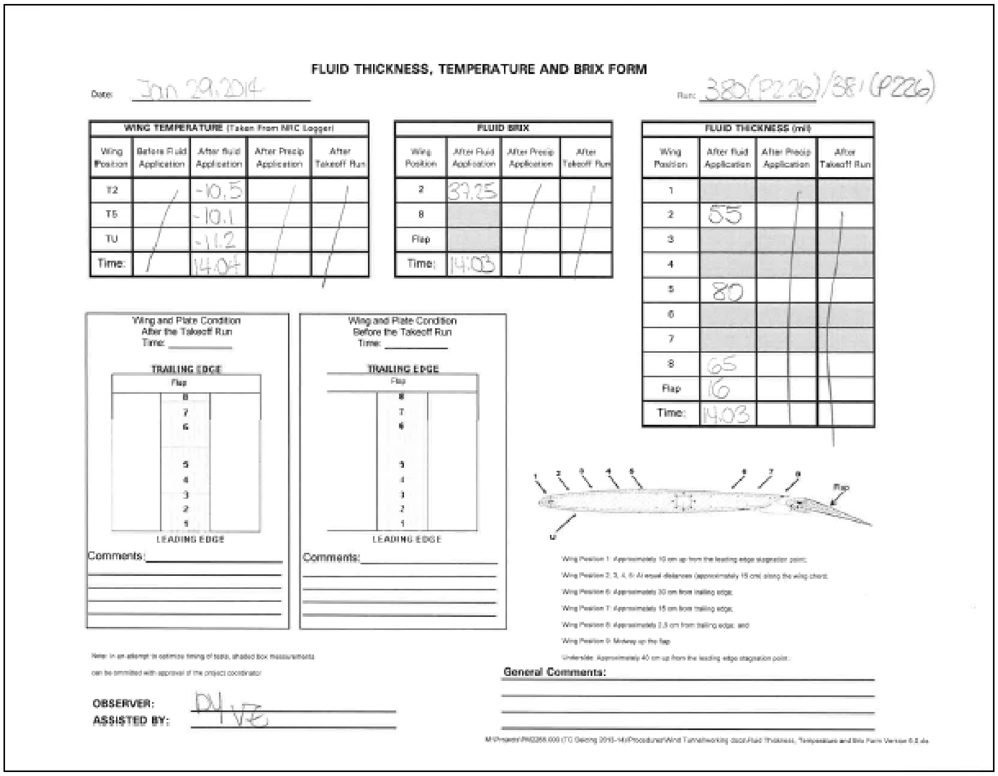
TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments:

OBSERVER: DY
ASSISTED BY: VB

General Comments:

Figure C52: Test # 380



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 29, 2014

Run: 380(P226)/381(P226)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-10.5	/	/
T5	/	-10.1	/	/
TU	/	-11.2	/	/
Time:	/	14:04	/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	/	/
8		/	/
Flap		/	/
Time:	14:03	/	/

FLUID THICKNESS (mil)			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
1		/	
2	55	/	/
3		/	/
4		/	/
5	80	/	/
6		/	/
7		/	/
8	65	/	/
Flap	16	/	/
Time:	14:03	/	/

Wing and Plate Condition After the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

TRAILING EDGE / Flap / 8 7 6 5 4 3 2 1 / LEADING EDGE

Comments: ______

Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;

Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;

Wing Position 6: Approximately 30 cm from trailing edge;

Wing Position 7: Approximately 15 cm from trailing edge;

Wing Position 8: Approximately 2.5 cm from trailing edge; and

Wing Position 9: Midway up the flap

Underside: Approximately 40 cm up from the leading edge stagnation point.

Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: ______

OBSERVER: DY

ASSISTED BY: VB

M:\Projects\PM2265.000 (TC Deicing 2013-14)\Procedures\Wind Tunnel\working docs\Fluid Thickness, Temperature and Brix Form Version 6.0.xls

Figure C53: Test # 381

This page intentionally left blank.

APPENDIX D

TYPE I VERY LOW SPEED BLDT TESTING RESULTS

AERODYNAMIC ACCEPTANCE
TESTING OF AIRCRAFT
DE-ICING FLUIDS

Prepared for

TRANSPORTATION DEVELOPMENT CENTRE
OF TRANSPORT CANADA

by

Anti-icing Materials International Laboratory (AMIL)
Université du Québec à Chicoutimi (UQAC)

Laboratoire international des matériaux antigivre LIMA AMIL Anti-icing Materials International Laboratory

January 2015

AERODYNAMIC ACCEPTANCE TESTING OF AIRCRAFT DE-ICING FLUIDS

Prepared for

TRANSPORTATION DEVELOPMENT CENTRE OF TRANSPORT CANADA

by

Diane Paradis, B.Sc., Chemistry
Marc Mario Tremblay, B.Sc., Chemist
Eric Villeneuve B. Ing. Jr., M. Sc. A.

Anti-icing Materials International Laboratory (AMIL)
Université du Québec à Chicoutimi (UQAC)

Laboratoire international des matériaux antigivre LIMA AMIL Anti-icing Materials International Laboratory

January 2015

Prepared by: Diane Paradis 2015/01/22

Diane Paradis, B. Sc., Chemistry
Research Assistant

Date

Reviewed by: 2015/01/22

Eric Villeneuve, B. Ing. Jr., M. Sc. A.
Research Assistant

Date

Approved by: 2015·01·22

Mar Mario Tremblay, B. Sc., Chemist
Fluid Testing Manager and Project Leader

Date

2012-MT-13, Year 3

AMIL, 2015-01-20

Table of Contents

List of Figures

List of Tables

GLOSSARY

Abbreviations

AC	Audit Criteria
AIR	Aerospace Information Report
AMIL	Anti-icing Materials International Laboratory
AMS	Aerospace Material Specification
AS	Aerospace Standard
BLDT	Boundary Layer Displacement Thickness
FAA	Federal Aviation Administration
FP	Flat Plate elimination test identification number
FPC	Flat Plate Calibration test identification number
FPD	Flat Plate elimination test Dry (without fluid)
FPET	Flat Plate Elimination Test
HOT	Holdover Times Guidelines
NRC	Canadian National Research Center
PRI	Performance Review Institute
SAE	Society of Automotive Engineers
TC	Transport Canada
UQAC	University of Quebec at Chicoutimi

Parameters

c	Cross section perimeter at Station 3 of wind tunnel
D_0	Maximum acceptable value for δ^*_f at 0°C
D_{20}	Maximum acceptable value for δ^*_f at -20°C
FE	Fluid Elimination during the test (%)
P	Static Pressure as measured by gauges positioned at points # 1, 2 and 3 in the set-up (mPa)
Rh	Relative humidity (%)
S	Test section duct cross section area
t	Thickness of the film fluid on the plate (μm)
T_a	Air Temperature as recorded at the top of the cross-section 2 in the set up (°C)
T_f	Fluid Temperature as recorded in the fluid film at the bottom of the cross-section 3 (°C)
U_α	Free flow speed
δ^*	Boundary Layer Displacement Thickness (BLDT) over the test section perimeter at cross-section 3
δ^*_{ave}	average Boundary Layer Displacement Thickness (BLDT) over the test section perimeter at cross-section 3
δ^*_d	BLDT over dry surface (at cross-section 3)
δ^*_f	BLDT over fluid-coated surface (at cross-section 3)
δ^*_r	δ^*_f value for reference fluid
ρ	Gas density mass per unit volume
V	Air Velocity derived from the measurement of the pressure difference P1 - P2
WC	Water Change (% w/w)

1. INTRODUCTION

This report presents Flat Plate Elimination Test (FPET) results of AMS1424 Type I fluid samples provided by APS Aviation at targeted temperatures under Modified and Standard Aerodynamic Acceptance Tests (AAT) simulating take-off conditions as defined in SAE Aerospace Standard AS5900 [1].

There is currently no Standard Test Method for Aerodynamic Acceptance of AMS1424 Type I fluid for aircraft having rotating speeds below 60 knots. However several operators have aircraft that rotate below 60 knots that encounter ground icing conditions during winter operations. Aerodynamic testing can provide insight into alternatives for operating in such conditions; i.e. limit LOUT for lower rotation speeds, use diluted fluid, delay rotation when at Vr, increase the rotation speed etc. These operators have requested that TC provides operational guidance when using Type I fluids on these aircraft.

This report details the performance of fluid, identified in **Table 1**, when subjected to the Flat Plate Elimination Test, denoted FPET hereafter. The FPET procedure follows the Aerospace Standard AS5900 for de-icing fluid on the high speed ramp (3.3.4.1 a), low speed ramp (3.3.4.1 b) and two modified low rotation speed ramps. The aerodynamic acceptance test parameters and test description are presented in **Table 1.** As requested by APS Aviation, for the four speed ramps tested, no reference fluid was tested along with test fluids, therefore no acceptance criteria was generated. The tests were carried out in the Luan Phan refrigerated wind tunnel of the "Anti-icing Materials International Laboratory" (AMIL) at the "Université du Québec à Chicoutimi" (UQAC) [2]. The UQAC facility is operated independently from fluid manufacturers and meets the requirements of the aerodynamic acceptance testing standards. It was found qualified on September 11, 1997 (reconfirmed September 13th 2012) by the Performance Review Institute according to PRI document AC3001, “audit criteria for compliance to SAE AMS 1424 and AMS 1428”.

1.1 Objectives

The objective of this study was to measure and compare the BLDT values obtained with standard and modified Flat Plate Elimination Tests (FPET) according to AS5900 [1] on AMS1424 [3] Type I fluid samples obtained from APS Aviation.

1.2 Scope

Testing involved Flat Plate Elimination Tests (FPET) for aerodynamic acceptance as per AS5900 B for the high speed ramp, low speed ramp and two modified low rotation speed ramps at temperature targets defined in **Table 1.** The BLDT values were measured and compared and no acceptance criteria were generated.

Table 1 – Fluid Identification and Test Parameters

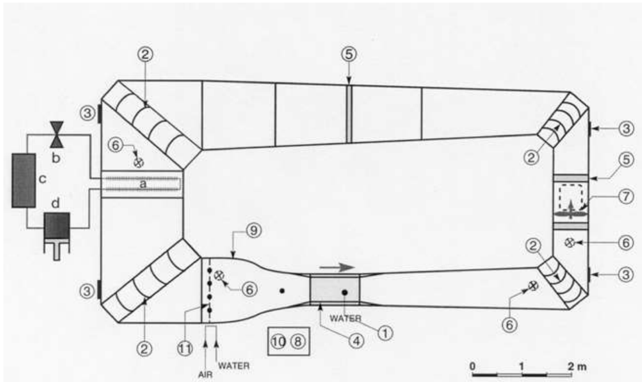
Fluid	AAT Test Description Vmax	APS Test #	Temp (°C)	AMIL Code	Reception date
Polar Plus 63/37 lot # 13403	126 knots (65 ± 5 m/s) Ramp Time : 25 s BLDT : 27-33 s	16	-19	J495	2014-03-10
		20	-23		
		1	-25		
		8	-27		
		3	-32		
XL54 RTU		2	-23	J496	
		12	-27		
		4	-33		
Polar Plus 63/37 lot # 13403	68 knots (35 ± 3 m/s) Ramp Time : 17 s BLDT : 19-21 s	15	-19	J495	
		19	-23		
		5	-27		
XL54 RTU		9	-27	J496	
Polar Plus 63/37 lot # 13403	62 knots (32 ± 3 m/s) Ramp Time : 16 s BLDT : 18-20 s	14	-19	J495	
		17	-23		
		6	-27		
XL54 RTU		10	-27	J496	
Polar Plus 63/37 lot # 13403	51 knots (26 ± 3 m/s) Ramp Time : 13 s BLDT : 15-17 s	13	-19	J495	
		18	-23		
		7	-27		
XL54 RTU		11	-27	J496	

2 TEST DESCRIPTION

2.1 Flat Plate Elimination Test

This test is designed to measure the Boundary Layer Displacement Thickness, BLDT, which is related to lift loss [4]. The flat plate set-up consists of a duct inserted in the test section of AMIL's refrigerated wind tunnel. In this tunnel, the airflow and the fluid can be maintained at a constant temperature, between 5°C ± 1°C and –45°C ± 2°C. A sketch of the set-up is given in **Figure 1**.

The FPET procedure consists of submitting a 2 mm thick layer of de-icing fluid covering a 1.6 m long, 300 mm wide test section duct floor of the wind tunnel (**Figure 1**) to different flow accelerations, simulating aircraft take-offs of various type jet aircraft. The test parameters include final speed, ramp time and averaged BLDT measurement as described in **Table 1. Figure 2** presents an example of a FPET run for high speed ramp. The FPET test procedure is detailed in Aerospace Standard AS5900 B [1].



1	TEST SECTION		REFRIGERATING SYSTEM
2	CORNER VANES	a	EVAPORATOR
3	ACCESS DOORS	b	EXPANSION VALVE
4	ACCESS PANELS	c	CONDENSER
5	THERMAL EXPANSION JOINTS	d	COMPRESSOR (75 hp)
6	DRAIN		
7	FAN AND MOTOR		
8	MOTOR CONTROL PANEL		
9	CONTRACTION CONE		
10	CONTROL CONSOLE		
11	SPRAY NOZZLES		

Figure 1 - Luan Phan Refrigerated Icing Wind Tunnel

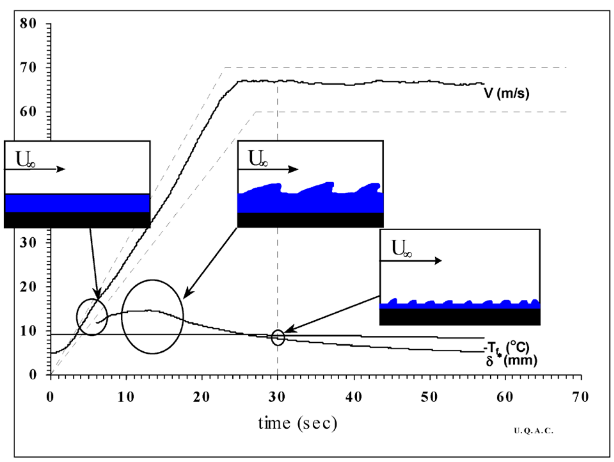


Figure 2 - FPET Test Run for the High Speed Ramp

2.2 Measurements

In a FPET, the fluid performance is evaluated from BLDT measurements. The BLDT value used for the fluid evaluation is the average of the BLDT measured between the 27th and the 33rd seconds after the beginning of the test for the high speed ramp, between the 19th and the 21st seconds for the low speed ramp, between the 18th and the 20th seconds for the 62 knot speed ramp and between the 15th and the 17th seconds for the 51 knot speed ramp. The starting time (t = 0) is evaluated by extrapolating the straight line of the acceleration ramp to the point where V = 0 m/s.

In addition, the following parameters are measured:

1. **refractive index which is used to determine the water change (%)**
   Refractive Index measured with a REICHERT AR7 SERIES Refractometer, Reichert, Inc., model AR70.
2. **fluid film thickness (μm) at the beginning and at the end of the FPET.**

2.3 Calibration and Acceptance Criteria

For a formal fluid qualification, the calibration is obtained from dry tests, performed without fluid, and Reference Fluid tests (as described in AS5900B paragraphs 2.1.3 and 2.1.4), for which BLDT results are well documented. However in this study, as requested by APS Aviation, the acceptance criteria based on the reference fluid BLDT values and dry BLDT values was not calculated and presented. In order to verify the dryness of the wind tunnel between each test, the dry BLDT values were measured all the same, and are presented in **Table 4**.

3. TEST RESULTS

FPET results including BLDT, fluid thickness and water change values for each test are presented in **Table 2. Figure 3** shows the refractive index as a function of the fluid concentration. **Figure 4** presents BLDT results for all speed ramp tests performed with the two fluids tested. **Figures 5 and 6** present BLDT results obtained for J495 and J496 fluids respectively. The individual BLDT data for each speed ramp tested are presented in **Figures 7 to 10**. Finally, **Table 3** presents refractive index data and water change calculations. Fluid elimination and relative humidity are presented as a function of test temperature in **Figure 11 and Figure 12** respectively.

Table 2 – Aerodynamic Performance Test Data Results

TYPE I FLUIDS - VARIOUS SPEED RAMPS

Speed	TEST CODE	T_a °C	T_f °C	Rh %	t_o(1) µm	t_{end}(2) µm	FE(3) %	WC(4) %	V(5) m/s	δ* mm
26 m/s	J495E303	-18.8	-19.3	67.8	1800	424	76.4	-0.16	25.3	9.90
	J495F306	-22.7	-23.2	65.0	1800	508	71.8	-0.66	25.6	10.94
	J495F311	-27.5	-27.2	59.4	1800	577	67.9	-0.82	25.4	11.89
	J496F312	*-27.3*	*-27.1*	*60.3*	*2000*	*297*	*85.2*	*-1.80*	*26.2*	*6.64*
32 m/s	J495E302	-18.9	-19.3	67.0	1800	330	81.7	-0.33	32.3	8.52
	J495F305	-22.8	-23.1	65.5	1800	389	78.4	-0.33	32.3	9.87
	J495F309	-27.3	-27.1	60.4	1800	439	75.6	0.00	32.9	10.90
	J496F310	*-27.8*	*-27.2*	*57.6*	*1933*	*236*	*87.8*	*-1.62*	*31.6*	*6.81*
35 m/s	J495E301	-19.3	-19.4	61.0	1800	287	84.0	-0.66	36.7	7.81
	J495F304	-22.1	-22.9	68.6	1800	356	80.2	-0.16	36.9	8.84
	J495F307	-28.7	-27.5	57.8	1800	389	78.4	-0.16	36.5	10.34
	J496F308	*-27.8*	*-27.3*	*58.9*	*1800*	*203*	*88.7*	*-4.50**	*35.9*	*6.19*
65 m/s	J495E317	-18.8	-19.4	64.1	1800	152	91.5	0.49	67.6	5.46
	J495E318	-23.7	-23.0	60.9	1800	178	90.1	-0.66	67.5	6.35
	J495F320	-27.1	-25.1	55.5	1800	203	88.7	0.00	67.4	6.92
	J495F321	-27.6	-27.1	58.2	1800	211	88.3	-0.33	68.0	7.26
	J495H323	-34.5	-32.2	52.1	1800	236	86.9	-0.82	67.4	9.38
	J496E319	*-23.7*	*-23.1*	*58.9*	*2000*	*119*	*94.0*	*-2.70**	*67.8*	*3.60*
	J496F322	*-27.8*	*-27.0*	*60.9*	*2000*	*127*	*93.6*	*-2.52**	*67.3*	*3.91*
	J496H324	*-34.1*	*-33.1*	*53.6*	*1933*	*160*	*91.7*	*-0.54*	*67.4*	*4.21*

J495 : Polar Plus 63/37, lot # 13403
J496 : XL54 RTU
*caution : value outside the ± 2% range

(1) Thickness of the fluid measured at the beginning of the test.
(2) Thickness of the fluid measured at the end of the test.
(3) Fluid Elimination.
(4) Water Change.
(5) Air velocity 30 seconds after the beginning of the test.

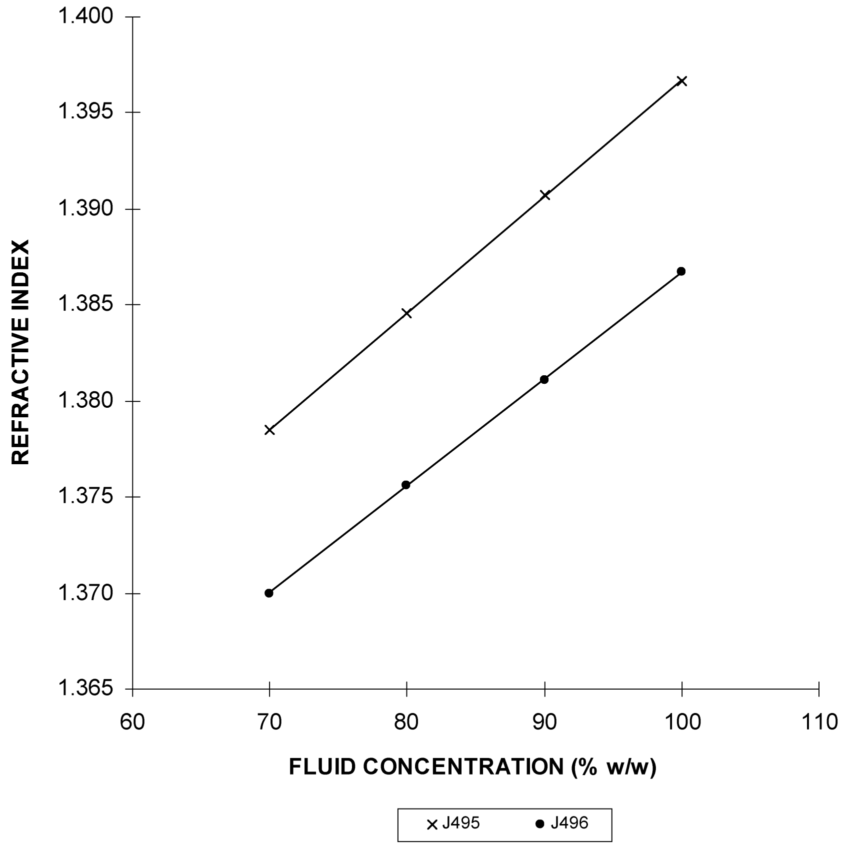
2012-MT-13, Year 3 5 *AMIL, 2015-01-22*

Table 3 – Refractive Index Data and Water Change Data Results

Speed	TEST CODE	RI Initial	RI Final	ΔRI	WC % W/W	Rh %
26 m/s	J495E303	1.3968	1.3969	0.0001	-0.16	67.8
	J495F306	1.3965	1.3969	0.0004	-0.66	65.0
	J495F311	1.3964	1.3969	0.0005	-0.82	59.4
	J496F312	*1.3866*	*1.3876*	*0.0010*	*-1.80*	*60.3*
32 m/s	J495E302	1.3967	1.3969	0.0002	-0.33	67.0
	J495F305	1.3968	1.3970	0.0002	-0.33	65.5
	J495F309	1.3968	1.3968	0.0000	0.00	60.4
	J496F310	*1.3866*	*1.3875*	*0.0009*	*-1.62*	*57.6*
35 m/s	J495E301	1.3963	1.3967	0.0004	-0.66	61.0
	J495F304	1.3969	1.3970	0.0001	-0.16	68.6
	J495F307	1.3968	1.3969	0.0001	-0.16	57.8
	J496F308	*1.3866*	*1.3891*	*0.0025*	*-4.50**	*58.9*
65 m/s	J495E317	1.3967	1.3964	-0.0003	0.49	64.1
	J495E318	1.3963	1.3967	0.0004	-0.66	60.9
	J495F320	1.3967	1.3967	0.0000	0.00	55.5
	J495F321	1.3967	1.3969	0.0002	-0.33	58.2
	J495H323	1.3964	1.3969	0.0005	-0.82	52.1
	J496E319	*1.3863*	*1.3878*	*0.0015*	*-2.70**	*58.9*
	J496F322	*1.3857*	*1.3871*	*0.0014*	*-2.52**	*60.9*
	J496H324	*1.3864*	*1.3867*	*0.0003*	*-0.54*	*53.6*

J495 : Polar Plus 63/37, lot # 13403
J496 : XL54 RTU
*caution : value outside the ±2% range

2012-MT-13, Year 3 6 *AMIL, 2015-01-22*



J495: RI = 0.000607 % w/w + 1.336030
J496 : RI = 0.000556 % w/w + 1.331090

BASIS : for each curve presented, 100% w/w corresponds to the fluid concentration tested in aerodynamic acceptance test.

Figure 3 - Refractive Index versus Water Content

2012-MT-13, Year 3 7 *AMIL, 2015-01-22*

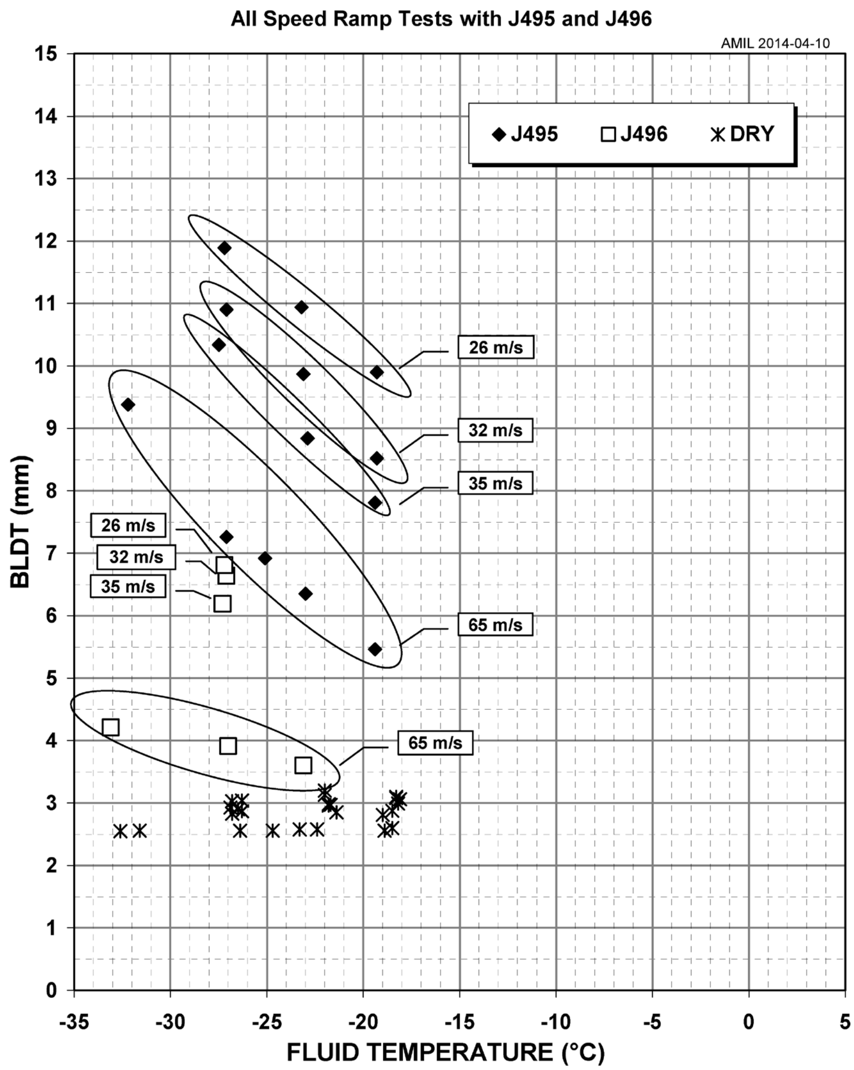


Figure 4 - Aerodynamic Test Results, J495 and J496 all speed ramps

2012-MT-13, Year 3 *8* *AMIL, 2015-01-22*

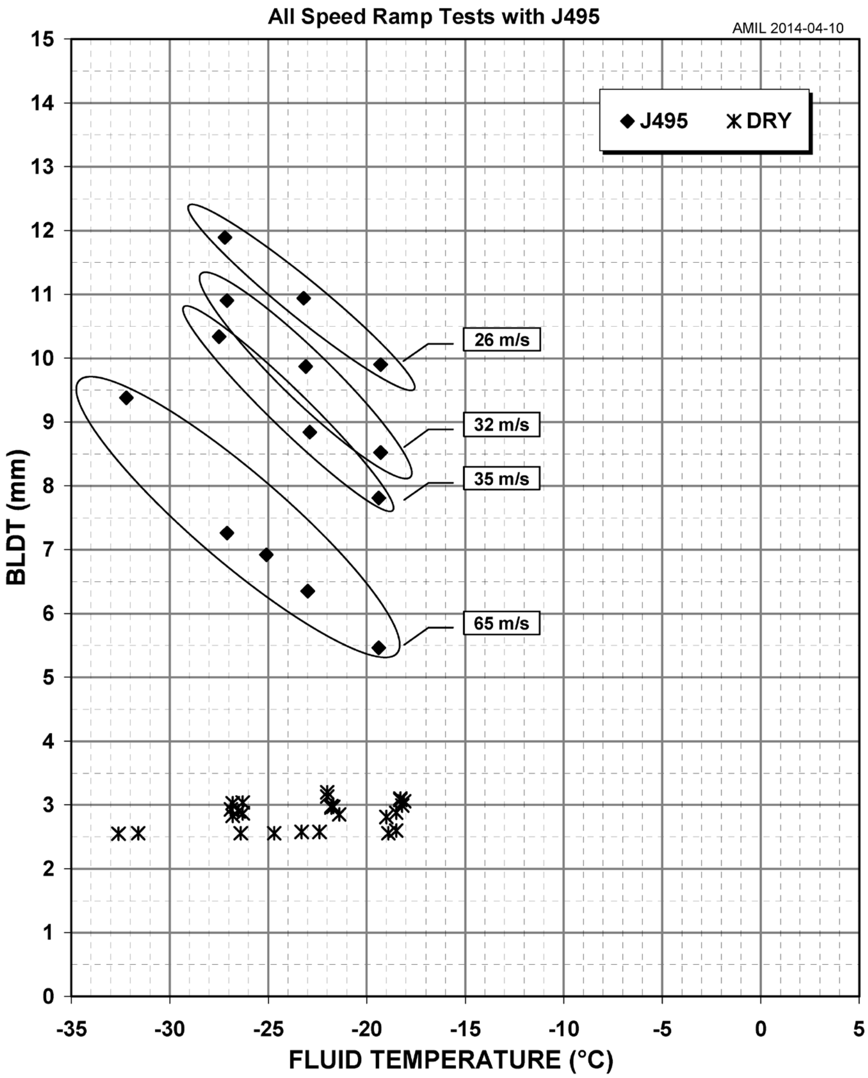


Figure 5 - Aerodynamic Test Results, J495 all speed ramps

2012-MT-13, Year 3 9 *AMIL, 2015-01-22*

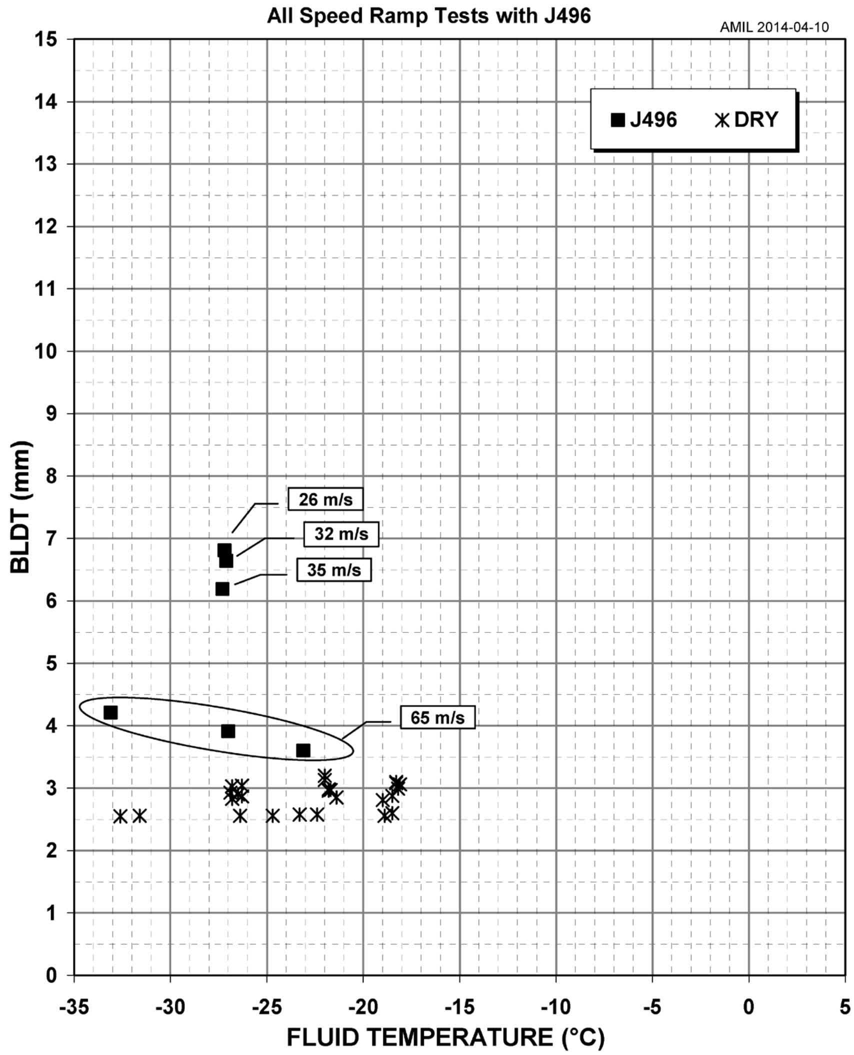


Figure 6 - Aerodynamic Test Results, J496 all speed ramps

2012-MT-13, Year 3 *10* *AMIL, 2015-01-22*

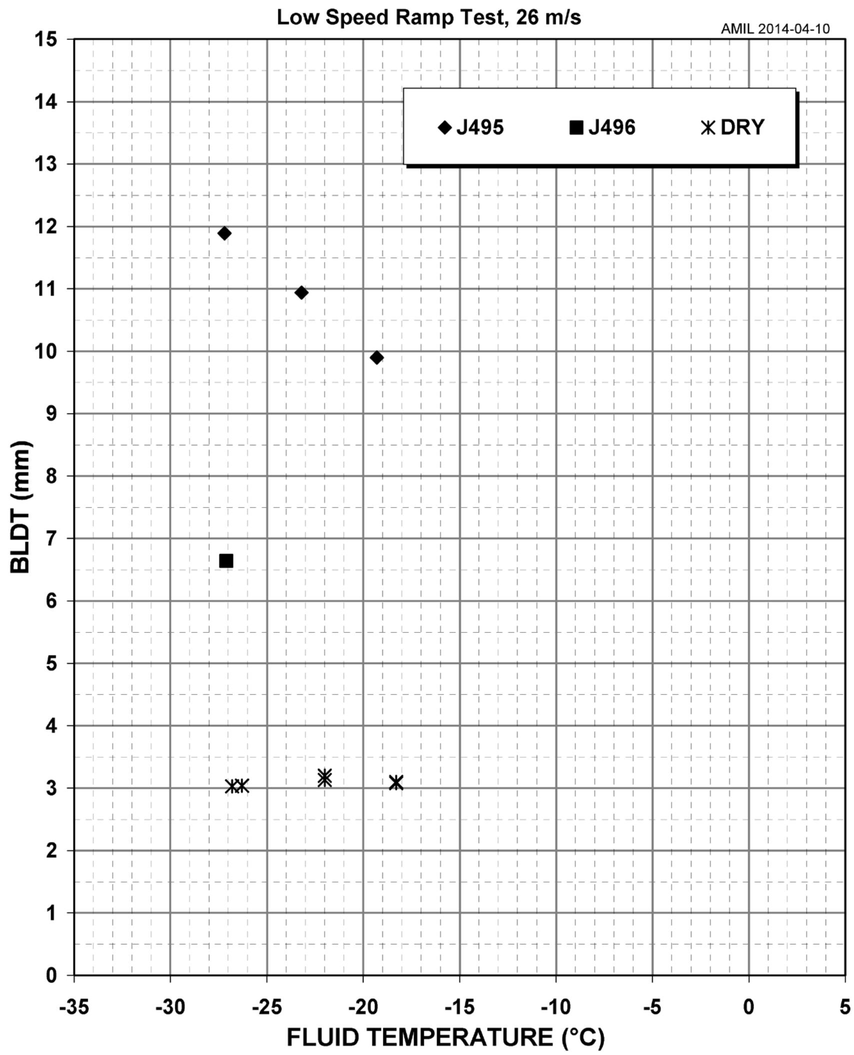


Figure 7 - Aerodynamic Test Results, 26 m/s

2012-MT-13, Year 3 *11* *AMIL, 2015-01-22*

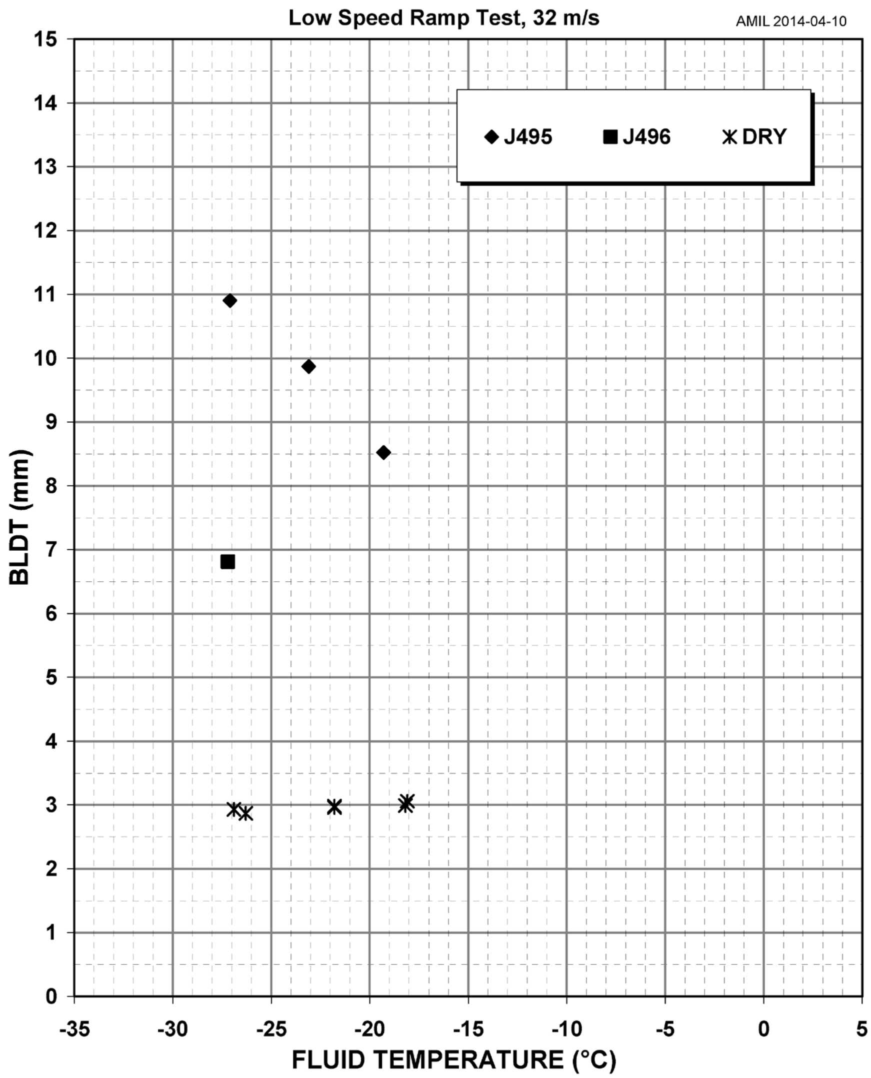


Figure 8 - Aerodynamic Test Results, 32 m/s

2012-MT-13, Year 3 12 *AMIL, 2015-01-22*

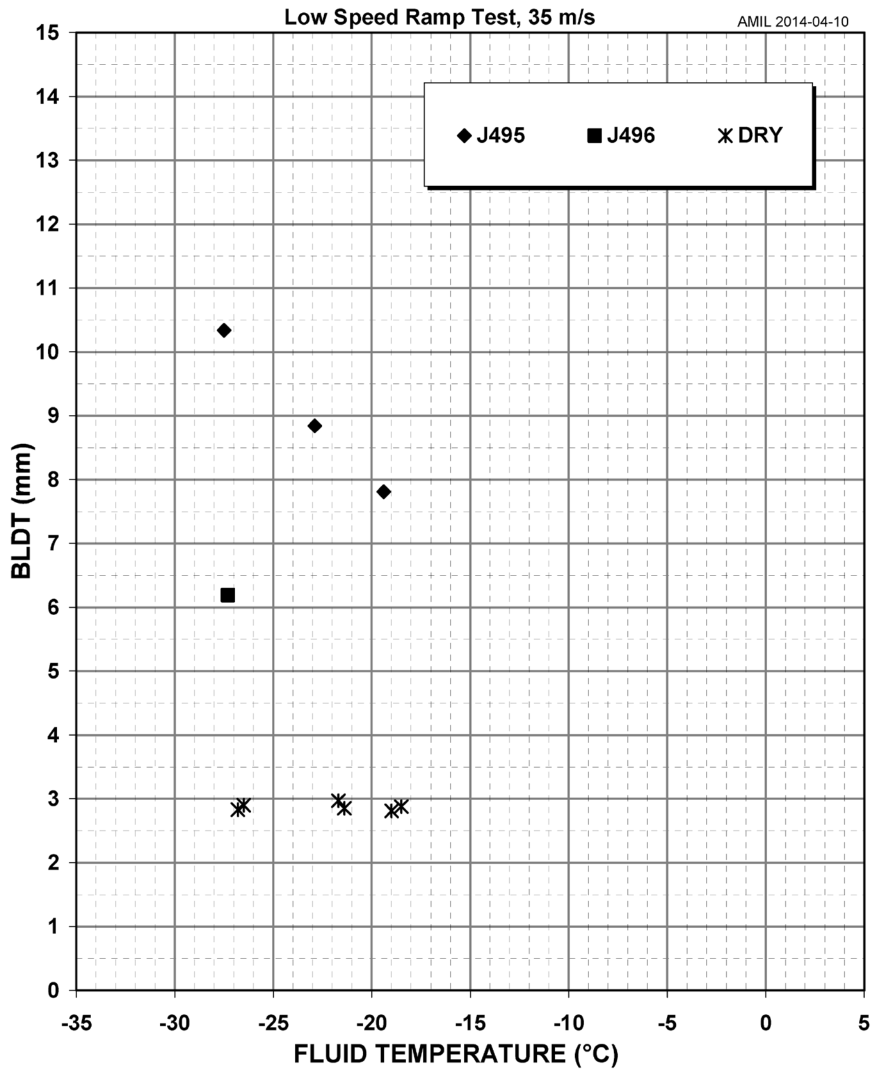


Figure 9 - Aerodynamic Test Results, 35 m/s

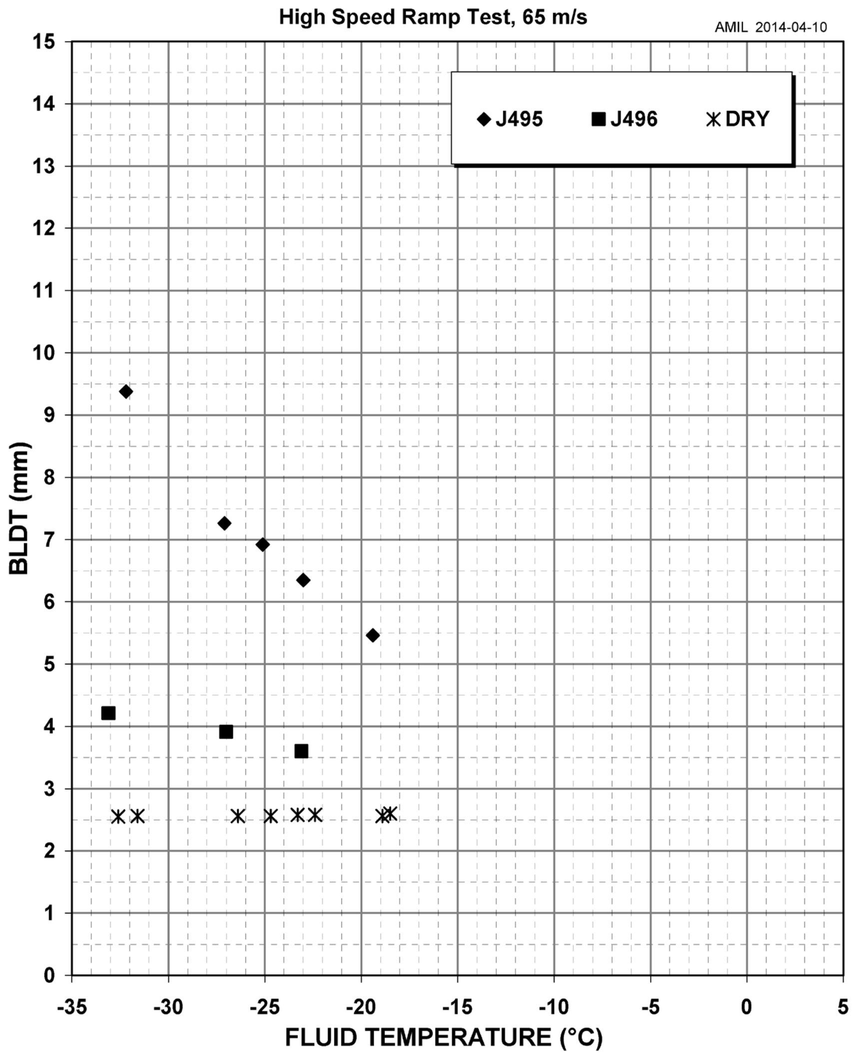


Figure 10 - Aerodynamic Test Results, 65 m/s

2012-MT-13, Year 3 *14* *AMIL, 2015-01-22*

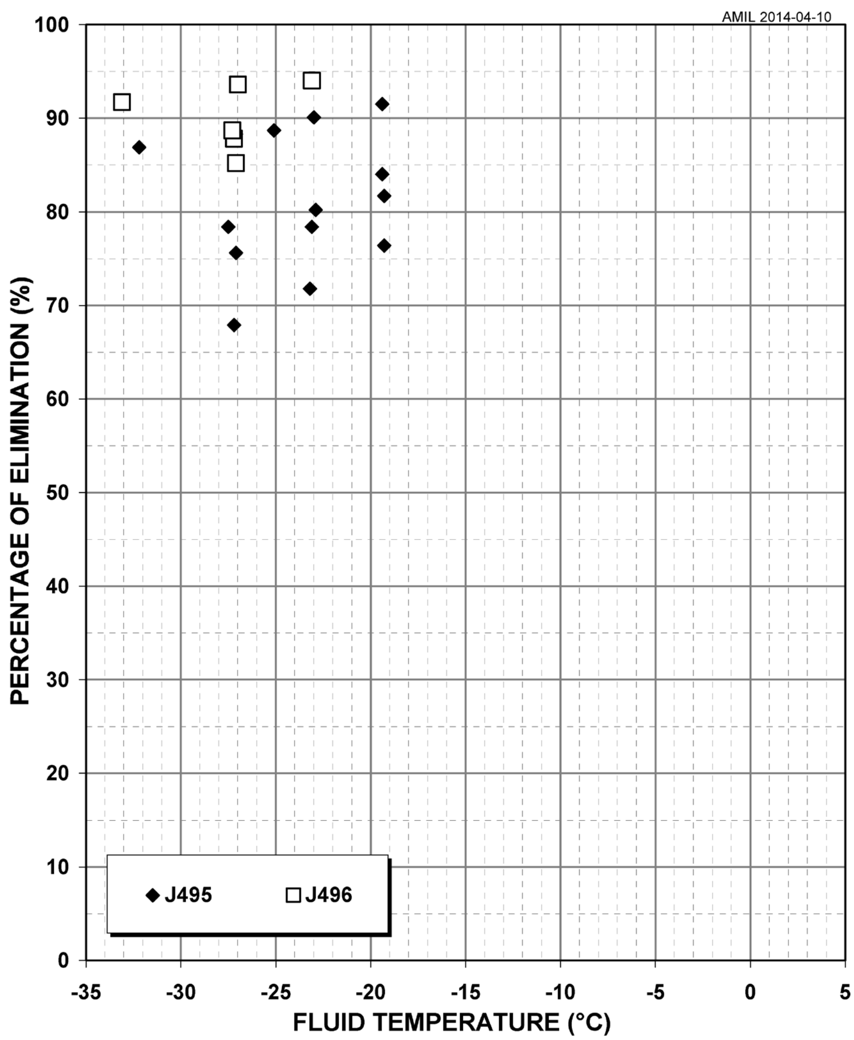


Figure 11 - Elimination

2012-MT-13, Year 3 *15* *AMIL, 2015-01-22*

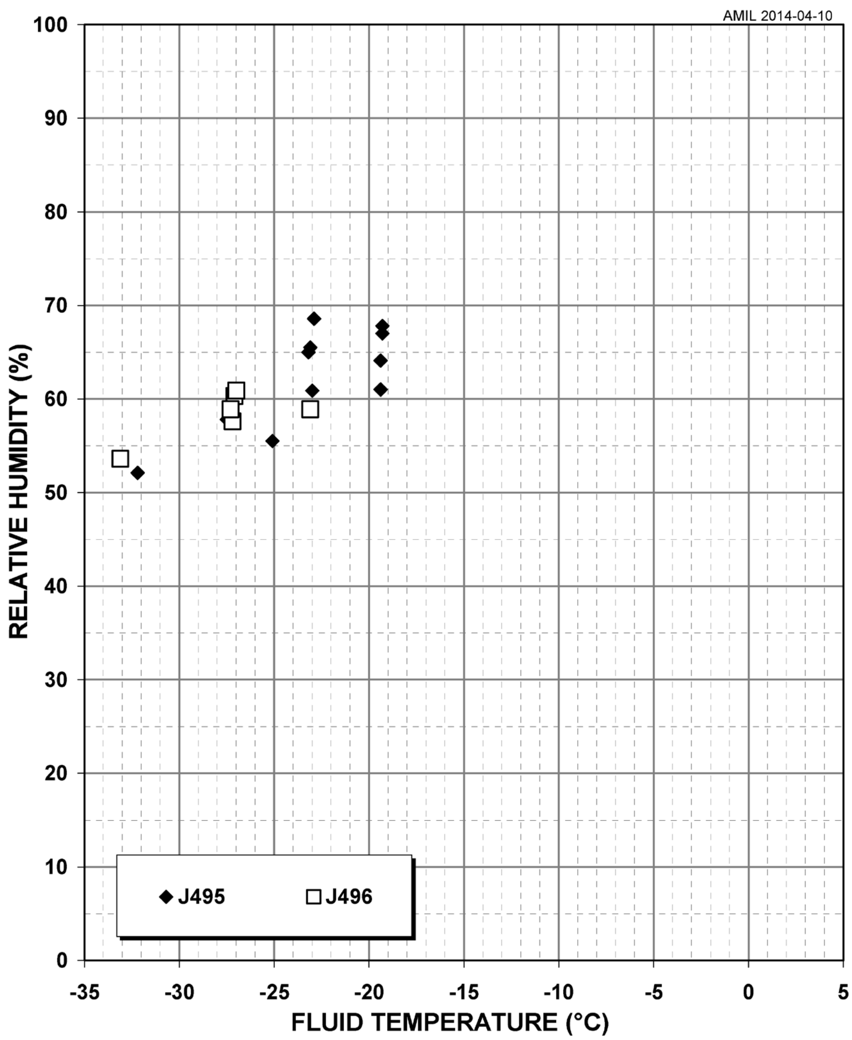


Figure 12 - Humidity

2012-MT-13, Year 3 16 *AMIL, 2015-01-22*

Table 4 – Dry Test Data

TEST CODE	T_a °C	T_f °C	Rh(%)	V(1)(m/s)	δ^*_{dry} (mm)
DRY_E067	-18.8	**-18.3**	66.9	26.3	**3.10**
DRY_E068	-18.9	**-18.3**	67.1	27.2	**3.08**
DRY_F073	-22.3	**-22.0**	66.9	26.2	**3.20**
DRY_F074	-22.2	**-22.0**	66.9	26.3	**3.13**
DRY_F080	-26.8	**-26.3**	62.2	26.5	**3.04**
DRY_F079	-27.6	**-26.8**	59.3	26.1	**3.03**
DRY_E066	-18.9	**-18.1**	67.1	32.0	**3.06**
DRY_E065	-18.8	**-18.2**	66.1	32.5	**2.99**
DRY_F071	-22.7	**-21.8**	67.7	32.7	**2.98**
DRY_F072	-22.9	**-21.8**	66.4	32.3	**2.96**
DRY_F078	-26.9	**-26.3**	62.6	32.3	**2.87**
DRY_F077	-27.6	**-26.9**	59.4	32.4	**2.93**
DRY_E064	-19.0	**-18.5**	61.2	35.1	**2.88**
DRY_E063	-20.5	**-19.0**	56.5	35.7	**2.81**
DRY_F069	-22.3	**-21.4**	67.8	35.7	**2.85**
DRY_F070	-22.7	**-21.7**	64.6	35.4	**2.97**
DRY_F076	-27.7	**-26.5**	61.1	34.4	**2.90**
DRY_F075	-28.5	**-26.8**	60.1	34.2	**2.83**
DRY_E096	-21.0	**-18.5**	62.9	64.6	**2.60**
DRY_E095	-20.5	**-18.9**	59.9	64.9	**2.56**
DRY_E097	-24.7	**-22.4**	58.2	64.1	**2.58**
DRY_F098	-25.7	**-23.3**	60.1	64.3	**2.58**
DRY_F099	-27.8	**-24.7**	56.1	64.2	**2.56**
DRY_F100	-28.4	**-26.4**	58.3	64.1	**2.56**
DRY_H101	-34.0	**-31.6**	54.6	64.5	**2.56**
DRY_H102	-34.2	**-32.6**	54.5	64.1	**2.55**

(1) Air velocity 30 seconds after the beginning of the test

2012-MT-13, Year 3 *17* *AMIL, 2015-01-22*

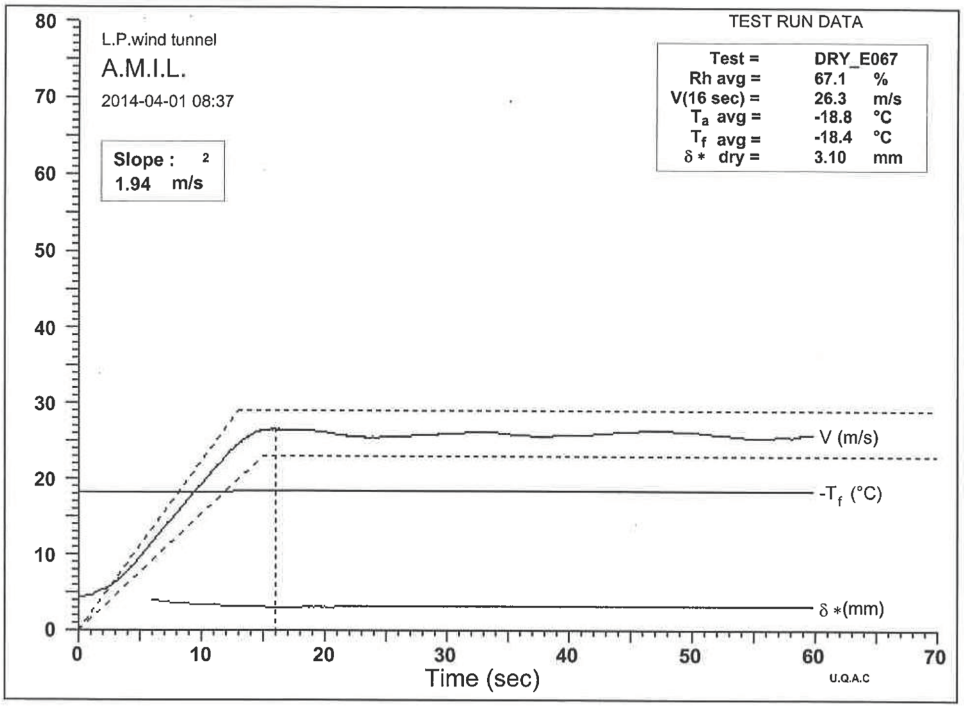
4. REFERENCES

1. *SAE International Aerospace Standard, "Standard Test Method for Aerodynamic Acceptance of SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids", AS5900, revision B, July 1, 2007.*
2. *Laforte, J.-L., P. Louchez, G. Bouchard, and M. Farzaneh, "A Facility to Evaluate Performance of Aircraft Ground De/Anti-Icing Fluids Subjected to Freezing Rain". Cold Regions Science and Technology, 1990.* ***18****: p. 161-171.*
3. *SAE International Aerospace Material Specification, "Deicing/Anti-icing Fluid, Aircraft, SAE Type I", AMS 1424, revision K, March 2012.*
4. *Laforte, J.-L., P. Louchez, and G. Bouchard, "Experimental Evaluation of Flat Plate Boundary Layer Growth over an Anti-Icing Fluid Film". Canadian Aeronautics and Space Journal, 1993.* ***39****(2): p. 96-104.*

ATTACHMENT 1 – TEST DATA SHEETS

DRY RUNS

FPD-067



CRITICAL TIME TEST DATA

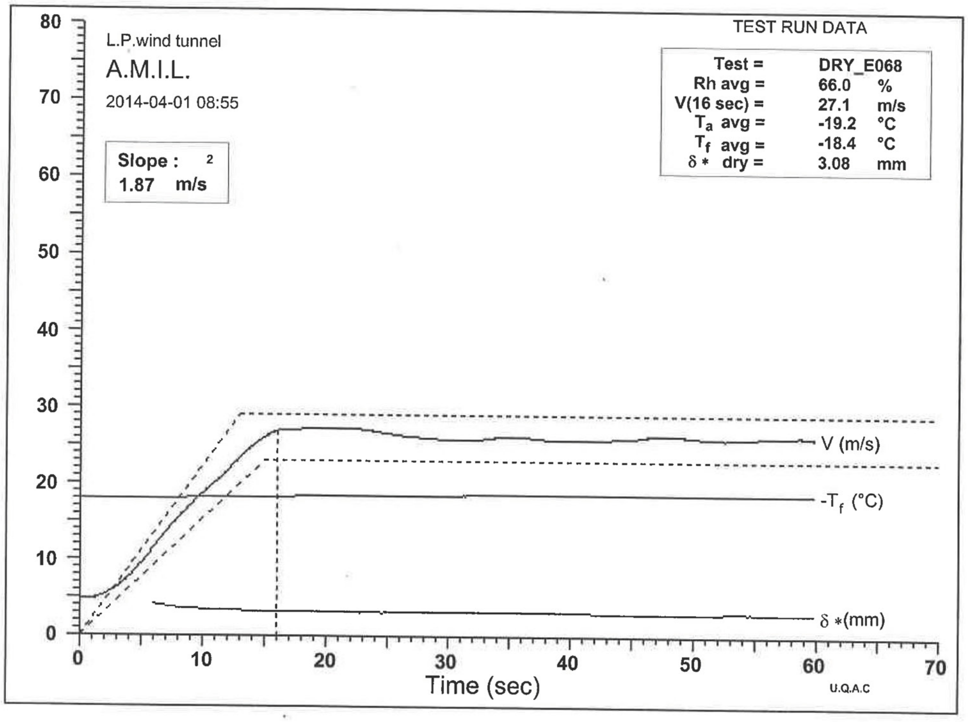
Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
15	-18.8	-18.3	67.2	1.96	26.7	0.01	3.02
16	-18.9	-18.3	66.9	1.89	26.2	0.02	3.13
17	-18.8	-18.3	66.6	1.87	26.1	0.02	3.12
Averages							
16	-18.8	-18.3	66.9	1.90	26.3	0.02	3.10

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 A-2 AMIL, 2015-01-22

FPD-068



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
15	-18.7	-18.2	67.4	2.00	27.0	0.01	3.08
16	-18.9	-18.3	67.0	2.03	27.1	0.02	3.11
17	-18.9	-18.3	67.1	2.04	27.2	0.01	3.04

Averages

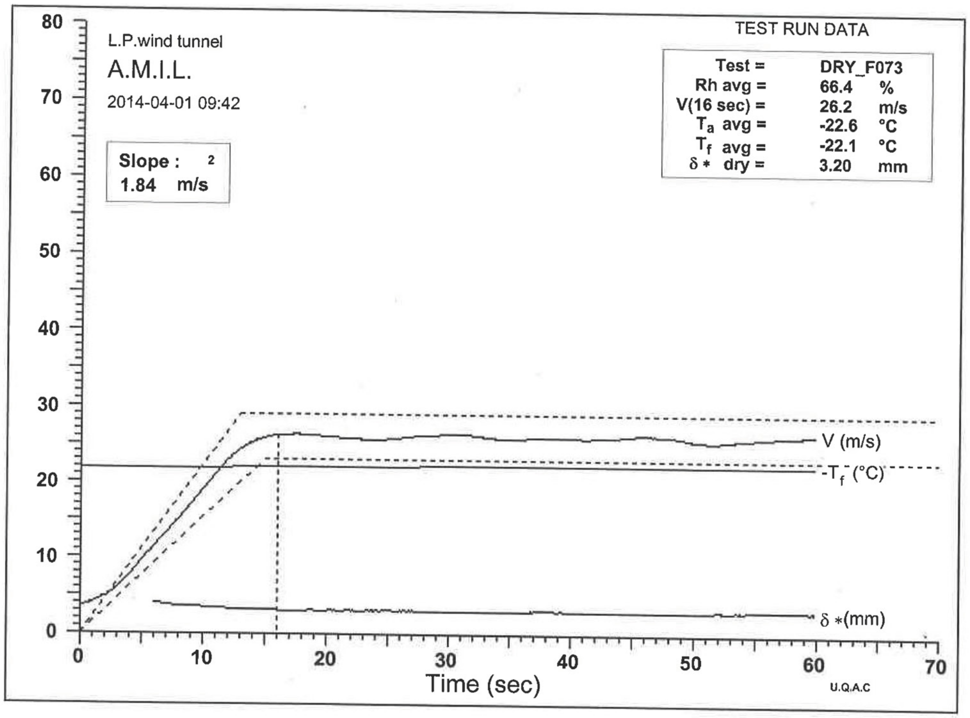
16	-18.9	-18.3	67.1	2.03	27.1	0.02	3.08

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-3* *AMIL, 2015-01-22*

FPD-073



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
15	-22.1	-22.0	66.9	1.89	26.1	0.02	3.12
16	-22.4	-22.0	66.9	1.94	26.3	0.03	3.21
17	-22.4	-22.0	67.0	1.91	26.2	0.03	3.24

Averages

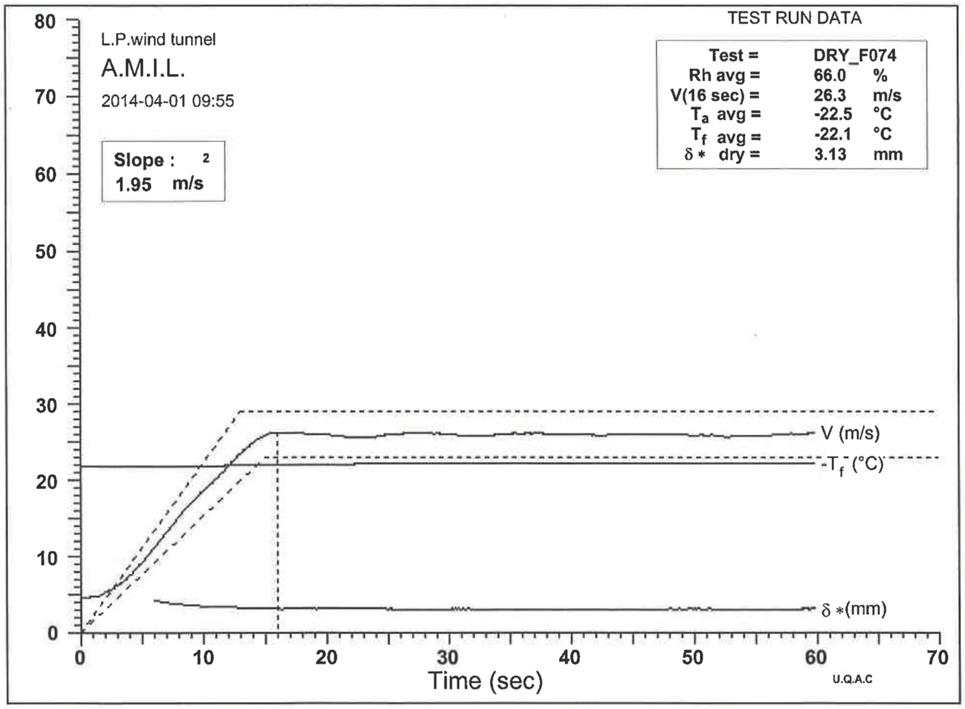
16	-22.3	-22.0	66.9	1.92	26.2	0.03	3.20

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-4* *AMIL, 2015-01-22*

FPD-074



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
15	-22.0	-22.0	66.9	1.93	26.3	0.02	3.09
16	-22.2	-22.0	66.9	1.92	26.3	0.02	3.13
17	-22.2	-22.0	67.0	1.94	26.4	0.03	3.18

Averages

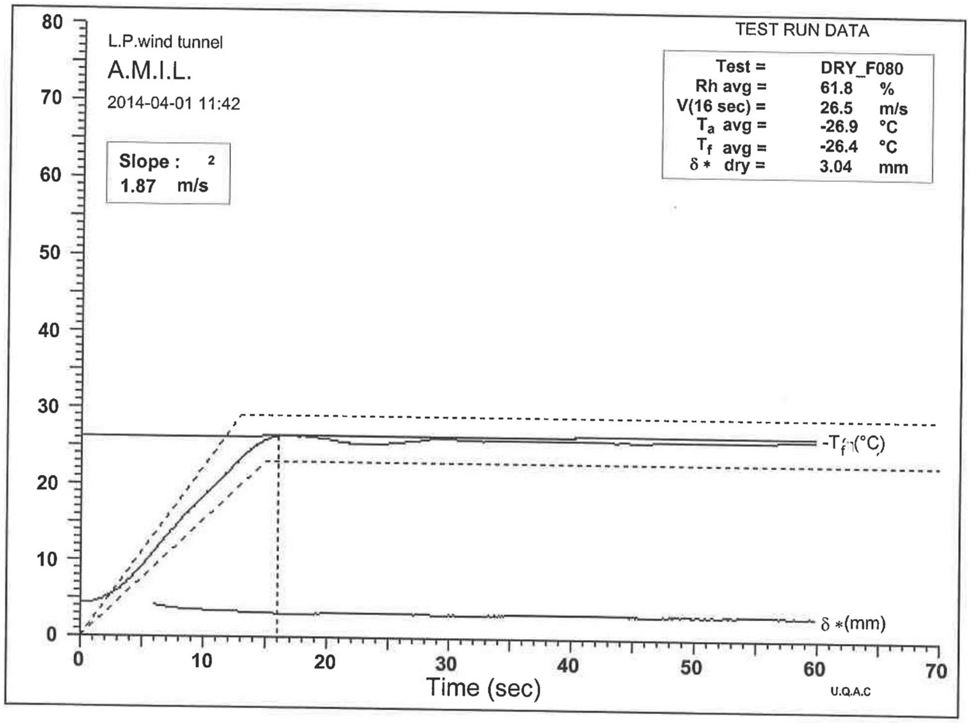
16	-22.2	-22.0	66.9	1.93	26.3	0.02	3.13

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-5* *AMIL, 2015-01-22*

FPD-080



CRITICAL TIME TEST DATA

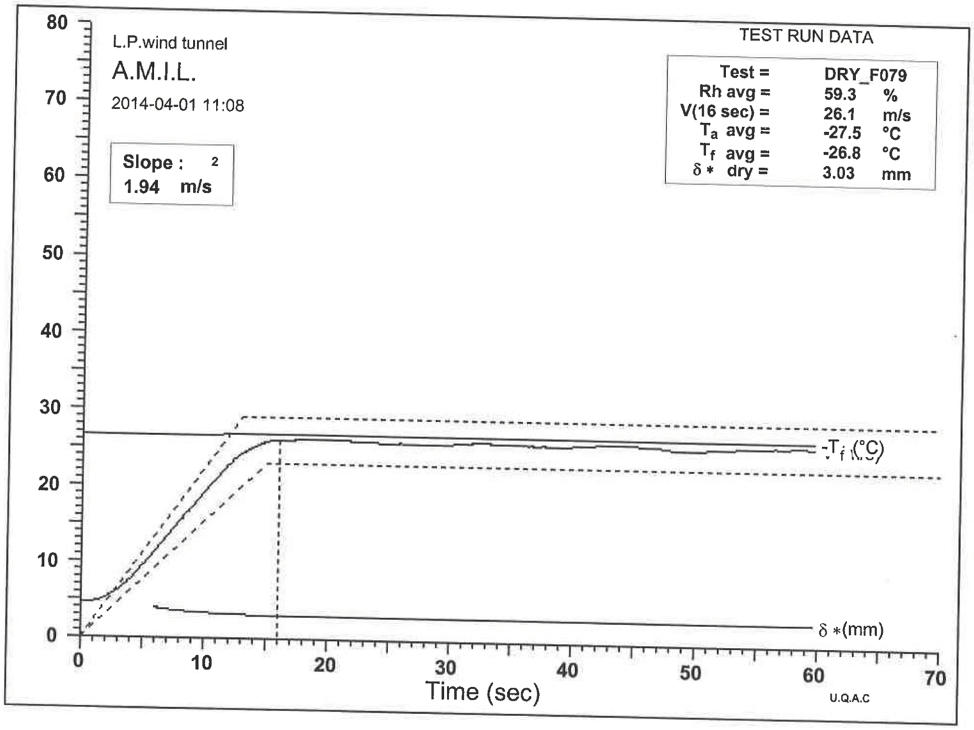
Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
15	-26.6	-26.3	62.1	1.98	26.4	0.01	3.07
16	-26.8	-26.3	62.2	1.99	26.5	0.01	3.04
17	-26.8	-26.3	62.3	2.00	26.5	0.01	3.02
Averages							
16	-26.8	-26.3	62.2	1.99	26.5	0.01	3.04

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 A-6 AMIL, 2015-01-22

FPD-079



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
15	-27.6	-26.7	59.4	1.86	25.5	0.01	3.06
16	-27.7	-26.8	59.3	1.97	26.3	0.01	2.99
17	-27.6	-26.8	59.1	1.97	26.3	0.01	3.06

Averages

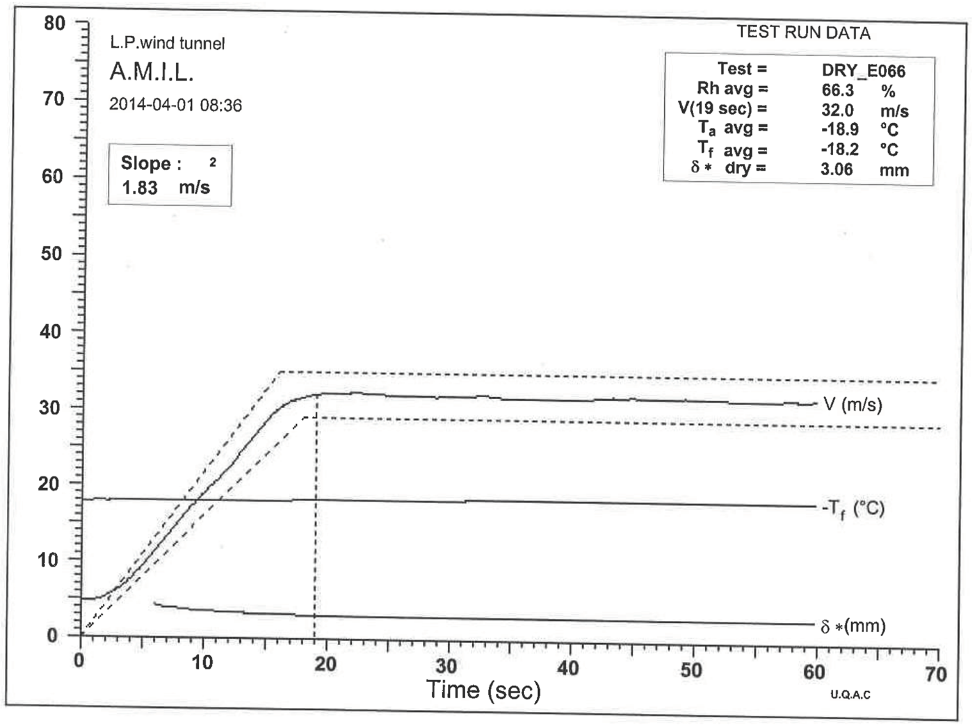
16	-27.6	-26.8	59.3	1.94	26.1	0.01	3.03

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 A-7 AMIL, 2015-01-22

FPD-066



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
18	-18.9	-18.1	67.0	2.82	32.0	0.02	3.07
19	-18.9	-18.1	67.2	2.81	32.0	0.02	3.06
20	-19.0	-18.2	67.1	2.83	32.1	0.02	3.04

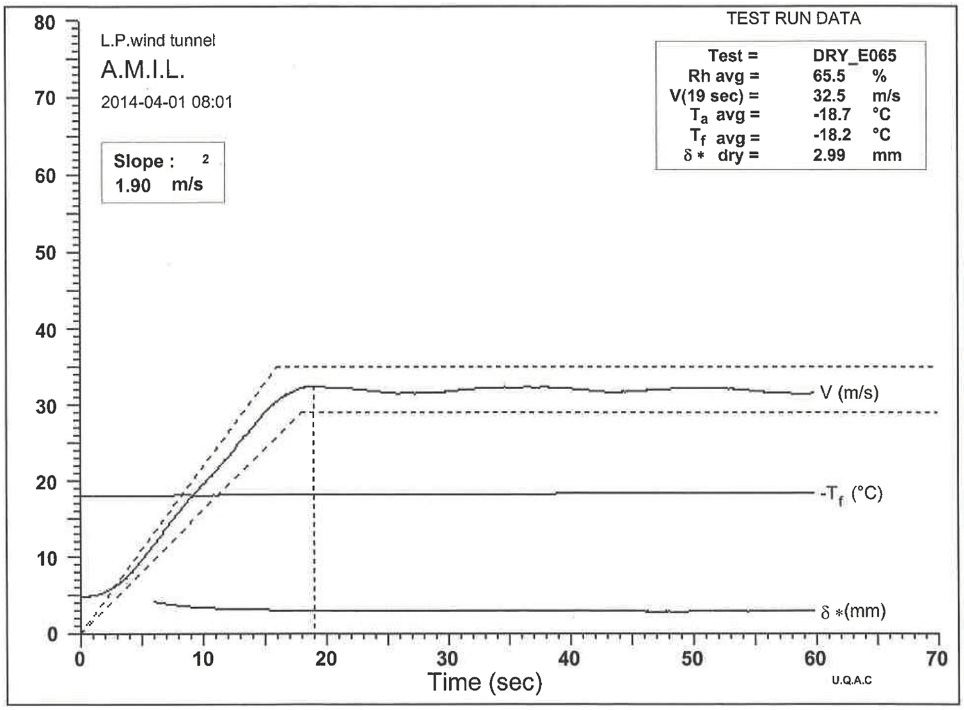
Averages

19	-18.9	-18.1	67.1	2.82	32.0	0.02	3.06

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

FPD-065



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
18	-18.8	-18.2	66.3	2.94	32.7	0.02	3.03
19	-18.8	-18.2	66.1	2.89	32.4	0.01	2.99
20	-18.9	-18.2	66.0	2.89	32.4	0.00	2.95

Averages

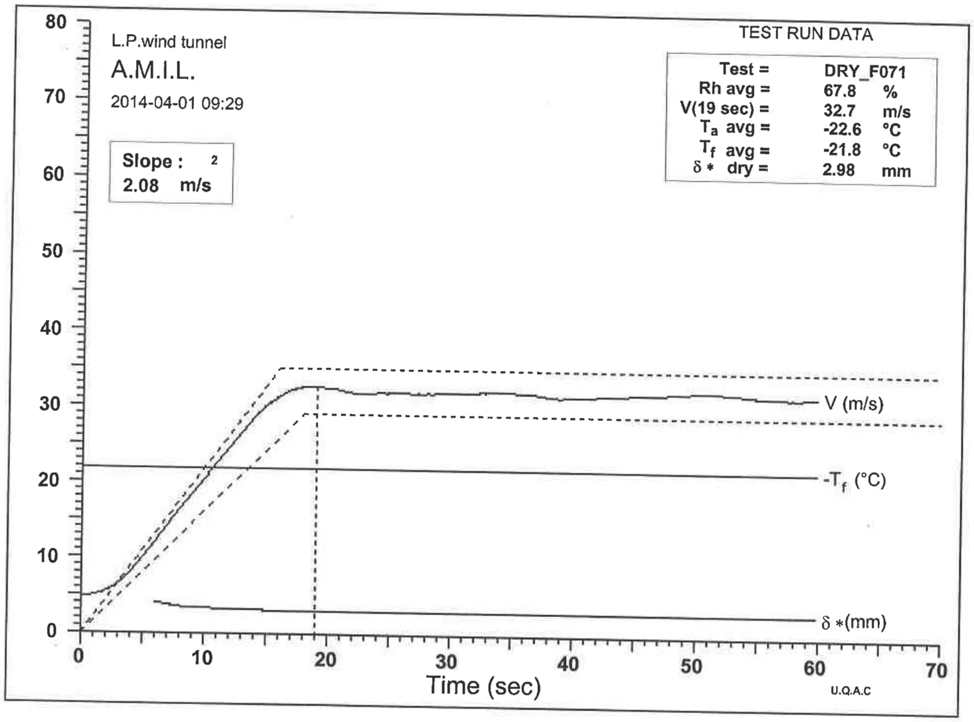
19	-18.8	-18.2	66.1	2.90	32.5	0.01	2.99

Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

2012-MT-13, Year 3   *A-9*   *AMIL, 2015-01-22*

FPD-071



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
18	-22.7	-21.8	67.8	2.92	32.3	0.01	3.00
19	-22.7	-21.9	67.5	3.00	32.8	0.01	2.98
20	-22.7	-21.8	67.8	3.01	32.8	0.00	2.97

Averages

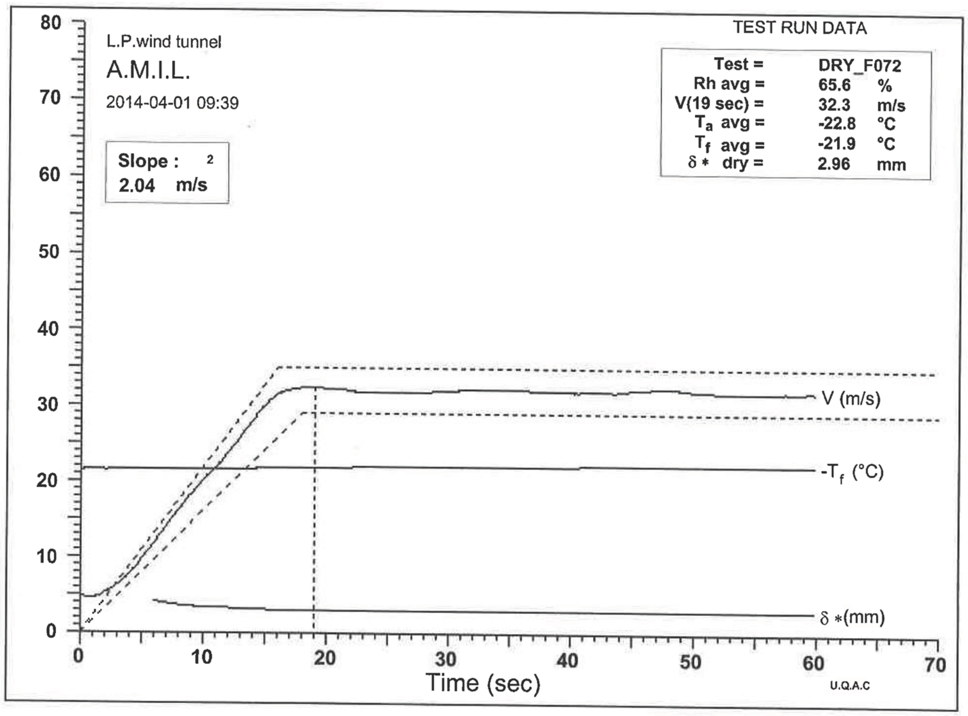
19	-22.7	-21.8	67.7	2.98	32.7	0.01	2.98

Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

2012-MT-13, Year 3   *A-10*   *AMIL, 2015-01-22*

FPD-072



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
18	-22.8	-21.8	66.5	2.90	32.2	0.00	2.94
19	-22.9	-21.8	66.3	2.90	32.2	0.00	2.93
20	-22.9	-21.9	66.5	2.98	32.6	0.01	3.02

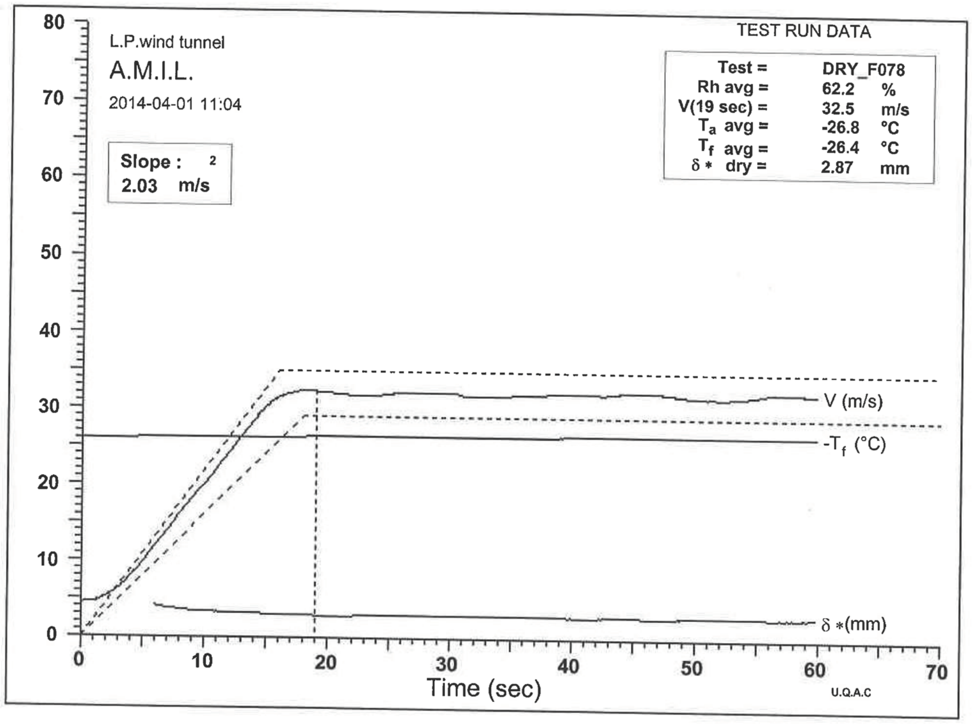
Averages

19	-22.9	-21.8	66.4	2.92	32.3	0.00	2.96

Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

FPD-078



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ * mm
18	-26.9	-26.3	62.6	2.98	32.4	-0.01	2.87
19	-26.9	-26.3	62.6	2.98	32.4	-0.01	2.90
20	-27.0	-26.3	62.6	3.03	32.7	-0.02	2.82

Averages

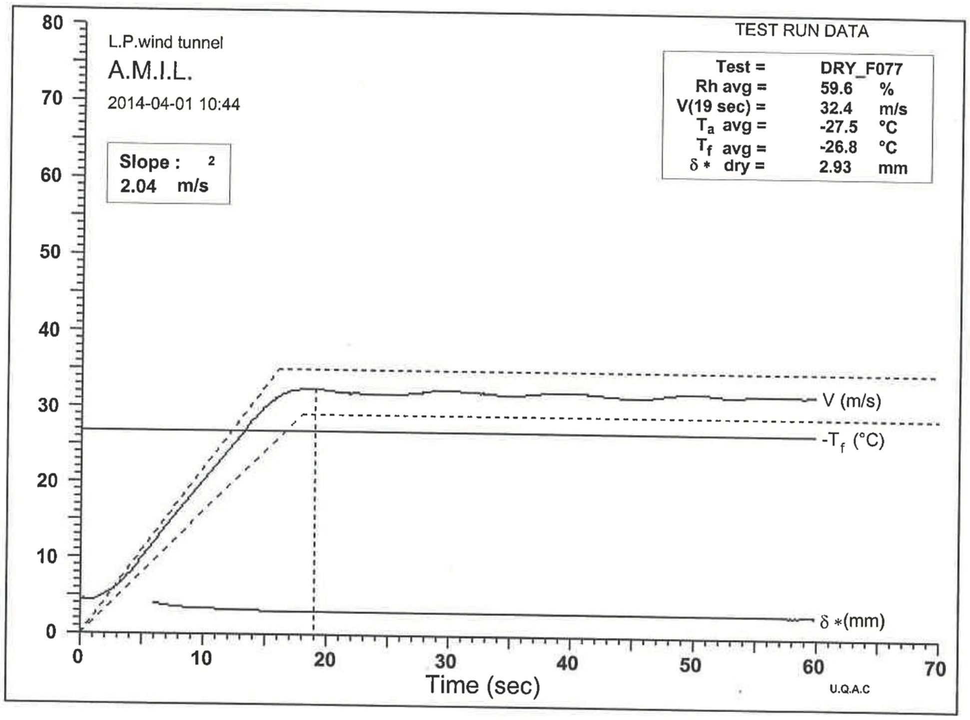
19	-26.9	-26.3	62.6	2.99	32.5	-0.01	2.87

Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

2012-MT-13, Year 3   *A-12*   *AMIL, 2015-01-22*

FPD-077



CRITICAL TIME TEST DATA

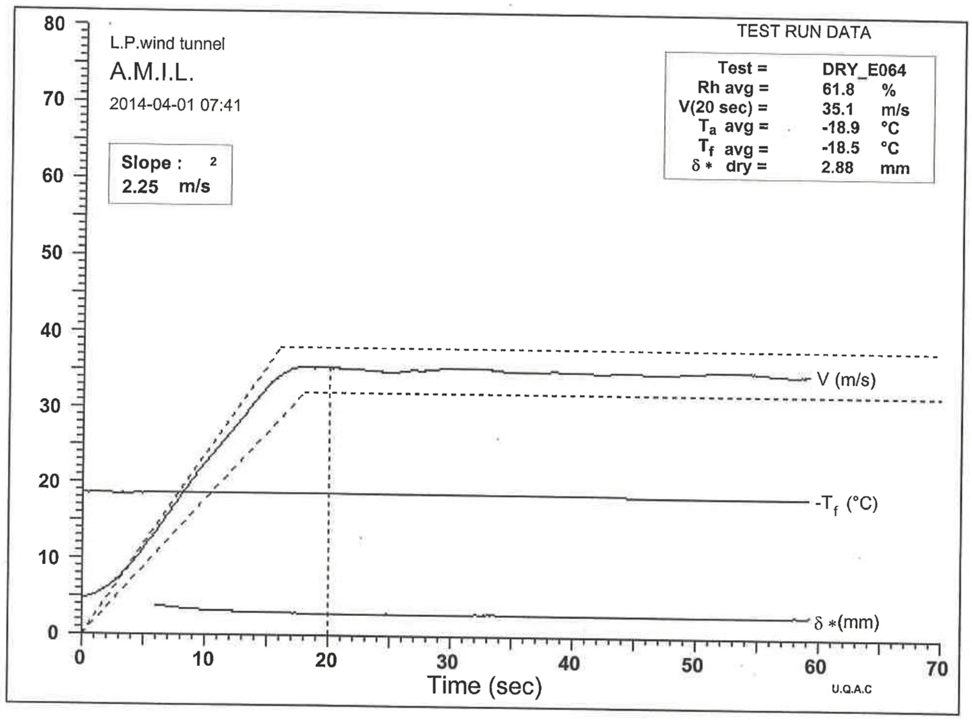
Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
18	-27.6	-26.9	59.3	3.02	32.5	0.01	3.01
19	-27.6	-26.9	59.5	3.01	32.5	-0.01	2.89
20	-27.6	-26.9	59.2	2.96	32.2	0.00	2.94
Averages							
19	-27.6	-26.9	59.4	3.00	32.4	0.00	2.93

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-13* *AMIL, 2015-01-22*

FPD-064



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
19	-19.0	-18.5	61.3	3.46	35.4	-0.03	2.77
20	-19.0	-18.5	61.2	3.36	34.9	0.00	2.93
21	-19.0	-18.5	61.1	3.40	35.1	-0.01	2.88

Averages

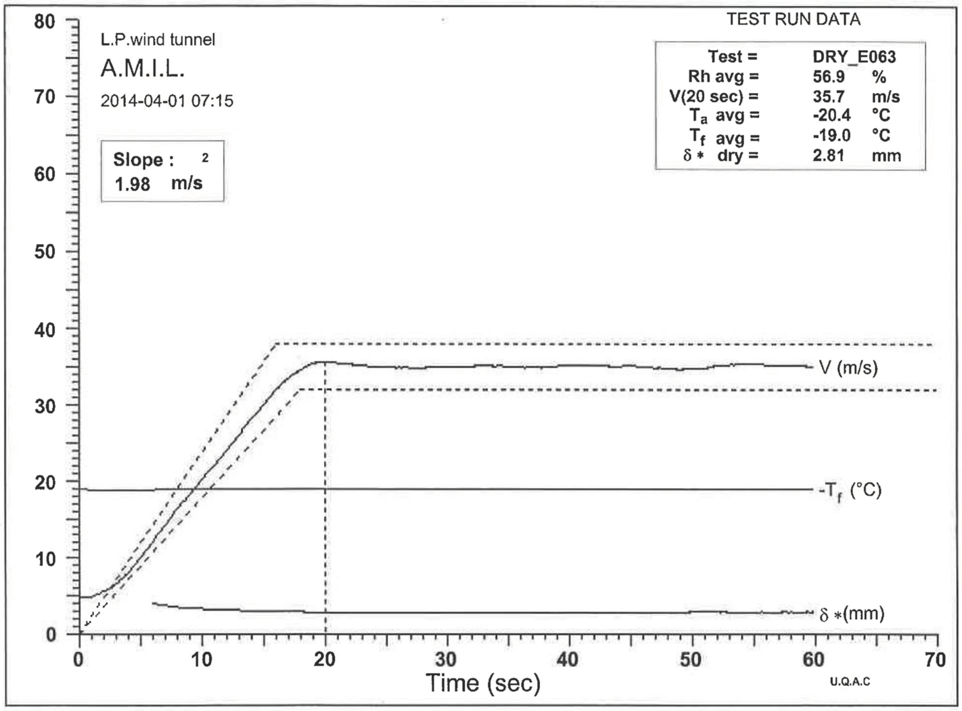
20	-19.0	-18.5	61.2	3.39	35.1	-0.01	2.88

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 A-14 AMIL, 2015-01-22

FPD-063



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ * mm
19	-20.6	-19.0	56.6	3.55	35.8	-0.03	2.78
20	-20.5	-19.0	56.5	3.54	35.8	-0.02	2.81
21	-20.5	-19.0	56.6	3.52	35.7	-0.02	2.83

Averages

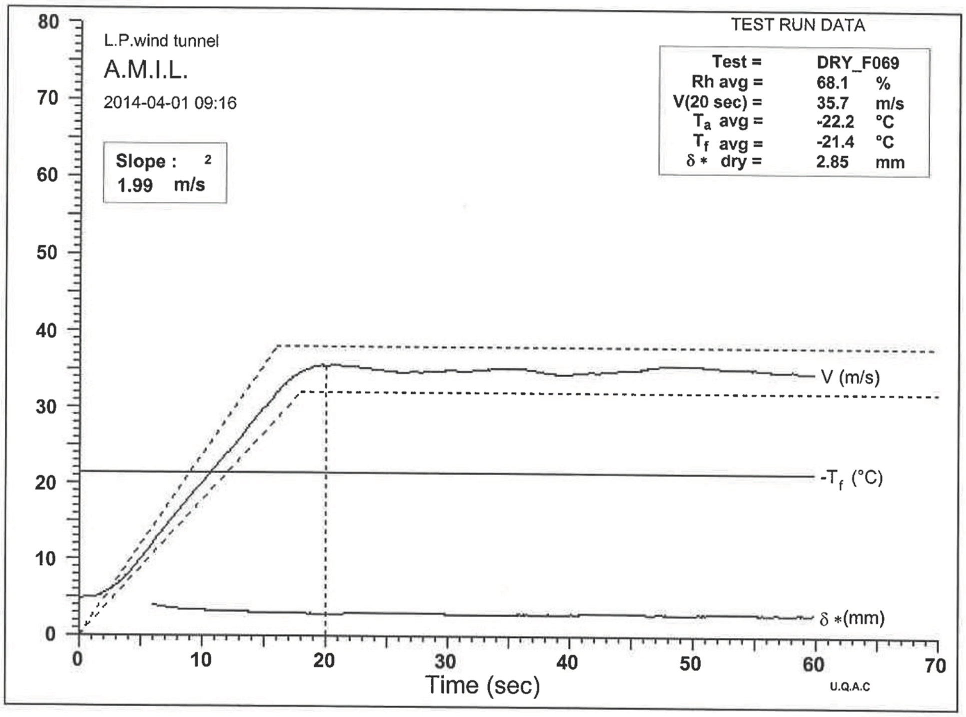
20	-20.5	-19.0	56.5	3.54	35.7	-0.02	2.81

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-15* *AMIL, 2015-01-22*

FPD-069



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
19	-22.3	-21.4	67.8	3.60	35.9	-0.01	2.88
20	-22.3	-21.4	67.8	3.51	35.5	-0.02	2.85
21	-22.3	-21.4	67.9	3.60	35.9	-0.02	2.85

Averages

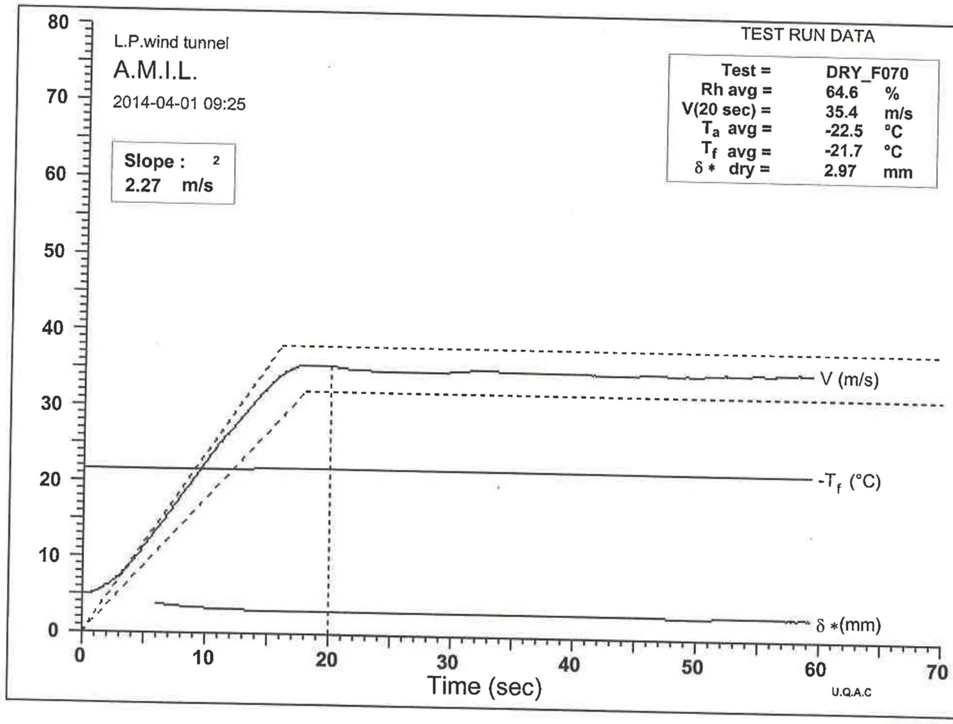
20	-22.3	-21.4	67.8	3.56	35.7	-0.02	2.85

Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

2012-MT-13, Year 3   *A-16*   *AMIL, 2015-01-22*

FPD-070



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ * mm
19	-22.7	-21.7	64.4	3.50	35.4	0.01	2.97
20	-22.7	-21.7	64.6	3.49	35.3	0.01	2.99
21	-22.7	-21.7	64.8	3.52	35.5	0.00	2.93

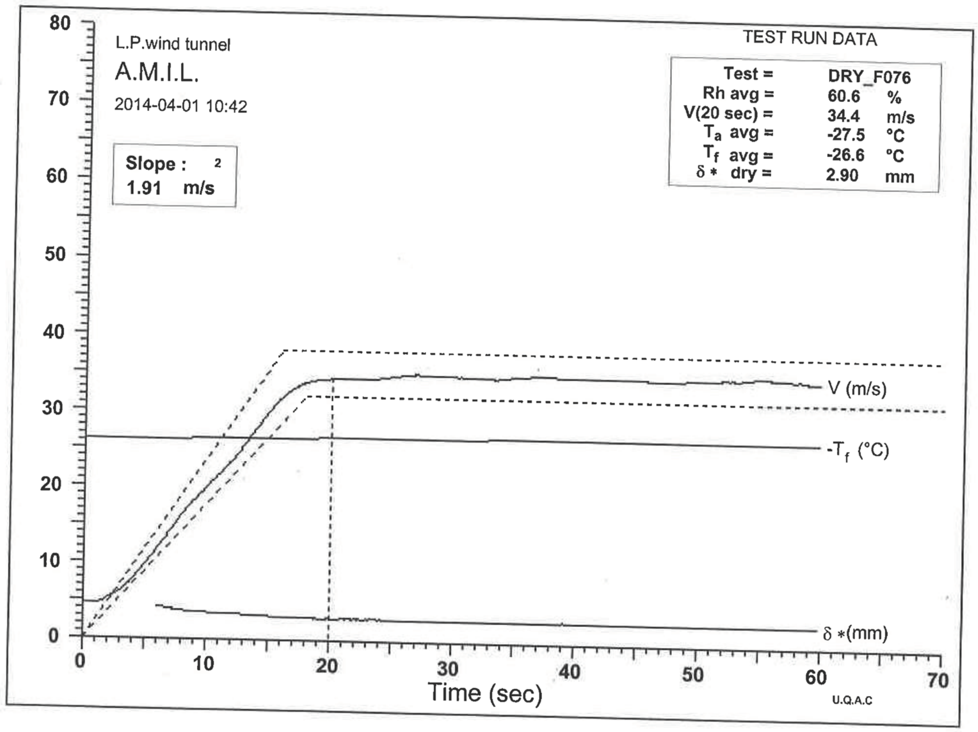
Averages

20	-22.7	-21.7	64.6	3.50	35.4	0.01	2.97

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

FPD-076



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ * mm
19	-27.6	-26.5	61.0	3.36	34.4	0.01	2.97
20	-27.7	-26.5	61.1	3.37	34.4	-0.01	2.90
21	-27.7	-26.5	61.2	3.40	34.5	-0.02	2.83

Averages

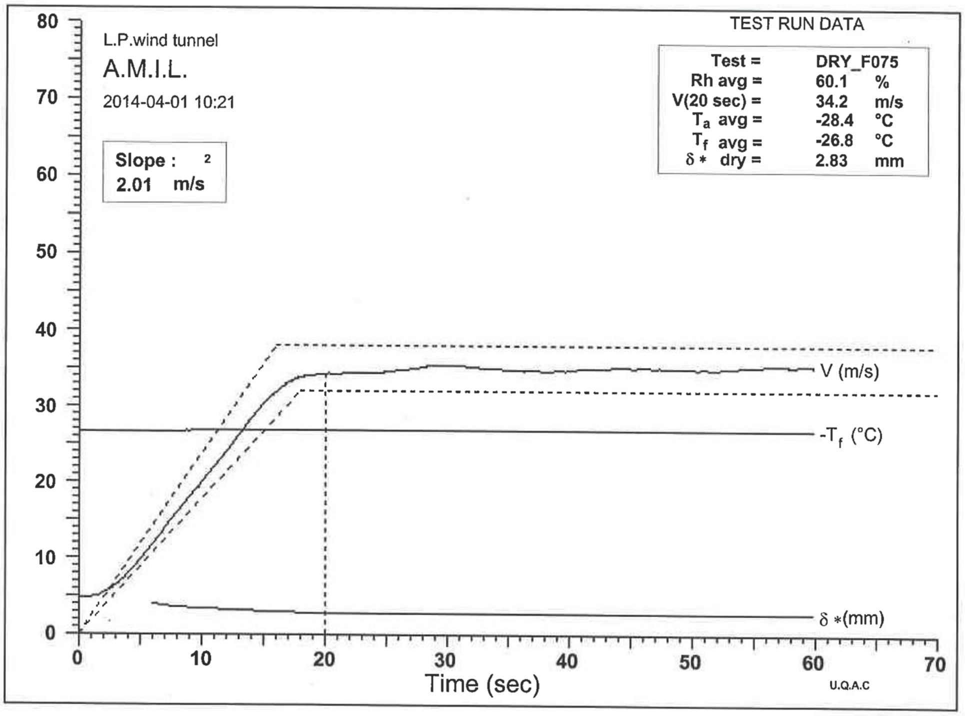
20	-27.7	-26.5	61.1	3.38	34.4	-0.01	2.90

Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

2012-MT-13, Year 3   *A-18*   *AMIL, 2015-01-22*

FPD-075



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
19	-28.5	-26.8	60.0	3.28	33.9	-0.02	2.84
20	-28.5	-26.8	60.1	3.33	34.1	-0.02	2.84
21	-28.6	-26.8	60.0	3.43	34.6	-0.02	2.81

Averages

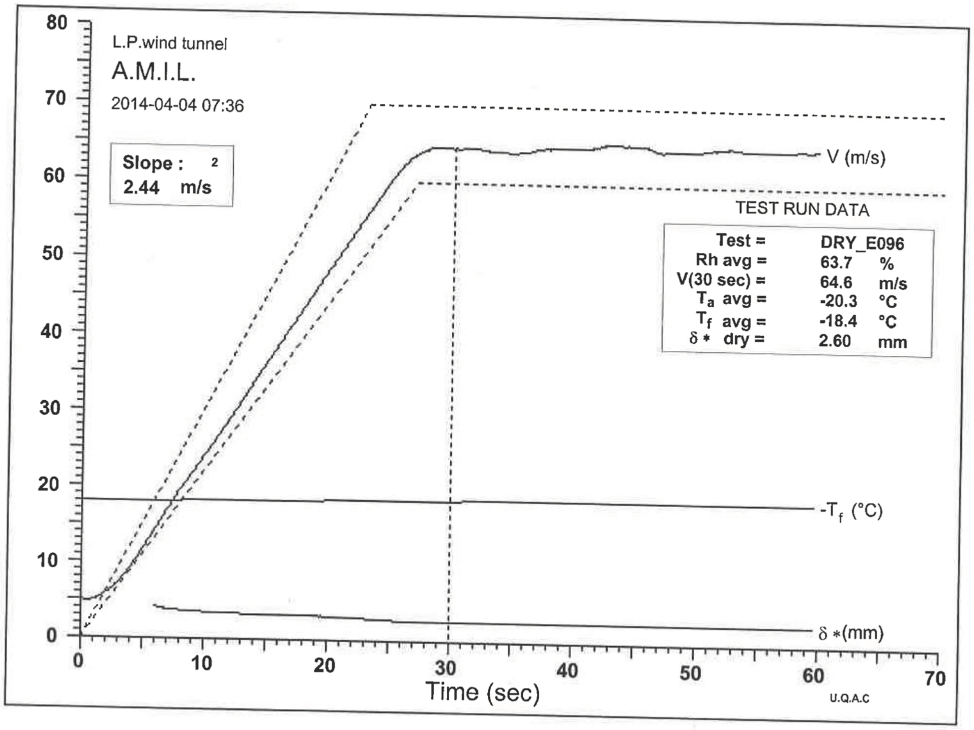
20	-28.5	-26.8	60.1	3.35	34.2	-0.02	2.83

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 A-19 AMIL, 2015-01-22

FPD-096



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
27	-21.1	-18.4	63.2	11.57	64.6	-0.17	2.65
28	-21.0	-18.5	63.1	11.72	65.0	-0.25	2.54
29	-21.0	-18.5	62.9	11.43	64.2	-0.20	2.61
30	-21.0	-18.5	62.8	11.59	64.6	-0.20	2.61
31	-21.0	-18.5	62.9	11.55	64.5	-0.16	2.68
32	-20.9	-18.5	62.8	11.61	64.7	-0.22	2.58
33	-20.9	-18.5	62.4	11.63	64.8	-0.23	2.57

Averages

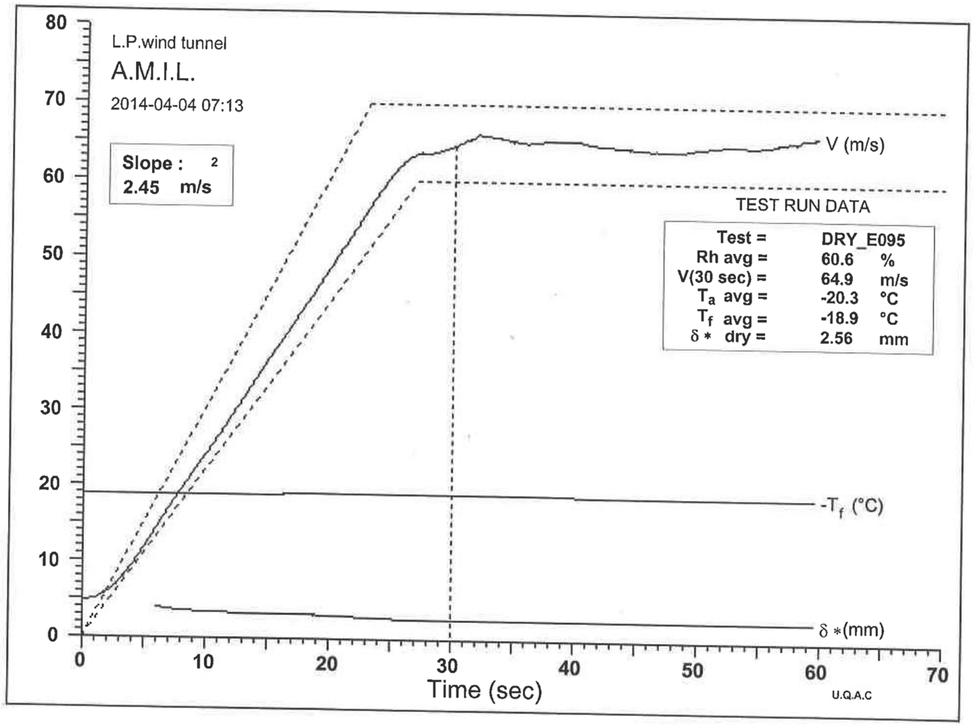
30	-21.0	-18.5	62.9	11.58	64.6	-0.21	2.60

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-20* *AMIL, 2015-01-22*

FPD-095



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
27	-20.6	-18.9	59.8	11.61	64.7	-0.24	2.54
28	-20.5	-18.9	59.7	11.20	63.6	-0.16	2.66
29	-20.5	-18.9	59.7	11.10	63.3	-0.22	2.56
30	-20.4	-19.0	60.1	11.36	64.0	-0.22	2.58
31	-20.4	-18.9	60.0	12.19	66.3	-0.31	2.45
32	-20.4	-18.9	60.1	12.18	66.3	-0.23	2.59
33	-20.4	-18.9	60.3	12.24	66.5	-0.25	2.55

Averages

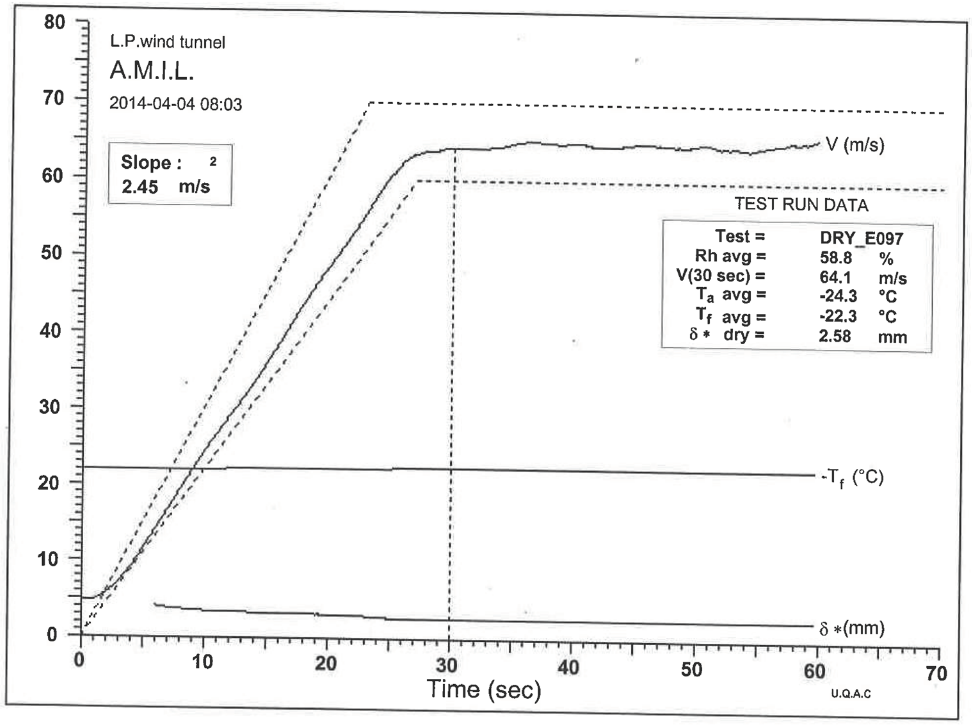
30	-20.5	-18.9	59.9	11.67	64.9	-0.23	2.56

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-21* *AMIL, 2015-01-22*

FPD-097



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
27	-24.8	-22.3	58.4	11.30	63.3	-0.20	2.60
28	-24.8	-22.3	58.1	11.63	64.2	-0.16	2.67
29	-24.8	-22.3	58.0	11.46	63.8	-0.21	2.60
30	-24.8	-22.4	58.4	11.58	64.1	-0.28	2.49
31	-24.7	-22.4	58.1	11.87	64.9	-0.21	2.61
32	-24.6	-22.4	58.0	11.54	64.0	-0.23	2.56
33	-24.6	-22.4	58.3	11.45	63.8	-0.24	2.54

Averages

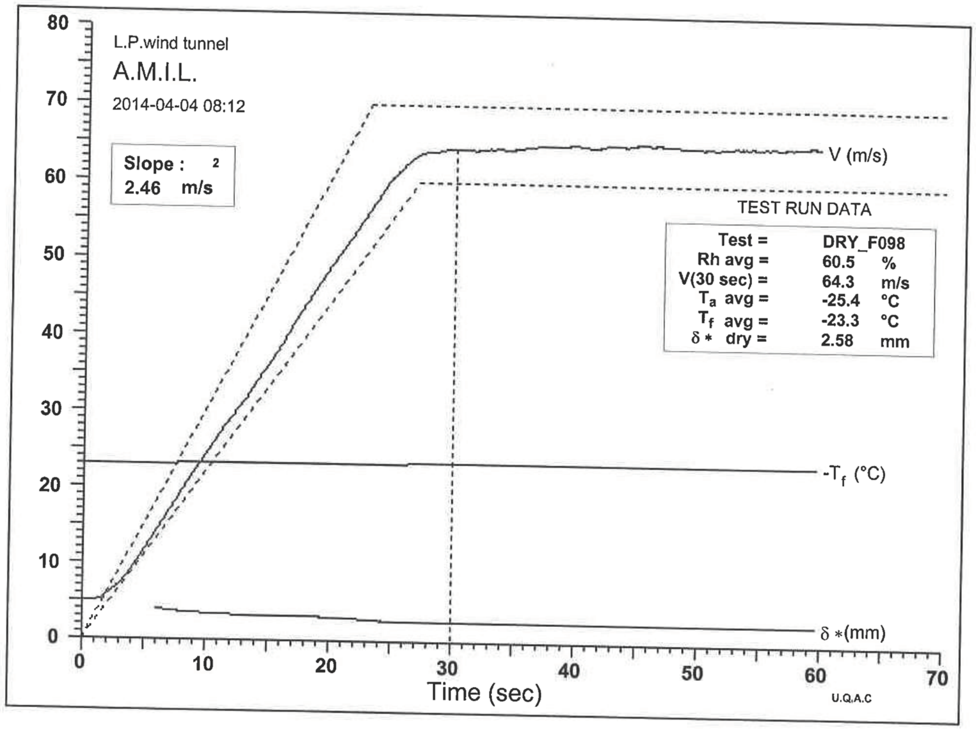
30	-24.7	-22.4	58.2	11.57	64.1	-0.22	2.58

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-22* *AMIL, 2015-01-22*

FPD-098



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
27	-25.8	-23.3	60.4	11.34	63.3	-0.24	2.54
28	-25.7	-23.3	60.3	11.75	64.5	-0.16	2.68
29	-25.7	-23.3	59.9	11.76	64.5	-0.28	2.49
30	-25.7	-23.3	60.1	11.68	64.3	-0.17	2.66
31	-25.6	-23.3	59.9	11.68	64.3	-0.24	2.54
32	-25.6	-23.3	60.0	11.80	64.6	-0.24	2.56
33	-25.6	-23.3	60.1	11.64	64.2	-0.22	2.58

Averages

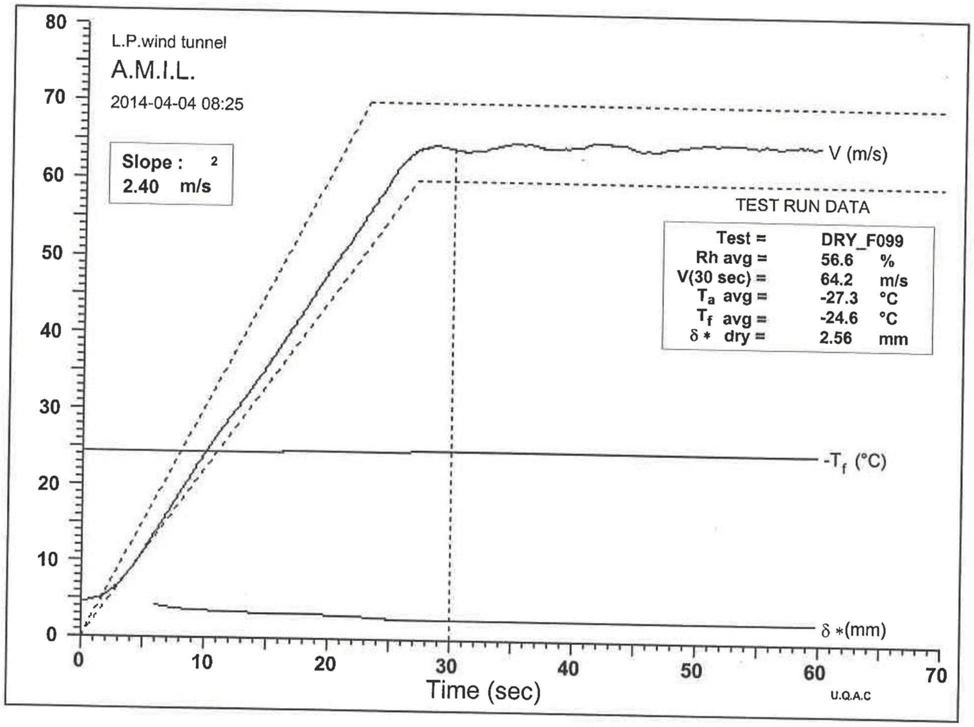
30	-25.7	-23.3	60.1	11.69	64.3	-0.22	2.58

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 A-23 AMIL, 2015-01-22

FPD-099



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
27	-27.9	-24.7	56.1	12.19	65.4	-0.28	2.51
28	-27.9	-24.7	56.1	11.93	64.6	-0.26	2.53
29	-27.9	-24.7	56.1	11.83	64.4	-0.23	2.58
30	-27.8	-24.7	56.2	11.81	64.3	-0.25	2.54
31	-27.8	-24.8	56.3	11.59	63.7	-0.24	2.55
32	-27.7	-24.8	55.8	11.49	63.5	-0.18	2.64
33	-27.7	-24.8	56.0	11.58	63.7	-0.22	2.58

Averages

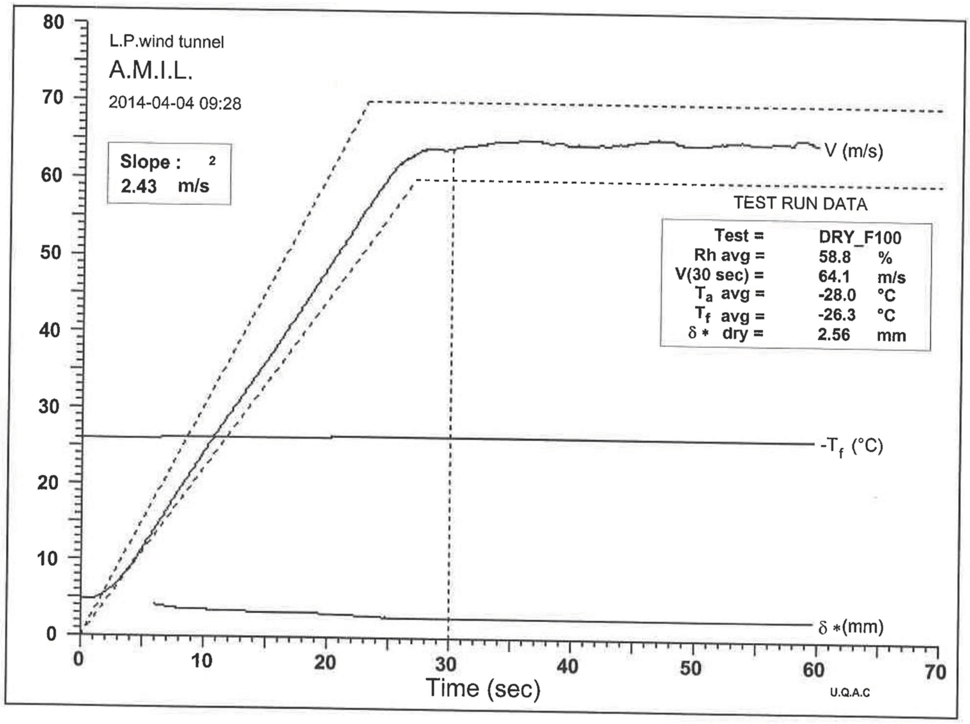
30	-27.8	-24.7	56.1	11.75	64.2	-0.23	2.56

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-24* *AMIL, 2015-01-22*

FPD-100



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	$P_1 - P_2$ "H_2O	V m/s	$P_2 - P_3$ "H_2O	δ * mm
27	-28.5	-26.4	58.4	11.89	64.5	-0.26	2.52
28	-28.5	-26.4	58.2	11.50	63.4	-0.26	2.51
29	-28.5	-26.4	58.2	11.73	64.1	-0.22	2.58
30	-28.4	-26.4	58.1	11.72	64.0	-0.18	2.64
31	-28.3	-26.4	58.5	11.74	64.1	-0.24	2.56
32	-28.3	-26.4	58.3	11.94	64.6	-0.21	2.60
33	-28.3	-26.4	58.1	12.02	64.8	-0.30	2.46

Averages

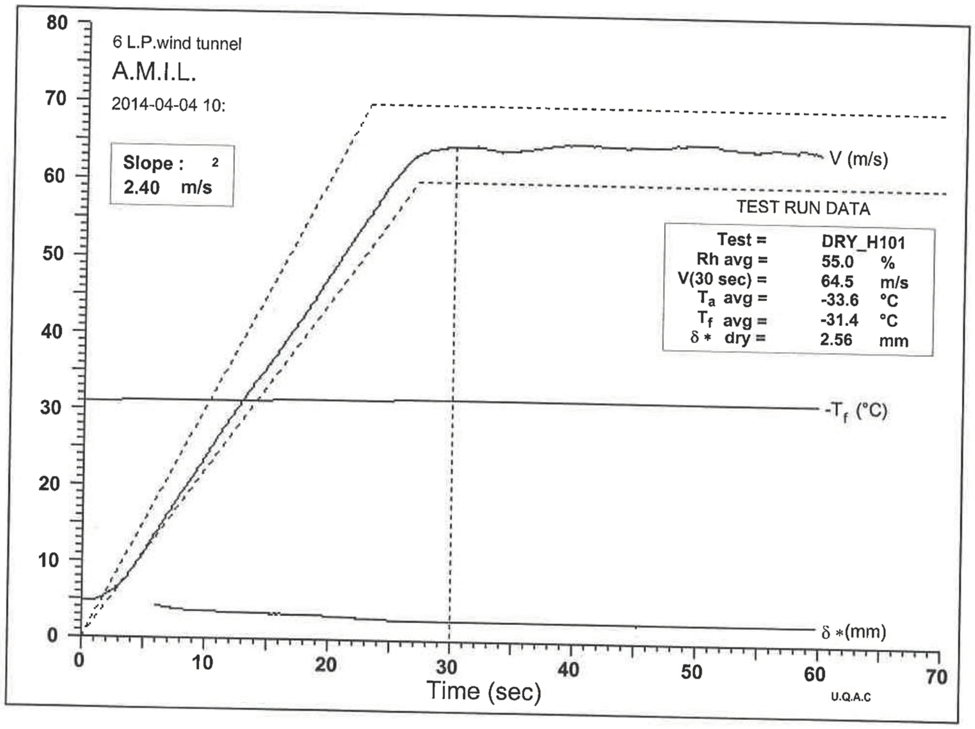
30	-28.4	-26.4	58.3	11.77	64.1	-0.23	2.56

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *A-25* *AMIL, 2015-01-22*

FPD-101



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
27	-34.2	-31.5	54.6	12.10	64.3	-0.25	2.55
28	-34.2	-31.5	54.8	12.20	64.5	-0.22	2.60
29	-34.1	-31.6	54.7	11.77	63.4	-0.27	2.49
30	-34.0	-31.6	54.5	12.40	65.1	-0.25	2.56
31	-33.9	-31.6	54.6	12.45	65.2	-0.25	2.56
32	-33.9	-31.6	54.4	12.16	64.5	-0.25	2.54
33	-33.9	-31.6	54.5	12.19	64.6	-0.21	2.61

Averages

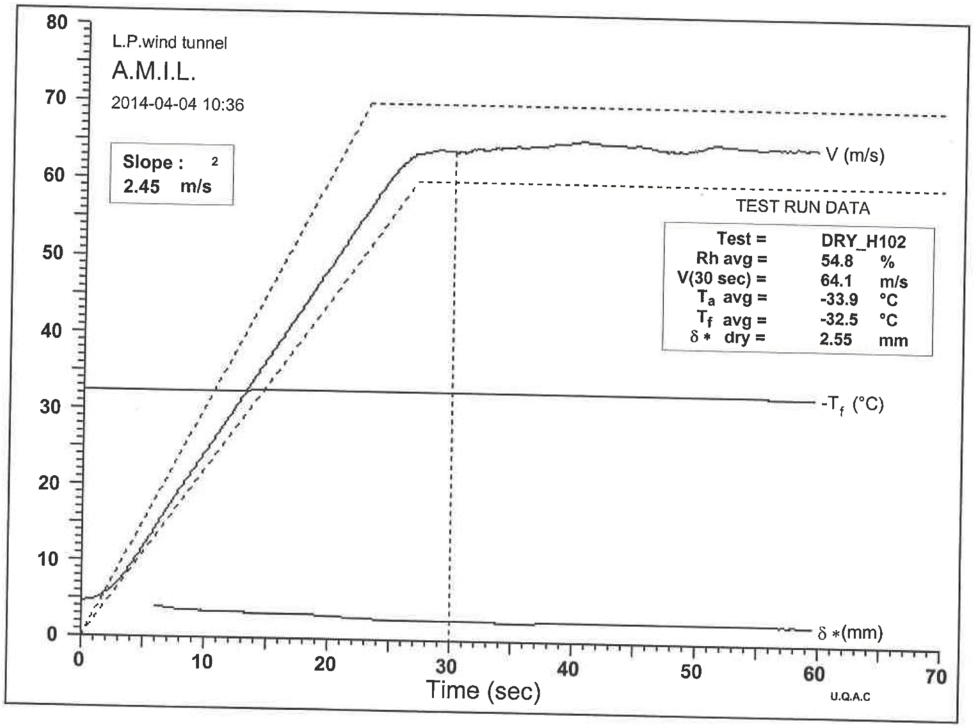
30	-34.0	-31.6	54.6	12.19	64.5	-0.24	2.56

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 A-26 AMIL, 2015-01-22

FPD-102



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
27	-34.3	-32.6	54.7	12.42	65.1	-0.28	2.51
28	-34.3	-32.6	54.3	12.07	64.2	-0.26	2.53
29	-34.2	-32.6	54.6	11.64	63.0	-0.20	2.62
30	-34.1	-32.6	54.6	12.23	64.6	-0.30	2.47
31	-34.1	-32.6	54.4	11.96	63.9	-0.27	2.51
32	-34.1	-32.6	54.3	12.06	64.2	-0.20	2.63
33	-34.1	-32.6	54.7	11.92	63.8	-0.22	2.58

Averages

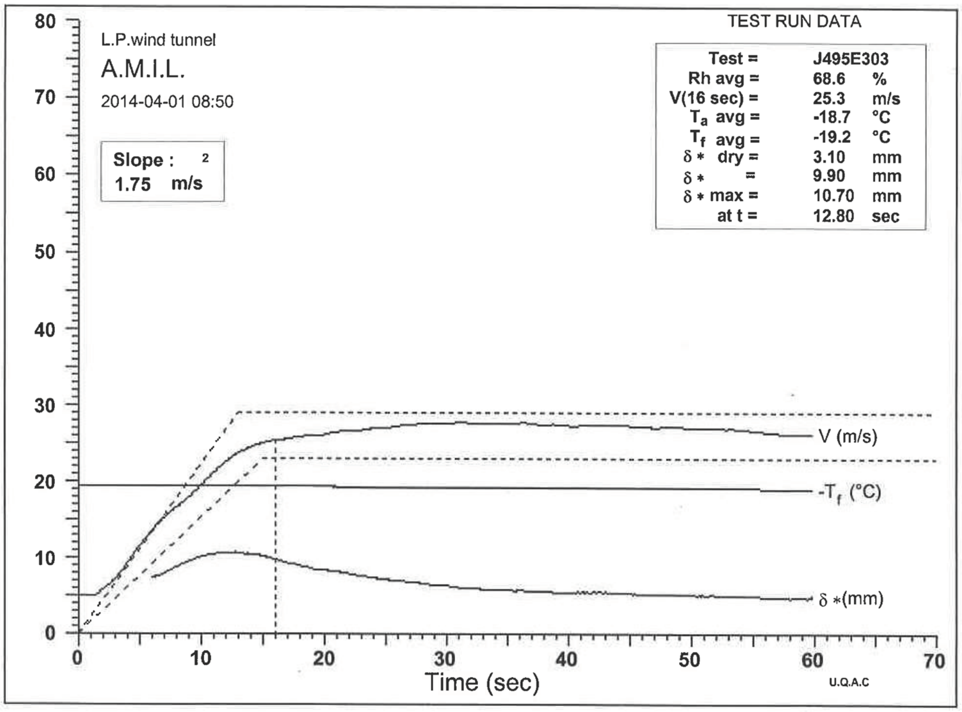
30	-34.2	-32.6	54.5	12.02	64.1	-0.25	2.55

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

Polar Plus 63/37, lot # 13403 (J495)

FP-303



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
15	-18.8	-19.3	67.7	1.68	24.7	0.26	9.75
16	-18.8	-19.3	67.8	1.77	25.4	0.29	10.00
17	-18.8	-19.3	68.0	1.84	25.8	0.29	9.84

Averages

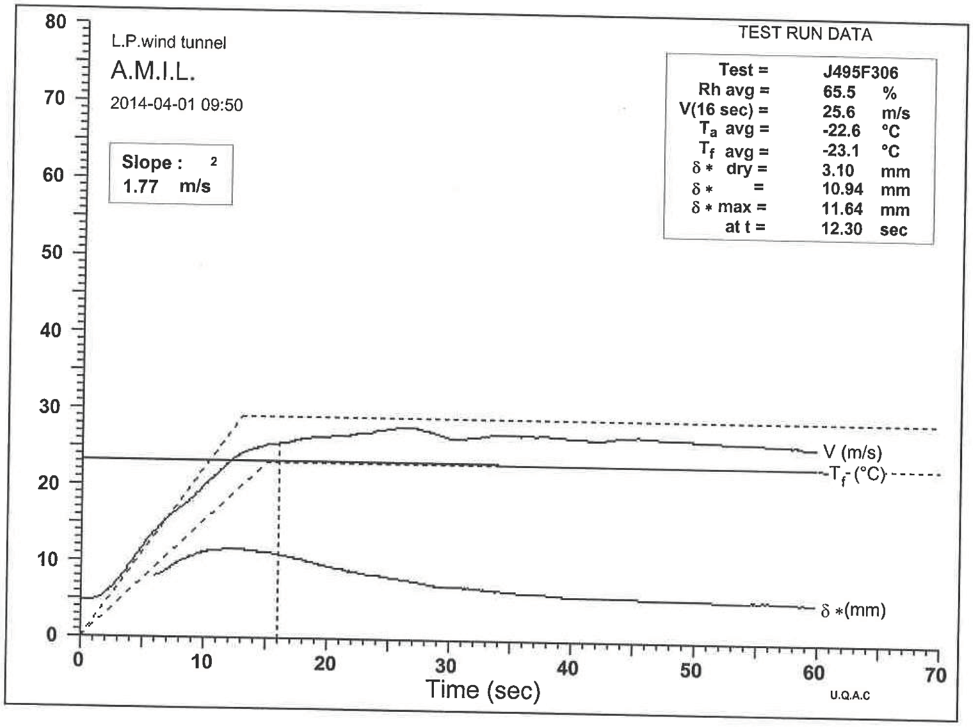
16	-18.8	-19.3	67.8	1.77	25.3	0.28	9.90

Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

2012-MT-13, Year 3   *B-2*   *AMIL, 2015-01-22*

FP-306



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
15	-22.7	-23.2	64.9	1.77	25.2	0.33	11.07
16	-22.7	-23.2	65.1	1.81	25.4	0.33	10.82
17	-22.7	-23.2	64.9	1.93	26.3	0.36	11.05

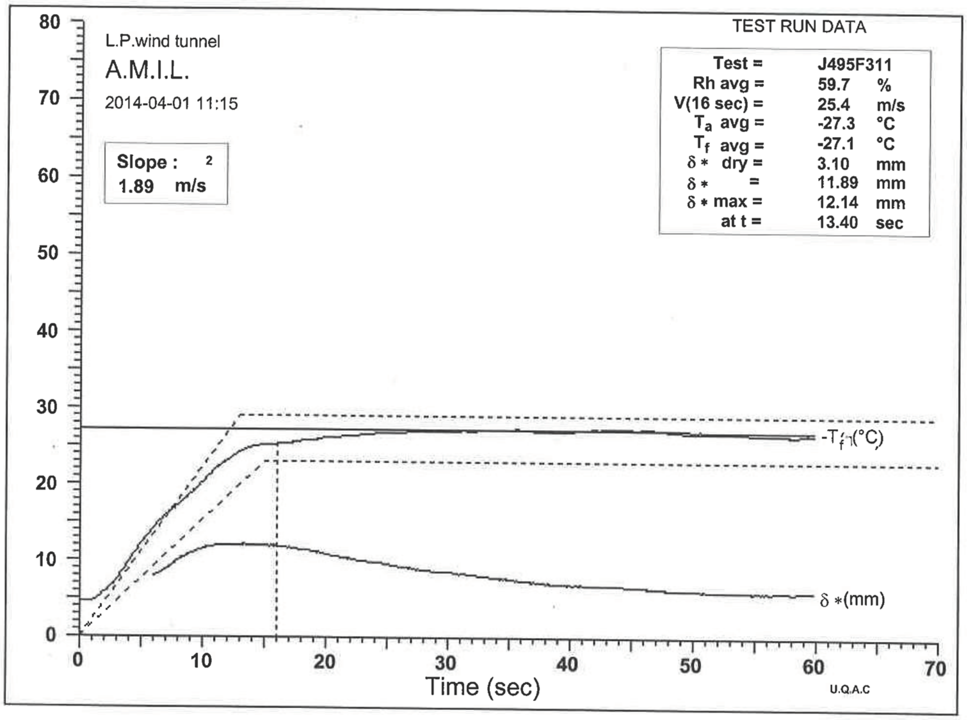
Averages

16	-22.7	-23.2	65.0	1.83	25.6	0.34	10.94

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

FP-311



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
15	-27.5	-27.2	59.2	1.85	25.5	0.40	12.20
16	-27.5	-27.2	59.3	1.85	25.5	0.39	11.86
17	-27.5	-27.2	59.6	1.81	25.2	0.37	11.71

Averages

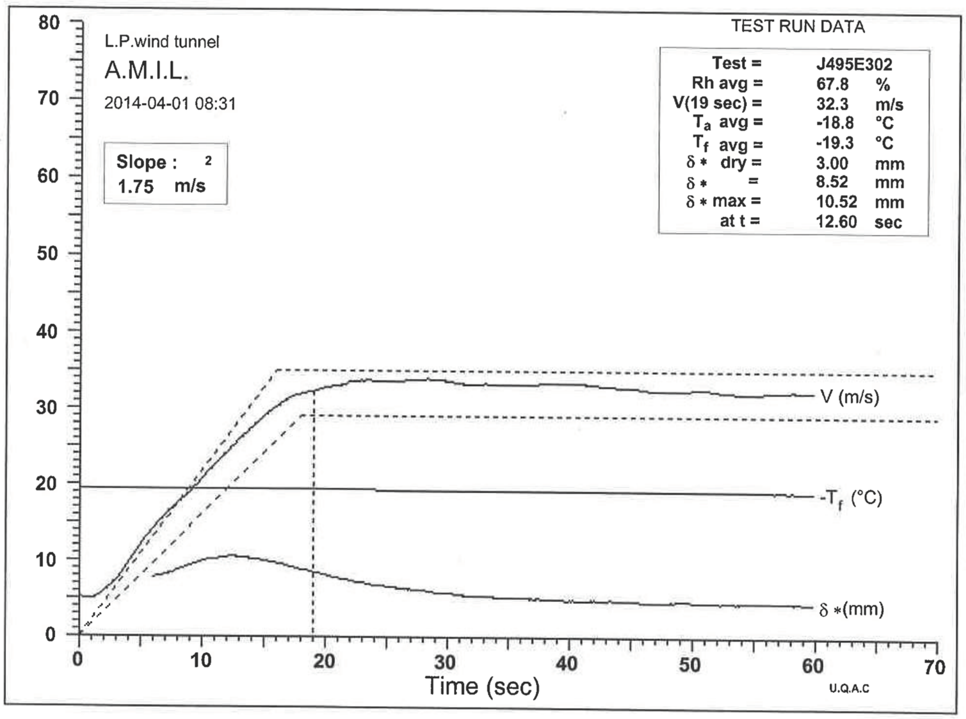
16	-27.5	-27.2	59.4	1.84	25.4	0.39	11.89

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 B-4 AMIL, 2015-01-22

FP-302



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
18	-19.0	-19.3	66.9	2.87	32.3	0.41	9.43
19	-18.9	-19.3	67.0	2.93	32.6	0.34	8.21
20	-18.9	-19.3	67.1	2.80	31.9	0.33	8.28

Averages

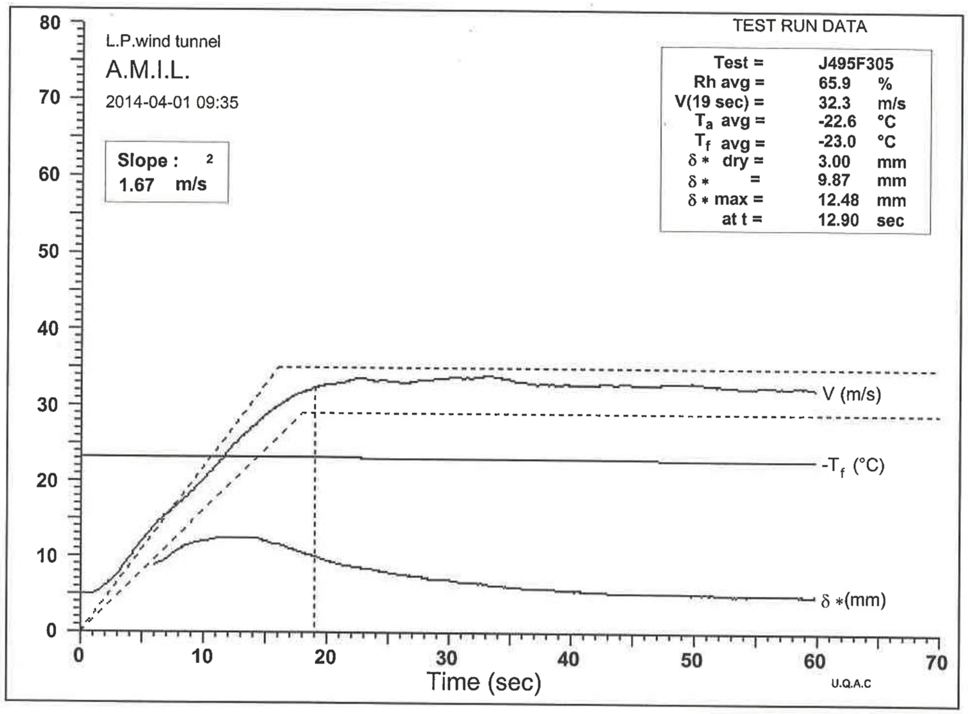
19	-18.9	-19.3	67.0	2.88	32.3	0.35	8.52

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *B-5* *AMIL, 2015-01-22*

FP-305



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
18	-22.8	-23.1	65.2	2.89	32.2	0.50	10.60
19	-22.8	-23.1	65.7	2.98	32.6	0.45	9.76
20	-22.8	-23.1	65.5	2.82	31.8	0.41	9.45

Averages

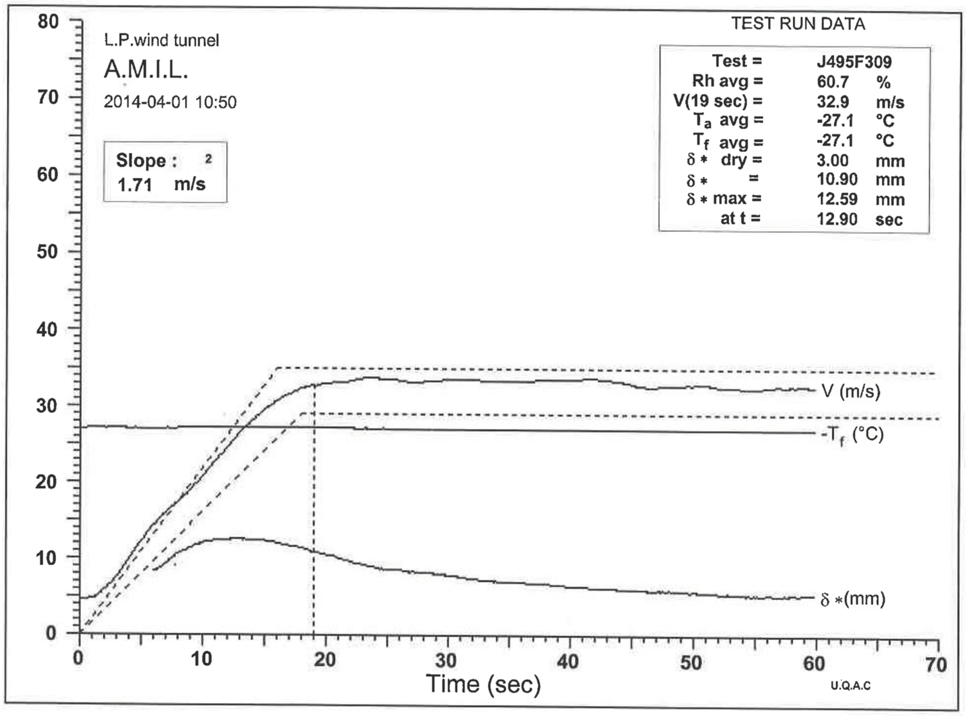
19	-22.8	-23.1	65.5	2.91	32.3	0.45	9.87

Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

2012-MT-13, Year 3   *B-6*   *AMIL, 2015-01-22*

FP-309



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
18	-27.3	-27.1	60.6	3.01	32.5	0.54	10.93
19	-27.3	-27.1	60.4	3.04	32.7	0.56	11.11
20	-27.3	-27.1	60.4	3.19	33.5	0.54	10.53

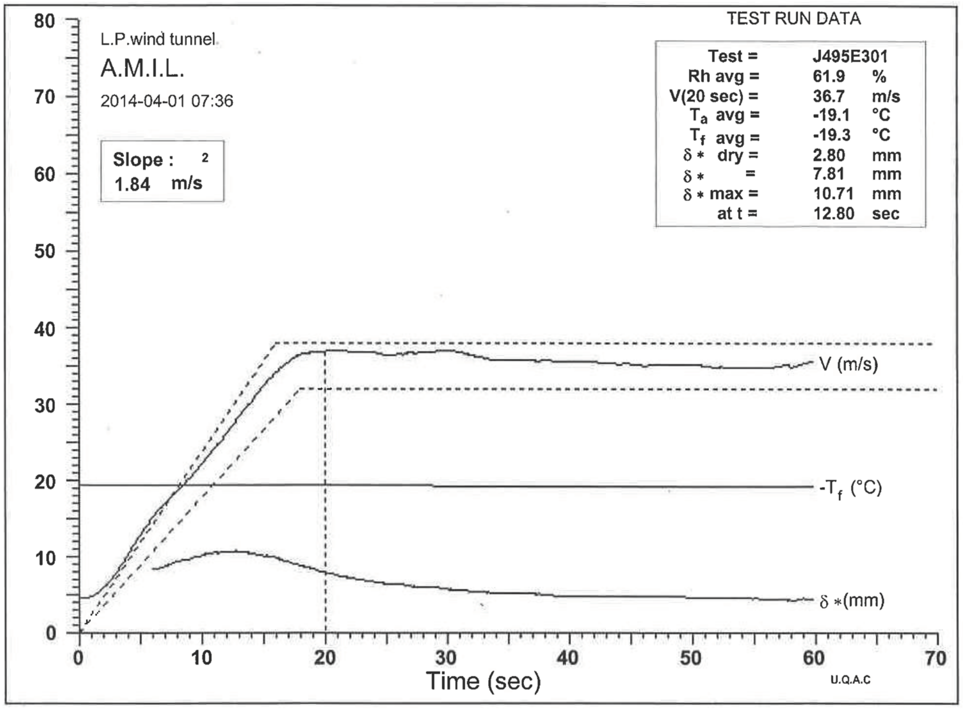
Averages

19	-27.3	-27.1	60.4	3.08	32.9	0.55	10.90

Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

FP-301



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
19	-19.3	-19.4	60.9	3.80	37.1	0.39	8.08
20	-19.3	-19.4	61.0	3.68	36.6	0.36	7.77
21	-19.2	-19.3	61.0	3.67	36.5	0.34	7.64

Averages

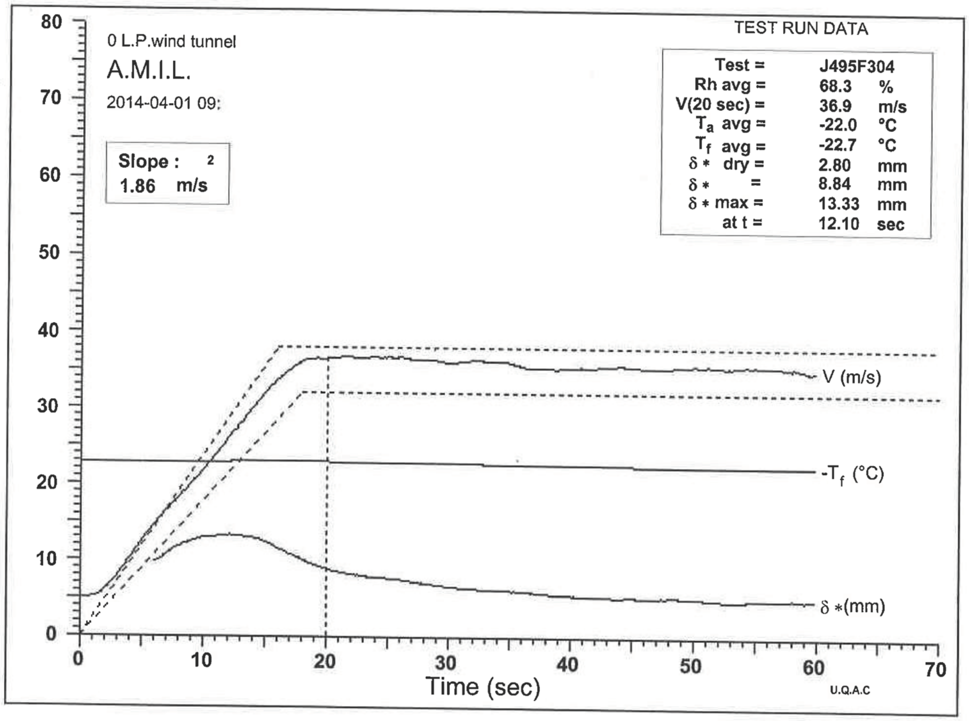
20	-19.3	-19.4	61.0	3.71	36.7	0.36	7.81

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *B-8* *AMIL, 2015-01-22*

FP-304



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
19	-22.1	-22.9	68.6	3.76	36.7	0.49	9.22
20	-22.1	-22.9	68.5	3.93	37.5	0.45	8.60
21	-22.1	-22.9	68.8	3.64	36.1	0.45	8.91

Averages

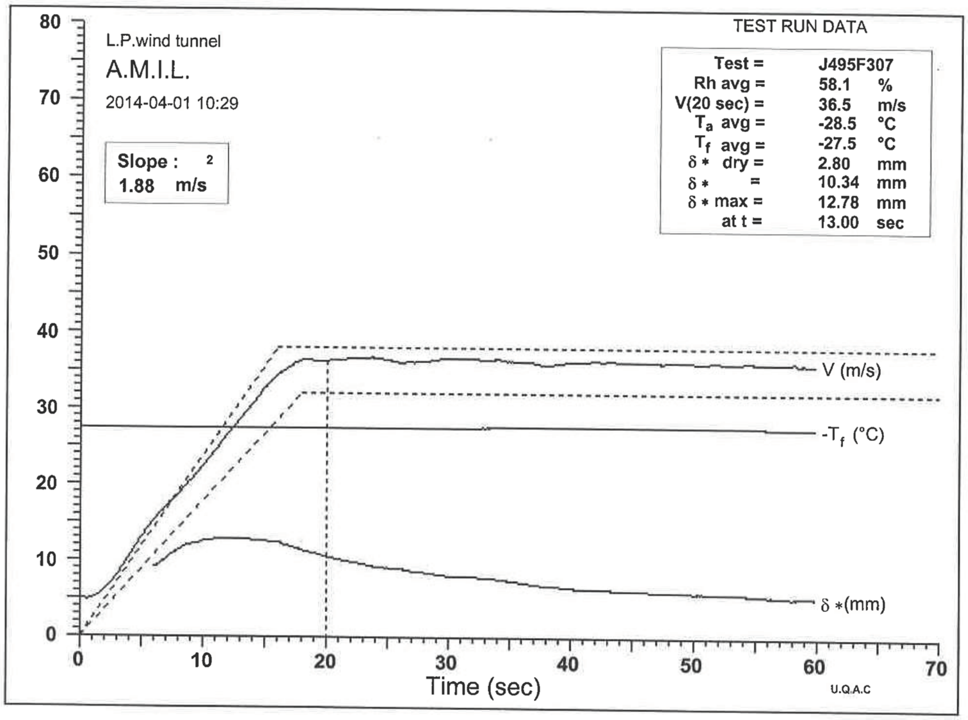
20	-22.1	-22.9	68.6	3.81	36.9	0.46	8.84

Test Duct Dimensions :

S2 = 0 mm²   S3 = 30835.968 mm²   B3 = 33260.382 mm   C3 = 302.324 mm

2012-MT-13, Year 3   *B-9*   *AMIL, 2015-01-22*

FP-307



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
19	-28.8	-27.4	57.9	4.03	37.5	0.59	9.90
20	-28.8	-27.5	57.9	3.80	36.4	0.59	10.33
21	-28.7	-27.4	57.6	3.63	35.6	0.60	10.71

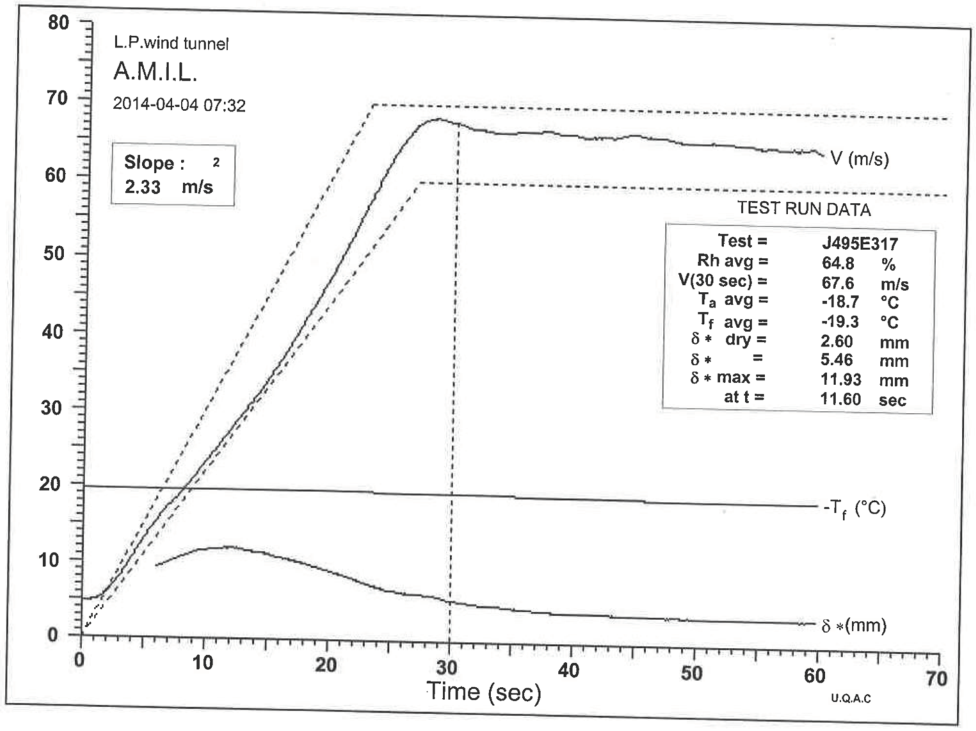
Averages

20	-28.7	-27.5	57.8	3.81	36.5	0.60	10.34

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

FP-317



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
27	-18.9	-19.5	63.8	12.96	68.6	0.76	6.39
28	-18.9	-19.4	63.6	12.90	68.5	0.64	5.95
29	-18.8	-19.4	63.8	12.79	68.2	0.61	5.89
30	-18.8	-19.4	64.0	12.72	68.0	0.51	5.50
31	-18.7	-19.4	64.4	12.31	66.9	0.34	4.91
32	-18.7	-19.4	64.5	12.47	67.3	0.32	4.82
33	-18.6	-19.4	64.7	11.89	65.8	0.37	5.07

Averages

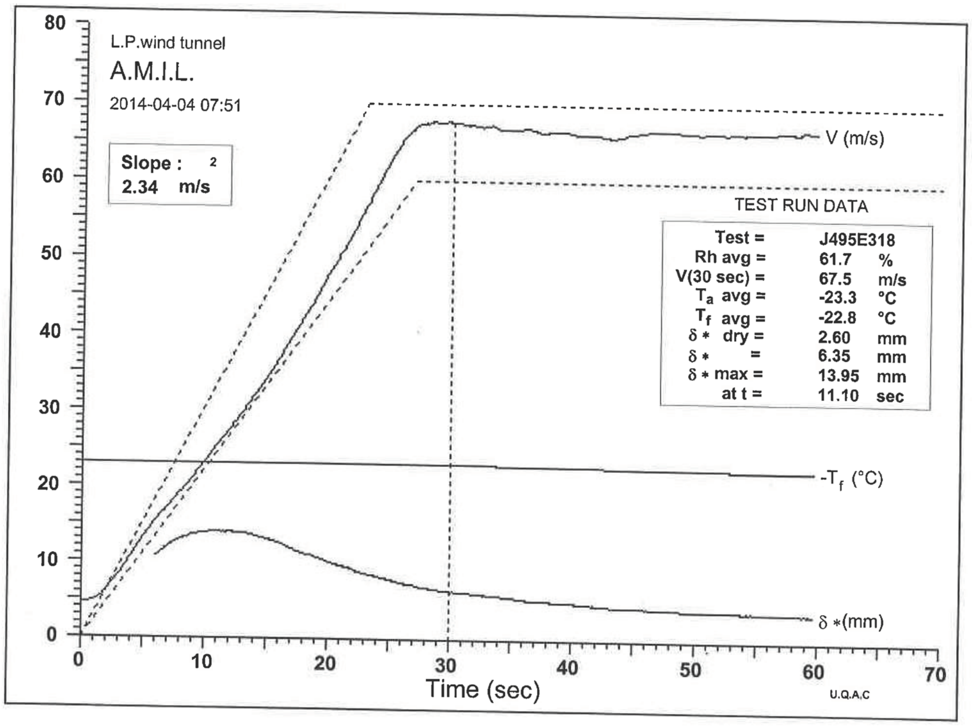
30	-18.8	-19.4	64.1	12.59	67.6	0.50	5.46

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 B-11 AMIL, 2015-01-22

FP-318



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ * mm
27	-23.9	-23.0	60.8	12.56	66.9	0.87	6.87
28	-23.8	-23.0	60.8	13.07	68.2	0.87	6.74
29	-23.8	-23.0	61.1	12.82	67.6	0.74	6.33
30	-23.7	-22.9	60.8	12.83	67.6	0.80	6.56
31	-23.6	-23.0	60.8	12.75	67.4	0.66	6.06
32	-23.6	-22.9	60.8	12.82	67.6	0.67	6.08
33	-23.5	-22.9	61.2	12.36	66.4	0.60	5.92

Averages

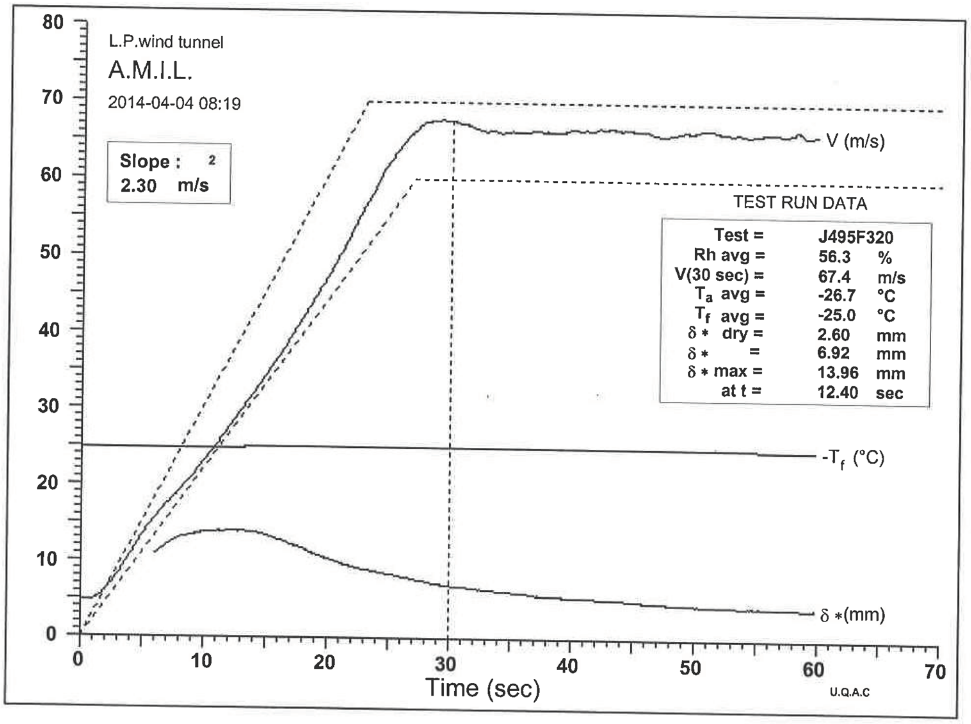
30	-23.7	-23.0	60.9	12.78	67.5	0.74	6.35

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *B-12* *AMIL, 2015-01-22*

FP-320



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
27	-27.3	-25.1	54.6	12.94	67.4	1.09	7.55
28	-27.3	-25.1	55.1	13.06	67.7	1.08	7.49
29	-27.2	-25.1	55.6	13.25	68.2	0.91	6.85
30	-27.1	-25.1	55.7	13.10	67.9	0.94	6.99
31	-27.0	-25.1	55.3	12.66	66.7	0.82	6.68
32	-27.0	-25.1	55.7	12.56	66.5	0.82	6.70
33	-26.9	-25.1	55.9	12.88	67.3	0.72	6.26

Averages

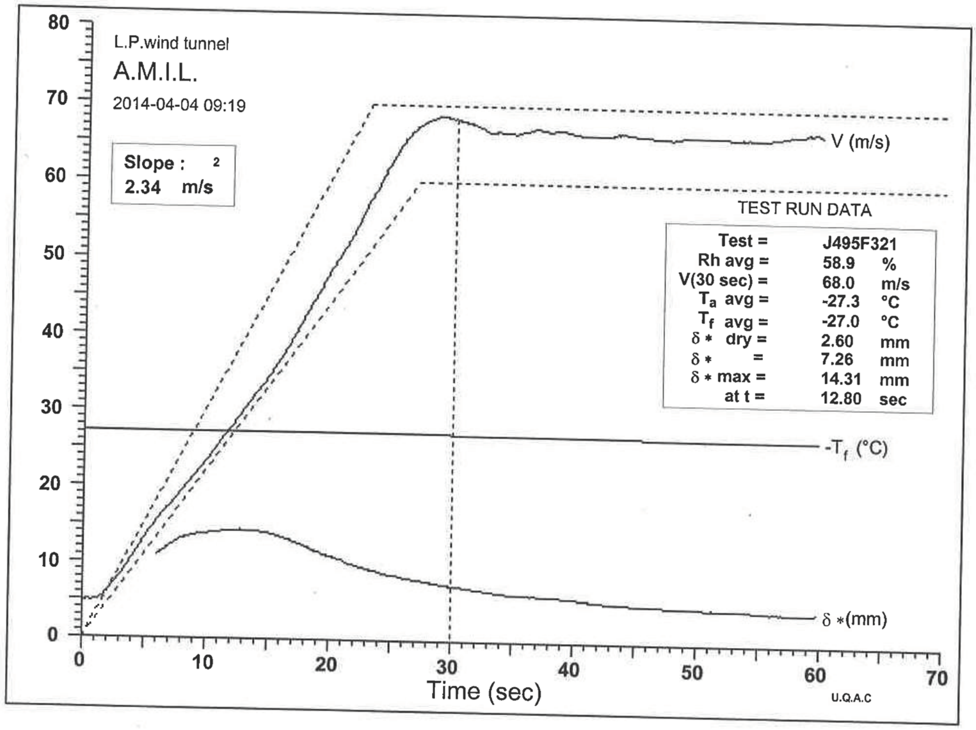
30	-27.1	-25.1	55.5	12.92	67.4	0.91	6.92

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *B-13* *AMIL, 2015-01-22*

FP-321



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
27	-27.8	-27.1	58.2	13.46	68.7	1.24	7.92
28	-27.7	-27.1	58.4	13.43	68.6	1.10	7.47
29	-27.7	-27.1	58.2	13.27	68.2	1.14	7.65
30	-27.6	-27.1	58.1	13.67	69.3	1.09	7.36
31	-27.6	-27.1	58.3	13.03	67.6	0.93	6.95
32	-27.5	-27.1	58.4	12.73	66.9	0.90	6.93
33	-27.4	-27.1	57.9	12.75	66.9	0.81	6.61

Averages

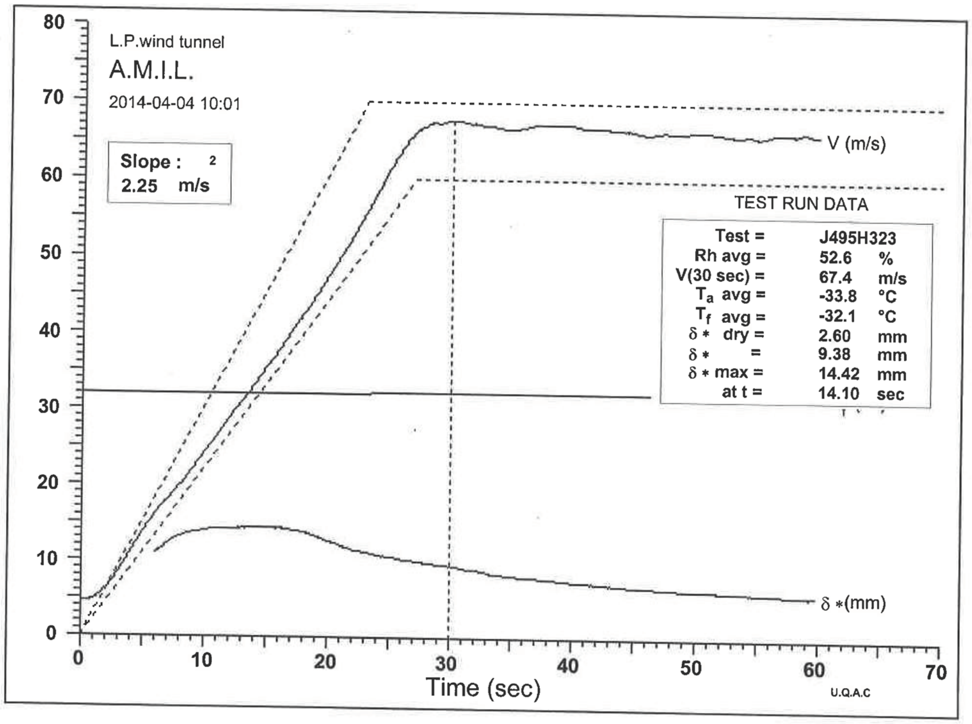
30	-27.6	-27.1	58.2	13.20	68.0	1.03	7.26

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *B-14* *AMIL, 2015-01-22*

FP-323



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ * mm
27	-34.7	-32.2	51.8	12.95	66.4	1.88	10.22
28	-34.6	-32.2	51.9	13.35	67.5	1.75	9.61
29	-34.5	-32.2	52.4	13.27	67.2	1.81	9.82
30	-34.5	-32.2	52.3	13.45	67.7	1.65	9.27
31	-34.4	-32.2	52.0	13.41	67.6	1.69	9.40
32	-34.3	-32.2	52.1	13.40	67.6	1.52	8.82
33	-34.2	-32.2	52.4	13.03	66.7	1.40	8.61

Averages

30	-34.5	-32.2	52.1	13.31	67.4	1.67	9.38

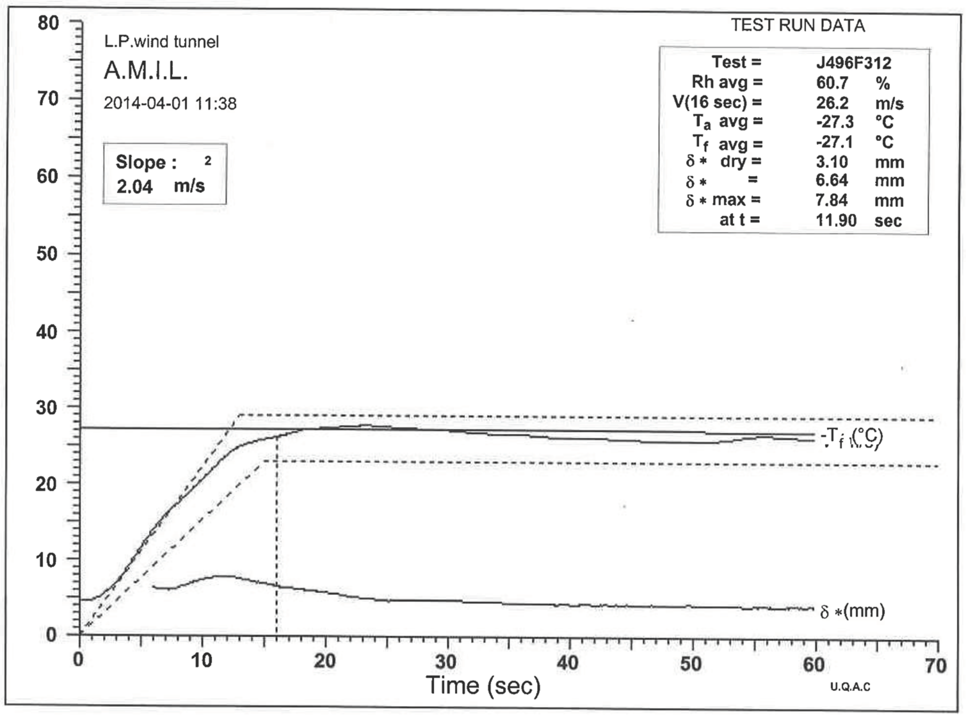
Test Duct Dimensions :

S2 = 30835.968 mm²   S3 = 33260.382 mm²   B3 = 302.324 mm   C3 = 825.017 mm

2012-MT-13, Year 3   *B-15*   *AMIL, 2015-01-22*

XL54 RTU (J496)

FP-312



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
15	-27.3	-27.1	60.0	1.89	25.8	0.18	7.11
16	-27.4	-27.1	60.5	1.93	26.0	0.16	6.54
17	-27.3	-27.2	60.1	2.02	26.6	0.16	6.42

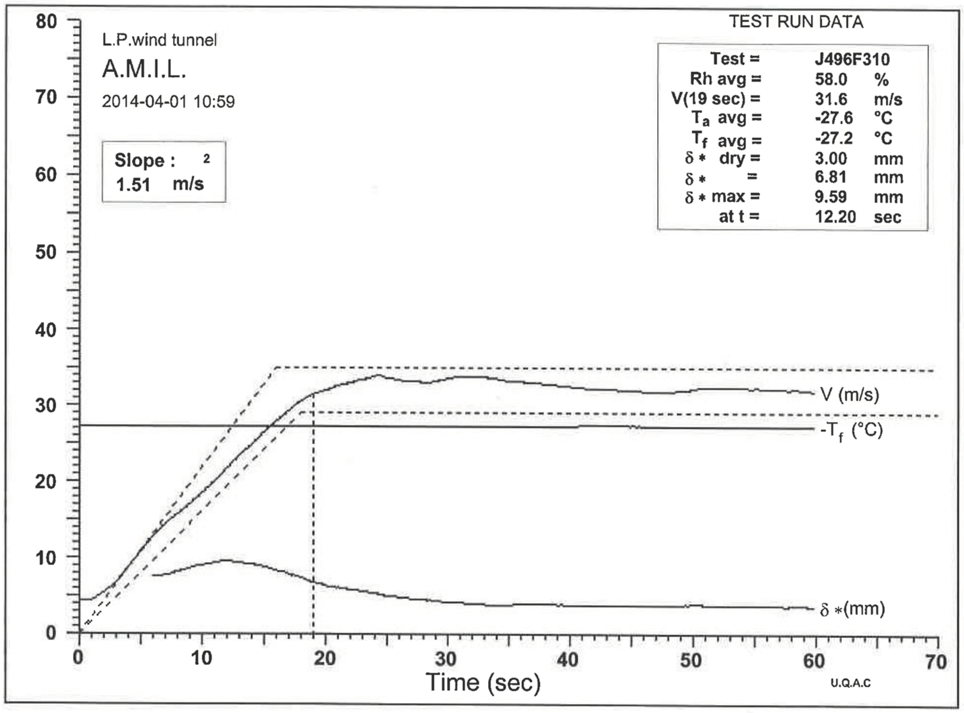
Averages

16	-27.3	-27.1	60.3	1.95	26.2	0.16	6.64

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

FP-310



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
18	-27.8	-27.2	57.8	2.71	30.8	0.24	7.11
19	-27.8	-27.2	57.4	2.88	31.8	0.24	6.89
20	-27.8	-27.2	57.8	2.94	32.1	0.22	6.41

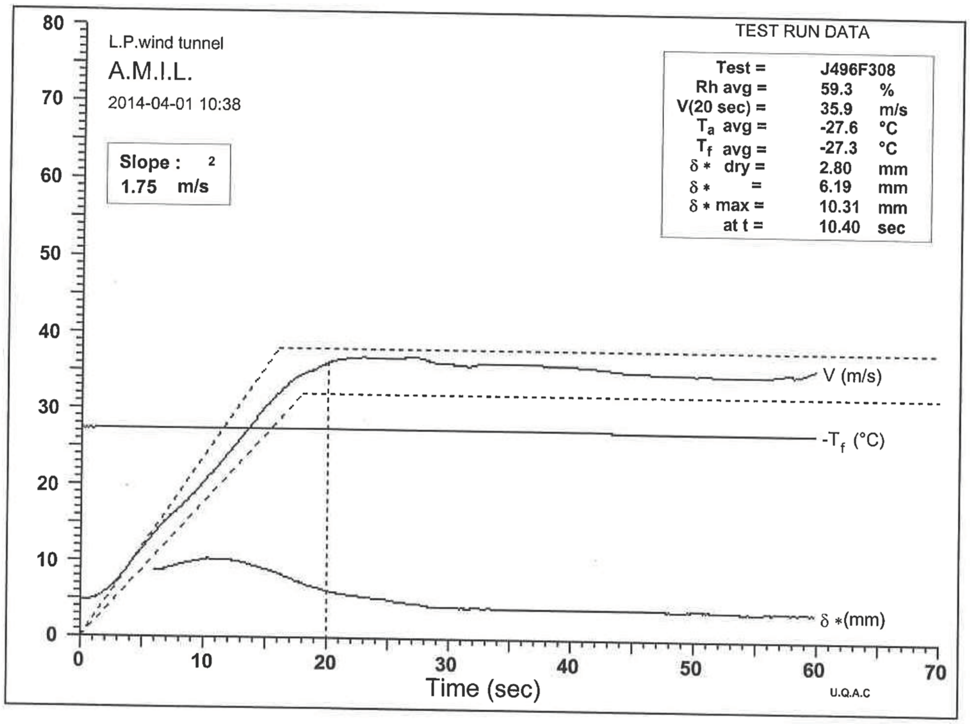
Averages

19	-27.8	-27.2	57.6	2.86	31.6	0.24	6.81

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

FP-308



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
19	-27.8	-27.3	59.0	3.57	35.4	0.21	6.09
20	-27.8	-27.3	58.8	3.65	35.8	0.22	6.07
21	-27.8	-27.3	59.0	3.83	36.7	0.26	6.47

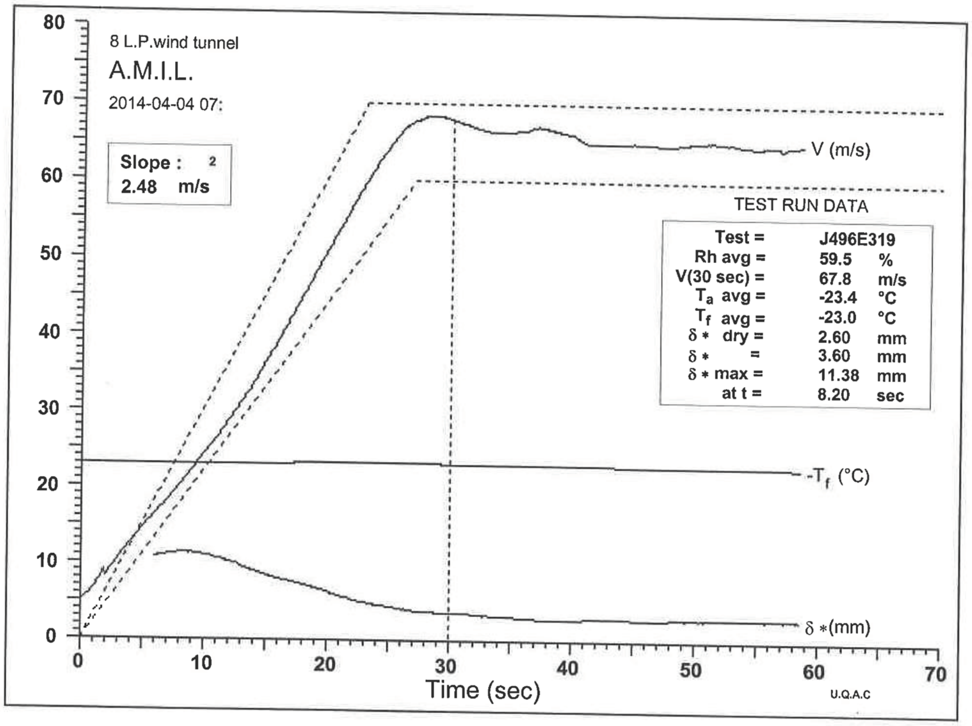
Averages

20	-27.8	-27.3	58.9	3.68	35.9	0.23	6.19

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

FP-319



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
27	-23.8	-23.1	58.7	13.43	69.2	0.14	4.05
28	-23.8	-23.1	58.6	13.35	69.0	-0.01	3.49
29	-23.7	-23.1	58.9	13.01	68.1	0.04	3.67
30	-23.7	-23.1	58.9	13.02	68.1	0.07	3.79
31	-23.6	-23.1	59.1	12.82	67.6	0.00	3.54
32	-23.6	-23.1	59.3	12.54	66.9	-0.03	3.39
33	-23.6	-23.0	59.1	12.19	65.9	-0.02	3.45

Averages

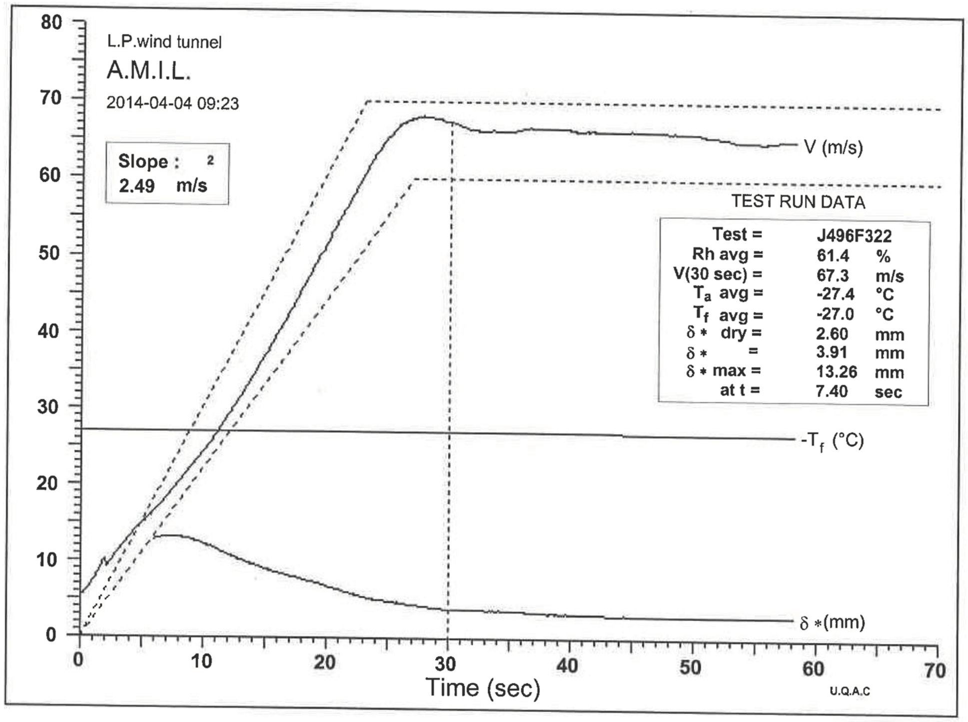
30	-23.7	-23.1	58.9	12.91	67.8	0.02	3.60

Test Duct Dimensions :

S2 = 0 mm² S3 = 30835.968 mm² B3 = 33260.382 mm C3 = 302.324 mm

2012-MT-13, Year 3 *C-5* *2015-01-22*

FP-322



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 - P_2 "H_2O	V m/s	P_2 - P_3 "H_2O	δ* mm
27	-27.9	-27.1	61.2	13.35	68.4	0.29	4.59
28	-27.9	-27.1	60.7	13.10	67.8	0.13	4.02
29	-27.9	-27.1	60.7	13.49	68.8	0.11	3.93
30	-27.8	-27.1	61.0	12.87	67.2	0.09	3.88
31	-27.8	-27.0	61.0	12.46	66.1	0.05	3.74
32	-27.7	-27.0	60.9	12.64	66.6	0.06	3.77
33	-27.7	-27.0	60.7	12.52	66.3	0.03	3.64

Averages

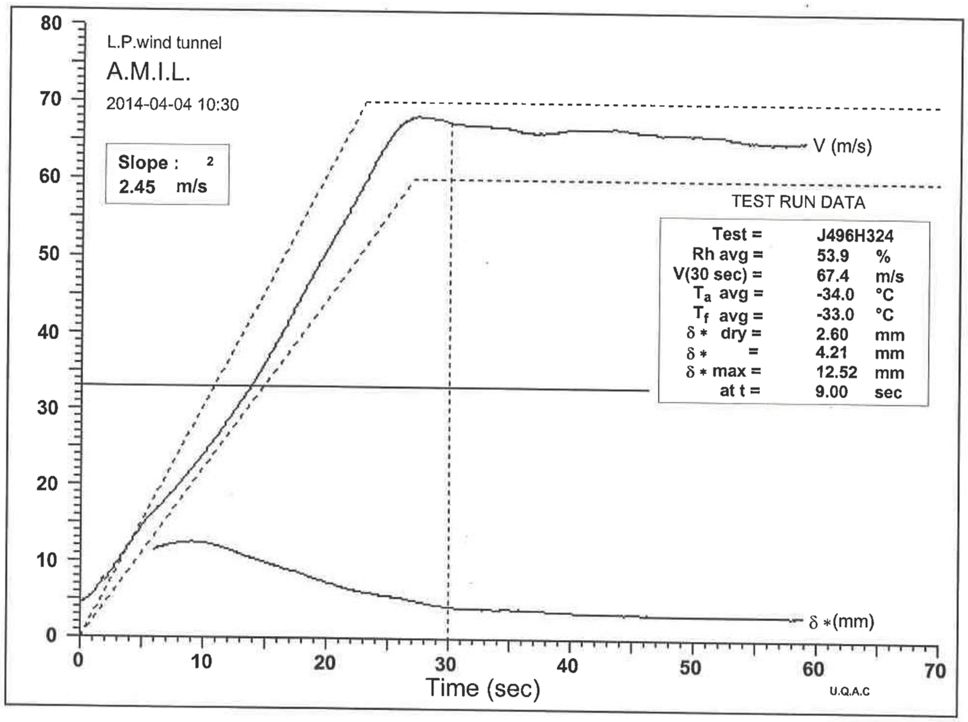
30	-27.8	-27.0	60.9	12.91	67.3	0.10	3.91

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *C-6* *2015-01-22*

FP-324



CRITICAL TIME TEST DATA

Time Sec.	T_a °C	T_f °C	Rh %	P_1 -P_2 "H_2O	V m/s	P_2 -P_3 "H_2O	δ* mm
27	-34.3	-33.1	53.7	13.72	68.4	0.34	4.74
28	-34.2	-33.1	53.4	13.50	67.9	0.30	4.65
29	-34.2	-33.1	53.4	13.43	67.7	0.21	4.30
30	-34.1	-33.1	53.4	13.40	67.6	0.16	4.14
31	-34.1	-33.1	53.7	13.24	67.2	0.13	4.01
32	-34.0	-33.1	53.8	12.95	66.5	0.08	3.84
33	-34.0	-33.1	53.9	13.09	66.9	0.12	3.98

Averages

30	-34.1	-33.1	53.6	13.32	67.4	0.18	4.21

Test Duct Dimensions :

S2 = 30835.968 mm² S3 = 33260.382 mm² B3 = 302.324 mm C3 = 825.017 mm

2012-MT-13, Year 3 *C-7* *2015-01-22*

This page intentionally left blank.