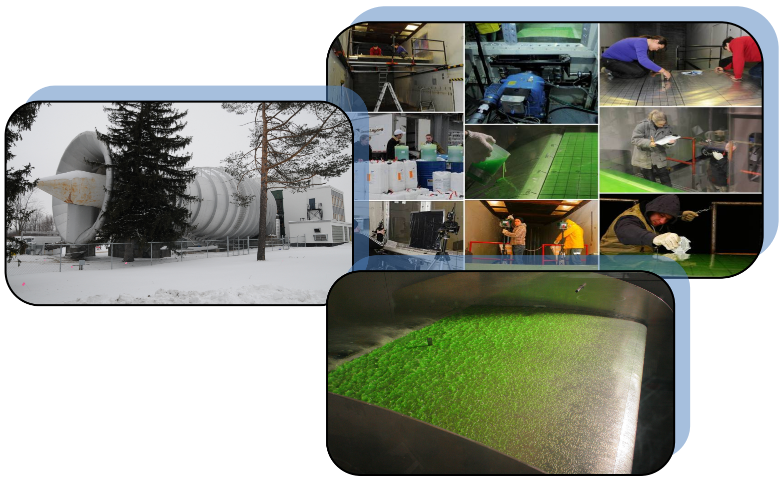
TP15232E

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

Volume 4



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Transportation Development Centre

In cooperation with

Civil Aviation
Transport Canada

and

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William J. Hughes Technical Center

Prepared by:

APS Aviation Inc.

November 2013
Final Version 1.0

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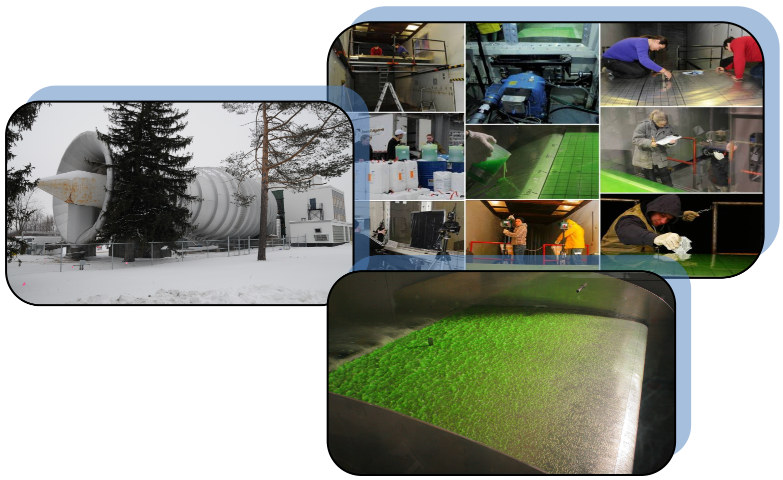

By:

Marco Ruggi

Prepared by:

APS Aviation Inc.

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

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Prepared by:

Oct 23, 2020

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

Reviewed by:

Oct 23, 2020

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

Approved by: **

John Detombe — Date
Chief Engineer
ADGA Group Consultant Inc.

Un sommaire français se trouve avant la table des matières.

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EXECUTIVE SUMMARY

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. 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 National Research Council Canada (NRC) 3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel (PIWT) using a thin high-performance wing model to determine the flow-off characteristics of anti-icing fluid with and without mixed precipitation conditions with ice pellets.

Background and Objective

Due to industry concern with the validity of the results obtained during previous year's ice pellet testing campaigns, and with the relevance of the test methods to operational aircraft, it was recommended that testing during the winter of 2011-12 focus on surveying and characterizing the wind tunnel to obtain a better sense of the repeatability of results. With the support and under the direction of National Aeronautics and Space Administration (NASA), a large series of test runs (both dry and with fluid) were planned to better understand the performance characteristics of the wind tunnel and airfoil.

Conclusions and Recommendations

Wind Tunnel Facility Calibration

As reported by the NRC, 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 takeoff profiles.

Dry Wing Calibration and Characterization

As reported by NASA, the characterization of the current dry wing model with original endplates demonstrated appropriate aerodynamic behaviour.

Fluid and Contamination Testing - Calibration and Characterization

The back-to-back fluid-only runs demonstrated excellent repeatability of test methods and this was reflected in the aerodynamic data collected. Variation in year-to-year

results of fluid-only tests runs demonstrated some differences which can be attributed to ramp time, temperature and fluid viscosity. The additional variable of contamination generated slightly more variation in the test results, however, this is considered acceptable given the number of variables such as temperature, ramp time, fluid viscosity, and contamination.

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. Repeatability or integrity of data was not affected by the larger endplate configurations, but the lift loss measured at $\alpha = 8$ degrees was larger than for original endplates. The scatter and dynamic nature of the stall tests demonstrated the difficulties with using two-dimensional model stall data for evaluating allowance times.

Type IV High-Speed Allowance Times

Testing was not conducted during the winter of 2011-12, with the objective of further developing or substantiating the current ice pellet allowance times. No changes were made to the values in the Type IV allowance time table, however, additional guidance was included to explicitly indicate that guidance material is for SAE Type IV undiluted fluid only and that all fluids are propylene glycol-based, with the exception of the Dow Chemical EG 106 fluid. The updated table has been published in the July 2012 Revision 1.0 version of the Transport Canada Holdover Time (HOT) Guidelines and a similar table has been published by the FAA.

Future Research

Possible future areas of research for the winter of 2012-13 may include:

- Allowance time testing to expand the guidance for mixed conditions, including light ice pellets with light or moderate snow conditions;
- Investigation of the higher lift losses observed at lower temperatures;
- Further substantiation of the ice pellet allowance times with new fluids, or fluids previously tested but with limited data;
- Evaluation of the effect of fluid viscosity on aerodynamics;
- Additional testing and analysis to further develop the PIWT results correlation to the Boundary Layer Displacement Thickness (BLDT) test; and
- Follow-up testing to support the 2011-12 calibration and characterization work conducted.

SOMMAIRE

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. Dans le cadre d'un plus vaste programme de recherche étudiant le ruissellement du liquide de dégivrage et d'antigivrage durant le décollage simulé d'un aéronef, 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), au moyen d'un modèle d'aile haute performance à profil mince, afin de déterminer les caractéristiques de ruissellement du liquide d'antigivrage avec et sans conditions de précipitations mixtes avec granules de glace.

Contexte et objectif

En raison de préoccupations du secteur concernant la validité des résultats obtenus durant les campagnes d'essais sur les granules de glace de l'année précédente et la pertinence des méthodes utilisées pour les aéronefs en mouvement, il a été recommandé que les essais menés à l'hiver 2011-2012 servent à examiner et à caractériser la soufflerie afin d'avoir une meilleure idée de la répétabilité des résultats. Avec l'appui et sous la direction de la National Aeronautics and Space Administration (NASA), un grand nombre d'essais (tant à sec qu'avec des liquides) ont été prévus afin de mieux comprendre les caractéristiques de performance de la soufflerie et de la surface portante.

Conclusions and Recommandations

Étalonnage de la soufflerie

Comme indiqué par le CNRC, les améliorations apportées chaque année aux installations et à l'équipement ont augmenté l'intégrité des données aérodynamiques produites, de sorte que la soufflerie peut reproduire de très près les profils de décollage d'un aéronef.

Étalonnage et caractérisation de l'aile sèche

Comme indiqué par la NASA, la caractérisation du modèle d'aile sèche actuel avec les dérives d'origine a démontré un comportement aérodynamique approprié.

Essais sur les liquides et la contamination – étalonnage et caractérisation

Les essais menés successivement avec du liquide non contaminé ont démontré une excellente répétabilité de la méthode, ce qui s'est reflété dans les données aérodynamiques recueillies. Les variations observées d'une année à l'autre dans les résultats des essais menés avec du liquide non contaminé font état de quelques différences, lesquelles peuvent être attribuées au temps d'accélération, à la température et à la viscosité du liquide. Les autres paramètres de contamination ont généré des variations légèrement supérieures dans les résultats des essais ; de telles variations sont toutefois jugées acceptables étant donné le nombre de paramètres tels que la température, le temps d'accélération, la viscosité du liquide et la contamination.

La répétabilité des essais a été jugée acceptable pour ce type de test aérodynamique et ne témoignait pas d'erreurs systématiques sur le plan des procédures ou de l'équipement. Les configurations de dérive plus larges n'ont eu aucune incidence sur la répétabilité et l'intégrité des données, mais la perte de portance mesurée à $\alpha = 8$ degrés était supérieure à celle observée avec les dérives d'origine. La nature diffuse et dynamique des essais de décrochage a mis en lumière les difficultés associées à l'utilisation des données de décrochage d'un modèle bidimensionnel pour évaluer les marges de tolérance.

Marges de tolérance pour les liquides de type IV à haute vitesse

Aucun essai n'a été réalisé au cours de l'hiver 2011-2012 dans le but de développer ou de valider les marges de tolérance actuelles concernant les granules de glace. Aucun changement n'a été apporté aux valeurs du tableau des marges de tolérance pour les liquides de type IV ; toutefois, d'autres lignes directrices ont été ajoutées afin d'indiquer explicitement que les marges s'appliquent uniquement aux liquides de type IV non dilués de la SAE et que tous les liquides sont à base de propylène glycol, à l'exception du Dow Chemical EG106. Le tableau actualisé a été publié dans la version 1.0 de la révision de juillet 2012 des lignes directrices sur les durées d'efficacité de Transport Canada, et un tableau semblable a été publié par la FAA.

Recherches à venir

Voici certains éléments qui pourraient être étudiés à l'hiver 2012-2013 :

- Essais sur les marges de tolérance visant à élargir les lignes directrices dans des conditions mixtes de façon à inclure les conditions de granules de glace légers avec de la neige légère ou modérée ;

- Analyse des pertes de portance supérieures observées à basse température ;
- Corroboration supplémentaire des marges de tolérance dans des conditions de granules de glace avec les nouveaux liquides, ou avec les liquides déjà testés, mais pour lesquels les données sont limitées ;
- Évaluation de l'effet de la viscosité des liquides sur les propriétés aérodynamiques ;
- Essais et analyses supplémentaires visant à établir une corrélation entre les résultats obtenus dans la soufflerie de givrage à propulsion et ceux des essais sur l'épaisseur de déplacement de la couche limite (EDCL) ; et
- Essais de suivi visant à appuyer les travaux d'étalonnage et de caractérisation menés en 2011-2012.

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GLOSSARY

AAT	Aerodynamic Acceptance Test
APS	APS Aviation Inc.
AWG	G-12 Aerodynamics Working Group
BLDT	Boundary Layer Displacement Thickness
EG	Ethylene Glycol
FAA	Federal Aviation Administration
HOT	Holdover Time
MSC	Meteorological Service of Canada
NASA	National Aeronautics and Space Administration
NRC	National Research Council Canada
NRCIAR	National Research Council Canada Institute for Aerospace Research
OAT	Outside Air Temperature
PG	Propylene Glycol
PIWT	3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel
RTD	Resistance Temperature Detector
SAE	Society of Automotive Engineers
TC	Transport Canada
TDC	Transportation Development Centre
UPS	United Parcel Service

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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 supercritical wing model to determine the flow-off characteristics of anti-icing fluid with and without mixed precipitation conditions with ice pellets.

NOTE: The documentation of this project has been divided into five separate volumes: one summary report, and four detailed reports on each of the respective testing years' activities. The volumes are as follows:

Volume 1:	*Summary Report*
Volume 2:	*2009-10 Testing Report*
Volume 3:	*2010-11 Testing Report*
Volume 4:	*2011-12 Testing Report*
Volume 5:	*2012-13 Testing Report*

This report is Volume 4 of 5.

1.1 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-takeoff 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-takeoff contamination checks by the onboard crew were not possible. Fed-Ex had been faced with similar problems in Memphis. Following this event, in October 2005, the FAA issued two notices restricting takeoffs 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 TC report, TP 14718E, *Preliminary Endurance Time Testing in Simulated Ice Pellet Conditions*, (1)]. 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 the Falcon 20 aerodynamic research [see TC report, TP 14716E, *Falcon 20 Trials to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets* (2)]; these results were presented at the Society of Automotive Engineers (SAE) meeting in Lisbon in May 2006. To address the option of a pre-takeoff contamination check, the 20-minute targeted allowance was extended to 25 minutes; pre-takeoff 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, TC and the FAA provided allowance time guidance material for operations in mixed conditions with ice pellets. These allowance times were based on the research conducted during the winter of 2006-07 [see TC report, TP 14779E, *Development of Allowance Times for Aircraft Deicing Operations During Conditions with Ice Pellets* (3)]. The recommended allowance times were based on aerodynamic research conducted using the 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 on the lack of data in specific conditions.

During the winter of 2007-08, additional endurance time testing and aerodynamic research was conducted to support and further expand the ice pellet allowance times [see TC report, TP 14871E, *Research for Further Development of Ice Pellet Allowance Times: Aircraft Trials to Examine Anti-Icing Fluid Flow-Off Characteristics Winter 2007-08,* (4)]. Full-scale testing with the NRC Falcon 20 and T-33 aircraft was conducted in mixed conditions with ice pellets and in non-precipitation conditions. Testing was primarily geared towards simulating low rotation speed aircraft. No changes to the allowance times were made as a result of this work as aerodynamic data was not available.

During the winter of 2008-09, testing was conducted in the PIWT using a National Aeronautics and Space Administration (NASA) LS-0417 to validate and potentially expand the allowance times. As a result of this testing, a reduction to the light ice pellets mixed with moderate snow allowance time was issued for Outside Air Temperature (OAT) above -5ºC: the allowance time was reduced from 25 minutes to 10 minutes. The testing conducted also allowed the expansion of the table to include a new 25-minute allowance time for light ice pellets mixed with moderate rain for above -5ºC conditions, as well as a new 15-minute allowance time for light ice pellets mixed with light snow for -5ºC to -10ºC conditions. A newly updated version of the Type IV allowance time table was developed and adopted for the 2009-10 version of the HOT Guidelines. It was recommended that additional testing be conducted in the PIWT during the winter of 2009-10 using a supercritical airfoil to validate the allowance time for use with newer generation aircraft.

A series of tests were designed and carried out during the winter of 2009-10 using a newly constructed thin high-performance airfoil. In general, higher lift losses were observed with the thin high-performance wing compared to previous wings tested. Although initially 5 percent lift loss was used as the cut-off for evaluating each test, this was expanded to 8 percent based on the data collected; 8 percent lift loss correlated well with the visual observations recorded. More specifically, lift losses greater than 8 percent on the 2D model were recorded during light ice pellet and moderate ice pellet conditions below -10ºC. The data was re-analysed and extrapolated, indicating that the allowance times would be acceptable for rotation speeds of 115 knots or greater (compared to 100 knots or greater). It was recommended that a footnote restricting the use of propylene glycol (PG) fluids to aircraft with rotation greater than 115 knots during light ice pellet and moderate ice pellet conditions below -10ºC be included in the allowance time table for the winter of 2010-11. In addition, fluid failure issues with the thin high-performance wing were observed with PG fluids during moderate ice pellets above -5ºC. The relatively flat surface of the wing had less fluid flow-off and resulted in an earlier fluid failure for PG fluids. Data collected indicated that an allowance time of 15 minutes would be more appropriate. It was recommended that a footnote reducing the allowance time to 15 minutes for PG fluids during moderate ice pellet conditions above -5ºC be included in the allowance time table for the winter of 2010-11. 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 (AATs) for fluid certification.

Results from the 2010-11 testing demonstrated results similar to the 2009-10 testing in that the results indicated fluid flow-off issues with the thin high-performance 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 AAT. Based on the work that was conducted by NASA and APS, it was determined that a maximum lift loss of 5.24 percent on the B737-200ADV airplane is equivalent to a lift loss of 7.29 percent on the PIWT model. Due to the scatter in the data, the standard error of the estimate determined an upper limit of lift loss on the PIWT model of 9.2 percent and a lower limit of 5.4 percent. Currently, the scatter in the “review” range is somewhat large and causes ambiguities when analysing the data collected. It is anticipated that as future testing progresses and as more data is collected, a more narrow range or single-value pass/fail cut-off may be 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 characterizing the wind tunnel to obtain a better sense of the repeatability of results. With the support and under the direction of NASA, a large series of test runs (both dry and with fluid) were planned to better understand the performance characteristics of the wind tunnel and airfoil.

Table 1.1 describes the timeline of the developed allowance time guidance material.

Table 1.1: Timeline of Developed Allowance Time Guidance Material

Winter Testing	Research Conducted	FAA Allowance Time	TC Allowance Time	Report TP #	Related Winter HOT Guidelines
2004-05	UPS Research APS PMG Research	October 2005 Notices 8000.309 and 8000.313 (no takeoff in IP)	No Changes to Guidelines	Data available through UPS & TP 14718	2005-06
2005-06	APS Falcon 20	20 minutes targeted, 25 minutes recommended *(to include 5 min PTCC)*	Note include indicating no changes to guidelines	TP 14716E	2006-07
2006-07	APS Wind Tunnel & Falcon 20	Allowance Time Table 1st Version	Allowance Time Table 1st Version (October 2007)	TP 14779E	2007-08
2007-08	APS Falcon 20	Allowance Time Table 1st Version	Allowance Time Table 1st Version	TP 14871E	2008-09
2008-09	APS Wind Tunnel	Allowance Time Table 2nd Version	Allowance Time Table 2nd Version	TP 14935E	2009-10
2009-10	APS Wind Tunnel	Allowance Time Table 3rd Version	Allowance Time Table 3rd Version	TP 15232E (Vol 2)	2010-11
2010-11	APS Wind Tunnel	No Changes to Guidelines	No Changes to Guidelines	TP 15232E (Vol 3)	2011-12
2011-12	APS Wind Tunnel	No Changes to Guidelines	No Changes to Guidelines	TP 15232E (Vol 4)	2012-13

1.2 Program Objectives

A test program was developed for the winter of 2011-12 with the primary objectives of conducting aerodynamic testing with a thin high-performance airfoil to:

- Thoroughly survey the clean wing performance through pitch pause, angle sweeps, and stall runs, and to verify repeatability;
- Perform oil flow visualization to better understand boundary layer separation and uniformity of flow;
- Install a boundary layer rake to quantify boundary layer separation and uniformity of flow;
- Install boundary layer trips to establish wing sensitivity;
- Install larger end plates to evaluate potential 3D effects; and
- Conduct fluid testing with and without contamination to evaluate repeatability of results.

The work statement for these tests is provided in Appendix A.

1.3 Historical Falcon 20 Full-Scale Aerodynamic Testing

Previous trials to examine the elimination of failed SAE Type IV fluids from aircraft wings during takeoff were conducted during the 1997-98 and 1998-99 winter seasons. These trials, based on simulated takeoff tests using the NRC Falcon 20 aircraft, showed that the test approach was a viable one. The Falcon 20 test program conducted during the winters of 2001-02 and 2002-03 addressed the effects of unshed anti-icing fluid on aircraft takeoff performance.

This research is documented in detail in a series of five reports written by APS for TC:

- TP 13316E, *Contaminated Aircraft Takeoff Test for the 1997-98 Winter* (5);
- TP 13479E, *Contaminated Aircraft Takeoff Test for the 1998-99 Winter* (6);
- TP 13666E, *Contaminated Aircraft Simulated Takeoff Tests for the 1999-2000 Winter: Preparation and Procedures* (7);
- TP 13995E, *Aircraft Takeoff Test Program for Winter 2001-02: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid* (8); and
- TP 14147E, *Aircraft Takeoff Test Program for Winter 2002-03: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid* (9).

Research was conducted during the winter of 2005-06 using the Falcon 20 aircraft to determine the maximum amount of ice pellet contamination that will flow-off an anti-iced aircraft at takeoff. This research is documented in detail in a report written by APS for TC [see TP 14716E (2)].

During the winter of 2006-07, extensive testing was conducted in mixed ice pellet conditions in the NRC PIWT. The Falcon 20 aircraft was used to validate the results obtained in the NRC PIWT by conducting a limited number of validation tests. This research is documented in detail in a report written by APS for TC [see TP 14779E (3)].

The details of the methodology used for this testing are documented in a report written by APS for TC:

- TP 14778E*, Flow of Contaminated Fluid from Aircraft Wings: Feasibility Report* (10).

During the winter of 2007-08, the NRC PIWT was not available for testing during the winter months. The Falcon 20 aircraft was used to conduct simulated low rotation speed tests in mixed conditions with ice pellets. Two tests were also conducted with the NRC T-33 aircraft to validate the low rotation speed results obtained with the Falcon 20. This research is documented in detail in a report written by APS for TC [see TP 14871E (4)].

1.4 Historical NRC Wind Tunnel Full-Scale Aerodynamic Testing

Previous trials to examine aerodynamic performance effects of de/anti-icing fluids that had been contaminated by varying quantities of freezing precipitation were conducted over three winter seasons at the NRC PIWT. The airfoil tested was a full-scale NASA LS(1)-0417 section with a Fowler flap deployed at 15 degrees. A spray bar located in the wind tunnel settling chamber produced artificial snow. Takeoff was simulated by accelerating the test section wind speed, and aerodynamic data was obtained while pitching the airfoil to the stall. These trials, based on takeoff simulations, showed that the test approach was a viable one.

This research is documented in detail in a report written in May 1999 by the National Research Council Canada Institute for Aerospace Research (NRCIAR) for TC, TP 13426E, *Air-Flap Performance with De-Anti-Icing Fluids and Freezing Precipitation* (11).

During the winter of 2006-07, extensive testing was conducted in simulated mixed ice pellet conditions in the NRC PIWT using a NACA 23012 wing section. Testing was primarily geared towards expansion of the 25-minute allowance time for ice pellets. Testing included mixed ice pellet conditions as well as preliminary testing in heavy snow conditions. This research is documented in detail in TP 14779E (3). The details of the methodology used for this testing are documented in TP 14778E (10).

During the winter of 2008-09, aerodynamic research was conducted in the NRC PIWT using a NASA LS(1)-0417 section to investigate fluid flow-off of contaminated fluid following simulated ice pellet and mixed conditions to substantiate and further develop the current ice pellet allowance times. High-speed and low-speed ramp testing were conducted using Type IV fluid, as well as limited testing with Type II and III fluids. This research is documented in detail in a report written by APS, TC report, TP 14935E, *Research for Further Development of Ice Pellet Allowance Times: Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics Winter 2008-09* (12).

During the winter of 2009-10, a series of tests were designed and carried out using a newly constructed thin high-performance airfoil. In general, higher lift losses were observed with the thin high-performance wing compared to previous wings tested. The intent was to validate the allowance times for use with newer generation aircraft. The new wing section demonstrated greater sensitivity to lift losses, especially at colder temperatures. This research is documented in detail in a report written by APS for TC, 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 (Vol. 2) (13).

Testing was continued with the same thin high-performance wing during the winter of 2010-11. 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 thin high-performance wing when using PG fluids at the lower temperatures. Also, a large part of the 2010-11 work was focused on developing a correlation between the PIWT and the AAT. This research is documented in detail in TP 15232E (Vol. 3) (13).

1.5 Overview of 2011-12 Testing

Full-scale testing during the winter of 2011-12 was conducted using the NRC PIWT.

The primary focus of the testing was aimed at calibrating and characterizing the wind tunnel in dry conditions and with fluid to obtain a better sense of the repeatability of the results produced.

This calibration and characterization testing was conducted with the support and direction of NASA experts. To complete this work, limited APS staff was required to support the testing when dry wing testing was conducted (including all tests where no de/anti-icing fluid was required). When fluid testing was planned, the full APS team was required to conduct the tests.

In addition, some preliminary work was conducted as a lower priority to address current industry concerns. This research is typically documented in a separate exploratory wind tunnel research report; however, due to the limited exploratory testing conducted in 2011-12, the results have been documented within the TC report, TP 15202E, *Aircraft Ground Icing General Research Activities During the 2011-12 Winter* (14).

Table 1.2 demonstrates the groupings for the global set of tests conducted at the wind tunnel during the winter of 2011-12. Only tests pertaining to the dry wing fluid calibration and characterization work (objectives 1 and 2) are described in this report. Table 1.3 demonstrates in greater detail the exploratory research tests (objective 3 from Table 1.2).

Table 1.2: Summary of 2011-12 Wind Tunnel Tests by Objective

OBJECTIVE	RUN #	TOTAL RUNS
1. Dry Wing Calibration and Characterization Tests	1-48, 60-101, 112-114, 126, 127, 139-146, 153, 154, 161-164, 173-176, 184, 185	**115**
2. Fluid Calibration and Characterization Tests	49-59, 102-111, 115-125, 147-152, 155-160, 168-172, 177-182	**55**
3. Exploratory Research Tests	128-138, 165-167, 183	**15**
	TOTAL	**185**

Table 1.3: Summary of 2011-12 Exploratory Research Objectives

EXPLORATORY RESEARCH OBJECTIVES	RUN #	TOTAL RUNS
Wind Shield Washer Fluid De/Anti-Icing	128-138	**11**
Testing to Support Development of Light Snow (S-) andVery Light Snow (S--) HOT's	165-167	**3**
Heavy Contamination	183	**1**
	TOTAL	**15**

1.6 Report Format

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

a) Section 2 describes the methodology used in testing, as well as equipment and personnel requirements necessary to carry out testing;

b) Section 3 describes data collected during the full-scale testing conducted;

c) Section 4 describes the analysis methodology used to evaluate the wind tunnel tests conducted;

d) Section 5 describes the work conducted to calibrate and characterize the wind tunnel facility;

e) Section 6 describes the work conducted to calibrate and characterize the dry wing section performance;

f) Section 7 describes the work conducted to calibrate and characterize the clean and contaminated fluid flow-off performance;

g) Section 8 presents a summary of the conclusions and observations; and

h) Section 9 lists the recommendations for future testing.

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2. METHODOLOGY

This section describes the test methodology and equipment specific to the full-scale aerodynamic tests conducted at the NRC PIWT, as well as general testing methodology and equipment.

NOTE: A significant portion of the dry wing calibration and characterization tests required specific methodologies and procedures that are not included in this section. Details on these specific procedures are included in Section 6 as well as in the procedure included in Appendix B.

2.1 Wind Tunnel Test Site

The 2011-12 PIWT tests were performed at the NRC Aerospace Facilities, Building M-46, at the NRC Montreal Road campus, located in Ottawa, Canada. Figure 2.1 provides a schematic of the NRC Montreal Road campus showing the location of the NRC PIWT. Photo 2.1 shows an outside view of the wind tunnel test facility. Photo 2.2 shows an inside view of the wind tunnel test section. The open-circuit layout, with a fan at entry, permits contaminants associated with the test articles (such as heat or de/anti-icing fluid) to discharge directly, without recirculating or contacting the fan. The fan is normally driven electrically, but high-speed operation can be accommodated by a gas turbine drive system. Due to the requirements of both high-speed and low-speed operations during the testing, the gas turbine was selected to allow for greater flexibility; the gas turbine drive can perform both low- and high-speed operations, whereas the electric drive is limited to low-speed operations.

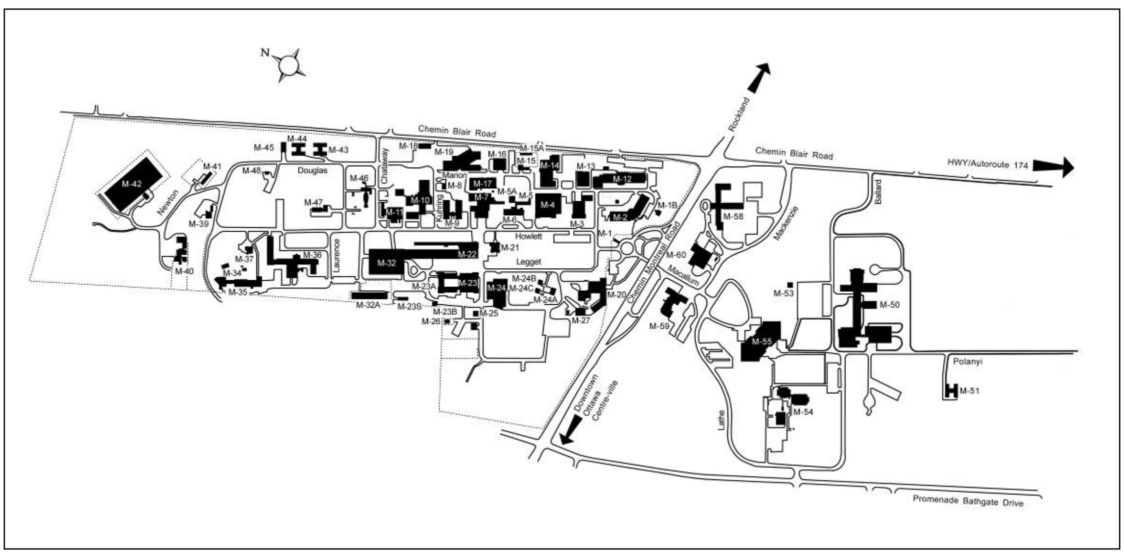

Figure 2.1: Schematic of NRC Montreal Road Campus

2.2 Test Schedule

Testing was conducted over a period of three weeks starting January 16, 2012, and ending February 3, 2012. Setup and teardown time was minimal and was done on the first and last day of testing. Testing was conducted during 13 days over the three-week period; testing days were selected based on weather. Table 2.1 presents the calendar of wind tunnel tests performed in 2011-12. It should be noted that the tests listed comprise all the tests conducted, including the tests not pertaining to the calibration and characterization test objectives. At the beginning of each test day, a plan was developed that included the list of tests (taken from the global test plan) to be completed based on the weather conditions and testing priorities. This daily plan was discussed, approved, and modified (if necessary) by TC, the FAA, NASA, and APS.

Table 2.1: Calendar of Tests

Date	Number of Test Runs	Test Numbers
16-Jan-12	14	Setup, then 1 to 14
17-Jan-12	12	15 to 26
18-Jan-12	8	27 to 34
19-Jan-12	10	35 to 44
20-Jan-12	15	45 to 59
21-Jan-12	0	No Tests
22-Jan-12	0	No Tests
23-Jan-12	0	No Tests
24-Jan-12	23	60 to 82
25-Jan-12	14	83 to 96
26-Jan-12	16	97 to 112
27-Jan-12	0	No Tests
28-Jan-12	0	No Tests
29-30-Jan-12	14	113 to 126
30-31-Jan-12	13	127 to 139
31-Jan - 01-Feb-12	23	140 to 162
01-02-Feb-12	12	163 to 174
02-03-Feb-12	11	175 to 185, then teardown
Total	**185**	

2.3 Wind Tunnel Procedure

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

The procedure for each fluid test was as follows:

a) The wing section was treated with anti-icing fluid, poured in a one-step operation (no Type I fluid was used during the tests);
b) 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; and
c) At the end of the contamination period, the tunnel was cleared of all equipment and scaffolding.

The wind tunnel was subsequently operated through a simulated takeoff and climb-out test. 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 trials is included in Appendix B. The procedure includes details regarding the test objectives, test plan, procedure and methodology, and pertinent information and documentation.

It should be noted that dry wing and other calibration/characterization tests may have used different testing procedures to satisfy the specific test objective.

2.4 Test Sequence

The length of each test (from start of setup to end of last measurement) varied largely due to the length of exposure to precipitation (if applicable). Time required for setup and teardown, as well as preparing and configuring the wing section, was relatively the same from test to test. Figure 2.2 demonstrates a sample timeline for a typical wind tunnel test. It should be noted that a precipitation exposure time of 30 minutes was used for demonstration purposes; this time varied for each test depending on the objective.

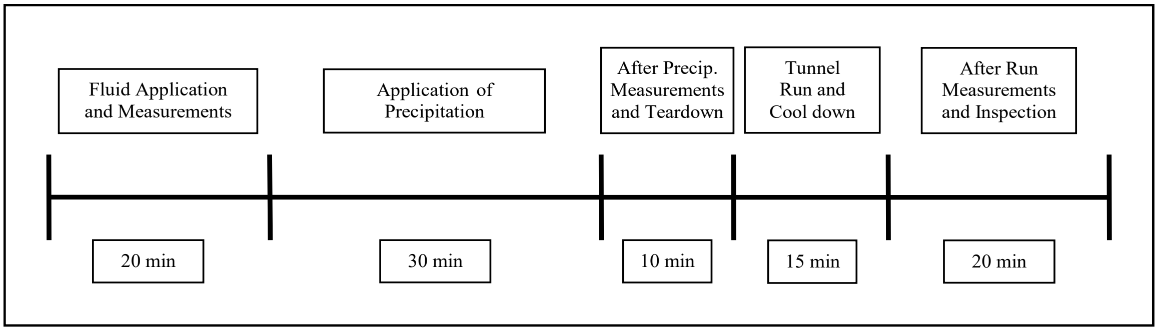

Figure 2.2: Typical Wind Tunnel Test Timeline

2.5 Wind Tunnel

The following sections describe the wind tunnel and major components.

2.5.1 Propulsion Icing Wind Tunnel

The experiments were performed in the NRC PIWT. This facility is an open-circuit wind tunnel with a fan at the entry, drawing air from and exhausting to the outdoors; this design is ideal for de/anti-icing tests as it prevents contaminants from recirculating within the tunnel. This design also permits sub-freezing air to be drawn in during the Ottawa winter, thereby providing test section temperatures appropriate to these experiments. The test section is 3 m (10 ft.) wide by 6 m (20 ft.) high by 12 m (40 ft.) long, with a maximum wind speed of 78 knots when using the electrical turbine drive and with a maximum wind speed of just over 115 knots when using the gas turbine drive. Scaffolding was constructed to allow access to the wing section, which facilitated the application of fluids and the subsequent inspection and cleaning of the airfoil.

2.5.2 Generic High-Performance "Supercritical" Commuter Airfoil

The wing section used for testing was a generic high-performance commuter airfoil, also referred to as "supercritical." This wing section was constructed by the NRC in 2009 specifically to conduct these tests following extensive consultations with an airframe manufacturer to ensure a representative supercritical design. The original wing design was representative of an outboard section and did not include a flap; the flap was later added at the request of TC, the FAA, and APS. A CFD analysis of the modified wing section was conducted by the airframe manufacturer, and it was confirmed that the wing section provided a good representation of a flapped section of an operational thin high-performance wing. Photo 2.3 shows the wing section used for testing.

2.5.3 Generic "Supercritical" Wing Design Characteristics

A cross sectional view of the supercritical wing section used for testing has been included in Figure 2.3; the dimensions indicated are in metres. Some of the pertinent dimensions of the wing section are:

a) Chord length not including flap: 1.4 m (4.6 ft.); and
b) Width: 2.4 m (8 ft.).

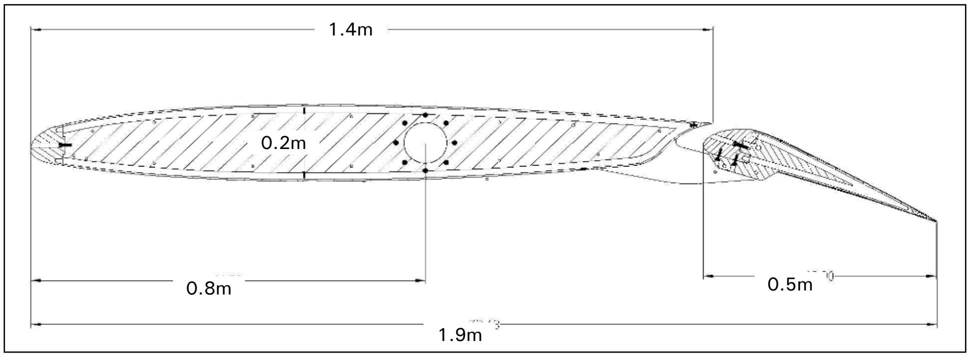

Figure 2.3: Generic "Supercritical" Wing Section

An analysis of the wing section model was conducted by the airframe manufacturer to determine the typical rest position of this type of wing section. It was determined that on a typical commuter aircraft, this section of wing would typically be pitched forward by 2º when sitting on the ground. As a result, the NRC ensured the rest position of the wing model was set to -2º for each test.

The wing section was fitted with a hinged flap. The flap position was fixed at 20º and was not intended to be changed during testing. The top surface of the flap wing section had a steeper angle; a flap setting of 20º created close to a 26º slope on the top surface of the flap (with the wing pitched forward by 2º). As testing progressed, the ability to change the flap setting from 0º to 20º was necessary; contrary to a nested flap, which is typically protected during precipitation, a hinged flap is always exposed, and results indicated earlier failures were due to the shallower angle of the hinged flap. Modifications were made by the NRC to allow the flap setting to alternate between 0º and 20º for the fluid application and contamination periods; however, all takeoff simulations were conducted with the flap set to 20º. No moveable devices were available on the wing section. Detailed coordinates for this airfoil are available.

End plates were installed on the wing section to eliminate the "wall effects" from the wind tunnel walls and to provide a better aerodynamic flow-off above the test area. Figure 2.4 demonstrates the end plates installed on the thin high-performance wing section (note: the wing section is depicted without the top wing skin).

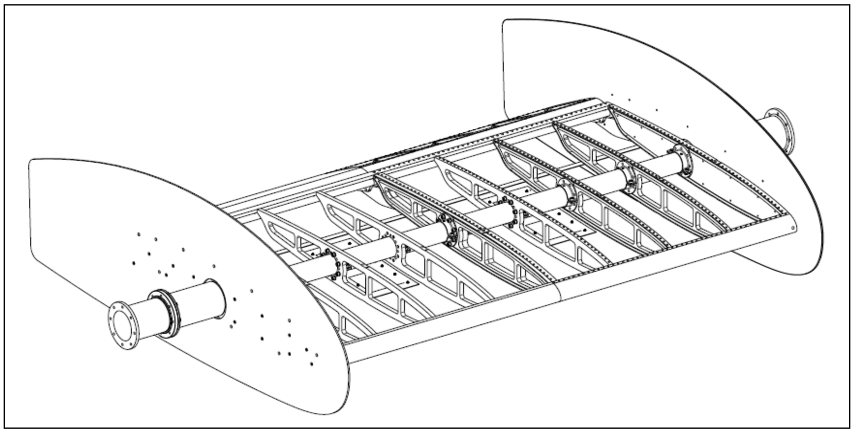

Figure 2.4: End Plates Installed on Supercritical Wing Section

2.5.4 Wind Tunnel Measurement Capabilities

The supercritical wing section was supported on either side by 2-axis weigh scales capable of measuring drag and lift forces generated on the wing section. The wing section was attached to servo-systems capable of pitching the wing section to a static angle or generating dynamic movements. The servo-system was programmed to simulate pitch angles during takeoff and climb-out based on operational aircraft flight profiles.

The wing section was also equipped with eight Resistance Temperature Detectors (RTDs); these were installed by NRC personnel to record the skin temperature on the leading edge (LE), mid chord (MID), trailing edge (TE), and under-wing (UND). RTDs were placed along a chord 0.5 m (1.5 ft.) in pairs to the left and to the right of the wing centreline. The following are the locations of the RTDs:

- RTD LE located approximately 25 cm from the leading edge (as measured along wing skin curvature);
- RTD MID located approximately 70 cm from the leading edge (as measured along wing skin curvature);
- RTD TE located approximately 30 cm from the trailing edge (as measured along wing skin curvature); and
- RTD UND located approximately 45 cm from the leading edge.

Figure 2.5 demonstrates the general location of the RTDs. These RTDs were primarily used to monitor the skin temperature in real-time through the NRC data display system and were recorded by APS personnel as described in Subsection 2.14.3.

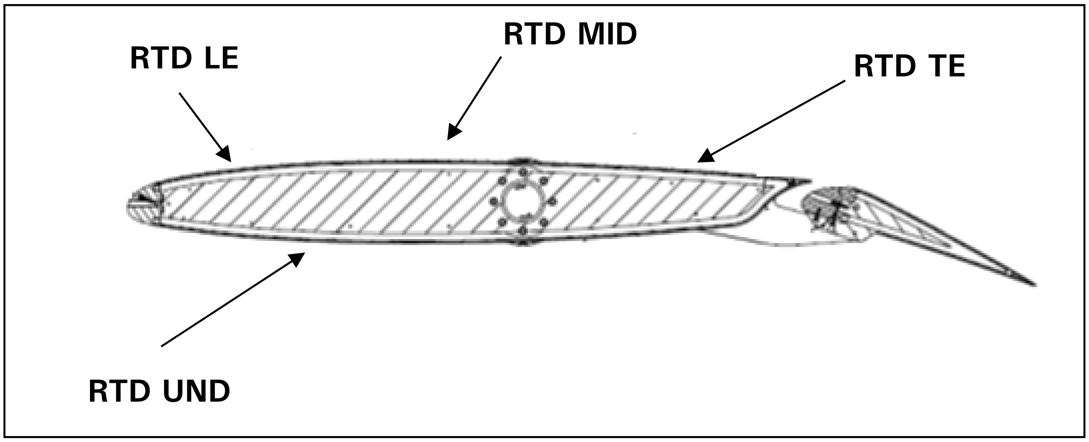

Figure 2.5: Location of RTDs Installed Inside Supercritical Wing

The wind tunnel was also equipped with sensors recording the following parameters:

- Air temperature inside the tunnel;
- Outside air temperature (OAT);
- Air pressure;
- Wind speed; and
- Relative humidity.

2.5.5 Test Area Grid

In previous years, APS personnel used markers to draw a grid on the wing upper surface (excluding the flap). Each grid cell measured 5.1 cm x 5.1 cm (2 in. x 2 in.) with the cell axis positioned perpendicular and parallel to the leading edge (see Photo 2.4). The grid section was 2.4 m (8 ft.), which covered the entire wing section. The grid markings began approximately 10.1 cm (4 in.) aft of the leading edge stagnation point and continued along the length of the main chord; grid markings were not drawn on the flap section. The grid was used to facilitate observations of the fluid shearing off the wing and the movement of ice pellets during takeoff.

This year, a grid was not drawn on the wing section. Faint markings from the previous two years still remained on the wing section and were sufficient for the minimal fluid testing planned. It is recommended that, for future testing, the grid should be re-drawn.

2.6 Equipment

A considerable amount of test equipment was required to perform these tests. Key items are described in the following subsections; a full list of equipment is provided in the test procedure, which is included in Appendix B.

2.7 Simulated Precipitation

2.7.1 Ice Pellets

In a previous analysis of natural ice pellet events, the diameter of ice pellets was measured. It was found that the ice pellets generally ranged from 1 mm to 3 mm. During moderate to heavy ice pellet conditions, the diameter of the ice pellets measured up to 5 mm. Based on this observation, ice pellets were produced with diameters ranging from 1.4 mm to 4.0 mm to represent the most common ice pellet sizes observed during natural events.

The ice pellets were manufactured inside a refrigerated truck (see Photo 2.5). Cubes of ice were crushed and passed through calibrated sieves (see Photo 2.6) to obtain the required ice pellet size range. Hand-held motorized dispensers were used to dispense the ice pellets. The ice pellets were applied to the leading and trailing edges of the wing at the same time.

2.7.2 Snow

Snow was produced using the same method for producing ice pellets. The snow used consisted of small ice crystals measuring less than 1.4 mm in diameter. Previous testing conducted by APS investigated the dissolving properties of the simulated snow versus natural snow. The simulated snow was selected as an appropriate substitute for natural snow.

The snow was manufactured inside a refrigerated truck. Cubes of ice were crushed and passed through calibrated sieves to obtain the required snow size range. Hand-held motorized dispensers were used to dispense the snow. The snow was applied to the leading and trailing edges of the wing at the same time.

2.7.3 Freezing Rain/Rain

The same sprayer head and scanner used for HOT testing at the NRC Climatic Engineering Facility was employed for testing. The sprayer system uses compressed air and distilled water to produce freezing rain. The temperature of the water is controlled and is kept just above freezing temperature in order to produce freezing rain. To produce rain, the temperature of the water is raised until the precipitation no longer freezes on the test surfaces.

2.8 Simulated Precipitation Related Equipment

2.8.1 Ice Pellet and Snow Dispenser

Calibration work was performed on the modified ice pellet/snow dispensers during the winter of 2007-08. The purpose of this calibration work was to determine the dispensers' distribution footprint for when dispensing both ice pellets and snow. A series of tests were performed in various conditions:

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

These tests were conducted using 121 collection pans, each measuring 15 cm x 15 cm, over an area 3.4 m x 3.4 m. Pre-measured amounts of IP/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.

Using the results from these calibration tests, it was determined that the most appropriate distribution for the wind tunnel tests would be attained by using four dispensers (two on the leading edge and two on the trailing edge) and by moving them through a cycle of four positions 0.3 m (1 ft.) apart; this essentially simulated sixteen dispensers positioned 0.3m (1 ft.) apart along the leading and trailing edge of the wing.

Dispensing was done by placing known quantities of simulated ice pellets or snow into the dispensing bucket and allowing the dispenser to completely empty the contents over a set period of time (usually 1 minute). After the dispensing bucket was emptied, the dispenser was shifted over to the next of four positions per dispenser. The dispensers were refilled every minute for the duration of the test (see Photo 2.7). The calculated efficiencies were accounted for when weighing the required amounts of ice pellets and snow. Details regarding the distribution pattern can be found in Attachments XI and XII of the wind tunnel procedure found in Appendix B.

During the winter of 2009-10, the methodology for dispensing snow was modified for tests requiring heavier snow intensities. Snow was dispensed manually by sifting snow directly onto the wing using calibrated sieves. This method was found to be more efficient, and it provided a more even application for cases where higher intensity snow precipitation rates were required.

2.8.2 Freezing Rain Sprayer

Simulated freezing rain was generated by the NRC freezing rain sprayer system. The same sprayer head and scanner used for HOT testing at the NRC Climatic Engineering Facility was employed for testing. The sprayer system uses compressed air and distilled water to produce freezing rain. Two hypodermic needles are mounted onto a sprayer head whose movement is controlled by a 2-axis scanner. Approximately 2 seconds are required for the sprayer to disperse across the 2.4 m (8 ft.) width of the wing. The spray pattern is an “S” shape form, and a total of 54 seconds is required to complete a full cycle. Two full cycles are required to completely cover the wing (the second cycle is offset to generate a more even distribution). The freezing rain sprayer is shown in Photo 2.8.

2.9 Definition of Precipitation Rates

When simulating precipitation rates for full-scale and plate testing, the rate limits defined for standard HOT testing were referenced. Figure 2.6 demonstrates the HOT testing rate precipitation breakdown.

HOT testing protocol for ice pellets does not currently exist. As a result, ice pellet precipitation rate limits were based upon the freezing rain rate breakdown. The following precipitation rates were used for the full-scale and flat plate testing conducted during the winter of 2008-09:

- Light Ice Pellets: 13-25 $g/dm^2/h$;
- Moderate Ice Pellets: 25-75 $g/dm^2/h$;
- Light Freezing Rain: 13-25 $g/dm^2/h$;
- Moderate Freezing Drizzle: 5-13 $g/dm^2/h$;
- Light Rain: 13-25 $g/dm^2/h$;
- Moderate Rain: 25-75 $g/dm^2/h$;
- Light Snow: 4-10 $g/dm^2/h$; and
- Moderate Snow 10-25 $g/dm^2/h$.

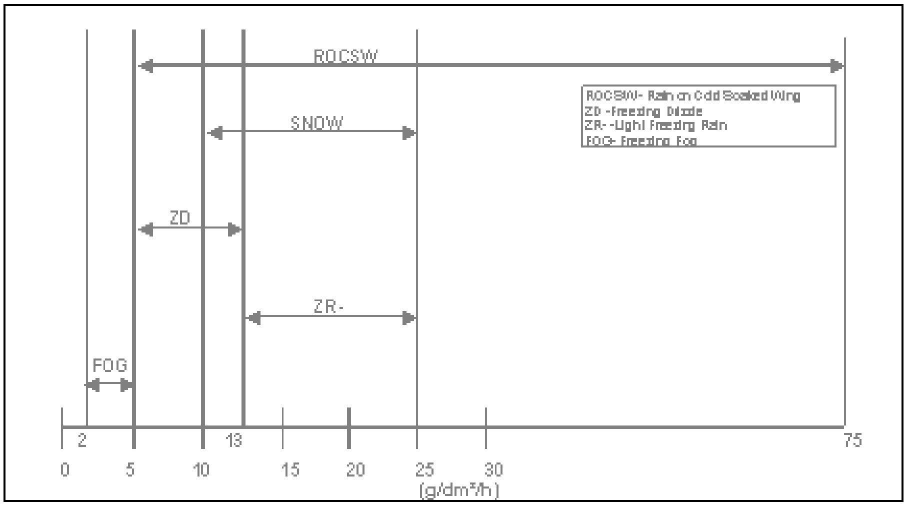

Figure 2.6: Precipitation Rate Breakdown

2.10 Video and Photo Equipment

Two Canon Digital Rebel XT digital still cameras were used to obtain high-speed, high-resolution photographs of the testing. The 8 mega-pixel resolution cameras are capable of taking up to three pictures per second in continuous shooting mode. As of 2009-10, the cameras were fitted with an intervalometer, and the frames were set at one per second; this reduced the storage size required for the photos while still providing sufficient detail of fluid flow-off. The cameras were fitted with 18-55 mm lenses.

To create a consistent and stable setup for the cameras, APS mounted the cameras in the observation window overlooking the wing section. The flashes, operated through radio-triggering sensors, were positioned in the opposing observation window; this created a shadow effect that could be used to measure and calculate the magnitude of the fluid waves and protruding contamination. An additional observation window was installed during the winter of 2009-10 directly overlooking the wing. The purpose was to allow observers to get a close look at the wing without interfering with the camera setup. Photos 2.9 and 2.10 demonstrate the camera setup used for the testing period.

The camera setup used during the winter of 2010-11 was similar to the setup used in 2009-10. The cameras were positioned to obtain a wide-angle view of the leading edge and close-up view of the trailing edge. In comparison to the 2006-07 and 2008-09 camera test setup, the positioning of the cameras was modified slightly due to the end plates installed on the wing and the wing geometry, both of which affected the camera view. During the 2006-07 tests, the cameras' primary focus was on the starboard section of the wing, whereas during the 2008-09 and 2009-10 tests, the primary focus point was on the center section of the wing; this was due to the restricted viewpoints resulting from the changes in the wing setup. The trailing edge lens was also changed from a 105 mm macro lens (2006-07) to a 18-55 mm lens (2008-09 and 2009-10), as the primary focus point had been moved further away from the camera. Additional information regarding the camera setup used is documented and available upon request.

About midway during the 2010-11 testing, a requirement to shoot videos of the test runs became apparent during the wing stall runs. The still photos were not able to clearly demonstrate the wing buffeting and flow reversal effects. As a result, a hand-held camera with video recording capabilities was fitted onto the observation window overlooking the wing, and videos were taken of most of the test runs thereafter.

In addition, a professional photographer used a digital still camera to take pictures of the test setup and all phases of the test from both inside and outside the test section.

The photography and videography setup remained the same for the winter 2011-12 testing. Due to the high wear-and-tear that the camera and flash equipment endure during the high-speed photography, consideration should be given to replacing the full photography gear in the next two years to avoid breakdowns during testing, which could be costly and inconvenient.

2.11 Additional Photos Taken During Precipitation Phase

In 2009-10, the cameras were fitted with an intervalometer to limit the number of frames taken during the high-speed run and to reduce the storage size of the photos. The same intervalometer was used for taking pictures during the precipitation phase. The cameras were set to trigger every minute and, during shorter tests, at shorter intervals as required. These photos proved to be useful for demonstrating the progression of contamination, as well as for reviewing and comparing tests. This protocol has been adopted as part of the regular testing procedure for future testing.

2.12 Type II/III/IV Fluid Application Equipment

The Type II/III/IV fluids were stored outside the wind tunnel and were kept at air temperature. The fluids were poured rather than sprayed so that application would not change the fluid viscosity. This methodology was appropriate given the relatively small test area of the wing section and the goal of minimizing the amount of fluid flowing off the wing.

Type II/III/IV fluids were generally received in 20 L containers; however, during the 2010-11 testing, some select fluids were received in large 200 L barrels and larger 1000 L totes. The fluid was applied to the wing section by using smaller 2 L containers (see Photo 2.11). Approximately 16 L to 20 L of fluid were applied to the wing section for each test; less fluid was required for the less viscous Type II and III fluids. Due to the flat top surface of the supercritical wing, the thickened fluid did not easily settle and flow on the top surface. The wing was therefore tilted forward (by approximately 10 degrees) for 1 minute following the end of fluid application to allow for the fluid to spread out evenly over the top surface of the wing.

2.13 Waste Fluid Collection

Using a relatively small test area and applying the fluids by pouring minimized the amount of fluid falling off the wing. APS personnel used a vacuum to collect the fluid that would drip onto the tunnel floor prior to each test. The NRC also fitted the wind tunnel with appropriate drainage tubes to collect spent fluid during the takeoff test runs. At the end of the testing period, the services of Safety-Kleen were employed to safely dispose of the waste glycol fluid.

2.14 Personnel

Personnel requirements during the winter of 2011-12 varied depending on the testing objective. To reduce costs, APS involvement was minimized during the calibration and characterization testing.

During the calibration and characterization testing, one APS staff member and one additional person from Ottawa were required to support the tests. A professional photographer was retained to record digital images of the test setup and test. NASA representatives led the testing initiatives and were involved with setting up and analysing the individual tests. Representatives from the TDC and the FAA provided direction in testing and participated as observers. NRC personnel operated the wind tunnel.

During the fluid testing and exploratory research testing, four APS staff members were required to conduct the tests, and three additional persons from Ottawa were tasked to manufacture and dispense ice pellets as well as to help with general setup tasks. A professional photographer was retained to record digital images of the test setup and test runs. Representatives from NASA, the TDC, and the FAA provided direction in testing and participated as observers. Photo 2.12 shows a portion of the 2011-12 research team (due to scheduling, not all participants were available for the photo).

2.15 Measurement of Test Parameters

2.15.1 Measurement Locations

For each test, the fluid thickness, skin temperature, and fluid Brix were measured at eight locations along the center chord. Measurements were taken during four stages of a typical test:

a) Before fluid application;
b) After fluid application;
c) After application of contamination; and
d) After the simulated takeoff test.

The locations designated for measurement, identified in Figure 2.7, were the following:

- Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
- Wing Position 2: Approximately 25 cm up from the leading edge stagnation point;
- Wing Position 3: Approximately 40 cm up from the leading edge stagnation point;
- Wing Position 4: Approximately 55 cm up from the leading edge stagnation point;
- Wing Position 5: Approximately 70 cm up from the leading edge stagnation point;
- Wing Position 6: Approximately 30 cm from the trailing edge;
- Wing Position 7: Approximately 15 cm from the trailing edge;
- Wing Position 8: Approximately 2.5 cm from the trailing edge;
- Wing Position 9: Midway up the flap; and
- Underside: Approximately 40 cm up from the leading edge stagnation point.

The wing positions were measured along the curvature of the wing.

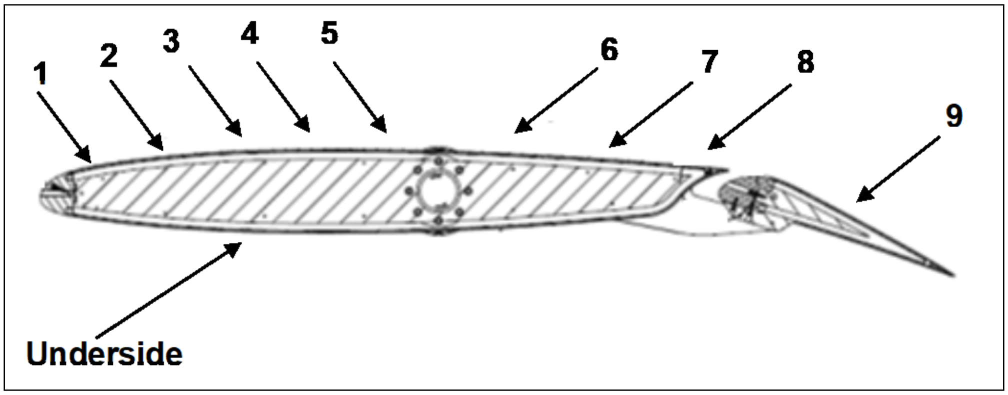

Figure 2.7: Measurement Locations Along Chord of Supercritical Wing Section

2.15.2 Fluid Thickness

Fluid thickness was measured using wet film thickness gauges at three stages of a typical test:

a) After fluid application;

b) After application of contamination; and

c) After the simulated takeoff test.

The locations designated for fluid thickness measurements, identified in Figure 2.7, were the following:

- Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
- Wing Position 2: Approximately 25 cm up from the leading edge stagnation point;
- Wing Position 3: Approximately 40 cm up from the leading edge stagnation point;
- Wing Position 4: Approximately 55 cm up from the leading edge stagnation point;
- Wing Position 5: Approximately 70 cm up from the leading edge stagnation point;
- Wing Position 6: Approximately 30 cm from the trailing edge;
- Wing Position 7: Approximately 15 cm from the trailing edge;
- Wing Position 8: Approximately 2.5 cm from the trailing edge;
- Wing Position 9: Midway up the flap; and

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

The wing positions were measured along the curvature of the wing. Photo 2.13 shows the fluid thickness gauges used for the testing.

2.15.3 Wing Skin Temperature

During the winter of 2009-10 and prior, wing temperatures were measured using a hand-held temperature probe at three locations during four stages of a typical test:

a) Before fluid application;
b) After fluid application;
c) After application of contamination; and
d) After the simulated takeoff test.

The locations designated for skin temperature measurements, identified in Figure 2.7, were the following:

- Wing Position 2: Approximately 25 cm up from the leading edge stagnation point;
- Wing Position 5: Approximately 70 cm up from the leading edge stagnation point; and
- Underside: Approximately 40 cm up from the leading edge stagnation point.

The wing positions were measured along the curvature of the wing. Photo 2.14 shows the skin temperature probe used for the testing.

During the winter 2009-10 testing, the hand-held measurements were compared to the NRC-monitored data from the RTDs located inside the wing (see Subsection 2.5.3). The average of the temperatures recorded by the pairs of RTDs denoted by RTD LE, RTD MID, and RTD UND were comparable to the manual measurements taken by APS using a hand-held temperature probe on positions 2, 5, and Underside, respectively. Therefore, early on, the manual measurements were replaced by the data logged by the NRC (APS recorded an instantaneous average value from the NRC data at the required intervals for analysis purposes). The average instantaneous temperature indicated by the three pairs of RTDs (located to the left and right of the centreline) were recorded for each of the three locations where APS typically measured skin temperature. This methodology was continued for the winter of 2010-11 and also for the winter of 2011-12, and the collection of manual skin temperature measurements was eliminated.

2.15.4 Fluid Brix

Fluid Brix was measured using hand-held refractometers at three stages of a typical test:

a) After fluid application;
b) After application of contamination; and
c) After the simulated takeoff test.

The locations designated for fluid Brix measurements, identified in Figure 2.7, were the following:

- Wing Position 2: Approximately 25 cm up from the leading edge stagnation point; and
- Wing Position 5: Approximately 70 cm up from the leading edge stagnation point.

The wing positions were measured along the curvature of the wing. Figure 2.8 and Photo 2.15 shows the hand-held Brixometer used for the testing.

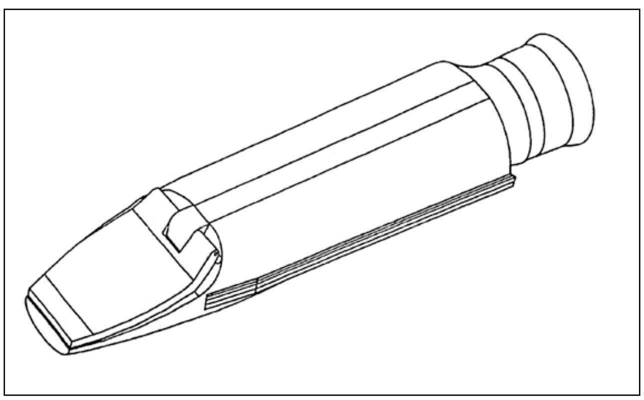

Figure 2.8: Hand-Held Brixometer

2.16 Data Forms

Several different forms were used to facilitate the documentation of the various data collected in the wind tunnel tests. These forms include:

a) General Form;
b) Wing Temperature, Fluid Thickness and Fluid Brix Form;

c) Ice Pellet and Snow Dispensing Forms;

d) Sprayer Calibration Form;

e) Visual Evaluation Rating Form

f) Condition of Wing and Plate Form;

g) Fluid Receipt Form; and

h) Log of Fluid Sample Bottles.

Copies of these forms are provided in the test procedure, which is included in Appendix B. Completed data forms have been included in Appendix C.

2.17 General Methodology

This section describes equipment and general information used for the wind tunnel tests. A considerable amount of test equipment was required to perform these tests. Key items are described in the following subsections; a full list of equipment is provided in the test procedure, which is included in Appendix B.

2.17.1 Refractometer

Fluid freezing points were measured using a hand-held Misco 10431VP refractometer with a Brix scale. The freezing points of the various fluid samples were determined using the conversion curve or table provided to APS by the fluid manufacturer. The following tables contain the fluid freezing points for the various fluids tested and the relevant conversion data:

- Table 2.2 - Kilfrost ABC-S Plus
- Table 2.3 - Clariant MPIII 2031 ECO
- Table 2.4 - Clariant MPIV Launch
- Table 2.5 - Brix to Refractive Index Conversion Table

Figure 2.9 illustrates the fluid freezing points for the Dow EG 106 fluid. It should be noted that conversion tables were not included for Dow AD-49 and Octagon Maxflight; however, the dilution curve would be very similar to Tables 2.2 to 2.5.

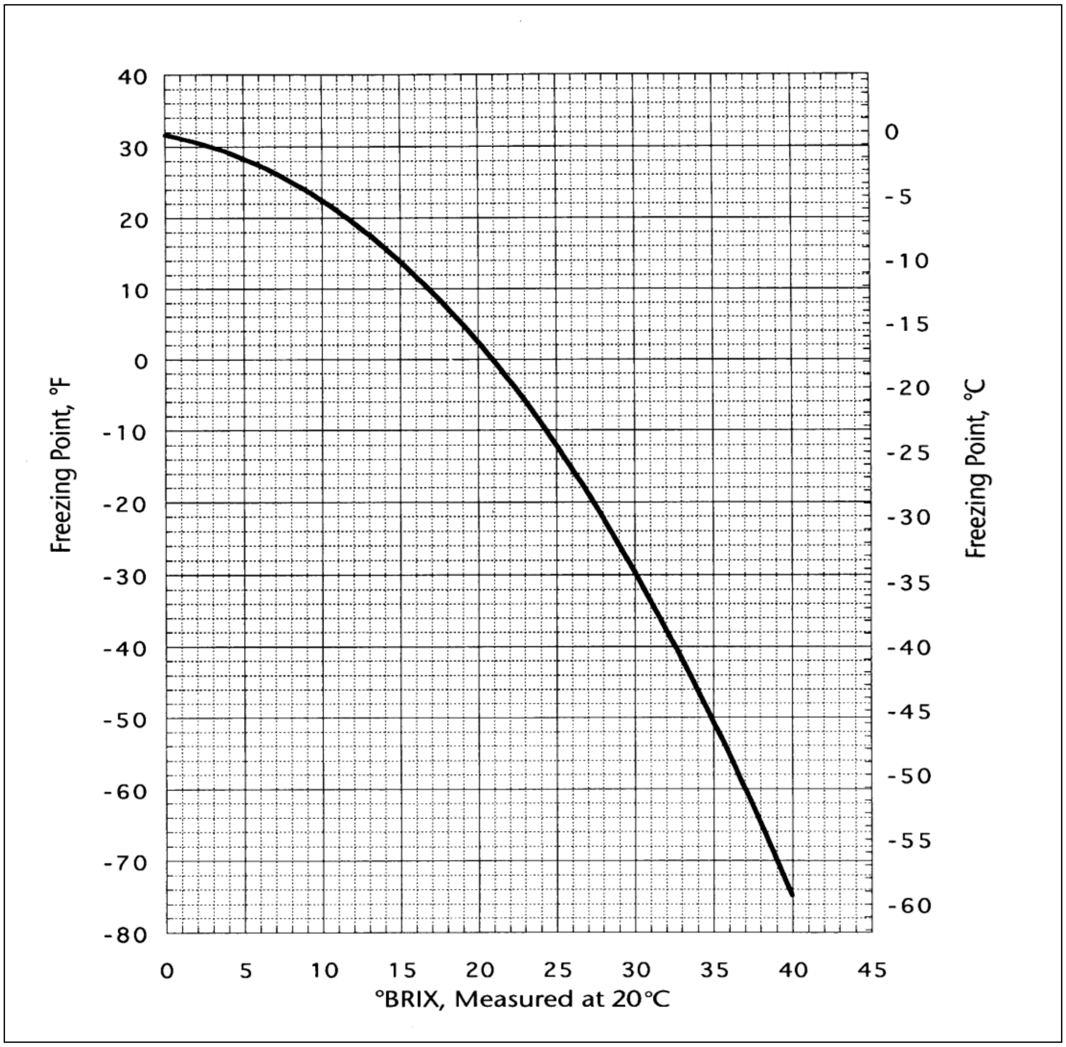

Figure 2.9: Freezing Point vs. Brix of Aqueous Solutions of Dow EG106

2.17.2 Temperature Sensor

When required, wing skin temperature and fluid temperature were measured using a Wahl digital heat-probe thermometer Model 392Vxc. A surface temperature probe was used for wing skin temperature measurements (generally, wing-mounted RTDs were used), and an immersion probe was used for measuring and monitoring fluid temperatures.

Table 2.2: Freezing Point vs. Brix of Aqueous Solutions of Kilfrost ABC-S Plus

Conc. (% Vol)	BRIX (20°C)	RI (20°C)	Freezing Point (20°C)	Conc. (% Vol)	BRIX (20°C)	RI (20°C)	Freezing Point (20°C)	Conc. (% Vol)	BRIX (20°C)	RI (20°C)	Freezing Point (20°C)
20%	8.20	1.345	-3.4	**50%**	**18.90**	**1.362**	**-10.6**	80%	29.40	1.380	-23.1
21%	8.59	1.345	-3.6	51%	19.26	1.363	-11.1	81%	29.73	1.380	-23.7
22%	8.98	1.346	-3.8	52%	19.62	1.364	-11.6	82%	30.06	1.381	-24.2
23%	9.37	1.346	-4.0	53%	19.98	1.364	-12.0	83%	30.36	1.382	-24.8
24%	9.76	1.347	-4.2	54%	20.34	1.365	-12.4	84%	30.72	1.382	-25.4
25%	10.15	1.348	-4.4	55%	20.70	1.365	-12.8	85%	31.05	1.383	-26.0
26%	10.54	1.348	-4.6	56%	21.06	1.366	-13.1	86%	31.38	1.383	-26.7
27%	10.93	1.349	-4.9	57%	21.42	1.366	-13.4	87%	31.71	1.384	-27.3
28%	11.32	1.349	-5.1	58%	21.78	1.367	-13.8	88%	32.04	1.384	-28.0
29%	11.71	1.350	-5.3	59%	22.14	1.368	-14.1	89%	32.37	1.385	-28.6
30%	12.10	1.351	-5.5	60%	22.50	1.368	-14.5	90%	32.70	1.386	-29.3
31%	12.43	1.351	-5.8	61%	22.85	1.369	-14.9	91%	33.02	1.386	-30.1
32%	12.76	1.352	-6.0	62%	23.20	1.369	-15.2	92%	33.34	1.387	-30.8
33%	13.09	1.352	-6.3	63%	23.55	1.370	-15.7	93%	33.66	1.387	-31.5
34%	13.42	1.353	-6.5	64%	23.90	1.371	-16.0	94%	33.98	1.388	-32.2
35%	13.75	1.354	-6.8	65%	24.25	1.371	-16.4	95%	34.30	1.389	-33.0
36%	14.08	1.354	-7.0	66%	24.60	1.372	-16.8	96%	34.62	1.389	-33.8
37%	14.41	1.355	-7.3	67%	24.95	1.372	-17.2	97%	34.94	1.390	-34.6
38%	14.74	1.355	-7.6	68%	25.30	1.373	-17.6	98%	35.26	1.391	-35.4
39%	15.07	1.356	-7.9	69%	25.65	1.373	-18.0	99%	35.58	1.391	-36.2
40%	15.40	1.356	-8.1	70%	26.00	1.374	-18.4	**100%**	**35.90**	**1.392**	**-37.0**
41%	15.75	1.357	-8.4	71%	26.34	1.375	-18.9				
42%	16.10	1.358	-8.7	72%	26.68	1.375	-19.3				
43%	16.45	1.358	-9.0	73%	27.02	1.376	-20.0				
44%	16.80	1.359	-9.3	74%	27.36	1.376	-20.7				
45%	17.15	1.359	-9.5	**75%**	**27.70**	**1.377**	**-21.4**				
46%	17.50	1.360	-9.8	76%	28.04	1.378	-21.7				
47%	17.85	1.361	-10.0	77%	28.38	1.379	-22.0				
48%	18.20	1.361	-10.2	78%	28.72	1.379	-22.3				
49%	18.55	1.362	-10.4	79%	29.06	1.379	-22.6				

Table 2.3: Dilution Chart for Clariant MPIII 2031 ECO

DILUTION (v/v) Safewing : Water	**BRIX (°)** MISCO 10431 VP	**FREEZING POINT (°C)**
100 : 0	34.3 to 36.0	-31 to -34
95 : 5	33.4	-29
90 : 10	31.8	-26
85 : 15	30.2	-23
80 : 20	28.8	-21
75 : 25	27.2	-18
70 : 30	25.4	-16
65 : 35	24.0	-14
60 : 40	22.2	-12
55 : 45	20.4	-11
50 : 50	18.8	-10

Table 2.4: Dilution Chart for Clariant MPIV Launch

Concentration (% Volume)	RI (+20°C) (±0,001)	Freezing Point (°C)	Concentration (% Volume)	RI (+20°C) (±0,001)	Freezing Point (°C)
20%	1,345	-3,0	61%	1,369	-14,5
21%	1,346	-3,3	62%	1,370	-14,9
22%	1,346	-3,5	63%	1,371	-15,5
23%	1,347	-3,7	64%	1,371	-16,0
24%	1,347	-3,9	65%	1,372	-16,5
25%	1,348	-4,1	66%	1,372	-16,9
26%	1,348	-4,4	67%	1,373	-17,4
27%	1,349	-4,7	68%	1,373	-17,8
28%	1,350	-4,8	69%	1,374	-18,3
29%	1,350	-5,0	70%	1,374	-18,7
30%	1,351	-5,5	71%	1,375	-19,0
31%	1,351	-5,7	72%	1,375	-19,4
32%	1,352	-5,9	73%	1,376	-19,8
33%	1,353	-6,1	74%	1,376	-20,3
34%	1,353	-6,4	75%	1,377	-20,8
35%	1,354	-6,6	76%	1,377	-21,0
36%	1,355	-6,8	77%	1,378	-21,5
37%	1,355	-6,9	78%	1,379	-21,9
38%	1,356	-7,0	79%	1,379	-22,2
39%	1,356	-7,3	80%	1,380	-22,6
40%	1,357	-7,5	81%	1,380	-23,0
41%	1,358	-8,0	82%	1,381	-23,5
42%	1,358	-8,5	83%	1,381	-23,9
43%	1,359	-8,9	84%	1,382	-24,3
44%	1,359	-9,2	85%	1,383	-24,8
45%	1,361	-9,5	86%	1,383	-25,4
46%	1,361	-9,7	87%	1,384	-26,0
47%	1,362	-10,0	88%	1,384	-26,5
48%	1,362	-10,2	89%	1,385	-27,2
49%	1,363	-10,4	90%	1,385	-27,7
50%	1,363	-10,7	91%	1,386	-28,4
51%	1,363	-11,0	92%	1,387	-29,2
52%	1,364	-11,2	93%	1,387	-29,8
53%	1,364	-11,5	94%	1,388	-30,6
54%	1,365	-11,8	95%	1,388	-31,4
55%	1,365	-12,3	96%	1,388	-32,2
56%	1,366	-12,5	97%	1,389	-33,5
57%	1,367	-12,8	98%	1,389	-34,2
58%	1,368	-13,3	99%	1,390	-35,0
59%	1,368	-13,7	100%	1,390	-36,0
60%	1,369	-14,0			

Table 2.5: Brix to Refractive Index Conversion Chart

MISCO Model 10431VP • Hand-Held Refractometer
0-50 Brix Scale - Automatically Temperature Compensated

Brix % to Refractive Index @ 20°C

	0.0	0.25	0.50	0.75		0.00	0.25	0.50	0.75
0	1.3330	1.3334	1.3337	1.3341	26	1.3741	1.3745	1.3749	1.3754
1	1.3344	1.3348	1.3351	1.3355	27	1.3758	1.3763	1.3767	1.3772
2	1.3359	1.3363	1.3366	1.3370	28	1.3776	1.3780	1.3785	1.3789
3	1.3373	1.3377	1.3381	1.3384	29	1.3794	1.3798	1.3803	1.3807
4	1.3388	1.3392	1.3395	1.3399	30	1.3812	1.3816	1.3821	1.3825
5	1.3403	1.3407	1.3410	1.3414	31	1.3830	1.3834	1.3839	1.3843
6	1.3418	1.3421	1.3425	1.3429	32	1.3848	1.3852	1.3857	1.3862
7	1.3433	1.3437	1.3440	1.3444	33	1.3866	1.3871	1.3875	1.3880
8	1.3448	1.3452	1.3455	1.3459	34	1.3885	1.3889	1.3894	1.3899
9	1.3463	1.3467	1.3471	1.3475	35	1.3903	1.3908	1.3913	1.3917
10	1.3478	1.3482	1.3486	1.3490	36	1.3922	1.3927	1.3931	1.3936
11	1.3494	1.3498	1.3502	1.3506	37	1.3941	1.3946	1.3950	1.3955
12	1.3509	1.3513	1.3517	1.3521	38	1.3960	1.3965	1.3970	1.3974
13	1.3525	1.3529	1.3533	1.3537	39	1.3979	1.3984	1.3989	1.3994
14	1.3541	1.3545	1.3549	1.3553	40	1.3999	1.4004	1.4008	1.4013
15	1.3557	1.3561	1.3565	1.3569	41	1.4018	1.4023	1.4028	1.4033
16	1.3573	1.3577	1.3581	1.3585	42	1.4038	1.4043	1.4048	1.4053
17	1.3589	1.3593	1.3597	1.3602	43	1.4058	1.4063	1.4068	1.4073
18	1.3605	1.3610	1.3614	1.3618	44	1.4078	1.4083	1.4088	1.4093
19	1.3622	1.3626	1.3630	1.3634	45	1.4098	1.4103	1.4108	1.4113
20	1.3638	1.3643	1.3647	1.3651	46	1.4118	1.4123	1.4128	1.4133
21	1.3655	1.3660	1.3664	1.3668	47	1.4139	1.4144	1.4149	1.4154
22	1.3672	1.3676	1.3680	1.3685	48	1.4159	1.4164	1.4170	1.4175
23	1.3689	1.3693	1.3698	1.3702	49	1.4180	1.4185	1.4190	1.4196
24	1.3706	1.3711	1.3715	1.3719	50	1.4201			
25	1.3723	1.3728	1.3732	1.3736					

2.17.3 Thickness Gauges

Wet film thickness gauges, shown in Figure 2.9, were used to measure fluid film thickness. These gauges were selected because they provide an adequate range of thicknesses (0.1 mm to 10.2 mm) for Type I/II/III/IV fluids. The rectangular gauge shown in Figure 2.10 has a finer scale and was used in some cases when the fluid film was thinner (towards the end of a test). The observer recorded a thickness value (in mils), as read directly from the thickness gauge. The recorded value was the last wetted tooth of the thickness gauge; however, the true thickness lies between the last wetted tooth and the next un-wetted tooth. A thickness conversion table (shown in Table 2.6) was used to convert the recorded thickness values into the corrected thickness values.

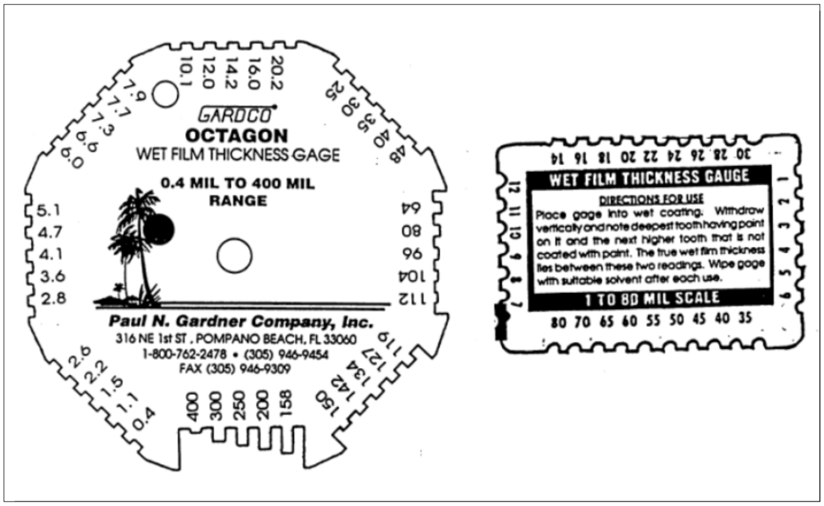

Figure 2.10: Thickness Gauges

2.17.4 Viscometer

Historically, viscosity measurements were carried out using a Brookfield viscometer (Model DV-1+, shown in Photo 2.16) fitted with a recirculating fluid bath and small sample adapter.

In recent years, on-site measurements are done with the Stony Brook PDVdi-120 Falling Ball Viscometer (Photo 2.17) to obtain a verification of the fluid integrity; falling ball tests are much faster and more convenient to perform compared to tests with the Brookfield viscometer.

2.17.5 Fluids

Three fluids were used during the wind tunnel tests conducted during the winter of 2011-12. The fluid used for testing was at mid-production viscosity. The viscosity of the fluids received was measured using the Stony Brook PDVdi-120 Falling Ball Viscometer to ensure the fluid was within the fluid manufacturer production specifications and comparable to previous samples received. The pertinent characteristics of these fluids are given in Table 2.7 along with the historical fluid information for the testing conducted since 2009-10 with the thin high-performance wing section.

Table 2.6: Film Thickness Conversion Table

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

* Reading of last wetted tooth.

Table 2.7: Test Fluids

		Wind Tunnel 2011-12			Wind Tunnel 2010-11			Wind Tunnel 2009-10		
Fluid Name	**LOWV (cP)**	**Batch #**	**Measured Viscosity (cP)**	**Falling Ball (sec)**	**Batch #**	**Measured Viscosity (cP)**	**Falling Ball (sec)**	**Batch #**	**Measured Viscosity (cP)**	**Falling Ball (sec)**
Clariant Produkte Launch	7550	DEG4146145	12597	24	USHA024295 (Same as 09-10)	10258	30	USHA024295	Measured in 2010-11	29
Dow Chemical Company AD-49	12150	-	-	-	TANK#UL24	13097	23	-	-	-
Dow Chemical Company EG106	24850	GMID297182/ 2L1701GKH6	37192	66	GMID297182 /Batch 5	39792	54	WH0601GKDR	37200	48
Kilfrost Limited ABC-S PLUS	17900	B/13/12/11	19396	27	P/282/12/10	24695	32	P/22/12/09	20225	26
Octagon Process Inc. MaxFlight	5540	-	-	-	WL-122210-4	12437	19	-	-	-

Note: Viscosity measured using manufacturer-stated method.

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Photo 2.1: Outside View of NRC Wind Tunnel Facility

Photo 2.2: Inside View of NRC Wind Tunnel Test Section

Photo 2.3: Thin High-Performance Wing Section Used for Testing

Photo 2.4: Grid Markings on Thin High-Performance Wing Section

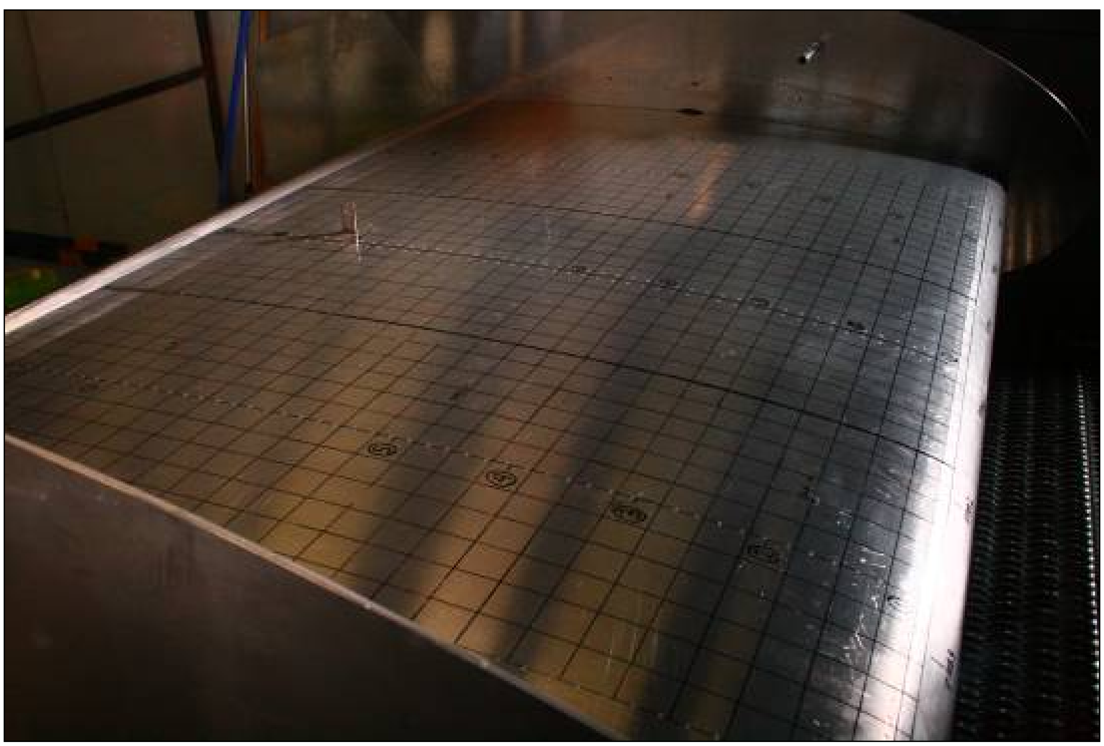

Photo 2.5: Refrigerated Truck Used for Manufacturing Ice Pellets

Photo 2.6: Calibrated Sieves Used to Obtain Desired Size Distribution

Photo 2.7: Ice Pellet Dispensers Operated by APS Personnel

Photo 2.8: Ceiling-Mounted Freezing Rain Sprayer

Photo 2.9: Wind Tunnel Setup for Flashes

Photo 2.10: Wind Tunnel Setup for Digital Cameras

Photo 2.11: Fluid Pour Containers

Photo 2.12: 2011-12 Research Team

Photo 2.13: Wet Film Thickness Gauges

Photo 2.14: Hand-Held Temperature Probe

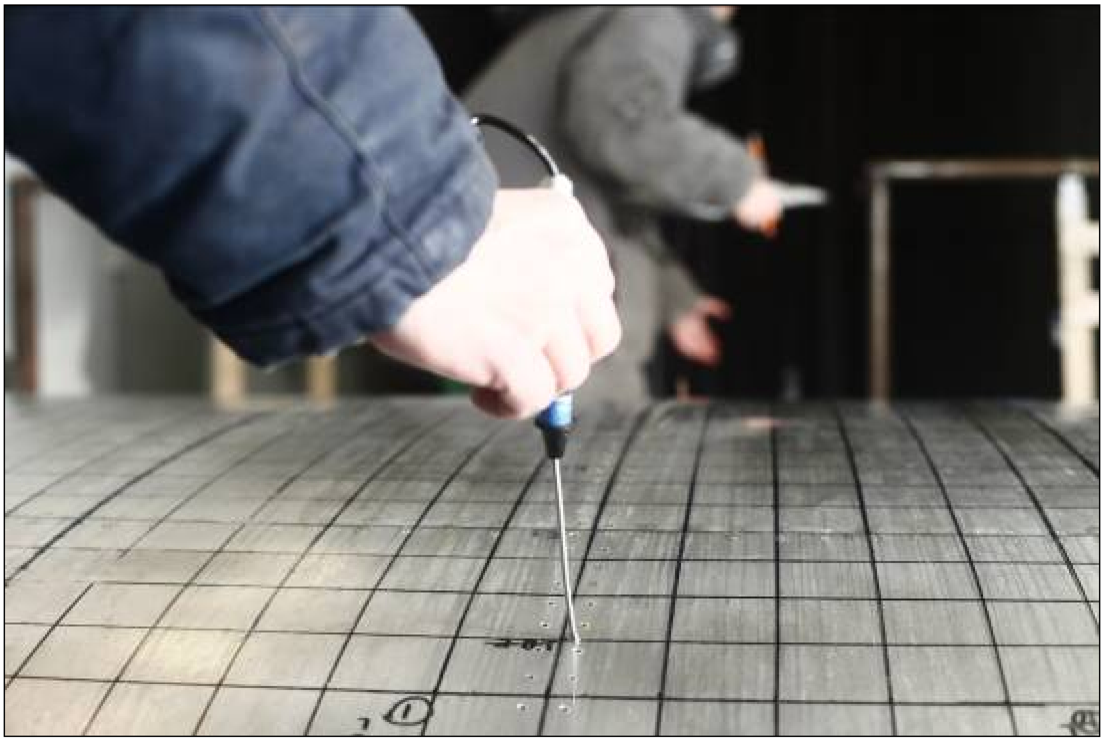

Photo 2.15: Hand-Held Brixometer (Misco 10431VP)

Photo 2.16: Brookfield Digital Viscometer Model DV-1+

Photo 2.17: Stony Brook PDVdi-120 Falling Ball Viscometer

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3. FULL-SCALE DATA COLLECTED

3.1 Test Log

A calendar of the tests conducted during the winter of 2011-12 can be found in Table 2.1. A detailed log of the tests conducted in the NRC PIWT is shown in Table 3.1. Data pertaining to all test objectives (exploratory research objectives as well) is included in the log. Table 3.1 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 3.1:

Run #:	Exclusive number identifying each test run.
Test Plan #:	Exclusive number used for planning purposes and identified in the test procedure.
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:	Aircraft anti-icing fluid used during the test.
Rotation Angle:	Maximum angle of rotation obtained during simulated takeoff run; began testing with a max 8º rotation angle and increased to 20º as testing progressed.
Speed (kts):	Maximum speed obtained during simulated takeoff run, recorded in knots.
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.
Precipitation End Time:	End time of the application of precipitation, recorded in local time.
Tunnel Start Time:	Start of the simulated takeoff run, recorded in local time.

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 air 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.*
Avg. Wing Temp. Before Test (ºC):	Average of the wing skin temperature measurements just before the start of the simulated takeoff test, recorded in degrees Celsius.
Precipitation Rate (Type: [g/dm²/h]):	Simulated freezing 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.
CL at 0º Before Rotation:	Calculated lift coefficient at the 0º wing angle position just prior to the start of the rotation; data provided by the NRC.
CL at 8º During Rotation:	Calculated lift coefficient at the 8º wing rotation angle position; data provided by the NRC.
CL at 4º Following End of Rotation:	Calculated lift coefficient at the 4º wing rotation angle position attained at the end of the rotation cycle; data provided by the NRC.
% Lift Loss:	Percentage lift loss calculated based on the comparison of the 8º lift coefficient during the test run versus the dry wing average lift coefficient.

Table 3.1: Wind Tunnel Test Log 2011-12

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing 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)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
1	2011-12	Clean Wing	None	none	8	20	16-Jan-12	-	-	-18.9	n/a	-	-	-	-	-	-	-	-	1.492	-	-0.27%
2	2011-12	Clean Wing	None	none	8	20	16-Jan-12	-	-	-18.6	n/a	-	-	-	-	-	-	-	-	1.483	-	0.37%
3	2011-12	Clean Wing	None	none	22	20	16-Jan-12	-	-	n/a	n/a	-	-	-	-	-	-	-	-	1.481	-	0.45%
4	2011-12	Clean Wing	None	none	22	20	16-Jan-12	-	-	n/a	-18.6	-	-	-	-	-	-	-	-	1.497	-	-0.59%
5	2011-12	Clean Wing	None	none	22	20	16-Jan-12	-	-	-15.8	-9.2	-	-	-	-	-	-	-	-	1.481	-	0.48%
6	2011-12	Clean Wing	None	none	22	20	16-Jan-12	-	-	n/a	n/a	-	-	-	-	-	-	-	-	1.483	-	0.34%
7	2011-12	Clean Wing	None	none	8	20	16-Jan-12	-	-	-15	-12.3	-	-	-	-	-	-	-	-	1.493	-	-0.35%
8	2011-12	Clean Wing	None	none	22	20	16-Jan-12	-	-	-15	-12	-	-	-	-	-	-	-	-	1.479	-	0.60%
9	2011-12	Clean Wing	None	none	8	20	16-Jan-12	-	-	-15	-12	-	-	-	-	-	-	-	-	1.483	-	0.34%
10	2011-12	Clean Wing	None	none	22	20	16-Jan-12	-	-	-15	-13	-	-	-	-	-	-	-	-	1.487	-	0.08%
11	2011-12	Clean Wing	None	none	22	20	16-Jan-12	-	-	-15	-12	-	-	-	-	-	-	-	-	1.498	-	-0.68%
12	2011-12	Clean Wing	None	none	22	20	16-Jan-12	-	-	-15	-13	-	-	-	-	-	-	-	-	1.485	-	0.22%
13	2011-12	Roughness (Trips)	150-grit	none	22	20	16-Jan-12	-	-	-13.8	-11.5	-	-	-	-	-	-	-	-	1.472	-	1.11%
14	2011-12	Roughness (Trips)	150-grit	none	22	20	16-Jan-12	-	-	-13.7	15.7	-	-	-	-	-	-	-	-	1.484	-	0.30%
15	2011-12	Roughness (Trips)	40-grit	none	15	20	17-Jan-12	-	-	-8.7	18.9	-	-	-	-	-	-	-	-	1.456	-	2.15%
16	2011-12	Roughness (Trips)	40-grit	none	15	20	17-Jan-12	-	-	-8.7	-6	-	-	-	-	-	-	-	-	1.465	-	1.55%
17	2011-12	Roughness (Trips)	80-grit	none	15	20	17-Jan-12	-	-	-7.9	13.1	-	-	-	-	-	-	-	-	1.468	-	1.36%

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing 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)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
18	2011-12	Roughness (Trips)	80-grit	none	15	20	17-Jan-12	-	-	-7.9	-5.6	-	-	-	-	-	-	-	-	1.475	-	0.90%
19	2011-12	Roughness (Trips)	Full Wing 80 Grit	none	15	20	17-Jan-12	-	-	-5.1	16.7	-	-	-	-	-	-	-	-	1.380	-	7.24%
20	2011-12	Roughness (Trips)	Full Wing 80 Grit	none	15	20	17-Jan-12	-	-	-4.9	0.3	-	-	-	-	-	-	-	-	1.380	-	7.28%
21	2011-12	Roughness (Trips)	Full Wing 80 Grit	none	15	20	17-Jan-12	-	-	-5	-3	-	-	-	-	-	-	-	-	1.377	-	7.46%
22	2011-12	Roughness (Trips)	Grit (-30% grit on LE)	none	20	20	17-Jan-12	-	-	-4.1	14.4	-	-	-	-	-	-	-	-	1.388	-	6.71%
23	2011-12	Roughness (Trips)	Grit (-30% grit on LE)	none	22	20	17-Jan-12	-	-	-4.1	-2	-	-	-	-	-	-	-	-	1.392	-	6.46%
24	2011-12	Roughness (Trips)	Grit (-30% grit on LE)	none	24	20	17-Jan-12	-	-	-4.1	-2.1	-	-	-	-	-	-	-	-	1.382	-	7.13%
25	2011-12	Roughness (Trips)	Grit (-60% grit on LE)	none	22	20	17-Jan-12	-	-	-3.6	14	-	-	-	-	-	-	-	-	1.412	-	5.11%
26	2011-12	Roughness (Trips)	Grit (-60% grit on LE)	none	22	20	17-Jan-12	-	-	-3.6	-2	-	-	-	-	-	-	-	-	1.405	-	5.59%
27	2011-12	Roughness (Trips)	Grit (only flap)	none	22	20	18-Jan-12	-	-	11.3	-14.3	-	-	-	-	-	-	-	-	1.417	-	4.77%
28	2011-12	Roughness (Trips)	Grit (only flap)	none	22	20	18-Jan-12	-	-	-11.5	-14.4	-	-	-	-	-	-	-	-	1.414	-	4.96%
29	2011-12	Clean Wing	None	none	22	20	18-Jan-12	-	-	-13.7	n/a	-	-	-	-	-	-	-	-	1.483	-	0.37%
30	2011-12	Clean Wing	None	none	22	20	18-Jan-12	-	-	-13.7	-11.3	-	-	-	-	-	-	-	-	1.482	-	0.40%
31	2011-12	Clean Wing	None	none	22	20	18-Jan-12	-	-	-13.7	-11.3	-	-	-	-	-	-	-	-	1.492	-	-0.25%
32	2011-12	Flow Visualization	Tufts	none	20	20	18-Jan-12	-	-	-12.7	-8.6	-	-	-	-	-	-	-	-	1.478	-	0.66%
33	2011-12	Flow Visualization	Tufts	none	22	20	18-Jan-12	-	-	-12.4	-10.8	-	-	-	-	-	-	-	-	1.484	-	0.30%
34	2011-12	Clean Wing/Oil Flow Vis	None	none	22	20	18-Jan-12	-	-	-12	-3	-	-	-	-	-	-	-	-	1.492	-	-0.28%

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation 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)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
35	2011-12	Oil Flow Visualization	Oil	none	8 static	20	19-Jan-12	-	-	-17.9	-7.8	-	-	-	-	-	-	-	-	-	-	-
36	2011-12	Oil Flow Visualization	Oil	none	12 static	20	19-Jan-12	-	-	-16.7	-9.2	-	-	-	-	-	-	-	-	-	-	-
37	2011-12	Oil Flow Visualization	Oil	none	12 then sweep to 16	20	19-Jan-12	-	-	-15.9	-9.2	-	-	-	-	-	-	-	-	-	-	-
38	2011-12	Oil Flow Visualization	Oil	none	12 then sweep to 18	20	19-Jan-12	-	-	-14.9	-8.2	-	-	-	-	-	-	-	-	-	-	-
39	2011-12	Oil Flow Visualization	Oil	none	12 then sweep to 20	20	19-Jan-12	-	-	-13.7	-6.7	-	-	-	-	-	-	-	-	-	-	-
40	2011-12	Oil Flow Visualization	Oil	none	8	20	19-Jan-12	-	-	-12.6	-6.4	-	-	-	-	-	-	-	-	-	-	-
41	2011-12	Boundary Layer Rake	None	none	20	20	19-Jan-12	-	-	-11.4	-1.9	-	-	-	-	-	-	-	-	-	-	-
42	2011-12	Boundary Layer Rake	None	none	20	20	19-Jan-12	-	-	-11	-4.5	-	-	-	-	-	-	-	-	-	-	-
43	2011-12	Boundary Layer Rake	None	none	20	20	19-Jan-12	-	-	-10.8	-6.3	-	-	-	-	-	-	-	-	-	-	-
44	2011-12	Boundary Layer Rake	None	none	20	20	19-Jan-12	-	-	-10.6	-5	-	-	-	-	-	-	-	-	-	-	-
45	2011-12	Boundary Layer Rake	None	none	20	20	20-Jan-12	-	-	-19.7	-15	-	-	-	-	-	-	-	-	-	-	-
46	2011-12	Boundary Layer Rake	None	none	20	20	20-Jan-12	-	-	-19.8	-18.1	-	-	-	-	-	-	-	-	-	-	-
47	2011-12	Clean Wing	None	none	20	20	20-Jan-12	-	-	-20	-15.8	-	-	-	-	-	-	-	-	1.501	-	-0.84%
48	2011-12	Clean Wing	None	none	-2 to 22	20	20-Jan-12	-	-	-20	-17.4	-	-	-	-	-	-	-	-	1.495	-	-0.47%
49	2011-12	Fluid Tests - Repeatibility	Fluid Only	EG 106 (100)	8	20	20-Jan-12	-	10:00	-19.4	-14.8	-14	-	-	1,1,1	1,1,1	1,1,1	-	-	N/A	-	-
50	2011-12	Fluid Tests - Repeatibility	Fluid Only	EG 106 (100)	8	20	20-Jan-12	-	10:44	-18.9	-15.2	-13.2	-	-	1.1.1	1.1.1	1.1.1	0.452	1.282	1.499	1.141538	-0.76%
51	2011-12	Fluid Tests - Repeatibility	Fluid Only	EG 106 (100)	8	20	20-Jan-12	-	11:19	-18	-13.1	-12.5	-	-	1,1,1	1,1,1	1,1,1	0.439	1.283	1.449	1.136534	2.59%
52	2011-12	Fluid Tests - Repeatibility	Fluid Only	EG 106 (100)	8	20	20-Jan-12	-	11:52	-17.1	-12.4	-12.3	-	-	1,1,1	1,1,1	1,1,1	0.500	1.285	1.437	1.142768	3.43%

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation 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)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
53	2011-12	Fluid Tests - Data at Stall	Fluid Only	EG 106 (100)	18	20	20-Jan-12	-	12:22	-16.5	-13.4	-12.5	-	-	1,1,1	1,1,1	1,1,1	0.475	1.281	1.422	1.142166	4.41%
54	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	20-Jan-12	-	12:58	-16.4	-12.9	-12.4	-	-	1,1,1	1,1,1	1,1,1	0.495	1.243	1.398	1.124306	6.02%
55	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	20-Jan-12	-	13:24	-16.4	-12.5	-12.4	-	-	1,1,1	1,1,1	1,1,1	-	-	-	-	-
56	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	20-Jan-12	-	14:08	-15.7	-12.4	-12.3	-	-	1,1,1	1,1,1	1,1,1	0.593	1.250	1.407	1.121894	5.43%
57	2011-12	Fluid Tests - Data at Stall	Fluid Only	ABC-S Plus (100)	18	20	20-Jan-12	-	14:41	-15.6	-11.3	-11.8	-	-	1,1,1	1,1,1	1,1,1	0.588	1.252	1.408	1.128807	5.37%
58	2011-12	Fluid Tests - Repeatibility	IP Mod	ABC-S Plus (100)	8	20	20-Jan-12	15:20	15:27	-15.3	-12.1	-11.5	IP: 75	10	2.7,2.5, 4	1,2,2.8	1,1,2	0.519	1.171	1.341	1.085832	9.91%
59	2011-12	Fluid Tests - Repeatibility	IP Mod	ABC-S Plus (100)	8	20	20-Jan-12	16:11	16:16	-15.5	-10.1	-13	IP: 75	10	2.3,2.5, 3.8	1,1.8,2. 8	1,1,1.8	0.496	1.166	1.326	1.112432	10.88%
60	2011-12	END PLATES - Clean Wing	None	none	8	20	24-Jan-12	-	-	1.2	2	-	-	-	-	-	-	-	-	1.750	-	0.09%
61	2011-12	END PLATES - Clean Wing	None	none	8	20	24-Jan-12	-	-	1.2	2	-	-	-	-	-	-	-	-	1.752	-	-0.01%
62	2011-12	END PLATES - Clean Wing	None	none	22	20	24-Jan-12	-	-	1.2	2	-	-	-	-	-	-	-	-	1.758	-	-0.34%
63	2011-12	END PLATES - Clean Wing	None	none	-2 to 22	20	24-Jan-12	-	-	1.2	2	-	-	-	-	-	-	-	-	1.769	-	-0.95%
64	2011-12	END PLATES - Clean Wing	None	none	22	20	24-Jan-12	-	-	1.2	2	-	-	-	-	-	-	-	-	1.749	-	0.19%
65	2011-12	END PLATES - Clean Wing	None	none	22	20	24-Jan-12	-	-	1.2	2	-	-	-	-	-	-	-	-	1.750	-	0.13%
66	2011-12	END PLATES - Clean Wing	None	none	8	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.751	-	0.08%
67	2011-12	END PLATES - Clean Wing	None	none	8	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.748	-	0.23%
68	2011-12	END PLATES - Clean Wing	None	none	18	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.743	-	0.51%

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation 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)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
69	2011-12	END PLATES - Clean Wing	None	none	-2 to 18	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.765	-	-0.72%
70	2011-12	END PLATES - Clean Wing	None	none	18	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.742	-	0.57%
71	2011-12	END PLATES - Clean Wing	None	none	18	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.745	-	0.40%
72	2011-12	END PLATES - Rough(Trips)	40-grit	none	15	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.712	-	2.29%
73	2011-12	END PLATES - Rough(Trips)	40-grit	none	-2 to 15	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.703	-	2.82%
74	2011-12	END PLATES - Rough(Trips)	150-grit	none	15	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.739	-	0.73%
75	2011-12	END PLATES - Rough(Trips)	150-grit	none	-2 to - 15	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.744	-	0.45%
76	2011-12	END PLATES - Rough(Trips)	80-grit	none	15	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.726	-	1.48%
77	2011-12	END PLATES - Rough(Trips)	80-grit	none	-2 to - 15	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.727	-	1.42%
78	2011-12	END PLATES - Rough(Trips)	Grit (only flap)	none	15	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.635	-	6.69%
79	2011-12	END PLATES - Rough(Trips)	Grit (only flap)	none	-2 to 15	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.624	-	7.33%
80	2011-12	END PLATES - Clean Wing	None	none	18	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.761	-	-0.51%
81	2011-12	END PLATES - Clean Wing	None	none	18	20	24-Jan-12	-	-	1	2	-	-	-	-	-	-	-	-	1.754	-	-0.09%
82	2011-12	END PLATES - Clean Wing	None	none	18	20	24-Jan-12	-	-	1	d	-	-	-	-	-	-	-	-	1.771	-	-1.06%
83	2011-12	Boundary Layer Rake	None	none	16	20	25-Jan-12	-	-	-7.7	4.7	-	-	-	-	-	-	-	-	-	-	-
84	2011-12	Boundary Layer Rake	None	none	16	20	25-Jan-12	-	-	-7.7	4.3	-	-	-	-	-	-	-	-	-	-	-
85	2011-12	Boundary Layer Rake	None	none	16	20	25-Jan-12	-	-	-7.6	4.3	-	-	-	-	-	-	-	-	-	-	-

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation 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)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
86	2011-12	Boundary Layer Rake	None	none	16	20	25-Jan-12	-	-	-7.8	-1	-	-	-	-	-	-	-	-	-	-	-
87	2011-12	Boundary Layer Rake	None	none	16	20	25-Jan-12	-	-	-7.6	-1	-	-	-	-	-	-	-	-	-	-	-
88	2011-12	Boundary Layer Rake	None	none	16	20	25-Jan-12	-	-	-7.4	-1	-	-	-	-	-	-	-	-	-	-	-
89	2011-12	END PLATES - Clean Wing	None	none	18	20	25-Jan-12	-	-	-7.1	0.6	-	-	-	-	-	-	-	-	1.765	-	-0.76%
90	2011-12	END PLATES - Clean Wing	None	none	-2 to 18	20	25-Jan-12	-	-	-7	-5	-	-	-	-	-	-	-	-	1.772	-	-1.12%
91	2011-12	Flow Visualization	Tufts	none	16	20	25-Jan-12	-	-	-6.1	4	-	-	-	-	-	-	-	-	-	-	-
92	2011-12	Flow Visualization	Tufts	none	18	20	25-Jan-12	-	-	-6.1	-4.1	-	-	-	-	-	-	-	-	-	-	-
93	2011-12	Flow Visualization	Tufts	none	18	20	25-Jan-12	-	-	-6.1	-4.1	-	-	-	-	-	-	-	-	-	-	-
94	2011-12	END PLATES - Oil Flow Vis	Oil	none	5	20	25-Jan-12	-	-	-5.2	6.2	-	-	-	-	-	-	-	-	-	-	-
95	2011-12	END PLATES - Oil Flow Vis	Oil	none	8	20	25-Jan-12	-	-	-5.2	6	-	-	-	-	-	-	-	-	-	-	-
96	2011-12	END PLATES - Oil Flow Vis	Oil	none	12	20	25-Jan-12	-	-	-5	4.5	-	-	-	-	-	-	-	-	-	-	-
97	2011-12	END PLATES - Oil Flow Vis	Oil	none	TBD	20	26-Jan-12	-	-	-13	-10	-	-	-	-	-	-	-	-	-	-	-
98	2011-12	END PLATES - Clean Wing	Oil	none	stall -4 to stall +4	20	26-Jan-12	-	-	-13	-10	-	-	-	-	-	-	-	-	-	-	-
99	2011-12	END PLATES - Oil Flow Vis	Oil	none	TBD	20	26-Jan-12	-	-	-13	-10	-	-	-	-	-	-	-	-	-	-	-
100	2011-12	END PLATES - Clean Wing	None	none	stall -4 to stall +4	20	26-Jan-12	-	-	-12.1	-5.7	-	-	-	-	-	-	-	-	-	-	-
101	2011-12	END PLATES - Clean Wing	None	none	stall -4 to stall +4	20	26-Jan-12	-	-	-11.7	-9.2	-	-	-	-	-	-	-	-	-	-	-
102	2011-12	END PLATES - Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	26-Jan-12	-	10:21	-10.6	-7.1	-6	-	-	1,1,1	1,1,1	1,1,1	0.697	1.477	1.648	1.362165	5.96%

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation 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)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
103	2011-12	END PLATES - Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	26-Jan-12	-	10:57	-8.9	-5.5	-5.5	-	-	1,1,1	1,1,1	1,1,1	0.677	1.465	1.648	1.36452	5.95%
104	2011-12	END PLATES - Fluid Tests - Data at Stall	Fluid Only	ABC-S Plus (100)	13	20	26-Jan-12	-	11:29	-8.1	-4.5	-4.2	-	-	1,1,1	1,1,1	1,1,1	0.669	1.470	1.657	1.370797	5.40%
105	2011-12	END PLATES - Fluid Tests - Repeatibility	Fluid Only	EG 106 (100)	8	20	26-Jan-12	-	12:01	-7.8	-3.6	-4.1	-	-	1,1,1	1,1,1	1,1,1	0.728	1.525	1.697	1.367494	3.11%
106	2011-12	END PLATES - Fluid Tests - Repeatibility	Fluid Only	EG 106 (100)	8	20	26-Jan-12	-	12:45	-6.9	-2.7	-3.6	-	-	1,1,1	1,1,1	1,1,1	0.750	1.530	1.697	1.366801	3.17%
107	2011-12	END PLATES - Fluid Tests - Data at Stall	Fluid Only	EG 106 (100)	16	20	26-Jan-12	-	13:16	-6.5	-2.8	-3.3	-	-	1,1,1	1,1,1	1,1,1	-	-	1.684	-	3.91%
108	2011-12	END PLATES - Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	26-Jan-12	-	13:49	-5.9	-1.8	-3	-	-	1,1,1	1,1,1	1,1,1	0.651	1.430	1.616	1.339081	7.76%
109	2011-12	END PLATES - Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	26-Jan-12	-	N/A	-5.9	-2.1	-3	-	-	1,1,1	1,1,1	1,1,1	0.662	1.453	1.636	1.347895	6.62%
110	2011-12	END PLATES - Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	26-Jan-12	-	14:52	-5.9	-2.3	-3	-	-	1,1,1	1,1,1	1,1,1	0.657	1.434	1.622	1.347233	7.40%
111	2011-12	END PLATES - Fluid Tests - Data at Stall	Fluid Only	Launch (100)	15	20	26-Jan-12	-	15:18	-5.7	-2.6	-3.1	-	-	1,1,1	1,1,1	1,1,1	0.657	1.448	1.623	1.345724	7.38%
112	2011-12	Clean Wing	None	none	8	20	26-Jan-12			-5.9	-2.6	-	-	-	-	-	-	-	-	1.761	-	-0.52%
113	2011-12	Clean Wing	None	none	stall	20	29-Jan-12	-	-	-5.2	-1.4	-	-	-	-	-	-	-	-	1.480	-	0.53%
114	2011-12	Clean Wing	None	none	8	20	29-Jan-12	-	-	-5.2	-1.4	-	-	-	-	-	-	-	-	1.491	-	-0.22%
115	2011-12	Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	29-Jan-12	-	23:04	-5.1	-1.6	-1.4	-	-	1,1,1	1,1,1	1,1,1	0.609	1.259	1.408	1.138277	5.38%

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0º, 20º)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation 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)	CL at -2º Before Rotation	CL at 6º During Rotation	CL at 8º	CL at 4º Following End of Rotation	% Lift Loss (8º CL vs. Dry CL)
116	2011-12	Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	29-Jan-12	-	23:32	-5.1	-1.4	-1.4	-	-	1,1,1	1,1,1	1,1,1	0.594	1.262	1.402	1.131644	5.80%
117	2011-12	Fluid Tests - Data at Stall	Fluid Only	Launch (100)	18	20	29-Jan-12	-	23:59	-5	-1.5	-1.4	-	-	1,1,1	1,1,1	1,1,1	0.588	1.251	1.407	1.134258	5.47%
118	2011-12	Fluid Tests - Repeatibility	IP Mod	Launch (100)	8	20	30-Jan-12	0:50	0:54	-6.1	-4	-8.2	IP: 75	25	3.2,3.5,3.2	1.5,2.2,2	1,1,1	0.564	1.243	1.395	1.137091	6.28%
119	2011-12	Fluid Tests - Repeatibility	IP Mod	Launch (100)	8	20	30-Jan-12	1:45	1:50	-7.2	-4.4	-8.9	IP: 75	25	3,3,3.5	1.1,1.7,2	1,1,1.2	0.556	1.231	1.378	1.135609	7.38%
120	2011-12	Fluid Tests - Data at Stall	IP Mod	Launch (100)	18	20	30-Jan-12	2:53	N/A	-8.1	-4.9	-9.7	IP: 75	25	3,3,3.5	1,1.8,2	1,1,1.1	0.552	1.210	1.375	1.140375	7.63%
121	2011-12	Fluid Tests - Repeatibility	Fluid Only	EG 106 (100)	8	20	30-Jan-12	-	3:27	-8.8	-6.2	-4.8	-	-	1,1,1	1,1,1	1,1,1	0.645	1.280	1.435	1.142525	3.56%
122	2011-12	Fluid Tests - Repeatibility	Fluid Only	EG 106 (100)	8	20	30-Jan-12	-	3:55	-9.3	-6.4	-4.8	-	-	1,1,1	1,1,1	1,1,1	0.638	1.124	1.436	1.139937	3.52%
123	2011-12	Fluid Tests - Data at Stall	Fluid Only	EG 106 (100)	18	20	30-Jan-12	-	4:24	-9.6	-6.6	N/A	-	-	1,1,1	1,1,1	1,1,1	0.636	1.283	1.444	1.141452	2.94%
124	2011-12	Fluid Tests - Repeatibility	IP Mod	EG 106 (100)	8	20	30-Jan-12	5:15	5:19	-9.8	-3.5	-11.5	IP: 75	25	2.4, 2.4, 3.8	1, 1.1, 1.2	1, 1, 1	0.657	1.298	1.461	1.152297	1.83%
125	2011-12	Fluid Tests - Repeatibility	IP Mod	EG 106 (100)	18	20	30-Jan-12	5:35	6:12	-10.4	-4.1	-11.2	IP: 75	25	2, 2, 3.8	1, 1, 1.1	1, 1, 1	0.659	1.317	1.463	1.157082	1.69%
126	2011-12	Clean Wing	None	none	stall	20	30-Jan-12	N/A	N/A	-11	-10	N/A	-	-	N/A	N/A	N/A	0.697	1.342	1.474	1.176099	0.97%
127	2011-12	Clean Wing	None	none	stall	20	30-Jan-12	N/A	N/A	-11	-10	N/A	-	-	N/A	N/A	N/A	0.718	1.343	1.500	1.188891	-0.79%
128	2011-12	Windshield Washer Fluid	Fluid Only	Costco Green WWF	8	20	30-Jan-12	-	23:07	-9.7	-4.8	-3.1	-	-	1,1,1	1,1,1	1,1,1	0.715	1.350	1.486	1.185672	0.17%
129	2011-12	Windshield Washer Fluid	Fluid Only	Rain X WWF	8	20	30-Jan-12	-	23:47	-10.2	-4.4	-4	-	-	1,1,1	1,1,1	1,1,1	0.713	1.333	1.483	1.182709	0.35%
130	2011-12	Windshield Washer Fluid	Fluid Only	Octaflo EF	8	20	31-Jan-12	-	0:42	-10.6	-4.7	-2.8	-	-	1,1,1	1,1,1	1,1,1	0.692	1.323	1.466	1.173857	1.49%
131	2011-12	Windshield Washer Fluid	Frost	Costco Green WWF	8	20	31-Jan-12	1:11	1:45	-10.8	-5.4	-5.1	Frost: 0.3	22.5	3, 4, 5	5, 5, 5	5, 5, 5	0.705	1.330	1.470	1.17122	1.19%
132	2011-12	Windshield Washer Fluid	Frost	Rain X WWF	8	20	31-Jan-12	2:13	2:48	-10.6	-6.8	-6.4	Frost: 0.3	22.5	5, 5, 5	5, 5, 5	5, 5, 5	0.703	1.338	1.468	1.171489	1.34%

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation 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)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
133	2011-12	Windshield Washer Fluid	Frost	Octaflo EF	8	20	31-Jan-12	3:12	3:48	-10.5	-6.2	-4.7	Frost: 0.3	22.5	N/A	N/A	N/A	0.694	1.316	1.472	1.167721	1.08%
134	2011-12	Other Fluid Tests: Frost Spot Deicing	Frost	Octaflo EF	8	20	31-Jan-12	4:09	4:14	-10.4	-5.5	N/A	-	-	N/A	N/A	N/A	0.705	1.322	1.472	1.17582	1.07%
135	2011-12	Windshield Washer Fluid	Fluid Only	Prestone	8	20	31-Jan-12	-	4:43	-10.3	-6.1	-3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.694	1.334	1.476	1.176478	0.82%
136	2011-12	Windshield Washer Fluid	Frost	Prestone	8	20	31-Jan-12	5:05	5:44	-10.2	-5	-3.9	Frost: 0.3	45	1, 1, 1	1, 1, 1	1, 1, 1	0.703	1.346	1.482	1.177596	0.37%
137	2011-12	Windshield Washer Fluid	Fluid Only	Hot Water	8	20	31-Jan-12	-	6:14	-10	-3.6	-3.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.709	1.337	1.479	1.179743	0.58%
138	2011-12	Windshield Washer Fluid	Frost	Hot Water	8	20	31-Jan-12	6:28	6:57	-9.7	-2.8	-1.2	Frost: 0.3	45	1, 1, 1,	1, 5, 5	1, 5, 5	0.714	1.335	1.485	1.178964	0.18%
139	2011-12	Clean Wing	None	none	stall	20	31-Jan-12	-	-	-9.6	-5.3	-	-	-	-	-	-	-	-	1.477	-	0.75%
140	2011-12	Clean Wing	None	none	stall	20	31-Jan-12	-	-	-7.7	-0.2	-	-	-	-	-	-	-	-	1.495	-	-0.44%
141	2011-12	Clean Wing	None	none	8	20	31-Jan-12	-	-	-7.7	0.1	-	-	-	-	-	-	-	-	1.491	-	-0.23%
142	2011-12	Clean Wing	None	none	stall	20	31-Jan-12	-	-	-7.7	0.1	-	-	-	-	-	-	-	-	1.488	-	-0.01%
143	2011-12	Clean Wing	None	none	8	20	31-Jan-12	-	-	-7.6	-3.9	-	-	-	-	-	-	-	-	1.469	-	1.30%
144	2011-12	Clean Wing	None	none	stall	20	31-Jan-12	-	-	-7.6	-3.9	-	-	-	-	-	-	-	-	1.489	-	-0.09%
145	2011-12	Clean Wing	None	none	8	20	31-Jan-12	-	-	-7.7	-5.1	-	-	-	-	-	-	-	-	1.485	-	0.21%
146	2011-12	Clean Wing	None	none	stall	20	31-Jan-12	-	-	-7.7	-5.1	-	-	-	-	-	-	-	-	1.501	-	-0.89%
147	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	31-Jan-12	-	23:41	-7.6	-3.6	-3.9	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.620	1.276	1.426	1.147261	4.14%
148	2011-12	Fluid Tests - Repeatibility (under-wing not squeegeed)	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	0:07	-7.5	-3.2	-3.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.607	1.265	1.411	1.143607	5.16%
149	2011-12	Fluid Tests - Repeatibility (under-wing not squeegeed)	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	0:35	-7.4	-3.2	-4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.606	1.259	1.411	1.140752	5.16%

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0°, 20°)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	AVG Wing Temp. Before Test (°C)	Precipiation 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)	CL at -2° Before Rotation	CL at 6° During Rotation	CL at 8°	CL at 4° Following End of Rotation	% Lift Loss (8° CL vs. Dry CL)
150	2011-12	Fluid Tests - Repeatibility (under-wing not squeegeed)	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	0:59	-7.4	-3	-3.5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.589	1.258	1.406	1.140586	5.48%
151	2011-12	Fluid Tests - Repeatibility (under-wing not squeegeed)	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	1:31	-7.3	-1.9	-3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.583	1.251	1.406	1.131125	5.53%
152	2011-12	Fluid Tests - Repeatibility (under-wing not squeegeed)	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	1:56	-7.2	-2.9	-3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.583	1.248	1.394	1.127261	6.31%
153	2011-12	Clean Wing	None	none	8	20	1-Feb-12	-	-	-7.3	-3.5		-	-	-	-	-	-	-	1.491	-	-0.22%
154	2011-12	Clean Wing	None	none	stall	20	1-Feb-12	-	-	-7.3	-3.5		-	-	-	-	-	-	-	1.487	-	0.10%
155	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	N/A	-7.3	-2.3	-3.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.620	1.271	1.420	1.145659	4.59%
156	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	3:28	-7.2	-2.1	-3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.615	1.276	1.414	1.145837	4.96%
157	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	4:01	-7	-2.4	-2.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.619	1.259	1.419	1.145506	4.62%
158	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	4:27	-7	-2.2	-3.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.614	1.257	1.417	1.145295	4.77%
159	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	4:59	-6.9	-1.7	-2.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.613	1.269	1.418	1.145416	4.68%
160	2011-12	Fluid Tests - Repeatibility	Fluid Only	ABC-S Plus (100)	8	20	1-Feb-12	-	5:31	-6.8	-1.7	-2.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.620	1.276	1.418	1.145772	4.73%
161	2011-12	Clean Wing	None	none	8	20	1-Feb-12			-6.8	-2.3		-	-	-	-	-	-	-	1.494	-	-0.43%
162	2011-12	Clean Wing	None	none	stall	20	1-Feb-12			-6.8	-2.3		-	-	-	-	-	-	-	1.496	-	-0.57%
163	2011-12	Clean Wing	None	none	stall	20	1-Feb-12			-3.3	-1.5		-	-	-	-	-	-	-	1.505	-	-1.15%
164	2011-12	Clean Wing	None	none	8	20	1-Feb-12			-3.3	-1.5		-	-	-	-	-	-	-	1.497	-	-0.63%
165	2011-12	TC R&D - S- & S--	S--	ABC-S Plus (50)	8	20	1-Feb-12	23:37	23:59	-4.1	-2	-1.7	SN: 3	72	1.8, 1.8, 3.8	1, 1.3, 2.5	1, 1, 2.2	0.677	1.328	1.466	1.173243	1.45%
166	2011-12	TC R&D - S- & S--	Mod S (Baseline)	ABC-S Plus (50)	8	20	1-Feb-12	0:22	0:51	-4.4	-2.3	-4.8	SN: 25	25	2.5, 2.8, 4.2	1, 1.7, 2.5	1, 1, 1.3	0.675	1.327	1.458	1.169201	2.02%

Table 3.1: Wind Tunnel Test Log 2011-12 (cont'd)

Run #	Year	Objective	Test Condition	Fluid	Rotation Angle	Flap Angle (0º, 20º)	Date	Precip. End Time	Tunnel Start Time	OAT Before Test (ºC)	Tunnel Temp. Before Test (ºC)	AVG Wing Temp. Before Test (ºC)	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)	CL at -2º Before Rotation	CL at 6º During Rotation	CL at 8º	CL at 4º Following End of Rotation	% Lift Loss (8º CL vs. Dry CL)
167	2011-12	TC R&D - S- & S--	Fluid Only (Baseline)	ABC-S Plus (50)	8	20	2-Feb-12	1:13	1:25	-4.6	-2.3	-1.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.675	1.327	1.460	1.169201	1.91%
168	2011-12	Fluid Tests - Repeatibility	IP Mod	ABC-S Plus (100)	8	20	2-Feb-12	2:29	2:33	-5.5	-2.6	-7.6	IP: 75	10	2, 2, 2.4	1, 1.4, 1.4	1, 1, 1	0.603	1.280	1.415	1.158222	4.92%
169	2011-12	Fluid Tests - Repeatibility	IP Mod	ABC-S Plus (100)	8	20	2-Feb-12	2:55	3:17	-6.2	-2.9	-7.8	IP: 75	10	2, 2, 2.8	1, 1.3, 1.3	1, 1, 1	0.603	1.245	1.403	1.158356	5.70%
170	2011-12	Fluid Tests - Repeatibility	IP Mod	ABC-S Plus (100)	8	20	2-Feb-12	3:40	4:03	-6.1	-3.8	-8.4	IP: 75	10	2, 2, 2.3	1, 1.5, 1.8	1, 1, 1	0.601	1.259	1.404	1.156352	5.66%
171	2011-12	Fluid Tests - Repeatibility	IP Mod	ABC-S Plus (100)	8	20	2-Feb-12	4:40	4:45	-6.2	-3.7	-8.5	IP: 75	10	2, 2, 2.4	1, 1.5, 1.5	1, 1, 1	-	-	1.404	-	5.65%
172	2011-12	Fluid Tests - Repeatibility	IP Mod	ABC-S Plus (100)	8	20	2-Feb-12	-	-	-6.4	-3.4	-	IP: 75	10	-	-	-	-	-	1.399	-	5.97%
173	2011-12	Clean Wing	None	none	8	20	2-Feb-12	-	-	-5.7	-3.4	-	-	-	-	-	-	-	-	1.495	-	-0.48%
174	2011-12	Clean Wing	None	none	stall	20	2-Feb-12	-	-	-5.7	-3.4	-	-	-	-	-	-	-	-	1.500	-	-0.79%
175	2011-12	Clean Wing	None	none	stall	20	2-Feb-12	-	-	-8.2	-6	-	-	-	-	-	-	-	-	1.494	-	-0.38%
176	2011-12	Clean Wing	None	none	8	20	2-Feb-12	-	-	-8.2	-6	-	-	-	-	-	-	-	-	1.499	-	-0.71%
177	2011-12	Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	2-Feb-12	-	22:33	-8	-5	-5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.623	1.262	1.422	1.147726	4.44%
178	2011-12	Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	2-Feb-12	-	23:02	-8.6	-8	-4.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.611	1.273	1.406	1.145226	5.48%
179	2011-12	Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	2-Feb-12	-	0:01	-10.1	-5.6	-4.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.611	1.259	1.415	1.145434	4.88%
180	2011-12	Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	2-Feb-12	-	0:57	-10.8	-5.4	-4.9	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.605	1.259	1.410	1.144216	5.23%
181	2011-12	Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	2-Feb-12	-	1:24	-11.2	-7.7	-6.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.609	1.261	1.410	1.144446	5.21%
182	2011-12	Fluid Tests - Repeatibility	Fluid Only	Launch (100)	8	20	2-Feb-12	-	1:54	-11.4	-6.8	-6.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	0.605	1.269	1.406	1.144885	5.53%
183	2011-12	Heavy Contamination (Armageddon)	IP+	Launch (100)	18	20	2-Feb-12	2:14	2:51	-12.1	-6.3	-11.5	IP: 260	20	4,4,4	1, 2, 2.3	1, 1.4, 1.4	0.530	1.208	1.357	1.152448	8.79%
184	2011-12	Clean Wing	None	none	8	20	2-Feb-12	-	-	-12.1	-6.7	-	-	-	-	-	-	-	-	1.495	-	-0.44%
185	2011-12	Clean Wing	None	none	stall	20	2-Feb-12	-	-	-12.1	-6.7	-	-	-	-	-	-	-	-	1.490	-	-0.12%

4. ANALYSIS METHODOLOGY

This section provides an overview of the typical analysis methodology used to evaluate the fluid flow-off wind tunnel tests conducted. Due to the large amount of data collected during each test, a methodology was developed in order to facilitate the analysis process.

NOTE: A significant portion of the dry wing calibration and characterization tests required specific analysis techniques that are not included in this section. Details on these specific analysis techniques are included in Sections 5 to 7.

4.1 Visual Contamination Ratings

The wind tunnel was equipped with observation windows overlooking the wing section. During each of the tests conducted, visual contamination ratings were determined by three observers: one observer from the FAA and two observers from APS. The level of contamination present on the leading edge and trailing edge of the wing, as well as on the flap, was quantified using a scale of one-to-five with five being the worst case scenario; partial numbers were sometimes assigned when cases were also marginally above or below a specific rating. These observations were taken three times during each test: at the start of the test (just prior to the wind tunnel ramp-up), at the time of rotation, and at the end of the test. The values assigned by the three observers were then averaged and used for comparative analysis. The following is a description of the rating system used:

Visual Contamination Ratings (1 to 5):

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

It should be noted that the visual contamination ratings were subjective due to the various conditions tested; it was not feasible to develop rating descriptions that were applicable to all conditions. The descriptions were primarily used as an aid for determining the numerical visual contamination rating. Having the same three observers for all the tests provided a level of consistency in the rating system, which allowed for a more accurate comparison system.

The visual contamination ratings were evaluated based on pre-determined criteria; less than or equal to 3 on the leading and trailing edge, less than or equal to 4 on the flap at the start of the test, and equal to 1 on the leading edge at the time of rotation were considered acceptable. Ratings higher than these indicated potential fluid contamination or fluid flow-off issues; these results were supported by the lift coefficient data collected.

4.2 Lift Coefficient Data

The NRC collected various parameters during each of the wind tunnel test runs. The data was collected at a rate of 250 samples per second. Parameters such as lift force, normal force, drag force, wind speed, and pitch angle were collected and used to calculate the lift, normal, and drag coefficients. For the purpose of the tests conducted, the lift coefficient was primarily used as the evaluation criteria when analysing the fluid flow-off performance during the tests. The calculated lift coefficient at an 8-degree rotation angle was typically evaluated against the dry wing average data. Lift losses below 5.4 percent compared to the dry wing were considered acceptable, lift losses between 5.4 percent and 9.2 percent were considered marginal, and lift losses greater than 9.2 percent were considered severe.

The lift coefficient data is a normalized measure of lift and is not a function of airspeed. As a result, the lift generated during a dry wing scenario for a low-speed and high-speed test run should generate similar lift profiles. During the fluid tests, variations in airspeed could potentially cause variations in the data collected; the fluid shearing is a function of the airspeed, and this would be demonstrated in the data. Therefore, when comparing lift coefficient data under similar conditions, differences as a result of airspeed would only be apparent during the fluid cases and not the dry wing cases.

4.2.1 Sequence of When Test Parameters Were Recorded

Figure 4.1 demonstrates the lift coefficient data collected during an example test run. The x-axis shows the time in seconds as of the start of the test; rotation begins at approximately 28 seconds, the wing rotates to a maximum angle of 8 degrees in approximately 3.7 seconds, and then it is rotated back to 4 degrees over a period of approximately 16 seconds. The y-axis indicates the calculated lift coefficient. The visual observations of the condition of the wing were recorded at the start of the test (time = 0), just before the start of rotation (time = 28 sec.), at the end of the rotation (time = 32 sec.), and at the end of the test (time = 60 sec.). The lift coefficient data used to calculate lift losses compared to the baseline test (typically, the dry wing case) was measured at the 8° angle of rotation.

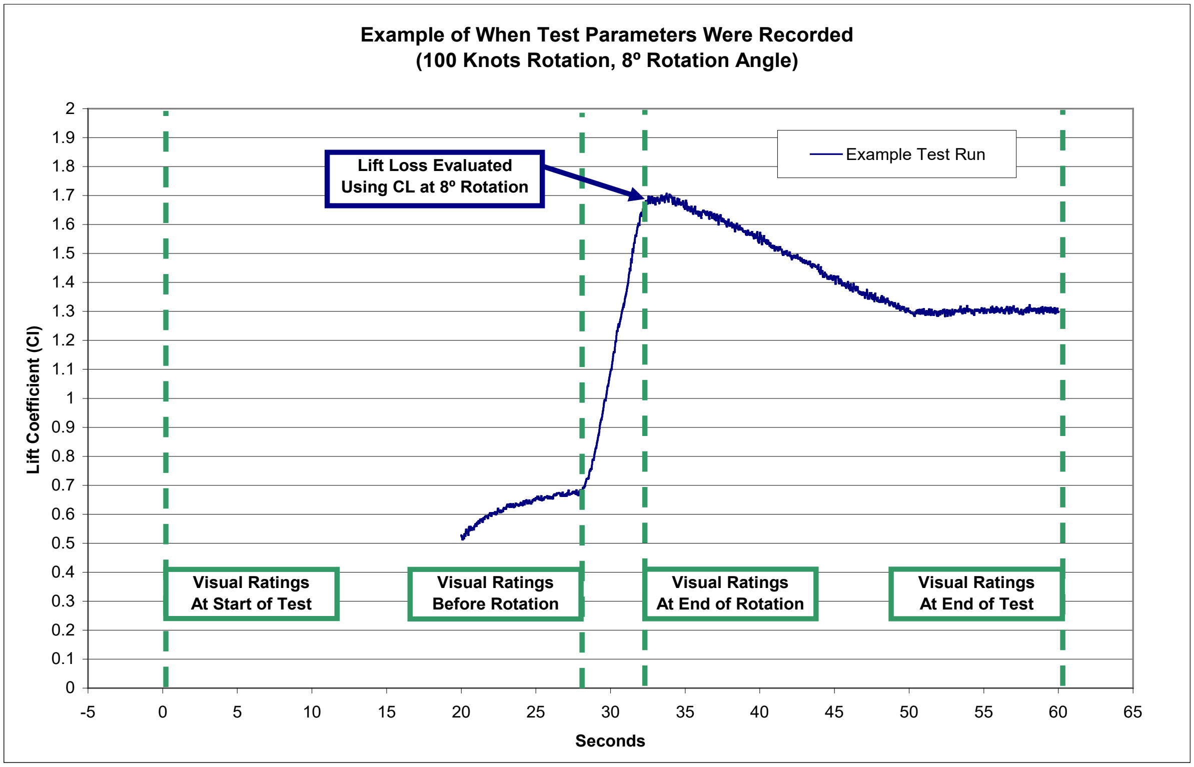

Figure 4.1: Example of When Test Parameters Were Recorded

4.3 Analysis Summary Worksheets

Due to the large amount of data to be processed for each of the tests conducted, analysis worksheets were developed and completed for each of the tests to provide a summary regarding the status of each test. Figure 4.2 demonstrates a typical worksheet. Each worksheet comprised eleven rows: the first three rows indicated the test objective, fluid, and test number, and the next eight rows evaluated the status of the tunnel temperature before the start of the test, rate of precipitation, exposure time of precipitation, associated fluid only case, visual contamination ratings at the start of the test and time of rotation, calculated lift coefficient at 6 and 8 degree rotation, the calculated lift loss at 8 degree rotation, and finally an overall status summarizing the test. The evaluation grades included "very good," "good," "good/review," "fair," and "bad," and they were determined based on whether the criteria satisfied the test objective requirements or not. In the case of the Tunnel Temperature before the start of the test, Rate, and Exposure Time; these parameters were compared against the target parameters determined from the test plan (i.e., a colder temperature than the target would constitute a more conservative test and was therefore "good," whereas a warmer temperature would be considered "fair" or "bad"). The visual contamination ratings were evaluated based on pre-determined criteria; less than or equal to 3 on the leading and trailing edge and less than or equal to 4 on the flap at the start of the test were considered "good" or "very good"; equal to 1 on the leading edge at the time of rotation was also considered "good" or "very good" (greater than 1 to 1.5 on the leading edge was considered "review"). The calculated life coefficient at the 8 degree rotation angle was evaluated against the corresponding lift loss cut-off of <5.4%, 5.4% to 9.2%, and >9.2% (as described in Subsection 4.2). The overall status provided a summary of the test and indicated whether or not the test objective was met with successful results. It should be note that summary sheets were not completed for the testing conducted during the winter of 2011-12 as they were not necessary for the analysis of the test objectives.

Objective	TYPE IV FLUID VAL
Fluid Name	EG106
Test # / Test Plan #	RUN 51 (P23A)
Tunnel OAT (°C)	Target: −25°C Actual: −11.1°C
Rate (g/dm²/hr)	IP= 25 ✓
Exposure Time	30 min ✓
Rotation Angle	8° ✓
Flap Setting (20°, 0°) / SPEED (KTS)	20° / 100 KTS ✓
Ramp-up Time (40 kts to Rotation)	19 sec GOOD
Associated Fluid Only Case	
Visual Contamination Rating	START: 2.2 / 2 / 2.8 GOOD ROT: 1 / 1.2 / 1.3 GOOD
Lift Coefficient	6°: 1.219 8°: 1.379
Lift Loss At 8°	1.6% GOOD
OVERALL STATUS (Good, Bad, or Review)	GOOD

NOTE: For the purpose of the worksheets, OAT refers to the Tunnel Temperature Before the start of the test.

Figure 4.2: Typical Worksheet Used for Analysis

4.4 Ice Pellet Summary Worksheet Analysis Criteria

As described in Subsection 4.3, analysis worksheets were developed and completed for all ice pellet tests conducted.

Each ice pellet test was 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° 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 4.3 shows a summary of each test objective and criteria.

4.4.1 Test Parameters

Several test parameters were evaluated, such as tunnel temperature before the start of the test, rate of precipitation, and exposure time of precipitation. These parameters were compared against the target parameters described in the test plan. The ramp-up time was also evaluated and compared to the target ramp-up time determined.

4.4.2 Visual Ratings at the Start of the Test

The visual contamination rating criteria at the start of the test on both the leading and trailing edge must be equal to or less than 3 in order to pass. The flap must have a rating of 4 or less. For a review grade to be given, the leading and trailing edge must have a rating between 3 and 3.5, and the flap must have a rating between 4 and 4.5. Any rating greater than 3.5 on the leading and trailing edge is considered a fail, while anything greater than 4.5 on the flap is a fail.

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 4.3: Ice Pellet Test Analysis Criteria

4.4.3 Visual Ratings at Rotation

The visual contamination rating criteria at the time of rotation on the leading edge must be equal to or less than 1 in order to pass. For a review grade to be given, the leading edge must have a rating between 1 and 1.5. Any rating on the leading edge greater than 1.5 is considered a fail.

4.4.4 Eight Degree Lift Loss

Subsection 4.2 outlines how the lift loss criteria at the 8° rotation was determined. For a pass, the lift loss must be less than 5.4 percent. A review grade was given should the lift loss be between 5.4 percent and 9.2 percent. Any lift loss greater than 9.2 percent is considered a fail.

4.4.5 Overall Test Status

After all objectives were analysed, an overall status was given a “good,” “review,” or “bad.” This provided an overall summary for each test. The overall status was determined by the worst case scenario from any of the test objectives; if any of the criteria were given a “bad” grade, the overall status would be bad and the test is considered a fail.

4.5 Comparison of Test Methodologies

4.5.1 Methodology Used for 2006-07 vs. 2008-09

During the 2008-09 testing, lift data collected from the NRC was monitored in real-time and was provided to APS at the end of each test run. This allowed TC, the FAA, and APS personnel to better assess and modify the test plan according to the results obtained. During the 2006-07 testing, data was only made available at the very end of the testing period; therefore, lift data was only used to confirm the visual observations and was not efficiently used as a decision-making tool for planning during the testing.

As a result of the availability of real-time lift data, a more structured approach was employed during the 2008-09 testing that encompassed the critical aspects of the data collected. Marginal tests were more easily identified and were dealt with accordingly following the end of the test (in some cases, marginal tests were re-run or modified in order to be able to satisfy test objectives). Compared to the 2006-07 testing, the analysis was ultimately based on the same type of evaluation criteria (visual and lift data); however, the 2008-09 methodology had a more conservative analysis approach as a result of the real-time data provided by the NRC.

4.5.2 Methodology Used for 2009-10 vs. 2008-09

During the 2009-10 testing, the lift data collected by the NRC was provided to APS at the end of each test run, and as in 2008-09, testing was monitored in real-time. Due to some software upgrades, preliminary analysis was done following each test run during the winter of 2009-10, which provided guidance when modifying the test plan on-site. The analysis methodology and criteria used to evaluate each test during the winter of 2009-10 were essentially the same as those used during the winter of 2008-09.

4.5.3 Methodology Used for 2010-11 vs. 2009-10

During the 2010-11 testing, the test methodology was the same as 2009-10; however, some upgrades in measurement equipment and software were made by the NRC. The result was aerodynamic data that was corrected for 2D and 3D effects and various tunnel effects. An effort was also made to reprocess the previous year's databased on the new software upgrades to have a consistent two-year data set. The analysis methodology and criteria used to evaluate each test during the winter of 2010-11 was essentially the same as was used during the winter of 2009-10; however, the lift coefficient evaluation criteria was further refined.

4.5.4 Methodology Used for 2011-12 vs. 2010-11

During the 2011-12 testing, the typical testing and analysis methodology remained the same as the 2010-11 methodology. It should be noted, however, that a significant portion of the calibration and characterization testing required non-typical test procedures, which required specific analysis methodologies based on the testing objective. These specific analysis methodologies are described in Sections 5 to 7.

5. WIND TUNNEL FACILITY CALIBRATION

This section describes the work conducted and led by the NRC to verify the calibration of the wind tunnel facility. This work was not completely specific to the wing model tested; some testing was done with an empty wind tunnel.

5.1 Testing Overview

During the recent years of ice pellet allowance time testing, the PIWT has undergone several upgrades in order to improve safety, repeatability, and quality of data produced. Improvements have included a new gantry system, larger end plates to reduce 3D effects, load cells with greater capacity, and new data reduction algorithms that correct for 2D model testing effects.

The objective of the testing conducted by the NRC during the winter of 2011-12 was to verify the calibration and characterization of the PIWT to provide an indication of the reliability and integrity of the results being produced. To do so, the NRC conducted tests and analysis, which are briefly described below:

- Empty Tunnel Calibration
  - Correlate the test section velocity to the contraction pressure change using a pitot static probe.
- Wing Balance Load Cell Verification
  - Load cells individually calibrated and then load using the ceiling crane.
- Angle of Attack Measurements
  - Wing pitch set using inclinometer and correlated to potentiometer on gearbox.
- Data Reduction Sequence
  - Verify integrity of the data correction and reduction procedures and the algorithm used to correct for solid blockage, wake blockage, and streamline curvature.
- Uncertainty Analysis
  - Evaluate the uncertainty due to equipment errors.
- Analysis of year-to-year and dry wing repeatability
  - Evaluate the consistency in results produced.

5.2 Summary of Test Results

As reported by the NRC, the year-to-year equipment and facility upgrades have improved the integrity of the aerodynamic data produced, and the wind tunnel can closely simulate aircraft takeoff profiles. Taking into account equipment error resulting from installation fine-tuning, year-to-year tests show good repeatability in lift coefficient data and stall behaviour. The combined uncertainty and repeatability of C_L at $\alpha=8°$ is $\pm1\%$ (equivalent of $\pm1\%$ in lift loss for fluid tests).

5.3 Documentation of Test Results

The work described in Section 5 was presented by the NRC to the G-12 Aerodynamics Working Group (AWG) during the Prague SAE G-12 meeting in May 2012. A copy of the presentation has not been included in this report; however, a full detailed and finalized report is being prepared and will be published by the NRC on this subject.

6. DRY WING CALIBRATION AND CHARACTERIZATION

This section describes the work led by NASA and supported by the NRC and APS to verify the calibration and characterization of the thin high-performance wing section. This testing was done without the use of de/anti-icing fluid. The results of this work are specific to the wing model tested and may not be representative of different model types. Additional testing with fluids was also conducted and is described in Section 7.

6.1 Testing Overview

The NASA-led research aimed at systematically subjecting the wing section to various conditions to better understand the performance characteristics and to increase confidence in the repeatability and accuracy of the results obtained. This was achieved through the following testing objectives, which are described in greater detail in Sections 6.1.1 to 6.1.6:

- Survey of Clean Wing Performance;
- Oil Flow Visualization;
- Tufts Flow Visualization;
- Boundary Layer Rake Test;
- Sandpaper Roughness Tests; and
- Larger End Plates.

Details of the procedures used to conduct these tests can be found in Appendix B.

6.1.1 Survey of Clean Wing Performance

Testing was conducted to verify the clean wing performance and to investigate the integrity and sensitivity of the data provided from the force balances supporting the wing. This was done through pitch pause test runs whereby, at a constant airspeed, the wing was incrementally rotated to higher pitch angles and held for a few seconds; this was done to obtain lift data at static angles of attack. Dynamic Angle sweep tests were also conducted where, at a constant speed, the wing was dynamically rotated, simulating a takeoff. Both the pitch pause and angle sweep tests were performed at the stall angle as well as at the typical 8 degree rotation angle used for the ice pellet allowance time testing. The differences in results and the repeatability of the tests were analysed and compared. Photo 6.1 demonstrates the dry wing section during these tests.

6.1.2 Oil Flow Visualization

The objective of these tests was to document the oil flow patterns on the surface of the wing when set to a fixed angle of attack, with the intent of identifying potential aerodynamic anomalies, such as span-wise variation in flow and boundary layer separation, and to help characterize the stall type. To do so, the wing was covered with a protective plastic sheet, and an oil powdered carbon mixture was thinly applied to the surface of the wing using a paint roller. As the airspeed increased, the oil/carbon mixture would begin to flow and eventually reach a steady state, at which point the test was stopped and the wing was inspected. Each different angle of attack test required a fresh application of oil/carbon. Testing was done up to the stall angle. Photo 6.2 demonstrates the oil flow pattern at the end of one of the tests conducted.

6.1.3 Tufts Flow Visualization

The tufts flow visualization tests were complementary to the oil flow visualization tests in that they provided a more dynamic indication of potential anomalies because the testing could be done with angle sweeps rather than at fixed angles of attack. To do so, a special tape with fabric tufts was applied span-wise on the wing section at intervals along the chord and on the flap. In the laminar airflow, the tufts would line up straight; however, once a boundary layer separation occurred during rotation, the tufts would begin to erratically spin on the surface. Photo 6.3 demonstrates the tufts in laminar airflow.

6.1.4 Boundary Layer Rake

A boundary layer rake was installed towards the end of the tufts flow visualization tests. The purpose of these tests was to help identify the boundary layer separation on the trailing edge section of the main wing section and on the flap. The boundary layer rake was fastened to the wing section using speed-tape and was re-positioned in different locations along the span of the trailing edge and flap. Testing was done during both angle sweeps and fixed pitch testing. Photo 6.4 shows the boundary layer rake installed mid-span on the trailing edge of the wing.

6.1.5 Sandpaper Roughness Tests

The objective of these tests was to determine the wing sensitivity to different levels of roughness simulating frost and to better understand how roughness relates to fluid flow-off. To do so, different grades of sandpaper were used (150, 40, and 80 grit) to simulate various levels of contamination. These tests were done with the full wing and flap covered in sandpaper, and then the sand paper was removed in incremental configurations starting from the leading edge simulating fluid flow-off. Photo 6.5 shows the different sand paper configurations tested.

6.1.6 Larger End Plate Tests

The objective of these tests was to determine if larger end plates would reduce the 3D surface flow effects and result in less span-wise variation. To do so, a subset of the tests described in Sections 6.1.1 to 6.1.5 were repeated with the larger end plates and compared to the results with the smaller end plates. A similar comparative method was done with anti-icing fluids and is described in Section 7. Photo 6.6 shows the larger end plate wing setup.

6.2 Summary of Test Results

As reported by NASA, the flow visualization confirmed 2D, leading edge type stall on the clean wing with original end plates installed. The effect of leading edge roughness and simulated frost on overall lift was significant but expected, and it is comparable to archival data sets. The aerodynamic effects of fluids and contamination were similar to various chord-wise coverage of simulated frost. The tests conducted with large end plates indicated potential for asymmetric stalling characteristics due to sidewall separation; however, further tests with large end plates are not recommended due to procedural limitations. The characterization of the current dry wing model with original end plates demonstrated appropriate aerodynamic behaviour.

6.3 Documentation of Test Results

The work described in Section 6 was presented by NASA to the AWG during the Prague SAE G-12 meeting in May 2012. A copy of the presentation has not been included in this report; however, a full detailed and finalized report is being prepared and will be published by NASA on this subject.

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Photo 6.1: Survey of Clean Wing Performance

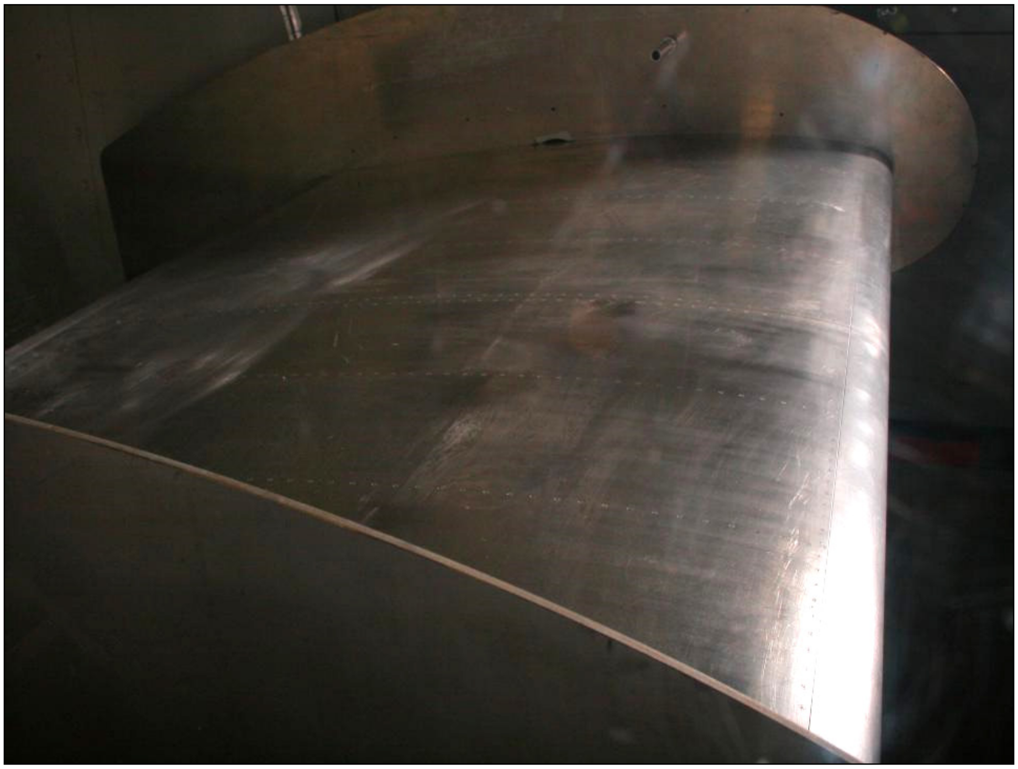


Photo 6.2: Oil Flow Visualization Test

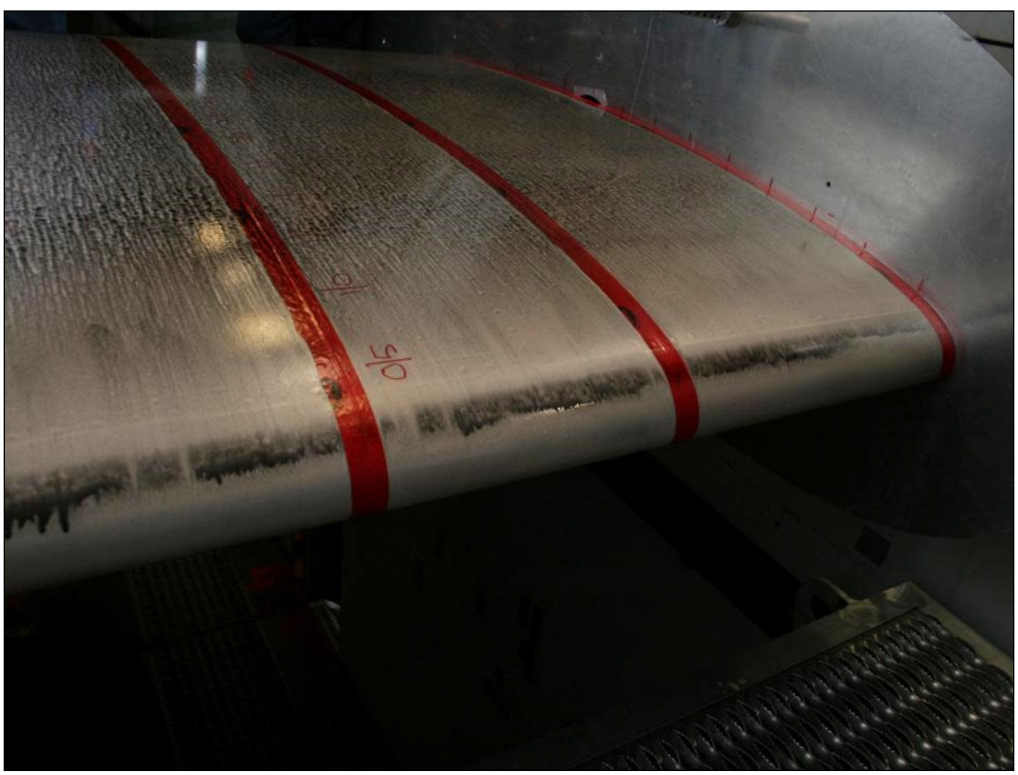
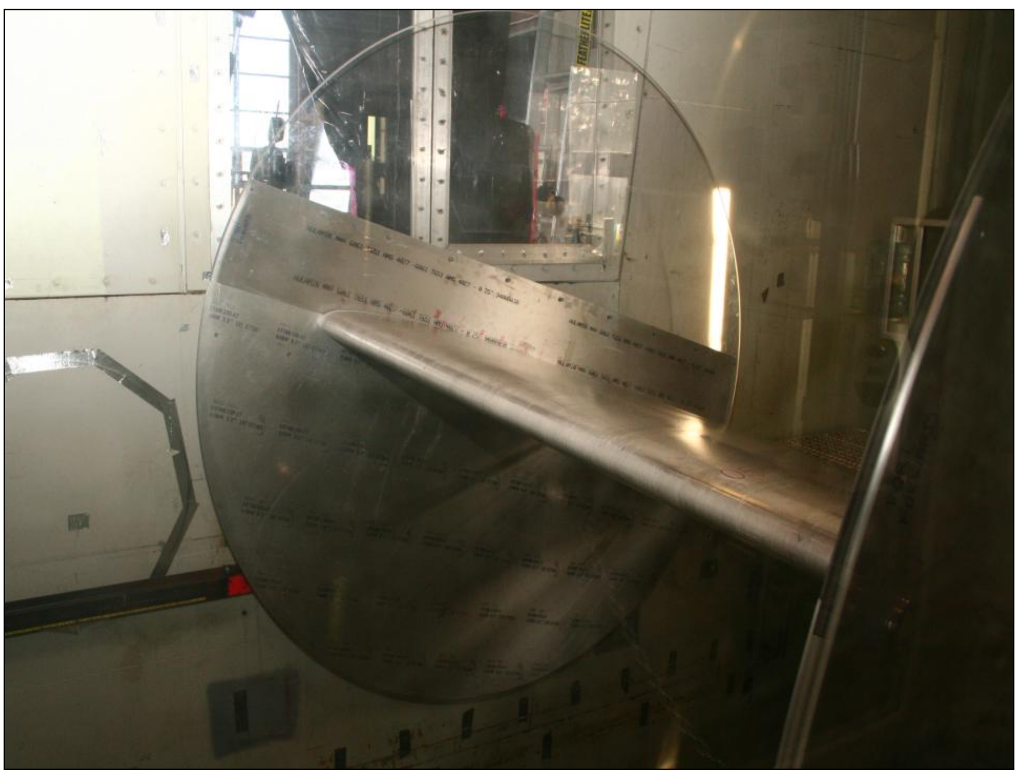


Photo 6.3: Tufts Flow Visualization

Photo 6.4: Boundary Layer Rake Tests

Photo 6.5: Sandpaper Roughness Tests

Photo 6.6: Larger End Plates



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7. FLUID AND CONTAMINATION TESTING - CALIBRATION AND CHARACTERIZATION

This section describes the work led by NASA and APS to verify the calibration and characterization of the thin high-performance wing section. This testing was done with the same anti-icing fluids typically used for the development of ice pellet allowance times. This results of this work are specific to the wing model tested and may not be representative of different model types.

7.1 Testing Overview

The NASA and APS-led research aimed at systematically subjecting the anti-iced wing section to various conditions to better understand the performance characteristics and to increase confidence in the repeatability and accuracy of the results obtained. This was achieved through the following testing objectives, which are described in greater detail in Sections 7.1.1 to 7.1.6:

- Repeatability of Fluid Only Tests;
- Repeatability of Fluid and Contamination Tests;
- Stall Tests with Clean and Contaminated Fluid; and
- Larger End Plates (Fluid Only Testing).

Details of the procedures used to conduct these tests can be found in Appendix B.

7.1.1 Repeatability of Fluid Only Tests

Testing was conducted to verify the repeatability of the data during the fluid only testing. These tests were done without contamination to minimize the elements that could potentially influence repeatability. As during typical ice pellet allowance time testing, the fluid temperature, thickness, and Brix measurements were monitored during the test, and batch viscosity samples were analysed to better understand the results and any potential influences on fluid flow-off. Back-to-back tests were conducted with the same fluid; each set of tests consisted of three to six sequential tests with the same fluid (some of which were rotated to stall). These results were also compared to the previous years fluid only testing results. Testing was conducted with two PG fluids and one ethylene glycol (EG) fluid in neat concentration. Photo 7.1 demonstrates the fluid flow-off during one of the tests conducted.

7.1.2 Repeatability of Fluid and Contamination Tests

This testing was conducted to verify the repeatability of the data during the fluid and contamination testing. During these tests, fluid was applied to the wing section, followed by a real-time exposure to simulated precipitation; moderate ice pellet conditions were selected due to their shorter allowance times. As during typical ice pellet allowance time testing, the fluid temperature, thickness, and Brix measurements were monitored during the test, and batch viscosity samples were analysed to better understand the results and any potential influences on fluid flow-off. Visual observations of the contamination levels and flow-off performance were also recorded. Back-to-back tests were conducted with the same fluid and same level of contamination; each set of tests consisted of three to six sequential tests with the same fluid (some of which were rotated to stall). These results were also compared to the previous years fluid and contamination testing results. Testing was conducted with two PG fluids and one EG fluid in neat concentration. Photo 7.2 demonstrates the fluid and contamination flow-off during one of the tests conducted.

7.1.3 Stall Tests with Clean and Contaminated Fluid

As part of the clean and contaminated fluid repeatability testing, an additional testing objective was to investigate the effects of stall. To do so, clean and contaminated fluid tests were rotated to stall (which typically occurred between 14 degrees and 18 degrees), and the flow-off and aerodynamic results were compared to typical 8-degree rotation runs. Videos recorded during these test runs better demonstrate the boundary layer separation and reversal of flow as compared to still photos; these videos are available upon request. Photo 7.3 demonstrates the fluid and contamination flow-off during a stall run when flow reversal occurred.

7.1.4 Large End Plate Tests (Fluid Only Testing)

As part of the clean and contaminated fluid repeatability testing, an additional testing objective was to investigate the effects of larger end plates. To do so, fluid only tests were conducted and were compared to the smaller end plate test results. Unfortunately, the size of the end plates limited the use of the scaffolding system, which was satisfactory for applying fluid but would not permit contamination testing to be conducted. In addition, the larger end plate limited the view of the wing section. Photo 7.4 demonstrates the fluid flow-off during a larger end plate test run with fluid only.

7.2 Summary of Test Results

The back-to-back fluid only runs demonstrated excellent repeatability of test methods, and this was reflected in the aerodynamic data collected. Variation in year-to-year fluid only test runs demonstrated some differences that can be attributed to differences in ramp-up time, temperature, and fluid viscosity. The additional variable of contamination generated slightly more variation in the test results; however, it is considered acceptable given the number of variables such as temperature, ramp-up time, fluid viscosity, and contamination.

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. Repeatability or integrity of data was not affected by the larger end plate configurations, but the lift loss measured at $\alpha = 8$ degrees was larger than for the smaller end plates. The scatter and dynamic nature of the stall tests demonstrated the difficulties with using 2D model stall data for evaluating allowance times.

7.3 Documentation of Test Results

The work described in Section 7 was presented by NASA to the AWG during the Prague SAE G-12 meeting in May 2012. A draft copy of the presentation is provided in Appendix D for documentation purposes; however, it may require corrections or have omissions. A full detailed and finalized report is being prepared and will be published by NASA on this subject.

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Photo 7.1: Fluid Only Repeatability Test

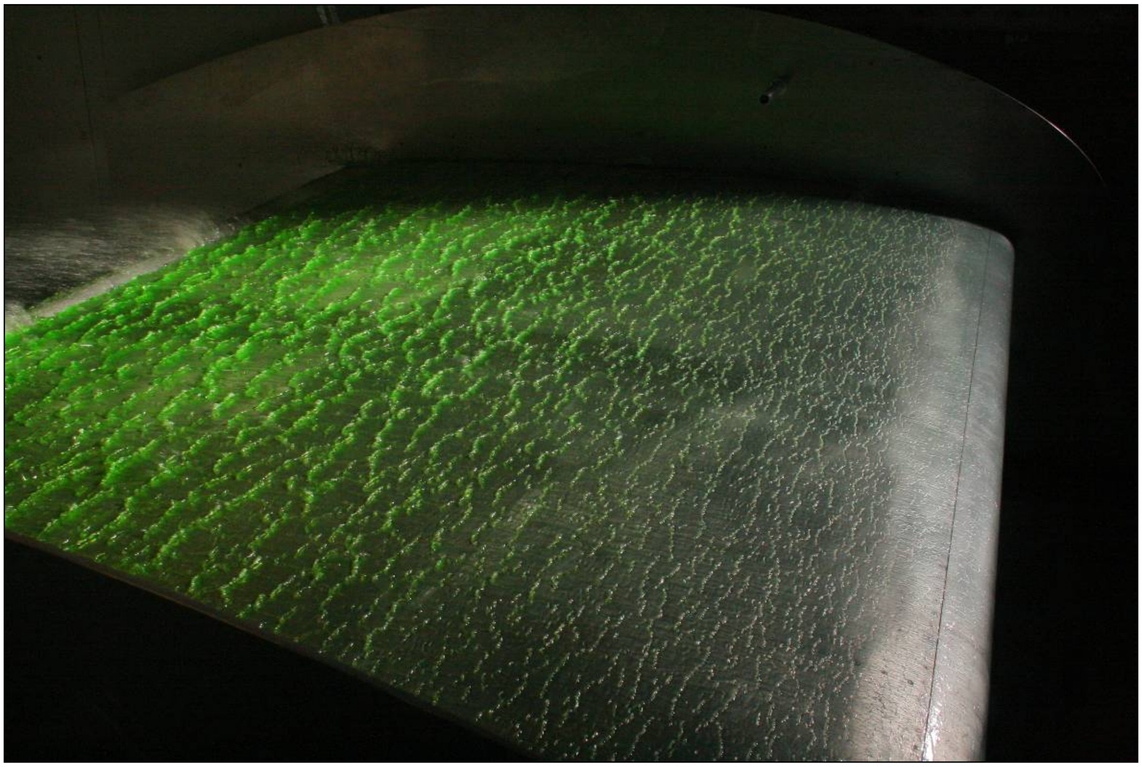


Photo 7.2: Fluid and Contamination Repeatability Test

Photo 7.3: Stall Test - Fluid Only

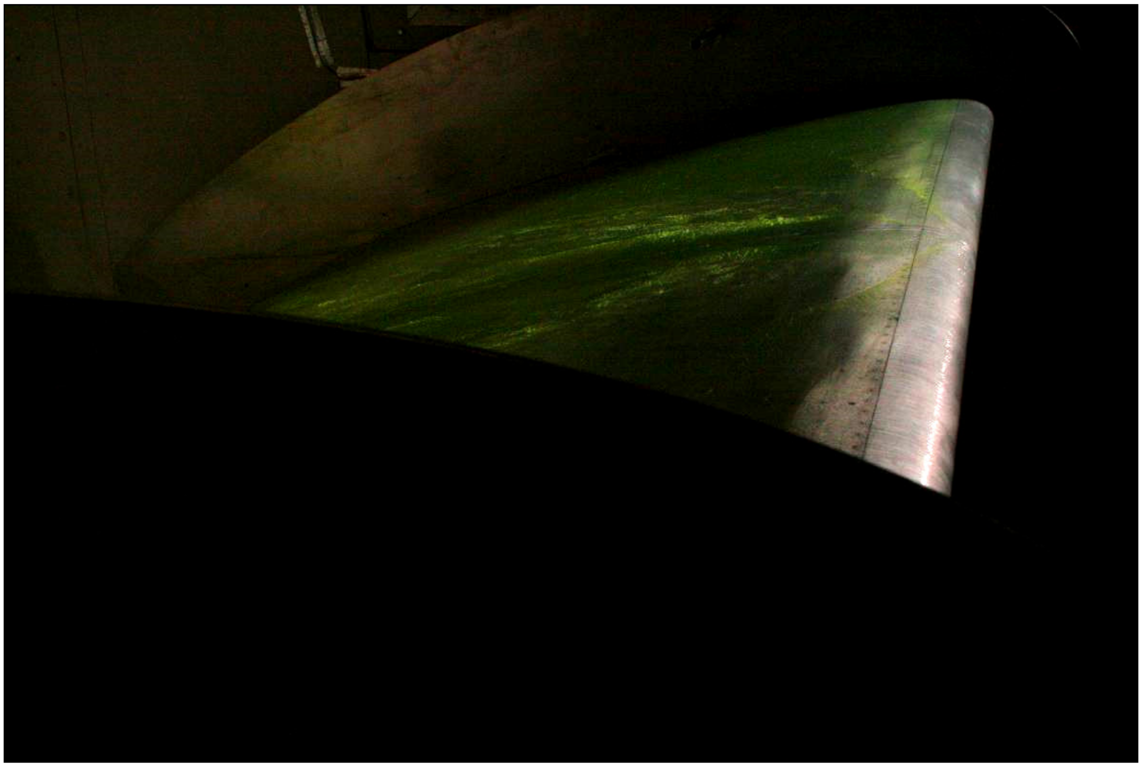
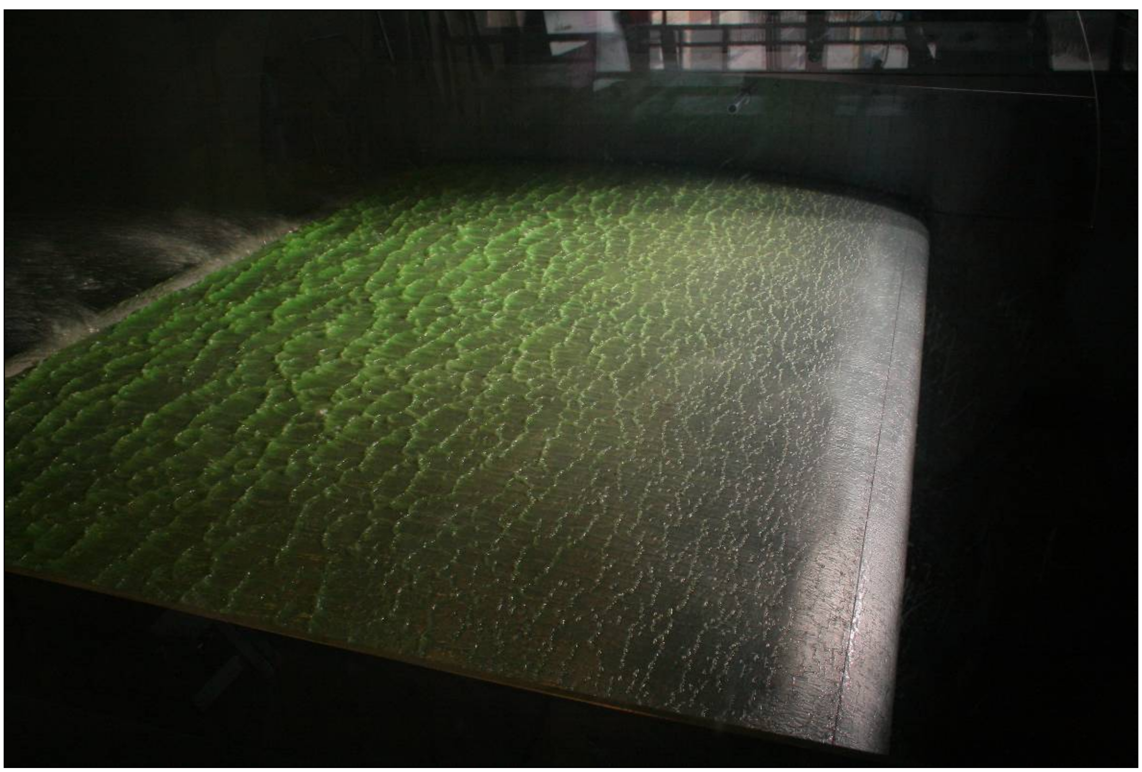


Photo 7.4: Large End Plate Test - Fluid Only



8. CONCLUSIONS AND OBSERVATIONS

These observations and conclusions were derived from the testing conducted during the winter of 2011-12.

8.1 Wind Tunnel Facility Calibration

As reported by the NRC, 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 takeoff profiles. Taking into account equipment error resulting from installation fine-tuning, year-to-year tests show good repeatability in lift coefficient data and stall behaviour. The combined uncertainty and repeatability of C_L at $\alpha = 8°$ is ±1% (equivalent of ±1% in lift loss for fluid tests).

8.2 Dry Wing Calibration and Characterization

As reported by NASA, the flow visualization confirmed 2D, leading edge stall on the clean wing with original end plates installed. The effect of leading edge roughness and simulated frost on overall lift was significant but expected, and it is comparable to archival data sets. The aerodynamic effects of fluids and contamination were similar to various chord-wise coverage of simulated frost. The tests conducted with large end plates indicated potential for asymmetric stalling characteristics due to sidewall separation; however, further tests with large end plates are not recommended due to procedural limitations. The characterization of the current dry wing model with original end plates demonstrated appropriate aerodynamic behaviour.

8.3 Fluid and Contamination Testing - Calibration and Characterization

The back-to-back fluid only runs demonstrated excellent repeatability of test methods, and this was reflected in the aerodynamic data collected. Variation in year-to-year fluid only tests runs demonstrated some differences that can be attributed to ramp-up time, temperature, and fluid viscosity. The additional variable of contamination generated slightly more variation in the test results; however, it is considered acceptable given the number of variables, such as temperature, ramp-up time, fluid viscosity, and contamination.

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. Repeatability or integrity of data was not affected by the larger end plate configurations, but the lift loss measured at $\alpha = 8$ degrees was larger than for original end plates. The scatter and dynamic nature of the stall tests demonstrated the difficulties with using 2D model stall data for evaluating stall.

8.4 Type IV High-Speed Allowance Times

Testing was not conducted during the winter of 2011-12 with the objective of further developing or substantiating the current ice pellet allowance times. However, the calibration and characterization results described in this report further increase the confidence in the previous work conducted to develop the guidance.

8.5 Correlation of Fluid Certification BLDT Results with NRC Wind Tunnel Lift Loss Results

Testing was not conducted during the winter of 2011-12 with the objective of further refining the correlation between the fluid certification boundary layer displacement thickness (BLDT) results and the NRC wind tunnel lift loss results. A spot-check was conducted with the 2011-12 fluid only test results to ensure the results were in line with previous results. They were as expected, and no anomalies were observed.

9. RECOMMENDATIONS

The following recommendations were compiled based on the work conducted during the winter of 2011-12.

9.1 Future Testing Using the PIWT and Thin High-Performance Wing Model

The testing results have demonstrated the the PIWT and thin high-performance wing model are appropriate for the testing and comparative evaluation of de/anti-icing fluid flow-off with and without contamination. It is recommended that testing continue using the existing methodologies with an outlook to continue improving on testing protocols and procedures.

9.2 Follow-Up Testing to Support Calibration and Characterization Work

It is anticipated that a small portion of the work planned for the winter of 2012-13 will include some follow-up testing to support the calibration and characterization work conducted in 2011-12. This testing will be planned in cooperation with NASA aerodynamicists to resolve outstanding issues or questions.

9.3 Type IV High-Speed Allowance Time Table

Testing was not conducted during the winter of 2011-12 with the objective of further developing or substantiating the current ice pellet allowance times.

Based on the 2011-12 wind tunnel test results, no changes were made to the values in the Type IV allowance time table; however, additional guidance was included to explicitly indicate that guidance material is for SAE Type IV undiluted fluid only and that all fluids are PG-based with the exception of Dow Chemical EG 106 fluid. The updated table has been published in the July 2012 Revision 1.0 version of the TC HOT Guidelines, and a similar table has been published by the FAA. The updated allowance time table is shown in Table 9.1.

Table 9.1: 2012-13 Ice Pellet Allowance Time Table

ICE PELLET ALLOWANCE TIMES FOR WINTER 2012-2013

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.

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

NOTES

1 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).
2 Allowance time is 15 minutes for propylene glycol (PG) fluids or when the fluid type is unknown.
3 No allowance times exist in this condition for temperatures below 0°C; consider use of light ice pellets mixed with light freezing rain.
4 No allowance times exist in this condition for temperatures below 0°C.

9.4 Future Research

The following sections describe higher priority areas of possible future research for the winter of 2012-13 wind tunnel testing plan. These areas of future research have been determined based on consultations with TC, the FAA, NASA, and through industry discussions, and as such they may not be directly linked to the research described in this report. These areas of research have been listed below for ease of reference and to maintain continuity in the year-to-year reporting.

9.4.1 Allowance Time Expansion of Light Ice Pellets Mixed with Light and Moderate Snow Conditions

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°C to -10°C where no allowance times currently exist. It is recommended that future research targets these conditions in order to allow greater flexibility to operators in conditions of ice pellets mixed with light or moderate snow as initial results from the 2010-11 testing have indicated a potential for new, longer allowance times.

9.4.2 Investigation of Higher Lift Losses at Lower Temperatures

Additional testing is also recommended in moderate ice pellets close to the lower end of the -10°C to -25ºC range where the higher lift losses were observed during the winter of 2010-11. The additional testing is recommended in order to better understand the impact of the higher lift losses and to determine if changes to the guidance material are required in the future.

9.4.3 Substantiation of Ice Pellet Allowance Times with New Fluids

Testing should investigate different Type IV fluids to further substantiate the ice pellet allowance times. Testing should consider new fluids or fluids previously tested but with limited data (i.e., AD-49, Cryotech fluids).

9.4.4 Evaluate Effect of Fluid Viscosity on Aerodynamics

Testing could be conducted to investigate the effect of fluid viscosity on aerodynamics. Testing could look at high and low ends of production fluid viscosities and possibly also investigate mechanically or chemically degraded fluids.

9.4.5 Additional Testing and Analysis to Further Develop the PIWT Results Correlation to the BLDT Test

Additional analysis paired with wind tunnel testing is recommended to develop a correlation between the lift losses observed in the wind tunnel and the AAT, which is the basis for the fluid certification process. Currently, the scatter in the data is still large and results in uncertainties when analysing the data. It is anticipated that as future testing progresses and as more data is collected, a narrower range or single-value pass/fail cut-off will be developed similar to the AAT and B737-200ADV airplane tests.

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2011-12

TRANSPORTATION DEVLOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2011-12

6.3 AIRCRAFT PERFORMANCE RESEARCH

(Contract T-8200-088510/001/MTB)

6.3.1 Wind Tunnel Testing to Refine Allowance Times

a) Meet with NRC personnel to arrange for access to the Propulsion Wind Tunnel (PWT) in M46 at the NRC Montreal Road facility in Ottawa;

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) Participate in the modification of the recently constructed super-critical airfoil model to be used for testing (modifications may include moveable flap, leading edge devices etc.); and

c) Develop a procedure and test plan with the NRC staff who operates the PWT. It is anticipated that testing will be conducted over a period of three weeks. It is anticipated that much of the testing will be conducted during overnight hours.

3. DETAILED WORK DESCRIPTION FOR YEAR 1 (2011-12)

(Contract T8125-110167/001/TOR)

3.13 Wind Tunnel Testing to Refine Allowance Times

a) Perform wind tunnel tests to possibly expand current allowance times published by TC and FAA and to validate the results for super-critical airfoils. Testing may also be conducted to potentially develop an allowance time table for use with Type III fluid;

b) Perform wind tunnel tests with ethylene glycol and a propylene glycol anti-icing fluids at low temperatures;

c) Perform wind tunnel tests to simulate low speed and high speed takeoffs in accordance with the speed and angle of attack profiles provided by TDC and airframe manufacturers. The simulated take-off profile will target the clean wing stall angle as the maximum angle of attack in order to obtain CLmax data. The analysis will evaluate the lift results at an angle approximately halfway between the typical angle of attack at rotation and the stall angle. In addition, fluid only data points will be collected close to the BLDT limits in order to develop a correlation between the lift losses observed in the NRC wind tunnel and the fluid certification tests (consider feasibility of using BLDT measurement device for wind tunnel tests);

d) During contaminated test runs, a baseline fluid only case will be run immediately before, or after the contaminated test run to provide a direct correlation of the results;

e) Perform correlation testing to calibrate the TC model and to demonstrate repeatability;

f) Collect the following data during the tests:

   i. Type and amount of fluid applied;

   ii. Type and rate of contamination applied; and

   iii. Extent of fluid contamination prior to the test run.

g) Take a series of high resolution photos of the fluid motion at the leading and trailing edges of the wing at a rate of about 3 frames per second, with lighting adequate to see the fluid waves and ripples of about 1mm in height, even when the wing is at 12 degrees angle of attack;

h) Document the appearance of fluid on the wing during the simulated takeoff run and climb of the aircraft by analyzing the photographic records; and

i) Report the findings, and prepare presentation material for the SAE G-12 meetings.

APPENDIX B

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

CM2265.001

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

Winter 2011-12

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

APS Aviation Inc.

January 13, 2012
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 results. With the support and under direction of NASA, a large series of test runs are anticipated to better understand the performance characteristics of the wind tunnel and airfoil. Some limited fluid tests will also be conducted, however will be of lower priority.

2. OBJECTIVES

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

- Thoroughly survey the clean wing performance through pitch pause, angle sweeps, and stall runs, and verify repeatability;
- Perform oil flow visualization to better understand boundary layer separation and uniformity of flow;
- Install boundary layer trips to establish wing sensitivity;
- Conduct fluid testing with and without contamination to evaluate repeatability of results;
- Install larger end plates to evaluate potential 3D effects;
- Obtain additional fluid data in all dilations to correlate the lift losses observed in the NRC PIWT with the fluid aerodynamic acceptance test protocol (5.24% LL);

See Attachment I for further details.

As lower priority objectives, testing may be conducted to investigate the following:

- Heavy Snow;
- Snow on an Un-Protected Wing;
- Ice Phobic Coatings;
- Heavily Contaminated Vertical Stabilizer;
- Type I Spot Deicing during CSW Frost;
- Light and Very Light Snow HOT's;
- Windshield Washer Used as a Type I Deicer; and
- Effect of fluid seepage on dry wing performance.

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.

Three weeks of testing have been scheduled for the conduct of these tests. The start date for testing is currently scheduled for January 16th and testing will continue until February 3rd (see Figure 2.2).

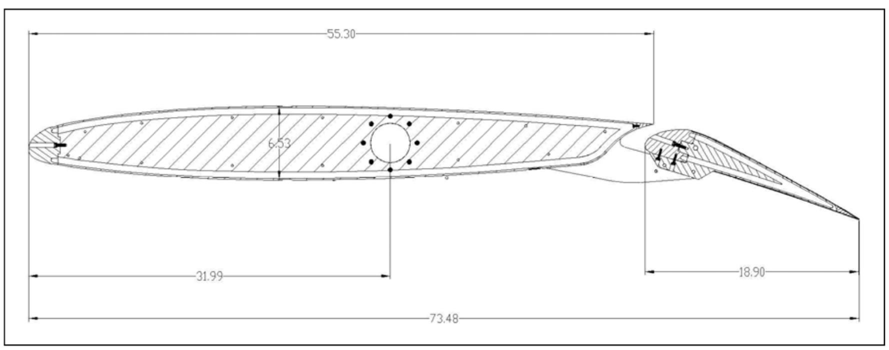


Figure 2.1: Super-Critical Wing Section

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLETS

Figure 2.2: Test Calendar

Week	Monday	Tuesday	Wednesday	Thursday	Friday
1	**Setup & Clean Wing Any Temp** Pitch-pause AoA sweeps Stall Discrepency *APS: MR, BG, JS, JD, DY, VZ, JsD (4 hrs)*	**Oil Flow Visualization Any Temp** Doc. boudary Layer Doc. Separation Boundary Layer Rake *APS: MR, BG, JS*	**Boundary Layer Trips Any Temp** Roughness (sand paper) Simulated frost Establish sensitivity *APS: MR, BG, JS*	**Boundary Layer Trips (cont'd) Any Temp** Roughness (sand paper) Simulated frost Establish sensitivity APS: MR, BG, JS	**Fluid testing With and without ice pellets** Temp = available temp Conditions to be tested: fluid Repeats of past cases for continuity, C_L Max, BLDT Fluids-Launch, EG106,ABC S+ 2 runs each = 6 runs *APS: MR, BG, JS, YOWx2, JD, DY, VZ*
	12 TESTS	**12 TESTS**	**6 TESTS**	**6 TESTS**	**17 TESTS**
2	**Fluid testing With and without ice pellets** Temp = available temp Conditions to be tested: IP Repeats of past cases for continuity, C_L Max, BLDT Fluids-Launch, EG106,ABC S+ 2 runs each = 6 runs Additional runs TBD *APS: MR, BG, JS, YOWx2, JD, DY, VZ*	**Remove Standard End Plates, Install Large End Plates** **NRC - ALL DAY INSTALLATION** *No APS*	**LARGE END PLATE TESTS Clean Wing Any Temp** Pitch-pause AoA sweeps Stall Discrepency *APS: MR, BG, JS, JsD (4 hrs)*	**LARGE END PLATE TESTS Oil Flow Visualization Any Temp** Doc. boudary Layer Doc. Separation Boundary Layer Rake *APS: MR, BG, JS*	**LARGE END PLATE TESTS Boundary Layer Trips Any Temp** Roughness (sand paper) Simulated frost Establish sensitivity *APS: MR, BG, JS*
	19 TESTS		**12 TESTS**	**12 TESTS**	**12 TESTS**
Fluid-test Leads: FAA & APS (night time)					
3	**LARGE END PLATE TESTS Fluid testing With and without ice pellets** Temp = available temp Conditions to be tested; fluid Repeats of cases from week 1, Fri *APS: MR, BG, JS, YOWx2, JD, DY, VZ*	**LARGE END PLATE TESTS Fluid testing With and without ice pellets** Temp = available temp Conditions to be tested:IP Repeats of cases from week 2, Mon *APS: MR, BG, JS, YOWx2, JD, DY, VZ*	**LARGE END PLATE TESTS Fluid testing** <-15ºC Add to BLDT data New & 2010-11 Fluid 75/25 & 100/0 BLDT Fluid Seapage ***Warren & John revise if and as necessessary*** *APS: MR, BG, JS, YOWx2, JD, DY, VZ*	**LARGE END PLATE TESTS Fluid testing** <-15ºC Add to BLDT data New & 2010-11 Fluid 75/25 & 100/0 BLDT Fluid Seapage ***Warren & John revise if and as necessessary*** *APS: MR, BG, JS, YOWx2, DY, VZ*	**LARGE END PLATE TESTS OTHER FLUID TESTS: <0ºC S++,–V-Stab, Frost Spot Deicing, Snow no Fluid** TC R&D ITEMS <0ºC, S- & S--, Ice Phobic Vanes, Windshield Washer Fluid ***Warren & John revise if and as necessessary*** *APS: MR, BG, JS, YOWx2, DY, VZ* **(TEARDOWN)**
	13 TESTS	**8 TESTS**	**9 TESTS**	**6 TESTS**	**14 TESTS**
4				**NRC Flow Survey** No Charge and No APS/TC/FAA Involvement	
Aug	**NACA 23012 Wing Model Calibration (see NRC email Nov 2011)** Will likely be done after NRC restructuring, however pending approval by NRC				

Part 1: days 1-4
Dry airfoil with standard end plates

Part 2: days 5-6
Airfoil with fluids, uncontaminated and contaminated with ice pellets, with standard end plates. Repeats of past cases.

Part 3: day 7
Change from standard to large end plates.

Part 4: days 8-10
Dry airfoil with large end plates.

Part 5: days 11-12
Airfoil with fluids, uncontaminated and contaminated with ice pellets, with large end plates. Repeats of cases from Part 2.

Part 6: days 13-15
Other testing with fluids, uncontaminated and contaminated

Notes:

1.) The first two weeks of the test entry are aero-testing. This will be lead by NASA - Andy Broeren and Sam Lee, and NRC - Katherine Clark. They will be supported by FAA - Warren Underwood and Tom Bond, and staff from APS.

2.) The third week will be fluids testing and will be lead by FAA - Warren Underwood and TC in collaboration with APS. NRC will support the testing. NASA will not be available.

3.) Current start date is set for Monday January 16th. Three weeks of testing are planned.

4.) Test days are placeholders and can be adjusted: first prirority is the aerodynamic testing, second priority is the fluids testing. The fluids testing will be done in the third week if the aerodynamic test matrix is completed. The conditions and daily test schedule can be modified based on temperature or other test considerations.

5.) 1800L of fluid ordered 600L EG106, 400L Launch & 800L ABC-S+

6.) Calibration model PIWT tests tentatively in August 2012. Support for this test will be from NRC, NASA, FAA, and APS.

Test Runs With Fluids – to be run on small end plate (days 5 and 6) and large end plate (days 11 and 12) configurations.

Fluids to be used, all Type IV:
Clariant Safewing MPIV Launch- PG
Dow EG106 (EG106) – EG
Kilfrost ABC S+ - PG

Runs with fluid only: (days 5&6 – small end plates – and 11&12 – large end plates)
1)Clariant Launch @100Kt
2)Repeat 1
3) Clariant Launch @100Kt with moderate IP for 15min.
4) Repeat 3
5)EG106 @100Kt
6)Repeat 5
7) Dow EG106 @100Kt with moderate IP for 30min.
8) Repeat 7
9)ABC S+ @100Kt
10)Repeat 9
11) Kilfrost ABC S+ @100Kt with moderate IP for 15min.
12) Repeat 11

This should not take 2 full days. Additional runs TBD.

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 II to V present the generic holdover time guidelines for Type I and 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 VI.

The calendar shown in Table 2.1 presents each of the major test objectives, however 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 3.1.

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.

Table 3.1: Proposed Test Plan

Test Plan #	Day	Objective	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	Exposure Time
P001	1	Clean Wing	1	None	8	100	any	none	-	-	-
P002	1	Clean Wing	1	None	8	80	any	none	-	-	-
P003	1	Clean Wing	1	None	stall	80	any	none	-	-	-
P004	1	Clean Wing	1	None	stall	80	any	none	-	-	-
P005	1	Clean Wing	1	None	stall	80	any	none	-	-	-
P006	1	Clean Wing	1	None	stall -4 to stall +4	80	any	none	-	-	-
P007	1	Clean Wing	1	None	8	100	any	none	-	-	-
P008	1	Clean Wing	1	None	8	80	any	none	-	-	-
P009	1	Clean Wing	1	None	stall	80	any	none	-	-	-
P010	1	Clean Wing	1	None	stall	80	any	none	-	-	-
P011	1	Clean Wing	1	None	stall	80	any	none	-	-	-
P012	1	Clean Wing	1	None	stall -4 to stall +4	80	any	none	-	-	-
P013	2	Oil Flow Visualization	1	Oil	8	80	any	none	-	-	-
P014	2	Oil Flow Visualization	1	Oil	4 or 6	80	any	none	-	-	-
P015	2	Oil Flow Visualization	1	Oil	stall	80	any	none	-	-	-
P016	2	Oil Flow Visualization	1	Oil	stall-1	80	any	none	-	-	-
P017	2	Oil Flow Visualization	1	Oil	stall-2	80	any	none	-	-	-
P018	2	Oil Flow Visualization	1	Oil	stall-4	80	any	none	-	-	-
P019	2	Oil Flow Visualization	1	Oil	stall-8	80	any	none	-	-	-
P020	2	Oil Flow Visualization	1	Oil	TBD	TBD	TBD	none	-	-	-
P021	2	Oil Flow Visualization	1	Oil	TBD	TBD	TBD	none	-	-	-
P022	2	Oil Flow Visualization	1	Oil	TBD	TBD	TBD	none	-	-	-
P023	2	Oil Flow Visualization	1	Oil	TBD	TBD	TBD	none	-	-	-
P024	2	Oil Flow Visualization	1	Oil	TBD	TBD	TBD	none	-	-	-
P025	3	Roughness (Trips)	1	40-grit	stall	80	same as P013	none	-	-	-
P026	3	Roughness (Trips)	1	40-grit	stall -4 to stall +4	80	same as P016	none	-	-	-
P027	3	Roughness (Trips)	1	150-grit	stall	80	same as P013	none	-	-	-
P028	3	Roughness (Trips)	1	150-grit	stall -4 to stall +4	80	same as P016	none	-	-	-
P029	3	Roughness (Trips)	1	80-grit	stall	80	same as P013	none	-	-	-
P030	3	Roughness (Trips)	1	80-grit	stall -4 to stall +4	80	same as P016	none	-	-	-
P031	4	Roughness (Trips)	1	Full Wing Grit	stall	80	same as P013	none	-	-	-
P032	4	Roughness (Trips)	1	Full Wing Grit	stall -4 to stall +4	80	same as P016	none	-	-	-
P033	4	Roughness (Trips)	1	Grit (-30% grit on LE)	stall	80	same as P013	none	-	-	-
P034	4	Roughness (Trips)	1	Grit (-30% grit on LE)	stall -4 to stall +4	80	same as P016	none	-	-	-
P035	4	Roughness (Trips)	1	Grit (-60% grit on LE)	stall	80	same as P013	none	-	-	-
P036	4	Roughness (Trips)	1	Grit (-60% grit on LE)	stall -4 to stall +4	80	same as P016	none	-	-	-
P037	6	Fluid Tests - Repeatibility	1	Fluid Only	8	100	-12 to -13	ABC-S Plus (100)	-	-	-
P038	6	Fluid Tests - Repeatibility	2	Fluid Only	8	100	-12 to -13	ABC-S Plus (100)	-	-	-
P039	5	Fluid Tests - Repeatibility	1	Fluid Only	8	100	-15 to -18	EG 106 (100)	-	-	-
P040	5	Fluid Tests - Repeatibility	2	Fluid Only	8	100	-15 to -18	EG 106 (100)	-	-	-

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Day	Objective	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate ($g/dm^2/h$)	SN Rate ($g/dm^2/h$)	Exposure Time
P041	5	Fluid Tests - Repeatibility	1	Fluid Only	8	100	-3 to -5	Launch (100)	-	-	-
P042	5	Fluid Tests - Repeatibility	2	Fluid Only	8	100	-3 to -5	Launch (100)	-	-	-
P043	5	Fluid Tests - Repeatibility	1	IP-	8	100	-11 to -13	EG 106 (100)	25	-	30
P044	5	Fluid Tests - Repeatibility	2	IP-	8	100	-11 to -13	EG 106 (100)	25	-	30
P045	5	Fluid Tests - Repeatibility	1	IP Mod	8	100	-4 to -6	Launch (100)	75	-	25
P046	5	Fluid Tests - Repeatibility	2	IP Mod	8	100	-4 to -6	Launch (100)	75	-	25
P047	6	Fluid Tests - Repeatibility	1	IP Mod	8	100	-13 to -15	ABC-S Plus (100)	75	-	10
P048	6	Fluid Tests - Repeatibility	2	IP Mod	8	100	-13 to -15	ABC-S Plus (100)	75	-	10
P049	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	ABC-S Plus (100)	-	-	-
P050	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	ABC-S Plus (100)	-	-	-
P051	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	ABC-S Plus (100)	-	-	-
P052	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -20	ABC-S Plus (75)	-	-	-
P053	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -20	ABC-S Plus (75)	-	-	-
P054	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -20	ABC-S Plus (75)	-	-	-
P055	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	EG 106 (100)	-	-	-
P056	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	EG 106 (100)	-	-	-
P057	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	EG 106 (100)	-	-	-
P058	5	Fluid Tests - New BLDT	1	Fluid Only	8	100	below -25	Launch (100)	-	-	-
P059	5	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	Launch (100)	-	-	-
P060	5	Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	Launch (100)	-	-	-
P061	6	Fluid Tests - New BLDT	1	Fluid Only	8	100	-15 to -21	Launch (75)	-	-	-
P062	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	-15 to -21	Launch (75)	-	-	-
P063	6	Fluid Tests - New BLDT	2	Fluid Only	8	100	-15 to -21	Launch (75)	-	-	-
P064	6	Fluid Tests - Data at Stall	2	Fluid Only	8	100	-12 to -13	ABC-S Plus (100)	-	-	-
P065	5	Fluid Tests - Data at Stall	2	Fluid Only	8	100	-15 to -18	EG 106 (100)	-	-	-
P066	5	Fluid Tests - Data at Stall	2	Fluid Only	8	100	-3 to -5	Launch (100)	-	-	-
P067	5	Fluid Tests - Data at Stall	2	IP-	8	100	-11 to -13	EG 106 (100)	25	-	30
P068	5	Fluid Tests - Data at Stall	2	IP Mod	8	100	-4 to -6	Launch (100)	75	-	25
P069	6	Fluid Tests - Data at Stall	2	IP Mod	8	100	-13 to -15	ABC-S Plus (100)	75	-	10
P070	6	Fluid Tests - Clean LE	2	Fluid Only	8	100	-12 to -13	ABC-S Plus (100)	-	-	-
P071	5	Fluid Tests - Clean LE	2	Fluid Only	8	100	-15 to -18	EG 106 (100)	-	-	-
P072	5	Fluid Tests - Clean LE	2	Fluid Only	8	100	-3 to -5	Launch (100)	-	-	-
P073	8	END PLATES - Clean Wing	1	None	8	100	any	none	-	-	-
P074	8	END PLATES - Clean Wing	1	None	8	80	any	none	-	-	-
P075	8	END PLATES - Clean Wing	1	None	stall	80	any	none	-	-	-
P076	8	END PLATES - Clean Wing	1	None	stall	80	any	none	-	-	-
P077	8	END PLATES - Clean Wing	1	None	stall	80	any	none	-	-	-
P078	8	END PLATES - Clean Wing	1	None	stall -4 to stall +4	80	any	none	-	-	-
P079	8	END PLATES - Clean Wing	1	None	8	100	any	none	-	-	-
P080	8	END PLATES - Clean Wing	1	None	8	80	any	none	-	-	-

WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH MIXED ICE PELLETS

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Day	Objective	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	Exposure Time
P081	8	END PLATES - Clean Wing	1	None	stall	80	any	none	-	-	-
P082	8	END PLATES - Clean Wing	1	None	stall	80	any	none	-	-	-
P083	8	END PLATES - Clean Wing	1	None	stall	80	any	none	-	-	-
P084	8	END PLATES - Clean Wing	1	None	stall -4 to stall +4	80	any	none	-	-	-
P085	9	END PLATES - Oil Flow Vis	1	Oil	8	80	any	none	-	-	-
P086	9	END PLATES - Oil Flow Vis	1	Oil	4 or 6	80	any	none	-	-	-
P087	9	END PLATES - Oil Flow Vis	1	Oil	stall	80	any	none	-	-	-
P088	9	END PLATES - Oil Flow Vis	1	Oil	stall-1	80	any	none	-	-	-
P089	9	END PLATES - Oil Flow Vis	1	Oil	stall-2	80	any	none	-	-	-
P090	9	END PLATES - Oil Flow Vis	1	Oil	stall-4	80	any	none	-	-	-
P091	9	END PLATES - Oil Flow Vis	1	Oil	stall-8	80	any	none	-	-	-
P092	9	END PLATES - Oil Flow Vis	1	Oil	TBD	TBD	TBD	none	-	-	-
P093	9	END PLATES - Oil Flow Vis	1	Oil	TBD	TBD	TBD	none	-	-	-
P094	9	END PLATES - Oil Flow Vis	1	Oil	TBD	TBD	TBD	none	-	-	-
P095	9	END PLATES - Oil Flow Vis	1	Oil	TBD	TBD	TBD	none	-	-	-
P096	9	END PLATES - Oil Flow Vis	1	Oil	TBD	TBD	TBD	none	-	-	-
P097	10	END PLATES - Rough(Trips)	1	40-grit	stall	80	same as P013	none	-	-	-
P098	10	END PLATES - Rough(Trips)	2	40-grit	stall -4 to stall +4	80	same as P016	none	-	-	-
P099	10	END PLATES - Rough(Trips)	1	150-grit	stall	80	same as P013	none	-	-	-
P100	10	END PLATES - Rough(Trips)	2	150-grit	stall -4 to stall +4	80	same as P016	none	-	-	-
P101	10	END PLATES - Rough(Trips)	1	80-grit	stall	80	same as P013	none	-	-	-
P102	10	END PLATES - Rough(Trips)	2	80-grit	stall -4 to stall +4	80	same as P016	none	-	-	-
P103	10	END PLATES - Rough(Trips)	1	Full Wing Grit	stall	80	same as P013	none	-	-	-
P104	10	END PLATES - Rough(Trips)	2	Full Wing Grit	stall -4 to stall +4	80	same as P016	none	-	-	-
P105	10	END PLATES - Rough(Trips)	1	Grit (-30% grit on LE)	stall	80	same as P013	none	-	-	-
P106	10	END PLATES - Rough(Trips)	2	Grit (-30% grit on LE)	stall -4 to stall +4	80	same as P016	none	-	-	-
P107	10	END PLATES - Rough(Trips)	1	Grit (-60% grit on LE)	stall	80	same as P013	none	-	-	-
P108	10	END PLATES - Rough(Trips)	2	Grit (-60% grit on LE)	stall -4 to stall +4	80	same as P016	none	-	-	-
P109	12	END PLATES - Fluid Tests - Repeatibility	1	Fluid Only	8	100	-12 to -13	ABC-S Plus (100)	-	-	-
P110	12	END PLATES - Fluid Tests - Repeatibility	2	Fluid Only	8	100	-12 to -13	ABC-S Plus (100)	-	-	-
P111	11	END PLATES - Fluid Tests - Repeatibility	1	Fluid Only	8	100	-15 to -18	EG 106 (100)	-	-	-
P112	11	END PLATES - Fluid Tests - Repeatibility	2	Fluid Only	8	100	-15 to -18	EG 106 (100)	-	-	-
P113	11	END PLATES - Fluid Tests - Repeatibility	1	Fluid Only	8	100	-3 to -5	Launch (100)	-	-	-
P114	11	END PLATES - Fluid Tests - Repeatibility	2	Fluid Only	8	100	-3 to -5	Launch (100)	-	-	-
P115	11	END PLATES - Fluid Tests - Repeatibility	1	IP-	8	100	-11 to -13	EG 106 (100)	25	-	30
P116	11	END PLATES - Fluid Tests - Repeatibility	2	IP-	8	100	-11 to -13	EG 106 (100)	25	-	30
P117	11	END PLATES - Fluid Tests - Repeatibility	1	IP Mod	8	100	-4 to -6	Launch (100)	75	-	25
P118	11	END PLATES - Fluid Tests - Repeatibility	2	IP Mod	8	100	-4 to -6	Launch (100)	75	-	25
P119	12	END PLATES - Fluid Tests - Repeatibility	1	IP Mod	8	100	-13 to -15	ABC-S Plus (100)	75	-	10
P120	12	END PLATES - Fluid Tests - Repeatibility	2	IP Mod	8	100	-13 to -15	ABC-S Plus (100)	75	-	10

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Day	Objective	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	Exposure Time
P121	13	END PLATES - Fluid Tests - New BLDT	1	Fluid Only	8	100	below -25	ABC-S Plus (100)	-	-	-
P122	13	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	ABC-S Plus (100)	-	-	-
P123	13	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	ABC-S Plus (100)	-	-	-
P124	14	END PLATES - Fluid Tests - New BLDT	1	Fluid Only	8	100	-15 to -21	ABC-S Plus (75)	-	-	-
P125	14	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	-15 to -21	ABC-S Plus (75)	-	-	-
P126	14	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	-15 to -21	ABC-S Plus (75)	-	-	-
P127	14	END PLATES - Fluid Tests - New BLDT	1	Fluid Only	8	100	below -25	EG 106 (100)	-	-	-
P128	14	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	EG 106 (100)	-	-	-
P129	14	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	EG 106 (100)	-	-	-
P130	13	END PLATES - Fluid Tests - New BLDT	1	Fluid Only	8	100	below -25	Launch (100)	-	-	-
P131	13	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	Launch (100)	-	-	-
P132	13	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	below -25	Launch (100)	-	-	-
P133	13	END PLATES - Fluid Tests - New BLDT	1	Fluid Only	8	100	-15 to -21	Launch (75)	-	-	-
P134	13	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	-15 to -21	Launch (75)	-	-	-
P135	13	END PLATES - Fluid Tests - New BLDT	2	Fluid Only	8	100	-15 to -21	Launch (75)	-	-	-
P136	12	END PLATES - Fluid Tests - Data at Stall	1	Fluid Only	8	100	-12 to -13	ABC-S Plus (100)	-	-	-
P137	12	END PLATES - Fluid Tests - Data at Stall	1	Fluid Only	8	100	-15 to -18	EG 106 (100)	-	-	-
P138	11	END PLATES - Fluid Tests - Data at Stall	1	Fluid Only	8	100	-3 to -5	Launch (100)	-	-	-
P139	11	END PLATES - Fluid Tests - Data at Stall	1	IP-	8	100	-11 to -13	EG 106 (100)	25	-	30
P140	11	END PLATES - Fluid Tests - Data at Stall	1	IP Mod	8	100	-4 to -6	Launch (100)	75	-	25
P141	12	END PLATES - Fluid Tests - Data at Stall	1	IP Mod	8	100	-13 to -15	ABC-S Plus (100)	75	-	10
P142	12	END PLATES - Fluid Tests - Clean LE	1	Fluid Only	8	100	-12 to -13	ABC-S Plus (100)	-	-	-
P143	11	END PLATES - Fluid Tests - Clean LE	1	Fluid Only	8	100	-15 to -18	EG 106 (100)	-	-	-
P144	11	END PLATES - Fluid Tests - Clean LE	1	Fluid Only	8	100	-3 to -5	Launch (100)	-	-	-
P145	15	Other Dry Tests: SN w/ No Fluid	3	none	8	100	any	Dry - Cold Wing	See details in procedure		
P146	15	Other Dry Tests: SN w/ No Fluid	3	None	8	100	any	Dry - Warm Wing	See details in procedure		
P147	15	TC R&D - S- & S--	1	S--	8	100	above -3	ABC-S Plus (50)	-	3	See details in procedure
P148	15	TC R&D - S- & S--	1	Mod S (Baseline)	8	100	above -3	ABC-S Plus (50)	-	25	See details in procedure
P149	15	TC R&D - S- & S--	1	Fluid Only (Baseline)	8	100	above -3	ABC-S Plus (50)	-	-	-
P150	15	TC R&D: I-PH VANES	1	None	8	100	any	See Details in Procedure			
P151	15	Other Fluid Tests: V-Stab	3	S++	8	100	any	See Details in Procedure			
P152	15	Other Fluid Tests: Frost Spot Deicing	3	Frost	8	100	any	See Details in Procedure			
P153	15	Windshield Washer Fluid	1	Fluid Only	8	100	any	Type I	-	-	-
P154	15	Windshield Washer Fluid	1	Fluid Only	8	100	any	Windshield Washer Fluid	-	-	-
P155	15	Windshield Washer Fluid	1	Frost	8	100	any	Windshield Washer Fluid	-	0.3	45
P156	15	Other Fluid Tests: S++	2	S	8	100	any	See Details in Procedure	-	25	See HOT
P157	15	Other Fluid Tests: S++	2	S++	8	100	any	See Details in Procedure	-	50	1/2 of HOT
P158	15	Other Fluid Tests: S++	2	S++	8	100	any	See Details in Procedure	-	50	3/4 of HOT

4. PRE-TEST SETUP

The following describes the activities to be performed prior to the conduct of any tests:

- Co-ordinate with NRC wind tunnel personnel;
- Co-ordinate with APS photographer;
- Conduct dry photography test of old vs. new camera positioning;
- Document new final camera and flash locations;
- Arrange for hotel accommodations for APS personnel;
- Ensure availability of de/anti-icing fluid (shipped directly to NRC);
- Conduct falling ball tests on received fluids;
- Collect fluid samples for viscosity verification at APS office;
- Arrange personnel travel to Ottawa;
- Ensure proper functioning of ice pellet dispenser equipment;
- Ensure proper functioning of freezing rain sprayer equipment (not applicable);
- Mark wing data collection locations and draw grid on the wing (not applicable). Refer to Feasibility report for diagrams;
- Prepare and arrange for transport of equipment to Ottawa;
- Co-ordinate fabrication of ice pellets/snow/snow pellets; and
- Arrange for storage of ice pellets/snow/snow pellets.

The task list for setup and testing is included as Attachment VII.

5. DATA FORMS

The following data forms are required for the January – February 2012 wind tunnel tests:

- Attachment VIII - General Form/Calibration;
- Attachment IX – General Form;
- Attachment X – Wing Temperature, Fluid Thickness and Fluid Brix Measurements and Condition of Wing and Plate Form;
- Attachment XI, XII and XIII – Ice Pellet, Snow and Sifted Snow Dispensing Forms;
- Attachment XIV – Visual Evaluation Rating Form
- Attachment XV – Fluid Receipt Form (Generic form used by APS; will be used for this project as appropriate);
- Attachment XVI – 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. For the majority of the tunnel surveying and calibration (FAA initiative tests), only the general form will be filled out for record keeping purposes, and the electronic data log will be updated accordingly.

6.1 Initial Test Conditions Survey

- Record ambient conditions of the test (Attachment VIII/IX); and
- Record wing temperature (Attachment X).

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 IX);
- Record fluid application quantities (Attachment IX);
- 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 X);
- Record wing temperature (Attachment X).
- Measure fluid Brix value (Attachment X); and
- Photograph and videotape the appearance of the fluid on the wing;

Note: At the request of TC/FAA, a standard aluminum test plate will 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 XI and XII 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 XIII.

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 IX). Any comments regarding dispensing activities should be documented directly on the form.

6.4 Prior to Engines-On Wind Tunnel Test

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

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 consider 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/videotape 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 XIV); 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 X);
- Measure fluid Brix value (Attachment X);
- Record wing temperatures (Attachment X);
- Observe and record the status of the fluid/contamination (Attachment X);
- Fill out visual evaluation rating form (Attachment XIV);
- 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 XV) 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 XVI). 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 services of Safety-Kleen (or other glycol recovery service) 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 2008-09. 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
8:00:00	START OF TEST. ALL EQUIPMENT READY.
8:00:00	- Record test conditions.
8:05:00	- Prepare wing for fluid application (clean wing, etc).
8:15:00	- Measure wing temperature. - Ensure clean wing for fluid application
8:20:00	- Pour fluid over test area.
8:30:00	- Measure Brix, thickness, wing temperature. - Photograph test area.
8:35:00	- Apply contamination over test area. (i.e. 30 min)
9:05:00	- Measure Brix, thickness, wing temperature. - Photograph test area.
9:10:00	- Clear area and start wind tunnel
9:25:00	- Wind tunnel stopped
9:35:00	- Measure Brix, thickness, wing temperature. - Photograph test area. - Record test observations
9:45:00	END OF TEST

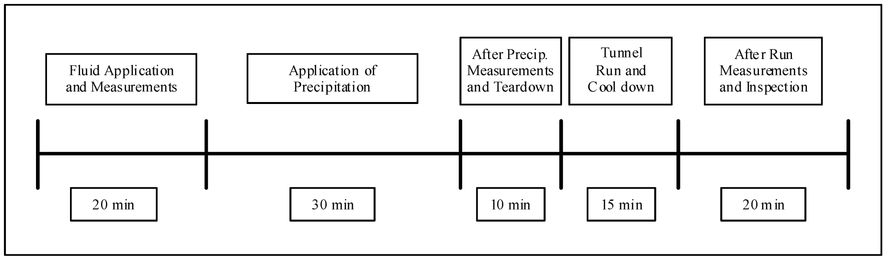


Figure 6.1: Typical Wind Tunnel Run Timeline

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:

- Heavy Snow (Attachment XVII);
- Snow on an Un-Protected Wing (Attachment XVIII);
- Ice Phobic Coatings (Attachment XIX);
- Heavily Contaminated Vertical Stabilizer (Attachment XX);
- Type I Spot Deicing during CSW Frost (Attachment XXI);
- Light and Very Light Snow HOT's (Attachment XXII); and
- Windshield Washer Used as a Type I Deicer (Attachment XXIII).

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 indicated in parentheses above. 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 Equipment			**Ice Pellets Fabrication Equipment**	
Large and small tape measure			Refrigerated Truck	
Fluids (ORDER and SHIP to Ottawa)			Ice pellets Styrofoam containers x20	
Horse and tap for fluid barrel x 2			Ice bags	
Funnels			Ice bags storage freezer	
Sample bottles for viscosity measurement x10			Blenders x6+	
Squeegees			Ice pellets sieves	
Isopropyl x24			Folding tables	
Gloves, paper towel (lots)			Measuring cups (1L and smaller)	
Extension cords			Wooden Spoons	
Clipboards, pencils, wing markers for sample locations and solvent			Rubber Mats	
Large Clock x1				
Walkie Talkies x8			**Freezing Rain Equipment**	
Envelopes and labels			NRC Freezing rain sprayer (not required)	
Previous 05-06 to 10-11 F20/WT reports			APS PC equipped with rate station software	
Grid Section + Location docs			White plastic rate pans (100)	
Large Sharpies for Grid Section			Wooden boards for rate pans (x8)	
Projector for laptop			Rubber suction cup feet for wooden boards	
YOW employee contracts			Sartorius Weigh Scale x1 + NCAR Scale x 1	
Blow Horns x4			Black Shelving Unit (or plastic)	
Stop Watches x4				
Calculators x3				
Scissors				
Exacto Knives x2				
APS Laptops x5				
Camera Equipment				
Digital still cameras x4 (with lenses, chargers, batteries, etc)				
Flashes and tripods				
Memory card reader				
Test Equipment				
Test Procedures, data forms, printer paper				
Electronic copy of the whole wind tunnel procedure folder, incl all forms and working docs (maybe Falcon too).				
Hard Drive (3 x New)				
Test Plate				
Speed tape (large and small)				
Thickness Gauges				
Temperature Probe x 2 and spare batteries				
Brixometers X4				
Adherence Probes (Oral B) x4 with tips and charger				
Fluid pouring jugs x40 (10 per fluid + extra)				
Ice pellets dispersers x6				
Stands for ice pellets dispensing devices x6				
Ice Pellet control wires and boxes (all)				
Ice pellet box supports for railing x4				
Hot Plate x3 and Large Pots with rubber handles				
Watmans Paper and conversion charts				
Long Ruler for marking wing x2				
Small 90° aluminum ruler for wing				
20L containers x12 (DY order from YUL)				
hard water chemicals				
Thermometer for Reefer Truck				
Poster board (8"x3") for flap section				

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 Manufacturer	Fluid Name	Type	2011-12 Quantity Ordered (Planned) (L)
Dow Chemical Company	EG106	IV	600 (400)
Kilfrost Limited	ABC-S PLUS	IV	800 (580)
Clariant Produkte	Launch	IV	400 (520)
		Total	1800

3600 L Ordered For 2009-10 Testing (18 Days)

3200 L Ordered For 2010-11 Testing (15 Days)

1800 L to be Ordered For 2011-12 Testing (7 of 15 days will be fluid testing)

9. PERSONNEL

Four APS staff members are required for the tests at the NRC wind tunnel. Three additional persons 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. The level of personnel has been reduced from previous test campaigns due to budgetary constraints.

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

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;
- 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;
- Appropriate footwear and 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 – AERODYNAMIC CHARACTERIZATION OF THIN, HIGH-PERFORMANCE WING IN THE NRC PIWT TEST PLAN AND RATIONALE FOR WINTER 2012 CAMPAIGN

FAA/TC/APS/NRC/NASA Test Team

Version 1.0
25 November 2011

Overall Goal and Desired Results
Determine the baseline aerodynamic characteristics of the current model configuration—thin, high-performance wing. Improve our understanding and general applicability of the fluids and contamination tested on this wing model configuration.

1. Angle of Attack Sweeps

Objective and Rationale: verify fixed rotation rate method for acquiring wing performance data from force balance, particularly with regard to repeatability in maximum lift ($C_{L,max}$) and stall angle (α_{stall}). Note that we should also be reducing, plotting and analyzing pitching-moment and drag data from the force balance—assuming that these are deemed reliable.

1.1 Perform standard speed ramp profile and rotation to α = 8 deg. and hold. V = 100 kts. Compare C_L, C_M and C_D versus α results to data from previous test campaigns.
1.2 Perform standard speed ramp profile and rotation to α = 8 deg., and hold. V = 80 kts. Compare CL, CM and CD to data from 1.1.
1.3 Perform standard speed ramp profile and rotation to α = 8 deg., and hold, then continue rotation through stall. V = 80 kts. Compare CL, CM and CD to data from 1.1 and 1.2.
1.4 Perform standard speed ramp profile and rotation through stall. V = 80 kts. Compare CL, CM and CD to data from 1.1, 1.2 and 1.3.
1.5 Set V = 80 kts and measure performance data from α = -4 deg. to αstall+4 deg. in one degree increments (pitch & pause mode), then take data for decreasing angle of attack also at one degree increments. Note that the V = 80 kts should be maintained as the angle and blockages increase. Compare CL, CM and CD.
1.6 Perform repeat runs of 1.1 – 1.5 as time allows during the remainder of the test campaign.

2. Surface-oil Flow Visualization

Objective and Rationale: document the flow patterns on the surface of the wing for select angles of attack leading up to stall, specifically looking for evidence of spanwise variation, boundary-layer transition and separation to determine the stall type of the wing (e.g., leading-edge stall vs. trailing-edge stall.). Knowledge of the baseline wing flow patterns will help determine the general applicability of the fluids testing results.

Preparations: clean the upper surface of the wing and flap, develop and apply two strips of tape in the chordwise direction marking the %-chord on the model from leading edge to trailing edge. Locate oil with appropriate dye or color for good visibility under normal light. Apply oil to entire upper surface of the wing using a paint roller (foam (sponge) roller preferred, but fiber roller with short nap may also work).

General Procedure: roll oil to uniform coverage and photograph. Set desired angle of attack and set tunnel speed (probably 80 kts to correspond to 1.5). Observe flow of oil on the surface and shut down tunnel when steady state is achieved. Take photographs to document features. Re-distribute oil on the surface with roller to prepare for next run.

2.1 Perform flow viz run at α = 8 deg. since this is the angle of interest for fluids evaluation. Repeat as many times as needed to get high-quality images.

2.2 Depending upon extend of separation and spanwise flow, it may be necessary to perform flow viz run at a lower angle (say 4 or 6 deg.). For example, if spanwise flow is noted at α = 8 deg., then it may be useful to document the angle of attack at which the spanwise flow is mitigated.

2.3 Perform flow viz runs at incremental angles of attack leading up to stall. For example, if CL,max occurs at α = αstall = 20 deg. Then a suggested matrix is α = 12, 16, 18, 19 and 20. This will characterize the surface flow leading to stall and hence determine the stall type.

2.4 Based upon results of flow visualization, define and conduct test matrix for boundary-layer rake data acquisition.

3. Surface Roughness Tests

Objective and Rationale: determine the wing sensitivity to various sizes and configurations of roughness and simulated frost. Knowledge of wing sensitivity to roughness and roughness extent may help determine the general applicability of the fluids effects.

Preparations: need to develop suitable methods for applying and removing roughness in cold environment without damaging the wing surface.

3.1 Apply 40-grit sandpaper (k/c = 0.00023) roughness to leading edge from x/c = 0.08 on the upper surface to x/c = 0.08 on the lower surface. Acquire performance data through stall according to 1.4 or 1.5 or both.

3.2 Assuming that the performance effects from 3.1 are significant apply 150-grit sandpaper (k/c = 0.000050) roughness to leading edge from x/c = 0.08 on the upper surface to x/c = 0.08 on the lower surface. Acquire performance data through stall according to 1.4 or 1.5 or both.

3.3 If a larger variation in performance is observed between 3.1 and 3.2 consider applying 80-grit sandpaper (k/c = 0.00010) roughness to leading edge from x/c = 0.08 on the upper surface to x/c = 0.08 on the lower surface. Acquire performance data through stall according to 1.4 or 1.5 or both.

3.4 Based upon the results from 3.1 to 3.2 select one of the roughness sizes for an study of upper surface frost. Cover the entire upper surface of the wing with roughness and acquire performance data through stall according to 1.4 or 1.5 or both.

3.5 After running 3.4 remove the roughness from the first 30% of chord, leaving the aft 70% covered with roughness and acquire performance data through stall according to 1.4 or 1.5 or both.

3.6 After running 3.5 remove the roughness from the first 60% of chord, leaving the aft 40% covered with roughness and acquire performance data through stall according to 1.4 or 1.5 or both.

4. Tests with Uncontaminated and Contaminated Fluids

Objective and Rationale: gather data to show year-to-year repeatability for selected fluid and fluid+contamination cases; gather new data for uncontaminated fluid cases to add to BLDT correlation (suggested to use 75/25 mixture to obtain data closer to AAT failure limit at warmer temperatures). Also, look at acquiring fluid and fluid+contamination data at stall.

4.1 Select cases for uncontaminated fluid repeat runs (temperature dependent).

4.2 Select cases for fluid+contamination repeat runs (temperature dependent).

4.3 Select cases for uncontaminated fluid runs to add to BLDT correlation (e.g., 75/25 fluid) (temperature dependent).

4.4 Repeat runs from 4.1 and 4.2, but rotating model through stall, with usual hold at α = 8 deg.

4.5 Repeat runs from 4.1 and 4.2, but rotating model through stall, without hold at = 8 deg.

4.6 If possible, apply fluid to only the aft portion of the wing, leaving the leading edge clean and conduct usual ramp and rotation as in 4.1 and 4.2 (temperature dependent).

5. Tests with New Endplates

Objective and Rationale: determine if larger endplates result in reduced 3D surface flow effects and less spanwise variation. Also, show that fluid and fluid+contamination effects observed at α = 8 deg. are similar to that previously observed with the original endplates.

Probably need to repeat a subset of all tests in 1-4 above. Of course this depends upon how the data compare to the original configuration as they are acquired.

ATTACHMENT II – Generic Type I Holdover Time Table

TABLE 1-A

SAE TYPE I FLUID HOLDOVER GUIDELINES ON ALUMINUM WING SURFACES FOR WINTER 2011-2012[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	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	CAUTION: No holdover time guidelines exist	
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 is 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.**

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

TABLE 4-D-E106

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2011-2012[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**	**Snow, Snow Grains or Snow Pellets[3]**	**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	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						
below -3 to -14	below 27 to 7	100/0	1:50 – 3:20	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	0:15 – 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 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 IV – Kilfrost ABC-S Plus Type IV Holdover Time Table

TABLE 4-K-ABC-S+

KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2011-2012[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	Snow, Snow Grains or Snow Pellets[3]	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	1:15 – 2:00	1:50 – 2:00	1:05 – 2:00	0:25 – 2:00	
		75/25	1:25 – 2:40	0:45 – 1:15	1:00 – 1:20	0:30 – 0:50	0:10 – 1:20	
		50/50	0:30 – 0:55	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	1:00 – 1:45	0:25 – 1:35[7]	0:20 – 0:30[7]	CAUTION: No holdover time guidelines exist	
		75/25	0:45 – 1:50	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	0:15 – 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 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 V – Clariant Safewing MP IV Launch Type IV Holdover Time Table

TABLE 4-C-LAUNCH

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2011-2012[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	Snow, Snow Grains or Snow Pellets[3]	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	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	1:00 – 1:45	1:40 – 2:00	0:45 – 1:15	0:10 – 1:45	
		50/50	1:25 – 2:45	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	0:50 – 1:20	0:35 – 1:40[7]	0:25 – 0:45[7]		
		75/25	0:40 – 1:20	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	0:15 – 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 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 VI– Ice Pellet Allowance Time Table

Transport Canada Holdover Time Guidelines **Winter 2011-2012**

TABLE 11

ICE PELLET ALLOWANCE TIMES FOR WINTER 2011-2012

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

NOTES

1. 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).
2. Allowance time is 15 minutes for propylene glycol (PG) fluids, or when the fluid type is unknown.
3. No allowance times exist in this condition for temperatures below 0°C; consider use of light ice pellets mixed with light freezing rain.
4. No allowance times exist in this condition for temperatures below 0°C.

ATTACHMENT VII – 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 personnel travel to Ottawa;	VZ	
6	Hire YOW personnel	VZ	
7	Complete contract for YOW personnel	VZ/PG	
8	Co-ordinate with APS photographer	MR	
9	Ensure availability of freezing rain sprayer equipment;	MR	
10	Prepare and Arrange Office Materials for YOW	VZ	
11	Prepare Data forms and procedure	VZ	
12	Prepare Test Log (See JD with it)	VZ	
13	Finalize and complete list of equipment/materials required	MR	
14	Prepare and Arrange Site Equipment for YOW	MR/DY	
15	Ensure proper functioning of ice pellet dispenser equipment;	MR/VZ	
16	Review IP/ZR/SN dispersal techniques and location	VZ/MR	
17	Update IP Rate File (if necessary)	VZ/MR	
18	Arrange for freezer storage of ice pellets/snow/snow pellets.	VZ	
19	Check weather prior to establishing test dates	MR	
20	Arrange for pallets to lift up 1000L totes (if applicable)	MR	
21	Purchase new 20 L containers (as necessary)	DY	
22	Complete purchase list and shopping	VZ	
	Monday Jan 16		
23	Pack and leave YUL for YOW on Jan 16th	APS	
24	Safety Briefing & Training (APS/YOW)	MR	
25	Unload Truck and organize equipement in lower, middle, or office area	APS	
26	Verify and Organize Fluid Recieved (labels and fluid receipt forms)	DY/JS	
27	Transfer Fluids from 1000 L Totes to 20 L containers	DY/JS	
28	Collect fluid samples for viscosity and falling ball verification at APS office	DY/VZ	
29	Confirm ice and freezer delivery	DY	
30	Setup general office and testing equipment	VZ	
31	Setup Projector	VZ	
32	Setup Printer	VZ	
33	Setup rate station	DY	
34	Setup IP/SN manufacturing material in reefer truck	JS	
35	Test and prepare IP dispensing equipment	JS	
36	Train IP making personnel (ongoing)	JS/YOW	
37	Co-ordinate fabrication of ice pellets/snow	VZ/JS	
38	IP/SN/ZR Calibration (if necessary)	DY/VZ/MR	
39	Start IP manufacturing	JS	
40	Mark wing (only if requested);	VZ	
41	Setup Still and Video Cameras same as 2010-11	BG/JsD	
42	Verify 2010-11 vs 2011-12 photo and video angles, resolution, etc	BG/JsD/MR	
43	Document new final camera and flash locations	BG/JsD	
44	General safety briefing and update on testing	APS/NRC/YOW	
45	Dry Run of tests with APS and NRC (if necessary)	APS/NRC	
46	Start Testing	APS/NRC	
	Each Testing Day		
47	Check with NRC the status of the testing site, tunnel, weather etc	MR	
48	Deicide personnel requirements for following day for 24hr notice	MR/WU	
49	Prepare equipment and fluid to be used for test	DY	
50	Manufacture ice pellets	JS/YOW	
51	Prepare photography equipment	BG	
52	Prepare data forms for test	VZ	
53	Conduct tests based on test plan	APS	
54	Modify test plan based on results obtained	WU/JD/MR	
55	Update ice pellet, snow, raw ice, and fluid Inventory (end of day)	VZ/JS	
56	Update Test Log and Test Plan (ongoing and end of day)	VZ	

ATTACHMENT VIII – General Form/ Calibration

GENERAL FORM (EVERY CALIBRATION TEST)

DATE: ______________________ RUN # (Plan #): ____________

OJECTIVE: ☐ Angle of Attack Sweeps ☐ Surface-oil Flow Visualization ☐ Surface Roughness Tests

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

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

WIND TUNNEL START TIME: __________ ROTATION ANGLE: __________

WIND TUNNEL END TIME: __________ PROJECTED SPEED (S/KTS): __________

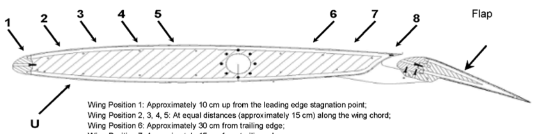
FLAP SETTING (20°, 0°): __________

OIL APPLIED: Y / N OIL DETAILS: ______________________

☐ Full Wing ☐ Partial Wing (describe) ______________________

GRIT APPLIED: Y / N GRIL DETAILS: ______________________

☐ Full Wing ☐ Partial Wing (describe) ______________________

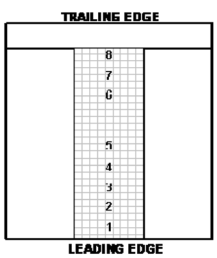


☐ Small Endplates

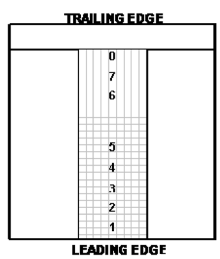
☐ Large Endplates

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;
Wing Position 9: Midway up the flap; and
Underside: Approximately 40 cm up from the leading edge stagnation point.

<u>Before the Takeoff Run</u>



<u>After the Takeoff Run</u>



COMMENTS : ______________________

____

____

____

____

HANDWRITTEN BY: ______________________

☐ Check if further details are available behind this sheet

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\Wind Tunnel\Final Version 1.0\Wind Tunnel Tests Final Version 1.0.doc
Final Version 1.0, January 11

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ATTACHMENT IX – 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°): ____________

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/dm^2/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/dm^2/h):		Droplet Size (mm):	
Exposure Time:		Needle:	
		Flow:	
		Pressure	

SNOW APPLICATION (if applicable)			
Actual start time:		Actual End Time:	
Rate of Snow Applied (g/dm^2/h):		Snow Size (mm):	<1.4 mm
Exposure Time:		Method:	☐ Dispenser ☐ Sieve
Total SN Required per Dispenser:			

COMMENTS ____________

MEASUREMENTS BY: ____________ HANDWRITTEN BY: ____________

ATTACHMENT X – 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:				

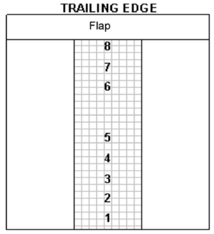
FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2			
8			
Flap			
Time:			

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

Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: __________

TRAILING EDGE

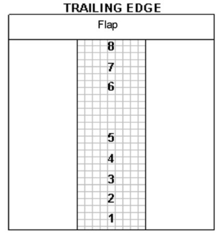


LEADING EDGE

Comments:____________________

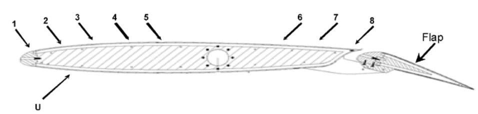
Wing and Plate Condition
Before the Takeoff Run
Time: __________

TRAILING EDGE



LEADING EDGE

Comments:____________________



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 XI – 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 completed 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 XII – 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	g
In each Dispensor	336	g

Snow needed for entire test

In each Dispensor	336	g
Total Amount Snow Needed for Entire Test	1344	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 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. The use of Dispensor Stand Extention is needed.

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

ATTACHMENT XIII – 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 XIV – 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 XV – Fluid Receipt Form

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 XVI – Log of Fluid Sample Bottles

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

ATTACHMENT XVII – 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 2008-11.

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/dm²/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/dm²/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.

ATTACHMENT XVIII – 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. Full-scale testing is required to investigate the aerodynamic performance of a wing section contaminated with dry, un-adhered snow.

Objective

To investigate the aerodynamic performance of a wing section contaminated with dry, un-adhered 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 XIX – Procedure: Ice Phobic Coatings

Background

There has been a recent industry interest in the use of ice phobic coatings to protect aircraft critical surfaces. Currently, some non-commercial operators are using ice phobic coatings on the aircraft radome and other aircraft surfaces. Previous work was conducted during the winter of 2009-10 with a severely contaminated wing section. It was recommended that application of these materials on different parts of the wing surface be investigated i.e. wing and flap leading edge, quiet areas, etc. It was recommended that testing be continued to investigate the protective properties of these coatings in precipitation conditions, and to verify the compatibility of these products with glycol de/anti-icing fluids.

Due to procedural limitations, it was not possible to have the ice phobic coatings applied to the airfoil. Instead, the ice phobic coating will be applied to one of the vertical turning vanes at the back end of the wind tunnel.

Objective

To gather observational data regarding the performance of the coatings following repeated applications of glycol and potential residue formations.

Methodology

The vertical turning vanes at the back end of the tunnel (which are essentially vertical airfoils) are approximately 20ft tall and with a 5ft chord. The intent is to coat the lower half of a vane with an ice phobic coating which results in 2 x 10ft X 5ft sections, or about 100ft² of coated surface. These vanes are typically covered in glycol and residues by the end of the wind tunnel testing period, therefore, by having one of the vanes coated may provide some observational indication into how the coatings behave with repeated applications of glycol and potential residue formations

- One vane should be treated with the ice phobic coating as per the manufacturer specification. The other vanes should be left untreated;
- Run wind tunnel with fluids as per schedule;
- DO NOT CLEAN VANES IN BETWEEN TEST RUNS;
- At the end of the testing period, the performance of the treated and un-treated sections of the wing should be compared.

Test Plan

Ongoing and independent of wind tunnel test plan.

ATTACHMENT XX – Procedure: Heavily Contaminated Vertical Stabilizer (Testing Feasibility)

Background

Preliminary flat plate testing has indicated that fluid endurance times can be significantly reduced on vertical surfaces, primarily due to fluid flow off and increased "catch-factor" resulting from high winds. The preliminary endurance time testing indicated that during snow conditions, a vertical surface failure is similar to a heavy snow condition due to the increased "catch-factor". It was recommended that preliminary testing be conducted on the current wing section to investigate the lift losses associated, which could then be translated to a vertical stabilizer.

Objective

To investigate the aerodynamic effects of a heavily contaminated vertical stabilizer.

Methodology

- Conduct a heavy snow test on the upper surface of the wing;
- Once the contamination is complete, apply a generous coating of the same anti-icing fluid to the underside of the wing;
- Run the wind tunnel to obtain aerodynamic data;
- Repeat test with un-contaminated fluid on both the upper and underside of the wing;
- Document results and develop methodology to translate the results to a vertical surface to simulate un-even contamination due to cross winds.

Test Plan

Testing should be limited due to the preliminary nature of the procedure. If results are promising, investigate feasibility of using a vertical stabilizer wing section for future wind tunnel testing.

ATTACHMENT XXI – Procedure: Type I Spot Deicing during CSW Frost Conditions

Background

The fundamental difference between both types of frost is how the wing skin temperature is cooled below ambient: radiation cooling versus conduction cooling. During natural active frost, the wing skin temperature will be cooled below ambient temperature as a result of radiation cooling from the cold clear sky. During cold soak wing conditions, however, the wing skin temperature is cooled and maintained at a temperature below ambient as a result of conduction cooling from the cold fluid stored inside the wing; either the aircraft was refueled with cold fuel, or following a flight, the wing and fluid will be cold soaked. Full-scale data is recommended to investigate the aerodynamic effects of CSW frost on a deiced airfoil protected with Type I fluid.

Objective

To investigate the aerodynamic effects of CSW frost on a deiced airfoil protected with Type I fluid.

Methodology

- Dilute Type I fluid to a 0ºC buffer with respect to the wing skin temperature (to simulate CSW);
- Apply fluid heated to 60ºC to wing section;
- Wait 45 minutes (the Type I HOT in frost) or until fluid fails;
- Run the wind tunnel and collect data; and
- Compare results to baseline uncontaminated Type I tests.

Test Plan

One to two tests are anticipated.

ATTACHMENT XXII – Procedure: Light and Very Light Snow HOT's

Background

Holdover time determination systems have been developed to provide greater accuracy for determining rate of precipitation and allowing for a better use of the holdover time tables. Some recent discussion has been raised about HOT's for light and very light snow with respect to the fluid condition at the end of the several hour holdover time and potential concerns with fluid dripping off and thinning out. It was recommended that some preliminary testing be conducted in the wind tunnel to see how the fluid fails on an airfoil and to investigate the resulting aerodynamic effects.

Objective

To investigate the potential light and very light snow HOT's failure patterns and the respective effects on aerodynamic performance.

Methodology

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

- For a chosen fluid (ABC-S Plus suggested), conduct a test simulating very light snow conditions for an exposure time (72 minutes for rate of 3 $g/dm^2/h$) derived from the fluid specific HOT regression equations;
- Evaluate the condition of fluid and any potential dry-out or thinning of fluid at end of exposure period;
- Record lift data, visual observations, and manually collected data.

Test Plan

One to four comparative tests are anticipated for comparison to a baseline condition. The baseline should either be fluid only (50/50) or moderate snow, or both.

ATTACHMENT XXIII – 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.

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

One to four tests are anticipated.

APPENDIX C

FLUID THICKNESS, TEMPERATURE, AND BRIX DATA FORMS

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20/2012

Run: 49 (P039)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-16.1	-13.1	/	-15.1
T5	-16.1	-13.2	/	-14.6
TU	-16.3	-15.4	/	-15.3
Time:	09:40	9:54	/	10:14

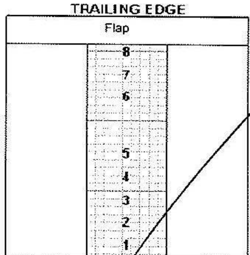
FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25	/	36.00
8		/	35.50
Flap		/	36.25
Time:	9:54	/	10:16

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	/	3
3			
4			
5	127	/	7
6			
7			
8	158	/	5
Flap	40	/	4
Time:	9:55	/	10:14

Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

TRAILING EDGE

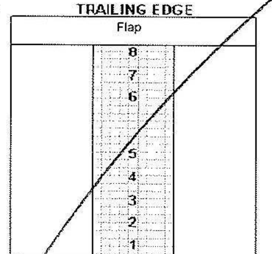


LEADING EDGE

Comments:

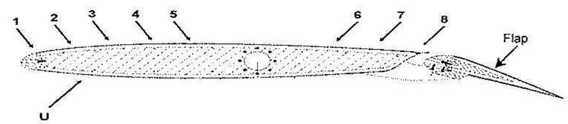
Wing and Plate Condition
Before the Takeoff Run
Time: ___________

TRAILING EDGE



LEADING EDGE

Comments:



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: -10 tilt after fluid pour

OBSERVER: DAVID

ASSISTED BY: VICTORIA

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Figure C1: Test # 49 (P039)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20/2012

Run: 50 (P039)

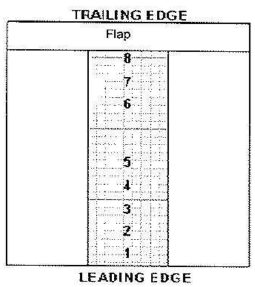
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.7	-13.1	/	-13.7
T5	-14.8	-13.4	/	-13.5
TU	-14.5	-13.2	/	-14.0
Time:	10:28	10:39	/	10:55

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	3300	/	35.25
8		/	34.50
Flap		/	34.50
Time:	10:38	/	10:56

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	2
3			
4			
5	134	/	9
6			
7			
8	150	/	7
Flap	45	/	7
Time:	10:38	/	10:55

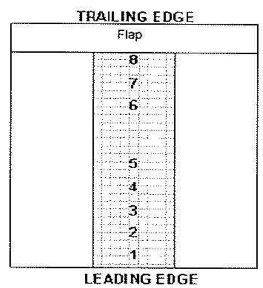
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

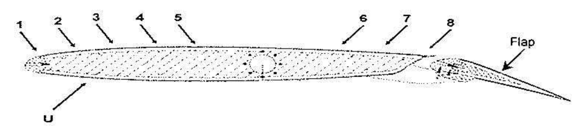


Comments:____________________

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: David

ASSISTED BY: Victoria

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Figure C2: Test #50 (P039)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20/2012

Run: 51 (P040)

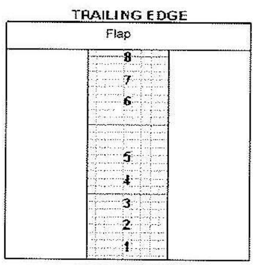
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.4	-12.1		-13.1
T5	-14	-12.6	/	-12.9
TU	-14	-12.7	/	-13.7
Time:	11:03	11:12	/	11:31

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25	/	34.75
8		/	35.00
Flap		/	35.00
Time:	11:12	/	11:32

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	/	4
3			
4			
5	150	/	6
6			
7			
8	158	/	7
Flap	40	/	4
Time:	11:12	/	11:31

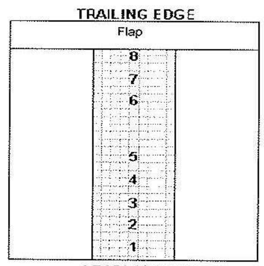
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

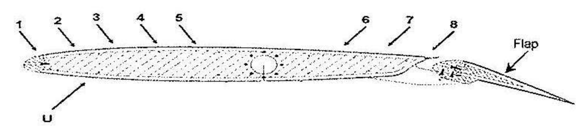


Comments: ____________

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: DAVID

ASSISTED BY: VICTORIA

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Figure C3: Test #51 (P040)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20/2012

Run: 52 (P040)

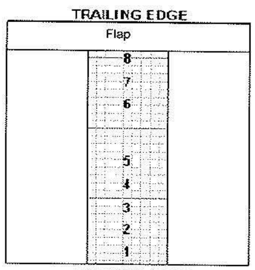
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-12.1	-12.3	/	-13.1
T5	-12.4	-12.6	/	-12.8
TU	-12.1	-12.1	/	-13.5
Time:	11:40	11:48	/	12:04

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	3350	/	3750
8		/	3525
Flap		/	3550
Time:	11:48	/	12:04

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	3
3			
4			
5	134	/	7
6			
7			
8	158	/	5
Flap	50	/	3
Time:	11:47	/	12:03

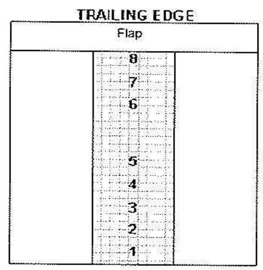
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

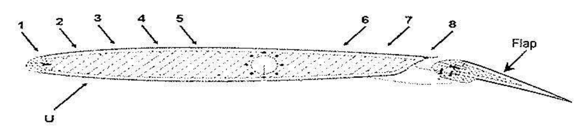


Comments:______________________

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

OBSERVER: DAVID

ASSISTED BY: VICTORIA

General Comments:______________________

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Figure C4: Test #52 (P040)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20/2012

Run: 53 (P065)

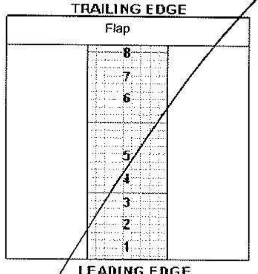
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-13.0	-12.4	/	-13.7
T5	-12.7	-12.4	/	-13.7
TU	-12.8	-12.7	/	-13.7
Time:	12:10	12:18	/	12:30

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	3450	/	35.75
8		/	35.00
Flap		/	35.75
Time:		/	12:33

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	/	1
3			
4			
5	134	/	9
6			
7			
8	142	/	7
Flap	45	/	9
Time:	12:17	/	12:33

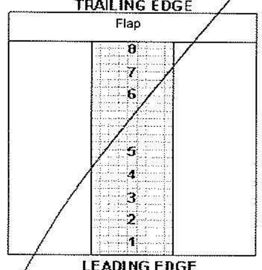
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

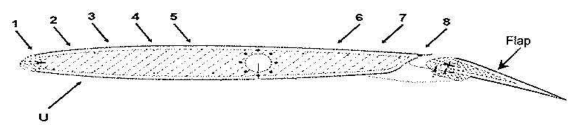


Comments: ____________

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: DAVID

ASSISTED BY: VICTORIA

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Figure C5: Test #53 (P065)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 20/2012

Run: 54 (P037)

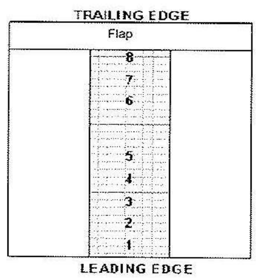
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-12.4	-12.4	/	-13.4
T5	-12.3	-12.3	/	-13.3
TU	-12.7	-12.6		-13.7
Time:	12:43	12:53	—	13:08

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	32.75	/	37.75
8		/	38.25
Flap			38.00
Time:	12:55	—	13:08

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40	—	1
3			
4			
5	80	—	4
6			
7			
8	65	/	7
Flap	18	/	10
Time:	12:53	—	13:08

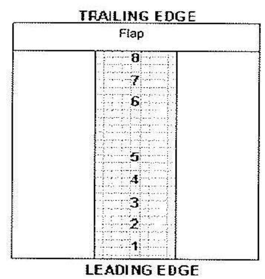
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

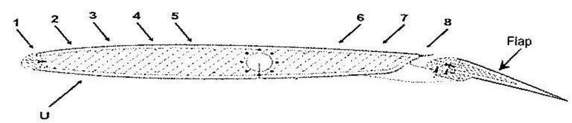


Comments:____________________

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: DAVID
ASSISTED BY: VICTORIA

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Figure C6: Test #54 (P037)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 20, 2012

Run: 55 (P038)

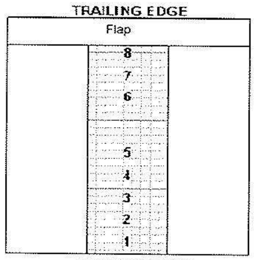
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-130	-12.3	/	test scrapped
T5	-12.8	-12.6	/	
TU	-13.2	-12.2	/	
Time:	13:11	13:18	/	

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	3750	/	test scrapped
8		/	
Flap		/	
Time:		/	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			test scrapped
2	55	—	
3			
4			
5	96	—	
6			
7			
8	70	—	
Flap	22	—	/
Time:	13:19	—	

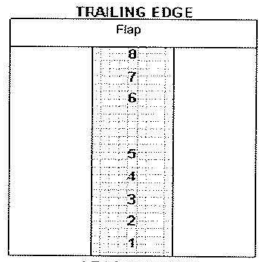
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

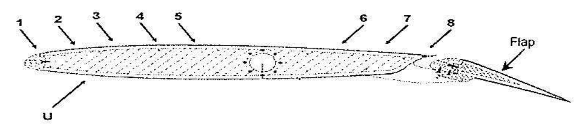


Comments: ____________

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: DAVID

ASSISTED BY: VICTORIA

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Figure C7: Test #55 (P038)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20/2012

Run: 56(P038)

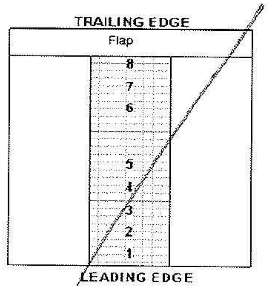
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-12.9	-12.4	/	-11.6
T5	-12.9	-12.5	/	-11.1
TU	-12.6	-12.0	/	-12.2
Time:	13:52	14:01	/	14:21

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	/	38.75
8		/	38.25
Flap		/	38.00
Time:	14:03	/	14:21

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	45	/	<1
3			
4			
5	104	/	6
6			
7			
8	80	/	7
Flap	24	/	9
Time:	14:02	/	14:21

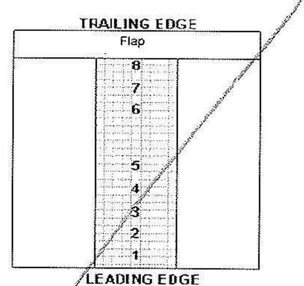
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

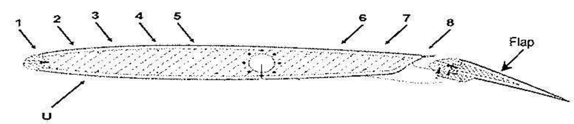


Comments: ____________

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: DAVID
ASSISTED BY: VICTORIA

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Figure C8: Test #56 (P038)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 20 2012 Run: 57 (P064)

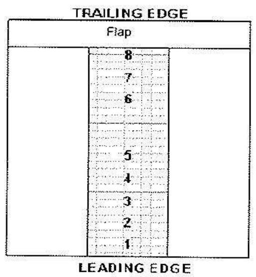
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-12.0	-11.8	/	-11.6
T5	-11.7	-12.2	/	-11.4
TU	-11.5	-11.5	/	-11.8
Time:	14:28	14:36	/	14:52

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	/	38.25
8	[shaded]	/	38.75
Flap	[shaded]	/	39.00
Time:	14:37	/	14:5

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	[shaded]	[shaded]	[shaded]
2	45	—	<1
3	[shaded]	[shaded]	[shaded]
4	[shaded]	[shaded]	[shaded]
5	96	/	5
6	[shaded]	[shaded]	[shaded]
7	[shaded]	[shaded]	[shaded]
8	70	/	7
Flap	24	/	7
Time:	14:35	—	14:51

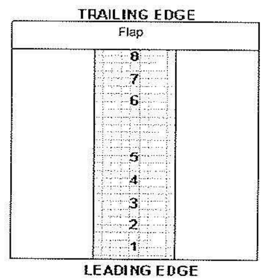
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

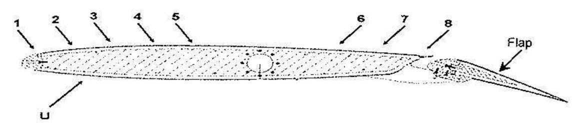


Comments: ____________

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: DAVID
ASSISTED BY: VICTORIA

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Figure C9: Test #57 (P064)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 20/2012

Run: 58(P047)

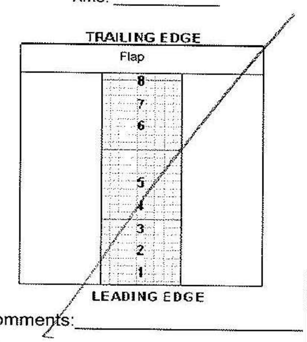
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-12.6	-11.5	-11.7	-13.3
T5	-13.0	-11.6	-11.3	-13.4
TU	-11.4	-11.6	N/A	-12.9
Time:	14:58	15:07	15:21	15:35

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	38.5	31.5	33.00
8		31.50	31.75
Flap		24.0	38.75
Time:	1508	1521	15:37

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	50	40	5
3			
4			
5	96	119	5
6			
7			
8	70	96	4
Flap	20	35	6
Time:	1508	15.21	15:37

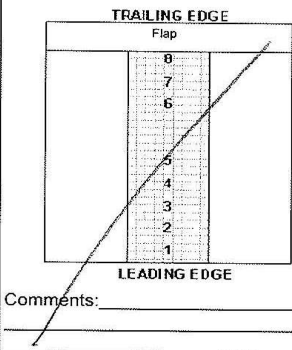
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

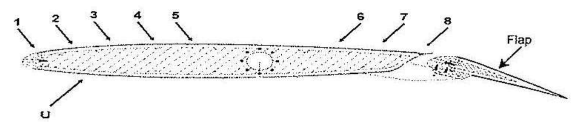


Comments: ____________

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

OBSERVER: DAVID

ASSISTED BY: VICTORIA

General Comments: ____________

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Figure C10: Test #58 (P047)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20, 2012

Run: 59 (P048)

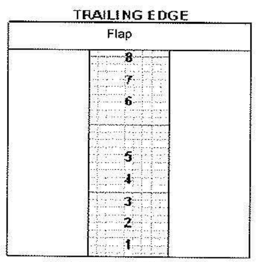
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-12.4	-12.0	-14.2	-13.6
T5	-12.9	-12.1	-14.3	-14.4
TU	-11.6	-12.3	-10.6	-13.3
Time:	15:50	15:58	16:12	16:20

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	29.0	31.75
8		31.50	29.75
Flap		27.50	32.00
Time:	15:59	16:11	16:25

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	50	96	3
3			
4			
5	80	127	3
6			
7			
8	70	150	3
Flap	22	6	3
Time:	15:58	16:11	16:24

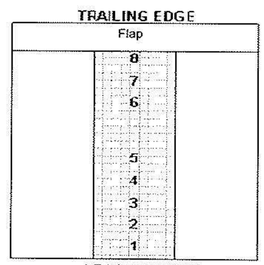
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ________

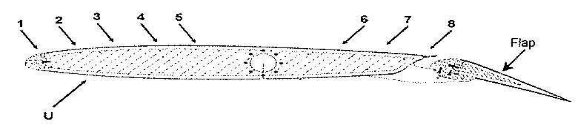


Comments: ________

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: DAVID
ASSISTED BY: VICTORIA

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Figure C11: Test #59 (P048)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26, 2012

Run: 100(P109)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.3	-6.1	/	-6.5
T5	-6.1	-6.3	/	-6.4
TU	-5.2	-5.3	/	-6.2
Time:	10:06	10:18	/	10:31

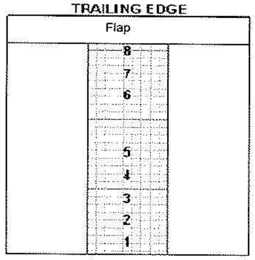
FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	—	/	—
8	37.00	/	37.25
Flap	[shaded]	/	37.25
Time:	10:19	/	10:32

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	[shaded]	[shaded]	[shaded]
2	—	—	—
3	[shaded]	[shaded]	[shaded]
4	[shaded]	[shaded]	[shaded]
5	—	—	—
6	[shaded]	[shaded]	[shaded]
7	[shaded]	[shaded]	[shaded]
8	119	/	10
Flap	30	/	7
Time:	10:18	/	10:31

Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

TRAILING EDGE

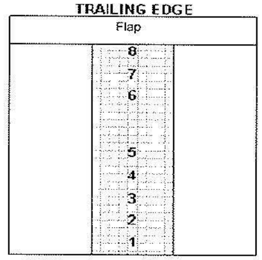


LEADING EDGE

Comments:____________________

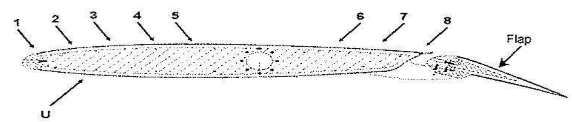
Wing and Plate Condition Before the Takeoff Run
Time: ____________

TRAILING EDGE



LEADING EDGE

Comments:____________________



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

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Figure C12: Test #102 (P109)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26, 2012

Run: 103 (P110)

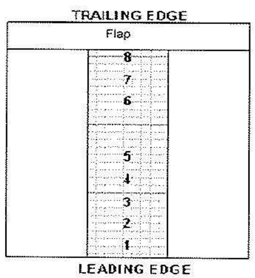
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.5	-5.6	/	-4.8
T5	-5.9	-6.1	/	-4.4
TU	-5.6	-4.8	/	-4.7
Time:	10:34	10:45	/	11:07

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	—	—	—
8	36.78	/	37.00
Flap	—	/	37.25
Time:	10:46	/	11:09

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	—	—	—
3			
4			
5	—	—	—
6			
7			
8	119	/	8
Flap	30	/	8
Time:	10:44	/	11:08

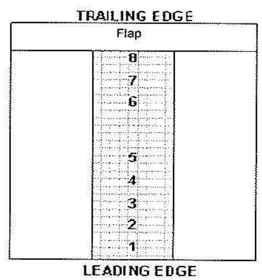
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

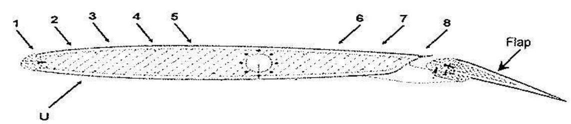


Comments:

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: DY
ASSISTED BY: VB

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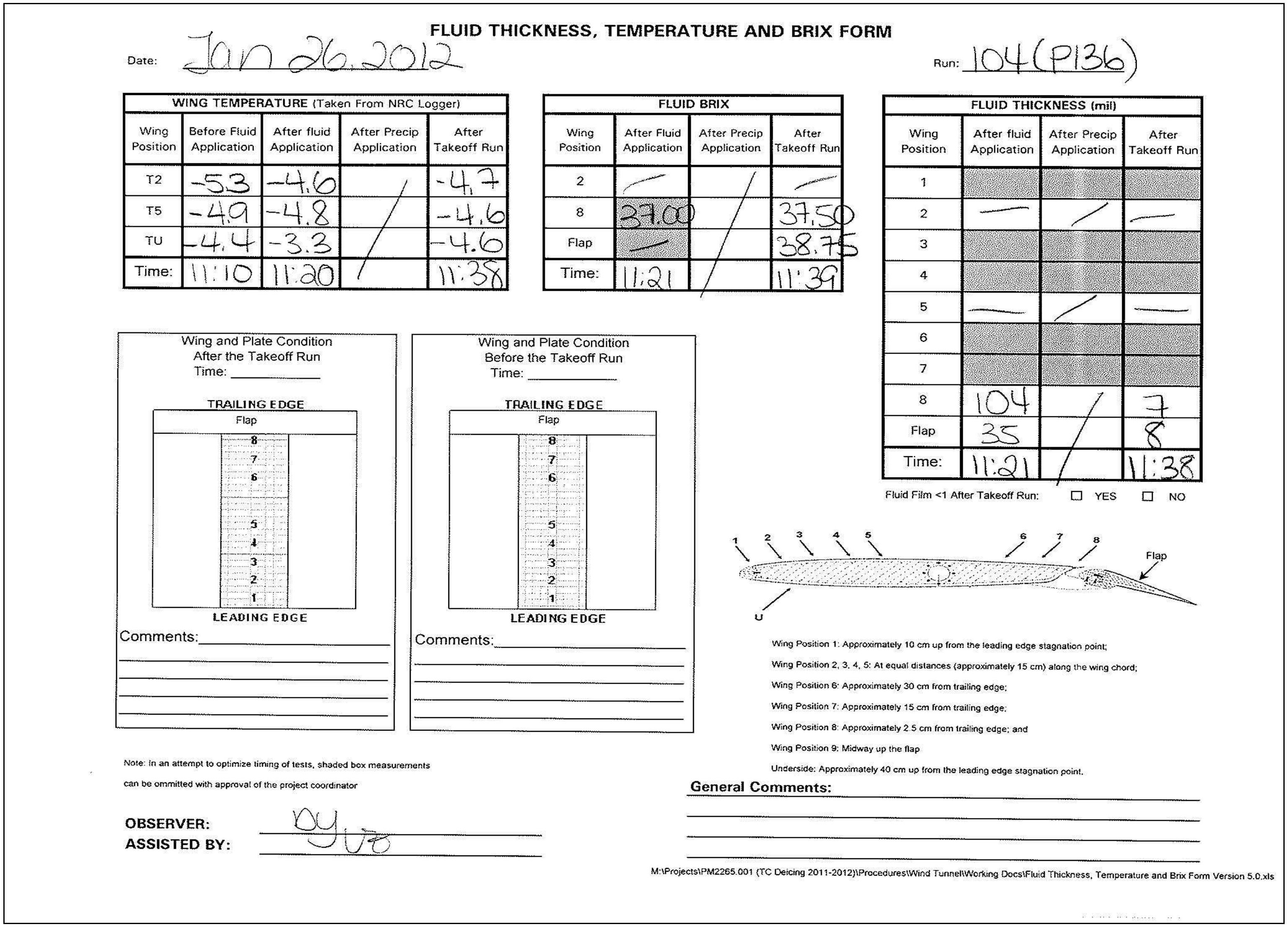
Figure C13: Test #103 (P110)



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26, 2012

Run: 104 (P136)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.3	-4.6	/	-4.7
T5	-4.9	-4.8	/	-4.6
TU	-4.4	-3.3	/	-4.6
Time:	11:10	11:20	/	11:38

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	—	/	—
8	37.00	/	37.50
Flap	—	/	38.75
Time:	11:21	/	11:39

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	—	/	—
3			
4			
5	—	/	—
6			
7			
8	104	/	7
Flap	35	/	8
Time:	11:21	/	11:38

Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

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 ommitted with approval of the project coordinator

General Comments: ____________

OBSERVER: DY
ASSISTED BY: VB

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Figure C14: Test #104 (P136)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26, 2012

Run: 105(P111)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-4.6	/	-4.2
T5	/	-4.5	/	-4.3
TU	/	-3.1	/	-4.3
Time:	/	11:54	/	12:11

FLUID BRIX

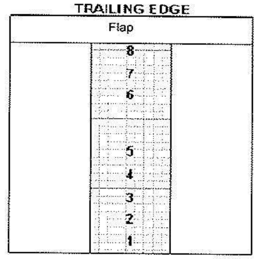
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	/	/	/
8	3300	/	3450
Flap	—	/	34.75
Time:	11:58	/	12:10

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	/	/	/
3		/	
4		/	
5	/	/	/
6		/	
7		/	
8	119	/	9
Flap	45	/	5
Time:	11:57	/	12:10

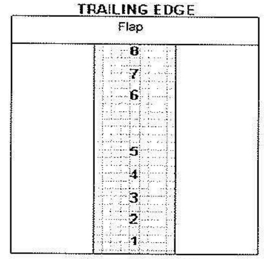
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ________

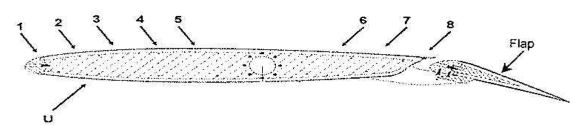


Comments:________________

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

OBSERVER: DY

ASSISTED BY: UTO

General Comments:

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Figure C15: Test #105 (P111)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26, 2012

Run: 106(P112)

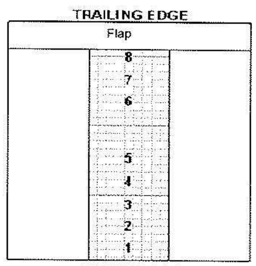
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-2.6	-3.8	/	-2.7
T5	-2.2	-4.8	/	-2.6
TU	-2.1	-2.3	/	-2.9
Time:	12:30	12:38	/	12:57

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	—	/	—
8	33.50	/	35.75
Flap	—	/	35.50
Time:	12:41	/	12:57

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	—	—	—
3			
4			
5	—	—	—
6			
7			
8	112	/	9
Flap	45	/	7
Time:	12:41	—	12:57

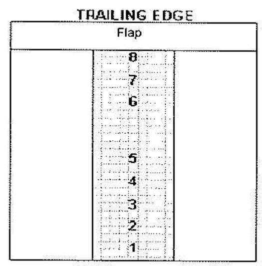
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

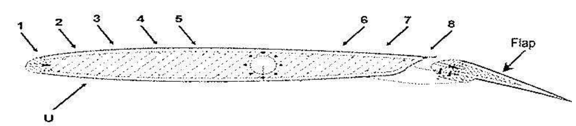


Comments: ____________

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: DY UB

ASSISTED BY: ____________

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Figure C16: Test #106 (P112)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26, 2012

Run: 107(P137)

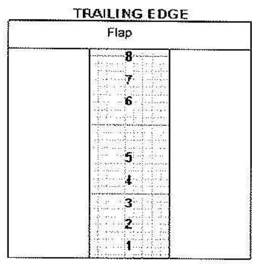
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-2.4	-3.4	/	-3.0
T5	-2.8	-4.0	/	-3.1
TU	-2.7	-2.5	/	-3.2
Time:	13:01	13:13	/	13:24

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	—	/	—
8	33.25	/	35.50
Flap		/	36.50
Time:	13.13	/	13:25

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	—	/	—
3		/	
4		/	
5	—	/	—
6		/	
7		/	
8	119	/	7
Flap	45	/	5
Time:	13:13	/	13.24

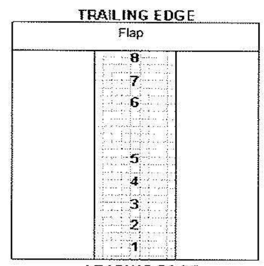
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

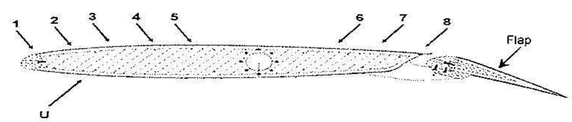


Comments: ___________

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: DY
ASSISTED BY: UB

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Figure C17: Test #107(P137)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26, 2012

Run: 108 (P113)

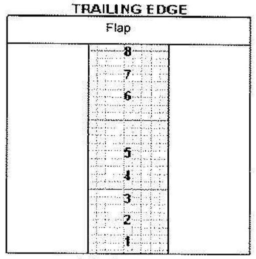
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-3.4	-3.1	/	-2.4
T5	-2.3	-3.9	/	-2.1
TU	-2.2	-1.9	/	-2.2
Time:	13:33	13:45	/	14:04

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	/	/	/
8	36.25	/	39.25
Flap		/	42.00
Time:	13:44	/	14:05

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	—	—	—
3			
4			
5	—	—	—
6			
7			
8	104	/	8
Flap	30	/	<1
Time:	13:44	/	14:04

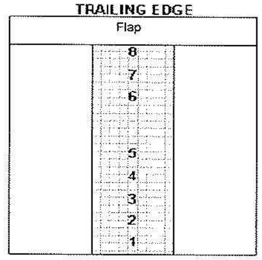
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

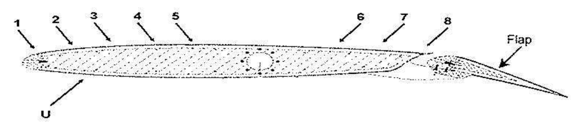


Comments: ____________

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: DY

ASSISTED BY: [illegible]

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Figure C18: Test #108 (P113)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26, 2012

Run: 109 (P114)

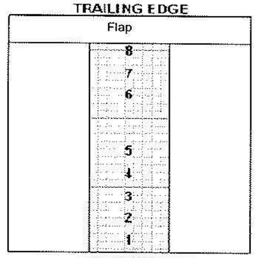
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous test	-3.0	/	-2.5
T5		-3.7	/	-2.6
TU		-2.4	/	-2.3
Time:		14:20	/	14:33

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	—	/	—
8		/	38.78
Flap	36.25	/	45.75
Time:	14:20	/	14:34

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	—	/	—
3		/	
4		/	
5	—	/	—
6		/	
7		/	
8	112	/	7
Flap	30	/	<1
Time:	14:19	/	14:34

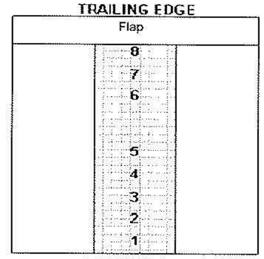
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ___________

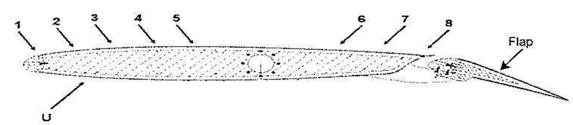


Comments: ___________

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: DY
ASSISTED BY: JJ / VB

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Figure C19: Test #109 (P114)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26, 2012

Run: 110(P114)

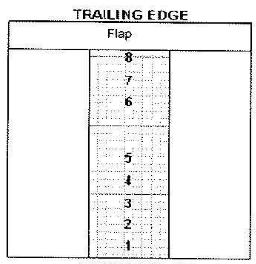
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous end temp	-3.1	/	-2.8
T5		-4.1		-3.1
TU		-1.9		-2.6
Time:		14:47		15:00

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	/	/	/
8	35.75		38.75
Flap			43.50
Time:	12:48	/	15:00

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	—	—	—
3			
4			
5	—	—	—
6			
7			
8	112	/	8
Flap	30	/	<1
Time:	12:47	/	1500

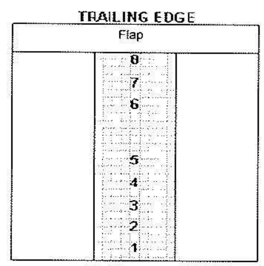
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

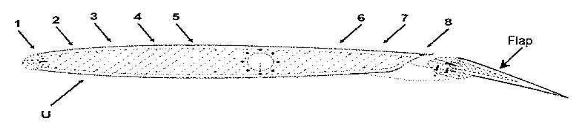


Comments:____________________

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: DY

ASSISTED BY: JJ UB

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Figure C20: Test #110 (P114)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 26/2012

Run: 111(P138)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-3.2	/	-2.8
T5		-4.1	/	-3.0
TU		-2.1	/	-2.6
Time:		15:15	/	15:25

FLUID BRIX

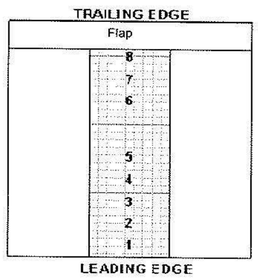
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	/	/	/
8	36.00	/	38.50
Flap		/	39.25
Time:	15:15	/	15:25

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	—	—	—
3			
4			
5	—	—	—
6			
7			
8	119	/	8
Flap	40	/	2
Time:	15:15	/	15:25

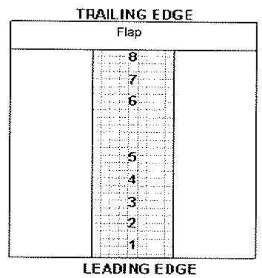
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

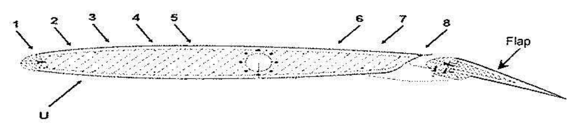


Comments:___________________

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: DY

ASSISTED BY: VT

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Figure C21: Test #111 (P138)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 29, 2012

Run: 115 (P041)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-2.6	-1.1	/	-2.5
T5	-2.4	-1.5	/	-2.6
TU	-1.9	-1.7	/	-2.3
Time:	22:50	22:58	/	23:13

FLUID BRIX

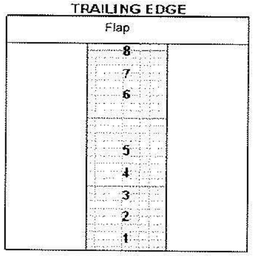
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.75	/	36.50
8		/	35.75
Flap		/	36.50
Time:	22:58	/	

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65	/	<1
3			
4			
5	119	/	7
6			
7			
8	96	/	8
Flap	30	/	2
Time:	22.58	—	23.12

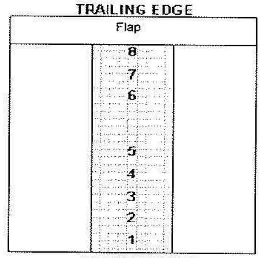
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

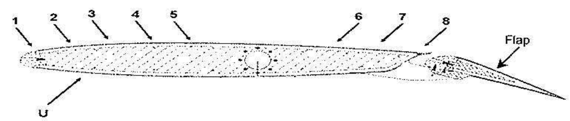


Comments:____________________

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: DY
ASSISTED BY: UD

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Figure C22: Test #115 (P041)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 29, 2012

Run: 116 (P042)

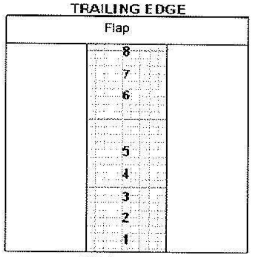
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-1.7	-1.4	/	-1.9
T5	-1.8	-1.8	/	-1.8
TU	-1.6	-1.1	/	-1.7
Time:	23:20	23:28	/	23:44

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	38.00	/	37.25
8	(shaded)	/	36.50
Flap	(shaded)	/	37.50
Time:	23:28	/	23:43

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	(shaded)	(shaded)	(shaded)
2	70	—	1
3	(shaded)	(shaded)	(shaded)
4	(shaded)	(shaded)	(shaded)
5	112	—	4
6	(shaded)	(shaded)	(shaded)
7	(shaded)	(shaded)	(shaded)
8	104	/	7
Flap	35	/	4
Time:	23:28	/	23:43

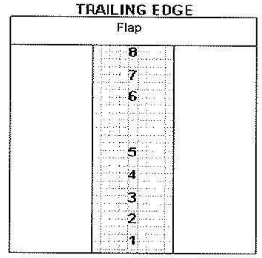
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

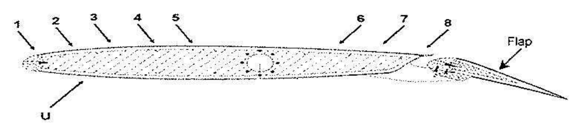


Comments: ____________________

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: DY
ASSISTED BY: UZ

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Figure C23: Test #116 (P042)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 29, 2012

Run: 117(P066)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	See previous test	-1.4	/	-2.7
T5		-1.8	/	-3.2
TU		-1.1	/	-2.4
Time:		23:54	/	00:06

FLUID BRIX

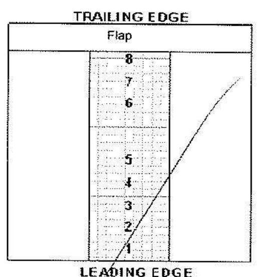
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.75	/	37.75
8		/	36.25
Flap		/	37.00
Time:	23:54	/	00:09

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	—	3
3			
4			
5	119	—	6
6			
7			
8	96	/	8
Flap	28	/	4
Time:	23:54	/	00:08

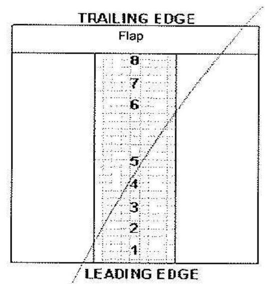
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

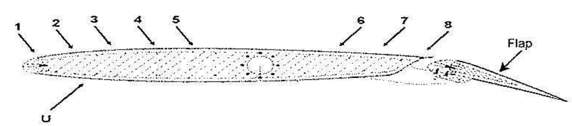


Comments: ____________

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: DY
ASSISTED BY: VE

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Figure C24: Test #117 (P066)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 30, 2012

Run: 118 (P045)

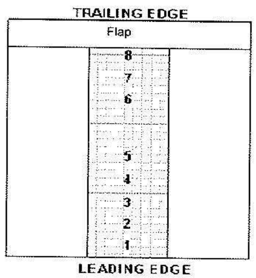
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-1.9	-10.4	-4.6
T5		-2.3	-10	-4.7
TU		-1.8	-4.2	-4.4
Time:		00:22	00:48	1:04

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.75	20.25	26.00
8		19.0	26.50
Flap		17.0	25.50
Time:	00:22	0:48	1:03

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	112	<1
3			
4			
5	119	158	6
6			
7			
8	96	158	4
Flap	30	9	6
Time:	00:21	0:48	1:03

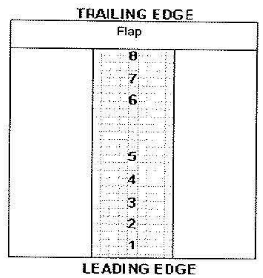
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

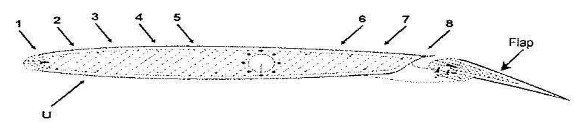


Comments: ____________

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: DY

ASSISTED BY: VZ

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Figure C25: Test #118 (P045)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 30, 2012

Run: 119 (P046)

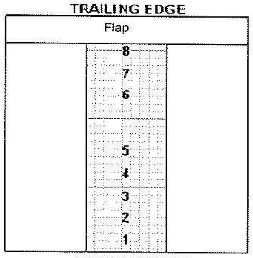
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	[illegible]	-3.2	-10.7	-5.0
T5		-3.7	-10.8	-5.2
TU		-4.1	-5.3	-4.9
Time:		1:19	1:49	2:04

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.50	20.0	31.00
8		25.0	26.00
Flap		19.50	26.00
Time:	1:17	1:43	2:03

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65	96	1
3			
4			
5	119	158	6
6			
7			
8	96	158	8
Flap	30	12	8
Time:	1:17	1:43	2:02

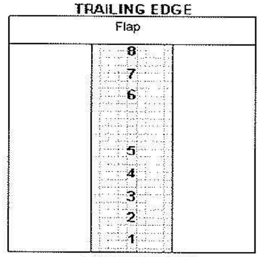
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

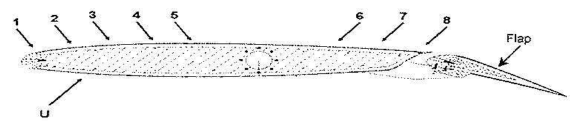


Comments:______________________

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: DY
ASSISTED BY: JP

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Figure C26: Test #119 (P046)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 30, 2012

Run: 120 (P068)

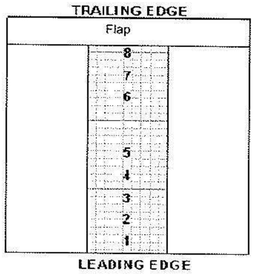
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	per pump	-3.5	-11.5	-6.3
T5		-4.0	-11.3	-6.4
TU		-4.0	-6.3	-6.3
Time:		2:25	2:51	3:05

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.50	22.0	26.25
8		21.5	25.00
Flap		15.5	27.50
Time:	2:26	2:49	3:

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	96	<1
3			
4			
5	127	158	7
6			
7			
8	104	112	4
Flap	30	5	4
Time:	2:26	2:47	3:

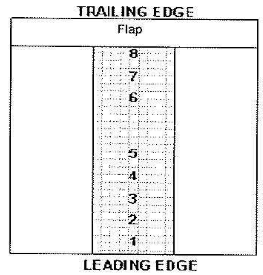
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

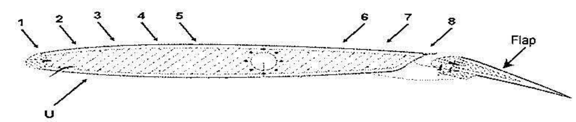


Comments: ____________

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: DY

ASSISTED BY: UB

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Figure C27: Test #120 (P068)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 30, 2012

Run: 121 (P039A)

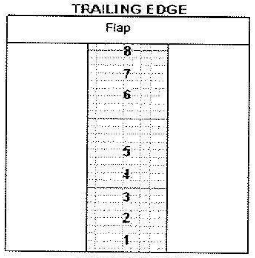
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous test	-4.3	/	-5.5
T5		-4.6	/	-6.2
TU		-5.5	/	-6.0
Time:		3:25	/	3:37

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.75	/	35.00
8		/	34.00
Flap		/	33.75
Time:	3:23	/	3:36

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	—	1
3			
4			
5	119	—	7
6			
7			
8	127	/	9
Flap	45	/	4
Time:	3:24	/	3:36

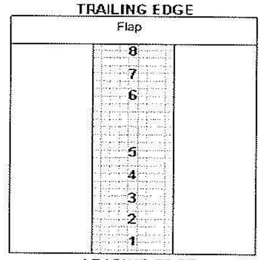
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

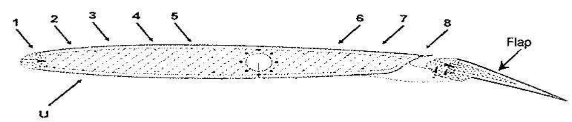


Comments: ___________

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: PY
ASSISTED BY: VZ

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Figure C28: Test #121 (P039A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 30, 2012

Run: 122 (P039A)

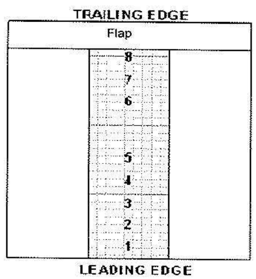
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous test	-4.6	/	-6.9
T5		-5.0	/	-7.4
TU		-4.7	/	-7.0
Time:		3:50	/	3:58

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25	/	33.75
8		/	34.50
Flap		/	34.25
Time:	3:51	/	4:07

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	1
3			
4			
5	96	/	9
6			
7			
8	34	/	8
Flap	30	/	7
Time:	3:49	/	4:06

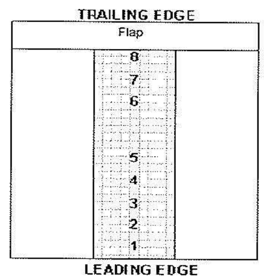
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

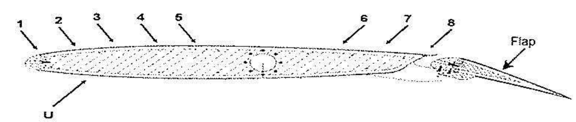


Comments: ____________

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: DY

ASSISTED BY: JUB

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Figure C29: Test #122 (P039A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 30, 2012

Run: 123 (P065A)

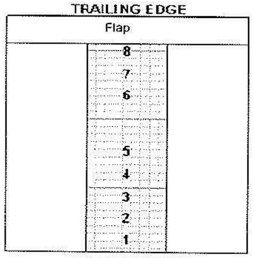
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	See previous test	N/A	/	-6.0
T5		N/A	/	-6.2
TU		N/A	/	-6.1
Time:		—	/	4:35

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.25	/	35.50
8		/	34.25
Flap		/	34.75
Time:	4:20	/	4:35

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	—	2
3			
4			
5	150	—	8
6			
7			
8	104	/	7
Flap	35	/	5
Time:	4:20	/	4:34

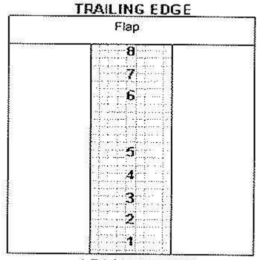
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

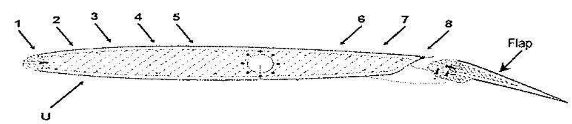


Comments: ____________

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: DY
ASSISTED BY: VT

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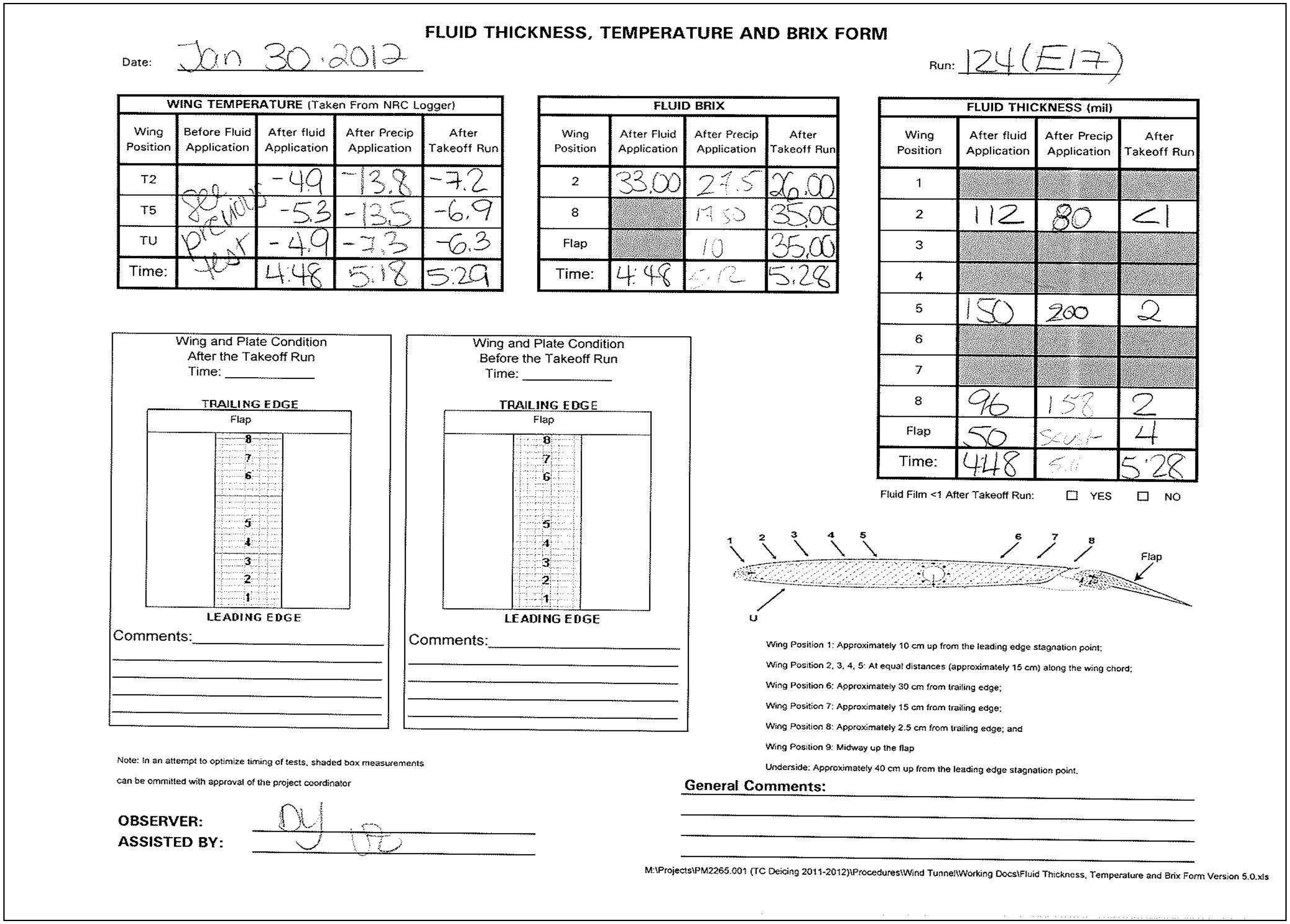
Figure C30: Test #123 (P065A)



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 30 2012

Run: 124 (E17)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous test	-4.9	-13.8	-7.2
T5		-5.3	-13.5	-6.9
TU		-4.9	-7.3	-6.3
Time:		4:48	5:18	5:29

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.00	27.5	26.00
8		17.50	35.00
Flap		10	35.00
Time:	4:48	5:12	5:28

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	112	80	<1
3			
4			
5	150	200	2
6			
7			
8	96	158	2
Flap	50	[illegible]	4
Time:	448	[illegible]	5:28

Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

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 ommitted with approval of the project coordinator

OBSERVER: DY
ASSISTED BY: VB

General Comments: ______

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Figure C31: Test #124 (E17)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 30, 2012

Run: 125 (E18)

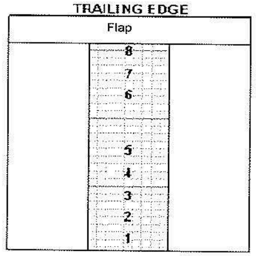
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	[illegible]	-5.1	-13.6	-9.2
T5		-5.1	-13.1	-9.2
TU		-4.7	-6.9	-8.6
Time:		5:41	6:11	6:18

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	33.50	16.75	27.75
8		19.75	25.50
Flap		8.0	25.50
Time:	5:42	6:06	6:22

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	65	<1
3			
4			
5	119	158	4
6			
7			
8	96	158	3
Flap	40	2	1
Time:	5:41	6:06	6:21

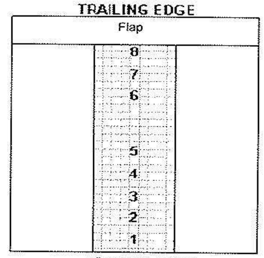
Fluid Film <1 After Takeoff Run: YES NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

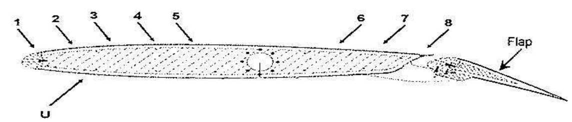


Comments:___________________

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: DY

ASSISTED BY: VB

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Figure C32: Test #125 (E18)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 31/2012

Run: 147 (P037A)

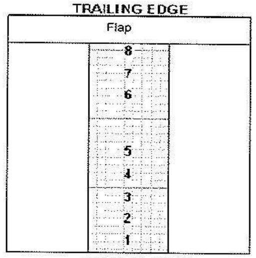
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-4.5	-3.8	/	-3.9
T5	-4.7	-4.1	/	-3.9
TU	-4.2	-3.9	/	-4.1
Time:	23:28	23:38	/	23:51

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	3600	/	36.25
8		/	36.25
Flap		/	36.50
Time:	23:37	/	23:50

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	—	5
3			
4			
5	134	—	9
6			
7			
8	119	/	10
Flap	65	/	9
Time:	23:38	/	23:50

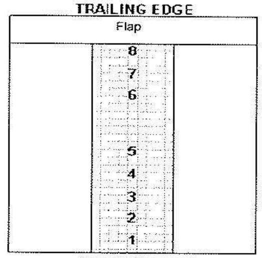
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

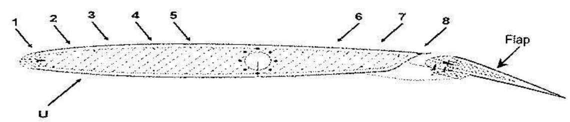


Comments: ____________

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

OBSERVER: DY
ASSISTED BY: VB

General Comments: ____________

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Figure C33: Test #147 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 31/2012

Run: 148(P037A)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-3.9	/	-3.0
T5		-4.4	/	-3.1
TU		-3.1	/	-3.2
Time:		00:02	/	00:19

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.25	/	36.50
8		/	36.00
Flap		/	36.50
Time:	00:02	/	00:18

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65	—	4
3			
4			
5	112	—	6
6			
7			
8	96	/	10
Flap	55	/	7
Time:	00:02	/	00:18

Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

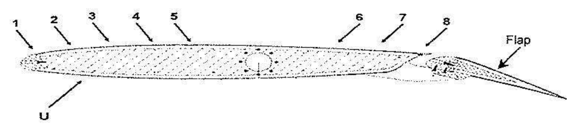
TRAILING EDGE
Flap
8 7 6 5 4 3 2 1
LEADING EDGE

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

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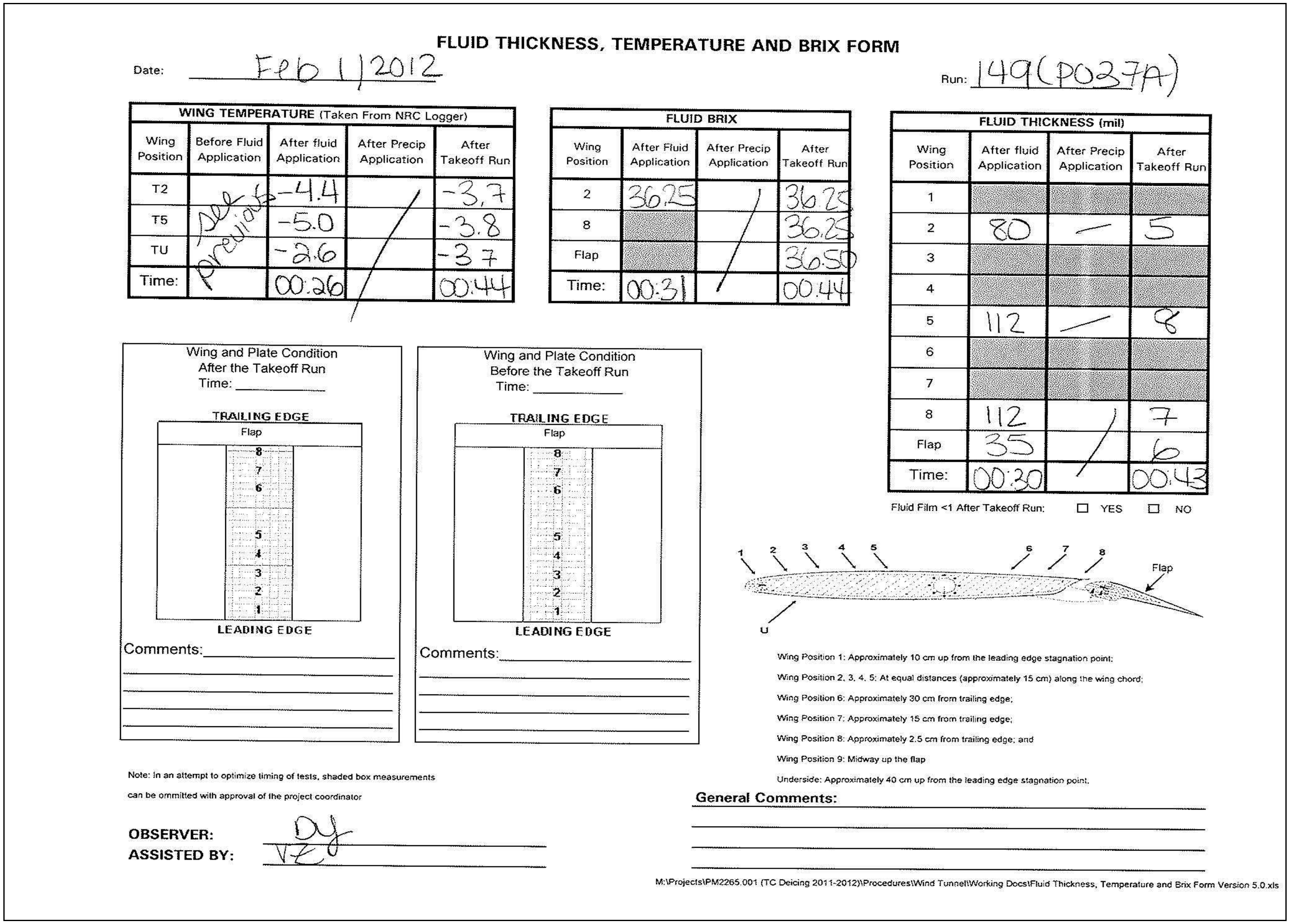
Figure C34: Test #148 (P037A)



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Feb 1 2012

Run: 149(P037A)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-4.4	/	-3.7
T5		-5.0	/	-3.8
TU		-2.6	/	-3.7
Time:		00:26	/	00:44

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.25	/	36.25
8		/	36.25
Flap		/	36.50
Time:	00:31	/	00:44

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	—	5
3			
4			
5	112	—	8
6			
7			
8	112	/	7
Flap	35	/	6
Time:	00:30	/	00:43

Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

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 ommitted with approval of the project coordinator

General Comments: ____________

OBSERVER: DY
ASSISTED BY: VZ

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Figure C35: Test #149 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: FEB 1 /2012

Run: 150(P037A)

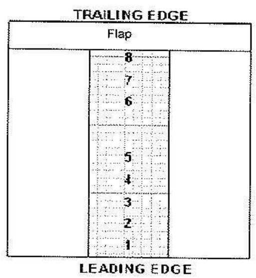
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-3.6	/	-3.6
T5		-4.2	/	-3.8
TU		-2.7	/	-3.6
Time:		00:56	/	1:09

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.25	/	36.00
8		/	36.25
Flap		/	36.50
Time:	00:55	/	1:09

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65	/	3
3			
4			
5	119	/	8
6			
7			
8	112	/	9
Flap	35	/	9
Time:	0:55	/	1:08

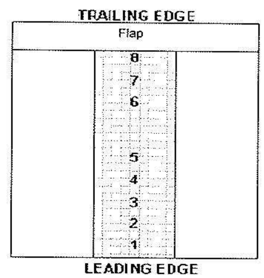
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

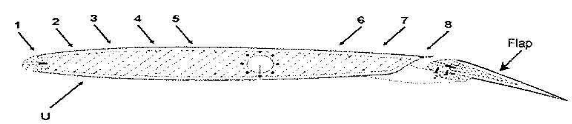


Comments: ____________

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

OBSERVER: DY
ASSISTED BY: VT

General Comments: ____________

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Figure C36: Test #150 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Feb 1 /2012

Run: 151 (P037A)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-3.1	/	-3.8
T5		-3.7		-4.1
TU		-2.0		-3.6
Time:		01:27		01:38

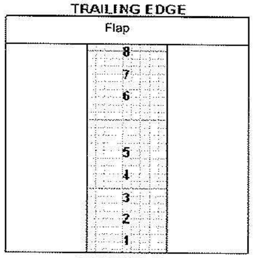
FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.25	/	36.25
8			35.75
Flap			36.50
Time:	01:27	/	1:40

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	—	3
3			
4			
5	127	—	9
6			
7			
8	142	/	10
Flap	40	/	9
Time:	1:26	/	1:39

Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

TRAILING EDGE

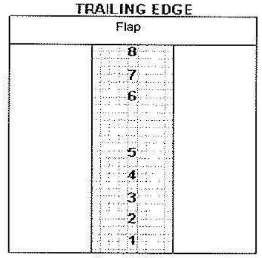


LEADING EDGE

Comments:

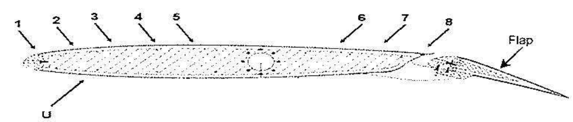
Wing and Plate Condition Before the Takeoff Run
Time: ____________

TRAILING EDGE



LEADING EDGE

Comments:



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

OBSERVER: DY

ASSISTED BY: VZ

General Comments:

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Figure C37: Test #151 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 1/2012

Run: 152(P037A)

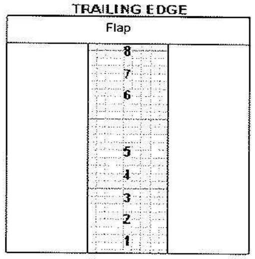
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-3.1	/	-3.1
T5		-3.6		-3.3
TU		-2.3		-3.2
Time:		01:54		2:06

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.25	/	36.50
8			36.25
Flap			36.50
Time:	1:53		2:05

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	—	4
3			
4			
5	134	—	4
6			
7			
8	112	/	10
Flap	35		8
Time:	1:53		2:05

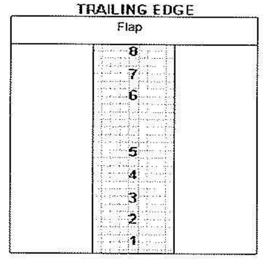
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

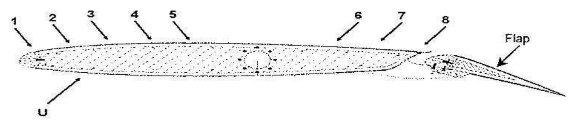


Comments:___________

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: DY

ASSISTED BY: VZ

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Figure C38: Test #152 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 1, 2012

Run: 155 (P037A)

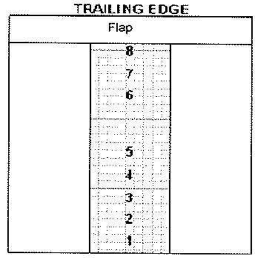
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-3.6	-3.2	/	-3.8
T5	-3.5	-3.7	/	-4.0
TU	-3.0	-2.9	/	-3.8
Time:	02:41	02:51	/	03:04

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.00	/	36.25
8		/	36.00
Flap		/	36.25
Time:		/	3:05

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	4
3			
4			
5	127	/	8
6			
7			
8	119	/	10
Flap	35	/	6
Time:	2:50	/	3:05

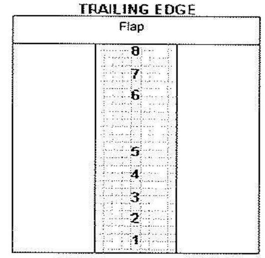
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ____________

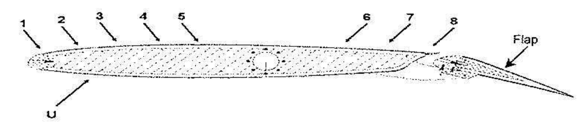


Comments: ____________

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: DY VB

ASSISTED BY: ____________

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Figure C39: Test #155 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Feb 1/2012

Run: 156(P037A)

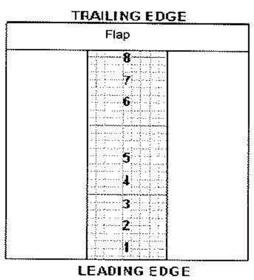
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-3.1	/	-3.9
T5		-3.8	/	-4.6
TU		-2.0	/	-4.0
Time:		3:22		3:34

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.75	/	36.25
8		/	36.00
Flap		/	36.25
Time:	3:23	/	3:37

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	3
3			
4			
5	134	/	7
6			
7			
8	119	/	9
Flap	35	/	8
Time:	03:23	/	3:37

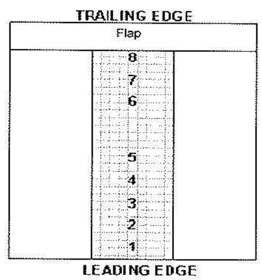
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

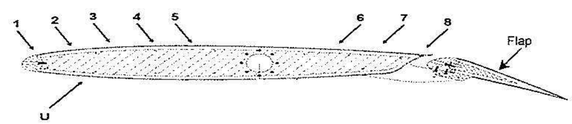


Comments: ____________

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: DY

ASSISTED BY: VZ

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Figure C40: Test #156 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Feb 1/2012

Run: 157 (P037A)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-2.6	/	-3.8
T5		-3.2	/	-4.4
TU		-2.1	/	-3.8
Time:		03:58	/	4:05

FLUID BRIX

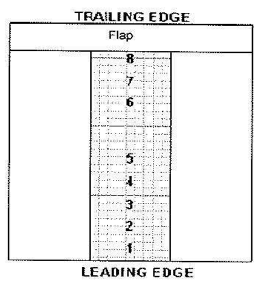
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.50	/	36.50
8		/	36.00
Flap		/	36.00
Time:	3:55	/	4:10

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	4
3			
4			
5	119	/	7
6			
7			
8	134	/	9
Flap	30	/	9
Time:	3:55	/	4:10

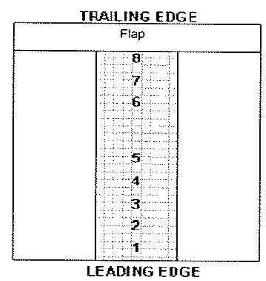
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

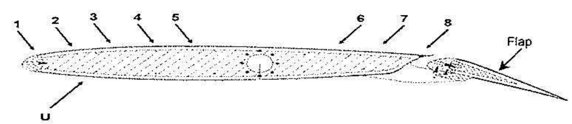


Comments:___________________

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

OBSERVER: DY

ASSISTED BY: VFt

General Comments:___________________

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Figure C41: Test #157 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Feb 1, 2012

Run: 158 (P037A)

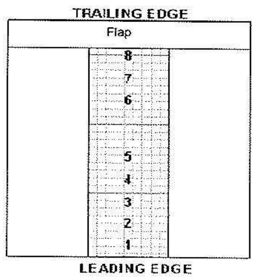
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-4.2	/	-2.6
T5		-4.3	/	-2.7
TU		-2.5	/	-2.9
Time:		4:18	/	4:39

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.50	/	36.25
8		/	35.75
Flap		/	36.00
Time:	4:23	/	4:38

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	/	5
3			
4			
5	134	/	9
6			
7			
8	96	/	9
Flap	35	/	7
Time:	4:23	/	4:38

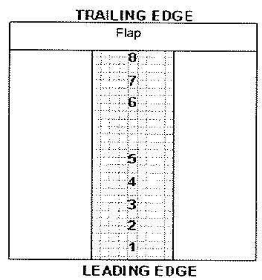
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

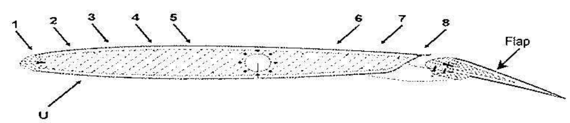


Comments:___________________

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: DY

ASSISTED BY: VZ

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Figure C42: Test #158 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: FEB 1, 2012

Run: 159 (P037A)

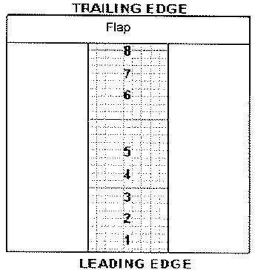
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-2.8	/	-3.4
T5		-3.4	/	-3.6
TU		-2.2	/	-3.0
Time:		4:54	/	5:01

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.25	/	35.75
8		/	35.75
Flap		/	35.75
Time:	4:55	/	5:11

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	/	3
3			
4			
5	104	/	8
6			
7			
8	104	/	11
Flap	35	/	4
Time:	4:54	/	5:10

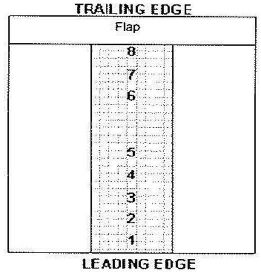
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ____________

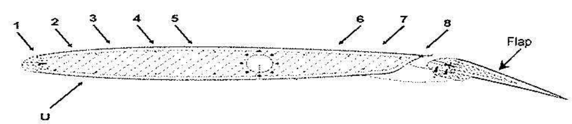


Comments: ____________

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: DY

ASSISTED BY: VF

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\Wind Tunnel\Working Docs\Fluid Thickness, Temperature and Brix Form Version 5.0.xls

Figure C43: Test #159 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: February 1, 2012

Run: 160 (P037A)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-2.4	/	-2.8
T5		-3.0		-3.0
TU		-1.8		-3.1
Time:		5:29		5:41

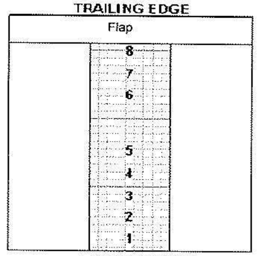
FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	3600	/	3625
8			3600
Flap			3600
Time:	5:28		5:40

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	64	/	4
3			
4			
5	134	/	5
6			
7			
8	112	/	9
Flap	35	/	6
Time:	5:28	/	5:40

Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition After the Takeoff Run
Time: ______

TRAILING EDGE

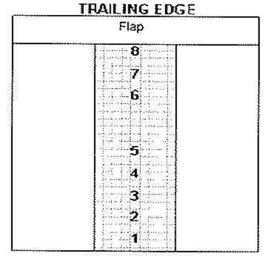


LEADING EDGE

Comments: ______

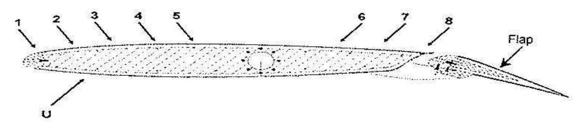
Wing and Plate Condition Before the Takeoff Run
Time: ______

TRAILING EDGE



LEADING EDGE

Comments: ______



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

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\Wind Tunnel\Working Docs\Fluid Thickness, Temperature and Brix Form Version 5.0.xls

Figure C44: Test #160 (P037A)

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Feb 1/2012

Run: 165 (P147)

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	-1.4	-1.7
T5	-1.6	-0.8	-1.9	-2.1
TU	-1.2	-0.9	-1.8	-2.0
Time:	2225	2242	2356	00:08

FLUID BRIX

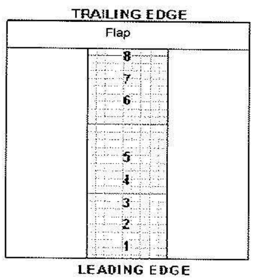
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	19.25	9.75	28.75
8		15.25	23.50
Flap		9.25	23.00
Time:	22:42	23:53	00:08

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	28	9	<1
3			
4			
5	50	22	<1
6			
7			
8	40	16	1
Flap	8	<1	<1
Time:	22:42	23:53	00:07

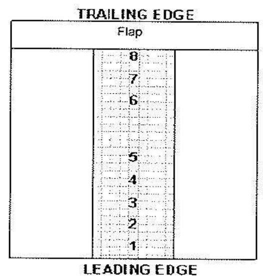
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

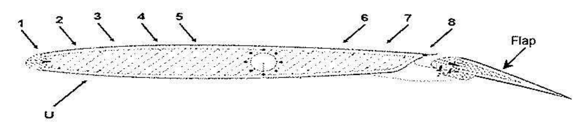


Comments: ___________

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: slush on flap not adhered

OBSERVER: DY

ASSISTED BY: VB

M:\Projects\PM2265.001 (TC Deicing 2011-2012)\Procedures\Wind Tunnel\Working Docs\Fluid Thickness, Temperature and Brix Form Version 5.0.xls

Figure C45: Test #165 (P147)

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APPENDIX D

REPEATABILITY OF FLUID/CONTAMINATION TESTS – SAE G-12 AWG MEETING 2012

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Repeatability of Fluid/Contamination Tests

Andy Broeren
NASA Glenn Research Center

Catherine Clark
Aviation Aerodynamics, Aerospace Portfolio, NRC

Marco Ruggi and John D'Avirro
APS Aviation Inc.

SAE G-12 AWG Meeting Prague, Czech Republic May 3 & 4, 2012

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Outline

- Summary of fluid test procedures
- Repeatability of fluid-only tests
- Repeatability of fluid + contamination tests
- Effect of fluid + contamination on stall
- Effects of large endplates on fluid-only tests
- Summary

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APS Fluid Test Procedures

- Ensure wing is clean and squeegee.
- Apply 18-20L of fluid, and let fluid settle for 5 min.
- Measure initial fluid thickness, brix, and temperature.
- Apply contamination in real-time.
- Re-measure fluid thickness, brix, and temperature.
- Tear down gantry, equipment, and clear tunnel.
- Run wind tunnel, take photos, record visual observations.
- Re-install gantry.
- Measure final fluid thickness, brix, and temperature.
- Perform final inspection of wing section.

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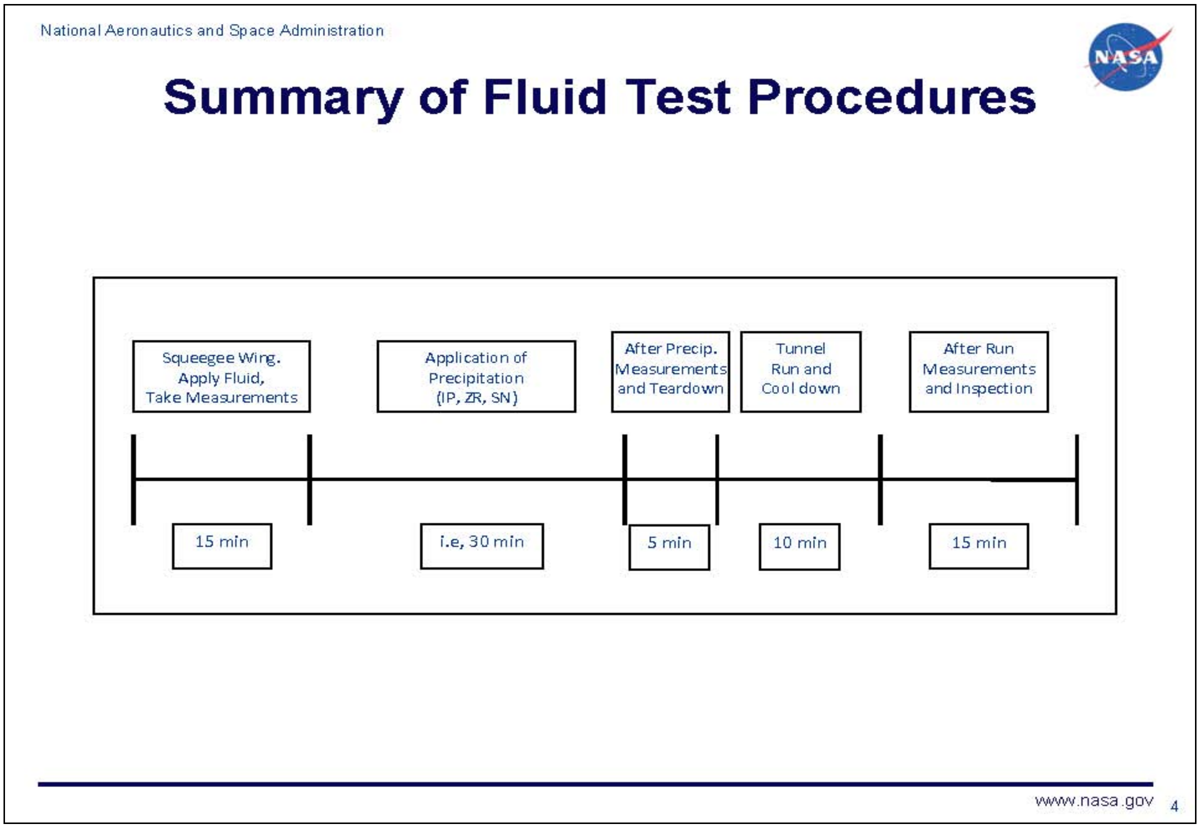
National Aeronautics and Space Administration
NASA
Summary of Fluid Test Procedures
Squeegee Wing. Apply Fluid, Take Measurements
Application of Precipitation (IP, ZR, SN)
After Precip. Measurements and Teardown
Tunnel Run and Cool down
After Run Measurements and Inspection
15 min
i.e, 30 min
5 min
10 min
15 min
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4


APS

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Fluid Viscosity

- Mid production fluids used for testing.
- Viscosity measured to better understand aerodynamic effects.

		Wind Tunnel 2012			Wind Tunnel 2011			Wind Tunnel 2010		
Fluid Name	LOWV (cP)	Batch #	Measured Viscosity (cP)	Falling Ball (sec)	Batch #	Measured Viscosity (cP)	Falling Ball (sec)	Batch #	Measured Viscosity (cP)	Falling Ball (sec)
Clariant Produkte Launch	7550	DEG4146145	12597	24	USHA024295 (Same as 2010)	10258	30	USHA024295	Measured in 2011	29
Dow Chemical Company EG106	24850	GMID297182/2L1701GKH6	37192	66	GMID297182 Batch 5	39792	54	WH0601GKDR	37200	48
Kilfrost Limited ABC-S PLUS	17900	B/13/12/11	19396	27	P/282/12/10	24695	32	P/22/12/09	20225	26
Octagon Process Inc. MaxFlight	5540	-	-	-	WL-122210-4	12437	19	-	-	-
Dow Chemical Company AD-49	12150	-	-	-	TANK#UL24	13097	23	-	-	-

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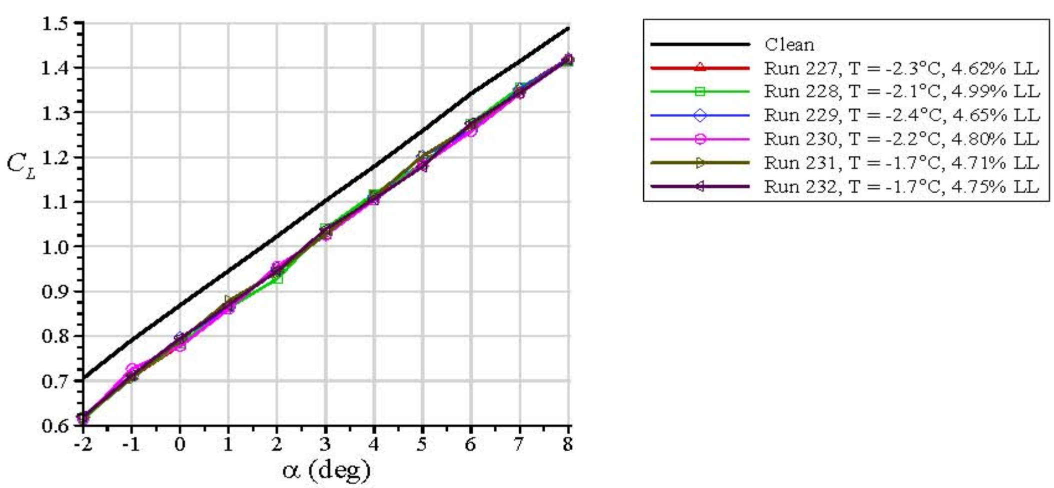
Fluid-Only Repeatability

- 2012 Tests using ABC-S PLUS fluid in back-to-back runs.
- Average C_L at 8 deg. = 1.418, σ = 0.002 or 0.14%
- Average Lift Loss at 8 deg. = 4.75%, σ = 0.13%



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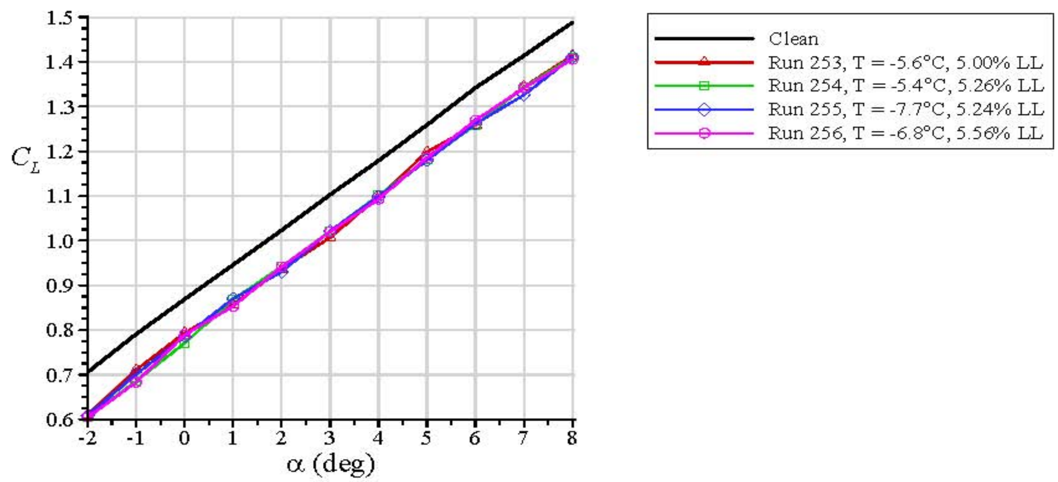
Fluid-Only Repeatability

- 2012 Tests using Launch fluid in back-to-back runs.
- Average C_L at 8 deg. = 1.410, σ = 0.003 or 0.24%
- Average Lift Loss at 8 deg. = 5.26%, σ = 0.23%



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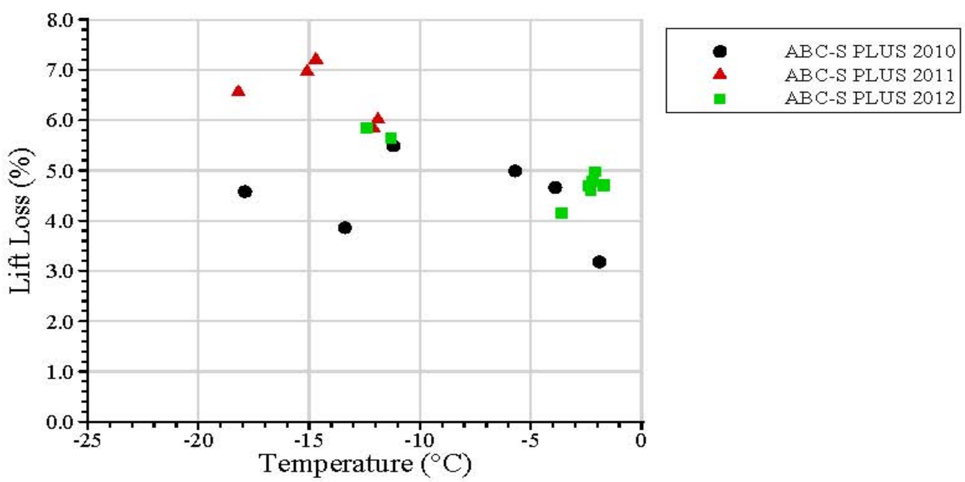
Fluid-Only Repeatability

- Year-to-year repeatability using ABC-S PLUS fluid.
- Data corrected to 19 sec. ramp time.



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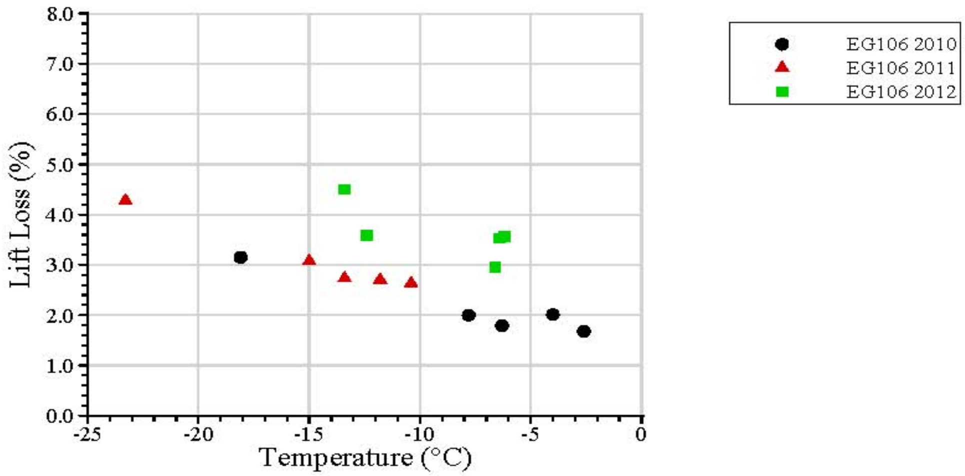
Fluid-Only Repeatability

- Year-to-year repeatability using EG106 fluid.
- Data corrected to 19 sec. ramp time.



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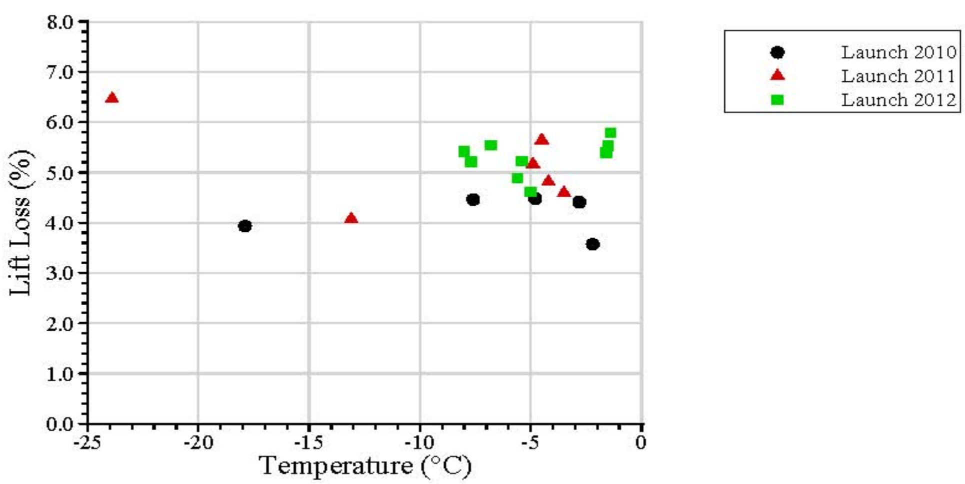
Fluid-Only Repeatability

- Year-to-year repeatability using Launch fluid.
- Data corrected to 19 sec. ramp time.



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Fluid-Only Repeatability Summary

- Results for the back-to-back runs demonstrates the repeatability of the test methods and aerodynamic data.
- Results for comparing runs from 2010, 2011 and 2012 showed good repeatability.
  - Lift loss is affected by variations in temperature and fluid viscosity.
  - Correction is applied for differences in ramp time.

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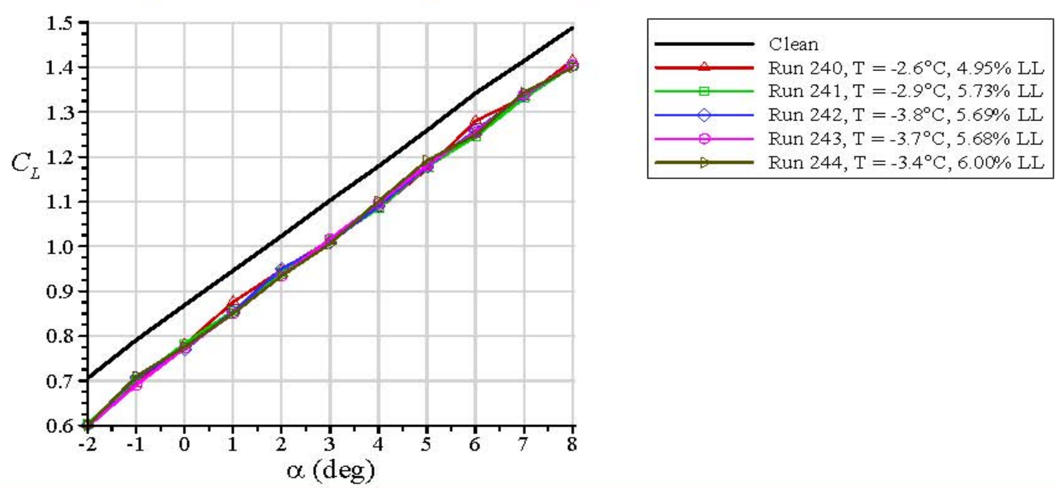
Fluid + Contamination Repeatability

- 2012 Tests using ABC-S PLUS fluid with moderate ice pellets in back-to-back runs.
- Average C_L at 8 deg. = 1.405, σ = 0.006 or 0.41%
- Average Lift Loss at 8 deg. = 5.61%, σ = 0.39%



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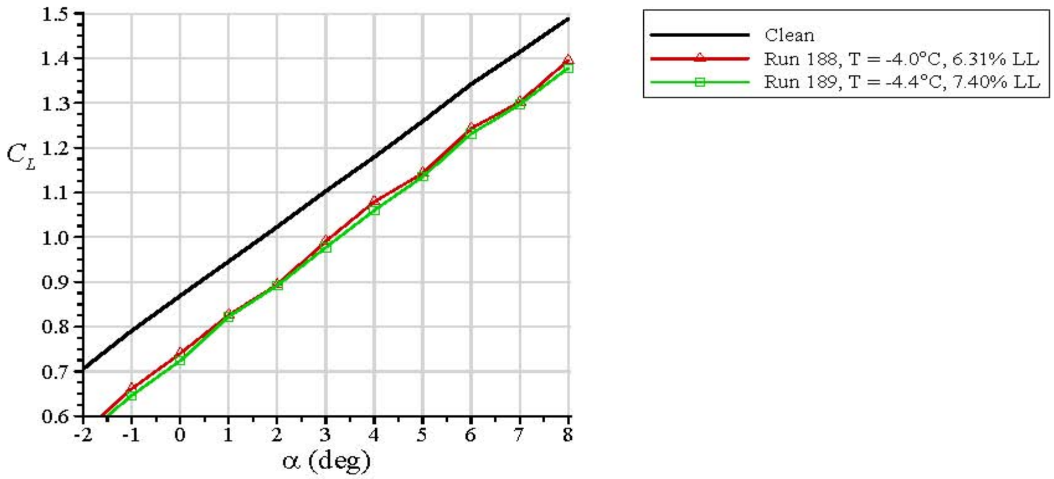
Fluid + Contamination Repeatability

- 2012 Tests using Launch fluid with moderate ice pellets in back-to-back runs.



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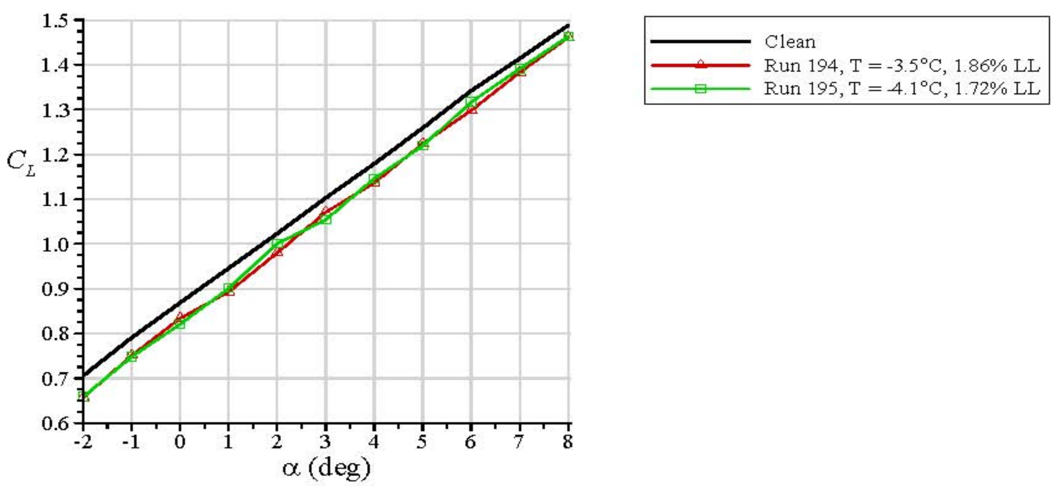
Fluid + Contamination Repeatability

- 2012 Tests using EG106 fluid with moderate ice pellets in back-to-back runs.



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Fluid + Contamination Repeatability

- Year-to-year repeatability for fluid + contamination test runs.

ABC-S PLUS, Moderate Ice Pellets, 10 min.			
Year	Run	Temp (°C)	Lift Loss at 8 deg.
2011	92	-14.0	12.8%
2012	59	-10.1	10.9%
		Avg. =	11.9%

EG106, Moderate Ice Pellets, 25 min.			
Year	Run	Temp (°C)	Lift Loss at 8 deg.
2010	21	-4.0	0.8%
2012	124	-3.5	1.8%
2012	125	-4.1	1.7%
		Avg. =	1.4%

Launch, Moderate Ice Pellets, 25 min.			
Year	Run	Temp (°C)	Lift Loss at 8 deg.
2010	47	-4.9	7.5%
2011	131	-4.5	5.1%
2012	118	-4.0	6.3%
2012	119	-4.4	7.4%
		Avg. =	6.6%
		Std. Dev. =	1.1%

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Repeatability Summary

- Summary of repeatability for 2012 test campaign, all data for $\alpha = 8$ deg.

Case	No. of Runs	Mean C_L	Standard Deviation	Std. Dev./Mean
Clean—entire campaign	37	1.487	0.0084	0.56%
Clean—back to back	6	1.484	0.0053	0.36%
ABC-S PLUS only back-to-back	6	1.418	0.0020	0.14%
Launch only back-to-back	4	1.410	0.0030	0.24%
ABC-S PLUS + Contamination back-to-back	5	1.405	0.0060	0.41%

Case	No. of Runs	Mean Lift Loss	Standard Deviation
ABC-S PLUS only back-to-back	6	4.75%	0.13%
Launch only back-to-back	4	5.26%	0.23%
ABC-S PLUS + Contamination back-to-back	5	5.61%	0.39%

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Fluid + Contamination Repeatability Summary

- Results for the back-to-back runs demonstrates the repeatability of the test methods and aerodynamic data.
- There was slightly higher back-to-back variation than fluid-only cases, which may be expected due to the addition of contamination.
- There were only a small number of comparable fluid and contamination cases from 2010, 2011 and 2012.
- Repeatability is considered acceptable given the number of variables such as temperature, ramp time, fluid viscosity, contamination, etc.

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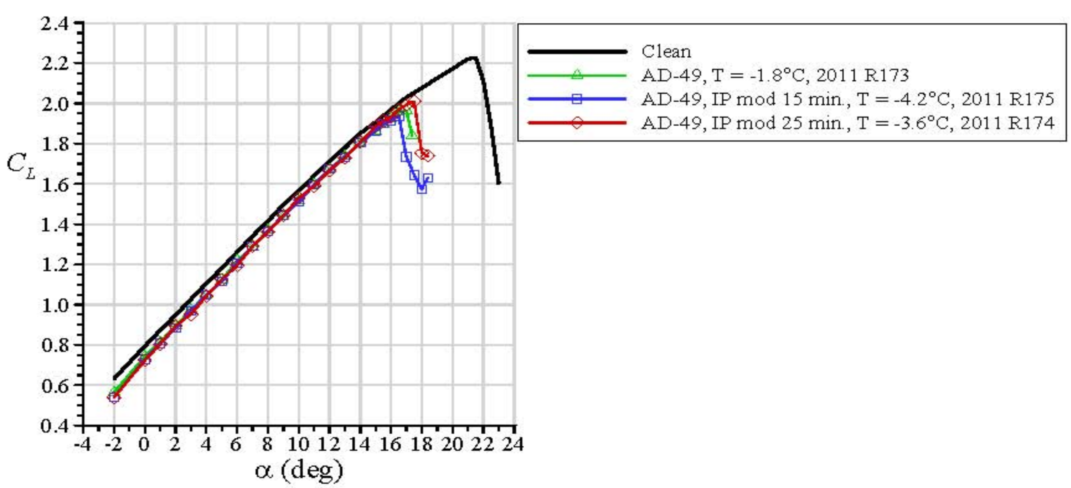
Fluid + Contamination Effects on Stall

- 2011 Tests with AD-49 fluid with and without contamination.



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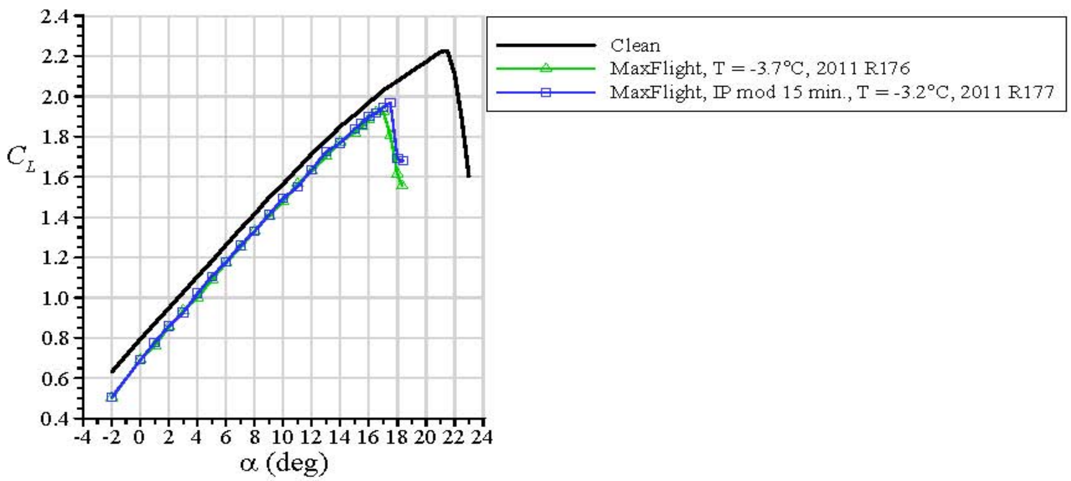
Fluid + Contamination Effects on Stall

- 2011 Tests with MaxFlight fluid with and without contamination.



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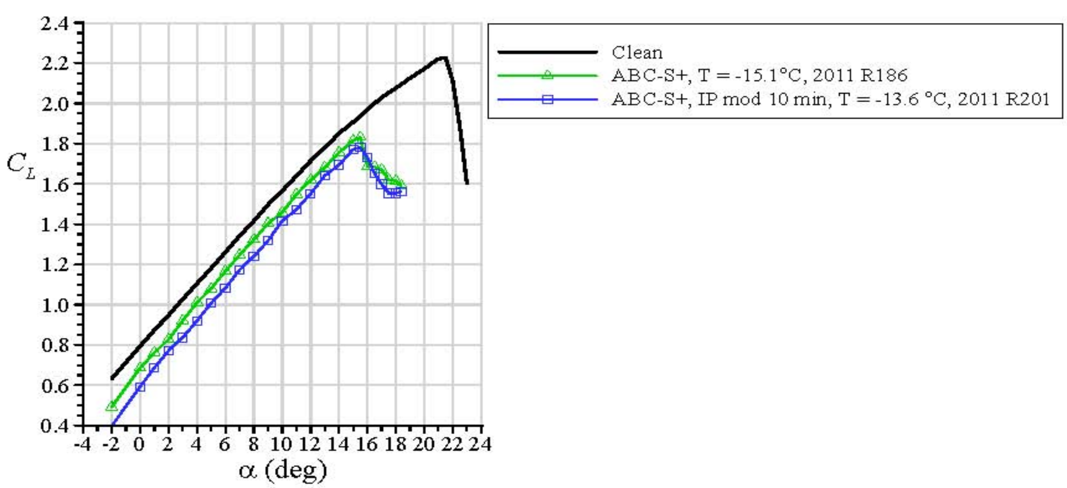
Fluid + Contamination Effects on Stall

- 2011 Tests with ABC-S PLUS fluid with and without contamination.



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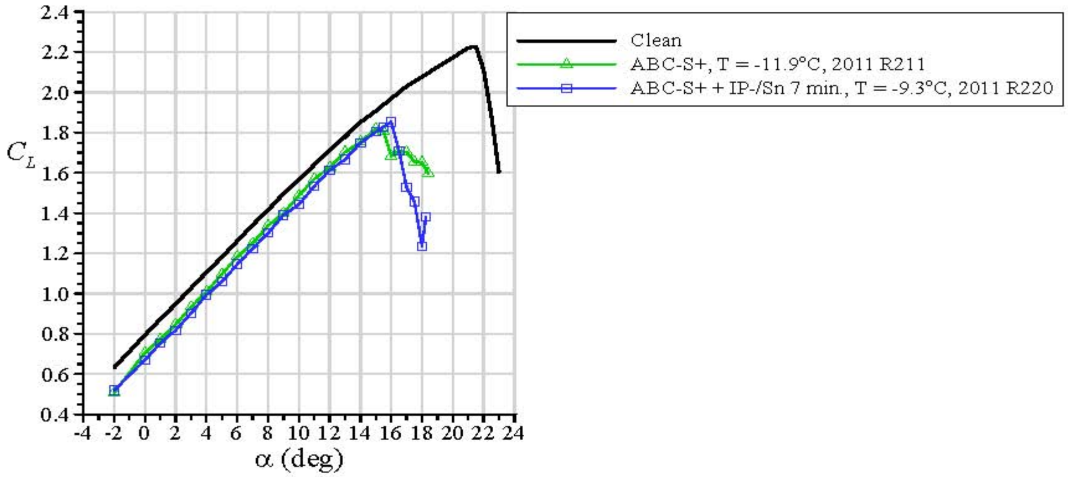
Fluid + Contamination Effects on Stall

- 2011 Tests with ABC-S PLUS fluid with and without contamination.



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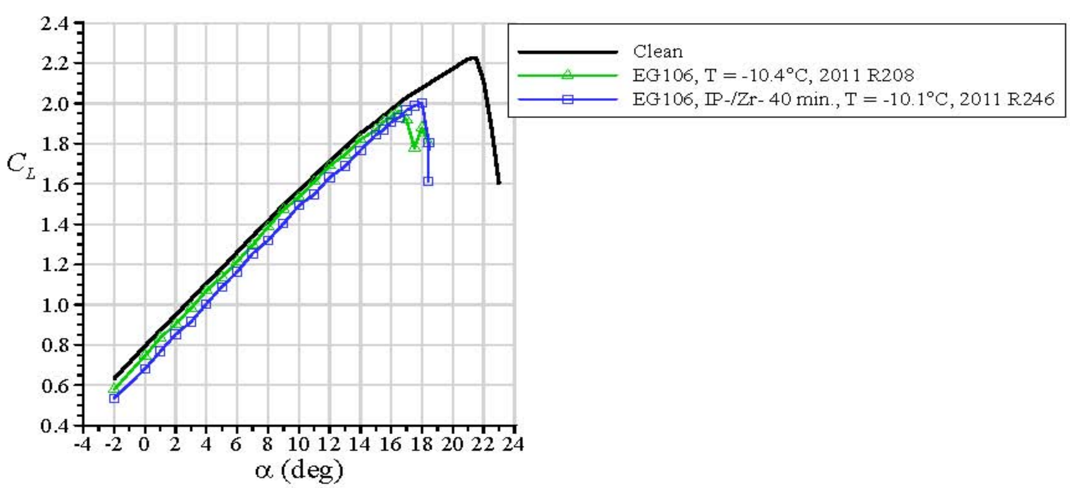
Fluid + Contamination Effects on Stall

- 2011 Tests with EG106 fluid with and without contamination.



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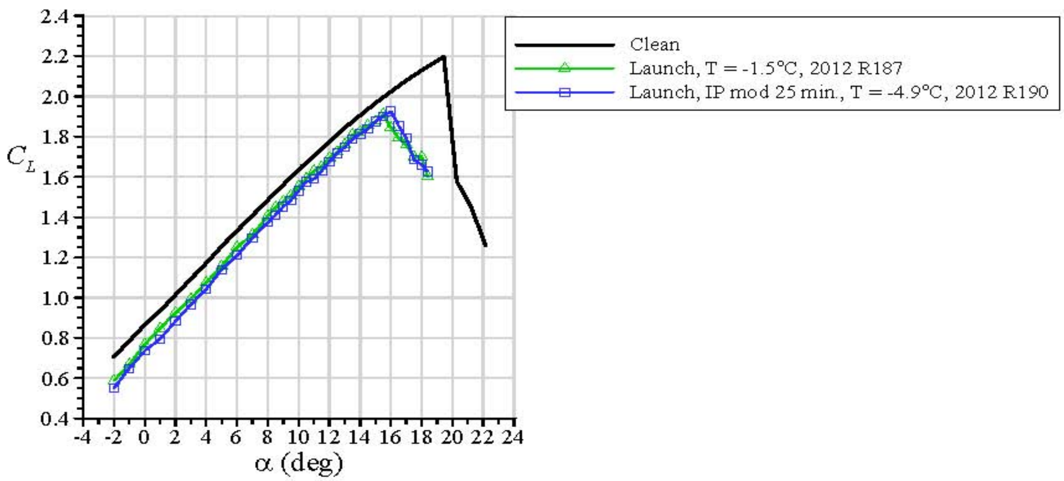
Fluid + Contamination Effects on Stall

- 2012 Tests with Launch fluid with and without contamination.



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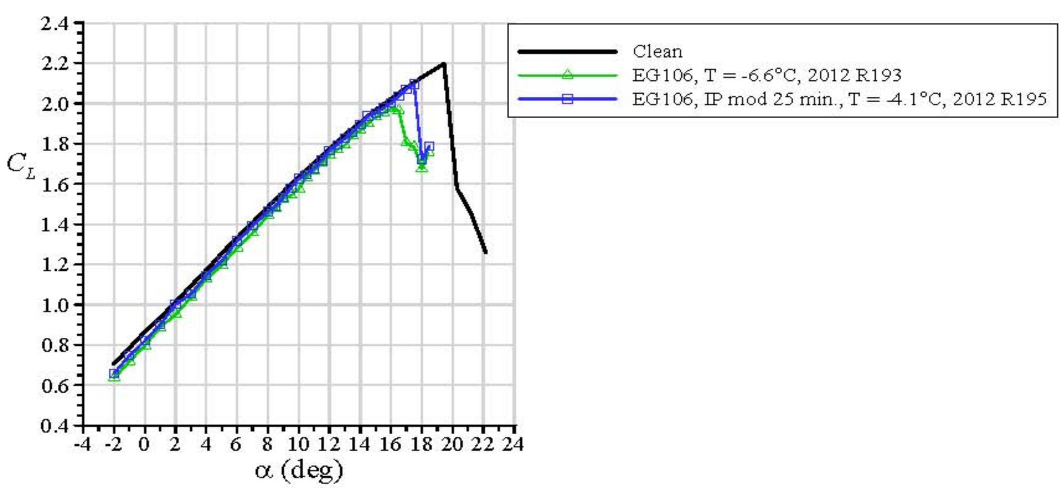
Fluid + Contamination Effects on Stall

- 2012 Tests with EG106 fluid with and without contamination.



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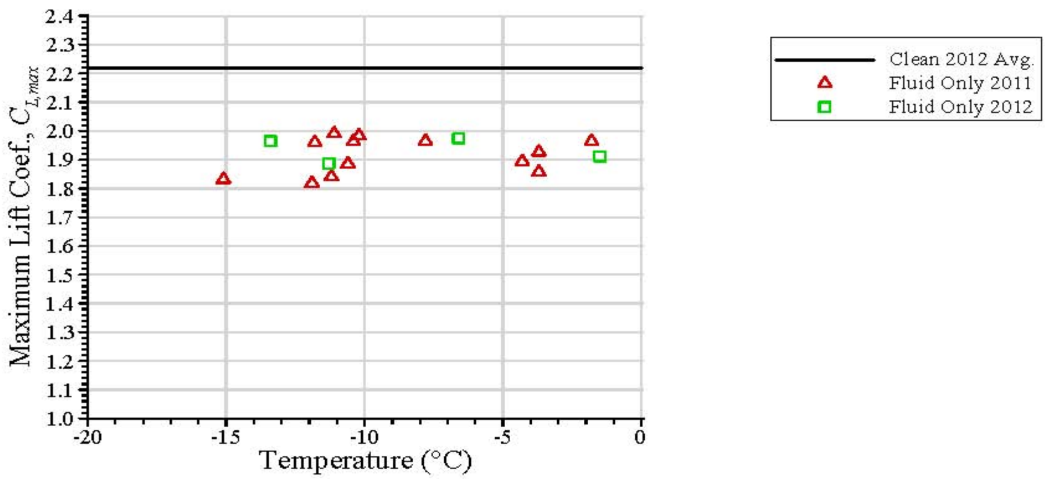
Fluid + Contamination Effects on Stall

- Summary of fluid only effect on maximum lift coefficient.



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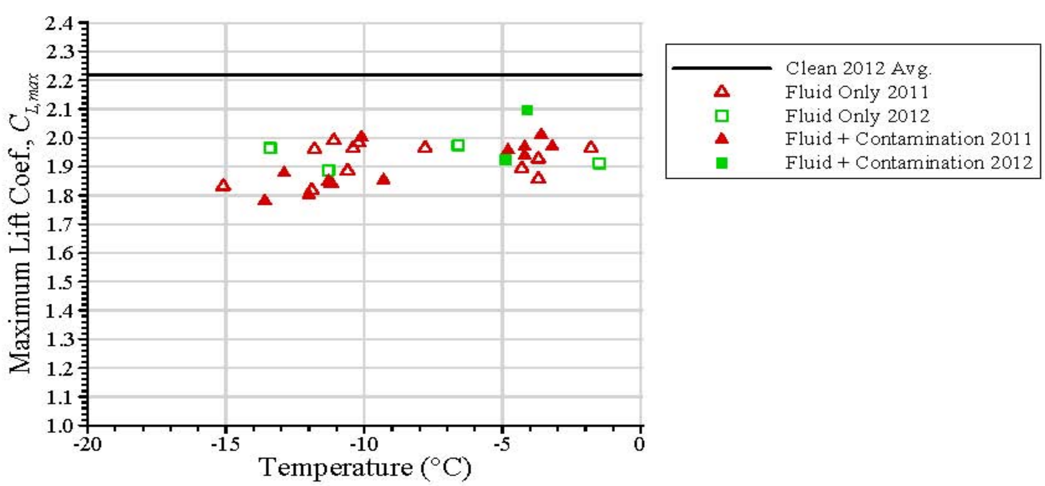
Fluid + Contamination Effects on Stall

- Summary of fluid only and fluid + contamination effect on maximum lift coefficient.



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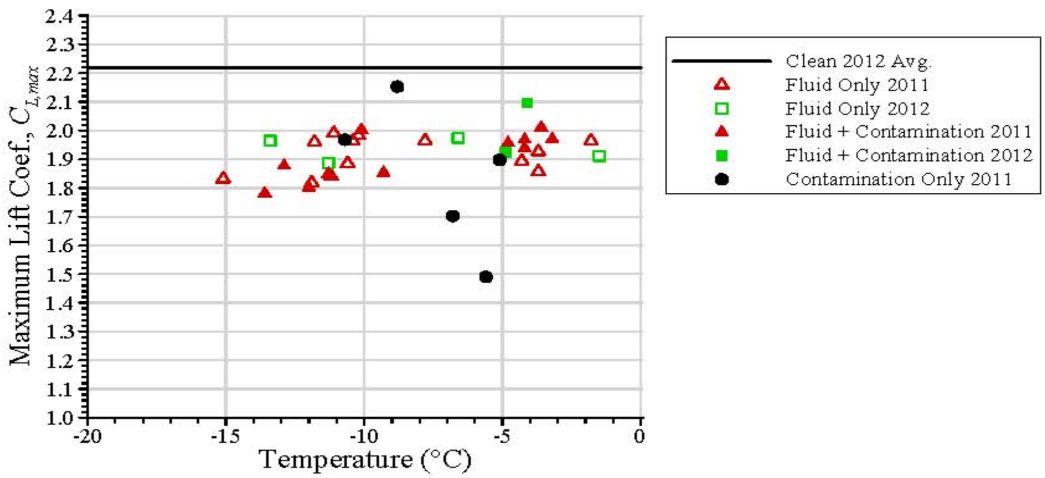
Fluid + Contamination Effects on Stall

- Summary of fluid only, fluid + contamination, and contamination only effect on maximum lift coefficient.



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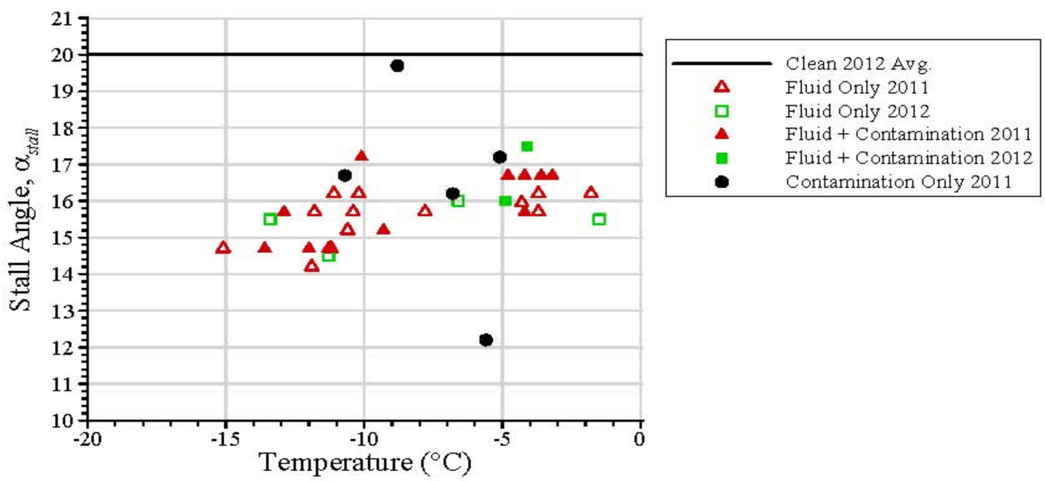
Fluid + Contamination Effects on Stall

- Summary of fluid only, fluid + contamination, and contamination only effect on stall angle.



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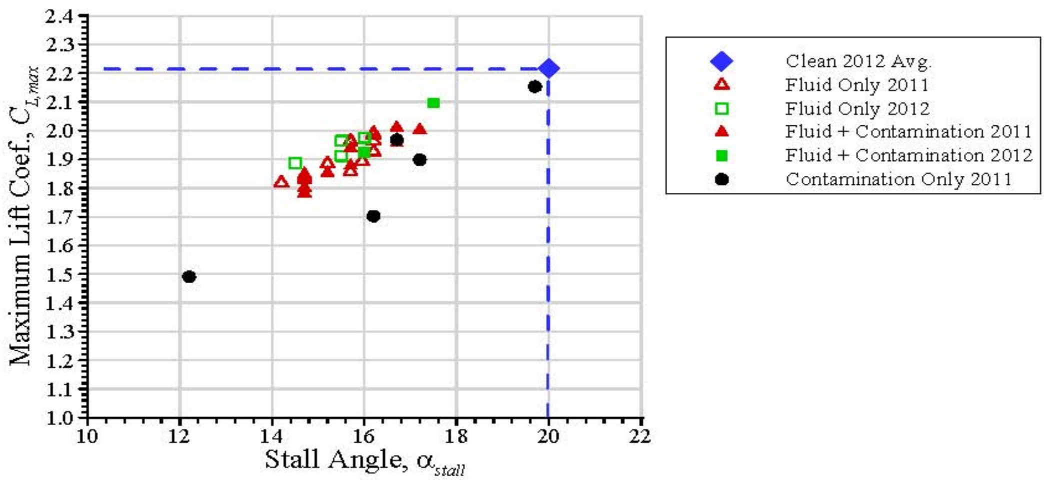
Fluid + Contamination Effects on Stall

- Summary of fluid only, fluid + contamination, and contamination only effect on maximum lift and stall angle.



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Summary of Fluid + Contamination Effects on Stall

- For some cases, the effect of fluid + contamination on maximum lift was less than that observed for the effect of the fluid only on maximum lift.
- This is the opposite trend that is observed at α = 8 deg.
- These differences illustrate the difficulties applying two-dimensional model data at stall.
  - Similar observation noted by Hill and Zierten (NASA TP-3228): two-dimensional data cannot be used directly to estimate airplane lift losses.
- Lift losses at stall are driven by amount of fluid or fluid + contamination that flow off the wing during the ramp and rotation.
  - The sensitivity of wing stall to effective roughness height on the aft section and flap is unclear.

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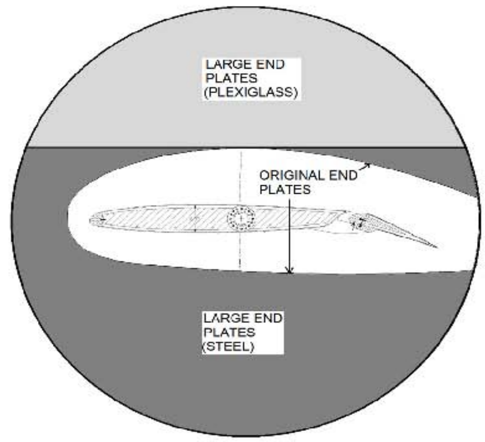
Effect of Endplates on Fluid Results

- Tests were conducted for fluid-only cases with large endplates to determine if there was any effect of the large endplates on the results.
- Several repeat runs were performed to demonstrate run-to-run repeatability. These results were similar to that shown previously for the original endplates.



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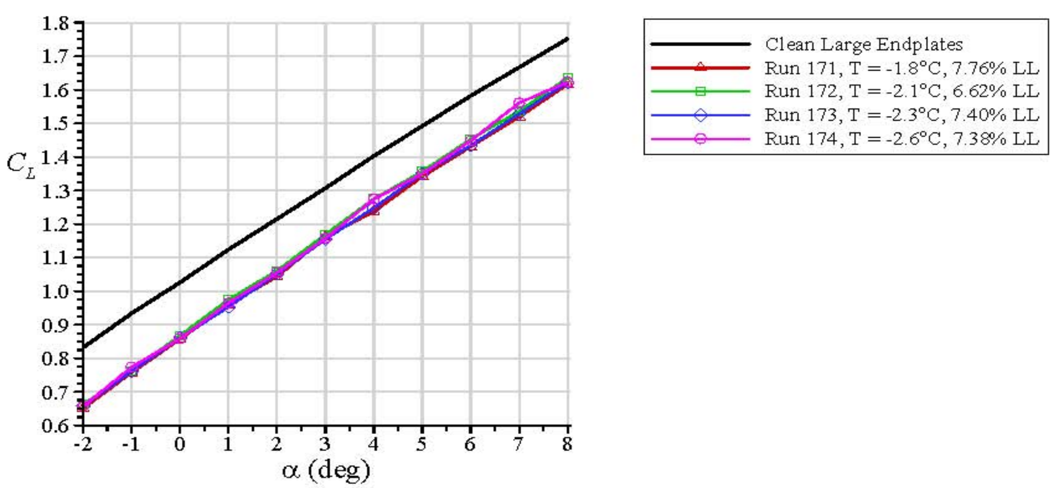
Fluid-Only Repeatability Large Endplates

- 2012 Tests using Launch fluid in back-to-back runs with large endplates.
- Average C_L at 8 deg. = 1.624, σ = 0.008 or 0.52%
- Average Lift Loss at 8 deg. = 7.30%, σ = 0.48%



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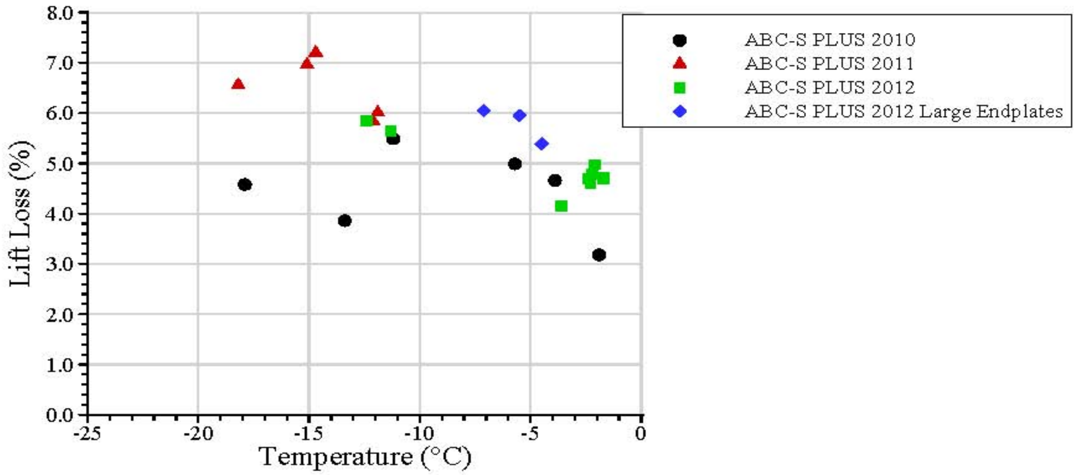
Effect of Large Endplates

- Effect of large endplates using ABC-S PLUS fluid.
- Data corrected to 19 sec. ramp time.



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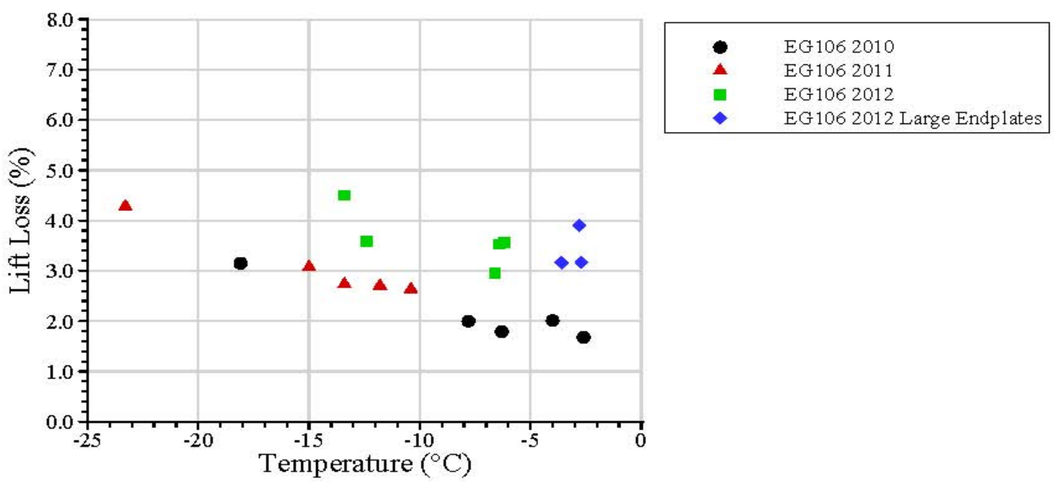
Effect of Large Endplates

- Effect of large endplates using EG106 fluid.
- Data corrected to 19 sec. ramp time.



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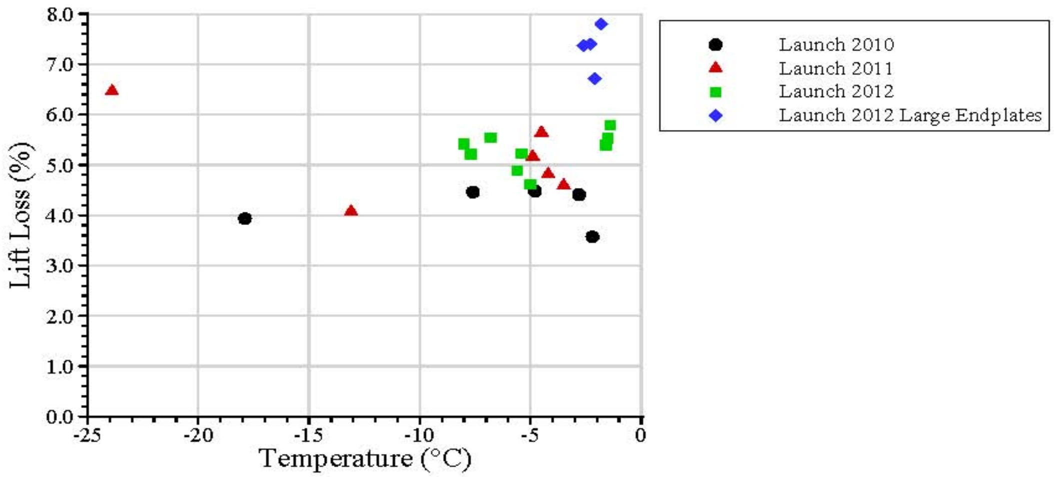
Effect of Large Endplates

- Effect of large endplates using Launch fluid.
- Data corrected to 19 sec. ramp time.



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Effect of Large Endplates Summary

- Fluid-only tests with large endplates demonstrated similar run-to-run repeatability to original endplates.
- It appears that fluid-only tests with large endplates resulted in higher lift losses at α = 8 deg. compared to original endplates.
  - This is consistent with *k/c* = 0.0001 (80-grit) roughness located on the flap which resulted in 6.68% lift loss at α = 8 deg. with large endplates vs. 4.47% lift loss at α = 8 deg. with original endplates.
- Such changes in lift data affect the year-to-year data continuity.
- Large endplates affected photographic image quality and prohibited access to the model leading edge using the gantry system.
- Therefore, it is recommended to use original endplates for future tests with the thin, high-performance wing.

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Summary of Fluid Repeatability

- Back-to-back fluid only runs demonstrated excellent repeatability of test methods and aerodynamic data.
- There was more variation year-to-year of fluid-only runs due to differences in temperature and fluid viscosity.
- Adding the additional variable of contamination resulted in slightly more variation of year-to-year results.
- All repeatability is considered acceptable for this work and not indicative of systematic errors.
- Repeatability was not affected by large endplate configurations, but lift loss measured at α = 8 deg. was larger than for original endplates.
- Differences in fluid only vs. fluid + contamination effects that were observed at stall illustrate the difficulties using two-dimensional model stall data to develop allowance times.

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Additional information if needed.

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Ramp Time Correction Procedure

- Ramp up time can vary for tests.
  - Was previously human operator driven system.
  - 2011-12 improvement made it semi-automatic.
- Comparative tests were conducted with fluid and fluid/contamination to investigate the effect of a longer ramp up time.
  - Test #1: Ramp to V_R and rotate.
  - Test #2: Ramp to V_R, Hold, then rotate.
- Results were used to normalize 2009-12 tests to a standard 19 second ramp time based on the calculated correction factor.
- Due to facility improvements, this correction may not be needed in future tests.

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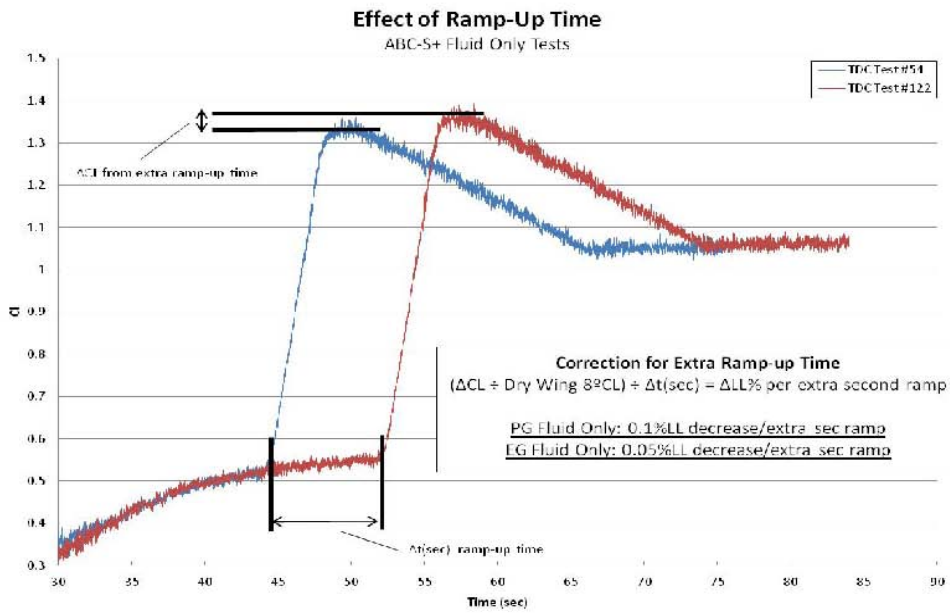
Ramp Time Correction Procedure



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