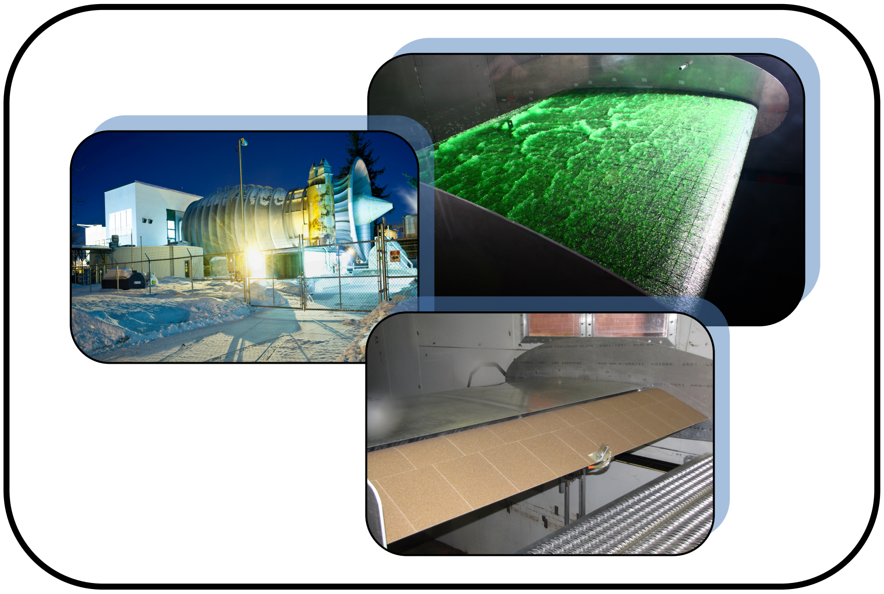
TP15232E

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 5



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Transportation Development Centre

In cooperation with

Civil Aviation
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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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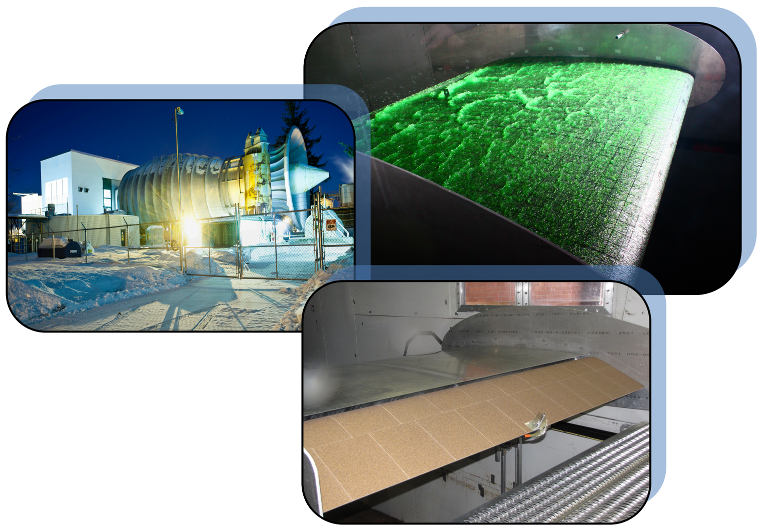

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The contents of this report reflect the views of APS Aviation Inc. and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

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

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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

The primary focus of the testing was aimed at completing the outstanding calibration and characterization testing in the wind tunnel in dry conditions and with fluid with the support and direction of National Aeronautics and Space Administration (NASA) experts. In addition, testing initiatives for the winter of 2012-13 were re-focused on the further development and validation of the ice pellet allowance times.

As secondary research objectives, testing was conducted to investigate the aerodynamic impacts of ice phobic coatings during icing conditions with and without fluid, as well as the evaluation of an airfoil performance monitor and the ability to detect airflow separation (stall).

Conclusions and Observations

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

Future Research

Possible future areas of research for the winter of 2013-14 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 close to the fluid Lowest Operational Use Temperature (LOUT) to determine the aerodynamic effects of ice pellet contamination at these colder 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; and
- Additional testing and analysis to further develop the PIWT results correlation to the Boundary Layer Displacement Thickness (BLDT) test.

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

Les essais visaient principalement à réaliser les tests d'étalonnage et de caractérisation restants dans la soufflerie sur des ailes sèches et traitées avec du liquide avec l'appui et sous la direction des experts de la National Aeronautics and Space Administration (NASA). En outre, les essais de l'hiver 2012-2013 ont été réorientés vers le développement et la validation des marges de tolérance pour les granules de glace.

Des essais ont été menés avec comme objectif secondaire d'étudier les effets aérodynamiques de revêtements glaciophobes dans des conditions de givrage avec et sans liquide, ainsi que pour évaluer un moniteur de performance du profil d'aile et la capacité de détecter le décollement des filets d'air (décrochage).

Conclusions et observations

Durant l'hiver 2012-2013, la répétabilité des données obtenues aux essais aérodynamiques sur des ailes propres et sèches a été confirmée par rapport aux données précédentes ; les données supplémentaires recueillies en 2012-2013 ont contribué à étayer ces constatations. Les caractéristiques de décrochage de l'aile recouverte de liquide (ou de liquide contaminé) semblaient suscitées par des effets d'onde transversale près du bord d'attaque ; ces effets étant difficiles à interpréter sur le modèle bidimensionnel comparativement à une aile en trois dimensions, ils ne devraient pas être utilisés dans l'élaboration des marges de tolérance. D'autres données de corrélation sur l'échelle des pertes de portance avec différents liquides par temps froid ont confirmé la validité des limites précédentes concernant la perte de portance. Quarante essais sur les marges de tolérance concernant les granules de glace ont été réalisés afin de valider et, possiblement, d'élargir les marges actuelles.

Les données ont permis de valider les marges de tolérance actuelles avec de nouveaux liquides et ont aussi démontré la possibilité d'élargir les marges de façon à inclure les conditions mixtes de granules de glace légers avec de la neige légère et modérée.

Recherches à venir

Voici certains éléments qui pourraient être étudiés à l'hiver 2013-2014 :

- 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 se rapprochant de la température minimale d'utilisation opérationnelle du liquide (LOUT) afin de déterminer les effets aérodynamiques de la contamination par des granules de glace à ces températures plus froides ;
- 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 ; et
- 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).

CONTENTS Page

LIST OF APPENDICES

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LIST OF TABLES Page

LIST OF FIGURES Page

LIST OF PHOTOS Page

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
LOUT	Lowest Operational Use Temperature
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 5 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 was 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 were 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 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. 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 resulted in a range of values that 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 narrower 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.

During the winter 2011-12 testing, 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, which 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, this variation 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 greater 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.

The testing results from the 2011-12 winter demonstrated that 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 was recommended that testing continue using the existing methodologies with an outlook to continue improving on testing protocols and procedures. As such, the testing initiatives for the winter of 2012-13 were re-focused on the further development and validation of the ice pellet allowance times.

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

1.2 Program Objectives

A wind tunnel testing program was developed for the winter of 2012-13 with the primary objectives of conducting aerodynamic testing with a thin high-performance airfoil to:

- Ensure the repeatability of the dry wing performance;
- Expand the ice pellet allowance times for light ice pellets mixed with light or moderate snow conditions;
- Investigate the higher lift losses observed at lower temperatures with PG fluids;
- Substantiate the current ice pellet allowance times with new fluids or fluids previously tested but with limited data;
- Evaluate the effects of fluid viscosity on aerodynamic performance;
- Further develop the PIWT testing results correlation to the boundary layer displacement thickness (BLDT) test;
- Evaluate the use of a stall warning sensor with and without de/anti-icing fluids;
- Evaluate the interaction of an ice phobic coated wing skin with fluid and contamination; and
- Evaluate the effect of ice phobic coatings on the fluid BLDT at low rotation speeds.

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

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
2012-13	APS Wind Tunnel	No Changes to Guidelines	No Changes to Guidelines	TP 15232E (Vol. 5)	2013-14
				TP 115232E (Vol. 1)	

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 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 was 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, 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, 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 TC, TP 15232E (Vol. 3) (13).

Testing once again continued with the same wing test section during the winter of 2011-12, with the focus of 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. This research is documented in detail in TP 15232E (Vol. 4) (13)

1.5 Overview of 2012-13 Testing

Full-scale testing during the winter of 2012-13 was conducted using the NRC PIWT.

The primary focus of the testing was aimed at completing the outstanding calibration and characterization testing in the wind tunnel in dry conditions and with fluid with the support and direction of NASA experts. In addition, testing initiatives for the winter of 2012-13 were re-focused on the further development and validation of the ice pellet allowance times.

As secondary research objectives, testing was conducted to investigate the aerodynamic impacts of ice phobic coatings during icing conditions with and without fluid, as well as the evaluation of an airfoil performance monitor and the ability to detect airflow separation (stall).

This research is documented in a separate exploratory wind tunnel research report, TC report, TP 15233E, *Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2012-13* (14).

Table 1.2 demonstrates the groupings for the global set of tests conducted at the wind tunnel during the winter of 2012-13. Only tests pertaining to the dry wing and fluid calibration and characterization work and ice pellet allowance time testing (Objectives 1 and 2) are described in this report.

Table 1.2: Summary of 2012-13 Wind Tunnel Tests by Objective

Objective	# of Runs
1. Wing Calibration and Characterization	125
2. Ice Pellet Allowance Times	40
3. Ice Phobic Coatings	40
4. Airfoil Performance Monitor	8
Total	***213***

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

d) Section 5 describes the work conducted to calibrate and characterize the wing model;

e) Sections 6 to 10 describe the testing conducted to further develop the allowance time tables:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Moderate Rain;
- Section 9: Light Ice Pellets and Light Snow; and
- Section 10: Light Ice Pellets and Moderate Snow.

f) Section 11 presents a summary of the conclusions and observations; and

g) Section 12 lists the recommendations for future testing.

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 5 as well as in the procedure included in Appendix B.

2.1 Wind Tunnel Test Site

The 2012-13 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.

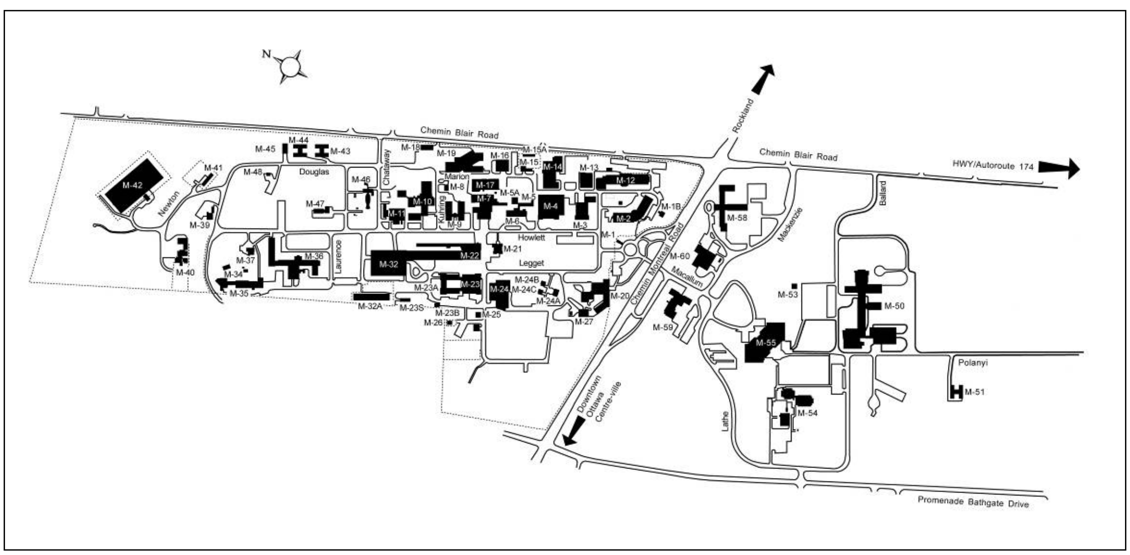

Figure 2.1: Schematic of NRC Montreal Road Campus

2.2 Test Schedule

Eighteen days of testing were conducted over a period of seven weeks starting December 19, 2012, and ending February 1, 2013. Setup and teardown time was minimal and was done on the first and last day of testing. 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 test objectives discussed in this report. At the beginning of each test day, a plan was developed, which 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 (start date in case of overnight)	**# of Test Runs**
December 19, 2012	8
December 20, 2012	28
December 21, 2012	15
January 8, 2013	8
January 13, 2013	0
January 14, 2013	10
January 15, 2013	12
January 16, 2013	13
January 17, 2013	11
January 20, 2013	13
January 21, 2013	9
January 22, 2013	13
January 23, 2013	15
January 24, 2013	14
January 27, 2013	12
January 28, 2013	12
January 31, 2013	13
February 1, 2013	7
Total	**213**

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;
c) At the end of the contamination period, the tunnel was cleared of all equipment and scaffolding;
d) The wind tunnel was subsequently operated through a simulated takeoff and climb-out test; and
e) The behaviour of the fluid during takeoff and climb-out was recorded with digital high-speed still cameras. In addition, windows overlooking the wing section allowed observers to document the fluid elimination performance in real-time.

The procedure for the wind tunnel 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.

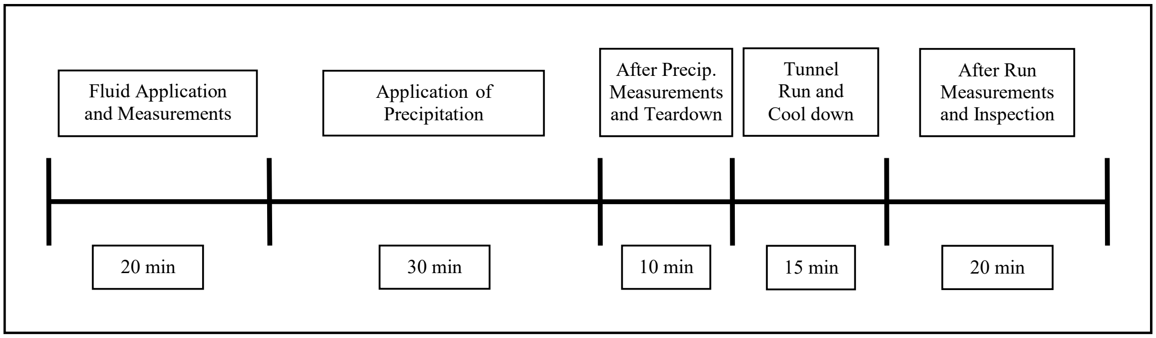

Figure 2.2: Typical Wind Tunnel Test Timeline

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 computational fluid dynamics 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.).

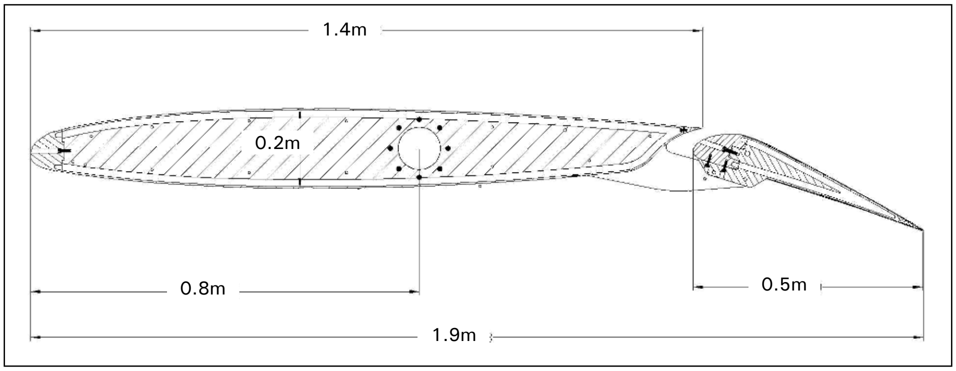

Figure 2.3: Generic "Supercritical" Wing Section

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).

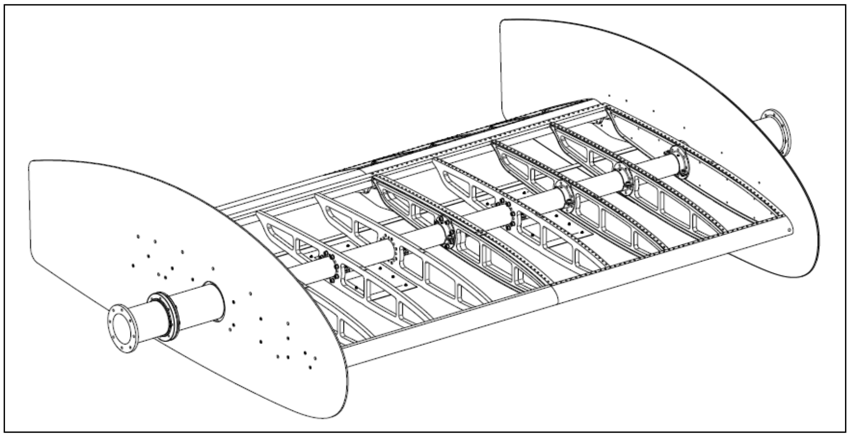

Figure 2.4: End Plates Installed on Supercritical Wing Section

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) recording the skin temperature on the leading edge (LE), mid chord (MID), trailing edge (TE), and under-wing (UND). RTDs were placed along a chord 0.5m (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 2.15.3.

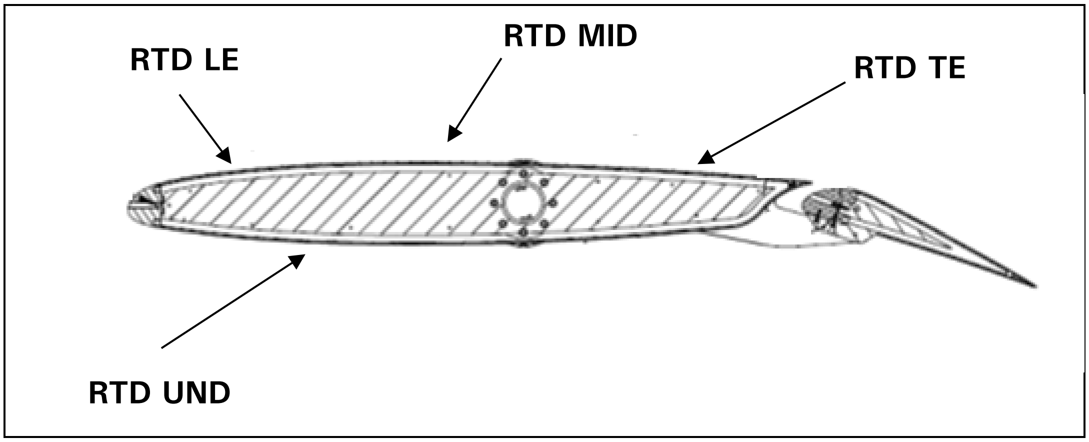

Figure 2.5: Location of RTDs Installed Inside Supercritical Wing

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

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

2.5.5 Test Area Grid

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.

It should be noted that the grid was not re-drawn on the ice phobic skins installed over top of the wing section because the previous grid markings were still visible; however, this should be considered for future tests.

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 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 km/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 0.3 m (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 re-filled 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 2.4m (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 2012-13:

- 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 $g/dm^2/h$.

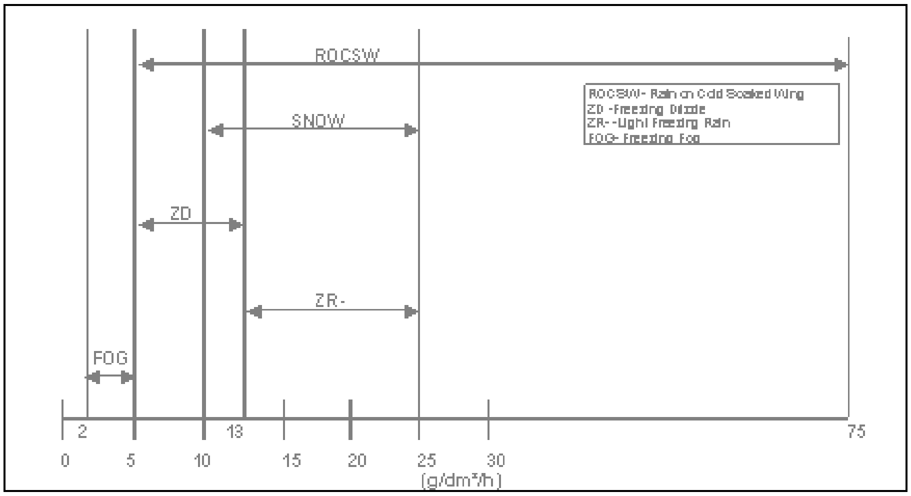

Figure 2.6: Precipitation Rate Breakdown

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 an 18-55 mm lens (2008-09 and 2009-10) as the primary focus point had been moved farther away from the camera. Additional information regarding the camera setup used is documented and available upon request.

About midway through 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, it was suggested to replace the full photography gear within the next two years to avoid breakdowns during testing, which could be costly and inconvenient.

For the Winter 2012-13 testing, three new Canon EOS Rebel T2i 18.0MP DSLR cameras were purchased to replace the existing older generation cameras. These cameras provide a higher resolution, quicker response, and better compatibility with current peripherals. In addition, a GoPro HD HERO2 Outdoor camcorder was also purchased and used for filming the wind tunnel runs (the rugged design also allows it to be installed in areas prone to damage from water, ice, wind, etc. with no effect on the camera).

Currently, the Profoto flash system elements are nearing the end of their life cycle; therefore, they should be the next items on the list of equipment to replace 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. Those same intervalometers were also 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 III fluid. 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 Lacombe Waste Services were employed to safely dispose of the waste glycol fluid.

2.14 Personnel

Personnel requirements during the winter of 2012-13 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 runs. 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 five 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 2012-13 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.

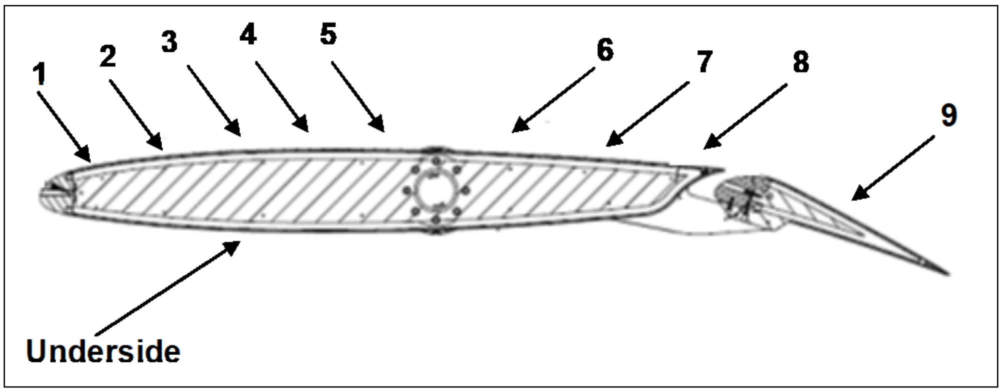

Figure 2.7: Measurement Locations Along Chord of Supercritical Wing Section

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 onwards, 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.

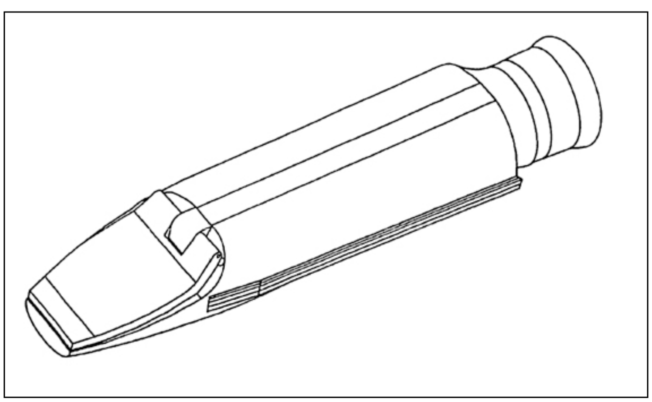

Figure 2.8: Hand-Held Brixometer

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 wing temperature, fluid thickness, and fluid Brix 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 MP IV Launch; and
- 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, Clariant Max Flight 04 (also referred to as Max Flight), and Cryotech Polar Guard Advance; however, the dilution curve would be very similar to Tables 2.2 to 2.5.

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.

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 (toward 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.

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 MP IV 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					

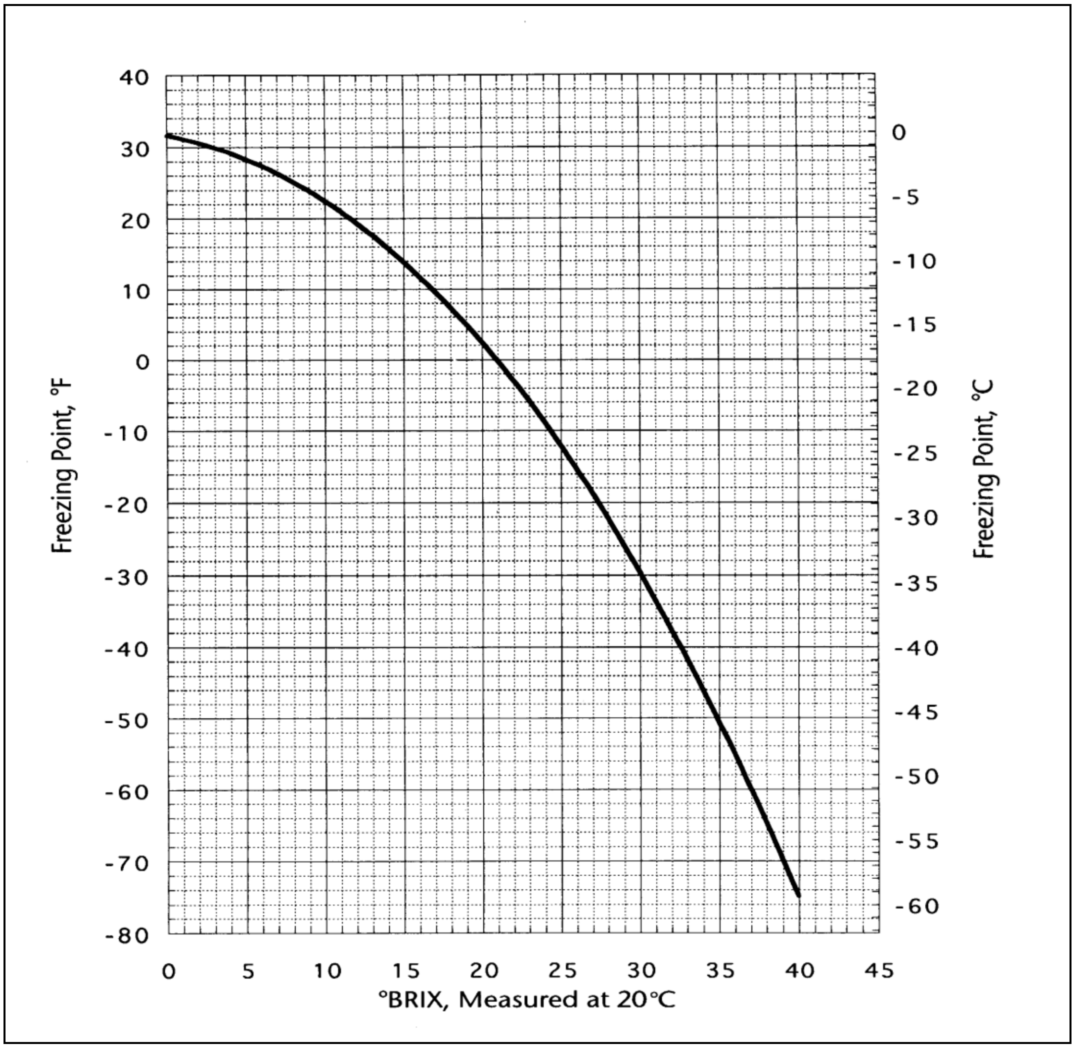

Figure 2.9: Freezing Point vs. Brix of Aqueous Solutions of Dow EG106

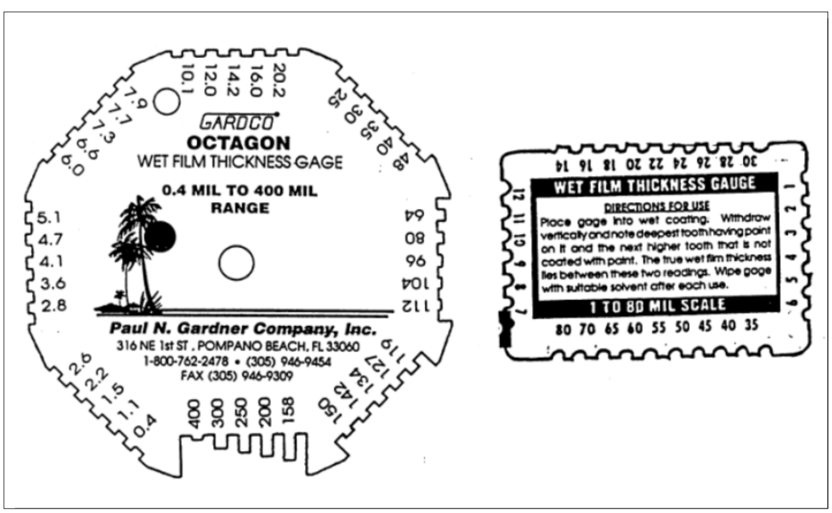

Figure 2.10: Thickness Gauges

Table 2.6: Film Thickness Conversion Table

RECTANGULAR GAUGE			OCTAGON GAUGE		
Reading*	Calculated Thickness		Reading*	Calculated Thickness	
(mil)	(mil)	(mm)	(mil)	(mil)	(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.

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

Seven fluids were used during the wind tunnel tests conducted during the winter of 2012-13. The neat fluid used for testing in most cases included low and mid viscosity formulations, and in some cases the fluid was also diluted to a 75/25 dilution. The viscosity of the fluids received was measured using the Stony Brook PDVdi-120 Falling Ball Viscometer and the Brookfield Digital Viscometer Model DV-1+ 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. The historical fluid information for the testing conducted since 2009-10 with the thin high-performance wing section in included in Table 2.8.

Table 2.7: 2012-13 Fluids Tested

Sample Name	Batch #	Dilution	MID OR LOW VISCOSITY	Receiving Quantity	Method	Can-Am Result (cP)	LOWV
Kilfrost ABC-S Plus	WT.12.13.ABC-S+	100/0	MID	500	c	19,996	17,900
Kilfrost ABC-S Plus	WT.12.13.ABC-S+	100/0	LOW	60	c	10,498	17,900
Dow FlightGuard AD-49	L12-328	100/0	MID	700	k	14,397	12,150
Dow FlightGuard AD-49	L12-331	100/0	LOW	60	k	8,898	12,150
DOW EG 106	1J0201GKDR	100/0	MID	800	g	3,979	24,850
CLARIANT 2031	USHA035838	100/0	MID	200	h	554	30
Clariant MP IV Launch	USHA039555	100/0	MID	400	g	13,997	7,550
Clariant MP IV Launch	DEG4146139	100/0	LOW	60	g	6,839	7,550
Clariant Max Flight 04	U49E001966	100/0	MID	700	d	11,658	5,540
Clariant Max Flight 04	U49E001966	100/0	LOW	60	d	5,019	5,540
Cryotech Polar Guard Advance	13342	100/0	MID	600	n	15,200	4,400
Cryotech Polar Guard Advance	13102	100/0	LOW	60	n	3,800	4,400
Kilfrost ABC-S Plus		75/25	MID	made from quantity received	c	n/a	12,000
Dow FlightGuard AD-49	L12-328	75/25	MID	made from quantity received	k	n/a	30,700
CLARIANT 2031	USHA035838	75/25	MID	made from quantity received	h	n/a	55
Clariant MP IV Launch	USHA039555	75/25	MID	made from quantity received	g	n/a	18,000
Clariant Max Flight 04	U49E001966	75/25	MID	made from quantity received	g	n/a	n/a
Cryotech Polar Guard Advance	13342	75/25	MID	made from quantity received	n	n/a	11,600

Table 2.8: Historical Fluids Tested with Thin High-Performance Wing

		[redacted]	Wind Tunnel 2011-12			Wind Tunnel 2010-11			Wind Tunnel 2009-10		
Fluid Name	**LOWV (cP)**	[redacted]	**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	[redacted]	DEG4146145	12597	24	USHA024295 (Same as 09-10)	10258	30	USHA02429 5	Measured in 2010-11	29
Dow Chemical Company AD-49	12150	[redacted]	-	-	-	TANK#UL24	13097	23	-	-	-
Dow Chemical Company EG106	24850	[redacted]	GMID297182/ 2L1701GKH6	37192	66	GMID297182 / Batch 5	39792	54	WH0601GKD R	37200	48
Kilfrost Limited ABC-S PLUS	17900	[redacted]	B/13/12/11	19396	27	P/282/12/10	24695	32	P/22/12/09	20225	26
Octagon Process Inc. Max Flight 04	5540	[redacted]	-	-	-	WL-122210-4	12437	19	-	-	-

Note: Viscosity measured using manufacturer stated method.

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

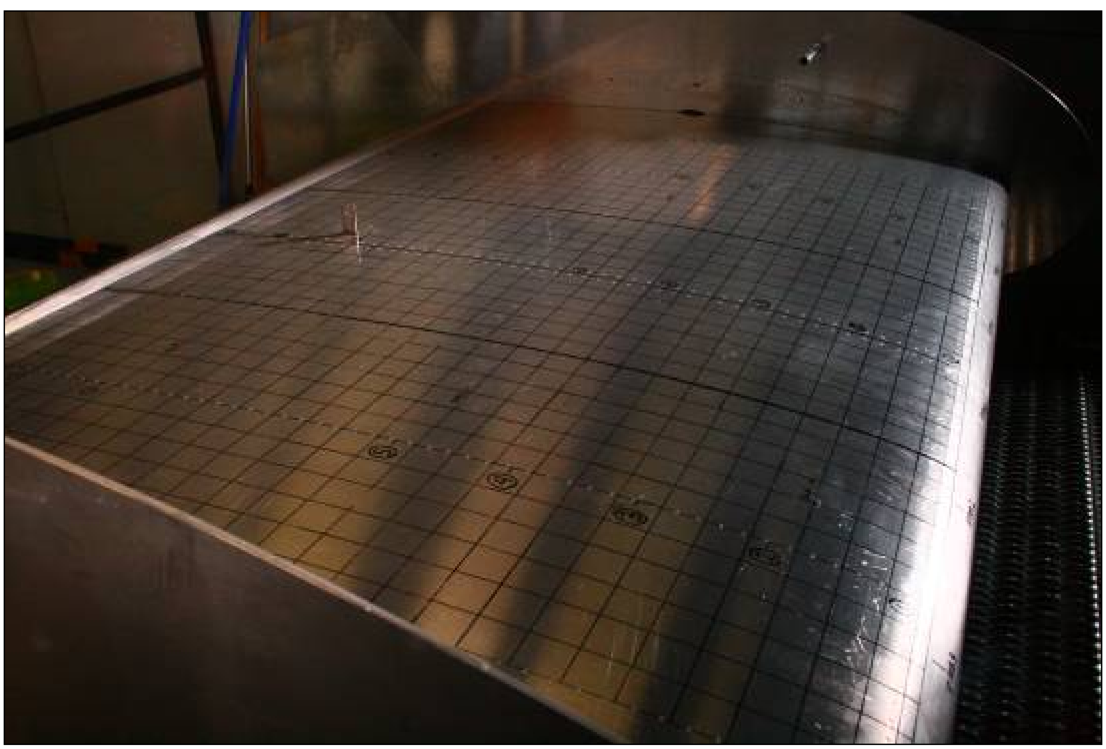

Photo 2.5: Refrigerated Truck Used for Manufacturing Ice Pellets

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: 2012-13 Research Team

Photo 2.13: Wet Film Thickness Gauges

Photo 2.14: Hand-Held Temperature Probe

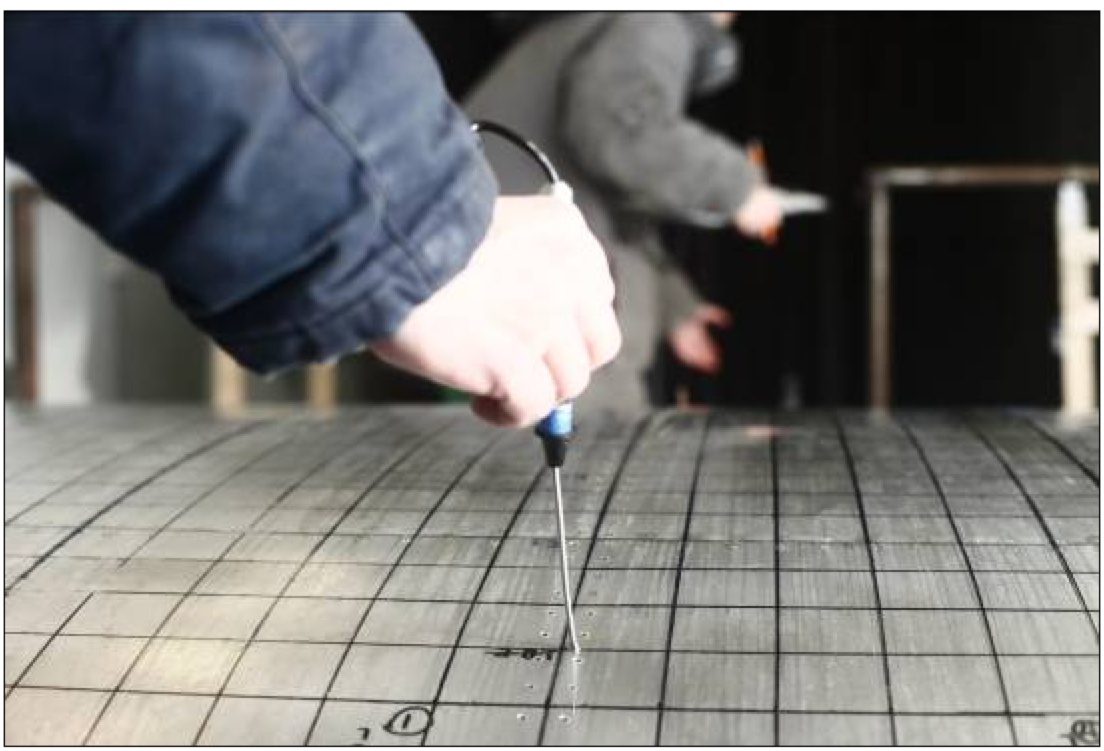

Photo 2.15: Hand-Held Brixometer (Misco 10431VP)

Photo 2.16: Brookfield Digital Viscometer Model DV-1+

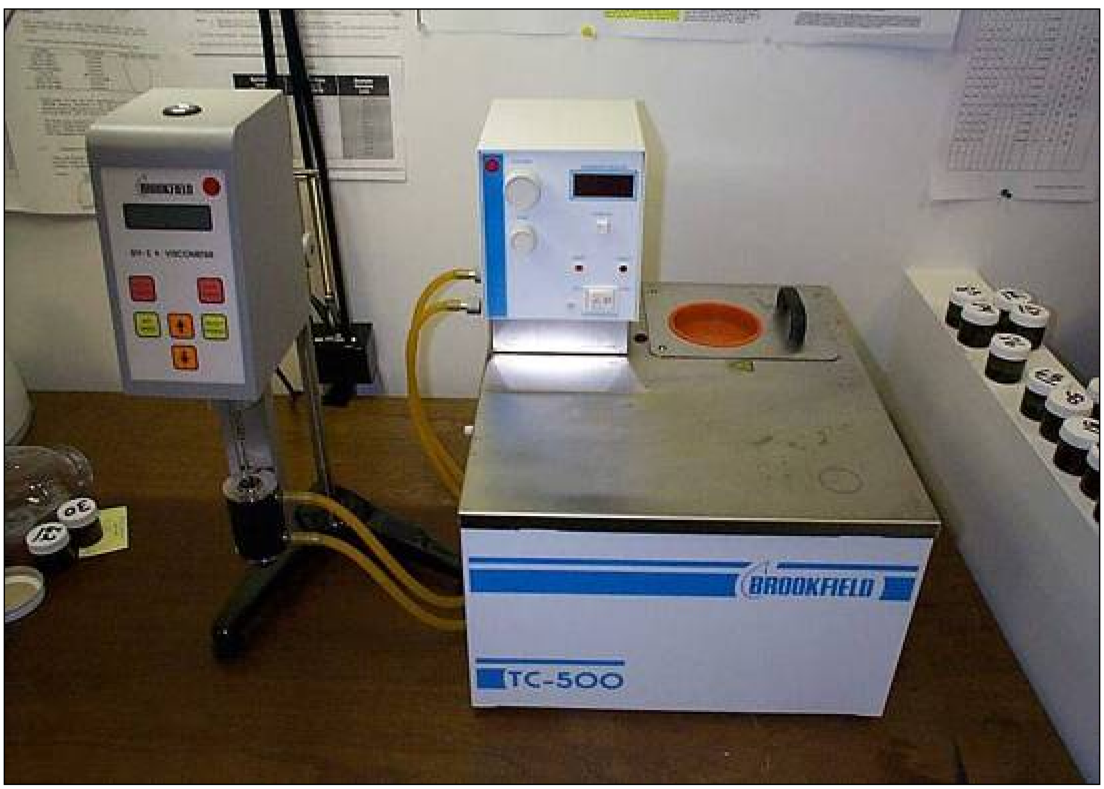

Photo 2.17: Stony Brook PDVdi-120 Falling Ball Viscometer

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3. FULL-SCALE DATA COLLECTED

3.1 Test Log

A calendar of the tests conducted during the winter of 2012-13 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 2012-13

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	Corrected for 3D Effects CL at 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL
1	2012-13	Clean Wing	Dry Wing	none	-2 to 22	20	19-Dec-12	1	n/a	-	-	-	-	-	1.475	-0.62%
2	2012-13	Clean Wing	Dry Wing	none	-2 to 22	20	19-Dec-12	1	n/a	-	-	-	-	-	1.478	-0.80%
3	2012-13	Clean Wing	Dry Wing	none	8	20	19-Dec-12	1	n/a	-	-	-	-	-	1.468	-0.12%
4	2012-13	Roughness	Dry Wing	none	8	20	19-Dec-12	1.6	2.1	-	-	-	-	-	1.387	5.41%
5	2012-13	Roughness	Dry Wing	none	8	20	19-Dec-12	1.6	2.1	-	-	-	-	-	1.374	6.29%
6	2012-13	Roughness	Dry Wing	none	-2 to 22	20	19-Dec-12	0.5	1	-	-	-	-	-	1.384	5.59%
7	2012-13	Roughness	Dry Wing	none	-2 to 22	20	19-Dec-12	0.5	0.9	-	-	-	-	-	1.376	6.15%
8	2012-13	Boundary Layer Rake	Dry Wing	none	-2 to 18	20	19-Dec-12	0.1	0.5	-	-	-	-	-	1.225	16.45%
9	2012-13	Boundary Layer Rake	Dry Wing	none	-2 to 18	20	20-Dec-12	-5.7	-5.4	-	-	-	-	-	1.402	4.36%
10	2012-13	Boundary Layer Rake	Dry Wing	none	-2 to 18	20	20-Dec-12	-4.7	-3.7	-	-	-	-	-	1.299	11.39%
11	2012-13	Boundary Layer Rake	Dry Wing	none	-2 to 18	20	20-Dec-12	-3.4	-3	-	-	-	-	-	1.182	19.38%
12	2012-13	Roughness	Dry Wing	none	8	20	20-Dec-12	-3	-1	-	-	-	-	-	1.280	12.66%
13	2012-13	Roughness	Dry Wing	none	22	20	20-Dec-12	-3	-1.8	-	-	-	-	-	n/a	n/a
14	2012-13	Roughness	Dry Wing	none	-2 to 22	20	20-Dec-12	-3	-2.1	-	-	-	-	-	1.277	12.88%
15	2012-13	Roughness	Dry Wing	none	-2 to 22	20	20-Dec-12	-3	-2.5	-	-	-	-	-	1.269	13.44%
16	2012-13	Clean Wing	Dry Wing	none	22	20	20-Dec-12	-2.4	0	-	-	-	-	-	1.464	0.16%
17	2012-13	Clean Wing	Dry Wing	none	8	20	20-Dec-12	-2.4	-0.5	-	-	-	-	-	1.469	-0.20%
18	2012-13	Clean Wing	Dry Wing	none	8	20	20-Dec-12	-2.4	-1.1	-	-	-	-	-	1.462	0.25%
19	2012-13	Roughness	Dry Wing	none	8	20	20-Dec-12	-3	-2	-	-	-	-	-	1.432	2.29%
20	2012-13	Roughness	Dry Wing	none	22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.454	0.80%
21	2012-13	Roughness	Dry Wing	none	-4 to 22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.474	-0.56%
22	2012-13	Roughness	Dry Wing	none	8	20	20-Dec-12	-3	-2	-	-	-	-	-	1.473	-0.50%
23	2012-13	Roughness	Dry Wing	none	-4 to 22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.473	-0.50%
24	2012-13	Roughness	Dry Wing	none	8	20	20-Dec-12	-3	-2	-	-	-	-	-	1.463	0.21%
25	2012-13	Roughness	Dry Wing	none	22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.473	-0.49%
26	2012-13	Roughness	Dry Wing	none	-4 to 22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.468	-0.15%

Table 3.1: Wind Tunnel Test Log 2012-13 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	Corrected for 3D Effects CL at 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL
27	2012-13	Roughness	Dry Wing	none	8	20	20-Dec-12	-3	-2	-	-	-	-	-	1.467	-0.09%
28	2012-13	Roughness	Dry Wing	none	22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.460	0.39%
29	2012-13	Roughness	Dry Wing	none	8	20	20-Dec-12	-3	-2	-	-	-	-	-	1.469	-0.23%
30	2012-13	Roughness	Dry Wing	none	-4 to 22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.478	-0.80%
31	2012-13	Roughness	Dry Wing	none	22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.452	0.95%
32	2012-13	Roughness	Dry Wing	none	8	20	20-Dec-12	-3	-2	-	-	-	-	-	1.459	0.48%
33	2012-13	Roughness	Dry Wing	none	-4 to 22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.461	0.33%
34	2012-13	Roughness	Dry Wing	none	22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.465	0.07%
35	2012-13	Roughness	Dry Wing	none	8	20	20-Dec-12	-3	-2	-	-	-	-	-	1.461	0.36%
36	2012-13	Roughness	Dry Wing	none	-4 to 22	20	20-Dec-12	-3	-2	-	-	-	-	-	1.456	0.70%
37	2012-13	Roughness	Dry Wing	none	8	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.462	0.28%
38	2012-13	Roughness	Dry Wing	none	22	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.454	0.80%
39	2012-13	Roughness	Dry Wing	none	-4 to 22	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.468	-0.15%
40	2012-13	Roughness	Dry Wing	none	8	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.454	0.79%
41	2012-13	Roughness	Dry Wing	none	22	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.462	0.30%
42	2012-13	Roughness	Dry Wing	none	-4 to 22	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.471	-0.31%
43	2012-13	Roughness	Dry Wing	none	8	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.452	0.96%
44	2012-13	Roughness	Dry Wing	none	22	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.463	0.23%
45	2012-13	Roughness	Dry Wing	none	-4 to 22	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.465	0.07%
46	2012-13	Roughness	Dry Wing	none	8	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.451	1.01%
47	2012-13	Roughness	Dry Wing	none	22	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.446	1.38%
48	2012-13	Roughness	Dry Wing	none	-4 to 22	20	21-Dec-12	0.5	1.5	-	-	-	-	-	1.463	0.22%
49	2012-13	Roughness	Dry Wing	none	8	20	21-Dec-12	0.4	1.4	-	-	-	-	-	1.462	0.25%
50	2012-13	Roughness	Dry Wing	none	22	20	21-Dec-12	0.4	1.4	-	-	-	-	-	1.475	-0.61%
51	2012-13	Roughness	Dry Wing	none	-4 to 22	20	21-Dec-12	0.4	1.4	-	-	-	-	-	1.470	-0.30%
52	2012-13	Evaluation of Stallwarning Sensor	none	none	stall	20	8-Jan-13	-	-	-	-	-	-	-	1.464	0.15%

Table 3.1: Wind Tunnel Test Log 2012-13 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	Corrected for 3D Effects CL at 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL
SENSOR INSTALLED WITH SHIM																
53	2012-13	Evaluation of Stallwarning Sensor	none	none	stall	20	8-Jan-13	0.7	11.6	-	-	-	-	-	1.438	1.94%
54	2012-13	Evaluation of Stallwarning Sensor	none	none	stall	20	8-Jan-13	1	10	-	-	-	-	-	1.447	1.28%
55	2012-13	Evaluation of Stallwarning Sensor	Fluid Only	Type I EG	stall	20	8-Jan-13	2.8	3	-	-	-	-	-	1.430	2.48%
56	2012-13	Evaluation of Stallwarning Sensor	Fluid Only	EG 106	stall	20	8-Jan-13	3.1	2.9	-	-	-	-	-	1.390	5.20%
FLUSH MOUNTED SENSOR INSTALLED																
57	2012-13	Evaluation of Stallwarning Sensor	none	none	stall	20	8-Jan-13	2.1	3	-	-	-	-	-	1.423	2.93%
58	2012-13	Evaluation of Stallwarning Sensor	none	none	stall	20	8-Jan-13	2.1	3	-	-	-	-	-	1.439	1.85%
59	2012-13	Evaluation of Stallwarning Sensor	Fluid Only	EG 106	stall	20	8-Jan-13	1.9	2.8	-	-	-	-	-	1.402	4.38%
60	2012-13	Baseline	Dry Wing	none	8	20	14-Jan-13	-1	-0.4	-	-	-	-	-	1.465	0.06%
61	2012-13	Baseline	Dry Wing	none	8	20	14-Jan-13	-1	-0.4	-	-	-	-	-	1.470	-0.29%
62	2012-13	Baseline	Dry Wing	none	stall	20	14-Jan-13	-1	-0.4	-	-	-	-	-	1.460	0.40%
63	2012-13	IP Validation with New Fluids	IP- / R Mod	Polar Guard Advance	8	20	15-Jan-13	-1.5	3.1	IP: 25 R: 75	25	1, 1, 1	1, 1, 1	1, 1, 1	1.421	3.04%
64	2012-13	Baseline	Dry Wing	none	stall	20	15-Jan-13	-2.4	-1.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.460	0.41%
65A	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-2.6	0	-	-	1, 1, 1	1, 1, 1	1, 1, 1	n/a	n/a
65B	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-2.8	1.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.451	0.99%
66	2012-13	Baseline	Fluid Only	Max-Flight	stall	20	15-Jan-13	-3.5	-0.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.353	7.71%
67A	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-4	-1.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	n/a	n/a
67B	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-4.2	-1.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.444	1.48%
68	2012-13	Baseline	Dry Wing	none	8	20	15-Jan-13	-2.5	0.5	-	-	-	-	-	1.461	0.35%
69	2012-13	Baseline	Dry Wing	none	stall	20	15-Jan-13	-	-1	-	-	-	-	-	1.465	0.04%
70A	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-2.7	-1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	n/a	n/a
70B	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-2.8	-1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.431	2.37%
71A	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-2.7	0	-	-	1, 1, 1	1, 1, 1	1, 1, 1	n/a	n/a
71B	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-2.8	-1.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.448	1.20%
72A	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-3.1	-0.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	n/a	n/a

Table 3.1: Wind Tunnel Test Log 2012-13 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	Corrected for 3D Effects CL at 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL
72B	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-3.2	-1.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.450	1.12%
73	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	15-Jan-13	-3.9	-0.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.446	1.39%
74	2012-13	IP Validation with New Fluids	IP- / R Mod	Polar Guard Advance	8	20	16-Jan-13	-5.4	2.9	IP: 25 R:75	25	1, 1, 1.2	1, 1, 1.2	1, 1, 1.1	1.417	3.33%
75	2012-13	IP Validation with New Fluids	IP-	Polar Guard Advance	8	20	16-Jan-13	-6.2	-1.1	IP: 25	15	1.8, 1.8, 2.4	1, 1, 1.3	1, 1, 1.2	1.377	6.09%
76	2012-13	IP Validation with New Fluids	IP-	Polar Guard Advance	8	20	16-Jan-13	-6.4	-0.9	IP: 25	50	2, 2, 3	1, 1.2, 1.5	1, 1, 1.1	1.398	4.64%
77	2012-13	Baseline	Dry Wing	none	8	20	16-Jan-13	0.6	1.1	-	-	-	-	-	1.464	0.17%
78	2012-13	Baseline	Dry Wing	none	stall	20	16-Jan-13	0.6	1.1	-	-	-	-	-	1.466	0.00%
79A	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	16-Jan-13	0.8	1.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	n/a	n/a
79B	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	16-Jan-13	0.9	1.5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.436	2.08%
80	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	17-Jan-13	0.9	1.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.457	0.63%
81	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	17-Jan-13	0.9	1.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.442	1.63%
82	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	Max-Flight	stall	20	17-Jan-13	0.9	1.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.457	0.64%
83	2012-13	Baseline	Fluid Only	ABC-S Plus	stall	20	17-Jan-13	0.6	1.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.373	6.37%
84A	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	ABC-S Plus	stall	20	17-Jan-13	0.2	0.9	-	-	1, 1, 1	1, 1, 1	1, 1, 1	n/a	n/a
84B	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	ABC-S Plus	stall	20	17-Jan-13	0.1	1.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.447	1.30%
85	2012-13	2nd Wave of Fluid During Rotation	Fluid Only	ABC-S Plus	stall	20	17-Jan-13	-2.4	-1.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.441	1.69%
86	2012-13	IP Validation with New Fluids	IP mod	Polar Guard Advance	8	20	17-Jan-13	-6.3	-4.7	IP: 75	15	2, 2, 2.5	1, 1.7, 1.8	1, 1, 1.1	1.376	6.15%
87	2012-13	IP Validation with New Fluids	IP- / SN-	Polar Guard Advance	8	20	17-Jan-13	-9.7	-6.6	IP: 25 SN: 10	25	2, 2.2, 2.7	1.1, 2, 1.7	1, 1, 1.3	1.373	6.35%
88	2012-13	Baseline	Dry Wing	none	stall	20	17-Jan-13	-18.2	-10.2	-	-	-	-	-	1.467	-0.09%
89	2012-13	Baseline	Dry Wing	none	8	20	17-Jan-13	-18.2	-10.2	-	-	-	-	-	1.460	0.41%
90	2012-13	IP Flow-Off Issues	IP-	Polar Guard Advance	8	20	17-Jan-13	-17.6	-10.2	IP: 25	30	2, 2.1, 2.6	1.1, 1.7, 2.2	1, 1.3, 1.9	1.333	9.07%
91	2012-13	IP Flow-Off Issues	IP-	Polar Guard Advance	8	20	17-Jan-13	-19	-11.9	IP: 25	30	2, 2.2, 2.6	1, 1.4, 2.0	1, 1, 1.3	1.370	6.58%
92	2012-13	IP Flow-Off Issues	IP mod	Polar Guard Advance	8	20	17-Jan-13	-19.1	-14.4	IP: 75	10	2, 2.17, 2.5	1, 1.3, 2.0	1, 1.0, 1.3	1.348	8.05%
93	2012-13	IP Flow-Off Issues	IP mod	Polar Guard Advance	8	20	18-Jan-13	-18.8	-12.7	IP: 75	10	2.1, 2.2, 2.8	1.2, 1.7, 2.2	1, 1.3, 1.7	1.298	11.46%
94	2012-13	Baseline	Fluid Only	Polar Guard Advance	8	20	18-Jan-13	-18.9	-14.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.349	7.98%
95	2012-13	IP Flow-Off Issues	IP mod	ABC-S Plus	8	20	18-Jan-13	-18.5	-13.8	IP: 75	10	2.2, 2.1, 3.2	1, 1.7, 2.1	1, 1, 1.3	1.357	7.44%
96	2012-13	IP Flow-Off Issues	IP mod	ABC-S Plus	8	20	18-Jan-13	-19.1	-13.7	IP: 75	10	2.2, 2.2, 3	1.2, 1.9, 2.5	0.7, 1.2, 1.9	n/a	n/a

Table 3.1: Wind Tunnel Test Log 2012-13 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	Corrected for 3D Effects CL at 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL
96A	2012-13	IP Flow-Off Issues	IP mod	ABC-S Plus	8	20	18-Jan-13	-19.7	-13.6	IP: 75	10	2.4, 2.3, 3.1	1.1, 1.7, 2.1	1, 1.2, 1.6	1.318	10.09%
97	2012-13	IP Flow-Off Issues	IP-	ABC-S Plus	8	20	18-Jan-13	-19.5	-14	IP: 25	30	2.2, 2.2, 3.1	1, 1.6, 1.9	1, 1.1, 1.5	1.355	7.58%
98	2012-13	Baseline	Dry Wing	none	8	20	20-Jan-13	-15.7	-13.6	-	-	-	-	-	1.463	0.18%
99	2012-13	Baseline	Dry Wing	none	stall	20	20-Jan-13	-15.9	-15.3	-	-	-	-	-	1.467	-0.04%
100	2012-13	IP Validation with New Fluids	IP-	Polar Guard Advance	8	20	20-Jan-13	-16.2	-12.9	IP: 25	30	2.2, 2.2, 2.7	1.2, 1.6, 2.0	1, 1.3, 1.7	1.322	9.79%
101	2012-13	Effect of Ice Phobic Coatings on BLDT	Fluid Only	MP III 2031	8	20	21-Jan-13	-17.2	-15	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.377	6.08%
102	2012-13	Ice Phobic Coating R&D	None	none	8	20	21-Jan-13	-	n/a	-	-	-	-	-	1.457	0.64%
103	2012-13	Ice Phobic Coating R&D	None	none	22	20	21-Jan-13	-	n/a	-	-	-	-	-	1.456	0.67%
104	2012-13	Effect of Ice Phobic Coatings on BLDT	Fluid Only	MP III 2031	8	20	21-Jan-13	-18.4	-12.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.370	6.54%
105	2012-13	Ice Phobic Coating R&D	None	Max-Flight	8	20	21-Jan-13	-18.9	-13.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.362	7.12%
106	2012-13	Ice Phobic Coating R&D	None	EG 106	8	20	21-Jan-13	-19.6	-14.9	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.400	to be calculated
107	2012-13	Ice Phobic Coating R&D	None	none	8	20	21-Jan-13	-	n/a	-	-	-	-	-	1.450	1.09%
108	2012-13	Ice Phobic Coating R&D	None	none	22	20	21-Jan-13	-	n/a	-	-	-	-	-	1.443	1.55%
109	2012-13	Baseline	Dry Wing	none	8	20	22-Jan-13	-	n/a	-	-	-	-	-	1.461	0.32%
110	2012-13	Baseline	Dry Wing	none	8	20	22-Jan-13	-	n/a	-	-	-	-	-	1.456	0.71%
111	2012-13	Baseline	Dry Wing	none	stall	20	22-Jan-13	-	n/a	-	-	-	-	-	1.467	-0.08%
112	2012-13	Baseline	Dry Wing	none	8	20	22-Jan-13	-	n/a	-	-	-	-	-	1.460	0.43%
113	2012-13	IP Flow-Off Issues	IP mod	Max-Flight	8	20	22-Jan-13	-19.2	-13.7	IP: 75	10	2, 2.3, 3.1	1.0, 1.2, 1.6	1, 1, 1.2	1.359	7.31%
113A	2012-13	IP Flow-Off Issues	IP mod	Max-Flight	8	20	22-Jan-13	-18.7	-13.4	IP: 75	10	2.3, 2.3, 3	1, 1.4, 1.7	1.0, 1, 1.2	1.337	8.83%
114	2012-13	IP Expansion	IP- / SN-	Polar Guard Advance	8	20	22-Jan-13	-18.4	-10	IP: 25 SN: 10	5	2.2, 2.2, 2.8	1.0, 1.4, 1.8	1, 1, 1.3	1.361	7.14%
115	2012-13	IP Expansion	IP- / SN-	Max-Flight	8	20	22-Jan-13	-18.6	-9.3	IP: 25 SN: 10	5	2.1, 2, 3	1.1, 1.5, 1.8	1, 1, 1.2	1.356	7.48%
116	2012-13	IP Expansion	IP- / SN	Max-Flight	8	20	22-Jan-13	-18.7	-8.7	IP: 25 SN: 25	10	2.3, 2.2, 2.8	1.2, 1.6, 1.9	1, 1.0, 1.2	1.352	7.74%
117	2012-13	IP Expansion	IP- / SN	Polar Guard Advance	8	20	22-Jan-13	-18.7	-10.3	IP: 25 SN: 25	10	2.2, 2, 3.1	1.1, 1.4, 1.7	1, 1.1, 1.3	1.325	9.65%
118	2012-13	IP Expansion	IP- / SN	Polar Guard Advance	8	20	22-Jan-13	-18.8	-10.8	IP: 25 SN: 25	7	2.1, 2, 2.6	1.1, 1, 1.8	1, 1.1, 1.3	1.329	9.32%
119	2012-13	Baseline	Dry Wing	none	stall	20	22-Jan-13	-21.8	n/a	-	-	-	-	-	1.471	-0.31%
120	2012-13	Baseline	Dry Wing	none	8	20	22-Jan-13	-21.8	n/a	-	-	-	-	-	1.460	0.43%
121	2012-13	IP Flow-Off Issues	IP mod	ABC-S Plus	8	20	22-Jan-13	-24	-19.9	IP: 75	10	3, 2.7, 3.8	1.1, 1.8, 2.1	1, 1, 1.2	1.370	6.56%

Table 3.1: Wind Tunnel Test Log 2012-13 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	Date	OAT Before Test (°C)	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Visual Contamination Rating at Rotation (LE, TE, Flap)	Visual Contamination Rating After Takeoff (LE, TE, Flap)	Corrected for 3D Effects CL at 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL
122	2012-13	Baseline (BLDT)	Fluid Only	ABC-S Plus - 75/25	8	20	23-Jan-13	-24.5	-21.2	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.392	5.07%
123	2012-13	Baseline (BLDT)	Fluid Only	Polar Guard Advance - 75/25	8	20	24-Jan-13	-25.1	-21.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.417	3.35%
124	2012-13	Baseline (BLDT)	Fluid Only	Max-Flight - 75/25	8	20	23-Jan-13	-25.4	-21.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.397	4.71%
125	2012-13	Baseline (BLDT)	Fluid Only	Launch - 75/25	8	20	23-Jan-13	-25.8	-21.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.372	6.39%
126	2012-13	Baseline (BLDT)	Fluid Only	AD-49 - 75/25	8	20	23-Jan-13	-26.4	-21.5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.390	5.21%
127	2012-13	IP Flow-Off Issues	IP-	Polar Guard Advance	8	20	23-Jan-13	-27.1	-20.5	IP: 25	30	2.2, 2.2, 3	1.1, 1.6, 1.9	1, 1.1, 1.4	1.331	9.18%
128	2012-13	IP Flow-Off Issues	IP mod	Polar Guard Advance	8	20	23-Jan-13	-27.5	-22.4	IP: 75	10	2.4, 2.2, 3.2	1.1, 1.7, 2.2	1, 1.1, 1.5	1.337	8.78%
129	2012-13	IP Flow-Off Issues	IP-	Max-Flight	8	20	23-Jan-13	-27.8	-22.5	IP: 25	30	2.7, 2.2, 3.2	1, 1.5, 1.9	1, 1.1, 1.3	1.361	7.14%
130	2012-13	IP Flow-Off Issues	IP mod	Max-Flight	8	20	23-Jan-13	-28	-22.6	IP: 75	10	2.5, 2.4, 3.0	1.2, 1.6, 1.8	1, 1.2,1.3	1.348	8.08%
131	2012-13	Effect of Viscosity on Fluid Aerodynamics	Fluid Only	Max-Flight	8	20	23-Jan-13	-28.1	-23.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	n/a	n/a
132	2012-13	Baseline	Dry Wing	none	stall	20	23-Jan-13	-25	-20.1	-	-	-	-	-	1.463	0.19%
133	2012-13	Baseline	Dry Wing	none	8	20	23-Jan-13	-25	-20.1	-	-	-	-	-	1.462	0.27%
134	2012-13	IP Flow-Off Issues	IP mod	AD-49	8	20	23-Jan-13	-25	-22.1	IP: 75	10	3, 3, 3.9	1.1, 1.6, 2.2	1, 1.1,1.8	1.387	5.38%
135	2012-13	Baseline (BLDT)	Fluid Only	AD-49	8	20	23-Jan-13	-5	-22.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.408	3.99%
136	2012-13	Effect of Viscosity on Fluid Aerodynamics	Fluid Only	AD-49	8	20	23-Jan-13	-24.9	-22.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.417	3.37%
137	2012-13	IP Flow-Off Issues	IP-	ABC-S Plus	8	20	23-Jan-13	-24.7	-22.7	IP: 25	30	2.8, 2.8, 3.6	1.1, 1.5, 2.0	1, 1.1, 1.3	1.368	6.71%
138	2012-13	Baseline (BLDT)	Fluid Only	ABC-S Plus	8	20	24-Jan-13	-25.2	-22.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.395	4.83%
139	2012-13	Effect of Viscosity on Fluid Aerodynamics	Fluid Only	ABC-S Plus	8	20	24-Jan-13	-25.4	-22.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.386	5.46%
140	2012-13	Baseline (BLDT)	Fluid Only	ABC-S Plus - 75/25	8	20	24-Jan-13	-25.3	-22.5	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.389	5.28%
141	2012-13	IP Flow-Off Issues	IP mod	ABC-S Plus	8	20	24-Jan-13	-25.6	-22.6	IP: 75	10	2.3, 2.2, 3.4	1.1, 1.4, 1.8	1, 1.1, 1.3	1.366	6.82%
142	2012-13	IP Flow-Off Issues	IP mod	Max-Flight	8	20	24-Jan-13	-25.5	-22.8	IP: 75	10	2.4, 2.3, 2.3	1.0, 2.0, 2	1, 1.1, 1.3	1.368	6.66%
143	2012-13	Baseline (BLDT)	Fluid Only	Max-Flight	8	20	24-Jan-13	-25.4	-23.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.375	6.21%
144	2012-13	Effect of Viscosity on Fluid Aerodynamics	Fluid Only	Max-Flight	8	20	24-Jan-13	-25.2	-23.1	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.379	5.96%
145	2012-13	Baseline (BLDT)	Fluid Only	Max-Flight - 75/25	8	20	24-Jan-13	-25.5	-23	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.399	4.54%
146	2012-13	Baseline (BLDT)	Fluid Only	Polar Guard Advance	8	20	24-Jan-13	-25.5	-23.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.349	7.99%
147	2012-13	Baseline	Dry Wing	none	stall	20	24-Jan-13	n/a	n/a	-	-	-	-	-	1.457	0.59%
148	2012-13	Baseline	Dry Wing	none	8	20	24-Jan-13	n/a	n/a	-	-	-	-	-	1.462	0.24%

Table 3.1: Wind Tunnel Test Log 2012-13 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0º, 20º)	Date	OAT Before Test (ºC)	Tunnel 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)	Corrected for 3D Effects CL aat 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL
149	2012-13	IP Flow-Off Issues	IP mod	Polar Guard Advance	8	20	24-Jan-13	-19.7	-17.2	IP: 75	10	2.2, 2.2, 3.4	1.1, 1.6, 2.0	1, 1, 1.2	1.331	9.24%
150	2012-13	Effect of Viscosity on Fluid Aerodynamics	IP mod	Polar Guard Advance	8	20	24-Jan-13	-20	-17.1	IP: 75	10	1, 1, 1	1, 1, 1	1, 1, 1	1.369	6.65%
151	2012-13	Baseline (BLDT)	Fluid Only	Polar Guard Advance - 75/25	8	20	24-Jan-13	-20	-16.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.420	3.17%
152	2012-13	Baseline (BLDT)	Fluid Only	Polar Guard Advance	8	20	25-Jan-13	-20.3	-17.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.389	5.25%
153	2012-13	Effect of Viscosity on Fluid Aerodynamics	Fluid Only	Polar Guard Advance	8	20	25-Jan-13	-20.4	-17.3	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.399	4.54%
154	2012-13	IP Flow-Off Issues	IP mod	AD-49	8	20	25-Jan-13	-20.7	-6.5	IP: 75	10	3.0, 2.9, 4.0	1.1, 1.5, 2.0	1.0, 1.2, 1.7	1.395	4.86%
155	2012-13	Baseline (BLDT)	Fluid Only	Launch	8	20	25-Jan-13	-21	-17.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.372	6.40%
156	2012-13	IP Flow-Off Issues	IP mod	Launch	8	20	25-Jan-13	-21.1	-16.8	IP: 75	10	2.3, 2.2, 3.4	1.1, 1.4, 1.7	1, 1.1, 1.2	1.333	9.06%
157	2012-13	Effect of Viscosity on Fluid Aerodynamics	Fluid Only	Launch	8	20	25-Jan-13	-21.2	-17.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.370	6.53%
158	2012-13	Baseline (BLDT)	Fluid Only	EG106	8	20	25-Jan-13	-21.3	-17.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.416	3.43%
159	2012-13	IP Flow-Off Issues	IP-	AD-49	8	20	25-Jan-13	-21.5	-16.2	IP: 25	30	3.2, 3.2, 3.9	1.1, 1.6, 2.2	1.1, 1.3, 2.0	1.370	6.53%
160	2012-13	IP Flow-Off Issues	IP-	AD-49	8	20	25-Jan-13	-21.7	-17.4	IP: 25	15	2.5, 2.3, 3.3	1.1, 1.6, 1.8	1.0, 1.2, 1.3	1.393	4.95%
161	2012-13	Baseline	Dry Wing	none	stall	20	27-Jan-13	-11.8	-4.7	-	-	-	-	-	1.454	0.82%
162	2012-13	Baseline	Dry Wing	none	8	20	27-Jan-13	-11.8	-4.7	-	-	-	-	-	1.464	0.14%
163	2012-13	IP Validation with New Fluids	IP mod	ABC-S Plus	8	20	27-Jan-13	-11.8	-3.8	IP: 75	15	2.4, 2, 3.1	1, 1.4, 1.3	1, 1, 1.1	1.374	6.27%
164	2012-13	Effect of Viscosity on Fluid Aerodynamics	IP mod	ABC-S Plus	8	20	27-Jan-13	-11.2	-4.9	IP: 75	15	2, 2.1, 3.2	1, 1.4, 1.5	1, 1, 1.1	1.366	6.79%
165	2012-13	IP Validation with New Fluids	IP-	Max-Flight	8	20	28-Jan-13	-11.8	-4.8	IP: 25	50	2.3, 2.3, 3.3	1, 1.4, 1.3	1, 1, 1.0	1.400	4.53%
FLUSH MOUNTED SENSOR INSTALLED																
166	2012-13	Baseline	Dry Wing	none	stall	20	28-Jan-13	-12	6.2	-	-	-	-	-	1.422	3.03%
167	2012-13	Baseline	Dry Wing	none	pitch-stall	20	28-Jan-13	-12	6.2	-	-	-	-	-	1.443	1.57%
168	2012-13	Baseline	Dry Wing	none	8	20	28-Jan-13	-12	6.2	-	-	-	-	-	1.432	2.30%
169	2012-13	Baseline (BLDT)	Fluid Only	AD-49	8	20	28-Jan-13	-11.9	-8.6	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.383	5.64%
170	2012-13	IP Validation with New Fluids	IP- / SN-	AD-49	8	20	28-Jan-13	-11.8	-4.7	IP: 25 SN: 10	40	3.8, 3.3, 4	1.5, 2, 3.5	1.2, 1.8, 3.4	1.294	11.70%
FLUSH MOUNTED SENSOR REMOVED																
171	2012-13	IP Validation with New Fluids	IP- / SN-	AD-49	8	20	28-Jan-13	-11.8	-5.4	IP: 25 SN: 10	25	3, 2.9, 3.8	1.2, 1.5, 2	1.1, 1.1, 1.6	1.355	7.54%
172	2012-13	Effect of Viscosity on Fluid Aerodynamics	Fluid Only	AD-49	8	20	28-Jan-13	-12	-5.6	IP: 25 SN: 10	25	1, 1, 1	1, 1, 1	1, 1, 1	1.376	6.15%
173	2012-13	Ice Phobic Coating R&D	None	none	8	20	28-Jan-13	-7.2	-0.9	-	-	-	-	-	1.457	0.63%

Table 3.1: Wind Tunnel Test Log 2012-13 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0º, 20º)	Date	OAT Before Test (ºC)	Tunnel 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)	Corrected for 3D Effects CL at 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL
174	2012-13	Ice Phobic Coating R&D	None	none	stall	20	28-Jan-13	-7.2	-6	-	-	-	-	-	1.444	1.49%
175	2012-13	Ice Phobic Coating R&D	None	none	stall	20	28-Jan-13	-7.2	-6	-	-	-	-	-	1.460	0.41%
176	2012-13	Ice Phobic Coating R&D	Fluid Only	EG106	8	20	28-Jan-13	-7.5	-4.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.418	3.25%
177	2012-13	Ice Phobic Coating R&D	Fluid Only	EG106	stall	20	28-Jan-13	-7.8	0.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.407	4.02%
178	2012-13	Ice Phobic Coating R&D	ZR	EG106	8	20	29-Jan-13	-7.2	0.1	ZR: 25	50	1, 1, 4.3	1, 1, 5	1, 1, 5	1.418	3.28%
179	2012-13	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	20	29-Jan-13	-8.3	-0.5	IP: 25 ZR: 25	25	1.8, 1.8, 3.7	1, 1.1, 1.5	1, 1, 1.3	1.408	3.95%
180	2012-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	20	29-Jan-13	-9.5	-1.9	IP: 75	15	2.3, 2.3, 3	1, 1.4, 1.5	1, 1, 1.1	1.383	5.67%
181	2012-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	20	29-Jan-13	-9.6	-2.9	IP: 75	15	2.2, 2.2, 3.0	1, 1.4, 1.4	1, 1, 1.1	1.392	5.04%
182	2012-13	Ice Phobic Coating R&D	SN	none	8	20	29-Jan-13	-9.6	-1.6	SN: 10	15	4, 4, 4	5, 5, 5	5, 5, 5	1.414	3.56%
183	2012-13	Ice Phobic Coating R&D	ZR	none	8	20	29-Jan-13	-9.4	-0.4	ZR: 25	15	5, 5, 5	5, 5, 5	5, 5, 5	1.418	3.30%
184	2012-13	Ice Phobic Coating R&D	ZR	none	stall	20	29-Jan-13	-	-6.1	-	-	-	-	-	1.418	3.28%
185	2012-13	Ice Phobic Coating R&D	None	none	8	20	31-Jan-13	-2.8	-1.4	-	-	-	-	-	1.458	0.52%
186	2012-13	Ice Phobic Coating R&D	None	none	stall	20	31-Jan-13	-3.2	-2.9	-	-	-	-	-	1.445	1.40%
187	2012-13	Ice Phobic Coating R&D	Fluid Only	EG 106	8	20	31-Jan-13	-3.6	-2.8	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.416	3.39%
188	2012-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	20	31-Jan-13	-5.2	-3.9	IP: 75	15	2, 2.2, 2.8	1, 1.4, 1.5	1, 1, 1.1	1.370	6.57%
189	2012-13	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	20	31-Jan-13	-7.1	-5.7	IP: 25 ZR: 25	25	2.4, 2.3, 3.5	1.0, 1.6, 2	1, 1.1, 1.3	1.394	4.89%
190	2012-13	Ice Phobic Coating R&D	ZR	none	8	20	31-Jan-13	-8.6	-7.1	ZR: 25	15	5, 5, 5	5, 5, 5	5, 5, 5	1.398	4.66%
191	2012-13	Ice Phobic Coating R&D	ZR	none	stall	20	31-Jan-13	-8.6	-7.1	ZR: 25	15	-	-	-	1.390	5.20%
192	2012-13	Ice Phobic Coating R&D	None	none	8	20	31-Jan-13	-10.1	-0.5	-	-	-	-	-	1.451	1.02%
193	2012-13	Ice Phobic Coating R&D	None	none	stall	20	31-Jan-13	-8.6	-7.1	-	-	-	-	-	1.447	1.31%
194	2012-13	Ice Phobic Coating R&D	Fluid Only	EG106	8	20	31-Jan-13	-10.6	-8.7	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.414	3.53%
195	2012-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	20	31-Jan-13	-10.9	-9.2	IP: 75	15	2.5, 2.2, 3.1	1, 1.4, 1	1, 1, 1.1	1.344	8.30%
196	2012-13	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	20	31-Jan-13	-11.4	-8.6	IP: 25 ZR: 25	25	3, 3.2, 4	1, 1.4, 2.9	1, 1, 1.1	1.362	7.10%
197	2012-13	Ice Phobic Coating R&D	SN	none	8	20	31-Jan-13	-11.6	-6.5	SN: 10	15	4, 4, 4	5, 5, 5	5, 5, 5	1.392	5.04%
198	2012-13	Ice Phobic Coating R&D	None	none	8	20	1-Feb-13	-15.5	-8	-	-	-	-	-	1.447	1.30%
199	2012-13	Ice Phobic Coating R&D	None	none	stall	20	1-Feb-13	-15.5	-13.9	-	-	-	-	-	1.441	1.73%
200	2012-13	Ice Phobic Coating R&D	Fluid Only	EG106	8	20	1-Feb-13	-15.3	-12.4	-	-	1, 1, 1	1, 1, 1	1, 1, 1	1.413	3.58%

Table 3.1: Wind Tunnel Test Log 2012-13 (cont'd)

Test #	Test Year	Objective	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0º, 20º)	Date	OAT Before Test (ºC)	Tunnel 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)	Corrected for 3D Effects CL at 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL
201	2012-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	20	1-Feb-13	-14.4	-11.9	IP: 75	10	2.2, 2.2, 2.8	1.1, 1.5, 1	1, 1, 1.1	1.333	9.08%
202	2012-13	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	20	1-Feb-13	-13.8	-7.8	IP: 25 ZR: 25	10	2.3, 1.8, 2.8	1, 1.4, 1.6	1, 1, 1.1	1.362	7.08%
203	2012-13	Ice Phobic Coating R&D	ZR	none	8	20	1-Feb-13	-13.1	-3.3	ZR: 25	15	-	-	-	1.418	3.30%
204	2012-13	Ice Phobic Coating R&D	ZR	none	stall	20	1-Feb-13	-13.2	-12.8	-	-	-	-	-	1.409	3.88%

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 4 or in Section 5. Details on these specific analysis techniques are included in a separate report issued by NASA.

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 that 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 as acceptable. Ratings higher than this indicated potential fluid contamination or fluid flow-off issues; these results were supported by the lift coefficient data collected. Figures 4.1 and 4.2 summarize the visual ratings at the start of the test (after precipitation) and at the start of rotation; in both cases, the values are indicative of the condition of the leading edge.

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 loss in lift coefficient at the 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. These limits were determined based on the calibration work conducted in conjunction with NASA.

The lift coefficient is a non-dimensional 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 coefficient profiles. During the fluid tests, variations in airspeed could potentially cause variations in the lift 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 variations 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 4.3 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 during some limited tests in 2009-10 (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.

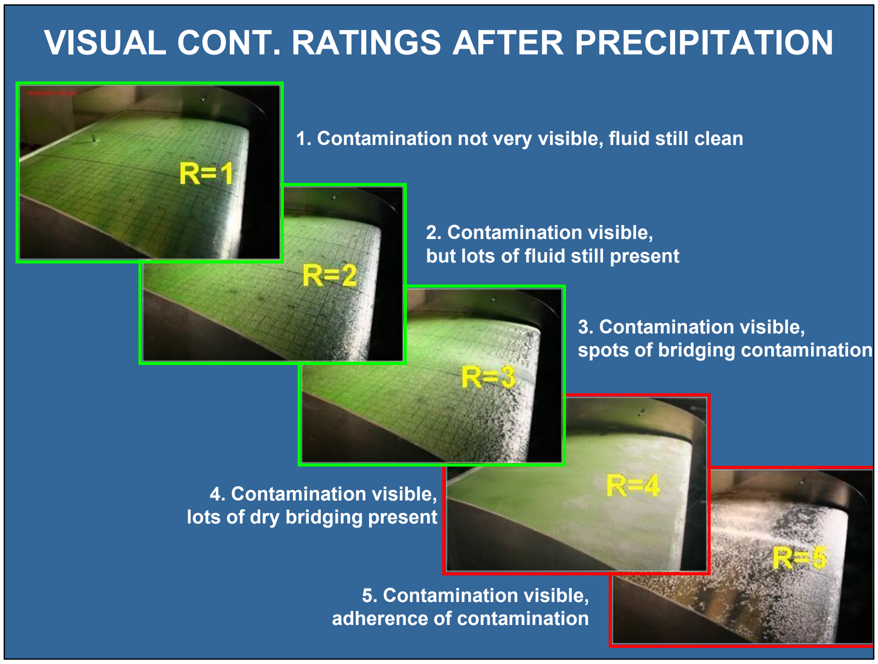

Figure 4.1: Example of Visual Contamination Ratings at Start of Test (After Precipitation)

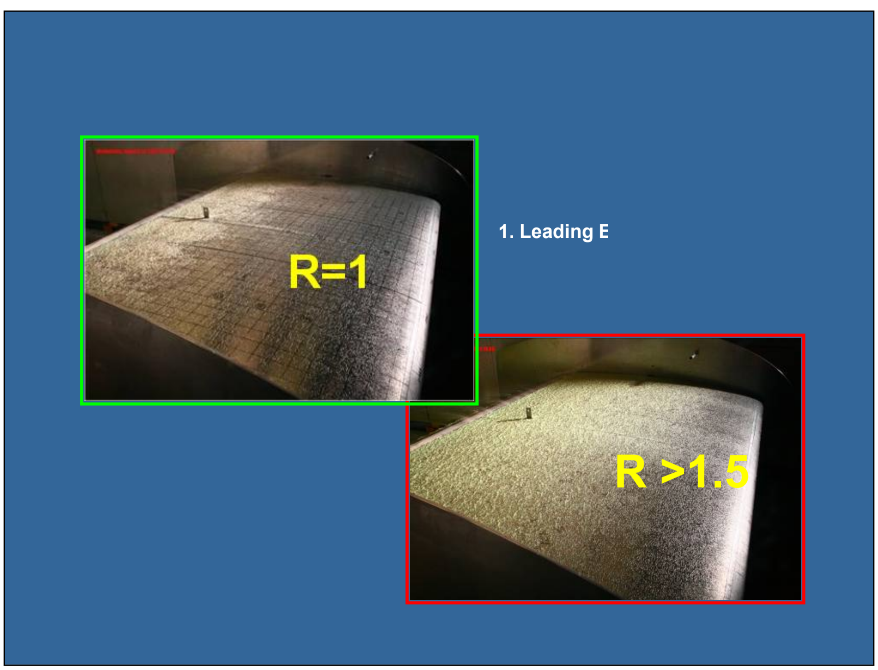

Figure 4.2: Example of Visual Contamination Ratings at Start of Rotation

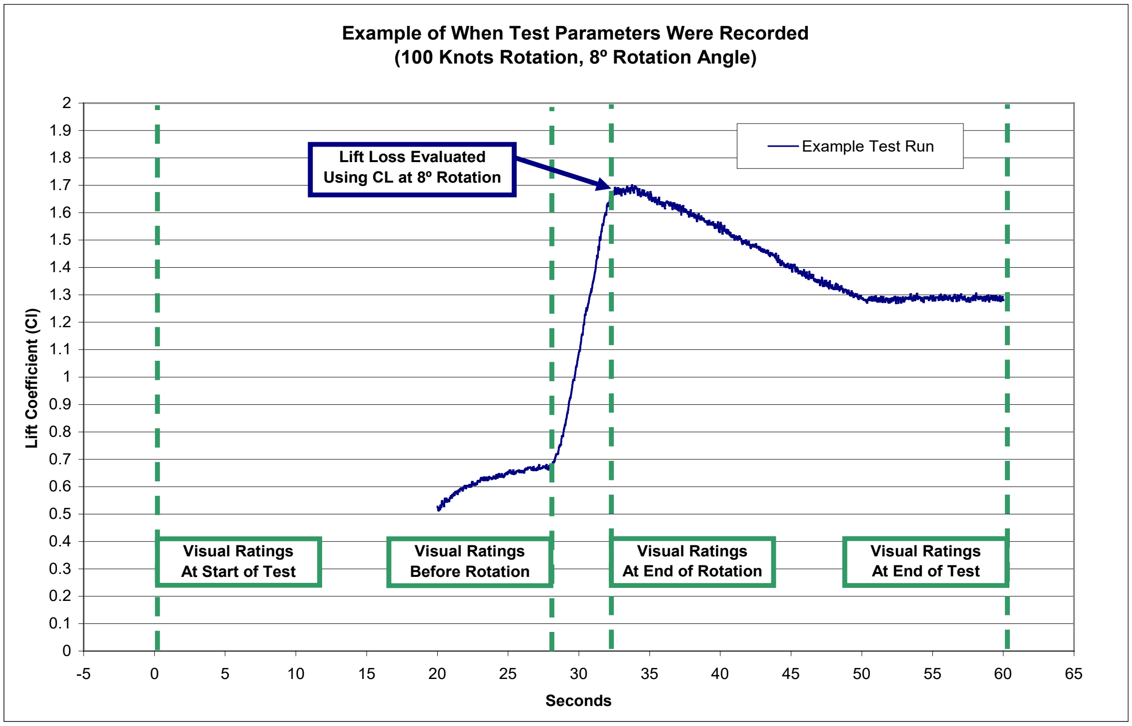

Figure 4.3: Example of When Test Parameters Were Recorded

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 4.4 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 “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 as “good” or “very good”; equal to 1 on the leading edge at the time of rotation was also considered as “good” or “very good” (greater than 1 to 1.5 on the leading edge was considered "review"). The calculated lift 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 noted 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.

The use of the summary sheets was discontinued for the 2012-13 analysis. These sheets served an important purpose as reference material while developing and finalizing the analysis methodology from 2009-10 onwards, but as the methodology matured, these sheets are no longer necessary. Instead the information has been provided in table format only in the respective test analysis sections (6 to 11).

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 4.4: Typical Worksheet Used for Analysis

4.4 Ice Pellet Summary Worksheet Analysis Criteria

As described in Subsection 4.3, analysis worksheets were previously developed and completed for all ice pellet tests conducted; however, this analysis is now only included in the respective analysis sections 6 to 10.

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 4.5 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; this became less of an issue after 2011-12 with the use of the automated ramp-up system instead of the previous manual system.

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 3 or less 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.

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 1 or less 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.

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 4.5: Ice Pellet Test Analysis Criteria

4.4.4 Eight-Degree Rotation Lift Loss

Subsection 4.2 outlines how the 8° rotation lift loss criteria were 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 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 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). As 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 was 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 that used during the 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 that used during the winter of 2009-10; however, the lift coefficient evaluation criteria were 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 those used during 2010-11. 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.

4.5.5 Methodology Used for 2012-13 vs. 2011-12

During the 2012-13 testing, the typical testing and analysis methodology remained the same as those used during the 2010-11. Similar to 2011-12, 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 6 to 10.

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5. WING CALIBRATION AND CHARACTERIZATION

This section briefly 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 primarily 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.

5.1 Testing Overview

The testing conducted in 2012-13 was a follow-up to the 2011-12 testing program, and it essentially attempted to acquire missing or lacking data to support the previous conclusions and observations. 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 5.1.1 to 5.1.6:

- Survey of Clean Wing Performance;
- Boundary Layer Rake Test;
- Sandpaper Roughness Tests;
- Second Wave of Fluid Tests; and
- Lift Loss Scaling.

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

5.1.1 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 sweeps 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 5.1 demonstrates the dry wing section during these tests.

5.1.2 Boundary Layer Rake

A boundary layer rake was installed on the wing with the purpose of identifying 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 using both angle sweeps and fixed pitch testing. Photo 5.2 shows the boundary layer rake installed mid-span on the trailing edge of the wing.

5.1.3 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 sandpaper was removed in incremental configurations starting from the leading edge, simulating fluid flow-off. The 2012-13 testing focused on the sandpaper roughness effect on the flap only and served to provide the missing data not previously collected in 2011-12. Photo 5.3 shows the different sand paper configurations tested.

5.1.4 Second Wave of Fluid

The objective of these tests was to document the aerodynamic effects of the second wave of fluid. Previous wind tunnel testing has shown that during a simulated takeoff roll following de/anti-icing, fluid will shear off the wing section; however, a small amount of fluid can remain trapped along the leading edge at the stagnation point. This “trapped” fluid begins to flow over the wing only once the wing is rotated; the stagnation point shifts below the leading edge, and the “trapped” fluid begins to shear off as a second wave. Testing was simulated in a static model using strips of speed-tape and cork-tape strategically located on the leading edge of the wing section (along the span where the separation bubble will typically occur). A separate set of dynamic tests simulated the second wave with actual anti-icing fluid; sheared fluid prior to rotation was left only in select areas either below or above the stagnation point and then the flow was observed during a typical rotation. Photo 5.4 shows the speed-tape used to simulate the second wave thickness. Photo 5.5 shows the simulated 2nd wave of fluid setups.

5.1.5 Lift Loss Scaling

The lift losses due to uncontaminated anti-icing fluids measured on the NRC PIWT wing at $\alpha = 8$ degrees were scaled to the percent reduction in maximum lift of the full-scale B737-200ADV through the use of the AAT. This result was used to develop a lift loss criterion used to help develop the ice pellet allowance times. This work was also documented in NASA/TM-2012-216014 (also DOT/FAA/TC-12/32), distributed at the Montreal G-12 Aerodynamics Working Group (AWG) meeting in 2012. During the 2013 PIWT test campaign, additional uncontaminated fluid tests were performed at colder temperatures to supplement the existing database.

5.2 Summary of Test Results

As reported by NASA, the clean, dry wing aerodynamic repeatability was confirmed in comparison with previous data. The additional data collected in 2012-13 helped in substantiating these findings. The stalling characteristics of the wing with fluid only (or fluid with contamination) appear to be driven by secondary wave effects near the leading edge; these effects are difficult to interpret on the 2D model relative to a fully 3D wing and should not be used in developing allowance times. Additional lift loss scaling correlation data with different fluids at colder temperatures confirmed that previous lift loss limits are still valid.

5.3 Documentation of Test Results

The work described in Section 6 was presented by NASA to the AWG during the New Orleans SAE G-12 meeting in May 2013. 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 5.1: Survey of Clean Wing Performance

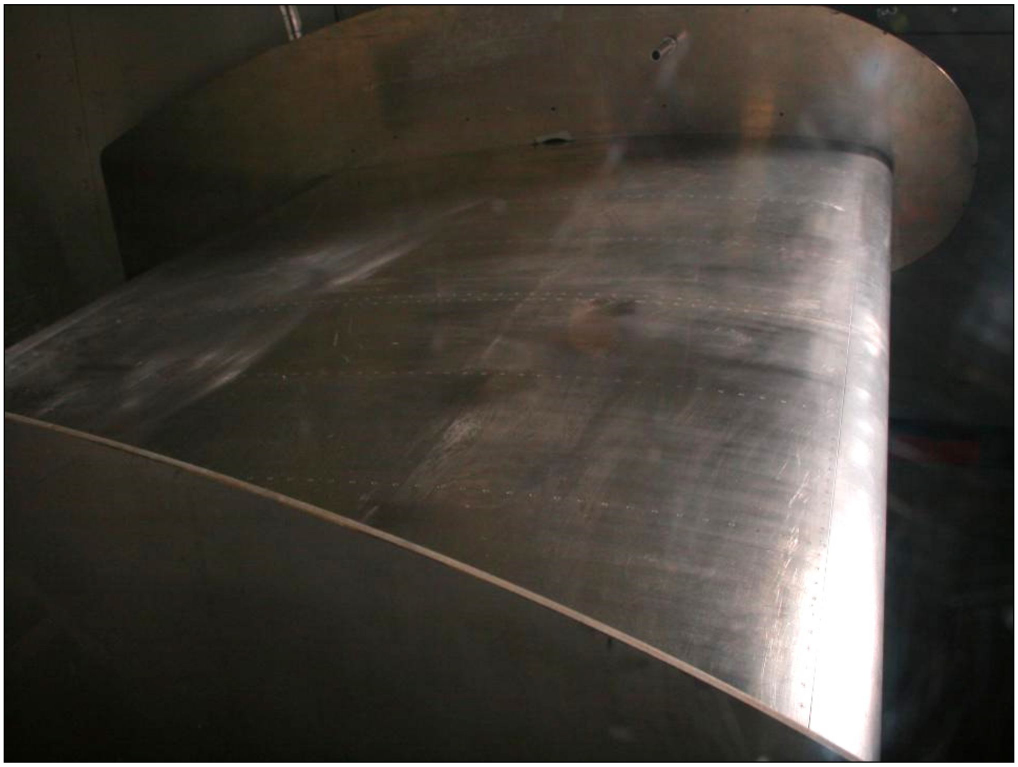


Photo 5.2: Boundary Layer Rake Tests

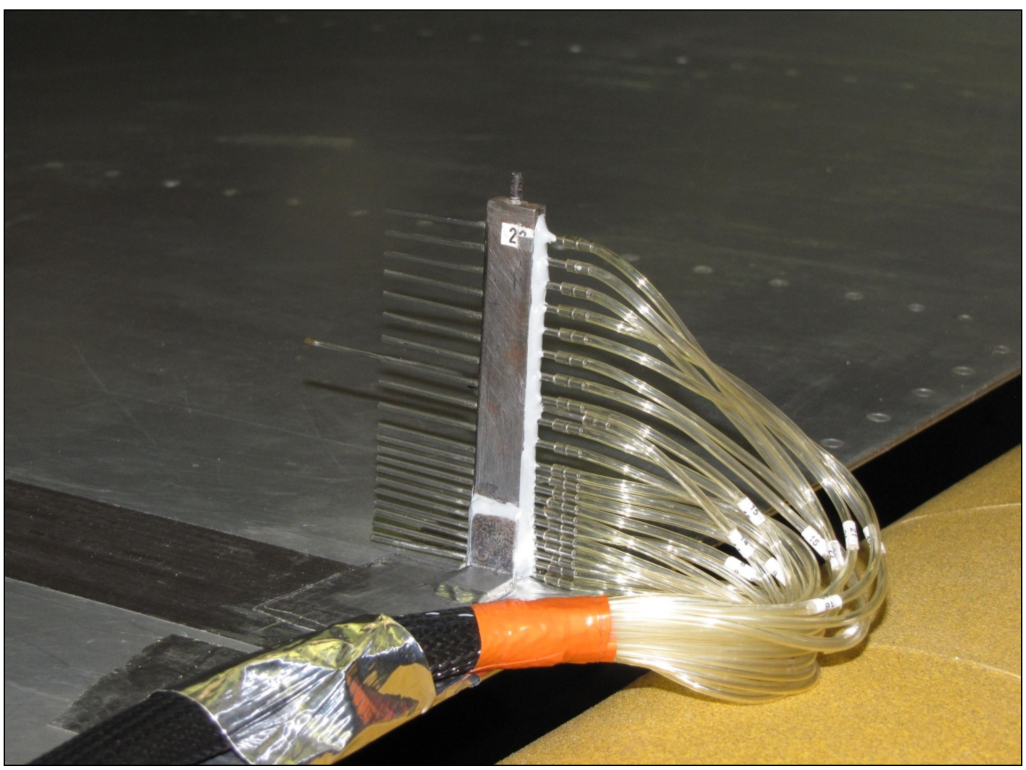


Photo 5.3: Sandpaper Roughness Tests

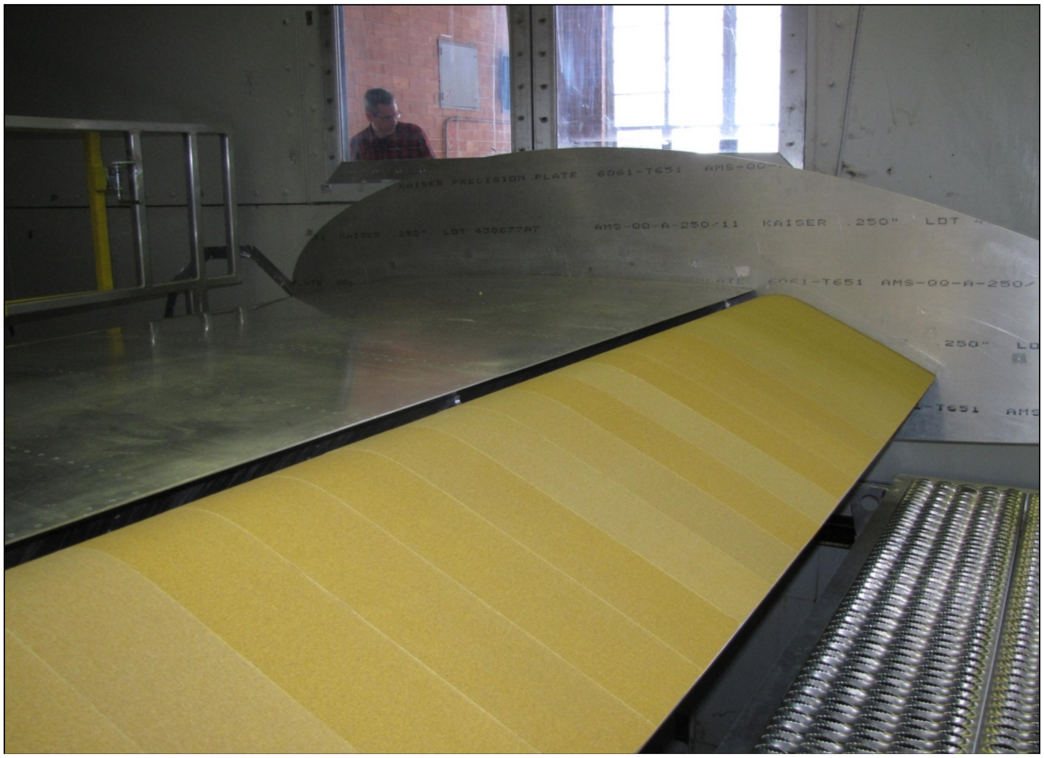


Photo 5.4: Second Wave of Fluid Tests

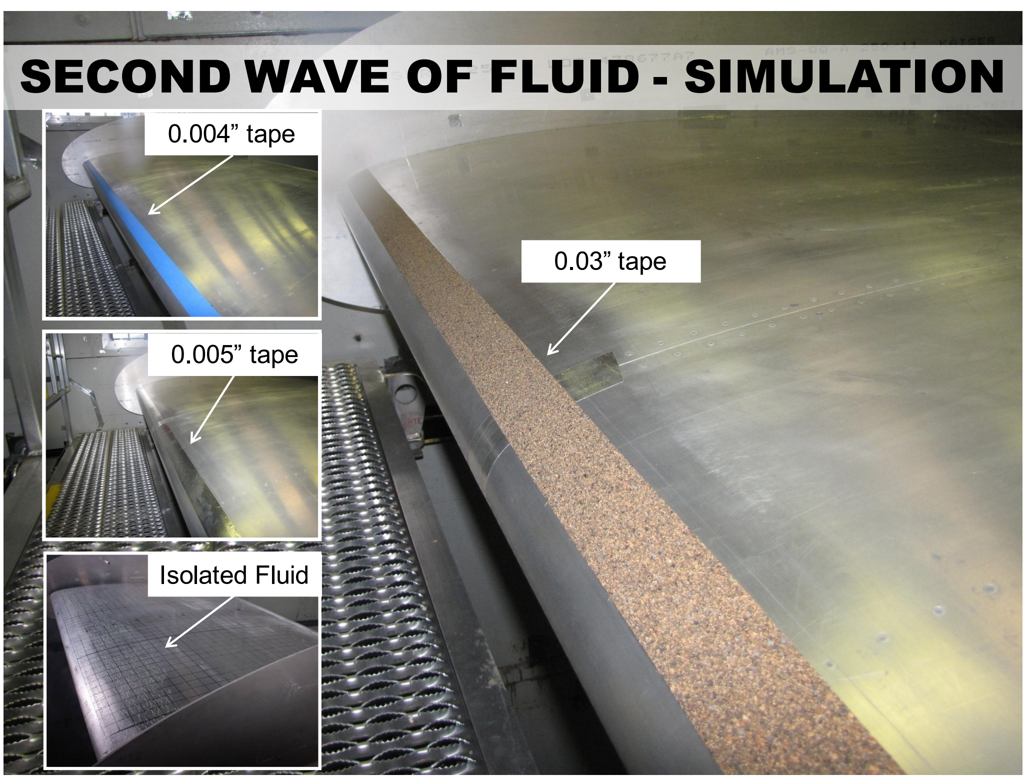
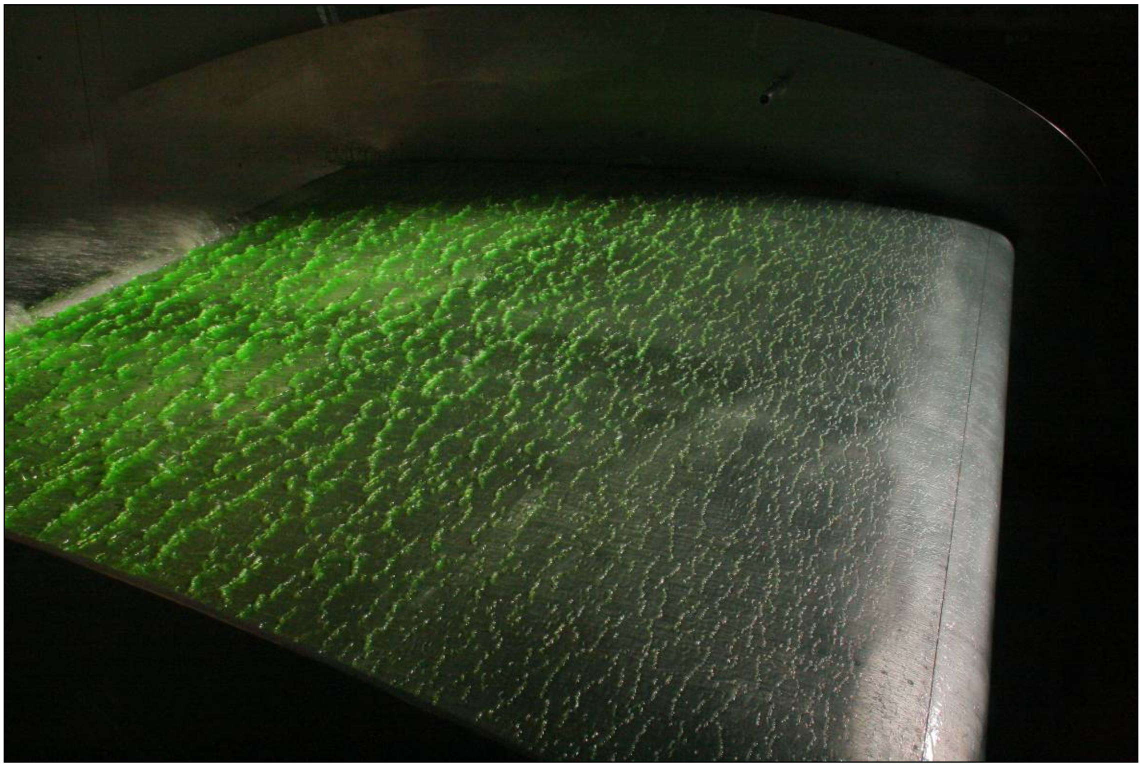


Photo 5.5: Fluid Only Test for Lift Loss Scaling



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6. LIGHT ICE PELLET ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Testing started in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Moderate Rain;
- Section 9: Light Ice Pellets and Light Snow; and
- Section 10: Light Ice Pellets and Moderate Snow.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellet conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

6.1 Overview of Tests

A summary of the Light Ice Pellet tests conducted in the wind tunnel is shown in Table 6.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1.

Table 6.1: Summary of 2012-13 Light Ice Pellet Testing

Test No.	Date	Fluid	Condition	Precip. Rate (g/dm2/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Flap Angle (°)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
75*	16-Jan-13	Polar Guard Advance	IP-	25	15	-1.1	N/A	20	100	2 , 2 , 2	1 , 1 , 1	1.377	6.09%
76	16-Jan-13	Polar Guard Advance	IP-	25	50	-0.9	N/A	20	100	2 , 2 , 3	1 , 1 , 2	1.398	4.64%
90	17-Jan-13	Polar Guard Advance	IP-	25	30	-10.2	N/A	20	100	2 , 2 , 3	1 , 2 , 2	1.333	9.07%
91	17-Jan-13	Polar Guard Advance	IP-	25	30	-11.9	N/A	20	115	2 , 2 , 3	1 , 1 , 2	1.370	6.58%
97	18-Jan-13	ABC-S Plus	IP-	25	30	-14	N/A	20	115	2 , 2 , 3	1 , 2 , 2	1.355	7.58%
100	20-Jan-13	Polar Guard Advance	IP-	25	30	-12.9	N/A	20	100	2 , 2 , 3	1 , 2 , 2	1.322	9.79%
127	23-Jan-13	Polar Guard Advance	IP-	25	30	-20.5	N/A	20	115	2 , 2 , 3	1 , 2 , 2	1.331	9.18%
129	23-Jan-13	Max-Flight	IP-	25	30	-22.5	N/A	20	115	3 , 2 , 3	1 , 1 , 2	1.361	7.14%
137	23-Jan-13	ABC-S Plus	IP-	25	30	-22.7	N/A	20	115	3 , 3 , 4	1 , 2 , 2	1.368	6.71%
159	25-Jan-13	AD-49	IP-	25	30	-16.2	N/A	20	115	3 , 3 , 4	1 , 2 , 2	1.370	6.53%
160	25-Jan-13	AD-49	IP-	25	15	-17.4	N/A	20	115	3 , 2 , 3	1 , 2 , 2	1.139	4.95%
165	28-Jan-13	Max-Flight	IP-	25	50	-4.8	N/A	20	100	2 , 2 , 3	1 , 1 , 1	1.400	4.53%

* Problem with precipitation time; should have been 25-mintutes.

6.2 Fluid Brix, Fluid Thickness, and Skin Temperature

Fluid thickness, fluid Brix, and skin temperature measurements were collected by APS personnel. The measurements were collected before and after fluid application, after the application of contamination, and at the end of the test. Details regarding the measurement intervals and locations are included in Subsection 2.15. The completed data forms have been scanned and included in Appendix C for referencing purposes.

6.3 Photos

High-speed digital photography of each test was taken (see Subsections 2.10 and 2.11 for more details). In addition, videos were also taken during a greater portion of the tests. Due to the large amount of data available, photos of the individual tests have not been included in this report, but rather the high-resolution photos are available in electronic format upon request and have been made available to the TDC.

6.4 Summary of Results

6.4.1 OAT -5°C and Above

Two tests (#76 and #165) were conducted with exposure times of 50 minutes in this cell (see Table 6.2). The results from both tests indicated acceptable visual contamination ratings and lift losses below the 5.4 percent safety criteria.

An additional test (#75) was conducted but with an insufficient exposure time: 15 minutes instead of 50 minutes. This test indicated acceptable visual contamination ratings and lift losses just above the 5.4 percent lower limit but below the 9.2 percent upper limit.

This test demonstrated positive results, indicating that the current allowance time of 50 minutes for this cell is still acceptable and validated.

6.4.2 OAT Less than -5°C to -10°C

No testing was conducted in this condition. Based on historical data collected, the current allowance time of 30 minutes for this cell is satisfactory at this time based on the limited results obtained. It is, however, recommended that if additional testing is conducted in the future, that data in this cell be collected with newer generation fluids.

6.4.3 OAT Less than -10°C

Two tests (#90 and #100) were conducted in this cell with an exposure time of 30 minutes based on a test run of 100 knots. The results indicated that although the visual contamination ratings were acceptable, the lift losses were close to, or above, the 9.2 percent upper limit. This provides further substantiation of the fact that the 30-minute allowance time is not appropriate for PG fluids when rotating at 100 knots.

Six other tests (#91, #97, #127, #129, #137, and #159) were also conducted with 30-minute exposure times but based on a test run of 115 knots instead of 100 knots. In general, all tests demonstrated acceptable visual contamination ratings, and lift losses within the marginal lift loss range of 5.4 percent to 9.2 percent. One test (#127) did record a lift loss of 9.18 percent, just at the limit of the range. If additional testing is conducted, a repeat of this test should be attempted at the colder temperature range.

One additional test (#160) was conducted with a 15-minute exposure time instead of 30 minutes based on a test run of 115 knots. The results from the test indicated acceptable visual contamination ratings and lift losses below the 5.4 percent safety criteria. This indicates that reducing the allowance time by half in this condition should improve the aerodynamic performance.

The data indicated that the current allowance time of 30 minutes is acceptable for PG fluids with rotation speeds of 115 knots or greater; at 100 knots, the lift losses were unacceptable. It should, however, be noted that one test (#127) indicated borderline results. If additional testing is conducted, a repeat of this test should be attempted at the colder temperature range. Alternatively, consideration could be given to reducing the 115 knot PG allowance times to provide a greater safety buffer.

Table 6.2: Light Ice Pellets Allowance Time Tests Winter 2012-13

Light Ice Pellets	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
100 kts Runs	50 minutes Test # 76, 165	30 minutes	30 minutes Test # 90, 100
	15 minutes Test # 75		
115 kts Runs	50 minutes	30 minutes	30 minutes Test # 91, 97, 127,129, 137, 159
			15 minutes Test # 160

Table 6.3: Summary of Light Ice Pellets Allowance Time Test Results

OAT -5°C AND ABOVE 100 Kts (50 MINUTES)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
76	Polar Guard Advance	-0.9	25	50	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	4.64	GOOD	GOOD
165	Max-Flight	-4.8	25	50	2 , 2 , 3	GOOD	1 , 1 , 1	GOOD	4.53	GOOD	GOOD
OAT -5°C AND ABOVE 100 Kts (15 MINUTES)											
75	Polar Guard Advance	-1.1	25	15	2 , 2 , 2	GOOD	1 , 1 , 1	GOOD	6.09	REVIEW	REVIEW
CONCLUSION: ALLOWANCE TIME AT 50 MINUTES IS GOOD											

OAT LESS THAN -5°C TO -10°C (30 MINUTES)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
-	-	-	-	-	-	-	-	-	-	-	-
Notes: No Notes											
CONCLUSION: NO TESTING CONDUCTED THEREFORE BASED ON HISTORICAL DATA, ALLOWANCE TIME AT 30 MINUTES IS OK											

Table 6.3: Summary of Light Ice Pellets Allowance Time Test Results (cont'd)

OAT LESS THAN -10°C (30 MINUTES)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts											
90	Polar Guard Advance	-10.2	25	30	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	9.07	REVIEW	REVIEW
100	Polar Guard Advance	-12.9	25	30	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	9.79%	BAD	BAD
115 kts											
91	Polar Guard Advance	-11.9	25	30	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	6.58	REVIEW	REVIEW
97	ABC-S Plus	-14	25	30	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	7.58%	REVIEW	GOOD
127	Polar Guard Advance	-20.5	25	30	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	9.18%	REVIEW	REVIEW
129	Max-Flight	-22.5	25	30	3 , 2 , 3	GOOD	1 , 1 , 2	GOOD	7.14%	REVIEW	REVIEW
137	ABC-S Plus	-22.7	25	30	3 , 3 , 4	GOOD	1 , 2 , 2	GOOD	6.71%	REVIEW	REVIEW
159	AD-49	-16.2	25	30	3 , 3 , 4	GOOD	1 , 2 , 2	GOOD	6.53%	REVIEW	REVIEW
OAT LESS THAN -10°C (15 MINUTES)											
115 kts											
160	AD-49	-17.4	25	15	3 , 2 , 3	GOOD	1 , 2 , 2	GOOD	4.95%	GOOD	GOOD
CONCLUSION: ALLOWANCE TIME AT 30 MINUTES IS OK FOR 115 KTS. CANNOT GO BACK TO 100 KTS FOR PROPYLENE											

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7. MODERATE ICE PELLETS

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Testing started in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Moderate Rain;
- Section 9: Light Ice Pellets and Light Snow; and
- Section 10: Light Ice Pellets and Moderate Snow.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Moderate Ice Pellet conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

7.1 Overview of Tests

A summary of the Moderate Ice Pellet tests conducted in the wind tunnel is shown in Table 7.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1.

Table 7.1: Summary of 2012-13 Moderate Ice Pellet Testing

Test No.	Date	Fluid	Condition	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Flap Angle (°)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
86	17-Jan-13	Polar Guard Advance	IP Mod	IP:75	15	-4.7	N/A	20	100	2 , 2 , 3	1 , 2 , 2	1.376	6.15%
92	17-Jan-13	Polar Guard Advance	IP Mod	IP:75	10	-14.4	N/A	20	115	2 , 2 , 3	1 , 1 , 2	1.348	8.05%
93	18-Jan-13	Polar Guard Advance	IP Mod	IP:75	10	-12.7	N/A	20	100	2 , 2 , 3	1 , 2 , 2	1.298	11.46%
95	18-Jan-13	ABC-S Plus	IP Mod	IP:75	10	-13.8	N/A	20	115	2 , 2 , 3	1 , 2 , 2	1.357	7.44%
96	18-Jan-13	ABC-S Plus	IP Mod	IP:75	10	-13.7	N/A	20	100	2 , 2 , 3	1 , 2 , 3	n/a	n/a
96A	18-Jan-13	ABC-S Plus	IP Mod	IP:75	10	-13.6	N/A	20	100	2 , 2 , 3	1 , 2 , 2	1.318	10.09%
113	22-Jan-13	Max-Flight	IP Mod	IP:75	10	-13.7	N/A	20	115	2 , 2 , 3	1 , 1 , 2	1.359	7.31%
113A	22-Jan-13	Max-Flight	IP Mod	IP:75	10	-13.4	N/A	20	115	2 , 2 , 3	1 , 1 , 2	1.337	8.83%
121	22-Jan-13	ABC-S Plus	IP Mod	IP:75	10	-19.9	N/A	20	115	3 , 3 , 4	1 , 2 , 2	1.370	6.56%
128	23-Jan-13	Polar Guard Advance	IP Mod	IP:75	10	-22.4	N/A	20	115	2 , 2 , 3	1 , 2 , 2	1.337	8.78%
130	23-Jan-13	Max-Flight	IP Mod	IP:75	10	-22.6	N/A	20	115	3 , 2 , 3	1 , 2 , 2	1.348	8.08%
134	23-Jan-13	AD-49	IP Mod	IP:75	10	-22.1	N/A	20	115	3 , 3 , 4	1 , 2 , 2	1.387	5.38%
141	24-Jan-13	ABC-S Plus	IP Mod	IP:75	10	-22.6	N/A	20	115	2 , 2 , 3	1 , 1 , 2	1.366	6.82%
142	24-Jan-13	Max-Flight	IP Mod	IP:75	10	-22.8	N/A	20	115	2 , 2 , 2	1 , 2 , 2	1.368	6.66%
149	24-Jan-13	Polar Guard Advance	IP Mod	IP:75	10	-17.2	N/A	20	115	2 , 2 , 3	1 , 2 , 2	1.331	9.24%
154	25-Jan-13	AD-49	IP Mod	IP:75	10	-6.5	N/A	20	115	3 , 3 , 4	1 , 2 , 2	1.395	4.86%
156	25-Jan-13	Launch	IP Mod	IP:75	10	-16.8	N/A	20	115	2 , 2 , 3	1 , 1 , 2	1.333	9.06%
163	27-Jan-13	ABC-S Plus	IP Mod	IP:75	15	-3.8	N/A	20	100	2 , 2 , 3	1 , 1 , 1	1.374	6.27%

7.2 Fluid Brix, Fluid Thickness, and Skin Temperature

Fluid thickness, fluid Brix, and skin temperature measurements were collected by APS personnel. The measurements were collected before and after fluid application, after the application of contamination, and at the end of the test. Details regarding the measurement intervals and locations are included in Subsection 2.14. The completed data forms have been scanned and included in Appendix C for referencing purposes.

7.3 Photos

High-speed digital photographs of each test were taken (see Subsections 2.10 and 2.11 for more details). In addition, videos were also taken during a greater portion of the tests. Due to the large amount of data available, photos of the individual tests have not been included in this report, but rather the high-resolution photos are available in electronic format upon request and have been made available to the TDC.

7.4 Summary of Results

7.4.1 OAT -5°C and Above

Two PG fluid tests were conducted with exposure times of 15 minutes in this cell: Tests #86, and #163. In both tests, the data demonstrated acceptable visual contamination ratings and lift losses within the marginal lift loss range of 5.4 percent to 9.2 percent.

In conclusion, the current allowance time of 15 minutes is acceptable for PG fluids. The 25-minute allowance time for ethylene glycol (EG) fluids was not tested, as previous historical data has not indicated any issues.

7.4.2 OAT Less than -5°C to -10°C

One test (#154) was conducted in this cell with an exposure time of 10 minutes based on a test run of 115 knots. It should be noted that this test was intended to simulate less than -10ºC conditions, but due to the tunnel temperature rising during setup and dispensing of contamination, this test was put into the higher temperature bracket. As such, this test does not validate the current moderate ice pellet allowance times for -5ºC to -10ºC because of the higher speeds of 115 knots.

In conclusion, the current data is not usable for substantiating the current allowance time of 10 minutes for PG fluids. It is recommended that if further testing is conducted, additional testing in this condition be conducted.

7.4.3 OAT Less than -10°C

Eleven tests were conducted in this cell based on a test run of 115 knots and exposure times of 10 minutes: Tests #92, #95, #113, #113A, #121, #128, #130, #134, #141, #142, #149, and #156. An additional three tests were also conducted with the same exposure time but based on the lower speed of 100 knots: Tests #93, #96 (not a valid test due to lack of lift data), and #96A (repeat of 96).

In general, the tests conducted at 115 knots demonstrated acceptable visual contamination ratings and lift losses within the marginal lift loss range of 5.4 percent to 9.2 percent. The lift losses were typically higher at the lower temperature ranges.

The tests conducted at 100 knots indicated that although the visual contamination ratings were acceptable, the lift losses were close to, or above, the 9.2 percent upper limit. These results further support the 115 knots restriction for PG fluids in this condition.

In conclusion, the current allowance time of 10 minutes is acceptable for PG fluids when operating at 115 knots. The additional testing at 100 knots further supports the 115 knots restriction for PG fluids in this condition. The 10-minute allowance time at 100 knots for EG fluids was not tested, as previous historical data has not indicated any issues.

Table 7.2: Moderate Ice Pellets Allowance Time Tests Winter 2012-13

Moderate Ice Pellets	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
100 kts	25 minutes	10 minutes	10 minutes Test # 93, 96, 96A
	15 Minutes Test # 86, 163		
115 kts	25 minutes	10 minutes Test # 154	10 minutes Test # 92, 95, 113, 113A, 121, 128, 130, 134, 141, 142, 149, 156

Table 7.3: Summary of Moderate Ice Pellets Allowance Time Test Results

OAT -5°C AND ABOVE (25 MINUTES)											
Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
-	-	-	-	-	-	-	-	-	-	-	-
OAT -5°C AND ABOVE 100 kts (15 MINUTES)											
86	Polar Guard Advance	-4.7	15	15	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	6.15%	REVIEW	REVIEW
163	ABC-S Plus	-3.8	15	15	2 , 2 , 3	GOOD	1 , 1 , 1	GOOD	6.27%	REVIEW	REVIEW
CONCLUSION: ALLOWANCE TIME AT 15 MINUTES FOR PG FLUIDS IS OK											

Table 7.3: Summary of Moderate Ice Pellets Allowance Time Test Results (cont'd)

OAT LESS THAN -5°C TO -10°C 115 kts (10 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (ºC)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
154	AD-49	-6.5	75	10	3 , 3 , 4	GOOD	1 , 2 , 2	GOOD	4.86%	GOOD	GOOD
CONCLUSION: TESTING NOT REPRESENTATIVE OF CURRENT ALLOWANCE TIME. SHOULD BE REDONE AT 100 KTS											

OAT LESS THAN -10°C (10 MINUTES)

Run #	Fluid	Tunnel Temp. Before Test (ºC)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
100 kts											
93	Polar Guard Advance	-12.7	75	10	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	11.46%	BAD	BAD
96	ABC-S Plus	-13.7	75	10	2 , 2 , 3	GOOD	1 , 2 , 3	GOOD	n/a	n/a	n/a
96A	ABC-S Plus	-13.6	75	10	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	10.09%	BAD	BAD
115 kts											
92	Polar Guard Advance	-14.4	75	10	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	8.05%	REVIEW	REVIEW
95	ABC-S Plus	-13.8	75	10	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	7.44%	REVIEW	REVIEW
113	Max-Flight	-13.7	75	10	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	7.31%	REVIEW	REVIEW

Table 7.3: Summary of Moderate Ice Pellets Allowance Time Test Results (cont'd)

Run #	Fluid	Tunnel Temp. Before Test (ºC)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
113A	Max-Flight	-13.4	75	10	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	8.83%	REVIEW	REVIEW
121	ABC-S Plus	-19.9	75	10	3 , 3 , 4	GOOD	1 , 2 , 2	GOOD	6.56%	REVIEW	REVIEW
128	Polar Guard Advance	-22.4	75	10	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	8.78%	REVIEW	REVIEW
130	Max-Flight	-22.6	75	10	3 , 2 , 3	GOOD	1 , 2 , 2	GOOD	8.08%	REVIEW	REVIEW
134	AD-49	-22.1	75	10	3 , 3 , 4	GOOD	1 , 2 , 2	GOOD	5.38%	GOOD	GOOD
141	ABC-S Plus	-22.6	75	10	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	6.82%	REVIEW	REVIEW
149	Max-Flight	-22.8	75	10	2 , 2 , 2	GOOD	1 , 2 , 2	GOOD	6.66%	REVIEW	REVIEW
156	Launch	-16.8	75	10	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	9.06%	REVIEW	REVIEW
CONCLUSION: ALLOWANCE TIME AT 10 MINUTES IS OK FOR PG FLUIDS AT 115 KTS											

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8. LIGHT ICE PELLETS MIXED WITH MODERATE RAIN ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Testing started in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Moderate Rain;
- Section 9: Light Ice Pellets and Light Snow; and
- Section 10: Light Ice Pellets and Moderate Snow.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellets and Moderate Rain conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

8.1 Overview of Tests

A summary of the Light Ice Pellets and Moderate Rain tests conducted in the wind tunnel is shown in Table 8.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1.

Table 8.1: Summary of 2012-13 Light Ice Pellets and Moderate Rain Testing

Test No.	Date	Fluid	Condition	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	Flap Angle (°)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
63	15-Jan-13	Polar Guard Advance	IP- / R Mod	IP: 25 R: 75	25	3.1	20	100	1 , 1 , 1	1 , 1 , 1	1.421	3.04%
74	16-Jan-13	Polar Guard Advance	IP- / R Mod	IP: 25 R: 75	25	2.9	20	100	1 , 1 , 1	1 , 1 , 1	1.417	3.33%

8.2 Fluid Brix, Fluid Thickness, and Skin Temperature

Fluid thickness, fluid Brix, and skin temperature measurements were collected by APS personnel. The measurements were collected before and after fluid application, after the application of contamination, and at the end of the test. Details regarding the measurement intervals and locations are included in Subsection 2.14. The completed data forms have been scanned and included in Appendix C for referencing purposes.

8.3 Photos

High-speed digital photographs of each test were taken (see Subsections 2.10 and 2.11 for more details). In addition, videos were also taken during a greater portion of the tests. Due to the large amount of data available, photos of the individual tests have not been included in this report, but rather the high-resolution photos are available in electronic format upon request and have been made available to the TDC.

8.4 Summary of Results

8.4.1 OAT -5°C and Above

Two tests were conducted with exposure times of 25 minutes in this cell: #63 and #74. In both cases, the results indicated acceptable visual contamination ratings and lift losses below the 5.4 percent safety criteria. In conclusion, these tests demonstrated positive results, indicating that the current allowance time of 25 minutes for this cell is acceptable and validated.

Table 8.2: Light Ice Pellet Light Ice Pellets and Moderate Rain Allowance Time Tests Winter 2012-13

Light Ice Pellets Mixed with Moderate Rain	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
100 kts	25 minutes Test # 63,74	Caution: No allowance times currently exist	

Table 8.3: Summary of Light Ice Pellet Light Ice Pellets and Moderate Rain Allowance Time Test Results

OAT -5°C AND ABOVE (50 MINUTES)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
63	Polar Guard Advance	3.1	IP: 25 R: 75	25	1 , 1 , 1	GOOD	1 , 1 , 1	GOOD	3.04%	GOOD	GOOD
74	Polar Guard Advance	2.9	IP: 25 R: 75	25	1 , 1 , 1	GOOD	1 , 1 , 1	GOOD	3.33%	GOOD	GOOD
Notes:											
CONCLUSION: ALLOWANCE TIME AT 25 MINUTES IS GOOD											

9. LIGHT ICE PELLETS MIXED WITH LIGHT SNOW ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Testing started in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Moderate Rain;
- Section 9: Light Ice Pellets and Light Snow; and
- Section 10: Light Ice Pellets and Moderate Snow.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellets and Light Snow conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

9.1 Overview of Tests

A summary of the Light Ice Pellets and Light Snow tests conducted in the wind tunnel is shown in Table 9.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1.

Table 9.1: Summary of 2012-13 Light Ice Pellets and Light Snow Testing

Test No.	Date	Fluid	Condition	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	AVG Wing Temp. Before Test (°C)	Flap Angle (°)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
87	17-Jan-13	Polar Guard Advance	IP- / SN-	IP:25 , SN:10	25	-6.6	N/A	20	100	2 , 2 , 3	1 , 2 , 2	1.373	6.35%
114	22-Jan-13	Polar Guard Advance	IP- / SN-	IP:25 , SN:10	5	-10	N/A	20	115	2 , 2 , 3	1 , 1 , 2	1.361	7.14%
115	22-Jan-13	Max-Flight	IP- / SN-	IP:25 , SN:10	5	-9.3	N/A	20	115	2 , 2 , 3	1 , 1 , 2	1.356	7.48%
170	28-Jan-13	AD-49	IP- / SN-	IP:25 , SN:10	40	-4.7	N/A	20	100	4 , 3 , 4	1 , 2 , 4	1.294	11.70%
171	28-Jan-13	AD-49	IP- / SN-	IP:25 , SN:10	25	-5.4	N/A	20	100	3 , 3 , 4	1 , 2 , 2	1.355	7.54%

9.2 Fluid Brix, Fluid Thickness, and Skin Temperature

Fluid thickness, fluid Brix, and skin temperature measurements were collected by APS personnel. The measurements were collected before and after fluid application, after the application of contamination, and at the end of the test. Details regarding the measurement intervals and locations are included in Subsection 2.14. The completed data forms have been scanned and included in Appendix C for referencing purposes.

9.3 Photos

High-speed digital photographs of each test were taken (see Subsections 2.10 and 2.11 for more details). In addition, videos were also taken during a greater portion of the tests. Due to the large amount of data available, photos of the individual tests have not been included in this report, but rather the high-resolution photos are available in electronic format upon request and have been made available to the TDC.

9.4 Summary of Results

9.4.1 OAT -5°C and Above

One test #170 was conducted with an exposure time of 40 minutes in this cell with the purpose of potentially expanding the current 25-minute allowance time. The results from this test indicated unacceptable levels of visual contamination on the wing prior to the start of the test, and the lift losses were well above the 9.2 percent upper limit.

In conclusion, this test demonstrated that a 40-minute allowance time is not appropriate for this condition; therefore, the current 25-minute allowance should remain the status quo.

9.4.2 OAT Less than -5°C to -10°C

Two tests were conducted with an exposure time of 25 minutes in this cell with the purpose of potentially expanding the current 15-minute allowance time. In both cases, the results indicated acceptable visual contamination ratings and lift losses within the marginal lift loss range of 5.4 percent to 9.2 percent. An additional test (#115) was conducted but will be analysed as part of the below -10ºC data set.

In conclusion, these tests demonstrated positive results, indicating that the current allowance time of 15 minutes for this cell can potentially be expanded to 25 minutes.

9.4.3 OAT Less than -10°C

Two tests were conducted with an exposure time of 5 minutes in this cell with the purpose of potentially expanding the allowance time table; currently, no times exist for this condition. In both cases, the results indicated acceptable visual contamination ratings and lift losses within the marginal lift loss range of 5.4 percent to 9.2 percent.

In conclusion, these tests demonstrated positive results, indicating that the current table can potentially be expanded to include an allowance time of 5 minutes for this cell.

Table 9.2: Light Ice Pellets and Light Snow Allowance Time Tests Winter 2012-13

Light Ice Pellets Mixed with Light Snow	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
100 kts	25 minutes	15 minutes	Caution: No allowance times currently exist
	40 minutes Test # 170	25 minutes Test # 87, 171	5 minutes
115 kts	25 minutes	15 minutes	Caution: No allowance times currently exist
		5 minutes Test # 115*	5 minutes Test # 114, 115

***Test #115 was analysed as part of "OAT Less than -10°C"**

Table 9.3: Summary of Light Ice Pellets Allowance Time Test Results

OAT -5°C AND ABOVE (25 MINUTES)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts											
170	AD-49	-4.7	IP:25 ,SN:10	40	4 , 3 , 4	GOOD	1 , 2 , 4	GOOD	11.70%	BAD	BAD
Notes:											
CONCLUSION: ALLOWANCE TIME EXPANSION TO 40 MINUTES IS BAD, SHOULD REMAIN AT CURRENT 25 MINUTES											

OAT LESS THAN -5°C TO -10°C (15 MINUTES)											
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts											
87	Polar Guard Advance	-6.6	IP:25 ,SN:10	25	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	6.35%	REVIEW	REVIEW
171	AD-49	-5.4	IP:25 ,SN:10	25	3 , 3 , 4	GOOD	1 , 2 , 2	GOOD	7.54%	REVIEW	REVIEW
115 kts											
115*	Max-Flight	-9.3	IP:25 ,SN:10	5	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	7.48%	REVIEW	REVIEW
Notes: Test #115 should be analysed as part of "OAT Less than -10ºC" set											
CONCLUSION: POTENTIAL TO EXPAND CURRENT 15 MINUTES ALLOWANCE TIME TO 25 MINUTES											

Table 9.3: Summary of Light Ice Pellets Allowance Time Test Results (cont'd)

OAT LESS THAN -10°C (30 MINUTES)												
Run #	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm²/h)**	**Exposure Time (min)**	**Visual Contamination Rating Before Takeoff (LE, TE, Flap)**	**Before Takeoff Status**	**Visual Contamination Rating at Rotation (LE, TE, Flap)**	**At Rotation Status**	**% Lift Loss**	**Lift Loss Status**	**Overall Status**
100 kts												
-	-	-	-	-	-	-	-	-	-	-	-
115 kts												
114	Polar Guard Advance	*-10*	IP:25 ,SN:10	*5*	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	7.14%	REVIEW	REVIEW
115	Max-Flight	-9.3	IP:25 ,SN:10	5	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	7.48%	REVIEW	REVIEW
CONCLUSION: POTENTIAL TO EXPAND TABLE TO INCLUDE 5-MINUTE ALLOWANCE TIME												

10. LIGHT ICE PELLETS MIXED WITH MODERATE SNOW ALLOWANCE TIMES

Aerodynamic testing was conducted to validate and further develop the Type IV high-speed ice pellet allowance times in the NRC wind tunnel. Testing started in 2009-10 aimed at validating the existing guidance material for use with newer generation aircraft operating with thin high-performance wings. Due to the larger lift losses observed on the more sensitive wing section, it was recommended that more thorough and comprehensive testing be conducted with the thin high-performance wing section. Additional testing was also required to provide guidance material where data was limited or non-existent. The results of this testing have been separated by test condition, and the details can be found in the following sections:

- Section 6: Light Ice Pellets;
- Section 7: Moderate Ice Pellets;
- Section 8: Light Ice Pellets and Moderate Rain;
- Section 9: Light Ice Pellets and Light Snow; and
- Section 10: Light Ice Pellets and Moderate Snow.

This section provides an overview of each test conducted to substantiate and further develop the current high-speed allowance times for Type IV fluids in Light Ice Pellets and Moderate Snow conditions. Testing was conducted in simulated precipitation conditions. The parameters for each test are detailed, and a description of the data collected during each test is provided.

10.1 Overview of Tests

A summary of the Light Ice Pellets and Moderate Snow tests conducted in the wind tunnel is shown in Table 10.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested using the wind tunnel is provided in Subsection 3.1.

Table 10.1: Summary of 2012-13 Light Ice Pellets Mixed with Moderate Snow Testing

Test No.	Date	Fluid	Condition	Precipitation Rate (g/dm²/h)	Precipitation Time (min)	Tunnel Temp. at Start of Test (°C)	Flap Angle (°)	AVG Wing Temp. Before Test (°C)	Speed (kts)	Visual Cont. Rating Before Takeoff (LE, TE, Flap)	Visual Cont. Rating at Rotation (LE, TE, Flap)	CL at 8° During Rotation	8° Lift Loss (%)
116	22-Jan-13	Max-Flight	IP- / SN	IP:25 , SN:25	10	-8.7	20	N/A	100	2 , 2 , 3	1 , 2 , 2	1.352	7.74%
117	22-Jan-13	Polar Guard Advance	IP- / SN	IP:25 , SN:25	10	-10.3	20	N/A	100	2 , 2 , 3	1 , 1 , 2	1.325	9.65%
118	22-Jan-13	Polar Guard Advance	IP- / SN	IP:25 , SN:25	7	-10.8	20	N/A	100	2 , 2 , 3	1 , 1 , 2	1.329	9.32%

10.2 Fluid Brix, Fluid Thickness, and Skin Temperature

Fluid thickness, fluid Brix, and skin temperature measurements were collected by APS personnel. The measurements were collected before and after fluid application, after the application of contamination, and at the end of the test. Details regarding the measurement intervals and locations are included in Subsection 2.14. The completed data forms have been scanned and included in Appendix C for referencing purposes.

10.3 Photos

High-speed digital photographs of each test were taken (see Subsections 2.10 and 2.11 for more details). In addition, videos were also taken during a greater portion of the tests. Due to the large amount of data available, photos of the individual tests have not been included in this report, but rather the high-resolution photos are available in electronic format upon request and have been made available to the TDC.

10.4 Summary of Results

10.4.1 OAT Less than -5°C to -10°C

One test (#116) was conducted with an exposure time of 10 minutes in this cell with the purpose of potentially expanding the allowance time table; currently, no times exist for this condition. The results indicated acceptable visual contamination ratings and lift losses within the marginal lift loss range of 5.4 percent to 9.2 percent.

In conclusion, the test demonstrated positive results, indicating that the current table can potentially be expanded to include an allowance time of 5 minutes for this cell.

10.4.2 OAT Less than -10°C

Two tests (#117 and #118) were conducted for this cell with an exposure time of 10 minutes and 7 minutes, respectively, with the purpose of potentially expanding the allowance time table; currently, no times exist for this condition. The results from these tests indicated acceptable levels of visual contamination ratings but poor aerodynamic performance with lift losses above the 9.2 percent upper limit. A slight improvement in aerodynamic performance was observed during the 7-minute test. Possibly, a 5-minute allowance time should be attempted if future testing is conducted.

In conclusion, these tests demonstrated that a 7-minute or 10-minute allowance time is not appropriate for this condition; therefore, no changes should be made to this cell in the current allowance time table.

Table 10.2: Light Ice Pellets Mixed with Moderate Snow Allowance Time Tests Winter 2012-13

Moderate Ice Pellets Mixed with Moderate Snow	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
100 kts	10 minutes	Caution: No allowance times currently exist	Caution: No allowance times currently exist
		10 minutes Test # 116	10 minutes Test # 117
			7 minutes Test # 118

Table 10.3: Summary of Light Ice Pellets Mixed with Moderate Snow Allowance Time Test Results

OAT LESS THAN -5°C TO -10°C (10 MINUTES)											
Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
100 kts											
116	Max-Flight	-8.7	IP:25 , SN:25	10	2 , 2 , 3	GOOD	1 , 2 , 2	GOOD	7.74%	REVIEW	REVIEW
Notes:											
CONCLUSION: POTENTIAL TO EXPAND TABLE TO INCLUDE 5-MINUTE ALLOWANCE TIME											

OAT LESS THAN -10°C (10 MINUTES)											
Run #	Fluid	Tunnel Temp. Before Test (°C)	Precipitation Rate (g/dm²/h)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE, TE, Flap)	Before Takeoff Status	Visual Contamination Rating at Rotation (LE, TE, Flap)	At Rotation Status	% Lift Loss	Lift Loss Status	Overall Status
100 kts											
117	Polar Guard Advance	-10.3	IP:25 , SN:25	10	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	9.65%	BAD	BAD
118	Polar Guard Advance	-10.8	IP:25 , SN:25	7	2 , 2 , 3	GOOD	1 , 1 , 2	GOOD	9.32%	BAD	BAD
Notes:											
CONCLUSION: ALLOWANCE TIME EXPANSION TO 7 OR 10 MINUTES IS BAD, SHOULD REMAIN WITH NO GUIDANCE FOR THIS CONDTION											

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11. CONCLUSIONS AND OBSERVATIONS

These observations and conclusions were derived from the testing conducted during the winter of 2012-13.

11.1 Wing Calibration and Characterization

As reported by NASA, the clean, dry wing aerodynamic repeatability was confirmed in comparison with previous data, and the additional data collected in 2012-13 helped in substantiating these findings. The stalling characteristics of the wing with fluid only (or fluid with contamination) appear to be driven by secondary wave effects near the leading edge; these effects are difficult to interpret on the 2D model relative to a fully 3D wing and should not be used in developing allowance times. Additional lift loss scaling correlation data with different fluids at colder temperatures confirmed that previous lift loss limits are still valid.

This work was presented by NASA to the AWG during the New Orleans SAE G-12 meeting in May 2013. A copy of the presentation has not been included in this report; however, a fully detailed and finalized report is being prepared and will be published by NASA on this subject.

11.2 Type IV High-Speed Allowance Times

Testing was conducted during the winter of 2012-13 with the objective of further developing and substantiating the current ice pellet allowance times. The following sections briefly describe the results obtained.

11.2.1 Light Ice Pellets

The testing at -5ºC and above demonstrated positive results, indicating that the current allowance time of 50 minutes for this cell is still acceptable and validated. No testing was conducted in the -5°C to -10°C condition. The data below -10ºC indicated that the current allowance time of 30 minutes is acceptable (however, one test was borderline) for PG fluids with rotation speeds of 115 knots or greater; at 100 knots, the lift losses were unacceptable.

11.2.2 Moderate Ice Pellets

Testing at -5°C and above indicated that the current allowance time of 15 minutes is acceptable for PG fluids. No useable data was collected in the -5°C to -10°C range. Below -10ºC, the current allowance time of 10 minutes was validated for PG fluids when operating at 115 knots; at 100 knots, the lift losses were unacceptable.

11.2.3 Light Ice Pellets and Moderate Rain

The tests conducted demonstrated positive results, indicating that the current allowance time of 25 minutes for this cell is acceptable and validated.

11.2.4 Light Ice Pellets and Light Snow

At the -5°C and above condition, the test conducted demonstrated that a 40-minute allowance time is not appropriate for this condition; therefore, the current 25-minute allowance should remain the status quo. In the -5°C to -10°C conditions, the tests demonstrated positive results, indicating that the current allowance time of 15 minutes for this cell can potentially be expanded to 25 minutes. Below -10ºC, the tests demonstrated positive results, indicating that the current table can potentially be expanded to include an allowance time of 5 minutes for this cell.

11.2.5 Light Ice Pellets and Moderate Snow

No testing was conducted above -5ºC. The test conducted in the -5°C to -10°C condition demonstrated positive results, indicating that the current table can potentially be expanded to include an allowance time of 5 minutes. However, below -10ºC, the tests demonstrated that a 7-minute or 10-minute allowance time is not appropriate for this condition, and therefore no changes should be made to this cell in the current allowance time table.

12. RECOMMENDATIONS

The following recommendations were compiled based on the work conducted during the winter of 2012-13.

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

The testing results have demonstrated that 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.

12.2 Testing to Support Calibration and Characterization Work

If deemed necessary, a small portion of the work planned for the winter of 2013-14 may be dedicated to follow-up testing to support the calibration and characterization work conducted in 2011-12 and 2012-13 or, alternatively, to support the lift loss scaling correlation. This testing will be planned in cooperation with NASA aerodynamicists.

12.3 Type IV High-Speed Allowance Time Table

No changes were made to the values in the Type IV allowance time table based on the 2012-13 wind tunnel test results. The updated TC allowance time table is shown in Table 12.1.

12.4 Future Research

The following sections describe higher priority areas of possible future research for the winter of 2013-14 wind tunnel testing plan. These areas of future research have been determined based on consultations with TC, the FAA, and 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.

Table 12.1: 2013-14 Ice Pellet Allowance Time Table

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

TABLE 11

ICE PELLET ALLOWANCE TIMES FOR WINTER 2013-2014

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

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

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

NOTES

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

CAUTIONS

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

12.4.1 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. Some additional data has been collected in 2012-13 that supports a potential for guidance in these conditions. A detailed analysis of the data collected to date in these conditions should be conducted to determine the possibility of issuing guidance material and to determine any possible future research needs, if necessary.

12.4.2 Lift Losses at LOUT

Previous testing has shown that lift losses in general significantly increase at the lower temperatures. Limited data is available at (or very near) the fluid lowest operational use temperature (LOUT). Additional testing is recommended to obtain data close to the fluid LOUT to determine the aerodynamic effects of ice pellet contamination at these colder temperatures.

12.4.3 Substantiation of Ice Pellet Allowance Times with New Fluids

Testing should continue to 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., Max Flight, Polar Guard Advance).

12.4.4 Evaluate Effect of Fluid Viscosity on Aerodynamics

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

12.4.5 Lift Loss Scaling with NASA LS-0417 and NACA 23012 Wing Sections

The extensive work conducted with the thin high-performance wing section has led to the development of a methodology for evaluating aerodynamic performance based on a lift loss scaling between the model results and the AS5900 AAT. If research capacities are available, it is recommended that limited testing be conducted with the wing sections previously tested in 2006-07 and 2008-09 to better understand the sensitivity of these models used in the development of the ice pellet allowance time tables.

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2012-13

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2012-13

4. DETAILED WORK DESCRIPTION FOR YEAR 2 (2012-13)

4.23 Wind Tunnel Testing

NOTE: This task is scheduled for 3 weeks of testing, 2 of which are related to ice pellet allowance time development, and 1 week of which is to support the development of aircraft ground deicing related procedures and technologies. As such, the costing has been split accordingly: 2/3 and 1/3 of total cost.

a) Meet and discuss 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) Develop a procedure and test plan with the NRC staff who operates the PIWT. 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; The procedure will specify the collection of the following data during the tests:

   i. Type and amount of fluid applied;

   ii. Type and rate of contamination applied;

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

   iv. Fluid brix, thickness, and temperature measurements;

   v. High speed photography and videography.

c) Conduct pre-testing setup and calibration work;

d) Perform wind tunnel tests to further refine ice pellet allowance times with ethylene glycol and propylene glycol anti-icing fluids, to validate and possibly expand current allowance times published by TC and FAA for super-critical airfoils; and

   a. 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;

   b. Perform correlation testing to calibrate the TC model and to demonstrate repeatability;
   c. Testing will investigate colder temperatures;
   d. Testing will support the development of a correlation to the BLDT test;
   e. Testing will investigate colder temperatures;
   f. Testing will attempt to expand the ice pellet allowance times cells for mixed ice pellet and snow conditions;
   g. Testing may also be conducted to potentially develop an allowance time table for use with Type III fluid;

e) Perform wind tunnel tests to support the development of aircraft ground deicing related procedures and technologies;
   a. Testing to evaluate a stall sensor apparatus;
   b. Testing with a ROGIDS camera;
   c. Testing to address industry concerns and interests; and

f) Analyze the data collected, 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

CM2265.002

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

Winter 2012-13

Prepared for

Transportation Development Centre
Transport Canada

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APS Aviation Inc.

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Final Version 1.0

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

1. BACKGROUND

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

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

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

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

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

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

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

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

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

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

FAA and TC were satisfied with calibration technical evaluation results, and therefore it was recommended that testing during the winter of 2012-13 revert back to the initial research and development objectives of further refining and substantiating the ice pellet allowance times.

2. OBJECTIVES

Note, some limited follow-up testing to support the 2011-12 calibration and characterization work conducted will be performed by NASA and NRC prior to the start of the 2012-13 testing campaign. See Attachment I for further details.

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

- Ensure the repeatability of the dry wing performance;
- Expand the ice pellet allowance times for light ice pellets mixed with light or moderate snow conditions;
- Investigate of the higher lift losses observed at lower temperatures with PG fluids;
- Substantiate the current ice pellet allowance times with new fluids, or fluids previously tested but with limited data;
- Evaluate the effects of fluid viscosity on aerodynamic performance;
- Further develop the PIWT testing results correlation to the BLDT test;
- Evaluate the use of a stall warning sensor with and without de/anti-icing fluids;
- Evaluate the interaction of an ice phobic coated wing skin with fluid and contamination; and
- Evaluate the effect of ice phobic coatings on the fluid BLDT at low rotation speeds.

Also, plans are to have a ROGIDS installed in the wind tunnel to collect data of a contaminated wing.

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

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

- Fluid and contamination at LOUT;
- Heavy snow;
- Heavy contamination;
- Small hail;
- Frost simulation in the wind tunnel;
- Wind tunnel test section cooling;
- Flaps/Slats testing to support YMX tests;
- Mixed HOT conditions;
- Frost spot deicing/anti-icing;

- Snow on an un-protected wing;
- Feasibility of IP testing at higher speed (130-150kts);
- 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.

Four weeks of testing have been scheduled for the conduct of these tests. The start date for testing is currently scheduled for January 8th and testing will continue until February 1st (see Figure 2.2).

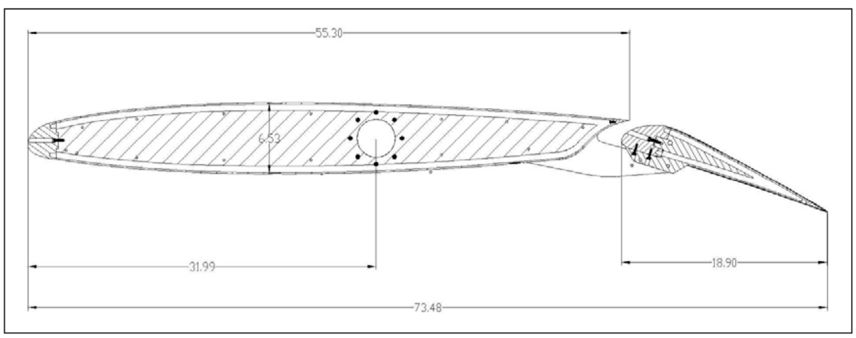


Figure 2.1: Super-Critical Wing Section

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 V to XI present the generic holdover time guidelines for Type I and III as well as the fluid-specific holdover time guidelines for the representative Type IV fluids that will be tested. The current Ice Pellet Allowance Time table has been included in XII.

Wind Tunnel 2012-13
Anticipated Calender of Tests
JANUARY 2013

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
NASA WT Calibration (DEC 19 & 20) TEST DAYS 1 & 2		1	2 NRC back from holidays	3	4	5
6	7 Pack Truck and leave for YOW	8 ***TEST DAY 3*** -Set-up, calibration, training, briefing **EVALUATION OF STALLWARNING SENSOR** *any temp* ***Priority 1***	9 ***TEST DAY 4*** **IP VALIDATION (DAY 1 OF 3)** *-5 °C and above* ***Priority 2***	10 ***TEST DAY 5*** **IP VALIDATION (DAY 2 OF 3)** *-5°C and above* ***Priority 2***	11 ***TEST DAY 6*** **IP VALIDATION (DAY 3 OF 3)** *-5 to -10 °C* ***Priority 2***	12
13	14 ***TEST DAY 7*** **IP FLOW-OFF (DAY 1 OF 3)** *below -10 °C* ***Priority 1***	15 ***TEST DAY 8*** **IP FLOW-OFF (DAY 2 OF 3)** *below -10 °C* ***Priority 1***	16 ***TEST DAY 9*** **IP FLOW-OFF (DAY 3 OF 3)** *below -10 °C* ***Priority 1***	17 ***TEST DAY 10*** **EFFECT OF VISCOSITY ON AERODYNAMICS (DAY 1 OF 2)** *below -20°C* ***Priority 2***	18 ***TEST DAY 11*** **EFFECT OF VISCOSITY ON AERODYNAMICS (DAY 2 OF 2)** *-20°C and above* ***Priority 2***	19
20	21 ***TEST DAY 12*** **BLDT CORRELATION (DAY 1 OF 3)** *-15 to -22.5 °C* ***Priority 2***	22 ***TEST DAY 13*** **BLDT CORRELATION (DAY 2 OF 3)** *-22.5 to -35 °C* ***Priority 2***	23 ***TEST DAY 14*** **BLDT CORRELATION (DAY 3 OF 3)** *-22.5 to -35°C* ***Priority 2***	24 ***TEST DAY 15*** **IP EXPANSION** ***IP-/SN & IP-/SN-*** **(DAY 1 OF 2)** *-15 to -25°C* ***Priority 2***	25 ***TEST DAY 16*** **IP EXPANSION** ***IP-/SN & IP-/SN-*** **(DAY 2 OF 2)** *-5 to -10°C* ***Priority 2***	26
27	28 ***TEST DAY 17*** **ICE PHOBIC BLDT** *-6 to -20 °C* ***Priority 1***	29 ***TEST DAY 18*** **ICE PHOBIC R&D (DAY 1 OF 3)** *<-10 °C* ***Priority 1***	30 ***TEST DAY 19*** **ICE PHOBIC R&D (DAY 2 OF 3)** *-5 to -15 °C* ***Priority 1***	31 ***TEST DAY 20*** **ICE PHOBIC R&D (DAY 3 OF 3)** *<-5 °C* ***Priority 1***	FEB 1 ***TEST DAY 21*** **DRY RUNS (dry runs every day accumulates over test period ~ 1 day)**	FEB 2
FEB 3	FEB 4 ***SPARE***	FEB 5 ***WEEK AVAILABLE***	FEB 6 ***IF TEMPS ARE***	FEB 7 ***NOT GOOD IN***	FEB 8 ***JANUARY***	FEB 9

NOTES

Anticipate Mon-Fri Testing, However, Weekend May be Needed Due to Temperature.
First week of testing to be conducted during daytime and the following weeks will be overnights. This will be dependent on the weather forecast and required temperature needed for testing.
Testing will Likely be Conducted During Overnight Periods (i.e. 8PM - 6AM), Unless Temperatures are Suitable for Day, Evening Testing. Typical Test Day is 8hrs for APS Staff.
If 20th day required, consider 1-2 hours longer per day.

Figure 3.1: Test Calendar

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

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

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

A presentation was prepared to describe the test plan in further detail, see Appendix A.

Table 3.1: Preliminary List of Testing Objectives for Winter 2012-13 Wind Tunnel Testing

Focus of testing will primarily be on Priority 1 & 2
Some Priority 3 may be completed at request of the TC/FAA

Item #	Objective	Priority	Description	# of Days
1	Dry Wing Baseline Repeatability	1	Baseline test at beginning of each day. Ensure repeatability	1
2	IP Flow-Off Issues (IP - and IP Mod <-10ºC)	1	Collect data in problem area conditions where data showed flow-off issues. I.e. IP- and IP <-10ºC and diff fluids	3
3	ROGIDS Piggyback Testing in Wind Tunnel	1	Non-intrusive testing with PV Labs, so no extra days needed. Observe icing tests with different conditions i.e. Ice Pellets.	0
4	Ice Phobic Coating R&D	1	Aero research with ice phobic treated surfaces. Possibly construct different test models i.e. Skins or Streamline posts	3
5	Effect of Ice Phobic Coatings on BLDT	1	Aero research comparing fluid Δcl data with and without coatings at different temps	1
6	Evaluation of Stallwarning Sensor	1	Testing with Marinvent sensor to evaluate potential for use in ground icing operations with and without fluids	1
7	Effect of Viscosity on Fluid Aerodynamics	2.1	Evaluate effect of viscosity on aero flow-off to better understand year to year differences with same fluid (test high and low visc)	2
8	BLDT Correlation	2.2	Fluid only testing to further develop BLDT/Aero test correlation and to include different fluids	3
9	IP Expansion (IP-/SN and IP-/SN-)	2.3	Expand IP Allowance Time Table for IP-/SN and IP-/SN-	2
10	IP Validation with New Fluids	2.4	Spot check validation testing with new fluids or fluids that have limited data i.e. Cryotech?, AD-49? etc	3
11	Fluid + Cont @ LOUT	3	Effect of contamination on fluid performance at LOUT with IP, SN, ZF,Frost etc.	2
12	Heavy Snow	3	Continue Heavy Snow Research comparing lift losses with Light/Moderate Snow vs. heavy Snow	2
13	Aero vs. Visual Fail (Surface Roughness)	3	Continue work looking at aerodynamic failure vs. HOT defined failure, and effect of surface roughness on lift degradation	2
14	Small Hail	3	Develop HOT Guidance for small hail. Requires consult with meteorologist for specific conditions	1
15	Simulate Frost in Wind Tunnel	3	Attempt to simulate frost conditions in wind tunnel.	1
16	Tunnel Test Section Cooling System	3	Investigate methods for cooling wind tunnel	1
17	2nd Wave of Fluid During Rotation	3	Investigate the aero effects of the 2nd wave of fluid created from fluid at the stagnation point which flows over the LE during rotation	1
18	Other	3	Any potential suggestions from industry	1
19	Flaps/Slats to Support YMX	4	Conduct flaps failure research to support UPS/SWA trials, comparative fluid/cont. and possibly sandpaper tests	2
20	Mixed HOT Conditions	4	Develop HOT Guidance for mixed conditions i.e. ZR/SN, R/SN, ZD/SN	2
21	Aero WG Outstanding Items	4	Testing to address outstanding items from technical questions sent from Aero WG	3
22	Frost CSW Spot Deicing	4	Aerodynamic lift losses associated with CSW spot deicing. Look at thickened fluids. Aero vs FFP limited	1
23	Snow on Un-protected Wing	4	Continue previous research	1
24	130-150 Knots IP Testing	4	Conduct IP testing at 130-150 knots NEED TO MODIFY TUNNEL	5
25	IP Validation with Slatted Wing (e.g. CRJ 700, B737)	4	IP testing with new slatted wing model e.g. CRJ 700, B737 NEED TO BUILD WING TO DO TESTING	5
26	Horizontal Stabilizer Testing	4	Testing with undermounted camera to investigate fluid flow on underside of H-Stab section. NEED TO BUILD H-STAB	10
27	V-Stab	4	Effect of heavily contaminated tail (un-even contamination) NEED TO BUILD V-STAB	5
28	Ice Phobic Coatings on V-Stab	4	Potential benefits of coatings on V-Stab NEED V-STAB MODEL OR ALTERNATIVE	4
29	BLDT Testing with Old wings	4	BLDT correlation work with NACA 23012 and LS0417 wing sections	5
30	Type IV Low Speed	5	Continue LS Type IV IP Allowance Time Testing	5
31	Type III IP Allowance Times (HS)	5	Conduct High Speed IP Allowance time testing with Type III fluid (Hot and Cold) in all cells to potentially develop Type III table	5
32	Type II IP Testing	6	Develop Type II IP Allowance Times	5
33	Type III IP Allowance Times (LS)	6	Conduct Low Speed IP Allowance time testing with Type III fluid (Hot and Cold) in all cells to potentially develop Type III table	5

Table 3.1: Proposed Test Plan

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	Dilution	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	Coating	Exposure Time	COMMENT
P001	Baseline	1	1	Dry Wing	8	100	any	none		-	-	-		-	to be conducted daily before start ot tests
P002	Baseline	1	1	Dry Wing	stall	100	any	none		-	-	-		-	to be conducted daily before start ot tests
P003	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	ABC-S Plus	100/0	25	-	-		30	
P004	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	ABC-S Plus	100/0	25	-	-		30	
P005	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	Launch	100/0	25	-	-		30	
P006	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	Launch	100/0	25	-	-		30	
P007	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	AD-49	100/0	25	-	-		30	
P008	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	AD-49	100/0	25	-	-		30	
P009	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	Max-Flight	100/0	25	-	-		30	
P010	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	Max-Flight	100/0	25	-	-		30	
P011	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	Polar Guard Advance	100/0	25	-	-		30	
P012	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	Polar Guard Advance	100/0	25	-	-		30	
P013	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	ABC-S Plus	100/0	75	-	-		5	
P014	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	ABC-S Plus	100/0	75	-	-		5	
P015	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	Launch	100/0	75	-	-		5	
P016	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	Launch	100/0	75	-	-		5	
P017	IP Flow-Off Issues	1	2	IP mod	8	100	< -10°C	AD-49	100/0	75	-	-		5	
P018	IP Flow-Off Issues	1	2	IP mod	8	115	< -10°C	AD-49	100/0	75	-	-		5	
P019	IP Flow-Off Issues	1	2	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-		5	
P020	IP Flow-Off Issues	1	2	IP mod	8	115	< -10°C	Max-Flight	100/0	75	-	-		5	
P021	IP Flow-Off Issues	1	2	IP mod	8	100	< -10°C	Polar Guard Advance	100/0	75	-	-		5	
P022	IP Flow-Off Issues	1	2	IP mod	8	115	< -10°C	Polar Guard Advance	100/0	75	-	-		5	
P023	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	ABC-S Plus	100/0	75	-	-		10	
P024	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	ABC-S Plus	100/0	75	-	-		10	
P025	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	Launch	100/0	75	-	-		10	
P026	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	Launch	100/0	75	-	-		10	

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	Dilution	IP Rate ($g/dm^2/h$)	SN Rate ($g/dm^2/h$)	ZR Rate ($g/dm^2/h$)	Coating	Exposure Time	COMMENT
P027	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	AD-49	100/0	75	-	-		10	
P028	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	AD-49	100/0	75	-	-		10	
P029	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-		10	
P030	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	Max-Flight	100/0	75	-	-		10	
P031	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	Polar Guard Advance	100/0	75	-	-		10	
P032	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	Polar Guard Advance	100/0	75	-	-		10	
P033	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	CO	-	C0 Objective: Baseline
P034	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C1	-	C1 Objective: Baseline
P035	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C2	-	C2 Objective: Baseline
P036	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C3	-	C3 Objective: Baseline
P037	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C4	-	C4 Objective: Baseline
P038	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C5	-	C5 (USE P001 OF THE DAY) Objective: Baseline
P039	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C0	10	C0 Objective: Flow-off
P040	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C1	10	C1 Objective: Flow-off
P041	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C2	10	C2 Objective: Flow-off
P042	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C3	10	C3 Objective: Flow-off
P043	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C4	10	C4 Objective: Flow-off
P044	Ice Phobic Coating R&D	2	2	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C5	10	C5 Objective: Flow-off
P045	Ice Phobic Coating R&D	2	2	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	ANY	10	any of C1 or C2 or C3 or C4 Objective: effect of viscosity (use LOWV fluid)
P046	Ice Phobic Coating R&D	1	1	Fluid only	8	100	-5 to -15	EG106	100/0	-	-	-	C0	-	C0 Objective: adhesion
P047	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	EG106	100/0	-	-	25	C0	20	C0 Objective: adhesion
P048	Ice Phobic Coating R&D	1	1	IP- / ZR	8	100	-5 to -15	EG106	100/0	25	-	25	C0	20	C0 Objective: adhesion
P049	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	none	-	-	-	25	C0	20	C0 Objective: adhesion
P050	Ice Phobic Coating R&D	1	1	Fluid only	8	100	-5 to -15	EG106	100/0	-	-	-	C1	-	C1 Objective: adhesion
P051	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	EG106	100/0	-	-	25	C1	20	C1 Objective: adhesion
P052	Ice Phobic Coating R&D	1	1	IP- / ZR	8	100	-5 to -15	EG106	100/0	25	-	25	C1	20	C1 Objective: adhesion

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	Dilution	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	Coating	Exposure Time	COMMENT
P053	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	none	-	-	-	25	C1	20	C1 Objective: adhesion
P054	Ice Phobic Coating R&D	1	1	Fluid only	8	100	-5 to -15	EG106	100/0	-	-	-	C2	-	C2 Objective: adhesion
P055	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	EG106	100/0	-	-	25	C2	20	C2 Objective: adhesion
P056	Ice Phobic Coating R&D	1	1	IP- / ZR	8	100	-5 to -15	EG106	100/0	25	-	25	C2	20	C2 Objective: adhesion
P057	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	none	-	-	-	25	C2	20	C2 Objective: adhesion
P058	Ice Phobic Coating R&D	1	1	Fluid only	8	100	-5 to -15	EG106	100/0	-	-	-	C3	-	C3 Objective: adhesion
P059	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	EG106	100/0	-	-	25	C3	20	C3 Objective: adhesion
P060	Ice Phobic Coating R&D	1	1	IP- / ZR	8	100	-5 to -15	EG106	100/0	25	-	25	C3	20	C3 Objective: adhesion
P061	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	none	-	-	-	25	C3	20	C3 Objective: adhesion
P062	Ice Phobic Coating R&D	1	1	Fluid only	8	100	-5 to -15	EG106	100/0	-	-	-	C4	-	C4 Objective: adhesion
P063	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	EG106	100/0	-	-	25	C4	20	C4 Objective: adhesion
P064	Ice Phobic Coating R&D	1	1	IP- / ZR	8	100	-5 to -15	EG106	100/0	25	-	25	C4	20	C4 Objective: adhesion
P065	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	none	-	-	-	25	C4	20	C4 Objective: adhesion
P066	Ice Phobic Coating R&D	1	2	Fluid only	8	100	-5 to -15	EG106	100/0	-	-	-	C5	-	C5 Objective: adhesion
P067	Ice Phobic Coating R&D	1	2	ZR	8	100	-5 to -15	EG106	100/0	-	-	25	C5	20	C5 Objective: adhesion
P068	Ice Phobic Coating R&D	1	2	IP- / ZR	8	100	-5 to -15	EG106	100/0	25	-	25	C5	20	C5Objective: adhesion
P069	Ice Phobic Coating R&D	1	2	ZR	8	100	-5 to -15	none	-	-	-	25	C5	20	C5 Objective: adhesion
P070	Ice Phobic Coating R&D	1	2	IP- / ZR	8	115	-5 to -15	EG106	100/0	25	-	25	ANY	20	any of C1 or C2 or C3 or C4 Objective: adhesion
P071	Ice Phobic Coating R&D	1	2	IP- / ZR	8	115	-5 to -15	EG106	100/0	25	-	25	ANY	20	any of C1 or C2 or C3 or C4 Objective: adhesion
P072	Ice Phobic Coating R&D	1	2	IP- / ZR	8	80	-5 to -15	EG106	100/0	25	-	25	ANY	20	any of C1 or C2 or C3 or C4 Objective: adhesion
P073	Ice Phobic Coating R&D	1	2	IP- / ZR	8	80	-5 to -15	EG106	100/0	25	-	25	ANY	20	any of C1 or C2 or C3 or C4 Objective: adhesion
P074	Ice Phobic Coating R&D	1	2	SN	8	100	-5 to -15	none	-	-	TBD	-	ANY	TBD	any of C1 or C2 or C3 or C4 Objective: adhesion
P075	Ice Phobic Coating R&D	1	2	SN	8	115	-5 to -15	none	-	-	TBD	-	SAME AS P072	TBD	same surface as P072 Objective: adhesion
P076	Ice Phobic Coating R&D	1	1	Fluid Only	8	100	< -5	EG106	100/0	-	-	-	C1/C5	-	C1 & C5 Objective: visual comparison
P077	Ice Phobic Coating R&D	1	1	ZR	8	100	< -5	EG106	100/0	-	-	50	C1/C5	115?? (as per 2010-11)	C1 & C5 Objective: visual comparison

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (ºC)	Fluid	Dilution	IP Rate ($g/dm^2/h$)	SN Rate ($g/dm^2/h$)	ZR Rate ($g/dm^2/h$)	Coating	Exposure Time	COMMENT
P078	Ice Phobic Coating R&D	1	1	Fluid Only	8	100	< -5	EG106	100/0	-	-	-	C0/C5	-	C0 & C5 Objective: visual comparison
P079	Ice Phobic Coating R&D	1	1	ZR	8	100	< -5	EG106	100/0	-	-	50	C0/C5	115? (as 2010-11)	C0 & C5 Objective: visual comparison
P080	Ice Phobic Coating R&D	1	1	Fluid Only	8	100	< -5	EG106	100/0	-	-	-	C1/C2	-	C1 & C2 Objective: visual comparison
P081	Ice Phobic Coating R&D	1	1	ZR	8	100	< -5	EG106	100/0	-	-	50	C1/C2	115? (as 2010-11)	C1 & C2 Objective: visual comparison
P082	Ice Phobic Coating R&D	1	1	Fluid Only	8	100	< -5	EG106	100/0	-	-	-	C3/C4	-	C3 & C4 Objective: visual comparison
P083	Ice Phobic Coating R&D	1	1	ZR	8	100	< -5	EG106	100/0	-	-	50	C3/C4	115? (as 2010-11)	C3 & C4 Objective: visual comparison
P084	Ice Phobic Coating R&D	1	2	Fluid Only	8	100	< -5	EG106	100/0	-	-	-	C0/ANY	-	C0 & one of C1, C2, C3 or C4 Objective: visual comparison
P085	Ice Phobic Coating R&D	1	2	ZR	8	100	< -5	EG106	100/0	-	-	50	C0/ANY	115? (as 2010-11)	C0 & one of C1, C2, C3 or C4 Objective: visual comparison
P086	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C0	-	C0
P087	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C1	-	C1
P088	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C2	-	C2
P089	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C3	-	C3
P090	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C4	-	C4
P091	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C5	-	C5
P092	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	-9 +/- 3	MP III 2031	75/25	-	-	-	C0	-	C0
P093	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	-9 +/- 3	MP III 2031	75/25	-	-	-	C5	-	C5
P094	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	-9 +/- 3	MP III 2031	75/25	-	-	-	ANY	-	Pick one of C1, C2, C3 or C4
P095	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C0	-	C0
P096	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C1	-	C1
P097	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C2	-	C2
P098	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C3	-	C3
P099	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C4	-	C4
P100	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C5	-	C5
P101	Evaluation of Stallwarning Sensor	1	1	none	stall	100	any	none	-	-	-	-		-	NO SENSOR ensure sensor is non intrusive
P102	Evaluation of Stallwarning Sensor	1	2	none	stall	100	any	none	-	-	-	-		-	NO SENSOR (REPEAT) ensure sensor is non intrusive
P103	Evaluation of Stallwarning Sensor	1	1	none	stall	100	any	none	-	-	-	-		-	WITH SENSOR ensure sensor is non intrusive

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	Dilution	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	Coating	Exposure Time	COMMENT
P104	Evaluation of Stallwarning Sensor	1	2	none	stall	100	any	none	-	-	-	-		-	WITH SENSOR (REPEAT) ensure sensor is non intrusive
P105	Evaluation of Stallwarning Sensor	1	1	Fluid Only	stall	100	any	EG106	100/0	-	-	-		-	NO SENSOR ensure sensor is non intrusive
P106	Evaluation of Stallwarning Sensor	1	2	Fluid Only	stall	100	any	EG106	100/0	-	-	-		-	NO SENSOR (REPEAT) ensure sensor is non intrusive
P107	Evaluation of Stallwarning Sensor	1	1	Fluid Only	stall	100	any	EG106	100/0	-	-	-		-	WITH SENSOR ensure sensor is non intrusive
P108	Evaluation of Stallwarning Sensor	1	2	Fluid Only	stall	100	any	EG106	100/0	-	-	-		-	WITH SENSOR (REPEAT) ensure sensor is non intrusive
P109	Evaluation of Stallwarning Sensor	1	1	Fluid Only	stall	100	any	EG106	100/0	75	-	-		15-35	WITH SENSOR ensure sensor is working
P110	Evaluation of Stallwarning Sensor	1	1	Fluid Only	stall	100	any	Type I EG	100/0	-	-	-		-	WITH SENSOR ensure sensor is working
P111	BLDT Correlation	2.1	1	Fluid only	8	100	-22.5 to -35	ABC-S Plus	100/0	-	-	-		-	
P112	BLDT Correlation	2.1	1	Fluid only	8	100	-22.5 to -35	ABC-S Plus	100/0	-	-	-		-	
P113	BLDT Correlation	2.1	2	Fluid only	8	100	-22.5 to -35	ABC-S Plus	100/0	-	-	-		-	
P114	BLDT Correlation	2.1	1	Fluid only	8	100	-15 to -22.5	ABC-S Plus	75/25	-	-	-		-	
P115	BLDT Correlation	2.1	2	Fluid only	8	100	-15 to -22.5	ABC-S Plus	75/25	-	-	-		-	
P116	BLDT Correlation	2.1	1	Fluid only	8	100	-22.5 to -35	EG106	100/0	-	-	-		-	
P117	BLDT Correlation	2.1	1	Fluid only	8	100	-22.5 to -35	EG106	100/0	-	-	-		-	
P118	BLDT Correlation	2.1	2	Fluid only	8	100	-22.5 to -35	EG106	100/0	-	-	-		-	
P119	BLDT Correlation	2.1	1	Fluid only	8	100	-22.5 to -35	Launch	100/0	-	-	-		-	
P120	BLDT Correlation	2.1	1	Fluid only	8	100	-22.5 to -35	Launch	100/0	-	-	-		-	
P121	BLDT Correlation	2.1	2	Fluid only	8	100	-22.5 to -35	Launch	100/0	-	-	-		-	
P122	BLDT Correlation	2.1	1	Fluid only	8	100	-15 to -22.5	Launch	75/25	-	-	-		-	
P123	BLDT Correlation	2.1	2	Fluid only	8	100	-15 to -22.5	Launch	75/25	-	-	-		-	
P124	BLDT Correlation	2.1	1	Fluid only	8	100	-22.5 to -35	AD-49	100/0	-	-	-		-	
P125	BLDT Correlation	2.1	1	Fluid only	8	100	-22.5 to -35	AD-49	100/0	-	-	-		-	
P126	BLDT Correlation	2.1	2	Fluid only	8	100	-22.5 to -35	AD-49	100/0	-	-	-		-	
P127	BLDT Correlation	2.1	1	Fluid only	8	100	-15 to -22.5	AD-49	75/25	-	-	-		-	
P128	BLDT Correlation	2.1	2	Fluid Only	8	100	-15 to -22.5	AD-49	75/25	-	-	-		-	
P129	BLDT Correlation	2.1	1	Fluid Only	8	100	-22.5 to -35	Polar Guard Advance	100/0	-	-	-		-	

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	Dilution	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	Coating	Exposure Time	COMMENT
P130	BLDT Correlation	2.1	1	Fluid Only	8	100	-22.5 to -35	Polar Guard Advance	100/0	-	-	-		-	
P131	BLDT Correlation	2.1	2	Fluid Only	8	100	-22.5 to -35	Polar Guard Advance	100/0	-	-	-		-	
P132	BLDT Correlation	2.1	1	Fluid Only	8	100	-15 to -22.5	Polar Guard Advance	75/25	-	-	-		-	
P133	BLDT Correlation	2.1	2	Fluid Only	8	100	-15 to -22.5	Polar Guard Advance	75/25	-	-	-		-	
P134	BLDT Correlation	2.1	1	Fluid Only	8	100	-22.5 to -35	Max-Flight	100/0	-	-	-		-	
P135	BLDT Correlation	2.1	1	Fluid Only	8	100	-22.5 to -35	Max-Flight	100/0	-	-	-		-	
P136	BLDT Correlation	2.1	2	Fluid Only	8	100	-22.5 to -35	Max-Flight	100/0	-	-	-		-	
P137	BLDT Correlation	2.1	1	Fluid Only	8	100	-15 to -22.5	Max-Flight	75/25	-	-	-		-	
P138	BLDT Correlation	2.1	2	Fluid Only	8	100	-15 to -22.5	Max-Flight	75/25	-	-	-		-	
P139	Effect of Viscosity on Fluid Aerodynamics	2.2	1	Fluid only	8	100	-20 and above	ABC-S Plus	100/0	-	-	-		-	low viscosity
P140	Effect of Viscosity on Fluid Aerodynamics	2.2	1	Fluid only	8	100	-20 and above	ABC-S Plus	100/0	-	-	-		-	mid viscosity
P141	Effect of Viscosity on Fluid Aerodynamics	2.2	1	Fluid only	8	100	-20 and above	Launch	100/0	-	-	-		-	low viscosity
P142	Effect of Viscosity on Fluid Aerodynamics	2.2	1	Fluid only	8	100	-20 and above	Launch	100/0	-	-	-		-	mid viscosity
P143	Effect of Viscosity on Fluid Aerodynamics	2.2	2	Fluid only	8	100	-20 and above	AD-49	100/0	-	-	-		-	low viscosity
P144	Effect of Viscosity on Fluid Aerodynamics	2.2	2	Fluid only	8	100	-20 and above	AD-49	100/0	-	-	-		-	mid viscosity
P145	Effect of Viscosity on Fluid Aerodynamics	2.2	2	Fluid only	8	100	-20 and above	Polar Guard Advance	100/0	-	-	-		-	low viscosity
P146	Effect of Viscosity on Fluid Aerodynamics	2.2	2	Fluid only	8	100	-20 and above	Polar Guard Advance	100/0	-	-	-		-	mid viscosity
P147	Effect of Viscosity on Fluid Aerodynamics	2.2	1	Fluid only	8	100	below -20	ABC-S Plus	100/0	-	-	-		-	low viscosity
P148	Effect of Viscosity on Fluid Aerodynamics	2.2	1	Fluid only	8	100	below -20	ABC-S Plus	100/0	-	-	-		-	mid viscosity
P149	Effect of Viscosity on Fluid Aerodynamics	2.2	1	Fluid only	8	100	below -20	Launch	100/0	-	-	-		-	low viscosity
P150	Effect of Viscosity on Fluid Aerodynamics	2.2	1	Fluid only	8	100	below -20	Launch	100/0	-	-	-		-	mid viscosity
P151	Effect of Viscosity on Fluid Aerodynamics	2.2	2	Fluid only	8	100	below -20	AD-49	100/0	-	-	-		-	low viscosity
P152	Effect of Viscosity on Fluid Aerodynamics	2.2	2	Fluid only	8	100	below -20	AD-49	100/0	-	-	-		-	mid viscosity
P153	Effect of Viscosity on Fluid Aerodynamics	2.2	2	Fluid only	8	100	below -20	Polar Guard Advance	100/0	-	-	-		-	low viscosity
P154	Effect of Viscosity on Fluid Aerodynamics	2.2	2	Fluid only	8	100	below -20	Polar Guard Advance	100/0	-	-	-		-	mid viscosity
P155	IP Expansion	2.3	1	IP- / SN-	8	100	-10	EG106	100/0	25	10	10		5-10	

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	Dilution	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	Coating	Exposure Time	COMMENT
P156	IP Expansion	2.3	1	IP- / SN-	8	100	-10	ABC-S Plus	100/0	25	10	10		5	
P157	IP Expansion	2.3	1	IP- / SN-	8	100	-10	Launch	100/0	25	10	10		5	
P158	IP Expansion	2.3	1	IP- / SN-	8	100	-10	Max-Flight	100/0	25	10	10		5	
P159	IP Expansion	2.3	1	IP- / SN-	8	100	-10	AD-49	100/0	25	10	10		5	
P160	IP Expansion	2.3	1	IP- / SN-	8	100	-10	Polar Guard Advance	100/0	25	10	10		5	
P161	IP Expansion	2.3	2	IP- / SN-	8	100	-15	EG106	100/0	25	10	10		5-10	
P162	IP Expansion	2.3	2	IP- / SN-	8	100	-15	ABC-S Plus	100/0	25	10	10		5	
P163	IP Expansion	2.3	2	IP- / SN-	8	100	-15	Launch	100/0	25	10	10		5	
P164	IP Expansion	2.3	2	IP- / SN-	8	100	-15	Max-Flight	100/0	25	10	10		5	
P165	IP Expansion	2.3	2	IP- / SN-	8	100	-15	AD-49	100/0	25	10	10		5	
P166	IP Expansion	2.3	2	IP- / SN-	8	100	-15	Polar Guard Advance	100/0	25	10	10		5	
P167	IP Expansion	2.3	2	IP- / SN-	8	100	-25	EG106	100/0	25	10	10		5-10	
P168	IP Expansion	2.3	2	IP- / SN-	8	100	-25	ABC-S Plus	100/0	25	10	10		5	
P169	IP Expansion	2.3	2	IP- / SN-	8	100	-25	Launch	100/0	25	10	10		5	
P170	IP Expansion	2.3	2	IP- / SN-	8	100	-25	Max-Flight	100/0	25	10	10		5	
P171	IP Expansion	2.3	2	IP- / SN-	8	100	-25	AD-49	100/0	25	10	10		5	
P172	IP Expansion	2.3	2	IP- / SN-	8	100	-25	Polar Guard Advance	100/0	25	10	10		5	
P173	IP Expansion	2.3	2	IP- / SN	8	100	-5 to -10	EG106	100/0	25	25	25		5-10	
P174	IP Expansion	2.3	2	IP- / SN	8	100	-5 to -10	ABC-S Plus	100/0	25	25	25		5	
P175	IP Expansion	2.3	2	IP- / SN	8	100	-5 to -10	Launch	100/0	25	25	25		5	
P176	IP Expansion	2.3	2	IP- / SN	8	100	-5 to -10	Max-Flight	100/0	25	25	25		5	
P177	IP Expansion	2.3	2	IP- / SN	8	100	-5 to -10	AD-49	100/0	25	25	25		5	
P178	IP Expansion	2.3	2	IP- / SN	8	100	-5 to -10	Polar Guard Advance	100/0	25	25	25		5	
P179	IP Validation with New Fluids	2.4	2.4	IP-	8	100	-5 and above	Max-Flight	100/0	25	-	-		50	
P180	IP Validation with New Fluids	2.4	2.4	IP-	8	100	-5 and above	AD-49	100/0	25	-	-		50	
P181	IP Validation with New Fluids	2.4	2.4	IP-	8	100	-5 and above	Polar Guard Advance	100/0	25	-	-		50	

Table 3.1 (cont'd): Proposed Test Plan

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (°C)	Fluid	Dilution	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	Coating	Exposure Time	COMMENT
P182	IP Validation with New Fluids	2.4	2.4	IP mod	8	100	-5 and above	Max-Flight	100/0	75	-	-		25	
P183	IP Validation with New Fluids	2.4	2.4	IP mod	8	100	-5 and above	AD-49	100/0	75	-	-		25	
P184	IP Validation with New Fluids	2.4	2.4	IP mod	8	100	-5 and above	Polar Guard Advance	100/0	75	-	-		25	
P185	IP Validation with New Fluids	2.4	2.4	IP-	8	100	-5 to -10	Max-Flight	100/0	25	-	-		30	
P186	IP Validation with New Fluids	2.4	2.4	IP-	8	100	-5 to -10	AD-49	100/0	25	-	-		30	
P187	IP Validation with New Fluids	2.4	2.4	IP-	8	100	-5 to -10	Polar Guard Advance	100/0	25	-	-		30	
P188	IP Validation with New Fluids	2.4	2.4	IP mod	8	100	-5 to -10	Max-Flight	100/0	75	-	-		10	
P189	IP Validation with New Fluids	2.4	2.4	IP mod	8	100	-5 to -10	AD-49	100/0	75	-	-		10	
P190	IP Validation with New Fluids	2.4	2.4	IP mod	8	100	-5 to -10	Polar Guard Advance	100/0	75	-	-		10	
P191	IP Validation with New Fluids	2.4	2.4	IP- / ZR-	8	100	-5 and above	Max-Flight	100/0	25	-	25		25	
P192	IP Validation with New Fluids	2.4	2.4	IP- / ZR-	8	100	-5 and above	AD-49	100/0	25	-	25		25	
P193	IP Validation with New Fluids	2.4	2.4	IP- / ZR-	8	100	-5 and above	Polar Guard Advance	100/0	25	-	25		25	
P194	IP Validation with New Fluids	2.4	2.4	IP- / ZR-	8	100	-5 to -10	Max-Flight	100/0	25	-	25		10	
P195	IP Validation with New Fluids	2.4	2.4	IP- / ZR-	8	100	-5 to -10	AD-49	100/0	25	-	25		10	
P196	IP Validation with New Fluids	2.4	2.4	IP- / ZR-	8	100	-5 to -10	Polar Guard Advance	100/0	25	-	25		10	
P197	IP Validation with New Fluids	2.4	2.4	IP- / ZR Mod	8	100	-5 and above	Max-Flight	100/0	25	-	75		25	
P198	IP Validation with New Fluids	2.4	2.4	IP- / ZR Mod	8	100	-5 and above	AD-49	100/0	25	-	75		25	
P199	IP Validation with New Fluids	2.4	2.4	IP- / ZR Mod	8	100	-5 and above	Polar Guard Advance	100/0	25	-	75		25	

4. PRE-TESTING SETUP ACTIVITIES

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

5. DATA FORMS

The following data forms are required for the January – February 2013 wind tunnel tests:

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

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

6. PROCEDURE

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

6.1 Initial Test Conditions Survey

- Record ambient conditions of the test (Attachment XIV/XV); and
- Record wing temperature (Attachment XVI).

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

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

6.3 Application of Contamination

6.3.1 Ice Pellet/Snow Dispenser Calibration and Set-Up

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

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

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

6.3.2 Dispensing Ice Pellets/Snow for Wind Tunnel Tests

Using the results from these calibration tests, a decision was made to use two dispensers on each of the leading and trailing edges of wing; each of the four dispensers are moved to four different positions along each edge during the dispensing process. Attachments XVII and XVIII 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 XIX.

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 XV). 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 XVI);
- Measure fluid Brix value (Attachment XVI);
- Record wing temperatures (Attachment XVI);
- Record start time of test (Attachment XV); and
- Fill out visual evaluation rating form (Attachment XVI).

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

6.5 During Wind Tunnel Test:

- Take still pictures and video the behavior of the fluid on the wing during the takeoff run, capturing any movement of fluid/contamination;
- Fill out visual evaluation rating form at the time of rotation (Attachment XX); 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 XVI);
- Measure fluid Brix value (Attachment XVI);
- Record wing temperatures (Attachment XVI);
- Observe and record the status of the fluid/contamination (Attachment XX);
- Fill out visual evaluation rating form (Attachment XVI);
- 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 XXI) 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 XXII). A falling ball viscosity test should be performed on site to confirm that fluid viscosity is appropriate before testing.

6.8 At the End of Each Test Session

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

6.9 Camera Setup

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

6.10 Demonstration of a Typical Wind Tunnel Test Sequence

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

Table 6.1: Typical Wind Tunnel Test

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

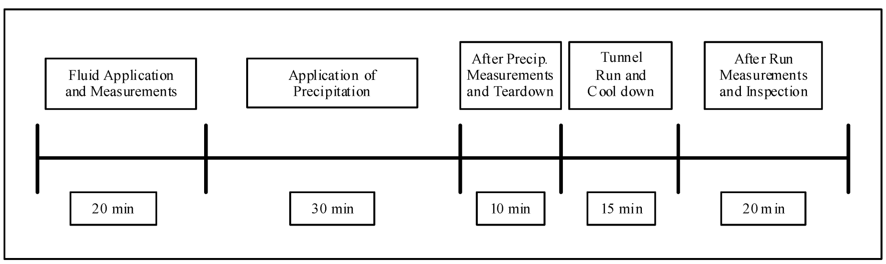


Figure 6.1: Typical Wind Tunnel Run Timeline

6.11 Procedures for R&D Activities

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

- Fluid and contamination at LOUT;
- Heavy snow;
- Heavy contamination;
- Small hail;
- Frost simulation in the wind tunnel;
- Wind tunnel test section cooling;
- Flaps/Slats testing to support YMX tests;
- Mixed HOT conditions;
- Frost spot deicing/anti-icing;
- Snow on an un-protected wing;
- Feasibility of IP testing at higher speed (130-150kts);
- Light and very light snow HOT's;
- Windshield washer used as a Type I deicer;
- Effect of fluid seepage on dry wing performance; and
- 2nd wave of fluid during rotation.

As these full-scale R&D activities have in general not been previously attempted, therefore brief summaries of the anticipated procedures have been prepared to provide guidance at the time of testing. These procedures are attached to this document as Attachments XXIII to XXXVII. 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		***Camera Equipment***	
Large and small tape measure		Digital still cameras x3 (two suitcases)	
Fluids (ORDER and SHIP to Ottawa)		Flashes and tripods (in APS storage)	
Horse and tap for fluid barrel x 2		GoPro Camera	
Funnels		Older Xti (x3) cameras (as back-up for first week)	
Sample bottles for viscosity measurement x10		Obsolete Cameras (to be given to TC)	
Squeegees			
Isopropyl x24		***Ice Pellets Fabrication Equipment***	
Gloves, paper towel (lots)		Refrigerated Truck	
Extension cords		Ice pellets Styrofoam containers x20	
Clipboards, pencils, wing markers for sample locations and solvent		Ice bags	
Large Clock x1		Ice bags storage freezer	
Walkie Talkies x8		Blenders x6+	
Envelopes and labels		Ice pellets sieves	
Previous F20/WT reports (Elecronic Copies)		Folding tables	
Grid Section + Location docs		Measuring cups (1L and smaller ones for dispensing)	
Large Sharpies for Grid Section		Wooden Spoons	
Projector for laptop		Rubber Mats	
YOW employee contracts		NCAR Scale x1	
Blow Horns x4			
Stop Watches x4		***Freezing Rain Equipment***	
Calculators x3		NRC Freezing rain sprayer (not required)	
Scissors		APS PC equipped with rate station software	
Exacto Knives x2		White plastic rate pans (1 to 8 x 2) if necessary	
APS Laptops x5		Wooden boards for rate pans (x8)	
Dry eraser markers		Rubber suction cup feet for wooden boards	
		Sartorius Weigh Scale x1	
Test Equipment		Black Shelving Unit (or plastic)	
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) 2-APS 1-WU 0-TC??			
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 90º 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	Viscosity	2012-13 Quantity Ordered (L)
ABAX	Ecowing AD-49	IV	Mid	700
			Low	60
Clariant Produkte	Launch	IV	Mid	400
			Low	60
	Max-Flight 04	IV	Mid	700
			Low	60
	MP III 2031 ECO	III	Mid	200
Cryotech	Polar Guard Advance	IV	Mid	600
			Low	60
Dow Chemical Company	EG106	IV	Mid	800
Kilfrost Limited	ABC-S PLUS	IV	Mid	500
			Low	60
			Total	4200

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. Four additional persons (with one back-up) will be required from Ottawa for making and dispensing the ice pellets and snow. One additional person from Ottawa will be required to photograph the testing. Table 9.1 demonstrates the personnel required and their associated tasks.

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

Table 9.1: Personnel List

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

NRC Institute of Aerospace Research Contacts

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

10. SAFETY

- A safety briefing will be done on the first day of testing;
- Personnel should be familiar with NRC emergency procedures i.e. DO NOT CALL 9-1-1, instead call the NRC Emergency Center as they will contact and direct the necessary services;

- All personnel must be familiar with the Material Safety Data Sheets (MSDS) for fluids;
- Prior to operating the wind tunnel, loose objects should be removed from the vicinity;
- When wind tunnel is operating, ensure that ear plugs are worn if necessary and personnel keep safe distances;
- When working on ladders, ensure equipment is stable;
- CSA approved footwear and appropriate clothing for frigid temperatures are to be worn by all personnel;
- Caution should be taken when walking in the test section due to slippery floors, and dripping fluid from the wing section;
- If fluid comes into contact with skin, rinse hands under running water; and
- If fluid comes into contact with eyes, flush with the portable eye wash station.

ATTACHMENT I - AERODYNAMIC CHARACTERIZATION OF THIN, HIGH-PERFORMANCE WING IN THE NRC PIWT TEST PLAN AND RATIONALE FOR WINTER 2013 CAMPAIGN

Limited Follow-on Testing
FAA/TC/APS/NRC/NASA Test Team

3 October 2012

Background and Overall Goal
Resulting from the discussions at the AWG meeting in Prague (May 2012), there were a few open questions regarding the aerodynamic characterization of the thin, high performance wing in the PIWT. These questions focused on the aerodynamics of the flap and how this contributes to the performance effects from the fluids/contamination. It is necessary to better understand these details in order to show that the fluids/contamination effects are not unique to this model, or to lessen the extent that they may be unique to this model. This understanding is necessary for the broad application for which the ice-pellet tests are intended.

1. Baseline (clean model) Repeatability

Objective and Rationale: verify that clean model aerodynamic data agree with the data acquired last year. Given the various issues with repeatability and angle of attack offsets in the past, this is an important step prior to fluids testing. Note that we should have the boundary-layer rake handy and ready to use if needed. This has the advantage of being the only independent measurement and could be used to sort out any discrepancies in the repeatability. Although very large discrepancies are considered highly unlikely, it would be good to have the necessary supplies to repeat the surface-oil flow visualization (self-adhesive film covering, mineral oil, black dye, paint roller, etc.).

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 C_L, C_M and C_D to data from 1.1.

1.3 Perform standard speed ramp profile and rotation through stall. V = 80 kts. Compare C_L, C_M and C_D to data from 1.1, 1.2 and 1.3.

1.4 Set V = 80 kts and measure performance data from α = -4 deg. to α_{stall}+4 deg. in one degree increments (pitch & pause mode), then take data for decreasing angle of attack also at one degree increments. Compare C_L, C_M and C_D versus α results to data from previous test campaign (January 2012).

1.5 If there are any discrepancies in the repeatability consider installing the boundary layer rake to repeat previous measurements. Plotting the displacement and/or momentum thickness vs. angle of attack could provide useful information to sort out any discrepancies.

1.6 Perform repeat runs of 1.1 – 1.4 as time allows during the remainder of the test campaign.

2. Surface Roughness Tests

Objective and Rationale: to determine the influence of contamination on the flap and leading edge on wing performance. Data are needed to supplement the results of the January 2012 tests. These tests are designed to determine the performance sensitivity of the flap and leading edge to fluid/contamination. Note that use of the boundary-layer rake is requested for these tests.

2.1 Apply 80-grit sandpaper on the flap and acquire performance data through stall according to 1.1-1.4. Compare C_L, C_M and C_D versus α results to data from previous test campaign (January 2012) to make sure that there are no discrepancies.

2.2 Apply various sizes of roughness and simulated fluid on flap (e.g., use 150 and 40-grit sandpaper and a “smooth paper” thickness TBD) and acquire performance data through stall according to 1.1-1.4. For each of these cases, install the boundary-layer rake at two locations: midspan trailing edge of main element and midspan trailing edge of flap to measure status of boundary layer with simulated fluid on the flap.

2.3 Experiment with simulated fluid on the model leading edge. Simulated fluid to consist of smooth layer of tape or other covering. Thickness and width (streamwise distance) to be determined in consultation with the research team. Several locations should be tested acquiring performance data through stall according to 1.1-1.4.

2.4 Based upon the results from 2.1 to 2.3 select a few combinations of the simulated leading edge fluid and flap contamination and acquire performance data through stall according to 1.1-1.4.

ATTACHMENT II – Procedure: Ice Phobic Testing

Background

Ice build-up on aircraft is a major safety concern for both on-ground and in-flight aircraft operations. In recent years, there has been significant industry interest in the use of coatings to protect aircraft critical surfaces. Some recent work has studied these coatings (sometimes designed and marketed as ice phobic coatings) during in-flight operations, but the behavior and performance of these coatings during ground icing operations has yet to be fully investigated.

Previous preliminary work has been conducted during the winters of 2009-10 and 2010-11 and the results are described in the TC report TP 15055E, *Emerging De/Anti-Icing Technology: Evaluation of Ice Phobic Products for Potential Use in Aircraft Operation* (1) and in the TC report TP 15158E, *Aircraft Ground Icing Research General Activities During the 2010-11 Winter (2)*.

A broader test plan was developed and conducted during the winter of 2011-12 to investigate some additional areas of research not previously studied to gain some new insight into the potential applications of these coatings for aircraft operations, and to continue the research to include newly developed coating formulations. The results are described in the Interim TC report, *Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates.* It was recommended that testing continue to investigate the effects of these coatings on de/anti-icing fluids from a HOT and aerodynamic perspective.

Objective

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

Methodology

Testing will be conducted using wing skins specifically manufactured to fit onto the existing thin high performance wing section and be secured by bolts. To cover the entire test wing, two individual wing skin halves are required. Testing may be conducted by mix-matching two halves in order to obtain comparative data.

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

- For each specific coating, conduct a fluid test simulating ice pellets and/or freezing rain, for an exposure time derived from the HOT table or allowance time table;

- Record lift data, visual observations, and manually collected data;
- Compare the aerodynamic performance to the baseline un-coated wing skin tests as well as to other coatings;
- In some cases, 2 different wing skin halves may be installed to provide a visual comparison of the fluid flow-off results. In such cases, the aerodynamic data collected should be dismissed;

Note: Consideration should be given to the time required to switch-over the wing skins as this will have significant impacts on scheduling.

Test Plan

Four days of testing are planned, however testing maybe reduced based on the results obtained at the discretion of the TC officer.

ATTACHMENT III – Procedure: Stall Warning Sensor

Background

Some current aircraft stall warning systems and ice detection systems may not account for contamination on the wing, give information during the take off roll, be effective at detecting high-speed stalls, be effective at measuring a tail stall, predict aerodynamic effect of contamination, or determine the extent of icing. Most importantly, some current stall warning systems may not be effective at preventing accidents involving icing.

Airfoil performance monitors (APM) are being developed and can be installed on any airfoil on an aircraft, including the tail. APM is designed to measure the airflow over the wing, which reveals how well the wing is working. As a wing becomes contaminated, the APM should measure the changing airflow and lift generated by the wing. The APM is designed to alert the crew if the airflow degrades below a configurable threshold, giving the crew time to correct a potential stall before it happens. It was recommended that testing be conducted with a Canadian developed APM to evaluate potential for use in ground icing operations with and without icing.

Objective

To evaluate the ability of the stall warning APM sensor to properly identify stall with and without icing conditions.

Methodology

- Conduct dry wing baseline testing with and without the installation to understand any potential aerodynamic influences the sensor may have;
- With the sensor installed conduct dry wing tests to stall.
- Repeat tests with fluid only to stall;
- Repeat tests with fluid and contamination to stall;
- Compare the APM measured stall to the stall observed through the aerodynamic data collected;

Test Plan

Six tests are anticipated for a total of one day of testing.

ATTACHMENT IV – Procedure: ROGIDS

Background

Remote on-ground ice detection systems (ROGIDS) have been in development for the aircraft ground icing industry for many years. A significant amount of research has been conducted with these systems to assess their performance, with varying results over the years. In 2004-05 research demonstrated that in certain circumstances ROGIDS are more reliable than human visual and/or tactile check in detecting clear ice on aircraft critical surfaces. An SAE working group was subsequently formed, and a standard for post-deicing was published by SAE in September 2007 followed by TC and FAA Advisory Circulars in the years following. Discussions in the working group about other potential applications for ROGIDS determined the next focus should be at the departure end of the runway. A flight crew survey completed in 2011-12 illustrated that locating a ROGIDS at the departure end of the runway could have a significant positive impact on safety. As a result, it was recommended that resources be allocated to advance the use of ROGIDS technology for the end-of-runway application

Objective

To support the development of ROGIDS technology by conducting post-deicing and end-of-runway testing.

Methodology

Arrangements have been made between FAA/TC and the ROGIDS manufacturers to have the systems installed in the wind tunnel during the winter 2012-13 testing. It is anticipated that the ROGIDS system will piggy-back on the current testing plans and will be non-intrusive. The ROGIDS operator will be able to collect video/photo data of a clean and contaminated wing.

Test Plan

This will be non-intrusive testing with so no extra days needed.

ATTACHMENT V – Generic Type I Holdover Time Table

TABLE 1-A

SAE TYPE I FLUID HOLDOVER GUIDELINES ON ALUMINUM WING SURFACES FOR WINTER 2012-2013[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)							
		Freezing Fog	Snow, Snow Grains or Snow Pellets			Freezing Drizzle[4]	Light Freezing Rain	Rain on Cold Soaked Wing[5]	Other[6]
Degrees Celsius	Degrees Fahrenheit		Very Light[3]	Light[3]	Moderate				
-3 and above	27 and above	11 – 17	18	11 – 18	6 – 11	9 – 13	4 – 6	2 – 5	CAUTION: No holdover time guidelines exist
below -3 to -6	below 27 to 21	8 – 13	14	8 – 14	5 – 8	5 – 9	4 – 6		
below -6 to -10	below 21 to 14	6 – 10	11	6 – 11	4 – 6	4 – 7	2 – 5		
below -10	below 14	5 – 9	7	4 – 7	2 – 4				

NOTES
1 Type I Fluid / Water Mixture 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 VI – Generic Type III Holdover Time Table

TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013

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

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

NOTES

1. Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type III fluid cannot be used.
2. Use light freezing rain holdover times in conditions of very light or light snow mixed with light rain.
3. Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
4. No holdover guidelines exist for this condition for 0°C (32°F) and below.
5. Heavy snow, ice pellets, moderate and heavy freezing rain, and hail.
6. For outside air temperatures below -9°C (15.8°F) to -10°C (14°F), these holdover times only apply to aircraft with a take-off profile conforming to the high speed aerodynamic test criterion (refer to Section 8.1.6.1 f) of TP 14052E). If uncertain whether the aircraft performance conforms to this criterion, consult the aircraft manufacturer.

CAUTIONS

- **The only acceptable decision-making criterion, for takeoff without a pre-takeoff contamination inspection, is the shorter time within the applicable holdover time table cell.**
- **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 VII – Dow Chemical UCAR Endurance EG106 Type IV Holdover Time Table

TABLE 4-D-E106

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013[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 VIII – Kilfrost ABC-S Plus Type IV Holdover Time Table

TABLE 4-K-ABC-S+

KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013[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	CAUTION: No holdover time guidelines exist	
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]		
		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 IX – Clariant Safewing MP IV Launch Type IV Holdover Time Table

TABLE 4-C-LAUNCH

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013[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 X – Cryotech Polar Guard Advance Type IV Holdover Time Table

TABLE 4-CR-PG-A

CRYOTECH TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013[1]
POLAR GUARD ADVANCE

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

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	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	2:50 – 4:00	1:20 – 1:50	1:35 – 2:00	1:15 – 1:30	0:15 – 2:00	CAUTION: No holdover time guidelines exist
		75/25	2:30 – 4:00	0:45 – 1:20	1:40 – 2:00	0:40 – 1:10	0:09 – 1:40	
		50/50	0:50 – 1:25	0:15 – 0:35	0:20 – 0:45	0:09 – 0:20		
below -3 to -14	below 27 to 7	100/0	0:55 – 2:30	0:55 – 1:15	0:35 – 1:35[7]	0:35 – 0:45[7]		
		75/25	0:40 – 1:30	0:35 – 1:00	0:25 – 1:05[7]	0:35 – 0:45[7]		
below -14 to -30.5	below 7 to -22.9	100/0	0:25 – 0:50	0:15 – 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 XI – ABAX ECOWING AD-49 Type IV Holdover Time Table

TABLE 4-A-Ecowing AD-49

ABAX TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013[1]
ECOWING AD-49

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

Outside Air Temperature[2]		Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)	Approximate Holdover Times Under Various Weather Conditions (hours:minutes)					
Degrees Celsius	Degrees Fahrenheit		Freezing Fog	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	3:20 – 4:00	1:10 – 1:50	1:25 – 2:00	1:00 – 1:25	0:10 – 1:55	
		75/25	2:25 – 4:00	1:20 – 1:40	1:55 – 2:00	0:50 – 1:30	0:10 – 1:40	
		50/50	0:25 – 0:50	0:15 – 0:25	0:15 – 0:30	0:10 – 0:15		
below -3 to -14	below 27 to 7	100/0	0:20 – 1:35	1:10 – 1:50	0:25 – 1:25[7]	0:20 – 0:25[7]		CAUTION: No holdover time guidelines exist
		75/25	0:30 – 1:10	1:20 – 1:40	0:15 – 1:05[7]	0:15 – 0:25[7]		
below -14 to -26	below 7 to -14.8	100/0	0:25 – 0:40	0:15 – 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 XII– Ice Pellet Allowance Time Table

Transport Canada Holdover Time Guidelines — Winter 2012-2013

TABLE 11

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.

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

ATTACHMENT XIV – General Form/ Calibration

GENERAL FORM (EVERY CALIBRATION TEST)

DATE: ______________________ RUN # (Plan #): ____________

OJECTIVE: ☐ Angle of Attack Sweeps ☐ 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: __________

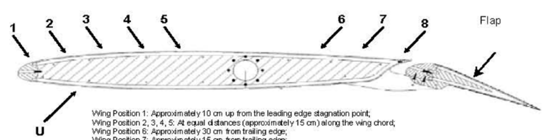
WIND TUNNEL END TIME: __________ PROJECTED SPEED (S/KTS): __________

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) ______________________

OTHER APPLIED: Y / N OTHER DETAILS: ______________________
☐ Full Wing ☐ Partial Wing (describe) ______________________

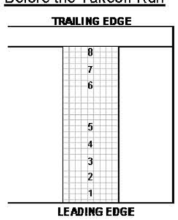


Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately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

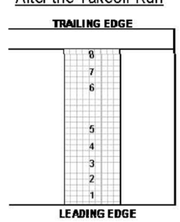
☐ Small Endplates

☐ Large Endplates

Before the Takeoff Run



After the Takeoff Run



COMMENTS : ______________________

HANDWRITTEN BY: __________

☐ Check if further details are available behind this sheet

ATTACHMENT XV – General Form

Form 1

GENERAL FORM (EVERY TEST)

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

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

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

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

ROTATION ANGLE: ________ EXTRA RUN INFO: ________

FLAP SETTING (20°, 0°): ________

☐ Check if additional notes provided on a separate sheet

FLUID APPLICATION

Actual start time: ________ Actual End Time: ________

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

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

ICE PELLETS APPLICATION (if applicable)

Actual start time: ________ Actual End Time: ________

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

Exposure Time: ________

Total IP Required per Dispenser: ________

FREEZING RAIN/DRIZZLE APPLICATION (if applicable)

Actual start time: ________ Actual End Time: ________

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

Exposure Time: ________ Needle: ________

Flow: ________

Pressure ________

SNOW APPLICATION (if applicable)

Actual start time: ________ Actual End Time: ________

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

Exposure Time: ________ Method: ☐ Dispenser ☐ Sieve

Total SN Required per Dispenser: ________

COMMENTS ________

MEASUREMENTS BY: ________ **HANDWRITTEN BY:** ________

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

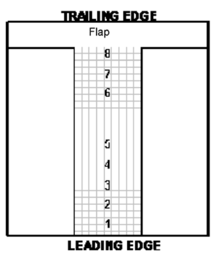
Date: ______________________ Run: ________________

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

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

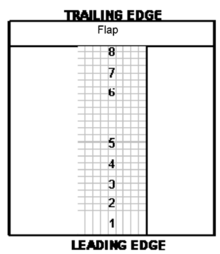
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2			
3			
4			
5			
6			
7			
8			
Flap			
Time:			

Wing and Plate Condition
After the Takeoff Run
Time: ___________

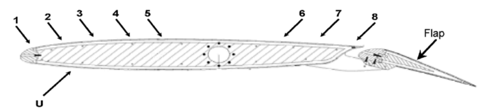


Comments:______________________

Wing and Plate Condition
Before the Takeoff Run
Time: ___________



Comments:______________________



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

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

General Comments:

OBSERVER: ______________________

ASSISTED BY: ______________________

ATTACHMENT XVII – Example Ice Pellet Dispensing Form

WING TRAILING EDGE

8 ft = 24.4 dm

6 ft = 18.3 dm

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

WING LEADING EDGE

Precipitation Type	IP		Date			Run #	

Field to be manipulated

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

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

IP needed per 5min

In each position	81	g
In each Dispensor	323	g

IP needed for entire test

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

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

NOTE:

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

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

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

ATTACHMENT XVIII – 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 XIX – Example Snow Dispensing Form

Precipitation Type	Sifted Snow

Date	

Run #	

* ***Field to be manipulated***

Target Rate	**25**	**$g/dm^2/h$**
Duration	**5**	**minutes**

Footprint Rate	25	$g/dm^2/h$
Stdev of Rate	10	$g/dm^2/h$

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 XX – 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 XXI – Fluid Receipt Form

(Consider using electronic auto-fill format)

SECTION A - SITE

☐ HOT SAMPLE ☐ RESEARCH/OTHER SAMPLE

Receiving Location: ____________________ **Date of Receiving:** ____________________

Manufacturer: ________________ **Fluid Name:** ____________________ **Fluid Type:** _____

Date of Production: ____________________ **Batch #:** ____________________

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

Note any additional information included on fluid containers:

Received by: ____________________
(PRINT NAME)

on: ____________________
(DATE)

SECTION B - OFFICE

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

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

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

FFP Curves Received:[2] ☐

[1] Type II/III/IV fluids only

[2] Type I fluids only

ATTACHMENT XXII – Log of Fluid Sample Bottles

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

ATTACHMENT XXIII – Procedure: Fluid and Contamination at LOUT

Background

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

Objective

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

Methodology

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

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

Test Plan

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

ATTACHMENT XXIV – Procedure: Heavy Snow

Background

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

Objective

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

Methodology

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

- For a chosen fluid, conduct a test simulating moderate snow conditions (rate of 25 g/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. See previous reports for suggested test plan.

ATTACHMENT XXV – Procedure: Heavy Contamination

Background

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

Objective

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

Methodology

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

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

Test Plan

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

ATTACHMENT XXVI – Procedure: Small Hail

Background

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

Objective

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

Methodology

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

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

Test Plan

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

ATTACHMENT XXVII – Procedure: Frost Simulation in the Wind Tunnel

Background

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

Objective

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

Methodology

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

Test Plan

One or two tests is anticipated.

ATTACHMENT XXVIII – Procedure: Wind Tunnel Test Section Cooling

Background

Recent wind tunnel research has been limited by the ambient temperature in wind tunnel test section; in sunny conditions, the radiation will raise the temperature in the test section making testing difficult. To mitigate this effect, testing is often conducted overnight, however in some cases, even body heat from people working in the test area (specifically during long precipitation exposure tests) can effect the temperature. It was recommended that initial testing be performed to investigate whether it would be feasible to install a cooling system in the wind tunnel, or to possibly use mitigation tactics such as blower fans to increase airflow and stabilize temperature.

Objective

To investigate the feasibility of stabilizing the temperature in the PIWT test section by using mitigation tactics or technologies.

Methodology

This work is exploratory, so no exact procedure exists. A more specific methodology may be determined on site following a brain-storm with onsite technicians.

Test Plan

One or two tests is anticipated, or could be ongoing during the testing if non-intrusive.

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

Background

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

Objective

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

Methodology

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

- For a chosen fluid, conduct a test simulating moderate snow conditions (rate of 25 $g/dm^2/h$) for an exposure time derived from the HOT table based on the tunnel temperature at the time of the test;
- Simulate early fluid failure on the fixed leading edge by applying higher rates of contamination on this area (record additional amounts);
- The flap is a hinged flap, so will be subject to early failure by design;
- Record lift data, visual observations, and manually collected data;
- Conduct a fluid only baseline test at the same temperature;
- Compare the aerodynamic performance;
- Consideration should be given to conducting Type I tests.

Test Plan

Two to four comparative tests are anticipated.

ATTACHMENT XXX – Procedure: Mixed HOT Conditions

Background

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

Objective

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

Methodology

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

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

Test Plan

Two to four comparative tests are anticipated.

ATTACHMENT XXXI – Procedure: 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. One test was conducted in 2011-12 to investigate the aerodynamic effects of CSW frost on a deiced airfoil protected with Type I fluid. It was recommended that testing be repeated with thickened Type IV fluid.

Objective

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

Methodology

- Apply fluid to wing section (2 areas of approximately 315cm²);
- Run the wind tunnel and collect data; and
- Compare results to baseline uncontaminated tests.

Test Plan

One to two tests are anticipated.

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

Background

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

Objective

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

Methodology

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

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

Test Plan

One to four comparative tests are anticipated.

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

Background

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

Objective

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

Methodology

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

Test Plan

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

ATTACHMENT XXXIV – 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. Limited testing was conducted during the winter of 2011-12 and it was recommended that testing continue for 2012-13.

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. Previous 2011-12 work should be referenced when developing test plan.

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

Background

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

Objective

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

Methodology

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

Test Plan

No testing is planned unless indicated otherwise by TC.

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

Background

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

Objective

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

Methodology

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

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

Test Plan

One to three comparative tests are anticipated

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

Background

Previous wind tunnel testing has shown that during a simulated take-off roll following de/anti-icing, fluid will shear off the wing section, however a small amount of fluid can remain trapped along the leading edge at the stagnation point. This "trapped" fluid begins to flow over the wing only once the wing is rotated; the stagnation point shifts below the leading edge, and the "trapped" fluid begins to shear off as a second wave. There is limited information as to the aerodynamic effects of this second wave of fluid, therefore it was recommended that preliminary testing be conducted to collect aerodynamic and observational data.

Objective

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

Methodology

This work is exploratory, so no exact procedure exists. A more specific methodology may be determined on site following a brain-storm with onsite technicians and NASA experts. It is expected that the general methodology to be used during these tests will be in accordance with the methodologies used for typical fluid only testing.

One test methodology may be to install a HD video camera to the end plates of the wing section during specific fluid tests to obtain high quality video documentation of the fluid flow-off. The video camera should be focused on the leading edge stagnation point.

Another possible test methodology may include:

- Apply fluid to wing section;
- Run the wind tunnel up to rotation speed and stop;
- Squeegee all fluid aft of the leading edge;
- Re-run the wind tunnel and do a full rotation; and
- Compare results to fluid only and dry uncontaminated tests.

Test Plan

One to four tests are anticipated.

APPENDIX A

PRESENTATION: WIND TUNNEL TESTING
WINTER 2012-13

WIND TUNNEL TESTING WINTER 2012-13

Objective: PRE TESTING	
Priority:	1
Number of days:	2 *(December 19-20, 2012)*
Number of tests:	TBD
Description of tests:	See Andy Broeren test plan

WIND TUNNEL TESTING WINTER 2012-13

Objective: DRY WING BASELINES REPEATABILITY	
Priority:	1
Number of days:	1 *(allocated based on 20 days)*
Number of tests:	2 per day
Description of tests:	Dry wing run @ 8° (1 x every start of day)
	Dry wing run @ stall (1 x every start of day)

WIND TUNNEL TESTING WINTER 2012-13

Objective: IP FLOW OFF ISSUES (IP- & IP MOD <-10°C)	
Priority:	1
Number of days:	3
Number of tests:	30
Description of tests:	IP- @ <-10°C - 100 knots / fluid *(30 min exposure)*
	IP- @ <-10°C - 115 knots / fluid *(30 min exposure)*
	IP Mod @ <-10°C - 100 knots / fluid *(10 min exposure)*
	IP Mod @ <-10°C - 115 knots / fluid *(10 min exposure)*
	IP Mod @ <-10°C - 100 knots / fluid *(5 min exposure)*
	IP Mod @ <-10°C - 115 knots / fluid *(5 min exposure)*
Fluids:	ABC-S Plus, Launch, AD-49, Max-Flight, Polar Guard Advance

WIND TUNNEL TESTING WINTER 2012-13

Objective: ROGIDS PIGGYBACK TESTING IN WT	
Priority:	1
Number of days:	0
Number of tests:	TBD
Description of tests:	*Non-intrusive testing with PV Labs, so no extra days needed. Observe icing tests with different conditions i.e. Ice Pellets.*

WIND TUNNEL TESTING WINTER 2012-13

Objective: ICE PHOBIC COATING R&D (1 of 3)	
Priority:	1
Number of days:	3
Number of tests:	53 *(total for flow-off , adhesion and visual comparison objectives)*
Description of tests:	Flow-off *(13 tests)*
	Dry wing @ <-10°C - 100 knots *(baseline)*
	IP Mod @ <-10°C - 100 knots / coating *(10 min exposure)*
	IP Mod @ <-10°C - 100 knots with one coating using Max-Flight LOWV fluid *(10 min exposure)*
Fluids:	Max-Flight, none
Coatings:	C0: *Skin with no coating* C1: *Skin treated with coating #1* C2: *Skin treated with coating #2* C3: *Skin treated with coating #3* C4: *Skin treated with coating #4* C5: *baseline test*

WIND TUNNEL TESTING WINTER 2012-13

Objective: ICE PHOBIC COATING R&D (2 of 3)	
Description of tests:	Adhesion *(30 tests)*
	ZR @ -10°C - 100 knots / coating *(20 min exposure with fluid)*
	ZR @ -10°C - 100 knots / coating *(20 min exposure without fluid)*
	IP/ZR @ -10°C - 100 knots / coating *(20 min exposure)*
	BASELINE @ -10°C - 100 knots / coating *(fluid only test)*
	IP-/ZR @ -5 to -10°C - 80 knots x any 2 different coatings
	IP-/ZR @ -5 to -10°C - 115 knots x any 2 different coatings
	SN @ -5 to -10°C - 100 knots x one coating *(no fluid)*
	SN @ -5 to -10°C - 115 knots x one coating *(no fluid)*
Fluids:	EG106
Coatings:	C0: *Skin with no coating* C1: *Skin treated with coating #1* C2: *Skin treated with coating #2* C3: *Skin treated with coating #3* C4: *Skin treated with coating #4* C5: *baseline test*

WIND TUNNEL TESTING WINTER 2012-13

Objective: ICE PHOBIC COATING R&D (3 of 3)	
Description of tests:	Visual Comparison *(10 tests)* *using 2 coatings per run, visually compare the results*
	ZR @ <-5°C - 100 knots / coating *(exposure TBD)*
	BASELINE @ <-5°C - 100 knots / coating *(fluid only test)*
Fluids:	EG106
Coatings*:	C0 & C5 C1 & C5 C1 & C2 C3 & C4 C0 & one of C1 or C2 or C3 or C4

* C0: *Skin with no coating*
C1: *Skin treated with coating #1*
C2: *Skin treated with coating #2*
C3: *Skin treated with coating #3*
C4: *Skin treated with coating #4*
C5: *baseline test*

WIND TUNNEL TESTING WINTER 2012-13

Objective: EFFECT OF ICE PHOBIC COATING BLDT (1 of 3)	
Priority:	1
Number of days:	1
Number of tests:	15 *(Total for Type III 100/0, Type III 75/25 and Type IV 100/0)*
Description of tests:	Type III 100/0 LOUT expansion *(6 tests)*
	BASELINE@ -16.5°C - 67 knots / coating
Fluids:	MP III 2031 ECO *(100/0)*
Coatings:	C0: *Skin with no coating* C1: *Skin treated with coating #1* C2: *Skin treated with coating #2* C3: *Skin treated with coating #3* C4: *Skin treated with coating #4* C5: *baseline test*

WIND TUNNEL TESTING WINTER 2012-13

Objective: EFFECT OF ICE PHOBIC COATING BLDT (2 of 3)	
Description of tests:	Type III 75/25 LOUT expansion *(3 tests)*
	BASELINE@ -9°C - 67 knots / coating
Fluids:	MP III 2031 ECO *(75/25)*
Coatings:	C0: *Skin with no coating; and* C5: *baseline test;* *With the choice of one of the following:* C1 : *Skin treated with coating #1; or* C2: *Skin treated with coating #2; or* C3: *Skin treated with coating #3; or* C4: *Skin treated with coating #4.*

WIND TUNNEL TESTING WINTER 2012-13

Objective: EFFECT OF ICE PHOBIC COATING BLDT (3 of 3)	
Description of tests:	Type IV LOUT expansion *(6 tests)*
	BASELINE @ -26°C - 100 knots / coating
Fluids:	AD-49 *(100/0)*
Coatings:	C0: *Skin with no coating* C1: *Skin treated with coating #1* C2: *Skin treated with coating #2* C3: *Skin treated with coating #3* C4: *Skin treated with coating #4* C5: *baseline test*

WIND TUNNEL TESTING WINTER 2012-13

Objective: EVALUATION OF STALLWING SENSOR	
Priority:	1
Number of days:	1
Number of tests:	10
Description of tests:	*Ensure that the sensor is non intrusive.* BASELINE @ ANY°C at stall x 2 *(with sensor)* BASELINE @ ANY°C at stall x 2 *(without sensor)*
Fluids:	EG106, none
Description of tests:	*Ensure that the sensor is working* IP MOD @ ANY°C at stall *(15-35 min exposure EG106 only)* BASELINE @ ANY°C at stall *(Type I fluid only)*
Fluids:	EG106 *(for IP Mod)* and Type I Fluid *(TBD, for baseline)*

WIND TUNNEL TESTING WINTER 2012-13

Objective: EFFECT OF VISCOSITY ON FLUID AERODYNAMICS	
Priority:	2.1
Number of days:	2
Number of tests:	16
Description of tests:	BASELINE @ below -20°C - 100 knots/ fluid *(low viscosity)* BASELINE @ below -20°C - 100 knots/ fluid *(mid viscosity)* BASELINE @ -20°C and above - 100 knots / fluid *(low viscosity)* BASELINE @ -20°C and above - 100 knots / fluid *(mid viscosity)*
Fluids:	ABC-S Plus, Launch, AD-49, Polar Guard Advance

WIND TUNNEL TESTING WINTER 2012-13

Objective: BLDT CORRELATION	
Priority:	1
Number of days:	3
Number of tests:	28
Description of tests:	BASELINE @ -15 to -22.5°C - 100 knots x 2 / fluid *(75/25 only)* BASELINE @ -22.5 to -35°C - 100 knots x 3 / fluid *(100/0 only)*
Fluids:	EG106 *(tested 100/0 only)*, ABC-S Plus, Launch, AD-49, Max-Flight, Polar Guard Advance

WIND TUNNEL TESTING WINTER 2012-13

Objective: IP EXPANSION (IP-/SN and IP-/SN-)	
Priority:	1
Number of days:	2
Number of tests:	36
Description of tests:	IP-/SN @ -5 to -10°C - 100 knots / fluid IP-/SN @ -10 to -15°C - 100 knots / fluid IP-/SN @ -15 to -25°C - 100 knots / fluid IP-/SN- @ -5 to -10°C - 100 knots / fluid IP-/SN- @ -10 to -15°C - 100 knots / fluid IP-/SN- @ -15 to -25°C - 100 knots / fluid
Fluids:	EG106, ABC-S Plus, Launch, AD-49, Max-Flight, Polar Guard Advance

WIND TUNNEL TESTING WINTER 2012-13

Objective: IP VALIDATION WITH NEW FLUIDS	
Priority:	1
Number of days:	3
Number of tests:	27
Description of tests:	IP- @ -5°C and above - 100 knots / fluid *(50 min exposure)* IP Mod @ -5°C and above - 100 knots / fluid *(25 min exposure)* IP- @ -5 to -10°C - 100 knots / fluid *(30 min exposure)* IP Mod @ -5 to -10°C - 100 knots / fluid *(10 min exposure)* IP- /ZR- @ -5°C and above - 100 knots / fluid *(25 min exposure)* IP- /ZR- @ -5 to -10°C - 100 knots / fluid *(10 min exposure)* IP- /R Mod @ -5°C and above - 100 knots / fluid *(25 min exposure)* IP- /SN- @ -5°C and above - 100 knots / fluid *(25 min exposure)* IP- /SN- @ -5 to -10°C - 100 knots / fluid *(15 min exposure)*
Fluids:	AD-49, Max-Flight, Polar Guard Advance

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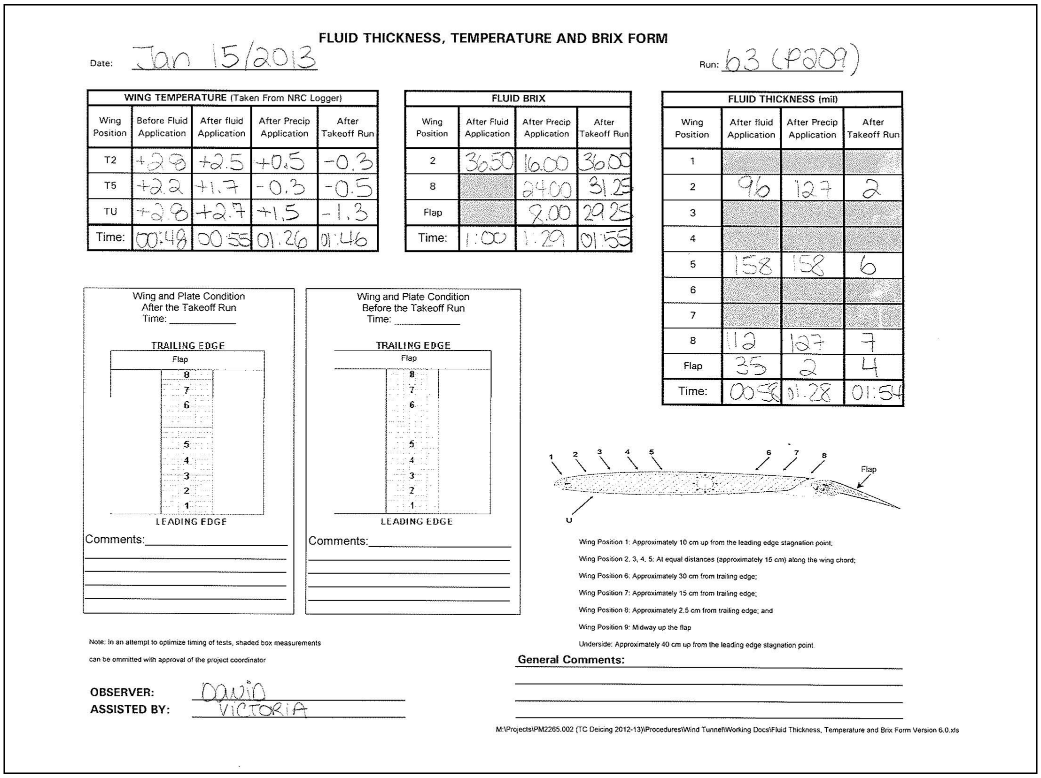
APPENDIX C

FLUID THICKNESS, TEMPERATURE, AND BRIX DATA FORMS



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15/2013

Run: 63 (P209)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	+2.8	+2.5	+0.5	-0.3
T5	+2.2	+1.7	-0.3	-0.5
TU	+2.8	+2.7	+1.5	-1.3
Time:	00:48	00:55	01:26	01:46

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.50	16.00	36.00
8		24.00	31.25
Flap		8.00	29.25
Time:	1:00	1:29	01:55

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	127	2
3			
4			
5	158	158	6
6			
7			
8	112	127	7
Flap	35	2	4
Time:	00:58	01:28	01:54

Wing and Plate Condition After the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition Before the Takeoff Run
Time: ____________

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

Comments: ____________

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: DAVID
ASSISTED BY: VICTORIA

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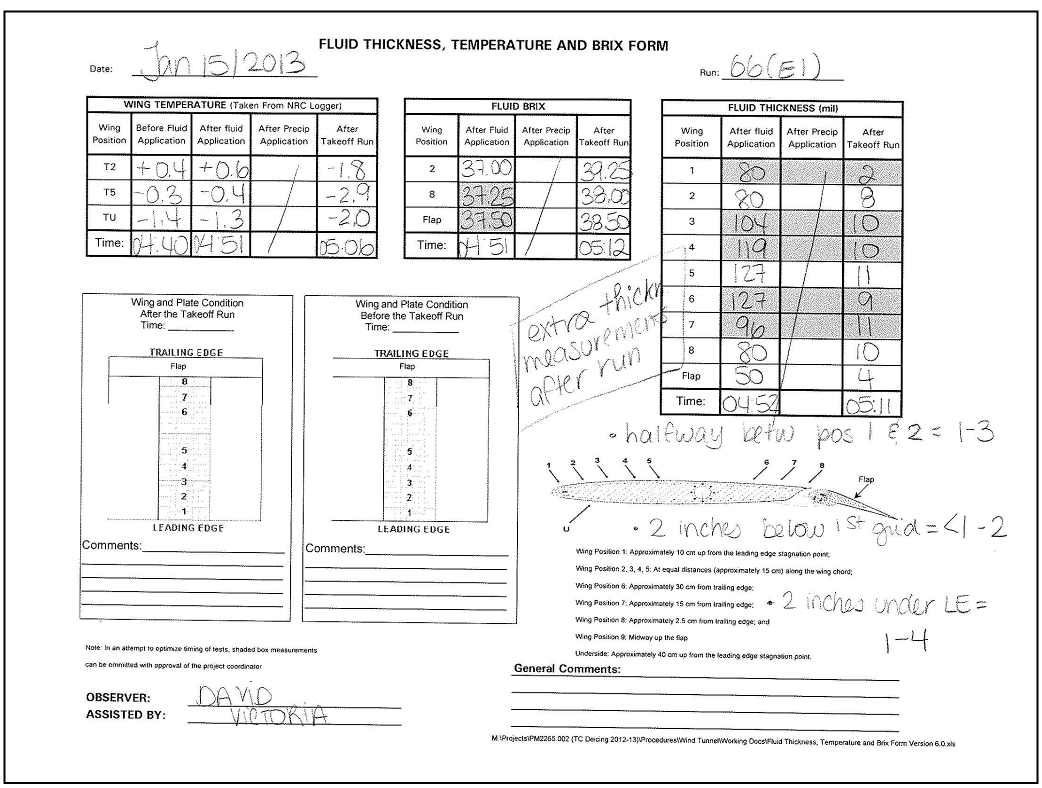
Figure C1: Test # 63



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 15/2013

Run: 66(E1)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	+0.4	+0.6	/	-1.8
T5	-0.3	-0.4	/	-2.9
TU	-1.4	-1.3	/	-2.0
Time:	04:40	04:51	/	05:06

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	/	39.25
8	37.25	/	38.00
Flap	37.50	/	38.50
Time:	04:51	/	05:12

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	80	/	2
2	80	/	8
3	104	/	10
4	119	/	10
5	127	/	11
6	127	/	9
7	96	/	11
8	80	/	10
Flap	50	/	4
Time:	04:52	/	05:11

extra thickn measurements after run

• halfway betw pos 1 & 2 = 1-3

• 2 inches below 1st grid = <1 - 2

• 2 inches under LE = 1-4

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: DAVID
ASSISTED BY: VICTORIA

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Figure C2: Test #66

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 16/2013

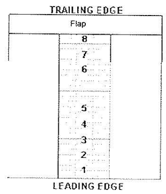
Run: 74 (P211)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	+0.6	-0.7	+0.1	-1.1
T5	0.0	-1.4	-1.2	-1.1
TU	+0.2	+0.3	+0.3	-2.3
Time:	02:11	02:17	02:56	03:11

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.50	11.50	30.50
8		15.25	32.50
Flap		1.00	26.50
Time:	02:23	02:48	03:10

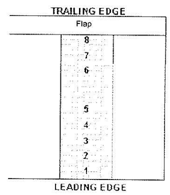
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	127	<1
3			
4			
5	150	200	6
6			
7			
8	119	134	7
Flap	35	5	4
Time:	02:22	02:50	03:10

Wing and Plate Condition
After the Takeoff Run
Time: ____________

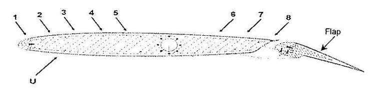


Comments:____________________

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 #74

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 16/2013

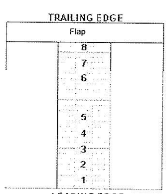
Run: 75 (P196)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-2.1	-1.0	-5.2	-4.1
T5	-2.7	-1.6	-6.1	-4.5
TU	-3.1	-2.4	-3.4	-4.9
Time:	03:44	03:59	04:23	04:34

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.00	32.00	33.00
8	36.50	30.00	34.25
Flap	36.50	30.00	30.50
Time:	04:00	04:20	04:40

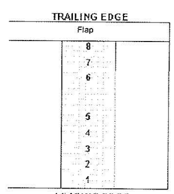
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	104	104	7
3			
4			
5	142	158	7
6			
7			
8	119	134	8
Flap	35	40	7
Time:	03:59	4.19	4:40

Wing and Plate Condition
After the Takeoff Run
Time: ____________

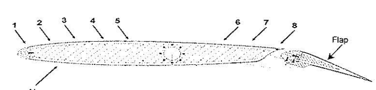


Comments:____________________

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 C4: Test #75

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 16/2013

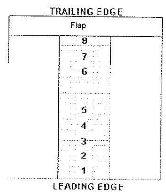
Run: 76 (P183)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2		-1.0	-6.7	-2.6
T5	/	-1.5	-7.2	-2.5
TU	/	-2.4	-4.3	-4.5
Time:	/	05:04	05:55	06:11

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	16.00	23.75
8		16.00	28.00
Flap		16.00	24.75
Time:	05:05	05:51	06:10

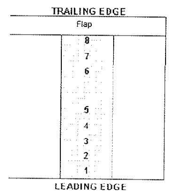
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	142	4
3			
4			
5	142	250	7
6			
7			
8	112	158	9
Flap	35	35	6
Time:	05:04	05:51	06:10

Wing and Plate Condition
After the Takeoff Run
Time: __________

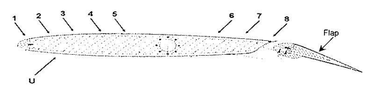


Comments:

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 #76

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 17/2013

Run: 83 (P224)

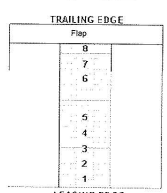
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	+1.6	+3.5	/	+1.8
T5	+1.0	+2.9	/	+1.6
TU	+1.1	+1.2	/	+0.8
Time:	01:43	01:59	/	02:24

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	/	36.50
8	36.50	/	37.00
Flap	37.00	/	37.25
Time:	2:02	/	02:25

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	60	/	8
2	80	/	10
3	104	/	9
4	112	/	9
5	119	/	10
6	127	/	11
7	119	/	10
8	96	/	9
Flap	30*	/	10*
Time:	2:01	/	02:24

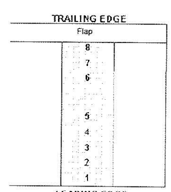
*45 top part of flap (1" from nose)
* <1

Wing and Plate Condition
After the Takeoff Run
Time: __________

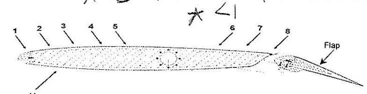


Comments:

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 #83

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 17, 2013

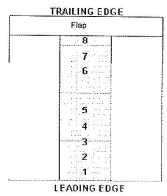
Run: 86(P196)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-1.8	-1.7	-10.5	-6.7
T5	-2.6	-2.3	-9.8	-7.0
TU	-2.3	-3.1	-4.1	-6.3
Time:	04:41	04:48	05.12	05:21

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	23.00	25.50
8		22.00	32.00
Flap		20.00	32.00
Time:	04:5	05:10	05:30

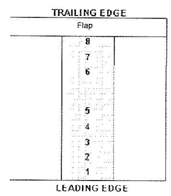
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	104	142	6
3			
4			
5	158	200	6
6			
7			
8	119	158	6
Flap	35	30	6
Time:	04:52	05:09	05:29

Wing and Plate Condition
After the Takeoff Run
Time: ___________

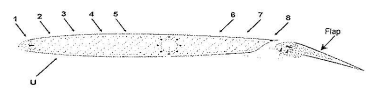


Comments:___________________

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 #86

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 17, 2013

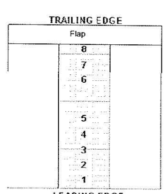
Run: 87 (P214)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.3	-4.1	-10.1	-8.8
T5	-6.6	-4.4	-10.0	-9.4
TU	-6.7	-6.5	-7.6	-9.1
Time:	05:37	05:48	06:20	06:31

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	23.00	30.50
8		25.00	32.00
Flap		20.00	29.00
Time:	05:51	06:14	06:35

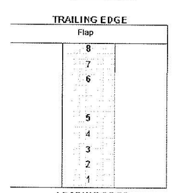
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	134	134	10
3			
4			
5	158	200	14
6			
7			
8	112	142	14
Flap	40	65	14
Time:	05:52	6:13	06:35

Wing and Plate Condition
After the Takeoff Run
Time: ___________

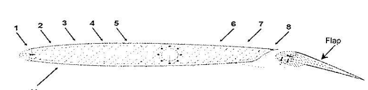


Comments:___________________

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 #87

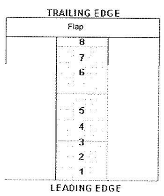
Date: Jan 17 2013 **FLUID THICKNESS, TEMPERATURE AND BRIX FORM** Run: 90(P011)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2		-11.1	-13.2	-13.1
T5	N/A	-11.3	-13.1	-12.6
TU		-13.9	-13.9	-15.8
Time:		22:54	23:25	23:41

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.25	30.00	33.50
8		31.50	31.00
Flap		25.50	31.75
Time:	22:53	23:25	23:41

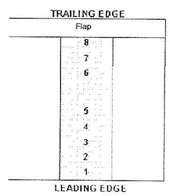
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	119	6
3			
4			
5	119	158	6
6			
7			
8	96	127	8
Flap	35	50	10
Time:	22:53	23:20	23:41

Wing and Plate Condition
After the Takeoff Run
Time: ___________

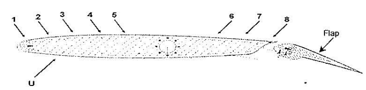


Comments:___________

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: MARCO
ASSISTED BY: VICTORIA

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Figure C9: Test #90 (P064)

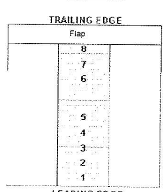
Date: Jan 17, 2013 **FLUID THICKNESS, TEMPERATURE AND BRIX FORM** Run: 91(P012)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-12.7	-12.1	-14.1	-16.7
T5	-11.8	-12.2	-14.2	-17.9
TU	-15.0	-14.1	-13.3	-17.3
Time:	23:45	00:01	00:35	00:43

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	32.50	32.50
8		29.50	32.50
Flap		27.50	33.25
Time:	00:00	00:30	00:55

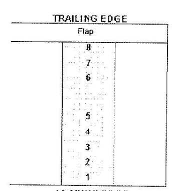
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	96	6
3			
4			
5	119	158	6
6			
7			
8	96	119	9
Flap	35	40	7
Time:	00:00	00:30	00:55

Wing and Plate Condition
After the Takeoff Run
Time: ___________

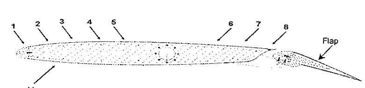


Comments:___________

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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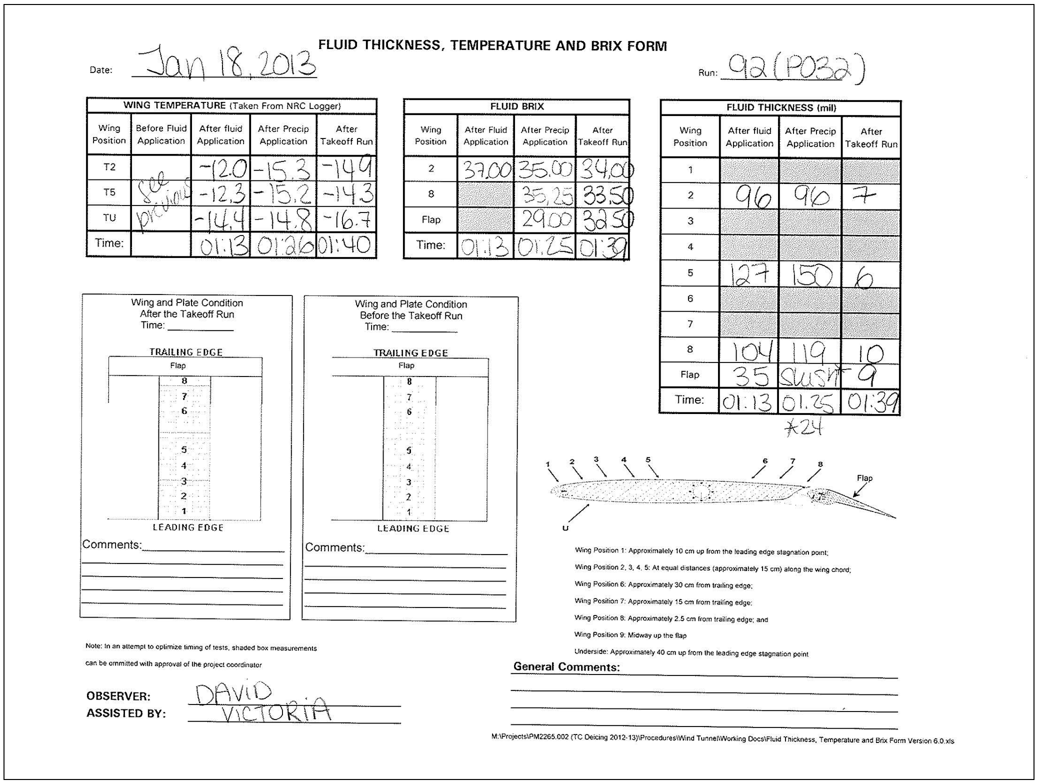
Figure C10: Test #91



Date: Jan 18, 2013

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Run: 92 (P032)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-12.0	-15.3	-14.9
T5		-12.3	-15.2	-14.3
TU		-14.4	-14.8	-16.7
Time:		01:13	01:26	01:40

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	35.00	34.00
8		35.25	33.50
Flap		29.00	32.50
Time:	01:13	01:25	01:39

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	96	7
3			
4			
5	127	150	6
6			
7			
8	104	119	10
Flap	35	slush*	9
Time:	01:13	01:25	01:39

*24

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: DAVID
ASSISTED BY: VICTORIA

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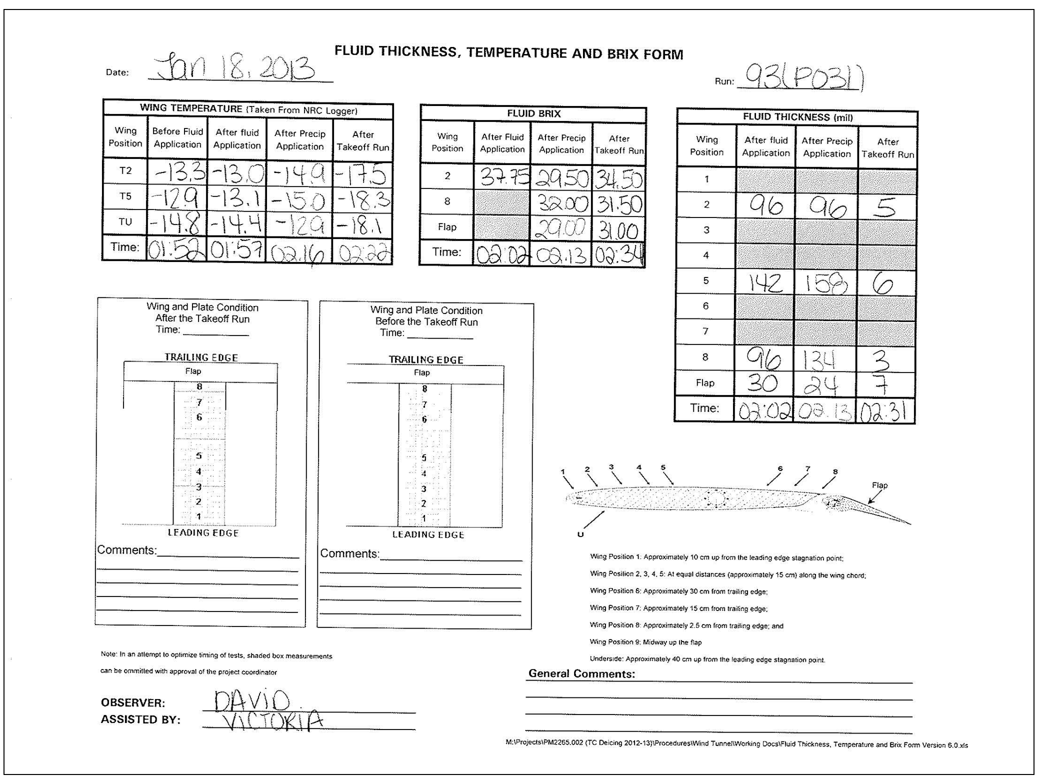
Figure C11: Test #92



Date: Jan 18, 2013

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Run: 93(P031)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-13.3	-13.0	-14.9	-17.5
T5	-12.9	-13.1	-15.0	-18.3
TU	-14.8	-14.4	-12.9	-18.1
Time:	01:52	01:57	02:16	02:22

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.75	29.50	34.50
8		32.00	31.50
Flap		29.00	31.00
Time:	02:02	02:13	02:34

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	96	5
3			
4			
5	142	158	6
6			
7			
8	96	134	3
Flap	30	24	7
Time:	02:02	02:13	02:31

Wing and Plate Condition After the Takeoff Run Time: ______

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

Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

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

Comments: ______

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

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

General Comments: ______

OBSERVER: DAVID
ASSISTED BY: VICTORIA

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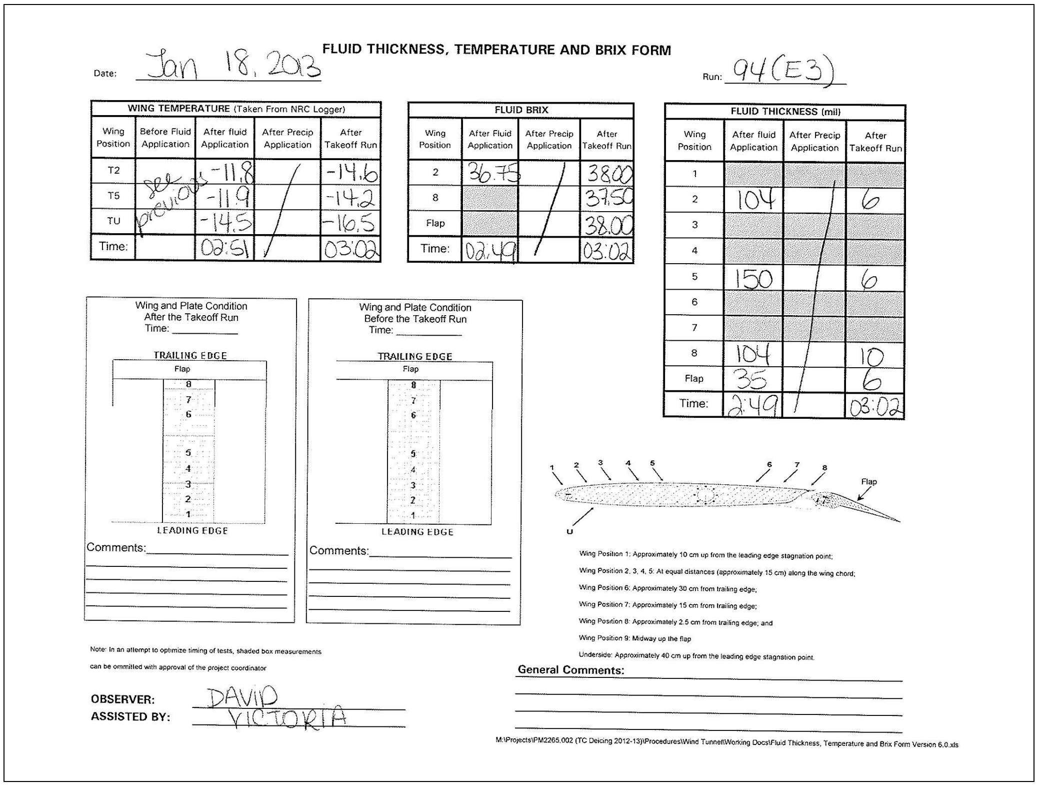
Figure C12: Test #93



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 18, 2013 Run: 94(E3)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-11.8	/	-14.6
T5		-11.9	/	-14.2
TU		-14.5	/	-16.5
Time:		02:51	/	03:02

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.75	/	38.00
8		/	37.50
Flap		/	38.00
Time:	02:49	/	03:02

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	104	/	6
3			
4			
5	150	/	6
6			
7			
8	104	/	10
Flap	35	/	6
Time:	2:49	/	03:02

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: DAVID
ASSISTED BY: VICTORIA

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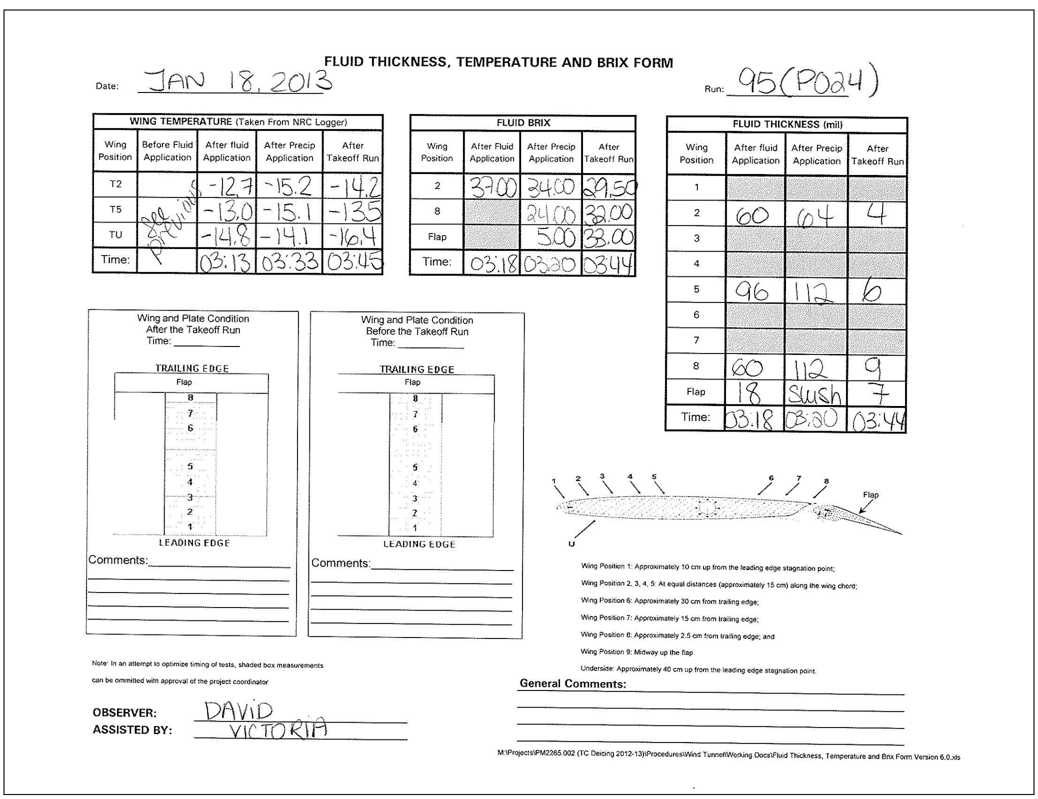
Figure C13: Test #94



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 18, 2013 Run: 95(P024)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-12.7	-15.2	-14.2
T5		-13.0	-15.1	-13.5
TU		-14.8	-14.1	-16.4
Time:		03:13	03:33	03:45

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	34.00	29.50
8		24.00	32.00
Flap		5.00	33.00
Time:	03:18	03:30	03:44

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	60	64	4
3			
4			
5	96	112	6
6			
7			
8	60	112	9
Flap	18	Slush	7
Time:	03:18	03:30	03:44

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

Comments: ______

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

Comments: ______

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 C14: Test #95

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 18, 2013

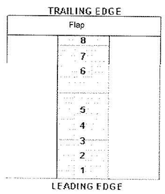
Run: 96(P023)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	See previous	-12.9	-16.6	n/a
T5		-13.4	-16.4	
TU		-15.2	-14.6	
Time:		03:55	04:10	

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	32.00	n/a
8		32.00	
Flap		n/a	
Time:	04:00	03:10	

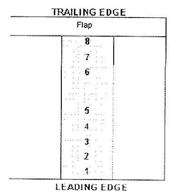
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	60	60	n/a
3			
4			
5	80	119	
6			
7			
8	50	119	n/a
Flap	18	Slush	
Time:	03:59	03:10	

Wing and Plate Condition After the Takeoff Run
Time: ________

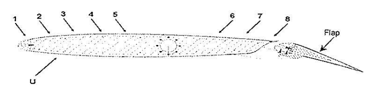


Comments: ________

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 C15: Test #96

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 18, 2013

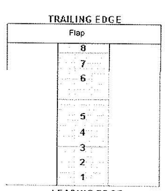
Run: 96A(P023)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-15.0	-12.1	-16.1	-15.4
T5	-14.1	-12.3	-15.8	-14.9
TU	-15.3	-15.3	-14.7	-17.7
Time:	04:42	04:47	05:06	05:17

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	30.00	29.75
8		32.00	28.50
Flap		23.50	n/a
Time:	0453	0502	05:18

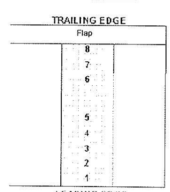
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65	64	7
3			
4			
5	96	127	6
6			
7			
8	55	104	7
Flap	20	Slush	8
Time:	0452	0502	05:18

Wing and Plate Condition After the Takeoff Run
Time: ________

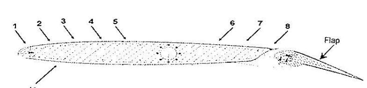


Comments: ________

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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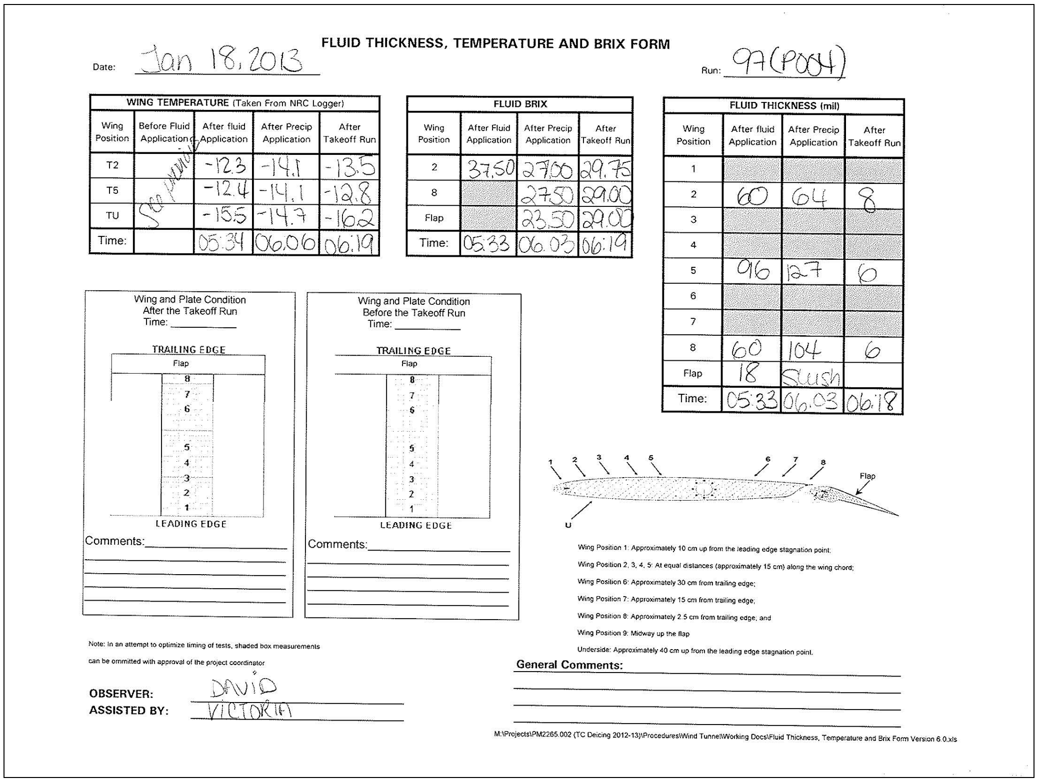
Figure C16: Test #96A



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 18, 2013

Run: 97(P004)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	See comment	-12.3	-14.1	-13.5
T5		-12.4	-14.1	-12.8
TU		-15.5	-14.7	-16.2
Time:		05:34	06:06	06:19

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	27.00	29.75
8		27.50	29.00
Flap		23.50	29.00
Time:	05:33	06:03	06:19

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	60	64	8
3			
4			
5	96	127	6
6			
7			
8	60	104	6
Flap	18	Slush	
Time:	05:33	06:03	06:18

Wing and Plate Condition After the Takeoff Run Time: ______

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

Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

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

Comments: ______

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

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

General Comments: ______

OBSERVER: DAVID
ASSISTED BY: VICTORIA

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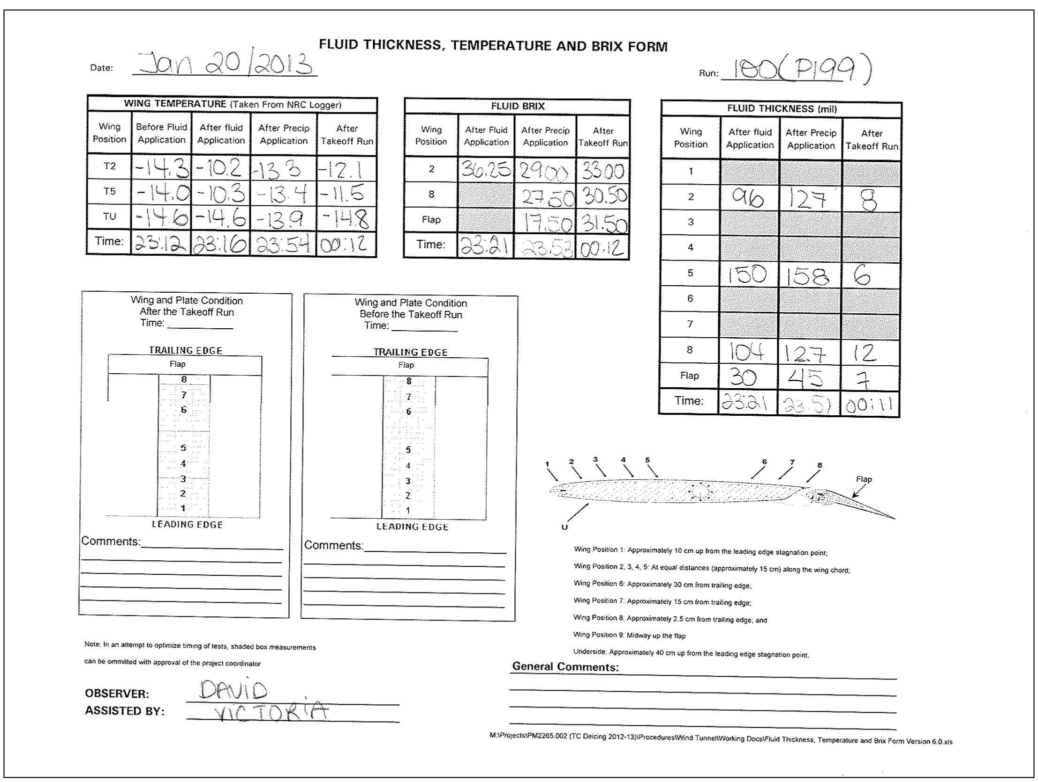
Figure C17: Test #97



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 20/2013

Run: 100(P199)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.3	-10.2	-13.3	-12.1
T5	-14.0	-10.3	-13.4	-11.5
TU	-14.6	-14.6	-13.9	-14.8
Time:	23:12	23:16	23:54	00:12

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.25	29.00	33.00
8		27.50	30.50
Flap		17.50	31.50
Time:	23:21	23:53	00:12

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	127	8
3			
4			
5	150	158	6
6			
7			
8	104	127	12
Flap	30	45	7
Time:	23:21	23:51	00:11

Wing and Plate Condition After the Takeoff Run Time: ______

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

Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

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

Comments: ______

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

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

General Comments: ______

OBSERVER: DAVID
ASSISTED BY: VICTORIA

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Figure C18: Test #100

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2013

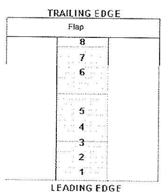
Run: 113(P030)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	n/a	-15.1	-16.3	-17.7
T5		-15.4	-16.5	-17.8
TU		-15.2	-14.2	-17.9
Time:		01:16	01:35	01:40

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	31.00	no post measure
8		29.00	
Flap		27.50	
Time:		02:22	

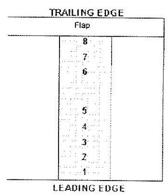
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	96	
3			
4			n/a
5	80	142	
6			
7			
8	80	127	
Flap	35	slush	
Time:	01:19	02:21	

Wing and Plate Condition After the Takeoff Run
Time: ___________

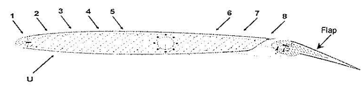


Comments: ___________

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: no post measurements bad run

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Figure C19: Test #113

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22/2013

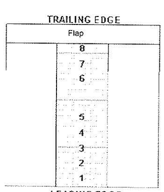
Run: 113A(P030)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.0	-14.4	-16.6	-13.5
T5	-13.7	-14.5	-16.8	-13.0
TU	-15.7	-15.7	-14.3	-15.7
Time:	01:48	02:02	02:13	02:28

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	27.00	27.75
8		30.00	32.25
Flap		26.00	32.25
Time:	02:01	02:11	02:29

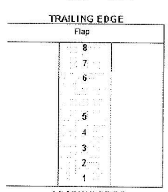
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	119	3
3			
4			
5	80	134	4
6			
7			
8	65	96	6
Flap	24	10	3
Time:	02:01	02:10	02:29

Wing and Plate Condition After the Takeoff Run
Time: ___________

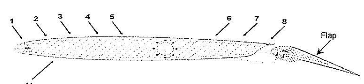


Comments: ___________

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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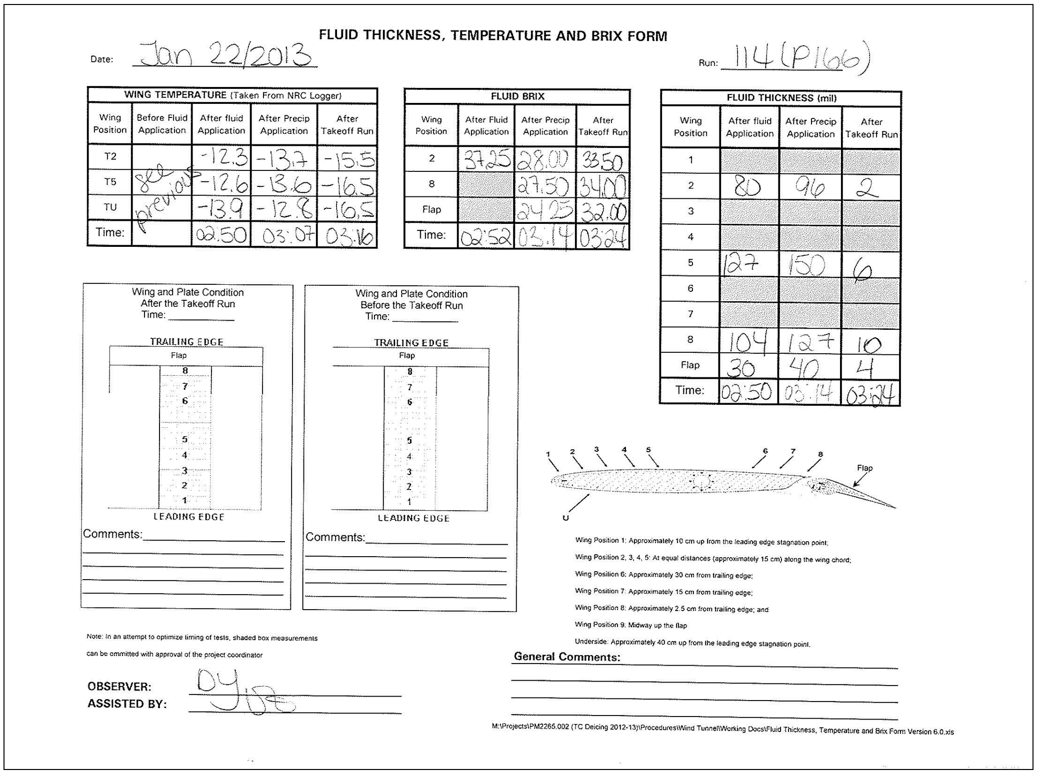
Figure C20: Test #113A



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22/2013

Run: 114 (P166)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-12.3	-13.7	-15.5
T5		-12.6	-13.6	-16.5
TU		-13.9	-12.8	-16.5
Time:		02:50	03:07	03:16

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	28.00	33.50
8		27.50	34.00
Flap		24.25	32.00
Time:	02:52	03:14	03:24

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	96	2
3			
4			
5	127	150	6
6			
7			
8	104	127	10
Flap	30	40	4
Time:	02:50	03:14	03:24

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: JB

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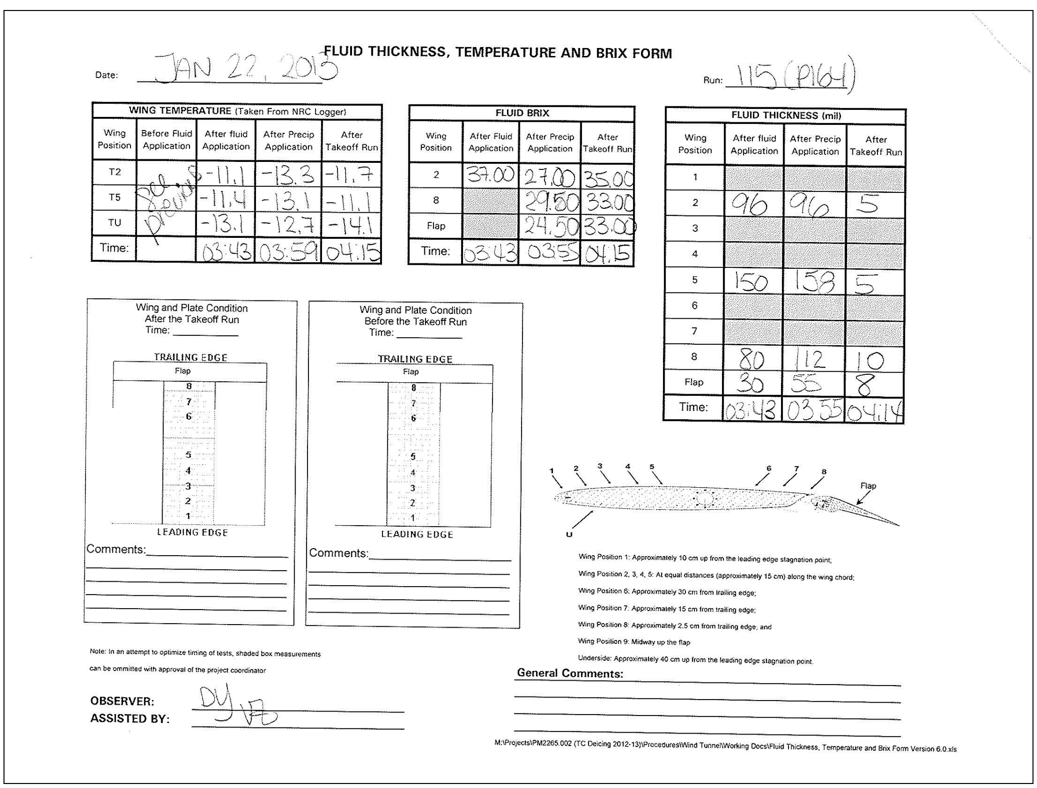
Figure C21: Test #114



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: JAN 22, 2013

Run: 115 (P164)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-11.1	-13.3	-11.7
T5		-11.4	-13.1	-11.1
TU		-13.1	-12.7	-14.1
Time:		03:43	03:59	04:15

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	27.00	35.00
8		29.50	33.00
Flap		24.50	33.00
Time:	03:43	03:55	04:15

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	96	5
3			
4			
5	150	158	5
6			
7			
8	80	112	10
Flap	30	55	8
Time:	03:43	03:55	04:14

Wing and Plate Condition After the Takeoff Run Time: ________

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

Comments: ________

Wing and Plate Condition Before the Takeoff Run Time: ________

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

Comments: ________

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 C22: Test #115

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2013

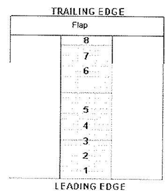
Run: 116 (P176)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-10.3	-12.9	-12.6
T5		-11.0	-12.9	-12.2
TU		-10.1	-12.6	-15.2
Time:		04:29	04:45	04:57

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	23.50	32.25
8		29.75	31.00
Flap		23.50	31.25
Time:	04:30	04:41	04:57

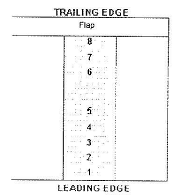
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	104	8
3			
4			
5	96	127	8
6			
7			
8	60	96	10
Flap	28	22	5
Time:	04:28	4:41	04:57

Wing and Plate Condition
After the Takeoff Run
Time: ___________

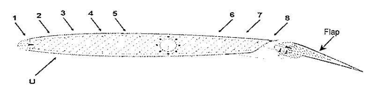


Comments: ___________

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 C23: Test #116

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2013

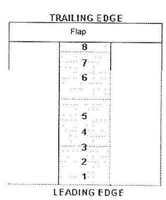
Run: 117 (P178)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-11.7	-14.0	
T5		-12.1	-13.3	
TU		-13.6	-12.8	
Time:		05:08	05:24	

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	34.25	33.00
8		27.00	31.25
Flap		29.50	32.50
Time:	05:11	05:21	05:37

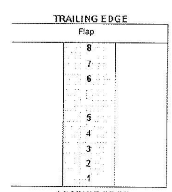
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	80	6
3			
4			
5	142	158	10
6			
7			
8	96	112	30
Flap	35	40	12
Time:	05:11	05:20	05:36

Wing and Plate Condition
After the Takeoff Run
Time: ___________

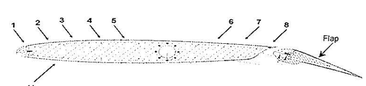


Comments: ___________

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 C24: Test #117

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2013

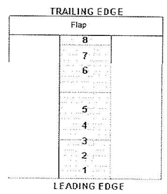
Run: 118 (P178R)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-12.0	n/a	-13.5	-15.1
T5	-11.4		-13.4	-15.5
TU	-14.2		-13.2	-16.3
Time:	05:44		06:09	06:15

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	31.00	35.25
8		28.00	33.00
Flap		28.00	33.00
Time:	05:55	05:05	06:22

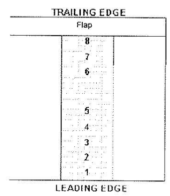
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	80	8
3			
4			
5	127	127	8
6			
7			
8	80	112	10
Flap	30	25	8
Time:	05:55	05:04	6:22

Wing and Plate Condition
After the Takeoff Run
Time: ___________

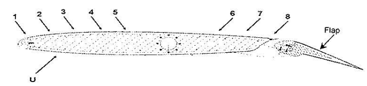


Comments: ___________

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: VP

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Figure C25: Test #118

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22, 2012

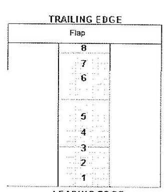
Run: 121 (P024)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-20.7	-17.7	-19.0	-18.5
T5	-20.6	-18.2	-19.2	-18.5
TU	-21.0	-20.8	-20.6	-21.6
Time:	23:27	23:35	23:53	00:04

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	35.00	33.50
8		33.50	33.75
Flap		Slush	31.50
Time:	23:39	23:48	00:08

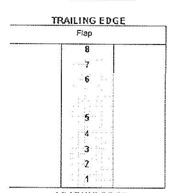
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	50	70	3
3			
4			
5	80	104	4
6			
7			
8	40	96	4
Flap	9	Slush	3
Time:	23:39	23:48	00:08

Wing and Plate Condition
After the Takeoff Run
Time: ___________

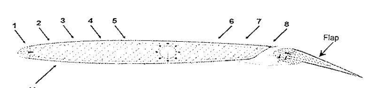


Comments: ___________

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: VP

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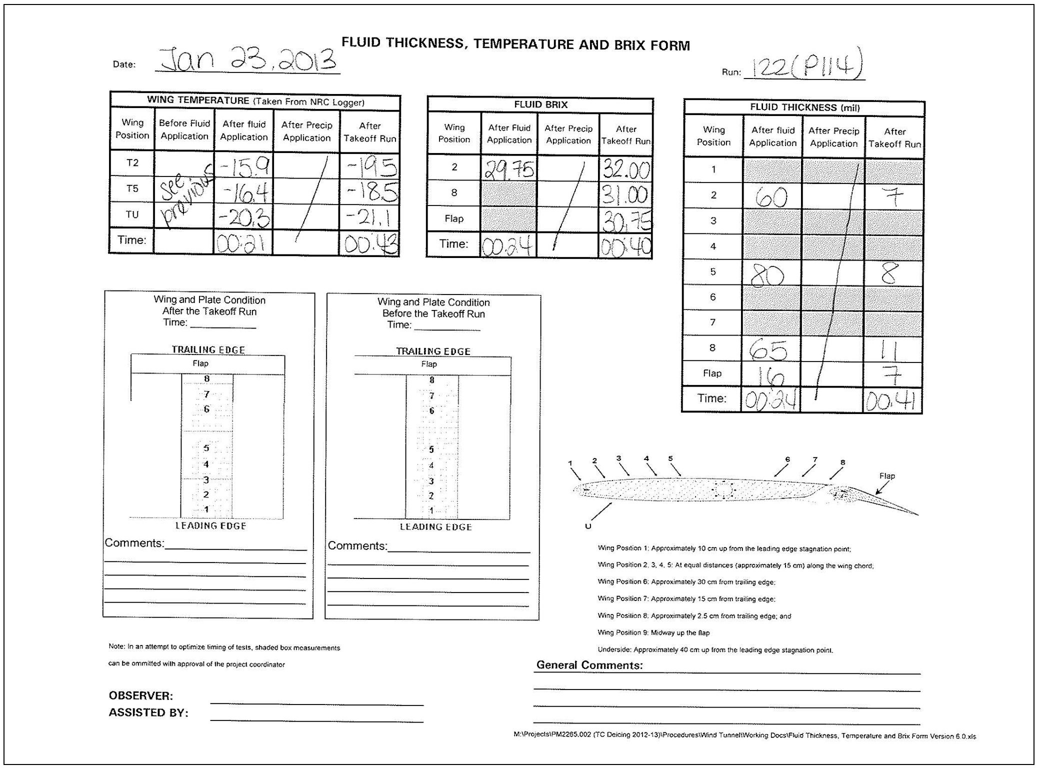
Figure C26: Test #121



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23, 2013

Run: 122(P114)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-15.9	/	-19.5
T5		-16.4		-18.5
TU		-20.3		-21.1
Time:		00:21		00:43

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	29.75	/	32.00
8			31.00
Flap			30.75
Time:	00:24		00:40

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	60		7
3			
4			
5	80		8
6			
7			
8	65		11
Flap	16		7
Time:	00:24		00:41

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:
ASSISTED BY:

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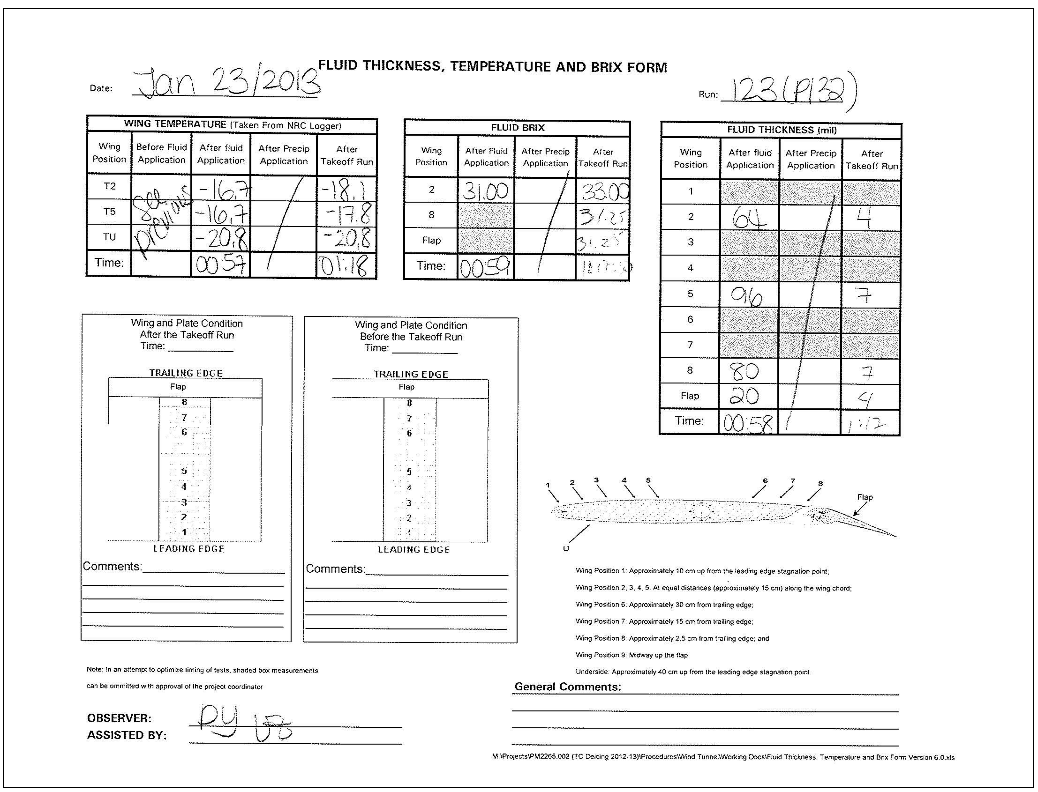
Figure C27: Test #122



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23/2013

Run: 123(P132)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-16.7	/	-18.1
T5		-16.7		-17.8
TU		-20.8		-20.8
Time:		00:57		01:18

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	31.00	/	33.00
8			31.25
Flap			31.25
Time:	00:59		1:17:30

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	64		4
3			
4			
5	96		7
6			
7			
8	80		7
Flap	20		4
Time:	00:58		1:17

Wing and Plate Condition After the Takeoff Run Time: ______

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

Comments:

Wing and Plate Condition Before the Takeoff Run Time: ______

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

Comments:

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: PY JB
ASSISTED BY: VB

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Figure C28: Test #123

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 22/2013

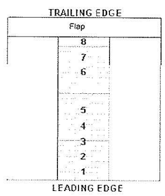
Run: 124 (P137)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-16.7	/	-20.5
T5		-16.6	/	-20.7
TU		-20.7	/	-22.1
Time:		01:31	/	01:43

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	31.00	/	31.25
8		/	31.00
Flap		/	31.25
Time:	01:30	/	01:46

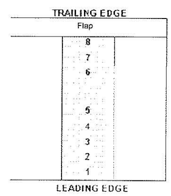
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	50	/	5
3		/	
4		/	
5	70	/	8
6		/	
7		/	
8	60	/	10
Flap	18	/	4
Time:	01:30	/	01:45

Wing and Plate Condition
After the Takeoff Run
Time: ___________

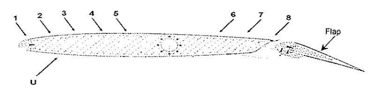


Comments: ___________

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/MR
ASSISTED BY: VT

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Figure C29: Test #124

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23/2013

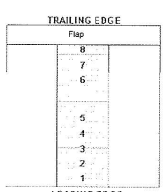
Run: 125 (P122)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-18.4	/	-22.1
T5		-18.4	/	-22.3
TU		-21.7	/	-23.7
Time:		02:00	/	02:21

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	28.75	/	30.50
8	29.00	/	30.00
Flap		/	29.25
Time:	02:06	/	02:22

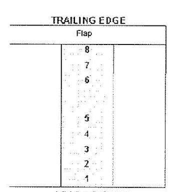
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	80	/	5
3		/	
4		/	
5	127	/	7
6		/	
7		/	
8	112	/	11
Flap	35	/	10
Time:	02:05	/	02:22

Wing and Plate Condition
After the Takeoff Run
Time: ___________

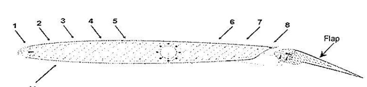


Comments: ___________

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/MR
ASSISTED BY: VT

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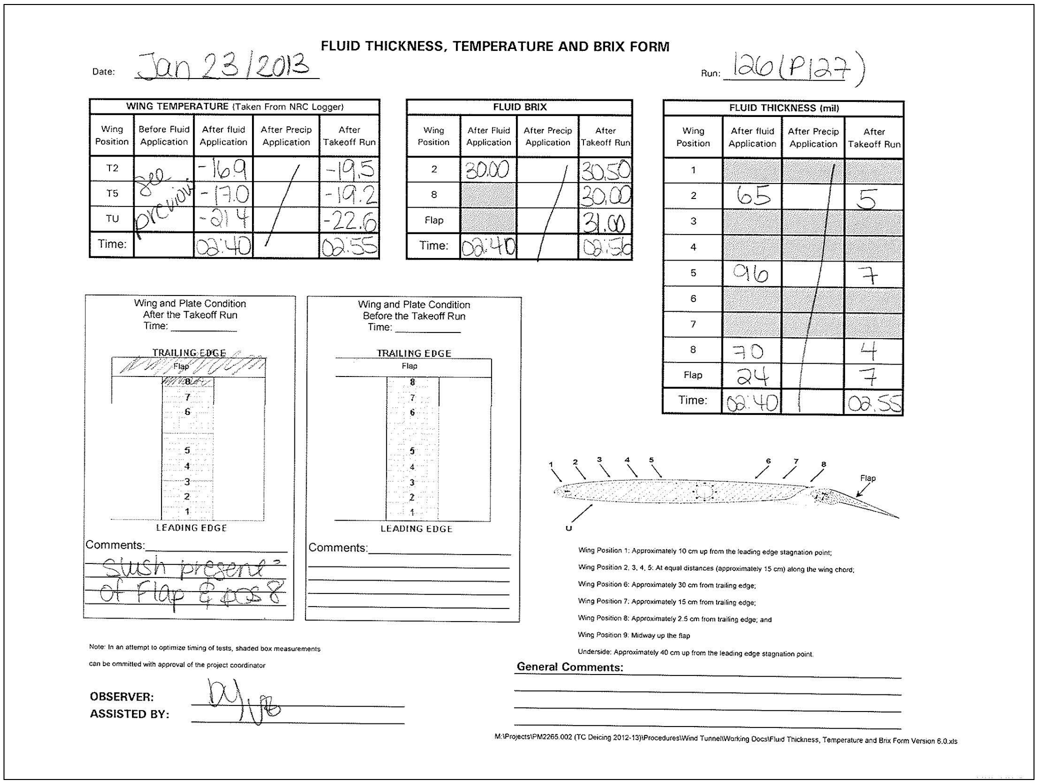
Figure C30: Test #125



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23/2013

Run: 126(P127)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-16.9	/	-19.5
T5		-17.0		-19.2
TU		-21.4		-22.6
Time:		02:40		02:55

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	30.00	/	30.50
8			30.00
Flap			31.00
Time:	02:40		02:56

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	65		5
3			
4			
5	96		7
6			
7			
8	70		4
Flap	24		7
Time:	02:40		02:55

Wing and Plate Condition After the Takeoff Run Time: ______

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

Comments: Slush present at Flap & pos 8

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: JB

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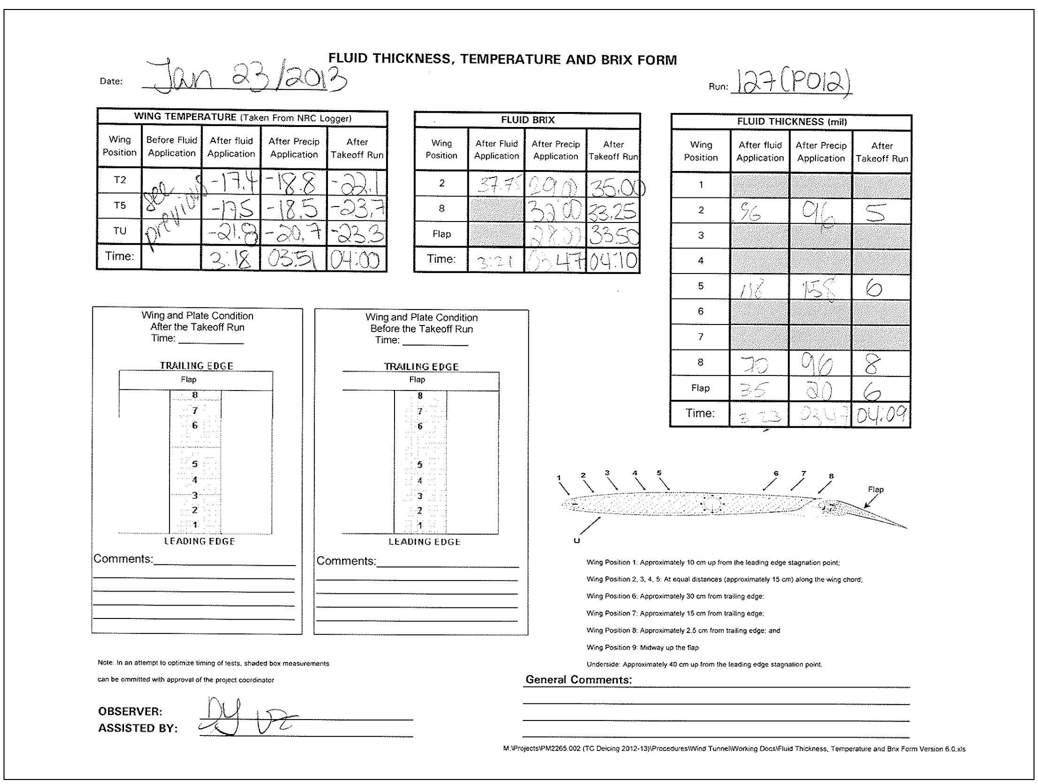
Figure C31: Test #126



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23/2013

Run: 127(P012)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-17.4	-18.8	-22.1
T5		-17.5	-18.5	-23.7
TU		-21.8	-20.7	-23.3
Time:		3:18	03:51	04:00

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.75	29.00	35.00
8		32.00	33.25
Flap		28.00	33.50
Time:	3:21	03:47	04:10

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	96	96	5
3			
4			
5	118	158	6
6			
7			
8	70	96	8
Flap	35	20	6
Time:	3:23	03:47	04:09

Wing and Plate Condition After the Takeoff Run Time: ______

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

Comments: ______

Wing and Plate Condition Before the Takeoff Run Time: ______

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

Comments: ______

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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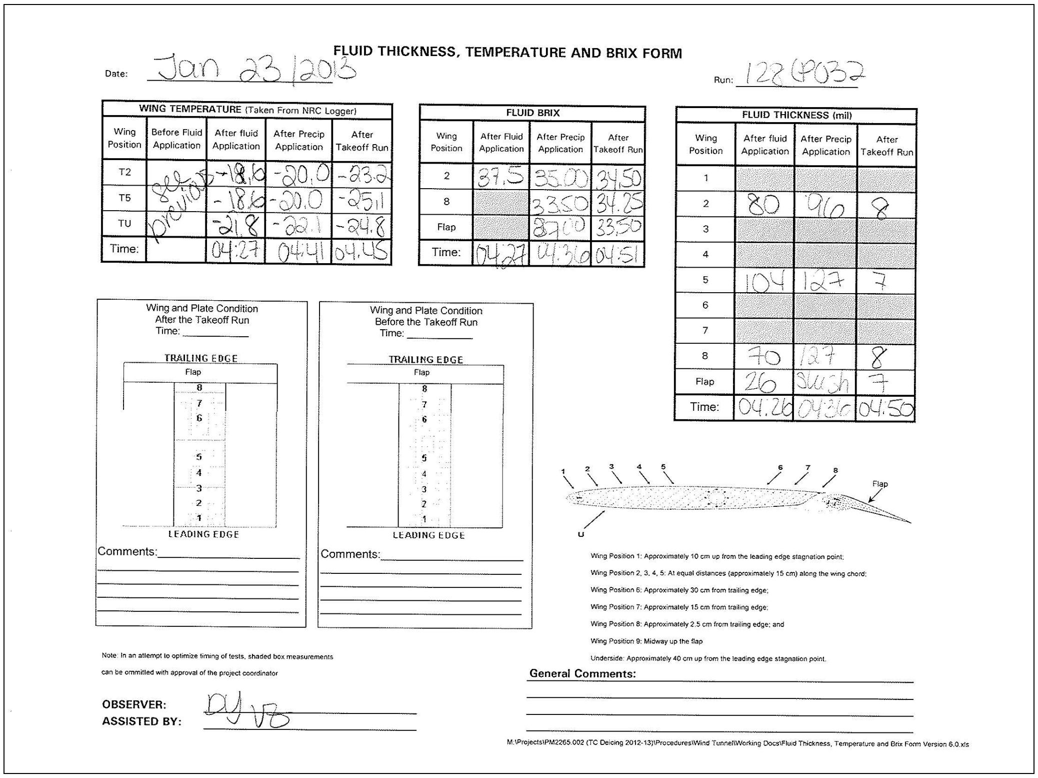
Figure C32: Test #127



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23/2013 Run: 128(P032)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-18.6	-20.0	-23.2
T5		-18.6	-20.0	-25.1
TU		-21.8	-22.1	-24.8
Time:		04:27	04:41	04:45

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.5	35.00	34.50
8	–	33.50	34.25
Flap	–	32.00	33.50
Time:	04:27	04:36	04:51

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	–	–	–
2	80	96	8
3	–	–	–
4	–	–	–
5	104	127	7
6	–	–	–
7	–	–	–
8	70	127	8
Flap	26	slush	7
Time:	04:26	04:36	04:50

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

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

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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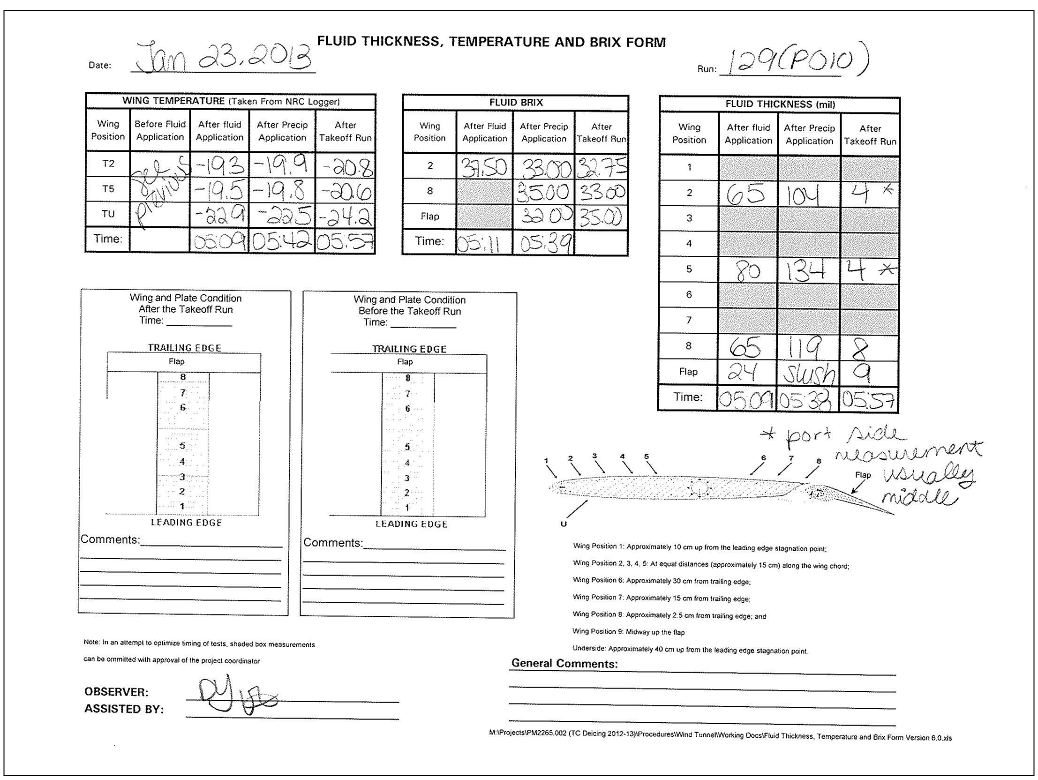
Figure C33: Test #128



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23, 2013 Run: 129(P010)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-19.3	-19.9	-20.8
T5		-19.5	-19.8	-20.6
TU		-22.9	-22.5	-24.2
Time:		05:09	05:42	05:57

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	33.00	32.75
8	–	35.00	33.00
Flap	–	32.00	35.00
Time:	05:11	05:39	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	–	–	–
2	65	104	4 *
3	–	–	–
4	–	–	–
5	80	134	4 *
6	–	–	–
7	–	–	–
8	65	119	8
Flap	24	slush	9
Time:	05:09	05:38	05:57

* port side measurement usually middle

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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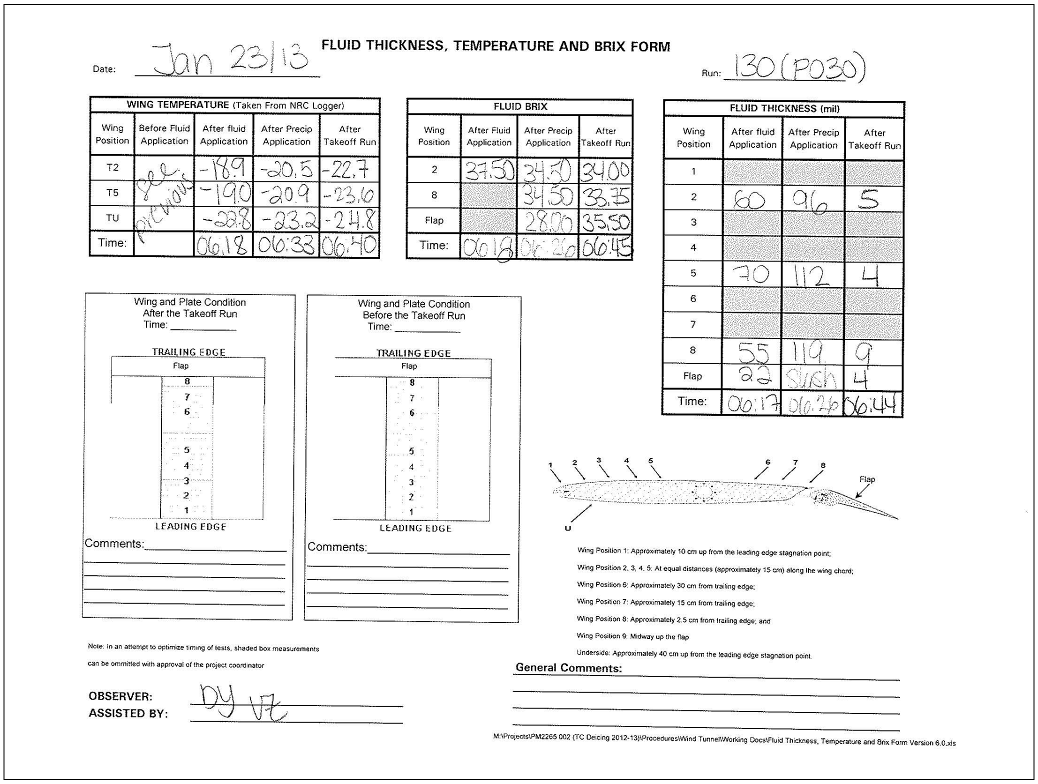
Figure C34: Test #129



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23/13

Run: 130 (P030)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-18.9	-20.5	-22.7
T5		-19.0	-20.9	-23.6
TU		-22.8	-23.2	-24.8
Time:		06:18	06:33	06:40

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	34.50	34.00
8		34.50	33.75
Flap		28.00	35.50
Time:	06:18	06:26	06:45

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	60	96	5
3			
4			
5	70	112	4
6			
7			
8	55	119	9
Flap	22	Slush	4
Time:	06:17	06:26	06:44

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

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

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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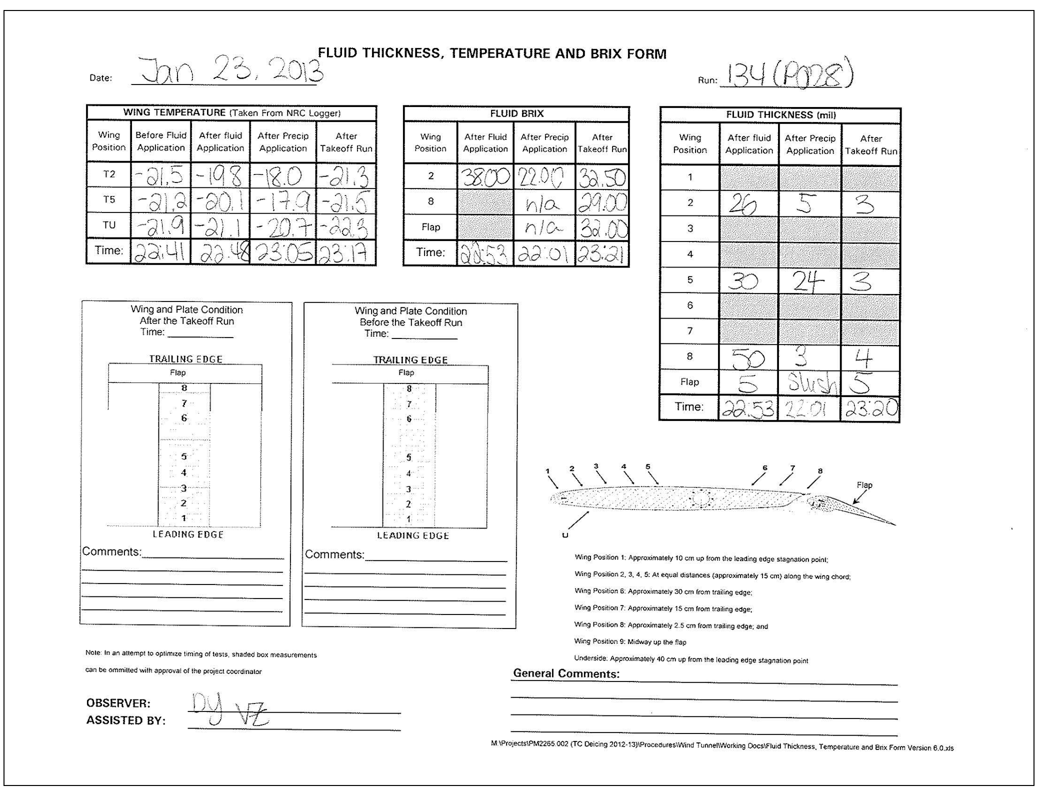
Figure C35: Test #130



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23, 2013

Run: 134 (P028)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-21.5	-19.8	-18.0	-21.3
T5	-21.2	-20.1	-17.9	-21.5
TU	-21.9	-21.1	-20.7	-22.3
Time:	22:41	22:48	23:05	23:17

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	38.00	22.00	32.50
8		n/a	29.00
Flap		n/a	32.00
Time:	22:53	22:01	23:21

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	26	5	3
3			
4			
5	30	24	3
6			
7			
8	50	3	4
Flap	5	Slush	5
Time:	22:53	22:01	23:20

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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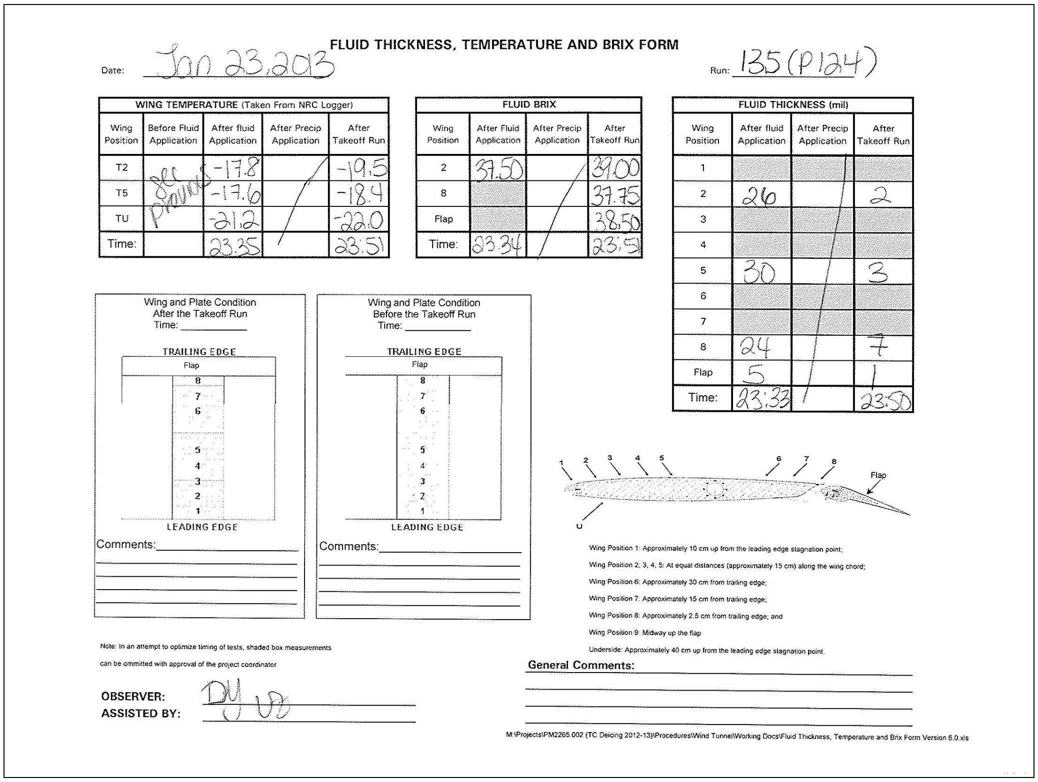
Figure C36: Test #134



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 23, 2013 Run: 135 (P124)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-17.8	/	-19.5
T5		-17.6		-18.4
TU		-21.2		-22.0
Time:		23:35		23:51

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	/	39.00
8			37.75
Flap			38.50
Time:	23:34		23:51

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	26		2
3			
4			
5	30		3
6			
7			
8	24		7
Flap	5		1
Time:	23:33		23:50

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: VD

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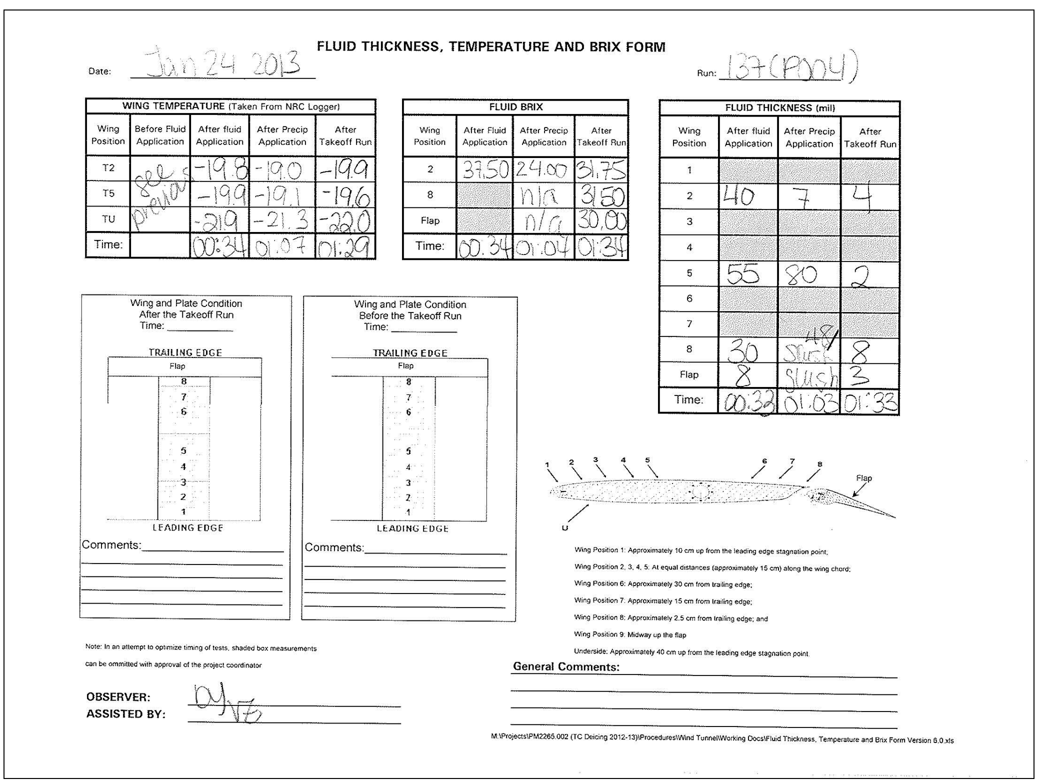
Figure C37: Test #135



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 24 2013 Run: 137 (P004)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-19.8	-19.0	-19.9
T5		-19.9	-19.1	-19.6
TU		-21.9	-21.3	-22.0
Time:		00:34	01:07	01:29

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	24.00	31.75
8		n/a	31.50
Flap		n/a	30.00
Time:	00:34	01:04	01:34

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40	7	4
3			
4			
5	55	80	2
6			
7			
8	30	48/ slush	8
Flap	8	slush	3
Time:	00:32	01:03	01:33

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: VD

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Figure C38: Test #137

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 24, 2013

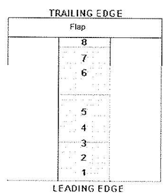
Run: 138(P112)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-18.9	/	-19.3
T5		-19.3	/	-18.8
TU		-21.3	/	-21.3
Time:		01:49	/	02:15

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	/	38.25
8		/	37.50
Flap		/	38.00
Time:	01:51	/	02:13

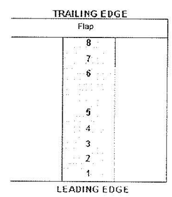
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	35	/	6
3		/	
4		/	
5	60	/	5
6		/	
7		/	
8	40	/	10
Flap	11	/	3
Time:	01:49	/	02:12

Wing and Plate Condition After the Takeoff Run
Time: ____________

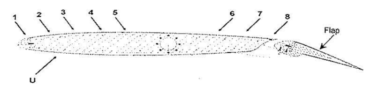


Comments: ____________

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 C39: Test #138

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 24, 2013

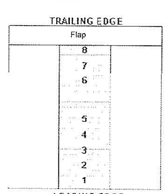
Run: 140(P115)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-18.0	/	-21.5
T5		-18.4	/	-22.2
TU		-20.8	/	-22.8
Time:		02:58	/	03:07

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	30.00	/	31.25
8		/	30.50
Flap		/	31.25
Time:	02:59	/	03:12

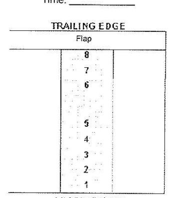
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	55	/	8
3		/	
4		/	
5	96	/	6
6		/	
7		/	
8	55	/	10
Flap	22	/	4
Time:	02:57	/	03:11

Wing and Plate Condition After the Takeoff Run
Time: ____________

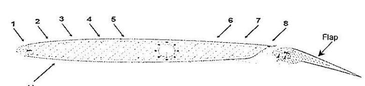


Comments: ____________

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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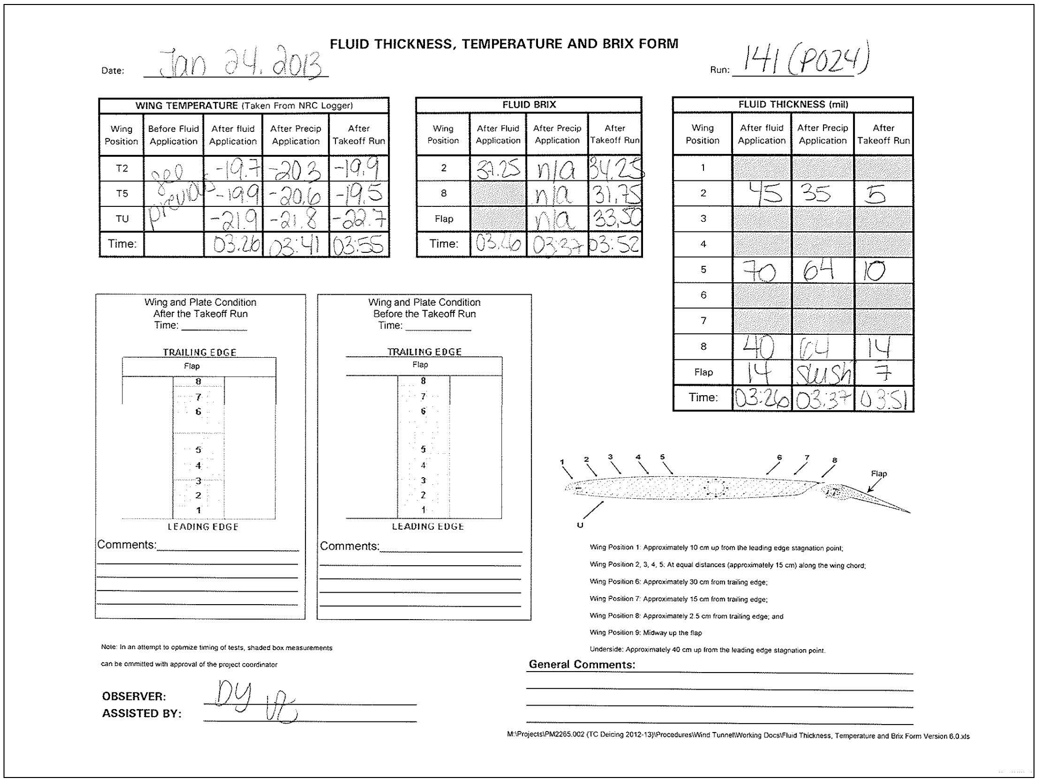
Figure C40: Test #140



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 24. 2013

Run: 141 (P024)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-19.7	-20.3	-19.9
T5		-19.9	-20.6	-19.5
TU		-21.9	-21.8	-22.7
Time:		03:26	03:41	03:55

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	n/a	34.25
8		n/a	31.75
Flap		n/a	33.50
Time:	03:46	03:37	03:52

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	45	35	5
3			
4			
5	70	64	10
6			
7			
8	40	64	14
Flap	14	slush	7
Time:	03:26	03:37	03:51

Wing and Plate Condition After the Takeoff Run Time: ____

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

Comments: ____

Wing and Plate Condition Before the Takeoff Run Time: ____

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

Comments: ____

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

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

General Comments: ____

OBSERVER: DY

ASSISTED BY: VB

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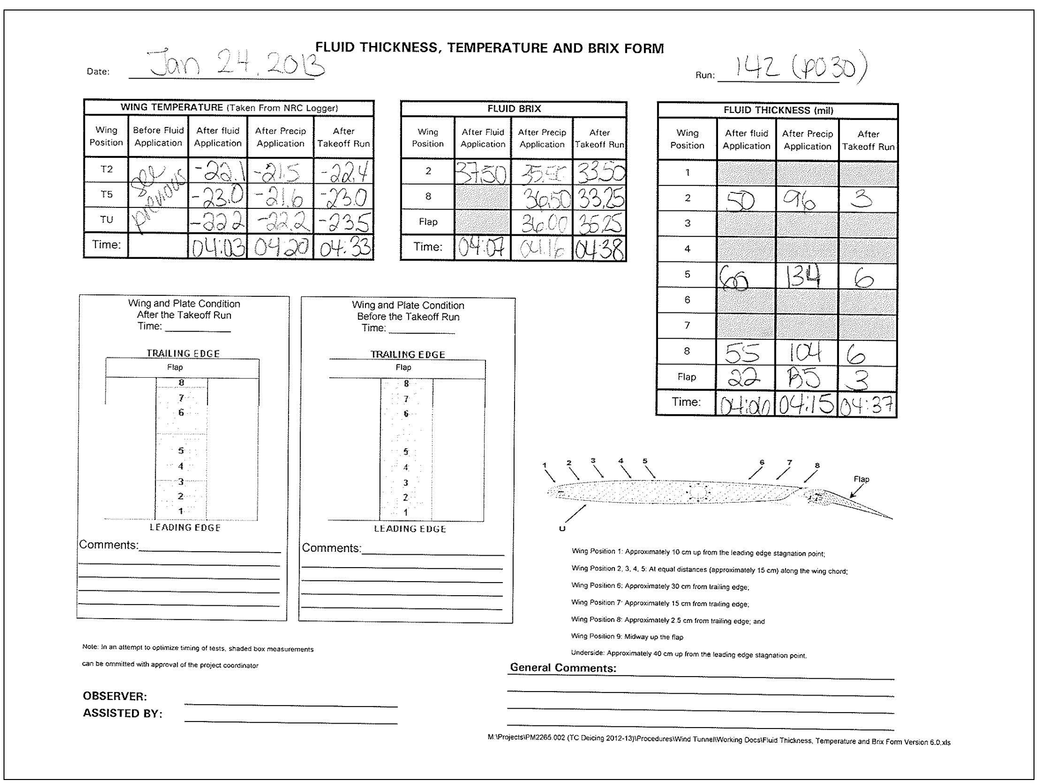
Figure C41: Test #141



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 24. 2013

Run: 142 (P030)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-22.1	-21.5	-22.4
T5		-23.0	-21.6	-23.0
TU		-22.2	-22.2	-23.5
Time:		04:03	04:20	04:33

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	35.50	33.50
8		36.50	33.25
Flap		36.00	35.25
Time:	04:07	04:16	04:38

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	50	96	3
3			
4			
5	66	134	6
6			
7			
8	55	104	6
Flap	22	85	3
Time:	04:00	04:15	04:37

Wing and Plate Condition After the Takeoff Run Time: ____

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

Comments: ____

Wing and Plate Condition Before the Takeoff Run Time: ____

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

Comments: ____

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

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

General Comments: ____

OBSERVER: ____

ASSISTED BY: ____

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Figure C42: Test #142

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

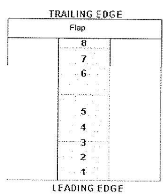
Date: Jan 24, 2013 Run: 143 (P34)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-22.3		
T5		-22.5		
TU		-22.3		
Time:		04:44		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.75		
8			
Flap			
Time:	04:47		

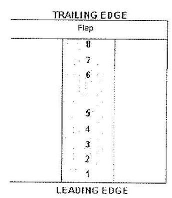
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	35		
3			
4			
5	70		
6			
7			
8	65		
Flap	20		
Time:	04:47		

Wing and Plate Condition
After the Takeoff Run
Time: ________

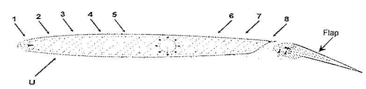


Comments:________________

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 C43: Test #143

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

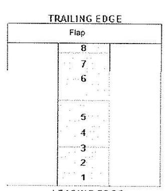
Date: Jan 24, 2013 Run: 145 (E6)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-20.8	-19.0		
T5	-20.5	-19.5		
TU	-22.8	-21.9		
Time:	05:37	05:48		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	30.00		
8			
Flap			
Time:	05:48		

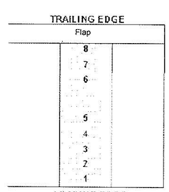
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	26		
3			
4			
5	35		
6			
7			
8	30		
Flap	8		
Time:	05:47		

Wing and Plate Condition
After the Takeoff Run
Time: ________

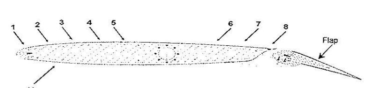


Comments:________________

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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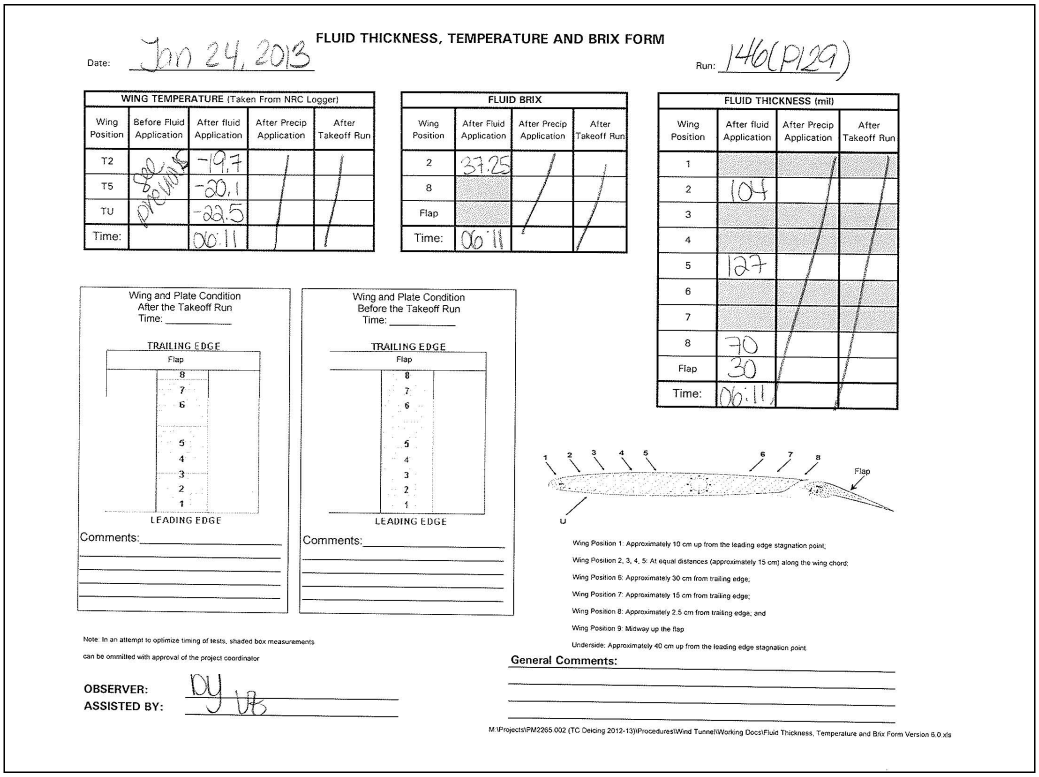
Figure C44: Test #145



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 24, 2013

Run: 146(P129)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	See previous	-19.7	/	/
T5		-20.1	/	/
TU		-22.5	/	/
Time:		06:11	/	/

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	/	/
8		/	/
Flap		/	/
Time:	06:11	/	/

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	/
2	104	/	/
3		/	/
4		/	/
5	127	/	/
6		/	/
7		/	/
8	70	/	/
Flap	30	/	/
Time:	06:11	/	/

Wing and Plate Condition After the Takeoff Run Time:

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

Comments:

Wing and Plate Condition Before the Takeoff Run Time:

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

Comments:

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

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

General Comments:

OBSERVER: DY
ASSISTED BY: VB

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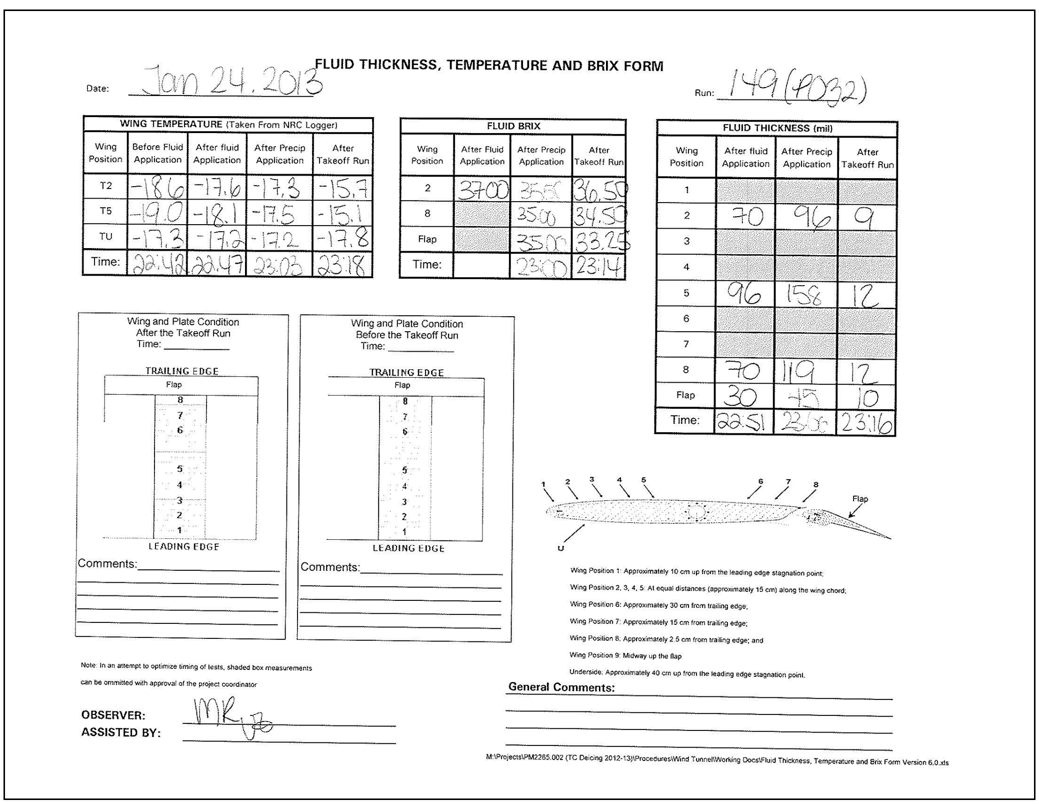
Figure C45: Test #146



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 24, 2013

Run: 149(P032)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-18.6	-17.6	-17.3	-15.7
T5	-19.0	-18.1	-17.5	-15.1
TU	-17.3	-17.2	-17.2	-17.8
Time:	22:42	22:47	23:03	23:18

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	35.50	36.50
8		35.00	34.50
Flap		35.00	33.25
Time:		23:00	23:14

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	96	9
3			
4			
5	96	158	12
6			
7			
8	70	119	12
Flap	30	45	10
Time:	22:51	23:06	23:16

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: MR
ASSISTED BY: JB

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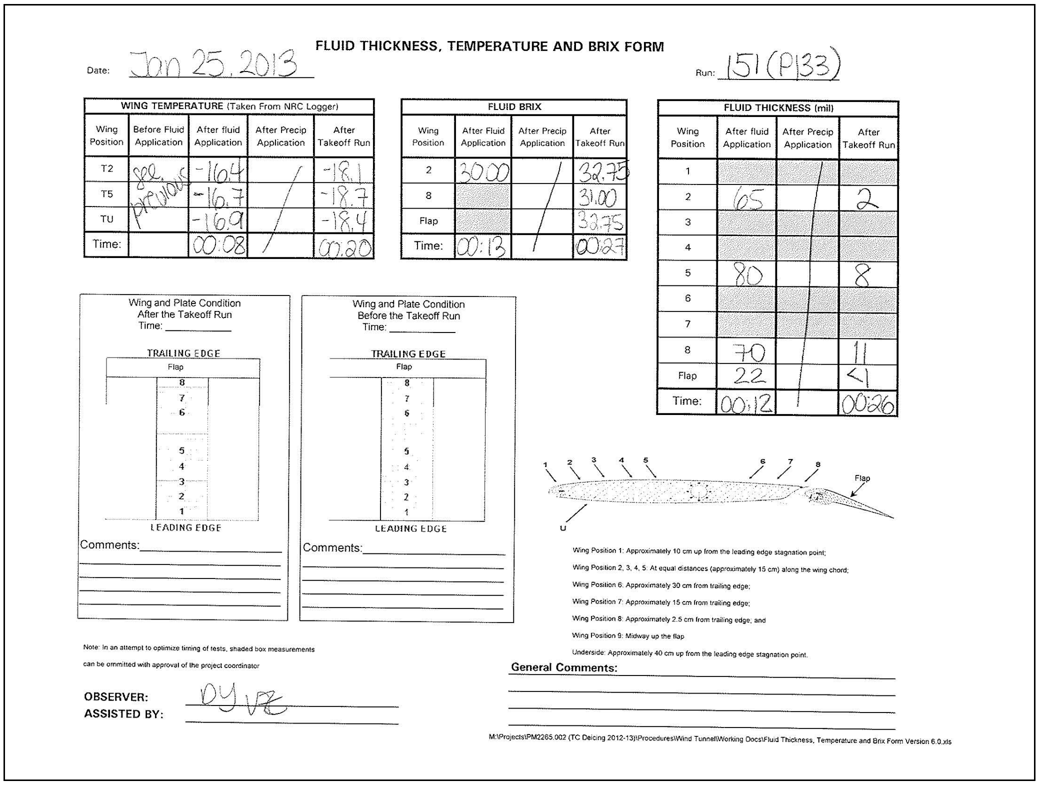
Figure C46: Test #149



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 25, 2013   Run: 151 (P133)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-16.4	/	-18.1
T5		-16.7	/	-18.7
TU		-16.9	/	-18.4
Time:		00:08	/	00:20

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	30.00	/	32.75
8		/	31.00
Flap		/	32.75
Time:	00:13	/	00:27

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65		2
3			
4			
5	80		8
6			
7			
8	70		11
Flap	22		<1
Time:	00:12		00:26

Wing and Plate Condition After the Takeoff Run Time: ___

Wing and Plate Condition Before the Takeoff Run Time: ___

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

Comments: ___

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

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

General Comments: ___

OBSERVER: DY VB
ASSISTED BY: ___

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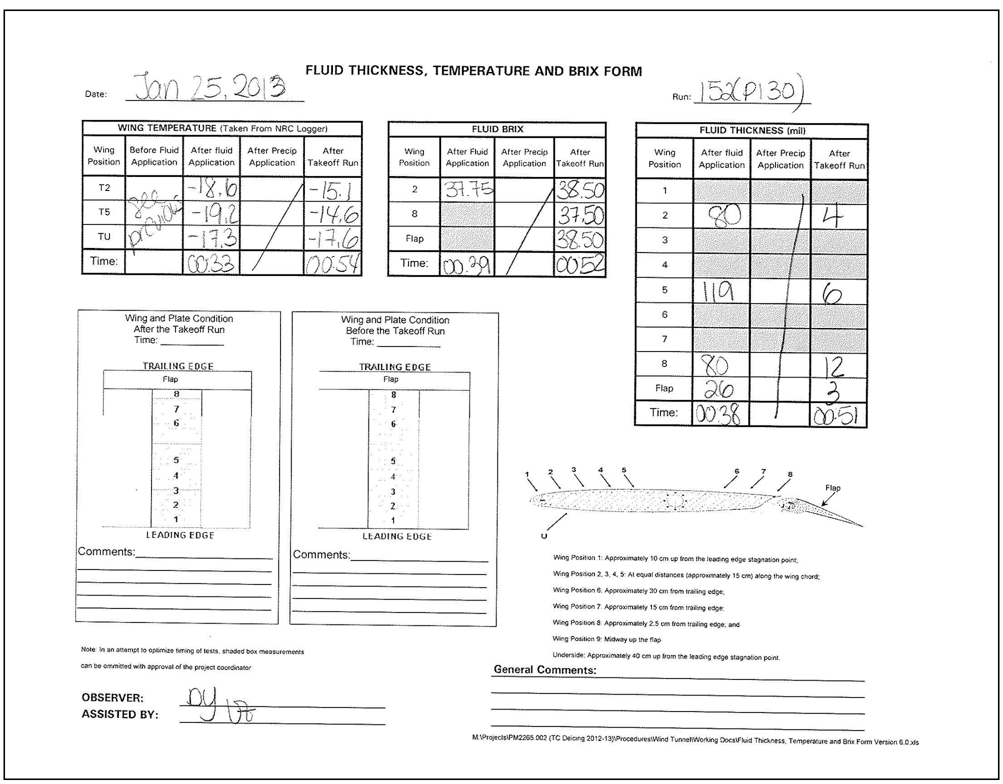
Figure C47: Test #151



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 25, 2013   Run: 152 (P130)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-18.6	/	-15.1
T5		-19.2	/	-14.6
TU		-17.3	/	-17.6
Time:		00:33	/	00:54

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.75	/	38.50
8		/	37.50
Flap		/	38.50
Time:	00:39	/	00:52

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80		4
3			
4			
5	119		6
6			
7			
8	80		12
Flap	26		3
Time:	00:38		00:51

Wing and Plate Condition After the Takeoff Run Time: ___

Wing and Plate Condition Before the Takeoff Run Time: ___

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

Comments: ___

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

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

General Comments: ___

OBSERVER: DY VB
ASSISTED BY: ___

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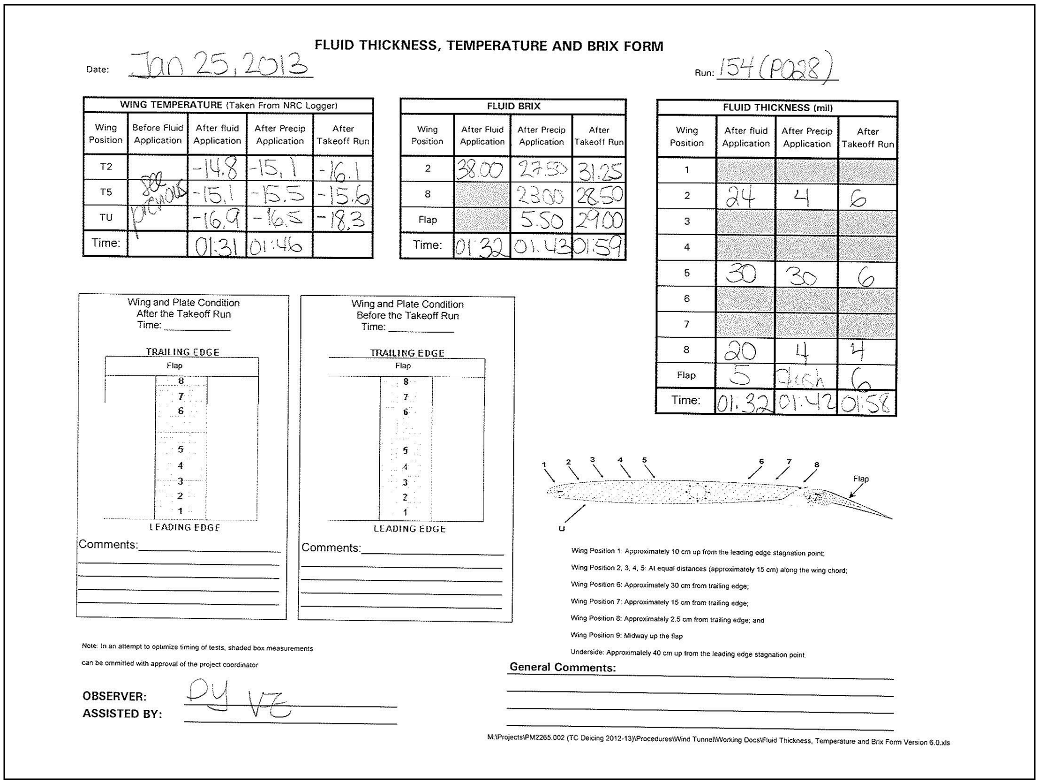
Figure C48: Test #152



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 25, 2013

Run: 154 (P028)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-14.8	-15.1	-16.1
T5		-15.1	-15.5	-15.6
TU		-16.9	-16.5	-18.3
Time:		01:31	01:46	

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	38.00	27.50	31.25
8		23.00	28.50
Flap		5.50	29.00
Time:	01:32	01:43	01:59

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	24	4	6
3			
4			
5	30	30	6
6			
7			
8	20	4	4
Flap	5	flush	6
Time:	01:32	01:42	01:58

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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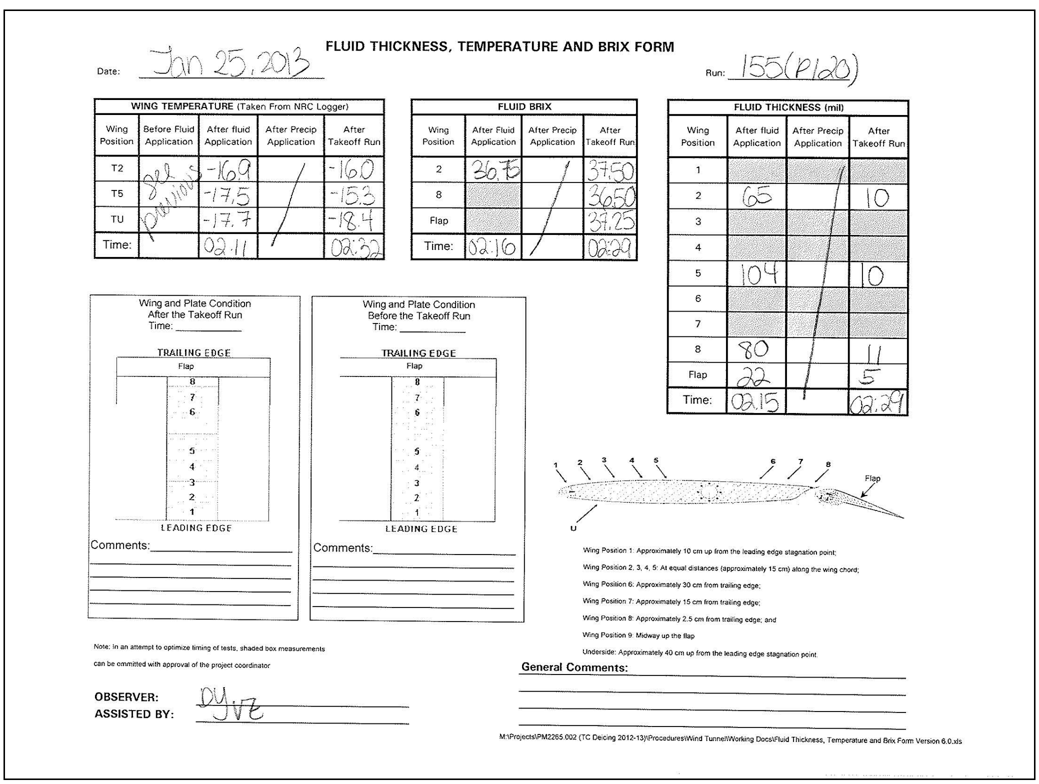
Figure C49: Test #154



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 25, 2013

Run: 155 (P120)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-16.9	/	-16.0
T5		-17.5		-15.3
TU		-17.7		-18.4
Time:		02:11		02:32

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.75	/	37.50
8			36.50
Flap			37.25
Time:	02:16		02:29

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	65		10
3			
4			
5	104		10
6			
7			
8	80		11
Flap	22		5
Time:	02:15		02:29

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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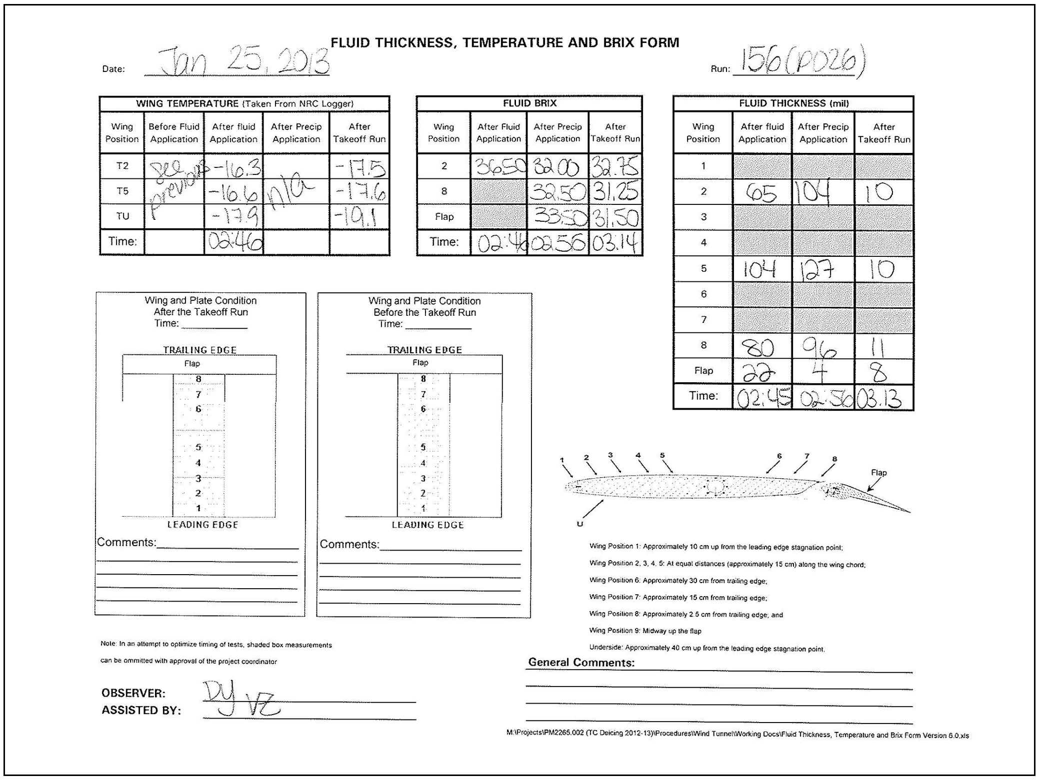
Figure C50: Test #155



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 25, 2013

Run: 156 (P026)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-16.3	n/a	-17.5
T5		-16.6		-17.6
TU		-17.9		-19.1
Time:		02:46		

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.50	32.00	32.75
8		32.50	31.25
Flap		33.50	31.50
Time:	02:46	02:56	03:14

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65	104	10
3			
4			
5	104	127	10
6			
7			
8	80	96	11
Flap	22	4	8
Time:	02:45	02:56	03:13

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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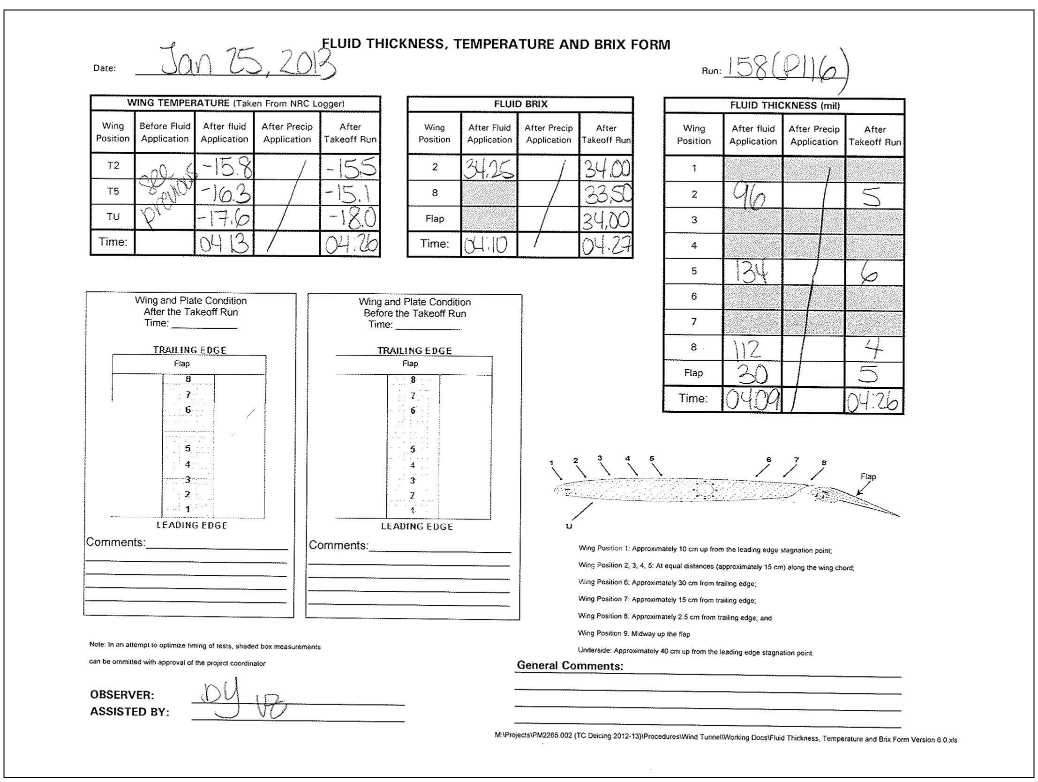
Figure C51: Test #156



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 25, 2013

Run: 158 (P116)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-15.8	/	-15.5
T5		-16.3		-15.1
TU		-17.6		-18.0
Time:		04:13		04:26

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.25	/	34.00
8			33.50
Flap			34.00
Time:	04:10		04:27

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		/	
2	96		5
3			
4			
5	134		6
6			
7			
8	112		4
Flap	30		5
Time:	04:09		04:26

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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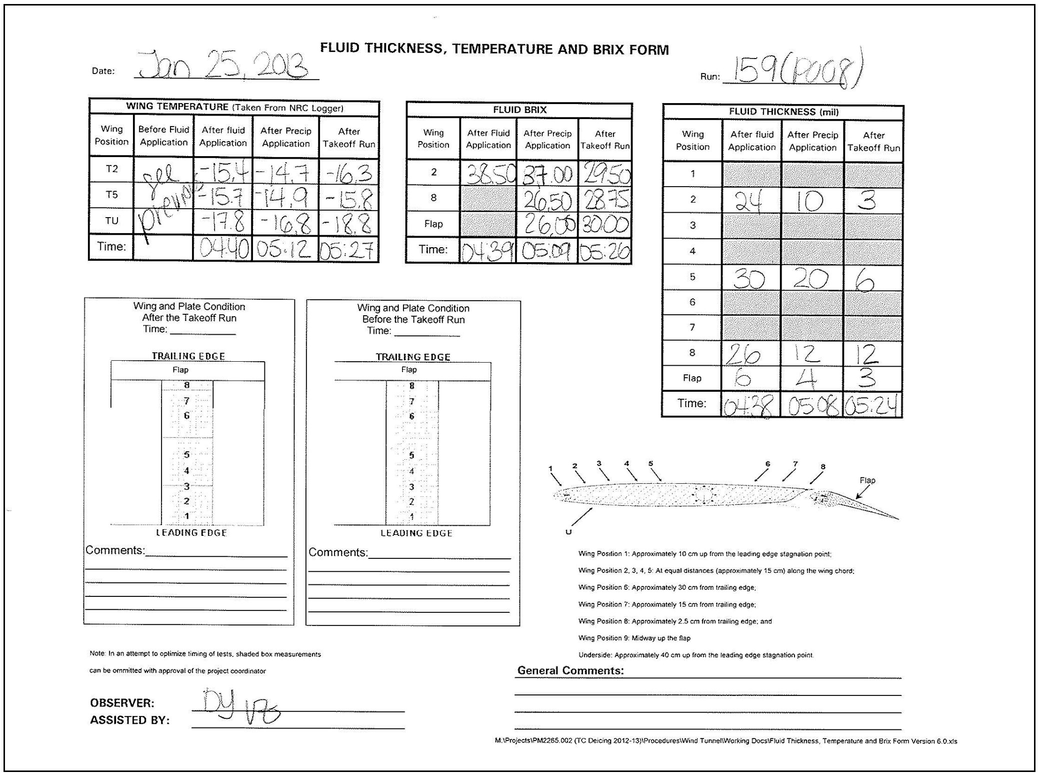
Figure C52: Test #158



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 25, 2013

Run: 159 (P008)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	gel previous	-15.4	-14.7	-16.3
T5		-15.7	-14.9	-15.8
TU		-17.8	-16.8	-18.8
Time:		04:40	05:12	05:27

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	38.50	37.00	29.50
8		26.50	28.75
Flap		26.00	30.00
Time:	04:39	05:09	05:26

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	24	10	3
3			
4			
5	30	20	6
6			
7			
8	26	12	12
Flap	6	4	3
Time:	04:38	05:08	05:24

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.

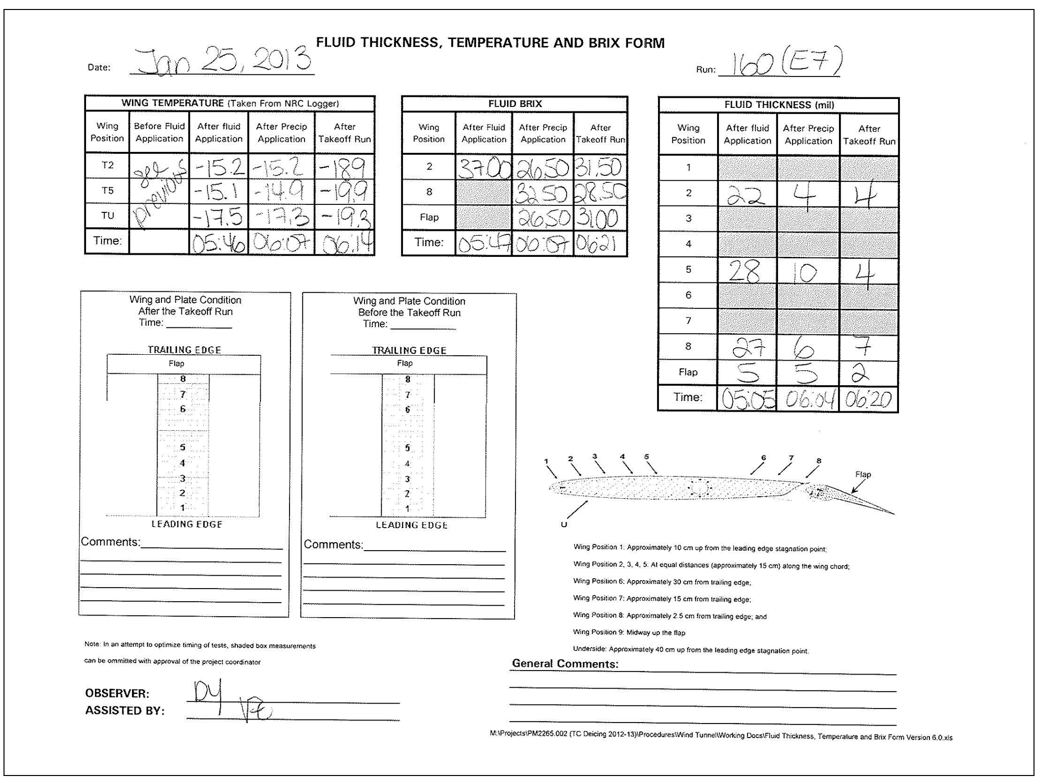
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: ________

OBSERVER: DY
ASSISTED BY: VB

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Wind Tunnel\Working Docs\Fluid Thickness, Temperature and Brix Form Version 6.0.xls

Figure C53: Test #159



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 25, 2013

Run: 160 (E7)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	gel S previous	-15.2	-15.2	-18.9
T5		-15.1	-14.9	-19.9
TU		-17.5	-17.3	-19.3
Time:		05:46	06:07	06:14

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	26.50	31.50
8		32.50	28.50
Flap		26.50	31.00
Time:	05:47	06:07	06:21

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	22	4	4
3			
4			
5	28	10	4
6			
7			
8	27	6	7
Flap	5	5	2
Time:	05:05	06:04	06:20

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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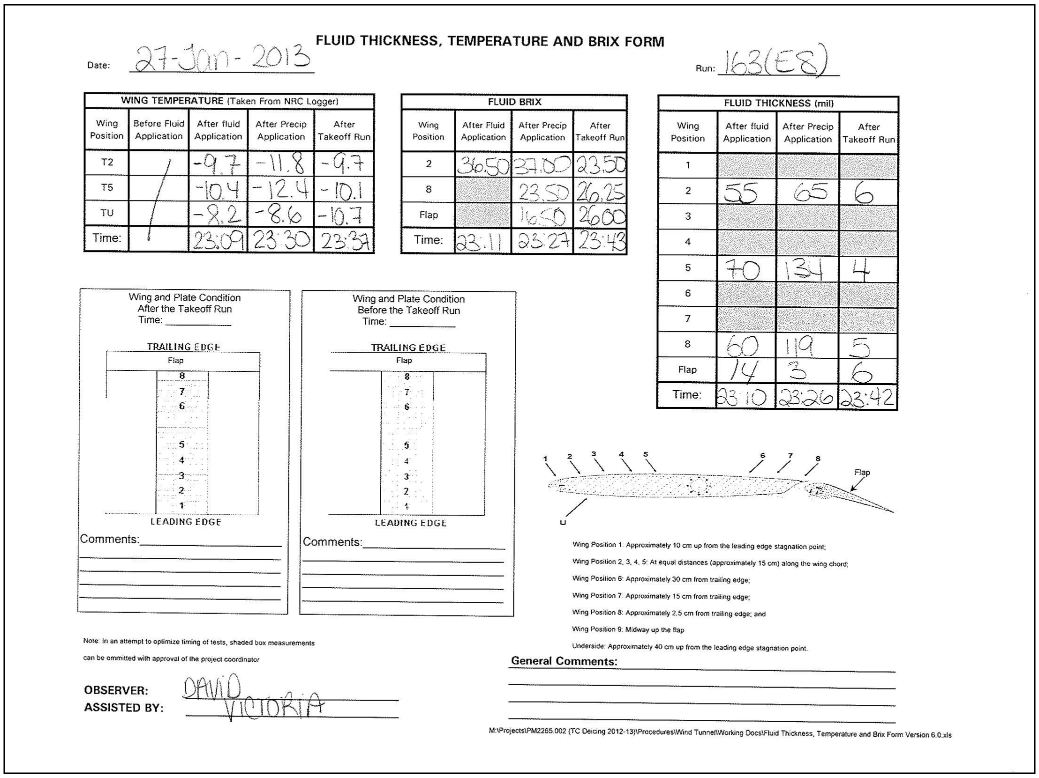
Figure C54: Test #160



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: 27-Jan-2013

Run: 163(E8)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-9.7	-11.8	-9.7
T5	/	-10.4	-12.4	-10.1
TU	/	-8.2	-8.6	-10.7
Time:	/	23:09	23:30	23:37

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.50	37.00	23.50
8		23.50	26.25
Flap		16.50	26.00
Time:	23:11	23:27	23:43

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	55	65	6
3			
4			
5	70	134	4
6			
7			
8	60	119	5
Flap	14	3	6
Time:	23:10	23:26	23:42

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

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

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

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

General Comments:

OBSERVER: DAVID
ASSISTED BY: VICTORIA

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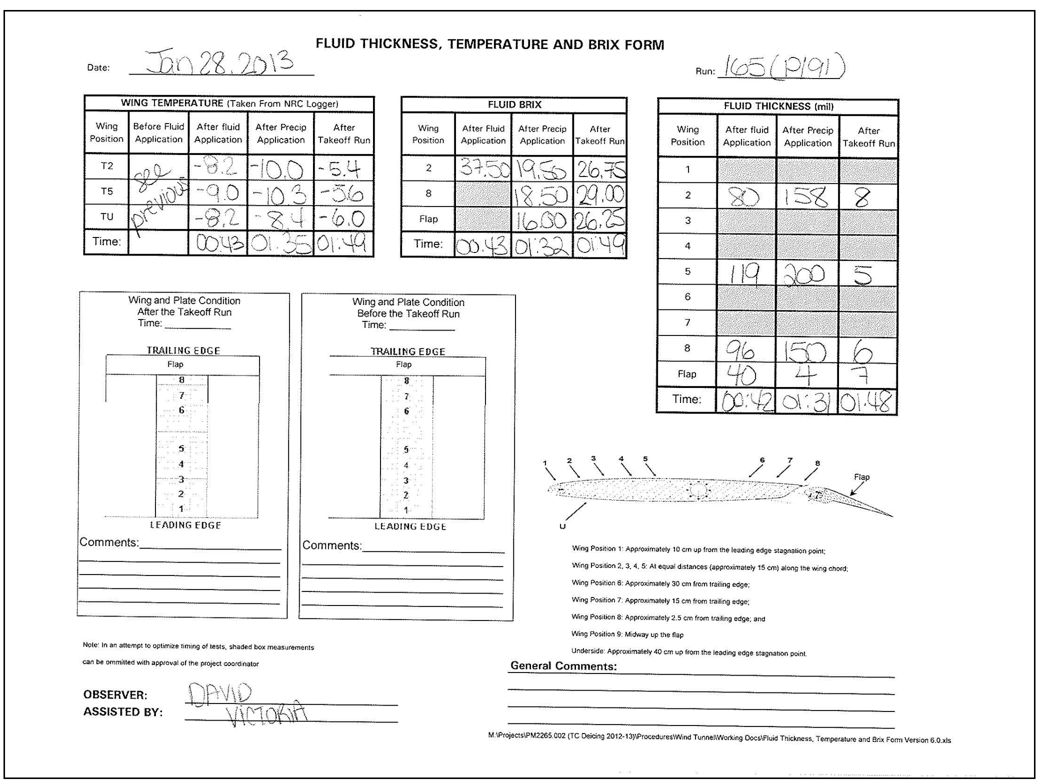
Figure C55: Test #163



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 28, 2013

Run: 165(P191)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-8.2	-10.0	-5.4
T5		-9.0	-10.3	-5.6
TU		-8.2	-8.4	-6.0
Time:		00:43	01:35	01:49

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.50	19.50	26.75
8		18.50	29.00
Flap		16.00	26.25
Time:	00:43	01:32	01:49

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	80	158	8
3			
4			
5	119	200	5
6			
7			
8	96	150	6
Flap	40	4	7
Time:	00:42	01:31	01:48

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: DAVID
ASSISTED BY: VICTORIA

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Figure C56: Test #165

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 28, 2013 Run: 169 (P/24)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	/	-7.6	/	-7.7
T5	/	-7.4	/	-7.4
TU	/	-9.2	/	-9.7
Time:	/	03:12	/	03:27

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	/	38.50
8		/	38.00
Flap		/	40.50
Time:	03:12	/	03:28

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	20	/	6
3			
4			
5	26	/	10
6			
7			
8	18	/	9
Flap	3	/	2
Time:	03:11	/	03:27

Wing and Plate Condition After the Takeoff Run Time: ________

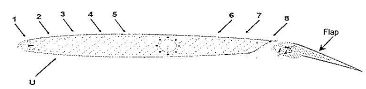
TRAILING EDGE / Flap / 8 / 7 / 6 / 5 / 4 / 3 / 2 / 1 / LEADING EDGE

Comments: ________

Wing and Plate Condition Before the Takeoff Run Time: ________

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

Comments: ________



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

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

General Comments: ________

OBSERVER: DY
ASSISTED BY: VB

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Figure C57: Test #169

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 28, 2013 Run: 170 (P213R)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	see previous	-6.6	-8.3	-6.5
T5		-6.9	-9.3	-7.5
TU		-8.0	-7.9	-8.2
Time:		03:45	04:28	04:48

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.50	13.00	27.00
8		11.50	15.00
Flap		6.00	8.00
Time:	03:46	04:28	04:47

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	26	127	3
3			
4			
5	30	127	5
6			
7			
8	20	104	9
Flap	6	slush	2
Time:	03:45	04:25	04:46

Wing and Plate Condition After the Takeoff Run Time: ________

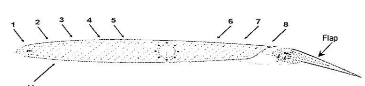
TRAILING EDGE / Flap / 8 / 7 / 6 / 5 / 4 / 3 / 2 / 1 / LEADING EDGE

Comments: ________

Wing and Plate Condition Before the Takeoff Run Time: ________

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

Comments: ________



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

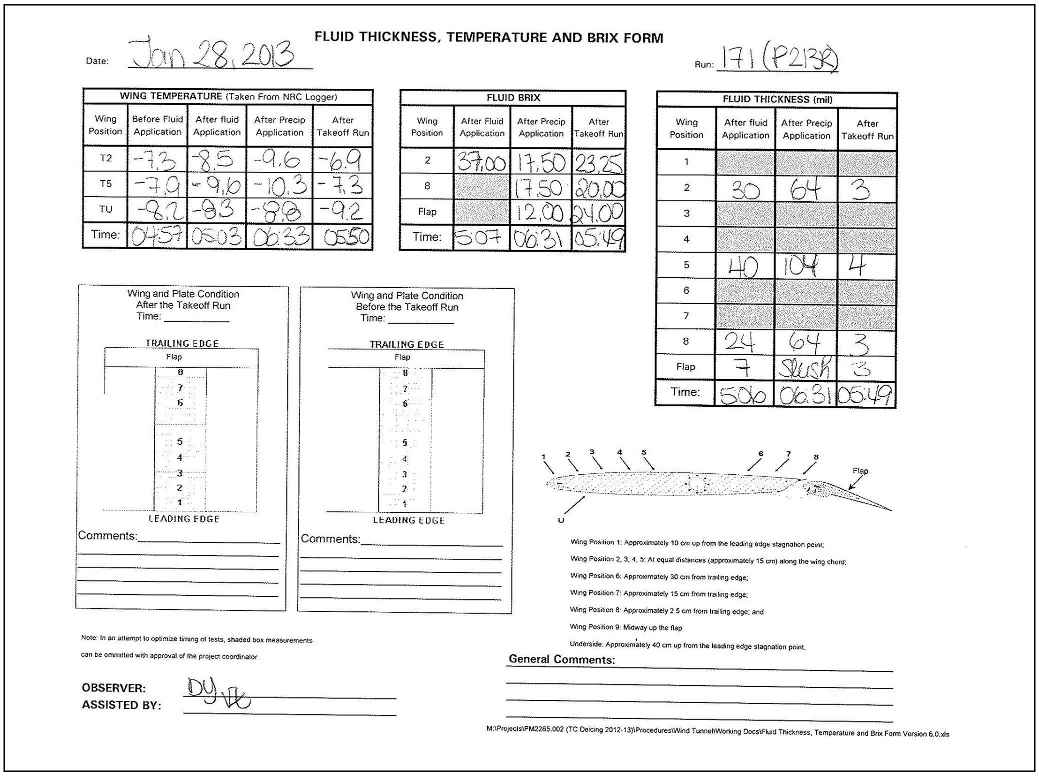
Note: In an attempt to optimize timing of tests, shaded box measurements can be ommitted with approval of the project coordinator

General Comments: ________

OBSERVER: DY
ASSISTED BY: VB

M:\Projects\PM2265.002 (TC Deicing 2012-13)\Procedures\Wind Tunnel\Working Docs\Fluid Thickness, Temperature and Brix Form Version 6.0.xls

Figure C58: Test #170



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: Jan 28, 2013

Run: 171 (P213R)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-7.3	-8.5	-9.6	-6.9
T5	-7.9	-9.6	-10.3	-7.3
TU	-8.2	-8.3	-8.8	-9.2
Time:	04:57	05:03	06:33	05:50

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.00	17.50	23.25
8		17.50	20.00
Flap		12.00	24.00
Time:	5:07	06:31	05:49

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	30	64	3
3			
4			
5	40	104	4
6			
7			
8	24	64	3
Flap	7	Slush	3
Time:	5:06	06:31	05:49

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 C59: Test #171