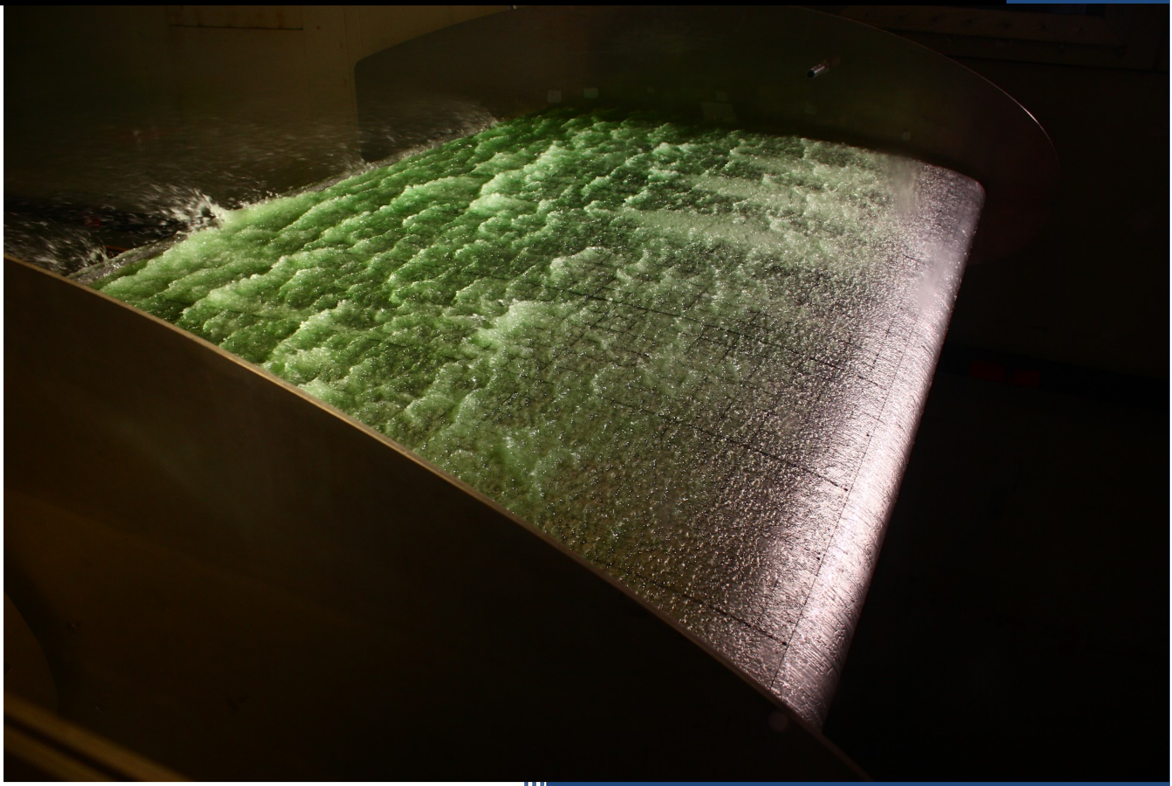
TP 15341E

WIND TUNNEL TRIALS TO SUPPORT FURTHER DEVELOPMENT OF ICE PELLET ALLOWANCE TIMES: WINTER 2015-16



Prepared for the
Transportation Development Centre
In cooperation with
Transport Canada Civil Aviation
and the
Federal Aviation Administration
William J. Hughes Technical Center

Final Version 1.0
December 2016

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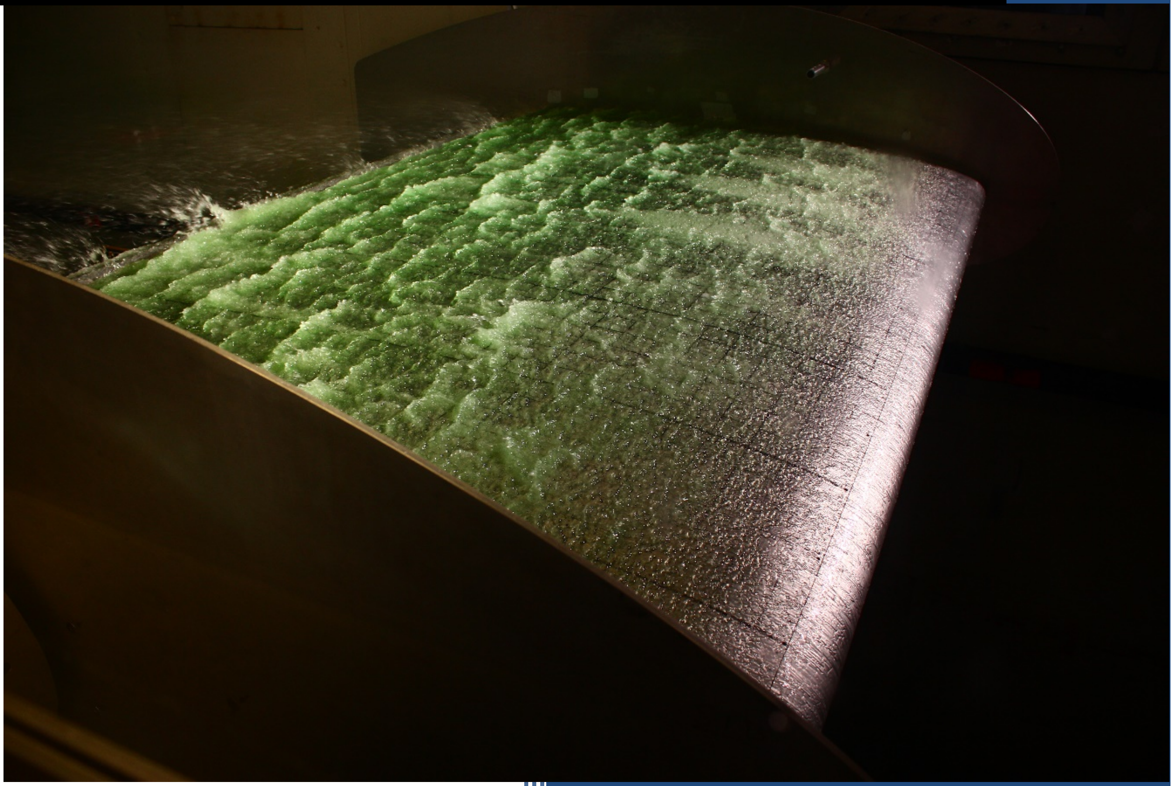

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Marco Ruggi
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PREFACE

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

- To develop holdover time data for all newly-qualified de/anti-icing fluids and update and maintain the website for the holdover time guidelines;
- To evaluate fluid holdover times for snow at very cold temperatures close to -25°C;
- To conduct heavy snow research to determine the highest usable precipitation rate for which operations are permitted;
- To evaluate the effects of deploying flaps and slats, prior to takeoff, on fluid protection times;
- To conduct exploratory testing to evaluate fluid effectiveness and characterize contamination on high angle vertical surfaces;
- To conduct general and exploratory de/anti-icing research;
- To obtain full-scale operational documentation of anti-icing fluid flow-off, fluid freezing-in-flight, and residual fluid thickness;
- To conduct wind tunnel testing to support the development of the guidance material for operating in conditions mixed with ice pellets;
- To update the regression coefficient report with the newly-qualified de/anti-icing fluids; and
- To update the source documents used by Transport Canada and the Federal Aviation Administration for the maintenance and publication of the holdover time guidance material.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2015-16 are documented in five reports. The titles of the reports are as follows:

TP 15338E	Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2015-16 Winter;
TP 15339E	Regression Coefficients and Equations Used to Develop the Winter 2016-17 Aircraft Ground Deicing Holdover Time Tables;
TP 15340E	Aircraft Ground Icing General Research Activities During the 2015-16 Winter;
TP 15341E	Wind Tunnel Trials to Support Further Development of Ice Pellet Allowance Times: Winter 2015-16; and
TP 15342E	Testing of Endurance Times on Extended Flaps and Slats.

This report, TP 15341E has the following objective:

- To conduct research in the 3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel with a thin high-performance wing section to further support and develop the anti-icing fluid ice pellet allowance times.

This objective was met by conducting a series of full-scale tests using a thin high-performance wing model in the National Research Council Canada Propulsion Icing Wind Tunnel with the cooperation of Transport Canada and the Federal Aviation Administration.

PROGRAM ACKNOWLEDGEMENTS

This multi-year research program has been funded by Transport Canada with support from the Federal Aviation Administration, William J. Hughes Technical Center, Atlantic City, NJ. This program could not have been accomplished without the participation of many organizations. APS Aviation Inc. would therefore like to thank the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, National Research Council Canada, and supporting members of the SAE International G-12 Aircraft Ground Deicing Committee.

APS Aviation Inc. would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: Yelyzaveta Asnytska, Brandon Auclair, Steven Baker, Stephanie Bendickson, Benjamin Bernier, Chloë Bernier, Trevor Butler, John D'Avirro, Jesse Dybka, Ben Falvo, Benjamin Guthrie, Michael Hawdur, Gabriel Maatouk, Philip Murphy, Matthew Pilling, Dany Posteraro, Marco Ruggi, Gordon Smith, David Youssef, and Nondas Zoitakis.

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

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APS Aviation Inc. would like to acknowledge the team at the National Research Council Canada who operate the Propulsion Icing Wind Tunnel, especially Catherine Clark for engineering support and aerodynamic expertise, and Lucio Del Ciotto for operating the facility. APS Aviation Inc. would also like to acknowledge the fluid manufacturers who have provided samples over the years to support the wind tunnel testing: ABAX Industries, AllClear Systems, Clariant Produkte (Deutschland) GmbH, Cryotech Deicing Technology, Dow Chemical Company, Kilfrost Limited, LNT Solutions, and Newave Aerochemical Co. Ltd.

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

16. Abstract

As part of a larger research program, APS Aviation Inc. conducted a series of full-scale tests in the National Research Council Canada 3 m x 6 m Open-Circuit Propulsion and Icing Wind Tunnel 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.

A wind tunnel testing program was developed for the winter of 2015-16 with the primary objectives of conducting aerodynamic testing with the airfoil to: substantiate the current Type III ice pellet allowance times with new fluids, to investigate lower rotation speeds (80 knots), and time permitting, application methods (hot vs. cold); substantiate the current Type IV ice pellet allowance times with new fluids, and weather permitting, at temperatures close to the lowest operational use temperature (LOUT); to expand the current Type IV ice pellet allowance times to include more conditions commonly reported by METAR and to further develop the current mixed ice pellet and snow guidance.

Type III testing conducted during the winter of 2015-16 validated the current Type III allowance times for use with the new to market AllClear AeroClear MAX; this is applicable to aircraft with rotation speeds above 100 knots. Type IV testing conducted during the winter of 2015-16 validated the current Type IV allowance times for use with the new to market LNT E450 and FCY 9311 fluids. Testing was also conducted to support the expansion of the existing allowance times to include longer times and more conditions including Moderate Ice pellet mixed with Moderate Freezing Drizzle, Moderate Ice Pellets mixed with Moderate Rain, and Light Ice Pellets mixed with Light and Moderate Snow. In addition, and through consultation with Transport Canada and the Federal Aviation Administration, modifications to the ice pellet allowance times guidance material were proposed.

Possible future areas of research may include: substantiation of ice pellet allowance times with new fluids; testing with the National Aeronautics and Space Administration LS-0417 wing section to support development of Type III low speed allowance times; lift losses at LOUT; allowance time expansion; and analysis of METAR data to determine conditions requiring guidance.

17. Key Words
Ice Pellet, Allowance Time, High Speed Rotation, Low Speed Rotation, Type II, Type III, Type IV, Fluid Adherence, Fluid Flow-Off, Wind Tunnel, Propulsion Icing Wind Tunnel, Wing Aerodynamics

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Plusieurs rapports de recherche sur des essais de technologies de dégivrage et d'antigivrage ont été produits au cours des hivers précédents pour le compte de Transports Canada. Ils sont disponibles auprès du Centre de développement des transports. Plusieurs rapports ont été rédigés dans le cadre du programme de recherche de cet hiver. Leur objet apparaît à l'avant-propos. Les travaux décrits dans ce rapport ont été en partie coparrainés par la Federal Aviation Administration.

16. Résumé

Dans le cadre d'un programme de recherches plus large, APS Aviation Inc. a mené une série d'essais pleine grandeur réalisés dans la soufflerie de givrage à propulsion et à circuit ouvert de 3 m sur 6 m du Conseil national de recherches Canada, 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 comprenant des granules de glace.

Un programme d'essais en soufflerie a été élaboré pour l'hiver 2015-2016 avec comme principaux objectifs de réaliser des tests aérodynamiques au moyen d'une surface portante afin de corroborer les marges de tolérance actuelles concernant les granules de glace avec de nouveaux liquides de type III, d'étudier des vitesses de rotation plus basses (80 nœuds) et, selon les contraintes de temps, les méthodes d'application (liquide chaud ou froid), de corroborer les marges de tolérance actuelles pour les granules de glace avec de nouveaux liquides de type IV et, selon les conditions météorologiques, à des températures se rapprochant de la température minimale d'utilisation opérationnelle (LOUT), d'élargir les marges de tolérance actuelles pour les liquides de type IV dans des conditions de granules de glace de façon à inclure un plus grand nombre de conditions souvent signalées par METAR et à développer davantage les lignes directrices actuelles dans des conditions mixtes de granules de glace et de neige.

Des essais menés à l'hiver 2015-2016 sur des liquides de type III ont permis de valider les marges de tolérance actuelles à utiliser avec le liquide nouvellement commercialisé AllClear AeroClear MAX ; ces marges s'appliquent aux aéronefs dont la vitesse de rotation est supérieure à 100 nœuds. Des essais menés à l'hiver 2015-2016 sur des liquides de type IV ont permis de valider les marges de tolérance actuelles à utiliser avec les liquides nouvellement commercialisés LNT E450 et FCY 9311. Des essais ont aussi été réalisés afin d'étayer l'élargissement des marges de tolérance actuelles de façon à inclure des marges plus longues et un plus grand nombre de conditions, y compris les granules de glace modérés avec la bruine verglaçante modérée, les granules de glace modérés avec la pluie modérée et les granules de glace légers avec la neige légère et modérée. En outre, après consultation avec Transports Canada et la Federal Aviation Administration, des modifications aux marges de tolérance pour les granules de glace ont été proposées.

De futures recherches pourraient être menées dans le but de corroborer les marges de tolérance pour les granules de glace avec de nouveaux liquides, de mettre à l'essai le profil d'aile LS-0417 de la National Aeronautics and Space Administration afin d'appuyer l'élaboration de marges de tolérance à basse vitesse pour les liquides de type III, d'étudier les pertes de portance à la température minimale d'utilisation opérationnelle et d'analyser les données METAR pour déterminer les conditions pour lesquelles des lignes directrices sont nécessaires.

17. Mots clés
Granule de glace, marge de tolérance, rotation à haute vitesse, rotation à basse vitesse, Type II, Type III, Type IV, adhérence de liquide, écoulement de liquide, soufflerie, soufflerie de givrage à propulsion, aérodynamisme des ailes

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EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada (TC) with support from the Federal Aviation Administration (FAA), APS Aviation Inc. (APS) has undertaken a research program to advance aircraft ground de/anti-icing technology.

As part of a larger research program, 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 supercritical wing model to determine the flow-off characteristics of anti-icing fluid with and without mixed precipitation conditions with ice pellets.

Background and Objective

A wind tunnel testing program was developed for the winter of 2015-16 with the primary objectives of conducting aerodynamic testing with a thin high-performance airfoil to:

- Substantiate the current Type III ice pellet allowance times with new fluids, to investigate lower rotation speeds (80 knots), and time permitting, application methods (hot vs. cold);
- Substantiate the current Type IV ice pellet allowance times with new fluids and, and weather permitting, at temperatures close to the lowest operational use temperature (LOUT); and
- Expand the current Type IV ice pellet allowance times to include more conditions commonly reported by METAR and to further develop the current mixed ice pellet and snow guidance.

In addition, baseline dry wing tests were conducted daily and following any system changes to validate the repeatability of the wind tunnel. One heavy contamination test was also conducted.

Conclusions

Type III testing conducted during the winter of 2015-16 validated the current Type III allowance times for use with the new to market AllClear AeroClear MAX; this is applicable to aircraft with rotation speeds above 100 knots. Efforts were made to support the development of an *80 knots or greater* rotation speed Type III allowance time table, however the results are still under review, and further testing is likely required.

Type IV testing conducted during the winter of 2015-16 validated the current Type IV allowance times for use with the new to market LNT E450 and FCY 9311 fluids. Testing was also conducted to support the expansion of the existing allowance times to include longer times and more conditions including "Moderate Ice pellet mixed with Moderate Freezing Drizzle," "Moderate Ice Pellets mixed with Moderate Rain," and "Light Ice Pellets mixed with Light and Moderate Snow".

In addition, and through consultation with TC and FAA, modifications to the ice pellet allowance times guidance material were proposed. These proposals were analytically based and developed based on industry requests and operational concerns.

Future Research

Possible future areas of research may include:

- Substantiation of ice pellet allowance times with new fluids;
- Testing with the National Aeronautics and Space Administration (NASA) LS-0417 wing section to support development of Type III low speed allowance times;
- Lift losses at LOUT;
- Allowance time expansion; and
- Analysis of METAR data to determine conditions requiring guidance.

SOMMAIRE

En vertu d'un contrat avec le Centre de développement des transports (CDT) de Transports Canada (TC), avec l'appui 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 programme de recherches plus large, APS a mené une série d'essais pleine grandeur réalisés 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 supercritique, afin de déterminer les caractéristiques de ruissellement du liquide d'antigivrage avec et sans conditions de précipitations mixtes comprenant des granules de glace.

Contexte et objectif

Un programme d'essais en soufflerie a été élaboré pour l'hiver 2015-2016 avec comme principaux objectifs de réaliser des tests aérodynamiques au moyen d'une surface portante haute performance à profil mince afin :

- De corroborer les marges de tolérance actuelles concernant les granules de glace avec de nouveaux liquides de type III, d'étudier des vitesses de rotation plus basses (80 nœuds) et, selon les contraintes de temps, les méthodes d'application (liquide chaud ou froid) ;
- De corroborer les marges de tolérance actuelles pour les granules de glace avec de nouveaux liquides de type IV et, selon les conditions météorologiques, à des températures se rapprochant de la température minimale d'utilisation opérationnelle (LOUT) ; et
- D'élargir les marges de tolérance actuelles pour les liquides de type IV dans des conditions de granules de glace de façon à inclure un plus grand nombre de conditions souvent signalées par METAR et à développer davantage les lignes directrices actuelles dans des conditions mixtes de granules de glace et de neige.

En outre, des essais de référence sur aile sèche ont été réalisés quotidiennement et après chaque changement apporté aux systèmes afin de valider la répétabilité de la soufflerie. Un essai avec forte contamination a aussi été mené.

Conclusions

Des essais menés à l'hiver 2015-2016 sur des liquides de type III ont permis de valider les marges de tolérance actuelles à utiliser avec le liquide nouvellement commercialisé AllClear AeroClear MAX ; ces marges s'appliquent aux aéronefs dont la vitesse de rotation est supérieure à 100 nœuds. Des efforts ont été déployés afin d'appuyer l'élaboration d'un tableau de marges de tolérance pour les liquides de type III à des vitesses de rotation de *80 nœuds ou plus* ; toutefois, les résultats sont toujours en cours d'examen et d'autres essais seront probablement requis.

Des essais menés à l'hiver 2015-2016 sur des liquides de type IV ont permis de valider les marges de tolérance actuelles à utiliser avec les liquides nouvellement commercialisés LNT E450 et FCY 9311. Des essais ont aussi été réalisés afin d'étayer l'élargissement des marges de tolérance actuelles de façon à inclure des marges plus longues et un plus grand nombre de conditions, y compris les granules de glace modérés avec la bruine verglaçante modérée, les granules de glace modérés avec la pluie modérée et les granules de glace légers avec la neige légère et modérée.

En outre, après consultation avec TC et la FAA, des modifications aux marges de tolérance pour les granules de glace ont été proposées. Ces propositions ont été basées sur des analyses et développées en tenant compte des demandes et préoccupations opérationnelles du secteur.

Recherches à venir

Les domaines de recherches futurs possibles peuvent inclure :

- La corroboration des marges de tolérance pour les granules de glace avec de nouveaux liquides ;
- Les essais avec le profil d'aile LS-0417 de la National Aeronautics and Space Administration (NASA) afin d'appuyer l'élaboration de marges de tolérance à basse vitesse pour les liquides de type III ;
- Les pertes de portance à la LOUT ;
- L'expansion des marges de tolérance ; et
- L'analyse des données METAR pour déterminer les conditions pour lesquelles des lignes directrices sont nécessaires.

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GLOSSARY

APS	APS Aviation Inc.
AWG	G-12 Aerodynamics Working Group
BLDT	Boundary Layer Displacement Thickness
EASA	European Aviation Safety Agency
EG	Ethylene Glycol
FAA	Federal Aviation Administration
HOT	Holdover Time
LOUT	Lowest Operational Use Temperature
NASA	National Aeronautics and Space Administration
NRC	National Research Council Canada
OAT	Outside Air Temperature
PG	Propylene Glycol
PIWT	3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel
RTD	Resistance Temperature Detector
SAE	SAE International
TC	Transport Canada
TDC	Transportation Development Centre

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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), 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.

1.1 Background

In 2005-06, the inability for operators to release aircraft in ice pellet conditions led TC and the FAA to begin a research campaign to develop allowance times. Developing holdover times (HOTs) was not feasible due to the properties of the ice pellets; they remain embedded in the fluid and take long to dissolve compared to snow, which is immediately absorbed and dissolved. Research was initiated through live aircraft testing with the NRC Falcon 20 in Ottawa, Canada, and later evolved to a more controlled environment with the NRC 3 m x 6 m Open-Circuit Propulsion Icing Wind Tunnel (PIWT), also in Ottawa.

The early testing in 2005-06 with the Falcon 20 primarily used visual observations to evaluate fluid flow-off. During the Falcon 20 work, the wing was anti-iced and exposed to contamination, and aborted takeoff runs allowed researchers onboard to observe and evaluate the fluid flow-off. Testing in 2006-07 began in the PIWT, allowing aerodynamic data to be used for evaluating fluid flow-off performance. The PIWT also allowed for a more controlled environment less susceptible to the elements.

The work continued each year, and the test methods and equipment improved, allowing for real-time data analysis, better repeatability, and overall greater confidence in the results. The work conducted by the FAA and TC was presented by APS to the G-12 Aerodynamics Working Group (AWG) and the HOT Committee yearly since 2006. Additional presentations were also given to the AWG in May 2012 and May 2013 by National Aeronautics and Space Administration (NASA) and the NRC that focused on the extensive calibration and characterization work performed with a generic thin high-performance airfoil. This work also helped increase confidence in how the data was used to help support develop TC/FAA guidance material. A detailed account of the more recent work conducted is included in TC report, TP 15232E*, Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics and to Support the Development of Ice Pellet Allowance Times, Winters 2009-10 to 2012-13* (1).

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

Testing was once again focused on the development of ice pellet allowance times for the winter of 2013-14. During the winter of 2014-15, the ice pellet allowance time testing was suspended to allow for a European Aviation Safety Agency (EASA)-led project looking at thickened fluid effects on unpowered elevators; TC and APS were also involved in this research. Ice pellet allowance time testing resumed for the winter of 2015-16, the details of which are described in this report.

1.2 Program Objectives

A wind tunnel testing program was developed for the winter of 2015-16 with the primary objectives of conducting aerodynamic testing with a thin high-performance airfoil to:

- Substantiate the current Type III ice pellet allowance times with new fluids, to investigate lower rotation speeds (80 knots), and, time permitting, application methods (hot vs. cold);
- Substantiate the current Type IV ice pellet allowance times with new fluids and, weather permitting, at temperatures close to the lowest operational use temperature (LOUT); and

- Expand the current Type IV ice pellet allowance times to include more conditions commonly reported by METAR and to further develop the current mixed ice pellet and snow guidance material.

In addition, baseline dry wing tests were conducted daily as well as following system changes to validate the repeatability of the wind tunnel. One heavy contamination test was also conducted.

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

Table 1.1 demonstrates the groupings for the global set of tests conducted at the wind tunnel during the winter of 2015-16. Only tests pertaining to the baseline and ice pellet allowance time testing (Objectives #1, #2, #3, and #4) are described in this report; however, the details of Objective #5 have not been reported on, as this was primarily exploratory.

Table 1.1: Summary of 2015-16 Wind Tunnel Tests by Objective

Objective #	Objective	# of Runs
1	Baseline (Dry Wing)	24
2	Type IV IP AT Validation (New Fluids)	24
3	IP AT Expansion (IP/ZD, IP/R, IP/SN, IP-/SN-, IP-/SN)	28
4	Type III IP AT Validation (New Fluid, 80 Knots)	28
5	R&D (Heavy Contamination)	1
	Total	***105***

1.3 Previous Ice Pellet Allowance Time Tables

The Type IV allowance time tables have been available since the winter of 2007-08. Each year, the Type IV testing has built upon the latest version of the allowance time table published in the TC and FAA HOT Guidelines.

In the case of Type III fluid, a preliminary table was developed during the winter of 2008-09; however, allowance time tables have only been available and published since the winter of 2014-15 following some more extensive testing. Future testing will build upon the latest version of the allowance time table published in the TC and FAA HOT Guidelines.

1.4 Report Format

The wind tunnel work has been conducted since the winter of 2006-07 and has been documented in yearly reports. TP 15232E (1), contains more thorough details regarding the testing methodologies as well as links to previous historical reports. The current report has been prepared in a more abbreviated 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) Sections 4 to 12 describe the testing conducted to further develop the allowance time tables in each respective condition;

d) Section 13 describes the results from Type III fluid lift loss scaling for low-speed rotation;

e) Section 14 describes the general changes to ice pellet guidance material;

f) Section 15 describes the conclusions and observations; and

g) Section 16 describes the recommendations.

2. METHODOLOGY

This section provides a brief description of the test methodology and equipment specific to the full-scale aerodynamic tests conducted at the NRC PIWT.

For more details, TP 15232E (1), contains more thorough details regarding the testing methodologies.

2.1 Test Schedule

Ten days of testing were conducted over a period of two weeks starting January 18, 2016, and ending January 29, 2016. Setup and teardown time was kept to a minimum and was done during the first two hours on the first day of testing and during the last two hours on the last day of testing. Testing days were selected based on weather. Table 2.1 presents the calendar of wind tunnel tests performed. It should be noted that the tests listed comprise all the tests conducted, which also include the tests pertaining to other objectives not discussed in this report. At the beginning of each test day, a plan was developed that included the list of tests (taken from the global test plan) to be completed based on the weather conditions and testing priorities. This daily plan was discussed, approved, and modified (if necessary) by TC, the FAA, and APS.

Table 2.1: Calendar of Tests

Date (Start date of overnight)	**# of Tests Run**
17 January 2016	1
18 January 2016	14
19 January 2016	10
20 January 2016	12
21 January 2016	11
22 January 2016	12
23 January 2016	0
24 January 2016	9
25 January 2016	13
26 January 2016	0
27 January 2016	13
28 January 2016	10
Total	105

2.1.1 Wind Tunnel Procedure

To satisfy the fluid testing objective, simulated takeoff and climb-out tests were performed with the supercritical wing section. 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 in 2009 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) When applicable, 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.

2.1.2 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 2.1 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 illustration purposes; this time varied for each test depending on the objective.

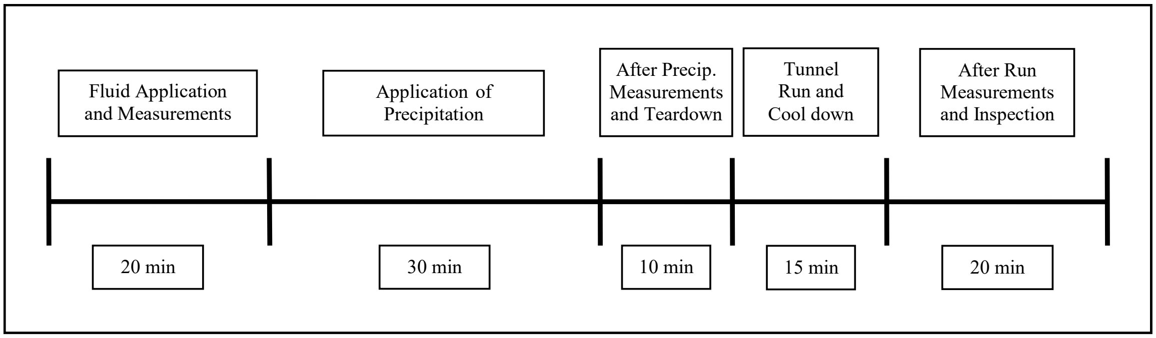


Figure 2.1: Typical Wind Tunnel Test Timeline

2.2 Methodology for Developing or Expanding New Allowance Times

Initial testing to first develop the allowance times is done with representative “grandfather” fluids (fluids with a long history of data). Testing is conducted at different temperatures and rates, and the allowance times are based on the limits where tests fail the acceptance criteria (based on visual ratings and aerodynamic performance). Much “trial and error” is needed to determine where the limits of the allowance times are (i.e., it may require running tests with a grandfather fluid at 15, 20, and 25 minutes to determine that the allowance time should be limited to 20 minutes). Once the target allowance times are determined, they are validated with other fluids; this is done using limited spot checks with multiple fluids.

2.3 Methodology for Validating New Fluids for Use with Allowance Times

Over the years, all new commercially available fluids have been tested. This is typically done within 1-2 years of the fluid being available on the market. At a minimum, testing is conducted in a subset of the conditions; the allowance times are generic, so this process is satisfactory and provides a “first alert” in the event that a fluid may be underperforming, in which case further action would be required.

2.4 Procedural Modification for Type III Testing in 2015-16

To serve a dual purpose, the tests run to validate the Type III allowance times for aircraft with rotation speeds greater than 100 knots were also run at 80 knots; it was expected that the Type III fluid would perform very well and pass all criteria even at 80 knots, which it did. The purpose is to eventually use this 80-knots data to support the development of a low-speed Type III allowance time table.

2.5 Wind Tunnel and Airfoil Model Technical Overview

The following sections describe the wind tunnel and major components.

2.5.1 Wind Tunnel Test Site

PIWT tests are performed at the NRC Aerospace Facilities, Building M-46, at the NRC Montreal Road campus, located in Ottawa, Canada. Figure 2.2 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 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. 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. 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.

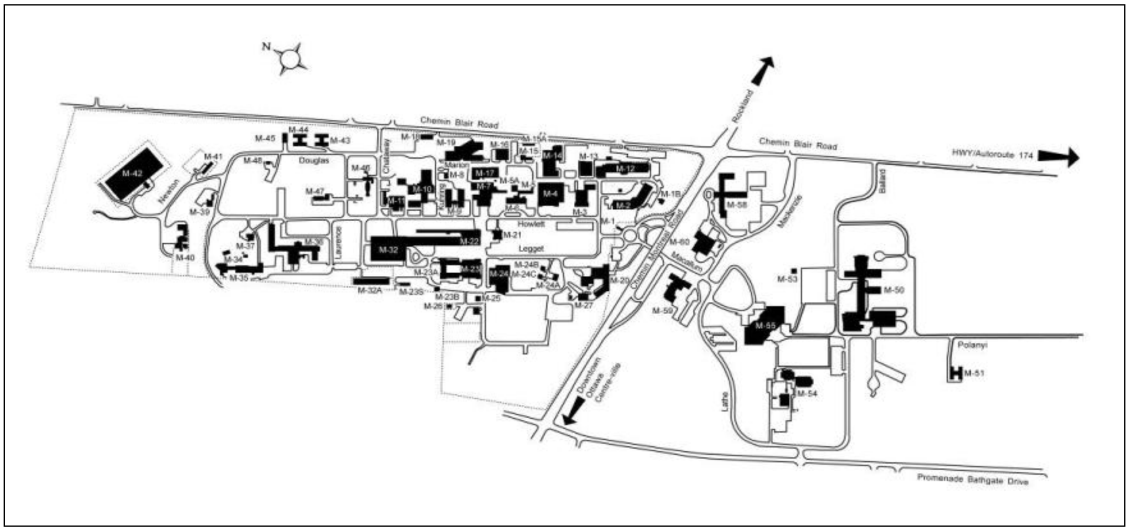


Figure 2.2: Schematic of NRC Montreal Road Campus

A cross sectional view of the supercritical wing section used for testing has been included in Figure 2.3; the dimensions indicated are in meters. 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.).

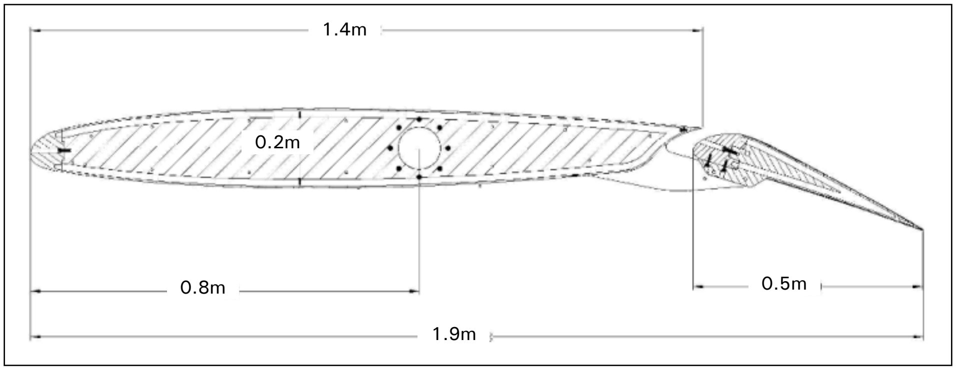


Figure 2.3: Generic "Supercritical " Wing Section

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 2° when sitting on the ground. As a result, the NRC ensured the rest position of the wing model was set to -2° 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).

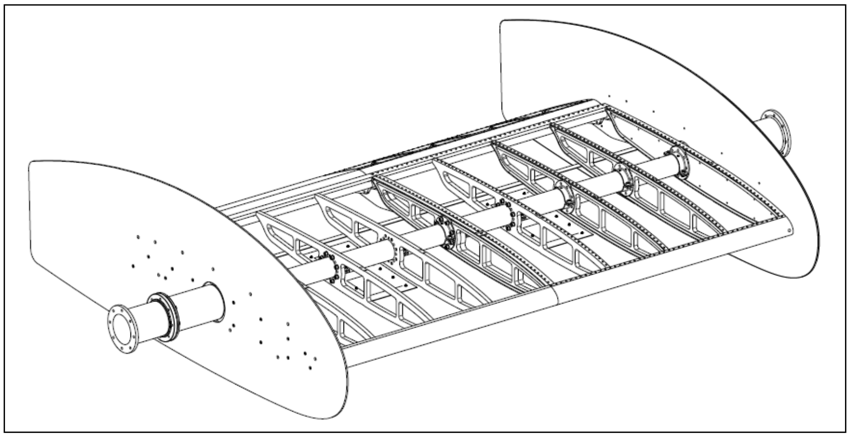


Figure 2.4: End Plates Installed on Supercritical Wing Section

2.5.3 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.

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 0.5 m (1.5 ft.) in pairs to the left and to the right of the wing centreline. The following are the locations of the RTDs:

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

Figure 2.5 demonstrates the general location of the RTDs. These RTDs were primarily used to monitor the skin temperature in real-time through the NRC data display system and were recorded by APS personnel as described in Subsection 2.10.

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.

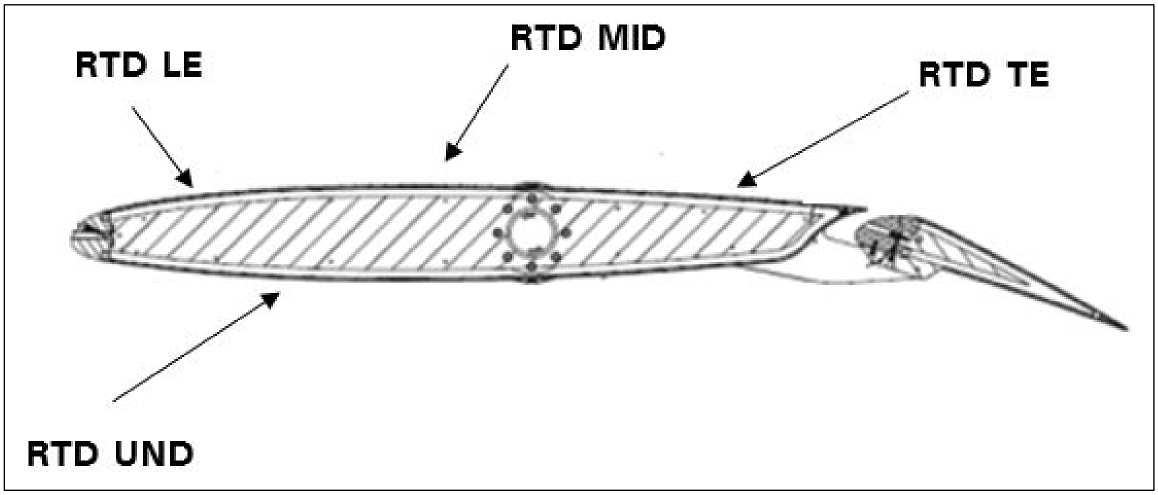


Figure 2.5: Location of RTDs Installed Inside Supercritical Wing

2.6 Simulated Precipitation

The following types of precipitation have been simulated for aerodynamic research in the PIWT:

- Ice Pellets;
- Snow;
- Freezing Rain/Rain; and
- Other conditions related to HOTs.

2.6.1 Ice Pellets

Simulated 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.

2.6.2 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.

2.6.3 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.

2.6.4 Definition of Precipitation Rates

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

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

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

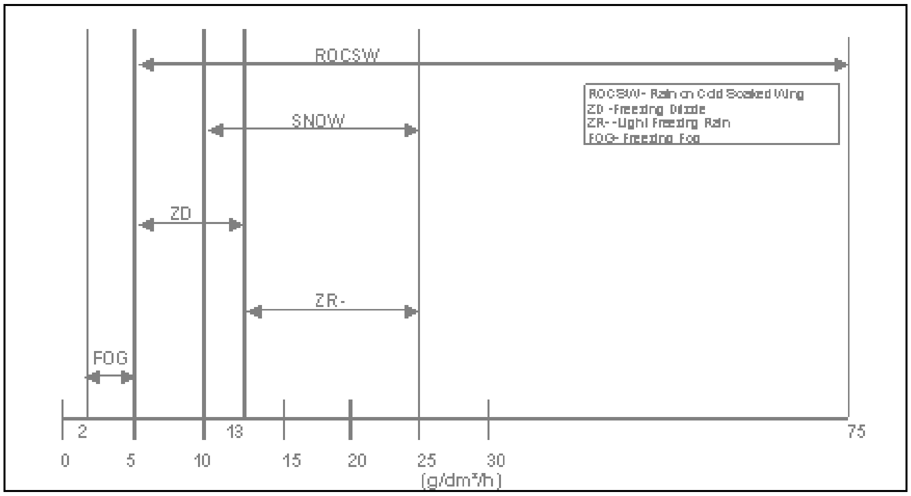


Figure 2.6: Precipitation Rate Breakdown

2.7 Test Equipment

A considerable amount of test equipment was used 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.

2.7.1 Video and Photo Equipment

APS used the observation windows on the sides of the test section to install Canon EOS XTi DSLR cameras and Profoto Compact 600 flashes capable of second-by-second photography with an intervalometer. In addition, GoPro cameras were used for wide-angle filming of fluid flow-off during the test runs. Photos 2.9 and 2.10 demonstrate the camera setup used for the testing period.

2.7.2 Refractometer/Brixometer

Fluid freezing points were measured using a hand-held Misco 10431VP refractometer with a Brix scale (shown in Figure 2.7). The freezing points of the various fluid samples were determined using the conversion curve or table provided to APS by the fluid manufacturer.

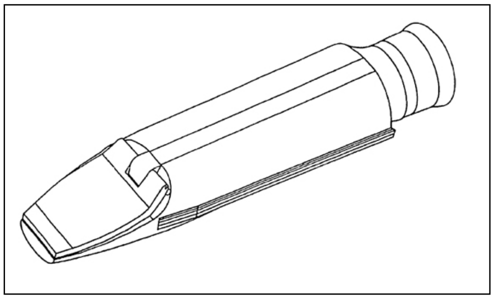


Figure 2.7: Hand-Held Refractometer/Brixometer

2.7.3 Wet Film Thickness Gauges

Wet film thickness gauges, shown in Figure 2.8, 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 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 was used to convert the recorded thickness values into the corrected thickness values.

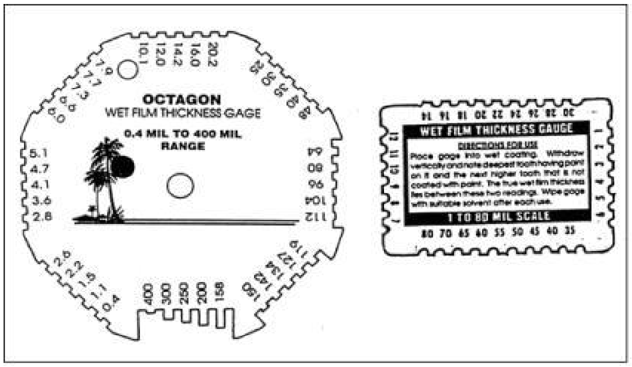


Figure 2.8: Wet Film Thickness Gauges

2.7.4 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 (however, generally the wing-mounted RTDs were used), and an immersion probe was used for measuring and monitoring fluid temperatures.

2.8 Personnel

During the fluid testing and exploratory research testing, four APS staff members were required to conduct the tests, and four 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 research team (due to scheduling, not all participants were available for the photo).

2.9 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.

2.10 Data Collection

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. The completed data forms have been scanned and included in Appendix C for referencing purposes.

High-speed digital photographs of each test were taken. 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 available in electronic format have been provided to the TDC and can be made available upon request.

2.11 De/Anti-Icing Fluids

Ten fluids were used during the wind tunnel tests conducted during the winter of 2015-16. Seven fluids were leftover inventory acquired during the 2012-13, 2013-14, and 2014-15 winter seasons that were verified for viscosity and overall integrity prior to the 2015-16 testing. 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 2.2.

Table 2.2: Wind Tunnel Fluid Viscosity Information for 2015-16 Testing

								2012-13			2013-14			2014-15			2015-16		
Sample Name	**Dilution**	**Batch #**	**Year Rec'd**	**Project Rec'd For**	**Supplier**	**2015-16 Receiving Quantity (L)**	**Leftover Inventory Pre 2015-16 (L)**	**Measured Viscosity (cP)**	**Falling Ball Temp. (°C)**	**Falling Ball Time (mm:ss)**	**Measured Viscosity (cP)**	**Falling Ball Temp. (°C)**	**Falling Ball Time (mm:ss)**	**Measured Viscosity (cP)**	**Falling Ball Temp. (°C)**	**Falling Ball Time (mm:ss)**	**Measured Viscosity (cP)**	**Falling Ball Temp. (°C)**	**Falling Ball Time (mm:ss)**
Clariant Safewing MP II FLIGHT	100/0	DEG 4145408	2014-15	EASA	Clariant	250	150							13,600	22.4	0:26		22.9	0:26
Dow UCAR™ FlightGuard AD-49	75/25	L14-290	2014-15	EASA	Dow	300	136							36,000	22.0	0:48		20.2	0:47
Cryotech Polar Guard Advance	50/50	12964	2014-15	EASA	Cryotech	200	110							5320	22.4	0:03			
AllClear Systems LLC Lift-Off E-188	aprox 60/40	AEROMAG	2014-15	EASA	Aeromag 2000 Ottawa	40	20							n/a	n/a	n/a		n/a	n/a
Kilfrost ABC-S Plus	100/0	WT 13-14 ABC-S+	2013-14	TC-WT	Kilfrost	400	352				19,800	21.7	0:37				27,100	19.5	0:32
Dow FlightGuard AD-49	100/0	WT 12-13 AD-49	2012-13	TC-WT	Dow	700	270	14,397	21.6	0:19	14,100	20.5	0:21				13,200	19.4	0:22
Cryotech Polar Guard Advance	100/0	WT 13-14 PGA	2013-14	TC-WT	Cryotech	400	270				15,400	20.6	0:25				16040	19.5	0:24
AeroClear Max	100/0	TAB15-PB1112	2015-16	TC-WT	AllClear	400	40										13,800	19.7	0:02
LNT E450	100/0	WT.15.16.LNTE450	2015-16	TC-WT	LNT	200	0										47,400	20.5	0:42
FCY 9311	100/0	151113005	2015-16	TC-WT	Newave	200	0										24500	20.1	0:42

Note: Viscosity measured using manfucaturer method.

2.11.1 Viscometer

Historically, viscosity measurements have been carried out using a Brookfield viscometer (Model DV-1+, shown in Photo 2.13) fitted with a recirculating fluid bath and small sample adapter. In recent years, on-site measurements are also done with the Stony Brook PDVdi-120 Falling Ball Viscometer (Photo 2.14) to obtain a verification of the fluid integrity. The falling ball tests are much faster and more convenient to perform compared to tests with the Brookfield viscometer; however, they do not provide the absolute value of viscosity but rather a time interval that is compared to historical samples to identify changes in viscosity.

2.11.2 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, and IV fluids are generally received in 20 L containers; however, some fluids are received in large 200 L barrels and larger 1000 L totes. The fluid is applied to the wing section by using smaller 2 L containers (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.

2.11.3 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.

2.12 Analysis Methodology

The following provides a brief description of the analysis methodology. More details on the analysis methodology can be found in TP 15232E (1).

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 2.9 shows a summary of each test objective and criteria.

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.

2.12.1 Visual Ratings at the Start of the Test

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.

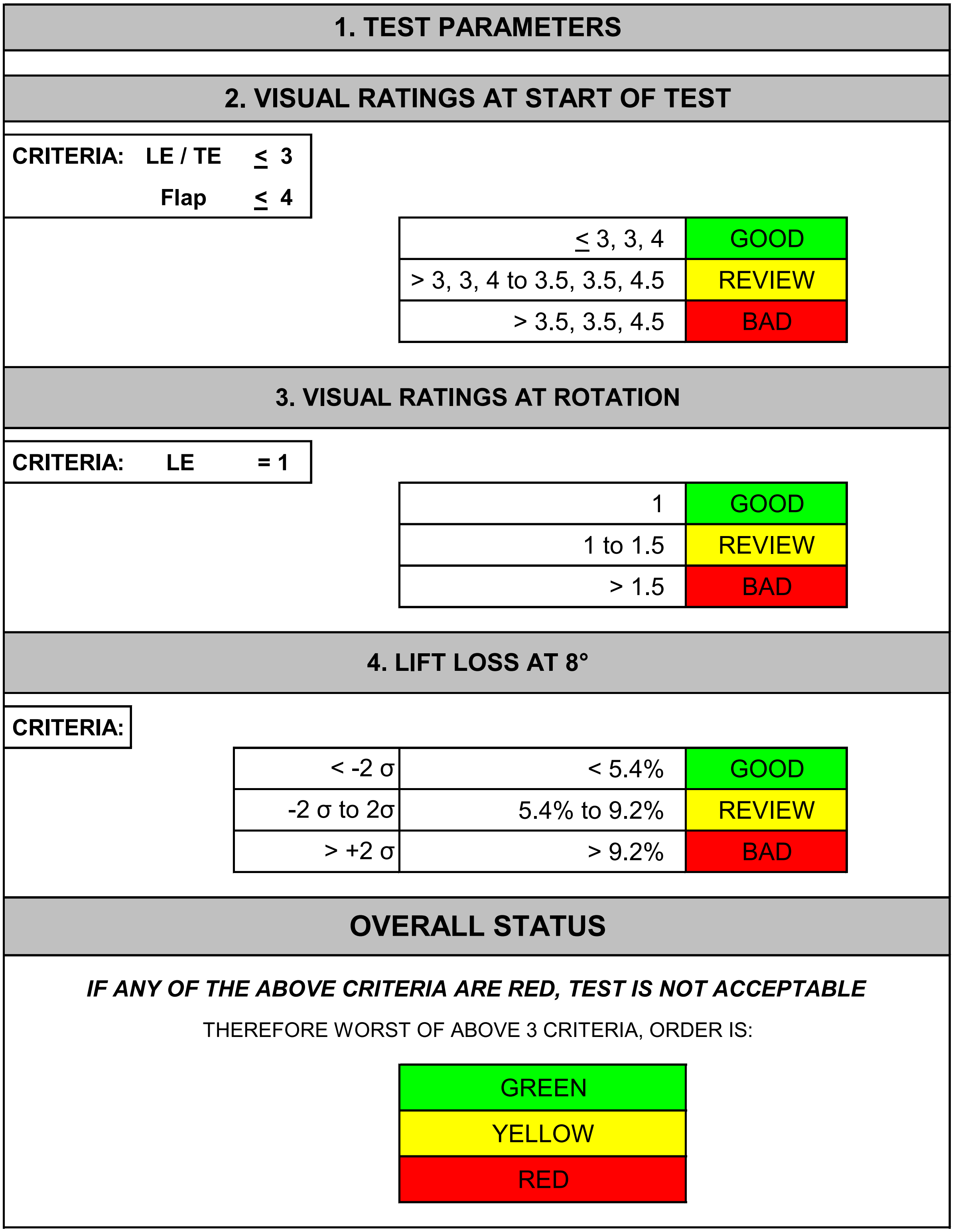
The visual contamination rating criteria at the start of the test on both the leading and trailing edge must be equal to 3 or less in order to pass. The flap must have a rating of 4 or less. For a review grade to be given, the leading and trailing edge must have a rating between 3 and 3.5, and the flap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

2.12.2 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.

2.12.3 Eight Degree Lift Loss

For a pass, the 8° lift loss must be less than 5.4 percent. A review grade was given should the lift loss be between 5.4 percent and 9.2 percent. Any lift loss greater than 9.2 percent is considered a fail.



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 2.9: Ice Pellet Test Analysis Criteria

2.12.4 Overall Test Status

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

2.12.5 Dry Wing Calibration

To ensure the accuracy of the testing results, a dry wing calibration test was conducted at the start of each day. The dry wing test allowed the research team to ensure that the model aerodynamics did not change due to mechanical, communication, or analytical errors. Dry wing tests were also conducted following any mechanical modification to the airfoil (i.e., after applying the ice phobic wing skins). During the winter of 2015-16, the dry wing results demonstrated that the changes in dry wing performance were within the range of experimental error and did not indicate any repeatability issues with the model.

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

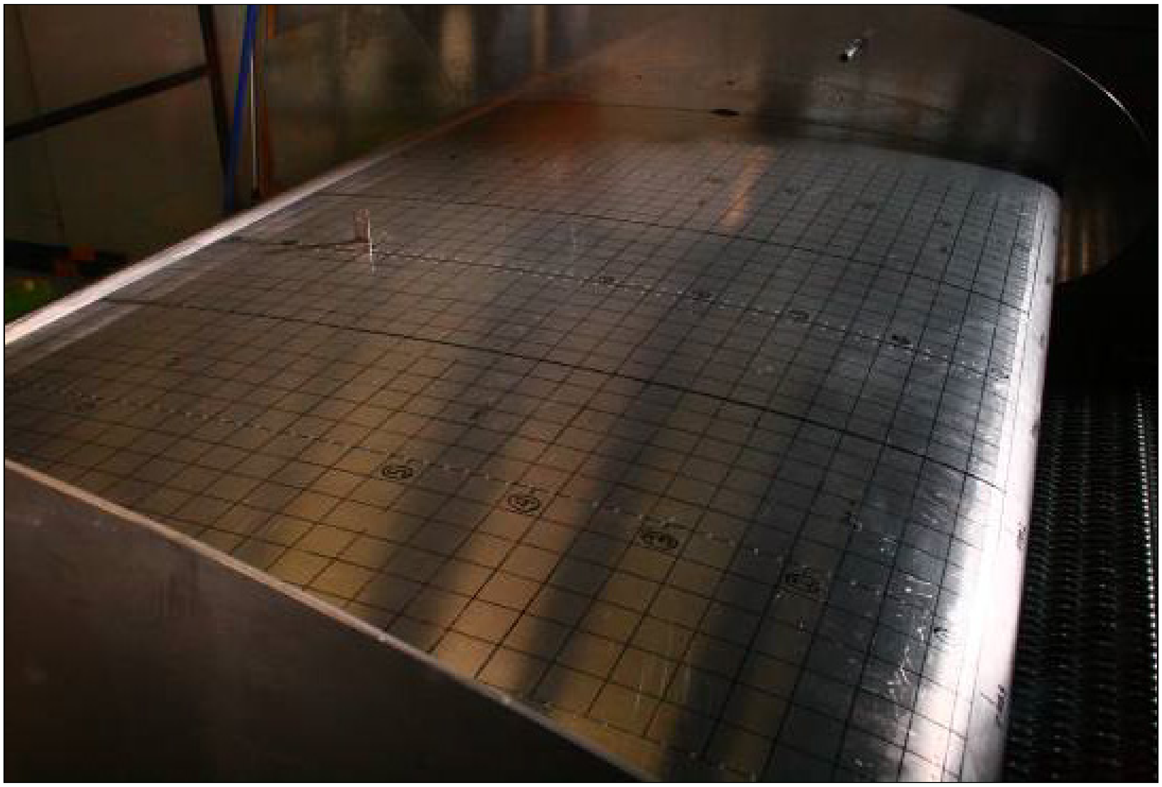


Photo 2.5: Refrigerated Truck Used for Manufacturing Ice Pellets

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

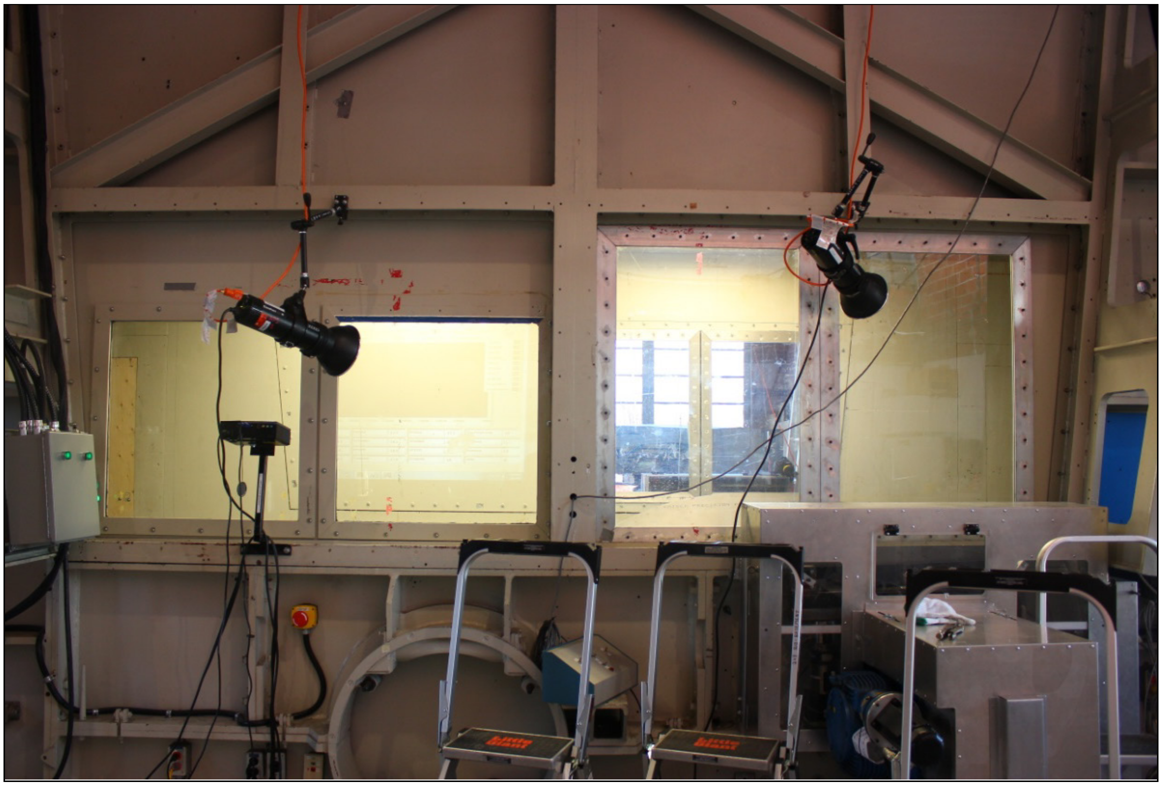


Photo 2.10: Wind Tunnel Setup for Digital Cameras

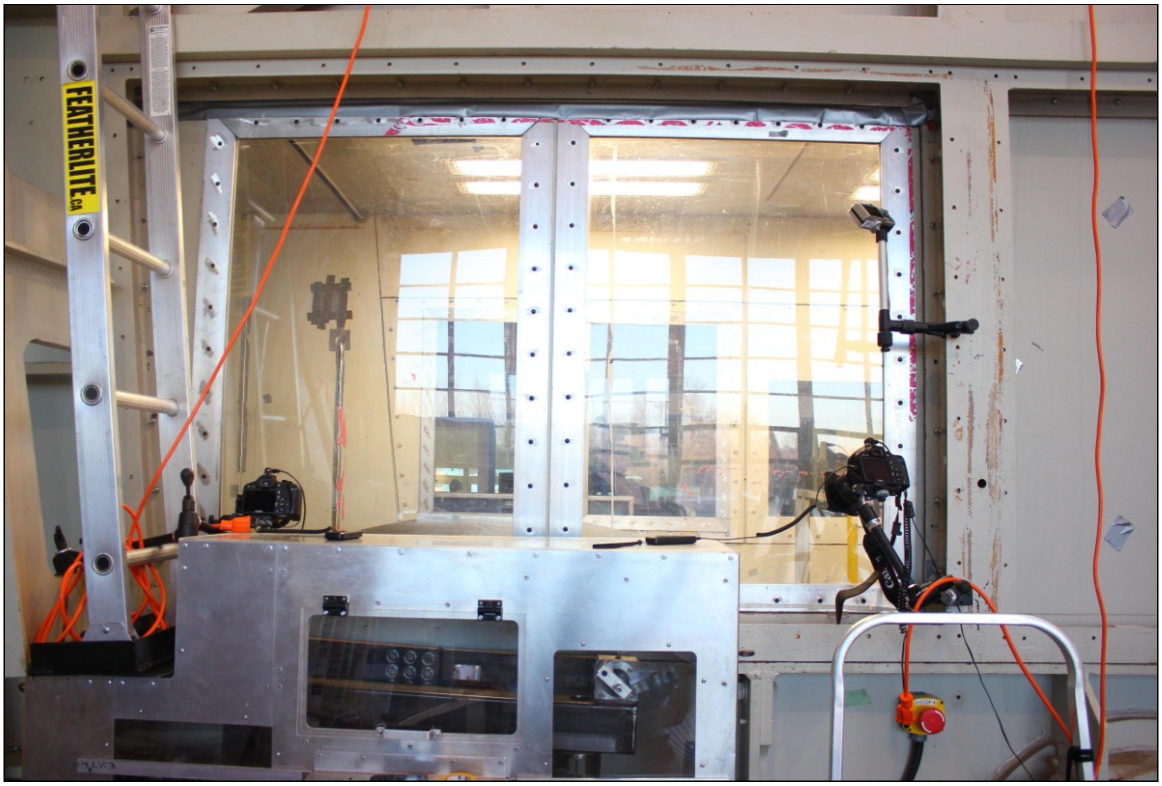


Photo 2.11: Fluid Pour Containers

Photo 2.12: 2015-16 Research Team

Photo 2.13: Brookfield Digital Viscometer Model DV-1+

Photo 2.14: 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 2015-16 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. It should be noted that a cumulative log of all tests completed since the ice pellet work started with the thin high-performance wing in 2009-10 has been maintained and used during the testing sessions; this log can be made available upon request. The following is a brief description of the column headings for Table 3.1:

Test #:	Exclusive number identifying each test run.
Test Year:	The year in which the test was conducted.
Objective:	Main objective of the test.
Test Condition:	Description of the simulated conditions for the test.
Fluid Name:	Aircraft anti-icing fluid used during the test.
Rotation Angle:	Maximum angle of rotation obtained during simulated takeoff run; began testing with a max 8° rotation angle and increased to 20° as testing progressed.
Flap Angle (0°, 20°):	Positioning of the flap during the precipitation period; either 0° (retracted) or 20° (extended). *Note: Flap was always extended at 20° during the takeoff run.*
Date:	Date when the test was conducted.
OAT Before Test (°C):	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 (°C):	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.
Precipitation Rate (Type: [g/dm^2/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.

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

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

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

Table 3.1: Wind Tunnel Test Log 2015-16

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 C_L at 8°	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
1	2015-16	Type IV Validation and New Fluids	IP- / ZR-	AD-49 (75/25)	8	20	18-Jan-16	-7.5	-5.5	IP=25 ZR=25	10	-	-	-	1.425	3.32%	100
2	2015-16	Baseline	Dry Wing	none	8	20	18-Jan-16	-14.7	-12.4	-	-	-	-	-	n/a	n/a	100
3	2015-16	Baseline	Dry Wing	none	22	20	18-Jan-16	-14.7	-12.4	-	-	-	-	-	n/a	n/a	80
4	2015-16	Baseline	Dry Wing	none	8	20	18-Jan-16	-15.2	-14.3	-	-	-	-	-	n/a	n/a	100
5	2015-16	Baseline	Dry Wing	none	22	20	18-Jan-16	-15.2	-15.2	-	-	-	-	-	n/a	n/a	80
6	2015-16	Baseline	Dry Wing	none	22	20	18-Jan-16	-15.4	-14.6	-	-	-	-	-	n/a	n/a	80
7	2015-16	Baseline	Dry Wing	none	22	20	18-Jan-16	-15.5	-15.4	-	-	-	-	-	1.455	1.29%	80
8	2015-16	Baseline	Dry Wing	none	8	20	18-Jan-16	-15.5	-15.6	-	-	-	-	-	1.474	0.01%	100
9	2015-16	Type IV Validation and New Fluids	IP-	FCY 9311	8	20	19-Jan-16	-16.2	-15.4	IP=25	30	2.4, 2.4, 3.8	1.1, 1.7, 2.3	1, 1.2, 1.3	1.325	10.09%	100
10	2015-16	Type IV Validation and New Fluids	IP-	LNT E450	8	20	19-Jan-16	-16.8	-15.2	IP=25	30	2.2, 2.2, 2.6	1, 1.3, 1.7	1, 1, 1.2	1.388	5.82%	100
11	2015-16	Type IV Validation and New Fluids	IP Mod	LNT E450	8	20	19-Jan-16	-17.1	-16.8	IP=75	10	2, 2.2, 2.6	1.1, 1.3, 1.8	1, 1, 1.2	1.386	5.97%	100

Table 3.1: Wind Tunnel Test Log 2015-16 (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 ($g/dm^2/h$)	Exposure Time (min)	Visual Contamination Rating Before Takeoff (LE,TE,Flap)	Visual Contamination Rating at Rotation (LE,TE,Flap)	Visual Contamination Rating After Takeoff (LE,TE,Flap)	Corrected for 3D Effects CL at 8°	Corrected for 3D Effects % Lift Loss on 8° CL vs. Dry CL	Speed Kts
12	2015-16	Type IV Validation and New Fluids	Fluid Only	LNT E450	8	20	19-Jan-16	-17	-15.7	-	-	-	-	-	1.379	6.46%	100
13	2015-16	Type IV Validation and New Fluids	IP Mod	LNT E450	8	20	19-Jan-16	-17	-15.4	IP=75	10	2.2, 2.2, 2.6	1.1, 1.4, 2.2	1, 1, 1.3	1.379	6.43%	100
14	2015-16	Type IV Validation and New Fluids	IP Mod	FCY 9311	8	20	19-Jan-16	-17.2	-15.8	IP=75	10	2.5, 2.7, 3.8	1, 1.7, 2.7	1, 1.1, 1.2	1.349	8.45%	115
15	2015-16	Type IV Validation and New Fluids	Fluid Only	FCY 9311	8	20	19-Jan-16	-16.7	-15.7	-	-	-	-	-	1.379	6.41%	100
16	2015-16	Baseline	Dry Wing	none	8	20	19-Jan-16	n/a	-10.7	-	-	-	-	-	1.465	0.61%	100
17	2015-16	Baseline	Dry Wing	none	22	20	19-Jan-16	n/a	-11.1	-	-	-	-	-	1.457	1.12%	80
18	2015-16	IP Expansion	Fluid Only	ABC-S Plus	8	20	19-Jan-16	-11	-11.1	-	-	-	-	-	1.388	5.85%	100
19	2015-16	Type IV Validation and New Fluids	IP- / ZR-	FCY 9311	8	20	19-Jan-16	-10	-8.5	IP=25 ZR=25	10	2.5, 2.5, 3.5	1, 1.5, 1.8	1, 1, 1	1.382	6.27%	100
20	2015-16	Type IV Validation and New Fluids	IP- / ZR-	LNT E450	8	20	20-Jan-16	-8.9	-7.6	IP=25 ZR=25	10	1.8, 2, 2	1, 1.1, 1.5	1, 1, 1	1.402	4.90%	100
21	2015-16	Type IV Validation and New Fluids	IP- / SN-	LNT E450	8	20	20-Jan-16	-9.2	-6.6	IP=25 SN=10	15	1.7, 2, 2.4	1, 1.4, 1.7	1, 1, 1.2	1.395	5.35%	100
22	2015-16	Type IV Validation and New Fluids	IP- / SN-	FCY 9311	8	20	20-Jan-16	-9.6	-6.5	IP=25 SN=10	15	2.4, 2.8, 3.5	1.1, 1.5, 2.1	1, 1.1, 1.2	1.371	6.95%	100

Table 3.1: Wind Tunnel Test Log 2015-16 (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 ($g/dm^2/h$)	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 C_L at 8°	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
23	2015-16	IP Expansion - METAR	IP / SN	ABC-S Plus	8	20	20-Jan-16	-10.2	-8.2	IP=75 SN=25	7	2.3, 2.7, 3.5	1.1, 1.7, 2.4	1, 1, 1.2	1.365	7.38%	100
24	2015-16	IP Expansion - METAR	IP / SN	ABC-S Plus	8	20	20-Jan-16	-10.4	-7.7	IP=75 SN=25	10	3, 3, 4	1.2, 1.8, 2.5	1, 1.1, 1.2	1.354	8.16%	100
25	2015-16	IP Expansion - METAR	IP / ZD	ABC-S Plus	8	20	20-Jan-16	-10.3	-7.2	IP=75 R=13	10	2.4, 2.5, 3.2	1.1, 1.5, 2.1	1, 1.1, 1.1	1.371	7.01%	100
26	2015-16	Baseline	Dry Wing	none	8	20	20-Jan-16	-8.9	-8.0	-	-	-	-	-	1.472	0.10%	100
27	2015-16	Baseline	Dry Wing	none	22	20	20-Jan-16	-8.9	-8.0	-	-	-	-	-	1.488	-0.98%	80
28	2015-16	Type III Allowance Times	IP-	AeroClear MAX - Cold	8	20	20-Jan-16	-9	-5.5	IP=25	10	2.2, 2, 2.4	1, 1, 1.5	1, 1, 1.1	1.434	2.73%	80
29	2015-16	Type III Allowance Times	IP Mod	AeroClear MAX - Cold	8	20	20-Jan-16	-9	-5.3	IP=75	5	2, 2, 2.7	1, 1.2, 1.4	1, 1, 1.1	1.442	2.14%	80
30	2015-16	Type III Allowance Times	IP- / ZR-	AeroClear MAX - Cold	8	20	21-Jan-16	-9.7	-4.1	IP=25 ZR=25	5	1.8, 2, 2.1	1, 1, 1.2	1, 1, 1	1.437	2.52%	80
31	2015-16	Type III Allowance Times	IP- / SN-	AeroClear MAX - Cold	8	20	21-Jan-16	-10.1	-5.1	IP=25 SN=10	10	2, 1.7, 3	1, 1.2, 1.7	1, 1, 1.5	1.446	1.91%	80
32	2015-16	Type III Allowance Times	IP- / SN	AeroClear MAX - Cold	8	20	21-Jan-16	-10.3	-5.4	IP=25 SN=25	10	2, 2.7, 3.8	1, 1.5, 2.5	1, 1, 1.4	1.434	2.69%	80
33	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	21-Jan-16	-10.7	-7.2	-	-	-	-	-	1.422	3.52%	80

Table 3.1: Wind Tunnel Test Log 2015-16 (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/dm^2/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 C_L at 8°	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
34	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	21-Jan-16	-11	-6.3	-	-	-	-	-	1.434	2.72%	100
35	2015-16	IP Expansion - METAR	IP / ZD	Polar Guard Advance	8	20	21-Jan-16	-11.6	-6.9	IP=75 ZR=13	10	2.7, 2.7, 3.9	1, 1.7, 2.5	1, 1, 1.2	1.337	9.32%	100
36	2015-16	IP Expansion - METAR	IP / SN	Polar Guard Advance	8	20	21-Jan-16	-12	-7.4	IP=75 SN=25	10	3, 3, 4	1.2, 1.7, 2.6	1, 1, 1.4	1.311	11.06%	100
37	2015-16	IP Expansion - METAR	IP / SN	Polar Guard Advance	8	20	21-Jan-16	-12.6	-7.7	IP=75 SN=25	7	2.8, 2.5, 3.7	1.1, 1.4, 2.5	1, 1.1, 1.4	1.335	9.42%	100
38	2015-16	Baseline	Dry Wing	none	8	20	21-Jan-16	-6.9	-6.8	-	-	-	-	-	1.470	0.25%	100
39	2015-16	Baseline	Dry Wing	none	22	20	21-Jan-16	-6.9	-6.8	-	-	-	-	-	1.482	-0.58%	80
40	2015-16	IP Expansion - METAR	IP / SN	ABC-S Plus	8	20	21-Jan-16	-6.9	-3.5	IP=75 SN=25	7	2.9, 2.7, 3.4	1.1, 1.9, 2.1	1, 1, 1.1	1.375	6.70%	100
41	2015-16	IP Expansion - METAR	IP / SN	ABC-S Plus	8	20	21-Jan-16	-7	-3.8	IP=75 SN=25	10	2.8, 2.8, 3.7	1.2, 2, 2.3	1, 1, 1.1	1.364	7.48%	100
42	2015-16	IP Expansion - METAR	IP / ZD	ABC-S Plus	8	20	22-Jan-16	-7.1	-3.1	IP=75 ZR=13	15	3, 3, 4	1.1, 1.7, 2	1, 1, 1.1	1.385	6.06%	100
43	2015-16	IP Expansion - Current IP and SN	IP- / SN-	ABC-S Plus	8	20	22-Jan-16	-7.5	-4.3	IP=25 SN=10	40	2.8, 2.8, 4	1.2, 1.7, 1.9	1, 1.1, 1.2	1.372	6.91%	100
44	2015-16	IP Expansion - Current IP and SN	IP- / SN	ABC-S Plus	8	20	22-Jan-16	-7.6	-4.4	IP=25 SN=25	20	3.2, 2.8, 3.8	1.3, 2, 2.3	1, 1.4, 1.3	1.376	6.66%	100

Table 3.1: Wind Tunnel Test Log 2015-16 (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 ($g/dm^2/h$)	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 C_L at 8°	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
45	2015-16	IP Expansion - METAR	IP / SN	AD-49	8	20	22-Jan-16	-7.7	-4.4	IP=75 SN=25	10	2.9, 2.8, 4	1.1, 1.7, 2.1	1, 1.1, 1.2	1.366	7.34%	100
46	2015-16	IP Expansion - Current IP and SN	IP- / SN-	AD-49	8	20	22-Jan-16	-8.1	-4.0	IP=25 SN=10	40	3.1, 3, 4	1.2, 1.8, 2.5	1, 1.2, 1.2	1.392	5.56%	100
47	2015-16	IP Expansion - METAR	IP / ZD	AD-49	8	20	22-Jan-16	-8.5	-4.9	IP=75 ZR=13	15	2.8, 2.7, 3.8	1.1, 1.5, 1.9	1, 1.1, 1.3	1.384	6.07%	100
48	2015-16	IP Expansion - Current IP and SN	IP- / SN	AD-49	8	20	22-Jan-16	-8.9	-4.7	IP=25 SN=25	20	2.8, 2.7, 3.8	1.2, 1.7, 2.8	1, 1.1, 1.5	1.361	7.63%	100
49	2015-16	Baseline	Dry Wing	none	8	20	22-Jan-16	-8.6	-8.2	-	-	-	-	-	1.479	-0.35%	100
50	2015-16	Baseline	Dry Wing	none	22	20	22-Jan-16	-8.6	-8.2	-	-	-	-	-	1.483	-0.60%	80
51	2015-16	IP Expansion - Current IP and SN	IP- / SN-	Polar Guard Advance	8	20	22-Jan-16	-9.5	-5.1	IP=25 SN=10	40	2.8, 2.8, 4	1.1, 1.4, 2.6	1, 1, 1.3	1.345	8.73%	100
52	2015-16	IP Expansion - METAR	IP / SN	Polar Guard Advance	8	20	23-Jan-16	-10.1	-4.9	IP=75 SN=25	10	2.7, 2.8, 4	1.1, 1.4, 2.5	1, 1, 1.2	1.337	9.27%	100
53	2015-16	IP Expansion - METAR	IP / ZD	Polar Guard Advance	8	20	23-Jan-16	-10.6	-4.8	IP=75 ZR=13	15	2.8, 3, 3.8	1, 1.5, 2.3	1, 1.2, 1.1	1.353	8.23%	100
54	2015-16	IP Expansion - Current IP and SN	IP- / SN	Polar Guard Advance	8	20	23-Jan-16	-10.8	-5.2	IP=25 SN=25	20	2.8, 3.1, 3.9	1.1, 1.6, 2.6	1, 1.1, 1.9	1.332	9.63%	100
55	2015-16	IP Expansion - Current IP and SN	IP- / SN	Polar Guard Advance	8	20	23-Jan-16	-11.4	-6.2	IP=25 SN=25	15	2.8, 2.9, 3.7	1.2, 1.6, 2.4	1, 1, 1.4	1.343	8.85%	100

Table 3.1: Wind Tunnel Test Log 2015-16 (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 C_L at 8°**	**Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L**	**Speed Kts**
56	2015-16	Type III Allowance Times	IP- / SN	AeroClear MAX - Cold	8	20	23-Jan-16	-12	-6.4	IP=25 SN=25	10	2.3, 2.2, 3.8	1, 1.2, 1.6	1, 1, 1.1	1.434	2.71%	80
57	2015-16	Type III Allowance Times	IP- / SN	AeroClear MAX - Cold	8	20	23-Jan-16	-12.3	-7.5	IP=25 SN=25	10	2.5, 2.4, 3.6	1, 1.2, 1.6	1, 1, 1.1	1.436	2.57%	80
58	2015-16	Type III Allowance Times	IP- / SN	AeroClear MAX - Cold	8	20	23-Jan-16	-12.7	-7.2	IP=25 SN=25	10	2.7, 2.7, 3.5	1, 1.2, 1.3	1, 1, 1.1	1.443	2.12%	100
59	2015-16	Type III Allowance Times	IP- / ZR-	AeroClear MAX - Cold	8	20	23-Jan-16	-13	-6.6	IP=25 ZR=25	7	1.7, 1.7, 2.5	1, 1, 1.4	1, 1, 1.1	1.433	2.79%	80
60	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	23-Jan-16	-13.3	-9.6	-	-	-	-	-	1.388	5.81%	68
61	2015-16	Baseline	Dry Wing	none	8	20	24-Jan-16	-8.2	-1.2	-	-	-	-	-	1.465	0.59%	100
62	2015-16	Baseline	Dry Wing	none	22	20	24-Jan-16	-8.2	-1.2	-	-	-	-	-	1.475	-0.08%	80
63	2015-16	Type IV Validation and New Fluids	IP-	FCY 9311	8	20	24-Jan-16	-7.1	-2.6	IP=25	50	2.7, 2.8, 4	1, 1.4, 1.6	1, 1.1, 1.2	1.423	3.46%	100
64	2015-16	Type IV Validation and New Fluids	IP- / ZR-	FCY 9311	8	20	25-Jan-16	-7.6	-1.5	IP=25 ZR=25	25	2.7, 2.8, 4.3	1, 1.1, 5	1.1, 1.1, 4.7	1.350	8.40%	100
65	2015-16	Type IV Validation and New Fluids	IP- / ZR-	ABC-S Plus	8	20	25-Jan-16	-7.5	-1.5	IP=25 ZR=25	25	2.8, 2.8, 5	1, 1.3, 5	1, 1, 4	1.393	5.51%	100
66	2015-16	Type IV Validation and New Fluids	IP- / ZR-	Polar Guard Advance	8	20	25-Jan-16	-7.2	-0.6	IP=25 ZR=25	25	2.6, 2.7, 4.7	1, 1.1, 5	1, 1, 5	1.388	5.82%	100

Table 3.1: Wind Tunnel Test Log 2015-16 (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 $(g/dm^2/h)$	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 C_L at 8°	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
67	2015-16	Type IV Validation and New Fluids	IP- / ZR-	AD-49	8	20	25-Jan-16	-7	-1.5	IP=25 ZR=25	25	2.8, 2.8, 5	1, 1.3, 5	1, 1, 5	1.378	6.49%	100
68	2015-16	Type IV Validation and New Fluids	IP- / ZR-	LNT E450	8	20	25-Jan-16	-6.7	-1.3	IP=25 ZR=25	25	2, 2, 2.3	1, 1, 1.1	1, 1, 1	1.428	3.11%	100
69	2015-16	Type IV Validation and New Fluids	IP Mod	LNT E450	8	20	25-Jan-16	-6.6	-2.0	IP=75	25	2.3, 2.5, 4	1, 1.4, 1.9	1, 1, 1	1.425	3.30%	100
70	2015-16	Baseline	Dry Wing	none	8	20	25-Jan-16	-3.3	3.3	-	-	-	-	-	1.465	0.61%	100
71	2015-16	Baseline	Dry Wing	none	22	20	25-Jan-16	-3.3	3.3	-	-	-	-	-	1.476	-0.14%	80
72	2015-16	Type III Allowance Times	IP- / R-	AeroClear MAX - Cold	8	20	25-Jan-16	-3.5	2.4	IP=25 R=25	7	1, 1.3, 1.4	1, 1, 1.2	1, 1, 1.1	1.444	2.02%	80
73	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	25-Jan-16	-3.6	1.5	-	-	-	-	-	1.435	2.65%	80
74	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	25-Jan-16	-3.6	1.1	-	-	-	-	-	1.413	4.12%	68
75	2015-16	Type IV Validation and New Fluids	IP- / R-	FCY 9311	8	20	26-Jan-16	-3.9	0.0	IP=25 R=25	25	1.7, 2.3, 3.8	1, 1, 2.8	1, 1, 2.8	1.414	4.09%	100
76	2015-16	Type IV Validation and New Fluids	IP- / R-	LNT E450	8	20	26-Jan-16	-4	0.0	IP=25 R=25	25	1.3, 1.3, 3.2	1, 1.1, 1.1	1, 1, 1	1.411	4.28%	100
77	2015-16	IP Expansion - METAR	IP / R	AD-49	8	20	26-Jan-16	-4.5	-0.7	IP=75 R=75	25	2.7, 3, 5	2.3, 1.2, 5	2.3, 1.1, 5	1.291	12.38%	100

Table 3.1: Wind Tunnel Test Log 2015-16 (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 C_L at 8°	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
78	2015-16	IP Expansion - METAR	IP / R	AD-49	8	20	26-Jan-16	-0.43	-1.1	IP=75 R=75	10	2.3, 2.5, 3.8	1, 1, 1.8	1, 1, 1.2	1.429	3.02%	100
79	2015-16	IP Expansion - METAR	IP / R	AD-49	8	20	26-Jan-16	-4	0.0	IP=75 R=75	15	2.7, 2.8, 5	1, 1, 5	1, 1, 3.3	1.359	7.79%	100
80	2015-16	IP Expansion - METAR	IP / R	FCY 9311	8	20	26-Jan-16	-3.8	-0.4	IP=75 R=75	15	2.3, 2.7, 5	1, 1.1, 4	1, 1, 5	1.350	8.41%	100
81	2015-16	IP Expansion - METAR	IP / R	Polar Guard Advance	8	20	26-Jan-16	-3	0.4	IP=75 R=75	15	2.7, 2.8, 5	1, 1.1, 5	1, 1, 5	1.397	5.23%	100
82	2015-16	IP Expansion - METAR	IP / R	ABC-S Plus	8	20	26-Jan-16	-2.6	1.3	IP=75 R=75	15	2.5, 2.7, 5	1, 1.3, 5	1, 1, 5	1.375	6.72%	100
83	2015-16	Baseline	Dry Wing	none	8	20	27-Jan-16	-7.1	-3.4	-	-	-	-	-	1.481	-0.49%	100
84	2015-16	Baseline	Dry Wing	none	22	20	27-Jan-16	-7.1	-3.4	-	-	-	-	-	1.482	-0.57%	80
85	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	27-Jan-16	-7.9	-2.5	-	-	-	-	-	1.406	4.62%	68
86	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	27-Jan-16	-9.2	-4.0	-	-	-	-	-	1.427	3.17%	80
87	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	22	20	27-Jan-16	-9.6	-4.8	-	-	-	-	-	1.439	2.36%	80
88	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	28-Jan-16	-9.6	-4.7	-	-	-	-	-	1.436	2.55%	100

Table 3.1: Wind Tunnel Test Log 2015-16 (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 C_L at 8°	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
89	2015-16	Baseline	Dry Wing	none	22	20	28-Jan-16	-9.1	-8.1	-	-	-	-	-	1.478	-0.29%	68
90	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	22	20	28-Jan-16	-8.7	-6.1	-	-	-	-	-	1.419	3.74%	68
91	2015-16	Type III Allowance Times	IP- / ZR-	AeroClear MAX - Cold	8	20	28-Jan-16	-8.4	-2.7	IP=25 ZR=25	7	1.5, 1.7, 2.3	1, 1, 1.1	1, 1, 1.1	1.436	2.54%	80
92	2015-16	IP Expansion - Current IP and SN	IP- / SN-	FCY 9311	8	20	28-Jan-16	-8.5	-4.0	IP=25 SN=10	40	2.9, 2.8, 4	1.1, 1.5, 2.3	1, 1.3, 1.2	1.356	7.99%	100
93	2015-16	Type IV Validation and New Fluids	IP- / SN-	FCY 9311	8	20	28-Jan-16	-7.6	-1.7	IP=25 SN=10	25	2.5, 2.7, 3.8	1, 1.5, 2.2	1, 1.1, 1.2	1.389	5.75%	100
94	2015-16	Type IV Validation and New Fluids	IP- / ZR-	FCY 9311	8	20	28-Jan-16	-7.3	-2.1	IP=25 ZR=25	25	2.3, 2.8, 5	1, 1.4, 5	1, 1, 5	1.328	9.91%	100
95	2015-16	Type IV Validation and New Fluids	IP- / ZR-	FCY 9311	8	0	28-Jan-16	-6.7	-1.7	IP=25 ZR=25	25	2.3, 2.3, 3	1, 1.1, 1.2	1, 1, 1	1.437	2.52%	100
96	2015-16	Baseline	Dry Wing	none	8	20	28-Jan-16	-1	5.3	-	-	-	-	-	1.493	-1.32%	100
97	2015-16	Baseline	Dry Wing	none	22	20	28-Jan-16	-1	5.3	-	-	-	-	-	1.492	-1.20%	80
98	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	28-Jan-16	-1.1	2.2	-	-	-	-	-	1.427	3.19%	68
99	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	22	20	28-Jan-16	-1.1	2.2	-	-	-	-	-	1.430	2.98%	68

Table 3.1: Wind Tunnel Test Log 2015-16 (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 C_L at 8°	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
100	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	28-Jan-16	-1.1	1.8	-	-	-	-	-	1.447	1.81%	80
101	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	22	20	28-Jan-16	-1.2	1.7	-	-	-	-	-	1.447	1.84%	80
102	2015-16	Type III Allowance Times	Fluid Only	AeroClear MAX - Cold	8	20	29-Jan-16	-1.2	1.7	-	-	-	-	-	1.456	1.20%	100
103	2015-16	Type III Allowance Times	IP Mod	AeroClear MAX - Cold	8	20	29-Jan-16	-1.2	2.1	IP=75	5	1.8, 2, 2.2	1, 1, 1.1	1, 1, 1	1.458	1.04%	80
104	2015-16	Type III Allowance Times	IP Mod	AeroClear MAX - Cold	8	20	29-Jan-16	-1.4	2.9	IP=75	15	2.2, 2.5, 4	1, 1, 1.1	1, 1, 1	1.462	0.83%	80
105	2015-16	Heavy Contamination	IP+/ZR-	AeroClear MAX - Cold	22	20	29-Jan-16	-1.1	2.3	IP=150 ZR=25	25	4.3, 4.3, 4.7	1, 1, 5	1, 1, 1	1.156	21.54%	80

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4. LIGHT ICE PELLET ALLOWANCE TIMES

A summary of the light ice pellet tests conducted with Type III fluids in the wind tunnel is shown in Table 4.1. A summary of the light ice pellet tests conducted with Type IV fluids in the wind tunnel is shown in Table 4.2. These tables provide 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.

4.1 Analysis of Data Collected

The data collected has been sorted according to test parameters and included in the respective cells of the ice pellet allowance time table format for ease of reference; this is shown in Table 4.3 and Table 4.4 for Types III and IV fluids, respectively. A more detailed analysis separating the data according to the allowance time cell and rotation speed has been conducted and is shown in Table 4.5 and Table 4.6. In addition, a conclusion regarding the test results has also been included for each condition.

4.2 Overall Summary of Results

The following sections provide an overall summary of the results.

4.2.1 Type III Testing

The testing results indicated that the current allowance time of 10 minutes was acceptable for the new Type III fluid (AllClear AeroClear MAX) down to -10ºC when applied cold (air temperature). The test results also indicate some margin to increase the current allowance time; however, additional testing is required.

4.2.2 Type IV Testing

The test results indicated that the current allowance times for Light Ice Pellets are acceptable for the new-to-market FCY 9311 and LNT E450 fluids.

One test (#9) with FCY 9311 was conducted at 100 knots instead of 115 knots, which yielded unacceptable results. Temperatures above -10ºC were expected and hence the 100-knot test was performed; however, the actual temperature was lower. Below -10ºC, propylene glycol (PG) fluid is only allowed for aircraft with rotation speeds above 115 knots. The test was not re-run due to limited fluid supplies; however, based on the fluid performance at 100 knots compared to other PG Type IV fluids, it was expected that the results would also be acceptable at 115 knots.

Table 4.1: Summary of 2015-16 Type III Light Ice Pellet Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
28	IP-	AeroClear MAX - Cold	8	20	-9	-5.5	IP=25	10	2.2, 2, 2.4	1, 1, 1.5	2.73%	80

Table 4.2: Summary of 2015-16 Type IV Light Ice Pellet Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
9	IP-	FCY 9311	8	20	-16.2	-15.4	IP=25	30	2.4, 2.4, 3.8	1.1, 1.7, 2.3	10.09%	100
10	IP-	LNT E450	8	20	-16.8	-15.2	IP=25	30	2.2, 2.2, 2.6	1, 1.3, 1.7	5.82%	100
63	IP-	FCY 9311	8	20	-7.1	-2.6	IP=25	50	2.7, 2.8, 4	1, 1.4, 1.6	3.46%	100

Table 4.3: Type III Light Ice Pellets Allowance Time Tests Winter 2015-16

Light Ice Pellets	**OAT -5°C and Above**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
80 kts	10 Minutes N/A	10 Minutes Test # 28	No Allowance Times Currently Exist N/A

Table 4.4: Type IV Light Ice Pellets Allowance Time Tests Winter 2015-16

Light Ice Pellets	**OAT -5°C and Above**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
100 kts	50 Minutes Test #63	30 Minutes N/A	30 Minutes Tests # 9, 10

Table 4.5: Summary of Type III Light Ice Pellets Allowance Time Test Results

OAT Less than -5°C To -10°C 80 Knots (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**
28	AeroClear MAX - Cold	-5.5	IP=25	10	2.2, 2, 2.4	Good	1, 1, 1.5	Good	2.73%	Good	Good
Conclusion: 10-minute allowance time is good for cold fluid and could be increased.											

Table 4.6: Summary of Type IV Light Ice Pellets Allowance Time Test Results

<table>
<tr><th colspan="12">OAT -5°C and Above 100 Knots (50 Minutes)</th></tr>
<tr><th>Run(hs)#</th><th>Fluid</th><th>Tunnel Temp. Before Test (°C)</th><th>Precipitation Rate (g/dm²/h)</th><th>Exposure Time (min)</th><th>Visual Contamination Rating Before Takeoff (LE, TE, Flap)</th><th>Before Takeoff Status</th><th>Visual Contamination Rating at Rotation (LE, TE, Flap)</th><th>At Rotation Status</th><th>% Lift Loss</th><th>Lift Loss Status</th><th>Overall Status</th></tr>
<tr><td>63</td><td>FCY 9311</td><td>-2.6</td><td>IP=25</td><td>50</td><td>2.7, 2.8, 4</td><td>Good</td><td>1,1.4, 1.6</td><td>Good</td><td>3.46</td><td>Good</td><td>Good</td></tr>
<tr><td colspan="12">Conclusion: 50 minute allowance time is good.</td></tr>
<tr><th colspan="12">OAT Less than -10°C 100 Knots (30 Minutes)</th></tr>
<tr><th>Run(hs)#</th><th>Fluid</th><th>Tunnel Temp. Before Test (°C)</th><th>Precipitation Rate (g/dm²/h)</th><th>Exposure Time (min)</th><th>Visual Contamination Rating Before Takeoff (LE, TE, Flap)</th><th>Before Takeoff Status</th><th>Visual Contamination Rating at Rotation (LE, TE, Flap)</th><th>At Rotation Status</th><th>% Lift Loss</th><th>Lift Loss Status</th><th>Overall Status</th></tr>
<tr><td>9*</td><td>FCY 9311</td><td>-15.4</td><td>IP=25</td><td>30</td><td>2.4, 2.4, 3.8</td><td>Good</td><td>1.1, 1.7, 2.3</td><td>Review</td><td>10.09%</td><td>Bad</td><td>Bad</td></tr>
<tr><td>10</td><td>LNT E450</td><td>-15.2</td><td>IP=25</td><td>30</td><td>2.2, 2.2, 2.6</td><td>Good</td><td>1, 1.3, 1.7</td><td>Good</td><td>5.82%</td><td>Review</td><td>Review</td></tr>
<tr><td colspan="12">* Test run at 100 kts, but should have been 115 kts; test expected to be acceptable at 115 kts.</td></tr>
<tr><td colspan="12">Conclusion: 30-minute allowance time is good at 115 kts.</td></tr>
</table>

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5. MODERATE ICE PELLET ALLOWANCE TIMES

A summary of the moderate ice pellet tests conducted with Type III and Type IV fluids in the wind tunnel is shown in Table 5.1 and Table 5.2, respectively. The tables provide 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.

5.1 Analysis of Data Collected

The data collected has been sorted according to test parameters and included in the respective cells of the ice pellet allowance time table format for ease of reference; this is shown in Table 5.3 and Table 5.4. A more detailed analysis separating the data according to the allowance time cell and rotation speed has been conducted and is shown in Table 5.5 and Table 5.6. In addition, a conclusion regarding the test results has also been included for each condition.

5.2 Overall Summary of Results

The following sections provide an overall summary of the results.

5.2.1 Type III Testing

The testing results indicated that the current allowance time of 5 minutes is acceptable for the new Type III fluid when applied cold at temperatures below -5°C to -10°C (no tests were performed below this temperature). The fluid also yielded acceptable results when exposed to contamination for 15 minutes at temperatures above -5°C, indicating a potential to increase the allowance time with additional data.

5.2.2 Type IV Testing

The testing results showed that the current allowance times for Moderate Ice Pellets are valid for both LNT E450 and FCY 9311. The performance was comparable with other ethylene glycol (EG) and PG fluids previously tested.

Table 5.1: Summary of 2015-16 Type III Moderate Ice Pellet Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
29	IP Mod	AeroClear MAX - Cold	8	20	-9	-5.3	IP=75	5	2, 2, 2.7	1, 1.2, 1.4	2.14%	80
103	IP Mod	AeroClear MAX - Cold	8	20	-1.2	2.1	IP=75	5	1.8, 2, 2.2	1, 1, 1.1	1.04%	80
104	IP Mod	AeroClear MAX - Cold	8	20	-1.4	2.9	IP=75	15	2.2, 2.5, 4	1, 1, 1.1	0.83%	80

Table 5.2: Summary of 2015-16 Type IV Moderate Ice Pellet Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
11	IP Mod	LNT E450	8	20	-17.1	-16.8	IP=75	10	2, 2.2, 2.6	1.1, 1.3, 1.8	5.97%	100
13	IP Mod	LNT E450	8	20	-17	-15.4	IP=75	10	2.2, 2.2, 2.6	1.1, 1.4, 2.2	6.43%	100
14	IP Mod	FCY 9311	8	20	-17.2	-15.8	IP=75	10	2.5, 2.7, 3.8	1, 1.7, 2.7	8.45%	115
69	IP Mod	LNT E450	8	20	-6.6	-2.0	IP=75	25	2.3, 2.5, 4	1, 1.4, 1.9	3.30%	100

Table 5.3: Type III Moderate Ice Pellets Allowance Time Tests Winter 2015-16

Moderate Ice Pellets	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
80 kts	5 Minutes Test # 103	5 Minutes Test # 29	No Allowance Times Currently Exist N/A
	15 Minutes Test # 104		

Table 5.4: Type IV Moderate Ice Pellets Allowance Time Tests Winter 2015-16

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 Test # 69	10 Minutes N/A	10 Minutes Tests # 11, 13
115 kts			10 Minutes Test # 14

Table 5.5: Summary of Type III Moderate Ice Pellets Allowance Time Test Results

<table>
<tr><th colspan="12">OAT -5°C and Above 80 Knots (5 Minutes)</th></tr>
<tr><th>Run(hs)#</th><th>Fluid</th><th>Tunnel Temp. Before Test (°C)</th><th>Precipitation Rate (g/dm²/h)</th><th>Exposure Time (min)</th><th>Visual Contamination Rating Before Takeoff (LE, TE, Flap)</th><th>Before Takeoff Status</th><th>Visual Contamination Rating at Rotation (LE, TE, Flap)</th><th>At Rotation Status</th><th>% Lift Loss</th><th>Lift Loss Status</th><th>Overall Status</th></tr>
<tr><td>103</td><td>AeroClear MAX - Cold</td><td>2.1</td><td>IP=75</td><td>5</td><td>1.8, 2, 2.2</td><td>Good</td><td>1, 1, 1.1</td><td>Good</td><td>1.04%</td><td>Good</td><td>Good</td></tr>
<tr><th colspan="12">80 Knots (15 Minutes)</th></tr>
<tr><td>104</td><td>AeroClear MAX - Cold</td><td>2.9</td><td>IP=75</td><td>15</td><td>2.2, 2.5, 4</td><td>Good</td><td>1, 1, 1.1</td><td>Good</td><td>0.83%</td><td>Good</td><td>Good</td></tr>
<tr><td colspan="12">Conclusion: 5-minute allowance time is good for cold fluid and could be increased.</td></tr>
</table>

<table>
<tr><th colspan="12">OAT Less than -5°C to-10°C 80 Knots (5 Minutes)</th></tr>
<tr><th>Run(hs)#</th><th>Fluid</th><th>Tunnel Temp. Before Test (°C)</th><th>Precipitation Rate (g/dm²/h)</th><th>Exposure Time (min)</th><th>Visual Contamination Rating Before Takeoff (LE, TE, Flap)</th><th>Before Takeoff Status</th><th>Visual Contamination Rating at Rotation (LE, TE, Flap)</th><th>At Rotation Status</th><th>% Lift Loss</th><th>Lift Loss Status</th><th>Overall Status</th></tr>
<tr><td>29</td><td>AeroClear MAX - Cold</td><td>-5.3</td><td>IP=75</td><td>5</td><td>2, 2, 2.7</td><td>Good</td><td>1, 1.2, 1.4</td><td>Good</td><td>2.14%</td><td>Good</td><td>Good</td></tr>
<tr><td colspan="12">Conclusion: 5-minute allowance time is good for cold fluid.</td></tr>
</table>

Table 5.6: Summary of Type IV Moderate Ice Pellets Allowance Time Test Results

OAT -5°C and Above 100 Knots (25 Minutes)											
Run(hs)#	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm^2/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**
69	LNT E450	-2.0	IP=75	25	2.3, 2.5, 4	**Good**	1, 1.4, 1.9	**Good**	3.30%	**Good**	**Good**
Conclusion: 25 minute allowance time is good.											

OAT Less than -10°C 100 Knots (10 Minutes)											
Run(hs)#	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm^2/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**
11	LNT E450	-16.8	IP=75	10	2, 2.2, 2.6	**Good**	1.1, 1.3, 1.8	**Review**	5.97%	**Review**	**Review**
13	LNT E450	-15.4	IP=75	10	2.2, 2.2, 2.6	**Good**	1.1, 1.4, 2.2	**Review**	6.43%	**Review**	**Review**
115 Knots (10 Minutes)											
14	FCY 9311	-15.8	IP=75	10	2.5, 2.7, 3.8	**Good**	1, 1.7, 2.7	**Good**	8.45%	**Review**	**Review**
Conclusion: 10-minute allowance time good for EG fluids with rotation speeds >100 knots and for PG fluids to -16°C with rotation speeds >115 knots.											

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6. LIGHT ICE PELLETS MIXED WITH LIGHT FREEZING RAIN ALLOWANCE TIMES

A summary of the light ice pellets mixed with light freezing rain tests conducted with Type III and Type IV fluids in the wind tunnel is shown in Table 6.1 and Table 6.2. The tables provide 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.

It should be noted that the guidance issued for Light Ice Pellets Mixed with Light Freezing Rain is also applied to Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle.

6.1 Analysis of Data Collected

The data collected has been sorted according to test parameters and included in the respective cells of the ice pellet allowance time table format for ease of reference; this is shown in Table 6.3 and Table 6.4. A more detailed analysis separating the data according to the allowance time cell and rotation speed has been conducted and is shown in Table 6.5 and Table 6.6. In addition, a conclusion regarding the test results has also been included for each condition.

6.2 Overall Summary of Results

The following sections provide an overall summary of the results.

6.2.1 Type III Testing

The testing results indicated that the current Type III allowance times for Light Ice Pellets Mixed with Light Freezing Rain are acceptable for Aeroclear MAX. In -5ºC and above condition, the wing area test temperatures were slightly more conservative (below -5ºC); however, the results were positive. In the case of the below -5ºC to -10ºC conditions, the wing area temperature was slightly above the upper limit; however, the results indicated sufficient margins in the visual and aerodynamic performance.

6.2.2 Type IV Testing

The testing results indicated that the current Type IV allowance times for Light Ice Pellets Mixed with Light Freezing Rain are acceptable for LNT E450 and FCY 9311.

In the case of the FCY 9311, higher lift losses and poor visual ratings before the start of the tests were experienced due to the significant fluid failure on the extended flap configuration in the -5°C and above condition. Previous wind tunnel research has shown that when the airfoil is configured with the flap set to 0º (retracted) during the exposure to precipitation and then returned to 20º (extended) for takeoff, the results significantly improve; see TP 15232E (1). Some additional tests (#65, 66, 67) were conducted in 2015-16 with historical PG fluids to confirm a performance similar to that of FCY 9311. This issue of early failure on flaps and slats is being investigated separately. The EG-based LNT E450 performed similarly to historical EG fluids and experienced less severe failure patterns compared to the PG fluids. No issues were observed below -5°C to -10°C for either LNT E450 or FCY 9311.

Table 6.1: Summary of 2015-16 Type III Light Ice Pellets Mixed with Light Freezing Rain Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
30	IP- / ZR-	AeroClear MAX - Cold	8	20	-9.7	-4.1	IP=25 ZR=25	5	1.8, 2, 2.1	1, 1, 1.2	2.52%	80
59	IP- / ZR-	AeroClear MAX - Cold	8	20	-13	-6.6	IP=25 ZR=25	7	1.7, 1.7, 2.5	1, 1, 1.4	2.79%	80
91	IP- / ZR-	AeroClear MAX - Cold	8	20	-8.4	-2.7	IP=25 ZR=25	7	1.5, 1.7, 2.3	1, 1, 1.1	2.54%	80

Table 6.2: Summary of 2015-16 Type IV Light Ice Pellets Mixed with Light Freezing Rain Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
19	IP- / ZR-	FCY 9311	8	20	-10	-8.5	IP=25 ZR=25	10	2.5, 2.5, 3.5	1, 1.5, 1.8	6.27%	100
20	IP- / ZR-	LNT E450	8	20	-8.9	-7.6	IP=25 ZR=25	10	1.8, 2, 2	1, 1.1, 1.5	4.90%	100
64	IP- / ZR-	FCY 9311	8	20	-7.6	-1.5	IP=25 ZR=25	25	2.7, 2.8, 4.3	1, 1.1, 5	8.40%	100
65	IP- / ZR-	ABC-S Plus	8	20	-7.5	-1.5	IP=25 ZR=25	25	2.8, 2.8, 5	1, 1.3, 5	5.51%	100
66	IP- / ZR-	Polar Guard Advance	8	20	-7.2	-0.6	IP=25 ZR=25	25	2.6, 2.7, 4.7	1, 1.1, 5	5.82%	100
67	IP- / ZR-	AD-49	8	20	-7	-1.5	IP=25 ZR=25	25	2.8, 2.8, 5	1, 1.3, 5	6.49%	100
68	IP- / ZR-	LNT E450	8	20	-6.7	-1.3	IP=25 ZR=25	25	2, 2, 2.3	1, 1, 1.1	3.11%	100
94	IP- / ZR-	FCY 9311	8	20	-7.3	-2.1	IP=25 ZR=25	25	2.3, 2.8, 5	1, 1.4, 5	9.91%	100
95	IP- / ZR-	FCY 9311	8	0	-6.7	-1.7	IP=25 ZR=25	25	2.3, 2.3, 3	1, 1.1, 1.2	2.52%	100

Table 6.3: Type III Light Ice Pellets Mixed with Light Freezing Rain Allowance Time Tests Winter 2015-16

Light Ice Pellets Mixed with Light Freezing Rain	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
80 kts	7 Minutes Test # 59, 91	5 Minutes Test # 30	No Allowance Times Currently Exist N/A

Table 6.4: Type IV Light Ice Pellets Mixed with Light Freezing Rain Allowance Time Tests Winter 2015-16

Light Ice Pellets Mixed with Light Freezing Rain	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
100 kts	25 Minutes Tests # 64, 65, 66, 67, 68, 94, 95	10 Minutes Tests # 19, 20	No Allowance Times Currently Exist N/A

Table 6.5: Summary of Type III Light Ice Pellets Mixed with Light Freezing Rain Allowance Time Test Results

OAT -5°C and Above 80 Knots (7 Minutes)

Run(hs)#	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
30	AeroClear MAX - Cold	-4.1	IP=25 ZR=25	5	1.8, 2, 2.1	Good	1, 1, 1.2	Good	2.52%	Good	Good
91	AeroClear MAX - Cold	-2.7	IP=25 ZR=25	7	1.5, 1.7, 2.3	Good	1, 1, 1.1	Good	2.54%	Good	Good

Conclusion: 7-minute allowance time is good for cold fluid.

OAT Below -5°C to -10°C 80 Knots (5 Minutes)

Run(hs)#	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
59	AeroClear MAX - Cold	-6.6	IP=25 ZR=25	7	1.7, 1.7, 2.5	Good	1, 1, 1.4	Good	2.79%	Good	Good

Conclusion: 5-minute allowance time is good for cold fluid.

Table 6.6: Summary of Type IV Light Ice Pellets Mixed with Light Freezing Rain Allowance Time Test Results

OAT -5°C and Above 100 Knots (25 Minutes)

Run(hs)#	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
64	FCY 9311	-1.5	IP=25 ZR=25	25	2.7, 2.8, 4.3	Review	1, 1.1, 5	Good	8.40%	Review	Review
65	ABC-S Plus	-1.5	IP=25 ZR=25	25	2.8, 2.8, 5	Review*	1, 1.3, 5	Good	5.51%	Review	Review*
66	Polar Guard Advance	-0.6	IP=25 ZR=25	25	2.6, 2.7, 4.7	Review*	1, 1.1, 5	Good	5.82%	Review	Review*
67	AD-49	-1.5	IP=25 ZR=25	25	2.8, 2.8, 5	Review*	1, 1.3, 5	Good	6.49%	Review	Review*
68	LNT E450	-1.3	IP=25 ZR=25	25	2, 2, 2.3	Good	1, 1, 1.1	Good	3.11%	Good	Good
94	FCY 9311	-2.1	IP=25 ZR=25	25	2.3, 2.8, 5	Review*	1, 1.4, 5	Good	9.91%	Bad	Review*
95	FCY 9311	-1.7	IP=25 ZR=25	25	2.3, 2.3, 3	Good	1, 1.1, 1.2	Good	2.52%	Good	Good

* Significant fluid failure was present on the flap when in extended configuration during exposure. Although this is considered "bad," previous work has shown that the failure is directly due to the configuration. With flaps in the retracted configuration, fluid performance is significantly improved, and therefore this scenario is acceptable. For this reason, the visual rating and overall rating are given a "Review" status.

Conclusion: 25-minute allowance times is good for new FCY 9311 and LNT E450 fluids. Higher lift losses due to flaps down configuration for PG fluids validated by re-running historical fluids.

OAT Less than -5°C to -10°C 100 Knots (10 Minutes)

Run(hs)#	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
19	FCY 9311	-8.5	IP=25 ZR=25	10	2.5, 2.5, 3.5	Good	1, 1.5, 1.8	Good	6.27%	Review	Review
20	LNT E450	-7.6	IP=25 ZR=25	10	1.8, 2, 2	Good	1, 1.1, 1.5	Good	4.90%	Good	Good

Conclusion: 10-minute allowance time is good.

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7. LIGHT ICE PELLETS MIXED WITH LIGHT RAIN ALLOWANCE TIMES

A summary of the light ice pellets mixed with light rain tests conducted with Type III and Type IV fluids in the wind tunnel is shown in Table 7.1 and Table 7.2, respectively. The tables provide 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.

7.1 Analysis of Data Collected

The data collected has been sorted according to test parameters and included in the respective cells of the ice pellet allowance time table format for ease of reference; this is shown in Table 7.3 and Table 7.4. A more detailed analysis separating the data according to the allowance time cell and rotation speed has been conducted and is shown in Table 7.5 and Table 7.6. In addition, a conclusion regarding the test results has also been included for each condition.

7.2 Overall Summary of Results

The following sections provide an overall summary of the results.

7.2.1 Type III Testing

The testing results indicated that the current Type III allowance time of 7 minutes for Light Ice Pellets Mixed with Light Rain is valid for AeroClear MAX when applied cold.

7.2.2 Type IV Testing

The testing results indicated that the current Type IV allowance time of 25 minutes for Light Ice Pellets Mixed with Light Rain is valid for both new fluids tested (LNT E450 and FCY 9311).

Table 7.1: Summary of 2015-16 Type III Light Ice Pellets Mixed with Light Rain Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
72	IP- / R-	AeroClear MAX - Cold	8	20	-3.5	2.4	IP=25 R=25	7	1, 1.3, 1.4	1, 1, 1.2	2.02%	80

Table 7.2: Summary of 2015-16 Type IV Light Ice Pellets Mixed with Light Rain Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
75	IP- / R-	FCY 9311	8	20	-3.9	0.0	IP=25 R=25	25	1.7, 2.3, 3.8	1, 1, 2.8	4.09%	100
76	IP- / R-	LNT E450	8	20	-4	0.0	IP=25 R=25	25	1.3, 1.3, 3.2	1, 1.1, 1.1	4.28%	100

Table 7.3: Type III Light Ice Pellets Mixed with Light Rain Testing Allowance Time Tests Winter 2015-16

Light Ice Pellets Mixed with Light Rain	**OAT -5°C and Above** **(No allowance times below 0°C)**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
80 kts	7 Minutes Test # 72	No Allowance Times Currently Exist N/A	No Allowance Times Currently Exist N/A

Table 7.4: Type IV Light Ice Pellets Mixed with Light Rain Allowance Time Tests Winter 2015-16

Light Ice Pellets Mixed with Light Rain	**OAT -5°C and Above** **(No allowance times below 0°C)**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
100 kts	25 Minutes Tests # 75, 76	No Allowance Times Currently Exist N/A	No Allowance Times Currently Exist N/A

Table 7.5: Summary of Type III Light Ice Pellets Mixed with Light Rain Allowance Time Test Results

OAT -5°C and Above 80 Knots (7 Minutes)											
Run(hs)#	**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**
72	AeroClear MAX - Cold	2.4	IP=25 R=25	7	1, 1.3, 1.4	Good	1, 1, 1.2	Good	2.02%	Good	Good
Conclusion: 7-minute allowance time good for cold fluid.											

Table 7.6: Summary of Type IV Light Ice Pellets Mixed with Light Rain Allowance Time Test Results

OAT -5°C and Above 100 Knots (25 Minutes)											
Run(hs)#	**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**
75	FCY 9311	0.0	IP=25 R=25	25	1.7, 2.3, 3.8	Good	1, 1, 2.8	Good	4.09%	Good	Good
76	LNT E450	0.0	IP=25 R=25	25	1.3, 1.3, 3.2	Good	1, 1.1, 1.1	Good	4.28%	Good	Good
Conclusion: 25-minute allowance time is good.											

8. MODERATE ICE PELLETS MIXED WITH MODERATE RAIN ALLOWANCE TIMES

A summary of the moderate ice pellets mixed with moderate rain tests conducted with Type IV fluids 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.

8.1 Analysis of Data Collected

The data collected has been sorted according to test parameters and included in the respective cells of the ice pellet allowance time table format for ease of reference; this is shown in Table 8.2. A more detailed analysis separating the data according to the allowance time cell and rotation speed has been conducted and is shown in Table 8.3. In addition, a conclusion regarding the test results has also been included for each condition.

8.2 Overall Summary of Results

The following sections provide an overall summary of the results.

8.2.1 Type IV Testing

Prior to the winter of 2015-16, allowance times did not exist for this condition. Testing aimed at providing guidance to support operations as this was identified as an operationally significant condition based on potential METAR-reported conditions. Testing targeted conditions at or above 0°C, using a range of exposure times in order to determine the appropriate allowance time based on the aerodynamic and visual performance.

The majority of the tests were conducted with 15-minute exposure times, and the results were positive; however, higher lift losses and poor visual ratings at the start of the tests were experienced due to the significant fluid failure on the extended flap configuration. Previous wind tunnel research has shown that when the airfoil is configured with the flap set to 0° (retracted) for the exposure to precipitation and then returned to 20° (extended) for takeoff, the results significantly improve; see TP 15232E (1). This issue of early failure on flaps and slats is being investigated separately, and a final report is expected to be completed for the Winter 2015-16 testing season. One test was conducted at a 10-minute exposure that confirmed the expected improvement, and an additional test was conducted at a 25-minute exposure that indicated the detrimental effect of the severity of contamination due to longer exposure times. Although the majority of the tests were done with 15-minute exposure times and the results were positive, a 10-minute allowance time is better suited as an interim conservative allowance time. With some additional testing to support the current data, the allowance time should be increased to 15 minutes or potentially 20 minutes.

Table 8.1: Summary of 2015-16 Type IV Moderate Ice Pellets Mixed with Moderate Rain Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
77	IP / R	AD-49	8	20	-4.5	-0.7	IP=75 R=75	25	2.7, 3, 5	2.3, 1.2, 5	12.38%	100
78	IP / R	AD-49	8	20	-0.43	-1.1	IP=75 R=75	10	2.3, 2.5, 3.8	1, 1, 1.8	3.02%	100
79	IP / R	AD-49	8	20	-4	0.0	IP=75 R=75	15	2.7, 2.8, 5	1, 1, 5	7.79%	100
80	IP / R	FCY 9311	8	20	-3.8	-0.4	IP=75 R=75	15	2.3, 2.7, 5	1, 1.1, 4	8.41%	100
81	IP / R	Polar Guard Advance	8	20	-3	0.4	IP=75 R=75	15	2.7, 2.8, 5	1, 1.1, 5	5.23%	100
82	IP / R	ABC-S Plus	8	20	-2.6	1.3	IP=75 R=75	15	2.5, 2.7, 5	1, 1.3, 5	6.72%	100

Table 8.2: Type IV Moderate Ice Pellets Mixed with Moderate Rain Allowance Time Tests Winter 2015-16

Moderate Ice Pellets Mixed with Moderate Snow	**OAT -5°C and Above** **(No allowance times below 0°C)**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
100 kts	No Allowance Times Currently Exist N/A	No Allowance Times Currently Exist N/A	No Allowance Times Currently Exist N/A
	10 Minutes Test # 78		
	15 Minutes Tests # 79, 80, 81, 82		
	25 Minutes Test # 77		

Table 8.3: Summary of Type IV Moderate Ice Pellets Mixed with Moderate Rain Allowance Time Test Results

Run(hs)#	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 Knots (10 Minutes)											
78	AD-49	-1.1	IP=75 R=75	10	2.3, 2.5, 3.8	Good	1, 1, 1.8	Good	3.02%	Good	Good
100 Knots (15 Minutes)											
79	AD-49	0.0	IP=75 R=75	15	2.7, 2.8, 5	Review*	1, 1, 5	Good	7.79%	Review	Review*
80	FCY 9311	-0.4	IP=75 R=75	15	2.3, 2.7, 5	Review*	1, 1.1, 4	Good	8.41%	Review	Review*
81	Polar Guard Advance	0.4	IP=75 R=75	15	2.7, 2.8, 5	Review*	1, 1.1, 5	Good	5.23%	Good	Review*
82	ABC-S Plus	1.3	IP=75 R=75	15	2.5, 2.7, 5	Review*	1, 1.3, 5	Good	6.72%	Review	Review*
100 Knots (25 Minutes)											
77	AD-49	-0.7	IP=75 R=75	25	2.7, 3, 5	Bad	2.3, 1.2, 5	Bad	12.38%	Bad	Bad

* Significant fluid failure was present on the flap when in extended configuration during exposure. Although this is considered "bad," previous work has shown that the failure is directly due to the configuration. With flaps in the retracted configuration, fluid performance is significantly improved, and therefore this scenario is acceptable. For this reason, the visual rating and overall rating are given a "Review" status.

Conclusion: Based on the performance at 15 minutes, 10 minutes expected to be acceptable and conservative.

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9. MODERATE ICE PELLETS MIXED WITH MODERATE FREEZING DRIZZLE

A summary of the moderate ice pellets mixed with moderate freezing drizzle tests conducted with Type IV fluids 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.

9.1 Analysis of Data Collected

The data collected has been sorted according to test parameters and included in the respective cells of the ice pellet allowance time table format for ease of reference; this is shown in Table 9.2. A more detailed analysis separating the data according to the allowance time cell and rotation speed has been conducted and is shown in Table 9.3. In addition, a conclusion regarding the test results has also been included for each condition of Table 9.3.

9.2 Overall Summary of Results

Prior to the winter of 2015-16, allowance times did not exist for this condition; testing aimed at providing guidance to support operations as this was identified as an operationally significant condition based on potential METAR-reported conditions. Testing targeted conditions above -10°C, using a range of exposure times in order to determine the appropriate allowance time based on the aerodynamic and visual performance.

Testing targeted 15 minutes for -5°C and above conditions and 10 minutes for -5°C to -10°C conditions; no allowance times currently exist for these conditions. Acceptable results were obtained with 15-minute exposure times at -5°C and above. At -5°C to -10°C, one test provided results that were slightly above the acceptable aerodynamic limit; however, the fluid used tended to result in higher lift losses, likely due to the viscosity of the sample being in the higher end of the production range. To be conservative, allowance times of 10 minutes and 7 minutes, respectively, would provide some additional safety margins.

No testing was conducted with Type III fluids for this condition as Type III fluid is not thought to be suitable for the relatively heavy precipitation involved.

Table 9.1: Summary of 2015-16 Type IV Moderate Ice Pellets Mixed with Moderate Freezing Drizzle Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
25	IP / ZD	ABC-S Plus	8	20	-10.3	-7.2	IP = 75 ZD = 13	10	2.4, 2.5, 3.2	1.1, 1.5, 2.1	7.01%	100
35	IP / ZD	Polar Guard Advance	8	20	-11.6	-6.9	IP = 75 ZD = 13	10	2.7, 2.7, 3.9	1, 1.7, 2.5	9.32%	100
42	IP / ZD	ABC-S Plus	8	20	-7.1	-3.1	IP = 75 ZD = 13	15	3, 3, 4	1.1, 1.7, 2	6.06%	100
47	IP / ZD	AD-49	8	20	-8.5	-4.9	IP = 75 ZD = 13	15	2.8, 2.7, 3.8	1.1, 1.5, 1.9	6.07%	100
53	IP / ZD	Polar Guard Advance	8	20	-10.6	-4.8	IP = 75 ZD = 13	15	2.8, 3, 3.8	1, 1.5, 2.3	8.23%	100

Table 9.2: Type IV Moderate Ice Pellets Mixed with Moderate Freezing Drizzle Allowance Time Tests Winter 2015-16

Moderate Ice Pellets Mixed with Moderate Freezing Drizzle	OAT -5°C and Above	OAT Less than -5°C to -10°C	OAT Less than -10°C
100 kts	No Allowance Times Currently Exist N/A	No Allowance Times Currently Exist N/A	No Allowance Times Currently Exist N/A
	15 Minutes Test # 42, 47, 53	10 Minutes Tests # 25, 35	

Table 9.3: Summary of Type IV Moderate Ice Pellets Mixed with Moderate Freezing Drizzle Allowance Time Test Results

OAT -5°C and Above 100 Knots (15 Minutes)

Run(hs)#	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
42	ABC-S Plus	-3.1	IP = 75 ZD = 13	15	3, 3, 4	Good	1.1, 1.7, 2	Review	6.06%	Review	Review
47	AD-49	-4.9	IP = 75 ZD = 13	15	2.8, 2.7, 3.8	Good	1.1, 1.5, 1.9	Review	6.07%	Review	Review
53	Polar Guard Advance	-4.8	IP = 75 ZD = 13	15	2.8, 3, 3.8	Good	1, 1.5, 2.3	Good	8.23%	Review	Review

Conclusion: Based on the performance at 15 minutes, 10 minutes expected to be acceptable and conservative.

OAT Less than -5°C to -10°C 100 Knots (10 Minutes)

Run(hs)#	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
25	ABC-S Plus	-7.2	IP = 75 ZD = 13	10	2.4, 2.5, 3.2	Good	1.1, 1.5, 2.1	Review	7.01%	Review	Review
35	Polar Guard Advance	-6.9	IP = 75 ZD = 13	10	2.7, 2.7, 3.9	Good	1, 1.7, 2.5	Good	9.32%	Bad	Bad

Conclusion: Based on the performance at 10 minutes, 7 minutes expected to be acceptable and conservative.

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10. LIGHT ICE PELLETS MIXED WITH LIGHT SNOW ALLOWANCE TIMES

A summary of the light ice pellets mixed with light snow tests conducted with Type III and Type IV fluids in the wind tunnel is shown in Table 10.1 and Table 10.2. The tables provide 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.

It should be noted that testing in this condition with the objective of increasing the existing allowance times has been ongoing since 2009-10. The cumulative data set is discussed in Subsection 10.3.

10.1 Analysis of Data Collected in 2015-16

The data collected has been sorted according to test parameters and included in the respective cells of the ice pellet allowance time table format for ease of reference; this is shown in Table 10.3 and Table 10.4. A more detailed analysis separating the data according to the allowance time cell and rotation speed has been conducted and is shown in Table 10.5 and Table 10.6. In addition, a conclusion regarding the test results has also been included for each condition.

10.2 Overall Summary of 2015-16 Results

The following sections provide an overall summary of the results.

10.2.1 Type III Testing

The testing results indicated that the current allowance time of 10 minutes is valid for AllClear AeroClear MAX.

10.2.2 Type IV Testing

The tests conducted with FCY 9311 and LNT E450 demonstrated that the allowance times are valid for these fluids in both previously existing temperature bands. Additional tests were conducted with FCY 9311 and other fluids previously tested to support increasing and expanding the allowance times. These additional tests were analysed along with other data collected since 2009-10 to support the expansion of the allowance times. The details of the expansion analysis are included in Subsection 10.3.

Table 10.1: Summary of 2015-16 Type III Light Ice Pellets Mixed with Light Snow Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
31	IP- / SN-	AeroClear MAX - Cold	8	20	-10.1	-5.1	IP=25 SN=10	10	2, 1.7, 3	1, 1.2, 1.7	1.91%	80

Table 10.2: Summary of 2015-16 Type IV Light Ice Pellets Mixed with Light Snow Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
21	IP- / SN-	LNT E450	8	20	-9.2	-6.6	IP=25 SN=10	15	1.7, 2, 2.4	1, 1.4, 1.7	5.35%	100
22	IP- / SN-	FCY 9311	8	20	-9.6	-6.5	IP=25 SN=10	15	2.4, 2.8, 3.5	1.1, 1.5, 2.1	6.95%	100
43	IP- / SN-	ABC-S Plus	8	20	-7.5	-4.3	IP=25 SN=10	40	2.8, 2.8, 4	1.2, 1.7, 1.9	6.91%	100
46	IP- / SN-	AD-49	8	20	-8.1	-4.0	IP=25 SN=10	40	3.1, 3, 4	1.2, 1.8, 2.5	5.56%	100
51	IP- / SN-	Polar Guard Advance	8	20	-9.5	-5.1	IP=25 SN=10	40	2.8, 2.8, 4	1.1, 1.4, 2.6	8.73%	100
92	IP- / SN-	FCY 9311	8	20	-8.5	-4.0	IP=25 SN=10	40	2.9, 2.8, 4	1.1, 1.5, 2.3	7.99%	100
93	IP- / SN-	FCY 9311	8	20	-7.6	-1.7	IP=25 SN=10	25	2.5, 2.7, 3.8	1, 1.5, 2.2	5.75%	100

Table 10.3: Type III Light Ice Pellets Mixed with Light Snow Allowance Time Tests Winter 2015-16

Light Ice Pellets Mixed with Moderate Snow	**OAT -5°C and Above**	**OAT Less than -5°C to -10°C**	**OAT Less than -10°C**
80 Kts	10 Minutes N/A	10 Minutes Test # 31	No Allowance Times Currently Exist N/A

Table 10.4: Type IV Light Ice Pellets Mixed with Light Snow Allowance Time Tests Winter 2015-16

Light 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	25 Minutes Test # 93	15 Minutes Tests # 21, 22	No Allowance Times Currently Exist N/A
	40 Minutes Test # 43, 46, 51, 92		

Table 10.5: Summary of 2015-16 Type III Light Ice Pellets Mixed with Light Snow Allowance Time Test Results

OAT Less than -5°C to -10°C 80 Knots (10 Minutes)											
Run(hs)#	**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**
31	AeroClear MAX - Cold	-5.1	IP=25 SN=10	10	2, 1.7, 3	Good	1, 1.2, 1.7	Good	1.91	Good	Good
Conclusion: 10 minutes is good for cold fluid.											

Table 10.6: Summary of 2015-16 Type IV Light Ice Pellets Mixed with Light Snow Allowance Time Test Results

OAT -5°C and Above 100 Knots (25 Minutes)											
Run(hs)#	**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**
93	FCY 9311	-1.7	IP=25 SN=10	25	2.5, 2.7, 3.8	Good	1, 1.5, 2.2	Good	5.75	Review	Review
100 Knots (40 Minutes)											
43	ABC-S Plus	-4.3	IP=25 SN=10	40	2.8, 2.8, 4	Good	1.2, 1.7, 1.9	Review	6.91%	Review	Review
46	AD-49	-4.0	IP=25 SN=10	40	3.1, 3, 4	Review	1.2, 1.8, 2.5	Review	5.56%	Review	Review
51	Polar Guard Advance	-5.1	IP=25 SN=10	40	2.8, 2.8, 4	Good	1.1, 1.4, 2.6	Review	8.73%	Review	Review
92	FCY 9311	-4.0	IP=25 SN=10	40	2.9, 2.8, 4	Good	1.1, 1.5, 2.3	Review	7.99%	Review	Review
Conclusion: Allowance time is valid and can be expanded to 40 minutes; see Subsection 10.3 for additional information.											

OAT Less than -5°C to -10°C 100 Knots (15 Minutes)											
Run(hs)#	**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**
21	LNT E450	-6.6	IP=25 SN=10	15	1.7, 2, 2.4	Good	1, 1.4, 1.7	Good	5.35%	Good	Good
22	FCY 9311	-6.5	IP=25 SN=10	15	2.4, 2.8, 3.5	Good	1.1, 1.5, 2.1	Review	6.95%	Review	Review
Conclusion: 15-minute allowance time is good.											

10.3 Expansion of Light Ice Pellet Mixed with Light Snow Allowance Times

Research has been ongoing since 2009-10 to support the expansion of the Light Ice Pellet Mixed with Light Snow allowance times; therefore, a significant amount of data has been collected. The details of the tests conducted during the winters of 2009-10 to 2014-15 can be found in the wind tunnel testing report for the respective year; only a summary of those tests along with the current year's tests is presented here. The cumulative data sets have been separated into two sets: -5ºC and above and below -5ºC. Table 10.7 and Table 10.8 show the summarized information for each of the relevant tests.

Table 10.7: Cumulative Summary of Type IV Light Ice Pellets Mixed with Light Snow Allowance Time Test Results for Target >-5ºC from 2009-10 to 2015-16

Test Year	Test #	Fluid Name	Tunnel Temp. Before Test (ºC)	Exposure Time (min)	Speed Kts	**Lift Loss @8º (%)**	Rating Before Takeoff Run LE	Rating Before Takeoff Run TE	Rating Before Takeoff Run Flap	Rating at Rotation LE	Overall Status
Winter 2015-16	93	FCY 9311	-1.7	25	100	5.75%	2.5	2.7	3.8	1.0	*Review*
Winter 2009-10	5	ABC-S Plus	-4.8	25	100	1.83%	2	2	3	1	*Good*
Winter 2010-11	*74*	*Max-Flight*	*-4.8*	*25*	*100*	*6.75%*	*2.5*	*2.3*	*3*	*1*	*Review*
Winter 2012-13	171	AD-49	-5.4	25	100	7.54%	3	2.9	3.8	1.2	*Review*
Winter 2012-13	172	AD-49 (LOWV)	-5.6	25	100	6.15%	2.7	2.3	3.5	1.1	*Review*
Winter 2009-10	23	EG106	-3.2	40	100	1.15%	2.3	2.2	4	1	*Good*
Winter 2009-10	57	Launch	-3.6	40	100	4.19%	2.7	2.6	4	1	*Good*
Winter 2015-16	92	FCY 9311	-4.0	40	100	7.99%	2.9	2.8	4.0	1.1	*Review*
Winter 2015-16	46	AD-49	-4.0	40	100	5.56%	3.1	3.0	4.0	1.2	*Review*
Winter 2009-10	57A	Launch	-4.2	40	100	2.53%	2.6	2.6	3	1	*Good*
Winter 2015-16	43	ABC-S Plus	-4.3	40	100	6.91%	2.8	2.8	4.0	1.2	*Review*
Winter 2015-16	51	Polar Guard Advance	-5.1	40	100	8.73%	2.8	2.8	4.0	1.1	*Review*
Winter 2009-10	11	ABC-S Plus	-5.9	40	100	4.55%	3	2.3	4	1	*Good*

Table 10.8: Cumulative Summary of Type IV Light Ice Pellets Mixed with Light Snow Allowance Time Test Results for Target <-5°C from 2009-10 to 2015-16

Test Year	Test #	Fluid Name	Tunnel Temp. Before Test (°C)	Exposure Time (min)	Speed Kts	**Lift Loss @8° (%)**	Rating Before Takeoff Run LE	Rating Before Takeoff Run TE	Rating Before Takeoff Run Flap	Rating at Rotation LE	Overall Status
Winter 2012-13	115	Max-Flight	-9.3	5	115	7.48%	2.1	2	3	1.1	*Review*
Winter 2012-13	114	Polar Guard Advance	-10	5	115	7.14%	2.2	2.2	2.8	1.0	*Review*
Winter 2010-11	*46*	*Launch*	*-13.5*	*5*	*100*	*7.06%*	*1.75*	*1.75*	*3*	*1.25*	*Review*
Winter 2009-10	78	ABC-S Plus	-16	5	100	7.48%	2.3	2.2	3	1.4	*Review*
Winter 2013-14	9	ABC-S Plus	-7.3	10	100	6.47%	2	2	2.5	1	*Review*
Winter 2009-10	77	ABC-S Plus	-14.1	10	100	8.81%	2.8	2.7	3.7	1.7	*Review*
Winter 2009-10	79	EG106	-14.8	10	100	3.16%	2.2	2	2.5	1	*Good*
Winter 2010-11	*84*	*Launch*	*-17.4*	*10*	*115*	*8.37%*	*3*	*2.8*	*3.9*	*1.2*	*Review*
Winter 2013-14	315	AD-49	-19.4	10	115	7.14%	2.9	2.8	3.8	1.2	*Review*
Winter 2009-10	94	ABC-S Plus	-6.3	15	100	4.60%	2.5	2	2.8	1	*Good*
Winter 2015-16	22	FCY 9311	-6.5	15	100	6.95%	2.4	2.8	3.5	1.1	*Review*
Winter 2015-16	21	LNT E450	-6.6	15	100	5.35%	1.7	2.0	2.4	1.0	*Good*
Winter 2010-11	*56*	*AD-49*	*-9.6*	*15*	*100*	*6.78%*	*3*	*2.8*	*4*	*1.5*	*Review*
Winter 2010-11	*58*	*Max-Flight*	*-11.2*	*15*	*100*	*7.63%*	*2.3*	*2.3*	*3.2*	*1.3*	*Review*
Winter 2010-11	*45*	*EG106*	*-12.9*	*15*	*100*	*2.35%*	*2.25*	*2*	*3*	*1*	*Good*
Winter 2013-14	304	Polar Guard Advance	-14.6	15	115	8.01%	2.5	2.7	3.8	1.2	*Review*
Winter 2013-14	313	Max-Flight	-15.3	15	115	8.54%	2.6	2.5	3.5	1.1	*Review*
Winter 2010-11	*82*	*ABC-S Plus*	*-16*	*15*	*115*	*8.37%*	*2.8*	*2.5*	*3.7*	*1.3*	*Review*
Winter 2013-14	310	EG106	-17.4	15	115	2.00%	1.7	1.7	2.3	1	*Good*
Winter 2013-14	312	Launch	-17.4	15	115	9.11%	2.8	2.7	3.7	1.1	*Review*
Winter 2013-14	311	EG106	-18.1	15	100	4.06%	1.9	1.9	2.3	1.1	*Good*
Winter 2013-14	314	AD-49	-19.8	15	115	8.39%	3	2.4	4	1.3	*Review*
Winter 2012-13	87	Polar Guard Advance	-6.6	25	100	6.35%	2	2.2	2.7	1.1	*Review*
Winter 2010-11	*78*	*EG106*	*-13.8*	*25*	*100*	*2.67%*	*2.7*	*2.2*	*4*	*1*	*Good*

10.3.1 Light Ice Pellets Mixed with Light Snow Above -5°C

Table 10.7 demonstrates the data collected. Tests were conducted at both 25-minute exposure times and 40-minute exposure times, all with 100knots rotation speeds; the data is separated by exposure time and sorted by temperature. In all cases tested, the overall results were either "Good" or "Review." In some cases, lift losses were in the higher end of the review range (5.4 percent to 9.2 percent); however, these fluids typically had higher lift losses for the fluid cases alone; fluids may have been at the higher end of the fluid production range. The visual ratings were all within the acceptable range. The data supports increasing the ice pellet allowance times to 40 minutes from the existing 25 minutes for Light Ice Pellets and Light Snow above -5°C.

10.3.2 Light Ice Pellets Mixed with Light Snow Below -5°C

Table 10.8 demonstrates the data collected. Tests were conducted with exposure times ranging from 5 minutes to 25 minutes and with rotation speeds of 100 knots and 115 knots; the data is separated by exposure time and sorted by temperature. The existing allowance time of 15 minutes is limited to temperatures of -10°C, so the intent was to develop allowance times below -10°C. In all cases tested, the overall results were either "Good" or "Review." The data shows a trend for lift losses to increase for PG based fluids as the temperature decreases. The majority of the PG fluid tests were conducted with 115 knots rotation, as previous research has shown that the lift losses at 100 knots may reach or exceed the higher end of the allowable lift loss (9.2 percent); the EG fluid tests were conducted at 100 knots. The majority of the tests conducted below -10°C were with 15-minute exposure time; in addition, this data set includes tests as cold as -19.8°C. Although some limited testing at 25 minutes was conducted with positive results, the data generally supports the expansion of the allowance times to include 15 minutes below -10°C. Future testing can look at expanding the existing allowance time from 15 minutes to possibly 20 or 25 minutes. Due to limited data in the -20°C and below range, and because a limitation of PG fluids already exists for Moderate Ice Pellets below -16°C, a limitation of the condition to -16°C would also be recommended in order to be conservative. No expansion of the -5°C to -10°C range is recommended based on the data collected.

11. LIGHT ICE PELLETS MIXED WITH MODERATE SNOW ALLOWANCE TIMES

A summary of the light ice pellets mixed with moderate snow tests conducted with Type III and Type IV fluids in the wind tunnel is shown in Table 11.1 and Table 11.2. The tables provide 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.

It should be noted that testing in this condition with the objective of increasing the existing allowance times has been ongoing since 2009-10. The cumulative data set is discussed in Subsection 11.3.

11.1 Analysis of Data Collected

The data collected has been sorted according to test parameters and included in the respective cells of the ice pellet allowance time table format for ease of reference; this is shown in Table 11.3 and Table 11.4. A more detailed analysis separating the data according to the allowance time cell and rotation speed has been conducted and is shown in Table 11.5 and Table 11.6. In addition, a conclusion regarding the test results has also been included for each condition.

11.2 Overall Summary of Results

The following sections provide an overall summary of the results.

11.2.1 Type III Testing

The testing results indicated that the current allowance time of 10 minutes is valid for AllClear AeroClear MAX. It should be noted that the Type III allowance time for below -5°C to -10°C was published as 10 minutes, though it should have been 5 minutes; this change is expected for winter of 2016-17. Nonetheless, the data collected supports the 10-minute allowance, so 5 minutes will be an acceptable conservative allowance time.

Table 11.1: Summary of 2015-16 Type III Light Ice Pellets Mixed with Moderate Snow Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
32	IP- / SN	AeroClear MAX - Cold	8	20	-10.3	-5.4	IP = 25 SN = 25	10	2, 2.7, 3.8	1, 1.5, 2.5	2.69%	80
56	IP- / SN	AeroClear MAX - Cold	8	20	-12	-6.4	IP = 25 SN = 25	10	2.3, 2.2, 3.8	1, 1.2, 1.6	2.71%	80
57	IP- / SN	AeroClear MAX - Cold	8	20	-12.3	-7.5	IP = 25 SN = 25	10	2.5, 2.4, 3.6	1, 1.2, 1.6	2.57%	80
58	IP- / SN	AeroClear MAX - Cold	8	20	-12.7	-7.2	IP = 25 SN = 25	10	2.7, 2.7, 3.5	1, 1.2, 1.3	2.12%	100

Table 11.2: Summary of 2015-16 Type IV Light Ice Pellets Mixed with Moderate Snow Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
44	IP- / SN	ABC-S Plus	8	20	-7.6	-4.4	IP = 25 SN = 25	20	3.2, 2.8, 3.8	1.3, 2, 2.3	6.66%	100
48	IP- / SN	AD-49	8	20	-8.9	-4.7	IP = 25 SN = 25	20	2.8, 2.7, 3.8	1.2, 1.7, 2.8	7.63%	100
54	IP- / SN	Polar Guard Advance	8	20	-10.8	-5.2	IP = 25 SN = 25	20	2.8, 3.1, 3.9	1.1, 1.6, 2.6	9.63%	100
55	IP- / SN	Polar Guard Advance	8	20	-11.4	-6.2	IP = 25 SN = 25	15	2.8, 2.9, 3.7	1.2, 1.6, 2.4	8.85%	100

Table 11.3: Type III Light Ice Pellets Mixed with Moderate Snow Allowance Time Tests Winter 2015-16

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
80 kts	10 minutes N/A	10 Minutes Tests # 32, 56, 57	No Allowance Times Currently Exist N/A
100 kts		10 Minutes Test # 58	

Table 11.4: Type IV Light Ice Pellets Mixed with Moderate Snow Allowance Time Tests Winter 2015-16

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 N/A	7 minutes N/A	No Allowance Times Currently Exist N/A
	15 Minutes Test # 55		
	20 Minutes Test # 44, 48, 54		

Table 11.5: Summary of Type III Light Ice Pellets Mixed with Moderate Snow Allowance Time Test Results

Run(hs)#	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 Less than -5°C to -10°C 80 Knots (10 Minutes)											
32	AeroClear MAX - Cold	-5.4	IP = 25 SN = 25	10	2, 2.7, 3.8	Good	1, 1.5, 2.5	Good	2.69%	Good	Good
56	AeroClear MAX - Cold	-6.4	IP = 25 SN = 25	10	2.3, 2.2, 3.8	Good	1, 1.2, 1.6	Good	2.71%	Good	Good
57	AeroClear MAX - Cold	-7.5	IP = 25 SN = 25	10	2.5, 2.4, 3.6	Good	1, 1.2, 1.6	Good	2.57%	Good	Good
OAT Less than -5°C to -10°C 100 Kts (10 Minutes)											
58	AeroClear MAX - Cold	-7.2	IP = 25 SN = 25	10	2.7, 2.7, 3.5	Good	1, 1.2, 1.3	Good	2.12	Good	Good
Conclusion: 10 minutes good for cold fluid.											

Table 11.6: Summary of Type IV Light Ice Pellets Mixed with Moderate Snow Allowance Time Test Results

Run(hs)#	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 Knots (15 Minutes)											
55	Polar Guard Advance	-6.2	IP = 25 SN = 25	15	2.8, 2.9, 3.7	Good	1.2, 1.6, 2.4	Review	8.85	Review	Review
100 Knots (20 Minutes)											
44	ABC-S Plus	-4.4	IP = 25 SN = 25	20	3.2, 2.8, 3.8	Review	1.3, 2, 2.3	Review	6.66%	Review	Review
48	AD-49	-4.7	IP = 25 SN = 25	20	2.8, 2.7, 3.8	Good	1.2, 1.7, 2.8	Review	7.63%	Review	Review
54	Polar Guard Advance	-5.2	IP = 25 SN = 25	20	2.8, 3.1, 3.9	Good	1.1, 1.6, 2.6	Review	9.63	Bad	Bad
Conclusion: Allowance time can be expanded to 20 minutes; see Subsection 11.3 for additional information.											

11.2.2 Type IV Testing

Testing was not conducted with the new FCY 9311 and LNT E450 fluids in this condition; tests were run as a spot check in light ice pellets mixed with light snow, and based on positive results and limited fluid supplies, it was decided that testing in this condition was not necessary. However, additional tests were conducted with fluids previously tested to support increasing and expanding the allowance times. These additional tests were analysed along with other data collected since 2009-10 to support the expansion of the allowance times. The details of the expansion analysis are included in Subsection 11.3.

11.3 Expansion of Light Ice Pellet Mixed with Moderate Snow Allowance Times

Research has been ongoing since 2009-10 to support the expansion of the Light Ice Pellet Mixed with Moderate Snow allowance times; therefore, a significant amount of data has been collected since. The details of the tests conducted during the winters of 2009-10 to 2014-15 can be found in the wind tunnel testing report for the respective year; only a summary of those tests is presented here alongside the current year's tests. The cumulative data sets have been separated into two sets: -5°C and above and below -5°C. Table 11.7 and Table 11.8 show the summarized information for each of the relevant tests.

Table 11.7: Cumulative Summary of Type IV Light Ice Pellets Mixed with Moderate Snow Allowance Time Test Results for Target >-5°C from 2009-10 to 2015-16

Test Year	Test #	Fluid Name	Tunnel Temp. Before Test (°C)	Exposure Time (min)	Speed Kts	**Lift Loss @8° (%)**	Rating Before Takeoff Run LE	Rating Before Takeoff Run TE	Rating Before Takeoff Run Flap	Rating at Rotation LE	Overall Status
Winter 2009-10	16	ABC-S Plus	-4.2	5	100	**5.51%**	1.4	1.7	1.8	1	Review
Winter 2013-14	12	AD-49	-3.3	10	100	**5.75%**	2	2	3.5	1	Review
Winter 2010-11	73	Max-Flight	-4.2	10	100	**6.47%**	2.7	2.3	3.1	1	Review
Winter 2009-10	15	ABC-S Plus	-4.3	10	100	**4.81%**	1.8	2	2.7	1	Good
Winter 2013-14	11	Launch	-5.2	10	100	**6.70%**	2	1.75	3.25	1	Review
Winter 2009-10	14	ABC-S Plus	-4.4	15	100	**5.55%**	2.2	2	2.8	1	Review
Winter 2009-10	58	Launch	-3.1	20	100	**4.66%**	2.8	2.6	3	1	Good
Winter 2009-10	24	EG106	-3.7	20	100	**1.25%**	2.5	1.8	4	1	Good
Winter 2015-16	44	ABC-S Plus	-4.4	20	100	**6.66%**	3.2	2.8	3.8	1.3	Review
Winter 2009-10	13	ABC-S Plus	-4.6	20	100	**6.10%**	3	2	3.5	1	Review
Winter 2015-16	48	AD-49	-4.7	20	100	**7.63%**	2.8	2.7	3.8	1.2	Review
Winter 2015-16	54	Polar Guard Advance	-5.2	20	100	**9.63%**	2.8	3.1	3.9	1.1	Bad

Table 11.8: Cumulative Summary of Type IV Light Ice Pellets Mixed with Moderate Snow Allowance Time Test Results for Target <-5°C from 2009-10 to 2015-16

Test Year	Test #	Fluid Name	Tunnel Temp. Before Test (°C)	Exposure Time (min)	Speed Kts	**Lift Loss @8° (%)**	Rating Before Takeoff Run LE	Rating Before Takeoff Run TE	Rating Before Takeoff Run Flap	Rating at Rotation LE	Overall Status
Winter 2010-11	47	Launch	-13.3	5	100	**8.20%**	2.25	2	3.5	1.3	Review
Winter 2009-10	82	ABC-S Plus	-15.8	5	100	**8.24%**	2.5	2.2	3.2	1.5	Review
Winter 2009-10	81	EG106	-17.3	5	100	**3.19%**	1.8	2	2.3	1	Good
Winter 2010-11	85	Launch	-17.4	5	115	**8.09%**	2.6	2.5	3.5	1.1	Review
Winter 2010-11	104	Launch	-7.5	7	100	**6.47%**	2.8	2.5	3.1	1.1	Review
Winter 2010-11	105	ABC-S Plus	-9.3	7	100	**8.51%**	2.3	2.2	2.8	1.1	Review
Winter 2010-11	106	AD-49	-9.4	7	100	**7.24%**	1.4	2.2	3.1	1.2	Review
Winter 2012-13	118	Polar Guard Advance	-10.8	7	100	**9.32%**	2.1	2	2.6	1.1	Bad
Winter 2013-14	10	ABC-S Plus	-6.7	10	100	**6.38%**	2	2	3	1	Review
Winter 2009-10	97	ABC-S Plus	-8.3	10	100	**5.10%**	2.9	2.3	3	1.3	Good
Winter 2012-13	116	Max-Flight	-8.7	10	100	**7.74%**	2.3	2.2	2.8	1.2	Review
Winter 2012-13	117	Polar Guard Advance	-10.3	10	100	**9.65%**	2.2	2	3.1	1.1	Bad
Winter 2010-11	44	EG106	-13.2	10	100	**2.85%**	2.25	2	3.5	1.15	Good
Winter 2010-11	83	ABC-S Plus	-15.2	10	115	**9.77%**	3	2.5	4	1.4	Bad
Winter 2015-16	55	Polar Guard Advance	-6.2	15	100	**8.85%**	2.8	2.9	3.7	1.2	Review
Winter 2010-11	79	EG106	-15.1	15	100	**3.02%**	2.8	2.6	4	1.1	Good
Winter 2015-16	54	Polar Guard Advance	-5.2	20	100	**9.63%**	2.8	3.1	3.9	1.1	Bad

11.3.1 Light Ice Pellets Mixed with Moderate Snow Above -5°C

Table 11.7 demonstrates the data collected. Tests were conducted with exposure times ranging from 5 minutes to 20 minutes, all with rotation speeds of 100 knots; the data is separated by exposure time and sorted by temperature. In all but one of the cases tested, the overall results were either "Good" or "Review." In one test with a PG fluid, the lift losses were higher than the acceptable limit of 9.2 percent; however, this fluid was at the higher end of the fluid production range, and the test was conducted slightly below the -5°C cut-off. The visual ratings were all generally within the acceptable range. The data supports increasing the ice pellet allowance times to 20 minutes from the existing 10 minutes for Light Ice Pellets Mixed with Moderate Snow above -5°C.

11.3.2 Light Ice Pellets Mixed with Moderate Snow Below -5ºC

Table 11.8 demonstrates the data collected. Tests were conducted with exposure times ranging from 5 minutes to 20 minutes and with rotation speeds of 100 knots and 115 knots; the data is separated by exposure time and sorted by temperature. The data demonstrated greater lift losses and worsening visual ratings as the temperature decreased and the exposure time increased. The results indicated that the higher 115-knots speeds did not offset the lift losses for the higher exposure times. The results support an allowance time of 5 minutes for below -10ºC. Due to limited data in the -20ºC and below range, and because a limitation of PG fluids already exists for Moderate Ice Pellets below -16ºC, a limitation of the condition to -16ºC would also be recommended in order to be conservative. No expansion of the -5ºC to -10ºC range is recommended based on the data collected.

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12. MODERATE ICE PELLETS MIXED WITH MODERATE SNOW

A summary of the tests conducted with Type IV fluids in the wind tunnel for moderate ice pellets mixed with moderate snow is shown in Table 12.1. 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.

12.1 Analysis of Data Collected

The data collected has been sorted according to test parameters and included in the respective cells of the ice pellet allowance time table format for ease of reference; this is shown in Table 12.2. A more detailed analysis separating the data according to the allowance time cell and rotation speed has been conducted and is shown in Table 12.3. In addition, a conclusion regarding the test results has also been included for each condition.

12.2 Overall Summary of Results

The following sections provide an overall summary of the results.

12.2.1 Type IV Testing

Allowance times did not exist for this condition; testing aimed at providing guidance to support operations. Testing targeted conditions above -10ºC, using a range of exposure times in order to determine the appropriate allowance time based on the aerodynamic and visual performance.

Testing targeted 7 to 10 minutes for -5ºC and above conditions and 7 to 10 minutes for -5ºC to -10ºC conditions; no allowance times currently exist for these conditions. Test results were marginal in both conditions, and slightly worse for the colder temperatures. The test results collected did not support the development of a new allowance times for Moderate Ice Pellets Mixed with Moderate Snow. Future testing with potentially shorter exposure times may provide more positive results.

Table 12.1: Summary of 2015-16 Type IV Moderate Ice Pellets Mixed with Moderate Snow Testing

Test #	Test Condition	Fluid Name	Rotation Angle	Flap Angle (0°, 20°)	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)	Corrected for 3D Effects % Lift Loss on 8° C_L vs. Dry C_L	Speed Kts
23	IP / SN	ABC-S Plus	8	20	-10.2	-8.2	IP = 75 SN = 25	7	2.3, 2.7, 3.5	1.1, 1.7, 2.4	7.38%	100
24	IP / SN	ABC-S Plus	8	20	-10.4	-7.7	IP = 75 SN = 25	10	3, 3, 4	1.2, 1.8, 2.5	8.16%	100
36	IP / SN	Polar Guard Advance	8	20	-12	-7.4	IP = 75 SN = 25	10	3, 3, 4	1.2, 1.7, 2.6	11.06%	100
37	IP / SN	Polar Guard Advance	8	20	-12.6	-7.7	IP = 75 SN = 25	7	2.8, 2.5, 3.7	1.1, 1.4, 2.5	9.42%	100
40	IP / SN	ABC-S Plus	8	20	-6.9	-3.5	IP = 75 SN = 25	7	2.9, 2.7, 3.4	1.1, 1.9, 2.1	6.70%	100
41	IP / SN	ABC-S Plus	8	20	-7	-3.8	IP = 75 SN = 25	10	2.8, 2.8, 3.7	1.2, 2, 2.3	7.48%	100
45	IP / SN	AD-49	8	20	-7.7	-4.4	IP = 75 SN = 25	10	2.9, 2.8, 4	1.1, 1.7, 2.1	7.34%	100
52	IP / SN	Polar Guard Advance	8	20	-10.1	-4.9	IP = 75 SN = 25	10	2.7, 2.8, 4	1.1, 1.4, 2.5	9.27%	100

Table 12.2: Type IV Moderate Ice Pellets Mixed with Moderate Snow Allowance Time Tests Winter 2015-16

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	No Allowance Times Currently Exist N/A	No Allowance Times Currently Exist N/A	No Allowance Times Currently Exist N/A
	7 Minutes Test # 40	7 Minutes Test # 23, 37	
	10 Minutes Tests # 41, 45, 52	10 Minutes Tests # 24, 36	

Table 12.3: Summary of Type IV Moderate Ice Pellets Mixed with Moderate Snow Allowance Time Test Results

OAT -5°C and Above 100 Knots (7 Minutes)											
Run(hs)#	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm^2/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**
40	ABC-S Plus	-3.5	IP=75 SN=25	7	2.9, 2.7, 3.4	Good	1.1, 1.9, 2.1	Review	6.70	Review	Review
100 Knots (10 Minutes)											
41	ABC-S Plus	-3.8	IP=75 SN=25	10	2.8, 2.8, 3.7	Good	1.2, 2, 2.3	Review	7.48%	Review	Review
45	AD-49	-4.4	IP=75 SN=25	10	2.9, 2.8, 4	Good	1.1, 1.7, 2.1	Review	7.34%	Review	Review
Conclusion: 7 minutes may be possible; however, limited data and marginal results do not support this at the moment.											

OAT Less than -5°C to -10°C 100 Knots (7 Minutes)											
Run(hs)#	**Fluid**	**Tunnel Temp. Before Test (°C)**	**Precipitation Rate (g/dm^2/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**
23	ABC-S Plus	-8.2	IP=75 SN=25	7	2.3, 2.7, 3.5	Good	1, 1, 1.2	Good	7.38%	Review	Review
37	Polar Guard Advance	-7.7	IP=75 SN=25	7	2.8, 2.5, 3.7	Good	1, 1.1, 1.4	Good	9.42%	Bad	Bad
100 Knots (10 Minutes)											
24	ABC-S Plus	-7.7	IP=75 SN=25	10	3, 3, 4	Good	1.2, 1.8, 2.5	Review	8.16%	Review	Review
36	Polar Guard Advance	-7.4	IP=75 SN=25	10	3, 3, 4	Good	1.2, 1.7, 2.6	Review	11.06%	Bad	Bad
52	Polar Guard Advance	-4.9	IP=75 SN=25	10	2.7, 2.8, 4	Good	1.1, 1.4, 2.5	Review	9.27%	Bad	Bad
Conclusion: 7 minutes or less may be possible; however, limited data and marginal results do not support this at the moment.											

13. TYPE III FLUID LIFT LOSS SCALING FOR LOW-SPEED ROTATION

A summary of the Type III fluid only tests conducted to support a lift loss scaling for low-speed rotation is described in this section.

13.1 Background

As part of the Type IV allowance time testing, a significant amount of work was conducted to better understand the lift losses experienced in the wind tunnel and how they correlate to operational aircraft. The lift losses due to uncontaminated anti-icing fluids measured on the NRC PIWT thin high-performance wing at α = 8 degrees were scaled to the percent reduction in maximum lift of the full-scale B737-200ADV through the use of the aerodynamic acceptance test. This result was used to develop a lift loss criterion 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 AWG meeting in 2012. This lift loss scaling correlation was deemed valid for aircraft with rotation speeds above 100 knots.

When testing the Type III fluid during the winter of 2015-16, it was recommended by TC/FAA/NASA/APS that a series of fluid only tests be conducted with the Type III fluid at lower speeds in order to develop a specific lift loss scaling correlation for aircraft with rotation speeds greater than 80 knots.

13.2 Summary of Methodology

Similar to the work conducted to develop the Type IV lift loss criteria described in TP 15232E (1), fluid only tests were conducted at the NRC PIWT. Fluid samples were retained and tested at the same conditions according to the aerodynamic acceptance test, also known as the boundary layer displacement thickness (BLDT) test. The BLDT results (ratio of the result versus the failure limit) were used to scale the respective NRC PIWT lift loss result to determine the failure limit for the wind tunnel test. To do so, Type III fluid only tests were conducted at 80 knots using a standard α = 8 degrees sweep; additional stall runs, 68-knot tests, and 100-knots tests were conducted to yield exploratory data but were not considered for the analysis. The retained samples were then tested in accordance with the Low-Speed Ramp Aerodynamic Tests, described in AS 5900, at the same temperature as the 80-knot wind tunnel tests.

13.3 Analysis and Summary of Results

Figure 13.1 demonstrates all the fluid only tests conducted with Type III fluid at the NRC PIWT during the winter of 2015-16. The lift loss results are plotted versus the test temperature. Tests were conducted at various speeds, and some tests were run to stall rather than to the standard α = 8 degrees; these are identified in the chart. In addition, the BLDT test results are superimposed over the chart. The BLDT test temperatures were selected to be as close to the standard 80-knot test temperatures as possible, at the BLDT limit of -16°C for the fluid (as determined by the LOUT), and at some additional points in between to be able to generate a smooth curve.

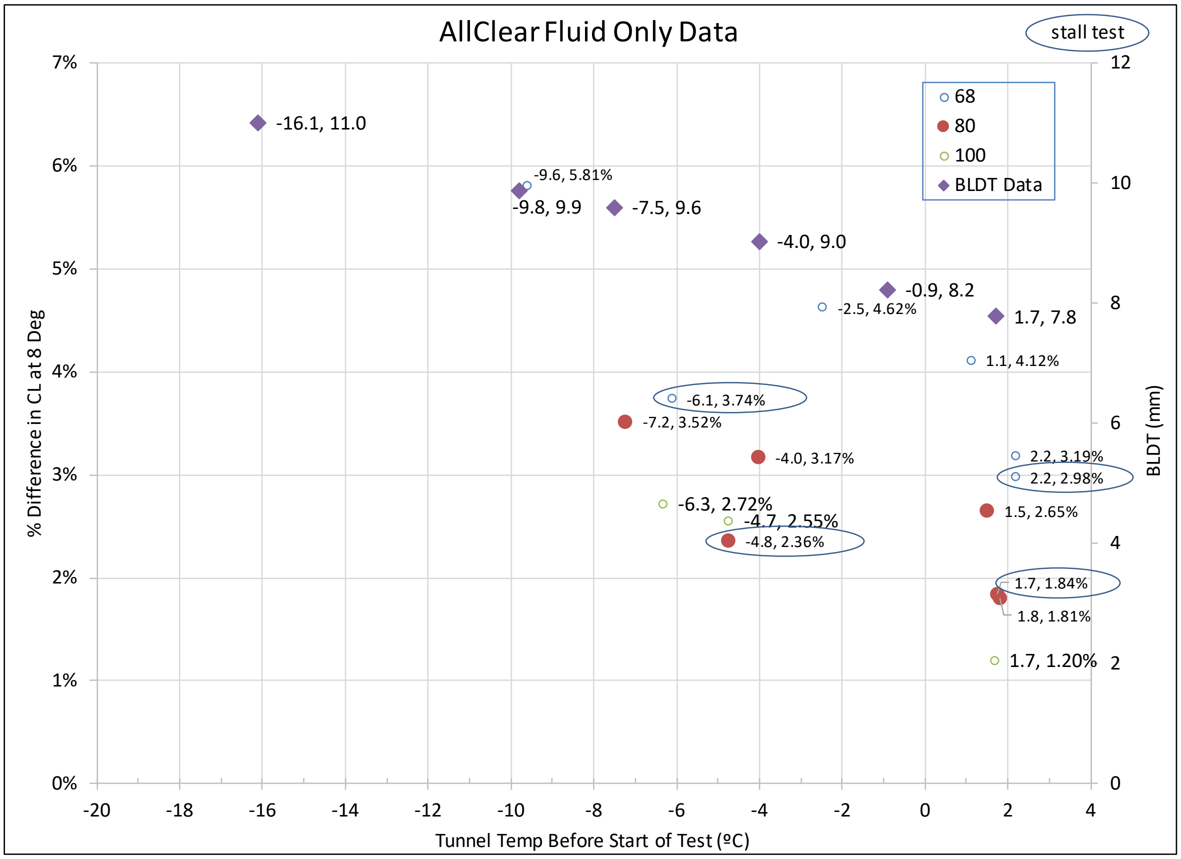


Figure 13.1: Summary of All Type III Fluid Only Tests with Superimposed BLDT Test Results

Table 13.1 provides a summary of the BLDT test conditions and results. The measured BLDT and actual test temperature are included. Figure 13.2 provides a graphical representation of this data. The increase in BLDT versus the test temperature is generally linear. It should be noted that the BLDT crosses the limit of 10.5 mm at approximately -13°C, warmer than the -16°C limit, which may indicate that the viscosity may have been higher than the originally certified sample.

Table 13.1: Summary of BLDT Tests Results

BLDT Test Matrix							
Data Point	**APS Test #**	**Fluid Name**	**Dilution**	**Test Temp (C°)**	**Measured BLDT (mm)**	**Actual Test Temp (C°)**	**Comments**
1	100	AeroClear MAX	100/0	**1.8**	**7.8**	**1.7**	
2	-	AeroClear MAX	100/0	**-1.0**	**8.2**	**-0.9**	extra point for help extrapolation of BLDT data
3	86	AeroClear MAX	100/0	**-4.0**	**9.0**	**-4.0**	
4	33	AeroClear MAX	100/0	**-7.2**	**9.6**	**-7.5**	
5	-	AeroClear MAX	100/0	**-9.6**	**9.9**	**-9.8**	extra point for help extrapolation of BLDT data. Also related to Test #60
6	-	AeroClear MAX	100/0	**-16.0**	**11.0**	**-16.1**	BLDT Limit

The aerodynamic acceptance test for low-speed rotation aircraft described in the SAE International (SAE) AS5900 is built on the premise that a 10.5 mm BLDT correlates to an 8 percent lift loss on a 2D model of a Dash-8 type aircraft. The BLDT results were therefore converted to a percentage lift loss for a 2D model based on a ratio of the measured BLDT versus the 10.5 mm limit. For each wind tunnel test, lift loss was adjusted for rotation speed and ramp-up time. The estimated 2D lift loss was then regressed against the adjusted lift loss measured in the wind tunnel. The regression results were then used to determine the average, and one standard error of estimate was used to determine the upper and lower correlation based on the 8 percent 2D lift loss, as shown in Table 13.2. A summary of the Table 13.2 results is shown in Table 13.3 and is a preliminary interpretation of the lift losses for analysis of the low-speed Type III test.

13.4 Adoption of Analysis for Developing Guidance Material

The results have been shared with TC/FAA and with NASA; however, at the moment, there is reluctance to issue guidance changes based on the limited data collected to date. One of the concerns is the use of the thin high-performance wing section (a high-speed wing) for developing this low-speed correlation. It has been recommended that testing be conducted using the existing LS-0417 wing section, as this may be better suited for this type of work. This testing is planned for the winter of 2016-17.

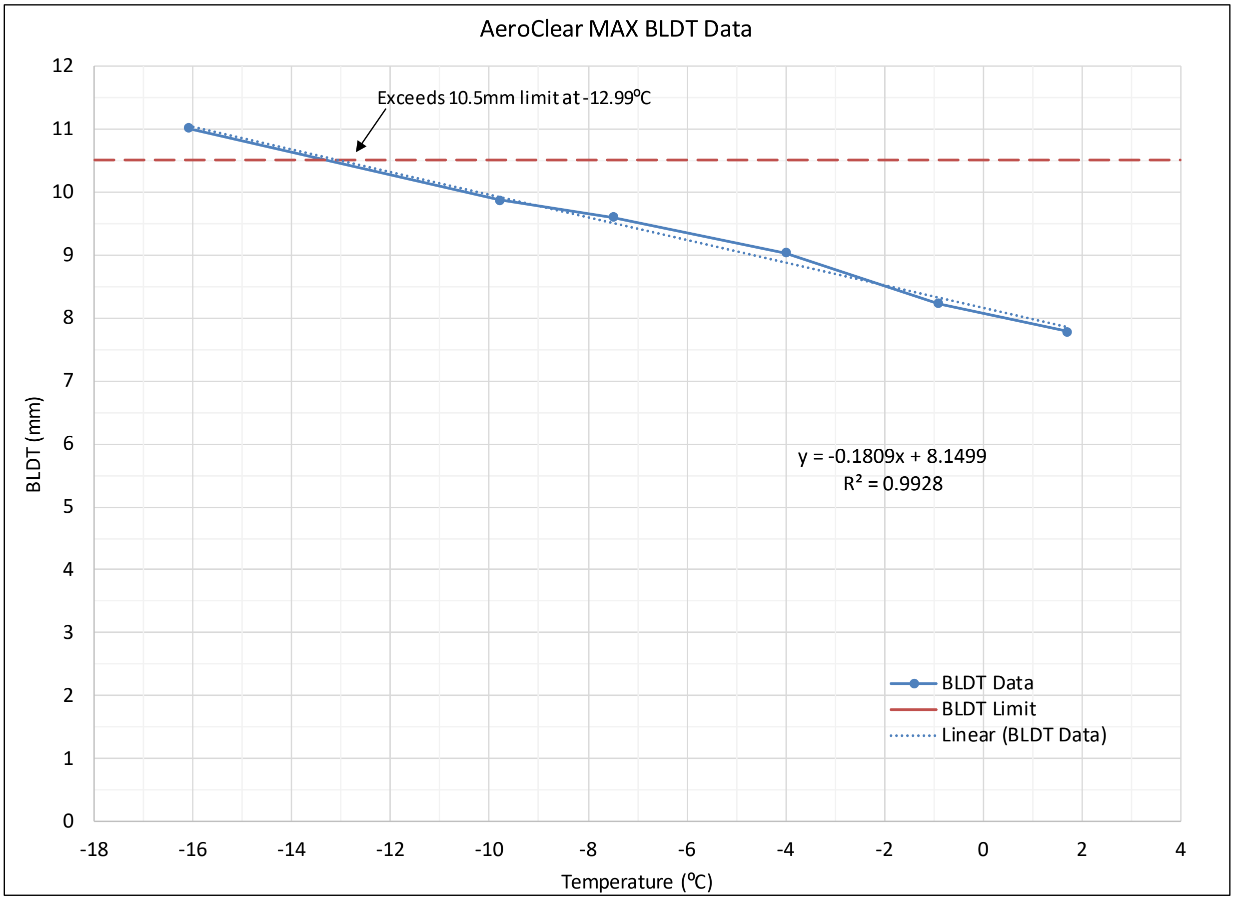


Figure 13.2: Graphical Representation of BLDT Results

Table 13.2: Correlation Results Using Standard Error of Estimate Method

	Method	# pts	Lower	Middle	Higher	Standard Error	X Variable 1
Type III 80 kts 8 deg rot	Using Standard Error of Estimate (based on 8% 2D limit)	4 pts	2.7%	3.9%	5.1%	0.01187	2.05220

Table 13.3: Summary of Proposed Lift Loss Limits for Type III Low-Speed Testing at PIWT

Satisfactory	<2.7% Lift Loss
Review	2.7% to 5.1% Lift Loss
Not Acceptable	> 5.1% Lift Loss

14. GENERAL CHANGES TO ICE PELLET GUIDANCE MATERIAL

This sections describes the analytically based modifications to ice pellet guidance material developed through consultations with TC and the FAA during the winter of 2015-16.

14.1 Division of the Below -10°C Temperature Band and Limiting to -22°C

As a result of the two new conditions (Light Ice Pellets Mixed with Light and Moderate Snow) with allowance times in the -10°C to -16°C temperature band, and due to the existing limitation of Moderate Ice Pellets or Small Hail to -16°C, it was recommended by TC and the FAA that the ice pellet allowance time table temperature bands be changed to facilitate referencing. The below -10°C temperature band should be separated to include a new -10°C to -16°C range for ease of referencing.

The lower temperature band was previously “Below -10°C” and fluids could be used down to LOUT. Over the last several years, testing at temperatures close to LOUT has been attempted but not successful because temperatures below -25°C are infrequent in Ottawa. As a result, no ice pellet allowance time data exists below -22°C. TC and the FAA recommended limiting ice pellet allowance times to -22°C until sufficient data is available. This should have little to no impact on operations as ice pellet occurrence is very small at those cold temperatures. The lower temperature band of the Type IV ice pellet allowance time table should be below -16°C to -22°C.

14.2 Harmonization of the Ice Pellet Allowance Times Background and Operational Guidance

In an effort to harmonize guidance material issued by both TC and the FAA, the background and operational guidance that precedes the ice pellet allowance time tables was modified. The background and operational guidance was modified to be as identical as possible for both regulators with the exception of regulator-specific terminology and regulations. The harmonized versions will be included in the 2016-17 HOT Guidelines.

14.3 Update Guidance for Small Hail

The 2015-16 HOT Guidelines included small hail as part of the ice pellet allowance times; however, this only applied to Light Ice Pellets and Moderate Ice Pellets allowance times with no mixed conditions allowed. For the 2016-17 HOT Guidelines, allowance times may be used for small hail mixed with other conditions provided allowance times exist as described in the note below:

> *"If no intensity is reported with small hail, use the "moderate ice pellets or small hail" allowance times. If an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. if light small hail is reported, the "light ice pellets" allowance times can be used. This also applies in mixed conditions, e.g. if light small hail mixed with light snow is reported, use the "light ice pellets mixed with light snow" allowance times."*

14.4 Re-Ordering of Rows

To facilitate the referencing of the allowance times, the rows in the Type III and Type IV tables were re-ordered. The new tables will include conditions mixed with light ice pellets first, followed by conditions mixed with moderate ice pellets. The intensity of the secondary precipitation type was also used to order the conditions from light to moderate to heavy. The changes will be included in the 2016-17 HOT Guidelines.

14.5 Note for Aircraft Rotation Speeds

In order to better clarify the guidance, and in light of work being conducted to develop low-speed allowance times for Type III fluids, a new note was included in the guidelines to explicitly state that:

> *"These allowance times are for use with aircraft with rotation speeds of 100 knots or greater."*

This was previously only included in the background and operational guidance for the ice pellet allowance times; however, it will now be included directly in the tables themselves to eliminate ambiguity. The changes will be included in the 2016-17 HOT Guidelines.

14.6 Reduction in Type III Allowance Time for Light Ice Pellets Mixed with Moderate Snow Below -5°C to -10°C

During a review of the 2015-16 published HOT Guidelines, it was discovered that the Type III allowance time for Light Ice Pellets Mixed with Moderate Snow below -5°C to -10°C was erroneously published as 10 minutes, whereas the correct allowance time should have been 5 minutes. This correction will be included in the 2016-17 HOT Guidelines.

15. CONCLUSIONS AND OBSERVATIONS

These observations and conclusions were derived from the testing conducted during the winter of 2015-16.

15.1 Type III Allowance Times

The following sections describe the conclusions and observations for the Type III allowance times.

15.1.1 New Fluid (AllClear AeroClear MAX)

Testing was conducted during the winter of 2015-16 that validated the current Type III allowance times for use with the new-to-market AllClear AeroClear MAX; these results are applicable to aircraft with rotation speeds above 100 knots. Testing was conducted in a subset of the existing allowance time conditions. Current allowance times are generic and conservative, and therefore this method is appropriate and testing in all conditions was not necessary.

To serve a dual purpose, the tests run to validate the Type III allowance times for aircraft with rotation speeds greater than 100 knots were also run at 80 knots; it was expected that the Type III fluid would perform very well and pass all criteria even at 80 knots, which it did. The purpose is to eventually use this 80-knots data to support the development of a low-speed Type III allowance time table.

15.1.2 Low-Speed Testing

Type III fluid only data was collected to support a lift loss scaling analysis for low-speed tests. The results are still under review; however, it has been recommended that testing be conducted with the LS-0417 wing section to validate the results observed before guidance be issued for low-speed operations.

15.2 Type IV High-Speed Allowance Times

The following sections describe the conclusions and observations for the Type IV high-speed allowance times.

15.2.1 New Fluids

Testing was conducted during the winter of 2015-16 that validated the current Type IV allowance times for use with the new-to-market LNT E450 and FCY 9311. Testing was conducted in a subset of the existing allowance time conditions; current allowance times are generic and conservative, and therefore this method is appropriate and testing in all conditions was not necessary.

15.2.2 Expansion of Type IV Allowance Times

Testing was conducted to support the expansion of the existing allowance times to include longer times and more conditions, including Moderate Ice Pellets Mixed with Moderate Freezing Drizzle, Moderate Ice Pellets Mixed with Moderate Rain, and Light Ice Pellets Mixed with Light and Moderate Snow.

15.3 General Changes to the Ice Pellet Allowance Time Tables

Through consultation TC and the FAA, modifications to the ice pellet allowance time guidance material were proposed. These proposals were analytically based and developed based on industry requests and operational concerns. Changes were proposed for the following:

- Division of the below -10ºC temperature band and limiting operations to -22ºC;
- Harmonization of the ice pellet allowance time background and operational guidance;
- Update guidance for inclusion of small hail;
- Re-ordering of rows in the allowance time tables;
- Inclusion of an explicit note in the table specifying aircraft with 100knots rotation speeds; and
- Reduction in Type III allowance time for Light Ice Pellets Mixed with Moderate Snow below -5ºC to -10ºC.

16. RECOMMENDATIONS

The following recommendations were compiled based on the work conducted during the winter of 2015-16 and based on consultations with TC and the FAA.

16.1 Changes to Ice Pellet Allowance Time Guidance

The following changes were made to the **Type III** Ice Pellet Allowance Time guidance material based on the 2015-16 wind tunnel test results:

- The use of Type III allowance times will be allowed for use with AllClear AeroClear MAX;
- A correction to the Light Ice Pellets mixed with Moderate Snow below -5ºC to -10ºC allowance time (was 10 minutes and will be reduced to 5 minutes);
- Harmonization of the TC and FAA ice pellet allowance time background and operational guidance;
- Updated guidance for small hail;
- Re-ordering of the rows in the allowance time tables; and
- Inclusion of an explicit note in the table specifying aircraft with 100-knots rotation speeds.

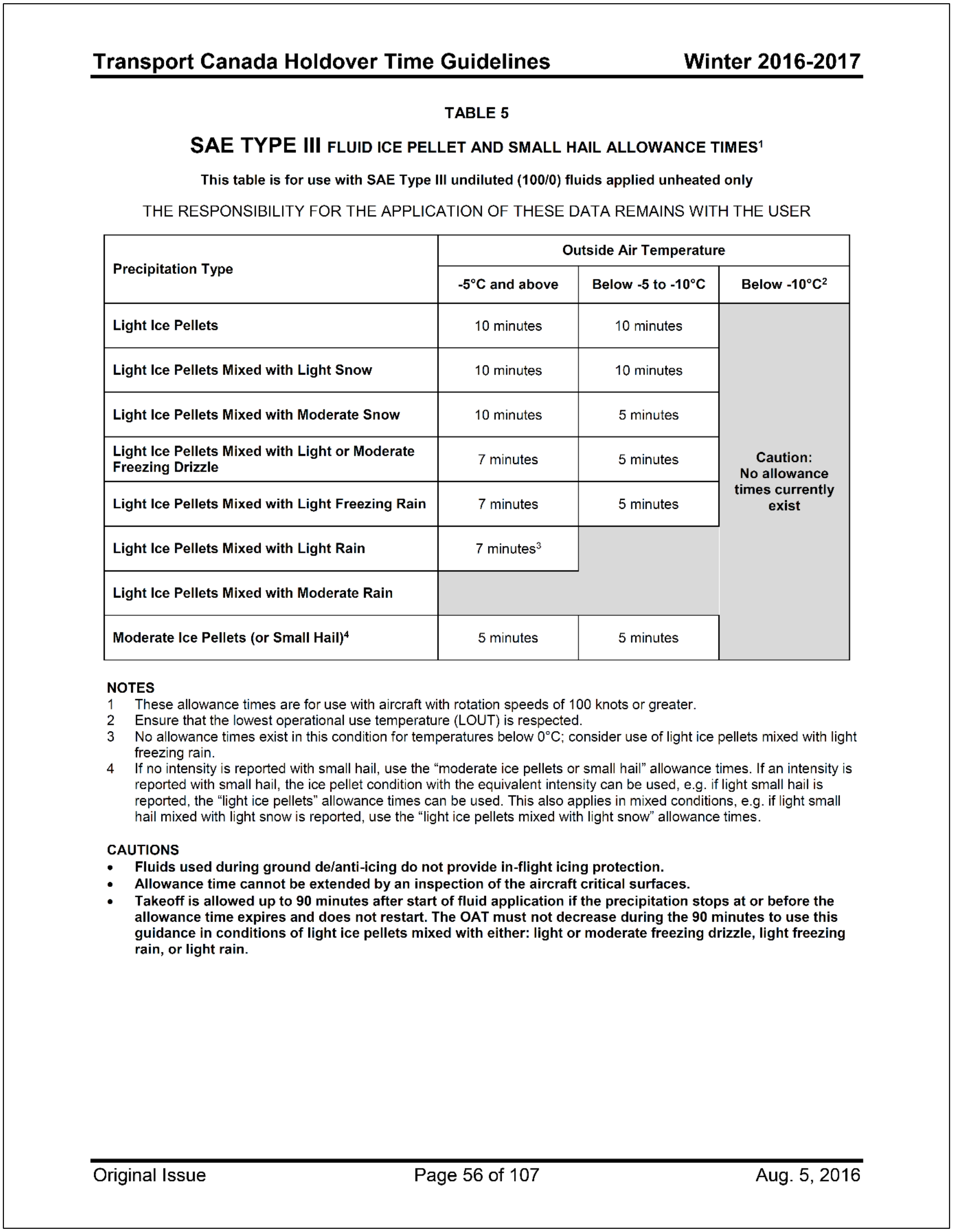
The following changes were made to the **Type IV** Ice Pellet Allowance Time guidance material based on the 2015-16 wind tunnel test results:

- New allowance times for Moderate Ice Pellets Mixed with Moderate Freezing Drizzle for -5ºC and above and below -5ºC to -10ºC conditions;
- New allowance times for Moderate Ice Pellets Mixed with Moderate Rain for -5ºC and above conditions;
- Increase to allowance times for “Light Ice Pellets Mixed with Light Snow” for -5ºC and above conditions;
- Increase to allowance times for Light Ice Pellets Mixed with Moderate Snow for -5ºC and above conditions;
- New allowance times for Light Ice Pellets Mixed with Light Snow for -10ºC to -16ºC conditions;
- New allowance times for Light Ice Pellets Mixed with Moderate Snow for -10ºC to -16ºC conditions;
- Division of the below -10ºC temperature band into below -10ºC to -16ºC and below -16ºC to -22ºC;

- Limiting ice pellet operations to -22ºC;
- Harmonization of the TC and FAA ice pellet allowance time background and operational guidance;
- Updated guidance for small hail;
- Re-ordering of the rows in the allowance time tables; and
- Inclusion of an explicit note in the table specifying aircraft with 100-knots rotation speeds.

The updated winter 2016-17 Type III allowance time table is shown in Table 16.1 for TC and Table 16.2 for the FAA, and the updated winter 2016-17 Type IV allowance time table is shown in Table 16.3 for TC and Table 16.4 for the FAA. It should be noted that the 90 percent adjusted tables were also published by TC and the FAA for those operations when flaps and slats are deployed prior to de/anti-icing; however, these tables have not been included in this report for brevity.

Table 16.1: 2016-17 TC Type III Ice Pellet Allowance Time Table



Transport Canada Holdover Time Guidelines **Winter 2016-2017**

TABLE 5

SAE TYPE III FLUID ICE PELLET AND SMALL HAIL ALLOWANCE TIMES[1]

This table is for use with SAE Type III undiluted (100/0) fluids applied unheated only

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

Precipitation Type	Outside Air Temperature		
	-5°C and above	Below -5 to -10°C	Below -10°C[2]
Light Ice Pellets	10 minutes	10 minutes	Caution: No allowance times currently exist
Light Ice Pellets Mixed with Light Snow	10 minutes	10 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes	5 minutes	
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	7 minutes	5 minutes	
Light Ice Pellets Mixed with Light Freezing Rain	7 minutes	5 minutes	
Light Ice Pellets Mixed with Light Rain	7 minutes[3]		
Light Ice Pellets Mixed with Moderate Rain			
Moderate Ice Pellets (or Small Hail)[4]	5 minutes	5 minutes	

NOTES

1 These allowance times are for use with aircraft with rotation speeds of 100 knots or greater.

2 Ensure that the lowest operational use temperature (LOUT) is respected.

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 If no intensity is reported with small hail, use the "moderate ice pellets or small hail" allowance times. If an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. if light small hail is reported, the "light ice pellets" allowance times can be used. This also applies in mixed conditions, e.g. if light small hail mixed with light snow is reported, use the "light ice pellets mixed with light snow" allowance times.

CAUTIONS

- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**
- **Allowance time cannot be extended by an inspection of the aircraft critical surfaces.**
- **Takeoff is allowed up to 90 minutes after start of fluid application if the precipitation stops at or before the allowance time expires and does not restart. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, or light rain.**

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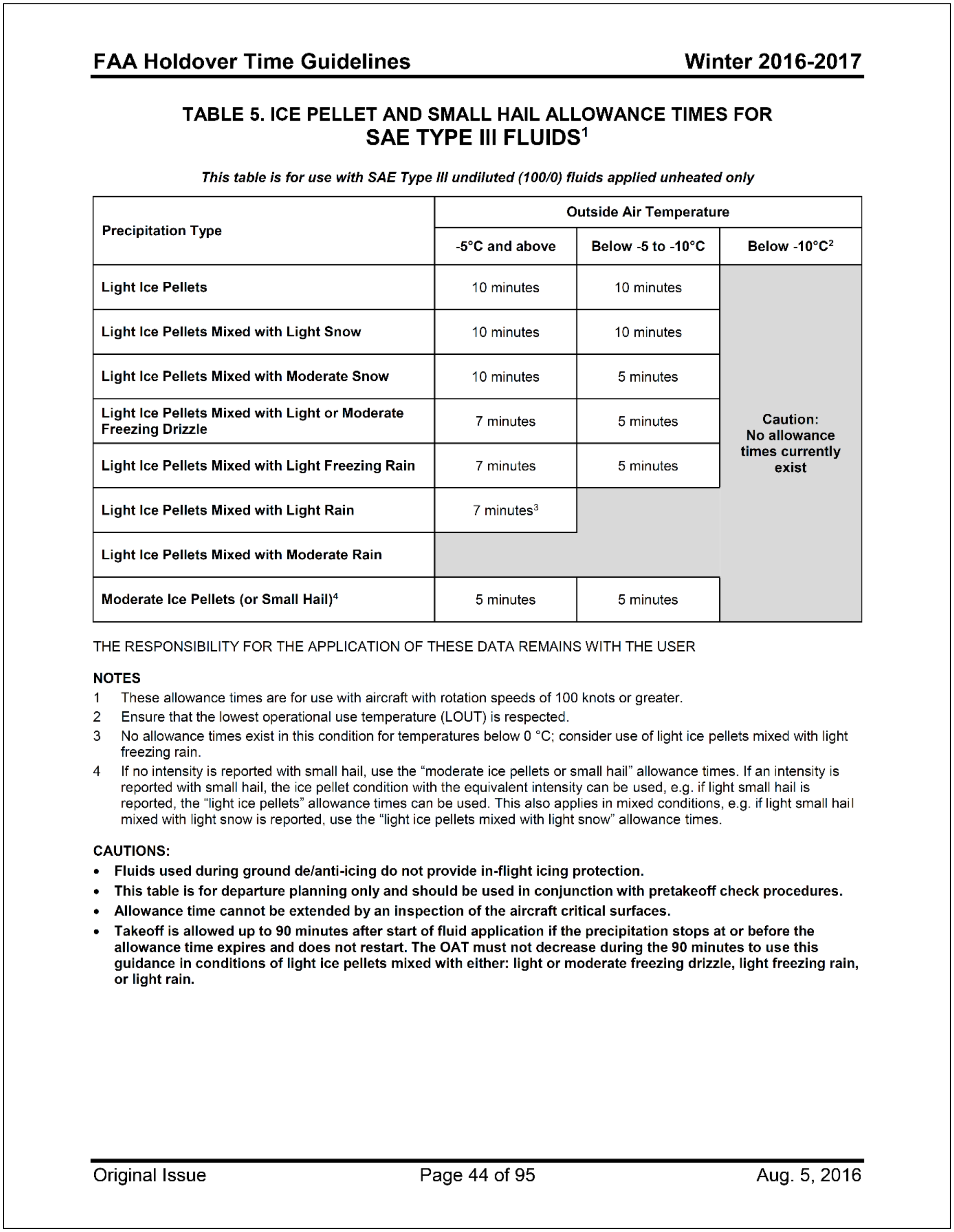
Table 16.2: 2016-17 FAA Type III Ice Pellet Allowance Time Table



FAA Holdover Time Guidelines Winter 2016-2017

TABLE 5. ICE PELLET AND SMALL HAIL ALLOWANCE TIMES FOR SAE TYPE III FLUIDS[1]

This table is for use with SAE Type III undiluted (100/0) fluids applied unheated only

Precipitation Type	**Outside Air Temperature**		
	-5°C and above	**Below -5 to -10°C**	**Below -10°C[2]**
Light Ice Pellets	10 minutes	10 minutes	**Caution: No allowance times currently exist**
Light Ice Pellets Mixed with Light Snow	10 minutes	10 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes	5 minutes	
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	7 minutes	5 minutes	
Light Ice Pellets Mixed with Light Freezing Rain	7 minutes	5 minutes	
Light Ice Pellets Mixed with Light Rain	7 minutes[3]		
Light Ice Pellets Mixed with Moderate Rain			
Moderate Ice Pellets (or Small Hail)[4]	5 minutes	5 minutes	

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

NOTES

1 These allowance times are for use with aircraft with rotation speeds of 100 knots or greater.

2 Ensure that the lowest operational use temperature (LOUT) is respected.

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 If no intensity is reported with small hail, use the “moderate ice pellets or small hail” allowance times. If an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. if light small hail is reported, the “light ice pellets” allowance times can be used. This also applies in mixed conditions, e.g. if light small hail mixed with light snow is reported, use the “light ice pellets mixed with light snow” allowance times.

CAUTIONS:

- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**
- **This table is for departure planning only and should be used in conjunction with pretakeoff check procedures.**
- **Allowance time cannot be extended by an inspection of the aircraft critical surfaces.**
- **Takeoff is allowed up to 90 minutes after start of fluid application if the precipitation stops at or before the allowance time expires and does not restart. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, or light rain.**

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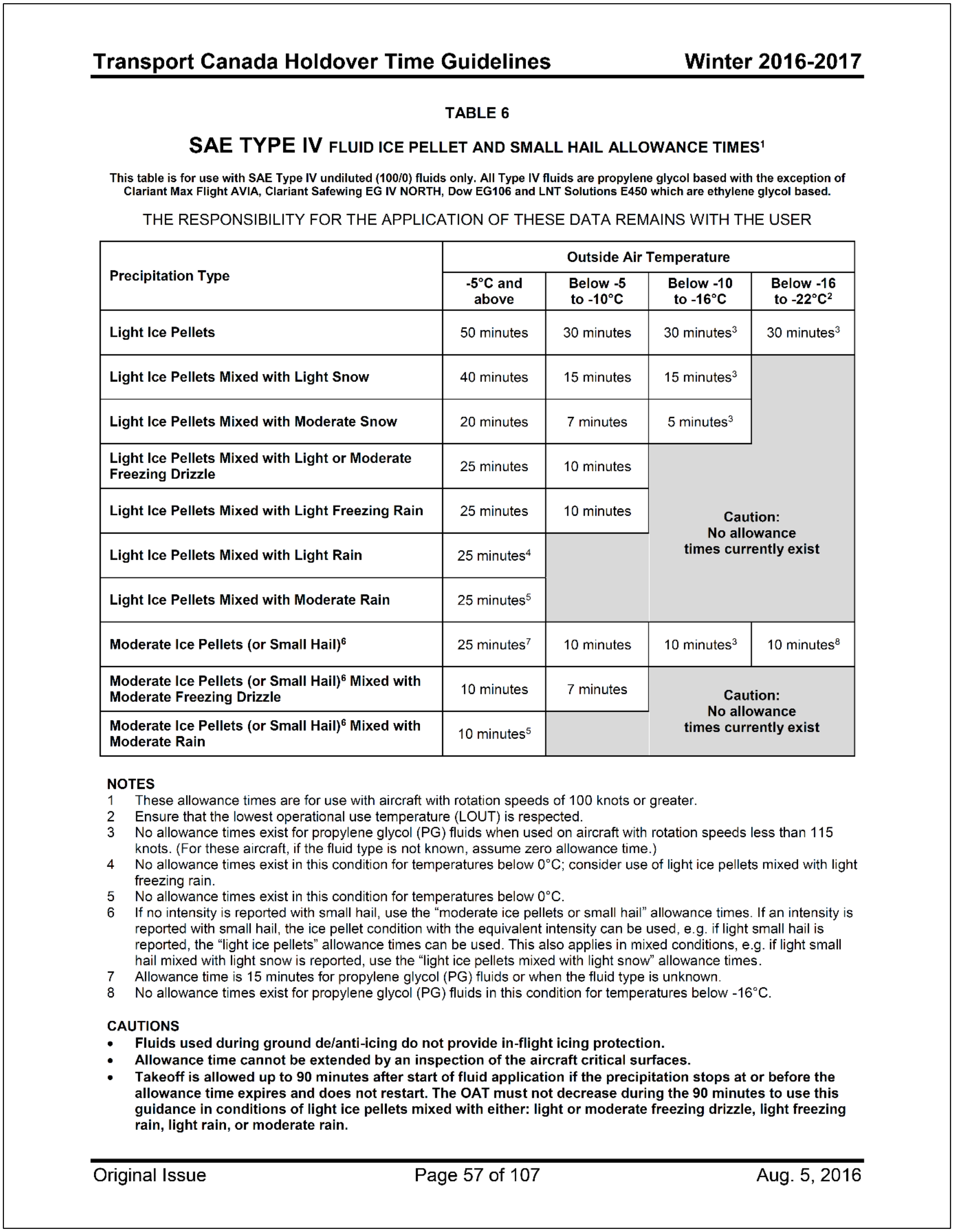
Table 16.3: 2016-17 TC Type IV Ice Pellet Allowance Time Table



Transport Canada Holdover Time Guidelines **Winter 2016-2017**

TABLE 6

SAE TYPE IV FLUID ICE PELLET AND SMALL HAIL ALLOWANCE TIMES[1]

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 Clariant Max Flight AVIA, Clariant Safewing EG IV NORTH, Dow EG106 and LNT Solutions E450 which are ethylene glycol based.

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

Precipitation Type	Outside Air Temperature			
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C[2]
Light Ice Pellets	50 minutes	30 minutes	30 minutes[3]	30 minutes[3]
Light Ice Pellets Mixed with Light Snow	40 minutes	15 minutes	15 minutes[3]	
Light Ice Pellets Mixed with Moderate Snow	20 minutes	7 minutes	5 minutes[3]	
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	25 minutes	10 minutes	Caution: No allowance times currently exist	
Light Ice Pellets Mixed with Light Freezing Rain	25 minutes	10 minutes		
Light Ice Pellets Mixed with Light Rain	25 minutes[4]			
Light Ice Pellets Mixed with Moderate Rain	25 minutes[5]			
Moderate Ice Pellets (or Small Hail)[6]	25 minutes[7]	10 minutes	10 minutes[3]	10 minutes[8]
Moderate Ice Pellets (or Small Hail)[6] Mixed with Moderate Freezing Drizzle	10 minutes	7 minutes	Caution: No allowance times currently exist	
Moderate Ice Pellets (or Small Hail)[6] Mixed with Moderate Rain	10 minutes[5]			

NOTES

1 These allowance times are for use with aircraft with rotation speeds of 100 knots or greater.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 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.)
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.
6 If no intensity is reported with small hail, use the "moderate ice pellets or small hail" allowance times. If an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. if light small hail is reported, the "light ice pellets" allowance times can be used. This also applies in mixed conditions, e.g. if light small hail mixed with light snow is reported, use the "light ice pellets mixed with light snow" allowance times.
7 Allowance time is 15 minutes for propylene glycol (PG) fluids or when the fluid type is unknown.
8 No allowance times exist for propylene glycol (PG) fluids in this condition for temperatures below -16°C.

CAUTIONS

- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**
- **Allowance time cannot be extended by an inspection of the aircraft critical surfaces.**
- **Takeoff is allowed up to 90 minutes after start of fluid application if the precipitation stops at or before the allowance time expires and does not restart. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, light rain, or moderate rain.**

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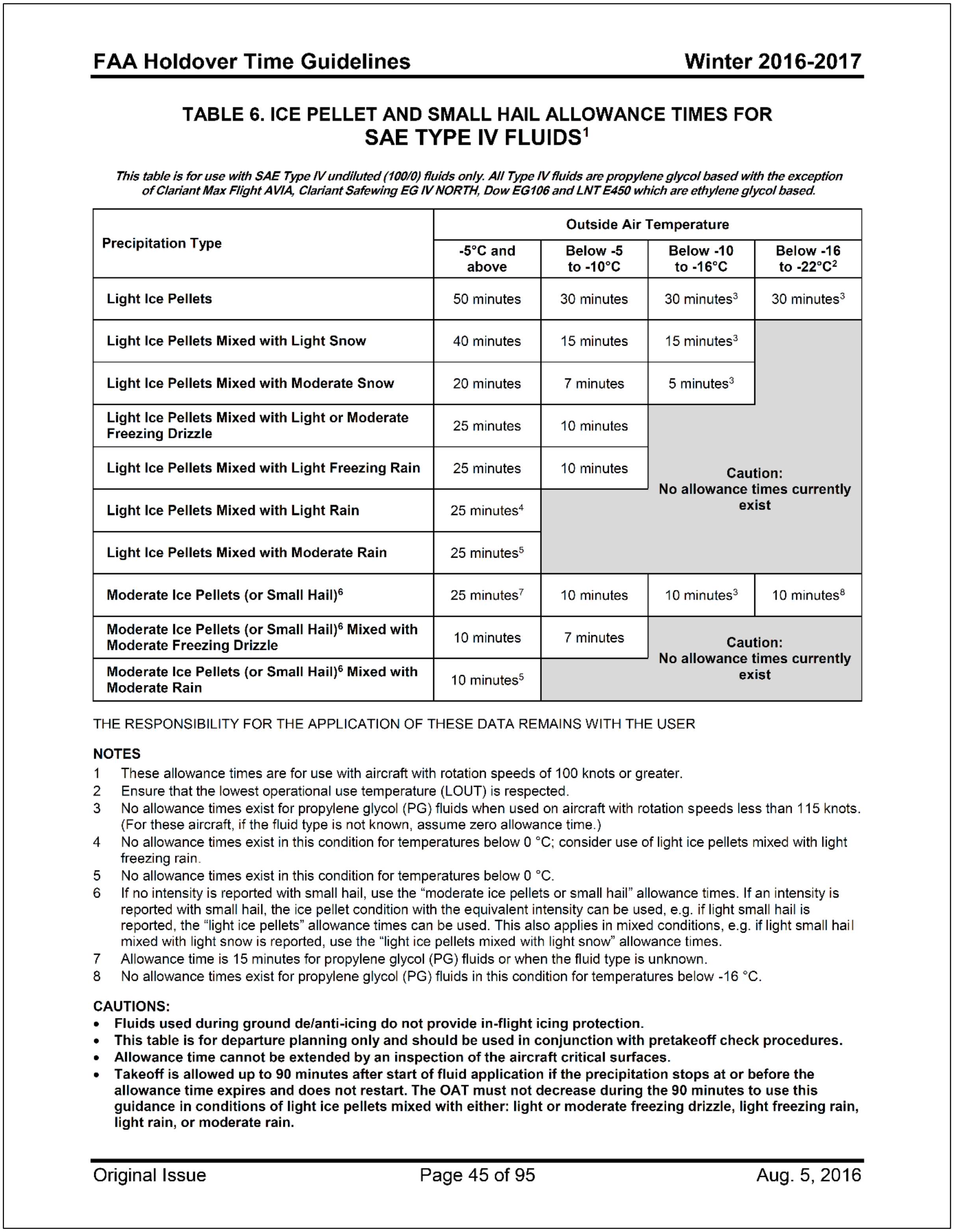
Table 16.4: 2016-17 FAA Type IV Ice Pellet Allowance Time Table



FAA Holdover Time Guidelines **Winter 2016-2017**

TABLE 6. ICE PELLET AND SMALL HAIL ALLOWANCE TIMES FOR SAE TYPE IV FLUIDS[1]

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 Clariant Max Flight AVIA, Clariant Safewing EG IV NORTH, Dow EG106 and LNT E450 which are ethylene glycol based.

Precipitation Type	Outside Air Temperature			
	-5°C and above	Below -5 to -10°C	Below -10 to -16°C	Below -16 to -22°C[2]
Light Ice Pellets	50 minutes	30 minutes	30 minutes[3]	30 minutes[3]
Light Ice Pellets Mixed with Light Snow	40 minutes	15 minutes	15 minutes[3]	
Light Ice Pellets Mixed with Moderate Snow	20 minutes	7 minutes	5 minutes[3]	
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	25 minutes	10 minutes	**Caution:** **No allowance times currently exist**	
Light Ice Pellets Mixed with Light Freezing Rain	25 minutes	10 minutes		
Light Ice Pellets Mixed with Light Rain	25 minutes[4]			
Light Ice Pellets Mixed with Moderate Rain	25 minutes[5]			
Moderate Ice Pellets (or Small Hail)[6]	25 minutes[7]	10 minutes	10 minutes[3]	10 minutes[8]
Moderate Ice Pellets (or Small Hail)[6] Mixed with Moderate Freezing Drizzle	10 minutes	7 minutes	**Caution:** **No allowance times currently exist**	
Moderate Ice Pellets (or Small Hail)[6] Mixed with Moderate Rain	10 minutes[5]			

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

NOTES

1 These allowance times are for use with aircraft with rotation speeds of 100 knots or greater.
2 Ensure that the lowest operational use temperature (LOUT) is respected.
3 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.)
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.
6 If no intensity is reported with small hail, use the "moderate ice pellets or small hail" allowance times. If an intensity is reported with small hail, the ice pellet condition with the equivalent intensity can be used, e.g. if light small hail is reported, the "light ice pellets" allowance times can be used. This also applies in mixed conditions, e.g. if light small hail mixed with light snow is reported, use the "light ice pellets mixed with light snow" allowance times.
7 Allowance time is 15 minutes for propylene glycol (PG) fluids or when the fluid type is unknown.
8 No allowance times exist for propylene glycol (PG) fluids in this condition for temperatures below -16 °C.

CAUTIONS:

- **Fluids used during ground de/anti-icing do not provide in-flight icing protection.**
- **This table is for departure planning only and should be used in conjunction with pretakeoff check procedures.**
- **Allowance time cannot be extended by an inspection of the aircraft critical surfaces.**
- **Takeoff is allowed up to 90 minutes after start of fluid application if the precipitation stops at or before the allowance time expires and does not restart. The OAT must not decrease during the 90 minutes to use this guidance in conditions of light ice pellets mixed with either: light or moderate freezing drizzle, light freezing rain, light rain, or moderate rain.**

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16.2 Future Research

The following sections describe higher priority areas of possible future wind tunnel testing and research. 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.

16.2.1 Substantiation of Ice Pellet Allowance Times with New Fluids

Testing should continue to investigate different Type III and IV fluids to further substantiate the ice pellet allowance times. Testing should consider new fluids or fluids previously tested but with limited data.

16.2.2 Testing with the NASA LS-0417 Wing Section to Support Development of Type III Low-Speed Allowance Times

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 aerodynamic acceptance test. It is recommended that the same methodology be used to develop a lift loss correlation for the LS-0417 wing section, which may be better suited for the development of low-speed Type III allowance times. Once a correlation has been developed, the Type III high-speed allowance times should be validated using the LS-0417 wing section and a low-speed ramp. Heated fluid tests should also be considered.

16.2.3 Lift Losses at LOUT

Previous testing has shown that lift losses generally increase significantly at the lower temperatures. Currently no data is available below -22ºC, and as a result, TC and the FAA will limit allowance times to -22ºC for the winter of 2016-17 until data is available. 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. Testing at these colder temperatures is challenging as these conditions do not occur frequently.

In addition, if resources permit, LNT E450 fluid should be tested at temperatures below -17°C to better understand the performance of this fluid compared to historically tested EG-based Type IV fluids at colder temperatures.

16.2.4 Allowance Time Expansion

Previous testing has shown that the allowance times for Type IV and especially Type III fluids are conservative and have room for expansion. Testing should be conducted to obtain longer times and to include additional conditions for both Type III and Type IV fluids. Fluid-specific allowance times, or at a minimum PG and EG specific allowance times, may help facilitate this process.

16.2.5 Analysis of METAR Data to Determine Conditions Requiring Guidance

A preliminary analysis done in 2015-16 and documented in TC report, TP 15340E, *Aircraft Ground Icing General Research Activities During the 2015 16 Winter* (2), has demonstrated that historical METAR data available online can be used to provide valuable insight into the frequency distribution of precipitation conditions occurring at airports, more specifically conditions related to ground icing and ice pellets or small hail. It is recommended that a thorough and comprehensive analysis of 20+ representative airports be conducted. This data will be useful for guiding effective HOT and ice pellet-related research efforts for the future.

REFERENCES

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

2. APS Aviation Inc., *Aircraft Ground Icing General Research Activities During the 2015-16 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, January 2017, TP 15340E, XX (to be published).

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2015-16

TRANSPORTATION DEVLOPMENT CENTRE
WORK STATEMENT EXCERPT –
AIRCRAFT & ANTI-ICING FLUID
WINTER TESTING 2015-16

3.27 Wind Tunnel Testing to Refine Allowance Times

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;

a) Coordinate with staff of NRC M-46 for scheduling and to organize any modifications to the wind tunnel, model, or related equipment;

b) Develop a procedure and test plan with the NRC staff that operates the PIWT. It is anticipated that testing will be conducted over a period of two weeks. It is anticipated that much of the testing will be conducted during overnight hours;

   The typical procedure is described as follows, but may be modified to address specific testing objectives. Prior to starting each test event, correlation testing is required to calibrate the TC model and to demonstrate repeatability. Wind tunnel tests will be performed with ethylene glycol and propylene glycol anti-icing fluids at below freezing temperatures. Tests will simulate low speed or high speed takeoffs in accordance with the speed and angle of attack profiles provided by TDC and airframe manufacturers. The simulated take-off profile may target the clean wing stall angle as the maximum angle of attack in order to obtain CLmax data. During contaminated test runs, a baseline fluid only case may be run immediately before, or after the contaminated test run to provide a direct correlation of the results. High resolution photos will be taken of the fluid motion at the leading and trailing edges of the wing at a rate of about 3 frames per second, with lighting adequate to see the fluid waves and ripples of about 1mm in height, even when the wing is at maximum angle of attack. Observers will document the appearance of fluid on the wing during the simulated takeoff run and climb of the aircraft by analyzing the photographic records. The testing team will collect, among other things, the following data during the tests: type and amount of fluid applied, type and rate of contamination applied, and extent of fluid contamination prior to the test run;

c) Perform wind tunnel tests (3 days) to validate the existing Type III fluid allowance times for use with the newly certified anti-icing fluid;

d) Perform wind tunnel tests (4 days) to validate the existing Type IV fluid allowance times for use with the newly certified anti-icing fluids, or with fluids for which data is lacking;

e) Perform wind tunnel tests (3 days) to expand the ice pellet allowance time table format to include additional conditions that may be of operational concern or of high occurrence;

f) Analyze data; and

g) Report the findings, and prepare presentation material for the SAE G-12 meeting.

APPENDIX B

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

CM2480.002

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

Winter 2015-16

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi

Reviewed by: John D'Avirro

January, 2016
Final Version 1.1

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

1. BACKGROUND

In 2005-06, the inability for operators to release aircraft in ice pellet conditions led TC and FAA to begin a research campaign to develop allowance times for these conditions. Developing holdover times was not feasible due to the properties of the ice pellets; they remain embedded in the fluid and take long to dissolve as compared to snow which is immediately absorbed and dissolved. Research was initiated by live aircraft testing with the NRC Falcon 20 in Ottawa Ontario, and later evolved to testing in a more controlled environment with the NRC Propulsion Icing Wind Tunnel also in Ottawa Ontario.

The early testing in 2005-06 with the Falcon 20 primarily used visual observations to evaluate fluid flow off. During the Falcon 20 work the wing was anti-iced, exposed to contamination, and aborted take-off runs were performed allowing researchers on-board to observe and evaluate the fluid flow-off. Testing in 2006-07 began in the propulsion icing wind tunnel (PIWT) allowing aerodynamic data to be used for evaluating fluid flow-off performance. The PIWT also allowed for a more controlled environment less susceptible to the elements.

The work continued each year, and the test methods and equipment improved allowing for real-time data analysis, better repeatability, and overall greater confidence in the results. The work conducted by FAA/TC was presented by APS to G-12 AWG and HOT Committee yearly since 2006. Additional presentations were also given at the AWG in May 2012 and May 2013 by NASA and NRC which focused on the extensive calibration and characterization work performed with a generic thin high performance airfoil. This work also helped increase confidence in how the data was used to help support TC/FAA rule-making. A detailed account of the more recent work conducted is included in the report, TP 15232E*, "Wind Tunnel Trials to Examine Anti-Icing Fluid Flow-Off Characteristics and to Support the Development of Ice Pellet Allowance Times, Winter 2009-10 to 2012-13"* (1).

Following the extensive calibration and characterization efforts, ice pellet allowance time testing resumed in 2013-14. Testing was expected to continue during the winter of 2014-15, however due to noise abatement issues, the PIWT was unavailable for overnight testing; therefore no ice pellet testing was conducted. Instead, a separate project lead by EASA was conducted in 2014-15 during daytime operating hours to evaluate the effects of anti-icing fluid on unpowered elevator forces.

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

For the Winter 2015-16, the primary focus of testing will be on the ice pellet allowance time validation and development.

2. OBJECTIVES

The objective of this testing is to conduct aerodynamic testing with a thin high performance airfoil to:

- Substantiate the current Type IV ice pellet allowance times with new fluids and at temperatures close to the lowest operational use temperature (LOUT);
- Substantiate the current Type III ice pellet allowance times with new fluids, and to investigate lower rotation speeds (80 knots) and application methods (hot vs. cold); and
- Expand the current Type IV ice pellet allowance times to include conditions more commonly reported by METAR and to further develop the current mixed ice pellet and snow guidance;

To satisfy these objectives, a thin high performance 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 thin high performance design.

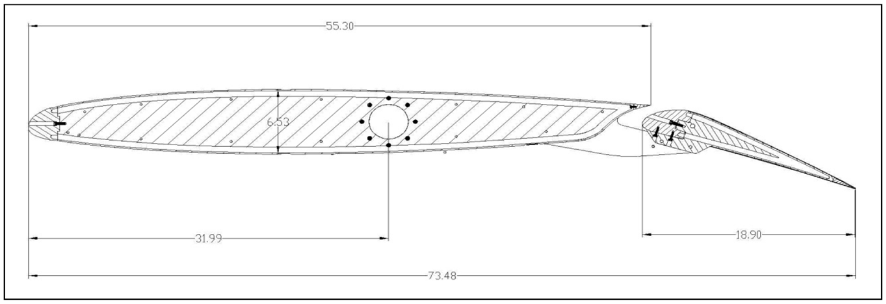
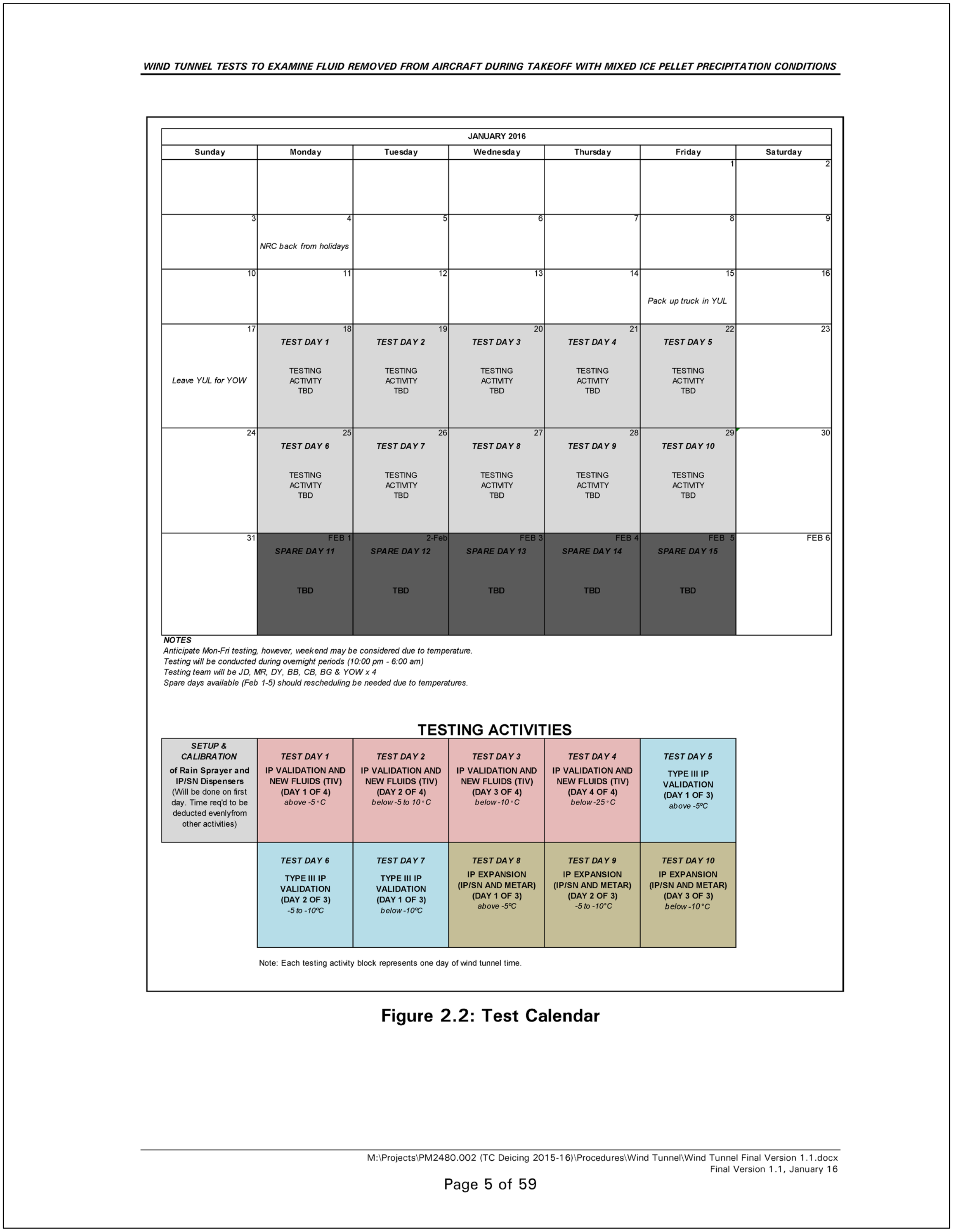


Figure 2.1: Thin High Performance Wing Section

Ten days of testing over a period of three weeks have been scheduled for the conduct of these tests. The available testing days will be from January 18th to February 5th (see Figure 2.2). Testing will likely be conducted during overnight periods (i.e. 10 pm – 6 am), unless temperatures are suitable for day/evening testing. The weekends will be considered only if deemed necessary. The first day will be dedicated to setup and calibration of the rain sprayer and ice pellet and snow dispensers; time permitting testing will begin as per the test plan. The time required for the setup and calibration will be evenly deducted from the other objectives in order to still meet the ten day testing plan. The precipitation conditions to be calibrated could include the following:

- ZR – 25g/dm²/h
- R – 25g/dm²/h
- R – 75g/dm²/h
- ZD – 5g/dm²/h
- ZD – 13g/dm²/h
- SN – 10g/dm²/h
- SN – 25g/dm²/h
- IP – 25g/dm²/h
- IP – 75g/dm²/h



JANUARY 2016

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
3	4 *NRC back from holidays*	5	6	7	8	9
10	11	12	13	14	15 *Pack up truck in YUL*	16
17 *Leave YUL for YOW*	18 ***TEST DAY 1*** TESTING ACTIVITY TBD	19 ***TEST DAY 2*** TESTING ACTIVITY TBD	20 ***TEST DAY 3*** TESTING ACTIVITY TBD	21 ***TEST DAY 4*** TESTING ACTIVITY TBD	22 ***TEST DAY 5*** TESTING ACTIVITY TBD	23
24	25 ***TEST DAY 6*** TESTING ACTIVITY TBD	26 ***TEST DAY 7*** TESTING ACTIVITY TBD	27 ***TEST DAY 8*** TESTING ACTIVITY TBD	28 ***TEST DAY 9*** TESTING ACTIVITY TBD	29 ***TEST DAY 10*** TESTING ACTIVITY TBD	30
31	FEB 1 ***SPARE DAY 11*** TBD	2-Feb ***SPARE DAY 12*** TBD	FEB 3 ***SPARE DAY 13*** TBD	FEB 4 ***SPARE DAY 14*** TBD	FEB 5 ***SPARE DAY 15*** TBD	FEB 6

NOTES

Anticipate Mon-Fri testing, however, weekend may be considered due to temperature.
Testing will be conducted during overnight periods (10:00 pm - 6:00 am)
Testing team will be JD, MR, DY, BB, CB, BG & YOW x 4
Spare days available (Feb 1-5) should rescheduling be needed due to temperatures.

TESTING ACTIVITIES

SETUP & CALIBRATION **of Rain Sprayer and IP/SN Dispensers** (Will be done on first day. Time req'd to be deducted evenlyfrom other activities)	***TEST DAY 1*** **IP VALIDATION AND NEW FLUIDS (TIV) (DAY 1 OF 4)** *above -5 ∘ C*	***TEST DAY 2*** **IP VALIDATION AND NEW FLUIDS (TIV) (DAY 2 OF 4)** *below -5 to 10 ∘ C*	***TEST DAY 3*** **IP VALIDATION AND NEW FLUIDS (TIV) (DAY 3 OF 4)** *below -10 ∘ C*	***TEST DAY 4*** **IP VALIDATION AND NEW FLUIDS (TIV) (DAY 4 OF 4)** *below -25 ∘ C*	***TEST DAY 5*** **TYPE III IP VALIDATION (DAY 1 OF 3)** *above -5ºC*
	TEST DAY 6 **TYPE III IP VALIDATION (DAY 2 OF 3)** *-5 to -10ºC*	***TEST DAY 7*** **TYPE III IP VALIDATION (DAY 1 OF 3)** *below -10ºC*	***TEST DAY 8*** **IP EXPANSION (IP/SN AND METAR) (DAY 1 OF 3)** *above -5ºC*	***TEST DAY 9*** **IP EXPANSION (IP/SN AND METAR) (DAY 2 OF 3)** *-5 to -10°C*	***TEST DAY 10*** **IP EXPANSION (IP/SN AND METAR) (DAY 3 OF 3)** *below -10°C*

Note: Each testing activity block represents one day of wind tunnel time.

Figure 2.2: Test Calendar

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.

A preliminary list of test objectives is shown in Table 3.1 (only Priority 1 and 2 objectives will be attempted unless indicated otherwise by TC/FAA directive). 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 test matrix (subject to change) 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 on-site experts when applicable. The overall rating will provide insight into the severity of the conditions observed. A test failure (failure to shed the fluid at time of rotation) shall be determined by the on-site experts based on residual contamination.

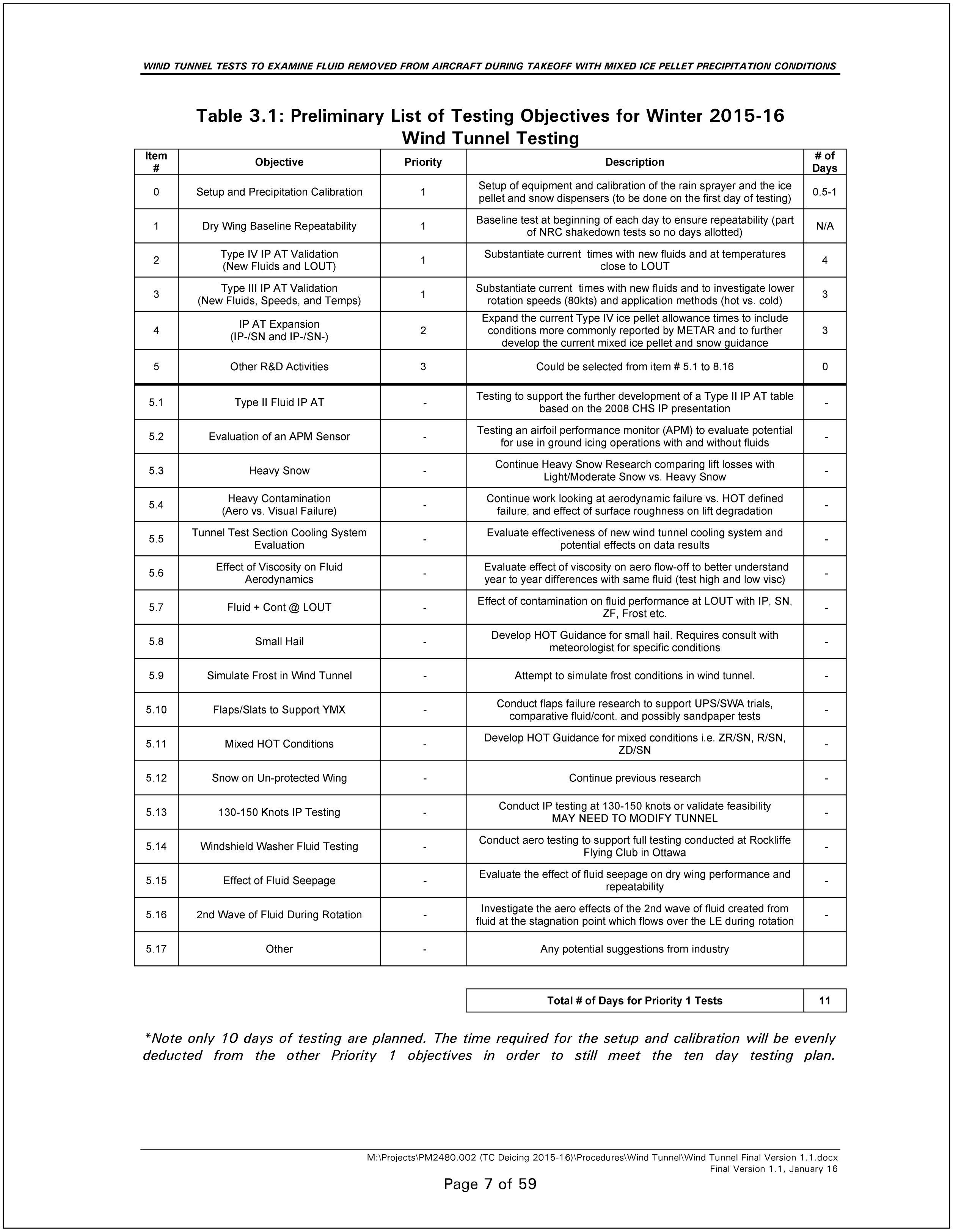


Table 3.1: Preliminary List of Testing Objectives for Winter 2015-16 Wind Tunnel Testing

Item #	Objective	Priority	Description	# of Days
0	Setup and Precipitation Calibration	1	Setup of equipment and calibration of the rain sprayer and the ice pellet and snow dispensers (to be done on the first day of testing)	0.5-1
1	Dry Wing Baseline Repeatability	1	Baseline test at beginning of each day to ensure repeatability (part of NRC shakedown tests so no days allotted)	N/A
2	Type IV IP AT Validation (New Fluids and LOUT)	1	Substantiate current times with new fluids and at temperatures close to LOUT	4
3	Type III IP AT Validation (New Fluids, Speeds, and Temps)	1	Substantiate current times with new fluids and to investigate lower rotation speeds (80kts) and application methods (hot vs. cold)	3
4	IP AT Expansion (IP-/SN and IP-/SN-)	2	Expand the current Type IV ice pellet allowance times to include conditions more commonly reported by METAR and to further develop the current mixed ice pellet and snow guidance	3
5	Other R&D Activities	3	Could be selected from item # 5.1 to 8.16	0
5.1	Type II Fluid IP AT	-	Testing to support the further development of a Type II IP AT table based on the 2008 CHS IP presentation	-
5.2	Evaluation of an APM Sensor	-	Testing an airfoil performance monitor (APM) to evaluate potential for use in ground icing operations with and without fluids	-
5.3	Heavy Snow	-	Continue Heavy Snow Research comparing lift losses with Light/Moderate Snow vs. Heavy Snow	-
5.4	Heavy Contamination (Aero vs. Visual Failure)	-	Continue work looking at aerodynamic failure vs. HOT defined failure, and effect of surface roughness on lift degradation	-
5.5	Tunnel Test Section Cooling System Evaluation	-	Evaluate effectiveness of new wind tunnel cooling system and potential effects on data results	-
5.6	Effect of Viscosity on Fluid Aerodynamics	-	Evaluate effect of viscosity on aero flow-off to better understand year to year differences with same fluid (test high and low visc)	-
5.7	Fluid + Cont @ LOUT	-	Effect of contamination on fluid performance at LOUT with IP, SN, ZF, Frost etc.	-
5.8	Small Hail	-	Develop HOT Guidance for small hail. Requires consult with meteorologist for specific conditions	-
5.9	Simulate Frost in Wind Tunnel	-	Attempt to simulate frost conditions in wind tunnel.	-
5.10	Flaps/Slats to Support YMX	-	Conduct flaps failure research to support UPS/SWA trials, comparative fluid/cont. and possibly sandpaper tests	-
5.11	Mixed HOT Conditions	-	Develop HOT Guidance for mixed conditions i.e. ZR/SN, R/SN, ZD/SN	-
5.12	Snow on Un-protected Wing	-	Continue previous research	-
5.13	130-150 Knots IP Testing	-	Conduct IP testing at 130-150 knots or validate feasibility MAY NEED TO MODIFY TUNNEL	-
5.14	Windshield Washer Fluid Testing	-	Conduct aero testing to support full testing conducted at Rockliffe Flying Club in Ottawa	-
5.15	Effect of Fluid Seepage	-	Evaluate the effect of fluid seepage on dry wing performance and repeatability	-
5.16	2nd Wave of Fluid During Rotation	-	Investigate the aero effects of the 2nd wave of fluid created from fluid at the stagnation point which flows over the LE during rotation	-
5.17	Other	-	Any potential suggestions from industry	

Total # of Days for Priority 1 Tests	11

**Note only 10 days of testing are planned. The time required for the setup and calibration will be evenly deducted from the other Priority 1 objectives in order to still meet the ten day testing plan.*

Table 3.2 Proposed Test Plan

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (º)	Ramp (s/kts)	Target OAT (ºC)	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P001	Baseline	1	Dry Wing	8	100	any	none	-	-	-	-	-	-	1	@start of day
P002	Baseline	1	Dry Wing	22	80	any	none	-	-	-	-	-	-	1	@start of day
P003	Type III Allowance Times	1	IP-	8	100	>-5	AeroClear MAX - Cold	25	-	-	-	10	-	1	Increase time if 80kts passed
P004	Type III Allowance Times	1	IP Mod	8	100	>-5	AeroClear MAX - Cold	75	-	-	-	5	-	1	Increase time if 80kts passed
P005	Type III Allowance Times	1	IP- / ZR-	8	100	>-5	AeroClear MAX - Cold	25	-	25	-	7	-	1	Increase time if 80kts passed
P006	Type III Allowance Times	1	IP- / R-	8	100	>0	AeroClear MAX - Cold	25	-	-	25	7	-	1	Increase time if 80kts passed
P007	Type III Allowance Times	1	IP- / SN-	8	100	>-5	AeroClear MAX - Cold	25	10	-	-	10	-	1	Increase time if 80kts passed
P008	Type III Allowance Times	1	IP- / SN	8	100	>-5	AeroClear MAX - Cold	25	25	-	-	10	-	1	Increase time if 80kts passed
P009	Type III Allowance Times	1	IP-	8	100	-5 to -10	AeroClear MAX - Cold	25	-	-	-	10	-	1	Increase time if 80kts passed
P010	Type III Allowance Times	1	IP Mod	8	100	-5 to -10	AeroClear MAX - Cold	75	-	-	-	5	-	1	Increase time if 80kts passed
P011	Type III Allowance Times	1	IP- / ZR-	8	100	-5 to -10	AeroClear MAX - Cold	25	-	25	-	5	-	1	Increase time if 80kts passed
P012	Type III Allowance Times	1	IP- / SN-	8	100	-5 to -10	AeroClear MAX - Cold	25	10	-	-	10	-	1	Increase time if 80kts passed
P013	Type III Allowance Times	1	IP- / SN	8	100	-5 to -10	AeroClear MAX - Cold	25	25	-	-	5	-	1	could do 10-min or more (80kts)
P014	Type III Allowance Times	1	IP-	8	100	-10 to -20	AeroClear MAX - Cold	25	-	-	-	10	-	1	Increase time if 80kts passed
P015	Type III Allowance Times	1	IP Mod	8	100	-10 to -20	AeroClear MAX - Cold	75	-	-	-	5	-	1	Increase time if 80kts passed
P016	Type III Allowance Times	1	IP-	8	100	-20 to -30	AeroClear MAX - Cold	25	-	-	-	10	-	1	Increase time if 80kts passed
P017	Type III Allowance Times	1	IP Mod	8	100	-20 to -30	AeroClear MAX - Cold	75	-	-	-	5	-	1	Increase time if 80kts passed
P018	Type III Allowance Times	1	Fluid Only	8	100	-5 to -10	AeroClear MAX - Cold	-	-	-	-	-	-	1	Baseline Test
P019	Type III Allowance Times	1	Fluid Only	8	100	<-15	AeroClear MAX - Cold	-	-	-	-	-	-	1	Baseline Test
P020	Type III Allowance Times	1	IP-	8	80	>-5	AeroClear MAX - Cold	25	-	-	-	10	-	1	
P021	Type III Allowance Times	1	IP Mod	8	80	>-5	AeroClear MAX - Cold	75	-	-	-	5	-	1	
P022	Type III Allowance Times	1	IP- / ZR-	8	80	>-5	AeroClear MAX - Cold	25	-	25	-	7	-	1	
P023	Type III Allowance Times	1	IP- / R-	8	80	>0	AeroClear MAX - Cold	25	-	-	25	7	-	1	
P024	Type III Allowance Times	1	IP- / SN-	8	80	>-5	AeroClear MAX - Cold	25	10	-	-	10	-	1	
P025	Type III Allowance Times	1	IP- / SN	8	80	>-5	AeroClear MAX - Cold	25	25	-	-	10	-	1	

Table 3.2: Proposed Test Plan (cont.)

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (°)	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P026	Type III Allowance Times	1	IP-	8	80	-5 to -10	AeroClear MAX - Cold	25	-	-	-	10	-	1	
P027	Type III Allowance Times	1	IP Mod	8	80	-5 to -10	AeroClear MAX - Cold	75	-	-	-	5	-	1	
P028	Type III Allowance Times	1	IP- / ZR-	8	80	-5 to -10	AeroClear MAX - Cold	25	-	25	-	5	-	1	
P029	Type III Allowance Times	1	IP- / SN-	8	80	-5 to -10	AeroClear MAX - Cold	25	10	-	-	10	-	1	
P030	Type III Allowance Times	1	IP- / SN	8	80	-5 to -10	AeroClear MAX - Cold	25	25	-	-	5	-	1	could do 10-min
P031	Type III Allowance Times	1	IP-	8	80	-10 to -20	AeroClear MAX - Cold	25	-	-	-	10	-	1	
P032	Type III Allowance Times	1	IP Mod	8	80	-10 to -20	AeroClear MAX - Cold	75	-	-	-	5	-	1	
P033	Type III Allowance Times	1	IP-	8	80	-20 to -30	AeroClear MAX - Cold	25	-	-	-	10	-	1	
P034	Type III Allowance Times	1	IP Mod	8	80	-20 to -30	AeroClear MAX - Cold	75	-	-	-	5	-	1	
P035	Type III Allowance Times	1	Fluid Only	8	80	-5 to -10	AeroClear MAX - Cold	-	-	-	-	-	-	1	Baseline Test
P035	Type III Allowance Times	1	Fluid Only	8	80	-5 to -10	AeroClear MAX - Cold	-	-	-	-	-	1	Baseline Test	P035
P036	Type III Allowance Times	1	Fluid Only	8	80	<-15	AeroClear MAX - Cold	-	-	-	-	-	1	Baseline Test	P036
P037	Type III Allowance Times	1	IP-	8	100	>-5	AeroClear MAX - Hot	25	-	-	-	10	2	Increase time if 80kts passed	P037
P038	Type III Allowance Times	1	IP Mod	8	100	>-5	AeroClear MAX - Hot	75	-	-	-	5	2	Increase time if 80kts passed	P038
P039	Type III Allowance Times	1	IP- / ZR-	8	100	>-5	AeroClear MAX - Hot	25	-	25	-	7	2	Increase time if 80kts passed	P039
P040	Type III Allowance Times	1	IP- / R-	8	100	>0	AeroClear MAX - Hot	25	-	-	25	7	2	Increase time if 80kts passed	P040
P041	Type III Allowance Times	1	IP- / SN-	8	100	>-5	AeroClear MAX - Hot	25	10	-	-	10	2	Increase time if 80kts passed	P041
P042	Type III Allowance Times	1	IP- / SN	8	100	>-5	AeroClear MAX - Hot	25	25	-	-	10	2	Increase time if 80kts passed	P042
P043	Type III Allowance Times	1	IP-	8	100	-5 to -10	AeroClear MAX - Hot	25	-	-	-	10	2	Increase time if 80kts passed	P043
P044	Type III Allowance Times	1	IP Mod	8	100	-5 to -10	AeroClear MAX - Hot	75	-	-	-	5	2	Increase time if 80kts passed	P044
P045	Type III Allowance Times	1	IP- / ZR-	8	100	-5 to -10	AeroClear MAX - Hot	25	-	25	-	5	2	Increase time if 80kts passed	P045
P046	Type III Allowance Times	1	IP- / SN-	8	100	-5 to -10	AeroClear MAX - Hot	25	10	-	-	10	2	Increase time if 80kts passed	P046
P047	Type III Allowance Times	1	IP- / SN	8	100	-5 to -10	AeroClear MAX - Hot	25	25	-	-	5	2	could do 10-min or more (80kts)	P047

Table 3.2: Proposed Test Plan (cont.)

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (º)	Ramp (s/kts)	Target OAT (ºC)	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P048	Type III Allowance Times	1	IP-	8	100	-10 to -20	AeroClear MAX - Hot	25	-	-	-	10	2	Increase time if 80kts passed	P048
P049	Type III Allowance Times	1	IP Mod	8	100	-10 to -20	AeroClear MAX - Hot	75	-	-	-	5	2	Increase time if 80kts passed	P049
P050	Type III Allowance Times	1	IP-	8	100	-20 to -30	AeroClear MAX - Hot	25	-	-	-	10	2	Increase time if 80kts passed	P050
P051	Type III Allowance Times	1	IP Mod	8	100	-20 to -30	AeroClear MAX - Hot	75	-	-	-	5	2	Increase time if 80kts passed	P051
P052	Type III Allowance Times	1	Fluid Only	8	100	-5 to -10	AeroClear MAX - Hot	-	-	-	-	-	2	Baseline Test	P052
P053	Type III Allowance Times	1	Fluid Only	8	100	<-15	AeroClear MAX - Hot	-	-	-	-	-	2	Baseline Test	P053
P054	Type III Allowance Times	1	IP-	8	80	>-5	AeroClear MAX - Hot	25	-	-	-	10	2		P054
P055	Type III Allowance Times	1	IP Mod	8	80	>-5	AeroClear MAX - Hot	75	-	-	-	5	2		P055
P056	Type III Allowance Times	1	IP- / ZR-	8	80	>-5	AeroClear MAX - Hot	25	-	25	-	7	2		P056
P057	Type III Allowance Times	1	IP- / R-	8	80	>0	AeroClear MAX - Hot	25	-	-	25	7	2		P057
P058	Type III Allowance Times	1	IP- / SN-	8	80	>-5	AeroClear MAX - Hot	25	10	-	-	10	2		P058
P059	Type III Allowance Times	1	IP- / SN	8	80	>-5	AeroClear MAX - Hot	25	25	-	-	10	2		P059
P060	Type III Allowance Times	1	IP-	8	80	-5 to -10	AeroClear MAX - Hot	25	-	-	-	10	2		P060
P061	Type III Allowance Times	1	IP Mod	8	80	-5 to -10	AeroClear MAX - Hot	75	-	-	-	5	2		P061
P062	Type III Allowance Times	1	IP- / ZR-	8	80	-5 to -10	AeroClear MAX - Hot	25	-	25	-	5	2		P062
P063	Type III Allowance Times	1	IP- / SN-	8	80	-5 to -10	AeroClear MAX - Hot	25	10	-	-	10	2		P063
P064	Type III Allowance Times	1	IP- / SN	8	80	-5 to -10	AeroClear MAX - Hot	25	25	-	-	5	2	could do 10-min	P064
P065	Type III Allowance Times	1	IP-	8	80	-10 to -20	AeroClear MAX - Hot	25	-	-	-	10	2		P065
P066	Type III Allowance Times	1	IP Mod	8	80	-10 to -20	AeroClear MAX - Hot	75	-	-	-	5	2		P066
P067	Type III Allowance Times	1	IP-	8	80	-20 to -30	AeroClear MAX - Hot	25	-	-	-	10	2		P067
P068	Type III Allowance Times	1	IP Mod	8	80	-20 to -30	AeroClear MAX - Hot	75	-	-	-	5	2		P068
P069	Type III Allowance Times	1	Fluid Only	8	80	-5 to -10	AeroClear MAX - Hot	-	-	-	-	-	2	Baseline Test	P069
P070	Type III Allowance Times	1	Fluid Only	8	80	<-15	AeroClear MAX - Hot	-	-	-	-	-	2	Baseline Test	P070
P071	Type IV Validation and New Fluids	1	IP-	8	100	>-5	LNT E450	25	-	-	-	50	1		P071
P072	Type IV Validation and New Fluids	1	IP Mod	8	100	>-5	LNT E450	75	-	-	-	25	1		P072
P073	Type IV Validation and New Fluids	1	IP- / ZR-	8	100	>-5	LNT E450	25	-	25	-	25	1		P073
P068	Type III Allowance Times	1	IP Mod	8	80	-20 to -30	AeroClear MAX - Hot	75	-	-	-	5	2		P068

Table 3.2: Proposed Test Plan (cont.)

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (°)	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P069	Type III Allowance Times	1	Fluid Only	8	80	-5 to -10	AeroClear MAX - Hot	-	-	-	-	-	2	Baseline Test	P069
P070	Type III Allowance Times	1	Fluid Only	8	80	<-15	AeroClear MAX - Hot	-	-	-	-	-	2	Baseline Test	P070
P071	Type IV Validation and New Fluids	1	IP-	8	100	>-5	LNT E450	25	-	-	-	50	1		P071
P072	Type IV Validation and New Fluids	1	IP Mod	8	100	>-5	LNT E450	75	-	-	-	25	1		P072
P073	Type IV Validation and New Fluids	1	IP- / ZR-	8	100	>-5	LNT E450	25	-	25	-	25	1		P073
P074	Type IV Validation and New Fluids	1	IP- / R-	8	100	>0	LNT E450	25	-	-	25	25	1		P074
P075	Type IV Validation and New Fluids	1	IP- / SN-	8	100	>-5	LNT E450	25	10	-	-	25	1		P075
P076	Type IV Validation and New Fluids	1	IP- / SN	8	100	>-5	LNT E450	25	25	-	-	10	1		P076
P077	Type IV Validation and New Fluids	1	IP-	8	100	-5 to -10	LNT E450	25	-	-	-	30	1		P077
P078	Type IV Validation and New Fluids	1	IP Mod	8	100	-5 to -10	LNT E450	75	-	-	-	10	1		P078
P079	Type IV Validation and New Fluids	1	IP- / ZR-	8	100	-5 to -10	LNT E450	25	-	25	-	10	1		P079
P080	Type IV Validation and New Fluids	1	IP- / SN-	8	100	-5 to -10	LNT E450	25	10	-	-	15	1		P080
P081	Type IV Validation and New Fluids	1	IP- / SN	8	100	-5 to -10	LNT E450	25	25	-	-	7	1		P081
P082	Type IV Validation and New Fluids	1	IP-	8	100	-10 to -16	LNT E450	25	-	-	-	30	1		P082
P083	Type IV Validation and New Fluids	1	IP Mod	8	100	-10 to -16	LNT E450	75	-	-	-	10	1		P083
P084	Type IV Validation and New Fluids	1	IP-	8	100	-16 to -25	LNT E450	25	-	-	-	30	1		P084
P085	Type IV Validation and New Fluids	1	IP Mod	8	100	-16 to -25	LNT E450	75	-	-	-	10	1		P085
P086	Type IV Validation and New Fluids	1	Fluid Only	8	100	-5 to -10	LNT E450	-	-	-	-	-	1	Baseline Test	P086
P087	Type IV Validation and New Fluids	1	Fluid Only	8	100	<-15	LNT E450	-	-	-	-	-	1	Baseline Test	P087
P088	Type IV Validation and New Fluids	1	IP-	8	100	>-5	FCY 9311	25	-	-	-	50	1		P088
P089	Type IV Validation and New Fluids	1	IP Mod	8	100	>-5	FCY 9311	75	-	-	-	25	1		P089
P090	Type IV Validation and New Fluids	1	IP- / ZR-	8	100	>-5	FCY 9311	25	-	25	-	25	1		P090
P091	Type IV Validation and New Fluids	1	IP- / R-	8	100	>0	FCY 9311	25	-	-	25	25	1		P091
P092	Type IV Validation and New Fluids	1	IP- / SN-	8	100	>-5	FCY 9311	25	10	-	-	25	1		P092
P093	Type IV Validation and New Fluids	1	IP- / SN	8	100	>-5	FCY 9311	25	25	-	-	10	1		P093
P094	Type IV Validation and New Fluids	1	IP-	8	100	-5 to -10	FCY 9311	25	-	-	-	30	1		P094
P095	Type IV Validation and New Fluids	1	IP Mod	8	100	-5 to -10	FCY 9311	75	-	-	-	10	1		P095
P096	Type IV Validation and New Fluids	1	IP- / ZR-	8	100	-5 to -10	FCY 9311	25	-	25	-	10	1		P096
P097	Type IV Validation and New Fluids	1	IP- / SN-	8	100	-5 to -10	FCY 9311	25	10	-	-	15	1		P097

Table 3.2: Proposed Test Plan (cont.)

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (º)	Ramp (s/kts)	Target OAT (ºC)	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P098	Type IV Validation and New Fluids	1	IP- / SN	8	100	-5 to -10	FCY 9311	25	25	-	-	7	1		P098
P099	Type IV Validation and New Fluids	1	IP-	8	100	-10 to -16	FCY 9311	25	-	-	-	30	1		P099
P100	Type IV Validation and New Fluids	1	IP Mod	8	100	-10 to -16	FCY 9311	75	-	-	-	10	1		P100
P101	Type IV Validation and New Fluids	1	IP-	8	115	-16 to -25	FCY 9311	25	-	-	-	30	1	note 115 kts	P101
P102	Type IV Validation and New Fluids	1	IP Mod	8	115	-16 to -25	FCY 9311	75	-	-	-	10	1	note 115 kts	P102
P103	Type IV Validation and New Fluids	1	Fluid Only	8	100	-5 to -10	FCY 9311	-	-	-	-	-	1	Baseline Test	P103
P104	Type IV Validation and New Fluids	1	Fluid Only	8	100	<-15	FCY 9311	-	-	-	-	-	1	Baseline Test	P104
P105	Type IV Validation and New Fluids	1	IP-	8	100	<-25	LNT E450	25	-	-	-	30	1		P105
P106	Type IV Validation and New Fluids	1	IP Mod	8	100	<-25	LNT E450	75	-	-	-	10	1		P106
P107	Type IV Validation and New Fluids	1	Fluid Only	8	100	<-25	LNT E450	-	-	-	-	-	1	Baseline Test	P107
P108	Type IV Validation and New Fluids	1	IP-	8	115	<-25	FCY 9311	25	-	-	-	30	1	note 115 kts	P108
P109	Type IV Validation and New Fluids	1	IP Mod	8	115	<-25	FCY 9311	75	-	-	-	10	1	note 115 kts	P109
P110	Type IV Validation and New Fluids	1	Fluid Only	8	100	<-25	FCY 9311	-	-	-	-	-	1	Baseline Test	P110
P111	Type IV Validation and New Fluids	1	IP-	8	115	<-25	Launch	25	-	-	-	30	1	note 115 kts	P111
P112	Type IV Validation and New Fluids	1	IP Mod	8	115	<-25	Launch	75	-	-	-	10	1	note 115 kts	P112
P113	Type IV Validation and New Fluids	1	Fluid Only	8	100	<-25	Launch	-	-	-	-	-	1	Baseline Test	P113
P114	Type IV Validation and New Fluids	1	IP-	8	115	<-25	AD-49	25	-	-	-	30	1	note 115 kts	P114
P115	Type IV Validation and New Fluids	1	IP Mod	8	115	<-25	AD-49	75	-	-	-	10	1	note 115 kts	P115
P116	Type IV Validation and New Fluids	1	Fluid Only	8	100	<-25	AD-49	-	-	-	-	-	1	Baseline Test	P116
P119	Type IV Validation and New Fluids	1	Fluid Only	8	100	<-25	ABC-S Plus	-	-	-	-	-	1	Baseline Test	P119
P120	Type IV Validation and New Fluids	1	IP-	8	115	<-25	Polar Guard Advance	25	-	-	-	30	1	note 115 kts	P120
P121	Type IV Validation and New Fluids	1	IP Mod	8	115	<-25	Polar Guard Advance	75	-	-	-	10	1	note 115 kts	P121
P122	Type IV Validation and New Fluids	1	Fluid Only	8	100	<-25	Polar Guard Advance	-	-	-	-	-	1	Baseline Test	P122
P123	IP Expansion - METAR	2	IP / R	8	100	>0	LNT E450	75	-	-	75	25	1	7-25min (tbd)	P123
P124	IP Expansion - METAR	2	IP / SN	8	100	>-5	LNT E450	75	25	-	-	20	1	10-20 min (tbd)	P124
P125	IP Expansion - METAR	2	IP / SN	8	100	-5 to -10	LNT E450	75	25	-	-	10	1	5-10 min (tbd)	P125

Table 3.2: Proposed Test Plan (cont.)

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (°)	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P126	IP Expansion - METAR	2	IP / SN	8	100	-10 to -16	LNT E450	75	25	-	-	10	1	5-10 min (tbd)	P126
P127	IP Expansion - METAR	2	IP / SN	8	100	<-16	LNT E450	75	25	-	-	10	1	5-10 min (tbd)	P127
P128	IP Expansion - METAR	2	IP / ZD	8	100	>-5	LNT E450	75	-	5	-	20	1	consider ZD13. 10-20 min (tbd)	P128
P129	IP Expansion - METAR	2	IP / ZD	8	100	-5 to -10	LNT E450	75	-	5	-	7	1	5-7 min (tbd)	P129
P130	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	>-5	LNT E450	25	10	-	-	40	2	aim for 40-min	P130
P131	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	-5 to -10	LNT E450	25	10	-	-	25	2	aim for 25-min (tbd)	P131
P132	IP Expansion - Current IP and SN	2	IP- / SN	8	100	>-5	LNT E450	25	25	-	-	20	2	aim for 20 min (tbd)	P132
P133	IP Expansion - Current IP and SN	2	IP- / SN	8	100	-5 to -10	LNT E450	25	25	-	-	10	2	aim for 10-min (tbd)	P133
P134	IP Expansion - New IP and SN	2	IP- / SN-	8	100	-10 to -16	LNT E450	25	10	-	-	15	2	aim for 15-min (tbd)	P134
P135	IP Expansion - New IP and SN	2	IP- / SN-	8	115	<-16	LNT E450	25	10	-	-	15	2	aim for 15-min (tbd)	P135
P136	IP Expansion - New IP and SN	2	IP- / SN	8	100	-10 to -16	LNT E450	25	25	-	-	10	2	aim for 10-min (tbd)	P136
P137	IP Expansion - New IP and SN	2	IP- / SN	8	115	<-16	LNT E450	25	25	-	-	10	2	aim for 5-10-min (tbd)	P137
P138	IP Expansion - METAR	2	IP / R	8	100	>0	FCY 9311	75	-	-	75	25	1	7-25min (tbd)	P138
P139	IP Expansion - METAR	2	IP / SN	8	100	>-5	FCY 9311	75	25	-	-	20	1	10-20 min (tbd)	P139
P140	IP Expansion - METAR	2	IP / SN	8	100	-5 to -10	FCY 9311	75	25	-	-	10	1	5-10 min (tbd)	P140
P141	IP Expansion - METAR	2	IP / SN	8	100	-10 to -16	FCY 9311	75	25	-	-	10	1	5-10 min (tbd)	P141
P142	IP Expansion - METAR	2	IP / SN	8	100	<-16	FCY 9311	75	25	-	-	10	1	5-10 min (tbd)	P142
P143	IP Expansion - METAR	2	IP / ZD	8	100	>-5	FCY 9311	75	-	5	-	20	1	consider ZD13. 10-20 min (tbd)	P143
P144	IP Expansion - METAR	2	IP / ZD	8	100	-5 to -10	FCY 9311	75	-	5	-	7	1	5-7 min (tbd)	P144
P145	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	>-5	FCY 9311	25	10	-	-	40	2	aim for 40-min	P145
P146	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	-5 to -10	FCY 9311	25	10	-	-	25	2	aim for 25-min (tbd)	P146
P147	IP Expansion - Current IP and SN	2	IP- / SN	8	100	>-5	FCY 9311	25	25	-	-	20	2	aim for 20 min (tbd)	P147
P148	IP Expansion - Current IP and SN	2	IP- / SN	8	100	-5 to -10	FCY 9311	25	25	-	-	10	2	aim for 10-min (tbd)	P148
P149	IP Expansion - New IP and SN	2	IP- / SN-	8	100	-10 to -16	FCY 9311	25	10	-	-	15	2	aim for 15-min (tbd)	P149

Table 3.2: Proposed Test Plan (cont.)

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (°)	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P150	IP Expansion - New IP and SN	2	IP- / SN-	8	115	<-16	FCY 9311	25	10	-	-	15	2	aim for 15-min (tbd)	P150
P151	IP Expansion - New IP and SN	2	IP- / SN	8	100	-10 to -16	FCY 9311	25	25	-	-	10	2	aim for 10-min (tbd)	P151
P152	IP Expansion - New IP and SN	2	IP- / SN	8	115	<-16	FCY 9311	25	25	-	-	10	2	aim for 5-10-min (tbd)	P152
P153	IP Expansion - METAR	2	IP / R	8	100	>0	Launch	75	-	-	75	25	1	7-25min (tbd)	P153
P154	IP Expansion - METAR	2	IP / SN	8	100	>-5	Launch	75	25	-	-	20	1	10-20 min (tbd)	P154
P155	IP Expansion - METAR	2	IP / SN	8	100	-5 to -10	Launch	75	25	-	-	10	1	5-10 min (tbd)	P155
P156	IP Expansion - METAR	2	IP / SN	8	100	-10 to -16	Launch	75	25	-	-	10	1	5-10 min (tbd)	P156
P157	IP Expansion - METAR	2	IP / SN	8	100	<-16	Launch	75	25	-	-	10	1	5-10 min (tbd)	P157
P158	IP Expansion - METAR	2	IP / ZD	8	100	>-5	Launch	75	-	5	-	20	1	consider ZD13. 10-20 min (tbd)	P158
P159	IP Expansion - METAR	2	IP / ZD	8	100	-5 to -10	Launch	75	-	5	-	7	1	5-7 min (tbd)	P159
P160	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	>-5	Launch	25	10	-	-	40	2	aim for 40-min	P160
P161	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	-5 to -10	Launch	25	10	-	-	25	2	aim for 25-min (tbd)	P161
P162	IP Expansion - Current IP and SN	2	IP- / SN	8	100	>-5	Launch	25	25	-	-	20	2	aim for 20 min (tbd)	P162
P163	IP Expansion - Current IP and SN	2	IP- / SN	8	100	-5 to -10	Launch	25	25	-	-	10	2	aim for 10-min (tbd)	P163
P164	IP Expansion - New IP and SN	2	IP- / SN-	8	100	-10 to -16	Launch	25	10	-	-	15	2	aim for 15-min (tbd)	P164
P165	IP Expansion - New IP and SN	2	IP- / SN-	8	115	<-16	Launch	25	10	-	-	15	2	aim for 15-min (tbd)	P165
P166	IP Expansion - New IP and SN	2	IP- / SN	8	100	-10 to -16	Launch	25	25	-	-	10	2	aim for 10-min (tbd)	P166
P167	IP Expansion - New IP and SN	2	IP- / SN	8	115	<-16	Launch	25	25	-	-	10	2	aim for 5-10-min (tbd)	P167
P168	IP Expansion	2	Fluid Only	8	100	-5 to -10	Launch	-	-	-	-	-	2	Baseline Test	P168
P169	IP Expansion	2	Fluid Only	8	100	<-15	Launch	-	-	-	-	-	2	Baseline Test	P169
P170	IP Expansion - METAR	2	IP / R	8	100	>0	AD-49	75	-	-	75	25	1	7-25min (tbd)	P170
P171	IP Expansion - METAR	2	IP / SN	8	100	>-5	AD-49	75	25	-	-	20	1	10-20 min (tbd)	P171
P172	IP Expansion - METAR	2	IP / SN	8	100	-5 to -10	AD-49	75	25	-	-	10	1	5-10 min (tbd)	P172
P173	IP Expansion - METAR	2	IP / SN	8	100	-10 to -16	AD-49	75	25	-	-	10	1	5-10 min (tbd)	P173

Table 3.2: Proposed Test Plan (cont.)

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (°)	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P174	IP Expansion - METAR	2	IP / SN	8	100	<-16	AD-49	75	25	-	-	10	1	5-10 min (tbd)	P174
P175	IP Expansion - METAR	2	IP / ZD	8	100	>-5	AD-49	75	-	5	-	20	1	consider ZD13. 10-20 min (tbd)	P175
P176	IP Expansion - METAR	2	IP / ZD	8	100	-5 to -10	AD-49	75	-	5	-	7	1	5-7 min (tbd)	P176
P177	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	>-5	AD-49	25	10	-	-	40	2	aim for 40-min	P177
P178	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	-5 to -10	AD-49	25	10	-	-	25	2	aim for 25-min (tbd)	P178
P179	IP Expansion - Current IP and SN	2	IP- / SN	8	100	>-5	AD-49	25	25	-	-	20	2	aim for 20 min (tbd)	P179
P180	IP Expansion - Current IP and SN	2	IP- / SN	8	100	-5 to -10	AD-49	25	25	-	-	10	2	aim for 10-min (tbd)	P180
P181	IP Expansion - New IP and SN	2	IP- / SN-	8	100	-10 to -16	AD-49	25	10	-	-	15	2	aim for 15-min (tbd)	P181
P182	IP Expansion - New IP and SN	2	IP- / SN-	8	115	<-16	AD-49	25	10	-	-	15	2	aim for 15-min (tbd)	P182
P183	IP Expansion - New IP and SN	2	IP- / SN	8	100	-10 to -16	AD-49	25	25	-	-	10	2	aim for 10-min (tbd)	P183
P184	IP Expansion - New IP and SN	2	IP- / SN	8	115	<-16	AD-49	25	25	-	-	10	2	aim for 5-10-min (tbd)	P184
P185	IP Expansion	2	Fluid Only	8	100	-5 to -10	AD-49	-	-	-	-	-	2	Baseline Test	P185
P186	IP Expansion	2	Fluid Only	8	100	<-15	AD-49	-	-	-	-	-	2	Baseline Test	P186
P187	IP Expansion - METAR	2	IP / R	8	100	>0	ABC-S Plus	75	-	-	75	25	1	7-25min (tbd)	P187
P188	IP Expansion - METAR	2	IP / SN	8	100	>-5	ABC-S Plus	75	25	-	-	20	1	10-20 min (tbd)	P188
P189	IP Expansion - METAR	2	IP / SN	8	100	-5 to -10	ABC-S Plus	75	25	-	-	10	1	5-10 min (tbd)	P189
P190	IP Expansion - METAR	2	IP / SN	8	100	-10 to -16	ABC-S Plus	75	25	-	-	10	1	5-10 min (tbd)	P190
P191	IP Expansion - METAR	2	IP / SN	8	100	<-16	ABC-S Plus	75	25	-	-	10	1	5-10 min (tbd)	P191
P192	IP Expansion - METAR	2	IP / ZD	8	100	>-5	ABC-S Plus	75	-	5	-	20	1	consider ZD13. 10-20 min (tbd)	P192
P193	IP Expansion - METAR	2	IP / ZD	8	100	-5 to -10	ABC-S Plus	75	-	5	-	7	1	5-7 min (tbd)	P193
P194	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	>-5	ABC-S Plus	25	10	-	-	40	2	aim for 40-min	P194
P195	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	-5 to -10	ABC-S Plus	25	10	-	-	25	2	aim for 25-min (tbd)	P195
P196	IP Expansion - Current IP and SN	2	IP- / SN	8	100	>-5	ABC-S Plus	25	25	-	-	20	2	aim for 20 min (tbd)	P196
P197	IP Expansion - Current IP and SN	2	IP- / SN	8	100	-5 to -10	ABC-S Plus	25	25	-	-	10	2	aim for 10-min (tbd)	P197
P198	IP Expansion - New IP and SN	2	IP- / SN-	8	100	-10 to -16	ABC-S Plus	25	10	-	-	15	2	aim for 15-min (tbd)	P198
P199	IP Expansion - New IP and SN	2	IP- / SN-	8	115	<-16	ABC-S Plus	25	10	-	-	15	2	aim for 15-min (tbd)	P199
P200	IP Expansion - New IP and SN	2	IP- / SN	8	100	-10 to -16	ABC-S Plus	25	25	-	-	10	2	aim for 10-min (tbd)	P200
P201	IP Expansion - New IP and SN	2	IP- / SN	8	115	<-16	ABC-S Plus	25	25	-	-	10	2	aim for 5-10-min (tbd)	P201

Table 3.2: Proposed Test Plan (cont.)

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (º)	Ramp (s/kts)	Target OAT (ºC)	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P202	IP Expansion	2	Fluid Only	8	100	-5 to -10	ABC-S Plus	-	-	-	-	-	2	Baseline Test	P202
P203	IP Expansion	2	Fluid Only	8	100	<-15	ABC-S Plus	-	-	-	-	-	2	Baseline Test	P203
P204	IP Expansion - METAR	2	IP / R	8	100	>0	Polar Guard Advance	75	-	-	75	25	1	7-25min (tbd)	P204
P205	IP Expansion - METAR	2	IP / SN	8	100	>-5	Polar Guard Advance	75	25	-	-	20	1	10-20 min (tbd)	P205
P206	IP Expansion - METAR	2	IP / SN	8	100	-5 to -10	Polar Guard Advance	75	25	-	-	10	1	5-10 min (tbd)	P206
P207	IP Expansion - METAR	2	IP / SN	8	100	-10 to -16	Polar Guard Advance	75	25	-	-	10	1	5-10 min (tbd)	P207
P208	IP Expansion - METAR	2	IP / SN	8	100	<-16	Polar Guard Advance	75	25	-	-	10	1	5-10 min (tbd)	P208
P209	IP Expansion - METAR	2	IP / ZD	8	100	>-5	Polar Guard Advance	75	-	5	-	20	1	consider ZD13. 10-20 min (tbd)	P209
P210	IP Expansion - METAR	2	IP / ZD	8	100	-5 to -10	Polar Guard Advance	75	-	5	-	7	1	5-7 min (tbd)	P210
P211	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	>-5	Polar Guard Advance	25	10	-	-	40	2	aim for 40-min	P211
P212	IP Expansion - Current IP and SN	2	IP- / SN-	8	100	-5 to -10	Polar Guard Advance	25	10	-	-	25	2	aim for 25-min (tbd)	P212
P213	IP Expansion - Current IP and SN	2	IP- / SN	8	100	>-5	Polar Guard Advance	25	25	-	-	20	2	aim for 20 min (tbd)	P213
P214	IP Expansion - Current IP and SN	2	IP- / SN	8	100	-5 to -10	Polar Guard Advance	25	25	-	-	10	2	aim for 10-min (tbd)	P214
P215	IP Expansion - New IP and SN	2	IP- / SN-	8	100	-10 to -16	Polar Guard Advance	25	10	-	-	15	2	aim for 15-min (tbd)	P215
P216	IP Expansion - New IP and SN	2	IP- / SN-	8	115	<-16	Polar Guard Advance	25	10	-	-	15	2	aim for 15-min (tbd)	P216
P217	IP Expansion - New IP and SN	2	IP- / SN	8	100	-10 to -16	Polar Guard Advance	25	25	-	-	10	2	aim for 10-min (tbd)	P217
P218	IP Expansion - New IP and SN	2	IP- / SN	8	115	<-16	Polar Guard Advance	25	25	-	-	10	2	aim for 5-10-min (tbd)	P218
P219	IP Expansion	2	Fluid Only	8	100	-5 to -10	Polar Guard Advance	-	-	-	-	-	2	Baseline Test	P219
P220	IP Expansion	2	Fluid Only	8	100	<-15	Polar Guard Advance	-	-	-	-	-	2	Baseline Test	P220
P221	R&D	3	IP TypeII	TBD	TBD	TBD	Flight (EASA) ?	TBD	TBD	TBD	TBD	TBD	3	Prelim table exists	P221
P222	R&D	3	APM Unit	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	Marinvent	P222
P223	R&D	3	S+++	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	Heavy snow	P223
P224	R&D	3	Heavy Cont	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	Heavy contamination	P224
P225	R&D	3	Cooling Syst	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	Evaluate NRC cooling system	P225
P226	R&D	3	Effect of Visc.	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	Effec of viscosity on flow-off	P226
P227	R&D	3	LOUT w/ Cont.	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	Test w/ contamination @ LOUT	P227
P228	R&D	3	Small Hail	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3		P228

Table 3.2: Proposed Test Plan (cont.)

Test Plan #	Objective	Objective Priority	Test Condition	Rotation Angle (°)	Ramp (s/kts)	Target OAT (°C)	Fluid	IP Rate (g/dm^2/h)	SN Rate (g/dm^2/h)	ZR Rate (g/dm^2/h)	R Rate (g/dm^2/h)	Exposure Time (Min)	Coating	Priority	COMMENT
P229	R&D	3	Frost	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3		P229
P230	R&D	3	Flaps/Slats	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3		P230
P231	R&D	3	Mixed Cond.	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	mixed conditions	P231
P232	R&D	3	SN on Dry Wing	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	snow on a dry wing	P232
P233	R&D	3	IP @ >130kts	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	IP testing a higher speeds	P233
P234	R&D	3	WWF Tests	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	windshield washer fluid	P234
P235	R&D	3	Residual Fluid	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	sfluid seepage	P235
P236	R&D	3	2nd Wave	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	3	2nd wave of fluid at rot.	P236

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 1.

5. DATA FORMS

The following data forms are required for the January 2016 wind tunnel tests:

- Attachment 2: General Form;
- Attachment 3: Wing Temperature, Fluid Thickness and Fluid Brix Form;
- Attachment 4: Example Ice Pellet Dispensing Form;
- Attachment 5: Example Snow Dispensing Form;
- Attachment 6: Example Snow Dispensing Form (Manual Method);
- Attachment 7: Visual Evaluation Rating Form;
- Attachment 8: Fluid Receipt Form (Electronic Form); and
- Attachment 9: 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 2); and
- Record wing temperature (Attachment 3).

6.2 Fluid Application (Pour)

- Hand pour 20L of anti-icing fluid over the test area (fluid can be poured directly out of pails or transferred into smaller 3L jugs);
- Record fluid application times and quantities (Attachment 2);

- 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 3);
- Record wing temperature (Attachment 3);
- Measure fluid Brix value (Attachment 3);
- Photograph and videotape the appearance of the fluid on the wing; and
- 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.

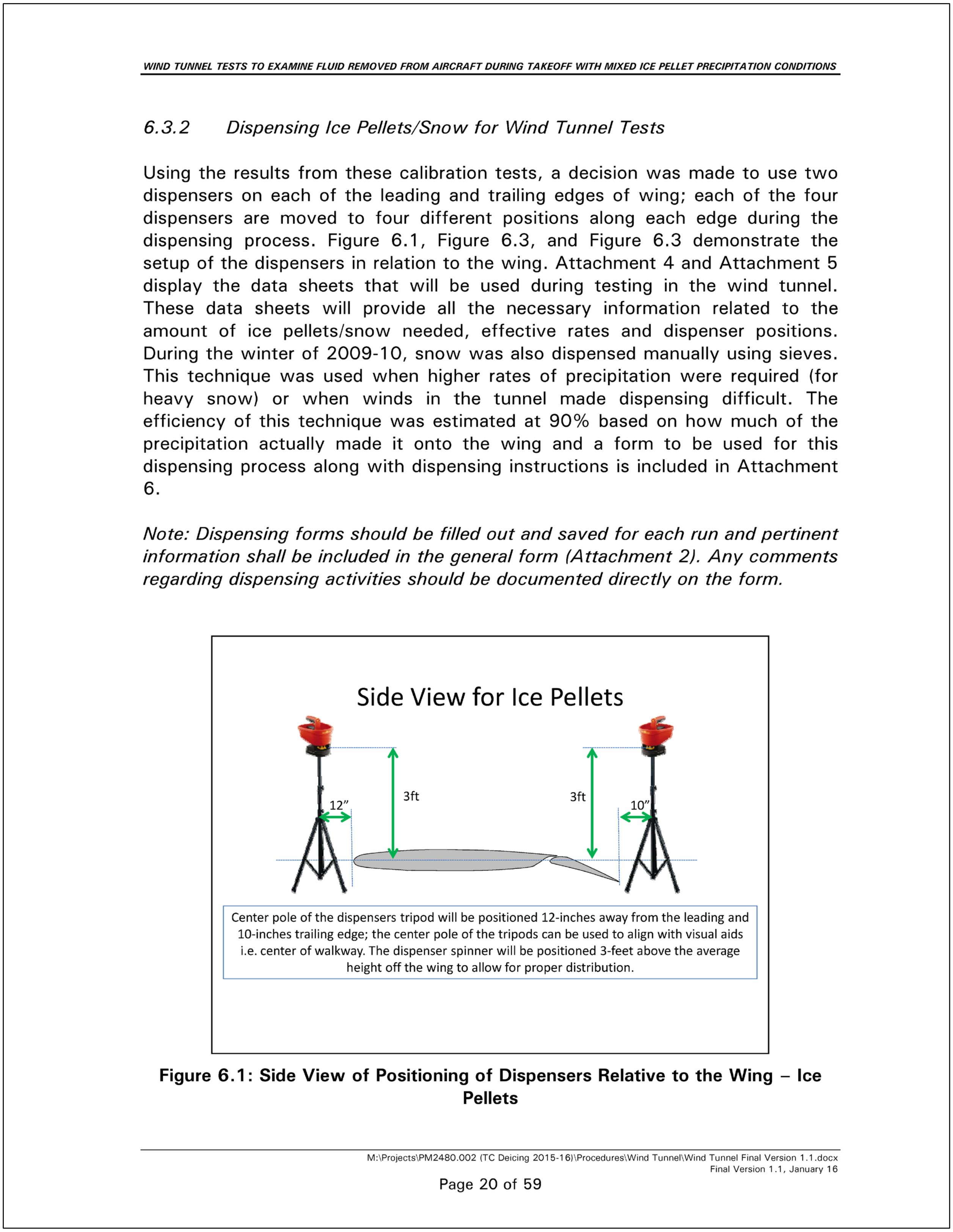
6.3 Application of Contamination

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:

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



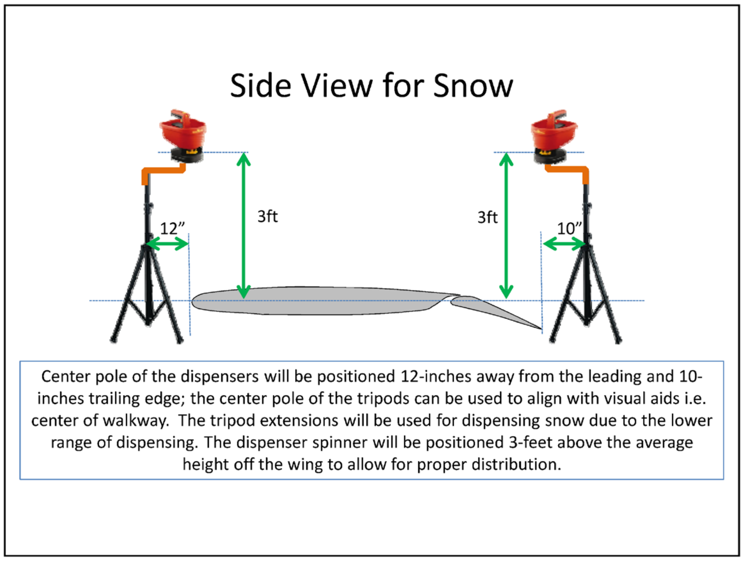
6.3.2 Dispensing Ice Pellets/Snow for Wind Tunnel Tests

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. Figure 6.1, Figure 6.3, and Figure 6.3 demonstrate the setup of the dispensers in relation to the wing. Attachment 4 and Attachment 5 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% based on how much of the precipitation actually made it onto the wing and a form to be used for this dispensing process along with dispensing instructions is included in Attachment 6.

Note: Dispensing forms should be filled out and saved for each run and pertinent information shall be included in the general form (Attachment 2). Any comments regarding dispensing activities should be documented directly on the form.

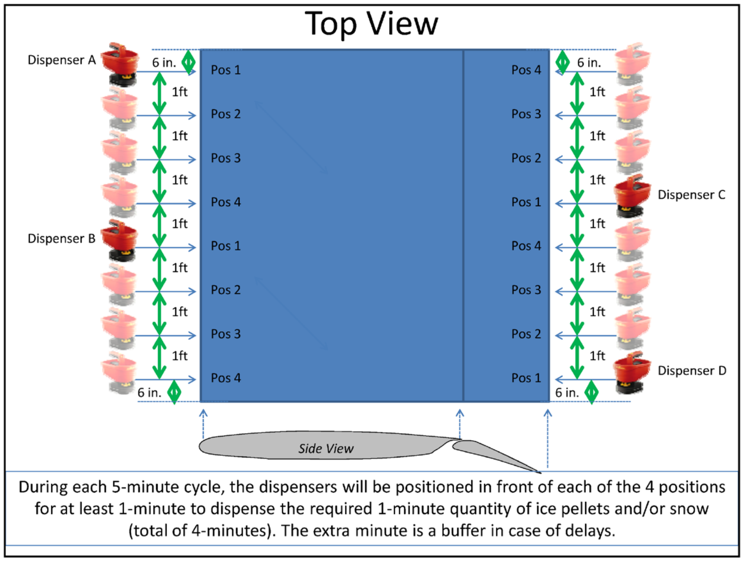
Center pole of the dispensers tripod will be positioned 12-inches away from the leading and 10-inches trailing edge; the center pole of the tripods can be used to align with visual aids i.e. center of walkway. The dispenser spinner will be positioned 3-feet above the average height off the wing to allow for proper distribution.

Figure 6.1: Side View of Positioning of Dispensers Relative to the Wing – Ice Pellets



Center pole of the dispensers will be positioned 12-inches away from the leading and 10-inches trailing edge; the center pole of the tripods can be used to align with visual aids i.e. center of walkway. The tripod extensions will be used for dispensing snow due to the lower range of dispensing. The dispenser spinner will be positioned 3-feet above the average height off the wing to allow for proper distribution.

Figure 6.2: Side View of Positioning of Dispensers Relative to the Wing – Snow



During each 5-minute cycle, the dispensers will be positioned in front of each of the 4 positions for at least 1-minute to dispense the required 1-minute quantity of ice pellets and/or snow (total of 4-minutes). The extra minute is a buffer in case of delays.

Figure 6.3: Top View of Positioning of Dispensers Relative to the Wing

6.3.3 New Ice Pellets/Snow Dispensing Systems for 2014 Onwards

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

In the winter of 2012-13, seed spreaders historically modified and used for applying ice pellets during wind tunnel and flat plate testing, were no longer available as the manufacturer stopped production of the model. A new replacement seed spreader system (Wolf Garten) was found which is similar (but not identical). Some calibration work was required to demonstrate an equivalency in the two systems; testing was conducted at the NRC CEF prior to the wind tunnel testing to verify the distribution of the historical system versus the new replacement system the details of which are included in the TC report TP 15230E Aircraft Ground Icing General Research Activities During the 2012-13 Winter (4).

The data collected demonstrated that the new system is very similar to old system; some small variation was present in distribution within the footprint, but equivalent efficiency on the overall footprint. Based on this it was concluded that for ice pellets, the new system can be used as a direct replacement. For snow, the new system was more efficient, therefore a reduction of 10% should be used for the snow mass requested.

Comparative wind tunnel testing was conducted in the winter of 2013-14 to further validate the equivalency of the systems, the details of which are included in the TC report TP 15274E Exploratory Wind Tunnel Aerodynamic Research. The results indicated that the differences in recorded lift losses were generally very small (less than 1.3%) when comparing back-to-back tests with no bias towards one system or the other. The differences were even smaller when looking at the average of the four comparative sequential tests (Test #330 to #337) which was 0.1%. In addition, the tests were visually evaluated to verify that the distribution of the ice pellets was similar, further supporting the similarity in aerodynamic results between the two dispenser systems.

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

6.4 Prior to Engines-On Wind Tunnel Test

- Measure fluid thickness at the pre-determined locations on the wing (Attachment 3);
- Measure fluid Brix value (Attachment 3);
- Record wing temperatures (Attachment 3);
- Record start time of test (Attachment 2); and
- Fill out visual evaluation rating form (Attachment 7).

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 has been given to reducing the number of measurements 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 7); 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 3);
- Measure fluid Brix value (Attachment 3);
- Record wing temperatures (Attachment 3);
- Observe and record the status of the fluid/contamination (Attachment 3);
- Fill out visual evaluation rating form (Attachment 7);
- Obtain lift data (excel file) from NRC; and
- Update APS test log with pertinent information.

6.7 Fluid Sample Collection for Viscosity Testing

Two liters of each fluid to be tested are to be collected on the first day of testing. The fluid receipt form (Attachment 8) 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 9). 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, NRC will organize for a glycol recovery service provider 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 2013-14. Modifications may be necessary and will be dealt with on-site. 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 6.4 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

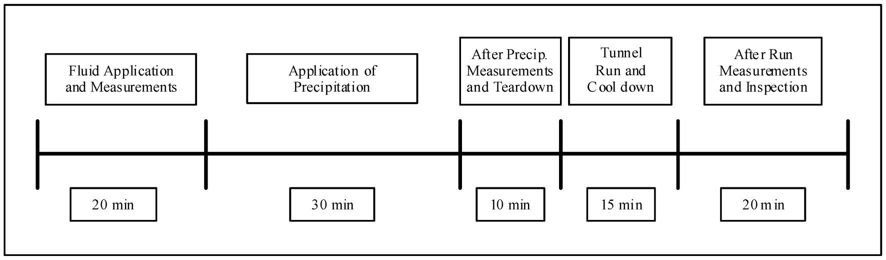


Figure 6.4: Typical Wind Tunnel Run Timeline

6.11 Procedures for Primary Testing Objectives

There are three primary testing objectives for the winter of 2015-16. Details have been included in the following attachments:

- Attachment 10: Procedure - Dry Wing Performance
- Attachment 11: Procedure – Type IV Ice Pellet Allowance Time Validation with New Fluids and at Temperatures Close to the LOUT
- Attachment 12: Procedure – Type III Ice Pellet Allowance Time Validation with New Fluids, Speed (80 knots) and Application Temperatures (Hot vs. Cold)
- Attachment 13: Procedure –Type IV Ice Pellet Allowance Time Expansion (METAR and Mixed IP and Snow Conditions)
- Procedures for Optional R&D Activities

R&D testing is not planned for the winter of 2015-16; however the preliminary procedures related to some of the testing objectives considered in the past have been included in this procedure for reference. At the discretion of the TC/FAA research officer, limited testing may be considered. Details have been included in the following Attachment 14 to Attachment 29.

7. EQUIPMENT

Equipment to be employed is shown in Table 7.1.

Table 7.1: Equipment List

EQUIPMENT	STATUS		EQUIPMENT	STATUS
General Support and Testing Equipment			**Camera Equipment**	
20L containers x 12			AA Batteries x 48	
Adherence Probes Kit			C2032 Batteries x 10	
Barrel Opener (steel)			Digital still cameras x3 (two suitcases)	
Black Shelving Unit (or plastic)			Flashes and tripods (in APS storage)	
Blow Horns x 4			GoPro Cameras x 3 and related hardware	
Electrical tape x 5				
Envelopes and labels				
Exacto Knives x 2			**Ice Pellets Fabrication Equipment**	
Extension cords (power bars x 6 + reels x 4)			Blenders x 12 in good condition	
Falling Ball Viscometer			Folding tables (2 large, 1 small)	
Fluid pouring jugs x 60			Ice bags	
Fluids (ORDER and SHIP to Ottawa)			Ice bags storage freezer x 3	
Funnels(1 big + 1 small)			Ice pellets sieves (base, 1.4 mm, 4 mm)	
Gloves - black and yellow			Ice pellets Styrofoam containers x20	
Gloves - cotton (1 box)			Measuring cups (1L and smaller ones for dispensing)	
Gloves - latex (2 boxes)			NCAR Scale x 1	
Grid Section + Location docs			Refrigerated Truck	
Hard water chemicals x 3 premixes			Rubber Mats x all	
Horse and tap for fluid barrel x all			Wooden Spoons	
Hot Plate x 3 and Large Pots with rubber handles for Type III				
Ice pellet box supports for railing x4			**Freezing Rain Equipment**	
Ice Pellet control wires and boxes (all for new and old)			APS PC equipped with rate station software	
Ice pellets dispersers x 12 (6 new and 6 old)			NRC Freezing rain sprayer (NRC will provide)	
Inclinometer (yellow level) x 2			Rubber suction cup feet for wooden boards	
Isopropyl x 24			White plastic rate pans (1 to 8 x 2)	
Large and small tape measure			Wooden boards for rate pans (x8)	
Large Sharpies for Grid Section				
Long Ruler for marking wing x 2				
Marker for waste x 2			**Office Equipment**	
Paper towel x 48			Accordion Folder	
Protective clothing (all) and personnel clothing			APS Laptops x 6 with mouse and chargers	
Sample bottles for viscosity measurement x 8			APS tuques x 10	
Sartorius Weigh Scale x 1			Calculators x 3	
Scrapers x 5			Clip boards x 8	
Shop Vac			Dry eraser markers	
Speed tape x 1 small			Envelopes (9x12) x box	
Squeegees (5 small + 3 large floor)			Hard drive with all WT Photos	
Stands for ice pellets dispensing devices x 6			Hard Drive x 2	
Stop Watches x 4			Pencils + sharpies/markers	
Temperature probes: immersion x 3			Projector for laptop	
Temperature probes: surface x 3			Scissors	
Temperature readers x 2 + spare batteries			Small 90º aluminum ruler for wing	
Test Plate x 1			Test Procedures x 8, data forms, printer paper	
Thermometer for Reefer Truck			YOW employee contracts	
Thickness Gauges (5 small, 5 big)				
Vise grip (large) + rubber opener for containers				
Walkie Talkies x 12				
Water (2 x 18L) for hard water				
Watmans Paper and conversion charts				
Red Thermoses for Type III Transport				

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). A total of 1840L of 100/0 Type III and Type IV fluid are expected to be available; an additional 440L of other fluids are also available if needed. 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	Type	DILUTION	ORDERED (L)	IN STOCK (L)
AeroClear MAX	III	100/0	400	-
LNT E450	IV	100/0	200	-
FCY 9311	IV	100/0	200	-
UCAR™ FlightGuard AD-49	IV	100/0	-	270
ABC-S Plus	IV	100/0	-	352
Polar Guard® Advance	IV	100/0	-	270
Safewing MP II FLIGHT	II	100/0	-	150
UCAR™ FlightGuard AD-49	IV	75/25	-	136
Polar Guard® Advance	IV	50/50	-	110
Lift-Off E-188	I	Brix 26.25	-	20

3600 L ordered for 2009-10 testing (18 days)
3200 L ordered for 2010-11 testing (15 days)
1800 L ordered for 2011-12 testing (7 of 15 days will be fluid testing)
4200 L ordered for 2012-13 testing (15 days)
1300L ordered for 2013-14 testing (15 days), 1900L previously in stock
1700L available for 2015-16 Testing (10 days)

9. PERSONNEL

Five 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 2015-16 - Tentative	
Person	**Responsibility**
John	Director
Marco	Lead Engineer and Project Coordinator
Chloë	Data documentation (forms, logs, camera setup, etc)
Dave / Ben B*	Data Collection / Fluid Manager (inventory and application) / IP Manager / YOW Pers. Manager
YOW Personnel	
Ben G/Jesse*	Photography / Camera Documentation
Steve	Fluids / IP / Dispensing / General Support
YOW 1	Fluids / IP / Dispensing
YOW 2	Fluids / IP / Dispensing
YOW 3	Fluids / IP / Dispensing
YOW 4	Back-up

*Present only for an initial portion of the testing unless workloads dictate otherwise.

NRC Institute of Aerospace Research Contacts

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

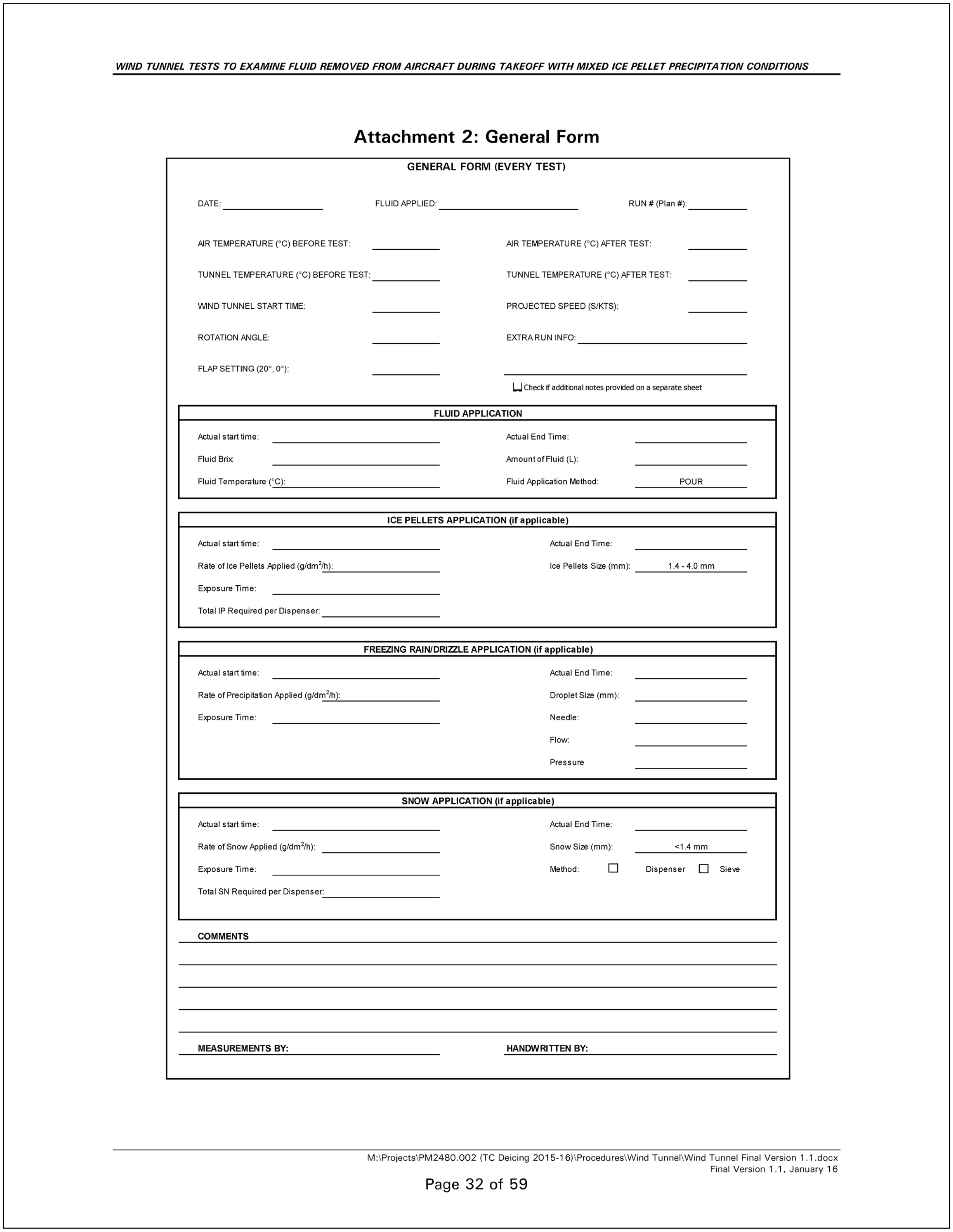
10. SAFETY

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



Attachment 2: General Form

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 3: Wing Temperature, Fluid Thickness and Fluid Brix Form

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: ______________________________

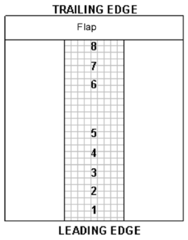
Run: ____________________

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:			

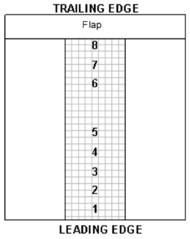
FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2			
3			
4			
5			
6			
7			
8			
Flap			
Time:			

Wing and Plate Condition
Before the Takeoff Run
Time: ___________



Comments:______________________
_
____
_
____
_

Wing and Plate Condition
After the Takeoff Run
Time: ___________



Comments:______________________
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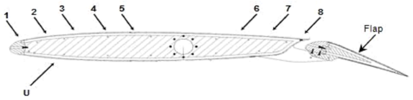


Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;

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

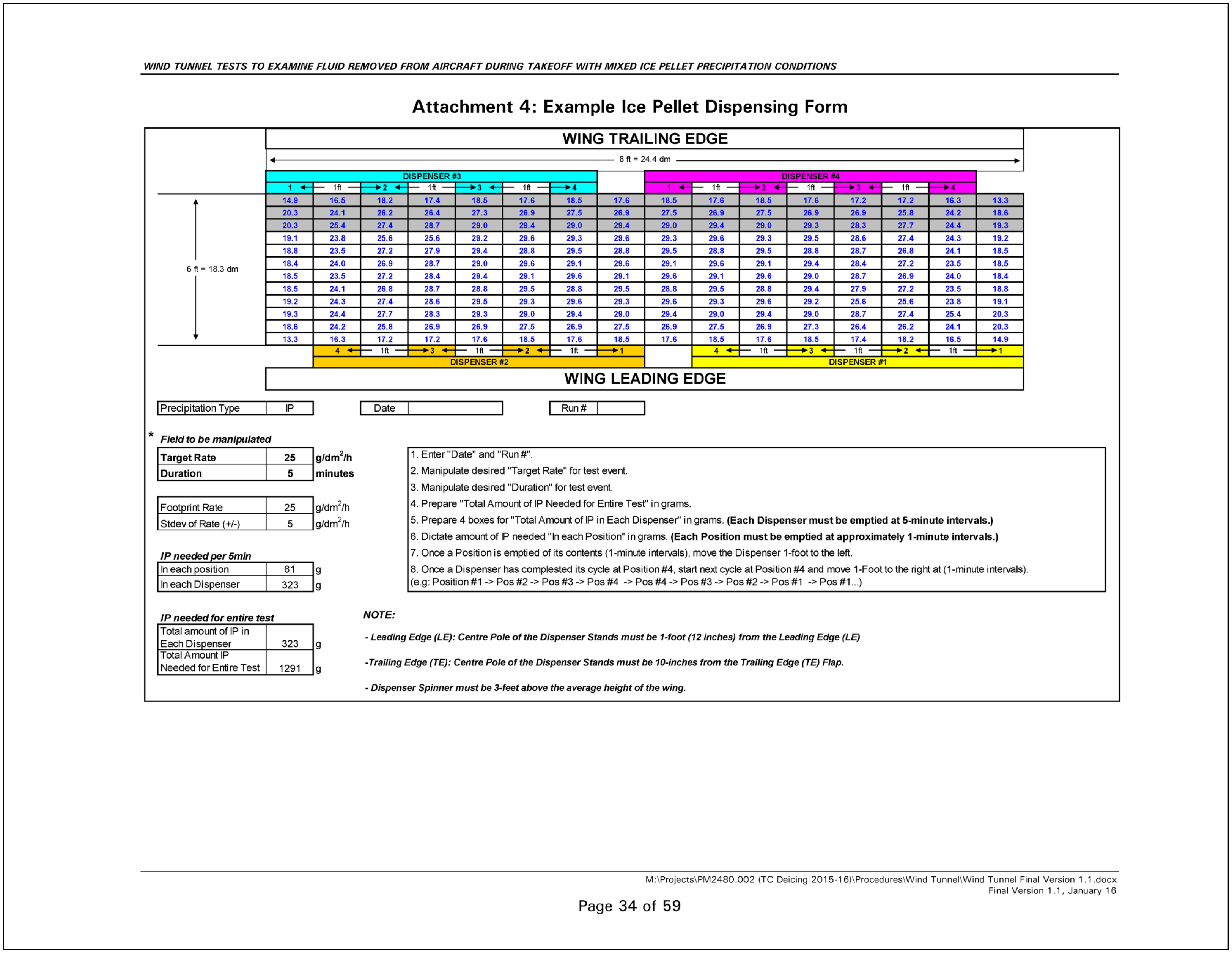
Underside: Approximately 40 cm up from the leading edge stagnation point.

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 4: Example Ice Pellet Dispensing Form

WING TRAILING EDGE

8 ft = 24.4 dm

	DISPENSER #3								DISPENSER #4							
	1	1ft	2	1ft	3	1ft	4		1	1ft	2	1ft	3	1ft	4	
6 ft = 18.3 dm	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
		DISPENSER #2								DISPENSER #1						

WING LEADING EDGE

Precipitation Type	IP	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 (+/-)	5	g/dm^2/h

IP needed per 5min

In each position	81	g
In each Dispenser	323	g

IP needed for entire test

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

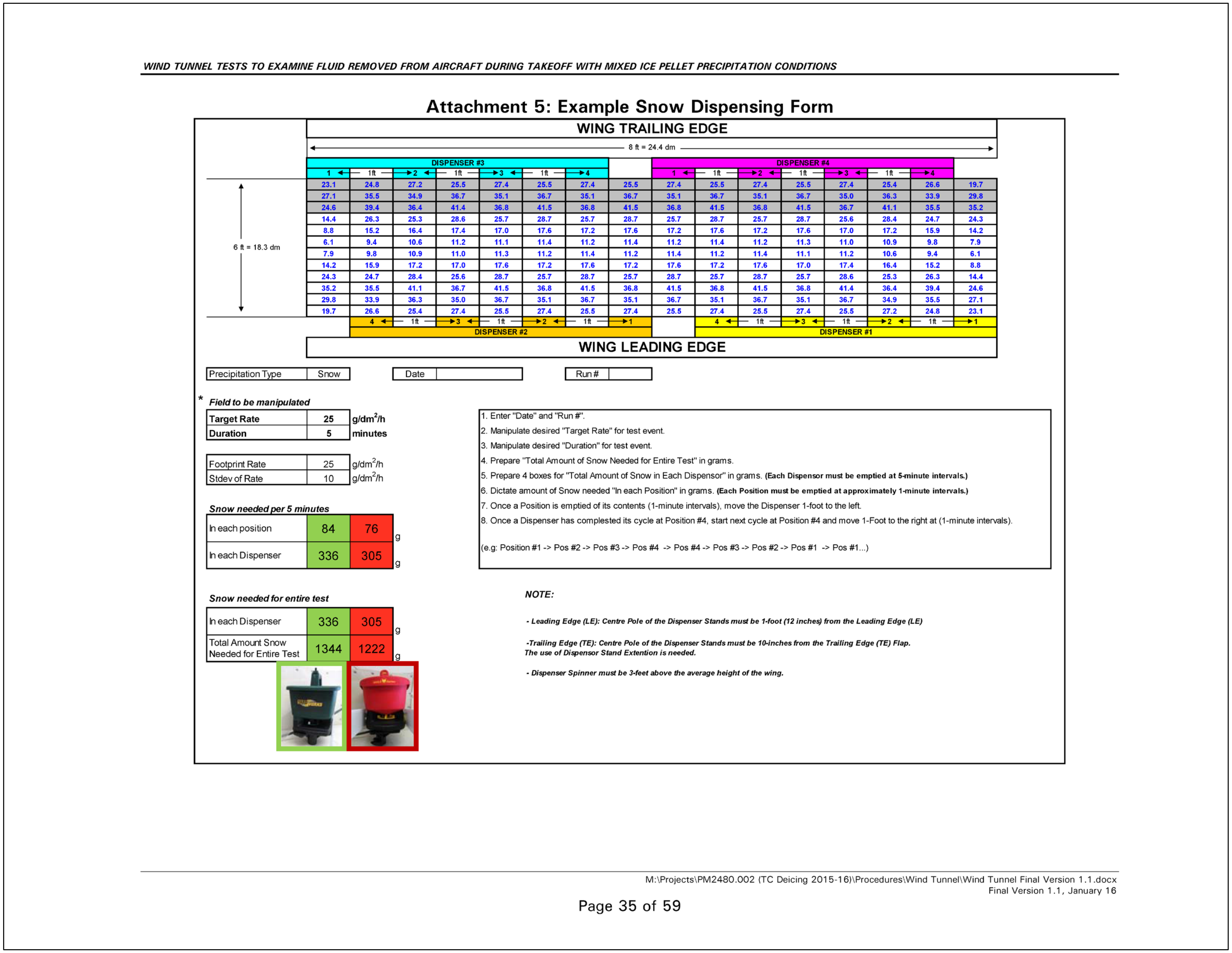
1. Enter "Date" and "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of IP Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of IP in Each Dispenser" in grams. **(Each Dispenser must be emptied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

NOTE:

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

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

- Dispenser Spinner must be 3-feet above the average height of the wing.



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

Attachment 5: Example Snow Dispensing Form

WING TRAILING EDGE

8 ft = 24.4 dm

DISPENSER #3								DISPENSER #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
	DISPENSER #2								DISPENSER #1						

6 ft = 18.3 dm

WING LEADING EDGE

Precipitation Type	Snow
Date	
Run #	

* *Field to be manipulated*

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

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

Snow needed per 5 minutes

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

Snow needed for entire test

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

1. Enter "Date" and "Run #".
2. Manipulate desired "Target Rate" for test event.
3. Manipulate desired "Duration" for test event.
4. Prepare "Total Amount of Snow Needed for Entire Test" in grams.
5. Prepare 4 boxes for "Total Amount of Snow in Each Dispensor" in grams. **(Each Dispensor must be emptied at 5-minute intervals.)**
6. Dictate amount of Snow needed "In each Position" in grams. **(Each Position must be emptied at approximately 1-minute intervals.)**
7. Once a Position is emptied of its contents (1-minute intervals), move the Dispenser 1-foot to the left.
8. Once a Dispenser 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 Dispenser Stands must be 1-foot (12 inches) from the Leading Edge (LE)

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

- Dispenser Spinner must be 3-feet above the average height of the wing.

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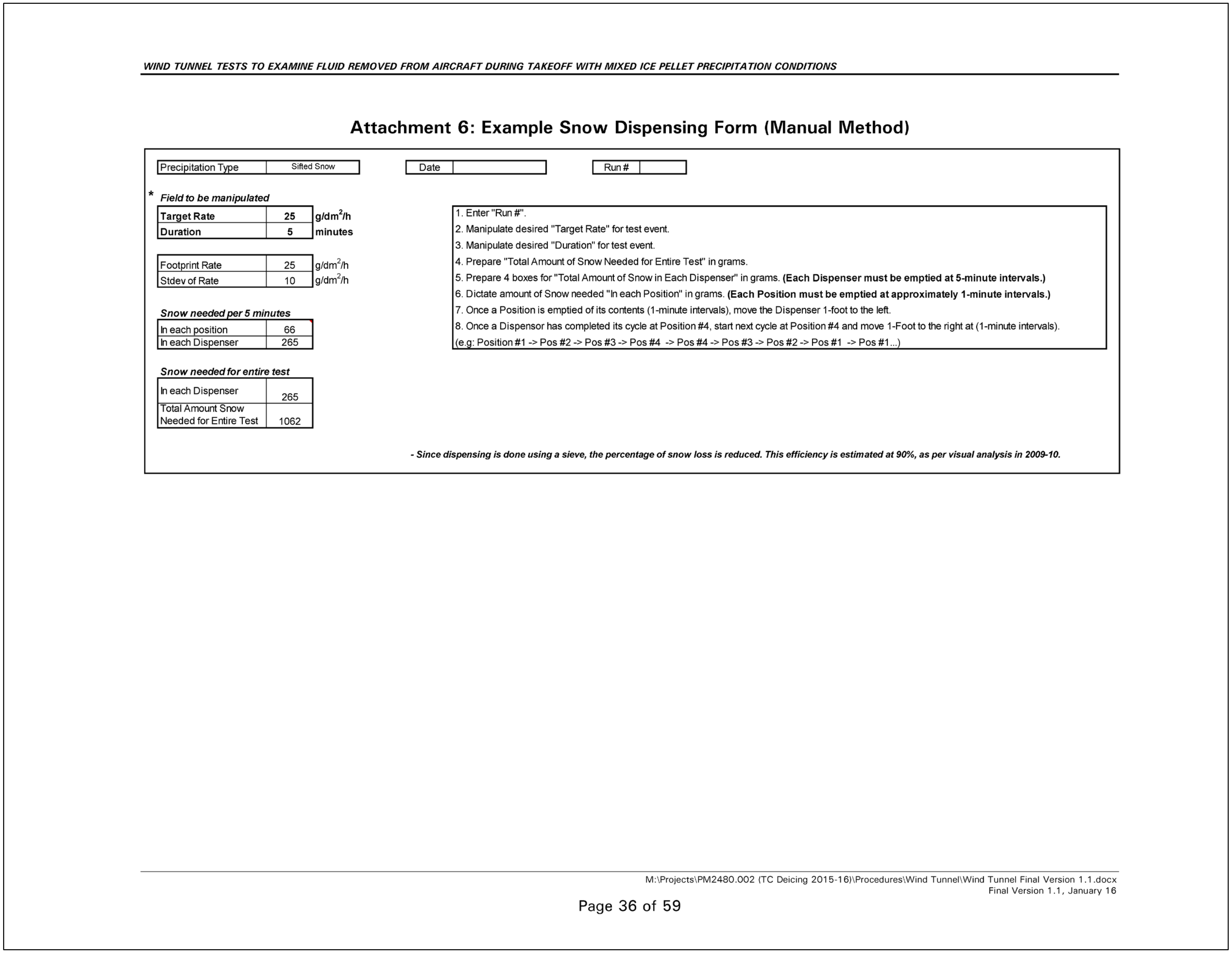


Attachment 6: Example Snow Dispensing Form (Manual Method)

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 Dispenser	265

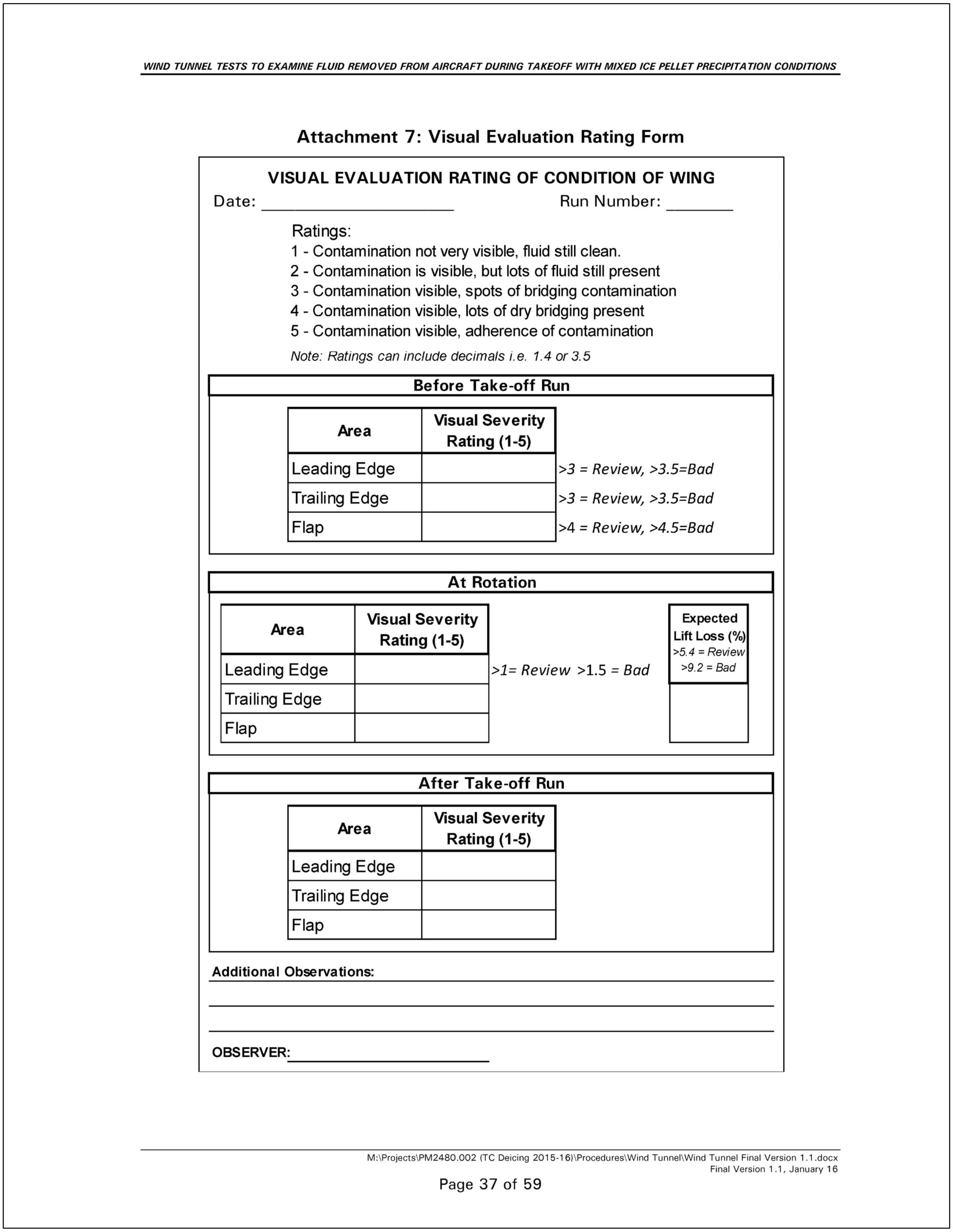
Snow needed for entire test

In each Dispenser	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 Dispenser" in grams. **(Each Dispenser 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 Dispenser 1-foot to the left.
8. Once a Dispensor has completed its cycle at Position #4, start next cycle at Position #4 and move 1-Foot to the right at (1-minute intervals).

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

- 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.



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

Attachment 7: 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 - Contamination visible, adherence of contamination

Note: Ratings can include decimals i.e. 1.4 or 3.5

Before Take-off Run

Area	Visual Severity Rating (1-5)	
Leading Edge		*>3 = Review, >3.5=Bad*
Trailing Edge		*>3 = Review, >3.5=Bad*
Flap		*>4 = Review, >4.5=Bad*

At Rotation

Area	Visual Severity Rating (1-5)	
Leading Edge		*>1= Review >1.5 = Bad*
Trailing Edge		
Flap		

Expected Lift Loss (%) *>5.4 = Review* *>9.2 = Bad*

After Take-off Run

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

Additional Observations: ____

____

____

OBSERVER:________________________

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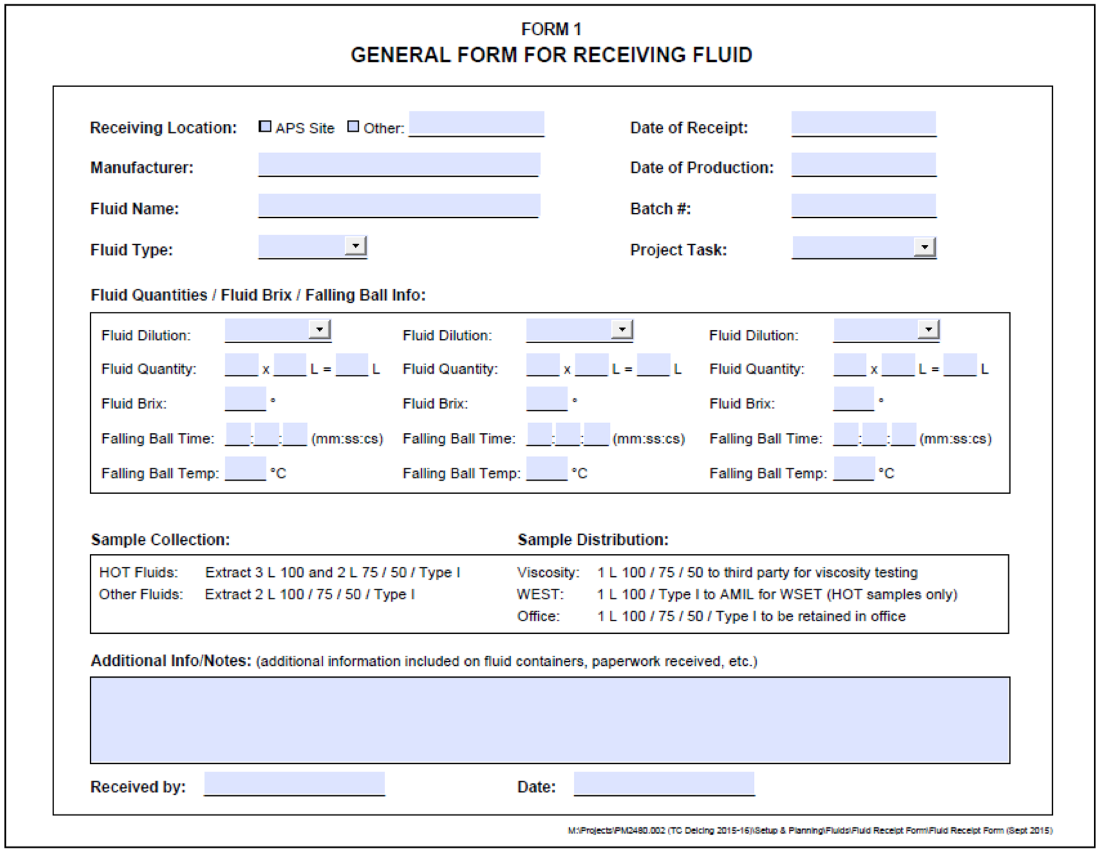
Attachment 8: Fluid Receipt Form (Electronic Form)



FORM 1

GENERAL FORM FOR RECEIVING FLUID

Receiving Location: ☐ APS Site ☐ Other: ____

Date of Receipt: ____

Manufacturer: ____

Date of Production: ____

Fluid Name: ____

Batch #: ____

Fluid Type: ▾

Project Task: ▾

Fluid Quantities / Fluid Brix / Falling Ball Info:

Fluid Dilution: ▾	Fluid Dilution: ▾	Fluid Dilution: ▾
Fluid Quantity: ___ x ___ L = ___ L	Fluid Quantity: ___ x ___ L = ___ L	Fluid Quantity: ___ x ___ L = ___ L
Fluid Brix: ___ °	Fluid Brix: ___ °	Fluid Brix: ___ °
Falling Ball Time: ___:___:___ (mm:ss:cs)	Falling Ball Time: ___:___:___ (mm:ss:cs)	Falling Ball Time: ___:___:___ (mm:ss:cs)
Falling Ball Temp: ___ °C	Falling Ball Temp: ___ °C	Falling Ball Temp: ___ °C

Sample Collection:

HOT Fluids:	Extract 3 L 100 and 2 L 75 / 50 / Type I
Other Fluids:	Extract 2 L 100 / 75 / 50 / Type I

Sample Distribution:

Viscosity:	1 L 100 / 75 / 50 to third party for viscosity testing
WEST:	1 L 100 / Type I to AMIL for WSET (HOT samples only)
Office:	1 L 100 / 75 / 50 / Type I to be retained in office

Additional Info/Notes: (additional information included on fluid containers, paperwork received, etc.)

Received by: ____

Date: ____

M:\Projects\PM2480.002 (TC Deicing 2015-16)\Setup & Planning\Fluids\Fluid Receipt Form\Fluid Receipt Form (Sept 2015)

Attachment 9: 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 10: Procedure - Dry Wing Performance

Background

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

Objective

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

Methodology

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

Test Plan

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

Attachment 11: Procedure – Type IV Ice Pellet Allowance Time Validation with New Fluids and at Temperatures Close to the LOUT

Background

The Type IV ice pellet allowance times are conservative, generic guidance developed based on data collected using commercially available Type IV fluids. As new fluids are developed and become commercially available, it is important to evaluate these fluids against the current allowance times to ensure the validity of the generic guidance. Systematic "spot-checking" is used in order to identify any potential issues. In addition, testing is recommended with all fluids available to obtain data close to the fluid LOUT to determine the aerodynamic effects of ice pellet contamination at these colder temperatures.

Objective

To evaluate newly commercialized Type IV fluids against the existing allowance times, and to collect data close to the fluid LOUT.

Methodology

- Conduct testing with any new commercially available Type IV fluids in each of the cells of the ice pellet allowance times table;
- Record lift data, visual observations, and manually collected data;
- Adjust testing plan accordingly based on aerodynamic data collected.
- Weather permitting, conduct testing close to the fluid LOUT (-25 to -30ºC) with appropriate conditions to address data gaps;

Test Plan

Four days of testing are planned, however a portion of this testing is temperature critical and requires very low temperatures below -25°C.

Attachment 12: Procedure – Type III Ice Pellet Allowance Time Validation with New Fluids, Speed (80 knots) and Application Temperatures (Hot vs. Cold)

Background

Allowance times for Type III fluids have just recently been developed. Similar to the Type IV ice pellet allowance times, the Type III allowance times are also intended to be conservative, generic guidance developed based on data collected using commercially available Type III fluids. As new fluids are developed and become commercially available, it is important to evaluate these fluids against the current allowance times to ensure the validity of the generic guidance. Systematic "spot-checking" is used in order to identify any potential issues. In addition, testing is recommended at lower speeds (80 knots) and with heated fluid applications to address operational needs.

Objective

To evaluate newly commercialized Type III fluids against the existing allowance times, and to investigate lower rotation speeds (80 knots) and application methods (hot vs. cold).

Methodology

- Conduct testing with any new commercially available Type III fluids in each of the cells of the ice pellet allowance times table;
- Record lift data, visual observations, and manually collected data;
- Adjust testing plan accordingly based on aerodynamic data collected; and
- Consider additional testing with lower rotation speeds and with heated fluid applications.

Test Plan

Three days of testing are planned.

Attachment 13: Procedure –Type IV Ice Pellet Allowance Time Expansion (METAR and Mixed IP and Snow Conditions)

Background

In an effort to continually improve the guidance provided, research is being conducted to expand the current Type IV allowance times to include additional conditions, or to potentially increase the existing times in some cells. Testing is recommended to evaluate new cells better suited to METAR reporting formats which do not include mixed precipitation intensities i.e. light ice pellets and moderate snow. Testing is also recommended to expand the existing mixed ice pellet and snow allowance times to have longer times, and potentially new cells.

Objective

To conduct testing to support the expansion of the Type IV ice pellet allowance times to include conditions more commonly reported by METAR and to further develop the current mixed ice pellet and snow guidance;

Methodology

- Conduct testing with multiple Type IV fluids in each of the cells of the targeted new or potentially modified ice pellet allowance times table cells;
- Record lift data, visual observations, and manually collected data; and
- Adjust testing plan accordingly based on aerodynamic data collected.

Test Plan

Three days of testing are planned.

Attachment 14: Procedure - Stall Warning Sensor

Background

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

Objective

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

Methodology

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

Test Plan

Four tests are anticipated.

Attachment 15: 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 16: 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 17: Procedure - Wind Tunnel Test Section Cooling

Background

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

Objective

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

Methodology

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

EXAMPLE OF COMPARATIVE DATA TO BE COLLECTED

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

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

Test Plan

Three tests at a minimum are expected.

Attachment 18: Procedure - Effect of Fluid Viscosity

Background

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

Objective

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

Methodology

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

Test Plan

Two to four tests are anticipated.

Attachment 19: 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); and
- 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 20: 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; and
- 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 21: 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 on-site technicians.

Test Plan

One or two tests are anticipated.

Attachment 22: Procedure - Flaps/Slats Testing to Support YMX Tests

Background

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

Objective

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

Methodology

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

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

Test Plan

Two to four comparative tests are anticipated.

Attachment 23: 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;
- Conduct a test with an existing relative HOT condition to evaluate the severity of the condition;
- Compare the aerodynamic performance; or
- 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 24: 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" 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 with 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.

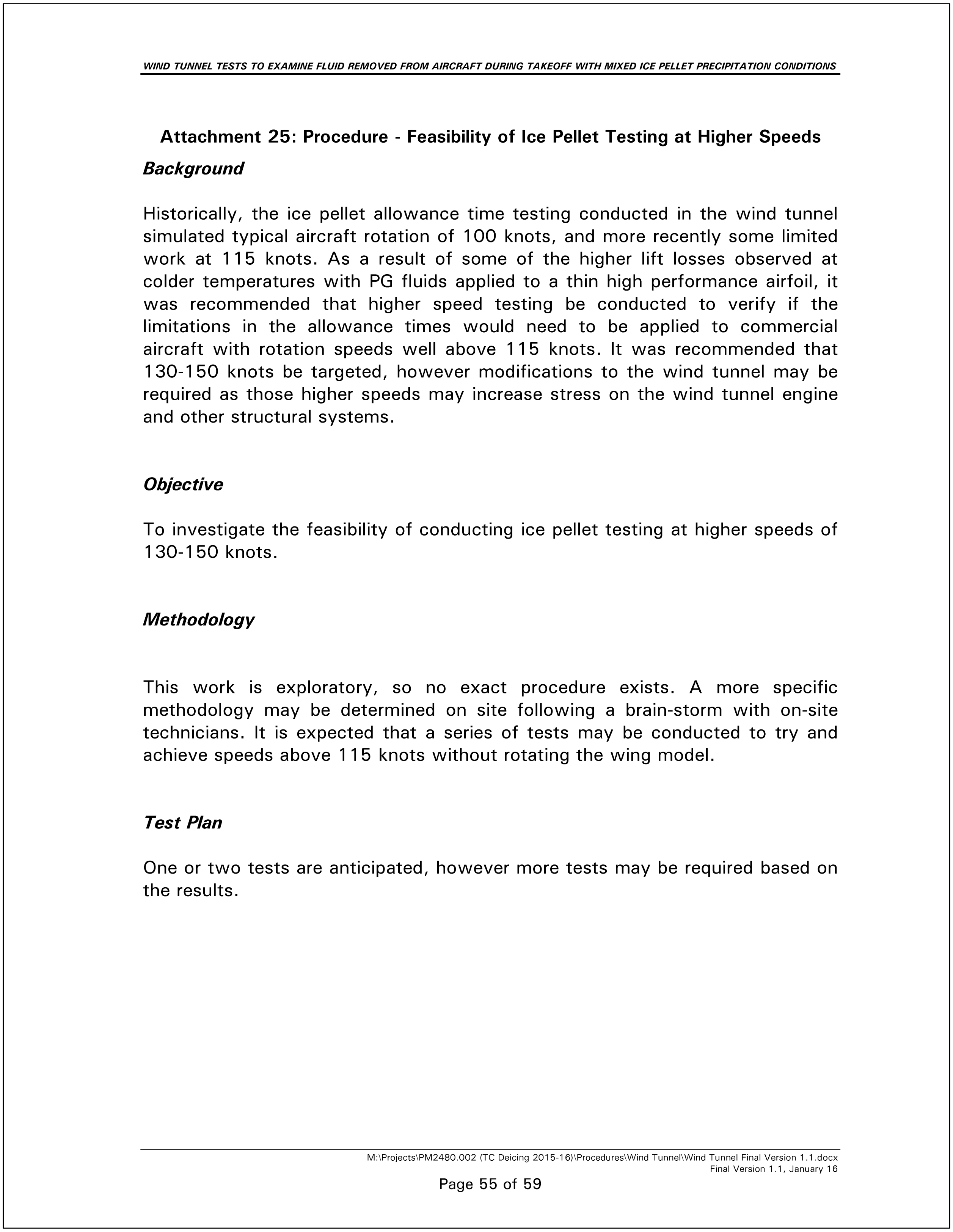
Methodology

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 (-5°C 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; and
- Compare the results to baseline fluid only and dry wing test results;

Test Plan

One to four comparative tests are anticipated.



Attachment 25: 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 on-site 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 26: 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

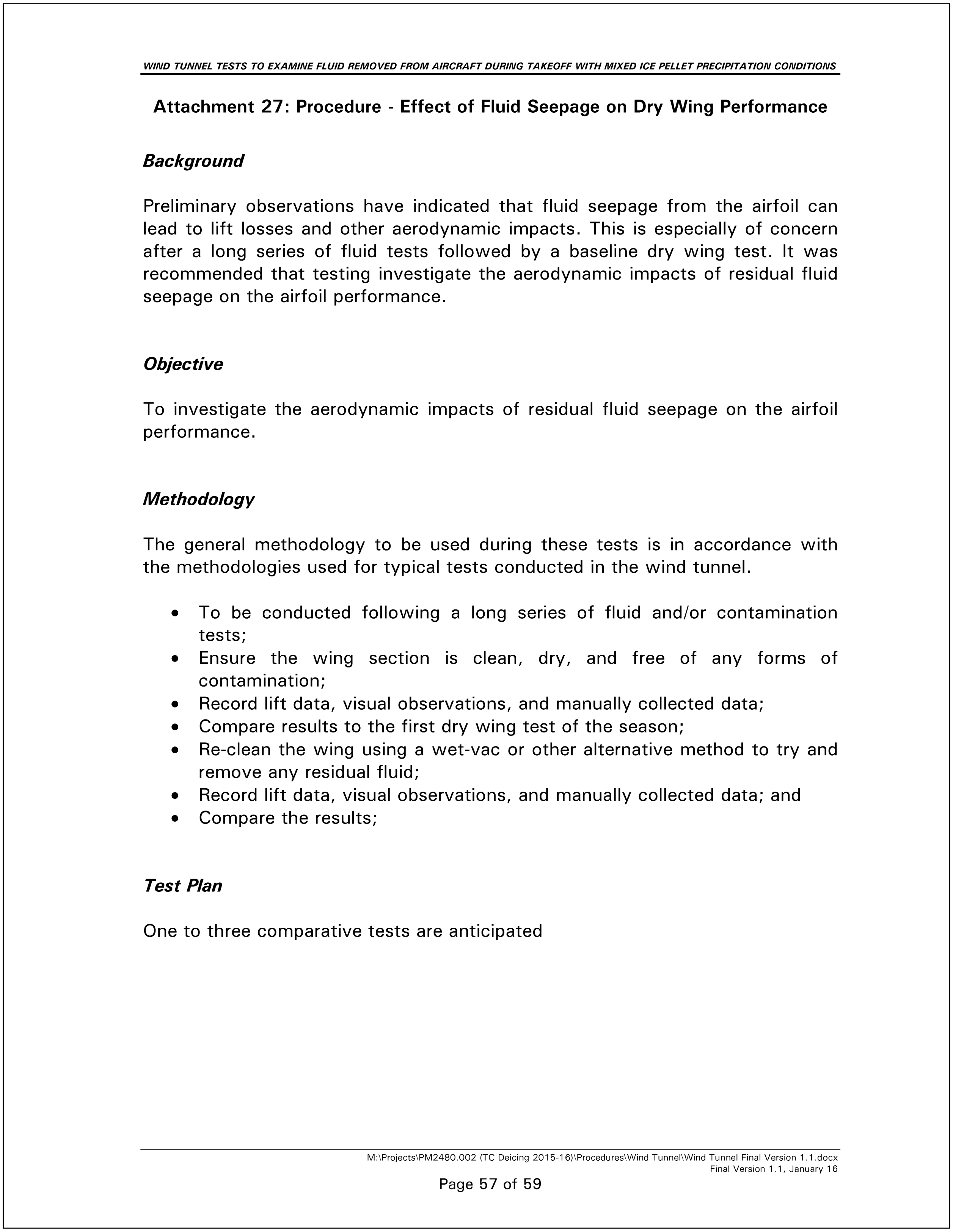
To evaluate the holdover time and aerodynamic effects windshield washer fluid when used a substitute for an aircraft ground deicing Type I fluid.

Methodology

- Purchase various formulations of windshield washer fluid with varying freeze points;
- Apply fluid heated to 20°C 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 27: Procedure - Effect of Fluid Seepage on Dry Wing Performance

Background

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

Objective

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

Methodology

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

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

Test Plan

One to three comparative tests are anticipated

Attachment 28: Procedure - 2nd Wave of Fluid during Rotation

Background

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

Objective

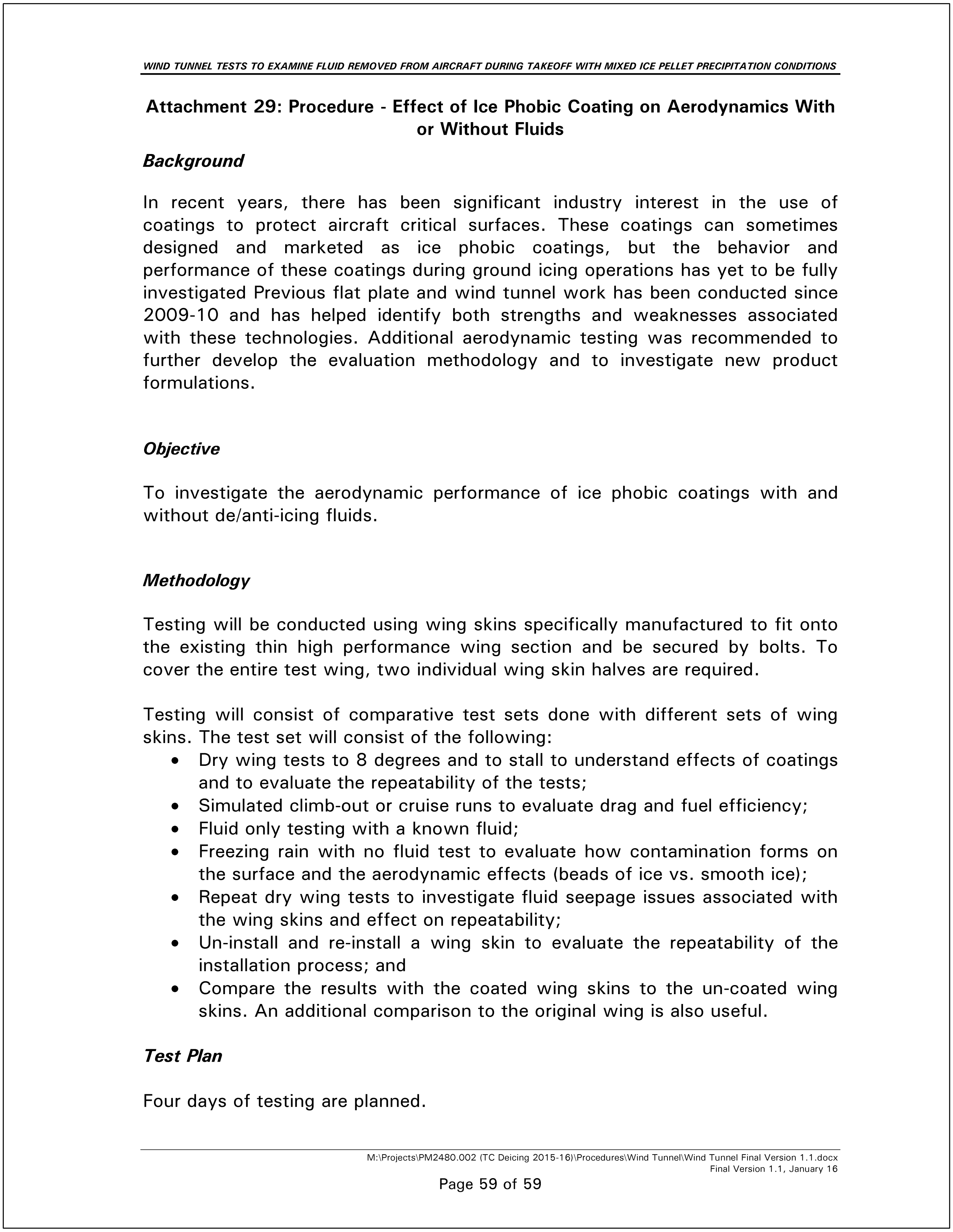
To investigate the aerodynamic effects of the second wave of fluid flow during rotation.

Methodology

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

Test Plan

One to four tests are anticipated.



Attachment 29: Procedure - Effect of Ice Phobic Coating on Aerodynamics With or Without Fluids

Background

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

Objective

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

Methodology

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

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

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

Test Plan

Four days of testing are planned.

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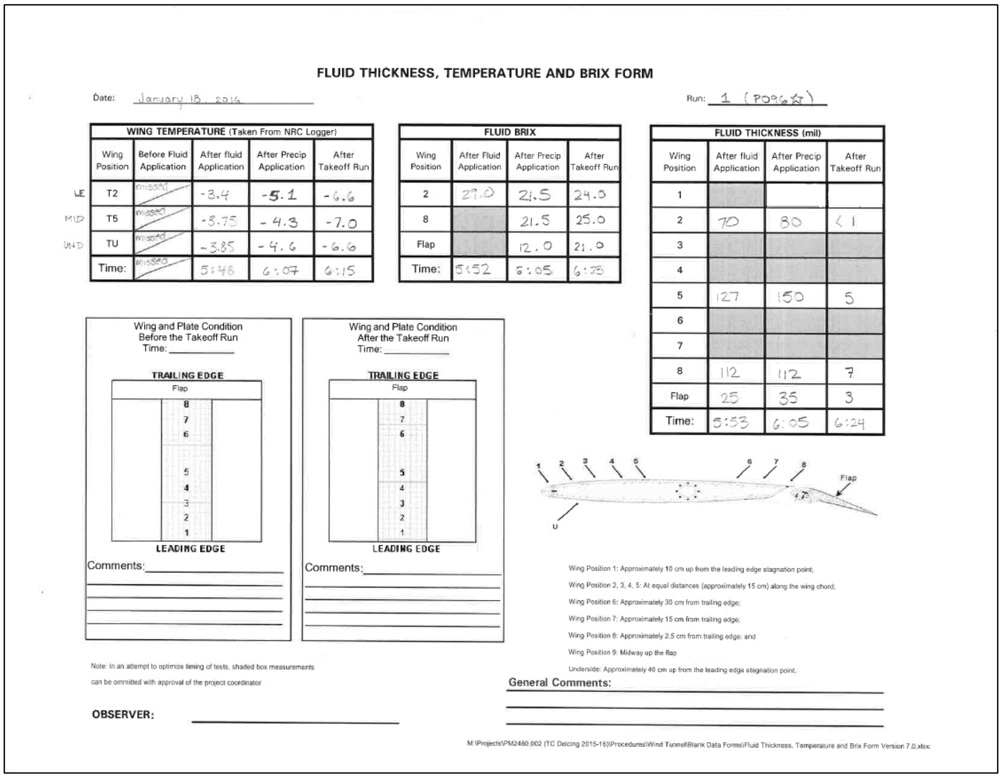
APPENDIX C

FLUID THICKNESS, TEMPERATURE, AND BRIX DATA FORMS



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 18, 2016

Run: 1 (PO96☆)

	WING TEMPERATURE (Taken From NRC Logger)				
	Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
LE	T2	missed	-3.4	-5.1	-6.6
MID	T5	missed	-3.75	-4.3	-7.0
UND	TU	missed	-3.85	-4.6	-6.6
	Time:	missed	5:48	6:07	6:15

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	29.0	21.5	24.0
8		21.5	25.0
Flap		12.0	21.0
Time:	5:52	5:05	6:23

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	80	<1
3			
4			
5	127	150	5
6			
7			
8	112	112	7
Flap	25	35	3
Time:	5:53	6:05	6:24

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Comments: ____________

Wing and Plate Condition
After 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: ____________

General Comments: ____________

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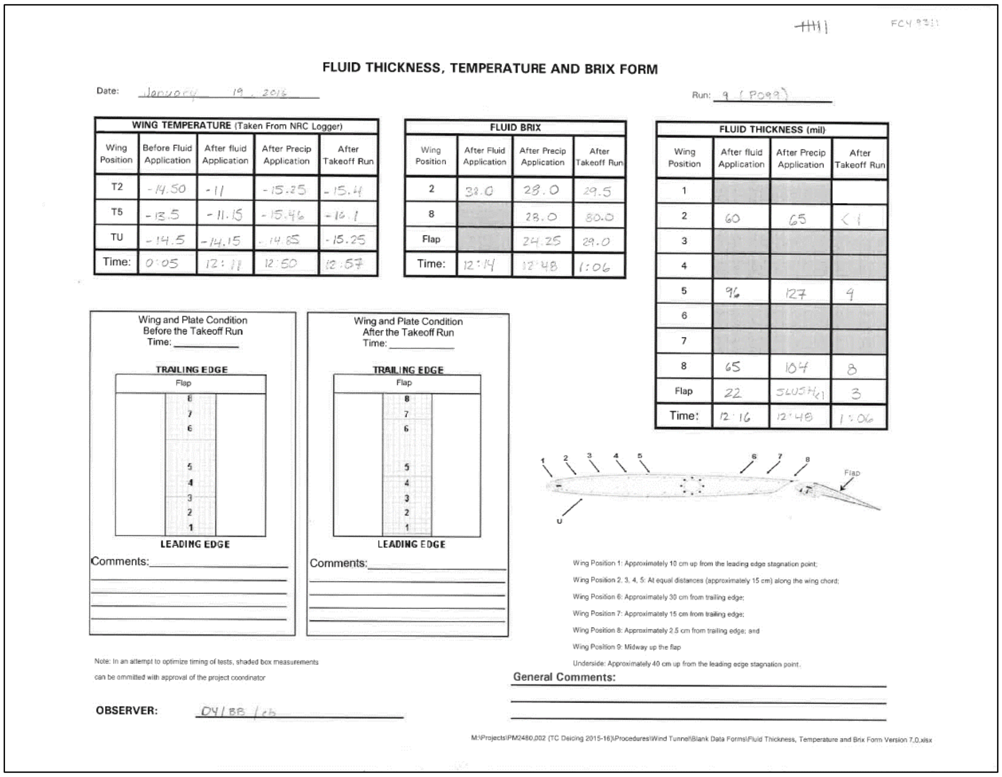
Figure C1: Run # 1

No Data Available

Figure C2: Run # 2 to Run # 8



FC4 931

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 19, 2016

Run: 9 (P099)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.50	-11	-15.25	-15.4
T5	-13.5	-11.15	-15.46	-16.1
TU	-14.5	-14.15	-14.85	-15.25
Time:	0:05	12:11	12:50	12:57

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	32.0	28.0	29.5
8	▨	28.0	30.0
Flap	▨	24.25	29.0
Time:	12:14	12:48	1:06

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	
2	60	65	<1
3	▨	▨	▨
4	▨	▨	▨
5	96	127	4
6	▨	▨	▨
7	▨	▨	▨
8	65	104	8
Flap	22	SLUSH<1	3
Time:	12:16	12:48	1:06

Wing and Plate Condition
Before the Takeoff Run
Time: ________

TRAILING EDGE
Flap
LEADING EDGE

Comments: ________

Wing and Plate Condition
After the Takeoff Run
Time: ________

TRAILING EDGE
Flap
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: D4 / BB / cb

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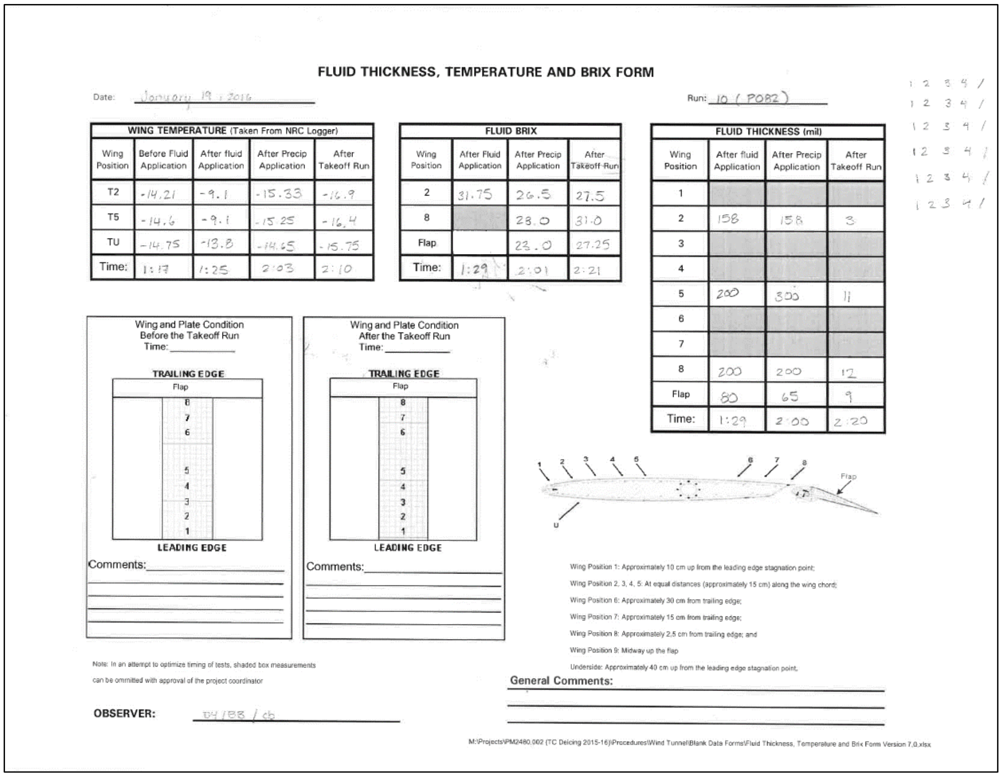
Figure C3: Run # 9



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 19, 2016

Run: 10 (P082)

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.21	-9.1	-15.33	-16.9
T5	-14.6	-9.1	-15.25	-16.4
TU	-14.75	-13.8	-14.65	-15.75
Time:	1:17	1:25	2:03	2:10

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	31.75	26.5	27.5
8	▨	28.0	31.0
Flap		23.0	27.25
Time:	1:29	2:01	2:21

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	158	158	3
3	▨	▨	▨
4	▨	▨	▨
5	200	300	11
6	▨	▨	▨
7	▨	▨	▨
8	200	200	12
Flap	80	65	9
Time:	1:29	2:00	2:20

Wing and Plate Condition
Before the Takeoff Run
Time: ________

TRAILING EDGE
Flap
LEADING EDGE

Comments: ________

Wing and Plate Condition
After the Takeoff Run
Time: ________

TRAILING EDGE
Flap
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: D4 / BB / cb

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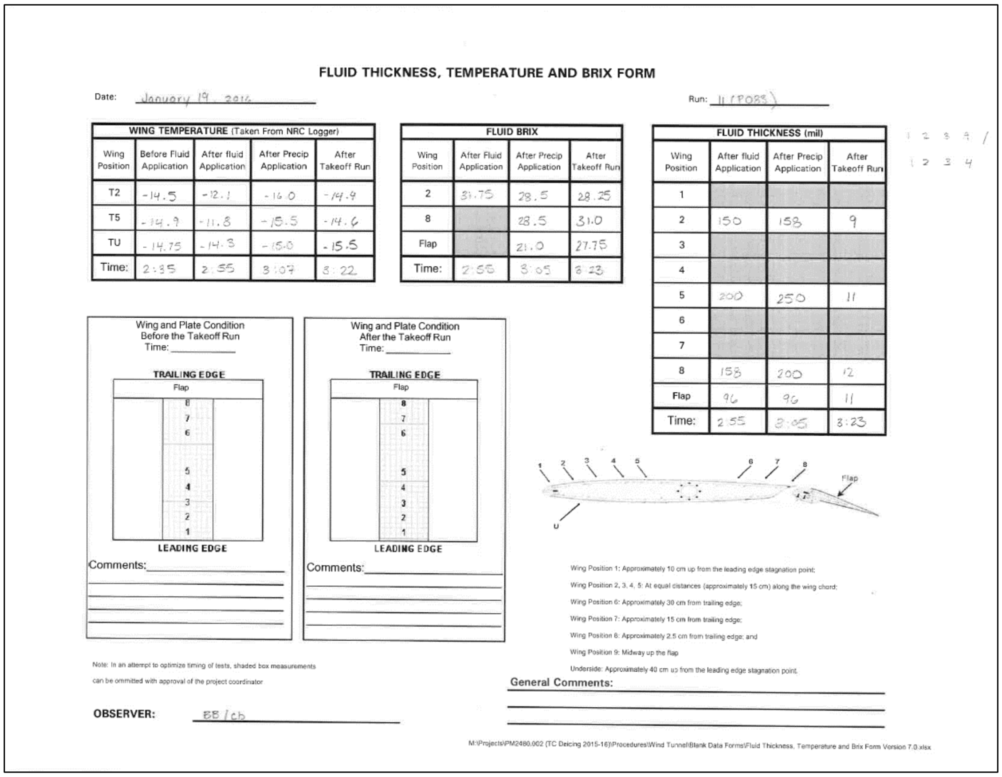
Figure C4: Run # 10



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 19, 2016

Run: 11 (P083)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.5	-12.1	-16.0	-14.9
T5	-14.9	-11.8	-15.5	-14.6
TU	-14.75	-14.3	-15.0	-15.5
Time:	2:35	2:55	3:07	3:22

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	31.75	28.5	28.25
8	▨	28.5	31.0
Flap	▨	21.0	27.75
Time:	2:55	3:05	3:23

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	150	158	9
3	▨	▨	▨
4	▨	▨	▨
5	200	250	11
6	▨	▨	▨
7	▨	▨	▨
8	158	200	12
Flap	96	96	11
Time:	2:55	3:05	3:23

1 2 3 9 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: __________

Comments: __________

Wing and Plate Condition
After 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: BB / cb

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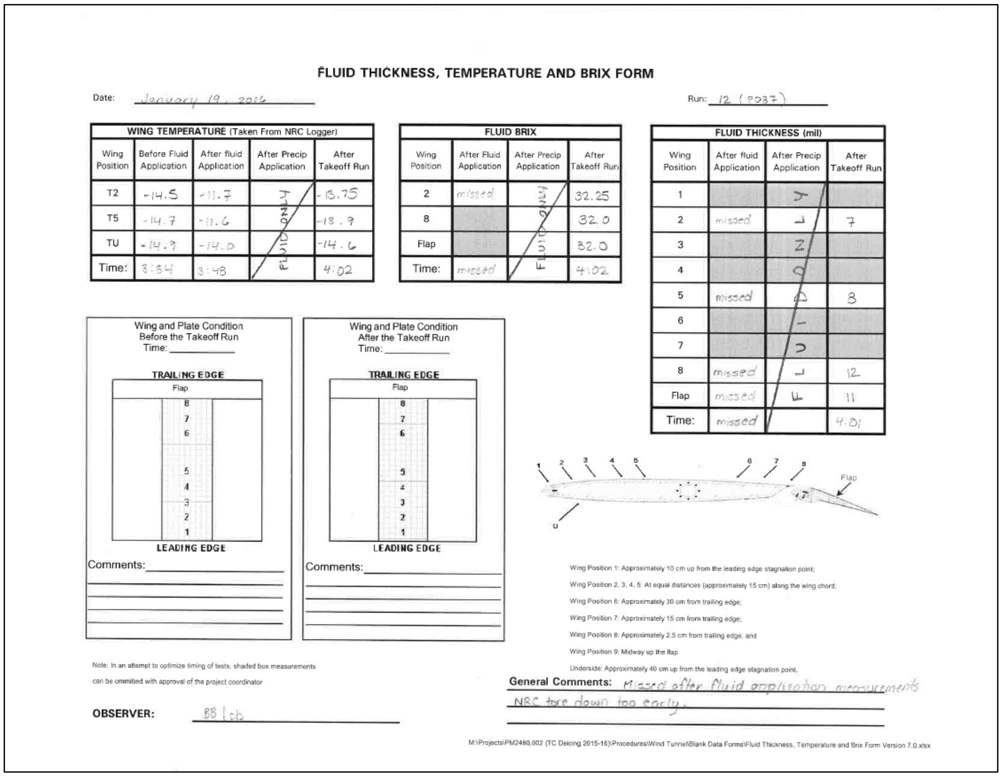
Figure C5: Run # 11



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 19, 2016

Run: 12 (P037)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.5	-11.7	FLUID ONLY	-13.75
T5	-14.7	-11.6		-13.9
TU	-14.9	-14.0		-14.6
Time:	3:34	3:48		4:02

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	missed	FLUID ONLY	32.25
8	▨		32.0
Flap	▨		32.0
Time:	missed		4:02

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	FLUID ONLY	▨
2	missed		7
3	▨		▨
4	▨		▨
5	missed		8
6	▨		▨
7	▨		▨
8	missed		12
Flap	missed		11
Time:	missed		4:01

Wing and Plate Condition
Before the Takeoff Run
Time: __________

Comments: __________

Wing and Plate Condition
After 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: Missed after fluid application measurements
NRC tore down too early.

OBSERVER: BB / cb

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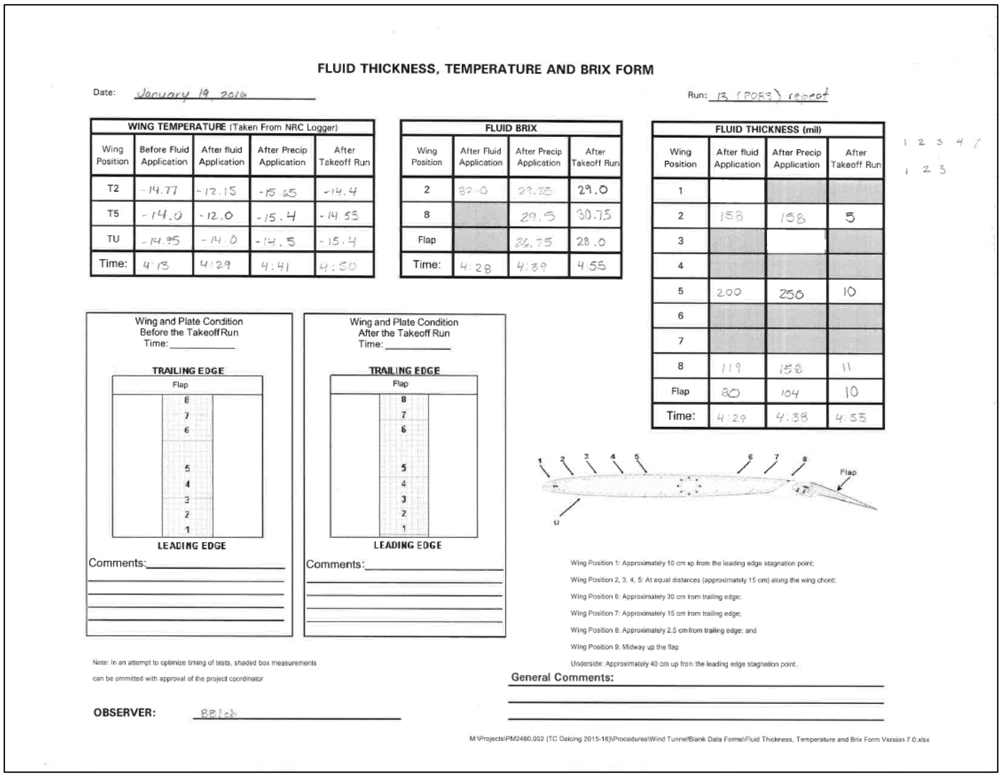
Figure C6: Run # 12



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 19, 2016

Run: 13 (P083) repeat

1 2 3 4 /
1 2 3

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.77	-12.15	-15.65	-14.4
T5	-14.0	-12.0	-15.4	-14.55
TU	-14.95	-14.0	-14.5	-15.4
Time:	4:13	4:29	4:41	4:50

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	32.0	29.25	29.0
8	▨	29.5	30.75
Flap	▨	26.75	28.0
Time:	4:28	4:39	4:55

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		▨	▨
2	158	158	5
3	▨		▨
4	▨	▨	▨
5	200	250	10
6	▨	▨	▨
7	▨	▨	▨
8	119	158	11
Flap	80	104	10
Time:	4:29	4:38	4:55

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Comments: ____________

Wing and Plate Condition
After 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: BB/cb

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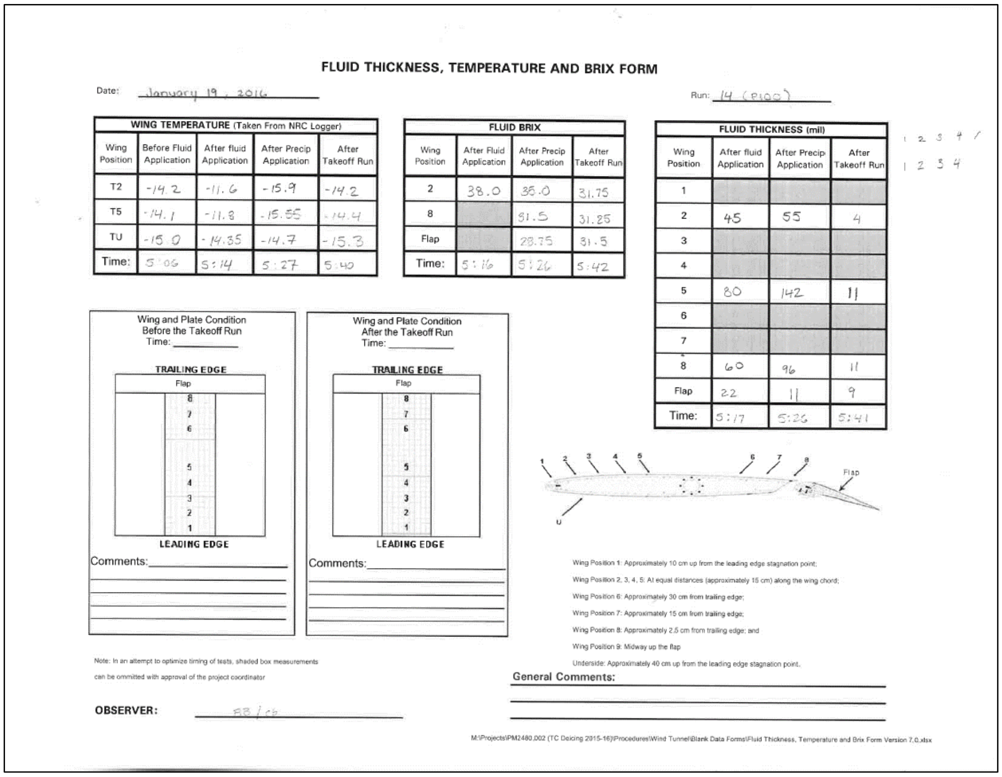
Figure C7: Run # 13



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 19, 2016

Run: 14 (P100)

1 2 3 4 /
1 2 3 4

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-14.2	-11.6	-15.9	-14.2
T5	-14.1	-11.8	-15.55	-14.4
TU	-15.0	-14.35	-14.7	-15.3
Time:	5:06	5:14	5:27	5:40

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	38.0	35.0	31.75
8	▨	31.5	31.25
Flap	▨	28.75	31.5
Time:	5:16	5:26	5:42

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	45	55	4
3	▨	▨	▨
4	▨	▨	▨
5	80	142	11
6	▨	▨	▨
7	▨	▨	▨
8	60	96	11
Flap	22	11	9
Time:	5:17	5:26	5:41

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Comments: ____________

Wing and Plate Condition
After 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: BB/cb

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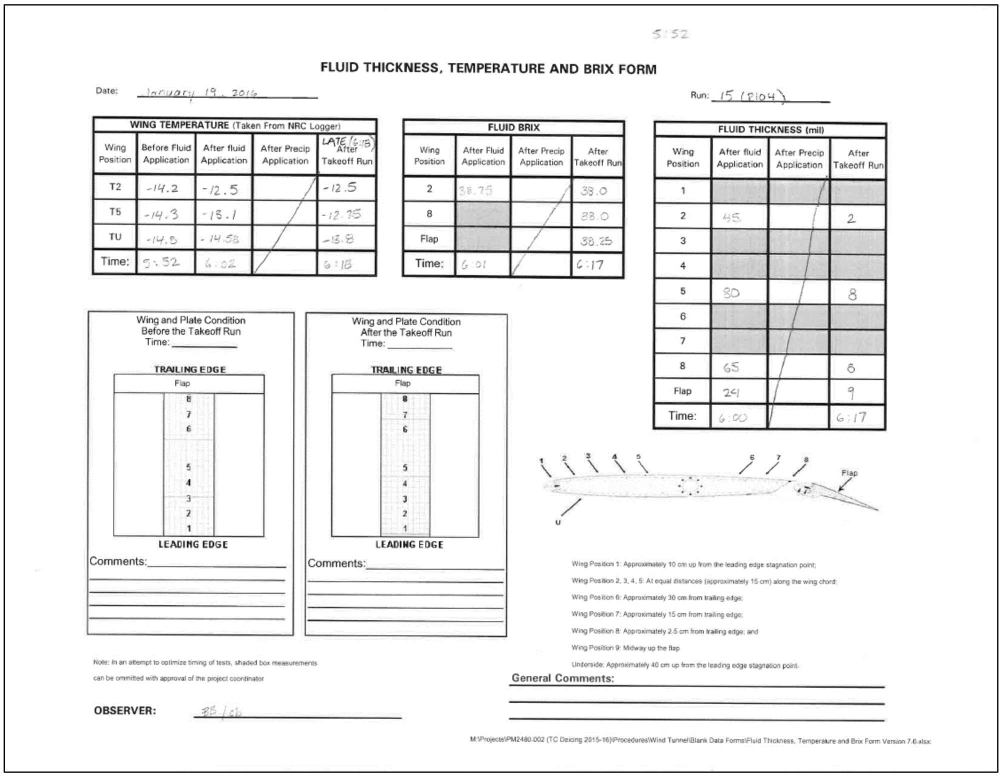
Figure C8: Run # 14



5:52

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 19, 2016

Run: 15 (P104)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	LATE (6:18) After Takeoff Run
T2	-14.2	-12.5		-12.5
T5	-14.3	-13.1		-12.75
TU	-14.8	-14.58		-13.8
Time:	5:52	6:02		6:18

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	38.75		38.0
8	▨		38.0
Flap	▨		38.25
Time:	6:01		6:17

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	45		2
3	▨	▨	▨
4	▨	▨	▨
5	80		8
6	▨	▨	▨
7	▨	▨	▨
8	65		8
Flap	24		9
Time:	6:00		6:17

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:

Wing and Plate Condition
After 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: BB / cb

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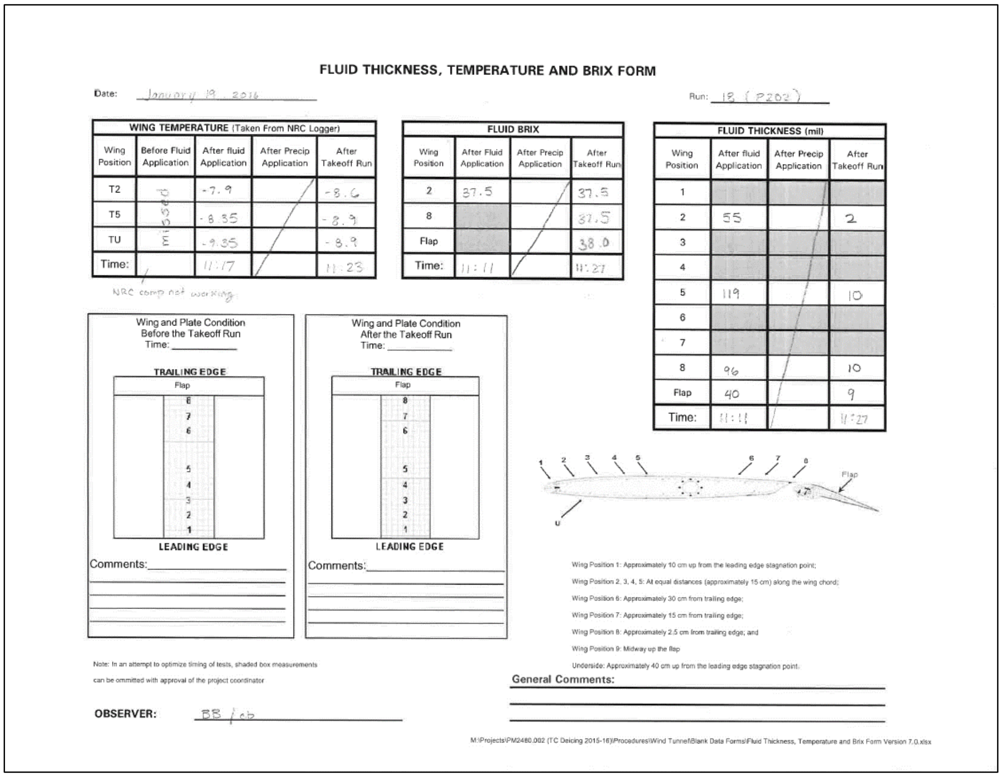
Figure C9: Run # 15

No Data Available

Figure C10: Run # 16 to Run #17



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 19, 2016

Run: 18 (P202)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	Missed	-7.9		-8.6
T5		-8.35		-8.9
TU		-9.35		-8.9
Time:		11:17		11:23

NRC comp not working

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.5		37.5
8			37.5
Flap			38.0
Time:	11:11		11:27

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	55		2
3			
4			
5	119		10
6			
7			
8	96		10
Flap	40		9
Time:	11:11		11:27

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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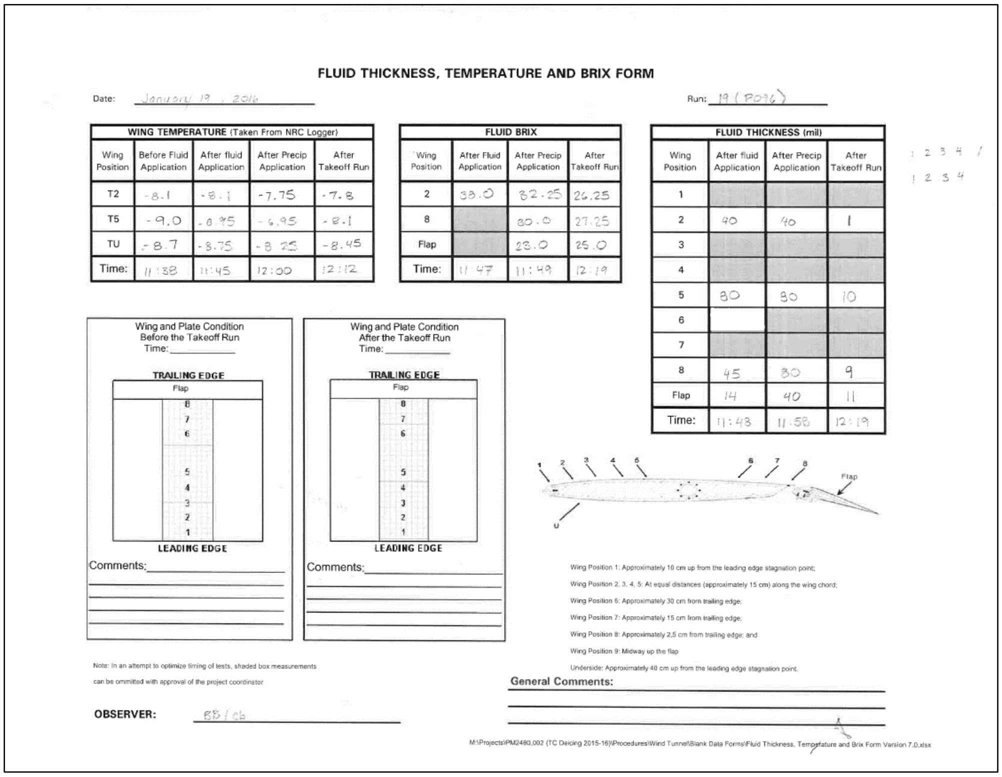
Figure C11: Run # 18



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 19, 2016

Run: 19 (P096)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-8.1	-8.1	-7.75	-7.8
T5	-9.0	-8.95	-6.95	-8.1
TU	-8.7	-8.75	-8.25	-8.45
Time:	11:38	11:45	12:00	12:12

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	38.0	32.25	26.25
8		30.0	27.25
Flap		23.0	25.0
Time:	11:47	11:49	12:19

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40	40	1
3			
4			
5	80	80	10
6			
7			
8	45	80	9
Flap	14	40	11
Time:	11:48	11:58	12:19

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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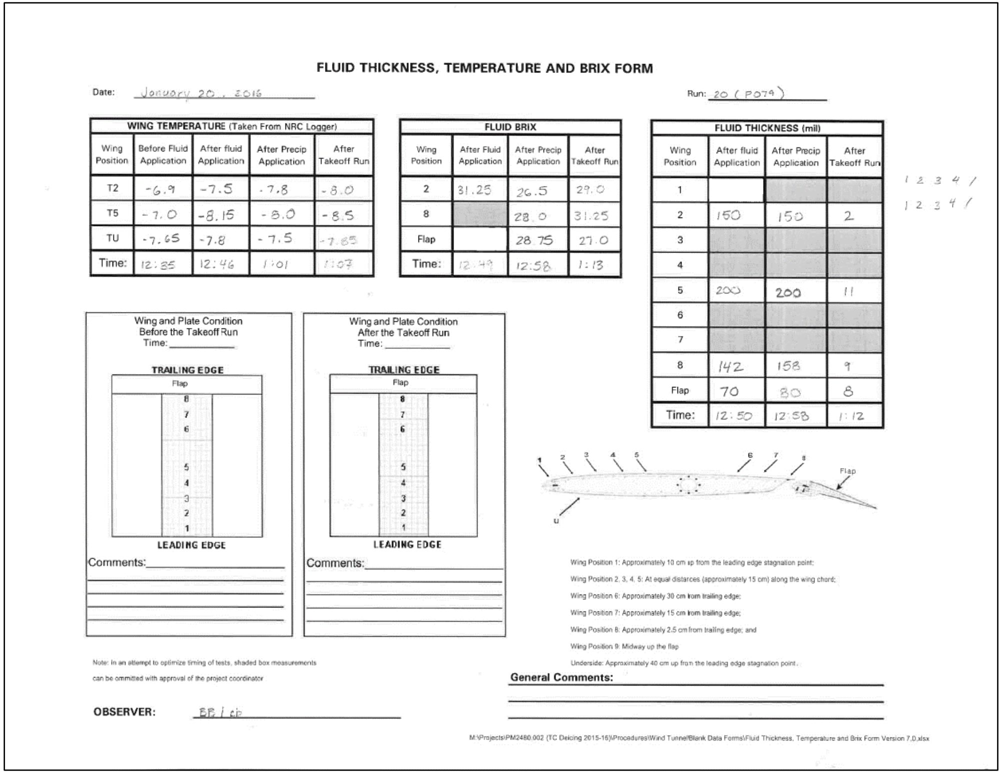
Figure C12: Run # 19



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 20, 2016

Run: 20 (P079)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.9	-7.5	-7.8	-8.0
T5	-7.0	-8.15	-8.0	-8.5
TU	-7.65	-7.8	-7.5	-7.85
Time:	12:35	12:46	1:01	1:07

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	31.25	26.5	29.0
8	▨	28.0	31.25
Flap		28.75	27.0
Time:	12:49	12:58	1:13

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		▨	▨
2	150	150	2
3	▨	▨	▨
4	▨	▨	▨
5	200	200	11
6	▨	▨	▨
7	▨	▨	▨
8	142	158	9
Flap	70	80	8
Time:	12:50	12:58	1:12

1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ________

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

Comments:

Wing and Plate Condition
After 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: BB / cb

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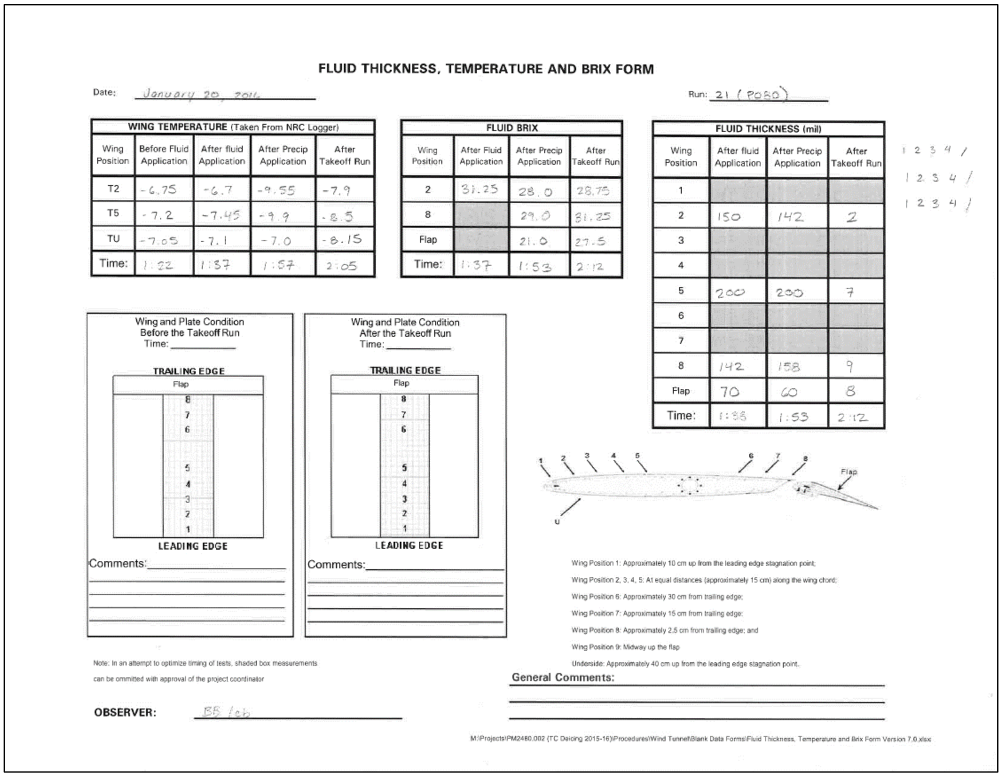
Figure C13: Run # 20



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 20, 2016

Run: 21 (P080)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.75	-6.7	-9.55	-7.9
T5	-7.2	-7.45	-9.9	-8.5
TU	-7.05	-7.1	-7.0	-8.15
Time:	1:22	1:37	1:57	2:05

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	31.25	28.0	28.75
8	▨	29.0	31.25
Flap	▨	21.0	27.5
Time:	1:37	1:53	2:12

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	150	142	2
3	▨	▨	▨
4	▨	▨	▨
5	200	200	7
6	▨	▨	▨
7	▨	▨	▨
8	142	158	9
Flap	70	60	8
Time:	1:38	1:53	2:12

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ________

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

Comments:

Wing and Plate Condition
After 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: BB / cb

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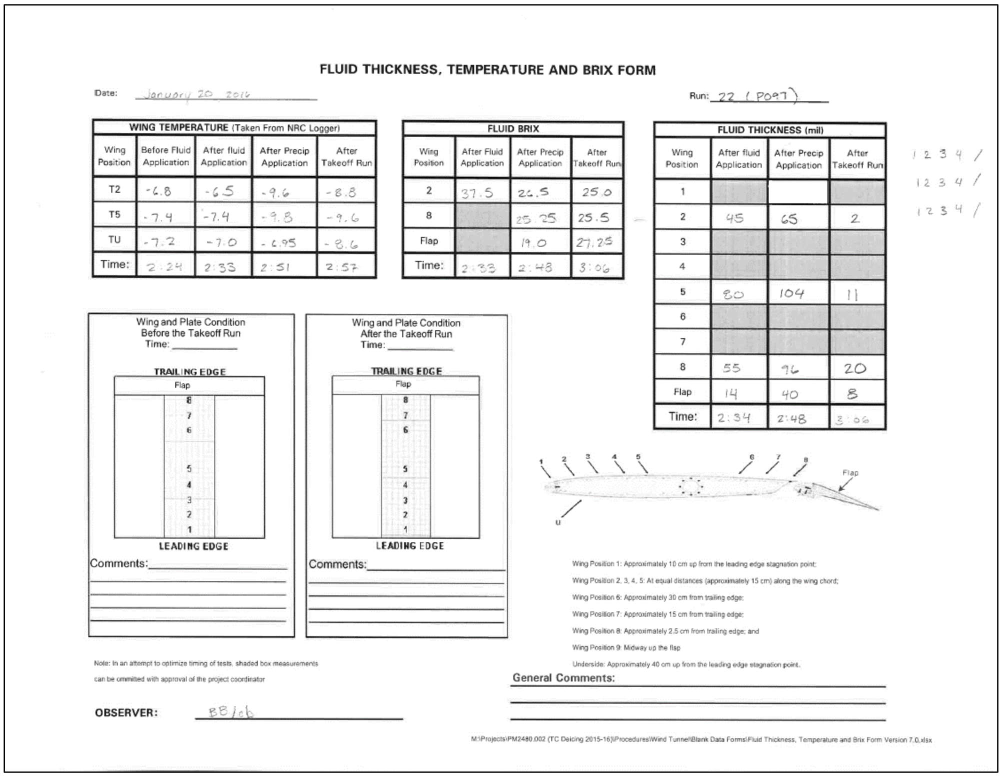
Figure C14: Run # 21



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 20 2016

Run: 22 (P097)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.8	-6.5	-9.6	-8.8
T5	-7.4	-7.4	-9.8	-9.6
TU	-7.2	-7.0	-6.95	-8.6
Time:	2:24	2:33	2:51	2:57

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.5	26.5	25.0
8	▨	25.25	25.5
Flap	▨	19.0	27.25
Time:	2:33	2:48	3:06

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨		▨
2	45	65	2
3	▨	▨	▨
4	▨	▨	▨
5	80	104	11
6	▨	▨	▨
7	▨	▨	▨
8	55	96	20
Flap	14	40	8
Time:	2:34	2:48	3:06

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments: ___________

Wing and Plate Condition
After 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: BB/cb

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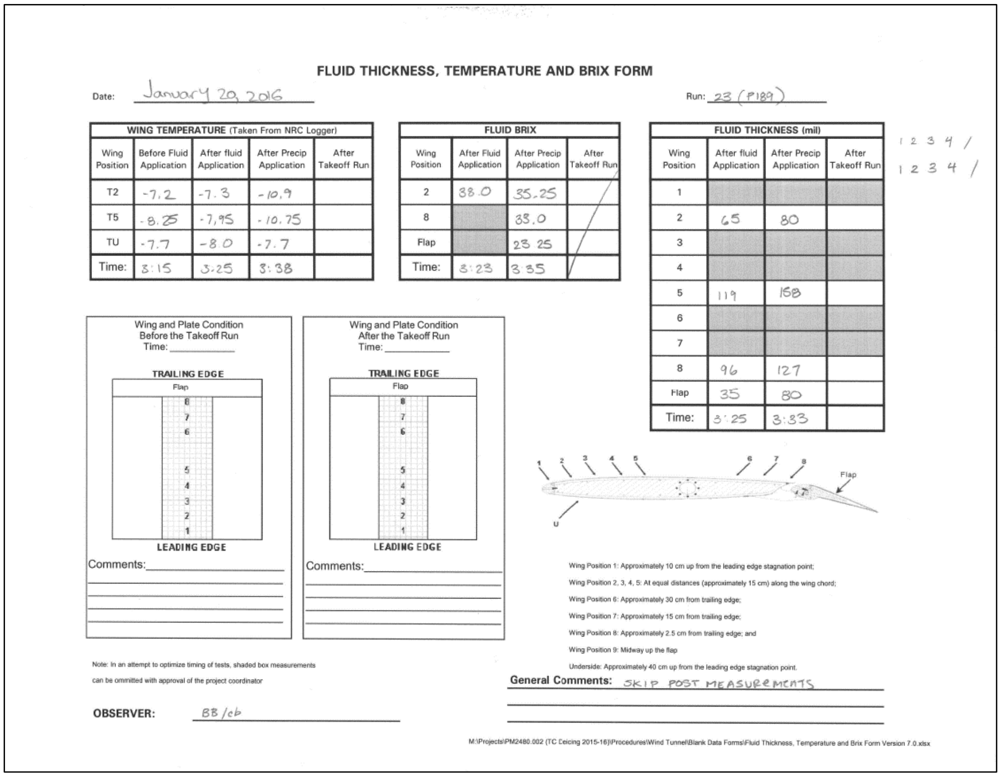
Figure C15: Run # 22



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 20, 2016

Run: 23 (P189)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-7.2	-7.3	-10.9	
T5	-8.25	-7,95	-10.75	
TU	-7.7	-8.0	-7.7	
Time:	3:15	3:25	3:38	

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	38.0	35.25	
8	▨	33.0	
Flap	▨	23 25	
Time:	3:23	3:35	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	65	80	
3	▨	▨	▨
4	▨	▨	▨
5	119	158	
6	▨	▨	▨
7	▨	▨	▨
8	96	127	
Flap	35	80	
Time:	3:25	3:33	

1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments: ___________

Wing and Plate Condition
After 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: SKIP POST MEASUREMENTS

OBSERVER: BB/cb

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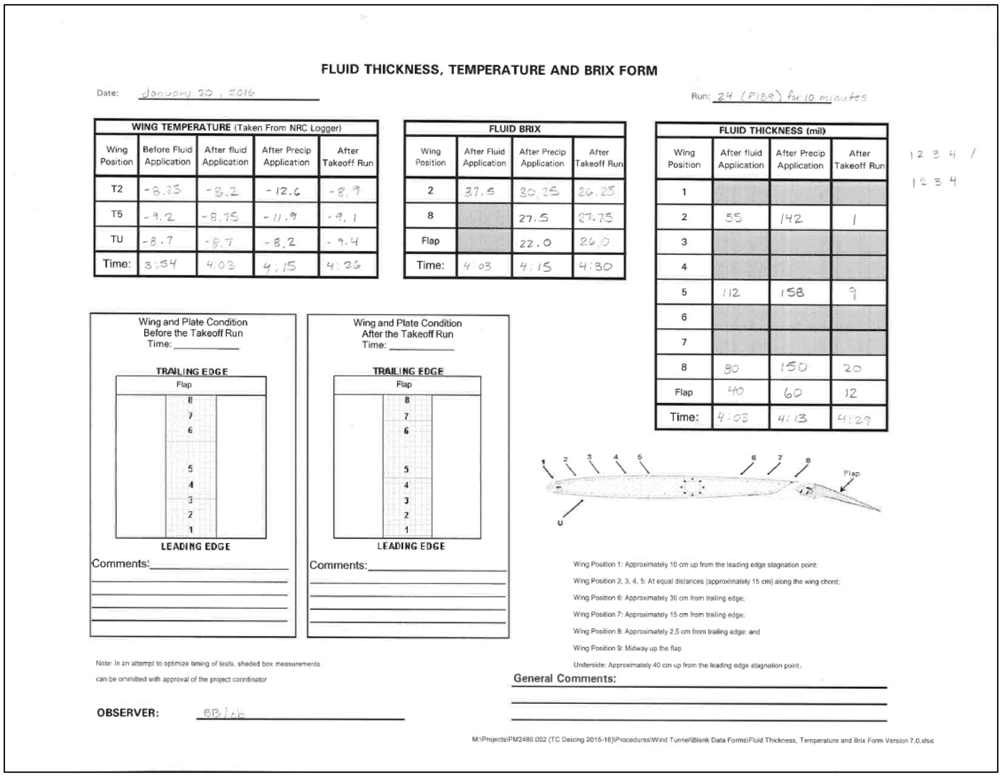
Figure C16: Run # 23



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 20, 2016

Run: 24 (P189) for 10 minutes

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-8.25	-8.2	-12.6	-8.9
T5	-9.2	-8.75	-11.9	-9.1
TU	-8.7	-8.7	-8.2	-9.4
Time:	3:54	4:03	4:15	4:26

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.5	30.25	26.25
8		27.5	27.75
Flap		22.0	26.0
Time:	4:03	4:15	4:30

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	55	142	1
3			
4			
5	112	158	9
6			
7			
8	80	150	20
Flap	40	60	12
Time:	4:03	4:13	4:29

12 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ______

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

Comments:

Wing and Plate Condition
After 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: BB/cb

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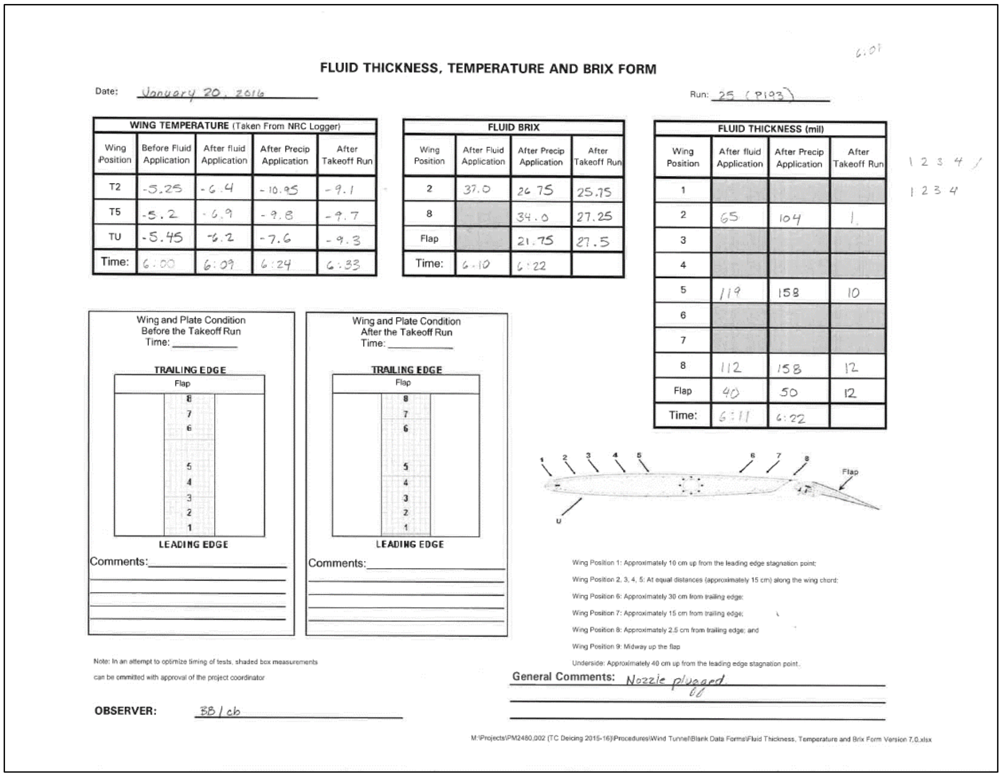
Figure C17: Run # 24



6:01

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 20, 2016

Run: 25 (P193)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.25	-6.4	-10.95	-9.1
T5	-5.2	-6.9	-9.8	-9.7
TU	-5.45	-6.2	-7.6	-9.3
Time:	6:00	6:09	6:24	6:33

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	26.75	25.75
8		34.0	27.25
Flap		21.75	27.5
Time:	6:10	6:22	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	65	104	1
3			
4			
5	119	158	10
6			
7			
8	112	158	12
Flap	40	50	12
Time:	6:11	6:22	

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ______

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

Comments:

Wing and Plate Condition
After 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: Nozzle plugged.

OBSERVER: BB/cb

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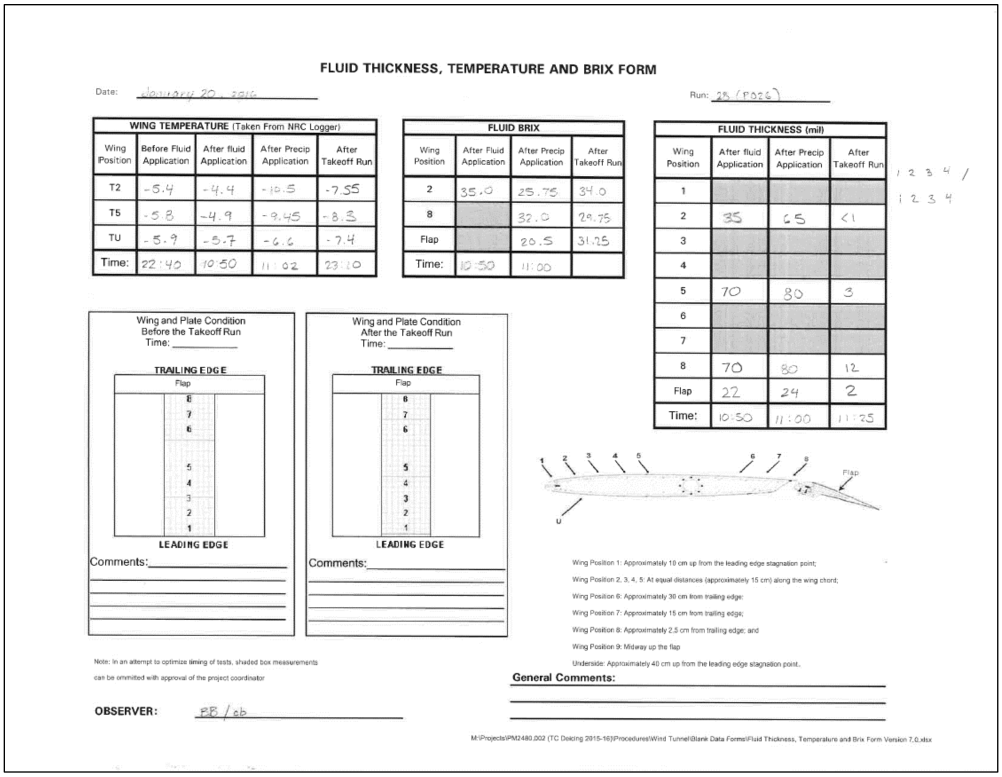
Figure C18: Run # 25

No Data Available

Figure C19: Run # 26 to Run #27



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 20, 2016

Run: 28 (P026)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.4	-4.4	-10.5	-7.55
T5	-5.8	-4.9	-9.45	-8.3
TU	-5.9	-5.7	-6.6	-7.4
Time:	22:40	10:50	11:02	23:10

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0	25.75	34.0
8		32.0	29.75
Flap		20.5	31.25
Time:	10:50	11:00	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	35	65	<1
3			
4			
5	70	80	3
6			
7			
8	70	80	12
Flap	22	24	2
Time:	10:50	11:00	11:25

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:

Wing and Plate Condition
After 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: BB / cb

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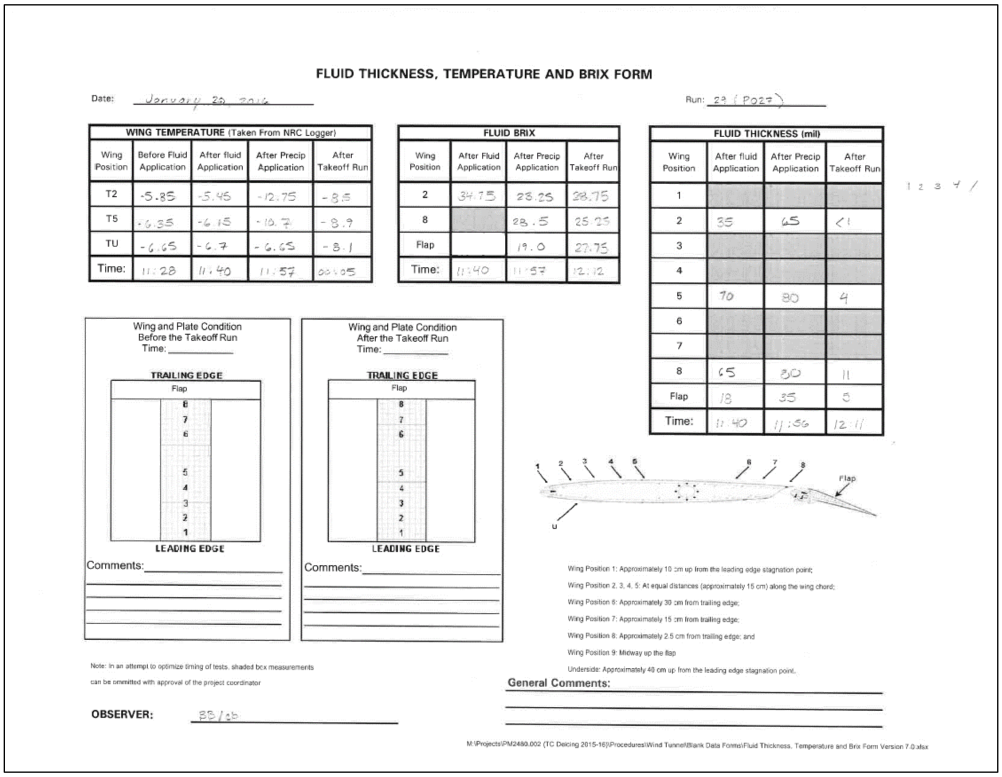
Figure C20: Run # 28



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 20, 2016

Run: 29 (P027)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.85	-5.45	-12.75	-8.5
T5	-6.35	-6.15	-10.7	-8.9
TU	-6.65	-6.7	-6.65	-8.1
Time:	11:28	11:40	11:57	00:05

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.75	23.25	28.75
8	▨	28.5	25.25
Flap		19.0	27.75
Time:	11:40	11:57	12:12

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	35	65	<1
3	▨	▨	▨
4	▨	▨	▨
5	70	80	4
6	▨	▨	▨
7	▨	▨	▨
8	65	80	11
Flap	18	35	5
Time:	11:40	11:56	12:11

1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments:

Wing and Plate Condition
After 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: BB/cb

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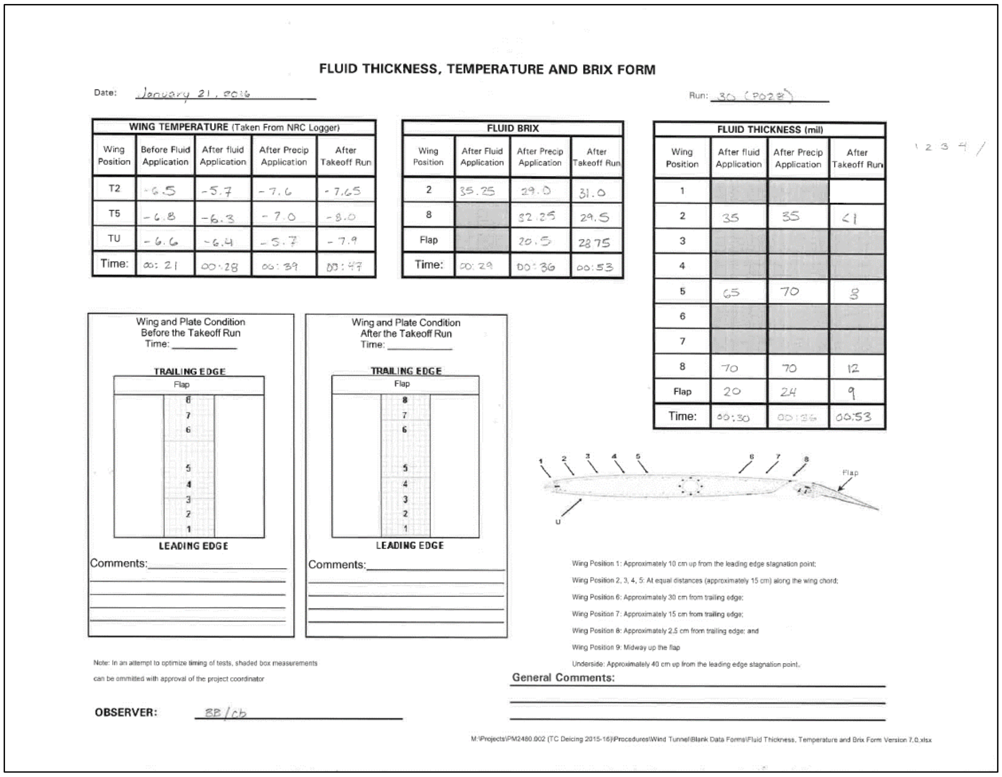
Figure C21: Run # 29



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 30 (P028)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.5	-5.7	-7.6	-7.65
T5	-6.8	-6.3	-7.0	-8.0
TU	-6.6	-6.4	-5.7	-7.9
Time:	00:21	00:28	00:39	00:47

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.25	29.0	31.0
8	▨	32.25	29.5
Flap	▨	20.5	28.75
Time:	00:29	00:36	00:53

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	
2	35	35	<1
3	▨	▨	▨
4	▨	▨	▨
5	65	70	8
6	▨	▨	▨
7	▨	▨	▨
8	70	70	12
Flap	20	24	9
Time:	00:30	00:36	00:53

1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments:

Wing and Plate Condition
After 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: BB/cb

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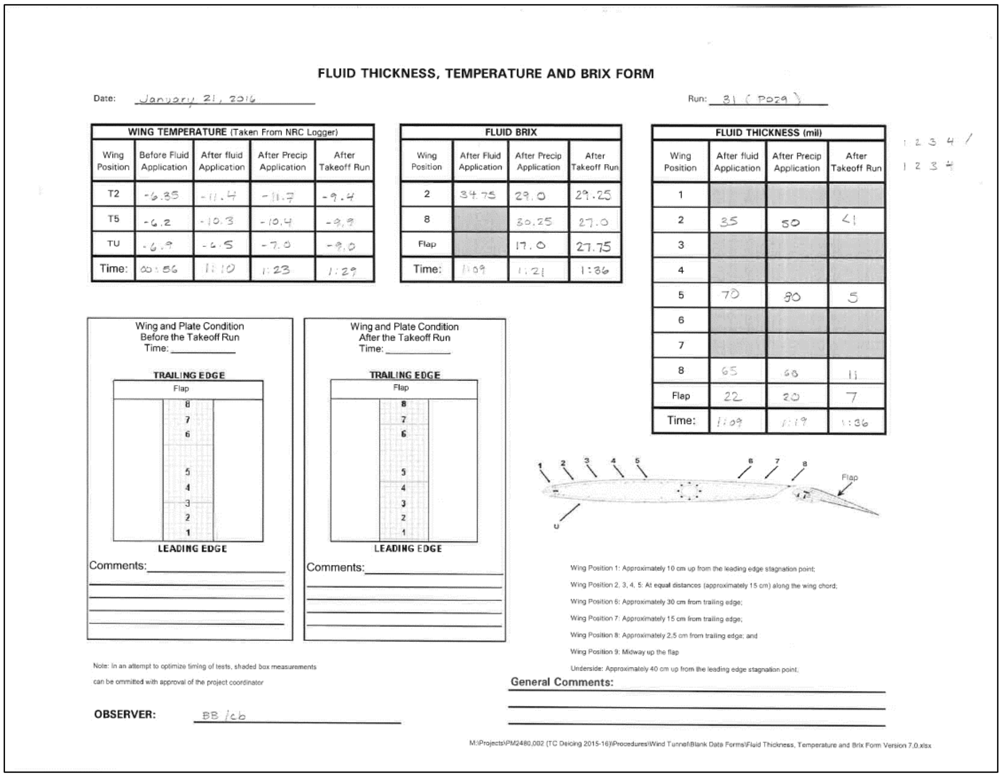
Figure C22: Run #30



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 31 (P029)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.35	-11.4	-11.7	-9.4
T5	-6.2	-10.3	-10.4	-9.9
TU	-6.9	-6.5	-7.0	-9.0
Time:	00:56	1:10	1:23	1:29

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.75	29.0	29.25
8		30.25	27.0
Flap		17.0	27.75
Time:	1:09	1:21	1:36

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	35	50	<1
3			
4			
5	70	80	5
6			
7			
8	65	68	11
Flap	22	20	7
Time:	1:09	1:19	1:36

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:

Wing and Plate Condition
After 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: BB / cb

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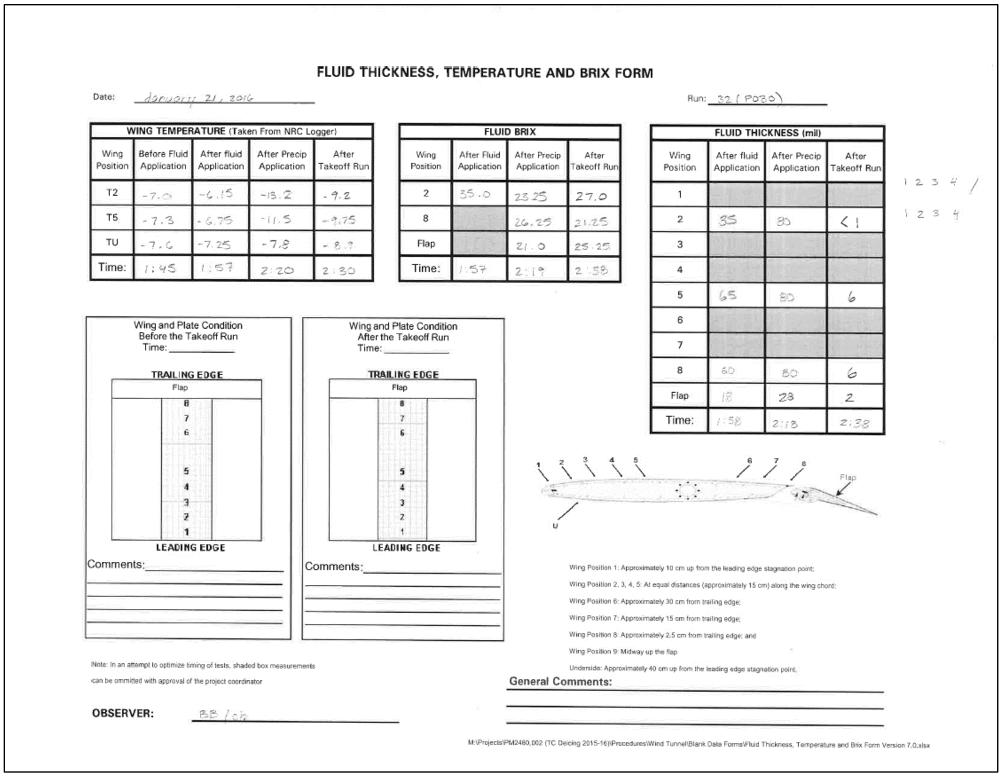
Figure C23: Run # 31



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 32 (P030)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-7.0	-6.15	-13.2	-9.2
T5	-7.3	-6.75	-11.5	-9.75
TU	-7.6	-7.25	-7.8	-8.9
Time:	1:45	1:57	2:20	2:30

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0	23.25	27.0
8		26.25	21.25
Flap		21.0	25.25
Time:	1:57	2:19	2:38

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	35	80	<1
3			
4			
5	65	80	6
6			
7			
8	60	80	6
Flap	18	28	2
Time:	1:58	2:18	2:38

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:

Wing and Plate Condition
After 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: BB / cb

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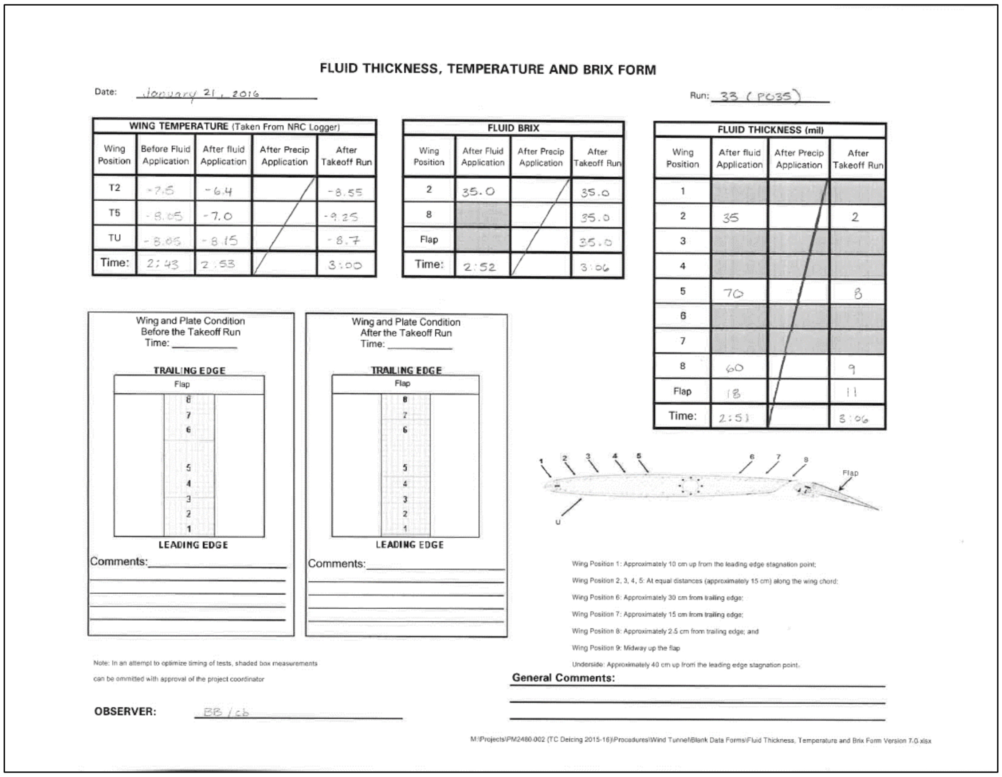
Figure C24: Run # 32



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 33 (P035)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-7.5	-6.4		-8.55
T5	-8.05	-7.0		-9.25
TU	-8.05	-8.15		-8.7
Time:	2:43	2:53		3:00

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0		35.0
8			35.0
Flap			35.0
Time:	2:52		3:06

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	35		2
3			
4			
5	70		8
6			
7			
8	60		9
Flap	18		11
Time:	2:51		3:06

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments: ___________

Wing and Plate Condition
After 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: BB / cb

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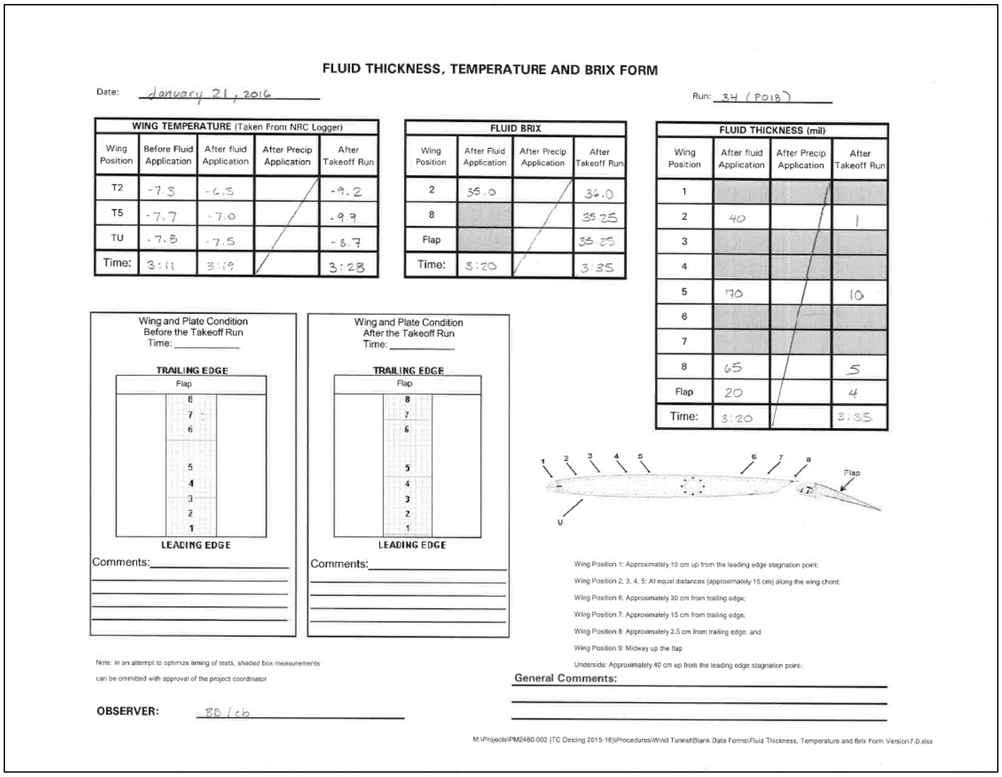
Figure C25: Run # 33



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 34 (P018)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-7.3	-6.5		-9.2
T5	-7.7	-7.0		-9.9
TU	-7.8	-7.5		-8.7
Time:	3:11	3:19		3:28

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0		36.0
8			35.25
Flap			35.25
Time:	3:20		3:35

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40		1
3			
4			
5	70		10
6			
7			
8	65		5
Flap	20		4
Time:	3:20		3:35

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments: ___________

Wing and Plate Condition
After 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: BB / cb

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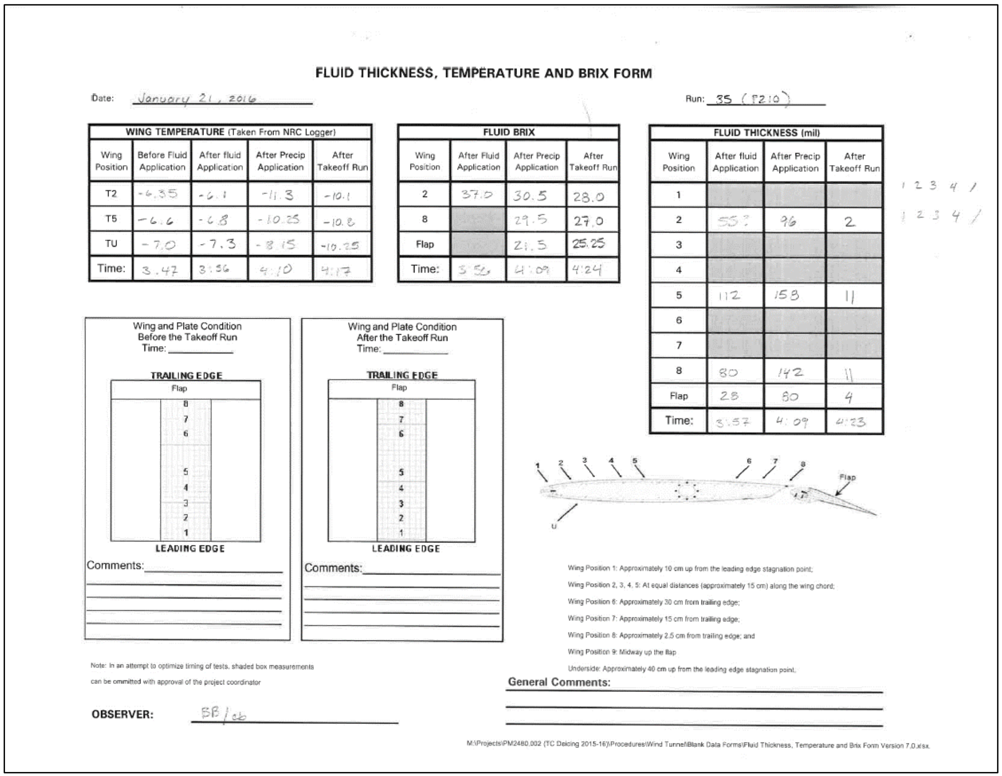
Figure C26: Run # 34



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 35 (P210)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.35	-6.1	-11.3	-10.1
T5	-6.6	-6.8	-10.25	-10.8
TU	-7.0	-7.3	-8.15	-10.25
Time:	3.47	3:56	4:10	4:17

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	30.5	28.0
8	▨	29.5	27.0
Flap	▨	21.5	25.25
Time:	3:56	4:09	4:24

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	55?	96	2
3	▨	▨	▨
4	▨	▨	▨
5	112	158	11
6	▨	▨	▨
7	▨	▨	▨
8	80	142	11
Flap	28	80	4
Time:	3:57	4:09	4:23

1 2 3 4 /

1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

TRAILING EDGE

LEADING EDGE

Comments: ____________

Wing and Plate Condition
After the Takeoff Run
Time: ____________

TRAILING EDGE

LEADING EDGE

Comments: ____________

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

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

OBSERVER: BB/cb

General Comments: ____________

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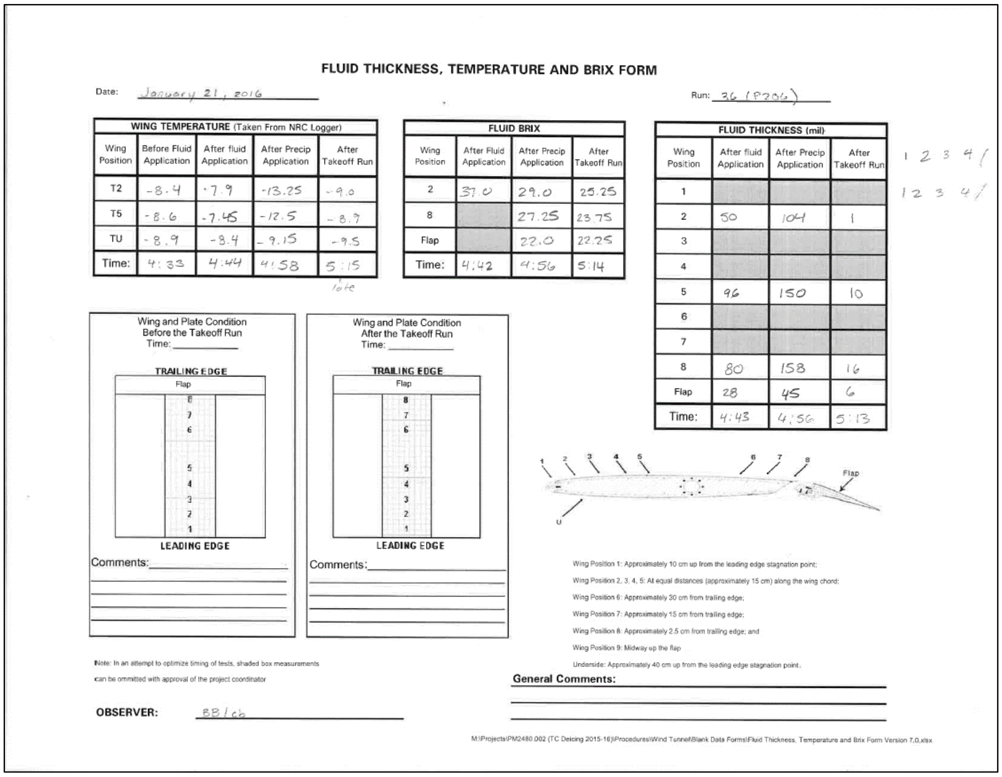
Figure C27: Run # 35



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 36 (P206)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-8.4	-7.9	-13.25	-9.0
T5	-8.6	-7.45	-12.5	-8.9
TU	-8.9	-8.4	-9.15	-9.5
Time:	4:33	4:44	4:58	5:15 late

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	29.0	25.25
8	▨	27.25	23.75
Flap	▨	22.0	22.25
Time:	4:42	4:56	5:14

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	50	104	1
3	▨	▨	▨
4	▨	▨	▨
5	96	150	10
6	▨	▨	▨
7	▨	▨	▨
8	80	158	16
Flap	28	45	6
Time:	4:43	4:56	5:13

1 2 3 4 /

1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

TRAILING EDGE

LEADING EDGE

Comments: ____________

Wing and Plate Condition
After the Takeoff Run
Time: ____________

TRAILING EDGE

LEADING EDGE

Comments: ____________

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

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

OBSERVER: BB/cb

General Comments: ____________

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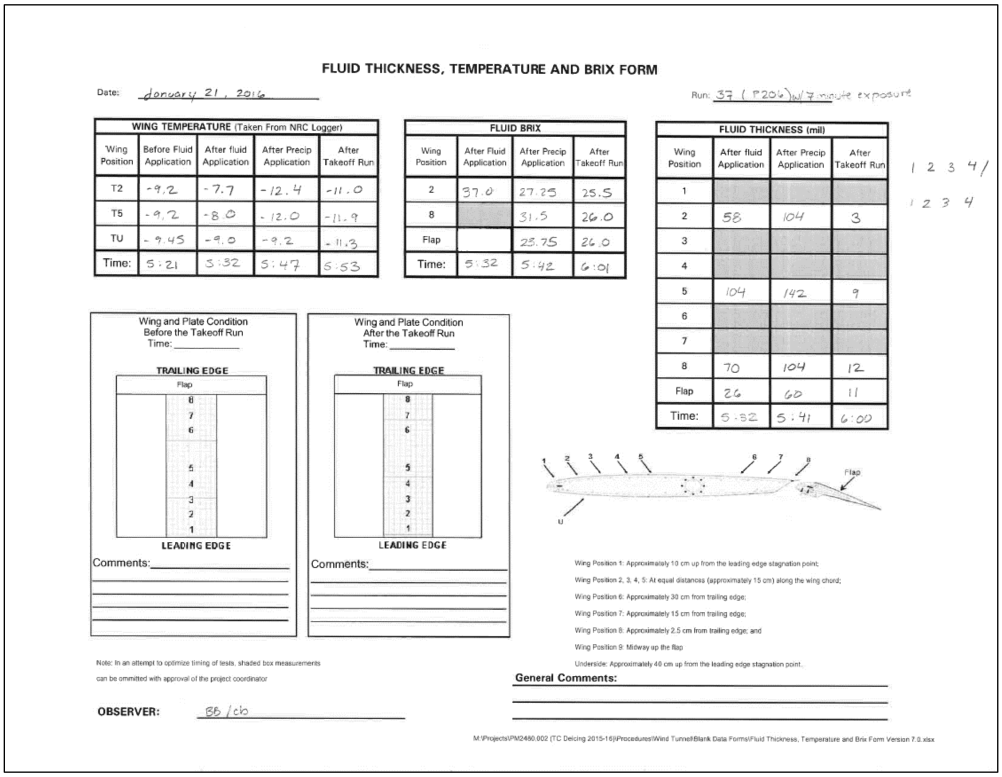
Figure C28: Run # 36



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 37 (P206) w/ 7 minute exposure

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-9.2	-7.7	-12.4	-11.0
T5	-9.2	-8.0	-12.0	-11.9
TU	-9.45	-9.0	-9.2	-11.3
Time:	5:21	5:32	5:47	5:53

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	27.25	25.5
8	▨	31.5	26.0
Flap		23.75	26.0
Time:	5:32	5:42	6:01

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	58	104	3
3	▨	▨	▨
4	▨	▨	▨
5	104	142	9
6	▨	▨	▨
7	▨	▨	▨
8	70	104	12
Flap	26	60	11
Time:	5:32	5:41	6:00

1 2 3 4 /

1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Comments: ___________

Wing and Plate Condition
After 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: BB / cb

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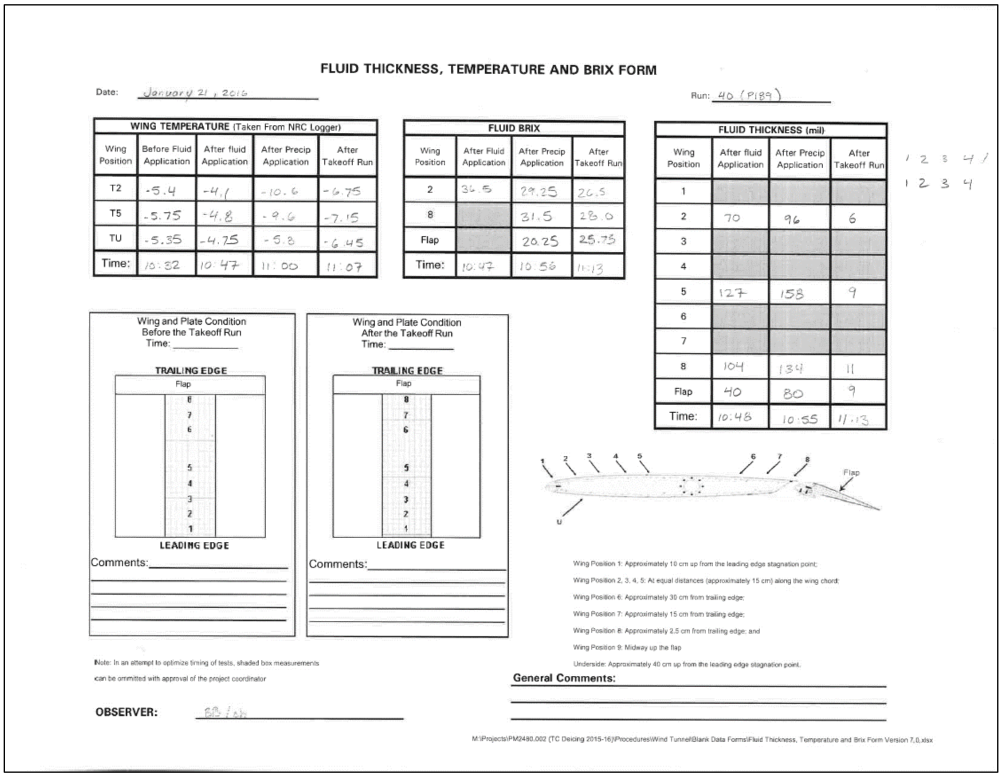
Figure C29: Run # 37

No Data Available

Figure C30: Run # 38 to Run #39



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 40 (P189)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.4	-4.1	-10.6	-6.75
T5	-5.75	-4.8	-9.6	-7.15
TU	-5.35	-4.75	-5.8	-6.45
Time:	10:32	10:47	11:00	11:07

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.5	29.25	26.5
8	▨	31.5	28.0
Flap	▨	20.25	25.75
Time:	10:47	10:56	11:13

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	70	96	6
3	▨	▨	▨
4	▨	▨	▨
5	127	158	9
6	▨	▨	▨
7	▨	▨	▨
8	104	134	11
Flap	40	80	9
Time:	10:48	10:55	11:13

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments:

Wing and Plate Condition
After 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: BB / ch

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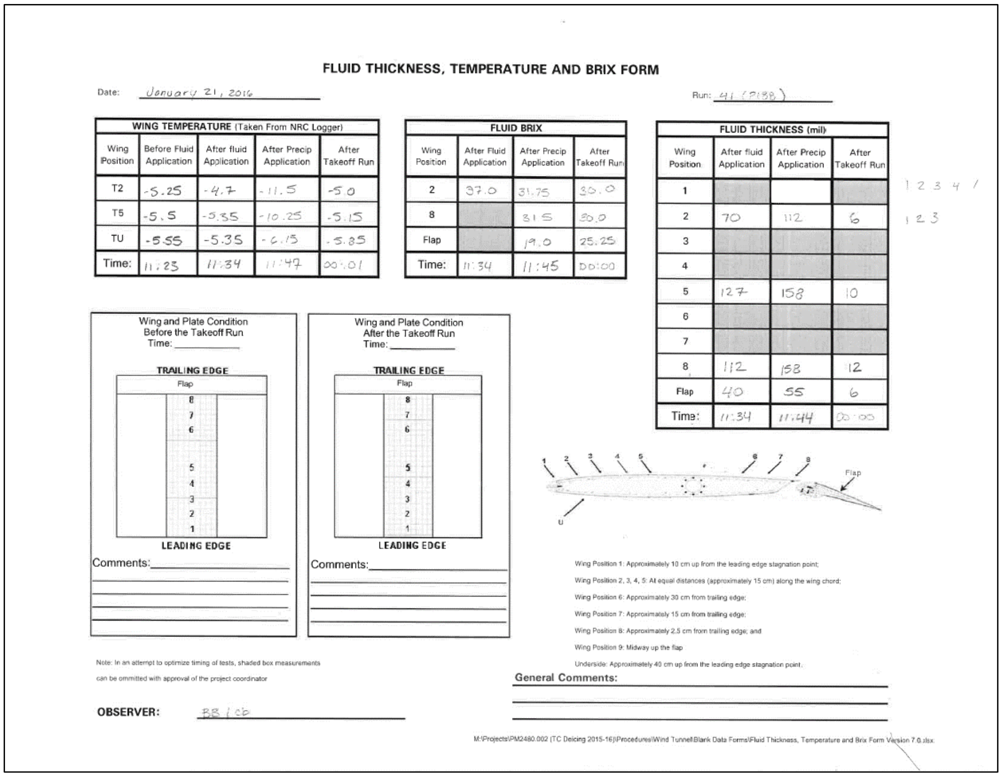
Figure C31: Run # 40



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 21, 2016

Run: 41 (P188)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.25	-4.7	-11.5	-5.0
T5	-5.5	-5.35	-10.25	-5.15
TU	-5.55	-5.35	-6.15	-5.85
Time:	11:23	11:34	11:47	00:01

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	31.75	30.0
8	▨	31.5	30.0
Flap	▨	19.0	25.25
Time:	11:34	11:45	00:00

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨		▨
2	70	112	6
3	▨	▨	▨
4	▨	▨	▨
5	127	158	10
6	▨	▨	▨
7	▨	▨	▨
8	112	158	12
Flap	40	55	6
Time:	11:34	11:44	00:00

1 2 3 4 /
1 2 3

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments:

Wing and Plate Condition
After 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: BB / cb

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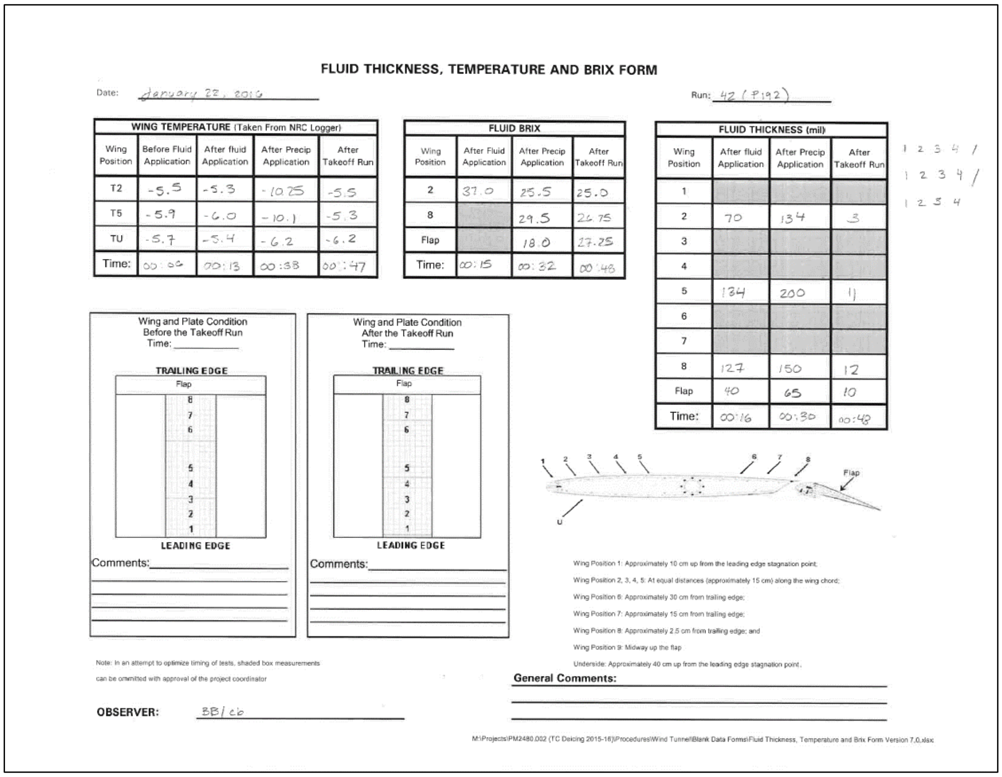
Figure C32: Run # 41



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 22, 2016

Run: 42 (P192)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.5	-5.3	-10.25	-5.5
T5	-5.9	-6.0	-10.1	-5.3
TU	-5.7	-5.4	-6.2	-6.2
Time:	00:06	00:13	00:38	00:47

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	25.5	25.0
8		29.5	26.75
Flap		18.0	27.25
Time:	00:15	00:32	00:48

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	134	3
3			
4			
5	134	200	11
6			
7			
8	127	150	12
Flap	40	65	10
Time:	00:16	00:30	00:48

1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition
After 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: BB/cb

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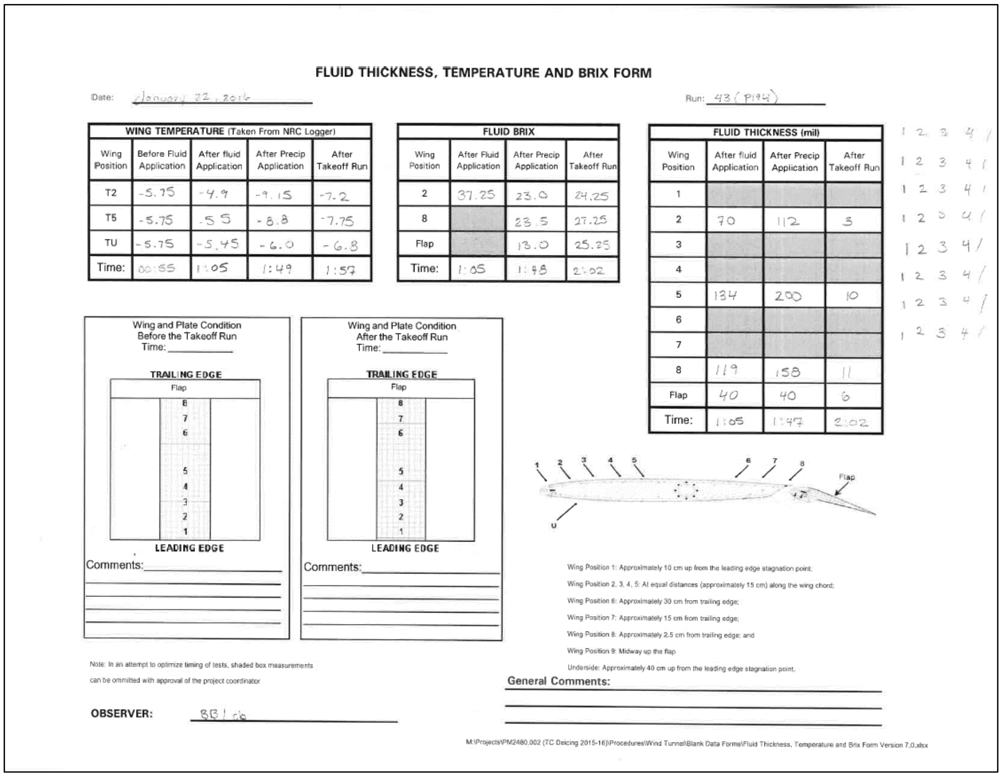
Figure C33: Run # 42



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 22, 2016

Run: 43 (P194)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.75	-4.9	-9.15	-7.2
T5	-5.75	-5.5	-8.8	-7.75
TU	-5.75	-5.45	-6.0	-6.8
Time:	00:55	1:05	1:49	1:57

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	23.0	24.25
8		23.5	27.25
Flap		13.0	25.25
Time:	1:05	1:48	2:02

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	70	112	3
3			
4			
5	134	200	10
6			
7			
8	119	158	11
Flap	40	40	6
Time:	1:05	1:47	2:02

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition
After 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: BB/cb

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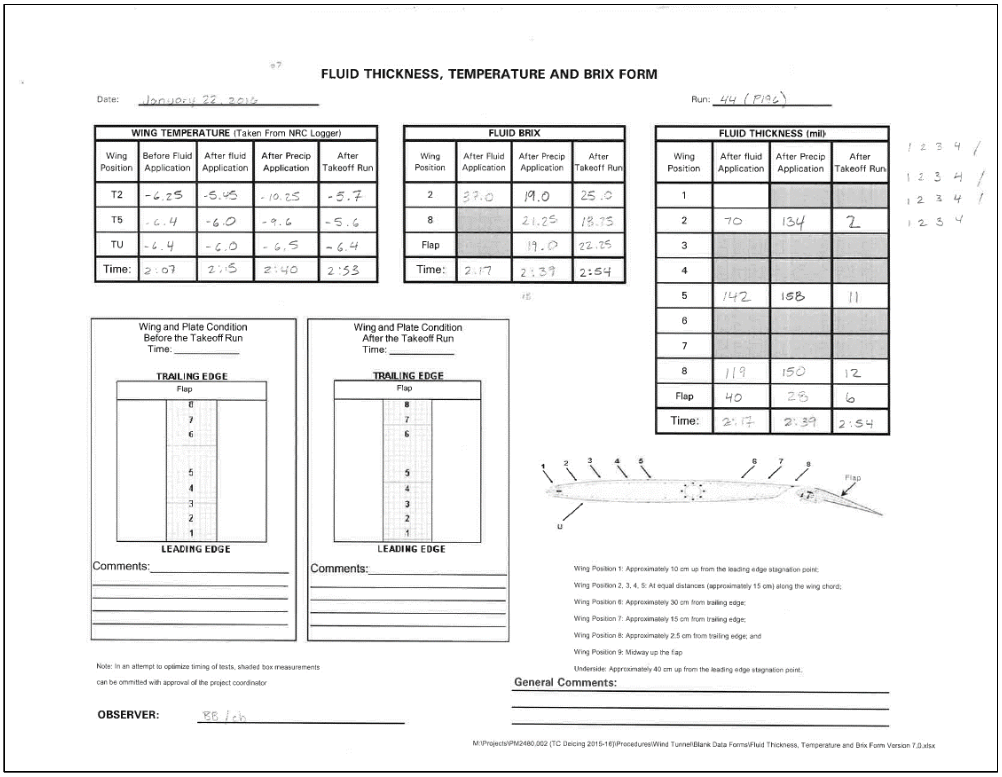
Figure C34: Run # 43



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 22, 2016

Run: 44 (P196)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.25	-5.45	-10.25	-5.7
T5	-6.4	-6.0	-9.6	-5.6
TU	-6.4	-6.0	-6.5	-6.4
Time:	2:07	2:15	2:40	2:53

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	19.0	25.0
8	▨	21.25	18.75
Flap	▨	19.0	22.25
Time:	2:17	2:39	2:54

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		▨	▨
2	70	134	2
3	▨	▨	▨
4	▨	▨	▨
5	142	158	11
6	▨	▨	▨
7	▨	▨	▨
8	119	150	12
Flap	40	28	6
Time:	2:17	2:39	2:54

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments: ___________

Wing and Plate Condition
After 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: BB / cb

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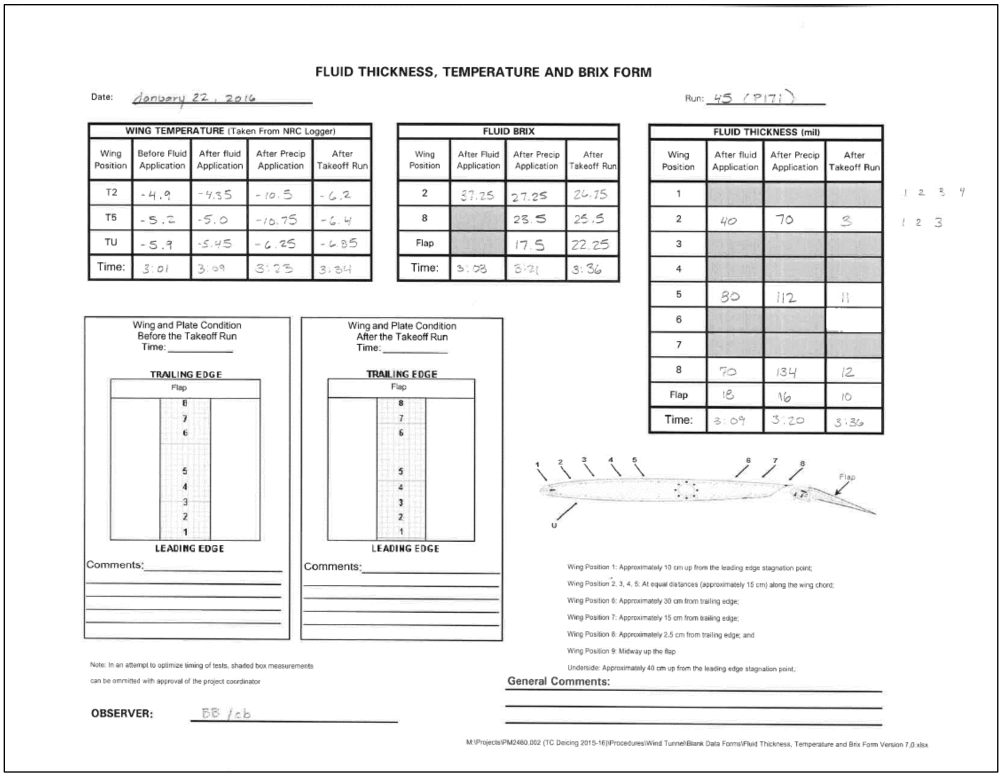
Figure C35: Run # 44



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 22, 2016

Run: 45 (P171)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-4.9	-4.35	-10.5	-6.2
T5	-5.2	-5.0	-10.75	-6.4
TU	-5.9	-5.45	-6.25	-6.85
Time:	3:01	3:09	3:23	3:34

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	27.25	26.75
8	▨	23.5	25.5
Flap	▨	17.5	22.25
Time:	3:08	3:21	3:36

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40	70	3
3	▨	▨	▨
4	▨	▨	▨
5	80	112	11
6	▨	▨	
7	▨	▨	▨
8	70	134	12
Flap	18	16	10
Time:	3:09	3:20	3:36

1 2 3 4
1 2 3

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments: ___________

Wing and Plate Condition
After 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: BB / cb

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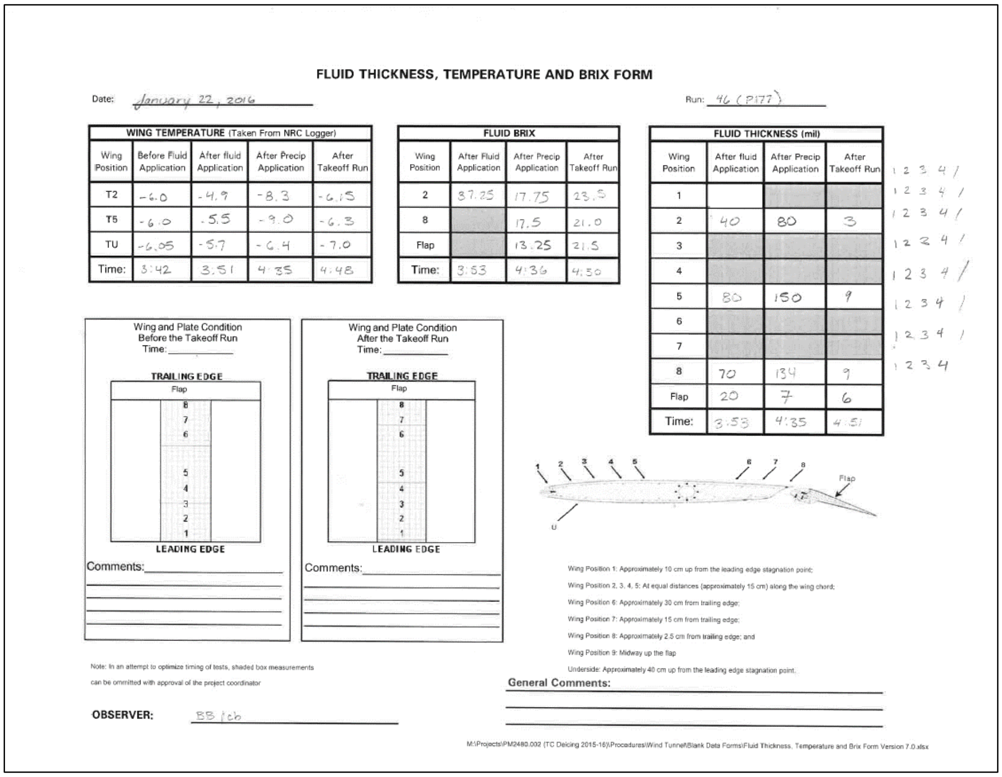
Figure C36: Run #45



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 22, 2016

Run: 46 (P177)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.0	-4.9	-8.3	-6.15
T5	-6.0	.5.5	-9.0	-6.3
TU	-6.05	-5.7	-6.4	-7.0
Time:	3:42	3:51	4:35	4:48

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	17.75	23.5
8		17.5	21.0
Flap		13.25	21.5
Time:	3:53	4:36	4:50

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40	80	3
3			
4			
5	80	150	9
6			
7			
8	70	134	9
Flap	20	7	6
Time:	3:53	4:35	4:51

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time:

Comments:

Wing and Plate Condition
After 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: BB / cb

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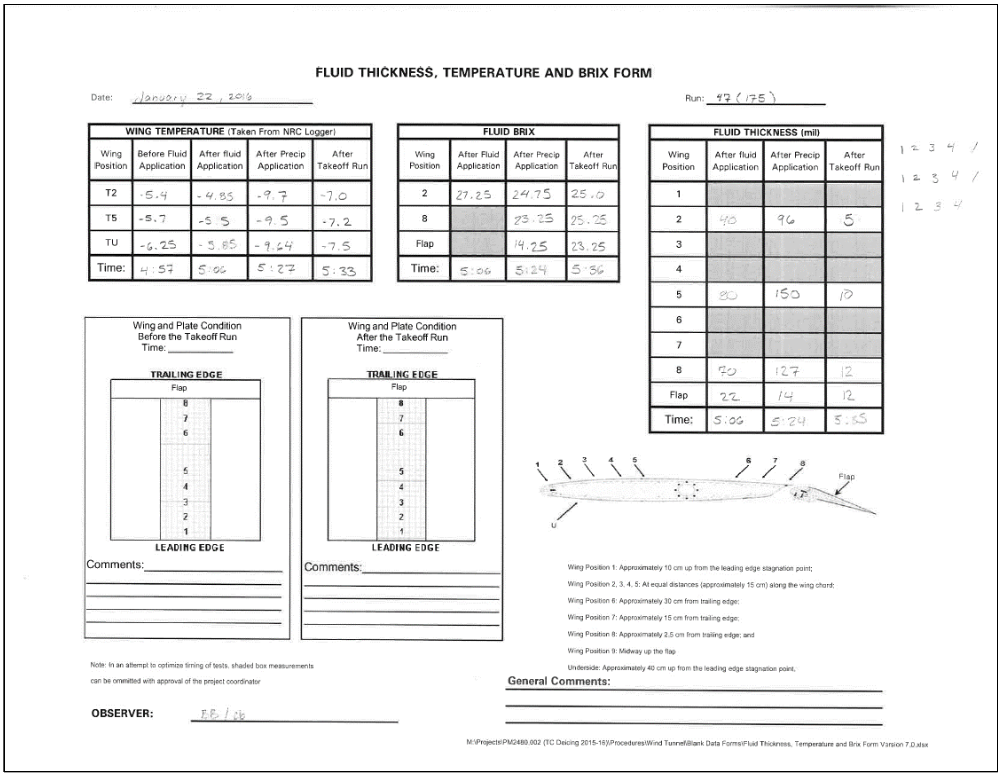
Figure C37: Run # 46



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 22, 2016

Run: 47 (175)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.4	-4.85	-9.7	-7.0
T5	-5.7	-5.5	-9.5	-7.2
TU	-6.25	-5.85	-9.64	-7.5
Time:	4:57	5:06	5:27	5:33

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	27.25	24.75	25.0
8		23.25	25.25
Flap		14.25	23.25
Time:	5:06	5:24	5:36

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40	96	5
3			
4			
5	80	150	10
6			
7			
8	70	127	12
Flap	22	14	12
Time:	5:06	5:24	5:35

1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time:

Comments:

Wing and Plate Condition
After 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: BB / cb

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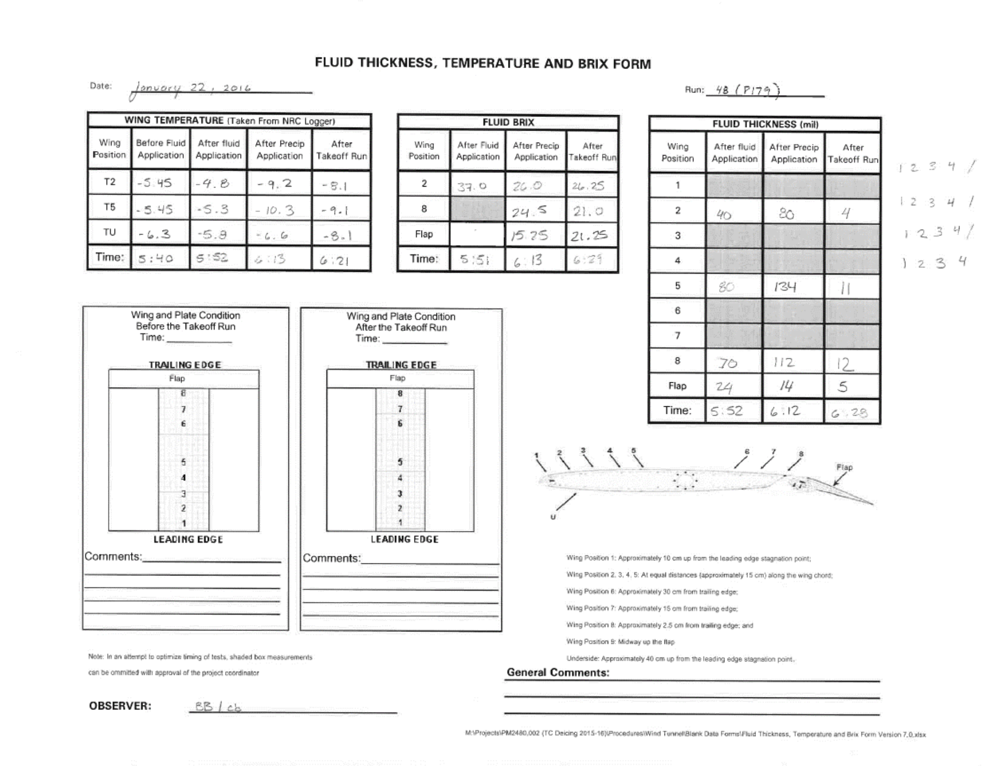
Figure C38: Run # 47



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 22, 2016

Run: 48 (P179)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.45	-4.8	-9.2	-8.1
T5	-5.45	-5.3	-10.3	-9.1
TU	-6.3	-5.8	-6.6	-8.1
Time:	5:40	5:52	6:13	6:21

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	26.0	26.25
8	▨	24.5	21.0
Flap		15.25	21.25
Time:	5:51	6:13	6:29

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40	80	4
3	▨	▨	▨
4	▨	▨	▨
5	80	134	11
6	▨	▨	▨
7	▨	▨	▨
8	70	112	12
Flap	24	14	5
Time:	5:52	6:12	6:28

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Comments: ___________

Wing and Plate Condition
After 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: BB / cb

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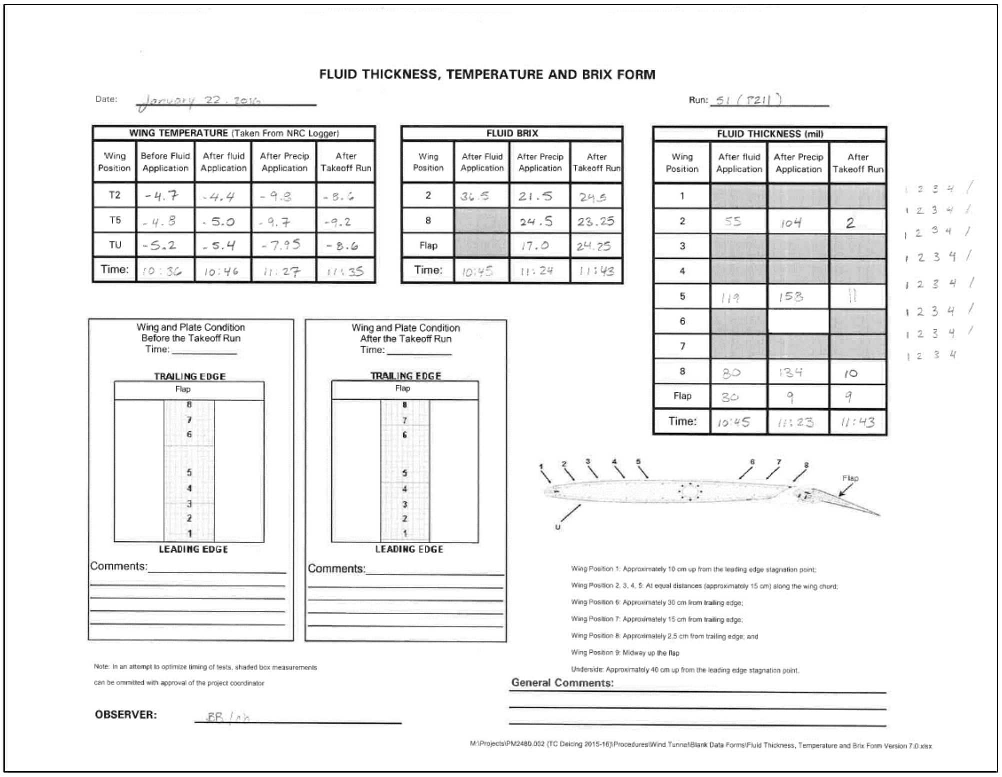
Figure C39: Run # 48

No Data Available

Figure C40: Run # 49 to Run #50



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 22, 2016

Run: 51 (P211)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-4.7	-4.4	-9.8	-8.6
T5	-4.8	-5.0	-9.7	-9.2
TU	-5.2	-5.4	-7.95	-8.6
Time:	10:36	10:46	11:27	11:35

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.5	21.5	24.5
8		24.5	23.25
Flap		17.0	24.25
Time:	10:45	11:24	11:43

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	55	104	2
3			
4			
5	119	158	11
6			
7			
8	80	134	10
Flap	30	9	9
Time:	10:45	11:23	11:43

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Comments: ___________

Wing and Plate Condition
After 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: EB / cb

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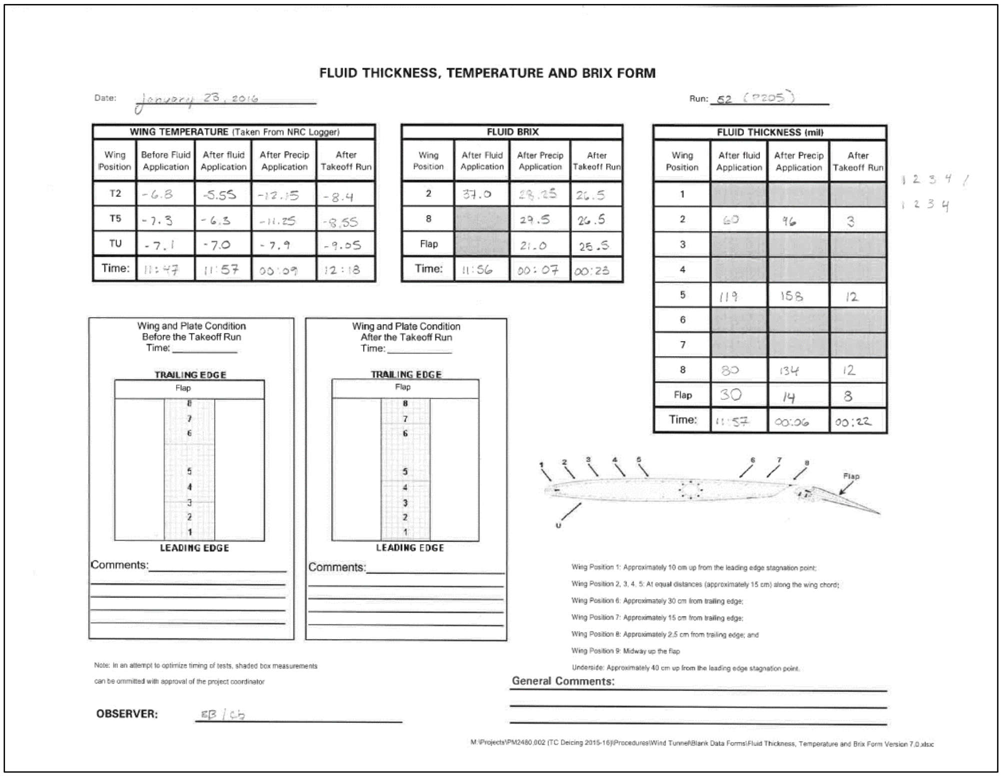
Figure C41: Run # 51



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 23, 2016

Run: 52 (P205)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-6.8	-5.55	-12.15	-8.4
T5	-7.3	-6.3	-11.25	-8.55
TU	-7.1	-7.0	-7.9	-9.05
Time:	11:47	11:57	00:09	12:18

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	28.25	26.5
8		29.5	26.5
Flap		21.0	25.5
Time:	11:56	00:07	00:23

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	60	96	3
3			
4			
5	119	158	12
6			
7			
8	80	134	12
Flap	30	14	8
Time:	11:57	00:06	00:22

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Comments: ___________

Wing and Plate Condition
After 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: EB / cb

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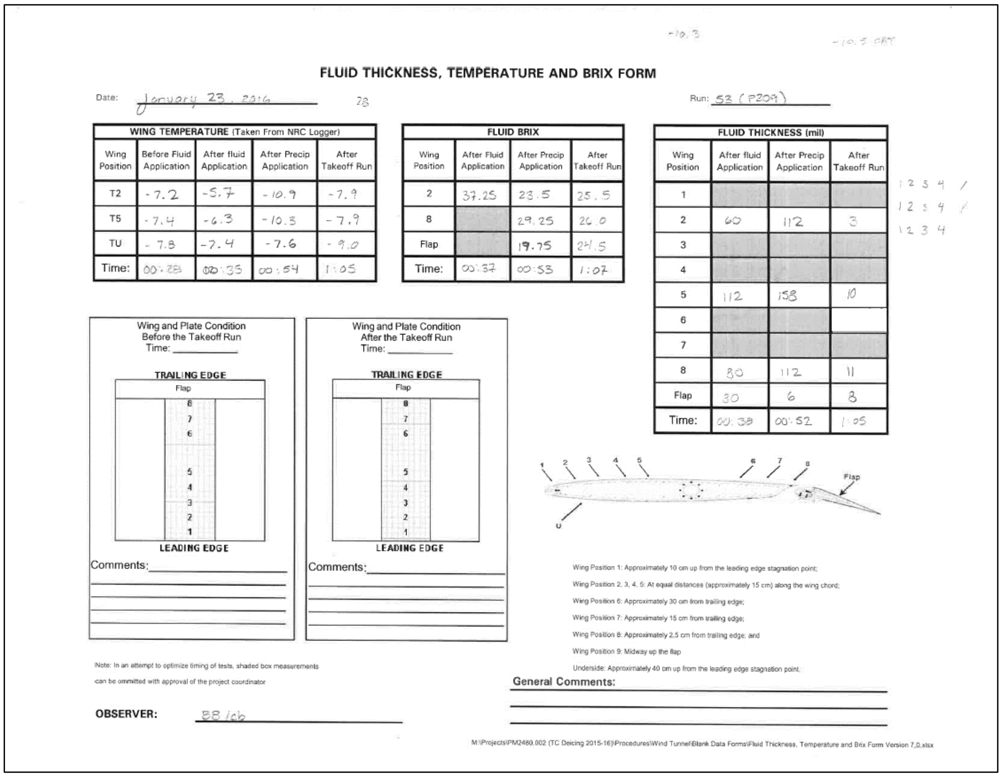
Figure C42: Run # 52



-10.3

-10.5 OAT

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 23, 2016 28

Run: 53 (P209)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-7.2	-5.7	-10.9	-7.9
T5	-7.4	-6.3	-10.3	-7.9
TU	-7.8	-7.4	-7.6	-9.0
Time:	00:28	00:35	00:54	1:05

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	23.5	25.5
8	▨	29.25	26.0
Flap	▨	19.75	24.5
Time:	00:37	00:53	1:07

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	60	112	3
3	▨	▨	▨
4	▨	▨	▨
5	112	158	10
6	▨	▨	
7	▨	▨	▨
8	80	112	11
Flap	30	6	8
Time:	00:38	00:52	1:05

1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Wing and Plate Condition
After the Takeoff Run
Time: ____________

Comments: ____________

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: BB/cb

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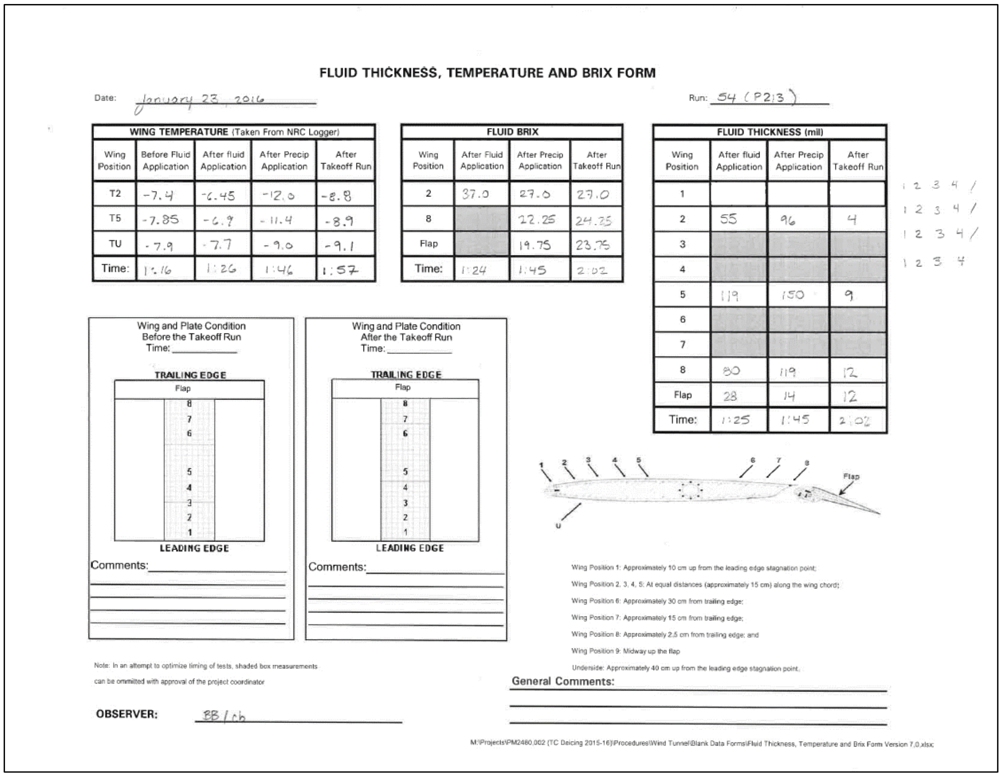
Figure C43: Run # 53



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 23, 2016

Run: 54 (P213)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-7.4	-6.45	-12.0	-8.8
T5	-7.85	-6.9	-11.4	-8.9
TU	-7.9	-7.7	-9.0	-9.1
Time:	1:16	1:26	1:46	1:57

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	27.0	27.0
8	▨	22.25	24.25
Flap	▨	19.75	23.75
Time:	1:24	1:45	2:02

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	55	96	4
3	▨	▨	▨
4	▨	▨	▨
5	119	150	9
6	▨	▨	▨
7	▨	▨	▨
8	80	119	12
Flap	28	14	12
Time:	1:25	1:45	2:02

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Wing and Plate Condition
After the Takeoff Run
Time: ____________

Comments: ____________

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: BB/cb

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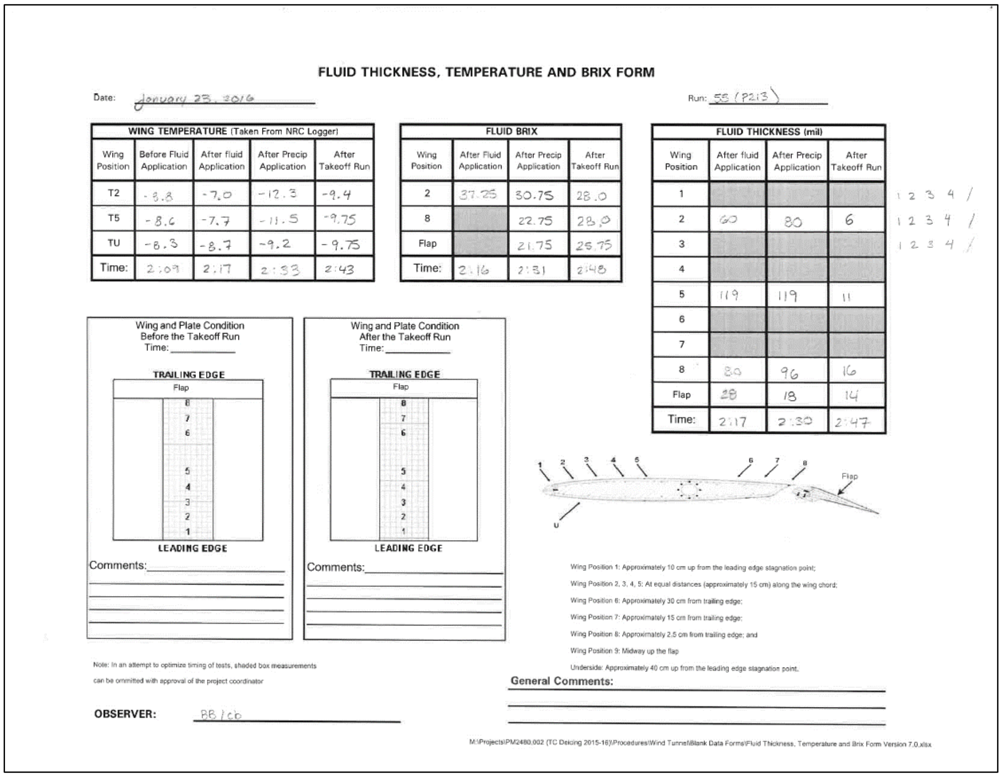
Figure C44: Run # 54



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 23, 2016

Run: 55 (P213)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-8.8	-7.0	-12.3	-9.4
T5	-8.6	-7.7	-11.5	-9.75
TU	-8.3	-8.7	-9.2	-9.75
Time:	2:09	2:17	2:33	2:43

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	30.75	28.0
8		22.75	28.0
Flap		21.75	25.75
Time:	2:16	2:31	2:48

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	60	80	6
3			
4			
5	119	119	11
6			
7			
8	80	96	16
Flap	28	18	14
Time:	2:17	2:30	2:47

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:___________

Wing and Plate Condition
After 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: BB / cb

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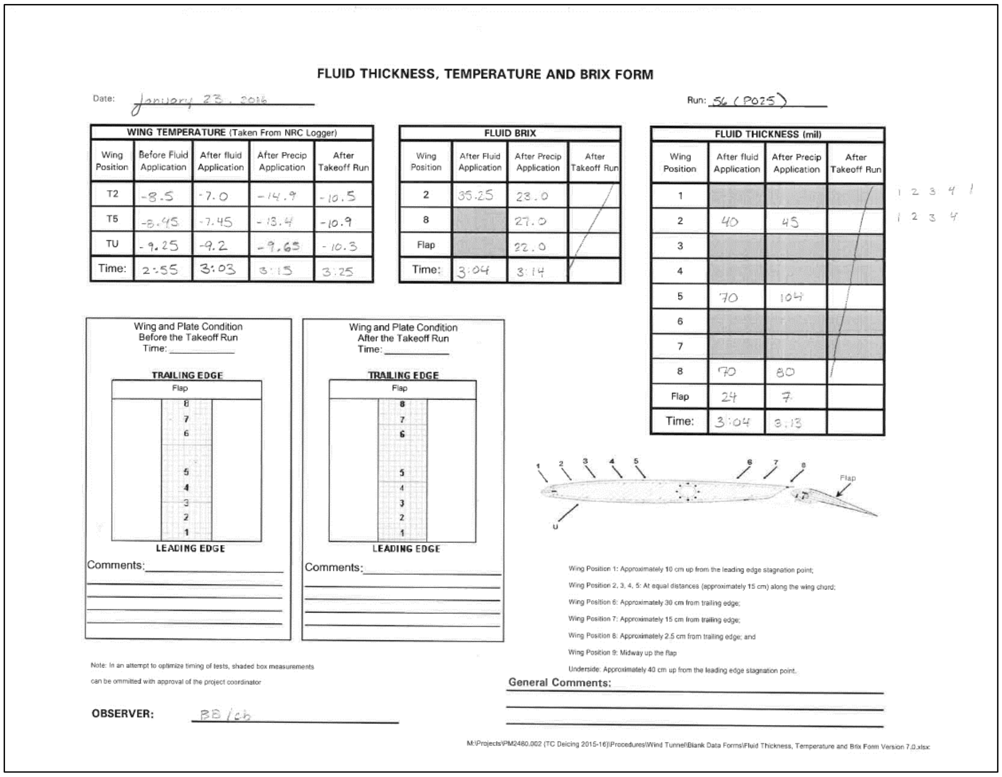
Figure C45: Run # 55



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 23, 2016

Run: 56 (P025)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-8.5	-7.0	-14.9	-10.5
T5	-8.45	-7.45	-13.4	-10.9
TU	-9.25	-9.2	-9.65	-10.3
Time:	2:55	3:03	3:15	3:25

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.25	23.0	
8		27.0	
Flap		22.0	
Time:	3:04	3:14	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40	45	
3			
4			
5	70	104	
6			
7			
8	70	80	
Flap	24	7	
Time:	3:04	3:13	

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:___________

Wing and Plate Condition
After 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: BB / cb

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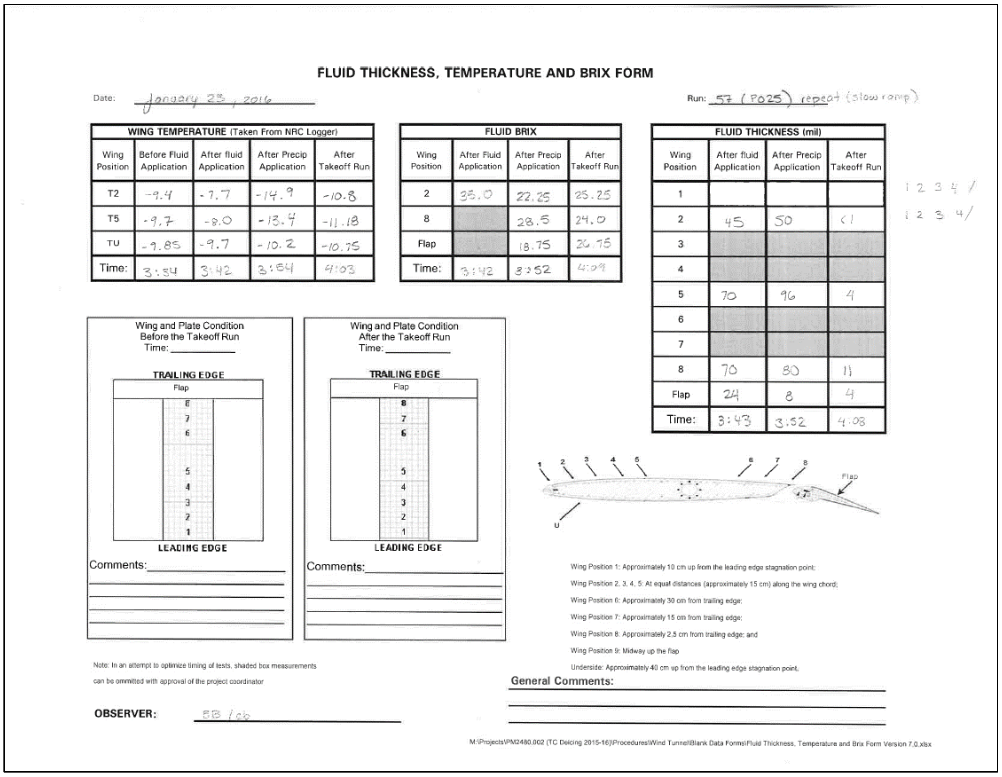
Figure C46: Run # 56



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 23, 2016

Run: 57 (P025) repeat (slow ramp)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-9.4	-7.7	-14.9	-10.8
T5	-9.7	-8.0	-13.4	-11.18
TU	-9.85	-9.7	-10.2	-10.75
Time:	3:34	3:42	3:54	4:03

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0	22.25	25.25
8		28.5	24.0
Flap		18.75	26.75
Time:	3:42	3:52	4:09

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	45	50	<1
3			
4			
5	70	96	4
6			
7			
8	70	80	11
Flap	24	8	4
Time:	3:43	3:52	4:08

1 2 3 4 /
1 2 3 4/

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Comments: ___________

Wing and Plate Condition
After 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: BB / cb

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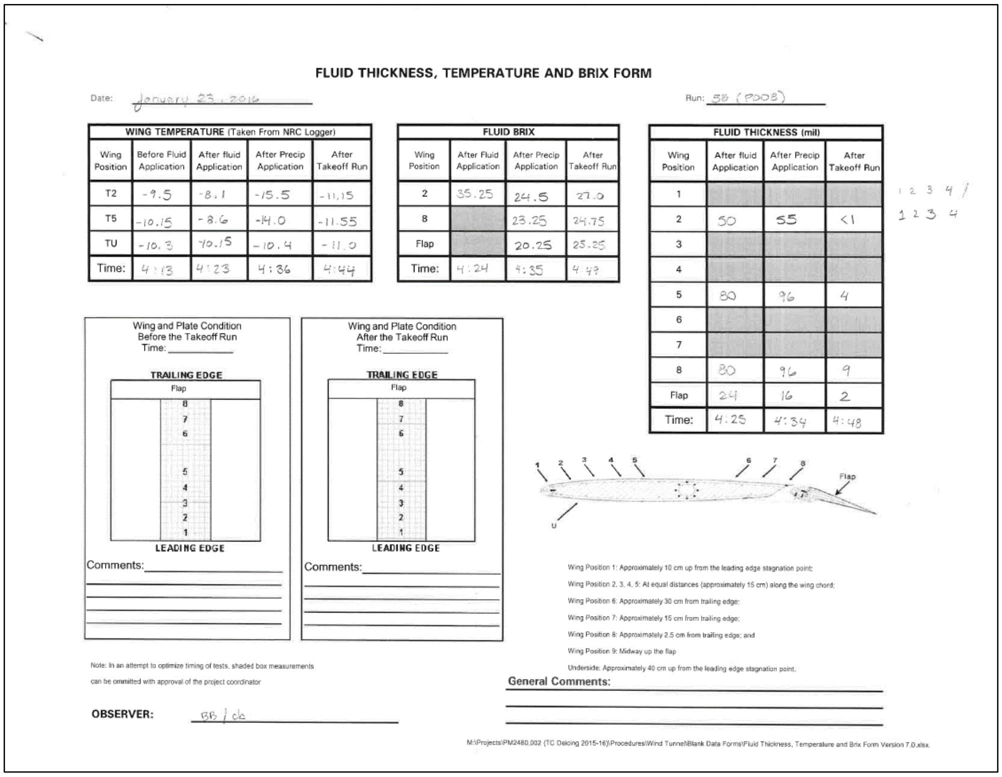
Figure C47: Run # 57



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 23, 2016

Run: 58 (P008)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-9.5	-8.1	-15.5	-11.15
T5	-10.15	-8.6	-14.0	-11.55
TU	-10.3	-10.15	-10.4	-11.0
Time:	4:13	4:23	4:36	4:44

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.25	24.5	27.0
8		23.25	24.75
Flap		20.25	25.25
Time:	4:24	4:35	4:49

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	50	55	<1
3			
4			
5	80	96	4
6			
7			
8	80	96	9
Flap	24	16	2
Time:	4:25	4:34	4:48

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Comments: ___________

Wing and Plate Condition
After 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: BB / cb

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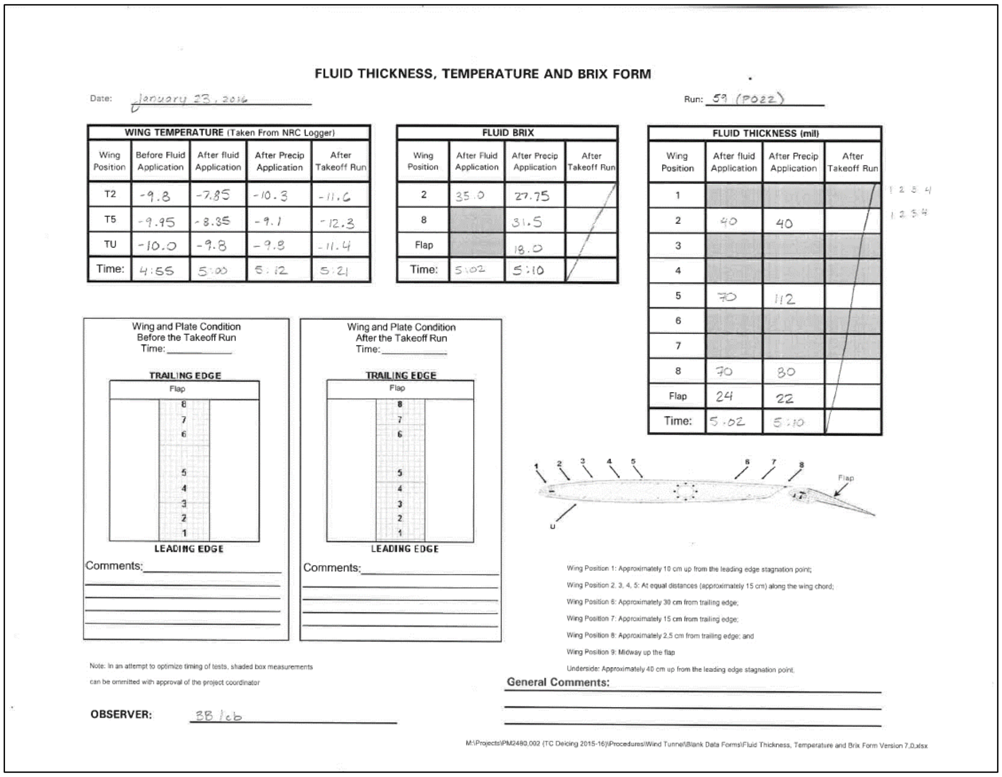
Figure C48: Run # 58



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 23, 2016

Run: 59 (P022)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-9.8	-7.85	-10.3	-11.6
T5	-9.95	-8.35	-9.1	-12.3
TU	-10.0	-9.8	-9.8	-11.4
Time:	4:55	5:00	5:12	5:21

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0	27.75	
8	▨	31.5	
Flap	▨	18.0	
Time:	5:02	5:10	

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40	40	
3	▨	▨	▨
4	▨	▨	▨
5	70	112	
6	▨	▨	▨
7	▨	▨	▨
8	70	80	
Flap	24	22	
Time:	5:02	5:10	

1 2 3 4
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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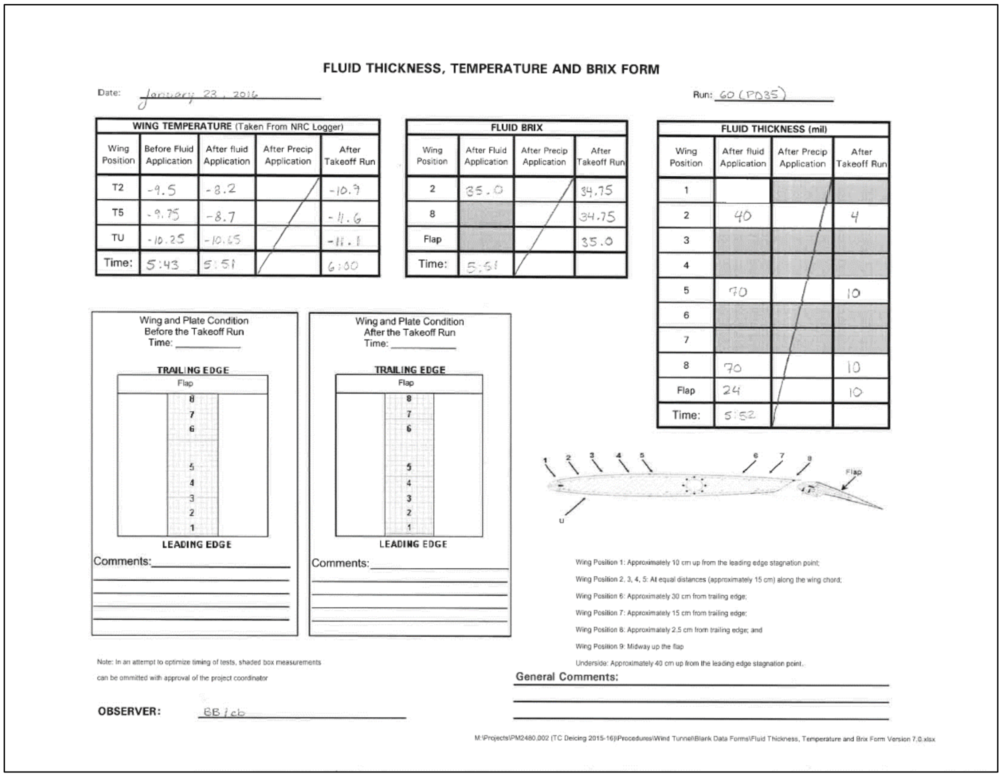
Figure C49: Run # 59



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 23, 2016

Run: 60 (PD35)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-9.5	-8.2		-10.7
T5	-9.75	-8.7		-11.6
TU	-10.25	-10.65		-11.1
Time:	5:43	5:51		6:00

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0		34.75
8	▨		34.75
Flap	▨		35.0
Time:	5:51		

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		▨	▨
2	40		4
3	▨	▨	▨
4	▨	▨	▨
5	70		10
6	▨	▨	▨
7	▨	▨	▨
8	70		10
Flap	24		10
Time:	5:52		

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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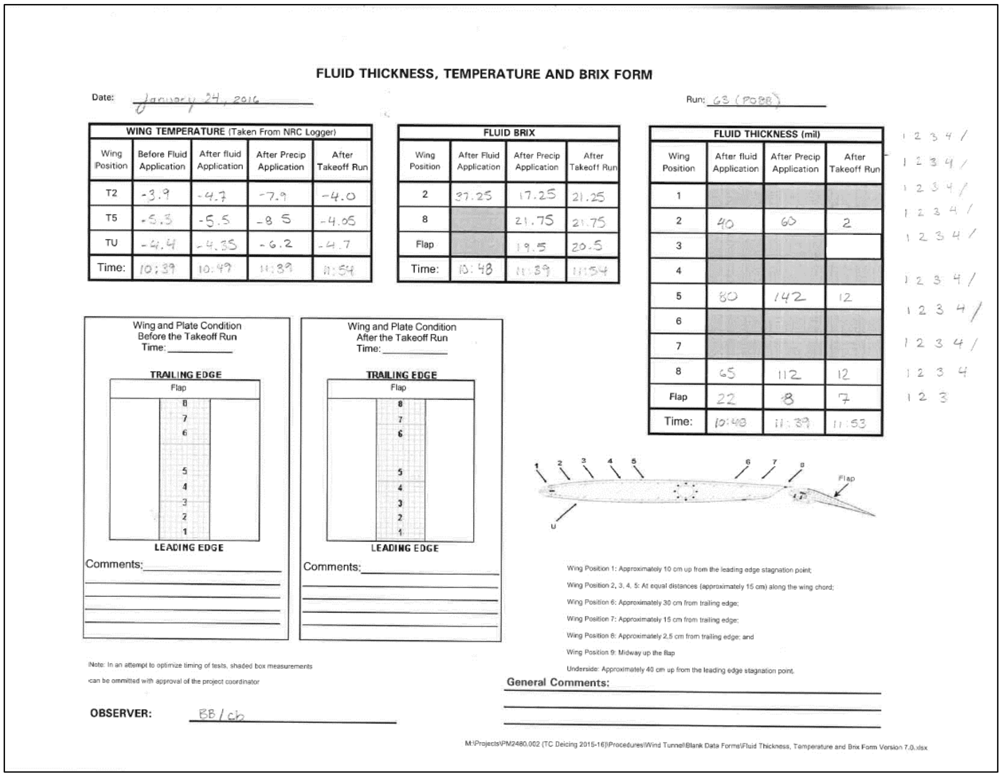
Figure C50: Run # 60

No Data Available

Figure C51: Run # 61 to Run # 62



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 24, 2016

Run: 63 (POBR)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-3.9	-4.7	-7.9	-4.0
T5	-5.3	-5.5	-8 5	-4.05
TU	-4.4	-4.35	-6.2	-4.7
Time:	10:39	10:49	11:39	11:54

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	17.25	21.25
8	▨	21.75	21.75
Flap	▨	19.5	20.5
Time:	10:48	11:39	11:54

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40	60	2
3	▨	▨	
4	▨	▨	▨
5	80	142	12
6	▨	▨	▨
7	▨	▨	▨
8	65	112	12
Flap	22	8	7
Time:	10:48	11:39	11:53

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4
1 2 3

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition
After 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: BB/cb

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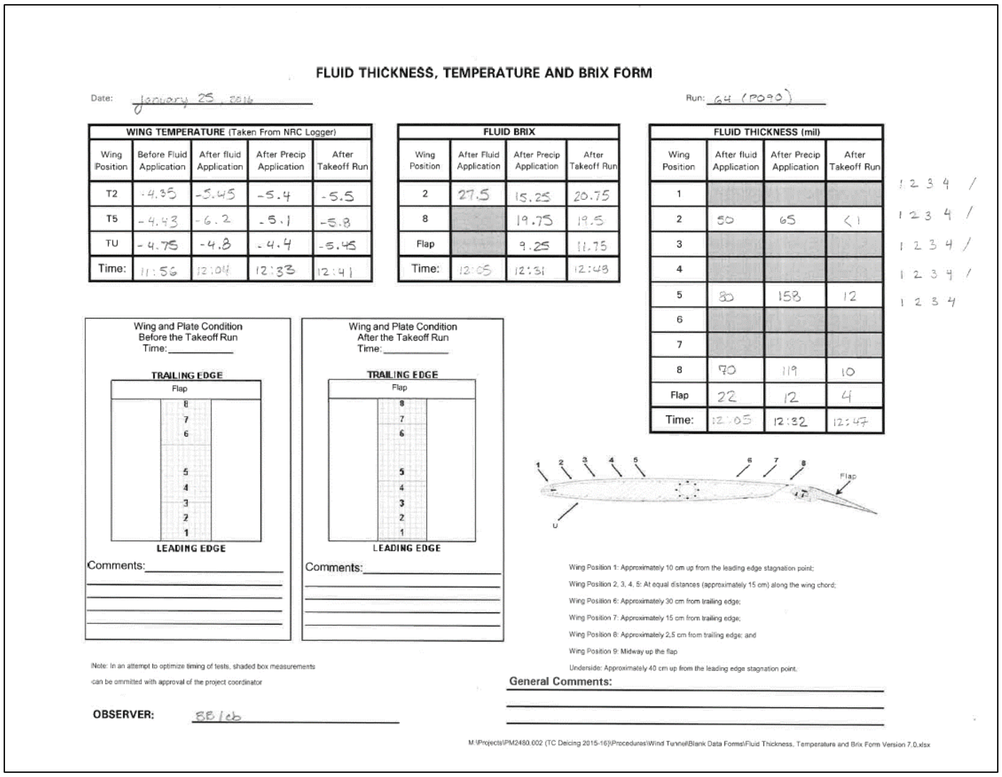
Figure C52: Run # 63



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25, 2016

Run: 64 (P090)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-4.35	-5.45	-5.4	-5.5
T5	-4.43	-6.2	-5.1	-5.8
TU	-4.75	-4.8	-4.4	-5.45
Time:	11:56	12:04	12:33	12:41

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	27.5	15.25	20.75
8		19.75	19.5
Flap		9.25	11.75
Time:	12:05	12:31	12:48

FLUID THICKNESS (mil)				
Wing Position	After fluid Application	After Precip Application	After Takeoff Run	
1				1 2 3 4 /
2	50	65	<1	1 2 3 4 /
3				1 2 3 4 /
4				1 2 3 4 /
5	80	158	12	1 2 3 4
6				
7				
8	70	119	10	
Flap	22	12	4	
Time:	12:05	12:32	12:47	

Wing and Plate Condition
Before the Takeoff Run
Time:__________

Comments:__________

Wing and Plate Condition
After 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 ommited with approval of the project coordinator

General Comments:__________

OBSERVER: BB/cb

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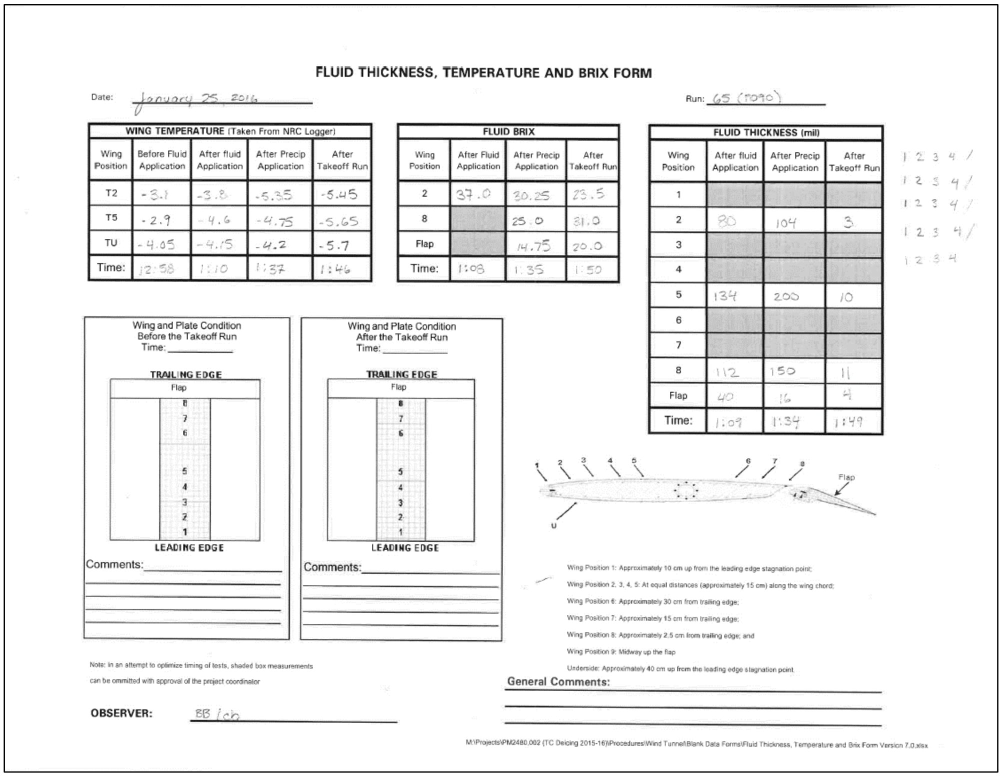
Figure C53: Run # 64



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25, 2016

Run: 65 (T090)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-3.1	-3.8	-5.35	-5.45
T5	-2.9	-4.6	-4.75	-5.65
TU	-4.05	-4.15	-4.2	-5.7
Time:	12:58	1:10	1:37	1:46

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	30.25	23.5
8		25.0	31.0
Flap		14.75	20.0
Time:	1:08	1:35	1:50

FLUID THICKNESS (mil)				
Wing Position	After fluid Application	After Precip Application	After Takeoff Run	
1				1 2 3 4 /
2	80	104	3	1 2 3 4 /
3				1 2 3 4 /
4				1 2 3 4 /
5	134	200	10	1 2 3 4
6				
7				
8	112	150	11	
Flap	40	16	4	
Time:	1:09	1:34	1:49	

Wing and Plate Condition
Before the Takeoff Run
Time:__________

Comments:__________

Wing and Plate Condition
After 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 ommited with approval of the project coordinator

General Comments:__________

OBSERVER: BB/cb

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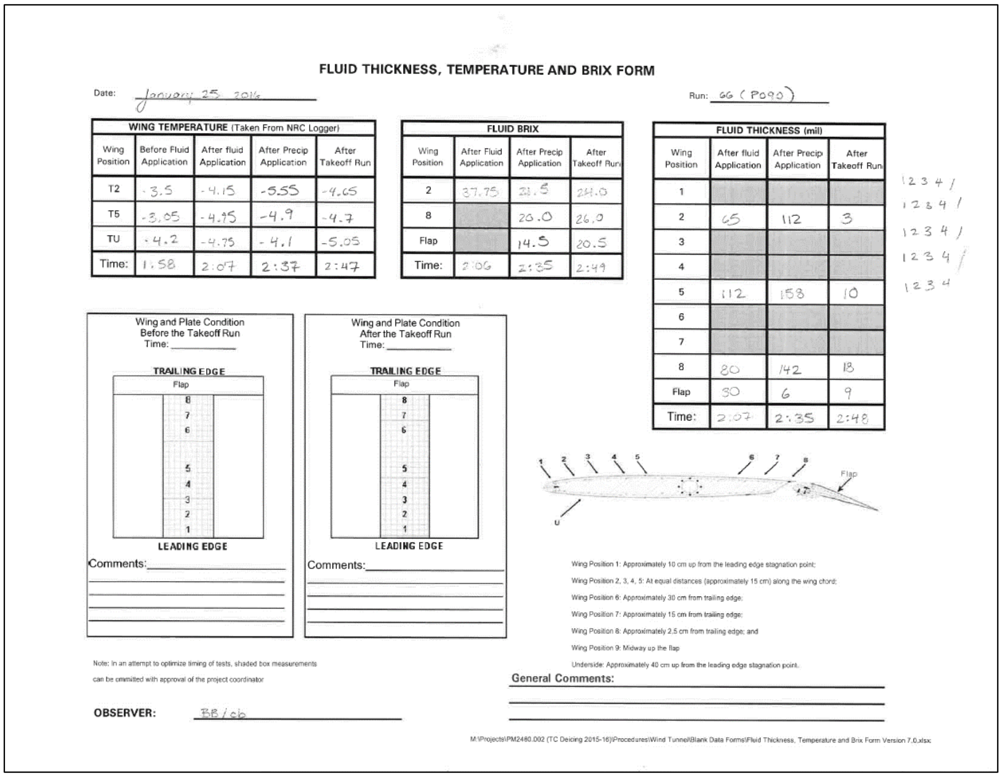
Figure C54: Run # 65



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25 2016

Run: 66 (P090)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-3.5	-4.15	-5.55	-4.65
T5	-3.05	-4.95	-4.9	-4.7
TU	-4.2	-4.75	-4.1	-5.05
Time:	1:58	2:07	2:37	2:47

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.75	21.5	24.0
8	▨	20.0	26.0
Flap	▨	14.5	20.5
Time:	2:06	2:35	2:49

FLUID THICKNESS (mil)				
Wing Position	After fluid Application	After Precip Application	After Takeoff Run	
1	▨	▨	▨	1 2 3 4 /
2	65	112	3	1 2 3 4 /
3	▨	▨	▨	1 2 3 4 /
4	▨	▨	▨	1 2 3 4 /
5	112	158	10	1 2 3 4
6	▨	▨	▨	
7	▨	▨	▨	
8	80	142	18	
Flap	30	6	9	
Time:	2:07	2:35	2:48	

Wing and Plate Condition
Before the Takeoff Run
Time: __________

Comments:

Wing and Plate Condition
After 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: BB / cb

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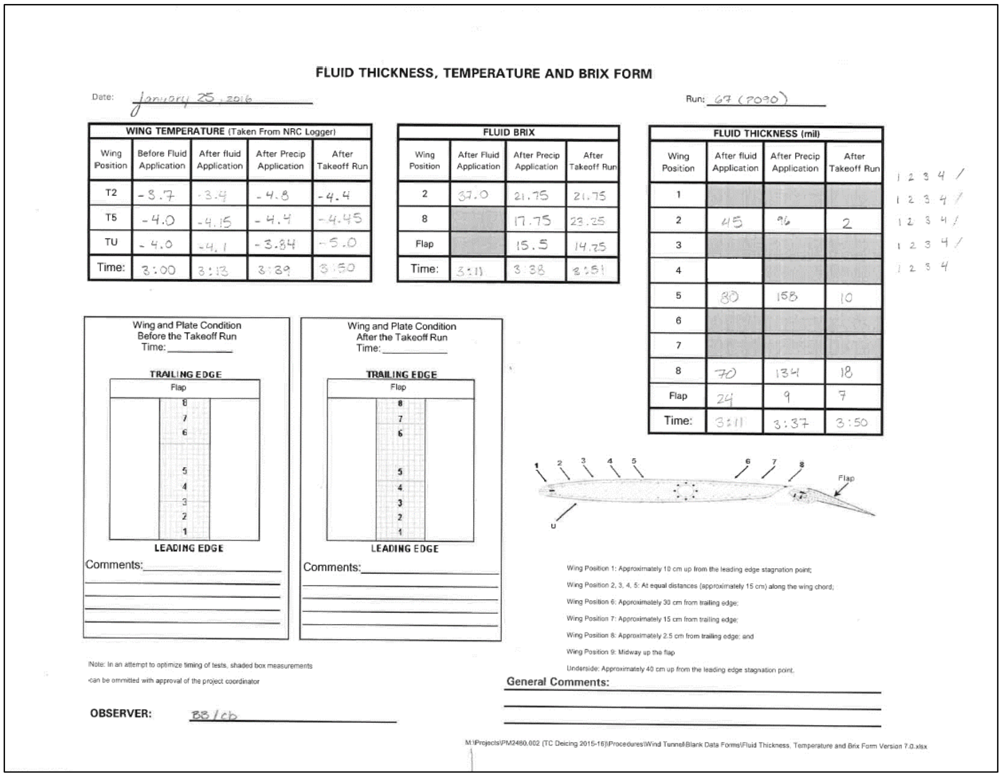
Figure C55: Run # 66



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25, 2016

Run: 67 (P090)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-3.7	-3.4	-4.8	-4.4
T5	-4.0	-4.15	-4.4	-4.45
TU	-4.0	-4.1	-3.84	-5.0
Time:	3:00	3:13	3:39	3:50

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	21.75	21.75
8	▨	17.75	23.25
Flap	▨	15.5	14.75
Time:	3:11	3:38	3:51

FLUID THICKNESS (mil)				
Wing Position	After fluid Application	After Precip Application	After Takeoff Run	
1	▨	▨	▨	1 2 3 4 /
2	45	96	2	1 2 3 4 /
3	▨	▨	▨	1 2 3 4 /
4		▨	▨	1 2 3 4 /
5	80	158	10	1 2 3 4
6	▨	▨	▨	
7	▨	▨	▨	
8	70	134	18	
Flap	24	9	7	
Time:	3:11	3:37	3:50	

Wing and Plate Condition
Before the Takeoff Run
Time: __________

Comments:

Wing and Plate Condition
After 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: BB / cb

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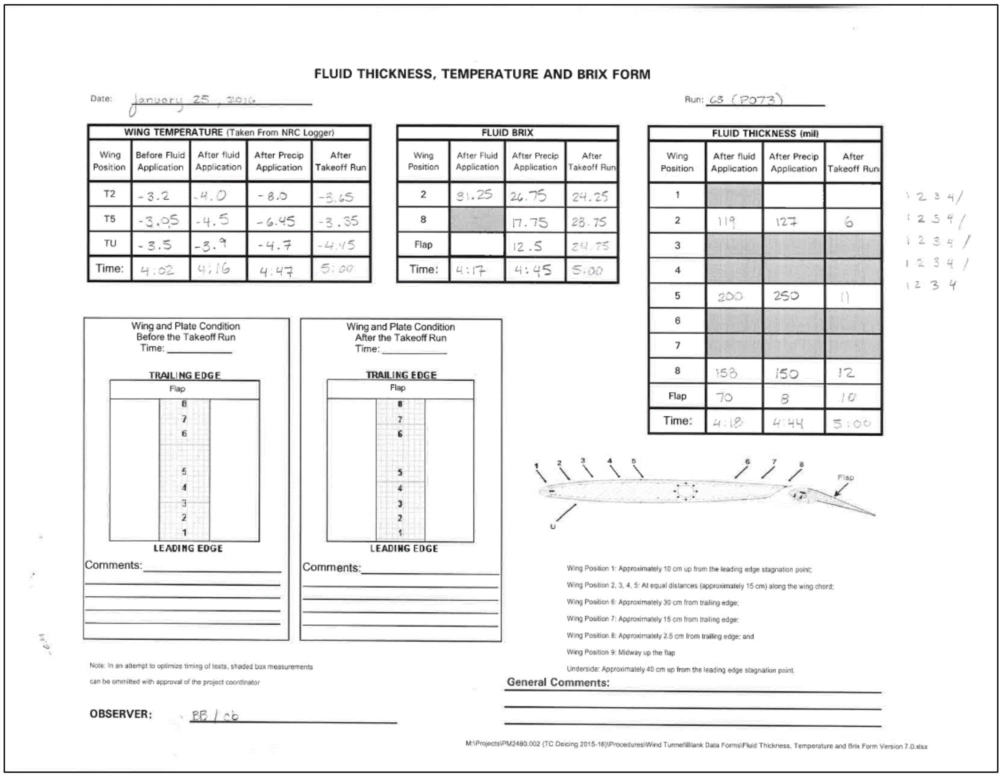
Figure C56: Run # 67



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25, 2016

Run: 68 (P073)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-3.2	-4.0	-8.0	-3.65
T5	-3.05	-4.5	-6.45	-3.35
TU	-3.5	-3.9	-4.7	-4.45
Time:	4:02	4:16	4:47	5:00

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	31.25	26.75	24.25
8		17.75	23.75
Flap		12.5	24.75
Time:	4:17	4:45	5:00

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	119	127	6
3			
4			
5	200	250	11
6			
7			
8	158	150	12
Flap	70	8	10
Time:	4:18	4:44	5:00

1 2 3 4/
1 2 3 4/
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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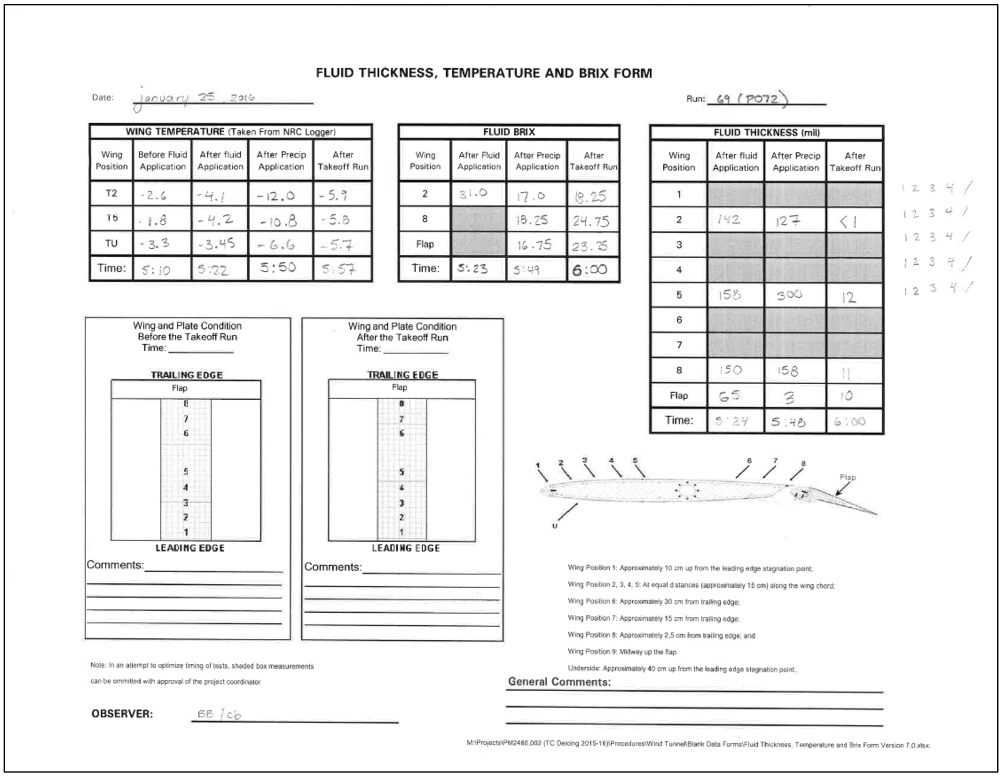
Figure C57: Run # 68



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25, 2016

Run: 69 (P072)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-2.6	-4.1	-12.0	-5.9
T5	-1.8	-4.2	-10.8	-5.8
TU	-3.3	-3.45	-6.6	-5.7
Time:	5:10	5:22	5:50	5:57

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	31.0	17.0	18.25
8		18.25	24.75
Flap		16.75	23.75
Time:	5:23	5:49	6:00

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	142	127	<1
3			
4			
5	158	300	12
6			
7			
8	150	158	11
Flap	65	3	10
Time:	5:24	5:48	6:00

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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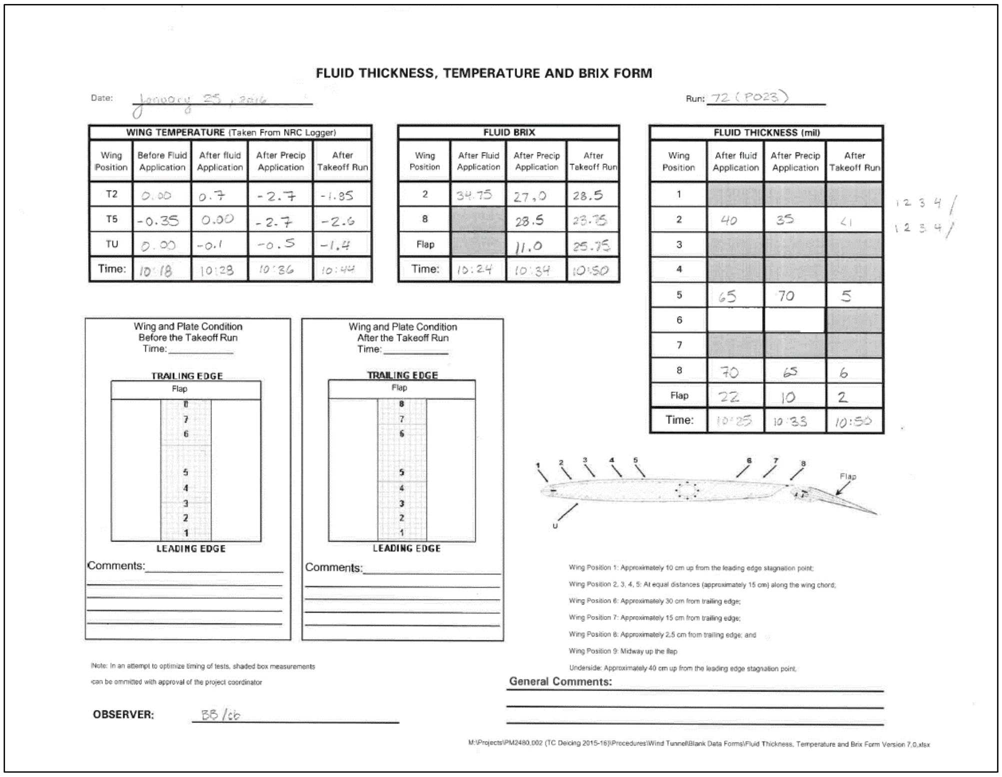
Figure C58: Run # 69

No Data Available

Figure C59: Run # 70 to Run #71



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25, 2016

Run: 72 (P023)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	0.00	0.7	-2.7	-1.85
T5	-0.35	0.00	-2.7	-2.6
TU	0.00	-0.1	-0.5	-1.4
Time:	10:18	10:28	10:36	10:44

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.75	27.0	28.5
8	▨	28.5	23.75
Flap	▨	11.0	25.75
Time:	10:24	10:34	10:50

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40	35	<1
3	▨	▨	▨
4	▨	▨	▨
5	65	70	5
6			▨
7	▨	▨	▨
8	70	65	6
Flap	22	10	2
Time:	10:25	10:33	10:50

1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time:__________

TRAILING EDGE

LEADING EDGE

Comments:__________

Wing and Plate Condition
After the Takeoff Run
Time:__________

TRAILING EDGE

LEADING EDGE

Comments:__________

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

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

General Comments:__________

OBSERVER: BB/cb

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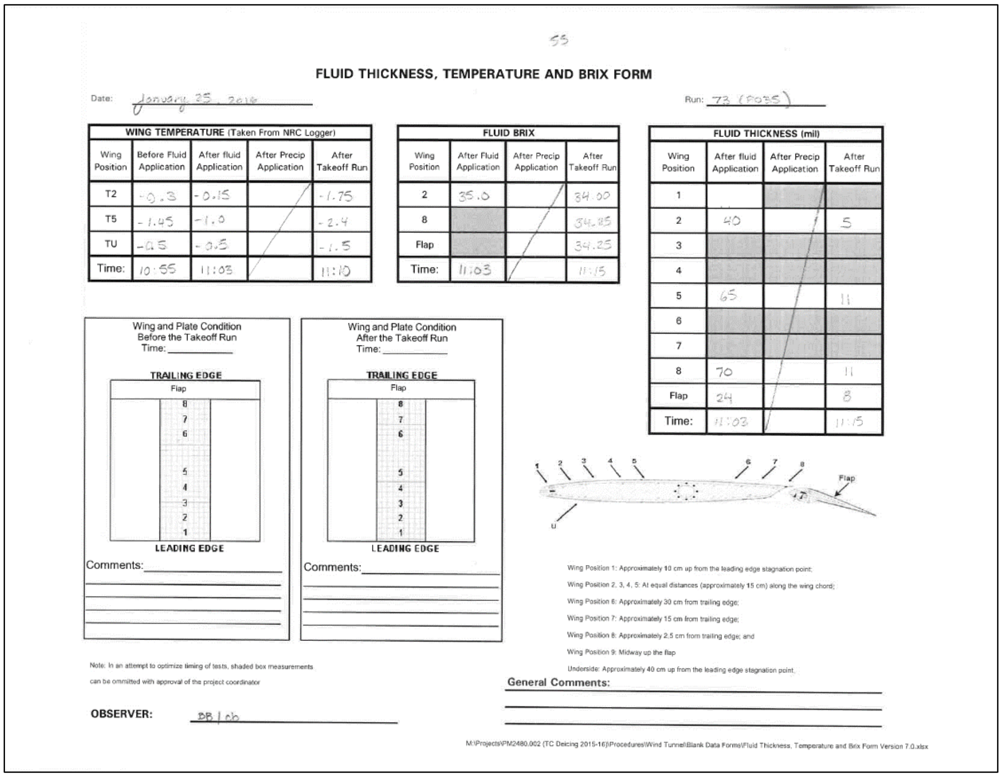
Figure C60: Run # 72



55

FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25, 2016

Run: 73 (P035)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-0.3	-0.15		-1.75
T5	-1.45	-1.0		-2.4
TU	-0.5	-0.5		-1.5
Time:	10:55	11:03		11:10

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0		34.00
8			34.85
Flap			34.25
Time:	11:03		11:15

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40		5
3			
4			
5	65		11
6			
7			
8	70		11
Flap	24		8
Time:	11:03		11:15

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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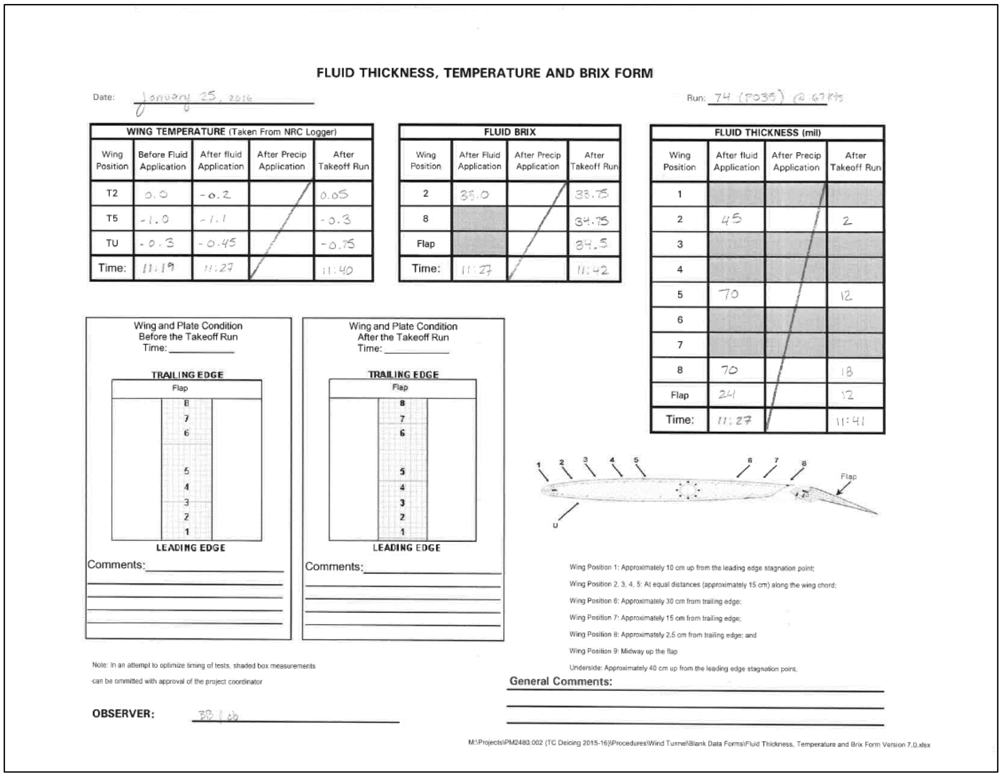
Figure C61: Run # 73



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25, 2016

Run: 74 (P035) @ 67Kts

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	0.0	-0.2		0.05
T5	-1.0	-1.1		-0.3
TU	-0.3	-0.45		-0.75
Time:	11:19	11:27		11:40

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0		33.75
8			34.75
Flap			34.5
Time:	11:27		11:42

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	45		2
3			
4			
5	70		12
6			
7			
8	70		18
Flap	24		12
Time:	11:27		11:41

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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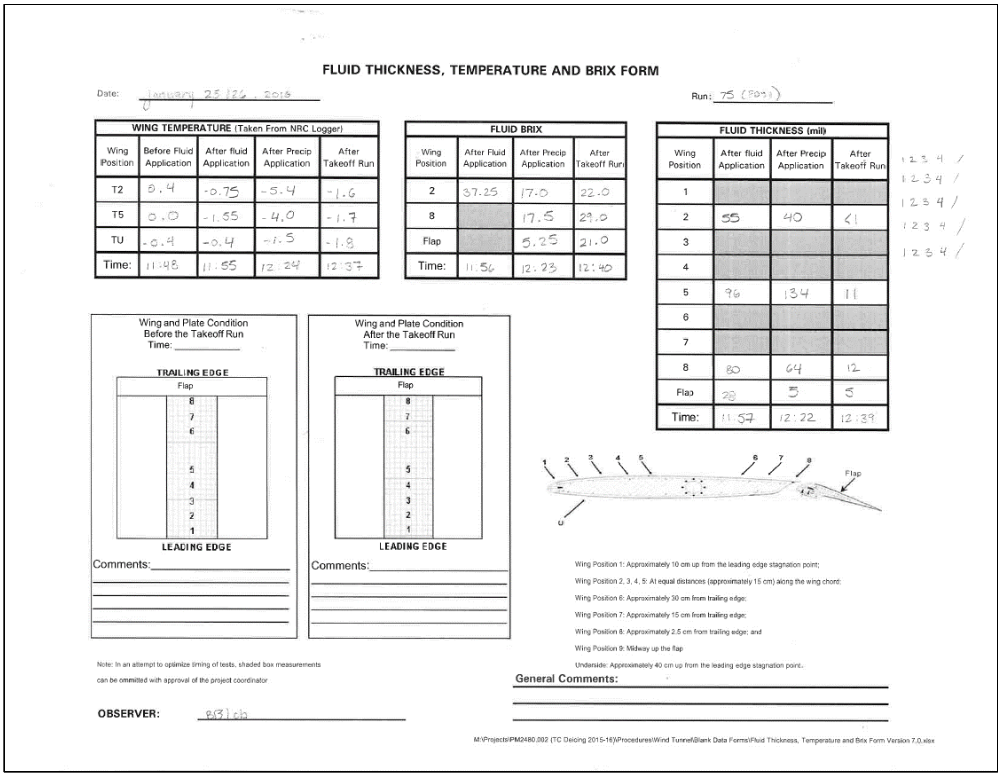
Figure C62: Run # 74



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 25/26, 2016

Run: 75 (P073)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	0.4	-0.75	-5.4	-1.6
T5	0.0	-1.55	-4.0	-1.7
TU	-0.4	-0.4	-1.5	-1.8
Time:	11:48	11:55	12:24	12:37

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.25	17.0	22.0
8	▨	17.5	29.0
Flap	▨	5.25	21.0
Time:	11:56	12:23	12:40

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	55	40	<1
3	▨	▨	▨
4	▨	▨	▨
5	96	134	11
6	▨	▨	▨
7	▨	▨	▨
8	80	64	12
Flap	28	5	5
Time:	11:57	12:22	12:39

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Wing and Plate Condition
After the Takeoff Run
Time: ___________

Comments:___________

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: BB / cb

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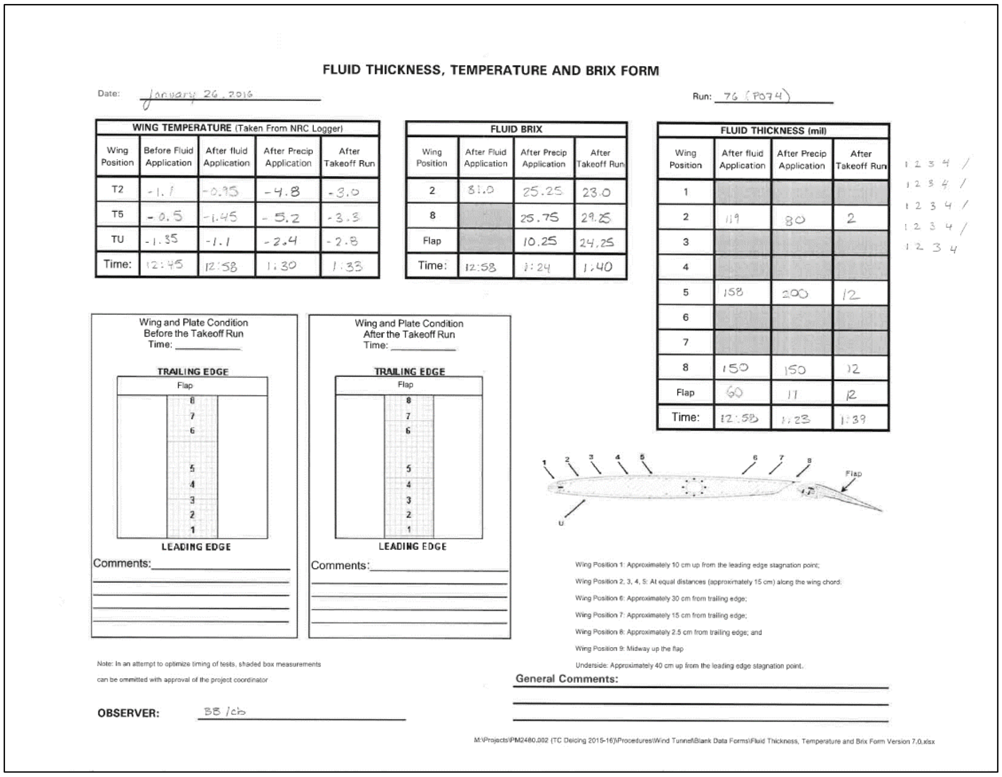
Figure C63: Run # 75



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 26, 2016

Run: 76 (P074)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-1.1	-0.95	-4.8	-3.0
T5	-0.5	-1.45	-5.2	-3.3
TU	-1.35	-1.1	-2.4	-2.8
Time:	12:45	12:58	1:30	1:33

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	31.0	25.25	23.0
8	▨	25.75	29.25
Flap	▨	10.25	24.25
Time:	12:58	1:24	1:40

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	119	80	2
3	▨	▨	▨
4	▨	▨	▨
5	158	200	12
6	▨	▨	▨
7	▨	▨	▨
8	150	150	12
Flap	60	11	12
Time:	12:58	1:23	1:39

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Wing and Plate Condition
After the Takeoff Run
Time: ___________

Comments:___________

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: BB /cb

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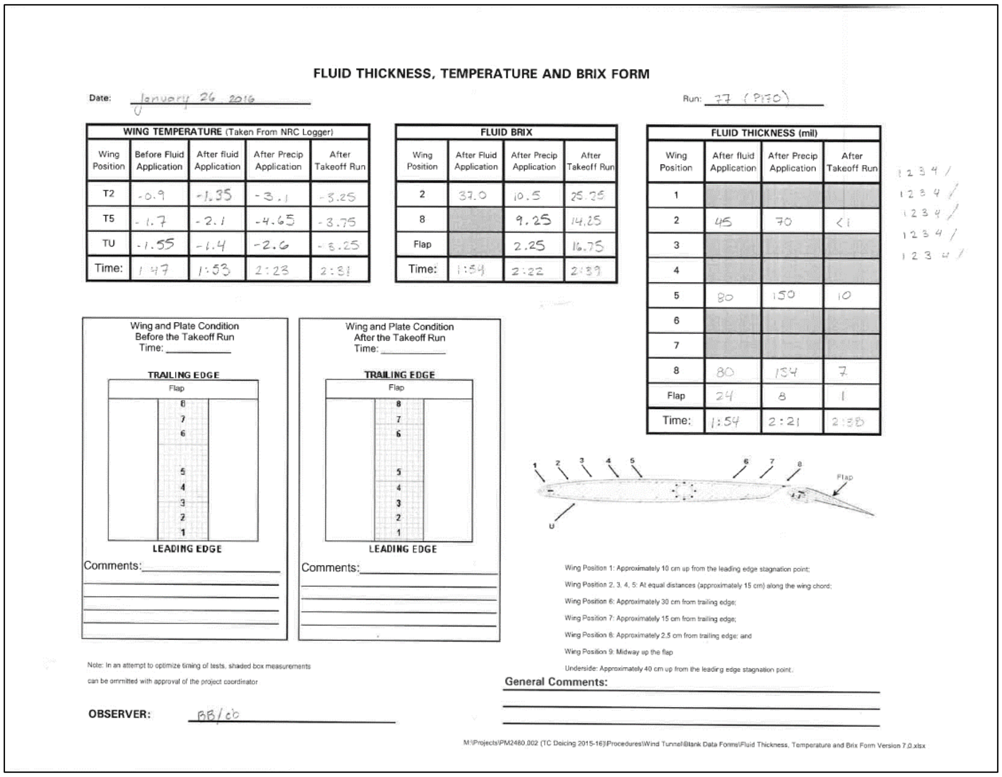
Figure C64: Run # 76



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 26 2016

Run: 77 (P170)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-0.9	-1.35	-3.1	-3.25
T5	-1.7	-2.1	-4.65	-3.75
TU	-1.55	-1.4	-2.6	-3.25
Time:	1:47	1:53	2:23	2:31

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	10.5	25.25
8	▨	9.25	14.25
Flap	▨	2.25	16.75
Time:	1:54	2:22	2:39

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	45	70	<1
3	▨	▨	▨
4	▨	▨	▨
5	80	150	10
6	▨	▨	▨
7	▨	▨	▨
8	80	134	7
Flap	24	8	1
Time:	1:54	2:21	2:38

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments: ___________

Wing and Plate Condition
After 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: BB/cb

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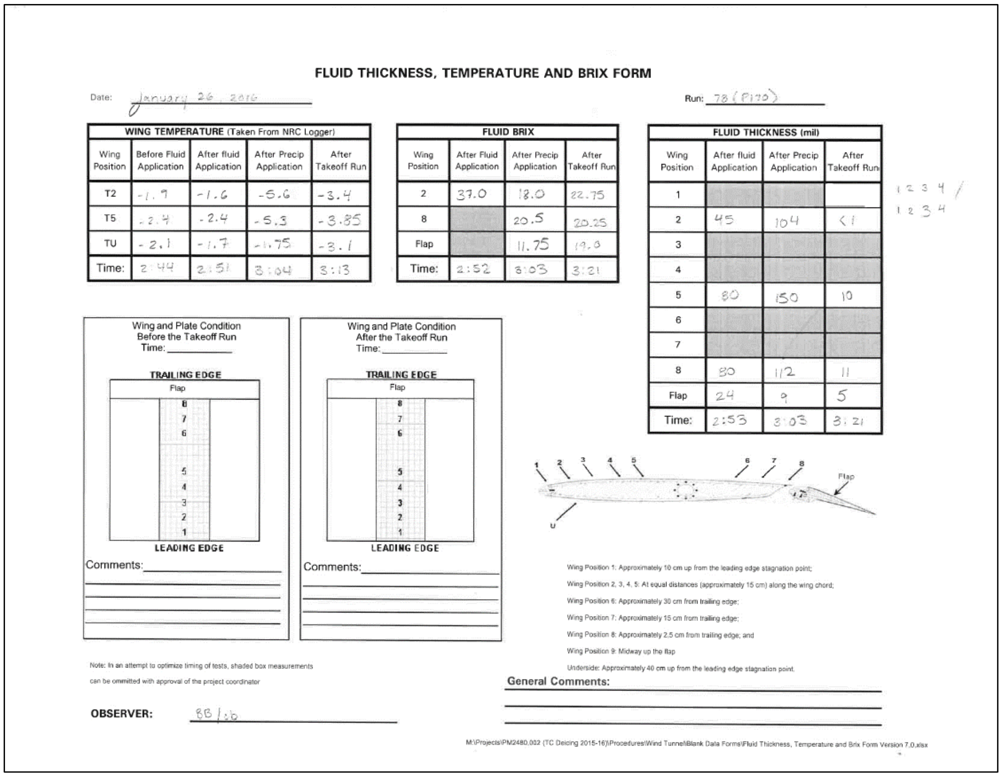
Figure C65: Run # 77



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 26, 2016

Run: 78 (P170)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-1.9	-1.6	-5.6	-3.4
T5	-2.4	-2.4	-5.3	-3.85
TU	-2.1	-1.7	-1.75	-3.1
Time:	2:44	2:51	3:04	3:13

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	18.0	22.75
8	▨	20.5	20.25
Flap	▨	11.75	19.0
Time:	2:52	3:03	3:21

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	
2	45	104	<1
3	▨	▨	▨
4	▨	▨	▨
5	80	150	10
6	▨	▨	▨
7	▨	▨	▨
8	80	112	11
Flap	24	9	5
Time:	2:53	3:03	3:21

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments: ___________

Wing and Plate Condition
After 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: BB/cb

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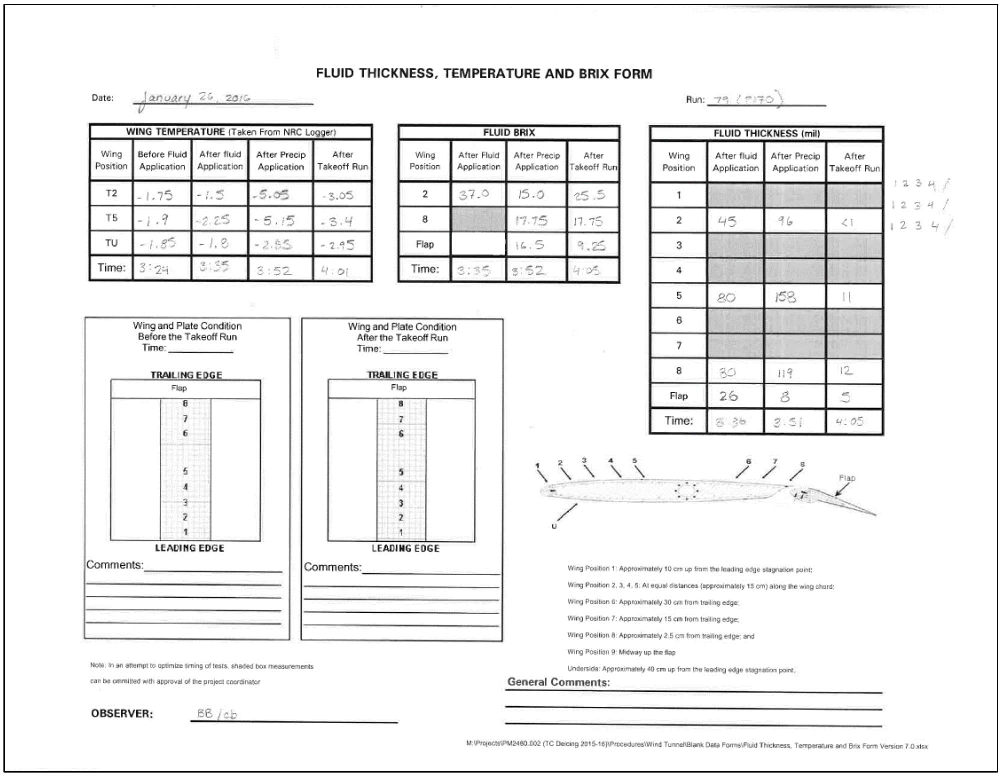
Figure C66: Run # 78



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 26, 2016

Run: 79 (P170)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-1.75	-1.5	-5.05	-3.05
T5	-1.9	-2.25	-5.15	-3.4
TU	-1.85	-1.8	-2.85	-2.95
Time:	3:24	3:35	3:52	4:01

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	15.0	25.5
8		17.75	17.75
Flap		16.5	9.25
Time:	3:35	3:52	4:05

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	45	96	<1
3			
4			
5	80	158	11
6			
7			
8	80	119	12
Flap	26	8	5
Time:	3:36	3:51	4:05

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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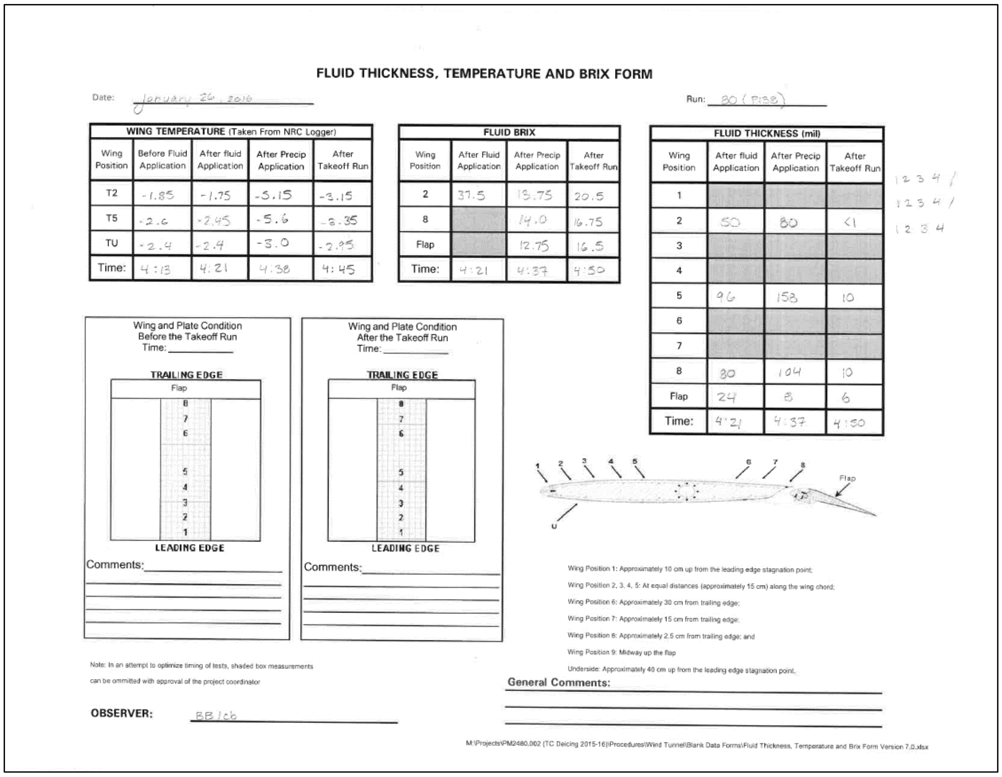
Figure C67: Run # 79



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 26, 2016

Run: 80 (P138)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-1.85	-1.75	-5.15	-3.15
T5	-2.6	-2.45	-5.6	-3.35
TU	-2.4	-2.4	-3.0	-2.95
Time:	4:13	4:21	4:38	4:45

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.5	13.75	20.5
8		14.0	16.75
Flap		12.75	16.5
Time:	4:21	4:37	4:50

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	50	80	<1
3			
4			
5	96	158	10
6			
7			
8	80	104	10
Flap	24	8	6
Time:	4:21	4:37	4:50

1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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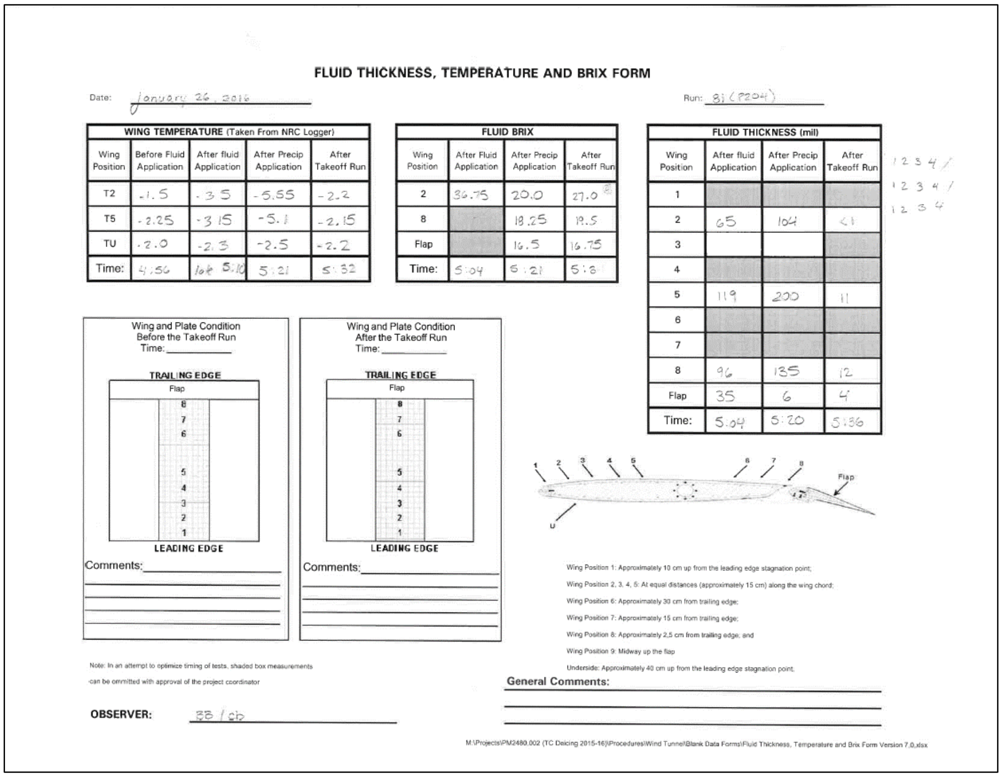
Figure C68: Run # 80



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 26, 2016

Run: 81 (P204)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-1.5	-3.5	-5.55	-2.2
T5	-2.25	-3.15	-5.1	-2.15
TU	-2.0	-2.3	-2.5	-2.2
Time:	4:56	104 5:10	5:21	5:32

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	36.75	20.0	27.0
8	▨	18.25	19.5
Flap	▨	16.5	16.75
Time:	5:04	5:21	5:3

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	65	104	<1
3			▨
4	▨	▨	▨
5	119	200	11
6	▨	▨	▨
7	▨	▨	▨
8	96	135	12
Flap	35	6	4
Time:	5:04	5:20	5:36

1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

TRAILING EDGE

Flap

LEADING EDGE

Comments:

Wing and Plate Condition
After the Takeoff Run
Time: ____________

TRAILING EDGE

Flap

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: BB / cb

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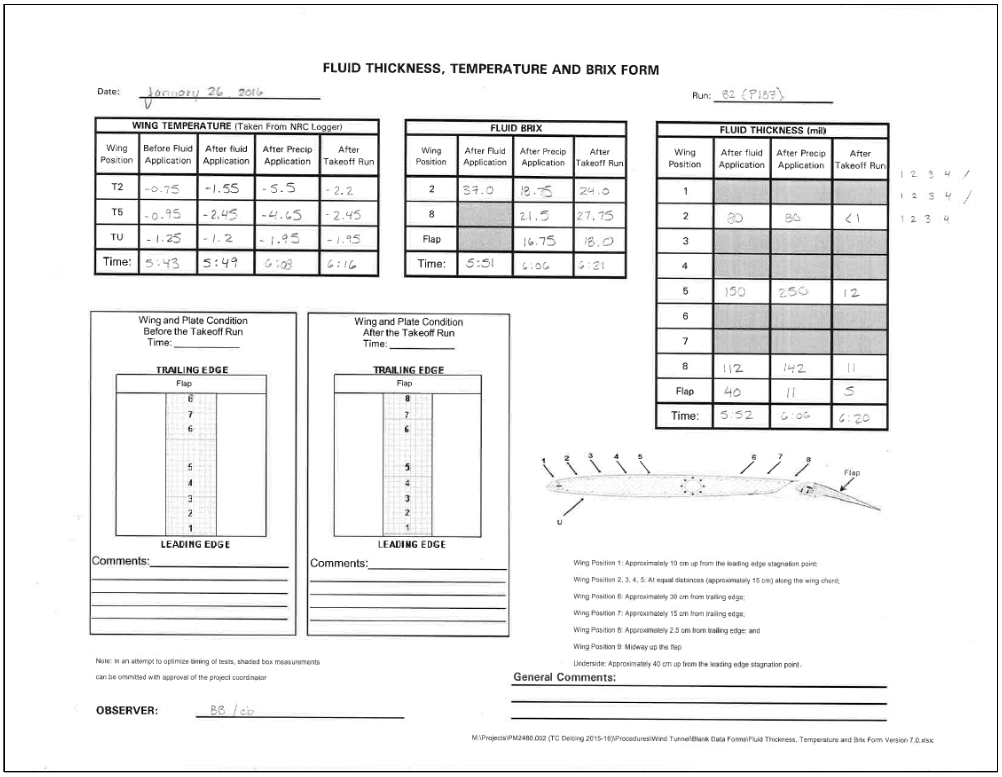
Figure C69: Run # 81



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 26, 2016

Run: 82 (P187)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-0.75	-1.55	-5.5	-2.2
T5	-0.95	-2.45	-4.65	-2.45
TU	-1.25	-1.2	-1.95	-1.95
Time:	5:43	5:49	6:08	6:16

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.0	18.75	24.0
8	▨	21.5	27.75
Flap	▨	16.75	18.0
Time:	5:51	6:06	6:21

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	80	80	<1
3	▨	▨	▨
4	▨	▨	▨
5	150	250	12
6	▨	▨	▨
7	▨	▨	▨
8	112	142	11
Flap	40	11	5
Time:	5:52	6:06	6:20

1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

TRAILING EDGE

Flap

LEADING EDGE

Comments:

Wing and Plate Condition
After the Takeoff Run
Time: ____________

TRAILING EDGE

Flap

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: BB / cb

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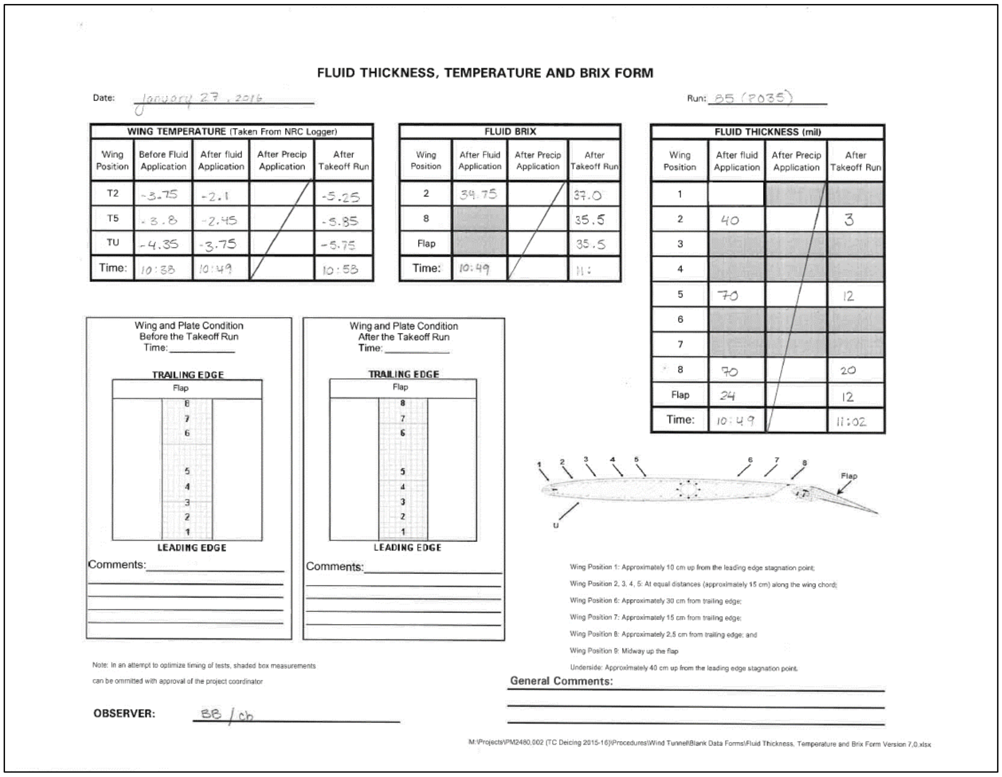
Figure C70: Run # 82

No Data Available

Figure C71: Run # 83 to Run #84



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 27, 2016

Run: 85 (P035)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-3.75	-2.1		-5.25
T5	-3.8	-2.45		-5.85
TU	-4.35	-3.75		-5.75
Time:	10:38	10:49		10:58

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.75		37.0
8	▨		35.5
Flap	▨		35.5
Time:	10:49		11:

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		▨	▨
2	40		3
3	▨	▨	▨
4	▨	▨	▨
5	70		12
6	▨	▨	▨
7	▨	▨	▨
8	70		20
Flap	24		12
Time:	10:49		11:02

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

Comments: ____________

Wing and Plate Condition
After 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: BB / cb

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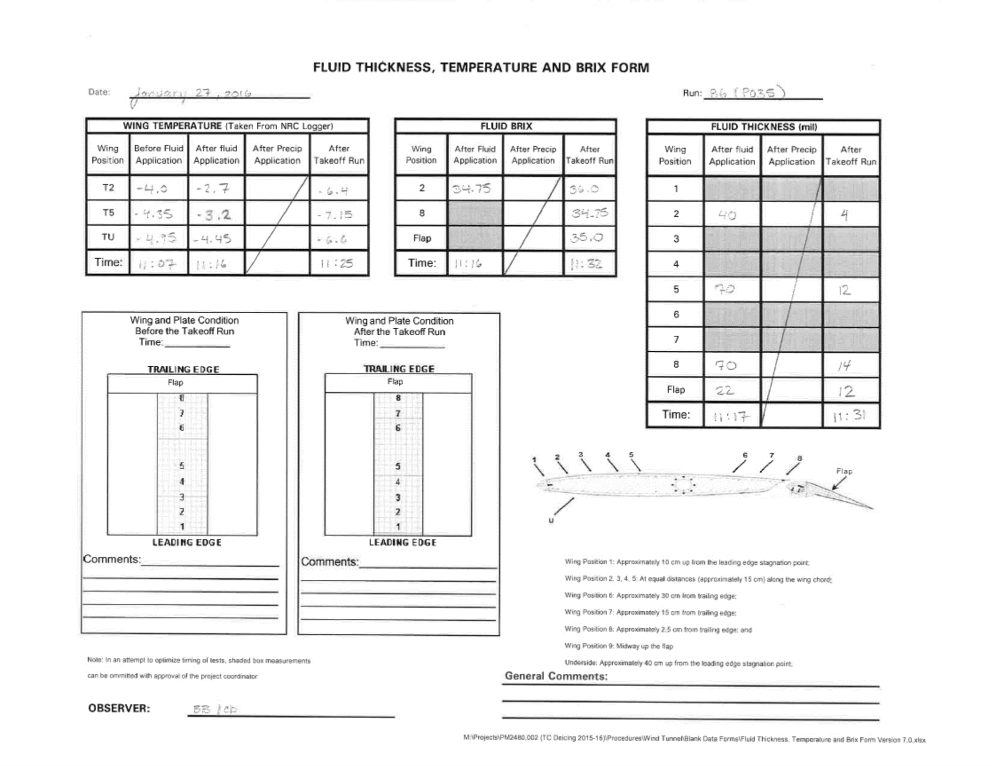
Figure C72: Run # 85



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 27, 2016

Run: 86 (P035)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-4.0	-2.7		-6.4
T5	-4.35	-3.2		-7.15
TU	-4.95	-4.45		-6.6
Time:	11:07	11:16		11:25

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.75		36.0
8	▨		34.75
Flap	▨		35.0
Time:	11:16		11:32

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40		4
3	▨	▨	▨
4	▨	▨	▨
5	70		12
6	▨	▨	▨
7	▨	▨	▨
8	70		14
Flap	22		12
Time:	11:17		11:31

Wing and Plate Condition
Before the Takeoff Run
Time: __________

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

Wing and Plate Condition
After 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: BB / cp

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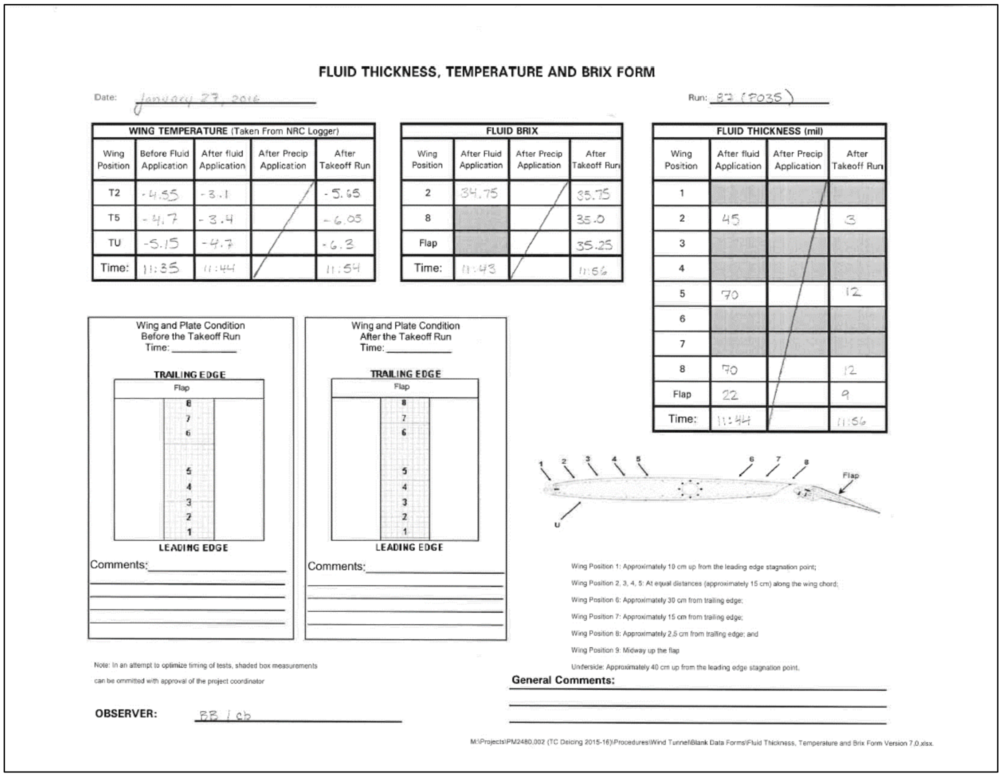
Figure C73: Run # 86



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 27, 2016

Run: 87 (P035)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-4.55	-3.1		-5.65
T5	-4.7	-3.4		-6.05
TU	-5.15	-4.7		-6.3
Time:	11:35	11:44		11:54

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.75		35.75
8	▨		35.0
Flap	▨		35.25
Time:	11:43		11:56

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	45		3
3	▨	▨	▨
4	▨	▨	▨
5	70		12
6	▨	▨	▨
7	▨	▨	▨
8	70		12
Flap	22		9
Time:	11:44		11:56

Wing and Plate Condition
Before the Takeoff Run
Time: __________

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

Wing and Plate Condition
After 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: BB / cb

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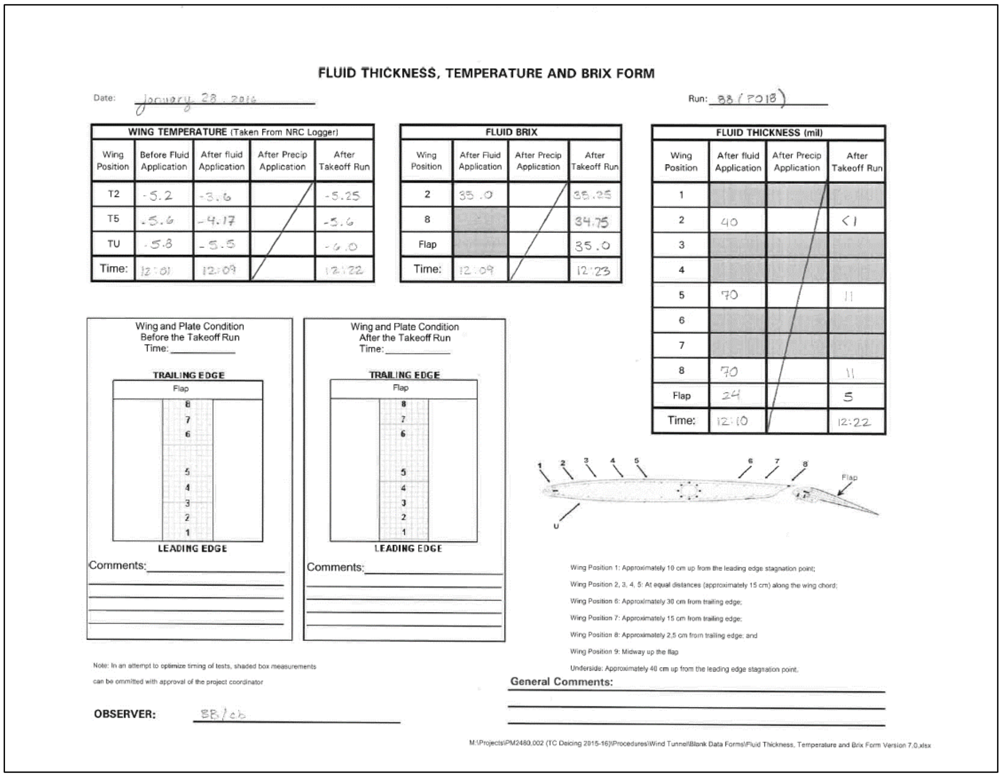
Figure C74: Run # 87



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 88 (P018)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.2	-3.6		-5.25
T5	-5.6	-4.17		-5.6
TU	-5.8	-5.5		-6.0
Time:	12:01	12:09		12:22

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0		35.25
8	▨		34.75
Flap	▨		35.0
Time:	12:09		12:23

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40		<1
3	▨	▨	▨
4	▨	▨	▨
5	70		11
6	▨	▨	▨
7	▨	▨	▨
8	70		11
Flap	24		5
Time:	12:10		12:22

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Comments: ___________

Wing and Plate Condition
After 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: BB/cb

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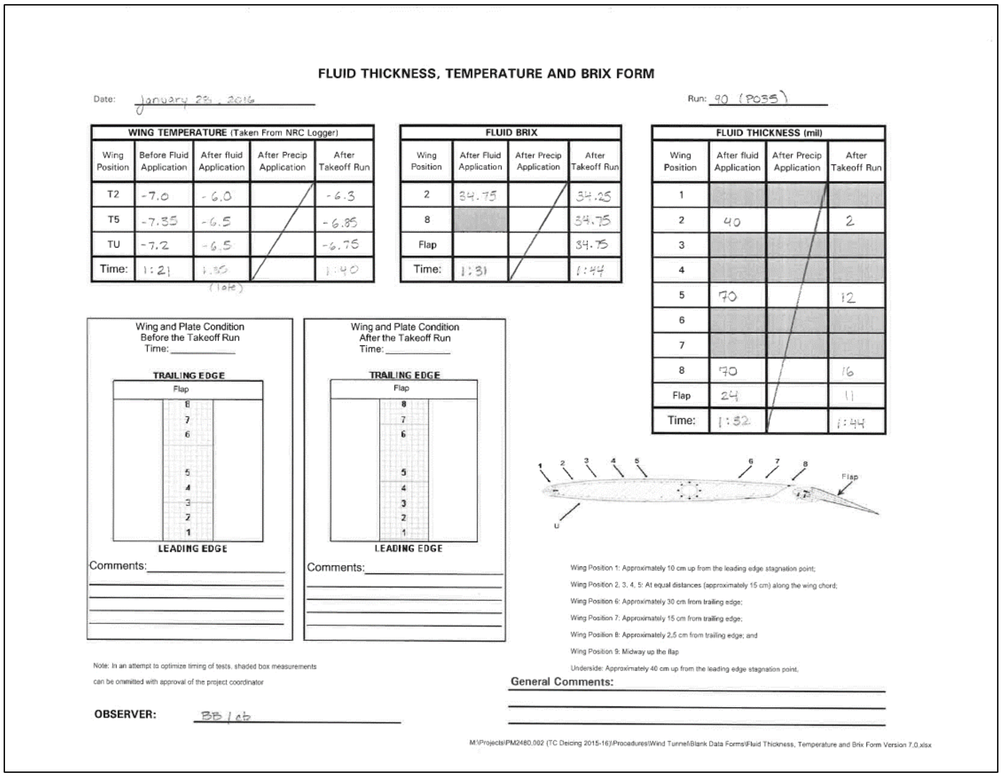
Figure C75: Run # 88

No Data Available

Figure C76: Run # 89



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 90 (P035)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-7.0	-6.0		-6.3
T5	-7.35	-6.5		-6.85
TU	-7.2	-6.5		-6.75
Time:	1:21	1:35 (late)		1:40

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.75		34.25
8	▨		34.75
Flap			34.75
Time:	1:31		1:44

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40		2
3	▨	▨	▨
4	▨	▨	▨
5	70		12
6	▨	▨	▨
7	▨	▨	▨
8	70		16
Flap	24		11
Time:	1:52		1:44

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

TRAILING EDGE

LEADING EDGE

Comments:

Wing and Plate Condition
After the Takeoff Run
Time: ____________

TRAILING EDGE

LEADING EDGE

Comments:

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

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

General Comments:

OBSERVER: BB / cb

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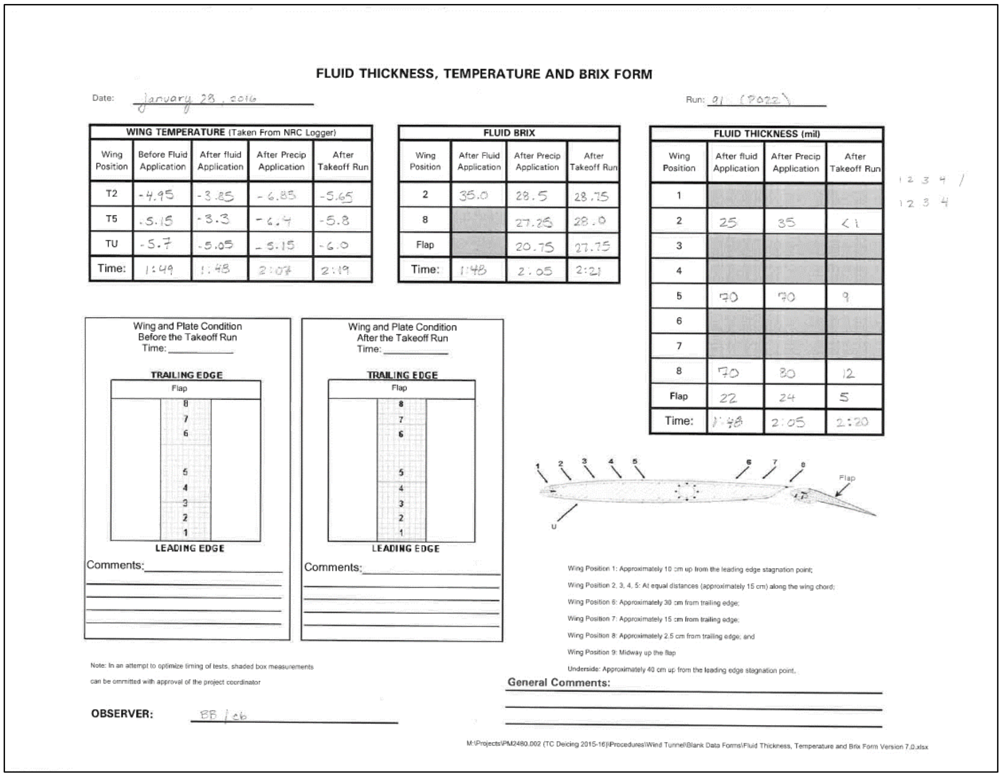
Figure C77: Run # 90



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 91 (P022)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-4.95	-3.85	-6.85	-5.65
T5	-5.15	-3.3	-6.4	-5.8
TU	-5.7	-5.05	-5.15	-6.0
Time:	1:49	1:48	2:07	2:19

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	35.0	28.5	28.75
8	▨	27.25	28.0
Flap	▨	20.75	27.75
Time:	1:48	2:05	2:21

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	25	35	<1
3	▨	▨	▨
4	▨	▨	▨
5	70	70	9
6	▨	▨	▨
7	▨	▨	▨
8	70	80	12
Flap	22	24	5
Time:	1:48	2:05	2:20

1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

TRAILING EDGE

LEADING EDGE

Comments:

Wing and Plate Condition
After the Takeoff Run
Time: ____________

TRAILING EDGE

LEADING EDGE

Comments:

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

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

General Comments:

OBSERVER: BB / cb

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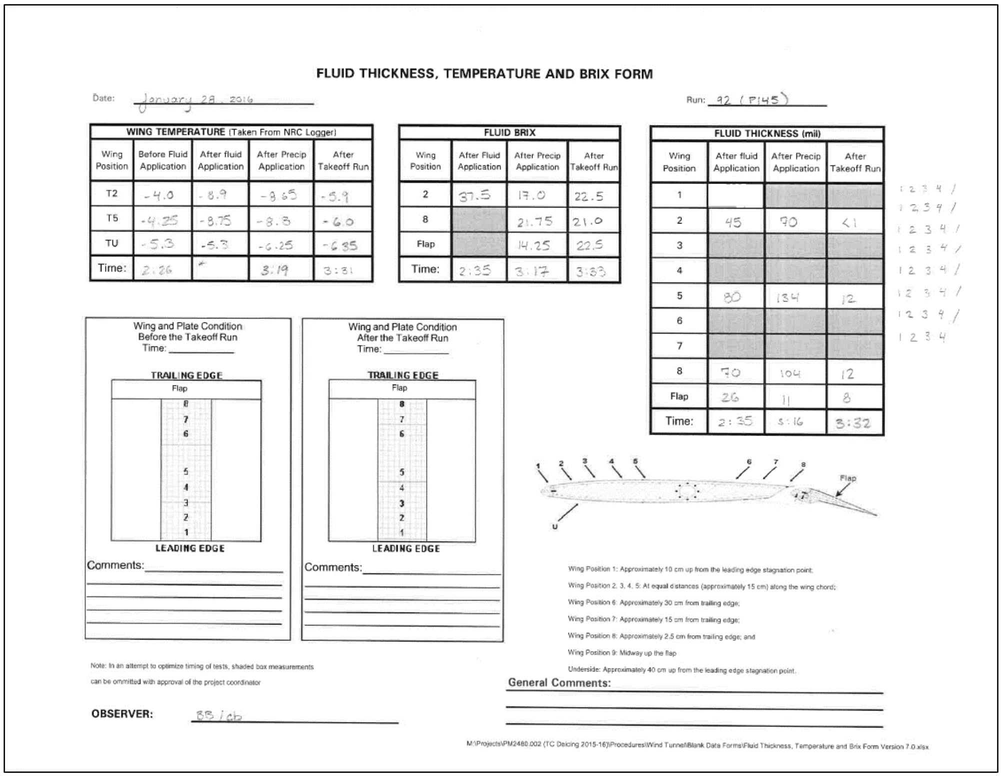
Figure C78: Run # 91



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 92 (P145)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-4.0	-8.9	-8.65	-5.9
T5	-4.25	-8.75	-8.3	-6.0
TU	-5.3	-5.3	-6.25	-6.35
Time:	2:26	*	3:19	3:31

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.5	17.0	22.5
8	▨	21.75	21.0
Flap	▨	14.25	22.5
Time:	2:35	3:17	3:33

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		▨	▨
2	45	70	<1
3	▨	▨	▨
4	▨	▨	▨
5	80	134	12
6	▨	▨	▨
7	▨	▨	▨
8	70	104	12
Flap	26	11	8
Time:	2:35	3:16	3:32

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Wing and Plate Condition
After the Takeoff Run
Time: ___________

Comments: ___________

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: BB / cb

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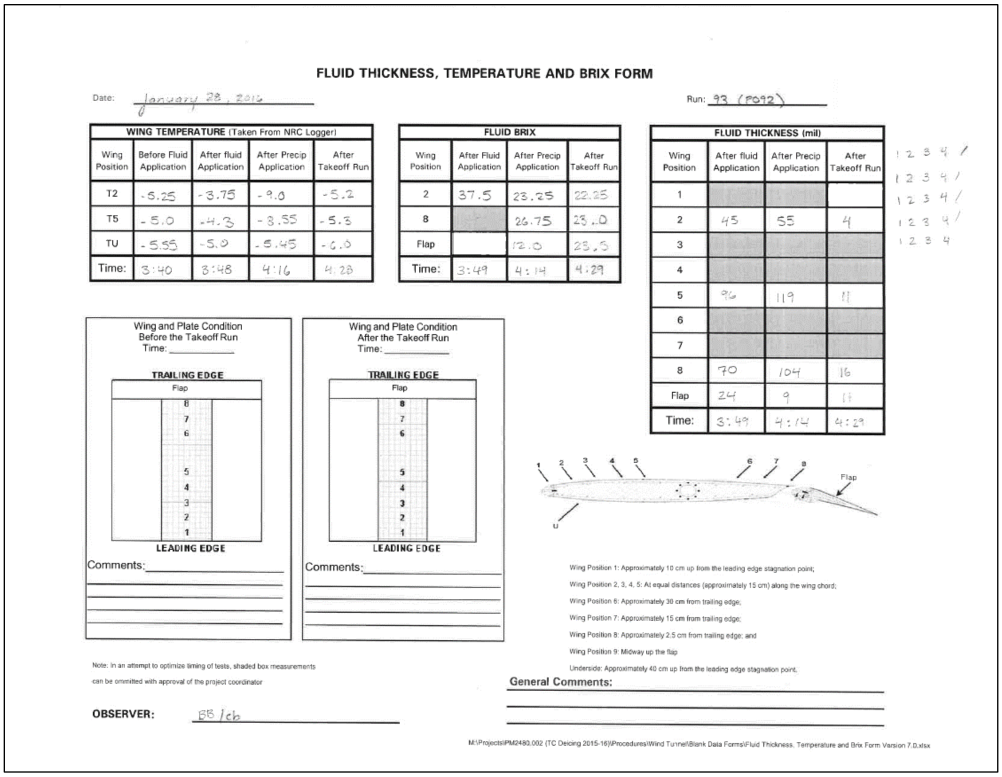
Figure C79: Run # 92



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 93 (P092)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-5.25	-3.75	-9.0	-5.2
T5	-5.0	-4.3	-8.55	-5.3
TU	-5.55	-5.0	-5.45	-6.0
Time:	3:40	3:48	4:16	4:28

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.5	23.25	22.25
8	▨	26.75	23.0
Flap		12.0	23.5
Time:	3:49	4:14	4:29

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	
2	45	55	4
3	▨	▨	▨
4	▨	▨	▨
5	96	119	11
6	▨	▨	▨
7	▨	▨	▨
8	70	104	16
Flap	24	9	17
Time:	3:49	4:14	4:29

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Wing and Plate Condition
After the Takeoff Run
Time: ___________

Comments: ___________

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: BB / cb

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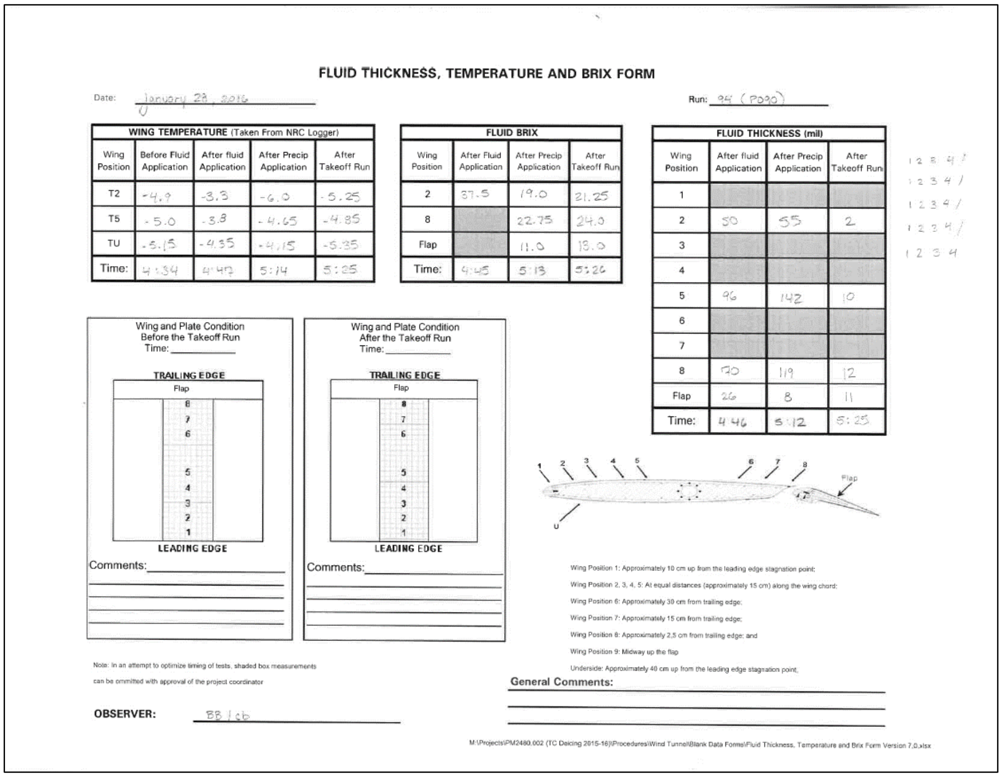
Figure C80: Run # 93



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 94 (P090)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-4.9	-3.3	-6.0	-5.25
T5	-5.0	-3.8	-4.65	-4.85
TU	-5.15	-4.35	-4.15	-5.35
Time:	4:34	4:47	5:14	5:25

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.5	19.0	21.25
8		22.75	24.0
Flap		11.0	13.0
Time:	4:45	5:13	5:26

FLUID THICKNESS (mil)				
Wing Position	After fluid Application	After Precip Application	After Takeoff Run	
1				1 2 3 4 /
2	50	55	2	1 2 3 4 /
3				1 2 3 4 /
4				1 2 3 4 /
5	96	142	10	1 2 3 4
6				
7				
8	70	119	12	
Flap	26	8	11	
Time:	4:46	5:12	5:25	

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:

Wing and Plate Condition
After 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: BB / cb

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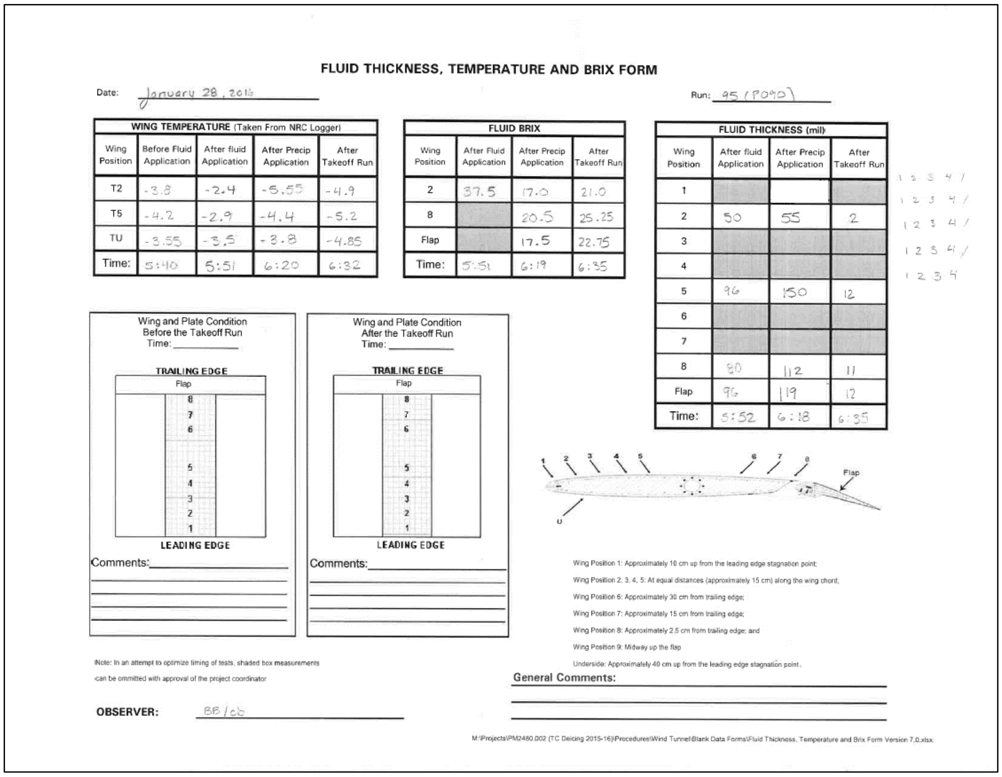
Figure C81: Run # 94



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 95 (P090)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-3.8	-2.4	-5.55	-4.9
T5	-4.2	-2.9	-4.4	-5.2
TU	-3.55	-3.5	-3.8	-4.85
Time:	5:40	5:51	6:20	6:32

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	37.5	17.0	21.0
8		20.5	25.25
Flap		17.5	22.75
Time:	5:51	6:19	6:35

FLUID THICKNESS (mil)				
Wing Position	After fluid Application	After Precip Application	After Takeoff Run	
1				1 2 3 4 /
2	50	55	2	1 2 3 4 /
3				1 2 3 4 /
4				1 2 3 4 /
5	96	150	12	1 2 3 4
6				
7				
8	80	112	11	
Flap	96	119	12	
Time:	5:52	6:18	6:35	

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:

Wing and Plate Condition
After 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: BB / cb

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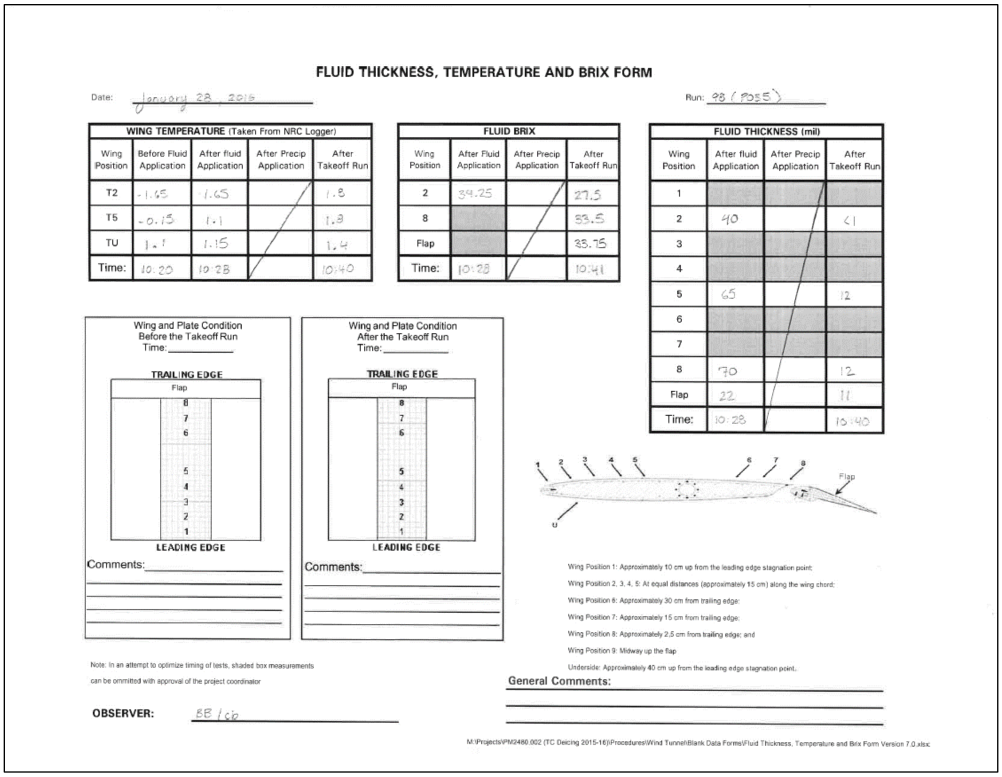
Figure C82: Run # 95

No Data Available

Figure C83: Run # 96 to Run #97



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 98 (P055)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-1.65	-1.65		1.8
T5	-0.15	1.1		1.8
TU	1.1	1.15		1.4
Time:	10:20	10:28		10:40

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.25		27.5
8	▨		33.5
Flap	▨		33.75
Time:	10:28		10:41

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40		<1
3	▨	▨	▨
4	▨	▨	▨
5	65		12
6	▨	▨	▨
7	▨	▨	▨
8	70		12
Flap	22		11
Time:	10:28		10:40

Wing and Plate Condition
Before the Takeoff Run
Time:

Comments:

Wing and Plate Condition
After 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: BB / cb

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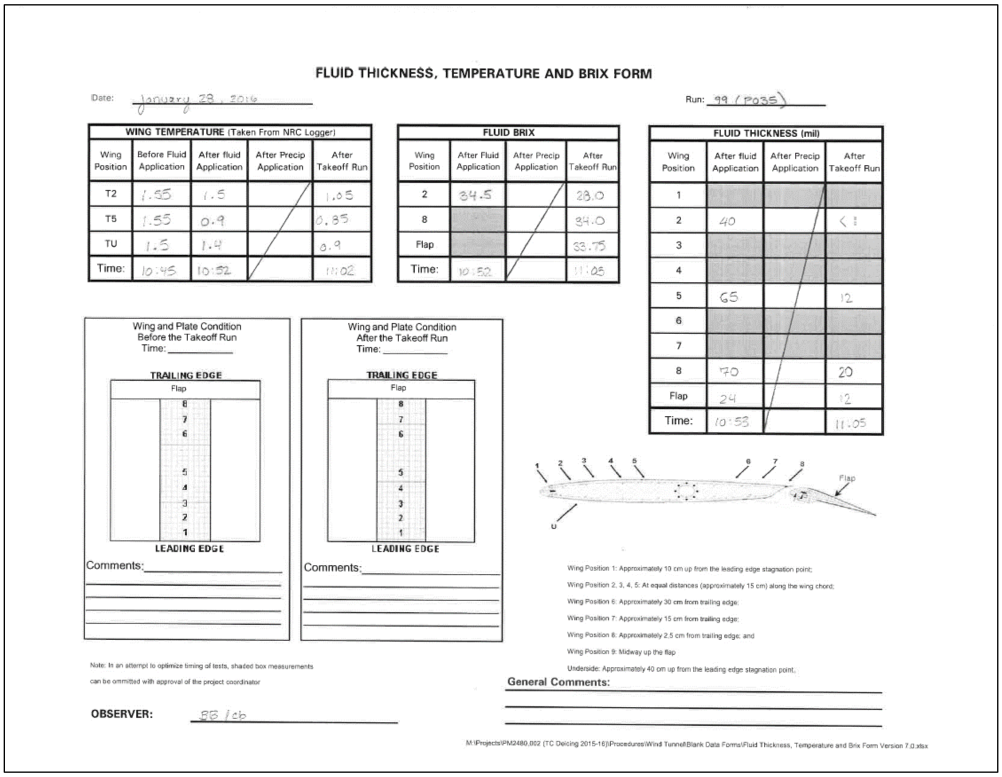
Figure C84: Run # 98



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 99 (P035)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	1.55	1.5		1.05
T5	1.55	0.9		0.85
TU	1.5	1.4		0.9
Time:	10:45	10:52		11:02

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.5		28.0
8			34.0
Flap			33.75
Time:	10:52		11:05

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40		< 1
3			
4			
5	65		12
6			
7			
8	70		20
Flap	24		12
Time:	10:53		11:05

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

TRAILING EDGE

Flap

LEADING EDGE

Comments: ___________

Wing and Plate Condition
After the Takeoff Run
Time: ___________

TRAILING EDGE

Flap

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: BB / cb

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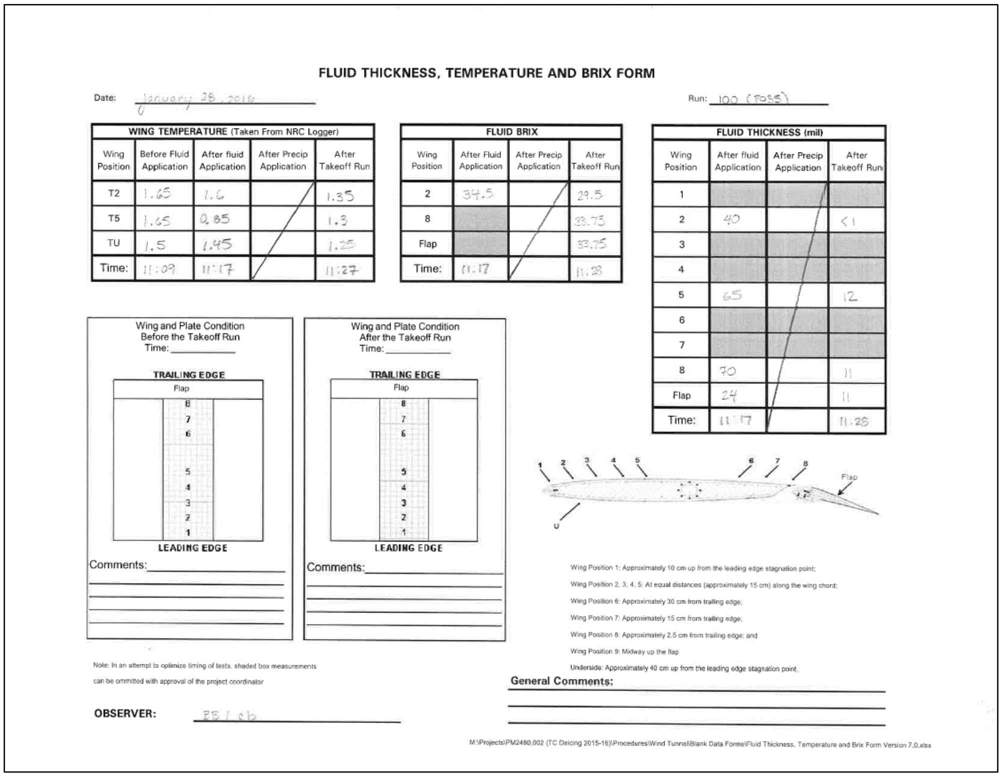
Figure C85: Run # 99



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 100 (P035)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	1.65	1.6		1.35
T5	1.65	0.85		1.3
TU	1.5	1.45		1.25
Time:	11:09	11:17		11:27

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.5		29.5
8			33.75
Flap			33.75
Time:	11:17		11:28

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40		<1
3			
4			
5	65		12
6			
7			
8	70		11
Flap	24		11
Time:	11:17		11:28

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

TRAILING EDGE

Flap

LEADING EDGE

Comments: ___________

Wing and Plate Condition
After the Takeoff Run
Time: ___________

TRAILING EDGE

Flap

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: BB / cb

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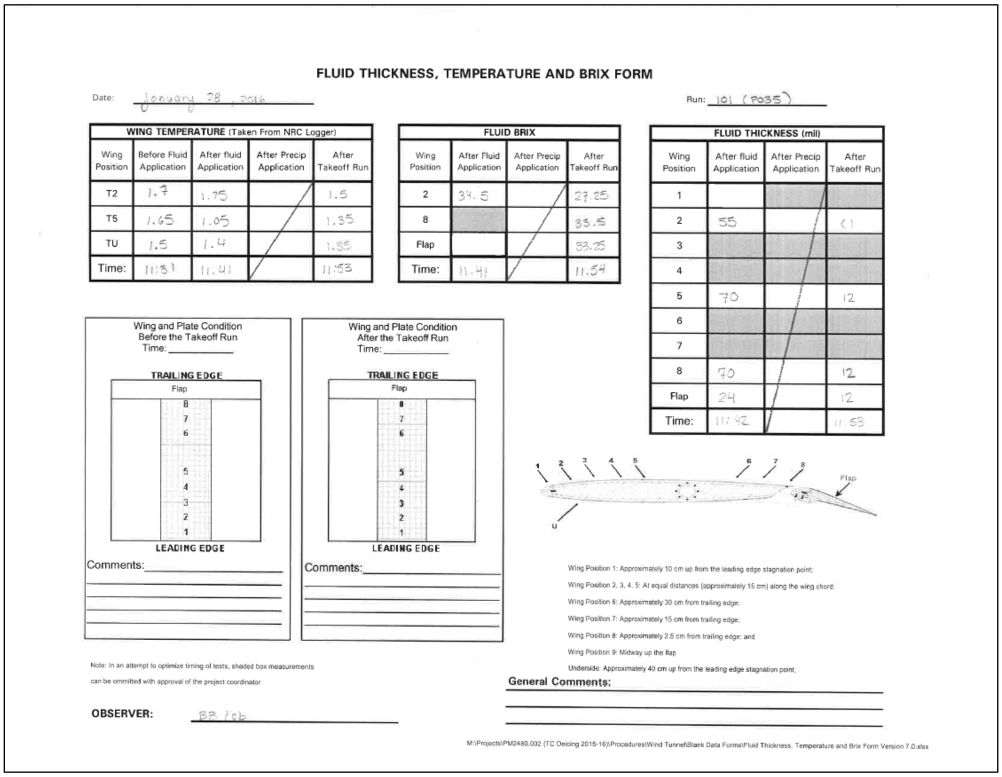
Figure C86: Run # 100



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 28, 2016

Run: 101 (P035)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	1.7	1.75		1.5
T5	1.65	1.05		1.35
TU	1.5	1.4		1.35
Time:	11:31	11:41		11:53

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.5		27.25
8	▨		33.5
Flap			33.25
Time:	11:41		11:54

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1		▨	▨
2	55		<1
3	▨	▨	▨
4	▨	▨	▨
5	70		12
6	▨	▨	▨
7	▨	▨	▨
8	70		12
Flap	24		12
Time:	11:42		11:53

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments:

Wing and Plate Condition
After 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: BB /cb

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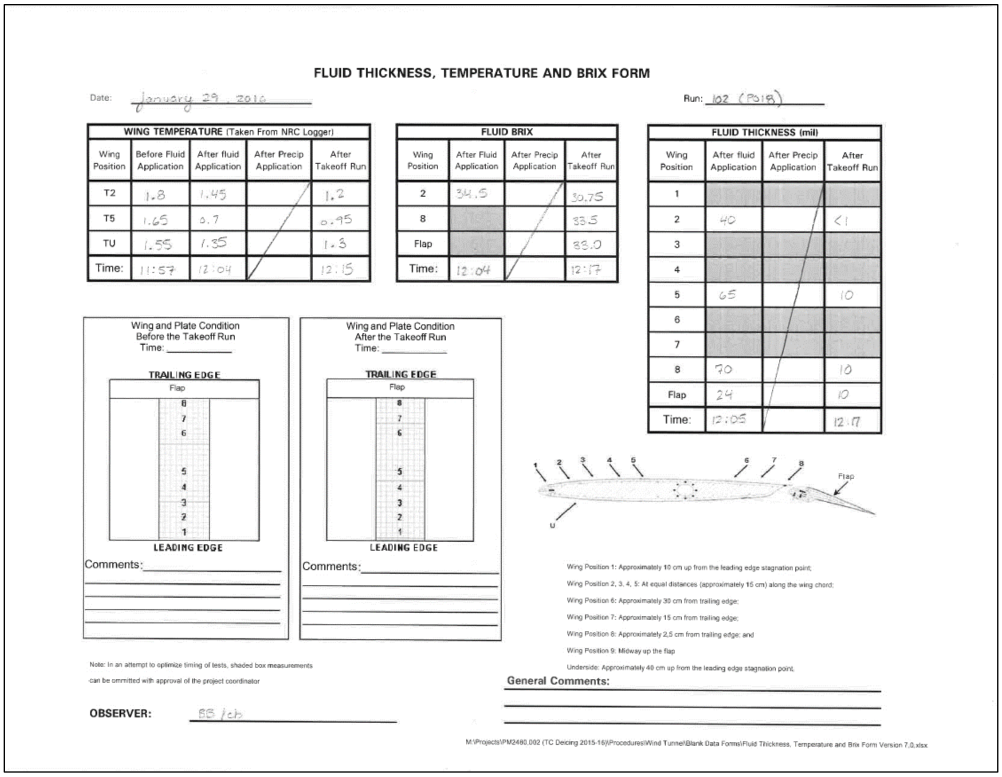
Figure C87: Run # 101



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 29, 2016

Run: 102 (P018)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	1.8	1.45		1.2
T5	1.65	0.7		0.95
TU	1.55	1.35		1.3
Time:	11:57	12:04		12:15

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.5		30.75
8	▨		33.5
Flap	▨		33.0
Time:	12:04		12:17

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	40		<1
3	▨	▨	▨
4	▨	▨	▨
5	65		10
6	▨	▨	▨
7	▨	▨	▨
8	70		10
Flap	24		10
Time:	12:05		12:17

Wing and Plate Condition
Before the Takeoff Run
Time: ____________

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

Comments:

Wing and Plate Condition
After 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: BB /cb

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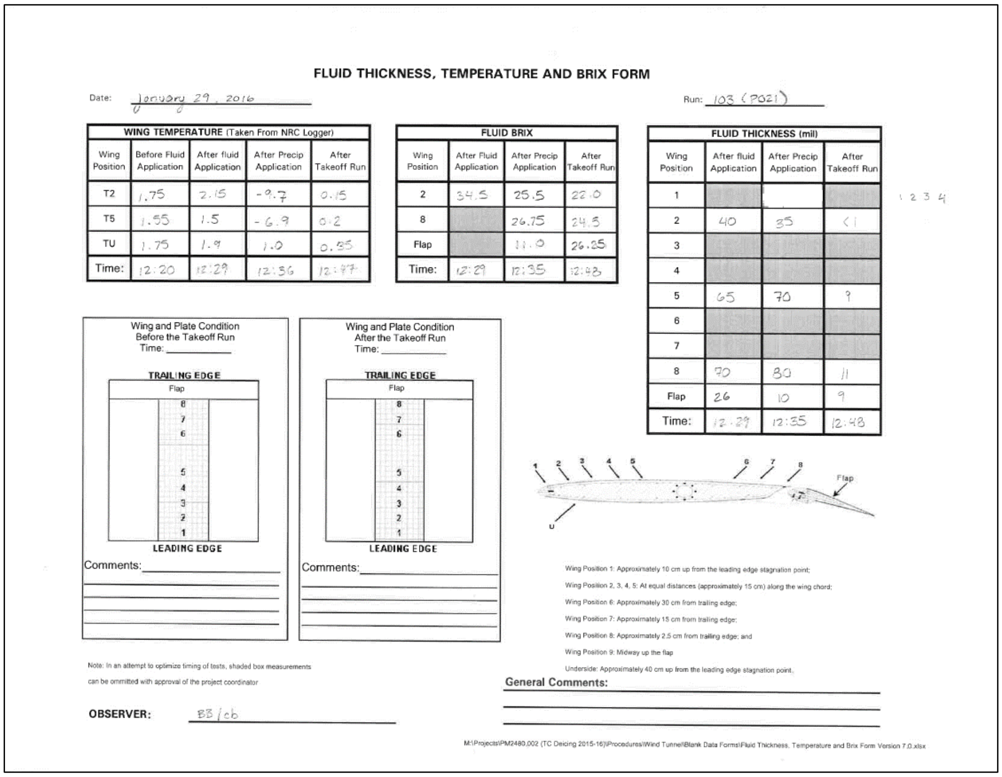
Figure C88: Run # 102



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 29, 2016

Run: 103 (P021)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	1.75	2.15	-9.7	0.15
T5	1.55	1.5	-6.9	0.2
TU	1.75	1.9	1.0	0.35
Time:	12:20	12:29	12:36	12:47

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.5	25.5	22.0
8		26.75	24.5
Flap		11.0	26.25
Time:	12:29	12:35	12:48

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40	35	<1
3			
4			
5	65	70	9
6			
7			
8	70	80	11
Flap	26	10	9
Time:	12:29	12:35	12:48

1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:

Wing and Plate Condition
After 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: BB/cb

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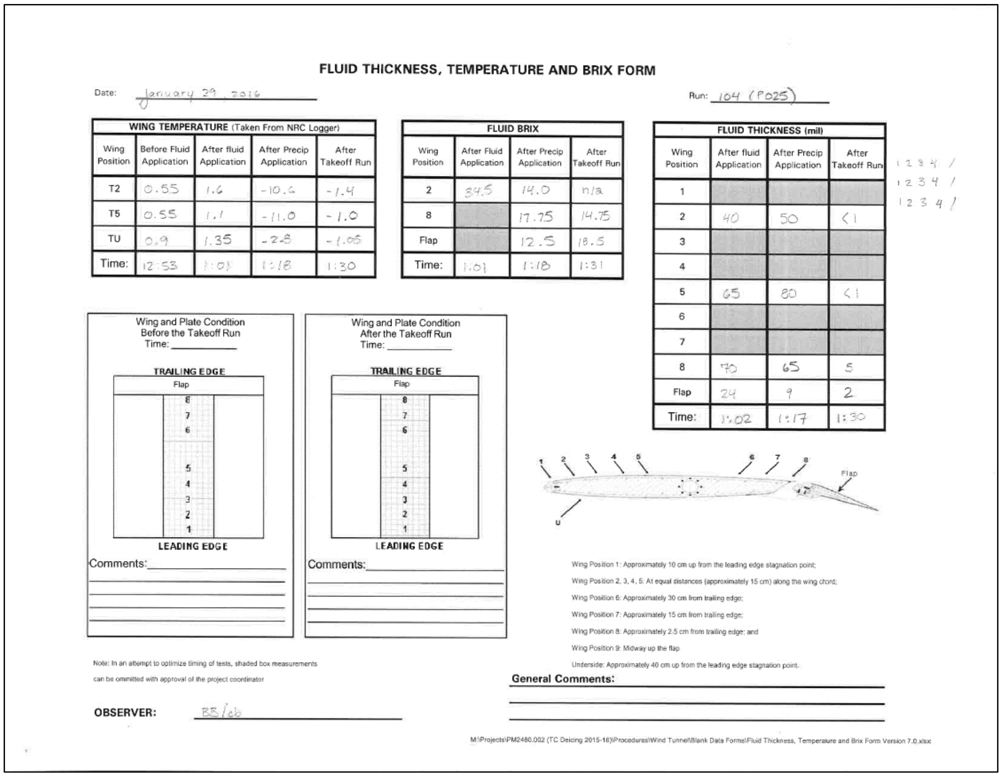
Figure C89: Run # 103



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 29, 2016

Run: 104 (P025)

WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	0.55	1.6	-10.6	-1.4
T5	0.55	1.1	-11.0	-1.0
TU	0.9	1.35	-2.8	-1.05
Time:	12:53	1:01	1:18	1:30

FLUID BRIX			
Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.5	14.0	n/a
8		17.75	14.75
Flap		12.5	18.5
Time:	1:01	1:18	1:31

FLUID THICKNESS (mil)			
Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1			
2	40	50	<1
3			
4			
5	65	80	<1
6			
7			
8	70	65	5
Flap	24	9	2
Time:	1:02	1:17	1:30

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

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

Comments:

Wing and Plate Condition
After 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: BB/cb

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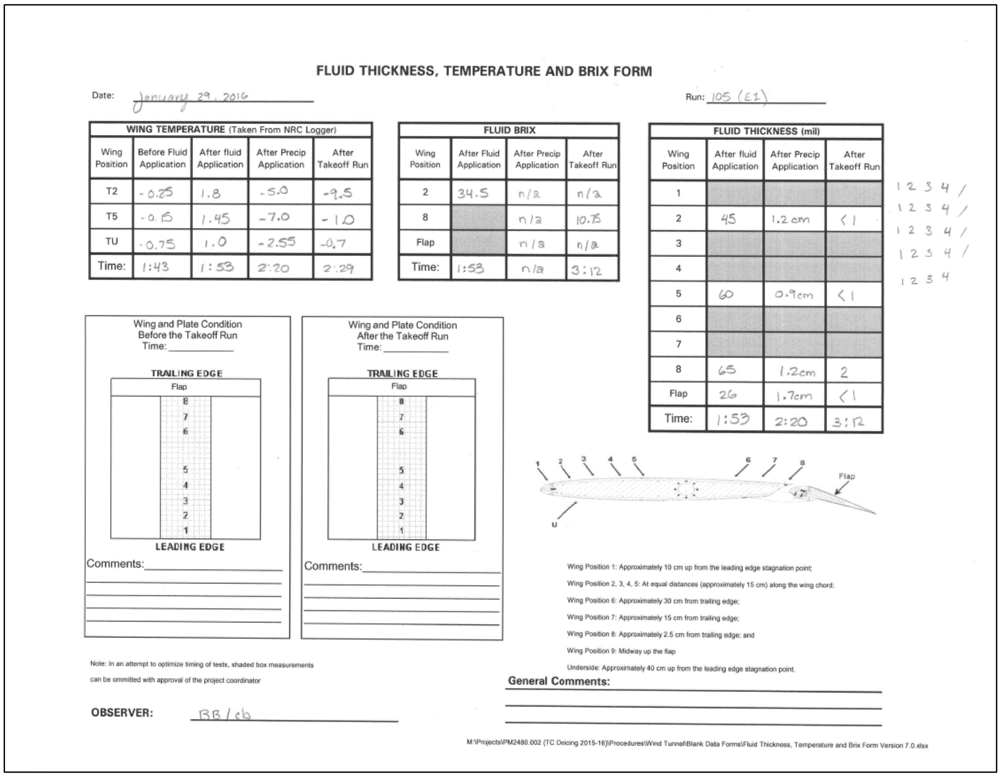
Figure C90: Run # 104



FLUID THICKNESS, TEMPERATURE AND BRIX FORM

Date: January 29, 2016

Run: 105 (E1)

WING TEMPERATURE (Taken From NRC Logger)

Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2	-0.25	1.8	-5.0	-9.5
T5	-0.15	1.45	-7.0	-1.0
TU	-0.75	1.0	-2.55	-0.7
Time:	1:43	1:53	2:20	2:29

FLUID BRIX

Wing Position	After Fluid Application	After Precip Application	After Takeoff Run
2	34.5	n/a	n/a
8	▨	n/a	10.75
Flap	▨	n/a	n/a
Time:	1:53	n/a	3:12

FLUID THICKNESS (mil)

Wing Position	After fluid Application	After Precip Application	After Takeoff Run
1	▨	▨	▨
2	45	1.2 cm	<1
3	▨	▨	▨
4	▨	▨	▨
5	60	0.9cm	<1
6	▨	▨	▨
7	▨	▨	▨
8	65	1.2cm	2
Flap	26	1.7cm	<1
Time:	1:53	2:20	3:12

1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4 /
1 2 3 4

Wing and Plate Condition
Before the Takeoff Run
Time: ___________

Comments: ___________

Wing and Plate Condition
After 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: BB/cb

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Figure C91: Run # 105