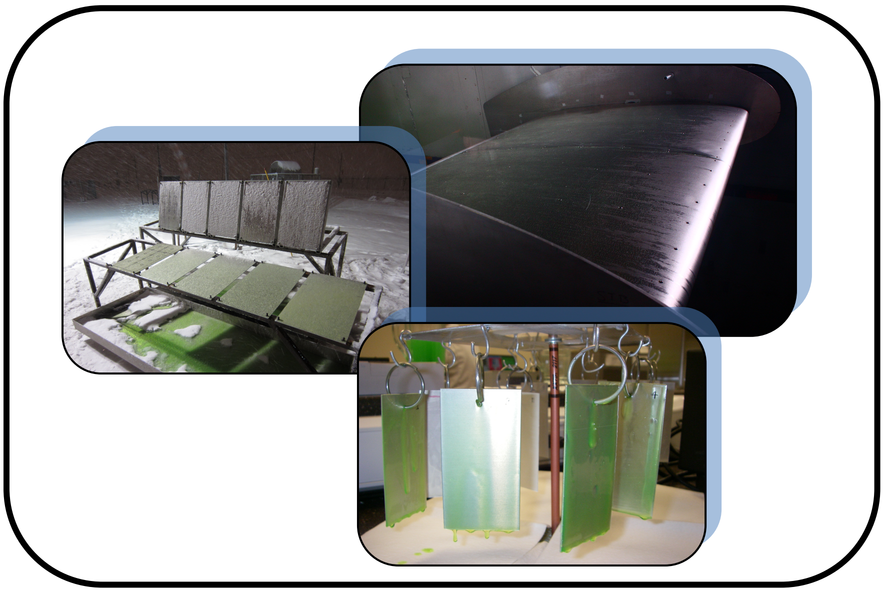
TP 15275E

Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates

Volume 3 of 4

(Year 2 of 3: 2012-13 Testing Report)



Prepared for
Transportation Development Centre

In cooperation with

Civil Aviation
Transport Canada

and

The Federal Aviation Administration
William J. Hughes Technical Center

Prepared by:

APS Aviation Inc.

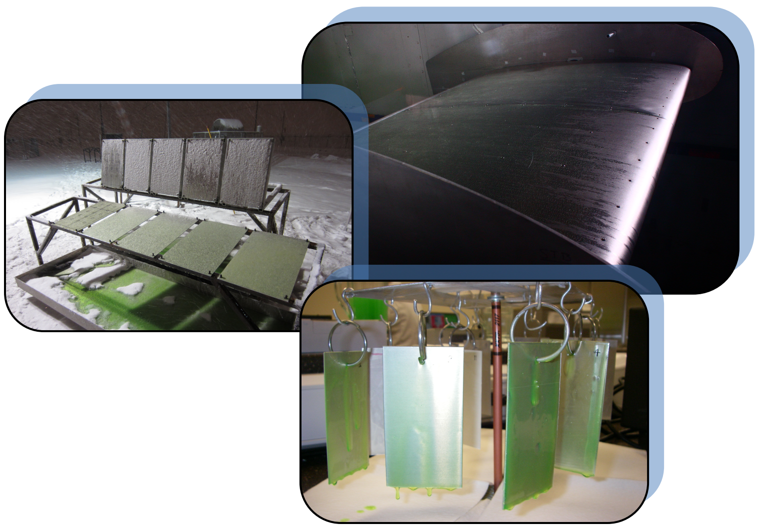
October 2014
Final Version 1.0

TP 15275E

Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates

Volume 3 of 4

(Year 2 of 3: 2012-13 Testing Report)



by:

Marco Ruggi, David Youssef, and Victoria Zoitakis

Prepared by:

APS Aviation Inc.

October 2014

Final Version 1.0

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

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

DOCUMENT ORIGIN AND APPROVAL RECORD

Prepared by:

July 28, 2017

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

Date

And by: David Youssef and Victoria Zoitakis

Reviewed by:

July 28, 2017

John D'Avirro, Eng.
Director, Aviation Services

Date

Approved by: **

John Detombe
Chief Engineer, Defence and Security
ADGA Group Consultants Inc.

Date

**This report was prepared and signed by Marco Ruggi, reviewed and signed by John D'Avirro, and approved by John Detombe in (December 2014) as part of the first submission to Transport Canada (Final Draft 1.0). A final Transport Canada technical and editorial review was completed in (July 2017); John Detombe was not available to participate in the final review or to sign the current version of this report.

Un sommaire français se trouve avant la table des matières.

EXECUTIVE SUMMARY

Under contract to TDC, APS Aviation Inc. (APS) undertook a test program to investigate the performance of de/anti-icing fluids on aluminum surfaces treated with ice phobic products and the possibility to reduce aircraft icing in northern and cold climates.

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

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

In 2011-2012, a three-year project was launched to assess the safety and effectiveness of ice phobic materials/coating and investigate the feasibility of employing ice phobic materials in the design of aircraft or specific aircraft sections that are more prone to icing.

Testing in 2011-12 (year 1 of 3) included natural snow testing, indoor simulated freezing precipitation testing, and wind tunnel testing. The main purpose of this testing was to investigate some additional areas of research not previously studied to gain some new insight into the potential applications of these coatings for aircraft operations, and to continue the research to include newly developed coating formulations. TC report, *TP 15275E, Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates, Volume 2 of 4 (Year 1 of 3: 2011-2012 Testing Report*) contains the research from Year 1 of the three year program.

This report contains the ice phobic research from Year 2 (2012-13) of the three year program.

General Comments and Recommendations

Testing conducted was limited and served as a scoping study. Only a limited number of products and conditions were tested. The main purpose of this testing was to investigate some additional areas of research not previously studied, to

gain some new insight into the potential applications of these coatings for aircraft operations, and to continue the research including newly developed coating formulations. More extensive material-specific data would be needed to demonstrate usability of products on aircraft critical surfaces.

The results obtained have demonstrated a potential for future applications of ice phobic coatings in aircraft operations. More specifically, significant benefits are possible on vertical surfaces which are subject to early contamination due to fluid runoff. The use of coatings on the vertical surfaces (i.e. vertical stabilizer, winglets, fuselage, etc.) could provide added protection from adherence of contamination.

Preliminary work done simulating aerodynamically quiet areas in aircraft also indicated potential benefits to using ice phobic coatings. These results indicate a potential solution to minimize residues formation, which could be applicable in such areas.

The application of coatings to the main wing sections has demonstrated mixed results and is highly dependent on the coatings used; some coatings have proven to be better than others in terms of compatibility with fluids. Nonetheless, one manufacturer has demonstrated continual improvement in the coatings submitted for testing, indicating that these coatings can potentially evolve to be complementary to de/anti-icing fluids.

In general, testing has indicated that with proper knowledge of the effects these coatings have on de/anti-icing fluid, the benefits of using these coatings can be had through adapted deicing procedures without compromising aircraft safety.

The following are potential areas for future research:

- Conduct evaluation of newly developed coatings;
- Conduct wind tunnel testing with a thin high performance wing model to refine the test methodology, and to investigate coating performance during ground icing conditions with and without fluid, and with contamination;
- Investigate potential use of coatings in areas prone to icing but where de/anti-icing protection is limited, or not available (e.g. cowlings, landing gear);
- Investigation of different types of adhered contamination on vertical surfaces, and their effects on aerodynamics;
- Investigate dynamic taxi situations, simulating aircraft vibration; and
- Conduct research to support development of the new SAE AIR document.

SOMMAIRE

En vertu d'un contrat avec le CDT, APS Aviation Inc. (APS) a entrepris un programme d'essais pour évaluer la performance de liquides de dégivrage et d'antigivrage sur des surfaces d'aluminium traitées avec des produits glaciophobes et sur la possibilité de réduire le givrage d'aéronefs dans les climats nordiques et froids.

La formation de glace sur les aéronefs est une préoccupation importante en terme de sécurité, autant pour l'exploitation d'aéronefs au sol qu'en vol. Au cours des dernières années, l'industrie a démontré un grand intérêt dans l'utilisation de recouvrements pour protéger les surfaces critiques des aéronefs. Des travaux récents ont étudié ces recouvrements (parfois conçus et mis en marché sous le nom de recouvrements glaciophobes) en vol, mais leur comportement et leur performance lors de dégivrages au sol n'ont pas encore été complètement examinés.

Les résultats des travaux préliminaires menés durant les hivers 2009-2010 et 2010-2011 sont précisés dans le rapport TP 15055E de TC : *Emerging De/Anti-Icing Technology: Evaluation of Ice Phobic Products for Potential Use in Aircraft Operation* (1) et dans le rapport TP 15158E de TC : *Aircraft Ground Icing Research General Activities During the 2010-11 Winter* (2).

En 2011-2012, un projet d'une durée de trois ans a été entrepris pour évaluer la sécurité et l'efficacité de matériaux et recouvrements glaciophobes et pour examiner la faisabilité d'utiliser des matériaux glaciophobes dans la conception d'aéronefs ou de sections particulières d'aéronef qui sont plus sujettes au givrage.

Les essais de 2011-2012 (1ère de 3 années) comprenaient des essais à l'extérieur dans la neige, des essais à l'intérieur dans la précipitation verglaçante simulée et des essais en soufflerie. Ces essais avaient pour objectif principal d'examiner des domaines de recherche additionnels non étudiés auparavant, afin de mieux comprendre les applications possibles de ces revêtements pour l'exploitation d'aéronefs, ainsi que de poursuivre la recherche en y incluant des formules de revêtement nouvellement élaborées. Le rapport *TP 15275E de TC : Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates, Volume 2 of 4 (*1ère de 3 années *: Rapport d'essais de 2011-2012*) couvre la recherche de la 1ère année du programme de 3 ans.

Le présent rapport couvre la recherche sur les matériaux glaciophobes de la deuxième (2012-2013) des 3 années du programme.

Observations générales et recommandations

Les essais étaient limités et ont servi d'étude exploratoire. Un nombre limité seulement de produits et de conditions a été mis à l'essai. Ces essais avaient pour objectif principal d'examiner des domaines de recherche additionnels non étudiés auparavant, afin de mieux comprendre les applications possibles de ces revêtements pour l'exploitation d'aéronefs, ainsi que de poursuivre la recherche en y incluant des formules de revêtement nouvellement élaborées. Des données plus complètes, spécifiques aux matériaux utilisés, seraient nécessaires pour prouver l'utilité des produits sur les surfaces critiques des aéronefs.

Les résultats obtenus ont démontré un potentiel pour l'application de revêtements glaciophobes aux aéronefs à l'avenir. Plus précisément, des bénéfices importants sont possibles sur les surfaces verticales, qui sont susceptibles de contamination précoce en raison de l'écoulement du liquide. L'utilisation de revêtements sur les surfaces verticales (par exemple le stabilisateur vertical, les ailettes de bout d'aile, le fuselage, etc.) pourrait ajouter une protection contre l'adhésion de contamination.

Des travaux préliminaires qui simulaient les zones à l'abri d'écoulement aérodynamique indiquaient également des bénéfices potentiels à utiliser des revêtements glaciophobes. Ces résultats indiquent une façon possible de minimiser la formation de résidus, qui pourrait convenir aux zones d'aéronefs à l'abri d'écoulement aérodynamique.

L'application de revêtements sur les principales sections des ailes a donné des résultats mitigés et dépend grandement des revêtements utilisés. Certains revêtements se sont avérés meilleurs que d'autres en termes de compatibilité avec les liquides. Néanmoins, un fabricant a démontré une amélioration constante des revêtements soumis aux essais, ce qui indique que ces revêtements pourraient évoluer et compléter les liquides de dégivrage et d'antigivrage.

De manière générale, les essais ont démontré que, si l'on connait bien les effets de ces recouvrements sur le liquide de dégivrage et d'antigivrage, leur utilisation peut apporter des bénéfices en adaptant les procédures de dégivrage, sans compromettre la sécurité des aéronefs.

Les domaines suivant pourraient faire l'objet de recherches futures :

- Évaluer les revêtements nouvellement élaborés;
- Mener des essais en soufflerie avec un modèle d'aile mince de haute performance afin de raffiner la méthodologie des essais, ainsi que pour

examiner le rendement du revêtement dans des conditions de givrage au sol, avec ou sans liquide et avec contamination;

- Examiner la possibilité d'utiliser des revêtements sur les zones sujettes au givrage lorsque la protection contre le dégivrage ou l'antigivrage est limitée ou non disponible (par exemple le capot ou le train d'atterrissage);
- Examiner les différents types de contamination adhérés aux surfaces verticales et leurs effets sur l'aérodynamisme;
- Examiner des situations dynamiques de circulation au sol qui simulent la vibration de l'aéronef; et
- Mener des recherches en appui au développement du nouveau document SAE AIR.

This page intentionally left blank.

TABLE OF CONTENTS

Page

LIST OF APPENDICES

This page intentionally left blank.

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF PHOTOS

Page

GLOSSARY

AIR	Aerospace Information Report
APS	APS Aviation Inc.
BLDT	Boundary Layer Displacement Thickness
CEF	Climatic Engineering Facility
FAA	Federal Aviation Administration
HOT	Holdover Time
MSC	Meteorological Service of Canada
NRC	National Research Council Canada
PIWT	Propulsion and Icing Wind Tunnel
SAE	Society of Automotive Engineers
TC	Transport Canada
TDC	Transportation Development Centre

This page intentionally left blank.

1. INTRODUCTION

Over the past several years, the Transportation Development Centre (TDC), 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 US Federal Aviation Administration (FAA), the National Research Council (NRC), Meteorological Service of Canada (MSC), several major airlines, and deicing fluid manufacturers. The TDC is continuing its research, development, testing and evaluation program.

Under contract to TDC, APS Aviation Inc. (APS) undertook a test program to investigate the performance of de/anti-icing fluids on aluminum surfaces treated with ice phobic coatings and the potential to reduce aircraft icing in northern and cold climates.

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

Volume 1:	*Summary Report*
Volume 2:	*Year 1 of 3: 2011-12 Testing Report*
Volume 3:	*Year 2 of 3: 2012-13 Testing Report*
Volume 4:	*Year 3 of 3: 2013-14 Testing Report*

This report is Volume 3 of 4.

1.1 Background

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

The results of testing in 2009-10 indicated that ice phobic products investigated were not an appropriate stand-alone substitute for de/anti-icing, as they did not necessarily prevent freezing and adhesion of contamination, but could delay the onset of freezing. With respect to fluid thickness and endurance time testing, some ice phobic products demonstrated minimal differences compared to the baseline, whereas others demonstrated significant wetting issues and resulting endurance time reductions; these differences were coating and fluid specific. These results are described in detail in the TC report, TP 15055E, *Emerging De/Anti-Icing Technology: Evaluation of Ice Phobic Products for Potential Use in Aircraft Operation* (1).

In addition to the 2009-10 testing, work was conducted during the winter of 2010-11. This testing was limited and preliminary due to limited available funding and the timing of the tests. The main purpose of this testing was to obtain some initial insight into the potential new applications of these coatings for aircraft operations, and to continue the research to include newly developed coating formulations. These results are described in detail in the TC report, TP 15158E, *Aircraft Ground Icing Research General Activities During the 2010-11 Winter* (2).

In 2011-2012, a three-year project was launched to assess the safety and effectiveness of ice phobic materials/coating and investigate the feasibility of employing ice phobic materials in the design of aircraft or specific aircraft sections that are more prone to icing.

Testing in 2011-12 (Year 1 of 3) included natural snow testing, indoor simulated freezing precipitation testing, and wind tunnel testing. The main purpose of this testing was to investigate some additional areas of research not previously studied to gain some new insight into the potential applications of these coatings for aircraft operations, and to continue the research to include newly developed coating formulations. TC report, TP 15275E*, Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates, Volume 2 of 4 (Year 1 of 3: 2011-2012 Testing Report)* contains the research from Year 1 of the three year program.

This report contains the ice phobic research from Year 2 (2012-13) of the three year program.

1.2 Objective

The objective of this year's research was to investigate the holdover time performance of fluids applied to surfaces treated with ice phobic products, as well as the performance of bare surfaces treated with ice phobic products.

Eight types of tests, described below, were conducted to meet the objective.

1. **Endurance Time Tests**: Evaluate fluid endurance times of Type I and IV fluids when applied to surfaces treated with ice phobic products;

2. **Adherence Tests**: Evaluate potential to delay the onset of adherence on bare surfaces treated with ice phobic products during freezing precipitation conditions;
3. **Fluid Wetting and Thickness Tests**: Evaluate de/anti-icing fluid ability to properly wet and provide appropriate fluid thickness when applied to ice phobic surfaces;
4. **Hot Water Deicing Tests**: Evaluate the anti-icing performance of coated surfaces when treated with standard hot water;
5. **Fluid Viscosity Tests**: Evaluate whether lowest on-wing viscosity fluid or mid-viscosity fluid should be used for evaluation of holdover times on coated surfaces;
6. **Vertical Stabilizer Tests**: Evaluate the endurance time performance on vertical surfaces treated with an ice phobic coating;
7. **Reduction of Residues in Quiet Areas**: Investigate potential application of ice phobic products in quiet areas to reduce residues by evaluating ability to facilitate fluid drainage; and
8. **Wind Tunnel Tests:** To investigate the aerodynamic performance of an airfoil treated with a coating, with and without de/anti-icing fluids.

In addition, a significant amount of work was done in developing a new Society of Automotive Engineers (SAE) Aerospace Information Report (AIR) for evaluating the interaction of de/anti-icing fluids with aircraft after-market coatings.

The sections of the TDC work statement pertaining to the work described in this report are provided in Appendix A.

1.3 Report Format

The following list provides short descriptions of the main sections of this report:

a) Section 2 provides a description of the methodology used to carry out the tests during the winter of 2012-13;

b) Section 3 summarizes the results from endurance time testing conducted during the winter of 2012-13;

c) Section 4 summarizes the results from the adherence testing conducted during the winter of 2012-13;

d) Section 5 summarizes the results from the fluid wetting and fluid thickness testing conducted during the winter of 2012-13;

e) Section 6 summarizes the results from the hot water deicing testing conducted during the winter of 2012-13;

f) Section 7 summarizes the results from the fluid viscosity testing conducted during the winter of 2012-13;

g) Section 8 summarizes the results from the vertical stabilizer testing conducted during the winter of 2012-13;

h) Section 9 summarizes the results from the investigation of the application of ice phobic products in quiet areas during the winter of 2012-13;

i) Section 10 summarizes the results from the wind tunnel testing conducted during the winter of 2012-13;

j) Section 11 summarizes the activities regarding the development of the SAE Aerospace Information Report (AIR) being developed for evaluating the interaction of de/anti-icing fluids with aircraft after-market coating;

k) Section 12 presents the observations conclusions; and

l) Section 13 presents the recommendations.

2. METHODOLOGY

This section describes the overall approach, test parameters and experimental procedures followed during the 2012-13 project.

APS measurement instruments and test equipment are calibrated and verified on an annual basis. This calibration is carried out according to a calibration plan derived from approved ISO 9001:2008 standards, and developed internally by APS.

2.1 Test Facilities

The following sections describe the different testing facilities used to conduct the various ice phobic tests.

2.1.1 APS Pierre Elliott Trudeau (P.E.T.) Airport Outdoor Test Site

Fluid endurance time testing during natural snow conditions was conducted at the APS test site (Photo 2.1 and Photo 2.2) located at the P.E.T. International Airport (Montreal-Trudeau) in Montreal. Testing was conducted by APS personnel. The location of the test site is shown on the plan view of the airport in Figure 2.1.

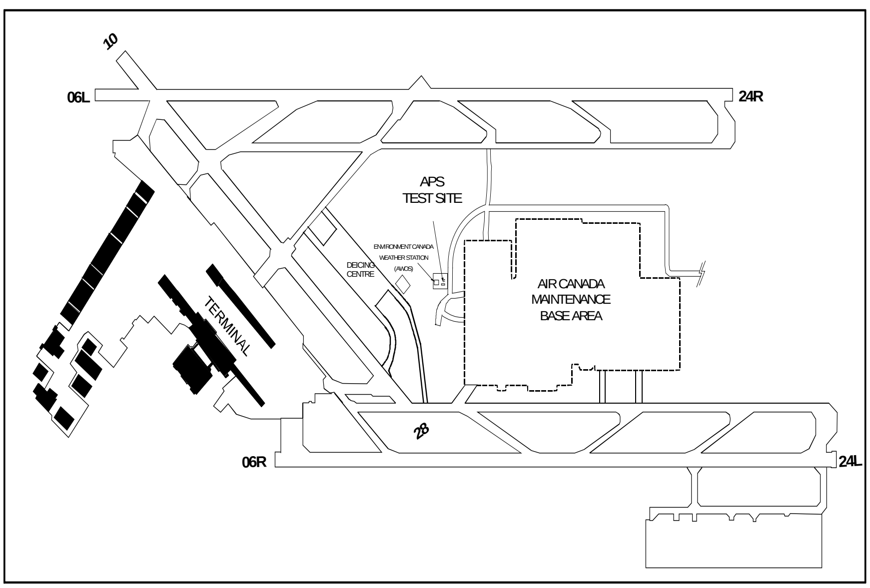


Figure 2.1: Plan View of APS Montreal-Trudeau Airport Test Site

2.1.2 NRC Climatic Engineering Facility (CEF)

To obtain the necessary fluid endurance time data for the freezing precipitation conditions, testing was carried out at the NRC CEF (Photo 2.3) using a sprayer assembly (Photo 2.4) to simulate the required freezing precipitation conditions. Testing was conducted by APS personnel. Figure 2.2 provides a schematic of the NRC Uplands campus showing the location of the U-88/U-89 facility.

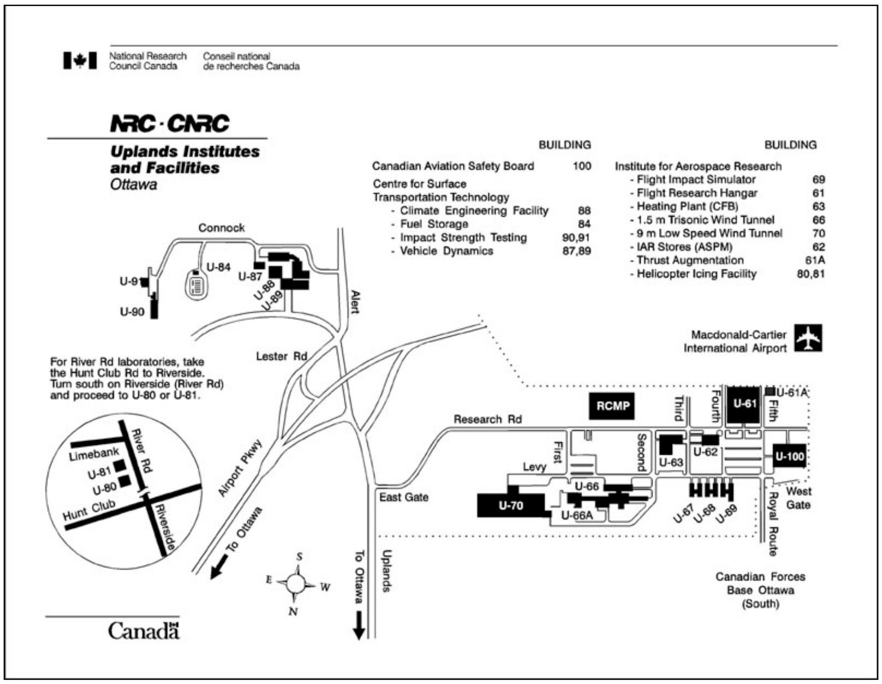


Figure 2.2: Schematic of NRC Uplands Campus

2.1.3 NRC Open Circuit Wind Tunnel Test Site

The Propulsion and Icing Wind Tunnel (PIWT) tests were performed at the NRC Aerospace Facilities, Building M-46, at the NRC Montreal Road campus, located in Ottawa, Canada. Figure 2.3 provides a schematic of the NRC Montreal Road campus showing the location of the NRC PIWT. Photo 2.5 shows an outside view of the wind tunnel test facility. Photo 2.6 shows an inside view of the wind tunnel test section. The open-circuit layout, with fan at entry, permits contaminants associated with the test articles (such as heat, or de/anti-icing fluid) to discharge directly, without re-circulating or contacting the fan. The fan is normally driven electrically but high-speed operation can be accommodated by a gas turbine drive system. Due to the requirements of both high speed and low speed operation during the testing, the gas turbine was selected to allow for greater flexibility.

The gas turbine drive can perform both low and high speed operations whereas the electric drive is limited to low speed operations.

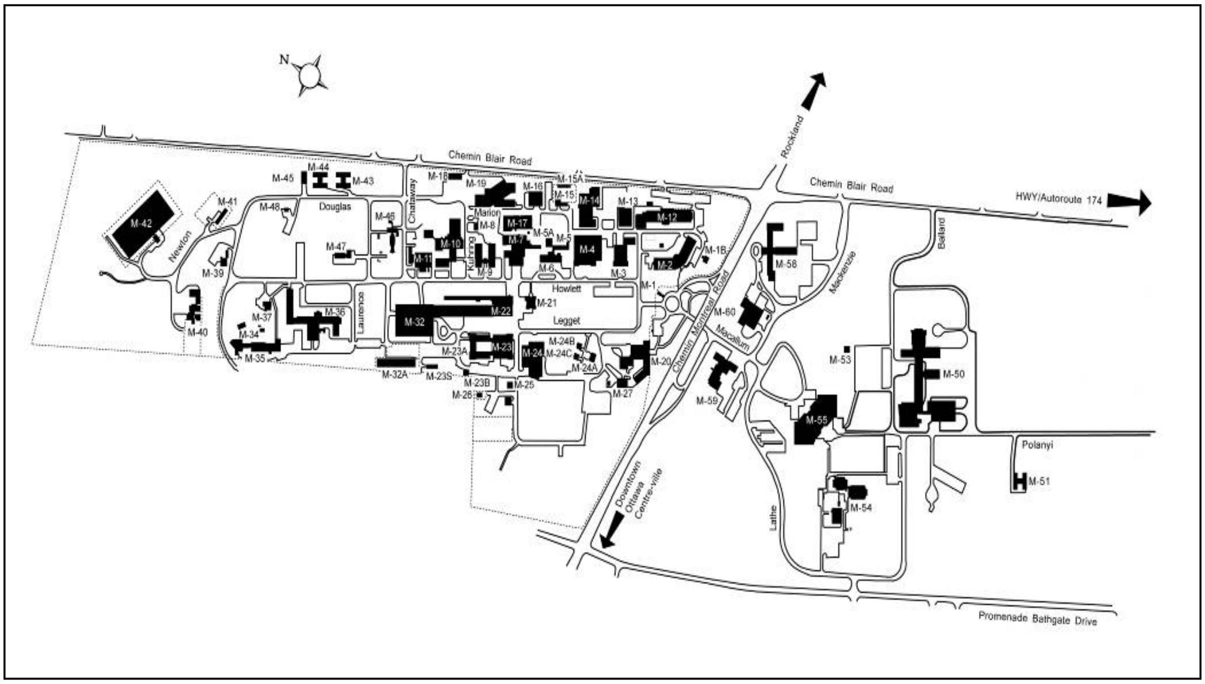


Figure 2.3: Schematic of NRC Montreal Road Campus

2.2 Materials Tested

2.2.1 Ice Phobic Products

To investigate the effects of ice phobic treated aluminum surfaces on de/anti-icing fluid performance, five products were evaluated during the winter of 2012-13. The choices in materials were made based on availability and potential for use in current aircraft operations. Table 2.1 lists the products tested to date along with the reference codes used in this report. Only the 2012-13 testing year results are described in this report.

2.2.2 Flat Pate Testing Baseline Surfaces

During each flat plate test, the performance of the ice phobic treated standard aluminum test plate was compared to a baseline untreated standard 2024-T3 aluminum test plate. In previous years, during some limited flat plate tests, a polished and a painted plate were also used for comparison (the objective was to compare the ice phobic performance to industry available surface finishes). Table 2.2 lists the baseline surface used for comparison.

Table 2.1: List of Ice Phobic Product Tested and Reference Codes

Testing Year	APS Reference Code	Manufacturer	Product Applied
2012-13	I-PH B12	Manufacturer B	Product 1
2012-13	I-PH B13	Manufacturer B	Product 2
2012-13	I-PH C3	Manufacturer C	Product 1
2012-13	I-PH D1	Manufacturer D	Product 1
2012-13	I-PH D2	Manufacturer D	Product 2

Table 2.2: List of Flat Plate Baseline Surfaces Tested

APS Reference Code	Material	Treatment Used
Baseline	2024-T3 Aluminum	Not Treated

2.3 Test Methodology

The test methodologies used to conduct the various ice phobic tests are described in the following sections.

2.3.1 Description of Fluid Endurance Time Testing Procedures

2.3.1.1 Description of Indoor Fluid Endurance Time Testing Procedure

Testing was conducted in simulated precipitation conditions at the NRC climatic engineering facility. Tests were carried out using standard endurance time testing protocol. When possible, Brix and thickness measurements were taken 5 minutes after fluid application and at the time of failure. Testing was conducted with ice phobic products as well as the baseline aluminum plate. Details of this procedure are included in Appendix B. (Note: this procedure was developed several years ago; the same procedure applies).

2.3.1.2 Description of Outdoor Fluid Endurance Time Testing Procedure

Testing was conducted in natural snow conditions at the APS P.E.T Airport test site. Tests were carried out using standard endurance time testing protocol. When possible, Brix and thickness measurements were taken 5 minutes after fluid application and at the time of failure. Testing was conducted with ice phobic products as well as the baseline aluminum plate. Testing was limited and ad-hoc, therefore no official procedure was published, however the procedure in Appendix C was used as reference.

2.3.2 Description of Fluid Wetting and Thickness Testing Procedure

The testing methodology was based on the protocol used to measure fluid thickness of new endurance time fluids. The procedure is entitled *Experimental Program to Establish Film Thickness Profiles for De-Icing and Anti-Icing Fluids on Flat Plates* and can be found in Appendix I of TC report, TP 13991E, *Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 2001-2002 Winter* (3). Comparative flat plate tests were conducted with all ice phobic products as well as the baseline aluminum plate. These tests were conducted in dry conditions (no precipitation). The thickened fluid tests consisted of recording the fluid thickness decay over a 30-minute period. The Type I tests, however, consisted of recording the percentage of the plate that remained wetted over a period of 15-minutes. Due to the thinness of the fluid layer, fluid thickness was not an appropriate evaluation method. Details of this procedure are included in Appendix B.

2.3.3 Description of Adherence Testing Procedure

Testing was conducted without fluid to evaluate the potential to delay the onset of adherence on surfaces treated with ice phobic products relative to the baseline aluminum surface. Comparative flat plate tests were conducted with all ice phobic products as well as the baseline plate. Testing was conducted in light freezing rain. The dry, clean plates were simultaneously exposed to the simulated freezing contamination. Data regarding the time for ice to form, and the time for the ice to adhere were recorded. The adhesion was verified using the "APS Adherence Tester" which has been historically used, and has been calibrated to represent the shear forces typically experienced during takeoff. Observational data during the tests was also recorded. Details of this procedure are included in Appendix B.

2.3.4 Description of Hot Water Testing Procedure

Testing was conducted without fluid to evaluate the anti-icing performance of coated surfaces when treated with hot water. Comparative flat plate tests were conducted with all ice phobic products as well as the baseline plate. Testing was conducted in light freezing rain.

2.3.5 Description of Fluid Viscosity Testing Procedure

In the development of AIR6232, the question was raised as to whether lowest on-wing viscosity fluid or mid-viscosity fluid should be used for evaluation of holdover times on coated surfaces. Moreover, would differences in endurance time be affected by fluid viscosity? Limited testing in both natural snow and simulated freezing conditions were completed to investigate this. Comparative flat plate tests were conducted with all ice phobic products as well as the baseline plate. Details of this procedure are included in Appendix D.

2.3.6 Description of Vertical Stabilizer Testing Procedure

Due to the early fluid failures observed on vertical surfaces, it was suggested that tests be conducted with ice phobic treated surfaces to investigate any potential benefits. Tests were conducted under natural snow conditions at the APS test site facility located at Montreal-Trudeau Airport in Montreal. Standard endurance time test and rate collection protocol were followed during the execution of these tests. Type IV tests were conducted with a vertical plate (positioned at 80º instead of the typical 10º) which was coated with an ice phobic coating, and the performance was compared to a vertical baseline plate which was not coated. Details of this procedure are included in Appendix C and in Appendix E.

2.3.7 Description of Wind Tunnel Testing Procedure

Testing was conducted using wing skins specifically manufactured to fit onto the existing thin, high performance wing section and be secured by flush-mounted screws. To cover the entire test wing, two individual wing skin halves were required. The wing skins were treated with the various coatings prior to testing to allow the proper curing times.

The general methodology used for these tests was in accordance with the methodologies used for typical fluid and contamination tests conducted in the wind tunnel. The evaluation methodology was modified to allow a comparison among the different wing skin coatings. Details of this procedure are included in Appendix F.

2.3.8 Description of Residues Testing Procedure

A comparative testing methodology was developed by APS with TC/FAA based on the “Successive Dry-out and Rehydration Test” from Appendix A of AMS1428G. The residues formed on coated plates were compared to the baseline aluminum plate. Coated aluminum test plates and selected fluids were provided to AMIL for testing.

2.4 Data Forms

The data forms used for the various test objectives are provided in the respective procedures given in Appendix B, C and D.

2.5 Equipment

The test equipment for standard HOT testing and typical wind tunnel testing was used to conduct the ice phobic product evaluation. Subsections 2.5.1 to 2.5.4 briefly describe some of the equipment used.

2.5.1 Wind Tunnel Super-Critical Wing Section

A new generation thin and flat wing section (Figure 2.4) was used for testing in the NRC PIWT. The dimensions indicated are in inches. This wing section was constructed by the NRC specifically for conducting these tests followed by extensive consultations with an airframe manufacturer to ensure a representative super-critical design.

Testing was conducted using wing skins specifically manufactured to fit onto the existing thin high performance wing section and be secured by 68 flush-mounted screws. To cover the entire test wing, two individual wing skin halves were required.

The general methodology that was used during these tests is in accordance with the methodologies used for typical fluid and contamination tests conducted in the wind tunnel.

2.5.2 Test Surfaces

Flat plate endurance time testing was conducted using standard aluminum test plates that were treated with ice phobic products (paint, or polish) or left un-treated (baseline). A schematic of a test plate is shown in Figure 2.5.

For the residues testing, smaller test plates were used (Photo 2.7). For all wind tunnel testing, custom made wing skin were manufactured and coated with ice phobic products (Photo 2.8).

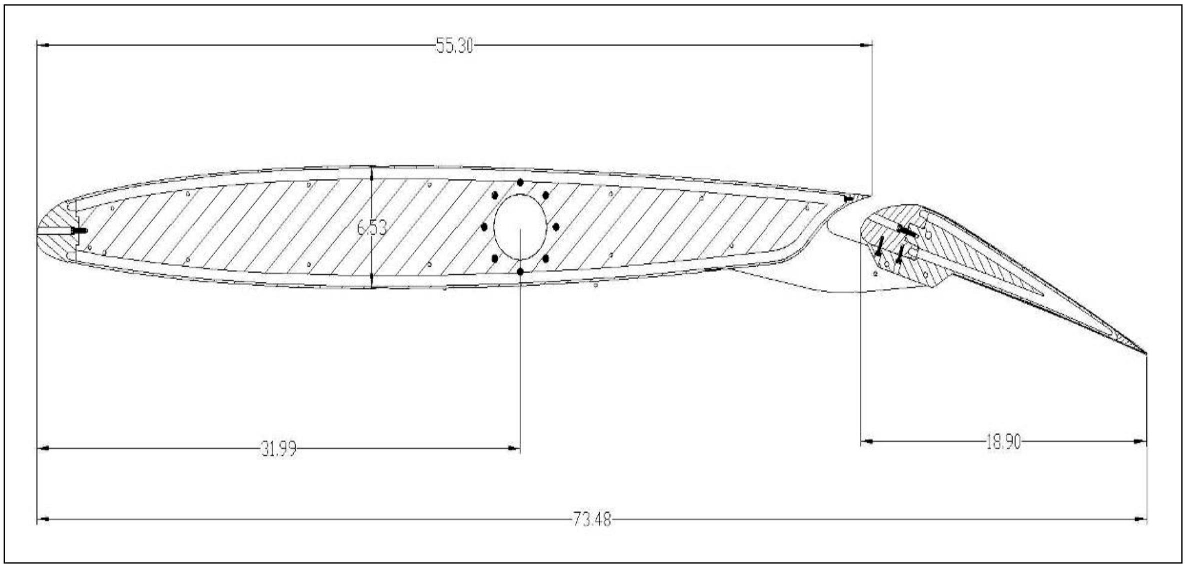


Figure 2.4: Wing Section

2.5.3 Wet Film Thickness Gauge

Wet film fluid thickness measurements were recorded during endurance time tests. Figure 2.6 shows the schematic of the wet film thickness gauges.

2.5.4 Brixometer

The Brixometer provides data relevant to the fluid concentration (Brix measurements) and monitors fluid dilution. Figure 2.7 shows a hand-held Brixometer.

2.6 Fluids

Commercially available Type I, II, III and IV fluids were used in this testing. For certain objectives, lowest-on-wing viscosity fluid samples were used.

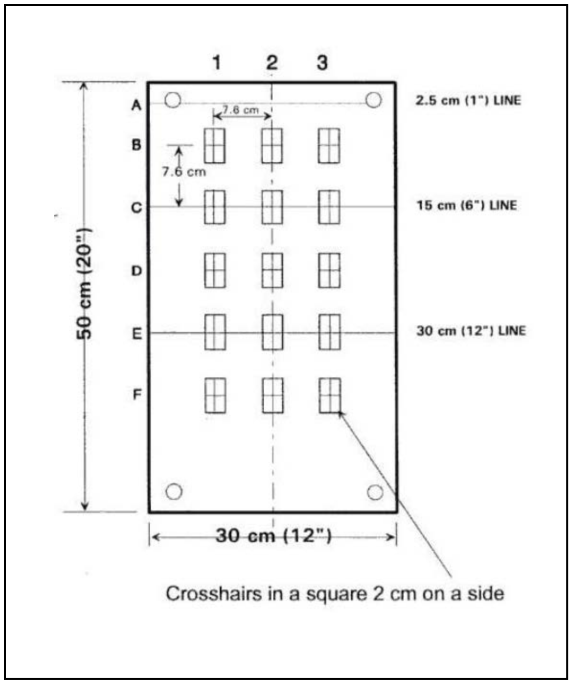


Figure 2.5: Schematic of Standard Holdover Time Test Plate

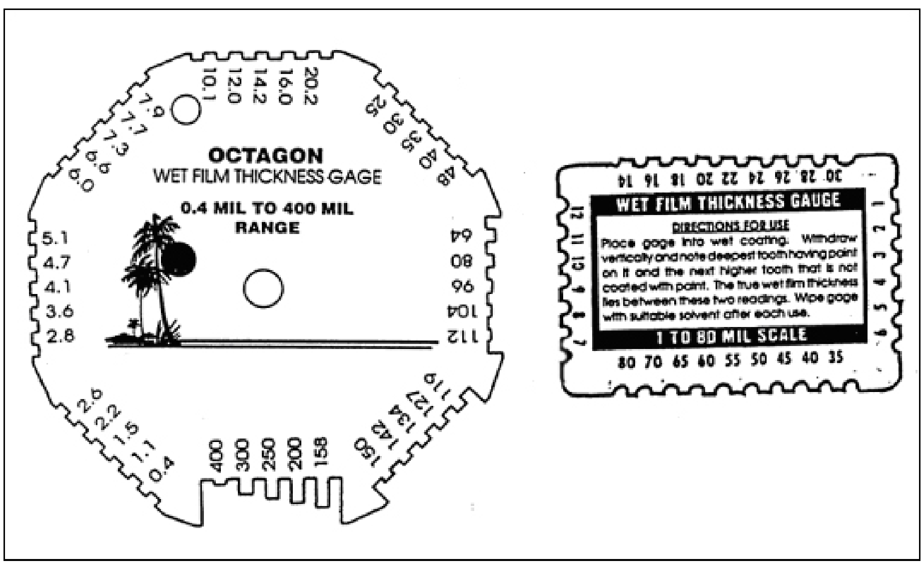


Figure 2.6: Wet Film Thickness Gauges

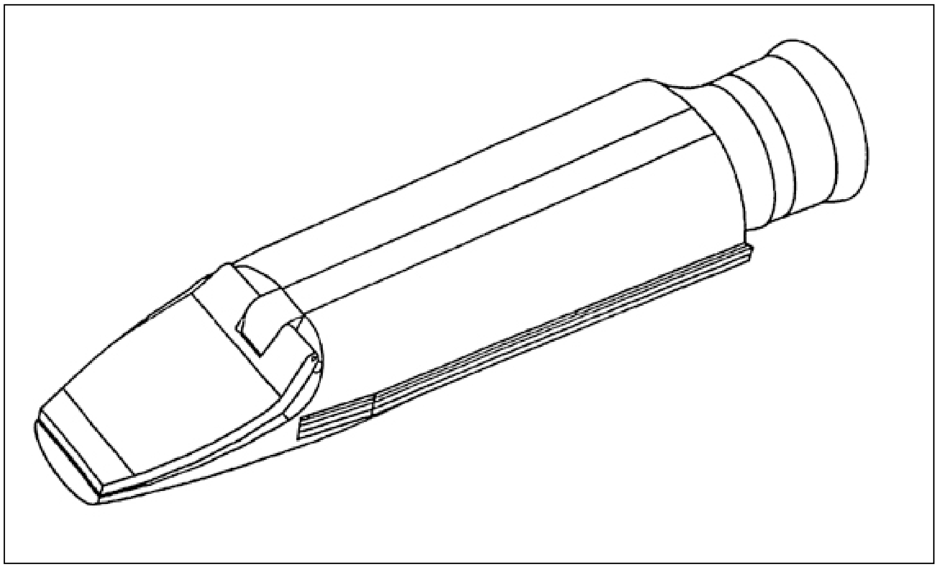


Figure 2.7: Hand-Held Brixometer

Photo 2.1: APS Test Site - View from Test Pad

Photo 2.2: APS Test Site - View from Trailer

Photo 2.3: Inside View of NRC Climate Engineering Facility

Photo 2.4: Sprayer Assembly Used to Produce Fine Droplets

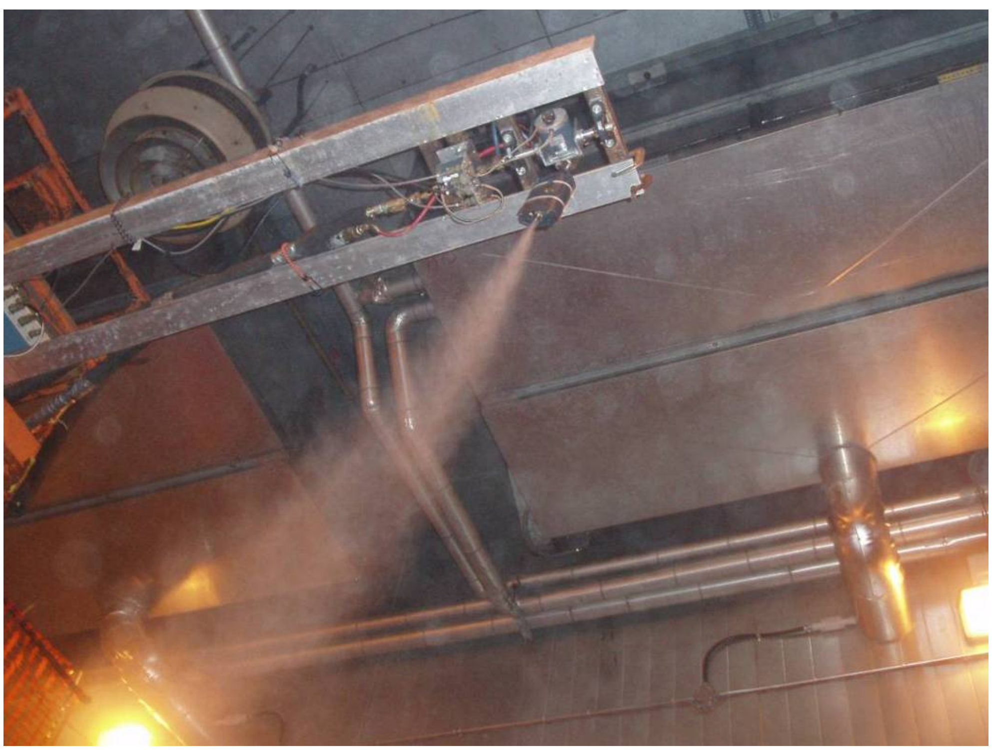


Photo 2.5: Outside View of NRC Wind Tunnel Facility

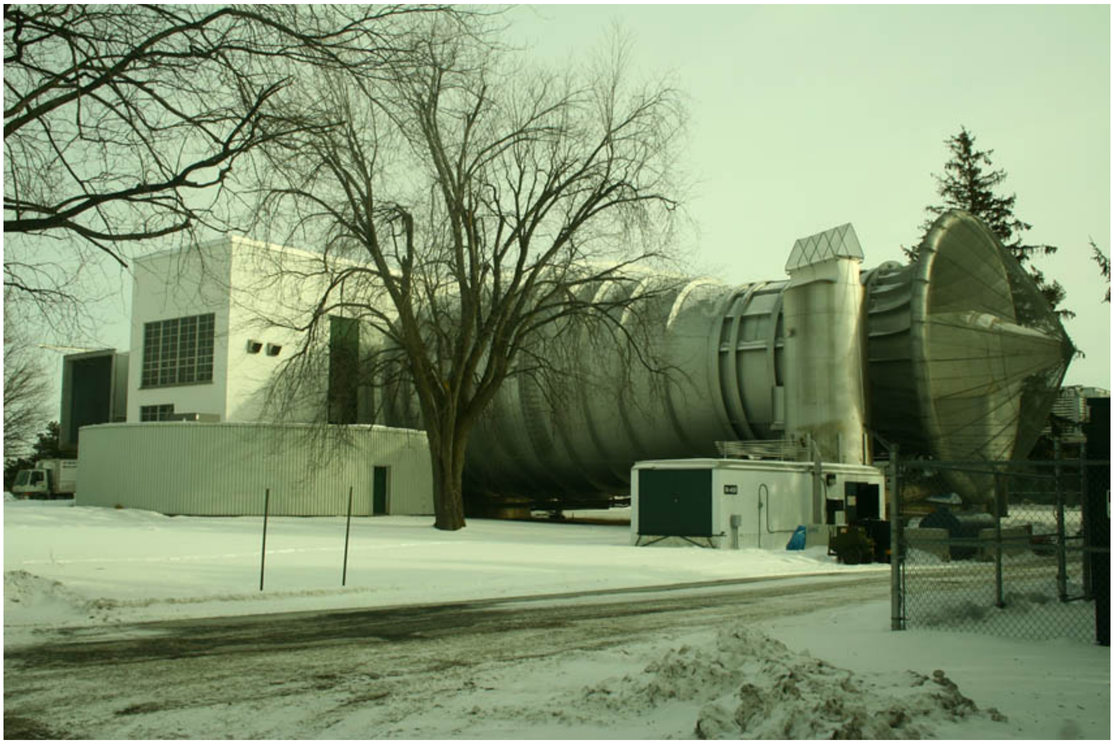


Photo 2.6: Inside View of NRC Wind Tunnel Test Section

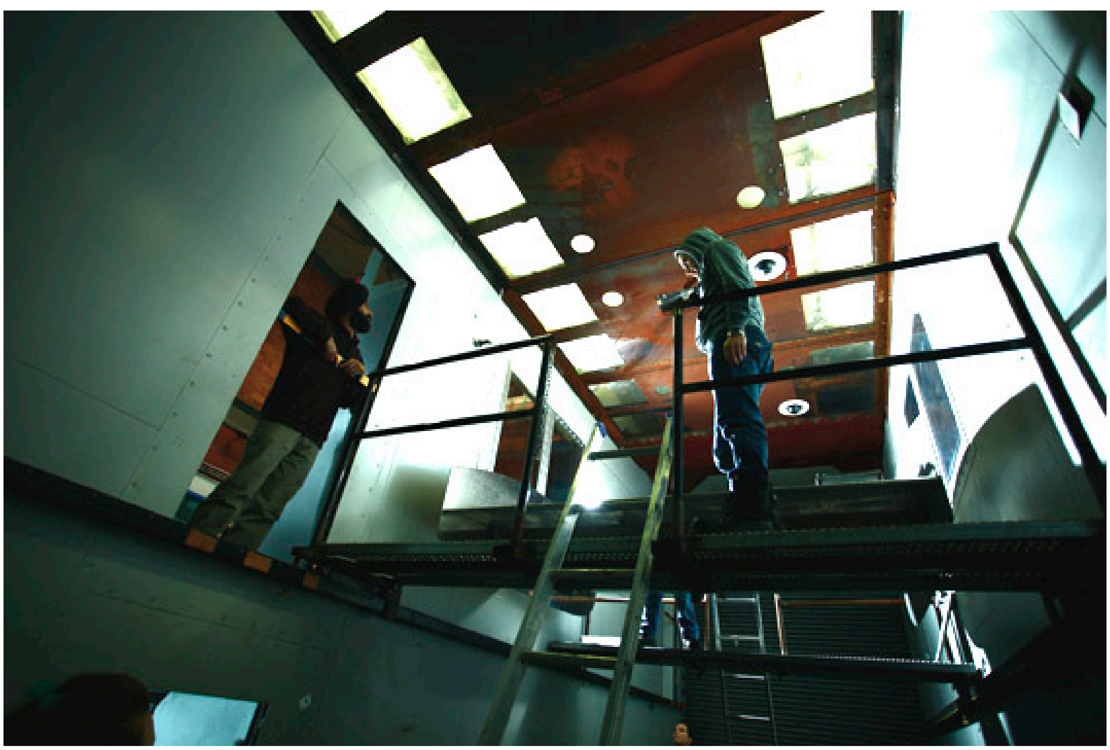


Photo 2.7: Smaller Test Plates for Residue Testing

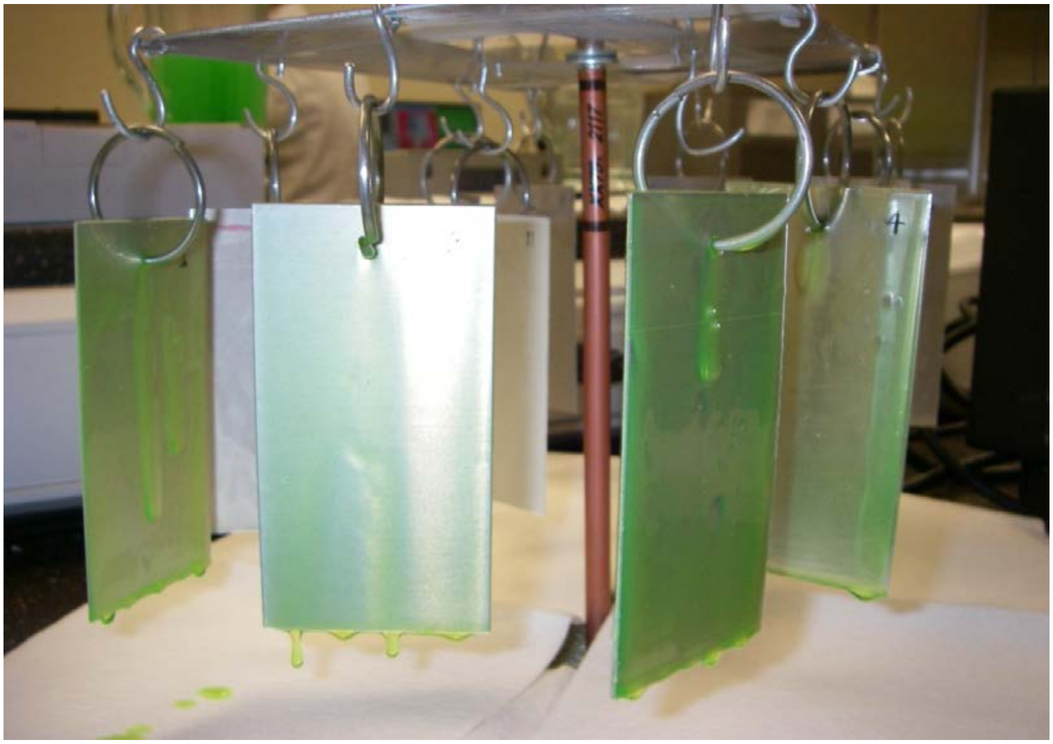
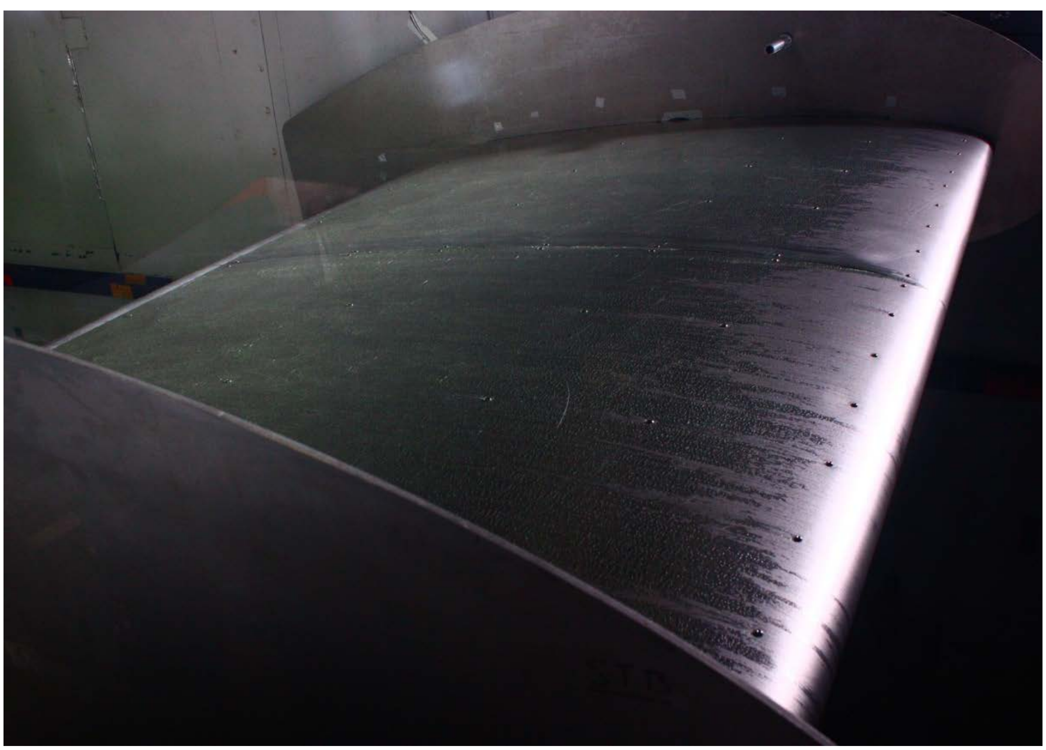


Photo 2.8: Custom Designed Wing Skin



3. ENDURANCE TIME TESTING DATA AND RESULTS

In this section, the endurance time testing data collected during the winter of 2012-13 is analysed and discussed. The treated surfaces were evaluated against the baseline plate to investigate potential adverse effects on fluid holdover times (HOT) when applied to surfaces treated with ice phobic products. Testing was conducted with the five new coatings:

- B12
- B13
- C3
- D1
- D2

Photo 3.1 and Photo 3.2 at the end of this chapter depict the setup for this testing.

3.1 Log of Endurance Time Tests Conducted

To facilitate the accessibility of the data collected, a log was created for the series of tests conducted by APS at the NRC CEF and at the P.E.T. airport site during the winter of 2012-13. The log presented in Table 3.1 and Table 3.2 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.

Table 3.1: Log of Simulated Precipitation Endurance Time Tests

Run #	Test #	Condition	Date	Fluid	Dilution	Surface	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Endurance Time (min)	Adjusted ET (min)	EC OAT (ºC)	Precip. Rate (g/dm²/h)	Thickness @ 5 min	Brix @ Fail
1	PH01	Light Freezing Rain	9-Apr-13	Octagon Octaflo EF	10°B (B=27.0)	Baseline	11:49:53	11:56:08	6.3	6.3	-10	12.6	n/a	n/a
	PH02	Light Freezing Rain	9-Apr-13	Octagon Octaflo EF	10°B (B=27.0)	B12	11:50:18	11:56:30	6.2	6.2	-10	12.6	n/a	n/a
	PH03	Light Freezing Rain	9-Apr-13	Octagon Octaflo EF	10°B (B=27.0)	B13	11:50:41	11:57:00	6.3	6.2	-10	12.4	n/a	n/a
	PH04	Light Freezing Rain	9-Apr-13	Octagon Octaflo EF	10°B (B=27.0)	C3	11:51:01	11:57:30	6.5	6.4	-10	12.4	n/a	n/a
	PH05	Light Freezing Rain	9-Apr-13	Octagon Octaflo EF	10°B (B=27.0)	D1	11:51:24	11:58:00	6.6	6.4	-10	12.3	n/a	n/a
	PH06	Light Freezing Rain	9-Apr-13	Octagon Octaflo EF	10°B (B=27.0)	D2	11:52:46	11:57:40	4.9	4.8	-10	12.4	n/a	n/a
2	PH07	Light Freezing Rain	9-Apr-13	AD-49	75/25	Baseline	11:06:59	11:40:00	33.0	33.0	-10	13.6	80.0	20.50
	PH08	Light Freezing Rain	9-Apr-13	AD-49 (WT)	75/25	B12	11:07:17	11:37:30	30.2	30.0	-10	13.5	80.0	22.00
	PH09	Light Freezing Rain	9-Apr-13	AD-49 (WT)	75/25	B13	11:07:38	11:37:30	29.9	28.3	-10	12.9	80.0	21.00
	PH10	Light Freezing Rain	9-Apr-13	AD-49 (WT)	75/25	C3	11:08:02	11:38:43	30.7	28.9	-10	12.8	80.0	21.50
	PH11	Light Freezing Rain	9-Apr-13	AD-49 (WT)	75/25	D1	11:08:25	11:37:30	29.1	27.6	-10	12.9	80.0	21.50
	PH12	Light Freezing Rain	9-Apr-13	AD-49 (WT)	75/25	D2	11:08:45	11:38:30	29.8	28.0	-10	12.8	70.0	21.00
3	PH13	Freezing Drizzle	8-Apr-13	Cryotech PGA	100/0	Baseline	13:35:10	14:00:10	25.0	25.0	-10	13.6	70.0	28.50
	PH14	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT)	100/0	B12	13:35:33	14:00:10	24.6	23.7	-10	13.1	70.0	25.50
	PH15	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT)	100/0	B13	13:35:56	14:00:10	24.2	22.5	-10	12.6	70.0	26.50
	PH16	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT)	100/0	C3	13:36:18	14:00:10	23.9	21.8	-10	12.4	70.0	26.50
	PH17	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT)	100/0	D1	13:36:47	14:00:10	23.4	21.8	-10	12.7	70.0	27.00
	PH18	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT)	100/0	D2	13:37:16	14:00:10	22.9	22.1	-10	13.1	70.0	26.50
4	PH19	Light Freezing Rain	8-Apr-13	Dow UCAR EG106	100/0	Baseline	16:47:55	17:38:00	50.1	50.1	-10	26.1	80.0	11.00
	PH20	Light Freezing Rain	8-Apr-13	Dow UCAR EG106	100/0	B12	16:48:23	17:37:00	48.6	48.4	-10	26.0	80.0	10.00
	PH21	Light Freezing Rain	8-Apr-13	Dow UCAR EG106	100/0	B13	16:49:03	17:37:30	48.5	47.3	-10	25.5	80.0	10.00
	PH22	Light Freezing Rain	8-Apr-13	Dow UCAR EG106	100/0	C3	16:49:34	17:42:00	52.4	50.4	-10	25.1	80.0	10.00
	PH23	Light Freezing Rain	8-Apr-13	Dow UCAR EG106	100/0	D1	16:50:11	17:42:00	51.8	50.0	-10	25.2	80.0	9.50
	PH24	Light Freezing Rain	8-Apr-13	Dow UCAR EG106	100/0	D2	16:50:48	17:44:00	53.2	50.8	-10	24.9	80.0	9.50
5	PH25	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	Baseline	8:52:58	9:05:54	12.9	12.9	-3	6.0	n/a	n/a
	PH26	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	B12	8:53:24	9:23:00	29.6	28.6	-3	5.8	n/a	n/a
	PH27	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	B13	8:53:50	9:23:00	29.2	26.7	-3	5.5	n/a	n/a
	PH28	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	C3	8:54:10	9:08:10	14.0	11.9	-3	5.1	n/a	n/a
	PH29	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	D1	8:54:31	9:09:30	15.0	12.2	-3	4.9	n/a	n/a
	PH30	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	D2	8:54:55	9:07:00	12.1	10.1	-3	5.0	n/a	n/a
	PH31	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	D2	9:30:28	9:45:00	14.5	14.5	-3	6.0	n/a	11.00

Table 3.1: Log of Simulated Precipitation Endurance Time Tests (cont'd)

Run #	Test #	Condition	Date	Fluid	Dilution	Surface	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Endurance Time (min)	Adjusted ET (min)	EC OAT (°C)	Precip. Rate (g/dm²/h)	Thickness @ 5 min	Brix @ Fail
6	FM08	Freezing Drizzle	10-Apr-13	Octagon Octaflo EF	10°B (B=21.25)	Baseline	10:14:59	10:30:40	15.7	15.7	-3	5.5	n/a	n/a
	PH32	Freezing Drizzle	10-Apr-13	Octagon Octaflo EF	10°B (B=21.25)	B12	9:30:50	10:08:00	37.2	39.2	-3	5.8	n/a	9.50
	PH33	Freezing Drizzle	10-Apr-13	Octagon Octaflo EF	10°B (B=21.25)	B13	9:31:12	10:08:00	36.8	36.8	-3	5.5	n/a	13.00
	PH34	Freezing Drizzle	10-Apr-13	Octagon Octaflo EF	10°B (B=21.25)	C3	9:31:30	9:47:45	16.2	15.1	-3	5.1	n/a	15.00
	PH35	Freezing Drizzle	10-Apr-13	Octagon Octaflo EF	10°B (B=21.25)	D1	9:31:53	9:48:00	16.1	14.4	-3	4.9	n/a	13.50
	PH36	Freezing Drizzle	10-Apr-13	Octagon Octaflo EF	10°B (B=21.25)	D2	9:32:19	9:45:15	12.9	11.8	-3	5.0	n/a	14.00
7	PH37	Freezing Drizzle	10-Apr-13	AD-49	50/50	Baseline	12:50:31	13:17:15	26.7	26.7	-3	13.9	45.0	4.50
	PH38	Freezing Drizzle	10-Apr-13	AD-49 (WT)	50/50	B12	12:50:49	13:17:25	26.6	25.5	-3	13.3	45.0	4.00
	PH39	Freezing Drizzle	10-Apr-13	AD-49 (WT)	50/50	B13	12:51:05	13:17:30	26.4	24.5	-3	12.9	45.0	3.00
	PH40	Freezing Drizzle	10-Apr-13	AD-49 (WT)	50/50	C3	12:51:22	13:16:00	24.6	22.7	-3	12.8	45.0	5.00
	PH41	Freezing Drizzle	10-Apr-13	AD-49 (WT)	50/50	D1	12:51:41	13:16:55	25.2	23.6	-3	13.0	45.0	5.00
	PH42	Freezing Drizzle	10-Apr-13	AD-49 (WT)	50/50	D2	12:51:57	13:16:55	25.0	23.9	-3	13.3	35.0	6.00
8	PH43	Light Freezing Rain	11-Apr-13	ABC-S Plus	75/25	Baseline	8:35:07	9:55:50	80.7	80.7	-3	25.0	134.0	3.00
	PH44	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT)	75/25	B12	8:35:27	9:44:30	69.0	68.2	-3	24.7	119.0	2.00
	PH45	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT)	75/25	B13	8:35:46	9:33:00	57.2	54.9	-3	24.0	119.0	5.50
	PH46	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT)	75/25	C3	8:36:06	9:55:25	79.3	76.1	-3	24.0	127.0	4.00
	PH47	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT)	75/25	D1	8:36:25	9:54:35	78.2	75.7	-3	24.2	127.0	4.00
	PH48	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT)	75/25	D2	8:36:46	9:50:40	73.9	72.1	-3	24.4	96.0	4.50
9	PH49	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	Baseline	13:27:27	13:42:05	14.6	14.6	-3	13.9	n/a	n/a
	PH50	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	B12	13:27:47	13:50:35	22.8	21.8	-3	13.3	n/a	n/a
	PH51	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	B13	13:28:11	13:54:25	26.2	24.3	-3	12.9	n/a	n/a
	PH52	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	C3	13:28:28	13:42:00	13.5	12.5	-3	12.8	n/a	n/a
	PH53	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	D1	13:28:47	13:39:20	10.5	9.9	-3	13.0	n/a	n/a
	PH54	Freezing Drizzle	10-Apr-13	Dow UCAR ADF (EG)	10°B (B=17.6)	D2	13:29:11	13:40:15	11.1	10.5	-3	13.2	n/a	n/a
10	PH-V01	Light Freezing Rain	9-Apr-13	AD-49	75/25	Baseline	11:09:20	11:36:30	27.2	27.2	-10	12.6	45.0	17.5
	PH-V02	Light Freezing Rain	9-Apr-13	AD-49 (WT LOWV)	75/25	B12	11:09:40	11:36:00	26.3	26.3	-10	12.6	40.0	17
	PH-V03	Light Freezing Rain	9-Apr-13	AD-49 (WT LOWV)	75/25	B13	11:10:02	11:36:30	26.5	26.0	-10	12.4	40.0	17
	PH-V04	Light Freezing Rain	9-Apr-13	AD-49 (WT LOWV)	75/25	C3	11:10:20	11:38:00	27.7	27.2	-10	12.4	45.0	17
	PH-V05	Light Freezing Rain	9-Apr-13	AD-49 (WT LOWV)	75/25	D1	11:10:40	11:38:20	27.7	27.0	-10	12.3	40.0	17
	PH-V06	Light Freezing Rain	9-Apr-13	AD-49 (WT LOWV)	75/25	D2	11:11:03	11:38:20	27.3	26.9	-10	12.4	40.0	17.5

Table 3.1: Log of Simulated Precipitation Endurance Time Tests (cont'd)

Run #	Test #	Condition	Date	Fluid	Dilution	Surface	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Endurance Time (min)	Adjusted ET (min)	EC OAT (°C)	Precip. Rate (g/dm²/h)	Thickness @ 5 min	Brix @ Fail
11	PH-V07	Freezing Drizzle	8-Apr-13	Cryotech PGA	100/0	Baseline	13:37:59	14:04:30	26.5	26.5	-10	13.8	65.0	26
	PH-V08	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT LOWV)	100/0	B12	13:38:25	14:04:30	26.1	25.7	-10	13.6	60.0	25
	PH-V09	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT LOWV)	100/0	B13	13:38:54	14:04:30	25.6	24.9	-10	13.4	60.0	25
	PH-V10	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT LOWV)	100/0	C3	13:39:19	14:04:30	25.2	24.5	-10	13.4	55.0	25.5
	PH-V11	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT LOWV)	100/0	D1	13:39:46	14:04:30	24.7	24.4	-10	13.6	60.0	25
	PH-V12	Freezing Drizzle	8-Apr-13	Cryotech PGA (WT LOWV)	100/0	D2	13:40:13	14:04:30	24.3	24.3	-10	13.8	55.0	25
12	PH-V13	Freezing Drizzle	10-Apr-13	AD-49	50/50	Baseline	12:52:28	13:04:20	11.9	11.9	-3	13.2	12.0	3.5
	PH-V14	Freezing Drizzle	10-Apr-13	AD-49 (WT LOWV)	50/50	B12	12:52:49	13:05:45	12.9	12.8	-3	13.1	12.0	4
	PH-V15	Freezing Drizzle	10-Apr-13	AD-49 (WT LOWV)	50/50	B13	12:53:08	13:05:45	12.6	12.6	-3	13.2	14.0	3
	PH-V16	Freezing Drizzle	10-Apr-13	AD-49 (WT LOWV)	50/50	C3	12:53:26	13:05:30	12.1	11.7	-3	12.8	14.0	3.5
	PH-V17	Freezing Drizzle	10-Apr-13	AD-49 (WT LOWV)	50/50	D1	12:53:44	13:05:00	11.3	11.4	-3	13.4	12.0	3.5
	PH-V18	Freezing Drizzle	10-Apr-13	AD-49 (WT LOWV)	50/50	D2	12:54:02	13:05:30	11.5	11.4	-3	13.1	12.0	3
13	PH-V19	Light Freezing Rain	11-Apr-13	ABC-S Plus	75/25	Baseline	8:37:59	9:02:05	24.1	24.1	-3	24.7	55.0	4.5
	PH-V20	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT LOWV)	75/25	B12	8:38:19	9:02:45	24.4	24.2	-3	24.5	55.0	5.25
	PH-V21	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT LOWV)	75/25	B13	8:38:37	9:03:35	25.0	24.4	-3	24.1	55.0	2.5
	PH-V22	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT LOWV)	75/25	C3	8:38:53	9:07:00	28.1	27.7	-3	24.3	60.0	5.5
	PH-V23	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT LOWV)	75/25	D1	8:39:12	9:04:00	24.8	24.4	-3	24.3	60.0	5.5
	PH-V24	Light Freezing Rain	11-Apr-13	ABC-S Plus (WT LOWV)	75/25	D2	8:39:32	9:07:00	27.5	26.5	-3	23.8	55.0	5.5

Table 3.2: Log of Natural Snow Endurance Time Tests

Run #	Date	Fluid/Dilution	Mid/Low Viscosity	Surface	Start Time (min)	End Time (min)	Endurance Time (min)	Adjusted ET	EC OAT (ºC)	Precip. Rate (g/dm²/h)	EC Wind Speed (km/h)	Thickness @ 5 min	Brix @ Fail
STANDARD ENDURANCE TIME TESTS													
1	27-Dec-12	Launch, 100/0	Mid	Baseline	7:29:28	8:20:00	50.5	50.5	-6.2	60.4	32	104	15.0
	27-Dec-12	Launch, 100/0	Mid	I-PH C3	7:29:50	8:20:00	50.2	50.3	-6.2	60.6	32	96	15.5
	27-Dec-12	Launch, 100/0	Mid	I-PH D1	7:30:10	8:20:00	49.8	50.0	-6.2	60.7	32	104	14.3
2	27-Dec-12	EG106-100/0	Mid	Baseline	8:44:42	9:13:00	28.3	28.3	-5.5	66.7	28	104	11.5
	27-Dec-12	EG106-100/0	Mid	I-PH C3	8:45:23	9:06:00	20.6	20.7	-5.5	67.1	28	80	N/A
	27-Dec-12	EG106-100/0	Mid	I-PH D1	8:45:51	9:10:00	24.2	24.3	-5.5	67.1	28	96	N/A
3	19-Feb-13	ABC-S+, 100/0	Mid	Baseline	19:17:10	21:11:00	113.8	113.8	-3.2	10.12	7	70	10.0
	19-Feb-13	ABC-S+, 100/0	Mid	I-PH B12	19:20:10	21:01:00	100.8	93.0	-3.3	9.33	7	80	12.0
	19-Feb-13	ABC-S+, 100/0	Mid	I-PH B13	19:20:30	21:00:00	99.5	91.5	-3.2	9.31	7	80	12.0
	19-Feb-13	ABC-S+, 100/0	Mid	I-PH C3	19:20:47	21:12:13	111.4	112.3	-3.2	10.2	7	80	11.5
	19-Feb-13	ABC-S+, 100/0	Mid	I-PH D1	19:21:11	21:06:00	104.8	98.9	-3.2	9.55	7	80	11.0
4	19-Feb-13	Launch, 100/0	Mid	Baseline	21:36:36	23:16:00	99.4	99.4	-1.1	20.66	16	70	7.0
	19-Feb-13	Launch, 100/0	Mid	I-PH B12	21:36:56	22:25:00	48.1	47.8	-1.4	20.55	13	70	7.5
	19-Feb-13	Launch, 100/0	Mid	I-PH B13	21:37:20	22:24:00	46.7	46.0	-1.4	20.36	16	70	7.5
	19-Feb-13	Launch, 100/0	Mid	I-PH C3	21:37:46	22:56:00	78.2	83.2	-1.1	21.96	16	70	7.0
	19-Feb-13	Launch, 100/0	Mid	I-PH D1	21:38:08	22:50:00	71.9	76.1	-1.1	21.87	16	80	5.0

Table 3.2: Log of Natural Snow Endurance Time Tests (cont'd)

Run #	Date	Fluid/Dilution	Mid/Low Viscosity	Surface	Start Time (min)	End Time (min)	Endurance Time (min)	Adjusted ET	EC OAT (°C)	Precip. Rate (g/dm²/h)	EC Wind Speed (km/h)	Thickness @ 5 min	Brix @ Fail
MID AND LOW VISCOSITY (INCLUDED AS ENDURANCE TIME TESTS)													
5	27-Dec-12	Launch, 100/0	Low	Baseline	10:17:27	11:02:17	44.8	44.8	-3.9	60.6	13	80	14.00
	27-Dec-12	Launch, 100/0	Low	I-PH C3	10:18:01	10:56:00	38.0	38.6	-3.9	61.5	13	80	14.00
6	27-Dec-12	Launch, 100/0	Mid	Baseline	10:15:39	11:08:25	52.8	52.2	-3.9	59.9	13	96	15.00
	27-Dec-12	Launch, 100/0	Mid	I-PH C3	10:16:10	11:06:14	50.1	48.8	-3.9	60.0	13	96	14.00
	27-Dec-12	Launch, 100/0	Mid	I-PH D1	10:16:43	11:00:00	43.3	43.6	-3.9	61.0	13	96	12.00
7	19-Jan-13	Launch, 100/0	Low	Baseline	2:46:40	4:54:00	127.3	127.3	-6.7	7.7	22	50	17.00
	19-Jan-13	Launch, 100/0	Low	I-PH B12	2:46:58	3:55:00	68.0	71.5	-6.9	8.0	23	45	15.50
	19-Jan-13	Launch, 100/0	Low	I-PH B13	2:47:21	3:57:00	69.7	73.0	-6.9	8.0	23	50	15.25
	19-Jan-13	Launch, 100/0	Low	I-PH C3	2:47:46	4:43:00	115.2	113.1	-6.7	7.5	22	55	16.00
	19-Jan-13	Launch, 100/0	Low	I-PH D1	2:48:10	4:44:00	115.8	113.7	-6.7	7.5	22	55	15.50
8	19-Jan-13	Launch, 100/0	Mid	Baseline	2:45:01	4:57:00	132.0	132.0	-6.7	7.7	22	70	17.25
	19-Jan-13	Launch, 100/0	Mid	I-PH B12	2:45:20	4:12:00	86.7	86.8	-6.9	7.7	23	70	15.25
	19-Jan-13	Launch, 100/0	Mid	I-PH B13	2:45:38	4:20:00	94.4	91.8	-6.9	7.5	23	70	15.25
	19-Jan-13	Launch, 100/0	Mid	I-PH C3	2:45:58	4:57:00	131.0	130.9	-6.7	7.7	22	70	18.00
	19-Jan-13	Launch, 100/0	Mid	I-PH D1	2:46:12	4:47:00	120.8	118.6	-6.7	7.6	22	70	15.50
9	19-Jan-13	ABC-S+, 100/0	Low	Baseline	5:28:38	7:07:00	98.4	98.4	-5.8	8.6	20	65	14.00
	19-Jan-13	ABC-S+, 100/0	Low	I-PH B12	5:29:08	6:38:00	68.9	66.9	-5.8	8.3	20	55	15.00
	19-Jan-13	ABC-S+, 100/0	Low	I-PH B13	5:29:39	6:39:00	69.4	67.3	-5.8	8.3	20	60	14.00
	19-Jan-13	ABC-S+, 100/0	Low	I-PH C3	5:30:22	7:02:00	91.6	91.5	-5.8	8.5	20	65	15.00
	19-Jan-13	ABC-S+, 100/0	Low	I-PH D1	5:30:45	6:46:45	76.0	74.3	-5.8	8.4	20	65	15.00
10	19-Jan-13	ABC-S+, 100/0	Mid	Baseline	5:25:50	7:35:00	129.2	129.2	-5.5	8.6	20	65	13.00
	19-Jan-13	ABC-S+, 100/0	Mid	I-PH B12	5:26:18	6:46:00	79.7	77.9	-5.8	8.4	20	55	15.00
	19-Jan-13	ABC-S+, 100/0	Mid	I-PH B13	5:26:50	6:43:00	76.2	74.0	-5.8	8.4	20	55	15.25
	19-Jan-13	ABC-S+, 100/0	Mid	I-PH C3	5:27:17	7:21:00	113.7	113.2	-5.8	8.6	20	60	13.50
	19-Jan-13	ABC-S+, 100/0	Mid	I-PH D1	5:27:47	7:08:00	100.2	99.2	-5.8	8.6	20	70	14.00

3.2 Data Analysis

The endurance time testing results were separated into three groups to provide a general summary of the results. The three test groupings are as follows:

- Natural Snow Testing with Type IV Fluids
- Freezing Precipitation Testing with Type IV Fluids
- Freezing Precipitation Testing with Type I Fluids

Figure 3.1 to Figure 3.3 indicate the endurance time results of ice phobic coated surfaces as compared to the baseline standard aluminum surface. The baseline surface is represented in the graph as 100 percent.

Fluid endurance time performance varied depending on individual coatings. Natural snow endurance times on coated surface with Type IV fluids were on average 75 percent of the baseline, ranging from 63 percent to 90 percent. Coating B12 and B13 sometimes demonstrated a different failure mechanism in which fluid was shed early allowing snow to bridge on the surface. However, the snow did not adhere to the surface.

Freezing precipitation endurance times on coated surface with Type IV fluids were on average 94 percent of the baseline, ranging from 92 to 96 percent.

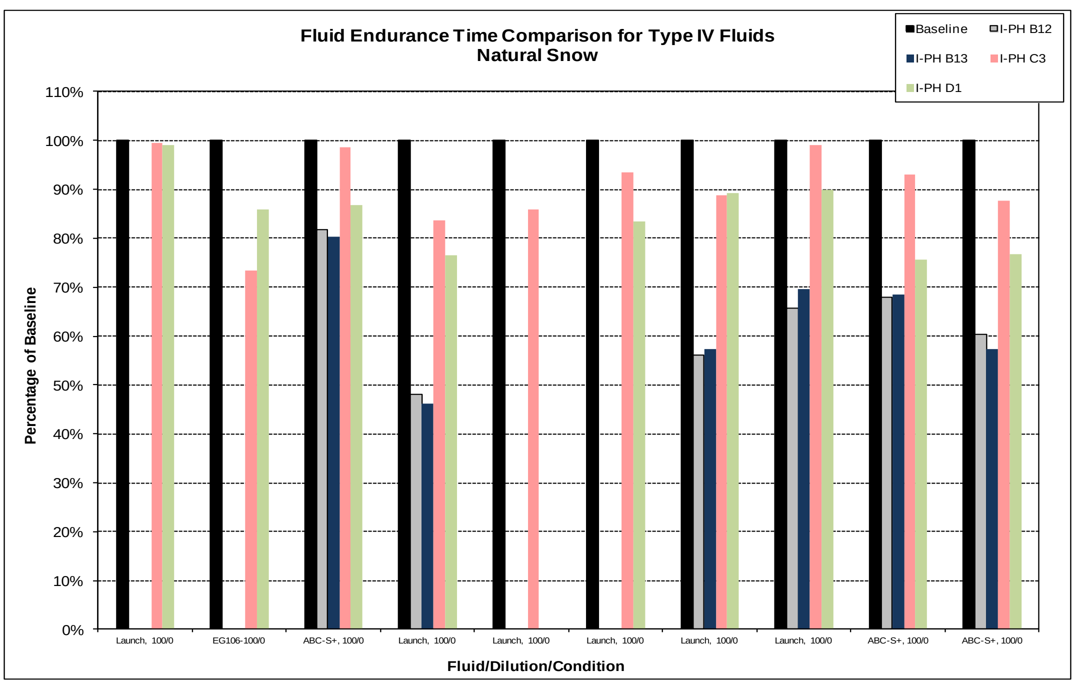


Figure 3.1: Fluid Endurance Time Comparison for Type IV Fluids – Natural Snow

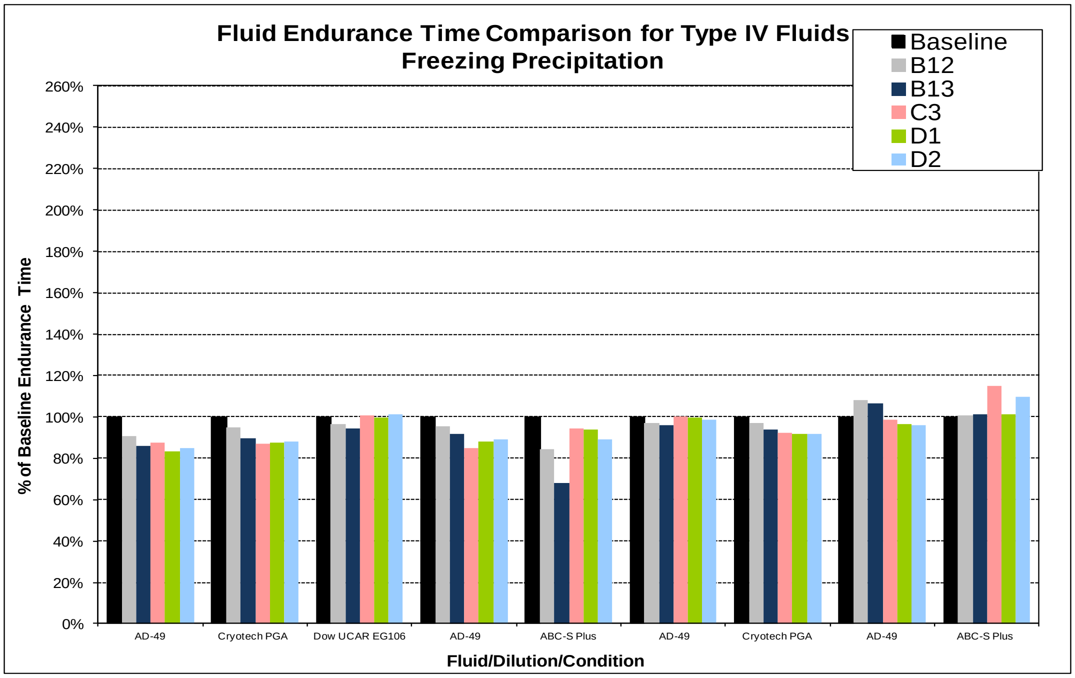


Figure 3.2: Fluid Endurance Time Comparison for Type IV Fluids – Freezing Precipitation

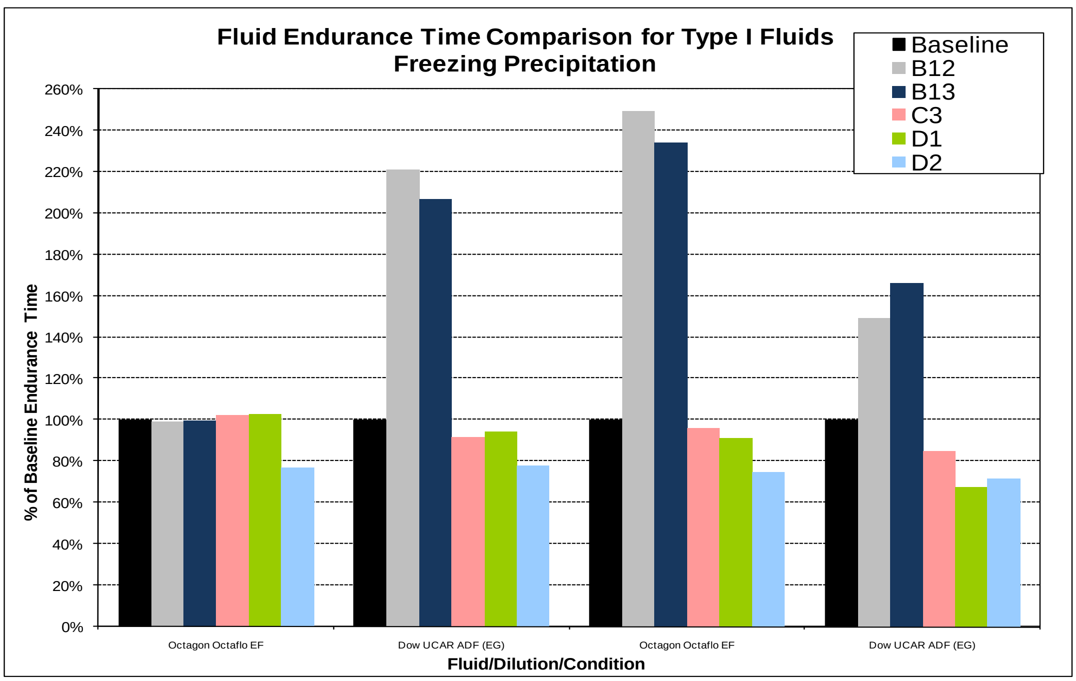


Figure 3.3: Fluid Endurance Time Comparison for Type I Fluids – Freezing Precipitation

Freezing precipitation endurance times on coated surface with Type I fluids demonstrated results similar to Type IV, with the exception of coating B12 and B13, which demonstrated different failure mechanisms. At -3°C, these coatings delayed ice from adhering to the surface, resulting in extended endurance times of 180 percent and 177 percent for B12 and B13, respectively.

3.3 General Observations

In general, endurance time performance depends on individual coatings. The fluid protection time when applied to coated surfaces was reduced. This reduction, however, was not significant. Table 3.3 depicts a summary of the results.

Table 3.3: Summary of Results

Coating	Average ET as Percentage of Baseline Aluminum Plate		
	Type IV Snow	Type IV ZP	Type I ZP
B12	63%*	96%	180%*
B13	63%*	92%	177%*
C3	90%	96%	94%
D1	86%	94%	89%
D2	n/a	94%	83%

*In some cases, fluid was shed from plate and had bare spots, however contamination did not adhere, or in the case of snow, was blown off the surface. The "fail time" was considered the time when ice present on those bare areas or in the fluid covered more than 33 percent of the plate.

This page intentionally left blank.

Photo 3.1: Test Stand Setup (Freezing Precipitation)

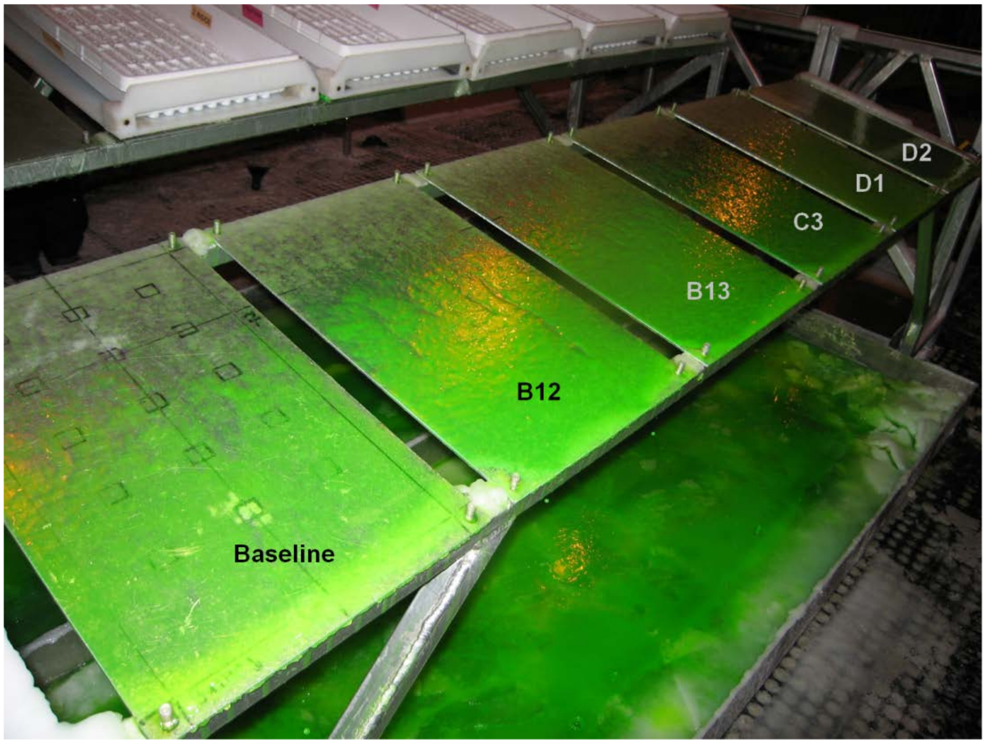


Photo 3.2: Test Stand Setup (Natural Snow)

This page intentionally left blank.

4. ADHERENCE TESTING DATA AND RESULTS

In this section, the adherence testing data collected during the winter of 2012-13 is analysed and discussed. The coated surfaces were evaluated against the baseline plate based on the potential to delay the onset of adherence when exposed to simulated freezing contamination. Testing was conducted in light freezing rain as this is considered a worst case scenario with regard to adhesion to surfaces.

4.1 Log of Adherence Tests Conducted

To facilitate the accessibility of the data collected, a log was created for the tests conducted by APS at the NRC CEF during the winter of 2012-13. The log presented in Table 4.1 provides relevant information for each of the tests, as well as the final values used for the data analysis. Each row contains data specific to one test.

Table 4.1: Log of Adherence Tests Conducted

Test #	Precip. Type	Temp (°C)	Precip. Rate (g/dm²/h)	Test Surface	Time: 30% Ice Coverage	Comments on Characteristics
PH-AD1	Light Freezing Rain	-10	12.7	Baseline	20 seconds	Instantly Froze, Flat Ice
PH-AD2	Light Freezing Rain	-10	12.6	B12	17 seconds	Slight Delay in freezing, beads of ice
PH-AD3	Light Freezing Rain	-10	12.7	B13	22 seconds	Slight Delay in freezing, beads of ice
PH-AD4	Light Freezing Rain	-10	12.6	C3	18 seconds	Slight Delay in freezing, beads of ice
PH-AD5	Light Freezing Rain	-10	12.7	D1	50 seconds	Not much difference to baseline
PH-AD6	Light Freezing Rain	-10	12.6	D2	50 seconds	Not much difference to baseline

4.2 Test Summary

Testing was completed with a baseline aluminum plate and five coated plates. Frozen ice was present on all plates seconds after exposure. There was a minimal delay observed with some of the coated plates.

Some differences in adhered contamination exist between the baseline and the coated plates with respect to the surface roughness of the plate after freezing. Photo 4.1 demonstrates the setup used in this testing and also indicates the findings of this testing.

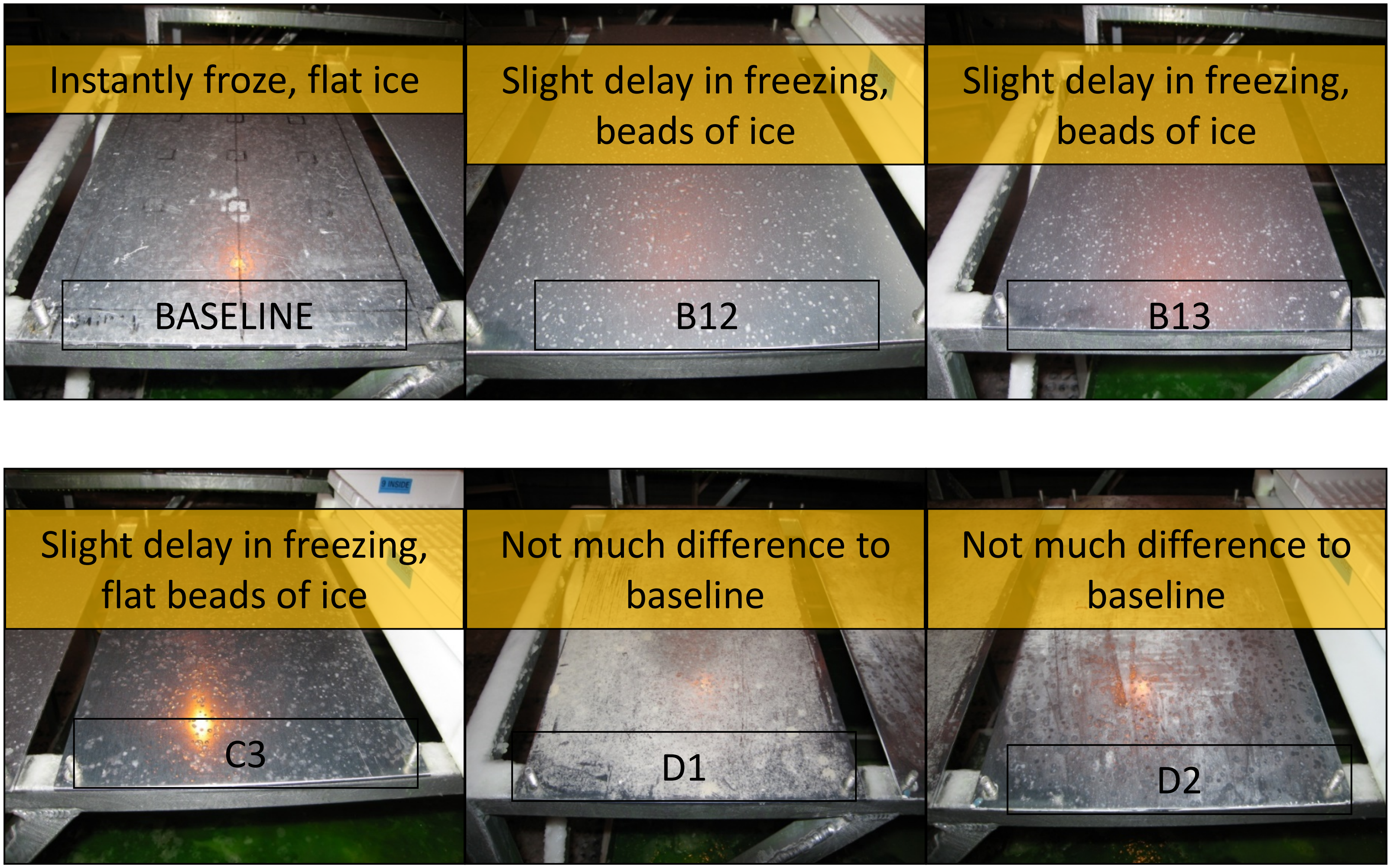
4.3 General Observations

When left undisturbed, the coated surfaces were able to delay the onset of adherence and ice formation, as compared to the baseline test plate. In addition, the removal of the contamination was easier on the coated surface.

Some concern remains with the ice formation on the coated surface. The coated surface typically results in bumpier, higher contact angle ice formations. Aerodynamic research to investigate the effects is recommended.

Similar trends were seen with other coatings from the same manufacturer.

Photo 4.1: Setup and Findings



This page intentionally left blank.

5. FLUID WETTING AND FLUID THICKNESS TESTING DATA AND RESULTS

In this section, the fluid thickness testing data collected during the winter of 2012-13 is analysed and discussed. The coated surface was evaluated against the baseline plate based on de/anti-icing fluid's ability to properly wet and provide appropriate fluid thickness when applied to the test surface. Testing was conducted at -3°C in non precipitation conditions at the NRC CEF. Fluid thickness was measured for the Type IV fluid test (fluid wetting was not necessary, as plate typically remains fully wetted). Fluid wetting was measured for Type I fluids because fluid thickness is not representative (thickness is usually in the range from 0 to 1 mm for all Type I fluids) and because wetting issues are more apparent due to the lack of fluid thickeners.

5.1 Log of Tests Conducted

To facilitate the accessibility of the data collected, a log was created for the tests conducted by APS at NRC CEF during the winter of 2012-13. The log presented in Table 5.1 and Table 5.2 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.

5.2 Test Summary

The Type I wetting tests indicated potential wetting problems with the coated test surfaces. Wetting issues were observed 5 minutes following fluid application; this wetting issue was worse with 10º buffer fluid as compared to standard mix fluid, which is more concentrated. It should be noted that during the endurance time tests with Type I fluids, in some cases the lack of wetting was offset by the ability of the coating to delay adherence, thereby generating longer protection times (see Photo 5.1).

With the exception of coating D1, the Type IV fluid thickness test (Photo 5.2) demonstrated minor degradation in fluid thickness 5-minutes after application. Coating D1 appeared to react chemically with the fluid and caused a reduction in thickness right from the start.

Table 5.1: Log of Type I Fluid Wetting Tests Conducted

Run #	Fluid Name	Fluid Type	Fluid Dilution	Test Surface	% of Plate Wetted @ 2 Min	% of Plate Wetted @ 5 Min	% of Plate Wetted @ 15 Min	% of Plate Wetted @ 30 Min
1	Type I EG - D	Type I EG	10ºC Buffer	**Baseline**	100	100	100	100
1	Type I EG - D	Type I EG	10ºC Buffer	**B-12**	95	90	85	25
1	Type I EG - D	Type I EG	10ºC Buffer	**B-13**	95	80	15	<5
1	Type I EG - D	Type I EG	10ºC Buffer	**C-3**	100	100	100	100
1	Type I EG - D	Type I EG	10ºC Buffer	**D-1**	95	90	80	70
1	Type I EG - D	Type I EG	10ºC Buffer	**D-2**	100	100	95	95
2	Type I EG - D	Type I EG	STD. MIX	**Baseline**	100	100	100	100
2	Type I EG - D	Type I EG	STD. MIX	**B-12**	95	90	80	50
2	Type I EG - D	Type I EG	STD. MIX	**B-13**	90	70	20	5
2	Type I EG - D	Type I EG	STD. MIX	**C-3**	100	100	100	100
2	Type I EG - D	Type I EG	STD. MIX	**D-1**	100	95	90	85
2	Type I EG - D	Type I EG	STD. MIX	**D-2**	100	100	100	100

Note: Testing was conducted at -3ºC

Table 5.2: Log of Type I Fluid Wetting Tests Conducted

Run #	Fluid Name	Fluid Type	Fluid Dilution	Test Surface	Thickness @ 2 min (mm)	Thickness @ 5 min (mm)	Thickness @ 20 min (mm)	Thickness @ 30 min (mm)
1	PG - C	Type IV PG	100/0	**Baseline**	1.2	1.0	0.6	0.6
1	PG - C	Type IV PG	100/0	**B12**	1.1	0.8	0.5	0.5
1	PG - C	Type IV PG	100/0	**B-13**	1.2	1.0	0.6	0.5
1	PG - C	Type IV PG	100/0	**C-3**	1.2	1.0	0.6	0.5
1	PG - C	Type IV PG	100/0	**D-1**	0.4*	0.3	0.1	0.1
1	PG - C	Type IV PG	100/0	**D-2**	1.2	1.0	0.6	0.6

Note: Testing was conducted at -3ºC
**A reaction seemed to occur when fluid was applied to Coating D-1. Was the first time the coated plate was exposed to fluid.*

Photo 5.1: Type I Fluid Wetting Test

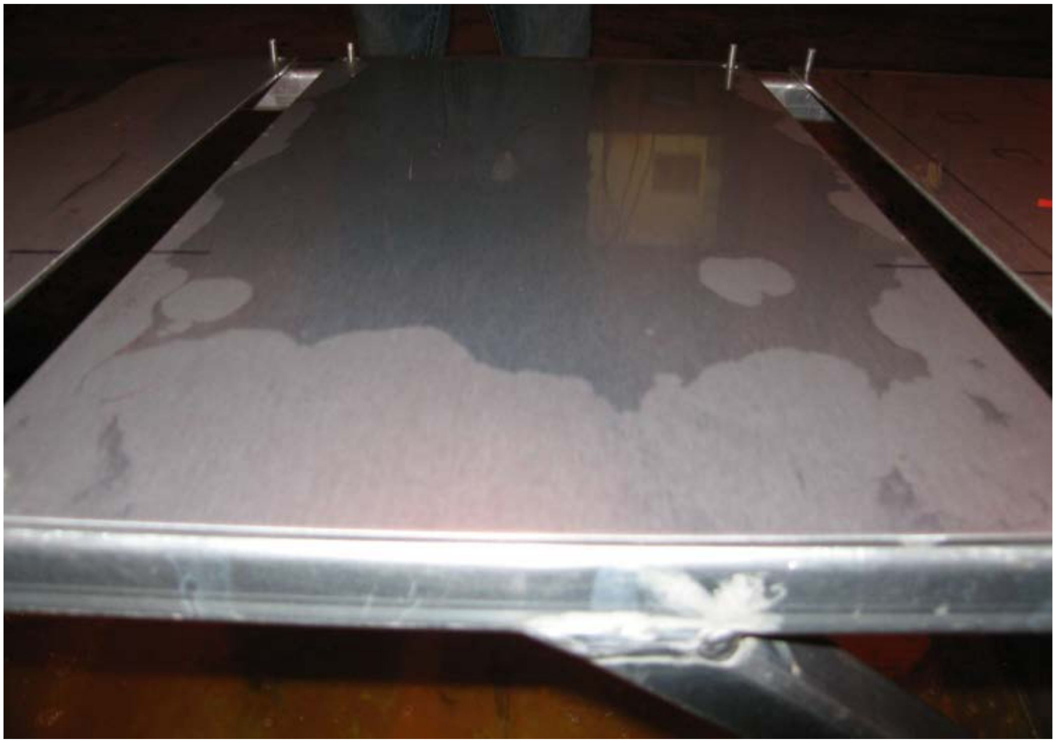
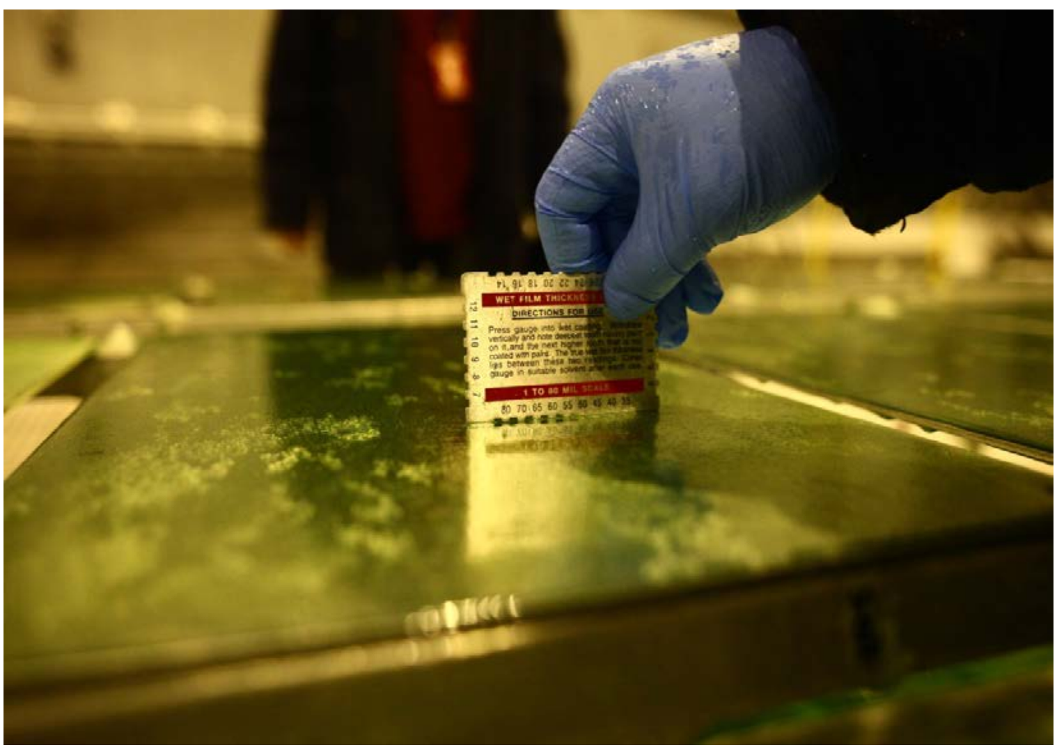


Photo 5.2: Type IV Fluid Thickness Test



This page intentionally left blank.

6. HOT WATER DEICING FOR COATINGS

Some coating manufacturers have indicated that, for the first-step of a two-step de/anti-icing process, it may be possible to use hot water as a substitute to glycol. This is due to the slope of the treated surface allowing water to slide off the wing before nucleating into ice. The same effect would happen if glycol was applied, leaving to question whether glycol would even be needed when deicing ice phobic surfaces. If effective, this could have significant environmental benefits.

In this section, the hot water testing data collected during the winter of 2012-13 is analysed and discussed. The coated surface (treated with hot water) was evaluated against the baseline plate (treated with Type I deicing fluid at a 10°C buffer).

6.1 Log of Hot Water Tests Conducted

To facilitate the accessibility of the data collected, a log was created for the tests conducted (two preliminary test runs were conducted) by APS at NRC CEF during the winter of 2012-13. The log presented in Table 6.1 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. Tests were conducted on April 5 and April 9, 2013.

Table 6.1: Log of Hot Water Tests Conducted

Run #	Test #	Condition	Fluid	Surface	Fluid Dilution	Endurance Time (min)	Adjusted Endurance Time (min)	Actual Rate of Precip (g/dm²/hr)	Ambient Temp (°C)
1	PH-HW7	Freezing Drizzle	Octagon Octaflo EF	Baseline	10°B (B =27.0)	6.5	6.5	6.1	-10
	PH-HW8	Freezing Drizzle	Hot Water (1L @20°C)	B12	n/a	5.2	5.1	6.0	-10
	PH-HW9	Freezing Drizzle	Hot Water (1L @20°C)	B13	n/a	6.9	6.9	6.1	-10
	PH-HW10	Freezing Drizzle	Hot Water (1L @20°C)	C3	n/a	6.2	6.1	6.0	-10
	PH-HW11	Freezing Drizzle	Hot Water (1L @20°C)	D1	n/a	5.8	5.8	6.1	-10
	PH-HW12	Freezing Drizzle	Hot Water (1L @20°C)	D2	n/a	5.2	5.1	6.0	-10
2	PH-HW1	Freezing Fog	Octagon Octaflo EF	Baseline	10°B (B =27.0)	3.1	3.1	1.9	-10
	PH-HW2	Freezing Fog	Hot Water (1L @20°C)	B12	n/a	3.1	3.0	1.8	-10
	PH-HW3	Freezing Fog	Hot Water (1L @20°C)	B13	n/a	3.2	3.2	1.9	-10
	PH-HW4	Freezing Fog	Hot Water (1L @20°C)	C3	n/a	3.6	3.4	1.8	-10
	PH-HW5	Freezing Fog	Hot Water (1L @20°C)	D1	n/a	3.7	3.7	1.9	-10
	PH-HW6	Freezing Fog	Hot Water (1L @20°C)	D2	n/a	3.5	3.3	1.8	-10

6.2 Test Summary

Testing was conducted at -10°C in both freezing drizzle and freezing fog. Both Type I and hot water were applied according to the standard of 1 litre with a fluid temperature of 20°C. Figure 6.1 demonstrates the two tests conducted.

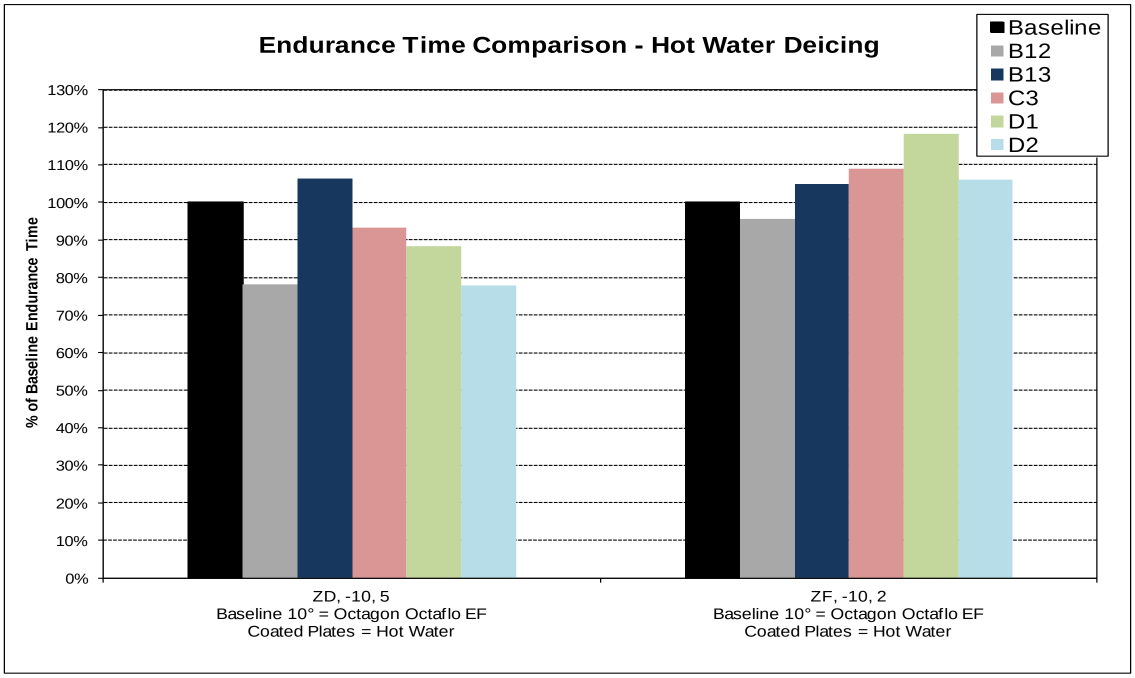


Figure 6.1: Hot Water Deicing Results

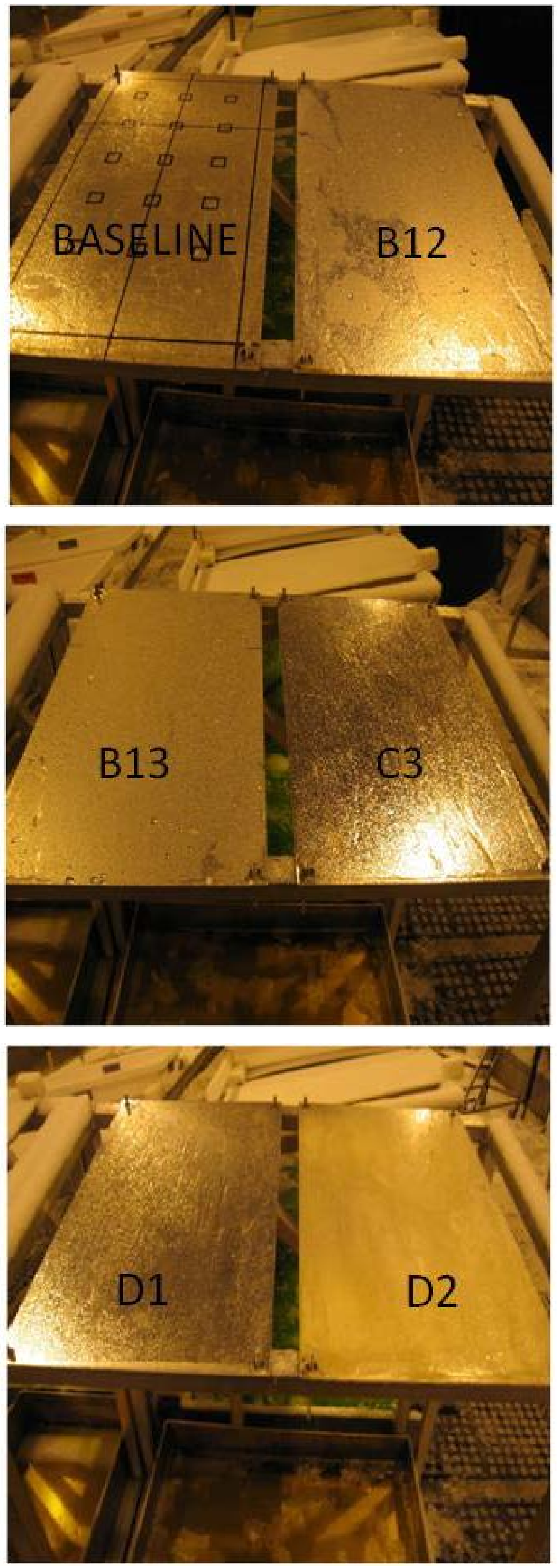
6.3 General Observations

The hot water endurance times on the coated surfaces were generally comparable to the Type I endurance times on the baseline plate. In some cases, the coated surfaces delayed the onset of adhered contamination and provided longer protection times.

Additional testing in all test conditions is suggested to further investigate coatings with hot water deicing.

Photo 6.1 depicts the plates under freezing drizzle conditions. All plates formed ice by the end of the test. Coated plates tended to have beads of ice, whereas the baseline plate had a smooth layer of ice.

Photo 6.1: Run 1: Freezing Drizzle Test



This page intentionally left blank.

7. EFFECT OF FLUID VISCOSITY ON ICE PHOBIC TREATED MATERIALS

In the development of AIR6232, the question was raised as to whether lowest on-wing viscosity fluid or mid-viscosity fluid should be used for evaluation of endurance times on coated surfaces. Moreover, would differences in endurance time be affected by fluid viscosity? Limited testing in both natural snow and simulated freezing conditions were completed to investigate this.

7.1 Log of Fluid Viscosity Tests Conducted

To facilitate the accessibility of the data collected, a log was created for the tests conducted by APS during the winter of 2012-13. The log presented in Table 7.1 provides relevant information for each of the tests, as well as final values used for the data analysis. The log shows all the tests grouped into sets which are separated by a solid line.

This log and the subsequent analysis in Section 7.2 contains/uses the adjusted endurance time for each test to compensate for rated differences. The precipitation rate of the low viscosity aluminum test was used as the basis for ET adjustment.

Table 7.1: Log of Fluid Viscosity Tests Conducted

Test #	Date	Precip Type General	Fluid/Dilution	Dilution	Low/Mid Viscosity	Surface	Endurance Time (min)	Adjusted Endurance Time (min)	EC OAT (°C)	Precip. Rate (g/dm²/h)
SN 1	27-Dec-12	SN	Launch, 100/0	100%	Mid	Baseline	52.8	52.2	-3.9	59.9
SN 2	27-Dec-12	SN	Launch, 100/0	100%	Mid	I-PH C3	50.1	49.5	-3.9	60.0
SN 3	27-Dec-12	SN	Launch, 100/0	100%	Mid	I-PH D1	43.3	43.5	-3.9	61.0
SN 4	27-Dec-12	SN	Launch, 100/0	100%	Low	Baseline	44.8	44.8	-3.9	60.6
SN 5	27-Dec-12	SN	Launch, 100/0	100%	Low	I-PH C3	38.0	38.5	-3.9	61.5
SN 6	19-Jan-13	SN	Launch, 100/0	100%	Mid	Baseline	132.0	133.0	-6.7	7.7
SN 7	19-Jan-13	SN	Launch, 100/0	100%	Low	Baseline	127.3	127.3	-6.7	7.7
SN 8	19-Jan-13	SN	Launch, 100/0	100%	Mid	I-PH B12	86.7	87.5	-6.9	7.7
SN 9	19-Jan-13	SN	Launch, 100/0	100%	Low	I-PH B12	68.0	71.5	-6.9	8.0
SN 10	19-Jan-13	SN	Launch, 100/0	100%	Mid	I-PH B13	94.4	92.5	-6.9	7.5
SN 11	19-Jan-13	SN	Launch, 100/0	100%	Low	I-PH B13	69.7	73.0	-6.9	8.0
SN 12	19-Jan-13	SN	Launch, 100/0	100%	Mid	I-PH C3	131.0	131.9	-6.7	7.7
SN 13	19-Jan-13	SN	Launch, 100/0	100%	Low	I-PH C3	115.2	113.1	-6.7	7.5
SN 14	19-Jan-13	SN	Launch, 100/0	100%	Mid	I-PH D1	120.8	119.5	-6.7	7.6
SN 15	19-Jan-13	SN	Launch, 100/0	100%	Low	I-PH D1	115.8	113.7	-6.7	7.5
SN 16	19-Jan-13	SN	ABC-S+, 100/0	100%	Mid	Baseline	129.2	130.5	-5.5	8.6
SN 17	19-Jan-13	SN	ABC-S+, 100/0	100%	Low	Baseline	98.4	98.4	-5.8	8.6
SN 18	19-Jan-13	SN	ABC-S+, 100/0	100%	Mid	I-PH B12	79.7	78.7	-5.8	8.4
SN 19	19-Jan-13	SN	ABC-S+, 100/0	100%	Low	I-PH B12	68.9	66.9	-5.8	8.3
SN 20	19-Jan-13	SN	ABC-S+, 100/0	100%	Mid	I-PH B13	76.2	74.7	-5.8	8.4
SN 21	19-Jan-13	SN	ABC-S+, 100/0	100%	Low	I-PH B13	69.4	67.3	-5.8	8.3
SN 22	19-Jan-13	SN	ABC-S+, 100/0	100%	Mid	I-PH C3	113.7	114.4	-5.8	8.6
SN 23	19-Jan-13	SN	ABC-S+, 100/0	100%	Low	I-PH C3	91.6	91.5	-5.8	8.5
SN 24	19-Jan-13	SN	ABC-S+, 100/0	100%	Mid	I-PH D1	100.2	100.2	-5.8	8.6
SN 25	19-Jan-13	SN	ABC-S+, 100/0	100%	Low	I-PH D1	76.0	74.3	-5.8	8.4
PH07	9-Apr-13	ZR	AD-49 (WT)	75/25	Mid	Baseline	33.0	35.6	-10	13.6
PH08	9-Apr-13	ZR	AD-49 (WT)	75/25	Mid	B12	30.2	32.4	-10	13.5
PH09	9-Apr-13	ZR	AD-49 (WT)	75/25	Mid	B13	29.9	30.6	-10	12.9
PH10	9-Apr-13	ZR	AD-49 (WT)	75/25	Mid	C3	30.7	31.2	-10	12.8
PH11	9-Apr-13	ZR	AD-49 (WT)	75/25	Mid	D1	29.1	29.8	-10	12.9
PH12	9-Apr-13	ZR	AD-49 (WT)	75/25	Mid	D2	29.8	30.2	-10	12.8
PH13	8-Apr-13	ZD	Cryotech PGA (WT)	100/0	Mid	Baseline	25.0	24.6	-10	13.6
PH14	8-Apr-13	ZD	Cryotech PGA (WT)	100/0	Mid	B12	24.6	23.4	-10	13.1
PH15	8-Apr-13	ZD	Cryotech PGA (WT)	100/0	Mid	B13	24.2	22.1	-10	12.6
PH16	8-Apr-13	ZD	Cryotech PGA (WT)	100/0	Mid	C3	23.9	21.4	-10	12.4
PH17	8-Apr-13	ZD	Cryotech PGA (WT)	100/0	Mid	D1	23.4	21.5	-10	12.7
PH18	8-Apr-13	ZD	Cryotech PGA (WT)	100/0	Mid	D2	22.9	21.7	-10	13.1
PH37	10-Apr-13	ZD	AD-49 (WT)	50/50	Mid	Baseline	26.7	28.2	-3	13.9
PH38	10-Apr-13	ZD	AD-49 (WT)	50/50	Mid	B12	26.6	26.8	-3	13.3
PH39	10-Apr-13	ZD	AD-49 (WT)	50/50	Mid	B13	26.4	25.8	-3	12.9
PH40	10-Apr-13	ZD	AD-49 (WT)	50/50	Mid	C3	24.6	23.9	-3	12.8
PH41	10-Apr-13	ZD	AD-49 (WT)	50/50	Mid	D1	25.2	24.9	-3	13.0
PH42	10-Apr-13	ZD	AD-49 (WT)	50/50	Mid	D2	25.0	25.2	-3	13.3
PH43	11-Apr-13	ZR	ABC-S Plus (WT)	75/25	Mid	Baseline	80.7	81.7	-3	25.0
PH44	11-Apr-13	ZR	ABC-S Plus (WT)	75/25	Mid	B12	69.0	69.0	-3	24.7
PH45	11-Apr-13	ZR	ABC-S Plus (WT)	75/25	Mid	B13	57.2	55.6	-3	24.0
PH46	11-Apr-13	ZR	ABC-S Plus (WT)	75/25	Mid	C3	79.3	77.1	-3	24.0
PH47	11-Apr-13	ZR	ABC-S Plus (WT)	75/25	Mid	D1	78.2	76.6	-3	24.2
PH48	11-Apr-13	ZR	ABC-S Plus (WT)	75/25	Mid	D2	73.9	73.0	-3	24.4

Table 7.1: Log of Fluid Viscosity Tests Conducted (cont'd)

Test #	Date	Precip Type General	Fluid/Dilution	Dilution	Low/Mid Viscosity	Surface	Endurance Time (min)	Adjusted Endurance Time (min)	EC OAT (°C)	Precip. Rate (g/dm²/h)
PH-V01	9-Apr-13	ZR	AD-49 (WT LOWV)	75/25	Low	Baseline	27.2	27.2	-10	12.6
PH-V02	9-Apr-13	ZR	AD-49 (WT LOWV)	75/25	Low	B12	26.3	26.3	-10	12.6
PH-V03	9-Apr-13	ZR	AD-49 (WT LOWV)	75/25	Low	B13	26.5	26.0	-10	12.4
PH-V04	9-Apr-13	ZR	AD-49 (WT LOWV)	75/25	Low	C3	27.7	27.2	-10	12.4
PH-V05	9-Apr-13	ZR	AD-49 (WT LOWV)	75/25	Low	D1	27.7	27.0	-10	12.3
PH-V06	9-Apr-13	ZR	AD-49 (WT LOWV)	75/25	Low	D2	27.3	26.9	-10	12.4
PH-V07	8-Apr-13	ZD	Cryotech PGA (WT LOWV)	100/0	Low	Baseline	26.5	26.5	-10	13.8
PH-V08	8-Apr-13	ZD	Cryotech PGA (WT LOWV)	100/0	Low	B12	26.1	25.7	-10	13.6
PH-V09	8-Apr-13	ZD	Cryotech PGA (WT LOWV)	100/0	Low	B13	25.6	24.9	-10	13.4
PH-V10	8-Apr-13	ZD	Cryotech PGA (WT LOWV)	100/0	Low	C3	25.2	24.5	-10	13.4
PH-V11	8-Apr-13	ZD	Cryotech PGA (WT LOWV)	100/0	Low	D1	24.7	24.4	-10	13.6
PH-V12	8-Apr-13	ZD	Cryotech PGA (WT LOWV)	100/0	Low	D2	24.3	24.3	-10	13.8
PH-V13	10-Apr-13	ZD	AD-49 (WT LOWV)	50/50	Low	Baseline	11.9	11.9	-3	13.2
PH-V14	10-Apr-13	ZD	AD-49 (WT LOWV)	50/50	Low	B12	12.9	12.8	-3	13.1
PH-V15	10-Apr-13	ZD	AD-49 (WT LOWV)	50/50	Low	B13	12.6	12.6	-3	13.2
PH-V16	10-Apr-13	ZD	AD-49 (WT LOWV)	50/50	Low	C3	12.1	11.7	-3	12.8
PH-V17	10-Apr-13	ZD	AD-49 (WT LOWV)	50/50	Low	D1	11.3	11.4	-3	13.4
PH-V18	10-Apr-13	ZD	AD-49 (WT LOWV)	50/50	Low	D2	11.5	11.4	-3	13.1
PH-V19	11-Apr-13	ZR	ABC-S Plus (WT LOWV)	75/25	Low	Baseline	24.1	24.1	-3	24.7
PH-V20	11-Apr-13	ZR	ABC-S Plus (WT LOWV)	75/25	Low	B12	24.4	24.2	-3	24.5
PH-V21	11-Apr-13	ZR	ABC-S Plus (WT LOWV)	75/25	Low	B13	25.0	24.4	-3	24.1
PH-V22	11-Apr-13	ZR	ABC-S Plus (WT LOWV)	75/25	Low	C3	28.1	27.7	-3	24.3
PH-V23	11-Apr-13	ZR	ABC-S Plus (WT LOWV)	75/25	Low	D1	24.8	24.4	-3	24.3
PH-V24	11-Apr-13	ZR	ABC-S Plus (WT LOWV)	75/25	Low	D2	27.5	26.5	-3	23.8

7.2 Test Methodology and Summary

The methodology in this testing was to compare the endurance time ratio between low and mid-viscosity on coated plates to the endurance time ratio between low and mid-viscosity on baseline aluminum plates. Figure 7.1 depicts this methodology. Photo 7.1 depicts the test plate setup for this testing.

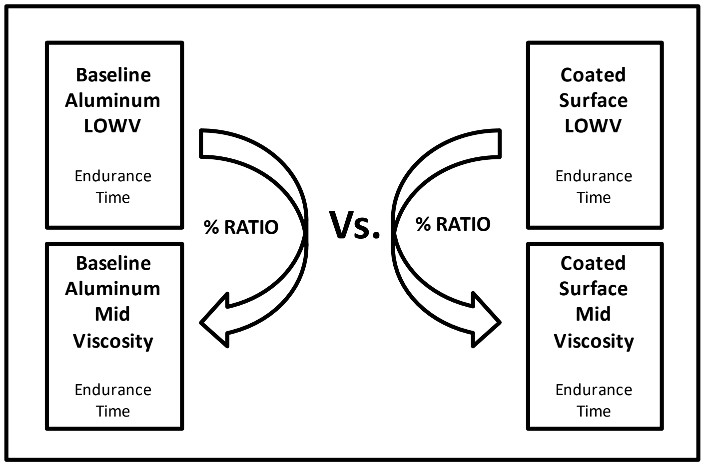


Figure 7.1: Testing Methodology

Figure 7.2 graphically demonstrates that there is minimal difference between the baseline ratio and the coatings ratio. Figure 7.3 separates the analysis by coating.

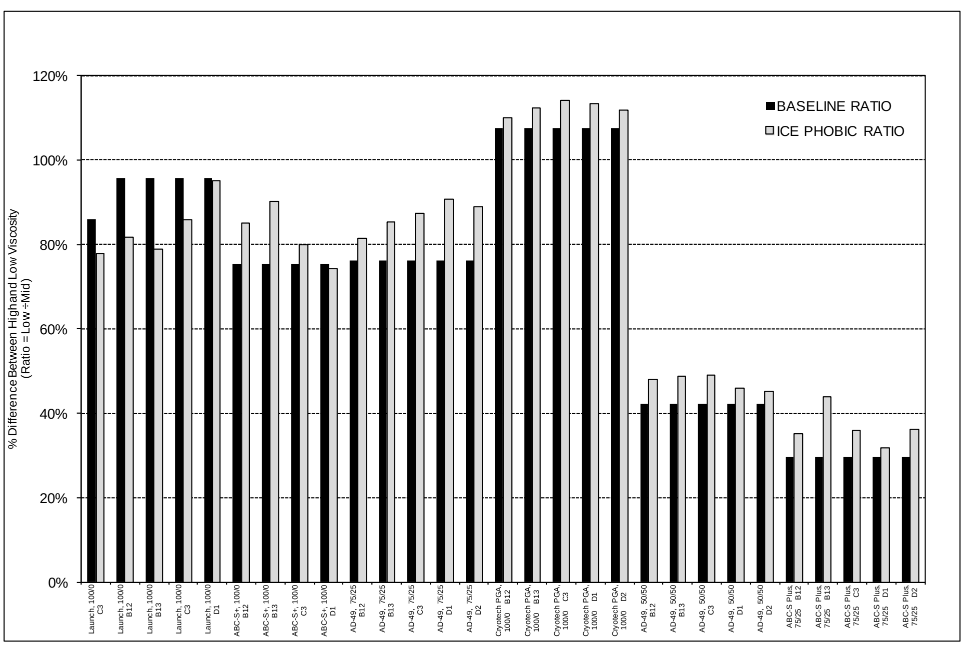


Figure 7.2: Testing Methodology

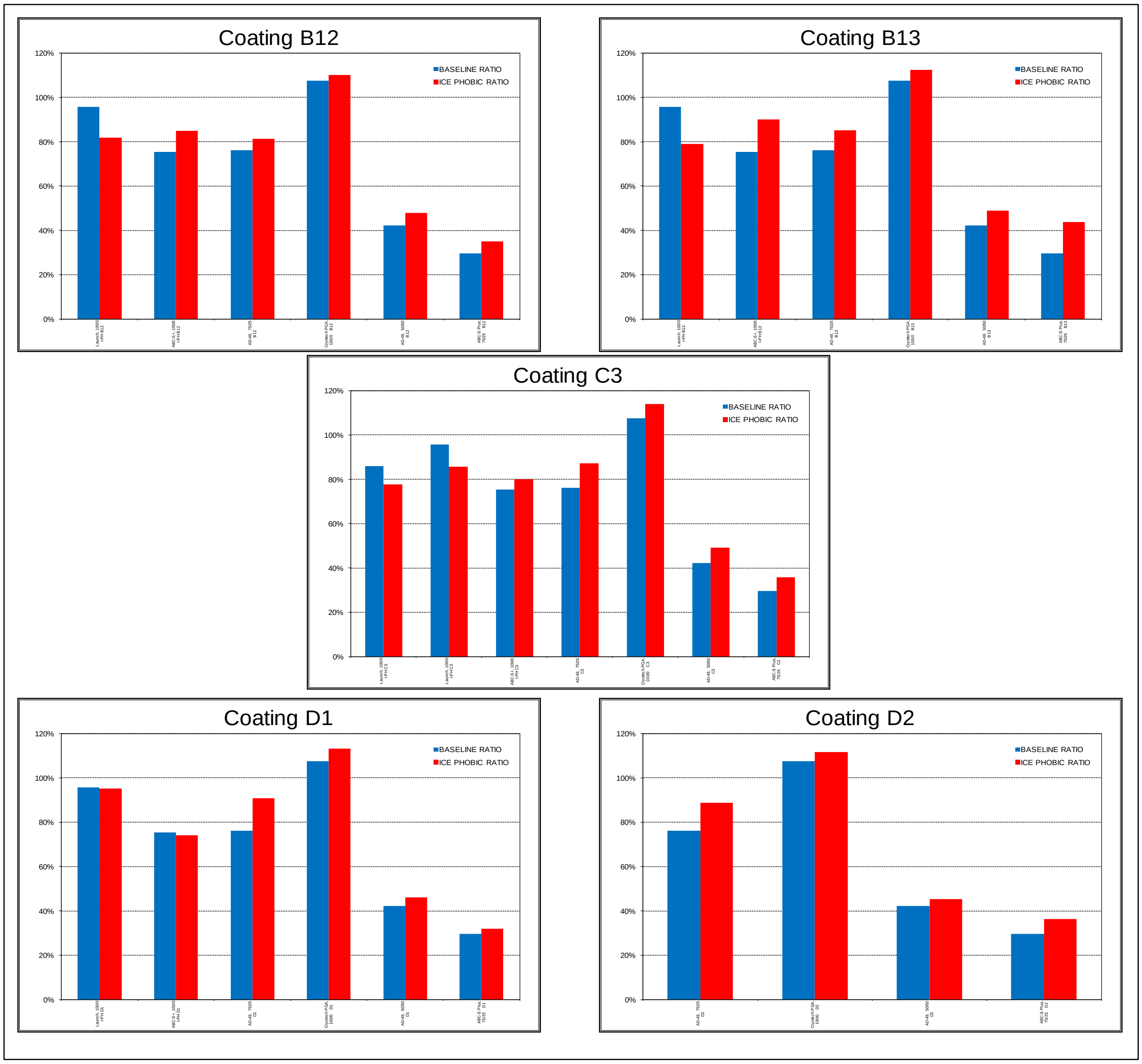


Figure 7.3: Testing Methodology

Table 7.2 demonstrates the ratios for each coating. The results indicate a less than 5 percent difference in the LOWV vs. mid-viscosity when compared to the baseline.

Table 7.2: Log of Fluid Viscosity Tests Conducted

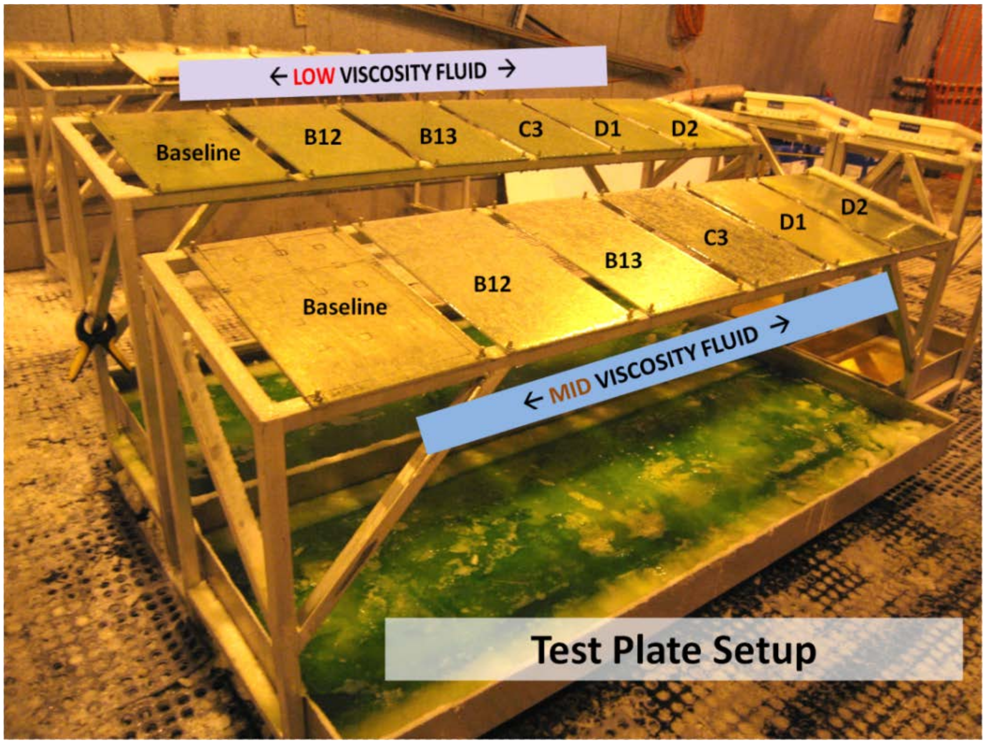
Test Plate	Average % Ratio of LOWV vs. Mid Viscosity Fluid ET's	Difference from Baseline
Baseline	**73%**	**-**
B12	74%	+1%
B13	77%	+4%
C3	76%	+3%
D1	75%	+2%
D2	71%	-2%

7.3 Recommendations

The results of this testing indicate that either lowest on-wing viscosity fluid or mid viscosity fluid are adequate for evaluation of coatings with respect to endurance times.

It is recommended that no changes be made to Section 3.1 of Aerospace Information Report, AIR6232.

Photo 7.1: Test Setup



This page intentionally left blank.

8. VERTICAL STABILIZER TESTING DATA AND RESULTS

In this section, the vertical stabilizer testing data collected during the winter of 2012-13 is analysed and discussed. Due to the early fluid failures observed on vertical surfaces, it was suggested that tests be conducted with ice phobic treated surfaces to investigate any potential benefits. Type IV tests were conducted with a vertical plate (see Photo 8.1) which was coated with an ice phobic coating, and the performance was compared to a baseline vertical plate which was not coated (see Photo 8.2).

Previous limited testing was conducted in Winter 2010-11 [TC report, TP 15158E, *Aircraft Ground Icing Research General Activities During the 2010-11 Winter* (2)] and 2011-12 [TC interim report, *Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates* (4)]; this work is not described in this report.

8.1 Log of Endurance Time Tests Conducted

To facilitate the accessibility of the data collected, a log was created for the series of tests conducted by APS at the P.E.T. Airport test site during the winter of 2012-13. The log presented in Table 8.1 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.

Table 8.1: Log of Vertical Stabilizer Endurance Time Tests

			BASELINE 80 Degree Plate			ICE PHOBIC 80 Degree Plate			RATIO
				B			C		
Fluid/Dilution	Coating	EC OAT (ºC)	Endurance Time (min)	Endurance Time ADJUSTED TO BASELINE 80 DEGREE (min)	Precip. Rate (g/dm²/h)	Endurance Time (min)	Endurance Time ADJUSTED TO BASELINE 80 DEGREE (min)	Precip. Rate (g/dm²/h)	ICE PHOBIC RATIO (C ÷ B)
Launch, 100/0	C3	-6.2	6.3	6.3	47.16	6.0	6.2	49.12	98%
Launch, 100/0	D1	-6.2	6.3	6.3	47.16	5.8	6.3	51.29	100%
EG 106-100/-0	C3	-5.5	5.0	5	63.17	2.2	2.2	61.33	44%
EG 106-100/-0	D1	-5.5	5.0	5	63.17	4.6	4.6	64.42	92%
ABC-S+, 100/0	B12	-3.3	43.5	43.5	7.29	47.9	48.5	7.39	111%
ABC-S+, 100/0	B13	-3.3	43.5	43.5	7.29	45.7	45.5	7.26	105%
ABC-S+, 100/0	C3	-3.3	43.5	43.5	7.29	44.2	43.3	7.15	100%
ABC-S+, 100/0	D1	-3.3	43.5	43.5	7.29	45.6	44.9	7.18	103%
Launch, 100/0	B12	-1.4	31.5	31.5	17.07	23.9	21.4	15.32	68%
Launch, 100/0	B13	-1.4	31.5	31.5	17.07	23.8	21.5	15.42	68%
Launch, 100/0	C3	-1.4	31.5	31.5	17.07	26.4	24.3	15.75	77%
Launch, 100/0	D1	-1.4	31.5	31.5	17.07	24.5	22.5	15.64	71%
Launch, 100/0	B12	0.1	8.0	8.0	46.8	7.4	6.9	44.3	87%
Launch, 100/0	B13	0.1	8.0	8.0	46.8	8.0	7.4	43.3	92%
Launch, 100/0	C3	0.1	8.0	8.0	46.8	8.1	7.3	42.3	91%
Launch, 100/0	D1	0.1	8.0	8.0	46.8	8.3	7.3	41.3	91%

Condition: Natural snow, 100 percent dilution, 80 degree surface angle

8.2 Data Analysis

The ratio of coated vertical surfaces to a baseline aluminum vertical surface was the primary focus of analysis. Figure 8.1 and Table 8.2 demonstrates the ET ratio of each coated vertical surface to that of the baseline coated surface.

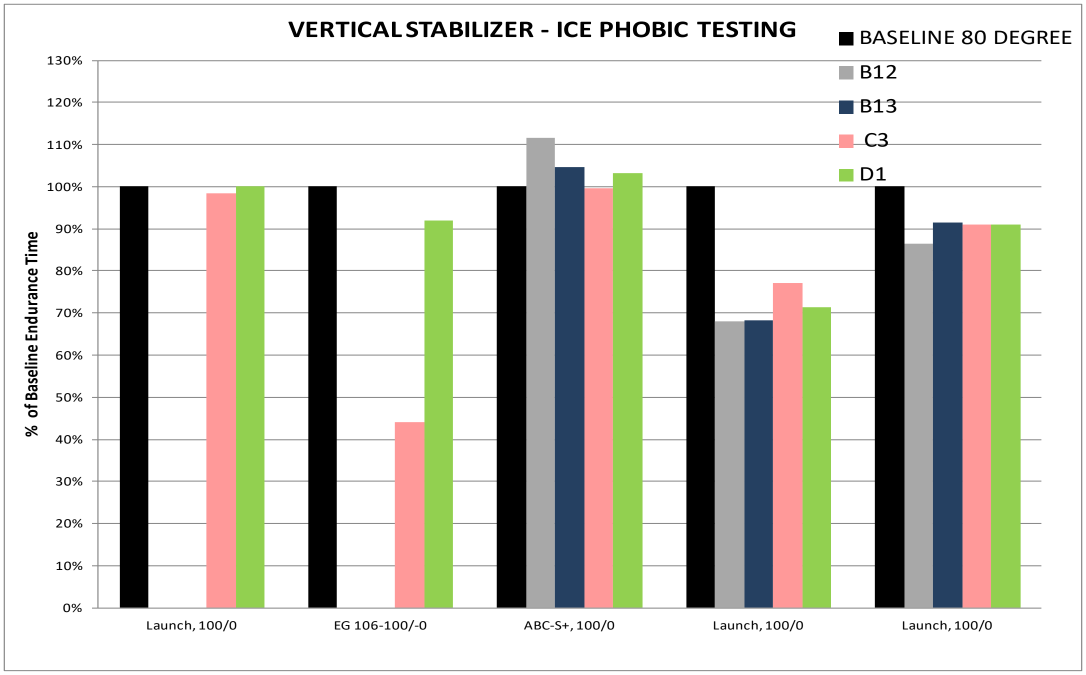


Figure 8.1: Vertical Stabilizer Ice Phobic Testing

Table 8.2: Ratio of Coated Vertical Surfaces to Baseline Coated Surface

COATINGS	ET RATIO COMPARED TO BASELINE
I-PH B12	89%
I-PH B13	88%
I-PH C3	82%
I-PH D1	92%
Grand Total	**88%**

The average ratio of coated vertical surfaces to the baseline coated surface is 88 percent.

In general, in this small number of tests, the fluid endurance times on the vertical coated surfaces were shorter when compared to the vertical baseline aluminum plate. However as this approach potentially offers a significant advancement, further research is warranted.

Photo 8.1: Vertical Test Surfaces

Photo 8.2: Outdoor Testing Setup

This page intentionally left blank.

9. REDUCTION OF RESIDUES IN AERODYNAMICALLY QUIET AREAS IN AIRCRAFT

In many cases, surface coatings can have hydrophobic properties which can repel fluids. From a ground deicing perspective, this may have a negative effect on wings. However, in the aerodynamically quiet areas in aircraft where deicing fluid residues can form, this may have its advantages. It was recommended that testing be conducted to investigate if aircraft surface coatings could potentially reduce the formation of residues.

A comparative testing methodology was developed by APS with TC/FAA based on the “Successive Dry-out and Rehydration Test” from Appendix A of AMS1428G. The residues formed on coated plates were compared to the baseline aluminum plate. Coated aluminum test plates and selected fluids were provided to AMIL for testing.

In this section, the data from the “Successive Dry-out and Rehydration” testing, also referred to as the “Residues” testing, is discussed. A detailed report was provided by AMIL following the conduct of the tests. This report provides the necessary summary of the results.

9.1 Test Plan

A limited test plan was submitted to AMIL which included two sets of tests with two different thickened anti-icing fluids. Fluids selection was biased towards fluids likely to cause most residues. A baseline plate and coated plates were tested for both fluids. The test plan presented in Table 9.1 provides a reference for the tests.

Table 9.1: Test Plan

TEST #	SET #	COATING	FLUID (DILUTION)
1	1	Baseline Aluminum	Clariant SAfewing MP III 2031 ECO (100/0)
2		B12	
3		B13	
4		C3	
5		D1	
6		D2	
7	2	Baseline Aluminum	Dow UCAR Endurance EG106 (100/0)
8		B12	
9		B13	
10		C3	
11		D1	
12		D2	

9.2 Test Summary

For each of the tests, the individual test plate was repeatedly dipped in fluid (Photo 9.1) and left to drip (Photo 9.2). The weight of the wet fluid on the plate was then plotted on the graph (5 min and 30 min weights). The plates were then left to dry-out completely in an oven (Photo 9.3) and this weight was recorded (Dry Residue weight). Once the plates were completely dry, they were immersed in water for 10 minutes, and the increase in weight of the gel residues formed were recorded (water immersion number 1 to 10). The results of the two tests have been included in Figure 9.1 and Figure 9.2.

9.3 General Observations

In both test sets, the coated plates generated less residue as compared to the baseline aluminum plate. It should be noted that this testing is based on single tests and additional testing would be required to further substantiate these results. Typically, repeats of each test are conducted to ensure accuracy in the results obtained. In both cases coatings B12 and B13 generated the least amount of residues, whereas the rest of the coatings did not demonstrate any clear comparative trend.

These results indicate a potential solution to minimize residues formation which could be applied to the aerodynamically quiet areas in aircraft. Consideration should be given to including this test methodology in a future revision of AIR6232.

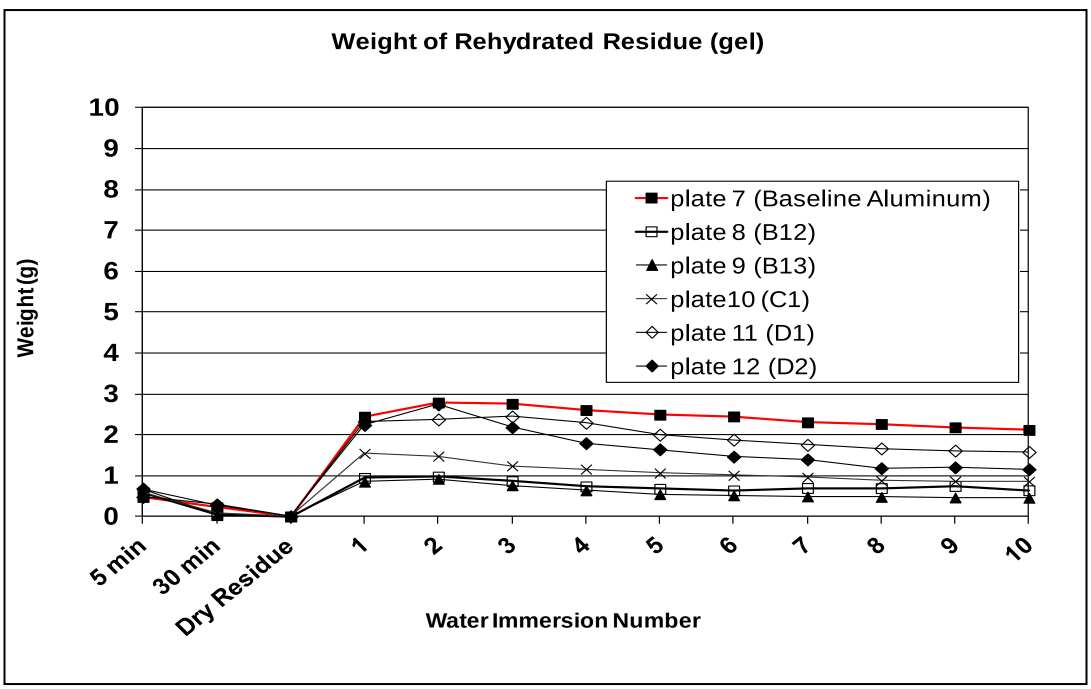


Figure 9.1: Test Set #1 – Clariant Safewing MP III 2031 ECO

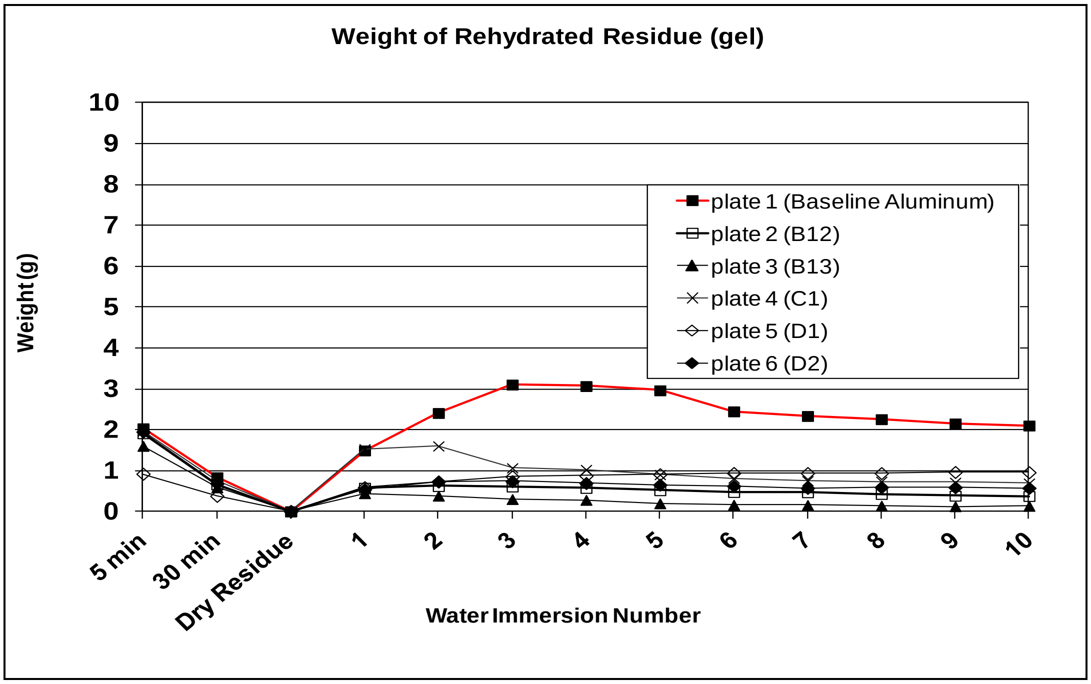


Figure 9.2: Test Set #2 – Dow UCAR Endurance EG106

This page intentionally left blank.

Photo 9.1: Plate Being Dipped in Fluid

Photo 9.2: Plates Hanged to Drip Off Wet Fluid

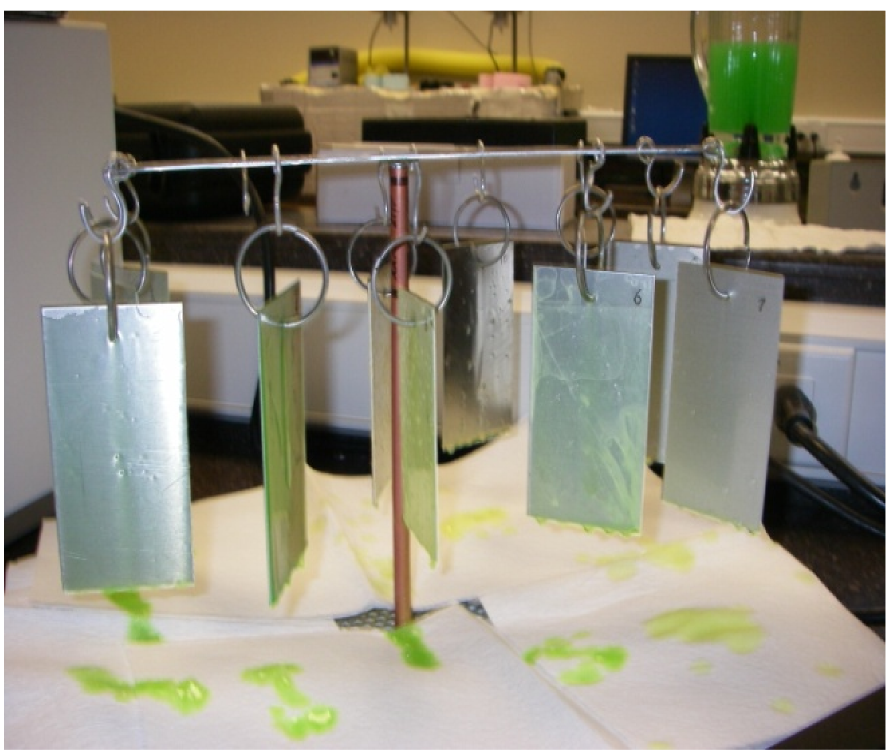
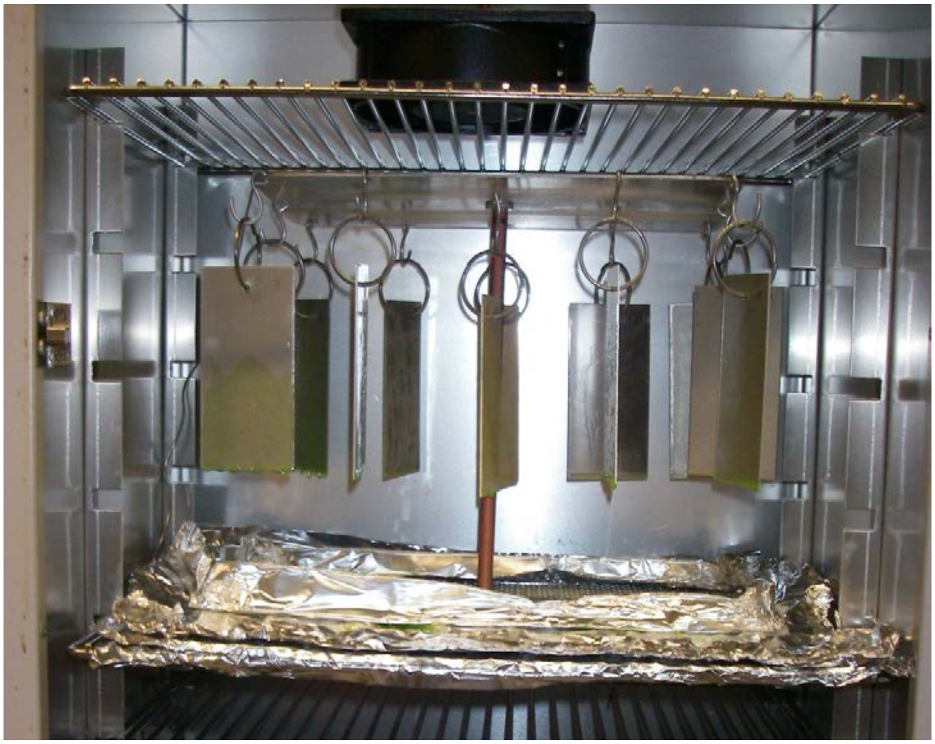


Photo 9.3: Plates in Oven to Allow Complete Drying



10. WIND TUNNEL TESTING – ICE PHOBIC COATINGS

10.1 Background

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

A broader test plan was developed and conducted during the winter of 2012-13 to investigate some additional areas to gain new insight into the potential applications of these coatings for aircraft operations, and to continue the research to include newly developed coating formulations. As part of this test plan, it was recommended that testing continue to investigate the effects of these coatings on de/anti-icing fluids from a HOT and aerodynamic perspective.

10.2 Objective

To investigate the aerodynamic performance of an airfoil treated with a coating, with and without de/anti-icing fluids.

10.3 General Methodology

Testing was conducted using wing skins specifically manufactured to fit onto the existing thin high performance wing section and be secured by flush-mounted screws. To cover the entire test wing, two individual wing skin halves were required. The wing skins were treated with the various coatings prior to testing to allow the proper curing times.

The general methodology used for these tests was in accordance with the methodologies used for typical fluid and contamination tests conducted in the wind tunnel. The evaluation methodology was modified to allow a comparison among the different wing skin performances:

- The lift aerodynamic performance of the dry wing with the uncoated wing skin installed was verified and compared to the typical dry wing baseline to determine the effect of the wing skin alone (recorded lift loss was recorded was used as the baseline for all wing skin tests);

- The lift aerodynamic performance of the dry wing with the coated wing skin installed was verified and compared to the uncoated wing skin performance to determine the effect of the coating; and
- For each specific coating, fluid, and fluid and contamination tests were conducted and compared to the un-coated skin performance, or in some cases to the original wing with no wing skin.

It should be noted that the original test plan called for an extensive set of comparative tests contingent on the fact that the skins would be easily interchanged for each test. After the first test it was determined that to change the wing skin was extremely time consuming, therefore a new plan of approach was consequently developed and the tests conducted were not as originally planned.

10.4 Data Collected

Forty tests were conducted with the various wing skins, dry and with fluid. A summary of the test data is in included in Table 10.1.

The following is a brief description of the column headings for Table 10.1:

Test Year	The year in which the test was conducted.
Test #:	Exclusive number identifying each test run.
Date:	Date when 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.
Speed (kts):	Maximum speed obtained during simulated takeoff run, recorded in knots.
Extra Run Information:	Description of the any additional important run information.
% Lift Loss:	% Lift Loss calculated based on the comparison of the 8º lift coefficient during

	the test run versus the dry wing average lift coefficient.
Tunnel Temp Before Test (°C):	Static tunnel ambient temperature recorded just before the start of the simulated takeoff test, measured in degrees Celsius. *Note: This parameter was used as the actual test temperature for analysis.*
Fluid Amount (L):	Amount of fluid in litres applied to the wing surface.
OAT Before Test (°C):	Outside ambient 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.*
Precipitation Rate (Type: [g/dm²/h]):	Simulated freezing precipitation rate (or combination of different precipitation rates). N/A indicates that no precipitation was applied.
Exposure Time:	Simulated precipitation period, recorded in minutes.

Table 10.1: Summary of 2012-13 Wind Tunnel Ice Phobic Testing

Test Year	Test #	Date	Objective	Test Condition	Fluid Name	Rotation Angle	Speed Kts	Extra Run Information	**Corrected for 3D Effects** % Lift Loss On 8° Cl vs Dry Cl	Tunnel Temp. Before Test (ºC)	Fluid Amount (L)	OAT Before Test (ºC)	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)
Winter 2012-13	**101**	21-Jan-13	Effect of Ice Phobic Coatings on BLDT	Fluid Only	MP III 2031	8	67	ramp of 16 sec determined based upon discussion with NRC and extrapolation of other ramps and previous testing on January 31, 2011 C5 (no skin)	6.08%	-15	12	-17.2	-	-	-	-	-
Winter 2012-13	**102**	21-Jan-13	Ice Phobic Coating R&D	None	none	8	100	C0 (skin no coating) Objective: Baseline	0.64%	n/a	-	-	-	-	-	-	-
Winter 2012-13	**103**	21-Jan-13	Ice Phobic Coating R&D	None	none	22	80	C0 (skin no coating) Objective: Baseline	0.67%	n/a	-	-	-	-	-	-	-
Winter 2012-13	**104**	21-Jan-13	Effect of Ice Phobic Coatings on BLDT	Fluid Only	MP III 2031	8	67	C0 (skin no coating)	6.54%	-12.8	12	-18.4	-	-	-	-	-
Winter 2012-13	**105**	21-Jan-13	Ice Phobic Coating R&D	None	Max-Flight	8	100	C0 (skin no coating)	7.12%	-13.7	18	-18.9	-	-	-	-	-
Winter 2012-13	**106**	21-Jan-13	Ice Phobic Coating R&D	None	EG106	8	100	pitch was one minute longer than usual C0 (skin no coating)	to be calculated	-14.9	20	-19.6	-	-	-	-	-
Winter 2012-13	**107**	21-Jan-13	Ice Phobic Coating R&D	None	none	8	100	repeat of 102 C0 (skin no coating) Objective: Baseline	1.09%	n/a	-	-	-	-	-	-	-
Winter 2012-13	**108**	21-Jan-13	Ice Phobic Coating R&D	None	none	22	80	repeat of 103 C0 (skin no coating) Objective: Baseline	1.55%	n/a	-	-	-	-	-	-	-
Winter 2012-13	**173**	28-Jan-13	Ice Phobic Coating R&D	None	none	8	100	coating C3	0.63%	-0.9	-	-7.2	-	-	-	-	-
Winter 2012-13	**174**	28-Jan-13	Ice Phobic Coating R&D	None	none	stall	80	coating C3	1.49%	-6	-	-7.2	-	-	-	-	-
Winter 2012-13	**175**	28-Jan-13	Ice Phobic Coating R&D	None	none	stall	80	coating C3	0.41%	-6	-	-7.2	-	-	-	-	-
Winter 2012-13	**176**	28-Jan-13	Ice Phobic Coating R&D	Fluid only	EG106	8	100	coating C3	3.25%	-4.7	18	-7.5	-	-	-	-	-

Table 10.1: Summary of 2012-13 Wind Tunnel Ice Phobic Testing (cont'd)

Test Year	Test #	Date	Objective	Test Condition	Fluid Name	Rotation Angle	Speed Kts	Extra Run Information	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Tunnel Temp. Before Test (ºC)	Fluid Amount (L)	OAT Before Test (ºC)	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)
Winter 2012-13	177	28-Jan-13	Ice Phobic Coating R&D	Fluid Only	EG106	stall	80	sprayer system not working coating C3	4.02%	0.8	18	-7.8	-	-	-	-	-
Winter 2012-13	178	29-Jan-13	Ice Phobic Coating R&D	ZR	EG106	8	100	coating C3	3.28%	0.1	18	-7.2	-	-	25	-	50
Winter 2012-13	179	29-Jan-13	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	100	coating C3	3.95%	-0.5	16	-8.3	25	-	25	-	25
Winter 2012-13	180	29-Jan-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	100	coating C3	5.67%	-1.9	16	-9.5	75	-	-	-	15
Winter 2012-13	181	29-Jan-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	100	coating C3	5.04%	-2.9	13	-9.6	75	-	-	-	15
Winter 2012-13	182	29-Jan-13	Ice Phobic Coating R&D	SN	none	8	100	coating C3	3.56%	-1.6	-	-9.6	-	10	-	-	15
Winter 2012-13	183	29-Jan-13	Ice Phobic Coating R&D	ZR	none	8	100	coating C3	3.30%	-0.4	-	-9.4	-	-	25	-	15
Winter 2012-13	184	29-Jan-13	Ice Phobic Coating R&D	ZR	none	stall	80	Tunnel rerun right after previous test with remaining contamination from previous test coating C3	3.28%	-6.1	-	-	-	-	-	-	-
Winter 2012-13	185	31-Jan-13	Ice Phobic Coating R&D	None	none	8	100	coating B13	0.52%	-1.4	-	-2.8	-	-	-	-	-
Winter 2012-13	186	31-Jan-13	Ice Phobic Coating R&D	None	none	stall	80	coating B13	1.40%	-2.9	-	-3.2	-	-	-	-	-
Winter 2012-13	187	31-Jan-13	Ice Phobic Coating R&D	Fluid only	EG106	8	100	coating B13	3.39%	-2.8	18	-3.6	-	-	-	-	-
Winter 2012-13	188	31-Jan-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	100	coating B13	6.57%	-3.9	18	-5.2	75	-	-	-	15
Winter 2012-13	189	31-Jan-13	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	100	coating B13	4.89%	-5.7	16	-7.1	25	-	25	-	25

Table 10.1: Summary of 2012-13 Wind Tunnel Ice Phobic Testing (cont'd)

Test Year	Test #	Date	Objective	Test Condition	Fluid Name	Rotation Angle	Speed Kts	Extra Run Information	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Tunnel Temp. Before Test (ºC)	Fluid Amount (L)	OAT Before Test (ºC)	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)
Winter 2012-13	190	31-Jan-13	Ice Phobic Coating R&D	ZR	none	8	100	coating B13	4.66%	-7.1	-	-8.6	-	-	25	-	15
Winter 2012-13	191	31-Jan-13	Ice Phobic Coating R&D	ZR	none	stall	80	rerun of tunnel right after run 190 with remaining contamination from previous test coating B13	5.20%	-7.1	-	-8.6	-	-	25	-	15
Winter 2012-13	192	31-Jan-13	Ice Phobic Coating R&D	None	none	8	100	coating B12	1.02%	-0.5	-	-10.1	-	-	-	-	-
Winter 2012-13	193	31-Jan-13	Ice Phobic Coating R&D	None	none	stall	80	coating B12	1.31%	-7.1	-	-8.6	-	-	-	-	-
Winter 2012-13	194	31-Jan-13	Ice Phobic Coating R&D	Fluid only	EG106	8	100	coating B12	3.53%	-8.7	18	-10.6	-	-	-	-	-
Winter 2012-13	195	31-Jan-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	100	coating B12	8.30%	-9.2	16	-10.9	75	-	-	-	15
Winter 2012-13	196	31-Jan-13	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	100	coating B12	7.10%	-8.6	16	-11.4	25	-	25	-	25
Winter 2012-13	197	31-Jan-13	Ice Phobic Coating R&D	SN	none	8	100	coating B12	5.04%	-6.5	-	-11.6	-	10	-	-	15
Winter 2012-13	198	1-Feb-13	Ice Phobic Coating R&D	None	none	8	100	Coating D1	1.30%	-8	-	-15.5	-	-	-	-	-
Winter 2012-13	199	1-Feb-13	Ice Phobic Coating R&D	None	none	stall	80	Coating D1	1.73%	-13.9	-	-15.5	-	-	-	-	-
Winter 2012-13	200	1-Feb-13	Ice Phobic Coating R&D	Fluid only	EG106	8	100	Coating D1	3.58%	-12.4	18	-15.3	-	-	-	-	-
Winter 2012-13	201	1-Feb-13	Ice Phobic Coating R&D	IP mod	Max-Flight	8	100	Coating D1	9.08%	-11.9	16	-14.4	75	-	-	-	10
Winter 2012-13	202	1-Feb-13	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	100	Coating D1	7.08%	-7.8	16	-13.8	25	-	25	-	10

Table 10.1: Summary of 2012-13 Wind Tunnel Ice Phobic Testing (cont'd)

Test Year	Test #	Date	Objective	Test Condition	Fluid Name	Rotation Angle	Speed Kts	Extra Run Information	Corrected for 3D Effects % Lift Loss On 8° Cl vs Dry Cl	Tunnel Temp. Before Test (ºC)	Fluid Amount (L)	OAT Before Test (ºC)	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)
Winter 2012-13	203	1-Feb-13	Ice Phobic Coating R&D	ZR	none	8	100	Coating D1	3.30%	-3.3	-	-13.1	-	-	25	-	15
Winter 2012-13	204	1-Feb-13	Ice Phobic Coating R&D	ZR	none	stall	80	rerun of tunnel with contamination from previous run Coating D1	3.88%	-12.8	-	-13.2	-	-	-	-	-

10.4.1 Effect of Coating on Dry Wing Aerodynamics

Testing was conducted in dry conditions without fluids to evaluate the aerodynamic effects of the various coated wing skins alone. Table 10.2 demonstrates the lift losses measured with a coated dry wing skins as compared to the uncoated dry wing skin; the baseline used for calculating lift losses is the original wing without a skin or coating.

Figure 10.1 graphically shows the data collected with rotation to 8 degrees (instead of stall). The results show that the aerodynamic performance of the coatings vary and can be equal to, worse, or better when compared to the uncoated surface. The scatter in the data collected, especially with the baseline test, indicates that future testing should focus on the repeatability of the data produced.

Table 10.2: Coated Dry Wing Tests

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED (kts)	TEMP (°C)	L_L	COMMENT
174	Ice Phobic Coating R&D	None	none	stall	80	-6	1.5%	coating C3
175	Ice Phobic Coating R&D	None	none	stall	80	-6	0.4%	coating C3
186	Ice Phobic Coating R&D	None	none	stall	80	-2.9	1.4%	coating B13
193	Ice Phobic Coating R&D	None	none	stall	80	-7.1	1.3%	coating B12
199	Ice Phobic Coating R&D	None	none	stall	80	-13.9	1.7%	Coating D1
103	Ice Phobic Coating R&D	None	none	22	80	n/a	0.7%	C0 (skin no coating)
108	Ice Phobic Coating R&D	None	none	22	80	n/a	1.5%	repeat of 103 C0 (skin no coating)
102	Ice Phobic Coating R&D	None	none	8	100	n/a	0.6%	C0 (skin no coating)
107	Ice Phobic Coating R&D	None	none	8	100	n/a	1.1%	repeat of 102 C0 (skin no coating).
173	Ice Phobic Coating R&D	None	none	8	100	-0.9	0.6%	coating C3
185	Ice Phobic Coating R&D	None	none	8	100	-1.4	0.5%	coating B13
192	Ice Phobic Coating R&D	None	none	8	100	-0.5	1.0%	coating B12
198	Ice Phobic Coating R&D	None	none	8	100	-8	1.3%	Coating D1
Conclusion: there seems to be a slight difference between coatings, but more repetitions would be needed to conclude as there is some scatter in baseline.								

* Some fluid seeped from wing skin and may have caused larger lift losses.

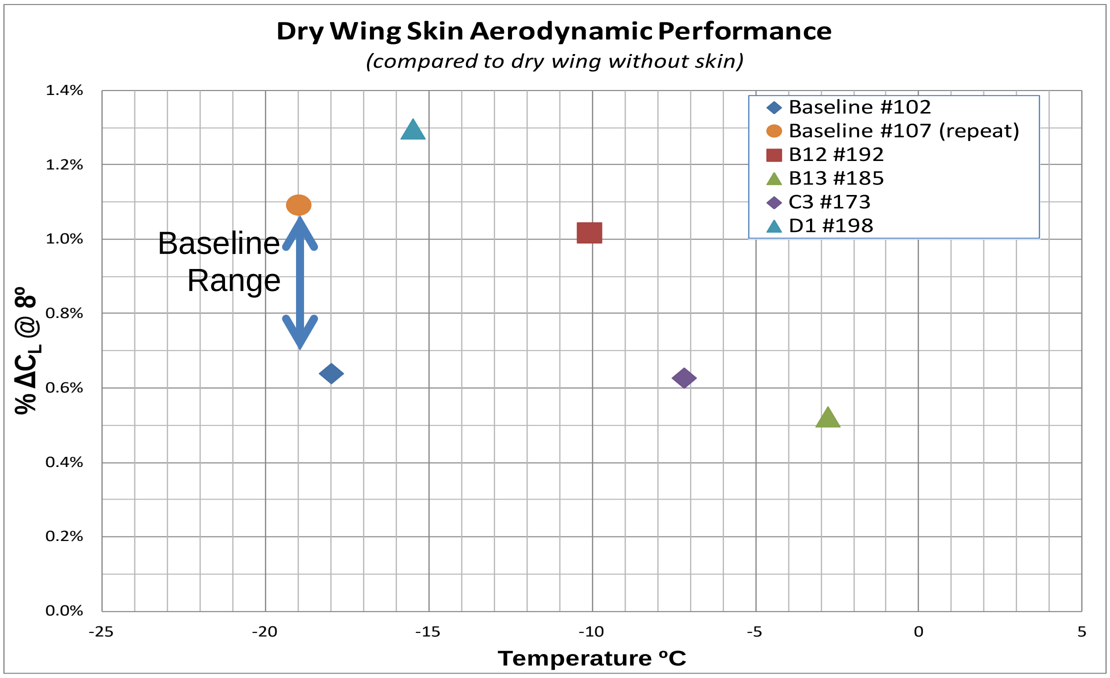


Figure 10.1: Coated Dry Wing Performance

10.4.2 Adhesion Prevention

Testing was conducted with contamination alone, without the use of de/anti-icing fluids, to evaluate the ability of the coating to protect against freezing or frozen contamination. Table 10.3 to Table 10.9 demonstrate the lift losses measured with precipitation on a coated dry wing as compared to the coated wing alone without precipitation. In all cases the exposure to frozen contamination generated higher lift losses, indicating that none of the coatings were able to completely protect from the freezing rain or snow contamination. This was also confirmed by the visual observations which indicated that much of the contamination was still present after rotation.

An interesting observation from the plot in Figure 10.2 is that the lift loss in tests conducted with coating B13 were higher than the rest. This may have been directly linked to the coating, which has hydrophobic properties. This caused the freezing rain to bead on the surface. Those beads later froze and may have been aerodynamically worse as compared to other surfaces that were less hydrophobic and caused flatter ice.

Table 10.3: Coating C3 With and Without ZR

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	ZR Rate (g/dm²/h)	Exposure Time (min)	LL	COMMENT
183	Ice Phobic Coating R&D	ZR	none	8	100	-0.4	25	15	3.3%	coating C3
173	Ice Phobic Coating R&D	None	none	8	100	-0.9	-	-	0.6%	coating C3
Conclusion: Coating does not prevent adhesion because the L_L with ZR > dry test										

Table 10.4: Coating C3 With and Without SN

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	SN Rate (g/dm²/h)	Exposure Time (min)	L_L	COMMENT
182	Ice Phobic Coating R&D	SN	none	8	100	-1.6	10	15	3.6%	coating C3
173	Ice Phobic Coating R&D	None	none	8	100	-0.9	-	-	0.6%	coating C3
Conclusion: Adhesion present therefore the L_L with SN > dry test										

Table 10.5: Coating B13 With and Without ZR

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	ZR Rate (g/dm²/h)	Exposure Time (min)	L_L	COMMENT
186	Ice Phobic Coating R&D	None	none	stall	80	-2.9	-	-	1.4%	coating B13
190	Ice Phobic Coating R&D	ZR	none	8	100	-7.1	25	15	4.7%	coating B13
191*	Ice Phobic Coating R&D	ZR	none	stall	80	-7.1	25	15	5.2%	coating B13
Conclusion: Coating does not prevent adhesion because the L_L with ZR > dry test										

* rerun of tunnel right after run 190 with remaining contamination from previous test

Table 10.6: Coating B12 With and Without SN

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	SN Rate (g/dm²/h)	Exposure Time (min)	L_L	COMMENT
197	Ice Phobic Coating R&D	SN	none	8	100	-6.5	10	15	5.0%	coating B12
192	Ice Phobic Coating R&D	None	none	8	100	-0.5	-	-	1.0%	coating B12
Conclusion: Coating does not prevent adhesion because the L_L with SN > dry test										

Table 10.7: Coating D1 With and Without ZR

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	ZR Rate (g/dm²/h)	Exposure Time (min)	LL	COMMENT
198	**Ice Phobic Coating R&D**	**None**	**none**	**8**	**100**	**-8**	**-**	**-**	**1.3%**	**Coating D1**
203	**Ice Phobic Coating R&D**	**ZR**	**none**	**8**	**100**	**-3.3**	**25**	**15**	**3.3%**	**Coating D1**
204*	**Ice Phobic Coating R&D**	**ZR**	**none**	**stall**	**80**	**-12.8**	**-**	**-**	**3.9%**	**Coating D1**
Conclusion: Coating does not prevent adhesion because the L_L with ZR > dry test										

* rerun of tunnel with contamination from previous run

Table 10.8: Coating B13 With and Without ZR

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	ZR Rate (g/dm²/h)	Exposure Time (min)	LL	COMMENT
185	Ice Phobic Coating R&D	None	none	8	100	-1.4	-	-	0.5%	coating B13
190	Ice Phobic Coating R&D	ZR	none	8	100	-7.1	25	15	4.7%	coating B13
Conclusion: Coating does not prevent adhesion because the L_L with ZR > dry test										

Table 10.9: All Coatings With ZR

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	ZR Rate (g/dm²/h)	Exposure Time (min)	LL	COMMENT
183	Ice Phobic Coating R&D	ZR	none	8	100	-0.4	25	15	3.3%	coating C3
184*	Ice Phobic Coating R&D	ZR	none	stall	80	-6.1	-	-	3.3%	coating C3
190	Ice Phobic Coating R&D	ZR	none	8	100	-7.1	25	15	4.7%	coating B13
191*	Ice Phobic Coating R&D	ZR	none	stall	80	-7.1	25	15	5.2%	coating B13
203	Ice Phobic Coating R&D	ZR	none	8	100	-3.3	25	15	3.3%	Coating D1
204*	Ice Phobic Coating R&D	ZR	none	stall	80	-12.8	-	-	3.9%	Coating D1
127 (2010-11)	Heavy Cont.	ZR	none	23	80	-10.7	25	5	2.9%	alum
127A (2010-11)	Heavy Cont.	ZR	none	23	80	-8.8	75 (Then 35)	12	1.1%	alum
Conclusion: There seems to be an increase in LL due to beading on the ice phobic products. To be confirmed on photographs. After comparing the coatings amongst themselves, its noted that coating B13 performs a little worse than the others. . Note than when comparing to historical regular wing test the lift losses should be increased by about 1 percent to account for the lift losses associated with the wing skin alone.										

* tunnel rerun right after previous test with remaining contamination from previous test

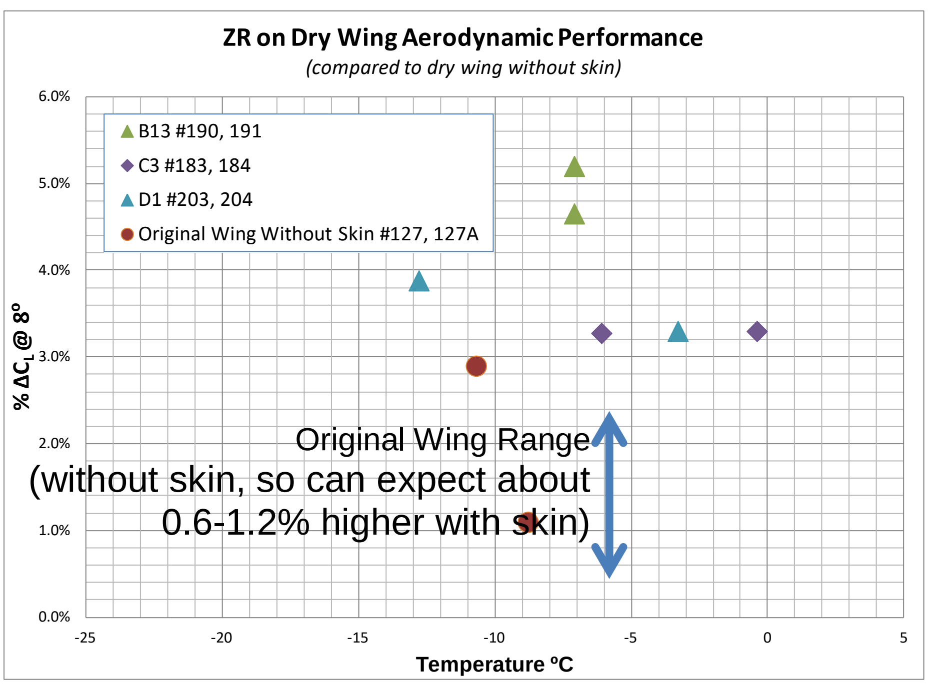


Figure 10.2: Coatings B13, C3, and D1 with ZR

10.4.3 Fluid Flow-Off with Coatings

Testing was conducted to evaluate the aerodynamic effects of the various coated wing skins on fluid flow-off, with and without contamination. Table 10.10 to Table 10.12 demonstrate the lift losses measured with coated wing skins with fluid and contamination compared to the original wing in the same condition. The uncoated wing skin was not tested in this case. Table 10.13 demonstrates the same type of data but for a fluid-only case with EG106.

Figure 10.3 graphically shows the data collected for the fluid-only testing with EG106. The results indicated that in general there were no significant effects on the fluid flow-off performance as a result of the coatings. The results were more ambiguous in the case of the fluid and contamination tests due to the additional variables. Future testing should focus on fluid-only flow-off in order to minimize the amount of variable to control and to obtain a better comparison data set.

Table 10.10: Fluid Flow-Off on Coated Surfaces with AD-49

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	IP Rate (g/dm²/h)	ZR Rate (g/dm²/h)	Exposure Time (min)	L_L	COMMENT
189	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	100	-5.7	25	25	25	4.9%	coating B13
128 *(2010-11)*	Type IV Fluid Val	IP- / ZR	AD-49	8	100	-3.2	25	25	25	4.2%	no skin
196	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	100	-8.6	25	25	25	7.1%	coating B12
202	Ice Phobic Coating R&D	IP- / ZR	AD-49	8	100	-7.8	25	25	10	7.1%	Coating D1
Conclusion: Coating B13 is possibly better than B12 & D1. When comparing coating B13 to historical point there is not much of a different with regular wing. . Note that when comparing to historical regular wing test the lift losses should be increased by about 1 percent to account for the lift losses associated with the wing skin alone.											

Table 10.11: Fluid Flow-Off on Coated Surfaces with Maxflight

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	IP Rate (g/dm²/h)	Exposure Time (min)	L_L	COMMENT
180	Ice Phobic Coating R&D	IP mod	Max-Flight	8	100	-1.9	75	15	5.7%	coating C3
188	Ice Phobic Coating R&D	IP mod	Max-Flight	8	100	-3.9	75	15	6.6%	coating B13
201	Ice Phobic Coating R&D	IP mod	Max-Flight	8	100	-11.9	75	10	9.1%	Coating D1
14 *(2010-11)*	IP Validation	IP mod	Max-Flight	8	100	-12	75	10	8.0%	alum
Conclusion: Test 180 & 188 are comparable and the results are not significantly different. Tests 201 & 14 (2010-11) are similar and so therefore no effect of the coating can be determined. Note that when comparing to historical regular wing test the lift losses should be increased by about 1 percent to account for the lift losses associated with the wing skin alone.										

Table 10.12: Fluid Flow-Off on Coated Surfaces with EG106

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	R Rate (g/dm²/h)	Exposure Time (min)	LL	COMMENT
178	**Ice Phobic Coating R&D**	**ZR**	**EG106**	**8**	**100**	**0.1**	**-**	**-**	**25**	**-**	**50**	**3.3 %**	**coating C3**
176	**Ice Phobic Coating R&D**	**Fluid only**	**EG106**	**8**	**100**	**-4.7**	**-**	**-**	**-**	**-**	**-**	**3.3 %**	**coating C3**
Conclusion: No conclusion, possibly consider running a ZR R=25 for 50 mins on a skin no coating as baseline to better understand the effect of the coating.													

Table 10.13: Fluid Only Flow-Off on Coated Surfaces with EG106

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	L_L	COMMENT
176	Ice Phobic Coating R&D	Fluid only	EG106	8	100	-4.7	3.3%	coating C3
see comment	BLDT	Fluid only	EG106	8	100	-5.7	2.8%	average of alum tests 25 &100 (2009-10) and tests 121 & 122 (2011-12)
106	Ice Phobic Coating R&D	Fluid Only	EG106	8	100	-14.9	4.5%	pitch was one minute longer than usual C0 (skin no coating)
187	Ice Phobic Coating R&D	Fluid only	EG106	8	100	-2.8	3.4%	coating B13
55 *(2009-10)*	BLDT	Fluid only	EG106	8	100	-2.6	1.7%	alum
194	Ice Phobic Coating R&D	Fluid only	EG106	8	100	-8.7	3.5%	coating B12
see comment	BLDT	Fluid only	EG106	8	100	-8.9	3.0%	average of alum tests 100 (2009-10) and tests 51,52,121 & 122 (2011-12)
200	Ice Phobic Coating R&D	Fluid only	EG106	8	100	-12.4	3.6%	Coating D1
52 *(2011-12)*	BLDT	Fluid only	EG106	8	100	-12.4	3.4%	alum
Conclusion: no conclusion can be made due to the temp variation from test to test amongst the coating tests. For Test 187 & 55 it appears that the LL are worse with coating B13. There is no difference when comparing historical alum tests to Test 176 for coating C3. Due to lack of data at -9C, a comparison to Test 194 cannot be made; Therefore if using same analysis as coating C3, the LL for coating B12 and alum are not much different. Test 200 & 52 have similar LL, therefore no effect on coating D1. Note that when comparing to historical regular wing test the lift losses should be increased by about 1 percent to account for the lift losses associated with the wing skin alone.								

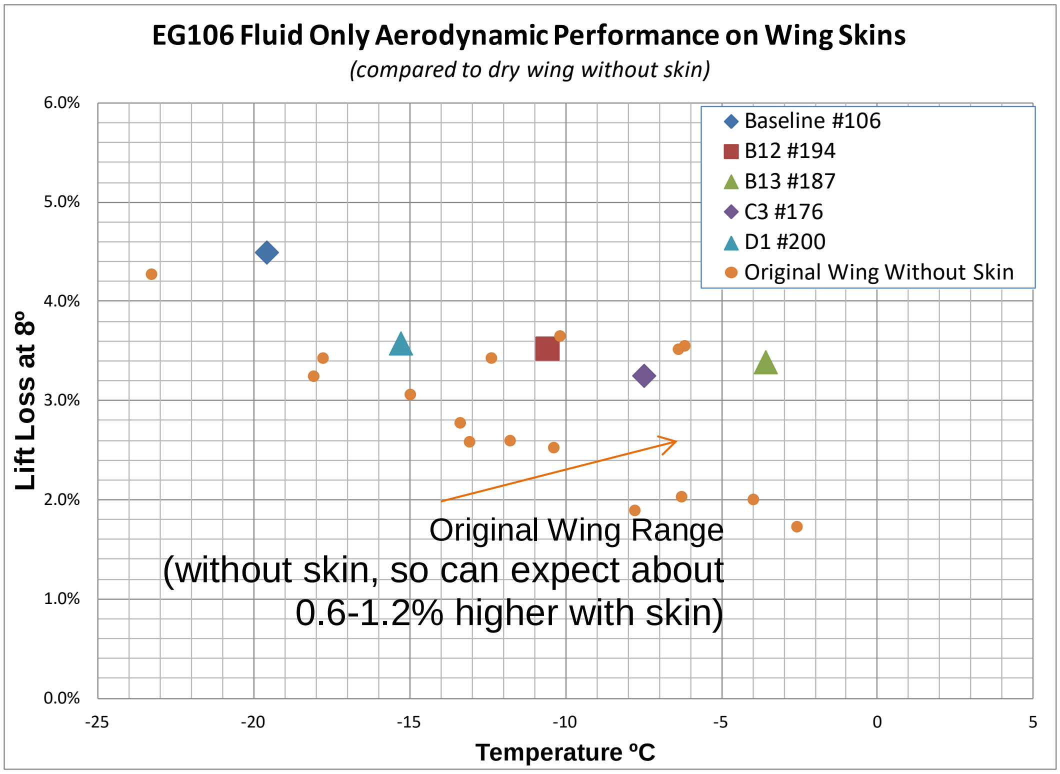


Figure 10.3: Fluid only Testing – LL with Different Coatings

10.4.4 Effect of Fluid Viscosity

Testing was conducted to evaluate the aerodynamic effects of fluid viscosity on flow-off. Limited data were collected and is demonstrated in Table 10.14. As expected, the lift losses with the LOWV fluid were less as compared to the mid-viscosity fluid.

Table 10.14: Effect of Fluid Viscosity

TEST #	OBJECTIVE	CONDITION	FLUID	ROTATION	SPEED	TEMP	IP Rate (g/dm²/h)	Exposure Time (min)	LL	COMMENT
180	Ice Phobic Coating R&D	IP mod	Max-Flight	8	100	-1.9	75	15	5.7%	coating C3
181	Ice Phobic Coating R&D	IP mod	Max-Flight-LOWV	8	100	-2.9	75	15	5.0%	coating C3
33 (2010-11)	BLDT	Fluid Only	Max-Fllight	8	100	-24	-	-	8.3%	no skin
144	Effect of Viscosity on Fluid Aerodynamics	Fluid only	Max-Flight-LOWV	8	100	-23.1	-	-	6.0%	no skin

10.4.5 Effect on BLDT

Boundary Layer Displacement Thickness (BLDT) is the measured displacement of the air flow over a surface. The increase in BLDT over the flat plate surface caused by the fluid flow-off during the AS5900 aerodynamic acceptance is directly related to loss of lift during takeoff.

Testing was planned to investigate potential benefits to using coatings to improve the BLDT results and possibly allow for lower fluid LOUT. This testing was not completed, as the ideal ambient temperatures required were never obtained.

10.4.6 Visual Effect on Coatings Flow-off

In general, the coatings seemed to affect the flow-off of fluid, especially on the leading edge once the fluid layer became very thin from shearing. The coatings seemed to help the thin fluid layer remove itself easier. This did not seem to demonstrate itself in the fluid flow-off data; however, with some additional repeatability studies trends may become more apparent.

10.5 Summary of Test Results

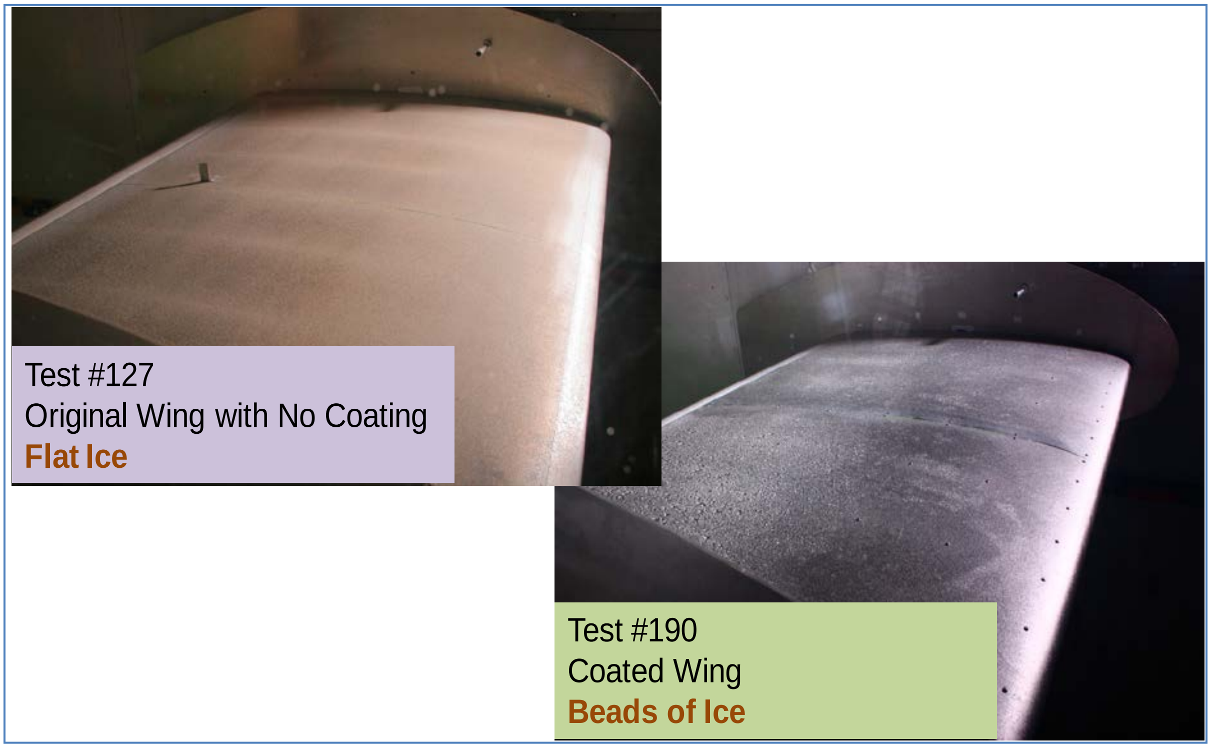
Testing is still preliminary and exploratory, however early testing indicates that:

- Coatings alone may have effects on aerodynamic performance (either for better or for worse);
- Frozen contamination on coated surfaces can be aerodynamically rougher; and
- Coatings do not seem to have significant effects on fluid flow-off performance.

The testing methodology is still premature, and future work should focus on repeatability in order to better develop the testing procedures; however, the wind tunnel can be a good platform for a full-scale evaluation of the coating performance. If the methodology does mature, consideration should be given to including the details in a future revision of AIR6232.

This page intentionally left blank.

Photo 10.1: Comparison of Frozen ZR on Uncoated and Coated Wing



This page intentionally left blank.

11. DEVELOPMENT OF SAE AIR DOCUMENT

In this section, the activities related to the development of a new Society of Automotive Engineers (SAE) Aerospace Information Report (AIR) for evaluating the interaction of de/anti-icing fluids with aircraft after-market coatings are discussed.

11.1 Background Leading to the Development of the SAE AIR

There is currently is no standardized approach for evaluating aircraft after-market coatings with respect to fluid HOT's. Although limited research has been conducted by TC and FAA over the last four years, a minimum set of evaluation criteria has yet to be developed. At the November 2011 SAE G-12 Fluids Committee meeting in YUL, a workgroup was formed with the objective of developing an SAE specification for evaluating coating technologies with respect to fluid HOT's. This working group consisted of close to 30 industry members including operators, airframe manufacturers, fluid manufacturers, coating manufacturers, and research laboratories, which provided a good cross section of the SAE G-12 demographic.

11.2 Overview of the Working Group Activities to Date

General email discussions were held between November, 2011 and March, 2012. In March 2012, APS Aviation Inc. developed a draft version of an SAE AIR which would serve as the starting point for discussion. A start-up teleconference was held with a sub-group (which consisted of approximately 10 selected members) on March 30th, 2012. The objective was to review document and agree on the general direction of the documents before going to the group at large. Following this discussion, an initial teleconference with the whole work group was held on April 13th, 2012 with the purpose of reviewing the document and receiving feedback. Changes were made to the document, and an in-person working group meeting was scheduled on May 9th, 2012 in Prague during the SAE G-12. At this meeting, there was a general discussion regarding the overall direction of the document. It was agreed that APS would make additional changes to the document based on the feedback received.

Since the May 9th, 2012 meeting, the document had been updated and working group members have been solicited to provide missing or lacking sections of the AIR. From November 2012 to February 2013, changes were made to the document and a Final Version Draft 1.0 was issued, to begin the balloting process. The final ballot was passed in June 2013 and published in August 2013.

11.3 Principle Focus of Draft AIR

The latest draft of the SAE AIR has been included in Appendix G.

The principle focus of the AIR document is the impact coatings have on aircraft ground de/anti-icing fluid. This is addressed in two main section of the AIR:

- Section 3: Fluid Endurance Time Testing
    - To evaluate how coatings impact fluid HOT's
    - Flat plate testing protocol modelled after AA Tests
    - Methodology based on ARP 5945 and ARP 5485
    - Provides good indication of potential effects of coating
- Section 4: Fluid Aerodynamic Testing
    - To evaluate how coatings influence fluid flow-off
    - Methodology currently being developing based on AS5900

An additional Section 5 has also been included in the AIR to reference other test methods which may provide informational insight into the performance of the coatings which may or may not be directly related to the impact on de/anti-icing fluid HOT's.

The AIR format was selected because it was felt by the workgroup that the development of an SAE AIR would be faster than the development of an ARP; also the AIR could eventually be changed to an ARP once performance criteria were developed.

11.4 General Comments and Observations

The working group approach has been proving to be an effective medium for developing and refining the SAE AIR. It is anticipated that communication with the working group shall continue to include email and teleconference discussions along with in person meeting in conjunction with the SAE G-12 meetings.

11.5 Future Initiatives

Future working group discussion/meetings will be organized on an as-needed basis.

Future focuses of the group should include:

- Changes based on operational feedback;
- Potential evolution of the AIR to an ARP;
- Information dissemination to non-G12 members; and
- Surface coatings being used or considered for aircraft use should be tested according to the test methods described in AIR6232.

This page intentionally left blank.

12. OBSERVATIONS AND CONCLUSIONS

The observations and conclusions drawn from the tests performed during the winter of 2012-13 are described in this section.

12.1 General Comments Regarding 2012-13 Testing

Testing conducted was limited and served as a scoping study; only a limited number of products and conditions were tested. The main purpose of this testing was to investigate some additional areas of research not previously studied, to gain some new insight into the potential applications of these coatings for aircraft operations, and to continue the research to include newly developed coating formulations. More extensive material-specific data would be needed to demonstrate usability of products on aircraft critical surfaces.

12.2 Fluid Endurance Time Testing

Fluid endurance time performance varied depending on individual coatings. Natural snow endurance times on coated surface with Type IV fluids were on average 75 percent of the baseline, ranging from 63 percent to 90 percent. Coating B12 and B13 sometimes demonstrated a different failure mechanism in which fluid was shed early allowing snow to bridge on the surface.

Freezing precipitation endurance times on coated surface with Type IV fluids were on average 94 percent of the baseline, ranging from 92 percent to 96 percent.

Freezing precipitation endurance times on coated surface with Type I fluids demonstrated similar results with the exception of coating B12 and B13, which demonstrated different failure mechanisms. At -3°C, these coatings delayed ice from forming on the surface, resulting in endurance times of 180 percent and 177 percent for B12 and B13, respectively.

12.3 Adherence Testing

When left undisturbed, some of the coated surfaces were able to slightly delay the onset of adherence and ice formation when compared to the baseline test plate. All plates eventually formed ice. However, the removal of the contamination was easier on the coated surface.

Some concern remains with the ice formation on the coated surface. The coated surface typically results in bumpier, higher contact angle ice formations. Aerodynamic research to investigate its effects is recommended.

12.4 Fluid Wetting and Fluid Thickness Testing

The Type I wetting tests indicated potential wetting problems with the coated test surfaces. Wetting issues were observed 5-minutes after fluid application; this wetting issue was worsened with the 10º buffer fluid when compared to standard mix fluid, which is more concentrated.

With the exception of coating D1, the Type IV fluid thickness test demonstrated minor degradation in fluid thickness 5-mintues after application. Coating D1 appeared to react chemically with the fluid and caused a reduction in thickness right from the start.

12.5 Hot Water Testing

The hot water endurance times on the coated surfaces were generally comparable to the Type I endurance times on the baseline plate. In some cases, the coated surfaces delayed the onset of adhered contamination and provided slightly longer protection times.

12.6 Fluid Viscosity Testing

In the development of AIR6232, the question was raised as to whether lowest on-wing viscosity fluid or mid viscosity fluid should be used for evaluation of endurance times on coated surfaces. The results of this testing indicate that either lowest on-wing viscosity fluid or mid-viscosity fluid are adequate for evaluation of coatings with respect to endurance times.

12.7 Vertical Stabilizer Testing

The endurance times of the vertical coated surfaces were less than the vertical baseline surface.

In all cases, the endurance times of the vertical surfaces were significantly shorter than the 10° baseline plate.

12.8 Residues Testing for Aerodynamically Quiet Areas in Aircraft

Results indicate a potential solution to reduce residues formation in the aerodynamically quiet areas in aircraft. Consideration should be given to including this test methodology in a future revision of AIR6232.

12.9 Wind Tunnel Testing - Ice Phobic Coatings

Testing is still preliminary and exploratory, however early testing indicates that:

- Coatings alone may have effects on aerodynamic performance (either for better or for worse);
- Frozen contamination on coated surfaces can be aerodynamically rougher; and
- Coatings do not seem to have significant effects on fluid flow-off performance.

The testing methodology is still premature, and future work should focus on repeatability in order to better develop the testing procedures. However, the wind tunnel can be a good platform for a full-scale evaluation of the coating performance. If the methodology does mature, consideration should be given to including the details in a future revision of AIR6232.

12.10 Development of SAE AIR6232

The principle focus of this AIR document is the impact coatings have on aircraft ground de/anti-icing fluid. This is addressed in two main section of the AIR:

- Section 3: Fluid Endurance Time Testing
- Section 4: Fluid Aerodynamic Testing

An additional Section 5 has also been included in the AIR to reference other test methods which may provide informational insight into the performance of the coatings which may or may not be directly related to the impact on de/anti-icing fluid HOT's.

The AIR format was selected because it was felt by the workgroup that the development of an SAE AIR would be faster than the development of an ARP. Additionally, the AIR could eventually be changed to an ARP once performance criteria were developed.

A draft document was prepared and finalized. The final ballot was passed in June 2013, and published in August 2013.

This page intentionally left blank.

13. RECOMMENDATIONS

The following recommendations were compiled following the testing conducted during the winter of 2012-13 as well as industry feedback regarding the results obtained.

13.1 Potential Future Applications

The results obtained have demonstrated a potential for future applications of ice phobic coatings in aircraft operations. More specifically, benefits may be available for vertical surfaces which are subject to early fluid failure due to the steeper surface slopes. The use of coatings on the vertical surfaces (i.e. vertical stabilizer, winglets, fuselage, etc.) could provide added protection from adherence of contamination.

Preliminary work done simulating the aerodynamically quiet areas in aircraft also indicated potential benefits to using ice phobic coatings. These results indicate a potential solution to minimize residues formation which could be applicable to such areas.

The application of coatings to the main wing sections has demonstrated mixed results and is highly dependent on the coatings used; some coatings have proven to be better than others in terms of compatibility with fluids. Nonetheless, one manufacturer has demonstrated continual improvement in the coatings submitted for testing, indicating that these coatings can potentially evolve to be complementary to de/anti-icing fluids.

In general, testing has indicated that with proper knowledge of the effects these coatings have on de/anti-icing fluid, the benefits of using these coatings can be had through adapted deicing procedures without compromising aircraft safety.

13.2 Future Research and Activities

The following are potential areas for future research:

- Conduct evaluation of newly developed coatings;
- Conduct wind tunnel testing with a thin, high performance wing model to refine the test methodology, and to investigate coating performance during ground icing conditions with and without fluid, and with contamination;

- Investigation of different types of adhered contamination on vertical surfaces, and their effects on aerodynamics;
- Investigate potential use of coatings in areas prone to icing but where de/anti-icing protection is limited, or not available (e.g. cowlings, landing gear);
- Investigate dynamic taxi situation, simulating aircraft vibration; and
- Conduct research to support development of the new SAE AIR document.

13.3 Operational Considerations

Testing is still preliminary, therefore more extensive material specific data would be needed to demonstrate usability of products on aircraft critical surfaces. If there is a strong industry request to evaluate these products for use in aircraft operations, an SAE AIR has been developed and should be referenced to evaluate these technologies with respect to fluid HOTs.

REFERENCES

1) Ruggi, M., Emerging De/Anti-Icing Technology: Evaluation of Ice Phobic Products for Potential Use in Aircraft Operation., APS Aviation Inc., Transportation Development Centre, Montreal, March 2011, TP 15055E, XX, (to be published).

2) Bendickson, S., D'Avirro, J., Gravito, P., Ruggi, M., Youssef, D., Zoitakis, V., Aircraft Ground Icing Research General Activities During the 2010-11 Winter, APS Aviation Inc., Transportation Development Centre, Montreal, January 2012, TP 15158E, XX, (to be published).

3) Chaput, M., Campbell, R, Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Test Program for the 2001-02 Winter, APS Aviation Inc., Transportation Development Centre, Montreal, December 2002, TP 13991E, XX, (to be published).

4) Ruggi, M., Investigation of Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates, APS Aviation Inc., Transportation Development Centre, Montreal, October 2012, XX (interim).

This page intentionally left blank.

APPENDIX A

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

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

4.7 Investigation of the Effects of De/Anti-Icing Fluids Ice Phobic Technologies to Reduce Aircraft Icing in Northern and Cold Climates

The overall goals of this multi-year project will be to assess the safety and effectiveness of ice phobic materials as a means to manage aircraft icing, provide a comparative analysis of these ice phobic materials/coatings and investigate the feasibility of employing ice phobic materials in the design of aircraft or specific aircraft sections that are more prone to icing (e.g. stabilizers). There is the potential use of this technology as a supplement or substitute to existing or future ice management technologies recognizing the potential limitations and drawbacks of these current technologies. This project will also comparatively examine the technological costs and benefits between existing de/anti-icing fluids and ice phobic materials and coatings.

The specific research and work required for these activities include:

- A review of existing or emerging ice phobic technologies utilized within various industry sectors, including aviation;
- Identify optimal ice phobic material or coating technologies for further research and technical assessment, and identify technical limitations;
- Conduct stakeholder consultations and participate with industry members (ice phobic materials manufacturers, aircraft manufacturers and operators) to identify research priorities and development of testing parameters;
- Carry out multi-staged testing of ice phobic technologies in various climatic conditions and provide reports to Transport Canada and stakeholders;
- Identify technological implications, benefits and limitations of ice phobic technologies;
- Evaluate potential air safety and environmental impacts of ice phobic technologies;
- Disseminate the results via presentations and documents; and
- As part of this project, work will be conducted according to the following tasks.

4.8 Use of Ice Phobic Products on Aircraft Surfaces Prone to Icing Issues

a) Solicit manufacturers of ice phobic materials to determine potential new research areas of interest and to encourage participation in research. Based on recent industry feedback, some potential areas prone to icing on which application of ice phobic materials could be feasible and beneficial include: vertical stabilizer, flap leading edges, quiet areas, fan blades and cowlings, as well as runways and deicing pads etc;

b) Conduct site visit of manufacturer laboratories to build closer relationships with these manufacturers due to the direct impact of guidance being developed for coating interaction with deicing fluids to ensure developed guidance does not "kill" future technologies, ensure manufacturer interest is protected, to gain manufacturer insight onto technology, and to identify synergies to further advance technology. One or two visits to laboratories in North America and possibly Europe are expected;

c) Develop methodology and procedure for the preliminary evaluation of the performance of ice phobic products on selected surfaces. Testing will primarily include a scoping study to investigate:

d) The behaviour of de/anti-icing fluid on ice phobic treated surfaces;

e) The behaviour of ice adherence on ice phobic treated surfaces;

f) Coordinate samples and prepare samples for testing;

g) Conduct limited preliminary testing in natural snow conditions at the P.E.T test site. It is anticipated that testing will be conducted in conjunction with standard HOT testing;

h) Conduct limited preliminary testing in simulated freezing precipitation conditions at the NRC chamber. It is anticipated that testing will be conducted in conjunction with standard HOT testing;

i) Analyze data and results; and

j) Prepare a test report of the findings and prepare presentation material for the SAE G-12 meetings.

4.8.1 Development of SAE AIR for Evaluation of Aircraft Coatings (Ice Phobic)

a) Continue the development of AIR document for testing aircraft after-market coatings with respect to de/anti-icing fluid performance;

b) Organize and participate in G-12 coatings working group meetings consisting of regulators, manufacturers, airlines, and industry members;

c) Prepare document for balloting;

d) Address industry comments and feedback with respect to AIR guidance; and

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

4.8.2 Vertical Stabilizer, Winglets, and Other High Angle Surface Anti-Icing and Use of Ice Phobics

a) Review (and modify if necessary) methodology and procedure for simulating high angle anti-icing with and without ice phobic treated surfaces;

b) Conduct comparative endurance time testing with select fluids in natural snow conditions at the P.E.T test site. Testing should be conducted in various wind speed conditions. Testing should include Type I testing (as well as Type IV) as previous results have shown potential benefits to using coated surfaces on vertical surfaces;

c) Analyze data and results;

d) Possibly develop alternatives for potential guidance material for anti-icing vertical stabilizer surfaces;

e) Consult with the SAE G-12 Aerodynamics working group regarding best practice solutions; and

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

4.8.3 Evaluate Performance of High and Low Fluid Viscosities When Applied to Ice Phobic Coated Surfaces

a) Develop methodology and procedure for conducting comparative endurance time testing on flat plate coated surfaces to include various fluid viscosities;

b) Solicit fluid manufacturers for high and low fluid viscosity samples, or mechanically or chemically shear existing fluid samples;

c) Conduct comparative endurance time testing with select fluids (one sample of Type II and two Type IV's) at the NRC CEF in less than 20% of the conditions. Consider tests in natural snow conditions;

d) Analyze data and results;

e) Consult with the SAE G-12 Coatings working group regarding impact on AIR; and

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

APPENDIX B

PROCEDURE:
OVERALL PROGRAM OF TESTS AT NRC, APRIL 2013
Winter 2012-13

CM2265.002 (12-13)

OVERALL PROGRAM OF TESTS AT NRC, APRIL 2013

Winter 2012-13

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Stephanie Bendickson

Reviewed by: John D'Avirro

April 2, 2013
Final Version 1.0

OVERALL PROGRAM OF TESTS AT NRC, APRIL 2013
WINTER 2012-13

1. INTRODUCTION

This document was prepared to bring together several projects that require testing at the National Research Council Climactic Engineering Facility (NRC) in Ottawa. Tests will be carried out from April 4-11, 2013.

The primary objective of the test session is to measure the endurance times of new de/anti-icing fluids. Testing for several other related research projects will be scheduled around the endurance time tests as time and space permit. This document provides the schedule, personnel, fluid, and equipment requirements for each of the projects involved.

A tentative test schedule is included in Figure 1.

2. PROJECTS, PROCEDURES AND OBJECTIVES

The projects that will be carried out at the April 2013 NRC test session are listed in this section. Each project has been given a shortened name (shown in brackets following full title) which is used in subsequent sections of this document. A description of each project, its objective and its test procedure are provided. The test procedures for several projects are provided in separate detailed documents, which are referenced in the appropriate subsection and listed in Section 9.

General comments on procedures and setup:

- Endurance time tests will be carried out according to the protocol provided in Aerospace Recommended Practice 5485, *Endurance Time Tests for Aircraft Deicing/Anti-Icing Fluids SAE Type II, III, and IV* (1), except as noted;
- There will be two test stands positioned under the sprayer (main stand with two 6-position stands and side stand with one 3-position stand) and a third stand that will be positioned outside the spray area in the small area of the climate chamber. The test stands should be situated in the cold chamber as per the measurements provided in Figure 2; and
- A complex rate management program was developed in the early 2000s to assist in managing the measurement of precipitation rates. This

program will be used. A guide to the rate management program is available to help with training of any new rate station managers.

2.1 Endurance Times of New Fluids (New Fluid ETs)

The objective of this project is to measure endurance times of new fluids. This will include Type III and Type IV tests, as described below.

Type III Tests: Tests will be conducted with a commercial Type III fluid, Clariant Safewing MP III 2031 ECO, using the Type I test protocol. The main difference in this protocol and the Type II/III/IV protocol (which was used in the original tests with this fluid) is that fluids are applied at 20°C rather than at ambient air temperature. Tests will be conducted over the entire range of freezing precipitation conditions encompassed by the Type III HOT table.

Type III Supplemental Tests: Several sets of supplemental Type III endurance times will be conducted with the Type III fluid:

- Composite Surface Tests: Limited tests (6) will be conducted on composite surfaces to gather preliminary data to determine if heated Type III endurance times are reduced on composite surfaces; and
- Ambient Fluid Application Temperature Tests: Limited tests (6) will be conducted with fluid applied at ambient temperature to compare endurance times of the 2013 fluid sample to those obtained with the original endurance time testing sample (tested in 2004).

Type IV Tests: One new Type IV fluid, Clariant Safewing MP IV Launch Plus, will be tested over the entire range of freezing precipitation conditions encompassed by the Type IV HOT tables.

The procedure for conducting endurance time tests is given in the document *Test Requirements for Simulated Freezing Precipitation Flat Plate Testing* (2). Cold soak boxes should be prepared using the procedure provided in Attachment 1.

The test plan for the new fluid endurance time tests is given in Table 1. All tests will be conducted on the main test stand.

2.2 Supplemental Testing of Commercial Type IV Fluid (Commercial)

Supplemental testing will be conducted with a commercialized Type IV fluid as a result of abnormal results obtained during outdoor testing with the fluid for a separate project. Limited tests will be conducted with neat fluid and 75/25 and 50/50 dilutions. The test plan for the supplemental commercial fluid tests is given in Table 2.

2.3 Thickness of New Fluids (Fluid Thickness)

The objective of these tests is to measure the thickness new fluids on flat plates. The procedure for these tests is entitled *Experimental Program to Establish Film Thickness Profiles for De-Icing and Anti-Icing Fluids on Flat Plates* (3) and can be found in Transport Canada Report TP 13991E, Appendix I. It should be noted that Type III tests will be conducted with fluid at 20°C and Type IV tests will be conducted with fluid at ambient temperature (-3°C).

The test plan for Fluid Thickness tests is given in Table 3. The tests will be conducted at the small end of the chamber outside of the spray area.

2.4 Inspection Immediately Prior to Takeoff (5 Minute Rule)

Current guidance stipulates aircraft surfaces must be inspected within five minutes of beginning the takeoff roll. If it is not possible to take-off within five minutes, the aircraft return and be re-treated. The objective of this project is to evaluate the appropriateness of this guidance by evaluating the condition of test plates five minutes after fluid failure is called. Initial tests were completed in March 2012; the objective of the April 2013 testing is to collect additional data.

This project will be carried out by conducting additional observations on tests being conducted for other projects. Tests with Type III and IV fluids will be piggybacked on the new fluid endurance time tests (see Section 2.1). Type I tests will be piggybacked on the ice phobic endurance time tests (see Section 2.6) and the deployed flaps tests (see Section 2.7). Several independent Type I tests will be conducted to complete the testing.

There is no formal procedure for this project, however, the following points are of importance:

- After fluid failure is recorded for the selected tests, the test plates will be left under the freezing precipitation spray for five minutes. At the five minute mark the percentage of the plate covered with fluid failure will be recorded (using the ET data form).

- Testing will be conducted in the following conditions:
  - Freezing Rain, -3°C, 13 and 25 g/dm^2/h (Type III/IV only);
  - Freezing Rain, -10°C, 13 and 25 g/dm^2/h;
  - Freezing Drizzle, -3°C, 5 g/dm^2/h;
  - Freezing Drizzle, -3°C, 13 g/dm^2/h (Type I only);
  - Freezing Drizzle, -10°C, 5 g/dm^2/h (Type I only); and
  - Freezing Fog, -3°C, 2 g/dm^2/h.

The test plan for the 5 minute rule tests is given in Table 4.

2.5 NCAR Snowmaker Testing (Snowmaker)

Testing is being conducted with the NCAR snowmaker in the winter of 2012-13 to meet several objectives, as listed below. The snowmaker will be brought to the NRC test session to work on these objectives.

1. **Light Snow / Very Light Snow Calibration:** The purpose of these tests is to validate that the snowmaker can reproduce results obtained in outdoor light snow / very light snow conditions. The conditions of select outdoor light snow / very light data points will be reproduced in controlled laboratory conditions. Tests will be conducted with three fluids. The procedure for the conduct of these tests is provided in the document *Endurance Time Test Requirements for Simulated Snow Flat Plate Testing, Type II, III, and IV Fluids* (4). The test plan is given in Table 5.
2. **Heavy Snow:** The objective of this activity is to try to determine why differences are seen between endurance times measured in natural snow and with the snowmaker. The conditions in which three select natural snow tests were conducted will be reproduced in controlled laboratory conditions using the NCAR snow machine. Each of the three tests will be reproduced three times. The procedure for the conduct of these tests is provided in the document *Endurance Time Testing with Heavy Snow with the Snowmaker in Comparison with Natural Snow* (5). These tests require Brix and thickness measurements and photos to enable correlation with the outdoor endurance times. The test plan for the snowmaker tests is given in Table 6.
3. **Light Snow / Very Light Snow:** Testing with the NCAR snowmaker is planned for the week of April 22 at the PMG Technologies cold chamber in Blainville, Quebec. The objective of the testing is to measure endurance times in light and very light snow at -25°C. Preliminary testing for this project will be conducted at the NRC test session to ensure feasibility of the project test plan. The procedure for the conduct of these tests is provided in

the document *Endurance Time Test Requirements for Simulated Snow Flat Plate Testing, Type II, III, and IV Fluids* (4). The test plan is given in Table 7.

4. **Rate Distribution:** Rate distribution on the snowmaker test plate will be evaluated using the protocol provided in ARP 5485. A limited number of tests will be conducted in advance of testing, typically on a daily basis close to the expected temperatures and precipitation rates of that particular day's testing.

The snowmaker will be set up in the small end of the chamber away from the freezing precipitation sprayer. A calendar is included (see Figure 3) to identify which snowmaker tests will be conducted during each cold chamber condition.

2.6 Evaluation of Ice Phobic Products (Ice Phobic)

The objective of this project is to continue the evaluation of newly developed ice phobic products. The project has five sub-objectives as described below.

1. **Endurance Times:** Evaluation of impact of ice phobic products on fluid endurance times. Tests will be conducted with five coatings and seven fluids. The procedure for the conduct of these tests is provided in the document *Effect of Ice Phobic Products on HOTs* (6). The test plan is given in Table 8.
2. **Thickness:** Evaluation of ice phobic products on fluid thickness. The standard procedure for measuring fluid thickness will be used (see Subsection 2.3). Notably, thickness (Type II fluid) or percent wetted (Type I fluid) will be measured at 15 cm line at time of application and 2, 5, 15, and 30 minutes after. The test plan is given in Table 9. Tests will be conducted at the small end of the chamber outside of the spray area.
3. **Adhesion:** Evaluation of impact of ice phobic products on fluid adhesion. These tests will be conducted without fluid. The test plan is given in Table 10.
4. **High vs. Low Viscosity:** Evaluation of the endurance times of high and low viscosity fluids when applied to ice phobic coated surfaces; this is being done in support of the fluid selection process for AIR 6232 (in development). Testing will be done in conjunction with the ice phobic endurance times testing to minimize the number of tests required. The tests are included in the endurance time test plan provided in Table 8.
5. **Hot Water:** Evaluate the potential for using only hot water as a deicer for end of runway or deicing only type applications. Some coatings may delay the onset of adherence of precipitation and therefore may result in equal or

longer protection times than a Type I fluid. The test plan is given in Table 11.

Except where noted, tests will be conducted on the main and/or side stand.

2.7 Endurance Times on Flaps/Slats (Flaps)

The objective of this project is to continue the evaluation of endurance time performance of anti-icing fluids on wing surfaces with deployed flaps. Limited testing with Type I fluids is being carried out at this test session to supplement previously collected data.

The procedure for the conduct of these tests is provided in the document *Evaluation of Endurance Times on Deployed Flaps* (7). The procedure was written for testing in outdoor conditions; changes to the procedure required for indoor testing and the indoor test plan are provided herein.

Tests will be conducted using standard holdover time testing procedures. Each comparative test will include a baseline test (conducted on plate inclined to a 10° slope) and two non-nested flap tests (conducted on plates inclined to a 20° and 35° slope). Tests with nested plates will also be done to demonstrate that nesting does not have an impact. In addition to failure time, fluid thickness and Brix will be taken as detailed in the test plan.

The test plan for Deployed Flaps tests is given in Table 12. The tests will be conducted on the main and/or side stand. Tests requiring plates oriented to 20° or 35° must be positioned on the lower main stand or on the side stand.

2.7.1 Supplemental Flap/Slat Extension Tests

Supplemental tests will be conducted to investigate the effects of extending a flap or slat during the holdover time. This will be achieved by overlapping two plates in either a flap or slat configuration and fully separating them midway during the expected holdover time. Particular attention will be given to investigating how the bare areas on the plates behave with the precipitation. The test plan for the flap/slat extension tests is provided in Table 13.

2.8 ROGIDS

The manufacturer of the only know remote on-ground ice detection system (ROGIDS) will be invited to participate at the April 2013 NRC tests session on a non-obtrusive basis.

3. PERSONNEL REQUIREMENTS/RESPONSIBILITIES

The personnel responsibilities are listed below.

1. New Fluid ETs/Commercial:
   - Manager: JD (pours fluids, calls failures);
   - Assistant: VZ (preps fluids/data forms); and
   - Rates Team: SB, YOW1.
2. Fluid Thickness:
   - Manager: MR (runs tests, takes measurements); and
   - Assistant: YOW2 (records measurements).
3. 5 Minute Rule:
   - Manager: VZ (tracks timing, records measurements);
   - Failure Calls: JD/MR (depending on piggybacked project), and
   - Rates Team: SB, YOW1.
4. Snowmaker:
   - Manager: DY (runs tests, takes measurements).
5. Ice Phobic ETs:
   - Manager: MR (runs tests, takes measurements);
   - Assistant: YOW2 (records measurements, assists as needed); and
   - Rates Team: SB, YOW1.
6. Flaps/Slats:
   - Manager: MR (runs tests, takes measurements);
   - Assistant: YOW2 (records measurements); and
   - Rates Team: SB, YOW1.

The Rates Team will consist of:

- Rate Manager: SB (runs rate station); and
- Rate Assistant: YOW1 (runs pans, refills fluids).

In the condition of Cold Soak Wing, additional personnel will be required:

- Box Prep Manager: MR; and
- Box Prep Assistants: DY, YOW2.

In addition, personnel will be designated responsible for:

- Equipment: MR/DY;
- Pre-test Setup: MR/DY;
- Data Form Manager: VZ;
- HOT Data Management: SB;
- Fluid Management: SB/VZ; and
- Photographer: BG.

4. FLUIDS

The required fluids and fluid quantities are shown in Table 14. Type I fluids will be diluted prior to testing using the dilution tables provided in Table 15.

5. EQUIPMENT

Table 16 provides a list of the general equipment required. A supplemental equipment list for snowmaker testing is provided in Table 17.

6. DATA FORMS

The data forms required for each project are listed below.

1. New Fluid ETs:
   - Freezing Precipitation Endurance Time Data Form (Figure 4); and
   - Rate Management Form (Figure 5).
2. Fluid Thickness:

- Fluid Thickness Data Form (Figure 6).

3. 5 Minute Rule:
   - No data forms required; observations recorded on endurance time data forms.

4. Snowmaker
   - Snowmaker End Condition Data Form (Figure 7) and
   - Fluid Brix and Thickness Data Form (Figure 8).

5. Ice Phobic ETs:
   - Ice Phobic End Condition Data Form (Figure 9); and
   - Ice Phobic Thickness Data Form (Figure 10).

6. Flaps/Slats:
   - Freezing Precipitation Endurance Time Data Form (Figure 4).

7. PRE–TEST SET–UP ACTIVITIES

The following activities need to be completed prior to arrival at the NRC:

1. Mark plates with plate numbers (MR);
2. ~~Check rate pans: check quantity, check for holes, and check all pans are properly labelled;~~
3. Ensure plates and boxes are equipped with operational and verified thermistors or smart buttons (MR);
4. ~~Prepare labels for pour containers (VZ);~~
5. Ensure fluids are prepared in advance according to Table 14 (DP);
6. Clean and label 1 litre pour containers (DP);
7. ~~Check laptops (2) work for rate station (MR);~~
8. ~~Rent cube van (VZ);~~
9. ~~Book hotel (VZ);~~
10. ~~Update and print chamber settings file (EA);~~
11. Print data forms and procedures (EA);
12. Print chamber condition sheets (SB/VZ);

13. Contact Medhat (DY);
    - confirm availability of NRC camera system for rates;
    - distilled water for ice cores; and
    - waste tote.
14. Figure out logging intervals of smart buttons (MR/DY);
15. Inventory at test site (MR/DY);
    - Latex gloves; and
    - Whiteboard.
16. Get yellow fluid carrying case from GTCA (MR/DY);
17. Order two inclinometers (AE/VZ);
18. Speak to BG re testing schedule (VZ);
19. Leave 1 camera bag (old Canon camera) at site (DY);
20. Back up MTL drive (Projects and General folders) (AE/VZ);
21. Install Trendreader on all laptops (MR/VZ);
22. Pack snowmaker (DY); and
23. Talk to Ben re rate station observation (SB).

The following items should be purchased prior to arrival at the NRC:

1. Scrapers x5
2. IKEA cart, Purchase 2 (VZ)

8. SAFETY ISSUES

Managers of each subproject must ensure that personnel involved in the set-up and conduct of their respective projects are aware of the following:

1. Fluid MSDS sheets are available for review;
2. Waterproof clothing and gloves are available;
3. Rubber mats must be properly placed in and around the test area and cleaned as necessary;
4. Care should be taken when circulating near the test stand due to slipperiness;
5. First aid kit, water and fire extinguisher are available; and
6. All NRC safety guidelines must be followed.

9. REFERENCES

1. SAE Aerospace Recommended Practice 5485, Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids: SAE Type II, III, and IV, July 2004.

2. Test Requirements For Simulated Freezing Precipitation Flat Plate Testing, Version 1.0, January 15, 2004.

3. Experimental Program to Establish Film Thickness Profiles for De-Icing and Anti-Icing Fluids on Flat Plates, Version 1.0, April 3, 2002.

4. Endurance Time Test Requirements for Simulated Snow Flat Plate Testing, Type II, III, and IV Fluids, Final Version 1.2, January 23, 2008.

5. Endurance Time Testing with Heavy Snow with the Snowmaker in Comparison with Natural Snow, Final Version 1.0, January 2, 2009.

6. Effect of Ice Phobic Products on Holdover Times, Final Version 1.0, December 24, 2009.

7. Evaluation of Endurance Times on Deployed Flaps, Final Version 1.0, January 25, 2012.

FIGURE 1: TEST SCHEDULE

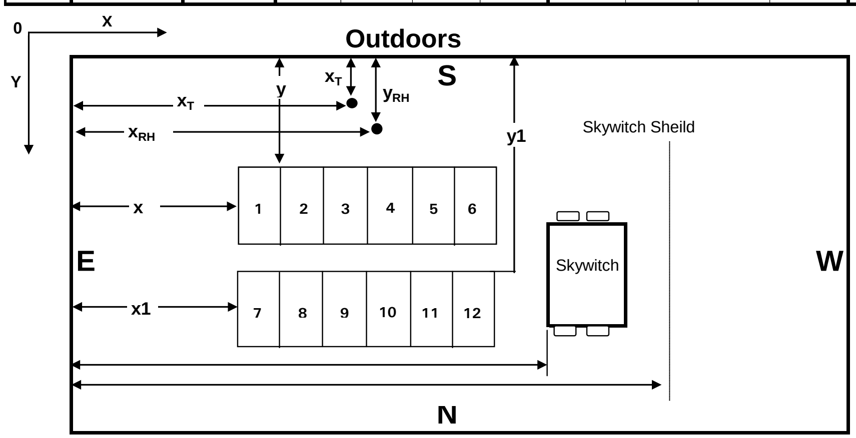
	Tues Apr-02	Wed Apr-03	Thurs Apr-04	Fri Apr-05		Mon Apr-08	Tues Apr-09	Wed Apr-10	Thurs Apr-11	Fri Apr-12
9:00	Packup	Drive to YOW	**ZF,-3,2** HOT=12 MF=2 FM=1 (TI)	**ZF,-14,2** HOT=4		**ZF,-25,2** HOT=4	**ZD,-10,5** HOT=10 FM=1 (TI) DF=5 (TI)	**ZD,-3,5** HOT=12 MF=4 PH=12 (TI) DF=2 (TI)	**ZR,-3,25** HOT=14 MF=4 PH=12 FSE=2	Spare Day
9:30										
10:00										
10:30						**ZF,-25,5** HOT=4				
11:00										
11:30						Take down ZF and Warm to -10°C	**ZR,-10,13** HOT=8 MF=2 FM=1 (TI) PH=18 PH-AD=6 PH-HW=6			
12:00		Setup at NRC		**ZF,-14,5** HOT=4						
12:30									Warm to +1°C	
13:00						**ZD,-10,13** HOT=8 PH=12 FSE=2 DF=3 (TI)		**ZD,-3,13** HOT=14 MF=4 PH=18 DF=5 (TI)		
13:30									**CSW,1,5** HOT=8	
14:00			**ZF,-3,5** HOT=14 MF=2 DF=3 (TI)	Warm to -10°C						
14:30										
15:00				**ZF,-10,5** HOT=5			Warm to -3°C			
15:30										
16:00							**ZR,-3,13** HOT=14 MF=4		**CSW,1,75** HOT=8	
16:30				**ZF,-10,2** HOT=6 PH-HW=6						
17:00						**ZR,-10,25** HOT=8 MF=2 FM=2 (TI) PH=6 DF=3 (TI)				
17:30									Pack up	
18:00										
18:30										
19:00										
19:30										

*Consider doing airfoil test in less busy condition

FIGURE 2: TEST STAND LOCATION MEASUREMENTS

LOCATION: CEF (Ottawa) **DATE:** **CONDITION: ZR3H ZR3L ZR10H ZR10L ZD3H ZD3L ZD10H ZD10L ZF3H ZF3L ZF10H ZF10L ZF14H ZF14L ZF25H ZF25L CSWH CSWL**

Test	Date of Final Position	Condition	Sensor Position				Stand Position				Skywitch Position	Skywitch Sheild Position (*)	Nozzle Position (**)	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						
1	04-Apr-01	ZR3H					24' 2"	7'	22' 7"	9' 10"				Very Good		Top Stand 19' from snow fence
2	04-Apr-01	ZR3L					24' 2"	7'	22' 7"	9' 10"				Very Good		Top Stand 19' from snow fence
3	02/04/2001	ZR10H					24'	6' 9"	24' 5"	9' 6"				Very Good		Top stand is 20 ft. from snow fence
4	02-Apr-01	ZR10L					24'	6' 9"	24' 5"	9' 6"				Very Good		Top stand is 20 ft. from snow fence
5	27-Mar-01	ZD3H					24' 5"	6'6"	22'	10'4"				Very Good		
6	28-Mar-01	ZD3L					25' 3"	7'3"	25' 3"	9' 6"				Good		
7	02-Apr-01	ZD10H					24'	7'11"	25' 3"	9' 6"				Very Good		
8	02-Apr-01	ZD10L					24'	7' 7"	24' 7"	9' 11"				Good		20 ft. from Snow Fence
9	10-Apr-01	ZFog3H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
10	10-Apr-01	ZFog3L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
11	10-Apr-01	ZFog10H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
12	10-Apr-01	ZFog10L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
13	09-Apr-01	ZFog14H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
14	09-Apr-01	ZFog14L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
15	06-Apr-01	ZFog25H					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
16	06-Apr-01	ZFog25L					24'	6'6"	21'11"	8'10"	34' 2"from x	40'2" from x	top of plate 11	Good	144"	
17	29-Mar-01	CSWH					25'3"		25'3"	9' 6"						
18	29-Mar-01	CSWL					23'11"	7'3"	25'3"	9' 6"						



Notes:

* - "From X" refers to the distance from the East wall.
** - The nozzle should be between positions 5 and 11
RH - Relative Humidity Sensor
T - Temperature Sensor

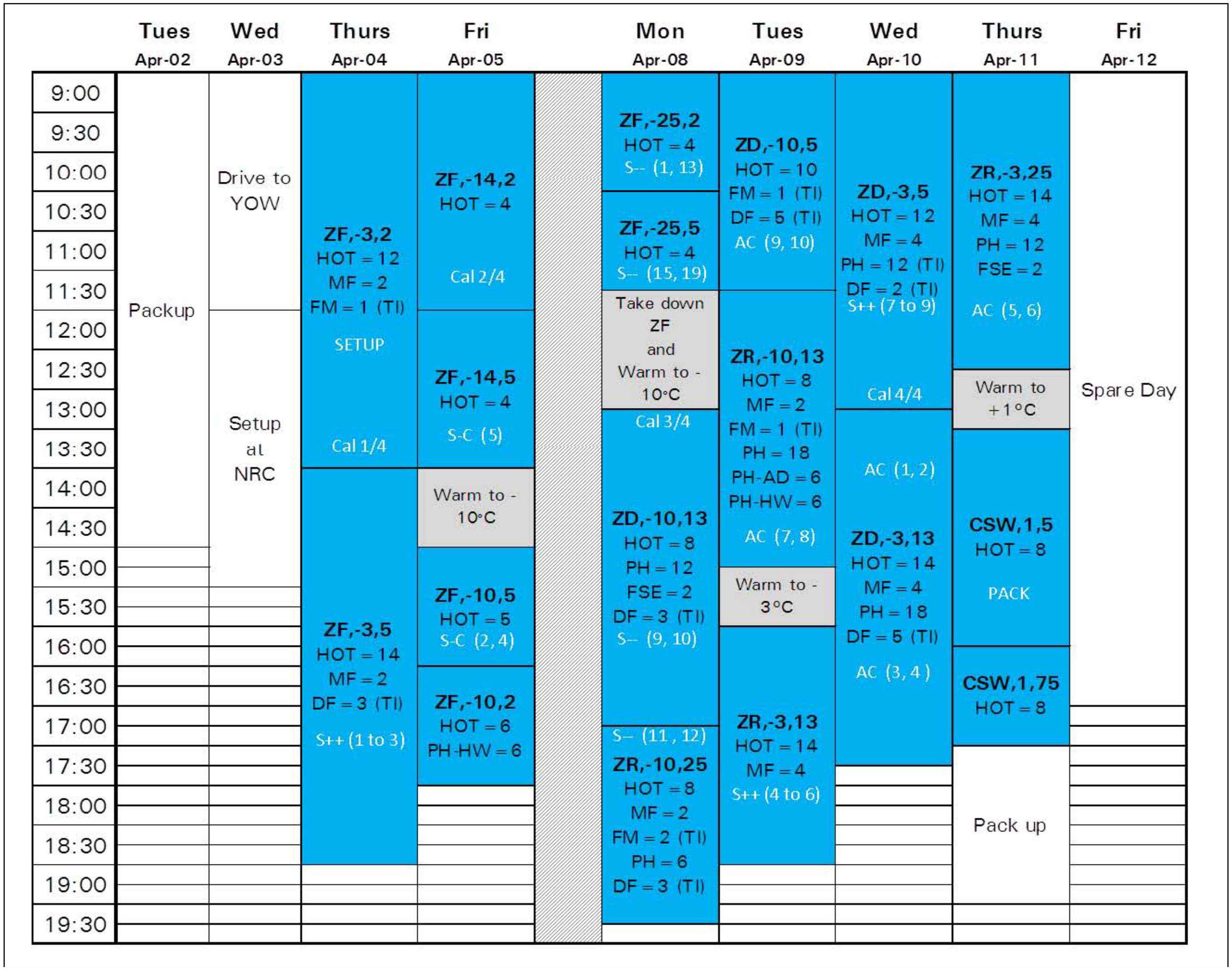
WEIGH SCALE TECHNICIAN: ______________________

LEADER: ______________________

NEW VALUES (IF DIFFERENT)

Test	Date of Final Position	Condition	Sensor Position				Stand Position				Skywitch Position	Skywitch Sheild Position (*)	Nozzle Position (**)	Rate	Height of nozzle over plate	Comments
			X_T	Y_T	X_{RH}	Y_{RH}	x	y	x1	y1						

FIGURE 3: SNOWMAKER TEST CALENDAR



ATTACHMENT 1: COLD SOAK BOX PREPARATION PROCEDURE

1. Put containers (20 L) of CSW box fluid (propylene 65/35) in cold (-30 ± 5°C) freezer overnight. Freezers to be kept in large end of the chamber.

2. Put all filled CSW boxes in warmer (-11 ± 1°C) freezer overnight.

3. Next morning, if freezer in step (2) does not provide fluid and box temperature of -11 ± 1°C, then empty boxes in pail and achieve fluid at -12 ± 1°C in pail.

4. Prepare step (3) in corner of large chamber that is at +1°C; ensure boxes are cooled to about -11°C. Go to step (6).

5. After first series of tests, empty fluid from boxes into separate pail. Put empty boxes in freezer to keep cool at -11 ± 2°C.

6. Prepare fluid to -12 ± 1°C by mixing (use small amounts of hot water and/or cold fluid). Agitate fluid mixture frequently.

7. Fill boxes, ensure -11 ± 1°C on surface of box. This process shall be done while rates are being measured.

8. Position on stand with cover, but no insulation on top surface. Connect thermocouples.

9. Allow warming to -10 ± 0.5°C. This process needs monitoring with rates measurement to not overshoot temperature (place insulation on top surface if required).

10. Start test.

11. At end of test, remove box from stand, measure rates, and go to step (5).

TABLE 1: ENDURANCE TIME TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
1	Freezing Fog	-3	2	Clariant Launch Plus	100	Al. Plate	5 min failure
2	Freezing Fog	-3	2	Clariant Launch Plus	100	Al. Plate	
3	Freezing Fog	-3	2	Clariant Launch Plus	75	Al. Plate	5 min failure
4	Freezing Fog	-3	2	Clariant Launch Plus	75	Al. Plate	
5	Freezing Fog	-3	2	Clariant Launch Plus	50	Al. Plate	5 min failure
6	Freezing Fog	-3	2	Clariant Launch Plus	50	Al. Plate	
7	Freezing Fog	-3	2	Clariant MP III 2031	100	Al. Plate	5 min failure
8	Freezing Fog	-3	2	Clariant MP III 2031	100	Al. Plate	
9	Freezing Fog	-3	2	Clariant MP III 2031	75	Al. Plate	5 min failure
10	Freezing Fog	-3	2	Clariant MP III 2031	75	Al. Plate	
11	Freezing Fog	-3	2	Clariant MP III 2031	50	Al. Plate	5 min failure
12	Freezing Fog	-3	2	Clariant MP III 2031	50	Al. Plate	
13	Freezing Fog	-3	5	Clariant Launch Plus	100	Al. Plate	
14	Freezing Fog	-3	5	Clariant Launch Plus	100	Al. Plate	
15	Freezing Fog	-3	5	Clariant Launch Plus	75	Al. Plate	
16	Freezing Fog	-3	5	Clariant Launch Plus	75	Al. Plate	
17	Freezing Fog	-3	5	Clariant Launch Plus	50	Al. Plate	
18	Freezing Fog	-3	5	Clariant Launch Plus	50	Al. Plate	
19	Freezing Fog	-3	5	Clariant MP III 2031	100	Al. Plate	
20	Freezing Fog	-3	5	Clariant MP III 2031	100	Al. Plate	
21	Freezing Fog	-3	5	Clariant MP III 2031	75	Al. Plate	
22	Freezing Fog	-3	5	Clariant MP III 2031	75	Al. Plate	
23	Freezing Fog	-3	5	Clariant MP III 2031	50	Al. Plate	
24	Freezing Fog	-3	5	Clariant MP III 2031	50	Al. Plate	
CD24	Freezing Fog	-3	5	Clariant MP III 2031 COLD	50	Al. Plate	Fluid @ OAT
CP24	Freezing Fog	-3	5	Clariant MP III 2031	50	Comp. Plate	
25	Freezing Fog	-10	2	Clariant MP III 2031	100	Al. Plate	
26	Freezing Fog	-10	2	Clariant MP III 2031	100	Al. Plate	
27	Freezing Fog	-10	2	Clariant MP III 2031	75	Al. Plate	
28	Freezing Fog	-10	2	Clariant MP III 2031	75	Al. Plate	
CD28	Freezing Fog	-10	2	Clariant MP III 2031 COLD	75	Al. Plate	Fluid @ OAT
CP28	Freezing Fog	-10	2	Clariant MP III 2031	75	Comp. Plate	
29	Freezing Fog	-10	5	Clariant MP III 2031	100	Al. Plate	
30	Freezing Fog	-10	5	Clariant MP III 2031	100	Al. Plate	
31	Freezing Fog	-10	5	Clariant MP III 2031	75	Al. Plate	
32	Freezing Fog	-10	5	Clariant MP III 2031	75	Al. Plate	
33	Freezing Fog	-14	2	Clariant Launch Plus	100	Al. Plate	
34	Freezing Fog	-14	2	Clariant Launch Plus	100	Al. Plate	
35	Freezing Fog	-14	2	Clariant Launch Plus	75	Al. Plate	
36	Freezing Fog	-14	2	Clariant Launch Plus	75	Al. Plate	
37	Freezing Fog	-14	5	Clariant Launch Plus	100	Al. Plate	
38	Freezing Fog	-14	5	Clariant Launch Plus	100	Al. Plate	
39	Freezing Fog	-14	5	Clariant Launch Plus	75	Al. Plate	
40	Freezing Fog	-14	5	Clariant Launch Plus	75	Al. Plate	
41	Freezing Fog	-25	2	Clariant Launch Plus	100	Al. Plate	
42	Freezing Fog	-25	2	Clariant Launch Plus	100	Al. Plate	
43	Freezing Fog	-25	2	Clariant MP III 2031	100	Al. Plate	

TABLE 1: ENDURANCE TIME TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
44	Freezing Fog	-25	2	Clariant MP III 2031	100	Al. Plate	
45	Freezing Fog	-25	5	Clariant Launch Plus	100	Al. Plate	
46	Freezing Fog	-25	5	Clariant Launch Plus	100	Al. Plate	
47	Freezing Fog	-25	5	Clariant MP III 2031	100	Al. Plate	
48	Freezing Fog	-25	5	Clariant MP III 2031	100	Al. Plate	
49	Light Freezing Rain	-3	13	Clariant Launch Plus	100	Al. Plate	5 min failure
50	Light Freezing Rain	-3	13	Clariant Launch Plus	100	Al. Plate	
51	Light Freezing Rain	-3	13	Clariant Launch Plus	75	Al. Plate	5 min failure
52	Light Freezing Rain	-3	13	Clariant Launch Plus	75	Al. Plate	
53	Light Freezing Rain	-3	13	Clariant Launch Plus	50	Al. Plate	5 min failure
54	Light Freezing Rain	-3	13	Clariant Launch Plus	50	Al. Plate	
55	Light Freezing Rain	-3	13	Clariant MP III 2031	100	Al. Plate	5 min failure
56	Light Freezing Rain	-3	13	Clariant MP III 2031	100	Al. Plate	
57	Light Freezing Rain	-3	13	Clariant MP III 2031	75	Al. Plate	5 min failure
58	Light Freezing Rain	-3	13	Clariant MP III 2031	75	Al. Plate	
CD58	Light Freezing Rain	-3	13	Clariant MP III 2031 COLD	75	Al. Plate	Fluid @ OAT
CP58	Light Freezing Rain	-3	13	Clariant MP III 2031	75	Comp. Plate	
59	Light Freezing Rain	-3	13	Clariant MP III 2031	50	Al. Plate	5 min failure
60	Light Freezing Rain	-3	13	Clariant MP III 2031	50	Al. Plate	
61	Light Freezing Rain	-3	25	Clariant Launch Plus	100	Al. Plate	5 min failure
62	Light Freezing Rain	-3	25	Clariant Launch Plus	100	Al. Plate	
63	Light Freezing Rain	-3	25	Clariant Launch Plus	75	Al. Plate	
64	Light Freezing Rain	-3	25	Clariant Launch Plus	75	Al. Plate	5 min failure
65	Light Freezing Rain	-3	25	Clariant Launch Plus	50	Al. Plate	5 min failure
66	Light Freezing Rain	-3	25	Clariant Launch Plus	50	Al. Plate	
67	Light Freezing Rain	-3	25	Clariant MP III 2031	100	Al. Plate	5 min failure
68	Light Freezing Rain	-3	25	Clariant MP III 2031	100	Al. Plate	
CD68	Light Freezing Rain	-3	25	Clariant MP III 2031 COLD	100	Al. Plate	Fluid @ OAT
CP68	Light Freezing Rain	-3	25	Clariant MP III 2031	100	Comp. Plate	
69	Light Freezing Rain	-3	25	Clariant MP III 2031	75	Al. Plate	5 min failure
70	Light Freezing Rain	-3	25	Clariant MP III 2031	75	Al. Plate	
71	Light Freezing Rain	-3	25	Clariant MP III 2031	50	Al. Plate	5 min failure
72	Light Freezing Rain	-3	25	Clariant MP III 2031	50	Al. Plate	
73	Light Freezing Rain	-10	13	Clariant Launch Plus	100	Al. Plate	5 min failure
74	Light Freezing Rain	-10	13	Clariant Launch Plus	100	Al. Plate	
75	Light Freezing Rain	-10	13	Clariant Launch Plus	75	Al. Plate	5 min failure
76	Light Freezing Rain	-10	13	Clariant Launch Plus	75	Al. Plate	
77	Light Freezing Rain	-10	13	Clariant MP III 2031	100	Al. Plate	5 min failure
78	Light Freezing Rain	-10	13	Clariant MP III 2031	100	Al. Plate	
79	Light Freezing Rain	-10	13	Clariant MP III 2031	75	Al. Plate	5 min failure
80	Light Freezing Rain	-10	13	Clariant MP III 2031	75	Al. Plate	
81	Light Freezing Rain	-10	25	Clariant Launch Plus	100	Al. Plate	5 min failure
82	Light Freezing Rain	-10	25	Clariant Launch Plus	100	Al. Plate	
83	Light Freezing Rain	-10	25	Clariant Launch Plus	75	Al. Plate	5 min failure
84	Light Freezing Rain	-10	25	Clariant Launch Plus	75	Al. Plate	
85	Light Freezing Rain	-10	25	Clariant MP III 2031	100	Al. Plate	5 min failure
86	Light Freezing Rain	-10	25	Clariant MP III 2031	100	Al. Plate	
87	Light Freezing Rain	-10	25	Clariant MP III 2031	75	Al. Plate	5 min failure

TABLE 1: ENDURANCE TIME TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface	Comments
88	Light Freezing Rain	-10	25	Clariant MP III 2031	75	Al. Plate	
89	Freezing Drizzle	-3	5	Clariant Launch Plus	100	Al. Plate	5 min failure
90	Freezing Drizzle	-3	5	Clariant Launch Plus	100	Al. Plate	
91	Freezing Drizzle	-3	5	Clariant Launch Plus	75	Al. Plate	5 min failure
92	Freezing Drizzle	-3	5	Clariant Launch Plus	75	Al. Plate	
93	Freezing Drizzle	-3	5	Clariant Launch Plus	50	Al. Plate	5 min failure
94	Freezing Drizzle	-3	5	Clariant Launch Plus	50	Al. Plate	
95	Freezing Drizzle	-3	5	Clariant MP III 2031	100	Al. Plate	5 min failure
96	Freezing Drizzle	-3	5	Clariant MP III 2031	100	Al. Plate	
97	Freezing Drizzle	-3	5	Clariant MP III 2031	75	Al. Plate	5 min failure
98	Freezing Drizzle	-3	5	Clariant MP III 2031	75	Al. Plate	
99	Freezing Drizzle	-3	5	Clariant MP III 2031	50	Al. Plate	5 min failure
100	Freezing Drizzle	-3	5	Clariant MP III 2031	50	Al. Plate	
101	Freezing Drizzle	-3	13	Clariant Launch Plus	100	Al. Plate	
102	Freezing Drizzle	-3	13	Clariant Launch Plus	100	Al. Plate	
103	Freezing Drizzle	-3	13	Clariant Launch Plus	75	Al. Plate	
104	Freezing Drizzle	-3	13	Clariant Launch Plus	75	Al. Plate	
105	Freezing Drizzle	-3	13	Clariant Launch Plus	50	Al. Plate	
106	Freezing Drizzle	-3	13	Clariant Launch Plus	50	Al. Plate	
107	Freezing Drizzle	-3	13	Clariant MP III 2031	100	Al. Plate	
108	Freezing Drizzle	-3	13	Clariant MP III 2031	100	Al. Plate	
109	Freezing Drizzle	-3	13	Clariant MP III 2031	75	Al. Plate	
110	Freezing Drizzle	-3	13	Clariant MP III 2031	75	Al. Plate	
111	Freezing Drizzle	-3	13	Clariant MP III 2031	50	Al. Plate	
112	Freezing Drizzle	-3	13	Clariant MP III 2031	50	Al. Plate	
CD112	Freezing Drizzle	-3	13	Clariant MP III 2031 COLD	50	Al. Plate	Fluid @ OAT
CP112	Freezing Drizzle	-3	13	Clariant MP III 2031	50	Comp. Plate	
113	Freezing Drizzle	-10	5	Clariant Launch Plus	100	Al. Plate	
114	Freezing Drizzle	-10	5	Clariant Launch Plus	100	Al. Plate	
115	Freezing Drizzle	-10	5	Clariant Launch Plus	75	Al. Plate	
116	Freezing Drizzle	-10	5	Clariant Launch Plus	75	Al. Plate	
117	Freezing Drizzle	-10	5	Clariant MP III 2031	100	Al. Plate	
118	Freezing Drizzle	-10	5	Clariant MP III 2031	100	Al. Plate	
CD118	Freezing Drizzle	-10	5	Clariant MP III 2031 COLD	100	Al. Plate	Fluid @ OAT
CP118	Freezing Drizzle	-10	5	Clariant MP III 2031	100	Comp. Plate	
119	Freezing Drizzle	-10	5	Clariant MP III 2031	75	Al. Plate	
120	Freezing Drizzle	-10	5	Clariant MP III 2031	75	Al. Plate	
121	Freezing Drizzle	-10	13	Clariant Launch Plus	100	Al. Plate	
122	Freezing Drizzle	-10	13	Clariant Launch Plus	100	Al. Plate	
123	Freezing Drizzle	-10	13	Clariant Launch Plus	75	Al. Plate	
124	Freezing Drizzle	-10	13	Clariant Launch Plus	75	Al. Plate	
125	Freezing Drizzle	-10	13	Clariant MP III 2031	100	Al. Plate	
126	Freezing Drizzle	-10	13	Clariant MP III 2031	100	Al. Plate	
127	Freezing Drizzle	-10	13	Clariant MP III 2031	75	Al. Plate	
128	Freezing Drizzle	-10	13	Clariant MP III 2031	75	Al. Plate	
129	Cold Soak Box	1	5	Clariant Launch Plus	100	Box	
130	Cold Soak Box	1	5	Clariant Launch Plus	100	Box	
131	Cold Soak Box	1	5	Clariant Launch Plus	75	Box	

TABLE 1: ENDURANCE TIME TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate ($g/dm^2/h$)	Fluid	Fluid Dilution (%)	Test Surface	Comments
132	Cold Soak Box	1	5	Clariant Launch Plus	75	Box	
133	Cold Soak Box	1	5	Clariant MP III 2031	100	Al. Box	
134	Cold Soak Box	1	5	Clariant MP III 2031	100	Al. Box	
135	Cold Soak Box	1	5	Clariant MP III 2031	75	Al. Box	
136	Cold Soak Box	1	5	Clariant MP III 2031	75	Al. Box	
137	Cold Soak Box	1	75	Clariant Launch Plus	100	Box	
138	Cold Soak Box	1	75	Clariant Launch Plus	100	Box	
139	Cold Soak Box	1	75	Clariant Launch Plus	75	Box	
140	Cold Soak Box	1	75	Clariant Launch Plus	75	Box	
141	Cold Soak Box	1	75	Clariant MP III 2031	100	Al. Box	
142	Cold Soak Box	1	75	Clariant MP III 2031	100	Al. Box	
143	Cold Soak Box	1	75	Clariant MP III 2031	75	Al. Box	
144	Cold Soak Box	1	75	Clariant MP III 2031	75	Al. Box	
132	Cold Soak Box	1	5	Clariant Launch Plus	75	Box	
133	Cold Soak Box	1	5	Clariant MP III 2031	100	Al. Box	
134	Cold Soak Box	1	5	Clariant MP III 2031	100	Al. Box	
135	Cold Soak Box	1	5	Clariant MP III 2031	75	Al. Box	
136	Cold Soak Box	1	5	Clariant MP III 2031	75	Al. Box	
137	Cold Soak Box	1	75	Clariant Launch Plus	100	Box	
138	Cold Soak Box	1	75	Clariant Launch Plus	100	Box	
139	Cold Soak Box	1	75	Clariant Launch Plus	75	Box	
140	Cold Soak Box	1	75	Clariant Launch Plus	75	Box	
141	Cold Soak Box	1	75	Clariant MP III 2031	100	Al. Box	
142	Cold Soak Box	1	75	Clariant MP III 2031	100	Al. Box	
143	Cold Soak Box	1	75	Clariant MP III 2031	75	Al. Box	
144	Cold Soak Box	1	75	Clariant MP III 2031	75	Al. Box	

TABLE 2: SUPPLEMENTAL COMMERCIAL FLUID TEST PLAN

Test #	**Precipitation Type**	**Temp** (°C)	**Precip. Rate** ($g/dm^2/h$)	**Fluid**	**Fluid Dilution** (%)	**Test Surface**
MF1	Freezing Drizzle	-3	5	MF04-2	100	Al. Plate
MF2	Freezing Drizzle	-3	13	MF04-2	100	Al. Plate
MF3	Light Freezing Rain	-3	13	MF04-2	100	Al. Plate
MF4	Light Freezing Rain	-3	25	MF04-2	100	Al. Plate
MF5	Light Freezing Rain	-10	13	MF04-2	100	Al. Plate
MF6	Light Freezing Rain	-10	25	MF04-2	100	Al. Plate
MF7	Freezing Drizzle	-3	5	MF04-2	75	Al. Plate
MF8	Freezing Drizzle	-3	13	MF04-2	75	Al. Plate
MF9	Light Freezing Rain	-3	13	MF04-2	75	Al. Plate
MF10	Light Freezing Rain	-3	25	MF04-2	75	Al. Plate
MF11	Light Freezing Rain	-10	13	MF04-2	75	Al. Plate
MF12	Light Freezing Rain	-10	25	MF04-2	75	Al. Plate
MF13	Freezing Drizzle	-3	5	MF04-2	50	Al. Plate
MF14	Freezing Drizzle	-3	13	MF04-2	50	Al. Plate
MF15	Light Freezing Rain	-3	13	MF04-2	50	Al. Plate
MF16	Light Freezing Rain	-3	25	MF04-2	50	Al. Plate
MF17	Freezing Fog	-3	2	MF04-2	50	Al. Plate
MF18	Freezing Fog	-3	5	MF04-2	50	Al. Plate
MF19	Freezing Drizzle	-3	5	MF04-1	50	Al. Plate
MF20	Freezing Drizzle	-3	13	MF04-1	50	Al. Plate
MF21	Light Freezing Rain	-3	13	MF04-1	50	Al. Plate
MF22	Light Freezing Rain	-3	25	MF04-1	50	Al. Plate
MF23	Freezing Fog	-3	2	MF04-1	50	Al. Plate
MF24	Freezing Fog	-3	5	MF04-1	50	Al. Plate

TABLE 3: FLUID THICKNESS TEST PLAN

Test #	Fluid	Fluid Dilution	Fluid Temp	Test Surface	Ambient Air Temp
TH1	Cryotech X	100/0	-3°C	Al. Plate	-3°C
TH2	Cryotech X	100/0	-3°C	Al. Plate	-3°C
TH3	Cryotech X	75/25	-3°C	Al. Plate	-3°C
TH4	Cryotech X	75/25	-3°C	Al. Plate	-3°C
TH5	Cryotech X	50/50	-3°C	Al. Plate	-3°C
TH6	Cryotech X	50/50	-3°C	Al. Plate	-3°C
TH7	Clariant 2031	100/0	20°C	Al. Plate	-3°C
TH8	Clariant 2031	100/0	20°C	Al. Plate	-3°C
TH9	Clariant 2031	75/25	20°C	Al. Plate	-3°C
TH10	Clariant 2031	75/25	20°C	Al. Plate	-3°C
TH11	Clariant 2031	50/50	20°C	Al. Plate	-3°C
TH12	Clariant 2031	50/50	20°C	Al. Plate	-3°C
TH13	Clariant Launch Plus	100/0	-3°C	Al. Plate	-3°C
TH14	Clariant Launch Plus	100/0	-3°C	Al. Plate	-3°C
TH15	Clariant Launch Plus	75/25	-3°C	Al. Plate	-3°C
TH16	Clariant Launch Plus	75/25	-3°C	Al. Plate	-3°C
TH17	Clariant Launch Plus	50/50	-3°C	Al. Plate	-3°C
TH18	Clariant Launch Plus	50/50	-3°C	Al. Plate	-3°C

Notes:

- The quantity of fluid that will be poured for each test is 1.0 L
- Measurements should be made at the 15-cm line at the time of fluid application, and after 2 minutes, 5 minutes, 15 minutes, and 30 minutes.
- If the results for one fluid vary by more than 10% repeat the two tests and disregard the highest and lowest values

TABLE 4: FIVE MINUTE RULE TEST PLAN

Test #	Piggyback Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution (%)	Test Surface
TYPE I TESTS							
FM1	DF12	Freezing Fog	-3	2	Dow UCAR ADF (EG)	10°B (B=17.6)	Al. Plate
FM2	n/a	Freezing Fog	-3	2	Octagon Octaflo EF	10°B (B=21.25)	Al. Plate
FM3	n/a	Light Freezing Rain	-10	13	Dow UCAR ADF (EG)	10°B (B=22.9)	Al. Plate
FM4	PH1	Light Freezing Rain	-10	13	Octagon Octaflo EF	10°B (B=27.0)	Al. Plate
FM5	n/a	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10°B (B=22.9)	Al. Plate
FM6	n/a	Light Freezing Rain	-10	25	Octagon Octaflo EF	10°B (B=27.0)	Al. Plate
FM7	PH25	Freezing Drizzle	-3	5	Dow UCAR ADF (EG)	10°B (B=17.6)	Al. Plate
FM8	DF1/PH31	Freezing Drizzle	-3	5	Octagon Octaflo EF	10°B (B=21.25)	Al. Plate
FM9	PH49	Freezing Drizzle	-3	13	Dow UCAR ADF (EG)	10°B (B=17.6)	Al. Plate
FM10	DF15	Freezing Drizzle	-3	13	Octagon Octaflo EF	10°B (B=21.25)	Al. Plate
FM11	n/a	Freezing Drizzle	-10	5	Dow UCAR ADF (EG)	10°B (B=22.9)	Al. Plate
FM12	DF4	Freezing Drizzle	-10	5	Octagon Octaflo EF	10°B (B=27.0)	Al. Plate
TYPE II, III, IV TESTS							
FM13	1	Freezing Fog	-3	2	Clariant Launch Plus	100	Al. Plate
FM14	3	Freezing Fog	-3	2	Clariant Launch Plus	75	Al. Plate
FM15	5	Freezing Fog	-3	2	Clariant Launch Plus	50	Al. Plate
FM16	7	Freezing Fog	-3	2	Clariant 2031 WARM	100	Al. Plate
FM17	9	Freezing Fog	-3	2	Clariant 2031 WARM	75	Al. Plate
FM18	11	Freezing Fog	-3	2	Clariant 2031 WARM	50	Al. Plate
FM19	49	Light Freezing Rain	-3	13	Clariant Launch Plus	100	Al. Plate
FM20	51	Light Freezing Rain	-3	13	Clariant Launch Plus	75	Al. Plate
FM21	53	Light Freezing Rain	-3	13	Clariant Launch Plus	50	Al. Plate
FM22	55	Light Freezing Rain	-3	13	Clariant 2031 WARM	100	Al. Plate
FM23	57	Light Freezing Rain	-3	13	Clariant 2031 WARM	75	Al. Plate
FM24	59	Light Freezing Rain	-3	13	Clariant 2031 WARM	50	Al. Plate
FM25	61	Light Freezing Rain	-3	25	Clariant Launch Plus	100	Al. Plate
FM26	64	Light Freezing Rain	-3	25	Clariant Launch Plus	75	Al. Plate
FM27	65	Light Freezing Rain	-3	25	Clariant Launch Plus	50	Al. Plate
FM28	67	Light Freezing Rain	-3	25	Clariant 2031 WARM	100	Al. Plate
FM29	69	Light Freezing Rain	-3	25	Clariant 2031 WARM	75	Al. Plate
FM30	71	Light Freezing Rain	-3	25	Clariant 2031 WARM	50	Al. Plate
FM31	73	Light Freezing Rain	-10	13	Clariant Launch Plus	100	Al. Plate
FM32	75	Light Freezing Rain	-10	13	Clariant Launch Plus	75	Al. Plate
FM33	77	Light Freezing Rain	-10	13	Clariant 2031 WARM	100	Al. Plate
FM34	79	Light Freezing Rain	-10	13	Clariant 2031 WARM	75	Al. Plate
FM35	81	Light Freezing Rain	-10	25	Clariant Launch Plus	100	Al. Plate
FM36	83	Light Freezing Rain	-10	25	Clariant Launch Plus	75	Al. Plate
FM37	85	Light Freezing Rain	-10	25	Clariant 2031 WARM	100	Al. Plate
FM38	87	Light Freezing Rain	-10	25	Clariant 2031 WARM	75	Al. Plate
FM39	89	Freezing Drizzle	-3	5	Clariant Launch Plus	100	Al. Plate
FM40	91	Freezing Drizzle	-3	5	Clariant Launch Plus	75	Al. Plate
FM41	93	Freezing Drizzle	-3	5	Clariant Launch Plus	50	Al. Plate
FM42	95	Freezing Drizzle	-3	5	Clariant 2031 WARM	100	Al. Plate
FM43	97	Freezing Drizzle	-3	5	Clariant 2031 WARM	75	Al. Plate
FM44	99	Freezing Drizzle	-3	5	Clariant 2031 WARM	50	Al. Plate

TABLE 5: LIGHT SNOW / VERY LIGHT SNOW CALIBRATION TEST PLAN

Test #	Fluid Name	Fluid Dilution	Fluid Type	Endurance Time (mins)	Rate [g/dm²/h]	Temp [°C]	Plate Temp [°C]
~~1~~	~~ABAX Ecowing 26~~	~~75%~~	~~II~~	~~27.0~~	~~7.5~~	~~-8.5~~	~~-9.5~~
2	ABAX Ecowing 26	75%	II	47.4	3.7	-7.8	-8.5
~~3~~	~~ABAX AD-49~~	~~100%~~	~~IV~~	~~82.0~~	~~8.7~~	~~-8.6~~	~~-9.7~~
4	Cryotech Polar Guard Advance	75%	IV	94.0	8.8	-8.6	-9.7
5	Clariant Launch	100%	IV	97.2	4.0	-10.3	-11.1

Tests listed with a strikethrough do not need to be conducted as they have already been completed at the APS test site in March 2013.

TABLE 6: HEAVY SNOW TEST PLAN

Test #	Fluid Name	Fluid Dilution	Batch No.	Fluid Type	Endurance Time (mins)	Rate [g/dm²/h]	Temp [°C]	Plate Temp
1	Kilfrost ABC-S Plus	100%	WT 11-12	IV	33.9	65.0	-5.5	-10.2
2	Kilfrost ABC-S Plus	100%	WT 11-12	IV	33.9	65.0	-5.5	-10.2
3	Kilfrost ABC-S Plus	100%	WT 11-12	IV	33.9	65.0	-5.5	-10.2
4	Dow EG106	100%	WT 11-12	IV	25.2	63.9	-5.5	-10.2
5	Dow EG106	100%	WT 11-12	IV	25.2	63.9	-5.5	-10.2
6	Dow EG106	100%	WT 11-12	IV	25.2	63.9	-5.5	-10.2
7	Clariant Launch	100%	WT 11-12	IV	29.4	65.0	-5.5	-10.2
8	Clariant Launch	100%	WT 11-12	IV	29.4	65.0	-5.5	-10.2
9	Clariant Launch	100%	WT 11-12	IV	29.4	65.0	-5.5	-10.2

TABLE 7: LIGHT SNOW / VERY LIGHT SNOW TEST PLAN

Test #	Fluid	Type	Dilution	Fluid Qty (L)	Condition Temp. (°C)	Precip. Rate (g/dm²/h)	Plate Set Temp (°C)	Priority	Generic HOT (mins)	Predicted HOT (mins)
1	Clariant MP II Flight Plus	II	100	1	-25.0	3.0	-25.7	1	75	185
2	Clariant MP II Flight Plus	II	100	1	-25.0	4.0	-25.8	1	60	145
3	LNT P250	II	100	1	-25.0	3.0	-25.7	1	75	200
4	LNT P250	II	100	1	-25.0	4.0	-25.8	1	60	170
5	Clariant MP III 2031 ECO(10)	III	100	0.5	-25.0	3.0	-25.7	1	37	37
6	Clariant MP III 2031 ECO(10)	III	100	0.5	-25.0	4.0	-25.8	1	30	30
7	Clariant MP III 2031 ECO(10)	III	100	0.5	-25.0	10.0	-26.2	1	16	16
8	Clariant MP III 2031 ECO(10)	III	100	0.5	-25.0	25.0	-27.1	1	9	9
9	Clariant MP III 2031 ECO(10)	III	100	0.5	-10.0	3.0	-25.7	1	42	42
10	Clariant MP III 2031 ECO(10)	III	100	0.5	-10.0	4.0	-25.8	1	35	35
11	Clariant MP III 2031 ECO(10)	III	100	0.5	-10.0	10.0	-26.2	1	18	18
12	Clariant MP III 2031 ECO(10)	III	100	0.5	-10.0	25.0	-27.1	1	10	10
13	ABAX FlightGuard AD-49	IV	100	1	-25.0	3.0	-25.7	1	75	190
14	ABAX FlightGuard AD-49	IV	100	1	-25.0	4.0	-25.8	1	60	170
15	Kilfrost ABC-S Plus	IV	100	1	-25.0	3.0	-25.7	1	75	190
16	Kilfrost ABC-S Plus	IV	100	1	-25.0	4.0	-25.8	1	60	160
17	Kilfrost ABC-S Plus	IV	100	1	-25.0	10.0	-26.2	1	30	95
18	Kilfrost ABC-S Plus	IV	100	1	-25.0	25.0	-27.1	1	15	55
19	Clariant Launch	IV	100	1	-25.0	3.0	-25.7	1	75	135
20	Clariant Launch	IV	100	1	-25.0	4.0	-25.8	1	60	115
21	Clariant Launch	IV	100	1	-25.0	10.0	-26.2	1	30	70
22	Clariant Launch	IV	100	1	-25.0	25.0	-27.1	1	15	43
23	Clariant Launch Plus	IV	100	1	-25.0	3.0	-25.7	2	75	250
24	Clariant Launch Plus	IV	100	1	-25.0	4.0	-25.8	2	60	190
25	Clariant Max-Flight 04	IV	100	1	-25.0	3.0	-25.7	1	75	115
26	Clariant Max-Flight 04	IV	100	1	-25.0	4.0	-25.8	1	60	95
27	Cryotech Polar Guard	IV	100	1	-25.0	3.0	-25.7	1	75	100
28	Cryotech Polar Guard	IV	100	1	-25.0	4.0	-25.8	1	60	90

NOTES:

1. Objective: Develop generic holdover times for very light snow and light snow at -25°C.
2. Standard ARP5485 procedure shall be used to conduct tests.
3. Testing shall be conducted with LOWV fluid samples.
4. The fluid temperature is within 3ºC of the enclosure temperature.
5. The enclosure temperature is typically 2ºC below the plate temperature (no tolerance specified).
6. The plate temperature shall be within ±0.5 (°C)
7. Measurement of Brix at 15 cm line is required at time of failure.
8. Photo should be taken at time of failure. Position camera at an angle of 30 degrees facing the plate and capturing the whole plate + 20%.
9. See TP 14376E for historical -25°C data collected.
10. Type III fluid must be applied at 60°C.

TABLE 8: ICE PHOBIC ENDURANCE TIME TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Name	Fluid Dilution	Test Surface	Comments	Fluid Req'd (L)	Priority
PH1	Light Freezing Rain	-10	13 (25)	Octagon Octaflo EF	10°B (B=27.0)	Baseline	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH2	Light Freezing Rain	-10	13 (25)	Octagon Octaflo EF	10°B (B=27.0)	B12	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH3	Light Freezing Rain	-10	13 (25)	Octagon Octaflo EF	10°B (B=27.0)	B13	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH4	Light Freezing Rain	-10	13 (25)	Octagon Octaflo EF	10°B (B=27.0)	C3	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH5	Light Freezing Rain	-10	13 (25)	Octagon Octaflo EF	10°B (B=27.0)	D1	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH6	Light Freezing Rain	-10	13 (25)	Octagon Octaflo EF	10°B (B=27.0)	D2	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH7	Light Freezing Rain	-10	13 (25)	AD-49 (WT)	75/25	Baseline	Thick @ 5 mins, Brix at fail	1	1
PH8	Light Freezing Rain	-10	13 (25)	AD-49 (WT)	75/25	B12	Thick @ 5 mins, Brix at fail	1	1
PH9	Light Freezing Rain	-10	13 (25)	AD-49 (WT)	75/25	B13	Thick @ 5 mins, Brix at fail	1	1
PH10	Light Freezing Rain	-10	13 (25)	AD-49 (WT)	75/25	C3	Thick @ 5 mins, Brix at fail	1	1
PH11	Light Freezing Rain	-10	13 (25)	AD-49 (WT)	75/25	D1	Thick @ 5 mins, Brix at fail	1	1
PH12	Light Freezing Rain	-10	13 (25)	AD-49 (WT)	75/25	D2	Thick @ 5 mins, Brix at fail	1	1
PH-V1	Light Freezing Rain	-10	13 (25)	AD-49 (WT LOWV)	75/25	Baseline	Thick @ 5 mins, Brix at fail	1	1
PH-V2	Light Freezing Rain	-10	13 (25)	AD-49 (WT LOWV)	75/25	B12	Thick @ 5 mins, Brix at fail	1	1
PH-V3	Light Freezing Rain	-10	13 (25)	AD-49 (WT LOWV)	75/25	B13	Thick @ 5 mins, Brix at fail	1	1
PH-V4	Light Freezing Rain	-10	13 (25)	AD-49 (WT LOWV)	75/25	C3	Thick @ 5 mins, Brix at fail	1	1
PH-V5	Light Freezing Rain	-10	13 (25)	AD-49 (WT LOWV)	75/25	D1	Thick @ 5 mins, Brix at fail	1	1
PH-V6	Light Freezing Rain	-10	13 (25)	AD-49 (WT LOWV)	75/25	D2	Thick @ 5 mins, Brix at fail	1	1
PH13	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT)	100/0	Baseline	Thick @ 5 mins, Brix at fail	1	1
PH14	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT)	100/0	B12	Thick @ 5 mins, Brix at fail	1	1
PH15	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT)	100/0	B13	Thick @ 5 mins, Brix at fail	1	1
PH16	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT)	100/0	C3	Thick @ 5 mins, Brix at fail	1	1
PH17	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT)	100/0	D1	Thick @ 5 mins, Brix at fail	1	1
PH18	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT)	100/0	D2	Thick @ 5 mins, Brix at fail	1	1
PH-V7	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT LOWV)	100/0	Baseline	Thick @ 5 mins, Brix at fail	1	1
PH-V8	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT LOWV)	100/0	B12	Thick @ 5 mins, Brix at fail	1	1
PH-V9	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT LOWV)	100/0	B13	Thick @ 5 mins, Brix at fail	1	1
PH-V10	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT LOWV)	100/0	C3	Thick @ 5 mins, Brix at fail	1	1
PH-V11	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT LOWV)	100/0	D1	Thick @ 5 mins, Brix at fail	1	1
PH-V12	Freezing Drizzle	-10	13 (5)	Polar Guard Advance (WT LOWV)	100/0	D2	Thick @ 5 mins, Brix at fail	1	1

Note: LOWV should be done at same time as comaprative tests (with extra set of plates), or back-to back on same plates

TABLE 8: ICE PHOBIC ENDURANCE TIME TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Name	Fluid Dilution	Test Surface	Comments	Fluid Req'd (L)	Priority
PH19	Light Freezing Rain	-10	25 (13)	Dow UCAR EG106	100/0	Baseline	Thick @ 5 mins, Brix at fail	1	1
PH20	Light Freezing Rain	-10	25 (13)	Dow UCAR EG106	100/0	B12	Thick @ 5 mins, Brix at fail	1	1
PH21	Light Freezing Rain	-10	25 (13)	Dow UCAR EG106	100/0	B13	Thick @ 5 mins, Brix at fail	1	1
PH22	Light Freezing Rain	-10	25 (13)	Dow UCAR EG106	100/0	C3	Thick @ 5 mins, Brix at fail	1	1
PH23	Light Freezing Rain	-10	25 (13)	Dow UCAR EG106	100/0	D1	Thick @ 5 mins, Brix at fail	1	1
PH24	Light Freezing Rain	-10	25 (13)	Dow UCAR EG106	100/0	D2	Thick @ 5 mins, Brix at fail	1	1
PH25	Freezing Drizzle	-3	5 (13)	Dow UCAR ADF (EG)	10°B (B=17.6)	Baseline	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH26	Freezing Drizzle	-3	5 (13)	Dow UCAR ADF (EG)	10°B (B=17.6)	B12	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH27	Freezing Drizzle	-3	5 (13)	Dow UCAR ADF (EG)	10°B (B=17.6)	B13	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH28	Freezing Drizzle	-3	5 (13)	Dow UCAR ADF (EG)	10°B (B=17.6)	C3	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH29	Freezing Drizzle	-3	5 (13)	Dow UCAR ADF (EG)	10°B (B=17.6)	D1	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH30	Freezing Drizzle	-3	5 (13)	Dow UCAR ADF (EG)	10°B (B=17.6)	D2	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH31	Freezing Drizzle	-3	5 (13)	Octagon Octaflo EF	10°B (B=21.25)	Baseline	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH32	Freezing Drizzle	-3	5 (13)	Octagon Octaflo EF	10°B (B=21.25)	B12	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH33	Freezing Drizzle	-3	5 (13)	Octagon Octaflo EF	10°B (B=21.25)	B13	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH34	Freezing Drizzle	-3	5 (13)	Octagon Octaflo EF	10°B (B=21.25)	C3	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH35	Freezing Drizzle	-3	5 (13)	Octagon Octaflo EF	10°B (B=21.25)	D1	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH36	Freezing Drizzle	-3	5 (13)	Octagon Octaflo EF	10°B (B=21.25)	D2	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	1
PH37	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT)	50/50	Baseline	Thick @ 5 mins, Brix at fail	1	1
PH38	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT)	50/50	B12	Thick @ 5 mins, Brix at fail	1	1
PH39	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT)	50/50	B13	Thick @ 5 mins, Brix at fail	1	1
PH40	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT)	50/50	C3	Thick @ 5 mins, Brix at fail	1	1
PH41	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT)	50/50	D1	Thick @ 5 mins, Brix at fail	1	1
PH42	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT)	50/50	D2	Thick @ 5 mins, Brix at fail	1	1
PH-V13	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT LOWV)	50/50	Baseline	Thick @ 5 mins, Brix at fail	1	1
PH-V14	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT LOWV)	50/50	B12	Thick @ 5 mins, Brix at fail	1	1
PH-V15	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT LOWV)	50/50	B13	Thick @ 5 mins, Brix at fail	1	1
PH-V16	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT LOWV)	50/50	C3	Thick @ 5 mins, Brix at fail	1	1
PH-V17	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT LOWV)	50/50	D1	Thick @ 5 mins, Brix at fail	1	1
PH-V18	Freezing Drizzle	-3	13 (5)	ABAX AD-49 (WT LOWV)	50/50	D2	Thick @ 5 mins, Brix at fail	1	1

Note: LOWV should be done at same time as comaprative tests (with extra set of plates), or back-to back on same plates

TABLE 8: ICE PHOBIC ENDURANCE TIME TEST PLAN (CONT'D)

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Name	Fluid Dilution	Test Surface	Comments	Fluid Req'd (L)	Priority
PH43	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT)	75/25	Baseline	Thick @ 5 mins, Brix at fail	1	2
PH44	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT)	75/25	B12	Thick @ 5 mins, Brix at fail	1	2
PH45	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT)	75/25	B13	Thick @ 5 mins, Brix at fail	1	2
PH46	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT)	75/25	C3	Thick @ 5 mins, Brix at fail	1	2
PH47	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT)	75/25	D1	Thick @ 5 mins, Brix at fail	1	2
PH48	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT)	75/25	D2	Thick @ 5 mins, Brix at fail	1	2
PH-V19	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT LOWV)	75/25	Baseline	Thick @ 5 mins, Brix at fail	1	2
PH-V20	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT LOWV)	75/25	B12	Thick @ 5 mins, Brix at fail	1	2
PH-V21	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT LOWV)	75/25	B13	Thick @ 5 mins, Brix at fail	1	2
PH-V22	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT LOWV)	75/25	C3	Thick @ 5 mins, Brix at fail	1	2
PH-V23	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT LOWV)	75/25	D1	Thick @ 5 mins, Brix at fail	1	2
PH-V24	Light Freezing Rain	-3	25 (13)	ABC-S Plus (WT LOWV)	75/25	D2	Thick @ 5 mins, Brix at fail	1	2
PH49	Freezing Drizzle	-3	13 (5)	Dow UCAR ADF (EG)	10°B (B=17.6)	Baseline	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	2
PH50	Freezing Drizzle	-3	13 (5)	Dow UCAR ADF (EG)	10°B (B=17.6)	B12	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	2
PH51	Freezing Drizzle	-3	13 (5)	Dow UCAR ADF (EG)	10°B (B=17.6)	B13	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	2
PH52	Freezing Drizzle	-3	13 (5)	Dow UCAR ADF (EG)	10°B (B=17.6)	C3	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	2
PH53	Freezing Drizzle	-3	13 (5)	Dow UCAR ADF (EG)	10°B (B=17.6)	D1	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	2
PH54	Freezing Drizzle	-3	13 (5)	Dow UCAR ADF (EG)	10°B (B=17.6)	D2	1 L at 20°C, Thick @ 5 mins, Brix at fail	1	2

Note: LOWV should be done at same time as comparative tests (with extra set of plates), or back-to back on same plates

TABLE 9: ICE PHOBIC THICKNESS TEST PLAN

Test #	Priority	Fluid Name	Fluid Type	Fluid Dilution	Test Surface Treatment*	Ambient Air Temperature
PH-TH1	1	Dow UCAR ADF (EG)	Type I EG	10°B (B=17.6)	Baseline	-3°C
PH-TH2	1	Dow UCAR ADF (EG)	Type I EG	10°B (B=17.6)	B12	-3°C
PH-TH3	1	Dow UCAR ADF (EG)	Type I EG	10°B (B=17.6)	B13	-3°C
PH-TH4	1	Dow UCAR ADF (EG)	Type I EG	10°B (B=17.6)	C3	-3°C
PH-TH5	1	Dow UCAR ADF (EG)	Type I EG	10°B (B=17.6)	D1	-3°C
PH-TH6	1	Dow UCAR ADF (EG)	Type I EG	10°B (B=17.6)	D2	-3°C
PH-TH7	2	Dow UCAR ADF (EG)	Type I EG	FFP=-35°C (B=30.5)	Baseline	-3°C
PH-TH8	2	Dow UCAR ADF (EG)	Type I EG	FFP=-35°C (B=30.5)	B12	-3°C
PH-TH9	2	Dow UCAR ADF (EG)	Type I EG	FFP=-35°C (B=30.5)	B13	-3°C
PH-TH10	2	Dow UCAR ADF (EG)	Type I EG	FFP=-35°C (B=30.5)	C3	-3°C
PH-TH11	2	Dow UCAR ADF (EG)	Type I EG	FFP=-35°C (B=30.5)	D1	-3°C
PH-TH12	2	Dow UCAR ADF (EG)	Type I EG	FFP=-35°C (B=30.5)	D2	-3°C
PH-TH13	1	Cryotech 13552	Type II PG	100/0	Baseline	-3°C
PH-TH14	1	Cryotech 13552	Type II PG	100/0	B12	-3°C
PH-TH15	1	Cryotech 13552	Type II PG	100/0	B13	-3°C
PH-TH16	1	Cryotech 13552	Type II PG	100/0	C3	-3°C
PH-TH17	1	Cryotech 13552	Type II PG	100/0	D1	-3°C
PH-TH18	1	Cryotech 13552	Type II PG	100/0	D2	-3°C

Procedure: Measure thickness (TII) at 15 cm line or % wetted (TI) at application and 2, 5, 15, and 30 minutes after pouring

TABLE 10: ICE PHOBIC ADHERENCE TEST PLAN

Test #	Priority	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dilution	Test Surface	Comments
PH-AD1	1	Light Freezing Rain	-10	13	No fluid	n/a	Baseline	Measure time of adherence
PH-AD2	1	Light Freezing Rain	-10	13	No fluid	n/a	B12	Measure time of adherence
PH-AD3	1	Light Freezing Rain	-10	13	No fluid	n/a	B13	Measure time of adherence
PH-AD4	1	Light Freezing Rain	-10	13	No fluid	n/a	C3	Measure time of adherence
PH-AD5	1	Light Freezing Rain	-10	13	No fluid	n/a	D1	Measure time of adherence
PH-AD6	1	Light Freezing Rain	-10	13	No fluid	n/a	D2	Measure time of adherence

NOTE: Can be done a few a time, or all at once by moving 6pos stand into spray area. Can consider other conditions with large spray area

TABLE 11: ICE PHOBIC HOT WATER TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Name	Fluid Dilution (%)	Test Surface	Comments	Fluid Required (L)	Priority
PH-HW1	Freezing Fog	-10	2	Octagon Octaflo EF	10ºC Buff	Baseline	Measure time of adherence	1	1
PH-HW2	Freezing Fog	-10	2	Hot Water (1L @ 20°C)	n/a	B12	Measure time of adherence	1	1
PH-HW3	Freezing Fog	-10	2	Hot Water (1L @ 20°C)	n/a	B13	Measure time of adherence	1	1
PH-HW4	Freezing Fog	-10	2	Hot Water (1L @ 20°C)	n/a	C3	Measure time of adherence	1	1
PH-HW5	Freezing Fog	-10	2	Hot Water (1L @ 20°C)	n/a	D1	Measure time of adherence	1	1
PH-HW6	Freezing Fog	-10	2	Hot Water (1L @ 20°C)	n/a	D2	Measure time of adherence	1	1
PH-HW7	Light Freezing Rain	-10	13	Octagon Octaflo EF	10ºC Buff	Baseline	Measure time of adherence	1	1
PH-HW8	Light Freezing Rain	-10	13	Hot Water (1L @ 20°C)	n/a	B12	Measure time of adherence	1	1
PH-HW9	Light Freezing Rain	-10	13	Hot Water (1L @ 20°C)	n/a	B13	Measure time of adherence	1	1
PH-HW10	Light Freezing Rain	-10	13	Hot Water (1L @ 20°C)	n/a	C3	Measure time of adherence	1	1
PH-HW11	Light Freezing Rain	-10	13	Hot Water (1L @ 20°C)	n/a	D1	Measure time of adherence	1	1
PH-HW12	Light Freezing Rain	-10	13	Hot Water (1L @ 20°C)	n/a	D2	Measure time of adherence	1	1

NOTE: This could be done outside the spray area

TABLE 12: DEPLOYED FLAPS TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Name	Fluid Dilution (%)	Test Surface*	Comments	Fluid Req'd (L)	Priority
DF1	Freezing Drizzle	-3	5	Octagon Octaflo EF	10º Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
DF2	Freezing Drizzle	-3	5	Octagon Octaflo EF	10º Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	1
DF3	Freezing Drizzle	-3	5	Octagon Octaflo EF	10º Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	1
DF4	Freezing Drizzle	-10	5	Octagon Octaflo EF	10º Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
DF5	Freezing Drizzle	-10	5	Octagon Octaflo EF	10º Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	1
DF6	Freezing Drizzle	-10	5	Octagon Octaflo EF	10º Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	1
DF7	Freezing Drizzle	-10	5	Octagon Octaflo EF	10º Buff	Plate (20°) Nested	Thickness at 5 mins, Brix at failure	2	1
DF8	Freezing Drizzle	-10	5	Octagon Octaflo EF	10º Buff	Plate (35°) Nested	Thickness at 5 mins, Brix at failure	2	1
DF9	Freezing Drizzle	-10	13	Octagon Octaflo EF	10º Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	2
DF10	Freezing Drizzle	-10	13	Octagon Octaflo EF	10º Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	2
DF11	Freezing Drizzle	-10	13	Octagon Octaflo EF	10º Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	2
DF12	Freezing Fog	-3	5	Dow UCAR ADF (EG)	10º Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
DF13	Freezing Fog	-3	5	Dow UCAR ADF (EG)	10º Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	1
DF14	Freezing Fog	-3	5	Dow UCAR ADF (EG)	10º Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	1
DF15	Freezing Drizzle	-3	13	Octagon Octaflo EF	10º Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
DF16	Freezing Drizzle	-3	13	Octagon Octaflo EF	10º Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	1
DF17	Freezing Drizzle	-3	13	Octagon Octaflo EF	10º Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	1
DF18	Freezing Drizzle	-3	13	Octagon Octaflo EF	10º Buff	Plate (20°) Nested	Thickness at 5 mins, Brix at failure	2	2
DF19	Freezing Drizzle	-3	13	Octagon Octaflo EF	10º Buff	Plate (35°) Nested	Thickness at 5 mins, Brix at failure	2	2
DF20	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10º Buff	Plate (10°)	Thickness at 5 mins, Brix at failure	1	2
DF21	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10º Buff	Plate (20°)	Thickness at 5 mins, Brix at failure	1	2
DF22	Light Freezing Rain	-10	25	Dow UCAR ADF (EG)	10º Buff	Plate (35°)	Thickness at 5 mins, Brix at failure	1	2

*NOTE: 20º and 35º plates need to be positioned on bottom HOT stand (pos 7-12) or on side stand (1s-3s)

TABLE 13: FLAPS SLATS EXTENSION TEST PLAN

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid	Fluid Dil. (%)	Test Surface	Comments	Fluid Required (L)	Priority
FSE1	Freezing Drizzle	-10	13	Clariant Launch Plus	100/0	Plate (10°)	Thickness at 5 mins, Brix at failure	1	1
FSE2	Freezing Drizzle	-10	13	Clariant Launch Plus	100/0	2 Plates (20°) Slat	Extend after 5-10min. Thickness at 5 mins, Brix at fail	1.5	1
FSE3	Freezing Drizzle	-10	13	Clariant Launch Plus	100/0	2 Plates (20°) Flap	Extend after 5-10min. Thickness at 5 mins, Brix at fail	1.5	1
FSE4	Light Freezing Rain	-3	25	Clariant Launch Plus	75/25	Plate (10°)	Thickness at 5 mins, Brix at failure	1	2
FSE5	Light Freezing Rain	-3	25	Clariant Launch Plus	75/25	2 Plates (35°) Slat	Extend after 5-10min. Thickness at 5 mins, Brix at fail	1.5	2
FSE6	Light Freezing Rain	-3	25	Clariant Launch Plus	75/25	2 Plates (35°) Flap	Extend after 5-10min. Thickness at 5 mins, Brix at fail	1.5	2

NOTE: 2 plates used. 1 on top of other at 10° to start (with overlap), then split into 10° and 20/35°

TABLE 14: LIST OF FLUIDS

Fluid	Batch #	Fluid Temp	Fluid Dil or Brix (FFP)	Litres Required per Project													Total Litres	Pour Bottles	Notes
				ET	TH	CML	5-MIN	AS-CAL	AS-VLS	AS-HS	PH-ET	PH-TH	PH-AD	PH-HW	FSE	DF			
Type II, II, IV (HOT)																			
Clariant Safewing 2031 WARM	USHA035838	20°C	100	34	2	-	-	-	8	-	-	-	-	-	-	-	**44**	**8***	**3 x 20L jugs********
Clariant Safewing 2031 WARM	USHA035838	20°C	75	30	2	-	-	-	-	-	-	-	-	-	-	-	**32**	**8***	**2 x 20L jugs********
Clariant Safewing 2031 WARM	USHA035838	20°C	50	14	2	-	-	-	-	-	-	-	-	-	-	-	**16**	**8***	**1 x 50L jug********
Clariant Safewing 2031 COLD	USHA035838	OAT	100	2	-	-	-	-	-	-	-	-	-	-	-	-	**2**	**2**	**** and ********
Clariant Safewing 2031 COLD	USHA035838	OAT	75	2	-	-	-	-	-	-	-	-	-	-	-	-	**2**	**2**	
Clariant Safewing 2031 COLD	USHA035838	OAT	50	2	-	-	-	-	-	-	-	-	-	-	-	-	**2**	**2**	
Clariant Launch Plus	TV 523	OAT	100	32	2	-	-	-	2	-	-	-	-	-	3	-	**39**	**8***	**3 x 20L jugs********
Clariant Launch Plus	TV 523	OAT	75	28	2	-	-	-	-	-	-	-	-	-	3	-	**33**	**8***	**2 x 20L jugs********
Clariant Launch Plus	TV 523	OAT	50	12	2	-	-	-	-	-	-	-	-	-	-	-	**14**	**8***	**1 x 20L jugs********
Type II, II, IV (R&D)																			
Cryotech 13552	13552	OAT	100	-	-	-	-	-	-	-	-	6	-	-	-	-	**6**	**6**	**
Clariant Max-Flight 04 B1	U 49 E 001966	OAT	50	-	-	6	-	-	-	-	-	-	-	-	-	-	**6**	**6**	**
Clariant Max-Flight 04 B2	U 49 E 002061	OAT	100	-	-	6	-	-	2	-	-	-	-	-	-	-	**8**	**3**	**prepare pour containers, bring empty*****
Clariant Max-Flight 04 B2	U 49 E 002061	OAT	75	-	-	6	-	-	-	-	-	-	-	-	-	-	**6**	**3**	
Clariant Max-Flight 04 B2	U 49 E 002061	OAT	50	-	-	6	-	-	-	-	-	-	-	-	-	-	**6**	**3**	
Type II, III, IV (SNOWMAKER)																			
ABAX Ecowing 26	L12-321	OAT	75	-	-	-	-	1	-	-	-	-	-	-	-	-	**1**	**1**	**fill pour containers plus bring 1 larger container as spare if available**
Clariant Launch	WT 10-11	OAT	100	-	-	-	-	-	-	3	-	-	-	-	-	-	**3**	**3**	
Clariant Launch	DEG4 146164	OAT	100	-	-	-	-	1	4	-	-	-	-	-	-	-	**5**	**3**	
Cryotech Polar Guard Advance	13102	OAT	100	-	-	-	-	-	2	-	-	-	-	-	-	-	**2**	**2**	
Cryotech Polar Guard Advance	13102	OAT	75	-	-	-	-	1	-	-	-	-	-	-	-	-	**1**	**1**	
Dow EG106	WT 10-11	OAT	100	-	-	-	-	-	-	3	-	-	-	-	-	-	**3**	**3**	
ABAX FlightGuard AD-49	L12-318	OAT	100	-	-	-	-	-	2	-	-	-	-	-	-	-	**2**	**2**	
Kilfrost ABC-S Plus	WT 10-11	OAT	100	-	-	-	-	-	-	3	-	-	-	-	-	-	**3**	**3**	
Kilfrost ABC-S Plus	B/50/11/12 (P2549)	OAT	100	-	-	-	-	-	4	-	-	-	-	-	-	-	**4**	**4**	
LNT P250	53563-40	OAT	100	-	-	-	-	-	2	-	-	-	-	-	-	-	**2**	**2**	
MP II Flight Plus	TV513	OAT	100	-	-	-	-	-	2	-	-	-	-	-	-	-	**2**	**2**	
Type II, III, IV (WT FLUIDS)																			
ABAX AD-49 (WT)	L-12-328	OAT	75	-	-	-	-	-	-	-	10	-	-	-	-	-	**10**	**nil**	**bring fluid in 10L containers, do not fill or label any pour containers, pack 12 empty no label pour containers**
ABAX AD-49 (LOWV)	L-12-331	OAT	75	-	-	-	-	-	-	-	10	-	-	-	-	-	**10**	**nil**	
ABAX AD-49 (WT)	L-12-328	OAT	50	-	-	-	-	-	-	-	10	-	-	-	-	-	**10**	**nil**	
ABAX AD-49 (LOWV)	L-12-331	OAT	50	-	-	-	-	-	-	-	10	-	-	-	-	-	**10**	**nil**	
Kilfrost ABC-S+ (WT)	WT.12.13.ABC-S+	OAT	75	-	-	-	-	-	-	-	10	-	-	-	-	-	**10**	**nil**	
Kilfrost ABC-S+ (LOWV)	WT.12.13.ABC-S+	OAT	75	-	-	-	-	-	-	-	10	-	-	-	-	-	**10**	**nil**	
Cryotech Polar Guard Advance (WT)	13342	OAT	100	-	-	-	-	-	-	-	10	-	-	-	-	-	**10**	**nil**	
Cryotech Polar Guard Advance (LOWV)	13102	OAT	100	-	-	-	-	-	-	-	10	-	-	-	-	-	**10**	**nil**	
Dow UCAR EG106 (WT)	1J0201GKDR	OAT	100	-	-	-	-	-	-	-	10	-	-	-	-	-	**10**	**nil**	
Type I																			
Octagon Octaflo EF	?	20°C	21.25 (-13°C)	-	-	-	1	-	-	-	6	-	-	-	-	10	**17**	**6**	**Bring amount required plus extra container of undiluted fluid (one Octaflo, one Dow ADF)**
Octagon Octaflo EF	?	20°C	27.0 (-20°C)	-	-	-	1	-	-	-	6	-	-	2	-	10	**19**	**6**	
Dow UCAR ADF (EG)	?	20°C	17.6 (-13°C)	-	-	-	-	-	-	-	12	6	-	-	-	6	**24**	**6**	
Dow UCAR ADF (EG)	?	20°C	22.9 (-20°C)	-	-	-	3	-	-	-	-	-	-	-	-	-	**3**	**3**	
Dow UCAR ADF (EG)	?	20°C	30.5 (-35°C)	-	-	-	-	-	-	-	-	6	-	-	-	-	**6**	**6**	
All Fluids				**156**	**12**	**24**	**5**	**3**	**28**	**9**	**114**	**18**	**0**	**2**	**6**	**26**	**403**	**160**	

Notes
* pour bottles already exist at site, pack them
**Fluid requirements met by fluid brought in pour containers, no large containers need to be brought
***Fluid will be shipped directly to NRC
****WARM / COLD labels go on all pour / large 2031 containers

Warm Storage Fluid (orange shading)
Cold Storage Fluid (blue shading)

TABLE 15: TYPE I DILUTION TABLES

Octagon Octaflo EF (PG)					
FFP (°C)	Test Temp (10°B)	% Fluid	Brix	Glycol for 4 L	Water for 4 L
-13	-3	32.0	21.25	1.3	2.7
-20	-10	43.0	27.0	1.7	2.3
-24	-14	47.0	29.50	1.9	2.1
-35	-25	56.0	34.50	2.2	1.8

Dow UCAR ADF (EG)					
FFP (°C)	Test Temp (10°B)	% Fluid	Brix	Glycol for 4 L	Water for 4 L
-13	-3	27.4	17.6	1.1	2.9
-20	-10	36.3	22.9	1.5	2.5
-35	-25	50.3	30.5	2.0	2.0

TABLE 16: GENERAL EQUIPMENT LIST

HOT, 5 MIN, PH-ET,THICKNESS AND PH-TH PROJECTS			
EQUIPMENT	**LOCATION**	**EQUIPMENT**	**LOCATION**
10L & 20L aqua packs jug for PH-ET tests	Site	Sample bottles x6 for MF04 viscosity tests	Site
1L Pour containers (see separate list)	Site	Test Stands: 2 x 6-position (main stand)	Site
Barrel Opener	Site	Test Stands: 3 position (side stand) (2 + 1)	Site
Boards for cold-soak test x 15	Site	Thickness Gauges (8 x small 4 x large)	Site
Brixometer x 4	Site	Vise grip (large) + rubber opener for containers	Site
Calculators x 3	Site	Walkie Talkies x 4	Site
Close circuit TV camera for rates	Site	Washers x 1 box	Site
Cold-soak boxes x 15	Site	Waste containers (use 20 L pails) x 3	Site
Collection pans for stands (one per stand)	Site	Water (1 x 18L) for hard water	Site
Composite Boxes x 2	Site	Weigh Scale x 2 (sartorius) + wiring	Site
Composite Plates x 2	Site	White boards for water run-off	Site
Electrical Extension Cords x 4	Site	Yellow Carrying Cases x2	Site
Empty 20 L cont. for -30C CSW fluid x 4	Site	Yellow Ice Pic	Site
Falling Ball Viscometer	Site	Thermistors (for Type III ZR -25 tests	Site
Flashlights x 2	Site	Black computer (for Type III ZR -25 tests)	Site
Fluids (see Table 14)	Site		
Funnels x 4 (big and small)	Site	Cold-soak box filling stand	NRC
Gloves - black and yellow	Site	Cold-soak fluid pump	NRC
Gloves - cotton (1 box)	Site	Copper tubing insulation (for passing wires)	NRC
Gloves - latex (2 boxes)	Site	Fluid for cold-soak boxes (barrel)	NRC
Half plates x all	Site	Rubber Mats	NRC
Hard water chemicals x 3 premixes	Site	Tie wraps	NRC
Ice Phobic Plates x 10	Site	Tools	NRC
Inclinometer (yellow level) x 2	Site	Tote for Waste Fluid	NRC
Isopropyl x 15	Site		
Large digital clock x 2	Site	Accordian Folder	Office
Marker for Waste x 2	Site	Camera Suitcase Pack (2 suitcases +backpack)	Office
Measuring Cups x 10	Site	Chamber Settings + Stand settings	Office
Mixing bins for CSW fluid x 5 (rubbermaids)	Site	Clipboards x 10	Office
Nuts to separate plates x 100 (full box)	Site	Data Forms (on water phobic paper)	Office
Outdoor Rate Pan x1	Site	Envelopes (9x12) x box	Office
Paper Towels (4 packs)	Site	Go pro camera	Office
Plate covers x 16	Site	Hard Drive with Current Project folder	Office
Plates: 12 w/smart buttons & 15 without	Site	iPads x 3	Office
Power bars x 5	Site	Laptop for rates x2	Office
Precipitation Rate Pans x 100	Site	Laptop for smart button (MR)	Office
Printer & Ink Cartridge	Site	Mouse for Rate Station and keypad	Office
Protective clothing (all) and personel clothin	Site	Paper for printer (1 pack)	Office
Rubber Mats	Site	Pencils (sharpened) + pens + markers	Office
Rubber squeegees x 10	Site	Test Procedures x 2 (1 sided)	Office
Scrapers x 10	Site	Waterproof paper (100 sheets)	Office
Shelving unit x 1 (black one)	Site	Watmans paper	Office
Shop Vac + Sump Pump + Tubing	Site		
Small folding table x 1	Site	**PH-ADHERENCE PROJECT**	
Smart button kits x 2 + extension wire	Site	**EQUIPMENT**	**LOCATION**
Speed tape x 1 and electrical tape x 5	Site	Adhesion probe	Site
Tape measure (yellow + small)	Site		
Temperature probes: immersion x 3	Site	**DEPLOYED FLAPS PROJECT**	
Temperature probes: surface x 3	Site	**EQUIPMENT**	**LOCATION**
Temperature readers x 2	Site	20° Stand x 2 with plates	Site
Test Stand Shims (poker chips) x 1 box	Site	35° Stand x 2 with plates	Site
Test Stands: 2 x 6 position (for small end)	Site	Drilled plates x 2	Site
IKEA cart x2	Site		

TABLE 17: SNOWMAKER EQUIPMENT LIST

EQUIPMENT	LOCATION
Snow making machine and related equipment	Site
NCAR Computer, Monitor and Control Box	Site
NCAR Weigh Scale x2	Site
Air Compressor	Site
Heat Gun	Site
Small Important Allen Keys	Site
Revco Freezer	Site
All Large Ice Core Molds, 2-3 short Ice core molds	Site
Stryofoam Covers for Ice Core Molds	Site
PVC Pipe for Temporary Storage of Ice Cores	Site
Clean Bucket and Clean Funnel for Ice Core Filling	Site
18 litre containers of water (3)	Site
Sartorius 2 g Scale with Cabling for Comm with Laptop	Site
Aluminum plates with heating pads	Site
Insulated box for heated tests	Site
Snow Distribution Pans 100mm X 150mm (6 Pans)	Site
Extra Wizz Pads	Site
Additonal PVC Wizz Pad Aparatus	Site
Backup Drill Bit	Site
Extra Coupler and GTCA coupler	Site
2 additional Small Folding Tables	Site
Electronic NCAR files	Site
Squeegee/scraper	Site
Extension cord	Site
Wet vacuum	Site
Blue Towel	Site
Waste Container	Site
Measuring Cup	Site
Thermos x 1 and spreader x 1	Site
Microwave	Site
Small box to transport small allen keys and other equip	Site
NCAR tool box	Site
Rate Distribution Excel file	Office
Data Forms	Office
NCAR Manual	Office
Procedures	Office

FIGURE 4: FREEZING PRECIPITATION ENDURANCE TIME DATA FORM

REMEMBER TO SYNCHRONIZE TIME

LOCATION: CEF (Ottawa) **DATE:** **RUN NUMBER:** **STAND # :**

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 0.5°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/BATCH						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						
FAILURE CALL (circle)	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy
HRZ. AIR VELOCITY * (circle)	A B C	A B C	A B C	A B C	A B C	A B C

	Plate 7	Plate 8	Plate 9	Plate 10	Plate 11	Plate 12
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 0.5°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/BATCH						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						
FAILURE CALL (circle)	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy	V. Difficult Difficult. Easy
HRZ. AIR VELOCITY * (circle)	A B C	A B C	A B C	A B C	A B C	A B C

PRECIP (circle): ZF , ZD , ZR-, MOD

AMBIENT TEMPERATURE: ________ °C

NOTE:
* **A: HORIZONTAL AIR VELOCITY ≤ 0.4 m/s**
B: 0.4 m/s < HORIZONTAL AIR VELOCITY ≤ 1.0 m/s
C: HORIZONTAL AIR VELOCITY > 1.0 m/s

COMMENTS:

LEADER / MANAGER: ____________________

FIGURE 5: NRC RATE MANAGEMENT FORM

DATE: ____________________

CONDITION: ____________________ **TECHNICIAN:** ____________________

PAN #	TAB	TIME OUT	1st or 2nd Rate	PAN #	TAB	TIME OUT	1st or 2nd Rate

Retired: 1 2 3 4 5 6 7 8 9 10 11 12

FIGURE 6: FLUID THICKNESS DATA FORM

DATE: _______________ **TEMPERATURE °C (beg.):** _______________ **PERFORMED BY:** _______________
TEST #: ________ **to** ________ **WIND SPEED, kph (beg.):** _______________ **WRITTEN BY:** _______________
STAND: _______________ **LOCATION:** __CEF (NRC)__

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

I:\Groups\Cm1680 (01-02)\Procedures\Thickness\Thickness Form

Notes:
- The quantity of fluid that will be poured for each test is 1.0 L
- Measurements should be made at the 15-cm line at the time of fluid application, and after 2, 5, 15 and 30 minutes
- If the results for one fluid vary by more than 10% repeat the two tests and disregard the highest and lowest values

Figure 7: SNOWMAKER END CONDITION DATA FORM

Version 1.0 Winter 2009-10

LOCATION: DATE: RUN # : STAND # : NCAR

OUTPUT FILENAME:________________________________.txt

OAT: ________°C

PRECIPITATION RATE: ________g/dm²/h

FLUID TEMPERATURE: ________°C

FLUID QUANTITY APPLIED: ________Litres

PLATE WASHING METHOD: ______________

PLATE TEMPERATURE (OMEGA): ______________ ºC

OTHER COMMENTS (Fluid Batch, etc):

____

____

____

____

____

____

____

	PRINT	SIGN
FAILURES CALLED BY :	______	______
HAND WRITTTEN BY :	______	______
LEADER :	______	______

*TIME (After Fluid Application)
TO FAILURE FOR INDIVIDUAL CROSSHAIRS (h:min)

Time of Fluid Application: ________ h:min

FLUID NAME			
B1 B2 B3			
C1 C2 C3			
D1 D2 D3			
E1 E2 E3			
F1 F2 F3			

CALCULATED FAILURE TIME (MINUTES) [ ]

Final Brix (o)

B2	C1	C2	C3	D2	E2

FIGURE 8: FLUID BRIX / THICKNESS DATA FORM

FLUID BRIX/THICKNESS DATA FORM

DATE: ______________ PERFORMED BY: ________________

RUN #: ______________ WRITTEN BY: ________________

STAND: ______________ LOCATION: ________________

Plate/BOX:			Plate/BOX:			Plate/BOX:			Plate/BOX:		
Fluid:			Fluid:			Fluid:			Fluid:		
TIME	Brix at 15 cm Line	Thick. at 15 cm Line	TIME	Brix at 15 cm Line	Thick. at 15 cm Line	TIME	Brix at 15 cm Line	Thick. at 15 cm Line	TIME	Brix at 15 cm Line	Thick. at 15 cm Line

Figure 9: ICE PHOBIC END CONDITION DATA FORM

LOCATION: NRC	DATE:	RUN #:	STAND #:

FLUID / DILUTION ______ ______ ______ ______ ______ ______

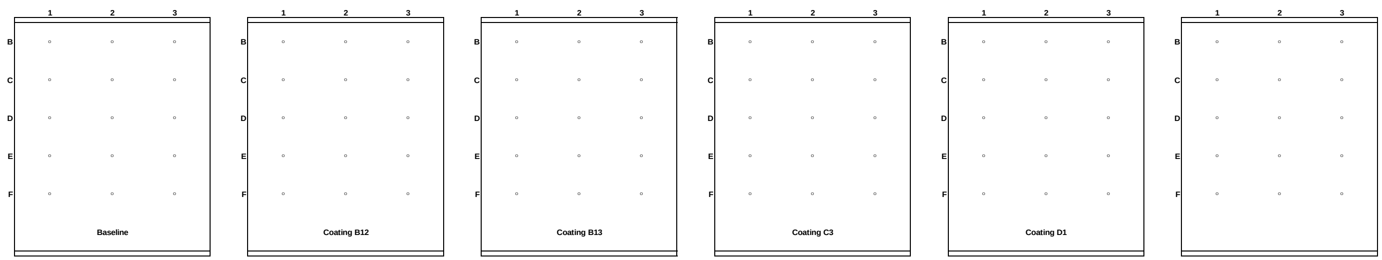
		Plate 1 Baseline	Plate 2 Coating B12	Plate 3 Coating B13	Plate 4 Coating C3	Plate 5 Coating D1	Plate 6 Coating D2
		1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
DESCRIBED ADHESION	B	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘
AND DRAW FAILURE	C	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘
AT TIME OF	D	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘
PLATE 1 FAILURE	E	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘
	F	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘	∘ ∘ ∘
TIME OF FLUID APPLICATION		______	______	______	______	______	______
TIME OF FLUID FAILURE		______	______	______	______	______	______
FAILURE TIME (MIN)							
BRIX MEASUREMENTS TIME / BRIX	5 MIN	/	/	/	/	/	/
	END	/	/	/	/	/	/
	AT P1 FAIL		/	/	/	/	/
THICKNESS MEAS. TIME / THICKNESS	5 MIN	/	/	/	/	/	/
	END	/	/	/	/	/	/
	AT P1 FAIL		/	/	/	/	/

FAILURES CALLED BY: ______________

FIGURE 10: ICE PHOBIC THICKNESS DATA FORM

LOCATION: NRC CONDITION: DATE: RUN#: STAND#:

PLATE #						
SURFACE	Baseline	Coating B12	Coating B13	Coating C3	Coating D1	Coating D2
FLUID/DIL.						
TIME OF FLUID APP.						



THICKNESS MEASUREMENTS (mil)

Time	6" LINE	Time	6" LINE	Time	6" LINE	Time	6" LINE	Time	6" LINE	Time	6" LINE

PERFORMED BY: ______________________ WRITTEN BY: ____________________

This page intentionally left blank.

APPENDIX C

PROCEDURE:
EFFECT OF ICE PHOBIC PRODUCTS ON HOT'S

CM2169.002

PROCEDURE:
EFFECT OF ICE PHOBIC PRODUCTS ON HOT'S

Winter 2009-10

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Michelle Pineau

Reviewed by: John D'Avirro

APS Aviation Inc.

December 24, 2009
Final Version 1.0

**EFFECT OF ICE PHOBIC PRODUCTS ON HOT'S
WINTER 2009-10**

1. BACKGROUND

Ice build-up can cause major safety concerns for both on-ground and in-flight aircraft operations. As a result, there has been a great industry interest in the use of ice phobic coatings to protect aircraft critical surfaces. Recent work has looked at in-flight operations, however the behavior and performance of the products during ground icing operations has yet to be investigated.

A series of preliminary outdoor tests will be conducted by APS personnel during the Winter 2009-10 testing season to evaluate the effect ice phobic products have on endurance times. Future work indoors at the National Research Council (NRC) climatic chamber is anticipated.

In addition, a discussion with NRC personnel on previous testing with ice phobic products for electrical power line applications may provide beneficial information while performing these tests.

2. OBJECTIVE

The objective of this project is to investigate the fluid performance of surfaces treated with ice phobic products using standard endurance time testing protocol. Limited testing will also look at the performance of bare plates treated with ice phobic products.

During the analysis stage, the performance of the fluid on the ice phobic treated surfaces will be compared to that of the baseline test. If positive results are demonstrated using the representative de/anti-icing fluids stated, additional preliminary work alongside the vertical stabilizer project will be considered.

This document describes the procedure for outdoor tests. A separate procedure for indoor tests will be developed following the successful completion of outdoor testing.

3. PROCEDURE

Tests will be conducted under natural snow conditions at the APS test site facility located at Montreal-Trudeau Airport in Montreal.

Standard endurance time test and rate collection protocol will be followed during the execution of these tests. A six-position test stand will be required to conduct tests, as shown in Figure 3.1. Position 1 will be the rate collection station, followed by the baseline standard aluminium plate in Position 2. The remaining plates, Position 3 through 6, will be standard aluminium plates treated with ice phobic products.

It is important to note, typical Type I HOT procedures call for Type I fluids to be applied to a cold-soak box in natural snow conditions. Due to these comparative tests being in the preliminary stage of investigation, standard aluminium plates will be used during these tests.

3.1 Behaviour of De/Anti-Icing Fluids on Ice Phobic Surfaces

Initial tests will aim at investigating the behaviour of de/anti-icing fluids on ice phobic treated surfaces. Factors which will be observed include fluid separation/fluid beading, fluid thickness and fluid endurance times (separate specific tests are planned in Section 3.3).

The following outlines the steps necessary to conduct tests:

i) 1 L of Type II/IV fluids will be applied to the test surfaces according to the test plan found in Attachment I. For Type I fluid, 0.5 L at 60°C will be applied. All pertinent information will be recorded on the end condition data form.

ii) Thickness and brix measurements will be taken 5 minutes after pouring and at failure of the baseline plate. Measurements will be recorded on the fluid brix/thickness data form.

In addition to these tests, tests will be conducted to compare fluid performance of standard aluminium plates versus untreated ice phobic plates (see Section 3.2). Ice adherence will be monitored during these tests.

During the execution of these test runs, the ice phobic treated plates will be monitored. Should they begin to yield comparable results, the amount of treated plates may be reduced for testing purposes. A representative sample will be selected to facilitate testing.

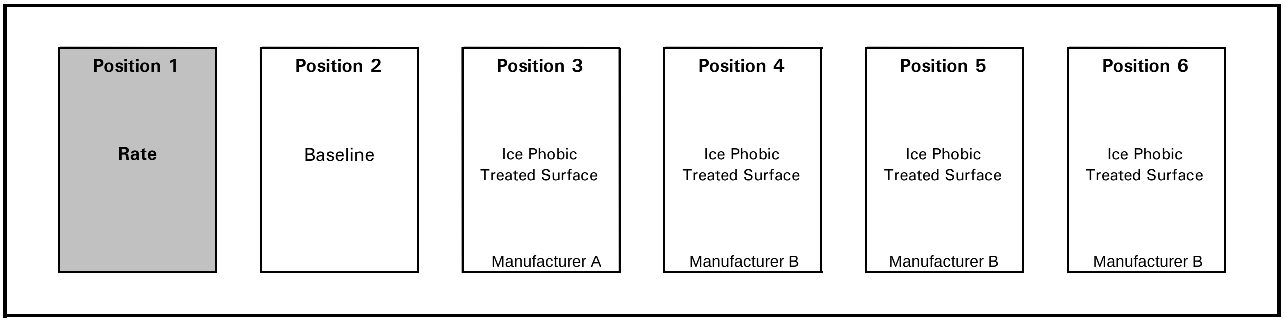


Figure 3.1: Example of Six-Position Test Stand Setup for ET Tests

3.2 Adhesion Tests During Precipitation

In addition to these tests, tests will be conducted to compare fluid performance of standard aluminium plates versus untreated ice phobic plates (see Section 3.2). Ice adherence will be monitored during these tests.

Notes:

- Do for one Manufacturer B product only;
- Measure adhesion;
- Do two runs only;
- Consider doing additional runs if results are positive;
- Do with Type I fluid (1st run);
- Do with Type IV fluid (2nd run); and
- See Figure 3.2.

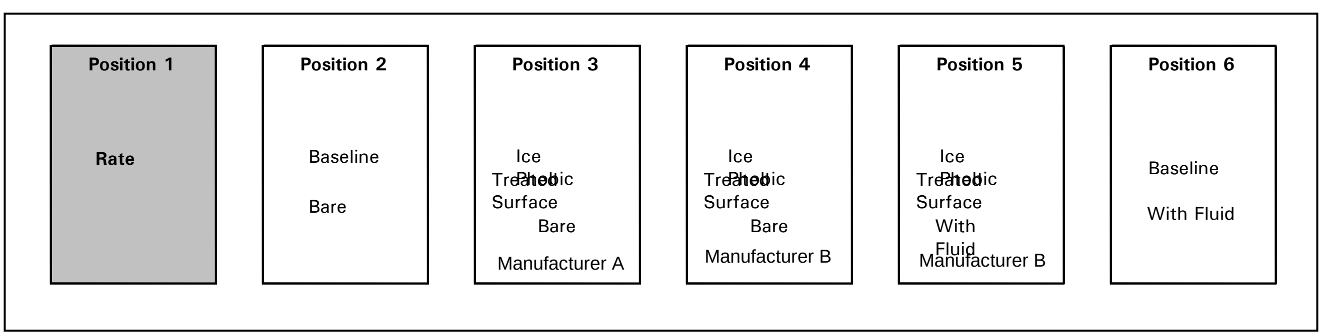


Figure 3.2: Example of Six-Position Test Stand Setup for Adhesion Tests

3.3 Thickness and Wetting Tests

In addition to the main set of endurance time tests, a series of thickness and wetting tests will be carried out.

Notes:

- Do for each of the 5 fluids;
- Do in sets of three (baseline, Manufacturer B (Product 1), Manufacturer A);
- Consider set of four with 2nd Manufacturer B Product;
- To be done outdoors if time permits on indoors at NRC;
- To be done in non-precipitation;
- Measure thickness over minimum 30 minutes at 15 cm line (see Attachment II);
- Observe fluid separation or beading; and
- See Attachment III.

4. FLUIDS

Five fluids will be used, including a Type I PG, a Type II PG, a Type IV EG and two Type IV PG fluids. Fluids are detailed in Table 4.1.

Table 4.1: Required Fluids

Fluid Manufacturer	Fluid Name	Batch Number	Fluid Type	Dilution	Quantity Required
Octagon Process Inc.	Octaflo EF	WL-120108	Type I PG	10°C Buffer	6 L
Kilfrost Limited	ABC-2000	KIL08-09LOWV	Type II PG	100/0	10 L
Clariant Produkte	Safewing MP IV LAUNCH	C02192009IV	Type IV PG	100/0	10 L
Kilfrost Limited	ABC-S PLUS	K21012009IV	Type IV PG	100/0	10 L
Dow Chemical Company	UCAR EG 106	XA2201GKI6	Type IV EG	100/0	10 L

5. TEST PLATES

Two ice phobic manufacturers provided samples for testing purposes, Manufacturer B and Manufacturer A.

Manufacturer A has provided APS with one treated ice phobic plate for testing purposes.

Manufacturer B has provided 6 varieties of ice phobic treated plates. Initial tests will be carried out with all six plates; only on or two of these will be used after the initial set of tests.

6. TEST PLAN

Refer to Attachment I for a detailed plan for outdoor tests. Attachment III lists the necessary tests to measure thickness.

7. EQUIPMENT

Equipment identical to equipment used for standard endurance time tests will be used, as well as the following:

- Fluid thickness gauge;
- Brixometer; and
- Adhesion probe.

8. PERSONNEL

Two APS personnel will be required to conduct endurance time testing. A third person may be required to aid in initial setup or offer support during testing.

9. DATA FORMS

Attachment IV illustrates the end condition form for endurance time testing that will be completed during each test run.

ATTACHMENT I: TEST PLAN

TEST NO.	PLATE POSITION	FLUID NAME	FLUID TYPE	DILUTION	COMMENTS
1	2	Clariant MP IV LAUNCH	Type IV PG	100/0	Baseline
	3	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer A Treated Surface
	4	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	5	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	6	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	*EXTRA MANUFACTURER B PLATES	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
2	2	Octagon Octaflo EF	Type I PG	10° Buffer, Heated to 60°C	Baseline
	3	Octagon Octaflo EF	Type I PG	10° Buffer, Heated to 60°C	Manufacturer A Treated Surface
	4	Octagon Octaflo EF	Type I PG	10° Buffer, Heated to 60°C	Manufacturer B Ice Phobic Treated Surface
	5	Octagon Octaflo EF	Type I PG	10° Buffer, Heated to 60°C	Manufacturer B Ice Phobic Treated Surface
	6	Octagon Octaflo EF	Type I PG	10° Buffer, Heated to 60°C	Manufacturer B Ice Phobic Treated Surface
	*EXTRA MANUFACTURER B PLATES	Octagon Octaflo EF	Type I PG	10° Buffer, Heated to 60°C	Manufacturer B Ice Phobic Treated Surface
		Octagon Octaflo EF	Type I PG	10° Buffer, Heated to 60°C	Manufacturer B Ice Phobic Treated Surface
		Octagon Octaflo EF	Type I PG	10° Buffer, Heated to 60°C	Manufacturer B Ice Phobic Treated Surface
3	2	Kilfrost ABC-S Plus	Type IV PG	100/0	Baseline
	3	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer A Treated Plate
	4	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	5	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	6	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	*EXTRA MANUFACTURER B PLATES	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
4	2	Dow UCAR EG106	Type IV EG	100/0	Baseline
	3	Dow UCAR EG106	Type IV EG	100/0	Manufacturer A Treated Surface
	4	Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
	5	Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
	6	Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
	*EXTRA MANUFACTURER B PLATES	Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
		Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
		Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
5	2	Kilfrost ABC-2000	Type II PG	100/0	Baseline
	3	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer A Treated Surface
	4	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
	5	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
	6	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
	*EXTRA MANUFACTURER B PLATES	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
6	2	Clariant MP IV LAUNCH	Type IV PG	100/0	Baseline
	3	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer A Treated Surface
	4	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	5	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	6	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	*EXTRA MANUFACTURER B PLATES	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
7	2	Kilfrost ABC-S Plus	Type IV PG	100/0	Baseline
	3	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer A Treated Surface
	4	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	5	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	6	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
	*EXTRA MANUFACTURER B PLATES	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface
8	2	Dow UCAR EG106	Type IV EG	100/0	Baseline
	3	Dow UCAR EG106	Type IV EG	100/0	Manufacturer A Treated Surface
	4	Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
	5	Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
	6	Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
	*EXTRA MANUFACTURER B PLATES	Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
		Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
		Dow UCAR EG106	Type IV EG	100/0	Manufacturer B Ice Phobic Treated Surface
9	2	Kilfrost ABC-2000	Type II PG	100/0	Baseline
	3	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer A Treated Surface
	4	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
	5	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
	6	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
	*EXTRA MANUFACTURER B PLATES	Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface
		Kilfrost ABC-2000	Type II PG	100/0	Manufacturer B Ice Phobic Treated Surface

ATTACHMENT II: BRIX/THICKNESS FORM

FLUID BRIX / THICKNESS DATA FORM

DATE: ______________ **PERFORMED BY:** ______________

RUN #: ______________ **WRITTEN BY:** ______________

STAND: ______________ **LOCATION:** ______________

Plate / BOX: Fluid:			Plate / BOX: Fluid:			Plate / BOX: Fluid:			Plate / BOX: Fluid:			Plate / BOX: Fluid:		
TIME	**Brix at 15 cm Line**	**Thick. at 15 cm Line**	**TIME**	**Brix at 15 cm Line**	**Thick. at 15 cm Line**	**TIME**	**Brix at 15 cm Line**	**Thick. at 15 cm Line**	**TIME**	**Brix at 15 cm Line**	**Thick. at 15 cm Line**	**TIME**	**Brix at 15 cm Line**	**Thick. at 15 cm Line**

ATTACHMENT III: TEST PLAN FOR THICKNESS TESTS

TEST NO.	PLATE POSITION	FLUID NAME	FLUID TYPE	DILUTION	COMMENTS
1	2	Clariant MP IV LAUNCH	Type IV PG	100/0	Baseline
	3	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer A Treated Surface
	4	Clariant MP IV LAUNCH	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface (Product 1)
2	2	Octagon Octaflo EF	Type IV PG	100/0	Baseline
	3	Octagon Octaflo EF	Type IV PG	100/0	Manufacturer A Treated Surface
	4	Octagon Octaflo EF	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface (Product 1)
3	2	Kilfrost ABC-S Plus	Type IV PG	100/0	Baseline
	3	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer A Treated Surface
	4	Kilfrost ABC-S Plus	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface (Product 1)
4	2	Dow UCAR EG106	Type IV PG	100/0	Baseline
	3	Dow UCAR EG106	Type IV PG	100/0	Manufacturer A Treated Surface
	4	Dow UCAR EG106	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface (Product 1)
5	2	Kilfrost ABC-2000	Type IV PG	100/0	Baseline
	3	Kilfrost ABC-2000	Type IV PG	100/0	Manufacturer A Treated Surface
	4	Kilfrost ABC-2000	Type IV PG	100/0	Manufacturer B Ice Phobic Treated Surface (Product 1)

ATTACHMENT IV: END CONDITION FORM FOR ENDURANCE TIME TESTING

END CONDITION FORM FOR ENDURANCE TIME TESTING

LOCATION: DORVAL TEST SITE **DATE:** **RUN #:** **STAND #:**

SURFACE		________	________	________	________	________
FLUID NAME		________	________	________	________	________
DESCRIBE ADHESION AND DRAW FAILURE AT TIME OF PLATE 1 FAILURE		1 2 3 B ∘ ∘ ∘ C ∘ ∘ ∘ D ∘ ∘ ∘ E ∘ ∘ ∘ F ∘ ∘ ∘	1 2 3 B ∘ ∘ ∘ C ∘ ∘ ∘ D ∘ ∘ ∘ E ∘ ∘ ∘ F ∘ ∘ ∘	1 2 3 B ∘ ∘ ∘ C ∘ ∘ ∘ D ∘ ∘ ∘ E ∘ ∘ ∘ F ∘ ∘ ∘	1 2 3 B ∘ ∘ ∘ C ∘ ∘ ∘ D ∘ ∘ ∘ E ∘ ∘ ∘ F ∘ ∘ ∘	1 2 3 B ∘ ∘ ∘ C ∘ ∘ ∘ D ∘ ∘ ∘ E ∘ ∘ ∘ F ∘ ∘ ∘
TIME OF FLUID APPLICATION		________	________	________	________	________
TIME OF FLUID FAILURE		________	________	________	________	________
FAILURE TIME (MIN)						
BRIX MEASUREMENTS TIME / BRIX	**5 MIN**	/	/	/	/	/
	END	/	/	/	/	/
	AT P1 FAIL		/	/	/	/
THICKNESS MEAS. TIME / THICKNESS	**5 MIN**	/	/	/	/	/
	END	/	/	/	/	/
	AT P1 FAIL		/	/	/	/
FAILURES CALLED BY:		________				

This page intentionally left blank.

APPENDIX D

TEST PLAN –
EVALUATE PERFORMANCE OF HIGH AND LOW FLUID VISCOSITIES WHEN APPLIED TO ICE PHOBIC COATED SURFACES – NATURAL SNOW
WINTER 2012-13

TEST PLAN
EVALUATE PERFORMANCE OF HIGH AND LOW FLUID VISCOSITIES WHEN APPLIED TO ICE PHOBIC COATED SURFACES – NATURAL SNOW WINTER 2012-13

Version 1.0, November 23, 2012

- Use procedure December 24, 2009 (Effect of Ice Phobic Products on HOT's);
- Use four plates (10°) simultaneously (coated vs. baseline for high and low viscosity). Attempt to run each coating over course of winter;
- Plan to run 1 or 2 sets per storm;
- Five fluids (Kilfrost ABC-S +, AD49, Launch, Max Flight, Polar Guard Advance) have been requested to send low viscosity fluids;
- Five coatings will be provided;
- This results in 25 combinations (runs);
- Attempt 10 runs over course of winter and then conduct balance (15 runs) at NRC Cold Chamber; and
- For the outdoor tests, attempt to run each coating twice and each fluid twice maximum.

This page intentionally left blank.

APPENDIX E

PROCEDURE:
ADDENDUM TO PROCEDURE:
EVALUATION OF ENDURANCE TIME PERFORMANCE ON VERTICAL SURFACES

CM2265.001

ADDENDUM TO PROCEDURE: EVALUATION OF ENDURANCE TIME PERFORMANCE ON VERTICAL SURFACES

Vertical Surfaces Treated with Ice Phobic Coatings

Winter 2011-12

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: David Youssef

Reviewed by: John D'Avirro

APS Aviation Inc.

January 25, 2012
Final Version 1.0

ADDENDUM TO PROCEDURE: EVALUATION OF ENDURANCE TIME PERFORMANCE ON VERTICAL SURFACES

Vertical Surfaces Treated with Ice Phobic Coatings

1. BACKGROUND

Preliminary testing results on vertical surfaces have indicated a reduction in fluid protection time when applied to vertical surfaces. It was therefore recommended that limited testing be conducted using vertical aluminum surfaces treated with ice phobic materials to identify any potential benefits in protection time or adhesion. Preliminary testing was conducted in 2010-11 in conjunction with the testing for vertical surfaces. It is recommended that additional testing be conducted during the winter of 2011-12 independent of the work done on vertical surfaces.

2. OBJECTIVE

To investigate the endurance time performances of vertical surfaces treated with an ice phobic coating. It is anticipated that 3 to 4 Type I or Type IV test runs will be conducted during 6 or more winter storms.

3. PROCEDURE

Endurance time tests will be conducted using the procedures outlined in the program procedure: *Evaluation of Endurance Time Performance on Vertical Surfaces, December 21st 2009.* Standard fluid endurance time test procedures will apply. A new setup will be used for this testing. Plate 4 will no longer be used for a two-step application test, but will be changed to an ice phobic treated plate; the coating used will be a Manufacturer B product unless other manufacturers provide samples for testing. Plate 3 will serve as the comparative baseline Type I or Type IV test. Plates 1 and 2 will not be used for these tests. Figure 3.1 demonstrates this new general setup for the conduct of the tests.

Note: Limited testing should also be conducted to investigate the effects of 80º (current setup) vs. 90º plates on fluid endurance times; 2-3 tests should be planned.

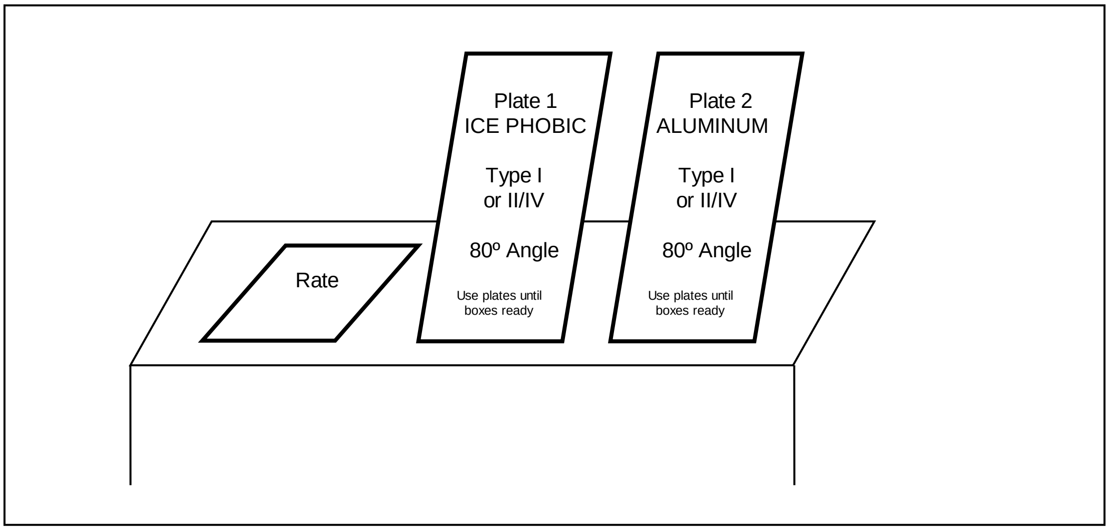


Figure 3.1: New General Setup

APPENDIX F

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

CM2265.002

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

Winter 2012-13

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: Marco Ruggi and Victoria Zoitakis

Reviewed by: John D'Avirro

APS Aviation Inc.

January 3, 2013
Final Version 1.0

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

1. BACKGROUND

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

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

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

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

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

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

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

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

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

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

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

2. OBJECTIVES

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

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

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

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

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

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

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

- o Snow on an un-protected wing;
- o Feasibility of IP testing at higher speed (130-150kts);
- o Light and very light snow HOT's;
- o Windshield washer used as a Type I deicer; and
- o Effect of fluid seepage on dry wing performance.

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

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

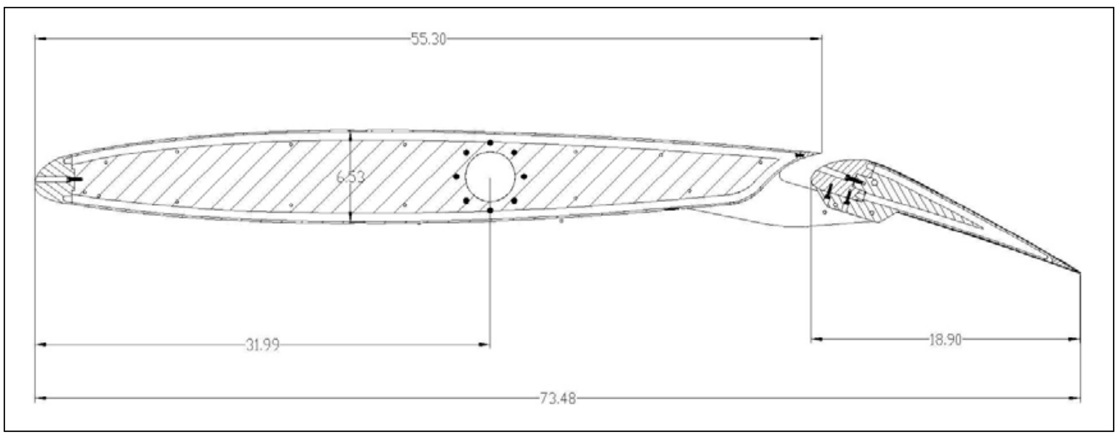


Figure 2.1: Super-Critical Wing Section

3. TEST PLAN

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

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

Wind Tunnel 2012-13
Anticipated Calender of Tests
JANUARY 2013

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

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

Figure 3.1: Test Calendar

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

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

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

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

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

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

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

Table 3.1: Proposed Test Plan

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (ºC)	Fluid	Dilution	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	Coating	Exposure Time	COMMENT
P001	Baseline	1	1	Dry Wing	8	100	any	none		-	-	-		-	to be conducted daily before start ot tests
P002	Baseline	1	1	Dry Wing	stall	100	any	none		-	-	-		-	to be conducted daily before start ot tests
P003	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	ABC-S Plus	100/0	25	-	-		30	
P004	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	ABC-S Plus	100/0	25	-	-		30	
P005	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	Launch	100/0	25	-	-		30	
P006	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	Launch	100/0	25	-	-		30	
P007	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	AD-49	100/0	25	-	-		30	
P008	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	AD-49	100/0	25	-	-		30	
P009	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	Max-Flight	100/0	25	-	-		30	
P010	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	Max-Flight	100/0	25	-	-		30	
P011	IP Flow-Off Issues	1	1	IP-	8	100	< -10°C	Polar Guard Advance	100/0	25	-	-		30	
P012	IP Flow-Off Issues	1	1	IP-	8	115	< -10°C	Polar Guard Advance	100/0	25	-	-		30	
P013	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	ABC-S Plus	100/0	75	-	-		5	
P014	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	ABC-S Plus	100/0	75	-	-		5	
P015	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	Launch	100/0	75	-	-		5	
P016	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	Launch	100/0	75	-	-		5	
P017	IP Flow-Off Issues	1	2	IP mod	8	100	< -10°C	AD-49	100/0	75	-	-		5	
P018	IP Flow-Off Issues	1	2	IP mod	8	115	< -10°C	AD-49	100/0	75	-	-		5	
P019	IP Flow-Off Issues	1	2	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-		5	
P020	IP Flow-Off Issues	1	2	IP mod	8	115	< -10°C	Max-Flight	100/0	75	-	-		5	
P021	IP Flow-Off Issues	1	2	IP mod	8	100	< -10°C	Polar Guard Advance	100/0	75	-	-		5	
P022	IP Flow-Off Issues	1	2	IP mod	8	115	< -10°C	Polar Guard Advance	100/0	75	-	-		5	
P023	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	ABC-S Plus	100/0	75	-	-		10	
P024	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	ABC-S Plus	100/0	75	-	-		10	
P025	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	Launch	100/0	75	-	-		10	
P026	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	Launch	100/0	75	-	-		10	

Table 3.1: Proposed Test Plan (cont'd)

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (ºC)	Fluid	Dilution	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	Coating	Exposure Time	COMMENT
P027	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	AD-49	100/0	75	-	-		10	
P028	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	AD-49	100/0	75	-	-		10	
P029	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-		10	
P030	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	Max-Flight	100/0	75	-	-		10	
P031	IP Flow-Off Issues	1	1	IP mod	8	100	< -10°C	Polar Guard Advance	100/0	75	-	-		10	
P032	IP Flow-Off Issues	1	1	IP mod	8	115	< -10°C	Polar Guard Advance	100/0	75	-	-		10	
P033	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	CO	-	C0 Objective: Baseline
P034	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C1	-	C1 Objective: Baseline
P035	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C2	-	C2 Objective: Baseline
P036	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C3	-	C3 Objective: Baseline
P037	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C4	-	C4 Objective: Baseline
P038	Ice Phobic Coating R&D	2	1	None	8	100	< -10°C	none	-	-	-	-	C5	-	C5 (USE P001 OF THE DAY) Objective: Baseline
P039	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C0	10	C0 Objective: Flow-off
P040	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C1	10	C1 Objective: Flow-off
P041	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C2	10	C2 Objective: Flow-off
P042	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C3	10	C3 Objective: Flow-off
P043	Ice Phobic Coating R&D	2	1	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C4	10	C4 Objective: Flow-off
P044	Ice Phobic Coating R&D	2	2	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	C5	10	C5 Objective: Flow-off
P045	Ice Phobic Coating R&D	2	2	IP mod	8	100	< -10°C	Max-Flight	100/0	75	-	-	ANY	10	any of C1 or C2 or C3 or C4 Objective: effect of viscosity (use LOWV fluid)
P046	Ice Phobic Coating R&D	1	1	Fluid only	8	100	-5 to -15	EG106	100/0	-	-	-	C0	-	C0 Objective: adhesion
P047	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	EG106	100/0	-	-	25	C0	20	C0 Objective: adhesion
P048	Ice Phobic Coating R&D	1	1	IP- / ZR	8	100	-5 to -15	EG106	100/0	25	-	25	C0	20	C0 Objective: adhesion
P049	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	none	-	-	-	25	C0	20	C0 Objective: adhesion
P050	Ice Phobic Coating R&D	1	1	Fluid only	8	100	-5 to -15	EG106	100/0	-	-	-	C1	-	C1 Objective: adhesion
P051	Ice Phobic Coating R&D	1	1	ZR	8	100	-5 to -15	EG106	100/0	-	-	25	C1	20	C1 Objective: adhesion
P052	Ice Phobic Coating R&D	1	1	IP- / ZR	8	100	-5 to -15	EG106	100/0	25	-	25	C1	20	C1 Objective: adhesion

Table 3.1: Proposed Test Plan (cont'd)

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

Table 3.1: Proposed Test Plan (cont'd)

Test Plan #	Objective	Objective Priority	Priority	Test Condition	Rotation Angle	Ramp (s/kts)	Target OAT (ºC)	Fluid	Dilution	IP Rate (g/dm²/h)	SN Rate (g/dm²/h)	ZR Rate (g/dm²/h)	Coating	Exposure Time	COMMENT
P078	Ice Phobic Coating R&D	1	1	Fluid Only	8	100	< -5	EG106	100/0	-	-	-	C0/C5	-	C0 & C5 Objective: visual comparison
P079	Ice Phobic Coating R&D	1	1	ZR	8	100	< -5	EG106	100/0	-	-	50	C0/C5	115? (as 2010-11)	C0 & C5 Objective: visual comparison
P080	Ice Phobic Coating R&D	1	1	Fluid Only	8	100	< -5	EG106	100/0	-	-	-	C1/C2	-	C1 & C2 Objective: visual comparison
P081	Ice Phobic Coating R&D	1	1	ZR	8	100	< -5	EG106	100/0	-	-	50	C1/C2	115? (as 2010-11)	C1 & C2 Objective: visual comparison
P082	Ice Phobic Coating R&D	1	1	Fluid Only	8	100	< -5	EG106	100/0	-	-	-	C3/C4	-	C3 & C4 Objective: visual comparison
P083	Ice Phobic Coating R&D	1	1	ZR	8	100	< -5	EG106	100/0	-	-	50	C3/C4	115? (as 2010-11)	C3 & C4 Objective: visual comparison
P084	Ice Phobic Coating R&D	1	2	Fluid Only	8	100	< -5	EG106	100/0	-	-	-	C0/ANY	-	C0 & one of C1, C2, C3 or C4 Objective: visual comparison
P085	Ice Phobic Coating R&D	1	2	ZR	8	100	< -5	EG106	100/0	-	-	50	C0/ANY	115? (as 2010-11)	C0 & one of C1, C2, C3 or C4 Objective: visual comparison
P086	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C0	-	C0
P087	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C1	-	C1
P088	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C2	-	C2
P089	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C3	-	C3
P090	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C4	-	C4
P091	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	below -16.5 +/- 3	MP III 2031	100/0	-	-	-	C5	-	C5
P092	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	-9 +/- 3	MP III 2031	75/25	-	-	-	C0	-	C0
P093	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	-9 +/- 3	MP III 2031	75/25	-	-	-	C5	-	C5
P094	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	LS (67?)	-9 +/- 3	MP III 2031	75/25	-	-	-	ANY	-	Pick one of C1, C2, C3 or C4
P095	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C0	-	C0
P096	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C1	-	C1
P097	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C2	-	C2
P098	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C3	-	C3
P099	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C4	-	C4
P100	Effect of Ice Phobic Coatings on BLDT	1	1	Fluid Only	8	100	-26 +/- 3	AD-49	100/0	-	-	-	C5	-	C5
P101	Evaluation of Stallwarning Sensor	1	1	none	stall	100	any	none	-	-	-	-		-	NO SENSOR ensure sensor is non intrusive
P102	Evaluation of Stallwarning Sensor	1	2	none	stall	100	any	none	-	-	-	-		-	NO SENSOR (REPEAT) ensure sensor is non intrusive
P103	Evaluation of Stallwarning Sensor	1	1	none	stall	100	any	none	-	-	-	-		-	WITH SENSOR ensure sensor is non intrusive

Table 3.1: Proposed Test Plan (cont'd)

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

Table 3.1: Proposed Test Plan (cont'd)

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

Table 3.1: Proposed Test Plan (cont'd)

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

Table 3.1: Proposed Test Plan (cont'd)

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

4. PRE-TESTING SETUP ACTIVITIES

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

5. DATA FORMS

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

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

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

6. PROCEDURE

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

6.1 Initial Test Conditions Survey

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

6.2 Fluid Application (Pour)

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

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

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

6.3.2 Dispensing Ice Pellets/Snow for Wind Tunnel Tests

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

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

6.4 Prior to Engines-On Wind Tunnel Test

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

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

6.5 During Wind Tunnel Test:

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

6.6 After the Wind Tunnel Test:

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

6.7 Fluid Sample Collection for Viscosity Testing

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

6.8 At the End of Each Test Session

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

6.9 Camera Setup

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

6.10 Demonstration of a Typical Wind Tunnel Test Sequence

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

Table 6.1: Typical Wind Tunnel Test

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

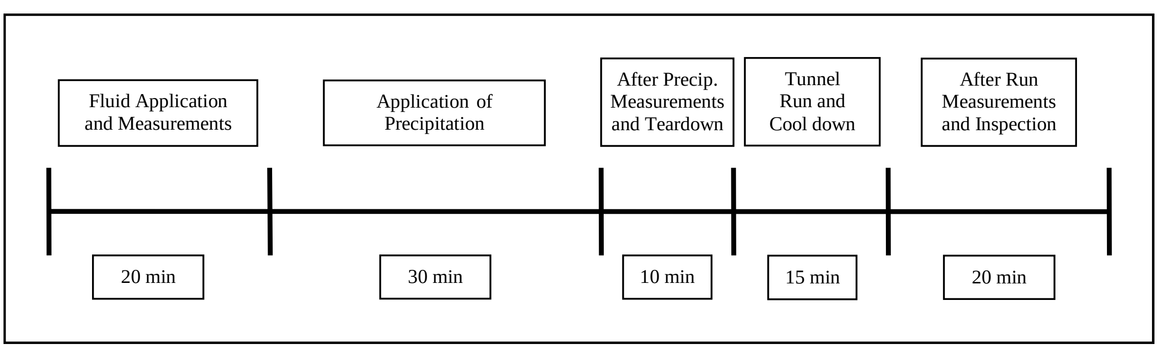


Figure 6.1: Typical Wind Tunnel Run Timeline

6.11 Procedures for R&D Activities

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

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

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

7. EQUIPMENT

Equipment to be employed is shown in Table 7.1.

Table 7.1: Test Equipment Checklist

EQUIPMENT	STATUS	EQUIPMENT	STATUS
General Support Equipment		***Camera Equipment***	
Large and small tape measure		Digital still cameras x3 (two suitcases)	
Fluids (ORDER and SHIP to Ottawa)		Flashes and tripods (in APS storage)	
Horse and tap for fluid barrel x 2		GoPro Camera	
Funnels		Older Xti (x3) cameras (as back-up for first week)	
Sample bottles for viscosity measurement x10		Obsolete Cameras (to be given to TC)	
Squeegees			
Isopropyl x24		***Ice Pellets Fabrication Equipment***	
Gloves, paper towel (lots)		Refrigerated Truck	
Extension cords		Ice pellets Styrofoam containers x20	
Clipboards, pencils, wing markers for sample locations and solvent		Ice bags	
Large Clock x1		Ice bags storage freezer	
Walkie Talkies x8		Blenders x6+	
Envelopes and labels		Ice pellets sieves	
Previous F20/WT reports (Elecronic Copies)		Folding tables	
Grid Section + Location docs		Measuring cups (1L and smaller ones for dispensing)	
Large Sharpies for Grid Section		Wooden Spoons	
Projector for laptop		Rubber Mats	
YOW employee contracts		NCAR Scale x1	
Blow Horns x4			
Stop Watches x4		***Freezing Rain Equipment***	
Calculators x3		NRC Freezing rain sprayer (not required)	
Scissors		APS PC equipped with rate station software	
Exacto Knives x2		White plastic rate pans (1 to 8 x 2) if necessary	
APS Laptops x5		Wooden boards for rate pans (x8)	
Dry eraser markers		Rubber suction cup feet for wooden boards	
		Sartorius Weigh Scale x1	
Test Equipment		Black Shelving Unit (or plastic)	
Test Procedures, data forms, printer paper			
Electronic copy of the whole wind tunnel procedure folder, incl all forms and working docs (maybe Falcon too).			
Hard Drive (3 x New) 2-APS 1-WU 0-TC??			
Test Plate			
Speed tape (large and small)			
Thickness Gauges			
Temperature Probe x 2 and spare batteries			
Brixometers X4			
Adherence Probes (Oral B) x4 with tips and charger			
Fluid pouring jugs x40?? (10 per fluid + extra)			
Ice pellets dispersers x6			
Stands for ice pellets dispensing devices x6			
Ice Pellet control wires and boxes (all)			
Ice pellet box supports for railing x4			
Hot Plate x3 and Large Pots with rubber handles			
Watmans Paper and conversion charts			
Long Ruler for marking wing x2			
Small 90º aluminum ruler for wing			
20L containers x12 (DY order from YUL)			
hard water chemicals			
Thermometer for Reefer Truck			
Poster board (8"x3") for flap section			

8. FLUIDS

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

Table 8.1: Fluid Available for Wind Tunnel Tests

Fluid Manufacturer	Fluid Name	Type	Viscosity	2012-13 Quantity Ordered (L)
ABAX	Ecowing AD-49	IV	Mid	700
			Low	60
Clariant Produkte	Launch	IV	Mid	400
			Low	60
	Max-Flight 04	IV	Mid	700
			Low	60
	MP III 2031 ECO	III	Mid	200
Cryotech	Polar Guard Advance	IV	Mid	600
			Low	60
Dow Chemical Company	EG106	IV	Mid	800
Kilfrost Limited	ABC-S PLUS	IV	Mid	500
			Low	60
			Total	4200

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

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

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

9. PERSONNEL

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

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

Table 9.1: Personnel List

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

NRC Institute of Aerospace Research Contacts

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

10. SAFETY

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

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

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

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

3 October 2012

Background and Overall Goal

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

1. Baseline (clean model) Repeatability

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

1.1 Perform standard speed ramp profile and rotation to $\alpha = 8$ deg. and hold. V = 100 kts. Compare C_L, C_M and C_D versus α results to data from previous test campaigns.

1.2 Perform standard speed ramp profile and rotation to $\alpha = 8$ deg., and hold. V = 80 kts. Compare C_L, C_M and C_D to data from 1.1.

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

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

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

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

2. Surface Roughness Tests

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

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

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

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

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

ATTACHMENT II – Procedure: Ice Phobic Testing

Background

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

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

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

Objective

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

Methodology

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

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

- For each specific coating, conduct a fluid test simulating ice pellets and/or freezing rain, for an exposure time derived from the HOT table or allowance time table;
- Record lift data, visual observations, and manually collected data;
- Compare the aerodynamic performance to the baseline un-coated wing skin tests as well as to other coatings; and
- In some cases, 2 different wing skin halves may be installed to provide a visual comparison of the fluid flow-off results. In such cases, the aerodynamic data collected should be dismissed.

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

Test Plan

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

ATTACHMENT III – Procedure: Stall Warning Sensor

Background

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

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

Objective

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

Methodology

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

Test Plan

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

ATTACHMENT IV – Procedure: ROGIDS

Background

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

Objective

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

Methodology

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

Test Plan

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

ATTACHMENT V – Generic Type I Holdover Time Table

TABLE 1-A

SAE TYPE I FLUID HOLDOVER GUIDELINES ON ALUMINUM WING SURFACES FOR WINTER 2012-2013[1]

This table applies to aircraft with critical surfaces constructed predominantly or entirely of aluminum materials that have demonstrated satisfactory use of these holdover times.

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

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

NOTES

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

CAUTIONS

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

ATTACHMENT VI – Generic Type III Holdover Time Table

Transport Canada Holdover Time Guidelines — Winter 2012-2013

TABLE 3

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013

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

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

NOTES

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

CAUTIONS

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

Page 24 of 57 July 2012

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

Transport Canada Holdover Time Guidelines **Winter 2012-2013**

TABLE 4-D-E106

DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013[1]
UCAR™ ENDURANCE EG106

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

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

NOTES

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

CAUTIONS

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

Page 32 of 57 July 2012

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

Transport Canada Holdover Time Guidelines **Winter 2012-2013**

TABLE 4-K-ABC-S+

KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013[1]
ABC-S PLUS

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

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

NOTES

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

CAUTIONS

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

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

Transport Canada Holdover Time Guidelines **Winter 2012-2013**

TABLE 4-C-LAUNCH

CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2012-2013[1]
SAFEWING MP IV LAUNCH

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

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

NOTES

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

CAUTIONS

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

Page 29 of 57 July 2012

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

TABLE 4-CR-PG-A

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

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

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

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

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

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

TABLE 4-A-Ecowing AD-49

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

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

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

NOTES

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

CAUTIONS

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

ATTACHMENT XII– Ice Pellet Allowance Time Table

Transport Canada Holdover Time Guidelines Winter 2012-2013

TABLE 11

ICE PELLET ALLOWANCE TIMES FOR WINTER 2012-2013

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

	OAT -5°C and above	OAT less than -5°C to -10°C	OAT less than -10°C
Light Ice Pellets	50 minutes	30 minutes	30 minutes[1]
Moderate Ice Pellets	25 minutes[2]	10 minutes	10 minutes[1]
Light Ice Pellets Mixed with Light or Moderate Freezing Drizzle	25 minutes	10 minutes	**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[3]		
Light Ice Pellets Mixed with Moderate Rain	25 minutes[4]		
Light Ice Pellets Mixed with Light Snow	25 minutes	15 minutes	
Light Ice Pellets Mixed with Moderate Snow	10 minutes		

NOTES

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

ATTACHMENT XIII – Task List for Setup and Actual Tests

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

ATTACHMENT XIV – General Form/ Calibration

GENERAL FORM (EVERY CALIBRATION TEST)

DATE: ______________________ RUN # (Plan #): ____________

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

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

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

WIND TUNNEL START TIME: __________ ROTATION ANGLE: __________

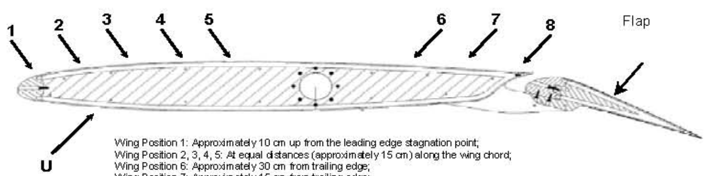
WIND TUNNEL END TIME: __________ PROJECTED SPEED (S/KTS): __________

FLAP SETTING (20°, 0°): __________

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

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

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

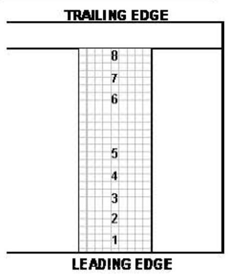


Wing Position 1: Approximately 10 cm up from the leading edge stagnation point;
Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) along the wing chord;
Wing Position 6: Approximately 30 cm from trailing edge;
Wing Position 7: Approximately 15 cm from trailing edge;
Wing Position 8: Approximately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

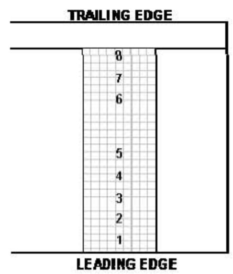
☐ Small Endplates

☐ Large Endplates

Before the Takeoff Run



After the Takeoff Run



COMMENTS : ______________________

HANDWRITTEN BY: ______________________

☐ Check if further details are available behind this sheet

ATTACHMENT XV – General Form

Form 1

GENERAL FORM (EVERY TEST)

DATE: ______________________ FLUID APPLIED: ______________________ RUN # (Plan #): __________

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

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

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

ROTATION ANGLE: __________ EXTRA RUN INFO: ______________________

FLAP SETTING (20°, 0°): __________ ______________________

☐ Check if additional notes provided on a separate sheet

FLUID APPLICATION

Actual start time: ______________________ Actual End Time: ______________________

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

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

ICE PELLETS APPLICATION (if applicable)

Actual start time: ______________________ Actual End Time: ______________________

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

Exposure Time: ______________________

Total IP Required per Dispenser: ______________________

FREEZING RAIN/DRIZZLE APPLICATION (if applicable)

Actual start time: ______________________ Actual End Time: ______________________

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

Exposure Time: ______________________ Needle: ______________________

Flow: ______________________

Pressure ______________________

SNOW APPLICATION (if applicable)

Actual start time: ______________________ Actual End Time: ______________________

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

Exposure Time: ______________________ Method: ☐ Dispenser ☐ Sieve

Total SN Required per Dispenser: ______________________

COMMENTS ____

____

____

MEASUREMENTS BY: ______________________ HANDWRITTEN BY: ______________________

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

Date: ____________________ Run: ______________

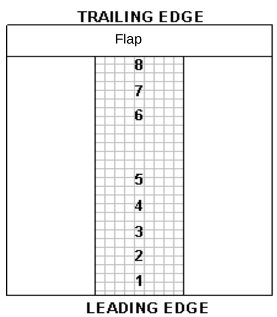
WING TEMPERATURE (Taken From NRC Logger)				
Wing Position	Before Fluid Application	After fluid Application	After Precip Application	After Takeoff Run
T2				
T5				
TU				
Time:				

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

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

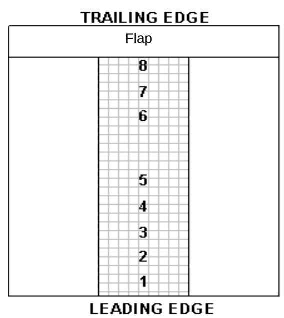
Fluid Film <1 After Takeoff Run: ☐ YES ☐ NO

Wing and Plate Condition
After the Takeoff Run
Time: ___________

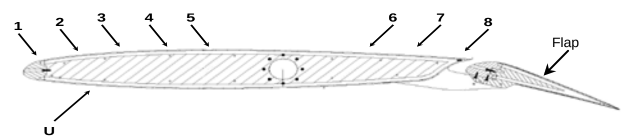


Comments:______________________
____
____
____
____

Wing and Plate Condition
Before the Takeoff Run
Time: ___________



Comments:______________________
____
____
____
____



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

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

Wing Position 6: Approximately 30 cm from trailing edge;

Wing Position 7: Approximately 15 cm from trailing edge;

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

Wing Position 9: Midway up the flap

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

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

General Comments: ______________________
____
____
____

OBSERVER: ______________________

ASSISTED BY: ______________________

ATTACHMENT XVII – Example Ice Pellet Dispensing Form

WING TRAILING EDGE

← 8 ft = 24.4 dm →

6 ft = 18.3 dm

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

WING LEADING EDGE

Precipitation Type	IP

Date	

Run #	

Field to be manipulated

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

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

IP needed per 5min

In each position	81	g
In each Dispensor	323	g

IP needed for entire test

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

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

NOTE:

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

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

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

ATTACHMENT XVIII – Example Snow Dispensing Form

WING TRAILING EDGE

8 ft = 24.4 dm

6 ft = 18.3 dm

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

WING LEADING EDGE

Precipitation Type	Snow		Date			Run #	

** Field to be manipulated*

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

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

Snow needed per 5 minutes

In each position	84	g
In each Dispensor	336	g

Snow needed for entire test

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

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

NOTE:

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

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

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

ATTACHMENT XIX – Example Snow Dispensing Form

Precipitation Type	Sifted Snow

Date	

Run #	

* *Field to be manipulated*

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

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

Snow needed per 5 minutes

In each position	66
In each Dispensor	265

Snow needed for entire test

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

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

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

NOTE:

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

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

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

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

ATTACHMENT XX – Visual Evaluation Rating Form

VISUAL EVALUATION RATING OF CONDITION OF WING

Date: ____________________ Run Number: _______

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

Before Take-off Run

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

At Rotation

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

Expected Lift Loss (%)

After Take-off Run

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

Additional Observations:
____
____
____

OBSERVER: ______________________

ATTACHMENT XXI – Fluid Receipt Form

(Consider using electronic auto-fill format)

SECTION A - SITE

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

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

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

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

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

Note any additional information included on fluid containers:

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

SECTION B - OFFICE

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

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

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

FFP Curves Received:[2] ☐

[1] Type II/III/IV fluids only

[2] Type I fluids only

ATTACHMENT XXII – Log of Fluid Sample Bottles

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

ATTACHMENT XXIII – Procedure: Fluid and Contamination at LOUT

Background

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

Objective

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

Methodology

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

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

Background

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

Objective

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

Methodology

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

- For a chosen fluid, conduct a test simulating moderate snow conditions (rate of 25 g/dm²/h) for an exposure time derived from the HOT table based on the tunnel temperature at the time of the test;
- Record lift data, visual observations, and manually collected data;
- Conduct two comparative tests simulating heavy snow conditions (rate of 50 g/dm²/h or higher) for the same exposure time used during the moderate snow test;
    - NOTE: previous testing has indicated that using half, to ¾ of the moderate snow HOT generates similar end conditions, whereas using the full moderate HOT for heavy snow conditions generates a more sever fluid failure which behaves worse aerodynamically;
- Record lift data, visual observations, and manually collected data;
- Compare the heavy snow results to the moderate snow results. If the heavy snow results are worse, repeat the heavy snow test with a

reduced exposure time, if the results are better, repeat the heavy snow test with an increased exposure time;

- Repeat until similar lift data, and visual observations are achieved for both heavy snow and moderate snow; and
- Document the percentage of the moderate snow HOT that is acceptable for heavy snow conditions.

Test Plan

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

ATTACHMENT XXV – Procedure: Heavy Contamination

Background

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

Objective

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

Methodology

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

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

Test Plan

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

ATTACHMENT XXVI – Procedure: Small Hail

Background

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

Objective

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

Methodology

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

- For a chosen fluid, conduct a test simulating small hail for an exposure time derived from the current ice pellet allowance time table as a starting point;
- Record lift data, visual observations, and manually collected data;
- Conduct a fluid only baseline test at the same temperature; 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 XXVII – Procedure: Frost Simulation in the Wind Tunnel

Background

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

Objective

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

Methodology

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

Test Plan

One or two tests is anticipated.

ATTACHMENT XXVIII – Procedure: Wind Tunnel Test Section Cooling

Background

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

Objective

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

Methodology

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

Test Plan

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

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

Background

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

Objective

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

Methodology

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

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

Test Plan

Two to four comparative tests are anticipated.

ATTACHMENT XXX – Procedure: Mixed HOT Conditions

Background

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

Objective

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

Methodology

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

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

Test Plan

Two to four comparative tests are anticipated.

ATTACHMENT XXXI – Procedure: Spot Deicing During CSW Frost Conditions

Background

The fundamental difference between both types of frost is how the wing skin temperature is cooled below ambient: radiation cooling versus conduction cooling. During natural active frost, the wing skin temperature will be cooled below ambient temperature as a result of radiation cooling from the cold clear sky. During cold soak wing conditions, however, the wing skin temperature is cooled and maintained at a temperature below ambient as a result of conduction cooling from the cold fluid stored inside the wing; either the aircraft was refueled with cold fuel, or following a flight, the wing and fluid will be cold soaked. One test was conducted in 2011-12 to investigate the aerodynamic effects of CSW frost on a deiced airfoil protected with Type I fluid. It was recommended that testing be repeated with thickened Type IV fluid.

Objective

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

Methodology

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

Test Plan

One to two tests are anticipated.

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

Background

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

Objective

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

Methodology

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

- Ensure the wing section and tunnel temperature are well below freezing (-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 XXXIII – Procedure: Feasibility of Ice Pellet Testing at Higher Speeds

Background

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

Objective

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

Methodology

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

Test Plan

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

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

Background

Holdover time determination systems have been developed to provide greater accuracy for determining rate of precipitation and allowing for a better use of the holdover time tables. Some recent discussion has been raised about HOT's for light and very light snow with respect to the fluid condition at the end of the several hour holdover time and potential concerns with fluid dripping off and thinning out. It was recommended that some preliminary testing be conducted in the wind tunnel to see how the fluid fails on an airfoil and to investigate the resulting aerodynamic effects. Limited testing was conducted during the winter of 2011-12 and it was recommended that testing continue for 2012-13.

Objective

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

Methodology

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

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

Test Plan

One to four comparative tests are anticipated for comparison to a baseline condition. Previous 2011-12 work should be referenced when developing test plan.

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

Background

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

Objective

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

Methodology

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

Test Plan

No testing is planned unless indicated otherwise by TC.

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

Background

Preliminary observations have indicated that fluid seepage from the airfoil can lead to lift losses and other aerodynamic impacts. This is especially of concern after a long series of 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 XXXVII – Procedure: 2nd Wave of Fluid during Rotation

Background

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

Objective

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

Methodology

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

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

Another possible test methodology may include:

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

Test Plan

One to four tests are anticipated.

This page intentionally left blank.

APPENDIX F

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

PRESENTATION: WIND TUNNEL TESTING WINTER 2012-13

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING WINTER 2012-13

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

WIND TUNNEL TESTING
WINTER 2012-13

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

WIND TUNNEL TESTING
WINTER 2012-13

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

WIND TUNNEL TESTING
WINTER 2012-13

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

APPENDIX G

AEROSPACE INFORMATION REPORT

SAE Aerospace An SAE International Group	AEROSPACE INFORMATION REPORT	AIR 6232	Final Version 1.3
		Issued: July 8, 2013 Revised: N/A	

AIRCRAFT SURFACE COATING INTERACTION WITH
AIRCRAFT DEICING/ANTI-ICING FLUIDS

RATIONALE

This SAE Aerospace Information Report (AIR) provides a description of screening methods for verifying whether aircraft surface coatings have adverse effects on aircraft deicing/anti-icing fluid performance as published in the holdover time guidelines. The surface coatings include thin film coatings, typically less than 1 mil (0.0254 millimeters) thick and sometimes called paint sealants or protectants, as well as bulk coatings that are typically greater than 2 mils (0.0508 millimeters) thick. Although recommended performance criteria have been outlined, ultimately, the interpretation of the test results outlined in this document will be left to the discretion of the aircraft operator.

FOREWORD

Aircraft operators rely on the use of SAE AMS 1424 and/or SAE AMS 1428 deicing/anti-icing fluids during winter operations to provide a limited period of protection against frozen or freezing precipitation while the aircraft is on the ground. Methods of protection of aircraft surfaces with these fluids are described in ARP 4737. The protection time can be estimated using fluid-specific holdover time guidelines that are published by the Federal Aviation Administration (FAA) and Transport Canada (TC). Holdover time values for deicing/anti-icing fluids are derived from standard endurance time testing procedures that are described in SAE ARP 5945 and SAE ARP 5485. The aerodynamic performance of deicing/anti-icing fluids is evaluated according to the procedure described in SAE AS 5900.

Recently, aircraft operators have expressed interest in the use of after-market coatings on aircraft surfaces for various purposes, including appearance enhancement, fuel savings, and ice shedding. The coatings may be designed to have hydrophilic or hydrophobic properties, and therefore, the interaction of these coatings with SAE AMS 1424 and/or SAE AMS 1428 deicing/anti-icing fluids and their associated holdover times is unclear. Since aircraft coatings may affect fluid wetting capability and resulting fluid thickness, they could affect a fluid’s holdover time protection. Therefore, the interaction of aircraft surface coatings and aircraft deicing/anti-icing fluids should be -evaluated with respect to holdover time performance and aerodynamic performance. In addition, test methods are available to help characterize the various aircraft surface coating properties, including durability, hardness, weathering, effect on aerodynamic drag, ice adhesion, ice accumulation, contact angle, and thermal conductivity. This AIR 6232 provides test methods which can serve as screening indicators for compatibility and additional test methods which can be used to characterize the different coatings.

1. SCOPE

This SAE Aerospace Information Report (AIR) provides descriptions of test methods for determining if an aircraft surface coating of any thickness has adverse effects on aircraft deicing/anti-icing fluids with respect to fluid holdover time performance and aerodynamic performance.

Although not the primary mandate of the G-12 Aircraft Ground Deicing Committee, this document also provides descriptions of suggested test methods for evaluating aircraft surface coatings with respect to durability, hardness, weathering, aerodynamic drag, ice adhesion, ice accumulation, contact angle, and thermal conductivity. These additional tests can provide informational data for characterizing the coatings and may be useful to operators when evaluating the coatings.

1.1 Purpose

To provide a reference method for evaluating the interaction of aircraft surface coatings with respect to aircraft deicing/anti-icing fluid holdover time performance and aerodynamic performance.

To provide additional informational test methods that can be used for characterizing the aircraft surface coatings.

1.2 Definitions and Abbreviations

- ADVANCING CONTACT ANGLE: The advancing angle is the largest possible contact angle attained by the drop during volume addition before the motion of the contact line. Similarly, it is the maximum angle attained by the advancing front on an inclined surface before the motion of the contact line.
- AERODYNAMIC ACCEPTANCE TEST: A performance test required under §3.2.5 of AMS 1428 and defined in AS 5900.
- AIRCRAFT SURFACE COATING: A coating applied to an aircraft surface with properties that may be icephobic, hydrophobic, super-hydrophobic, or hydrophilic. This term as used in the document is not intended to refer to surface finishes that have been qualified by the original equipment manufacturer
- BOUNDARY LAYER DISPLACEMENT THICKNESS (BLDT): The measured displacement of the air flow over a surface. The increase in BLDT over the flat plate surface caused by the fluid flow-off during the AS 5900 aerodynamic acceptance is directly related to loss of lift during takeoff.
- BUFFER: The difference between OAT and the freezing point of the fluids used.
- CASSIE STATE: When the liquid of a drop does not fill the voids in the solid on which it sits and the voids remain filled with air, resulting in a hydrophobic condition, the opposite of Wenzel State.
- CONTACT ANGLE: The angle, conventionally measured relative to the liquid-air and liquid-sold interfaces, quantifying the wettability of a solid surface by a liquid.
- CONTACT ANGLE HYSTERESIS: The difference between the advancing and receding contact angles.
- ENDURANCE TIME: Time that a fluid can endure defined and controlled temperature and precipitation conditions before visual failure. Endurance time tests are defined in ARP 5485 and ARP 5945.
- FAA: United States Department of Transportation, Federal Aviation Administration.
- HOLDOVER TIME (HOT): Starting from the time of initial application of an anti-icing fluid, the time that the fluid is expected to provide protection of an aircraft against freezing or frozen precipitation.
- HOLDOVER TIME GUIDELINE: A table giving the holdover time for various precipitation conditions and temperatures, with cautions and notes, giving guidance to ground

deicing/anti-icing crews and pilots. The “holdover time guideline” is also often referred to as the “holdover time table”.

- HYDROPHILIC SURFACE: A surface producing a contact angle of θ < 90°.
- HYDROPHOBIC SURFACE: A surface producing a contact angle of θ > 90°.
- ICEPHOBIC SURFACE: A surface producing a reduction in ice adhesion.
- LOWEST ON-WING VISCOSITY (LOWV): Lowest viscosity of a fluid for which the applicable holdover time table can be used.
- LOWEST OPERATIONAL USE TEMPERATURE (LOUT): The lowest temperature at which a Type I/II/III/IV fluid can be used on an aircraft, generally recognized as the higher of:
    a. the lowest temperature at which it meets the aerodynamics acceptance test (AS 5900) for a given type of aircraft; or
    b. the freezing point of the fluid plus the freezing point buffer of 7 °C for Type II/III/IV fluids, or 10 °C for Type I fluids.
- MAXIMUM ON-WING VISCOSITY (MOWV): Maximum viscosity of a fluid which is still aerodynamically acceptable.
- OAT: Outside Air Temperature.
- RECEDING CONTACT ANGLE: The receding angle is smallest possible angle which can be measured when liquid is removed from the drop. Similarly, it is the minimum angle attained by the receding front on an inclined surface before the motion of the contact line.
- ROLL-OFF ANGLE; The tilt angle of a surface relative to horizontal at which the water drop starts to slide on the surface and varies between 0 and 90 degrees. Also called sliding angle.
- SLIDING ANGLE: The tilt angle at which the water drop starts to slide on the surface and varies between 0 and 90 degrees. Also called roll-off angle.
- STANDARD ALUMINUM TEST PLATE: Aluminum test plate surface used for endurance time testing of Type I and Type II/III/IV fluids in accordance with ARP 5945 and ARP 5485.
- SUPER-HYDROPHOBIC SURFACE: A surface producing a static contact angle of θ > 150° and a roll-off angle of less than 10º.
- TREATED SURFACE: A surface that has been treated with an aircraft surface coating of any thickness.
- UNTREATED SURFACE: A surface in its original condition from the airplane manufacturer, or a surface that has been painted with a coating qualified by the manufacturer for use on that surface, that has not been treated with an aircraft surface coating.
- WENZEL STATE: When the liquid of a drop fills the voids in the solid on which it sits, the opposite of Cassie State.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AIR 6130-2011 Cadmium Plate Cyclic Corrosion Test

AMS 1424 Deicing/Anti-icing Fluid, Aircraft, SAE Type I

AMS 1428 Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV

AMS 1650 Polish, Aircraft Metal

AMS 3095 Paint, Gloss, Airline Exterior System

AMS-C-83231A Coatings, Polyurethane, Rain Erosion Resistant for Exterior Aircraft and Missile Plastic Parts

ARP 4737 Aircraft Deicing/Anti-Icing Methods

ARP 5485 Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Type II, III, and IV

ARP 5945 Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Type I

AS 5900 Standard Test Method for Aerodynamic Acceptance for SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids

2.2 FAA Publications

Available from the Federal Aviation Administration at http://www.faa.gov/.

- Official FAA Holdover Time Tables Winter 20XX-20XX. (New document published for each winter. Always use the latest issue; search for “FAA Holdover Time”.)
- FAA-Approved Deicing Program Updates, Winter 20XX-20XX. (New document published for each winter. Always use the latest issue; search for “FAA-Approved Deicing Program”.)

2.3 Transport Canada Publications

Available from Transport Canada, Civil Aviation Directorate, Standards Branch, 330 Sparks Street, Ottawa, Ontario, K1A 0N5, Canada and at http://www.tc.gc.ca/eng/civilaviation/standards/commerce-holdovertime-menu-1877.htm.

- Transport Canada Holdover Time Guidelines Winter 20XX-20XX. (New document published for each winter. Always use the latest issue).
- Guidelines for Aircraft Ground Icing Operations. TP14052E, April 2005.
- Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Testing Program for the 2001-02 Winter. TP13991E, December 2002.

2.4 Other Publications

Goldhammer, Mark I., and Plendl, Bruce R., “Surface Coatings and Drag Reduction,” *AERO* magazine, The Boeing Company, edition Q1, 2013.

AIMS 09-00-002	Evaluation of Maintenance Materials, Airbus
AIP 94, 133109-1	Nonwetting of Impinging Droplets on Textured Surfaces
AIP 97, 234102	Frost Formation and Ice Adhesion on Superhydrophobic Surfaces
APS 106, 036102	Rapid Deceleration-Driven Wetting Transition during Pendant Drop Deposition on Superhydrophobic Surfaces
ASTM C518 – 10	Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
ASTM D5930-01	Standard Test Method for Thermal Conductivity of Plastics by Means of a Transient Line-Source Technique
ASTM E1225-04	Standard Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique
ASTM F483	Standard Practice for Total Immersion Corrosion Test for Aircraft Maintenance Chemicals
ASTM F484	Standard Test Method for Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds
ASTM F502	Standard Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces
ASTM F519-93	Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments
ASTM F1110	Standard Test Method for Sandwich Corrosion Test
D6-17487	Evaluation of Airplane Maintenance Materials, Boeing
ISO 8301	Thermal insulation -- Determination of steady-state thermal resistance and related properties -- Heat flow meter apparatus"
ISO 11507	Paints and varnishes -- Exposure of coatings to artificial weathering -- Exposure to fluorescent UV lamps and water
ISO 22007-2:2008	Plastics -- Determination of thermal conductivity and thermal diffusivity -- Part 2: Transient plane heat source (hot disc) method"
ISO 22007-3:2008	Plastics -- Determination of thermal conductivity and thermal diffusivity -- Part 3: Temperature wave analysis method"
ISO 22007-4:2008	Plastics -- Determination of thermal conductivity and thermal diffusivity -- Part 4: Laser flash method

3. COMPARATIVE FLUID ENDURANCE TIME TESTS

Tests should be conducted with SAE AMS 1424 Type I fluids and SAE AMS 1428 Type II/III/IV fluids to compare the endurance times of fluids applied to aluminum test plate surfaces treated with the aircraft surface coating to the endurance times of the same fluids applied to an untreated standard aluminum test plate (and as an optional test, a freshly painted aluminum test plate which serves as reference tool). If the coating being tested will typically be applied to painted surfaces, consideration should be given to conducting testing using painted, untreated and treated test plates.

Comparative endurance time testing should be conducted according to the procedures described in ARP 5945 and ARP 5485.

3.1 Fluid Selection

The aircraft operator or coating manufacturer should determine the fluid brands to be tested. The following are recommended criteria for selecting the fluids for the comparative endurance time testing:

- Minimum of two SAE AMS 1424 Type I fluids. Consideration should be given to testing both an ethylene-glycol and a propylene-glycol fluid diluted to a 10ºC freezing point buffer, and possibly also the standard mix. A non-glycol formulation may also be considered depending on the expected operations.

- Minimum of two SAE AMS 1428 Type II/III/IV fluids. Consideration should be given to testing both an ethylene-glycol and a propylene-glycol fluid at 100/0 fluid/water dilution (also referred to as undiluted or “neat”), and possibly also at 75/25 and 50/50 dilutions. A non-glycol formulation may also be considered depending on the expected operations. Fluid viscosity should be within the production range specified by the fluid manufacturer that meets on-wing viscosity limits.

3.2 Test Surfaces

The following is a description of the test surfaces that should used for the comparative endurance time testing:

- Standard Aluminum Test Plate (Baseline Surface)
    - Material Aluminum alloy AMS 4037 or 4041
    - Test plate dimensions 500 mm long x 300 mm wide x 3.2 mm thick
    - Angle 10.0° ± 0.2°
    - Average surface roughness: Ra ≤ 0.5 μm

- Treated Test Plate
    - Same material and construction as the “Standard Aluminum Test Plate” described above, however, treated using aircraft surface coating according to coating manufacturer specifications.

- Painted Test Plate (Optional)
    - Same material and construction as the “Standard Aluminum Test Plate” described above, however, painted using representative aircraft grade primer and paint according to AMS 3095 specifications.

Note: In the case of outdoor natural snow testing with Type I fluid, the test surface is considered as the upper plate surface of the empty aluminum box described in ARP 5945.

3.3 Precipitation Conditions for Holdover Time Evaluation

Comparative endurance time testing will evaluate the fluid performance on a treated test plate versus a standard aluminum test plate, and in some cases versus a painted test plate. Testing in each of the holdover time precipitation conditions described in ARP 5945 and ARP 5485 with each of the selected fluids is not practical in most cases. For that reason, Table 1 provides a suggested minimum set of precipitation conditions for comparative testing. All possible testing conditions have been included in Table 1 for planning purposes, with a minimum suggested set of precipitation conditions for comparative testing indicated by “X”. When selecting conditions, the objective is to try to obtain a broad range of temperatures and precipitation rates.

Natural snow tests have been specified with ranges of air temperature and icing intensity; as testing is conducted outdoors, conditions may vary depending on weather. In the event that natural snow testing is not possible, consideration can be given to conducting artificial snow testing.

A recommended set of frost tests has been included in Table 1 which may be modified in future revisions of this document to reflect new frost testing procedures being developed for inclusion in ARP 5945 and ARP 5485.

TABLE 1 – Matrix of Suggested HOT Testing Conditions for Comparative Testing

Precipitation Type	Precipitation ID.	Air temperature, °C	Icing intensity, g/dm²/h	Type I Fluid A	Type I Fluid B	Type II/III/IV Fluid C	Type II/III/IV Fluid D
Frost	FROST - A	>-3	<0.3	X*		X*	
	FROST - B	-3 to -14	<0.3	X	X	X	X
	FROST - C	-14 to -25	<0.3	X		X	
Freezing Fog	FOG-A	-3 ± 0.5	2.0 ± 0.2				
	FOG-B	-3 ± 0.5	5.0 ± 0.2	X*		X*	
	FOG-S	-6 ± 0.5	2.0 ± 0.2				
	FOG-T	-6 ± 0.5	5.0 ± 0.2				
	FOG-C	-14 ± 0.5	2.0 ± 0.2				
	FOG-D	-14 ± 0.5	5.0 ± 0.2				
	FOG-E	-25 ± 1	2.0 ± 0.2	X		X	
	FOG-F	-25 ± 1	5.0 ± 0.2				
Freezing Drizzle	ZL-A	-3 ± 0.5	5 ± 0.2				
	ZL-B	-3 ± 0.5	13 ± 0.5	X		X*	X
	ZL-S	-6 ± 0.5	5 ± 0.2				
	ZL-T	-6 ± 0.5	13 ± 0.5				
	ZL-C	-10 ± 0.5	5 ± 0.2		X*	X*	
	ZL-D	-10 ± 0.5	13 ± 0.5			X	X
Light Freezing Rain	LZR-A	-3 ± 0.5	13 ± 0.5	X*	X	X*	
	LZR-B	-3 ± 0.5	25 ± 1.0			X	X
	LZR-S	-6 ± 0.5	13 ± 0.5				
	LZR-T	-6 ± 0.5	25 ± 1.0				
	LZR-C	-10 ± 0.5	13 ± 0.5				
	LZR-D	-10 ± 0.5	25 ± 1.0	X		X	X*
Rain on Cold Soaked Wing	RCSW-A	1 ± 0.5	5.0 ± 0.4				
	RCSW-B	1 ± 0.5	75.0 ± 3.0				
Natural Snow	SNW-K	>-3	2 to 10				
	SNW-L	>-3	10 to 25	X	X	X	X
	SNW-M	-3 to -6	2 to 10	X*	X	X*	X
	SNW-N	-3 to -6	10 to 25				
	SNW-O	-6 to -10	2 to 10	X		X	
	SNW-P	-6 to -10	10 to 25	X	X	X	X
	SNW-Q	-10 to -14	2 to 10				
	SNW-R	-10 to -14	10 to 25				
	SNW-S	-14 to -25	2 to 10				
	SNW-T	-14 to -25	10 to 25				

X = Comparative Fluid Endurance Time Test on: 1. Standard Aluminum Test Plate and 2. Treated Test Plate
X* = Comparative Fluid Endurance Time Test on: 1. Standard Aluminum Test Plate, 2. Treated Test Plate, and 3. Painted Test Plate

3.4 Fluid Thickness and Fluid Wetting Tests

Comparative testing should be conducted using the same protocol used to characterize the fluid thickness decay profile of fluids submitted for endurance time testing. The procedure is entitled, “Experimental Program to Establish Film Thickness Profiles for De-Icing and Anti-Icing Fluids on Flat Plates”, and can be found in Transport Canada Report TP 13991E, Appendix I. The procedure specifies that fluid thickness measurements be made at the 15 cm line of a 10º inclined test plate at 2, 5, 15, and 30 minutes following fluid application. In the case of Type I fluids, fluid wetting should be evaluated rather than fluid thickness. These tests should not be conducted under precipitation. Table 2 suggests a minimum set of tests for comparative fluid thickness and wetting. Consideration should be given to expanding this matrix to include other dilutions if used by the aircraft operator.

TABLE 2 – Selected Fluid Thickness and Wetting Testing Conditions for Comparative Testing

Test ID	Fluid	Fluid Dilution	Air Temperature, °C	Test Plates
TH1	Type I B	10° Buffer	-3°C	Standard and Treated
TH2	Type I A	10° Buffer	-3°C	Standard, Treated, and Painted
TH3	Type I A	Standard Mix (50/50)	-3°C	Standard and Treated
TH4	Type II/III/IV C	100/0	-3°C	Standard and Treated
TH5	Type II/III/IV D	100/0	-3°C	Standard and Treated

3.5 Interpretation of Test Results

The comparative endurance time tests will provide a good indication of fluid endurance time performance when applied to aircraft surfaces treated with coatings. The interpretation of the test results, and ultimately the decision to use the coating on aircraft, is the responsibility of the aircraft operator.

3.6 Testing Organization

As of the date of publication of the AIR, the following organization is known to provide testing for anti-icing fluids. This is not an endorsement by SAE for this organization but simply to facilitate the location of laboratories for those seeking testing. Please enquire directly with the organization for a full list of testing available.

APS Aviation Inc., 6700, chemin de la Côte-de-Liesse, Suite 105, Saint-Laurent, Quebec, H4T 2B5, Canada; 514-878-4388, www.adga.ca/aps.

4. COMPARATIVE FLUID AERODYNAMIC TESTS

Aircraft surface coatings may influence the fluid flow-off behavior. These coatings may result in flow-off improvement, or they may cause adverse effects on aerodynamic performance. For this reason, it is suggested that testing be conducted to evaluate the impact of aircraft surface coatings on fluid flow-off characteristics. Tests should be conducted with SAE AMS 1424 Type I fluids and SAE AMS 1428 Type II/III/IV fluids. The purpose is to compare the aerodynamic test results of a fluid applied on top of an aircraft surface coating to those of the same fluid without the coating. The basis of the comparative test methodology should be the fluid aerodynamic acceptance test AS 5900.

4.1 Fluid Selection

The fluid selection should be in accordance with Section 3.1.

4.2 Test Surfaces

The following is a description of the test surfaces that should be used for the comparative aerodynamic testing:

- Standard Test Duct Floor (Baseline Surface)
  - Plexiglas
  - Test duct floor dimensions 1600 mm long x 302 mm wide
  - Horizontal
  - Surface shall be hydraulically smooth, resulting in a dry boundary layer displacement thickness (BLDT) ≤ 3.0 mm at duct end at 65 m/s ± 5 m/s, or a dry BLDT ≤ 3.3 mm at duct end at 35 m/s ± 3 m/s.

- Aluminum Test Plate
  - Material Aluminum alloy 2024-T3
  - Test plate dimensions 1600 mm long x 302 mm wide x 1.6 mm thick
  - Horizontal
  - Surface finish Average surface roughness: Ra ≤ 30 µm
  - Plate fixed over the standard test duct floor with double-sided tape 0.17mm thick

- Treated Test Plate
  - Same material and construction as the ‘‘Aluminum Test Plate’’ described above, however,
  - Treated using aircraft surface coating according to manufacturer specifications.

Note: If the coating being tested will typically be applied to painted surfaces, consideration should be given to conducting testing using painted untreated and treated test plates.

4.3 Test Conditions

Full testing of the fluids according to AS 5900 with both treated and untreated test duct floor/plates is not practical in most cases. At a minimum, it is recommended that comparative testing be conducted with each selected fluid in accordance with AS 5900, at one data point, run three times, using the neat fluid. The one data point shall represent the lowest temperature ±1 °C (2 °F) at which the fluids met the aerodynamic performance requirements with the standard test duct floor.

4.4 Interpretation of Test Results

The comparative fluid aerodynamic tests will provide a good indication of fluid aerodynamic performance when applied to aircraft surfaces treated with coatings. The interpretation of the test results, and ultimately the decision to use the coating or paint on aircraft, is the responsibility of the aircraft operator.

4.5 Testing Organization

As of the date of publication of the AIR, the following organization is known to provide testing for anti-icing fluids. This is not an endorsement by SAE for this organization but simply to facilitate the location of laboratories for those seeking testing. Please enquire directly with the organization for a full list of testing available.

Anti-icing Materials International Laboratory (AMIL), 555, boulevard de l'Université, Chicoutimi, Québec,
G7H 2B1, Canada; 418-545-2918. www.uqac.ca/amil.

5. ADDITIONAL INFORMATIONAL TEST METHODS

The following describe test methodologies that may be used to conduct testing to help characterize aircraft surface coatings. These tests are outside of the scope of the SAE G-12 Aircraft Ground Deicing Committee but are provided here for reference purposes. The interpretation of these tests results, and ultimately the decision to use the coating on aircraft, is the responsibility of the aircraft operator.

5.1 Aircraft Surface Coating Compatibility and Integrity Tests

Aircraft surface coatings should be tested for: compatibility with airplane surfaces; durability, hardness and weathering; exposure to deicing/anti-icing fluids; and compatibility with other fluids. Tests should be run on both treated and untreated surfaces. Treated surfaces should preferably show no additional degradation. Consideration should be given to conducting additional comparative endurance time testing and fluid aerodynamic acceptance testing with weathered treated surfaces if dramatic changes in coating properties are experienced following the compatibility and integrity tests.

5.1.1 Compatibility with Airplane Surfaces

Tests should include those conducted for evaluation of airplane maintenance waxes and polishes, as well as exterior cleaners (if a pre-clean step is required), per industrial standards, such as SAE AMS 1526, SAE AMS 1650, or per requirements of commercial aircraft manufacturers, such as Boeing D6-17487 and Airbus AIMS 09-00-002.

These tests can include, but might not be limited to: sandwich corrosion in accordance with ASTM F1110, acrylic and polycarbonate crazing in accordance with ASTM F484, paint softening in accordance with ASTM F502, hydrogen embrittlement in accordance with ASTM F519, and total immersion tests in accordance with ASTM F483.

These tests are intended to ensure that the surface coatings are not detrimental to airplane surfaces. They are not intended to judge performance.

5.1.2 Durability, Hardness, and Weathering

Tests should be conducted on treated and untreated, unpainted and painted panels, as applicable, in accordance with AMS 3095 for the following properties: gloss, initial color, adhesion, impact-reverse, flexibility, water, and fluid resistance. Note that the requirement for AMS 3095 properties, such as 60° gloss greater than 90 units and color, might not be applicable, but failures of other property requirements should be further investigated with careful interpretation.

Tests should be conducted on treated and untreated, unpainted and painted panels, as applicable, in accordance with AMS 3095 for artificial weathering, except that the exposure time should be adjusted to the anticipated treatment lifetime. The 1000-hour exposure specified in AMS 3095 is assumed to be a 5-year lifetime. Example: if the treatment is expected to last one year, then the exposure time should be 200 hours.

Tests should be conducted on treated and untreated, unpainted and painted, ice centrifuge adhesion test sample beams, as applicable, in accordance with Section 5.3.1 after artificial weathering (UV exposure) in accordance with AMS 3095, except that the exposure time should be adjusted to the anticipated treatment lifetime. The 1000-hour exposure specified in AMS 3095 is assumed to be a 5-year lifetime. Example: If the treatment is expected to last one year, then the exposure time should be 200 hours. Compare ice adhesion for the exposed beams to that for the unexposed beams.

For treatments applied to the leading edge of aircraft surfaces, the rain erosion test from SAE AMS-C-83231A "Coatings, Polyurethane, Rain Erosion Resistant for Exterior Aircraft and Missile Plastic Parts", section 4.9.15.2, should be considered as a relative evaluation of coating longevity.

5.1.3 Exposure to Deicing/Anti-Icing Fluids

The following tests should be conducted with AMS 1424 Type I fluid and AMS 1428 Type II/III/IV fluid on treated and untreated, unpainted and painted panels (see Section 3.1 for guidelines on fluid selection). The fluid, when heated to 149 °F ± 4 (65 °C ± 2) and applied to a surface having an initial surface temperature of 72 °F ± 2 (22 °C ± 1), shall not produce any streaking, discoloration, or blistering of the treated panel. For treated, painted panels, the fluid should not decrease paint film hardness by more than two pencil hardness numbers from either the untreated, unexposed panel value or the treated, unexposed panel value when determined in accordance with ASTM F 502.

5.1.4 Immersion Tests for Compatibility Screening

Airline operators and manufacturers need to understand any possible deleterious effects and interactions that might arise from the use of coatings on aircraft surfaces. Any such interactions can be caused by direct contact with the aircraft surface or possibly through complex interactions in combination with fluids commonly encountered during the service life of an aircraft.

Immersion tests can help as a screening tool in order to highlight potential incompatibilities on pristine surfaces. Such tests, however, are by no means a guarantee of in-service performance as they fail to account for in-service wear and tear from abrasion, variances in operator application techniques, and other such variables.

As a guide in evaluating product suitability, consideration should be given to:

- Surfaces affected (treated or untreated, aluminum or composite, etc.)
- Exposure to various fluids that may be encountered by the treated surface:
    - Hydraulic fluid (an applicable test is in AMS 3095)
    - Aircraft deicing/anti-icing fluids and runway deicing/anti-icing fluids (or solids if applicable); a relevant test is discussed in section 5.1.3
    - Detergents
    - Fuel
- Suitable exposure scenarios including potential photo, ultraviolet, ozonization, acid rain, or oxidation effects (some applicable tests can be found in ISO 11507)
- Pre- and post-immersion performance tests

A number of aircraft manufacturer and SAE materials specifications reference ASTM F483, which can be used as a basis for developing a total-immersion test for the above fluids. A cyclical immersion protocol is detailed in SAE AIR 6130-2011, which can be used as a basis for testing when a cyclical exposure scenario is required.

5.2 Aerodynamic Drag Evaluation Test

5.2.1 Background Information about Aircraft Drag

The total drag of an aircraft is often broken down into several components such as induced drag and profile drag. The manufacturers of some coatings have claimed that their products reduce aircraft drag. To verify or evaluate this claimed benefit, it is important to understand how aircraft drag reduction could be achieved by application of a surface coating. In most cases, it is anticipated that the mechanism by which a drag reduction would be achieved is by reducing the profile drag via a reduction of the skin friction drag.

5.2.2 Drag Evaluation Considerations

- Well-established fluid dynamics theory says that if a surface is rough, then the skin friction, and therefore the drag, will be higher than for a smooth surface. By making a rough surface smoother, the skin friction drag will be reduced. However, if a surface is already "hydrodynamically smooth", as aircraft surfaces should be, further smoothing will not yield any drag-reduction benefits for a turbulent boundary layer.

- Some coatings could cause a drag increase. For example, coatings intended to have hydrophobic properties via micro-textured surfaces have some inherent surface roughness that, if not hydrodynamically smooth, could adversely affect skin friction drag.

- The drag effects of a coating could be evaluated using 2D or 3D aircraft model wind tunnel testing. This approach could utilize a generic model to provide a general indication of the effect of a coating, or the effect on a specific aircraft model could be evaluated.

- Comparative testing could also be conducted using a flat-plate wind tunnel test, with the plate both treated and untreated under the same conditions. For this approach, comparative changes to fluid flow-off properties, such as ∆BLDT, could give an indication of the drag effects.

- Wind tunnel testing for drag evaluation introduces issues that should be considered, such as:
    - There will be Reynolds number differences between the real aircraft and the sub-scale model or flat-test plates, which affects the skin friction drag that the sub-scale model will experience. This affects the total drag and could affect the incremental effect of a coating.
    - Some of the claimed drag benefits due to coatings could potentially be realized due to restoring the integrity of a worn painted finish to that of a freshly painted surface. Overall, the combination of Reynolds number effects and this surface texture scaling will lead to difficulties in interpreting any measured drag benefits.
    - Wind tunnel flow and measurement devices may mask the ability to determine the effects of a coating.
    - Sub-scale wind tunnel testing results may not be representative of the full-scale effect, however if significant drag effects are indicated from wind tunnel testing, consideration should be given to evaluation on a real aircraft and/or consultation with the aircraft manufacturer.

- Testing a coating on a real aircraft will avoid many of the difficulties described above. However, accurate drag measurements via flight testing are challenging, and therefore small differences will likely not be measureable.

Additional information on surface coatings and drag reduction has also been published in The Boeing Company's *AERO* magazine referenced in Section 2.4.

5.3 Ice Adhesion Test

The following are two different test procedures for evaluating ice adhesion.

5.3.1 Centrifuge Ice Adhesion Test

The Centrifuge Adhesion Test consists of a two-step procedure. In the first step, the extremity of small aluminum sample beams, treated and untreated, accrete ice in either a cold room or an icing wind tunnel (testing may also be considered with painted treated and untreated sample beams). In the second step, the ice adhesion is measured by rotating the iced beams in a centrifuge at an accelerating rate until the ice detaches; the adhesion stress from the centrifugal force is calculated using detachment speed, the mass of the ice accreted on the extremity of the beam prior to the test, and the beam length. The Adhesion Reduction Factor can then be calculated using the adhesion stress measured on the treated beam compared to the untreated beam. Figure 1 demonstrates an example of the centrifuge ice adhesion test apparatus.

FIGURE 1

5.3.2 Zero-Degree Cone Test

The zero-degree cone test is used to measure the adhesive strength of ice to a substrate treated with a layer of icephobic material or other coating. The test apparatus consists of two concentric cones (referred to as a pile and mold) bonded together with ice. The cones are typically metallic (aluminum or stainless steel); however, cones can also be made from composites or other non-metallic materials. Figure 2 demonstrates an example of the zero-degree cone test apparatus.

Three piles are treated with a representative layer of an icephobic material or other coating. Each pile is then placed in a concentric mold and the mold is filled with ASTM Type II water. The mold is then placed in a -10 ± 2°C freezer for 48 ± 2 hours. The load required to push the pile through the ice is subsequently measured using a tensile tester equipped with an environmental chamber that maintains a -10 ± 2°C environment throughout the test. The nominal shear stress can be calculated by dividing the measured load by the surface area of the ice/pile interface. Consideration may be given to conducting this test at other freezing temperatures, i.e., -20ºC or colder.

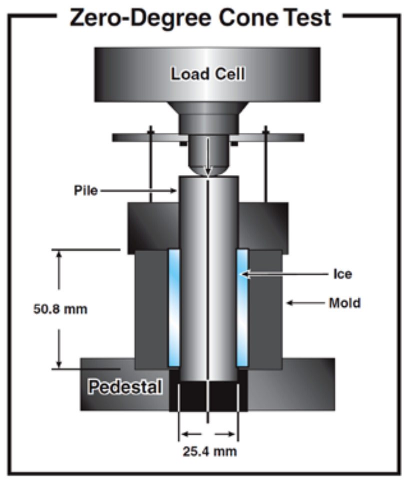


FIGURE 2

5.4 Ice Accumulation

The following are two different test procedures for evaluating ice accumulation.

5.4.1 Static Ice Accumulation

This test determines the reduction in the mass accumulation of ice when icephobic treated samples, positioned horizontally and at 45° and 80° from the horizontal, are exposed to freezing precipitation. The mass of ice accumulated on the icephobic samples are compared to that of bare samples at the same angles. This test can be run at different temperatures and under different precipitation types.

5.4.2 In-Flight Ice Accretion

Comparative testing should be performed in an icing wind tunnel with a treated and untreated model under the same conditions. The location, shape, thickness, surface quality, and any other noted characteristics of the accreted ice should be well documented (good-quality photographs are recommended) for comparing the treated and untreated results. Consideration may also be given to testing models with a heated leading edge, as well as a painted treated and untreated model.

Tests with generic models may provide a general indication of a coating's potential to provide icephobic results (reduced ice accretion). However, generic-model test results should not be assumed to be directly applicable to specific aircraft (e.g., model geometry, configuration details, etc.). Note that this type of testing provides comparative results between treated and untreated ice accretion. Flight test results may vary from icing tunnel test results due to several variables, such as differences in the actual icing conditions, flight conditions, scale and modeling effects, etc..

The ice accretions generated could then be evaluated for aerodynamic effects in an aerodynamic wind tunnel or in flight.

5.5 Contact Angle (CA), Contact Angle Hysteresis (CAH), and Roll-Off Angle (ROA)

Measure the contact angle (CA) of water on the surface using small drop volumes, smaller than ~10μL (to avoid distortion due to gravity). If the CA > 90°, the surface can be considered hydrophobic;

and when CA < 90, the surface can be considered hydrophilic. Note that hydrophobicity or super-hydrophobicity *does not* imply icephobicity as described below.

Measure the advancing contact angle (ACA) and receding contact angle (RCA) on the treated substrate. The ACA and RCA can be measured by the volume addition and removal methods, respectively. Another method involved uses a tilt stage. Tilting the surface and measuring the contact angles at the advancing and receding fronts before the drop slides, yields ACA and RCA. The difference between ACA and RCA is Contact Angle Hysteresis (CAH). A low RCA of water could indicate high adhesion strength of ice to the surface.

Measure roll-off angle (ROA) of a 10μL water droplet on the surface by using a tilt stage which varies between 0 and 90 degrees. An ROA~ 0 degrees indicates superior slippery properties and low CAH. Such surfaces could result in low ice adhesion provided the droplet does not impale into surface textures (Wenzel state) while freezing (which is possible due to various reasons such as dynamic impact or frost). An ROA close to 90 degrees indicates high drop adhesion, and consequently large ice adhesion.

5.6 Droplet Impact Resistance

Dynamic pressures generated under droplet impact are significantly higher than the static pressures and can cause droplets to transition from the non-wetting (Cassie) state to the wetting (Wenzel) state (see Deng, et.al., Appl. Phys. Lett., AIP 94, 133109-1, 2009; Kwon, et.al., Phys. Rev. Lett, APS 106, 036102, 2011). These dynamic wetting pressures are referred to as water hammer pressure and Bernoulli pressure. Textured hydrophobic surfaces (e.g., super-hydrophobic surfaces) resist wetting by generating anti-wetting capillary pressures. When the wetting pressures exceed the anti-wetting pressures, droplet transition into the wetting state (Wenzel) occurs. Once the transition occurs, ice accretion will dramatically increase. These are illustrated in the Figures 3 and 4 below.

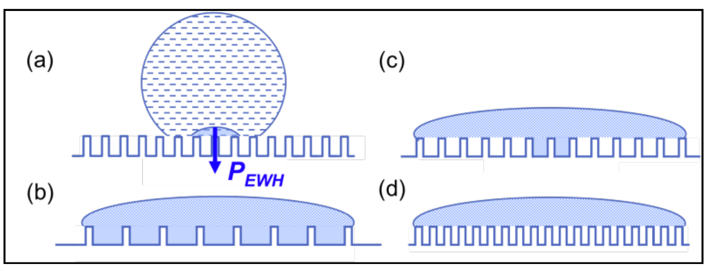


FIGURE 3

Figure 3 (adapted from Figure 1 of Deng, et.al., Appl. Phys. Lett., AIP 94, 133109-1, 2009): Relative magnitude of the wetting and anti-wetting pressures decides the wetting states of impinging droplets:

a) P_{EWH} the effective water hammer pressure is generated during the contact stage as the droplet impinges on the textured surface. P_D is the dynamic Bernoulli pressure and P_C is the anti-wetting capillary pressure.

b) Total wetting state ($P_{EWH} > P_D > P_C$) as water penetrates in both contact and spreading stage.

c) Partial wetting state ($P_{EWH} > P_C > P_D$) as water penetrates only during contact stage.

d) Total non-wetting state ($P_C > P_{EWH} > P_D$) as the structure resist wetting in both stages.

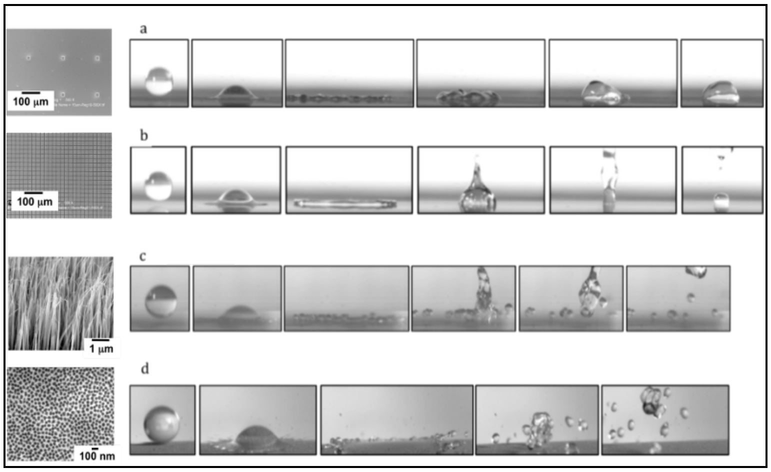


FIGURE 4

Figure 4 (adapted from Deng, et.al., Appl. Phys. Lett., AIP 94, 133109-1, 2009): Dynamic interactions of 1 mm diameter droplets with a variety of surfaces captured using a high-speed camera:

(a) Micro-textured surface consisting of 15 µm posts spaced apart by 150 µm – droplet does not recoil and impales into texture. Such structures will increase ice accretion.

(b) Partial drop recoil on micro-textured surface consisting of 15 µm posts spaced apart by 5 µm; such small impaled regions will over time lead to enhanced ice accretion.

(c) Complete drop recoil on 100nm dendritic structures.

(d) Complete drop recoil on metal-oxide nanoporous surface with ~38 nm pores.

Conduct droplet impact experiments on the treated substrate to characterize the dynamic wetting resistance of the substrate. Ideally, the impact experiments should be conducted with typical drop sizes and impact speeds experienced under field conditions, i.e., at large Weber numbers.

5.7 Frost Endurance Test

Frost is formed either via deposition of water vapor directly into ice or via condensation of water droplets followed by freezing. These occur as a result of either convective or radiation cooling of the surface. When meteorological conditions cause either to occur, surface textures and coatings can become covered with a layer of frost, which then makes the surface hydrophilic and results in increased ice adhesion and ice accretion (e.g., Varanasi, et.al., Appl. Phys. Lett., AIP 97, 234102, 2010). This phenomenon poses a significant limitation to the use of super-hydrophobic coatings in icephobic applications, and hence, hydrophobic does not necessarily imply icephobic properties (see Varanasi, et.al., Appl. Phys. Lett., AIP 97, 234102, 2010). Figure 5 and Figure 6 below illustrate these effects.

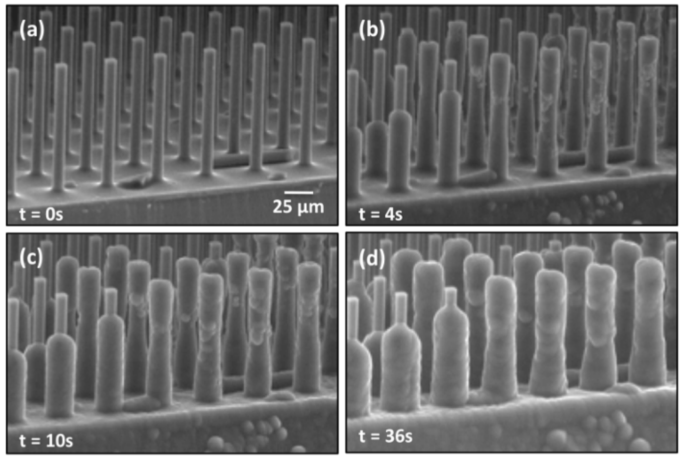


FIGURE 5

Figure 5 (adapted from Varanasi, et.al., Appl. Phys. Lett., AIP 97, 234102, 2010): environmental scanning electron microscope (ESEM) images of frost formation on a super-hydrophobic surface comprising of an array of hydrophobic square posts.

(a) Dry surface.

[(b)-(d)] Snapshot images of frost formation on the surface. The intrinsic water contact angle of the hydrophobic coating on the posts is ~110º. The surface is maintained at a temperature -13ºC by means of a cold stage accessory of the ESEM. At the beginning of the experiment the chamber pressure is maintained ~ 100 Pa, well below the saturation pressure to ensure a dry surface. The vapor pressure in the chamber is then slowly increased until frost nucleation is observed. Frost nucleation and growth occurs without any particular spatial preference on all of the available area including post tops, sidewalls and valleys due to the uniform intrinsic wettability of the surface.

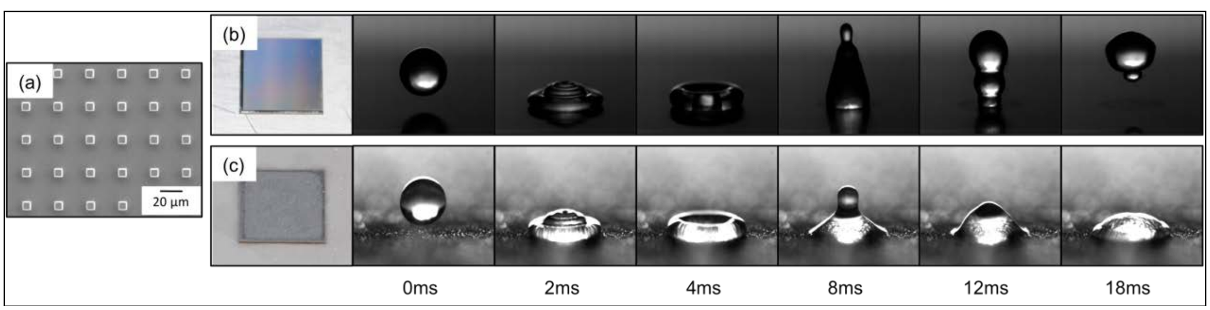


FIGURE 6

Figure 6 (adapted from Varanasi, et.al., Appl. Phys. Lett., AIP 97, 234102, 2010): Droplet impact measurements on dry and frosted super-hydrophobic surface conducted using droplets of 1mm radius impacting the surface at velocity ~ 0.7 m/s

(a) Top view ESEM image of the representative Si silicone post array surface.

(b) Photograph of the dry surface along with sequential high-speed video images of droplet impact. As expected, droplet recoils from the surface, as the anti-wetting capillary pressure is greater than the dynamic wetting pressures.

(c) Photograph of the frosted surface along with sequential high-speed video images of droplet impact. Frost alters the wetting properties of the surface, making the surface hydrophilic, and causing Cassie-to-Wenzel wetting transition of the impacting drop and subsequent pinning to the surface.

The following battery of tests, ranging from simple to complex, is recommended to fully quantify the performance of the coating under frost. For the following testing, consider a saturated water vapor environment with substrate sub-cooling that promote direct deposition or condensation followed by freezing. For example, if the environment is not pure water vapor, consider high relative humidity (>90%) and substrate temperature below the freezing point. The pressure can be altered to promote condensation or deposition. Under these conditions, the following should be performed:

a) Visual inspections of frost build up.

b) Measure contact angle to ascertain the hydrophobicity of the surface. Because of the presence of nucleated water or ice in the textures, the surface could display hydrophilic behavior. Such a surface could be compromised.

c) Conduct ROA angle measurements. If the SLA increases from the dry surface, then frost-induced impalement is occurring and the surface is compromised.

d) Droplet impact experiments to ascertain the hydrophobic drop shedding properties. If shedding is arrested, then surface could be compromised.

e) Ice adhesion testing under frosting conditions. Due to interlocking, the adhesion testing under frost conditions should be higher than for the smooth surface of identical surface chemistry. Increase in adhesion strength could indicate frost-induced adhesion and potential loss of coating functionality.

5.8 Thermal Conductivity

Consider testing a sample, representative of the aircraft surface, treated with the surface coating to assess its overall thermal conductivity or heat transfer properties. The thermal conductivity of a material, k (W/m -K) is the property of a material's ability to conduct heat. The normal conductivities of typical aluminum or composite aircraft surfaces may be modified due to the addition of a coating between the skin and the heated fluid or contamination.

Additionally, thermal conductivity of materials are temperature dependent. Surface coatings and heated fluids, in combination with various forms of precipitation and temperatures, may lead to modified anti-icing fluid performance and holdover times.

Various methods exist for determining thermal conductivity of substrates. The following are some standards that may be useful to assess:

i. ASTM Standard C518 - 10, "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus"

ii. ASTM Standard E1225-04, "Standard Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique"

iii. ASTM Standard D5930-01, "Standard Test Method for Thermal Conductivity of Plastics by Means of a Transient Line-Source Technique"

iv. ISO 8301, "Thermal insulation -- Determination of steady-state thermal resistance and related properties -- Heat flow meter apparatus"

v. ISO 22007-2:2008 "Plastics -- Determination of thermal conductivity and thermal diffusivity -- Part 2: Transient plane heat source (hot disc) method"

vi. ISO 22007-3:2008 "Plastics -- Determination of thermal conductivity and thermal diffusivity -- Part 3: Temperature wave analysis method"

vii. ISO 22007-4:2008 "Plastics -- Determination of thermal conductivity and thermal diffusivity -- Part 4: Laser flash method"

5.9 Testing Organizations

As of the date of publication of the AIR the following organizations are known to provide testing for aircraft coatings. This is not an endorsement by SAE for these laboratories but simply a list to facilitate the location of organizations for those seeking testing. Please enquire directly with the laboratories for a full list of testing available.

Anti-icing Materials International Laboratory (AMIL), 555, boulevard de l'Université, Chicoutimi, Québec, G7H 2B1, Canada; 418-545-2918. www.uqac.ca/amil .

APS Aviation Inc., 6700, chemin de la Côte-de-Liesse, Suite 105, Saint-Laurent, Quebec, H4T 2B5, Canada; 514-878-4388, www.adga.ca/aps.

Scientific Material International, 12219 SW 131st Avenue, Miami, Florida, USA 33186-6401; 305-971-7047; www.smiinc.com .

6. NOTES

6.1 Keywords

Aircraft Coating, Icephobic, Hydrophobic, Hydrophilic, Endurance Time, Holdover, Aircraft, Surface, Frost, Ice, Freezing, Rain, Drizzle, Fog, Cold Soaked Wing, Snow.

PREPARED UNDER THE JURISDICTION OF
SAE COMMITTEE G–12, AIRCRAFT GROUND DEICING