TP 14781E

# Aircraft Ground Icing General Research Activities During the 2006-07 Winter




*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.

**January 2008**
**Final Version 1.0**

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

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

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# PREFACE

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

- To develop holdover time data for all newly-qualified de/anti-icing fluids;
- To evaluate whether holdover times should be developed for ice pellet conditions;
- To examine the effect of heated fluids on Type II, III, and IV fluid endurance times;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To assist in the testing of flow of contaminated fluid from aircraft wings during takeoff;
- To assist in the testing of flow of contaminated fluid from simulated aircraft wings during takeoff;
- To validate the laboratory snow test protocol with Type II and IV fluids;
- To develop performance specifications for an integrated weather system that measures holdover time;
- To provide support for the development of a standard that evaluates remote on-ground ice detection systems;
- To conduct general and exploratory de/anti-icing research;
- To conduct endurance time tests on non-aluminum plates;
- To conduct endurance time tests in frost on various test surfaces;
- To conduct preliminary wind tunnel endurance time tests in heavy snow;
- To compile historical data for calculation of holdover times based on a small number of inputs;
- To examine the use of non-glycol tempered steam technology to deice aircraft; and
- To assist Department of National Defence Canada in evaluating the effects of slipstream on anti-icing fluid.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2006-07 are documented in eight reports. The titles of the reports are as follows:

- TP 14452E Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681;
- TP 14776E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2006-07 Winter;
- TP 14777E Winter Weather Impact on Holdover Time Table Format (1995-2007);
- TP 14778E Flow of Contaminated Fluid from Aircraft Wings: Feasibility Report;

- TP 14779E Development of Allowance Times for Aircraft Deicing Operations During Conditions with Ice Pellets;
- TP 14780E Evaluation of Tempered Steam Technology (TST) for Aircraft Deicing Applications;
- TP 14781E Aircraft Ground Icing General Research Activities During the 2006-07 Winter; and
- TP 14782E Regression Coefficients Used to Develop the Winter 2007-08 Type I Generic and Dow UCAR Endurance EG106 Holdover Time Tables.

In addition, the following six interim reports are being prepared:

- *Preliminary Aircraft Deicing Research in Heavy Snow Conditions;*
- *Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2006-07;*
- *Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions;*
- *Effect of Heat on Fluid Endurance Times Using Composite Surfaces;*
- *Effect of Heat on Endurance Times of Anti-Icing Fluids; and*
- *Regression Coefficients Used to Develop Aircraft Ground Deicing Holdover Time Tables: Winter 2007-08.*

In addition, the following report was written for Department of National Defence as part of this contract; this report does not have a TP number:

- Support for Testing to Ascertain the Effects of SAE Type IV De/Anti-Icing Fluids on CC-130 Hercules and CP-140 Aurora Aircraft Takeoff Handling.

This report, TP 14781E, has the following objective:

- To document the exploratory research and general activities carried out for the Transportation Development Centre during the winter of 2006-07.

## PROGRAM ACKNOWLEDGEMENTS

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

APS Aviation Inc. would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: George Balaban, Katrina Bell, Stephanie Bendickson, Ryan Brydges, Michael Chaput, John D'Avirro, Peter Dawson, Dany Posteraro, Marco Ruggi, Joey Tiano, and David Youssef.

Special thanks are extended to Barry Myers, Frank Eyre, and Yagusha Bodnar, who on behalf of the Transportation Development Centre, have participated, contributed, and provided guidance in the preparation of these documents.

## REPORT ACKNOWLEDGEMENTS

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

16. Abstract

This report documents the general activities completed by APS Aviation Inc. (APS) related to aircraft ground deicing research in the winter of 2006-07. The activities documented in this report were carried out in addition to the main research projects completed in the winter of 2006-07, which are documented in separate reports. The six activities included in this report are described below.

1. Support for Development of SAE AS5681: APS is supporting the development of Aerospace Standard (AS) 5681 by providing expert opinion and clerical support for the development of the standard on remote on-ground ice detection systems.
2. Holdover Time Guidelines Website: APS developed and implemented a website for the official Transport Canada 2007-08 holdover time guidelines tables.
3. Support for Development of SAE ARP5718: APS is supporting the development of Aerospace Recommended Practice (ARP) 5718 by providing expert opinion for the development of the recommended practice that describes the process by which an experimental fluid becomes a fully qualified fluid.
4. Holdover Time Determination Systems (D-Ice): APS conducted tests with the D-Ice Information System to examine the implementation of holdover time determination systems (HOTDS). They also provided expert opinion for the development of an exemption document for HOTDS.
5. Test Procedures, Presentations, and Fluid Manufacturer Reports: An account of the test procedures, presentations, and fluid manufacturer reports that were produced for the 2006-07 test program is included in this report.
6. Aerodynamic Testing of Anti-Icing Fluids Contaminated with Heavy Snow: Aerodynamic testing of anti-icing fluid exposed to simulated heavy snow conditions demonstrated visually severe conditions, but the lift data collected did not show significant lift losses directly attributable to the contamination. Further testing is recommended to determine the aerodynamic failure of a fluid following excessive exposure to precipitation.

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Plusieurs rapports de recherche ont été produits au nom de Transports Canada sur les essais réalisés au cours des hivers antérieurs. Ceux-ci sont disponibles auprès du Centre de développement des transports. Plusieurs rapports ont été produits dans le cadre du programme de recherche de cet hiver. On trouvera dans la préface l'objet de ces rapports. Les travaux décrits dans ce rapport ont été en partie coparrainés par la Federal Aviation Administration.

16. Résumé

Ce rapport fait état des activités générales menées par APS Aviation Inc. (APS) en matière de recherche sur le dégivrage d'aéronefs au sol au cours de l'hiver 2006-2007. Les activités dont fait état ce rapport ont été effectuées en plus des projets de recherche principale menés pendant l'hiver 2006-2007, qui sont documentés dans des rapports distincts. Les six activités qui font l'objet du présent rapport sont énumérées ci-dessous.

1. Contribution à l'élaboration de la norme AS5681 de la SAE : APS contribue à l'élaboration de la norme aérospatiale (AS) 5681 en fournissant des avis d'experts et un soutien administratif pour la mise au point de la norme sur les systèmes de détection de glace au sol à distance.
2. Site Web des lignes directrices sur les durées d'efficacité : APS a conçu et mis en place un site Web présentant les lignes directrices officielles de Transport Canada sur les durées d'efficacité pour 2007-2008.
3. Contribution à l'élaboration de la pratique recommandée ARP5718 de la SAE : APS contribue à l'élaboration de la pratique recommandée en aérospatiale (ARP) 5718 en fournissant des avis d'experts pour la mise au point de la pratique recommandée qui décrit le processus par lequel un liquide expérimental devient un liquide pleinement qualifié.
4. Mise en œuvre des systèmes de détermination des durées d'efficacité (D-Ice) : APS a mené des essais avec le système d'information D-Ice pour examiner la mise en œuvre des systèmes de détermination des durées d'efficacité (HOTDS). L'entreprise a également fourni des avis d'experts pour l'élaboration d'un document d'exemption pour HOTDS.
5. Procédures d'essais, présentations et rapports des fabricants de fluides : Un certain nombre de procédures d'essais, de présentations et de rapports des fabricants de fluides ont été produits dans le cadre du programme d'activités de 2006 2007. Ceux-ci sont inclus dans le présent rapport.
6. Essais aérodynamiques sur des liquides d'antigivrage contaminés par la neige forte : Des essais aérodynamiques réalisés sur des liquides d'antigivrage exposés à des conditions de neige forte simulées ont démontré des conditions graves sur le plan visuel, mais les données de portance recueillies n'ont pas démontré de pertes de portance importantes directement attribuables à la contamination. Il est recommandé de procéder à des essais supplémentaires afin de déterminer la perte d'efficacité aérodynamique d'un liquide exposé à des précipitations excessives.

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# EXECUTIVE SUMMARY

This report documents the general activities related to aircraft ground deicing research completed by APS Aviation Inc. (APS) in the winter of 2006-07 on behalf of the Transportation Development Centre (TDC) of Transport Canada (TC) and the Federal Aviation Administration (FAA). The six activities documented in this report are described below and were carried out in addition to the main research projects completed in the winter of 2006-07, which are documented in separate reports.

### Support for Development of SAE AS5681 (Section 2)

The proposed Society of Automotive Engineers (SAE) Aerospace Standard (AS) 5681 specifies the minimum performance requirements of remote on-ground ice detection systems (ROGIDS). APS has supported the development of AS5681 by providing expert opinion and clerical support.

### Holdover Time Guidelines Website (Section 3)

APS developed and implemented a website for the official TC Holdover Time (HOT) Guidelines in 2003 to eliminate the safety risks associated with discrepancies occurring as a result of HOT information being published in multiple locations. APS updated this website in July 2007 with the 2007-08 HOT Guidelines. A revision was made to the 2007-08 guidelines in October 2007 to include ice pellet allowance times.

### Support for Development of SAE ARP5718 (Section 4)

The proposed SAE Aerospace Recommended Practice (ARP) 5718 describes the processes by which an experimental fluid becomes a fully qualified fluid. APS has supported the development of ARP5718 by providing expert opinion.

### Implementation of Holdover Time Determination Systems (D-Ice) (Section 5)

APS assisted in the development and subsequent amendment of an *Air Carrier Exemption* and *Minimum Assurance Requirements and Performance Specifications* for the implementation of holdover rime determination systems (HOTDS) into Canadian air operations.

### Test Procedures, Presentations, and Fluid Manufacturer Reports (Section 6)

A number of test procedures, presentations, and fluid manufacturer reports were produced by APS for the 2006-07 test program. An account of these activities is included in this report.

### Aerodynamic Testing of Anti-Icing Fluids Contaminated with Heavy Snow (Section 7)

TC and the FAA conducted a series of preliminary tests to investigate the aerodynamic properties of heavily contaminated anti-icing fluid exposed to simulated snow conditions. Visual observations during the wind tunnel and Falcon 20 tests reported residual contamination at the end of the heavy snow tests. Although this was visually deemed a severe condition, the lift data did not show significant lift losses directly attributable to the heavy snow contamination. Further testing in heavy snow conditions is recommended to determine the aerodynamic failure of a fluid following excessive exposure to precipitation.

# SOMMAIRE

Ce rapport fait état de la recherche exploratoire et des activités générales se rapportant à la recherche sur le dégivrage d'aéronefs au sol menée par APS Aviation Inc. (APS), au cours de l'hiver 2006-2007, pour le compte du Centre de développement des transports (CDT) de Transports Canada (TC) et de la Federal Aviation Administration (FAA). Les six activités dont fait état ce rapport sont décrites ci-dessous et ont été effectuées en plus des projets de recherche principale menés pendant l'hiver 2006-2007, qui sont documentés dans des rapports distincts.

**Contribution à l'élaboration de la norme AS5681 de la SAE (Section 2)**

La norme aérospatiale (AS) 5681 proposée par la Society of Automotive Engineers (SAE) précise les exigences minimales de rendement des systèmes de détection de glace au sol à distance (ROGIDS). APS a contribué à l'élaboration de la norme AS5681 en fournissant des avis d'experts et un soutien administratif.

**Site Web des lignes directrices sur les durées d'efficacité (Section 3)**

En 2003, APS a conçu et mis en place un site Web présentant les lignes directrices officielles de TC sur les durées d'efficacité, afin d'éliminer les risques pour la sécurité associés à la possibilité de divergences lorsque l'information sur les durées d'efficacité est publiée à plusieurs endroits. En juillet 2007, APS a mis à jour ce site Web avec les lignes directrices sur les durées d'efficacité de 2007-2008. Une révision des lignes directrices de 2007-2008 a eu lieu en octobre 2007 afin d'inclure les marges de tolérance des granules de glace.

**Contribution à l'élaboration de la pratique recommandée ARP5718 de la SAE (Section 4)**

Le document de pratique recommandée en aérospatiale (ARP) 5718 proposé par la SAE décrit les processus par lesquels un liquide expérimental devient un liquide pleinement qualifié. APS a contribué à l'élaboration du document ARP5718 en fournissant des avis d'experts.

**Mise en œuvre des systèmes de détermination des durées d'efficacité (D-Ice) (Section 5)**

APS a participé à l'élaboration et à la modification subséquente d'une exemption pour transporteurs aériens et d'exigences minimales d'assurance et de spécifications de rendement pour la mise en œuvre des systèmes de détermination des durées d'efficacité (HOTDS) dans les exploitations aériennes canadiennes.

**Procédures d'essais, présentations et rapports des fabricants de fluides (Section 6)**

APS a produit un certain nombre de procédures d'essais, de présentations et de rapports aux fabricants de fluides pour le programme d'essais de l'hiver 2006-2007. Le présent rapport contient une description de ces activités.

**Essais aérodynamiques sur des liquides d'antigivrage contaminés par la neige forte (Section 7)**

TC et la FAA ont réalisé une série d'essais préliminaires afin d'étudier les propriétés aérodynamiques de liquides d'antigivrage fortement contaminés dans des conditions de neige simulées. À la fin d'essais dans des conditions de neige forte réalisés en soufflerie et sur le Falcon 20, des observations visuelles ont permis de constater une contamination résiduelle. Bien que, visuellement, les conditions aient été jugées graves, les données de portance n'ont pas démontré de pertes de portance importantes directement attribuables à la contamination par la neige forte. Il est recommandé de procéder à des essais supplémentaires dans des conditions de neige forte afin de déterminer la perte d'efficacité aérodynamique d'un liquide exposé à des précipitations excessives.

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# GLOSSARY

| | |
|---|---|
| AMS | Aerospace Material Specification |
| APS | APS Aviation Inc. |
| ARP | Aerospace Recommended Practice |
| AS | Aerospace Standard |
| CARs | Canadian Aviation Regulations |
| CBAAC | Commercial and Business Aviation Advisory Circular |
| CDF | Central Deicing Facility |
| DAQCP | De-Icing/Anti-Icing Quality Control Pool |
| ET | Endurance Time |
| FAA | Federal Aviation Administration |
| HOT | Holdover Time |
| HOTDS | Holdover Time Determination Systems |
| IATA | International Air Transport Association |
| LOWV | Lowest On-Wing Viscosity |
| MSC | Meteorological Service of Canada |
| NRC | National Research Council Canada |
| ROGIDS | Remote On-Ground Ice Detection Systems |
| SAE | Society of Automotive Engineers |
| TC | Transport Canada |
| TCCA | Transport Canada Civil Aviation |
| TDC | Transportation Development Centre |
| YUL | Montréal–Pierre Elliott Trudeau International Airport |
| YYZ | Toronto Pearson International Airport |

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# 1. INTRODUCTION

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

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

Under contract to the TDC, with financial support from the FAA, APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti-icing technology. Each of the major research projects is documented in a separate individual report. The general activities are documented in this report.

The relevant sections of the TC work statement can be found in Appendix A.

## 1.1 General Activities

### 1.1.1 Support for Development of SAE AS5681

The proposed Society of Automotive Engineers (SAE) Aerospace Standard (AS) 5681 specifies the minimum performance requirements of remote on-ground ice detection systems (ROGIDS). APS has supported the development of AS5681 by providing expert opinion and clerical support for the development of the standard. This topic is discussed in Section 2.

### 1.1.2 Holdover Time Guidelines Website

In July 2003, APS developed and implemented a website for the official TC Holdover Time (HOT) Guidelines. This was done in order to eliminate the discrepancies and potential safety risks associated with publishing the information in several locations, including websites and documents. In July 2007, APS updated the website with the new 2007-08 HOT Guidelines. In October 2007, Revision 1.0 of the 2007-08 HOT Guidelines was published, which incorporated ice pellet allowance times. This topic is discussed in Section 3.

### 1.1.3 Support for Development of SAE ARP5718

The proposed SAE Aerospace Recommended Practice (ARP) 5718 describes the processes by which an experimental fluid becomes a fully qualified fluid. APS has supported the development of ARP5718 by providing expert opinion for the development of this standard. This topic is discussed in Section 4.

### 1.1.4 Implementation of Holdover Time Determination Systems (D-Ice)

In Winter 2005-06, APS was contracted by the TDC to examine the implementation of holdover time determination systems (HOTDS), in this case the D-Ice Information System. In February 2006, APS, in partnership with TC, NAV CANADA, and D-Ice (formerly Dan-Ice), agreed that a performance-based specification should be developed to permit HOTDS technologies to operate under an Exemption from Canadian Aviation Regulations (CARs) Standard 622.11.

In 2006-07, further limited work was performed to advance the implementation of HOTDS into Canadian air operations. The focus of this activity was mainly on the refinement of the *Air Carrier Exemption* and *Minimum Assurance Requirements and Performance Specifications*. This activity is discussed in Section 5.

### 1.1.5 Test Procedures, Presentations, and Fluid Manufacturer Reports for 2006-07

Section 6 contains an account of the test procedures, presentations, and fluid manufacturer reports that were prepared by APS in 2006-07.

### 1.1.6 Support to Other Working Groups

Several other support activities were carried out by APS, including the following:

- Participating in activities to support the Dedicated Deicing Facilities Working Group;
- Participating in a meeting held by International Air Transport Association (IATA) related to the De-Icing/Anti-Icing Quality Control Pool (DAQCP); and
- Participating in and developing minutes for the SAE G-12 HOT Subcommittee meeting in San Diego in May 2007.

These topics are not described in this report.

### 1.1.7 Aerodynamic Testing of Anti-Icing Fluids Contaminated with Heavy Snow

The goal of this project was to evaluate the aerodynamic impact of heavily contaminated anti-icing fluid under simulated heavy snow conditions. Aerodynamic testing was carried out as part of the ice pellet allowance time research initiative. The findings were detailed in an interim report submitted to TC and the FAA.

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# 2. SUPPORT FOR DEVELOPMENT OF SAE AS5681

Human factor tests, documented in the Federal Aviation Administration (FAA) report, DOT/FAA/TC-06/21, *Human Visual and Tactile Ice Detection Capabilities under Aircraft Post Deicing Conditions* (1), have demonstrated that the ability to detect ice can be somewhat difficult with both visual and tactile detection. It has been determined that, under certain circumstances, remote on-ground ice detection systems (ROGIDS) can be more reliable than human visual or tactile ice detection.

The proposed Society of Automotive Engineers (SAE) Aerospace Standard (AS) 5681 specifies the minimum performance requirements of ROGIDS. As a ground-based system, the main objective of ROGIDS is to allow flight crews and deicing technicians to determine whether frozen contamination is present on aircraft surfaces. Therefore, ROGIDS are intended to be used during aircraft ground operations to provide information about the condition of the monitored aircraft surfaces.

In collaboration with regulatory authorities, APS Aviation Inc. (APS) supported the development of AS5681 by providing expert opinion and clerical support for the development of this standard.

## 2.1 Development of Standard

APS has been an ongoing contributor to the development of AS5681 through continued support at all industry meetings. The following is a list of the relevant meetings.

Pre-Meeting: *Fall 2005, Atlantic City, Regulatory Approval Working Group Meeting*: Decision made to set up a focus group to revise AS5116B (now AS5681) to incorporate findings from recent human factors research (see OT/FAA/TC-06/21 [1]).

Meeting 1: *March 28-30, 2006, Montreal*: Updated previous specifications from Section 1 to the beginning of Section 6.

Meeting 2: *April 25-27, 2006, Montreal*: Continued development of Section 6 and development of tests to be conducted (Appendix A).

Meeting 3: *May 21-25, 2006, Lisbon, SAE G-12 Aircraft Ground Deicing Committee Meetings*: No progress on the document. Discussions focussed on ice detection in general for the SAE G-12 committee.

Meeting 4: *June 20-22, 2006, Ottawa*: Further development of Section 6.

Meeting 5: *October 3-5, 2006, Atlantic City*: Sections 3, 5, and 6 were further developed and Appendix E was added.

Meeting 6: *November 14-16, 2006, Montreal*: Document reviewed to the end of Section 7.

Meeting 7: *December 11-13, 2006, Montreal*: Rewriting of Appendix E (now Appendix D) discussed, and Sections 5 to 7 further developed. Proposed cancellation of AS5116.

Meeting 8: *February 13-15, 2007, Ottawa*: Section 7 rewritten to include operational evaluation tests and further work done on Appendix E (now Appendix D).

Meeting 9: *April 24-26, 2007, Toronto*: Results of March 26-28 feasibility tests discussed. These tests were conducted by APS in March 2007 and demonstrated that controlled environment tests could be performed. The results are documented in the Transport Canada (TC) report, TP 14452E, *Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681* (2). Document fully reviewed up to Section 6.

Meeting 10: *May 16, 2007, San Diego*: Final review of Section 6 and part of Section 7.

Meeting 11: *June 19-21, 2007, Atlantic City*: Document review finalized. Document ready to be submitted for ballot.

## 2.2 Current Version of Standard

The July 2007 version of AS5681, which was submitted for ballot, is included for reference purposes in Appendix B. The standard was approved and issued for publication on September 27, 2007. AS5681 supersedes AS5116, *Minimum Operational Performance Specification for Ground Ice Detection Systems*, which has been cancelled.

TC and the FAA intend to develop advisory circulars in the coming months for potential ROGIDS use.

# 3. HOLDOVER TIME GUIDELINES WEBSITE

## 3.1 Background

The development and use of holdover time (HOT) tables have represented an important contribution to the enhancement of flight safety in winter aircraft operations throughout the industry. In the years since their introduction, these tables have become a standard and essential part of winter operations.

Two kinds of HOT Guidelines currently exist: fluid-specific HOT Guidelines and generic HOT Guidelines. Once developed, the tables are published or referenced in various industry media. At one time, Transport Canada (TC) published the tables in both English and French in three different locations:

- The Transport Canada Civil Aviation (TCCA) Commercial and Business Aviation Advisory Circular (CBAAC) document;
- The TCCA website; and
- The Transportation Development Centre (TDC) website.

It is not unusual that the processing of common information for use in different media results in discrepancies between displays. The formatting of website contents in different computer languages can easily lead to errors in content and format. Translations between English and French can also cause these errors. Reducing the number of information sources available to operators was seen as a way to eliminate potential sources of incorrect information.

Therefore, in the summer of 2003, TC asked APS Aviation Inc. (APS) to develop and implement a website for official TC HOT Guidelines in order to standardize the HOT information published online and to eliminate the safety risks associated with information discrepancies. This single source of HOT information was first made available when the 2003-04 HOT Guidelines were published on a common website in July 2003. The information was provided in both English and French, primarily for Canadian operators, although it was made publicly accessible for others to use.

## 3.2 Changes to the Website

Since 2003, APS has published the HOT Guidelines for the upcoming winter on the website each July. In July 2007, the 2007-08 HOT Guidelines were published on the website and replaced the 2006-07 HOT Guidelines, which were archived on the site. Appendix C contains a draft of Revision 1.0 of the 2007-08 HOT Guidelines as

they will appear in English on the website. As has been done in other years, the changes from the previous year's guidelines are summarized on Page 3 of the document and explained in detail in the TC report, TP 14776E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2006-07 Winter* (3).

The changes made for the 2007-08 HOT Guidelines include the following:

- Addition of one new Type IV fluid: Lyondell Arctic Shield®;
- Addition of two new Type II fluids: Aviation Xi'An High-Tech KHF-II and Newave Aerochemical FCY-2;
- Inclusion of lowest on-wing viscosities (LOWVs) of diluted fluids; and
- Inclusion of ice pellet allowance times.

In order for the changes to be approved, APS is required to obtain approval from both TC and the TDC. Figure 3.1 shows the form used for this purpose.

## 3.3 Future Responsibilities

APS has undertaken the responsibility to ensure that the website is operational, in terms of Internet availability, for a one-year period. In the summer of 2008, APS intends to update the website with new data from 2007-08 testing and publish the 2008-09 HOT Guidelines.

# Request for Change to Holdover Time Guidelines Website

Date: _____

Description of Change: _____

_____

_____

Affected Pages: _____

Requested By: _____

Reason for Change: _____

_____

_____

Confirmed by:

_____
Barry Myers
Senior Development Officer
Transportation Development Centre

Confirmed by:

_____
Douglas Ingold
Specialist Flight Technical
Transport Canada Civil Aviation

*Procedure for making changes to the holdover time guidelines website:*

1. Fill out this form
2. Submit to APS (John D'Avirro/Nicoara Moc)
3. APS will acquire the necessary signatures or email confirmations
4. APS will submit changes to its IT department after approval is received[1]

[1] The website files are located on a secure server with restricted access. This access is limited to the APS IT department.

**Figure 3.1: HOT Guideline Change Form**

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# 4. SUPPORT FOR DEVELOPMENT OF SAE ARP5718

It is not sufficient for an anti-icing fluid to meet all the requirements of Society of Automotive Engineers (SAE) Aerospace Material Specification (AMS) 1428 for airlines to be able to use the fluid. For such a fluid to be used commercially, it must also have Holdover Time (HOT) Guidelines and be identified on a list of qualified fluids acceptable to regulators. Before commercialization, it is further recommended that a field spray test be conducted with the anti-icing fluid to demonstrate acceptable performance.

Therefore, Aerospace Recommended Practice (ARP) 5718 is in development. It will describe the following:

- The steps to certify anti-icing fluids according to AMS1428;
- The methodology for preparation of samples for endurance time (ET) testing according to ARP5485;
- The protocol to generate draft HOT Guidelines;
- The role of the SAE G-12 HOT Subcommittee; and
- The process for publication of HOT Guidelines.

The intent of this ARP is to help fluid manufacturers and users to understand the overall process that a fluid must go through to be used in aviation. It describes and documents the processes by which an experimental fluid may become a fully qualified fluid.

This ARP further documents the following steps and processes:

- Select samples for testing experimental Type II, III, and IV fluids according to AMS1428 and ARP5485;
- Run field spray tests;
- Generate HOT Guidelines from ET data; and
- Add and remove fluids from the list of qualified fluids published by regulators, namely Transport Canada (TC) and the Federal Aviation Administration (FAA).

In collaboration with regulatory authorities, APS Aviation Inc. (APS) is supporting the development of ARP5718 by providing expert opinion.

## 4.1 Development of Recommended Practice

APS has been an ongoing contributor to the development of ARP5718 through continued support at all industry meetings.

A meeting was held in January 2007 at the Transportation Development Centre (TDC) offices in Montreal to lay out and develop the document.

The document entitled *Qualification Process for SAE AMS1428 Type II, III, and IV Fluids* was balloted in August 2007, and the balloted version is included for reference purposes in Appendix D.

# 5. IMPLEMENTATION OF HOLDOVER TIME DETERMINATION SYSTEMS (D-ICE)

## 5.1 Background

Holdover time determination systems (HOTDS) are designed for implementation at airports and would record measurements of the weather conditions at pre-determined intervals. The systems would compute the precipitation rate for any given weather condition, thus enabling the determination of a "single-value" fluid holdover time (HOT) for any combination of condition, fluid, and temperature. The information could then be relayed electronically to pilots in the flight deck.

In Winter 2005-06, APS Aviation Inc. (APS) was contracted by the Transportation Development Centre (TDC) to examine implementation issues with HOTDS.

In February 2006, a D-Ice Information System was installed at the central deicing facility (CDF) at Toronto Pearson International Airport (YYZ). The system was equipped with radio modems to communicate the electronic system output information from the unit to a computer installed in the CDF icehouse. The computer was configured to allow WestJet to employ information from the D-Ice Information System as an "advisory" tool in winter operations planning. WestJet amended its program to allow for the use of the D-Ice Information System, and Transport Canada (TC) approved this amendment.

Consultations were performed with TC, Environment Canada, and NAV CANADA to examine issues of system "certification." Discussions indicated that the system outputs consist of an operational tool and could be introduced under an Exemption from Canadian Aviation Regulations (CARs). At a meeting in February 2006, it was agreed that a performance-based specification would be developed to permit HOTDS to be operated under an Exemption from CARs Standard 622.11.

As part of a previous contract with the TDC, APS prepared and submitted the following draft documents to TC:

- Draft exemption document from Sections 3.0, 6.0, 6.2, and 6.3 of CARs Standard 622.11;
- Draft *Minimum Assurance Requirements and Performance Specifications* for HOTDS; and
- Draft assessment paper regarding the Exemption from CARs Standard 622.11, Sections 3.0, 6.0, 6.2, and 6.3.

It was recommended that TC initiate the process for implementation of the Exemption from CARs 622.11 to enable operational use of HOTDS. APS submitted an interim report underlining the development and implementation of a performance specification and the Exemption from CARs 622.11.

## 5.2 Project Objectives

The statement of work is included in Appendix A. It states that the ability of HOTDS to compute "single-value" fluid HOTs should be evaluated. It also states that consultations and proposed strategies concerning the system's implementation issues and obstacles should be conducted.

## 5.3 Project Activities

The version of the draft *Minimum Assurance Requirements and Performance Specifications for Holdover Time Determination Systems*, which was included in the above-mentioned interim report, was considered preliminary; further refinements would be required prior to publication.

The ability of HOTDS to compute "single-value" fluid HOTs is greatly dependent on the system's ability to compute an accurate precipitation rate. To this end, data collected from the APS evaluation of the D-Ice Information System at Montréal–Pierre Elliott Trudeau International Airport (YUL) was employed to provide support for the refinements to the draft *Minimum Assurance Requirements and Performance Specifications for Holdover Time Determination Systems.* This issue will be addressed in Subsection 5.4.

APS met with TC officials on several occasions in Ottawa to discuss issues related to the draft Exemption and draft *Minimum Assurance Requirements and Performance Specifications*. During these meetings, pertinent details to be included within the amended documentation were discussed and decided upon, and matters related to HOTDS implementation issues and obstacles were addressed. Final versions of these documents were submitted to TC for legal review and oversight in February 2007.

In March 2007, the Exemption from Subsection 602.11(4) of the Canadian Aviation Regulations and Sections 1.0, 3.0, 6.0, 6.2, 6.3 and 7.1.1.1 of Standard 622.11 Ground Icing Operations was signed by the TC Director Standards. This Exemption allowed WestJet to employ the HOTDS outputs for use in winter planning and operations. This document has been provided in Appendix E.

Although additional work was performed by APS on the HOTDS Exemption subject matter subsequent to March 2007, this report only contains information related to the development of the particular documentation that was signed by TC in March 2007.

## 5.4 Revision of HOTDS Documentation

The version of the draft *Minimum Assurance Requirements and Performance Specifications for Holdover Time Determination Systems* that was included in the interim report mentioned in Subsection 5.1 was modified prior to publication of the Exemption, based on data that was collected by APS with the D-Ice HOTDS.

The major revisions to the draft *Minimum Assurance Requirements and Performance Specifications* were focused on the following areas:

- Precipitation rate measurement technical requirements (Subsection 5.4.1); and
- HOT determination technical requirements (Subsection 5.4.2).

### 5.4.1 Precipitation Rate Measurement Technical Requirements

In this subsection, the preliminary and amended precipitation rate measurement technical requirements will be presented, along with a justification for the amendments.

#### *5.4.1.1 Preliminary Rate Measurement Technical Requirements*

The original *Minimum Assurance Requirements and Performance Specifications* was included in Appendix C of the interim report mentioned in Subsection 5.1. In Section 4 of the document, the *Technical Requirements for Data Inputs and Holdover Time Predictions* were specified. In Provision 4.1.8, the technical requirements for rate measurement capabilities of the HOTDS were defined as follows.

> 4.1.8 The Holdover Time Determination System precipitation rate measurements shall conform to the glycol pan measurements such as to be equal to or greater by up to XX% with XX% confidence (values to be determined when data analysis is completed).

No specific rate tolerances or confidence percentages were included within the preliminary version of the document.

### *5.4.1.2 Amended Rate Measurement Technical Requirements*

In the *Minimum Assurance Requirements and Performance Specifications* that were signed by TC in March 2007 (shown in Appendix E of this report), several amendments were made in the precipitation rate measurement technical requirements (Section 5 in the new document) as follows.

> 5.1.8 The Holdover Time Determination System precipitation rate measurements shall conform to the glycol pan measurements (ref.: SAE ARP5485), within the following tolerances:
>
> | | | |
> |---|---|---|
> | 5.1.8.1 | From 0 to 10 g/dm$^2$/h: | +/- 1.5 g/dm$^2$/h |
> | 5.1.8.2 | Above 10 to 25 g/dm$^2$/h: | +/- 3.5 g/dm$^2$/h |
> | 5.1.8.3 | Above 25 g/dm$^2$/h: | +/- 6.0 g/dm$^2$/h |
>
> 5.1.9 The accuracy requirements of Subsection 5.1.8 shall be demonstrated with at least a 95% confidence level during comparative tests with the HOTDS and glycol pans.
>
> 5.1.10 The precipitation rate input for the purpose of computing fluid holdover time (Subsections 5.1.11 to 5.1.13) shall be the precipitation rate determined by the HOTDS plus the positive tolerance (within a 95% confidence level) that has been demonstrated for each type of HOTDS. The precipitation rate input shall not be less than 2.0 g/dm$^2$/h.

The precipitation rate data produced by the D-Ice Information System was analysed in reference to simultaneously recorded glycol pan measurements in order to develop the rate tolerance values shown in Provision 5.1.8.1, Provision 5.1.8.2, and Provision 5.1.8.3 of the document. These tolerances were a result of a descriptive statistical analysis of the differences between the measured precipitation rates. The accuracy of these tolerances was designed to demonstrate a confidence level of at least 95 percent. This confidence level was subsequently added to the document in Provision 5.1.9.

In order to ensure that conservative HOTs were provided by the HOTDS, Provision 5.1.10 was included. Provision 5.1.10 states that the positive rate tolerance shall be added to the rate measured by the HOTDS to account for any rate under catch that occurs as part of the variance between the glycol pans and the HOTDS rate outputs. For example, if the HOTDS measures a rate of 6.3 g/dm$^2$/h, the rate input that shall be employed by the HOTDS for computation of the fluid HOTs is 7.8 g/dm$^2$/h (6.3 g/dm$^2$/h plus 1.5 g/dm$^2$/h, which is the rate tolerance for the HOTDS in the range of 0 to 10 g/dm$^2$/h).

In addition, a lower-level cap of 2 g/dm$^2$/h was implemented on the rate of precipitation. This cap prevents the use of precipitation rates below 2 g/dm$^2$/h from being used in the computation of fluid HOTs, as the slopes of the regression curves used to determine fluid HOTs become steep below this precipitation rate. Minor changes in rates below this level can result in large changes in HOT, and therefore the 2 g/dm$^2$/h cut-off was included in Provision 5.1.10 as a safety precaution.

## 5.4.2 Holdover Time Determination Technical Requirements

In this subsection, the preliminary and amended HOT determination technical requirements will be presented, along with a justification for the amendments.

### *5.4.2.1 Preliminary Holdover Time Determination Technical Requirements*

In Provision 4.1.9 and Provision 4.1.10 of the preliminary *Minimum Assurance Requirements and Performance Specifications,* included in Appendix C of the interim report mentioned in Subsection 5.1, the technical requirements for HOT determinations from the HOTDS were defined as follows.

> 4.1.9 Holdover Time Determinations shall be compared to regression analysis data for fluid holdover times.
>
> 4.1.10 Holdover Time Determinations from the system shall conform to holdover time data produced from trials as per ARP5945 and 5485 such that Holdover Time Determinations are equal to or less than trial data by up to XX% with a confidence level of XX% (values to be determined when data analysis is completed).

No specific tolerance or confidence percentages were included within the preliminary version of the document for HOT determinations.

#### *5.4.2.2 Amended Holdover Time Determination Technical Requirements*

In the *Minimum Assurance Requirements and Performance Specifications* that were signed by TC in March 2007 (shown in Appendix E of this report), several amendments were made to the HOT determination requirements (Section 5 in the new document) as follows:

5.1.11 The regression curves and associated coefficients incorporated into the HOTDS algorithm are either:

5.1.11.1 Those generated by TDC, or

5.1.11.2 Traceability and validity of the chosen regression curves and associated coefficients to plate pan measurements conducted by TC and the FAA must be demonstrated.

5.1.12 Holdover Time Determinations from the system for all de/anti-icing fluids shall be computed using the regression curves and associated coefficients referenced in 5.1.1.

5.1.13 In accordance with the currently accepted practice for HOT development, Holdover Time determinations from the system for Type II and Type IV de/anti-icing fluids shall be capped as follows:

| | |
|---|---|
| Freezing Fog | 4 hrs; |
| Snow | 2 hrs; |
| Freezing Drizzle | 2 hrs; |
| Light Freezing Rain | 2 hrs; |
| Rain on a Cold-Soaked Wing | 2 hrs. |

Rather than comparing the HOT determinations from the system to those generated by the regression analysis data, as proposed in the preliminary requirements, it was decided that a more appropriate approach would be to focus attention on the data input requirements (rate, precipitation type, and temperature) and then to specify the regression curves and coefficients that shall be employed in the computation of HOT by the HOTDS (see Provision 5.1.11 and Provision 5.1.12).

In addition, it was determined that the HOT outputs from the HOTDS shall be capped in a similar fashion to the current HOT Guidelines (see Provision 5.1.13).

## 5.5 Recommendations

Amendments to the exemption document and the *Minimum Assurance Requirements and Performance Specifications* are anticipated. Therefore, it is proposed that additional activities be conducted to develop and document further amendments, if necessary, as well as to advance the implementation of HOTDS technologies in Canadian air operations.

At the time of writing of this report, amendments have already been made to the *Minimum Assurance Requirements and Performance Specifications*, and these changes will be documented in a subsequent report.

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# 6. TEST PROCEDURES, PRESENTATIONS, AND FLUID MANUFACTURER REPORTS

This section contains an account of the test procedures, presentations, and fluid manufacturer reports that were prepared by APS Aviation Inc. (APS) in 2006-07.

## 6.1 Procedures

Several procedures were developed to guide and support the research team in the methodology for conducting tests. Table 6.1 at the end of this section provides a list of the procedures developed for each major project. Each major project has been documented in a separate report, and each complete procedure has been included in at least one of these reports.

## 6.2 Presentations

During the course of a research program, subcommittees of the Society of Automotive Engineers (SAE) G-12 Committee hold several meetings. During these and other meetings, APS presents the findings of the work that has been completed. Much of the research presented at these meetings is eventually documented in various reports.

In 2006-07, the following meetings were held:

1) Standing Committee Meeting, Ottawa, Canada, September 2006;
2) SAE G-12 HOT Subcommittee and HOT Working Group Meetings, Montreal, Canada, November 2006;
3) SAE G-12 HOT Subcommittee Working Group Meeting, Montreal, Canada, May 2007;
4) SAE G-12 HOT Subcommittee Meeting, San Diego, US, May 2007; and
5) ROGIDS Working Group Meetings, Atlantic City, US, November 2006, and Toronto, Canada, April 2007.

The presentations given by APS at each of these meetings are listed in the following subsections. Copies of the presentations are contained in Appendix F.

### 6.2.1 Standing Committee Meeting, Ottawa, Canada, September 2006

Three presentations were prepared for the Standing Committee for Operations Under Icing Conditions meeting held in Ottawa on September 28, 2006:

1) De/Anti-Icing Fluid Holdover Time Update – 2006-07 Winter Operations;
2) Aircraft Deicing Research in Simulated Ice Pellet Conditions; and
3) Integration of Holdover Time Determination Systems into Canadian Airport Operations.

### 6.2.2 SAE G-12 HOT Subcommittee and HOT Working Group Meetings, Montreal, Canada, November 2006

Three presentations were prepared for the SAE G-12 HOT Subcommittee and HOT Working Group meetings held in Montreal in November 2006:

1) Lowest On-Wing Viscosity for Dilutions: Type II & IV Fluids (at both Working Group and Subcommittee);
2) Fluid Adhesion During Mixed Precipitation Conditions – Ice Pellets/Light Freezing Rain (Working Group); and
3) Fluid Adhesion During Mixed Ice Pellet Precipitation Conditions (Subcommittee).

### 6.2.3 SAE G-12 HOT Subcommittee Working Group Meeting, Montreal, Canada, May 2007

Four presentations were prepared for the SAE G-12 HOT Subcommittee Working Group meeting held in Montreal on May 1, 2007:

1) Summary of Holdover Time Developments from the 2006-07 Winter Test Season;
2) Preliminary Aircraft Ground Deicing Research Using Composite Materials;
3) Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions; and
4) Aircraft Deicing Research in Simulated Mixed Conditions with Ice Pellets.

### 6.2.4 SAE G-12 HOT Subcommittee Meeting, San Diego, US, May 2007

Six presentations were prepared for the SAE G-12 HOT Subcommittee meeting held in San Diego on May 14, 2007:

1) Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2006-07 Winter Test Season – Type I fluid;
2) Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2006-07 Winter Test Season – Type II fluid;

3) Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2006-07 Winter Test Season – Type III fluid;
4) Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2006-07 Winter Test Season – Type IV fluid;
5) Aircraft Deicing Research in Simulated Mixed Conditions with Ice Pellets; and
6) Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions.

### 6.2.5 ROGIDS Working Group Meetings

Two presentations were given at the ROGIDS Working Group meetings held in November 2006 in Atlantic City, US, and in April 2007 in Toronto, Canada, respectively:

1) Ice Disk Degradation Following De/Anti-Icing Application; and
2) Demonstration of Conditions for ROGIDS Performance Specification.

## 6.3 Fluid Manufacturer Reports

As part of the research program, several fluids are tested for holdover performance every year. Some of this data is then published for holdover time (HOT) use in the industry, while the remaining data is maintained by the fluid manufacturers for research purposes.

During the 2006-07 winter, seven fluids were tested. APS prepared a report for each fluid and provided these reports directly to the fluid manufacturers. Reports were prepared for the following:

1) Clariant Safewing MP IV Launch (snow only) (Type IV);
2) Kilfrost ABC-S PLUS (Type IV) (P1797A);
3) Kilfrost DFsustain (Type I);
4) Lyondell Arctic Shield® (Type IV);
5) Lyondell 6166 (Type IV);
6) Newave Aerochemical FCY-2 (Type II);
7) Xi'An High-Tech KHF-II (Type II); and
8) Octagon (Battelle) EcoFlo (Type I).

The reports for the qualified anti-icing fluids and Octagon (Battelle) EcoFlo Type I have also been included as appendices to TP 14776E (3).

## Table 6.1: List of Procedures for Winter 2006-07

| Program Element # | ID # | Program Element | Name of Procedure | Date of Latest Version | Version # | Report |
|---|---|---|---|---|---|---|
| 6.2.1 | 5.1 | INCLUSION OF ICE PELLETS IN HOLDOVER TIME GUIDELINES | Adhesion of Aircraft De/Anti-Icing Fluids on Aluminum Surfaces During Mixed Precipitation | 28-Aug-06 | 1.0 | IP ALLOWANCE |
| 6.2.1 | 5.2 | INCLUSION OF ICE PELLETS IN HOLDOVER TIME GUIDELINES | Photography of Mixed Ice Pellet Precipitation on Whatman's Filter Paper | 17-Nov-06 | 1.0 | IP ALLOWANCE |
| 6.2.1 | 5.3 | INCLUSION OF ICE PELLETS IN HOLDOVER TIME GUIDELINES | Endurance Time Testing in Mixed Ice Pellets and Snow Precipitation Conditions | 28-Nov-06 | 1.0 | IP ALLOWANCE |
| 6.2.1 | 5.4 | INCLUSION OF ICE PELLETS IN HOLDOVER TIME GUIDELINES | Operational Data Collection During Ice Pellet Precipitation Conditions | 29-Nov-06 | 1.0 | IP ALLOWANCE |
| 6.2.2 | 6.1 | AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME TESTING | Test Requirements for Simulated Freezing Precipitation Flat Plate Testing | 15-Jan-04 | 1.0 | HOT |
| 6.2.2 | 6.2 | AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME TESTING | Test Requirements for Natural Precipitation Flat Plate Testing | 23-Dec-04 | 1.0 | HOT |
| 6.2.2 | 6.3 | AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME TESTING | Endurance Time Test Requirements for Simulated Snow Flat Plate Testing | 19-Dec-06 | 1.0 | NCAR |
| 6.2.2 | 6.4 | AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME TESTING | Overall Program of Tests at NRC, March-April 2007 | 23-Mar-07 | 1.0 | HOT, IP ALLOWANCE |
| 6.2.2 | 6.5 | AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME TESTING | Determination of Endurance Times of Type I Fluids Under Natural Snow Precipitation at Dorval | 27-Feb-06 | 1.0 | HOT |
| 6.2.2 | 6.6 | AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME TESTING | Overall Program of Tests at NRC, July 2007 | 11-Jul-07 | 1.1 | HOT, IP ALLOWANCE, EFFECT OF HEAT |
| 6.2.3 | 7.1 | EVALUATION OF ENDURANCE TIMES IN HEAVY SNOW | Fluid Testing with Heavy Snow from Snowmaker in Comparison with Natural Snow | 20-Dec-06 | 1.0 | HEAVY SNOW |
| 6.2.3 | 7.2 | EVALUATION OF ENDURANCE TIMES IN HEAVY SNOW | Determination of Test Plate Temperature in Heavy Snow | 20-Dec-06 | 1.0 | HEAVY SNOW |

## Table6.1: List of Procedures for Winter 2006-07 (cont'd)

| Program Element # | ID # | Program Element | Name of Procedure | Date of Latest Version | Version # | Report |
|---|---|---|---|---|---|---|
| 6.2.3 | 7.3 | EVALUATION OF ENDURANCE TIMES IN HEAVY SNOW | Operational Data Collection During Heavy Snow Precipitation Conditions | 19-Dec-06 | 1.0 | HEAVY SNOW |
| 6.2.4 | 8.1 | ENDURANCE TIME TESTING IN FROST - TYPE I/II/III/IV FLUID | Exp. Program - Endurance Time Testing in Frost with Type I, II, III, and IV Fluids | 13-Nov-03 | 1.0 | FROST |
| 6.2.5 | 9.1 | ENDURANCE TIME TESTING OF NON-ALUMINUM PLATES | Type I Endurance Time Testing on Non-Aluminum Leading Edge Thermal Equivalent Boxes - Natural Snow | 17-Nov-06 | 1.0 | COMPOSITE |
| 6.3.1 | 14.1 | FLOW OF CONTAMINATED FLUID FROM AIRCRAFT WINGS DURING TAKEOFF (FALCON 20 TESTS) | Falcon 20 Trials to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets, Snow, and/or Freezing Rain | 5-Jan-07 | 1.0 | IP ALLOWANCE/ FEASIBILITY, HEAVY SNOW |
| 6.3.2 | 15.1 | FLOW OF CONTAMINATED FLUID FROM SIMULATED AIRCRAFT WINGS DURING TAKEOFF (WIND TUNNEL TESTS) | Wind Tunnel Tests to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets, Snow, and/or Freezing Rain | 21-Dec-06 | 1.0 | IP ALLOWANCE/ FEASIBILITY, HEAVY SNOW |
| 6.3.3 | 16.1 | FLOW OF TYPE IV FLUID ON DND CANADA AIRCRAFT | Support for Testing to Ascertain the Effects of SAE Type IV De/Anti-Icing Fluids on CC-130 Hercules and CP-140 Aurora Aircraft Takeoff Handling | 26-Jan-07 | 1.0 | DND |
| 6.3.3 | 16.2 | FLOW OF TYPE IV FLUID ON DND CANADA AIRCRAFT | Slipstream Survey: Support for Testing to Ascertain Fluid Displacement by Propeller Wash on CC-130 and CP-140 Aircraft | 26-Jan-07 | 1.0 | DND |
| 6.5.1 | 19.1 | SUPPORT FOR DEVELOPMENT OF PERFORMANCE SPECIFICATIONS FOR ROGIDS | Evaluation of Ice Disk Sample Decay Following Application of De/Anti-Icing Fluid | 6-Nov-06 | 1.0 | ROGIDS |
| 6.5.1 | 19.2 | SUPPORT FOR DEVELOPMENT OF PERFORMANCE SPECIFICATIONS FOR ROGIDS | NRC Feasibility Testing | 22-Mar-07 | 1.0 | ROGIDS |
| 6.6.1 | 20.1 | EVALUATION OF TEMPERED STEAM DEICING | Tempered Steam Deicing Tests with DND Aircraft | 27-Mar-07 | 1.0 | TEMPERED STEAM |

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# 7. AERODYNAMIC TESTING OF ANTI-ICING FLUIDS CONTAMINATED WITH HEAVY SNOW

The objective of this project was to determine the aerodynamic effects of heavily contaminated anti-icing fluid subjected to simulated heavy snow conditions. Aerodynamic testing was conducted in conjunction with the ice pellet allowance time research program. The research was documented in an interim report, which was provided to Transport Canada (TC) and the Federal Aviation Administration (FAA). A copy of the interim report is included in Appendix G.

## 7.1 Background and Objectives

The recent industry requirement for guidance material for aircraft operations in mixed conditions with ice pellets necessitated the use of aerodynamic testing due to the melting properties of ice pellets. Embedded ice pellets required a significantly longer time in comparison to snow to dissolve in anti-icing fluid; therefore, the standard protocol that is used to measure endurance times (ETs) could not be applied. As a direct result of the ice pellet research conducted, the use of holdover times (HOTs) for determining the protection time provided by anti-icing fluids was questioned. The focus was turned towards "aerodynamic failure," which would be defined as a significant lift loss due to the contamination of the anti-icing fluid. Heavy snow conditions were selected for this study for two reasons. First, snow conditions account for the most significant portion of deicing operations globally. Second, there has been recent industry interest in having HOTs for heavy snow conditions, as these conditions typically occur three percent of the time during snow events.

To benefit from economies of scale, TC and the FAA opted to conduct a series of preliminary tests to investigate the aerodynamic properties of heavily contaminated anti-icing fluid exposed to simulated snow conditions in conjunction with the ice pellet research being conducted at the National Research Council Canada (NRC) open circuit wind tunnel and with the Falcon 20 aircraft.

## 7.2 Data Collection and Testing

At the start of each aerodynamic test (both for the wind tunnel tests and the Falcon 20 tests), the test wing was treated with anti-icing fluid using a one-step operation. Simulated precipitation was then applied over the anti-iced test section until specified levels of contamination were achieved. Data such as fluid thickness, wing temperatures, and fluid freezing points was recorded. The wind tunnel and the Falcon 20 aircraft was then operated through a simulated takeoff test. The behaviour of the fluid during the simulated takeoff was documented with high-speed digital still cameras and video cameras.

During the wind tunnel tests, drag and lift data collected by the NRC was used to generate lift coefficient curves for each of the tests conducted in the wind tunnel. The lift data collected during contaminated fluid tests was compared to the data collected during the baseline *fluid only* and *dry-wing* tests. The Falcon 20 tests were primarily conducted as a verification of the results obtained in the wind tunnel using the NACA 23012 test wing section; lift data was not collected.

## 7.3 Conclusions

Visual observations during the wind tunnel tests reported residual contamination on the trailing edge of the wing section at the end of the heavy snow tests; the condition worsened as the precipitation rate was increased. During one test, some contamination was still present on the leading edge at the end of the test; the contamination was not adhered to the surface. Although this was visually deemed a severe condition, the lift data did not show significant lift losses directly attributable to the heavy snow contamination.

Visual contamination results obtained with the Falcon 20 confirmed the results obtained in the wind tunnel.

## 7.4 Recommendations

Further testing is recommended as a result of the observations made during the 2006-07 tests. It is recommended that additional testing be conducted at the NRC wind tunnel and with the Falcon 20 aircraft. Testing should be conducted in heavy snow conditions to determine the aerodynamic failure of a fluid following excessive exposure to precipitation. To obtain a visual benchmark, testing should also be conducted in light or moderate snow conditions, with contamination levels within the appropriate HOT, to obtain a visual reference of acceptable aerodynamic fluid flow-off.

# REFERENCES

1. Bender, K., D'Avirro, J., Eyre, F., Marcil, I., Pugacz, E., Sierra Jr., E. A., *Human Visual and Tactile Ice Detection Capabilities under Aircraft Post Deicing Conditions*, FAA, February 2006, DOT/FAA/TC-06/21, 113. Retrieved from http://www.tc.faa.gov/its/worldpac/techrpt/tc06-21.pdf

2. Balaban, G., Bell, K., D'Avirro, J., Ruggi, M., *Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2007, TP 14452E, 50.

3. Bendickson, S., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2006-07 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, November 2007, TP 14776E, 70.

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# APPENDIX A

## TRANSPORTATION DEVELOPMENT CENTRE
## WORK STATEMENT EXCERPT
## AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2006-07

# TRANSPORTATION DEVELOPMENT CENTRE
# WORK STATEMENT EXCERPT
# AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2006-07

## 6.1.3 Holdover Time Prediction Systems (Dan-Ice)

a) De/Anti-Icing Fluid Holdover Time Table Implications:

   i) Evaluate the DIIS' ability to compute "single-value" fluid holdover times based on recorded DIIS measurements of precipitation rate, precipitation type and temperature;

   ii) Examine the implications on air carrier operations, and therefore on air carrier deicing programs, of moving to "single-value" or extended fluid holdover times based on DIIS measurements; and

   iii) Examine the implications on regulatory guidance material and policies of moving to "single-value" or extended fluid holdover times based on DIIS measurements.

b) DIIS Implementation Issues and Obstacles:

   i) Conduct consultations with two (2) Canadian air carriers, two (2) airport authorities, and two (2) deicing service providers to examine and identify potential system implementation obstacles and issues; and

   ii) Propose strategies to resolve any concerns that arise from this activity.

## 6.27 Exploratory Research and Standards

a) Provide support to modifying and updating ARP5485;

b) Further develop, advance and ballot, as required, SAE Aerospace Recommended Practice ARP5945 for Type I fluids;

c) Develop or acquire viscosities for Clariant Type III, Clariant 1951, Kilfrost ABC-3 and also for the dilutions of all other fluids. Provide this information to the FAA and TC for their consideration for inclusion in the table of viscosities;

d) Prepare presentation of all changes agreed upon by the HOT workgroup meeting and deliver at the next SAE G-12 HOT Subcommittee meeting;

e) Support activities of SAE G-12 Field Viscosity Workgroup;

f) Support round robin testing of any new viscometer with all certified fluids to ensure safe levels;

g) Support activities of SAE G-12 Dry-Out Workgroup; and

h) Gather previous endurance time data collected in natural snow to determine if snow pellets were mixed with snow.

### 6.28 Participation In and Support of Fluid Certification Working Group

a) Participate in the workgroup regarding the certification process of aircraft de/anti-icing fluids;

b) Assist in the development of a new guideline that should be useful for:

   i) Fluid manufacturers;

   ii) Testing facilities; and

   iii) End-users.

## 6.4 Deicing Operations Research

### 6.1.4 Support to Dedicated Deicing Facility Operations Standardization, and New Deicing Approach Testing

a) Participate in the activities of the SAE G-12 Subcommittee for Deicing Facilities, including:

   i) Monitor the activities of the SAE G-12 Facilities Subcommittee, act as secretary and participate in sub-committee activities; consider the implications of the G-12 Facilities 'Environmental Task Force' guidelines; provide inputs as appropriate and co-ordinate TDC activities;

   ii) Monitor the on-going work of the SAE G-12 Equipment and Methods Sub-committees to assess the impact of their activities on Facility operations; and

   iii) Participate in the activities of the SAE G-12 Ground De-Icing Steering Committee and appropriate subcommittees.

### 6.4.1 Support to Development and Implementation of International Audit Pool for Aircraft Ground Deicing

a) Participate in the activities, work groups and task forces that will be set up by IATA to audit service providers to ensure safe deicing practices. Areas of interest include training and fluid quality; and

b) Promote the safety aspects to ensure that the Holdover Time Guidelines are being used properly and that the fluids are in accordance with the Lowest on Wing Viscosities stipulated in the guidance material published by TC and the FAA.

## 6.7 Research Information Dissemination

### 6.7.1 Provision of Support Services and Other Activities

a) Provide support services to assist TDC with testing, refining data, and reporting;

b) Present findings and prepare reports on each activity described herein; and

c) Maintain and update fluids information files.

### 6.7.2 Web Site for HOT Guidelines Tables

a) Ensure the website is operational, in terms of Internet availability, for a one-year period;

b) Maintain a log of proposed changes to be done on the website;

c) Update the website with data from new testing; and

d) Implement changes to the website and post the new HOT Guidelines in summer of 2007 for use in winter of 2007-08.

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# APPENDIX B

# PROPOSED AEROSPACE STANDARD 5681: MINIMUM OPERATIONAL PERFORMANCE SPECIFICATION FOR REMOTE ON-GROUND ICE DETECTION SYSTEMS

SAE Aerospace
An SAE International Group

# AEROSPACE STANDARD

| AS5681 | |
|---|---|
| Issued Proposed Draft (July 07) | |

## Minimum Operational Performance Specification for Remote On-Ground Ice Detection Systems

### RATIONALE

AS 5116, Minimum Operational Performance Specification for Ground Ice Detection Systems, has been cancelled. After review it was determined that the scope for AS 5116 was too broad and there is a need for separate standards for Remote On-Ground, Remote On-Board, and In-Situ Sensors.

This Minimum Operational Performance Specification, AS 5681, provides a standard for Remote On-Ground Ice Detection Systems (ROGIDS).

### FOREWORD

Exposure to weather conditions on the ground that are conducive to clear ice formation can cause aircraft surfaces and components to adversely affect aircraft performance, stability, and control.

Specific rules for aircraft operations in ground icing conditions are set forth in United States Federal Aviation Regulations (FAR's), (European) Joint Aviation Regulations (JAR's), Canadian Aviation Regulations (CAR's), and others. The intent of the applicable regulations is to ensure that no one attempts to dispatch an aircraft with frozen contamination adhering to any aircraft component critical to safe flight.

The Human Factors tests reported in FAA reports DOT/FAA/TC-06/20 and DOT/FAA/TC-06/21 have shown that, based on the particular conditions of the tests, remote on-ground sensors that meet the requirements of this standard perform more consistently and are more reliable than human visual, and/or tactile detection of clear ice on an aircraft critical surface in winter conditions.

Human Factors tests have demonstrated that in certain circumstances respect for the regulations may be most reliably achieved by use of remote on-ground sensors. These circumstances do not include the specific case of frost. Frost is generally readily detected visually, and may affect the takeoff performance of an aircraft at roughness levels below the reliable detection threshold of sensors available at the time of publication of this document.

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**Fax: 724-776-0790**
**Email: custsvc@sae.org**
**SAE WEB ADDRESS:** **http://www.sae.org**

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1. SCOPE

This SAE Aerospace Standard (AS)/Minimum Operational Performance Specification (MOPS) specifies the minimum performance requirements of Remote On-Ground Ice Detection Systems (ROGIDS). These systems are ground-based. They provide information that indicates whether frozen contamination is present on aircraft surfaces.

Chapter 1 provides information required to understand the need for the ROGIDS, ROGIDS characteristics, and tests that are defined in subsequent chapters. It describes typical ROGIDS applications and operational objectives and is the basis for the performance criteria stated in Chapter 3 through Chapter 5.

Chapter 2 provides reference information, including related documents, abbreviations and definitions.

Chapter 3 contains general design requirements for the ROGIDS.

Chapter 4 contains the Minimum Operational Performance Requirements for the ROGIDS, which define performance in icing conditions likely to be encountered during ground operations.

Chapter 5 describes environmental test conditions that provide laboratory means of testing the overall performance characteristics of the ROGIDS in conditions that may be encountered in actual operations.

Chapter 6 describes recommended test procedures for demonstrating compliance with Chapters 3 and 4.

Chapter 7 contains the operational evaluation requirements for verifying the performance of the ROGIDS when installed for in-service use.

1.1 Applications of This Document:

Compliance with this AS/MOPS ensures that the ROGIDS will satisfactorily perform its intended functions.

Compliance with this AS/MOPS does not necessarily constitute compliance with regulatory requirements. Any application of this document in whole or in part is the sole responsibility of the appropriate regulatory agencies. It is recommended to seek guidance from the regulatory agencies before developing any test plans or test procedures. The manufacturer should confer with the regulatory agencies to determine those tests that need to be witnessed or performed by the regulatory agencies or other acceptable entity(s) and any associated reporting requirements.

The measured values of the ROGIDS performance characteristics may be a function of the method of measurement. Therefore, controlled test conditions and methods of testing are recommended in this document.

Mandating and Recommendation Phrases:

a. “Shall”

The use of the word “shall” indicates a mandated criterion; i.e., compliance with the particular procedure or specification is mandatory and no alternative may be applied.

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b. "Should"

The use of the word "should" (and phrases such as, "it is recommended that...", etc.) indicates that although the procedure or criterion is regarded as the preferred option, alternative procedures, specifications or criteria may be applied, provided that the manufacturer, installer or tester can provide information or data to adequately support and justify the alternative.

1.2 Safety

While the materials, methods, applications, and processes described or referenced in this procedure may involve the use of hazardous materials, this procedure does not address the hazards that may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and processes, and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

1.3 Functional Description of System

The function of ROGIDS is to detect clear ice on aircraft surfaces.

ROGIDS are intended to be used during aircraft ground operations to inform the ground crew and/or the flight crew and/or a relevant system about the condition of monitored aircraft surfaces.

ROGIDS make a remote measurement of a monitored surface, and may be hand held, pedestal or vehicle mounted.

The ROGIDS may provide an alternative to the visual and tactile post-deicing checks required by aviation regulatory agencies, including the European Aviation Safety Agency (EASA), the United States Federal Aviation Administration (FAA) and Transport Canada Civil Aviation (TCCA), to determine the condition of aircraft critical surfaces in operating conditions involving freezing contamination. Approval for the use of ROGIDS as an advisory or primary means of performing post-deicing checks rests with the appropriate regulatory agency.

In addition, the ROGIDS may also supplement visual and tactile pre-deicing checks for clear ice. Approval for the use of ROGIDS as an advisory means of performing pre-deicing checks rests with the appropriate regulatory agency.

1.4 The ROGIDS should typically include:

a. At least one sensor that is directly or indirectly sensitive to the physical phenomena of aircraft icing during weather conditions consistent with ground icing operations.
b. A processing unit to perform signal processing. The unit may either be integrated with or separate from the sensor(s).
c. A device to provide information to the flight and/or ground crew.

2. REFERENCES

2.1 Applicable Documents

Unless otherwise specified, the current versions of the following publications form a part of this document. 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.

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2.1.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org

| | |
|---|---|
| AMS 1424 | Deicing Anti-icing, Aircraft, Fluid, SAE Type I |
| AMS 1428 | Deicing Anti-icing, Fluid, Aircraft, Non-newtonian (Pseudoplastic), SAE Types II, III, and IV |
| ARP 1971 | Aircraft Deicing Vehicle Self-Propelled, Large and Small Capacity |
| ARP 4256 | Design Objectives for Liquid Crystal Displays for Part 25 (Transport) |
| ARP 4737 | Aircraft Deicing/Anti-icing methods |
| ARP 5485 | Endurance Time Tests For Aircraft Deicing/Anti-icing Fluids SAE Type II, Type III and Type IV |
| ARP 5945 | Endurance Time Tests For Aircraft Deicing/Anti-Icing Fluids SAE Type I |
| ARP 926 | Fault/Failure Analysis Procedure |
| ARP 4761 | Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment |
| SAE J1211 | Recommended Environmental Practices for Electronic Equipment Design |

2.1.2 RTCA/ EUROCAE or SAE/ EUROCAE Publications

RTCA documents (DO) available from RTCA, One McPherson Square, 1225 K Street N.W., Suite 500, Washington, DC 20005.

EUROCAE Documents (ED) available from EUROCAE, 17, rue Hamelin 75783 PARIS, Cedex 16, France, Tel: +33 1 45 05 71 88, eurocae@compuserve.com

| | |
|---|---|
| RTCA DO-160/ ED-14/ | Environmental Conditions and Test Procedures for Airborne Equipment |
| RTCA DO-178/ ED-12/ | Software Considerations in Airborne Systems and Equipment Certification |
| RTCA DO-216 | Minimum General Specification for Ground-Based Electronic Equipment |
| RTCA DO-254/ED-80 | Design Assurance Guidance for Airborne Electric Hardware |

2.1.3 US Government Publications

FAA/FAR/AC documents available from Federal Aviation Administration 800 Independence Avenue, SW Washington, DC 20591, Tel: 1-866-TELL-FAA (1-866-835-5322), www.faa.gov/regulations_policies /faa_regulations

| | |
|---|---|
| AC 00-34A | Aircraft Ground Handling and Servicing |

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| | |
|---|---|
| AC 20-117 | Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing |
| AC 120-58 | Pilot Guide for Large Aircraft Ground Deicing |
| AC 120-60 | Ground Deicing and Anti-Icing Program |
| AC 135-16 | Ground Deicing & Anti-Icing Training & Checking |
| AC 135-17 | Pilot Guide - Small Aircraft Ground Deicing |
| AC 150/5300-14 | Design of Aircraft Deicing Facilities |
| DOT/FAA/TC-06/20 | Comparison of Human Ice Detection Capabilities and Ground Ice Detection System Performance under Post-deicing Conditions http://www.tc.faa.gov/acb300/Techreports/TC06_20_GIDS.pdf |
| DOT/FAA/TC-06/21 | Human Visual and Tactile Ice Detection Capabilities under Aircraft Post Deicing Conditions http://www.tc.faa.gov/acb300/Techreports/TC06_21_GIDS_new.pdf |
| FAR Part 91 | General Operating and Flight Rules |
| FAR Part 121 | Certification and Operations: Domestic Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft |
| FAR Part 125 | Certification and Operations: Airplanes Having a Seating Capacity of 20 or More Passengers or a Maximum Payload Capacity of 6,000 Pounds or More |
| FAR Part 129 | Operations: Foreign Air Carriers and Foreign Operators of U.S.- Registered Aircraft Engaged in Common Carriage |
| FAR Part 135 | Air Taxi Operators and Commercial Operators |
| HF-STD-001 | FAA Human Factors Design Standard http://acb220.tc.faa.gov/hfds/default.htm |
| Code of Federal Regulations, Title 47: | Federal Communications Commission Part 15 – Radio Frequency Devices Section 15.109 Radiated Emission Limits |

2.1.4 JAA Publications

JAA/JAR documents are available from JAA, Saturnusstraat 8-10 PO Box 3000 2130 KA Hoofddorp The Netherlands, Tel: +31 23 5679 764, publications@jaa.nl, www.jaa.nl.

JAA/Leaflet #4 to JAR/OPS1 Ice and Other Contaminants Procedures

| | |
|---|---|
| JAR-1 | Definitions and Abbreviations |
| JAR TSO | Joint Technical Standard Orders |
| JAR/OPS 1, [2] | Commercial Air Transportation (Aeroplanes) |

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2.1.5 Transport Canada Publications

Transport Canada documents are available fom Transport Canada, Tower C, Place de Ville, 330 Sparks Street Ottawa, Ontario K1A 0N5, Tel: 1-800-305-2059, www.tc.gc.ca.

| | |
|---|---|
| TP 14449 | Development of Ice Samples for Visual and Tactile Ice Detection Capability Tests |
| TP 14450 | Development of Ice Samples for Comparison Study of Human and Sensor Capability to Detect Ice on Aircraft |
| TP 14452 | Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS5681 (not yet published) |
| TC-CASS 622.11 | Commercial Air Service Standard - Ground Icing Operations Standard |
| TC CAR 602.11 | Canadian Aviation Regulation - Aircraft Icing |

2.1.6 CEN/IEC/ISO Publications

CEN/EN documents available from CEN, 36, rue de Stassart B-1050 Brussels, Tel: +32 2 550 0811, infodesk@cenorm.be.

| | |
|---|---|
| CEN 50081-2 | Electromagnetic compatibility - Generic emission standard - Part 2: Industrial environment |
| CEN 50082-2 | Electromagnetic compatibility - Generic immunity standard - Part 2: Industrial environment |

2.1.7 ARINC Publications

Available from ARINC, 2551 Riva Road, Annapolis, MD 21401, www.arinc.com.

| | |
|---|---|
| ARINC-415 | Operational and Technical Guidelines on Failure Warning and Functional Test |
| ARINC-604 | Guidance for Design and Use of Built-in Test Equipment (BITE) |

2.1.8 Weather Related Publications

WMO documents are available from World Meteorological Organization, P.O. Box 2300, CH-1211, Geneva 2, Switzerland, Tel: 617 227 2425, wmopubs@ametsoc.org.

World Meteorological Organization Aerodrome Reports and Forecasts – Doc No. 782, revised 1 Jan 1996

2.2 Definitions and Abbreviations

2.2.1 Definitions

ANTI-ICING: A precautionary procedure that provides protection of an aircraft against the formation of frost or ice and accumulation of snow or slush on treated surfaces of the aircraft for a limited period of time.

CLEAR ICE: Clear ice forms at temperatures at or below 0ºC, often associated with a high concentration

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of large supercooled water droplets. It can also be a residual product of an incomplete deicing process. Clear ice is hard, and appears as a smooth and glassy coating that can be very difficult to detect without a tactile inspection. Clear ice may not be seen during a walkaround, particularly if the wing is wet or during night-time operations. Clear ice can occur inflight or on the ground. Clear ice adheres firmly to surfaces, is difficult to remove, and requires special care during deicing/anti-icing.

DEICING: A procedure by which frost, ice, snow or slush is removed from the aircraft in order to provide aerodynamically clean surfaces. This is typically performed using heated (at least $60^0$C) deicing fluid.

DEICING EVENT: A deicing event is the series of action required to deice and inspect one aircraft, culminating with the release of that aircraft in what is considered to be a state compliant with the ground icing regulatory requirements.

DEICING (and ANTI-ICING) FLUIDS: The fluids used for conduct of the deicing (and anti-icing) procedures. These are typically ethylene or propylene glycol based.

FALSE NEGATIVE: An indication of the absence of frozen contamination when frozen contamination is present on the reference surface.

FALSE POSITIVE: An indication of the presence of frozen contamination when no frozen contamination is present on the reference surface.

DEICING/ANTI-ICING FLUID FAILURE: When the deicing/anti-icing fluid can no longer absorb incoming precipitation and provide protection from the adherence of frozen contamination on treated surfaces. Characteristics of fluid failure can be surface freezing or snow accumulation, random snow accumulation and/or dulling of surface reflectivity caused by the gradual deterioration of the deicing/anti-icing fluid, possibly indicated by the presence of frozen contamination in or on the de/anti-icing fluid.

FROZEN CONTAMINATION/CONTAMINANTS: For the purpose of this AS/MOPS: frost, ice, snow, slush.

ILLUMINANCE: The amount of visible light power incident per unit area of a surface; measured in lux (lumens/meter$^2$) or foot-candles (Lumens/foot$^2$)

LATENT FAILURE: A latent failure is one that is inherently undetected when it occurs.

MAXIMUM DETECTION ANGLE: The maximum angle with respect to the surface being monitored that the ROGIDS sensor can be aimed and still be expected to achieve the performance specified in this MOPS.

MAXIMUM DETECTION DISTANCE: The furthest the ROGIDS sensor can be from the surface being monitored that the ROGIDS sensor can be aimed and still be expected to achieve the performance specified in this MOPS.

MINIMUM DETECTION ANGLE: The minimum angle with respect to the surface being monitored that the ROGIDS sensor can be aimed and still be expected to achieve the performance specified in this MOPS.

MINIMUM DETECTION DISTANCE: The closest the ROGIDS sensor can be to the surface being monitored that the ROGIDS sensor can be aimed and still be expected to achieve the performance specified in this MOPS.

MONITORED SURFACE: The surface of concern regarding ice hazard.

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PRE-DEICING CHECK: An examination of an aircraft's wings and/or other critical surfaces to check for the presence of frozen contamination. Usually performed to determine the need for deicing.

POST-DEICING CHECK: An examination of an aircraft's wings and/or other critical surfaces after a deicing has been performed to determine the presence of any remaining frozen contamination.

Ra: Average surface roughness.

ROGIDS: A system that makes a remote measurement of a monitored surface to determine whether frozen contamination is present.

SYSTEM: A combination of components which are inter-connected to perform one or more functions.

2.2.2 Abbreviations

| | |
|---|---|
| AC | Advisory Circular (FAA) |
| AMJ | Advisory Material Joint (JAA) |
| ARINC | Aeronautical Radio, Inc. |
| ARP | Aerospace Recommended Practice |
| AS | Aerospace Standard |
| BIT | Built In Test |
| BITE | Built In Test Equipment |
| CEN | Comité Européen de Normalisation. European Committee for Standardisation. Europäisches Komitee für Normung. |
| EASA | European Aviation Safety Agency |
| EN | Norme Européenne. European Standard. Europäische Norm. |
| EUROCAE | The European Organisation for Civil Aviation Equipment |
| FAA | Federal Aviation Administration (USA) |
| FAR | Federal Aviation Regulations (USA) |
| FOD | Foreign Object Damage |
| FPD | Freezing Point Depressant; used to qualify the nature of deicing/anti-icing fluids |
| FTA | Fault Tree Analysis |
| GIDS | Ground Ice Detection System |
| IEC | International Electricity Committee |
| ISO | International Organization for Standardization |

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| | |
|---|---|
| JAA | Joint Aviation Authorities (Europe) |
| JAR | Joint Aviation Requirements (Europe) |
| min | Minute |
| MOPS | Minimum Operational Performance Specification |
| MTBF | Mean Time Between Failure |
| OAT | Outside Air Temperature |
| ROGIDS | Remote On-Ground Ice Detection System(s) |
| RTCA | Radio Technical Commission for Aeronautics |
| TC - CAR | Transport Canada - Civil Aviation Requirements |
| TC | Transport Canada (Canadian Civil Aviation Authority) |

3. GENERAL DESIGN REQUIREMENTS

3.1 Introduction

This chapter identifies general design considerations for ROGIDS.

3.2 Complex Hardware and Software Design

The design of complex hardware such as large scale integrated circuits shall follow the guidelines specified in document RTCA DO-254/EUROCAE ED-80. The hardware criticality level will depend on the particular ROGIDS function and application.

3.2.1 Software design

Software design shall follow the guidelines specified in document RTCA DO-178/EUROCAE ED-12. The software criticality level will depend on the particular ROGIDS function and application.

3.3 Technical Requirements

3.3.1 Materials

Materials should be of a quality which experience and/or tests have demonstrated to be suitable and dependable for use in the ROGIDS.

3.3.2 Workmanship

All components shall be fitted properly and firmly in their appropriate positions. All electrical connections shall be mechanically secured and electrically sound. Care shall be given to neatness and thoroughness of soldering, wiring, welding, brazing, surface treatments, painting, screwed and bolted assemblies, marking of parts and assemblies, and elimination of burrs and sharp edges.

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3.3.3 Mean Time Between Failure (MTBF)

The manufacturer shall report the MTBF.

3.3.4 Electrical Bonding and Grounding

The ROGIDS grounding system should provide for separation of AC power, DC power, chassis ground and signal ground(s). Optionally, signal ground(s) may be "referenced" to chassis ground. Wire shields shall not be used as a signal return.

On non-conductive enclosures, controls or metal parts which may be touched shall be bonded to ground. Case ground shall not be used for electrical power returns. Materials, surface preparation and finishes for electric bonding surfaces shall be compatible with preservation of adequate electrical conductivity over the life of the ROGIDS. The maximum resistance across any bonding or grounding junction shall be 0.25 Ω, as manufactured.

3.3.5 Interchangeability

All major components having the same part number shall be interchangeable with each other physically and functionally.

3.3.6 Marking

Permanently and legibly mark each major component with the following information:

1. Name and address of the manufacturer.
2. The name, type, part number or model designation of the component.
3. The serial number and the date of manufacture of the component.

If the component includes software, the part number shall either include hardware and software identification, or use separate part numbers for hardware and software identification. The part number shall uniquely identify the hardware and software design, including modification status.

3.4 Exposure During Normal Operations

ROGIDS parts exposed to the external environment should be designed to withstand the temperature, pressure, chemical and/or radiation environment associated with deicing/anti-icing conditions. ROGIDS parts exposed to the external environment should be designed to withstand impact from ice particles shed from the aircraft and remain functional.

3.5 Foreign Object Damage (FOD)

The ROGIDS should be constructed so that in the normal operating environment parts do not become loose in service and create a FOD hazard.

3.6 Human Factors

Design of any ROGIDS should include consideration of the applicable human factors enumerated in FAA Human Factors Design Standard HF-STD-001. As a minimum, each design shall consider the following factors:

3.6.1 Installation

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Mounting location is dependent on local factors. For vehicle mounted units this includes vehicle type, cab type, and optional equipment installed.

Mounting of the ROGIDS shall not interfere with the primary deicing/anti-icing functions of the deicing equipment. The mounting location of the sensor shall be such that it can obtain a clear scan of aircraft surfaces to be monitored. The ROGIDS display shall be mounted in a location easily visible to the operator responsible for checking the monitored surface during or after deicing/anti-icing operations.

The ROGIDS shall be compatible with the physical and environmental conditions of installation. Installation of the equipment should permit ease of access for maintenance and testing. Each element of the ROGIDS shall be designed, or distinctly and permanently marked, to minimize the probability of incorrect assembly that could result in the malfunctioning of the system.

3.6.2 Hazards

The ROGIDS shall not present a hazard to personnel or property when in normal use. ROGIDS using laser-based or other potentially hazardous imaging technologies shall use an eye-safe design.

3.6.3 Interface Design

The display design shall:

a. Utilize natural and meaningful symbology that is readily understood.

b. Provide information that is immediately discernible. Results provided by the system shall be readily interpretable by a trained operator.

c. Provide a clear indication when the ROGIDS is inoperative.

d. Provide adequate display readability during normal operating conditions.

e. In the event that the display does not encompass the entire surface to be checked, the interface shall be designed in a way that allows the operator to clearly identify the location of the area displayed in relation to the overall wing (or other entire surface to be checked). This is to ensure that no part of the surface to be checked has been omitted or erroneously duplicated.

3.7 Safety Requirements

3.7.1 Safety Assessment

A structured safety assessment shall be conducted to evaluate the failure modes and their effects on system operation.

The intent is to ensure that ground and flight crew are not presented with misleading information (false negatives) generated by system malfunctions which would allow dispatch and takeoff of an aircraft with contamination on the critical surfaces within the performance defined in Chapters 4 and 5 of this AS/MOPS. System malfunctions may include:

a. Malfunctions that are readily detected by the trained operator; and
b. Malfunctions not detectable by the trained operator.

Acceptable structured assessment procedures include but are not limited to:

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a. System Safety Assessment;
b. Functional Hazard Assessment;
c. Failure Modes and Effects Analysis; and
d. Fault Tree Analysis.

Appropriate software and hardware design assurance levels shall be selected based on a structured safety assessment process.

ROGIDS shall be designed, installed, operated, and maintained according to applicable safety standards defined by the authority having jurisdiction.

Overall equipment failure rate, including active failures, shall be provided by the ROGIDS manufacturer.

3.7.2 Latent Failure Rate

Appendix D contains background material and rationale for the determination of the acceptable latent failure rate.

The acceptable rate for latent failures that lead to false negatives shall be on the order of 1 in 10,000 deicing events ($10^{-4}$ per deicing events).

Fault Tree Analysis and Failure Modes and Effects Analysis shall be conducted and documented to establish that the equipment false negative rate due to malfunction is less than the acceptable rate as defined above.

3.8 ROGIDS Operation

3.8.1 ROGIDS Controls

The operation of ROGIDS controls in all possible positions, combinations and sequences, shall not be detrimental to the continued normal operation of the ROGIDS.

ROGIDS controls that are not intended to be adjusted in normal operation shall not be readily accessible to the ground crew.

3.8.2 Data Processing

Following acquisition, the processing and interpretation of data by the ROGIDS shall be automatic.

The system shall be designed in such a manner as to preclude the display of invalid output data.

3.8.3 Built In Test Equipment (BITE)

The ROGIDS shall include a confidence (BITE) test. The test function shall be automatic during operation.

The BITE shall support the safety objectives and the reliability requirements of this document. BITE shall provide a clear indication of detected ROGIDS failures to the operator.

3.8.4 Nuisance Alarms

Nuisance alarms should be minimized.

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3.8.5 Operating Weather Conditions

The ROGIDS shall perform its intended function during weather conditions consistent with ground icing operations.

3.9 Qualification Tests

3.9.1 Responsibility for Testing

The manufacturer of the product shall be responsible for the performance and documentation of all required tests specified in Chapters 5, 6 and 7 to demonstrate compliance with this AS/MOPS.

3.9.2 Test Article

The tests shall be conducted with one or more ROGIDS that are in full conformity with production build.

3.10 Test Plan(s)

The manufacturer shall prepare a test plan or test plans detailing at a minimum the following:

a. Purpose of Test;
b. Scope;
c. Test article configuration (the test shall be conducted with one or more ROGIDS that are in full conformity with the production build);
d. Applicable and reference documents;
e. Test administration:
    1. Test activities and Responsibilities; and
    2. Quality assurance.
f. Test Documentation and data recording/capture;
g. Pass/Fail Criteria;
h. Pass/Fail Reporting;
i. Actions to be taken in event of failure;
j. Test Equipment:
    1. Calibration;
    2. Safety and Hazards; and
    3. Material and handling.
k. Test Procedures to be prepared; and
l. Test Reports to be prepared.

3.11 Test Procedures

The manufacturer shall prepare test procedures detailing at a minimum the following:

a. Purpose;
b. Scope;
c. Test article configuration (the test shall be conducted with one or more ROGIDS that are in full conformity with the production build);
d. Applicable and reference documents;

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e. General Instructions:
   1. Test activities and Responsibilities;
   2. Quality Assurance and Inspection;
   3. Standard Test Conditions;
   4. Test Equipment Calibration; and
   5. Test Documentation.

f. Test Equipment Hardware and Software;

g. Test Configuration;

h. Test Sequence;

i. Test Procedures

j. Pass/Fail Criteria;

k. Pass/Fail Reporting; and

l. Actions to be taken in event of failure.

3.12 Test Report

The ROGIDS manufacturer shall prepare a test report detailing the following:

a. The part number and serial number, which identifies the ROGIDS as tested, and hardware/software revision numbers as applicable;

b. A description of the test facility and test procedures used; and

c. Results of all tests and technical data that substantiate the manufacturer's performance specifications.

The foregoing information shall be cross referenced to the appropriate sections of this AS/MOPS.

3.13 Compliance checklist

The manufacturer shall provide a declaration that design, verification, validation, testing and analysis confirms that the equipment complies with all the requirements of this document. A compliance checklist shall be provided to facilitate this task. It is acceptable for the compliance check to provide a cross reference between requirements in this document and manufacturer documents demonstrating compliance.

3.14 Manufacturer's Performance Specifications

The manufacturer shall provide performance specifications for the ROGIDS. These shall incude the maximum and minimum detection distances and angles.

3.15 Operating Procedures

A set of operating procedures for each specific ROGIDS shall be developed.

The manufacturer shall clearly identify all operational limitations.

4. MINIMUM PERFORMANCE SPECIFICATION

This chapter defines the minimum performance criteria that shall be used for the design of ROGIDS.

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4.1 Frozen Contamination Detection

ROGIDS shall be able to detect and communicate the presence of:

a. Clear Ice Pre-Deicing;
b. Residual Clear Ice Post-deicing; and
c. Residual Clear Ice Post-deicing During Precipitation.

ROGIDS performance standards for detection of frost, snow and slush on a critical surface have not been defined.

ROGIDS performance related to the detection of frost, snow and/or slush may be addressed in future versions of this document.

4.1.1 Detection Threshold

The ROGIDS detection threshold shall ensure the detection of clear ice of 0.5 mm thickness or less, continuously distributed over an area of 315 cm², or less.

4.1.2 Ice Above the Detection Threshold

The ROGIDS shall detect and indicate the presence of ice on the monitored surface in excess of the detection threshold.

4.2 Monitored Surface Finish, Illumination Conditions, and ROGIDS Performance

The material, the surface finish and/or the surface treatment of the monitored surface shall not adversely affect the ROGIDS performance.

The ROGIDS shall not be adversely affected by the transition between two or more surface finishes and/or illumination conditions.

4.3 Fluid Foaming Effects

The ROGIDS performance shall not be affected by foaming in applied deicing/anti-icing fluids.

5. MINIMUM PERFORMANCE SPECIFICATION IN ENVIRONMENTAL TEST CONDITIONS

5.1 Introduction

a. The environmental tests described in this section will determine the ROGIDS ability to operate in conditions representative of those that may be encountered in actual operation.

b. Tests 1-7 in Table 1, Required Tests, are mandatory. All seven tests shall be completed in full and passed.

c. Unless otherwise specified, the tests shall be conducted using ALL components of the ROGIDS.

d. Tests 1-6 specified in Table 1 have been adapted from RTCA DO-160E: *Environmental Conditions and Test Procedures for Airborne Equipment.* Guidance for adapting the specified DO-160E tests to ROGIDS testing is provided in the comments section for each test.

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e. For Test 4 in Table 1 (Fluids Susceptibility - ROGIDS External Components), it is permissible to remove the internal components of the ROGIDS for the duration of the test. However, Test 5 in Table 1 (Fluids Susceptibility - ROGIDS System) shall be performed using a fully functioning ROGIDS.

f. Table 2 provides a series of recommended tests. While these tests are optional, it is strongly recommended that tests from this list that apply to the operational environment in which the ROGIDS will be used be performed, and that the test results be reported.

5.1.1 Alternative References

In addition to recommended tests 9 and 16 in Table 2, SAE Surface Vehicle Recommended Practice J1211 is a good source of information on the environmental challenges electronic equipment face in the automotive environment, and contains useful optional additional test recommendations and procedures.

5.2 Test Plan, Procedures, and Reports

A test plan and test procedures shall be prepared in accordance with Subsections 3.10 and 3.11.

A report of test results shall be prepared in accordance with Subsection 3.12.

All test procedures shall be documented. Where physical facility limitations exist which influence the set-up and conduct of the tests, these limitations shall be noted.

5.3 Acceptance Criteria

In some of the tests specified in Tables 1 and 2, an ice detection test is called for in the comments column. The purpose of this test is to determine whether the ROGIDS has survived the environmental test and can still detect ice.

When “Perform an ice detection test” is called for in the comments column of the tests in Tables 1 and 2, at a minimum the following shall be done:

Using the four test plates described in Appendix B (Table B1 – Test Plates), develop a patch of clear ice of 0.5 mm thickness and a circular area of 315 $cm^2$ on each plate. A method for development of the ice patch is described in Transport Canada publications TP 14449 and TP 14450. There is no need for deicing/anti-icing fluid during this test; therefore the test plates may be mounted vertically, perpendicular to the ROGIDS. Place the ROGIDS at the manufacturer’s specified minimum operational distance from the test samples. Take an individual image of each of the four ice patches. Place the ROGIDS at the manufacturer’s specified maximum operational distance from the test samples. Take an individual image of each of the four ice patches. If the ROGIDS correctly detects all four patches at both the minimum and maximum operational distances (a total of 8 correct images), the test is passed. If the ROGIDS does not correctly detect all four ice patches at both the minimum and maximum operational distances, the test is failed.

The ice detection test described above shall also be used when DO 160E states DETERMINE COMPLIANCE WITH APPLICABLE EQUIPMENT PERFORMANCE STANDARDS.

5.4 Actions To Be Taken In Event Of Failure

If it is determined that the failure of a test may have been caused by incorrect environmental conditions or test setup it is permissable to correct those deficiencies and rerun that test.

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If it is determined that the failure of a test is due to system deficiency, the deficiency shall be corrected and all tests shall be rerun with the new system, unless the manufacturer can prove conclusively that the correction will only affect a limited set of tests.

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**TABLE 1 – REQUIRED TESTS**

| Test # | CONDITIONS | APPLICABLE DOCUMENT | COMMENTS |
|---|---|---|---|
| 1 | Ground Survival Low Temperature Test and Short-Time Operating Low Temperature Test. | DO-160E/ ED14E Section 4.5.1 | Use Category B3. The test shall be performed on all ROGIDS components exposed to the external environment. Use a survival low temperature of -40°C and a short-time operating low temperature of -30°C.<br>Conduct an ice detection test (see AS 5681, Section 5.3), during the Short-Time Operating Temperature Test – 'operate and test period' (DO-160E, Figure 4-1, T4 to T5). |
| 2 | Operating Low Temperature Test. | DO-160E/ ED14E Section 4.5.2 | Use Category B1 and a low temperature of -30°C. The test shall be performed on all ROGIDS components exposed to the external environment.<br>Conduct an ice detection test (see AS5681, Section 5.3) during the test period (DO-160E, Figure 4-2, T2 to T3). |
| 3 | Temperature Variation. | DO-160E/ ED14E Section 5 | Use temperature change rate Category A, with +25°C as the test operating high temperature.<br>In the test procedure described in DO-160E, Section 5.3.1, for Paragraphs C and E, perform the ice detection test (see AS5681, Section 5.3) at the end of the temperature change period instead of performing "DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS" during the temperature change period. |
| 4 | Fluids Susceptibility – ROGIDS External Components | DO-160E/ ED14E Section 11 | Perform only the spray test (DO 160E, Section 11.4.1). This test may be performed using only the ROGIDS enclosure(s) and external components (including cables, wiring harnesses and connectors) exposed to the external environment (The internal electronic and mechanical components may be removed.) Perform the Test with Neat (undiluted) propylene glycol-based SAE Anti-Icing Fluid Types II, III, and IV at +23°C.<br>Tests with different fluid types may be run concurrently on separate identical systems.<br>DO-160E specifies that the equipment be operated for 10 minutes at the end of the 24-hour spray test. This is not required in this test.<br>At the completion of the 24-hour spray test, conduct a thorough visual inspection of all components (enclosures, windows, cables, connectors, seals, etc). All components shall show no evidence of corrosion or functional deterioration. Verify that there is no deicing/anti-icing fluid ingress into any enclosure, connector or cable.<br>The "DETERMINE COMPLIANCE WITH THE APPLICABLE EQUIPMENT PERFORMANCE STANDARDS" test called for at the end of the 160 hour heating cycle is optional.<br>Conduct the Waterproofness Test (Table 1, Test 6) immediately following the completion of the Fluids Susceptibility – ROGIDS External Components Test on all test specimens. Verify that there is no water ingress at the completion of the Waterproofness Test. |

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**TABLE 1 (cont'd) – REQUIRED TESTS**

| Test # | CONDITIONS | APPLICABLE DOCUMENT | COMMENTS |
|---|---|---|---|
| 5 | Fluids Susceptibility - ROGIDS System | DO-160E/ ED14E Section 11 | Perform only the Spray Test (DO-160E, Section 11.4.1). The test shall be performed on all ROGIDS components exposed to the external environment. Perform the test using a Neat propylene glycol-based SAE Type I Deicing Fluid, diluted to a 50% concentration with water, and heated to +50°C. This test shall be performed using a fully functional ROGIDS system.<br>For the 160 hour heating cycle, the test shall be run at the manufacturer's specified maximum survival temperature.<br>Conduct the 'Waterproofness Test' (Table 1, Test 6) immediately following the completion of the 'Fluids Susceptibility – ROGIDS System Test' on all components. Verify that there is no water ingress at the completion of the 'Waterproofness Test'. |
| 6 | Waterproofness | DO-160E/ ED14E Section 10 | Note: This test is performed at the end of Tests 4 and 5. It does not need to be repeated separately.<br>Use Category R. The test shall be performed on all ROGIDS components exposed to the external environment. |
| 7 | Radio Frequency Emission | FCC 15.109(B) | Category FCC Class A |

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**TABLE 2 – RECOMMENDED TESTS**

| Test # | CONDITIONS | DOCUMENTS SECTION | COMMENTS |
|---|---|---|---|
| 1 | Ground Survival High Temperature Test and Short-Time Operating High Temperature Test | DO-160E/ ED14E Section 4.5.3 | Use a ground survival high temperature of +60°C. For the Short-Time Operating High Temperature Test, use the manufacturer's specified short-time operating high temperature. |
| 2 | Operating High Temperature | DO-160E/ ED14E Section 4.5.4 | Perform the test using an operating high temperature of at least +25 °C. |
| 3 | Operational Shock | DO-160E/ ED14E Section 7 And/Or SAE J1211 Section 4.8 | Categories A and D (DO-160E) |
| 4 | Vibration | DO-160E/ ED14E Section 8 And/Or SAE J1211 Section 4.7 | Category S (DO-160E) |
| 5 | Sand and Dust | DO-160E/ ED14E Section 12 And/Or SAE J1211 Section 4.5 | Category S (DO-160E). |
| 6 | Fungus Resistance | DO-160E/ ED14E Section 13.0 | |
| 7 | Salt Fog | DO-160E/ ED14E Section 14 | This test is required if the ROGIDS is to be used in a salt atmosphere or exposed to salt fog. |
| 8 | Magnetic Effect | DO-160E/ ED14E Section 15 | |

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**TABLE 2 (cont'd) – RECOMMENDED TESTS**

| Test # | CONDITIONS | DOCUMENTS SECTION | COMMENTS |
|---|---|---|---|
| 9 | Power input | SAE J1211 Sections 4.9, 4.10, 4.11 | |
| 10 | Voltage spike | DO-160E/ ED14E Section 17 And/Or ISO 7637-2 | Category B (DO-160E) |
| 11 | Icing | DO-160E/ ED14E Section 24 | Category C |
| 12 | Electrostatic Discharge | DO-160E/ ED14E Section 25 | |
| 13 | Audio Frequency Susceptibility | DO-160E/ ED14E Section 18 | |
| 14 | Induced Signal Susceptibility/EMI | DO-160E/ ED14E Section 19 | |
| 15 | Radio Frequency Susceptibility (ISO 7637) | EN 50082-2 Or DO160E Section 20 | |
| 16 | Humidity | DO160E/ ED14E Section 6.0 | Category C |

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6. MINIMUM OPERATIONAL PERFORMANCE TESTS

6.1 Performance Tests – General

The purpose of the performance capability tests is to demonstrate that the ROGIDS complies with the Minimum Performance Specification.

Appendix A lists the tests to be performed. Appendices B and C give the test parameters.

Conduct tests for the detection of clear ice:

a. In a controlled (laboratory) environment with and/or without deicing/anti-icing fluids, and in visibility conditions associated with rain and with freezing fog;

b. Under foamed fluid in a controlled (laboratory) environment;

c. In natural conditions with deicing/anti-icing fluids, and in visibility conditions associated with snow; and

d. On a wing surface in natural light conditions.

6.1.1 Test Plan, Procedures, and Reports

Detailed test plans, test procedures, and a report of test results shall be prepared.
The test procedures, ice thickness and area measurements, combined fluid thickness, fluid names, sensor sight angle and distance, visibility conditions, precipitation characteristics, and detection results for each test conducted shall be documented.

All test procedures, including the test set-up, and any deviations, and/or non-conformances to the test procedures shall be documented. Where physical facility limitations exist which influence the set-up and conduct of the tests, these limitations shall be noted.

6.1.2 Power Input Voltage

Unless otherwise specified, all tests shall be conducted at the designed power input voltage. The input voltage shall be measured at the equipment input terminals.

6.1.3 Power Input Frequency

In the case of equipment designed for operation from an AC power source of essentially constant frequency, tests shall be conducted at the designed input frequency.

6.1.4 Warm-up Period

All tests shall be conducted after the warm-up period specified by the manufacturer.

6.1.5 Test Parameters

Conduct tests using:

a. Flat test plates representative of aircraft surface materials and finishes (Appendix B, Table B1 and Figure B1); and

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b. Deicing and anti-icing fluids meeting SAE specifications (AMS 1424 and AMS 1428).

For test purposes, the following surfaces have been selected: bare aluminum; grey, white and red painted aluminum; white and red painted fiber reinforced composite; and deicing boot material.

6.2 Tests in Simulated Precipitation Conditions

The test conditions listed below were designed for testing in simulated precipitation conditions. These tests may be performed in equivalent natural conditions.

6.2.1 Test Applications

The tests for ROGIDS in a controlled environment address three applications:

a. Detection of Clear Ice Pre-Deicing;
b. Detection of Residual Clear Ice Post-deicing; and
c. Detection of Residual Clear Ice Post-deicing During Precipitation.

6.2.2 Test Principles

To demonstrate the capability to identify clear ice, the artificial precipitation conditions created in a temperature-controlled climatic chamber are considered to be consistent with natural icing conditions.

The tests have been adapted from and use similar principles as laboratory test procedures used to establish endurance times for aircraft deicing/anti-icing fluids (SAE Types I, II, III, and IV). These test procedures are described in SAE ARP 5485 and SAE ARP 5945.

6.2.3 Detection of Clear Ice Pre-Deicing

6.2.3.1 Test Outline

Conduct tests in Appendix A, Table A1, to demonstrate the capability of a ROGIDS to identify clear ice on an untreated surface.

a. Ensure the plates are clean and dry. The ambient air temperature is recommended to be less than or equal to -5°C.

b. Develop a circular layer of clear ice on each plate. Ensure the clear ice has a maximum thickness of 0.5 mm and a maximum area of 315 cm².

c. Take an image of the test plate with the ROGIDS.

d. Measure and record the ice thickness. Record any false positive indication on the area of the plate not covered by clear ice.

e. Complete for all the illumination conditions defined in Appendix C. The illumination conditions that will be considered include daylight, night-time illumination and a condition with shadows on the test plate.

f. Tests shall be completed with the ROGIDS placed at two locations:

    1. Far - A ROGIDS at manufacturer's specified minimum operational sight angle and maximum distance.

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2. Near - A ROGIDS at manufacturer's specified minimum distance and maximum operational sight angle.

g. False Positive Tests: Once each clear ice test is complete, a plate without clear ice will be placed above the original plate and tests shall be carried out with the ROGIDS in the far and near locations for each illumination condition.

6.2.3.2 Pass/Fail Criteria

a. False negatives

For each test in test set 1 (pre-deicing) the ROGIDS shall always correctly detect and indicate the presence of clear ice on each half or quadrant of the clear ice sample irrespective of:

1. The plate finish under the clear ice;
2. Illumination of clear ice sample;
3. Sensor location (near, far); and
4. Ambient Air Temperature.

b. False positives

For each clean plate test in test set 1 the ROGIDS shall not indicate the presence of ice irrespective of:

1. The plate finish;
2. Illumination of plate;
3. Sensor location (near, far); and
4. Ambient Air Temperature.

6.2.4 Detection of Residual Clear Ice Post-deicing

6.2.4.1 Test Outline

Conduct the tests in Appendix A, Table A2, to demonstrate the capability of a ROGIDS to identify residual clear ice beneath a deicing/anti-icing fluid layer. For these tests commercially available ethylene and propylene glycol based Type I, II, III and IV deicing/anti-icing fluids shall be used. If the ROGIDS is intended to be used with other glycol based fluids (e.g. diethylene) or non-glycol based fluids, then additional tests with these fluids will be required.

a. Ensure the plates are clean and dry. The ambient air temperature is recommended to be less than or equal to -5°C.

b. Develop a circular layer of clear ice on each plate. Ensure the clear ice has a maximum thickness of 0.5 mm and a maximum area of 315 cm² after the deicing/anti-icing fluid has been applied. For the thick ice test the ice thickness shall be 10 mm ± 1mm. For these tests the plates shall be horizontal in order to ensure a consistent and representative deicing/anti-icing fluid thickness over the ice.

c. Prior to application of the fluid, ensure that the ROGIDS is capable of detecting the ice. Measure and record the ice thickness.

d. Apply the appropriate fluid tempered and prepared in accordance with Appendix B, B.2. A

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retainer placed on the plate may be used to ensure that the required thickness is achieved. The procedure for the application of the fluid is as follows:

1. Apply Type I fluid to produce an average fluid thickness of 0.1 mm ± 0.05 mm.
2. Apply Type II fluid to produce an average fluid thickness of 3.0 mm ± 0.5 mm.
3. Apply Type III fluid to produce an average fluid thickness of 1.0 mm ± 0.02 mm.
4. Apply Type IV fluid to produce an average fluid thickness of 3.0 mm ± 0.5 mm.

e. Perform the test.

f. One clear ice sample may be used for more than one test.

NOTE: The fluid will dissolve the clear ice; therefore minimize the time between the fluid application and the performance of the test.

g. Complete under the night-time illumination conditions.

h. Complete with the ROGIDS placed at two locations:

1. Far - A ROGIDS at manufacturers specified minimum operational sight angle and maximum distance.
2. Near - A ROGIDS at manufacturers specified minimum distance and maximum operational sight angle.

i. False positive tests: Perform the tests with all fluids. Once each of the tests using 0.5 mm ice samples are completed, plates without ice shall be placed above the original plates and tests with fluid only shall be carried out with the ROGIDS in the far and near locations.

6.2.4.2 Pass/Fail Criteria

a. False negatives

For each test in test set 2 (post-deicing), the ROGIDS shall detect and indicate the presence of clear ice on each half or quadrant of the clear ice sample irrespective of:

1. The plate finish under the clear ice
2. Illumination of clear ice sample
3. Sensor location (near, far)
4. Ice thickness
5. Fluid type

b. False positives

For each of the clean plate tests in test set 2, excluding Tests 2-25, 2-26, 2-27, 2-28, 2-53, 2-54, 2-55 and 2-56, the ROGIDS shall not indicate the presence of ice irrespective of:

1. The plate finish
2. Fluid type
3. Sensor location (near, far)

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6.2.5 Detection of Residual Clear Ice Post-deicing During Precipitation

6.2.5.1 Test Outline

Conduct the tests in Appendix A, Table A3 to demonstrate the capability of a ROGIDS to identify residual clear ice beneath a deicing/anti-icing fluid layer in the obscured visibility conditions specified in Appendix B. For these tests, propylene glycol based Type I and IV deicing/anti-icing fluids shall be used.

a. Ensure the plates are clean. The recommended ambient air temperature for each test is specified in Table A3.

b. Develop a circular layer of clear ice on each plate. Ensure the clear ice has a maximum thickness of 0.5 mm and a maximum area of 315 cm² after the deicing/anti-icing fluid has been applied. For this test the plates shall be horizontal in order to ensure a consistent and representative deicing/anti-icing fluid thickness over the clear ice.

c. Create the specified precipitation conditions encompassing the ROGIDS field of view.

d. Prior to application of the fluid, ensure that the ROGIDS is capable of detecting the clear ice. Measure and record the ice thickness.

e. Apply the appropriate fluid tempered and prepared in accordance with Appendix B, B.2. A retainer placed on the plate may be used to ensure that the required thickness is achieved. The procedure for the application of the fluid is as follows:

   1. Apply Type I fluid to produce an average fluid thickness of 0.1 mm ± 0.05 mm.
   2. Immediately following the Type I fluid application, apply the Type IV fluid over the Type I fluid to produce an average combined fluid thickness of 3 mm ± 0.5 mm.

f. Perform the test.

g. One clear ice sample may be used for more than one test.

   NOTE: The fluid will slowly dissolve the clear ice; therefore minimize the time between the fluid application and the performance of the test.

h. Complete tests for all the illumination conditions listed in the test matrix in Appendix A, Table A3, and defined in Appendix C. The illumination conditions that shall be considered include daylight, night-time illumination and a condition with shadows on the test plate.

i. Complete tests with the ROGIDS placed at the far location (the manufacturer's specified minimum operational sight angle and maximum distance).

j. False positive tests: Repeat the tests on plates without ice. Once each ice test is complete, a plate without ice will be placed above the original plate and tests with fluid only shall be performed with the ROGIDS at the far location.

6.2.5.2 Pass/Fail Criteria

a. False negatives

For each test in test set 3 (post-deicing with precipitation) the ROGIDS shall detect and indicate the presence of clear ice on each half or quadrant of the clear ice sample irrespective of:

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1. The plate finish under the clear ice;
2. Illumination of clear ice sample;
3. Sensor location (far);
4. Fluid types;
5. Ambient Air Temperature; and
6. Precipitation.

b. False positives

For each designated clean plate test in test set 3 the ROGIDS shall not indicate the presence of ice irrespective of:

1. The plate finish;
2. Illumination of plate;
3. Sensor location (far);
4. Fluid types;
5. Ambient Air Temperature; and
6. Precipitation.

6.3 Fluid Foaming Effects (in Laboratory)

Verify that the ROGIDS performance is not affected by foaming of applied deicing fluids. A specially formulated fluid (described below) shall be applied as specified in the following test procedure.

The test surface shall be a flat aircraft type 2024 aluminum alloy plate painted with grey polyurethane (as described in Appendix B, Table B1, Note 1), 1 m x 1.5 m long with the long edge inclined at 10° to the horizontal.

6.3.1 Test Outline for Fluid Foaming Effects

Conduct the test with a 315 $cm^2$ circular ice patch centered laterally 125 cm from the top of the plate. As the fluid is warm, the ice will melt. Thus the initial ice patch thickness will, by necessity, be greater than 0.5 mm. Ensure the resulting ice patch thickness for the test is not more than 0.5 mm.

The environmental conditions for the test shall be as follows:

1. No precipitation; and
2. The ambient air temperature shall be -10°C or lower.

6.3.1.1 Fluid Preparation

a. Fluid Composition

The fluid used shall be a specially formulated fluid that replicates the foaming characteristics of certain deicing fluids. The formulation of the fluid shall consist of the components given in Table 3.

CAUTION: This fluid is for testing purposes only, and not for use in aircraft deicing procedures.

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**Table 3: Formulation for Foaming Test Deicing Fluid***

| COMPONENT | PERCENT BY WEIGHT |
|---|---|
| Propylene Glycol | 61.0 |
| Water | 38.5 |
| Dioctyl sulfosuccinate docusate sodium | 0.5 |

* This mixture shall result in a fluid with a Brix of approximately 38°. The fluid shall be homogeneous and completely miscible with water.

b. Equipment for Fluid Foaming

Use a laboratory blender (Waring model number 7012G, or equivalent) with a 1 L glass mixing container.

c. Modification and Calibration of Equipment

In order to measure the speed of the blender, the following modification is recommended: Place the blender on a stand and elongate the rotating shaft at the base. Use a non-contact optical tachometer to measure the rotation speed with the mixing container in place. Place 700 mL of the test fluid in the 1 L glass container and determine the dial setting in order to get a mix speed of 3400 rpm ±200 rpm.

d. Heating of Fluid

Heat 2000 mL of the test fluid to +60°C ±5°C (140°F ±9°F).

e. Foaming of Fluid

Separate the fluid into three equal batches. Pour the fluid into the blender glass container and mix each batch for 15 seconds at a speed of 3,400 rpm ± 200 rpm.

6.3.1.2 Fluid Application

Apply the 2000 mL of fluid to the plate immediately below the upper edge in a uniform back-and-forth motion to distribute the fluid as evenly as possible. Apply the fluid within 90 seconds of blending the first batch of fluid. Ensure that the ice patch is covered with the foamed fluid.

6.3.1.3 Conduct of Test

Conduct the test with the ROGIDS placed at the far location (at manufacturer's specified minimum operational sight angle and maximum distance) in the night-time illumination condition.

Photographs of the foamed fluid and the ice sample shall be taken at the end of the test and shall be included in the test report.

6.3.1.4 Pass/Fail Criteria

a. The ROGIDS shall not indicate the presence of ice where none is present; and
b. The ROGIDS shall indicate the presence of ice where ice is present.

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6.4 Testing in Natural Conditions – Snow Precipitation Tests

There is no practical method available for generation of artificial snow that has all of the important characteristics of natural snow for testing of ROGIDS over the necessary distances. Therefore, the snow tests shall be conducted outdoors in natural snow conditions.

6.4.1 Purpose of the Tests

The purpose of the tests is to demonstrate that the ROGIDS complies with the minimum performance specifications for the detection of clear residual ice covered with deicing/anti-icing fluids in obscured visibility conditions associated with natural snow.

6.4.2 Test Principles

The tests have been adapted from and use the same principles as laboratory test procedures to establish Endurance Times for aircraft deicing/anti-icing fluids (SAE Types I, II, III, and IV). These test procedures are described in SAE ARP5485 and SAE ARP5945.

6.4.3 Test Outline

Conduct the tests in Appendix A, Table A4 to demonstrate the capability of a ROGIDS to identify residual clear ice beneath a deicing/anti-icing fluid layer in the precipitation conditions specified in Appendix B. For these tests, propylene glycol based Type I and IV deicing/anti-icing fluids shall be used.

Conduct tests with snow precipitation between the plates and the sensor(s), and encompassing the sensor field of view. Protect the plates from precipitation until the start of the test.

a. Ensure the plates as defined in Appendix B are clean; the ambient air temperature is recommended to be less than or equal to 0°C.

b. Develop a circular layer of clear ice on each plate. Ensure the clear ice has a maximum thickness of 0.5 mm and a maximum area of 315 cm² after the deicing/anti-icing fluid has been applied. For this test the plates shall be horizontal in order to ensure a consistent and representative deicing/anti-icing fluid thickness over the clear ice.

c. Prior to application of the fluid, ensure that the ROGIDS is capable of detecting the clear ice. Measure and record the ice thickness.

d. Apply the appropriate fluid tempered and prepared in accordance with Appendix B, B.2. A retainer placed on the plate may be used to ensure that the required thickness is achieved. The procedure for the application of the fluid is as follows:

    1. Apply Type I fluid to produce an average fluid thickness of 0.1 mm ± 0.05 mm.

    2. Immediately following the Type I fluid application, apply the Type IV fluid over the Type I fluid to produce an average combined fluid thickness of 3 mm ± 0.5 mm.

e. Remove the plate protection and immediately perform the test.

f. One clear ice sample may be used for more than one test.

NOTE: The fluid will dissolve the ice; therefore minimize the time between the fluid application and the performance of the test.

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g. Conduct tests in both daylight and night-time natural conditions.

The maximum level of night-time illumination shall not exceed the level specified in Appendix C, Paragraph C2, 'Night-time illumination'.

h. Conduct tests with the ROGIDS placed at the far location (the manufacturer's specified minimum operational sight angle, and maximum distance).

i. False positive tests: Repeat the tests on plates without ice. Once each ice test is complete, a plate without ice will be placed above the original plate and tests with fluid only shall be performed with the ROGIDS at the far location.

6.4.3.1 Pass/Fail Criteria

a. False negatives

For each test the ROGIDS shall detect and indicate the presence of clear ice on each half of the clear ice sample irrespective of:

1. The plate finish under the clear ice;
2. Illumination of ice sample;
3. Sensor location (far);
4. Fluid types;
5. Temperature; and
6. Precipitation.

b. False positives

For each designated clean plate test in test set 4, the ROGIDS shall not indicate the presence of ice irrespective of:

1. The plate finish;
2. Illumination of plate;
3. Sensor location (far);
4. Fluid types;
5. Temperature; and
6. Precipitation.

6.5 Testing in Natural Conditions – Illumination

6.5.1 Purpose of Test

The purpose of this test is to verify that the ROGIDS performance is not adversely affected by natural and artificial visible and non-visible light typically found at deicing facilities.

6.5.1.1 Test Outline for Illumination Condition Effects

a. Conduct tests on a wing surface of at least 10 $m^2$ in two configurations: (a) wing clean and dry, and (b) wing treated with Type I fluid diluted per Appendix B.

b. Conduct tests at an operational deicing facility with typical lighting.

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c. The environmental conditions for the test shall be:

1. No precipitation;
2. Conduct one test in daylight under clear sky conditions;
3. Conduct one test at night-time;
4. Conduct 2 twilight tests. One morning twilight test (between half an hour before sunrise and sunrise) and one evening twilight test (between sunset and half an hour after sunset); and
5. An ambient air temperature of -10°C or lower is recommended to ensure that ice samples do not degrade.

A summary matrix of tests is given in Appendix A, Table A5.

d. Conduct tests with no ice present, and tests with ice patches ≤0.5mm thick ice over a circular area ≤315cm$^2$ at leading edge (LE), mid-chord, and trailing edge (TE) locations.

e. Apply Type I ethylene glycol or propylene glycol fluid to the section of the wing to be tested. The section of the wing that is treated shall include the ice patches, shall be greater than 10 m$^2$, and shall extend over the full chord.

f. Perform the test within a short period of time following fluid application to minimize ice patch degradation.

g. Complete with the ROGIDS placed at two locations:

1. Far - A ROGIDS at manufacturers specified minimum operational sight angle and maximum distance.
2. Near - A ROGIDS at manufacturers specified minimum distance and maximum operational sight angle.

6.5.1.2 Pass/Fail Criteria

a. The ROGIDS shall not indicate the presence of ice where none is present.
b. The ROGIDS shall indicate the presence of ice where ice is present.

6.6 Actions To Be Taken In Event Of Failure

If it is determined that the failure of a test may have been caused by incorrect environmental conditions or test setup it is permissable to correct those deficiencies and rerun that test.

If it is determined that the failure of a test is due to system deficiency, the deficiency shall be corrected and all tests shall be rerun with the new system, unless the manufacturer can prove conclusively that the correction will only affect a limited set of tests.

7. INSTALLED EQUIPMENT OPERATIONAL EVALUATION

Certain ROGIDS performance parameters may be affected by the end-user's physical installation and shall be verified after installation. This chapter specifies the operational evaluation that shall be performed to verify the performance of the ROGIDS when installed for in-service use.

7.1 Purpose of Evaluation

The purpose of the operational evaluation is to perform a qualitative assessment to verify that the

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ROGIDS performance is not adversely affected by normal operating conditions and environment.

The following are conditions or events that may adversely affect the operation of the ROGIDS:

a. Illumination effects;
b. Fluid foaming effects;
c. Compatibility with monitored surface (e.g., the ROGIDS shall not produce false positives due to the material, the surface finish and/or surface treatment of the monitored aircraft surface);
d. Effects of precipitation; and
e. Effects of non-frozen contaminants (e.g., grease, dirt, fuel) on the monitored surface.

7.2 General

The installed equipment operational evaluation addresses conditions arising during in-service operations that are not covered by the minimum operational performance tests of Chapter 6. Although ROGIDS may be hand-held, pedestal or vehicle mounted in-service, the evaluations specified in this chapter are based on a vehicle-mounted operation. Hand-held or pedestal mounted installations may warrant adaptation of this chapter, as appropriate.

The evaluation will be performed during actual aircraft deicing operations.

Prior to starting this evaluation, conduct a conformity inspection to ensure that the ROGIDS has been installed in accordance with the manufacturer's instructions.

The ROGIDS shall be operated in accordance with the manufacturer's operating procedures. During this evaluation the equipment shall not be subject to environmental conditions that exceed the manufacturer's specified operating environment.

Any ground-based electrical and mechanical equipment likely to be operated in proximity of the ROGIDS during normal operations shall be activated during this evaluation.

7.2.1 Operational Evaluation Plan, Procedures, and Reports

Detailed test plans, test procedures, and a report of test results shall be prepared in accordance with Section 3. Where physical facility limitations exist which influence the set-up and conduct of the operational evaluation, these limitations shall be noted.

7.2.2 Required Equipment and Personnel

At a minimum, conduct the evaluation using:

a. A ROGIDS installed on the vehicle in accordance with the manufacturer's installation instructions;
b. Operational aircraft when specified herein;
c. Deicing and anti-icing fluids meeting SAE specifications (AMS 1424 and AMS 1428); and
d. Operator(s) trained to use all equipment being used in the conduct of these tests.

7.3 Operational Evaluation

7.3.1 Evaluation Scenarios

The total number of deicing operations that will be evaluated will be provided in separate regulatory guidance material for the initial evaluation and follow-on evaluations. The evaluations shall include as wide a variety of the aircraft types and sizes expected to be deiced at the airport as possible. Table 4

provides guidance on the distribution of the various evaluation conditions.

**TABLE 4: Distribution of Evaluation Conditions**

| Condition[1] | Morning Twilight | Day | Evening Twilight | Night |
|---|---|---|---|---|
| | | | | |
| No Precipitation | 5% | 15% | 5% | 5% |
| Precipitation | 5% | 45% | 5% | 15% |

[1] 'No precipitation' evaluations should include frost. Precipitation evaluations shall include snow and should include other forms of precipitation, such as freezing drizzle, light freezing rain, freezing fog and rain on a cold-soaked wing.

7.3.2 Evaluation Conditions – Reporting Anomalies

Observe and note any anomolies in ROGIDS performance (e.g., false positives and false negatives) before and after fluid application due to the following:

a. Illumination effects: Artificial and natural;
b. Fluid foaming effects;
c. Compatibility with monitored surface;
d. Effects of precipitation;
e. Effects of non-frozen contaminants; and
f. Other.

Any anomalies identified during the evaluation shall be documented.

7.3.3 Display

Verify that the operator has an unobstructed view of the displayed data when in the normal operating position.

Display readability shall be adequate for data interpretation during normal operating conditions.

Verify that the display allows the operator to easily correlate the ROGIDS detection image with the surface being monitored.

7.3.4 Controls Accessibility and Operation

Verify that all necessary controls are readily accessible and operable from the operator's normal operating position.

7.3.5 Electromagnetic Interference Effects

Verify that the ROGIDS is not the source of electromagnetic interference to other equipment and is not adversely affected by electromagnetic interference from other equipment or systems.

7.3.6 Dynamic Effects

Verify that the ROGIDS performance is not adversely affected by dynamic conditions during normal operations (e.g. wind buffeting, or deicing vehicle vibration).

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7.3.7 Equipment Usability

Evaluate the ROGIDS usability in operational conditions to ensure that it performs its intended function without excessive workload such that the operators cannot be relied upon to perform their tasks accurately or completely.

7.3.8 Safety Precautions

Verify that there are no unusual characteristics or hazards to personnel or property (e.g., laser radiation, etc.) resulting from operation of the ROGIDS.

While the materials, methods, applications, and processes described or referenced in this procedure may involve the use of hazardous materials, this procedure does not address the hazards that may be involved in such use. It is the sole responsibility of the operator to ensure familiarity with the safe and proper use of any hazardous materials and processes, and to take the necessary precautionary measures to ensure the health and safety of all personnel involved.

7.4 Actions To Be Taken In Event Of Anomolies

Anomolies shall be investigated to determine the cause.

If it is determined that an anomoly is due to system (operator and/or equipment) deficiency, the deficiency shall be identified, corrected, and all tests shall be rerun with the new system, unless the manufacturer can prove conclusively that the correction will only affect a limited set of tests.

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PREPARED BY SAE SUBCOMMITTEE G-12ID, ICE DETECTION OF
COMMITTEE G-12, AIRCRAFT GROUND DEICING

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APPENDIX A: TEST MATRICES

TABLE A1: TEST SET 1 – DETECTION OF CLEAR ICE PRE-DEICING

| Test # | Test Plate | Sensor Location | Illumination |
|---|---|---|---|
| 1-1 | 1 | Far | Daylight |
| 1-2 | 2 | Far | Daylight |
| 1-3 | 3 | Far | Daylight |
| 1-4 | 4 | Far | Daylight |
| 1-5 | 1 | Near | Daylight |
| 1-6 | 2 | Near | Daylight |
| 1-7 | 3 | Near | Daylight |
| 1-8 | 4 | Near | Daylight |
| 1-9 | 1 | Far | Night-time |
| 1-10 | 2 | Far | Night-time |
| 1-11 | 3 | Far | Night-time |
| 1-12 | 4 | Far | Night-time |
| 1-13 | 1 | Near | Night-time |
| 1-14 | 2 | Near | Night-time |
| 1-15 | 3 | Near | Night-time |
| 1-16 | 4 | Near | Night-time |
| 1-17 | 1 | Far | Shadow |
| 1-18 | 2 | Far | Shadow |
| 1-19 | 3 | Far | Shadow |
| 1-20 | 4 | Far | Shadow |
| 1-21 | 1 | Near | Shadow |
| 1-22 | 2 | Near | Shadow |
| 1-23 | 3 | Near | Shadow |
| 1-24 | 4 | Near | Shadow |

Test Parameters:

1. Sensor Location: Minimum Sight Angle and Maximum Distance (Far) and Maximum Sight Angle and Minimum Distance (Near).
2. Precipitation Type: None
3. Recommended Temperature: ≤-5°C
4. Fluid Type Required: None
5. See Appendices B and C for definitions of parameters.

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TABLE A2: TEST SET 2 – DETECTION OF RESIDUAL CLEAR ICE POST-DEICING AT FAR LOCATION

| Test # | Test Plate | Fluid Type Required | Sensor Location |
|---|---|---|---|
| 2-1 | 1 | Type I (E base) over ice | Far |
| 2-2 | 2 | Type I (E base) over ice | Far |
| 2-3 | 3 | Type I (E base) over ice | Far |
| 2-4 | 4 | Type I (E base) over ice | Far |
| 2-5 | 1 | Type I (P base) over ice | Far |
| 2-6 | 2 | Type I (P base) over ice | Far |
| 2-7 | 3 | Type I (P base) over ice | Far |
| 2-8 | 4 | Type I (P base) over ice | Far |
| 2-9 | 1 | Type II (P base) over ice | Far |
| 2-10 | 2 | Type II (P base) over ice | Far |
| 2-11 | 3 | Type II (P base) over ice | Far |
| 2-12 | 4 | Type II (P base) over ice | Far |
| 2-13 | 1 | Type III (P base) over ice | Far |
| 2-14 | 2 | Type III (P base) over ice | Far |
| 2-15 | 3 | Type III (P base) over ice | Far |
| 2-16 | 4 | Type III (P base) over ice | Far |
| 2-17 | 1 | Type IV (E base) over ice | Far |
| 2-18 | 2 | Type IV (E base) over ice | Far |
| 2-19 | 3 | Type IV (E base) over ice | Far |
| 2-20 | 4 | Type IV (E base) over ice | Far |
| 2-21 | 1 | Type IV (P base) over ice | Far |
| 2-22 | 2 | Type IV (P base) over ice | Far |
| 2-23 | 3 | Type IV (P base) over ice | Far |
| 2-24 | 4 | Type IV (P base) over ice | Far |
| 2-25 | 1 | Type I (P base) over thick ice | Far |
| 2-26 | 2 | Type I (P base) over thick ice | Far |
| 2-27 | 3 | Type I (P base) over thick ice | Far |
| 2-28 | 4 | Type I (P base) over thick ice | Far |

Test Parameters:

1. Sensor Location: Minimum Sight Angle and Maximum Distance (Far).
2. Precipitation Type: None
3. Recommended Temperature: ≤-5°C
4. Illumination: Night-time
5. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol and E designates ethylene glycol.

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TABLE A2 CONTINUED: TEST SET 2 – DETECTION OF RESIDUAL CLEAR ICE POST-DEICING AT NEAR LOCATION

| Test # | Test Plate | Fluid Type Required | Sensor Location |
|---|---|---|---|
| 2-29 | 1 | Type I (E base) over ice | Near |
| 2-30 | 2 | Type I (E base) over ice | Near |
| 2-31 | 3 | Type I (E base) over ice | Near |
| 2-32 | 4 | Type I (E base) over ice | Near |
| 2-33 | 1 | Type I (P base) over ice | Near |
| 2-34 | 2 | Type I (P base) over ice | Near |
| 2-35 | 3 | Type I (P base) over ice | Near |
| 2-36 | 4 | Type I (P base) over ice | Near |
| 2-37 | 1 | Type II (P base) over ice | Near |
| 2-38 | 2 | Type II (P base) over ice | Near |
| 2-39 | 3 | Type II (P base) over ice | Near |
| 2-40 | 4 | Type II (P base) over ice | Near |
| 2-41 | 1 | Type III (P base) over ice | Near |
| 2-42 | 2 | Type III (P base) over ice | Near |
| 2-43 | 3 | Type III (P base) over ice | Near |
| 2-44 | 4 | Type III (P base) over ice | Near |
| 2-45 | 1 | Type IV (E base) over ice | Near |
| 2-46 | 2 | Type IV (E base) over ice | Near |
| 2-47 | 3 | Type IV (E base) over ice | Near |
| 2-48 | 4 | Type IV (E base) over ice | Near |
| 2-49 | 1 | Type IV (P base) over ice | Near |
| 2-50 | 2 | Type IV (P base) over ice | Near |
| 2-51 | 3 | Type IV (P base) over ice | Near |
| 2-52 | 4 | Type IV (P base) over ice | Near |
| 2-53 | 1 | Type I (P base) over thick ice | Near |
| 2-54 | 2 | Type I (P base) over thick ice | Near |
| 2-55 | 3 | Type I (P base) over thick ice | Near |
| 2-56 | 4 | Type I (P base) over thick ice | Near |

Test Parameters:

1. Sensor Location: Maximum Sight Angle and Minimum Distance (Near).
2. Precipitation Type: None
3. Recommended Temperature: ≤-5°C
4. Illumination: Night-time
5. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol and E designates ethylene glycol.

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TABLE A3: TEST SET 3 – DETECTION OF RESIDUAL CLEAR ICE POST-DEICING DURING PRECIPITATION – SIMULATED PRECIPITATION

| Test # | Precipitation Type | Precipitation Rate g/dm²/h | Recommended Temperature °C | Test Plate | Fluid Type Required | Illumination |
|---|---|---|---|---|---|---|
| 3-1 | Rain | 65-80 | > = -5 | 1 | Type IV P Over Type I P Over Ice | Daylight |
| 3-2 | Rain | 65-80 | > = -5 | 2 | Type IV P Over Type I P Over Ice | Daylight |
| 3-3 | Rain | 65-80 | > = -5 | 3 | Type IV P Over Type I P Over Ice | Daylight |
| 3-4 | Rain | 65-80 | > = -5 | 4 | Type IV P Over Type I P Over Ice | Daylight |
| 3-5 | Freezing Fog | Visibility <100m | <=-5 | 1 | Type IV P Over Type I P Over Ice | Daylight |
| 3-6 | Freezing Fog | Visibility <100m | <=-5 | 2 | Type IV P Over Type I P Over Ice | Daylight |
| 3-7 | Freezing Fog | Visibility <100m | <=-5 | 3 | Type IV P Over Type I P Over Ice | Daylight |
| 3-8 | Freezing Fog | Visibility <100m | <=-5 | 4 | Type IV P Over Type I P Over Ice | Daylight |
| 3-9 | Rain | 65-80 | > = -5 | 1 | Type IV P Over Type I P Over Ice | Night-time |
| 3-10 | Rain | 65-80 | > = -5 | 2 | Type IV P Over Type I P Over Ice | Night-time |
| 3-11 | Rain | 65-80 | > = -5 | 3 | Type IV P Over Type I P Over Ice | Night-time |
| 3-12 | Rain | 65-80 | > = -5 | 4 | Type IV P Over Type I P Over Ice | Night-time |
| 3-13 | Freezing Fog | Visibility <100m | <=-5 | 1 | Type IV P Over Type I P Over Ice | Night-time |
| 3-14 | Freezing Fog | Visibility <100m | <=-5 | 2 | Type IV P Over Type I P Over Ice | Night-time |
| 3-15 | Freezing Fog | Visibility <100m | <=-5 | 3 | Type IV P Over Type I P Over Ice | Night-time |
| 3-16 | Freezing Fog | Visibility <100m | <=-5 | 4 | Type IV P Over Type I P Over Ice | Night-time |
| 3-17 | Rain | 65-80 | > = -5 | 1 | Type IV P Over Type I P Over Ice | Shadow |
| 3-18 | Rain | 65-80 | > = -5 | 2 | Type IV P Over Type I P Over Ice | Shadow |
| 3-19 | Rain | 65-80 | > = -5 | 3 | Type IV P Over Type I P Over Ice | Shadow |
| 3-20 | Rain | 65-80 | > = -5 | 4 | Type IV P Over Type I P Over Ice | Shadow |
| 3-21 | Freezing Fog | Visibility <100m | <=-5 | 1 | Type IV P Over Type I P Over Ice | Shadow |
| 3-22 | Freezing Fog | Visibility <100m | <=-5 | 2 | Type IV P Over Type I P Over Ice | Shadow |
| 3-23 | Freezing Fog | Visibility <100m | <=-5 | 3 | Type IV P Over Type I P Over Ice | Shadow |
| 3-24 | Freezing Fog | Visibility <100m | <=-5 | 4 | Type IV P Over Type I P Over Ice | Shadow |

Test Parameters:

1. Sensor at Minimum Sight Angle and Maximum Distance (Far).
2. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol.

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TABLE A4: TEST SET 4 – DETECTION OF RESIDUAL CLEAR ICE POST-DEICING DURING PRECIPITATION – NATURAL SNOW

| Test # | Precipitation Type | Precipitation Rate g/dm²/h | Recommended Temperature ℃ | Test Plate | Fluid Type Required | Illumination |
|---|---|---|---|---|---|---|
| 4-1 | Snow | >15 and <50 | <=0 | 1 | Type IV P Over Type I P Over Ice | Daylight |
| 4-2 | Snow | >15 and <50 | <=0 | 2 | Type IV P Over Type I P Over Ice | Daylight |
| 4-3 | Snow | >15 and <50 | <=0 | 3 | Type IV P Over Type I P Over Ice | Daylight |
| 4-4 | Snow | >15 and <50 | <=0 | 4 | Type IV P Over Type I P Over Ice | Daylight |
| 4-5 | Snow | >15 and <50 | <=0 | 1 | Type IV P Over Type I P Over Ice | Night-time |
| 4-6 | Snow | >15 and <50 | <=0 | 2 | Type IV P Over Type I P Over Ice | Night-time |
| 4-7 | Snow | >15 and <50 | <=0 | 3 | Type IV P Over Type I P Over Ice | Night-time |
| 4-8 | Snow | >15 and <50 | <=0 | 4 | Type IV P Over Type I P Over Ice | Night-time |

Test Parameters:

1. Sensor Location: Minimum Sight Angle and Maximum Distance (Far).
2. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol.

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TABLE A5: TEST SET 5 – MATRIX OF ILLUMINATION CONDITION TESTS

| Test # | Fluid Type Required | Illumination | Sky Condition | Location of Ice |
|---|---|---|---|---|
| 5-1 | Dry Wing | Daylight | Clear | No ice |
| 5-2 | Dry Wing | Night-time | Any | No ice |
| 5-3 | Dry Wing | Morning | Twilight | No ice |
| 5-4 | Dry Wing | Evening | Twilight | No ice |
| 5-5 | Dry Wing | Daylight | Clear | Ice LE |
| 5-6 | Dry Wing | Night-time | Any | Ice LE |
| 5-7 | Dry Wing | Morning | Twilight | Ice LE |
| 5-8 | Dry Wing | Evening | Twilight | Ice LE |
| 5-9 | Dry Wing | Daylight | Clear | Ice mid-chord |
| 5-10 | Dry Wing | Night-time | Any | Ice mid-chord |
| 5-11 | Dry Wing | Morning | Twilight | Ice mid-chord |
| 5-12 | Dry Wing | Evening | Twilight | Ice mid-chord |
| 5-13 | Dry Wing | Daylight | Clear | Ice TE |
| 5-14 | Dry Wing | Night-time | Any | Ice TE |
| 5-15 | Dry Wing | Morning | Twilight | Ice TE |
| 5-16 | Dry Wing | Evening | Twilight | Ice TE |
| 5-17 | Type I (E base or P base) | Daylight | Clear | No ice |
| 5-18 | Type I (E base or P base) | Night-time | Any | No ice |
| 5-19 | Type I (E base or P base) | Morning | Twilight | No ice |
| 5-20 | Type I (E base or P base) | Evening | Twilight | No ice |
| 5-21 | Type I (E base or P base) | Daylight | Clear | Ice LE |
| 5-22 | Type I (E base or P base) | Night-time | Any | Ice LE |
| 5-23 | Type I (E base or P base) | Morning | Twilight | Ice LE |
| 5-24 | Type I (E base or P base) | Evening | Twilight | Ice LE |
| 5-25 | Type I (E base or P base) | Daylight | Clear | Ice mid-chord |
| 5-26 | Type I (E base or P base) | Night-time | Any | Ice mid-chord |
| 5-27 | Type I (E base or P base) | Morning | Twilight | Ice mid-chord |
| 5-28 | Type I (E base or P base) | Evening | Twilight | Ice mid-chord |
| 5-29 | Type I (E base or P base) | Daylight | Clear | Ice TE |
| 5-30 | Type I (E base or P base) | Night-time | Any | Ice TE |
| 5-31 | Type I (E base or P base) | Morning | Twilight | Ice TE |
| 5-32 | Type I (E base or P base) | Evening | Twilight | Ice TE |

Test Parameters:

1. Sensor Location: Minimum Sight Angle and Maximum Distance (Far) and Maximum Sight Angle and Minimum Distance (Near).
2. Precipitation Type: None
3. Recommended Temperature: ≤-10°C
4. See Appendices B and C for definitions of parameters.

Note: In the fluid type required column, P designates propylene glycol and E designates ethylene glycol.

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# APPENDIX B: DETAILED TEST PARAMETERS

## B.1 SCOPE

The test conditions required to demonstrate the ability of the ROGIDS to comply with the performance specifications of Chapters 3 and 4 use the same principles as laboratory test procedures to establish endurance times for aircraft deicing/anti-icing fluids (SAE Types I, II, III, and IV). These test procedures are described in SAE ARP5485 and SAE ARP5945.

### B.1.1 Safety

While the materials, methods, applications, and processes described or referenced in this procedure may involve the use of hazardous materials, this procedure does not address the hazards that may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and processes, and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

## B.2 FLUID SAMPLE SELECTION PROCEDURE FOR SAE TYPE I FLUIDS

### B.2.1 Requirements

B.2.1.1 Production Batch: The sample shall be a fluid taken from a manufacturer's production batch.

B.2.1.2 Fluid Selection: Fluid selection for Type I shall include ethylene glycol or propylene glycol based fluids as listed in Appendix A, Tables A2 and A3.

B.2.1.3 Fluid Concentration: All Type I fluid tests shall be performed using a fluid with a freezing point between -28°C and -43°C.

B.2.1.4 Manufacturer's Documentation:

(a) Fluid name, fluid type and batch number.
(b) The freezing point versus refraction at 20°C data for the fluid.

### B.2.2 Condition of the Sample to be Used for Test:

To minimize dissolving of the ice sample, it is strongly recommended that the fluid be applied as cold as possible, at a minimum, it should be applied 3°C above the freezing point of the fluid. The sample's refractive index shall be measured and recorded. Research has shown (Transport Canada publication *Feasibility of ROGIDS Test Conditions Stipulated in AS5681*) that lower levels of ice sample degradation occur when the temperature of the fluid is close to its freeze point.

## B.3 FLUID SAMPLE SELECTION PROCEDURE FOR SAE TYPE II, III, AND IV FLUIDS:

### B.3.1 Requirements

B.3.1.1 Production Batch

The sample shall be a neat sample taken from a manufacturer's production batch.

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B.3.1.2 Viscosity

The viscosity shall be equal to or greater than the lowest on-wing viscosity specified for the fluid in the specific holdover time (HOT) guidelines available from FAA or TC.

B.3.1.3 Fluid Selection

Fluid selection for Type II, Type III and Type IV shall include ethylene glycol or propylene glycol based fluids as listed in Appendix A, Tables A2 and A3.

B.3.1.4 Fluid Concentration: All tests shall be performed with neat 100% fluids.

B.3.1.5 Fluid Manufacturer's Documentation

a. Fluid name, fluid type and batch number.
b. The freezing point versus refraction at 20°C data for the fluid.

B.3.2 Condition of the Sample

To minimize dissolving of the ice sample, it is recommended that the fluid be applied as cold as possible; at a minimum, it should be applied above the freezing point of the fluid. The sample's refractive index shall be measured and recorded.

B.4 TEST PROCEDURE - GENERAL

B.4.1 Purpose

This section establishes the minimum requirements for test equipment and test procedures used to demonstrate the ability of the ROGIDS to comply with the performance specifications of Chapters 4 and 5.

Section B.4 covers requirements that are common to many or all conditions (except where otherwise noted). Section B.5 establishes the specific requirements for each precipitation condition.

B.4.2 ROGIDS Sensor and Plate Test Set-up

The size and surface finishes of the test plates shall be as described in Table B1 and are illustrated in Figure B1.

Develop the ice sample on each plate over a circular area of 315 cm². The ice sample shall be positioned so that it is equally distributed over both surface finishes of the pertinent test plates, where applicable. If the ice sample cannot be formed on the test surface the area where the ice sample is to be formed may be minimally roughened.

For the tests involving shadow illumination, the shadow shall be created to cover either the top or the bottom half of the ice sample, thereby creating four equal and distinct quadrants (two surface finishes, each with two illumination conditions on the sample).

Tests shall be performed with the ROGIDS placed at two locations unless otherwise noted:

a. Far: One ROGIDS at manufacturers specified minimum operational sight angle and maximum distance.
b. Near: One ROGIDS at manufacturers specified minimum distance and maximum operational sight angle.

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TABLE B1 – TEST PLATES

| | |
|---|---|
| **ALL TEST PLATES** | |
| Dimensions | 500 mm long x 300 mm wide. Recommended thickness = 3 mm |
| | |
| **TEST PLATE 1** | |
| Material | Aircraft type 2024 Aluminum alloy |
| Surface finish | Half area (150 mm wide) grey polyurethane (Note 1)<br>Half area bare aluminum (150 mm wide) Average surface roughness: Ra ≤ 0.2 µm |
| **TEST PLATE 2** | |
| Material | Aircraft type 2024 Aluminum alloy |
| Surface finish | Half area (150mm wide) white polyurethane (Note 1)<br>Half area (150 mm wide) red polyurethane (Note 1) |
| **TEST PLATE 3** | |
| Material | Fiber Reinforced Composite (Note 2) |
| Surface finish | Half area (150 mm wide) white polyurethane (Note 1)<br>Half area (150 mm wide) red polyurethane (Note 1) |
| **TEST PLATE 4** | |
| Material/ Surface finish | Deicing Boot Exterior Surface Material (Note 3) |
| | |

NOTES:

1. Test plate surfaces shall be prepared using typical aircraft surface preparation procedures. Record paint manufacturer, brand name, paint identification, and paint application method, and final finishing procedure.

2. Fiber reinforced composite surface shall be smooth and suitable for application of aircraft surface finishes.

3. The boot material should be attached to a flat test surface to give an exposed surface finish as near to flat as possible. Stretching the material may assist in this process.

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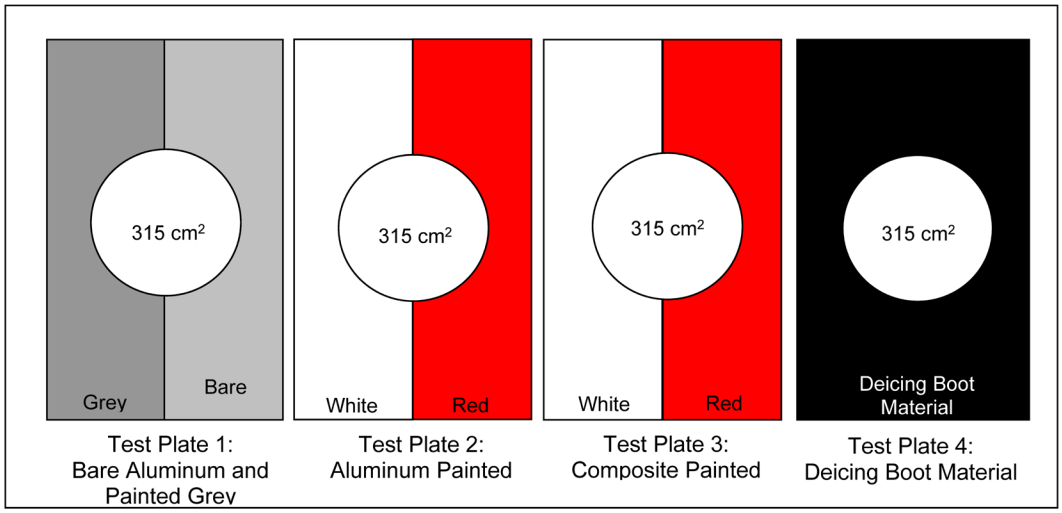


**FIGURE B1: Recommended Surface Finish and Ice Sample Location**

B.4.3 General Test Procedures

The tests may be run with multiple co-located plates (Table B1, Figure B1) and ROGIDS (far and near) simultaneously. If test facility constraints limit the evaluation of the ROGIDS, those limitations shall be documented and reported as per section 3.9.4.

B.4.3.1 Calibration and Measurement Methods: All test equipment used in the performance of these tests shall be identified by make, model, serial number and the calibration expiration date, and/or the valid period of calibration, where appropriate. When appropriate, all test equipment calibration standards shall be traceable to national and/or international standards.

B.4.3.2 Visibility: For visibility tests in freezing fog conditions, a calibrated airport transmissometer or equivalent equipment is recommended.

B.4.3.3 Suggested Methods for Ice Thickness Evaluation: A fluid film thickness gauge may be used. The gauge may be slightly heated to ensure that the reference surfaces of the gauge are directly in contact with the plate.

B.4.3.4 Test Plate Cleanliness: The test plates shall be free of all visible contamination, smears, or stains. Contamination shall be removed between test runs by washing with hot water immediately followed by an ethanol rinse. Allow the plates to dry after rinse and ensure that they are at the temperature required for the specific test.

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B.5 PRECIPITATION PARAMETERS FOR TESTING OF ROGIDS

B.5.1 Freezing Fog Test Equipment and Test Parameters

The environmental chamber and associated equipment shall be such that active precipitation is present between the ROGIDS and the test surface that is being detected. The spray equipment producing the precipitation shall provide a droplet median volume diameter of 22 µm ± 5 µm. The combination of precipitation rate and range shall be adjusted to give conditions equivalent to a field visibility of 100 m or less with the ROGIDS operating at its maximum range when in service. The ambient air temperature is recommended to be less than or equal to -5°C.

B.5.2 Rain Test Equipment and Test Parameters

The environmental chamber and associated equipment shall be such that active precipitation is present between the ROGIDS and the test surface that is being detected. The spray equipment producing the precipitation shall provide a droplet median volume diameter of 1000 µm ± 200 µm. The intensity shall be between 65 and 80 g/dm$^2$/h and the ambient air temperature is recommended to be ≥ -5$^0$C.

B.5.3 Snow Test Equipment and Test Parameters:

Tests shall be conducted in natural snow conditions with a precipitation rate ≥ 15 g/dm$^2$/h and ≤ 50 g/dm$^2$/h. Actual precipitation rate, wind speed, and temperature during the tests shall be recorded.

At the time of the publication of this document, no known technology exists to produce sufficient quantities of artificial snow, of an acceptable quality, in an environmental chamber. Therefore, until such equipment becomes available, the snow test shall be performed outdoors in natural conditions.

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## APPENDIX C: ILLUMINATION REQUIREMENTS

### C.1 PURPOSE

The purpose of this appendix is to define the illumination test requirements for daylight, night-time and shadow conditions.

Night-time illumination test conditions simulate the light levels during night-time or twilight deicing operations. Daylight illumination test conditions simulate the case of daylight deicing in full sunlight. Shadow test conditions simulate strong shadows on the inspected aircraft surface caused by sunlight being partially blocked by structures such as the aircraft fuselage or a deicing truck.

### C.2 ILLUMINATION REQUIREMENTS

The test plate illumination may be provided by natural light or, when the ROGIDS clear ice detection performance tests occur in a climatic chamber, by artificial sources located at an appropriate distance from the surface and oriented to eliminate direct (specular) reflections into the ROGIDS.

a. Night-time illumination

The average illumination on the test plate shall be between 100-500 lux (9-46 footcandles) [1] and color temperature of approximately 2100-3500K.

Artificial illumination used in a climatic chamber can be provided by diffused 150 watt high pressure sodium bulbs with a color temperature of 2,100 K [2].

Night-time illumination may be a combination of natural light and deicing pad illumination.

b. Daylight illumination

The illuminance on the test plate shall be greater than 25,000 lux (2,300 footcandles) and have a color temperature between 5500-6500$^0$K.

If testing in a climatic chamber, it is recommended to use 1000 watt metal halide bulbs with a color temperature between 5500 – 6500$^0$K. The light source should be placed directly above the test plates.

NOTE: High intensity lighting can cause premature melting of the ice samples.

Light bulb intensity and color temperature vary with the age of the bulb. The luminance and color temperature of the selected artificial lighting shall be verified via measurements at the test plate(s).

c. Shadow illumination

The illuminance on the test plate shall be greater than 25,000 lux (2,300 footcandles) and have a color temperature between 5500-6500$^0$K.

If testing in a climatic chamber, it is recommended to use 1000 watt metal halide bulbs with a color temperature between 5500 – 6500$^0$K. The light source should be placed directly above the test plates to provide a relatively sharp transition from direct light to shadow.

The shadow is created by fixing flat plates with straight edges in the path of the light source such that

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the shadow covers approximately half of the ice patch without obscuring the ROGIDS line of sight

CAUTION: High intensity lighting can cause premature melting of the ice samples.

Light bulb intensity and color temperature vary with the age of the bulb. The luminance and color temperature of the selected artificial lighting shall be verified via measurements at the test plate(s).

## References

1. Bond, D.S. and Henderson, F.P. The Conquest of Darkness, AD 346297, Defense Documentation Center, Alexandria, VA., 1963.

2. Kimberlea Bender, Edmundo A. Sierra, Jr., Isabelle Marcil, John D'Avirro, Edward Pugacz, and Frank Eyre, "Comparison of Human Ice Detection Capabilities and Ground Ice Detection System Performance Under Post Deicing Conditions", DOT/FAA/TC- 06/20 February 2006.

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APPENDIX D: DETERMINATION OF ROGIDS ACCEPTABLE LATENT FAILURE RATE

D.1 PURPOSE

This appendix describes the methodology and assessment used to determine an acceptable in-service rate of latent false negative output (i.e. misleading guidance to the operator) from a ROGIDS as a consequence of ROGIDS equipment malfunction. The appendix also contains background material and substantiation of numerical data used in making this assessment.

Active failures are not considered in the analysis because they will be annunciated by system BITE or detected by the operator. The ROGIDS is a ground-based system and any "active" failures will result in the failed equipment being removed from service and replaced with a fully functional ROGIDS, or by reversion to standard visual/tactile inspections.

D.2 BACKGROUND

Human Factors testing demonstrated that a ROGIDS could perform as well as, or better than, a human inspector for clear ice detection. This finding has allowed ROGIDS to be considered as a suitable candidate system for post-deicing inspection/detection on aircraft. To ensure consistent operational performance, the ROGIDS shall be shown to have acceptable false negative rates that could be caused by system malfunction. A false negative is defined as an indication by the ROGIDS of absence of frozen contamination when frozen contamination is present on the inspected surface. This is considered as misleading guidance to the end-user.

One method that could be used to determine an acceptable false negative rate is the Fault Tree Analysis (FTA) method. FTA was developed in 1962 for the U.S. Air Force by Bell Telephone Laboratories and was later adopted and extensively applied by The Boeing Company. FTA is a graphical technique that provides a systematic description of the combinations of possible occurrences (failures) in a system linked by "AND" and "OR" logic gates, which can result in an undesirable "top event" outcome. The FTA is a standard system safety analysis technique, commonly used to identify the failures that have the greatest influence on bringing about the top event.

A fault tree is constructed by relating the sequences of events using standard logic symbols, which individually or in combination, could lead to the top event.

FTA is a standard method used to determine and analyze the critical failure modes for aircraft design and certification. The analyses are usually conducted using failure rates expressed in "failures/flight hour".

For on-aircraft systems, a single failure is not acceptable if it can lead to a catastrophic event. If it is determined that the criticality of the top event is catastrophic then the probability of the occurrence of the top event shall be equal to or lower than $1x10^{-9}$ /flight hour. The probability of $1x10^{-9}$ /flight hour as an acceptable occurrence rate associated with a catastrophic event has its origins in the early 1960s during the development of the first auto land systems. At that time a need arose to state the acceptable level of risk in the form of the probability of a fatal accident due to system failure.[1]

New designs of large civil transport aircraft should be able to achieve a fatal accident rate of better than one in 10 million hours for all system causes. Individual features of individual systems can only contribute a small portion to this target; if one has ten systems with ten critical failures in each, this puts the allowable share to each feature at about one in 1,000 million hours, which implies not only very high

[1] System Safety, E.Llyod & W.Tye, CAA London 1982

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levels of reliability, which can only be achieved by fail safe features in some form, but also a very intense scrutiny to obtain reasonable assurance that the target is likely to be achieved.[1]

The above discussion is relevant for on-aircraft systems, specifically those that have an impact on the safe operation of aircraft.

ROGIDS is not an on-aircraft system, it is a ground-based device, which is intended to enhance and replace current post de-icing visual and tactile inspection methods.

Nevertheless, it is conceivable that certain failure conditions of ROGIDS equipment could contribute to a catastrophic event.

For the purpose of this discussion, the ROGIDS is considered as an inspection tool only for post-deicing use.

In the discussion and assessment that follows, failure rates are based on “failures/de-icing event” instead of “failures/flight hour”, which is more commonly used in on-aircraft systems design and analysis. This is necessary because the operating “mission profile” for a de-icing vehicle is different than that of an aircraft.

D.3 DISCUSSION

This section will provide discussion on:

1. Reviewing historical data to determine the current probability (failure rate) of encountering a catastrophic event post-deicing due to residual undetected contamination on the aircraft critical surfaces;

2. Using statistical data obtained from ROGIDS human factors testing to determine relative merit of using ROGIDS versus human inspectors; and

3. Postulating a latent failure rate for ROGIDS that will provide an increased level of safety when using ROGIDS as a post-deicing inspection tool.

D.3.1 Review of Historical Data

The present-day probability of aircraft loss due to undetected ice contamination can be estimated from the number of worldwide reported aircraft accidents and the total estimated number of worldwide deicing procedures performed.

The analysis utilizes worldwide data for the 20-year period 1985-2005. The period was selected because:

a. The events and their causes are generally well documented;
b. Modern deicing practices were in effect; and
c. The 20-year period provides a reasonable time period to estimate statistical averages.

The events and data sources used in the analysis are listed at the end of this appendix.

During this period there were 37 reported aircraft events caused by undetected frozen contamination on the aircraft either after inspection where no deicing was performed, or after deicing.[2.]

[2] http://aircrafticing.grc.nasa.gov/resources/related02.html

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To estimate the total number of worldwide deicing events during the 1985-2005 period it was assumed that the number of worldwide deicings increased linearly from the early 1960s when commercial airlines accepted the use of deicing solutions[3]. Given that the worldwide number of deicings for 2002 is estimated to be 600,000[4], the total number of deicings in the period 1985-2005 is approximately 10 million. The number of deicings is estimated using the following data and assumptions:

a. Approximately 600,000 deicings worldwide in 2002; and
b. Linear approximation using 2% growth rate based on Boeing statistics on worldwide departures for seven aircraft manufacturers and 35 significant aircraft (14 Boeing) types over the period 1970-2005.[5]

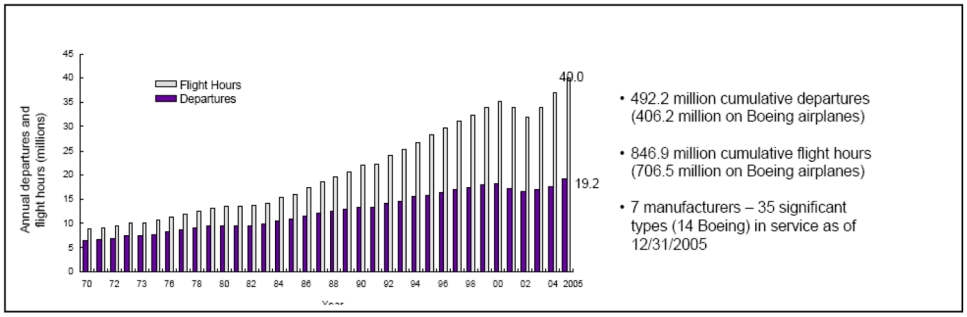


**FIGURE D1: Boeing Data On Worldwide Annual Aircraft Departures and Flight Hours 1970-2005[5]**

Aircraft accidents with the following characteristics were selected for the analysis:

a. Worldwide accidents caused by ground icing events; and
b. Events were sorted according to:

    1. Events caused by undetected frozen contamination without deicing performed. These events were excluded from the analysis;

    2. Events caused by detected, but ignored, frozen contamination with no deicing performed. These events were excluded from the analysis; and

    3. Events caused by undetected residual frozen contamination after deicing but excluding fluid failure are the only ones considered here because this analysis deals with post-deicing only. At this time ROGIDS is only considered for post-deicing inspections.

The data for a 20-year period 1985-2005 were used. There were 3 catastrophic accidents due to residual undetected ice after deicing was performed. The total number of deicings during this period was approximately 10 million or $10^7$. The probability of an accident is estimated to be the ratio of the number of events and the total number of deicing events, which is 3 in 10 million or 3 $x10^{-7}$.

[3] Report On Federal Aviation Administration Deicing Program Report, Number: E5-FA-7-001 Date: October 2, 1996 Office of the Inspector General
[4] APS Aviation estimate for 2002
[5] Statistical Summary of Commercial Jet Airplane Accidents 1955-2005, Boeing presentation, May 2006

D.3.2 Calculation of the ROGIDS Latent Failure Rate

The proposed ROGIDS Latent Failure Rate is calculated by using the historical data supplied in Section D.3.1 and applying a FTA to the ROGIDS performance and post-deicing aircraft inspection. In the analysis, it is assumed that the ROGIDS is used to detect ice that cannot be found by current visual and/or tactile processes: In the post-deicing scenario, the deicing operation has been completed to the best of the deicer's ability (i.e. the deicer believes that all the ice has been removed), and the deiced surface is inspected by the ROGIDS.

The Fault Tree is composed of two independent events whose occurrences may lead to the probability of an aircraft loss at takeoff due to ground ice contamination on the aircraft surfaces (see Figure D2). The fault tree is applicable to the post-deicing scenarios.

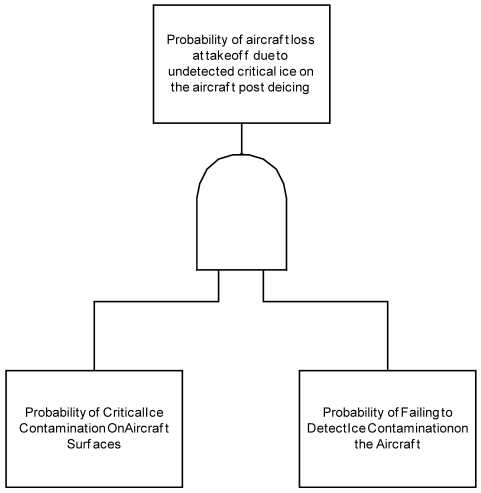


**FIGURE D2: FTA of Aircraft Loss Due To Ground Ice**

The presence of Critical Ice Contamination is the first factor that contributes to the loss of an aircraft at takeoff. Critical Ice Contamination is defined as ice contamination which leaves little or no aerodynamic lift or control margin and results in an aircraft accident. The amount, type (e.g. frost, clear ice) and spatial distribution of the contamination that is classified as critical is dependent on several variables including aircraft type and aircraft conditions at takeoff.

The second event is the probability that ice contamination on the critical aircraft surfaces is undetected. In the post-deicing scenario, the ice removal operation is completed and the deicer mistakenly believes that all of the ice has been removed. The probability that ice remains undetected is higher for the post-deicing scenario for a number of reasons: if performed incorrectly, the deicing process could create a thin and smooth layer of ice that is more difficult to see and the deicing/anti-icing fluid reduces the contrast of the ice on the aircraft surface.

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Assuming the two events are independent, the probability of a catastrophic loss of the aircraft at takeoff is the product of the probabilities of the two events. This means that a catastrophic accident will occur when undetected critical ice is present at takeoff.

Section D.3.1 shows the historical probability of a catastrophic accident due to undetected ice post-deicing is $3x10^{-7}$ accidents per deicing event. The probability of undetected ice post-deicing can be estimated from the series of human factor tests.[6]. In the Human Capability Test, ice below 0.8 mm thickness could not be visually detected beneath Type I fluid if the surface was painted white or if the ice covered the entire surface. In the comparison between ROGIDS and humans, only 15-60% of the thin ice patches on a test wing were visually detected and 30-80% were detected by tactile inspections.

In the case of light frozen contamination, e.g. frost or light adhering snow, the heat from the deicing fluid removes all of the frozen contamination. However, in the case of heavier frozen contamination, and based upon the Human Factors tests, the probability of undetected clear ice post-deicing is estimated to be $10^{-1}$.

Therefore the probability of Critical Ice Contamination post-deicing is $3x10^{-7}/10^{-1} = 3x10^{-6}$ events/deicing or approximately once in every 330,000 deicing events.

The use of ROGIDS should improve the safety of the overall deicing process in the post-deicing scenarios. An acceptable safety target of one catastrophic event every 1 billion deicing events is proposed. This is in line with airborne applications[7].

Keeping in mind that the probability of Critical Ice Contamination remains the same whether a ROGIDS or human inspection is performed, the required maximum probability of ROGIDS detection failure is $10^{-9}/3x10^{-6} = 3.3x10^{-4}$ latent failures per deicing event for the post-deicing scenario (see Table D1). This is two orders of magnitude better than current practices. Conservatively no credit is given for the human post-deicing inspection.

**TABLE D1: Maximum probability of ROGIDS detection failure**

| | Target top event (per deicing event) | Probability of critical ice contamination (per deicing event) | Maximum probability of ROGIDS detection failure (per deicing event) |
|---|---|---|---|
| Residual ice leading to a catastrophic accident | $1 x10^{-9}$ | $3 x10^{-6}$ | $3.3 x10^{-4}$ |

6

a) Bender K., Sierra, Jr., E. A., Terrace S. M., Marcil I., D'Avirro J., Pugacz, E., Eyre F., Comparison of Human Ice Detection Capabilities and Ground Ice Detection System Performance Under Post Deicing Conditions, FAA, December 2005, DOT/FAA/TC-06/20

b) Sierra, Jr., E. A., Bender K., Marcil I., D'Avirro J., Pugacz E., Eyre F., Human Visual and Tactile Ice Detection Capabilities Under Aircraft Post-Deicing Conditions, FAA, November 2005, DOT/FAA/TC-06/21.

c) Moc, M., Development of Ice Samples for Visual and Tactile Ice Detection Capability Tests, APS Aviation Inc., Transportation Development Centre, Montreal, September 2005, TP 14449E, 46.

d) Narlis, C., Development of Ice Samples for Comparison Study of Human and Sensor Capability to Detect Ice on Aircraft, APS Aviation Inc., Transportation Development Centre, Montreal, January 2006, TP 14450E, 54.

[7] See for example DO-178 or DO-254 aerospace standards.

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D.3.3 Sample Applications of ROGIDS Failure Rate to Equipment Design

In Section D.3.2 the maximum probability of ROGIDS detection failure was estimated as $3.3x10^{-4}$ per deicing event. Equipment failure rates are usually calculated on a per hour basis. This section provides two sample applications to calculate the ROGIDS latent failure rates on a per hour basis. The per hour rate is calculated using the time the ROGIDS is used for aircraft inspection during a deicing event.

A ROGIDS may have latent failure modes that are caused by hardware or software malfunctions. The ROGIDS may also incorporate a Built-in-test (BIT) device and/or software that can monitor the ROGIDS performance and detect any latent failures and annunciate them to the Operator. Consequently, a latent failure of the ROGIDS will remain undetected when the BIT system also malfunctions. The following analysis estimates the required maximum ROGIDS system and BIT failure rates:

The contamination detection failure probability, p, is calculated as the number of failures divided by the total number of deicing events or, equivalently, the total number of inspections. Inspection time is defined as the time the ROGIDS is performing contamination detection measurements and displaying information to the operator. It excludes activities such as system warm up time and standby time.

**Case 1: ROGIDS without latent failure detection BIT capability**

This case calculates the require ROGIDS latent failure rate assuming there is no BIT to detect and annunciate the latent failure to the operator.

Assuming an exponential probability function, the probability of contamination detection failure is given by

$p=e^{-\lambda \cdot T}$,
where

p is the probability of contamination detection failure caused by a latent failure of the ROGIDS hardware and/or software.

$\lambda$ is the ROGIDS latent failure rate (latent failures per inspection hour)
T is the ROGIDS latency period (hours between camera maintenance)

If $\lambda \cdot T << 1$ then the probability can be simplified to

$p \approx \lambda \cdot T$

or

$\lambda = p / T$

As an example, given the post-deicing scenario $p=3.3x10^{-4}$ from Table D1 and assuming T=100 hours of inspection time between maintenance checks then the maximum required failure rate is $\lambda = 3.3x10^{-6}$ latent failures per inspection hour.

**Case 2: ROGIDS with a BIT latent failure detection system**

This case calculates the required ROGIDS latent failure rate assuming there is a BIT to detect and annunciate the ROGIDS latent hardware/software failure to the operator.

The ROGIDS probability of a contamination detection failure is composed of the ROGIDS probability of latent system failure and the probability of a failure to detect and annunciate a latent failure (BIT failure).

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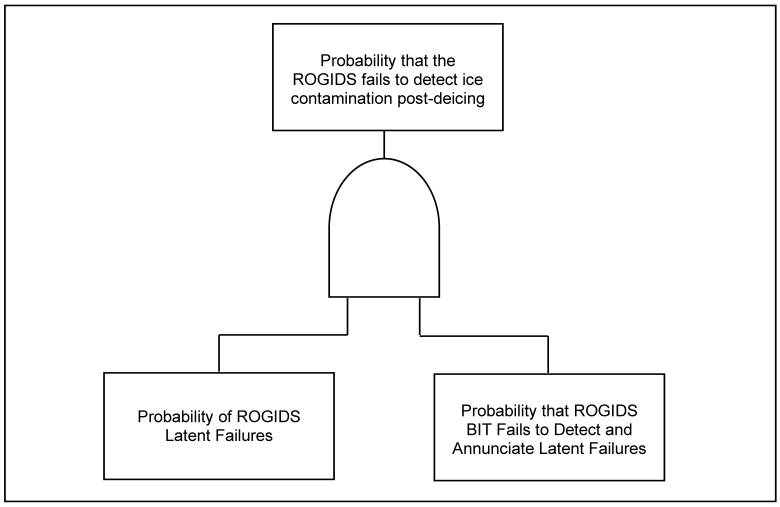


**FIGURE D3: FTA for ROGIDS Latent Failure Cases**

The probability of the ROGIDS contamination detection failure, p, is equal to the product of the combined latent failure of the ROGIDS system (failure rate λ System) and the failure of the BIT latent failure detection system (failure rate λ BIT) are related by the equation[8]:

$p = \lambda\ System \cdot T\ System \cdot \lambda\ BIT \cdot TBIT$

where

p is the probability of contamination detection failure caused by a latent failure of the ROGIDS hardware and/or software.

$\lambda_{System}$ is the camera latent failure rate (latent failures per inspection hour)
$T_{System}$ is the camera latency period (hours between camera maintenance)

$\lambda_{BIT}$ is the BIT failure rate (BIT failures per inspection hour)
$T_{BIT}$ is the BIT latency period (hours between BIT maintenance intervals)

If $T_{System} = T_{BIT} = T$ then

$\lambda_{System} \cdot \lambda_{BIT} = p / T^2$

Given $p=3.3x10^{-4}$ from Table D1 and assuming T=100 hrs then the combined ROGIDS failure rate is $\lambda_{System} \cdot \lambda_{BIT}=3.3x10^{-8}$ per inspection hour[2]. If, for example, the ROGIDS $\lambda_{System} =10^{-3}$ latent failures per

[8] C. Tanner, "ROGIDS Fault Tree Analysis (FTA) –ROGIDS for Pre and Post deicing operation", Discussion Paper, October, 2006.

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inspection hour, then the required BIT failure rate shall be less than $\lambda_{BIT}=3.3x10^{-5}$ failures per inspection hour.

D.4 SUMMARY AND RECOMMENDATIONS

D.4.1 Summary

On average, there has been a catastrophic accident every 3 million deicing events due to undetected critical contamination post-deicing.

Based upon the Human Factors tests, the probability of undetected clear ice post-deicing is estimated to be $10^{-1}$.

The probability of Critical Ice Contamination post-deicing is $3.3x10^{-6}$ events/deicing or approximately once in every 330,000 deicing events.

D.4.2 Recommendations

Current deicing methods and inspection procedures have been in place for about 20 years. These are proven, reliable methods. However, accidents still occur which can be traced back to undetected contamination post-deicing on critical surfaces.

One method to improve the safety record associated with aircraft deicing is the use of properly designed, tested, implemented and reliable inspection tools such as ROGIDS. Therefore, the following are recommended:

a. The maximum acceptable rate for the ROGIDS providing false negatives due to latent malfunctions shall be less than 3 in every 10,000 deicing events ($3x10^{-4}$ per deicing event);

b. The ROGIDS manufacturer shall conduct a thorough and systematic safety assessment to determine, classify, and document equipment failure modes and their effects;

c. Formal Fault Tree Analyses and Failure Modes and Effects Analyses shall be conducted to establish that the equipment false negative rate due to latent malfunctions is less than the maximum acceptable rate in (a) above.

D.5 HISTORICAL DATA ON AIRCRAFT GROUND-ICING ACCIDENTS

A. Undetected ice with no deicing (4)

Events (2)
- December 6, 2003 Reading Regional Airport in Reading Socata TBM-700
- March 14, 1997 Detroit, MI, USA - DC-9 Undetected clear ice on the wing

Catastrophic events (2)
- February 5, 1985 Philadelphia, PA, USA - DC-9 Undetected ice.
- March 10, 1989 Dryden Ontario F-28 Snow on wing undetected/ignored? by pilots

B. Residual ice after deicing (7)

Events (4)
- February 23, 2005 Aberdeen Scotland Jestream 4100 Residual ice after deicing

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- December 6, 2003 Reading Regional Airport in Reading Socata TBM-700
- November 4, 2003 Ottawa DHC-8-102 Residual ice after deicing
- February 16, 2002 Torino Italy Fokker F-70 Clear ice after deicing not detected

Catastrophic events (3)

- October 10 2001, Dillingham, AK, USA C-208 Residual ice after deicing
- December 27, 1991 Stockholm SAS MD-80 Clear ice not detected after two deicings
- November 25, 1989 Kimpo Korea Fokker 28 Residual ice after deicing

C. Detected ice that was ignored (2)

Catastrophic events (2)

- November 28, 2004 Canadair, Ltd., CL-600-2A12, N873G, Montrose, CO, NTSB/AAB-06/03
- January 17, 2004 Georgian Express Pelee Island C-208B

D. Accidents due to other/undetermined ground ice related causes (24)

Events (18)

- April 26, 2001White post VA Stinson-108
- January 19, 2001 Chillicothe OH PA-46
- February 7, 1999 Medina OH PA-32
- March 22, 1992, Flushing, NY
- February 17, 1991 Cleveland Ohio DC-9
- January 29, 1990 Williston, VT C-208
- January 10, 1988 Honshu Japan YS-11
- November 15, 1987 Denver CO DC-9
- January 6, 1987 Stockholm Caravelle
- January 18, 1985 Lubbock Tx C-208
- February 5, 1985 Philadelphia PA DC-9
- April 2, 1985 Johnson City NY C-421
- December 27, 1985 Spokane WA C-401
- January 31, 1985 Huntington W VA BE-18
- January 13, 1984 Jamaica NY Fokker F27
- March 19, 1984 Morrisonville NY BE-18
- December 12, 1985 Gander Newfoundland DC-8
- January 16, 1983 Anchorage AK C-206

Catastrophic events (6)

- January 4, 2002 Birmingham, England, Challenger 604
- November 24, 1994 Glenburn ME PA-18
- March 5, 1993 Skopje Macedonia Fokker F-100
- January 13, 1982 Washington DC B737
- February 18, 1980 Boston, MA
- November 27, 1978 Newark, NJ

D.5.1 References for historical data on aircraft ground-icing accidents

1. http://aircrafticing.grc.nasa.gov/resources/related02.html

2. http://www.caa.co.uk/default.aspx?categoryid=978&pagetype=90&pageid=6281

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3. Report on FAA deicing program Report Number: E5-FA-7-001 October 2, 1996 Office of the Inspector General: http://www.oig.dot.gov/StreamFile?file=/data/pdfdocs/e5fa7001.pdf

4. http://www.aopa.org/asf/ntsb/searchResults.cfm?tss=16

5. Swedish Civil Aviation Administration, Report C 1993:57: Air Traffic Accident, 27th December 1991, at Gottröra, AB County, 601 79 Norrköping

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# APPENDIX C

# TRANSPORT CANADA
# HOLDOVER TIME (HOT) GUIDELINES
# WINTER 2007-2008

# Transport Canada
# Holdover Time (HOT) Guidelines
# Winter 2007-2008

## Original Issue, July 2007
## Revision 1.0, October 2007

This document should be used in conjunction with *Guidelines for Aircraft Ground-Icing Operations* (TP 14052, second edition, April 2005)

The two documents complement each other and should be used together for a thorough understanding of the subject matter.

## CHANGE CONTROL RECORDS

This page indicates any changes made to individual pages within the document. Changed pages have the appropriate revision date in the footer. Sidebars are shown to assist in identifying where the changes have been made on these pages.

It is the responsibility of the end user to periodically check the following website for updates on Holdover Time Guidelines:
http://www.tc.gc.ca/CivilAviation/commerce/HoldoverTime/menu.htm.

| *REVISION* | *DATE* | *DESCRIPTION OF CHANGES* | *AFFECTED PAGES* | *AUTHOR* |
|---|---|---|---|---|
| 1.0 | Oct. 2007 | Addition of Ice Pellet Allowance Times | 3-4, 38-40 | TC / APS |
| | | Minor change to Type II fluids section of Summary of Changes page | 3 | TC / APS |
| | | First caution note in HOT Tables changed | 6-29 | TC / APS |
| | | Table 5 updated | 30-31 | TC / APS |
| | | Minor changes to Table 9-3 | 36 | TC / APS |
| | | | | |

## SUMMARY OF CHANGES FROM PREVIOUS YEAR

The principal changes from the previous year are briefly indicated herein.

**Type I Fluid**

The Type I holdover guideline values are unchanged.

**Type II Fluid**

Fluid-specific tables have been created for two new Type II fluids, Aviation Xi'An High-Tech KHF-II and Newave Aerochemical FCY-2. The addition of the Newave Aerochemical FCY-2 fluid caused reductions to the holdover times in four cells in the below -3 to -14°C row of the Type II generic holdover guidelines.

The Kilfrost ABC-TF2 fluid-specific table has been removed, as the fluid was never qualified.

**Type III Fluid**

The Type III holdover guideline values are unchanged.

**Type IV Fluid**

A fluid-specific table has been created for one new Type IV fluid, Lyondell ARCTIC Shield®. The Clariant Safewing MP IV 2030 ECO fluid-specific table has been removed, as the fluid was not commercialized. In addition, several other changes have been made to the Type IV guidelines:

- Holdover times in the Clariant Safewing MP IV Launch snow cells have increased as a result of natural snow testing conducted with this fluid.
- Significant changes have been made to the Kilfrost ABC-S PLUS fluid-specific table as a result of testing with a higher viscosity sample. The lowest on-wing viscosity value for this fluid has increased to 17,900 mPa.s.
- A change has been made to the Clariant Safewing MP IV 2012 Protect fluid-specific table to correct a clerical error. The holdover time for neat fluid in freezing fog at below -3 to -14°C is now 0:45 – 1:45.

The Type IV generic holdover guideline values are unchanged.

**Lowest On-Wing Viscosity Values**

The lowest on-wing viscosity values of Clariant Safewing MP II 1951, Clariant Safewing MP III 2031 ECO and Kilfrost ABC-3 have been added to Table 9. This table now also includes lowest on-wing viscosity values for the dilutions of the anti-icing fluids.

## OPERATIONS DURING ICE PELLET CONDITIONS

Transport Canada has conducted research to provide additional guidance for aircraft operations during ice pellet conditions. A separate section at the end of the document, addressing ice pellet allowance times and associated operational criteria, is included in this revision.

## CHANGES TO *Guidelines of Aircraft Ground-Icing Operations* (TP 14052, second ed., April 2005)

The following changes will be incorporated into TP 14052 at its next revision. They are recorded here in advance due to the longer life cycle time associated with the updating and publication of TP 14052 and are for immediate use.

**Replace Sub-Paragraph 10.13.3, "Hot Water", with the following:**

Hot water may be used to remove large amounts of contamination (such as ice) from an aircraft provided that the Outside Air Temperature is -3°C and above as per the application procedures for SAE Type I and SAE Type II, III and IV fluids described in tables 6 & 7 of the Transport Canada HOT Guidelines document.

**Delete Sub-Paragraph 10.13.3.1 Item g) only.**

**Replace Sub-Paragraph 11.1.5, "Elapsed time is less than the lowest time in the HOT cell", with the following:**

Transport Canada has previously considered that, under an approved ground icing program, if the lowest time in a cell has NOT been exceeded for conditions covered by the Guidelines, there is no requirement to inspect the aircraft's critical surfaces prior to commencing a takeoff.

This position was based on evidence gained during fluids testing. The HOT values are conservative for the lowest number in the cell, if:

a) The conditions present are NOT in excess of those conditions represented by the table (e.g. for snow it would be a moderate snow condition); and

b) The impact of other factors (e.g. jet blast) has been considered and deemed not to affect the HOT.

If there is doubt surrounding the conditions associated with using the lowest time as decision making criteria, an inspection prior to takeoff would be prudent. This inspection should be conducted in accordance with the procedures described in the Air Operator's Approved Ground Icing Program.

**Replace Paragraph 11.1.8 with the following:**

The HOT Guidelines do not include guidelines for all meteorological conditions.

Holdover time guidelines have not been assessed for the following conditions: a) Snow Pellets; b) Hail; c) Moderate and Heavy Freezing Rain; and d) Heavy Snow.

Notes: Operators need to assess whether operations can be safely conducted under these conditions.

Additionally, holdover time guidelines have not been assessed for the ice pellets since a formal protocol for ice pellet testing has not yet been developed and included in standard SAE testing methodologies and no visual failure criteria has yet been identified for ice pellet conditions. Instead an allowance time based upon research has been developed for operations during ice pellet conditions.

**Replace Paragraph 12.1.2 with the following**:

Holdover time guidelines have not been assessed for ice pellets since a formal protocol for ice pellet testing has not yet been developed and included in standard SAE testing methodologies and no visual failure criteria has yet been identified for ice pellet conditions.

However, comprehensive ice pellet research was conducted jointly by the research teams of the FAA and Transport Canada. This research consisted of extensive climatic chamber, wind tunnel, and live aircraft testing with ice pellets (light and moderate) and light ice pellets mixed with other forms of precipitation. Results of this research provide the basis for allowance times for operations in light and moderate ice pellets, as well as allowance times for operations in light ice pellets mixed with other forms of precipitation.

**Transport Canada Holdover Time Guidelines** **Winter 2007-2008**

## HOLDOVER TIME (HOT) GUIDELINES FOR WINTER 2007-2008


| | |
|---|---|
| Table 1 | SAE Type I Fluid Holdover Guidelines |
| Table 2-Generic | SAE Type II Fluid Holdover Guidelines |
| Table 2-A-KHF-II | Aviation Xi'an High-Tech Type II Fluid Holdover Guidelines KHF-II |
| Table 2-C-2025 | Clariant Type II Fluid Holdover Guidelines Safewing MP II 2025 ECO |
| Table 2-C-Flight | Clariant Type II Fluid Holdover Guidelines Safewing MP II Flight |
| Table 2-K-ABC-2000 | Kilfrost Type II Fluid Holdover Guidelines ABC-2000 |
| Table 2-K-ABC-II+ | Kilfrost Type II Fluid Holdover Guidelines ABC-II PLUS |
| Table 2-N-FCY-2 | Newave Aerochemical Type II Fluid Holdover Guidelines FCY-2 |
| Table 2-O-EM-II | Octagon Type II Fluid Holdover Guidelines E Max II |
| Table 2-S-E26 | SPCA Type II Fluid Holdover Guidelines Ecowing 26 |
| Table 3 | SAE Type III Fluid Holdover Guidelines |
| Table 4-Generic | SAE Type IV Fluid Holdover Guidelines |
| Table 4-C-2001 | Clariant Type IV Fluid Holdover Guidelines Safewing MP IV 2001 |
| Table 4-C-2012 | Clariant Type IV Fluid Holdover Guidelines Safewing MP IV 2012 Protect |
| Table 4-C-Launch | Clariant Type IV Fluid Holdover Guidelines Safewing MP IV Launch |
| Table 4-D-ULTRA+ | Dow Chemical Type IV Fluid Holdover Guidelines UCAR™ ADF/AAF ULTRA+ |
| Table 4-D-E106 | Dow Chemical Type IV Fluid Holdover Guidelines UCAR™ Endurance EG106 |
| Table 4-K-ABC-S | Kilfrost Type IV Fluid Holdover Guidelines ABC-S |
| Table 4-K-ABC-S PLUS | Kilfrost Type IV Fluid Holdover Guidelines ABC-S PLUS |
| Table 4-L-ARCTIC Shield | Lyondell Type IV Fluid Holdover Guidelines ARCTIC Shield® |
| Table 4-O-MF | Octagon Type IV Fluid Holdover Guidelines Max-Flight |
| Table 4-O-MF-04 | Octagon Type IV Fluid Holdover Guidelines Max-Flight 04 |
| Table 4-O-MFLO | Octagon Type IV Fluid Holdover Guidelines MaxFlo |
| Table 4-S-AD-480 | SPCA Type IV Fluid Holdover Guidelines AD-480 |
| Table 5 | Currently Qualified Fluids |
| Table 6 | SAE Type I Deicing Fluid Application Procedures |
| Table 7 | SAE Type II, Type III and Type IV Anti-Icing Fluid Application Procedures |
| Table 8 | Visibility in Snow vs. Snowfall Intensity Chart |
| Table 9 | Lowest On-Wing Viscosity Values for Anti-Icing Fluids |
| Table 10 | Ice Pellet Allowance Times |

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 1**

### SAE TYPE I[3] FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

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

| Outside Air Temperature[5] | | Approximate Holdover Times Under Various Weather Conditions (minutes) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Active Frost | Freezing Fog | Snow or Snow Grains[1] | | | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| | | | | Very Light | Light | Moderate | | | | |
| -3 and above | 27 and above | 45 | 11 – 17 | 18 | 11 – 18 | 6 – 11 | 9 – 13 | 4 – 6 | 2 – 5 | |
| below -3 to -6 | below 27 to 21 | 45 | 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 | 45 | 6 – 10 | 11 | 6 – 11 | 4 – 6 | 4 – 7 | 2 – 5 | | |
| below -10 | below 14 | 45 | 5 – 9 | 7 | 4 – 7 | 2 – 4 | | | | |

**NOTES**

1 To use these times, the fluid must be heated to a minimum temperature providing 60°C (140°F) at the nozzle and an average rate of at least 1 litre/$m^2$ (2 gal./100 sq. ft.) must be applied to deiced surfaces, OTHERWISE TIMES WILL BE SHORTER.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 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.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 2-Generic**

## SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 0:35 – 1:30 | 0:20 – 0:45 | 0:30 – 0:55 | 0:15 – 0:30 | 0:05 – 0:40 | |
| | | 75/25 | 5:00 | 0:25 – 1:00 | 0:15 – 0:30 | 0:20 – 0:45 | 0:10 – 0:25 | 0:05 – 0:25 | |
| | | 50/50 | 3:00 | 0:15 – 0:30 | 0:05 – 0:15 | 0:05 – 0:15 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:20 – 1:05 | 0:15 – 0:30 | 0:15 – 0:45[3] | 0:10 – 0:20[3] | | |
| | | 75/25 | 5:00 | 0:20 – 0:55 | 0:10 – 0:20 | 0:15 – 0:30[3] | 0:05 – 0:15[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00[5] | 0:15 – 0:20[5] | 0:15 – 0:30[5] | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

**NOTES**

1 Based on the lowest holdover times of the Type II fluids listed in Table 5-2.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

**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 deicing/anti-icing do not provide in-flight icing protection.**

TABLE 2-A-KHF-II

## AVIATION XI'AN HIGH-TECH TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## KHF-II

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 1:15 – 2:15 | 0:45 – 1:20 | 0:50 – 1:30 | 0:30 – 0:45 | 0:10 – 1:15 | |
| | | 75/25 | 5:00 | 0:45 – 1:00 | 0:25 – 0:40 | 0:25 – 0:45 | 0:15 – 0:25 | 0:05 – 0:45 | |
| | | 50/50 | 3:00 | 0:20 – 0:30 | 0:15 – 0:25 | 0:10 – 0:15 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 1:10 – 2:40 | 0:35 – 1:00 | 0:20 – 1:35[3] | 0:25 – 0:40[3] | | |
| | | 75/25 | 5:00 | 0:45 – 1:20 | 0:15 – 0:30 | 0:20 – 0:45[3] | 0:15 – 0:20[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:35 – 0:50 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 2-C-2025**

### CLARIANT TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
### SAFEWING MP II 2025 ECO

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 1:30 – 2:05 | 0:40 – 1:10 | 0:40 – 1:00 | 0:25 – 0:35 | 0:10 – 1:15 | |
| | | 75/25 | 5:00 | 0:55 – 1:45 | 0:25 – 0:45 | 0:25 – 0:45 | 0:20 – 0:25 | 0:05 – 0:50 | |
| | | 50/50 | 3:00 | 0:20 – 0:35 | 0:05 – 0:15 | 0:10 – 0:15 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:45 – 1:50 | 0:35 – 1:00 | 0:35 – 1:05[3] | 0:20 – 0:35[3] | | |
| | | 75/25 | 5:00 | 0:40 – 1:20 | 0:25 – 0:45 | 0:30 – 0:40[3] | 0:15 – 0:25[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:25 – 0:45 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 2-C-Flight**

### CLARIANT TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
### SAFEWING MP II FLIGHT

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 3:30 – 4:00 | 1:00 – 1:35 | 1:20 – 2:00 | 0:45 – 1:25 | 0:10 – 1:30 | |
| | | 75/25 | 5:00 | 2:30 – 4:00 | 0:40 – 1:20 | 1:15 – 2:00 | 0:30 – 0:55 | 0:05 – 1:20 | |
| | | 50/50 | 3:00 | 0:55 – 1:45 | 0:10 – 0:25 | 0:20 – 0:30 | 0:10 – 0:15 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:55 – 1:45 | 0:40 – 1:05 | 0:35 – 1:30[3] | 0:25 – 0:45[3] | | |
| | | 75/25 | 5:00 | 0:40 – 1:10 | 0:20 – 0:40 | 0:25 – 1:10[3] | 0:30 – 0:40[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:30 – 0:50 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 2-K-ABC-2000**

### KILFROST TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
### ABC-2000

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 1:30 – 3:05 | 0:30 – 1:00 | 0:55 – 1:35 | 0:40 – 0:50 | 0:15 – 1:10 | |
| | | 75/25 | 5:00 | 1:40 – 3:30 | 0:30 – 1:05 | 0:45 – 1:15 | 0:40 – 0:50 | 0:15 – 1:40 | |
| | | 50/50 | 3:00 | 1:00 – 2:10 | 0:15 – 0:30 | 0:15 – 0:25 | 0:05 – 0:15 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:35 – 1:25 | 0:25 – 0:45 | 0:25 – 0:50[3] | 0:10 – 0:30[3] | | |
| | | 75/25 | 5:00 | 0:35 – 1:15 | 0:25 – 0:50 | 0:25 – 0:55[3] | 0:15 – 0:30[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:20 – 0:45 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 2-K-ABC-II+**

### KILFROST TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
### ABC-II PLUS

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 1:10 – 2:25 | 0:25 – 0:55 | 0:35 – 1:10 | 0:30 – 0:40 | 0:05 – 1:00 | |
| | | 75/25 | 5:00 | 1:10 – 2:25 | 0:25 – 0:50 | 0:30 – 1:00 | 0:20 – 0:40 | 0:05 – 0:50 | |
| | | 50/50 | 3:00 | 0:15 – 0:45 | 0:15 – 0:35 | 0:05 – 0:25 | 0:05 – 0:15 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:30 – 1:05 | 0:15 – 0:35 | 0:15 – 0:45[3] | 0:10 – 0:30[3] | | |
| | | 75/25 | 5:00 | 0:20 – 0:55 | 0:15 – 0:35 | 0:15 – 0:30[3] | 0:10 – 0:20[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:15 – 0:20 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 2-N-FCY-2**

## NEWAVE AEROCHEMICAL TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## FCY-2

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 1:15 – 2:25 | 0:30 – 0:55 | 0:35 – 1:05 | 0:25 – 0:35 | 0:05 – 0:45 | |
| | | 75/25 | 5:00 | 0:50 – 1:30 | 0:20 – 0:40 | 0:25 – 0:45 | 0:15 – 0:25 | 0:05 – 0:25 | |
| | | 50/50 | 3:00 | 0:25 – 0:35 | 0:15 – 0:25 | 0:10 – 0:20 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:45 – 1:30 | 0:15 – 0:30 | 0:20 – 0:45[3] | 0:15 – 0:20[3] | | |
| | | 75/25 | 5:00 | 0:30 – 1:05 | 0:10 – 0:20 | 0:15 – 0:30[3] | 0:05 – 0:15[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:25 – 0:35 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 2-O-EM-II**

### OCTAGON TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
### E MAX II

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 2:05 – 3:45 | 0:40 – 1:20 | 0:45 – 1:35 | 0:30 – 0:40 | 0:15 – 1:30 | |
| | | 75/25 | 5:00 | 1:25 – 2:50 | 0:25 – 0:55 | 0:40 – 1:10 | 0:20 – 0:30 | 0:10 – 1:05 | |
| | | 50/50 | 3:00 | 0:30 – 0:55 | 0:10 – 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 | 8:00 | 0:50 – 1:45 | 0:35 – 1:10 | 0:35 – 1:00[3] | 0:20 – 0:30[3] | | |
| | | 75/25 | 5:00 | 0:30 – 1:20 | 0:25 – 0:50 | 0:35 – 1:05[3] | 0:15 – 0:30[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:20 – 0:35 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 2-S-E26**

### SPCA TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

### Ecowing 26

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 1:25 – 2:35 | 0:40 – 1:00 | 0:50 – 1:35 | 0:40 – 0:50 | 0:20 – 1:25 | |
| | | 75/25 | 5:00 | 1:05 – 1:55 | 0:25 – 0:45 | 0:45 – 1:05 | 0:25 – 0:35 | 0:10 – 1:00 | |
| | | 50/50 | 3:00 | 0:30 – 0:45 | 0:10 – 0:20 | 0:15 – 0:25 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:45 – 2:15 | 0:35 – 0:55 | 0:30 – 1:10[3] | 0:15 – 0:35[3] | | |
| | | 75/25 | 5:00 | 0:35 – 1:15 | 0:25 – 0:40 | 0:20 – 0:50[3] | 0:15 – 0:25[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:25 – 0:45 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 3**

### SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

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

| Outside Air Temperature[3] | | Approximate Holdover Times Under Various Weather Conditions (minutes) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Type III Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Active Frost | Freezing Fog | Snow or Snow Grains | | | Freezing Drizzle[1] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| | | | | | Very Light | Light | Moderate | | | | |
| -3 and above | 27 and above | 100/0 | 120 | 20 – 40 | 35 | 20 – 35 | 10 – 20 | 10 – 20 | 8 – 10 | 6 – 20 | |
| | | 75/25 | 60 | 15 – 30 | 25 | 15 – 25 | 8 – 15 | 8 – 15 | 6 – 10 | 2 – 10 | |
| | | 50/50 | 30 | 10 – 20 | 15 | 8 – 15 | 4 – 8 | 5 – 9 | 4 – 6 | CAUTION: No holdover time guidelines exist | |
| below -3 to -10 | below 27 to 14 | 100/00 | 120 | 20 – 40 | 30 | 15 – 30 | 9 – 15 | 10 – 20 | 8 – 10 | | |
| | | 75/25 | 60 | 15 – 30 | 25 | 10 – 25 | 7 – 10 | 9 – 12 | 6 – 9 | | |
| below -10 | below 14 | 100/0 | 120 | 20 – 40 | 30 | 15 – 30 | 8 – 15 | | | | |

**NOTES**

1 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 Ensure that the lowest operational use temperature (LOUT) is respected. Consider use of Type I when Type III fluid cannot be used.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 4-Generic**

## SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:15 – 2:30 | 0:35 – 1:15 | 0:40 – 1:10 | 0:25 – 0:40 | 0:10 – 0:50 | |
| | | 75/25 | 5:00 | 1:05 – 1:45 | 0:20 – 0:55 | 0:35 – 0:50 | 0:15 – 0:30 | 0:05 – 0:35 | |
| | | 50/50 | 3:00 | 0:15 – 0:35 | 0:05 – 0:15 | 0:10 – 0:20 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:20 – 1:20 | 0:20 – 0:40 | 0:20 – 0:45[3] | 0:10 – 0:25[3] | | |
| | | 75/25 | 5:00 | 0:25 – 0:50 | 0:15 – 0:35 | 0:15 – 0:30[3] | 0:10 – 0:20[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00[5] | 0:15 – 0:40[5] | 0:15 – 0:30[5] | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**

1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 4-C-2001**

## CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## SAFEWING MP IV 2001

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:20 – 3:20 | 1:00 – 1:55 | 0:55 – 1:55 | 0:40 – 1:00 | 0:15 – 2:00 | |
| | | 75/25 | 5:00 | 1:20 – 2:00 | 0:35 – 1:00 | 0:35 – 1:10 | 0:25 – 0:35 | 0:10 – 1:25 | |
| | | 50/50 | 3:00 | 0:15 – 0:40 | 0:10 – 0:20 | 0:10 – 0:20 | 0:05 – 0:15 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:45 – 1:35 | 0:30 – 0:50 | 0:55 – 1:35[3] | 0:30 – 0:45[3] | | |
| | | 75/25 | 5:00 | 0:30 – 1:00 | 0:20 – 0:35 | 0:40 – 1:10[3] | 0:20 – 0:30[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 – 0:45 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 4-C-2012**

### CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
### SAFEWING MP IV 2012 PROTECT

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:15 – 2:30 | 0:40 – 1:15 | 0:40 – 1:10 | 0:25 – 0:45 | 0:10 – 1:05 | |
| | | 75/25 | 5:00 | 1:10 – 2:05 | 0:25 – 0:55 | 0:35 – 0:50 | 0:15 – 0:30 | 0:05 – 0:40 | |
| | | 50/50 | 3:00 | 0:25 – 0:45 | 0:15 – 0:25 | 0:15 – 0:20 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:45 – 1:45 | 0:20 – 0:40 | 0:25 – 0:45[3] | 0:15 – 0:25[3] | | |
| | | 75/25 | 5:00 | 0:25 – 1:05 | 0:20 – 0:40 | 0:15 – 0:30[3] | 0:10 – 0:20[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 – 0:45 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 4-C-Launch**

## CLARIANT TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## SAFEWING MP IV LAUNCH

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 4:00 – 4:00 | 1:05 – 1:45 | 1:30 – 2:00 | 1:00 – 1:40 | 0:15 – 1:40 | |
| | | 75/25 | 5:00 | 3:40 – 4:00 | 1:00 – 1:45 | 1:40 – 2:00 | 0:45 – 1:15 | 0:10 – 1:45 | |
| | | 50/50 | 3:00 | 1:25 – 2:45 | 0:25 – 0:45 | 0:30 – 0:50 | 0:20 – 0:25 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 1:00 – 1:55 | 0:50 – 1:20 | 0:35 – 1:40[3] | 0:25 – 0:45[3] | | |
| | | 75/25 | 5:00 | 0:40 – 1:20 | 0:45 – 1:25 | 0:25 – 1:10[3] | 0:25 – 0:45[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:30 – 0:50 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 4-D-ULTRA+**

## DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## UCAR™ ADF/AAF ULTRA+

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:35 – 3:35 | 0:35 – 1:15 | 0:45 – 1:35 | 0:25 – 0:40 | 0:10 – 1:20 | |
| | | 75/25 | | | | | | CAUTION: No holdover time guidelines exist | |
| | | 50/50 | | | | | | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 1:25 – 3:00 | 0:25 – 0:55 | 0:45 – 1:25[3] | 0:30 – 0:45[3] | | |
| | | 75/25 | | | | | | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00[5] | 0:40 – 2:10[5] | 0:20 – 0:45[5] | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met.[5] Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 These holdover times only apply to outside air temperatures to -24°C (-11°F).

**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 deicing/anti-icing do not provide in-flight icing protection.**

TABLE 4-D-E106

## DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## UCAR™ ENDURANCE EG106

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 2:05 – 3:10 | 0:40 – 1:20 | 1:10 – 2:00 | 0:50 – 1:15 | 0:20 – 2:00 | |
| | | 75/25 | | | | | | CAUTION: No holdover time guidelines exist | |
| | | 50/50 | | | | | | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 1:50 – 3:20 | 0:30 – 1:05 | 0:55 – 1:50[3] | 0:45 – 1:10[3] | | |
| | | 75/25 | | | | | | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:30 – 1:05 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 4-K-ABC-S**

### KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
### ABC-S

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 2:35 – 4:00 | 1:00 – 1:40 | 1:20 – 1:50 | 1:00 – 1:25 | 0:20 – 1:15 | |
| | | 75/25 | 5:00 | 1:05 – 1:45 | 0:30 – 0:55 | 0:45 – 1:10 | 0:35 – 0:50 | 0:10 – 0:50 | |
| | | 50/50 | 3:00 | 0:20 – 0:35 | 0:05 – 0:15 | 0:15 – 0:20 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:45 – 2:05 | 0:45 – 1:20 | 0:20 – 1:00[3] | 0:10 – 0:30[3] | | |
| | | 75/25 | 5:00 | 0:25 – 1:00 | 0:25 – 0:50 | 0:20 – 1:10[3] | 0:10 – 0:35[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 – 0:40 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 4-K-ABC-S PLUS**

### KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
### ABC-S PLUS

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 2:10 – 4:00 | 1:15 – 2:00 | 1:50 – 2:00 | 1:05 – 2:00 | 0:25 – 2:00 | |
| | | 75/25 | 5:00 | 1:25 – 2:40 | 0:45 – 1:15 | 1:00 – 1:20 | 0:30 – 0:50 | 0:10 – 1:20 | |
| | | 50/50 | 3:00 | 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 | 12:00 | 0:55 – 3:30 | 1:00 – 1:45 | 0:25 – 1:35[3] | 0:20 – 0:30[3] | | |
| | | 75/25 | 5:00 | 0:45 – 1:50 | 0:35 – 1:00 | 0:20 – 1:10[3] | 0:15 – 0:25[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:40 – 1:00 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 4-L-ARCTIC Shield**

## LYONDELL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## ARCTIC SHIELD®

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:55 – 3:10 | 0:50 – 1:25 | 0:55 – 1:40 | 0:45 – 1:05 | 0:15 – 1:25 | |
| | | 75/25 | 5:00 | 1:20 – 2:15 | 0:40 – 1:05 | 0:55 – 1:25 | 0:30 – 0:45 | 0:05 – 1:20 | |
| | | 50/50 | 3:00 | 0:35 – 0:45 | 0:20 – 0:35 | 0:20 – 0:30 | 0:10 – 0:15 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 1:00 – 2:25 | 0:45 – 1:15 | 0:25 – 1:30[3] | 0:25 – 0:30[3] | | |
| | | 75/25 | 5:00 | 0:50 – 1:45 | 0:35 – 0:55 | 0:30 – 1:15[3] | 0:25 – 0:30[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:25 – 0:45 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 4-O-MF**

## OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## MAX-FLIGHT

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 2:40 – 4:00 | 0:50 – 1:35 | 0:55 – 2:00 | 0:35 – 1:00 | 0:15 – 1:15 | |
| | | 75/25 | 5:00 | 2:05 – 3:15 | 0:45 – 1:45 | 1:15 – 2:00 | 0:35 – 1:10 | 0:10 – 0:40 | |
| | | 50/50 | 3:00 | 0:55 – 1:45 | 0:25 – 1:15 | 0:35 – 1:00 | 0:15 – 0:30 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:50 – 2:30 | 0:25 – 0:50 | 0:25 – 1:10[3] | 0:20 – 0:40[3] | | |
| | | 75/25 | 5:00 | 0:30 – 1:05 | 0:20 – 0:50 | 0:20 – 1:00[3] | 0:15 – 0:30[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 – 0:45 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

TABLE 4-O-MF-04

## OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## MAX-FLIGHT 04

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 2:40 – 4:00 | 1:25 – 2:00 | 2:00 – 2:00 | 1:10 – 1:30 | 0:20 – 2:00 | |
| | | 75/25 | 5:00 | 2:05 – 3:15 | 1:05 – 2:00 | 1:50 – 2:00 | 1:00 – 1:20 | 0:20 – 2:00 | |
| | | 50/50 | 3:00 | 0:55 – 1:45 | 0:25 – 1:15 | 0:35 – 1:10 | 0:25 – 0:35 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:50 – 2:30 | 0:35 – 1:10 | 0:25 – 1:30[3] | 0:20 – 0:40[3] | | |
| | | 75/25 | 5:00 | 0:30 – 1:05 | 0:40 – 1:20 | 0:20 – 1:00[3] | 0:15 – 0:30[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 – 0:45 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 4-O-MFLO**

## OCTAGON TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
## MAXFLO

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

| Outside Air Temperature | | Type IV Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Neat Fluid/Water (Volume %/Volume %) | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 2:20 – 3:35 | 0:40 – 1:30 | 1:20 – 2:00 | 0:30 – 1:00 | 0:10 – 2:00 | |
| | | 75/25 | 5:00 | 1:25 – 2:00 | 0:20 – 0:55 | 0:40 – 1:05 | 0:20 – 0:35 | 0:05 – 1:15 | |
| | | 50/50 | 3:00 | 0:20 – 0:40 | 0:05 – 0:15 | 0:10 – 0:20 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 1:10 – 2:20 | 0:25 – 1:00 | 0:35 – 1:45[3] | 0:30 – 0:50[3] | | |
| | | 75/25 | 5:00 | 0:40 – 1:25 | 0:15 – 0:40 | 0:35 – 1:15[3] | 0:15 – 0:30[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:30 – 1:00 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 4-S-AD-480**

### SPCA TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008[1]
### AD-480

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 2:00 – 3:30 | 0:40 – 1:20 | 0:50 – 1:30 | 0:35 – 0:55 | 0:15 – 1:35 | |
| | | 75/25 | 5:00 | 1:30 – 2:45 | 0:30 – 1:05 | 0:50 – 1:15 | 0:30 – 0:45 | 0:10 – 1:15 | |
| | | 50/50 | 3:00 | 0:30 – 0:45 | 0:10 – 0:20 | 0:15 – 0:25 | 0:05 – 0:15 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:20 – 1:20 | 0:30 – 0:55 | 0:25 – 1:20[3] | 0:15 – 0:30[3] | | |
| | | 75/25 | 5:00 | 0:25 – 0:50 | 0:20 – 0:45 | 0:25 – 1:05[3] | 0:15 – 0:30[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:15 – 0:40 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**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 deicing/anti-icing do not provide in-flight icing protection.**

**TABLE 5**

**CURRENTLY QUALIFIED FLUIDS (2007-2008)**

| Table 5-1: Qualified Type I Anti-icing Fluids[1] [2] | | | |
|---|---|---|---|
| # | COMPANY NAME | FLUID NAME | EXPIRY (Y-M-D) |
| 1-1 | Arcton Ltd. | Arctica DG | 08-04-10 |
| 1-2 | Aviation Xi'an High-Tech | Aviation Xi'an KHF-1 | 07-09-22 |
| 1-3 | Battelle | $D^3$: Degradable by Design Deicer™ ADF 1006A | 08-01-13 |
| 1-4 | Beijing Wangye Aviation Chemical Product Co. Ltd. | KLA-1 | 07-09-07[4] |
| 1-5 | Clariant GmbH | Clariant Safewing MP I 1938 TF | 08-08-21 |
| 1-6 | Clariant GmbH | Clariant Safewing MP I 1938 TF Pre-Mix | *07-09-14*[3] |
| 1-7 | Clariant GmbH | Clariant Safewing MP I 1938 ECO (80) Pre-Mix | 09-03-01 |
| 1-8 | Clariant GmbH | Clariant Safewing MP I 1938 ECO | 08-08-17 |
| 1-9 | Clariant GmbH | Clariant Safewing EG I 1996 | 08-08-16 |
| 1-10 | Chemical Specialists and Development Inc. | Prist Wing De-Icer | 08-05-17 |
| 1-11 | Dow Chemical Company | Dow UCAR™ Aircraft Deicing Fluid Concentrate | 08-08-21 |
| 1-12 | Dow Chemical Company | Dow UCAR™ ADF XL-54 | 09-02-01 |
| 1-13 | Dow Chemical Company | Dow UCAR™ PG Aircraft Deicing Fluid | 08-02-02 |
| 1-14 | Dow Chemical Company | Dow UCAR™ PG ADF Dilute 55/45 | 08-02-02 |
| 1-15 | HOC Industries | SafeTemp I ES | 07-10-27 |
| 1-16 | HOC Industries | SafeTemp ES Plus | 07-09-15[4] |
| *1-17* | *Inland Technologies Inc.* | *Inland Duragly-P ready to use* | *05-09-11*[3] |
| *1-18* | *Inland Technologies Inc.* | *Inland Duragly-E ready to use* | *05-10-20*[3] |
| 1-19 | Kilfrost Limited | Kilfrost DF PLUS | 07-08-26[4] |
| 1-20 | Kilfrost Limited | Kilfrost DF PLUS (80) | 08-07-12 |
| 1-21 | Kilfrost Limited | Kilfrost DF PLUS (88) | 07-08-26[4] |
| 1-22 | Kilfrost Limited | Kilfrost $DF^{sustain}$ | 09-01-26 |
| 1-23 | Lyondell Chemical Co. | Lyondell ARCOPlus | 08-02-14 |
| 1-24 | Lyondell Chemical Co. | Lyondell ARCTIC Plus™ | 08-04-10 |
| 1-25 | Newave Aerochemical Co. Ltd. | Newave FCY-1A | 09-08-21 |
| 1-26 | Octagon Process Inc. | Octagon EcoFlo | 09-07-30 |
| 1-27 | Octagon Process Inc. | Octagon Octaflo EF | 09-07-11 |
| 1-28 | Octagon Process Inc. | Octagon Octaflo EG | *07-05-12*[3] |
| 1-29 | SPCA | SPCA DE-950 | 08-05-30 |
| *1-30* | *Viterbo S.A.* | *Jarkleer SAE Type I* | *07-01-20*[3] |

[1] Qualified solely with respect to anti-icing performance and aerodynamic acceptance by the Anti-icing Materials International Laboratory, Université du Québec à Chicoutimi. Web site: http://www.uqac.uquebec.ca/amil/

For other specification requirements for Type I fluids, see SAE AMS 1424 (latest version). Fluids that successfully qualify after the issuance of this list will appear in a later update.

[2] Concentrate fluids have also been qualified at 50/50 (glycol/water) dilution.

[3] Fluids listed in italics have expired and will be removed from this listing four years after expiry.

[4] Currently in qualification/re-qualification process.

**TABLE 5** (cont.)

**CURRENTLY QUALIFIED FLUIDS (2007-2008)**

| Table 5-2: Qualified[1] Type II Anti-icing Fluids | | | |
|---|---|---|---|
| **#** | **COMPANY NAME** | **FLUID NAME** | **EXPIRY (Y-M-D)** |
| 2-1 | Aviation Xi'an High-Tech | Aviation Xi'an KHF-II | 08-06-15 |
| 2-2 | Clariant GmbH | Clariant Safewing MP II 1951 | 09-05-08 |
| 2-3 | Clariant GmbH | Clariant Safewing MP II 2025 ECO | 08-06-26 |
| 2-4 | Clariant GmbH | Clariant Safewing MP II Flight | 08-04-27 |
| *2-5* | *Kilfrost Limited* | *Kilfrost ABC-II PLUS* | *05-10-29*[2] |
| 2-6 | Kilfrost Limited | Kilfrost ABC-3 | 08-07-07 |
| 2-7 | Kilfrost Limited | Kilfrost ABC-2000 | 08-07-12 |
| 2-8 | Newave Aerochemical Technology | Newave FCY-2 | 09-01-11 |
| 2-9 | Octagon Process Inc. | Octagon E Max II | 08-10-31 |
| 2-10 | SPCA | SPCA Ecowing 26 | 09-08-21 |

| Table 5-3: Qualified[1] Type III Anti-icing Fluids | | | |
|---|---|---|---|
| **#** | **COMPANY NAME** | **FLUID NAME** | **EXPIRY (Y-M-D)** |
| 3-1 | Clariant GmbH | Clariant Safewing MP III 2031 ECO | 09-05-02 |
| | **CAUTION**: The lowest operational use temperature (LOUT) is -16.5°C (2°F) for aircraft with rotation speeds less than 100 knots or -29°C (-20°F) for aircraft with higher rotation speeds. | | |

| Table 5-4: Qualified[1] Type IV Anti-icing Fluids | | | |
|---|---|---|---|
| **#** | **COMPANY NAME** | **FLUID NAME** | **EXPIRY (Y-M-D)** |
| 4-1 | Clariant GmbH | Clariant Safewing MP IV 2001 | 08-06-26 |
| *4-2* | *Clariant GmbH* | *Clariant Safewing MP IV 2012 Protect* | *07-07-12*[2] |
| 4-3 | Clariant GmbH | Clariant Safewing MP IV Launch | 08-05-16 |
| 4-4 | Dow Chemical Company | Dow UCAR ADF/AAF ULTRA+ | 08-08-21 |
| 4-5 | Dow Chemical Company | UCAR AAF FlightGuard AD-480 [3] | 08-05-31 |
| 4-6 | Dow Chemical Company | UCAR™ Endurance EG106 | 08-01-25 |
| *4-7* | *Ely Chemical Company* | *Octagon Max-Flight* | *06-07-06*[2] |
| 4-8 | Kilfrost Limited | Kilfrost ABC-S | 09-06-29 |
| 4-9 | Kilfrost Limited | ABC-S PLUS | 09-03-07 |
| 4-10 | Lyondell Chemical Co. | Lyondell ARCTIC Shield® | 08-04-26 |
| *4-11* | *Octagon Process Inc.* | *Octagon Max-Flight* | *06-07-06*[2] |
| 4-12 | Octagon Process Inc. | Octagon Max-Flight 04 | 08-05-30 |
| 4-13 | Octagon Process Inc. | Octagon MaxFlo | *07-03-24*[2] |
| 4-14 | SPCA | SPCA AD-480 | 09-07-30 |

[1] Qualified solely with respect to anti-icing performance and aerodynamic acceptance by the Anti-icing Materials International Laboratory, Université du Québec à Chicoutimi. Web site: http://www.uqac.uquebec.ca/amil/
For other specification requirements for Type II, III or IV fluids, see SAE AMS 1428 (latest version). Fluids that successfully qualify after the issuance of this list will appear in a later update.

[2] Fluids listed in italics have expired and will be removed from this listing four years after expiry.

[3] This product is identical to SPCA AD-480; the SPCA AD-480 holdover time table applies.

[4] Currently in re-qualification process.

**TABLE 6**

## SAE TYPE I DEICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type I fluid mixtures at minimum concentrations for the prevailing outside air temperature (OAT)

| Outside Air Temperature (OAT)[1] | One-Step Procedure Deicing/Anti-icing | Two-Step Procedure | |
|---|---|---|---|
| | | First Step: Deicing | Second Step: Anti-icing[2] |
| -3°C (27°F) and above | Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT | Heated water or a heated mix of fluid and water | Heated mix of fluid and water with a freezing point of at least 10°C (18°F) below OAT |
| Below -3°C (27°F) | | Freezing point of heated fluid mixture shall not be more than 3°C (5°F) above OAT | |

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes.

**NOTES**

- Temperature of water or fluid/water mixtures shall be at least 60°C (140°F) at the nozzle. Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.
- To use Type I holdover time guidelines in snow conditions, at least 1 litre/m² (~ 2 gal./100 sq. ft.) must be applied to the deiced surfaces.
- This table is applicable for the use of Type I Holdover Time Guidelines. If holdover times are not required, a temperature of 60°C (140°F) at the nozzle is desirable.

**CAUTION**

- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**

**TABLE 7**

## SAE TYPE II, TYPE III and TYPE IV ANTI-ICING FLUID APPLICATION PROCEDURES

Guidelines for the application of SAE Type II, III and IV fluid mixtures
(minimum concentrations in % by volume) as a function of outside air temperature (OAT)

| Outside Air Temperature (OAT)[1] | One-Step Procedure Deicing/Anti-icing | Two-Step Procedure | |
|---|---|---|---|
| | | First Step: Deicing | Second Step: Anti-icing[2] |
| -3°C (27°F) and above | 50/50 Heated[3] Type II/III/IV | Heated water or a heated mix of Type I, II, III or IV with water | 50/50 Type II/III/IV |
| -14°C (7°F) and above | 75/25 Heated[3] Type II/III/IV | Heated suitable mix of Type I, Type II/III/IV and water with FP not more than 3°C (5°F) above actual OAT | 75/25 Type II/III/IV |
| -25°C (-13°F) and above | 100/0 Heated[3] Type II/III/IV | Heated suitable mix of Type I, Type II/III/IV and water with FP not more than 3°C (5°F) above actual OAT | 100/0 Type II/III/IV |
| Below -25°C (-13°F) | Type II/III/IV fluid may be used below -25°C (-13°F) provided that the freezing point of the fluid is at least 7°C (13°F) below OAT and that aerodynamic acceptance criteria (LOUT) are met. Consider the use of Type I when Type II/III/IV fluid cannot be used (see Table 6). | | |

1 Fluids must not be used at temperatures below their lowest operational use temperature (LOUT).
2 To be applied before first step fluid freezes, typically within 3 minutes.
3 Clean aircraft may be anti-iced with unheated fluid.

**NOTES**
- For heated fluids, a fluid temperature not less than 60°C (140°F) at the nozzle is desirable.
- Upper temperature limit shall not exceed fluid and aircraft manufacturers' recommendations.

**CAUTIONS**
- **Wing skin temperatures may differ and in some cases may be lower than outside air temperatures; a stronger mix (more glycol) may be needed under these conditions.**
- **Whenever frost or ice occurs on the lower surface of the wing in the area of the fuel tank, indicating a cold soaked wing, the 50/50 dilutions of Type II, III or IV should not be used for the anti-icing step because fluid freezing may occur.**
- **An insufficient amount of anti-icing fluid may cause a substantial loss of holdover time. This is particularly true when using a Type I fluid mixture for the first step in a two-step procedure.**

**TABLE 8**

**VISIBILITY IN SNOW VS. SNOWFALL INTENSITY CHART[1]**

| Lighting | Temperature Range | | Visibility in Snow (Statute Miles) | | | |
|---|---|---|---|---|---|---|
| | ºC | ºF | Heavy | Moderate | Light | Very Light |
| Darkness | -1 and above | 30 and above | ≤1 | >1 to 2½ | >2½ to 4 | >4 |
| | Below -1 | Below 30 | ≤3/4 | >3/4 to 1½ | >1½ to 3 | >3 |
| Daylight | -1 and above | 30 and above | ≤½ | >½ to 1½ | >1½ to 3 | >3 |
| | Below -1 | Below 30 | ≤3/8 | >3/8 to 7/8 | >7/8 to 2 | >2 |

1 Based on: *Relationship between Visibility and Snowfall Intensity* (TP 14151E), Transportation Development Centre, Transport Canada, November 2003; and *Theoretical Considerations in the Estimation of Snowfall Rate Using Visibility* (TP 12893E), Transportation Development Centre, Transport Canada, November 1998.

**HOW TO READ THE TABLE**

Assume that the daytime visibility in snowfall is 1 statute mile and the temperature is -7°C. Based on these conditions, the snowfall intensity is light. This snowfall intensity is used to determine which holdover time guideline value is appropriate for the fluid in use.

**TABLE 9**

**LOWEST ON-WING VISCOSITY VALUES FOR ANTI-ICING FLUIDS**
***(See Table 9 endnotes)***

| Table 9-1: Type II Anti-Icing Fluids | | | |
|---|---|---|---|
| FLUID NAME | FLUID DILUTION | LOWEST ON-WING VISCOSITY [a] (mPa.s) | |
| | | MANUFACTURER METHOD | AIR 9968 REVISION A METHOD |
| Aviation Xi'An Hi-Tech KHF-II | 100/0 | 8 750 [c] | 7 690 [g] |
| | 75/25 | 6 400 [c] | 6 890 [g] |
| | 50/50 | 2 950 [c] | 3 150 [g] |
| Clariant Safewing MP II 2025 ECO | 100/0 | 5 500 [b] | 5 750 [g] |
| | 75/25 | 10 000 [b] | 10 000 [g] |
| | 50/50 | 3 000 [b] | 3 250 [g] |
| Clariant Safewing MP II Flight | 100/0 | 3 340 [g] | 3 340 [g] |
| | 75/25 | 17 500 [g] | 17 500 [g] |
| | 50/50 | 11 500 [g] | 11 500 [g] |
| Clariant Safewing MP II 1951 | 100/0 | 2 500 [b] | 2 750 [g] |
| | 75/25 | 2 900 [b] | 3 000 [g] |
| | 50/50 | 50 [b] | 50 [g] |
| Kilfrost ABC-3 | 100/0 | 2 500 [c] | 2 500 [j] |
| | 75/25 | 2 000 [c] | 2 000 [j] |
| | 50/50 | 400 [c] | 400 [j] |
| Kilfrost ABC-2000 | 100/0 | 2 350 [c] | 2 350 [g] |
| | 75/25 | 3 000 [c] | 3 000 [j] |
| | 50/50 | 1 000 [c] | 1 000 [j] |
| Kilfrost ABC-II Plus | 100/0 | 3 600 [c] | 3 600 [g] |
| | 75/25 | 4 000 [c] | 4 000 [j] |
| | 50/50 | 1 000 [c] | 1 000 [j] |
| Newave Aerochemical FCY-2 | 100/0 | 7 000 [c] | 8 920 [g] |
| | 75/25 | 18 550 [c] | 18 550 [c] |
| | 50/50 | 6 750 [c] | 7 030 [g] |
| Octagon E Max II | 100/0 | 13 520 [d] | 13 520 [g] |
| | 75/25 | 11 400 [g] | 11 400 [g] |
| | 50/50 | 2 820 [g] | 2 820 [g] |
| SPCA Ecowing 26 | 100/0 | 4 900 [e] | 4 600 [g] |
| | 75/25 | 2 200 [g] | 2 200 [g] |
| | 50/50 | 50 [g] | 50 [g] |

| Table 9-2: Type III Anti-Icing Fluids | | | |
|---|---|---|---|
| FLUID NAME | FLUID DILUTION | LOWEST ON-WING VISCOSITY [a] (mPa.s) | |
| | | MANUFACTURER METHOD | AIR 9968 REVISION A METHOD |
| Clariant Safewing MP III 2031 ECO | 100/0 | 30 [h] | Not Applicable |
| | 75/25 | 55 [h] | Not Applicable |
| | 50/50 | 10 [h] | Not Applicable |

**TABLE 9 (cont.)**

**LOWEST ON-WING VISCOSITY VALUES FOR ANTI-ICING FLUIDS**
***(See Table 9 endnotes)***

| Table 9-3: Type IV Anti-Icing Fluids | | | |
|---|---|---|---|
| FLUID NAME | FLUID DILUTION | LOWEST ON-WING VISCOSITY [a] (mPa.s) | |
| | | MANUFACTURER METHOD | AIR 9968 REVISION A METHOD |
| Clariant Safewing MP IV 2001 | 100/0 | 18 000 [b] | 18 000 [c] |
| | 75/25 | 8 000 [b] | 11 500 [g] |
| | 50/50 | 1 200 [b] | 1 750 [g] |
| Clariant Safewing MP IV 2012 Protect | 100/0 | 7 800 [b] | 7 250 [g] |
| | 75/25 | 17 800 [b] | 17 700 [c] |
| | 50/50 | 4 500 [b] | 4 250 [g] |
| Clariant Safewing MP IV Launch | 100/0 | 7 550 [g] | 7 550 [g] |
| | 75/25 | 18 000 [g] | 18 000 [g] |
| | 50/50 | 17 800 [g] | 17 800 [g] |
| Dow UCAR AAF FlightGuard AD-480 | 100/0 | 15 200 [e] | 12 800 [c] |
| | 75/25 | 16 000 [e] | 12 400 [c] |
| | 50/50 | 4 000 [e] | 3 800 [g] |
| Dow UCAR ADF/AAF ULTRA+ | 100/0 | 36 000 [f] | 28 000 [c] |
| | 75/25 | Dilution Not Applicable | Dilution Not Applicable |
| | 50/50 | Dilution Not Applicable | Dilution Not Applicable |
| Dow UCAR Endurance EG106 | 100/0 | 24 850 [f] | 2 230 [g] |
| | 75/25 | Dilution Not Applicable | Dilution Not Applicable |
| | 50/50 | Dilution Not Applicable | Dilution Not Applicable |
| Kilfrost ABC-S | 100/0 | 17 000 [c] | 17 000 [c] |
| | 75/25 | 12 000 [c] | 12 000 [c] |
| | 50/50 | 2 000 [c] | 2 000 [j] |
| Kilfrost ABC-S PLUS | 100/0 | 17 900 [c] | 17 900 [c] |
| | 75/25 | 18 300 [c] | 18 300 [c] |
| | 50/50 | 7 500 [c] | 7 500 [j] |
| Lyondell Arctic Shield® | 100/0 | 23 150 [i] | 28 000 [c] |
| | 75/25 | 21 700 [i] | 22 100 [c] |
| | 50/50 | 6 400 [i] | 7 640 [g] |
| Octagon Max-Flight | 100/0 | 5 540 [d] | 5 540 [g] |
| | 75/25 | 15 000 [g] | 15 000 [g] |
| | 50/50 | 5 200 [g] | 5 200 [g] |
| Octagon Max-Flight 04 | 100/0 | 5 540 [d] | 5 540 [g] |
| | 75/25 | 15 000 [g] | 15 000 [g] |
| | 50/50 | 5 200 [g] | 5 200 [g] |
| Octagon MaxFlo | 100/0 | 8 670 [g] | 8 670 [g] |
| | 75/25 | 8 200 [g] | 8 200 [g] |
| | 50/50 | 2 200 [g] | 2 200 [g] |
| SPCA AD-480 | 100/0 | 15 200 [e] | 12 800 [c] |
| | 75/25 | 16 000 [e] | 12 400 [c] |
| | 50/50 | 4 000 [e] | 3 800 [g] |

**TABLE 9 (cont.)**

**LOWEST ON-WING VISCOSITY VALUES FOR ANTI-ICING FLUIDS**

**NOTES**

a The Aerospace Information Report (AIR) 9968 Revision A (December 2004) viscosity method should only be used for field verification and auditing purposes; when in doubt as to which method is appropriate, use the manufacturer method.

b Brookfield Spindle SC4-34/13R, small sample adapter, 10 mL of fluid, at 20°C, 0.3 rpm, for 15 minutes 0 seconds.

c Brookfield Spindle LV2-disc with guard leg, 150 mL of fluid, at 20°C, 0.3 rpm, for 10 minutes 0 seconds.

d Brookfield Spindle LV1 with guard leg, 500 mL of fluid, at 20°C, 0.3 rpm, for 33 minutes 20 seconds.

e Brookfield Spindle SC4-34/13R, small sample adapter, 10 mL of fluid, at 20°C, 0.3 rpm, for 30 minutes 0 seconds.

f Brookfield Spindle SC4-31/13R, small sample adapter, 10 mL of fluid, at 0°C, 0.3 rpm, for 10 minutes 0 seconds.

g Brookfield Spindle LV1 with guard leg, 500 mL of fluid, at 20ºC, 0.3 rpm, for 10 minutes 0 seconds.

h Brookfield Spindle LV0, UL-Adapter, 16 mL of fluid, at 20ºC, 0.3 rpm, for 10 minutes 0 seconds.

i Brookfield Spindle SC4-31/13R, small sample adapter, 9 mL of fluid, at 20°C, 0.3 rpm, for 33 minutes 0 seconds.

j Brookfield Spindle LV1 with guard leg, 150 mL of fluid, at 20ºC, 0.3 rpm, for 10 minutes 0 seconds.

**SIGNIFICANCE OF THIS TABLE**

The viscosity values of the fluids in this table are those of the fluids provided by the manufacturers for holdover time testing. For the holdover time guidelines to be valid, the viscosity of the fluid on the wing shall not be lower than that listed in this table. The user should periodically ensure that the viscosity value of a fluid sample taken from the wing is not lower than that listed.

## ICE PELLET ALLOWANCE TIMES FOR WINTER 2007-2008

Comprehensive ice pellet research was conducted jointly by the research teams of the FAA and Transport Canada. This research consisted of extensive climatic chamber, wind tunnel, and live aircraft testing with ice pellets (light or moderate) and light ice pellets mixed with other forms of precipitation.

Results of this research provide the basis for allowance times for operations in ice pellets (light or moderate) and operations in light ice pellets when mixed with other forms of precipitation.

Additionally, Type IV anti-icing fluid with ice pellets embedded was evaluated for its aging qualities over periods of time beyond the allowance times, when the active precipitation time was limited to the allowance times.

**Operational Guidelines**

1) Tests have shown that ice pellets generally remain in the frozen state imbedded in Type IV anti-icing fluid, and are not dissolved by the fluid in the same manner as other forms of precipitation. Using current guidelines for determining anti-icing fluid failure, the presence of a contaminant not dissolved by the fluid (remaining embedded) would be an indication that the fluid has failed. These embedded ice pellets are generally not readily detectable by the human eye during pre-takeoff contamination inspection procedures.

2) The research data have also shown that after proper deicing and anti-icing, the accumulation of light ice pellets, moderate ice pellets, and light ice pellets mixed with other forms of precipitation in Type IV fluid will not prevent the fluid from flowing off the aerodynamic surfaces during takeoff.

3) The allowance times were developed based on this aerodynamic testing and are contained in Table 10.

4) The ice pellet allowances are contingent on the operator's approved ground icing program being updated to incorporate the ice pellet information contained herein including the following conditions and restrictions which must be satisfied:

   a) The aircraft critical surfaces must be properly deiced before the application of Type IV anti-icing fluid;

   b) The allowance time is valid only if the aircraft is anti-iced with undiluted Type IV fluid;

   c) These allowance times are from the start of the Type IV anti-icing fluid application;

   d) The allowance time is limited to aircraft with a rotation speed of 100 knots or greater;

   e) If the takeoff is not accomplished within the applicable allowance time in Table 10, the aircraft must be completely deiced, and if precipitation is still present, anti-iced again prior to a subsequent takeoff.

   f) The allowance time cannot be extended by an inspection of the aircraft critical surfaces from either inside or outside the aircraft;

   g) If the temperature decreases below the temperature on which the allowance time was based, where the new lower temperature has an associated allowance time for the precipitation

condition and the present time is within the new allowance time, then that new time must be used as the allowance time limit;

h) If ice pellet precipitation becomes heavier than moderate or if the light ice pellets mixed with other forms of allowable precipitation exceeds the listed intensities or temperature range, the allowance time cannot be used;

i) If the precipitation condition stops at or before the time limits of the applicable allowance time in Table 10 and does not restart the aircraft may takeoff up to 90 minutes after the start of the application of the Type IV anti-icing fluid. However, under conditions of light ice pellets mixed with light freezing rain, the OAT must not decrease during the 90-minute period.

5) Examples:

a) Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0°C, light ice pellets fall until 10:20 and stop and do not restart. The allowance time stops at 10:50; however, provided that no precipitation restarts after the allowance time of 10:50 the aircraft may takeoff without any further action up to 11:30.

b) Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0°C, light ice pellets mixed with freezing drizzle falls until 10:10 and stops and restarts at 10:15 and stops at 10:20. The allowance time stops at 10:25, however provided no precipitation restarts after the end of the allowance time at 10:25, the aircraft may takeoff without any further action up to 11:30.

c) Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0°C, light ice pellets mixed with light freezing rain falls until 10:10 and stops and restarts at 10:15 and stops at 10:20. The allowance time stops at 10:25, however provided that the OAT remains constant or increases and that no precipitation restarts after the end of the allowance time at 10:25, the aircraft may takeoff without any further action up to 11:30.

d) On the other hand, if Type IV anti-icing fluid is applied with a start of application time of 10:00, OAT is 0°C, light ice pellets mixed with freezing drizzle falls until 10:10 and stops and restarts at 10:30 with the allowance time stopping at 10:25 the aircraft may not takeoff**,** no matter how short the time or type of precipitation after 10:25, without being deiced and anti-iced if precipitation is present.

## Transport Canada Holdover Time Guidelines — Winter 2007-2008

**TABLE 10**

**ICE PELLET ALLOWANCE TIMES FOR WINTER 2007-2008**

| | 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 |
| **Moderate Ice Pellets** | 25 Minutes | 10 Minutes | 10 Minutes |
| **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 | | |
| **Light Ice Pellets Mixed with Light or Moderate Snow** | 25 Minutes | | |

# APPENDIX D

# PROPOSED AEROSPACE RECOMMENDED PRACTICE 5718: QUALIFICATION PROCESS FOR SAE AMS 1428 TYPE II, III, AND IV FLUIDS

| SAE Aerospace<br>An SAE International Group | AEROSPACE RECOMMENDED PRACTICE | ARP5718 | |
|---|---|---|---|
| | | Issued | Proposed Draft 2007-07-20 |
| | | Revised | |

Qualification Process for
SAE AMS 1428 Type II, III, and IV Fluids

RATIONALE

This ARP documents the steps and processes: a) to select samples for testing experimental Type II, III and IV fluids according to AMS 1428 and ARP 5485, b) run field spray tests, c) to generate holdover time guidelines from endurance time data, and d) to add and remove fluids from the list of qualified fluids published by regulators, namely Transport Canada and the FAA.

FOREWORD

It is not sufficient for an anti-icing fluid to meet all of the requirements of AMS 1428 for airlines to be able to use such fluid. For such a fluid to be used commercially, it must also have a holdover time guideline and be identified on a list of qualified fluids acceptable to regulators[1]. Before commercialization, it is further recommended that a field spray trial be conducted with the anti-icing fluid to demonstrate acceptable performance.

The intent of this ARP is to help fluid manufacturers and users to understand the overall process that a fluid must go through to be used in aviation. It describes and documents the processes by which an experimental fluid may become a fully qualified fluid.

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[1] The aircraft manufacturers must also identify the types of fluids which can be applied to their aircraft type. This information is usually located in the maintenance manual winter operations section or in the Aircraft Operating Manual (AOM).

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## 1. SCOPE

This document describes:

a) the preparatory steps to test experimental Type II, III and IV fluids according to AMS 1428;
b) the recommendations for the preparation of samples for endurance time testing according to ARP 5485;
c) a short description of recommended field spray test;
d) the protocol to generate draft holdover time guidelines from endurance time data as obtained from ARP 5485;
e) the role of the SAE G-12 Fluids Subcommittee;

f) the role of the SAE G-12 Holdover Time Subcommittee;
g) the process for the publication of holdover time guidelines and list of qualified Type II, III and IV fluids.

This document does not describe laboratory testing procedures.

This document does not include the qualification process for AMS 1424 Type I fluids.

1.1 Definitions and Abbreviations

Aerodynamic acceptance: a performance test required under §3.2.5 of AMS 1428 and defined in AS 5900.

Anti-icing fluid: a non-Newtonian fluid designed to protect aircraft on the ground against freezing or frozen precipitation for a limited time.

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.

FAA: United States Department of Transportation, Federal Aviation Administration.

Holdover time (HOT): time a fluid is expected to provide protection of an aircraft against freezing or frozen precipitation from the initial application of an anti-icing fluid.

Holdover time table: a table giving the holdover time for various precipitation conditions and temperatures.

Holdover time guideline: a holdover time table with cautions and notes giving guidance to ground deicing/anti-icing crews and pilots.

Lower sales specification viscosity limit: viscosity set by the fluid manufacturer for its sales specification. This viscosity must be equal to or higher than the AMS 1428 low viscosity.

Lowest on-wing viscosity (LOWV): viscosity reported by the laboratory performing the testing under §3.1.3 of ARP 5485. This LOWV is published with the specific holdover time guideline for that fluid. Fluids having an on-wing viscosity less than the LOWV cannot be used with holdover time guidelines.

Lowest operational use temperature (LOUT): the lowest operational use temperature of an anti-icing fluid is 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 7ºC (about 13ºF).

Maximum on-wing viscosity (MOWV): see AMS 1428 high viscosity. Fluids having a viscosity higher than the MOWV must not be used.

OAT: Outside Air Temperature.

Qualification: process by which an anti-icing fluid meeting all of the requirements of AMS 1428:

a) undergoes ARP 5485 testing;
b) obtains a fluid specific holdover time guideline;
c) fulfills any additional regulator requirements to be listed as a qualified fluid.

Qualified fluid: an anti-icing fluid meeting all the requirements to be on the FAA, Transport Canada or other appropriate regulatory authority list of qualified fluids.

Upper sales specification viscosity limit: viscosity set by the fluid manufacturer for its sales specification. This viscosity must be equal to or lower than the AMS 1428 high viscosity or MOWV.

Water spray endurance test (WSET): a performance test defined in AS 5901.

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, 400 Commonwealth Drive, Warrendale, PA 15096-0001, telephone: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), Web address: http://www.sae.org

AMS 1424 Deicing/Anti-icing Fluid, Aircraft, SAE Type I

AMS 1428[2] Fluid, Aircraft Deicing/Anti-icing Fluid, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV

ARP 5485 Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids SAE Types II, III and IV.

ARP 5945 Endurance Time Tests for Aircraft Deicing/Anti-icing Fluid SAE Type I.

AS 5900 Standard Test Method for Aerodynamic Acceptance for SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids.

AS 5901 Water Spray and High Humidity Endurance Test Methods for SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids.

2.2 Transport Canada Publications

Available from the Transportation Development Center, Transport Canada, 800, boul. René-Lévesque Ouest, 6th Floor, Montréal QC H3B 1X9, Canada and at http://www.tc.gc.ca/CivilAviation/commerce/HoldoverTime/menu.htm

Transport Canada Holdover Time Guidelines. (These are published every winter. Always use the latest issue).

Guidelines for Aircraft Ground Icing Operations. TP14052E, April 2005.

2.3 FAA Publications

Available from the Federal Aviation Administration at http://www.faa.gov/. (The following are published every winter. Always use the latest issue.):

Holdover Time Tables.

FAA-APPROVED DEICING PROGRAM UPDATES, WINTER 2006-2007. Notice N.8000.327 available at: http://www.faa.gov/library/manuals/examiners_inspectors/8000/

3. SAMPLE SELECTION AND LABORATORY TESTING

3.1 Preliminary Work

In the course of development work, it is normal for fluid manufacturers to prepare various samples and verify the physical and performance properties of the fluids. To do this they usually perform a certain amount of work within their own laboratories and will verify their results by having samples tested by the various external laboratories performing AMS 1428 testing. Such laboratories are listed in section 3.5.

3.2 Testing According to AMS 1428

3.2.1 Sample Selection

Fluid testing according to AMS 1428 is performed on two kinds of samples: the high viscosity preproduction sample and the low viscosity preproduction sample. AMS 1428 describes these samples (see §4.2.3 of AMS

[2] AMS 1428 paragraph numbers throughout this ARP 5718 are from AMS 1428F.

1428) and the tests to be performed on each. The fluid manufacturer should select these viscosities carefully as the viscosities measured will be used to establish quality control limits for fluid being delivered for use (see §3.2.3 of AMS 1428). The viscosity measured on the high viscosity preproduction sample will become the maximum on-wing viscosity (MOWV) for that fluid.

Typically, 12 liters of the high viscosity preproduction sample and 6 liters of the low viscosity sample are required to do the anti-icing performance (§3.2.4 of AMS 1428 and AS 5901) and aerodynamic acceptance (§3.2.5 of AMS 1428 and AS 5900) testing. Other AMS 1428 tests such as environmental testing (§3.1.4), flash point (§3.2.1.1), specific gravity (§3.2.1.2), pH (§3.2.1.3), fluid stability (§3.2.2), effect on aircraft materials (§3.3.2) require about 12 liters. Additional material is required to complete other technical requirements specified in AMS 1428. Ask the testing laboratories for the exact quantities to be shipped.

3.3 Endurance Time Testing According to ARP 5485

3.3.1 Sample Selection

It is specified in §3.1.1 of ARP 5485 that the fluid manufacturer must provide a sample from a production batch. The viscosity should be reduced by the manufacturer. The fluid manufacturer should select the viscosity carefully as the viscosity measured by the testing laboratory will be become the lowest on-wing viscosity (LOWV) for that fluid.

Quantities of anti-icing fluid required for the testing under ARP 5485 are about 120 liters for neat (100%) fluid, about 100 liters for 75/25 and about 60 liters for the 50/50. Ask the testing laboratory for the exact quantities required.

3.4 Water Spray Endurance Test Time Requirements

Refer to ARP 5485 (§3.2.1) and AMS 1428 (§3.2.4.1) for minimum WSET time requirement.

3.5 Testing Laboratories

As of the date of publication of the ARP the following laboratories are known to provide testing for anti-icing fluids. This is not an endorsement by SAE for these laboratories but simply a list to facilitate the finding of laboratories for those seeking fluid qualification. Please enquire directly with the laboratories 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 provides endurance time testing described in ARP 5485.

Anti-icing Materials International Laboratory (AMIL), 555, boulevard de l'Université, Chicoutimi, Québec, G7H 2B1, Canada; 418-545-5011 ext. 2406; www.uqac.ca/amil, provides testing for exposure to dry air (§3.2.2.2 of AMS 1428), anti-icing performance (§3.2.4 of AMS 1428 and AS 5901), aerodynamic acceptance (§3.2.5 of AMS 1428 and AS 5900) and endurance time testing described in ARP 5485.

Scientific Material International, 12219 SW 131st Avenue, Miami, Florida, USA 33186-6401; 305-971-7047; www.smiinc.com, provides testing to generate most environmental information (§3.1.4 of AMS 1428), several of the tests described under §3.2.1 of AMS 1428 and effect on materials testing (§3.3.2, §3.3.3, §3.3.4, §3.3.5 of AMS 1428).

4. FIELD SPRAY TESTING

4.1 Reason for field spray test

It has occurred in the past that anti-icing fluids meeting all the requirements of AMS 1428 could not be used commercially because of a significant flaw that could not be identified by laboratory testing but became known through a field spray trial. Every time this becomes known, every effort is made to add new laboratory test requirements to AMS 1428 to prevent a fluid with a serious flaw to be commercialized. Nevertheless, it is highly recommended to conduct such a spray trial as a) some fluid characteristics are not easily duplicated in the laboratory and b) some unknown flaw may not be covered by AMS 1428.

4.2 Sample Selection

The sample should be from a normal production batch. Usually, 1000 liters of anti-icing fluid is sufficient to run a field spray trial.

Sometimes it might be desirable to evaluate an experimental fluid before all testing is completed. Even if the fluid is washed away from the aircraft after the test, field test on aircraft must be done with anti-icing fluids that meet all the requirements of the Effect on Aircraft Materials (§3.3.2 of AMS 1428), Effect on Painted Surfaces (§3.3.3 of AMS 1428) and Effect on Unpainted Surfaces (§3.3.4 of AMS 1428) to ensure that no damage will be done to the aircraft.

Never attempt a flight with an anti-icing fluid unless it meets all requirements of AMS 1428.

4.3 Test Protocol

The anti-icing fluid should be applied as supplied or in intended use dilutions and heated to intended use temperatures, applied through commercial deicing/anti-icing vehicle systems to an inclined flat or curved surface, preferably an aircraft wing or horizontal stabilizer, at pressures and flow rates normal for the intended use. Such field spray testing should be accomplished by experienced personnel who will prepare a detailed test protocol, observe carefully the behavior of the fluid and be on the look-out for deficiencies such as:

1) tendency to foam as described in §3.2.2.9 of AMS 1428;
2) difficulty with the flow of the fluid over the surfaces to be covered;
3) insufficient color intensity to prevent interference from a layer of Type I fluid underneath (this phenomenon is known as bleed-through);
4) residues.

Pre- and post-nozzle samples should be gathered, viscosity measured and verification made to ensure that post-nozzle samples are above LOWV and below MOWV.

5. PREPARATION OF DRAFT HOLDOVER TIME GUIDELINES

5.1 Holdover Time Table Format

Holdover time tables for Type II, III and IV anti-icing fluids have 7 columns representing categories of freezing or frozen precipitation:

1) Active frost
2) Freezing fog
3) Snow or snow grains
4) Freezing drizzle
5) Light freezing rain
6) Rain on cold soaked wing
7) Other

For Type III holdover time tables, the snow or snow grain column is subdivided into very light, light and moderate.

Holdover time tables for Type II and Type IV anti-icing fluids have rows corresponding to the following temperature ranges: -3°C and above, below -3°C to -14°C, below -14°C to -25°C, and below –25°C.

Holdover time tables for Type III anti-icing fluids have rows corresponding to the following temperature ranges: -3°C and above, below -3°C to -10°C, and below –10°C.

The Type II and Type IV tables contain 45 cells. Each cell provides a range of time during which a fluid at a specified concentration (100/0, 75/25, 50/50) may provide protection for a particular temperature range in a particular category of precipitation. The time range in each cell is defined by a lower time and upper time, with the exception of the frost cells, which consist of a single value; these values represent the average failure time of the fluid at the upper and lower precipitation rate limits, respectively.

Generic and brand-specific holdover time guidelines will have an issue date and/or a revision date.

5.2 Notes

Notes are added to the holdover time tables, such as:

a) Use light freezing rain holdover time if positive identification of freezing drizzle is not possible.
b) "Other" comprises heavy snow, snow pellets, moderate and heavy freezing rain, and hail.
c) No holdover time exists for freezing drizzle or light freezing rain below OAT of -10ºC (-14ºF).
d) Ensure that the lowest operational temperature (LOUT) is respected.

5.3 Cautions

Cautions are added to the holdover tables, such as:

a) The time of protection will be shortened in heavy weather conditions, heavy precipitation rates or high moisture content.
b) High wind velocity or jet blast may reduce holdover time below the lowest stated time in the range.
c) Holdover time may be reduced when aircraft skin temperature is lower than OAT.
d) Anti-icing fluids used during ground deicing/anti-icing are not intended for and do not provide protection during flight.

5.4 Restrictions

Fluid manufacturers must inform the chairs of the Chairs of the SAE Holdover Time Subcommittee of the restrictions on use of their fluid, for instance, if the fluid is not to be used diluted or if the fluid cannot be used below a certain temperature. Brand-specific holdover time tables must reflect such restrictions.

5.5 Holdover Time Values from Endurance Time Data

ARP 5485 describes in detail all the conditions and the number of tests required to fill each of the cells of a holdover time table.

The endurance time data generated by ARP 5485 is converted to holdover time data by multiplying the endurance data by a factor which as of the publication of this ARP is one. Rounding is done in accordance with 5.6 below.

5.6 Rounding of Holdover Time Values

Holdover time values are rounded off to the nearest whole "5" digit. For example, 55.1 to 57.4 minutes is rounded down to 55 minutes; 57.5 to 59.9 minutes is rounded up to 60 minutes. In all cases where anti-icing fluid holdover times are below 10 minutes, the numbers are rounded down as a precautionary measure. For values below 10 minutes, round down to the nearest minute.

5.7 Capping of Holdover Time Values

Holdover time values are capped at 2 hours for freezing precipitation, 4 hours for freezing fog and 12 hours for frost.

5.8 Product Names

It is usual for anti-icing fluid manufacturers to submit anti-icing fluids bearing experimental names. This is normal as the decision to commercialize occurs generally after the result from ARP 5485 testing are shared with the manufacturer. If the manufacturer decides to commercialize the fluid, they must give the laboratories that tested for AMS 1428 and ARP 5485 and Transport Canada and the FAA who publish the holdover time guidelines the final commercial name prior to July 1st preceding the winter of commercial availability.

New fluids must be assigned new unique names. Fluids manufacturers who reformulate an existing fluid must give the fluid a new unique name (see also 5.9.2).

5.9 Development of Brand-Specific Holdover Time Tables

5.9.1 New Fluids

A draft holdover time guideline is prepared for every fluid submitted. The fluid manufacturer may request to see the brand-specific holdover time table in advance and may decide not to have it published.

5.9.2 Fluid Retesting

If a new sample of a fluid with the same name is submitted for ARP 5485 testing, even if it is submitted years after the earlier submission, the holdover time tables will be readjusted as follows:

a) If the LOWV of the new sample is the same as the original sample, the lowest test data from the two samples shall be used to calculate the brand-specific and generic holdover time tables.

b) If the LOWV of the new sample is above the original sample, the fluid manufacturer shall have the choice of:
   i) selecting the lower original LOWV for the brand-specific holdover time table in which case the lowest test data from the two samples shall be used to calculate the brand-specific and generic holdover time tables or
   ii) selecting the new higher LOWV for the brand-specific holdover time guideline in which case the data from the earlier sample shall be eliminated from the brand specific and generic holdover times and the new sample shall be used to calculate revised brand-specific and generic holdover time tables

c) If the LOWV of the new sample is below the original sample, the fluid manufacturer shall have the choice of:
   i) selecting the new lower LOWV for the brand-specific holdover time table in which case the lowest test data from the two samples shall be used to calculate the brand-specific and generic holdover time tables or
   ii) selecting the higher original LOWV for the brand-specific holdover time guideline in which case there shall be no change to the brand-specific and generic holdover time tables.

Should several samples be submitted, the decision process described above shall be used to handle multiple samples. Every time a new sample is submitted, the starting point shall be the endurance time data used to calculate the then-effective brand-specific holdover time table and the LOWV for that same brand-specific holdover time table.

5.10 Development of Generic Holdover Time Guidelines

The terms *generic* applies to holdover time guidelines comprised of the lowest holdover time performance (worst case) of all qualified fluids separated by AMS 1428 fluid type (II, III, or IV) under all conditions. The combined results of all tests conducted with any qualified anti-icing fluid are compared on a cell-by-cell basis to determine the lowest holdover time values for each cell of the holdover time table.

Three generic holdover time guidelines for anti-icing fluids are prepared: one for Type II, one for Type III and one for Type IV fluids.

5.11 Upper Limit of Type II Generic Holdover Time

All Type IV fluids qualify as Type II fluids and are expected to exhibit superior performance over that of Type II fluids; however, Type II fluids, do not qualify as Type IV fluids.

Therefore, the times in the cells of the generic Type II holdover time table must not exceed the times in the equivalent cells for Type IV generic holdover time. This means that if a reduction has been made to a cell of the *generic* holdover time table for Type IV fluid, the corresponding cell in the *generic* Type II table must be verified. If the holdover time in the Type II table is superior to the reduced time in the Type IV table, the Type II time must be reduced to match that of Type IV table.

5.12 Removal of Obsolete Data

5.12.1 Obligation of Fluid Manufacturers to Notify on Commercial Products

Fluid manufacturers must notify the chairs of SAE G-12 Holdover Time Subcommittee of the list of all Type II, III and IV fluids that are to be commercially available for the following winter no later than on the first of July, the notification day.

5.12.2 Test Qualification Report Expiry Dates Included in List of Qualified Fluids

The expiration date of the fluid's preproduction or periodic test qualification reports (see §5.13), may be included in the list of qualified fluids.

5.12.3 Removal from the Qualified List of Fluids and Removal of Brand-Specific Holdover Time Tables

Upon the earlier of i) four years after the notification day when the chairs of SAE G-12 are informed that a fluid will no longer be commercialized (or not informed that a product will be commercialized) or ii) four years after the expiration date on the fluid's preproduction or periodic test qualification reports (see §5.13), the following shall be done[3]:

a) the fluid shall be removed from the list of qualified fluids;
b) the fluid's endurance time data shall be removed from the appropriate generic holdover time table calculations and analysis; and
c) the brand-specific holdover time table shall no longer be published,

5.13 Fluid Periodic Test Requirements

Fluids must be periodically retested according to §4.2.2 of AMS 1428. The frequency and the tests to be performed are given in that same AMS 1428 section. Retesting according to ARP 5485 is not required unless fluid re-approval is required (see §4.4 of AMS 1428).

6. ROLE OF THE SAE G-12 FLUIDS SUBCOMMITTEE

The SAE G-12 Fluids Subcommittee is responsible for preparation and maintenance of fluid standards such as AMS 1424, AMS 1428, AS 5900, and AS 5901. Impact of fluid on aircraft or field performance should be presented and discussed during the annual general meeting of the SAE G-12 Fluids Subcommittee.

7. ROLE OF THE SAE G-12 HOLDOVER TIME SUCCOMMITTEE

In addition to its normal role of preparing and maintaining standards such as this ARP 5718, ARP 5485 and ARP 5945, the SAE G-12 Holdover Time Subcommittee acts as an advisory body to the FAA and Transport Canada, who publish the holdover time guidelines, on matters related to anti-icing fluid holdover times. The SAE G-12 Holdover Time Subcommittee is a normal path for recommendations to regulators on matters related to holdover time.

New draft holdover time guidelines should be presented for review to the SAE G-12 Holdover Time Subcommittee at least annually during the annual general meeting of the SAE G-12.

The impact of new or obsolete fluids on the generic holdover time guidelines should be presented and discussed during the meeting of the annual meeting of the SAE G-12. The benefits and disadvantages of new fluids should be examined by the SAE G-12 Holdover Time Subcommittee.

The SAE Holdover Time Subcommittee should recommend to the regulators to include data only for fluids that do not unnecessarily reduce holdover time.

[3] The implication is that a fluid manufacturer must not sell a fluid which may have been manufactured after a qualification test report has expired. A user should not use a fluid unless it is on the list of qualified fluids.

8. PUBLICATION OF HOLDOVER TIME GUIDELINES

8.1 Obligation of Fluid Manufacturers to Provide AMS 1428 Test Data

Fluids manufacturers must provide no later than December 01 the following information in electronic format to the Chairs of the SAE G-12 Holdover Time Subcommittee at the time of the original testing and at each periodic retesting as defined in AMS 1428 (§4.2.2):

8.1.1 Data for Type II and Type IV Anti-icing Fluids

a) climatic chamber evaluation qualification test report (defined in §3.2.4 AMS 1428 as Anti-icing Performance and tested in accordance with AS 5901);

b) large transport type jet aircraft aerodynamic qualification test report (defined in §3.2.5 AMS 1428 as Aerodynamic Acceptance and tested in accordance with AS 5900 High Speed Ramp);

c) freezing point of the 100, 75/25 and 50/50 dilutions (§3.2.4.1 of AMS 1428) which in conjunction with the large transport type jet aircraft aerodynamic qualification test report will be used to calculate the LOUT for large transport type jet aircraft

8.1.2 Data for Type III Anti-icing Fluids

a) climatic chamber evaluation qualification test report (defined in §3.2.4 of SAE AMS 1428 as Anti-icing Performance and tested according to AS 5901);

b) commuter type aircraft aerodynamic qualification test reports (defined §3.2.5 in AMS 1428 as Aerodynamic Acceptance and tested in accordance with AS 5900 Low Speed Ramp) and may optionally[4] provide large transport type jet aircraft aerodynamic qualification test report (defined in §3.2.5 of AMS 1428 as Aerodynamic Acceptance and tested in accordance with AS 5900 High Speed Ramp;

c) freezing point of the 100, 75/25 and 50/50 dilutions (§3.2.4.1 of AMS 1428) which in conjunction aerodynamic qualification test report(s) will be used to calculate the LOUT(s).

8.1.3 Data for Each Location Where Anti-icing Fluid is Produced

a) If the anti-icing fluid is produced in more than one location, the data listed above in §8.1.1 and §8.1.2 is required for each manufacturing location.

8.2 Additional Data Required by Regulators

Regulators may ask for additional data, such test results for all other technical requirements of AMS 1428 (often referred to as the material compatibility results) and any other data they deem necessary.

8.3 Publication of Holdover Time Guidelines and List of Qualified Fluids by Regulators

Transport Canada and the FAA will normally publish holdover time guidelines, and list of qualified fluid in late summer or early fall (northern hemisphere).

9. TIMELINE

May: The annual SAE G-12 meeting is usually held in mid-to-late May. All of the SAE-G12 Subcommittees meet including the Fluids and Holdover Time Subcommittees.

July 01 is the deadline for fluid manufacturers to give the chairs of the Holdover Time Subcommittee their list of qualified fluids that are or will be commercially available and a list of those still in testing that may be commercialized once test results are obtained for the coming winter (northern hemisphere).

Middle to end of July is the target period for the publication of the holdover time guidelines by the FAA and Transport Canada.

[4] Type III fluids, as defined in AMS 1428 (§1.1.1), are meant to be used on low-speed aircraft. A fluid manufacturer may optionally also obtain aerodynamic data for high-speed aircraft to enable the use of the fluid on such aircraft type at lower temperatures.

August through March are the months when the Transport Canada and the FAA may publish interim holdover time guidelines due to updated information or special issues.

October-November: The mid-year meetings for the Holdover Time and the Fluids Subcommittees are usually held in late October or early November.

December 01. Documentation described in §8.1, if submitted by fluid manufacturers after July 01 but before December 01, will be considered for inclusion in interim holdover time tables for the current winter.

PREPARED UNDER THE JURISDICTION OF
SAE COMMITTEE G–12, AIRCRAFT GROUND DEICING

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# APPENDIX E

# EXEMPTION FROM SUBSECTION 602.11(4) OF THE CANADIAN AVIATION REGULATIONS AND SECTIONS 1.0, 3.0, 6.0, 6.2, 6.3 AND 7.1.1.1 OF STANDARD 622.11 GROUND ICING OPERATIONS

**Exemption from Subsection 602.11(4) of the *Canadian Aviation Regulations* and Sections 1.0, 3.0, 6.0, 6.2, 6.3 and 7.1.1.1 of Standard 622.11 *Ground Icing Operations***

**WHEN A HOLDOVER TIME DETERMINATION REPORT (HOTDR), GENERATED BY A HOLDOVER TIME DETERMINATION SYSTEM (HOTDS)** is being utilized as part of an approved Ground Icing Operations Program,

pursuant to subsection 5.9(2) of the *Aeronautics Act*, and after taking into account that the exemption is in the public interest and is not likely to affect aviation safety, I hereby exempt **WestJet, 5055 11 St. NE, Calgary, Alberta, T2E 8N4, Canada** from the requirements related explicitly to the element of Holdover Timetables (hereinafter HOT) forming part of the Ground Icing Operations Program as stipulated in sections 1.0, 3.0, 6.0, 6.2, 6.3 and 7.1.1.1 of Standard 622.11 *Ground Icing Operations* made pursuant to subsection 602.11(4) of the *Canadian Aviation Regulations* (CARs). The above provisions are attached at Appendix A to this exemption.

**PURPOSE**

The purpose of this exemption, is to permit WestJet, **5055 11 St. NE, Calgary, Alberta, T2E 8N4, Canada** to utilize HOTDR generated by a HOTDS, in addition to or in lieu of their current HOT procedures, as part of their approved Ground Icing Operations Program.

**APPLICATION**

This exemption applies to **WestJet 5055 11 St. NE, Calgary, Alberta, T2E 8N4, Canada** when using a HOTDR generated from a HOTDS as part of an approved Ground Icing Operations Program at Canadian airports which are identified in WestJet's approved Ground Icing Operations Program.

**CONDITIONS**

This exemption is subject to the following conditions:

1. When not utilizing the HOTDS, all requirements/elements of Standard 622.11 *Ground Icing Operations*, shall continue to apply as part of the approved ground icing operations program;

2. When utilizing the HOTDS, every requirement/element of Standard 622.11 *Ground Icing Operations*, not explicitly exempted from in, or not related to, this Ministerial exemption, including those stipulated in sections 1.0, 3.0, 6.0, 6.2, 6.3, 7.1.1.1, shall continue to apply as part of the approved ground icing operations program;

3. Prior to its use, WestJet shall ensure that the HOTDS has been declared by the service provider and/or the manufacturer as applicable, to have met the applicable minimum performance specification attached at Appendix C to this exemption;

4. WestJet shall revise the Company Operations Manual (COM) to include operational procedures associated with the use of the HOTDS. The revised COM shall be approved by Transport Canada Civil Aviation prior to the utilization of the HOTDR;

5. WestJet shall have a contingency plan in the COM to address the possible outage of the HOTDS;

6. WestJet shall develop and provide a training program for their flight crew and operations personnel as approved by Transport Canada on the use of the applicable HOTDS and associated Reports;

7. When using a HOTDS (during active Freezing Fog, Rain on Cold Soaked Wing, Freezing Drizzle or Freezing Rain precipitation conditions) that outputs a single value Hold Over Time, the single value Hold Over Time shall be considered limiting. Under these conditions, take-off after the single value Hold Over Time is exceeded shall be prohibited unless an external tactile inspection is conducted and the aircraft is deemed acceptable for flight or the aircraft is re-deiced/anti-iced as required;

8. When using a HOTDS (during active snow precipitation conditions) that outputs a single value Hold Over Time, the single value Hold Over Time shall be considered limiting unless WestJet has identified acceptable procedures and inspections to ensure that contamination is not adhering to the critical surfaces;

9. Except where superseded in this exemption, all notes, conditions, lists of qualified fluids and application procedures contained in the Transport Canada Holdover Time Guidelines, published by Transport Canada, on an annual basis shall continue to apply; and

10. WestJet shall identify in the COM, the airports where it intends on using a HOTDS for HOT decision-making information.

**VALIDITY**

This Exemption is valid until the earliest of the following:

(a) 23:59 EST on April 30, 2009;

(b) the date on which any of the conditions of this exemption is breached; or

(c) the date on which this exemption is cancelled, in writing, by the Minister of Transport, where he is of the opinion that it is no longer in the public interest or that it is likely to affect aviation safety.

Dated at Ottawa, Ontario, Canada this 30th day of MARCH 2007, on behalf of the Minister of Transport.

Don Sherritt
Director Standards

**APPENDIX A**

***Canadian Aviation Regulations***

**602.11(4)**

**(4)** Where conditions are such that frost, ice or snow may reasonably be expected to adhere to the aircraft, no person shall conduct or attempt to conduct a take-off in an aircraft unless

*(a)* for aircraft that are not operated under Subpart 5 of Part VII,

(i) the aircraft has been inspected immediately prior to take-off to determine whether any frost, ice or snow is adhering to any of its critical surfaces, or

(ii) the operator has established an aircraft inspection program in accordance with the *Operating and Flight Rules Standards*, and the dispatch and take-off of the aircraft are in accordance with that program; and

*(b)* for aircraft that are operated under Subpart 5 of Part VII, the operator has established an aircraft inspection program in accordance with the *Operating and Flight Rules Standards*, and the dispatch and take-off of the aircraft are in accordance with that program.

***622.11 Ground Icing Operations***

**1.0 Introduction**

In order to operate an aircraft under icing conditions in accordance with the requirements of CAR Section 602.11, an operator must have a program as specified in these standards and the dispatch and take-off of the aircraft shall comply with that program. These Ground Icing Operations Standards specify the program elements, for both operations and training, that shall be addressed in an operator's Ground Icing Operations Program and described in the appropriate operator's manuals. As applied to Canadian operators, these Standards outline a Program's minimum requirements, which may be adapted according to the needs of the individual operator. Foreign operators should use this Standard as a guideline for the development of their Ground Icing Operations Program in Canada.

**3.0 Program Elements**

The following elements, which are described in the sections below, will be included in an operator's Ground Icing Operations Program and described in the appropriate manual(s):

- The Operator's Management Plan;
- Aircraft De-icing/Anti-icing Procedures;
- Holdover Timetables;
- Aircraft Inspection and Reporting Procedures; and
- Training and Testing.

*Appendix A*

**6.0 Holdover Timetables**

The use of holdover timetables is not mandatory. Holdover timetables, as approved by the Director, Air Carrier , may be used either as guidelines or decision-making criteria in assessing whether it is safe to take off. When holdover timetables are used as decision-making criteria, only high confidence level times shall be used and the procedures to be followed after holdover time has expired must be clearly documented. Where applicable in a Program, an operator's manual will cover the following areas with regard to holdover timetables:

**6.2 Use of Holdover Timetables**

Holdover timetables provide an estimate of the length of time de-icing/anti-icing fluids are effective. Because holdover time is influenced by a number of factors, established times may be adjusted by the pilot-in-command according to the weather or other conditions. Operators' manuals must describe the procedures to be followed for using holdover timetables. When the tables are used as decision-making criteria, the procedures to be followed by the pilot-in-command (PIC) for varying the established values must also be specified.

**6.3 Take-off after Holdover Times have been Exceeded**

When holdover timetables are used as decision-making criteria, take-off after holdover times have been exceeded can occur only if a pre-take-off contamination inspection is conducted or the aircraft is de-iced/anti-iced again. The operator's Program must specify the procedures to be followed when holdover time is exceeded, and these procedures must appear in the appropriate manuals.

**7.1.1.1**

Holdover timetables, approved according to the conditions outlined in section 6 of these Standards, may be used to determine, without a tactile or visual Pre-take-off Contamination Inspection, that critical surfaces are not contaminated.

*Appendix B*

**Appendix B**
**DEFINITIONS**

- **Anti-Icing Fluid** means a fluid applied to an aircraft as a precautionary procedure that provides protection against the formation of frost or ice and the accumulation of snow on treated surfaces of an aircraft for a period of time;

- **Deicing Fluid** means a fluid applied to an aircraft to remove contamination in the form of frost, ice or snow;

- **Glycol Pan Measurements** means a process to determine precipitation rate by using a glycol-wetted pan that is weighed precisely before and after a timed exposure to precipitation. This methodology has been included in SAE Aerospace Recommended Practice (ARP) 5485 and 5945, and has been historically employed by Transport Canada in the development of fluid holdover time tables for de/anti-icing fluids;

- **Holdover Time** means the determined time that an application of de/anti-icing fluid applied to an aircraft is nominally effective in preventing frost, ice or snow from adhering to the treated surfaces based on using Holdover timetables published by Transport Canada or based on a Holdover Time Determination System Report;

- **Holdover Time Determination System Report (HOTDR)** means a Holdover Time generated by a Holdover Time Determination System.

- **Holdover Time Determination System (HOTDS)** means a near real-time system that samples a number of atmospheric inputs and uses these in conjunction with HOT regression curves and associated coefficients for specific de/anti-icing fluids to produce a holdover time determination report;

- **Holdover Timetables** means tables of holdover times for de/anti-icing fluids published as Holdover Time (HOT) Guidelines, by Transport Canada;

- **Manufacturer** means the producer of a Holdover Time Determination System;

- **Regression Analysis** means a data analysis protocol used by Transport Canada to analyze fluid endurance time data for the generation of holdover times for de/anti-icing fluids; and

- **Service Provider**, in this context, means a person or organization that:
  1. provides holdover time reports using a Holdover Time Determination System that meets the application of this exemption; or
  2. provides precipitation rate, type and temperature information for use by a Holdover Time Determination System in computing Holdover Time Determination System reports that meet the application of this exemption.

*Appendix C*

**APPENDIX C**

**MINIMUM ASSURANCE REQUIREMENTS AND PERFORMANCE SPECIFICATIONS FOR HOLDOVER TIME DETERMINATION SYSTEMS**

Sections 1, 2 and 3 of this appendix specify the minimum assurance requirements and sections 4 and 5 the minimum performance specifications for the Holdover Time Determination Systems.

In this document, the "Air Operator" means **WestJet.**

## 1. QUALITY MANAGEMENT SYSTEM

1.1 The Air Operator shall ensure that the service provider or manufacturer, establish, document, implement and maintain a quality management system that comprises procedures, processes and resources necessary to provide for the quality management of the Holdover Time Determination System and reports to be supplied.

1.2 The quality management system required by Subsection 1.1 shall at a minimum:

a) Establish and maintain operational manuals and documentation;

b) Establish and maintain system commissioning protocols;

c) Establish and maintain system inspection requirements and methods;

d) Establish quality control and quality monitoring to include software integrity and data dissemination;

e) Specify qualifications and training requirements for personnel who commission, inspect or maintain the system, and

f) If non-conformance is identified, ensure that action is initiated to determine and correct the cause.

1.3 The documentation in Subsection 1.2 shall be made available to the Minister, upon reasonable notice by the Minister.

## 2. TRAINING AND QUALIFICATIONS

2.1 The Air Operator shall ensure and document that the manufacturer or service provider maintains records to demonstrate that all persons providing installation, commissioning, inspection and maintenance services of a Holdover Time Determination System are qualified persons who have received appropriate training and have demonstrated sufficient knowledge, skills and competence to perform their assigned duties.

Note: The Air Operator shall ensure and document that the manufacturer or service provider has specified the minimum training requirements applicable to persons engaged in these duties.

2.2 The Air Operator shall make a copy of the documentation referenced in 2.1 available to the Minister, upon reasonable notice by the Minister.

## 3. INSTALLATION, SITING, OPERATION & MAINTENANCE OF DEICING AND ANTI-ICING FLUID HOLDOVER TIME DETERMINATION SYSTEMS

3.1 The Air Operator shall ensure that the service provider or manufacturer as applicable, has established and followed practices, procedures and specifications for the siting, installation, commissioning, operation and maintenance of the Holdover Time Determination Systems, including the co-ordination of activities with the aerodrome operator.

Note: Specifications concerning the siting and installation of equipment on aerodromes are contained in TP312, Aerodrome Standards and Recommended Practices.

3.2 The input instruments shall be sited in sufficient proximity of each other to provide coherent sampling of meteorological inputs for holdover time determination in transitional weather conditions.

3.3 The Air Operator shall document the requirements of Subsection 3.1 and make a copy available to the Minister, upon reasonable notice by the Minister.

## 4. ACCURACY OF HOLDOVER TIME INPUT INSTRUMENTS AND DETERMINATION SYSTEMS

4.1 The Air Operator shall verify that the manufacturer obtains test data and establish practices and procedures that demonstrate that the data inputs and Holdover Time Determinations meet the accuracy requirements established for each element.

4.2 The Air Operator shall make the documentation required by Subsection 4.1 available to the Minister, upon reasonable notice by the Minister.

4.3 The Air Operator shall verify that the manufacturer has test data that demonstrates compliance of the data inputs and Holdover Time Determinations with Subsection 4.1 in accordance with the following requirements:

a) The test data shall be sufficiently complete to assure that the results are representative of the design and performance specifications of the system and include the following:

i. For those instruments for which it is practical, the relationship between the value indicated by an instrument and the corresponding known value of a measurand;

ii. The testing of instruments over a range that is representative of the expected environmental conditions (regardless of whether in a controlled environment or in the field); and

iii. Testing of instruments in comparison with other instruments or human observations, in the outdoor operational environment, where practical.

b) The test data shall consist of the following:

i. Raw data collected during testing, and
ii. The results of the reduction and analysis of the data.

c) The Air Operator shall verify that the person verifying the test data in accordance with paragraph (d) confirms that the results of the reduction and analysis of the test data demonstrate that the data inputs and Holdover Time Determinations meet the accuracy requirements set out in this Appendix under operational conditions encountered by the Holdover Time Determination System;

d) The Air Operator shall confirm that the manufacturer's test data have been verified as meeting the accuracy requirements of this Appendix by a person who is:

i. Independent from the manufacturer of the Holdover Time Determination System and from the service provider and has a degree in the natural or applied sciences of mathematics from a recognized university and experience in: instrumental references, standards and traceability, methods of statistical analysis and an understanding of the operating principles and use of the instruments involved; or
ii. A licensed professional engineer (P.Eng) in Canada.

e) The Air Operator shall verify that the manufacturer obtains a written confirmation of the verification of the test data from the person who verified the test data pursuant to paragraph (d) and shall, upon reasonable notice by the Minister, provide a copy to the Minister;

f) The Air Operator shall ensure that the manufacturer demonstrates and confirms that the HOTDS has built-in fault detection checks that, in the event of system input/output failure (such as loss of an input instrument or corruption of data in a HOTDR) or other critical system hardware or software failure, prevent a misleading report from being issued. Demonstration shall be carried out on an end-to-end basis from input instruments in the field to delivery of Holdover Time Determination System Reports to the Air Operator.

g) The Air Operator shall ensure that the manufacturer demonstrates initial and ensures ongoing quality assurance of the computational software, hardware and end to end data integrity as follows:

i. The software must be designed, developed, produced and maintained in accordance with appropriate software assurance standards.

ii. The hardware must be designed, developed, produced and maintained in accordance with appropriate hardware assurance standards.

iii. End-to-end data integrity shall include means of minimizing misleading data caused by all sources (ex: corrupted fluid coefficients, corrupted data transmissions, etc.) through the use of CRC checks or similar safeguards.

h) The Air Operator shall ensure that the manufacturer confirms that the accuracy of the timing methods or device used to establish the time of the report is sufficient for the intended purpose; and

i) The Air Operator shall ensure that the manufacturer documents the processes and procedures used to comply with the requirements of paragraphs (a) and (h) and shall make them available to the Minister, upon reasonable notice by the Minister.

## 5. TECHNICAL REQUIREMENTS FOR DATA INPUTS AND HOLDOVER TIME DETERMINATIONS

5.1 The Air Operator shall ensure that the manufacturer establishes and document practices and procedures for compliance with the provisions of Subsections 5.1.1 thru 5.1.16, which are applicable to the manufacturer's Holdover Time Determination System, and make a copy available to the Minister, upon reasonable notice by the Minister.

**Wind**

5.1.1 If required by the HOTDS, surface wind data inputs shall meet the following requirements:

a) Wind instruments shall be ice resistant by design;

b) The instruments shall be sited so as to provide representative input to any compensation factors that are generated to correct precipitation accumulation rates during high wind conditions; and

c) The instruments shall function for winds of at least 100 knots.

5.1.2 The accuracy of wind sensors and outputs shall be such that;

a) The direction, if utilized, is correctly measured within ± 10 degrees; and

b) The mean speed is correctly measured within ± 2 knots up to 20 knots and with 10% above 20 knots.

5.1.3 The accuracy of the wind instruments shall be established in accordance with Subsection 5.1.2, paragraphs (a) and (b), to at least a 95% confidence in wind tunnel testing.

**Precipitation**

5.1.4 Systems used for the determination of precipitation shall:

a) Meet or exceed accuracy requirements as follows with reference to human observations:

i. Correctly detect the presence of precipitation of a water equivalent rate of at least 2.0 g/dm$^2$/h, other than drizzle, at least 90% of the time;
ii. Correctly detect the presence of and distinguish between liquid or frozen precipitation, of a water equivalent rate of at least 2.0 g/dm$^2$/h, at least 80% of the time; and
iii. Correctly detect the presence of ice accretion or freezing precipitation, of at least 2.0 g/dm$^2$/h, with at least a 90% probability.

b) Except as addressed in accordance with (c), differentiate between and, where applicable determine the intensity of rain, freezing rain freezing drizzle and snow;

c) Accurately detect the presence of fog or freezing fog conditions;

d) Indicate that type of precipitation is "unknown", if the type cannot be determined; and

e) In the event of unknown precipitation, the equipment shall report that a holdover time is unavailable.

**Temperature**

5.1.5 Temperature measurements shall be accurate to within 1°C.

5.1.6 The accuracy requirements of Subsection 5.1.5 shall be demonstrated with at least a 95% confidence level during laboratory testing that is traceable to a reference standard.

**Precipitation Rate**

5.1.7 Precipitation rate measurements shall be analyzed in reference to simultaneously recorded glycol pan measurements.

5.1.8 The Holdover Time Determination System precipitation rate measurements shall conform to the glycol pan measurements ( ref.: SAE ARP 5485), within the following tolerances:

| | | |
|---|---|---|
| 5.1.8.1 | From 0 to 10 g/dm$^2$/h: | +/- 1.5 g/dm$^2$/h |
| 5.1.8.2 | Above 10 g/dm$^2$/h to 25 g/dm$^2$/h: | +/- 3.5 g/dm$^2$/h |
| 5.1.8.3 | Above 25 g/dm$^2$/h: | +/- 6.0 g/dm$^2$/h |

5.1.9 The accuracy requirements of Subsection 5.1.8 shall be demonstrated with at least a 95% confidence level during comparative tests with the HOTDS and glycol pans.

5.1.10 The precipitation rate input for the purpose of computing fluid holdover time (Subsections 5.1.11 to 5.1.13) shall be the precipitation rate determined by the HOTDS plus the positive tolerance (within a 95% confidence level) that has been demonstrated for each type of HOTDS. The precipitation rate input shall not be less than 2.0 $g/dm^2/h$.

**Holdover Time Determinations**

5.1.11 The regression curves and associated coefficients incorporated into the HOTDS algorithm are either:

5.1.11.1 those generated by TDC, or

5.1.11.2 traceability and validity of the chosen regression curves and associated coefficients to plate pan measurements conducted by TC and the FAA must be demonstrated.

5.1.12 Holdover Time Determinations from the system for all de/anti-icing fluids shall be computed using the regression curves and associated coefficients referenced in 5.1.11.

5.1.13 In accordance with the currently accepted practice for HOT table development, Holdover Time Determinations from the system for Type II and IV de/anti-icing fluids shall be capped as follows:

| | |
|---|---|
| Freezing Fog | 4 hrs; |
| Snow | 2 hrs; |
| Freezing Drizzle | 2 hrs; |
| Light Freezing Rain | 2 hrs; |
| Rain on Cold Soaked Wing | 2 hrs. |

**Holdover Time Determination Reports**

5.1.14 A Holdover Time Determination Report shall contain as a minimum de/anti-icing Holdover Time(s) and fluid type. The report may contain additional items such as:

a) Precipitation type;

b) Precipitation intensity;

c) Precipitation trend; and

d) Fluid brand

These additional items shall be as agreed to with the service provider and/or the aircraft operator.

5.1.15 The service provider shall retain a copy of each Holdover Time Determination Report for at least 24 months.

5.1.16 The service provider shall provide a copy of the Holdover Time Determination Reports required by 5.1.15 to the Minister, upon reasonable notice by the Minister.

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# APPENDIX F

# PRESENTATIONS AT VARIOUS MEETINGS

# PRESENTATIONS AT VARIOUS MEETINGS

## 1. Standing Committee Meeting, Ottawa, Canada, September 2006

a. De/Anti-Icing Fluid Holdover Time Update – 2006-07 Winter Operations;

b. Aircraft Deicing Research in Simulated Ice Pellet Conditions; and

c. Integration of Holdover Time Determination Systems into Canadian Airport Operations.

## 2. SAE G-12 HOT Subcommittee and HOT Working Group Meetings, Montreal, Canada, November 2006

a. Lowest On-Wing Viscosity for Dilutions: Type II & IV Fluids (at both Working Group and Subcommittee);

b. Fluid Adhesion During Mixed Precipitation Conditions – Ice Pellets/Light Freezing Rain (Working Group); and

c. Fluid Adhesion During Mixed Ice Pellet Precipitation Conditions (Subcommittee).

## 3. SAE G-12 HOT Subcommittee Working Group Meeting, Montreal, Canada, May 2007

a. Summary of Holdover Time Developments from the 2006-07 Winter Test Season;

b. Preliminary Aircraft Ground Deicing Research Using Composite Materials;

c. Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions; and

d. Aircraft Deicing Research in Simulated Mixed Conditions with Ice Pellets.

## 4. SAE G-12 HOT Subcommittee Meeting, San Diego, US, May 2007

a. Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2006-07 Winter Test Season – Type I Fluid;

b. Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2006-07 Winter Test Season – Type II Fluid;

c. Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2006-07 Winter Test Season – Type III Fluid;

d. Aircraft De/Anti-Icing Fluid Endurance Time Results for the 2006-07 Winter Test Season – Type IV Fluid;

e. Aircraft Deicing Research in Simulated Mixed Conditions with Ice Pellets; and

f. Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions.

**5. ROGIDS Working Group Meetings, Atlantic City, US, November 2006, and Toronto, Canada, April 2007**

a. Ice Disk Degradation Following De/Anti-Icing Application; and

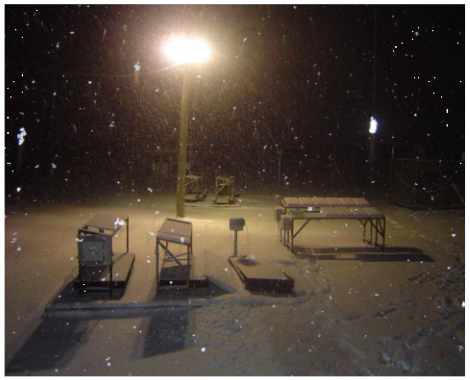
b. Demonstration of Conditions for ROGIDS Performance Specification.

# DE/ANTI-ICING FLUID HOLDOVER TIME UPDATE

# 2006-07 WINTER OPERATIONS







APS Aviation Inc.

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## TRANSPORT CANADA SCOUIC
## OTTAWA, ONTARIO
## SEPTEMBER 28, 2006

**MICHAEL CHAPUT**

**MANAGER, PROJECTS AND BUSINESS DEVELOPMENT**

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**PREPARED AND PRESENTED ON BEHALF OF:**

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

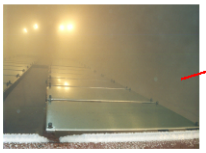
Transports Canada Transport Canada

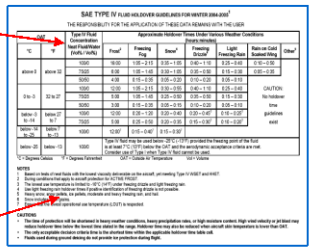
AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

## FLUID ENDURANCE TIME TESTING AND HOLDOVER TIME TABLE DEVELOPMENT







SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2004-2005[1]

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

| OAT | | Type IV Fluid Concentration: Neat Fluid/Water (Vol%/Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | |
|---|---|---|---|---|---|---|---|---|
| °C | °F | | Frost[2] | Freezing Fog | Snow[3] | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing |
| above 0 | above 32 | 100/0 | 10:00 | 1:00 – 2:15 | 0:30 – 1:00 | 0:40 – 1:10 | 0:20 – 0:40 | 0:10 – 0:20 |
| | | 75/25 | 6:00 | 1:00 – 1:45 | 0:30 – 1:00 | 0:35 – 0:50 | 0:15 – 0:35 | 0:05 – 0:20 |
| | | 50/50 | 4:00 | 0:15 – 0:35 | 0:05 – 0:20 | 0:10 – 0:20 | 0:05 – 0:15 | |
| 0 to -3 | 32 to 27 | 100/0 | 12:00 | 1:00 – 2:15 | 0:30 – 0:55 | 0:40 – 1:10 | 0:25 – 0:40 | CAUTION: No holdover time guidelines exist |
| | | 75/25 | 6:00 | 1:00 – 1:45 | 0:25 – 0:50 | 0:35 – 0:50 | 0:15 – 0:30 | |
| | | 50/50 | 3:30 | 0:15 – 0:35 | 0:05 – 0:15 | 0:10 – 0:20 | 0:05 – 0:10 | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:35 – 1:30 | 0:20 – 0:40 | 0:30 – 0:40 | 0:10 – 0:20 | |
| | | 75/25 | 5:30 | 0:25 – 0:50 | 0:20 – 0:35 | 0:15 – 0:30 | 0:10 – 0:20 | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:15 – 0:40 | 0:15 – 0:30 | | | |

Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.

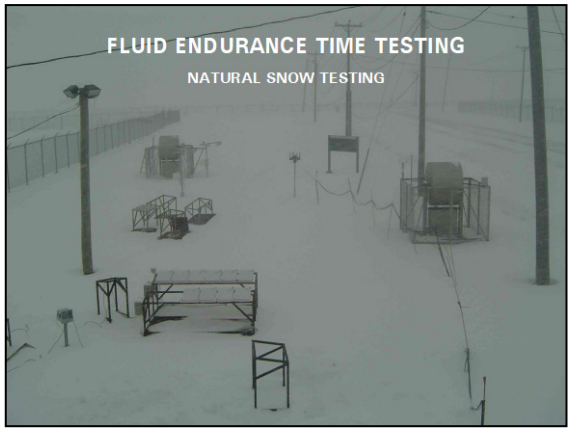
°C = Degrees Celsius °F = Degrees Fahrenheit OAT = Outside Air Temperature Vol = Volume

NOTES

1. Based on trials of neat fluids with the lowest viscosity dilutable on the aircraft, yet meeting Type IV ASD/ET and AMET.
2. During conditions that apply to aircraft protection for ACTIVE FROST.
3. Use light freezing rain holdover times for SNOW PELLETS, SNOW GRAINS and light freezing rain.
4. Use light freezing rain holdover times if duration and intensity of freezing drizzle is not possible.
5. Heavy snow, ice pellets, ice pellets, moderate and heavy freezing rain, and hail.
6. Snow Grains[5].
7. Do not exceed the lowest operational use temperature (LOUT) is respected.

CAUTIONS:

- 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 below the lowest time stated in the range. Holdover time may also be reduced when aircraft skin temperature is lower than OAT.
- The only acceptable decision criteria time is the shortest time within the applicable holdover time table cell.
- Fluids used during ground deicing do not provide ice protection during flight.

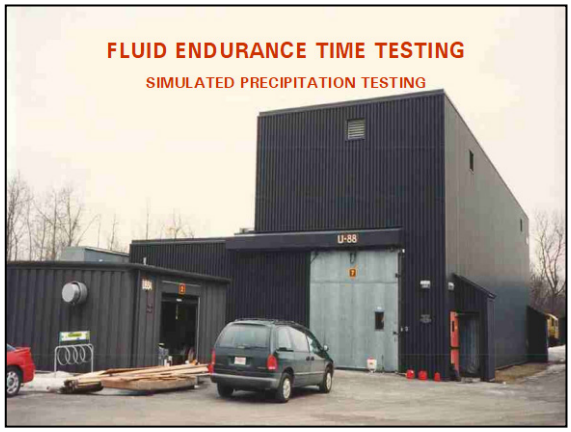



## FLUID ENDURANCE TIME TESTING

NATURAL SNOW TESTING

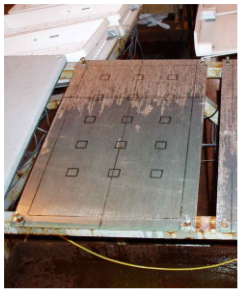









## DE/ANTI-ICING FLUIDS TESTED
### WINTER 2005-06



**TYPE I**

BATTELLE D3 ADF

**TYPE II**

CLARIANT SAFEWING MP II FLIGHT
KILFROST ABC-TF2

**TYPE IV**

CLARIANT SAFEWING MP IV LAUNCH
DOW UCAR ENDURANCE EG106
KILFROST ABC-S PLUS

## ENDURANCE TIME TESTS PERFORMED

| FLUID TYPE | SNOW | FREEZING DRIZZLE | LIGHT FREEZING RAIN | FREEZING FOG | COLD SOAK | TOTAL |
|---|---|---|---|---|---|---|
| Type IV | 143 | 81 | 80 | 100 | 32 | 436 |
| Type II | 44 | 40 | 40 | 49 | 16 | 189 |
| Type I | 4 | 10 | 4 | 12 | 4 | 34 |
| TOTAL | 191 | 131 | 124 | 161 | 52 | 659 |

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## FAA/TC TYPE IV HOT GUIDELINES 2006-07

FAA TYPE IV HOLDOVER TIME GUIDELINE

TABLE 4 - FAA Guideline for Holdover Times SAE Type IV Fluid Mixtures as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours: minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow/Snow Grains | Freezing Drizzle[1] | Light Freezing Rain | Rain on Cold Soaked Wing[1] | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:15-2:30 | 0:35-1:15 | 0:40-1:10 | 0:25-0:40 | 0:10-0:50 | |
| | | 75/25 | 5:00 | 1:05-1:45 | 0:20-0:55 | 0:35-0:50 | 0:15-0:30 | 0:05-0:35 | |
| | | 50/50 | 3:00 | 0:15-0:35 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:20-1:20 | 0:20-0:40 | ***0:20-0:45 | ***0:10-0:25 | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:25-0:55 | 0:15-0:35 | ***0:15-0:30 | ***0:10-0:20 | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:15-0:40 | 0:15-0:30 | | | | |
| below -25 | below -13 | 100/0 | SAE Type IV fluid may be used below -25°C (-13 °F) provided the freezing point of the fluid is at least 7°C (13°F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

NO CHANGES

SAE TYPE IV FLUID HOLDOVER GUIDELINE FOR WINTER 2005-2006[1]

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[2] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[3] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:15 – 2:30 | 0:35 – 1:15 | 0:40 – 1:10 | 0:25 – 0:40 | 0:10 – 0:50 | |
| | | 75/25 | 5:00 | 1:05 – 1:45 | 0:20 – 0:55 | 0:35 – 0:50 | 0:15 – 0:30 | 0:05 – 0:35 | |
| | | 50/50 | 3:00 | 0:15 – 0:35 | 0:05 – 0:15 | 0:10 – 0:20 | 0:05 – 0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:20 – 1:20 | 0:20 – 0:40 | 0:20 – 0:45[4] | 0:10 – 0:25[4] | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:25 – 0:55 | 0:15 – 0:35 | 0:15 – 0:30[4] | 0:10 – 0:20[4] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00[4] | 0:15 – 0:40[4] | 0:15 – 0:30[4] | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

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## TC/FAA TYPE IV FLUID-SPECIFIC HOT GUIDELINES 2006-07

1) CLARIANT SAFEWING MP IV 2001
2) CLARIANT SAFEWING MP IV PROTECT 2012
3) CLARIANT SAFEWING MP IV 2030 ECO
4) **CLARIANT SAFEWING MP IV LAUNCH (NEW)**
5) DOW UCAR ULTRA +
6) **DOW UCAR ENDURANCE EG106 (NEW)**
7) KILFROST ABC-S
8) **KILFROST ABC-S PLUS (NEW)**
9) OCTAGON MAX-FLIGHT
10) OCTAGON MAX-FLIGHT '04
11) OCTAGON MAXFLO
12) SPCA AD-480

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## FAA/TC TYPE II HOT GUIDELINES 2006-07

FAA TYPE II HOLDOVER TIME GUIDELINE

TABLE 2 - FAA Guideline for Holdover Times SAE Type II Fluid Mixtures as a Function of Weather Conditions and Outside Air Temperature.

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

| Outside Air Temperature | | Type II Fluid Concentration Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours: minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow/ Snow Grains | Freezing Drizzle[1] | Light Freezing Rain | Rain on Cold Soaked Wing[1] | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 0:35-1:30 | 0:20-0:45 | 0:30-0:55 | 0:15-0:30 | 0:05-0:40 | |
| | | 75/25 | 5:00 | 0:25-1:00 | 0:15-0:30 | 0:20-0:45 | 0:10-0:25 | 0:05-0:25 | |
| | | 50/50 | 3:00 | 0:15-0:30 | 0:05-0:15 | 0:05-0:15 | 0:05-0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:20-1:05 | 0:15-0:35 | 0:15-0:45[4] | 0:10-0:20[4] | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:20-0:55 | 0:15-0:25 | ***0:15-0:30[4] | ***0:10-0:20[4] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00[4] | 0:15-0:30[4] | 0:15-0:30[4] | | | | |
| below -25 | below -13 | 100/0 | SAE Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

NO CHANGES

SAE TYPE II FLUID HOLDOVER GUIDELINE FOR WINTER 2005-2006[1]

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

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[2] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[3] |
| -3 and above | 27 and above | 100/0 | 8:00 | 0:35 – 1:30 | 0:20 – 0:45 | 0:30 – 0:55 | 0:15 – 0:30 | 0:05 – 0:40 | |
| | | 75/25 | 5:00 | 0:25 – 1:00 | 0:15 – 0:30 | 0:20 – 0:45 | 0:10 – 0:25 | 0:05 – 0:25 | |
| | | 50/50 | 3:00 | 0:15 – 0:30 | 0:05 – 0:15 | 0:05 – 0:15 | 0:05 – 0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:20 – 1:05 | 0:15 – 0:35 | 0:15 – 0:45[4] | 0:10 – 0:20[4] | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:20 – 0:55 | 0:15 – 0:25 | 0:15 – 0:30[4] | 0:10 – 0:20[4] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00[4] | 0:15 – 0:30[4] | 0:15 – 0:30[4] | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

Transport Canada

## TC/FAA TYPE II FLUID-SPECIFIC HOT GUIDELINES 2006-07

1) CLARIANT SAFEWING MP II 2025 ECO
2) CLARIANT SAFEWING MP II FLIGHT (NEW)
3) KILFROST ABC-2000
4) KILFROST ABC-II PLUS
5) KILFROST ABC-TF2 (NEW)
6) OCTAGON E-MAX II
7) SPCA ECOWING 26

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## FAA/TC TYPE III HOT GUIDELINES 2006-07

FAA TYPE III HOLDOVER TIME GUIDELINE

Table 3. FAA Guideline for Holdover Times SAE Type III Fluid Mixtures as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

| Outside Air Temperature | | Approximate Holdover Times Under Various Weather Conditions (hours: minutes) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Type III Fluid Concentration Neat Fluid/Water (Volume % Volume %) | Active Frost | Freezing Fog | Snow/Snow Grains: Very Light | Snow/Snow Grains: Light | Snow/Snow Grains: Moderate | Freezing Drizzle[1] | Light Freezing Rain | Rain on Cold Soaked Wing[2] | Other[3] |
| -3 and above | 27 and above | 100/0 | 2:00 | 0:20 - 0:40 | 0:25 - 0:40 | 0:20 - 0:35 | 0:10 - 0:20 | 0:10 - 0:20 | 0:08 - 0:10 | 0:06 - 0:20 | |
| | | 75/25 | 1:00 | 0:15 - 0:30 | 0:25 - 0:35 | 0:15 - 0:25 | 0:08 - 0:15 | 0:08 - 0:15 | 0:06 - 0:10 | 0:02 - 0:10 | |
| | | 50/50 | 0:30 | 0:10 - 0:20 | 0:15 - 0:25 | 0:08 - 0:15 | 0:04 - 0:08 | 0:08 - 0:10 | | | |
| below -3 to -10 | below 27 to 21 | 100/0 | 2:00 | 0:20 - 0:40 | 0:30 - 0:35 | 0:15 - 0:30 | 0:08 - 0:15 | 0:10 - 0:20 | | | |
| | | 75/25 | 1:00 | 0:15 - 0:30 | 0:25 - 0:35 | 0:10 - 0:25 | 0:07 - 0:10 | | | | |
| below -10 | below 14 | 100/0 | 2:00 | 0:20 - 0:40 | 0:30 - 0:35 | 0:15 - 0:30 | 0:08 - 0:15 | | | | |

SAE Type III fluid may be used below -10°C (14°F), provided the freezing point of the fluid is at least 7°C [illegible] Consider the use of SAE Type I when Type III fluid cannot be used.

NO CHANGES

SAE TYPE III FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006

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

| Outside Air Temperature[1] | | Approximate Holdover Times Under Various Weather Conditions (minutes) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Type III Fluid Concentration Neat Fluid/Water (Volume % Volume %) | Active Frost | Freezing Fog | Snow or Snow Grains: Very Light | Snow or Snow Grains: Light | Snow or Snow Grains: Moderate | Freezing Drizzle[1] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 120 | 20 – 40 | 35 | 20 – 35 | 10 – 20 | 10 – 20 | 8 – 10 | 6 – 20 | |
| | | 75/25 | 60 | 15 – 30 | 25 | 15 – 25 | 8 – 15 | 8 – 15 | 6 – 10 | 2 – 10 | |
| | | 50/50 | 30 | 10 – 20 | 15 | 8 – 15 | 4 – 8 | 5 – 9 | 4 – 6 | | |
| below -3 to -10 | below 27 to 14 | 100/00 | 120 | 20 – 40 | 30 | 15 – 30 | 9 – 15 | 10 – 20 | 8 – 10 | | |
| | | 75/25 | 60 | 15 – 30 | 25 | 10 – 25 | 7 – 10 | 9 – 12 | 6 – 9 | | |
| below -10 | below 14 | 100/0 | 120 | 20 – 40 | 30 | 15 – 30 | 8 – 15 | | | | |

CAUTION: No holdover time guidelines exist

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## FAA/TC TYPE I HOT GUIDELINES 2006-07

FAA TYPE I HOLDOVER TIME GUIDELINE

Table 1. FAA Guideline for Holdover Times SAE Type I Fluid Mixtures as a Function of Weather Conditions and OAT.

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES.

| Outside Air Temperature | | Approximate Holdover Times Under Various Weather Conditions (hours: minutes) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Active Frost | Freezing Fog | Snow/Snow Grains: Very Light** | Snow/Snow Grains: Light** | Snow/Snow Grains: Moderate** | Freezing Drizzle[1] | Light Freezing Rain | Rain on Cold Soaked Wing[2] | Other[3] |
| -3 and above | 27 and above | 0:45 | 0:11 - 0:17 | 0:18-0:22 | 0:11 - 0:18 | 0:06 - 0:11 | 0:09 - 0:13 | 0:02 - 0:05 | 0:02-0:05 | |
| below -3 to -6 | below 27 to 21 | 0:45 | 0:08 - 0:13 | 0:14-0:17 | 0:08 - 0:14 | 0:05 - 0:08 | 0:05 - 0:09 | 0:02 - 0:05 | | |
| below -6 to -10 | below 21 to 14 | 0:45 | 0:06 - 0:10 | 0:11-0:13 | 0:06 - 0:11 | 0:04 - 0:06 | 0:04 - 0:07 | [illegible] | | |
| below -10 | below 14 | 0:45 | 0:05 - 0:09 | 0:07-0:08 | 0:04 - 0:07 | 0:02 - 0:04 | | | | |

NO CHANGES

SAE TYPE I[3] FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006

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

| Outside Air Temperature[1] | | Approximate Holdover Times Under Various Weather Conditions (minutes) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Active Frost | Freezing Fog | Snow or Snow Grains[1]: Very Light | Snow or Snow Grains[1]: Light | Snow or Snow Grains[1]: Moderate | Freezing Drizzle[1] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 45 | 11 – 17 | 18 | 11 – 18 | 6 – 11 | 9 – 13 | 4 – 6 | 2 – 5 | |
| below -3 to -6 | below 27 to 21 | 45 | 8 – 13 | 14 | 8 – 14 | 5 – 8 | 5 – 9 | 4 – 6 | | |
| below -6 to -10 | below 21 to 14 | 45 | 6 – 10 | 11 | 6 – 11 | 4 – 6 | 4 – 7 | 2 – 5 | | |
| below -10 | below 14 | 45 | 5 – 9 | 7 | 4 – 7 | 2 – 4 | | | | |

CAUTION: No holdover time guidelines exist

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## TC HOLDOVER TIME GUIDANCE MATERIAL

http://www.tc.gc.ca/CivilAviation/commerce/HoldoverTime/menu.htm

Guidance for Aircraft Ground Icing Operations – TP14052

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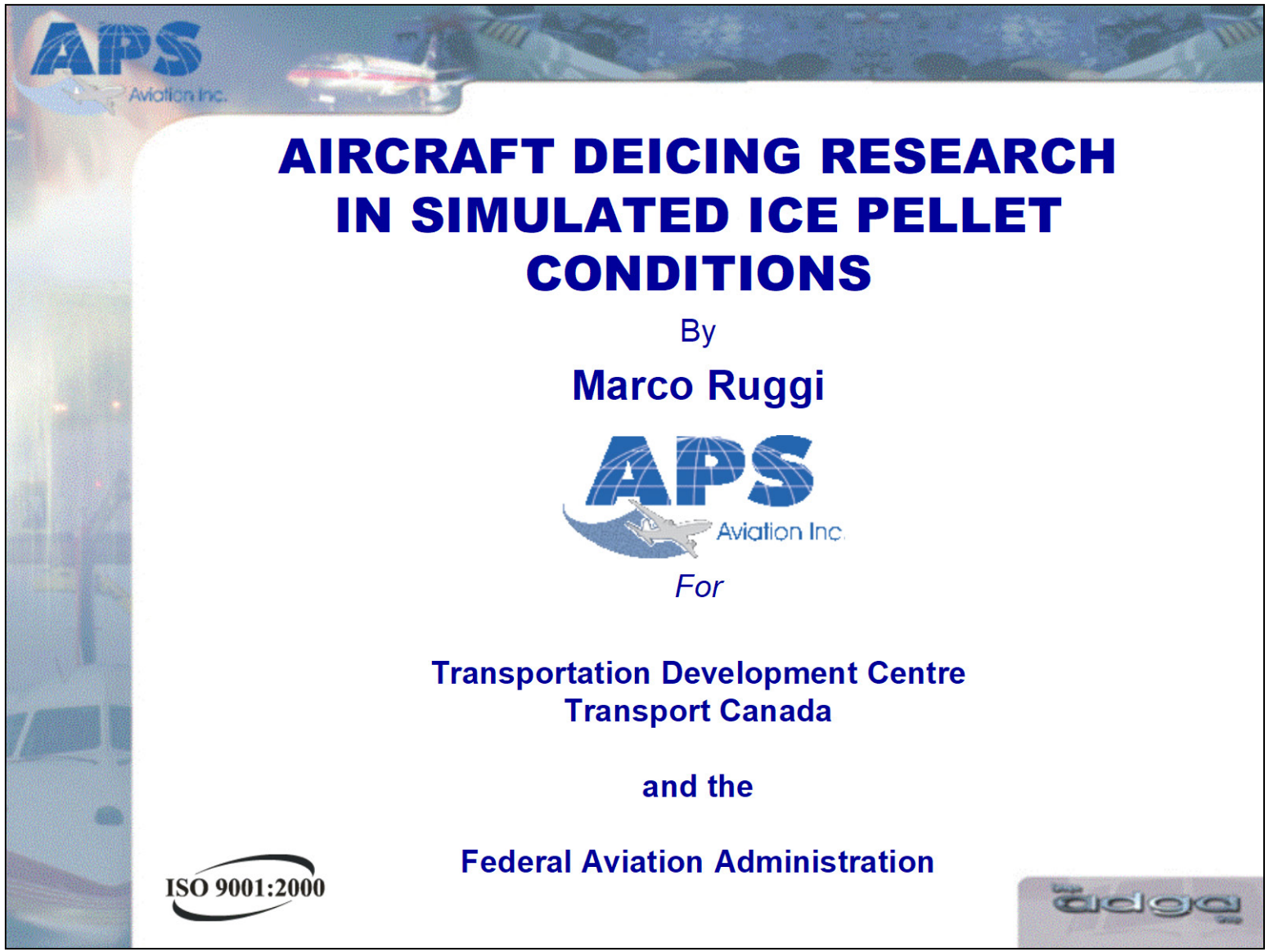

APS
Aviation Inc.
AIRCRAFT DEICING RESEARCH
IN SIMULATED ICE PELLET
CONDITIONS
By
Marco Ruggi
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000

## PRESENTATION OUTLINE

- BACKGROUND
- NATURAL ICE PELLET RESEARCH
- ICE PELLET DISSOLVING TIME RESEARCH
- FALCON 20 FULL-SCALE RESEARCH
- FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION
- BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
- CONCLUSIONS

## BACKGROUND

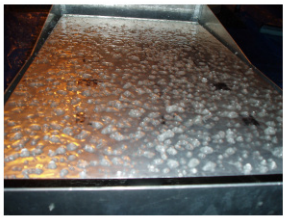
- Aircraft have departed during ice pellet conditions following aircraft deicing using a pre-takeoff contamination check
- Holdover times for ice pellets currently do not exist

## BACKGROUND

- As a result, industry has requested guidance material for operations in ice pellet conditions
- Preliminary endurance time testing and aerodynamic research was conducted in simulated ice pellet conditions

## BACKGROUND

- Fluid failure difficult to determine in ice pellet conditions
- Fluid condition appears severe after minimal exposure



## BACKGROUND

- Additional research was required to determine if contamination will be removed from critical surfaces at rotation

## PRESENTATION OUTLINE

- BACKGROUND
- NATURAL ICE PELLET RESEARCH
- ICE PELLET DISSOLVING TIME RESEARCH
- FALCON 20 FULL-SCALE RESEARCH
- FAR VS. NEAR –PERSPECTIVE PHOTO DOCUMENTATION
- BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
- CONCLUSIONS

## NATURAL ICE PELLET RESEARCH

- DEFINITION OF ICE PELLETS:
  - Precipitation of transparent or translucent pellets of ice, which are spherical or irregular, and which have a diameter of 5mm or less. The pellets of ice usually bounce when hitting hard ground.
- ICE PELLET INTENSITY DEFINITION:
  - Light – 0 to 25 g/dm²/hr
  - Moderate – 25 to 75 g/dm²/hr
  - Heavy – greater than 75 g/dm²/hr

## NATURAL ICE PELLET RESEARCH

- BLACK FELT PHOTOGRAPHY OF NATURAL ICE PELLET SAMPLES
  - Natural ice pellet samples were collected using trays lined with black felt
  - Macro photography of the samples were taken to obtain a size distribution
  - Rate of precipitation was measured during several events

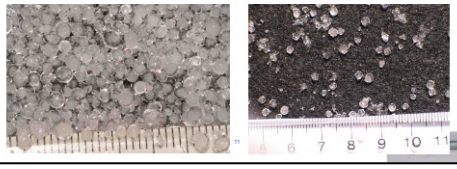
## NATURAL ICE PELLET RESEARCH

- LOG OF BLACK FELT PHOTOGRAPHY TESTS

| Test Event | Date | Start Time | End Time | Photos (#) | Film Clips (#) | Approx Rate (g/dm²/h) | Intermediate Rates (g/dm²/h) | Size | Location |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 15-Nov-05 | 12:08:00 | 12:12:00 | 11 | N/A | N/A | N/A | 1-2 mm | YUL (Near Concordia) |
| 2 | 23-Dec-05 | 1:50:00 | 1:51:00 | 4 | N/A | N/A | N/A | 2 mm | YUL Test Site |
| 3 | 25-Dec-05 | 21:00:00 | 21:15:00 | 40 | N/A | N/A | N/A | 1-3 mm | YUL (Marco's House) |
| 4 | 29-Dec-05 | 20:41:00 | 22:11:00 | 138 | 16 | 7 | 3, 2, 7, 11 | 1-2.5 mm | YUL Test Site |
| | 29-Dec-05 | 20:41:00 | 22:11:00 | 59 | N/A | 7 | 3, 2, 7, 11 | 1-2.5mm | YUL Test Site |
| 5 | Jan 4 2006 | 23:40:00 | 23:43:00 | 6 | N/A | N/A | N/A | N/A | N/A |
| 6 | 14-Jan-06 | 3:11:00 | 3:23:00 | 18 | 3 | N/A | N/A | 1-4 mm | YUL (Marco's House) |
| 7 | 17-Jan-06 | 20:33:00 | 22:00:00 | 79 | N/A | 30.5 | 8.5, 15, 16, 23, 17, 32, 31, 30, 29, 33, 38, 58, 50 | 1-4 mm | YUL Test Site |
| | 17-Jan-06 | 20:28:00 | 0:15:00 | 92 | 5 | 29.5 | 8.5, 15, 16, 23, 17, 32, 31, 30, 29, 33, 38, 58, 50 | 1-4 mm | YUL Test Site |
| | 17-Jan-06 | | | 7 | N/A | N/A | N/A | 1-4 mm | YUL Test Site |
| 8 | 21-Jan-06 | 11:34:00 | 11:52:00 | 28 | 5 | 26.7 | 33, 38, 36, 21, 16, 9 | 1-5 mm | YUL Test Site |
| | 21-Jan-06 | 11:35:00 | 12:01:00 | 43 | 1 | 20.9 | 33, 38, 36, 21, 16, 9, 10 | 1-5 mm | YUL Test Site |
| 9 | 30-Jan-06 | 13:20 | 13:45:00 | 15 | N/A | N/A | N/A | 1-2 mm | YUL Test Site |
| | 30-Jan-06 | 8:00 | 8:15:00 | 22 | N/A | N/A | N/A | 1-3mm | JD home |
| 10 | 30-Jan-06 | 13:12:00 | 13:38:00 | 35 | N/A | N/A | N/A | 1-2 mm | Downtown Office |
| 11 | 4-Feb-06 | 9:47:00 | 9:52:00 | 16 | N/A | N/A | N/A | 1-2 mm | YUL (Marco's House) |
| 12 | 16-Feb-06 | 21:35:00 | 22:45:00 | 101 | N/A | 25.6 | 8,21,36,52,9 | 1-3mm | YUL Test Site |
| 13 | 9-Mar-06 | 10:20:00 | 10:36:00 | 13 | N/A | N/A | N/A | 2-3mm | YOW /NRC (Falcon 20 test site) |

## NATURAL ICE PELLET RESEARCH

- SIZE DISTRIBUTION AND RATE OF PRECIPITATION
  - Diameter of natural ice pellets measured up to 5 mm
  - Rate of precipitation ranged from 2-58 g/dm²/hr
  - Larger ice pellets generally occurred when the rate of precipitation was highest
  - Aggregates (adhered clusters of ice pellets) commonly found amongst samples, mostly in warmer conditions



## NATURAL ICE PELLET RESEARCH

- OCCURRENCE OF MIXED PRECIPITATION
  - Ice pellets are generally a transitional condition
  - Ice pellets often occur during the transition from liquid to solid precipitation, or vice versa
  - As a result, ice pellets are often combined with freezing rain creating a risk of adhesion

## NATURAL ICE PELLET RESEARCH

- ENDURANCE TIME TESTING
  - 5 tests were conducted during 3 events
  - Testing was conducted outdoors at the APS Test Site during natural ice pellet conditions
  - Fluid failure difficult to determine and define
  - Fluid condition appears to be visually different based on angle of incidence

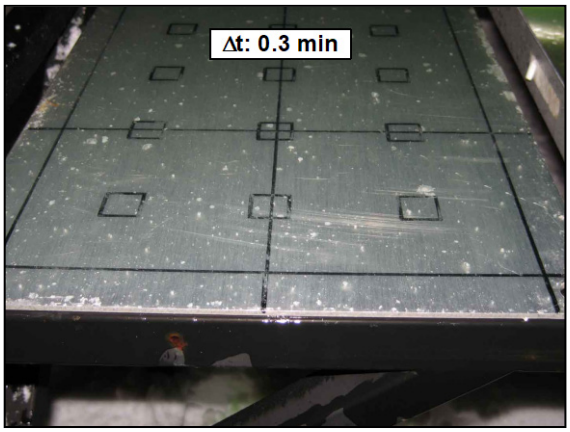
## ENDURANCE TIME TESTING IN NATURAL ICE PELLET CONDITIONS

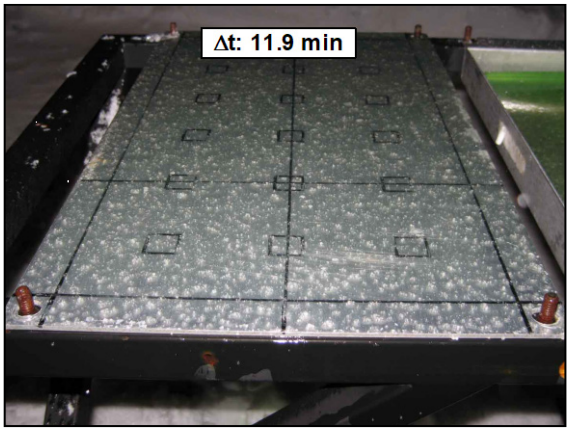
**Type IV PG 50/50**

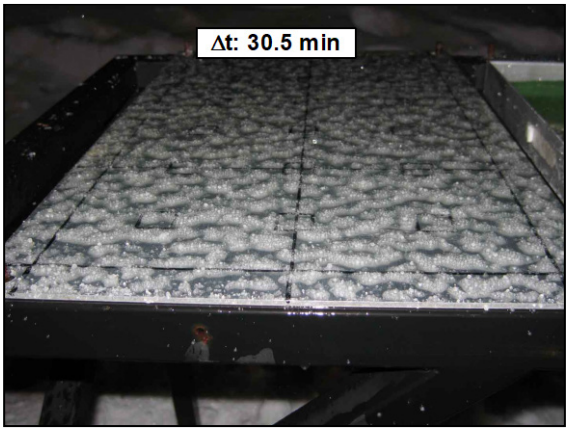
**Average Rate of Precipitation: 18 g/dm²/hr**

**Total Time: 30.5 min.**

Test Surface: Plate
Date: Feb 16, 2006
Start Time: 21:39:22




## NATURAL ICE PELLET RESEARCH

- CONCLUSIONS
  - Diameter of natural ice pellets generally from 1-3 mm
  - During severe ice pellet events, diameter of natural ice pellets measured up to 5 mm
  - Ice pellets conditions are generally transitional and can include freezing rain
  - Fluid failure difficult to determine in natural ice pellet conditions (much like in simulated ice pellets)

## PRESENTATION OUTLINE

- BACKGROUND
- NATURAL ICE PELLET RESEARCH
- ICE PELLET DISSOLVING TIME RESEARCH
- FALCON 20 FULL-SCALE RESEARCH
- FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION
- BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
- CONCLUSIONS

## ICE PELLET DISSOLVING TIME RESEARCH

- METHODOLOGY
  - Comparative study of time required to dissolve equal masses of simulated ice pellets, natural ice pellets, simulated snow, and natural snow
  - 1 dm² pan filled with 2 mm of aircraft de/anti-icing fluid
  - Ice pellet or snow is placed in the pan and the time required to dissolve is recorded

## ICE PELLET DISSOLVING TIME RESEARCH

- CONCLUSIONS
  - Snow requires less time to dissolve in comparison to ice pellets (considering equal masses)
    - i.e. Type IV PG Neat Fluid
      - 30 mg of simulated snow – approx 5 minutes to dissolve
      - 30 mg (4 mm) simulated ice pellet – approx 45 minutes to dissolve
  - Simulated ice pellets are comparable to natural ice pellets

## PRESENTATION OUTLINE

- BACKGROUND
- NATURAL ICE PELLET RESEARCH
- ICE PELLET DISSOLVING TIME RESEARCH
- FALCON 20 FULL-SCALE RESEARCH
- FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION
- BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
- CONCLUSIONS

## FALCON 20 FULL-SCALE RESEARCH

- OBJECTIVE: To determine the level of contamination of anti-icing fluid caused by ice pellets at which the airflow at takeoff fails to remove the resultant contamination.
- METHODOLOGY:
  - Calculate quantity of ice pellets based on 20 minutes at desired precipitation rate and test surface area (approx 3m²)
  - Anti-icing fluid applied approx. 30 minutes prior to brake release
  - Ice pellets applied over a short period of time approx. 5 minutes before brake release
  - Aircraft taken to rotation speed and then underwent inspection

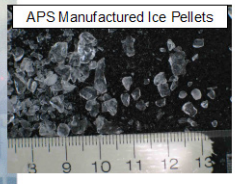
## FALCON 20 FULL-SCALE RESEARCH

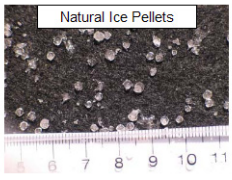
- SETUP



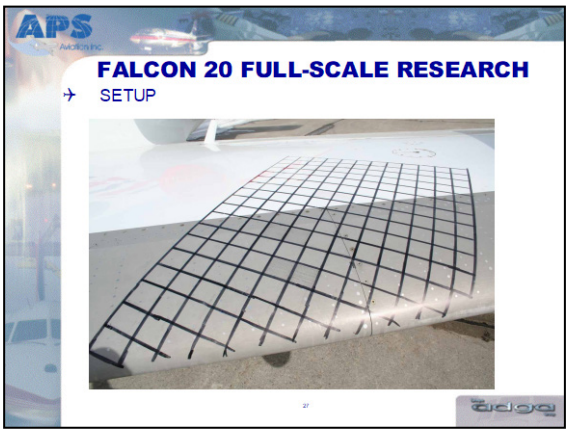

## FALCON 20 FULL-SCALE RESEARCH

- SETUP



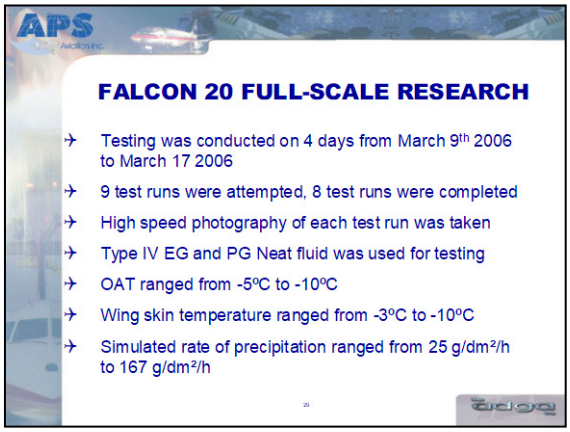



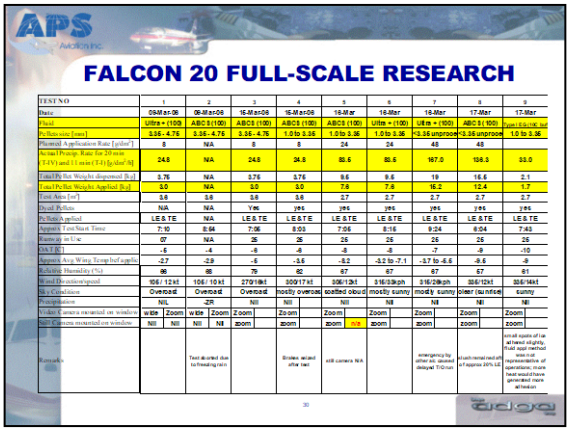


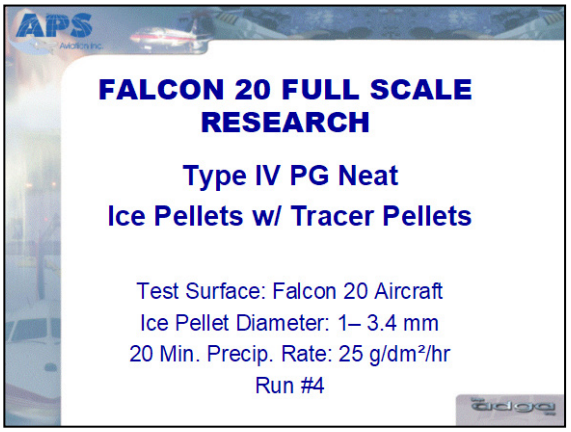




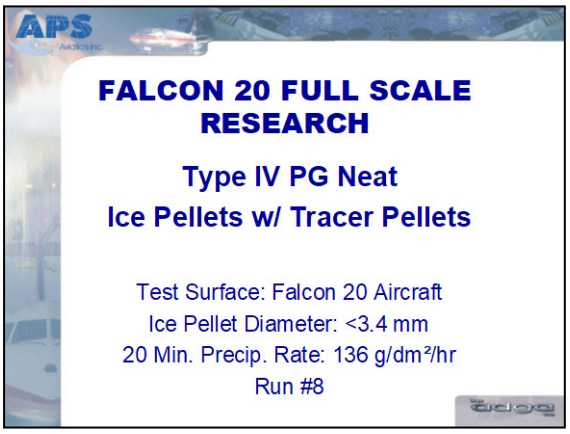


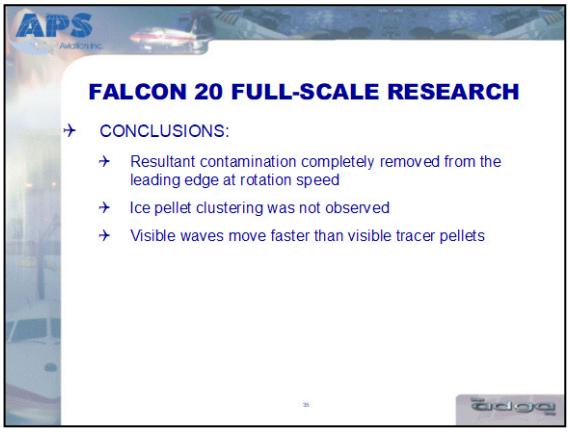

| TEST NO | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Date | 09-Mar-06 | 09-Mar-06 | 16-Mar-06 | 16-Mar-06 | 16-Mar | 16-Mar | 16-Mar | 17-Mar | 17-Mar |
| Fluid | Ultra + (100) | ABC S (100) | ABC S (100) | ABC S (100) | ABC S (100) | Ultra + (100) | Ultra + (100) | ABC S (100) | Type I (50/50) Ref |
| Pellet size [mm] | 3.35 - 4.75 | 3.35 - 4.75 | 3.35 - 4.75 | 1.0 to 3.35 | 1.0 to 3.35 | 1.0 to 3.35 | <3.35 unprocess | <3.35 unprocess | 1.0 to 3.35 |
| Planned Application Rate [g/dm²/h] | 8 | N/A | 8 | 8 | 24 | 24 | 48 | 48 | |
| Actual Precip. Rate for 20 min (T-4 IV) and 11 min (T-4) [g/dm²/h] | 24.0 | N/A | 24.0 | 24.0 | 85.6 | 85.6 | 167.0 | 106.3 | 33.0 |
| Total Pellet Weight dispensed [kg] | 3.76 | N/A | 3.76 | 3.76 | 9.6 | 9.6 | 19 | 16.6 | 2.1 |
| Total Pellet Weight Applied [kg] | 3.0 | N/A | 3.0 | 3.0 | 7.6 | 7.6 | 15.2 | 12.4 | 1.7 |
| Test Mass [m²] | 3.6 | 3.6 | 3.6 | 3.6 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| Dead Pellets | N/A | N/A | Yes | yes | yes | yes | yes | yes | yes |
| Pellets Applied | LE & TE | N/A | LE & TE | LE & TE | LE & TE | LE & TE | LE & TE | LE & TE | LE & TE |
| Approx. Test Start Time | 7:10 | 8:04 | 7:06 | 8:03 | 7:06 | 8:16 | 9:24 | 8:04 | 7:43 |
| Ratio g: in Use | 07 | N/A | 26 | 26 | 26 | 26 | 26 | 26 | 26 |
| OAT [C] | -5 | -4 | -8 | -8 | -8 | -8 | -7 | -9 | -10 |
| Approx. Avg. Wing Temp [ref applic] | -2.7 | -2.9 | -6 | -3.5 | -5.2 | -3.2 to -7.1 | -3.7 to -5.6 | -9.5 | -9 |
| Relative Humidity (%) | 98 | 98 | 75 | 92 | 67 | 67 | 67 | 67 | 61 |
| Wind Direction/speed | 106 / 12 kt | 106 / 10 kt | 270 Wkt | 009/17 kt | 026/13kt | 016/03kph | 016/29kph | 024/12kt | 024/14kt |
| Sky Condition | Overcast | Overcast | Overcast | mostly overcast | scattered cloud | mostly sunny | mostly sunny | clear (sunrise) | sunny |
| Precipitation | NIL | -ZR | Nil | Nil | Nil | Nil | Nil | Nil | Nil |
| Video Camera mounted on window | wide / Zoom | wide / Zoom | Zoom / Zoom | Zoom | Zoom | Zoom | Zoom | Zoom | Zoom |
| Still Camera mounted on window | Nil / Nil | Nil / Nil | zoom | zoom | zoom / N/A | Zoom | Zoom | Zoom | zoom |
| Remarks | | Test aborted due to freezing rain | | Strobes seized after test | still camera N/A | | emergency fly after ice, aborted delayed T/Ooff | wash/rinse/recoat on ac approx 20% LE | small ripple of ice at bend slightly, fluid appl method was not representative of operations; more pellets were sprinkled more at/near/on |

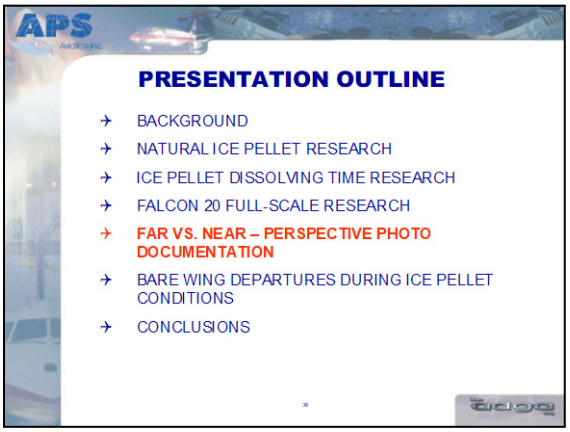


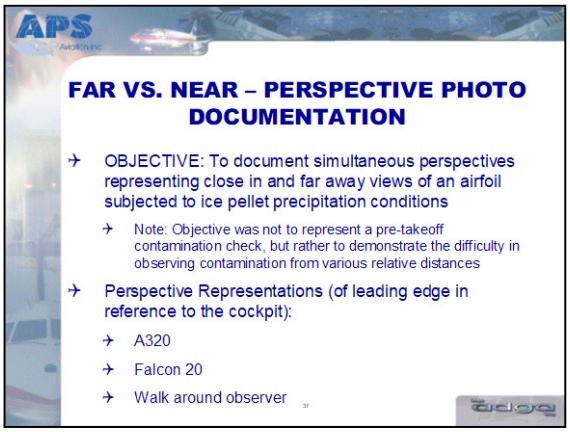

Photos
Run #4
RUN4.ppt


FALCON 20 FULL SCALE RESEARCH
Type IV PG Neat
Ice Pellets w/ Tracer Pellets
Test Surface: Falcon 20 Aircraft
Ice Pellet Diameter: <3.4 mm
20 Min. Precip. Rate: 136 g/dm²/hr
Run #8


Photos
Run #8
RUN8.ppt


FALCON 20 FULL-SCALE RESEARCH
CONCLUSIONS:
Resultant contamination completely removed from the leading edge at rotation speed
Ice pellet clustering was not observed
Visible waves move faster than visible tracer pellets


PRESENTATION OUTLINE
BACKGROUND
NATURAL ICE PELLET RESEARCH
ICE PELLET DISSOLVING TIME RESEARCH
FALCON 20 FULL-SCALE RESEARCH
FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION
BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
CONCLUSIONS


FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION
OBJECTIVE: To document simultaneous perspectives representing close in and far away views of an airfoil subjected to ice pellet precipitation conditions
Note: Objective was not to represent a pre-takeoff contamination check, but rather to demonstrate the difficulty in observing contamination from various relative distances
Perspective Representations (of leading edge in reference to the cockpit):
A320
Falcon 20
Walk around observer

## FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION

- METHODOLOGY
  - Quantity of ice pellets calculated based on 20 minutes at desired precipitation rate and test surface area
  - Ice pellets applied over a short period of time 5 minutes following fluid application
  - Aircraft perspective representations based on:
    - Distance from cockpit to leading edge
    - Height from cockpit to leading edge
    - Angle of leading edge with respect to cockpit

## FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION

| Test # | Aircraft Representation | Fluid | Fluid Quantity | Pellet Size | Ice Pellet Quantity | Ice Pellet Condition |
|---|---|---|---|---|---|---|
| FVN-1 | A320/Falcon 20 | Type IV - PG | 5L | 3mm | 0.45 Kg | Light |
| FVN-2 | A320/Falcon 20 | Type IV - PG | 5L | 3mm | 0.85 Kg | Light/Moderate |
| FVN-3 | A320/Falcon 20 | Type IV - PG | 5L | 3mm | 2.5 Kg | Moderate/Heavy |
| FVN-4 | A320/Falcon 20 | Type IV - PG | 5L | 3mm | 0.45 Kg | Light (w/ tracer pellets) |
| FVN-5 | A320/Falcon 20 | Type IV - PG | 5L | 3mm | 0.85 Kg | Light/Moderate (w/ tracer pellets) |
| FVN-6 | A320/Falcon 20 | Type IV - PG | 5L | 3mm | 2.5 Kg | Moderate/Heavy (w/ tracer pellets) |
| FVN-7 | A320/Falcon 20 | Type IV - PG | 5L | 5mm | 0.45 Kg | Light |
| FVN-8 | A320/Falcon 20 | Type IV - PG | 5L | 5mm | 0.85 Kg | Light/Moderate |
| FVN-9 | A320/Falcon 20 | Type IV - PG | 5L | 5mm | 2.5 Kg | Moderate/Heavy |
| FVN-10 | A320/Falcon 20 | Type IV - PG | 5L | 5mm | 0.45 Kg | Light (w/ tracer pellets) |
| FVN-11 | A320/Falcon 20 | Type IV - PG | 5L | 5mm | 0.85 Kg | Light/Moderate (w/ tracer pellets) |
| FVN-12 | A320/Falcon 20 | Type IV - PG | 5L | 5mm | 2.5 Kg | Moderate/Heavy (w/ tracer pellets) |
| FVN-13 | A320/Falcon 20 | Type II - PG | 5L | 3mm | 0.45 Kg | Light |
| FVN-14 | A320/Falcon 20 | Type II - PG | 5L | 3mm | 0.85 Kg | Light/Moderate |
| FVN-15 | A320/Falcon 20 | Type II - PG | 5L | 3mm | 2.5 Kg | Moderate/Heavy |
| FVN-16 | A320/Falcon 20 | Type II - PG | 5L | 3mm | 0.45 Kg | Light (w/ tracer pellets) |
| FVN-17 | A320/Falcon 20 | Type II - PG | 5L | 3mm | 0.85 Kg | Light/Moderate (w/ tracer pellets) |
| FVN-18 | A320/Falcon 20 | Type II - PG | 5L | 3mm | 2.5 Kg | Moderate/Heavy (w/ tracer pellets) |
| FVN-19 | A320/Falcon 20 | Type I - EG | 3L | 3mm | 0.45 Kg | Light |
| FVN-20 | A320/Falcon 20 | Type I - EG | 3L | 3mm | 0.85 Kg | Light/Moderate |
| FVN-21 | A320/Falcon 20 | Type I - EG | 3L | 3mm | 2.5 Kg | Moderate/Heavy |
| FVN-22 | A320/Falcon 20 | Type I - EG | 3L | 3mm | 0.45 Kg | Light (w/ tracer pellets) |
| FVN-23 | A320/Falcon 20 | Type I - EG | 3L | 3mm | 0.85 Kg | Light/Moderate (w/ tracer pellets) |
| FVN-24 | A320/Falcon 20 | Type I - EG | 3L | 3mm | 2.5 Kg | Moderate/Heavy (w/ tracer pellets) |

## FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION

**Moderate/Heavy Ice Pellets with Tracer Pellets**

**(approx. equivalent to 20 min at 75 g/dm²/h)**

**Ice Pellet Diameter: 2-4 mm**

**Type I PG Std Mix**

Test Surface: Airfoil

## A320 Perspective Representation

**(leading edge section in reference to cockpit)**



Type I Fluid
Moderate/Heavy IP w/ Tracers
2-4 mm Pellets

## Falcon 20 Perspective Representation

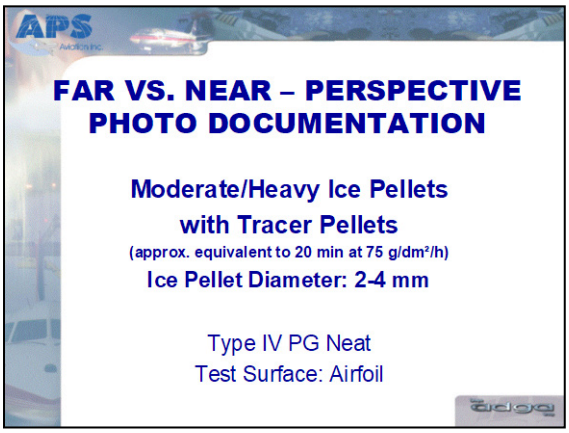
**(leading edge section in reference to cockpit)**

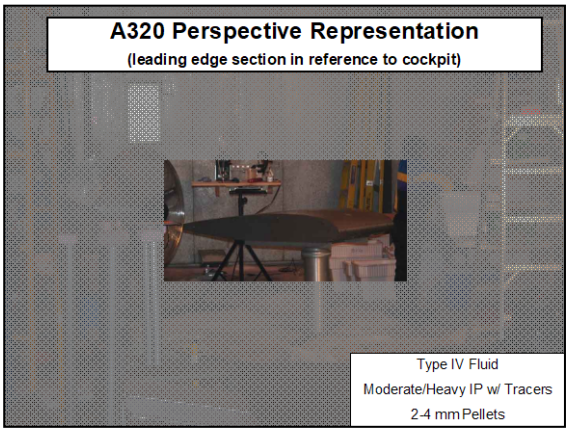


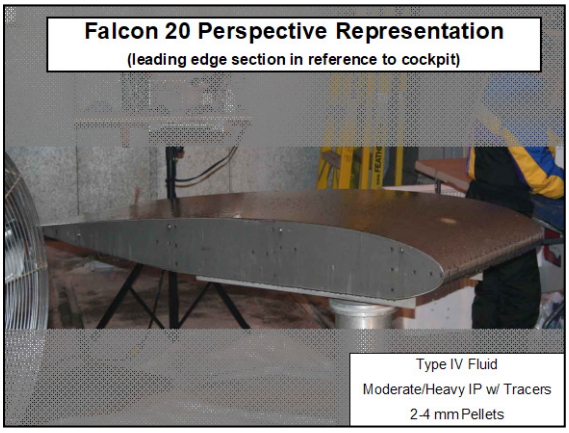
Type I Fluid
Moderate/Heavy IP w/ Tracers
2-4 mm Pellets

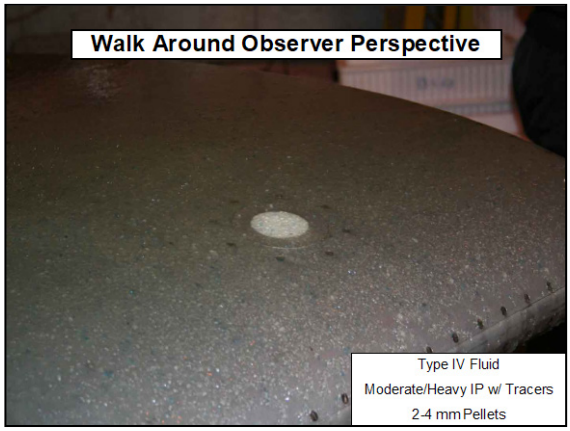
## Walk Around Observer Perspective

Type I Fluid
Moderate/Heavy IP w/ Tracers
2-4 mm Pellets


APS
FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION
Moderate/Heavy Ice Pellets
with Tracer Pellets
(approx. equivalent to 20 min at 75 g/dm²/h)
Ice Pellet Diameter: 2-4 mm
Type IV PG Neat
Test Surface: Airfoil


A320 Perspective Representation
(leading edge section in reference to cockpit)
Type IV Fluid
Moderate/Heavy IP w/ Tracers
2-4 mm Pellets


Falcon 20 Perspective Representation
(leading edge section in reference to cockpit)
Type IV Fluid
Moderate/Heavy IP w/ Tracers
2-4 mm Pellets

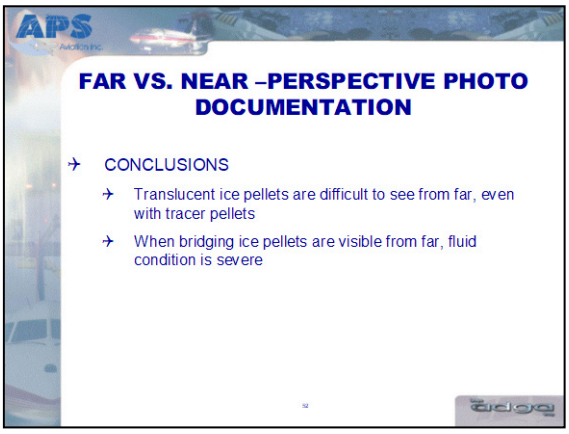

Walk Around Observer Perspective
Type IV Fluid
Moderate/Heavy IP w/ Tracers
2-4 mm Pellets

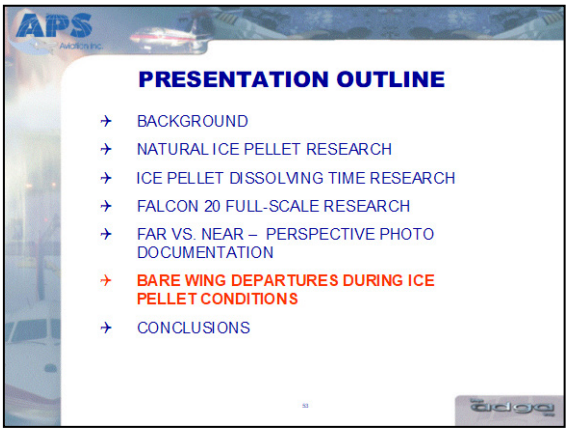

APS
FULL-SCALE FALCON 20
FAR VS. NEAR –PERSPECTIVE
PHOTO DOCUMENTATION
Moderate/Heavy Ice Pellets
Ice Pellet Diameter: 3.4-4.8 mm
Type IV PG Neat
Test Surface: Falcon 20

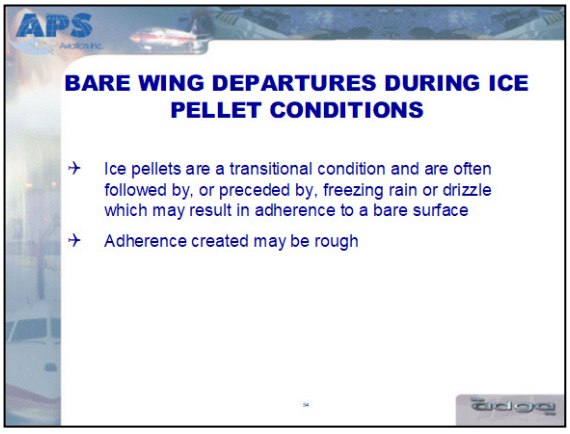

Falcon 20 Port Side View

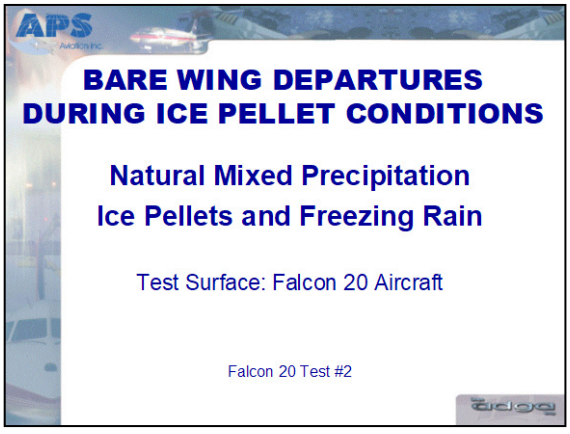

Falcon 20 Cockpit Perspective


Walk Around Observer Perspective

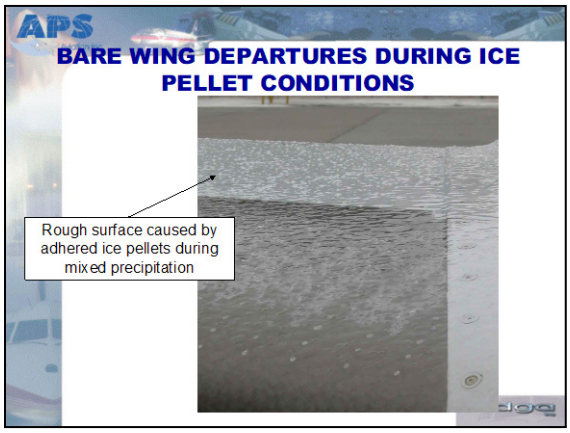

APS
FAR VS. NEAR –PERSPECTIVE PHOTO DOCUMENTATION
CONCLUSIONS
Translucent ice pellets are difficult to see from far, even with tracer pellets
When bridging ice pellets are visible from far, fluid condition is severe

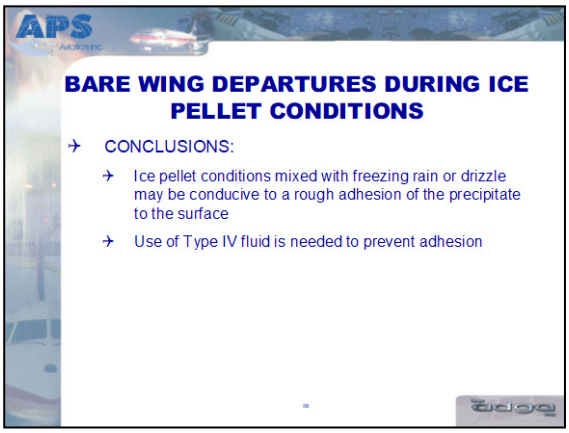

APS
PRESENTATION OUTLINE
BACKGROUND
NATURAL ICE PELLET RESEARCH
ICE PELLET DISSOLVING TIME RESEARCH
FALCON 20 FULL-SCALE RESEARCH
FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION
BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
CONCLUSIONS

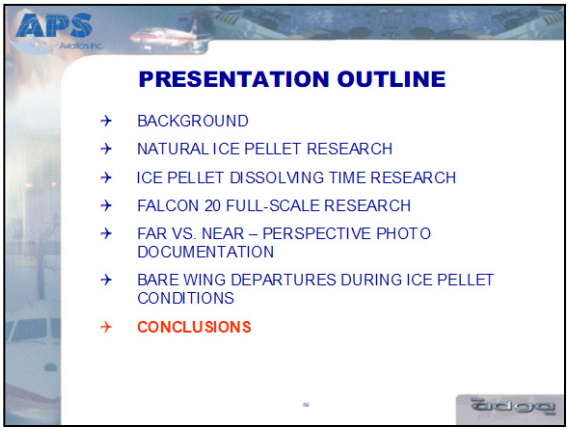

APS
BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
Ice pellets are a transitional condition and are often followed by, or preceded by, freezing rain or drizzle which may result in adherence to a bare surface
Adherence created may be rough

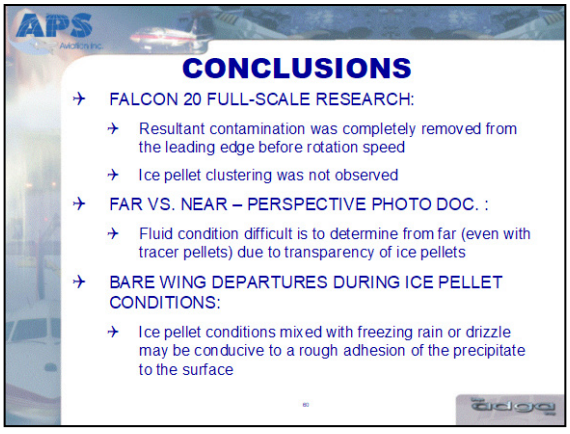

APS
BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
Natural Mixed Precipitation
Ice Pellets and Freezing Rain
Test Surface: Falcon 20 Aircraft
Falcon 20 Test #2


BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
Bare surface glazed with ice


BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
Rough surface caused by adhered ice pellets during mixed precipitation


BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
CONCLUSIONS:
Ice pellet conditions mixed with freezing rain or drizzle may be conducive to a rough adhesion of the precipitate to the surface
Use of Type IV fluid is needed to prevent adhesion


PRESENTATION OUTLINE
BACKGROUND
NATURAL ICE PELLET RESEARCH
ICE PELLET DISSOLVING TIME RESEARCH
FALCON 20 FULL-SCALE RESEARCH
FAR VS. NEAR – PERSPECTIVE PHOTO DOCUMENTATION
BARE WING DEPARTURES DURING ICE PELLET CONDITIONS
CONCLUSIONS


CONCLUSIONS
FALCON 20 FULL-SCALE RESEARCH:
Resultant contamination was completely removed from the leading edge before rotation speed
Ice pellet clustering was not observed
FAR VS. NEAR – PERSPECTIVE PHOTO DOC. :
Fluid condition difficult is to determine from far (even with tracer pellets) due to transparency of ice pellets
BARE WING DEPARTURES DURING ICE PELLET CONDITIONS:
Ice pellet conditions mixed with freezing rain or drizzle may be conducive to a rough adhesion of the precipitate to the surface

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# INTEGRATION OF HOLDOVER TIME DETERMINATION SYSTEMS INTO CANADIAN AIRPORT OPERATIONS









APS Aviation Inc.

ISO 9001:2000

## TRANSPORT CANADA SCOUIC
## OTTAWA, ONTARIO
## SEPTEMBER 28, 2006

**MICHAEL CHAPUT**

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**PREPARED AND PRESENTED ON BEHALF OF:**

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transports Canada Transport Canada

## HOLDOVER TIME TABLES

- The holdover time information provided to the industry for aircraft de/anti-icing fluids has been an important tool for safe winter operations
- Quality of the information contained within the various holdover time tables has improved dramatically
- Despite the improvement in the holdover time information, the pilot's ability to use the information has NOT improved

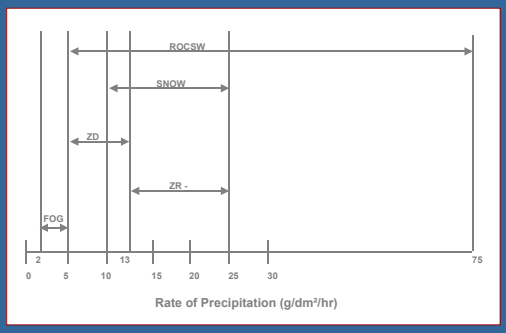
Transports Canada Transport Canada

## HOLDOVER TIME TABLES

- Holdover times are derived from tests performed at specific rates of precipitation for each meteorological condition
  - Liquid Water Content
- Holdover times are a range of times and not a single value
  - Values obtained from tests performed at low end and high end of the rate spectrum for each condition

Transports Canada Transport Canada

## PRECIPITATION RATE LIMITS FOR THE EVALUATION OF FLUID HOLDOVER TIMES




## CURRENT SITUATION

- The industry has long sought tools to assist flight crews in making holdover time decisions
- Currently, the pilot must rely solely on experience and training to:
  - Interpret the meaning of the holdover time range for each condition;
  - Determine an appropriate holdover time based solely on the reported weather conditions and/or visual observations

Transports Canada Transport Canada

## FLUID HOLDOVER TIME

SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]

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

| Outside Air Temperature | | Type IV Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Neat Fluid/Water (Volume %) | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[2] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[3] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:15 – 2:30 | 0:35 – 1:15 | 0:40 – 1:10 | 0:25 – 0:40 | 0:10 – 0:50 | |
| | | 75/25 | 5:00 | 1:05 – 1:45 | 0:20 – 0:55 | 0:35 – 0:50 | 0:15 – 0:30 | 0:05 – 0:35 | |
| | | 50/50 | 3:00 | 0:15 – 0:35 | 0:05 – 0:15 | 0:10 – 0:20 | 0:05 – 0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:25 – 1:20 | 0:20 – 0:40 | 0:20 – 0:45[4] | 0:10 – 0:20[4] | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:25 – 0:50 | 0:15 – 0:35 | 0:15 – 0:30[4] | 0:10 – 0:20[4] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00[5] | 0:15 – 0:40[5] | 0:15 – 0:30[5] | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

- The holdover time for any aircraft de/anti-icing fluid is a function of:
  - Rate of precipitation (in g/dm²/h)
  - Type of precipitation
  - Ambient temperature

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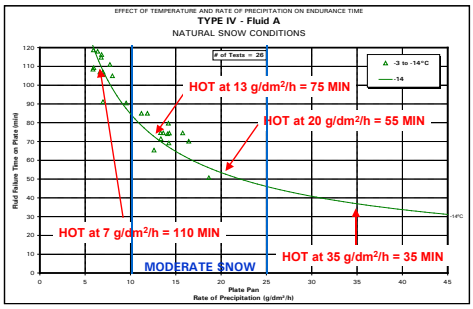
## HOLDOVER TIME DETERMINATION




CURRENT HOT RANGE = 45 TO 85 MINUTES

## CURRENT SITUATION

- Pilots use visual cues to assess intensity of snowfall
- TC / FAA provide carriers with visibility tables for the use of horizontal visibility to categorize the snowfall intensity
- Most meteorologists would agree that this method is not always accurate

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## TC VISIBILITY TABLE

| Lighting | Temperature Range | | Visibility in Snow (Statute Miles) | | | |
|---|---|---|---|---|---|---|
| | °C | °F | Heavy | Moderate | Light | Very Light |
| Darkness | -1 and above | 30 and above | ≤1 | >1 to 2½ | >2½ to 4 | >4 |
| | Below -1 | Below 30 | ≤3/4 | >3/4 to 1½ | >1½ to 3 | >3 |
| Daylight | -1 and above | 30 and above | ≤½ | >½ to 1½ | >1½ to 3 | >3 |
| | Below -1 | Below 30 | ≤3/8 | >3/8 to 7/8 | >7/8 to 2 | >2 |

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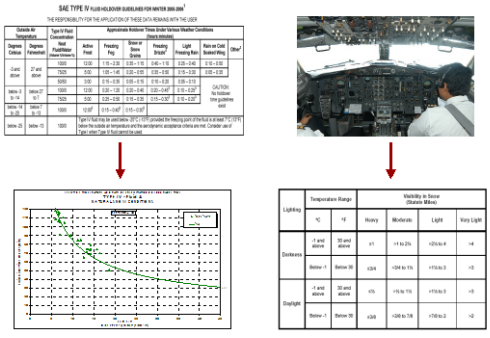
## DISCONNECT?



## INFORMATION GAP



EXCELLENT FLUID HOT INFORMATION EXISTS

TC / FAA PUBLISH THE HOT INFORMATION ANNUALLY

AIR CARRIERS AND FLIGHT CREWS HAVE ACCESS TO THE INFORMATION

FLIGHT CREWS CANNOT GET FULL VALUE OF THE HOT INFORMATION

**REASON: FLIGHT CREWS HAVE NO WAY TO DETERMINE THE INTENSITY OF THE PRECIPITATION THAT IS FALLING**

## HOLDOVER TIME

## DETERMINATION SYSTEM

## HOLDOVER TIME DETERMINATION SYSTEM

- Information system designed for airport use
- System consists of numerous sensors enabling the determination of:
  - Rate of precipitation
  - Type of precipitation
  - Ambient temperature
- System outputs will be used to generate a "single-value" holdover time for each departing aircraft

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## SCOUIC 2005

- Presentation was provided by APS on the testing of a Holdover Time Determination System
  - Dan-Ice Information System

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## DAN-ICE INFORMATION SYSTEM

## DAN-ICE INFORMATION SYSTEM

- System consists of numerous sensors enabling the determination of:
  - Rate of precipitation
  - Type of precipitation
  - Ambient temperature



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## PRECIPITATION RATE UNIT

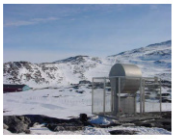


- Titanium turbine and snow collector mounted on weighing platform
- Known surface area enables computation of precipitation intensity in g/dm²/hr for any precipitation type

## DAN-ICE SYSTEM – DATA COLLECTION UNITS



NUUK, GREENLAND



SUNDSVALL, SWEDEN



COPENHAGEN, DENMARK



OSLO, NORWAY



MONTREAL, CANADA



TORONTO, CANADA

## TECHNICAL EVALUATION

- In August 2003, APS was contracted by Dan-Ice to conduct an independent technical evaluation of the Dan-Ice System
- Testing performed over three winters
- Evaluate the system's ability to:
  - Compute a precipitation rate
  - Determine the prevailing meteorological conditions
  - Determine a holdover time based on the prevailing conditions and computed rate

## TECHNICAL EVALUATION

- APS compared Dan-Ice System outputs (rate, precipitation classification, temperature) with:
  - Manual data collections (using historical holdover time precipitation rate methodology)
  - Environment Canada / NAV CANADA weather outputs

## TWO DAN-ICE UNITS INSTALLED AT YUL



## TEST SUMMARY – WINTER 2003-06



- 2003-04: 409 data points were collected during 24 data collection events
- 2004-05: 424 data points were collected during 20 data collection events
- 2005-06: Approx. 700 data points collected during 20+ data collection events; data collected with two units

## TEST RESULTS SUMMARY

- Analysis of the rate outputs of the Dan-Ice system is very positive: rates measured in snow, freezing rain, freezing drizzle, snow pellets, ice pellets compare to those measured using historical methodology
- High wind speeds result in decreased catch capability in snow conditions; compensation factor will be used to calibrate the snow data in this case
  - Ultrasonic anemometer was incorporated into the Dan-Ice system hardware in 2005-06 to measure wind speeds and trigger the use of the compensation factor in high winds
- Ability of the Dan-Ice system to measure accurate temperature and detect and identify precipitation type was also very favorable

## INTEGRATION OF HOLDOVER TIME DETERMINATION SYSTEMS INTO CANADIAN AIRPORT OPERATIONS

## POTENTIAL IMPACTS OF HOLDOVER TIME DETERMINATION SYSTEM IMPLEMENTATION

- Increased operational safety
- Economic savings due to reduced glycol use
- Better management of time and airport throughput
- Reduction of environmental impacts

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## EXAMINATION OF IMPLEMENTATION ISSUES WITH HOLDOVER TIME DETERMINATION SYSTEMS

- During the winter of 2005-06, APS performed the following tasks on behalf of TDC:
  - Provision for support for the installation of a Holdover Time Determination System at Toronto-Pearson International Airport (YYZ); and
  - Development of Performance Specification Documentation for Holdover Time Determination Systems

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## INSTALLATION OF A HOLDOVER TIME DETERMINATION SYSTEM AT TORONTO-PEARSON INTERNATIONAL AIRPORT (YYZ)

## DISMANTLING AND TRANSPORTATION OF DAN-ICE SYSTEM TO YYZ





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SITE SELECTION AT YYZ


ELECTRICAL INSTALLATION AT YYZ
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PHYSICAL INSTALLATION OF DAN-ICE SYSTEM AT YYZ
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WIRELESS DATA COMMUNICATION INSTALLATION
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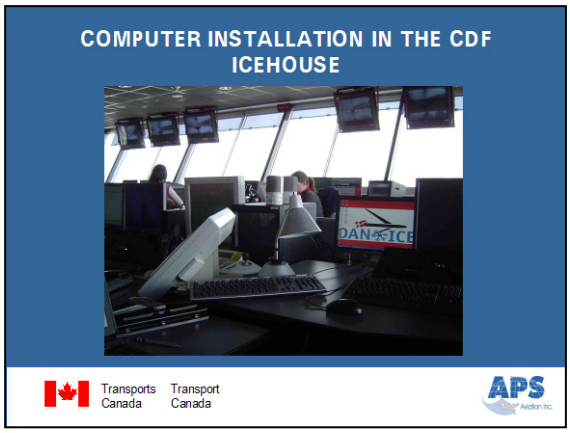
Transport Canada
APS


LINE OF SIGHT TO AND FROM THE SYSTEM


COMPUTER INSTALLATION IN THE CDF ICEHOUSE
DAN-ICE
Transports Canada
Transport Canada
APS

## DESIGN AND IMPLEMENTATION OF ELECTRONIC COMMUNICATION PATHWAY FOR SYSTEM INFORMATION



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## INFORMATION REQUEST VIA ACARS




## INFORMATION RECEIPT VIA ACARS




## OPERATIONAL DATA COLLECTED

- Little or no winter precipitation occurred in late March and April 2006 at YYZ
- Due to the late date of completion of the project, no operational data during actual deicing conditions were collected with the system at YYZ
- The Dan-Ice system at YUL was subsequently configured to communicate information to WestJet

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## LESSONS LEARNED

- Procedural portion of the installation highlighted the inputs required from all stakeholders, many of which were specific to this particular airport site
- Invaluable experience for installation of systems at other airport sites

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## DEVELOPMENT OF PERFOMANCE SPECIFICATION DOCUMENTATION FOR HOLDOVER TIME DETERMINATION SYSTEMS

## ISSUE OF CERTIFICATION

- Air carriers and airports, when approached about using a Holdover Time Determination System, invariably ask if the system is "certified"
- The issue of "certification" was discussed in great detail with Transport Canada, Environment Canada and NAV CANADA

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## APPROACHES FOR IMPLEMENTATION OF HOLDOVER TIME DETERMINATION SYSTEMS?

- Holdover Time Determination System output is an operational aviation product for use under ground icing operations and falls under CAR 622.11
- **SHORT TERM APPROACH**: Develop a performance specification as a means of granting the air carrier an Exemption from CAR 622.11 for operational use of the information provided by the Holdover Time Determination System
- **LONG TERM APPROACH**: Have the information provided by Holdover Time Determination Systems available for public use (METAR)

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## EXEMPTION EXAMPLE AWOS IMPLEMENTATION IN CANADA

- Transport Canada has developed AWOS performance specifications as part of an Exemption to Canadian Aviation Regulations (CAR) 804.01(c)
- NAV CANADA will collect AWOS and human observations and these data will be analyzed to demonstrate that the new AWOS meets the established TC performance specifications
- NAV CANADA does not intend to have its new AWOS "certified", but rather will declare its compliance with the performance specification

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## EXEMPTION APPROACH FOR HOLDOVER TIME DETERMINATION SYSTEMS

- The most expeditious means of realizing the benefits of Holdover Time Determination Systems was to develop a performance specification as a means of granting an Exemption from the CAR for operational use of such a system
- As part of its contract with TC, APS produced:
  - Draft Performance Specification document for Holdover Time Determination Systems
  - Draft Exemption document from CAR 622.11, Sections 3.0, 6.0, 6.2 and 6.3
  - Draft Assessment document

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## WINTER 2006-07

- Transport Canada Regulatory Affairs is currently reviewing the provided documentation
- Transport Canada Standards is currently reviewing required Exemption conditions (target date end of November 2006)
- Montreal (YUL) and Toronto (YYZ) will be the focal points for the provision of holdover time information during the upcoming winter
- Holdover time information will be provided to a Canadian air carrier at these two airports

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## ACKNOWLEDGEMENTS


- Greater Toronto Airports Authority (GTAA)
- Penauille Servisair (YYZ CDF)
- WestJet
- Aeromag 2000 (YUL CDF)


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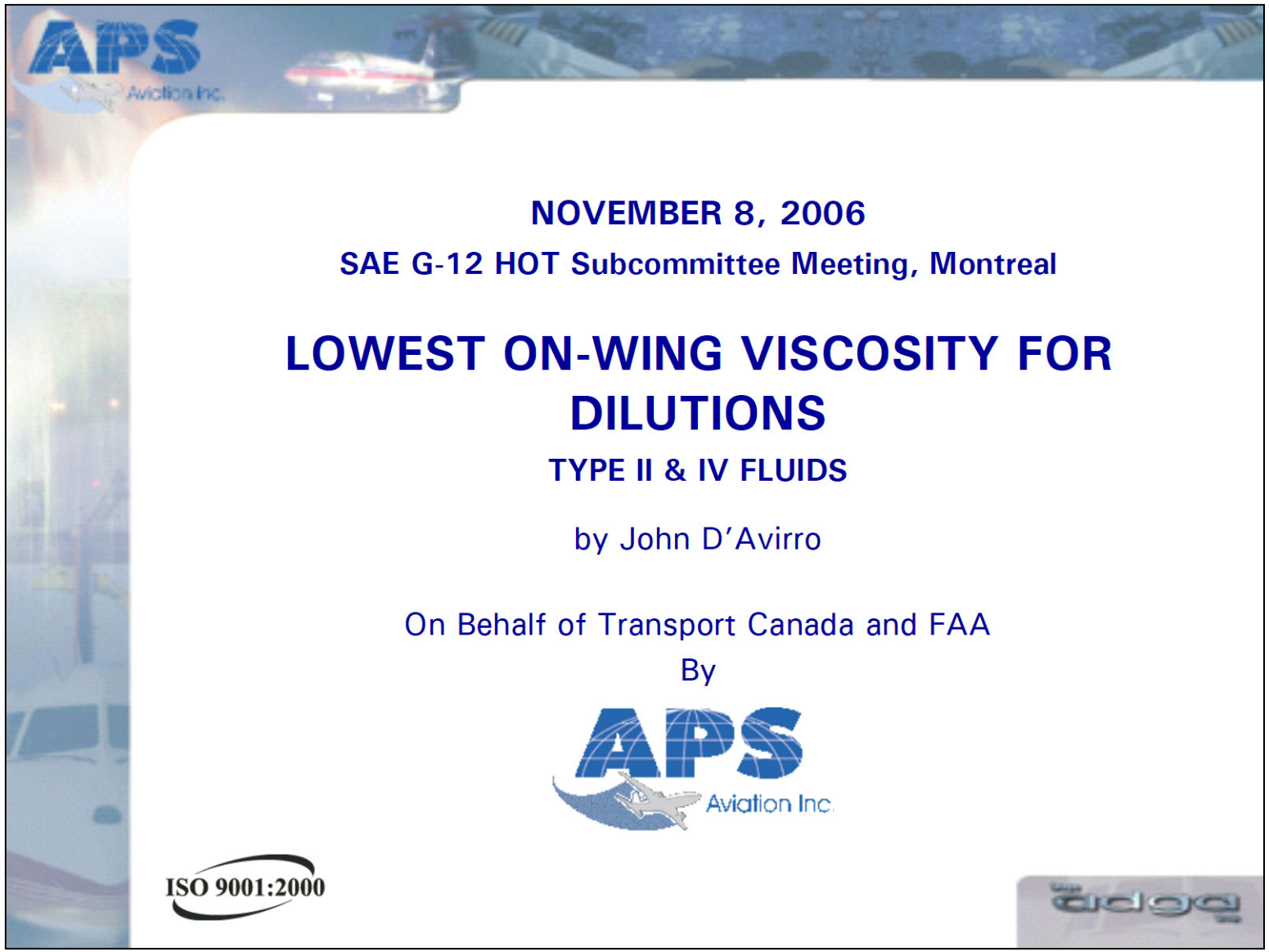
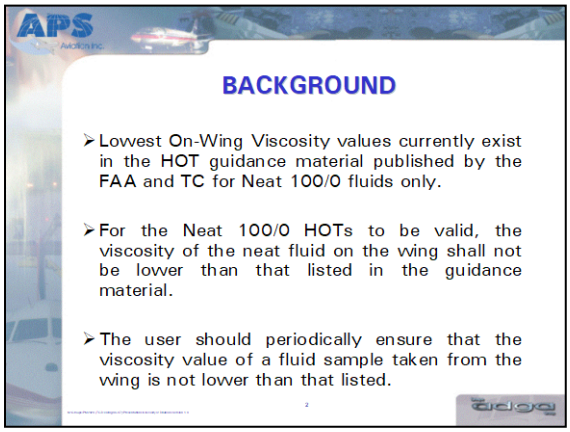
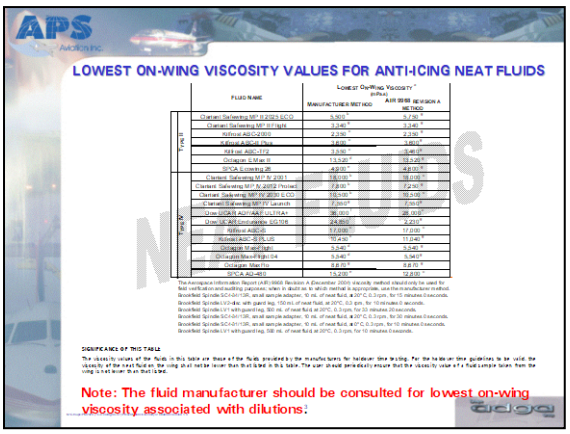
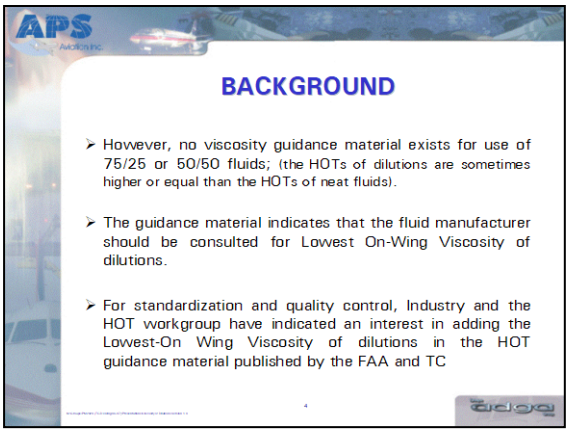
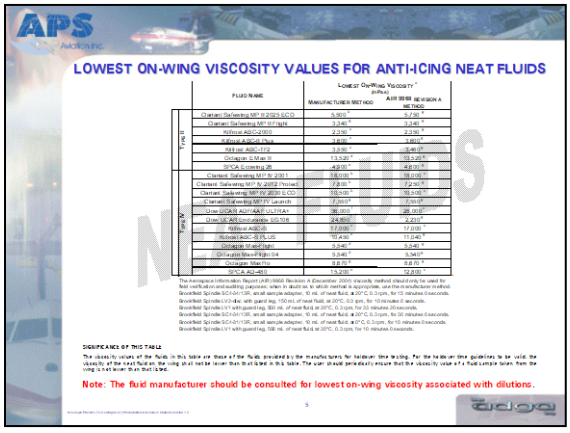
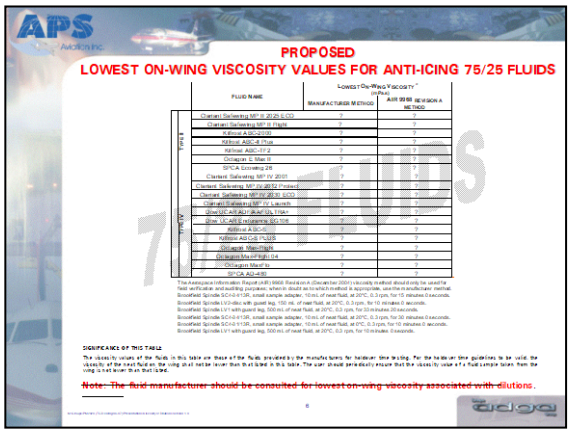

APS
Aviation Inc.
NOVEMBER 8, 2006
SAE G-12 HOT Subcommittee Meeting, Montreal
LOWEST ON-WING VISCOSITY FOR DILUTIONS
TYPE II & IV FLUIDS
by John D'Avirro
On Behalf of Transport Canada and FAA
By
APS
Aviation Inc.
ISO 9001:2000

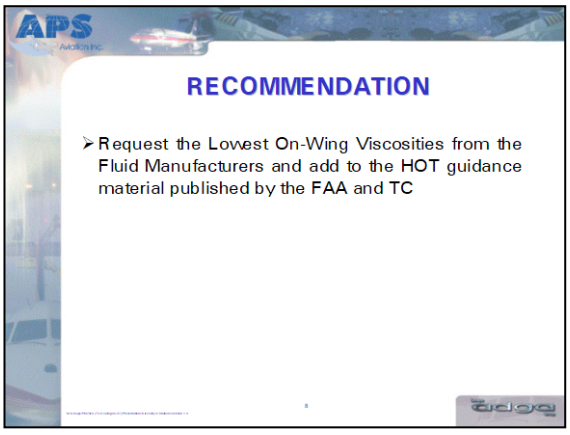

BACKGROUND
➢ Lowest On-Wing Viscosity values currently exist in the HOT guidance material published by the FAA and TC for Neat 100/0 fluids only.
➢ For the Neat 100/0 HOTs to be valid, the viscosity of the neat fluid on the wing shall not be lower than that listed in the guidance material.
➢ The user should periodically ensure that the viscosity value of a fluid sample taken from the wing is not lower than that listed.

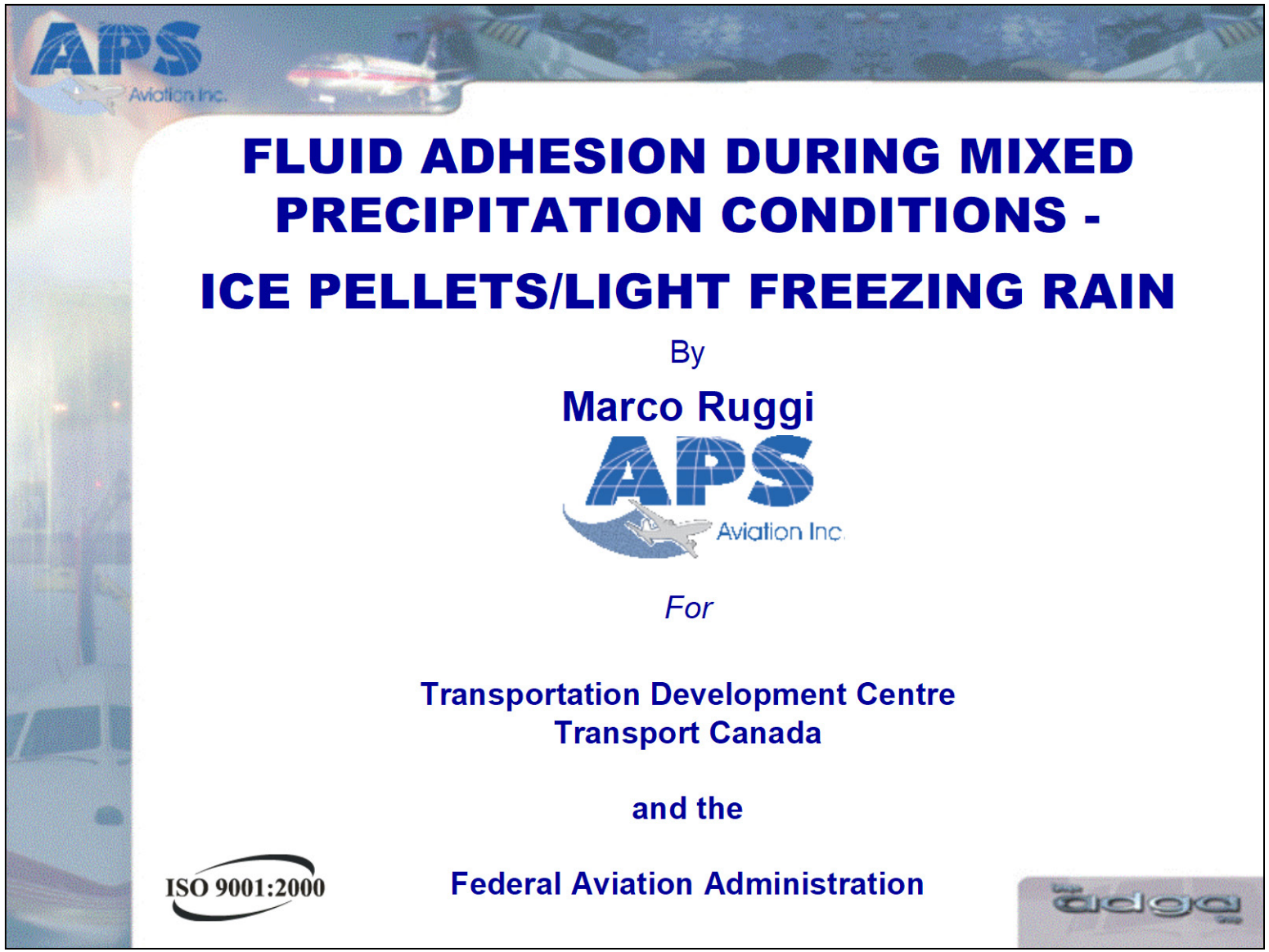

LOWEST ON-WING VISCOSITY VALUES FOR ANTI-ICING NEAT FLUIDS
Note: The fluid manufacturer should be consulted for lowest on-wing viscosity associated with dilutions.


BACKGROUND
➢ However, no viscosity guidance material exists for use of 75/25 or 50/50 fluids; (the HOTs of dilutions are sometimes higher or equal than the HOTs of neat fluids).
➢ The guidance material indicates that the fluid manufacturer should be consulted for Lowest On-Wing Viscosity of dilutions.
➢ For standardization and quality control, Industry and the HOT workgroup have indicated an interest in adding the Lowest-On Wing Viscosity of dilutions in the HOT guidance material published by the FAA and TC


LOWEST ON-WING VISCOSITY VALUES FOR ANTI-ICING NEAT FLUIDS
Note: The fluid manufacturer should be consulted for lowest on-wing viscosity associated with dilutions.


PROPOSED
LOWEST ON-WING VISCOSITY VALUES FOR ANTI-ICING 75/25 FLUIDS
Note: The fluid manufacturer should be consulted for lowest on-wing viscosity associated with dilutions.


RECOMMENDATION
➢ Request the Lowest On-Wing Viscosities from the Fluid Manufacturers and add to the HOT guidance material published by the FAA and TC


APS
Aviation Inc.
FLUID ADHESION DURING MIXED PRECIPITATION CONDITIONS -
ICE PELLETS/LIGHT FREEZING RAIN
By
Marco Ruggi
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000

## PREVIOUS RESEARCH

- Preliminary endurance time testing was conducted by APS at NRC during the spring of 2006.
- Test objective was to investigate which conditions were most conducive to adherence during ice pellet conditions.
- Testing was conducted in simulated precipitation conditions.

## PREVIOUS RESEARCH

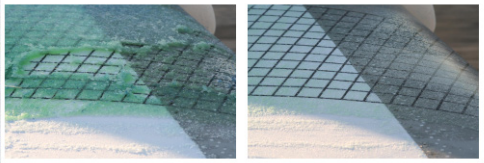
- Adherence was observed during:
  - Type I tests
  - Mixed precipitation tests (ice pellets and freezing rain/drizzle)
- Adherence caused by ice pellets and freezing rain/drizzle was rough and more severe than freezing rain or drizzle alone.
- Further testing was required using Neat Type IV fluid.

## PREVIOUS RESEARCH

- FALCON 20 FULL-SCALE RESEARCH
- OBJECTIVE: To determine the level of contamination of anti-icing fluid caused by ice pellets at which the airflow at takeoff failed to remove the resultant contamination.

## PREVIOUS RESEARCH

- FALCON 20 FULL-SCALE RESEARCH:
  - Resultant contamination was completely removed from the leading edge before rotation speed
  - Ice pellet clustering was not observed



## REGULATORY RECOMMENDATION

- 25-minute allowance was provided by FAA as a preliminary guideline in ice pellet conditions
- Guideline was followed by a list of restrictions
- Operations were restricted to ice pellet conditions only (no mixed precipitation)
- Recommendation was based primarily on Falcon 20 aerodynamic research

## REGULATORY RECOMMENDATION

- Further work work was recommended to explore the mixed precipitation conditions due to high risk of occurrence

## TEST OBJECTIVE

- Testing was conducted by APS at NRC in the Fall of 2006
- OBJECTIVE: To investigate the level of ice pellet and light freezing rain contamination required to cause fluid adherence to the test surface
- Testing was conducted primarily to validate 25-minute allowance time that was recommended by the FAA for aircraft operations in ice pellet only conditions

## METHODOLOGY

- METHODOLOGY:
  - NRC freezing rain sprayer was used in conjunction with ice pellet dispenser
  - Baseline tests were conducted in freezing rain conditions alone
  - Visual fluid failure was estimated
- FLUID ADHESION: Verified using a device which applies constant amount of force (calibrated device previously used for adherence research)

## SETUP AND TEST PHOTOS



## SETUP AND TEST PHOTOS



## SETUP AND TEST PHOTOS



## TEST PLAN

| Condtion | ZR- Rate (g/dm²/h) | IP Rate (g/dm²/h) | OAT (°C) | IP Size (mm) |
|---|---|---|---|---|
| High ZR- / Low IP | 25 | 5 | -3 | 2-5 |
| Approx. Equal IP and ZR- | 13 | 17 | -3 | 2-5 |
| High ZR- / Low IP | 25 | 5 | -10 | 2-5 |
| Approx. Equal IP and ZR- | 13 | 17 | -10 | 2-5 |
| High ZR- / Low IP | 25 | 5 | -3 | 1-2 |

Note: Baseline tests conducted in ZR- condition only

## TEST LOG

- 16 mixed precipitation tests were conducted
  - 10 High ZR-/Low IP tests
  - 6 Approx. equal ZR- and IP tests
- 16 baseline tests were conducted in ZR- conditions alone

## ADHERENCE DATA

| Test # | OAT (°C) | Mixed Precip 15 cm Adherence Time (min) | Baseline 15 cm Adherence Time (min) | %Ratio (Mixed / Baseline) (%) | Time Difference (Mixed / Baseline) (min) |
|---|---|---|---|---|---|
| **High ZR- / Low IP** | | | | | |
| 1-B1 | -3 | 42 | 47 | 88% | -5.5 |
| 2-B2 | -3 | 40 | 40 | 99% | -0.5 |
| 3-B3 | -3 | 40 | 46 | 88% | -5.5 |
| 4-B4 | -3 | 34 | 35 | 98% | -0.7 |
| 9-B9 | -10 | 32 | 42 | 77% | -9.8 |
| 10-B10 | -10 | 31 | 32 | 98% | -0.8 |
| 11-B11 | -10 | 36 | 40 | 91% | -3.5 |
| 12-B12 | -10 | 27 | 27 | 102% | 0.5 |
| E1-BE1 | -3 | 35 | 38 | 92% | -3.0 |
| E3-BE3 | -3 | 34 | 33 | 102% | 0.8 |
| | | | Average | 93% | |
| **Approx. Equal ZR- and IP** | | | | | |
| 5-B5 | -3 | 67 | 75 | 89% | -8.0 |
| 6-B6 | -3 | 63 | 65 | 96% | -2.7 |
| 7-B7 | -3 | 61 | 60 | 102% | 1.0 |
| 8-B8 | -3 | 53 | 59 | 90% | -5.7 |
| | | | Average | 94% | |
| **Approx. Equal ZR- and IP** | | | | | |
| 13-B13 | -10 | 37 | 51 | 73% | -14.0 |
| 15-B15 | -10 | 45 | 59 | 76% | -14.0 |
| | | | Average | 74% | |

## ADHERENCE DATA

- Adherence to 15 cm line during High ZR- / Low IP conditions
- Type IV PG Neat Fluid







## GENERAL OBSERVATIONS

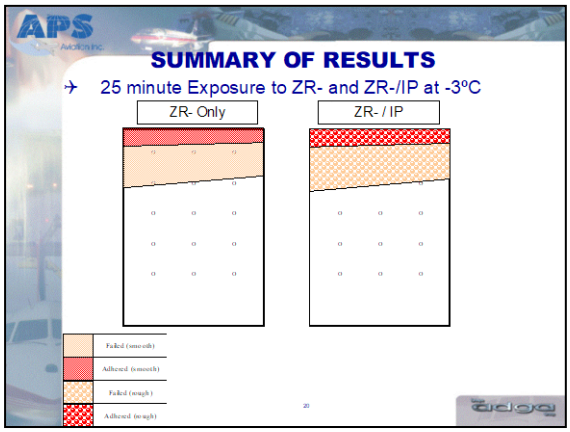
- **High ZR- / Low IP Tests (Large and Small Ice Pellets)**
  - Consistent results were obtained at -3°C and at -10°C
  - The time of adherence to the 15 cm line for the mixed icing (ZR- and IP) test was on average 7% shorter with respect to the baseline (ZR- only) test
    - Note: Mixed icing rate was greater than ZR- rate by 5 g/dm²/h
  - Adding ice pellet precipitation to ZR did not significantly reduce the time to adherence

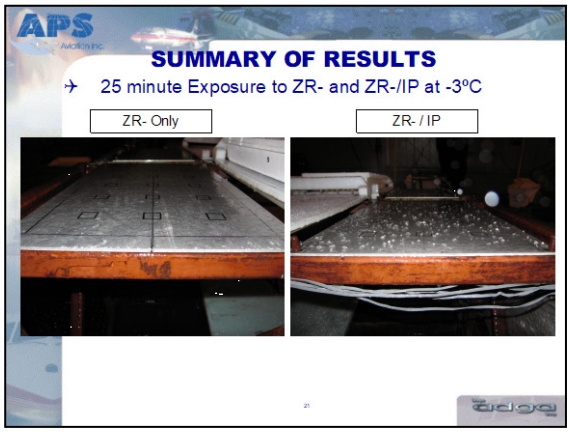
## GENERAL OBSERVATIONS

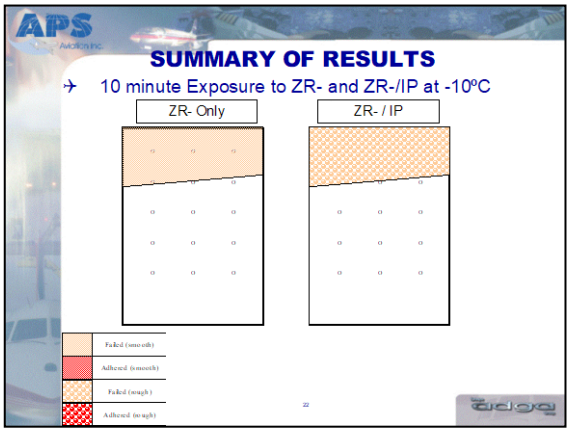
- **Approximately Equal ZR- and IP Tests at -3°C (Large Ice Pellets)**
  - The time of adherence to the 15 cm line for the mixed icing (ZR- and IP) test was on average 6% shorter with respect to the baseline (ZR- only) test
    - Note: Mixed icing rate was greater than ZR- rate by 17 g/dm²/h
  - Adding ice pellet precipitation to ZR did not significantly reduce the time to adherence
    - Previous research has also indicated that in predominantly ice pellets conditions, a lesser degree of adhesion may occur.

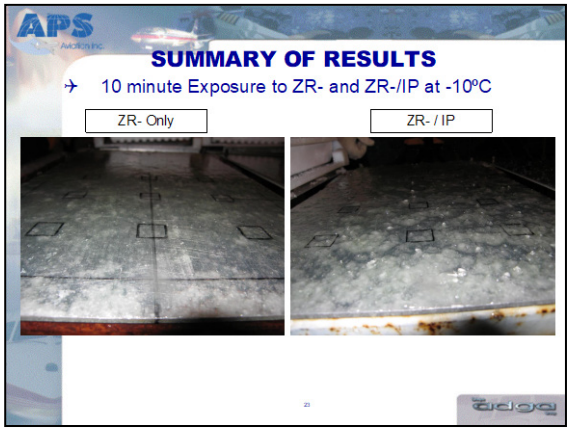
## GENERAL OBSERVATIONS

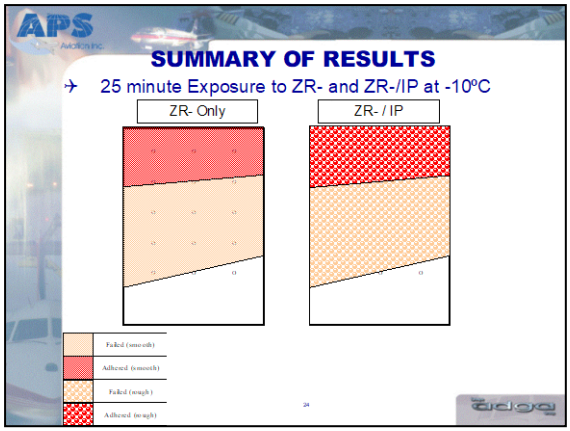
- **Approximately Equal ZR- and IP Tests at -10°C (Large Ice Pellets)**
  - The time of adherence to the 15 cm line for the mixed icing (ZR- and IP) test was on average 26% shorter with respect to the baseline (ZR- only) test
    - Note: Mixed icing rate was greater than ZR- rate by 17 g/dm²/h
  - At colder temperatures the adding ice pellet precipitation to ZR did significantly reduce the time to adherence.

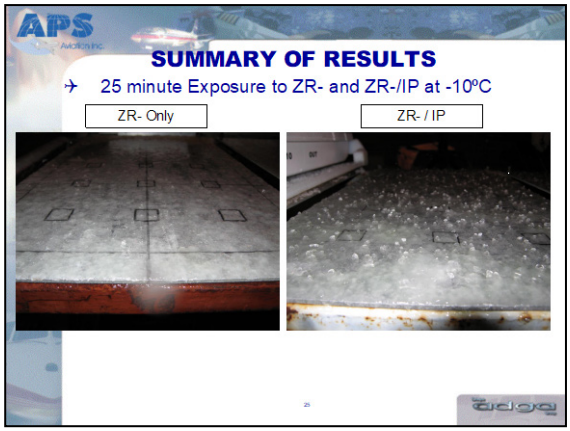

APS
SUMMARY OF RESULTS
25 minute Exposure to ZR- and ZR-/IP at -3ºC
ZR- Only
ZR- / IP
Failed (smooth)
Adhered (smooth)
Failed (rough)
Adhered (rough)

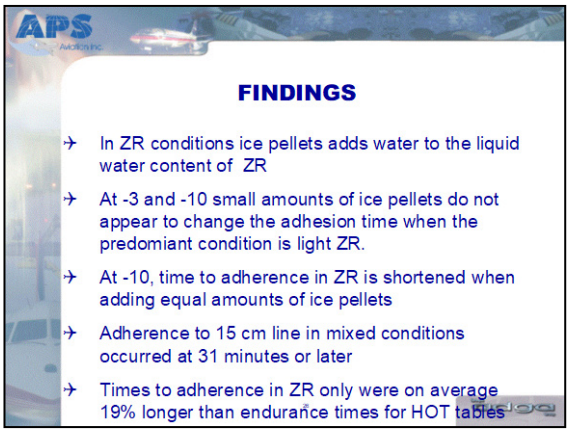

APS
SUMMARY OF RESULTS
25 minute Exposure to ZR- and ZR-/IP at -3ºC
ZR- Only
ZR- / IP

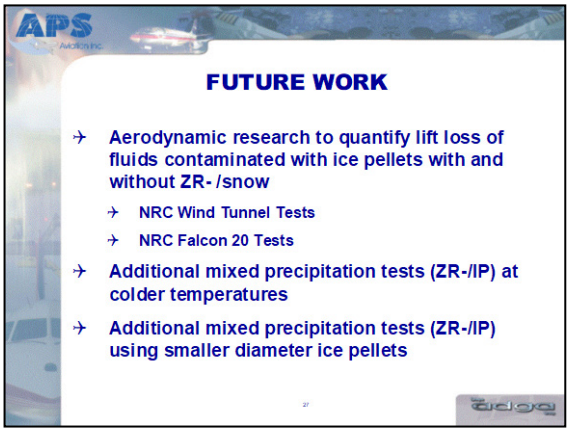

APS
SUMMARY OF RESULTS
10 minute Exposure to ZR- and ZR-/IP at -10ºC
ZR- Only
ZR- / IP
Failed (smooth)
Adhered (smooth)
Failed (rough)
Adhered (rough)

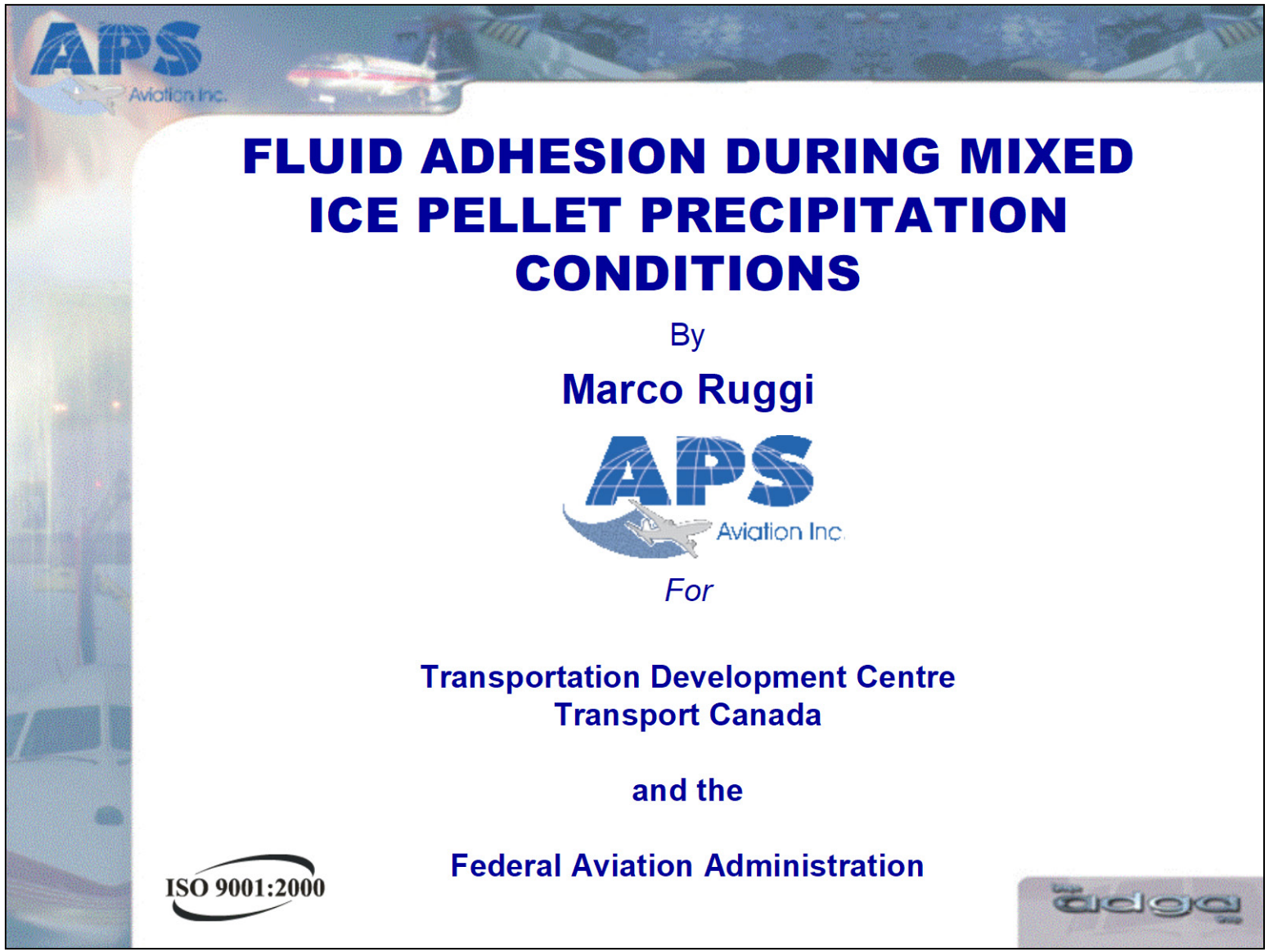

APS
SUMMARY OF RESULTS
10 minute Exposure to ZR- and ZR-/IP at -10ºC
ZR- Only
ZR- / IP


APS
SUMMARY OF RESULTS
25 minute Exposure to ZR- and ZR-/IP at -10ºC
ZR- Only
ZR- / IP
Failed (smooth)
Adhered (smooth)
Failed (rough)
Adhered (rough)


APS
SUMMARY OF RESULTS
25 minute Exposure to ZR- and ZR-/IP at -10ºC
ZR- Only
ZR- / IP


APS
FINDINGS
In ZR conditions ice pellets adds water to the liquid water content of ZR
At -3 and -10 small amounts of ice pellets do not appear to change the adhesion time when the predomiant condition is light ZR.
At -10, time to adherence in ZR is shortened when adding equal amounts of ice pellets
Adherence to 15 cm line in mixed conditions occurred at 31 minutes or later
Times to adherence in ZR only were on average 19% longer than endurance times for HOT tables


APS
FUTURE WORK
Aerodynamic research to quantify lift loss of fluids contaminated with ice pellets with and without ZR- /snow
NRC Wind Tunnel Tests
NRC Falcon 20 Tests
Additional mixed precipitation tests (ZR-/IP) at colder temperatures
Additional mixed precipitation tests (ZR-/IP) using smaller diameter ice pellets


APS
Aviation Inc.
FLUID ADHESION DURING MIXED ICE PELLET PRECIPITATION CONDITIONS
By
Marco Ruggi
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000

## PREVIOUS RESEARCH

- Preliminary endurance time testing was conducted by APS at NRC during the spring of 2006.
- Test objective was to investigate which conditions were most conducive to adherence during ice pellet conditions.
- Testing was conducted in simulated precipitation conditions.

## PREVIOUS RESEARCH

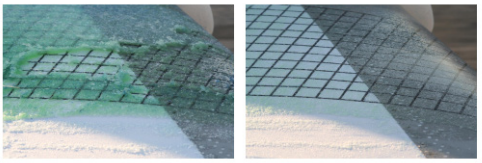
- Adherence was observed during:
  - Type I tests
  - Mixed precipitation tests (ice pellets and freezing rain/drizzle)
- Adherence caused by ice pellets and freezing rain/drizzle was rough and more severe than freezing rain or drizzle alone.
- Further testing was required using Neat Type IV fluid.

## PREVIOUS RESEARCH

- FALCON 20 FULL-SCALE RESEARCH
- OBJECTIVE: To determine the level of contamination of anti-icing fluid caused by ice pellets at which the airflow at takeoff failed to remove the resultant contamination.

## PREVIOUS RESEARCH

- FALCON 20 FULL-SCALE RESEARCH:
  - Resultant contamination was completely removed from the leading edge before rotation speed
  - Ice pellet clustering was not observed



## PREVIOUS RESEARCH – FALCON 20 FULL SCALE TESTING

Type IV PG Neat
Ice Pellets w/ Tracer Pellets

Test Surface: Falcon 20 Aircraft
Ice Pellet Diameter: 1– 3.4 mm
20 Min. Precip. Rate: 25 g/dm²/hr

Run #4

## Photos Run #4

RUN 4.ppt

## REGULATORY GUIDANCE

- 25-minute allowance was provided by FAA for ice pellet conditions
- Allowance was restricted to light ice pellet conditions only (no mixed precipitation)
- Allowance was based on Falcon 20 aerodynamic research

## FOLLOW UP RESEARCH

- Ice pellets are often accompanied by freezing precipitation or snow
- Further testing was recommended to explore these mixed precipitation conditions

## RESEARCH OBJECTIVES

- **MIXED FREEZING PRECIP/ICE PELLET RESEARCH**
- To investigate the level of ice pellet and light freezing rain contamination required to cause fluid adherence to the test surface
- The ice pellet testing was conducted by APS at NRC in September of 2006
- **MIXED SNOW/ICE PELLET RESEARCH**
- Conduct adherence research in mixed ice pellet and snow conditions
- Preliminary tests were conducted by APS at Montreal test site also in September

## MIXED FREEZING PRECIP/ICE PELLET RESEARCH

- NRC freezing rain sprayer was used in conjunction with ice pellet dispenser
- Baseline tests were conducted in freezing rain conditions alone
- Visual fluid failure was estimated based on standard freezing precipitation protocol or ice adhesion
- Ice adhesion was verified using a device which applies constant amount of force (calibrated device previously used for adherence research)

## SETUP AND TEST PHOTOS



## SETUP AND TEST PHOTOS



## SETUP AND TEST PHOTOS



## TEST PLAN

| Condtion | ZR- Rate (g/dm²/h) | IP Rate (g/dm²/h) | OAT (°C) | IP Size (mm) |
|---|---|---|---|---|
| High ZR- / Low IP | 25 | 5 | -3 | 2-5 |
| Approx. Equal ZR- and IP | 13 | 17 | -3 | 2-5 |
| High ZR- / Low IP | 25 | 5 | -10 | 2-5 |
| Approx. Equal ZR- and IP | 13 | 17 | -10 | 2-5 |
| High ZR- / Low IP | 25 | 5 | -3 | 1-2 |

- Baseline tests were conducted in ZR- conditions alone

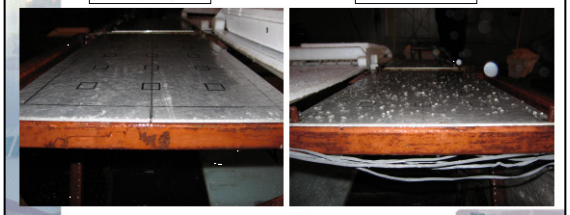
## TEST LOG

- 16 mixed precipitation tests were conducted
  - 10 High ZR-/Low IP tests
  - 6 Approx. equal ZR- and IP tests
- 16 baseline tests were conducted in ZR- conditions alone
- 4 Type IV Fluids Tested
- 2 Type II Fluids Tested

## ADHERENCE DATA

- ZR- and ZR-/IP at -3°C
- Type IV PG Neat – Fluid A
- **Adherence to 7.5 cm line**

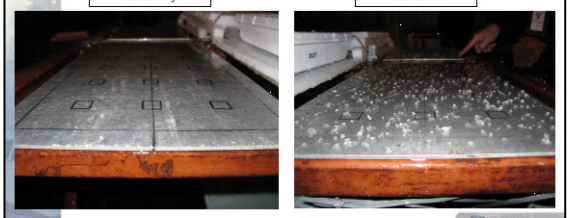
ZR- Only | ZR- / IP



## ADHERENCE DATA

- ZR- and ZR-/IP at -3°C
- Type IV PG Neat – Fluid B
- **Adherence to 15 cm line**

ZR- Only | ZR- / IP

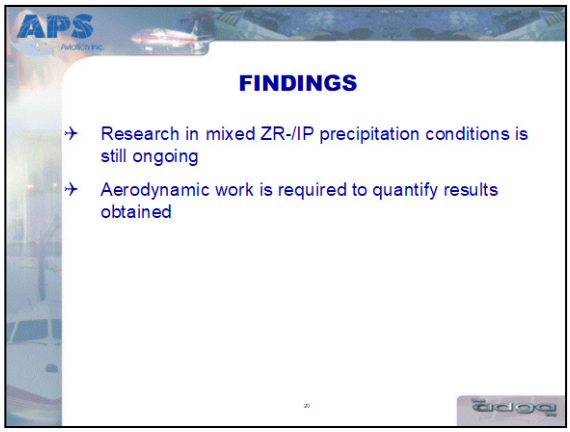


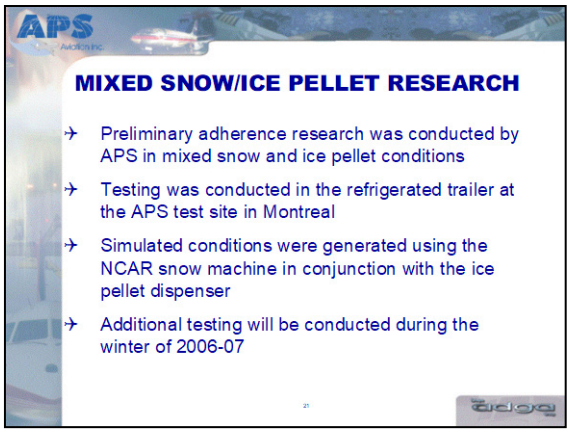
## ADHERENCE DATA

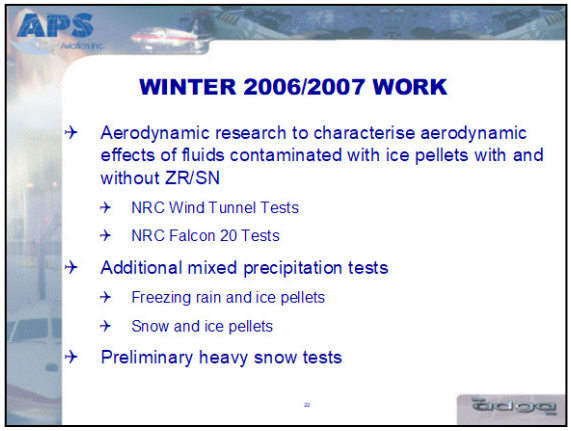
- ZR- and ZR-/IP at -10°C
- Type IV PG Neat – Fluid C
- **Adherence to 15 cm line**

ZR- Only | ZR- / IP




APS
Aviation Inc
FINDINGS
Research in mixed ZR-/IP precipitation conditions is still ongoing
Aerodynamic work is required to quantify results obtained


APS
Aviation Inc
MIXED SNOW/ICE PELLET RESEARCH
Preliminary adherence research was conducted by APS in mixed snow and ice pellet conditions
Testing was conducted in the refrigerated trailer at the APS test site in Montreal
Simulated conditions were generated using the NCAR snow machine in conjunction with the ice pellet dispenser
Additional testing will be conducted during the winter of 2006-07


APS
Aviation Inc
WINTER 2006/2007 WORK
Aerodynamic research to characterise aerodynamic effects of fluids contaminated with ice pellets with and without ZR/SN
NRC Wind Tunnel Tests
NRC Falcon 20 Tests
Additional mixed precipitation tests
Freezing rain and ice pellets
Snow and ice pellets
Preliminary heavy snow tests

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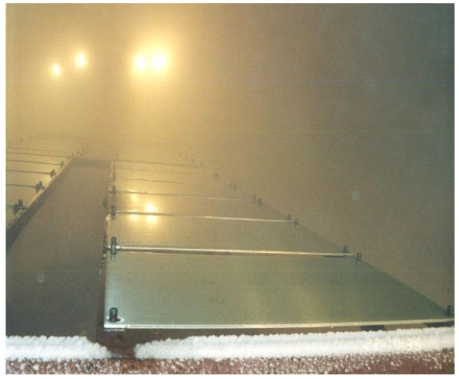
# SUMMARY OF HOLDOVER TIME DEVELOPMENTS FROM THE 2006-07 WINTER TEST SEASON







APS Aviation Inc.

ISO 9001:2000

## SAE G-12 HOLDOVER TIME SUBCOMMITTEE WORKGROUP MONTREAL - MAY 1, 2007

**PREPARED AND PRESENTED ON BEHALF OF:**

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transports Canada Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

## FLUIDS TESTED

- TYPE I: Kilfrost P1957B
- TYPE II: Aviation Xi'an KHF-II
  Newave Aerochemical FCY-2
- TYPE IV: Lyondell 2330
  Lyondell 6166
  Kilfrost P1797
  Clariant Launch (snow only)

Transports Canada Transport Canada

## TESTS CONDUCTED IN 2006-07

| FLUID TYPE | SNOW | FREEZING DRIZZLE | LIGHT FREEZING RAIN | FREEZING FOG | COLD SOAK | TOTAL |
|---|---|---|---|---|---|---|
| Type I | 22 | 8 | 4 | 14 | 4 | 52 |
| Type II (Neat) | 46 | 16 | 16 | 24 | 8 | 110 |
| Type II (75/25) | 46 | 16 | 18 | 16 | 8 | 104 |
| Type II (50/50) | 24 | 8 | 8 | 10 | 0 | 50 |
| Type IV (Neat) | 71 | 24 | 24 | 37 | 12 | 168 |
| Type IV (75/25) | 72 | 24 | 25 | 24 | 12 | 157 |
| Type IV (50/50) | 43 | 12 | 12 | 12 | 0 | 79 |
| TOTAL | 324 | 108 | 107 | 137 | 44 | 720 |

Transports Canada Transport Canada

## TEST RESULTS – TYPE I

- Kilfrost P1957B comparable to other Type I fluids and will be commercialized
  - *NO CHANGE TO TYPE I GUIDELINES*

Transports Canada Transport Canada

## TEST RESULTS – TYPE II

- Aviation Xi'an KHF-II and Newave FCY-2 will be commercialized
- Newave FCY-2 has some values below generic
  - *TWO NEW TYPE II FLUID-SPECIFIC TABLES*
  - *REDUCTIONS TO TYPE II GENERIC GUIDELINES*

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## TEST RESULTS – TYPE II

**SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008**

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

| Outside Air Temperature | | Type II Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Neat Fluid/Water (Volume %/Volume %) | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[1] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 0:35 – 1:30 | 0:20 – 0:45 | 0:30 – 0:55 | 0:15 – 0:30 | 0:05 – 0:40 | |
| | | 75/25 | 5:00 | 0:25 – 1:00 | 0:15 – 0:30 | 0:20 – 0:45 | 0:10 – 0:25 | 0:05 – 0:25 | |
| | | 50/50 | 3:00 | 0:15 – 0:30 | 0:05 – 0:15 | 0:05 – 0:15 | 0:05 – 0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:20 – 1:05 | 0:15 – **0:30** | 0:15 – 0:45[3] | 0:10 – **0:20**[3] | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:20 – 0:55 | **0:10 – 0:20** | 0:15 – 0:30[3] | **0:05 – 0:15**[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00[4] | 0:15 – 0:20[3] | 0:15 – 0:30[3] | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

Note: values in red have been reduced by 5 minutes

Transports Canada Transport Canada

## TEST RESULTS – TYPE IV

- One of the Lyondell fluids and Kilfrost P1797 will be commercialized
- Fluid-specific snow values will replace generic values for Clariant Launch
- All new values above Type IV generic
  - *TWO NEW TYPE IV FLUID-SPECIFIC TABLES*
  - *CHANGE TO CLARIANT LAUNCH SNOW VALUES*
  - *NO CHANGES TO TYPE IV GENERIC GUIDELINES*

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APS
Aviation Inc.
PRELIMINARY AIRCRAFT GROUND DEICING RESEARCH USING COMPOSITE MATERIALS
By
Marco Ruggi
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000

## PRESENTATION OUTLINE

- BACKGROUND – PREVIOUS WORK
- COMPOSITE MATERIALS TESTED
- OUTDOOR NATURAL SNOW PLATE TESTS
- OUTDOOR NATURAL FROST PLATE TESTS
- INDOOR SIMULATED FREEZING PRECIPITATION PLATE TESTS
- LEADING EDGE THERMAL EQUIVALENT BOX TESTS
- OBSERVATIONS AND RECOMMENDATIONS

2

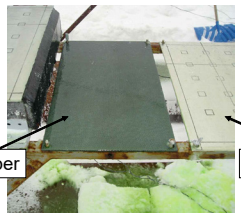
## BACKGROUND – PREVIOUS WORK

- COMPARATIVE ENDURANCE TIME TESTING
  - Preliminary testing was conducted during the winter of 2004-05
  - OBJECTIVE: investigate the impact of non-aluminum test plate material on fluid endurance time
  - 21 comparative tests were conducted in natural snow conditions
  - 6 comparative tests were conducted in simulated freezing precipitation conditions
  - 6 comparative tests were conducted in natural frost conditions

3

## BACKGROUND – PREVIOUS WORK

- MATERIALS USED
  - Cross weave carbon fiber test plate
  - Baseline standard aluminum test plate
  - Test plates were not painted for testing




## BACKGROUND– PREVIOUS WORK

- METHODOLOGY
  - Comparative endurance time testing with Type I fluids applied at 20ºC
  - Comparative endurance time testing with Type II/III/IV fluids at ambient temperature

5

## BACKGROUND – PREVIOUS WORK

- CONCLUSIONS
  - Natural Snow – Composite plate endurance time 10% longer than aluminum plate
  - Freezing Precipitation – Composite plate endurance time 4% longer than aluminum plate
  - Frost - Composite plate endurance time 19% shorter than aluminum plate (using only Type I)
  - Radiation effects on different colored surfaces may have created discrepancies in the results obtained

6

## PRESENTATION OUTLINE

- BACKGROUND – PREVIOUS WORK
- COMPOSITE MATERIALS TESTED
- OUTDOOR NATURAL SNOW PLATE TESTS
- OUTDOOR NATURAL FROST PLATE TESTS
- INDOOR SIMULATED FREEZING PRECIPITATION PLATE TESTS
- LEADING EDGE THERMAL EQUIVALENT BOX TESTS
- OBSERVATIONS AND RECOMMENDATIONS

7

## COMPOSITE MATERIALS TESTED

- CARBON FIBER PLAIN WEAVE FABRIC
  - 0.32 cm thick panel (will be referred to as Carbon 05)
- CARBON FIBER UNIDIRECTIONAL TAPE
  - 0.35 cm thick panel (will be referred to as Carbon 06 Thin)
  - 0.57 cm thick panel (will be referred to as Carbon 06 Thick)
- GLARE (Hybrid material using alternating layers of aluminum and glass fiber)
  - 0.38 cm thick panel (will be referred to as GLARE)

8

## COMPOSITE MATERIALS TESTED

- CROSS WEAVE CARBON FIBER




## COMPOSITE MATERIALS TESTED

- UNIDIRECTIONAL WEAVE CARBON FIBER




## COMPOSITE MATERIALS TESTED

- GLARE




## COMPOSITE MATERIALS TESTED

- Material samples were provided by
  - Aviation Equipment Inc.
  - Toray Composites (America) Inc.

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## COMPOSITE MATERIALS TESTED

- TEST SETUP
  - All composite test plates, and the baseline aluminum test plate, were painted white with aircraft grade paint
  - White paint allowed for equal radiation effects on all surfaces
  - Standard HOT test plate (or box for Type I) was not painted. Test was conducted in conjunction for reference purposes

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## PRESENTATION OUTLINE

- BACKGROUND – PREVIOUS WORK
- COMPOSITE MATERIALS TESTED
- OUTDOOR NATURAL SNOW PLATE TESTS
- OUTDOOR NATURAL FROST PLATE TESTS
- INDOOR SIMULATED FREEZING PRECIPITATION PLATE TESTS
- LEADING EDGE THERMAL EQUIVALENT BOX TESTS
- OBSERVATIONS AND RECOMMENDATIONS

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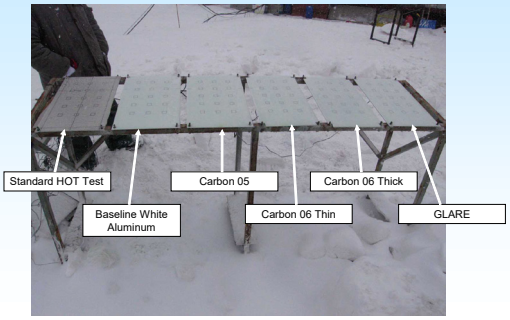
## OUTDOOR NATURAL SNOW TESTING

- METHODOLOGY:
  - Comparative endurance time testing was conducted using the same fluid and dilution, applied at the same temperature to each of the composite plates
  - Baseline tests were conducted following standard HOT protocol

15

## OUTDOOR NATURAL SNOW TESTING

- OUTDOOR TEST SETUP




16

## OUTDOOR NATURAL SNOW TESTING

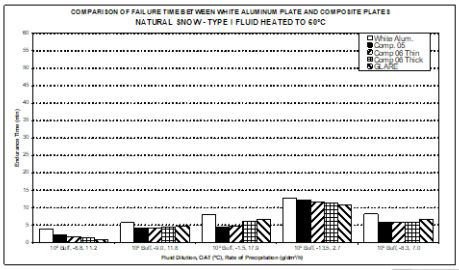
- SUMMARY OF COMPARATIVE TEST RUNS

| Test Objective | # of Comparative Test Runs |
|---|---|
| Type I Heated (60ºC) | 5 |
| Type II Heated (60ºC) | 1 |
| Type III Heated (60ºC) | 1 |
| Type IV at OAT | 4 |
| Type IV Heated (60ºC) | 4 |
| **TOTAL** | **15** |

17

## OUTDOOR NATURAL SNOW TESTING

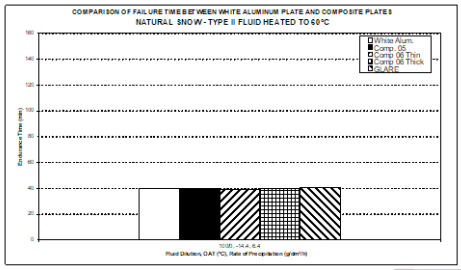
- TYPE I EG APPLIED AT 60ºC




18

## OUTDOOR NATURAL SNOW TESTING

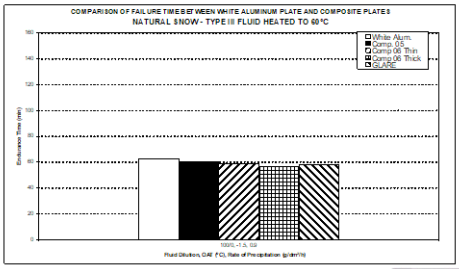
- TYPE II PG APPLIED AT 60ºC




19

## OUTDOOR NATURAL SNOW TESTING

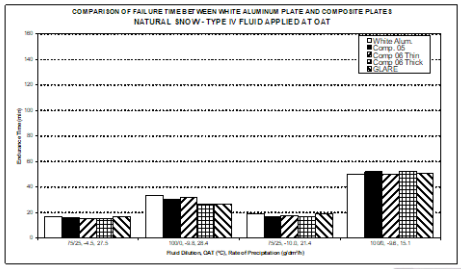
- TYPE III PG APPLIED AT 60ºC




20

## OUTDOOR NATURAL SNOW TESTING

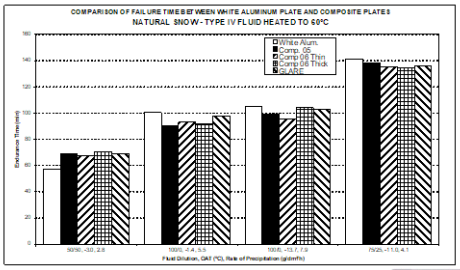
- TYPE IV PG APPLIED AT OAT




21

## OUTDOOR NATURAL SNOW TESTING

- TYPE IV PG APPLIED AT 60ºC




22

## OUTDOOR NATURAL SNOW TESTING

- SUMMARY OF RESULTS
  - Similar endurance time trends were observed amongst all composite materials
  - Analysis was conducted using:
    - White painted carbon fiber plain weave fabric (Carbon 05)
    - White painted aluminum test plate
  - Percentage ratio and endurance time difference was calculated for each test

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| Test # | Comp 05 Endurance Time (min) | White Alum. Endurance Time (min) | Endurance Time % Ratio (Comp05 / White Alum.) | Endurance Time Time Difference [min.] (Comp05 - White Alum.) |
|---|---|---|---|---|
| **Type I Fluid Heated to 60°C** | | | | |
| 2-3 | 2.2 | 3.8 | 57% | -1.6 |
| 32-33 | 4.3 | 5.7 | 75% | -1.4 |
| 68-69 | 4.5 | 8.2 | 55% | -3.7 |
| 92-93 | 12.2 | 12.7 | 97% | -0.4 |
| 104-105 | 5.8 | 8.2 | 71% | -2.4 |
| **Type II Fluid Heated to 60°C** | | | | |
| 86-87 | 39.8 | 40.2 | 99% | -0.4 |
| **Type III Fluid Heated to 60°C** | | | | |
| 56-57 | 60.4 | 62.9 | 96% | -2.5 |
| **Type IV Fluid Heated to 60°C** | | | | |
| 38-39 | 69.0 | 57.3 | 120% | 11.7 |
| 50-51 | 90.3 | 100.3 | 90% | -10.0 |
| 80-81 | 98.9 | 104.8 | 94% | -5.9 |
| 98-99 | 137.9 | 141.3 | 98% | -3.3 |
| **Type IV Fluid at OAT** | | | | |
| 8-9 | 15.8 | 16.9 | 93% | -1.1 |
| 14-15 | 30.3 | 33.7 | 90% | -3.4 |
| 20-21 | 16.8 | 19.2 | 87% | -2.4 |
| 26-27 | 52.0 | 50.3 | 103% | 1.7 |

## OUTDOOR NATURAL SNOW TESTING

- SUMMARY OF RESULTS
  - Type I Tests
    - Largest percentage difference (29% reduction) observed with Type I tests conducted
    - Reduction in Type I endurance times up to 3.7 minutes
  - Type II,III,IV Tests
    - In general, composite endurance times were comparable to aluminum endurance times

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## PRESENTATION OUTLINE

- BACKGROUND – PREVIOUS WORK
- COMPOSITE MATERIALS TESTED
- OUTDOOR NATURAL SNOW PLATE TESTS
- OUTDOOR NATURAL FROST PLATE TESTS
- INDOOR SIMULATED FREEZING PRECIPITATION PLATE TESTS
- LEADING EDGE THERMAL EQUIVALENT BOX TESTS
- OBSERVATIONS AND RECOMMENDATIONS

## NATURAL FROST COMPARATIVE ENDURANCE TIME TESTING

- METHODOLOGY:
  - Comparative endurance time testing with Type I fluids applied at 60ºC
  - Same setup used for natural snow testing
    - Un-painted aluminum test plate not required
  - Styrofoam insulation adhered to back of test plates (standard frost endurance time testing protocol)

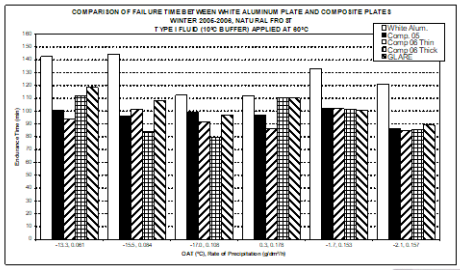
## NATURAL FROST COMPARATIVE ENDURANCE TIME TESTING

- SUMMARY OF COMPARATIVE TEST RUNS

| Test Objective | # of Comparative Test Runs |
|---|---|
| Type I Heated (60ºC) | 6 |
| **TOTAL** | **6** |

## NATURAL FROST COMPARATIVE ENDURANCE TIME TESTING

- TYPE I EG APPLIED AT 60ºC




## NATURAL FROST COMPARATIVE ENDURANCE TIME TESTING

- SUMMARY OF RESULTS
  - Similar endurance time trends were observed amongst all composite materials (as was seen in natural snow)
  - Analysis was conducted using:
    - White painted carbon fiber plain weave fabric (Carbon 05)
    - White painted aluminum test plate
  - Percentage ratio and endurance time difference was calculated for each test

| Test # | Comp 05 Endurance Time (min) | White Alum. Endurance Time (min) | Endurance Time % Ratio (Comp05 / White Alum.) | Endurance Time Time Difference [min.] (Comp05 - White Alum.) |
|---|---|---|---|---|
| Type I Fluid Heated to 60ºC | | | | |
| 1-5 | 100.3 | 142.6 | 70% | -42.2 |
| 6-10 | 96.1 | 144.4 | 67% | -48.3 |
| 11-15 | 99.1 | 112.3 | 88% | -13.3 |
| 16-20 | 96.7 | 112.2 | 86% | -15.4 |
| 21-25 | 102.5 | 133.0 | 77% | -30.5 |
| 26-30 | 86.4 | 120.9 | 71% | -34.5 |

## NATURAL FROST COMPARATIVE ENDURANCE TIME TESTING

- SUMMARY OF RESULTS
  - Type I Tests
    - Percentage difference (23% reduction) observed with Type I tests conducted
    - Reduction in Type I endurance times between 13 and 48 minutes

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## PRESENTATION OUTLINE

- BACKGROUND – PREVIOUS WORK
- COMPOSITE MATERIALS TESTED
- OUTDOOR NATURAL SNOW PLATE TESTS
- OUTDOOR NATURAL FROST PLATE TESTS
- INDOOR SIMULATED FREEZING PRECIPITATION PLATE TESTS
- LEADING EDGE THERMAL EQUIVALENT BOX TESTS
- OBSERVATIONS AND RECOMMENDATIONS

33

## INDOOR SIMULATED FREEZING PRECIPITATION TESTING

- SUMMARY OF RESULTS
  - Similar trend to snow data
  - Type I Tests
    - Largest percentage difference (26% reduction) observed with Type I tests conducted
    - Reduction in Type I endurance times up to 7.5 minutes
  - Type II,III,IV Tests
    - In general, composite endurance times were comparable to aluminum endurance times
    - Discrepancy in endurance time was less than 6 minutes

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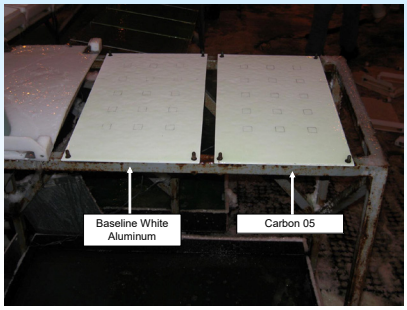
## INDOOR SIMULATED FREEZING PRECIPITATION TESTING

- INDOOR TEST SETUP




## INDOOR SIMULATED FREEZING PRECIPITATION TESTING

- SUMMARY OF COMPARATIVE TEST RUNS

| Test Objective | # of Comparative Test Runs |
|---|---|
| Type I Heated (60ºC) | 6 |
| Type I Heated (20ºC) | 1 |
| Type II Heated (60ºC) | 7 |
| Type IV Heated (60ºC) | 2 |
| **TOTAL** | **16** |

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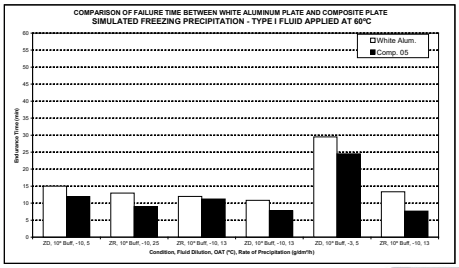
## INDOOR SIMULATED FREEZING PRECIPITATION TESTING

- TYPE I (Non-Glycol) APPLIED AT 60ºC

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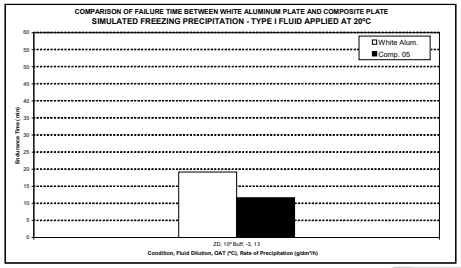
## INDOOR SIMULATED FREEZING PRECIPITATION TESTING

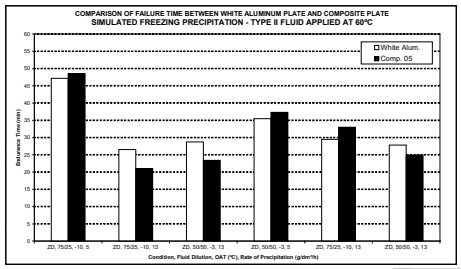
- TYPE I (Non-Glycol) APPLIED AT 20ºC




38

## INDOOR SIMULATED FREEZING PRECIPITATION TESTING

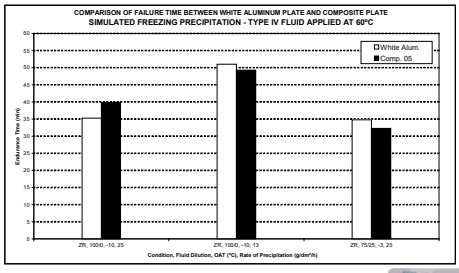
- TYPE II PG APPLIED AT 60ºC




39

## INDOOR SIMULATED FREEZING PRECIPITATION TESTING

- TYPE IV PG APPLIED AT 60ºC

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| Test # | Comp 05 Endurance Time (min) | White Alum. Endurance Time (min) | Endurance Time % Ratio (Comp 05 / White Alum.) | Endurance Time Time Difference [min.] (Comp05 - White Alum.) |
|---|---|---|---|---|
| **Type I Fluid Heated to 20ºC** | | | | |
| 39-40 | 11.7 | 19.2 | 61% | -7.5 |
| **Type I Fluid Heated to 60ºC** | | | | |
| 5-6 | 11.9 | 15.0 | 79% | -3.1 |
| 13-14 | 9.0 | 13.0 | 69% | -4.0 |
| 21-22 | 11.3 | 12.0 | 94% | -0.8 |
| 25-26 | 7.7 | 13.3 | 58% | -5.7 |
| 31-32 | 7.8 | 10.8 | 72% | -3.1 |
| 47-48 | 24.5 | 29.5 | 83% | -5.0 |
| **Type II Fluid Heated to 60ºC** | | | | |
| 1-2 | 48.5 | 47.2 | 103% | 1.3 |
| 27-28 | 21.0 | 26.5 | 79% | -5.5 |
| 35-36 | 23.4 | 28.8 | 81% | -5.4 |
| 43-44 | 37.3 | 35.5 | 105% | 1.8 |
| 51-52 | 33.0 | 29.5 | 112% | 3.5 |
| 59-60 | 24.9 | 27.8 | 89% | -2.9 |
| **Type IV Fluid Heated to 60ºC** | | | | |
| 9-10 | 39.8 | 35.3 | 113% | 4.5 |
| 17- 18 | 49.3 | 51.0 | 97% | -1.8 |
| 55-56 | 32.3 | 34.8 | 93% | -2.5 |

## INDOOR SIMULATED FREEZING PRECIPITATION TESTING

- METHODOLOGY:
  - In comparison to the white aluminum test plate, similar results amongst all composite materials were obtained in outdoor natural snow testing and natural frost testing
  - One representative composite test plate chosen to reduce testing in indoor conditions (Comp 05)
  - Indoor comparative endurance time testing was conducted with
    - White painted carbon fiber plain weave fabric (Carbon 05)
    - White painted aluminum test plate
    - Standard HOT test plate (in conjunction with HOT testing)

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## PRESENTATION OUTLINE

- BACKGROUND – PREVIOUS WORK
- COMPOSITE MATERIALS TESTED
- OUTDOOR NATURAL SNOW PLATE TESTS
- OUTDOOR NATURAL FROST PLATE TESTS
- INDOOR SIMULATED FREEZING PRECIPITATION PLATE TESTS
- LEADING EDGE THERMAL EQUIVALENT BOX TESTS
- OBSERVATIONS AND RECOMMENDATIONS

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## LEADING EDGE THERMAL EQUIVALENT BOX TESTS

- Based on testing conducted during 2005-06, it was recommended, that Type I testing be conducted using Leading Edge Thermal Equivalent Boxes (LETEB)
- Testing required to validate endurance time reduction measured using composite test plates
- A LETEB was constructed using a composite test surface and an aluminum box
- Composite material used
  - CARBON FIBER PLAIN WEAVE FABRIC (CARBON 05)

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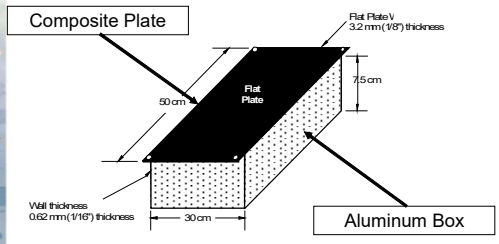
## SEALED BOXES FOR COLD-SOAK SIMULATION

## LEADING EDGE THERMAL EQUIVALENT BOX TESTS

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## LEADING EDGE THERMAL EQUIVALENT BOX TESTS

- METHODOLOGY:
  - Testing was conducted in natural snow conditions
  - Three LETEB were used to testing
    - Unpainted Aluminum Box
    - Baseline White Painted Aluminum Box
    - White Painted Composite Box
  - Comparative endurance time testing was conducted using the same fluid and dilution, applied at the same temperature to each of the boxes
  - Tests were conducted following standard Type I HOT protocol

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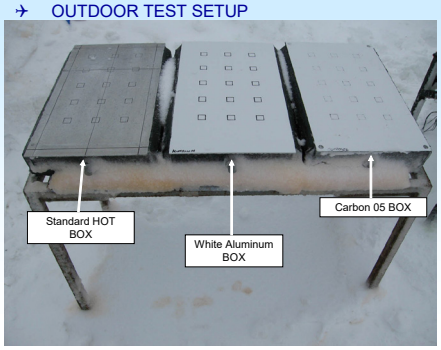
## LEADING EDGE THERMAL EQUIVALENT BOX TESTS

- OUTDOOR TEST SETUP




## LEADING EDGE THERMAL EQUIVALENT BOX TESTS

- SUMMARY OF COMPARATIVE TEST RUNS

| Test Objective | # of Comparative Test Runs |
|---|---|
| Type I Heated (60ºC) | 18 |
| **TOTAL** | **18** |

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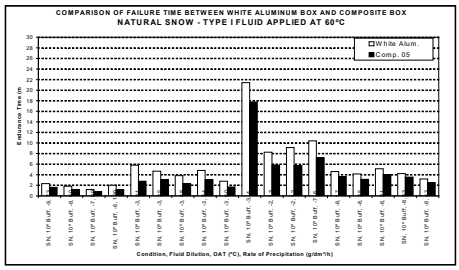
## LEADING EDGE THERMAL EQUIVALENT BOX TESTS

- TYPE I EG APPLIED AT 60ºC

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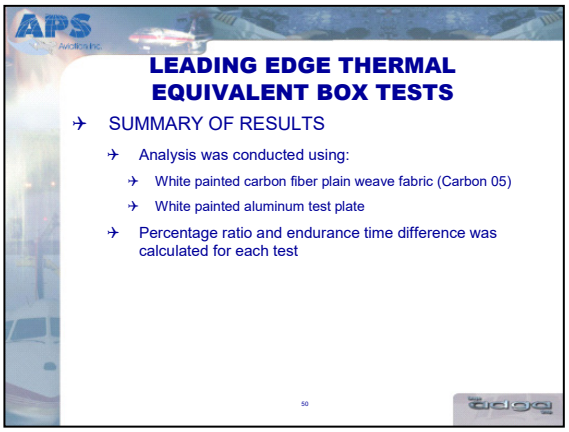
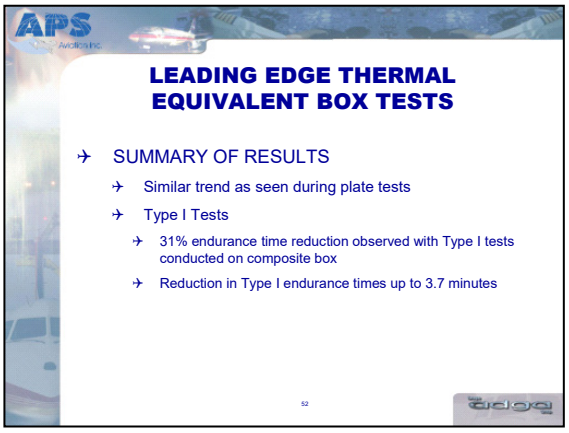
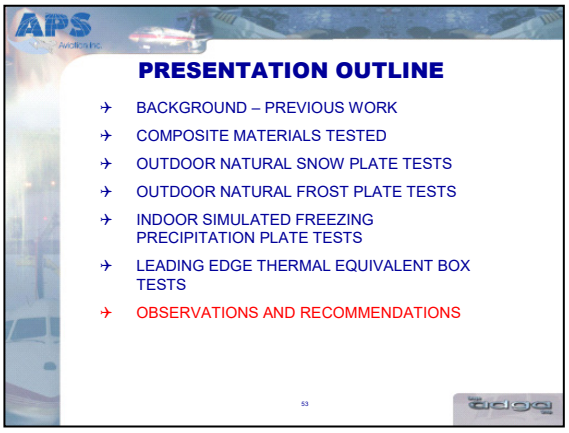
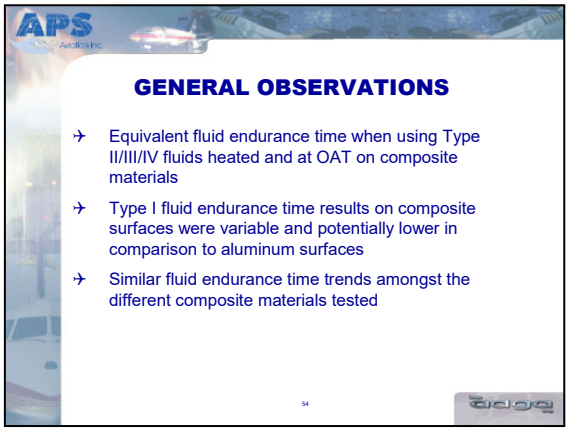


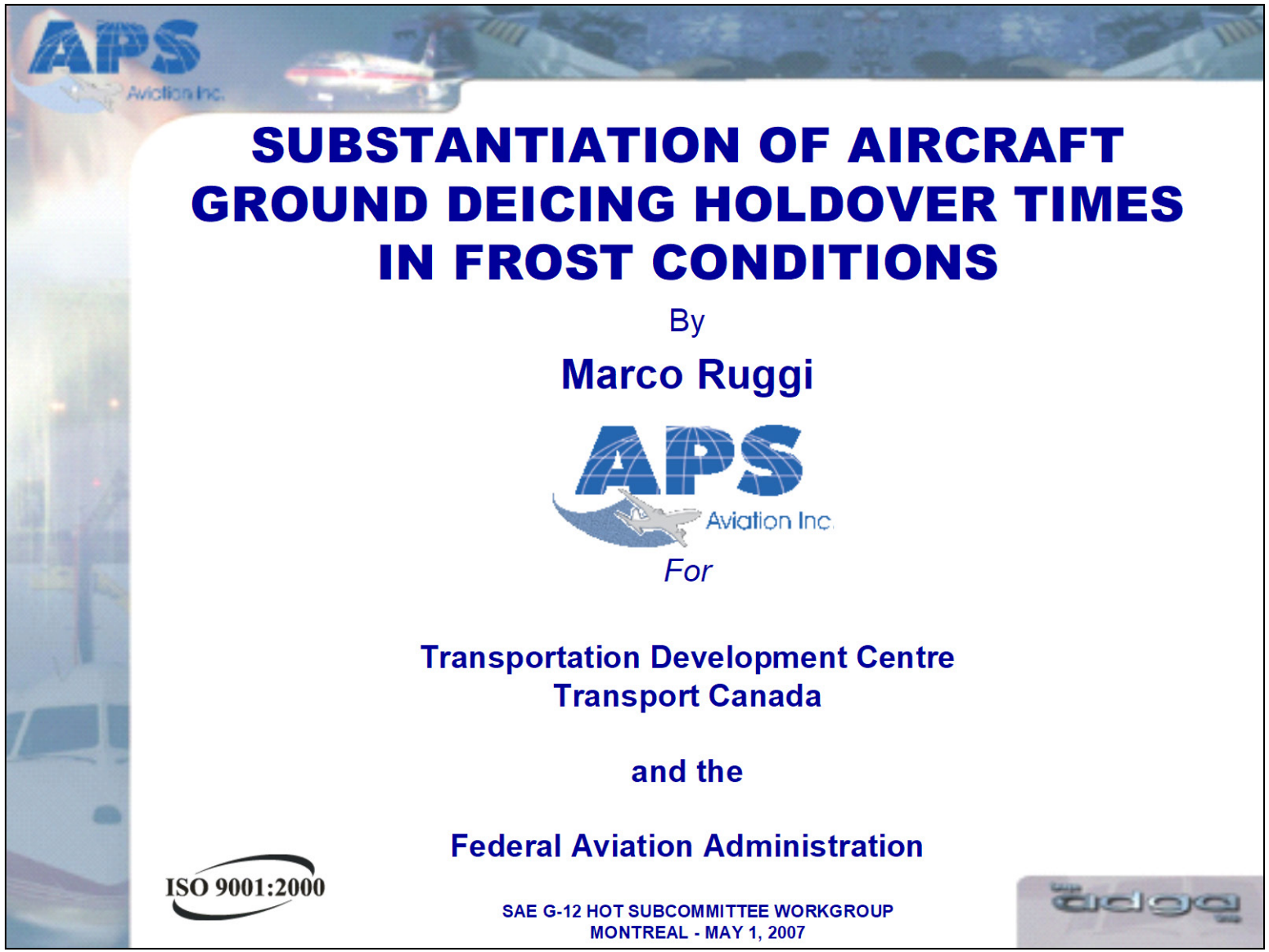

| Test # | Comp 05 Endurance Time (min) | White Alum. Endurance Time (min) | Endurance Time % Ratio (Comp 05 / White Alum.) | Endurance Time Time Difference [min.] (Comp05 - White Alum.) |
|---|---|---|---|---|
| Type I Fluid Heated to 60ºC | | | | |
| 2-3 | 1.6 | 2.3 | 70% | -0.7 |
| 5-6 | 1.2 | 1.8 | 65% | -0.6 |
| 8-9 | 0.8 | 1.2 | 67% | -0.4 |
| 11-12 | 1.2 | 2.0 | 58% | -0.8 |
| 14-15 | 2.8 | 5.8 | 48% | -3.0 |
| 17-18 | 3.1 | 4.7 | 65% | -1.6 |
| 20-21 | 2.3 | 3.8 | 61% | -1.5 |
| 23-24 | 3.1 | 4.8 | 64% | -1.7 |
| 26-27 | 1.7 | 2.8 | 60% | -1.1 |
| 29-30 | 17.7 | 21.4 | 83% | -3.7 |
| 32-33 | 5.8 | 8.3 | 71% | -2.4 |
| 35-36 | 5.7 | 9.1 | 63% | -3.4 |
| 38-39 | 7.2 | 10.4 | 69% | -3.2 |
| 41-42 | 3.7 | 4.6 | 80% | -0.9 |
| 44-45 | 3.1 | 4.1 | 76% | -1.0 |
| 47-48 | 4.0 | 5.1 | 79% | -1.1 |
| 50-51 | 3.6 | 4.2 | 84% | -0.7 |
| 53-54 | 2.5 | 3.2 | 79% | -0.7 |

51




APS
Aviation Inc.
SUBSTANTIATION OF AIRCRAFT GROUND DEICING HOLDOVER TIMES IN FROST CONDITIONS
By
Marco Ruggi
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000
SAE G-12 HOT SUBCOMMITTEE WORKGROUP
MONTREAL - MAY 1, 2007

## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

## BACKGROUND

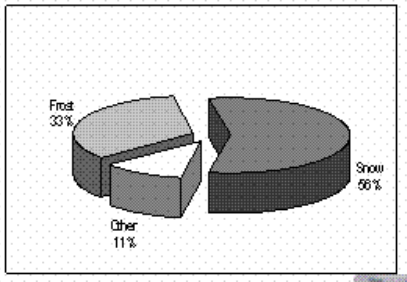
- FREQUENCY OF OCCURENCE
  - A survey of deicing activities at airports in North America, Europe and Asia was reported in TC report TP 14375E, *Winter Weather Impact on Holdover Time Table Format (1995-2004)*
  - The survey showed that in airline operations, removal of frost contamination represents a significant portion of deicing operations.

## BACKGROUND

- FREQUENCY OF OCCURENCE
  - The survey reported that at airport locations having relatively mild winter climates such as London and Paris, close to 90 percent of all deicing operations were frost removal.
  - In colder winter climates such as Montreal, where other forms of winter contamination such as snow are more prevalent, up to 25 percent of deicing operations are frost-related.

## BACKGROUND

- Frequency of Deicing Operations Airport Survey 2000-03




## BACKGROUND

- CURRENT HOT'S
  - HOT guidelines are based on endurance time test data for each certified fluid, measured in prescribed temperature and precipitation conditions.
  - Precipitation conditions include freezing fog, snow, freezing drizzle, freezing rain and rain on a cold-soaked wing.

## BACKGROUND

- CURRENT HOT'S
  - Frost HOT have always been a part of the HOT guidelines, however fluid endurance times in frost have never been measured.
  - The current values for frost HOT are simply based on results from High Humidity Endurance Tests (HHET).

## BACKGROUND

- CURRENT HOT'S

| OAT | Type II/III/IV Fluid Concentration Neat Fluid/Water (Vol% / Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | |
|---|---|---|---|---|---|
| °C | | Type II | Type IV | Type III | Type I |
| Above -3 | 100/0 | 8:00 | 12:00 | 2:00 | 0:45 |
| | 75/25 | 5:00 | 5:00 | 1:00 | |
| | 50/50 | 3:00 | 3:00 | 0:30 | |
| below -3 to -14 | 100/0 | 8:00 | 12:00 | 2:00 | |
| | 75/25 | 5:00 | 5:00 | 1:00 | |
| below -14 to -25 | 100/0 | 8:00 | 12:00 | 2:00 | |

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## BACKGROUND

- CURRENT HOT'S
  - Previous indoor laboratory attempts to substantiate current HOT showed some questionable discrepancies in the results
    - Testing conducted at Institut de Recherche d'Hydro-Québec (IREQ)
  - It was recommended that outdoor testing in natural frost conditions be conducted for Type I,II,III,IV fluids

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## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

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## METHODOLOGY

- Fluid endurance time testing in frost conditions was conducted using standard aluminum test plates painted white using aircraft grade paint.
- An insulation backing was mounted onto each white-painted test plate to avoid heat exchange via the underside
- Testing frost production on this surface was found to be representative of aircraft wing surfaces, where only the skin surface is exposed.

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## METHODOLOGY

- **Frost Plate with Insulated Backing**



## METHODOLOGY

- **Test Stand with Insulated Frost Test Plates**



## METHODOLOGY

- Tests were generally conducted whenever conditions were suitable for frost accretion
- Typical test conditions:
  - Outside Ambient Temperature: Below 3ºC
  - Relative Humidity: Above 60%
  - Wind Speed: Less than 5 km/h
  - Sky Condition: Clear

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## METHODOLOGY

- To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity
- Frost rates generally ranged from 0.02 to 0.2 g/dm²/hr
- Thermistor probes were attached at the 15 cm line of each test plate
  - Temperature was monitored and backed up at the end of each test session

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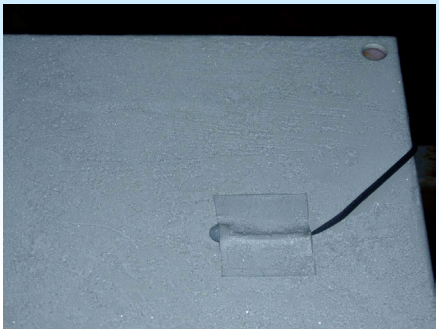
## METHODOLOGY

- **Plates to measure Icing Intensity**



## METHODOLOGY

- **Thermistor on Frosted Plate at 15 cm Line**



## METHODOLOGY

- FLUIDS TESTED
  - Type I – 4 fluids
  - Type II – 5 fluids
  - Type III – 1 fluid
  - Type IV – 8 fluids
- Type II,III,IV fluids were tested at neat, 75/25, and 50/50 dilutions

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## TEST PLAN

- Type I tests
- Type II, III, IV tests
- Measure and document icing intensities
- Type I tests using composite materials

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## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

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## TYPE I TESTS

- Forty-seven tests were conducted outdoors using insulated white-painted aluminum surfaces during two winter seasons
- A review of the measured test conditions indicated that the data set was generally comprehensive and representative of the natural environment.

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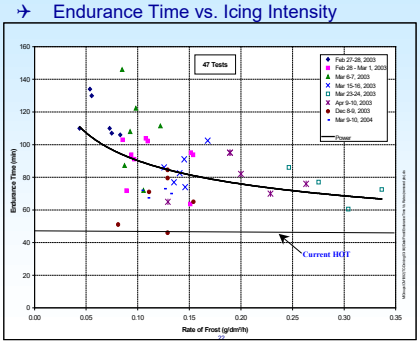
## TYPE I TESTS

- Endurance Time vs. Icing Intensity




22

## TYPE I TESTS

- CONCLUSION
  - The test results show that the measured endurance times do not violate the long used HOT of 45 minutes.
  - Two tests produced endurance times that came close to 45 minutes
  - Based on the data collected, the Type I HOTs have been substantiated.

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## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

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## TYPE II TESTS

- 62 tests were conducted outdoors using insulated white-painted aluminum surfaces
  - 26 tests were stopped due to fluid failure
  - 36 tests were prior to fluid failure
    - 34 tests did not fail before sunrise
    - 2 tests stopped due to rising wind conditions

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## TYPE II TESTS

- Frost HOT Values and Endurance Time Test Results

| OAT (°C) | Concentration | Type II | | |
|---|---|---|---|---|
| | | Current HOT Time | Failed Tests | Stopped Tests |
| Above -3 | 100/0 | 8.0 | | 11.8[13] 12.3[14] 10.8[15] 12.4[16] |
| | 75/25 | 5.0 | 7.4 | 10.7[7] 11.6[12] 11.6[16] 10.0[15] 11.6[16] |
| | 50/50 | 3.0 | 6.1 5.9 | 10.0[15] 11.6[16] |
| Below -3 to -14 | 100/0 | 8.0 | 9.5 10.5 10.4 11.9 | 9.5[1] 12.8[16] 13.6[4] 11.6[11] 13.5[4] 13.3[4] 12.8[4] 12.9[4] 12.8[4] 12.9[10] |
| | 75/25 | 5.0 | 8.2 2.8 9.5 3.4 6.7 4.1 3.3 3.2 3.1 1.6 3.1 1.5 3.1 1.1 2.2 4.5 2.5 3.7 | 10.1[3] 13.3[4] 13.3[4] 12.8[4] 12.7[4] 5.5[7] 12.9[10] 12.8[10] |
| Below -14 to -25 | 100/0 | 8.0 | 8.0 8.0 | 7.9[2] 7.8[2] 12.6[6] 12.6[5] 12.6[5] 12.7[6] 12.7[6] |

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## TYPE II TESTS

- OBSERVATIONS
  - 75/25 fluid endurance times at -3 to -14 range were significantly lower than the values issued in the HOT Guidelines
  - One 50/50 fluid test at above -3 range demonstrated a similar situation

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## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

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## TYPE III TESTS

- 16 tests were conducted outdoors using insulated white-painted aluminum surfaces
  - 13 tests were stopped due to fluid failure
  - 3 tests were prior to fluid failure
    - 2 tests did not fail before sunrise
    - 1 test stopped due to rising wind conditions

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## TYPE III TESTS

- Frost HOT Values and Endurance Time Test Results

| OAT (°C) | Concentration | Type III | | |
|---|---|---|---|---|
| | | Current HOT Time | Failed Tests | Stopped Tests |
| Above -3 | 100/0 | 2.0 | 4.7 | |
| | 75/25 | 1.0 | 5.2 | |
| | 50/50 | 0.5 | 3.0 1.4 | |
| Below -3 to -14 | 100/0 | 2.0 | 5.8 4.6 9.0 8.1 7.4 8.6 | |
| | 75/25 | 1.0 | 3.5 | |
| Below -14 to -25 | 100/0 | 2.0 | 5.4 5.3 | 7.8[2] 12.6[6] 7.3[5] |

30

## TYPE III TESTS

- OBSERVATIONS
  - Type III fluid endurance times were longer than the values issued in the HOT Guidelines.
  - Endurance times measured were at least double the current HOT for each cell

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## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

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## TYPE IV TESTS

- 90 tests were conducted outdoors using insulated white-painted aluminum surfaces
  - 35 tests were stopped due to fluid failure
  - 55 tests were prior to fluid failure
    - 49 tests did not fail before sunrise
    - 6 tests stopped due to rising wind conditions

33

## TYPE IV TESTS

- Frost HOT Values and Endurance Time Test Results

| OAT (°C) | Concentration | Type IV | | |
|---|---|---|---|---|
| | | Current HOT Time | Failed Tests | Stopped Tests |
| Above -3 | 100/0 | 12.0 | | 10.9[2] 10.8[15] 10.9[4] 10.8[16] 10.8[5] 12.3[16] 11.6[14] 12.3[16] 11.6[15] |
| | 75/25 | 5.0 | 4.6 | 10.8[8] 10.1[16] 10.1[10] 11.6[16] |
| | 50/50 | 3.0 | 3.2 3.2 4.5 7.5 5.3 | 5.7[14] 10.0[15] 10.1[16] 10.1[16] |
| Below -3 to -14 | 100/0 | 12.0 | 7.9 10.8 13.0 6.1 11.6 10.6 10.7 | 9.6[1] 12.6[8] 9.5[1] 12.7[7] 13.5[5] 12.9[16] 13.5[5] 12.9[16] 13.5[5] 12.8[15] 13.5[5] 11.6[11] 12.8[1] 11.6[11] 12.7[7] 12.8[12] 12.8[13] |
| | 75/25 | 5.0 | 4.82 2.5 5.85 9.8 3.3 7.1 3.1 3.9 1.6 1.3 1.3 3.3 1.6 4.8 | 7.2[1] 9.5[1] 13.3[7] 13.2[4] 12.6[8] 12.9[13] 12.9[13] |
| Below -14 to -25 | 100/0 | 12.0 | 5.9 10.3 11.0 6.3 6.3 12.1 12.1 12.1 | 7.9[2] 12.5[3] 7.8[2] 12.5[4] 7.8[2] 12.7[9] 7.8[2] 13.1[4] 7.8[2] 12.9[8] 7.8[2] 12.9[8] 12.5[3] 12.1[12] |

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## TYPE IV TESTS

- CONCLUSION
  - Neat and 75/25 fluid endurance times at -3 to -14 range were significantly lower than the values issued in the HOT Guidelines.
  - Neat fluid endurance times below -14 to -25 range were significantly lower than the values issued in the HOT Guidelines.

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## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

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## PLATE TEMPERATURE DATA

- OAT and test plate surface temperature were constantly monitored during each test
- Data collected demonstrated that during frost conditions the plate and OAT temperature differential could range from 2ºC to 9ºC.

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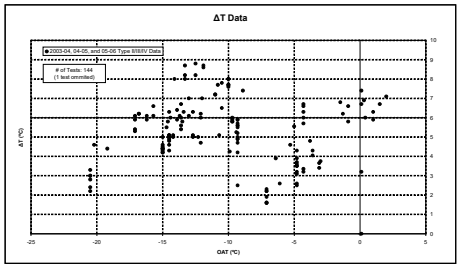
## PLATE TEMPERATURE DATA




38

## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

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## FLUID FREEZE POINT FAILURE

- A reduction in the Type II and Type IV fluid endurance was experienced below an OAT of -9ºC
- Once the OAT would begin to fall below -9ºC, the plate surface temperature would cool closer to the fluid freeze point
- Fluid failure occurred primarily because the surface temperature of the test plate reached the fluid freeze point
  - In comparison to tests where failure is due to fluid dilution

40

## FLUID FREEZE POINT FAILURE

- This phenomenon was primarily experienced with the 75/25 fluids tested
- The same result may be experienced with Neat and 50/50 fluids when approaching their freezing point limits

41

## FLUID FREEZE POINT FAILURE

- The HOT table provides operational ranges specifying limits based on OAT.
- In frost conditions, the skin temperature of an aircraft may be several degrees lower than the OAT
- If operating with a 75/25 fluid at the lower OAT limit during frost conditions, the skin temperature of the aircraft could reach the fluid freeze point potentially causing ice to form in the fluid

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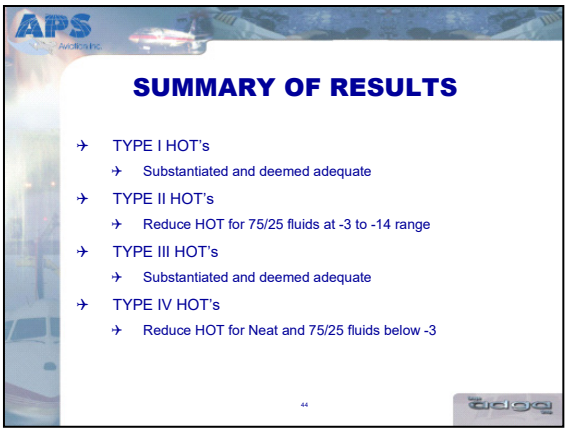
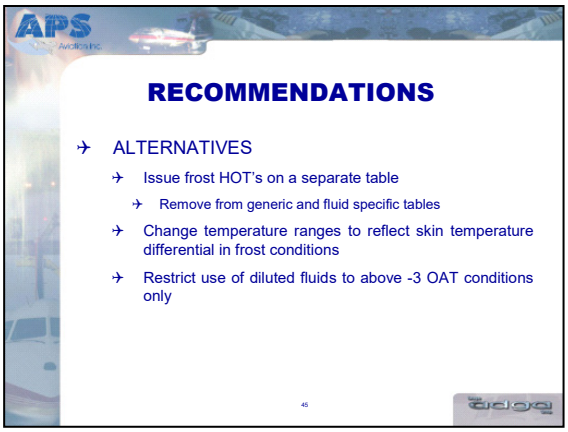
## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

36




## PROPOSED FROST TABLES
## Option 1

- Remove critical dilutions
- Reduce cells to reflect data collected
- Restrict HOT's for Type II, III, IV to -19°C

| OAT | Type II/III/IV Fluid Concentration Neat Fluid/Water (Vol% / Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | |
|---|---|---|---|---|---|
| °C | | Type II | Type IV | Type III | Type I |
| Above -3 | 100/0 | 8:00 | 12:00 | 2:00 | 0:45 |
| | 75/25 | 5:00 | 5:00 | 1:00 | |
| below -3 to -14 | 100/0 | 8:00 | 6:00 | 2:00 | |
| below -14 to -19 | 100/0 | 8:00 | 6:00 | 2:00 | |

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## PROPOSED FROST TABLES
## Option 2

- Change temperature ranges to reflect 6°C temperature differential between wing and OAT
- Reduce cells to reflect data collected

| OAT | Type II/III/IV Fluid Concentration Neat Fluid/Water (Vol% / Vol%) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | |
|---|---|---|---|---|---|
| °C | | Type II | Type IV | Type III | Type I |
| Above 3 | 100/0 | 8:00 | 12:00 | 2:00 | 0:45 |
| | 75/25 | 5:00 | 5:00 | 1:00 | |
| | 50/50 | 2:00 | 3:00 | 0:30 | |
| below 3 to -8 | 100/0 | 8:00 | 6:00 | 2:00 | |
| | 75/25 | 1:00 | 1:00 | 1:00 | |
| below -8 to -19 | 100/0 | 8:00 | 6:00 | 2:00 | |

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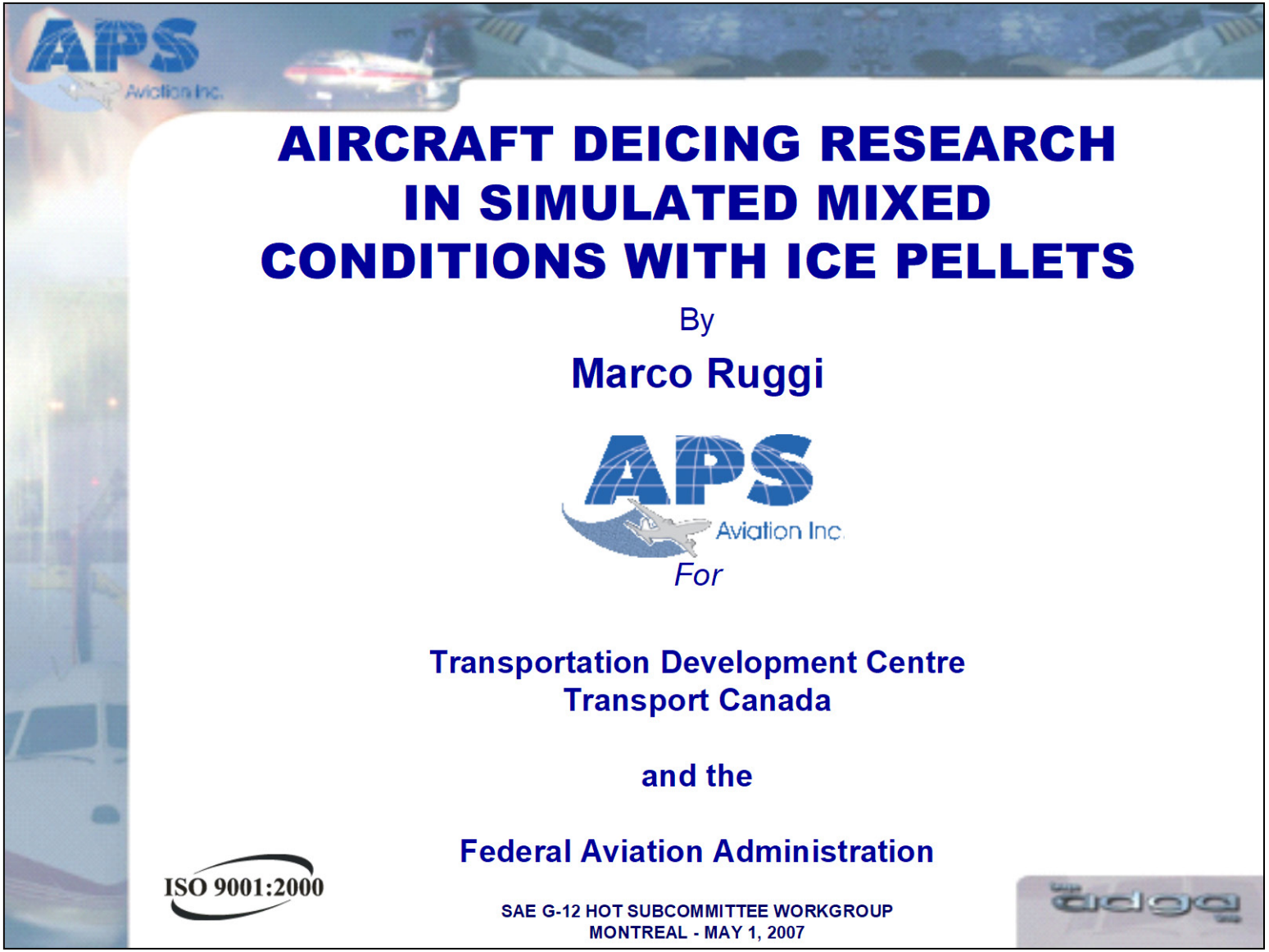

APS
Aviation Inc.
AIRCRAFT DEICING RESEARCH
IN SIMULATED MIXED
CONDITIONS WITH ICE PELLETS
By
Marco Ruggi
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000
SAE G-12 HOT SUBCOMMITTEE WORKGROUP
MONTREAL - MAY 1, 2007

## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- FLAT PLATE TESTING
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## BACKGROUND

- Recent industry need to provide aircraft operators with holdover times for ice pellet conditions
- During the winter of 2006, FAA provided a 25-minute allowance as a preliminary guideline
- Allowance based on the previous research conducted during the winter of 2005-06, primarily as a result of Falcon 20 aerodynamic research (SAE Lisbon 2006)
- Allowance was followed by a list of conditions restricting operations
  - i.e. Ice pellets alone, no mixed conditions

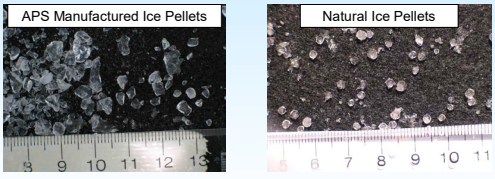
## BACKGROUND

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

## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- FLAT PLATE TESTING
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## APS SIMULATED ICE PELLETS




## 2005-06 FALCON 20 FULL-SCALE RESEARCH






## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- FLAT PLATE TESTING
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## OVERVIEW OF WINTER 2006-07 GENERAL OBJECTIVES

- Conduct research to substantiate and expand current 25-minute ice pellet only allowance time
- Conduct research to support guidance material in mixed ice pellet conditions
- Provide relief for current ice pellet guidance material

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## OVERVIEW OF WINTER 2006-07 FLAT PLATE TESTS

- Flat plate testing conducted to investigate fluid adherence in mixed ice pellet conditions
  - Light freezing rain and light ice pellets adherence testing (September 2006 at NRC)
  - Moderate snow and light ice pellets adherence testing (September 2006 at APS Facility)
  - Small vs. Large light ice pellets and light freezing rain adherence testing (April 2007 at NRC)

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## OVERVIEW OF WINTER 2006-07 AERODYNAMIC RESEARCH

- Aerodynamic research conducted to investigate fluid flow-off of contaminated fluid following simulated ice pellet and mixed conditions
  - Aerodynamic research conducted at the NRC open circuit wind tunnel
    - Conditions tested: ZR/IP, SN/IP, IP-, IP mod
  - Aerodynamic research conducted using the NRC Falcon 20 aircraft
    - Spot check and validation of results obtained in wind tunnel

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## PRESENTATION OUTLINE

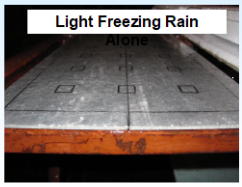
- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- FLAT PLATE TESTING
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

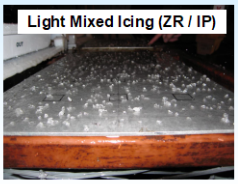
## ZR-/IP- Adherence Testing

- Objective: to investigate the level of ice pellet and freezing rain contamination required to cause fluid adherence to the test surface.
- Testing was primarily conducted to validate the 25-minute allowance time that was recommended by the FAA for aircraft operations in ice pellet only conditions.
- 6 fluids tested at -3ºC and -10ºC
- Conditions Tested:
  - ZR 25g/dm²/h + IP 5g/dm²/h
  - ZR 13g/dm²/h + IP 17g/dm²/h

## ZR-/IP- Adherence Testing

Adherence to 15 cm Line

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## ZR-/IP- Adherence Testing

- Conclusions
  - Adherence is primarily caused by the freezing rain considering the additional ice pellet precipitation did not significantly reduce the fluid protection time to adherence
  - Ice pellets will cause a rough "pimply" adherence to the test surface which may cause a more significant lift loss in comparison to freezing rain alone, therefore the first signs of adherence may cause potential safety concerns
- Recommendations
  - Aerodynamic research with contaminated wing
  - Small vs. Large Ice pellets with Light Freezing Rain

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## SN/IP- Adherence Testing

- Objective: investigate if ice pellet and snow contamination can cause fluid adherence to the test surface.
- 18 tests conducted
  - 7 tests simulated a cold front following fluid failure (OAT reduced up to 6º following failure)
- Conditions Tested:
  - Various ratios of mixed snow and ice pellets
  - Total mixed precipitation rate equalled 30 g/dm²/h

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## SN/IP- Adherence Testing

Fluid Failure




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## SN/IP- Adherence Testing

- Conclusions
  - No adherence was observed during tests conducted

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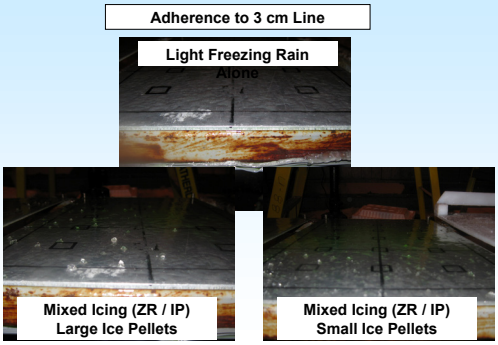
## ZR-/IP- (Large vs Small) Testing

- Objective: Investigate and compare the level of large or small ice pellets and freezing rain contamination required to cause fluid adherence to the test surface.
- Ice Pellet Sizes
  - Large: 3 to 5 mm
  - Small: 1 to 3 mm
- 5 fluids tested at -3ºC and -10ºC
- Conditions Tested:
  - ZR 25g/dm²/h & IP 5g/dm²/h (most conducive to adh.)

20

## ZR-/IP- (Large vs Small) Testing




21

## ZR-/IP- (Large vs Small) Testing

- Conclusions
  - Time of first adherence (adherence to 3cm line) was generally equal for both large and small ice pellets

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## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- FLAT PLATE TESTING
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## Wind Tunnel Testing

- Objective: To determine the level of contamination of anti-icing fluid at which the aerodynamic shear forces during take-off ground roll, rotation and lift off fails to remove the resultant slush.
- 22 tests conducted over a period of 2 weeks
- A NACA 23012 wing section was used for testing
- OAT varied during testing – open circuit tunnel

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## Wind Tunnel Testing

- Conditions Tested:
  - Mixed ZR and IP (5 tests)
  - Mixed SN and IP (4 tests)
  - IP only (4 tests)
  - Fluid only and dry tests (5 tests)
- Also investigated:
  - ZR only (1 test)
  - Simulated stall runs (3 tests)

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## Wind Tunnel Testing

- Fluid was applied to wing section approximately 20 minutes prior to the start of precipitation
- The wind tunnel was started approximately 20-25 minutes following the end of precipitation
- Wind tunnel test profile:
  - Initial angle of attack 0º
  - 0-100 Knots in 30-35 seconds
  - At 100 Knots, Pitch wing to 8º in 3 sec
  - Pitch wing back to 4º in 16 sec
  - Hold wing at 4º for 1 minute and stop test

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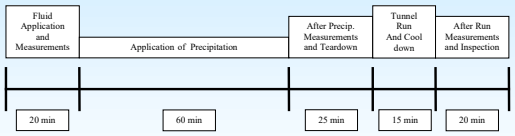
## Typical Run Timeline

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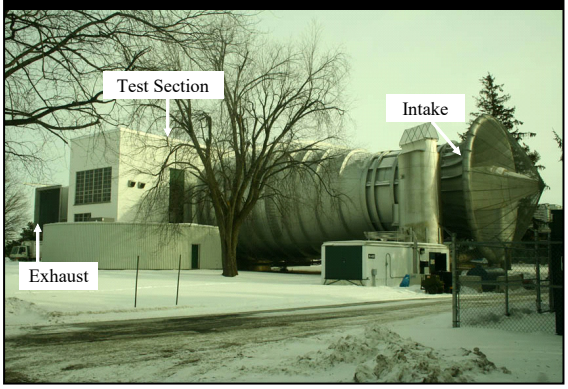
## Wind Tunnel Summary Test Log

| Wind Tunnel Tests | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) |
| 1 | 14 | Dry | Dry | 0 | 0 | 0 | - | -1.7 | -2 | - |
| 1A | 16 | Dry | Dry | 0 | 0 | 0 | - | -7 | N/A | - |
| 2 | 14 | PG | Baseline | 0 | 0 | 0 | - | -10 | -9 | - |
| 3 | 14 | EG | Baseline | 0 | 0 | 0 | - | -11 | -8 | - |
| 4 | 14 | PG | ZR | 28 | 0 | 0 | 60 | -2 | -1 | 1 |
| 5 | 15 | PG | IP | 0 | 25 | 0 | 60 | -16.8 | -13 | 4.5 |
| 6 | 15 | PG | ZR/IP | 20 | 5 | 0 | 40 | -8 | -7 | 5 |
| 6A | 15 | PG | ZR/IP | 20 | 5 | 0 | 20 | -8 | -7 | 1 |
| 7 | 22 | PG | IP | 0 | 25 | 0 | 60 | 1 | -5.5 | 1 |
| 8 | 22 | EG | IP | 0 | 25 | 0 | 60 | 1 | -9 | 1 |
| 9 | 22 | PG | IP (mod) | 0 | 75 | 0 | 30 | 3.2 | -7 | 2.5 |
| 10 | 23 | PG | IP/ZR | 7 | 20 | 0 | 40 | -7.2 | -7 | 3 |
| 11 | 23 | PG | ZR/IP | 20 | 5 | 0 | 40 | -1.9 | -4 | 2 |
| 12 | 23 | EG | ZR/IP | 20 | 5 | 0 | 40 | -5.9 | -4 | 1 |
| 13 | 23 | Dry | Dry | 0 | 0 | 0 | - | -5.7 | -5 | - |
| SP1 | 20 | PG | IP/SN | 0 | 20 | 5 | 40 | -2 | -7 | 2 |
| SP2 | 20 | PG | SN/IP | 0 | 5 | 20 | 40 | -3 | -6 | 1 |
| SP3 | 20 | EG | IP/SN | 0 | 20 | 5 | 40 | 1.2 | -8 | 1 |
| SP4 | 23 | PG | IP/SN | 0 | 25 | 25 | 30 | 3.2 | -7 | 2 |
| A1 | 21 | PG | Stall Run | 0 | 0 | 0 | - | 3.7 | 1 | - |
| A2 | 21 | EG | Stall Run | 0 | 0 | 0 | - | 4.6 | 0.5 | - |
| A3 | 21 | Dry | Stall Run | 0 | 0 | 0 | - | 2.3 | N/A | - |

## Wind Tunnel Testing



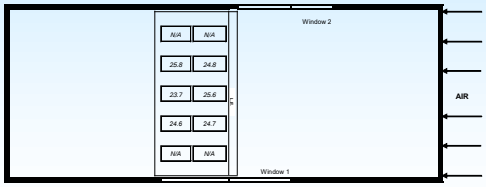

## Wind Tunnel Testing

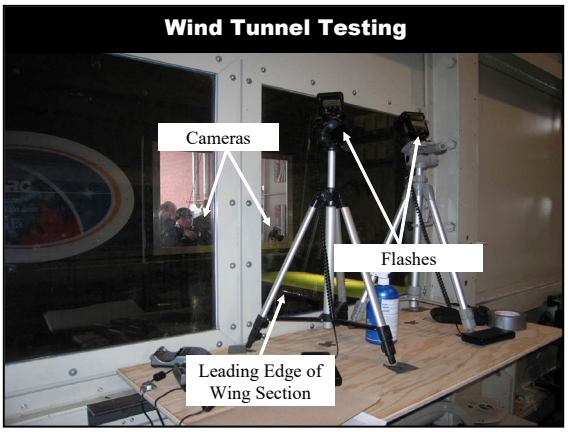


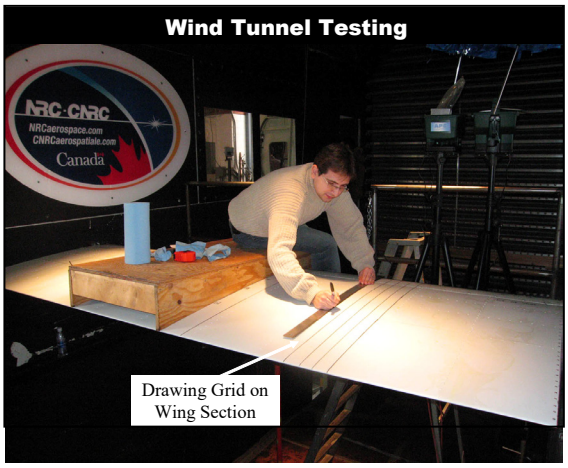

## Example of Rate Distribution

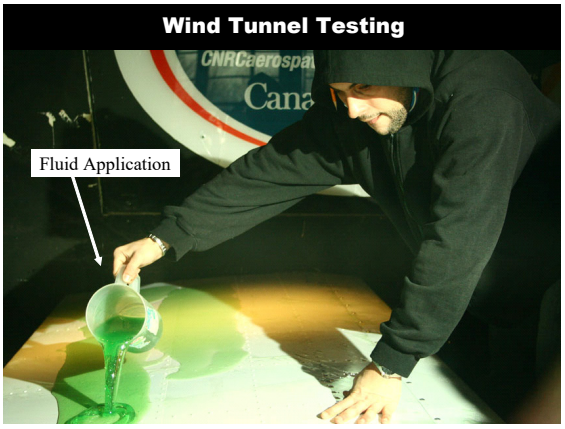
**Precipitation Rate Summary for Test No. 6**

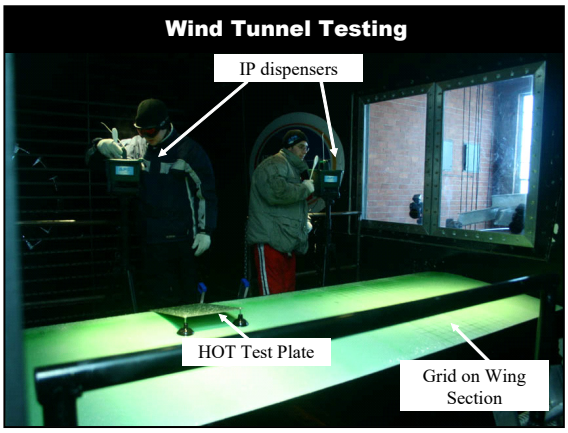
Date: 15-Feb-07
Precipitation Type ZR&IP
Average Combined Precipitation Rate: 25



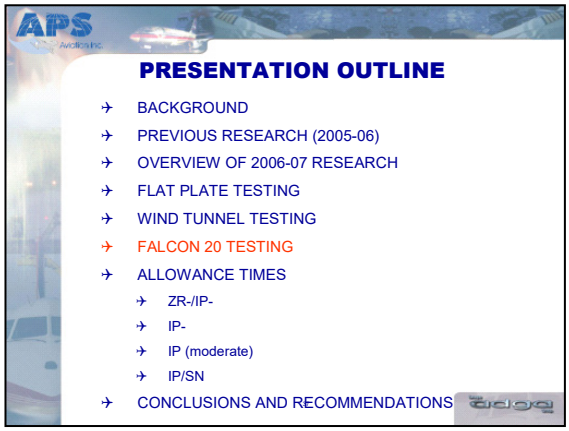

Wind Tunnel Testing
Cameras
Flashes
Leading Edge of Wing Section


Wind Tunnel Testing
NRC-CNRC
NRCaerospace.com
CNRCaerospatiale.com
Canada
Drawing Grid on Wing Section


Wind Tunnel Testing
Fluid Application


Wind Tunnel Testing
IP dispensers
HOT Test Plate
Grid on Wing Section


Wind Tunnel Testing
ZR sprayer


APS
PRESENTATION OUTLINE
BACKGROUND
PREVIOUS RESEARCH (2005-06)
OVERVIEW OF 2006-07 RESEARCH
FLAT PLATE TESTING
WIND TUNNEL TESTING
FALCON 20 TESTING
ALLOWANCE TIMES
ZR-/IP-
IP-
IP (moderate)
IP/SN
CONCLUSIONS AND RECOMMENDATIONS

## Falcon 20 Testing

- Objective:To determine the level of contamination of anti-icing fluid at which the aerodynamic shear forces during take-off ground roll and rotation fails to remove the resultant slush.
- 6 tests conducted over a period of 4 days
- Tests conducted at YOW
- Conditions Tested:
  - Mixed ZR and IP
  - Mixed SN and IP

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## Falcon 20 Testing

- Wing test surface area was approximately 3m²
- Two wings were tested per run
  - Baseline wing (fluid only)
  - Test wing (contamination)

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## Falcon 20 Testing

- Fluid was applied approximately 20 minutes prior to the start of precipitation
- Break release approximately 20-25 minutes following the end of precipitation
- Aircraft take-off run profile:
  - 0-120 knots in approx. 20-25 sec
  - Engines Cut-off at 120 knots
  - Rotate to approx. 8°
  - Keep nose up until 3000ft of runway left
  - Rotate down to 0°
  - Apply brakes (no spoilers)

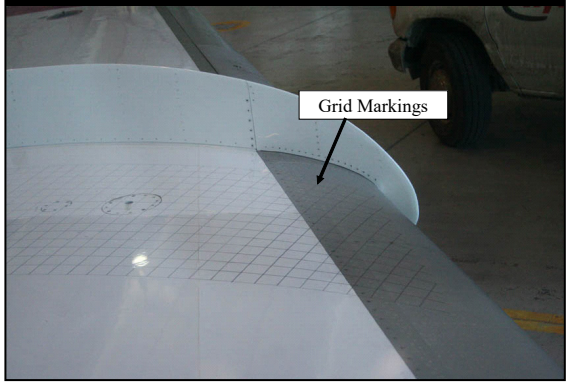
## Falcon 20 Summary Test Log

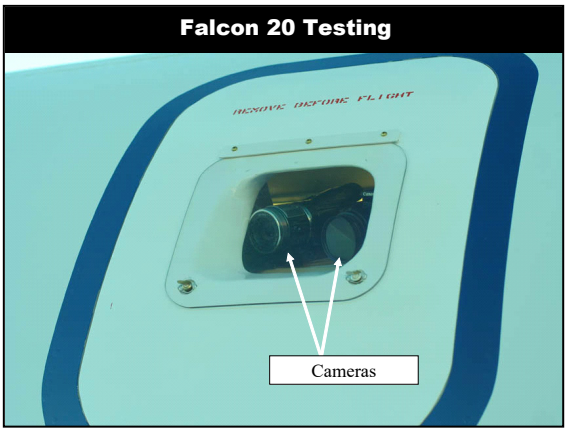
| Falcon 20 Tests | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test # | Date | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | OAT (°C) | Wing Avg Temp (°C) |
| 3S | Feb-28 | PG | IP/SN | - | 25 | 25 | 30 | -8 | -11 |
| 3P | Feb-28 | PG | Baseline | - | - | - | - | -8 | -10.5 |
| 4S | Feb-28 | PG | Baseline | - | - | - | - | -10 | -6 |
| 4P | Feb-28 | PG | ZR/IP | 20 | 5 | - | 40 | -10 | -6 |
| 5S | Mar-01 | EG | Baseline | - | - | - | - | -11 | -14 |
| 5P | Mar-01 | PG | IP/SN | - | 20 | 20 | 30 | -11 | -13 |

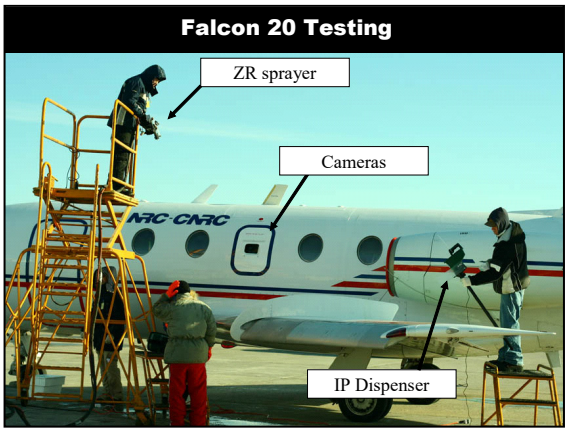
## Falcon 20 Testing

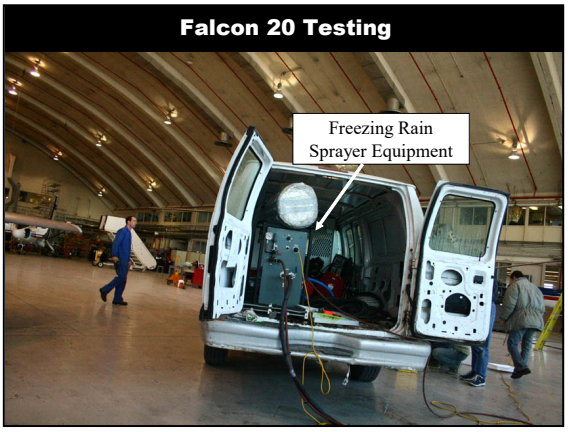


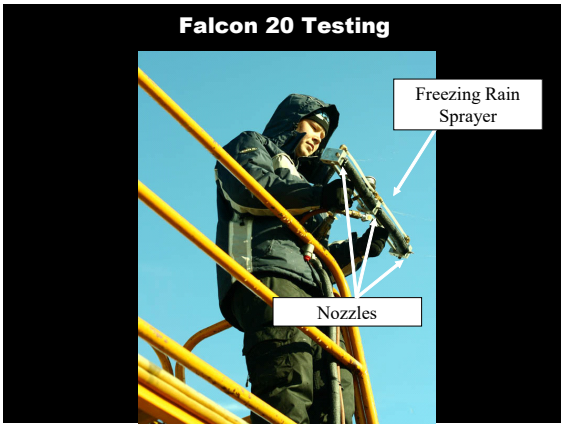

## Falcon 20 Testing

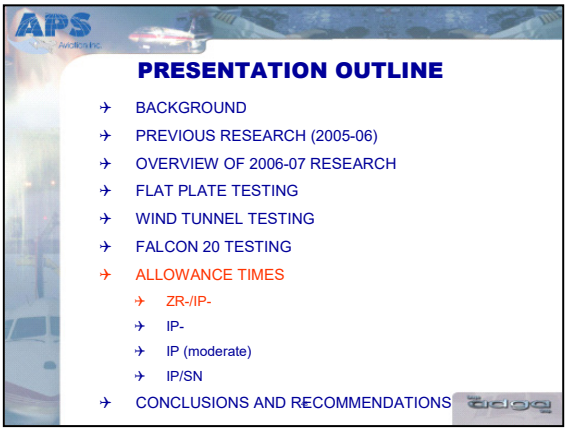


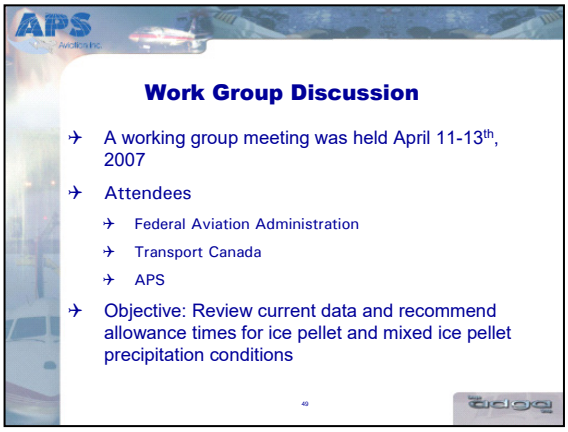

Falcon 20 Testing
Cameras


Falcon 20 Testing
ZR sprayer
Cameras
IP Dispenser


Falcon 20 Testing
Freezing Rain
Sprayer Equipment


Falcon 20 Testing
Freezing Rain
Sprayer
Nozzles


PRESENTATION OUTLINE
BACKGROUND
PREVIOUS RESEARCH (2005-06)
OVERVIEW OF 2006-07 RESEARCH
FLAT PLATE TESTING
WIND TUNNEL TESTING
FALCON 20 TESTING
ALLOWANCE TIMES
ZR-/IP-
IP-
IP (moderate)
IP/SN
CONCLUSIONS AND RECOMMENDATIONS


Work Group Discussion
A working group meeting was held April 11-13th, 2007
Attendees
Federal Aviation Administration
Transport Canada
APS
Objective: Review current data and recommend allowance times for ice pellet and mixed ice pellet precipitation conditions

## Mixed ZR- and IP- Conditions

- 5 Wind Tunnel Tests Conducted
- 2 Falcon 20 tests Conducted

**Wind Tunnel Tests**

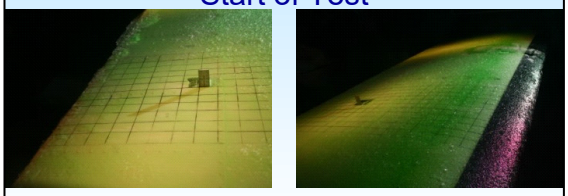
| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 15 | PG | ZR/IP | 20 | 5 | 0 | 40 | -8 | -7 | 5 |
| 6A | 15 | PG | ZR/IP | 20 | 5 | 0 | 20 | -8 | -7 | 1 |
| 10 | 23 | PG | IP/ZR | 7 | 20 | 0 | 40 | -7.2 | -7 | 3 |
| 11 | 23 | PG | ZR/IP | 20 | 5 | 0 | 40 | -1.9 | -4 | 2 |
| 12 | 23 | EG | ZR/IP | 20 | 5 | 0 | 40 | -5.9 | -4 | 1 |

**Falcon 20 Tests**

| Test # | Date | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | OAT (°C) | Wing Avg Temp (°C) |
|---|---|---|---|---|---|---|---|---|---|
| 4P | Feb-28 | PG | ZR/IP | 20 | 5 | - | 40 | -10 | -6 |
| 6P | Mar-01 | EG | ZR/IP | 20 | 5 | - | 30 | -11 | -4 |

50

**Test #6**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min,
OAT-8ºC, Wing -7°C
Start of Test



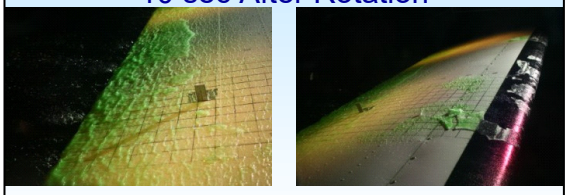
51

**Test #6**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min,
OAT-8ºC, Wing -7°C
Before Rotation



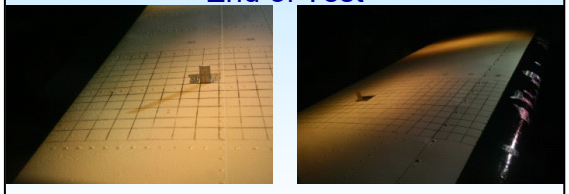
52

**Test #6**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min,
OAT-8ºC, Wing -7°C
10 sec After Rotation



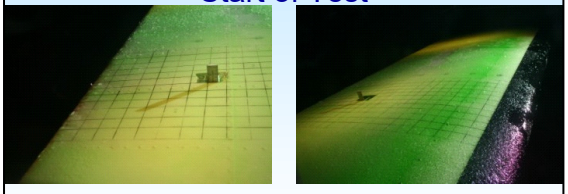
53

**Test #6**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min,
OAT-8ºC, Wing -7°C
End of Test



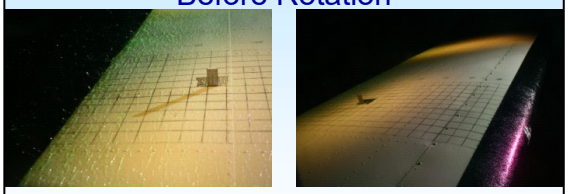
54

**Test #6A**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 20 min
OAT –7, Wing -7°C
Start of Test



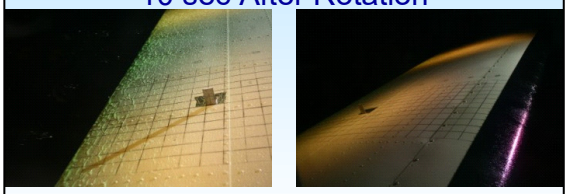
55

**Test #6A**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 20 min
OAT –7, Wing -7°C
Before Rotation



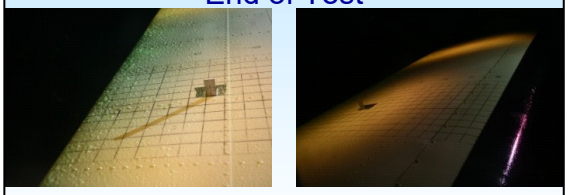
56

**Test #6A**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 20 min
OAT –7, Wing -7°C
10 sec After Rotation



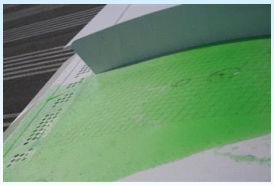
57

**Test #6A**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 20 min
OAT –7, Wing -7°C
End of Test



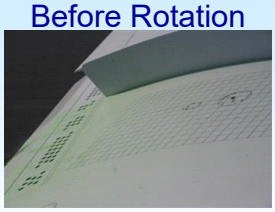
58

**Test #4p**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min
OAT -10°C, Wing -6ºC
Start of Test



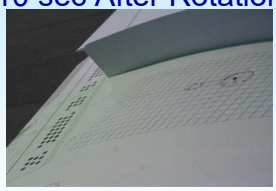
59

**Test #4p**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min
OAT -10°C, Wing -6ºC
Before Rotation



60

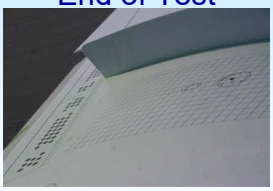
**Test #4p**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min
OAT -10°C, Wing -6ºC
10 sec After Rotation



61

**Test #4p**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min
OAT -10°C, Wing -6°C

## End of Test



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## Mixed ZR- and IP- Conditions

- Observations and Recommendations
  - ZR is the primary concern due to adherence and increased roughness due to presence of IP
  - Recommend using lower limit from Generic ZR HOT
    - -3 and above: 25 minutes
    - -3 to -10: 10 minutes
  - Use temperature -5 °C (instead of -3 °C) to allow for increased latitude to operators
    - Good results from data in -3 to -10°C temp range (I.e. lift loss and residual contamination)
  - Operations limited to -10°C
    - Occurrence of ZR below -10°C is infrequent
    - Limited data collected below -10°C

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## Mixed ZR- and IP- Conditions

- Recommended Allowance

| Light Ice Pellets mixed with Light Freezing Rain |
|---|
| |
| - 5° C and above : 25 min |
| |
| Less than - 5° to -10°C : 10 min |
| |

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## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- FLAT PLATE TESTING
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

65

## IP- Only Conditions

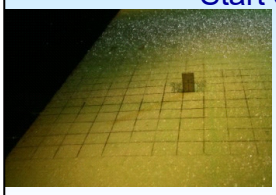
- 3 Wind Tunnel Tests Conducted
- IP only tests were NOT conducted with Falcon 20 this year
- 2005-06 Falcon 20 tests were referenced

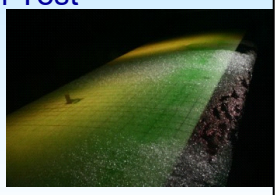
| Wind Tunnel Tests | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h | IP Rate g/dm²/h | SN Rate g/dm²/h | Precp. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) |
| 5 | 15 | PG | IP | 0 | 25 | 0 | 60 | -16.8 | -13 | 4.5 |
| 7 | 22 | PG | IP | 0 | 25 | 0 | 60 | 1 | -5.5 | 1 |
| 8 | 22 | EG | IP | 0 | 25 | 0 | 60 | 1 | -9 | 1 |

66

**Test #5**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT -17°C, Wing -13°C

## Start of Test





67

**Test #5**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT -17°C, Wing -13ºC
Before Rotation



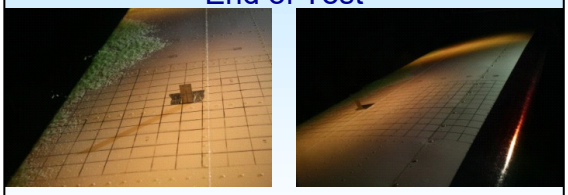
68

**Test #5**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT -17°C, Wing -13ºC
10 sec After Rotation



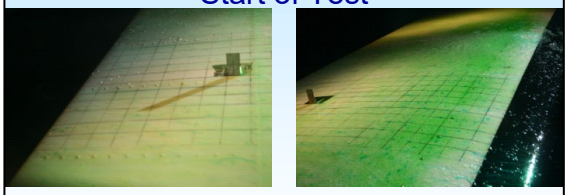
69

**Test #5**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT -17°C, Wing -13ºC
End of Test



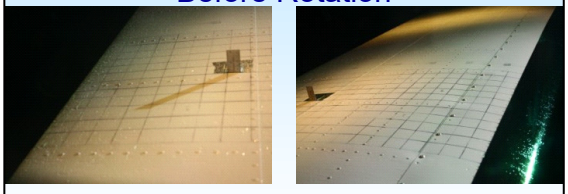
70

**Test #7**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT +1ºC, Wing -6°C
Start of Test



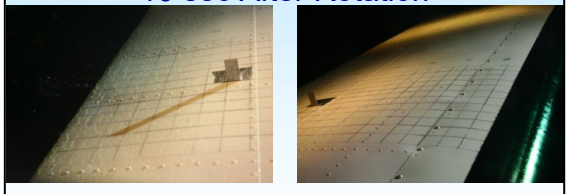
71

**Test #7**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT +1ºC, Wing -6°C
Before Rotation



72

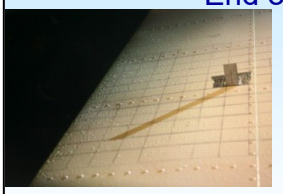
**Test #7**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT +1ºC, Wing -6°C
10 sec After Rotation

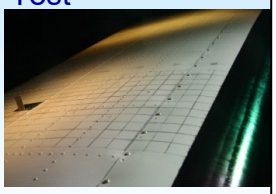


73

**Test #7**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT +1°C, Wing -6°C

## End of Test





74

## IP- Only Conditions

- Observations and Recommendations
  - Wind Tunnel 60min exposure tests at warmer temperatures demonstrated positive results (I.e. lift loss and visual contamination following run)
    - Suggest allowance of no more than 50 min for warmer temperatures due to lack of fluids tested and possible variability in rates
  - Test #5 for 60 min at colder temperature showed residual contamination
    - Suggest allowance of 30 min
  - -5°C temperature cut-off suggested to be consistent with ZR/IP

75

## IP- Only Conditions

- Allowance

| Light Ice Pellets Only |
|---|
| |
| - 5° C and above : 50 min |
| |
| Less than - 5°C : 30 min |
| |

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## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- FLAT PLATE TESTING
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## Moderate IP Only Conditions

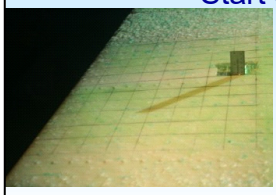
- 1 Wind Tunnel Test Conducted
- Moderate IP tests were NOT conducted with Falcon 20 this year
- 2005-06 Falcon 20 tests were referenced

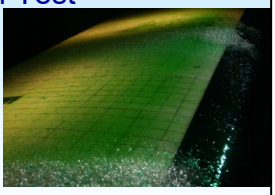
| Wind Tunnel Tests | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) |
| 9 | 22 | PG | IP (mod) | 0 | 75 | 0 | 30 | 3.2 | -7 | 2.5 |

78

**Test #9**
Type IV PG, IP 75 g/dm²/h, 30 min
OAT +3°C, Wing -7°C

## Start of Test

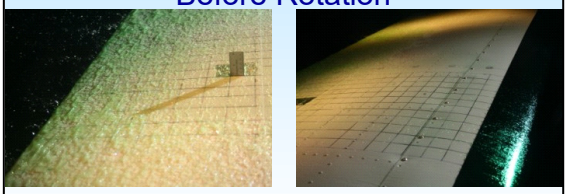




79

**Test #9**
Type IV PG, IP 75 g/dm²/h, 30 min
OAT +3ºC, Wing -7°C

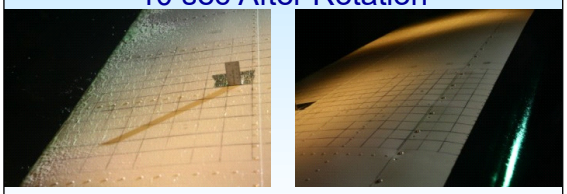
## Before Rotation



80

**Test #9**
Type IV PG, IP 75 g/dm²/h, 30 min
OAT +3ºC, Wing -7°C

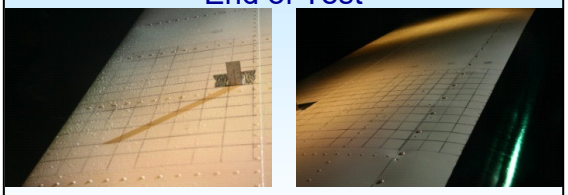
## 10 sec After Rotation



81

**Test #9**
Type IV PG, IP 75 g/dm²/h, 30 min
OAT +3ºC, Wing -7°C

## End of Test



82

## Moderate IP Only Conditions

- Observations and Recommendations
  - Wind Tunnel test demonstrated positive results (I.e. lift loss and minimal visual contamination following run)
    - Suggest reducing allowance to 25 min for warmer temperatures due to lack of fluids tested and possible variability in rates
    - Suggest reducing allowance to 10 min for temperatures below -5ºC based on wind tunnel test and previous Falcon 20 data collected (2005-06)
  - Flat plate tests conducted at moderate IP rates supported recommendations

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## Moderate IP Only Conditions

- Allowance

| Moderate Ice Pellets Only |
|---|
| |
| - 5° C and above : 25 min |
| |
| Less than - 5°C : 10 min |
| |

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## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- FLAT PLATE TESTING
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## IP-/SN Conditions

- 4 Wind Tunnel Tests Conducted
- 2 Falcon 20 tests Conducted

**Wind Tunnel Tests**

| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) |
|---|---|---|---|---|---|---|---|---|---|---|
| SP1 | 20 | PG | IP/SN | 0 | 20 | 5 | 40 | -2 | -7 | 2 |
| SP2 | 20 | PG | SN/IP | 0 | 5 | 20 | 40 | -3 | -6 | 1 |
| SP3 | 20 | EG | IP/SN | 0 | 20 | 5 | 40 | 1.2 | -8 | 1 |
| SP4 | 23 | PG | IP/SN | 0 | 25 | 25 | 30 | 3.2 | -7 | 2 |

**Falcon 20 Tests**

| Test # | Date | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | OAT (°C) | Wing Avg Temp (°C) |
|---|---|---|---|---|---|---|---|---|---|
| 3S | Feb-28 | PG | IP/SN | - | 25 | 25 | 30 | -8 | -11 |
| 5P | Mar-01 | PG | IP/SN | - | 20 | 20 | 30 | -11 | -13 |

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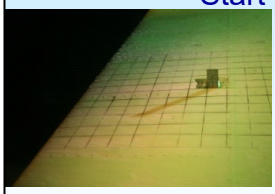
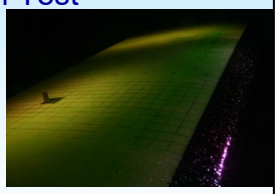
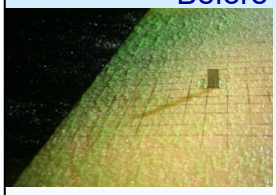
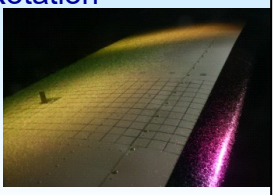
**Test #SP1**
Type IV PG, IP-&S 20+5 g/dm²/h, 40 min
OAT -2ºC, Wing -7°C
Start of Test

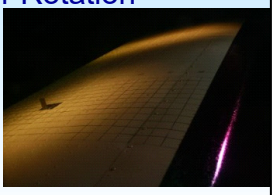
87

**Test #SP1**
Type IV PG, IP-&S 20+5 g/dm²/h, 40 min
OAT -2ºC, Wing -7°C
Before Rotation

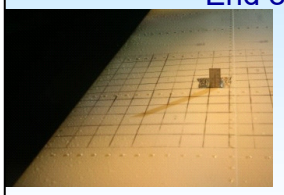
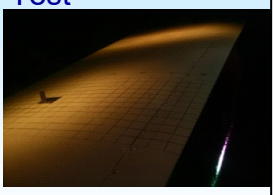
88

**Test #SP1**
Type IV PG, IP-&S 20+5 g/dm²/h, 40 min
OAT -2ºC, Wing -7°C
10 sec After Rotation

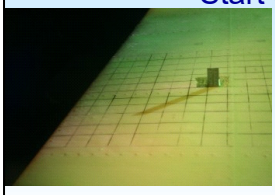
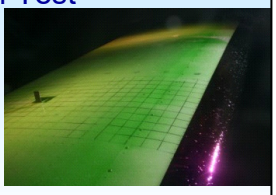
89

**Test #SP1**
Type IV PG, IP-&S 20+5 g/dm²/h, 40 min
OAT -2ºC, Wing -7°C
End of Test

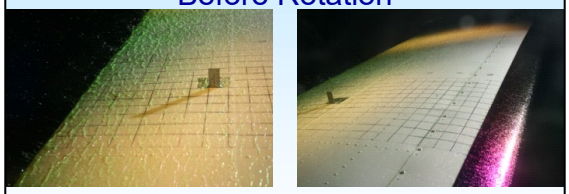
90

**Test #SP2**
Type IV PG, S&IP- 20+5 g/dm²/h, 40 min
OAT -3ºC, Wing -6°C
Start of Test

91

**Test #SP2**
Type IV PG, S&IP- 20+5 g/dm²/h, 40 min
OAT -3ºC, Wing -6°C
Before Rotation



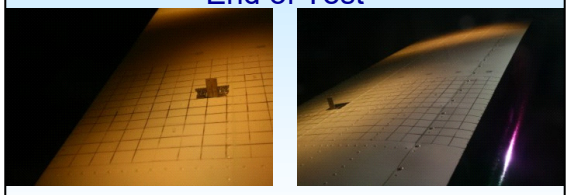
92

**Test #SP2**
Type IV PG, S&IP- 20+5 g/dm²/h, 40 min
OAT -3ºC, Wing -6°C
10 sec After Rotation



93

**Test #SP2**
Type IV PG, S&IP- 20+5 g/dm²/h, 40 min
OAT -3ºC, Wing -6°C
End of Test



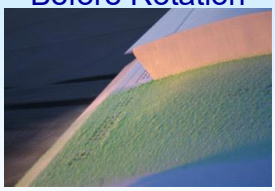
94

**Test #5p**
Type IV PG, S&IP 20+20 g/dm²/h, 30 min
OAT -11°C, Wing -13ºC
Start of Test



95

**Test #5p**
Type IV PG, S&IP 20+20 g/dm²/h, 30 min
OAT -11°C, Wing -13ºC
Before Rotation



96

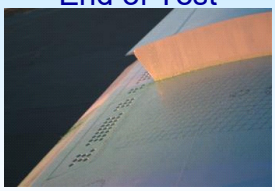
**Test #5p**
Type IV PG, S&IP 20+20 g/dm²/h, 30 min
OAT -11°C, Wing -13ºC
10 sec After Rotation



97

**Test #5p**
Type IV PG, S&IP 20+20 g/dm²/h, 30 min
OAT -11°C, Wing -13ºC

## End of Test



98

## IP-/SN Conditions

- Observations and Recommendations
  - Wind tunnel tests indicated that applying IP- only allowance times was not feasible
    - Testing at colder temperatures showed contamination at end of run
  - WT tests demonstrated minimal lift loss and minimal visual contamination following run at warmer temperatures
    - -5ºC temp range chosen to be consistent with ZR/IP allowance
    - Suggest allowance of 25 min for above -5ºC based on current data collected
    - No allowance for temperatures below -5ºC due to lack of data collected

99

## IP-/SN Conditions

- Allowance

| Light Ice Pellets mixed with Snow |
|---|
| |
| - 5° C and above : 25 min |
| |
| Less than - 5° : not tested |
| |

100

## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- FLAT PLATE TESTING
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## Summary of Ice Pellet Allowance Times

| Ice Pellet and Ice Pellet mixed with: Light Ice Pellets, Snow Allowance Times | | | |
|---|---|---|---|
| **Light Ice Pellets Only** | **Moderate Ice Pellets Only** | **Light Ice Pellets mixed with Snow** | **Light Ice Pellets mixed with Light Freezing Rain** |
| | | | |
| - 5° C and above : 50 min | - 5° C and above : 25 min | - 5° C and above : 25 min | - 5° C and above : 25 min |
| | | | |
| Less than - 5°C : 30 min | Less than - 5°C : 10 min | Less than - 5° : not tested | Less than - 5° to -10°C : 10 min |
| | | | |

102

## Recommendations

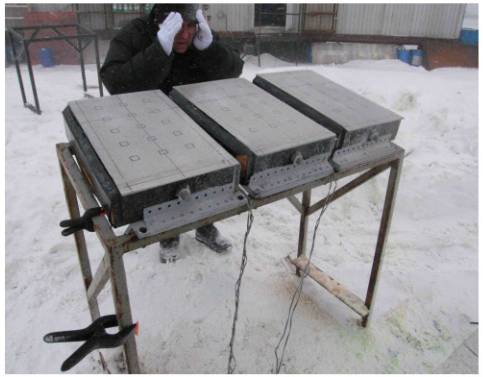
- Future Wind Tunnel Work
  - Additional testing to refine allowance times
  - Conduct testing with different wings i.e. super critical
  - Verify results at lower speeds
  - Conduct testing at lower temperatures

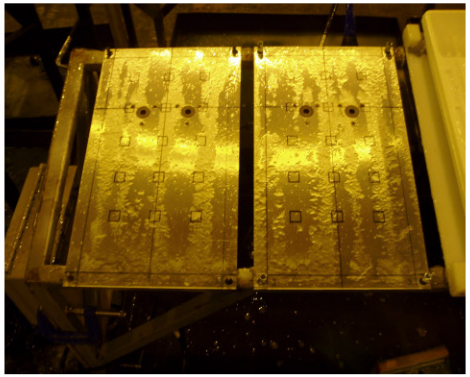
103

# AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME RESULTS FOR THE 2006-07 WINTER TEST SEASON

## TYPE I FLUID







APS Aviation Inc.

ISO 9001:2000

## SAE G-12 HOLDOVER TIME SUBCOMMITTEE
## SAN DIEGO - MAY 14, 2007

PREPARED AND PRESENTED ON BEHALF OF:

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transports Canada Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

## TYPE I FLUIDS TESTED

- One new Type I fluid, **Kilfrost DF$^{sustain}$**, was tested by APS for endurance times in 2006-07
- Endurance Time results of the Kilfrost fluid were compared to grandfathered Type I fluids

Transports Canada Transport Canada

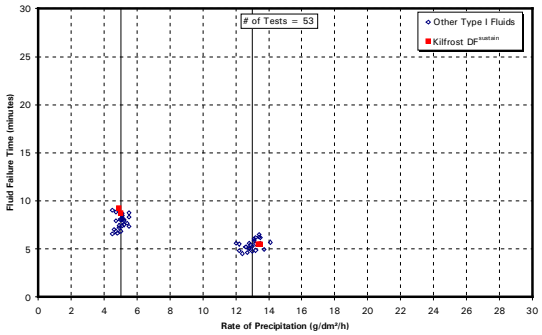
## WSET RESULTS - AMIL

**KILFROST DF$^{SUSTAIN}$**
**50/50 FLUID**

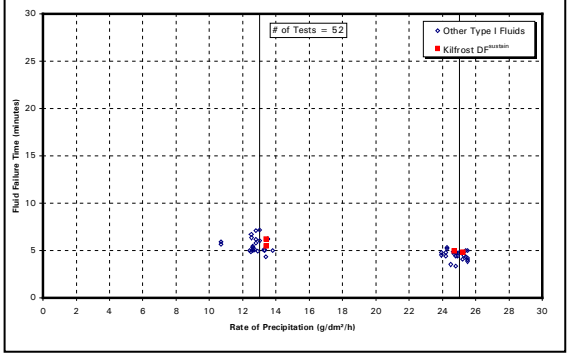
4.3 minutes

Transports Canada Transport Canada

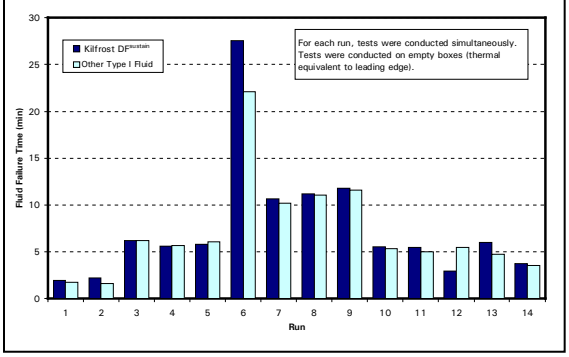
**Kilfrost DF$^{sustain}$ (10°C Buffer)**
FREEZING DRIZZLE @ -10°C




**Kilfrost DF$^{sustain}$ (10°C Buffer)**
FREEZING RAIN @ -10°C




**Kilfrost DF$^{sustain}$ (10°C Buffer)**
COMPARISON UNDER NATURAL SNOW CONDITION



## SUMMARY OF TYPE I FLUID ENDURANCE TESTING

- Endurance Time results of Kilfrost DF$^{sustain}$ compared well with grandfathered Type I fluid endurance time results
- No changes will be made to the generic Type I guidelines for 2007-08 winter operations, based on the recent testing

Transports Canada Transport Canada

## FAA/TC TYPE I HOT GUIDELINES 2007-08

FAA TYPE I HOLDOVER TIME GUIDELINE

TABLE 1. FAA GUIDELINES FOR HOLDOVER TIMES SAE TYPE I FLUID MIXTURES AS A FUNCTION OF WEATHER CONDITIONS AND OUTSIDE AIR TEMPERATURE

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRE-TAKEOFF CHECK PROCEDURES

| Outside Air Temperature | | Approximate Holdover Times Under Various Weather Conditions (hours: minutes) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Active Frost | Freezing Fog | Snow/Snow Grains: Very Light** | Snow/Snow Grains: Light ** | Snow/Snow Grains: Moderate** | Freezing Drizzle* | Light Freezing Rain | Rain on Cold Soaked Wing** | Other* |
| -3 and above | 27 and above | 0:45 | 0:11-0:17 | 0:18-0:22 | 0:11-0:18 | 0:06-0:11 | 0:09-0:13 | 0:02-0:05 | 0:02-0:05 | |
| below -3 to -6 | below 27 to 21 | 0:45 | 0:08-0:13 | 0:14-0:17 | 0:08-0:14 | 0:05-0:08 | 0:05-0:09 | | | |
| below -6 to -10 | below 21 to 14 | 0:45 | 0:05-0:10 | 0:11-0:13 | 0:06-0:11 | 0:04-0:05 | | | | |
| below -10 | below 14 | 0:45 | 0:05-0:09 | 0:07-0:08 | 0:04-0:06 | | | | | |

NO CHANGES

TYPE I FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008

RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER

| Outside Air Temperature* | | Approximate Holdover Times Under Various Weather Conditions (minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Active Frost | Freezing Fog | Snow or Snow Grains: Very Light | Snow or Snow Grains: Light | Snow or Snow Grains: Moderate | Freezing Drizzle* | Light Freezing Rain | Rain on Cold Soaked Wing | Other* |
| -3 and above | 27 and above | 45 | 11 – 17 | 18 | 11 – 18 | 6 – 11 | 9 – 13 | 4 – 6 | 2 – 5 | |
| below -3 to -6 | below 27 to 21 | 45 | 8 – 13 | 14 | 8 – 14 | 5 – 8 | 5 – 9 | 4 – 6 | | |
| below -6 to -10 | below 21 to 14 | 45 | 6 – 10 | 11 | 6 – 11 | 4 – 6 | 4 – 7 | 2 – 5 | CAUTION: No holdover time guidelines exist | |
| below -10 | below 14 | 45 | 5 – 9 | 7 | 4 – 7 | 2 – 4 | | | | |

Transport Canada



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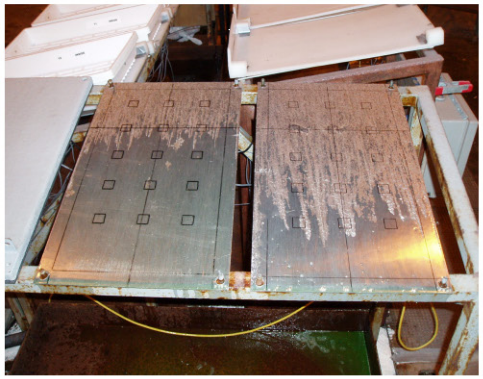
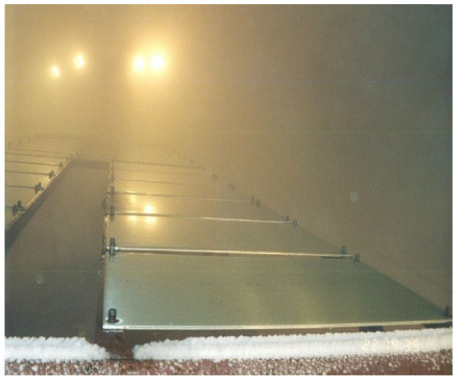
# AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME RESULTS FOR THE 2006-07 WINTER TEST SEASON

## TYPE II FLUID







APS Aviation Inc.

ISO 9001:2000

## SAE G-12 HOLDOVER TIME SUBCOMMITTEE
## SAN DIEGO - MAY 14, 2007

PREPARED AND PRESENTED ON BEHALF OF:

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transports Canada Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

## TYPE II FLUIDS TESTED

- Two new Type II fluids were tested by APS for endurance times in 2006-07
  - Aviation Xi'an Hi-Tech KHF-II
  - Newave Aerochemical FCY-2
- Both fluids will be commercialized

Transports Canada Transport Canada

## FLUID VISCOSITY

| Fluid | Manufacturer's Method | AIR Method |
|---|---|---|
| Aviation Xi'an Hi-tech KHF-II | 8,750<br>Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes | 7,690<br>Spindle LV1, 500 mL fluid, 20°C, 0.3 rpm, 10 minutes |
| Newave Aerochemical FCY-2 | 7,000<br>Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes | 8,920<br>Spindle LV1, 500 mL fluid, 20°C, 0.3 rpm, 10 minutes |

Transports Canada Transport Canada

## WSET RESULTS - AMIL

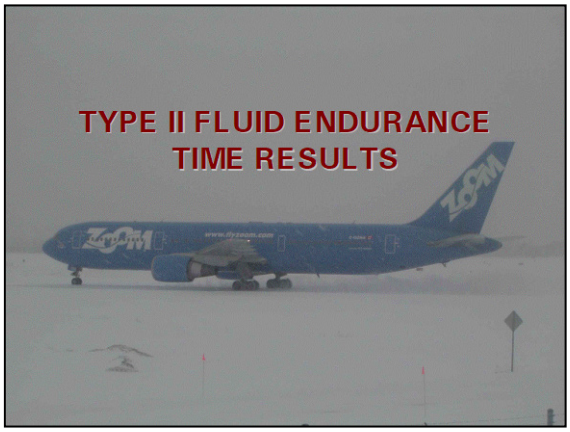
| AVIATION XI'AN HI-TECH KHF-II NEAT FLUID | NEWAVE AEROCHEMICAL FCY-2 NEAT FLUID |
|---|---|
| 48 min. | 44 min. |

Transports Canada Transport Canada

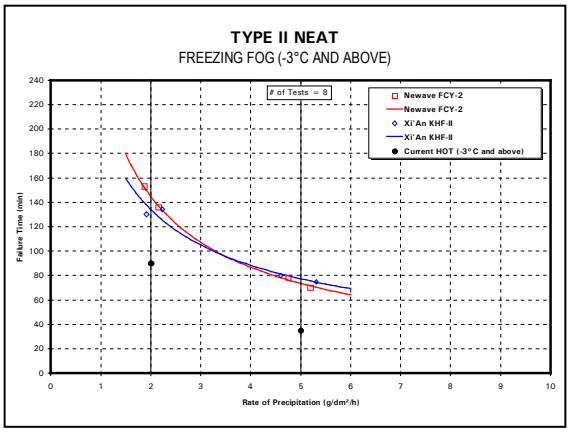
## TESTS CONDUCTED IN 2006-07

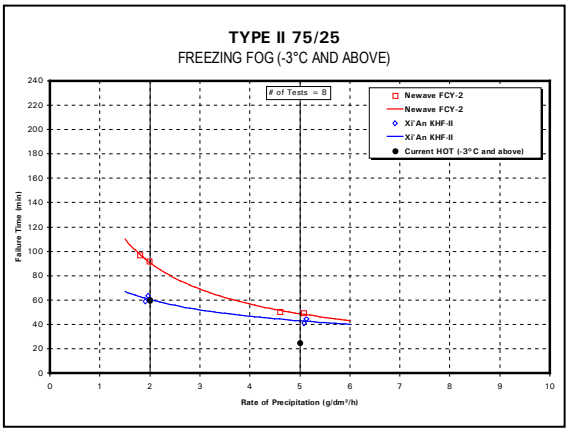
| FLUID TYPE | SNOW | FREEZING DRIZZLE | LIGHT FREEZING RAIN | FREEZING FOG | COLD SOAK |
|---|---|---|---|---|---|
| TYPE II (NEAT) | 46 | 16 | 16 | 24 | 8 |
| TYPE II (75/25) | 46 | 16 | 16 | 16 | 8 |
| TYPE II 50/50 | 24 | 8 | 8 | 10 | 0 |

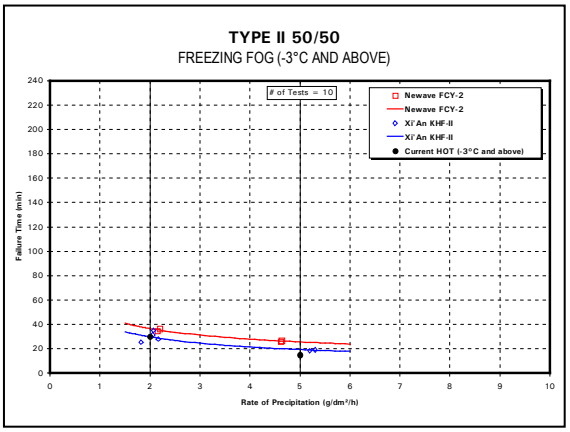
Transports Canada Transport Canada

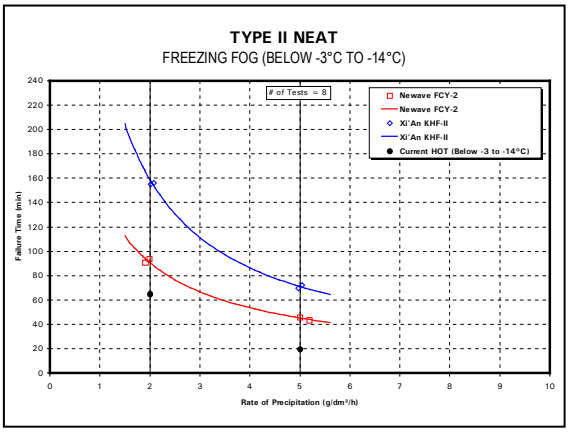


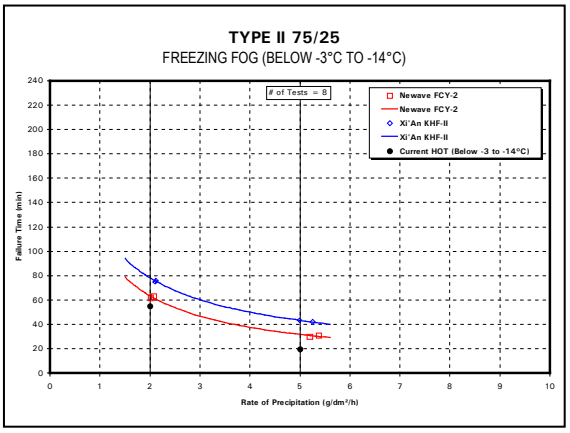

FREEZING FOG

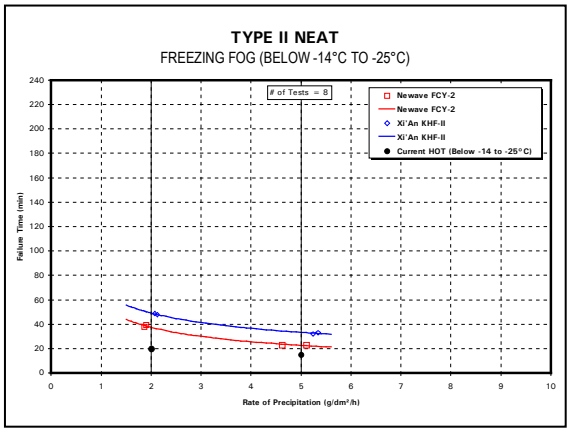

TYPE II NEAT
FREEZING FOG (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE II 75/25
FREEZING FOG (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

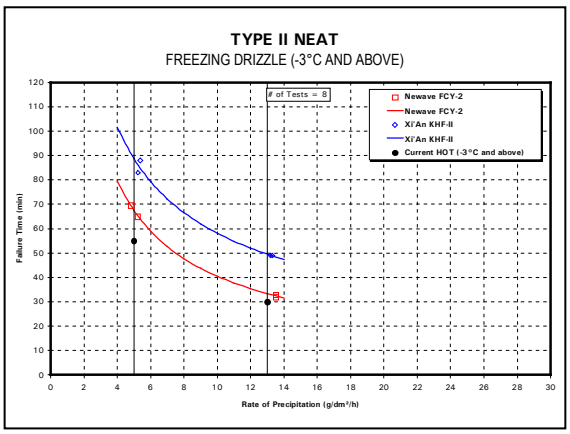

TYPE II 50/50
FREEZING FOG (-3°C AND ABOVE)
# of Tests = 10
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

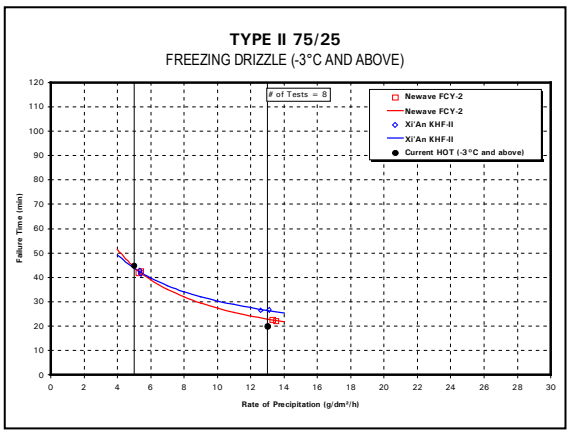

TYPE II NEAT
FREEZING FOG (BELOW -3°C TO -14°C)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (Below -3 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

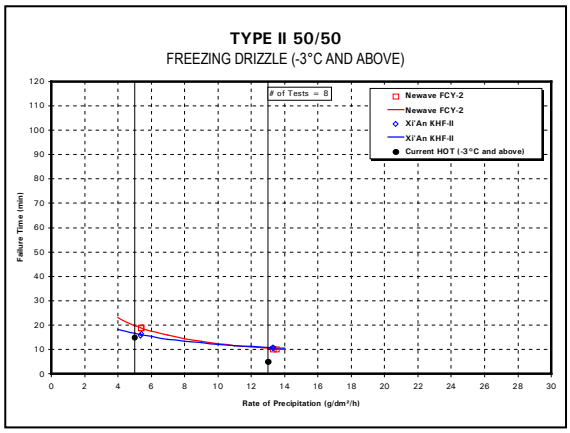

TYPE II 75/25
FREEZING FOG (BELOW -3°C TO -14°C)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (Below -3 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

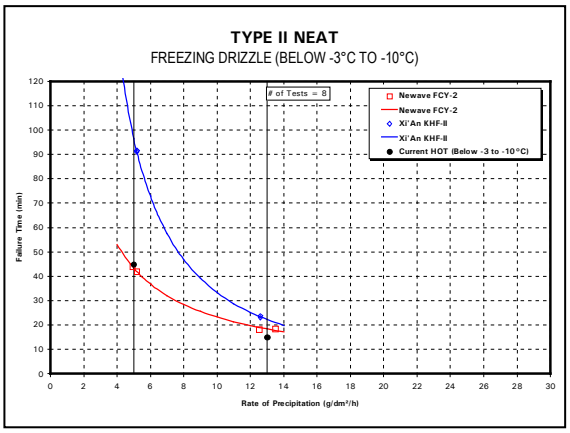

TYPE II NEAT
FREEZING FOG (BELOW -14°C TO -25°C)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (Below -14 to -25°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

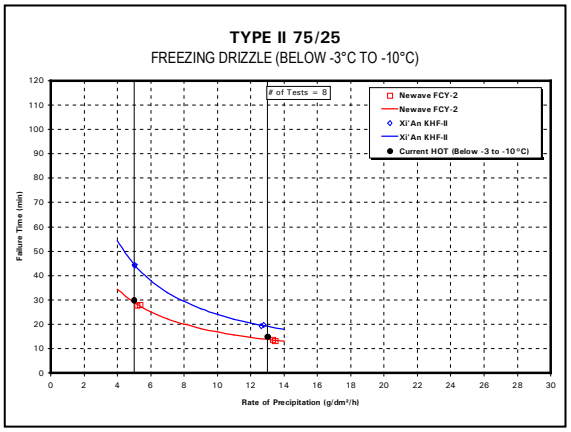

FREEZING DRIZZLE


TYPE II NEAT
FREEZING DRIZZLE (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

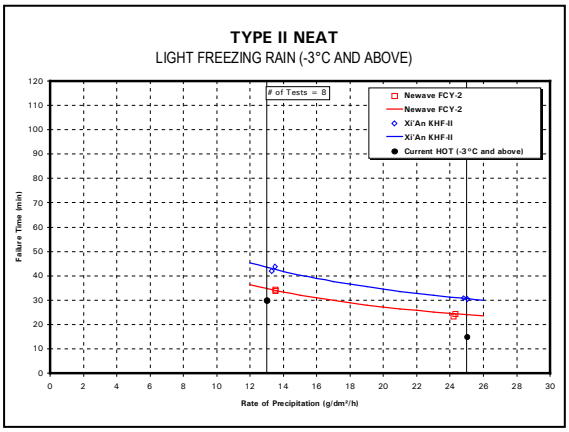

TYPE II 75/25
FREEZING DRIZZLE (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

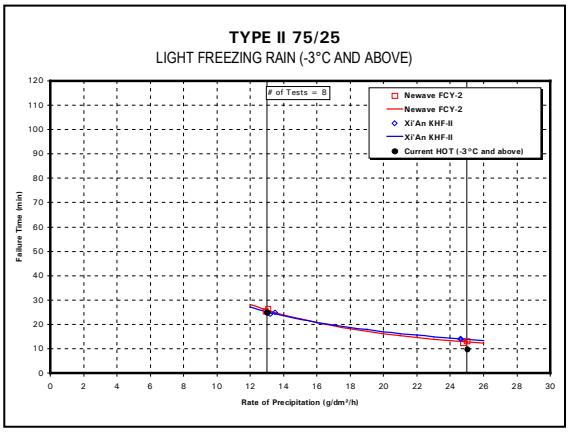

TYPE II 50/50
FREEZING DRIZZLE (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

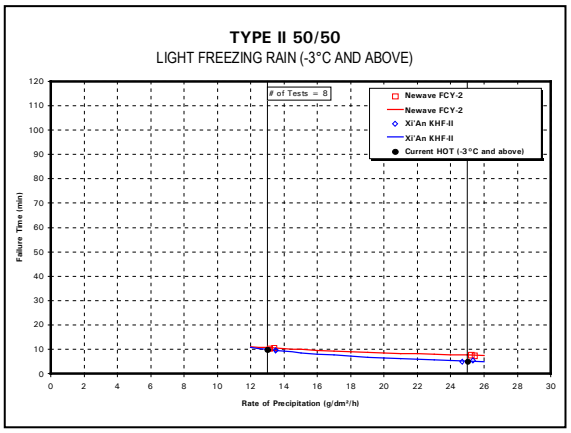

TYPE II NEAT
FREEZING DRIZZLE (BELOW -3°C TO -10°C)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (Below -3 to -10°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

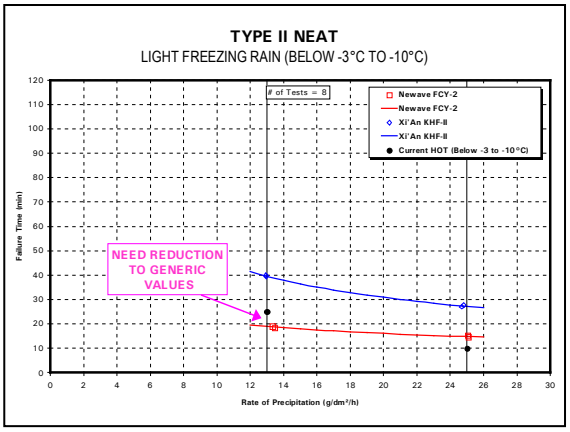

TYPE II 75/25
FREEZING DRIZZLE (BELOW -3°C TO -10°C)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (Below -3 to -10°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

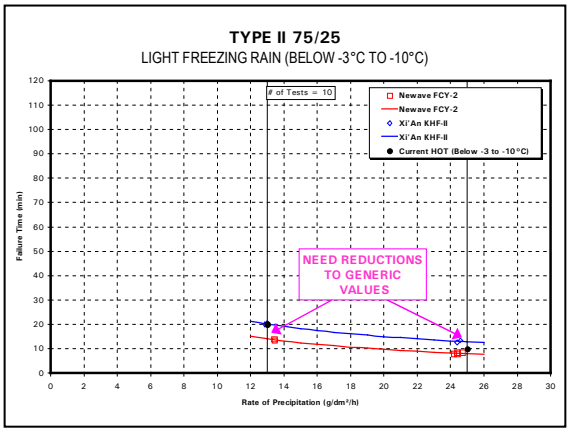

LIGHT FREEZING RAIN


TYPE II NEAT
LIGHT FREEZING RAIN (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

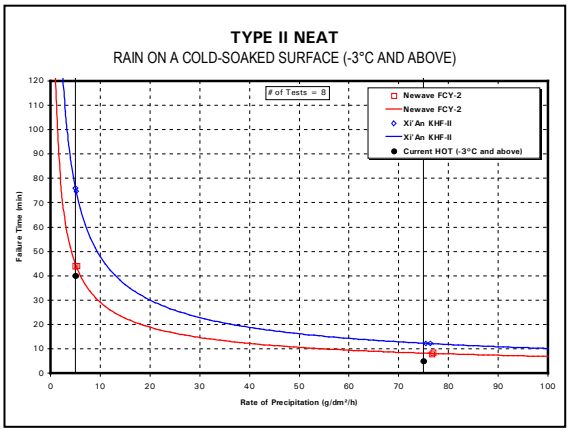

TYPE II 75/25
LIGHT FREEZING RAIN (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

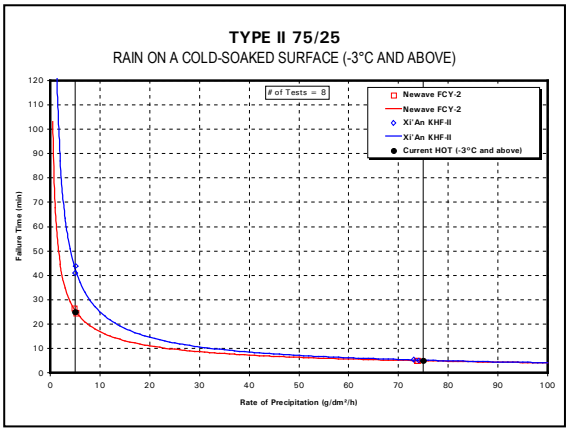

TYPE II 50/50
LIGHT FREEZING RAIN (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE II NEAT
LIGHT FREEZING RAIN (BELOW -3°C TO -10°C)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (Below -3 to -10°C)
NEED REDUCTION TO GENERIC VALUES
Failure Time (min)
Rate of Precipitation (g/dm²/h)

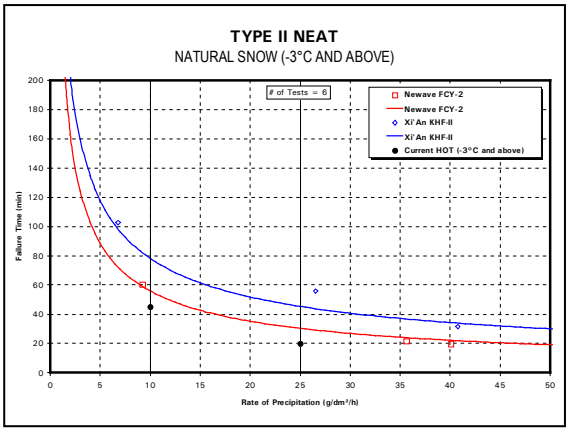

TYPE II 75/25
LIGHT FREEZING RAIN (BELOW -3°C TO -10°C)
# of Tests = 10
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (Below -3 to -10°C)
NEED REDUCTIONS TO GENERIC VALUES
Failure Time (min)
Rate of Precipitation (g/dm²/h)

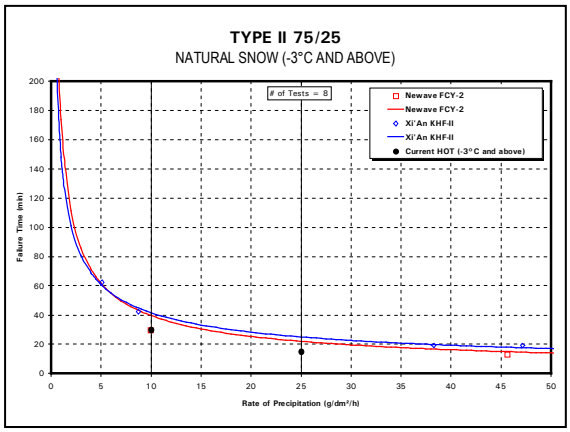

RAIN ON A COLD-SOAKED WING

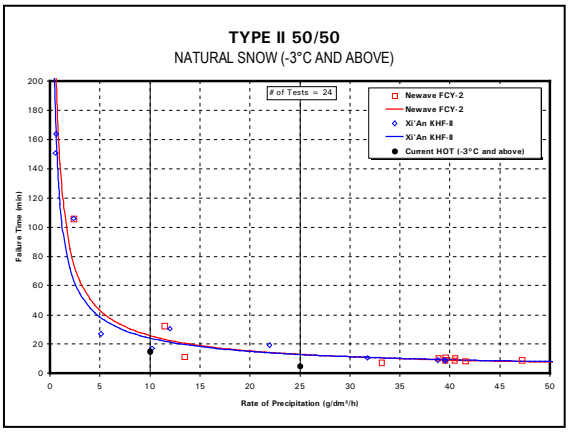

TYPE II NEAT
RAIN ON A COLD-SOAKED SURFACE (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

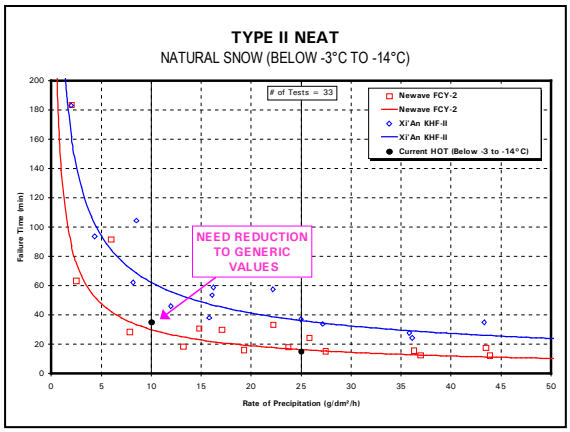

TYPE II 75/25
RAIN ON A COLD-SOAKED SURFACE (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

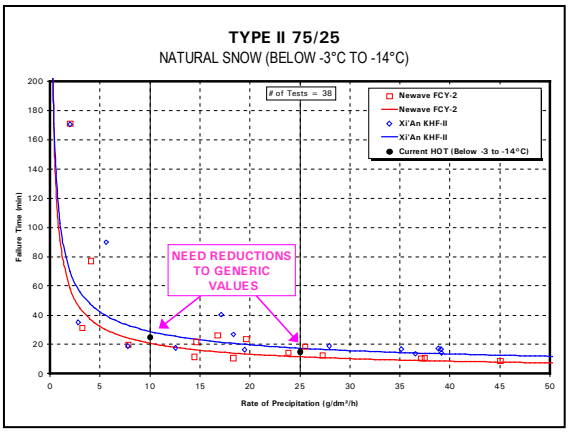

NATURAL SNOW

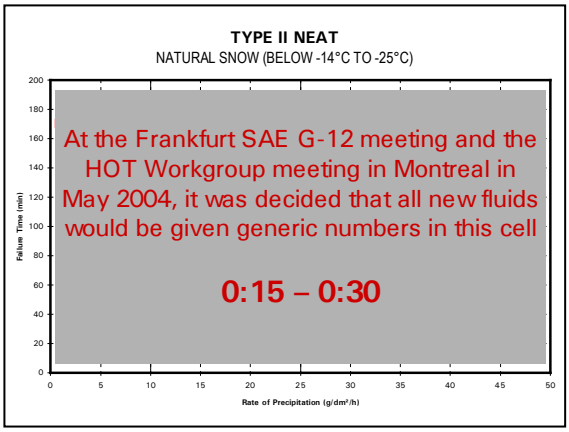

TYPE II NEAT
NATURAL SNOW (-3°C AND ABOVE)
# of Tests = 6
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

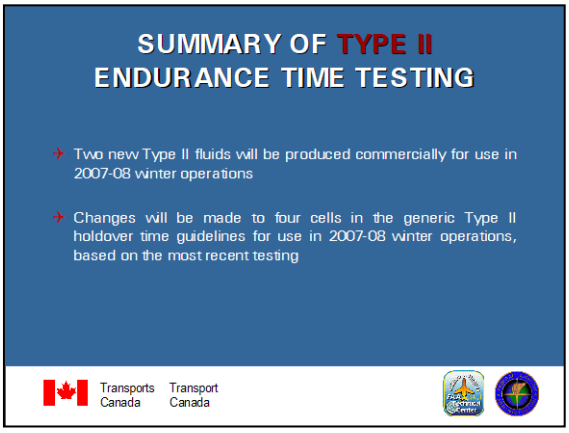

TYPE II 75/25
NATURAL SNOW (-3°C AND ABOVE)
# of Tests = 8
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE II 50/50
NATURAL SNOW (-3°C AND ABOVE)
# of Tests = 24
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE II NEAT
NATURAL SNOW (BELOW -3°C TO -14°C)
# of Tests = 33
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (Below -3 to -14°C)
NEED REDUCTION TO GENERIC VALUES
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE II 75/25
NATURAL SNOW (BELOW -3°C TO -14°C)
# of Tests = 38
Newave FCY-2
Newave FCY-2
Xi'An KHF-II
Xi'An KHF-II
Current HOT (Below -3 to -14°C)
NEED REDUCTIONS TO GENERIC VALUES
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE II NEAT
NATURAL SNOW (BELOW -14°C TO -25°C)
At the Frankfurt SAE G-12 meeting and the HOT Workgroup meeting in Montreal in May 2004, it was decided that all new fluids would be given generic numbers in this cell
0:15 – 0:30
Failure Time (min)
Rate of Precipitation (g/dm²/h)


SUMMARY OF TYPE II ENDURANCE TIME TESTING
Two new Type II fluids will be produced commercially for use in 2007-08 winter operations
Changes will be made to four cells in the generic Type II holdover time guidelines for use in 2007-08 winter operations, based on the most recent testing
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## CHANGES TO TYPE II GENERIC TABLE BASED ON 2006-07 TESTING

| Outside Air Temperature | | Fluid Dilution | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle | Light Freezing Rain | Rain on Cold Soaked Wing | Other |
| -3 and above | 27 and above | 100/0 | 8:00 | 0:35 – 1:30 | 0:20 – 0:45 | 0:30 – 0:55 | 0:15 – 0:30 | 0:05 – 0:40 | |
| | | 75/25 | 5:00 | 0:25 – 1:00 | 0:15 – 0:30 | 0:20 – 0:45 | 0:10 – 0:25 | 0:05 – 0:25 | |
| | | 50/50 | 3:00 | 0:15 – 0:30 | 0:05 – 0:15 | 0:05 – 0:15 | 0:05 – 0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:20 – 1:05 | 0:15 – ~~0:35~~ 0:30 | 0:15 – 0:45 | 0:10 – ~~0:25~~ 0:20 | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:20 – 0:55 | ~~0:15 – 0:25~~ 0:10 – 0:20 | 0:15 – 0:30 | ~~0:10 – 0:20~~ 0:05 – 0:15 | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:15 – 0:20 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below ²25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

## FAA/TC TYPE II HOT GUIDELINES 2007-08

FAA TYPE II HOLDOVER TIME GUIDELINE

| Outside Air Temperature | | Type II Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours: minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Neat Fluid/Water (Volume %/Volume %) | Active Frost | Freezing Fog | Snow/ Snow Grains | Freezing Drizzle* | Light Freezing Rain | Rain on Cold Soaked Wing** | Other† |
| -3 and above | 27 and above | 100/0 | 8:00 | 0:35-1:30 | 0:20-0:45 | 0:30-0:55 | 0:15-0:30 | 0:05-0:40 | |
| | | 75/25 | 5:00 | 0:25-1:00 | 0:15-0:30 | 0:20-0:45 | 0:10-0:25 | 0:05-0:25 | |
| | | 50/50 | 3:00 | 0:15-0:30 | 0:05-0:15 | 0:05-0:15 | 0:05-0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:20-1:05 | 0:15-~~0:35~~ 0:30 | ***0:15-0:45 | ***~~0:10~~-0:20 | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:20-0:55 | ~~0:15-0:25~~ 0:10-0:20 | ***0:15-0:30 | ***~~0:05~~-0:15 | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00 | 0:15-0:20 | 0:15-0:30 | | | | |
| below -25 | below -13 | 100/0 | SAE Type II fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of SAE Type I when SAE Type II fluid cannot be used. | | | | | | |

SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2007-2008†

| Outside Air Temperature | | Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[2] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 8:00 | 0:35 – 1:30 | 0:20 – 0:45 | 0:30 – 0:55 | 0:15 – 0:30 | 0:05 – 0:40 | |
| | | 75/25 | 5:00 | 0:25 – 1:00 | 0:15 – 0:30 | 0:20 – 0:45 | 0:10 – 0:25 | 0:05 – 0:25 | |
| | | 50/50 | 3:00 | 0:15 – 0:30 | 0:05 – 0:15 | 0:05 – 0:15 | 0:05 – 0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 8:00 | 0:20 – 1:05 | 0:15 – **0:30** | 0:15 – 0:45[1] | 0:10 – **0:20**[1] | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:20 – 0:55 | **0:10 – 0:20** | 0:15 – 0:30[1] | **0:05 – 0:15**[1] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 8:00[1] | 0:15 – 0:20[1] | 0:15 – 0:30[1] | | | | |
| below -25 | below -13 | 100/0 | Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used. | | | | | | |

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## TC/FAA TYPE II FLUID-SPECIFIC HOT GUIDELINES 2007-08

1) AVIATION XI'AN HI-TECH KHF-II (NEW)
2) CLARIANT SAFEWING MP II 2025 ECO
3) CLARIANT SAFEWING MP II FLIGHT
4) KILFROST ABC-2000
5) KILFROST ABC-II PLUS
6) KILFROST ABC-TF2
7) NEWAVE AEROCHEMICAL FCY-2 (NEW)
8) OCTAGON E-MAX II
9) SPCA ECOWING 26

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# AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME RESULTS FOR THE 2006-07 WINTER TEST SEASON

## TYPE III FLUID









APS Aviation Inc.

ISO 9001:2000

## SAE G-12 HOLDOVER TIME SUBCOMMITTEE
## SAN DIEGO - MAY 14, 2007

PREPARED AND PRESENTED ON BEHALF OF:

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transports Canada Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

## TYPE III FLUIDS TESTED

- No new Type III products were tested by APS for endurance times in 2006-07
- No changes will be made to the generic Type III guidelines for 2007-08 winter operations

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## FAA/TC TYPE III HOT GUIDELINES 2007-08

FAA TYPE III HOLDOVER TIME GUIDELINE

TABLE 3. FAA GUIDELINES FOR HOLDOVER TIMES SAE TYPE III FLUID MIXTURE AS A FUNCTION OF WEATHER CONDITIONS AND OUTSIDE AIR TEMPERATURE.

CAUTION: THIS TABLE IS FOR DEPARTURE PLANNING ONLY AND SHOULD BE USED IN CONJUNCTION WITH PRETAKEOFF CHECK PROCEDURES.

| Outside Air Temperature | | Approximate Holdover Times Under Various Weather Conditions (hours: minutes) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Type III Fluid Concentration Fluid/Water (Percent/Percent) | Active Frost | Freezing Fog | Snow/Snow Grains | | | Freezing Drizzle[1] | Light Freezing Rain | Rain on Cold Soaked Wing[2] | Other[3] |
| | | | | | Very Light | Light | Moderate | | | | |
| -3 and above | 27 and above | 100/0 | 2:00 | 0:20 - 0:40 | 0:35 - 0:40 | 0:20 - 0:35 | 0:10 - 0:20 | 0:10 - 0:20 | 0:05 - 0:10 | 0:05 - 0:20 | |
| | | 75/25 | 1:00 | 0:15 - 0:30 | 0:25 - 0:35 | 0:15 - 0:25 | 0:05 - 0:15 | 0:05 - 0:10 | 0:05 - 0:10 | 0:02 - 0:10 | |
| | | 50/50 | 0:30 | 0:10 - 0:20 | 0:15 - 0:20 | 0:05 - 0:15 | 0:04 - 0:05 | | 0:04 - 0:05 | | |
| below -3 to -10 | below 27 to 14 | 100/0 | 2:00 | 0:20 - 0:40 | 0:30 - 0:35 | 0:10 - 0:30 | 0:05 - 0:10 | | 0:05 - 0:10 | | |
| | | 75/25 | 1:00 | 0:15 - 0:30 | 0:25 - 0:30 | 0:10 - 0:25 | 0:05 - 0:10 | | 0:05 - 0:05 | | |
| below -10 | below 14 | 100/0 | 2:00 | 0:20 - 0:40 | 0:30 - 0:35 | | | | | | |

NO CHANGES

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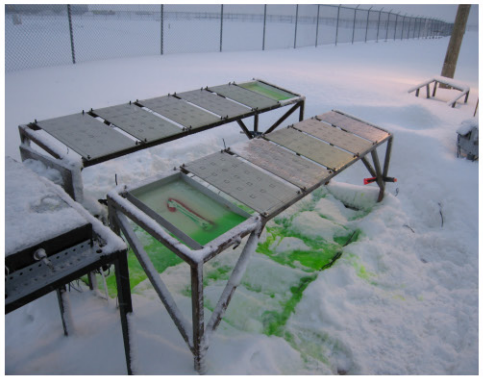
# AIRCRAFT DE/ANTI-ICING FLUID ENDURANCE TIME RESULTS FOR THE 2006-07 WINTER TEST SEASON

## TYPE IV FLUID







APS Aviation Inc.

ISO 9001:2000

## SAE G-12 HOLDOVER TIME SUBCOMMITTEE
## SAN DIEGO - MAY 14, 2007

**PREPARED AND PRESENTED ON BEHALF OF:**

TRANSPORTATION DEVELOPMENT CENTRE
TRANSPORT CANADA

Transports Canada Transport Canada

AND

FEDERAL AVIATION ADMINISTRATION
WILLIAM J. HUGHES TECHNICAL CENTRE

## TYPE IV FLUIDS TESTED

- Four Type IV products were tested by APS for endurance times in 2006-07
  - Kilfrost P 1797 (ABC-S Plus)
  - Lyondell Arctic Shield
  - Lyondell Arctic Shield-LS
  - Clariant Safewing MP IV Launch

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## CLARIANT SAFEWING MP IV LAUNCH

- In Lisbon, APS presented data for Clariant Safewing MP IV Launch
- Two samples of Clariant Safewing MP IV Launch were submitted for ET testing in 2005-06: high and low viscosity
- Clariant decided to commercialize the high viscosity sample, but no natural snow data existed for the high viscosity sample; snow data for low viscosity sample were used for the Launch fluid-specific table for 2006-07 winter operations
- Clariant stated that it would re-submit the Launch fluid for natural snow testing in 2006-07
- Launch snow data, shown in this presentation, will replace the current snow values in the 2006-07 Clariant Safewing MP IV Launch fluid-specific table

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## FLUID VISCOSITY

| Fluid | Manufacturer's Method | AIR Method |
|---|---|---|
| Kilfrost P1797 | 17,900 | 17,900 |
| | Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes | Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes |
| Lyondell ARCTIC Shield | 23,150 | 28,000 |
| | Spindle 31, 9 mL fluid, 20°C, 0.3 rpm, 33 minutes | Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes |
| Lyondell ARCTIC Shield LS | 24,600 | 29,600 |
| | Spindle 31, 9 mL fluid, 20°C, 0.3 rpm, 33 minutes | Spindle LV2-disc with guard leg, 150 mL fluid, 20°C, 0.3 rpm, 10 minutes |

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## WSET RESULTS - AMIL

| KILFROST P1797 NEAT FLUID | LYONDELL ARCTIC SHIELD NEAT FLUID | LYONDELL ARCTIC SHIELD-LS NEAT FLUID |
|---|---|---|
| 118 min. | 80 min. | 81 min. |

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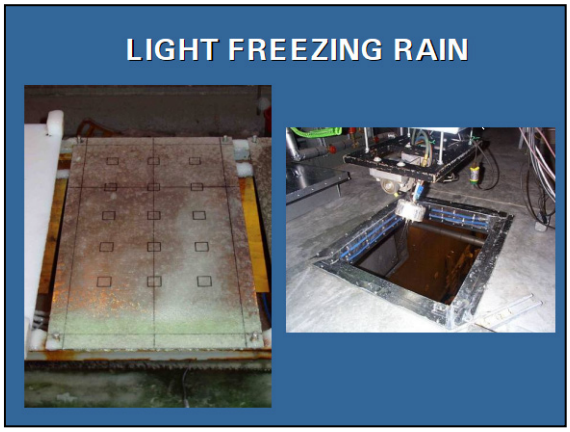
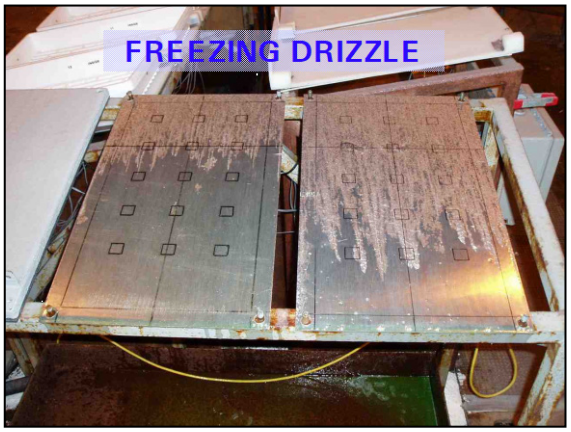
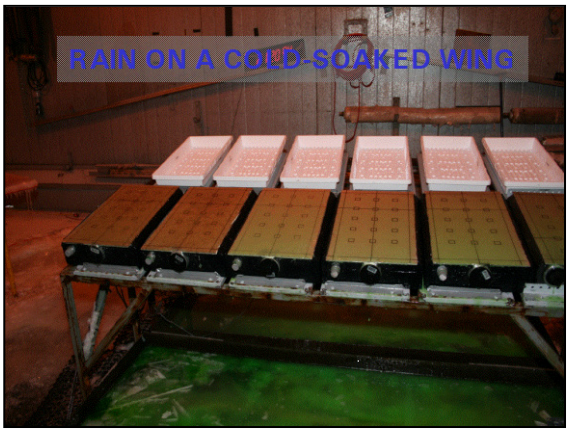
NATURAL SNOW


NRC CLIMATIC ENGINEERING FACILITY


FREEZING FOG


LIGHT FREEZING RAIN


FREEZING DRIZZLE


RAIN ON A COLD-SOAKED WING

## TESTS CONDUCTED IN 2006-07

| FLUID TYPE | SNOW | FREEZING DRIZZLE | LIGHT FREEZING RAIN | FREEZING FOG | COLD SOAK |
|---|---|---|---|---|---|
| TYPE IV (NEAT) | 71 | 24 | 24 | 37 | 12 |
| TYPE IV (75/25) | 72 | 24 | 25 | 24 | 12 |
| TYPE IV 50/50 | 43 | 12 | 12 | 12 | 0 |

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## ENDURANCE TIME DATA ANALYSIS METHODOLOGY

- Regression analysis that provides a power law relationship
- General form of the equation for light freezing rain, freezing drizzle, freezing fog, and rain on a cold-soaked wing is $t = cR^a$
- General form of the equation for snow is $t = cR^a(2\text{-}T)^b$

where $t$ = Time,
$R$ = Rate of precipitation,
$T$ = Temperature, and
$a, b, c$ = The coefficients determined from the regression

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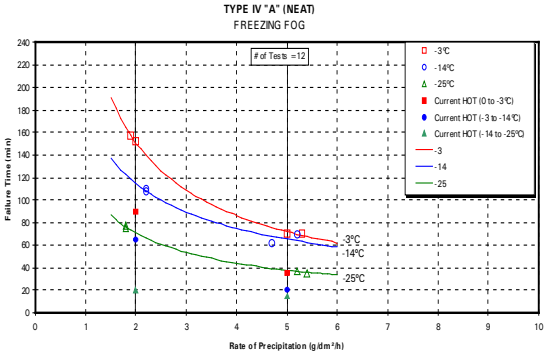
## EXAMPLE OF REGRESSION ANALYSIS




## SUMMARY OF PROCEDURE USED TO DETERMINE HOLDOVER TIME LIMITS

- Curves were plotted for each fluid and each cell of the holdover time table using the MOST RESTRICTIVE TEMPERATURE in that cell
- Upper and lower holdover time values were determined using specific precipitation rate ranges for each condition

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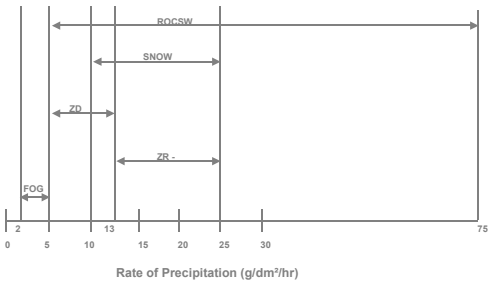
## DATA RANGES USED FOR EVALUATION OF HOLDOVER TIME LIMITS




## SUMMARY OF PROCEDURE USED TO DETERMINE HOLDOVER TIME LIMITS

**Determination of Generic HOT Table Values**

- The worst performing fluid values were selected for each cell of the holdover time table
- Round numbers to the nearest *whole "5" value*
- For safety reasons, holdover times below 10 minutes were always rounded down

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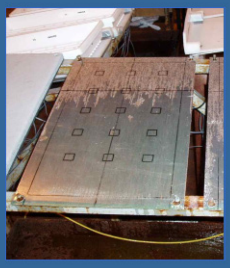
## FLUID FAILURE



Fluid failure occurs when:

- Accumulation of snow bridging on top of the fluid or plate
- Accumulation of ice on top of the fluid or plate, or ice suspended within the fluid

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## PLATE END CONDITION

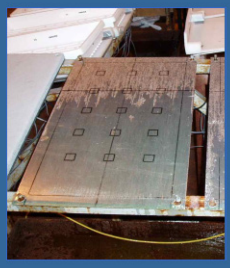

Plate end condition is achieved when fluid failures occur:

- At any 5 of the crosshair markings on the panel; or
- On more than 30% of the entire plate surface

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## TYPE IV FLUID ENDURANCE TIME RESULTS

## FREEZING FOG

## OVERVIEW OF FREEZING FOG TESTS

- Tests conducted at the NRC CEF in Ottawa
- Tests conducted at 2 and 5 g/dm²/h
- Test temperatures: -3, -14, and -25°C



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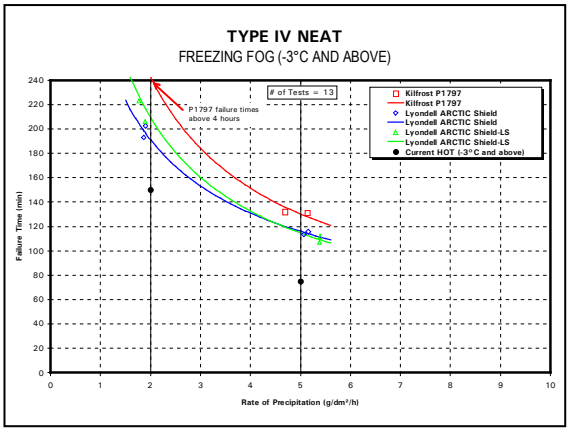
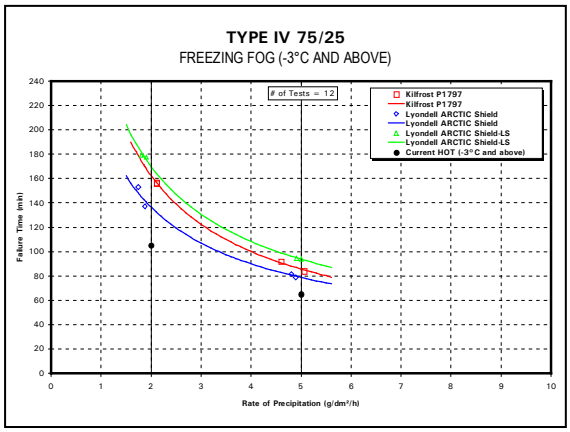
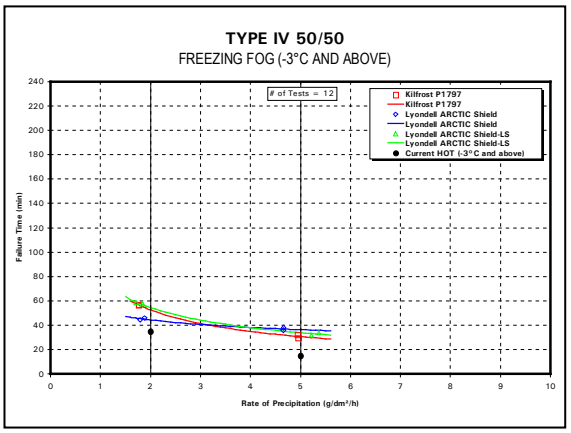
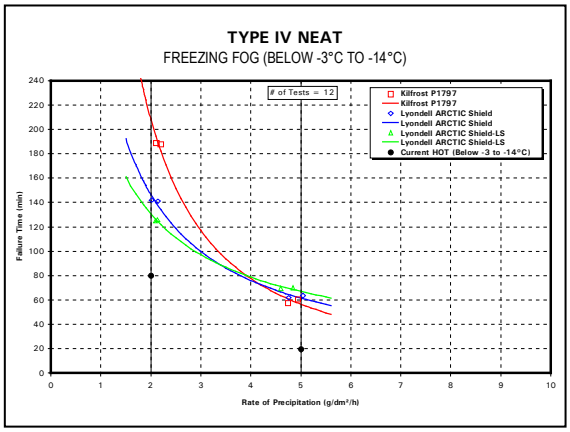
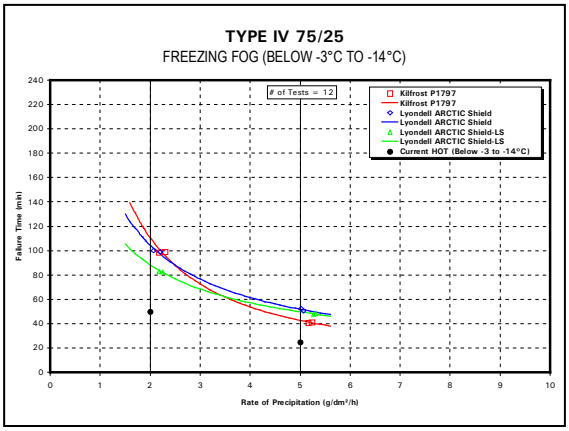
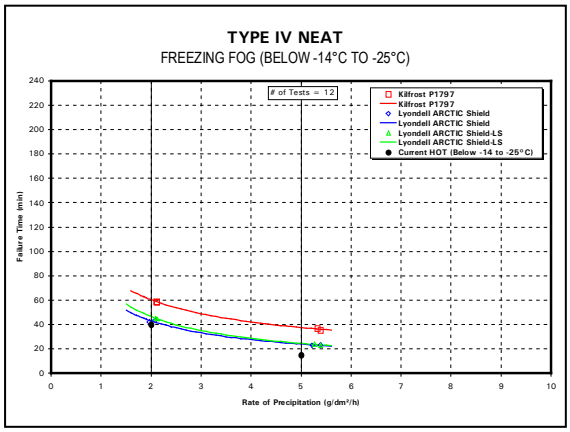



TYPE IV 75/25
FREEZING FOG (-3°C AND ABOVE)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

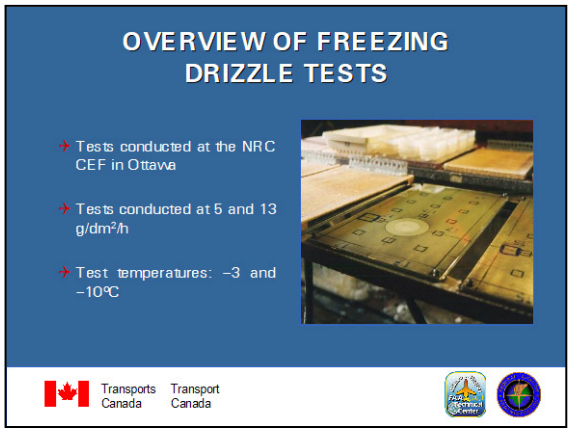

TYPE IV 50/50
FREEZING FOG (-3°C AND ABOVE)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV NEAT
FREEZING FOG (BELOW -3°C TO -14°C)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (Below -3 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV 75/25
FREEZING FOG (BELOW -3°C TO -14°C)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (Below -3 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV NEAT
FREEZING FOG (BELOW -14°C TO -25°C)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (Below -14 to -25°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


FREEZING DRIZZLE


OVERVIEW OF FREEZING DRIZZLE TESTS
Tests conducted at the NRC CEF in Ottawa
Tests conducted at 5 and 13 g/dm²/h
Test temperatures: –3 and –10ºC
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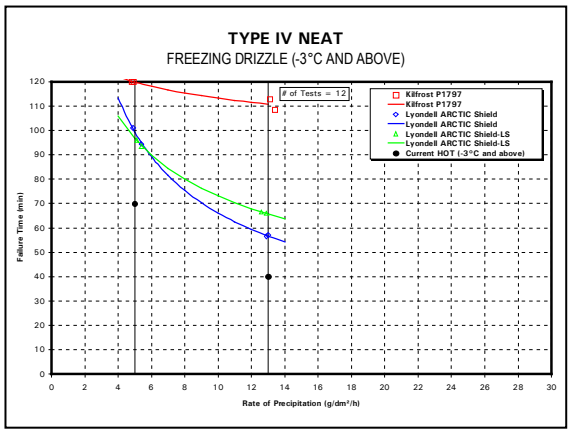
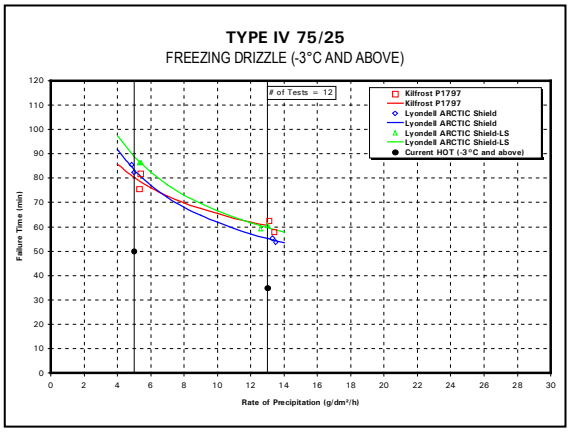
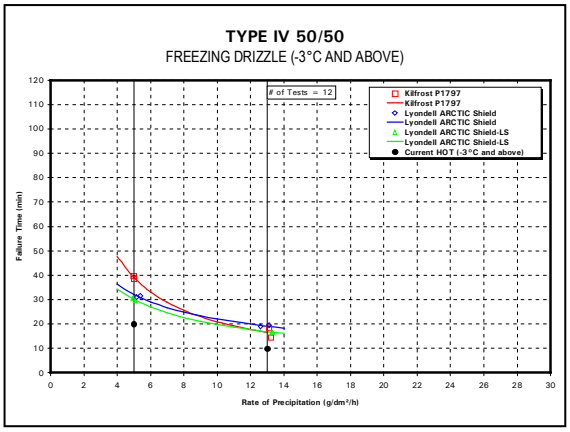
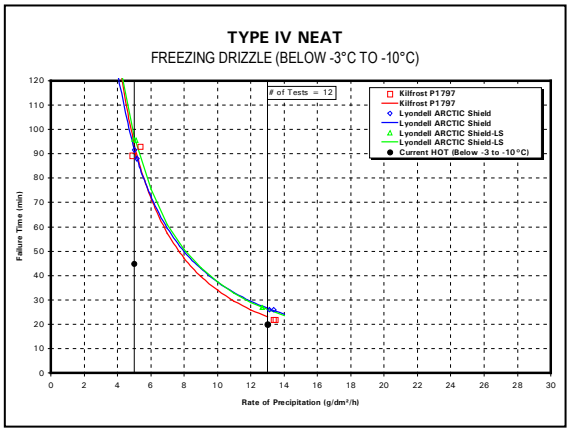
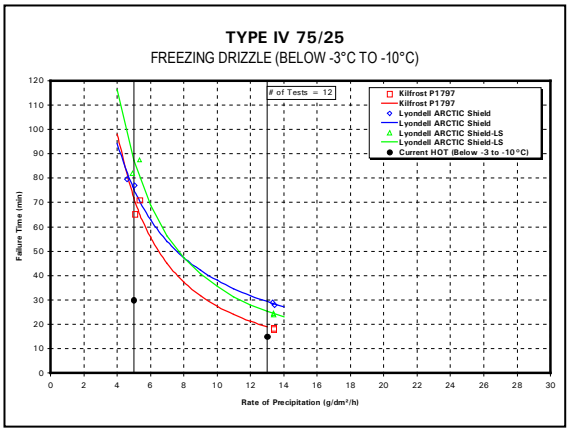

TYPE IV NEAT
FREEZING DRIZZLE (-3°C AND ABOVE)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

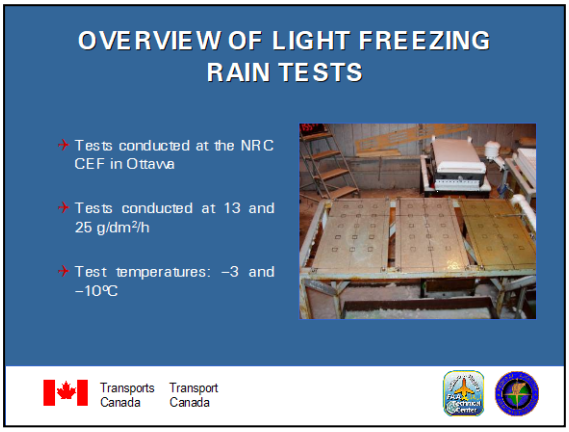

TYPE IV 75/25
FREEZING DRIZZLE (-3°C AND ABOVE)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

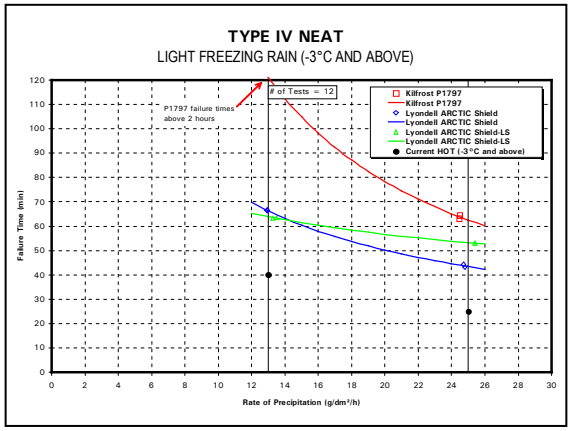

TYPE IV 50/50
FREEZING DRIZZLE (-3°C AND ABOVE)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

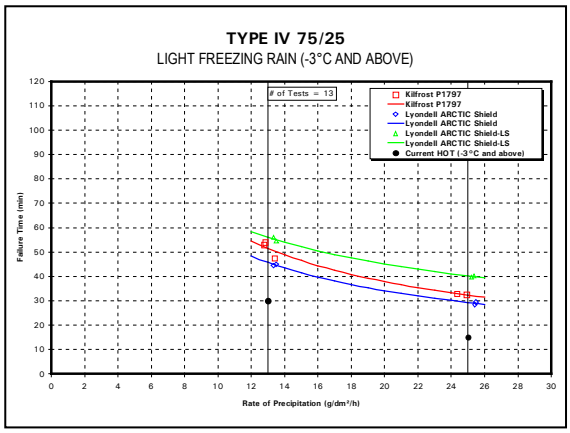

TYPE IV NEAT
FREEZING DRIZZLE (BELOW -3°C TO -10°C)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (Below -3 to -10°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

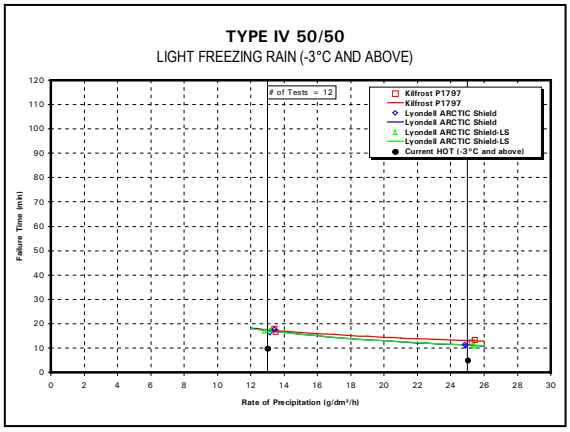

TYPE IV 75/25
FREEZING DRIZZLE (BELOW -3°C TO -10°C)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (Below -3 to -10°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

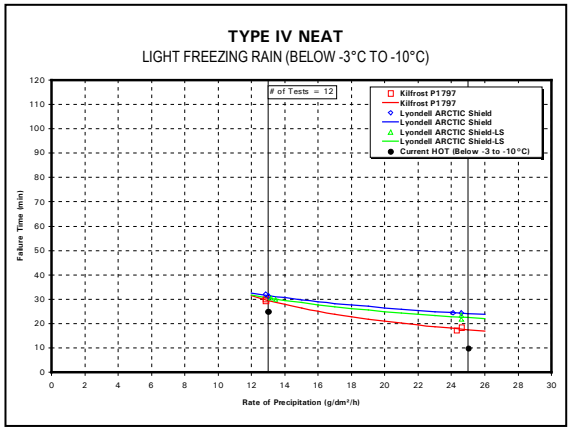

LIGHT FREEZING RAIN

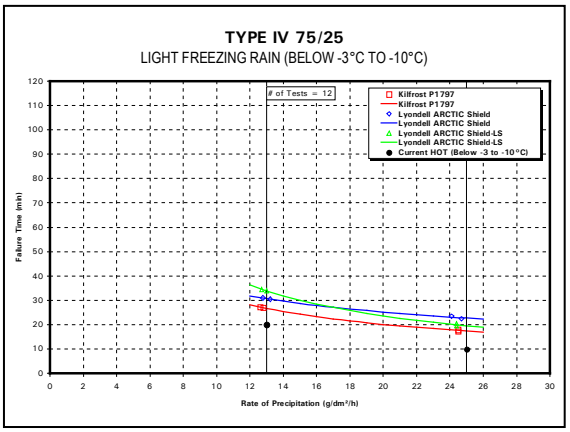

OVERVIEW OF LIGHT FREEZING RAIN TESTS
Tests conducted at the NRC CEF in Ottawa
Tests conducted at 13 and 25 g/dm²/h
Test temperatures: –3 and –10ºC
Transports Canada
Transport Canada


TYPE IV NEAT
LIGHT FREEZING RAIN (-3°C AND ABOVE)
P1797 failure times above 2 hours
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV 75/25
LIGHT FREEZING RAIN (-3°C AND ABOVE)
# of Tests = 13
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV 50/50
LIGHT FREEZING RAIN (-3°C AND ABOVE)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV NEAT
LIGHT FREEZING RAIN (BELOW -3°C TO -10°C)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (Below -3 to -10°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)







## OVERVIEW OF RAIN ON A COLD-SOAKED WING TESTS

**TEST SITE**

- Laboratory tests conducted at the National Research Council's Climatic Engineering Facility in Ottawa.

**TEST CONDITIONS**

- Drizzle and moderate rain were simulated:
  - Drizzle (low end) rate: 5 g/dm²/hr
  - Moderate rain (high end) rate: 75 g/dm²/hr

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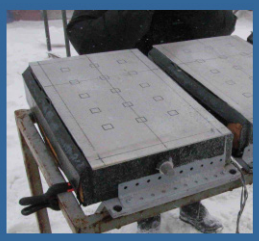
## OVERVIEW OF RAIN ON A COLD-SOAKED WING TESTS



- Boxes were filled with 65/35 glycol/water mixture which was cooled
- An insulating jacket was attached on all sides except the top
- Box depth was 7.5 cm
- The top surface was a standard flat plate

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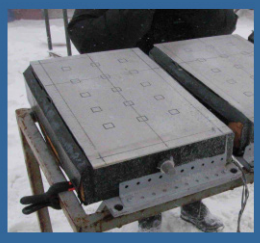
## OVERVIEW OF RAIN ON A COLD-SOAKED WING TESTS



- Plate surface temperatures were recorded using thermocouples embedded in the box
- Tests were started when the skin temperature was -10°C
- Ambient air temperature was 1°C

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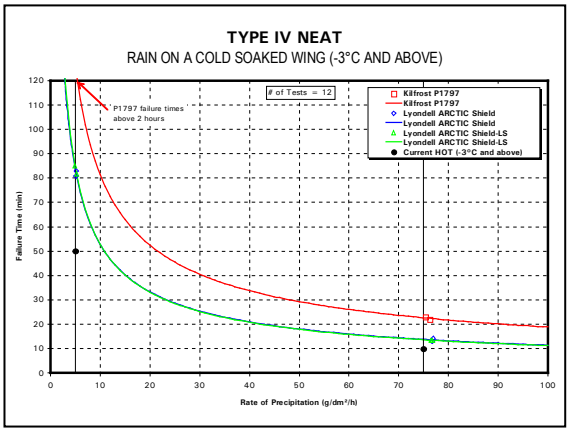
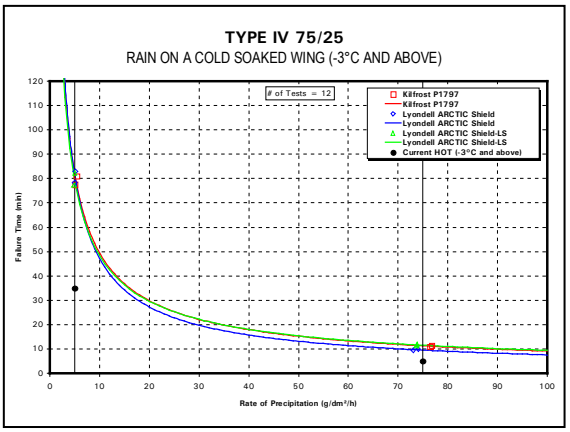
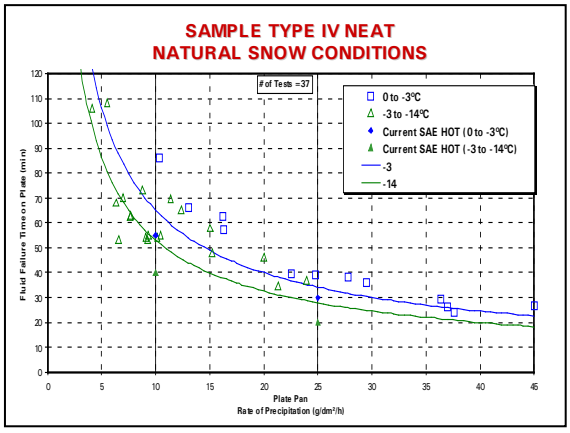
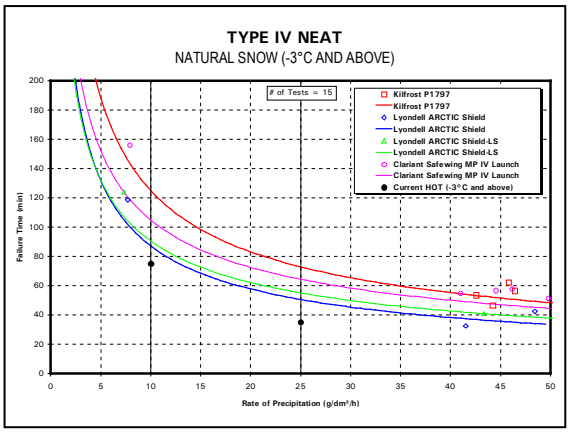


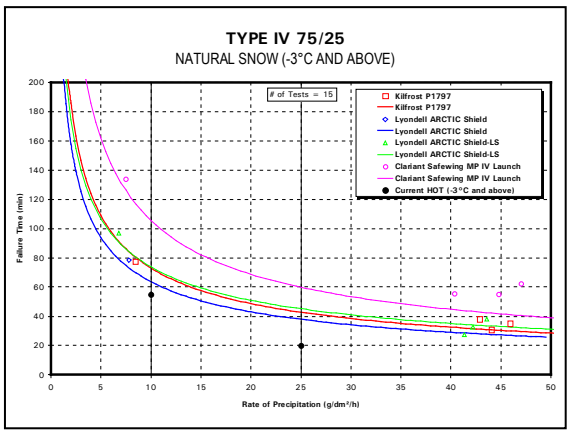

TYPE IV 75/25
RAIN ON A COLD SOAKED WING (-3°C AND ABOVE)
# of Tests = 12
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

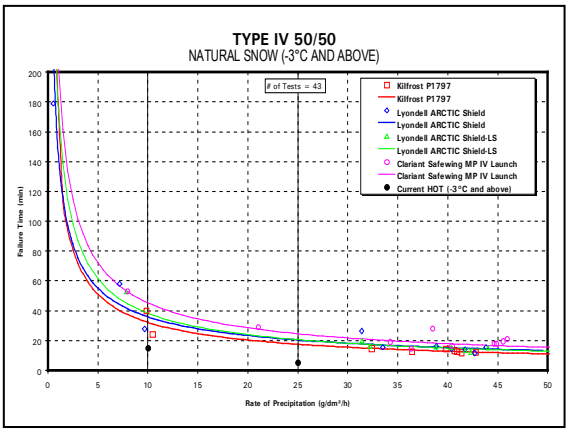

NATURAL SNOW

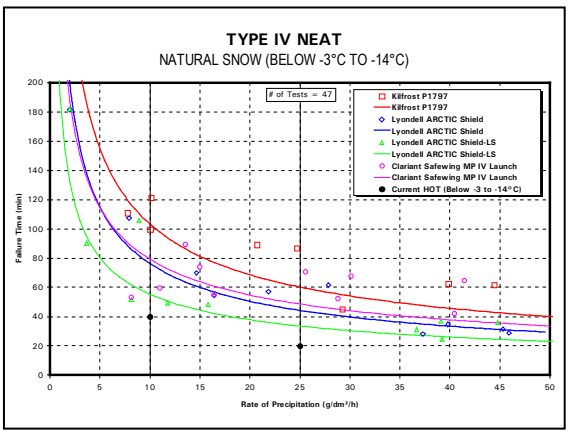

OVERVIEW OF NATURAL SNOW TESTS
Tests conducted at the APS test site at YUL
No control over rate, temperature, wind
Entire snow data set is considered when analyzing the performance of any fluid
Snow holdover time range is determined at 10 and 25 g/dm²/h
Transports Canada
Transport Canada

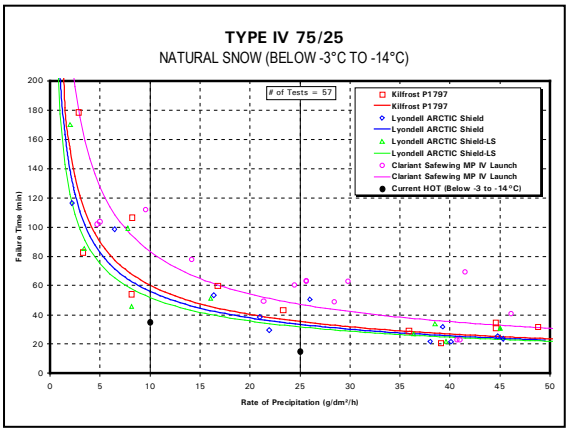

SAMPLE TYPE IV NEAT
NATURAL SNOW CONDITIONS
# of Tests =37
0 to -3°C
-3 to -14°C
Current SAE HOT (0 to -3°C)
Current SAE HOT (-3 to -14°C)
-3
-14
Fluid Failure Time on Plate (min)
Plate Pan
Rate of Precipitation (g/dm²/h)

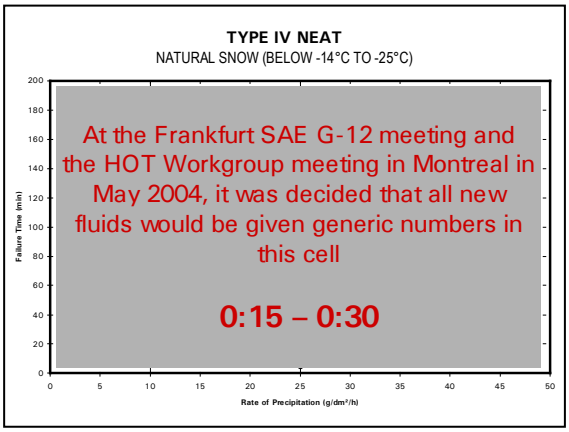

TYPE IV NEAT
NATURAL SNOW (-3°C AND ABOVE)
# of Tests = 15
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Clariant Safewing MP IV Launch
Clariant Safewing MP IV Launch
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

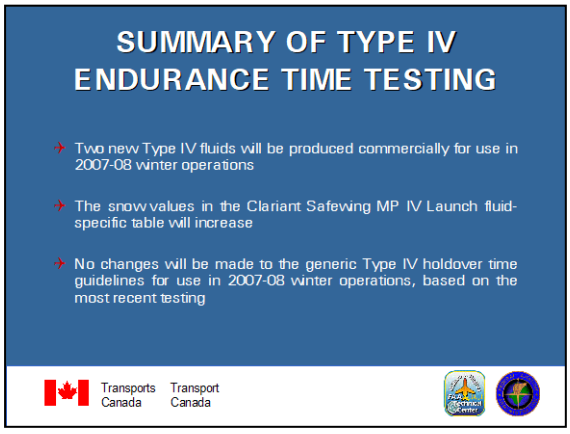

TYPE IV 75/25
NATURAL SNOW (-3°C AND ABOVE)
# of Tests = 15
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Clariant Safewing MP IV Launch
Clariant Safewing MP IV Launch
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)

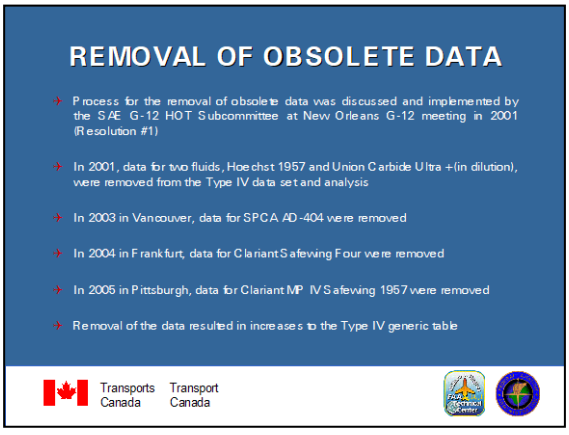

TYPE IV 50/50
NATURAL SNOW (-3°C AND ABOVE)
# of Tests = 43
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Clariant Safewing MP IV Launch
Clariant Safewing MP IV Launch
Current HOT (-3°C and above)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV NEAT
NATURAL SNOW (BELOW -3°C TO -14°C)
# of Tests = 47
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Clariant Safewing MP IV Launch
Clariant Safewing MP IV Launch
Current HOT (Below -3 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV 75/25
NATURAL SNOW (BELOW -3°C TO -14°C)
# of Tests = 57
Kilfrost P1797
Kilfrost P1797
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield
Lyondell ARCTIC Shield-LS
Lyondell ARCTIC Shield-LS
Clariant Safewing MP IV Launch
Clariant Safewing MP IV Launch
Current HOT (Below -3 to -14°C)
Failure Time (min)
Rate of Precipitation (g/dm²/h)


TYPE IV NEAT
NATURAL SNOW (BELOW -14°C TO -25°C)
At the Frankfurt SAE G-12 meeting and the HOT Workgroup meeting in Montreal in May 2004, it was decided that all new fluids would be given generic numbers in this cell
0:15 – 0:30
Failure Time (min)
Rate of Precipitation (g/dm²/h)


SUMMARY OF TYPE IV ENDURANCE TIME TESTING
Two new Type IV fluids will be produced commercially for use in 2007-08 winter operations
The snow values in the Clariant Safewing MP IV Launch fluid-specific table will increase
No changes will be made to the generic Type IV holdover time guidelines for use in 2007-08 winter operations, based on the most recent testing
Transports Canada
Transport Canada


REMOVAL OF OBSOLETE DATA
Process for the removal of obsolete data was discussed and implemented by the SAE G-12 HOT Subcommittee at New Orleans G-12 meeting in 2001 (Resolution #1)
In 2001, data for two fluids, Hoechst 1957 and Union Carbide Ultra +(in dilution), were removed from the Type IV data set and analysis
In 2003 in Vancouver, data for SPCA AD-404 were removed
In 2004 in Frankfurt, data for Clariant Safewing Four were removed
In 2005 in Pittsburgh, data for Clariant MP IV Safewing 1957 were removed
Removal of the data resulted in increases to the Type IV generic table
Transports Canada
Transport Canada

## REMOVAL OF OBSOLETE DATA

- Conditions for removal:
  - Not available for 4 years
  - Not re-certified
- No fluids appear to meet the conditions of Resolution #1 in 2007
- Resolution #1 will be included within the proposed ARP5718

Transports Canada Transport Canada

## FAA/TC TYPE IV HOT GUIDELINES 2007-08

FAA TYPE IV HOLDOVER TIME GUIDELINE

| Outside Air Temperature | | Type IV Fluid Concentration | Approximate Holdover Times Under Various Weather Conditions (hours: minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | Neat Fluid/Water (Volume %/Volume %) | Active Frost | Freezing Fog | Snow/ Snow Grains | Freezing Drizzle* | Light Freezing Rain | Rain on Cold Soaked Wing** | Other† |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:15-2:30 | 0:35-1:15 | 0:40-1:10 | 0:25-0:40 | 0:10-0:50 | |
| | | 75/25 | 5:00 | 1:05-1:45 | 0:20-0:55 | 0:35-0:50 | 0:15-0:30 | 0:05-0:35 | |
| | | 50/50 | 3:00 | 0:15-0:35 | 0:05-0:15 | 0:10-0:20 | 0:05-0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:20-1:20 | 0:20-0:45 | ***0:20-0:45 | ***0:10-0:25 | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:25-0:50 | 0:15-0:35 | ***0:15-0:30 | ***0:10-0:20 | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:15-0:40 | 0:15-0:30 | | | | |
| below -25 | below -13 | 100/0 | SAE Type IV fluid may be used below -25 °C (-13 °F) provided the freezing point of the fluid is at least 7 °C (13 °F) below the OAT and the aerodynamic acceptance criteria are met. Consider use of Type I when SAE Type IV fluid cannot be used. | | | | | | |

NO CHANGES

SAE TYPE IV FLUID HOLDOVER TIME GUIDELINES FOR WINTER 2007-2008[1]

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[2] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[3] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:15 – 2:30 | 0:35 – 1:15 | 0:40 – 1:10 | 0:25 – 0:40 | 0:10 – 0:50 | |
| | | 75/25 | 5:00 | 1:05 – 1:45 | 0:20 – 0:55 | 0:35 – 0:50 | 0:15 – 0:30 | 0:05 – 0:35 | |
| | | 50/50 | 3:00 | 0:15 – 0:35 | 0:05 – 0:15 | 0:10 – 0:20 | 0:05 – 0:10 | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:20 – 1:20 | 0:20 – 0:40 | 0:20 – 0:45[3] | 0:10 – 0:25[3] | CAUTION: No holdover time guidelines exist | |
| | | 75/25 | 5:00 | 0:25 – 0:50 | 0:15 – 0:35 | 0:15 – 0:30[3] | 0:10 – 0:20[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00[3] | 0:15 – 0:40[3] | 0:15 – 0:30[3] | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

Transport Canada

## TC/FAA TYPE IV FLUID-SPECIFIC HOT GUIDELINES 2007-08

1) CLARIANT SAFEWING MP IV 2001
2) CLARIANT SAFEWING MP IV PROTECT 2012
3) CLARIANT SAFEWING MP IV 2030 ECO
4) CLARIANT SAFEWING MP IV LAUNCH (REVISED)
5) DOW UCAR ULTRA+
6) DOW UCAR ENDURANCE EG106
7) KILFROST ABC-S
8) KILFROST ABC-S PLUS (REVISED)
9) LYONDELL ARCTIC SHIELD (NEW)
10) OCTAGON MAX-FLIGHT
11) OCTAGON MAX-FLIGHT '04
12) OCTAGON MAXFLO
13) SPCA AD-480

Transports Canada Transport Canada




APS
Aviation Inc.
AIRCRAFT DEICING RESEARCH
IN SIMULATED MIXED
CONDITIONS WITH ICE PELLETS
By
Marco Ruggi
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000
SAE G-12 HOT SUBCOMMITTEE
SAN DIEGO - MAY 14, 2007

## Allowance Times For Ice Pellets Conditions

- A working group meeting was held April 11-13th, 2007
- Attendees
  - Federal Aviation Administration
  - Transport Canada
  - APS
- Objective: Review current data and recommend allowance times for ice pellet and mixed ice pellet precipitation conditions

## Allowance Times For Ice Pellets Conditions

- Allowance times were generated for Ice pellet and mixed ice pellet conditions
- Results and recommendations have already been presented to industry

## Summary of Ice Pellet Allowance Times

| Ice Pellet and Ice Pellet mixed with: Light Ice Pellets, Snow Allowance Times | | | |
|---|---|---|---|
| Light Ice Pellets Only | Moderate Ice Pellets Only | Light Ice Pellets mixed with Snow | Light Ice Pellets mixed with Light Freezing Rain |
| | | | |
| - 5° C and above : 50 min | - 5° C and above : 25 min | - 5° C and above : 25 min | - 5° C and above : 25 min |
| | | | |
| Less than - 5°C : 30 min | Less than - 5°C : 10 min | Less than - 5° : not tested | Less than - 5° to -10°C : 10 min |
| | | | |

## Allowance Times For Ice Pellets Conditions

- Purpose of this presentation is to disseminate the information

## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## BACKGROUND

- Recent industry need to provide aircraft operators with holdover times for ice pellet conditions
- During the winter of 2006, FAA provided a 25-minute allowance as preliminary guideline
- Allowance based on the previous research conducted during the winter of 2005-06, primarily as a result of Falcon 20 aerodynamic research (SAE Lisbon 2006)
- Allowance was followed by a list of conditions restricting operations
  - i.e. Ice pellets alone, no mixed conditions

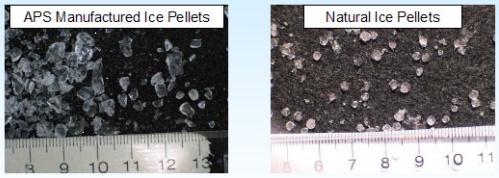
## BACKGROUND

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

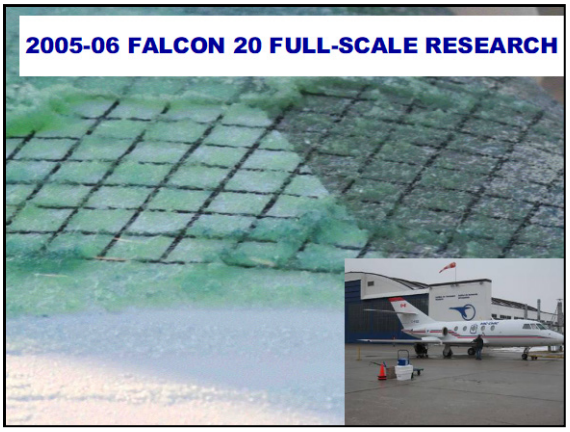
## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## APS SIMULATED ICE PELLETS




## 2005-06 FALCON 20 FULL-SCALE RESEARCH

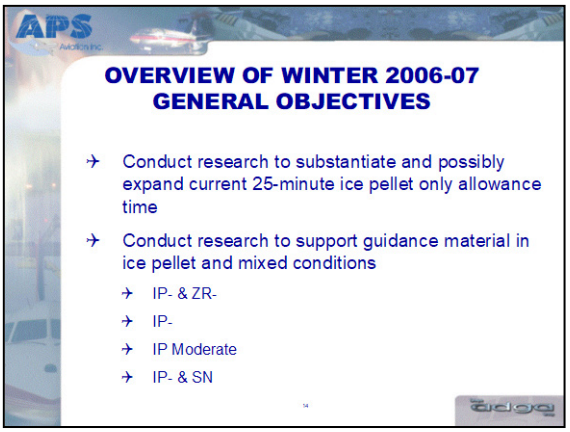


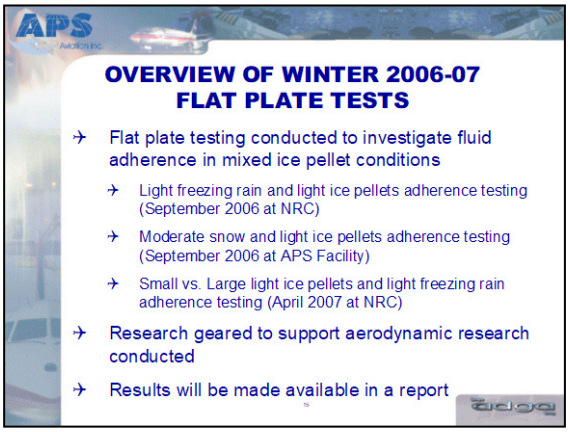
## 2005-06 NATURAL ICE PELLET ENDURANCE TIME RESEARCH

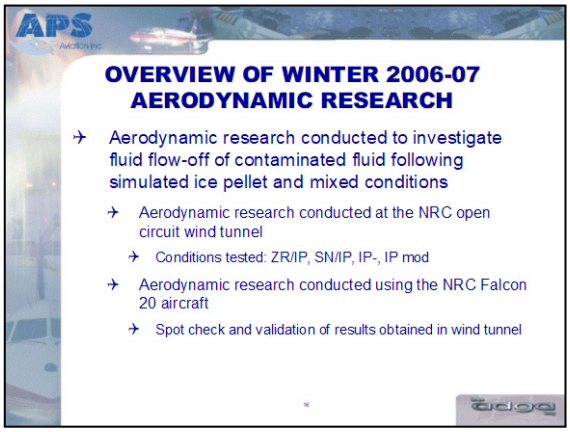


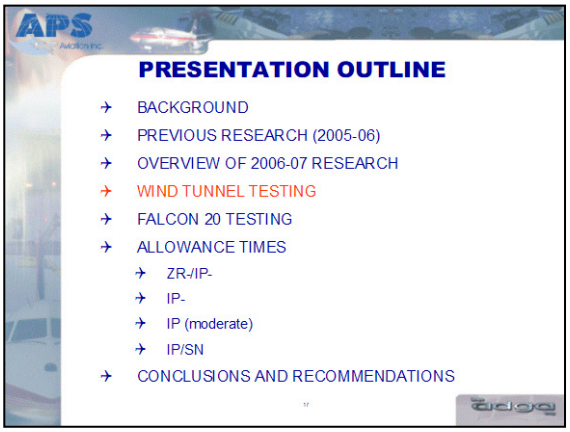
## PRESENTATION OUTLINE

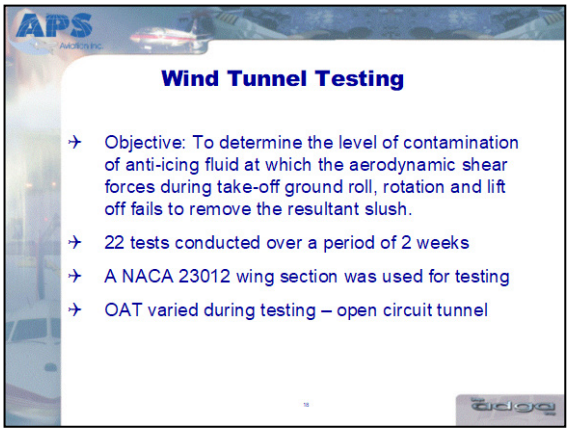
- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

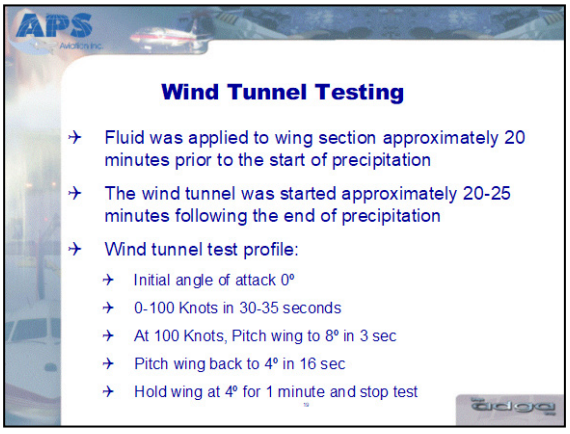

OVERVIEW OF WINTER 2006-07
GENERAL OBJECTIVES
Conduct research to substantiate and possibly expand current 25-minute ice pellet only allowance time
Conduct research to support guidance material in ice pellet and mixed conditions
IP- & ZR-
IP-
IP Moderate
IP- & SN

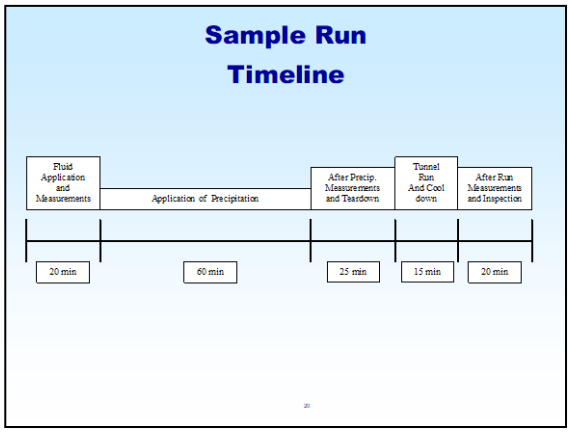

OVERVIEW OF WINTER 2006-07
FLAT PLATE TESTS
Flat plate testing conducted to investigate fluid adherence in mixed ice pellet conditions
Light freezing rain and light ice pellets adherence testing (September 2006 at NRC)
Moderate snow and light ice pellets adherence testing (September 2006 at APS Facility)
Small vs. Large light ice pellets and light freezing rain adherence testing (April 2007 at NRC)
Research geared to support aerodynamic research conducted
Results will be made available in a report

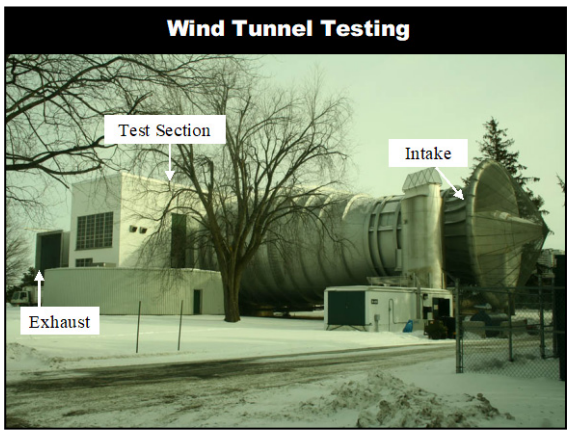

OVERVIEW OF WINTER 2006-07
AERODYNAMIC RESEARCH
Aerodynamic research conducted to investigate fluid flow-off of contaminated fluid following simulated ice pellet and mixed conditions
Aerodynamic research conducted at the NRC open circuit wind tunnel
Conditions tested: ZR/IP, SN/IP, IP-, IP mod
Aerodynamic research conducted using the NRC Falcon 20 aircraft
Spot check and validation of results obtained in wind tunnel


PRESENTATION OUTLINE
BACKGROUND
PREVIOUS RESEARCH (2005-06)
OVERVIEW OF 2006-07 RESEARCH
WIND TUNNEL TESTING
FALCON 20 TESTING
ALLOWANCE TIMES
ZR-/IP-
IP-
IP (moderate)
IP/SN
CONCLUSIONS AND RECOMMENDATIONS

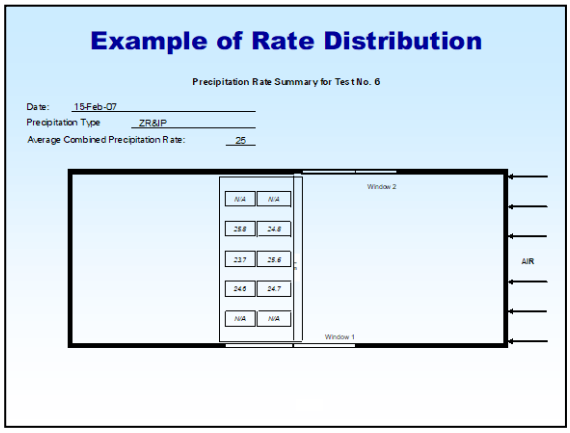

Wind Tunnel Testing
Objective: To determine the level of contamination of anti-icing fluid at which the aerodynamic shear forces during take-off ground roll, rotation and lift off fails to remove the resultant slush.
22 tests conducted over a period of 2 weeks
A NACA 23012 wing section was used for testing
OAT varied during testing – open circuit tunnel

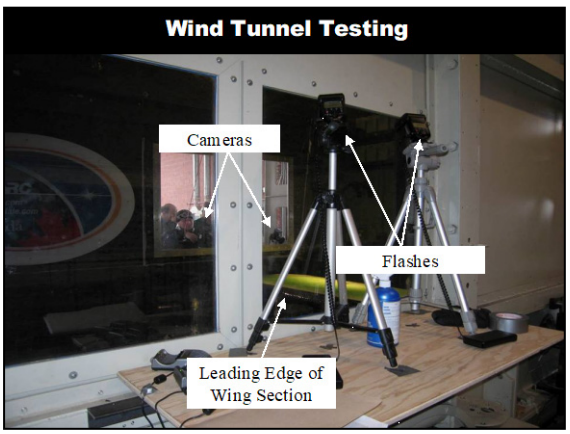

Wind Tunnel Testing
Fluid was applied to wing section approximately 20 minutes prior to the start of precipitation
The wind tunnel was started approximately 20-25 minutes following the end of precipitation
Wind tunnel test profile:
Initial angle of attack 0°
0-100 Knots in 30-35 seconds
At 100 Knots, Pitch wing to 8° in 3 sec
Pitch wing back to 4° in 16 sec
Hold wing at 4° for 1 minute and stop test

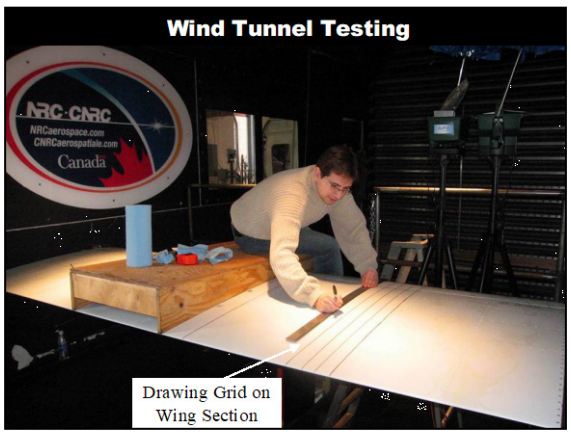

Sample Run
Timeline
Fluid Application and Measurements
Application of Precipitation
After Precip. Measurements and Teardown
Tunnel Run And Cool down
After Run Measurements and Inspection
20 min
60 min
25 min
15 min
20 min


Wind Tunnel Testing
Test Section
Intake
Exhaust

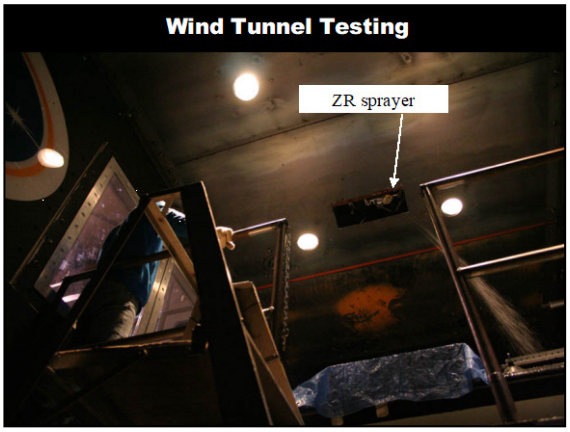

Wind Tunnel Testing
Trailing Edge of Wing Section
Rate Pans for Calibration


Example of Rate Distribution
Precipitation Rate Summary for Test No. 6
Date: 15-Feb-07
Precipitation Type ZR&IP
Average Combined Precipitation Rate: 25
Window 2
N/A
N/A
28.8
24.8
23.7
28.6
24.6
24.7
N/A
N/A
Window 1
AIR


Wind Tunnel Testing
Cameras
Flashes
Leading Edge of Wing Section


Wind Tunnel Testing
NRC·CNRC
NRCaerospace.com
CNRCaerospatiale.com
Canada
Drawing Grid on Wing Section




## Wind Tunnel Testing

- Conditions Tested:
  - Mixed ZR and IP (5 tests)
  - Mixed SN and IP (4 tests)
  - IP only (4 tests)
  - Fluid only and dry tests (5 tests)
- Also investigated:
  - ZR only (1 test)
  - Simulated stall runs (3 tests)

## Wind Tunnel Summary Test Log

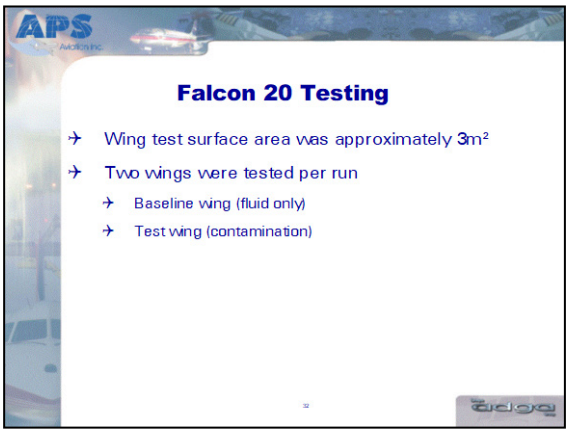
| Wind Tunnel Tests | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h | IP Rate g/dm²/h | SN Rate g/dm²/h | Precip. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) | Visual Severity Rating (1-5)<br>1 = best<br>5 = worst |
| 1 | 14 | Dry | Dry | 0 | 0 | 0 | - | -1.7 | -2 | - | |
| 1A | 16 | Dry | Dry | 0 | 0 | 0 | - | -7 | N/A | - | |
| 2 | 14 | PG | Baseline | 0 | 0 | 0 | - | -10 | -9 | - | |
| 3 | 14 | EG | Baseline | 0 | 0 | 0 | - | -11 | -8 | - | |
| 4 | 14 | PG | ZR | 26 | 0 | 0 | 60 | -2 | -1 | 1 | |
| 5 | 15 | PG | IP | 0 | 25 | 0 | 60 | -16.8 | -13 | 4.5 | |
| 6 | 15 | PG | ZR/IP | 20 | 5 | 0 | 40 | -8 | -7 | 5 | |
| 6A | 15 | PG | ZR/IP | 20 | 5 | 0 | 20 | -8 | -7 | 1 | |
| 7 | 22 | PG | IP | 0 | 25 | 0 | 60 | 1 | -5.5 | 1 | |
| 8 | 22 | EG | IP | 0 | 25 | 0 | 60 | 1 | -9 | 1 | |
| 9 | 22 | PG | IP (mod) | 0 | 75 | 0 | 30 | 3.2 | -7 | 2.5 | |
| 10 | 23 | PG | IP/ZR | 7 | 20 | 0 | 40 | -7.2 | -7 | 3 | |
| 11 | 23 | PG | ZR/IP | 20 | 5 | 0 | 40 | -1.9 | -4 | 2 | |
| 12 | 23 | EG | ZR/IP | 20 | 5 | 0 | 40 | -5.9 | -4 | 1 | |
| 13 | 23 | PG | Baseline | 0 | 0 | 0 | - | -5.7 | -5 | - | |
| SP1 | 20 | PG | IP/SN | 0 | 20 | 5 | 40 | -2 | -7 | 2 | |
| SP2 | 20 | PG | SN/IP | 0 | 5 | 20 | 40 | -3 | -6 | 1 | |
| SP3 | 20 | EG | IP/SN | 0 | 20 | 5 | 40 | 1.2 | -8 | 1 | |
| SP4 | 23 | PG | IP/SN | 0 | 25 | 25 | 30 | 3.2 | -7 | 2 | |
| A1 | 21 | PG | Stall Run | 0 | 0 | 0 | - | 3.7 | 1 | - | |
| A2 | 21 | EG | Stall Run | 0 | 0 | 0 | - | 4.6 | 0.5 | - | |
| A3 | 21 | Dry | Stall Run | 0 | 0 | 0 | - | 2.3 | N/A | | |

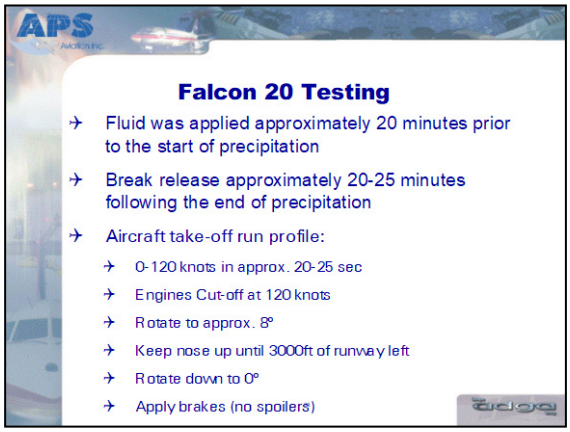
## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

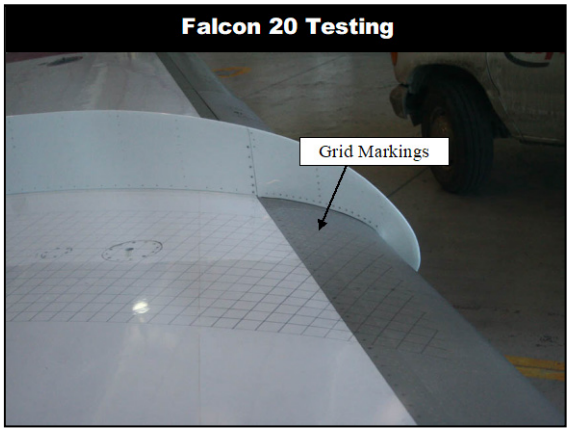
## Falcon 20 Testing

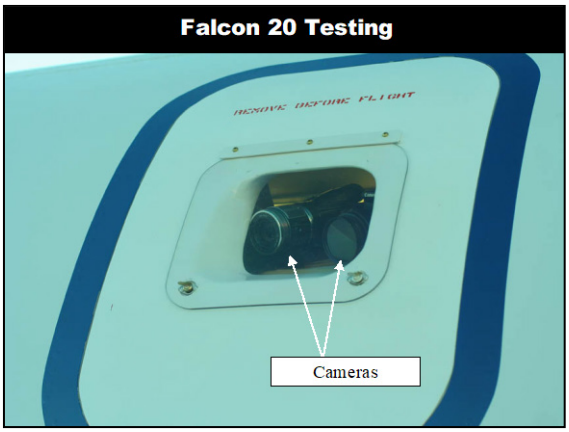
- Objective: To determine the level of contamination of anti-icing fluid at which the aerodynamic shear forces during take-off ground roll and rotation fails to remove the resultant slush.
- 6 tests conducted over a period of 4 days
- Tests conducted at YOW

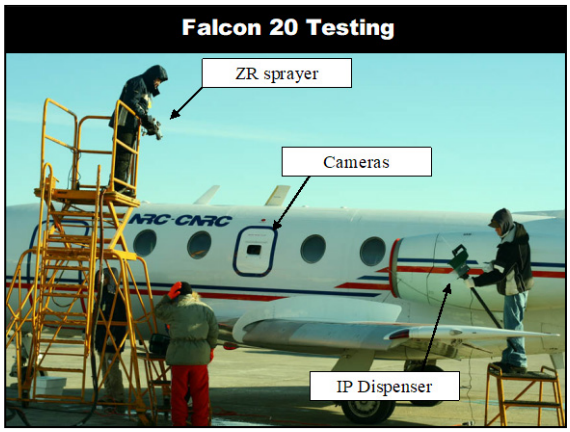

APS
Falcon 20 Testing
Wing test surface area was approximately 3m²
Two wings were tested per run
Baseline wing (fluid only)
Test wing (contamination)

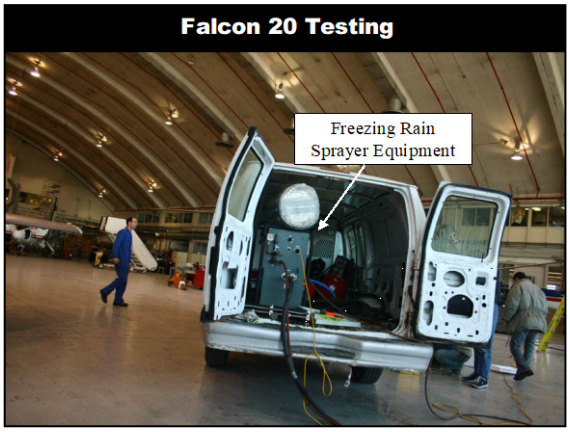

APS
Falcon 20 Testing
Fluid was applied approximately 20 minutes prior to the start of precipitation
Break release approximately 20-25 minutes following the end of precipitation
Aircraft take-off run profile:
0-120 knots in approx. 20-25 sec
Engines Cut-off at 120 knots
Rotate to approx. 8°
Keep nose up until 3000ft of runway left
Rotate down to 0°
Apply brakes (no spoilers)

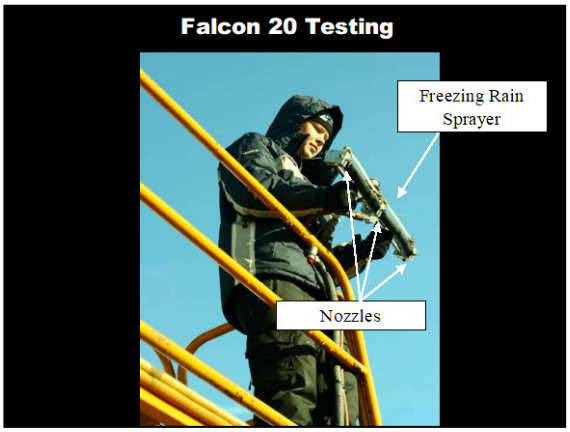

Falcon 20 Testing
Falcon 20 Aircraft

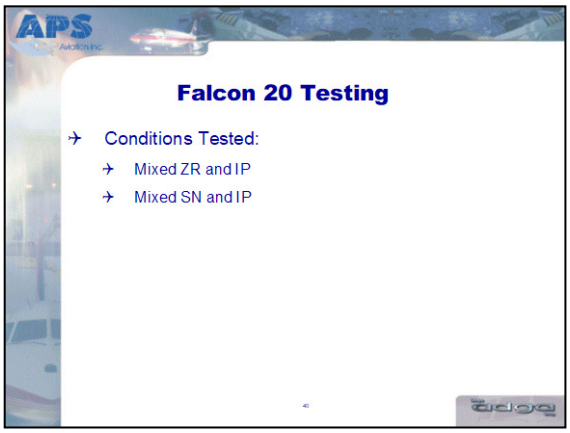

Falcon 20 Testing
Grid Markings


Falcon 20 Testing
Cameras


Falcon 20 Testing
ZR sprayer
Cameras
NRC·CNRC
IP Dispenser

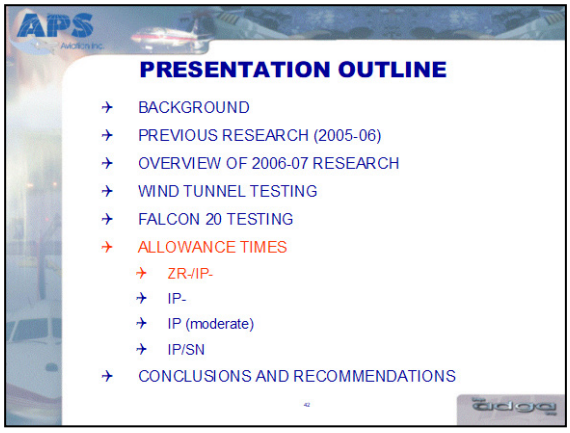


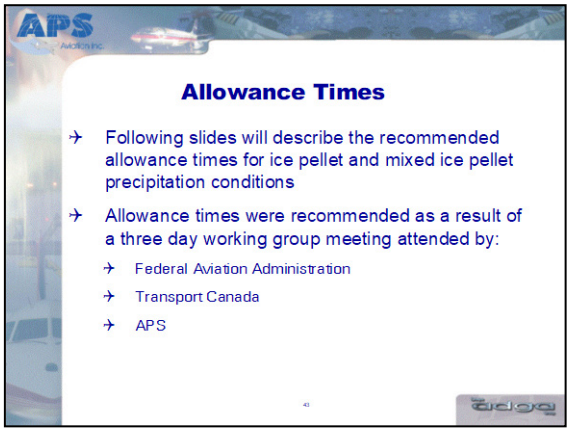




## Falcon 20 Summary Test Log

| Falcon 20 Tests | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Test # | Date | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | OAT (°C) | Wing Avg Temp (°C) |
| 3S | Feb-28 | PG | IP/SN | - | 25 | 25 | 30 | -8 | -11 |
| 3P | Feb-28 | PG | Baseline | - | - | - | - | -8 | -10.5 |
| 4S | Feb-28 | PG | Baseline | - | - | - | - | -10 | -6 |
| 4P | Feb-28 | PG | ZR/IP | 20 | 5 | - | 40 | -10 | -6 |
| 5S | Mar-01 | EG | Baseline | - | - | - | - | -11 | -14 |
| 5P | Mar-01 | PG | IP/SN | - | 20 | 20 | 30 | -11 | -13 |



## Allowance Times

- ANALYSIS METHODOLOGY
  - Contaminated fluid tests were compared to baseline fluid only tests and dry wing tests
  - Visual severity was determined based on observations during the test and review of photography
    - Ratings ranged from 1 to 5 with 5 being the worst
  - Lift coefficient data was acquired at the end of the testing and used to investigate the effects of contamination

## Mixed ZR- and IP- Conditions

- 5 Wind Tunnel Tests Conducted
- 2 Falcon 20 tests Conducted

Wind Tunnel Tests

| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 15 | PG | ZR/IP | 20 | 5 | 0 | 40 | -8 | -7 | 5 |
| 6A | 15 | PG | ZR/IP | 20 | 5 | 0 | 20 | -8 | -7 | 1 |
| 10 | 23 | PG | IP/ZR | 7 | 20 | 0 | 40 | -7.2 | -7 | 3 |
| 11 | 23 | PG | ZR/IP | 20 | 5 | 0 | 40 | -1.9 | -4 | 2 |
| 12 | 23 | EG | ZR/IP | 20 | 5 | 0 | 40 | -5.9 | -4 | 1 |

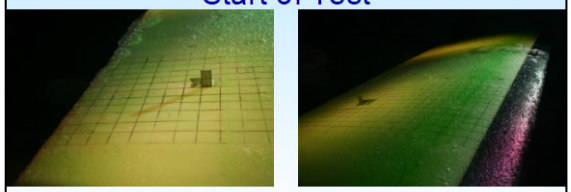
Falcon 20 Tests

| Test # | Date | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | OAT (°C) | Wing Avg Temp (°C) |
|---|---|---|---|---|---|---|---|---|---|
| 4P | Feb-28 | PG | ZR/IP | 20 | 5 | - | 40 | -10 | -6 |
| 6P | Mar-01 | EG | ZR/IP | 20 | 5 | - | 30 | -11 | -4 |

**Test #11**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min,
OAT-2°C, Wing -4°C
Photos

**Test #2**
Type IV PG, No Contamination
OAT-10°C, Wing -9°C
Photos

**Test #6**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min,
OAT-8°C, Wing -7°C
Start of Test

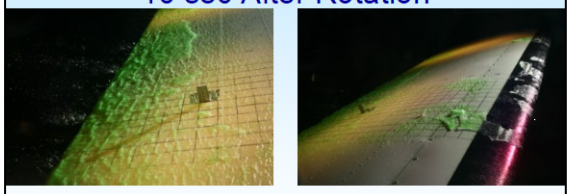


**Test #6**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min,
OAT-8°C, Wing -7°C
Before Rotation



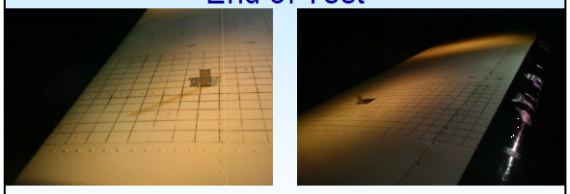
**Test #6**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min,
OAT-8ºC, Wing -7°C

10 sec After Rotation

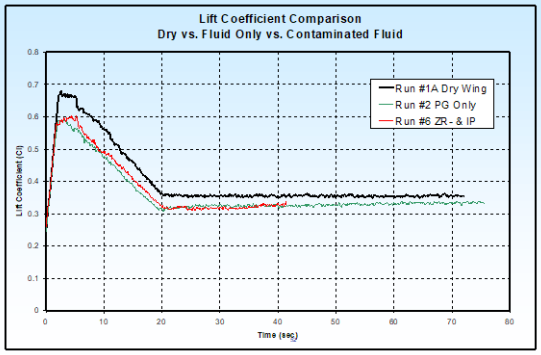


**Test #6**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min,
OAT-8ºC, Wing -7°C

End of Test



**Lift Coefficient Comparison**



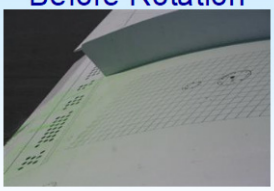

**Test #4p**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min
OAT -10°C, Wing -6ºC

Start of Test



**Test #4p**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min
OAT -10°C, Wing -6ºC

Before Rotation



**Test #4p**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min
OAT -10°C, Wing -6ºC

10 sec After Rotation



**Test #4p**
Type IV PG, ZR-&IP- 20+5 g/dm²/h, 40 min
OAT -10°C, Wing -6°C

## End of Test



## Mixed ZR- and IP- Conditions

- Observations and Recommendations
  - ZR is the primary concern due to adherence and increased roughness with presence of IP
  - Recommend using lower limit from Generic ZR HOT as basis
    - -3 and above: 25 minutes
    - -3 to -10: 10 minutes
  - Use temperature -5 ºC (instead of -3 ºC) to allow for increased latitude to operators
    - Good results from data in -3 to -10ºC temp range (I.e. lift loss and residual contamination)
  - Allow operations down to -10°C
    - Occurrence of ZR below -10ºC is infrequent
    - Limited data collected below -10ºC

## Mixed ZR- and IP- Conditions

- Recommended Allowance

| Light Ice Pellets mixed with Light Freezing Rain |
|---|
| |
| - 5° C and above : 25 min |
| |
| Less than - 5° to -10°C : 10 min |
| |

## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

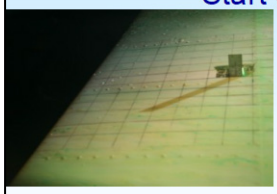
## IP- Only Conditions

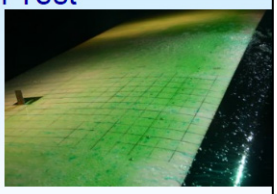
- 3 Wind Tunnel Tests Conducted
- IP only tests were NOT conducted with Falcon 20 this year
- 2005-06 Falcon 20 tests were referenced

| Wind Tunnel Tests | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) |
| 5 | 15 | PG | IP | 0 | 25 | 0 | 60 | -16.8 | -13 | 4.5 |
| 7 | 22 | PG | IP | 0 | 25 | 0 | 60 | 1 | -5.5 | 1 |
| 8 | 22 | EG | IP | 0 | 25 | 0 | 60 | 1 | -9 | 1 |

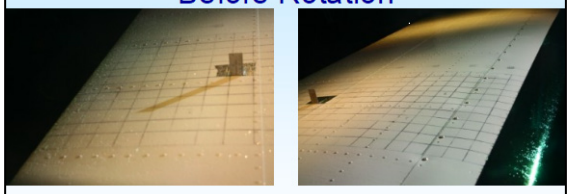
**Test #7**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT +1ºC, Wing -6°C

## Start of Test

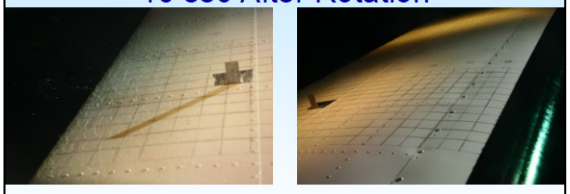




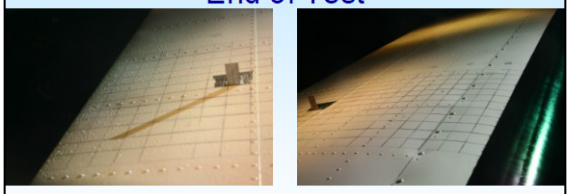
**Test #7**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT +1°C, Wing -6°C
Before Rotation



**Test #7**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT +1°C, Wing -6°C
10 sec After Rotation



**Test #7**
Type IV PG, IP- 25 g/dm²/h, 60 min
OAT +1°C, Wing -6°C
End of Test



## IP- Only Conditions

- Observations and Recommendations
  - Wind Tunnel 60min exposure tests at warmer temperatures demonstrated positive results (I.e. lift loss and visual contamination following run)
    - Suggest allowance of 50 min for warmer temperatures due to lack of fluids tested and possible variability in rates
  - Test #5 for 60 min at colder temperature showed residual contamination
    - Suggest allowance of 30 min for colder temperatures
    - -5°C temperature cut-off suggested to be consistent with ZR/IP

## IP- Only Conditions

- Allowance

| Light Ice Pellets Only |
|---|
| |
| - 5° C and above : 50 min |
| |
| Less than - 5°C : 30 min |
| |

## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## Moderate IP Only Conditions

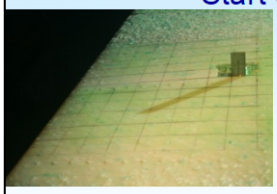
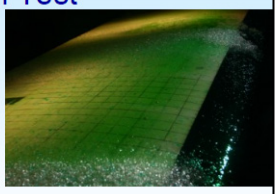
- 1 Wind Tunnel Test Conducted
- Moderate IP tests were NOT conducted with Falcon 20 this year
- 2005-06 Falcon 20 tests were referenced

Wind Tunnel Tests

| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h | IP Rate g/dm²/h | SN Rate g/dm²/h | Precp. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 22 | PG | IP (mod) | 0 | 75 | 0 | 30 | 3.2 | -7 | 2.5 |

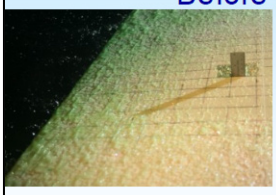
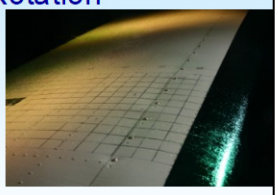
**Test #9**
Type IV PG, IP 75 g/dm²/h, 30 min
OAT +3ºC, Wing -7°C

## Start of Test

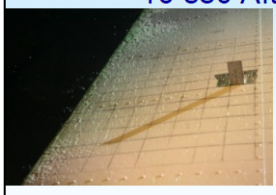
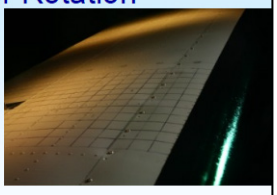
**Test #9**
Type IV PG, IP 75 g/dm²/h, 30 min
OAT +3ºC, Wing -7°C

## Before Rotation

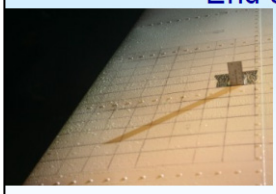
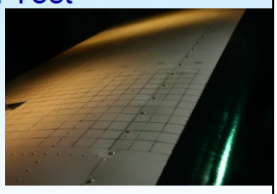
**Test #9**
Type IV PG, IP 75 g/dm²/h, 30 min
OAT +3ºC, Wing -7°C

## 10 sec After Rotation

**Test #9**
Type IV PG, IP 75 g/dm²/h, 30 min
OAT +3ºC, Wing -7°C

## End of Test

## Moderate IP Only Conditions

- Observations and Recommendations
  - Wind Tunnel test demonstrated positive results (I.e. lift loss and minimal visual contamination following run)
    - Suggest allowance of 25 min for warmer temperatures due to lack of fluids tested and possible variability in rates
    - Suggest allowance of 10 min for temperatures below -5ºC based on wind tunnel test and previous Falcon 20 data collected (2005-06)
  - Flat plate tests conducted at moderate IP rates supported recommendations

## Moderate IP Only Conditions

- Allowance

| Moderate Ice Pellets Only |
|---|
| - 5° C and above : 25 min |
| Less than - 5°C : 10 min |

## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## IP-/SN Conditions

- 4 Wind Tunnel Tests Conducted
- 2 Falcon 20 tests Conducted

Wind Tunnel Tests

| Test # | Feb day | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | Tunnel OAT (°C) | Wing Avg Temp (°C) | Visual Severity Rating (1-5) |
|---|---|---|---|---|---|---|---|---|---|---|
| SP1 | 20 | PG | IP/SN | 0 | 20 | 5 | 40 | -2 | -7 | 2 |
| SP2 | 20 | PG | SN/IP | 0 | 5 | 20 | 40 | -3 | -6 | 1 |
| SP3 | 20 | EG | IP/SN | 0 | 20 | 5 | 40 | 1.2 | -8 | 1 |
| SP4 | 23 | PG | IP/SN | 0 | 25 | 25 | 30 | 3.2 | -7 | 2 |

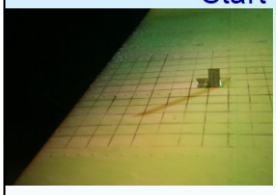
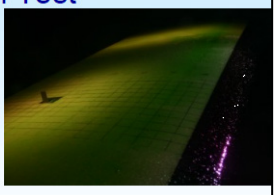
Falcon 20 Tests

| Test # | Date | Type IV Fluid | Condition | ZR Rate g/dm²/h) | IP Rate g/dm²/h) | SN Rate g/dm²/h) | Precp. Time (min) | OAT (°C) | Wing Avg Temp (°C) |
|---|---|---|---|---|---|---|---|---|---|
| 3S | Feb-28 | PG | IP/SN | - | 25 | 25 | 30 | -8 | -11 |
| 5P | Mar-01 | PG | IP/SN | - | 20 | 20 | 30 | -11 | -13 |

## Test #SP1

Type IV PG, IP-&S 20+5 g/dm²/h, 40 min
OAT -2ºC, Wing -7°C

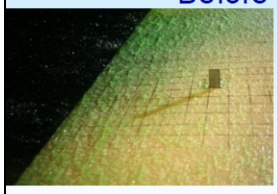
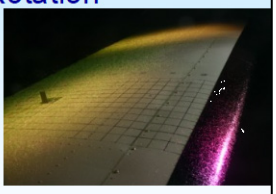
Start of Test

## Test #SP1

Type IV PG, IP-&S 20+5 g/dm²/h, 40 min
OAT -2ºC, Wing -7°C

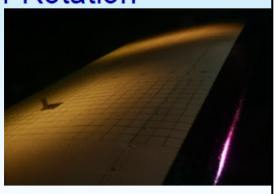
Before Rotation

## Test #SP1

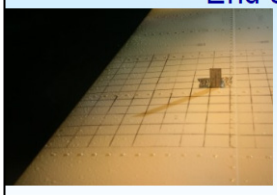
Type IV PG, IP-&S 20+5 g/dm²/h, 40 min
OAT -2ºC, Wing -7°C

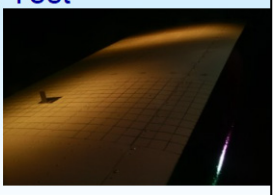
10 sec After Rotation

**Test #SP1**
Type IV PG, IP-&S 20+5 g/dm²/h, 40 min
OAT -2ºC, Wing -7°C

## End of Test





## IP-/SN Conditions

- Observations and Recommendations
  - Wind tunnel tests indicated that applying IP- only allowance times was not feasible
    - Testing at colder temperatures showed contamination at end of run
  - WT tests demonstrated minimal lift loss and minimal visual contamination following run at warmer temperatures
    - -5ºC temp range chosen to be consistent with ZR/IP allowance
    - Suggest allowance of 25 min for above -5ºC based on current data collected
    - No allowance for temperatures below -5ºC due to lack of data collected

## IP-/SN Conditions

- Allowance

| Light Ice Pellets mixed with Snow |
|---|
| |
| - 5° C and above : 25 min |
| |
| Less than - 5° : not tested |
| |

## PRESENTATION OUTLINE

- BACKGROUND
- PREVIOUS RESEARCH (2005-06)
- OVERVIEW OF 2006-07 RESEARCH
- WIND TUNNEL TESTING
- FALCON 20 TESTING
- ALLOWANCE TIMES
  - ZR-/IP-
  - IP-
  - IP (moderate)
  - IP/SN
- CONCLUSIONS AND RECOMMENDATIONS

## Summary of Ice Pellet Allowance Times

| Ice Pellet and Ice Pellet mixed with: Light Ice Pellets, Snow Allowance Times | | | |
|---|---|---|---|
| Light Ice Pellets Only | Moderate Ice Pellets Only | Light Ice Pellets mixed with Snow | Light Ice Pellets mixed with Light Freezing Rain |
| | | | |
| - 5° C and above : 50 min | - 5° C and above : 25 min | - 5° C and above : 25 min | - 5° C and above : 25 min |
| | | | |
| Less than - 5°C : 30 min | Less than - 5°C : 10 min | Less than - 5° : not tested | Less than - 5° to -10°C : 10 min |
| | | | |

## Recommendations

- Future Wind Tunnel Work
  - Additional testing to refine allowance times
  - Conduct testing with different wings (maybe super critical.)
  - Verify results at lower speeds
  - Conduct testing at lower temperatures
  - Conduct testing with bare wing contamination (no fluid)
  - Conduct tests in mixed Rain and Ice pellet conditions

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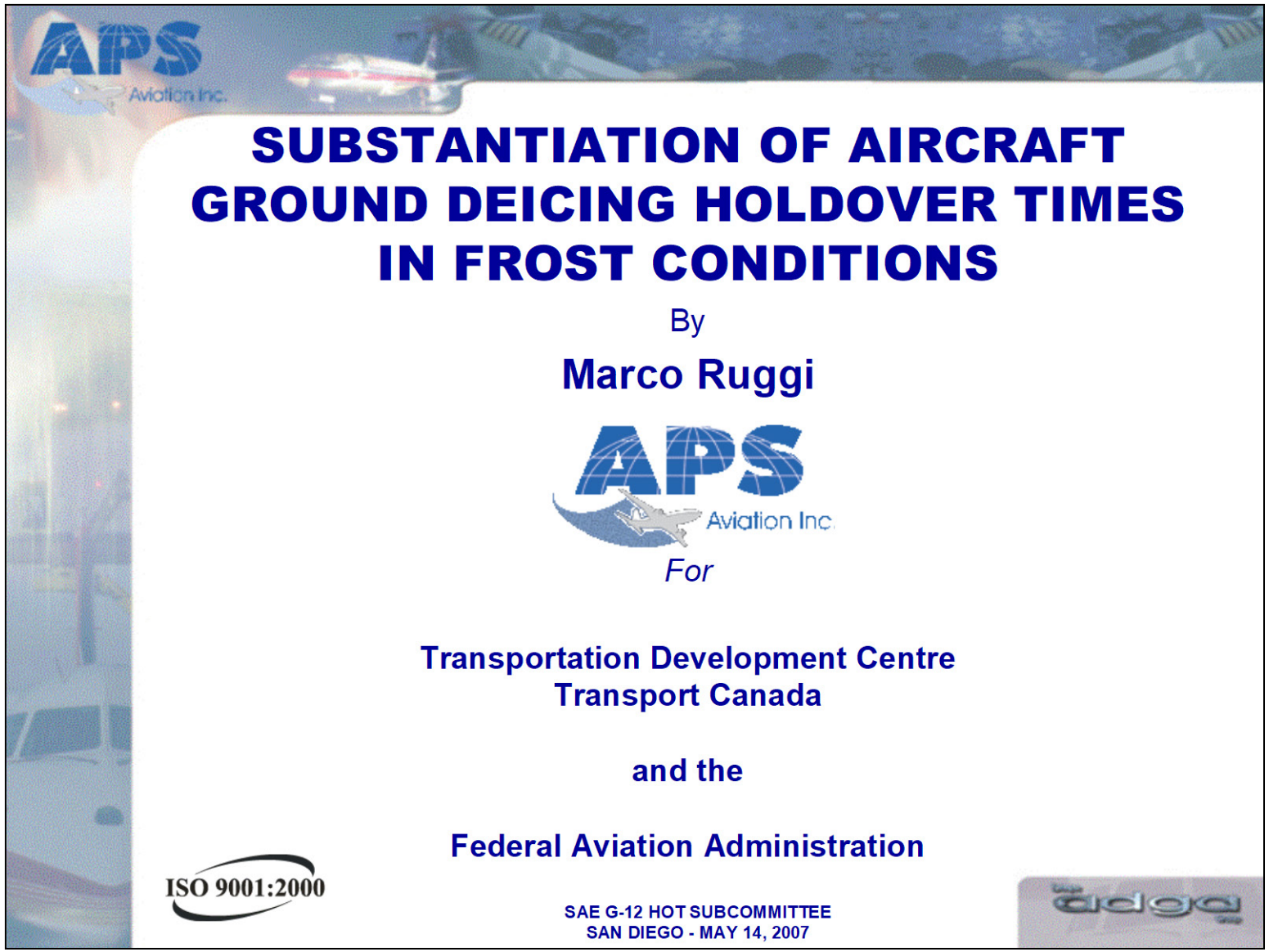

APS
Aviation Inc.
SUBSTANTIATION OF AIRCRAFT GROUND DEICING HOLDOVER TIMES IN FROST CONDITIONS
By
Marco Ruggi
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000
SAE G-12 HOT SUBCOMMITTEE
SAN DIEGO - MAY 14, 2007

## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

## BACKGROUND

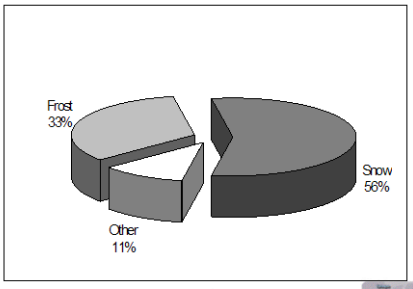
- FREQUENCY OF OCCURENCE
  - A survey of deicing activities at airports in North America, Europe and Asia was reported in TC report TP 14375E, *Winter Weather Impact on Holdover Time Table Format (1995-2004)*
  - The survey showed that in airline operations, removal of frost contamination represents a significant portion of deicing operations.

## BACKGROUND

- FREQUENCY OF OCCURENCE
  - The survey reported that at airport locations having relatively mild winter climates such as London and Paris, close to 90 percent of all deicing operations were frost removal.
  - In colder winter climates such as Montreal, where other forms of winter contamination such as snow are more prevalent, up to 25 percent of deicing operations are frost-related.

## BACKGROUND

- Frequency of Deicing Operations Airport Survey 2000-03




## BACKGROUND

- CURRENT HOT'S
  - HOT guidelines are based on endurance time test data for each certified fluid, measured in prescribed temperature and precipitation conditions.
  - Precipitation conditions include freezing fog, snow, freezing drizzle, freezing rain and rain on a cold-soaked wing.

## BACKGROUND

- CURRENT HOT'S
  - Frost HOT have always been a part of the HOT guidelines, however fluid endurance times in frost have never been measured.
  - The current values for frost HOT reflect information from High Humidity Endurance Tests (HHET).

## BACKGROUND

- CURRENT HOT'S

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water | Approximate Holdover Times Under Various (hours:minutes) | | | |
|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | (Volume %/Volume %) | Active Frost | | | |
| | | | Type I | Type II | Type III | Type IV |
| -3 and above | 27 and above | 100/0 | 0:45 | 8:00 | 2:00 | 12:00 |
| | | 75/25 | | 5:00 | 1:00 | 5:00 |
| | | 50/50 | | 3:00 | 0:30 | 3:00 |
| below -3 to -14 | below 27 to 7 | 100/0 | | 8:00 | 2:00 | 12:00 |
| | | 75/25 | | 5:00 | 1:00 | 5:00 |
| below -14 to -25 | below 7 to -13 | 100/0 | | 8:00 | 2:00 | 12:00 |

## BACKGROUND

- CURRENT HOT'S
  - Previous indoor laboratory attempts to substantiate current HOT showed some questionable discrepancies in the results
    - Testing conducted at Institut de Recherche d'Hydro-Québec (IREQ)
  - It was recommended that outdoor testing in natural frost conditions be conducted for Type I,II,III,IV fluids

## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

## METHODOLOGY

- Fluid endurance time testing in frost conditions was conducted using standard aluminum test plates painted white using aircraft grade paint.
- An insulation backing was mounted onto each white-painted test plate to avoid heat exchange via the underside
- Testing frost production on this surface was found to be representative of aircraft wing surfaces, where only the skin surface is exposed.
  - Previous full-scale validation of the test surfaces was conducted by APS

## METHODOLOGY

- **Frost Plate with Insulated Backing**



## METHODOLOGY

- **Test Stand with Insulated Frost Test Plates**



## METHODOLOGY

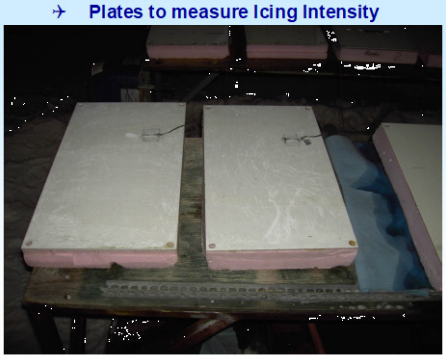
- Tests were generally conducted whenever conditions were suitable for frost accretion
- Typical test conditions:
  - Outside Ambient Temperature: Below 3°C
  - Relative Humidity: Above 60%
  - Wind Speed: Less than 5 km/h
  - Sky Condition: Clear

## METHODOLOGY

- To measure and document the rate of frost accretion, two test surfaces were weighed at half hour to one hour intervals depending on the frost accretion intensity
- Frost rates generally ranged from 0.02 to 0.2 g/dm²/hr
- Thermistor probes were attached at the 15 cm line of each test plate
  - Temperature was monitored and backed up at the end of each test session

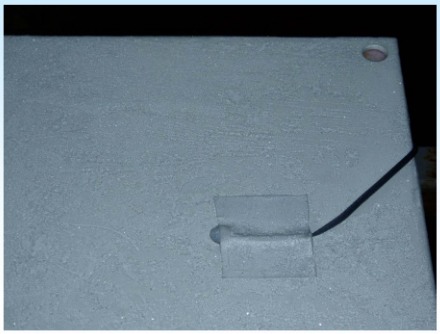
## METHODOLOGY

- Plates to measure Icing Intensity



## METHODOLOGY

- Thermistor on Frosted Plate at 15 cm Line



## METHODOLOGY

- FLUIDS TESTED
  - Type I – 4 fluids
  - Type II – 5 fluids
  - Type III – 1 fluid
  - Type IV – 8 fluids
- Type II,III,IV fluids were tested at neat, 75/25, and 50/50 dilutions

## TEST PLAN

- Type I tests
- Type II, III, IV tests
- Measure and document icing intensities
- Measure and document plate vs. OAT data

## PRESENTATION OUTLINE

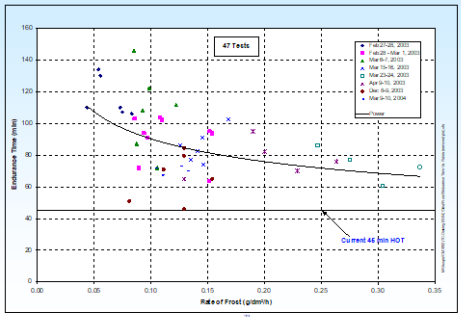
- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

## TYPE I TESTS

- Forty-seven tests were conducted outdoors using insulated white-painted aluminum surfaces during two winter seasons
- Testing was conducted with 4 Type I fluids
- A review of the measured test conditions indicated that the data set was generally comprehensive and representative of the natural environment.

## TYPE I TESTS

- Endurance Time vs. Icing Intensity




## TYPE I TESTS

- CONCLUSION
  - The test results show that the measured endurance times do not violate the long used HOT of 45 minutes.
  - Two tests produced endurance times that came close to 45 minutes
  - Based on the data collected, the Type I HOTs have been substantiated.
  - A note will be included in ARP 5945 indicating that testing is not required for frost if the fluid meets the certification requirements

## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

## TYPE II TESTS

- 62 tests were conducted outdoors using insulated white-painted aluminum surfaces
  - 26 tests were stopped due to fluid failure
  - 36 tests were stopped prior to fluid failure
    - 34 tests did not fail before sunrise
    - 2 tests stopped due to rising wind conditions
- Testing was conducted with 5 Type II fluids

## TYPE II TESTS

- Frost HOT Values and Endurance Time Test Results

| OAT (°C) | Concentration | Type II | | |
|---|---|---|---|---|
| | | Current HOT Time (hours) | Failed Tests (hours) | Stopped Tests (hours) |
| Above -3 | 100/0 | 8.0 | | 11.6[10] **12.3[10]**<br>**10.8[10]** **12.4[10]** |
| | 75/25 | 5.0 | **7.4** | 11.6[10] **11.6[10]**<br>**10.0[10]** **11.6[10]** |
| | 50/50 | 3.0 | 6.1<br>1.9 | **10.0[10]**<br>**11.6[10]** |
| Below -3 to -14 | 100/0 | 8.0 | 9.5<br>10.5<br>10.4<br>11.9 | 9.5[1] 12.8[10]<br>13.6[1] 11.6[11]<br>13.5[1]<br>13.3[1]<br>12.8[1]<br>12.9[1]<br>12.8[1]<br>12.9[10] |
| | 75/25 | 5.0 | 8.2 2.5<br>9.5 3.4<br>6.7 4.1<br>3.3 3.2<br>3.1 1.6<br>3.1 1.5<br>2.2 1.1<br>2.5 4.5<br>3.7 | 10.7[3]<br>13.3[1]<br>13.3[1]<br>12.8[1]<br>12.7[1]<br>5.5[3]<br>12.9[10]<br>12.8[10] |
| Below -14 to -25 | 100/0 | 8.0 | 8.0<br>8.0 | 7.9[2]<br>7.8[2]<br>12.6[5]<br>12.6[5]<br>12.6[5]<br>12.7[6]<br>12.7[6] |

## TYPE II TESTS

- Frost HOT Values and Endurance Time Test Results

| OAT (°C) | Concentration | Type II | | |
|---|---|---|---|---|
| | | Current HOT Time (hours) | Failed Tests (hours) | Stopped Tests (hours) |
| Above -3 | 100/0 | 8.0 | | 11.6[10] **12.3[10]**<br>**10.8[10]** **12.4[10]** |
| | 75/25 | 5.0 | **7.4** | 11.6[10] **11.6[10]**<br>**10.0[10]** **11.6[10]** |
| | 50/50 | 3.0 | 6.1<br>1.9 | **10.0[10]**<br>**11.6[10]** |
| Below -3 to -14 | 100/0 | 8.0 | 9.5<br>10.5<br>10.4<br>11.9 | 9.5[1] 12.8[10]<br>13.6[1] 11.6[11]<br>13.5[1]<br>13.3[1]<br>12.8[1]<br>12.9[1]<br>12.8[1]<br>12.9[10] |
| | 75/25 | 5.0 | 8.2 2.5<br>9.5 3.4<br>6.7 4.1<br>3.3 3.2<br>3.1 1.6<br>3.1 1.5<br>2.2 1.1<br>2.5 4.5<br>3.7 | 10.7[3]<br>13.3[1]<br>13.3[1]<br>12.8[1]<br>12.7[1]<br>5.5[3]<br>12.9[10]<br>12.8[10] |
| Below -14 to -25 | 100/0 | 8.0 | 8.0<br>8.0 | 7.9[2]<br>7.8[2]<br>12.6[5]<br>12.6[5]<br>12.6[5]<br>12.7[6]<br>12.7[6] |

## TYPE II TESTS

- OBSERVATIONS
  - 15 tests showed reductions in comparison to current Type II frost values issued in the HOT Guidelines
  - Discrepancy in endurance times was attributed to fluid freeze point issues for 14 of the 15 tests
    - To be discussed in detail later in the presentation
  - Indoor laboratory frost tests previously conducted also indicated reduced endurance times at colder temperatures

## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

## TYPE III TESTS

- 16 tests were conducted outdoors using insulated white-painted aluminum surfaces
  - 13 tests were stopped due to fluid failure
  - 3 tests were stopped prior to fluid failure
    - 2 tests did not fail before sunrise
    - 1 test stopped due to rising wind conditions
- Testing was conducted with 1 Type III fluid

## TYPE III TESTS

- Frost HOT Values and Endurance Time Test Results

| OAT (°C) | Concentration | Type III | | |
|---|---|---|---|---|
| | | Current HOT Time (hours) | Failed Tests (hours) | Stopped Tests (hours) |
| Above -3 | 100/0 | 2.0 | 4.7 | |
| | 75/25 | 1.0 | 5.2 | |
| | 50/50 | 0.5 | 3.0<br>1.4 | |
| Below -3 to -14 | 100/0 | 2.0 | 5.8<br>4.6<br>9.0<br>8.1<br>7.4<br>8.6 | |
| | 75/25 | 1.0 | 3.5 | |
| Below -14 to -25 | 100/0 | 2.0 | 5.4<br>5.3 | 7.8[2]<br>12.6[6]<br>7.3[6] |

## TYPE III TESTS

- OBSERVATIONS
  - Type III fluid endurance times were longer than the values issued in the HOT Guidelines.
  - Endurance times measured were at least double the current HOT for each cell

## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

## TYPE IV TESTS

- 90 tests were conducted outdoors using insulated white-painted aluminum surfaces
  - 35 tests were stopped due to fluid failure
  - 55 tests were stopped prior to fluid failure
    - 49 tests did not fail before sunrise
    - 6 tests stopped due to rising wind conditions
- Testing was conducted with 8 Type IV fluids

## TYPE IV TESTS

- Frost HOT Values and Endurance Time Test Results

| OAT (°C) | Concentration | Type IV | | |
|---|---|---|---|---|
| | | Current HOT Time (hours) | Failed Tests (hours) | Stopped Tests (hours) |
| Above -3 | 100/0 | 12.0 | | 11.6, 11.6, 10.8, 10.8, 12.3, 12.3 |
| | 75/25 | 5.0 | 4.6 | 10.1, 11.6 |
| | 50/50 | 3.0 | 3.2, 4.5, 5.3, 3.2, 7.5 | 5.7, 10.1, 10.0, 6.0 |
| Below -3 to -14 | 100/0 | 12.0 | 7.9, 10.8, 13.0, 6.1, 10.6, 10.7 | 9.6, 9.5, 10.9, 10.9, 10.8, 13.5, 13.5, 13.5, 12.8, 12.7, 12.6, 12.7, 12.9, 12.9, 12.8, 12.8, 11.6, 11.6, 12.8, 12.8 |
| | 75/25 | 5.0 | 4.8, 5.9, 3.3, 3.1, 1.8, 1.3, 1.8, 2.5, 9.8, 7.1, 3.9, 1.3, 3.3 | 7.2, 9.5, 13.3, 13.2, 10.8, 4.8, 12.6, 12.9, 12.9 |
| Below -14 to -25 | 100/0 | 12.0 | 5.9, 10.3, 11.0, 6.3, 6.3 | 7.5, 7.6, 7.5, 7.6, 7.6, 7.6, 7.5, 12.5, 12.5, 12.7, 13.1, 12.9, 12.9, 12.1 |

## TYPE IV TESTS

- Frost HOT Values and Endurance Time Test Results

| OAT (°C) | Concentration | Type IV | | |
|---|---|---|---|---|
| | | Current HOT Time (hours) | Failed Tests (hours) | Stopped Tests (hours) |
| Above -3 | 100/0 | 12.0 | | 11.6, 11.6, 10.8, 10.8, 12.3, 12.3 |
| | 75/25 | 5.0 | 4.6 | 10.1, 11.6 |
| | 50/50 | 3.0 | 3.2, 4.5, 5.3, 3.2, 7.5 | 5.7, 10.1, 10.0, 6.0 |
| Below -3 to -14 | 100/0 | 12.0 | 7.9, 10.8, 13.0, 6.1, 10.6, 10.7 | 9.6, 9.5, 10.9, 10.9, 10.8, 13.5, 13.5, 13.5, 12.8, 12.7, 12.6, 12.7, 12.9, 12.9, 12.8, 12.8, 11.6, 11.6, 12.8, 12.8 |
| | 75/25 | 5.0 | 4.8, 5.9, 3.3, 3.1, 1.8, 1.3, 1.8, 2.5, 9.8, 7.1, 3.9, 1.3, 3.3 | 7.2, 9.5, 13.3, 13.2, 10.8, 4.8, 12.6, 12.9, 12.9 |
| Below -14 to -25 | 100/0 | 12.0 | 5.9, 10.3, 11.0, 6.3, 6.3 | 7.5, 7.6, 7.5, 7.6, 7.6, 7.6, 7.5, 12.5, 12.5, 12.7, 13.1, 12.9, 12.9, 12.1 |

## TYPE IV TESTS

- CONCLUSION
  - 21 tests showed reductions in comparison to current Type II frost values issued in the HOT Guidelines
  - Discrepancy in endurance times was attributed to fluid freeze point issues for 17 of the 21 tests
    - To be discussed in detail later in the presentation
  - Indoor laboratory frost tests previously conducted also indicated reduced endurance times at colder temperatures

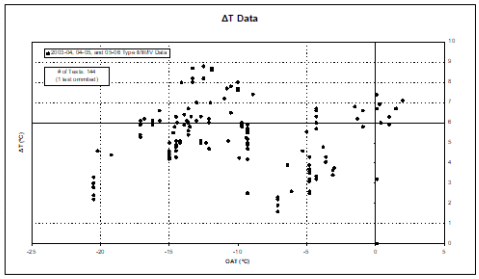
## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

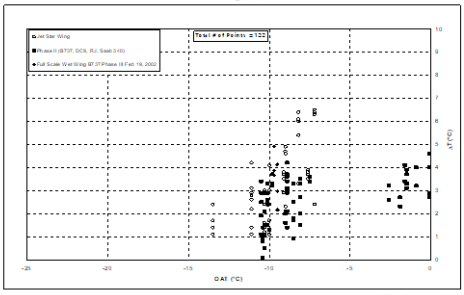
## PLATE TEMPERATURE DATA

- OAT and test plate surface temperature were constantly monitored during each test
- Data collected demonstrated that during frost conditions the plate and OAT temperature differential could range from 2ºC to 9ºC.
- Full-scale aircraft wing surface temperatures collected by APS in frost conditions showed temperature differentials that reached up to 6.5ºC

## PLATE TEMPERATURE DATA




## AIRCRAFT SKIN TEMPERATURE DATA




## PRESENTATION OUTLINE

- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

## FLUID FREEZE POINT FAILURE

- A reduction in the Type II and Type IV fluid endurance was experienced when approaching fluid LOUT
  - Occurred with neat and diluted fluids
- Once the OAT would begin to approach fluid LOUT , the plate surface temperature would cool closer to the fluid freeze point
- Fluid failure occurred primarily because the surface temperature of the test plate reached the fluid freeze point
  - Fluid dilution and erosion did not significantly contribute to the failure

## FLUID FREEZE POINT FAILURE

- EXAMPLE OF FLUID FREEZE POINT FAILURE IN FROST
  - Type IV 75/25 Fluid
  - OAT = **-13.9°C**
  - Plate Temperature = -13.9°C – (9°C) = **-22. 9°C**
  - Fluid Freeze Point = **-21°C**
    - Fluid would be designed with 7°C buffer based on LOUT of -14°C
  - **Fluid experiences contamination as ice crystals begin to form sporadically in fluid**

## FLUID FREEZE POINT FAILURE

- EXAMPLE OF FLUID FREEZE POINT FAILURE IN FROST

| Type II/IV Dilution | LOUT | Approximate FFP | Possible Surface Temp. During Frost Conditions at LOUT |
|---|---|---|---|
| Neat | -25 | -36 | -34 |
| 75/25 | -14 | -21 | -23 |
| 50/50 | -3 | -10 | -12 |

## FLUID FREEZE POINT FAILURE

- The HOT table provides operational ranges specifying limits based on OAT.
- In frost conditions, the skin temperature of an aircraft may be several degrees lower than the OAT
- If operating with a fluid close to the LOUT during frost conditions, the skin temperature of the aircraft could reach the fluid freeze point potentially causing ice to form in the fluid

## PRESENTATION OUTLINE

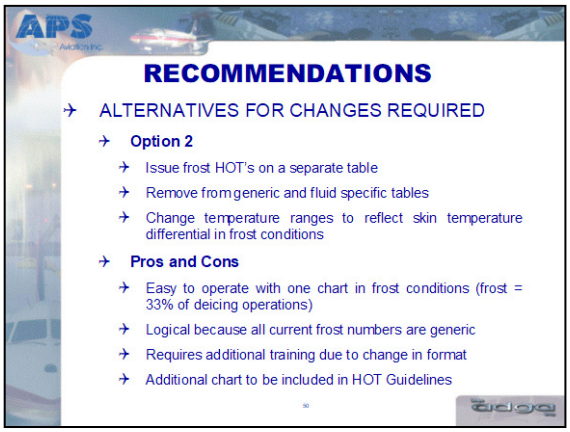
- BACKGROUND
- METHODOLOGY
- TYPE I TESTS
- TYPE II TESTS
- TYPE III TESTS
- TYPE IV TESTS
- PLATE TEMPERATURE DATA
- FLUID FREEZE POINT FAILURE
- SUMMARY AND RECOMMENDATIONS

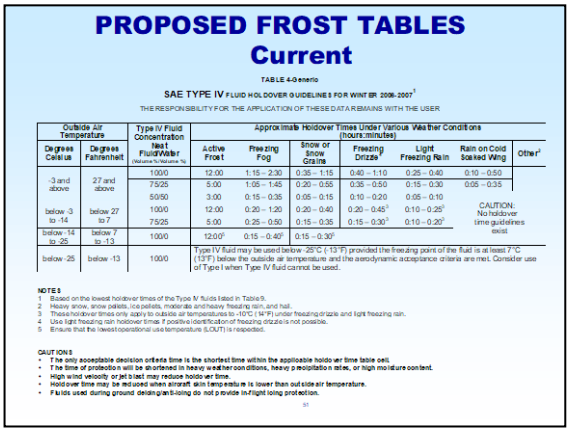
## SUMMARY OF RESULTS

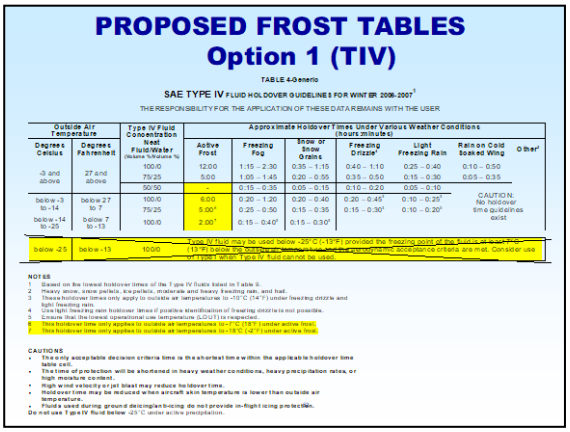
- TYPE I HOT's
  - Substantiated and deemed adequate
- TYPE II HOT's
  - Reduce HOT due to FFP issues
- TYPE III HOT's
  - Substantiated and deemed adequate
- TYPE IV HOT's
  - Reduce HOT due to FFP issues

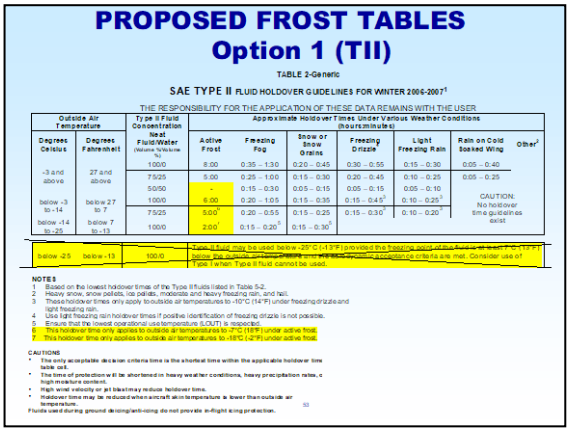
## RECOMMENDATIONS

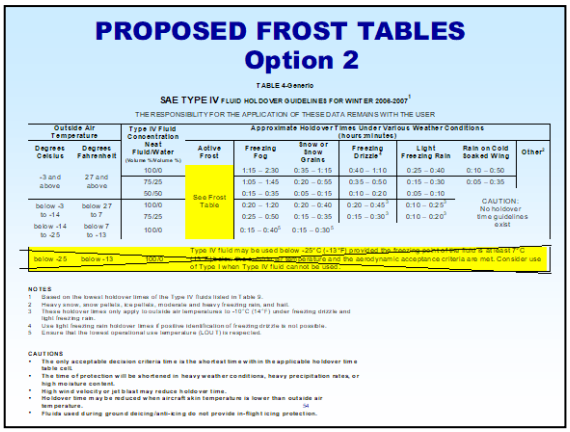
- ALTERNATIVES FOR CHANGES REQUIRED
  - **Option 1**
    - Make changes in current HOT tables
    - Restrict use of diluted fluids to reflect skin temperature differential in frost conditions
    - Include notes to describe temperature restrictions
  - **Pros and Cons**
    - No change in table format required
    - Allows for fluid specific frost numbers to be easily incorporated in the event that this was needed
    - Requires more notes, therefore tables become cluttered
    - Requires additional training due to temperature restrictions

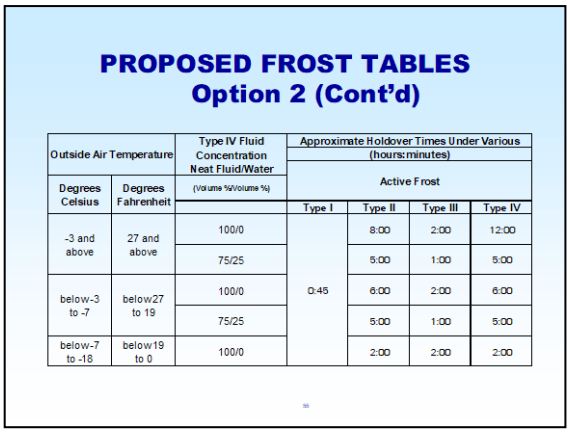

RECOMMENDATIONS
ALTERNATIVES FOR CHANGES REQUIRED
Option 2
Issue frost HOT's on a separate table
Remove from generic and fluid specific tables
Change temperature ranges to reflect skin temperature differential in frost conditions
Pros and Cons
Easy to operate with one chart in frost conditions (frost = 33% of deicing operations)
Logical because all current frost numbers are generic
Requires additional training due to change in format
Additional chart to be included in HOT Guidelines

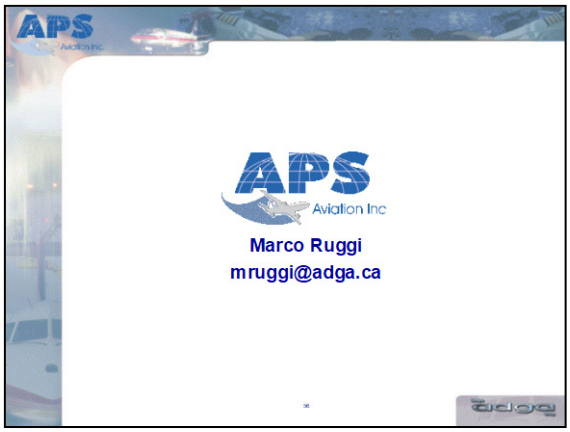

PROPOSED FROST TABLES
Current
TABLE 4-Generic
SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER
Outside Air Temperature
Degrees Celsius
Degrees Fahrenheit
Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)
Approximate Holdover Times Under Various Weather Conditions (hours:minutes)
Active Frost
Freezing Fog
Snow or Snow Grains
Freezing Drizzle
Light Freezing Rain
Rain on Cold Soaked Wing
Other[2]
-3 and above
27 and above
100/0
12:00
1:15 – 2:30
0:35 – 1:15
0:40 – 1:10
0:25 – 0:40
0:10 – 0:50
75/25
5:00
1:05 – 1:45
0:20 – 0:55
0:35 – 0:50
0:15 – 0:30
0:05 – 0:35
50/50
3:00
0:15 – 0:35
0:05 – 0:15
0:10 – 0:20
0:05 – 0:10
below -3 to -14
below 27 to 7
100/0
12:00
0:20 – 1:20
0:20 – 0:40
0:20 – 0:45[3]
0:10 – 0:25[3]
75/25
5:00
0:25 – 0:50
0:15 – 0:35
0:15 – 0:30[3]
0:10 – 0:20[3]
CAUTION: No holdover time guidelines exist
below -14 to -25
below 7 to -13
100/0
12:00[3]
0:15 – 0:40[3]
0:15 – 0:30[3]
below -25
below -13
100/0
Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.
NOTES
1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.
CAUTIONS
The only acceptable decision criteria time is the shortest 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 deicing/anti-icing do not provide in-flight icing protection.


PROPOSED FROST TABLES
Option 1 (TIV)
TABLE 4-Generic
SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER
Outside Air Temperature
Degrees Celsius
Degrees Fahrenheit
Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)
Approximate Holdover Times Under Various Weather Conditions (hours:minutes)
Active Frost
Freezing Fog
Snow or Snow Grains
Freezing Drizzle[1]
Light Freezing Rain
Rain on Cold Soaked Wing
Other[2]
-3 and above
27 and above
100/0
6:00
1:15 – 2:30
0:35 – 1:15
0:40 – 1:10
0:25 – 0:40
0:10 – 0:50
75/25
5:00
1:05 – 1:45
0:20 – 0:55
0:35 – 0:50
0:15 – 0:30
0:05 – 0:35
50/50
-
0:15 – 0:35
0:05 – 0:15
0:10 – 0:20
0:05 – 0:10
below -3 to -14
below 27 to 7
100/0
6:00
0:20 – 1:20
0:20 – 0:40
0:20 – 0:45[3]
0:10 – 0:25[3]
75/25
5:00[3]
0:25 – 0:50
0:15 – 0:35
0:15 – 0:30[3]
0:10 – 0:20[3]
CAUTION: No holdover time guidelines exist
below -14 to -25
below 7 to -13
100/0
2:00[3]
0:15 – 0:40[3]
0:15 – 0:30[3]
below -25
below -13
100/0
Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.
NOTES
1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.
6 This holdover time only applies to outside air temperatures to -7°C (19°F) under active frost.
7 This holdover time only applies to outside air temperatures to -18°C (-2°F) under active frost.
CAUTIONS
The only acceptable decision criteria time is the shortest 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 deicing/anti-icing do not provide in-flight icing protection.
Do not use Type IV fluid below -25°C under active precipitation.


PROPOSED FROST TABLES
Option 1 (TII)
TABLE 2-Generic
SAE TYPE II FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER
Outside Air Temperature
Degrees Celsius
Degrees Fahrenheit
Type II Fluid Concentration Neat Fluid/Water (Volume %/Volume %)
Approximate Holdover Times Under Various Weather Conditions (hours:minutes)
Active Frost
Freezing Fog
Snow or Snow Grains
Freezing Drizzle
Light Freezing Rain
Rain on Cold Soaked Wing
Other[2]
-3 and above
27 and above
100/0
8:00
0:35 – 1:30
0:20 – 0:45
0:30 – 0:55
0:15 – 0:30
0:05 – 0:40
75/25
5:00
0:25 – 1:00
0:15 – 0:30
0:20 – 0:45
0:10 – 0:25
0:05 – 0:25
50/50
-
0:15 – 0:30
0:05 – 0:15
0:05 – 0:15
0:05 – 0:10
below -3 to -14
below 27 to 7
100/0
6:00
0:20 – 1:05
0:15 – 0:35
0:15 – 0:45[3]
0:10 – 0:25[3]
CAUTION: No holdover time guidelines exist
75/25
5:00[3]
0:20 – 0:55
0:15 – 0:25
0:15 – 0:30[3]
0:10 – 0:20[3]
below -14 to -25
below 7 to -13
100/0
2:00[3]
0:15 – 0:20[3]
0:15 – 0:30[3]
below -25
below -13
100/0
Type II fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type II fluid cannot be used.
NOTES
1 Based on the lowest holdover times of the Type II fluids listed in Table 5-2.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.
6 This holdover time only applies to outside air temperatures to -7°C (19°F) under active frost.
7 This holdover time only applies to outside air temperatures to -18°C (-2°F) under active frost.
CAUTIONS
The only acceptable decision criteria time is the shortest 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 deicing/anti-icing do not provide in-flight icing protection.


PROPOSED FROST TABLES
Option 2
TABLE 4-Generic
SAE TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2006-2007[1]
THE RESPONSIBILITY FOR THE APPLICATION OF THESE DATA REMAINS WITH THE USER
Outside Air Temperature
Degrees Celsius
Degrees Fahrenheit
Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)
Approximate Holdover Times Under Various Weather Conditions (hours:minutes)
Active Frost
Freezing Fog
Snow or Snow Grains
Freezing Drizzle[1]
Light Freezing Rain
Rain on Cold Soaked Wing
Other[2]
-3 and above
27 and above
100/0
See Frost Table
1:15 – 2:30
0:35 – 1:15
0:40 – 1:10
0:25 – 0:40
0:10 – 0:50
75/25
1:05 – 1:45
0:20 – 0:55
0:35 – 0:50
0:15 – 0:30
0:05 – 0:35
50/50
0:15 – 0:35
0:05 – 0:15
0:10 – 0:20
0:05 – 0:10
below -3 to -14
below 27 to 7
100/0
0:20 – 1:20
0:20 – 0:40
0:20 – 0:45[3]
0:10 – 0:25[3]
CAUTION: No holdover time guidelines exist
75/25
0:25 – 0:50
0:15 – 0:35
0:15 – 0:30[3]
0:10 – 0:20[3]
below -14 to -25
below 7 to -13
100/0
0:15 – 0:40[3]
0:15 – 0:30[3]
below -25
below -13
100/0
Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used.
NOTES
1 Based on the lowest holdover times of the Type IV fluids listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 Ensure that the lowest operational use temperature (LOUT) is respected.
CAUTIONS
The only acceptable decision criteria time is the shortest 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 deicing/anti-icing do not provide in-flight icing protection.


PROPOSED FROST TABLES
Option 2 (Cont'd)
Outside Air Temperature
Degrees Celsius
Degrees Fahrenheit
Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %)
Approximate Holdover Times Under Various (hours:minutes)
Active Frost
Type I
Type II
Type III
Type IV
-3 and above
27 and above
100/0
0:45
8:00
2:00
12:00
75/25
5:00
1:00
5:00
below-3 to -7
below27 to 19
100/0
6:00
2:00
6:00
75/25
5:00
1:00
5:00
below-7 to -18
below19 to 0
100/0
2:00
2:00
2:00




## PROPOSED FROST TABLES
## Option 3

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water | Approximate Holdover Times Under Various (hours:minutes) | | | |
|---|---|---|---|---|---|---|
| | | | Active Frost | | | |
| Degrees Celsius | Degrees Fahrenheit | (Volume %/Volume %) | Type I | Type II | Type III | Type IV |
| -3 and above | 27 and above | 100/0 | 0:45 | 8:00 | 2:00 | 12:00 |
| | | 75/25 | | 5:00 | 1:00 | 5:00 |
| | | 50/50* | | 0:30 | 0:30 | 0:30 |
| below -3 to -7 | below 27 to 19 | 100/0 | | 6:00 | 2:00 | 6:00 |
| | | 75/25 | | 5:00 | 1:00 | 5:00 |
| below -7 to -18 | below 19 to 0 | 100/0 | | 2:00 | 2:00 | 2:00 |

* This holdover time only applies to outside air temperatures to -1°C (30°F) under active frost.

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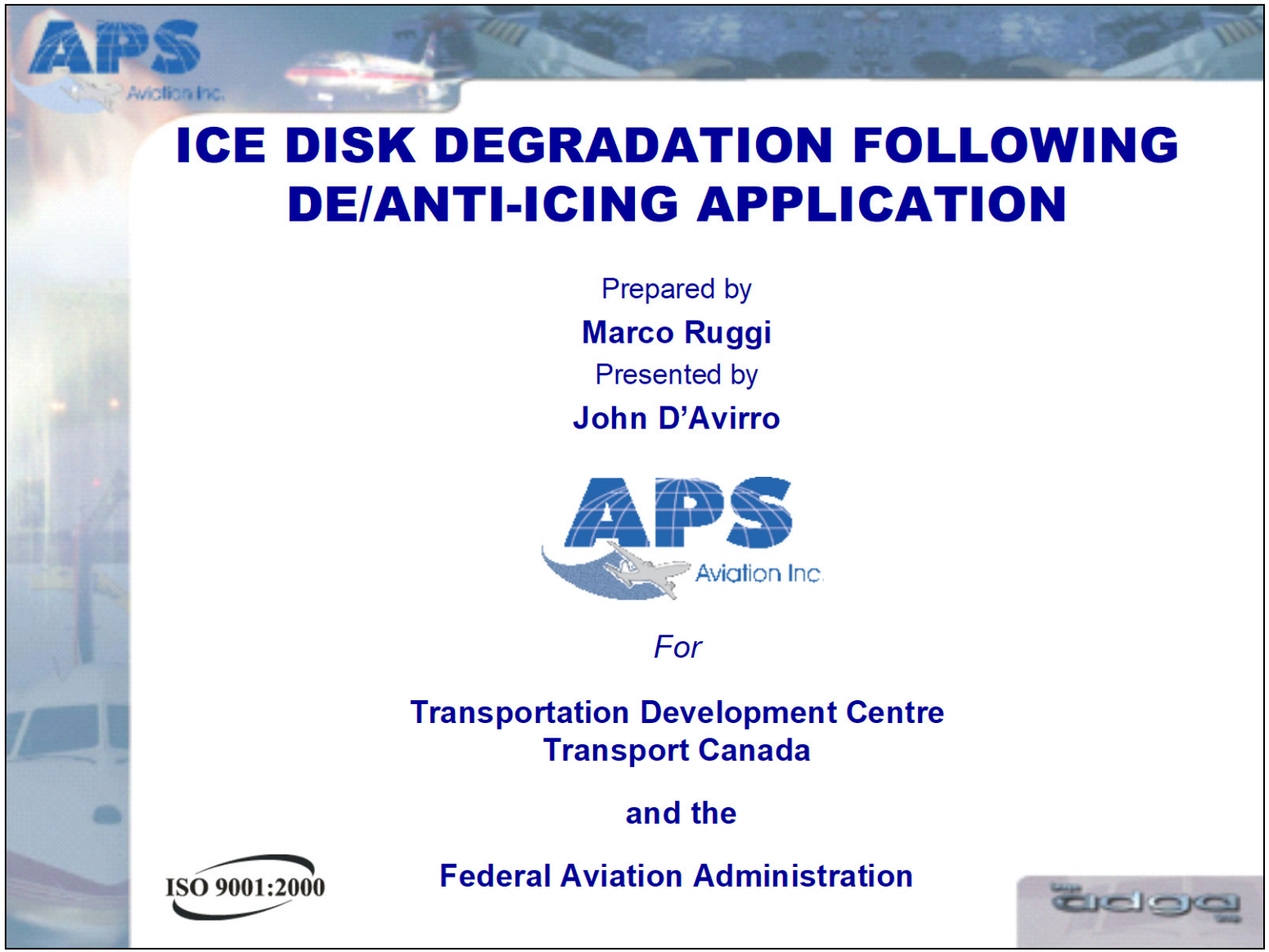
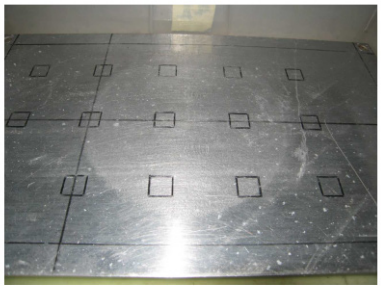

APS
Aviation Inc.
ICE DISK DEGRADATION FOLLOWING DE/ANTI-ICING APPLICATION
Prepared by
Marco Ruggi
Presented by
John D'Avirro
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
ISO 9001:2000

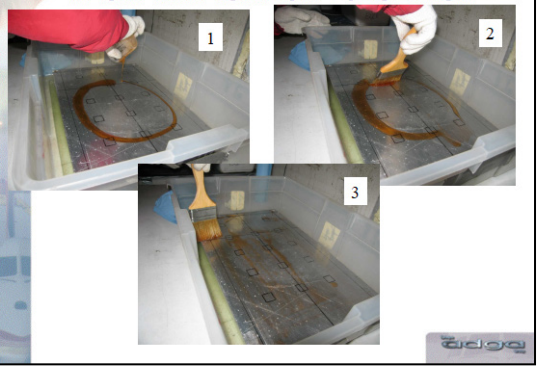
## PROCEDURE

- Prepare test plate with 0.5mm ice disk
- Prepare fluid to be applied to test plate and ice disk
- Monitor fluid temperature and plate temperature
- Carefully apply fluid to ice disk
- Remove fluid from ice disk
- Measure final ice disk thickness

## TEST PLATE PREPARED WITH ICE DISK



## FLUID APPLICATION TO ICE DISK




## REMOVING FLUID FROM ICE DISK

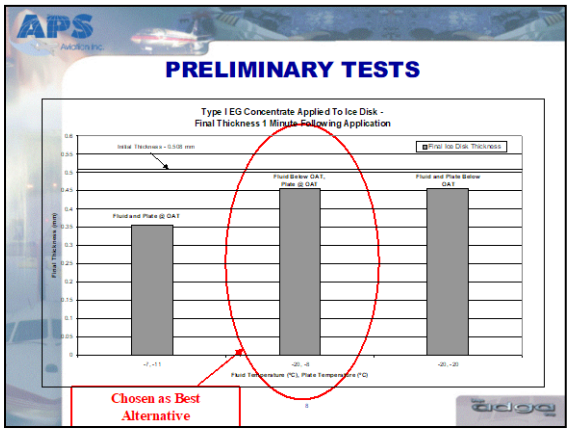


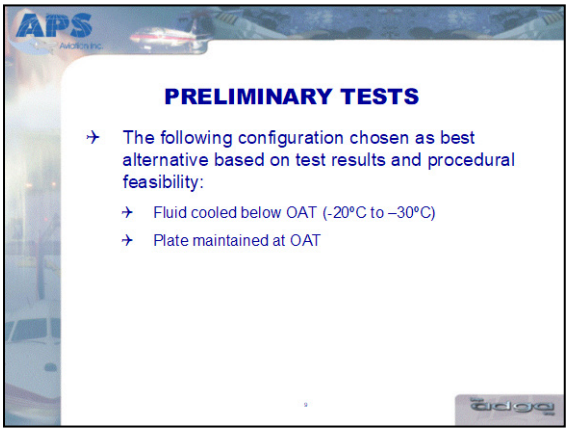
## ICE DISK FINAL THICKNESS MEASURMENT

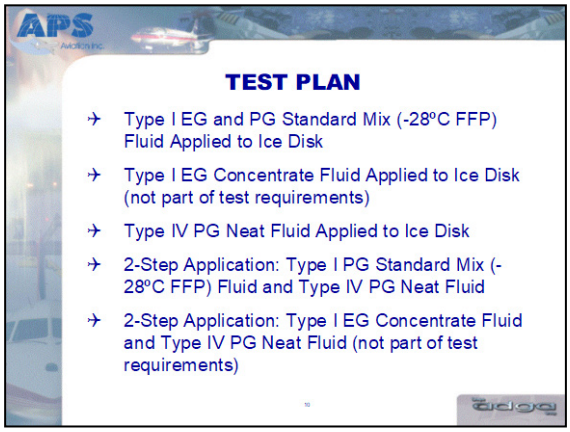


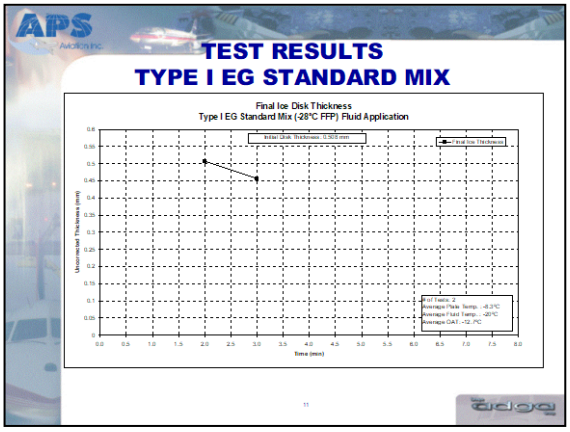
## PRELIMINARY TESTS

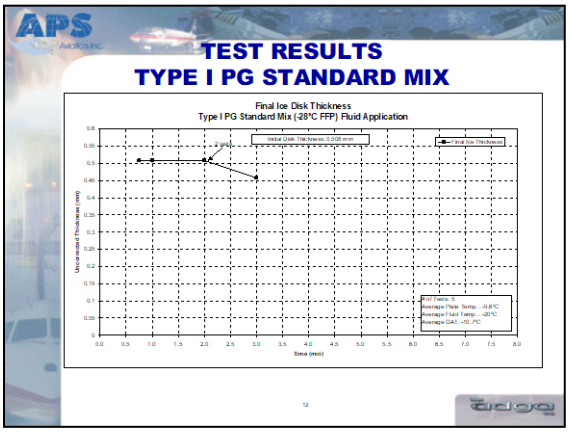
- Determine test plate and fluid condition least conducive to ice disk degradation:
  - Type I Conc. fluid @ OAT (-8°C) and Test Plate at OAT (-8°C)
  - Type I Conc. Fluid below OAT (-20°C) and Test Plate at OAT (-8°C)
  - Type I Conc. Fluid below OAT (-20°C) and Test Plate below OAT (-20°C)

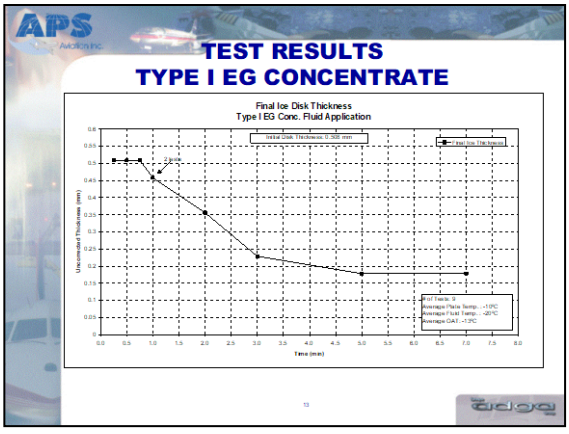

PRELIMINARY TESTS
Type I EG Concentrate Applied To Ice Disk -
Final Thickness 1 Minute Following Application
Initial Thickness = 0.508 mm
Final Ice Disk Thickness
Fluid and Plate @ OAT
Fluid Below OAT, Plate @ OAT
Fluid and Plate Below OAT
Final Thickness (mm)
Fluid Temperature (°C), Plate Temperature (°C)
Chosen as Best Alternative

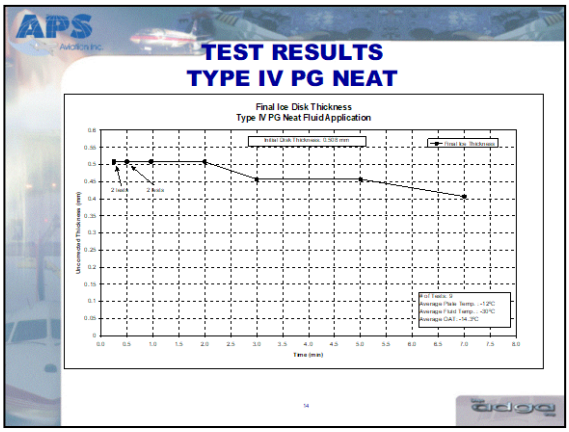

PRELIMINARY TESTS
The following configuration chosen as best alternative based on test results and procedural feasibility:
Fluid cooled below OAT (-20°C to –30°C)
Plate maintained at OAT

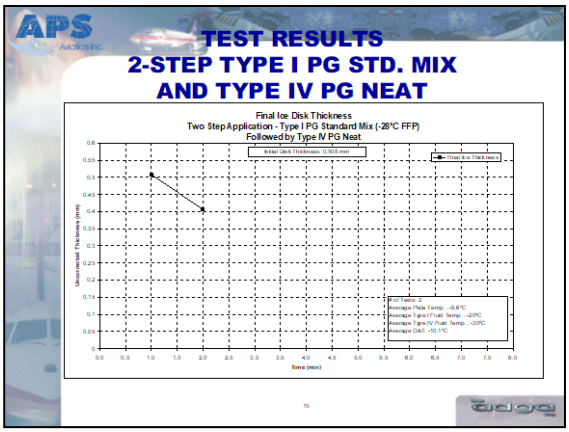

TEST PLAN
Type I EG and PG Standard Mix (-28°C FFP) Fluid Applied to Ice Disk
Type I EG Concentrate Fluid Applied to Ice Disk (not part of test requirements)
Type IV PG Neat Fluid Applied to Ice Disk
2-Step Application: Type I PG Standard Mix (-28°C FFP) Fluid and Type IV PG Neat Fluid
2-Step Application: Type I EG Concentrate Fluid and Type IV PG Neat Fluid (not part of test requirements)

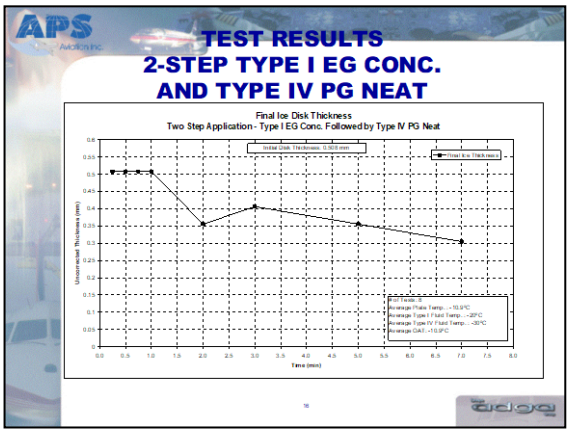

TEST RESULTS
TYPE I EG STANDARD MIX
Final Ice Disk Thickness
Type I EG Standard Mix (-28°C FFP) Fluid Application
Uncorrected Thickness (mm)
Time (min)

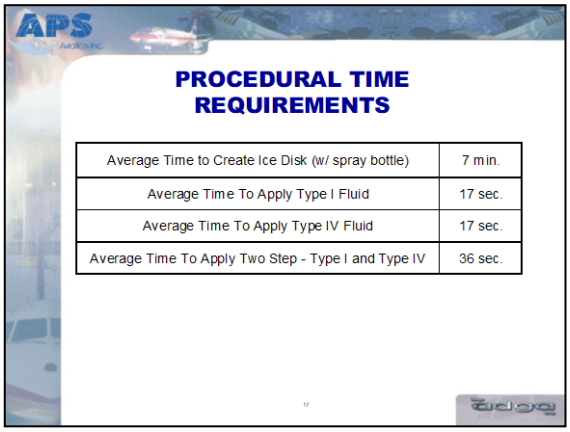

TEST RESULTS
TYPE I PG STANDARD MIX
Final Ice Disk Thickness
Type I PG Standard Mix (-28°C FFP) Fluid Application
Uncorrected Thickness (mm)
Time (min)


TEST RESULTS
TYPE I EG CONCENTRATE
Final Ice Disk Thickness
Type I EG Conc. Fluid Application
Uncorrected Thickness (mm)
Time (min)

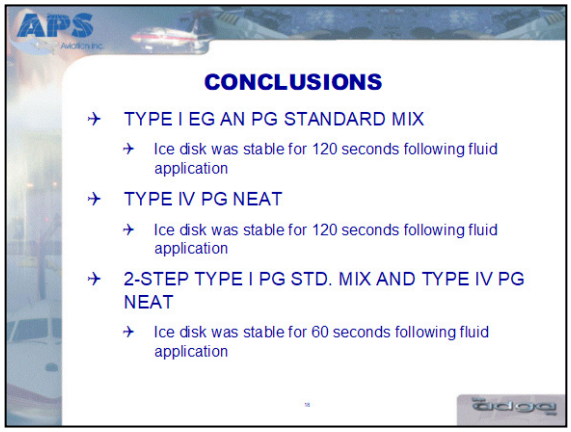


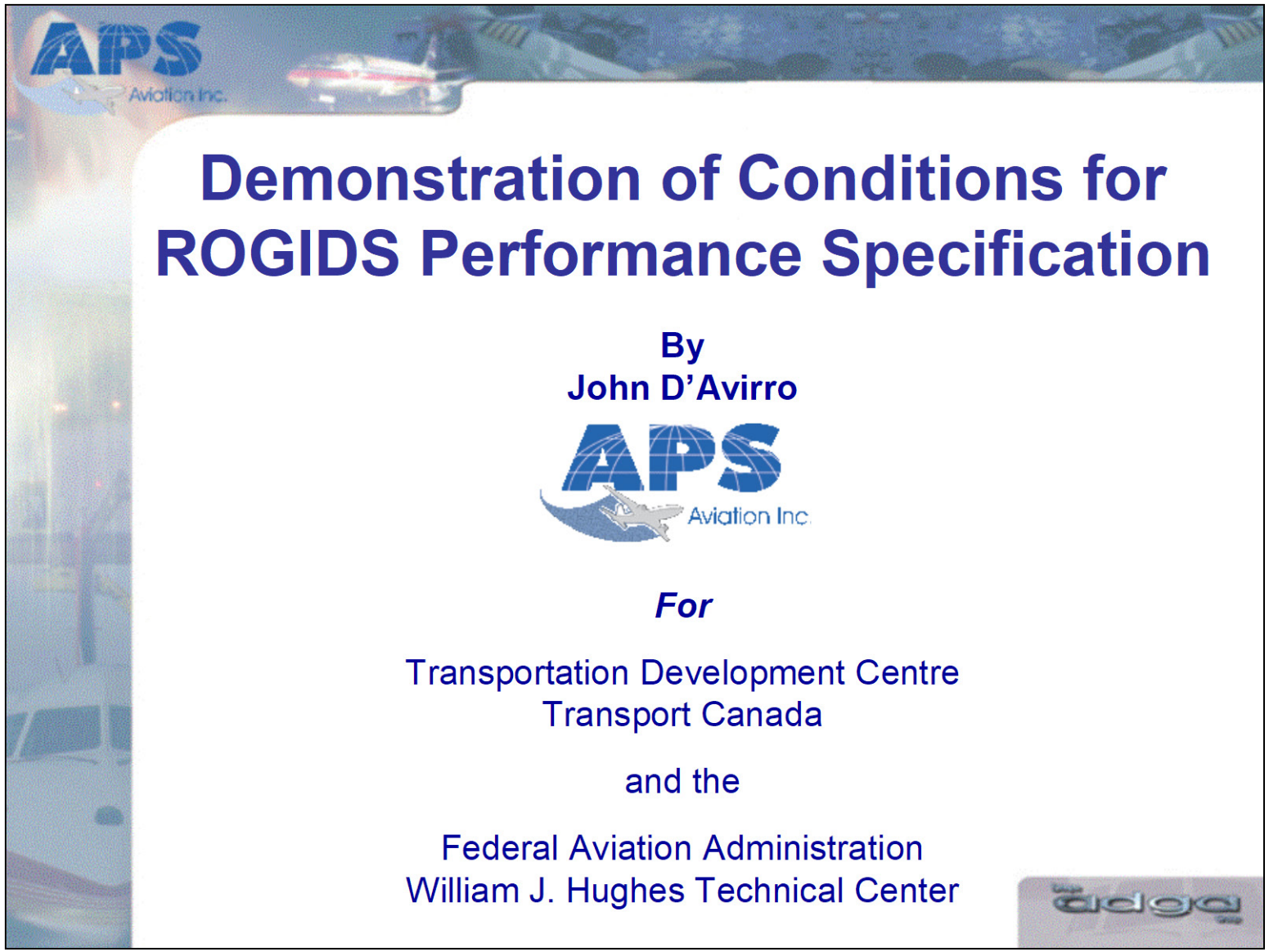



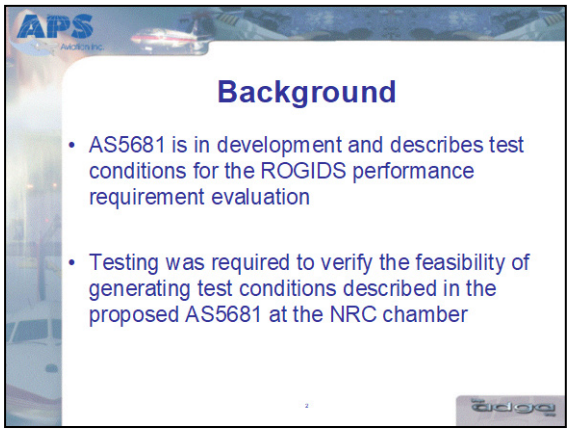



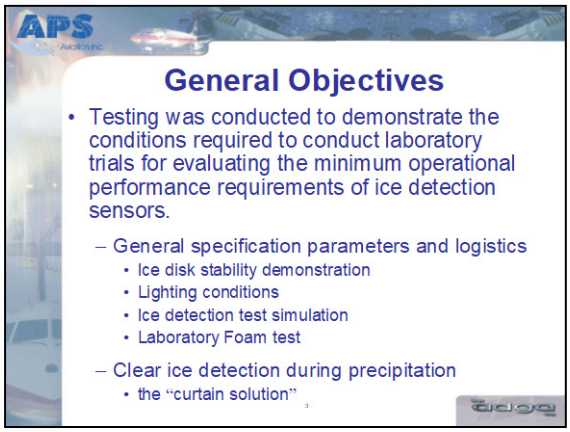



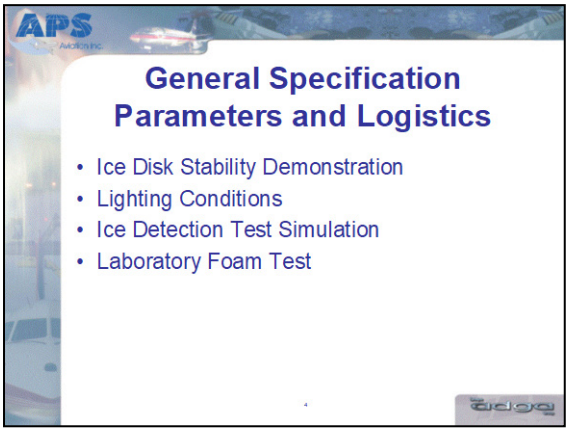

| | |
|---|---|
| Average Time to Create Ice Disk (w/ spray bottle) | 7 min. |
| Average Time To Apply Type I Fluid | 17 sec. |
| Average Time To Apply Type IV Fluid | 17 sec. |
| Average Time To Apply Two Step - Type I and Type IV | 36 sec. |

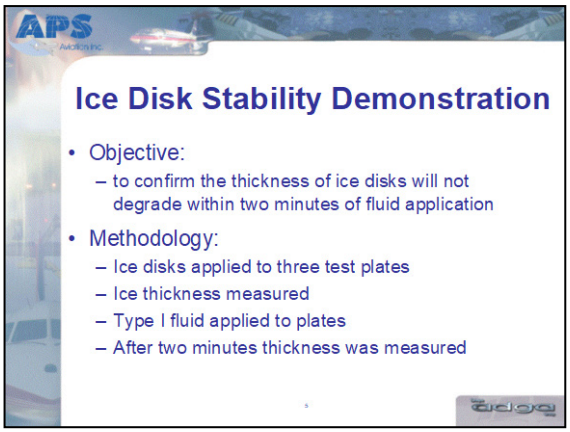


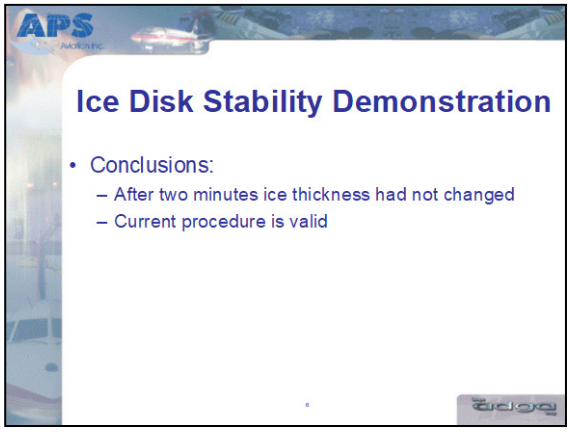

APS
Aviation Inc.
Demonstration of Conditions for
ROGIDS Performance Specification
By
John D'Avirro
APS
Aviation Inc.
For
Transportation Development Centre
Transport Canada
and the
Federal Aviation Administration
William J. Hughes Technical Center

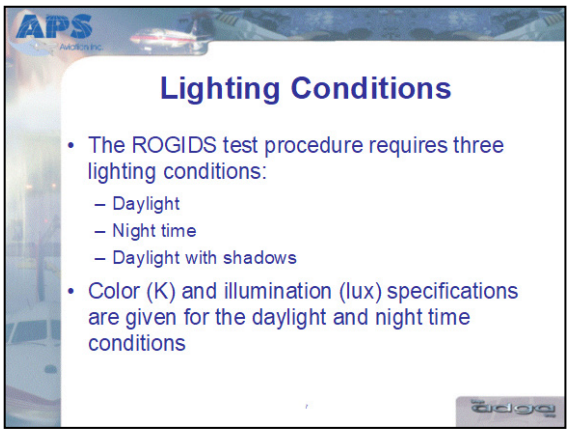

Background
• AS5681 is in development and describes test conditions for the ROGIDS performance requirement evaluation
• Testing was required to verify the feasibility of generating test conditions described in the proposed AS5681 at the NRC chamber


General Objectives
• Testing was conducted to demonstrate the conditions required to conduct laboratory trials for evaluating the minimum operational performance requirements of ice detection sensors.
– General specification parameters and logistics
• Ice disk stability demonstration
• Lighting conditions
• Ice detection test simulation
• Laboratory Foam test
– Clear ice detection during precipitation
• the "curtain solution"


General Specification Parameters and Logistics
• Ice Disk Stability Demonstration
• Lighting Conditions
• Ice Detection Test Simulation
• Laboratory Foam Test


Ice Disk Stability Demonstration
• Objective:
– to confirm the thickness of ice disks will not degrade within two minutes of fluid application
• Methodology:
– Ice disks applied to three test plates
– Ice thickness measured
– Type I fluid applied to plates
– After two minutes thickness was measured


Ice Disk Stability Demonstration
• Conclusions:
– After two minutes ice thickness had not changed
– Current procedure is valid


Lighting Conditions
• The ROGIDS test procedure requires three lighting conditions:
– Daylight
– Night time
– Daylight with shadows
• Color (K) and illumination (lux) specifications are given for the daylight and night time conditions

## Lighting Conditions

- Objective:
  - To produce lighting in the NRC chamber that meets the specifications for each of the lighting conditions
- Methodology
  - Test various lighting conditions currently available in the chamber
  - Add lighting if necessary

## Lighting Conditions

- Night time:
  - Standard lighting conditions in the chamber fell within the illumination spec and just outside the colour spec for the night time lighting condition:

| | Requirement | NRC Chamber |
|---|---|---|
| **Illumination** | 100 to 500 lux | 140 lux |
| **Colour** | 2,100 to 3,200 K | 3,500 K |

## Lighting Conditions

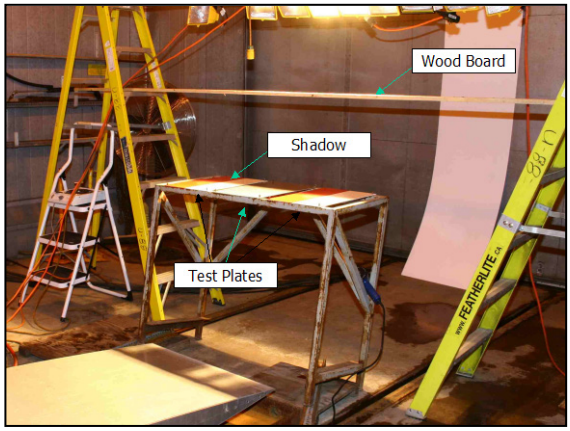
- Daylight:
  - The daylight lighting conditions were very close to specification with a metal halide light
    - Sylvania Metalarc BT56
    - ANSI luminance code "S"

| | Requirement | Metal Halide |
|---|---|---|
| **Illumination** | 25,000 lux | 28,000 lux |
| **Colour** | 5,000 to 6,500 K | 5,870 K |




## Lighting Conditions

- Daylight with Shadow:
  - The daylight with shadow lighting condition was produced using the fixed setup shown on the next page



## Lighting Conditions

- Recommendation: Increase the lighting specifications tolerances

| | | Current Requirement | Recommended Requirement |
|---|---|---|---|
| Day | Illumination | 25,000 lux | 25,000 to 30,000 lux |
| | Colour | 5,000 to 6,500 K | |
| Night | Illumination | 100 to 500 lux | |
| | Colour | 2,100 to 3,200 K | 2,100 to 3,600 K |

## Ice Detection Test Simulation

- Objective:
  - To illustrate that tests in the test plan can be conducted within a reasonable time frame
  - Two test sets: pre-deicing and post-deicing

## Ice Detection Test Simulation PRE-DEICING TESTS

- Objective:
  - To illustrate that all of the tests in Table A-1 can be completed within a reasonable time frame
- Methodology:
  - All 18 tests were carried out, including:
    - Three test surfaces (concurrently)
    - Daylight: far camera, near camera
    - Night time : far camera, near camera
    - Shadow : far camera, near camera

## Ice Detection Test Simulation PRE-DEICING TESTS

AS5681 Table A1

| Test # | Test Plate | Sensor Position | Illumination |
|---|---|---|---|
| 1-1 | 1 | Far | Daylight |
| 1-2 | 2 | Far | Daylight |
| 1-3 | 3 | Far | Daylight |
| 1-4 | 1 | Near | Daylight |
| 1-5 | 2 | Near | Daylight |
| 1-6 | 3 | Near | Daylight |
| 1-7 | 1 | Far | Night-time |
| 1-8 | 2 | Far | Night-time |
| 1-9 | 3 | Far | Night-time |
| 1-10 | 1 | Near | Night-time |
| 1-11 | 2 | Near | Night-time |
| 1-12 | 3 | Near | Night-time |
| 1-13 | 1 | Far | Shadow |
| 1-14 | 2 | Far | Shadow |
| 1-15 | 3 | Far | Shadow |
| 1-16 | 1 | Near | Shadow |
| 1-17 | 2 | Near | Shadow |
| 1-18 | 3 | Near | Shadow |

## Ice Detection Test Simulation PRE-DEICING TESTS

- Conclusion:
  - All tests were completed in approximately 30 seconds
  - Test protocol is valid





## Ice Detection Test Simulation POST-DEICING TESTS

- Objective:
  - To illustrate that six tests from Table A-2 can be completed within 2 minutes (before ice disk decay)
- Methodology:
  - Ice disks applied to three test plates
  - Tests conducted in night time lighting condition
  - Type I fluid applied to test plates
  - Simulated ROGIDS picture from far angle
  - Simulated ROGIDS picture from near angle

## Ice Detection Test Simulation POST-DEICING TESTS

- Conclusion:
  - All six tests were conducted in approximately 30 seconds
  - Test protocol is valid – tests can be conducted within the 2 minute window for ice disk stability



## Laboratory Foam Test

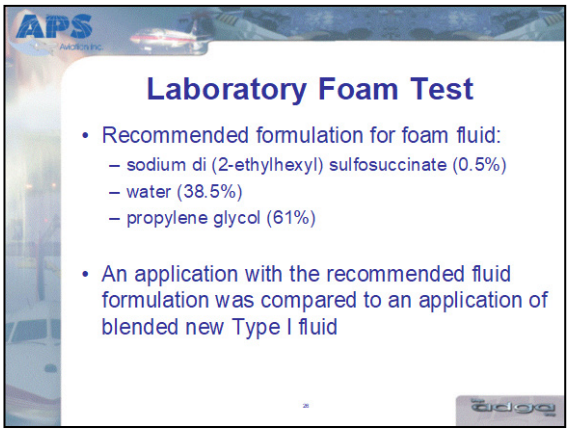
- Objective:
  - To investigate the suitability of a laboratory foam test that is being developed for the standard
    - The foam test has been included in the standard to ensure that ROGIDS performance is not affected by fluids that become foamy when applied

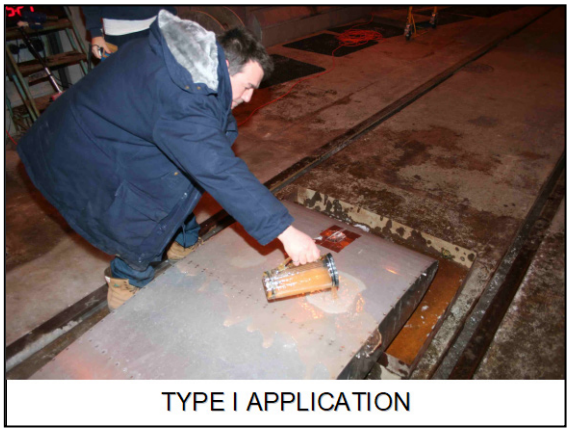
## Laboratory Foam Test

- Proposed formulation for foam fluid*:
  - sodium di (2-ethylhexyl) sulfosuccinate (0.5%)
  - water (11.5%)
  - propylene glycol (88%)

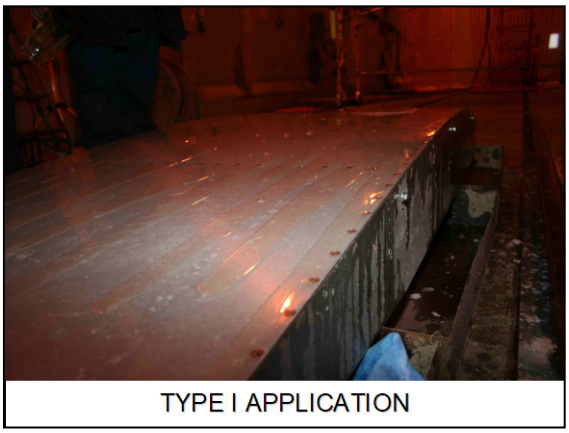
*based on the historical fluid used for aerodynamic acceptance tests, MIL-A-8243

- Issues with proposed formulation:
  - Did not produce enough foam/bubbles
  - Propylene glycol should have a FFP ~-40°C

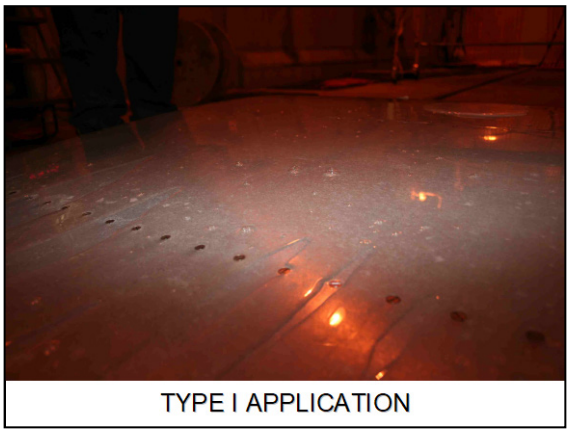


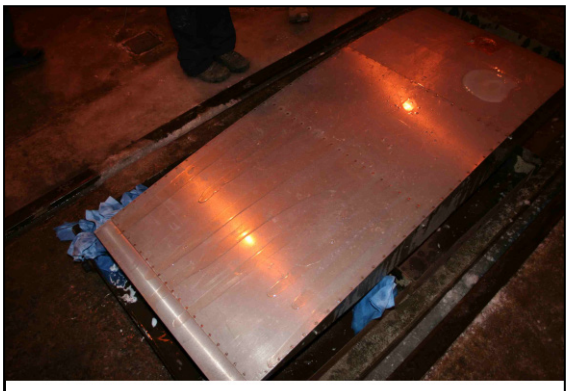
TYPE I APPLICATION



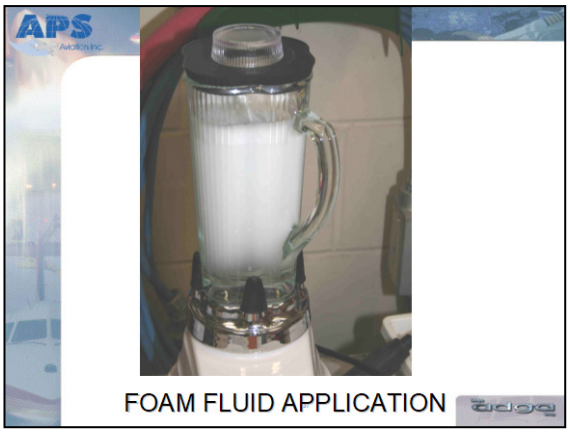
TYPE I APPLICATION



TYPE I APPLICATION



TYPE I APPLICATION




FOAM FLUID APPLICATION



FOAM FLUID APPLICATION



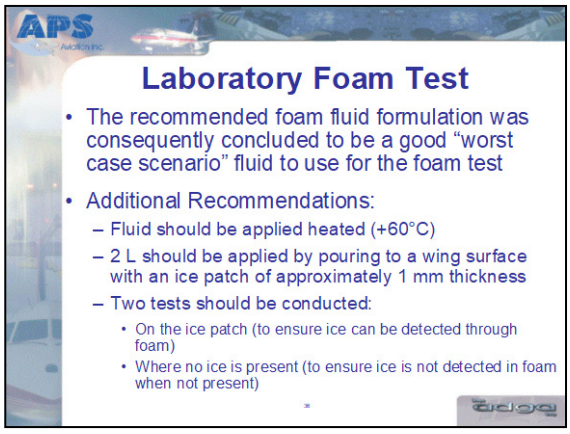
FOAM FLUID APPLICATION

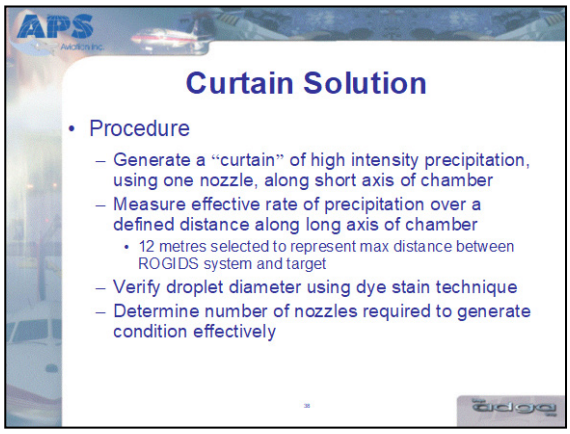


FOAM FLUID APPLICATION



FOAM FLUID APPLICATION

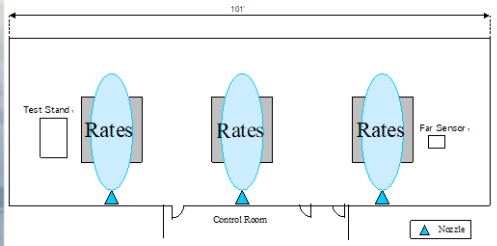


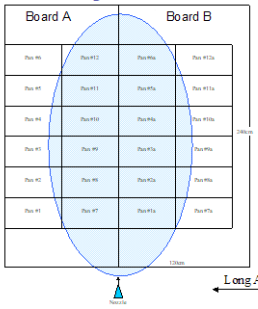
## Conditions Tested

- Light Freezing Rain
  - Precipitation rate: 19-25 g/dm$^2$/h
  - Droplet size: 1000μm±100
  - Temperature: <= -5 °C
- Freezing Drizzle
  - Precipitation rate: 5-10 g/dm$^2$/h
  - Droplet size: 300μm±100
  - Temperature: <= -5 °C
- Rain
  - Precipitation rate: 65-75 g/dm$^2$/h
  - Droplet size: 1000μm±100
  - Temperature: <= +1 °C

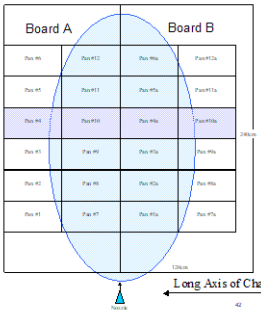
## NRC Chamber "Curtain" Setup




## Rate Pan Layout for 1 Nozzle




## Rate Calculation Per Axis Using 1 Nozzle




$$ER = AvgR \times \frac{WP}{DC}$$

ER = Effective Rate per Axis

AvgR = Average rate of 4 pans

WP = Width of 4 Pans

DC = Distance from Camera to Objective

## Effective Rate Calculation Using One Nozzle

Effective Rate (g/dm²/h) Using One Nozzle

| | 1 Nozzle |
|---|---|
| Long Axis 6&12 | 9.2 |
| Long Axis 5&11 | 10.3 |
| Long Axis 4&10 | 11.2 |
| Long Axis 3&9 | 11.6 |
| Long Axis 2&8 | 10.1 |
| Long Axis 1&7 | 8.1 |

Short Axis of Chamber

Long Axis of Chamber

Nozzle Side

## Effective Rate Calculation Using Multiple Nozzles

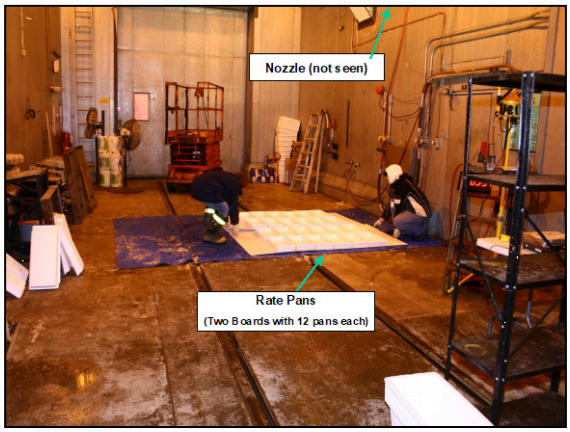
Effective Rate (g/dm²/h) Using Multiple Nozzles

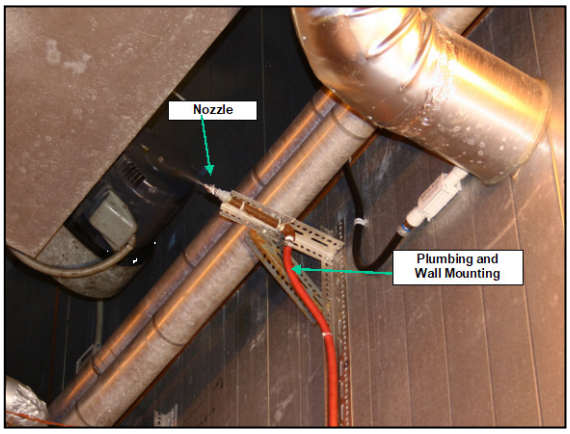
| | 1 Nozzle | 2 Nozzles | 3 Nozzles | 4 Nozzles | 5 Nozzles | 6 Nozzles |
|---|---|---|---|---|---|---|
| Long Axis 6&12 | 9.2 | 18.3 | 27.5 | 36.7 | 45.8 | 55.0 |
| Long Axis 5&11 | 10.3 | 20.5 | 30.8 | 41.0 | 51.3 | 61.6 |
| Long Axis 4&10 | 11.2 | 22.5 | 33.7 | 44.9 | 56.2 | 67.4 |
| Long Axis 3&9 | 11.6 | 23.2 | 34.7 | 46.3 | 57.9 | 69.5 |
| Long Axis 2&8 | 10.1 | 20.2 | 30.4 | 40.5 | 50.6 | 60.7 |
| Long Axis 1&7 | 8.1 | 16.3 | 24.4 | 32.5 | 40.7 | 48.8 |

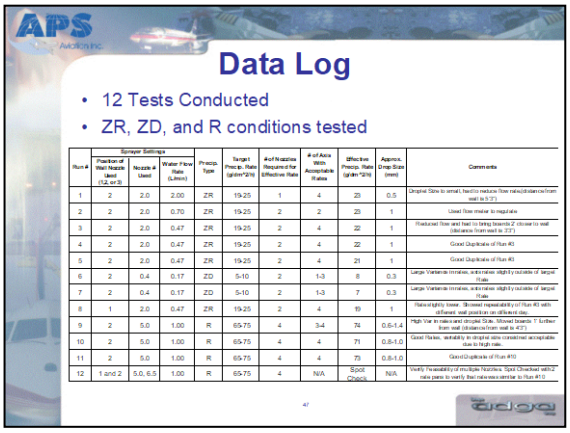
Short Axis of Chamber

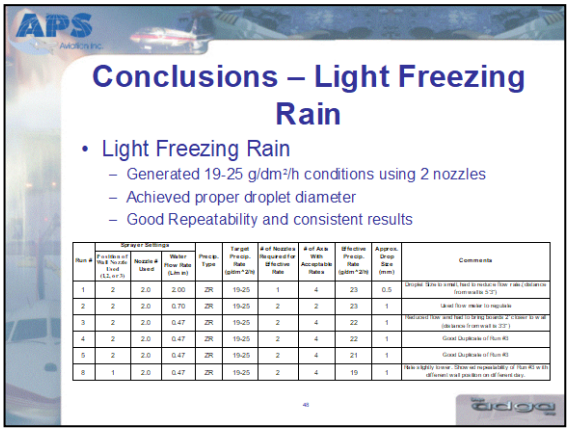
Long Axis of Chamber

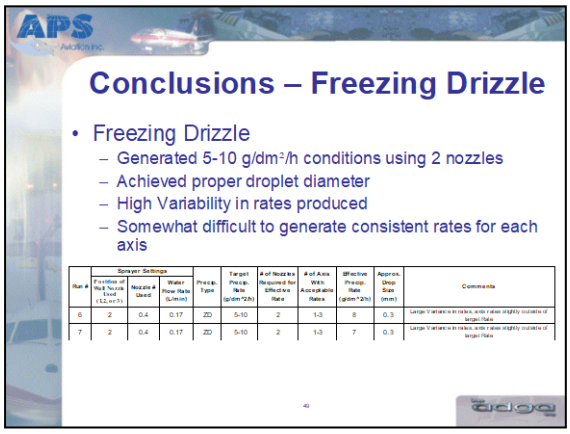
Nozzle Side

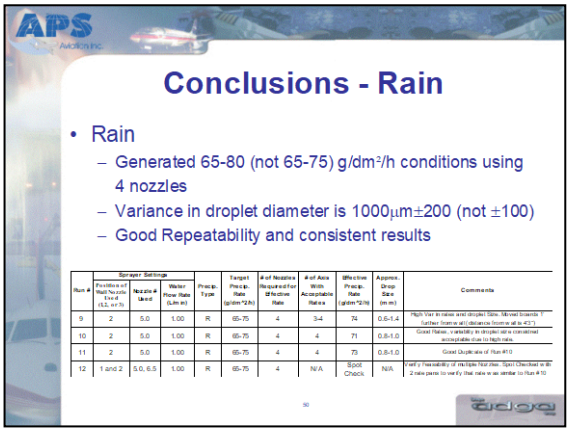

Nozzle (not seen)
Rate Pans
(Two Boards with 12 pans each)


Nozzle
Plumbing and
Wall Mounting


APS
Aviation Inc
Data Log
• 12 Tests Conducted
• ZR, ZD, and R conditions tested
Sprayer Settings
Run #
Position of Wall Nozzle Used (1,2, or 3)
Nozzle # Used
Water Flow Rate (L/min)
Precip. Type
Target Precip. Rate (g/dm^2/h)
# of Nozzles Required for Effective Rate
# of Axis With Acceptable Rates
Effective Precip. Rate (g/dm^2/h)
Approx. Drop Size (mm)
Comments
1 2 2.0 2.00 ZR 19-25 1 4 23 0.5 Droplet Size to small, had to reduce flow rate/distance from wall to 5.3"
2 2 2.0 0.70 ZR 19-25 2 2 23 1 Used flow meter to regulate
3 2 2.0 0.47 ZR 19-25 2 4 22 1 Reduced flow and had to bring boards 2" closer to wall (distance from wall is 3.2")
4 2 2.0 0.47 ZR 19-25 2 4 22 1 Good Duplicate of Run #3
5 2 2.0 0.47 ZR 19-25 2 4 21 1 Good Duplicate of Run #3
6 2 0.4 0.17 ZD 5-10 2 1-3 8 0.3 Large Variance in rates, axis rates slightly outside of target Rate
7 2 0.4 0.17 ZD 5-10 2 1-3 7 0.3 Large Variance in rates, axis rates slightly outside of target Rate
8 1 2.0 0.47 ZR 19-25 2 4 19 1 Rate slightly lower. Showed repeatability of Run #3 with different wall position on different day.
9 2 5.0 1.00 R 65-75 4 3-4 74 0.6-1.4 High Var in rates and droplet Size. Moved boards 1" further from wall (distance from wall is 4.3").
10 2 5.0 1.00 R 65-75 4 4 71 0.8-1.0 Good Rates, variability in droplet size considered acceptable due to high rate.
11 2 5.0 1.00 R 65-75 4 4 73 0.8-1.0 Good Duplicate of Run #10
12 1 and 2 5.0, 6.5 1.00 R 65-75 4 N/A Spot Check N/A Verify Repeatability of multiple Nozzles. Spot Checked with 2 rake pans to verify that rates were as similar to Run #10
47


APS
Aviation Inc
Conclusions – Light Freezing Rain
• Light Freezing Rain
– Generated 19-25 g/dm²/h conditions using 2 nozzles
– Achieved proper droplet diameter
– Good Repeatability and consistent results
Sprayer Settings
Run #
Position of Wall Nozzle Used (1,2, or 3)
Nozzle # Used
Water Flow Rate (L/m in)
Precip. Type
Target Precip. Rate (g/dm^2/h)
# of Nozzles Required for Effective Rate
# of Axis With Acceptable Rates
Effective Precip. Rate (g/dm^2/h)
Approx. Drop Size (mm)
Comments
1 2 2.0 2.00 ZR 19-25 1 4 23 0.5 Droplet Size to small, had to reduce flow rate/distance from wall to 5.3"
2 2 2.0 0.70 ZR 19-25 2 2 23 1 Used flow meter to regulate
3 2 2.0 0.47 ZR 19-25 2 4 22 1 Reduced flow and had to bring boards 2" closer to wall (distance from wall is 3.2")
4 2 2.0 0.47 ZR 19-25 2 4 22 1 Good Duplicate of Run #3
5 2 2.0 0.47 ZR 19-25 2 4 21 1 Good Duplicate of Run #3
8 1 2.0 0.47 ZR 19-25 2 4 19 1 Rate slightly lower. Showed repeatability of Run #3 with different wall position on different day.
48


APS
Aviation Inc
Conclusions – Freezing Drizzle
• Freezing Drizzle
– Generated 5-10 g/dm²/h conditions using 2 nozzles
– Achieved proper droplet diameter
– High Variability in rates produced
– Somewhat difficult to generate consistent rates for each axis
Sprayer Settings
Run #
Position of Wall Nozzle Used (1,2, or 3)
Nozzle # Used
Water Flow Rate (L/min)
Precip. Type
Target Precip. Rate (g/dm^2/h)
# of Nozzles Required for Effective Rate
# of Axis With Acceptable Rates
Effective Precip. Rate (g/dm^2/h)
Approx. Drop Size (mm)
Comments
6 2 0.4 0.17 ZD 5-10 2 1-3 8 0.3 Large Variance in rates, axis rates slightly outside of target Rate
7 2 0.4 0.17 ZD 5-10 2 1-3 7 0.3 Large Variance in rates, axis rates slightly outside of target Rate
49


APS
Aviation Inc
Conclusions - Rain
• Rain
– Generated 65-80 (not 65-75) g/dm²/h conditions using 4 nozzles
– Variance in droplet diameter is 1000μm±200 (not ±100)
– Good Repeatability and consistent results
Sprayer Settings
Run #
Position of Wall Nozzle Used (1,2, or 3)
Nozzle # Used
Water Flow Rate (L/m in)
Precip. Type
Target Precip. Rate (g/dm^2/h)
# of Nozzles Required for Effective Rate
# of Axis With Acceptable Rates
Effective Precip. Rate (g/dm^2/h)
Approx. Drop Size (m m)
Comments
9 2 5.0 1.00 R 65-75 4 3-4 74 0.6-1.4 High Var in rates and droplet Size. Moved boards 1" further from wall (distance from wall is 4.3").
10 2 5.0 1.00 R 65-75 4 4 71 0.8-1.0 Good Rates, variability in droplet size considered acceptable due to high rate.
11 2 5.0 1.00 R 65-75 4 4 73 0.8-1.0 Good Duplicate of Run #10
12 1 and 2 5.0, 6.5 1.00 R 65-75 4 N/A Spot Check N/A Verify Repeatability of multiple Nozzles. Spot Checked with 2 rake pans to verify that rates were as similar to Run #10
50

## Conclusions – Chamber Temperature

- Chamber Temperature
  - Refrigeration effects stability of spray curtain
  - Refrigeration needs to be turned off during calibration and test
  - Difficult to control temperature without refrigeration
  - Temperature range should be expanded to facilitate ease of testing

## Recommendations

- Remove the following conditions from test requirement:
  - Light Freezing Rain
  - Freezing Drizzle
- Increase precipitation range for Rain to 65-80 g/dm²/h (previously 65-75 g/dm²/h)
- Increase droplet diameter range for Rain to 1000μm±200 (previously 1000μm±100 )
- Change temperature requirement to ? -5°C to facilitate ease of testing

## Recommended Series of Tests

AS5681 Table A3

| Test # | Precipitation Type | Precipitation Rate g/dm²/h | Recommended Temperature °C | Test Plate | Fluid Type Required | Illumination |
|---|---|---|---|---|---|---|
| 3-1 | Rain | 65-80 | = or > -5 | 1 | Type IV P Over Type I PO over ite | Daylight |
| 3-2 | Rain | 65-80 | = or > -5 | 2 | Type IV P Over Type I PO over ite | Daylight |
| 3-3 | Rain | 65-80 | = or > -5 | 3 | Type IV P Over Type I PO over ite | Daylight |
| 3-4 | Freezing Fog | Visibility <100m | < or = -5 | 1 | Type IV P Over Type I PO over ite | Daylight |
| 3-5 | Freezing Fog | Visibility <100m | < or = -5 | 2 | Type IV P Over Type I PO over ite | Daylight |
| 3-6 | Freezing Fog | Visibility <100m | < or = -5 | 3 | Type IV P Over Type I PO over ite | Daylight |
| 3-7 | Rain | 65-80 | = or > -5 | 1 | Type IV P Over Type I PO over ite | Night-time |
| 3-8 | Rain | 65-80 | = or > -5 | 2 | Type IV P Over Type I PO over ite | Night-time |
| 3-9 | Rain | 65-80 | = or > -5 | 3 | Type IV P Over Type I PO over ite | Night-time |
| 3-10 | Freezing Fog | Visibility <100m | < or = -5 | 1 | Type IV P Over Type I PO over ite | Night-time |
| 3-11 | Freezing Fog | Visibility <100m | < or = -5 | 2 | Type IV P Over Type I PO over ite | Night-time |
| 3-12 | Freezing Fog | Visibility <100m | < or = -5 | 3 | Type IV P Over Type I PO over ite | Night-time |
| 3-13 | Rain | 65-80 | = or > -5 | 1 | Type IV P Over Type I PO over ite | Shadow |
| 3-14 | Rain | 65-80 | = or > -5 | 2 | Type IV P Over Type I PO over ite | Shadow |
| 3-15 | Rain | 65-80 | = or > -5 | 3 | Type IV P Over Type I PO over ite | Shadow |
| 3-16 | Freezing Fog | Visibility <100m | < or = -5 | 1 | Type IV P Over Type I PO over ite | Shadow |
| 3-17 | Freezing Fog | Visibility <100m | < or = -5 | 2 | Type IV P Over Type I PO over ite | Shadow |
| 3-18 | Freezing Fog | Visibility <100m | < or = -5 | 3 | Type IV P Over Type I PO over ite | Shadow |

## Data for "Curtain Solution"

## Data Log

| Run # | Spray per Settings: Roadway or Wall Nozzle Used (1,2, or 3) | Nozzle # Used | Water Flow Rate (L/min) | Precip. Type | Target Precip. Rate (g/dm²/h) | # of Nozzles Required for Effective Rate | # of Axis With Acceptable Rates | Effective Precip. Rate (g/dm²/h) | Approx. Drop Size (mm) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 2.0 | 2.00 | ZR | 19-25 | 1 | 4 | 23 | 0.5 | Droplet Size to small, facility nature Evernote (distance from wall to 3.2") |
| 2 | 2 | 2.0 | 0.70 | ZR | 19-25 | 2 | 2 | 23 | 1 | Used flow meter to regulate |
| 3 | 2 | 2.0 | 0.47 | ZR | 19-25 | 2 | 4 | 22 | 1 | Reduced flow and had to bring boards 2" closer to wall (distance from wall to 2.2") |
| 4 | 2 | 2.0 | 0.47 | ZR | 19-25 | 2 | 4 | 22 | 1 | Good Duplicate of Run #3 |
| 5 | 2 | 2.0 | 0.47 | ZR | 19-25 | 2 | 4 | 21 | 1 | Good Duplicate of Run #3 |
| 6 | 2 | 0.4 | 0.17 | ZD | 5-10 | 2 | 1-3 | 8 | 0.3 | Large Water droplets, axis values slightly outside of target Rate |
| 7 | 2 | 0.4 | 0.17 | ZD | 5-10 | 2 | 1-3 | 7 | 0.3 | Large Water droplets, axis values slightly outside of target Rate |
| 8 | 1 | 2.0 | 0.47 | ZR | 19-25 | 2 | 4 | 19 | 1 | Rate slightly lower. Showed repeatability of Run #3 with different wall positions and different day. |
| 9 | 2 | 5.0 | 1.00 | R | 65-75 | 4 | 3-4 | 74 | 0.6-1.4 | Flight Mist in rain and droplet Size. Moved towards 7" further from wall (distance from wall is 4.2") |
| 10 | 2 | 5.0 | 1.00 | R | 65-75 | 4 | 4 | 71 | 0.8-1.0 | Good Rate s, variability in droplet size considered acceptable due to high rate. |
| 11 | 2 | 5.0 | 1.00 | R | 65-75 | 4 | 4 | 73 | 0.8-1.0 | Good Duplicate of Run #10 |
| 12 | 1 and 2 | 5.0, 6.5 | 1.00 | R | 65-75 | 4 | N/A | Spot Check | N/A | Verify if repeatability of multiple Nozzles. Spot Checked with 2 rate pans to verify that rate was similar to Run #10 |

## Run 1

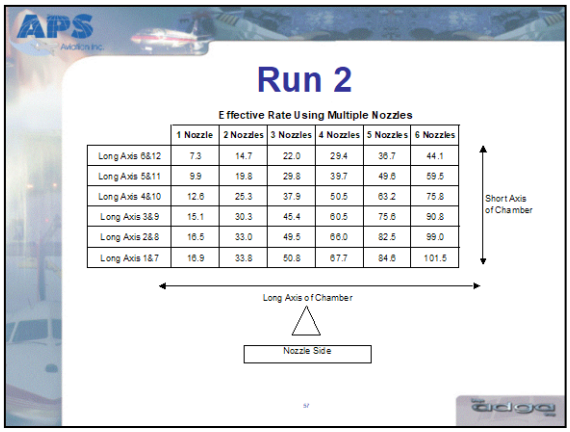
Effective Rate Using Multiple Nozzles

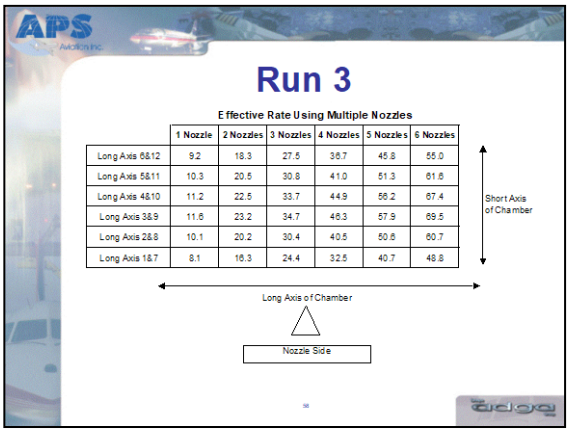
| | 1 Nozzle | 2 Nozzles | 3 Nozzles | 4 Nozzles | 5 Nozzles | 6 Nozzles |
|---|---|---|---|---|---|---|
| Long Axis 6&12 | 18.0 | 36.1 | 54.1 | 72.2 | 90.2 | 108.3 |
| Long Axis 5&11 | 21.0 | 42.0 | 63.0 | 84.1 | 105.1 | 126.1 |
| Long Axis 4&10 | 24.5 | 49.0 | 73.5 | 97.9 | 122.4 | 146.9 |
| Long Axis 3&9 | 28.5 | 57.0 | 85.5 | 114.0 | 142.5 | 171.0 |
| Long Axis 2&8 | 33.1 | 66.2 | 99.3 | 132.4 | 165.5 | 198.6 |
| Long Axis 1&7 | 37.4 | 74.8 | 112.2 | 149.6 | 187.1 | 224.5 |

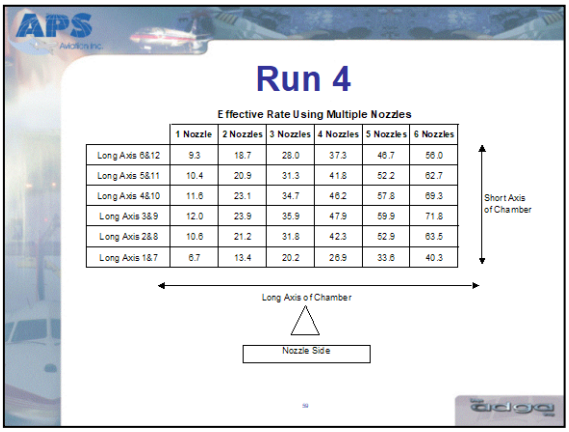
Short Axis of Chamber

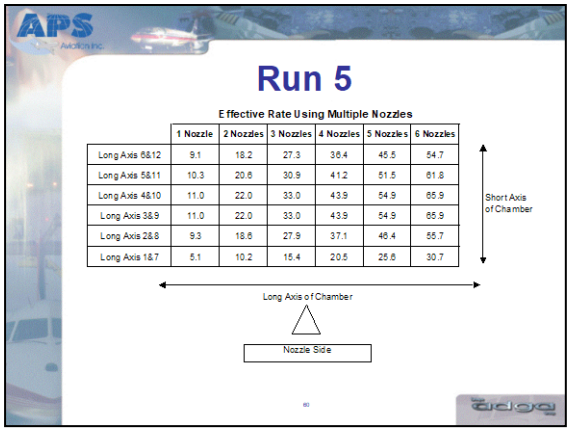
Long Axis of Chamber

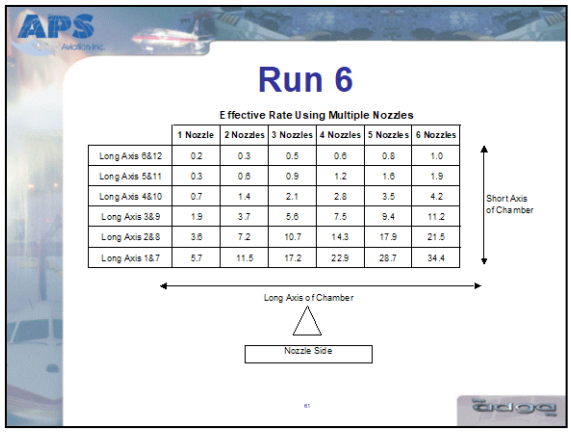
Nozzle Side


Run 2
Effective Rate Using Multiple Nozzles
1 Nozzle 2 Nozzles 3 Nozzles 4 Nozzles 5 Nozzles 6 Nozzles
Long Axis 6&12 7.3 14.7 22.0 29.4 36.7 44.1
Long Axis 5&11 9.9 19.8 29.8 39.7 49.6 59.5
Long Axis 4&10 12.6 25.3 37.9 50.5 63.2 75.8
Long Axis 3&9 15.1 30.3 45.4 60.5 75.6 90.8
Long Axis 2&8 16.5 33.0 49.5 66.0 82.5 99.0
Long Axis 1&7 16.9 33.8 50.8 67.7 84.6 101.5
Short Axis of Chamber
Long Axis of Chamber
Nozzle Side


Run 3
Effective Rate Using Multiple Nozzles
1 Nozzle 2 Nozzles 3 Nozzles 4 Nozzles 5 Nozzles 6 Nozzles
Long Axis 6&12 9.2 18.3 27.5 36.7 45.8 55.0
Long Axis 5&11 10.3 20.5 30.8 41.0 51.3 61.6
Long Axis 4&10 11.2 22.5 33.7 44.9 56.2 67.4
Long Axis 3&9 11.6 23.2 34.7 46.3 57.9 69.5
Long Axis 2&8 10.1 20.2 30.4 40.5 50.6 60.7
Long Axis 1&7 8.1 16.3 24.4 32.5 40.7 48.8
Short Axis of Chamber
Long Axis of Chamber
Nozzle Side


Run 4
Effective Rate Using Multiple Nozzles
1 Nozzle 2 Nozzles 3 Nozzles 4 Nozzles 5 Nozzles 6 Nozzles
Long Axis 6&12 9.3 18.7 28.0 37.3 46.7 56.0
Long Axis 5&11 10.4 20.9 31.3 41.8 52.2 62.7
Long Axis 4&10 11.6 23.1 34.7 46.2 57.8 69.3
Long Axis 3&9 12.0 23.9 35.9 47.9 59.9 71.8
Long Axis 2&8 10.6 21.2 31.8 42.3 52.9 63.5
Long Axis 1&7 6.7 13.4 20.2 26.9 33.6 40.3
Short Axis of Chamber
Long Axis of Chamber
Nozzle Side


Run 5
Effective Rate Using Multiple Nozzles
1 Nozzle 2 Nozzles 3 Nozzles 4 Nozzles 5 Nozzles 6 Nozzles
Long Axis 6&12 9.1 18.2 27.3 36.4 45.5 54.7
Long Axis 5&11 10.3 20.6 30.9 41.2 51.5 61.8
Long Axis 4&10 11.0 22.0 33.0 43.9 54.9 65.9
Long Axis 3&9 11.0 22.0 33.0 43.9 54.9 65.9
Long Axis 2&8 9.3 18.6 27.9 37.1 46.4 55.7
Long Axis 1&7 5.1 10.2 15.4 20.5 25.6 30.7
Short Axis of Chamber
Long Axis of Chamber
Nozzle Side


Run 6
Effective Rate Using Multiple Nozzles
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Long Axis 2&8 3.6 7.2 10.7 14.3 17.9 21.5
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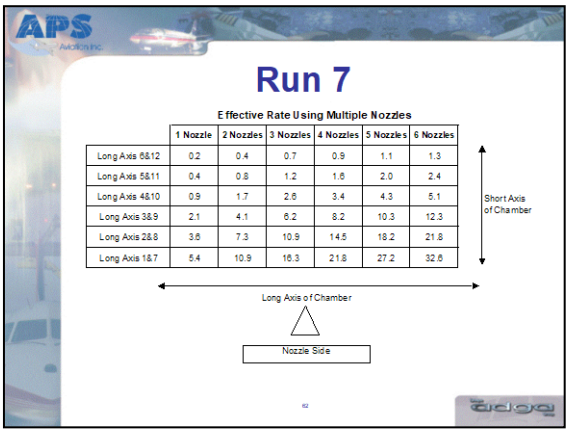
Short Axis of Chamber
Long Axis of Chamber
Nozzle Side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Long Axis 4&10 0.9 1.7 2.6 3.4 4.3 5.1
Long Axis 3&9 2.1 4.1 6.2 8.2 10.3 12.3
Long Axis 2&8 3.6 7.3 10.9 14.5 18.2 21.8
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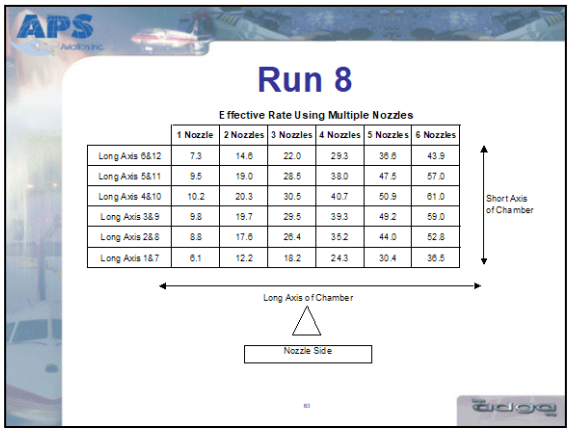
Short Axis of Chamber
Long Axis of Chamber
Nozzle Side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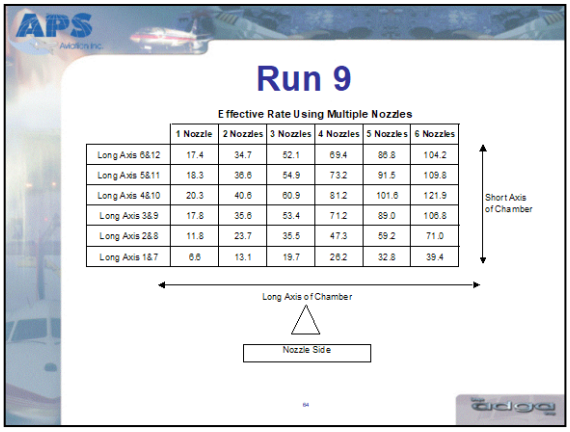
Long Axis 4&10 10.2 20.3 30.5 40.7 50.9 61.0
Long Axis 3&9 9.8 19.7 29.5 39.3 49.2 59.0
Long Axis 2&8 8.8 17.6 26.4 35.2 44.0 52.8
Long Axis 1&7 6.1 12.2 18.2 24.3 30.4 36.5
Short Axis of Chamber
Long Axis of Chamber
Nozzle Side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Long Axis 5&11 18.3 36.6 54.9 73.2 91.5 109.8
Long Axis 4&10 20.3 40.6 60.9 81.2 101.6 121.9
Long Axis 3&9 17.8 35.6 53.4 71.2 89.0 106.8
Long Axis 2&8 11.8 23.7 35.5 47.3 59.2 71.0
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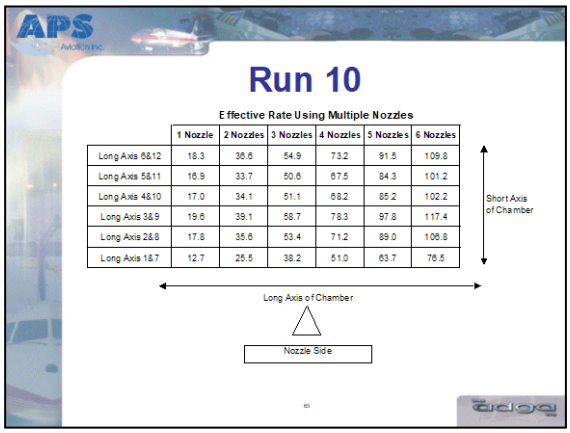
Short Axis of Chamber
Long Axis of Chamber
Nozzle Side


Run 10
Effective Rate Using Multiple Nozzles
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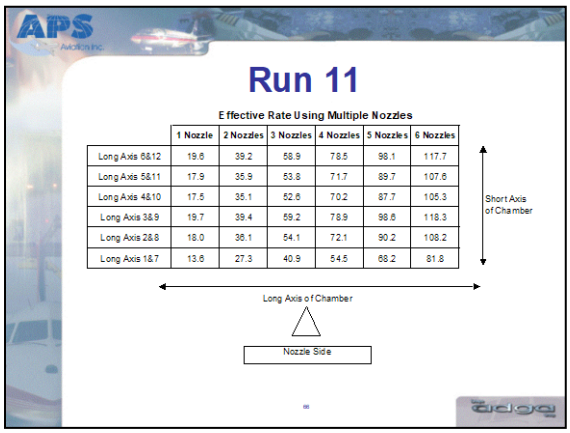
Long Axis 5&11 16.9 33.7 50.6 67.5 84.3 101.2
Long Axis 4&10 17.0 34.1 51.1 68.2 85.2 102.2
Long Axis 3&9 19.6 39.1 58.7 78.3 97.8 117.4
Long Axis 2&8 17.8 35.6 53.4 71.2 89.0 106.8
Long Axis 1&7 12.7 25.5 38.2 51.0 63.7 76.5
Short Axis of Chamber
Long Axis of Chamber
Nozzle Side


Run 11
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Long Axis of Chamber
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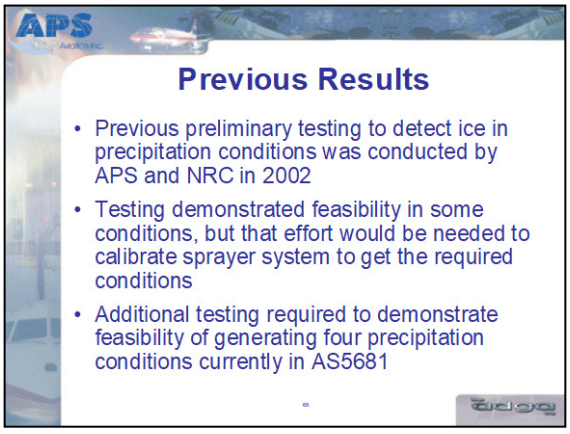
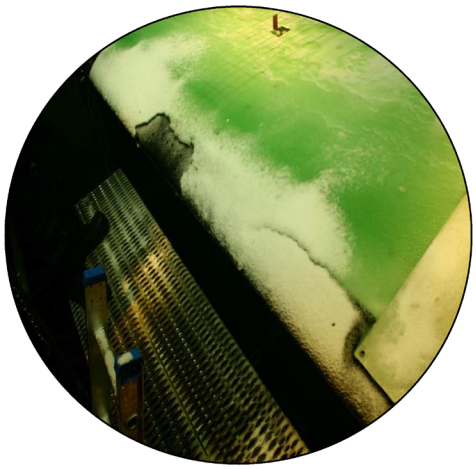

Previous Results
• Previous preliminary testing to detect ice in precipitation conditions was conducted by APS and NRC in 2002
• Testing demonstrated feasibility in some conditions, but that effort would be needed to calibrate sprayer system to get the required conditions
• Additional testing required to demonstrate feasibility of generating four precipitation conditions currently in AS5681

# APPENDIX G

# INTERIM REPORT:
# PRELIMINARY AIRCRAFT DEICING RESEARCH IN HEAVY SNOW CONDITIONS

Interim Report

# Preliminary Aircraft Deicing Research in Heavy Snow Conditions



*Prepared for*
**Transportation Development Centre**

*In cooperation with*

Civil Aviation
Transport Canada

And

The Federal Aviation Administration
William J. Hughes Technical Center

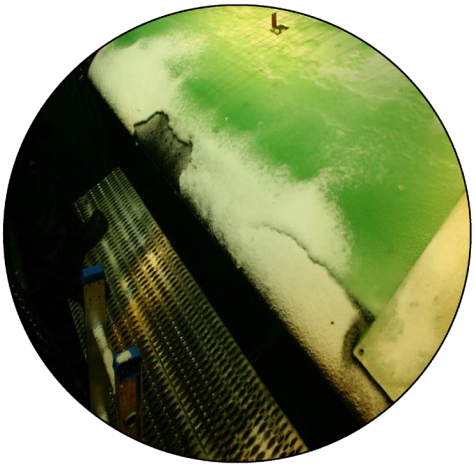
*Prepared by*

APS Aviation Inc.

January 2008
Final Draft 1.0

Interim Report

# Preliminary Aircraft Deicing Research in Heavy Snow Conditions



*by*
Marco Ruggi

APS Aviation Inc.

January 2008
Final Draft 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.

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Date

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Vice President, Communications Engineering
ADGA Group

Jan 30, 08
Date

Un sommaire français se trouve avant la table des matières.

## PREFACE

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

- To develop holdover time data for all newly-qualified de/anti-icing fluids;
- To evaluate whether holdover times should be developed for ice pellet conditions;
- To examine the effect of heated fluids on Type II/III/IV fluid endurance times;
- To evaluate weather data from previous winters to establish a range of conditions suitable for the evaluation of holdover time limits;
- To assist in the testing of flow of contaminated fluid from aircraft wings during takeoff;
- To assist in the testing of flow of contaminated fluid from simulated aircraft wings during takeoff;
- To validate the laboratory snow test protocol with Type II and IV fluids;
- To develop performance specifications for an integrated weather system that measures holdover time;
- To provide support for the development of a standard that evaluates remote on-ground ice detection systems;
- To conduct general and exploratory de/anti-icing research;
- To conduct endurance time tests on non-aluminum plates;
- To conduct endurance time tests in frost on various test surfaces;
- To conduct preliminary wind tunnel endurance time tests in heavy snow;
- To compile historical data for calculation of holdover times based on a small number of inputs;
- To examine the use of non-glycol tempered steam technology to deice aircraft; and
- To assist DND Canada in evaluating the effects of slipstream on anti-icing fluid.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2006-07 are documented in eight reports. The titles of the reports are as follows:

- TP (06-07)-01 Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2006-07 Winter;
- TP (06-07)-02 Winter Weather Impact on Holdover Time Table Format (1995-2007);
- TP (06-07)-03 Flow of Contaminated Fluid from Aircraft Wings: Feasibility Study;
- TP (06-07)-04 Development of Allowance Times For Aircraft Deicing Operations During Conditions With Ice Pellets;

- TP (06-07)-05 Evaluation of Tempered Steam Technology (TST) for Aircraft Deicing Applications;
- TP 14452E Feasibility of ROGIDS Test Conditions Stipulated in SAE Draft Standard AS 5681;
- TP (06-07)-07 Aircraft Ground Icing Research General Activities During the 2006-07 Winter; and
- TP (06-07)-08 Regression Coefficients Used to Develop the Winter 2007-08 Type I Generic and Dow UCAR Endurance EG106 Holdover Time Tables.

In addition, the following six interim reports are being prepared:

- *Preliminary Aircraft Deicing Research in Heavy Snow Conditions;*
- *Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2006-07;*
- *Effect of Heat on Fluid Endurance Times Using Composite Surfaces;*
- *Effect of Heat on Endurance Times of Anti-icing Fluids;*
- *Substantiation of Aircraft Ground Deicing Holdover Times in Frost Conditions; and*
- *Regression Coefficients Used to Develop Aircraft Ground Deicing Holdover Time Tables: Winter 2007-08.*

In addition, the following report was written for DND as part of this contract; this report does not have a TP number:

- Support for Testing to Ascertain the Effects of SAE Type IV De/Anti-Icing Fluids on CC-130 Hercules and CP-140 Aurora Aircraft Takeoff Handling.

This interim report has the following objective:

- To conduct preliminary flat plate and aerodynamic testing to determine the aerodynamic effects of heavily contaminated anti-icing fluid subjected to simulated snow conditions.

This objective was met by conducting small scale testing on flat plates, followed by a series of tests using the NRC open circuit wind tunnel and the NRC Falcon 20 aircraft. Aerodynamic testing was conducted in conjunction with the ice pellet allowance time research program.

## PROGRAM ACKNOWLEDGEMENTS

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

APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. This includes the following people: George Balaban, Katrina Bell, Stephanie Bendickson, Ryan Brydges, Michael Chaput, John D'Avirro, Peter Dawson, Dany Posteraro, Marco Ruggi, Joey Tiano, and David Youssef.

Special thanks are extended to Barry Myers, Frank Eyre and Yagusha Bodnar, who on behalf of the Transportation Development Centre, have participated, contributed and provided guidance in the preparation of these documents.

## PROJECT ACKNOWLEDGEMENTS

The author of this report would like to acknowledge and thank Barry Myers (Transport Canada) and Warren Underwood (Federal Aviation Administration) who's individual specializations played a critical role in directing the experiments. The author would also like to acknowledge and thank the staff of the NRC Open-Circuit Propulsion and Icing Wind Tunnel and the NRC Institute for Aerospace Research for their diligence and commitment in providing support for the conduct of the experiments.

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## EXECUTIVE SUMMARY

Under contract to the Transportation Development Centre (TDC) of Transport Canada, with support from the Federal Aviation Administration (FAA), and several fluid manufacturers, APS Aviation Inc. (APS) has undertaken a testing and research program to further advance aircraft ground de/anti-icing technology. The program has a number of objectives, and work completed to address these objectives is documented in a series of related reports. The objective of the project documented in this report was to determine the aerodynamic effects of heavily contaminated anti-icing fluid subjected to simulated snow conditions. Aerodynamic testing was conducted in conjunction with the ice pellet allowance time research program.

### Background and Objectives

The recent industry requirement for guidance material for aircraft operations in mixed conditions with ice pellets necessitated the use of aerodynamic testing due to the melting properties of ice pellets. Embedded ice pellets required a significantly longer time in comparison to snow to dissolve in anti-icing fluid, therefore, the standard protocol that is used to measure endurance times could not be applied. As a direct result of the ice pellet research conducted, the use of HOT's for determining the protection time provided by anti-icing fluids was questioned. The focus was turned towards "aerodynamic failure" which would be defined as a significant lift loss due to the contamination of the anti-icing fluid. Heavy snow conditions were selected for this study for two reasons. First, snow conditions account for the most significant portion of deicing operations globally. Secondly, there has been recent industry interest to have holdover times for heavy snow conditions, as this condition typically occurs 3% of the time during snow events.

To benefit from economies of scale, TC and the FAA opted to conduct a series of preliminary tests to investigate the aerodynamic properties of heavily contaminated anti-icing fluid exposed to simulated snow conditions in conjunction with the ice pellet research being conducted at the NRC open circuit wind tunnel and Falcon 20 aircraft.

### Data Collection and Testing

At the start of each aerodynamic test (both for the wind tunnel tests and the Falcon 20 tests), the test wing was treated with anti-icing fluid using a one-step operation. Simulated precipitation was then applied over the anti-iced test section until specified levels of contamination were achieved. Data such as fluid

thickness, wing temperatures, and fluid freeze points were recorded. The wind tunnel or Falcon 20 aircraft was then operated through a simulated takeoff test. The behaviour of the fluid during the simulated takeoff was documented with high-speed digital still cameras and video cameras.

During the wind tunnel tests, drag and lift data collected by the NRC was used to generate lift coefficient curves for each of the tests conducted in the wind tunnel. The lift data collected during contaminated fluid tests were compared to the data collected during the baseline fluid only and dry wing tests. The Falcon 20 tests were primarily conducted as a verification of the results obtained in the wind tunnel using the NACA 23012 test wing section; lift data was not collected.

**Conclusions**

Visual observations during the wind tunnel tests reported residual contamination on the trailing edge of the wing section at the end of the heavy snow tests; the condition worsened as the precipitation rate was increased. During one test, some contamination was still present on the leading edge at the end of the test; the contamination was not adhered to the surface. Although visually, this was deemed a severe condition, the lift data collected did not show significant signs of lift losses directly attributable to the heavy snow contamination.

Visual contamination results obtained with the Falcon 20 confirmed the results obtained in the wind tunnel.

**Recommendations**

Further testing is recommended as a result of the observations made during the 2006-07 tests. It is recommended that additional testing be conducted at the NRC wind tunnel and with the NRC Falcon 20 aircraft. Testing should be conducted in heavy snow conditions to determine the aerodynamic failure of a fluid following excessive exposure to precipitation. To obtain a visual benchmark, testing should also be conducted in light or moderate snow conditions, with contamination levels within the appropriate HOT, to obtain a visual reference of acceptable aerodynamic fluid flow-off.

## SOMMAIRE

***To be delivered by the TDC editor.***

SOMMAIRE

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# GLOSSARY

| | |
|---|---|
| APS | APS Aviation Inc. |
| CDU | Cockpit Display Unit |
| Cl | Lift Coefficient |
| Cn | Normal Coefficient |
| CSA | Canadian Space Agency |
| DAT | Digital Audio Tape |
| DND | Department of National Defence |
| EG | Ethylene Glycol |
| FAA | Federal Aviation Administration |
| GPS | Global Positioning System |
| HOT | Holdover Time |
| ILS | Instrument Landing System |
| MSC | Meteorological Service of Canada |
| MLS | Microwave Landing System |
| NACA | National Advisory Committee for Aeronautics |
| NASA | National Aeronautics and Space Administration |
| NCAR | National Center for Atmospheric Research |
| NRC | National Research Council Canada |
| OAT | Outside Air Temperature |
| Montreal-Trudeau | Pierre Elliott Trudeau International Airport |
| PG | Propylene Glycol |

| | |
|---|---|
| TC | Transport Canada |
| TDC | Transportation Development Centre |
| VOR | VHF Omnidirectional Range |
| YOW | MacDonald Cartier International Airport |

# 1 INTRODUCTION

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

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

As part of the research program APS conducted a series of small-scale plate tests and full-scale tests with the National Research Council (NRC) open circuit wind tunnel and Falcon 20 aircraft to examine the aerodynamic flow off properties of heavily contaminated anti-icing fluid during simulated snow conditions.

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## 1.1 Background

Due to the recent industry requirement for guidance material for aircraft operations in mixed conditions with ice pellets, APS conducted a series of plate tests and full-scale tests with the NRC open circuit wind tunnel and Falcon 20 aircraft. This research was conducted during the winter of 2006-07 to determine the maximum amount of ice pellet contamination that will flow off an anti-iced aircraft at takeoff. Aerodynamic testing was required due to the melting properties of ice pellets; embedded ice pellets required a significantly longer time in comparison to snow to dissolve in anti-icing fluid. Consequently, holdover times were not applicable for ice pellet conditions because contamination was present at the start of the holdover time; the criteria for fluid failure (or the end of the holdover time) is determined by contamination present

on 30% of the test plate. As a result, a series of allowance times were issued based on the aerodynamic data collected.

As a direct result of the ice pellet research conducted, the use of HOT's for determining the protection time provided by anti-icing fluids was questioned. The focus was turned towards "aerodynamic failure" which would be defined as a significant lift loss due to the contamination of the anti-icing fluid. Heavy snow conditions were selected for this study for two reasons. First, snow conditions account for the most significant portion of deicing operations globally. Secondly, there has been a recent industry interest for holdover time for heavy snow conditions.

To benefit from economies of scale, TC and the FAA opted to conduct a series of preliminary tests to investigate the aerodynamic properties of heavily contaminated anti-icing fluid exposed to simulated snow conditions in conjunction with the ice pellet research being conducted at the NRC open circuit wind tunnel and Falcon 20 aircraft.

## 1.2 Objective

APS conducted a series of preliminary tests during the winter of 2006-07 to determine the aerodynamic effects of heavily contaminated anti-icing fluid subjected to simulated snow conditions. Aerodynamic testing was conducted in conjunction with the ice pellet allowance time research program.

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

## 1.3 Previous Falcon 20 Full Scale Testing

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

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

1. TP 13316E, *Contaminated Aircraft Takeoff Test for the 1997-98 Winter* (1);



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2. TP 13479E, *Contaminated Aircraft Takeoff Test for the 1998-99 Winter* (2);
3. TP 13666E, *Contaminated Aircraft Simulated Takeoff Tests for the 1999-2000 Winter: Preparation and Procedures* (3);
4. TP 13995E, *Aircraft Takeoff Test Program for Winter 2001-02: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid* (4); and
5. TP 14147E, *Aircraft Takeoff Test Program for Winter 2002-03: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid* (5).

Research was conducted during the winter of 2005-06 using the Falcon 20 aircraft to determine the maximum amount of ice pellet contamination that will flow off an anti-iced aircraft at takeoff. This research is documented in detail in a report written by APS for Transport Canada:

*6.* TP 14716E, *Falcon 20 Trials to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets (6);*

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## 1.4 Previous NRC Wind Tunnel Full Scale Testing

Previous trials to examine aerodynamic performance effects of de/anti-icing fluids that had been contaminated by varying quantities of freezing precipitation were conducted over three winter seasons at the NRC 3 m x 6 m open circuit wind tunnel. The airfoil tested was a full-scale NASA LS(1)-0417 section with a Fowler flap deployed at 15 degrees. A spraybar located in the wind tunnel settling chamber produced artificial snow. Takeoff was simulated by accelerating the test section wind speed and aerodynamic data were obtained while pitching the airfoil to the stall. These trials, based on takeoff simulations, showed that the test approach was a viable one.

This research is documented in detail in a report written in May 1999 by the National Research Council Canada Institute for Aerospace Research for Transport Canada: TP 13426E, *Airfoil-Flap Performance with De/Anti-Icing Fluids and Freezing Precipitation* (7).

## 1.5 Overview of 2006-07 Testing

Testing during the winter of 2006-07 comprised of small scale testing conducted on flat plates, followed by full-scale testing conducted in the NRC

open circuit wind tunnel, and finally testing with the NRC Falcon 20 aircraft. The testing conducted is summarized below:

- Flat plate testing conducted to investigate fluid endurance time in heavy snow conditions:
  - National Center for Atmospheric Research (NCAR) snow machine testing to validate snow holdover times generated using the current holdover time (HOT) regression data (September 2006 at the APS Test Facility Refrigerated Chamber at the Pierre Elliott Trudeau International Airport (Montreal-Trudeau) in Montreal); and
  - Outdoor testing with leading edge thermal equivalent boxes to verify the effect of the latent heat of cooling generated by heavy snow conditions (Winter 2006-07 at APS Montreal-Trudeau Test Site).
- Aerodynamic research conducted to investigate fluid flow-off of heavily contaminated anti-icing fluid following simulated snow conditions:
  - Aerodynamic research conducted at the NRC open circuit wind tunnel; and
  - Aerodynamic research conducted using the NRC Falcon 20 aircraft as a spot check and validation of results obtained in wind tunnel.

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## 1.6 Report Format

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

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

b) Section 3 describes the results from the flat plate tests conducted in natural and simulated heavy snow conditions;

c) Section 4 describes data collected during the full-scale testing conducted;

d) Section 5 describes the baseline data, results, used as a comparative benchmark for aerodynamic research with contaminated fluids;

e) Section 6 describes the data and results collected during the aerodynamic testing conducted in the NRC open circuit wind tunnel and with the NRC Falcon 20 aircraft;

f) Section 7 describes the conclusions from the testing conducted; and

g) Section 8 lists recommendations for future testing.

# 2 METHODOLOGY

This section describes the test methodologies followed. The following list provides short descriptions of subsequent sub-sections:

- Section 2.1: Test methodologies and equipment specific to the Wind Tunnel Tests;
- Section 2.2: Test methodologies and equipment specific to the Falcon 20 aircraft tests; and
- Section 2.3: General testing methodologies and equipment.

## 2.1 Wind Tunnel Tests

### 2.1.1 Test Site

The 2006-07 Open-Circuit Wind Tunnel tests were performed at NRC Aerospace Facilities, Building M-46, at the NRC Montreal Road Campus, located in Ottawa. Figure 2.1 provides a schematic of the NRC Montreal Road Campus showing the location of the NRC Open-Circuit Propulsion and Icing Wind Tunnel. Photo 2.1 shows an outside view of the wind tunnel test facility. Photo 2.2 shows an inside view of the wind tunnel test section. The open-circuit layout, with fan at entry, permits contaminants associated with the test articles (such as heat, or de/anti-icing fluid) to discharge directly, without recirculating or contacting the fan. The fan is normally driven electrically but high-speed operation (as required for the 2006-07 tests) can be accommodated by a gas turbine drive system.

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### 2.1.2 Test Schedule

Testing was scheduled for the period of February 12, 2007 to February 23, 2007. Due to the complexity of the aircraft ground icing simulation tests being performed a set-up and calibration week was planned for the period of January 16, 2007 to January 19, 2007. Details of the set-up and calibration work conducted are included in the report TP (06-07)-03, *Flow of Contaminated Fluid from Aircraft Wings: Feasibility Report* – November 2007 (8).

A test plan was completed that allowed for modifications during the test period according to observations made during initial tests. Table 2.1 presents the calendar of wind Tunnel tests performed in 2007. Test numbers with the prefix "SS" indicate heavy snow aerodynamic tests.

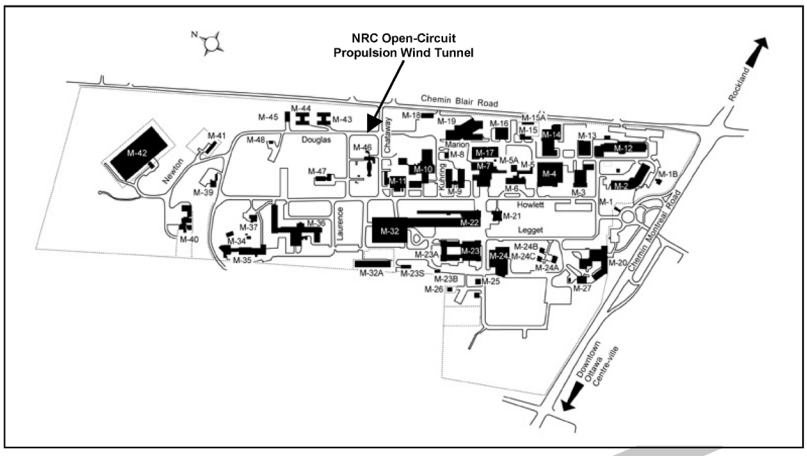


**Figure 2.1: Schematic of NRC Montreal Road Campus**

**Table 2.1: Calendar of Tests**

| Date | Number of Test Runs | Test Numbers |
|---|---|---|
| 16-Jan-07 | Set-up | n/a |
| 17-Jan-07 | Set-up/Precip Calib. | n/a |
| 18-Jan-07 | Set-up/Precip Calib. | n/a |
| 19-Jan-07 | Set-up/Dry Run | n/a |
| | | |
| 12-Feb-07 | Set-up | n/a |
| 13-Feb-07 | Set-up/Dry Run | n/a |
| 14-Feb-07 | 4 | 1, 2, 3, 4 |
| 15-Feb-07 | 3 | 5, 6, 6a |
| 16-Feb-07 | 3 | 1a, SS1, SS2 |
| | | |
| 19-Feb-07 | 4 | SS3, SS4, SS5, SS6 |
| 20-Feb-07 | 4 | SP1, SP2, SP3, SS7 |
| 21-Feb-07 | 3 | A1, A2, A3 |
| 22-Feb-07 | 4 | 7, 8, 9, SP4 |
| 23-Feb-07 | 4 | 10, 11, 12, 13 |

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### 2.1.3 Procedure

To satisfy the program objective, simulated takeoff and climb-out tests were performed with the NRC National Advisory Committee for Aeronautics (NACA) 23012 wing section, and different parameters, including fluid thickness, wing temperature, and fluid freezing point, were recorded at designated times during the tests.

The procedure for each was as follows:

a) The wing section was treated with Type IV fluid, poured in a one-step operation (no Type I fluid was used during the tests);

b) Contamination, in the form of simulated snow was applied to the wing section. Test parameters were measured at the beginning and end of the exposure to contamination; and

c) At the end of the contamination period, the tunnel was cleared of all equipment and scaffolding.

The wind tunnel was subsequently operated through a simulated takeoff and climb-out test. The behaviour of the fluid during takeoff and climb-out was recorded with digital video cameras and digital high-speed still cameras.

Tests results were compared to the results obtained with the Falcon 20 aircraft to validate the results obtained.

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### 2.1.4 Equipment

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

#### *2.1.4.1 Wind Tunnel*

The experiments were performed in the NRC's Propulsion Wind Tunnel. This facility is an open circuit wind tunnel with the fan at the entry, drawing air from and exhausting to the outdoors; this design is ideal for de/anti-icing tests as it prevents contaminants from recirculating within the tunnel. This design also permits sub-freezing air to be drawn in during the Ottawa winter, thereby providing test section temperatures appropriate to these experiments. The test section is 3 m (10 ft) wide by 6 m (20 ft) high by 12 m (40 ft) long, with a maximum wind speed of 78 knots when using the electrical turbine drive, and

with a maximum wind speed of 125 knots when using the gas turbine drive. Scaffolding was constructed to allow access to the wing section, which facilitated the application of fluids and the subsequent inspection and cleaning of the airfoil.

### *2.1.4.2 NACA 23012 Wing Section*

The wing section used for testing was a NACA 23012, acquired by the NRC. Photo 2.3 shows the wing section used for testing; APS was in the process of marking a reference grid on the test surface. The wing section used was hard wing similar to an airfoil of a Cessna Caravan. The NACA 23012 wing section had been used in recent years by the NRC for airborne icing experiments; this was the first time the wing section would be used for ground icing simulation tests.

### *2.1.4.3 NACA 23012 design characteristics*

A cross sectional view of the NACA 23012 wing section used for testing has been included in Figure 2.2. Some of the pertinent dimensions of the wing section are:

a) Wing span: 1.2 m (4 ft.);
b) Length: 3 m (10 ft.); and
c) Wing surface area: 3.6 $m^2$ (30 $ft.^2$).

The wing section was constructed of aluminum. The leading edge of the wing section was removable and was covered in a thick rubber material (simulating a leading edge boot). The wing section used did not have slats or flaps. No moveable devices were available on the wing section.

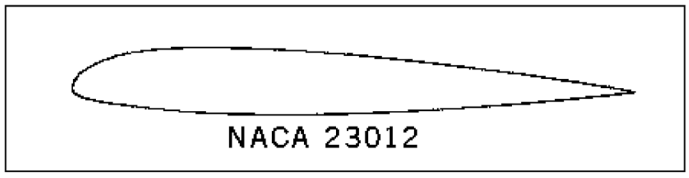


**Figure 2.2: Cross Sectional View of NACA 23012 Wing Section**

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#### 2.1.4.4 Wind Tunnel Measurement Capabilities

The NRC NACA 23012 wing section was supported on either side by 2-axis weigh scales capable of measuring drag and lift forces generated on the wing section. The wing section was attached to servo-systems capable of pitching the wing section to a static angle, or generating dynamic movements. The servo system was programmed to simulate pitch angles during takeoff and climb-out based on previous Falcon 20 data collected. The leading edge of the wing section was also equipped with thermistor sensors (these were installed by APS during the set-up week) recording the skin temperature at various locations on the leading edge.

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

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

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#### 2.1.4.5 Test Area Grid

Prior to the testing, APS personnel used permanent markers to draw a grid with dimensions of 0.61 m x 1.22 m (2 ft. x 4 ft.) along a chord approximately 0.65 m (2.1 ft.) from the tunnel wall. Smaller grids with dimensions of 5.1 cm x 5.1 cm (2 in. x 2 in.) were then drawn inside the larger grid, perpendicular and parallel to the leading edge (see Photo 2.4). The grid was used to provide a point of reference to facilitate observations of the fluid shearing off the wing and the movement of contamination during takeoff.

### 2.1.5 Simulated Precipitation Related Equipment

#### 2.1.5.1 Snow Dispenser

Snow was manufactured from ice cubes inside a rented refrigerated truck. The process required the use of blenders, calibrated sieves and large Styrofoam containers.

Once produced, the ice pellets were stored in the Styrofoam containers. They were applied over the test area using the specially modified handheld dispensers shown in Photo 2.5.

#### *2.1.5.2 Video and Photo Equipment*

Two Canon Digital Rebel XT digital still cameras were used to obtain high speed, high-resolution photographs of the testing. The 8 mega-pixel resolution cameras are capable of taking up to three pictures per second in continuous shooting mode. The cameras were used with two different lenses:

a) 18-55 mm standard lens for wide angle pictures; and
b) 105 mm macro lens for close ups.

Digital still cameras were used to record visual observations of the testing. To create a consistent and stable setup for the cameras, APS mounted the cameras in the observation window overlooking the wing section. The flashes, operated through infrared sensors, were positioned in the opposing observation window (Figure 2.3; this created a shadow effect, which could be used to measure and calculate the magnitude of the fluid waves and protruding contamination. Photos 2.6 and 2.7 demonstrate the camera setup used for the testing period. Video cameras, operated by NRC personnel, were positioned directly above the wing section. The cameras were zoomed in to observe the behaviour of the fluid and contamination on the wing.

In addition, a professional photographer used a digital still camera to take pictures of the test setup and all phases of the tests.

### 2.1.6 Type IV Fluid Application Equipment

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

Type IV fluids were applied to the wing section by pouring directly from the 20 L fluid containers, or from smaller 3 litre containers (see Photo 2.8). 20 L of fluid were applied to the wing section for each test.

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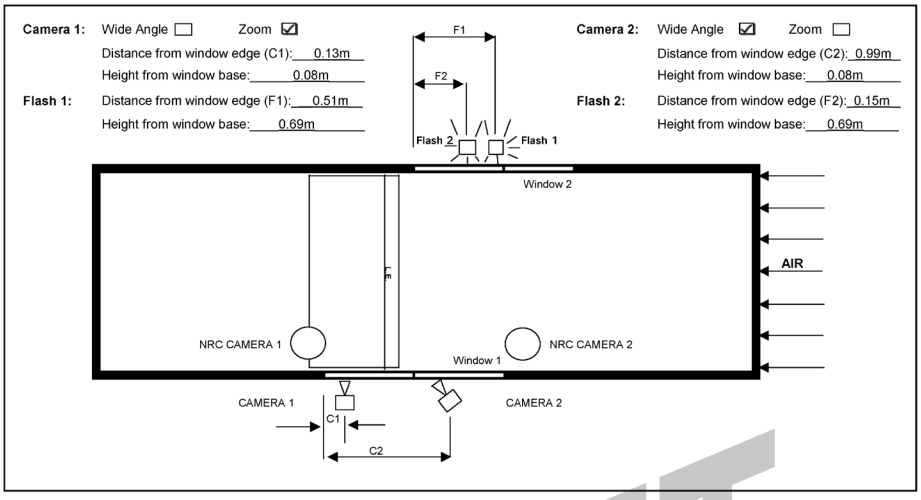


**Figure 2.3: Wind Tunnel Camera and Flash Setup**

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### 2.1.7 Personnel

NRC personnel operated the wind tunnel. Five APS staff members were required to conduct the tests and three additional persons from Ottawa were hired to manufacture the simulated snow. A professional photographer was retained to record digital images of the test setup and tests. Representatives from TDC and the FAA provided direction in testing and participated as observers.

### 2.1.8 Measurement of Test Parameters

#### *2.1.8.1 Fluid Thickness*

For each test, the fluid thickness of the anti-icing fluid was measured at eight locations along the wing chord just to the left of the test grid (closest to the centre of the wing section) using wet film thickness gauges (Photo 2.9). Measurements were taken during three stages in a typical test:

a) Before the snow application;
b) After the snow application; and
c) After the simulated takeoff test.

The locations designated for thickness measurement, identified in Figure 2.4, were the following:

- Wing Position 1: On the leading edge;
- Wing Position 2, 3, 4, 5: At equal distances (approximately 15 cm) between rivets 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
- Underside: The underside of wing section, as far as could be reached from the leading edge.

Measurements were taken along a chord approximately 1.3m (4.3 ft.) from the tunnel wall (left most section of the wing when facing the leading edge).

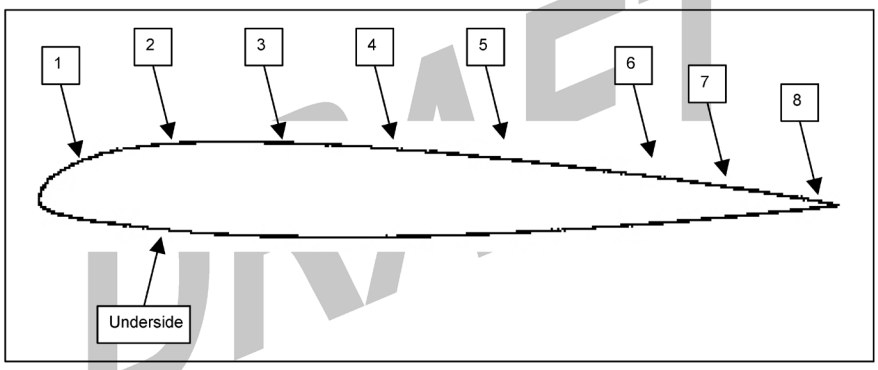


**Figure 2.4: Measurement Locations Along Chord of NACA 23012 Wing Section**

*2.1.8.2 Fluid Brix*

Fluid Brix was measured using hand-held refractometers (Photo 2.10) at three stages of the Type IV tests:

a) Before the snow application;
b) After the snow application; and
c) After the simulated takeoff test.

The locations designated for fluid Brix measurement, identified in Figure 2.4, were the following:

- Wing Position 2: On the leading edge; and
- Wing Position 5: As far as could be reached from the leading edge.

*2.1.8.3 Wing Skin Temperature*

Wing temperatures were measured using a hand-held temperature probe (Photo 2.11) at three locations at three stages of the Type IV tests:

a) Before the snow application;
b) After the snow application; and
c) After the simulated takeoff test.

The locations designated for skin temperature measurements, identified in Figure 2.4, were the following:

- Wing Position 2: On the leading edge;
- Wing Position 5: As far as could be reached from the leading edge; and
- Underside: The underside of wing section, as far as could be reached from the leading edge.

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### 2.1.9 Visual Severity Ratings

To facilitate analysis of the wind tunnel tests conducted, a visual severity ranking of the contaminated fluid flow off was based on the photography of the wing section during each test run. Rankings from 1-5 (with increasing severity) were assigned to each test. The following is a description of the criteria used for the ranking:

1-Trailing edge clean after 30 seconds (approximate time of rotation);
2-Trailing edge clean after 45 seconds;
3-Trailing edge clean after 60 seconds;
4-Trailing edge clean after >60 seconds, and some contamination left after the test; and
5-Same as Ranking 4, with contamination on leading edge after 45 seconds.

### 2.1.10 Data Forms

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

a) Fluid Receipt Form;
b) General Form (every test);
c) Wing Temperature Form (every test);
d) Fluid Thickness and Brix Form (every test);
e) Condition of Wing and Plate Form (every test);
f) Camera Location Form (used only if changes were made);
g) Wind Tunnel General Setup Form (used only once); and
h) Log of Fluid Sample Bottles.

These forms are provided in the test procedure, which is included in Appendix B.

## 2.2 Falcon 20 Tests

### 2.2.1 Test Site

The 2006-07 Falcon 20 tests were performed at MacDonald Cartier International Airport (YOW) in Ottawa. Figure 2.5 provides a schematic of the airport showing the runways and the location of the NRC hangar and apron. Photo 2.12 shows the NRC hangar.

### 2.2.2 Test Schedule

Testing was scheduled for the period of February 26 to March 1, 2007. February 26 was scheduled as a setup day. A test plan was created to allow for modifications during the test period according to observations made during initial tests. During each test, fluid was applied to a pre-marked section on both port and starboard wings. Contamination was applied to only one wing section; the other wing section remained uncontaminated and was used as a baseline for the test. Table 2.2 presents the calendar of Falcon 20 tests performed in 2007. For example, on February 28, 2007, two tests were completed. Test 3 tests were done on both the port (Test 3P) and starboard (Test 3S) wings. Similarly, Test 4 tests were also done on the two wings (Tests 4P and 4S). Only Test # 1S was conducted in heavy snow conditions.

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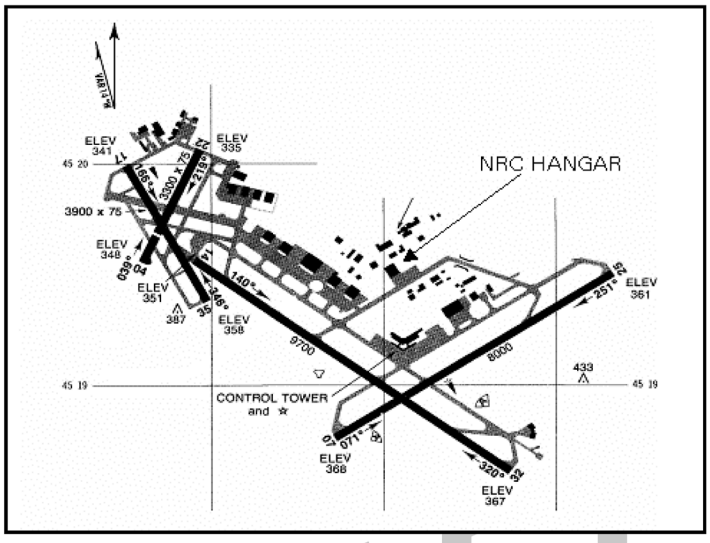


**Figure 2.5: Schematic of Ottawa Airport**

**Table 2.2: Calendar of Tests**

| Date | Number of Tests | Test Numbers |
|---|---|---|
| 26-Feb-07 | Set-up | n/a |
| 27-Feb-07 | 2 | 1p, 1s, 2p, 2s |
| 28-Feb-07 | 2 | 3p, 3s, 4p, 4s |
| 1-Mar-07 | 2 | 5p, 5s, 6p, 6s |

* Conducted in heavy snow

### 2.2.3 Procedure

To satisfy the program objective, simulated takeoff tests were performed with the NRC Falcon 20 research aircraft, and different parameters, including fluid thickness, wing temperature, and fluid freezing point, were recorded at designated times during the tests.

The procedure for each test was as follows:

a) A designated test area on the port and starboard wings was treated with Type IV fluid, poured in a one-step operation outside the NRC hangar;

b) Contamination, in the form of simulated snow was applied to only one wing section; the other wing section was left un-contaminated and used as a baseline comparison test. Test parameters were measured at the beginning and end of the exposure to contamination;

c) At the end of the contamination period, the aircraft taxied to the selected runway. Once at the threshold, APS personnel conducted an inspection of the contaminated wing section and measured selected test parameters; and

d) The aircraft was subsequently operated through a simulated takeoff test, excluding climb-out. The behaviour of the contaminated and un-contaminated fluid during the takeoff test was recorded with digital video cameras and digital high-speed still cameras.

Test results were compared to the results obtained in the NRC open circuit wind tunnel to validate the results previously obtained in the wind tunnel.

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### 2.2.4 Equipment

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

#### *2.2.4.1 Falcon 20 Research Aircraft*

The aircraft used for testing was a Dassault Falcon 20 twin-engine, mid-size business jet, operated by the NRC (see Photo 2.13). The aircraft is a multi-purpose platform that has been used in recent years for two major research programs:

a) The testing and evaluation of precision instrument approaches using augmented Global Positioning Systems (GPS) for guidance; and

b) The determination of aircraft performance characteristics on runways contaminated by winter precipitation.

With an extensive onboard data acquisition system, the aircraft can also be used for airborne geoscience studies, avionics research, and aircraft based sensor research.

NRC acquired the Falcon 20 from the Department of National Defense (DND) in 1991. In partnership with the Canadian Space Agency (CSA) and TC, NRC originally instrumented the aircraft to support micro-gravity research and curved path (area navigation) capabilities and procedures. These capabilities still exist with the modified aircraft fuel and hydraulic systems still in place to allow the aircraft to fly "zero" G parabolic manoeuvres, and the modified aircraft guidance systems available to fly curved path precision approaches using GPS-based receivers.

In partnership with TC, National Aeronautics and Space Administration (NASA), and DND, the NRC Falcon 20 was used in a five-year research program directed at standardizing runway friction reporting procedures for winter contaminated runways, and determining aircraft landing and takeoff performance changes as a result of runway contaminant.

*2.2.4.2 Falcon 20 design characteristics*

A three-view diagram of the Falcon 20 aircraft has been included in Figure 2.6: Some of the pertinent dimensions of the Falcon 20 are:

a) Wingspan: 16.32 m (53 ft. 7 in.);
b) Wing surface area (both wings): 41 $m^2$ (441.33 $ft.^2$); and
c) Length: 17.15 m (56 ft. 3 in.).

The Falcon 20 has slotted slats outboard of the fence on each wing; the wing section inboard of the fence contains no moveable devices.

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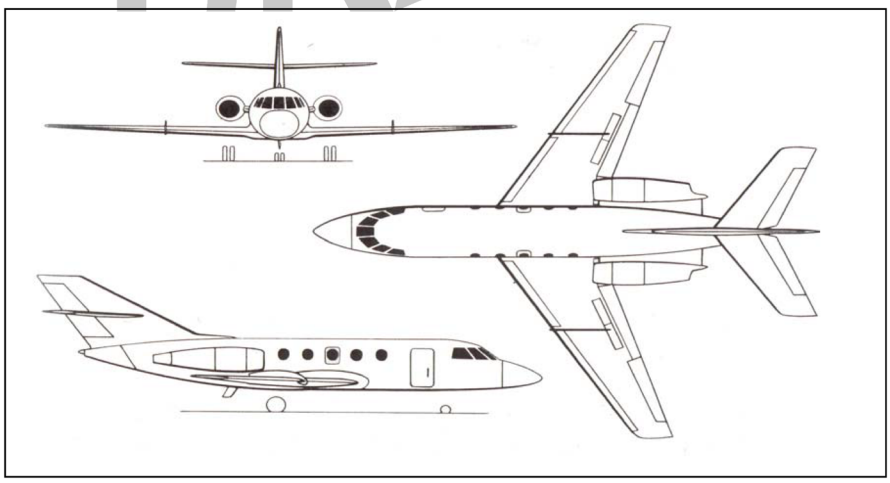

**Figure 2.6: Schematic View of Dassault Falcon 20**

### 2.2.4.3 Falcon 20 on-board installations

The NRC Falcon 20 research aircraft is equipped with the following on-board installations:

a) Engineering workstation containing computer with GPS receiver card, display and interface with the data acquisition system;

b) Data acquisition system based on LSI 11/73 digital computer, with Digital Audio Tape (DAT) and/or hard disk recording medium;

c) Multiple navigation sensors including VHF Omnidirectional Range (VOR), Instrument Landing System (ILS), Microwave Landing System (MLS), GPS, flight test differential GPS, and modified flight director; and

d) Cockpit mounted Cockpit Display Unit (CDU) to initiate GPS approaches and monitor selected test parameters.

### 2.2.4.4 Falcon 20 measurement capabilities

The NRC Falcon 20 research aircraft has the following measurement logging capabilities:

a) 3-axis accelerations and rates;
b) Aircraft attitude and heading;
c) Three-dimensional positions and velocities;
d) Static and dynamic pressures;
e) Outside air temperature; and
f) Flight director system signals.

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### 2.2.4.5 Test Area

Areas on the port and starboard wings, just inboard of the fences, were selected to serve as the test surfaces on the Falcon 20. The test area was made large enough to be representative of the entire wing and, at the same time, small enough to enable a simulated snow production rate that was reasonably achievable.

The areas selected covered 1.4 m of the leading edge, inboard of the fence and the entire chord of the wing, as illustrated in Figure 2.7. The test surfaces had areas of 2.7 $m^2$ and were used for all tests.

*2.2.4.6 Test Area Grid*

Prior to the testing, NRC personnel used markers to draw a grid with dimensions of 0.61 m x 0.61 m (2 ft. x 2 ft.) just inside the fence on the port and starboard wings of the Falcon 20. Smaller grids with dimensions of 5.1 cm x 5.1 cm (2 in x 2 in.) were then drawn inside the larger grid, perpendicular and parallel to the fence (see Photo 2.14) The grid was used to provide a point of reference for observations of the fluid shearing off the wing and the movement of ice pellets during takeoff.

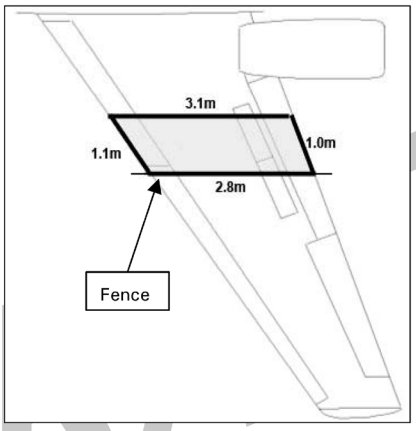


**Figure 2.7: Test Area**

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## 2.2.5 Simulated Precipitation Related Equipment

*2.2.5.1 Snow Dispenser*

Snow was manufactured from ice cubes inside a rented refrigerated truck. The process required the use of blenders, calibrated sieves, and large Styrofoam containers.

Once produced, the snow was stored in Styrofoam containers. They were applied over the test area using the specially modified handheld dispensers shown in Photo 2.15.

*2.2.5.2 Video and Photo Equipment*

Two Canon Digital Rebel XT digital still cameras were used to obtain high speed, high-resolution photographs of the testing. The 8 mega-pixel resolution cameras are capable of taking up to three pictures per second in continuous shooting mode. The cameras were used with two different lenses:

a) 18-55 mm standard lens for wide angle pictures; and
b) 105 mm macro lens for close ups.

Digital video and still cameras were used to record visual observations of the testing. To create a consistent and stable setup for the cameras and video cameras, NRC personnel replaced both emergency exit doors of the Falcon 20 with a temporary structure that had camera-mounting capability (see Photo 2.16); these structures were not airworthy and cannot be used during actual take-off. A video camera and a still camera were fitted to both port and starboard emergency exit doors. The cameras were zoomed in to observe the behaviour of the fluid and contamination on the wing.

In addition to the images obtained from the cameras mounted on the aircraft, a professional photographer used a digital still camera to take pictures of the test setup and all phases of the takeoff tests.

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### 2.2.6 Type IV Fluid Application Equipment

The Type IV fluids were kept at ambient temperature and applied to the aircraft outside the NRC hangar. The fluids were poured rather than sprayed so that application would not change the fluid viscosity. This methodology was appropriate because of the relatively small test area and to ensure that minimal amounts of fluid would flow off the wing.

Type IV fluids were applied to the Falcon 20 wing surfaces using several PVC pouring devices (Photo 2.17) manufactured for this purpose. Each 2.5 L device was fitted with pouring, refill, and breather holes, which permitted uniform fluid flow.

### 2.2.7 Waste Fluid Collection

A glycol mitigation plan was prepared for the Ottawa Airport Authority prior to the March 2006 tests. This plan is shown in Appendix D. APS personnel used a vacuum to collect the fluid that did reach the ground immediately following the departure of the aircraft from the application area.

### 2.2.8 Personnel

NRC personnel operated the Falcon 20 aircraft. Five APS staff members were required to conduct the tests and three additional persons from Ottawa were hired to manufacture snow. A professional photographer was retained to record digital images of the test setup and tests. Representatives from TDC and the FAA provided direction in testing and participated as observers.

### 2.2.9 Measurement of Test Parameters

#### *2.2.9.1 Fluid Thickness*

For each test, the fluid thickness of the anti-icing fluid was measured at five locations along the centreline of the test area (see Photo 2.18). Measurements were taken at four stages in a typical test:

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

The fluid thickness measurement locations on the port wing are shown in Figure 2.8; the same layout was used for the starboard wing. The locations designated for thickness measurement, identified in the data form, were the following:

- Wing Position 1: On the leading edge;
- Wing Position 2: On the leading edge, one inch from the joint;
- Wing Position 5: As far as could be reached from the leading edge;
- Wing Position 7: Just behind the spoiler; and
- Wing Position 8: Halfway between the trailing edge and the joint.

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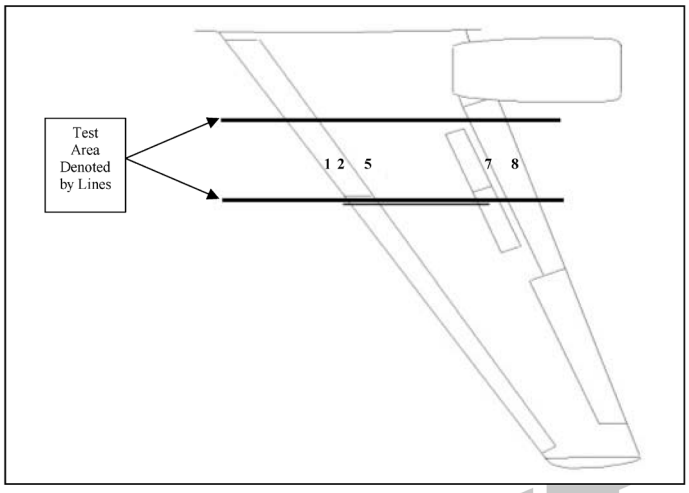


**Figure 2.8: Fluid Thickness and Fluid Brix Measurement Locations**

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*2.2.9.2 Fluid Brix*

Fluid Brix was measured at the leading edge and the trailing edge using hand-held refractometers (Photo 2.19) at four stages of the Type IV tests:

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

The locations designated for fluid Brix measurement, shown in Figure 2.8, were the following:

- Wing Position 2: On the leading edge, one inch from the joint; and
- Wing Position 8: Halfway between the trailing edge and the joint.

*2.2.9.3 Wing Skin Temperature*

Wing temperatures were measured at eight locations across the test area both before and after the simulated takeoff test:

- Positions 1 and 2: On the leading edge;
- Positions 3 and 4: On the leading edge, one inch from the joint;

- Positions 5 and 6: As far as could be reached from the leading edge; and
- Positions 7 and 8: Halfway between the trailing edge and the joint.

Wing temperatures were read directly off the temperature probe and recorded on the appropriate data form. Figure 2.9 shows the location of each measurement position.

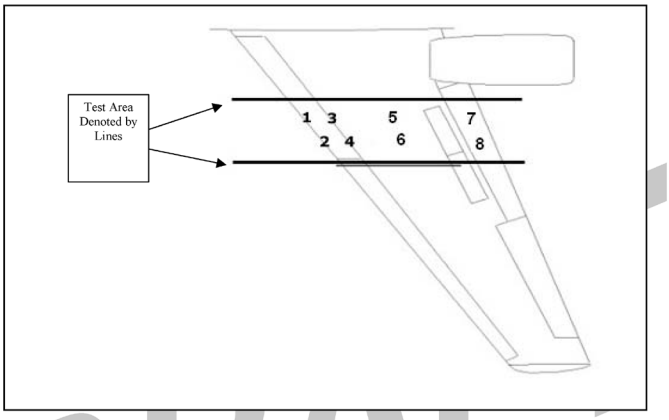


**Figure 2.9: Wing Temperature Data Form**

### 2.2.10 Data Forms

Several different forms were used to facilitate the documentation of the various data collected in the Falcon 20 tests. These forms include:

a) Fluid Receipt Form;
b) General Form (every test);
c) Wing Temperature Form (Port Wing);
d) Wing Temperature Form (Starboard Wing);
e) Fluid Thickness and Brix Form (Port Wing);
f) Fluid Thickness and Brix Form (Starboard Wing);
g) Freezing Rain/Snow Quantity Form
h) Test Results Form (Port Wing);
i) Test Results Form (Starboard Wing);
j) Time Record of Operations; and
k) Nominal Test Conditions.

Copies of these forms are provided in the test procedure, which is included in Appendix C.

## 2.3 General

This section describes equipment and general information used for both the wind tunnel and Falcon 20 tests.

### 2.3.1 Viscometer

Viscosity measurements were carried out using a Brookfield viscometer (Model DV-1+, shown in Photo 2.20) fitted with a re-circulating fluid bath and small sample adapter.

### 2.3.2 Fluid Freezing Point and Temperature Gauges

Fluid freezing points were measured using a hand-held Misco refractometer with a Brix scale. The freezing points of the various fluid samples were determined using the conversion curve or table provided to APS by the fluid manufacturer. The Kilfrost ABC-S table is shown in Table 2.3 and the Dow Ultra+ curve is shown in Figure 2.10.

Wing temperatures were measured using hand-held Wahl surface temperature probes.

### 2.3.3 Thickness Gauges

Wet film thickness gauges, shown in Figure 2.11, were used to measure fluid film thickness. These gauges were selected because they provide an adequate range of thickness (0.1 mm to 10.2 mm) for Type IV fluids. The rectangular gauge shown in Figure 2.11 has a finer scale and was used in some cases when the fluid film was thinner (toward the end of a test). The observer recorded an uncorrected thickness value (in mils), as read directly from the thickness gauge. These values were then converted to a corrected thickness in mm using the film thickness conversion information shown in Table 2.4.

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## Table 2.3: Freezing Point vs. Brix of Aqueous Solutions of Kilfrost ABC-S

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

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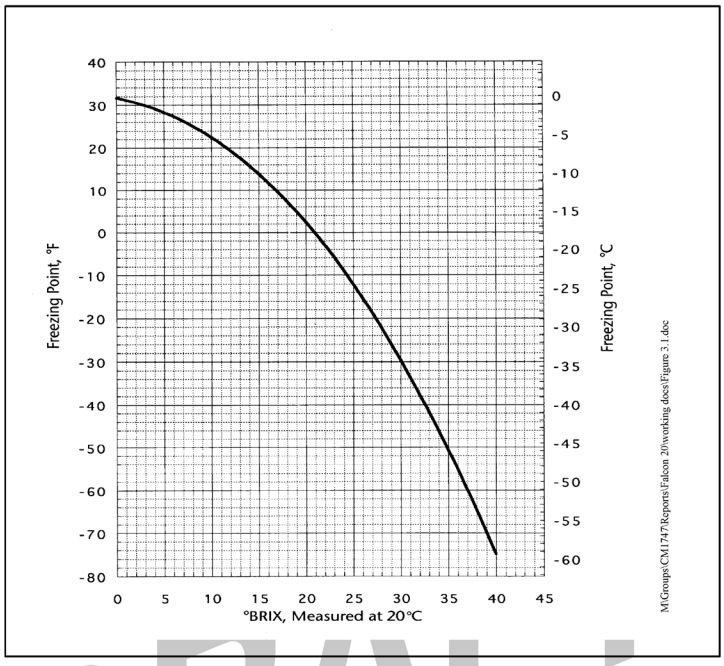


**Figure 2.10: Freezing Point vs. Brix of Aqueous Solutions of Dow UCAR Ultra+**

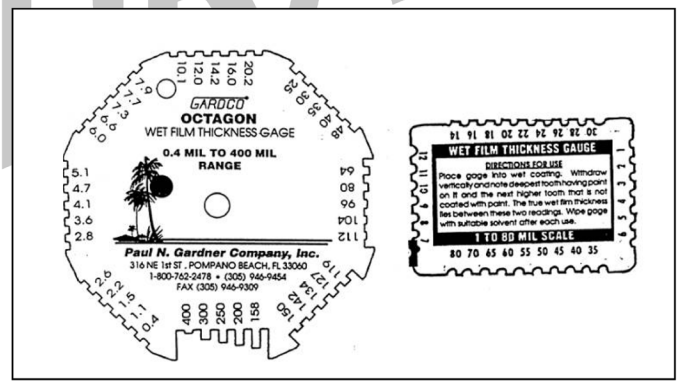


**Figure 2.11: Thickness Gauges**

**Table 2.4: Film Thickness Conversion Table**

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

* Reading of last wetted tooth.

### 2.3.4 Fluids

Two fluids were used during the aerodynamic tests: Dow Chemical UCAR Ultra+ and Kilfrost ABC-S. The pertinent characteristics of these fluids are given in Table 2.5. It should be noted that Ultra+ fluid obtained the previous year was used for certain designated tests; the viscosity and condition of the fluid was found to be acceptable.

**Table 2.5: Test Fluids**

| Fluid Name | Batch # | Quantity Received (L) | Date Received | Type | Formulation | Brix | Viscosity (mPa.s) |
|---|---|---|---|---|---|---|---|
| Dow Chemical UCAR Ultra+ | UA255553D4 | 200* | Winter 2006 | IV | EG | 40.0° | 48200** |
| Dow Chemical UCAR Ultra+ | UK205553D2 | 200 | Winter 2007 | IV | EG | 40.0° | 45300** |
| Kilfrost ABC-S | 10117 | 640 | Winter 2007 | IV | PG | 36.0° | 23400*** |

* Extra fluid from 2005-06 Falcon 20 tests

** Spindle SC4-31, 10 mL of fluid, 10 minutes, 0.3 rpm, 0°C

*** Equivalent to: Spindle LV-2, 150 mL of fluid, 10 minutes, 0.3 rpm, 20°C

### 2.3.5 Artificial Contamination

#### *2.3.5.1 Snow*

The simulated snow was manufactured inside a refrigerated truck (see Photo 2.21). Cubes of ice were crushed and passed through calibrated sieves (see Photo 2.22) to obtain the required simulated snow size range. The simulated snow used consisted of small ice crystals measuring less than 1.3 mm in diameter. Previous testing conducted by APS investigated the dissolving properties of the simulated snow versus natural snow; details of this testing can be found in the report TP14713E *"Aircraft Deicing Research in Natural Ice pellet Conditions – Phase 1" (9).* The simulated snow was selected as an appropriate substitute for natural snow. Handheld motorized dispensers were used to dispense the simulated snow. The contamination was applied to the leading and trailing edges of the wing at the same time.

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**Photo 2.1: Outside View of NRC Wind Tunnel Facility**



**Photo 2.2: Inside View of NRC Wind Tunnel Test Section**



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**Photo 2.3: NACA 23012 Wing Section Used for Testing**




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**Photo 2.4: Grid Markings on NACA 23012 Wing Section**

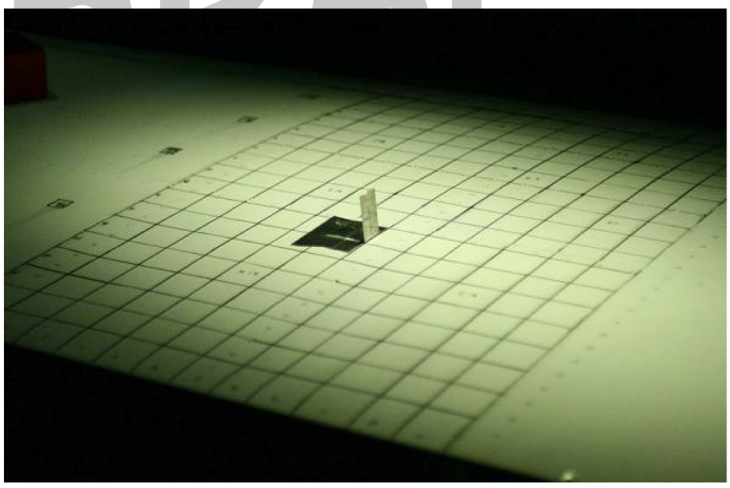

**Photo 2.5: Snow Dispensers Operated by APS Personnel**



**Photo 2.6: Wind Tunnel Setup for Flashes**



**Photo 2.7: Wind Tunnel Setup for Digital Cameras**



**Photo 2.8: Fluid "Pour" Application**



**Photo 2.9: Wet Film Thickness Gauges**




**Photo 2.10: Hand Held Brixometer**



**Photo 2.11: Hand Held Temperature Probe**



**Photo 2.12: NRC YOW Institute for Aerospace Research Hangar**



**Photo 2.13: NRC Falcon 20 Aircraft**



**Photo 2.14: Reference Grid Drawn on Both Port and Starboard Wing Test Sections**

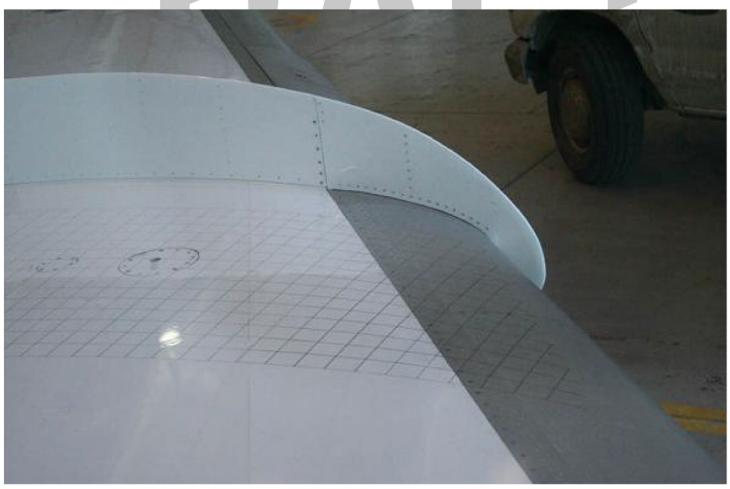

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**Photo 2.15: Snow Dispenser Setup for Falcon 20 Tests**




**Photo 2.16: Camera Positioning Inside Emergency Exit Windows**



**Photo 2.17: PVC Fluid Pouring Devices**



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**Photo 2.18: Fluid Thickness Measurement using Wet Film Thickness Gauge**



**Photo 2.19: Fluid Freeze Point Measurement using Handheld Brixometer**




**Photo 2.20: Brookfield Digital Viscometer Model DV-1+**




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**Photo 2.21: Refrigerated Truck Used for Manufacturing Ice Pellets**




**Photo 2.22: Calibrated Sieves Used to Obtain Desired Size Distribution**



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# 3 FLAT PLATE TESTING

This section provides an overview of the flat plate testing conducted as part of the test program. Each series of tests was performed with the objective of exploring heavy snow conditions with the aim of minimizing full-scale testing required. The following list provides short descriptions of subsequent sub-sections:

- Section 3.1: Endurance Time Testing in Artificial Heavy Snow; and
- Section 3.2: Latent Heat of Cooling During Heavy Snow Conditions

## 3.1 Endurance Time Testing in Artificial Heavy Snow

A test session conducted in 2005-06 in the refrigerated trailer was planned to study the ability of the snowmaker to perform tests is heavy snow at precipitation rates of 50 and 75 g/dm$^2$/h.

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### 3.1.1 Objective

The objective of the heavy snow tests performed in 2005-06 was to compare the NCAR snowmaker endurance times to the endurance time values obtained using outdoor snow methods.

### 3.1.2 Methodology

The methodology for conducting artificial snow tests with the NCAR snowmaker is detailed in TC report TP 14717E *Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2005-06* (10).

The plate temperature is a critical parameter of testing in artificial snow. The following equation is used to control the plate temperature for precipitation rated below 25 g/dm$^2$/h.

$$P_T = T_T - 0.065 * I_I - 0.5$$

where,

$P_T$ Plate temperature in °C;
$T_T$ Test condition temperature in °C; and
$I_I$ Icing intensity in g/dm$^2$/h.

For the 2005-06 heavy snow tests the plate temperature was set at -6°C, three degrees below the outside air temperature (OAT), rather than the -6.8°C and -8.4°C set points according to the plate temperature formula results for rates of 50 and 75 g/dm²/h. This decision was based on the assumption that the temperature decay of the plate during a test is not linearly dependent on the precipitation rate.

### 3.1.3 Results

Four tests were performed during the 2005-06 test session. The results are presented in section 5.4 of TC report TP 14717E (10).

It was noted that the endurance times obtained with the snowmaker were 25% to 50% below those obtained from natural snow data. Given that the most critical test parameter is the plate temperature, it was concluded that an in-depth study of the plate temperature drop is required to establish the precise test parameters of the NCAR snowmaker.

## 3.2 Latent Heat of Cooling During Heavy Snow Conditions

The tests performed in 2005-06 with the artificial snowmaker in heavy snow showed that the endurance times obtained indoors are considerably lower than the corresponding values generated using natural snow data. The tests showed that the plate temperature drop equation used for rates up to 25 g/dm$^2$/h cannot be applied for heavy snow testing. A preliminary study was performed in 2006-07 to address these issues.

### 3.2.1 Objective

The objective of the plate temperature drop study was to examine the plate temperature drop due to the latent heat of cooling under natural snow conditions and establish test parameters for indoor testing.

### 3.2.2 Methodology

During the natural heavy snow events, the Type IV deicing fluid was applied to a box using a one-step application method. The box temperature was logged using standard surface thermistors. Precipitation rate, wind speed and air temperature were measured during the tests.

All failure calls were made according to flat plate failure call standards for snow precipitation.

The logged box temperature was averaged over the duration of each test. The average box temperature was used in the plate temperature drop analysis.

### 3.2.3 Results

Ten tests were performed during the winter 2006-07 in the heavy snow study. Of the ten tests conducted, only half had an average precipitation rate of 50 g/dm$^2$/h or greater. Table 3.1 shows the log of tests.

**Table 3.1 Log of Plate Temperature Drop Study Tests**

| Date | Run Number | Fluid Name | Fluid Dilution (%) | Average Test OAT (°C) | Average Precip. Rate (g/dm2/h) | Endurance Time (min) | Average Box Temp. (°C) | Average Temp. Drop (°C) |
|---|---|---|---|---|---|---|---|---|
| 8-Jan-07 | 1 | DOW UCAR Ultra+ | 100 | 0.5 | 27.2 | 58.0 | -2.4 | 2.9 |
| 15-Jan-07 | 1 | DOW UCAR Ultra+ | 100 | -8.5 | 25.0 | 40.8 | -11.3 | 2.8 |
| 15-Jan-07 | 2 | Clariant MPIV Launch | 75 | -8.9 | 28.3 | 29.5 | -10.2 | 1.3 |
| 15-Jan-07 | 3 | DOW UCAR Ultra+ | 100 | -8.6 | 31.5 | 38.0 | -11.5 | 2.9 |
| 14-Feb-07 | 1 | Lyondell Arctic Shield | 100 | N/A | 37.8 | 14.5 | N/A | N/A |
| 2-Mar-07 | 1 | DOW UCAR Ultra+ | 100 | -7.9 | 59.0 | 24.0 | -11.6 | 3.7 |
| 2-Mar-07 | 2 | DOW UCAR Ultra+ | 100 | -6.9 | 90.9 | 19.5 | -10.6 | 3.7 |
| 2-Mar-07 | 3 | DOW UCAR Ultra+ | 100 | -6.2 | 73.3 | 32.0 | -10.6 | 4.4 |
| 2-Mar-07 | 4 | DOW UCAR Ultra+ | 100 | -5.0 | 84.3 | 29.0 | -9.2 | 4.2 |
| 2-Mar-07 | 5 | DOW UCAR Ultra+ | 100 | -0.9 | 46.1 | 43.0 | -5.6 | 4.7 |

An analysis of the above data shows that plate temperature drop for a rate of 50 g/dm$^2$/h is 3°C below OAT and 4°C below OAT for 75 g/dm$^2$/h.

The data confirms that the plate temperature drop equation used for lower rates is not applicable for heavy snow. The results also show that the 6°C plate temperature drop used in the 2005-06 indoor tests was too drastic. The excessive temperature drop could be the reason for obtaining considerably shorter endurance times indoors.

Additional artificial heavy snow tests will be conducted in 2007-08 in the refrigerated trailer. Individual natural heavy snow data points will be selected and then will be reproduced in controlled laboratory conditions using the NCAR snow machine. The natural snow data points will be replicated indoors using the plate temperature drop characteristics observed during the 2006-07 tests.

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# 4 FULL-SCALE DATA COLLECTED

## 4.1 Test Logs

### 4.1.1 Wind Tunnel Test Log

A detailed log of the tests conducted in the wind tunnel (WT) is shown in Table 4.1. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each column contains data specific to one test. The following is a brief description of the column headings for Table 4.1:

| | |
|---|---|
| Test #: | Exclusive number identifying each test. |
| Test Objective: | Test objective describing simulated test condition. |
| Date: | Date when the test was conducted. |
| Type IV Fluid: | Type IV aircraft deicing fluid. EG specifies an Ethylene Glycol fluid and PG specifies a Propylene Glycol fluid. |
| Test Area ($m^2$): | Wing section test area, measured in meters squared. |
| Ice Pellet Size (mm): | Size distribution of manufactured simulated ice pellets, measured in millimeters. |
| Duration of Precipitation (min): | Total duration of simulated precipitation condition, recorded in minutes. |
| Endurance Time on Plate (min): | Fluid endurance time recorded in minutes using reference test plate mounted on the wing section. |
| Ice Pellet Quantity (kg): | Total quantity of ice pellets applied to test section, measured in kilograms. |
| Effective Ice Pellet Rate ($g/dm^2/h$): | Simulated ice pellet precipitation rate, calculated in $g/dm^2/h$. |

| | |
|---|---|
| Freezing Precip. Type (ZD or ZR-): | Simulated freezing precipitation type (freezing drizzle or light freezing rain) generated from ceiling mounted sprayer system. |
| Freezing Precip. Rate (g/dm²/h): | Simulated freezing precipitation rate, calculated in g/dm²/h. |
| Snow Size (mm): | Size distribution of manufactured simulated snow, measured in millimeters. |
| Snow Quantity (kg): | Total quantity of snow applied to test section, measured in kilograms. |
| Snow Rate (g/dm²/h): | Simulated snow rate, calculated in g/dm²/h. |
| Fluid Application Start Time: | Start of the fluid application, recorded in local time. |
| Precipitation End Time: | End of the simulated precipitation period, recorded in local time. |
| Tunnel Start Time: | Start of the simulated takeoff test, recorded in local time. |
| OAT (ºC): | Outside ambient temperature recorded just before the start of the simulated takeoff test, measured in degrees Celsius, provided by NRC. |
| Tunnel OAT (ºC): | Static tunnel ambient temperature recorded just before the start of the simulated takeoff test, measured in degrees Celsius, provided by NRC. |
| Average Tunnel OAT from fluid application to start of takeoff test: | Average tunnel ambient temperature recorded from the start of fluid application to the start of the takeoff test, measured in degrees Celsius. |

| | |
|---|---|
| Avg OAT during last 10 min of precipitation: | Average tunnel ambient temperature recorded during the last 10 minutes of precipitation application, measured in degrees Celsius. |
| Avg Wing Temp before Test (ºC): | Average of the wing skin temperature measurements (excluding the under wing measurement) recorded in degrees Celsius. |
| Angle of Attack (deg) and Rate of Change (initial): | Simulated takeoff angle of attack (recorded in degrees) and time rate of change (in seconds) |
| Ramp time (s) and VR speed (kts): | Ramp time (measured in seconds) required for the wind tunnel to accelerate up to the target rotation speed (measured in knots). |
| Visual Severity Rating (1-5) *(WT tests)*: | Rank based on contamination flow off (photo analysis):<br>1-Trailing edge clean after 30sec (rotation)<br>2-Trailing edge clean after 45sec<br>3-Trailing edge clean after 60sec<br>4-Trailing edge clean after >60sec, contamination left after test<br>5-same as 4, plus contamination on leading edge after 45sec |

## Table 4.1: Wind Tunnel Test Log

| TEST NO | 1 | | 2 | | 3 | | 1a | SS1 |
|---|---|---|---|---|---|---|---|---|
| Test Comment (Precipitation) | Dry | | Fluid only with ABC-S | | Fluid only with Ultra + | | Dry | heavy snow (was S6) |
| Date | 14-Feb-07 | | 14-Feb-07 | | 14-Feb-07 | | 16-Feb-07 | 16-Feb-07 |
| Fluid | none (dry) | | ABC-S | | Ultra + | | none (dry) | Ultra + |
| Test Area [m2] | 3.7 | | 3.7 | | 3.7 | | 3.7 | 3.7 |
| Duration of simulation-actual(min) | none (dry) | | none(fluid only) | | none(fluid only) | | none (dry) | 60 |
| ET on Plate (min) | N/A | | N/A | | N/A | | N/A | 17 |
| Snow size [mm] | none (dry) | | N/A | | N/A | | none (dry) | see photo taken during run |
| Snow Quantity (kg) | none (dry) | | N/A | | N/A | | none (dry) | 2.1kg/disp/10min*2 dispensers |
| Snow application period (min) | none (dry) | | N/A | | N/A | | none (dry) | 60 |
| Snow rate (g/dm^2/h) | none (dry) | | N/A | | N/A | | none (dry) | 51 |
| Fluid application start time | N/A | | 12:52 | | 13:52 | | N/A | 14:30 |
| Precipitation end time | N/A | | N/A | | N/A | | N/A | 15:54 |
| Tunnel start time | 12:12 | | 13:24 | | 14:25 | | 13:48 | 16:13:30 |
| OAT [C] | -14.6 | | -13 | | -13 | | -7 | -4.7 |
| Tunnel OAT [C] | -1.7 | | -10 | | -11 | | ???? | -4.6 |
| Average Tunnel OAT from fluid application to start of takeoff run | N/A | | -10 | | -10.4 | | N/A | -0.4 |
| Average OAT during last 10 min of precip | N/A | | N/A | | N/A | | N/A | -0.2 |
| Average OAT from end of precip to start of takeoff run | N/A | | N/A | | N/A | | N/A | 0.1 |
| Approx Avg Wing Temp before Run [C] | -2 | | -9 | | -8 | | N/A | -11 |
| Angle of Attack (deg) and Rate of Change (initial) | 8 | in 3s | 8 | in 3s | 8 | in 3s | 8 in 3s | 8 in 3s |
| Ramp time (s) and $V_R$ speed (kts) | 35 | 100 | 35 | 100 | 35 | 100 | 35/100 | 35/100 |
| Still Camera 1 / Still Camera 2 | yes | yes | yes | yes | yes | yes | yes, yes | yes, yes |

## Table 4.1: Wind Tunnel Test Log (cont'd)

| TEST NO | SS2 | SS3 | SS4 | SS5 | SS6 |
|---|---|---|---|---|---|
| Test Comment (Precipitation) | heavy snow (was S5) | heavy snow | heavy snow | heavy snow | heavy snow |
| Date | 16-Feb-07 | 19-Feb-07 | 19-Feb-07 | 19-Feb-07 | 19-Feb-07 |
| Fluid | ABC-S | Ultra + | ABC-S | ABC-S | ABC-S |
| Test Area [m2] | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 |
| Duration of simulation-actual(min) | 30 | 20 | 20 | 20 | 10 |
| ET on Plate (min) | 8 | 11 | 8.5 | 7 | 7 |
| Snow size [mm] | same as SS1 | no photos taken | see photo taken during run | no photos taken | no photos taken |
| Snow Quantity (kg) | 2.1kg/disp/10min*2 dispensers | 1.8kg/disp/10min*4 dispensers | 1.8kg/disp/10min*4 dispensers | 1.8kg/disp/10min*4 dispensers | 1.8kg/disp/10min*4 dispensers |
| Snow application period (min) | 30 | 20 | 20 | 20 | 10 |
| Snow rate (g/dm^2/h) | 51 | 77 | 77 | 77 | 77 |
| Fluid application start time | 16:47 | 11:21 | 13:53 | 16:11 | 18:00 |
| Precipitation end time | 17:41 | 12:06 | 14:31 | 16:54 | 18:27 |
| Tunnel start time | 18:01:52 | 12:25:30 | 15:23 | 17:10 | 18:50 |
| OAT [C] | -5 | -15 | -12.7 | -13 | -14 |
| Tunnel OAT [C] | -0.5 | -3 | -4.4 | -2 | -2 |
| Average Tunnel OAT from fluid application to start of takeoff run | -0.1 | -3.9 | -3.5 | -2.7 | -2.6 |
| Average OAT during last 10 min of precip | 0.3 | -3.5 | -2.4 | -0.5 | -3 |
| Average OAT from end of precip to start of takeoff run | -0.4 | -2.7 | -3.3 | -0.7 | -2.2 |
| Approx Avg Wing Temp before Run [C] | -9 | -14 | -11 | -9.5 | -9.5 |
| Angle of Attack (deg) and Rate of Change (initial) | 8 in 3s | 8 in 3s | 8 in 3s | 8 in 3s | 8 in 3s |
| Ramp time (s) and $V_R$ speed (kts) | 35/100 | 35/100 | 35/100 | 35/100 | 35/100 |
| Still Camera 1 / Still Camera 2 | yes, yes | yes, yes | yes, yes | yes, yes | yes, yes |

## Table 4.1: Wind Tunnel Test Log (cont'd)

| TEST NO | SS7 | 13 |
|---|---|---|
| Test Comment (Precipitation) | heavy snow | Fluid only with ABC-S |
| Date | 20-Feb-07 | 23-Feb-07 |
| Fluid | Ultra + | ABC-S |
| Test Area [m2] | 3.7 | 3.7 |
| Duration of simulation-actual(min) | 20 | none |
| ET on Plate (min) | 13 | N/A |
| Snow size [mm] | no photos taken | N/A |
| Snow Quantity (kg) | 1.8kg/disp/10min*4 dispensers | N/A |
| Snow application period (min) | 20 | N/A |
| Snow rate (g/dm^2/h) | 77 | N/A |
| Fluid application start time | 18:16 | 15:04 |
| Precipitation end time | 19:02 | N/A |
| Tunnel start time | 19:19:10 | 15:23:10 |
| OAT [C] | -7 | -7.5 |
| Tunnel OAT [C] | 1.8 | -5.7 |
| Average Tunnel OAT from fluid application to start of takeoff run | 1.9 | -5.6 |
| Average OAT during last 10 min of precip | 1.3 | N/A |
| Average OAT from end of precip to start of takeoff run | 1.3 | N/A |
| Approx Avg Wing Temp before Run [C] | -9 | -5 |
| Angle of Attack (deg) and Rate of Change (initial) | 8 in 3s | 8 in 3s |
| Ramp time (s) and $V_R$ speed (kts) | 35/100 | 35/100 |
| Still Camera 1 / Still Camera 2 | yes, yes | yes, yes |

### 4.1.2 Falcon 20 Test Log

A detailed log of the tests conducted with the Falcon 20 aircraft is shown in Table 4.2. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each column contains data specific to one test. The following is a brief description of the column headings for Table 4.2:

| | |
|---|---|
| Test #: | Exclusive number identifying each test. |
| Test Objective: | Test objective describing simulated test condition. |
| Date: | Date when the test was conducted. |
| Type IV Fluid: | Type IV aircraft deicing fluid. EG specifies an Ethylene Glycol fluid and PG specifies a Propylene Glycol fluid. |
| Test Area ($m^2$): | Wing section test area, measured in meters squared. |
| Ice Pellet Size (mm): | Size distribution of manufactured simulated ice pellets, measured in millimeters. |
| Duration of Precipitation (min): | Total duration of simulated precipitation condition, recorded in minutes. |
| Ice Pellet Quantity (kg): | Total quantity of ice pellets applied to test section, measured in kilograms. |
| Effective Ice Pellet Rate ($g/dm^2/h$): | Simulated ice pellet precipitation rate, calculated in $g/dm^2/h$. |
| Freezing Precip. Type (ZD or ZR-): | Simulated freezing precipitation type (freezing drizzle or light freezing rain) generated from ceiling mounted sprayer system. |
| Freezing Precip. Rate ($g/dm^2/h$): | Simulated freezing precipitation rate, calculated in $g/dm^2/h$. |
| Snow Size (mm): | Size distribution of manufactured simulated snow, measured in millimeters. |

| | |
|---|---|
| Snow Quantity (kg): | Total quantity of snow applied to test section, measured in kilograms. |
| Snow Rate (g/dm²/h): | Simulated snow rate, calculated in g/dm²/h. |
| Measured rate on LE (g/dm²/h): | Combined rate of precipitation on leading edge of wing test section, measured using a rate pan weighed at set intervals during the test, and recorded in g/dm²/h. |
| Measured rate on TE (g/dm²/h): | Combined rate of precipitation on trailing edge of wing test section, measured using a rate pan weighed at set intervals during the test, and recorded in g/dm²/h. |
| Fluid Application Start Time: | Start of the fluid application, recorded in local time. |
| Precipitation End Time: | End of the simulated precipitation period, recorded in local time. |
| Takeoff test start time: | Start of the Falcon 20 aircraft takeoff test, recorded in local time. |
| OAT at start of test (°C): | Outside ambient temperature recorded just before the start of the takeoff test, measured in degrees Celsius, provided by METAR. |
| Wind Speed (knts): | Wind speed recorded just before the start of the takeoff test, measured in knots, provided by METAR. |
| Avg Wing Temp before Test (°C): | Average of the wing skin temperature measurements (excluding the under wing measurement) recorded in degrees Celsius. |
| Ramp time (s) and VR speed (kts): | Ramp time (measured in seconds) required for the aircraft to accelerate up to the target rotation speed (measured in knots). |

## Table 4.2: Falcon 20 Test Log

| TEST NO | 1s | 1p |
|---|---|---|
| Test Comment (Precipitation) | heavy snow | Fluid only with ABC-S |
| Date | 27-Feb-07 | 27-Feb-07 |
| Fluid | ABC-S | ABC-S |
| Test Area [m2] | 2.7 | 2.7 |
| Duration of simulation-actual(min) | 20 | none |
| Snow size [mm] | maybe photos taken? | N/A |
| Snow Quantity (kg) | 3.5 cups of 600g/10min/disp*2 disp | N/A |
| Snow application period (min) | 20 | N/A |
| Snow rate (g/dm^2/h) | 75 | N/A |
| Measured rate on LE (g/dm^2/h) | 65 | N/A |
| Measured rate on TE (g/dm^2/h) | 45 | N/A |
| Fluid application start time | 7:03 | 6:53 |
| Precipitation end time | 7:49 | N/A |
| Takeoff run start time | 8:33 | 8:33 |
| OAT at start of test [C] | -10 | -10 |
| wind speed kts | 3 | 3 |
| Approx Avg Wing Temp before Run [C] | -9.5 | -4 |
| Ramp time (s) and VR speed (kts) | 25/120 | 25/120 |
| Still Camera 1 / Still Camera 2 | yes, yes | yes, yes |

## 4.2 Precipitation Rate Measurement and Calibration

### 4.2.1 Snow

APS conducted testing to determine the efficiency of the snow dispersers. Calibration work was conducted at the APS test site at Montreal-Trudeau using surfaces representative of the wind tunnel test wing, as well as the designated test section of the Falcon 20 aircraft wing.

It was found that the distribution efficiency of the dispensing system varied depending on the surface dimensions. As a result, a dispensing efficiency was calculated for the NACA 23012 wing section dimensions, as well as for the Falcon 20 test section dimensions. It was estimated that the dispensing efficiency on the NACA 23012 wing section was approximately 50%, whereas for the Falcon 20 test section, the dispensing efficiency was approximately 80%. The difference in efficiencies for the two test surfaces was largely due to the chord length of the NACA 23012 wing section vs. the Falcon 20 test section. The NACA 23012 wing chord was less than half the length of the Falcon 20 chord; therefore a significant amount of snow was lost as a result of over spray.

Dispensing was done by placing known quantities of simulated snow into the dispensing bucket, and allowing the dispenser to completely empty the contents over a set period of time (usually 10 minutes). The dispensers were re-filled every 10 minutes for the duration of the test. The calculated efficiencies were accounted for when weighing the required amounts of snow.

### 4.2.2 Definition of Precipitation Rates

When simulating precipitation rates for full-scale and plate testing, the rate limits defined for standard HOT testing were referenced. Figure 4.1 demonstrates the HOT testing rate precipitation breakdown.

HOT testing protocol for heavy snow does not currently exist. The precipitation rate limit for heavy snow is defined as $>25 g/dm^2/h$.

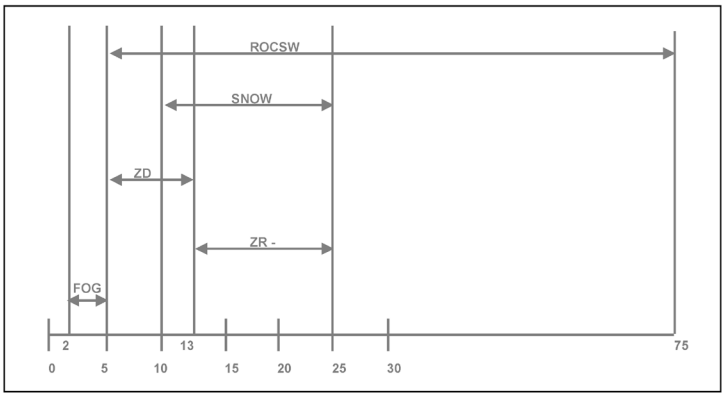


**Figure 4.1: Precipitation Rate Breakdown**

## 4.3 Wind Tunnel Temperature

### 4.3.1 Variation between OAT and Wind Tunnel Temperatures

The wind tunnel test area is enclosed in the wind tunnel building. The test temperature inside the wind tunnel is the most critical parameter for testing. The tunnel temperature is not a controlled variable because it depends on the outside air temperature, outside sky conditions and solar radiation, as well as the temperature inside the wind tunnel building. It is essential to maintain the air temperature inside the tunnel below freezing. The temperature inside the wind tunnel test area increases during the preparation of a typical wind tunnel test when people are working and emanating heat in this area. The temperature inside the wind tunnel can be lowered by leaving the wind tunnel doors opened, thus permitting outside air to circulate through the tunnel. However, the outside airflow affects adversely the effectiveness of freezing precipitation dispersion over the test area.

In general, the wind tunnel test area was warmer than the outside air temperature, on average, by 7°C. The average OAT during all 2006-07 wind tunnel tests was -9.5°C, while the average wind tunnel temperature was -2.8°C.

It is recommended to forecast the weather and plan wind tunnel tests when the OAT is below -8°C. This parameter becomes even more sensitive if sunny weather is present. During 2006-07 extreme cases were noticed when the tunnel temperature was up to 13°C above the OAT.

### 4.3.2 Wind Tunnel Air Temperature Analysis

The air temperature data inside the wind tunnel was monitored and logged by NRC personnel. The data was analyzed in order to select the test temperature that characterizes each wind tunnel test. The data is presented in Figures 4.2 and 4.3.

Four temperature parameters were considered in the analysis:

- Instantaneous tunnel OAT before test;
- Average tunnel OAT during last 10 minutes of precipitation;
- Average tunnel OAT from fluid application to start of takeoff test; and
- Average tunnel OAT from end of precipitation to start of takeoff test.

The analysis showed that the instantaneous tunnel temperature value might not be the correct temperature to be associated with the test. The temperature inside the wind tunnel varied considerably throughout the test. Also, the critical time of the precipitation phase takes place usually during the last minutes of precipitation when the fluid is failing. Therefore, a better and more conservative alternative is to consider the average temperature during the last 10 minutes of precipitation as the reference temperature for a typical test. This temperature value is usually one of the highest, hence most conservative, temperatures considered in Figures 4.2 and 4.3.

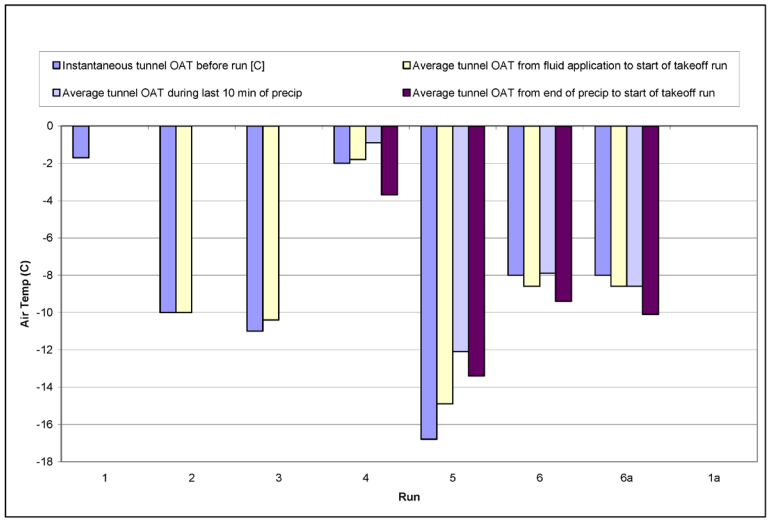


**Figure 4.2: Wind Tunnel Temperature Analysis Chart for Tests 1 – Test 1a**

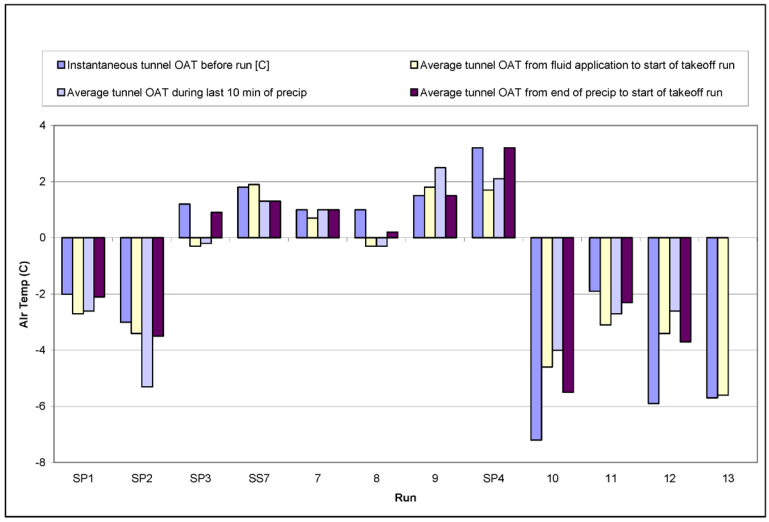


**Figure 4.3: Wind Tunnel Temperature Analysis Chart for Tests SP1 – Test 13**

## 4.4 Wing Skin Temperature Analysis

The wing skin temperature was measured at three locations during the different phases of a typical wind tunnel test:

- On the leading edge;
- Mid-chord; and
- Under the wing.

A similar analysis to the air temperature study presented in Section 4.3.2 was conducted to select the proper wing skin temperature associated with each test. The results are shown in Figures 4.4 and 4.5. For this purpose, three parameters were compared:

- Approximate average wing temperature before test (average of the measurements recorded on the top surface of the wing);
- Approximate leading edge temperature before test; and
- Approximate under wing temperature before test.

It was noted that the average wing skin and the leading edge temperatures were close for all tests. Therefore the average wing skin temperature parameter can be associated with the reference wing skin temperature for each wind tunnel test.

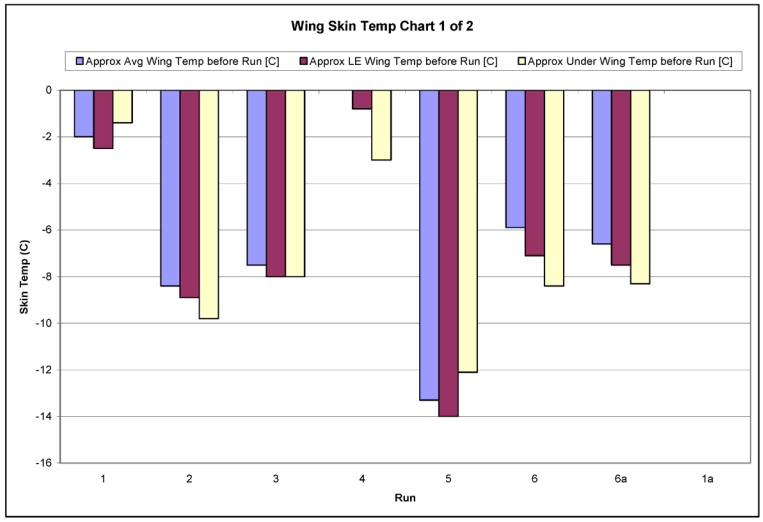


**Figure 4.4: Wing Skin Temperature Analysis Chart for Tests 1 – Test 1a**

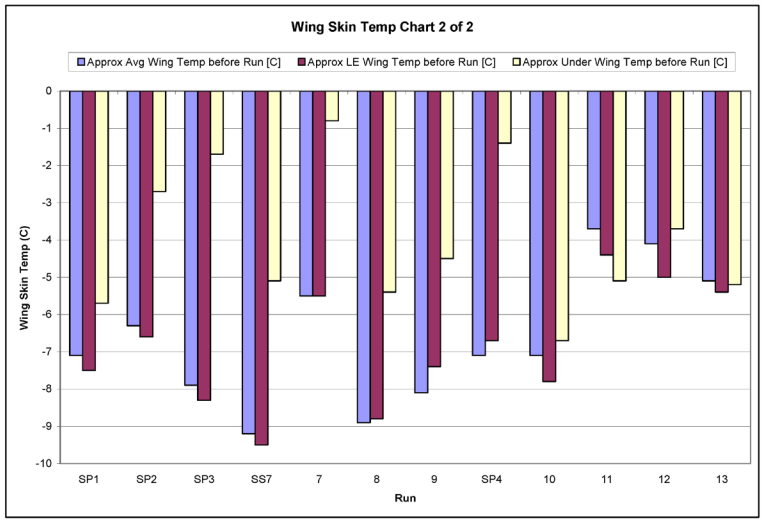


**Figure 4.5: Wing Skin Temperature Analysis Chart for Tests SP1 – Test 13**

## 4.5 Wing to Plate Failure Correlation

In an effort to correlate the fluid failure (or condition) observed on a wing to a test plate, a set-up was used during the wind tunnel tests to collect some preliminary data. A standard HOT test plate fitted with adjustable rubber feet was mounted onto the leading edge of the NACA 23012 wing section. The test plate was inclined at 10° and was anti-iced at the time of fluid application at the start of each wind tunnel test. The test plate was exposed to the same heavy snow conditions as the wing section. The plate fluid condition was recorded at the end of each test. The completed data forms for each test are included in Appendix E.

In general, bridging precipitation was observed on the test plate prior to becoming visible on the wing section. This indicates that the test plate methodology allows for a conservative estimate of the wing condition under mixed conditions with ice pellets. It is recommended that wing to plate correlation work be continued in the 2007-08 test season.

Wing to plate failure correlation was not conducted for the Falcon 20 tests, however the condition of the wing was documented at the end of each tests. Completed data forms are included in Appendix F.

## 4.6 Test Sequence

For both the wind tunnel and the Falcon 20 tests, the test sequence followed the same critical path. The length of each test (from start of set-up to end of last measurement) varied largely due to the time of exposure to precipitation. Time required for set up and teardown as well as preparing and configuring the wind tunnel and Falcon 20 aircraft stayed relatively the same from test to test. Figure 4.6 demonstrates a sample time line for a typical wind tunnel test. Figure 4.7 demonstrates a sample time line for a typical Falcon 20 test. It should be noted that in both figures, a precipitation exposure time of 60 minutes was used for demonstration purposes; this varied for each test depending on the objective.

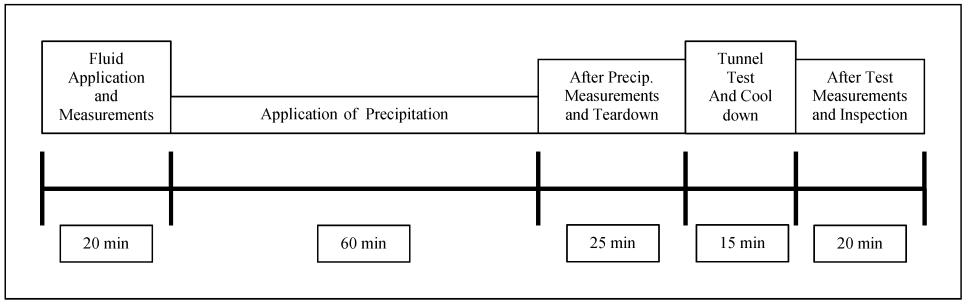


**Figure 4.6: Typical Wind Tunnel Test Timeline**

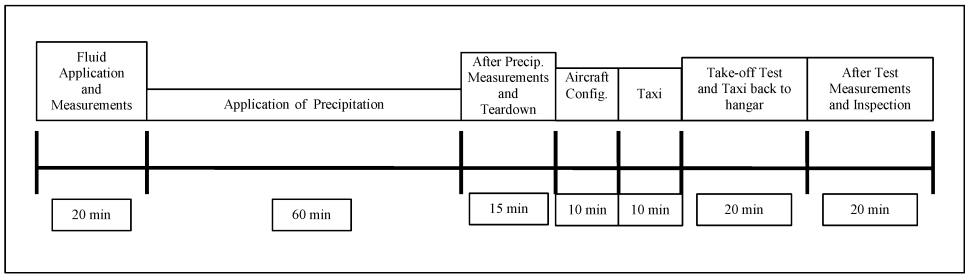


**Figure 4.7: Typical Falcon 20 Test Timeline**

# 5 BASELINE TESTING

This section provides an overview of the baseline testing (fluid only and dry wing) conducted to provide an objective perspective of the effects of heavy snow contamination on the flow-off properties of anti-icing fluid. The parameters for each test are detailed and a description of the data collected during each test is provided.

## 5.1 Overview of Tests

A summary of the baseline tests conducted in the wind tunnel (WT) is shown in Table 5.1. A summary of the baseline tests conducted using the Falcon 20 aircraft (F20) is shown in Table 5.2. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested in the wind tunnel, and with the Falcon 20 aircraft is provided in Section 4.1 and 4.2. The following is a brief description of the column headings for Table 5.1:

| | |
|---|---|
| Test #: | Exclusive number identifying each test. |
| Date: | Date when the test was conducted. |
| Type IV Fluid: | Type IV aircraft deicing fluid. EG specifies an Ethylene Glycol fluid and PG specifies a Propylene Glycol fluid. |
| Condition: | Simulated precipitation condition. |
| SN Rate (g/dm²/h): | Average simulated snow precipitation rate, measured in g/dm²/h. |
| Precip. Time: | Total time of exposure to simulated precipitation. |
| Last 10 min AVG OAT *(WT tests)*: | Average tunnel ambient temperature recorded during the last 10 minutes of precipitation application, measured in degrees Celsius. |

OAT *(F20 tests)*: The outside ambient temperature prior to the start of the simulated takeoff test, measured in degrees Celsius.

Wing Avg Temp (ºC): Average wing skin temperature, measured in degrees Celsius.

Visual Severity Rating (1-5) *(WT tests)*: Rank based on contamination flow off (photo analysis):
1-Trailing edge clean after 30 sec (rotation)
2-Trailing edge clean after 45 sec
3-Trailing edge clean after 60 sec
4-Trailing edge clean after >60 sec, contamination left after test
5-same as 4, plus contamination on leading edge after 45 sec

**Table 5.1: Summary of 2006-07 Baseline Testing in the NRC Wind Tunnel**

| Run # | Date | Type IV Fluid | Fluid | Condition | SN Rate (g/dm²/h) | Precp. Time (min) | Last 10 min AVG OAT (ºC) | Wing Avg Temp (ºC) | Visual Severity Rating (1-5) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 14-Feb-07 | Dry | Dry | Dry | - | - | -1.7 | -2 | - |
| 1A | 16-Feb-07 | Dry | Dry | Dry | - | - | -7 | N/A | - |
| 2 | 14-Feb-07 | PG | ABC-S | Baseline | - | - | -10 | -9 | - |
| 3 | 14-Feb-07 | EG | Ultra+ | Baseline | - | - | -11 | -8 | - |
| 13 | 23-Feb-07 | Dry | Dry | Baseline | - | - | -5.7 | -5 | - |

**Table 5.2: Summary of 2006-07 Baseline Testing with Falcon 20 Aircraft**

| Run # | Date | Type IV Fluid | Fluid | Condition | SN Rate (g/dm²/h) | Precp. Time (min) | OAT (ºC) | Wing Avg Temp (ºC) |
|---|---|---|---|---|---|---|---|---|
| 1S | 27-Feb-07 | PG | ABC-S | S++ | 75 | 20 | -10 | -9.5 |
| 1P | 27-Feb-07 | PG | ABC-S | Baseline | - | - | -10 | -4 |

## 5.2 Data Collected

### 5.2.1 Coefficient of Lift Curves

Dry wing testing was conducted in order to determine the lift characteristics of the NACA 23012 wing section. The lift data collected would be the baseline test profile to be used as a comparative data point for all other fluid tests conducted. Fluid only testing (i.e. no contamination applied) was also investigated.

Drag and lift coefficient data collected by the NRC in the wind tunnel was used to generate lift coefficient curves for each of the tests conducted in the wind tunnel. Figures 5.1 and 5.2 show the lift coefficient data for test Test #1 and Test #1a conducted with a dry wing. Figures 5.3 to 5.5 show the lift coefficient data for Test #2, Test #3, and Test #13 conducted with fluid only. The x-axis indicates the time in seconds as of the start of rotation. The y-axis indicates the Cn (normal coefficient) and Cl (lift coefficient) calculated from the data collected.

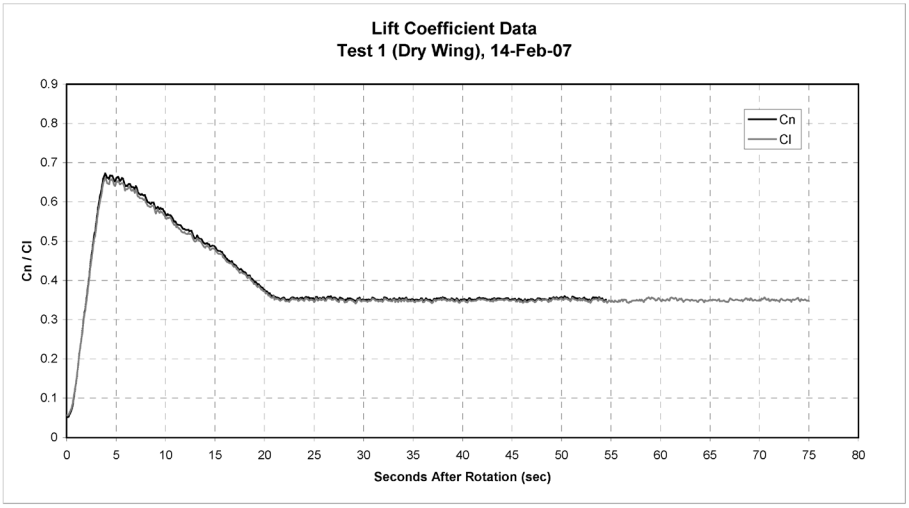


**Figure 5.1: Test #1 Lift Coefficient Data**

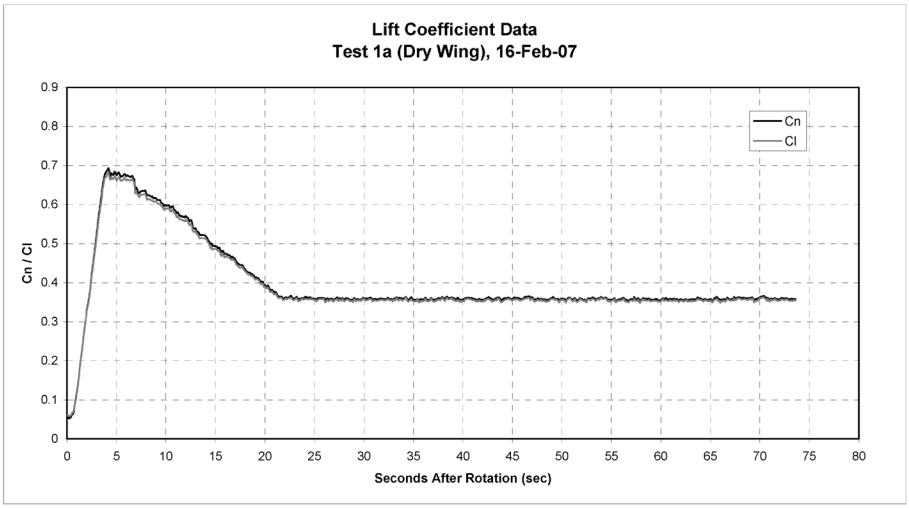


**Figure 5.2: Test #1a Lift Coefficient Data**

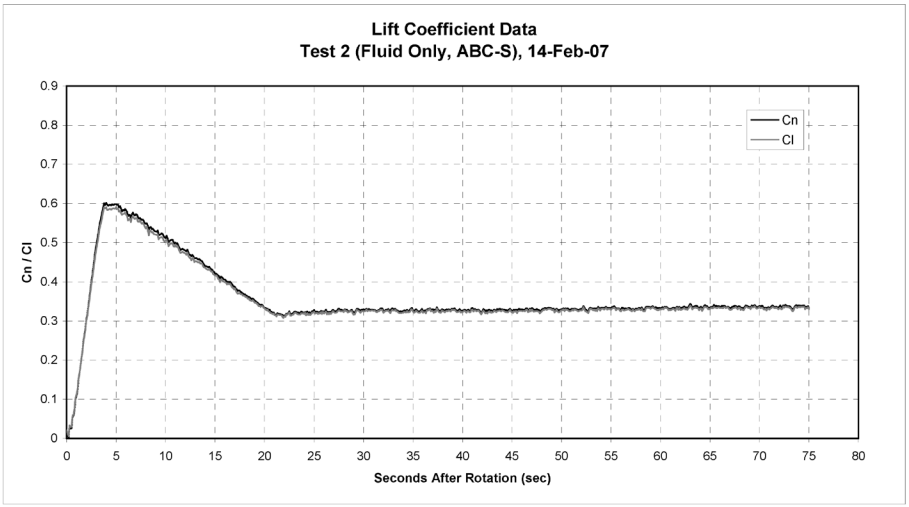


**Figure 5.3: Test #2 Lift Coefficient Data**

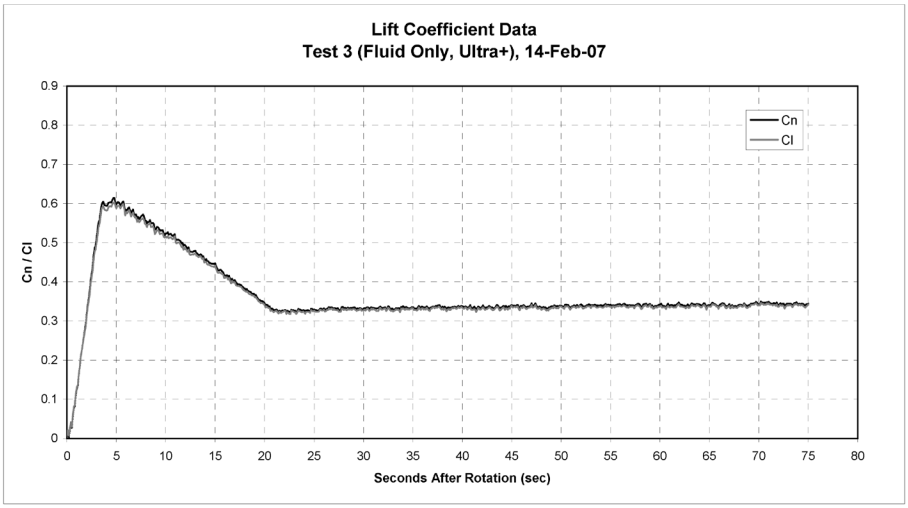


**Figure 5.4: Test #3 Lift Coefficient Data**

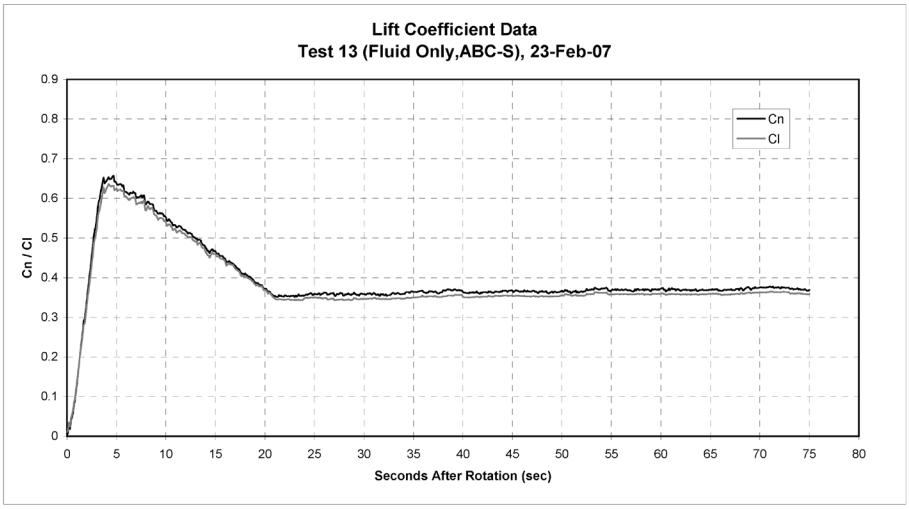


**Figure 5.5: Test #13 Lift Coefficient Data**

### 5.2.2 Fluid Thickness Data

Fluid thickness measurements were collected by APS personnel. The wing positions used for the wind tunnel tests and Falcon 20 tests are described in Section 2.1.8.1 and 2.2.9.1. Fluid thickness measurements were recorded at the following intervals:

- Wind Tunnel Tests
  - Approximately 5 minutes after fluid application; and
  - After the wind tunnel test (end of test).

- Falcon 20 Tests
  - Approximately 5 minutes after fluid application;
  - After the application of contamination (on the test wing, not the fluid only wing);
  - Before the takeoff test; and
  - After the takeoff test (end of test).

Tables 5.3 to 5.10 show the fluid thickness measurements collected during the tests. It should be noted that no thickness measurements were taken for the dry wing tests #1 and #1a conducted in the wind tunnel.

**Table 5.3: Test #2 Fluid Thickness Data**

| TEST 2: ABC-S, fluid only | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.1 | N/A | 0.1 |
| 2 | 3.1 | N/A | 0.1 |
| 3 | 3.9 | N/A | 0.1 |
| 4 | 3.1 | N/A | 0.2 |
| 5 | 2.5 | N/A | 0.2 |
| 6 | 2.5 | N/A | 0.2 |
| 7 | 2.2 | N/A | 0.2 |
| 8 | 1.2 | N/A | 0.4 |

### Table 5.4: Test #3 Fluid Thickness Data

| TEST 3: Ultra+, fluid only | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.2 | N/A | 0.0 |
| 2 | 4.5 | N/A | 0.1 |
| 3 | 5.7 | N/A | 0.1 |
| 4 | 4.5 | N/A | 0.1 |
| 5 | 3.3 | N/A | 0.1 |
| 6 | 3.5 | N/A | 0.2 |
| 7 | 3.1 | N/A | 0.2 |
| 8 | 2.2 | N/A | 0.6 |

### Table 5.5: Test #13 Fluid Thickness Data

| TEST 13: ABC-S, fluid only | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.1 | N/A | 0.0 |
| 2 | 3.1 | N/A | 0.0 |
| 3 | 5.7 | N/A | 0.0 |
| 4 | 3.3 | N/A | 0.1 |
| 5 | 2.9 | N/A | 0.2 |
| 6 | 2.7 | N/A | 0.2 |
| 7 | 2.7 | N/A | 0.3 |
| 8 | 2.2 | N/A | 0.5 |

### Table 5.6: Test #2P Fluid Thickness Data

| TEST 2P: ABC-S, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | 0.8 | 0.7 | N/A | N/A |
| 2 | 1.6 | 1.3 | N/A | N/A |
| 5 | 3.5 | 3.1 | N/A | N/A |
| 7 | 1.1 | 1.5 | N/A | N/A |
| 8 | 1.8 | 0.7 | N/A | N/A |

### Table 5.7: Test #3P Fluid Thickness Data

| TEST 3P: ABC-S, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | 1.1 | 0.7 | N/A | 0.1 |
| 2 | 1.7 | 1.2 | N/A | 0.2 |
| 5 | 3.5 | 3.1 | N/A | 0.2 |
| 7 | 2.2 | 1.6 | N/A | 0.2 |
| 8 | 1.6 | 0.7 | N/A | 0.2 |

### Table 5.8: Test #4S Fluid Thickness Data

| TEST 4S: ABC-S, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | 0.5 | N/A | N/A | 0.0 |
| 2 | 1.7 | N/A | N/A | 0.0 |
| 5 | 3.3 | N/A | N/A | 0.2 |
| 7 | 1.5 | N/A | N/A | 0.3 |
| 8 | 0.7 | N/A | N/A | 0.2 |

### Table 5.9: Test #5S Fluid Thickness Data

| TEST 5S: Ultra+, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | 1.1 | 0.8 | N/A | 0.1 |
| 2 | 2.2 | 1.8 | N/A | 0.2 |
| 5 | 4.5 | 4.5 | N/A | 0.2 |
| 7 | 2.2 | 2.2 | N/A | 0.2 |
| 8 | 2.2 | 2.2 | N/A | 0.2 |

### Table 5.10: Test #6S Fluid Thickness Data

| TEST 6S: Ultra+, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | 1.1 | 0.8 | N/A | 0.0 |
| 2 | 2.2 | 1.8 | N/A | 0.1 |
| 5 | 3.7 | 3.3 | N/A | 0.2 |
| 7 | 2.5 | 2.2 | N/A | 0.2 |
| 8 | 1.2 | 1.0 | N/A | 0.2 |

### 5.2.3 Skin Temperature Data

Skin temperature measurements were collected by APS personnel. The wing positions used for the wind tunnel tests and Falcon 20 tests are described in Section 2.1.8.3 and 2.2.9.3. Skin temperature measurements were recorded at the following intervals:

- Wind Tunnel Tests
  - Before the application of contamination; and
  - After the wind tunnel test (end of test).

- Falcon 20 Tests
  - After fluid application;
  - After the application of contamination (on the test wing, not the fluid only wing);
  - Before the takeoff test; and
  - After the takeoff test (end of test).

The wing temperature measurements recorded during each test are shown in Tables 5.11 to 5.19. Skin temperature measurements were not conducted during Test #1a.

**Table 5.11: Test #1 Skin Temperature Data**

| TEST 1: Dry | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 3.1 | N/A | 0.1 |
| 5 | 2.5 | N/A | 0.2 |
| Under wing | 1.2 | N/A | 0.4 |

**Table 5.12: Test #2 Skin Temperature Data**

| TEST 2: ABC-S, fluid only | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -6.0 | N/A | -7.5 |
| 5 | -4.5 | N/A | -6.2 |
| Under wing | -7.6 | N/A | -8.8 |

### Table 5.13: Test #3 Skin Temperature Data

| TEST 3: Ultra+, fluid only | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -8.0 | N/A | -6.9 |
| 5 | -7.0 | N/A | -5.8 |
| Under wing | -8.0 | N/A | -8.3 |

### Table 5.14: Test #13 Skin Temperature Data

| TEST 13: ABC-S, fluid only | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -5.4 | N/A | -4.3 |
| 5 | -4.7 | N/A | -3.9 |
| Under wing | -5.2 | N/A | -4.7 |

### Table 5.15: Test #2P Skin Temperature Data

| TEST 2P: ABC-S, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | -5.2 | 10.2 | N/A | -6.5 |
| 2 | -3.8 | -9.3 | -8.2 | -6.6 |
| 3 | -3.1 | 11.1 | N/A | -7.8 |
| 4 | -1.6 | 8.3 | -11.3 | -7.4 |
| 5 | -0.8 | 7.0 | N/A | -8.5 |
| 6 | -3.0 | 2.0 | N/A | -8.7 |
| 7 | 1.4 | 3.5 | N/A | -7.9 |
| 8 | 0.5 | 4.0 | N/A | -8.3 |

### Table 5.16: Test #3P Skin Temperature Data

| TEST 3P: ABC-S, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | -9.6 | -11.1 | N/A | -9.8 |
| 2 | -9.5 | -11.1 | N/A | -9.8 |
| 3 | -8.6 | -11.1 | N/A | -10.1 |
| 4 | -9.0 | -11.1 | N/A | -10.3 |
| 5 | -7.8 | -10.8 | N/A | -9.6 |
| 6 | -7.8 | -10.3 | N/A | -9.2 |
| 7 | -9.0 | -11.8 | N/A | -8.7 |
| 8 | -9.1 | -11.7 | N/A | -9.2 |

### Table 5.17: Test #4S Skin Temperature Data

| TEST 4S: ABC-S, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | -8.3 | N/A | N/A | 5.5 |
| 2 | -8.3 | N/A | N/A | 4.8 |
| 3 | -7.3 | N/A | N/A | 1.8 |
| 4 | -7.0 | N/A | N/A | 0.5 |
| 5 | -6.6 | N/A | N/A | -4.0 |
| 6 | -6.1 | N/A | N/A | -3.8 |
| 7 | -3.3 | N/A | N/A | -5.9 |
| 8 | -3.2 | N/A | N/A | -5.7 |

### Table 5.18: Test #5S Skin Temperature Data

| TEST 5S: Ultra+, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | -12.0 | -13.0 | N/A | -8.7 |
| 2 | -12.1 | -13.1 | N/A | -8.5 |
| 3 | -11.7 | -13.5 | N/A | -11.0 |
| 4 | -11.6 | -13.6 | N/A | -11.2 |
| 5 | -10.2 | -13.1 | N/A | -12.5 |
| 6 | -10.1 | -13.0 | N/A | -12.8 |
| 7 | -12.7 | -15.1 | N/A | -12.7 |
| 8 | -12.8 | -14.9 | N/A | -12.7 |

**Table 5.19: Test #6S Skin Temperature Data**

| TEST 6S: Ultra+, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test | After Takeoff Test |
| 1 | -3.6 | 2.5 | N/A | 1.9 |
| 2 | -3.7 | 0.2 | N/A | 0.7 |
| 3 | -6.4 | -0.4 | N/A | 0.9 |
| 4 | -6.1 | -0.5 | N/A | -0.1 |
| 5 | -6.6 | -4.2 | N/A | -4.9 |
| 6 | -6.4 | -3.7 | N/A | -3.8 |
| 7 | -7.9 | -8.8 | N/A | -6.4 |
| 8 | -7.1 | -8.5 | N/A | -6.0 |

### 5.2.4 Fluid Brix Data

Fluid Brix measurements were collected by APS personnel. The wing positions used for the wind tunnel tests and Falcon 20 tests are described in Section 2.1.8.2 and 2.2.9.2.

- Wind Tunnel Tests
  - Approximately 5 minutes after fluid application; and
  - After the wind tunnel test (end of test).
- Falcon 20 Tests
  - After fluid application;
  - After the application of contamination (on the test wing, not the fluid only wing);
  - Before the takeoff test; and
  - After the takeoff test (end of test).

Tables 5.20 to 5.27 show the fluid Brix measurements collected during the test. It should be noted that no Brix measurements were taken for the dry wing tests #1 and #1a conducted in the wind tunnel.

**Table 5.20: Test # 2 Fluid Brix Data**

| TEST 2: ABC-S, fluid only | | | |
|---|---|---|---|
| Wing Position | Fluid Brix (°) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 37.50 | N/A | 36.75 |
| 8 | 37.50 | N/A | 37.75 |

### Table 5.21: Test # 3 Fluid Brix Data

| TEST 3: Ultra+, fluid only | | | |
|---|---|---|---|
| Wing Position | Fluid Brix (°) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 40.25 | N/A | N/A |
| 8 | 40.50 | N/A | 38.25 |

### Table 5.22: Test # 13 Fluid Brix Data

| TEST 13: ABC-S, fluid only | | | |
|---|---|---|---|
| Wing Position | Fluid Brix (°) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 37.50 | N/A | 43.50 |
| 8 | 37.50 | N/A | 40.00 |

### Table 5.23: Test # 2P Fluid Brix Data

| TEST 2P: ABC-S, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Brix (°) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test. | After Takeoff Test |
| 2 | 37.00 | 37.50 | N/A | N/A |
| 5 | 37.00 | 37.00 | N/A | N/A |

### Table 5.24: Test # 3P Fluid Brix Data

| TEST 3P: ABC-S, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Brix (°) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test. | After Takeoff Test |
| 2 | 37.00 | 37.00 | N/A | 38.50 |
| 5 | 37.00 | 37.00 | N/A | 34.00 |

**Table 5.25: Test # 4S Fluid Brix Data**

| TEST 4S: ABC-S, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Brix (°) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test. | After Takeoff Test |
| 2 | 37.00 | N/A | N/A | N/A |
| 5 | 37.00 | N/A | N/A | N/A |

**Table 5.26: Test # 5S Fluid Brix Data**

| TEST 5S: Ultra+, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Brix (°) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test. | After Takeoff Test |
| 2 | 41.50 | 41.50 | N/A | 41.00 |
| 5 | 41.50 | 41.00 | N/A | 41.00 |

**Table 5.27: Test # 6S Fluid Brix Data**

| TEST 6S: Ultra+, fluid only | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Brix (°) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test. | After Takeoff Test |
| 2 | 41.00 | 41.00 | N/A | 49.00 |
| 5 | 41.00 | 41.00 | N/A | 43.00 |

## 5.3 Photos

High-speed digital photography of each test was taken. Photos of both the leading edge and trailing edge are shown. For each of the tests, a summary of the photos has been compiled comprising of four photos:

- Start of test;
- Time of rotation;
- 10 seconds after rotation; and
- End of test.

Photos 5.1 to 5.12 show the photo summaries for tests #2, #3 and #13; the Falcon 20 baseline test are not shown. A compilation of selected high-speed photos taken during Test 2 is included in Appendix G. A complete set of photos will be provided to TDC.

## 5.4 Results

Baseline testing conducted in the wind tunnel demonstrated a lift loss when comparing the fluid test to a dry wing test. The lift loss was a result of the anti-icing fluid applied to the wing section, which compromised the aerodynamic qualities of the wing section. Residual fluid was observed on the trailing edge of the wing section during the wind tunnel tests as well as during the Falcon 20 tests. The quantitative and qualitative aerodynamic data collected during the baseline fluid only testing was used for comparative analysis against the contaminated fluid tests presented in Section 6.

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**Photo 5.1: Test #2 – Start of Test**

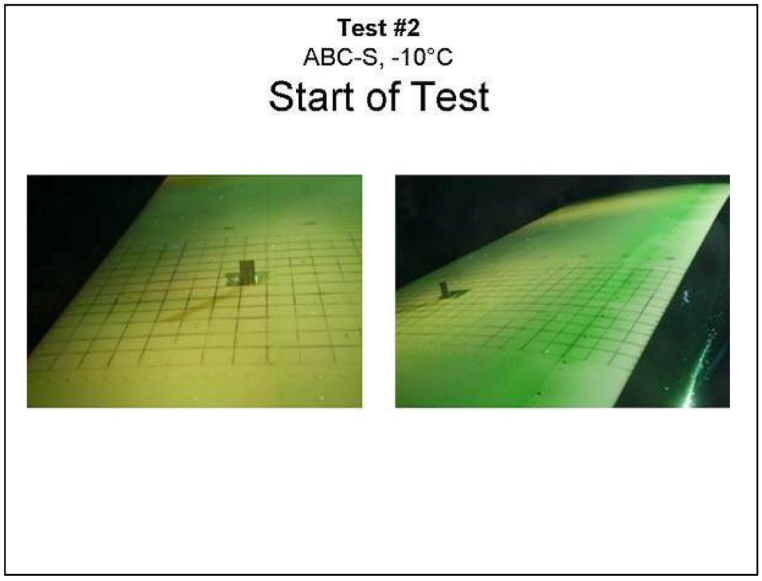



**Photo 5.2: Test #2 – Before Rotation**

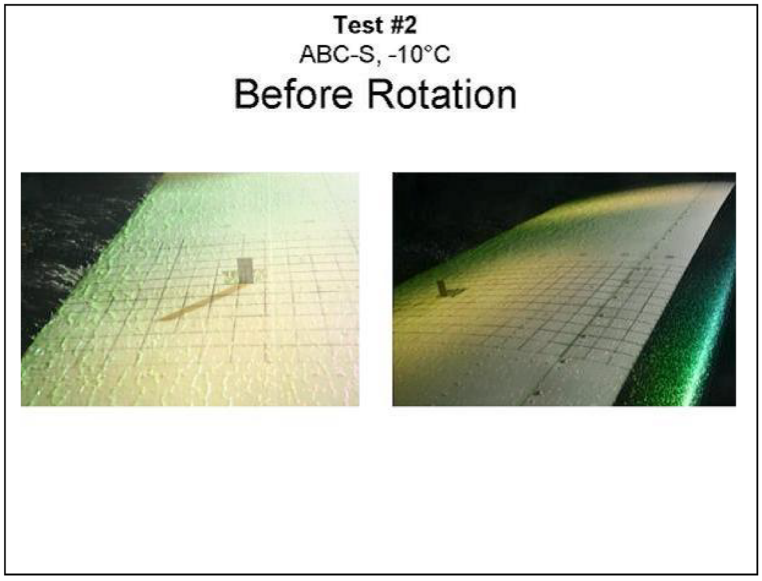


**Photo 5.3: Test #2 – 10 Seconds After Rotation**

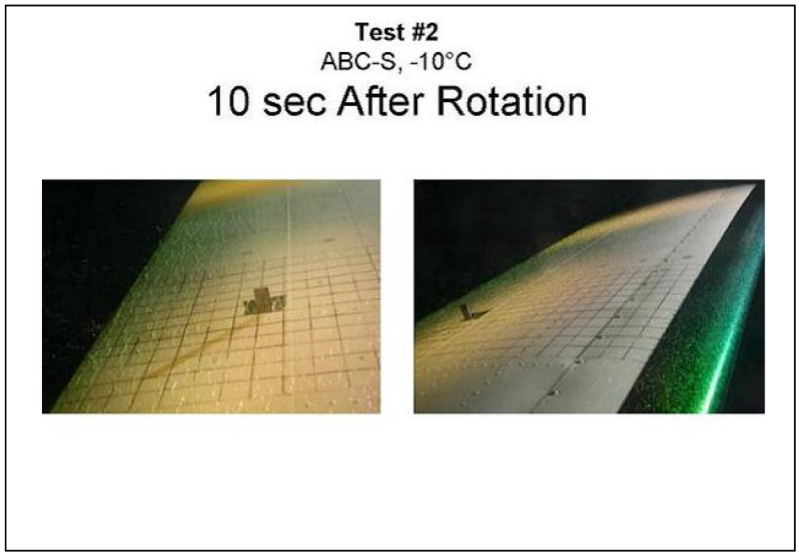



**Photo 5.4: Test #2 – End of Test**

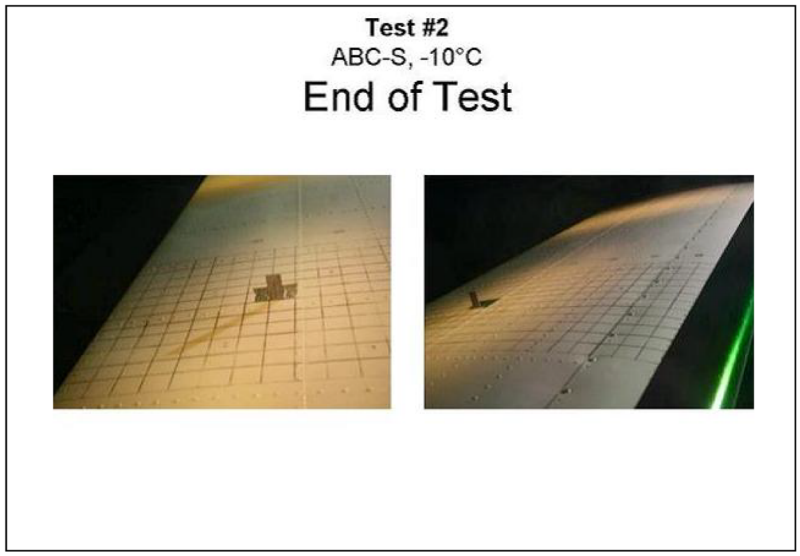


**Photo 5.5: Test #3 – Start of Test**

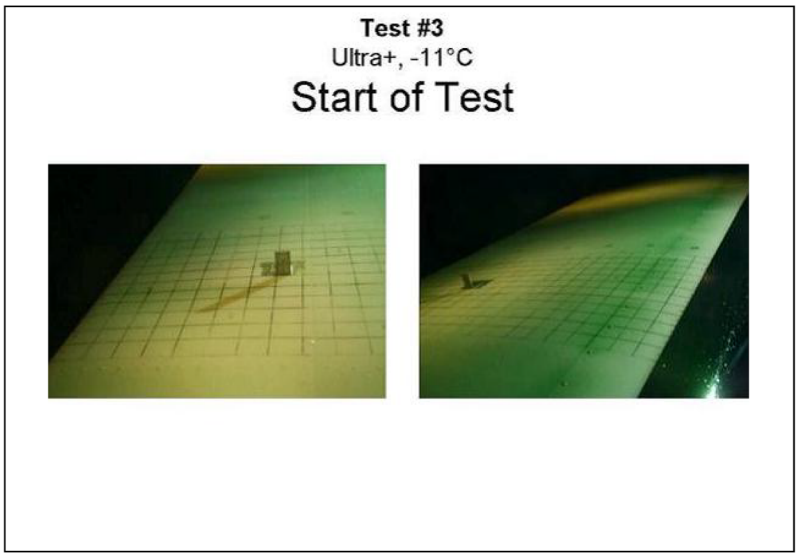



**Photo 5.6: Test #3 – Before Rotation**

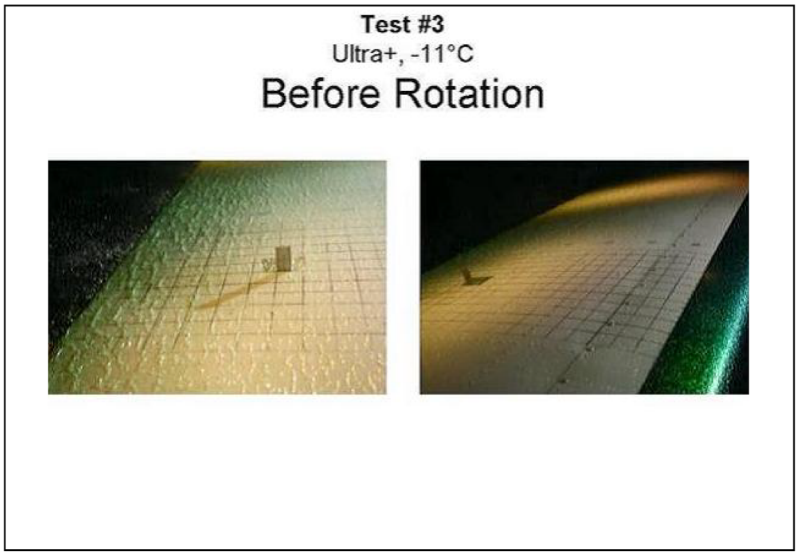


**Photo 5.7: Test #3 – 10 Seconds After Rotation**

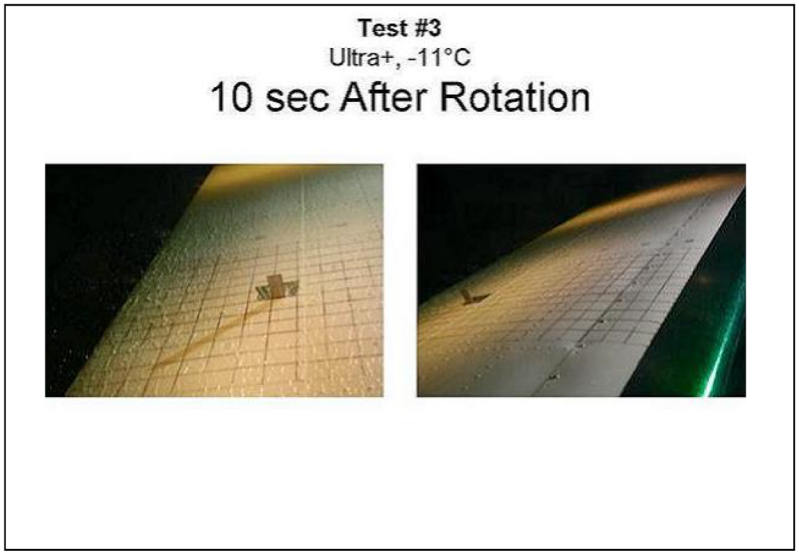



**Photo 5.8: Test #3 – End of Test**

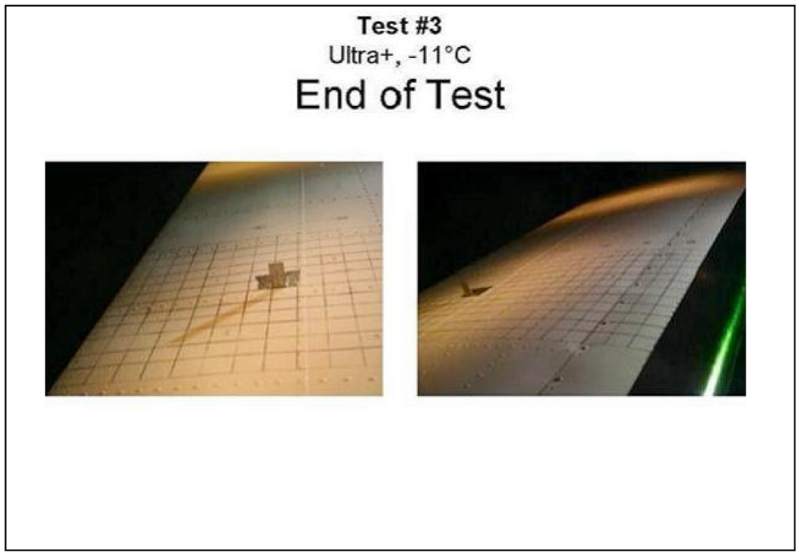


**Photo 5.9: Test #13 – Start of Test**

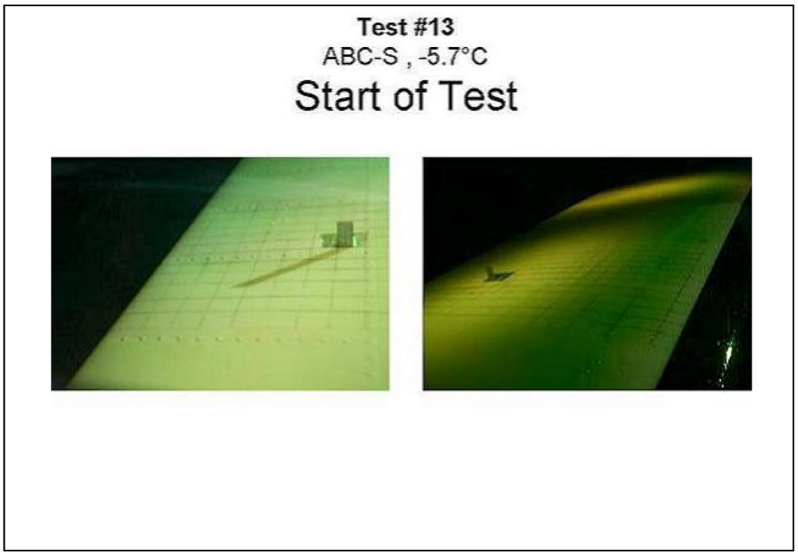



**Photo 5.10: Test #13 – Before Rotation**

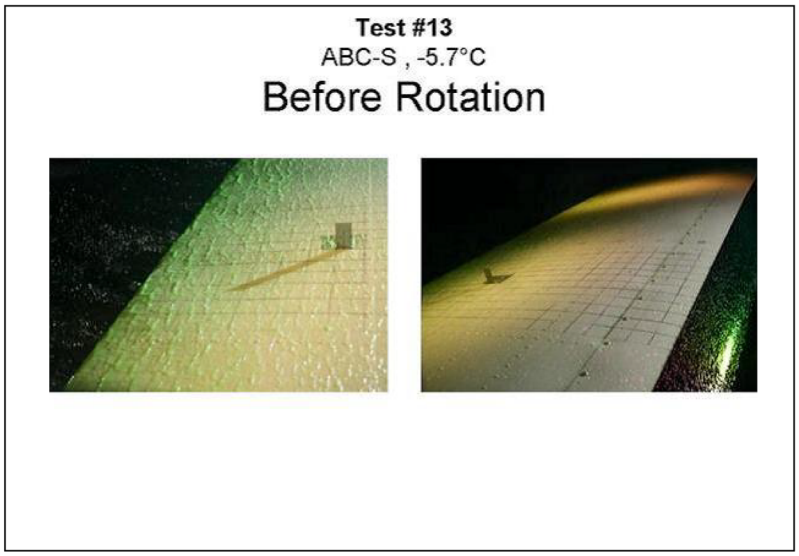


**Photo 5.11: Test #13 – 10 Seconds After Rotation**

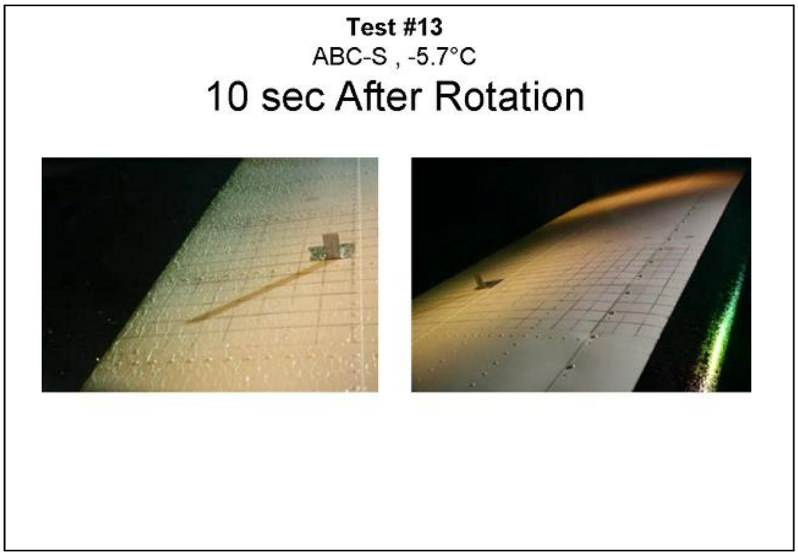
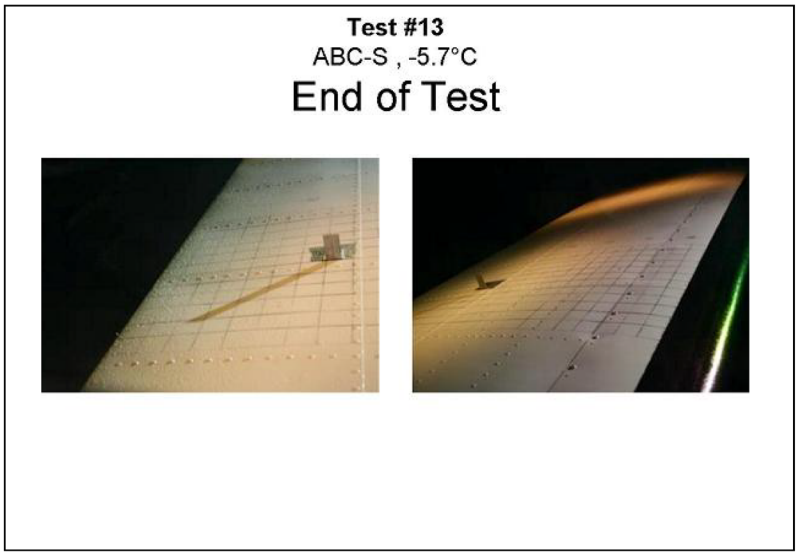



**Photo 5.12: Test #13 – End of Test**



# 6 HEAVY SNOW TESTING

This section provides an overview of each test conducted as part of the test program to evaluate the behaviour of anti-icing fluid exposed to heavy snow conditions. The parameters for each test are detailed and a description of the data collected during each test is provided.

## 6.1 Overview of Tests

A summary of the tests conducted in the wind tunnel during heavy snow conditions is shown in Table 6.1. A summary of the tests conducted using the Falcon 20 aircraft during heavy snow conditions is shown in Table 6.2. The table provides relevant information for each of the tests, as well as final values used for the data analysis. Each row contains data specific to one test. A more detailed test log of all conditions tested in the wind tunnel, and using the Falcon 20 aircraft is provided in Section 4.1 and 4.2. A brief description of the column headings can be found in Section 5.1.

**Table 6.1: Summary of 2006-07 IP-/ZR- Testing in the NRC Wind Tunnel**

| Test # | Date | Type IV Fluid | Condition | SN Rate ($g/dm^2/h$) | Precp. Time (min) | Last 10 min AVG OAT ($^oC$) | Wing Avg Temp ($^oC$) | Visual Severity Rating (1-5) |
|---|---|---|---|---|---|---|---|---|
| SS1 | 16-Feb-07 | EG | SN++ | 51 | 60 | -0.2 | -11 | 3 |
| SS2 | 16-Feb-07 | PG | SN++ | 54 | 30 | 0.3 | -9 | 3 |
| SS3 | 19-Feb-07 | EG | SN++ | 77 | 20 | -3.5 | -14 | 4 |
| SS4 | 19-Feb-07 | PG | SN++ | 77 | 20 | -2.4 | -11 | 5 |
| SS5 | 19-Feb-07 | PG | SN++ | 77 | 20 | -0.5 | -9.5 | 4.5 |
| SS6 | 19-Feb-07 | PG | SN++ | 77 | 10 | -3 | -9.5 | 5 |
| SS7 | 20-Feb-07 | EG | SN++ | 77 | 20 | 1.8 | -9 | 1 |

**Table 6.2: Summary of 2006-07 IP-/ZR- Testing with Falcon 20 Aircraft**

| Test # | Date | Type IV Fluid | Condition | SN Rate ($g/dm^2/h$) | Precp. Time (min) | OAT ($^oC$) | Wing Avg Temp ($^oC$) |
|---|---|---|---|---|---|---|---|
| 1S | 27-Feb-07 | PG | SN++ | 75 | 20 | -10 | -9.5 |

## 6.2 Data Collected

### 6.2.1 Coefficient of Lift Curves

Drag and lift data collected by the NRC in the wind tunnel was used to generate lift coefficient curves for each of the tests conducted in the wind tunnel. Figures 6.1 to 6.6 show the lift coefficient data for the tests SS1 to SS6 conducted in heavy snow conditions; it should be noted that lift data was not available during test SS7. The x-axis indicates the time in seconds as of the start of rotation. The y-axis indicates the Cn (normal coefficient) and Cl (lift coefficient) calculated from the data collected.

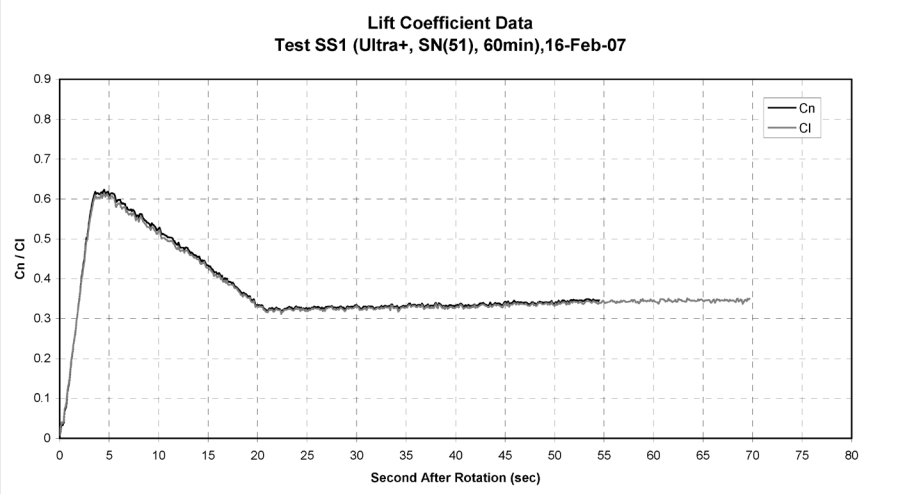



**Figure 6.1: Test #SS1 Lift Coefficient Data**

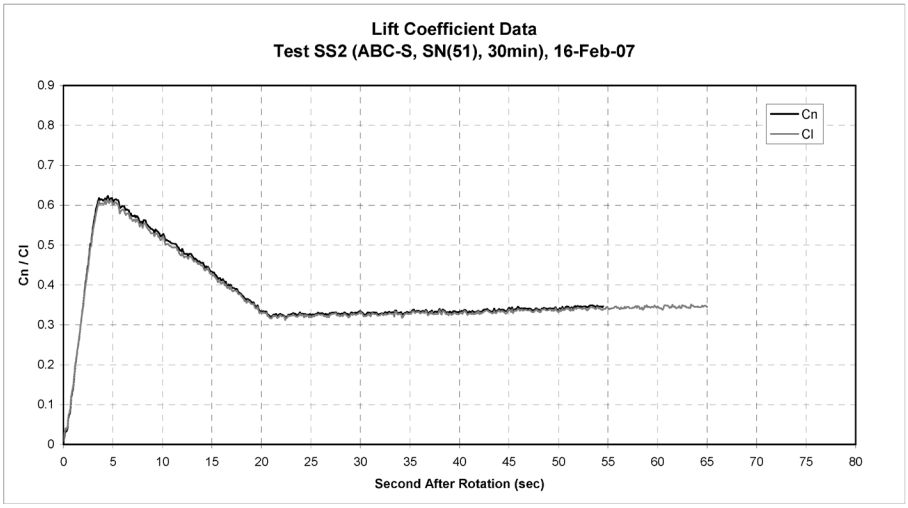



**Figure 6.2: Test #SS2 Lift Coefficient Data**

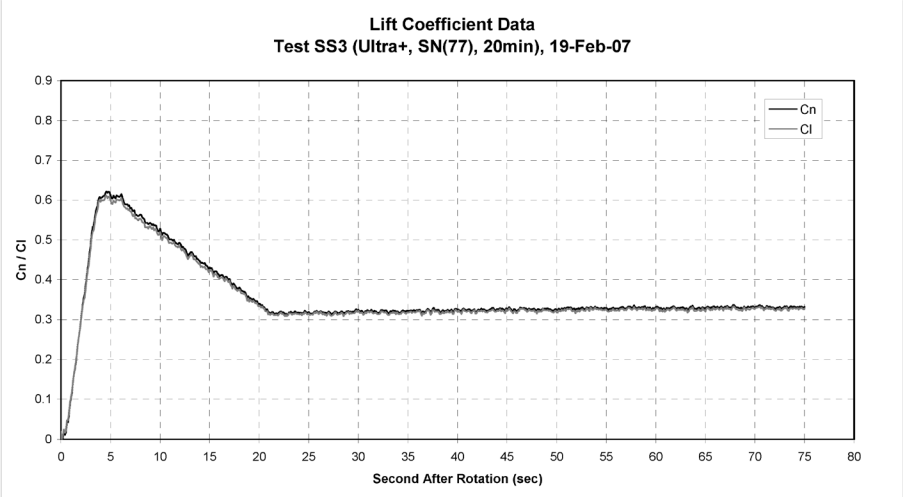



**Figure 6.3: Test #SS3 Lift Coefficient Data**

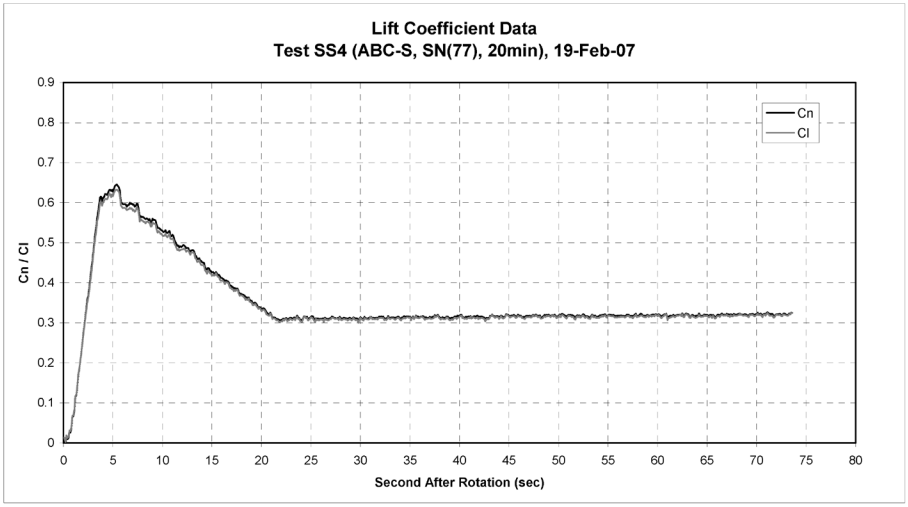



**Figure 6.4: Test #SS4 Lift Coefficient Data**

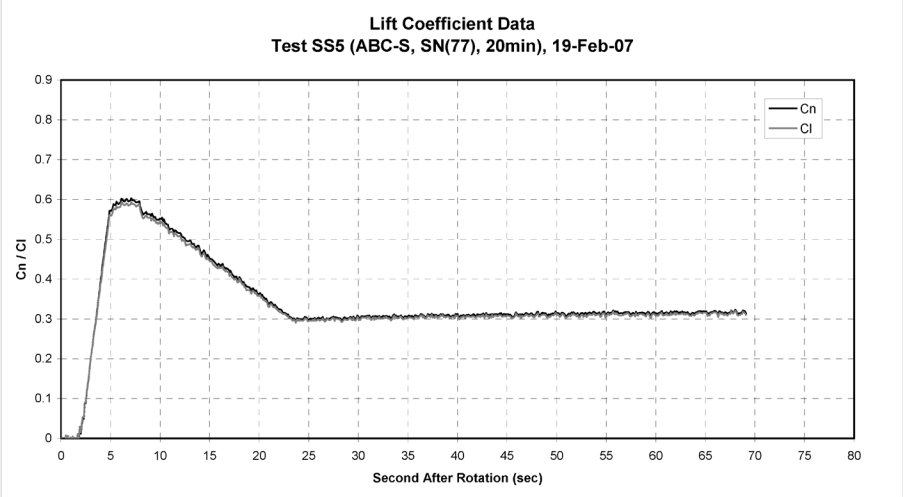



**Figure 6.5: Test #SS5 Lift Coefficient Data**

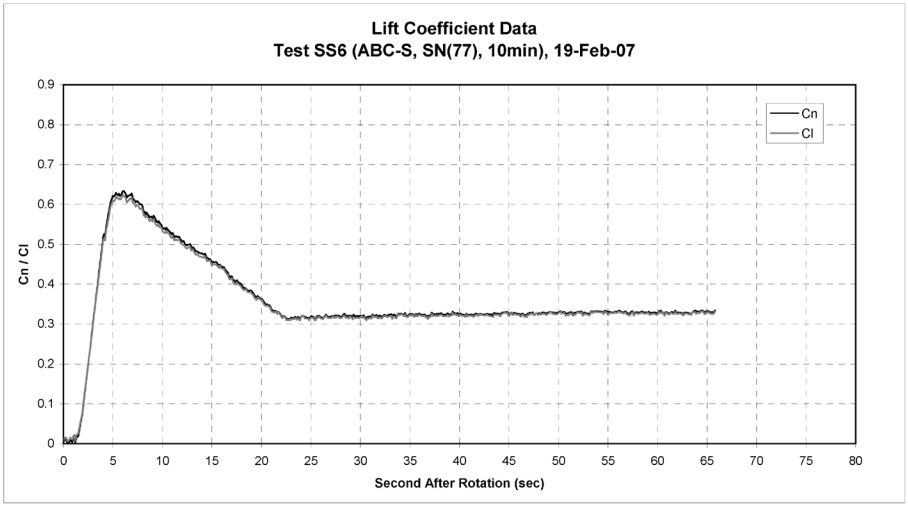



**Figure 6.6: Test #SS6 Lift Coefficient Data**

### 6.2.2 Fluid Thickness Data

Fluid thickness measurements were collected by APS personnel. The wing positions used for the wind tunnel tests and Falcon 20 tests are described in Section 2.1.8.1 and 2.2.9.1. Fluid thickness measurements were recorded at the following intervals:

- Wind Tunnel Tests
  - Approximately 5 minutes after fluid application; and
  - After the wind tunnel test (end of test).

- Falcon 20 Tests
  - Approximately 5 minutes after fluid application;
  - After the application of contamination (on the test wing, not the fluid only wing);
  - Before the takeoff test; and
  - After the takeoff test (end of test).

Tables 6.3 to 6.10 show the fluid thickness measurements collected during the test.

### Table 6.3: Test #SS1 Fluid Thickness Data

| TEST SS1: Ultra+, SN(51)-60min | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.8 | 10.2 | 0.0 |
| 2 | 3.3 | >10.2 | 0.0 |
| 3 | 5.7 | >10.2 | 0.0 |
| 4 | 4.5 | 8.9 | 0.0 |
| 5 | 3.9 | 5.7 | 0.0 |
| 6 | 3.3 | 1.8 | 0.0 |
| 7 | 3.1 | 1.8 | 0.0 |
| 8 | 2.5 | 1.4 | 0.0 |

### Table 6.4: Test #SS2 Fluid Thickness Data

| TEST SS2: ABC-S, SN(51)-30min | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.4 | 3.1 | 0.0 |
| 2 | 3.7 | 4.5 | 0.0 |
| 3 | 4.5 | 8.9 | 0.0 |
| 4 | 3.1 | 5.7 | 0.0 |
| 5 | 2.5 | 4.5 | 0.0 |
| 6 | 2.5 | 3.9 | 0.0 |
| 7 | 2.2 | 2.9 | 0.1 |
| 8 | 1.8 | 2.2 | 0.1 |

### Table 6.5: Test #SS3 Fluid Thickness Data

| TEST SS3: Ultra+, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.8 | 3.5 | 0.0 |
| 2 | 3.1 | 5.7 | 0.1 |
| 3 | 5.7 | 7.0 | 0.0 |
| 4 | 4.5 | 4.5 | 0.0 |
| 5 | 3.3 | 4.5 | 0.0 |
| 6 | 3.5 | 4.5 | 0.2 |
| 7 | 3.5 | 4.5 | 0.4 - 1.3 |
| 8 | 2.9 | 4.5 | 0.6 - 1.3 |

### Table 6.6: Test #SS4 Fluid Thickness Data

| TEST SS4: ABC-S, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.1 | 2.2 | 0.0 – 1.1 |
| 2 | 2.9 | 2.5 | 0.0 – 1.2 |
| 3 | 3.5 | 4.5 | 0.0 |
| 4 | 2.2 | 3.7 | 0.0 |
| 5 | 2.2 | 3.7 | 0.1 – 1.5 |
| 6 | 2.2 | 5.7 | 0.2 – 1.8 |
| 7 | 2.2 | 5.7 | 0.3 – 1.8 |
| 8 | 2.2 | 5.7 | 0.5 – 2.2 |

### Table 6.7: Test #SS5 Fluid Thickness Data

| TEST SS5: ABC-S, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.1 | 2.5 | 0.0 |
| 2 | 3.3 | 2.7 | 0.0 |
| 3 | 4.5 | 3.9 | 0.1 |
| 4 | 2.9 | 3.7 | 0.1 |
| 5 | 2.5 | 3.1 | 0.1 |
| 6 | 2.2 | 3.3 | 0.2 |
| 7 | 2.2 | 3.5 | 0.4 |
| 8 | 2.2 | 3.1 | 0.5 |

### Table 6.8: Test #SS6 Fluid Thickness Data

| TEST SS6: ABC-S, SN(77)-10min | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.4 | 1.4 | 0.0 |
| 2 | 2.2 | 3.5 | 0.0 |
| 3 | 3.9 | 4.5 | 0.1 |
| 4 | 2.7 | 3.3 | 0.1 |
| 5 | 3.1 | 2.9 | 0.1 |
| 6 | 2.2 | 2.7 | 0.2 |
| 7 | 2.2 | 2.7 | 0.4 |
| 8 | 1.8 | 2.2 | 0.4 |

**Table 6.9: Test #SS7 Fluid Thickness Data**

| TEST SS7: Ultra+, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | |
| | After Fluid Application | After Precip Application | After Wind Tunnel Test |
| 1 | 1.4 | 0.8 | 0.0 |
| 2 | 4.5 | 5.7 | 0.0 |
| 3 | 5.7 | 7.0 | 0.0 |
| 4 | 4.5 | 5.7 | 0.0 |
| 5 | 3.3 | 5.7 | 0.0 |
| 6 | 3.3 | 5.7 | 0.1 |
| 7 | 3.3 | 4.5 | 0.1 |
| 8 | 2.7 | 3.9 | 0.3 |

**Table 6.10: Test #1S Fluid Thickness Data**

| TEST 1S: ABC-S, SN(75) - 20 min | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Thickness (mm) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test. | After Takeoff Test |
| 1 | 0.8 | 3.5 | 3.1 | 0.0 |
| 2 | 1.6 | 5.7 | 5.7 | 0.1 |
| 5 | 3.3 | 7.0 | 7.0 | 0.7 |
| 7 | 1.6 | 2.9 | 4.5 | 0.7 |
| 8 | 1.5 | 3.9 | 5.7 | 0.2 |

### 6.2.3 Skin Temperature Data

Skin temperature measurements were collected by APS personnel. The wing positions used for the wind tunnel tests and Falcon 20 tests are described in Section 2.1.8.3 and 2.2.9.3. Skin temperature measurements were recorded at the following intervals:

- Wind Tunnel Tests
  - Before the application of contamination;
  - After the application of contamination; and
  - After the wind tunnel test (end of test).
- Falcon 20 Tests
  - After fluid application;
  - After the application of contamination;
  - Before the takeoff test; and
  - After the takeoff test (end of test).

The wing temperatures measurements recorded during each test are shown in Tables 6.11 to 6.18.

**Table 6.11: Test #SS1 Skin Temperature Data**

| TEST SS1: Ultra+, SN(51)-60min | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -4.6 | -12.6 | -0.4 |
| 5 | -3.5 | -10.7 | 1.7 |
| Under wing | -2.1 | -3.6 | 1.4 |

**Table 6.12: Test #SS2 Skin Temperature Data**

| TEST SS2: ABC-S, SN(51)-30min | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -4.1 | -10.0 | -1.3 |
| 5 | -2.9 | -9.3 | 0.1 |
| Under wing | -1.7 | -2.3 | -1.7 |

**Table 6.13: Test #SS3 Skin Temperature Data**

| TEST SS3: Ultra+, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -8.6 | -15.5 | -6.7 |
| 5 | -7.0 | -12.6 | -5.1 |
| Under wing | -10.8 | -6.8 | -7.0 |

**Table 6.14: Test #SS4 Skin Temperature Data**

| TEST SS4: ABC-S, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -8.8 | -10.8 | -6.0 |
| 5 | -8.3 | -11.2 | -3.6 |
| Under wing | -4.9 | -9.6 | -3.7 |

### Table 6.15: Test #SS5 Skin Temperature Data

| TEST SS5: ABC-S, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -6.5 | -9.9 | -5.1 |
| 5 | -4.8 | -9.1 | -2.7 |
| Under wing | -7.7 | -9.6 | -6.7 |

### Table 6.16: Test #SS6 Skin Temperature Data

| TEST SS6: ABC-S, SN(77)-10min | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -7.5 | -9.3 | -6.7 |
| 5 | -6.4 | -9.4 | -4.4 |
| Under wing | -6.4 | -10.0 | -8.0 |

### Table 6.17: Test #SS7 Skin Temperature Data

| TEST SS7: Ultra+, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | -2.7 | -9.5 | -1.4 |
| 5 | -1.7 | -8.8 | -0.2 |
| Under wing | -0.1 | -5.1 | -1.2 |

### Table 6.18: Test #1S Skin Temperature Data

| TEST 1S: ABC-S, SN(75)-20 min | | | | |
|---|---|---|---|---|
| Wing Position | Skin Temperature (°C) | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test. | After Takeoff Test |
| 1 | -11.1 | -13.3 | N/A | -6.5 |
| 2 | -11.9 | -13.6 | -8.2 | -6.6 |
| 3 | -11.2 | -13.8 | N/A | -7.8 |
| 4 | -11.2 | -14.1 | -11.3 | -7.4 |
| 5 | -10.6 | -15.0 | N/A | -8.5 |
| 6 | -10.4 | -15.2 | N/A | -8.7 |
| 7 | -12.0 | -15.3 | N/A | -7.9 |
| 8 | -12.0 | -14.9 | N/A | -8.3 |

### 6.2.4 Fluid Brix Data

Fluid Brix measurements were collected by APS personnel. The wing positions used for the wind tunnel tests and Falcon 20 tests are described in Section 2.1.8.2 and 2.2.9.2.

- Wind Tunnel Tests
  - Before the application of contamination;
  - After the application of contamination; and
  - After the wind tunnel test (end of test).
- Falcon 20 Tests
  - After fluid application;
  - After the application of contamination;
  - Before the takeoff test; and
  - After the takeoff test (end of test).

The fluid Brix measurements collected during each test are shown in tables 6.19 to 6.26.

**Table 6.19: Test #SS1 Fluid Brix Data**

| TEST SS1: Ultra+, SN(51)-60min | | | |
|---|---|---|---|
| Wing Position | Fluid Brix | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 40.75 | 15.25 | 40.00 |
| 8 | 40.75 | 14.75 | N/A |

**Table 6.20: Test #SS2 Fluid Brix Data**

| TEST SS2: ABC-S, SN(51)-30min | | | |
|---|---|---|---|
| Wing Position | Fluid Brix | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 37.00 | 15.00 | 29.75 |
| 8 | 37.00 | 13.50 | N/A |

**Table 6.21: Test #SS3 Fluid Brix Data**

| TEST SS3: Ultra+, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Fluid Brix | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 41.25 | 25.00 | 34.00 |
| 8 | 41.00 | 19.00 | 37.25 |

### Table 6.22: Test #SS4 Fluid Brix Data

| TEST SS4: ABC-S, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Fluid Brix | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 37.00 | 21.00 | 38.50 |
| 8 | 37.00 | 17.50 | 34.00 |

### Table 6.23: Test #SS5 Fluid Brix Data

| TEST SS5: ABC-S, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Fluid Brix | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 37.25 | 27.50 | 35.25 |
| 8 | 37.25 | 17.50 | 33.75 |

### Table 6.24: Test #SS6 Fluid Brix Data

| TEST SS6: ABC-S, SN(77)-10min | | | |
|---|---|---|---|
| Wing Position | Fluid Brix | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 37.25 | 31.00 | 35.00 |
| 8 | 37.25 | 25.00 | 36.00 |

### Table 6.25: Test #SS7 Fluid Brix Data

| TEST SS7: Ultra+, SN(77)-20min | | | |
|---|---|---|---|
| Wing Position | Fluid Brix | | |
| | Before Contamination | After Contamination | After Wind Tunnel Test |
| 2 | 40.00 | 13.50 | 33.00 |
| 8 | 40.50 | 15.50 | N/A |

### Table 6.26: Test #1S Fluid Brix Data

| TEST 1S: ABC-S, SN(75)-20 min | | | | |
|---|---|---|---|---|
| Wing Position | Fluid Brix | | | |
| | After Fluid Appl. | After Precip Appl. | Before Takeoff Test. | After Takeoff Test |
| 2 | 37.00 | 12.00 | 15.00 | 16.50 |
| 5 | 37.00 | 21.00 | 15.00 | 19.00 |

## 6.3 Photos

For each test, a summary of the photos has been compiled comprising of four photos:

- Start of test;
- Time of rotation;
- 10 seconds after rotation; and
- End of test.

Photos 6.1 to 6.32 show the photo summaries for tests #SS1 to #SS7 and test #1S. A compilation of selected high speed photos taken during Test SS6 are included Appendix G. A complete set of photos will be provided to TDC.

## 6.4 Results

The lift data collected during the heavy snow wind tunnel tests was compared to the fluid only tests. The results indicated that there were no significant lift losses experienced as a result of the added contamination. The lift data indicated that the airfoil generally experienced similar normal and lift forces during the heavy snow contamination tests in comparison to the fluid only tests.

These test results were counter-intuitive to visual observation, which noted the presence of residual contamination on the trailing edge of the wing section at the end of the heavy snow tests. The condition worsened as the precipitation rate was increased from 51 g/dm²/h for tests SS1 and SS2, to 77 g/dm²/h for tests SS3 to SS7. At the time of rotation for tests SS3 to SS4, a thin layer of slush was still present on the leading edge, which increased over the chord length. During test SS4, some contamination was still present on the leading edge at the end of the test; the contamination was not adhered to the surface. Based on the visual observations, it is recommended that testing in light and moderate snow conditions be conducted to obtain a visual reference for the aerodynamic properties of fluid contaminated with snow.

It should be noted that the lift coefficient data was only obtained following the end of the testing period. The test matrix was designed based on the visual observations recorded during each test. As a result, the precipitation rate was not increased beyond 77 g/dm²/h because this was deemed a severe condition due to the difficulty observed when the fluid was clearing the airfoil. Upon review of the lift data, it was determined that these conditions were not aerodynamically critical. It is strongly recommended that if testing is continued

during the winter of 2007-08, the lift data be reviewed following each of the tests to aid in the decision-making and project planning.

Test #1S conducted with the Falcon 20 aircraft generated comparable results to those obtained in the wind tunnel. Residual contamination was observed just aft of the leading edge and increased over the chord length. The Falcon 20 test results confirmed the data collected in the wind tunnel.

## 6.5 Correlation of Aerodynamic Work to HOT

Based on the test parameters collected in the wind tunnel and during the Falcon 20 test, a correlation analysis between the aerodynamic work conducted and the fluid specific regression generated HOTs was conducted. The fluid specific HOT for each test was calculated based on the average OAT during the last ten minutes of the precipitation, and the rate of precipitation. Table 6.27 demonstrates the results obtained.

**Table 6.27: Regression Generated HOT for Wind Tunnel and Falcon 20 Tests**

| Test # | Type IV Fluid | AVG Snow Precip. Rate (g/dm²/h) | AVG OAT During Last 10 min of Precip (°C) | Wing Skin Temp (°C) | Regression HOT based on OAT (min) | Exposure Time in Tunnel (min) |
|---|---|---|---|---|---|---|
| SS1 | EG | 51 | -0.2 | -11 | 26 | 60 |
| SS2 | PG | 51 | 0.3 | -9 | 47 | 30 |
| SS3 | EG | 77 | -3.5 | -14 | 14 | 20 |
| SS4 | PG | 77 | -2.4 | -11 | 31 | 20 |
| SS5 | PG | 77 | -0.5 | -9.5 | 35 | 20 |
| SS6 | PG | 77 | -3 | -9.5 | 30 | 10 |
| SS7 | EG | 77 | 1.3 | -9 | 27 | 20 |
| 1S | PG | 77 | -10 | -9.5 | 25 | 20 |

The holdover times generated with the fluid specific regression coefficients indicated that the condition of the wing section was within the HOT for 6 of the 8 tests conducted. In the two cases where the HOT was exceeded (test SS1 and SS3), the lift data collected did not indicate significant lift losses in comparison to the fluid only tests. Although residual contamination was observed during all the tests, none showed aerodynamically adverse effects. It is recommended that further testing be conducted during the winter of 2007-08 in heavy snow conditions. Exposure time to precipitation should exceed the regression based HOT in order to identify an aerodynamically critical condition.

It should be noted that the snow distribution over the wing section was difficult to control. As a result, sections of the wing directly in front of the snow dispensers were exposed to higher rates of precipitation. As a result, the average precipitation rate may not have accurately reflected certain sections of the wing. Further work is required to develop a suitable method for dispensing and quantifying the snow precipitation.

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**Photo 6.1: Test #SS1 – Start of Test**

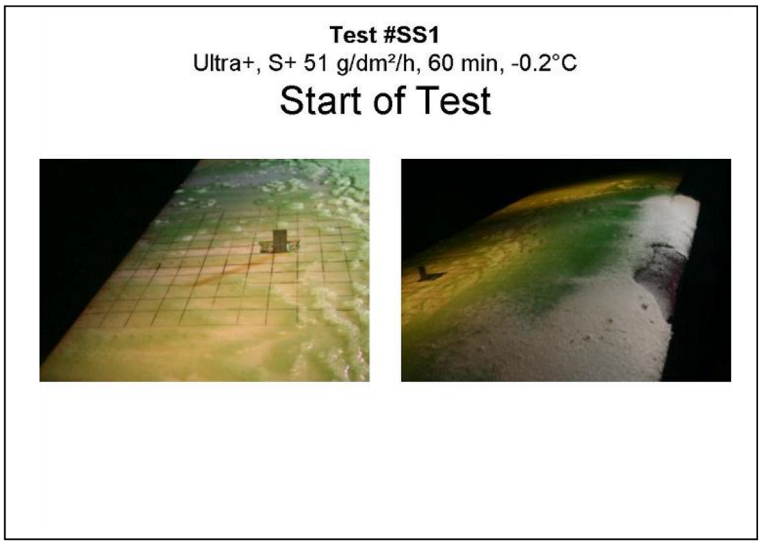



**Photo 6.2: Test # SS1 – Before Rotation**

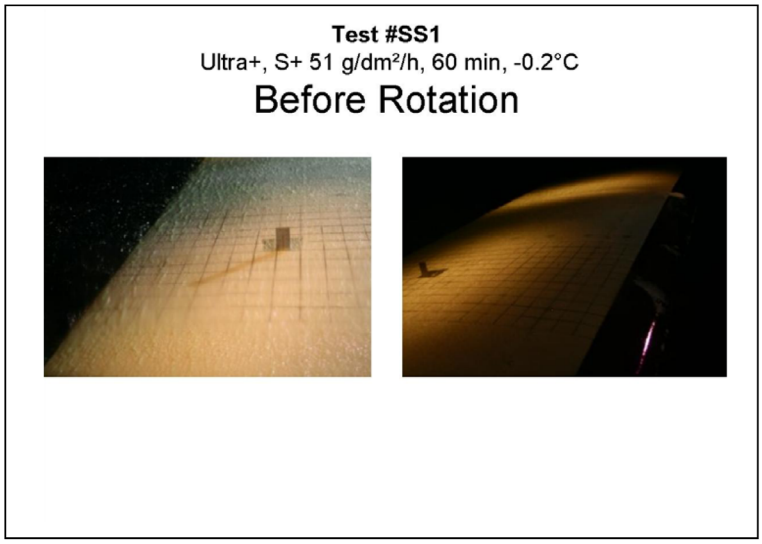


**Photo 6.3: Test # SS1 – 10 Seconds After Rotation**

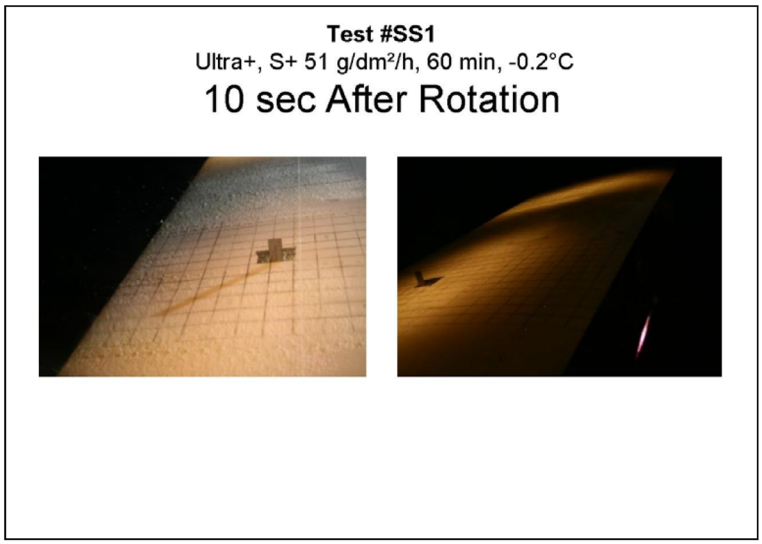



**Photo 6.4: Test # SS1 – End of Test**

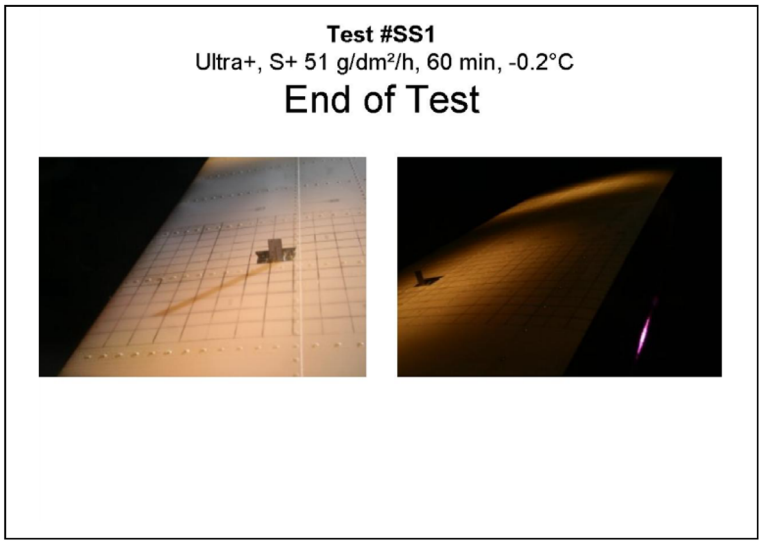


**Photo 6.5: Test #SS2 – Start of Test**

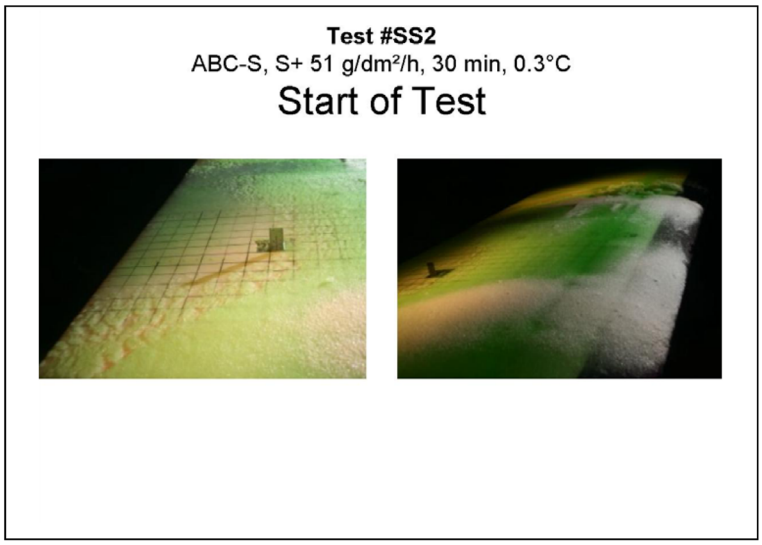



**Photo 6.6: Test # SS2 – Before Rotation**

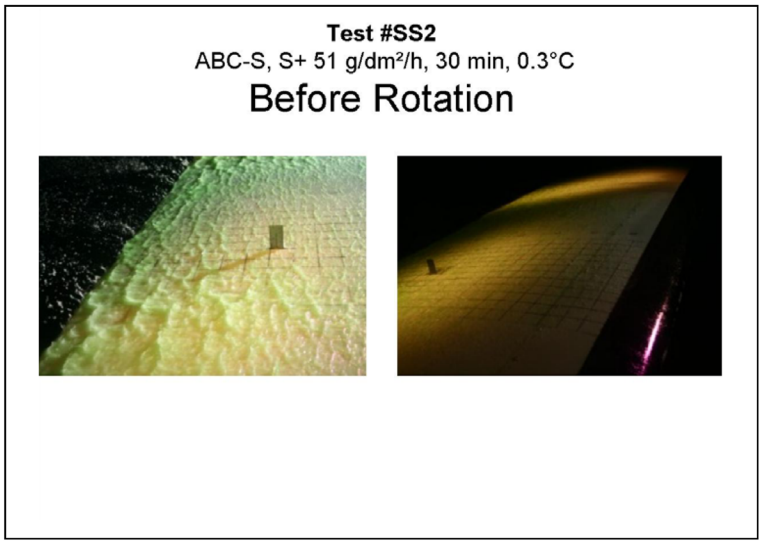


**Photo 6.7: Test # SS2 – 10 Seconds After Rotation**

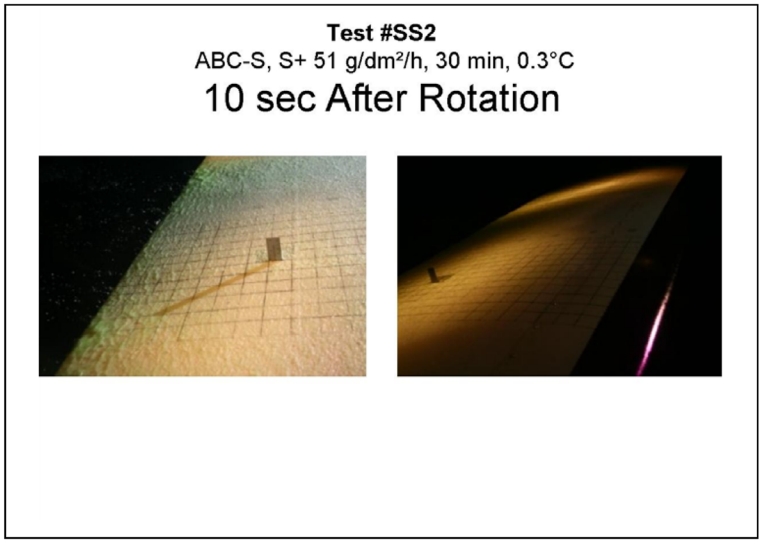



**Photo 6.8: Test # SS2 – End of Test**

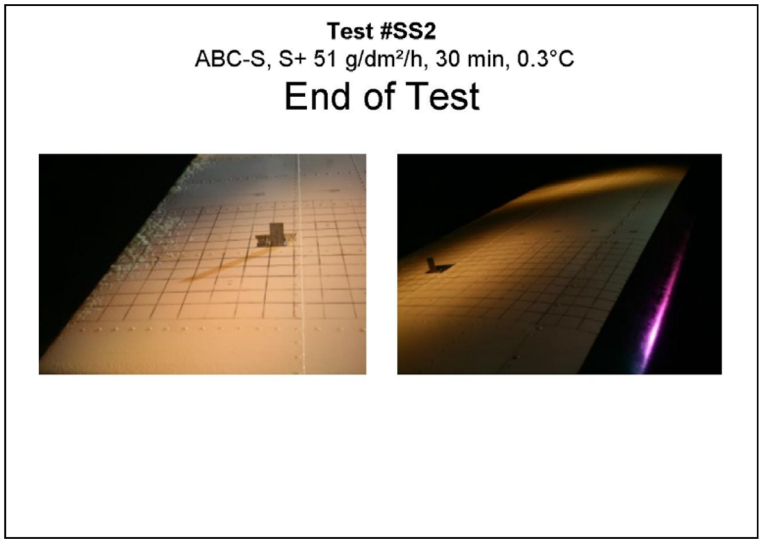


**Photo 6.9: Test # SS3 – Start of Test**

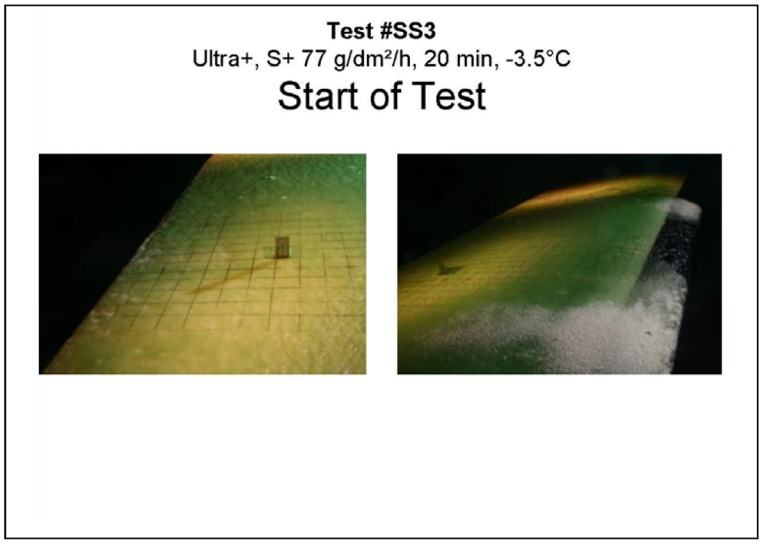



**Photo 6.10: Test # SS3 – Before Rotation**

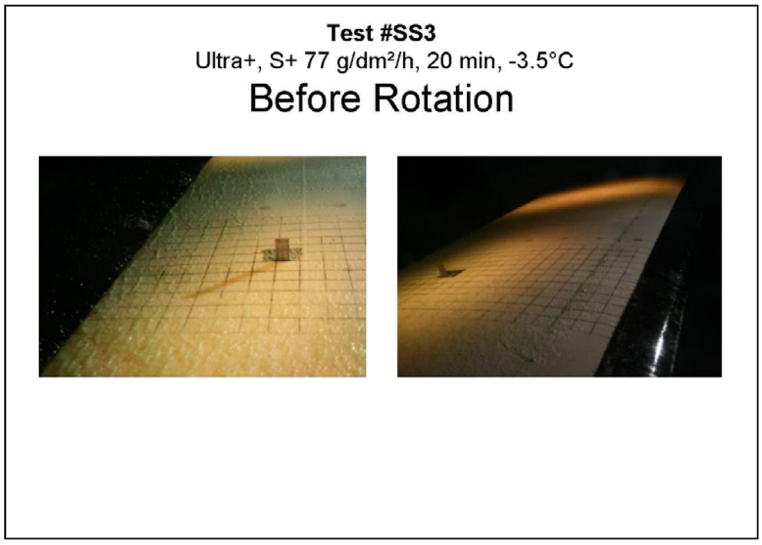


**Photo 6.11: Test # SS3– 10 Seconds After Rotation**

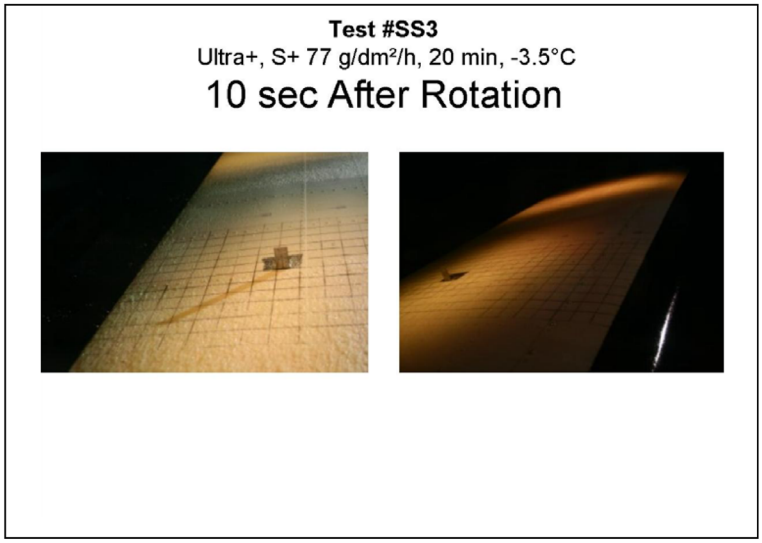



**Photo 6.12: Test # SS3 – End of Test**

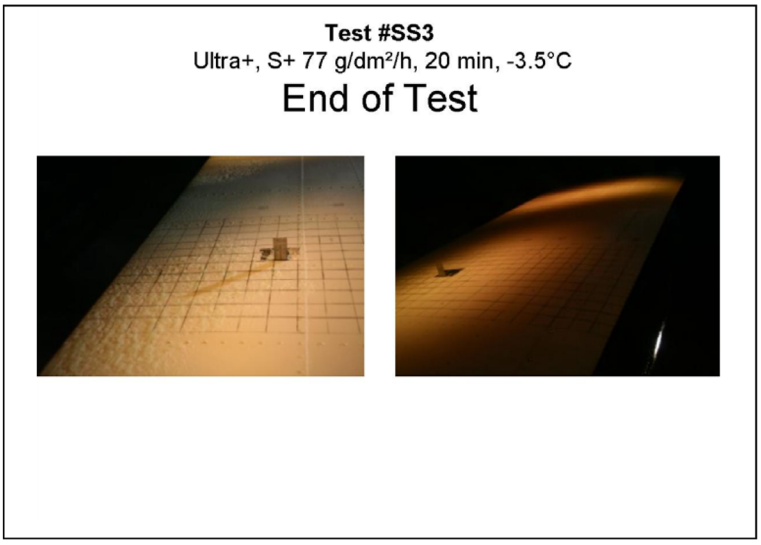


**Photo 6.13: Test # SS4– Start of Test**

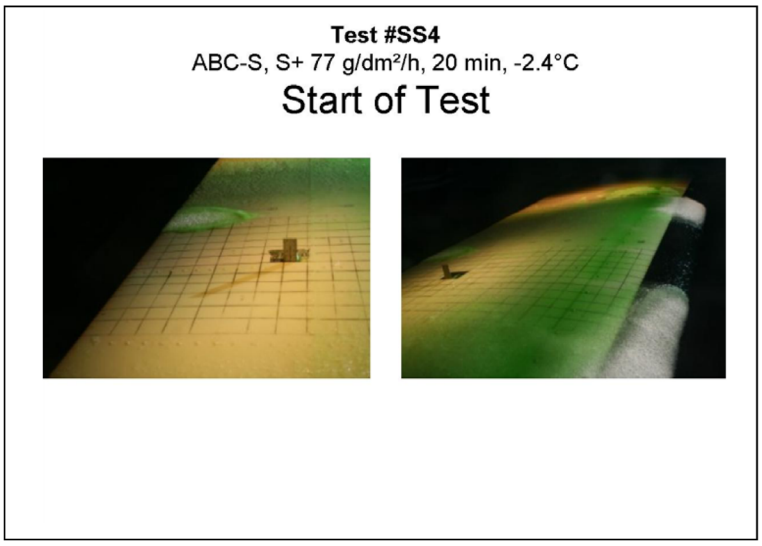



**Photo 6.14: Test # SS4 – Before Rotation**

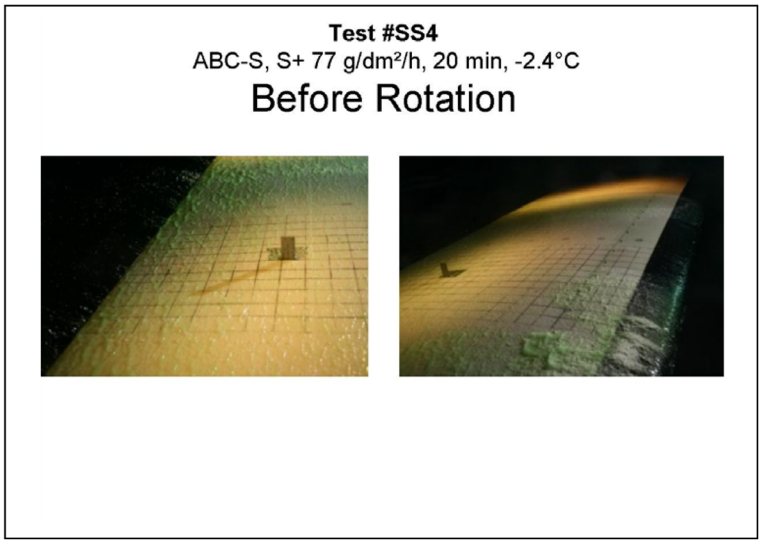


**Photo 6.15: Test # SS4 – 10 Seconds After Rotation**

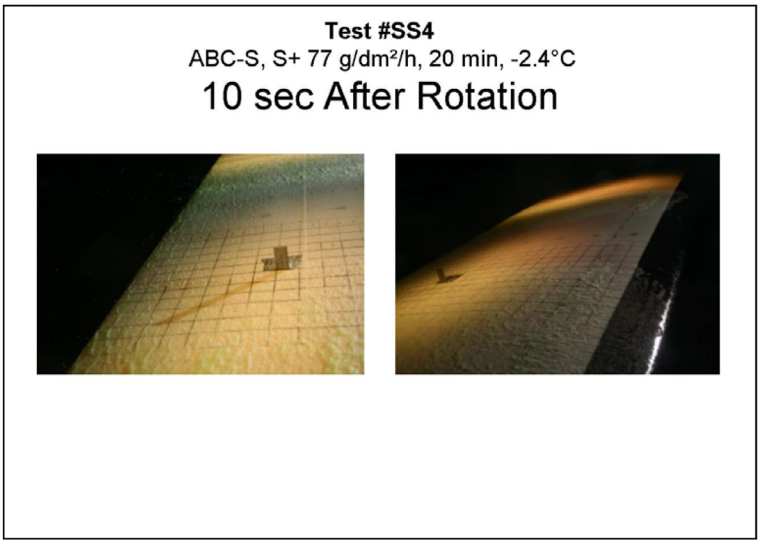



**Photo 6.16: Test # SS4 – End of Test**

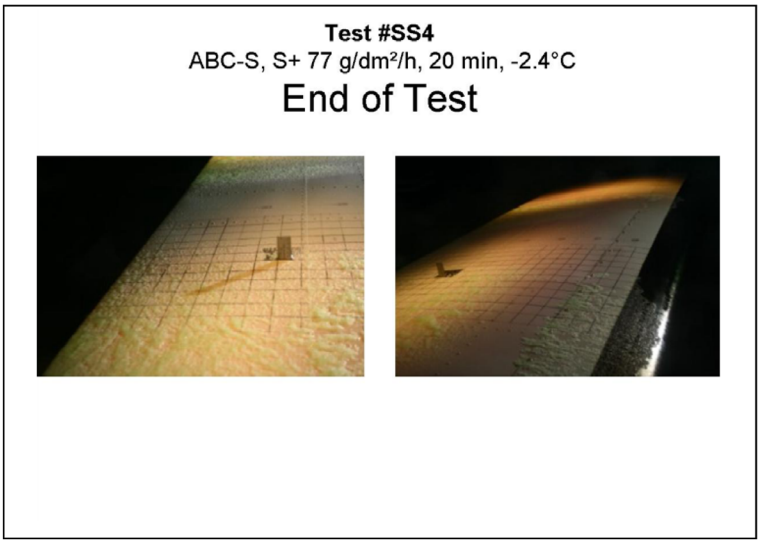


**Photo 6.17: Test # SS5 – Start of Test**

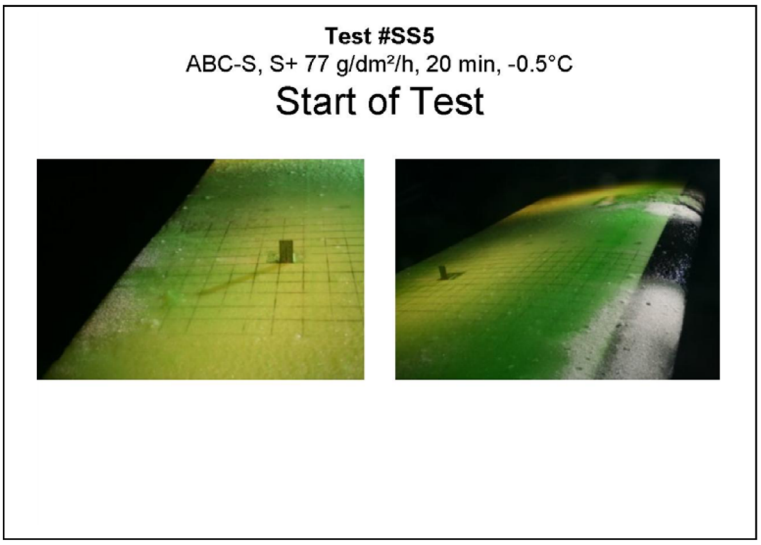



**Photo 6.18: Test # SS5 – Before Rotation**

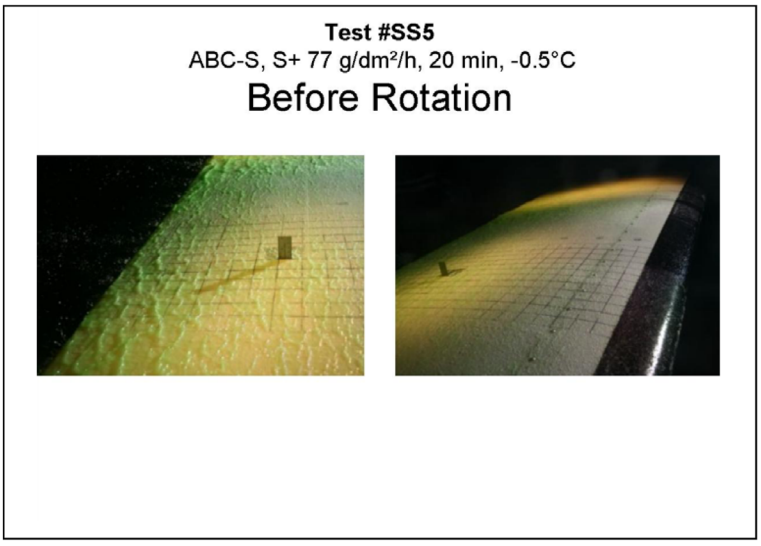


**Photo 6.19: Test # SS5 – 10 Seconds After Rotation**

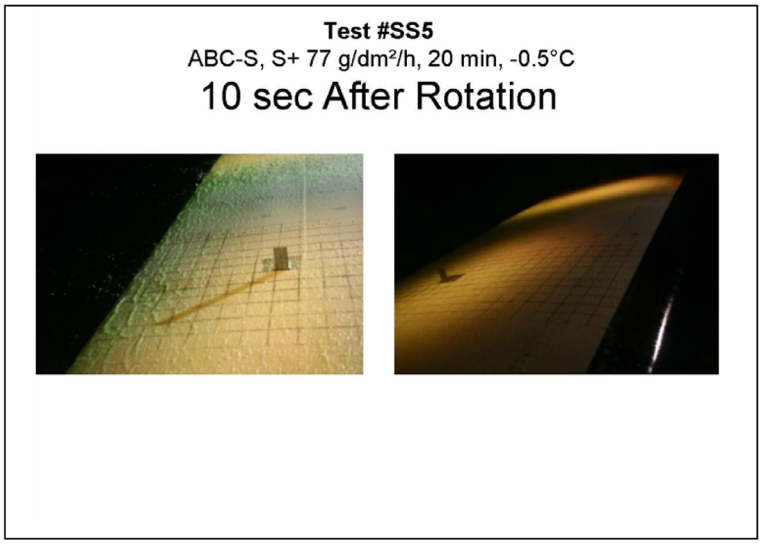



**Photo 6.20: Test # SS5 – End of Test**

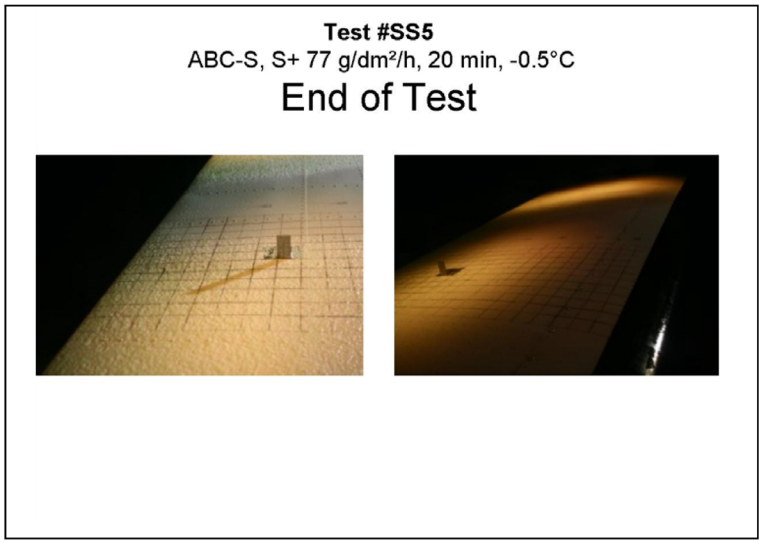


**Photo 6.21: Test # SS6 – Start of Test**

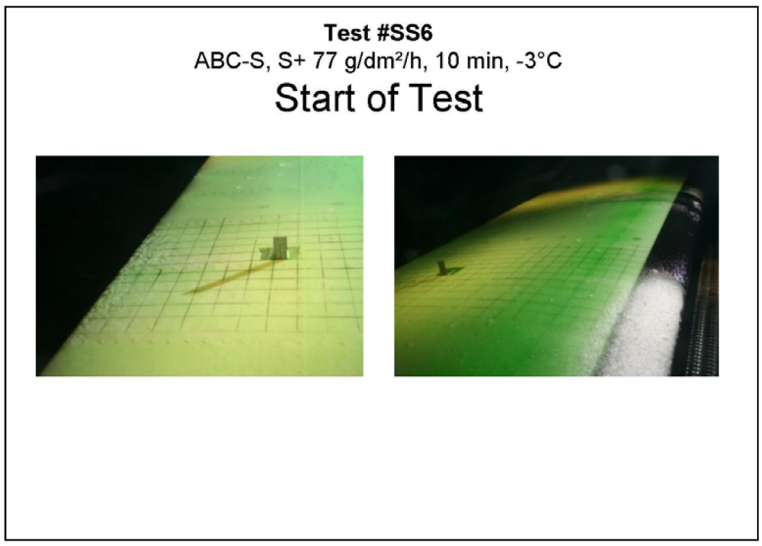



**Photo 6.22: Test # SS6 – Before Rotation**

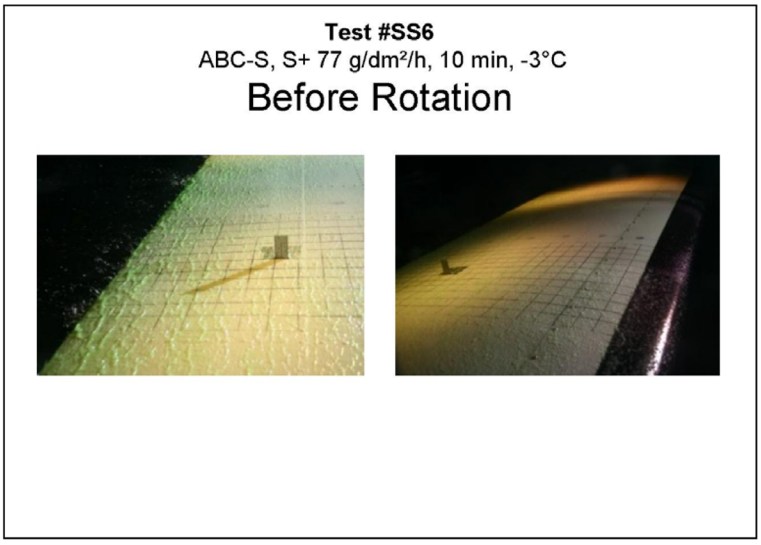


**Photo 6.23: Test # SS6 – 10 Seconds After Rotation**

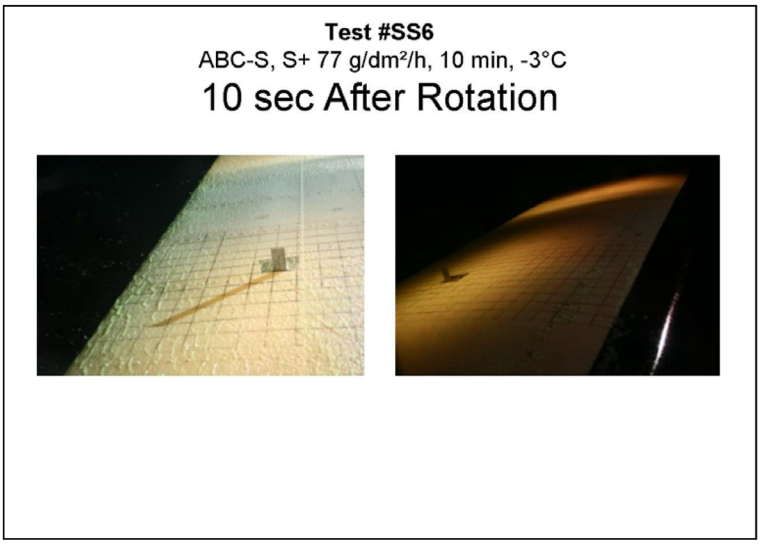



**Photo 6.24: Test # SS6 – End of Test**

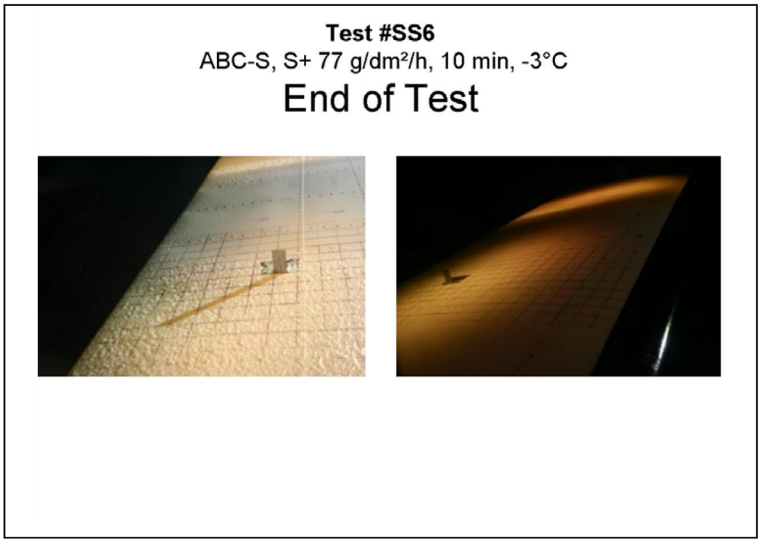


**Photo 6.25: Test # SS7 – Start of Test**

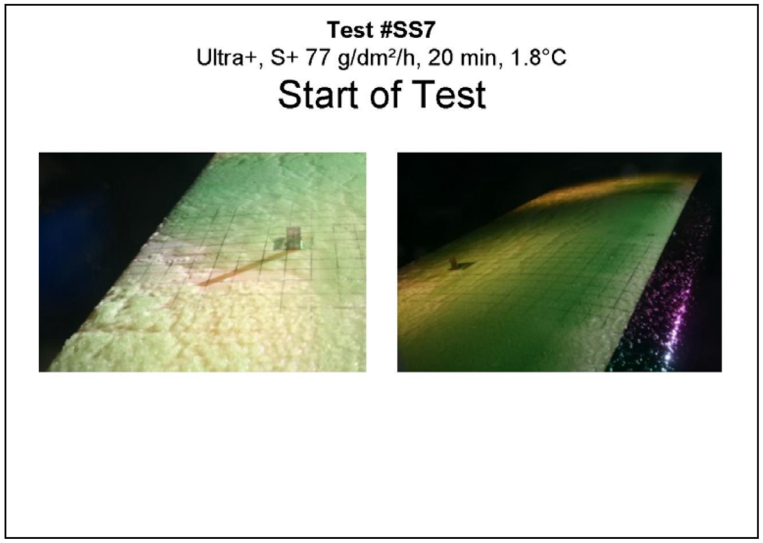



**Photo 6.26: Test # SS7 – Before Rotation**

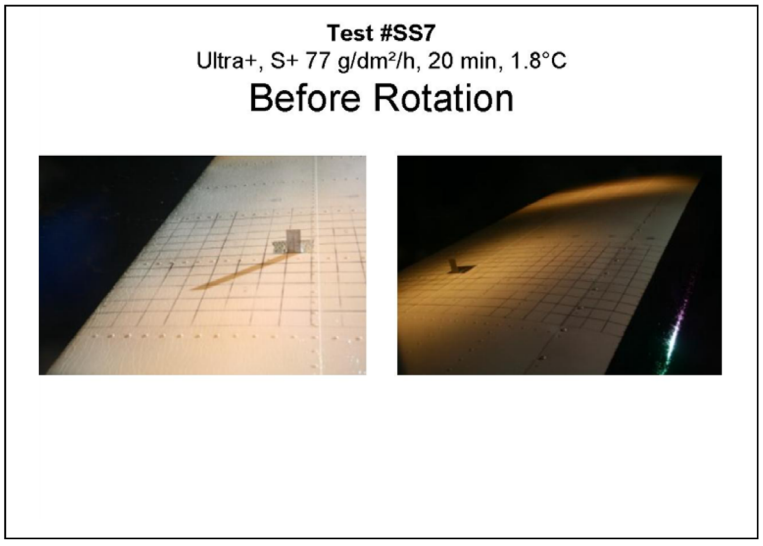


**Photo 6.27: Test # SS7 – 10 Seconds After Rotation**

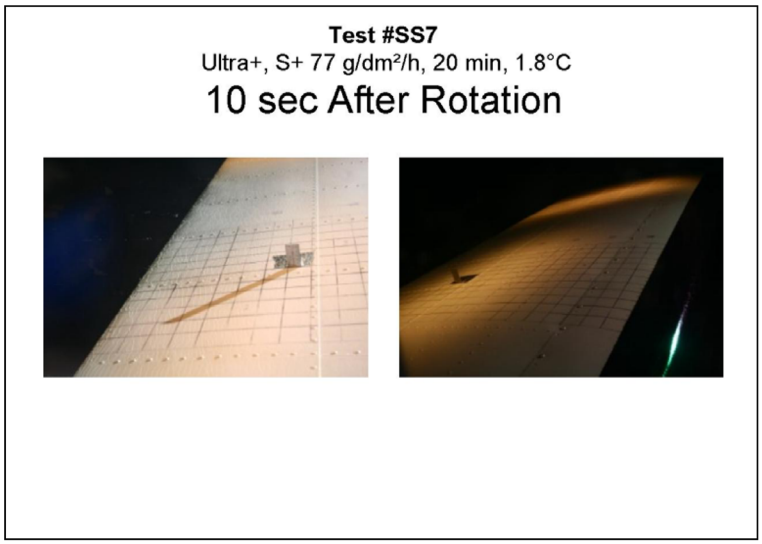



**Photo 6.28: Test # SS7 – End of Test**

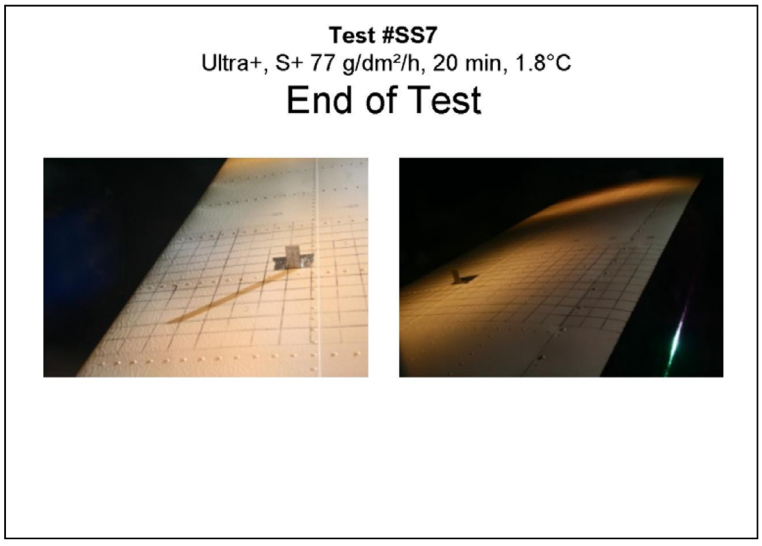


**Photo 6.29: Test #1S – Start of Test**

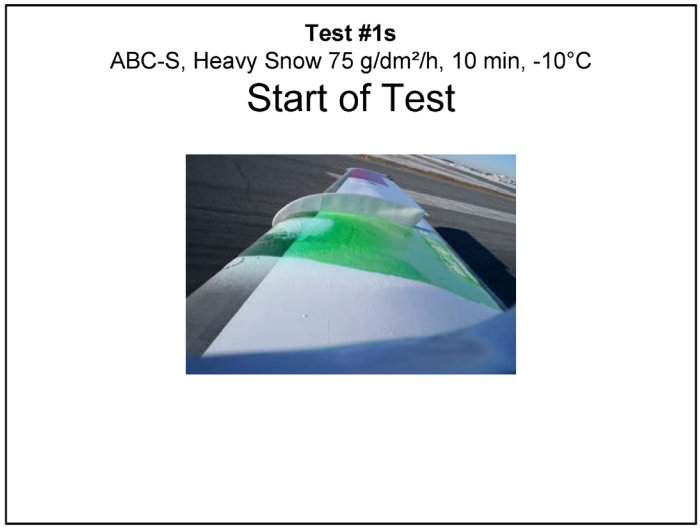



**Photo 6.30: Test #1S – Before Rotation**

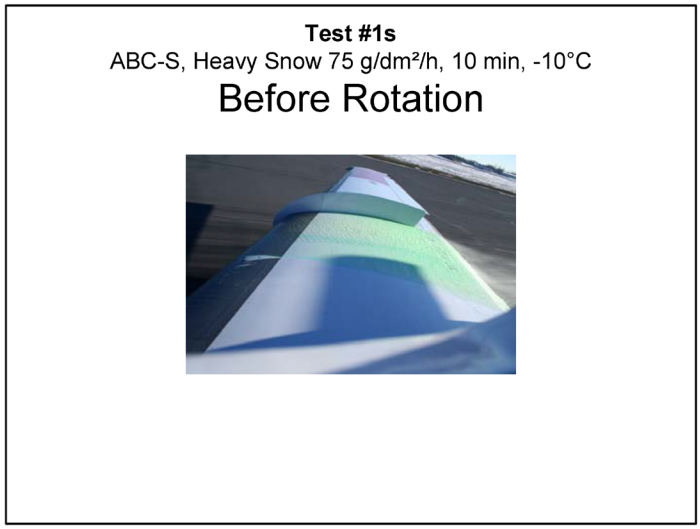


**Photo 6.31: Test #1S – 10 Seconds After Rotation**

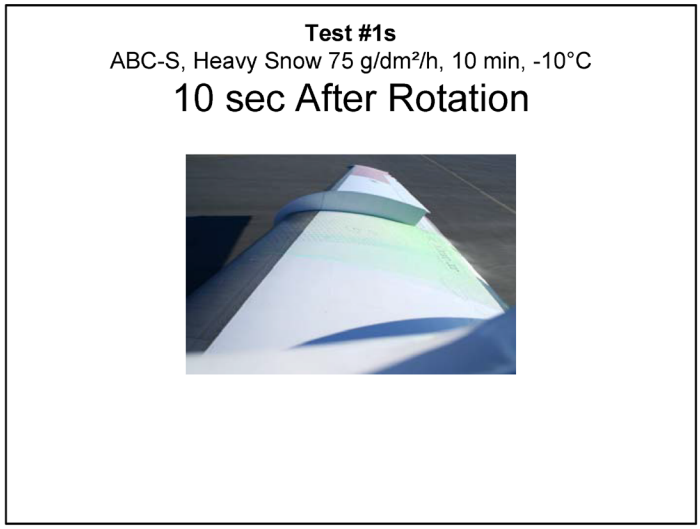
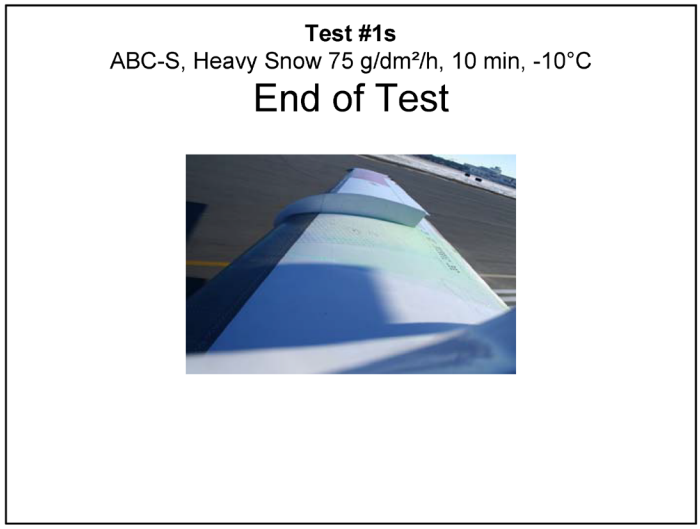



**Photo 6.32: Test #1S – End of Test**



# 7 CONCLUSIONS

The following conclusions were derived from the heavy snow testing conducted during the winter of 2006-07.

## 7.1 Wind Tunnel Testing

Visual observations during the wind tunnel tests reported residual contamination on the trailing edge of the wing section at the end of the heavy snow tests; the condition worsened as the precipitation rate was increased. In addition, at the time of rotation for tests SS3 to SS4, a thin layer of slush was still present on the leading edge, which increased over the chord length. During test SS4, some contamination was still present on the leading edge at the end of the test; the contamination was not adhered to the surface. Although visually, this was deemed a severe condition, the lift data collected did not show significant signs of lift losses directly attributable to the heavy snow contamination. Lift data was only obtained following the end of the test session, therefore, the aerodynamically critical fluid condition was not attempted; contamination was ceased at what appeared to be the visually critical level.

DRAFT

## 7.2 Falcon 20 Testing

Results obtained with the Falcon 20 confirmed the results obtained in the wind tunnel. Residual contamination was present just aft of the leading edge and was greatest on the trailing edge. The wind tunnel was deemed a suitable alternative for live-aircraft testing.

## 7.3 Flat Plate Testing in Heavy Snow Conditions

The plate temperature drop is a critical parameter in artificial heavy snow testing. The tests conducted in 2006-07 during natural snow conditions showed that the plate temperature should be kept 3°C below the test temperature for rates of 50 g/dm$^2$/h and 4°C below the test temperature for rates of 75 g/dm$^2$/h. Tests will be conducted indoors to verify these observations and further refine the plate temperature requirements for simulated heavy snow testing.

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# 8 RECOMMENDATIONS

The following future work is recommended for the winter of 2007-08.

## 8.1 Future Work

### 8.1.1 Development of a Repeatable Protocol

It is recommended that work be done to develop or redesign the current protocol for dispensing simulated snow. Focus should be geared towards the distribution and repeatability of the process.

### 8.1.2 Aerodynamic Examination of Current Snow HOT's

Additional wind tunnel testing in heavy snow conditions should be conducted during the winter of 2007-08. To obtain a visual benchmark, testing should also be conducted in light or moderate snow conditions, with contamination levels within the appropriate HOT, to obtain a visual reference of acceptable aerodynamic fluid flow-off. If conditions permit, testing should be conducted at lower ambient temperatures; testing in the evening should be considered to benefit from the cooler temperatures.

### 8.1.3 Exceeding HOT to Attain Aerodynamic Failure

Additional testing should be conducted in heavy snow conditions to determine the aerodynamic failure of a fluid following excessive exposure to precipitation. It is recommended that the regression based HOT, based on fluid, OAT, and rate of precipitation, be incrementally exceeded during a series of tests in order to achieve and quantify an aerodynamic failure.

### 8.1.4 Investigate Effect of Flaps on Fluid Flow-Off Properties

It is recommended that a wing section with a flap be acquired for testing in the wind tunnel. A flapped wing section will more accurately represent aircraft wing configuration during takeoff as well as possibly provide different aerodynamic forces resulting in different fluid flow-off properties.

### 8.1.5 Additional Flat Plate Testing

Natural heavy snow data collection should be continued during the winter of 2007-08. In addition, the NCAR snowmaker plate temperature settings for 50 g/dm$^2$/h and 75 g/dm$^2$/h testing should be further investigated.

# REFERENCES


1. Dawson, P., Hanna, M., Chaput, M., *Contaminated Aircraft Takeoff Test 1997/98 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, December 1998, TP 13316E, 52.

2. Dawson, P., Hanna, M., *Contaminated Aircraft Takeoff Tests for the 1998-99 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, October 1999, TP 13479E, 157.

3. Dawson, P., *Contaminated Aircraft Simulated Takeoff Tests for the 1999-2000 Winter: Preparation and Procedures*, APS Aviation Inc., Transportation Development Centre, Montreal, August 2000, TP 13666E, 18.

4. Chaput, M., Campbell, R., *Aircraft Takeoff Test Program for Winter 2001-02: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2002, TP 13995E, 92.

5. Chaput, M., *Aircraft Takeoff Test Program for Winter 2002-03: Testing to Evaluate the Aerodynamic Penalties of Clean or Partially Expended De/Anti-Icing Fluid,* APS Aviation Inc., Transportation Development Centre, Montreal, November 2003, TP 14147E, (to be published).

6. Balaban, G., *Falcon 20 Trials To Examine Fluid Removed From Aircraft During Takeoff With Ice Pellets,* APS Aviation Inc., Transportation Development Centre, Montreal, December 2006, TP 14716E, (to be published).

7. Oleskiw M. *Airfoil-flap performance with de/anti-icing fluids and freezing precipitation,* Institute for Aerospace Research, National Research Council Canada, Transportation Development Centre, Ottawa, May 1999, TP 13426E, 14.

8. Balaban, G., *Flow of Contaminated Fluid from Aircraft Wings: Feasibility Study,* APS Aviation Inc., Transportation Development Centre, Montreal, January 2008, TP (06-07)-03, (to be published).

9. Ruggi, M., *Aircraft Ground Deicing Research in Natural and Simulated Ice Pellet Conditions – Phase 1*, APS Aviation Inc., Transportation Development Centre, Montreal, October 2006, TP 14713E, (to be published).

10. Balaban, G., *Endurance Time Testing in Snow: Comparison of Indoor and Outdoor Data for 2005-06*, APS Aviation Inc., Transportation Development Centre, Montreal, December 2006, TP 14717E, (to be published).

**APPENDIX A**

**TRANSPORTATION DEVELOPMENT CENTRE**
**WORK STATEMENT EXCERPT**
**AIRCRAFT & ANTI-ICING FLUID WINTER TESTING**
**2006-07**

# TRANSPORTATION DEVELOPMENT CENTRE
# WORK STATEMENT EXCERPT
# AIRCRAFT & ANTI-ICING FLUID WINTER TESTING
# 2006-07

**6.2.3 Evaluation of Endurance Times in Heavy Snow** (Priority 1)

a) Prepare a procedure for testing fluids in heavy snow intensities with a snowmaker to determine differences, if any, with natural snow tests;

b) Acquire data to support and determine what the plate temperature should be during the conduct of tests in heavy snow; and

c) Conduct tests with heavy snow in the refrigerated trailer.

## 6.3 AIRCRAFT PERFORMANCE RESEARCH

**6.3.1 Flow of Contaminated Fluid from Aircraft Wings During Takeoff (Falcon 20 Tests)**

a) Develop a test plan jointly with the NRC staff who operate the aircraft. Consideration will be given to using both slatted and non-slatted wing aircraft i.e. Bombardier Global Express and Dassault Falcon 20;

b) Plan and co-ordinate the application of SAE Type IV fluid (ethylene and propylene-based) at Ottawa airport over a period of four days;

c) Plan and co-ordinate the application of controlled amounts of ice pellets, snow and/or freezing rain contamination on the applied fluids;

d) Document the appearance of fluids on the wing and adherence of fluid to the wing prior to departure of the aircraft for the test flight;

e) Collect the following data during the tests:

   i) Type and amount of fluid applied;
   ii) Type and rate of contamination applied;
   iii) Extent of fluid contamination prior to the takeoff run;
   iv) Document the appearance of fluid on the wings during the takeoff run and climb of the aircraft by analyzing the video records; and
   v) Measurements of thickness, concentration, viscosity, and adherence of clean and contaminated fluid prior to and following the takeoff run.

f) Co-ordinate the ground aspects of test activities and initiate tests in conjunction with NRC staff based on forecast weather and aircraft availability.

### 6.3.2 Flow of Contaminated Fluid from Simulated Aircraft Wings During Takeoff (Wind Tunnel Tests)

a) Develop a test plan jointly with the NRC staff who operate the wind tunnel;

b) Plan and co-ordinate the application of SAE Type IV fluid (ethylene and propylene-based) at the Ottawa NRC open circuit Propulsion Wind Tunnel over a period of five days to establish feasibility;

c) Plan and co-ordinate the application of controlled amounts of ice pellets, snow and/or freezing rain contamination on the applied fluids;

d) Document the appearance of fluids on the wing and adherence of fluid to the wing prior to, during and following the wind tunnel run;

e) Collect the following data during the tests:

   i) Type and amount of fluid applied;
   ii) Type and rate of contamination applied;
   iii) Extent of fluid contamination prior to the wind tunnel run;
   iv) Document the appearance of fluid on the wing during the simulated take off by analyzing the video records; and
   v) Measurements of thickness, concentration, viscosity, and adherence of clean and contaminated fluid prior to and following the tunnel test.

f) Co-ordinate the fluid contamination of test activities and initiate tests in conjunction with NRC staff based on forecast weather, testing over a period of ten days.

## APPENDIX B

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

CM2020.002 (06-07)

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

Prepared for

**Transportation Development Centre**
**Transport Canada**

Prepared by: Marco Ruggi, George Balaban and Joey Tiano

Reviewed by: John D'Avirro




February 8, 2007
Final Version 2.0

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

## 1. BACKGROUND

### 1.1 Ice Pellet Endurance Time Research

Preliminary endurance time testing during simulated ice pellet conditions was conducted by APS at the NRC research facility during the spring of 2006 with the primary objective to investigate which conditions are most conducive to fluid adherence. A series of tests were conducted in simulated ice pellet conditions. Adherence occurred during tests conducted with Type I heated fluid in ice pellet conditions, and with Type IV fluid during mixed precipitation conditions. The preliminary testing also showed that adherence produced during ice pellet conditions in combination with freezing rain/drizzle was rough and "pimply". In comparison to adherence caused by freezing rain/drizzle alone, this may be an aerodynamically more severe condition.

### 1.2 Ice Pellet Falcon 20 Research

During the 2005-06 winter season, testing was conducted to address the effects of de/anti-icing fluid contaminated with ice pellets that the airflow at takeoff fails to remove. This objective was met by performing a series of takeoff tests using the NRC Falcon 20 aircraft in March 2006. A series of simulated takeoff runs were performed with the National Research Council Falcon 20 research aircraft at the Ottawa Airport. Nine runs were performed with simulated ice pellet precipitation rates ranging from 25 g/dm$^2$/h to 167 g/dm$^2$/h and two de/anti-icing fluids, DOW UCAR Ultra+ and Kilfrost ABC-S. One run was completed with Type I EG deicing fluid.

For both EG and PG Type IV fluids, the airflow at takeoff removed ice-pellet contaminated anti-icing fluid from the leading edge, leaving only a very thin film of fluid even at very high precipitation rates. In one case, at a very high precipitation rate (effective rate of 136 g/dm$^2$/h), the entire 24 seconds of the takeoff run were required to clear the leading edge of any precipitation. In this case some contamination (up to 1 mm) remained on the trailing edge.

A test with Type I EG fluid showed some adhesion of ice to the wing surface following the transfer of heat from the heated fluid to the cold wing surface. The fluid application method was not representative of actual operations. A

normal deicing may generate more heat, which would likely generate more adhesion.

### 1.3 Regulatory Recommendation

As a result of the recent industry need to provide aircraft operators with holdover times for ice pellet conditions, the FAA provided a 25-minute allowance as a preliminary guideline. This allowance was followed by a list of conditions restricting operations, one condition being that the 25-minute allowance was acceptable in conditions with ice pellets alone. This recommendation was based on the previous endurance time research conducted during the winter of 2005-06, and as a result of Falcon 20 aerodynamic work. It was recommended to explore the worst-case mixed precipitation conditions in order to further evaluate or modify the current allowance time for ice pellet conditions.

## 2. OBJECTIVES

The objective of this project is to determine the level of contamination of anti-icing fluid at which the aerodynamic shear forces during take-off ground roll, rotation and lift off fails to remove the resultant slush. Contamination shall include simulated freezing drizzle or light freezing rain, both accompanied with ice pellets. As an additional objective, moderate and heavy snow contamination will be investigated.

To satisfy these objectives, a Cessna Caravan wing section will be subjected to a series of tests in the NRC wind tunnel. The tentative dates for testing will be February 12-23, 2007.

## 3. TEST PLAN

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

Representative Type IV propylene and ethylene fluids (ABC-S and ULTRA+) in neat form shall be evaluated against their uncontaminated performance; Attachment I and II presents the fluid specific Holdover Time guidelines of ABC-S and Ultra+ for reference purposes. A preliminary test plan summarizing the test objectives is shown in Table 3.1. Additional testing will be conducted depending on the results obtained during tests 1-7. A detailed preliminary test matrix is shown in Tables 3.2 and 3.3.

**Table 3.1: Summary of Test Plan**

| Test # | Fluid | Objective |
|---|---|---|
| 1 | None | Quantify aerodynamic properties of wing section |
| 2 | ABC-S | Baseline test with no contamination |
| 3 | Ultra+ | Baseline test with no contamination |
| 4 | ABC-S | Freezing Rain Only Test |
| 5 | ABC-S | Ice Pellet Only test |
| 6 | ABC-S | Freezing Rain / Ice Pellet Test |
| 7 | Ultra+ | Freezing Rain / Ice Pellet Test |
| >8 | TBD | TBD |

OAT during tests should be between -4ºC to -10ºC

**Table 3.2: Proposed Test Matrix (IP/ZR)**

| TEST NO | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Test Comment (Precipitation)** | Dry | | Fluid only with ABC-S | | Fluid only with Ultra + | | ZR- with ABC-S | | IP with ABC-S | | ZR-/IP with ABC-S | | ZR-/IP with Ultra + | | Future trials depend on results of run 6&7 |
| **Date** | | | | | | | | | | | | | | | |
| Fluid | none (dry) | | ABC-S | | Ultra + | | ABC-S | | ABC-S | | ABC-S | | Ultra + | | |
| Test Area [$m^2$] | 4.8 | | 4.8 | | 4.8 | | 4.8 | | 4.8 | | 4.8 | | 4.8 | | |
| Pellets size [mm] | none (dry) | | none(fluid only) | | none(fluid only) | | 1.0 to 3.35 | | 1.0 to 3.35 | | 1.0 to 3.35 | | 1.0 to 3.35 | | |
| HOT Duration of simulation (min) | none (dry) | | none(fluid only) | | none(fluid only) | | 60 | | 60 | | 60 | | 60 | | |
| Ice Pellet Quantity (kg) | none (dry) | | none(fluid only) | | none(fluid only) | | | | 12.0 | | 2.4 | | 2.4 | | |
| Ice pellet application period (min) | none (dry) | | none(fluid only) | | none(fluid only) | | | | 60 | | 60 | | 60 | | |
| Effective ice pellet rate (g/dm^2/h) | none (dry) | | none(fluid only) | | none(fluid only) | | 0 | | 25 | | 5 | | 5 | | |
| Freezing precipitation Type (Zd or ZR-) | none (dry) | | none(fluid only) | | none(fluid only) | | ZR- | | ZR- | | ZR- | | ZR- | | |
| Freezing precipitation Rate (g/dm^2/h) | none (dry) | | none(fluid only) | | none(fluid only) | | 25 | | 0 | | 20 | | 20 | | |
| Fluid application start time | | | | | | | | | | | | | | | |
| OAT [C] | | | | | | | | | | | | | | | |
| Approx Avg Wing Temp bef applic fluid [C] | | | | | | | | | | | | | | | |
| Angle of Attack and Rate of Change | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | |
| Ramp time (s) and $V_R$ speed (kts) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | |
| Still Camera 1 / Still Camera 2 | | | | | | | | | | | | | | | |
| Remarks | | | add few tracers before T/O | | add few tracers before T/O | | consider redoing with Ultra +??? | | consider redoing with Ultra +??? | | | | | | |

**Table 3.3: Proposed Test Matrix (IP/SN and SN++)**

| TEST NO | S1 | | S2 | | S3 | | S4 | | S5 | | S6 | | S7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Test Comment (Precipitation)** | IP+SN with ABC-S | | IP+SN with ABC-S | | IP+SN with Ultra+ | | IP+SN with Ultra+ | | SN+ with ABC-S | | SN+ with Ultra+ | | Future trials depend on results of prev runs | |
| **Date** | | | | | | | | | | | | | | |
| Fluid | ABC-S | | ABC-S | | Ultra+ | | Ultra+ | | ABC-S | | Ultra+ | | | |
| Test Area [$m^2$] | 4.8 | | 4.8 | | 4.8 | | 4.8 | | 4.8 | | 4.8 | | | |
| Pellets size [mm] | | | | | | | | | | | | | | |
| HOT Duration of simulation (min) | | | | | | | | | | | | | | |
| Ice Pellet Quantity (kg) | 3.7 | | 14.8 | | 3.7 | | 14.8 | | - | | - | | | |
| Ice pellet application period (min) | 60 | | 60 | | 60 | | 60 | | - | | - | | | |
| Effective ice pellet rate (g/dm^2/h) | 5 | | 20 | | 5 | | 20 | | - | | - | | | |
| Snow size [mm] | | | | | | | | | | | | | | |
| Snow Quantity (kg) | 12.4 | | 3.1 | | 12.4 | | 3.1 | | 15 | | 15 | | | |
| Snow application period (min) | 60 | | 60 | | 60 | | 60 | | 30 | | 30 | | | |
| Snow rate (g/dm^2/h) | 20 | | 5 | | 20 | | 5 | | 50 | | 50 | | | |
| Fluid application start time | | | | | | | | | | | | | | |
| OAT [C] | | | | | | | | | | | | | | |
| Approx Avg Wing Temp bef applic fluid [C] | | | | | | | | | | | | | | |
| Angle of Attack and Rate of Change | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | 8 (?) | 1°/s (?) | | |
| Ramp time (s) and $V_R$ speed (kts) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | 25 (?) | 100 (?) | | |
| Still Camera 1 / Still Camera 2 | | | | | | | | | | | | | | |
| Remarks | | | | | | | | | | | | | | |

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Initially, contamination applied to the wing section will be equivalent to a 60-minute exposure at a rate of 25g/dm²/h applied in real time. Failure shall be determined by the on-site experts based on residual contamination.

Each test shall comprise of one fluid at one temperature and one contamination scenario. A test series will comprise of one fluid, at one temperature, using one form of contamination, with varying levels of exposure to the contamination. The first test in a series will closely emulate expected holdover time conditions the second test will effectively double or halve the first condition depending on whether failure to clear has occurred. The third test will double or halve the previous condition or halve the interval to the previous test depending on the failure history. This decision matrix is shown in Figure 3.1.

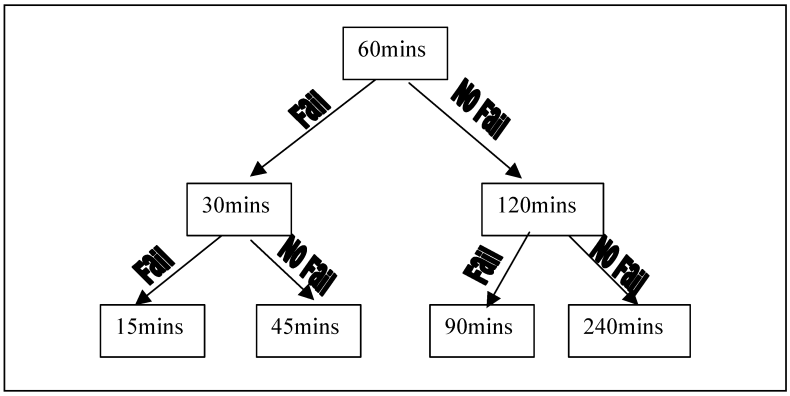



**Figure 3.1: Decision Matrix for Each Test Series**

## 4. PRE-TEST SETUP

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

- Co-ordinate with NRC wind tunnel personnel;
- Hotel accommodations for APS personnel;
- Arrange for vehicles to transport fluid and ice pellet material;
- Arrange personnel travel to Ottawa;
- Ensure proper functioning of ice pellets equipment;
- Mark wing data collection locations;
- Draw grid on the wing;
- Prepare and arrange for transport of equipment to Ottawa;
- Co-ordinate fabrication of ice pellets;

- Ensure the quantity of ice pellets is sufficient for the test; and
- Arrange for storage and transportation of ice pellets.

## 5. PROCEDURE

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

### 5.1 Initial Test Conditions Survey

- Synchronize all clocks (NRC, APS clock, computer, cameras, etc);
- Record the wing section location with respect to the wind tunnel using the Wind Tunnel General Setup Form (Attachment IX). Fill this form only once;
- Establish camera locations and mark them on the Camera Locations Form (Attachment VIII). Fill this form only once unless camera positions are changed;
- Place a standard aluminum test plate on the wing using suction cups as supports;
- Ensure the plate is at a 10-degree angle (from the horizontal);
- Ensure fluid is at or close to OAT and record temperature;
- Record ambient conditions of the test (Attachment IV);
- Collect virgin samples of Type IV fluid for viscosity tests; and
- Record wing temperature (Attachment V).

### 5.2 Fluid Application (Pour)

- First, pour fluid over the test plate;
- Pour fluid over the test area;
- Ensure the area under the test plate is covered by fluid;
- Record fluid application times (Attachment IV);
- Record fluid application quantities (Attachment IV);
- Let fluid settle for 5 minutes from start of Type IV application on wing;
- Measure fluid thickness at pre-determined locations on the wing (Attachment VI);
- Measure fluid Brix value (Attachment VI); and
- Photograph and videotape the appearance of the fluid on the wing.

## 5.3 Application of Contamination

### *5.3.1 Calculating Quantity of Ice Pellets Required for Dispersal*

The calculation of the quantity of ice pellets required for a test takes into account the precipitation rate, test area and the expected exposure time of the fluid.

For example:

Precipitation rate: 25 g/dm$^2$/h
Test Area: 4.8 m$^2$ = 480 dm$^2$
Estimated ET: 1 h

$Q_{Ice\ Pellets}$ = Rate X Test Area X Time = 12000 g = 12 kg

The ice pellets will be dispersed over the test area using handheld dispersers. Trials performed at the Dorval test site in January 2007 showed that the efficiency of the ice pellets dispensed over the wing area is 50%. For snow, the efficiency was estimated at 60%.

Therefore, the quantity required for one test is:

$Q_{dispersed} = Q_{ice\ pellets} / 0.5 = 12\ kg / 0.5 = 24\ kg$

A separate document showing the calibration was developed for the ice pellets and snow preparation and dispersion. This procedure is included in Appendix 2.

### *5.3.2 Application of Ice Pellets or Snow*

- Spread the ice pellets/snow evenly over the test area using the handheld dispenser;
- Apply precipitation until the observer calls the end condition of the aluminum test plate;
- Record the appearance of the contamination of both plate and wing (Attachment VII);
- Record quantity of ice pellets/snow dispersed (Attachment IV);
- Record application times of the contamination (Attachment IV);
- Measure fluid thickness (Attachment VI);
- Measure fluid Brix value (Attachment VI); and
- Photograph and videotape the appearance of the fluid on the wing.

### *5.3.3 Application of Freezing Rain/Drizzle*

- Ensure correct rate of precipitation is being generated by NRC freezing precipitation sprayer;
- Record rate of precipitation dispersed (Attachment IV);
- Record application times (Attachment IV);
- Apply precipitation until the observer calls the end condition of the aluminum test plate;
- A designated person must stop the sprayer in its home position to prevent additional precipitation (the sprayer starting at its home position does 18 swings before returning in its home position);
- NRC personnel must purge the sprayer to prevent freeze ups;
- Record the appearance of the contamination of both plate and wing (Attachment VII);
- Measure fluid thickness (Attachment VI);
- Measure fluid Brix value (Attachment VI); and
- Photograph and videotape the appearance of the fluid on the wing.

## 5.4 Prior to Wind Tunnel Test

- Measure fluid thickness at the pre-determined locations on the wing (Attachment VI);
- Measure fluid Brix value (Attachment VI);
- Record wing temperatures (Attachment V);
- APS personnel must signal NRC when the measurements are completed;
- NRC personnel must prepare the wind tunnel for the run and signal APS personnel when the tunnel is ready; and
- Record start time of the wind tunnel test (Attachment IV).

## 5.5 During Wind Tunnel Test

- One APS person must instruct NRC personnel when to start/stop the wind tunnel;
- Take still pictures/videotape the behavior of the fluid on the wing during the takeoff run, capturing any movement of fluid/contamination; and
- Record wind tunnel operation parameters.

## 5.6 After the Wind Tunnel Test

- Collect Type IV fluid samples from wings (if any) for later viscosity measurement;

- Measure thickness and Brix value (Attachment VI); and
- Observe and record the status of the fluid/ice pellets (Attachment VII).

### 5.7 At the End of Each Test Session

- All forms must be handed to the coordinator;
- The coordinator must check the forms for numbering and completeness;
- Decision will be taken for the next run; and
- Fill in the test matrix with the test data.

### 5.8 Timing and Process of a Typical Wind Tunnel Test

Table 5.1 demonstrates a typical Wind Tunnel test sequence of activities, assuming the test starts at 08:00:00.

**Table 5.1: Typical Wind Tunnel Test**

| TIME | TASK |
|---|---|
| 08:00:00 | START OF THE TEST. ALL EQUIPMENT READY. |
| 08:00:00 | Record test conditions. |
| 08:00:00 | Deice floor and anti-ice wing with the same fluid planned for the test. |
| 08:05:00 | Calibrate ZR (if applicable)/ Calculate and calibrate SN and/or IP (see Appendix 2, Table A2-1) |
| 08:15:00 | Prepare wing for fluid application (clean wing, etc). |
| 08:20:00 | Measure wing temperature prior to fluid application. |
| 08:25:00 | Pour fluid at OAT over test area. |
| 08:30:00 | Measure Brix, thickness, temperature.<br>Photograph test area. |
| 08:35:00 | Apply precipitation over test area. |
| 09:05:00 | Measure Brix, thickness, temperature.<br>Photograph test area. |
| 09:10:00 | Clear area and start wind tunnel |
| 09:15:00 | Wind tunnel stopped |
| 09:20:00 | Measure Brix, thickness, temperature.<br>Photograph test area.<br>Record test observations |
| 09:35:00 | END OF TEST |

## 6. EQUIPMENT

Equipment to be employed is shown in Table 6.1.

**Table 6.1: Test Equipment Checklist**

| TASK | STATUS |
|---|---|
| **Logistics for Every Test** | |
| Coordinate test initiation with NRC | |
| Fluid pouring device | |
| Fluid recovery containers | |
| Vacuum and tarps for fluid collection | |
| **Test Equipment** | |
| ***Camera Equipment*** | |
| Digital video camera | |
| Digital still camera | |
| ***General Support Equipment*** | |
| Large tape measure | |
| Step Ladders – Short + Tall | |
| ***Test Equipment*** | |
| Test Procedures, data forms | |
| Clipboards, pencils, wing markers for sample locations and solvent | |
| Sartorius weigh scale | |
| Thickness Gauges | |
| Temperature Probe x 2 and spare batteries | |
| Devices to lift fluid samples for viscosity | |
| Sample bottles for viscosity measurement | |
| ***Ice Pellets Fabrication Equipment*** | |
| Refrigerated Truck | |
| Ice pellets containers | |
| Ice pellets dispensers | |
| Ice bags | |
| Ice bags storage freezer | |
| Blenders | |
| Ice pellets filters | |
| Folding tables | |
| ***Freezing Rain Equipment*** | |
| NRC Freezing rain sprayer | |
| APS PC equiped with rate station software | |
| White plastic rate pans (100) | |
| Video equipment | |
| Sartorius Wieqh Scale (x2) | |
| Black Shelving Unit | |
| ***Personnel Equipment*** | |
| Hearing Protectors (yellow foam) | |

## 7. FLUIDS

Mid-viscosity samples of ethylene glycol-based UCAR Ultra+ Type IV and propylene glycol-based Kilfrost ABC-S Type IV will be used in the wind tunnel trials. Although the number off tests conducted will be determined based on the results obtained, the required fluid quantities were estimated and are shown in Table 7.1.

The fluid will be applied by pouring. It is estimated that approximately 20 liters of fluid are required for each test. The fluid must be pre-poured into small containers that will facilitate the application process. Samples of the on-wing fluid after the takeoff run will be collected for analysis.

**Table 7.1: Fluid Requirements for Wind Tunnel Tests**
**(Fluid from two batches of Dow UCAR Ultra+ is available for the tests)**

| Fluid | Dilution | Viscosity | Quantity (L) |
|---|---|---|---|
| Kilfrost ABC-S | 100/0 | Mid | 400 |
| Dow UCAR Ultra+ | 100/0 | Mid | 200 |

## 8. PERSONNEL

Five APS staff members are required for tests at the NRC wind tunnel. Four additional persons will be required from Ottawa for making and dispersing the ice pellets. One additional person will be required from Ottawa to photograph the testing.

Fluid and ice pellets applications will be performed by APS personnel at the NRC wind tunnel. Waste fluid clean-up and recovery will be performed by APS personnel. National Research Council personnel will operate the NRC wind tunnel and operate the freezing rain/drizzle sprayer. The following are the specific task assignments for APS personnel for the wind tunnel tests.

***Overall Co-ordinators (JD/MR)***

- Co-ordinate tests with NRC; and
- Provide direction as required during the tests.

***Co-ordinator 1 (GB)***

- Ensure that all required equipment is available and functional;
- Maintain data forms for every test;
- Ensure all data are collected and recorded, and that all test records submitted;
- Note the observed wing condition before and after each run (Attachment VII);
- Assist in setup of still cameras; and
- Communicate safety concerns.

***Data Collection (NB/DY)***

- Complete the Fluid Receipt Form (Attachment III) for each fluid (DY);
- Ensure the data forms are filed properly (DY);
- Ensure sample photos are taken to characterize the snow and ice pellets;
- Ensure Whatman paper samples are taken for freezing rain;
- Pour fluid over test area (including the test plate);
- Take temperature, thickness and Brix measurements;
- Assist in the collection of precipitation rates; and
- Assist with the snow/ice pellets dispersion.

***Ice Pellets Coordinator (JT/DP)***

- Supervise the production of ice pellets;
- Supply the ice pellet makers with raw ice;
- Ensure that the quantity of ice pellets produced is sufficient for the test requirements;
- Ensure proper storage of ice pellets and raw ice;
- Transport ice pellets to the test site; and
- Assist with ice pellets application.

***Ice Pellet/Snow Application (DP/DY)***

- Apply ice pellets/snow to the test area;
- Prepare the ice pellets/snow for the test; and
- Ensure the quantity(s) of ice pellets/snow is/are sufficient for the test.

***Photographer (from Ottawa)***

- Ensure time stamps are operating and accurately set;
- Videotape fluid on wing "before and after" each run and during wind tunnel test, ensuring constant viewing angles are used, to facilitate comparisons;
- Photograph samples of ice pellets and snow on black felt with ruler in the background;
- Photograph all test set-up; and
- Photograph the condition of wing with contamination at specified times.

***Ice Pellets Makers (2-4 persons from Ottawa)***

- Responsible for the fabrication of ice pellets;
- One ice pellet maker will operate the blender; and
- One ice pellet maker will filter the crushed ice.

***NRC Institute of Aerospace Research***

- Xing Zhong Huang: (613) 990-6796
- Myron Oleskiw: (613) 993-5339

## 9. SAFETY

- All personnel must be familiar with Material Safety Data Sheets (MSDS) for fluids;
- Particular attention is required when working inside the tunnel as the floor and ladder are very slippery;
- Caution when walking under the wing as fluid from the wing will drip;
- Prior to operating the wind tunnel, loose objects should be removed from the vicinity;
- When wind tunnel is operating, ensure ear plugs are worn and personnel keep safe distances;
- When working on ladders, ensure equipment is stable;
- Appropriate footwear and clothing for frigid temperatures are to be worn by all personnel;
- Safety goggles must be used when working with or around fluids;
- 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.

## 10. DATA FORMS

The following data forms are required for the February-March 2006 wind tunnel tests:

- Attachment III – Fluid Receipt Form (Generic form used by APS; will be used for this project as appropriate);
- Attachment IV – General Form (Every Test);
- Attachment V – Wing Temperature Form;
- Attachment VI – Fluid Thickness and Brix;
- Attachment VII – Condition of Wing and Plate Form;
- Attachment VIII – Camera Locations Form (use only once unless camera locations are changed;
- Attachment IX – Wind Tunnel General Setup Form (use only once); and
- Attachment X – Log of Fluid Sample Bottles

## ATTACHMENT I

## KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
## ABC-S

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 2:35 – 4:00 | 1:00 – 1:40 | 1:20 – 1:50 | 1:00 – 1:25 | 0:20 – 1:15 | |
| | | 75/25 | 5:00 | 1:05 – 1:45 | 0:30 – 0:55 | 0:45 – 1:10 | 0:35 – 0:50 | 0:10 – 0:50 | |
| | | 50/50 | 3:00 | 0:20 – 0:35 | 0:05 – 0:15 | 0:15 – 0:20 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:45 – 2:05 | 0:45 – 1:20 | 0:20 – 1:00[3] | 0:10 – 0:30[3] | | |
| | | 75/25 | 5:00 | 0:25 – 1:00 | 0:25 – 0:50 | 0:20 – 1:10[3] | 0:10 – 0:35[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 – 0:40 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**CAUTIONS**

- **The only acceptable decision criteria time is the shortest 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 deicing/anti-icing do not provide in-flight icing protection.**

## ATTACHMENT II

## DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
## UCAR™ ADF/AAF ULTRA+

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:35 – 3:35 | 0:35 – 1:15 | 0:45 – 1:35 | 0:25 – 0:40 | 0:10 – 1:20 | |
| | | 75/25 | | | | | | CAUTION: No holdover time guidelines exist | |
| | | 50/50 | | | | | | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 1:25 – 3:00 | 0:25 – 0:55 | 0:45 – 1:25[3] | 0:30 – 0:45[3] | | |
| | | 75/25 | | | | | | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00[5] | 0:40 – 2:10[5] | 0:20 – 0:45[5] | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met.[5] Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 These holdover times only apply to outside air temperatures to -24°C (-11°F).

**CAUTIONS**

- **The only acceptable decision criteria time is the shortest 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 deicing/anti-icing do not provide in-flight icing protection.**

## ATTACHMENT III: Fluid Receipt Form

| RECEIVING LOCATION: | DATE OF RECEIVING: | SAMPLE COLLECTED FROM BARREL: Y / N |
|---|---|---|

## GENERAL

Fluid Name: _____

Manufacturer: _____ Fluid Type: ____ Batch #: _____

APS Code: _____

Certificates of Conformance acc. to SAE AMS 1424: ☐ (check the box if received)

Fluid Freeze Point Curves (FP vs. Dilution & FP vs. Refraction): ☐ (for Type I Fluids only; check the box if received)

Lowest Operational Use Temperature: ☐ (check the box if received)

WSET Done by the Certification Agency: ☐ (check the box if received)

Date of Production: _____ Quantity: ___, ___, ___(L) Fluid Dilution: _____(100/75/50 or Neat)(%)

Manufacturer stated BRIX: _____ APS Measured BRIX: _____ MSDS Sheets Received: ☐

Manufacturer's Authorization to Proceed with Endurance Time Testing: ☐ (check the box if received) Authorized by: _____ (PRINT NAME)

on: _____ (DATE)

## TYPE IV FLUIDS

Manufacturers stated VISCOSITY: _____ mPa*s (cP) (VALUE)

APS Measured VISCOSITY: _____ mPa*s (cP) Using Manufacturer's Method (VALUE)

Viscosity shall be determined using the same Brookfield spindle/sample size combination as used for the AMS 1428 certification (most current).

## Attachment IV: General Form (every Test)

DATE: _____ FLUID APPLIED: _____ RUN #: _____

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

WIND TUNNEL START TIME: _____ WIND TUNNEL STOP TIME: _____

| FLUID APPLICATION | |
|---|---|
| Actual start time: | Actual End Time: |
| Fluid Brix: | Amount of Fluid (L): |
| Fluid Temperature (°C): | Fluid Application Method: |

| ICE PELLETS APPLICATION (if applicable) | |
|---|---|
| Actual start time: | Actual End Time: |
| Quantity of Ice Pellets Applied (kg): | Ice Pellets Size (mm): |
| Estimated Precipitation Rate (g/dm^2/h) | |

| FREEZING RAIN/DRIZZLE APPLICATION (if applicable) | |
|---|---|
| Actual start time: | Actual End Time: |
| Rate of Precipitation Applied (g/dm^2/h): | Nozzles Used: |

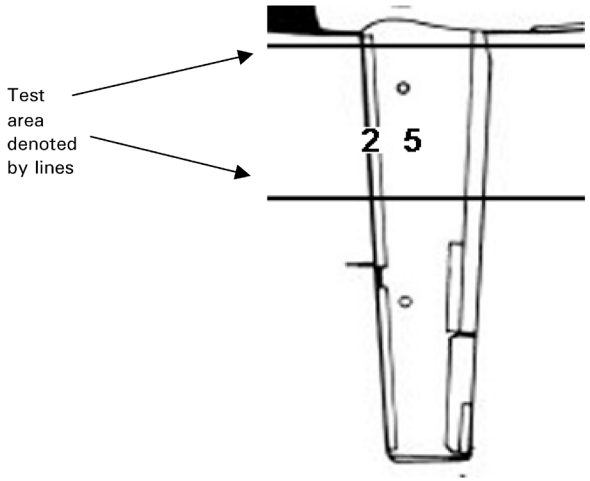
| SNOW APPLICATION (if applicable) | |
|---|---|
| Actual start time: | Actual End Time: |
| Quantity of Snow Applied (kg): | Snow Size (mm): |
| Estimated Precipitation Rate (g/dm^2/h) | |

**COMMENTS**

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

## Attachment V: Wing Temperature Form

Date: _____ Run Number: _____




**Skin Temperature**
Record temperature and time at the positions indicated on wing

| Test Phase | Position | Time | Temp (°C) |
|---|---|---|---|
| Before Contamination | 2 | | |
| | 5 | | |
| | Under wing | | |
| Before Run | 2 | | |
| | 5 | | |
| | Under wing | | |
| After Run | 2 | | |
| | 5 | | |
| | Under wing | | |

Comments: _____

**OBSERVER:** _____

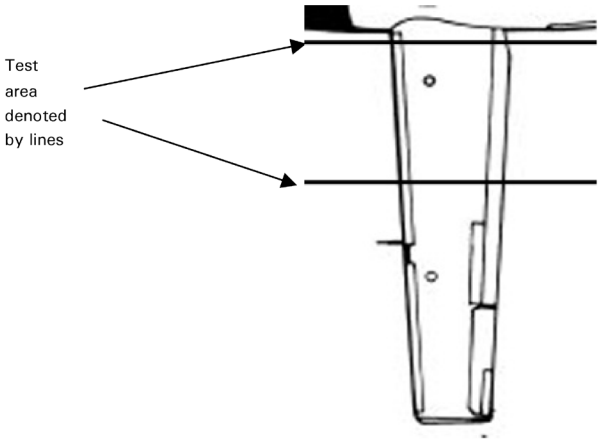
**ASSISTED BY:** _____

## Attachment VI: Fluid Thickness and Brix

Date: _____ Run Number: _____

| FLUID THICKNESS | | | |
|---|---|---|---|
| Wing Position | Before IP Application | After IP Application | After Wind Tunnel Run |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| START TIME | | | |
| END TIME | | | |

| FLUID BRIX | | | |
|---|---|---|---|
| Wing Position | Before IP Application | After IP Application | After Wind Tunnel Run |
| 2 | | | |
| 5 | | | |
| TIME | | | |




Location: 1 - Closest to the leading edge
2, 3, 4 - At equal distances between natural rivets, along the wing cord
5 - As far as one can reach

Note: - Measure thickness at locations
marked on wing (see Attachment IX - Form 6 ).

Comments: _____

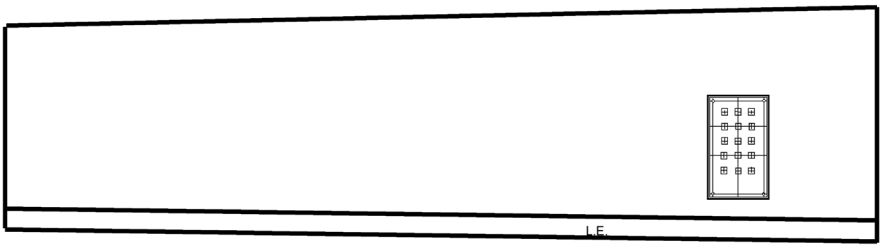
**OBSERVER:** _____
**ASSISTED BY:** _____

*APPENDIX B*

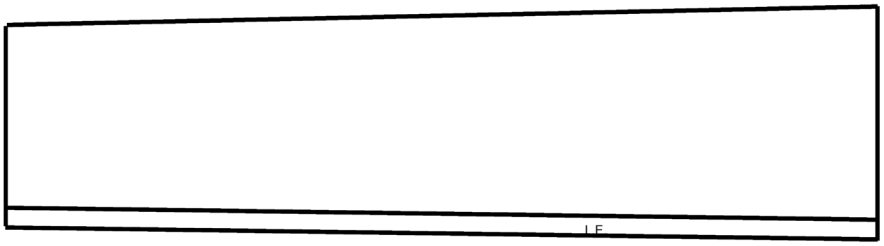
## Attachment VII – Condition of Wing and Plate Form

Date: _____ Run Number: _____

**Wing and Plate Condition Before the Takeoff Run (Time _____)**




**Wing Condition After the Takeoff Run (Time: _____)**




Observations: _____

_____

_____

_____

_____

**OBSERVER:** _____ **ASSISTED BY:** _____

## Attachment VIII – Camera Locations Form
## (Fill in only once unless camera locations are changed)

Date: _____ Time: _____ Run Numbers: _____

**Camera 1:** Wide Angle ☐ Zoom ☐

Distance from window edge (C1):_____

Height from window base:_____

**Flash 1:** Distance from window edge (F1):_____

Height from window base:_____

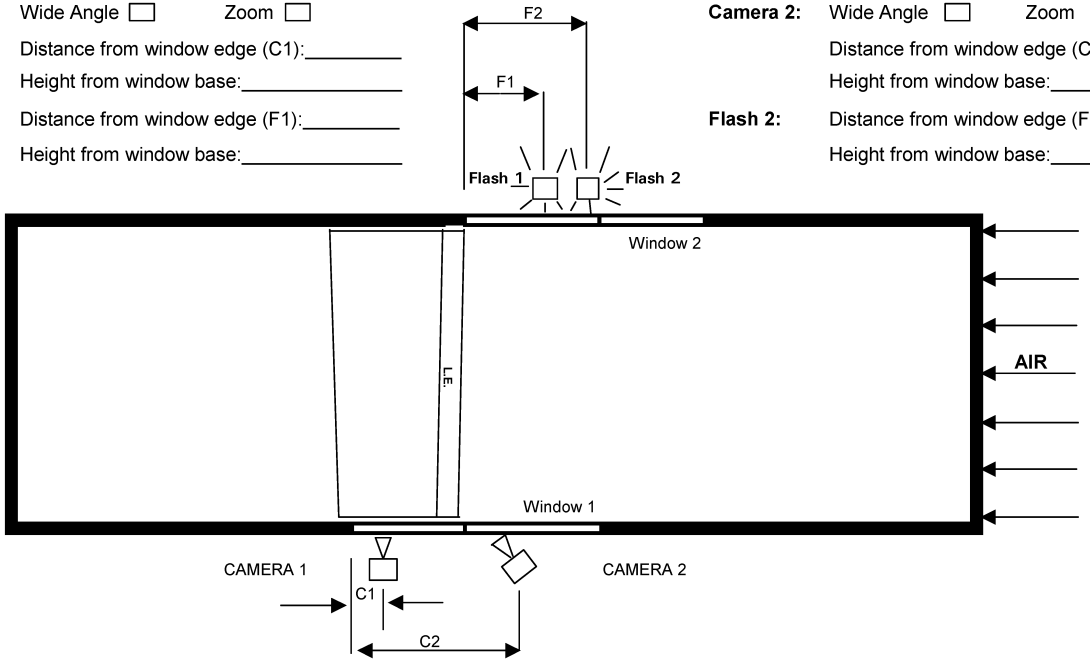
**Camera 2:** Wide Angle ☐ Zoom ☐

Distance from window edge (C2):_____

Height from window base:_____

**Flash 2:** Distance from window edge (F2):_____

Height from window base:_____




**OBSERVER:** _____

**ASSISTED BY:** _____

Observations: _____

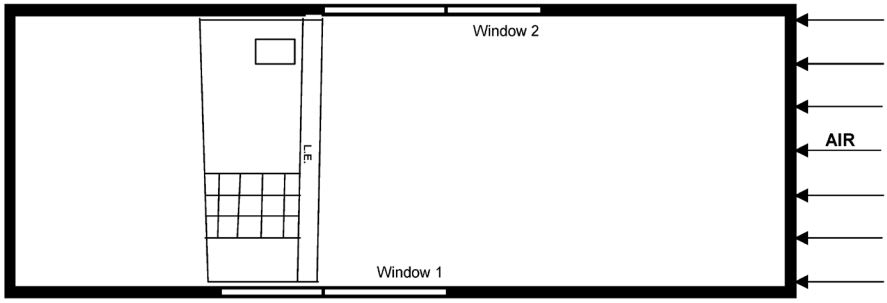
M:\Groups\PM2020 (TC-Deicing 06-07)\Reports\Heavy Snow WT\Report Components\Appendices\Appendix B.doc
Final Draft 1.0, January 08

B-24

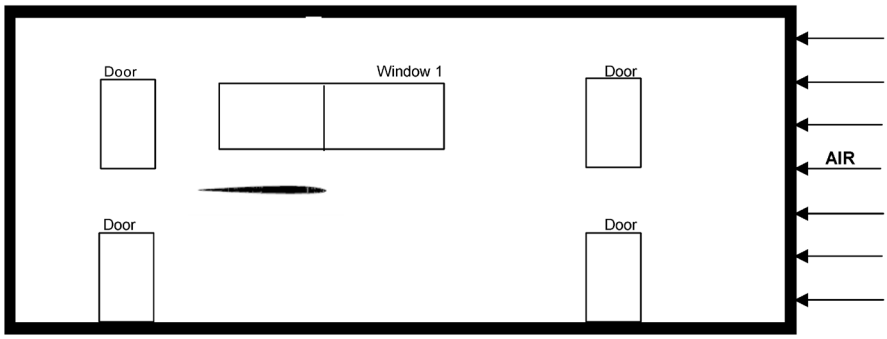
## Attachment IX – Wind Tunnel General Setup Form
## (Fill in with the coordinates of the wing section with respect to the wind tunnel)

Date: _____ Time: _____

**TOP VIEW**




**SIDE VIEW**




**Instructions:**
1. Record distances from the leading edge to the measuring locations 1-5.
2. Measure key distances and indicate them on the diagrams above
3. Show plate location on the wing

**OBSERVER:** _____

**ASSISTED BY:** _____

## Attachment X – Log of Fluid Sample Bottles

| Bottle Label # | Date of Extraction | Fluid and Dilution | Sample Source (on-wing/virgin) | Comments |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
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## APPENDIX 1 – Task List for Dry Run and Actual Tests

| No. | Task | Status |
|---|---|---|
| | | |
| | **Planning and Preperation** | |
| 1 | Establish quantities of fluid to be ordered | |
| 2 | Order fluid | |
| 3 | Investigate IP/ZR/SN dispersal techniques and location | |
| 4 | Arrange for Freezer in test area (for IP) | |
| 5 | Inquire about moving floor in tunnel | |
| 6 | Arrange for video/photo recording of the test | |
| 7 | Book Hotels for APS/TC/FAA personel | |
| 8 | Establish quantity of ice pellets required (and size) | |
| 9 | Estimate manufacturing time for ice pellets | |
| 10 | Pre-manufacture ice pellets | |
| 11 | Hire people in Ottawa to help with making of ice pellets | |
| 12 | Finalize list of materials required | |
| 13 | Prepare procedure | |
| 14 | Prepare data forms for the test | |
| | | |
| | **Perform Dry Run at NRC Test site** | |
| 15 | Check with NRC the status of the testing site, tunnel etc | |
| 16 | Check weather prior to establishing test dates | |
| 17 | Arrange for hotel and transportation for personnel | |
| | | |
| | **Day 1** | |
| | | |
| 18 | Pack and leave YUL for YOW | |
| 19 | Setup rate station | |
| 20 | Setup IP manufacturing material | |
| 21 | Test and prepare IP dispensing equipment | |
| 22 | Verify ZR sprayer installation | |
| 23 | Verify Grid on Wing Section | |
| 24 | Ice and freezer delivery | |
| 25 | Train IP making personnel | |
| | | |
| | **Day 2** | |
| | | |
| 26 | ZR Calibration (run 12 rates) | |
| 27 | IP manufacturing | |
| 28 | Investigate fluid application (wand vs APS spreader) | |

| No. | Task | Status |
|---|---|---|
| | **Day 3** | |
| | | |
| 29 | IP Dispenser Calibration (run 12 rates) | |
| 30 | Mixed IP Calibration | |
| 31 | Investigate SN (Myron bars vs. APS crushed ice) | |
| | | |
| | **Day 4** | |
| | | |
| 32 | Dry Run of tests (APS / NRC) | |
| 33 | Calibrate SN | |
| 34 | Pack up and leave for YUL | |
| | | |
| | **Day 5** | |
| | | |
| 35 | Spare Day... | |
| | | |
| | **Perform Tests at NRC Test site** | |
| 36 | Check with NRC the status of the testing site, tunnel etc | |
| 37 | Check weather prior to establishing test dates | |
| 38 | Arrange for hotel and transportation for personnel | |
| 39 | Prepare equipment and fluid to be used for test | |
| 40 | Manufacture ice pellets | |
| 41 | Arrange for photo doc. of the test (if necessary) | |
| 42 | Prepare data forms for test | |
| 43 | Conduct tests based on test plan | |
| 44 | Modify test plan based on results obtained | |

## APPENDIX 2

### Ice Pellet/Snow Dispenser Calibration and Set-Up for Wind Tunnel Testing

Calibration work was done on the modified dispensers prior to testing in the Wind Tunnel. Achieving rates of 5 and 25 ($g/dm^2/h$) for ice pellets, and 50 ($g/dm^2/h$) for snow, was successfully completed. The distribution and efficiencies of the dispensers were measured and are the prime factors in achieving the target rates for the specified precipitation type. The dispenser efficiencies are 50% for ice pellets and 60% for snow. The following will give a detailed description, and preparation for tests using the modified dispensers for tests in the Wind Tunnel.

#### Ice Pellet and Snow Preparation

A pre-measured amount of ice pellets and snow will be prepared prior to each test. The following steps will be repeated for the preparation of every test involving the use of ice pellets/snow:

1. Confirm the type and rate of the upcoming test;
2. Prepare the amount of ice pellets/snow needed, **by re-sieving the desired amount**. (Refer to Efficiency Table Below);
3. Pack desired amount of ice pellets/snow in a closed, labeled Styrofoam cooler, and transport it to the scaffold; and
4. Repeat steps 1-3 for proceeding tests.

#### Dispenser Set-Up

Two dispensers will be set-up on top of the scaffold facing the leading edge of the wing. The following steps will be repeated for every test involving the use of the dispensers.

1. Make sure the dispensers are completely emptied. (No Residue Ice/Snow from previous tests);
2. Each dispenser stand will be placed on the floating scaffold, 2½ ft from their respective side of the wall of the Wind Tunnel;
3. The center of the each dispenser stand will be 1 ft, from the leading edge;
4. The dispenser height from scaffold to opening of the bucket is 4 ft;

5. Each dispenser should be rotated approximately 30° clockwise from its normal;
6. Fix dispenser settings, depending on type, rate, and time. (Refer to Table A2-1);
7. Run dispensers for a few minutes before testing. (Warm up);
8. Fill buckets with pre-measured amount of ice pellets/snow. (Using the 10 minute amount in Table Below);
9. Commence dispensing;
10. Use the wooden spoons to unblock the opening of the dispensers to have a constant flow;

    (Note: For Snow, constant unblocking of the opening is needed to achieve the desired rate.)
11. Refill the buckets every 10 minutes, making sure the dispenser bucket is fully emptied before adding any more ice pellets/snow;
12. Test completed;
13. Clear the scaffold area (Stands, spoons, Styrofoam coolers, measuring cups, etc).
14. Repeat Steps 1-13, for the next test.

**Table A2-1 IP/Snow Calibration Table**

| Ice Pellet/Snow Dispenser Calibration Table for Wind Tunnel Tests | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Type | Target Rate (g/dm2/h) | Dispensor Settings | | | Total Amount of Precipitation Needed On Wing (kg) | Efficiency (%) | Total Amount of Precipitation to be Dispersed (kg) | | | |
| | | | | | | | Total | Per Dispenser | Total | Per Dispenser |
| | | Dial | Notch Openning | Speed | | | 1 Hour | 1 Hour | 10 Minutes | 10 Minutes |
| Ice Pellets | 5 | 1 | 1.25 | 8 | 1.9 | 50% | 3.7 | 1.9 | 0.6 | 0.3 |
| Ice Pellets | 25 | 2 | 2.25 | 8 | 9.3 | 50% | 18.6 | 9.3 | 3.1 | 1.5 |
| Snow | 50 | 5 | 6 | 8 | 18.6 | 60% | 31.0 | 15.5 | 5.2 | 2.6 |

## APPENDIX 3
## WIND TUNNEL NOMINAL TEST CONDITIONS (ZR/IP)

| **TEST NO** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Test Comment (Precipitation)** | | | | | | | | | | |
| **Date** | | | | | | | | | | |
| Fluid | | | | | | | | | | |
| Test Area [$m^2$] | | | | | | | | | | |
| Pellets size [mm] | | | | | | | | | | |
| HOT Duration of simulation (min) | | | | | | | | | | |
| Ice Pellet Quantity (kg) | | | | | | | | | | |
| Ice pellet application period (min) | | | | | | | | | | |
| Effective ice pellet rate (g/dm^2/h) | | | | | | | | | | |
| Freezing precipitation Type (Zd or ZR-) | | | | | | | | | | |
| Freezing precipitation Rate (g/dm^2/h) | | | | | | | | | | |
| Fluid application start time | | | | | | | | | | |
| OAT [C] | | | | | | | | | | |
| Approx Avg Wing Temp bef applic fluid [C] | | | | | | | | | | |
| Angle of Attack and Rate of Change | | | | | | | | | | |
| Ramp time (s) and $V_R$ speed (kts) | | | | | | | | | | |
| Still Camera 1 / Still Camera 2 | | | | | | | | | | |
| Remarks | | | | | | | | | | |

## WIND TUNNEL NOMINAL TEST CONDITIONS (SN/IP and SN + +)

| **TEST NO** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Test Comment (Precipitation)** | | | | | | | | | | |
| **Date** | | | | | | | | | | |
| Fluid | | | | | | | | | | |
| Test Area [$m^2$] | | | | | | | | | | |
| Pellets size [mm] | | | | | | | | | | |
| HOT Duration of simulation (min) | | | | | | | | | | |
| Ice Pellet Quantity (kg) | | | | | | | | | | |
| Ice pellet application period (min) | | | | | | | | | | |
| Effective ice pellet rate (g/dm^2/h) | | | | | | | | | | |
| Snow size [mm] | | | | | | | | | | |
| Snow Quantity (kg) | | | | | | | | | | |
| Snow application period (min) | | | | | | | | | | |
| Snow rate (g/dm^2/h) | | | | | | | | | | |
| Fluid application start time | | | | | | | | | | |
| OAT [C] | | | | | | | | | | |
| Approx Avg Wing Temp bef applic fluid [C] | | | | | | | | | | |
| Angle of Attack and Rate of Change | | | | | | | | | | |
| Ramp time (s) and $V_R$ speed (kts) | | | | | | | | | | |
| Still Camera 1 / Still Camera 2 | | | | | | | | | | |
| Remarks | | | | | | | | | | |

## APPENDIX 4
## Freezing Rain Sprayer Calibration Form

**WIND TUNNEL FREEZING RAIN SPRAYER CALIBRATION (Date: _____)**

| Trail No | Aprox Start Time | Sprayer Settings | | | | | | | Precipitation Rate (g/dm^2/h) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Translation | | Nozzles | Speed | Water Flow Rate (mL/min/nozzle) | Air Pressure | Software Setting | | |
| | | x | y | | | | | | | |
| Dry Run Settings | - | Full | Partial | 2x23, 2x24 | Low | 12.2 x 15 | 30 | Dry Run Setting | 22 | MVD = 1.2mm |
| | | | | | | | | | | |
| | | | | | | | | | | |
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## APPENDIX C

## PROCEDURE
## FALCON 20 TRIALS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH ICE PELLETS, SNOW AND/OR FREEZING RAIN

CM2020.002 (06-07)

# PROCEDURE
# FALCON 20 TRIALS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH ICE PELLETS, SNOW AND/OR FREEZING RAIN

Winter 2006-07

Prepared for

**Transportation Development Centre**
**Transport Canada**

Prepared by: George Balaban

Reviewed by: John D'Avirro




January 5, 2006
Final Version 1.0

# FALCON 20 TRIALS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH ICE PELLETS, SNOW AND/OR FREEZING RAIN

Winter 2006-07

*A series of wind tunnel tests will be conducted during the period February 12-23, 2007 at the NRC wind tunnel prior to the actual scheduled testing on February 26 – March 2, 2007. Details of the wind tunnel tests are outlined in the procedure "Wind Tunnel Tests to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets, Snow and/or Freezing Rain". Results from the wind tunnel tests may result in changes, or modifications to this procedure. An updated version of this procedure (Final Version 2.0) will be issued prior to conducting the actual testing and will include any changes.*

## 1. BACKGROUND

### 1.1 Previous Falcon 20 Tests

Previous trials to examine the elimination of failed SAE Type IV fluid from aircraft wings during takeoff were conducted during the 1997-98 and 1998-99 winter seasons. Those trials, based on simulated takeoff runs using a National Research Council (NRC) Falcon 20 aircraft, showed that the test approach was a viable one. The test program conducted during winter 2005-06 addressed the effects of deicing fluid contaminated with ice pellets that the airflow at takeoff fails to remove.

In March 2006, a series of simulated takeoff runs were performed with the National Research Council Falcon 20 research aircraft at the Ottawa Airport. Eight runs were performed with simulated ice pellet precipitation rates ranging from 25 g/dm$^2$/h to 167 g/dm$^2$/h and two Type IV de/anti-icing fluids, DOW UCAR Ultra+ and Kilfrost ABC-S. One run was completed with Type I EG deicing fluid.

The fluid present on the wings was almost completely eliminated during the takeoff. In general, a small film of fluid remained on certain wing surfaces, most notably on the trailing edge of the aircraft. The leading edge was cleared of any contamination during the takeoff run, even at very high precipitation rates. Some contamination was observed on the trailing edge at very high precipitation rates (136 g/dm$^2$/h). The Type I EG run showed that a small amount of ice was adhered to the wing surface at the end of the takeoff run.

### 1.2 Regulatory Recommendation

As a result of the recent industry need to provide aircraft operators with holdover times for ice pellet conditions, the FAA provided a 25-minute allowance as a preliminary guideline. This allowance was followed by a list of conditions restricting operations, one condition being that the 25-minute allowance was acceptable in conditions with ice pellets alone. This recommendation was based on the previous endurance time research conducted during the winter of 2005-06, and as a result of Falcon 20 aerodynamic work. It was recommended to explore the worst-case mixed precipitation conditions in order to further evaluate or modify the current allowance time for ice pellet conditions.

### 1.3 Mixed Precipitation Research

Preliminary endurance time testing in simulated freezing precipitation conditions was conducted by APS at the NRC research facility in 2006 to investigate which conditions are most conducive to fluid adherence. Adherence occurred during tests conducted with Type I heated fluid in ice pellet conditions, and with Type IV fluid during mixed precipitation conditions. The preliminary testing also showed that adherence produced during ice pellet conditions in combination with freezing rain/drizzle was rough in comparison to adherence caused by freezing rain/drizzle alone. This may be an aerodynamically more severe condition.

The 2007 Falcon 20 tests will be preceded by a series of tests studying ice pellets and mixed precipitation. These tests will be performed at the NRC Wind Tunnel in Ottawa. A separate procedure, *Wind Tunnel Tests to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets, Snow and/or Freezing Rain* was developed for this purpose.

During the course of the winter season, more procedures may be developed based upon results from initial testing and discussions with the industry.

The procedure *Falcon 20 Trials to Examine Fluid Removed from Aircraft During Takeoff with Ice Pellets, Snow and/or Freezing Rain* is described in this document; the other procedures are described in separate documents.

## 2. OBJECTIVES

The objective of this procedure is to determine the level of contamination of anti-icing fluid caused by ice pellets mixed with freezing rain and/or snow at which the airflow at takeoff fails to remove the resultant contamination.

To satisfy this objective, a series of simulated takeoff runs will be performed with the NRC Falcon 20 research aircraft.

## 3. TEST REQUIREMENTS

APS will co-ordinate the planned test activities and prepare a final report as well as present results at industry deicing meetings.

APS will provide support to these tests for instrumentation, fluid application, and artificial precipitation application. A high-quality digital videotape record and still pictures of fluid on aircraft wings during the simulated takeoff run are required.

Desired weather conditions are dry, with subfreezing outside air temperatures. Tests will be limited to a maximum of 10 kts crosswind. Overcast skies are very important to avoid overheating the aircraft wings from exposure to the sun. Runway conditions are to be clean and dry.

The Falcon 20 tests scheduled for February 26 – March 2 2007 will be based on the results of the wind tunnel tests performed in mixed precipitation conditions.

Attachment I presents the quantities of ice pellets required to achieve a target precipitation rate as well as the holdover time (HOT) tables for the fluids used in the tests. The ice pellet size is the same for both wind tunnel and Falcon 20 tests (1-3.35mm in diameter).

Attachment II contains a draft schedule that includes three types of tests. The test schedule may be revised based on the results of the wind tunnel tests:

- Tests with Type IV fluid exposed to ice pellets or freezing rain precipitation only;
- Tests with Type IV fluid exposed to ice pellets/freezing rain mixed precipitation; and
- Tests with Type IV fluid exposed to ice pellets/snow mixed precipitation.

A list of safety issues that must be considered when testing is shown in Attachment III.

A glycol mitigation plan was prepared for the Ottawa Airport Authority prior to requesting the approval for the conduct of tests at YOW. The mitigation plan is shown in Attachment IV.

## 4. EQUIPMENT AND FLUIDS

### 4.1 Equipment

Equipment to be employed is shown in Attachment V.

### 4.2 Fluids

Ethylene glycol-based DOW UCAR Ultra+ Type IV and propylene glycol-based Kilfrost ABC-S Type IV will be used in the February-March 2007 trials.

It is estimated that 200 L of Kilfrost ABC-S and 100 L of DOW UCAR Ultra+ will be used for the Falcon 20 tests.

## 5. PROCEDURE

The test procedures are shown in Attachment VI.

## 6. PERSONNEL

Six APS staff members are required for tests at the airport. Four additional persons will be required from Ottawa for making and dispersing the ice pellets. One additional person will be required from Ottawa to record images of the testing. Waste fluid clean-up and recovery will be performed by APS personnel.

Fluid and artificial precipitation application will be performed by APS personnel at the NRC hangar. NRC flight crews will operate the NRC aircraft.

Attachment VII provides task assignments.

## 7. DATA FORMS

The following data forms are required for the Falcon 20 tests to be conducted in February-March 2007:

- Attachment VIII – Fluid Receipt Form;
- Attachment IX – General Form (Every Test);
- Attachment X – Wing Temperature Form (Port Wing);
- Attachment XI – Wing Temperature Form (Starboard Wing);

- Attachment XII – Fluid Thickness and Brix (Port Wing);
- Attachment XIII – Fluid Thickness and Brix (Starboard Wing);
- Attachment XIV – Fluid Freeze Point Measurements (Port Wing);
- Attachment XV – Fluid Freeze Point Measurements (Starboard Wing);
- Attachment XVI – Freezing Rain/Snow Quantity Form;
- Attachment XVII – Test Results Form (Port Wing);
- Attachment XVIII – Test Results Form (Starboard Wing);
- Attachment XIX – Time Record of Operations; and
- Attachment XX – Nominal Test Conditions.

## ATTACHMENT I
## Ice Pellets Requirements

### 1. DOW UCAR ADF/AAF ULTRA+

#### 1.1 Rate of Precipitation

The baseline rate of precipitation for the 2007 Falcon 20 tests will be established following the wind tunnel tests. The rate of precipitation will be denoted "R" (in g/dm$^2$/h).

#### 1.2 Holdover Time for Ultra+

From the HOT table attached, Ultra+ has a HOT of 30 minutes in *light freezing rain conditions* at a rate of precipitation of 25 g/dm$^2$/h, in temperatures between -3°C and -14°C. The current FAA guidelines provide an allowance of 25 minutes, which is consistent with the HOT in *light freezing rain* conditions. An effective endurance time in mixed precipitation will be established following the wind tunnel tests. This reference time will be denoted "ET" (in hours).

#### 1.3 Quantity of Ice Pellets Required

The calculation of the quantity of ice pellets required for a test takes into account the precipitation rate, test area and the estimated endurance time of the fluid.

Precipitation rate: R (in g/dm$^2$/h)
Test Area: A (in dm$^2$)
Estimated HOT: ET (in h)

$Q_{Ice\ Pellets} = R \times A \times ET$

#### 1.4 Quantity of Ice Pellets Dispersed

The ice pellets will be dispersed over the test area using handheld dispersers. Trials performed at the Dorval test site in February 2006 showed that the efficiency of the ice pellets disperser is 80%.

Therefore, the quantity required for one test is:

$Q_{dispersed} = Q_{ice\ pellets} / 0.8 = R \times A \times ET / 0.8$

## 2. KILFROST ABC-S

The quantity of Kilfrost ABC-S required for the tests is similar to that for Ultra+. Since the HOT in light freezing rain conditions is highly dependent on temperature, adjustments may be necessary depending on the test conditions.

## ATTACHMENT I

## DOW CHEMICAL TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
## UCAR™ ADF/AAF ULTRA+

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 1:35 – 3:35 | 0:35 – 1:15 | 0:45 – 1:35 | 0:25 – 0:40 | 0:10 – 1:20 | |
| | | 75/25 | | | | | | CAUTION: No holdover time guidelines exist | |
| | | 50/50 | | | | | | | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 1:25 – 3:00 | 0:25 – 0:55 | 0:45 – 1:25[3] | 0:30 – 0:45[3] | | |
| | | 75/25 | | | | | | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00[5] | 0:40 – 2:10[5] | 0:20 – 0:45[5] | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met.[5] Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**

1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.
5 These holdover times only apply to outside air temperatures to -24°C (-11°F).

**CAUTIONS**

- **The only acceptable decision criteria time is the shortest 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 deicing/anti-icing do not provide in-flight icing protection.**

**ATTACHMENT I (cont.)**

## KILFROST TYPE IV FLUID HOLDOVER GUIDELINES FOR WINTER 2005-2006[1]
## ABC-S

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

| Outside Air Temperature | | Type IV Fluid Concentration Neat Fluid/Water (Volume %/Volume %) | Approximate Holdover Times Under Various Weather Conditions (hours:minutes) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Degrees Celsius | Degrees Fahrenheit | | Active Frost | Freezing Fog | Snow or Snow Grains | Freezing Drizzle[4] | Light Freezing Rain | Rain on Cold Soaked Wing | Other[2] |
| -3 and above | 27 and above | 100/0 | 12:00 | 2:35 – 4:00 | 1:00 – 1:40 | 1:20 – 1:50 | 1:00 – 1:25 | 0:20 – 1:15 | |
| | | 75/25 | 5:00 | 1:05 – 1:45 | 0:30 – 0:55 | 0:45 – 1:10 | 0:35 – 0:50 | 0:10 – 0:50 | |
| | | 50/50 | 3:00 | 0:20 – 0:35 | 0:05 – 0:15 | 0:15 – 0:20 | 0:05 – 0:10 | CAUTION: No holdover time guidelines exist | |
| below -3 to -14 | below 27 to 7 | 100/0 | 12:00 | 0:45 – 2:05 | 0:45 – 1:20 | 0:20 – 1:00[3] | 0:10 – 0:30[3] | | |
| | | 75/25 | 5:00 | 0:25 – 1:00 | 0:25 – 0:50 | 0:20 – 1:10[3] | 0:10 – 0:35[3] | | |
| below -14 to -25 | below 7 to -13 | 100/0 | 12:00 | 0:20 – 0:40 | 0:15 – 0:30 | | | | |
| below -25 | below -13 | 100/0 | Type IV fluid may be used below -25°C (-13°F) provided the freezing point of the fluid is at least 7°C (13°F) below the outside air temperature and the aerodynamic acceptance criteria are met. Consider use of Type I when Type IV fluid cannot be used. | | | | | | |

**NOTES**
1 These holdover times are derived from tests of this fluid having a viscosity as listed in Table 9.
2 Heavy snow, snow pellets, ice pellets, moderate and heavy freezing rain, and hail.
3 These holdover times only apply to outside air temperatures to -10°C (14°F) under freezing drizzle and light freezing rain.
4 Use light freezing rain holdover times if positive identification of freezing drizzle is not possible.

**CAUTIONS**
- **The only acceptable decision criteria time is the shortest 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 deicing/anti-icing do not provide in-flight icing protection.**

**ATTACHMENT II**
**Test Plan for Falcon 20 Tests in 2006-07**

| Test # | Wing | Fluid | Precipitation | Precipitation Rate |
|---|---|---|---|---|
| 1 | Port | Kilfrost ABC-S | IP + ZR | TBD* |
| | Starboard | Kilfrost ABC-S | IP + Snow | TBD* |
| 2 | Port | UCAR Ultra + | IP + ZR | TBD* |
| | Starboard | UCAR Ultra + | IP + Snow | TBD* |
| 3 | Port | TBD | TBD | TBD** |
| | Starboard | TBD | TBD | TBD** |
| 4 | Port | TBD | TBD | TBD** |
| | Starboard | TBD | TBD | TBD** |
| 5 | Port | TBD | TBD | TBD** |
| | Starboard | TBD | TBD | TBD** |
| 6 | Port | TBD | TBD | TBD** |
| | Starboard | TBD | TBD | TBD** |

* Precipitation rate will be based on NRC wind tunnel test results.
** Precipitation rate will be based on the results of the first Falcon 20 runs.

## ATTACHMENT III
## Safety Issues

- All personnel must be familiar with Material Safety Data Sheets (MSDS) for fluids;
- When in controlled airport areas, ensure correct procedures and make sure escorts are available;
- When engines are operating, no loose objects should be used around the engines;
- When engines are operating, ensure ear plugs are worn and keep safe distances;
- When working on ladders, ensure equipment is stable;
- Appropriate footwear and clothing for frigid temperatures are to be worn by all personnel;
- The test area must be cleared of snow and ice before testing;
- 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 IV**

**GLYCOL MITIGATION PLAN**

**APS AVIATION INC.**

**FALCON 20 TRIALS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH ICE PELLETS OTTAWA, ONTARIO (YOW) FEBRUARY 26 – MARCH 2, 2007**

## 1. CORPORATE PROFILE

APS Aviation Inc. (APS), member of the ADGA Group of companies, is a worldwide leader in aircraft de-icing research and development. Since 1990, APS has been contracted by the Transportation Development Centre (TDC) of Transport Canada to further advance aircraft pre-flight de/anti-icing technology.

## 2. BACKGROUND

At the request of the TDC of Transport Canada, APS has undertaken a research program to examine the potential aerodynamic penalties resulting from the presence of clean and diluted anti-icing fluid on aircraft wings.

Previous trials to examine the aerodynamic elimination of failed Type IV fluid from aircraft wings during takeoff were conducted on behalf of Transport Canada during the 1997-98 and 1998-99 and winter seasons at Mirabel Airport. Those trials, based on simulated takeoff runs using a National Research Council Falcon 20 aircraft, provided an improved understanding of the subject matter and demonstrated that the selected test approach was a viable one.

During the winter of 2001-02 and 2002-03, flight tests were performed at Ottawa International Airport (YOW). Tests were performed with one ethylene glycol-based Type IV fluid, Dow Ultra+, in neat and diluted form. Fluid was applied at the central de-icing pad at YOW by GlobeGround personnel.

The effects of (simulated) ice pellets mixed with freezing rain on the wing of Falcon 20 aircraft during takeoff are currently studied. Since the precipitation embedded in the fluid was not adhering according to previous tests, it is not known whether this contamination in the fluid would come off during aircraft rotation. As a result, the FAA has issued a notice that prevents operations from departing in ice pellets/freezing rain mixed precipitation conditions.

The February-March 2007 tests at YOW will address the effects of deicing fluid contaminated with ice pellets and/or freezing rain that the airflow at takeoff fails to remove.

This document describes the glycol mitigation plan for the planned tests as follows:

- The fluid application procedures;
- The locations designated for fluid application;
- The anticipated fluid quantities to be sprayed; and
- The fluid recovery plan.

## 3. FLUID APPLICATION PROCEDURES

In February-March 2007, tests will be conducted at YOW with ethylene and propylene glycol-based Type IV fluids.

APS personnel are highly experienced in aircraft deicing matters, and attempts will be made to limit the quantities of fluid applied to the aircraft. The fluids will be applied to a 2.7 square-meter section of the aircraft wing by pouring, thus limiting the amount of fluid that falls on the ground after application.

In previous tests conducted at YOW in March 2006 ethylene and propylene fluids were applied over the same 2.7 square-meter section. In total, 60 liters of ethylene fluid and 100 liters of propylene fluid were used for the entire test session. All deicing fluid that fell to the ground within the application area was properly recovered.

The fluid application will be performed by APS personnel at the NRC pad.

All Type IV fluids will be applied unheated to the wings of the Falcon 20. No Type I fluid will be applied prior to the Type IV.

## 4. LOCATIONS DESIGNATED FOR FLUID APPLICATION

The fluid application will be performed by APS personnel at the NRC pad.

Fluid applications at the NRC pad will be conducted in close proximity to the NRC hangar. Two separate areas will be assigned, one for ethylene applications, the other for propylene applications. NRC personnel will determine the precise locations prior to testing. The aircraft will not be positioned near the stormwater catch basins located on the southern edge of the NRC apron.

## 5. ANTICIPATED FLUID QUANTITIES TO BE SPRAYED

Six tests are anticipated for February-March 2007 at YOW. Of this total, four will be performed with Dow Ultra+ (ethylene) and two will be performed with Kilfrost ABC-S (propylene).

Based on preliminary testing, the estimated maximum amount of fluid required for the conduct of these tests will be 240 liters (160 of ethylene glycol and 80 of propylene glycol base). Of this quantity, roughly 20% falls to the ground immediately following application.

## 6. FLUID RECOVERY PLAN

The method of application, pouring, minimizes the fluid that is applied to the wing section and the fluid falling on the ground immediately after application. APS personnel will collect the excess fluid immediately after application using fluid collection containers, tarps and a powerful vacuum.

The waste solutions will be recovered and stored separately to prevent cross-contamination of the products. APS will incur the costs of these fluid recovery services.

## 7. ADDITIONAL REPORTS

Upon request, a report will be provided by APS to the airport authority following the conduct of tests at YOW to provide the quantities of fluid used in testing.

## ATTACHMENT V
## Test Equipment Checklist

| TASK<br>Test Equipment | STATUS |
|---|---|
| | |
| ***General Equipment*** | |
| Refrigerated truck | |
| Freezer for ice and ice pellets storage | |
| Portable radio | |
| Fluids (order and ship to Ottawa) | |
| Horse and tap for fluid barrel | |
| Vacuum and tarps for fluid collection | |
| Waste fluid containers | |
| Funnels | |
| Sample bottles for viscosity measurement | |
| Devices to lift fluid samples for viscosity | |
| Step Ladders – Short + Tall | |
| Squeegees | |
| Large tape measure | |
| Isopropyl | |
| Gloves, hearing protectors, paper towel | |
| Extension cords | |
| Security passes | |
| | |
| ***Camera Equipment*** | |
| Digital still cameras x3 (with lenses, chargers, batteries, etc) | |
| Video camera(s) provided by NRC | |
| | |
| ***Test Equipment*** | |
| Test Procedure, data forms | |
| Fluid pouring devices x6 | |
| Ice pellets dispensing devices x6 | |
| Desktop/Laptop computer with printer | |
| Portable hard drive and memory card reader | |
| Aluminum Rate pans | |
| Clipboards, pencils, wing markers for sample locations and solvent | |
| Temperature Probe x 2 and spare batteries | |
| Thickness Gauges (large and small) | |
| Brixometers X3 | |
| Weigh scale | |
| | |
| ***Ice Pellets Fabrication Equipment*** | |
| Styrofoam containers x20 | |
| Ice bags<br>Blenders (x6)<br>Ice pellets sieves | |
| Folding tables | |
| Scrapers | |

**ATTACHMENT V (cont.)**
**Test Equipment Checklist**

| *TASK*<br>**Test Equipment (cont.)** | *STATUS* |
|---|---|
| | |
| ***Freezing Rain Sprayer Equipment*** | |
| Freezing Rain Sprayer pump | |
| Air Compressors X2 | |
| Water container | |
| Water hoses | |
| Air hoses | |
| Freezing Rain Sprayer nozzles | |
| Needles for the nozzles | |
| Extension cords (heavy duty) | |
| Aluminum rate pans x2 | |
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## ATTACHMENT VI
## Test Procedures

### 1. PRE-TEST SETUP

- Co-ordinate with Ottawa Airport Authority;
- Arrange for security escorts and passes, if required;
- Find video/photo specialist in Ottawa to record behaviour of fluid on the aircraft during the precipitation phase, taxi and simulated takeoff run of the Falcon 20;
- Hotels and advances for APS personnel;
- Arrange for vehicles to transport fluid and ice pellets fabrication and dispersion material;
- Arrange personnel travel to Ottawa;
- Ensure proper functioning of mobile equipment;
- Ensure proper functioning of ice pellets dispersers;
- Ensure proper functioning of freezing rain sprayer;
- Ensure NRC personnel draw grid on aircraft wings;
- Prepare and arrange for transport of equipment to Ottawa;
- Co-ordinate fabrication of ice pellets;
- Ensure the quantity of ice pellets is sufficient for the test;
- Arrange for storage and transportation of ice pellets;
- Order fluids;
- Mark aircraft data collection locations; and
- Collect virgin samples of Type IV fluid for viscosity tests.

### 2. CONTACT LIST

- NRC Flight Research Laboratory: Matthew Bastian (613) 998-3337;
- Security escorts: Harvey Airfield: Doug Harvey (613) 794-6884; and
- Ottawa Airport Authority: Yvon Larochelle (613) 248-2000 ext. 1157.

### 3. CONDUCT TESTS

#### 3.1 Prior to Fluid Application:

- Record OAT, wind speed, direction and sky condition (Attachment IX); and
- Measure wing temperature (Attachment X and XI).

**3.2 Fluid Application (Pour):**

- Pour fluid at NRC hangar;
- Record fluid application times and quantities (Attachment IX);
- Let the fluid settle for 5 minutes;
- Measure thickness and Brix value (Attachment XII and XIII);
- Photograph and videotape the appearance of the fluid on the wing; and
- Collect the excess fluid.

**3.3 Freezing Precipitation Application:**

- Prepare and place rate pan on wing;
- Start the rate collection period;
- Record start of freezing precipitation application;
- Conduct freezing rain application;
- Spread the ice pellets evenly over the test area using the handheld dispenser;
- Measure the fluid freeze points at 2 numbered locations (see Attachments XIV and XV) at 5-minute intervals;
- When the desired level of precipitation has been applied to the wings, the wing observer will call for the end of the precipitation application process;
- Remove rate pans from the wing surface;
- Clean sprayer and prepare it for next run;
- Record quantity of ice pellets dispersed (Attachment IX);
- Record quantity of freezing rain applied (Attachments IX and XVI);
- Measure fluid thickness on the leading edge (Attachment XII and XIII);
- Measure fluid Brix value (Attachment XII and XIII); and
- Photograph and videotape the appearance of the fluid on the wing.

**3.4 Prior to Simulated Takeoff Run (at runway button):**

- Record wing temperatures at the numbered locations (Attachment X and XI);
- Measure fluid thickness (Attachment XII and XIII);
- Measure fluid Brix value (Attachment XII and XIII);
- Record departure runway, wind speed and direction (Attachment IX); and
- Record time of departure (Attachments IX and XIX).

**3.5 During Simulated Takeoff Run:**

- Take still pictures/videotape the behaviour of the fluid on the wing during the takeoff run, capturing any movement of fluid/ice pellets; and
- With a second camera, record readings from the air speed indicator (NRC to perform).

### 3.6 Upon Return to the De-icing Pad:

- Collect Type IV fluid samples from wings (if any) for later viscosity measurement; and
- Observe and record the status of the fluid/ice pellets (Attachment XVII and XVIII).

### 3.7 After Each Test Session

APS personnel will collect the waste solution from the NRC apron. APS will apply EG and PG-based Type IV fluids at different locations on the NRC apron to ensure the waste solutions are properly separated.

### 3.8 Typical Falcon 20 Test: Anticipating Timing

Below is a description of a typical Falcon 20 test, assuming the test starts at 08:00:00.

| APPROX. TIME | TASK |
|---|---|
| 08:00:00 | START OF THE TEST. ALL EQUIPMENT READY. |
| 08:00:00 | Record test conditions (OAT, wind, RH, sky condition, etc). |
| 08:05:00 | Prepare wings for fluid application (clean wing, etc). |
| 08:15:00 | Pour fluid over test area and let settle for 5 minutes |
| 08:15:00 | Start aircraft engines.<br>Pilots follow standard pre-departure procedures |
| 08:20:00 | Measure fluid Brix, thickness.<br>Photograph test area. |
| 08:30:00 | Disperse freezing precipitation over test area. |
| 09:00:00 | Measure Brix, thickness.<br>Photograph test area. |
| 09:20:00 | Aircraft starts to taxi towards runway.<br>Waste fluid collected and pad prepared for next test. |
| 09:30:00 | Aircraft is positioned for the simulated takeoff run.<br>Measure Brix, thickness.<br>Photograph test area. |
| 09:40:00 | Start of the simulated takeoff run. |
| 09:50:00 | Aircraft returns to the deicing pad. |
| 09:50:00 | Measure Brix, thickness.<br>Photograph test area.<br>Record test observations |
| 10:00:00 | END OF TEST |

### 3.9 Typical Falcon 20 Test: Number of People Required

Below is a description of the major steps of a typical Falcon 20 test and the number of people required for each test.

| STEP | TASKS | NO. OF PEOPLE REQUIRED |
|---|---|---|
| 1 | Complete general forms | 1 (APS) |
| | Prepare fluid | 2 (APS) |
| | Prepare IP for test | 2 (IP makers) |
| | Prepare sprayer | 2 (APS) |
| 2 | Pour fluid | 4 (APS) |
| | Refill fluid pouring devices | 2 (APS + IP makers) |
| 3 | Take measurements (temp, thickness, brix) | 2 (APS) |
| | Ready IP dispensers | 2 (APS + IP makers) |
| | Ready ZR sprayer | 2 (APS) |
| 4 | Apply IP | 4 (APS + IP makers) |
| | Apply ZR | 2 (APS) |
| | Assist with ZR application and take measurements | 1 (APS) |
| 5 | Take measurements at hangar | 2 (APS) |
| | Clean sprayer and prepare for next test | 2 (APS) |
| | Prepare fluid for next test | 2 (APS + IP makers) |
| 6 | Take measurements at button and record test results | 2 (APS) |

## ATTACHMENT VII
## APS Staff Task Description

***Overall Co-ordinator (JD)***

- Co-ordinate tests with NRC, TDC;
- Advise all other agencies, including security; and
- Provide direction as required during the tests.

***Co-ordinator 1 (GB)***

- Ensure that all required equipment is available and functional;
- Maintain General Form for every test (Attachment IX);
- Ensure all data are collected and recorded, and that all test records submitted;
- Measure temperature of the wing (Attachment X and XI) and Brix (Attachments XII, XIII, XIV and XV);
- Pour fluid over test area;
- Disperse ice pellets over the test area using the handheld disperser;
- Note the observed wing condition after each run (Attachment XIV); and
- Communicate safety concerns.

***Co-ordinator 2 (MR)***

- Pour fluid over test area;
- Measure thickness measurements (Attachments XI);
- Disperse ice pellets over the test area using the handheld disperser; and
- Note the observed wing condition after each run (Attachment XIV);

***Freezing Rain Sprayer Application (NB/DP/DY)***

- Ensure the proper operation of the sprayer;
- Calibrate the sprayer prior to the test session;
- Apply freezing rain as required for each test; and
- Clean the sprayer and prepare it for the next test.

***Data collection (DP/DY)***

- Complete the Fluid Receipt Form (Attachment VIII) for each fluid;

- Record temperature measurements (Attachment X and XI);
- Record Brix and thickness measurements (Attachment XII and XIII);
- Record start and end of fluid application (Attachment IX);
- Record start and end of freezing precipitation application (Attachment IX);
- Record amount of ice pellets applied (Attachment IX);
- Record quantity of freezing rain applied (Attachment XVI);
- Collect samples of fluid for viscosity tests:
  - Virgin Type IV prior to application;
  - Type IV fluid on wing applied by pouring;
  - Type IV fluid remaining on trailing edge following takeoff run; and
  - Record the specifics for each sample on the bottle in permanent marker.

***Videographer/Photographer (from Ottawa)***

- Ensure time stamps are operating and accurately set;
- Videotape fluid on wing "before and after" each run and during takeoff run, ensuring constant viewing angles are used, to facilitate comparisons; and
- Photograph all test set-up, outside and onboard the aircraft; and
- Photograph the condition of wing with ice pellets at specified times.

***Ice Pellets Makers (4 persons from Ottawa)***

- Responsible for the fabrication of ice pellets;
- One ice pellet maker will operate the blender;
- One ice pellet maker will filter the crushed ice; and
- Assist with the ice pellet application.

***Ice Pellets Co-ordinator (JT)***

- Supervise the production of ice pellets;
- Supply the ice pellet makers with raw ice;
- Ensure that the quantity of ice pellets produced is sufficient for the test requirements;
- Ensure proper storage of ice pellets and raw ice;
- Transport ice pellets to the test site; and
- Assist with ice pellets application

### *Falcon 20 Observer*

- One person seated inside the Falcon 20 during tests will keep a time record of operations (Attachment XV).

*APPENDIX C*

## ATTACHMENT VIII: Fluid Receipt Form

| RECEIVING LOCATION: | DATE OF RECEIVING: | SAMPLE COLLECTED FROM BARREL: Y / N |
|---|---|---|

## GENERAL

**Fluid Name:** _____

**Manufacturer:** _____ **Fluid Type:** ____ **Batch #:** _____

**APS Code:** _____

**Certificates of Conformance acc. to SAE AMS 1424:** ☐ (check the box if received)

**Fluid Freeze Point Curves (FP vs. Dilution & FP vs. Refraction):** ☐ (for Type I Fluids only; check the box if received)

**Lowest Operational Use Temperature:** ☐ (check the box if received)

**WSET Done by the Certification Agency:** ☐ (check the box if received)

**Date of Production:** _____ **Quantity:** ___ , ___ , ___ (L) **Fluid Dilution:** _____ (100/75/50 or Neat)(%)

**Manufacturer stated BRIX:** _____ **APS Measured BRIX:** _____ **MSDS Sheets Received:** ☐

**Manufacturer's Authorization to Proceed with Endurance Time Testing:** ☐ (check the box if received) **Authorized by:** _____ (PRINT NAME)

**on:** _____ (DATE)

## TYPE IV FLUIDS

**Manufacturers stated VISCOSITY:** _____ mPa*s (cP) (VALUE)

**APS Measured VISCOSITY:** _____ mPa*s (cP) **Using Manufacturer's Method** (VALUE)

Viscosity shall be determined using the same Brookfield spindle/sample size combination as used for the AMS 1428 certification (most current).

*APPENDIX C*

## ATTACHMENT IX: General Form (Every Test)

DATE: _____ AIRCRAFT TYPE: Falcon 20

RUN #: _____ AIRPORT: YOW

OAT BEFORE TEST: _____ (°C) OPERATOR: NRC

WIND SPEED / DIRECTION: _____ FIN #: _____

EXACT PAD LOCATION OF TEST: _____ FUEL LOAD: _____

FLUID APPLIED: _____ DIRECTION OF AIRCRAFT: _____ degrees

FLUID BRIX: _____ DRAW DIRECTION OF WIND WRT AIRCRAFT



| *FLUID APPLICATION - PORT / STARBOARD WING* | | | |
|---|---|---|---|
| ACTUAL START TIME: | / | ACTUAL END TIME: | / |
| FLUID TEMPERATURE | (°C) | AMOUNT OF FLUID: | / |
| FLUID APPLICATION METHOD: | | | |
| *ICE PELLETS APPLICATION - PORT / STARBOARD* | | *PHOTOGRAPH SAMPLE ( )* | |
| ACTUAL START TIME: | / | ACTUAL END TIME: | / |
| QUANTITY OF ICE PELLETS APPLIED | / kg | ICE PELLETS SIZE: | |
| *CONTAMINANT SPRAY APPLICATION - PORT / STARBOARD* | | | |
| ACTUAL START TIME: | / | ACTUAL END TIME: | / |
| QUANTITY OF PRECIPITATION APPLIED | / kg | | |

OAT AFTER TEST: _____ (°C) COMMENTS: _____

SKY CONDITIONS: _____

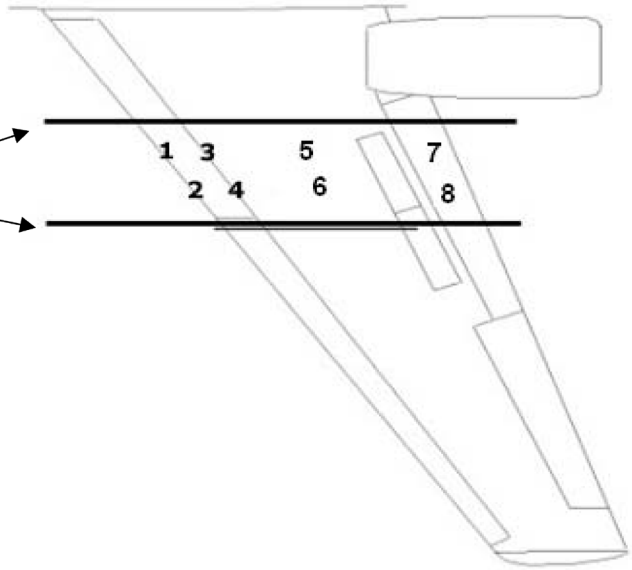
MEASUREMENTS BY: _____ HANDWRITTEN BY: _____

*APPENDIX C*

## ATTACHMENT X: Wing Temperature Form (Port Wing)

Date: _____ Time: _____ Run Number: _____

Test Phase: A- Before Fluid Application ☐ B- After Contamination ☐ C- Before Takeoff Run ☐ D- After Takeoff Run ☐




**Skin Temperature**
Record temperature and time at the positions indicated on the diagram

| Position | Time | Temp (°C) |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |

Comments: _____

**OBSERVER:** _____

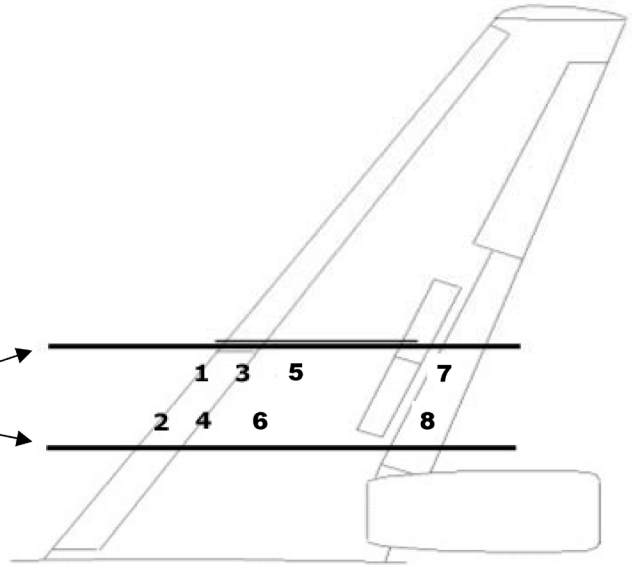
**ASSISTED BY:** _____

*APPENDIX C*

## ATTACHMENT XI: Wing Temperature Form (Starboard Wing)

Date: _____ Time: _____ Run Number: _____

Test Phase: A- Before Fluid Application ☐ B- After Contamination ☐ C- Before Takeoff Run ☐ D- After Takeoff Run ☐




**Skin Temperature**
Record temperature and time at the positions indicated on the diagram

| Position | Time | Temp (°C) |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |

Comments: _____

**OBSERVER:** _____

**ASSISTED BY:** _____

*APPENDIX C*

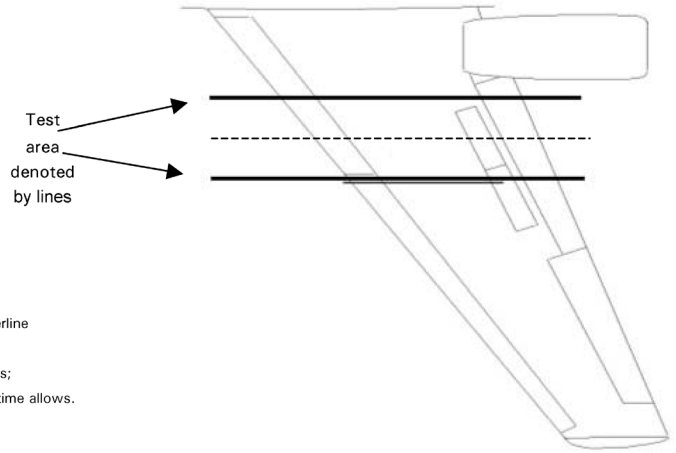
## ATTACHMENT XII: Fluid Thickness and Brix (Port Wing)

Date: _____ Run Number: _____

| FLUID THICKNESS | | | | |
|---|---|---|---|---|
| Wing Position | After fluid application | After Precip Application | Before Takeoff Run | After Takeoff Run |
| 1 | | | | |
| 2 | | | | |
| 5 | | | | |
| 7 | | | | |
| 8 | | | | |
| TIME | | | | |

| FLUID BRIX | | | | | | | |
|---|---|---|---|---|---|---|---|
| After Fluid Application (lead./trail.) | Wing Position | After Precip App. (lead./trail.) | Wing Position | Before Takeoff Run (lead./trail.) | Wing Position | After Takeoff Run (lead./trail.) | Wing Position |
| | | | | | | | |
| | | | | | | | |
| Time: | | time: | | time: | | time: | |




Location: 1 - LE nose
2,8 - Halfway
3,4,6,7 - 1" form joint
5 - As far as can reach
9 - 6" from TE

Notes: - Measure thickness along centerline indicated in the diagram.
- Give priority to circled locations; measure other locations only if time allows.

Comments: _____

**OBSERVER:** _____
**ASSISTED BY:** _____

*APPENDIX C*

## ATTACHMENT XIII: Fluid Thickness and Brix (Starboard Wing)

Date: _____ Run Number: _____

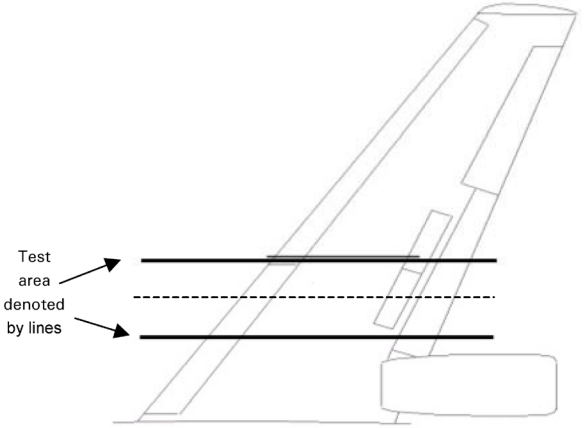
| FLUID THICKNESS | | | | |
|---|---|---|---|---|
| Wing Position | After fluid application | After Precip Application | Before Takeoff Run | After Takeoff Run |
| 1 | | | | |
| 2 | | | | |
| 5 | | | | |
| 7 | | | | |
| 8 | | | | |
| TIME | | | | |

| FLUID BRIX | | | | | | | |
|---|---|---|---|---|---|---|---|
| After Fluid Application (lead./trail.) | Wing Position | After Precip App. (lead./trail.) | Wing Position | Before Takeoff Run (lead./trail.) | Wing Position | After Takeoff Run (lead./trail.) | Wing Position |
| | | | | | | | |
| | | | | | | | |
| Time: | | time: | | time: | | time: | |



Location: 1 - LE nose
2,8 - Halfway
3,4,6,7 - 1" form joint
5 - As far as can reach
9 - 6" from TE

Notes: - Measure thickness along centerline indicated in the diagram.
- Give priority to circled locations; measure other locations only if time allows.




Comments: _____

**OBSERVER:** _____
**ASSISTED BY:** _____

*APPENDIX C*

## ATTACHMENT XIV: Fluid Freeze Point Measurements on Wing (Port Wing)

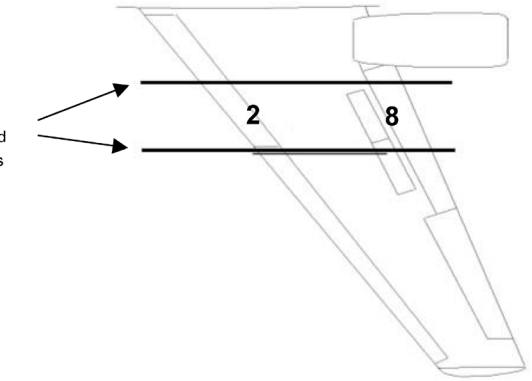
Date: _____ Run Number: _____ Fluid: _____

| Location | Time | Brix | Time | Brix | Time | Brix | Time | Brix | Time | Brix | Time | Brix | Time | Brix | Time | Brix |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | |

| UCAR ULTRA+ | |
|---|---|
| FFP (°C) | Brix |
| -2 | 5.6 |
| -4 | 8.8 |
| -6 | 11.2 |
| -8 | 13.3 |
| -10 | 15.1 |
| -12 | 16.8 |
| -14 | 18.3 |
| -16 | 19.7 |

| KILFROST ABC-S | |
|---|---|
| FFP (°C) | Brix |
| -2 | 5 |
| -4 | 8 |
| -6 | 12.5 |
| -8 | 17 |
| -10 | 19.3 |
| -12 | 22 |
| -14 | 23.5 |
| -16 | 25.5 |

Test area denoted by lines




Comments: _____

**OBSERVER:** _____

**ASSISTED BY:** _____

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Final Draft 1.0, January 08

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*APPENDIX C*

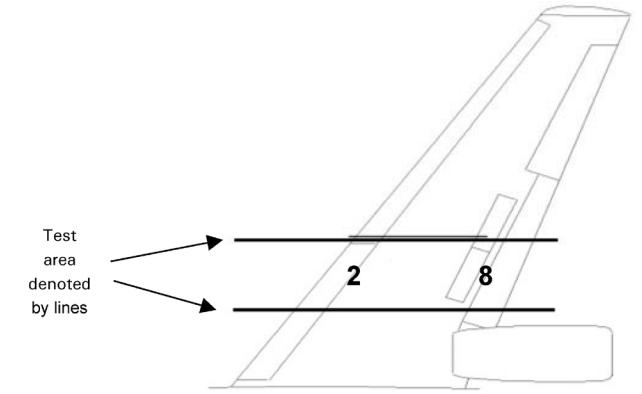
## ATTACHMENT XV: Fluid Freeze Point Measurements on Wing (Starboard Wing)

Date: _____ Run Number: _____ Fluid: _____

| Location | Time | Brix | Time | Brix | Time | Brix | Time | Brix | Time | Brix | Time | Brix | Time | Brix | Time | Brix |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | |

| UCAR ULTRA+ | |
|---|---|
| FFP (°C) | Brix |
| -2 | 5.6 |
| -4 | 8.8 |
| -6 | 11.2 |
| -8 | 13.3 |
| -10 | 15.1 |
| -12 | 16.8 |
| -14 | 18.3 |
| -16 | 19.7 |

| KILFROST ABC-S | |
|---|---|
| FFP (°C) | Brix |
| -2 | 5 |
| -4 | 8 |
| -6 | 12.5 |
| -8 | 17 |
| -10 | 19.3 |
| -12 | 22 |
| -14 | 23.5 |
| -16 | 25.5 |




Comments: _____

**OBSERVER:** _____

**ASSISTED BY:** _____

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Final Draft 1.0, January 08

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*APPENDIX C*

## ATTACHMENT XVI: Freezing Rain/Snow Quantity Form

DATE: _____

RUN #: _____

| Time Before | Time After | Run | ZR- or Snow | Container Weight (kg) | |
|---|---|---|---|---|---|
| | | | | Before | After |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
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| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

COMMENTS: _____

_____

_____

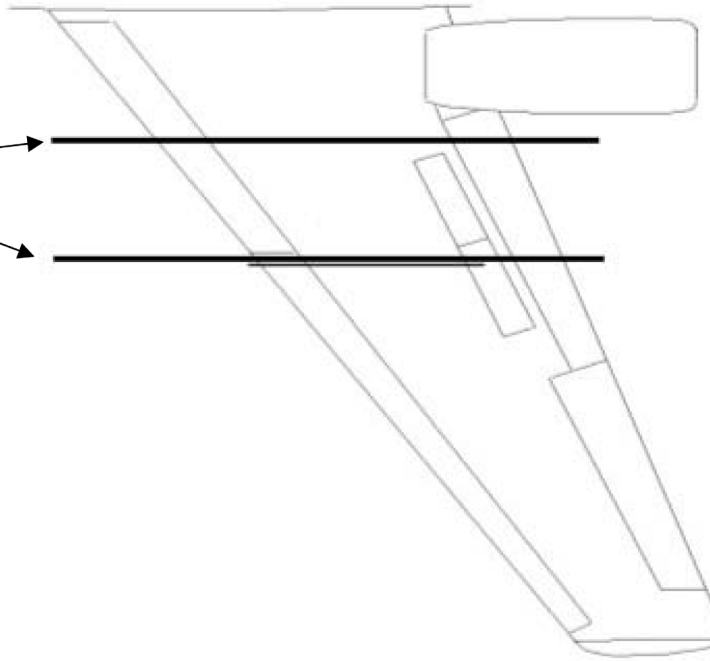
_____

MEASUREMENTS BY: _____

HANDWRITTEN BY: _____

## ATTACHMENT XVII: Test Results Form (Port Wing)

Date: _____ Time: _____ Run Number: _____



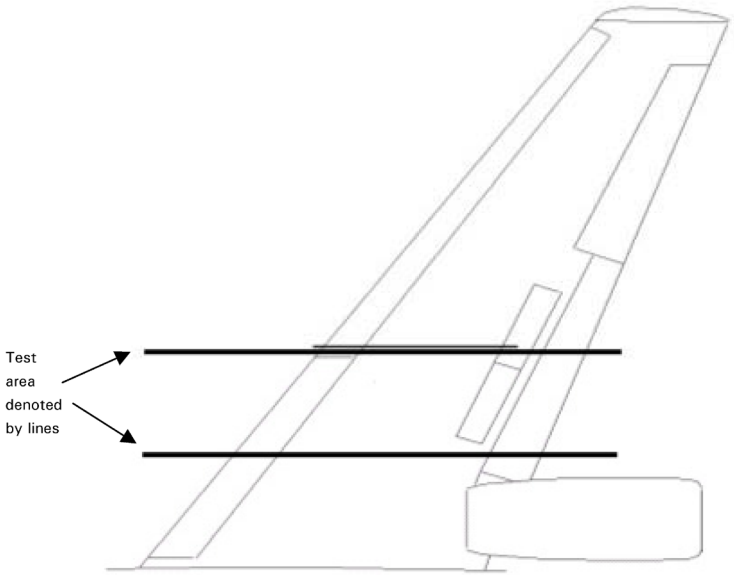

Observations:

**OBSERVER:** _____

**ASSISTED BY:** _____

## ATTACHMENT XVIII: Test Results Form (Starboard Wing)

Date: _____ Time: _____ Run Number: _____




Observations: _____

**OBSERVER:** _____

**ASSISTED BY:** _____

## ATTACHMENT XX: Time Record of Operations

**Run Number** _____ **Date** _____ **OBSERVER**_____

| OPERATION | TIME / OBSERVATION |
|---|---|
| Pilots Board | |
| Start Engines | |
| Systems Ready | |
| Measure Test Conditions (OAT, Sky Cond, etc) | |
| Fluid Application Start (Port / Starboard) | |
| Fluid Application Completed (Port / Starboard) | |
| Measure Fluid Thickness Brix and Temperature | |
| Start Pellet and ZR Application (Port/Starboard) | |
| Complete Pellet and ZR Application (Prt/Strbrd) | |
| Measure Fluid Thickness Brix and Temperature | |
| Close Door | |
| Ready to Roll | |
| Start Taxi | |
| Arrive Runway Hold | |
| Door Open | |
| Measure Fluid Thickness Brix and Temperature | |
| Door Closed | |
| Taxi to Take Off | |
| Start Cameras | |
| Start Take Off Roll | |
| End Acceleration | |
| End Take Off Roll | |
| Look for Remaining Contamination and Record | |
| Arrive at Hanger | |
| Engine Shut Down | |
| Door Open | |
| Measure Fluid Thickness Brix and Temperature | |

## ATTACHMENT XX: Nominal Test Conditions

| TEST NO | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Date | | | | | |
| Fluid | | | | | |
| Precipitation (PORT / STARBOARD) | / | / | / | / | / |
| Pellets size [mm] | | | | | |
| Dyed Pellets | | | | | |
| **PORT WING:** | - | - | - | - | - |
| Effective IP Rate [g/dm$^2$/h] | | | | | |
| Total Pellet Weight Applied [kg] | | | | | |
| Effective ZR Rate [g/dm$^2$/h] | | | | | |
| Quantity of water applied [kg] | | | | | |
| Brix after precipitation application | | | | | |
| **STARBOARD WING:** | - | - | - | - | - |
| Effective IP Rate [g/dm$^2$/h] | | | | | |
| Total Pellet Weight Applied [kg] | | | | | |
| Effective ZR Rate [g/dm$^2$/h] | | | | | |
| Quantity of water applied [kg] | | | | | |
| Brix after precipitation application | | | | | |
| Remarks | | | | | |

**APPENDIX D**

**GLYCOL MITIGATION PLAN**

**GLYCOL MITIGATION PLAN**

**APS AVIATION INC.**

**FALCON 20 TRIALS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH ICE PELLETS OTTAWA, ONTARIO (YOW) FEBRUARY 26 – MARCH 2, 2007**

## 1. CORPORATE PROFILE

APS Aviation Inc. (APS), member of the ADGA Group of companies, is a worldwide leader in aircraft de-icing research and development. Since 1990, APS has been contracted by the Transportation Development Centre (TDC) of Transport Canada to further advance aircraft pre-flight de/anti-icing technology.

## 2. BACKGROUND

At the request of the TDC of Transport Canada, APS has undertaken a research program to examine the potential aerodynamic penalties resulting from the presence of clean and diluted anti-icing fluid on aircraft wings.

Previous trials to examine the aerodynamic elimination of failed Type IV fluid from aircraft wings during takeoff were conducted on behalf of Transport Canada during the 1997-98 and 1998-99 and winter seasons at Mirabel Airport. Those trials, based on simulated takeoff runs using a National Research Council Falcon 20 aircraft, provided an improved understanding of the subject matter and demonstrated that the selected test approach was a viable one.

During the winter of 2001-02 and 2002-03, flight tests were performed at Ottawa International Airport (YOW). Tests were performed with one ethylene glycol-based Type IV fluid, Dow Ultra+, in neat and diluted form. Fluid was applied at the central de-icing pad at YOW by GlobeGround personnel.

The effects of (simulated) ice pellets mixed with freezing rain on the wing of Falcon 20 aircraft during takeoff are currently studied. Since the precipitation embedded in the fluid was not adhering according to previous tests, it is not known whether this contamination in the fluid would come off during aircraft rotation. As a result, the FAA has issued a notice that prevents operations from departing in ice pellets/freezing rain mixed precipitation conditions.

The February-March 2007 tests at YOW will address the effects of deicing fluid contaminated with ice pellets and/or freezing rain that the airflow at takeoff fails to remove.

This document describes the glycol mitigation plan for the planned tests as follows:

- The fluid application procedures;
- The locations designated for fluid application;
- The anticipated fluid quantities to be sprayed; and
- The fluid recovery plan.

## 3. FLUID APPLICATION PROCEDURES

In February-March 2007, tests will be conducted at YOW with ethylene and propylene glycol-based Type IV fluids.

APS personnel are highly experienced in aircraft deicing matters, and attempts will be made to limit the quantities of fluid applied to the aircraft. The fluids will be applied to a 2.7 square-meter section of the aircraft wings by pouring, thus limiting the amount of fluid that falls on the ground after application.

In previous tests conducted at YOW in March 2006 ethylene and propylene fluids were applied over the same 2.7 square-meter section. In total, 60 liters of ethylene fluid and 100 liters of propylene fluid were used for the entire test session. All deicing fluid that fell to the ground within the application area was properly recovered.

The fluid application will be performed by APS personnel at the NRC pad.

All Type IV fluids will be applied unheated to the wings of the Falcon 20. No Type I fluid will be applied prior to the Type IV.

## 4. LOCATIONS DESIGNATED FOR FLUID APPLICATION

The fluid application will be performed by APS personnel at the NRC pad.

Fluid applications at the NRC pad will be conducted in close proximity to the NRC hangar. Two separate areas will be assigned, one for ethylene applications, the other for propylene applications. NRC personnel will determine the precise locations prior to testing. The aircraft will not be

positioned near the stormwater catch basins located on the southern edge of the NRC apron.

## 5. ANTICIPATED FLUID QUANTITIES TO BE SPRAYED

Six tests are anticipated for February-March 2007 at YOW. Of this total, four will be performed with Dow Ultra+ (ethylene) and two will be performed with Kilfrost ABC-S (propylene).

Based on preliminary testing, the estimated maximum amount of fluid required for the conduct of these tests will be 240 liters (160 of ethylene glycol and 80 of propylene glycol base). Of this quantity, roughly 20% falls to the ground immediately following application.

## 6. FLUID RECOVERY PLAN

The method of application, pouring, minimizes the fluid that is applied to the wing section and the fluid falling on the ground immediately after application. APS personnel will collect the excess fluid immediately after application using fluid collection containers, tarps and a powerful vacuum.

The waste solutions will be recovered and stored separately to prevent cross-contamination of the products. APS will incur the costs of these fluid recovery services.

## 7. ADDITIONAL REPORTS

Upon request, a report will be provided by APS to the airport authority following the conduct of tests at YOW to provide the quantities of fluid used in testing.

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## APPENDIX E

## END CONDITION OF WING AND PLATE DATA FORMS

# APPENDIX E

# END CONDITION OF WING AND PLATE DATA FORMS

## INDEX

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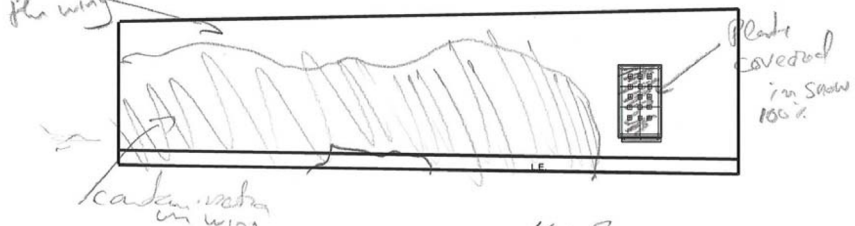
E-2

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

**Attachment VII – Condition of Wing and Plate Form**

Date: FEB 16 07 Run Number: 55 1

**Wing and Plate Condition Before the Takeoff Run (Time 16:00 )**




**Wing Condition After the Takeoff Run (Time: 16:30 )**




Observations: MR: Plate failure after 37 min
MR: Bridging failure after 48 min (15:42)

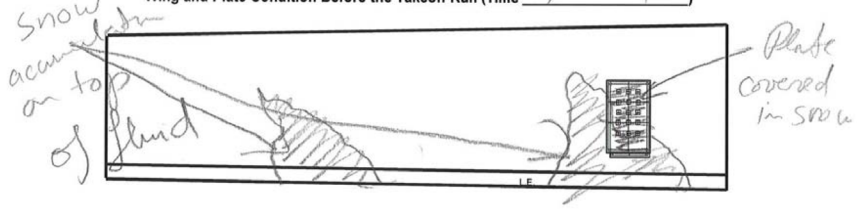
OBSERVER: _____ ASSISTED BY: _____

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

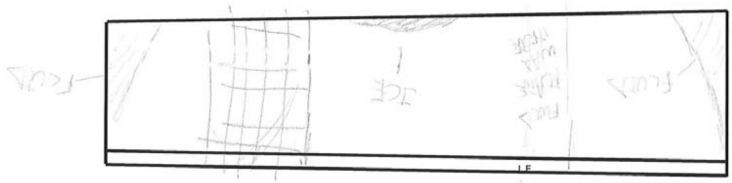
**Attachment VII – Condition of Wing and Plate Form**

Date: 16 FEB 07 Run Number: SS 2

**Wing and Plate Condition Before the Takeoff Run (Time 17:44)**




**Wing Condition After the Takeoff Run (Time: 18:20)**




Observations: MR: Plate fouled @ 17:19
MR: No adherence @ 17:41
→ Wing generally clean after test

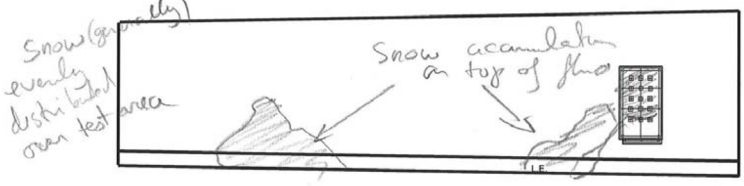
OBSERVER: _____ ASSISTED BY: _____

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

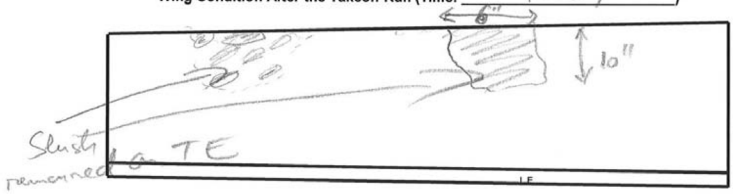
**Attachment VII – Condition of Wing and Plate Form**

Date: FEB 19, 07 Run Number: SS3

**Wing and Plate Condition Before the Takeoff Run (Time 12:12 )**




**Wing Condition After the Takeoff Run (Time: 12:49 )**




Observations: Plate failure after 11 min

After test. – LE clean
– Slush remained on TE
(see diagram above)

OBSERVER: _____ ASSISTED BY: _____

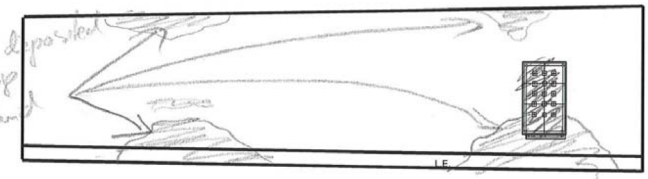
*WIND TUNNEL TESTS TO EXAMINE FLUID REMOVED FROM AIRCRAFT DURING TAKEOFF WITH ICE PELLETS*

**Attachment VII – Condition of Wing and Plate Form**

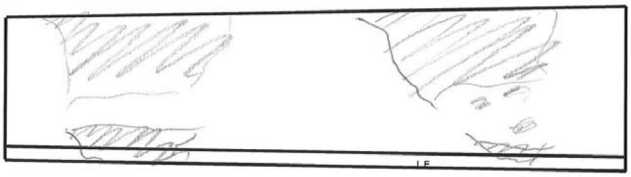
Date: FEB 19, 07 Run Number: SS4

**Wing and Plate Condition Before the Takeoff Run (Time 14:35 )**

Snow deposited on top of fluid




**Wing Condition After the Takeoff Run (Time: )**




Observations: 14:19:30 = Plate failed

Contamination present in the indicated locations after run

No adhesion @ end of test

OBSERVER: ASSISTED BY:

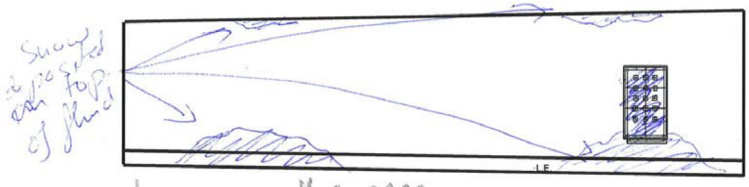
Cont. could be removed by blowing air over wing → near adhesion

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

**Attachment VII – Condition of Wing and Plate Form**

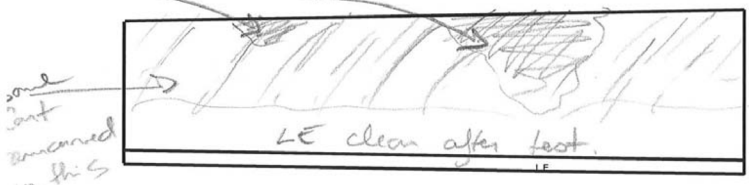
Date: 19 FEB 02 Run Number: SS5

**Wing and Plate Condition Before the Takeoff Run (Time 17 00 )**




Heavy cont remaining in this area

**Wing Condition After the Takeoff Run (Time: 17.36 )**




Observations: Plate fouled @ 16:41

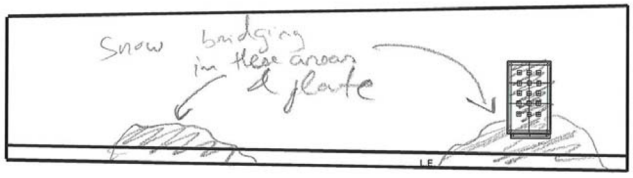
OBSERVER: _____ ASSISTED BY: _____

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

**Attachment VII – Condition of Wing and Plate Form**

Date: 19 FEB 07 Run Number: 556

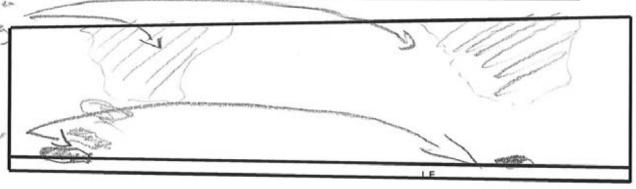
**Wing and Plate Condition Before the Takeoff Run (Time 18:31)**




**Wing Condition After the Takeoff Run (Time: 18:56)**

Contamination remaining on TE after test

Contamination on LE after test




Observations: Fail time 18:24
• Bridging on LE occurred at approx the same time the plate failed

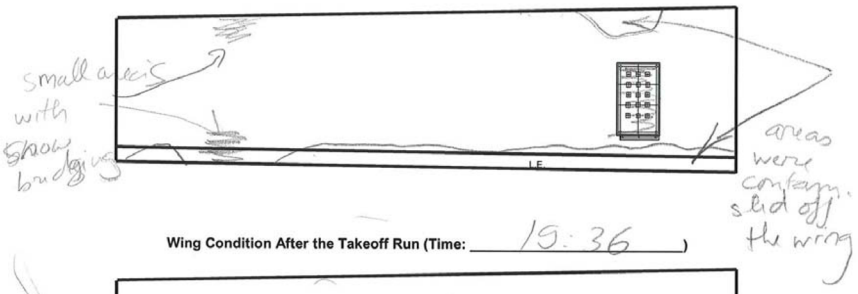
OBSERVER: _____ ASSISTED BY: _____

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

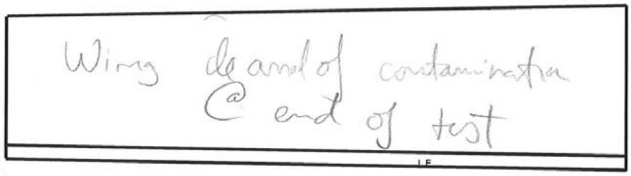
**Attachment VII – Condition of Wing and Plate Form**

Date: 20 FEB 07 Run Number: 557

**Wing and Plate Condition Before the Takeoff Run (Time 19.10)**




**Wing Condition After the Takeoff Run (Time: 19:36)**




Observations: Plate failure @ 18:55

OBSERVER: _____ ASSISTED BY: _____

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**APPENDIX F**

**FALCON 20 TEST RESULTS DATA FORMS**

# FALCON 20 TEST RESULTS DATA FORMS

## INDEX

Test 1P ..... F-3
Test 1S ..... F-4

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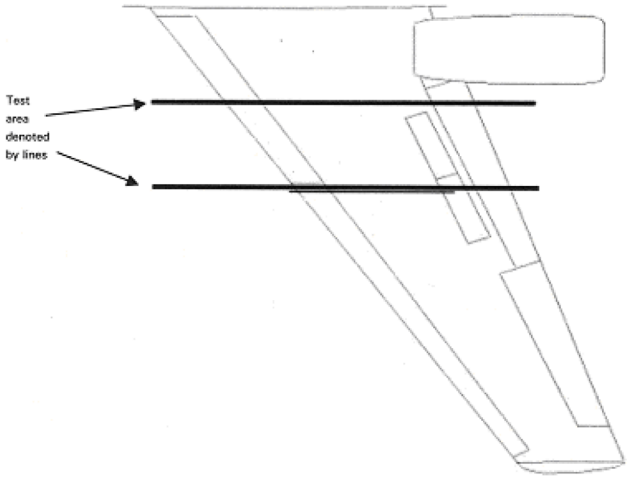
Form 7A

**TEST RESULTS FORM (PORT WING)**

Date: 27Feb07 Time: _____ Run Number: 1P




Observations:

Wing dea
after test

**OBSERVER:** _____

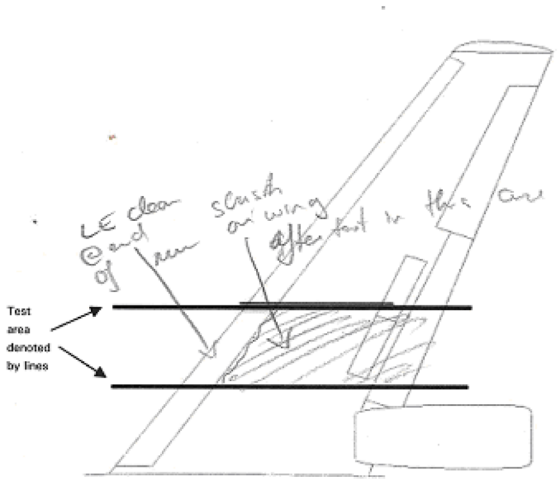
**ASSISTED BY:** _____

M:\Groups\PM2020 (TC-Deicing 06-07)\Procedures\Data Forms\Falcon Form 7A - Test Results Form
2/23/2007

Form 7B

**TEST RESULTS FORM (STARBOARD WING)**

Date: 27 FEB 02 Time: _____ Run Number: 15




Observations:

OBSERVER: _____

ASSISTED BY: _____

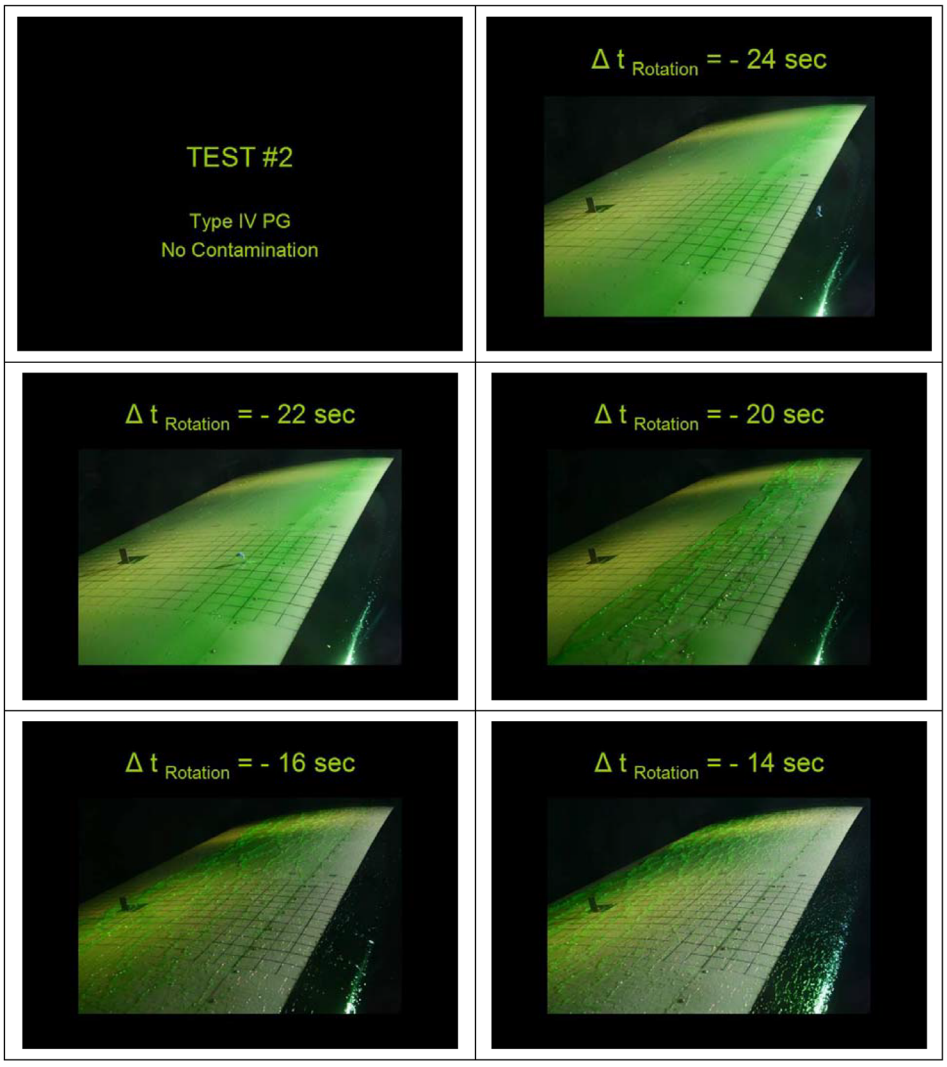
M:\Groups\PM2020 (TC-Deicing 06-07)\Procedures\Data Forms\Falcon Form 7B - Test Results Form (Starboard)
2/23/2007

# APPENDIX G

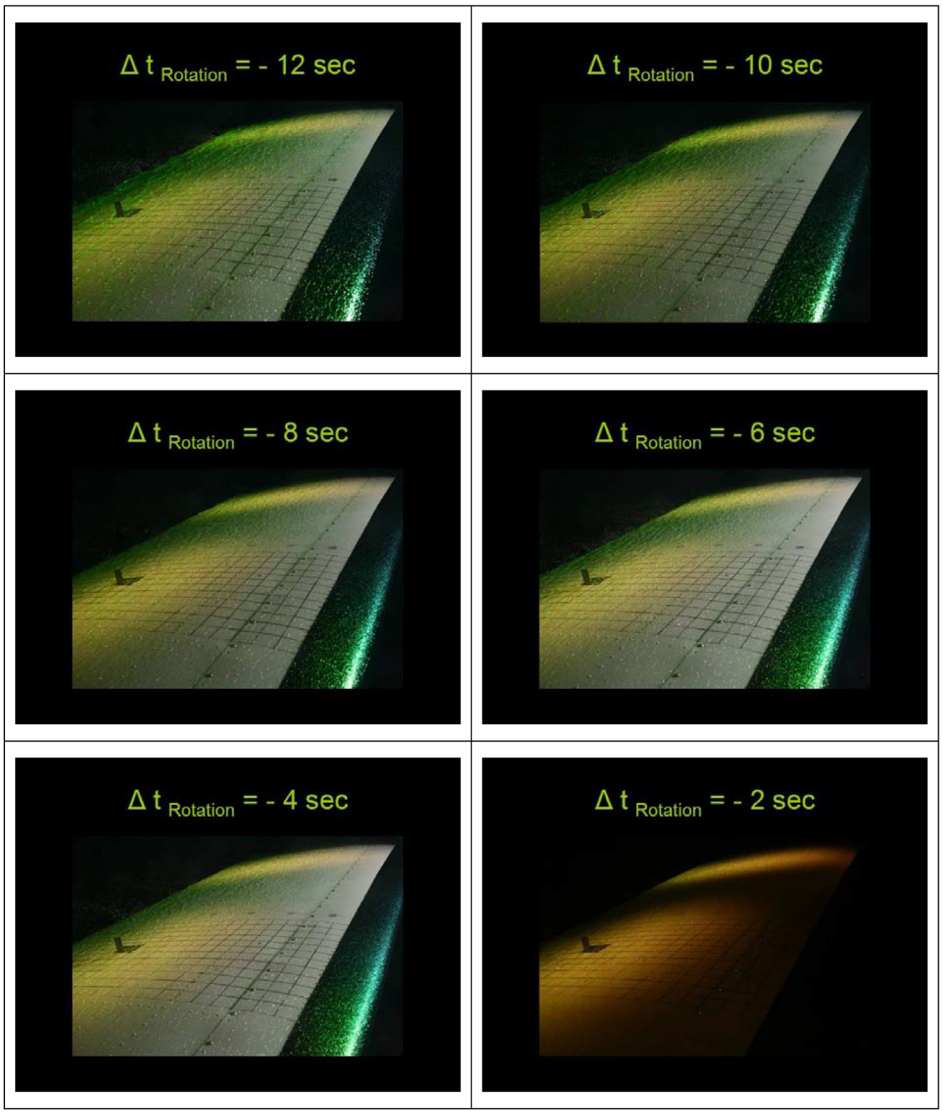
# PHOTO DOCUMENTATION OF TESTS 2 AND SS6 OF WIND TUNNEL TESTS

**PHOTO DOCUMENTATION OF TEST 2**

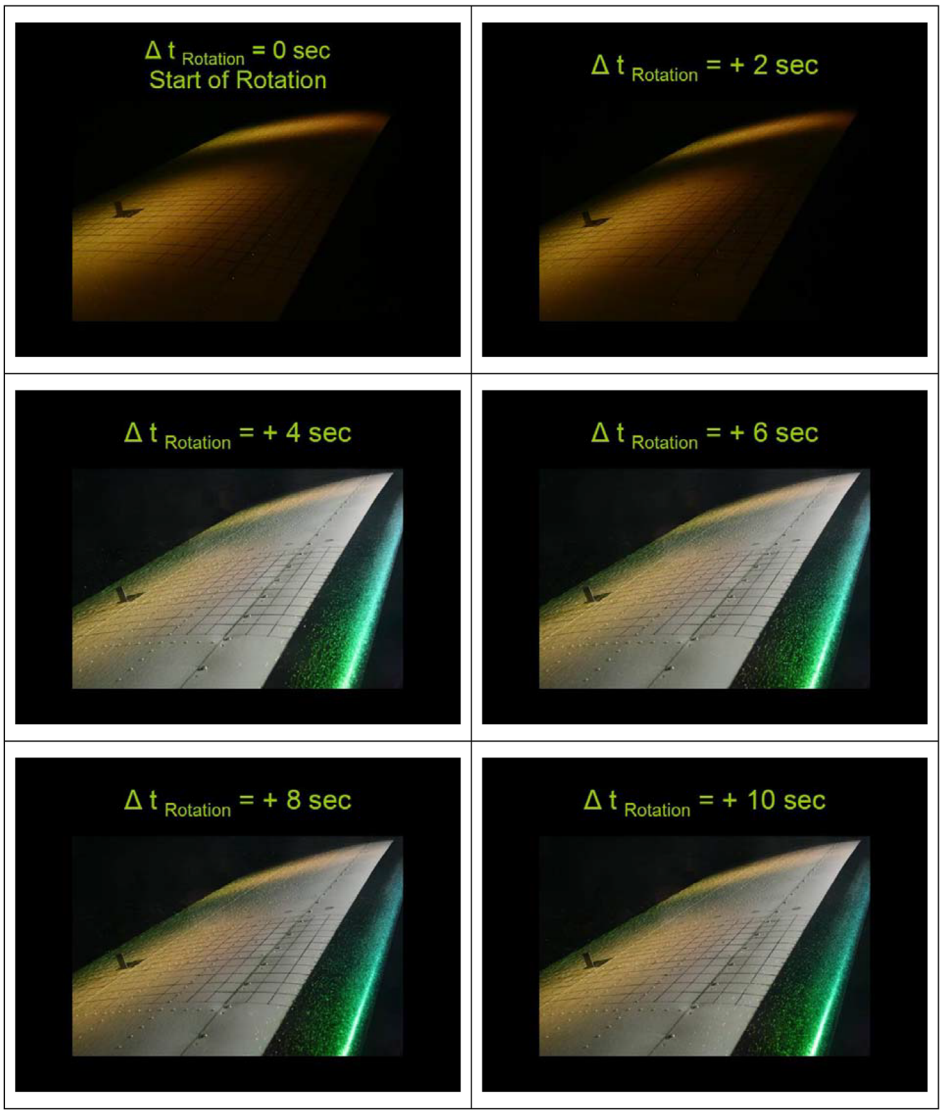
APPENDIX G


TEST #2
Type IV PG
No Contamination
Δ t Rotation = - 24 sec
Δ t Rotation = - 22 sec
Δ t Rotation = - 20 sec
Δ t Rotation = - 16 sec
Δ t Rotation = - 14 sec

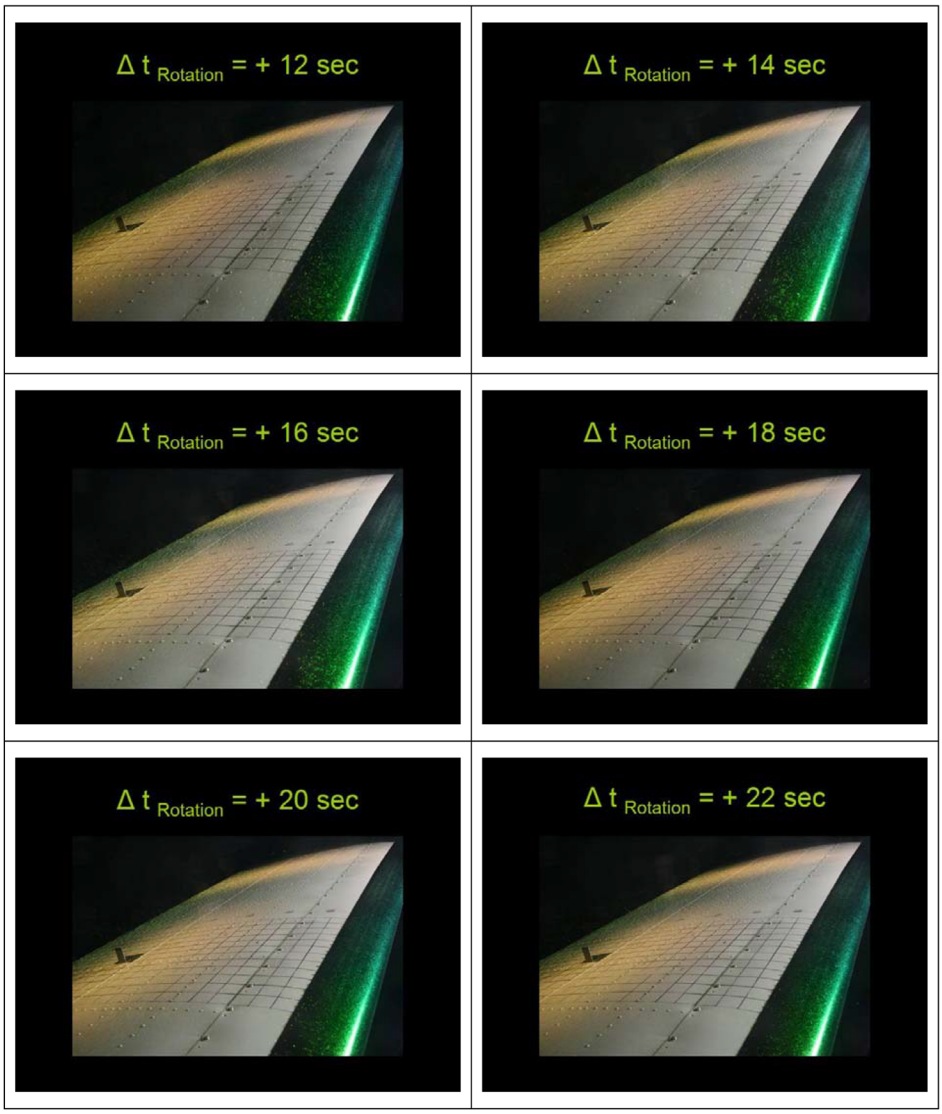
APPENDIX G


Δ t Rotation = - 12 sec
Δ t Rotation = - 10 sec
Δ t Rotation = - 8 sec
Δ t Rotation = - 6 sec
Δ t Rotation = - 4 sec
Δ t Rotation = - 2 sec

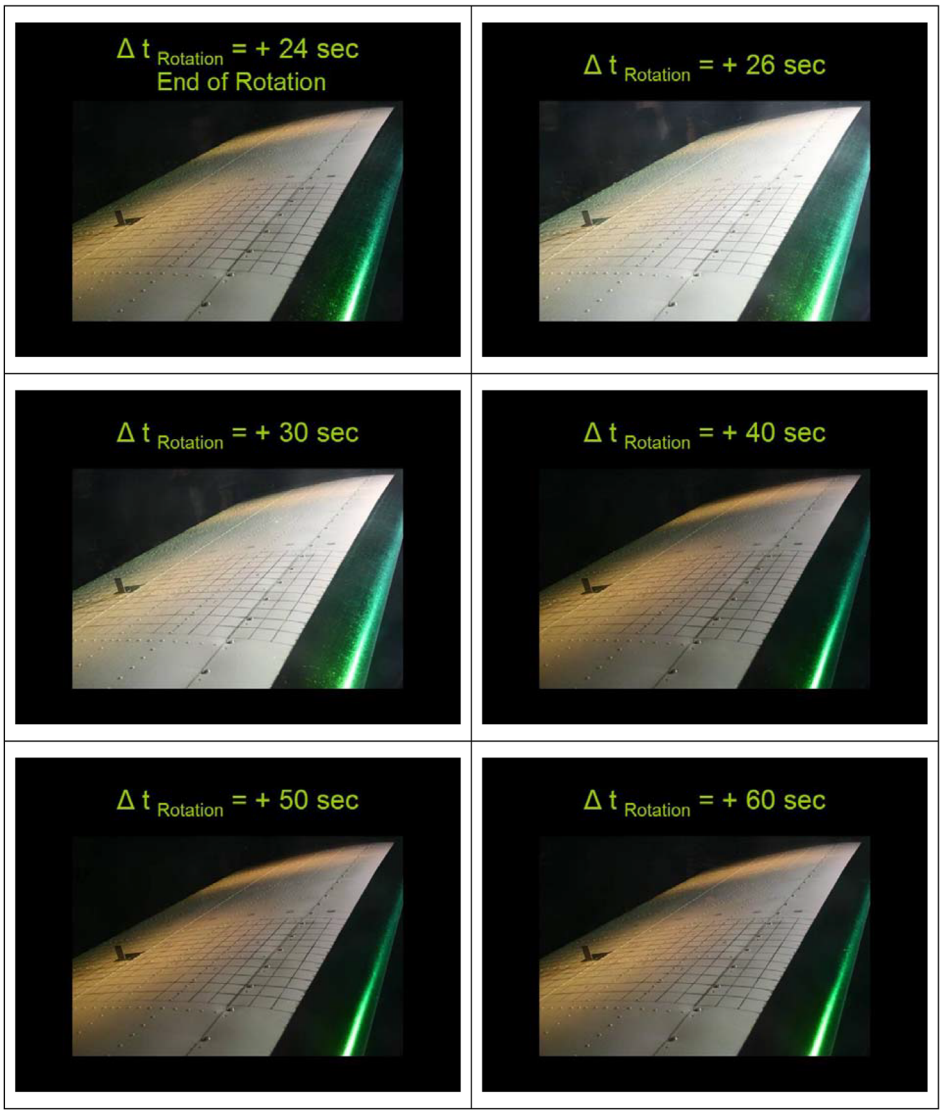
APPENDIX G


Δ t Rotation = 0 sec
Start of Rotation
Δ t Rotation = + 2 sec
Δ t Rotation = + 4 sec
Δ t Rotation = + 6 sec
Δ t Rotation = + 8 sec
Δ t Rotation = + 10 sec

APPENDIX G


Δ t Rotation = + 12 sec
Δ t Rotation = + 14 sec
Δ t Rotation = + 16 sec
Δ t Rotation = + 18 sec
Δ t Rotation = + 20 sec
Δ t Rotation = + 22 sec

APPENDIX G


Δ t Rotation = + 24 sec
End of Rotation
Δ t Rotation = + 26 sec
Δ t Rotation = + 30 sec
Δ t Rotation = + 40 sec
Δ t Rotation = + 50 sec
Δ t Rotation = + 60 sec

APPENDIX G

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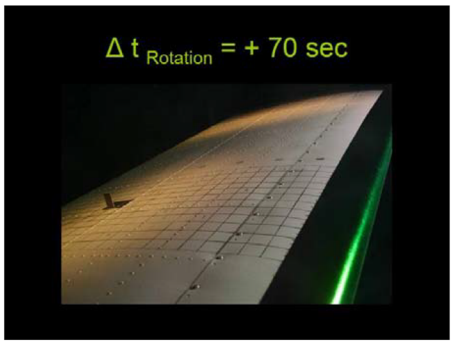
<td> 
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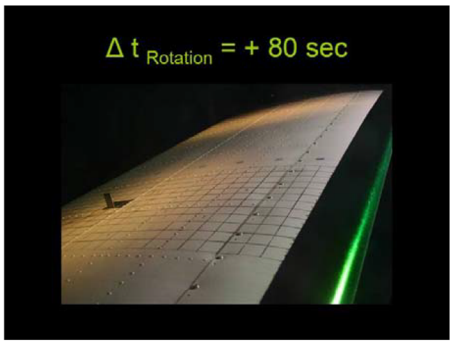
<td> 
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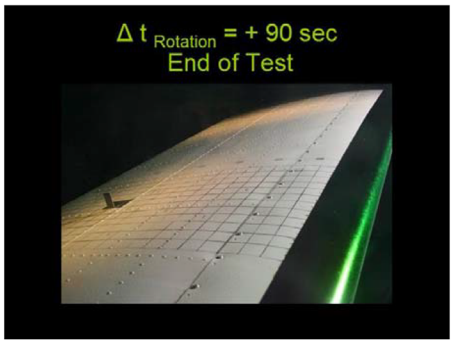
<td> 
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**PHOTO DOCUMENTATION OF TEST SS6**

G-7

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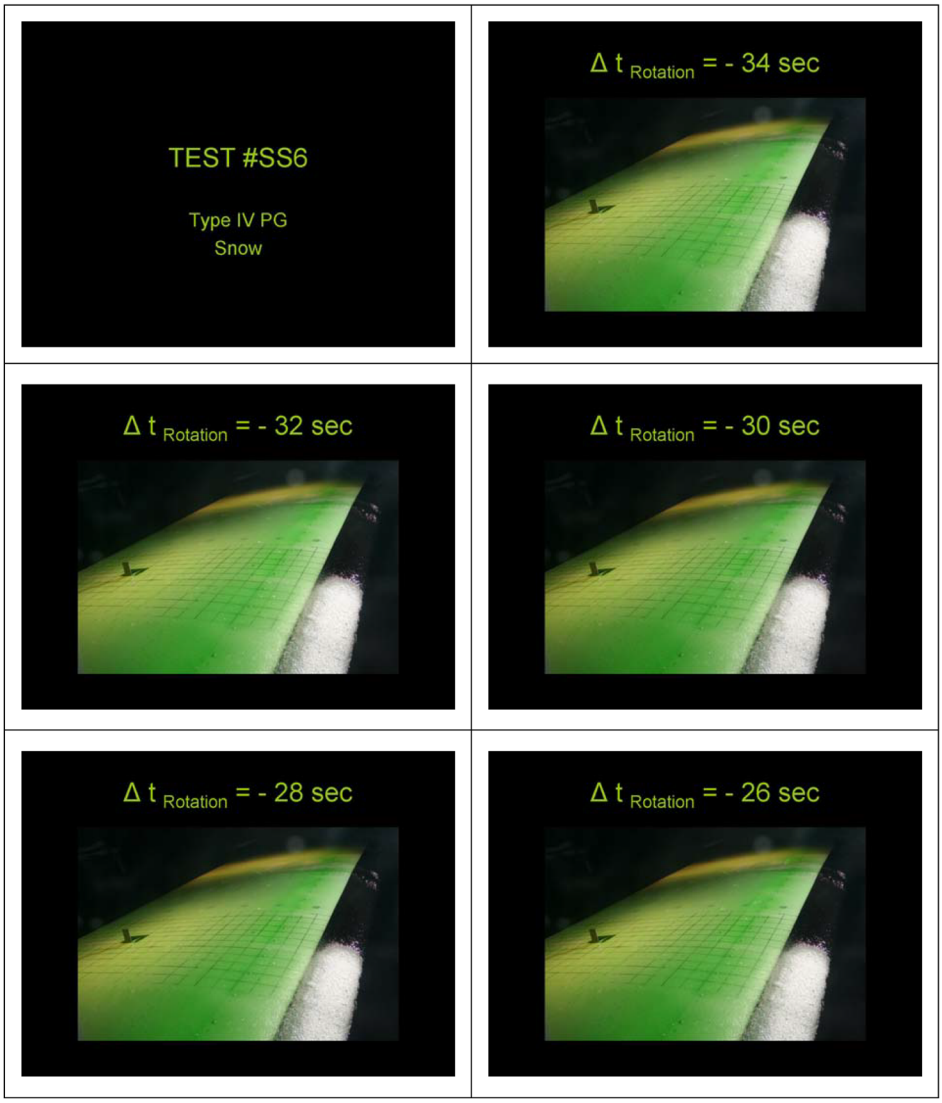
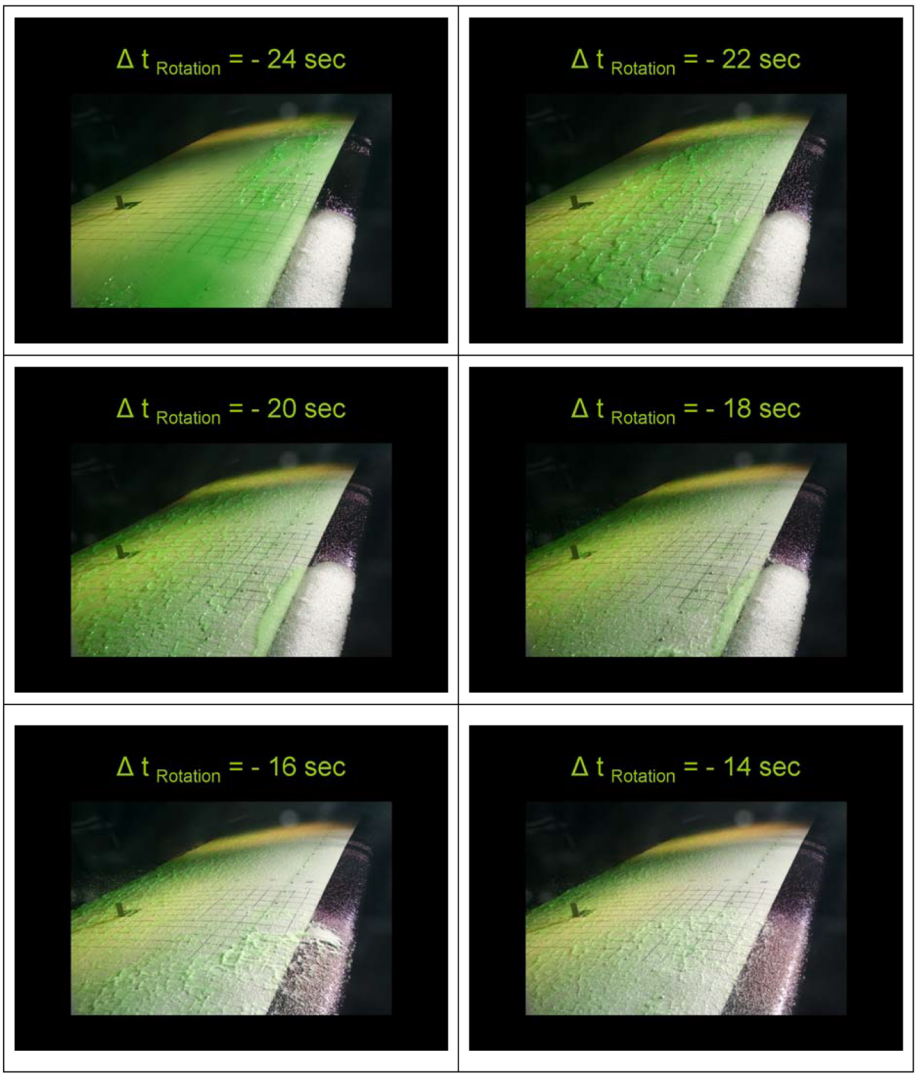
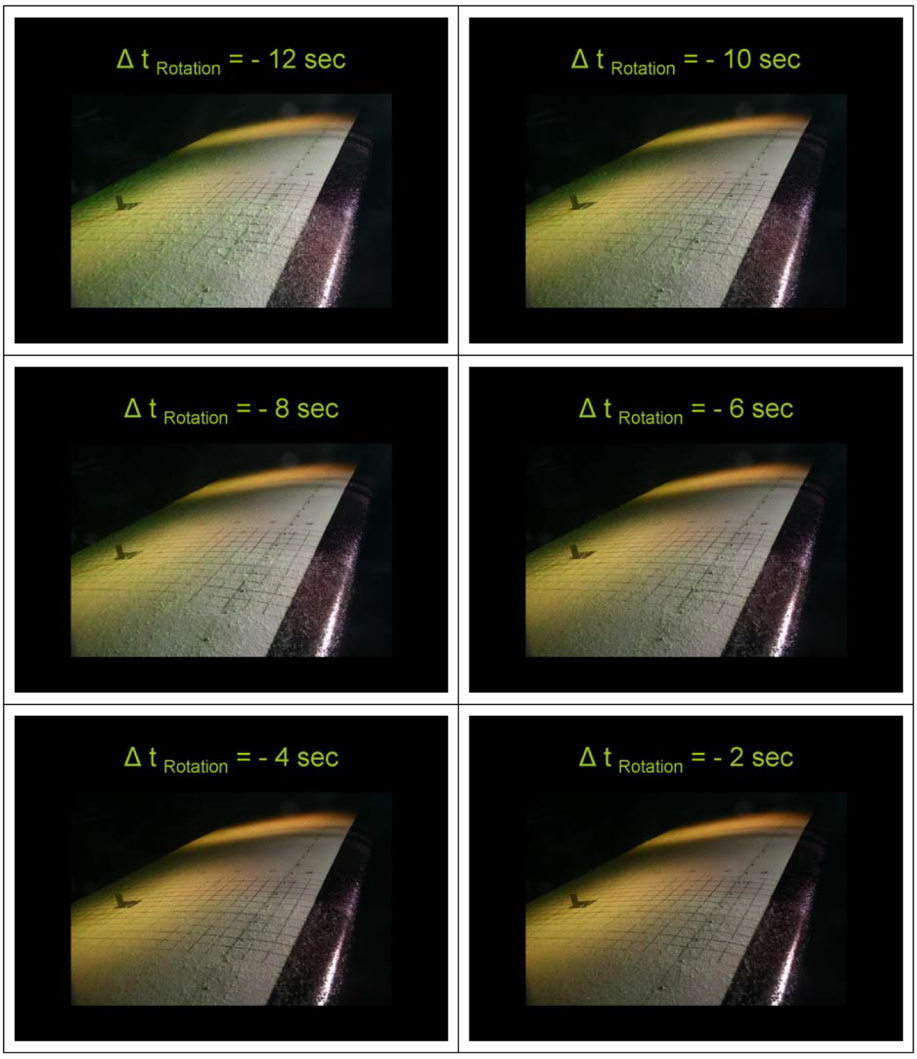
APPENDIX G


TEST #SS6
Type IV PG
Snow
Δ t Rotation = - 34 sec
Δ t Rotation = - 32 sec
Δ t Rotation = - 30 sec
Δ t Rotation = - 28 sec
Δ t Rotation = - 26 sec

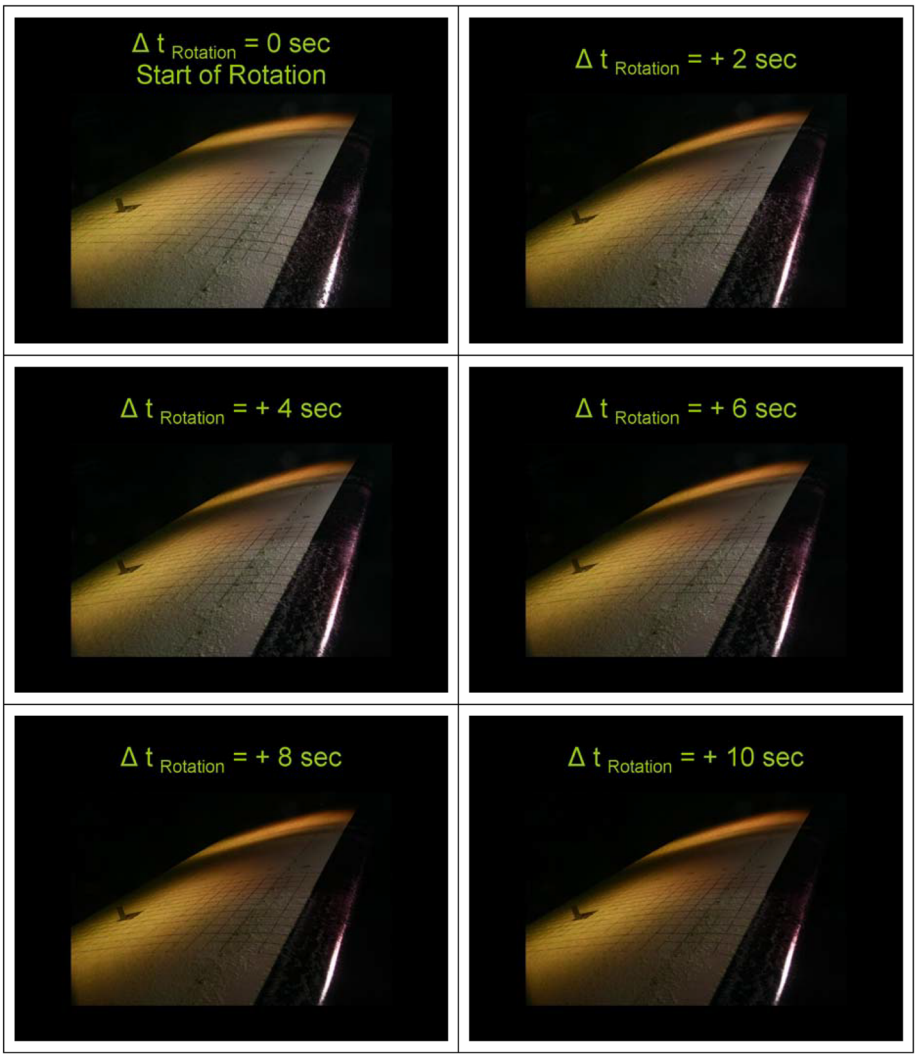
*APPENDIX G*


Δ t Rotation = - 24 sec
Δ t Rotation = - 22 sec
Δ t Rotation = - 20 sec
Δ t Rotation = - 18 sec
Δ t Rotation = - 16 sec
Δ t Rotation = - 14 sec

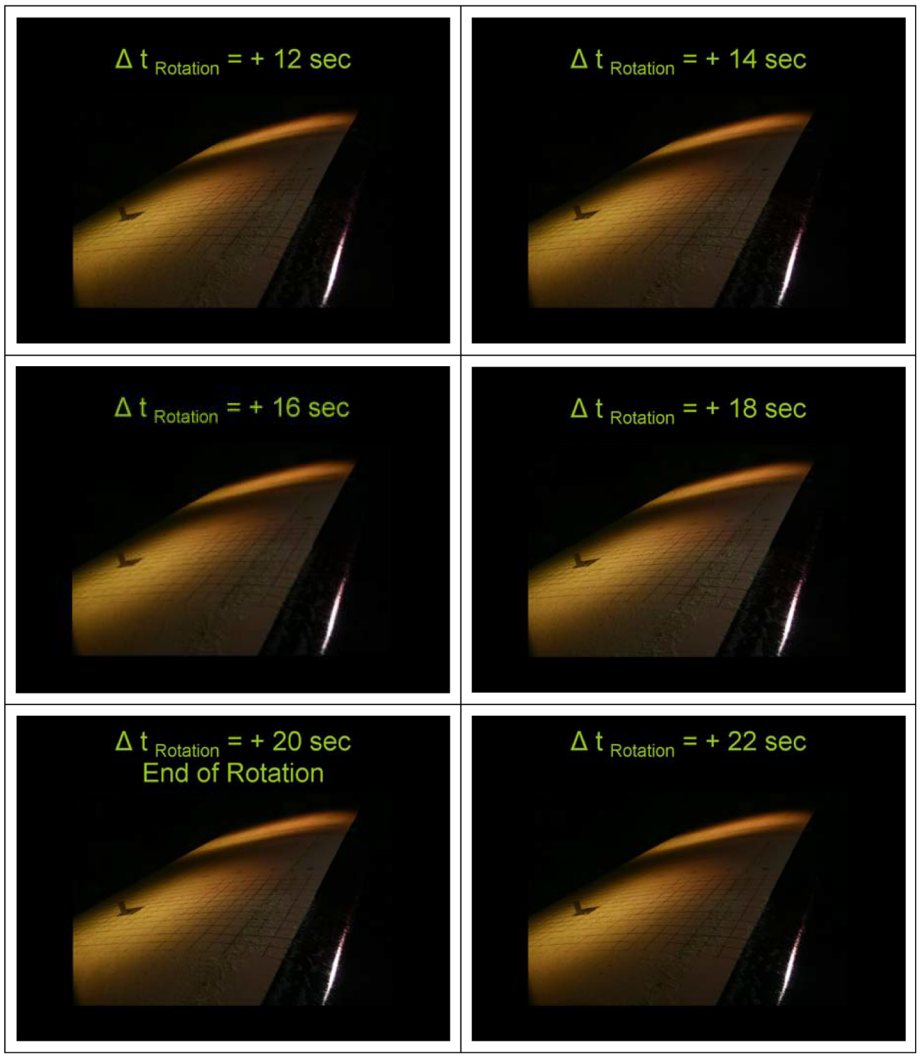
APPENDIX G


Δ t Rotation = - 12 sec
Δ t Rotation = - 10 sec
Δ t Rotation = - 8 sec
Δ t Rotation = - 6 sec
Δ t Rotation = - 4 sec
Δ t Rotation = - 2 sec

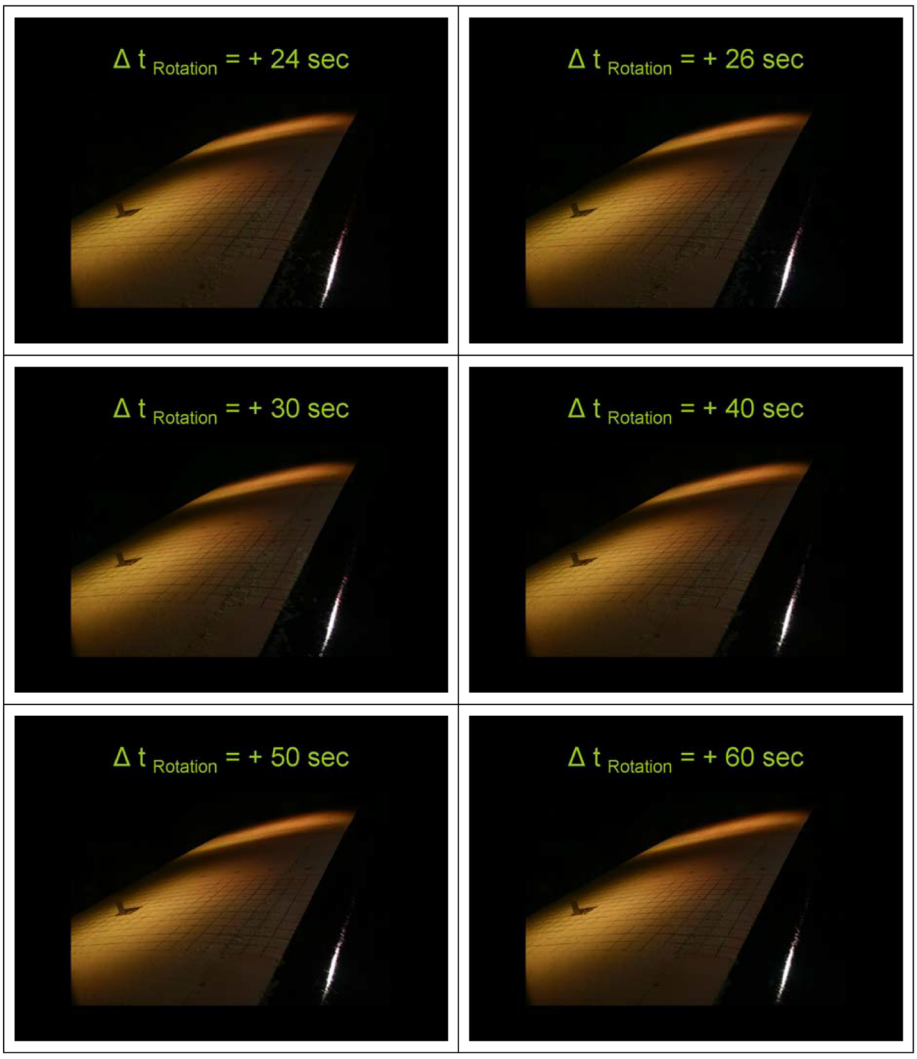
APPENDIX G


Δ t Rotation = 0 sec
Start of Rotation
Δ t Rotation = + 2 sec
Δ t Rotation = + 4 sec
Δ t Rotation = + 6 sec
Δ t Rotation = + 8 sec
Δ t Rotation = + 10 sec

APPENDIX G


Δ t Rotation = + 12 sec
Δ t Rotation = + 14 sec
Δ t Rotation = + 16 sec
Δ t Rotation = + 18 sec
Δ t Rotation = + 20 sec
End of Rotation
Δ t Rotation = + 22 sec

APPENDIX G


Δ t Rotation = + 24 sec
Δ t Rotation = + 26 sec
Δ t Rotation = + 30 sec
Δ t Rotation = + 40 sec
Δ t Rotation = + 50 sec
Δ t Rotation = + 60 sec

APPENDIX G

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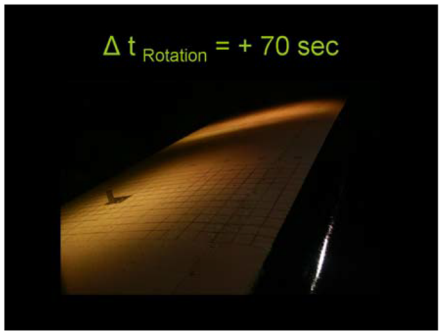
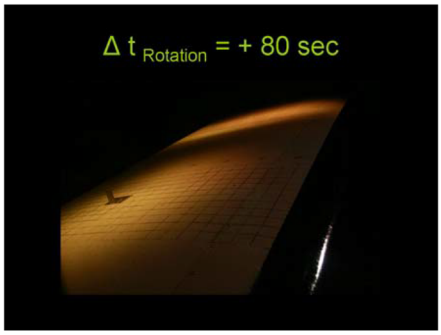
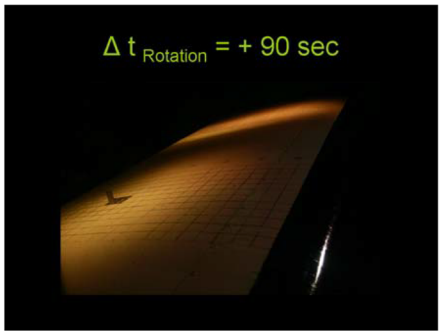
|  |  |
|  | ***This cell intentionally left blank.*** |
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