TP 15056E

Holdover Times Related to Aircraft Hangar Operations




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 2011
Final Version 1.0

TP 15056E

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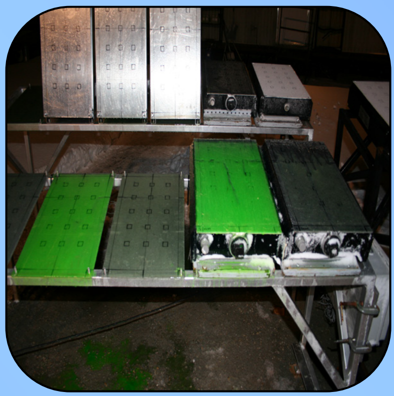


by:

Stephanie Bendickson

January 2011

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APS Aviation Inc.

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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; and update and maintain the website for the holdover time guidelines;
- To evaluate weather data from previous winters that can have an impact on the format of the holdover time guidelines;
- To develop Type I holdover times for composite surfaces; and evaluate first-step rule for use with composite surfaces;
- To conduct general and exploratory de/anti-icing research;
- To conduct endurance time tests simulating vertical stabilizer anti-icing;
- To conduct endurance time tests in simulated snow pellet conditions;
- To conduct endurance time tests with a snow machine in an attempt to refine the current test protocol;
- To conduct endurance time tests in heavy snow conditions;
- To support Federal Aviation Administration and Transport Canada in the development of an advisory circular for the implementation of a holdover time determination system;
- To evaluate the use of sensors in determining active frost conditions;
- To initiate research for development of ice detection capabilities for departing aircraft at the runway threshold;
- To evaluate frost holdover times for use during cold-soaked wing frost conditions;
- To update the regression coefficient report with the newly-qualified de/anti-icing fluids;
- To conduct endurance time tests on surfaces treated with ice phobic products;
- To evaluate holdover times for anti-icing in a hangar;
- To conduct research at the National Research Council Canada wind tunnel to further develop and expand ice pellet allowance times; and
- To conduct various aerodynamic research activities at the National Research Council Canada wind tunnel.

The research activities of the program conducted on behalf of Transport Canada during the winter of 2009-10 are documented in eight reports. The titles of the reports are as follows:

- TP 15050E Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2009-10 Winter;
- TP 15051E Winter Weather Impact on Holdover Time Table Format (1995-2010);

- TP 15052E Development of Type I Fluid Holdover Times for Use on Aircraft with Composite Surfaces;
- TP 15053E Aircraft Ground Icing General Research Activities During the 2009-10 Winter;
- TP 15054E Regression Coefficients and Equations Used to Develop the Winter 2010-11 Aircraft Ground Deicing Holdover Time Tables;
- TP 15055E Emerging De/Anti-Icing Technology: Evaluation of Ice Phobic Products for Potential Use in Aircraft Operations;
- TP 15056E Holdover Times Related to Aircraft Hangar Operations; and
- TP 15057E Exploratory Wind Tunnel Aerodynamic Research Examination of Contaminated Anti-Icing Fluid Flow-Off Characteristics Winter 2009-10.

In addition, the following interim report is being prepared:

- *Wind Tunnel Research to Support the Development of Ice Pellet Allowance Time Tables, Winter 2009-10.*

This report, TP 15056E, has the following objective:

- To evaluate holdover times of anti-icing fluids applied in aircraft hangars and to determine if additional guidance can be provided for operators conducting these types of operations.

This objective was met by conducting fluid thickness tests on aircraft and flat plates and conducting a series of endurance time tests in natural and simulated precipitation conditions.

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: Stephanie Bendickson, Michael Chaput, John D'Avirro, Peter Dawson, Jesse Dybka, Benjamin Guthrie, Michael Hawdur, Eric Perocchio, Michelle Pineau, Marco Ruggi, David Smith, James Smyth, Robert ter Beek, Joey Tiano, David Youssef and Victoria Zoitakis.

Special thanks are extended to Howard Posluns, Angelo Boccanfuso, Yagusha Bodnar, Doug Ingold and Warren Underwood, who on behalf of the Transportation Development Centre and the Federal Aviation Administration, have participated, contributed and provided guidance in the preparation of these documents.

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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. This project was co-sponsored by the Federal Aviation Administration.

16. Abstract

Additional research related to aircraft anti-icing in aircraft hangars was conducted in the winter of 2009-10. The objective of the research was to determine if any holdover time relief could be provided to operators conducting these types of operations, as currently they must start the holdover time clock when fluid application begins, even if the treated aircraft is not immediately exposed to precipitation.

A number of comparative endurance time tests were conducted to evaluate the protection time provided by anti-icing fluids applied in a hangar operation relative to the protection time of the same fluids applied in a standard operation. Tests were conducted in natural snow and in simulated freezing fog, light freezing rain and freezing drizzle.

Analysis of the data collected determined that allowance times can be provided for hangar anti-icing operations. The allowance times are calculated as a percentage of published holdover times and vary by fluid and precipitation type. Testing conducted in 2009 10 provided allowance times for two fluids, Dow UCAR Endurance EG 106 and Clariant Safewing MP IV Launch. The allowance times are limited to hangar waiting times of 30 minutes or less. Transport Canada guidance material was changed to enable operators to use these allowance times by incorporating them into their Transport Canada approved ground icing program.

Supplementary testing looked at the influence of pre-treatment anti-icing on aircraft holdover times. The limited testing indicated it may be possible to provide allowance times for pre-treatment anti-icing operations. It is recommended that further research on this topic only be conducted if required/requested by operators. If so, an allowance time approach is recommended.

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Plusieurs rapports de recherche sur des essais de technologies de dégivrage et d'antigivrage ont été produits au cours des hivers précédents pour le compte de Transports Canada. Ils sont disponibles au Centre de développement des transports. De nombreux rapports ont été rédigés dans le cadre du programme de recherche de cet hiver. Leur objet apparaît à l'avant-propos. Ce projet était coparrainé par la Federal Aviation Administration.

16. Résumé

Des essais supplémentaires ont été menés sur l'antigivrage d'aéronefs au hangar au cours de l'hiver 2009-2010. Cette recherche visait à déterminer si une telle approche pouvait offrir une marge de manœuvre accrue aux exploitants qui effectuent ces types d'opérations et qui doivent, à l'heure actuelle, calculer la durée d'efficacité à partir du moment où ils appliquent les liquides, même si l'aéronef n'est pas immédiatement exposé aux précipitations.

Plusieurs essais comparatifs de durées d'endurance ont été menés pour évaluer le temps de protection conféré par les liquides d'antigivrage appliqués à l'abri d'un hangar comparativement à celui d'une même opération réalisée dans un contexte normal. Des tests ont été menés dans des conditions de neige naturelle et des conditions simulées de brouillard verglaçant, de pluie verglaçante faible et de bruine verglaçante.

L'analyse des données recueillies a permis de constater que des marges de tolérance peuvent s'appliquer aux opérations d'antigivrage en hangar. Ces marges sont calculées en pourcentage des durées d'efficacité publiées et peuvent varier en fonction du type de liquide et de précipitation. Dans le cadre des essais menés en 2009-2010, des marges de tolérance ont été associées à deux liquides, soit Dow Chemical UCAR Endurance EG 106 et Clariant Safewing MP IV Launch. Elles sont toutefois limitées à un délai d'attente en hangar de 30 minutes ou moins. Les lignes directrices de Transports Canada ont été modifiées pour permettre aux exploitants de bénéficier de ces marges de tolérance en les incorporant à leur programme approuvé de dégivrage au sol.

Des essais supplémentaires ont exploré l'influence des prétraitements d'antigivrage sur les durées d'efficacité pour les aéronefs. Ces données limitées indiquent que des marges de tolérance pourraient potentiellement s'appliquer à de telles opérations. Il est recommandé que de plus amples recherches à ce sujet soient réalisées uniquement si les exploitants le demandent ou le requièrent. Le cas échéant, on recommande l'adoption d'une approche tenant compte des marges de tolérance.

17. Mots clés Antigivrage, dégivrage, liquide de dégivrage, durées d'efficacité, précipitation, temps d'endurance, type I, type II, type III, type IV, aéronef, sol, essai, hiver, hangar	18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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EXECUTIVE SUMMARY

In recent years, several operators have approached regulators looking for additional holdover time guidance for anti-icing operations conducted in aircraft hangars. Initial work completed in the winter of 2008-09 established that the holdover time clock cannot be started when aircraft anti-iced in hangars depart the hangar and are first exposed to precipitation – the clock must be started when fluid application begins. This is because fluid begins dripping off aircraft as soon as it is applied – regardless of whether precipitation is present – and fluid thickness affects holdover times.

Additional research was conducted in the winter of 2009-10 to determine if any holdover time relief could be provided to operators conducting these types of operations. Several comparative endurance time tests were conducted to evaluate the protection time provided by anti-icing fluids applied in a hangar operation relative to the protection time of the same fluids applied in a standard operation. Tests were conducted in natural snow and in simulated freezing fog, light freezing rain and freezing drizzle.

Preliminary work measuring fluid thicknesses on an aircraft wing and on flat plates established that 30 minutes was an appropriate waiting time to use in the comparative endurance time tests.

Analysis of the comparative endurance time data determined that allowance times can be provided for hangar anti-icing operations. The allowance times are calculated as a percentage of published holdover times and vary by fluid and precipitation type. Testing conducted in 2009-10 provided allowance times for two fluids, Dow UCAR Endurance EG 106 and Clariant Safewing MP IV Launch.

To use the allowance times provided in this report, an operator would need to incorporate the hangar guidance into their Transport Canada approved ground icing program.

Supplementary testing looked at the influence of pre-treatment anti-icing on aircraft holdover times. The limited testing indicated it may be possible to provide allowance times for pre-treatment anti-icing operations. It was recommended that further research only be conducted if required/requested by operators, and that any further research should follow an allowance time approach.

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SOMMAIRE

Au cours des dernières années, de nombreux exploitants se sont adressés aux organismes de réglementation pour demander la publication de lignes directrices additionnelles sur les durées d'efficacité pour les opérations d'antigivrage en hangar. Les travaux initiaux, achevés durant l'hiver 2008-2009, ont permis d'établir que le calcul des durées d'efficacité ne peut se faire à partir du moment où débute l'exposition aux précipitations d'un aéronef traité au moyen d'un liquide d'antigivrage en hangar – il doit se faire à partir du moment où les liquides sont appliqués. Cela s'explique par le fait que les liquides ruissèlent sur l'aéronef dès leur application – qu'il y ait présence de précipitations ou non – et que l'épaisseur des liquides influence les durées d'efficacité.

Des essais supplémentaires ont été menés durant l'hiver 2009-2010 pour déterminer si les exploitants effectuant ces types d'opérations pouvaient bénéficier de marges de manœuvre quant aux durées d'efficacité. Plusieurs essais comparatifs de durées d'endurance ont été menés pour évaluer le temps de protection conféré par les liquides d'antigivrage appliqués à l'abri d'un hangar comparativement à celui d'une même opération réalisée dans un contexte normal. Des tests ont été menés dans des conditions de neige naturelle et des conditions simulées de brouillard verglaçant, de pluie verglaçante faible et de bruine verglaçante.

Dans le cadre de ces essais comparatifs, les travaux préliminaires mesurant l'épaisseur d'un liquide sur une aile d'aéronef et sur des plaques planes ont permis d'établir qu'une période de 30 minutes constituait un délai d'attente avant utilisation adéquat.

L'analyse des données comparatives recueillies sur les durées d'endurance a permis de constater que des marges de tolérance peuvent s'appliquer aux opérations d'antigivrage en hangar. Ces marges sont calculées en pourcentage des durées d'efficacité publiées et peuvent varier en fonction du type de liquide et de précipitation. Dans le cadre des essais menés en 2009-2010, des marges de tolérance ont été associées à deux liquides, soit Dow Chemical UCAR Endurance EG 106 et Clariant Safewing MP IV Launch.

Pour mettre en pratique les marges de tolérance publiées dans ce rapport, un exploitant doit incorporer les lignes directrices relatives aux opérations en hangar à son programme de dégivrage au sol approuvé par Transports Canada.

Des essais supplémentaires ont exploré l'influence des prétraitements d'antigivrage sur les durées d'efficacité pour les aéronefs. Ces données limitées indiquent que des marges de tolérance pourraient potentiellement s'appliquer à de telles opérations. Il est recommandé que de plus amples recherches à ce sujet soient réalisées uniquement si les exploitants le demandent ou le requièrent, et que tout essai mené en ce sens adopte une approche tenant compte des marges de tolérance.

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GLOSSARY

APS	APS Aviation Inc.
EG	Ethylene Glycol
FAA	Federal Aviation Administration
NRC	National Research Council Canada
OAT	Outside Air Temperature
PG	Propylene Glycol
TDC	Transportation Development Centre

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1. INTRODUCTION

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

Since the early 1990s, the Transportation Development Centre (TDC) of Transport Canada 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, several major airlines, and deicing fluid manufacturers. The TDC is continuing its research, development, testing and evaluation program.

Under contract to the TDC, with financial support from the FAA, APS Aviation Inc. (APS) has undertaken research activities to further advance aircraft ground de/anti- icing technology.

1.1 Background

Until recently, the practice of anti-icing aircraft in hangars had not been examined in relation to fluid holdover times. However, questions and concerns from operators in recent years have stimulated research on this practice.

1.1.1 Hangar Anti-Icing

Some operators, typically operators of corporate and private jets, anti-ice aircraft inside aircraft hangars. Operators typically use this practice to avoid the delays and additional expenses associated with deicing (which are avoided by keeping aircraft sheltered from precipitation in the hangar) and with using central deicing facilities (which are typically operated by third parties and have queues).

After being anti-iced in a hangar, an aircraft may sit in the hangar for some time before departing. During this “waiting time” the applied fluid is not exposed to precipitation. This delay in exposure of the anti-icing fluid to precipitation is not typical of a standard anti-icing operation, where the applied anti-icing fluid is immediately exposed to precipitation.

Several years ago, several operators asked Transport Canada when the holdover time "clock" should be started in hangar anti-icing operations. Specifically, they wanted to know if holdover time starts when fluid application begins or if it starts when the aircraft departs the hangar and is first exposed to precipitation.

1.1.2 Initial Work – Winter 2008-09

This question stimulated a research program that was undertaken by APS on behalf of Transport Canada in the winter of 2008-09. The program included a literature review and a preliminary test program. The work completed in 2008-09 is summarized below. It is documented in detail in the Transport Canada report, TP 14936E, *Aircraft Ground Icing General Research Activities During the 2008-09 Winter* (1).

1.1.2.1 Literature Review

APS conducted a review of Transport Canada and FAA guidance materials in 2008-09 to ascertain their directions on when the holdover time clock should start for hangar anti-icing operations.

The Transport Canada document, TP 14052E, *Guidelines for Aircraft Ground Icing Operations (Second Edition)* (2), was found to have guidance for hangar operations. However, the guidance did not state when the holdover time clock should start. General guidance in the document, however, states the clock must be started when anti-icing fluid application begins.

No guidance specific to hangar operations was found in FAA documents. However, like Transport Canada, the FAA has several documents containing general guidance for when to start the holdover time clock, including:

1. *FAA-Approved Deicing Program Updates, Winter 2008-2009*, N 8900.55 [see section 6.a.(2)(f)] (3);

2. FAA Advisory Circular 135-17, *PILOT GUIDE Small Aircraft Ground Deicing* (4);

3. FAA Advisory Circular 135-16, *Ground Deicing and Anti-Icing Training and Checking* (5); and

4. FAA Advisory Circular 120-60B, *Ground Deicing and Anti-Icing Program* (6).

The guidance in these documents also indicates that holdover time must be started as soon as anti-icing begins.

As Transport Canada and FAA guidance materials did not indicate the holdover time clock should start at a different time for hangar anti-icing operations, it was concluded that the clock must be started when anti-icing fluid application begins in hangar operations, as it does for standard anti-icing operations.

1.1.2.2 Preliminary Test Program

A test program was recommended to determine if the current guidance provided in Transport Canada and FAA materials was appropriate. The objective of the test program was to examine the effect of delayed exposure to precipitation on fluid endurance time and to determine when the holdover time clock should be started for hangar anti-icing: if it must be started when fluid application begins or if it can safely be started when the fluid is first exposed to precipitation.

A limited number of tests were conducted in the winter of 2008-09. The results indicated that if the holdover time clock is started when the anti-icing fluid is exposed to precipitation rather than when it is applied to the aircraft in the hangar, the holdover time is often shorter than the holdover time for a standard operation where fluid is applied during active precipitation (on which the published holdover times are based). It was surmised that several factors contribute to this difference in holdover time, including fluid thickness and fluid temperature.

Based on these results, it was concluded that the safe approach was to start the holdover time clock when fluid application begins.

1.1.3 Changes to Guidance Material for 2009-10

Although the conclusions of the test program supported the published guidance material, it was felt that the guidance did not adequately make clear when the holdover time clock should be started for hangar operations. It was recommended that the guidance be clarified.

Transport Canada made changes to its guidance material in accordance with this recommendation. Specifically, the sentences underlined below were added to TP 14052E §10.11*.

> *The period of time after Type IV fluid application and the air temperature in the hangar both have an effect on the ability of the fluid to protect the aircraft when it is pulled out of the hangar and into freezing/frozen*

> *precipitation. The HOT for a fluid is based largely on the fluid's thickness on the surface. The fluid thickness varies with time and temperature. The holdover time clock must be started at the time of the first application of anti-icing fluid onto a clean wing. It may not be started when the aircraft is first exposed to freezing/frozen precipitation.*

These changes came into effect in July 2009.

**Note these changes were published in the Transport Canada HOT Guidelines for Winter 2009-10, which included a section on updates to TP 14052.*

1.1.4 Concerns with Changes to Guidance Material

When the changes were published, several operators expressed concerns that the new guidance would limit their ability to operate. They felt that if they started the holdover time clock when application of anti-icing fluid began, often their holdover time would be expired by the time the anti-iced aircraft was ready to depart the hangar. Despite the expiration of the holdover time, they suspected a layer of fluid would remain on the aircraft and that this fluid would still provide some protection time. However, they could not take advantage of the protection due to the expiration of the stated holdover time.

Transport Canada subsequently agreed to conduct additional research in the winter of 2009-10 to ascertain if additional guidance could provide some holdover time relief for hangar operations.

1.2 Objectives for Winter 2009-10 Test Program

A test program was undertaken in the winter of 2009-10 to evaluate the operators' theory that longer holdover time could be garnered from fluids applied in hangars. The primary objective of the test program was to determine if additional holdover time guidance could be provided to take advantage of any holdover time that remained after a waiting period between fluid application and exposure to precipitation.

The objective was achieved in several steps. The first step was to determine an appropriate "waiting time" (time between fluid application and departure from hangar). The waiting time had to be long enough to provide operators with needed operational flexibility, but short enough to ensure the progressive reduction in fluid thickness that occurred during the waiting period did not cause holdover time to be reduced to an unusable level. Preliminary fluid thickness tests were conducted to obtain an appropriate waiting time. These tests are detailed in Section 2.

The second step was to measure the holdover time available after the selected waiting time had elapsed and compare it to the holdover provided in an equivalent standard operation. This was achieved by conducting endurance time tests under simulated hangar conditions (fluid and aircraft at room temperature) and simulated standard conditions [fluid and aircraft at outside air temperature (OAT)]. These tests are detailed in Sections 3 and 4.

The last step was to analyse the results and, if appropriate, make recommendations for incorporating the results into operations. This work is detailed in Section 5.

The test program also had a secondary objective, which was to evaluate holdover times for the related practice of "pre-treatment" anti-icing. Pre-treatment anti-icing is the practice of anti-icing aircraft in periods of non-precipitation to protect the aircraft from anticipated future precipitation. Like hangar operations, pre-treatment anti-icing involves a delay in exposure of applied fluid to precipitation. However, because pre-treatment anti-icing is conducted outdoors, the fluid and aircraft are at OAT, not at room temperature as they are for hangar anti-icing. The supplemental research completed to achieve this objective is documented in Section 6.

The detailed objectives of this project are provided in Appendix A in an excerpt from the Transport Canada statement of work.

1.3 Report Format

The contents of the remaining sections in this report are summarized below.

- Section 2 (Preliminary Research): Describes the thickness tests that were conducted as preliminary research to determine an appropriate "waiting time" to use in the endurance time tests.
- Section 3 (Procedure): Describes the procedure used to conduct the endurance time tests.
- Section 4 (Data): Details the endurance time data collected.
- Section 5 (Analysis): Presents an analysis of the endurance time data and how it can be incorporated into operations.
- Section 6 (Supplemental Research): Describes supplemental research on holdover times related to pre-treatment operations.
- Section 7 (Conclusions): Presents conclusions derived from the work.
- Section 8 (Recommendations): Lists recommendations for future work.

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2. PRELIMINARY RESEARCH: THICKNESS TESTS

Preliminary research was conducted to determine an appropriate "waiting time" to use in the comparative endurance time tests (detailed in subsequent sections). The preliminary research is described in this section.

2.1 Objectives

The preliminary research consisted of conducting several fluid thickness tests on two surfaces, a Challenger 604 aircraft wing and a leading edge thermal equivalent box. The objective of the tests was to measure fluid thickness decay profiles of simulated hangar fluid applications to determine an appropriate waiting time to use in the endurance time tests.

A secondary objective of the tests was to evaluate the effect of fluid type, fluid temperature, surface temperature, and application method on fluid thickness.

2.2 Procedure

A procedure was prepared for the conduct of these tests. A copy of this procedure, entitled *Full-Scale Evaluation of Fluid Thickness on Indoor Aircraft Hangar Anti-Icing Applications*, is included in Appendix B. The procedure contains a detailed description of the test plan, test setup, fluid application protocol, equipment, and instructions for carrying out the tests step-by-step. The important aspects of the procedure are summarized below.

2.2.1 Measurements

Fluid thickness measurements were taken at regular intervals for 90 minutes following fluid application. Fluid thickness measurements were taken at several locations. On the leading edge thermal equivalent box, measurements were taken on the 2.5 cm, 15 cm, and 30 cm lines. On the aircraft wing, measurements were taken at six locations, as illustrated in Figure 2.1.

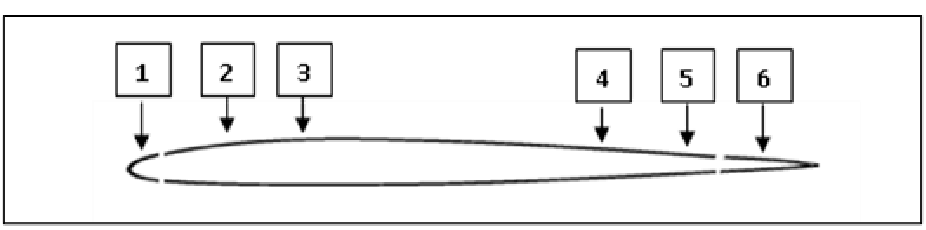

Figure 2.1: Thickness Measurement Locations on Wing

2.2.2 Test Variables

The procedure required several variables to be altered between tests. The variables are listed below.

1. Test Surface
   - Leading edge thermal equivalent box
   - Transport Canada Challenger 604 aircraft wing

2. Test Surface Temperature
   - Warm (room temperature, approximately 18–20°C)
   - Cold (outside air temperature)

3. Fluid Brand/Type
   - Dow UCAR EG106 (Type IV EG)
   - Clariant Safewing MP IV Launch (Type IV PG)

4. Fluid Temperature:
   - Warm (room temperature, approximately 18–20°C)
   - Cold (outside air temperature)

5. Fluid Application Method:
   - Pour (by hand)
   - Backpack Spray (equipment provided by Transport Canada)
   - Trolley Spray (equipment provided by Transport Canada)

2.3 Data

Testing was conducted on January 25, 2010 at the Transport Canada Hangar in Ottawa. A total of eleven tests were conducted. A log of tests is given in Table 2.1.

The log of tests shows the fluid thicknesses measured at 10, 30, 60, and 90 minutes after fluid application for each test. The measurements shown in the log were taken at the 15 cm line on the box and at position 2 on the wing (see Table 2.1).

A more detailed account of the measurements taken is provided in Appendix C, which includes a chart for each test showing all fluid thickness measurements taken for the test, including measurements taken at all positions and at all time intervals.

Several photos of the testing are included at the end of this section (see Photos 2.1, 2.2, 2.3, and 2.4).

Table 2.1: Log of Tests

Test #	Fluid	Surface	Application Method	Surface Temp.	Fluid Temp.	Fluid Thickness (mm)*			
						10 min	30 min	60 min	90 min
1	Dow EG106	Box	Trolley Spray	Warm	Warm	0.66	0.37	0.30	0.23
2	Dow EG106	Box	Pour	Warm	Warm	0.74	0.47	0.33	0.23
3	Dow EG106	Aircraft	Backpack Spray	Warm	Warm	1.52	1.17	0.82	0.67
4	Dow EG106	Aircraft	Trolley Spray	Warm	Warm	1.50	0.98	0.79	0.54
5	Dow EG106	Aircraft	Backpack Spray	Warm	Cold (-2°C)	1.76	1.32	0.94	0.73
6	Clariant Launch	Aircraft	Backpack Spray	Warm	Warm	1.53	1.15	1.00	0.87
7	Clariant Launch	Aircraft	Backpack Spray	Warm	Cold (-3°C)	1.55	1.26	1.11	1.00
8	Dow EG106	Box	Pour	Cold (-11°C)	Cold (-11°C)	1.84	1.11	1.10	1.10
9	Clariant Launch	Box	Pour	Cold (-11°C)	Cold (-11°C)	0.68	0.60	0.50	0.47
10	Dow EG106	Box	Pour	Warm	Warm	0.70	0.40	0.33	0.20
11	Clariant Launch	Box	Pour	Warm	Warm	0.97	0.43	0.12	0.00

*Thickness on box was taken at the 15 cm line. Thickness on aircraft was taken at position 2 (see Figure 2.1).

2.4 Observations

Several observations were made upon examination of the test results.

- The most significant reduction in thickness occurs immediately following application, but there is still a significant amount of decay thereafter.
- Thickness of cold fluid applied on a cold surface is significantly greater than warm fluid applied on a warm surface (Test 8 vs. Test 10; Test 9 vs. Test 11). This indicates that fluid thickness is greater for a standard operation fluid application (fluid is stored outdoors at OAT and aircraft is outdoors at OAT) than for a hangar operation fluid application (fluid and aircraft are both indoors at room temperature).
- Thickness of cold fluid applied on a warm surface is slightly greater than warm fluid applied on a warm surface (Test 3 vs. Test 5; Test 6 vs. Test 7); however, the difference is not as great as that of cold/cold relative to warm/warm (see bullet above). This indicates that storing fluid outdoors will increase fluid thickness for hangar operations, but it will not result in the same fluid thickness as a standard operation where cold fluid is applied on a cold surface.
- Fluid applied by spraying is thinner compared to fluid applied by pouring (Test 1 vs. Test 2).
- Thicknesses of both ethylene glycol (EG) and propylene glycol (PG) fluids are affected by fluid and surface temperature; EG fluid seems to be more affected.

2.5 Conclusions

The thickness data was reviewed to select an appropriate waiting time to use for the comparative endurance time tests. The goal was to select a time that allows the longest duration in the hangar while retaining a reasonable amount of fluid thickness and consequently fluid holdover time.

Examination of the data concluded that 30 minutes would be an appropriate waiting time to use. While a significant amount of fluid thickness is lost during the initial 30 minutes after fluid application (up to 50%), a reasonable amount of thickness remains. Less time would likely not provide a sufficient waiting time to be operationally useful; more time would likely result in very short holdover times as fluid thickness continues to decay beyond the initial 30 minutes.

Photo 2.1: Challenger Wing (Clean)

Photo 2.2: Challenger Wing (With Fluid)

Photo 2.3: Leading Edge Thermal Equivalent Boxes (Clean)

Photo 2.4: Leading Edge Thermal Equivalent Boxes (With Fluid)

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3. PRIMARY RESEARCH: PROCEDURE

The primary research completed for this project was a series of endurance time tests conducted in natural and simulated winter precipitation conditions on flat plates. The procedure for the conduct of these tests is outlined in this section.

3.1 Test Procedure

A procedure entitled *Evaluation of Endurance Time Values for Indoor Aircraft Hangar (and Pre-Treatment) Anti-Icing Applications* was written to detail the procedure to be followed in the conduct of these tests. A copy of this procedure is included in Appendix D.

The procedure was followed as written for tests conducted outdoors in natural snow. Several modifications were made to the procedure for indoor testing in simulated freezing precipitation conditions. These modifications are detailed in the procedure *Overall Program of Tests at NRC, March-April 2010*, which can be found in Appendix B of Transport Canada report, TP 15050E, *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2009-10 Winter* (7).

The key elements of the test procedure, including the test methodology, test protocol, test locations, and fluids, are described in the subsections below.

Key elements of the test procedure are also shown in Photos 3.1, 3.2, and 3.3, which are included at the end of this section.

3.2 Test Methodology

The methodology for this research was comparative testing. Comparative tests were conducted to evaluate the relative performance of:

- Anti-icing fluids applied in hangars and allowed to sit on the aircraft 30 minutes before being exposed to precipitation; and
- Anti-icing fluids applied in a standard operation, where fluids are applied outdoors and immediately exposed to precipitation.

Each comparative test included a standard test and a simulated hangar test. The standard test simulated a standard operation (cold fluid, cold aircraft, immediate exposure to precipitation); the hangar test simulated a hangar operation where the aircraft stays in the hangar for some time before departing and being exposed to precipitation (warm fluid, warm aircraft).

3.3 Test Protocol

Three variables differed between the simulated standard and hangar tests. These are shown in Table 3.1 and described further in the subsections below.

Table 3.1: Test Variables

Variable	Standard Test Protocol	Hangar Test Protocol
Surface Temperature	OAT	20°C
Fluid Temperature	OAT	20°C
Time between Fluid Application and Exposure to Precipitation	0 mins	30 mins

3.3.1 Surface Temperature

Aircraft are typically at OAT in standard operations (as they are kept outdoors) but typically at room temperature in hangar operations (as they are positioned in hangars until departure). Therefore, the standard test was conducted on a surface at OAT and the hangar test was conducted on a surface at room temperature (~20°C).

To ensure the test surfaces were at the correct temperature, the test surfaces for the hangar tests were kept indoors prior to testing to ensure they were at approximately 20°C at the beginning of the test. The test surfaces for the standard tests were kept in the test area to ensure they were at ambient temperature.

3.3.2 Fluid Temperature

Fluid is typically stored outdoors and is therefore at OAT during standard operations. However, fluid that is used in hangar operations is typically kept in the hangar and is therefore at room temperature when applied. Therefore, the standard test was conducted with fluid at OAT and the hangar test was conducted with fluid at room temperature (~20°C).

3.3.3 Time Between Fluid Application and Exposure to Precipitation

Exposure to precipitation is immediate in standard operations, as fluid application is done outdoors under precipitation. In hangar operations, there is frequently a delay between the time fluid is applied and the time it is exposed to precipitation (during this time the aircraft stays in the hangar, where it is protected from precipitation). Therefore, in the standard test the fluid was exposed to precipitation immediately after fluid application, and in the hangar test a 30-minute waiting time was allowed to elapse between fluid application and exposure to precipitation. (Thirty minutes was selected as an appropriate waiting time based on the results of the preliminary research thickness tests – see Section 2.)

Both the standard test surface and the hangar test surface were exposed to precipitation at the same time to ensure the two tests being compared were exposed to the same type and amount of precipitation. This required that fluid be applied to the hangar test surface 30 minutes in advance of both surfaces being exposed to precipitation.

The start time for both tests was the time of exposure to precipitation, not the time of fluid application, which occurred 30 minutes earlier for the hangar test.

3.4 Fluids

Testing was limited to two fluids, Clariant Safewing MP IV Launch and Dow UCAR EG106, due to budget constraints. These fluids were selected based on feedback from Canadian operators. Both fluids are commercially available, and the samples tested were of normal production range viscosity. Further details on the fluids are provided in Table 3.2.

Table 3.2: Test Fluids

Brand Name	Fluid Type	Fluid Base	Batch Number
Clariant Safewing MP IV Launch	Type IV	PG	USHA024295
Dow UCAR EG106	Type IV	EG	WH0601GKDR

3.5 Test Locations

Tests were conducted outdoors in natural snow at the APS test site at the Montreal Trudeau airport. Tests were conducted indoors in simulated freezing fog, freezing drizzle, and light freezing rain at the NRC Climatic Engineering Facility in Ottawa.

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Photo 3.1: Fluid Application (Simulated Hangar Test)

Photo 3.2: Waiting Time (Simulated Hangar Test)

Photo 3.3: Exposure to Precipitation (Hangar and Standard Tests)

4. PRIMARY RESEARCH: DATA

The primary research completed for this project was a set of comparative endurance time tests conducted on flat plate surfaces of leading edge thermal equivalent boxes. The data collected from these tests is detailed in this section.

4.1 Tests Conducted

In total, 44 comparative tests were conducted. Each comparative test consisted of two tests: one test conducted using the standard protocol (baseline test) and one test conducted using the hangar protocol (hangar test). The standard and hangar protocols are described in Section 3.

Tests were conducted with two Type IV anti-icing fluids in natural snow and in simulated freezing fog, freezing drizzle, and light freezing rain. Tests were conducted at various temperatures and under various precipitation rates.

The number of tests conducted is summarized below by fluid brand and precipitation type (Table 4.1), precipitation type and ambient temperature (Table 4.2), and precipitation type and precipitation rate (Table 4.3).

Table 4.1: Tests Conducted by Fluid (Type) / Precipitation Type

	Clariant Launch (PG)	Dow UCAR EG106 (EG)	Total
Snow	8	11	**19**
Freezing Fog	5	4	**9**
Freezing Drizzle	4	4	**8**
Light Freezing Rain	4	4	**8**
Total	**21**	**23**	**44**

Table 4.2: Tests Conducted by Precipitation Type / Ambient Temperature

	-25°C	-14°C	-12°C	-10°C	-3°C	-1°C	≥0°C	Total
Snow	-	-	2	-	2	4	11	**19**
Freezing Fog	4	3	-	-	2	-	-	**9**
Freezing Drizzle	-	-	-	4	4	-	-	**8**
Light Freezing Rain	-	-	-	4	4	-	-	**8**
Total	**4**	**3**	**2**	**8**	**12**	**4**	**11**	**44**

Table 4.3: Tests Conducted by Precipitation Type / Precipitation Rate (g/dm²/h)

	0-5	6-10	11-15	>15	Total
Snow	1	16	2	-	**19**
Freezing Fog	9	-	-	-	**9**
Freezing Drizzle	2	2	3	1	**8**
Light Freezing Rain	-	-	4	4	**8**
Total	**12**	**18**	**9**	**5**	**44**

4.2 Preliminary Log of Tests

A preliminary log of tests was created with the data collected. The log includes 44 entries – one entry for each comparative test conducted. Various parameters were recorded for each test.

- **Test #**: Comparative test number (in some cases the baseline and hangar tests had individual test numbers; in those cases the comparative test number is the individual test numbers combined).
- **Date**: Date test was conducted.
- **Fluid**: Test fluid (all tests with neat fluids, no tests with diluted fluids).
- **Ambient Temp.**: Air temperature during the exposure to precipitation phase of the test (in °C).
- **Precip. Type**: Snow, light freezing rain, freezing drizzle, or freezing fog.
- **Precip. Rate**: The rate of precipitation (measured in $g/dm^2/h$).
    - Baseline: Precipitation rate for baseline test.
    - Hangar: Precipitation rate for hangar test.
    - Diff.: Difference in precipitation rates for baseline and hangar tests (hangar relative to baseline, in percentage).
- **Endurance Time**: Time from start of test (first exposure to precipitation) to fluid failure (in minutes).
    - Baseline: Endurance time for baseline test.
    - Hangar: Endurance time for hangar test.

The preliminary log of tests is shown in Table 4.4.

Table 4.4: Preliminary Log of Tests

Test #	Date	Fluid	Ambient Temp. (°C)	Precip. Type	Precip. Rate (g/dm²/h)			Endurance Time (mins)	
					Baseline	Hangar	Diff.	Baseline	Hangar
S1E	3-Jan-10	Dow UCAR EG106	-11.5	Snow	13.6	12.8	-6%	69.0	52.0
S2E	18-Feb-10	Dow UCAR EG106	-1.2	Snow	4.6	4.0	-12%	178.9	164.0
S3E	18-Feb-10	Dow UCAR EG106	-3.4	Snow	8.2	11.2	37%	131.5	66.7
S4E	23-Feb-10	Dow UCAR EG106	-0.1	Snow	6.2	5.8	-6%	150.6	139.0
S5E	24-Feb-10	Dow UCAR EG106	-0.5	Snow	8.0	8.0	0%	155.8	104.0
S6E	24-Feb-10	Dow UCAR EG106	0.8	Snow	7.2	6.9	-4%	172.3	156.0
S7E	24-Feb-10	Dow UCAR EG106	0.8	Snow	9.1	8.6	-5%	128.9	120.0
S8E	24-Feb-10	Dow UCAR EG106	0.7	Snow	7.4	7.1	-4%	131.2	100.2
S9E	24-Feb-10	Dow UCAR EG106	0.4	Snow	7.1	9.5	34%	151.3	94.8
S10E	27-Feb-10	Dow UCAR EG106	0.9	Snow	9.5	8.0	-16%	130.1	97.0
S11E	27-Feb-10	Dow UCAR EG106	0.9	Snow	9.6	9.5	-1%	136.3	85.0
S1P	3-Jan-10	Clariant Launch	-11.5	Snow	14.1	13.6	-4%	79.5	70.0
S2P	18-Feb-10	Clariant Launch	-1.2	Snow	5.8	3.7	-36%	246.7	154.0
S3P	18-Feb-10	Clariant Launch	-3.4	Snow	5.9	10.6	80%	241.0	75.8
S5P	24-Feb-10	Clariant Launch	-0.5	Snow	8.9	7.4	-17%	151.0	193.0
S6P	24-Feb-10	Clariant Launch	0.8	Snow	6.6	7.5	12%	149.0	187.0
S8P	24-Feb-10	Clariant Launch	0.7	Snow	6.2	6.1	-1%	258.9	215.7
S9P	24-Feb-10	Clariant Launch	0.4	Snow	7.0	6.9	-1%	216.1	164.3
S10P	27-Feb-10	Clariant Launch	0.9	Snow	9.3	8.7	-6%	166.7	118.0
H1/H3	29-Mar-10	Dow UCAR EG106	-3	Freezing Drizzle	5.0	4.7	-6%	153.8	103.4
H2/H4	29-Mar-10	Clariant Launch	-3	Freezing Drizzle	5.0	5.4	7%	131.0	192.4
H6/H8	30-Mar-10	Dow UCAR EG106	-3	Freezing Drizzle	13.8	12.8	-7%	92.5	49.5
H7/H9	30-Mar-10	Clariant Launch	-3	Freezing Drizzle	14.5	14.4	-1%	115.0	72.5
H10/H12	29-Mar-10	Dow UCAR EG106	-10	Freezing Drizzle	6.8	6.3	-7%	85.4	54.8

Table 4.4: Preliminary Log of Tests (cont'd)

Test #	Date	Fluid	Ambient Temp. (°C)	Precip. Type	Precip. Rate (g/dm²/h)			Endurance Time (mins)	
					Baseline	Hangar	Diff.	Baseline	Hangar
H11/H13	29-Mar-10	Clariant Launch	-10	Freezing Drizzle	7.3	7.1	-3%	44.4	54.8
H14/H16	30-Mar-10	Dow UCAR EG106	-10	Freezing Drizzle	16.0	14.8	-8%	50.1	22.1
H15/H17	30-Mar-10	Clariant Launch	-10	Freezing Drizzle	13.4	13.2	-1%	17.7	31.1
H19/H21	31-Mar-10	Dow UCAR EG106	-3	Light Freezing Rain	13.5	14.0	4%	68.3	43.2
H20/H22	31-Mar-10	Clariant Launch	-3	Light Freezing Rain	13.6	13.1	-4%	121.1	69.2
H24/H26	31-Mar-10	Dow UCAR EG106	-3	Light Freezing Rain	26.5	25.3	-5%	47.5	25.3
H25/H27	31-Mar-10	Clariant Launch	-3	Light Freezing Rain	24.7	24.8	0%	55.7	33.3
H28/H30	30-Mar-10	Dow UCAR EG106	-10	Light Freezing Rain	13.8	13.2	-4%	88.0	30.0
H29/H31	30-Mar-10	Clariant Launch	-10	Light Freezing Rain	12.3	12.8	4%	46.6	38.0
H32/H34	30-Mar-10	Dow UCAR EG106	-10	Light Freezing Rain	26.1	24.9	-5%	50.7	19.0
H33/H35	30-Mar-10	Clariant Launch	-10	Light Freezing Rain	25.1	25.5	2%	30.3	30.0
H42/H44	1-Apr-10	Dow UCAR EG106	-3	Freezing Fog	4.2	3.7	-13%	138.3	119.0
H43/H45	1-Apr-10	Clariant Launch	-3	Freezing Fog	3.5	3.6	2%	227.0	140.0
H46/H48	6-Apr-10	Dow UCAR EG106	-14	Freezing Fog	2-5*	2-5*	0%	199.3	148.1
H47/H49	6-Apr-10	Clariant Launch	-14	Freezing Fog	1.9	2.0	5%	114.4	83.0
H51/H53	6-Apr-10	Clariant Launch	-14	Freezing Fog	3.7	3.1	-16%	44.2	62.5
H55/H57	6-Apr-10	Dow UCAR EG106	-25	Freezing Fog	1.4	1.3	-7%	54.8	56.2
H56/H58	6-Apr-10	Clariant Launch	-25	Freezing Fog	1.1	1.3	18%	49.2	46.2
H60/H62	6-Apr-10	Dow UCAR EG106	-25	Freezing Fog	4.0	3.8	-5%	33.8	39.3
H61/H63	6-Apr-10	Clariant Launch	-25	Freezing Fog	4.8	4.2	-13%	11.2	14.3

*This test was conducted while the precipitation rate at the climatic chamber was being changed from 2 g/dm²/h to 5 g/dm²/h. Exact rates not available.

4.3 Adjustments for Differences in Precipitation Rates

Endurance time is highly dependent on precipitation rate. Therefore, when conducting comparative endurance time testing, precipitation rates for the two test plates being compared must be similar.

Several steps are taken to ensure the test plates in comparative tests have equivalent precipitation rates. For example, in outdoor testing, tests are started at the same time so that plates are subjected to the same natural variations in precipitation rate over the duration of the test. In indoor testing, extensive calibration is conducted on individual test positions before testing begins to ensure similar precipitation rates are present. However, despite these steps, variations can still occur:

- When one test plate runs longer than the other in natural conditions, the precipitation rate can decrease or increase during the time when only the remaining test plate is running (changing the average precipitation rate for the test); and
- In laboratory testing, minor variations in precipitation rate can occur between test positions as a result of the spray pattern, variations in air flow, and other factors.

The precipitation rates measured for each of the corresponding baseline and hangar tests were therefore examined for differences. As expected, there were some differences in the precipitation rates and in some cases they were significant. Several actions were taken to modify the data to account for the differences in precipitation rates. For comparative tests with reasonably similar rates, the hangar endurance time was adjusted to correspond to the precipitation rate measured for the baseline test. Several tests were removed from the analysis, as the difference in precipitation rates was considered too great to adjust accurately. These adjustments are detailed below.

4.3.1 Adjustment to Hangar Endurance Time

The hangar endurance time was adjusted to reflect the endurance time that would be expected had the hangar plate been exposed to the same precipitation rate as the baseline plate. This was done by reducing or increasing the hangar endurance time by the percentage amount by which the hangar/baseline precipitation rate varied.

For example, consider Test S1E (see Table 4.4):

- Baseline precipitation rate: 13.6 $g/dm^2/h$
- Hangar precipitation rate: 12.8 $g/dm^2/h$

- Difference in precipitation rates: -6% ((12.8 – 13.6) / 13.6)
- Hangar Endurance Time (unadjusted): 52.0 minutes
- Hangar Endurance Time (adjusted): 48.7 minutes (52.0 + (52.0 x -6%))

The analysis results in an adjusted hangar endurance time of 48.7 minutes. This is the endurance time that corresponds to a precipitation rate of 13.6 $g/dm^2/h$, which is the precipitation rate that was measured on the baseline plate. The two endurance times (baseline and hangar) can now be compared without precipitation rate being a variable contributing to the difference in the two endurance times.

4.3.2 Removal of Data

The method of adjusting endurance times to account for differences in precipitation rates described in Subsection 4.3.1 is rudimentary and does not account for the power-law relationship between precipitation rate and endurance time. For these reasons, the adjustment method is considered reasonably accurate only if the difference in precipitation rates is not exceedingly large.

In this case, “exceedingly large” was defined as a rate difference of greater than 20%. The data was examined to determine if any comparative tests met this criterion. Four comparative tests did meet the criterion: S3E, S9E, S2P, and S3P. These tests were removed from the data set.

All four removed tests were conducted in snow. This is not surprising, as snow endurance time tests are conducted in natural conditions where precipitation rates cannot be controlled, whereas freezing precipitation tests are conducted in the laboratory, where precipitation can be accurately controlled.

4.4 Final Log of Tests

The final log of tests, which includes 40 comparative tests, is shown in Table 4.5. The four tests listed in Subsection 4.3.2 have been removed and the adjusted hangar endurance time has been added. The log includes various parameters for each test.

- **Test #**: Comparative test number (in some cases the baseline and hangar tests had individual test numbers; in these cases the comparative test number is the individual test numbers combined).
- **Date**: Date test was conducted.
- **Fluid**: Test fluid (all tests with neat fluids, no tests with diluted fluids).

- **Ambient Temp.**: Air temperature during the exposure to precipitation phase of the test (in °C).
- **Precip. Type**: Snow, light freezing rain, freezing drizzle, or freezing fog.
- **Precip. Rate**: The rate of precipitation (measured in $g/dm^2/h$).
  - Baseline: Precipitation rate for baseline test.
  - Hangar: Precipitation rate for hangar test.
  - Diff.: Difference in precipitation rates for baseline and hangar tests (hangar relative to baseline, in percentage).
- **Endurance Time**: Time from start of test to fluid failure (in minutes).
  - Baseline: Endurance time for baseline test.
  - Hangar (raw): Endurance time for hangar test.
  - Hangar (adjusted): Adjusted endurance time for hangar test.

Table 4.5: Final Log of Tests

Test #	Date	Fluid	Ambient Temp. (°C)	Precip. Type	Precip. Rate (g/dm²/h)			Endurance Time (mins)		
					Baseline	Hangar	Diff.	Baseline	Hangar (raw)	Hangar (adjusted)
S1E	3-Jan-10	Dow UCAR EG106	-11.5	Snow	13.6	12.8	-6%	69.0	52.0	48.7
S2E	18-Feb-10	Dow UCAR EG106	-1.2	Snow	4.6	4.0	-12%	178.9	164.0	144.3
S4E	23-Feb-10	Dow UCAR EG106	-0.1	Snow	6.2	5.8	-6%	150.6	139.0	130.3
S5E	24-Feb-10	Dow UCAR EG106	-0.5	Snow	8.0	8.0	0%	155.8	104.0	103.7
S6E	24-Feb-10	Dow UCAR EG106	0.8	Snow	7.2	6.9	-4%	172.3	156.0	149.3
S7E	24-Feb-10	Dow UCAR EG106	0.8	Snow	9.1	8.6	-5%	128.9	120.0	114.3
S8E	24-Feb-10	Dow UCAR EG106	0.7	Snow	7.4	7.1	-4%	131.2	100.2	96.4
S10E	27-Feb-10	Dow UCAR EG106	0.9	Snow	9.5	8.0	-16%	130.1	97.0	81.1
S11E	27-Feb-10	Dow UCAR EG106	0.9	Snow	9.6	9.5	-1%	136.3	85.0	84.4
S1P	3-Jan-10	Clariant Launch	-11.5	Snow	14.1	13.6	-4%	79.5	70.0	67.2
S5P	24-Feb-10	Clariant Launch	-0.5	Snow	8.9	7.4	-17%	151.0	193.0	159.9
S6P	24-Feb-10	Clariant Launch	0.8	Snow	6.6	7.5	12%	149.0	187.0	210.1
S8P	24-Feb-10	Clariant Launch	0.7	Snow	6.2	6.1	-1%	258.9	215.7	213.2
S9P	24-Feb-10	Clariant Launch	0.4	Snow	7.0	6.9	-1%	216.1	164.3	163.4
S10P	27-Feb-10	Clariant Launch	0.9	Snow	9.3	8.7	-6%	166.7	118.0	110.5
H1/H3	29-Mar-10	Dow UCAR EG106	-3	Freezing Drizzle	5.0	4.7	-6%	153.8	103.4	97.6
H2/H4	29-Mar-10	Clariant Launch	-3	Freezing Drizzle	5.0	5.4	7%	131.0	192.4	205.1
H6/H8	30-Mar-10	Dow UCAR EG106	-3	Freezing Drizzle	13.8	12.8	-7%	92.5	49.5	46.0
H7/H9	30-Mar-10	Clariant Launch	-3	Freezing Drizzle	14.5	14.4	-1%	115.0	72.5	72.0
H10/H12	29-Mar-10	Dow UCAR EG106	-10	Freezing Drizzle	6.8	6.3	-7%	85.4	54.8	50.8
H11/H13	29-Mar-10	Clariant Launch	-10	Freezing Drizzle	7.3	7.1	-3%	44.4	54.8	53.3
H14/H16	30-Mar-10	Dow UCAR EG106	-10	Freezing Drizzle	16.0	14.8	-8%	50.1	22.1	20.4
H15/H17	30-Mar-10	Clariant Launch	-10	Freezing Drizzle	13.4	13.2	-1%	17.7	31.1	30.6
H19/H21	31-Mar-10	Dow UCAR EG106	-3	Light Freezing Rain	13.5	14.0	4%	68.3	43.2	44.8

Table 4.5: Final Log of Tests (cont'd)

Test #	Date	Fluid	Ambient Temp. (°C)	Precip. Type	Precip. Rate ($g/dm^2/h$)			Endurance Time (mins)		
					Baseline	Hangar	Diff.	Baseline	Hangar (raw)	Hangar (adjusted)
H20/H22	31-Mar-10	Clariant Launch	-3	Light Freezing Rain	13.6	13.1	-4%	121.1	69.2	66.7
H24/H26	31-Mar-10	Dow UCAR EG106	-3	Light Freezing Rain	26.5	25.3	-5%	47.5	25.3	24.2
H25/H27	31-Mar-10	Clariant Launch	-3	Light Freezing Rain	24.7	24.8	0%	55.7	33.3	33.5
H28/H30	30-Mar-10	Dow UCAR EG106	-10	Light Freezing Rain	13.8	13.2	-4%	88.0	30.0	28.7
H29/H31	30-Mar-10	Clariant Launch	-10	Light Freezing Rain	12.3	12.8	4%	46.6	38.0	39.5
H32/H34	30-Mar-10	Dow UCAR EG106	-10	Light Freezing Rain	26.1	24.9	-5%	50.7	19.0	18.1
H33/H35	30-Mar-10	Clariant Launch	-10	Light Freezing Rain	25.1	25.5	2%	30.3	30.0	30.5
H42/H44	1-Apr-10	Dow UCAR EG106	-3	Freezing Fog	4.2	3.7	-13%	138.3	119.0	103.2
H43/H45	1-Apr-10	Clariant Launch	-3	Freezing Fog	3.5	3.6	2%	227.0	140.0	142.9
H46/H48	6-Apr-10	Dow UCAR EG106	-14	Freezing Fog	2-5*	2-5*	0%	199.3	148.1	148.1
H47/H49	6-Apr-10	Clariant Launch	-14	Freezing Fog	1.9	2.0	5%	114.4	83.0	87.4
H51/H53	6-Apr-10	Clariant Launch	-14	Freezing Fog	3.7	3.1	-16%	44.2	62.5	52.4
H55/H57	6-Apr-10	Dow UCAR EG106	-25	Freezing Fog	1.4	1.3	-7%	54.8	56.2	52.2
H56/H58	6-Apr-10	Clariant Launch	-25	Freezing Fog	1.1	1.3	18%	49.2	46.2	54.6
H60/H62	6-Apr-10	Dow UCAR EG106	-25	Freezing Fog	4.0	3.8	-5%	33.8	39.3	37.3
H61/H63	6-Apr-10	Clariant Launch	-25	Freezing Fog	4.8	4.2	-13%	11.2	14.3	12.5

*This test was conducted while the precipitation rate at the climatic chamber was being changed from 2 $g/dm^2/h$ to 5 $g/dm^2/h$. Exact rates not available.

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5. ANALYSIS

The analysis of the endurance time data (presented in Section 4) is described in this section. Additionally, the application of the analysis to provide operational guidance is detailed.

5.1 Relative Hangar Endurance Times

The endurance time data was analysed by looking at the hangar endurance times relative to the corresponding standard endurance times. The "relative hangar endurance time" was calculated by dividing the hangar endurance time by the corresponding standard test endurance time.

The results are presented by fluid brand and precipitation type (snow or simulated freezing precipitation) in the tables below as follows:

- Table 5.1: Dow UCAR EG106 freezing precipitation data;
- Table 5.2: Clariant Launch freezing precipitation data;
- Table 5.3: Dow UCAR EG106 snow data; and
- Table 5.4: Clariant Launch snow data.

Table 5.1: Relative Hangar Endurance Times: Freezing Precipitation, EG Fluid

Test #	Fluid	Precip. Type	Ambient Temp. (°C)	Precip. Rate (g/dm^2/h)	Hangar ET Relative to Baseline ET
H1/H3	Dow UCAR EG106	Freezing Drizzle	-3	5	63%
H6/H8	Dow UCAR EG106	Freezing Drizzle	-3	14	50%
H10/H12	Dow UCAR EG106	Freezing Drizzle	-10	7	59%
H14/H16	Dow UCAR EG106	Freezing Drizzle	-10	16	41%
H19/H21	Dow UCAR EG106	Light Freezing Rain	-3	14	66%
H24/H26	Dow UCAR EG106	Light Freezing Rain	-3	27	51%
H28/H30	Dow UCAR EG106	Light Freezing Rain	-10	14	33%
H32/H34	Dow UCAR EG106	Light Freezing Rain	-10	26	36%
H42/H44	Dow UCAR EG106	Freezing Fog	-3	4	75%
H46/H48	Dow UCAR EG106	Freezing Fog	-14	2-5	74%
H55/H57	Dow UCAR EG106	Freezing Fog	-25	1	95%
H60/H62	Dow UCAR EG106	Freezing Fog	-25	4	110%

Table 5.2: Relative Hangar Endurance Times: Freezing Precipitation, PG Fluid

Test #	Fluid	Precip. Type	Ambient Temp. (°C)	Precip. Rate (g/dm²/h)	Hangar ET Relative to Baseline ET
H2/H4	Clariant	Freezing Drizzle	-3	5	157%
H7/H9	Clariant	Freezing Drizzle	-3	15	63%
H11/H	Clariant	Freezing Drizzle	-10	7	120%
H15/H	Clariant	Freezing Drizzle	-10	13	173%
H20/H	Clariant	Light Freezing	-3	14	55%
H25/H	Clariant	Light Freezing	-3	25	60%
H29/H	Clariant	Light Freezing	-10	12	85%
H33/H	Clariant	Light Freezing	-10	25	100%
H43/H	Clariant	Freezing Fog	-3	4	63%
H47/H	Clariant	Freezing Fog	-14	2	76%
H51/H	Clariant	Freezing Fog	-14	4	119%
H56/H	Clariant	Freezing Fog	-25	1	111%
H61/H	Clariant	Freezing Fog	-25	5	112%

Table 5.3: Relative Hangar Endurance Times: Snow, EG Fluid

Test #	Fluid	Precip. Type	Ambient Temp. (°C)	Precip. Rate (g/dm²/h)	Hangar ET Relative to Baseline ET
S1E	Dow UCAR EG106	Snow	-12	14	71%
S2E	Dow UCAR EG106	Snow	-1	5	81%
S4E	Dow UCAR EG106	Snow	0	6	87%
S5E	Dow UCAR EG106	Snow	-1	8	67%
S6E	Dow UCAR EG106	Snow	1	7	87%
S7E	Dow UCAR EG106	Snow	1	9	89%
S8E	Dow UCAR EG106	Snow	1	7	73%
S10E	Dow UCAR EG106	Snow	1	10	62%
S11E	Dow UCAR EG106	Snow	1	10	62%

Table 5.4: Relative Hangar Endurance Times: Snow, PG Fluid

Test #	Fluid	Precip. Type	Ambient Temp. (°C)	Precip. Rate (g/dm²/h)	Hangar ET Relative to Baseline ET
S1P	Clariant	Snow	-12	14	85%
S5P	Clariant	Snow	-1	9	106%
S6P	Clariant	Snow	1	7	141%
S8P	Clariant	Snow	1	6	82%
S9P	Clariant	Snow	0	7	76%
S10P	Clariant	Snow	1	9	66%

5.2 Examination of Relative Hangar Endurance Times

Each of the data sets presented in Subsection 5.1 was examined to determine the minimum relative hangar endurance time, the average relative hangar endurance time, the standard deviation of the data set, and the average less 2 standard deviations of the data set. These statistics are provided in Table 5.5.

It should be noted that limited testing was conducted; it is expected that additional testing would provide improved standard deviation values.

Table 5.5: Statistics of Relative Hangar Endurance Time Data Sets

Precip. Type	Fluid	Minimum Values	Average	Standard Deviation (σ)	Average Less 2 σ
Freezing Precipitation	Dow UCAR EG106	33%, 36%	63%	23%	16%
	Clariant Launch	55%, 60%	100%	37%	25%
Snow	Dow UCAR EG106	62%, 62%	75%	11%	54%
	Clariant Launch	66%, 76%	93%	27%	38%

The statistics indicate that after a 30-minute waiting period, the anti-icing fluids tested under simulated hangar conditions (warm fluid, warm aircraft) do retain the ability to provide protection in the form of holdover time. These holdover times, however, are shorter than the holdover times that would be provided in a standard operation, with cold fluid applied to a cold aircraft and immediately exposed to precipitation.

Although the test results indicate a significant amount of holdover time remains after the waiting period (on average 63% to 100% depending on fluid and precipitation type), there was wide variation in the test results. It was therefore necessary to establish an appropriate analysis methodology to deduce appropriate operational guidance from the test results.

5.3 Analysis Methodology for Providing Operational Guidance

As the types of tests and the test results differed by precipitation type (snow vs. freezing precipitation), it was recommended that different analysis methodologies be used to provide operational guidance for snow and freezing precipitation.

5.3.1 Natural Snow

As test conditions cannot be controlled in natural snow and because limited data was collected, it was determined that the average relative endurance time less two standard deviations would be a suitable value to estimate a safe hangar endurance time in snow. Note: The average relative hangar endurance time ± two standard deviations encompasses 95% of data; only 2.5% of the data is expected to have a relative hangar endurance time less than the average less two standard deviations.

5.3.2 Freezing Precipitation

As testing in freezing precipitation encompassed the majority of weather conditions provided in the Type IV holdover time tables, it was determined that using the minimum relative hangar endurance times was a suitable value to estimate a safe hangar endurance time for freezing precipitation.

5.4 Operational Guidance

5.4.1 Allowance Times for Hangar Anti-Icing

Using the analysis criteria described in Subsections 5.3.1 and 5.3.2, the ratios given below were deemed appropriate for use in calculating allowance times that start when the aircraft departs from the hangar for hangar anti-icing operations that have up to 30 minutes between fluid application and exposure to precipitation. The ratios apply to the currently published holdover times.

Dow UCAR Endurance EG106

- Snow: 50% of published holdover time
- Freezing Precipitation: 35% of published holdover time

Clariant Safewing MP IV Launch

- Snow: 35% of published holdover time
- Freezing Precipitation: 50% of published holdover time

5.4.2 Sample Holdover Time Table for Hangar Operations

Table 5.6 shows prospective holdover time guidance for use in hangar operations. The sample table is for Dow UCAR Endurance EG106. The ratios given in

Subsection 5.4.1 (50% for snow, 35% for freezing precipitation) have been applied to the published holdover times to create allowance times for hangar anti-icing, which are shown along with the standard holdover times in the table.

Notes at the bottom of the table indicate that the holdover time clock (used with the standard holdover times) starts at the time of fluid application, and the allowance time clock (used with the hangar allowance times) starts when the aircraft departs from the hangar. It is also noted that the user needs to determine whether the holdover time or allowance time is more advantageous in each situation. This is partially dependent on the waiting time that elapses.

5.4.3 Required Change to Guidance Material

For operators to use the operational guidance provided, a change to TP 14052E (2) is needed. Transport Canada made the required change, as shown in the following excerpt from the document* (the revised text is underlined):

- **TP 14052E §10.11 (Applying Type IV Fluid in a Hangar):** *The period of time after fluid application and the air temperature in the hangar both have an effect on the ability of the fluid to protect the aircraft when it is pulled out of the hangar and into freezing/frozen precipitation. The HOT for a fluid is based largely on the fluid's thickness on the surface. The fluid thickness varies with time and temperature. <u>Unless otherwise approved in an air operator's program</u>, the holdover time clock must be started at the time of the first application of anti-icing fluid onto a clean wing. It may not be started when the aircraft is first exposed to freezing/frozen precipitation.*

This change allows operators to use the operational guidance for hangar anti-icing if it is incorporated into their approved ground icing program.

**Note this change was published in the Transport Canada HOT Guidelines for Winter 2010-11, which included a section on updates to TP 14052.*

5.4.4 Operational Guidance Limitation

It should be noted that the operational guidance provided in this report is fluid-specific. It does not apply to fluids other than Clariant Safewing MP IV Launch and Dow UCAR Endurance EG106. Additional testing would be required if an operator wanted to incorporate guidance for another fluid for use in hangar operations.

Table 5.6: Sample Holdover Times/Allowance Times for Hangar Anti-Icing with Dow UCAR EG106

<table>
<tr><th colspan="2">Outside Air Temperature</th><th rowspan="2">Guidance Type[1]</th><th colspan="6">Approximate Holdover Times / Allowance Times
Under Various Weather Conditions
(hours:minutes)</th></tr>
<tr><th>Degrees Celsius</th><th>Degrees Fahrenheit</th><th>Freezing Fog</th><th>Snow, Snow Grains or Snow Pellets</th><th>Freezing Drizzle</th><th>Light Freezing Rain</th><th>Rain on Cold Soaked Wing</th><th>Other</th></tr>
<tr><td rowspan="2">-3 and above</td><td rowspan="2">27 and above</td><td>Holdover Time[2]</td><td>2:05 – 3:10</td><td>0:40 – 1:20</td><td>1:10 – 2:00</td><td>0:50 – 1:15</td><td>0:20 – 2:00</td><td rowspan="6">CAUTION:
No holdover time guidelines exist</td></tr>
<tr><td>Allowance Time[3]</td><td>0:44 – 1:07</td><td>0:20 – 0:40</td><td>0:25 – 0:42</td><td>0:18 – 0:26</td><td>0:07 – 0:42</td></tr>
<tr><td rowspan="2">below -3 to -14</td><td rowspan="2">below 27 to 7</td><td>Holdover Time[2]</td><td>1:50 – 3:20</td><td>0:30 – 1:05</td><td>0:55 – 1:50</td><td>0:45 – 1:10</td><td rowspan="4"></td></tr>
<tr><td>Allowance Time[3]</td><td>0:39 – 1:10</td><td>0:15 – 0:32</td><td>0:19 – 0:39</td><td>0:16 – 0:24</td></tr>
<tr><td rowspan="2">below -14 to -25 or LOUT</td><td rowspan="2">below 7 to -13 or LOUT</td><td>Holdover Time[2]</td><td>0:30 – 1:05</td><td>0:15 – 0:30</td><td rowspan="2" colspan="2"></td></tr>
<tr><td>Allowance Time[3]</td><td>0:10 – 0:23</td><td>0:07 – 0:15</td></tr>
</table>

NOTES

1 It is the responsibility of the operator to determine the optimal (higher) holdover or allowance time for the given operation. This is partly dependent on the hangar waiting time.

2 Holdover times are based on current values in the holdover time guidelines; the holdover time clock starts at the initial application of the anti-icing fluid.

3 Allowance times apply if aircraft is anti-iced in a hangar and departs the hangar within 30 minutes of fluid application; the allowance time clock starts as soon as the aircraft departs the hangar.

6. SUPPLEMENTAL RESEARCH: HOLDOVER TIMES RELATED TO PRE-TREATMENT ANTI-ICING

Supplemental research was conducted on an anti-icing operational practice that is related to the practice of anti-icing in hangars. “Pre-treatment” anti-icing is the practice of applying fluid to aircraft in periods of non-precipitation to protect the aircraft from anticipated future precipitation. Like the hangar application, there is a “waiting time” between fluid application and exposure to precipitation. The main difference between hangar anti-icing and pre-treatment anti-icing is that the fluid and aircraft are typically at ambient temperature for pre-treatment anti-icing, rather than at room temperature for hangar anti-icing.

This section describes the supplemental research conducted on holdover times related to pre-treatment anti-icing.

6.1 Objective

Guidance materials state that the holdover time clock must be started when fluid application begins, even if there is no active precipitation. This can lead to the scenario where an aircraft is pre-treated, the holdover time expires, but there has been no active precipitation during the holdover time. If precipitation begins after the holdover time expires, operators must re-treat the aircraft (i.e., clean off the old fluid with deicing fluid and reapply anti-icing fluid), even if a layer of fluid remains on the aircraft and offers some protection time.

The objective of the supplemental research was to conduct a limited number of tests to investigate the impact of pre-treatment waiting time on holdover time.

6.2 Procedure

The pre-treatment tests were conducted in conjunction with the hangar anti-icing tests. The procedure for the conduct of the pre-treatment tests is provided in the same procedure that was written for the hangar anti-icing tests (included in Appendix D). The same methodology used for the hangar tests was used for the pre-treatment tests: comparative tests. In this case the relative holdover time performance of pre-treatment applications was compared to standard applications.

The same test methodology, test locations, and fluids were used for the pre-treatment tests (as detailed in Section 3). The test protocol for the standard test was the same; however, the test protocol for the pre-treatment tests differed, as they required the test surface and fluid temperature to be at OAT (as opposed to room temperature for the hangar tests). The three variables considered for the standard and pre-treatment tests are shown in Table 6.1.

As illustrated in Table 6.1, the only difference between the standard test protocol and the pre-treatment test protocol is the 30-minute waiting time between fluid application and exposure to precipitation required for the pre-treatment tests.

Table 6.1: Test Variables

Variable	Standard Test Protocol	Pre-Treatment Test Protocol
Surface Temperature	OAT	OAT
Fluid Temperature	OAT	OAT
Time Between Fluid Application and Exposure to Precipitation	0 mins	30 mins

6.3 Data

A total of 10 comparative tests were conducted. Tests were conducted with two fluids under natural (snow) and simulated (freezing fog, freezing drizzle, light freezing rain) precipitation conditions.

The number of tests conducted is summarized by fluid and precipitation type in Table 6.2 and by ambient temperature and precipitation type in Table 6.3.

Table 6.2: Tests Conducted by Fluid (Type) / Precipitation Type

	Clariant Launch (PG)	Dow UCAR EG106 (EG)	Total
Snow	2	2	**4**
Freezing Fog	1	1	**2**
Freezing Drizzle	1	1	**2**
Light Freezing Rain	1	1	**2**
Total	**5**	**5**	**10**

Table 6.3: Tests Conducted by Precipitation Type / Ambient Temperature

	-25°C	-14°C	-10°C	-3°C	≥0°C	Total
Snow	-	-	-	-	4	**4**
Freezing Fog	1	1	-	-	-	**2**
Freezing Drizzle	-	-	1	1	-	**2**
Light Freezing Rain	-	-	1	1	-	**2**
Total	**1**	**1**	**2**	**2**	**4**	**10**

The raw pre-treatment data was subjected to the same treatment as the hangar data (detailed in Subsection 4.3):

- The precipitation rate data was examined to determine if the difference between the precipitation rate measured on the pre-treatment plate and the rate measured on the baseline plate differed by more than 20% (no tests met this criterion, so no tests were removed); and

- The pre-treatment endurance times were adjusted to reflect the endurance times that would be expected had the pre-treatment plate been exposed to the same precipitation rate as the baseline plate (see example in Subsection 4.3.1).

The result of the treatment is the final log of tests shown in Table 6.4.

Table 6.4: Pre-Treatment Log of Tests

Test #	Date	Fluid	Ambient Temp. (°C)	Precip. Type	Precip. Rate ($g/dm^2/h$)			Endurance Time (mins)		
					Baseline	Pre-Treat.	Diff.	Baseline	Pre-Treat. (raw)	Pre-Treat. (adjusted)
1	23-Feb-10	Dow UCAR EG106	0	Snow	6.2	6.0	-3%	150.6	105.5	101.9
2	24-Feb-10	Clariant Launch	0	Snow	7.0	7.5	7%	216.1	142.8	153.4
3	24-Feb-10	Dow UCAR EG106	1	Snow	9.1	9.2	2%	128.9	126.9	128.8
4	27-Feb-10	Clariant Launch	1	Snow	9.3	8.8	-5%	166.7	125.3	118.7
H1/H5	29-Mar-10	Dow UCAR EG106	-3	Freezing Drizzle	5.0	4.3	-13%	153.8	145.5	127.3
H15/H18	30-Mar-10	Clariant Launch	-10	Freezing Drizzle	13.4	15.9	19%	17.7	13.3	15.8
H19/H23	31-Mar-10	Dow UCAR EG106	-3	Light Freezing Rain	13.5	13.7	1%	68.3	61.7	62.6
H33/H36	30-Mar-10	Clariant Launch	-10	Light Freezing Rain	25.1	25.8	3%	30.3	21.0	21.6
H51/H54	6-Apr-10	Clariant Launch	-14	Light Freezing Fog	3.7	3.7	0%	44.2	36.1	36.1
H55/H59	6-Apr-10	Dow UCAR EG106	-25	Light Freezing Fog	1.4	1.3	-11%	54.8	60.7	54.2

6.4 Analysis

The pre-treatment data was analysed in a similar manner as the hangar data (detailed in Section 5):

- The relative pre-treatment endurance time (compared to the baseline endurance time) was calculated; and
- For each of the PG and EG fluid data sets, the minimum relative endurance times were identified, and the average, standard deviation, and average less two standard deviations were calculated.

The relative pre-treatment endurance times are provided in Table 6.5. Table 6.6 shows the statistics calculated for the individual fluid data sets.

Table 6.5: Relative Pre-Treatment Endurance Times

Test #	Fluid	Precip. Type	Ambient Temp. (°C)	Precip. Rate (g/dm²/h)	Pre-Treat. ET Relative to Baseline ET
2	Clariant Launch	Snow	0.4	7.0	71%
4	Clariant Launch	Snow	0.9	9.3	71%
H15/H18	Clariant Launch	Freezing Drizzle	-10	13.4	89%
H33/H36	Clariant Launch	Light Freezing Rain	-10	25.1	71%
H51/H54	Clariant Launch	Freezing Fog	-14	3.7	82%
1	Dow EG106	Snow	-0.1	6.2	68%
3	Dow EG106	Snow	0.8	9.1	100%
H1/H5	Dow EG106	Freezing Drizzle	-3	5.0	83%
H19/H23	Dow EG106	Light Freezing Rain	-3	13.5	92%
H55/H59	Dow EG106	Freezing Fog	-25	1.4	99%

Table 6.6: Statistics of Relative Pre-Treatment Endurance Times

Fluid	Min Values	Average	Standard Deviation	Lower 2 σ
Clariant Launch	71%, 71%	77%	8%	60%
Dow UCAR EG106	68%, 83%	88%	13%	61%
All Data	**68%, 71%**	**83%**	**12%**	**58%**

6.5 Conclusions

The preliminary tests conducted to examine holdover times for pre-treatment anti-icing operations indicate it may be possible to provide additional holdover time guidance for pre-treatment operations. The results show that, on average, after a 30-minute waiting time, 83% of the holdover time remains. However, as only 10 tests were conducted, there is not enough data to draw a firm conclusion. More data would be required to confirm these results.

6.6 Recommendations

To provide general guidance for pre-treatment anti-icing operations, an extensive test program would be needed. The program would need to include the following, at a minimum:

1. Tests conducted under all precipitation rates, precipitation types, and ambient temperatures encompassed by the holdover time guidelines;
2. Tests conducted with various fluid brands; and
3. Tests conducted using various waiting times.

Due to the limited funding available for ground deicing research and the limited use of this practice in the industry, it is not feasible or recommended to complete such a program.

An alternative approach – developing allowance times for specific operations – is recommended. The precedent for using this type of approach was set several years ago with the introduction of allowance times for use in ice pellet conditions. In addition, a similar precedent was developed that allowed usage of forced air assist with specific thickened fluids, a specific nozzle brand, and nozzle settings. A similar approach was subsequently used to create allowance times for hangar anti-icing operations conducted with specific fluids, as described in Section 5 of this report.

This approach would permit allowance times to be developed for pre-treatment anti-icing operations under specific conditions. These conditions (i.e., precipitation types, ambient temperatures, fluids, waiting times) would be determined by the prevailing conditions for which individual operators require pre-treatment anti-icing holdover time guidance.

7. CONCLUSIONS

Conclusions are provided below for hangar anti-icing (preliminary research described in Section 2, primary research described in Sections 3 to 5) and pre-treatment anti-icing (supplemental research described in Section 6).

7.1 Hangar Anti-Icing

7.1.1 Preliminary Research: Thickness Tests

Preliminary research, consisting of measuring fluid thicknesses on aircraft surfaces and flat plates, concluded that 30 minutes was an appropriate waiting time to use in the hangar anti-icing comparative endurance time tests.

During these tests it was observed that the thickness of cold fluid applied on a cold surface is significantly greater than the fluid thickness of warm fluid applied on a warm surface. Further discussion following the completion of the tests, and a review of Winter 2008-09 endurance time data collected in snow, concluded that using warm fluid on a warm aircraft may result in holdover times that are shorter than those experienced in a standard operation (cold fluid, cold aircraft).

7.1.2 Primary Research: Endurance Times

Comparative endurance time testing established that endurance times of fluids applied in a hangar anti-icing operation (warm fluid, warm surface, 30-minute waiting time between fluid application and exposure to precipitation) are shorter than endurance times of fluids applied in a standard anti-icing operation (cold fluid, cold surface, immediate exposure to precipitation).

However, an analysis of the data concluded that allowance times that start when the aircraft departs the hangar can be provided for hangar anti-icing operations. The allowance times are calculated as a percentage of published holdover times and vary by fluid and precipitation type. Testing conducted in 2009-10 provided allowance times for two fluids, Dow UCAR Endurance EG106 and Clariant Safewing MP IV Launch. The allowance times are as follows:

- Dow UCAR Endurance EG106 (in snow): 50% of the published holdover time;
- Dow UCAR Endurance EG106 (in freezing precipitation): 35% of the published holdover time;

- Clariant Safewing MP IV Launch (in snow): 35% of the published holdover time; and
- Clariant Safewing MP IV Launch (in freezing precipitation): 50% of the published holdover time.

These results are fluid-specific and are limited to the two fluids tested and to hangar waiting times of 30 minutes or less. Additional testing would be required to determine allowance times for other fluids and for other waiting times.

To use these allowance times, an operator would need to incorporate this guidance into their Transport Canada approved ground icing program.

7.2 Pre-Treatment Anti-Icing

Supplementary research was conducted in conjunction with the hangar anti-icing research to examine holdover times for pre-treatment anti-icing operations. The research indicated it may be possible to provide allowance times for pre-treatment operations. However, more data would be required to confirm these results.

8. RECOMMENDATIONS

8.1 Recommendations for Operations

Following the conclusion of this research, a recommendation was made to Transport Canada to modify its guidance to allow operators to use the hangar guidance material provided in this report. Transport Canada subsequently made an addition to TP 14052 (published in the Winter 2010-11 HOT Guidelines) that allows operators to use the guidance if it is included in the operator's approved ground icing program.

It is therefore recommended that operators incorporate the guidance into their approved ground icing programs if they conduct hangar operations and want to use the guidance (allowance times) provided in this report.

8.2 Recommendations for Further Research

Further research should be conducted to evaluate endurance times for indoor warm soaked anti-icing applications (i.e., warm fluid, warm aircraft). This is a common scenario and may provide shorter endurance times compared to the current holdover times used for hangar operations. Limited testing could also investigate the effect of different fuel levels, as this will affect the wing's ability to remain cold or warm while soaked.

Further research should also be conducted to examine the effect of pre-treatment anti-icing on fluid holdover time. It is recommended that an allowance time approach – which would permit allowance times to be developed for pre-treatment anti-icing operations under specific conditions as required by individual operators – be taken.

Finally, if required by operators, further research should be conducted for hangar anti-icing operations with different fluid brands and different waiting times.

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5. Federal Aviation Administration Advisory Circular 135-16, *Ground Deicing and Anti-Icing Training and Checking*, December 1994.

6. Federal Aviation Administration Advisory Circular 120-60B, *Ground Deicing and Anti-Icing Program*, December 2004.

7. Bendickson, S., *Aircraft Ground De/Anti-Icing Fluid Holdover Time Development Program for the 2009-10 Winter*, APS Aviation Inc., Transportation Development Centre, Montreal, September 2010, TP 15050E, 86.

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APPENDIX A

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2009-10

TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT EXCERPT – AIRCRAFT & ANTI-ICING FLUID WINTER TESTING 2009-10

5.2 DE/ANTI-ICING FLUIDS RESEARCH (AND HOLDOVER TIME CREATION)

5.2.1 Aircraft De/Anti-Icing Fluid Endurance Time Testing

5.2.14 HOT's for Indoor (Aircraft Hangar) Anti-icing Applications

a) Develop methodology and procedure for simulating indoor anti-icing operations. Testing will aim at simulating various potential scenarios typical to an indoor anti-icing operation including different fuel temperatures, fuel levels, exposure delay time, etc. If possible, testing should also examine delay of start of precipitation following preventative anti-icing applications; attempts should be made to conduct this testing in conjunction with the hangar tests to minimize costs;

b) Consultations with NBAA or CBAA, to determine which areas of research are of most interest to the industry;

c) Review and finalize methodology and procedure;

d) Conduct natural snow tests at the P.E.T test site;

e) Conduct testing at the NRC Climatic Environment Facility (CEF). It is anticipated that testing will be conducted in conjunction with standard HOT testing;

f) Analyze data and results; and

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

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APPENDIX B

PROCEDURE:
FULL-SCALE EVALUATION OF FLUID THICKNESS ON INDOOR AIRCRAFT HANGER ANTI-ICING APPLICATIONS

CM2169.002

FULL-SCALE EVALUATION OF FLUID THICKNESS ON INDOOR AIRCRAFT HANGER ANTI-ICING APPLICATIONS

Winter 2009-10

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: David Youssef

Reviewed by: John D'Avirro

APS Aviation Inc.

December 22, 2009
Final Version 1.0

EVALUATION OF FLUID THICKNESS ON INDOOR AIRCRAFT HANGER ANTI-ICING APPLICATIONS

Winter 2009-10

1. BACKGROUND

In recent years, indoor application of anti-icing fluid on aircraft has been an important topic of industry discussion. It is understood that many fixed based operators anti-ice aircraft when they are still parked inside the hanger. Often this aircraft has been in the hanger for a long enough period of time that the skin temperature and fuel temperature is equal to the ambient indoor temperature.

The holdover time of a given fluid is calculated as beginning with the final application of the anti-icing fluid, and as expiring when the fluid is no longer effective. Once an aircraft is anti-iced inside a hanger there is an elapsed period of time from the end of fluid application to precipitation exposure. This elapsed time may be due to a delay in aircraft readiness, or more simply the time to marshal the aircraft outside of the hanger.

Questions have been raised concerning the effect this elapsed period may have on the endurance time of anti-icing fluids.

1.1 Effect of Time on Film Thickness Profiles and Temperature of Fluid

There is some industry concern related to the recent guidance material provided on hanger anti-icing. Since the holdover time clock commences at the start of application of anti-icing fluid, air operators are concerned that when anti-icing inside a heated hanger (say 1 hour before), there would be no holdover time left, despite the fact there is fluid still present on the wing. Operators are suggesting that with a stabilized fluid film thickness still present, there should be some reduced holdover time provided.

The temperature of the fluid may play a large role in the thickness decay rate of anti-icing fluids. An improved understanding of fluid temperature on thickness decay rates may shed some light on this.

1.2 Associated Research Activity

A separate program of tests is being developed simultaneously on flat plates to potentially determine allowance times.

The test activity described in that procedure may provide some guidance material related to the delay time (inside the hanger) of aircraft prior to exposure to precipitation. For example, should the delay time be 30 minutes or 60 minutes? (A 30 minute delay would provide higher allowance times than a 60 minute delay)

2. OBJECTIVE

The objective of the project is to measure the thickness decay profiles of anti-icing fluid that is applied indoors in a hanger setting. This profile will be compared to the more traditional approach of applying fluid outdoors. The temperature of the fluid and the aircraft will be altered to provide a variety of scenarios. Tests are anticipated on a fill-scale aircraft as well as cold-soak box surfaces.

3. TEST PLAN

3.1 Fluid Application Protocols

Testing will be conducted on one or two occasions at the Transport Canada Hanger at Ottawa Macdonald-Cartier International Airport. Testing should be conducted in periods of non-precipitation and mild winds. Because part of the testing requires a warm aircraft, a reasonable amount of warm-up time will be required. The test schedule will remain flexible and will be dependent on the availability of the aircraft.

Currently, three test types are proposed.

1. *Warm Fluid, Warm Aircraft*
    - Determining the thickness profile of applying warm anti-icing fluid, onto a warm aircraft.
2. *Cold Fluid, Warm Aircraft*
    - Determining the thickness profile of applying cold anti-icing fluid, onto a warm aircraft.
3. *Cold Fluid, Cold Aircraft*
    - Determining the thickness profile of applying cold anti-icing fluid, onto a cold aircraft.

For all tests, fluid will be applied to both the aircraft and two cold-soak boxes.

3.2 Test Set-up

3.2.1 Aircraft

The aircraft will be placed outside the hanger for all tests that require a cold wing surface. Alternatively, the aircraft will be brought inside the hanger for all tests requiring a warm surface.

3.2.2 Cold-Soak Boxes

Two standard cold soak boxes will be placed on two separate test stands situated near the wing of the aircraft. This will be inside the hanger when the test calls for a warm aircraft, and outside the hanger for a cold aircraft.

3.3 Surface and Fluid Temperatures

All initial surface and fluid temperatures should be recorded for each test.

3.4 Fluid Film Thickness Measurements

Fluid film thickness will be measured every 15 minutes from the time of fluid application to either a pre-determined time or until the thickness has stabilized.

Section 3.3.1 and 3.3.2 demonstrate how measurements will be observed on the aircraft and cold-soak boxes, respectively.

3.4.1 Aircraft

Specific measurement locations on each of two chords will be visually determined, and noted on a data form. There should be approximately three locations near the leading edge and three near the trailing edge. Some locations will be subject to “reach” of the observer.

Two chords will be indentified on the wing. This will be done such that the Figure 3.1.

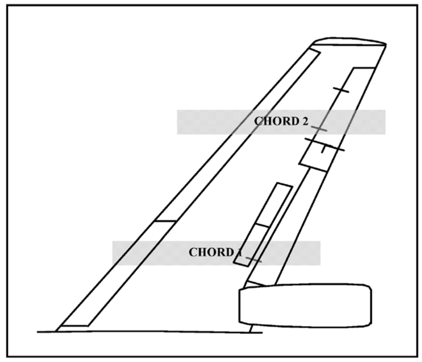


Figure 3.1: Wing Chords

On each of these chords, 6 positions will be identified as follows:

- Position 1: On Leading Edge, halfway point between LE nose and joint to rest of wing.)
- Position 2: On wing: 15 cm beyond joint
- Position 3: As far as can reach beyond Leading Edge Side
- Position 4: As far as can reach beyond Trailing Edge Side
- Position 5: 15 cm from Trailing Edge Gap
- Position 6: Halfway point between end of trailing edge and joint to wing.

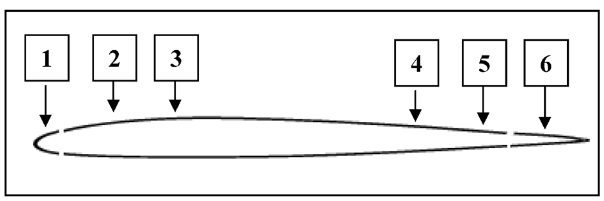


Figure 3.2: Shows the approximate location of each position.

3.4.2 Cold-Soak Boxes

Thickness measurements will be taken on the standard 2.5 cm, 15 cm, and 30 cm lines of each cold-soak box. To minimize errors resulting from deformations (divots) in the fluid caused specifically by the thickness gauge, measurement locations can be staggered slightly.

4. TEST PROCEDURE

As mentioned in Section 3.1, three fluid application protocols will be employed. Attachment I demonstrates the test plan instructions. As mentioned in Section 3.3 fluid film thickness will be measured every 15 minutes from the time of fluid application to either a pre-determined time or until the thickness has stabilized.

5. EQUIPMENT

A list of equipment required for this testing is included in Attachment II

6. FLUIDS

Dow EG106 Endurance fluid will be provided by Transport Canada for this testing. Fluid Samples should be taken from the fluid applied to the wing, and also from the truck tank.

7. PERSONNEL

Two personnel will be required to conduct these tests. One individual will be responsible to measure thickness and the other individual will prepare fluids, assist with fluid application, and record all measurements.

8. DATA FORMS

Standard data forms to measure thickness will be used in this testing. They are included in Attachment III.

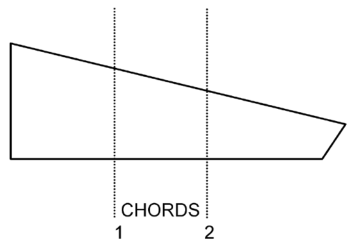
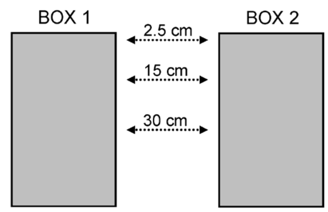
9. SAFETY PRECAUTIONS

- All personnel must be familiar with Material Safety Data Sheets (MSDS) for fluids;
- When in controlled airport areas, ensure correct procedures;
- When working on ladders, ensure equipment is stable;

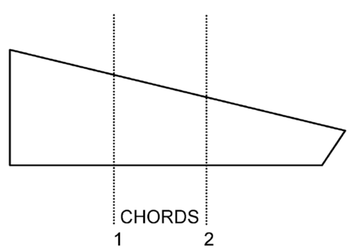
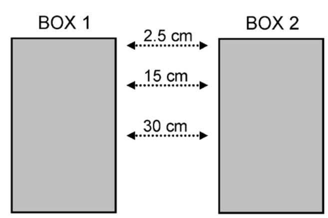
- When working about aircraft, maintain safe distance from all external sensors and sensitive aircraft surfaces
- Appropriate footwear and clothing for frigid temperatures are to be worn by all personnel;
- The test area must be cleared of snow and ice before testing;
- If fluid comes into contact with skin, rinse hands under running water; and
- If fluid comes into contact with eyes, flush with the portable eye wash station.

ATTACHMENT I

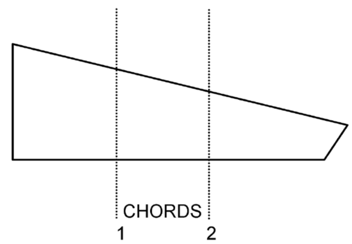
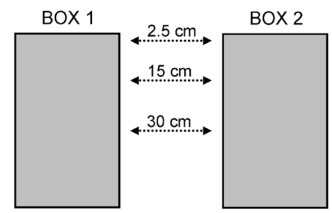
Test Protocol 1
Inside Hanger: Warm Fluid, Warm Aircraft

WING	BOXES
	
• Transport Canada will apply warm fluid to a warm wing, inside the hanger • APS will measure thickness on 2 chords on 6 positions.	• Box 1: Transport Canada will apply warm fluid to box 1 • Box 2: APS will apply warm fluid to box 2 • APS will measure thickness on the 2.5, 15 and 30 cm lines

Test Protocol 2.
Inside Hanger: Cold Fluid, Warm Aircraft

WING	BOXES
	
• Transport Canada will apply warm fluid to a warm wing, inside the hanger • APS will measure thickness on 2 chords on 6 positions.	• Box 1: Transport Canada will apply warm fluid to box 1 • Box 2: APS will apply warm fluid to box 2 • APS will measure thickness on the 2.5, 15 and 30 cm lines

Test Protocol 3.
Outside Hanger: Cold Fluid, Cold Aircraft

WING	BOXES
	
• Transport Canada will apply warm fluid to a warm wing, inside the hanger • APS will measure thickness on 2 chords on 6 positions.	• Box 1: Transport Canada will apply warm fluid to box 1 • Box 2: APS will apply warm fluid to box 2 • APS will measure thickness on the 2.5, 15 and 30 cm lines

ATTACHMENT II

List of Equipment

- 2 x 1-Position Test Stands
- 2 x Standard Aluminum Cold Soak Boxes
- 2 x Rectangular Wet Film Thickness Gauge
- 2 x Octogon Wet Film Thickness Gauge
- Stand-alone ladder
- Empty 1-litre bottles for fluid sampling
- Inclinometer
- Hand-held temperature reader
- Surface temperature probe
- Fluid temperature probe
- Drum Holder (Horse)
- Drum Tap

ATTACHMENT III

APS Aviation Inc.

DATA FORM: AIRCRAFT THICKNESS PROFILE

Date: ____________

Initial Aircraft Surface Temp ____________ Initial Aircraft Surface Temp ____________ Run # ____________

Initial Fluid Temp: ____________ Initial Fluid Temp: ____________ Location: ____________

CHORD ____________

POSITION 1		POSITION 2		POSITION 3		POSITION 4		POSITION 5		POSITION 6	
Time (hh:mm:ss)	Thickness(mils)	Time (hh:mm:ss)	Thickness(mils)	Time (hh:mm:ss)	Thickness(mils)	Time (hh:mm:ss)	Thickness(mils)	Time (hh:mm:ss)	Thickness(mils)	Time (hh:mm:ss)	Thickness(mils)

Note: Take Measurements every 15 Minutes

Comments:

____

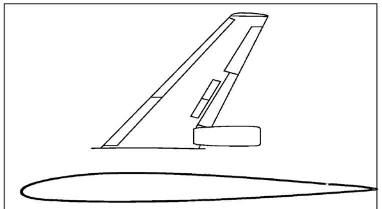
____

____

____

____

____



Mark approximate locations all positions on both top view and plan view

Written By: ____________

ATTACHMENT III (CONT'D)

APS Aviation Inc.

DATA FORM: BOX THICKNESS PROFILE

Date: ____________

Initial Aircraft Surface Temp ____________ Initial Aircraft Surface Temp ____________ Run # ____________

Initial Fluid Temp: ____________ Initial Fluid Temp: ____________ Location: ____________

BOX 1				BOX 2			
Time (hh:mm:ss)	2.5 cm Line	15 cm Line	30 cm Line	Time (hh:mm:ss)	2.5 cm Line	15 cm Line	30 cm Line

Note: Take Measurements every 15 Minutes

Comments:

Written By: ____________

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Final Version 1.0, December 09

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APPENDIX C

CHARTS OF FLUID THICKNESS TEST MEASUREMENTS

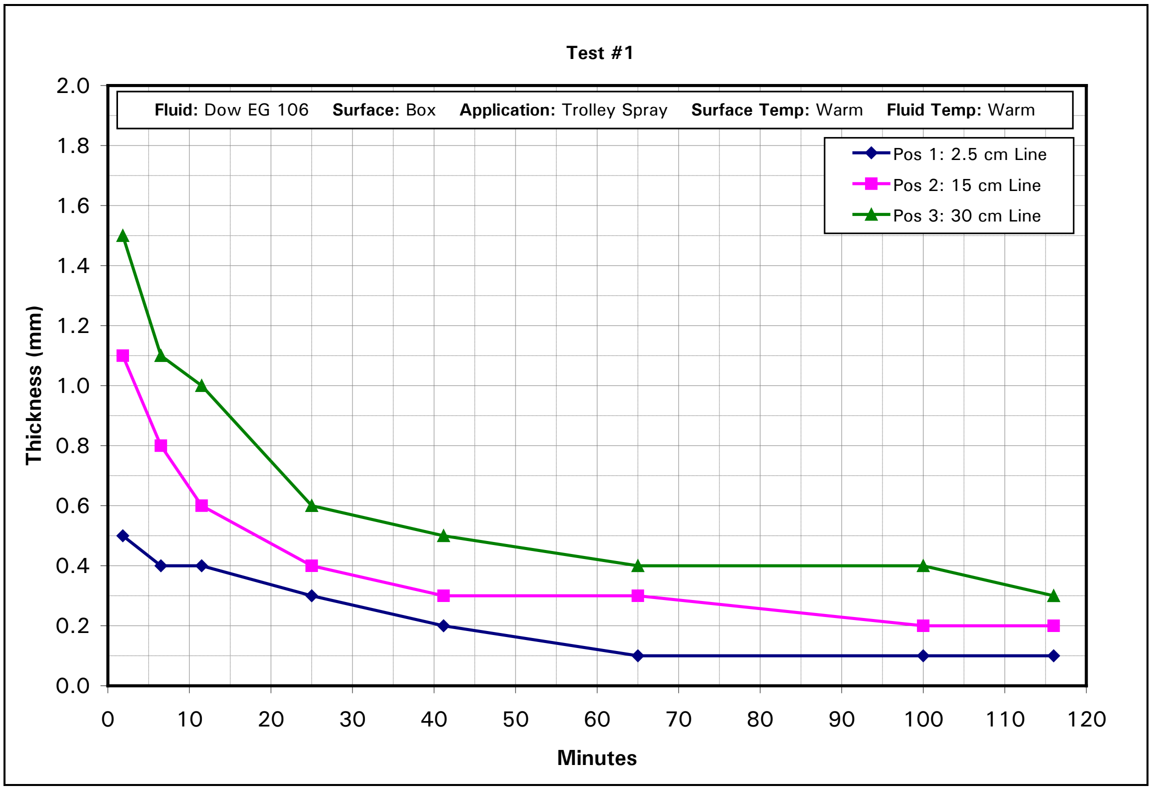

Figure C-1: Thickness Test #1

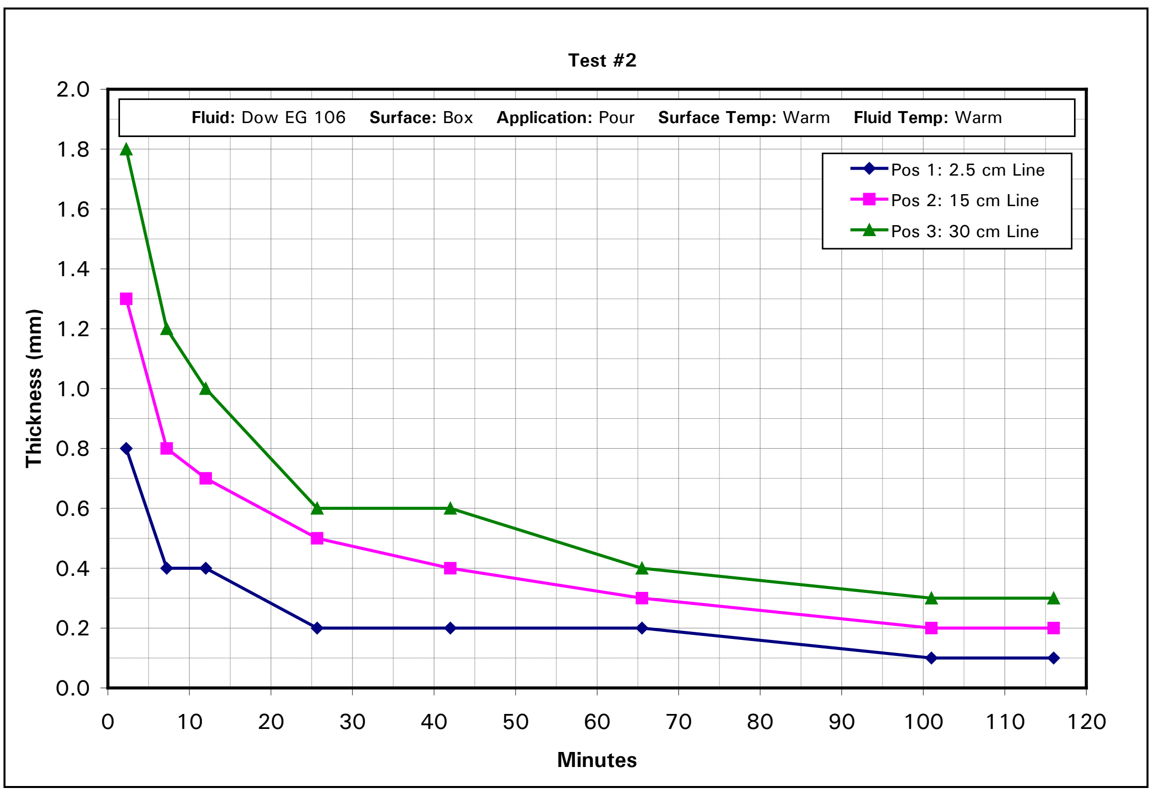

Figure C-2: Thickness Test #2

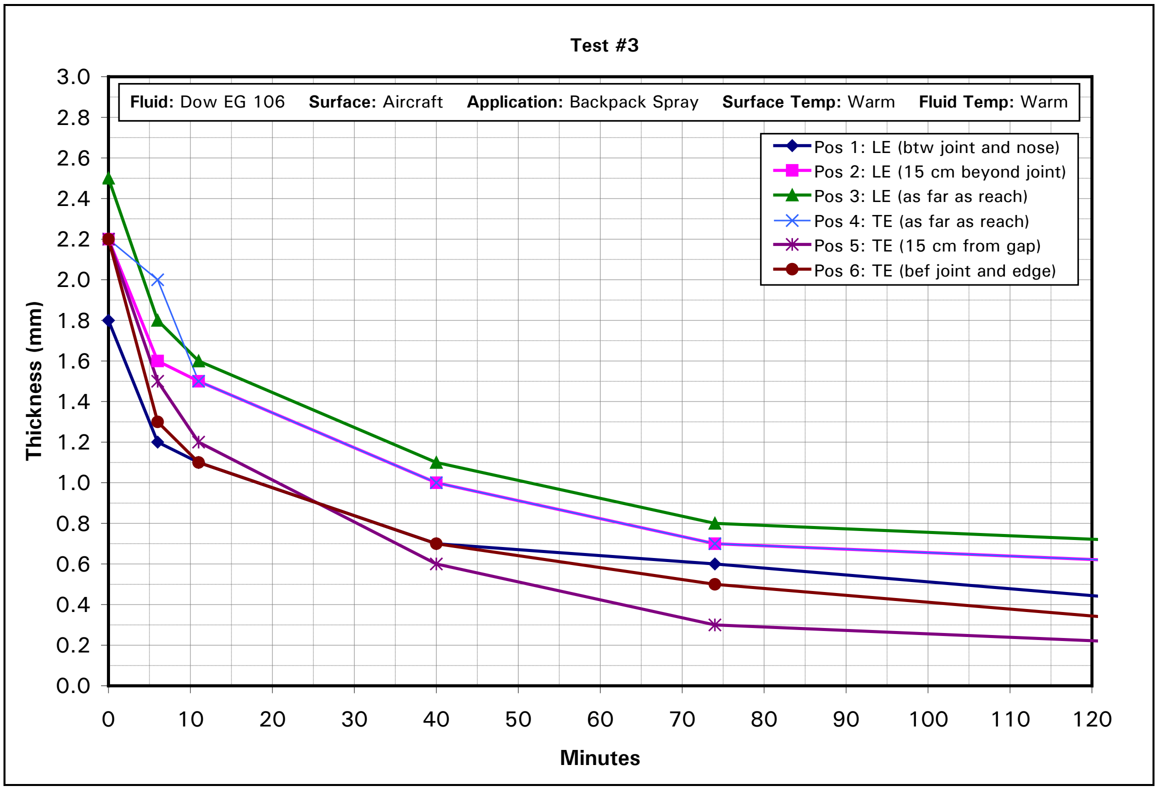

Figure C-3: Thickness Test #3

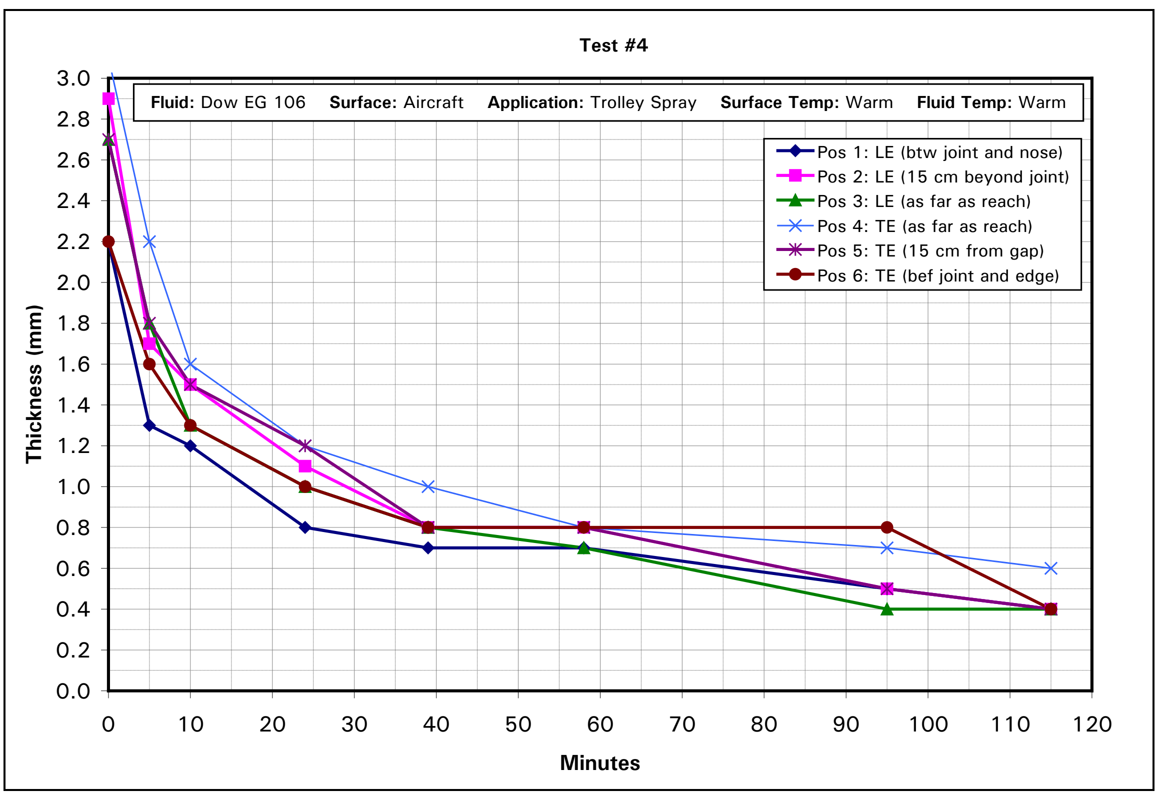

Figure C-4: Thickness Test #4

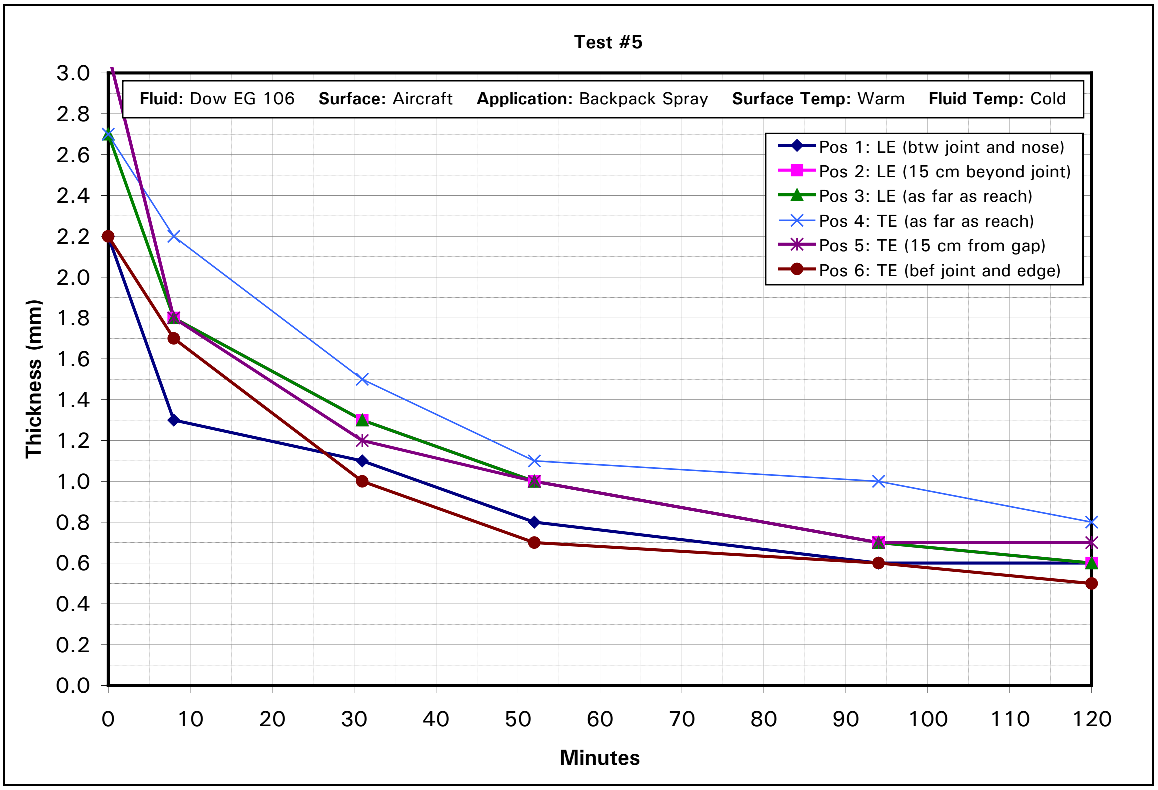

Figure C-5: Thickness Test #5

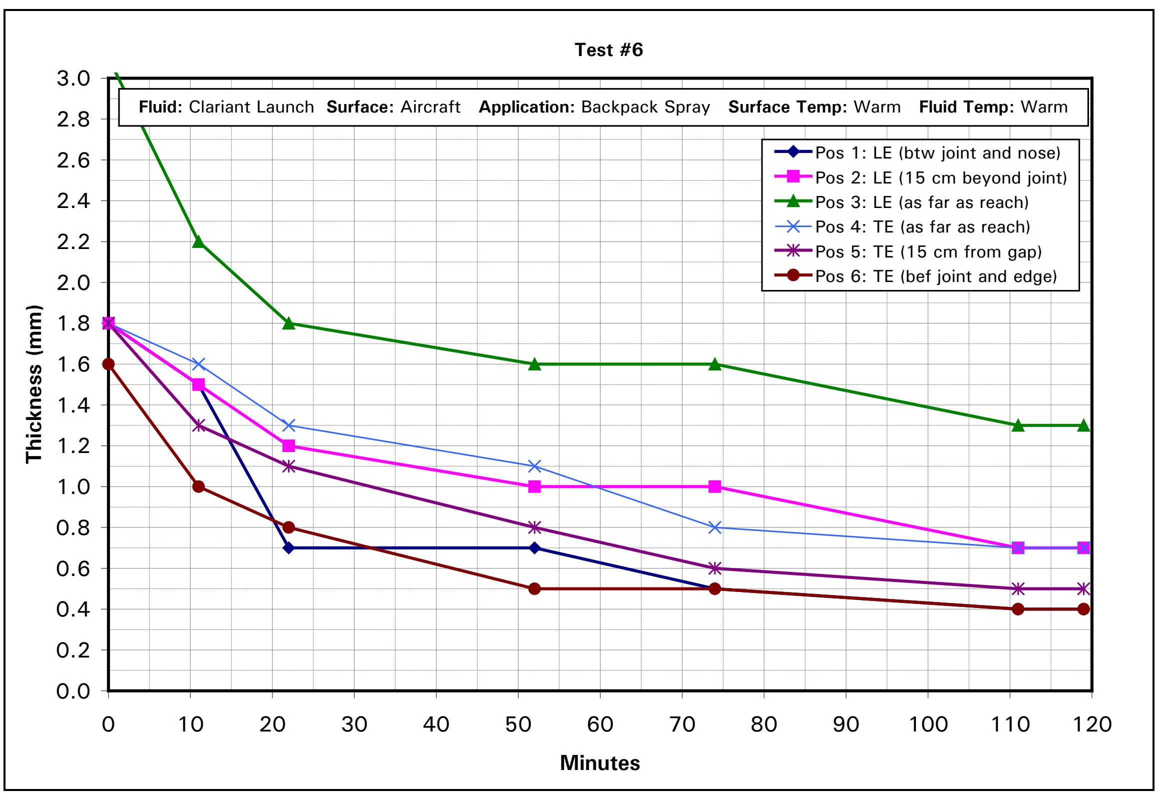

Figure C-6: Thickness Test #6

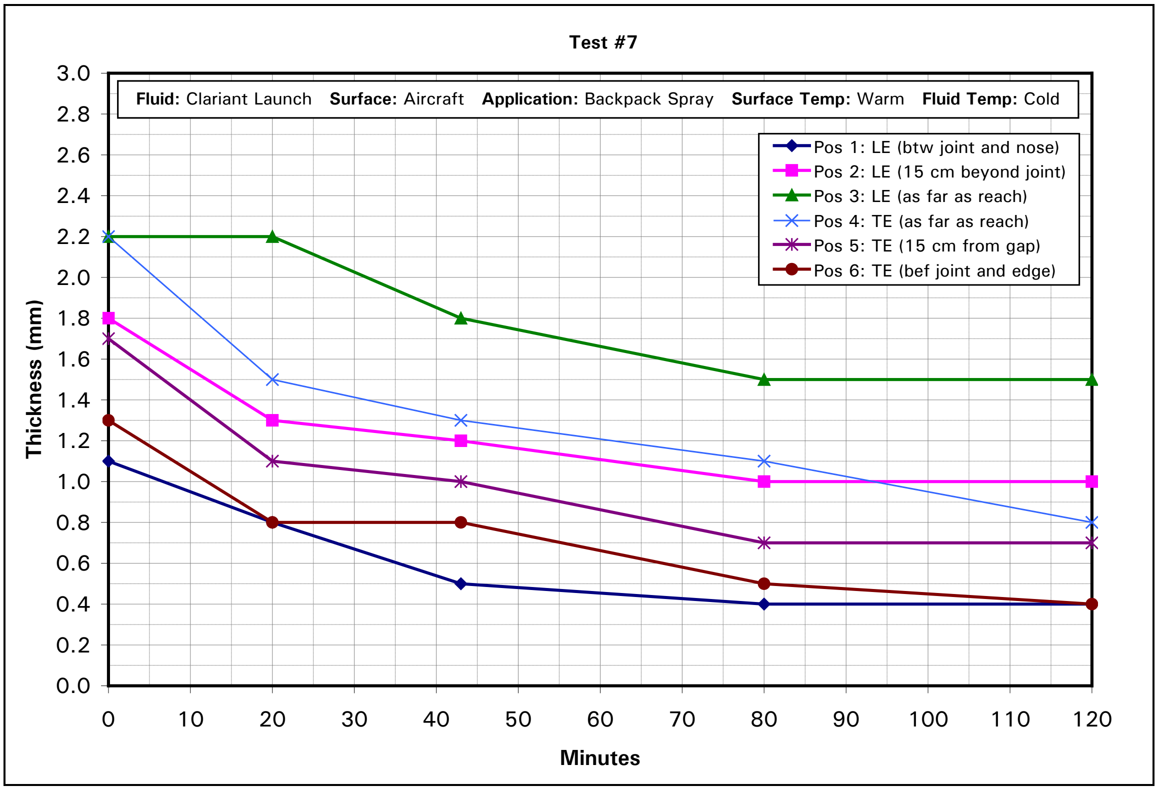

Figure C-7: Thickness Test #7

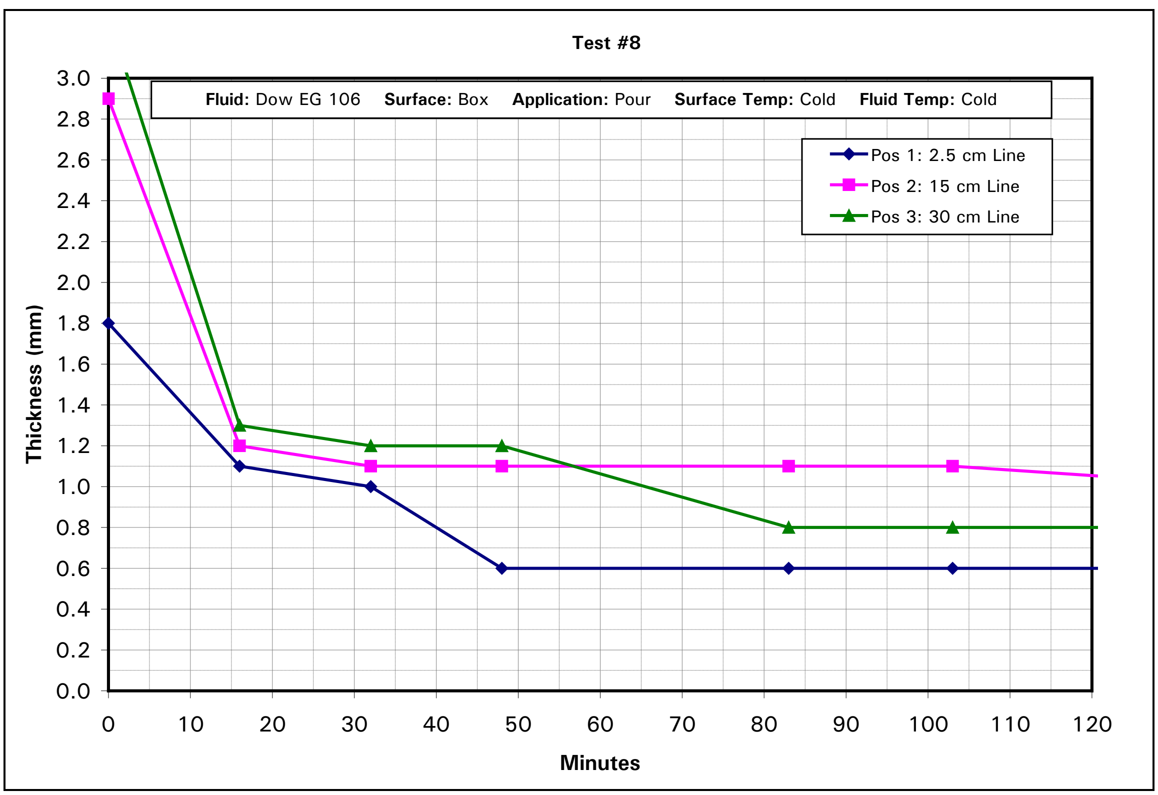

Figure C-8: Thickness Test #8

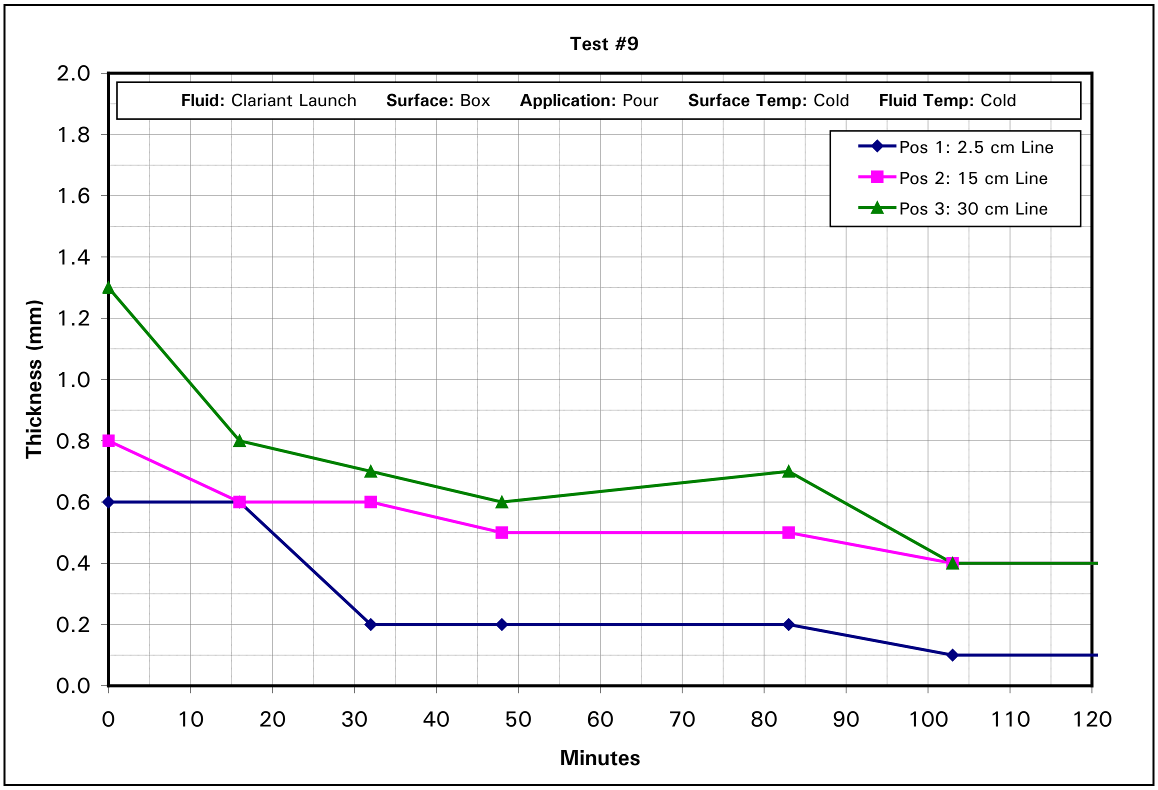

Figure C-9: Thickness Test #9

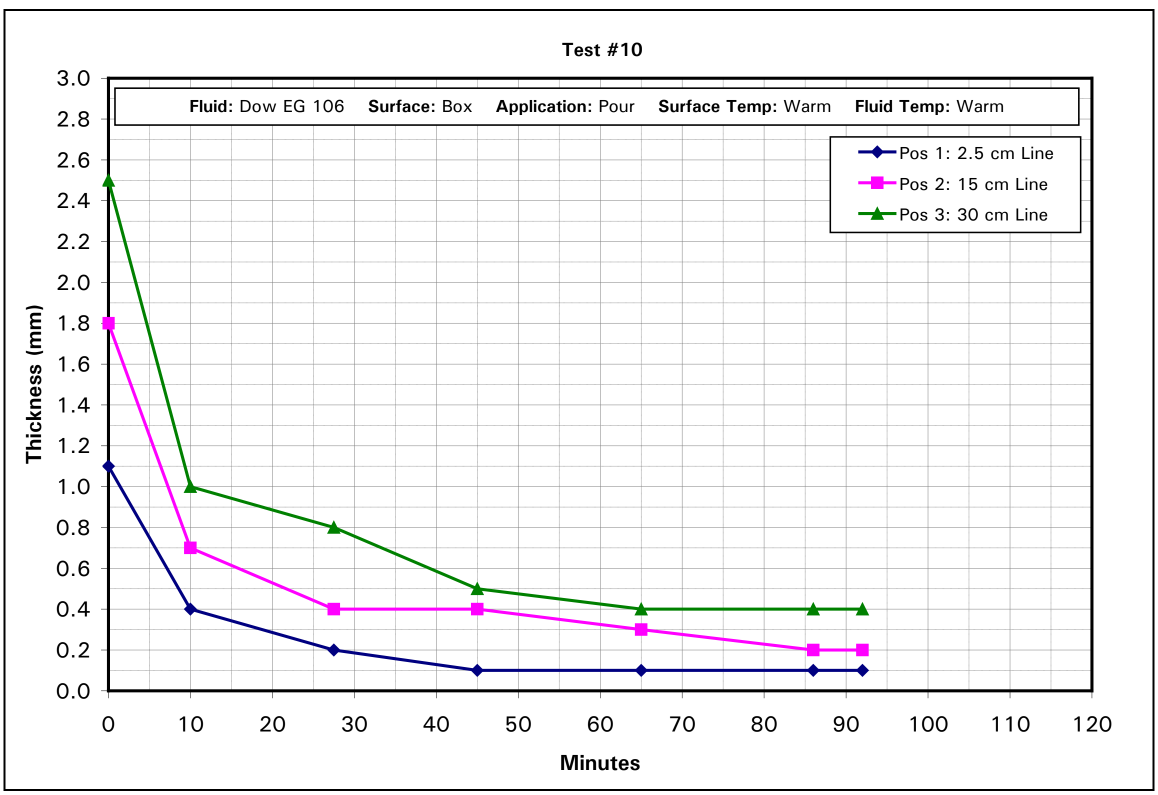

Figure C-10: Thickness Test #10

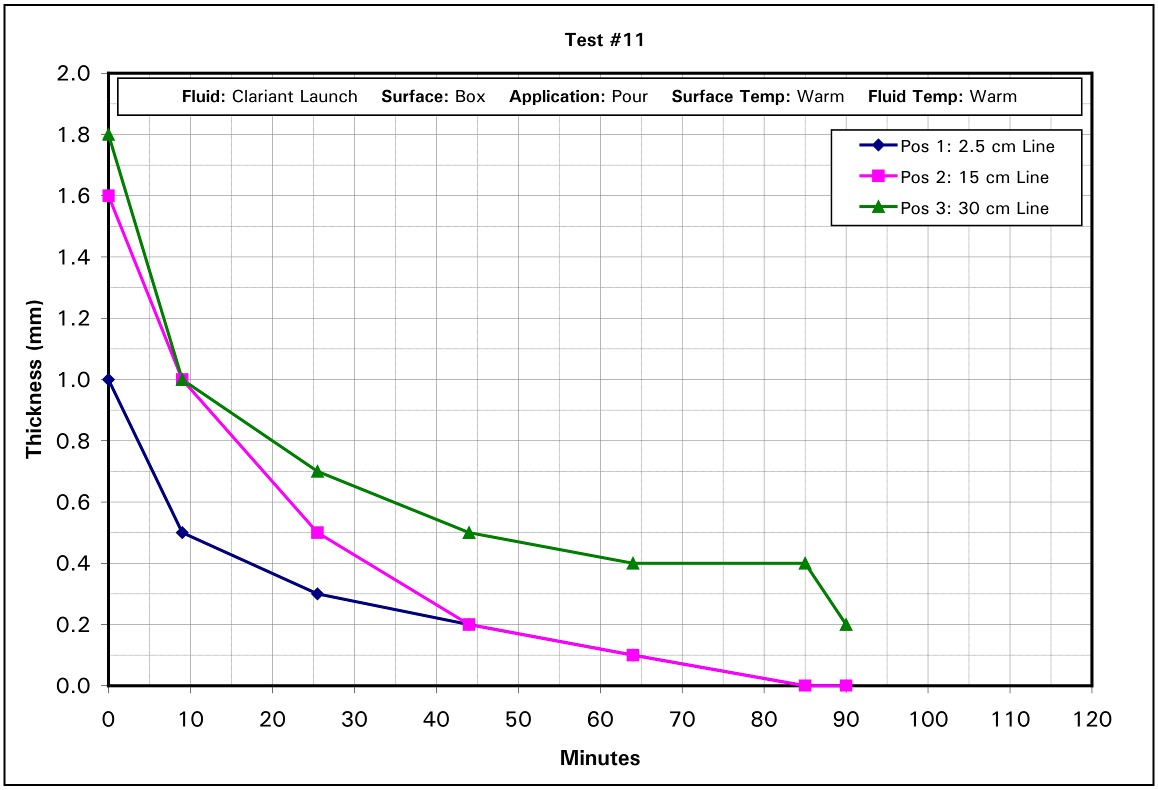

Figure C-11: Thickness Test #11

APPENDIX D

PROCEDURE:
EVALUATION OF ENDURANCE TIME VALUES FOR INDOOR AIRCRAFT HANGER (AND PRE-TREATMENT) ANTI-ICING APPLICATIONS

CM2169.002

PROCEDURE:
EVALUATION OF ENDURANCE TIME VALUES FOR INDOOR AIRCRAFT HANGER (AND PRE-TREATMENT) ANTI-ICING APPLICATIONS

Winter 2009-10

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: David Youssef

Reviewed by: John D'Avirro

APS Aviation Inc.

December 21, 2009
Final Version 1.0

EVALUATION OF HOLDOVER TIME VALUES FOR INDOOR AIRCRAFT HANGER (AND PRE-TREATMENT) ANTI-ICING APPLICATIONS

Winter 2009-10

1. BACKGROUND

In recent years, indoor application of anti-icing fluid on aircraft has been an important topic of industry discussion. It is understood that many fixed based operators is to anti-ice an aircraft when it is still parked inside the aircraft hanger. Often this aircraft has been in the hanger for a long enough period of time that the skin temperature and fuel temperature is equal to the ambient indoor temperature.

The holdover time of a given fluid is calculated as beginning with the final application of the anti-icing fluid, and as expiring when the fluid is no longer effective. Once an aircraft is anti-iced inside a hanger there is an elapsed period of time from the end of fluid application to precipitation exposure. This elapsed time may be due to a delay in aircraft readiness, or more simply the time to marshal the aircraft outside of the hanger.

Questions have been raised concerning the effect this elapsed period may have on the endurance time of Type II, III, and IV fluids.

1.1 Changes to Guideline Material for Hanger Application

In 2008-09, preliminary testing was conducted in both natural snow and in a simulated freezing precipitation laboratory. Based on the limited tests conducted, it was recommended that the holdover time clock be started when anti-icing fluid application begins, even if fluid application takes place in a hangar and the aircraft is not immediately exposed to precipitation.

It was recommended that regulators update their guidance material to clearly indicate when the holdover time clock should start for hangar operations, in accordance with the recommendation above.

Transport Canada subsequently made the following change to Section 10.11 of TP 14052E (previous version is shown in Section):

There are operational conditions when Air Operators may choose to anti-ice their aircraft while the aircraft remains in a heated hangar.

This is one way to reduce the consumption of deicing fluid and to minimize the environmental impact of deicing.

The period of time after Type IV fluid application and the air temperature in the hangar both have an effect on the ability of the fluid to protect the aircraft when it is pulled out of the hangar and into freezing/frozen precipitation. The HOT for a fluid is based largely upon the fluid's thickness on the surface. The fluid thickness varies with time and temperature. Therefore, the holdover time clock must be started at the time of first application of anti-icing fluid onto a clean wing. It may not be started when the aircraft is first exposed to frozen precipitation.

1.2 Industry Concerns with Guidance Material Change

There is some industry concern related to the guidance material stated above. Since the holdover time clock commences at the start of application of anti-icing fluid, air operators are concerned that when anti-icing inside a heated hanger say 1 hour before, there would be no holdover time left, despite the fact there is fluid still present on the wing.

Exactly how long before exposure to precipitation can a fluid be applied indoors is causing concern. Until now, much attention has been placed upon pouring fluid 1 hour before exposure to precipitation. It has been determined that more fluid application times should be examined. For example, 30 minutes before exposure to precipitation.

The objective is to provide the operator with both the largest amount of time inside the hanger, as well as the longest holdover time. For the purpose of this procedure the indoor application times will be left open-ended.

1.3 Proposed Approach to Potential Relief of Industry Concern

In an attempt to provide relief to the operators currently applying fluid indoors, a series of tests are proposed.

Testing will be conducted in natural snow and in all the freezing precipitation conditions outlined in the holdover timetable. Testing will be carried out using both an EG and PG fluid in the neat form. The approach would be to conduct comparative tests using the standard HOT protocol simultaneous with a protocol that simulates the hangar application, in an attempt to determine an endurance time reduction ratio.

Based on these comparative test results, it is anticipated that a statistical and analytical approach could be used to determine a "safe level" allowance time. It is anticipated that an allowance time of approximately 30 percent with the tested fluids may be achievable after a pro-longed wait inside the hanger.

1.4 Pre-treatment Application

Regulators have also indicated that there is a similar issue when fluid is applied outdoors but before any precipitation is occurring. Further testing in this area may be required.

2. OBJECTIVE

The objective of this project is to capture additional data to provide industry an allowance time when indoor (hanger) anti-icing is performed. A more standardized procedure will be employed in this testing, to eliminate any further variance.
In order to achieve this objective, a series of tests will be performed using two representative anti-icing fluids, on both standard aluminum plates and standard cold-soak boxes.

This procedure will investigate the above objectives in a natural snow setting, and in simulated freezing precipitation conditions.

3. PROCEDURE

3.1 Natural Snow Testing

Endurance time tests will be conducted outdoors with an Ethylene and Propylene fluid. A six-position stand will be required for this testing. This is demonstrated in Figure 3.1. Positions one and two will be used as the baseline for endurance times test. Fluid will be applied outdoors on positions one and two. Positions three and four will simulate an elapsed time between anti-icing and exposure to precipitation. This elapsed time will be determined in advance of testing. There is a related project that will be carried out on a full scale aircraft, in which thickness decay will be measured. Analysis of this project will determine the elapsed time. For the purpose of this project, the plan will be to start with 30 minutes elapsed time, until the results from the full-scale become available. Fluid will be applied indoors on box positions three and four. Position five will have a rate pan that will be used for measuring the rate of precipitation during each test. Standard cold soak boxes will be used, as they simulate heated fluid application.

	PLATE POSITION 1 BASELINE T = 0 MINUTES EG	PLATE POSITION 2 BASELINE T = 0 MINUTES PG	BOX POSITION 3 T = - x Min. EG	BOX POSITION 4 T = - x Min. PG	POSITION 5
APPLIED INDOOR/OUTDOOR?	OUTDOOR	OUTDOOR	INDOOR	INDOOR	RATE
AMBIENT TEMPERATURE	OAT	OAT	20°C	20°C	
APPLIED FLUID TEMPERATURE	OAT	OAT	20 °C	20 °C	
FLUID QUANTITY	1 LITRE	1 LITRE	1 LITRE	1 LITRE	

*Note: **- x min**. = Pre-determined time of fluid application.*
If x = 30 Minutes, then fluid will be applied inside 30 minutes before exposure to application.

- Testing will be conducted over 6 events.
- It is anticipated that there will be 2 runs per even
- Two Fluids will be used:
  - EG: Dow UCAR EG106
  - PG Clariant Launch
- It would be beneficial to capture different temperature and rates for different runs
- A minimum of ten runs is necessary to enable a reasonable comparison.

Figure 3.1: Typical Outdoor Test Plan

3.1.1 In Advance of Testing

Certain tasks must be completed in advance of testing. Table 3.1 outlines these tasks.

Table 3.1: Tasks to be completed in Advance of Testing

TIME	TASK	INSTRUCTIONS
T = Day Before Testing	PREPARATION OF 2 INDOOR BOXES. PREPARATION OF FLUID TO BE TESTED	• Place 2 Cold Soak Boxes indoors with fill caps removed for at least 12 hours before testing
		• Prepare all fluid to be applied at indoor ambient temperature, and leave indoors. • For all fluid to be applied at outdoor ambient temperature, leave outdoors.
T = 2 hours before testing	INDOOR STAND PREPARATION	• Bring inside one 2-position stands complete with wooden board holders and collection pans • Level to 10° and place CSW boxes on top.
T = 1 hour before testing	OUTDOOR STAND PREPARATION	• Level to 10°

3.1.2 Test Procedure

As mentioned at the beginning of this section, all positions will be exposed to precipitation at the same time; however the time of fluid application will vary.

Table 3.2 and 3.3 outline in chronological order the tasks of this testing.

Table 3.2: Test Procedure - Inside Application

TIME	TASK	INSTRUCTIONS
T = x Minutes before exposure to Precipitation	APPLY EG FLUID TO BOX POSITIONS 3	• Pour 1 litre of 20°C Fluid (EG) onto box positions 3
T = x Minutes before exposure to Precipitation	APPLY PG FLUID TO BOX POSITIONS 4	• Pour 1 litre of 20°C Fluid (PG) onto box positions 4

T = 1 MINUTE BEFORE EXPOSURE TO PRECIPITATION
← BRING BOX POSITION 3 AND 4 OUTSIDE AND PLACE ON STAND →

Table 3.3: Test Procedure - Outside Application

TIME	TASK	INSTRUCTIONS
T = 0 Minutes before exposure to Precipitation	APPLY EG FLUID TO PLATE POSITION 1	• Pour 1 litre of OAT Fluid (EG) onto Plate position 1
T = 0 Minutes before exposure to Precipitation	APPLY PG FLUID TO PLATE POSITION 2	• Pour 1 litre of OAT Fluid (PG) onto Plate position 2

3.2 Freezing Precipitation Testing

This research will also be completed in freezing precipitation conditions, as part of the overall program of tests completed at the National Research Council Climactic Engineering Facility (NRC) in Ottawa. The same setup that is used for outdoor snow testing will be used in freezing precipitation testing.

These tests will be run concurrently with endurance time tests, but will be conducted on the side stand positioned perpendicular to the holdover time test stand.

3.3 Pre-Treatment Testing

Testing to simulate a wing that is pre-treated with anti-icing fluid outside but before any precipitation is occurring may also be conducted. This procedure can be used, however, both Box Position 4 and 5 should be poured outside at some pre-determined time before precipitation begins to occur.

It is recommended that a limited number of tests be run to simulate pre-treatment. Appendix A provides a detailed test plan for Pre-Treatment testing.

4. MEASUREMENTS

4.1 Rate Measurements

Rate measurements will be taken according to Standard Holdover Time testing practices.

4.2 Fluid Thickness and Brix (Refractive Index)

To assist in analyzing the results, fluid thickness and Brix will be measured on all of the tests conducted. These measurements will be taken upon application of fluid, and at 15- 30-minute intervals throughout the test.

4.3 Plate Temperature

Plate Temperature will be measured at 15 - 30 minute intervals throughout the test.

5. TEST PLANS

5.1 Outdoor Testing

A test plan for outdoor testing has been compiled and is included in Attachment I.

5.2 Indoor Testing

A test plan for outdoor testing has been compiled and is included in Attachment II.

6. EQUIPMENT

The standard endurance time testing equipment from the procedure, *Test Requirements for Natural Precipitation Flat Plate Testing* (see Version 1.0 from December 23, 2004, located in Appendix B of TP14443E), will be used.

7. FLUIDS

The following fluids will be used for these tests:

Type IV: DOW EG-106 Endurance
Clariant Launch

8. PERSONNEL

Two personnel will be required to conduct these tests. One individual will be responsible to measure endurance times, and the remaining individual will prepare fluids, assist with fluid application, collect rates, and record measurements.

9. DATA FORMS

These tests will require the end condition data form that is included as Attachment III. Attachment IV depicts the data form to be used for recording Brix and thickness measurements.

10. SAFETY PRECAUTIONS

The following precautions will be taken when executing tests to ensure the safety of all personnel:

- Pathways, stairs and test areas are to be cleared of snow regularly;
- Appropriate footwear is to be worn by all personnel at the test site to prevent slipping;
- Warm clothing is to be worn by all personnel to prevent frostbite;

- Electrical appliances (including computers) are to be unplugged before any wires or connections are altered. If necessary, the affected breaker is to be turned off;
- 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 located inside the main trailer.

EVALUATION OF HOLDOVER TIME VALUES FOR INDOOR (AIRCRAFT HANGER) ANTI-ICING APPLICATIONS

ATTACHMENT I: MATRIX OF OUTDOOR TESTS

Run #	Test #	Fluid Brand	OAT [°C]	Fluid Temp. [°C]	Precip Rate [g/dm²/h]	Test Surface	TEST INSTRUCTION
1	Plate Position #1	DOW EG-106 Endurance	>-3	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	>-3	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	>-3	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	>-3	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
2	Plate Position #1	DOW EG-106 Endurance	>-3	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	>-3	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	>-3	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	>-3	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
3	Plate Position #1	DOW EG-106 Endurance	>-3	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	>-3	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	>-3	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	>-3	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
4	Plate Position #1	DOW EG-106 Endurance	>-3	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	>-3	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	>-3	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	>-3	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
5	Plate Position #1	DOW EG-106 Endurance	-3 to -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	-3 to -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	-3 to -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	-3 to -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.

Note: "x" minutes. = Pre-determined time of fluid application. If x = 30 Minutes, then fluid will be applied inside 30 minutes before exposure to application.
All Tests will be carried out on plates with Neat Fluids only

ATTACHMENT I (cont'd): MATRIX OF OUTDOOR TESTS

Run #	Test #	Fluid Brand	OAT [°C]	Fluid Temp. [°C]	Precip Rate [g/dm²/h]	Test Surface	TEST INSTRUCTION
6	Plate Position #1	DOW EG-106 Endurance	-3 to -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	-3 to -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	-3 to -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	-3 to -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
7	Plate Position #1	DOW EG-106 Endurance	-3 to -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	-3 to -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	-3 to -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	-3 to -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
8	Plate Position #1	DOW EG-106 Endurance	-3 to -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	< -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
9	Plate Position #1	DOW EG-106 Endurance	< -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	< -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
10	Plate Position #1	DOW EG-106 Endurance	< -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	< -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.

Note: "x" minutes. = Pre-determined time of fluid application. If x = 30 Minutes, then fluid will be applied inside 30 minutes before exposure to application.
All Tests will be carried out on plates with Neat Fluids only

ATTACHMENT I (cont'd): MATRIX OF OUTDOOR TESTS

Run #	Test #	Fluid Brand	OAT [°C]	Fluid Temp. [°C]	Precip Rate [g/dm²/h]	Test Surface	TEST INSTRUCTION
11	Plate Position #1	DOW EG-106 Endurance	< -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	< -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
12	Plate Position #1	DOW EG-106 Endurance	< -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Plate Position #2	Clariant Launch	< -14	OAT	Any	Std. Alum.	Baseline: Apply 1 litre of Fluid outside at Time of Exposure to Precipitation.
	Box Position #3	DOW EG-106 Endurance	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.
	Box Position #4	Clariant Launch	< -14	20°C	Any	Stand. CSW	Apply 1 Litre of Fluid inside "x" Minutes before Exposure to Precipitation.

Note: "x" minutes. = Pre-determined time of fluid application. If x = 30 Minutes, then fluid will be applied inside 30 minutes before exposure to application.
All Tests will be carried out on plates with Neat Fluids only

ATTACHMENT II: MATRIX OF INDOOR TESTS

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Test Type	Test Instruction
H1	Freezing Drizzle	-3	5	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H2	Freezing Drizzle	-3	5	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H3	Freezing Drizzle	-3	5	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H4	Freezing Drizzle	-3	5	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H5	Freezing Drizzle	-3	13	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H6	Freezing Drizzle	-3	13	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H7	Freezing Drizzle	-3	13	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H8	Freezing Drizzle	-3	13	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H9	Freezing Drizzle	-10	5	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H10	Freezing Drizzle	-10	5	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H11	Freezing Drizzle	-10	5	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H12	Freezing Drizzle	-10	5	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H13	Freezing Drizzle	-10	13	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H14	Freezing Drizzle	-10	13	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H15	Freezing Drizzle	-10	13	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H16	Freezing Drizzle	-10	13	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H17	Light Freezing Rain	-3	13	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H18	Light Freezing Rain	-3	13	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H19	Light Freezing Rain	-3	13	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H20	Light Freezing Rain	-3	13	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H21	Light Freezing Rain	-3	25	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H22	Light Freezing Rain	-3	25	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H23	Light Freezing Rain	-3	25	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H24	Light Freezing Rain	-3	25	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation

Note: "x" minutes. = Pre-determined time of fluid application. If x = 30 Minutes, then fluid will be applied inside 30 minutes before exposure to application.
All Tests will be carried out on plates with Neat Fluids only

ATTACHMENT II (cont'd): MATRIX OF INDOOR TESTS

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Test Type	Test Instruction
H25	Light Freezing Rain	-10	13	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H26	Light Freezing Rain	-10	13	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H27	Light Freezing Rain	-10	13	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H28	Light Freezing Rain	-10	13	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H29	Light Freezing Rain	-10	25	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H30	Light Freezing Rain	-10	25	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H31	Light Freezing Rain	-10	25	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H32	Light Freezing Rain	-10	25	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H33	Freezing Fog	-3	2	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H34	Freezing Fog	-3	2	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H35	Freezing Fog	-3	2	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H36	Freezing Fog	-3	2	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H37	Freezing Fog	-3	5	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H38	Freezing Fog	-3	5	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H39	Freezing Fog	-3	5	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H40	Freezing Fog	-3	5	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H41	Freezing Fog	-14	2	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H42	Freezing Fog	-14	2	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H43	Freezing Fog	-14	2	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H44	Freezing Fog	-14	2	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H45	Freezing Fog	-14	5	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H46	Freezing Fog	-14	5	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H47	Freezing Fog	-14	5	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H48	Freezing Fog	-14	5	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation

Note: "x" minutes. = Pre-determined time of fluid application. If x = 30 Minutes, then fluid will be applied inside 30 minutes before exposure to application.
All Tests will be carried out on plates with Neat Fluids only

ATTACHMENT II (cont'd): MATRIX OF INDOOR TESTS

Test #	Precipitation Type	Temp (°C)	Precip. Rate (g/dm²/h)	Fluid Brand	Test Type	Test Instruction
H49	Freezing Fog	-25	2	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H50	Freezing Fog	-25	2	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H51	Freezing Fog	-25	2	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H52	Freezing Fog	-25	2	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H53	Freezing Fog	-25	5	UCAR EG106	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H54	Freezing Fog	-25	5	Clariant Launch	Baseline	Standard HOT Test: 1 Litre Poured at OAT
H55	Freezing Fog	-25	5	UCAR EG106	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation
H56	Freezing Fog	-25	5	Clariant Launch	Simulated Hanger	1 Litre at 20°C Poured Indoors "x" minutes before Exposure to Precipitation

Note: "x" minutes. = Pre-determined time of fluid application. If x = 30 Minutes, then fluid will be applied inside 30 minutes before exposure to application.
All Tests will be carried out on plates with Neat Fluids only

EVALUATION OF HOLDOVER TIME VALUES FOR INDOOR (AIRCRAFT HANGER) ANTI-ICING APPLICATIONS

ATTACHMENT III: END CONDITION FORM FOR ENDURANCE TIME TESTING

REMEMBER TO SYNCHRONIZE TIME WITH MSC - USE LOCAL TIME

LOCATION: **DATE:** **RUN NUMBER:** **STAND # :**

TIME TO FAILURE FOR INDIVIDUAL CROSSHAIRS (real time)

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 2°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

	Plate 7	Plate 8	Plate 9	Plate 10	Plate 11	Plate 12
Time of Fluid Application:						
Initial Plate Temperature (°C) (NEEDS TO BE WITHIN 2°C OF AIR TEMP)						
Initial Fluid Temperature (°C) (NEEDS TO BE WITHIN 3°C OF AIR TEMP)						
FLUID NAME/DILUTION						
B1 B2 B3						
C1 C2 C3						
D1 D2 D3						
E1 E2 E3						
F1 F2 F3						
TIME TO FIRST PLATE FAILURE WITHIN WORK AREA						

AMBIENT TEMPERATURE: ________ °C

COMMENTS:

NOTE: **PLEASE ENSURE CORRECT FUNCTIONING OF PLATE TEMPERATURE LOGGING SYSTEM AT START OF TEST. AT THE END OF TEST SESSION, SAVE THE ELECTRONIC LOGGER FILE ON A FLOPPY DISK AND ALSO E-MAIL IT TO THE OFFICE. LABEL THE DISKETTE AND PLACE IT WITHIN THE DATA FORM ENVELOPE.**

FAILURES CALLED BY: ____________

LEADER / MANAGER: ____________

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ATTACHMENT IV: FLUID BRIX, FLUID THICKNESS, AND PLATE TEMPERATURE DATA FORM

FLUID BRIX / THICKNESS DATA FORM

DATE: ____________ PERFORMED BY: ____________

RUN #: ____________ WRITTEN BY: ____________

STAND: ____________ LOCATION: ____________

Plate / BOX: ________				Plate / BOX: ________				Plate / BOX: ________				Plate / BOX: ________			
Fluid:				Fluid:				Fluid:				Fluid:			
TIME	**Brix**	**Thickness**	**Plate Temp.**	**TIME**	**Brix**	**Thickness**	**Plate Temp.**	**TIME**	**Brix**	**Thickness**	**Plate Temp.**	**TIME**	**Brix**	**Thickness**	**Plate Temp.**

APPENDIX A

Test Plan for Pre-Treatment Testing

1. BACKGROUND

Several operators have asked regulators for guidance material for conditions in which aircraft are pre-treated with anti-icing fluid during a period of non-precipitation, and subsequently put at risk for contamination when precipitation begins.

Although it is known that the thickness of anti-icing fluid decays over time once applied to aircraft – even without the presence of precipitation, and it is also known that decreased fluid thickness reduces holdover time, the exact relationship between fluid thickness and holdover time is not known. Therefore, it is currently not possible to estimate how much protection time an anti-icing fluid will provide after it has been sitting on the aircraft for some time before being exposed to precipitation.

This "pre-treatment" scenario is similar to the hangar anti-icing scenario. In both cases, aircraft are not immediately exposed to precipitation after being treated with anti-icing fluid. The primary difference between the two scenarios is that fluid and wing temperatures are at room/hangar temperature (approximately 20°C) in the hangar scenario and at OAT in the pre-treatment scenario.

2. OBJECTIVE

The objective of this project is to piggyback a set of limited tests onto the hangar tests to determine if it would be possible to provide guidance material for the pre-treatment scenario (a more extensive test program will need to be carried out if the answer is yes). This piggybacking will include the addition of one additional test plate to select hangar test runs.

3. PROCEDURE

The same procedure that is used for Hanger testing may be used for pre-treatment, however box positions 3 and 4 should be poured outside at some pre-determined time before precipitation begins to occur.

4. TEST PLAN

4.1 Natural Snow

Table A-1 outlines the test plan for pre-application in natural snow.

Pre-treatment test plan in snow

4.2 Freezing Precipitation

Table A-2 outlines the test plan for pre-application in freezing precipitation.
Pre-treatment test plan in freezing precipitation

Table A-1: Test Plan for Pre-Application in Natural Snow

Run #	Test #	Fluid Brand	OAT [°C]	Fluid Temp. [°C]	Precip Rate [g/dm²/h]	Test Surface	TEST INSTRUCTION
1	Pre-Treatment	DOW EG-106 Endurance	>-3	OAT	Any	Stand. CSW	Apply 1 Litre of Fluid OUTSIDE "x" Minutes before Exposure to Precipitation.
2	Pre-Treatment	Clariant Launch	>-3	OAT	Any	Stand. CSW	Apply 1 Litre of Fluid OUTSIDE "x" Minutes before Exposure to Precipitation.
3	Pre-Treatment	DOW EG-106 Endurance	-3 to -14	OAT	Any	Stand. CSW	Apply 1 Litre of Fluid OUTSIDE "x" Minutes before Exposure to Precipitation.
4	Pre-Treatment	Clariant Launch	-3 to -14	OAT	Any	Stand. CSW	Apply 1 Litre of Fluid OUTSIDE "x" Minutes before Exposure to Precipitation.
5	Pre-Treatment	Clariant Launch	< -14	OAT	Any	Stand. CSW	Apply 1 Litre of Fluid OUTSIDE "x" Minutes before Exposure to Precipitation.
6	Pre-Treatment	DOW EG-106 Endurance	< -14	OAT	Any	Stand. CSW	Apply 1 Litre of Fluid OUTSIDE "x" Minutes before Exposure to Precipitation.

Table A-2: Test Plan for Pre-Application in Freezing Precipitation

Run #	Test #	Precipitation Type	Temp (°C)	Fluid Temp. [°C]	Precip. Rate (g/dm²/h)	Fluid Brand	Test Surface	Test Instruction
1	Pre-Treatment	Freezing Drizzle	-3	OAT	5	UCAR EG106	Stand. CSW	1 Litre at OAT Poured CLEAR OF PRECIPITATION SPRAY "x" minutes before Exposure to Precipitation
2	Pre-Treatment	Freezing Drizzle	-10	OAT	13	Clariant Launch	Stand. CSW	1 Litre at OAT Poured CLEAR OF PRECIPITATION SPRAY "x" minutes before Exposure to Precipitation
3	Pre-Treatment	Light Freezing Rain	-3	OAT	13	UCAR EG106	Stand. CSW	1 Litre at OAT Poured CLEAR OF PRECIPITATION SPRAY "x" minutes before Exposure to Precipitation
4	Pre-Treatment	Light Freezing Rain	-10	OAT	25	Clariant Launch	Stand. CSW	1 Litre at OAT Poured CLEAR OF PRECIPITATION SPRAY "x" minutes before Exposure to Precipitation
5	Pre-Treatment	Freezing Fog	-3	OAT	2	UCAR EG106	Stand. CSW	1 Litre at OAT Poured CLEAR OF PRECIPITATION SPRAY "x" minutes before Exposure to Precipitation
6	Pre-Treatment	Freezing Fog	-14	OAT	5	Clariant Launch	Stand. CSW	1 Litre at OAT Poured CLEAR OF PRECIPITATION SPRAY "x" minutes before Exposure to Precipitation
7	Pre-Treatment	Freezing Fog	-25	OAT	2	UCAR EG106	Stand. CSW	1 Litre at OAT Poured CLEAR OF PRECIPITATION SPRAY "x" minutes before Exposure to Precipitation

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